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Tsunami Glossary

A Glossary of Terms and Acronyms Used in the Tsunami Literature

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PREFACE

Tsunami Science is a relatively new field dating only a few decades. It is only in the last fifty years that the tsunami scientific literature proliferated. Many terms from other disciplines were adopted, modified, revised, and applied to the studies of the tsunami phenomena. Many other terms were redefined in the context of the components of this new scientific field.

This glossary is intended to list as many as possible of the terms found in the tsunami literature and provide their specific definitions. It is intended for students, scientists, administrators and for anyone interested in tsunami.

This book contains concise definitions of more than 2,000 terms. It includes terms from a multitude of disciplines. Primary, specialized and frequently-used tsunami terms are given with bolder headwords. Less frequently used terms are not highlighted.

As the tsunami scientific literature increases in the future, as our understanding becomes greater, and as our technology becomes more advanced, it is expected that new terms will be introduced. Such terms, and terms that have been omitted, will be included in a future edition. The present Glossary is viewed as an evolving document.

ACKNOWLEDGMENTS

No project of this magnitude goes forward without encouragement, support and helpful constructive criticism. I would like to thank all the people who have reviewed drafts of this Glossary and provided comments and advice. I am very grateful to them all. I would like to thank most particularly, the Intergovernmental Oceanographic Commission (IOC-UNESCO) and its International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) for support of this project, and in particular, Dr. I. Oliounine of IOC and Mr. H. Hagemeyer, Chairman, ICG/ITSU for giving me deadlines and keeping me on schedule. Otherwise I could have been on this project for several more years. I wish to extend my appreciation to Professor S. L. Soloviev and his colleagues in the USSR for reviewing earlier listings of terms and providing comments that were useful in the development of this Glossary. Furthermore, I wish to express my appreciation to the ICG/ITSU committee members who reviewed proposed terms, recommended their adoption and helped me differentiate between primary and secondary terms. for inclusion into the Glossary. Specifically, I wish to thank Dr. Mohammed El Sabh (Canada), Dr. Tad Murty (Canada), Mr. Emilio Lorca (Chile), Mr. James Lander (USA), and all the others that served in this ICG/ITSU reviewing committee.

Finally, I wish to thank Mrs. Millie Ching, ITIC Secretary, Mr. Loy Kuo, Graduate Assistant, Mr. Joseph Hunt, Mr. Joseph Edmon, Mr. Sam Kerner and all the others, who helped with research, typing, computer formatting, and computer preparation of the first Edition of this Glossary.

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INTRODUCTION

Background

At the first Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications held at Sidney, B.C., Canada on 29 July - 1 August 1985, the following recommendation was made:

"Recognizing that the diversity of terms used in describing the tsunami phenomenon which involves a wide variety of scientific and non-scientific groups in a variety of interdisciplinary fields, the Workshop recommends the preparation of a glossary of tsunami-related terms to serve as the basis for defining and understanding tsunami terminology."

At the subsequent Tenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) at the Institute of Ocean Sciences in Sidney, which followed the Tsunami Workshop, the Group accepted and adopted the recommendations proposed by the Workshop and requested the International Tsunami Information Center (ITIC) to take the necessary action for the implementation of this recommendation.

In response to this ITSU-X recommendation, in August 1985, ITIC began the compilation of a "Glossary of Terms and Acronyms Used in the Tsunami Literature." A preliminary draft of the glossary with a total of about 2200 entries was distributed to the ITSU editorial group in early 1988 and a revised version in November 1988. These early drafts included a number of oceanographic, meteorological and physical terms that may have appeared as not necessary for inclusion. However, the original intent was to compile a comprehensive draft glossary and then, by a process of elimination, retain those terms that are more appropriate or likely to be found in the tsunami literature.

Since November 1988, ITIC put a concerted effort to edit the earlier draft. A number of knowledgeable tsunami scientists were consulted as to what should be included in the glossary and a consensus of opinion was sought.

In August 1989, at the ITSU XII meeting in Novosibirsk, USSR, the Director of ITIC presented the Group a final listing of Glossary terms compiled by ITIC and a listing of terms proposed by Dr. S. L. Soloviev. The Group noted that there was a diversion of opinion as to what terms should be included. The Chairman appointed a Sessional Group to review the proposed terms and to report to the Session those terms to be included in the first edition. After reviewing both listings and the philosophy of development of the ITIC-compiled listing, the Committee recommended the adoptation of the ITIC version into the Glossary, but stressed that a differentiation needed to be made between the primary glossary terms that relate directly to the tsunami problem, and the secondary terms that are indirect and of general interest. The Committee identified the primary terms, which in the present Glossary are distinguished by bolder print. With the recommendation of the editorial committee, the Group mandated that the first edition of the Tsunami Glossary should be published without delay and asked the Director, ITIC, to provide the final version of the Glossary, reflecting the recommendations of the Sessional Group to the 10C Secretariat by 15 August 1990. This date was later changed to 31 December 1990. Furthermore, the 10C Secretariat was to arrange the printing of the Glossary and its distribution to ITSU National Contacts.

Philosophy of Glossary Development

The etymology of the word glossary comes from the Greek. Accordingly, the meaning of the word "glossary" signifies a term or a word which requires explanation or definition. A lexicographical compilation of pertinent words and terms with specific definition of usage and meaning is the basic prerequisite of every specialized discipline of science. This is very important as such words and terms are often used in different context or sense when applied to other disciplines or to spoken language. Furthermore, each discipline of science, as it develops, introduces its own specialized vocabulary which could be totally unfamiliar to others outside that particular field.

The field we call "tsunami" is a hybrid discipline of science encompassing principally, but not exclusively, aspects of solid earth geophysics and oceanography. As such, it has borrowed extensively terms and definitions from the many disciplines that comprise these fields, as well as from the basic sciences, engineering, and from mathematics. New specialized terms and definitions have also been introduced, some of them in languages other than English, which often elude universal acceptance and adoptation. Thus, there is a need to develop standardized tsunami terminology in the form of a glossary which has the endorsement of the appropriate scientific Groups.

International research on the tsunami phenomenon has increased considerably in the last forty years as several destructive tsunamis have hit many Pacific countries. As a result, the tsunami scientific literature has proliferated.

Interest in tsunamis and in the mitigation of tsunami disasters has also increased with the advent of new technology of data collection and communications and the development of early warning systems. Thus, a need has evolved for definition and proper usage of new terms which now appear frequently in the literature. The resulting philosophy is that a tsunami glossary should include, not only the direct terms related to tsunamis, but also terms from other fields of science that may be encountered by tsunami administrators or scientists, not only in their own field, but in peripheral fields of science or engineering where the terminology may be somewhat unfamiliar or utilized under a different context. Thus, the decision
was made to include terms that are often being used in such diverse subjects as plate tectonics, ocean engineering, coastal engineering, meteorology, disaster forecasting, hydrodynamic and fluid mechanics, earthquake engineering, tides, volcanology, physical and geological oceanography, remote sensing, seismology, geology, hydrology, geochemistry, astronomy, geodesy, coastal zone management, mathematics, statistics and many other subjects. The idea, of course, is that tsunami scientists would not have to start searching for definitions of terms in other glossaries of other disciplines, but they would use a tsunami glossary that was fairly complete.

Based on this philosophy, criteria for selection of terms were developed. Inclusion or non-inclusion of a term in the glossary had to meet some of the following testing:

1. Is the term currently used in the tsunami literature? (i.e. commonly used terms, such as "tsunami," "epicenter," and "focus").

2. Can the term be included in future tsunami literature? (i.e. uncommon terminology not frequently used, as for example, in work pertaining to the ionospheric signature of tsunamigenic earthquakes, and indirect means of measurement, utilizing, let's say, the "Doppler Effect").

3. Is the term used under a different context in tsunami work? (i.e. wave refraction: acoustic or optical wave refraction versus ocean wave refraction).

4. Is a mathematical law or application possible to tsunami-related work? (i.e. Fourier series analysis).

5. Is the term sufficiently descriptive or self evident? (i.e. "disastrous tsunami," that it needs no definition?).

6. If not in English, but in a foreign language, is the term used often enough to be included? (i.e. "tsunami" yes, "maremoto" maybe).

On the basis of such selective criteria, the first edition of the "Tsunami Glossary" has been considerably revised, most terms have been defined, and new appropriate terms have been introduced. The present Glossary contains about 2,000 terms. The present edition includes only the terms and their definition in alphabetical order. A future edition will include a listing of acronyms of organizations and scientific programs that often appear in the tsunami literature, as well as definitions and conversion factors for units of measurement commonly used in tsunami research and application work.

Finally, it is said that the Roman Emperor Justinian was the first to compile a special category of technical glossaries relating to the law. Since these glossaries interpreted the law, the emperor forbade under severe penalties all commentaries on this glossarized legislation. Contrary to Justinian, the present compiler of the Tsunami Glossary is a great deal more lenient to corrections and additions of the present Tsunami Glossary, which may enhance its content, scope, and usage. After all, the Tsunami Glossary is not carved in stone, as Justinian's Glossaries were, but resides in the memory of a computer, that readily, unquestionably, and obediently accepts editorial changes.

–A–

Abscissa – The horizontal coordinate in a two dimensional system of rectangular coordinates; usually denoted by x; also, the horizontal axis of any graph.

Absolute angular momentum – The angular momentum as measured in an absolute coordinate system; hence, the vector product of the position vector of a particle into the absolute momentum of the particle. In the ocean the absolute angular momentum M per unit mass of water is equal to the sum of the angular momentum relative to the earth and the angular momentum due to the rotation of the earth:

$$M = ua \cos f + \Omega a^2 \cos^2 \phi$$

where a is the radius of the earth, u the relative eastward speed, ϕ the latitude, and Ω the angular speed of the earth.

See angular momentum balance, conservation of angular momentum.

Absolute coordinate system – (Or absolute reference frame.) That initial coordinate system which has its origin on the axis of the earth and is fixed with respect to the stars. Thus, any mechanical quantities defined with respect to this frame take into account the movement of the earth.

See, for example, coriolis force, absolute vorticity.

Absolute momentum – (Often called absolute linear momentum.) The (linear) momentum of a particle as measured in an absolute coordinate system; hence, the sum of the (vector) momentum of the particle relative to the earth and the (vector) momentum of the particle due to the earth's rotation.

Absolute velocity – Velocity as measured in an absolute coordinate system; hence, the (vector) sum of the velocity of a fluid parcel relative to the earth and the velocity of the parcel due to the earth's rotation. The east-west component is the only one affected:

$$u_a = u + \Omega a \cos \phi ;$$

where u and u_a are the relative and absolute eastward speeds, Ω the angular speed of the earth's rotation, a the radius of the earth, and ϕ the latitude of the parcel.

Absolute vorticity – 1. The vorticity of a fluid particle determined with respect to an absolute coordinate system. 2. The vertical component η of the absolute vorticity (as defined above) given by the sum of the vertical component of the vorticity with respect to the earth (the relative vorticity) ζ and the vorticity of the earth (equal to the coriolis parameter) f:

$$\eta = \zeta + f$$

Absorption – Taking up, assimilation, or incorporation; e.g. of liquids in solids or of gases in liquids.

Acceleration – The rate of change with time of speed and / or velocity; strictly, the rate of change with time of the velocity vector of a particle. If V is the velocity, the acceleration may be written as $d\mathrm{V}/dt$, where d/dt is the total derivative.

In two-dimensional motion the acceleration may be decomposed, in natural coordinates, into the tangential acceleration along the streamline and the centripetal acceleration normal to the streamline:

$$\frac{d\mathrm{V}}{dt} = \frac{dV}{dt}\mathrm{t} + \frac{v^2}{R}\mathrm{n}$$

where V is the magnitude of V, t a unit vector along V, R the instantaneous radius of curvature of the path, and n a unit vector normal to V, in the direction of the center of curvature.

For most purposes in hydrodynamics where Eulerian coordinates are employed, the acceleration is decomposed as follows:

$$\frac{d\mathrm{V}}{dt} = \frac{\partial \mathrm{V}}{\partial t} + \mathrm{V} \cdot \nabla \mathrm{V}$$

where $\partial \mathrm{V}/\partial t$ is called the local acceleration, and $\mathrm{V} \cdot \nabla \mathrm{V}$ is called the convective acceleration.

Accretion – May be either natural or artificial. Natural accretion is the buildup of land, solely by the action of the forces of nature, on a beach by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. Also aggradation.

ACMRR - Advisory Committee on Marine Resources Research.

Actual elevation – The vertical distance above mean sea level of the ground at the point of measurement. This term is denoted by the symbol *H* in international usage.

Actual pressure – The atmospheric pressure at the level of the barometer (elevation of ivory point), as obtained from the observed reading after applying the necessary corrections for temperature, gravity, and instrumental errors. This may or may not be the same as station pressure.

Advance (of a beach) – 1 A continuing seaward movement of the shoreline.

2 A net seaward movement of the shoreline over a specified time. Also progression.

Affected coast– A coastline that has been struck by a tsunami.

Aftershocks – An earthquake which follows a larger earthquake or main shock and originates at or near the focus of the larger earthquake. Generally, major earthquakes are followed by a large number of aftershocks, decreasing in frequency with time.

Age (of tides)– The time interval between an astronomical event and the corresponding tidal phenomenon. For example, the lag in days between the occurrence of syzygy and the highest spring tide is the "age of the tide"; the lag between perigee and the highest perigean tide is the "age of parallax inequality"; etc.

Aggradation – See accretion.

Airy equations – The first-order, nonlinear shallow-water wave equations

Airy phase – The minimum in the group velocity curve is termed Airy Phase. A major feature of many surface wave records, it is a stationary phase and therefore has substantially greater relative amplitude than the rest of the surface wavetrain.

Alarm – Any sound, outcry, or information intended to warn of approaching danger. A warning sound.

Alongshore – Parallel to and near the shoreline; same as longshore.

Alternate vortex – A whirling body of water in the form of an eddy.

Amphidromic point – A point on a chart of cotidal lines from which the cotidal lines radiate.

Amphidromic region – An oceanic region whose cotidal lines radiate from one amphidromic point.

Amplification factor – Numerical factor of the amplifying effect of tsunami travelling over the continental shelf.

Amplitude – Half the height of the crest of a wave or ripple above the adjacent troughs. The magnitude of the displacement of a wave from a mean value. For a simple harmonic wave, it is the maximum displacement from the mean. For more complex wave motion, amplitude is usually taken as one-half the mean distance (or difference) between maxima and minima. An ocean surface wave has an amplitude equal to the vertical distance from still-water level to wave crest (compare wave height).

See also frequency, period, wave length, wave number.

Amplitude spectrum – . The amplitude spectra of digitized series is obtained by using discrete Fourier transform, and spectral-time obtained by the so-called multiply filter technique. For example, in studying seismic recordings,

It has been shown that there are distinct differences in the form of amplitude spectra of Rayleigh waves for two groups of earthquakes. The main maximum of spectra for the tsunamigenic earthquakes is much wider than for those nontsunamigenic and position is shifted to the low-frequency domain. Studying the spectral-time diagrams also shows that there are differences in their structure between both groups of earthquakes, which can be used to recognize tsunamigenic earthquakes.

Analog record – A continuous graphical recording by a tide gauge of sea-level fluctuations caused by tsunami waves.

Analysis of variance – A statistical technique for resolving the total variability of a set of data into systematic and random components. The analysis of variance is fundamentally a statistical estimating and/or testing procedure. It estimates the components of variance due to systematic and random causes, and it leads to significance tests of these components. The statistical assumptions required for a valid test are more stringent than those for estimating the components of variance.

Angle of incidence – The angle at which a ray of energy, or an object, impinges upon a surface, measured between the direction of propagation of the energy (or object) and a perpendicular to the surface at the point of impingement, or incidence.

Compare angle of arrival; see also angle of reflection, angle of refraction.

Angle of reflection – The angle at which a reflected ray of energy leaves a reflecting surface, measured between the direction of the outgoing ray and a perpendicular to the surface at the point of reflection.

Angle of refraction – The angle at which a refracted ray of energy leaves the interface at which the refraction occurred, measured between the direction of the refracted ray and a perpendicular to the interface at the point of refraction.

Angular velocity – A representation of the rate of rotation of a particle about the axis of rotation, with magnitude equal to the time rate of angular displacement of any point of the body. Angular velocity is a vector oriented in accordance with a right-hand rotation (i.e., when the fingers of the right hand are curved in the sense of rotation, the thumb in the direction of the angular velocity vector). The angular velocity of the earth (in the absolute coordinate system) is directed along the earth's axis toward the pole star and is equal in magnitude to 7.2921 X 10^{-5} radians per second.

Anomalous – Not encompassed by rules governing the majority of cases; distinguished from abnormal by implying a difference of kind rather than a difference merely of degree.

Apogean tide – Tides of decreased range occurring when the moon is near apogee.

Apogee – That point on the orbit of the moon (or any other earth satellite) which is farthest from the earth; opposed to perigee.

Compare aphelion.

Archimedes's principle – The statement that a net upward or buoyant force, equal in magnitude to the weight of the displaced fluid, acts upon a body either partly or wholly submerged in a fluid at rest under the influence of gravity. This force is known as the Archimedean buoyant force (or buoyancy) and is independent of the shape of the submerged body and does not depend upon any special properties of the fluid.

Array – An ordered arrangement of seismometers/geophones, the data from which feeds into a central receiver.

Arrival – The appearance of seismic energy on a seismic record.

Arrival time – The time at which a particular wave phase arrives at a detector.

Aseismic – Not associated with an earthquake

Asymptotic – Of or pertaining to an asymptote. In statistical terms, a distribution with absolute large values of the variate. In mathematics, an asymptote is a line that is the limiting position which is the tangent that a curve approaches, as the point of contact recedes indefinitely along an infinite branch of the curve.

Asthenosphere – A hypothetical zone of the earth which lies beneath the lithosphere and within which the material is believed to yield readily to persistent stresses.

Atmosphere – 1. The envelope of air surrounding the earth and bound to it more or less permanently by virtue of the earth's gravitational attraction; the system whose chemical properties, dynamic motions, and physical processes constitute the subject matter of meteorology. (Compare biosphere, geosphere, hydrosphere, lithosphere.)

The earth's atmosphere extends from the solid or liquid surface of the earth to an indefinite height, its density asymptotically approaching that of interplanetary space. At heights of the order of 80 km (50 mi) the atmosphere is barely dense enough to scatter sunlight to a visible degree. At heights of the order of 600 km (370 mi) the atmosphere's density becomes so low that the properties typical of a gas cease to exist and the free molecular paths are long enough that one must consider them as portions of elliptical orbits in the earth's gravitational field. At 1000 km (600 mi) the density of the atmosphere is still sufficient to yield readily observable auroral effects. At about 30,000 km (18,600 mi) above the earth's surface, a molecule moving as if in rigid rotation with the earth could not be held to such an orbit by the earth's gravitational attraction, so this height might be taken as an extreme upper limit of the possible atmosphere.

The atmosphere may be subdivided vertically into a number of atmospheric shells, but the most common basic subdivision is that which recognizes a troposphere from the surface to about ten kilometers, a stratosphere from about ten kilometers to about eighty kilometers, and an ionosphere above eighty kilometers; and each of these is often further subdivided.

Because the troposphere contains the bulk (about three-fourths) of the atmospheric mass and because it contains virtually all of the atmospheric water vapor, ordinarily weather events are most intimately concerned with the tropospheric phenomena.

The term atmosphere is also applied to the gaseous envelope surrounding any celestial body.

2. See standard atmosphere (1), model atmosphere.

Atmospheric acoustic-gravity wave – Large Tsunamigenic earthquakes which involve vertical crustal movements over large areas disturb the atmosphere and create atmospheric shock waves. These waves propagate from the earthquake area at a velocity of approximately 1050 ft/sec plus or minus 30 ft/sec (at approximately the speed of acoustic waves).

Atmospheric tsunami – A rapidly moving atmospheric pressure front moving over a shallow sea can couple with the sea surface and generate tsunami-like waves.

Atmospheric phenomenon – An observable occurrence of particular physical (as opposed to dynamic or synoptic) significance within the atmosphere.

Atmospheric pressure – (Also called barometric pressure.) The pressure exerted by the atmosphere as a consequence of gravitational attraction exerted upon the "column" of air lying directly above the point in question. As with any gas, the pressure exerted by the atmosphere is ultimately explainable in terms of bombardment by gas molecules; it is independent of the orientation of the surface on which it acts.

Atmospheric pressure is one of the basic meteorological elements. It is measured by many varieties of barometer, and is expressed in several unit systems. The most common unit used is the millibar (1 millibar equals 1000 dynes per cm^2). unique to the science of meteorology is the use of inches (or millimeters) of mercury; that is, the height of a column of mercury that exactly balances the weight of the column of atmosphere whose base coincides with that of the mercury column. Also employed are units of weight per area and units of force per area. A standard atmosphere has been defined in terms of equivalence to each of the above unit systems, and it is used as a unit itself.

See actual pressure, station pressure, sea-level pressure.

Atoll – A ring shaped coral reef, often carrying low sand islands, enclosing a lagoon.

Attenuation – In physics, any process in which the flux density (or power, amplitude, intensity, illuminance, etc.) of a "parallel beam" of energy decreases with increasing distance from the energy source. Attenuation is always due to the action of the transmitting medium itself (mainly by absorption and scattering). It would not be applied to the divergence of flux due to distance alone, as described by the inverse-square law.

Attenuation coefficient - A measure of the space rate of diminution or attenuation, of any transmitted energy. This quantity a may be identified in a form of Bouguer's Law *(or Beer's Law)*:

$$dI = -aIdx; \quad or$$
$$I = Ioe^{-ax}$$

where I is the flux density at the selected point in space, I_o is the flux density at the sourse, x is the distance from the sourse, and a is the attenuation coefficient. In general, the attenuation coefficient is specified only when the attenuation is known to be due to both absorption and scattering or when it is impossible to determine which is the cause. More common is the use of either the absorption coefficient or the scattering coefficient.

Audio – Pertaining to sound or to hearing; also applied to devices or systems designed to operate within the audio (sound-wave) frequency range, from about 20 to 15,000 cycles per second.

Autocorrelation – The simple linear correlation of a time series with its own past; that is, the correlation of the sequence of values $x(t)$ with the sequence of values $x(t + \tau)$ occurring τ units of time later. The time displacement τ is called the lag.

The autocorrelation function is the autocorrelation for variable lag.

See serial correlation.

Avalanche – 1. (Also called snowslide.) A mass of snow (perhaps containing ice and rocks) moving rapidly down a steep mountain slope.

Avalanches may be characterized as loose and turbulent, or slab; either type may be dry or wet according to the nature of the snow forming it, although dry snow usually forms loose avalanches and wet snow forms slabs.

2. (Also called landslide.) A mass of earth material (soil, rock, etc.) moving rapidly down a steep slope.

Awash – Situated so that the top is intermittently washed by waves or tidal action. Condition of being exposed or just bare at any stage of the tide between high water and chart datum.

Axial symmetry – The symmetry that describes a three-dimensional configuration which is the same in every plane containing the axis of symmetry. In cylindrical coordinates this implies independence of the azimuthal coordinate.

Axisymmetric – Having axial symmetry; independent of the azimuthal coordinate.

Azimuth – The length of the arc of the horizon (in degrees) intercepted between a given point and an adopted reference direction, usually true north, and measured clockwise from the reference direction. Thus, azimuth is a horizontal direction expressed in degrees. Azimuth may be synonymous with bearing, but the latter is a navigation term and can be modified in several ways. In seismology the epicenter of an earthquake could be approximated from data at one station by determining the time difference between p and s waves, which may give the distance to the earthquake source, and the azimuth which could be determined by differences in the time of arrival of the signal at two or more seismometers, or an array of seismometers, telemetering data to that station.

Any point on or above the horizon can be located by its angles of azimuth and elevation plus either height or distance (or slant range) data.

–B–

Backbeach – See backshore

Background noise – Any unwanted sound; and by extension, any "unwanted," usually random, fluctuation of a signal caused by background sources unrelated to the signal being measured; in statistics, any unwanted components of a time series.

Backrush – The seaward return of the water following the uprush of the waves. For any given tide stage the point of farthest return seaward of the backrush is known as the limit of the backrush or limit backrush.

Backshore – That zone of the shore or beach lying between the foreshore and the coastline and acted upon by waves only during severe storms, especially when combined with exceptionally high water. Also backbeach. It comprises berm or berms. (See Figure A-1.)

Backwash – Intermittent seaward flow of water across a beach; the return of swash to the sea.

Bank – 1. The rising ground bordering a lake, river, or sea; of a river channel, designated as right or left as it would appear facing downstream.

2. An elevation of the sea floor of large area, located on a continental (or island) shelf and over which the depth is relatively shallow but sufficient for safe surface navigation; a group of shoals.

3. In its secondary sense, a shallow area consisting of shifting forms of silt, sand, mud, and gravel, but in this case it is only used with a qualifying word such as "sandbank" or "gravelbank."

Bar – A submerged or emerged embankment of sand, gravel, or other unconsolidated material built on the sea floor in shallow water by waves and currents.

See baymouth barn cuspate bar. (See Figures A-2 and A-9.)

Baroclinic wave – In Meteorology,waves of the state in which surfaces of constant pressure and others of constant density are not parallel but intersect; any migratory cyclone more or less associated with strong baraclinity of the atmosphere, evidenced on synoptic charts by temperature gradients in the constant-pressure surfaces, vertical wind shear, tilt of pressure troughs with height, and concentration of solenoids in the frontal surface near the ground. Baroclinic disturbances play an important role in atmospheric energy conversion from potential energy to kinetic energy.

Barogram – The record of a barograph.

Barograph – A recording barometer. Barographs may be classified on the basis of their construction into the following types: (a) aneroid barograph (including microbarograph), (b) float barograph, (c) photographic barograph, and (d) weight barograph.

Barotropic disturbance – (Or barotropic wave.) 1. A wave-disturbance in a two-dimensional non-divergent flow, the driving mechanism for which lies in the variation of vorticity of the basic current and/or in the variation of the vorticity of the earth about the local vertical. When the basic current is uniform, the wave is a Rossby wave.

Barrier beach – A single, narrow, elongate sand ridge rising slightly above the high-tide level and extending generally parallel with the shore, but separated from it by a lagoon or marsh.

Barrier lagoon – A bay roughly parallel to the coast and separated from the open ocean by barrier islands. Also the body of water encircled by coral islands and reefs, in which case it may be called an atoll lagoon.

Barrier reef – A coral reef parallel to and separated from the coast by a lagoon that is too deep for coral growth. Generally, barrier reefs follow the coasts for long distances, and are cut through at irregular intervals by channels or passes.

Base map – A map designed for the presentation and analysis of data; it usually includes only the coordinates, geographical and major political outlines, and sometimes the larger lakes and rivers. Many modifications exist for specific uses throughout the geophysical sciences, such as the frequent inclusion of fixed reference points. Mountains and contour lines are generally omitted, but high ground may be indicated by a single contour line and light shading.

Basin, boat – A naturally or artificially enclosed or nearly enclosed harbor area for small craft.

Bathyal – Referring to that part of the ocean between depths of about 200 to 2,000m.

Bathymetric chart – A map delineating the form of the bottom of a body of water, usually by means of depth contours (isobaths).

Bathymetry – The measurement of depth in the oceans and the charting of the topography of the ocean floor.

Bathythermograph – An instrument used to measure temperature in the ocean.

Bay – A recess in the shore or an inlet of a sea between two capes or headlands, not as large as a gulf but larger than a cove.,

See also bight, embayment. (See figure A-9.)

Baymouth bar – A bar extending partly or entirely across the mouth of a bay.

Beach – The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach – unless otherwise specified – is the mean low water line. A beach includes foreshore and backshore. (See Figure A-1.)

Beach Accretion – See accretion.

Beach berm – A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several. (See Figure A-1.)

Beach cusp – See cusp.

Beach erosion – The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

Beach face – The section of the beach normally exposed to the action of the wave uprush. The foreshore of a beach. (Not synonymous with shoreface.) (See Figure A-2.)

Beachfront – The area adjacent to the beach.

Beach ridge – See ridge, beach.

Beach scarp – See scarp, beach.

Beach width – The horizontal dimension of the beach measured normal to the shoreline.

Beam – A ray or collection of focused rays of radiated energy.

See beam width, radiation pattern.

2. See electron beam.

Beat – A wave phenomenon which occurs when two or more waves of different frequencies become superimposed. The resultant wave has amplitude maxima ("beats") at the frequency equal to the difference of the frequencies of the initial waves.

Beating – Wave phenomenon which occurs when two or more waves of different frequencies become superimposed. The resultant wave has amplitude maxima ("beats") at the frequency equal to the difference of the frequencies of the initial waves. This process may be controlled (heterodyne) to produce a desired beat frequency; that is, to produce a resultant wave with a frequency that is ideally suited for a given operation.

Bench – 1. A level or gently sloping erosion plane inclined seaward.

2. A nearly horizontal area at about the level of maximum high water on the sea side of a dike.

Bedrock – A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.

Beinoff seismic zone – A plane beneath the trenches of the circum-Pacific belt, dipping toward the continents at an angle of about 45°, along which earthquake foci cluster. According to plate tectonics, lithospheric plates sink into the mantle through this zone.

Bench mark – A permanently fixed point of known elevation. A primary bench mark is one close to a tide station to which the tide staff and tidal datum originally are referenced.

Berm – Flat portion of a beach formed by wave action.

Berm, beach – See beach berm.

Berm crest – The seaward limit of a berm. Also berm edge. (See Figure A-1.)

Bernoulli's theorem – As originally formulated, a statement of the conservation of energy (per unit mass) for a non-viscous fluid in steady motion. the specific energy is composed of the kinetic energy $v^2/2$ where v is the speed of the fluid; the potential energy gz where g is the acceleration of gravity and z the height above an arbitrary reference level; and the work done by the pressure forces $\int \alpha dp$ where p is the pressure, α the specific volume, and the integration is always with respect to values of p and α on the same parcel. Thus, the relationship

$$\frac{v^2}{z} + gz + \int \alpha dp = \text{constant along a streamline,}$$

is valid for steady motion, since the streamline is also the path. If the motion is also irrotational, the same constant holds for the entire fluid.

The following special cares are important: (a) as originally formulated for a homogeneous incompressible fluid,

$$\int \alpha dp = \alpha p \ ;$$

and (b) for a perfect gas undergoing adiabatic processes,

$$\int \alpha dp = c_p T$$

where c_p is the specific heat at constant pressure and T the Kelvin temperature. If there is diabatic heating on the parcel at the rate dQ/dt per unit mass, then

$$\int \alpha dp = c_p T - \int dQ \ .$$

Prandtl, L., Essentials of Fluid Dynamics, 1952, Ch. II, passim.
Haurwitz, B., Dynamic meteorology, 1941, pp. 238-241

Bight – A bend in a coastline forming an open bay. A bay formed by such a bend. (See Figure A-8.)

Blast wave – A sharply defined wave of increased atmospheric pressure rapidly propagated through a surrounding medium from a center of detonation or similar disturbances.

Block faulting – A type of normal faulting in which the crust is divided into structural or fault blocks of different elevations and orientations.

Block tectonics – Type of normal or gravity faulting caused by earthquake activity in which the crust is separated into structural units or blocks of different orientations and elevations.

Bluff – A high steep bank or cliff.

Bold coast – A prominent land mass that arises steeply from the sea.

Body waves – A seismic wave that travels through the interior of the earth with a propagation mode that does not depend on any boundary surface. A body wave may be either longitudinal (a P wave) or transverse (a S wave).

Bore – A tidal flood with high abrupt front, due to a rapidly narrowing inlet or channel. They recur in given areas with timeless regularity.

Bottom (nature of) – The composition or character of the bed of an ocean or other body of water (e.g., clay, coral, gravel, mud, ooze, pebbles, rock, shell, shingle, hard, or soft).

Bottom friction – Friction caused by the interaction between the water wave and the bottom of the wave's medium. For water waves traveling onshore the average longshore velocity (V_L) is expressed by:

$$V_L \cong C^1 \langle \frac{SgH_0^2}{T} \sin 2d \rangle^{\frac{1}{3}}$$

S= ave. slope of beach
C^1= coefficient of bottom friction
generally has values of 1.5~3.5.

Bottom roughness – The state of uneven surface on the sea bottom.

Bottom water – The water mass at the deepest part of the water column. It is the densest water that is permitted to occupy that position by the regional topography. In the case of a basin, bottom water may be formed locally, or it may represent the densest water that has existed at sill depth in the recent past.

Boulder – A rounded rock more than 10 inches in diameter; larger than a cobblestone.

See soil classification.

Boundary conditions – Determined by the physical nature of the problem, and is a necessary part of the problem's complete formulation.

Boundary layer – The layer of fluid in the immediate vicinity of a bounding surface, referring ambiguously to the laminar boundary layer, turbulent boundary layer, planetary boundary layer, or surface boundary layer.

Boundary-value problem – A physical problem completely specified by a differential equation in

an unknown, valid in a certain region of space, and certain information (boundary conditions) about the unknown given on the boundaries of that region. The information required to determine the solution depends completely and uniquely on the particular problem.

Bourdon tube – (also called pressure sensor)

Boussinesq approximation – The assumption (frequently used in the theory of convection) that the fluid is incompressible except insofar as the thermal expansion produces a buoyancy, represented by the term $g\alpha T'$, where g is the acceleration of gravity, α the coefficient of thermal expansion, and T' the perturbation temperature.

Boussinesq number – The ratio of the eddy flux of some quantity to the molecular flux of that quantity.

Breached anticline – An anticline whose crest has been deeply eroded so that it is flanked by inward-facing erosional scarps.

Breaker – A sea-surface wave that has become so steep (wave steepness of 1/7) that the crest outraces the body of the wave and collapses into a turbulent mass on shore or over a reef of rock. Breaking usually occurs when the water depth is less than 1.28 times the wave height.Roughly, three kinds of breakers can be distinguished, depending primarily on the gradient of the bottom: (a) spilling breakers (over nearly flat bottom) which form a foamy patch at the crest and break gradually over a considerable distance; (b) plunging breakers (over fairly steep bottom gradient) which peak up, curl over with a tremendous overhanging mass, and then break with a crash; (c) surging breakers (over very steep bottom gradients) which do not spill or plunge but surge up the beach face. Waves also break in deep water if they build too high while being generated by the wind, but these are usually short-crested and are termed whitecaps.

Breaker depth – The stillwater depth at the point where a wave breaks. Also breaking depth. (See Figure A-2.)

Breaking criteria – When the steepness (ratio of wave height to wave length) exceeds 1/7, the laws which govern surface-wave motion can no longer be satisfied and the crest of the wave outraces the body of the wave and surges to the shore.

Breakwater – An offshore structure(as a wall) used to protect a harbor or beach from the force of waves.

Bulkhead – A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

Buoy – A float; especially a floating object moored to the bottom, to mark a channel, anchor, shoal, rock, etc.

Buoy system instrumentation – Instrumentation attached to the bottom - anchored or free-floating buoy system for the measurement of oceanographic and meteorological parameters.

Two basic systems involving the buoys and their moorings are used. The selection of either arrangement, used separately or in combination with the other, depends on the requirements of the scientist. In the slack wire system, sufficient slack is left in the line to avoid having the float submerge with changing tide and current and to allow sufficient scope to avoid dragging of the anchore.

The taut wire system is one in which a submerged or partially submerged float keeps the vertical line to the anchor taut and nearly vertical. The taut wire mooring system reduced the horizontal and vertical motion, and is thus advantageous for current meters and sensors in which constant depth and extraneous motions are critical. Another desirable feature is that it permits the submergence of a power supply and recorders, which may or may not be connected to a surface floating marker. This system makes it less likely for the valuable instrument package float to be run down by ships or stolen.

The uses of the buoy or floats vary widely. One role of the buoys is to serve as a marker float for navigational purposes or to fix a position for repeated observation at the same location.

Buoyancy – 1. That property of an object that enables it to float on the surface of a liquid, or ascend through and remain freely suspended in a compressible fluid such as the atmosphere. Quantitatively, it may be expressed as the ratio of the specific weight of the fluid to the specific weight of the object; or, in another manner, by the weight of the fluid displaced minus the weight of the object.

2. (Or buoyant force; also called Archimedean buoyant force.) The upward force exerted upon a parcel of fluid (or an object within the fluid) in a gravitational field by virtue of the density difference between the parcel (or object) and that of the surrounding fluid. The magnitude of the buoyancy force F per unit mass may be determined by Archimedes's principle as

$$F = g\left(\frac{\rho_0}{\rho} - 1\right)$$

where g is the acceleration of gravity, ρ the density of the buoyed fluid parcel or object, and ρ_0 the density of the surrounding fluid.

–C–

Cable – A nautical unit of horizontal distance, equal to 600 feet (100 fathoms) and approximately one-tenth of a nautical mile.

Cable system instrumentation – Direct line measurement uses a lead wire with a heavy end. Direct line measurement is somewhat obsolete.

Cake ice – Flat pieces of sea ice larger than brash. Cake ice often is tightly packed giving a mosaic appearance, but its surface is generally smooth in contrast to rough, hummocked pressure ice.

Calamity – grievous affliction; adversity; misery; a great misfortune; disaster [Random 208]

Caldera – A large, basin-shaped volcanic depression, more or less circular or circlelike in form, the diameter of which is many times greater than that of the included vent or vents, no matter what the steepness of the walls or form of the floor.

Calibration – The process whereby a position on the scale of an instrument is identified with the magnitude of the signal (or input force) actuating that instrument.

Calm – The absence of apparent motion.

Canal – An artificial watercourse cut through a land area for such uses as navigation and irrigation.

Candle ice – (Or candled ice; also called penknife ice, needle ice.) A form of rotten ice; disintegrating sea ice (or lake ice) consisting of ice prisms or cylinders oriented perpendicular to the original ice surface; these "ice fingers" may be equal in length to the thickness of the original ice before its disintegration.

Canyon – A relatively narrow, deep depression with steep slopes, the bottom of which grades continuously downward. May be underwater (submarine) or on land (subaerial).

Cape – A relatively extensive land area jutting seaward from a continent or large island which prominently marks a change in, or interrupts notably, the coastal trend; a prominent feature. (See Figure A-8.)

Capillary action – The depression or elevation of the meniscus of a liquid contained in a tube of small diameter due to the combined effects of surface tension and the forces of cohesion and adhesion. When the liquid wets the wall of a container, the meniscus is shaped convex downward; if the liquid does not wet the walls of the container, the miniscus is shaped convex upward.

Capillary wave – A wave whose wave length is shorter than 1.7cm and whose propagation velocity is controlled mainly by the surface tension of the liquid in which the wave is travelling.

Cartesian coordinates – A coordinate system in which the locations of points in space are expressed by reference to three planes, called coordinate planes, no two of which are parallel. The three planes intersect in three straight lines, called coordinate axes. The coordinate planes and coordinate axes intersect in a common point, called the origin. From any point P in space three straight lines may be drawn, each of which is parallel to one of the three coordinate axes; each of these lines will then intersect one (and only one) of the three coordinate planes. If A, B, C denote these points

of intersection, the Cartesian coordinates of P are the distances PA, PB, and PC. If the coordinate axes are mutually perpendicular, the coordinate system is rectangular; otherwise, oblique.

The most common orientation of the x, y, z rectangular Cartesian coordinates is such that the x-axis is directed toward the east, tangent to the earth's surface, the y-axis toward the north, tangent to the earth's surface, and the z-axis toward the local zenith, perpendicular to the earth's surface.

Catastrophic waves – Large waves, resulting from intense storms or submarine slumping, that can cause immense damage and loss of life.

Cauchy-Poisson problem –The generation of tsunami by a bottom disturbance can be treated as a shallow water case of the Gauchy-Poisson initial wave problem by taking the vertical velocity of the bottom movement as a boundary value of the velocity potential.

Cauchy-Poisson wave – The initial wave resulting from the vertical acceleration at the bottom as the forcing function.

Causeway – A raised road, across wet or marshy ground, or across water.

Caustic – In refraction of waves, the name given to the curve to which adjacent orthogonals of waves refracted by a bottom whose contour lines are curved, are tangents. The occurrence of a caustic always marks a region of crossed orthogonals and high wave convergence.

CCCO - Committee on Climatic Changes and the Ocean.

Celerity – Wave speed.

Celsius temperature scale – Same as centigrade temperature scale, by recent convention. The Ninth General Conference on Weights and Measures (1948) replaced the designation "degree centigrade" by "degree Celsius." Originally, Celsius took the boiling point as 0 degrees and the ice point as 100 degrees.

Centigrade temperature scale – (Abbreviated C.) A temperature scale with the ice point at 0 degrees and the boiling point of water at 100 degrees. Conversion to the Fahrenheit temperature scale is according to the formula

$$°C = \frac{5}{9}(°F - 32).$$

See Celsius temperature scale.

Centimeter-gram-second system – (Abbreviated cgs system.) A system of physical units based on the use of the centimeter, the gram, and the second as elementary quantities of length, mass, and time, respectively. In this system, density is expressed in gm/cm^3, speed in cm/sec, force in dynes (gm cm/sec^2), pressure in baryes (dyne/cm^2), and energy in ergs. While this is the most popular system of units in nearly all fields of science and technology, some of the meter-ton-second system units are more convenient for certain meteorological applications.

Central moment – In statistics, a moment taken about the mean.

Central tendency – In statistics, the general level, characteristic, or typical value that is representative of the majority of cases. Among several accepted measures of central tendency employed in data reduction, the most common are the arithmetic mean (simple average), the median, and the mode.

Centrifugal force – The apparent force in a rotating system, deflecting masses radially outward from the axis of rotation, with magnitude per unit mass $\omega^2 R$, where ω is the angular speed of rotation, and R is the radius of curvature of the path. This magnitude may also be written as V^2/R, in terms of the linear speed V. This force (per unit mass) is equal and opposite to the centripetal acceleration. The centrifugal force on the earth and atmosphere due to rotation about the earth's axis is incorporated with the field of gravitation to form the field of gravity.

Centripetal acceleration – The acceleration on a particle moving in a curved path, directed toward the instantaneous center of curvature of the path, with magnitude V^2/R, where V is the speed of the particle and R the radius of curvature of the path. This acceleration is equal and opposite to the centrifugal force per unit mass.

CERESIS - Regional Center for Seismology in South America.

Cfs – Abbreviation for cubic foot per second, a unit of discharge commonly used in hydrology and hydraulics.

CGOM - Consultative Group on Ocean Mapping.

Channel – 1. A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water.

2. The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation.

3. A large strait, as the English Channel.

4. The deepest part of a stream, bay, or strait through which the main volume or current of water flows.

Characteristic equation – 1. An equation defining the characteristics of a set of partial differential equations.

2. A linear algebraic equation determining the eigenvalues (see characteristic-value problem) or free waves of a boundary-value problem.

Characteristic length – Some representative length on a physical system, e.g., the radius of a vortex, the radius of the earth.

Characteristics – Lines or surfaces associated with a partial differential equation, or with a set of such equations, which are at all points tangent to characteristic directions, determined by certain specified linear combinations of the equations. The use of these lines or surfaces may facilitate the solution of the equations and is known as the method of characteristics. The method has been particularly successful, for example, in the problem of finite-amplitude expansion and shock waves.

Characteristic-value problem – A problem in which an undetermined parameter is involved in the coefficients of a differential equation, and in which the solution of the differential equation, with associated boundary conditions exists only for certain discrete values of the parameter, called eigenvalues (or characteristic values, sometimes principal values). An important example of a physical problem which leads to a characteristic-value problem is the determination of the modes and frequencies of a vibrating system. In this case the dependent variable of the differential equation represents the displacements of the system and the parameter represents the frequencies of vibration.

Characteristic velocity – Some representative velocity in a physical system.

Characteristic wave height – See significant wave height.

Chart datum – The tidal datum to which soundings on a navigation chart are referred. In order to provide a factor of safety, some level lower than mean sea level is generally selected, such as mean low water or mean lower low water.

Chi-square test – A statistical significance test based on frequency of occurrence; it is applicable both to qualitative attributes and quantitative variables. Among its many uses, the most common are tests of hypothesized probabilities or probability distributions (goodness of fit), statistical dependence or independence (association), and common population (homogeneity). The formula for chi square (x^2) depends upon intended use, but is often expressible as a sum of terms of the type $(f-h)^2/h$ where f is an observed frequency and h is its hypothetical value.

Chop – The short-crested waves that may spring up quickly in a moderate breeze, and break easily at the crest. Also wind chop.

Choppy sea – Popularly, descriptive of short, rough, irregular wave motion on a sea surface.

Chronograph – 1. A clock-driven device for recording the time of occurrence of an event. It is often used, for example, in conjunction with a contact anemometer and a wind vane to obtain a record of wind speed and direction as a function of time.

See multiple register.

2. A clock-driven device for measuring the time interval between the occurrence of events.

CIG - Comite International de Geophysique

Circular variable – A variable represented by a vector quantity in polar coordinates.

Circulation – The flow or motion of a fluid in or through a given area or volume.

Circulation integral – The line integral of an arbitrary vector taken around a closed curve. Thus

$$\oint a \cdot dr$$

is the circulation integral of the vector a around the closed curve. *dr* is an infinitesimal vector element of the curve. If the vector is the velocity, this integral is called the circulation.

CIRES - Cooperative Institute for Research in Environmental Sciences.

Clapotis – The French equivalent for a type of standing wave. In American usage it is usually associated with the standing wave phenomenon caused by the reflection of a nonbreaking wave train from a structure with a face that is vertical or nearly vertical. Full clapotis is one with 100 percent reflection of the incident wave; partial clapotis is one with less than 100 percent reflection.

Clastic – Pertaining to rock or sediment composed principally of mineral or rock fragments.

Clastic sediments – Composed primarily of detritus transported mechanically to its place of deposition, i.e., sand, silt, clay.

Cliff – A high, steep face of rock; a precipice.

See also sea cliff.

CLIMAP - Climate Long-range Mapping and Prediction.

CNET - Centre National d'Etudes des Télécommunications.

Cnoidal wave – A type of wave in shallow water (depth of water is less than 1/8 to 1/10 the wavelength). The surface profile is expressed in terms of the Jacobian elliptic function *cn u*; hence the term cnoidal.

Coast – A strip of land of indefinite width (may be several miles) that extends from the shoreline inland to the first major change in terrain features.

Coastal area – The land and sea area bordering the shoreline.

Coastal current – an ocean current near the coast which may be caused directly by the stress of wind on the sea surface, or the astronomical tides on periodic basis, or by transport induced by gravity waves or by fresh water entering the ocean with considerable momentum. Tsunami waves flooding a shore establish a hydraulic head near the shore and the water returning seaward often induces coastal currents which may vary in strength and may last for several hours after the first tsunami arrival.

Coastal plain – The plain composed of horizontal or gently sloping strata of clastic materials fronting the coast, and generally representing a strip of sea bottom that has emerged from the sea in recent geologic time.

Coastal engineering – The application of science and mathematics by which the properties of land near a shore are made useful to man in structures, machines, products, systems, and processes.

Coastal responce – Tsunami modification due to interaction with coastal topography and bathymetry.

Coastal topography – 1. The art or practice of graphic delineation in detail usually on maps or charts of land near a shore especially in a way to show relative positions and elevations.

2. The physical or natural features of a land near a shore and its structural relationship.

Coastal zone – A distinctive area near the seashore embracing both a strip of land and sea.

Coastline – 1. Technically, the line that forms the boundary between the coast and the shore.

2. Commonly, the line that forms the boundary between the land and the water.

COCORP - Consortium for Continental Reflection Profiling.

CODATA - Committee on Data for Science & Technology.

Comber – 1. A deepwater wave whose crest is pushed forward by a strong wind; much larger than a whitecap.

2. A long-period breaker.

Communication Plan for The Tsunami Warning System – A communications operating manual for the Tsunami Warning System for all participants listing tidal and seismological stations which participate in the warning system, preferred methods of communications between the stations and the Pacific Tsunami Warning Center, and criteria for reporting. The Plan also lists recipients of tsunami watch and warning messages and methods by which the messages are sent. The Plan provides also a general overview of the operational procedures of the Tsunami Warning System and of the nature of tsunamis.

Compressible fluid – Fluid that does not have constant volume. The volume can be forced into smaller space.

Compressibility – The quality or state of being compressible. The reciprocal of the bulk modulus, equal to the ratio of the fractional change in volume to the stress applied to a body.

Compressional, or P-Waves – Seismic waves, also known as body waves or primary waves, which travel through the body of the earth by the progressive compression of particles.

Computational instability – An instability in a finite difference equation which does not exist in the differential equation approximated thereby. If the instability exists, errors introduced from any source into the computation will grow in the iteration process until the resulting solution is without physical significance. The existence of computational instability depends on the particular finite-difference approximation employed.

Conditions of readiness – Those preliminary measures prescribed for a given area in anticipation of hazardous and destructive phenomena.

Conductivity – A unit measure of electrical conduction; the facility with which a substance conducts electricity, as represented by the current density per unit electrical-potential gradient in the direction of flow. Electrical conductivity is the reciprocal of electrical resistivity and is expressed in units, such as mhos (reciprocal ohms) per cm. It is an intrinsic property of a given type of material under given physical conditions (dependent mostly upon temperature). Conductance, on the other hand, varies with the dimensions of the conducting system, and is the reciprocal of the electrical resistance.

Confidence interval – (Also called fiducial interval, confidence band.) A range of values ($a_1<a<a_2$) determined from a sample by definite rules so chosen that in repeated random samples from the hypothesized population, an arbitrarily fixed proportion ($1 - \varepsilon$) of that range will include the true value α of an estimated parameter.

The limits (a_1 and a_2) are called confidence limits or fiducial limits; the relative frequency ($1 - \varepsilon$) with which these limits include α is called the confidence coefficient; and the complementary probability ε is called the confidence level. As with significance levels, confidence levels are commonly chosen as .05 or .01, the corresponding confidence coefficients being .95, .99.

Confidence intervals should never be interpreted as implying that the parameter itself has a range of values; it has only one value, α. On the other hand, the confidence limits (a_1, a_2), being derived from a sample, are random variables the values of which on a particular sample either do or do not include the true value α of the parameter. However, in repeated samples, a certain proportion (namely $1 - \varepsilon$) of these intervals will include α, provided that the actual population satisfies the initial hypothesis.

Confidence limits – (Also called fiducial limits.) See confidence interval.

– (Also called isogonal map, orthomorphic map.) A map which preserves angles; that is, a map such that if two curves intersect at a given angle, the images of the two curves on the map also intersect at the same angle. On such a map, at each point, the scale is the same in every direction. Shapes of small regions are preserved, but areas are only approximately preserved (the property of area conservation is peculiar to the equal-area map). The most commonly used conformal map is probably the Lambert conic projection, with standard latitudes at 30 degrees and 50 degrees N. On the standard latitudes, the scale is exact; between them, it is decreased by not more than about 1 percent; outside them, distortion increases rapidly. The Mercator and stereographic projections are also conformal maps.

Saucier, E.J., Principles of Meteorological Analysis, 1955

Conjunction – In astronomy, the juxtaposition of the earth, sun, and of the other planets or the moon, in which the angle subtended at the earth between the sun and the third body, in the plane of the ecliptic, is 0° (that is, the third body lies either between the sun and the earth, or on the opposite side of the sun from the earth. Compare opposition, quadrature.

Consecutive mean – Also called moving average, overlaping mean, running mean. A smoothed representation of a time series derived by replacing each observed value with a mean value computed over a selected interval. Consecutive means are used in smoothing to eliminate unwanted periodicities or minimize irregular variations.

Conservation of energy – The principle that the total energy of an isolated system remains constant. This principle takes into account all forms of energy in the system; it therefore provides a constraint on the conversions from one form to another. Such equations as the first law of thermodynamics and Bernoulli's equation are formulations of the conservation principle for systems admitting only certain forms.

Conservation of mass – The principle (of Newtonian mechanics) which states that mass cannot be created or destroyed but only transferred from one volume to another. This principle is generally expressed in the form of the equation of continuity.

Conservation of momentum – The principle that in the absence of forces absolute momentum is a property which cannot be created or destroyed.

Consolidated ice – An area of the sea covered by ice of various origins consolidated, by wind and currents, into a solid mass.

Continental drift – A theory, originally proposed by Wegner, that continents have moved laterally hundreds or thousands of kilometers over the past few hundreds of millions of years at very slow rates. South America, for example, was formerly continuous with southern Africa in this theory.

Continental margin – That portion of the ocean adjacent to the continent and separating it from the deep sea. The continental margin includes the continental shelf, continental slope, and continental rise.

Continental platform – The zone that includes both the continental shelf or continental borderland and the continental slope.

Continental rise – An area of gentle slope (usually less than half a degree or 1:100) at the base of the continental slope.

Continental shelf – That part of the continental margin that is between the shoreline and the continental slope (or, when there is no noticeable continental slope, adepth or 200 m). It is characterized by its very gentle slope of 0.1.

Continental slope – That part of the continental margin that is between the continental shelf and the continental rise of or oceanic trench. It is characterized by its relatively steep slope of 3.6.

Continuity – The property of a field, such that neighboring values of a parameter differ only by an arbitrarily small amount if they are close enough in space and/or time.

Continuity equation – See equation of continuity.

Continuous spectrum – A spectrum in which wave lengths (and wave numbers and frequencies) are represented by the continuum of real numbers (or a portion thereof) rather than by a discrete sequence of numbers. A continuous function on an infinite interval, even though the function is non-zero over only a finite interval, must be represented by the Fourier transform rather than by Fourier series, and the resulting spectrum will be continuous.

See also discrete spectrum.

Contour – Generally, an outline or configuration of a body or surface. Often, the term is used for one of a set of lines (contour lines) drawn to represent the configuration of a surface.

Contour line – Also called contour, isohypse, isoheight. A line of constant elevation above a certain reference level (usually mean sea level) on a previously defined surface which may be the earth's surface, a constant-pressure surface, an isentropic surface. A contour line of a given value is the intersection of the surface in question with the constant-height surface of the same elevation as the value of the contour line.

Contour map – A map that shows the configuration of a surface by means of contour lines drawn at regular intervals of elevation ("contour intervals") above a reference level.

Convection – In general, mass motions within a fluid resulting in transport and mixing of the properties of that fluid. Convection is a principal means of energy transfer. Distinction is made between: free convection (or gravitational convection), motion caused only by density differences within the fluid; and forced convection, motion induced by mechanical forces such as deflection by a large-scale surface irregularity, turbulent flow caused by friction at the boundary of a fluid, or motion caused by any applied external force.

Convective term – (Also called advective term.) Any term of the form $\mathbf{V} \cdot \nabla\xi$ where $\mathbf{V}$ is the velocity field, ∇ is the del-operator, and ξ is any field, vector or scalar. Thus, for example, $u(\partial u/\partial x)$ is a convective acceleration.

These are the non-linear terms in the Eulerian expressions for the rate of change of the dependent variables.

Convergence – 1. The contraction of a vector field; also, a precise measure thereof. Mathematically, convergence is negative divergence, and the latter term is used for both. (For mathematical treatment, see divergence.)

Compare confluence.

2. The property of a sequence or series of numbers or functions which ensures that it will approach a definite finite limit.

Coordinate system – (Also called reference frame.) Any scheme for the unique identification of each point of a given continuum. These may be points in space (Eulerian coordinates) or parcels of a moving fluid (Lagrangian coordinates). Newton's laws of motion do take different forms in different systems (see inertial coordinate system, relative coordinate system). The geometry of the system is a matter of convenience determined by the boundaries of the continuum or by other considerations.

See Cartesian coordinates, curvilinear coordinates.

Coral – 1. (Biology) Marine coelenterates (Madreporaria), solitary or colonial, which form a hard external covering of calcium compounds, or other materials. The corals which form large reefs are limited to warm, shallow waters, while those forming solitary, minute growths may be found in colder waters to great depths.

2. (Geology) The concretion of coral polyps, composed almost wholly of calcium carbonate, forming reefs, and tree-like and globular masses. May also include calcareous algae and other organisms producing calcareous secretion, such as bryozoans and hydrozoans.

Coral reef – A reef composed mainly of coral and other organic matter of which parts have solidified into limestone.

Core – A vertical cylindrical sample of the bottom sediments from which the nature and stratification of the bottom may be determined.

Core of the earth – Iron-nickel metal, in part molten, making up the innermost part of the earth.

Coriolis acceleration – An acceleration of a parcel moving in a (moving) relative coordinate system. The total acceleration of the parcel, as measured in an inertial coordinate acceleration of the relative system itself, and the coriolis acceleration. In the case of the earth, moving with angular velocity Ω, a parcel moving relative to the earth with velocity V has the coriolis acceleration $2\Omega \times V$. If Newton's laws are to be applied in the relative system, the coriolis acceleration and the acceleration of the relative system must be treated as forces.

See apparent force, coriolis force, inertial force, gravity.

Coriolis force – (Also called compound centrifugal force, deflecting force.) An apparent force on moving particles in a non-inertial coordinate system, i.e., the coriolis acceleration as seen in this (relative) system. Such a force is required if Newton's laws are to be applied in this system. The coriolis force per unit mass arises solely from the earth's rotation, and is equal to $-2\Omega \times V$, where Ω is the angular velocity of the earth, and V is the (relative) velocity of the particle. Thus the coriolis force acts as a "deflecting force," normal to the velocity, to the right of motion in the northern hemisphere and to the left in southern hemisphere. It cannot alter the speed of the particle. The three components toward east, north and zenith are, respectively, $2\Omega(v \sin \phi - w \cos \phi$, $-2\Omega u \sin \phi$, and $2\Omega u \cos \phi$, where u, v, w are the component velocities and ϕ the latitude.

Coriolis parameter – Twice the component of the earth's angular velocity about the local vertical, $2\Omega \sin \phi$, where Ω is the angular speed of the earth and ϕ is the latitude. Since the earth is in rigid rotation, the coriolis parameter is equal to the component of the earth's vorticity about the local vertical. If the coriolis parameter be denoted by f and the speed of a horizontally-moving fluid parcel by V, then fV is the magnitude of the horizontal coriolis force per unit mass on the parcel.

– 1. In general, a mutual relationship between variables or other entities. In statistical terminology, it is a form of statistical dependence.

2. When used without further qualification, the statistical term correlation usually refers to simple, linear correlation between two variables x, y and is measured by the product-moment coefficient of correlation or its sample estimate defined as follows, where the respective population mean values of x and y are denoted by ξ and ζ, the respective standard deviations by and $\sigma(x)$, and $\sigma(y)$, where E is the expected value:

$$\rho = \frac{E[(x - \xi)(y - \zeta)]}{\sigma(x)\,\sigma(y)};$$

$$r = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma(x_i - \bar{x})^2\,\Sigma(y_i - \bar{y})^2}}.$$

The product-moment $E[(x - \xi)(y - \zeta)]$is usually called the covariance of x and y. In connection with correlation, the word "simple" is used in contradistinction to other qualifiers such as "multiple" or "partial." The word "linear" refers to a linear relationship between the two variables, or more precisely, to a linear approximation of the regression function of either variate with respect to the other.

See autocorrelation, multiple correlation, partial correlation.

3. See correlation coefficient.

Correlation coefficient – 1. See correlation.

2. A measure of the persistence of eddy velocity as a function of time and space. Two types are distinguished.

(a) In the Eulerian correlation coefficient the time difference is zero,

$$R_{E^{ik}}(y_1 y_2) = \frac{\overline{u'(y_1)\,u'(y_2)}}{\sqrt{\overline{u_i'^2(y_1)}}\,\sqrt{\overline{u_k'^2(y_2)}}}$$

where u' is the eddy velocity. For homogeneous and homologous turbulence this correlation tensor depends only on the difference $(y_2 - y_1)$; and when the turbulence this correlation tensor depends only on the difference $(y_2 - y_1)$; and when the turbulence is isotropic, the tensor is spherically symmetric and $R_{E^{ik}} = R_{E^{ki}}$.

(b) In the Lagrangian correlation coefficient time and space are varied together in such a way that the same fluid parcel is being followed.

$$R_L{}^{ik}(t) = \frac{\overline{u'(y_1t_1)\,u'(y_2t_2)}}{\sqrt{u_i'^2(y_1t_1)}\,\sqrt{u_k'^2(y_2t_2)}}.$$

When the flow is one-dimensional and the mean velocity much greater than the eddy velocity, then a fixed point experiences approximately the same sequence of fluctuations that a fluid parcel does. The Lagrangian correlation coefficient can then be converted into the Eulerian by a proper scaling.

These correlation coefficients have the same form and meaning when any other fluctuating quantity is used, e.g., temperature or pressure.

Correlation ratio – A measure of statistical relationship which takes into account all functional relationship between random variables in contrast to the correlation coefficient which measures only the linear relationship.

Corrosion – The gradual deterioration of material by chemical processes, such as oxidation or attack by acids; if caused by an atmospheric effect, a form of weathering. Of great significance is the corrosion due to the combined effects of atmospheric temperature, humidity, and suspended impurities; for example, the rusting of iron, the direct effects upon a surface wetted by sea water, by acid rain water, or, indirectly, the rotting of wood caused by the action of fungi or bacteria in the soil and in enclosed spaces. Compare corrosion, erosion.

Co-spectrum – The real part of the cross-spectrum of two functions.

Cotidal – Indicating equality in the tides or a coincidence in the time of high or low tide.

Cotidal hour – (Also called high-water interval, lunitidal interval.) The average interval of time between the moon's passage over the meridian of Greenwich and the following high water at a specified place.

Cotidal line – A line connecting places having the same cotidal hour for a given lunar tidal component; or one connecting places that have high water (or low water) simultaneously.

Countercurrent – A current flowing adjacent to another current but in the opposite direction.

Countermeasure– An opposing or retaliatory move.

Covariance – The expected value of the product $(x - \xi)(y - \zeta)$, where ξ denotes the mean of x, and ζ the mean of y.

See correlation.

Cove – A small, sheltered recess in a coast, often inside a larger embayment. (See Figure A-8.)

Creep – See soil creep, creeping.

Crest length, wave – The length of a wave along its crest. Sometimes called crest width.

Crest of berm – The seaward limit of a berm. Also berm edge. (See Figure A-1.)

Crest of wave – 1. The highest part of a wave.

2. That part of the wave above stillwater level. (See Figure A-3.)

Crest width, wave – See crest length, wave.

Criteria for tsunami evaluation – During the real-time investigation of potential tsunamis, it is important to determine seismic and hydrodynamic parameters such as earthqake magnitude, epicenter, depth of focus, seismic moment, energy, intensity of surface seismic waves, and possible wave activity near the source area. In addition, the systematic information of historical tsunami and earthquake records, as well as empirical earthquake parameter relationships could be used in the evaluation of a potential tsunami and the issuance of a warning.

Critical flow – The flow condition of a fluid system when one of the fundamental nondimensional parameters has a critical value e.g., flow of water in an open channel at a Froude number of 1, flow of a gas at a Mach number of 1.

Cross section – Generally, a two-dimensional, representative picture of a three-dimensional entity; usually a section or "slice" perpendicular

to the principal axis of the entity, or passing through its center, or otherwise representative of a given aspect of the entity.

See scattering cross-section. Compare profile, contour.

Cross-spectrum – The Fourier transform of the cross-correlation of two functions.

Crust of the Earth – The outermost layer of the Earth above the Mohorouicic seismic discontinuity.

Crystal pressure transducer – A device which measures pressure variation at the sea bottom due to the passage of a tsunami wave by converting to frequency variation of a quartz oscillator which is immediately exposed to the ambient bottom water.

Current – A tidal or noontide movement of lake or ocean water.

Current chart – A map of a water area depicting ocean-current data by current roses, vectors, or other means.

Current, coastal – One of the offshore currents flowing generally parallel to the shoreline in the deeper water beyond and near the surf zone. They are not related genetically to waves and resulting surf, but may be related to tides, winds, or distribution of mass.

Current drift – A broad, shallow, slow-moving ocean or lake current. Opposite of current, stream.

Current, ebb – The tidal current away from shore or down a tidal stream. usually associated with the decrease in the height of the tide.

Current, eddy – See eddy.

Current elipse – A hodograph of vectors of a tidal current, or of a harmonic component of a tidal current, during a complete tidal cycle.

Currents, feeder – The parts of the nearshore current system that flow parallel to shore before converging and forming the neck of the rip current.

Current, flood – The tidal current toward shore or up a tidal stream. usually associated with the increase in the height of the tide.

Current, littoral – Any current in the littoral zone caused primarily by wave action, e.g., longshore current, rip current.

See also current, nearshore.

Current, longshore – The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

Current meter – Any one of numerous devices for the measurement of either speed alone or of both direction and speed (set and drift) in flowing water.

Current, nearshore – A current in the nearshore zone.

Current, offshore – See offshore current.

Current, periodic – See current, tidal.

Current, permanent – See permanent current.

Current pole – A pole used in measuring surface water current, especially from an anchored vessel such as a lightship. The drift of the pole is timed as it is allowed to carry out a graduated line; the azimuth and speed of the line gives the current velocity.

Current, rip – See rip current.

Current rose – A diagram which indicates, for a given ocean area, the average percentage of current setting toward each of the principal compass points. The distribution of drifts is sometimes also indicated. Compare wind rose.

Current, stream – A narrow, deep, and swift ocean current, as the Gulf Stream. Opposite of current, drift.

Current system, nearshore – See nearshore current system.

Current tables – Annual tables of daily predictions of times and velocities of maximum flood currents and ebb currents and the times of slack water to

be encountered in numerous coastal waterways. Such tables are constructed from astronomical data and the harmonic analysis of previous observations.

Current, tidal – The alternating horizontal movement of water associated with the rise and fall of the tide caused by the astronomical tide-producing forces. Also current, periodic.

Curve fitting – (Also called graduation.) The appropriate representation of empirical data by a mathematical functions, typically with arbitrary constraints determined by least squares.

See smoothing.

Curvilinear coordinates – Any linear coordinates which are not Cartesian coordinates. If u, v, w are three functions of the Cartesian coordinates x, y, z and if at least one of these functions is not linear combination of x, y, z, then u, v, w are curvilinear coordinates of the point whose Cartesian coordinates are x, y, z, provided the Jacobian $\partial(u,v,w)/\partial(x,y,z)$ is not equal to zero. Any surface along which one of the three curvilinear coordinates is constant is called a coordinate surface; there are three families of such surfaces. Any line along which two of the three curvilinear coordinate.

Cusp, cuspate – A landform characterized by a projection with indentations of crescent shape on either side. Some examples include the cuspate delta, cuspate bar, cuspate reef, and cuspate spit.

Cuspate bar – A crescent-shaped bar uniting with the shore at each end. It may be formed by a single spit growing from shore and then turning back to again meet the shore, or by two spits growing from the shore and uniting to form a bar of sharply cuspate form. (See Figure A-9.)

Cycle – One complete and consecutive set of all the changes which occur in a recurrent action or phenomenon, starting from any point in the action and ending with all conditions as they were at the start.

Cycloidal wave – A steep, symmetrical wave whose crest forms an angle of 120°. The wave form is that of a cycloid. A trochoidal wave of maximum steepness. See also trochoidal wave.

Cyclone – An atmospheric cyclonic circulation, a closed circulation (compare trough). A cyclone's direction of rotation (counterclockwise in the Northern Hemisphere) is opposite to that of an anticyclone.

Cyclonic – Current patterns in the atmosphere or ocean which move counterclockwise in the Northern hemisphere and clockwise in the Southern hemisphere.

Cylindrical coordinates – (Also called cylindrical polar coordinates, circular cylindrical coordinates.) A system of curvilinear coordinates in which the position of a point in space is determined by (a) its perpendicular distance from a given line, (b) its distance from a selected reference plane perpendicular to this line, and (c) its angular distance from a selected reference line when projected onto this plane. The coordinates thus form the elements of a cylinder, and, in the usual notation, are written r, θ, and z, where r is the radial distance from the cylinder's axis z, and θ is the angular position from a reference line in a cylindrical cross section normal to z. The relations between the cylindrical coordinates and the rectangular Cartesian coordinates (x,y,z) are $x=r\cos\theta$, $y=r\sin\theta$, $z=z$.

Cylindrical polar coordinates – Same as cylindrical coordinates.

Cymatogeny – Undulating movement or warping of the earth's crust to produce regional linear arching or doming with minimal deformation.

–D–

Daily retardation (of tides) – The amount of time by which corresponding tidal phases grow later day by day (about 50 minutes).

Damage – See Tsunami Damage.

Damping – The suppression of the growth of oscillations or disturbances.

Damping factor – The ratio of the amplitude of any one of a series of damped oscillations to that of the following one at the same phase.

Damping wave – A wave that has been caused to decrease in amplitude by viscosity or eddy viscosity.

Darcy's law – The law governing the movement of fluids in permeable media which states that the velocity of flow is directly proportional to the hydraulic gradient. This is applicable only for very low Reynolds' numbers.

Data processing – Processing of information, especially the handling of information by machines and computers in accordance.

Datum, chart – See chart datum.

Datum, plane – The horizontal plane to which soundings, ground elevations, or water surface elevations are referred. Also reference plane. The plane is called a tidal datum when defined by a certain phase of the tide. The following datums are ordinarily used on hydrographic charts:

Mean low water - Atlantic coast (U.S.), Argentina, Sweden, and Norway;

Mean lower low water - Pacific coast (U.S.);

Mean low water springs - United Kingdom, Germany, Italy, Brazil, and Chile'

Low water datum - Great Lakes (U.S. and Canada);

Lowest low water springs - Portugal;

Low water Indian springs - India and Japan (See Indian tide plane);

Lowest low water - France, Spain, and Greece.

A common datum used on topographic maps is based on mean sea level.

See also bench mark.

DBCP - Drifting Buoy Co-operation Panel.

Debris line – A line near the limit of storm wave uprush marking the landward limit of debris deposits.

Decay – 1. In general, a flow with dissipation, but no source, of kinetic energy.

2. In ocean wave studies, the loss of energy from wind-generated ocean waves after they have ceased to be acted on by the wind. This process is accompanied by an increase in wave length and a decrease in wave height.

3. See attenuation.

Decibar – A unit of pressure used principally in oceanography. One decibar (10^5 dynes:cm^2) equals 0.1 bar. In the ocean, hydrostatic pressure in decibars very nearly equals the corresponding depth in meters.

Decile – One of a set of numbers on the random-variable axis which divide a probability distribution into ten equal areas.

See quantile.

Decision-making process – A procedure, as an algorithm, for determining in a finite number of steps the validity of any of a certain class of propositions before making a decision on a needed course of action.

Deep-sea tide gauge – A pressure transducer used to detect, on the sea floor, the pressure signature associated with the passage of the tide or of a tsunami - for research puposes or for warning.

Deep water – Water so deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wavelength is considered deep water.

Deep water tsunami gauge – See Deep-sea tide gauge.

Deep water tsunami measurement – A quantitative measurement of tsunami height in the open sea recorded by a deep-water tsunami gauge.

Deep-water tsunami signature – Graphical and quantitative representation of the amplitude of tsunami waves with respect to time as recorded by a deep water tsunami gauge.

Deep-water wave – (Also called short wave, Stokesian wave.) A surface wave the length of which is less than twice the depth of the water. When this relationship exists the following approximation is valid:

$$c = \sqrt{\frac{gL}{2\pi}}$$

where c is the wave velocity, g is the acceleration of gravity, and L is the wave length. Thus, the velocity of deep-water waves is independent of the depth of water.

See shallow-water wave, tsunami.

Degree – 1. A unit of temperature. See absolute temperature scale, approximate absolute temperature scale, Celsius temperature scale, centigrade temperature scale, Fahrenheit temperature scale, Kelvin temperature scale, Reaumur temperature scale.

2. A unit of angular distance; 1/360 part of a circle.

See also radian.

Degrees of freedom – In an unconstrained dynamic or other system, the number of independent variables required to specify completely the state of the system at a given moment. If the system has constraints, i.e., kinematic or geometric relations between the variables, each such relation reduces by one the number of degrees of freedom of the system. In a continuous medium with given boundary conditions, the number of degrees of freedom is the number of normal modes of oscillation. Thus, a particle moving in space has three degrees of freedom; an incompressible fluid with a free surface has an infinite number of degrees of freedom.

Delay – The time (or equivalent distance) displacement of some characteristic of a wave relative to the same characteristic of a reference wave; that is, the difference in phase between the two waves.

Compare lag.

Del-operator – The operator, written ∇, used to transform a scalar field into the ascendent (the negative of the gradient) of that field.

In Cartesian coordinates the three-dimensional del-operator is

$$\nabla = \mathrm{i}\frac{\partial}{\partial x} + \mathrm{j}\frac{\partial}{\partial y} + \mathrm{k}\frac{\partial}{\partial z}$$

and the horizontal component is

$$\nabla_H = \mathrm{i}\frac{\partial}{\partial x} + \mathrm{j}\frac{\partial}{\partial y}.$$

Expressions for ∇ invarious systems of curvillinear coordinates may be found in any textbook of vector analysis.

Delta – 1. A sedimentary deposit formed at the mouth of a river debauching on a continental shelf.

2. The low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area.

Deluge – A great inundation or overflowing of the land by water.

Density – The mass of an object divided by the volume, under certain conditions the "weight" per unit volume.

Density current – The intrusion of a denser fluid beneath a lighter fluid, due mainly to the hydrostatic forces arising from gravity and the density differences. This term is used principally in engineering for such cases as the intrusion of salt water below fresh water in an estuary, or for currents caused by the presence of denser water with suspended silt at the bottom of a lake or ocean.

Density function – In statistical terminology, same as probability density function.

Density stratification – The beginning of ocean water of increasing density.

Departure – Same as deviation.

Dependence – See statistical independence.

Dependent variable – Any variable considered as a function of other variables, the latter being called independent. Whether a given quantity is best treated as a dependent or independent variable depends upon the particular problem.

See independent variable; compare parameter.

Depletion curve – See recession curve.

Deposits – Earth material of any type, either consolidated or unconsolidated, that has accumulated by some natural process or agent.

Depression – An atmospheric region of relatively low pressure. It may refer to the closed low-pressure area of cyclone type or to the open V-shaped trough of low pressure.

Depth – The vertical distance from a specified datum to the bottom of a body of water.

Depth of breaking – The stillwater depth at the point where the wave breaks. Also breaker depth.

Depth of seismic hypocenter – In seismology, the vertical distance from the bottom of the ocean or from the surface of the earth to the point within the earth that is the center of an earthquake. See seismic focus.

Design flood – The flood, either observed or synthetic, which is chosen as the basis for the design of a hydraulic structure.

Depth contour – See contour.

Design hurricane – See hypothetical hurricane.

Detector – In seismology or oceanography, the finding of the presence, existence, or fact of an event, or of a signal by means of an instrument.

Deterministic – Governed by and predictable in terms of definite laws, such as dynamic equations.

Compare nondeterministic.

Detritus – Loose rock and mineral material.

Deviation – (Also called departure.) In statistics, the difference between two numbers. It is commonly applied to the difference of a variable from its mean, or to the difference of an observed value from a theoretical value.

Diagnostic equation – Any equation governing a system which contains no time derivative and therefore specifies as a balance of quantities in space at a moment of time (for example, hydrostatic equation, balance equation.

Diatreme – 1. A breccia-filled volcanic pipe that was formed by a gaseous explosion.

2. A volcanic vent or pipe of explosive character.

Differential erosion – Erosion that occurs at irregular or varying rates because of the differences in the resistance of surface materials softer and weaker rocks are rapidly worn away while harder and more resistant rocks remain to form ridges, hills or mountains.

Diffraction – The bending of a wave in a body of water around an obstacle, e.g. the interruption of a wave train by a breakwater or other barrier.

Diffraction zone – (also called shadow zone.) With respect to radio propagation, that portion of any propagation path which lies below a line-of-sight path.

Digital record (marigram) – Recording of sea-level fluctuations involving or using numerical digits expressed in a scale of notation to represent discretely all variables occuring at a particular site.

Dike (dyke) – A wall or mound built around a low-lying area to prevent flooding.

Dimensional analysis – A method of analysis of physical systems which depends only on the dimensions of the physical variables involved. The technique is especially powerful in organizing experimental programs so as to make the most significant and economical choice of quantities to be measured. Dimensional analysis is closely related to inspectional analysis.

Dipole – A system composed of two equal charges of opposite sign separated by a finite distance. In tsunami literature it may refer to the movement of crustal plate along a fault after an earthquake where one side goes up while the other side goes down.

Dip-slip earthquake – A type of earthquake in which the ocean bottom predominantly moves in a vertical direction.

Direct route – The shortest navigational distance between two points on the earth's surface. The great circle is a direct route.

Direct tide – A gravitational solar or lunar tide in the ocean or atmosphere which is in phase with the apparent motions of the attracting body, and consequently has its local maxima directly under the tide-producing body and on the opposite side of the earth. A gravitational tide which is in opposite phase to the apparent motions of the sun or moon is called a reversed tide.

Disaster prevention – The act of keeping from happening or acting to prevent or mitigate a disaster and its effects.

Disaster relief – Alleviating, ease, mitigation, or deliverance through the removal of pain or distress caused by disaster. Aid in the form of money or necessities.

Discharge – The passage of a liquid through a conduit, channel, or opening.

Discontinuities – Zones which radically affect the speed of such waves that have encountered physical or chemical changes in the matter through which they pass or which has deflected them.

Discontinuity – The abrupt variation or jump of a variable at a line or surface. Discontinuities are said to be of zero order when an undifferentiated quantity is discontinuous, or of first order when a finest derivative of the quantity is discontinuous, etc.

Discontinuous wave – Wave that is not continuous and incoherent.

Discrete spectrum – A spectrum in which the component wavelengths (and wave numbers and frequencies) constitute a discrete sequence of values (finite or infinite in number rather than a continuum of values. A Fourier analysis of a function will yield a discrete spectrum only if the function is periodic, or is assumed to be so, or if the function is represented by a finite sample of its values. Fourier series may be used for the analysis.

Dislocation – A displacement. Movement out of the usual or proper place. In seismology, ground movement due to faulting which may be described as time-dependent slip occuring across well defined fault surfaces.

Dispersion – The separation of waves of different wavelengths due to a dependence of sound velocity on wave length in a medium. The process in which radiation is separated into its component wavelengths.

Huygen's principle explains this action by considering the continued formation and propagation of "wavelets" of all wavelengths within the radiation field. Refractive dispersion also may be considered the result of a differential change in velocity according to wavelength as the radiation passes through a refractive interface.

This principle is applied to wave propagation in a fluid, wherein the speed of a wave disturbance depends upon its wavelength. Any disturbance that can be analyzed into two or more harmonic wave trains will undergo dispersion, each component being propagated at its own group velocity, provided this velocity is not zero.

2. The rate of change with wavelength of the index of refraction of any refractive interface or discontinuity. The dispersion increases toward shorter wavelengths, and varies approximately inversely with the cube of the wavelength. In general, large refractive indices tend to produce correspondingly large dispersions. The dependence of dispersion on wavelength exhibits irregularities (called anomalous dispersion) near any absorption lines or absorption bands.

3. In statistics, the scattering of the values of a frequency distribution from their average.

Dispersion coefficient – A number that serves as a measure of dispersion, dispersion being a process in which radiation is separated into its component wavelengths. In oceanography, the speed of a wave disturbance depends upon its wavelength. Any disturbance that can be analyzed into two or more harmonic wave trains will undergo dispersion, each component being propagated at its own group velocity, provided this velocity is not zero.

Dispersion equation – Same as frequency equation.

Dispersion mechanism – A continual spreading out of a disturbance into trains of waves, given that the initial disturbance is confined to a finite range of x values, and that the medium is unlimited. An effect in which a wave disturbance in the sea separates into wave trains of different wavelengths travelling at different speed. This principle is applied, analogously, to wave propagation in a fluid, wherein the speed of a wave disturbance depends upon its wavelength.

Dispersive medium – A medium displaying wave motion in the component harmonic waves of which move at wave speeds which are functions of their wave lengths.

See dispersion.

Dispersive wave – Wave that disperses or scatters. See Dispersion mechanism.

Displacement – The relative movement of the two sides of a fault, measured in any chosen direction.

Dissipation – In thermodynamics, the conversion of kinetic energy into heat by work done against the viscous stresses. Sometimes the rate of conversion per unit volume is meant. If the Navier-Stokes equations of viscous flow are employed, Rayleigh's mathematical expression for the rate of viscous (or frictional) dissipation per unit volume is

$$\frac{2}{3}\mu\left[\left(\frac{\partial v}{\partial y}-\frac{\partial \omega}{\partial z}\right)^2+\left(\frac{\partial w}{\partial z}-\frac{\partial v}{\partial \xi}\right)^2+\left(\frac{\partial u}{\partial x}-\frac{\partial v}{\partial y}\right)^2\right]$$

$$+\mu\left[\left(\frac{\partial w}{\partial y}-\frac{\partial v}{\partial z}\right)^2+\left(\frac{\partial u}{\partial z}-\frac{\partial \omega}{\partial x}\right)^2+\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)^2\right]$$

where μ is the dynamic viscosity. The Navier-Stokes assumptions thus satisfy the primary requirement of the second law of thermodynamics that the rate of dissipation be positive and the process irreversible.

Distant tsunami – Tsunami originating from a distant source.

Distribution – Arrangement in time or space; or apportionment among various classes, or class intervals, especially ranges of values of a certain variable.

See probability distribution, frequency distribution.

Distribution function – (Also called probability distribution function.) A function $F(x)$ yielding the probability that a stated random variable will assume some value less than or equal to any arbitrary number x. By definition, the distribution function is identically zero for all values of x below the least admissible value of the random variable, and identically unity for all values of x below the least admissible value of the random variable, and identically unity for all values of x equal to or greater than the greatest admissible value of the random variable. Moreover, $F(x_2) \geq F(x_1)$ whenever . $x_2 > x_1$. Sometimes, for the sake of clarity, the distribution function is called the cumulative distribution function.

Compare probability density function.

Disturbance – In general, any agitation or disruption of a steady state.

Diurnal – Daily, especially pertaining to actions which are completed within twenty-four hours and which recur every twenty-four hours; thus, most reference is made to diurnal cycles, variations, ranges, maxima, etc.

Diurnal inequality – The difference between the heights of the two high waters or the two low waters of a lunar day.

Diurnal tide – A tide with one high water and one low water in a tidal day. (See Figure A-10.)

Divergence – The expansion or spreading out of a vector field; also, a precise measure thereof. In mathematical discussion, divergence is taken to include convergence, i.e., negative divergence.

The mean divergence of a field F within a volume is equal to the net penetration of the vectors F through the surface bounding the volume (see divergence theorem). The divergence is invariant with respect to coordinate transformations and may be written

$$\text{div } F \text{ or } -\nabla F$$

where ∇ is the del-operator. In Cartesian coordinates, if F has components F_x, F_y, F_z the divergence is

$$\frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}.$$

Expansions in other coordinate systems may be found in any text on vector analysis.

In hydrodynamics, if the vector field is unspecified, the divergence usually refers to the divergence of the velocity field. (See also mass divergence.)

Divergence equation – An equation for the rate of change of horizontal divergence on a parcel (in analogy to the vorticity equation). For frictionless flow this equation is

$$\frac{d}{dt}(\nabla_H \cdot V) = -(\nabla_h \cdot V)^2 + 2J(u, v) - \nabla_\omega \cdot \frac{\partial}{\partial p} - \beta u + f\zeta - \nabla^2 \phi$$

where $\nabla_H \cdot V$ is the horizontal divergence, $J(u,v)$ is the Jacobian, ω is the rate of change of pressure, β is the Rossby parameter, ζ is the vertical vorticity, and ϕ is the geopotential. All horizontal differentiations are carried out in a constant-pressure surface. The divergence equation is derived by taking the divergence of the vector equation of motion.

When the two terms in the divergence are neglected, this equation becomes the balance equation.

Divergence theorem – (Also called Gauss's theorem.) The statement that the volume integral of the divergence of a vector, such as the velocity V, over a volume V is equal to the surface integral of the normal component of V over the surface s of the volume (often called the "export" through the closed surface), provided that V and its derivatives are continuous and single-valued throughout V and s. This may be written

$$\iiint_v \nabla \cdot \mathrm{V}\, dV = \oiint_s \mathrm{V} \cdot \mathrm{n}\, ds$$

where n is a unit vector normal to the element of surface ds, and the $\oiint$ symbol indicates that the integration is to be carried out over a closed surface. This theorem is sometimes called Green's theorem in the plane for the case of two-dimensional flow, and Green's theorem in space for the three-dimensional case described above; see Green's theorem.

Doldrums – (Also called equatorial calms.) A nautical term for the equatorial trough, with special reference to the light and variable nature of the winds. Compare horse latitudes; see equatorial air.

Dolphin – A cluster of piles.

Doppler effect – The change in frequency with which energy reaches a receiver when the receiver and the energy source are in motion relative to each other. This effect, first noted in the case of sound waves by the Austrian physicist J.C. Doppler, in 1842, is of passing interest in sound phenomena, but becomes of extremely great importance in astronomy, optics, and radar.

Dormant Volcano – A volcano that is not presently erupting but that has, perhaps, done so within historic time and is considered likely to do so in the future. There is no precise distinction between a dormant and an active volcano.

Double-humped wave – Wave with characteristic of two crests.

Downbuckle – A compressional downfolding of sialic crust, associated with oceanic trenches.

Downwarping – The downward warping or subsidence of a regional area of the earth's crust, usually as the result of isostatic pressure; e.g., geosynclinal sedimentation.

Drag coefficient – A dimensionless ratio of (a) the component of force parallel to the direction of flow (drag) exerted on a body by a fluid to (b) the kinetic energy of the fluid multiplied by a characteristic surface area of the body. In symbols, the drag coefficient C_D is

$$C_D = \frac{\text{force of resistance}}{\frac{1}{2}\rho U^2 L^2}$$

where ρ is the fluid density, U the speed, and L a characteristic length of the body.

Rayleigh's formula expresses the drag coefficient as proportional to a power of the Raynolds number Re,

$$C_D = \text{const.}\ (\mathrm{Re})^n.$$

For Couett flow, $n = -1$ and the constant is 2.

Drift – 1. The effect of the velocity of fluid flow upon the velocity (relative to a fixed external point) of an object moving within the fluid; the vector difference between the velocity of the object relative to the fluid and its velocity relative to the fixed reference.

2. The speed of an ocean current. In publications for the mariner, drifts are usually given in miles per day or in knots.

3. "In geology, materials in transport by ice; deposits made by glacial ice on land in the sea, and in bodies of melt water." Drift ice – Any sea ice that has drifted from its place of origin. The term is used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how disposed.

Dry bed –The relatively dry ground area bordering the shore where a tsunami running up the shore forms a surge. The word "dry" does not necessarily imply that the soil is effectively dry, but from a fluid mechanics standpoint, the momentum transfer from the surge to the layer of fluid ahead is negligible, which is not the case of tidal bore or moving hydraulic jump as previously mentioned. From a fluid mechanics viewpoint, a surge on a dry bed is not a shock wave but rather a rarefaction wave.

Dunes – 1. Ridges or mounds of loose, wind-blown material, usually sand. (See Figure A-7.)

2. Bed forms smaller than bars but larger than ripples that are out of phase with any water-surface gravity waves associated with them.

Duration – In ocean-wave studies, the length of time that the wave-generating wind has blown. Fetch and duration are the variables determining the formation of wind waves by a given wind force. In Tsunami related studies the length of time that tsunami oscillations last.

Duration, minimum – The time necessary for steady-state wave conditions to develop for a given wind velocity over a given fetch length.

Dynamic boundary condition – The condition that the pressure must be continuous across an internal boundary or free surface in a fluid.

See also boundary condition, kinematic boundary condition.

Dynamic head – The energetic or forceful pressure of a moving fluid on a surface expressed in terms of force per unit area.

Dynamic pressure – (Also called velocity pressure, stagnation pressure.) In engineering fluid mechanics, the kinetic energy, $\frac{1}{2}\rho V^2$, of the fluid, where ρ is the density and V the speed. This applies in cases where this quantity may be conveniently considered as adding to the static pressure; that is, the dynamic pressure at a given point is the difference between the static pressure at that point and the total pressure at the stagnation point of the same streamline. This concept must be distinguished from the hydrodynamic pressure.

Dynamic similarity – A relation between two mechanical systems (often referred to as model and prototype) such that by proportional alterations of the units of length, mass, and time, measured quantities in the one system go identically (or with a constant multiple for each) into those in the other. In particular, this implies constant ratios of forces in the two systems.

Dynamic similarity between systems of fluid flow exists when the equations of motion and the boundary conditions of one system can be transformed into those of another by suitable dimensional changes. Two incompressible viscous flows, for example, are dynamically similar if the ratios of the inertial terms to the friction terms in the respective flows are of the same order of magnitude; this ratio is the Reynolds number of the flow, and, in an analogous way, the equality of other non-dimensional numbers (Rayleigh number, Rossby number, etc.) establishes the dynamic similarity of other pairs of flows.

Dyne – The unit of force in the centimeter-gram-second system of physical units, i.e., one gm cm per sec^2 equal to 10^{-10} kj or to 7.233×10^{-5} poundal.

–E–

Eagre – See bore.

Earth movements – 1) Rotational 23.5°; top like. 2) Revolve around the sun. 3) "Elasticrebound" theory by Reid: Earthquakes occur in regions subject to deformation due to external causes, generally regional tectonic stresses. When the accumulated strain at some point exceeds the strength of the rock there is brittle fractures at competent rock and/or slip on pre-existing zones of weakness.

Earth surface – The science of geomorphology divides the earth's surface into: 1) continental platforms and oceanic basins; 2) provincial features including continental shelves, coastal plains, mountain ranges; 3) massive structures such as single mountains, domes, basins.

Earth tide – The response of the solid Earth to the forces that produce the tides of the sea; semidaily earth tides have a fluctuation of between seven and fifteen centimeters.

Rising and falling of the earth's solid surface in response to the gravitational pull of the sun and the moon. Earth tides, like ocean tides, show the greatest rise when the moon and the sun are aligned (sping tide) and least rise when the moon and sun are perpendicular to each other (neap tide).

Earth's crust – The outer solid geosphere, the outermost layer of the earth, about 22 miles deep under the continents and 6 miles deep under the ocean separated from the upper mantle by the Moho boundary. It consists of three shells: a stratified sedimentary shell ("stratisphere"), composed mainly of sedimentary rocks; a "granitic" shell, distributed only beneath the continents and thinning out at the ocean boundaries; and a "basaltic" shell which has different structures under continents and under oceans. (These layers were identified nearly 100 years ago by Suess as SIAL and SIMA.)

Earthquake – A sudden motion of the earth caused by faulting or volcanic activity. Earthquakes can occur in the near surface rocks or down to as deep as 700km below the surface. The actual area of the earthquake is called the focus; the point on the earth's surface above the focus is called the epicenter.

Earthquake epicenter – A location on the earth's surface directly above an earthquake focus.

Earthquake evaluation – The determination of important earthquake parameters such as magnitude, epicenter and depth and the appraisal of its potential for destruction.

Earthquake foci – The points within the earth that are the centers of the main earthquake event and its aftershocks.

Earthquake magnitude – A measure of the strength of an earthquake, or the strain energy released by it, as determined by seismographic observations.

Earthquake Seismology - When a major earthquake occurs, the resultant energy released into the earth will propagate over a wide range of frequencies and velocities. Even though the earth movements discernible to the viewer may be confined to the general region of the earthquake origin, the various seismic wave phases propagating throughout the earth result in small, but measurable, ground displacements which can be detected by a seismometer. A seismograph then provides a visual analog record of the ground displacements at that station. For the purposes of the Tsunami Warning System, consideration is given to three significant seismic wave phases. The first, the P-wave, is a compressional wave travelling through the earth's interior at a velocity varying from approximately 8.0 km/second near the crust-mantle interface to about 13.5 km/second at the mantle-core interface. As such it is the first seismic phase to be recorded at any one seismic station and is the first indication that a distant earthquake has occurred. The second seismic phase of importance is the S-wave, or Secondary wave. This phase travels through the earth's interior as a shear wave, following approximately the same travel path as the P-wave but at a reduced velocity varying from approximately 6.7 km/second near the crust-mantle interface to about 8.0 km/second near the core. By measuring the time separation between the arrival of the P and S waves, the distance of the epicenter from that seismic station the origin time of the earthquake can be determined. By obtaining the P arrival times at a series of seismic stations appropriately located, the location of the earthquake epicenter can be

determined by assuming the "best fit" of a series of intersecting arcs representing distances from the various seismic stations used. These seismic wave phases are classified as body waves due to their propagation through the earth's interior. In addition to providing a location, body waves may be useful in determining the size of an earthquake.The third set of seismic phases to be considered are the surface waves resulting from ground displacements propagating outward along the surface of the earth. These are observed at a seismic station as local or regional surface waves and are the basis for measuring magnitude on the Richter scale. The actual energy released for each increment of the Richter scale is a factor of 32. Thus a magnitude 6.0 earthquake will release 32 times as much energy as a magnitude 5.0, and a magnitude 8.0 is more than 1000 times greater than a 6.0.

Earthquake source – Point from which earthquake originates.

Earthquake swarm – A series of minor earthquakes, none of which may be identified as the main shock, occurring in a limited area and time.

Earthquake waves - See Earthquake Seismology.

Ebb current – (Nontechnically called ebb tide.) The movement of a tidal current away from the coast or down an estuary or tidal waterway; the opposite of flood current.

Ebb tide – 1. Same as falling tide.

2. Same as ebb current.

Echo sounder – An electronic instrument used to determine the depth of water by measuring the time interval between emission of a sonic or ultrasonic signal and the return of its echo from the bottom.

Echo sounding – A method of determining depth of the ocean by measuring the time interval between the emission of an acoustic signal and its return or echo from the sea floor. The returning signal is usually printed to give a visual picture of the topography of the sea floor. The instrument used in this method is called an echo sounder.

ECOR - Engineering Committee on Oceanic Resources.

Eddy – 1. By analogy with a molecule, a "glob" of fluid within the fluid mass that has a certain integrity and life history of its own; the activities of the bulk fluid being the net result of the motion of the eddies.

2. Any circulation drawing its energy from a flow of much larger scale, and brought about by pressure irregularities as in the lee of a solid obstacle.

Eddy coefficients – Same as exchange coefficients.

Eddy current – See eddy.

Eddy diffusion coefficient – Same as eddy diffusivity.

Eddy diffusivity – (Also called coefficient of eddy diffusion, eddy diffusion coefficient.) The exchange coefficient for the diffusion of a conservative property by eddies in a turbulent flow.

Eddy flux – (Or turbulent flux.) The rate of transport (or flux) of fluid properties such as momentum, mass, heat, or suspended matter by means of eddies in a turbulent motion; the rate of turbulent exchange.

Eddy kinetic energy – (Also called turbulent energy.) The kinetic energy of that component of fluid flow which represents a departure from the average kinetic energy of the fluid, the mode of averaging depending on the particular problem. This eddy kinetic energy is represented by $\rho\overline{u'^2}$ where ρ is the density, u' is the eddy velocity, and the superior bar denotes an average.

Eddy spectrum – The distribution of the frequency of eddies of various sizes or scales in a turbulent flow, or the distribution of kinetic energy among eddies of various frequencies or sizes.

Eddy velocity – (Also called fluctuation velocity.) The difference between the mean velocity of fluid

flow and the instantaneous velocity at a point. For example,

$$u' = u - \bar{u}$$

where u' is the eddy velocity, u is instantaneous velocity, and $\bar{u}$ is mean velocity. Over the same interval which defines the mean velocity, the average value of the eddy velocity is necessarily zero.

Edge wave – An ocean wave traveling parallel to a coast, with crests normal to the coast line. Such a wave has a height that diminishes rapidly seaward and is negligible at a distance of one wave length offshore.These edge waves, the trapped mode of longshore wave motion, have wave periods which will be longer than the incident wave periods; standing edge waves will have peaks and nodes at points along the shoreline, although edge waves may be either standing or progressive waves.

Eigenvalue – See characteristic-value problem.

Ekman layer – Sometimes called spiral layer. The layer of transition between the surface boundary layer, where the shearing stress is constant, and the free atmosphere, where the atmosphere is treated as an ideal fluid in approximate geostrophic equilibrium. In Ekman's analysis (see Ekman spiral), the coefficient of eddy viscosity is assumed constant within this layer; subsequent calculations have relaxed this assumption.

Ekman spiral – As originally applied by Ekman to ocean currents, a graphic representation of the way in which the theoretical wind-driven currents in the surface layers of the sea vary with depth. In an ocean which is assumed to be homogeneous, infinitely deep, unbounded and having a constant eddy viscosity, over which a uniform steady wind blows, Ekman has computed that the current induced in the surface layers by the wind will have the following characteristics: (a) At the very surface the water will move at an angle of 45° cum sole from the wind direction. (b) In successively deeper layers the movement will be deflected farther and farther cum sole from the wind direction, and the speed will decrease. (c) A hodograph of the velocity vectors would form a spiral descending into the water and decreasing in amplitude exponentially with depth.

The depth at which the vector first points 180° from the wind vector is called the depth of frictional influence (or depth of frictional resistance). At this depth the speed is $e^{-\pi}$ times that at the surface. The layer from the surface to the depth of frictional influence is called the layer of frictional influence. If the velocity vectors from the surface the depth of frictional influence be integrated, the resultant motion is 90° cum sole from the wind direction.

Elastic Constant - One of various coefficients expressed in units of stress, that defines the elastic properties of matter.

Elastic Deformation - A deformation that disappears upon release of stress.

Elastic modules – A solid mass which yields by elastic strain. Ideally this strain follows Hooke's law according to which strain is proportional to stress.

Elastic discontinuity - A boundary between rock strata of differing density, or having different elastic properties. Seismic waves passing through rocks that are not uniform in all directions, or from one kind of rock into another (e.g. limestone to shale), are refracted or reflected. Where a P or S wave meets an elastic discontinuity, it generates two new P waves and two new S waves. See also: seismic waves.

Elastic Rebound theory - A theory of earthquake generation first propounded by H.F. Reid in 1911. In substance, it states that movement along a geological fault is the sudden release of a progressively increasing elastic strain between the rock masses on either side of the fault. The strain is the reaction to deformation by tectonic forces. Movement returns the rocks to a condition of little or no strain.

Elastic limit - The maximum stress that a body or material can sustain and beyond which it cannot return to its original shape or dimensions. Syn: yield point.

Elastic wave – A wave that is propagated by some kind of elastic deformation, that is, a deformation that disappears when the forces are removed. A seismic wave is a type of elastic wave.

Elevation – A measure (or condition) of height, especially with respect to the height of a point on the earth's surface above a reference plane (usually mean sea level).

Embankment – An artificial bank such as a mound or dike, generally built to hold back water or to carry a roadway.

Embayed – An indentation in the shoreline forming an open bay.

Emergency preparedness – Getting ready to deal with conditions requiring prompt action when the tsunami disaster strikes for the purpose of mitigating adverse effects.

Emergency response – Preforming on a predetermined plan of action related to the mitigation of the effects of a natural disaster.

Emission – With respect to radiation, the generation and sending out of radiant energy. It is to be distinguished from reflection and transmission.

See emittance, emissivity.

Energetics – The branch of study dealing with the systematic description of the energy conversion and transfer processes which take place within a physical system.

Energy – Capacity for performing work; energy comes in many forms; for example, heat energy, kinetic energy, electromagnetic energy, chemical energy, and potential energy; can be transformed from one form of energy to another, and is conserved.

Energy coefficient – The ration of the energy in a wave per unit crest length transmitted forward with the wave at a point in shallow water to the energy in a wave per unit crest length transmitted forward with the wave in deep water. On refraction diagrams this is equal to the ratio of the distance between a pair of orthogonals in deep water. Also the square of the refraction coefficient.

Energy conversion – (Also called energy transformation.) The process whereby energy changes from one form to another (for example, from potential energy to kinetic energy). It is common also to speak of energy release when referring to certain conversion processes, such as the release of latent heat energy, and the release of potential energy.

Compare energy transfer.

Energy density spectrum – (Sometimes called energy spectrum.) The square of the amplitude of the (complex) Fourier transform of an aperiodic function. Thus, if $f(t)$ is the given function, its Fourier transform is

$$F(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(t)e^{-i\omega t}\,dt$$

and the energy density spectrum is $|F(\omega)|^2$. It is assumed that the total energy

$$\int_{-\infty}^{\infty} |f|^2\,dt$$

is finite.

See power spectrum.

Energy dispersion – See dispersion, group velocity.

Energy equation – Mechanical energy equation (or kinetic energy equation): An expression for the rate of change of kinetic energy, which is obtained by scalar-multiplication of the 3-dimensional vector equation of motion by the vector velocity V; it maybe written in the form

$$\frac{\partial}{\partial t}\left(\rho\frac{\mathbf{V}^2}{2}\right) = 2 - \nabla\cdot\left(\rho\frac{\mathbf{V}^2}{2} + \rho\phi + p\right)\mathbf{V}$$

$$-\frac{\partial\rho\phi}{\partial t} + p\nabla\cdot\mathbf{V} - \mathbf{V}\cdot\mathbf{F}$$

where $\phi = gz$ is the geopotential energy, ρ is density, p is pressure, F is the vector frictional force per unit volume and ∇ is the del-operator.

Energy flux –

Energy release – See energy conversion.

Energy spectrum – Same as energy density spectrum.

Energy transfer – The transfer of energy of a given form among different scales of motion.

Energy transformation – See energy conversion.

Engineering protection – The practical application of science and mathematics in the proper design of structures for the purpose of defending against property damage and injury caused by natural or man-made hazards.

Entrance – The avenue of access or opening to a navigable channel.

Epeirogeny – Broad scale vertical movement that determines the elevation of the land surface and the depth of the sea floor.

Epicenter – The point on the Earth's surface directly above the focus of an earthquake.

Epoch – See geologic epoch.

Equal-area map – A map so drawn that a square mile in one portion of the map is equal in size to a square mile in any other portion. This is obtained by changing the scales along the meridians and parallels in inverse proportion to each other.

Equal-area maps covering the whole globe, such as the Sanson-Flamsteed sinusoidal projection, are approximately ellipitical. In Lambert's azimuthal equal-area projection the parallels of latitude come closer together as the equator is approached. Any map of the whole world or of a hemisphere necessarily distorts the shape of a region far from the center of the map, but such maps are useful for some climatological studies in which the correct representation of area is important. For limited parts of the globe equal-area projections are quite practical.

Equation of continuity – (Or continuity equation.) A hydrodynamical equation which expresses the principle of the conservation of mass in a fluid. It equates the increase in mass in a hypothetical fluid volume to the net flow of mass into the volume. The equation of continuity is usually written in either of two forms:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathrm{V} = 0 ;$$

or

$$\frac{\partial \rho}{\partial t} + \rho \nabla \cdot \mathrm{V} = 0;$$

where ρ is the fluid density and V the velocity vector. If pressure is taken as vertical coordinate, the equation takes the form

$$\frac{\partial}{\partial \pi}\left(\frac{d p}{d t}\right) + \nabla_p \cdot \mathrm{V} = 0$$

where p is the pressure and ∇_p is the del-operator in the isobaric surface.

Equation of impulse conservation –

Equation of motion – See equations of motion.

Equation of time – The difference at any instant between the apparent solar time and the mean solar time as measured at a specified place; it is the difference between the hour angles of the "apparent sun" and the "mean sun."

Tables of the equation of time are available in astronomical almanacs. The equation of time is zero at four times during a year, on about April 15, June 15, August 31, and December 24, at present. The algebraic sign associated with the equation of time varies from one source to another, a fact which must be kept in mind in abstracting values from almanacs.

See apparent solar day, mean solar day.

Equation of wave motion – Same as wave equation.

Equations of motion – A set of hydrodynamical equations representing the application of Newton's second law of motion to a fluid system. The total acceleration on an individual fluid particle is equated to the sum of the forces acting on the particle within the fluid.Written for a unit mass of fluid in motion in a coordinate system fixed at a point on the earth's surface, the vector equation of motion for the atmosphere is

$$\frac{d\mathrm{V}}{dt} = -2\Omega \times \mathrm{V} - g\mathrm{k} - \frac{1}{\rho}\nabla p + \mathrm{F}$$

where V is the three-dimensional velocity vector, Ω the angular velocity of the earth, k a unit vector directed upward, perpendicular to the earth's surface at the point in question, ρ the density, p the pressure, g the acceleration of gravity, and F the frictional force per unit mass. When applied

to the atmosphere's horizontal motion, the coriolis acceleration terms $2\Omega \times V$ are usually approximated by the two horizontal components $i2\Omega \sin \phi v$ and $-j2\Omega \sin \phi u$, where i and j are the unit vectors along the horizontal x and y axes, respectively, while u and v are the velocity components along these same axes. Here Ω is the magnitude of Ω , and ϕ is the geographical latitude. In the equation of vertical motion, the vertical component of the coriolis force is frequently neglected and it is often assumed, in addition, that $\frac{dw}{dt} = 0$, where w is the vertical velocity. With these simplifications, the equation of vertical motion is recognized as the hydrostatic equation.

The usual form for the scalar equations of motion in Cartesian coordinates (x, y, z), x taken positive eastward, y northward, and z locally upward, is as follows:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = fv - 2\omega \cos \phi w - \frac{1}{\rho}\frac{\partial p}{\partial x} + fx ;$$

$$\frac{\partial v}{\partial t} + \frac{\partial v}{\partial x} + \frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = fu\,\frac{\rho}{1}\frac{\partial y}{\partial p} + fy ;$$

$$\frac{\partial w}{\partial \cdot} + u\frac{\partial w}{\partial \cdot} + v\frac{\partial w}{\partial \cdot} + w\frac{\partial w}{\partial \cdot} = 2\omega \cos u - \frac{1}{\rho}\frac{\partial p}{\partial \cdot} + fz .$$

See Newton's laws of motion, vorticity equation.

Equations of motion – A set o

Equations of motion - Excitation – The differential equations of motion for a Newtonian fluid are called the Navier-Strokers equations. These equations are an expression of Newton's second law of motion in which the appropriate relationship of viscous stress to strain rate has been incorporated. For a compressible fluid with a single, constant coefficient of viscosity, the Navier-Strokes equations are

2):

$$P\{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\} =$$

$$-\frac{\partial v}{\partial t} + \frac{1}{3u}\frac{\partial 0}{\partial x} + u\nabla^2 u + pf_x$$

3):

$$P\{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\} =$$

$$-\frac{\partial p}{\partial y} + \frac{1}{3u}\frac{\partial 0}{\partial y} + u\nabla^2 v + pf_y$$

4):

$$P\{\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\} =$$

$$-\frac{\partial p}{\partial z} + \frac{1}{3u}\frac{\partial 0}{\partial z} + u\nabla^2 w + pf_x$$

where O is the rate of dilatation defined by

5):

$$0 = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial u}{\partial z} + \frac{\partial w}{\partial z}$$

and is ∇^2 the Laplacian operator

$$\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} ;$$

fx, fy and fz are composed of the body force per unit mass. In the case of the usual earth's gravity, g = 32.2 ft./sec(2), with the z axis vertical, $fx = fy = 0$ and $fz = -g$.

The brackets on the left hand of Eq.(2) represents the acceleration of the fluid in the x direction; the right-hand side represents forces per unit volume. The terms involving represent the effect of viscous stresses. For an incompressible fluid, the equation of continuity, Eq. (1), becomes 0 = 0 which simplifies Eqs. (2), (3) and (4) somewhat.

Equator – Geographically, the imaginary great circle of latitude 0° on the earth's surface, which is equidistant form the poles, and which separates the Northern Hemisphere from the Southern Hemisphere.

Equideparture – (Rare.) Equality of deviation (or departure) from a normal value. Lines or curves of equideparture are called isametrics.

Equigeopotential surface – Same as geopotential surface.

Equilibrium – In mechanics, a state in which the vector sum of all forces, i.e., the acceleration vector, is zero. In hydrodynamics, it is usually further required that a steady state exist throughout the atmospheric or fluid model. The equilibrium may be stable or unstable with respect to displacements therefrom.

Equilibrium spheroid – The shape that the earth would attain if it were entirely covered by a tideless ocean of constant depth.

Compare geoid.

Equilibrium tide – The tide that would exist if the tidal wave was in exact balance with the gravitational tide forces.

Equinoctial tide – Tide occurring when the sun is near equinox. During this period, spring-tide ranges are greater than average.

Equinox – 1. Either of the two points of intersection of the sun's apparent annual path and the plane of the earth's equator, i.e. a point of intersection of the ecliptic and the celestial equator.

2. Popularly, the time at which the sun passes directly above the equator; the "time of the equinox." In northern latitudes the vernal equinox falls on ar about March 21, and the autumnal equinox on or about September 22. These dates are reversed in the Southern Hemisphere. Compare solstice.

Equipotential surface – A surface in any conservative field of force (electrical, magnetic, gravitational, etc.), every point on which has the same potential.

Era – See geologic era.

Erg – The unit of energy in the centimeter-gram-second system of physical units; i.e., one dyne-centimeter. One erg is equal to 10^{-7} joule or 2.389×10^{-8} cal.

EROS - Earth Resources Observing Satellite.

Erosion – The general process or the group of processes whereby the materials of the Earth's crust are loosened, dissolved, or worn away, and simultaneously moved from one place to another, by natural agencies, which include weathering, solution, corrosion, and transportation, but usually exclude mass wasting.

Error – See instrument error, observational error, random error, systematic error, standard error.

Error distribution – The probability distribution of random errors, typically a normal distribution with a zero mean; that is,

$$f(v) + \frac{1}{\sigma\sqrt{2\pi}} e^{-v^2/2\sigma^2} \qquad (-\infty < v < \infty)$$

where v is the random error and σ is the standard deviation of v (in this connection, σ is commonly called the standard error); f(v) denotes the error distribution (or normal curve of error).

Error function – (Sometimes abbreviated erf.) Same as probability integral.

Error of estimate – Same as residual.

Eruptive mechanism – Character of explosive activity of a volcanic eruption.

ESA - European Space Agency

Escarpment – A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion or faulting. Also scarp. (See Figure A-1.)

Estimated time of arrival (ETA) – Time of tsunami arriving at a fixed location. as derived from tsunami velocity determined from tsunami wave refraction.

Estuary – 1. A coastal region influenced by fresh water supply by streams. Circulation is generally landward at the bottom and seaward at the surface.

2. A drowned river mouth formed by the subsidence of land near the coast or by the drowning of the lower portion of a nonglaciated valley due to the rise of sea level.

Eugeosyncline – A geosyncline, or regional depositional trough, in which volcanism is associated with rapid clastic sedimentation.

Eulerian coordinates – Any system of coordinates in which properties of a fluid are

assigned to points in space at each given time, without attempt to identify individual fluid parcels from one time to the next. Eulerian coordinates are to be distinguished from Lagrangian coordinates. The particular coordinate system used to identify points in space (Cartesian, cylindrical, spherical, etc.) is quite independent of whether the representation is Eulerian or Lagrangian.

Eulerian correlation – (Sometimes called synoptic correlation.) The correlation between the properties of a flow at various points in space at a single instant of time.

Compare Lagrangian correlation; see correlation coefficients.

Eulerian equations – Any of the fundamental equations of hydrodynamics expressed in Eulerian coordinates. These are so commonly used that the designation "Eulerian" is often omitted (See, for example, equations of motion).

Eustatic changes in sea level – Change in sea level due to increased or decreased volume of seawater in the oceans. This can either be due to ice storage on the continents or to the change in volume of the ocean basins due to large scale tectonism.

Evacuation – The process of notifying, guiding, assisting, or forcing people to depart from areas which seem to be hazardous.

Evacuation map – A drawing or representation that outlines danger zones and designates limits beyond which people must be evacuated to avoid harm from tsunami waves.

Evaluation – As applied to tsunami, the appraisal and assessment of the relative potential tsunami disaster risk as determined from measurement or determination of the threshold geographical and oceanographic parameters.

Exceedance interval – The average number of years between the occurrence of an event and that of a "greater" event.

See return period.

Excess – See kurtosis.

Expected value – (Also called expectation, mathematical expectation.) The arithmetic mean of a random variable, conceptually similar to the simple average but broader in scope. If $g(x)$ is a continuous function of x, then the expected value of $g(x)$, denoted by , $E[g(x)]$, is the integral (or sum, if x is discrete) of $g(x)$ times the probability element of x. Thus, if x is continuous with probability density function $f(x)$ defined in the range $a < x < b$ then

$$E[g(x)] \equiv \int_a^b g(x) f(x)\, dx ;$$

or, if x is discrete with possible values $x_1, x_2, \ldots, x_n$ and probability function $f(x_i)$, then

$$E[g(x)] \equiv \sum_{i=1}^{n} g(x_i) f(x_1) .$$

This reduces to the mean of x itself in case = x.

Experimental tank – An artificial basin containing a fluid used for testing empirically fluid mechanics.

Explosion – The act or instance of exploding; a violent expansion or bursting with noise.

External wave – A wave in fluid motion having its maximum amplitude at an external boundary such as a free surface. Any surface wave on the free surface of a homogeneous imcompressible fluid is an external wave.

See internal wave.

Extrapolation – The extension of a relationship between two or more variables beyond the range covered by knowledge, or the calculation of a value outside that range.

–F–

FAGS - Federation of Astronomical and Geophysical Data Analysis Centres.

Fahrenheit temperature scale – (Abbreviated F.) A temperature scale with the ice point at 32° and the boiling point of water at 212°. Conversion with the centigrade temperature scale (C) is accomplished by the formula

$$F = \frac{9}{5} C + 32.$$

Fairway – The parts of a waterway that are open and unobstructed for navigation. The main traveled part of a waterway; a marine thoroughfare.

Fall (in sea level) –

Fall equinox – Same as autumnal equinox.

Falling tide – (Sometimes called ebb tide.) The portion of the tide cycle between high water and the following low water.

FAO - Food and Agricultural Organization of the United Nations.

Fathom – The common unit of depth in the ocean, equal to six feet. It is also sometimes used in expressing horizontal distances, in which case 100 fathoms make one cable or very nearly one-tenth nautical mile.

Fathometer – The copyrighted trademark for a type of echo sounder.

Fault – A fracture in the Earth's crust accompanied by a displacement of one side of the fracture with respect to the other and in a direction parallel to the fracture.

Fault model – A representation of the structure of a fault.

Fault parameter- A characteristic element of a fault (i.e. relative displacement)

Feeling bottom – The action of a deep-water wave on running into shoal water and beginning to be influenced by the bottom.

Feeder current – See current, feeder.

Filtering – 1. The separation of a wanted component of a time series from any unwanted residue (noise).

2. The decomposition of a signal into its harmonic components.

Filtering approximations – A set of mathematical approximations introduced into a system of hydrodynamical partial differential equations to filter out or exclude solutions corresponding to those physical disturbances which are believed to contribute only negligibly to the problem at hand.

Finite difference – The difference between the values of a function at two discrete points, used to approximate the derivative of the function. The derivative $f'(x)$ of a function $f(x)$ at an arbitrary point x is usually approximated by finite differences in one of three ways:

$$f'(x) =^{\bullet} \frac{f(x+a)-f(x)}{a} \equiv \frac{\nabla f}{a}$$

where ∇f is called a forward difference;

$$f'(x) =^{\bullet} \frac{f(x+a/2)-f(x-a/2)}{a} \equiv \frac{\delta f}{a}$$

where δf is called a centered difference;

$$f'(x) =^{\bullet} \frac{f(x)-f(x-a)}{a} \equiv \frac{\nabla f}{a}$$

where ∇f is called a backward difference (not to be confused with the gradient). Of these approximations, the centered difference is the most accurate; but whether it is the most convenient or accurate for the problem as a whole depends on the character of the equations involved. Higher derivatives are approximated by iteration of these formulas.

Finite-difference equation – An equation resulting from the use of finite-difference approximations to the derivatives in an ordinary or partial differential equation. A finite-difference equation may have a solution (or solutions) the behavior of which is quite unlike that (or those) of the differential equation approximated, and care must be taken to exclude any such solutions in the computation.

Finite-difference method – A numerical method of solving a problem using finite differences.

Finite-difference model – A numerical model for solving problems using finite difference methods.

Finite elements method – Same as finite difference method.

Finite elements model – Same as finite difference model.

First Arrival – The first recorded signal attributable to seismic wave travel from a known source.

Firth – A narrow arm of the sea; also the opening of a river into the sea.

Fiord (fjord) – A narrow, deep, steep-walled inlet of the sea, usually formed by entrance of the sea into a deep glacial trough.

Fix – In navigation, the position of a craft as determined by some means without reference to any former position. Compare dead reckoning.

Flood – The condition that occurs when water overflows the natural or artificial confines of a body of water, or accumulates low-lying areas.

Flood current – (Nontechnically called flood tide.) The movement of a tidal current toward the coast, or up an estuary or tidal waterway; the opposite of ebb current.

Flood tide – 1. Same as rising tide.

2. Same as flood current.

Flood wave – Wave caused by the overflow of water over the natural or artificial confines of a stream or other body of water.

Flooding – A rising and overflowing of a body of water especially onto normally dry land.

Flow – 1) To issue or move in a stream with the continual change of place among the constituent particles. 2) To have a smooth uninterrupted continuity. 3) To deform under stress without cracking or rupturing. 4) A smooth uninterrupted movement. 5) The quantity that flows in a certain time. 6) The motion characteristics of fluids. 7) A continuous transfer of energy.

Flow break – An interruption in the continuity of a flow.

Fluctuation – The alternate rising and lowering of the water level either regularly or periodically.

Fluctuation velocity – Same as eddy velocity.

Flume – A channel used for studying the flow of fluids under gravity. The fluid is pumped from a sump to a stilling tank that acts as a reservoir from which the fluid is discharged down the flume at varying speeds. The motion is viewed from above or through glass sides.

Flux – A measure of the rate of movement of material or energy past a point; measured in units of material or energy to be transported per unit cross-sectional area per unit time.

Flux density – The flux (rate of flow) of any quantity, usually a form of energy, through a unit area of specified surface. (Note that this is not a volumetric density like radiant density.)

Foam line – The front of a wave as it advances shoreward, after it has broken.(See Figure A-4.)

Focal depth – The depth from the surface of the earth to the point within the earth which is the center of an eartquake.

Focal mechanism – The process of movement and rupture of crustal blocks resulting from an earthaquake.

Focal Sphere - An arbitrary sphere drawn about the focus or hypocenter of an earthquake, to which body waves recorded at the earth's surface are referred.

Focal zone – The rupture zone of an earthquake. In the case of a great earthquake, the focal zone may extend several hundred kilometers in length

Focus – 1. In seismology, the source of a given set of elastic waves, customarily an earthquake.

2. The point in the earth where rupture first occurs.

Fold - A bending, warping, or buckling in bedding, or other planar features of geologic strata varying in size from a few millimeters or centimeters to several kilometer's across.

Foot-pound – A unit of energy equal to 1.356 joules.

Force – The cause of the acceleration (i.e., the speeding up, the slowing down, or change in direction) of material including water and air.

Forced oscillation – See oscillation (1), forced wave.

Forced wave – Any wave which is required to fit irregularities at the boundary of a system or satisfy some impressed force within the system. The forced wave will not in general be a characteristic mode of oscillation of the system. It cannot be exhibited independently unless the system admits of no free waves. (A homogeneous incompressible fluid bounded by two rigid surfaces is an example of such a system.

Force of gravity – See gravity.

Forecast – The subjective estimates of quantitative parameters of an event for which the results are unknown, usually in the future. A forecast procedure is not fully teachable.

Forecast period – The time interval for which a forecast is made.

Foredune – The front dune immediately behind the backshore.

Forerunner – Low, long-period, ocean swell which commonly precedes the main swell from a distant storm, especially a tropical cyclone. Compare storm surge, tsunami forerunner.

Foreshocks – A small tremor that commonly precedes a larger earthquake or main shock by seconds to weeks and that originates at or near the focus of the larger earthquake.

Foreshore – The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

See beach face.

Fourier analysis – The representation of physical or mathematical data by the use of the Fourier series or Fourier integral.

Fourier coefficients – See Fourier series.

Fourier integral – The representation of a function $f(x)$ for all values of x in terms of infinite integrals in the form

$$f(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(t) \cos [u(t - x)]\, dt\, du .$$

Fourier series – The representation of a function $f(x)$ in an interval $(-L,L)$ by a series consisting of sines and cosines with a common period $2L$, in the form

$$f(x) = A_0 + \sum_{n=1}^{\infty} \left(A_n \cos \frac{n\pi x}{L} + B_n \sin \frac{n\pi x}{L} \right), \quad -L < x < L$$

where the Fourier coefficients are defined as

$$A_0 = \frac{1}{2L} \int_{-L}^{L} f(x)\, dx ,$$

$$A_n = \frac{1}{L} \int_{-L}^{L} f(x) \cos \frac{n\pi x}{L}\, dx ,$$

and

$$B_n = \frac{1}{L} \int_{-L}^{L} f(x) \sin \frac{n\pi x}{L}\, dx .$$

When $f(x)$ is an even function, only the cosine terms appear; when $f(x)$ is odd, only the sine terms appear.

The conditions on $f(x)$ guaranteeing convergence of the series are quite general, and the series may serve as a root mean square approximation even when it does not converge.

If the function is defined on an infinite interval and is not periodic, it is represented by the Fourier integral. By either representation, the function is decomposed into periodic components whose frequencies constitute the spectrum of the function. The Fourier series employes a discrete spectrum of wave lengths $2L/n$ (n – 1, 2, ...); the Fourier integral requires a continuous spectrum.

See also Fourier transform.

Fourier transform – An analytical transformation of a function f(x) obtained (if it exists) by

multiplying the function by e^{-iux} and integrating over all x,

$$F(u) = \int_{-\infty}^{\infty} e^{-iux} f(x)dx, \quad -\infty<u<\infty,$$

where u is the new variable of the transform F(u) and $i^2 = -1$. If the Fourier transform of a function is known, the function itself may be recovered by use of the inversion formula:

$$f(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} e^{iux} F(u)du, \quad -\infty<x<\infty.$$

The Fourier transform has the same uses as the Fourier series: for example, the integrand F(u) exp (iux) is a solution of a given linear differential equation, so that the integral sum of these solutions is the most general solution of the equation.

When the variable u is complex, the Fourier transform is equivalent to the Laplace transform.

See also Fourier integral, spectral function.

Fracture zone – A large linear and irregular area of the sea floor, characterized by ridges and seamounts. These features are commonly associated with the median ridge common to most ocean basins.

Free oscillations – An oscillation of a body, e.g. the earth, that occurs with out external influence other than the initiating force, and that has its own natural frequency. Such oscillations follow major earthquakes.

Free periods – Periods of free oscillations.

Free surface – The upper surface of a layer of liquid at which the pressure on the liquid is equal to the external atmospheric pressure, assumed constant.

The existence of a free surface is expressed, in hydrodynamics, by the relation $dp/dt = zero$ on the free surface, where p is the total fluid pressure; this relation is often referred to as the free-surface condition, and is a special case of a dynamic boundary condition.

Free-surface condition – See free surface.

Free wave – Any wave not acted upon by any external force except for the initial force that created it; a wave solution satisfying a homogeneous equation of motion and homogeneous boundary conditions. In a system with no impressed forces, a free wave has zero amplitude at the boundaries of the system. The phase speed, wave length, etc. of the free wave or waves are characteristics of the system.

In a steady-state solution, free waves have arbitrary amplitude. These may be specified by initial conditions to determine the solution completely. A free wave on a water surface is one created by a sudden impulse, thereafter influenced only by friction, the dimensions of the basin, and the dispersive character of the water medium it moves in. Most ocean surface waves except tidal waves are free waves.

Compare forced wave; see oscillation.

Freeboard – The additional height of a structure above design high water level to prevent overflow. Also, at a given time, the vertical distance between the water level and the top of the structure. On a ship, the distance from the waterline to main deck or gunwale.

Frequency – For periodic phenomena such as waves or vibrating strings; the number of cycles per unit time. In many types of studies the reciprocal of frequency, the recurrence interval, is used.

Frequency band – A range of frequencies lying within definite upper and lower limits.

Frequency curve – A curve of frequency distribution.

Frequency distribution – A curve whose coordinates are the values of the variable and the frequency of occurrence. It is often presented as a histogram.

Compare probability distribution.

Frequency equation – (Also called dispersion equation.) An equation relating phase speed to wave length and to the physical parameters of the system (fluid depth, current speed, temperature, etc.) in a linear oscillation.

Mathematically, the frequency equation is the result of substituting a simple harmonic solution in the homogeneous differential equations of motion and the homogeneous boundary conditions. The frequency equation thus describes the free waves of the system. If the wave length

does not appear in the expression for the phase speed, the system is non-dispersive.

See group velocity.

Frequency function – Same as probability density function.

Frequency response – A rating which indicates the frequency range over which an instrument will respond uniformly or within specified limits. The frequency response is an important parameter in evaluating the dynamic response of an instrument.

Friction – (Or frictional force.) The mechanical resistive force offered by one medium or body to the relative motion of another medium or body in contact with the first.

Solid bodies in relative motion display sliding and rolling friction which depend upon the forces pressing the bodies together but which are nearly independent of the shapes or relative speeds of the bodies. The resistance of fluids to the relative motion of a solid body is, however, dependent upon the relative speed and the shape of the body, as well as upon the character of the flow itself (see drag).

Friction coefficient – Same as skin-friction coefficient.

See also drag coefficient.

Friction factor – The resistance of a surface to the relative motion, as sliding or rolling of a body moving along a given surface.

Friction layer – Same as planetary boundary layer.

Friction loss – Loss of energy due to friction.

Frictional dissipation – See dissipation.

Frictional divergence – See frictional convergence.

Frictional force – Same as friction; see also drag, drag coefficient, skin friction coefficient.

Frictional torque – The torque exerted by the force of friction.

Fringing reef – A coral reef attached directly to an insular or continental shore.

Front – In meteorology, generally, the interface or transition zone between two air masses of different density. Since the temperature distribution is the most important regulator of atmospheric density, a front almost invariably separates air masses of different temperature.

Front conditions – Along with the basic density criterion and the common temperature criterion, many other features may distinguish a front, such as a pressure trough, a change in wind direction, a moisture discontinuity, and certain characteristic cloud and precipitation forms. The term front is used ambiguously for: a)frontal zone, the three-dimensional zone or layer of large horizontal density gradient, bounded by (b) frontal surfaces across which the horizontal density gradient is discontinuous (frontal surface usually refers specifically to the warmer side of the frontal zone); and c) surface front, the line of intersection of a frontal surface or frontal zone with the earth's surface or, less frequently, with a specified constant-pressure surface.

Froude number – The non-dimensional ratio of the inertial force to the force of gravity for a given fluid flow; the reciprocal of the Reech number. It may be given as

$$Fr = V^2 / Lg,$$

where V is a characteristic velocity, L a characteristic length, and g the acceleration of gravity; or as the square foot of this number.

Fundamental equations of hydrodynamics – The equations of motion, the equation of continuity, the energy equation, the equation of state, and the equation of continuity for water substance, considered together as a closed system of equations.

A simplified physical model can dispense with certain of these equations without sacrificing completeness, e.g., in two-dimensional homogeneous incompressible flow, kinetic energy is the only form of energy, and the equations of motion and continuity form a closed system.

Fundamental oscillation – Oscillation that has harmonic component of a complex wave that has the lowest frequency and commonly the greatest amplitude.

Fundamental unit – A unit measure of a basic physical quantity such as mass, length, time; e.g., one gram, one centimeter, one second, respectively. Other quantities, such as force, temperature, etc., may be considered fundamental and each assigned a fundamental unit.

-G-

Gain – An increase or amplification.

GAPA - Central Editorial Board for the Geological/Geophysical Atlases of the Atlantic and Pacific Oceans.

GARP - Global Atmospheric Research Program.

Gaussian distribution – Same as normal distribution.

Gaussian process – (Also called stationary Gaussian process, stationary Gaussian time series.) A stationary time series in which the joint probability distribution of any sequence of values, $x(t_1, x(t_2,...x(t_n)$, is a multivariate normal distribution; or a stationary random process that is completely determined by its spectrum or autocorrelation function.

Gauss curve – The normal probability density function. See normal distribution.

Gauss's theorem – Same as divergence theorem.

GDPS - Global Data Processing System.

GEBCO - General Bathymetric Chart of the Oceans.

Generalized hydrostatic equation – The vertical component of the vector equation of motion in natural coordinates when the acceleration of gravity is replaced by the virtual gravity. For most purposes it is identical to the hydrostatic equation.

Generating area – In wave forecasting, the continuous area of water surface over which the wind blows in nearly a constant direction. Sometimes used synonymously with fetch length. Also fetch.

Generation of tsunami – Tsunami are generated by disturbances assosiated primarily with earthquakes occuring below or near the ocean floor. Underwater volcanic eruptions and landslides can also generate tsunami.

Generation of waves – 1. The creation of waves by natural or mechanical means.

2. The creation of waves caused by a wind blowing over a water surface for a certain period of time. the area involved is called the generating area or fetch.

Gentle Slope – Slope with inclination of lass than 5 degrees.

Geodesy – The study of the shape and size of the earth.

Geodynamic height – Same as dynamic height.

Geographic coordinates – Same as spherical coordinates.

Geographic horizon – See horizon.

Geography – The study of all aspects of the Earth's surface including its natural and political divisions, the distribution and differentiation of areas and, often, man in relationship to his environment.

Geoid – The particular geopotential surface which most nearly coincides with the mean level of the oceans of the earth. For mapping purposes it is customary to use an ellipsoid of revolution as an adequate and convenient approximation to the geoid. The dimensions and orientation of the assumed ellipsoid may represent an attempt to find the ellipsoid that most nearly fits the geoid as a whole, or they may represent an attempt to fit only a particular part of the geoid without regard to the remainder of it. When mention is made of the dimensions of the earth, reference is usually made to the dimensions of the ellipsoid most nearly representing the geoid as a whole.

Geologic epoch – The third-order division of geologic time, delimited by partial withdrawal of the sea from land masses and by gentle crustal disturbances in localized areas.

Two or more epochs are required to make up a geologic period; and, in turn, two or more periods are needed to constitute a geologic era.

Geologic era – The primary and largest division of geologic time. Limits are rather arbitrary, but each begins and ends with a time of major crustal, climatic, and volcanic upheaval in some part of the earth, with a great world-wide withdrawal of the sea from land masses.

Five geologic eras are recognized: Archeozoic, Proterozoic, Paleozoic, Mesozoic, and Cenozoic. Some authorities regard the Cenozoic as actually two eras, the Tertiary and Quaternary. All eras are divided into a least two geologic periods and a number of geologic epochs.

Geologic period – The secondary division of geologic time, delimited by full-scale withdrawal of the sea from land masses and by limited crustal, climatic and volcanic upheaval in a localized area. Two or more periods are required to make up a geologic era, and each period is comprised of two or more geologic epochs.

Geologic time – Time as considered in terms of the vast geologic past, and basically divided into geologic eras, periods, and epochs. Seldom is geologic time expressed in increments as small as 10,000 years, but frequently it is expressed in millions of years.

Geomagnetic variations – Gradual changes of the Earth's magnetic field with respect to time, measured on a timescale of months to thousands of years.

Geometric shadow – In wave diffraction theory, the area outlined by drawing straight lines paralleling the direction of wave approach through the extremities of the protective structure. It differs from the actual protected area to the extent that the diffraction and refraction effects modify the wave pattern.

Geomorphology – The science of landforms and their development.

Geophysics – The study of the Earth by quantitative physical methods.

Geopotential – The potential energy of a unit mass relative to sea level, numerically equal to the work that would be done in lifting the unit mass from sea level to the height at which the mass is located; commonly expressed in terms of dynamic height or geopotential height. The geopotential Φ at height z is given mathematically by the expression,

$$\Phi = \int_0^z g dz$$

where g is the acceleration of gravity.

Geosphere – The "solid" portion of the earth, including water masses; the lithosphere plus the hydrosphere. Above the geosphere lies the atmosphere and at the interface between these two regions is found almost all of the biosphere, or zone of life.

Compare geoid, equilibrium spheriod.

Geostationary satellite – Stationary satellite positioned above the equator in synchronous rotation with the earth.

Geostrophic flow – A form of gradient flow where the coriolis force exactly balances the horizontal pressure force.

GIPME - Committee for the Global Investigation of Pollution in the Marine Environment.

Glacial – 1. Pertaining to ice, especially in great masses such as sheets of land ice or glaciers.

Compare pluvial.

2. Pertaining to an interval of geologic time which was marked by an equatorward advance of ice during an ice age; the opposite of interglacial. These intervals are variously called glacial periods, glacial epochs, glacial "stages," etc.

Glacial epoch – 1. Any of the geologic epochs characterized by an ice age. Thus, the Pleistocene epoch may be termed a "glacial epoch."

2. Generally, an interval of geologic time which was marked by a major equatorward advance of ice. This has been applied to an entire ice age or (rarely) to the individual glacial "stages" which make up an ice age. The term "epoch" here is not used in the most technical sense of a geologic epoch.

Glacial period – 1. Any of the geologic periods which embraced an ice age. For example, the Quaternary period may be called a "glacial period."

2. Generally, an interval of geologic time which was marked by a major equatorward advance of ice. This may be applied to an entire ice age or (rarely) to the individual glacial "stages" which make up an ice age. The term

"period" here is not used in the most technical sense of a geologic period.

See glacial (2).

GLOSS - Global Sea-Level Observing System.

GOCDB - Global Ocean Climate Data Base.

GOES - Geostationary Orbital Environment Satellites

GOS - Global Observing System.

Gram – A c.g.s unit of mass; originally defined as the mass of 1 cubic centimeter of water at 4° C; but now taken as the one- thousandth part of the standard kilogram, a mass preserved by the International Bureau of Weights and Measures at Sevres, France.

Gravel – See soil classification.

Gravitation – (Or force of gravitation.) The acceleration produced by the mutual attraction of two masses, directed along the line joining their centers of masses, and of magnitude inversely proportional to the square of the distance between the two centers of mass. This acceleration on a unit mass has the magnitude $G(m/r^2)$, where m is the mass of the attracting body, r is the distance between the centers of mass, and G is *Newton's universal gravitational constant* equal to $(6.670 \pm 0.005) \times 10^{-8}$ $cm^3/gm\ sec^2$.

In the case of masses in the earth's gravitational field, m is the mass of the earth, equal to $5.975X\ 10^{27}$ gm. However, the rotation of the earth and atmosphere modifies this field to produce the field of gravity.

Gravitational tide – An atmospheric tide due to gravitational attraction of the sun or moon. The semi-diurnal solar atmospheric tide is partly gravitational; the semi-diurnal lunar atmospheric tide is totally gravitational.

Gravitational wave – Same as gravity wave.

Gravity – (Or force of gravity.) The force imparted by the earth to a mass which is at rest relative to the earth. Since the earth is rotating, the force observed as gravity is the resultant of the force of gravitation and the centrifugal force arising from this rotation. It is directed normal to sea level and to its geopotential surfaces. The magnitude of the force of gravity at sea level decreases from the poles, where the centrifugal force is zero, to the equator, where the centrifugal force is a maximum but directed opposite to the force of gravitation. This difference is accentuated by the shape of the earth, which is nearly that of an oblate spheriod of revolution slightly depressed at the poles. Also, because of the asymmetric distribution of the mass of earth, the force of gravity is not directed precisely toward the earth's center.

The magnitude of the force of gravity per unit mass *(acceleration of gravity)* g may be determined at any latitude ϕ and at any geometric height z (meters) above sea level in the free air from the following empirical formula:

$$g = g_\phi - (3.085462 \times 10^{-4} + 2.27 \times 10^{-7} \cos 2\phi)z + (7.254 \times 10^{-11} + 1.0 \times 10^{-13} \cos 2\phi)z^2 - (1.517 \times 10^{-17} + 6 \times 10^{-20} \cos 2\phi)z^3\ (cm/sec^2)$$

where $g_\phi = 980.6160(1-0.0026373 \cos 2\phi + 0.0000059 \cos^2 2\phi)$ is the sea level value of gravity (cm/sec^2) at latitude ϕ. This formula indicates that gravity changes very little with height or latitude, so that for rough calculations a constant value of 980 cm/sec^2 may be used. Besides these variations in the magnitude of the force of gravity, there are more localized variations controlled by the topography of the earth's surface and the distribution of mass beneath. The magnitude of the force of gravity is usually called either gravity, acceleration of gravity, or apparent gravity.

See virtual gravity, geopotential height, standard gravity.

Gravity anomaly – The difference between the theoretical value of gravity at sea level and the observed value.

Gravity wave – (Also called gravitational wave.) A wave disturbance in which buoyancy (or reduced gravity) acts as the restoring force on parcels displaced from hydrostatic equilibrium. There is a direct oscillatory conversion between potential and kinetic energy in the wave motion. Pure gravity waves are stable for fluid systems which have static stability. This static stability may be (a) concentrated in an interface or (b) continuously distributed along the axis of gravity.

The following remarks apply to the two types, respectively.

A wave generated at an interface is similar to a surface wave, having maximum amplitude at the interface. A plane gravity wave is characteristically composed of a pair of waves, the two moving in opposite directions with equal speed relative to the fluid itself. In the case where the upper fluid has zero density, the interface is a free surface and the two gravity waves move with speeds

$$c = U \pm \left[\frac{gL}{2\pi} \tanh \frac{2\pi H}{L}\right]^{\frac{1}{2}}$$

where UU is the current speed of the fluid, g the acceleration of gravity, L the wave length, and H the depth of the fluid. For deep-water waves (or Stokesian waves or short waves), $H>>L$ and the wave speed reduces to

$$c = U \pm \sqrt{\frac{gL}{2\pi}} .$$

For shallow-water waves (or Lagrangian waves or long waves), $H<<L$, and

$$c = U \pm \sqrt{gH} .$$

All waves of consequence on the ocean surface or interfaces are gravity waves, for the surface tension of the water becomes negligible at wave lengths of greater than about one inch (see capillary wave).

Lamb, H., Hydrodynamics, 6th ed., 1953, pp. 417-426

Great circle – A line formed by the intersection of the surface of a sphere and a plane which passes through the center of the sphere.

Great-circle course – A course, route, or track along a great circle over the earth's surface. The great-circle course is the least distance between two points on a sphere. The angle between the great circle and true north changes along the course except along a meridian or the equator. See rhumb-line course, grid navigation.

Green-Naghdi equations – See Green's theorem.

Green's function – (Also called influence function.) A function which is the known solution of a homogeneous differential equation in a specified region and which may be generalized (if the equation is linear) to satisfy given boundary or initial conditions, or a non-homogeneous differential equation. It is thus an alternative method to the Fourier transform or Laplace transform, applicable to many of the same problems. The Green's function method takes a fundamental solution and assigns it a weight at each point, say, of the boundary, according to the value of the given boundary condition there; the Fourier method analyses the entire boundary condition into wave components thus assigning each of these a weight or amplitude. Both methods then obtain the final solution by summation or integration.

Green's theorem – A form of the divergence theorem applied to a vector field so chosen as to yield a formula useful in applying the Green's function method of solution of a boundary-value problem.

The most common form of the theorem is

$$\int_V (\phi\nabla^2\psi - \psi\nabla^2\phi)dV = \oint_S \left(\phi\frac{\partial\psi}{\partial n} - \psi\frac{\partial\phi}{\partial n}\right) dS$$

where dV and dS are elements of the volume V and closed bounding surface S, respectively, n is the outer normal to S and ∇^2 is the Laplacian operator.

Grid meridians – An arbitrary set of straight lines constructed parallel to the 180 degrees and 0 degrees meridians. They are used for grid navigations; grid north replaces true north.

Grid size – In numerical modeling the measurement of the amount of space taken up by a network of uniformly spaced horizontal and perpndicular lines at the intersection of which are points of data. Grid size is indicative of the density of data. If the data is uniform then a larger grid size does not affect the calculations. If the data changes rapidly and has a great deal of variation, then a smaller grid in a numerical model produces more accurate results. For example, in tsunami travel time calculations by computer methods using finite differences ttechniques,the smaller grid results in more accurate travel times. In addition to rectangular grids, triangular grids of varying grid sizes are often used for a multidude of studies.

Groin (British, groyne) – A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

Groin system – A series of groins acting together to protect a section of beach. Commonly called a groin field.

Ground water – (Sometimes called phreatic water.) Subsurface water which occupies the zone of saturation; thus, only the water below the water table, as distinguished from interflow and soil moisture.

Ground-water table – Same as water table.

Group velocity – The velocity of a wave disturbance as a whole, i.e., of an entire group of component simple harmonic waves. The group velocity G is related to the phase speed C of the individual harmonic waves of length L by the frequency equation

$$G = C - L\frac{dC}{dL};$$

the phase speed C is thus equal to the group velocity only in the case of non-dispersive waves, i.e., when dC/dL = zero. The significance of the concept of group velocity lies in the fact that the energy of the disturbed flow is, in a sense, propagated at this speed.

For water-surface waves, the group velocity of deep-water waves is equal to one-half the velocity of individual waves in the group; for shallow-water waves, it is the same as their velocity.

GTS - Global Telecommunication System.

Gulf – A large embayment in a coast; the entrance is generally wider than the length.

Gumbel distribution – A statistical distribution, or density of probability of the recurrence of a rare event for which very little data exists. Such a statistical approach may be used to indicate, with a great deal of variance and uncertainty, the recurrence frequency of large earthquakes or destructive tsunamis for which very little historical data exists.

Gut – 1. A narrow passage such as a strait or inlet.

2. A channel in otherwise shallower water, generally formed by water in motion.

Gutenberg discontinuity – The seismic velocity discontinuity marking the mantle-core boundary at which the velocities of P waves are reduced and S waves disappear. It probably reflects the change from a solid to a liquid phase.

Gutenberg-Richter recurrence relationship- The listing of earthquakes in an area, or in modern terms the creation of a seismicity catalog, dates from the seventeenth century in Europe: Global compilations, to determine seismic and nonseismic regions of the world, had to await the nineteenth century. On a global scale, this has meant seismicity maps unbiased by population distribution, the most notable early effort being that of Gutenberg and Richter; later work, while more accurate and complete, has not altered the basic picture of a few seismic belts. Especially for the deep ocean, where these belts could be seen to coincide with the mid-ocean rift, this observation was an important input to the ideas of plate tectonics. On a local scale, only instrumental records could reveal the patterns of the many unfelt earthquakes; a pioneering example was the southern California network established by H.O. Wood in the 1920s (Goodstein, 1984). The development of instrumental earthquake catalogs, with their improved coverage, also created both the need to quantify earthquake size and the data with which to do it. Richter's 1935 invention of a "magnitude" scale for local shocks, later extended by Gutenberg and Richter to teleseisms, soon became and largely remains the most used measure of earthquake size. Based on such extensive cataloguing of seismic data by Gutenberg and Richter, as well as others, recurrence relationships were established.

–H–

Half-tide level – The level midway between high water and low water for any series of tidal observations. It is generally different from mean sea level because of the existence of semi-annual, and longer-period, partial tides.

Harbor opening – The channel or entrances of the harbor that lead to the open sea.

Harbors – A small bay or a sheltered part of a sea, lake, or other large body of water, usually well protected either naturally or artificially against high waves and strong currents, and deep enough to provide safe anchorage for ships.

Harbor oscillation (harbor surging) – The nontidal vertical water movement in ha harbor or bay. Usually the vertical motions are low, but when oscillations are excited by a tsunami or storm surge, they may be quite large. Variable winds, air oscillations, or surf beat also may cause oscillations.

See seiche.

Harbor response – The set up of wavelike motion in a harbor resulting from tsunami wave action. A sloshing motion may be generated whithin the harbor which may last for several hours after initial tsunami arrival. The period of the slosh is determined by the depth of the water and the length of the h.arbor and is independent of the initial tsunami period.

Harmonic – 1. A sine or cosine component of the Fourier series representation of an empirical or theoretical function.

2. A wave or vibration having a frequency which is an integral multiple of the fundamental (lowest) or other reference frequency of vibration of a physical system.

Harmonic analysis – A statistical method for determining the amplitude and period of certain harmonic or wave components in a set of data with the aid of Fourier series.

Harmonic components – A component frequency of a harmonic motion that is an integral multiple of the fundamental frequency.

Harmonic function – Any solution of the Laplace equation.

Harmonic oscillations – the action or fact of oscillating expressible in terms of sine or cosine function.

Hazard (of tsunami) – As the tsunami enters the shoaling water of coastlines in its path, the velocity of its waves diminishes and wave height increases. It is in these shallow waters that tsunamis become a threat to life and property, for they can crest to considerable heights, and strike coastal communities with devastating force.

Hazard mitigation – Development of the ESSA Coast and Geodetic Survey's Pacific Tsunami Warning System, Regional Tsunami Warning System.

Hazard modeling – Production of a representation or simulation of a source of danger from a natural or man-made hazard.

Hazardicity – The relative level of risk from a tsunami, not usually perceived exactly.

Hazardous zone – An area involving or exposing one to risk.

Hazen method – 1. A method of computing the return period in which the mth highest event in t years has assigned to it a return period equal to

$$\frac{2t}{2m-1}.$$

2. A method of fitting a frequency curve to an observed series of floods on the assumption that the logarithms of the variate are normally distributed.

Head wave – A seismic wave travelling downward at the critical angle to a high-velocity layer, moving along the top of that layer, and later emerging at the critical angle.

Headland (head) – A high steep-faced promontory extending into the sea.

Head of rip – The part of a rip current that has widened out seaward of the breakers.

See also current, rip; current, feeder; and neck (rip).

Heave – 1. The motion imparted to a floating body by wave action. It includes both the vertical rise and fall, and the horizontal transport.

2. The up and down motion of the center of gravity of a ship.

Heaving – See Heave

Height – 1. See altitude, elevation.

2. See wave height.

Height of wave – See wave height.

Helmholtz equation – A linear second-order partial differential equation of the form

$$\nabla^2\psi = k\psi = 0$$

where ∇^2 is the Laplacian operator and k is a constant. In classical physics it is the equation of the vibrating membrane. The case $k = 0$ reduces to a Laplace equation.

Helmholtz instability – (Also called shearing instability.) The hydrodynamic instability arising from a shear, or discontinuity, in current speed at the interface between two fluids in two-dimensional motion. The perturbation gains kinetic energy at the expense of that of the basic currents.

According to the theory of small perturbations, waves of all wave lengths on such an interface are unstable, their rate of growth being exp μt with μ given by

$$\mu = \frac{\pi}{\lambda}|U - U'|$$

where λ is the wave length and U and U' the current speeds of the two fluids. Such waves are called Hemlholtz waves or shear waves, and move with a phase speed c equal to the mean of the current speeds

$$c = \frac{1}{2}(U + U') .$$

With an assumed density difference in the fluids, gravity waves may also be generated. The combination of these effects yields a critical wave length λ_c,

$$\lambda_c = \frac{2\pi}{g}\frac{\rho\rho'}{\rho^2 - \rho'^2}(U - U')^2$$

where ρ and ρ' are the densities of the lower and upper fluids respectively. Waves shorter than the critical are unstable; longer waves, stable.

Helmholtz's theorem – The statement that if F is a vector field satisfying certain quite general mathematical conditions, then F is the sum of two vectors, one of which is irrotational (has no vorticity), the other solenoidal (has no divergence).

Thus, the horizontal velocity field, for example, may be expressed by

$$V = \nabla_{H\alpha} + k \times \nabla_{H\psi} = V_\alpha + V_\psi$$

where **V** is irrotational, i.e., $\nabla_H \times V_\alpha = zero$, and V_ψ is solenoidal, i.e., $\nabla_H \times V_\phi = zero$. **k** is a unit vector directed vertically α and ψ are scalar functions.

Helmholtz wave – An unstable wave in a system of two homogeneous fluids with a velocity discontinuity at the interface.

Heterogeneous fluid – A fluid within which the density varies from point to point.

Hertz(Hz) – Unit of frequency. One Hz equals one cycle per second.

High tide – Same as high water.

High water – The highest water level reached during a tide cycle. The accepted popular term is high tide.

High-water interval – Same as cotidal hour.

High water of ordinary spring tides (HWOST) – A tidal datum appearing in some British publications, based on high water of ordinary spring tides.

High water line – In strictness, the intersection of the plane of mean high water with the shore. The shoreline delineated on the nautical charts of the U.S. Coast and Geodetic Survey is an approximation of the high water line. For specific occurrences, the highest elevation on the shore reached during a storm or rising tide, including meteorological effects.

Higher high water (HHW) – The higher of the two high waters of any tidal day. The single high water occurring daily during periods when the tide is diurnal is considered to be a higher high water. (See Figure A-10.)

Higher low water (HLW) – The higher of two low waters of any tidal day. (See Figure A-10.)

Hindcasting, wave – The use of historic synoptic wind charts to calculate wave characteristics that probably occurred at some past time.

Histogram – A graphical representation of a frequency distribution. The range of the variable is divided into class intervals for which the frequency of occurrence is represented by a rectangular column; the height of the column is proportional to the frequency of observations within the interval.

Historical records – The state or fact of being recorded of relating to, or having the characteristic of history. (historical tsunami records of pertinent data).

Homogeneous fluid – A fluid within which the density is uniform.

Hook – A spit or narrow cape of sand or gravel which turns landward at the outer end.

Human behavior – The response of humans to their environment.

Hurricane – A severe tropical cyclone in the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico and in the Eastern North Pacific of the west coast of Mexico, in which the wind velocity equals or exceeds 64 knots (73 mph). For more complete discussion, see tropical cyclone.

Hurricane eye – Usually the "eye of the storm; that is, the roughly circular area of comparatively light winds and fair weather found at the center of a severe tropical cyclone. The winds are generally ten knots or less; no rain occurs; sometimes bluesky may be seen. Eye diameters vary from four miles to more than forty miles; common magnitudes seem to be twelve to twenty-five miles. Modern observations indicate that the eye does not remain in steady state but is continuously undergoing changes in shape and size.

Hurricane-force wind – In the Beaufort wind scale, a wind whose speed is 64 knots (73 mph) or higher. Use of this term leads to some confusion among the unitiated, for hurricane-force winds do occur independently of hurricanes.

Hurricane path or track – Line of movement (proposation) of the eye through an area.

Hurricane stage hydrograph – A continuous graph representing water level stages that would be recorded in a gage will located at a specified point of interest during the passage of a particular hurricane, assuming that effects of relatively short-period waves are eliminated from the record by damping features of the gage well. Unless specifically excluded and separately accounted for, hurricane surge hydrographs are assumed to include effects of astronomical tides, barometric pressure differences, and all other factors that influence water level stages within a properly designed gage well located at a specific point.

Hurricane surge – Same as hurricane wave; see also storm surge.

Hurricane surge hydrograph – A continuous graph representing the difference between the hurricane stage hydrograph and the water stage hydrograph that would have prevailed at the same point and time if the hurricane had not occurred.

Hurricane tide – Same as hurricane wave; see also storm surge.

Hurricane warning – A warning of impending winds of hurricane force. For maritime interests, the storm-warning signals for this condition are (a) two square red flags with black centers by day, and (b) a white lantern between two red lanterns by night.

Hurricane watch – An announcement for a specific area that hurricane conditions pose a threat. Residents are cautioned to take stock of their preparedness needs, but, otherwise, are advised to continue normal activities.

Hurricane wave – (Also called hurricane surge, hurricane tide.) As experienced on islands and along a shore, a sudden rise in the level of the sea associated with a hurricane. In low latitudes, the hurricane wave appears to occur in the proximity of the storm's center. As the hurricane moves into higher latitudes, however, the maximum wave appears to become associated more and more with only the dangerous semicircle.

See storm surge, tsunami.

Huygen's principle – A very general principle applying to all forms of wave motion which states that every point on the instantaneous position of an advancing phase front (wave front) may be regarded as a source of secondary

spherical "wavelets." The position of the phase front a moment later is then determined as the envelope of all of the secondary wavelets (ad infinitum). This principle, stated by the Dutch physicist Christian Huygens (1629-1695), is extremely useful in understanding effects due to refraction, reflection, diffraction, and scattering, of all types of radiation, including sonic radiation as well as electromagnetic radiation and applying even to ocean wave, and tsunami wave propogation.

Huygen's wavelets – The assemblage of secondary waves asserted by Huygens to be set up at each instant at all points on the advancing surface of a wave, or phase front.

Hydraulic filter – A device or an opening in the well of a tide gauge which filters out short period oscillations of the sea caused by wave action and permits the continuous smooth recording of sea level oscillations caused by the tides or by tsunami waves.

Hydraulic gradient – The slope of the profile of the static level for a hydraulic system. In open channel flow the hydraulic gradient is the slope of the water surface taken parallel to the flow; in unconfined ground water flow it is the slope of the water table taken normal to its contours; and for artesian ground water it is the slope of the piezometric surface taken normal to its contours.

Hydraulic jump – A steady-state, finite-amplitude disturbance in a channel, in which water passes turbulently from a region of (uniform) low depth and high velocity to a region of (uniform) high depth and low velocity. When applied to hydraulic jumps, the usual hydraulic formulas governing the relations of velocity and depth do not conserve energy.

See also bore.

Hydraulic model – A physical scale model of a basin or a harbor used to simulate effects of wave action or flooding caused by hurricane surge or tsunami wave activity.

Hydraulic modelling – Mathematical formulations used in connection with a hydraulic physical model to simulate natural hydrologic phenomena which are considered as processes or as systems.

Hydraulic radius – The quotient of the cross-sectional area of a channel (below the water surface) divided by the wetted perimeter.

Hydraulics – A branch of engineering which comprises the study of the flow of fluids, especially the flow of water in rivers, canals, etc., and which is, therefore, a branch of applied hydrodynamics.

Hydroacoustic waves – Sound waves traveling through the water at a known rate which is dependent on the water temperature and temperature.

Hydrodynamic pressure – The difference between the pressure and the hydrostatic pressure. This concept is useful chiefly in problems of the steady flow of an imcompressible fluid in which the hydrostatic pressure is constant for a given elevation (as when the fluid is bounded above by a rigid plate), so that the external force field (gravity) may be eliminated from the problem. If p^* is the hydrodynamic pressure, ρ the density, and V the speed, Bernoulli's equation gives

$$p^* + \frac{1}{2}\rho V^2 = \text{onstant along a streamline.}$$

See also static pressure.

Hydrodynamics – The study of fluid motion. "Fluid" here refers ambiguously to liquids and gases.

Hydrograph – A graphical representation of stage or discharge at a point on a stream as a function of time. The most common type, the observed hydrograph, represents river gage readings plotted at time of observation. Other types of hydrograph which are statistically derived from observed data include the distribution graph and the unit hydrograph. The possible hydrograph varieties are numerous, representing averages, storm units, seasonal characteristics, etc., in cumulative or differential form, and utilizing a number of different graphing or tabulating methods.

Hydrography – The science that deals with the physical aspects of all waters on the Earth's surface

Hydrosphere – The realm of water including the oceans, ground water, and ice caps.

Hydrostatic equilibrium – The state of a fluid whose surfaces of constant pressure and constant mass (or density) coincide and are horizontal throughout. Complete balance exists between the force of gravity and the pressure force. The relation between the pressure and the geometric height is given by the hydrostatic equation.

Hydrostatic pressure – (Also called gravitational pressure.) The pressure in a fluid in hydrostatic equilibrium, i.e., the pressure at a point due solely to the weight of fluid above. This should not be confused with static pressure.

See also hydrodynamic pressure.

Hyperbolic point – (Sometimes called neutral point.) A singular point in a streamline field which constitutes the intersection of a convergence line and divergence line. It is analogous to a col in the field of a single-valued scalar quantity.

Hyperbolic wave – Relating to, or being analogous to, a plane curve generated by a point so moving that the difference of the distance from two fixed points is a constant, or being a space in which more than one line parallel to a given line passes through a point.

Hypocenter – The calculated location of the focus of an earthquake.

Hypsography – The height pattern of a physically defined surface, as revealed by contour lines.

Hypsometry – The science of height measurement.

–I–

IAEA - International Atomic Energy Agency.

IAEE - International Association of Earthquake Engineers

IAG - International Association of Geodesy

IAGA - International Association of Geomagnetism and Aeronomy

IAH - International Association of Hydrogeologists

IAHR - International Association for Hydraulic Research

IAHS - International Association of Hydrological Sciences

IAMAP - International Association of Meteorology and Atmospheric Physics

IAPSO - International Association for the Physical Sciences of the Oceans

IASPEI - International Association of Seismology and Physics of the Earth's Interior

IAU - International Astronomical Union

IAVCEI - International Association of Volcanology and Chemistry of the Earth's Interior

Ice age – A major interval of geologic time during which extensive ice sheets (continental glaciers) formed over many parts of the world.

The best known ice ages are: (a) the Huronian in Canada, occurring very early in the Proteozoic era; (b) the pre-Cambrian and early Cambrian which occurred in the early Paleozoic era (about 530 million years ago) and left traces widely scattered over the world; (c) the Permo-Carboniferous, occurring during the late Paleozoic era (from 275 million to 225 million years ago) and which was extensively developed in the Southern Hemisphere, with smaller ice sheets in northern India and northeastern United States; and (d) the Quaternary or Pleistocene which began about one million years ago and may not yet have ended. Ice ages are made up of alternate glacial and interglacial "states" (or "periods").

See glacial epoch, glacial period, paleoclimate.

Iceberg – A mass of land ice that has broken away from land and floats in the sea, or becomes stranded in shallow water; to be distinguished form floeberg. The unmodified term "iceberg" usually refers to the irregular masses of ice formed by the calving of glaciers along an orographically rough coast; whereas tabular icebergs and ice islands are calved from an ice shelf, and floebergs are formed from sea ice.

Ice cap – A perennial cover of ice and snow over an extensive portion of the earth's surface. There are several ice caps in the world, all of which may be

regarded as remnants of the Quaternary Ice Age. In the relatively recent geologic past (that is, during the climactic optimum), the extent of these has probably been much less than now. The most important of the existing ice caps are those on Antarctica and Greenland (the latter often called inland ice). The term was first used for the supposedly perennial ice cover at both poles of the earth. However, since it has been found that the ice of arctic waters is largely seasonal, the use of this term to denote arctic polar ice is now considered improper.

See continental ice, snow cap.

Icefall – A glaciological term which describes that portion of a glacier where a sudden steepening of descent causes a chaotic breaking up of the ice.

Ice field – A large, level area of ice, either of sea ice ("more than five miles across") or an ice cap or highland ice.

Ice foot – Sea ice firmly frozen to the shore at the high-tide line, and unaffected by tide. This type of fast ice is formed by the freezing of sea water during ebb tide, and of spray. It is separated from the floating sea ice by a tide crack; in many areas it offers a fairly level, continuous route for surface travel.

Ice front – The seaward facing, cliff-like edge of an ice shelf (so called by the British Antarctic Place-names Committee).

Ice island – One of the many, large tabular icebergs found in the Arctic Ocean.

ICES - International Council for the Exploration of the Sea.

Ice shelf – (Also called shelf ice; formerly barrier.) A thick ice formation with a fairly level surface, formed along a polar coast and in shallow bays and inlets, where it is fastened to the shore and often reaches bottom. It may grow hundreds of miles out to sea. It is usually an extension of land ice, and the seaward edge floats freely in deep water. The calving of an ice shelf forms tabular icebergs and ice islands.

ICET - International Centre for Earth Tides.

ICITA - International Cooperative Investigation of the Tropical Atlantic.

ICL - Inter-Union Commission on the Lithosphere.

IBCM - Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets.

ICG/ITSU - Abbreviation for International Coordination Group for the Tsunami Warning System in the Pacific. ICG/ITSU is an international cooperative effort involving many Member States of the Pacific Region, established in 1968 as a subsidiary body of the Intergovernmental Ocanographic Commission (IOC), of UNESCO. It meets every two years to review progress and coordinate activities resulting in improvements of the Tsunami Warning System. Present membership of ICG/ITSU is comprised of the following Member States: Australia, Canada, Chile, China, Colombia, Cook Islands, Democratic People's Republic of Korea, Ecuador, Fiji, France, Guatemala, Indonesia, Japan, Mexico, New Zealand, Peru, Philippines, Republic of Korea, Singapore, Thailand, USSR, United Kingdom (Hong Kong), USA, and Western Samoa.

ICRCM - International Centre for Recent Crustal Movement.

ICSI - International Commission on Snow & Ice.

ICSU - International Council of Scientific Unions.

IDA - International Deployment Accelerometers.

IDE - International Declared Event.

IDOE - International Decade of Ocean Exploration.

IERS - International Earth Rotation Service.

Igneous – Said of a rock or mineral that solidified from molten or partly molten material; (i.e., igneous, metamorphic, and sedimentary)

Igneous rocks – Rocks formed by the solidification of molten magma. Magma is composed of numerous minerals (mainly silicates) and grass derived from the earth's crust and mantle, and is in a melted state

IGBP - International Geosphere-Biosphere Program (Global Change).

IGC - International Geophysical Cooperation.

IGOSS - Integrated Global Ocean Services System.

IGU - International Geographical Union.

IGY - International Geophysical Year.

IHO - International Hydrographic Organization.

IHP - International Hydrological Programme.

IIOE - International Indian Ocean Expedition.

ILP - International Lithosphere Program.

ILS - International Latitude Service.

Imbricate structure – A series of nearly parallel and overlapping minor thrust faults, high-angle reverse faults, or slides.

Impermeable groin – A groin through which sand cannot pass.

Impulse –

IMS - International Magnetospheric Study.

Inaccuracy – The difference between the input quantity applied to a measuring instrument and the output quantity indicated by that instrument. The inaccuracy of an instrument is equal to the sum of its instrument error and its uncertainty.

Inch of mercury – A common unit used in the measurement of atmospheric pressure. One inch of mercury (in Hg) is defined as that pressure exerted by a one-inch column of mercury at standard gravity and a temperature of 0° C.

1 in Hg = 25.4 mm Hg
= 33.864 mb
= 1.00005 in Hg (45°)

Incident wave – Wave that is falling on or striking something.

Independent variable – Any of those variables of a problem, chosen according to convenience, which may arbitrarily be specified, and which then determine the other or dependent variables of the problem. The independent variables are often called the coordinates, particularly in problems involving motion in space. Dependent and independent variables can be interchanged, e.g. height and pressure.

Index – The indicating part of an instrument; for example, the hand of a watch or the meniscus of a mercury column.

Indian spring low water – The approximate level of the mean of lower low waters at spring tides, used principally in the Indian Ocean and along the east coast of Asia. Also Indian tide plane.

Indian tide plane – The datum of Indian spring low water.

Individual derivative – (Also called material derivative, particle derivative, substantial derivative.) The rate of change of a quantity with respect to time, following a fluid parcel. For example, if $\phi(x,y,z,t)$ is a property of the fluid and $x = x(t)$, $y = y(t)$, $z = z(t)$ are the equations of motion of a certain particle of this fluid, then the total derivative,

$$\frac{d\phi}{dt} = \frac{\partial \phi}{\partial t} + \frac{\partial \phi}{\partial x}\frac{dx}{dt} + \frac{\partial \phi}{\partial z}\frac{dz}{dt} = + \mathrm{V} \cdot \nabla \phi$$

(where V is the velocity of the fluid and ∇ is the del-operator), is an individual derivative. It gives the rate of change of the property of a given parcel of the fluid as opposed to the rate of change at a fixed geometrical point which is usually called the local derivative. The term $\mathrm{V} \cdot \nabla \phi$ is called the advective term, expressing the variation of on a parcel moving into regions of different ϕ.

See total derivative.

Inertia wave – 1. Any wave motion in which no form of energy other than kinetic energy is present. In this general sense, Helmholtz waves, barotropic disturbances, Rossby waves, etc., are inertia waves.

2. More restrictively, a wave motion in which the source of kinetic energy of the disturbance is the rotation of the fluid about some given axis.

Inertial flow – Flow in the absence of external forces.

Inertial force – (Or inertia force.) A force in a given coordinate system arising from the inertia of a parcel moving with respect to another coordinate system. For example, the coriolis acceleration on a parcel moving with respect to a coordinate system fixed in space becomes an inertial force, the coriolis force, in a coordinate system rotating with the earth.

Inertial instability – 1. (Also called dynamic instability.) Generally, instability in which the only form of energy transferred between the steady state and the disturbance is kinetic energy.

2. The hydrodynamic instability arising in a rotating fluid mass when the velocity distribution is such that the kinetic energy of a disturbance grows at the expense of kinetic energy of the rotation. For a small plane-symetric displacement (wave number zero) using the parcel method, this criterion for instability is that the centrifugal force on the displaced parcels is larger than the centrifugal force acting on the environment. On the assumption that absolute angular momentum is conserved, this states that the fluid is unstable if absolute angular momentum decreases outward from the axis;

$$R\,\frac{\partial \omega_a}{\partial R} + 2\omega_a < 0\,,$$

where ω_a is the absolute angular speed and R the distance from the axis.

Inertial oscillation – The latitudinal oscillation of a parcel in inertial flow.

Initial condition – A prescription of the state of a dynamical system at some specified time. For all subsequent times the equations of motion and boundary conditions determine the state of the system. In many contexts, initial conditions are considered as boundary conditions in the dimension of time.

Initial-value problem – (Also called transcient problem.) A dynamical problem whose solution determines the state of a system at all times subsequent to a given time at which the state of the system is specified by given initial conditions. The initial-value problem is contrasted with the steady-state problem, in which the state of the system remains unchanged in time.

See also boundary-value problem.

Inlet – 1. A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water.

2. An arm of the sea (or other body of water), that is long compared to its width, and may extend a considerable distance inland.

See also tidal inlet.

Inlet gorge – Generally, the deepest region of an inlet channel.

Input – (Or input signal.) The quantity to be measured (or modulated, or detected, or operated upon) which is received by an instrument.

Inshore (zone) – In beach terminology, the zone of variable width extending from the low water line through the breaker zone. Shoreface. (See Figure A-1.)

Instability – In oceanography the reference is usually to one of the following:

(a) static instability (or hydrostatic instability) of vertical displacements of a parcel in a fluid in hydrostatic equilibrium. (See condition instability, absolute instability, convective instability, gravitational instability.)

(b) Hydrodynamic instability (or dynamic instability) of parcel displacements or, more usually, of waves in a moving fluid system governed by the fundamental equations of hydrodynamics, to which the quasi- hydrostatic approximation may or may not apply. (See Helmholtz instability, inertial instability, shearing instability, baroclinic instability, barotrophic instability, rotational instability.) The space scale of unstable waves is important.

Hydrodynamic instability must not be confused with the phenomenon often referred to by mathematicians and physicists by the same term. A great deal of study has been devoted to the problem of the onset of turbulence in simple flows under laboratory conditions, and here viscosity is a source of instability.

Instrument correction – The mean difference between the readings of a given instrument and those of a standard instrument.

Instrument error – The correctable part of the inaccuracy of an instrument.

Instrument exposure – The physical location of an instrument.

Instrumentation – 1. The use of instruments; 2. The application of instruments for observation, measurement, or control.

Insular shelf – The zone surrounding an island extending from the low water line to the depth (usually about 100 fathoms) where there is a marked or rather steep descent toward the great depths.

Insulation – The prevention of the transfer of energy between two conductors by separating the conductors with a non-conducting material; or, the non-conducting material itself.

Intensity – A measure of the effects of an earthquake at a particular place on humans and (or) structures. The intensity at a point depends not only upon the strength of the earthquake (magnitude) but also upon the distance from the earthquake to the epicenter and the local geology at that point.

Interaction – With respect to wave components, the non-linear action by which properties of fluid flow (such as momentum, energy, vorticity), are transferred from one portion of the wave spectrum to another, or viewed in another manner, between eddies of different size-scales.

Interface – (Also called internal boundary.) A surface separating two fluids, across which there is a discontinuity of some fluid property, such as density, velocity, etc., or of some derivative of one of these properties in a direction normal to the interface. Therefore, the equations of motion do not apply at the interface but are replaced by the kinematic and dynamic boundary conditions.

Interference – The vector addition of two or more waves. Destructive and constructive interference result when two superposed waves are 180 or 360 degrees respectively out of phase.

Interference region – That region in space in which interference between wave trains occurs.

Interglacial – Pertaining to an interval of geologic time (tens or hundreds of thousands of years) marked by mild climate between the glacial stages of an ice age. In the Quaternary Ice Age there have been three interglacial stages, and we may now be in the fourth. In low latitudes beyond the reach of the glacierizations, the corresponding intervals are the interpluvial stages.

Internal tsunami – A tsunami wave manifested as an internal wave and traveling along a thermocline .See internal wave below.

Internal wave – A submerged wave occurring on a density surface, e.g. the thermocline, in density-stratified water. Because of the small density gradients involved in internal waves compared with external or surface waves, the internal wave heights, periods, and wavelengths are usually large. A wave in fluid motion having its maximum amplitude within the fluid or at an internal boundary (interface). The concepts of internal and external waves originated in the study of gravity waves in homogeneous incompressible fluids, and it makes no difference in the dynamics of the wave whether the static stability of the fluid is concentrated in a free surface or in an interface. However, internal waves in a fluid with continually varying density have maximum amplitudes and nodal surfaces within the fluid itself, so that these are properly distinguished from external waves.

See also surface wave.

Internal sea waves – See internal waves

Internal seiche – A free oscillation of a submerged layer in a stratified body of water occupying an enclosed or semi-enclosed basin.

Interpolation – The estimation of unknown intermediate values from known discrete values of a dependent variable. Various methods are available in one dimension for fitting polynomials or other functions to the known points, the elaborateness of the technique used depending on (among other things) the number and accuracy of the "known" values. The

analysis of a weather chart is an interpolation and smoothing in two dimensions.

Compare extrapolation.

Intrusive – Referring to material, such as molten rock, injected into other rock.

Inundation – The depth (relative to a stated reference level) to which a stated location is covered by water.

Inundation Area -An area that is flooded with water.

Inundation line (limit) – The inland limit of wetting, measured horizontally from the MSL line. Where MLLW was used, it should be converted to the MSL line (move inland to an elevation 0.7 feet higher. The vegetation line is sometimes used as a reference. If it can be determined that is more than 10 feet from the MSL line, adjust; otherwise, ignore. In tsunami science the landward limit of tsunami runup.

Inverse-square law – A relation between physical quantities of the form: x is proportional to $1/y^2$. y is most usually a distance and the x's are of two kinds, forces and fluxes.

IOC - International Oceanographic Commission.

IOCARIBE - IOC Sub-Commission for the Caribbean and Adjacent Regions.

IOCEA - Regional Committee for the Central Eastern Atlantic.

IOCSOC - Regional Committee for the Southern Ocean.

IOCINDIO - Regional Committee for the Co-operative Investigation in the North and Central Western Indian Ocean.

IODE - Committee on International Oceanographic Data and Information Exchange.

Ionosphere – The atmospheric shell characterized by a high ion density. Its base is at about 70 or 80 km and it extends to an indefinite height.

The ionosphere is classically subdivided into "layers." Each "layer," except for the D-layer, is supposedly characterized by a more or less regular maximum of electron density. The lowest clearly defined layer is the E-layer, occurring between 100 and 120 km. The F_1-layer and the F_2-layer occur in the general region between 150 and 300 km, the F_2-layer being always present and having the higher electron density. The existence of a G-layer has been suggested, but is questionable. The portions of the ionosphere in which these "layers" tend to form are known as ionospheric "regions."

The above assumption that the ionosphere is stratified in the vertical into discrete layers is currently under serious question. Some evidence supports a belief that ion clouds are the basic elements of the ionosphere. Other investigations appear to reveal the ionosphere as a generally ionized region characterized by more or less random fluctuations of electron density.

IPS - Interplanetary Scintillation.

IRI - International Reference Ionosphere.

IRIS - Incorporated Research Institutions in Seismology.

Irrotational – Applied to a vector field having zero vorticity or curl throughout the field. Two equivalent properties of an irrotational field are that there is no circulation about any reducible curve within the fluid, and that a potential exists.

Irrotational wave – A wave with fluid particles that do not revolve around an axis through their center, although the particles themselves may travel in circular or nearly circular orbits. Irrotational waves may be progressive, standing, oscillatory, or translatory. For example, the Airy, Stokes, cnoidal and solitary wave theories describe irrotational waves.

See trochoidal wave.

ISC - International Seismological Centre.

Island – A tract of land surrounded by water and smaller than a continent.

Island arc – Island chains which represent segments of an arc and are generally convex outward from the continental areas and are part of the major globe-encircling active orogenic belt systems. A single island arc consists of a single chain of volcanic islands. With further tectonic

development, double island arcs may be formed. These consist of an outer arc of sedimentary islands and a parallel inner arc of volcanic islands. Most of the single island arcs contain submerged or scattered traces of a second line. Certain single and double island arcs exhibit large transcurrent (or strike-slip) fault zones which suppress the ideal arcuate pattern. These island arcs are called fractured island arcs.

Isobath – (Sometimes called fathom curve.) A contour of equal depth in a body of water, represented on a bathymetric chart.

Isochrone – A line in a chart connecting all points having the same time of occurrence of a particular phenomenon or of a particular value of a quantity.

Isodynamic – In general, a line of equal magnitude of any force.

Isogram – (Or isoline.) A line, on a given reference surface, drawn through all points where a given quantity has the same numerical value. The reference surface can be any coordinate plane functionally related to the given quantity (this includes physically defined surfaces in space). This, therefore, is a very general term.

Isoline – Same as isogram.

Isoseismal line – A line connecting points on the Earth's surface at which earthquake intensity is the same. It is usually a closed curve around the epicenter.

Isotimic – Pertaining to a quantity which has equal value in space at a particular time.

Isotimic line – On a given reference surface in space, a line connecting points of equal value of some quantity.

Isotimic surface – A surface in space on which the value of a given quantity is everywhere equal.

Isthmus – A narrow strip of land, bordered on both sides by water, that connects two larger bodies of land.

ITIC - International Tsunami Information Center. Established in 1968 by the Intergovernmental O ceanographic Commission (UNESCO). ITIC works closely with the Pacific Tsunami Warning Center (PTWC) located in Honolulu, Hawaii. ITIC is responsible, among other functions for:

Monitoring the international tsunami wa activities in the Pacific and recmmending improvements with regard to communications, data networks, data aquisition, and information dissemination;

Bringing to Member and non-member S information on tsunami warning systems, on affairs of ITIC and on how to become active participants in the activities of ICG/ITSU;

Assisting Member States of ITSU esteblishment of national warning systems and improving preparedness for tsunamis for all nations throughout the Pacific Ocean;

Gathering and promulgating knowl tsunamis and fostering tsunami research and its application to prevent loss of life and damage to property.

ITWS - International Tsunami Warning System. See Tsunami Warning System in the Pacific.

ITSU - Abbreviation for "International Co-ordination Group for the Tsunami Warning System in the Pacific".

IUGG - International Union of Geodesy and Geophysics.

IUGS - International Union of Geological Sciences.

–J–

Jetty – 1. (U.S. usage) On open seacoasts, a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel.

2. (British usage) Jetty is synonymous with "wharf" or "pier."

See training wall.

Joule – A unit of energy equal to 10^7 ergs or to 0.2389 calories.

Joule's constant – (Also called mechanical equivalent of heat.). The ratio between heat and work units from experiments based on the first law of thermodynamics: 4.186 X 10^7 ergs/cal.

Jump – 1. See pressure jump.

2. A discontinuity in a function or a derivative of a function such that it assumes different values at a point when the point is approached from different directions.

Jury problem – A differential equation solved numerically by a method of successive approximations which fits the solution to given boundary conditions. Elliptic equations, such as the Poisson equation, lead to jury problems.

–K–

Kármán constant – See logarithmic velocity profile.

Kelvin edge wave – See edge waves.

Key – A low insular bank of sand, coral, etc., as one of the islets off the southern coast of Florida, also cay.

Kinematic boundary condition – The condition that the fluid velocity directed perpendicular to a solid boundary must vanish on the boundary itself. This may be stated mathematically by the expression

$$n \cdot V = 0$$

where n is a unit vector normal to a solid surface, and V is the fluid velocity vector. This boundary condition is often employed in considering flow near the earth's surface.

When the boundary is a fluid surface or interface, this condition applies to the vector difference of velocities across the interface and requires that the interface, although in motion, will at all times consist of the same fluid parcels. Such a condition must be applied at fronts and other surfaces of discontinuity.

See also dynamic boundary condition.

Kinematics – The branch of mechanics dealing with the description of the motion of bodies or fluids without reference to the forces producing the motion.

Kinetic energy – The energy which a body possesses as a consequence of its motion, defined as one-half the product of its mass and the square of its speed, $\frac{1}{2}mV^2$. The kinetic energy per unit volume of a fluid parcel is thus $\frac{1}{2}\rho V^2$, where ρ is the density and v the speed of the parcel.

See potential energy.

Kinetic energy equation – See energy equation.

Kinetic energy of waves – In a progressive oscillatory wave, a summation of the energy of motion of the particles within the wave.

Kinetic theory – The derivation of the bulk properties of fluids from the properties of their constituent molecules, their motions and interactions.

Knoll – A submerged elevation of rounded shape rising less than 1,000 meters from the ocean floor, and of limited extent across the summit.

See seamount.

Knot – The unit of speed in the nautical system; one nautical mile per hour. It is equal to 1.1508 statute miles per hour or 0.5144 meters per second.

Kurtosis – (Symbol β_2 or α_4). A descriptive measure of a random variable in terms of the flatness of its probability distribution. It is defined as follows:

$$\beta_2 = \mu_4/\sigma^4,$$

where μ_4 is the fourth (statistical) moment about the mean and σ^4 the variance. For the normal distribution, $\beta_2 = 3$; and it is commonly (though not invariably) found that curves for which $\beta_2 > 3$ are more sharply peaked than the normal, while those for which $\beta_2 < 3$ are flatter than the normal. In particular, the rectangular distribution $f(x) = 1$ $(0 < x < 1)$ has $\beta_2 = 1.8$.

The terms leptokurtic, mesokurtic, and platykurtic refer to curves for which the values of β_2 are, respectively, greater than 3, equal to 3, and less than 3.

Excess is a relative expression for kurtosis, and the coefficient of excess $\gamma 2$ is defined as $\beta_2 - 3$.

–L–

Labile – Unstable; literally, characterized by a tendency to slip.

Lability – Same as instability, but usually employed in the context of any of the various forms of static instability, as "conditional lability," etc.

Lag – 1. That part of the difference between the output of an instrument and its input which is due to the failure of the instrument to respond instantaneously to variations of the input signal. It is a function of the instrument's time constant.

2. A time displacement of a time series.

See autocorrelation.

3. The difference in phase between the voltage and the current it produces in an inductive circuit. See delay.

4. Same as time constant.

5. See time lag.

Lagging – See daily retardation (of tides).

Lagoon – A small body of water connecting to the open ocean at one or a few spots. Lagoons are generally shallow.

Lagrangian coordinates – 1. (Also called material coordinates.) A system of coordinates by which fluid parcels are identified for all time by assigning them coordinates which do not vary with time. Examples of such coordinates are (a) the values of any properties of the fluid conserved in the motion; or (b) more generally, the positions in space of the parcels at some arbitrarily selected moment. Subsequent positions in space of the parcels are then the dependent variables, functions of time and of the Lagrangian coordinates.

2. Same as generalized coordinates.

Lagrangian correlation – The correlation between the properties of a flow following a single parcel of fluid through its space and time variations.

Compare Eulerian correlation; see correlation coefficients.

Lagrangian equations – Any of the fundamental equations of hydrodynamics expressed in Lagrangian coordinates.

Lagrangian wave – Same as shallow-water wave.

Lambert conic projection – See conformal map.

Lamellar vector – A vector which may be represented as the gradient or ascendent of a scalar, in symbols, $\nabla\alpha$. Thus, a lamellar vector field is irrotational.

Land subsidence – The downward settling of the land material with little horizontal movement.

Land management guidelines – Instructions or ordinances pertaining to land utilization.

Landfall – Point of incidence on land of a hazard such as a hurricane , or a tsunami.

Landlocked – An area of water enclosed, or nearly enclosed, by land, as a bay or harbor (thus, protected from the sea).

Landmark – A conspicuous object natural or artificial, located near or on land which aids in fixing the position of an observer.

Landslide – That part of a near-water feature that is facing toward the land. Same as avalanche.

Laplace equation – The elliptic partial differential equation

$$\nabla^2 \varphi = 0$$

where φ is a scalar function of position and ∇^2 is the Laplacian operator. In rectangular Cartesian coordinates x, y, z, this equation may be written

$$\frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial y^2} + \frac{\partial^2\varphi}{\partial z^2} = 0$$

The Laplace equation is satisfied, for example, by the velocity potential in an irrotational flow, by gravitational potential in free space, by electrostatic potential in the steady flow of electric currents in solid conductors, and by the steady-state temperature distribution in solids.

A solution of the Laplace equation is called a harmonic function.

Compare Poisson equation.

Laplace operator – Same as Laplacian operator.

Laplace transform – (Also called Laplace transformation.) An integral transform of a function obtained by multiplying the given function $f(t)$ by e^{-pt}, where p is a new variable and integrating with respect to t from $t = 0$ to $t = \infty$. Thus, the Laplace transform of $f(t)$ is

$$\mathcal{L}\{f(t)\} = \int_0^\infty e^{-pt} f(t)\, dt$$

and may be denoted by the symbol $f(p)$. The Laplace transform is especially useful in solving initial-value problems associated with inhomogeneous linear differential equations with constant coefficients.

See Fourier transform.

Laplacian operator – (Or Laplace operator.) The mathematical operator $\nabla^2 = \nabla \cdot \nabla$ (or sometimes written $\triangle$) where ∇ is the del-operator. In rectangular Cartesian coordinates, the Laplacian operator may be expanded in the form

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.$$

See Laplace equation.

Lead line – A line, wire, or cord used in sounding. It is weighted at one end with a plummet (sounding lead). Also sounding line.

Leading wave – First wave of a tsunami.

Least squares – Any procedure that involves minimizing the sum of squared differences. For example, the deviation of the mean from the population is less, in the squared sense, than any other linear combination of the population values.

This procedure is most widely used to obtain the constants of a representation of a known variable Y in terms of others X_i. Let $Y(s)$ be represented by

$$\sum_{n=0}^{N} a_n f_n[X_i(s)].$$

The a_n's are the constants to be determined, the f_n's are arbitrary functions, and s is a parameter common to Y and X_i. N is usually far less than the number of known values of Y and X_i. The system of equations being overdetermined, the constants a_n must be "fitted." The least squares determination of this "fit" proceeds by summing, or integrating when Y and X_i are known continuously,

$$\left\{ Y(s) - \sum_{n=0}^{N} a_n f_n[x_i(s)] \right\}^2$$

and minimizing the sum with respect to the a_n's.

In particular, for example, if $f_n'[X_i.(s)] \equiv X_i.(s)$, then the regression function is being determined; and when $f_n'[X_i.(s)] \equiv \cos nX_i.(s)$, or $nX_i.(s)$, then Y is being represented by a multidimensional Fourier series.

Least squares is feasible only when the unknown constants a_n enter linearly.

The method of least squares was described independently by Legendre (1806), Gauss (1809), and Laplace (1812).

Leaking mode – A surface seismic wave which is imperfectly trapped so that its energy leaks or escapes across a layer boundary causing some attenuation.

Length of wave – The horizontal distance between similar points on tow successive waves measured perpendicularly to the crest. (See Figure A-3.)

Levee – A dike or embankment to protect land from inundation.

Limit of backrush, limit of backwash – See backwash.

Linear – Confined to first-degree albebraic terms in the relevant variables. For example: $a + bx + cy$ is linear in x and y; $a \sin x + b \cos y$ is linear in the coefficients a and b, but nonlinear in x and y.

Linear correlation – See correlation.

Linear differential equation – A differential equation which is linear in the dependent variable and derivatives thereof.

The existence of a wealth of mathematical techniques and tables for the treatment of linear equations guarantees that a physical problem representable by such an equation is very mush easier to solve and understand than a non-linear one.

Linear response – A mutual dependence of two events with quntitative equivalence.

Linear Theory - According to linear theory a small applied force leads to a small effect and a large applied force leads to a large effect. Opposite of nonlinear where a small force can have, unpredictably, either a small or a large effect. For example a small tsunami entering a basin or a harbor may excite resonance which may amplify the height of the tsunami whithin that basin or harbor.

Linearization – A process of reduction to linear form by appropriate change of variables. For example, the equation $Y = Ae^{bx}$ becomes $y = a + bx$ by the transformation: $y = log\ Y$; $a = \log A$.

Linearized differential equation – A differential equation which has been derived from an original non-linear equation by the treatment of each dependent variable as consisting of the sum of an undisturbed or steady component and a small perturbation or deviation from this mean. It is assumed that the product of two perturbation quantities is from this mean. It is assumed that the product of two perturbation quantities is negligible compared to the first order terms in the perturbations or to the undisturbed variables. This process of linearization, often called the method of small perturbations, leads to a linear differential equation with the perturbations of the original dependent variables as the new dependent variables.

Linear momentum – Same as momentum; see also angular momentum

Linear operator – 1. A mathematical operator which involves only a linear combination of terms or differential in the dependent variable; examples are the del-operator, the Laplacian operator, and the differential operator, L where

$$L = \frac{d^n}{dx^n} + a_1(x)\frac{d^{n-1}}{dx^{n-1}} + \cdots + a_{n-1}(x)\frac{d}{dx} + a_n(x)\ ;$$

the coefficients $a_1(x) \cdots a_n(x)$ may be functions of the independent variable x.

2. A weighting function which is applied to past values f a time series in order to obtain estimates of future values, determined mathematically in such a way that the mean square error of prediction is minimized. This technique can be extended to more than one variable, so that many tike series may be considered simultaneously.

Line integral – The integral of a function along a given curve. Mathematically, if s is a linear coordinate along the curve, the line integral of a function $f(s)$ between points A and B on the curve is

$$\int_A^B f(s)ds$$

The line integral of a vector field F along the same curve is

$$\int_A^B \mathrm{F} \cdot d\mathrm{r}$$

$f(s)$ where dr is a vector element along the curve of magnitude ds. In general the integral will depend on the curve; in the special case where the field F is irrotational, it depends only on the points A and B and therefore vanishes for a closed curve. In meteorology, line integrals are of frequent occurrence: e.g., in the circulation, and in the averaging of a quantity along a latitude circle.

Line of sight – (Or optical path, line-of-sight path.) In discussions of radio-wave propagation, any direct propagation path that lies wholly above the radio horizon.

Liquefaction – The transformation of the granular sediment material from its solid state into a liquified state as a result of increased pore water pressure. This pore water pressure results from upward movements caused by earthquake waves.

Lithosphere – The outer, solid portion of the earth; the crust of the earth; usually used in contexts wherein the lithosphere is said to make contact with the atmosphere and the hydrosphere.

See also biosphere, geosphere.

Littoral – Of or pertaining to a shore, especially of the sea.

Littoral current – See current, littoral.

Littoral deposits – Deposits of littoral drift.

Littoral drift – The sedimentary material moved in the littoral zone under the influence of waves and currents.

Littoral transport – The movement of littoral drift in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.

Littoral transport rate – Rate of transport of sedimentary material parallel to or perpendicular to the shore in the littoral zone. Usually expressed in cubic yards (meters) per year. Commonly used as synonymous with longshore transport rate.

Littoral zone – In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

Load – The quantity of sediment transported by a current. It includes the suspended load of small particles, and the bedload of large particles that move along the bottom.

Local Tsunami – A Tsunami originating within one wave length of the point of observation.

Log normal distribution – The fundamental frequency distribution of statistical analysis.

Logarithm – The logarithm of any positive number n to the base b is the power l to which that base must be raised in order to satisfy the identity $n = b^l : l = \log_b n$. Logarithms to the base 10 are called common logarithms and written log or $\log_{10}$. Logarithms to the base e=2.7182818284...are called natural (Napierian, hyperbolic) logarithms, and are often written $\log_e$ or ln. In any computations involving differention the natural logarithms are the more convenient.

Logarithmic differentiation – Finding derivatives by taking the logarithm of both sides of an equation and then differentiating.

Logarithmic scale – A non-uniform scale representing the function $y = \log x$.

See logarithm, alignment chart.

Long term prediction – Long term earthquake or tsunami predictions are based on statistical studies of recurrence. These studies may forecast events that are decades or even centuries away.

Long wave – (Or major wave; also called planetary wave.) See Rossby wave. In oceanography, same as shallow-water wave.

Long-wave formula – See Rossby wave.

Longitudinal wave – (Also called compressional wave.) A wave whose direction of propagation is parallel to the displacements of the medium, e.g., sound waves, pressure waves.

Compare transverse wave; see also compression wave.

Long period waves – With regard to atmospheric circulation, a wave in the major belt of westerlies which is characterized by large length and significant amplitude. The wave length is typically longer than that of the rapidly moving individual cyclonic and anticyclonic disturbances of the lower troposphere. The angular wave-number of long waves is generally taken to be from one to five.

Longshore – Parallel to and near the shoreline.

Longshore bar – A bar running roughly parallel to the shoreline.

Longshore current – Currents in the nearshore region that run essentially parallel to the coast.

Longshore transport rate – Rate of transport of sedimentary material parallel to the shore. Usually expressed in cubic yards (meters) per year. Commonly used as synonymous with littoral transport rate.

Loop – The part of a standing wave where the vertical motion is greatest and the horizontal velocities

are least. Loops (sometimes called antinodes) are associated with clapotis, and with seiche action resulting from wave reflections.

See also Node.

Love wave – A type of surface wave having a horizontal motion that is shear or transverse to the direction of propagation. Its velocity depends only on density and rigidity modulus and not on bulk modulus.

Low tide – Same as low water.

Low-velocity zone – Any layer in the Earth in which seismic wave velocities are lower than in the layers above and below.

Low water – The lowest water level reached during a tide cycle. The accepted popular term is low tide.

Lower high water (LHW) – The lower of the two high waters of any tidal day. (See Figure A-10.)

Lower low water (LLW) – The lower of the two low waters of any tidal day. The single low water occurring daily during periods when the tide is diurnal is considered to be a lower low water. (See Figure A-10.)

Low water datum – An approximation to the plane of mean low water that has been adopted as a standard reference plane.

See also datum plane and chart datum.

Low water line – The intersection of any standard low tide datum plane with the shore.

Low water of ordinary spring tides (LWOST) – A tidal datum appearing in some British publications, based on low water of ordinary spring tides.

–M–

Mach number – A non-dimensional number arising in problems of the flow of compressible fluids. It is written

$$M = U/c$$

where U is the speed of the fluid and c is the speed of sound in the medium.

Magma – Molten rock material derived from the earth's crust and mantle. When it is extruded and flows on the earth's surface (above or below water) it is called lava.

Magnitude – A measure of the strength of an earthquake or the strain energy released by it, as determined by seismographic observations. The local body-and surface-wave magnitudes will have approximately the same numerical value.

Major earthquake – An earthquake having a magnitude of 7 or greater on the Richter scale.

Manning coefficient – $\overline{V}$ is the velocity hydraulic flow, then:

$$d=\frac{aL_gQ_s}{\overline{V}}$$

In this equation, $\overline{V}$ is defined as:

$$\overline{V}=\frac{b}{n}R^{2/3}S^{1/}$$

Where b is another constant, n is Manning's number for roughness, R is the hydraulic radius of the channel of flow, and S is slope inclination, (usually expressed as a sine fuction..

Mantle magnitude – The low frequency magnitude scale based on the measurement of Mantle Raleigh waves at a variable period to determine a real time estimation of seismic moment.

Mantle of the Earth – The rocky layer of the Earth between the Mohorovicic seismic discontinuity and the core.

Mantle Rayleigh wave – The free surface of the Earth permits the existence of two additional types of seismic waves, called surface waves. Rayleigh waves have particle motions near the ground surface that are elliptical in a vertical plane; when surficial soil or rock layers are present, or there is a gradient in elastic properties, horizontally polarized surface waves called Love waves also propagate. Rayleigh waves propagate along the Earth's surface with retrograde elliptical motion in the vertical plane of propagation. The amplitude of the particle motion tends to die out at depth. In a homogeneous medium with a Poisson's ratio of

about 0.25 (commonly taken as the nominal value for rocks), Rayleigh waves will travel at a velocity of about 0.92 that of the shear velocity. Both Rayleigh and Love waves are spreading or dispersed waves that in the Earth travel with group and phase velocities that tend to be higher for low frequencies than for high frequencies. The mantle Rayleigh waves would be those waves with the longest periods.

Map factor – Same as scale factor.

Map scale – Same as scale factor.

Marching problem – A differential equation with initial conditions solved numerically by computing the values of the dependent variable recursively for systematically increasing values of the independent variable. For example, the wave equation is solved at each time-step before advancing to the next time-step. Hyperbolic equations may be formulated as marching problems.

See jury problem.

Mareogram – The record made by a marigraph. 2. Any graphic representation of the rise and fall of tide, with time as abscissa and height as ordinate.

Mareograph – A recording tide gage

Marigram – 1. The record made by a marigraph.

2. Any graphic representation of the rise and fall of tide, with time as abscissa and height as ordinate.

Marsden chart – A system introduced by Marsden early in the nineteenth century for showing the distribution of meteorological data on a chart, especially over the oceans. A Mercator map projection is used; the world between 80° N and 70° S latitudes being divided into Marsden "squares" each of 10° latitude by 10° longitude. These squares are systematically numbered to indicate position. Each square may be divided into quarter squares, or into 100 one-degree sub-squares numbered from 00 to 99 to give the position to the nearest degree.

Marsh – An area of soft, wet, or periodically inundated land, generally treeless and usually characterized by grasses and other low growth.

Marsh, salt – A marsh periodically flooded by salt water.

Mass curve – A plotting of the cumulative values of a variable as a function of time.

Mass divergence – The divergence of the momentum field, a measure of the rate of net flux of mass out of a unit volume of a system; in symbols, $\nabla \cdot \rho V$, where ρ is the fluid density, V the velocity vector, and ∇ the del-operator.

Mass transport – The momentum, ρV, where ρ is the fluid density and V the velocity vector, considered as the transport of fluid mass from one region of space to another.

Master plan – The principal plan which outlines the methods and procedures that need to be followed in order to accomplish the long term goals of a program.

Mathematical forecasting – Same as numerical forecasting.

Maximum – The greatest value attained (or attainable) by a function; the opposite of minimum.

An "absolute" maximum is the greatest value within a prescribed interval; while "relative" maxima are the greatest values within arbitrary sub-intervals, each one of which is "absolute" within its own sub-interval, and so on.

Mean – When used without further qualification, same as arithmetic mean.

Compare expected value.

Mean deviation – The mean of the absolute deviation from the mean.

Mean diameter, geometric – See geometric mean diameter.

Mean height of tsunami – The average height of the tsunami measuring from the lowest trough to the greatest height after subtracting the change in tidal level variation.

Mean higher high water (MHHW) – The average height of the higher high waters over a 19-year period. For shorter periods of observation,

corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-year value.

Mean high water – The average height of the high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semidiurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

Mean high water springs – The average height of the high waters occurring at the time of spring tide. Frequently abbreviated to high water springs.

Mean lower low water (MLLW) – The average height of the lower low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. Frequently abbreviated to lower low water.

Mean low water – The average height of the lower low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All low water heights are included in the average where the type of tide is either semidiurnal or mixed. Only lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as mean lower low water.

Mean low water springs – The average height of low waters occurring at the time of the spring tides. It is usually derived by taking a plane depressed below the half-tide level by an amount equal to one-half the spring range of tide, necessary corrections being applied to reduce the result to a mean value. This plane is used to a considerable extent for hydrographic work outside the United States and is the plane of reference for the Pacific approaches to the Panama Canal. Frequently abbreviated to low water springs.

Mean sea level – The average height of the sea surface, based upon hourly observation of tide height on the open coast or in adjacent waters which have free access to the sea. These observations are to have been made over a "considerable" period of time. In the United States, mean sea level is defined as the average height of the surface of the sea for all stages of the tide over a nineteen-year period. Selected values of mean sea level serve as the sea level datum for all elevation surveys in the United States. Along with mean high water, mean low water, and mean lower low water, mean sea level is a type of tidal datum. Compare half-tide level, still-water level.

Mean-square error – (Abbreviated MSE.) The mean square of any residual. In case the mean residual is zero, the mean-square error is the same as the residual variance.

See regression.

Mean tide level – A plane midway between mean high water and mean low water. Not necessarily equal to mean sea level. Also called half-tide level.

Mean velocity – The time average of the velocity of a fluid at a fixed point, over a somewhat arbitrary time interval T counted from some fixed time t_0. For example, the mean velocity of the u component is

$$\bar{u} = \frac{1}{t}\int_{t_0}^{t_0+T} u\,dt \ .$$

The time average of any other quantity can be defined in this manner.

Mechanism of tsunami generation – The theoretical problem of generation of the gravity wave (tsunami) in the layer of elastic liquid (an ocean) occuring on the surface of elastic solid half-space (the crust) in the gravity field can be studied with methods developed in the dynamic theory of elasticity. The source representing an earthquake focus is a discontinuity in the tangent component of the displacement on some element of area within the crust. For conditions representative of the Earth's oceans, the solution of the problem differs very little from the joint solution of two more simple problems: the

problem of generation of the displacement field by the given source in the solid elastic half-space with the free boundary (the bottom) considered quasi-static and the problem of the propagation of gravity wave in the layer of heavy incompressible liquid generated by the known (from the solution of the previous problem) motion of the solid bottom. There is a the oretical dependence of the gravity wave parameters on the source parameters (depth and orientation). In particular, a very rough estimation of the source energy passing into the gravity wave can be obtained . In general, a portion of it corresponds to the estimates obtained with empirical data. Also, tsunamis can be generated by other different mechanisms such as volcanic or nuclear explosions, landslides, rock falls and submarine slumps.

Median – One of several accepted measures of central tendency. (a) Pertaining to a series of numbers, the median is the middle term when the numbers are arranged in algebraic order. If the number of terms is even, the median is taken as halfway between the two middle terms. (b) Pertaining to a continuous random variable x, the median is that value which divides the probability distribution into two equal areas. Hence, in terms of the distribution function $F(x)$ the median is that value of x for which $F(x) = \frac{1}{2}$. In case $F(x)$ is discontinuous, the median is defined in such a way as to yield consistent results when the area is cumulated from either end of the distribution.

Megacycle – (Abbreviated Mc, mc.) A unit of frequency equal to one million (10^6) cycles per second.

Megaripple – See sand wave.

Mercator projection – See conformal map.

Mesokurtic – See kurtosis.

Mesosphere – The region below the asthenosphere which appears to have greater rigidity.

Meteorite – That portion of a relatively large meteoroid which survives its passage through the atmosphere and reaches the earth's surface.

Meteorological tide – Annual or semi-annual changes in sea level due to shifts in prevailing winds or seasonal changes in water temperature; distinguish from atmospheric tide.

Meteorological tsunami – See atmospheric tsunami.

Meter-ton-second system – (Abbreviated mts system.) A system of physical units based upon the use of the meter, the metric ton (10^6 tons), and the second as elementary quantities of length, mass, and time, respectively. In this system, density is expressed in ton/m^3, velocity or speed in m/sec, force in ton m/sec^2, pressure in centibars, and energy in kilojoules.

Method of characteristics – A method of solving systems of non-linear differential equations by constructing the characteristics for the equations over the region of known initial data and proceeding along these lines to determine the solutions for later times or for new regions of space.

Method of least squares – See least squares.

Method of small perturbations – (Also called method of perturbations, perturbation method.) The linearization of the appropriate equations governing a system by the assumption of a steady state, with departures therefrom limited to small perturbations.

See linearized differential equation.

Method of successive approximations – The solution of an equation or a set of simultaneous equations by proceeding from an initial approximation to a series of repeated trial solutions, each depending upon the immediately preceding approximation, in such a manner that the discrepancy between the newest estimated solution and the true solution is systematically reduced. Newton's method for determining the roots of an algebraic equation is an example of the method of successive approximations. For partial differential equations, the relaxation method is a widely applied example of the method of successive approximations.

Microbarogram – The record or trace made by a microbarograph.

Microbarograph – An aneroid barograph designed to record atmospheric pressure variations of very small magnitude. Microbarographs are in general

use at U.S. Weather Service stations and military weather stations.

Microearthquake – An earthquake having a magnitude of 2 or less on the Richter scale.

Micro-Tsunami – A tsunami of such small amplitude that it must be observed instrumentally; not detectable visually.

Microscale of turbulence – A length parameter taken as a measure of the average size of the smallest eddies, i.e., those presumed to be largely responsible for the dissipation of energy.

$$\frac{1}{\lambda^2} = \lim_{y \to 0}\left[\frac{1 - r(y)}{y^2}\right],$$

where R(y) is the normalized space correlation of the same component of the eddy velocity at points separated by distances y, and since R(y) has a maximum at the origin, measures the curvature of R(y) at y = 0.

See scale of turbulence.

Microseism – A feeble oscillatory disturbance of the earth's crust, detectable only by very sensitive seismographs. Certain types of microseisms seem to be closely correlated with pressure disturbances and can be used to locate such disturbances, especially in the case of tropical cyclones. In addition, traffic, industrial activities, and wind flexure of trees and tall structures can create microseisms.

Microzonation – The detailed designation of zones, either by tsunami risk or tsunamicity.

Millibar – (Abbreviated *mb.*) A pressure unit of 1000 dynes per cm^2, convenient for reporting atmospheric pressures. The millibar does not fit into any commonly employed system of physical units.

MIM - Marine Information Management.

Minimum – The least value attained (or attainable) by a function; the opposite of maximum. (See further discussion under maximum.)

Minimum detectable signal – Same as threshold signal.

Minimum duration – See duration, minimum.

Mitigation – To cause to become less harsh or hostile, less severe or painful.

Mixed layer – In oceanography, the surface layer of virtual isothermal water, which frequently exists above the thermocline.

See epilimnion.

Mixed tide – A tide in which the diurnal and semidiurnal components are both prominent. Diurnal inequality is present in high waters, low waters, or in both.

MM scale – Mercalli scale modified for North American conditions.

Mode – One of several accepted measures of central tendency. It is the most probable value of a discrete variate, or the point of maximum probability density in the case of a continuous variate.

Model – A miniature representation of something; an example for imitation or emulation; a description or analogy used to help visualize something that cannot be directly observed; a system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs.

Model basin – Any body of water more or less confined by land boundaries; thus, standing waves and seiches are considered in terms of the basins in which they develop. 2. Any body of water not having horizontal communication with the open ocean at all depths. The maximum depth at which there is horizontal communication is the sill depth.

Model calibration – Standardization (as a measuring instrument) by determining the deviation from a standard so as to ascertain the proper correction factor of a model.

Modeling – To plan or form after a pattern; to produce a representation or simulation of; being a miniature representation of something.

Modeling criteria – As applied to mechanical systems, the conditions that insure dynamic similarity of two systems.

Modulation – In radio, a process whereby the characteristics of a radio carrier-wave are modified by a second, or modulating, wave. A carrier wave (of constant radio frequency) must be modulated in order to carry information.

See amplitude modulation, frequency modulation, intensity modulation, pulse modulation.

Modulator – A device for effecting the process of modulation. The amplitude, frequency, or phase of a carrier signal is varied with time by an applied information signal.

Modulus – 1. A real, positive quantity which measures the magnitude of some number. For instance, the modulus of a complex number is the square root of the sum of squares of its components. Often it means, simply, the numerical ("absolute") value |x| of an algebraic quantity x.

2. A coefficient representing some elastic property of a body, such as the "modulus of elasticity" or the "modulus of resilience."

Mohorovicic discontinuity – The boundary surface or sharp seismic-velocity discontinuity that separates the Earth's crust from the underlying mantle.

Mole – In coastal terminology, a massive land-connected, solid-fill structure of earth (generally revetted), masonry, or large stone. It may serve as a breakwater or pier.

Moment – 1. The product of a distance and another parameter. The moment may be about a point, line, or plane; if the parameter is a vector, the moment is the vector product of the vector distance from the point, line, or plane, into the parameter.

Thus, the moment of the momentum of a fluid parcel per unit volume about an axis is $\mathbf{r} \times \rho\mathbf{v}$, where r is the vector from axis to the parcel, ρ the density, and v the velocity vector of the parcel; this is also called the angular momentum. The moment of a force F about an axis is $\mathbf{r} \times \mathbf{F}$, called the torque.

The second moment of a parameter is the moment of the first moment; and so on, for higher moments.

2. By analogy, in statistical terminology, the mean value of a power of a random variable.

The symbol μ_n' (or ν_n) is used for a raw moment as distinguished from the corresponding central moment μ_n taken about the mean μ. Thus the raw moments are

$$\mu_n' \equiv \nu_n \equiv E(x^n), \quad (n = 0, 1, 2, \ldots),$$

where $E(x^n)$ is the expected value of the variant x to the nth power. In particular, $\mu_0' \equiv 1$ and $\mu_1' \equiv \nu_1 \equiv \mu$.

The central moments are

$$\mu_n \equiv \nu_n \equiv E[(x - \mu)^n], \quad (n = 0, 1, 2, \ldots),$$

where $E[(x - \mu)^n]$ is the expected value of the nth power of the deviation of the variate from its mean. In particular, $\mu_0 \equiv 1$, $\mu_1 \equiv 0$, $\mu_2 \equiv \sigma_2$, where σ_2 is the variance.

Momentum – (Often called linear momentum.) That property of a particle which is given by the product of its mass with its velocity. If m is the mass of the particle and V is the velocity, the linear momentum, M, of the particle is given by

$$M=mV.$$

The momentum of a system of particles is given by the sum of the moments of the individual particles which make up the system, or by the product of the total mas of the system and the velocity of the center of gravity of the system.

The momentum of a continuous medium is given by the integral of the velocity over the mass of the medium, or by the product of the total mass of the medium and the velocity of the center of gravity of the medium.

See angular momentum, conservation of angular momentum.

Momentum-transport hypothesis – The hypothesis that momentum is conserved in turbulent eddy transfer. This hypothesis, together with that of the mixing length, leads to an expression for the variation of the shearing stress τ with height

$$\frac{\partial \tau}{\partial z} = \frac{\partial}{\partial z}\left(\mu \frac{d\bar{u}}{dz}\right)$$

where μ is the eddy viscosity and the mean horizontal wind.

This hypothesis is to be compared with the vorticity-transport hypothesis, the respective results being identical only if the eddy viscosity is constant.

Monitoring – To check, watch, observe, for a special purpose; to keep track of, regulate, or control the operation of.

Monochromatic waves – A series of waves generated in a laboratory; each wave has the same length and period.

Monolithic – Like a single stone or block. In coastal structures, the type of construction in which the structure's component parts are bound together to act as one.

Mud – A fluid-to-plastic mixture of finely divided particles of solid material and water.

Multiple correlation – The correlation between a random variable and its regression function.

If Y denotes the regression function of a random variable (variate) y with respect to certain other variates $x_1, x_2, \ldots x_n$ then the coefficient of multiple correlation between y and the x's is defined as the coefficient of simple, linear correlation between y and Y. However, the constants of the regression function automatically adjust for algebraic sign, with the result that the coefficient of correlation between y and Y cannot be negative; in fact, its value is precisely equal to the ratio of their two standard deviations, i.e., $\sigma(Y)/\sigma(y)$. Therefore, the coefficient of multiple correlation ranges from 0 to 1, and the square of the coefficient of multiple correlation is equal to the relative reduction (or per-cent reduction), that is, the ratio of explained variance to total variance.

Since, in practice, the true regression function Y is seldom known, it is ordinarily necessary to hypothesize its mathematical form and determine the constants by least squares, thus obtaining the approximation Y'. In that case, the conventional estimate of the multiple correlation is the sample value of the simple, linear correlation (symbol R) between y and Y', although a better estimate is obtained by incorporating a correction for degrees of freedom. Such a corrected value R' is given as follows:

$$R' = \sqrt{(N-1)R^2 - n} \,/\, \sqrt{N - (n+1)}$$

where N denotes the sample size and $n+1$ equals the total number of constants (including the absolute term) determined from the data. In case $(N-1)\,R^2<n$, the value of R' is taken as zero. See regression.

–N–

NASA - National Aeronautics and Space Administration

Natural coordinates – An orthogonal, or mutually perpendicular, system of curvilinear coordinates for the description of fluid motion, consisting of an axis t tangent to the instantaneous velocity vector and an axis n normal to this velocity vector to the left in the horizontal plane, to which a vertically directed axis z may be added for the description of three-dimensional flow. Such a coordinate system often permits a concise formulation of atmospheric dynamical problems, especially in the Lagrangian system of hydrodynamics.

Natural disaster – Any sudden calamitous event (caused by nature) bringing great damage.

Natural frequency – (Also called characteristic frequency.) The frequency at which a system will oscillate freely in the absence of external forces, for example, after release from a simple displacement from an equilibrium state. The natural frequency is determined by the dynamical parameters of the medium.

See oscillation (1), free wave.

Natural hazard – A source of danger and exposure to risk of loss of human life or property by an act of nature. For example an earthquake or a tsunami.

Natural oscillations – Vertical variation of water level whithin an enclosed body of water , such as a lake, or a semi-enclosed body of water, such as a harbor or a bay, caused by recurring phenomena acting on that body of water, such as tides and winds, which set off a resonance pattern within that basin,..

Natural period – The period of the natural oscillation characteristic of the basin , and dependent on the shape and size of that basin, as well as on the depth of the water.

Nautical mile – The distance unit in the nautical system, defined as the length of one minute of arc along any great circle on the earth's surface. Since this actual distance varies slightly with latitude, a nautical mile by international agreement is defined as 1852 meters (6076.103 feet or 1.1508 miles).

Nautical system – A system for expressing distance, speed, and acceleration in which: (a) the distance of one minute of arc along a meridian or great circle is one nautical mile; (b) a nautical mile per hour is a knot; (c) a nautical mile per hour per hour is the acceleration in knots per hour. Although the nautical system originated with marine operations it has been adopted to report winds and aircraft speeds.

Navier-Stokes equations – The equations of motion for a viscous fluid which may be written

$$\frac{dV}{dt} = -\frac{1}{\rho}\nabla p + F + \nu\,\nabla^2 V + \frac{1}{3}\,\nu\,\nabla(\nabla\cdot V)$$

where p is the pressure, ρ the density, F the total external force, V the fluid velocity, and ν the kinematic viscosity. For an incompressible fluid, the term in $\nabla\cdot V$ (divergence) vanishes and the effects of viscosity then play a role analogous to that of temperature in thermal conduction and to that of density in simple diffusion.

Solutions of the Navier-Stokes equations have been obtained only in a limited number of special cases; in atmospheric motion, the effects of molecular viscosity are usually overshadowed by the action of turbulent processes and the Navier-Stokes equations have been of little direct application. The use of the concept of eddy viscosity has overcome this limitation in certain problems.

The equations are derived on the basis of certain simplifying assumptions concerning the stress tensor of the fluid; in one dimension they represent the assumption referred to as the Newtonian friction law.

See also viscosity, Ekman spiral, logarithmic velocity profile.

Neap range – The average semidiurnal tidal range occurring at the time of neap tide.

Neap tide – A tide of decreased amplitude, occurring semimonthly one or two days after quadrature.

Compare spring tide, tropic tide, equatorial tide.

Near-field tsunami – A tsunami of close origin.

Nearshore (zone) – In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of nearshore currents. (See Figure A-1.)

Nearshore circulation – The ocean circulation pattern composed of the currents, nearshore and currents, coastal.

See current.

Nearshore current system – The current system caused primarily by wave action in and near the breaker zone, and which consists of four parts: the shoreward mass transport of water; longshore currents; seaward return flow, including rip currents; and the longshore movement of the expanding heads of rip currents. (See Figure A-7.)

See also nearshore circulation.

Neck – 1. The narrow band of water flowing seaward through the surf. Also rip.

2. The narrow strip of land connecting two larger bodies of land, as an isthmus.

Negative axis – See positive axis.

NEIS - National Earthquake Information Service.

Neutral equilibrium – (Also called indifferent equilibrium.) A property of the steady state of a system which exhibits neither instability nor stability according to the particular criterion under consideration. A disturbance introduced into such an equilibrium will thus be neither amplified nor damped. This term is most often used in connection with the parcel method of stability analysis; if the perturbation is a wave, "neutral equilibrium" and "stability" are often used interchangeably.

Neutral wave – Any wave whose amplitude does not change with time. In most contexts these waves are referred to as stable waves, the term "neutral wave" being used when it is important to emphasize that the wave is neither damped nor amplified.

See permanent wave.

Newtonian fluid – A fluid in which the stress tensor is proportional to the rate of deformation, that is, a fluid satisfying the Navier-Stokes equations.

Newtonian friction law – (Also called Newton's formula for the stress.) The statement that the tangential force (i.e., the force in the direction of the flow) per unit area acting at an arbitrary level within a fluid contained between two rigid horizontal plates, one of which is motionless and the other of which is in steady motion, is proportional to the shear of the fluid motion at that level. Mathematically, the law is given by

$$\tau = \mu \frac{\partial u}{\partial z}$$

where is the tangential force per unit area, usually called the shearing stress, a constant of proportionality called the dynamic viscosity, and the shear of the fluid flow normal to the resting plate.

In deriving this expression Newton assumed that either the speed of the moving plate or the distance between the plates was so small that, once a steady state was reached, the speed of the fluid increased linearly from zero at the resting plate to the speed at the moving plate. In this case both the shear of the motion and the shearing stress are constant throughout the fluid.

Newtonian mechanics – The system of mechanics based upon Newton's laws of motion in which mass and energy are considered as separate, conservative, mechanical properties, in contrast to their treatment in relativistic mechanics.

Newton's laws of motion – A set of three fundamental postulates motion – forming the basis of the mechanics of rigid bodies, and first formulated by Newton in 1687. The first law is concerned with the principle of inertia and states that if a body in motion is not acted upon by an external force, its momentum remains constant (law of conservation of momentum). The second law asserts that the rate of change of momentum of a body is proportional to the force acting upon the body and is in the direction of the applied force. A familiar statement of this is the equation

$$F = ma,$$

where F is vector sum of the applied forces, m the mass, and a the vector acceleration of the body. The third law is the principle of action and reaction, stating that for every force acting upon a body there exists a corresponding force of the same magnitude exerted by the body in the opposite direction.

NGDC - National Geophysical Data Center.

Nip – The current made by waves in a shoreline of emergence.

NMC - National Meteorological Center.

NOAA - National Oceanic and Atmospheric Administration

Nodal line – A line, on any oscillating surface, along which the oscillation has zero amplitude. Nodal lines are characteristic of stationary waves and standing waves.

Nodal-plane solution – Imagine a spherical surface around the earthquake source, then the pattern of constant P-wave polarity divides the spherical surface into four equal-sized quadrants. This pattern can be easily characterized by the two orthogonal "nodal" planes that separate the compressional and dilatational quadrants. These nodal planes are directly related to faulting geometry: one nodal plane coincides with the fault plane while the slip vector coincides with the pole of the other nodal plane (sometimes referred to as the auxillary plane).

Nodal zone – An area in which the predominant direction of the longshore transport changes.

NODC - National Oceanographic Data Center.

Node – Positions in a standing wave train of no vertical displacement.

Noise – Any unwanted sound; and, by extension, any "unwanted," usually random, fluctuations of a

signal (which therefore obscure it); in statistics, any unwanted components of a time series.

Noise level – Roughly, the total amount of noise in a signal. It is usually measured by the ratio of the root-mean-square signal to the root-mean-square noise. It imposes a limit below which signals cannot normally be distinguished from noise.

Nomogram – (Or alignment chart, also called momograph, momographic chart.) The graphical representation of an equation of three variables $f(u,v,w) = 0$, by means of three graphical scales (not necessarily straight), arranged in such a manner that any straight line, called an index line, cuts the scales in values of u, v, and w satisfying the equation. By introducing auxiliary variables and constructing auxiliary scales, equations containing more than three variables may also be represented by momograms.

Nomograph – Same as nomogram.

Nomographic chart – Same as nomogram.

Nondeterministic – Unpredictable in terms of observable antecedents and known laws. This is a relative term pertaining to a given state of knowledge but not necessarily implying ultimate unpredictability.

Compare deterministic, random.

Nonbreaking wave – A wave which advances withoutt its crest breakink. Usually a long period type of wave such as a tsunami or as an even longer period wave as the tide.

Non-dimensional equation – An equation in which each member has been rendered free of physical physical dimensions by the systematic introduction of a set of reference constants. The dynamical equations for two dimensional flow, for example, may be made non-dimensional by introducing the constants

$$l = \frac{x}{\xi}, \quad \delta = \frac{z}{\zeta}, \quad U = \frac{\tau l}{t},$$

where l is a characteristic length in the x-direction, δ a characteristic depth, and U a reference velocity; ξ, ζ, and τ are new non-dimensional variables or parameters replacing x, z, and t, respectively.

See dimensional analysis.

Non-dimensional number – A pure number not involving any physical dimensions, e.g., a ratio of two velocities or two lengths. Such numbers are fundamental descriptive quantities of a physical system. Non-dimensional numbers involving several variables often are interpreted as estimates of characteristic velocity ratios, force ratios, heat transfer ratios, frequency ratios, etc. Usually several different ratio interpretations are possible and useful for the same number. (See Mach number, Reynolds number, Boussinesq number, Cauchy number, Prandtl number, Peclet number, Rayleigh number, Rossby number, strouhal number, Richardson number, Nusselt number, Grashof number, Taylor number.)

See also dimensional analysis, inspectional analysis.

Non-dimensional parameter – Any parameter of a problem which has the dimensions of a pure number, usually rendered so deliberately (see non-dimensional equation).

See also non-dimensional number.

Nonlinear – Not a linear function of the relevant variables.

Nonlinear wave – A wave which behaves in a non-linear fashion. For example a wave breaking or a wave within a basin induced by a tsunami but affected by other conditions in the basin unrelated to the initial tsunami.

Normal – Referring to a normal distribution. Regular or typical in the sense of lying within the limits of common occurrence, but sometimes denoting a unique value, as a measure of central tendency. Either sense presupposes a stable probability distribution. In geometry, at right angles to; perpendicular.

Normal circular distribution – See normal distribution.

Normal curve of error – See normal distribution, error distribution.

Normal distribution – (Or Gaussian distribution.) The fundamental frequency distribution of statistical analysis. A continuous variate x is said to have a normal distribution or to be normally distributed

if it possesses a density function $f(x)$ which satisfies the equation

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}, \quad (-\infty < x < \infty)$$

where μ is the arithmetric mean (or first moment) and σ is the standard deviation. About two-thirds of the total area under the curve is included between $x = \mu - \sigma$ and $x = \mu + \sigma$.. The corresponding frequency distribution of vectors is the normal circular distribution in which the frequencies of vector deviations are represented by a series of circles centered on a vector mean. When applied to error distribution, this function is the normal law of errors, and the distribution called the normal curve of error.

Although discovered by DeMoivre, the normal distribution is usually called the Gaussian distribution. In early anthropometric studies and also investigations for random errors in physical measurements, the variates exhibited the normal distribution so faithfully that this distribution was mistakenly assumed to be the governing principle of nearly all random phenomena and was therefore given the name "normal." While less universal than formerly believed, the normal distribution does have remarkable breadth of application, inasmuch as the distribution of averages computed from repeated random samples of almost any population tends more and more nearly toward the "normal" form as the sample size increases. Formulated in precise terms, this proposition is known as the central limit theorem.

Normal functions – See orthogonal functions.

Normal law of errors – See normal distribution.

Normal map – Same as normal chart.

Normal mode – A normal mode of oscillation is a characteristic distribution of oscillation amplitudes among the parts of the system, each part of which is oscillating freely at the same frequency. Complex free oscillations are combinations of these simple oscillation forms.

Normal population – In statistical terminology, a collection of quantities having a normal distribution.

Normal type faulting – A fracture in earth materials, along which the opposite sides have been relatively displaced parallel to the plane of movement. Normal faults, also known as gravity faults, are produced by vertical compression. In such type of faulting, the hanging wall appears to have slipped downward relative to the footwall. The angle of dip is generally 45 to 90 degrees.

Normalize – 1. To change in scale so that the sum of squares, or the integral of the square, of the transformed quantity is unity. See orthogonal function.

2. To transform a random variable so that the resulting random variable has a normal distribution.

Nourishment – Th process of replenishing a beach. It may be brought about naturally, by longshore transport, or artificially by the deposition of dredged materials.

Nuclear power plant – 1. An electric utility station generating electricity with nuclear energy. Nuclear power plants are often located near the coast in areas that could be affected by tsunamis and must be properly designed as to eliminate the possibility of damage to the plant or its peripheral systems by a tsunami.

Numerical integration – 1. The integration of an analytical expression or of discrete or continuous data by approximate numerical methods. These methods usually involve fitting simple curves to successive groupings or sets of the data and performing the integration step-wise.

2. The solution of the dynamical or thermodynamical equations of atmospheric motion by numerical methods.

Numerical modeling – Numerical models have been used in recent years to simulate tsunami propagation and interaction with land masses. Such models usually solve similar equations but often employ different numerical techniques and are applied to different segments of the total problem of tsunami propagation from generation regions to distant areas of runup. For example, several numerical models have been used to simulate the interaction of tsunamis with islands. These models have used finite difference, finite element, and boundary integral methods to solve the linear long wave equations.These models

solve these relatively simple equations and provide reasonable simulations of tsunamis for engineering purposes .

–O–

Observatory – A building or location devoted to the observation of meteorological, geophysical, or astronomical phenomena.

Observer – Anyone who takes an observation.

Ocean – 1. (Or sea.) The intercommunicating body of salt water occupying the depressions of the earth's surface.

2. One of the major primary subdivisions of the above, bounded by continents, the equator, and other imaginary lines.

See sea.

Ocean basin – That portion of the ocean seaward of the continental margin which includes the deep-sea floor.

Ocean-bottom seismograph (OBS) – Seismographs deployed on the bottom of the sea transmitting signals via submarine cable on a continuous basis for the purpose of earthquake monitoring and prediction and for operational tsunami warning.

Oceanography – The study of the sea, embracing and integrating all knowledge pertaining to the sea's physical boundaries, the chemistry and physics of sea water, and marine biology.

Ocean station – As defined by the International Civil Aviation Organization, a specifically located area of ocean surface, roughly square and 200 nautical miles on a side. An ocean station vessel on patrol is said to be "on station" when it is within the perimeter of the area.

Offshore – 1. In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf.

2. A direction seaward from the shore.

Offshore barrier – See barrier beach.

Offshore current – 1. Any current in the offshore zone.

2.Any current flowing away from shore.

Onshore – A direction landward from the sea.

OPC - Committee on Ocean Processes and Climate.

Operator – A mathematical symbol which stands for a specific operation upon a variable or function.

Orbit – In water waves, the path of a water particle affected by the wave motion. In deepwater waves the orbit is nearly circular and in shallow-water waves the orbit is nearly elliptical. In general, the orbits are slightly open in the direction of wave motion giving rise to mass transport.

Ordinate – The vertical coordinate in a two-dimensional system of rectangular Cartesian coordinates; usually denoted by y. Also, the vertical axis of any graph.

ORFEUS - Observatories and Research Facilities for European Seismology.

Orthogonal – 1. Originally, at right angles; later generalized to mean the vanishing of a sum (or integral) of products.

The cosine of the angle between two vectors, V_1 and V_2 , with respective components, (x_1, y_1, z_1) and (x_2, y_2, z_2), is proportional to the sum of products, $x_1x_2 + y_1y_2 + z_1z_2$. Hence, if the vectors are perpendicular, the latter sum equals zero. For this reason any two series of numbers, $(x_1, x_2 \ldots, x_n)$ and $(y_1 y_2 \ldots, y_n)$ is said to be orthogonal if

$$\sum_i x_i y_i = 0 .$$

See orthogonal functions.

2. On an ocean-wave refraction diagram, a ray drawn everywhere at right angles to wave crests.

Orthogonal curvilinear coordinates – See curvilinear coordinates.

Orthogonal functions – A set of functions, any two of which, by analogy to orthogonal vectors, vanish if their product is summed by integration over a

specified interval. For example, $f(x)$ and $g(x)$ are orthogonal in the interval $x = a$ to $x = b$ if

$$\int_a^b f(x)g(x)dx = 0.$$

The functions are also said to be normal if

$$\int_a^b [f(x)]^2 dx = \int_a^b [g(x)]^2 dx = 1.$$

The most familiar examples of such functions, many of which have great importance in mathematical physics, are the sine and cosine functions between zero and 2π.

Oscillation – 1. Generally, the process of varying above and below a mean value; usually, a periodic process. (Compare fluctuation, cycle, wave.) Oscillations are commonly classified as follows: (a) a damped oscillation is one which is continually decreasing in amplitude; (b) a neutral, undamped, or persistent oscillation maintains constant amplitude; (c) an unstable oscillation, once started, grows in magnitude until it breaks down; (d) a stable oscillation is any one that is not unstable (i.e., it may be either damped or neutral); (e) a forced oscillation is set up by a periodic external force; and (f) a free oscillation occurs when a body is set into motion initially but no further external force is applied to it.

2. One single movement (or change) of an oscillating body from one extreme position to the other; in this sense, one-half of a cycle.

Oscillations – The repeated transgressions and regressions of the seas in constantly shifting patterns.,

Oscillatory wave – Same as wave of oscillation.

OSNLR - Ocean Science in Relation to Non-Living Resources.

Outfall – A structure extending into a body of water for the purpose of discharging sewage, storm runoff, or cooling water.

Output – (Or output signal.) The quantity that is delivered by an instrument or a component of an instrument; used in contradistinction to the input.

Overflow – A flowing over, inundation.

Overlapping mean – Same as consecutive mean.

Overtopping – Passing of water over the top of a structure as a result of wave runup or surge action.

Overwash – That portion of the uprush that carries over the crest of a berm or of a structure.

–P–

P wave – That type of seismic body wave that involves particle motion (alternating, compression and expansion) in the direction of propagation. It is fastest of the seismic waves, travelling 5.5 – 7.2 km/sec in the crust and 7.8 - 8.5 km/sec in the upper mantle. It is the first arrival of waves.

Pack ice – (Also called ice pack.) Ice covering more than half of the visible sea surface. Broken, loose, or open pack covers between 0.5 and 0.8 of the sea surface, while close, dense, thick, or tight pack covers more than 0.8 but shows some leads or polynya's; no open water whatever is visible in consolidated, solid, or unbroken pack. The thick and sometimes solid pack ice covering the central Arctic Ocean has been variously called "arctic ice pack," "arctic pack ice," "arctic pack," "polar cap ice," "polar ice," etc.

The terms pack ice and ice pack have been used indiscriminately for both the sea area containing floating ice, and the ice material itself.

Pacific-wide tsunami – A tsunami capable of destruction, not only in the immediate region of its generation, but across the entire Pacific Ocean.

Parameter – 1. In general, any quantity of a problem that is not an independent variable. More specifically, the term is often used to distinguish, from dependent variables, quantities which may be more or less arbitrarily assigned values for purposes of the problem at hand.

2. In statistical terminology, any numerical constant derived from a population or a probability distribution. Specifically, it is an arbitrary constant in the mathematical expression of a probability distribution. For example, in the distribution

$$f(x) = \alpha e^{-\alpha x}$$

given by the constant α is a parameter.

Parameterization – The representation, in a dynamic model, of physical effects in terms of admittedly oversimplified parameters, rather than realistically requiring such effects to be consequences of the dynamics of the system.

A common example is the assigning of a value to the static stability in a model when this property should properly be determined by the temperature variations at two or more levels. Such techniques are dictated by mathematical convenience, and the effects on the final results must be judged in the context of the particular problem treated.

Parametric equations – A set of equations in which the independent variables or coordinates are each expressed in terms of a parameter. For example, instead of investigating $y=f(x)$, or $F(x,y)=0$ it is often advantageous to express both x and y in terms of a parameter u: $x=g(u)$; $y=G(u)$. The parameter may or may not have a useful geometric or physical interpretation.

Parapet – A low wall built along the edge of a structure as on a seawall or quay.

Parseval's theorem – A theorem relating the product of two functions to the products of their Fourier series components. If the functions are $f(x)$ and $F(x)$, and their Fourier series components have respective amplitudes a_n, b_n, and A_n, B_n, Parseval's theorem states that under certain general conditions

$$\frac{1}{\pi}\int_{-\pi}^{\pi} f(x)F(x)dx = \frac{1}{2}a_0A_0 + \sum_{n=1}^{\infty} (a_nA_n + B_nb_n) .$$

There is an analogous theorem for Fourier transforms.

Partial correlation – The correlation between the residuals of two random variables with respect to common regressors. Denoting the regression function of two variates y and z with respect to a common set of regressors $x_1, x_2, ..., x_n$ by Y and Z, the coefficient of partial correlation between y and z is defined as the coefficient of simple, linear correlation between $(y - Y)$ and $(z - Z)$. To estimate the partial correlation, it is usually necessary to resort to sample approximations Y' and Z' of Y and Z. In that case, the estimate of the partial correlation is the sample value of the coefficient of simple, linear correlation between $(y - Y')$ and $(z - Z')$.

In the simple case in which Y' and Z' are taken as linear functions of a single variable x, the sample estimate $r_{yz.x}$ of the partial correlation coefficient is given by the formula

$$r_{yz.x} = \frac{r_{yz} - r_{yx}r_{zx}}{\sqrt{(1 - r_{yx}^2)(1 - r_{zx}^2)}}$$

where the symbol r_{uv} denotes the sample coefficient of linear correlation between any pair of variates u, v.

See regression.

Partial derivative – The ordinary derivative of a function of two or more variables with respect to one of the variables, the others being considered constants. If the variables are x and y, the partial derivatives of $f(x,y)$ are written $\partial f/\partial x$ and $\partial f/\partial y$, or $D_x f$ and $d_y f$, or f_x and f_y. The partial derivative of a variable with respect to time is known as the local derivative.

Partial tide – (Also called tidal component, tidal constituent.) One of the harmonic components comprising the tide at any point. The periods of the partial tides are derived from various combinations of the angular velocities of earth, sun, moon, and stars relative to each other.

Particle velocity – In ocean wave studies, the instantaneous velocity of a water particle undergoing orbital motion. It has the scalar value

$$\frac{\pi}{T} H e^{-2\pi z/L}$$

where T is the wave period, H the wave height, z the depth below still-water level, and L the wave length. At the crest, its direction is the same as the direction of progress of the wave, and at the trough it is in the opposite direction.

Pascal's law – A hydrostatic principle that pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and to the walls of the containing vessel.

Pass – In hydrographic usage, a navigable channel through a bar, reef, or shoal, or between closely adjacent islands.

Path – Same as trajectory.

Pattern recognition – The action of recognizing a reliable sample of traits, acts, or other observable features.

Payload – In referring to vehicles for scientific research and/or observation, the dimensions (often only the weight) of the scientific equipment carried. This usually includes sensors, data storage and telemeter gear, and instrument power supply, and sometimes special auxiliary equipment and recovery gear.

PDE - Preliminary Determination of Epicenters.

Pebbles – See soil classification.

Peninsula – An elongated body of land nearly surrounded by water, and connected to a larger body of land.

Percolation – The process by which water flows through the interstices of a sediment. Specifically, in wave phenomena, the process by which wave action forces water through the interstices of the bottom sediment. Tends to reduce wave heights.

Perfect fluid – 1. Same as inviscid fluid.

2. Sometimes used for an inviscid, incompressible, homogeneous fluid.

3. See perfect gas.

Perigean tide – Tide of increased range occurring when the moon is near perigee.

Period – 1. The time interval between passages, at a fixed point, of a given phase of a roughly periodic oscillation, or more specifically, of a simple harmonic wave. It is the reciprocal of frequency.

2. See geologic period.

Periodic current – A current caused by the tide-producing forces of the moon and the sun, a part of the same general movement of the sea that is manifested in the vertical rise and fall of the tides.

See also current, flood and current, ebb.

Periodic waves – Waves occuring or recurring at regular intervals.

Periodicity – The quality ascribed to a more or less periodic variation.

See period.

Permanent wave – A wave (in a fluid) moving with no change in streamline pattern, and which, therefore, is a stationary wave relative to a coordinate system moving with the wave.

Permeable groin – A groin with openings large enough to permit passage of appreciable quantities of littoral drift.

Persistence – 1. In general, the tendency for the occurrence of a specific event to be more probable, at a given time, if that same event has occurred in the immediately preceding time period.

2. The previous value in a time series. Thus, if $x(t)$ denotes the present value, the value of persistence would be $x(t-1)$, whence the latter value is regarded as "persisting."

Perturbation – Any departure introduced into an assumed steady state of a system. The magnitude of the departure is often assumed to be small so that product terms in the dependent variables may be neglected; the term "perturbation" is therefore sometimes used as synonymous with "small perturbation." The perturbation may be concentrated at a point or in a finite volume of space; or it may be a wave (sine or cosine function); or in the case of a rotating system, it may be symmetric about the axis of rotation; or it may be a displacement by the parcel method. The mathematical work in an instability problem may be facilitated by perturbation technique, whether or not the equations are linearized.

Perturbation equation – Any equation governing the behavior of a perturbation. This may or may not be a linearized differential equation.

Perturbation method – Same as method of small perturbations.

Perturbation motion – The motion of a disturbance (usually but not necessarily assumed infinitesimal), as opposed to the motion of the steady state of the system on which the perturbation is superimposed.

Perturbation theory – The systematic derivation of linearized equations of systems by the method of small perturbations, exhibiting the assumptions involved; or any model derived by use of this method.

Phase – The onset of a displacement or oscillation on a seismogram indicating the arrival of a different type of seismic wave.

Phase angle – 1. For any type of periodic motion (e.g., rotation, oscillation) a point or "stage" in the period to which the motion has advanced with respect to a given initial point. Specifically, phase or phase angle is the angular measure along a simple harmonic wave, the linear distance of one wavelength being 360° of phase measure. This is often generalized by equating one cycle of any oscillation to 360°. See delay, interference.

2. The State of aggregation of a substance, for example, solid, liquid, or gas.

Phase constant – See propagation constant.

Phase delay – See delay.

Phase distortion – The distortion which occurs in an instrument when the relative phases of the input signal differ from those of the output signal.

Phase front – (Or wave front.) A surface of constant phase (or phase angle) of a propagating wave disturbance. Generally, phase fronts spread out spherically from their source; but in cases where energy is assumed to travel in parallel rays (as in many radiation problems), phase fronts may be approximated as plane surfaces oriented perpendicularly to the rays.

Phase inequality – Variations in the tides or tidal currents associated with changes in the phase of the moon in relation to the sun.

Phase modulation – Modulation where information is conveyed by varying the phase of a constant-amplitude carrier wave.

Phase shift – A change in the phase relationship between two waves.

Phase speed – (Or wave speed; also called phase velocity, wave velocity.) The speed of propagation of a point of constant phase (or phase angle) of a simple harmonic wave component. Thus, the component $\sin(2\pi/\lambda)(x - ct)$ represents a wave of length λ traveling in the positive x-direction with phase speed c. This concept is to be distinguished from signal velocity, group velocity, and the velocity of fluid parcels. In oceanography, the terms wave velocity or wave celerity are used more commonly than "phase speed."

Phase velocity – Same as phase speed.

Physical forecasting – Same as numerical forecasting.

Physical hydrodynamics – See hydrodynamics.

Physical model – A scaled representation of a harbor, bay, a coastline, or any basin or body of water, constructed for the purpose of studying the effects of wave action, runup, or any type of flooding.

Physical modeling - The methodology used to duplicate processes and events which occur in nature and their effects with the use of scaled-down physical models.

Physiography – Same as geomorphology.

Pi-theorem – A principal theorem in dimensional analysis that may be stated as follows: Suppose we have a dimensionally homogeneous relation $G(\alpha, \beta, \gamma, ...) = 0$ in n dimensional variables, α, β, γ, ..., valid for a certain system of m fundamental units. The equation may then be put in the form $F(\pi_1, \pi_2, ...) = 0$, where the π's are the $n - m$ independent products of the variables α, β, γ, ..., which are dimensionless in the fundamental units.

Pier – A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, a recreational facility, etc., rather than to afford coastal protection. In the Great Lakes, a term sometimes improperly applied to jetties.

Pile – A long, heavy timber or section of concrete or metal to be driven or jetted into the earth or seabed to serve as a support or protection.

Pile, sheet – A pile with a generally slender flat cross section to be driven in the ground or seabed and meshed or interlocked with like members to form diaphragm, wall, or bulkhead.

Piling – A group of piles.

Plain, coastal – See coastal plain.

Planetary wave – 1. Same as long wave (1).

2. Same as Rossby wave.

Planetary-wave formula – See Rossby wave.

Plane wave – 1. Same as plane gravity wave; see gravity wave.

2. A wave in which successive phase fronts are plane surfaces, parallel to each other and oriented perpendicularly to the direction in which the wave is traveling. Plane waves may be assumed to exist over areas sufficiently far removed from the energy source.

3. (Also called two-dimensional wave.) Any wave represented on a flat surface

See plane atmospheric wave.

Plate tectonics – A model of the Earth's outer shell that assumes that it is made up of a small number of very large plates moving relative to each other.

Plate tectonic theory – Global tectonics based on an Earth model characterized by a small number (10 to 25) of large, broad, thick plates(blocks composed of areas of both continental and oceanic crust and mantle)each of which "floats" on some viscous underlayer in the mantle and moves more or less independently of the others. The continents form a part of the plates and move with them, like logs frozen in the ice floes.

Plateau – A land area (usually extensive) having a relatively level surface raised sharply above adjacent land on at least one side; table land. A similar undersea feature.

Pleistocene glacial epoch – Same as Quaternary Ice Age.

Pleistocene – The physical extent (glacierization) and/or glaciation – the geologic results of the most recent ice age, the Quaternary Ice Age. It is so named because it occurred in the Pleistocene epoch of the Quaternary period.

Pleistocene Ice Age – Same as Quaternary Ice Age.

Plotting – See map plotting.

Plunge point – 1. For a plunging wave, the point at which the wave curls over and falls.

2. The final braking point of the waves just before they rush upon the beach. (See Figure A-1.)

Plunging breaker – See breaker.

Pneumatic wave generator – A device used in conjuction with physical models to generate wave activity and powered by compressed air pressure.

Pocket beach – A beach, usually small, in a coastal reentrant or between two littoral barriers.

Point – Position or time of occurrence.

Point source – With respect to radiation, a single point in space emitting radiation. In hydrodynamics, a source of mass, i.e. a singular point in the field where the equation of continuity fails. For Tsunami purposes, volcanic eruptions, landlslides, and man -made explosions which may generate tsunamis, are considered as point sources.

Poisson distribution – A one-parameter discrete frequency distribution giving the probability that n points (or events) will be (or occur) in an interval (or time) x, provided that these points are individually independent and that the number occurring in a sub-interval does not influence the number occurring in any other non-overlapping sub-interval. It has the form $P(n,x) = e^{-kx}(kx)^n/n!$. The mean and variance are both kx, and k is the average density (or rate) with which the events occur.

When kx is large, the Poisson distribution approaches the normal distribution. The binomial distribution approaches the Poisson when the number of events n becomes large and the probability of success p becomes small in such a way that $np \rightarrow kx$. The Poisson distribution arises in such problems as radioactive and photoelectricemissions, thermal noise, service demands, and telephone traffic.

Poisson equation – The partial differential equation

$$\nabla^2\varphi = F$$

where ∇^2 is the laplacian operator, φ a scalar function of position, and F a given function of the independent space variables. For the special case $F = 0$, the Poisson equation reduces to the Laplace equation.

Poisson's ratio – Deformations are changes in form produced by external forces or loads that act on non-rigid bodies. Deformations are longitudinal, e, a lengthening (+) or shortening (-) of the body. Unit deformation (dimensionless number) is the deformation in unit distance. Unit longitudinal deformation is s=e/l. Accompanying a longitudinal deformation e is a lateral deformation e'. The ratio of s' / s is Poisson's ratio, which differs for different materials.

Polar axis – See polar coordinates.

Polar coordinates – 1. In the plane, a system of curvilinear coordinates in which a point is located by its distance r from the origin (or pole) and by the angle θ which a line joining the given point and the origin makes with a fixed reference line, called the polar axis. The relations between rectangular Cartesian coordinates and polar coordinates are,

$$x = r\cos\theta,\ r^2 = x^2 + y^2$$

where the origins of the two systems coincide and the polar axis coincides with with the x-axis.

2. In space, same as spherical coordinates. See also cylindrical coordinates.

Pole – 1. The origin of a system of polar coordinates.

2. For any circle on the surface of a sphere, the point of intersection of the surface of the sphere and the normal line through the center of the circle. The North and South geographic poles are the poles of the equator or of any other latitude circle.

3. A point of concentration of electric charge. See dipole.

4. A point of concentration of magnetic force. See magnetic pole.

Polynomial – A mathematical expression of the form

$$a_0 + a_1x + a_2x^2 = \ldots a_nx^n$$

where the a's are real or complex numbers and n is a positive integer, called the degree of the polynomial; or, in general, a weighted sum of products of integral powers of two or more variables.

Port – A place where vessels may discharge or receive cargo; may be the entire harbor including its approaches and anchorages, or bay be the commercial part of a harbor where the quays, wharves, facilities for transfer of cargo, docks, and repair shops are situated.

Potential – A function of space, the gradient of which is equal to a force. In symbols,

$$F = -\nabla\phi$$

where F is the force, ∇ the del-operator, and ϕ the potential. A force which may be so expressed is said to be "conservative," and the work done against it in motion from one given equipotential surface to another is independent of the path of the motion.

Potential energy – The energy which a body possesses as a consequence of its position in the field of gravity; numerically equal to the work required to bring the body from an arbitrary standard level, usually taken as mean sea level, to its given position.

See kinetic energy.

Potential energy of waves – In a progressive oscillatory wave, the energy resulting from the elevation or depression of the water surface from the undisturbed level.

Potential gradient – In general, the local space rate of change of any potential, as the gravitational potential gradient or the velocity potential gradient.

Potentiometer – 1. An instrument for measuring differences in electric potential. Essentially, this instrument balances the unknown voltage against a variable known voltage. If the balancing is accomplished automatically, the instrument is called a self-balancing potentiometer. Potentiometers are frequently used in conjunction with thermocouples for measuring temperature.

2. A variable electric resistor.

Power – The rate, often expressed in watts, at which energy is fed to or taken from a device; generally analogous to flux. In radar it usually refers to the rate at which radio energy is radiated from or received at the antenna.

Power density – Power per unit area; generally analogous to flux density.

Power density spectrum – (Sometimes called power spectrum.) A measure of the contribution to the total variance from a given frequency band in the generalized Fourier representation of a random function. If $f(t)$ is random function, the total energy $\int_{-\infty}^{\infty} f^2dt$ is infinite, so the Fourier integral representation is inadequate. If a transform is defined over a finite interval

$$F_T(\omega) = \frac{1}{2\pi}\int_{-T}^{T} f(t)e^{-i\omega t}dt$$

under suitably restrictive conditions the power density spectrum may be defined as

$$\lim_{T\to\infty} \frac{\pi}{T}|F_T(\omega)|^2 .$$

The theorem, proved by N. Wiener, establishing the analogy between the analysis of random functions and ordinary Fourier analysis, is that the power density spectrum is the Fourier transform of the autocorrelation functions, which is defined for random functions as

$$\lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} f(t)f(t+\tau)\,dt .$$

See power spectrum.

Power series – An infinite series of increasing powers of the variable, of the form

$$\sum_{n=0}^{\infty} a_nx^n \equiv a_0 + a_1x + a_2x^2 + \cdots + a_nx^n + \cdots .$$

Both the variable and the coefficients may take on complex values. The totality of values of x for which a power series is convergent is called the interval of convergence of the series.

Power spectrum – 1. The square of the amplitude of the (complex) Fourier coefficient of a given periodic function. Thus if $f(t)$ is periodic with period T, its Fourier coefficients are

$$F(n) = \frac{1}{T}\int_0^T f(t)e^{-in\omega t}dt$$

where $\omega = 2\pi/T$, and the power spectrum of $f(t)$ is $|F(n)|^2$. Here n takes integral values and the spectrum is discrete. The total energy of the periodic function is infinite, but the power, energy per unit period, is finite.

In the case of the aperiodic function containing finite total energy, the energy density spectrum is the corresponding spectral function. This is a continuous function of frequency and therefore has dimensions of energy/frequency (energy density).

In the case of a random function containing infinite total energy but not periodic, the power density spectrum is the corresponding spectral function.

The mathematical conditions governing analogous theorems in these three classes of functions are different. However, when actual computations of observational data are involved, a finite number of discrete values are used, and the effect is the same as if the function were assumed to be periodic outside the interval of computation. Thus, it is the power spectrum which is exhibited. But all types of spectra referred to may be considered as measures of the contribution of given frequencies in the Fourier representation of the original function.

The terms "power" and "energy" are usually retained to indicate relative dimensions regardless of the actual dimensions of the functions analyzed, which may be functions of space as well as time. Computation of the power spectrum in practice may be facilitated by use of the theorem that it is the Fourier coefficient of the autocorrelation function.

2. Same as power density spectrum.

Precursor – The observation of a number of anomalous physical phenomena prior to the occurrence of earthquakes (termed precursors) has prompted research into identifying and verifying them as possible indicators for routine use in earthquake prediction. They types of precursors that have been identified fall into the categories of crustal deformation, seismic activity, geochemical and hydrological anomalies, and other types of geophysical anomalies.

Predictand – See regression.

Prediction – The art of making a forecast; or, the forecast itself. The action or results of estimating objectively some quantitative parameters of events, for which the results are unknown, usually in the future. A prediction procedure is teachable.

Predictor – See regression.

Pressure wave – A short-period oscillation of pressure such as that associated with the propagation of sound through the atmosphere; a type of longitudinal wave. They are usually recorded on sensitive microbarographs capable of measuring pressure changes of amounts down to 10^{-4} mb. Typical values for the period and wave length of pressure waves are $\frac{1}{2}$ to 5 seconds and 100 m to 1500 m, respectively.

Prevention – The act of preventing or hindering.

Primary shorelines – Shorelines where the coastal region has been mainly formed by terrestrial agents, such as rivers, glaciers, deltas, volcanoes, folding, and faulting.

Primitive equations – The Eulerian equations of motion of a fluid in which the primary dependent variables are the fluid's velocity components. These equations govern a wide variety of fluid motions and form the basis of most hydrodynamical analysis.

Prism – See tidal prism.

Probability – The chance that a prescribed event will occur, represented as a pure number p in the range $0 \leq \pi \geq$. The probability of an impossible event is zero and that of an inevitable event is unity. Probability is estimated empirically by relative frequency, that is, the number of times the particular event occurs divided by the total count of all events in the class considered.

See probability theory.

Probability density function – (Or density function; also called frequency function.) The statistical function which shows how the density of possible observations in a population is distributed. It is the derivative $f(x)$ of the distribution function $F(x)$ of a random variable if $F(x)$ is differentiable. Geometrically, $f(x)$ is the ordinate of a curve such that $f(x)dx$ yields the probability that the random variable will assume some value within the range of dx of x. The density function is non-negative and its total integral is unity. Sometimes the probability density function is called the "distribution function," but this practice causes confusion and is not recommended.

Probability distribution – The mathematical description of a random variable in terms of its admissible values and the probability associated, in an appropriate sense, with each value. The probability distribution of a continuous variate is defined by stating the mathematical equation of the distribution function $F(x)$ or the probability density function $f(x)$ (if it exists) together with the range over which the equation holds. The probability distribution of a discrete variate is commonly defined by stating the equation for the probability $p(x)$ that the variate will assume any particular value x, and indicating what values are possible.

Probability distribution function – Same as distribution function.

Probability integral – (Also called error function, erf.) The classical form (still widely used in engineering work) of the definite integral of the special normal distribution for which the mean $\mu = 0$ and standard deviation $\sigma = 1/\sqrt{2}$. Geometrically, the probability integral equals the area under this density curve between $-z$ and z, where z is an arbitrary positive number. Often denoted by the symbol *erf z* (read "error function of z") the probability integral is defined thus:

$$\text{erf } z \equiv \frac{2}{\sqrt{\pi}} \int_0^z e^{-x^2} dx \ .$$

Modern statistical usage favors the unit normal variate u, which is such that $\mu = 0$ and $\sigma = 1$. The relation between the probability integral *erf z* and the distribution function $F(u)$ of the unit normal variate u is as follows

$$u \text{ positive:} \quad F(u) = \frac{1}{2} + \frac{1}{2} \text{erf } (u/\sqrt{2}) \ ,$$

$$u \text{ negative:} \quad F(u) = \frac{1}{2} - \frac{1}{2} \text{erf } (-u/\sqrt{2}) \ .$$

See unit normal distribution.

Probability theory – The mathematical theory of random (nondeterministic) phenomena.

Probable error – The magnitude of a deviation from a statistic which will be exceeded with probability of 0.50, or on half the occasions. For a normal distribution it is 0.6745 times the standard deviation. The probable error is not "probable" in any peculiar sense and should have no more significance attached to it than the above.

Probable maximum water level – A hypothetical water level (exclusive of wave runup from normal wind-generated waves) that might result from the most severe combination of hydrometeorological, geoseismic and other geophysical factors that is considered reasonably possible in the region involved, with each of these factors considered as affecting the locality in a maximum manner.

This level represents the physical response of a body of water to maximum applied phenomena such as hurricanes, moving squall lines, other cyclonic meteorological events, tsunamis, and astronomical tide combined with maximum probable ambient hydrological conditions such as wave setup, rainfall, runoff, and river flow. It is a water level with virtually no risk of being exceeded.

Product-moment – The expected value of a product.

Profile, beach – The intersection of the ground surface with a vertical plane; may extend from the top of the dune line wot the seaward limit of sand movement. (See Figure A-1.)

Profile (of wave) – In oceanography, a graph of the value of the scalar quantity of a wave versus a horizontal, vertical, or time scale. It usually refers to a vertical representation.

Prognostic equation – Any equation governing a system which contains a time derivative of a

quantity and therefore can be used to determine the value of that quantity at a later time when the other terms in the equation are known (for example, vorticity equation).

Compare diagnostic equation. See also regression.

Progression (of a beach) – See advance.

Progressive wave – A wave which moves relative to a fixed coordinate system in a fluid. Progressive waves are to be distinguished from stationary waves which show no relative translation. Standing waves can be treated mathematically as two equal and oppositely directed progressive waves superimposed upon each other.

Promontory – A high point of land projecting into a body of water; a headland.

Propagation – The act of causing to spread out and affect a greater number or greater area.

Propagation of waves – The transmission of waves across a body of water.

Protection – The act of defending against a danger. In the case of tsunami protection, the activities and safeguards employed to reduce or eliminate the potential destructive effects of a tsunami on people and property.

Prototype – In laboratory usage, the full-scale structure, concept, or phenomenon used as a basis for constructing a scale model or copy.

PSML - Permanent Service for Mean Sea Level.

PTWC - Abbreviation for Pacific Tsunami Warning Center. PTWC is the headquarters of the operational Tsunami Warning System in the Pacific and works closely with other regional national centers in monitoring seismological and tidal stations and instruments around the Pacific Ocean, to evaluate potentially tsunamigenic earthquakes. PTWC is operated by the United States National Weather Service.

Public Education – Activities, publications, audiovisual aids and any other educational materials or procedures used to instruct the general public about the potential risks of tsunamis in order to assist them in understanding the potential hazards and the means of protection

-Q-

Quartile – One of a set of numbers (a quantile) on the random variable axis which divide a probability distribution into four equal areas. The three quartile points which lie between the extremes of the distribution are designated as Q_1, Q_1, Q_3 and are defined in terms of the distribution function $F(x)$ as follows:

$$F(Q_1) = .25;\ F(Q_2) = .50;\ F(Q_3) = .75\ .$$

Thus Q_2 coincides with the median. In empirical relative frequency tables, the quartiles are estimated by interpolation.

The interquartile range $2Q$ is the distance from Q_1 to Q_3; half of this distance Q is called the semi-interquartile range (or quartile deviation) and is sometimes used as a crude measure of variability or spread.

Quasi-hydrostatic approximation – (Or quasi-hydrostatic assumption; also called hydrostatic approximation.) The use of the hydrostatic equation as the vertical equation of motion, thus implying that the vertical accelerations are small without constraining them to be zero. This compromise takes advantage of the smallness of organized vertical accelerations in cyclonic-scale motions while allowing theoretically for a realistic distribution of vertical velocities, which may be computed from the other equations of a closed system. Dynamically, the effect of the quasi-hydrostatic approximation is to eliminate or filter out the higher frequencies, corresponding to sound waves and certain (but not all) gravity waves, from the fundamental equations, while retaining the frequencies corresponding to cyclonic-scale motions.

Combined often with the quasi-geostrophic approximation, this assumption is much used in theoretical work associated with numerical forecasting. An example of phenomena to which it is inapplicable is the lee wave. For the discussion of this and other types of gravity waves, it is common to assume hydrostatic

equilibrium in the basic flow but not in the perturbation.

See filtering approximation, hydrostatic approximation.

Quaternary Ice Age – The ice age of the Quaternary period (the latest period of geologic time).

Quay (pronounced key) – A stretch of paved bank, or a solid artificial landing place parallel to the navigable waterway, for use in loading and unloading vessels.

–R–

Radial symmetry – The symmetry of a configuration whose properties are functions only of radial distance from an origin, and thus independent of the azimuthal coordinate in two dimensions and of azimuthal and latitudinal coordinates in three dimensions. Radial symmetry in two dimensions is often called circular symmetry; in three dimensions, spherical symmetry.

Radian – A unit of angular measure; one radian is that angle whose intercepted arc on a circle is equal in length to the radius of the circle. Thus, π radians equals 180°.

See also degree (2).

Radiant energy – 1. (Also called radiation.) The energy of any type of electromagnetic radiation.

2. Infrequently, any energy that may be radiated, as, for example, tsunami energy, or sonic energy.

Radiation pattern – (Also called antenna pattern, lobe pattern, coverage diagram.) A diagram showing the intensity of the radiation field in all directions from a transmitting radio or radar antenna at a given distance from the antenna. It usually refers to the geometrical solid in space which encompasses all of the lobes of the antenna. For a receiving antenna, it is the response of the antenna to a signal having unit field strength and arriving from all directions. The transmittting and receiving radiation patterns for a single antenna are identical.

Two types of radiation patterns should be distinguished. They are: (1) the free space radiation pattern which is the complete lobe pattern of the antenna and is a function of the wavelength, feed system and reflector characteristics, and (b) the field radiation pattern which differs primarily from the free space pattern by the formation of interference lobes whenever direct and reflected wavetrains interfere with each other as is found in most surface based radars. The envelope of these interference lobes has the same shape, but, for a perfectly reflecting surface, it has up to twice the amplitude of the free space radiation pattern.

Radio energy – Electromagnetic radiation of greater wavelength (lower frequency) than infrared radiation, that is, of wavelength greater than about 1000 microns (0.01 cm). The high-frequency end of the radio-energy spectrum is known as microwave radiation.

See also radar frequency bands, radio frequency bands.

Radio frequency – (Abbreviated RF.) 1. The frequency of radio energy. Roughly this lies between 10^4 and 10^{12} cycles per second.

Radio frequency band – A subdivision of the radio frequency portion of the electromagnetic spectrum. The following table identifies the particular bands now in use.

	FREQUENCY BAND	FREQUENCY RANGE
VLF	Very Low Frequency	>30kc
LF	Low Frequency	30-300kc
MF	Medium Frequency	300-3000kc
HF	High Frequency	3000-30,000kc
VHF	Very High Frequency	30-300mc
UHF	Ultra High Frequency	300-3000mc
SHF	Super High Frequency	3000-30,000mc
EHF	Extremely High Frequency	30,000-300,000mc

Radio hole – Strong fading of the radio signal at some position in space along an air-to-air or air-to-ground radio path. The effect is caused by the abnormal refraction of radio waves.

Radio horizon – The locus of points at which direct rays from a radio transmitter become tangential to the earth's surface. The radio horizon extends beyond (below) the geometrical and visible horizons as the result of normal atmospheric refraction. It may be decreased or increased in particular cases as standard propagation is replaced by substandard propagation or superstandard propagation, respectively.

Beyond the radio horizon, surface targets cannot be detected under normal atmospheric conditions although significant amounts of radio power have been detected in the diffraction zone below the horizon. It is now felt that this represents power scattered by turbulence-produced atmospheric inhomogeneities.

Assuming a smooth surface, the distance of the horizon is given approximately by the equation

$$R = \sqrt{2h}$$

where R is the distance in statute miles and h is the height, in feet, of the radar antenna above the surface.

See effective earth radius, scatter propagation.

Radio wave – See electromagnetic radiation, radio energy.

Radius vector – See spherical coordinates.

Random – Eluding precise prediction, completely irregular. In connection with probability and statistics, the term random implies collective or long-run regularity; thus a long record of the behavior of a random phenomenon presumably gives a fair indication of its general behavior in another long record, although the individual observations have no discernible system of progression.

Compare nondeterministic, stochastic.

Random error – The inherent imprecision of a given process of measurement; the unpredictable component of repeated independent measurements on the same object under sensibly uniform conditions. It is found experimentally that given sufficient refinement of reading, a series of independent measurements $x_1, x_2, \ldots, x_n$ will vary one from another even when conditions are most stringently controlled. Hence, any such measurement x_i may be regarded as composed of two terms:

$$x_i = \mu + v_i$$

where μ (ordinarily the true value) is a numerical constant common to all members of the series and v_i, the random error, is an unpredictable deviation from μ.

The principal conclusion of classical investigations of errors of measurement (by Gauss and Laplace) was that, as a consequence of the central limit theorem, repeated measurements under controlled conditions usually follow the normal distribution, and the corresponding distribution of the random error is known as the error distribution.

Random numbers – A set of numbers arranged in random order.

Random sample – A sample selected at random from a population.

Random variable – (Or variate.) A variable characterized by random behavior in assuming its different possible values. Mathematically, it is described by its probability distribution, which specifies the possible values of a random variable together with the probability associated (in an appropriate sense) with each value. A random variable is said to be continuous if its possible values extend over a continuum, discrete if its possible values are separated by finite intervals.

See probability theory, statistical independence.

Range – 1. The difference between the maximum and minimum of a given set of numbers; in a periodic process it is twice the amplitude, i.e., the wave height.

2. The distance between two objects, usually an observation point and an object under observation. See slant range.

Raw moment – In statistics, a moment taken about the origin.

Ray – An elemental path of radiated engery; or the energy following this path. It is perpendicular to the phase fronts of the radiation. In tsunami wave refraction, an orthogonal.

Ray diagram – A wave refraction diagram where the wave energy rays or orthogonals are shown with or without the wave fronts.

Ray tracing – A procedure used in the graphical determination of the path followed by a single ray of radiant energy as it travels through media

of varying index of refraction. Its defining equation is

$$k = \frac{|\nabla n|}{n} \sin \theta$$

where k is the curvature of the ray, ∇n the gradient of the index of refraction n, and the angle between the initial orientation of the ray and the vector giving the direction of ∇n.

Rayleigh wave – A type of surface wave having a retrograde, elliptical motion at the free surface. It is named after Lord Rayleigh, the English physicist who predicted its existence. It is a wave propagated along the surface of a semi-infinite elastic solid, and bearing certain analogies to a surface gravity wave in a fluid.

Real time monitoring – The continuous, around the clock, operational surveillance of instrumentation which monitors important seismic and oceanographic parameters for the purpose of detecting and measuring earthquake and tsunami characteristic elements necessary for the issuance of tsunami information, watches, and warnings.

Receiver – 1. The initial component or sensing element of a measuring system.

2. An instrument used to detect the presence of and to determine the information carried by electromagnetic radiation. A receiver includes circuits designed to detect, amplify, rectify, and shape the incoming radio-frequency signals received at the antenna in such a manner that the information-containing component of this received energy can be delivered to the desired indicating or recording equipment.

Receiver gain – See gain.

Recession – Drop in the level of the water usually proceeding the arrival of tsunami waves.

Recorder – A device or an instrument which records or registers in an analog or digital format a variation or change of an environmental parameter. In tsunami work, a device which records earthquake or water level data.

Rectangular Cartesian coordinates – See Cartesian coordinates.

Rectangular curvilinear coordinates – See curvilinear coordinates.

Recurrence formula – A formula which relates successive members of a sequence of terms or formulas to earlier members of the sequence, so that all members may be determined in order.

Recurrence frequency – The repetitive cycle of ocurrence of a natural disaster such as an earthquake or a tsunami.

Recurrence interval – Same as return period.

Recurrence period – When applied to the repetition of such rare events as large destructive earthquakes and tsunamis, a most elusive parameter, and yet one that has the most scientific and social impact. It is the estimated time interval between the occurrence of events. Usually, the larger the event is in magnitude and destruction, the longer is the recurrence period. For example incorporating the concept of recurrence intervals into the seismic gap model hypothesis has enabled the development of time-dependent earthquake forecasts, and probabilistic statements of earthquake hazards. The probability for the occurrence of a future event along a specific fault segment during some time interval is a function of both the amount of time elapsed since the previous large or great earthquake and the average recurrence time. Because of the observed variability of earthquake recurrence intervals at a single location or a fault segment, the temporal resolution available using historic and geologic data ranges from a few decades to a few years, at best. Hence, recurrence time estimates based on these types of data usually fall into the category of earthquake forecasts. The same applies to the estimates of the recurrence periods of large destructive tsunamis, but with a greater degree of uncertainty.

Reech number – The reciprocal Lg/v^2 of the Froude number, where g is the acceleration of gravity, L a characteristic length, and V a characteristic speed.

Reef – An offshore consolidated rock hazard to navigation with a least depth of 10 fathoms (about 20 meters) or less.

Reef, atoll – See atoll.

Reef, barrier – See barrier reef.

Reef, fringing – See fringing reef.

Reef, sand – Synonymous with bar.

Reference frame – Same as coordinate system.

Reference sea level – The observed elevation differences between geodetic bench marks are processed through least-squares adjustments to determine orthometric heights referred to a common vertical reference surface, which is the reference sea level. In this way, height values of all bench marks in the vertical control portion of a surveying agency are made consistent and can be compared directly to determine differences of elevation between bench marks in a gedetic reference system that may not be directly connected by lines of geodetic leveling. The vertical reference surface in use in the United States, as in most parts of the world, approximates the geoid. The geoid was assumed to be coincident with local mean sea level at 26 tidal stations to obtain the Sea Level Datum of 1929 (SLD 290). National Geodetic Vertical Datum of 1929 (NGVD 29) became a name change only; the same vertical reference system has been in use in the United States since 1929. This important vertical geodetic control system is made possible by a universally accepted, reference sea level.

Reference station – A place for which tidal constants have previously been determined and which is used as a standard for the comparison of simultaneous observations at a second station; also a station for which independent daily predictions are given in the tide or current tables from which corresponding predictions are obtained for other stations by means of differences or factors.

Reflected wave – That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.

Reflection – The process whereby a surface of discontinuity turns back a portion of the incident radiation into the medium through which the radiation approached. For true reflection to occur there must be a real discontinuity of the index of refraction or at least it must change over an interfacial layer of thickness small compared to the wavelength of the radiation. If the change of refractive index is gradual (as may occur in a stratified medium) radiation may be returned by a process of continuous refraction, not to be confused with reflection.

Reflection coefficient – In oceanography, the square root of the ratio of the spacing between orthogonals in deep water and in shallow water. It is a measure of the effect of refraction in diminishing wave height by increasing the length of the wave crest.

Refraction – The deflection of a ray of light or of an energy wave (such as seismic wave) due to its passage from the medium to another of differing density, which changes its velocity. The process in which the direction of energy propagation is changed as the result of a change in density within the propagating medium, or as the energy passes through the interface representing a density discontinuity between two media. In the first instance the rays undergo a smooth bending over a finite distance. In the second case the index of refraction changes through an interfacial layer that is thin compared to the wavelength of the radiation; thus, the refraction is abrupt, essentially discontinuous.

Two principles, the laws of refraction, in general describe the behavior of abruptly refracted energy: (first law) the refracted ray lies in the same plane as do the incident ray and the normal to the interface at the point of incidence, and it lies on the opposite side of the interface; (second law) the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant equal to the ratio of the sine of the indices of refraction of the two media. The second law was experimentally established by Willebrord Snell (about 1621) and is frequently referred to as Snell's law; this name sometimes is applied collectively to both principles. The fact that refraction varies with the wavelength of the radiation is not brought out by the above stated laws (the shorter wavelengths experience the greater "bending"), but this dispersion effect is employed by the science of spectrology.

The principles of refraction are applied analogously to the bending of waves on a water surface. In general, when the depth of the water is less than one-half wavelength, decreasing depth

will reduce the speed of the wave. This explains why waves approaching a beach always tend to parallel the shoreline.

In oceanography, the square root of the coefficient – ratio of the spacing between orthogonals in deep water and in shallow water. It is a measure of the effect of refraction in diminishng wave height by increasing the length of the wave crest. Tsunami waves behave as shallow water waves and are effected by refraction throughout their prpagation across the ocean.

Refraction coefficient – The square root of the ration of the spacing between adjacent orthogonals in dep water and in shallow water at a selected point. When multiplied by the shoaling factor and a factor for friction and percolation, this becomes the wave height coefficient or the ratio of the refracted wave height at any point to the deepwater wave height. Also the square root of the energy coefficient.

Refraction diagram – In oceanography, a chart showing the position of the wave crests at a particular time, or the successive positions of a particular wave crest as it moves shoreward, in respect to time.

Refraction map – A map showing the relative positions of wavefronts for selected isochronous intervals.

Register – The writing component of a recording instrument. Frequently is is located at some distance from the sensing portion of the instrument.

Registration – Act of Registering. To record regular entries of items or details. Tsunami registration is the characteristic signature on a tide gauge record of the water fluctuations due to a tsunami.

Regressand – See regression.

Regression – The statistical counterpart or analogue of the functional expression, in ordinary mathematics, of one variable in terms of others. A random variable is seldom uniquely determined by any other variables, but it may assume a unique mean value for a prescribed set of values of any other variables. The variate y is statistically dependent upon other variates $x_1, x_2, \ldots, x_n$ when it has different probability distributions for different sets of values of the x's. In that case its mean value, called its conditional mean, corresponding to given values of the x's will ordinarily be a function of the x's. The regression function Y of y with respect to $x_1, x_2, \ldots, x_n$ is the functional expression, in terms of the x's of the conditional mean of y. This is the basis of statistical estimation or prediction of y from known values of the x's.

From the definition of the regression function, we may deduce the following fundamental properties:

$$E(Y) = E(y), E(y - y) = 0;$$

$$E[Y(y - Y) = 0, E(y^2) = E(yY);$$

$$\sigma^2(y) = \sigma^2(y) = \sigma^2(Y) + \sigma^2(y-Y),$$

where $\sigma^2 w$ denotes the variance of any variate w, and $E(w)$ denotes the expected value of w.

The variate y is called the regressand, and the associated variates $x_1, x_2, \ldots, x_n$ are called regressors; or alternatively, y is called the predictand and the x's are called predictors. When it is necessary to resort to an approximation Y' of the true regression function Y, the approximating function is usually expanded as a series of terms $Y_1, Y_2, \ldots, Y_m$ each of which may involve one or more of the basic variates x_1, $x_2, \ldots, x_n$. By extension of the original definitions, the component functions $Y_1, Y_2, \ldots, Y_m$ are then also called regressors or predictors.

Various quantities associated with regression are referred to by the following technical terms: The variance $\sigma^2(y)$ of the regressand is called the total variance. The quantity $y - Y$ is variously termed the residual, the error, the error of estimate. Its variance $\sigma^2(y - Y)$ is called the unexplained variance, the residual variance, the mean-square error; and its positive square root $\sigma(y-Y)$ is called the residual standard deviation, the standard error of estimate, the standard error, the root-mean-square error. The variance $\sigma^2(Y)/\sigma^2(y)$ of the regression function is called the explained variance or the variance reduction; the ratio of explained to total variance is called the relative reduction, or expressed in per cent, the per-cent reduction.

Regression equation – The equation of the regression function. It may be of any functional form and the terms may be orthogonal or not.

Regression function – See regression.

Regressor – See regression.

Relative frequency – Proportionate frequency per observation. If an event occurs N' times in N trials, its relative frequency is N'/N. Relative frequency is the empirical counterpart of probability.

Relative momentum – The product of the mass of a particle and its relative velocity; or, in the case of a fluid, the product of density and relative velocity.

See momentum.

Relative reduction – See multiple correlation, regression.

Relative velocity – Velocity as measured in a relative coordinate system.

Relative vorticity – (Also called local vorticity.) The vorticity as measured in a system of coordinates fixed on the earth's surface. Usually, only the vertical component of the vorticity is meant.

See also geostrophic vorticity, vorticity equation.

Relaxation method – An iterative numerical method for solving elliptic partial differential equations, e.g., a Poisson equation, $\nabla^2\phi = F(x,y)$, where ∇^2 is the Laplacian operator and the function $F(x,y)$ is given. This method is widely used in numerical forecasting and is adaptable either to electronic digital or "hand" computation.

Remote sensing – Acquisition of information about objects or phenomena in the surficial environment(including land, oceans, and atmosphere) through the use of sensory devices at positions separated from (remotely situated) the subject under study; involves measurements of electromagnetic radiation, acoustical energy, force fields, or nuclear radiations.

Residual – (Also called error of estimate.) In general, the difference between any quantity and an approximation to it; in particular, the difference $y - Y$ between any random variable y and its regression function Y.

See regression.

Residual variance – (Also called unexplained variance.) In general, the variance of any residual; in particular, the variance $\sigma^2(y - Y)$ of the difference between any variate y and its regression function Y.

See mean-square error.

Resistance – 1. In general, any force tending to oppose motion.

2. In electricity, the opposition offered by a substance to the passage of an electric current; the reciprocal of conductance (see conductivity). By virtue of the resistance, a portion of the electrical energy is converted into heat.

See resistivity. 3. Same as drag.

Resonance – The phenomenon of amplification of a free wave or oscillation of a system by a forced wave or oscillation of exactly equal period. The forced wave may arise from an impressed force upon the system or from a boundary condition. The growth of the resonant amplitude is characteristically linear in time.

Responder – In general, an instrument that indicates reception of an electric or electromagnetic signal.

Compare transponder.

Resonant period – A characteristic, predominant, and intense period or frequency of large amplitude oscillations.

Response – The outcome or reaction to an action or impulse of an active force.For example the excitation of resonance effects in a semi-enclosed body of water by an incoming tsunami, would constitute the characteristic response of that basin to a tsunami of certain period. If the tsunami period or initial height changed, then the response of that basin could be different.

Response spectrum – The range of frequencies that may be excited by an outside impulse to produce a variety of responses.

Rest mass – According to relativistic theory, the mass which a body has when it is at absolute rest. Mass increases when the body is in motion according to

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

where m is its mass in motion, m_0 its rest mass, v the body's speed of motion, and c the speed of light. Newtonian physics, in contrast with relativistic physics, makes no distinction between rest mass and mass in general.

Retardation – The amount of time by which corresponding tidal phases grow later day by day (about 50 minutes).

Retrogression of a beach – 1. A continuing landward movement of the shoreline.

2. A net landward movement of the shoreline over a specified time. Also recession.

Return period – (Also called recurrence interval.) A statistical parameter used in frequency analysis as a measure of the average time interval between the occurrence of a given quantity and that of an equal or greater quantity.

See exceedance interval, Hazen method.

Reversing current – A tidal current which flows alternately in approximately opposite directions, with periods of slack water at each reversal. Such currents occur chiefly in restricted channels; open sea areas generally have rotary currents.

Reverse fault – A fault with a dip of 45 or less in which the upper block appears to have moved upward relative to the lower block. Horizontal compression rather than vertical displacement is its characteristic feature.

Revetment – A facing stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

Reynolds number – The non-dimensional ratio of the inertial force to the viscous force in fluid motion,

$$\mathrm{Re} = \frac{LU}{\nu}$$

where L is a characteristic length, ν the kinematic viscosity, and U a characteristic velocity. The Reynolds number is of great importance in the theory of hydrodynamic stability and the origin of turbulence.

Reynolds stresses – (Also called eddy stresses, virtual stresses, apparent stresses, turbulent shear stresses.) The components of the mean velocity of a viscous, incompressible, homogeneous fluid in turbulent motion will satisfy a set of equations of the same form as the Navier-Stokes equations when the viscous stress term is replaced by

τ_{xx} is replaced by $\bar{\tau}_{xx} - \overline{\rho u'^2}$,

τ_{xy} is replaced by $\bar{\tau}_{xy} - \overline{\rho u'v'}$,

τ_{xz} is replaced by $\bar{\tau}_{xz} - \overline{\rho u'w'}$, etc.

The bar denotes a time average, ρ is the density and u', v', w' are the eddy velocities. The terms $\overline{\rho u'v'}$ of the form are called the "Reynolds stresses." The Reynolds stresses are the representation of the transfer of the momentum due to turbulent fluctuations.

See stress tensor, eddy viscosity.

Ria – A long, narrow inlet, with depth gradually diminishing inward.

Ridge, beach – A nearly continuous mound of beach material that has been shaped up by wave or other action. Ridges may occur singly or as a series of approximately parallel deposits. (See Figure A-7.)

Right-handed rectangular coordinates – Rectangular Cartesian coordinates in which the coordinates x, y, and z are measured along three mutually perpendicular axes such that a rotation of the positive x-axis into the positive y-axis will drive a right-handed screw in the direction of the positive z-axis. The Cartesian coordinates most often used in meteorology form a right-handed system: x increasing to east, y to north, z to zenith.

Rill marks – Tiny drainage channels in a beach caused by the flow seaward of water left in the sands of the upper part of the beach after the retreat of the tide or after the dying down of storm waves.

Rip – The agitation of water caused by the interaction of water currents or by a rapid current setting in

over an irregular bottom; for example, a "tide rip."

Rip current – A narrow seaward-flowing current that results from breaking of waves and subsequent accumulation of water in the nearshore zone. A strong water-surface current of short duration flowing seaward from the shore; the return movement of water piled up on the shore by incoming waves and wind. It usually appears as a visible band of agitated water; and, with the outward movement concentrated in a limited band, its velocity is somewhat accentuated. A rip current is often miscalled a "rip tide." To swimmers, the phenomenon is known as "undertow."

Rip surf – See rip current.

Rip tide – See rip current.

Riparian – Pertaining to the banks of a body of water.

Ripple – 1. The ruffling of the surface of water, hence a little curling wave or undulation.

2. A wave less than 2 inches long controlled to a significant degree by both surface tension and gravity.

See wave, capillary and wave, gravity.

Ripples (bed forms) – Small bed forms with wavelengths less than 1 foot and heights less than 0.1 foot.

Riprap – A layer, facing, or protective mound stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also the stone so used.

Rise (in sea level) – The upward change in sea level associated with a tsunami, a hurricane, a tide, or some long term climatic effect.

Risk (of tsunami) – A danger element or factor. The exposure to loss, injury, or death associated with a forthcoming tsunami disaster.

Rising tide – (Sometimes called flood tide.) The portion of the tide cycle between low water and the following high water.

Roadstead (nautical) – A sheltered area of water near shore where vessels may anchor in relative safety. Also road.

Rock fall – A mass of sliding or falling rocks into or underneath the sea, which can generate a local tsunami.

Rollers – Swells coming from a great distance and forming large breakers on exposed coasts. They are best known on the islands of St. Helena and Ascension in the South Atlantic Ocean during the months from December to April, when they come from the northwest. They arrive often in calm weather, with practically no warning, and are dangerous to shipping. Rollers also occur at Fernando do Noronha, Tristan da Cunha, and on the coasts of West Africa, Peru, and the East Indies.

Root-mean-square – (Abbreviated RMSE; also called standard error – error of estimate, residual standard deviation.) The positive square root of the mean-square error. It is equal to the standard error only when the mean error is zero.

Rossby number – The non-dimensional ratio of the inertial force to the coriolis force for a given flow of a rotating fluid. It may be given as

$$\mathrm{Ro} = \frac{U}{fL}$$

where Ω is a characteristic velocity, f the coriolis parameter (or, if the system is cylindrical rather than spherical, twice the system's rotation rate), and L a characteristic length.

The Rossby number is a basic modeling criterion used in the "dishpan" investigations of the general circulation.

Compare thermal Rossby number.

Rossby parameter – (Also called Rossby term.) The northward variation of the coriolis parameter, arising from the sphericity of the earth. In symbols,

$$\beta = \frac{d}{dy}(2\Omega \sin \phi) = \frac{2\Omega \cos \phi}{a}$$

where Ω is the angular speed of the earth, ϕ the latitude, a the mean radius of the earth, and β the Rossby parameter.

The Rossby parameter, usually treated as a constant, is of importance dynamically as a stabilizing effect in certain types of wave motion.

See Rossby wave, barotropic instability, beta plane.

Rossby wave – (Also called planetary wave.) A wave on a uniform current in a two-dimensional non-divergent fluid system, rotating with varying angular speed about the local vertical (beta plane).

See long wave.

Rotary current – A tidal current that changes direction progressively through 360° during a tidal cycle.

See current ellipse; compare reversing current.

Rotating Reynolds number – (Or rotation Reynolds number.) – A non-dimensional number arising in problems of a rotating viscous fluid. It may appear either as $\Omega r^2/\nu$, in which case it equals one-half the square root of the Taylor number, or as $\Omega r^2/\nu$. r is a suitable radius, h a representative depth, Ω the absolute angular speed, and ν the kinematic viscosity.

Rotation – 1. The act or process of turning about on an axis or a center; 2. One complete turn: the angular displacement required to return a rotating body or figure to its original orientation.

Rotation of the earth – The revolution of the earth around its axis.

Rotational – Possessing vorticity. See also irrotational.

Rotational instability – In general, any instability of a rotating fluid system, usually synonymous with inertial instability (2).

Rubble – 1. Loose angular waterworn stones along a beach.

2. Rough, irregular fragments of broken rock.

Rubble-mound structure – A mound of random-shaped and random-placed stones protected with a cover layer of selected stones or specially shaped concrete armor units. (Armor units in primary cover layer may be placed in orderly manner or dumped at random.

Runnel – A corrugation or trough formed in the foreshore or in the bottom just offshore by waves or tidal currents.

Running mean – Same as consecutive mean.

Run-up – The value of absolute inundation at the maximum horizontal extent of flooding, measured perpendicular to the shoreline.

Run-up distribution – The diverse values of tsunami runup measured or observed along a coastline

Rupture (of the fault) – The breaking or tearing apart of the rocks or other surface formations along a rift , fracture,or schism delineating a fault on the surface of the earth, caused by a shallow focus earthquake.

– S –

S wave – Shear, secondary, rotational, tangential, equivoluminal, distortional, transverse, shake wave.

Salt marsh – A marsh periodically flooded by salt water.

Sample – In statistics, a group of observations selected from a statistical population by a set procedure. Samples may be selected at random or systematically. The sample is taken in an attempt to estimate the population.

Sand – See soil classification.

Sand bypassing – See bypassing, sand.

Sand reef – Synonymous with bar.

Sand wave (or megaripple) – A large wavelike sediment feature composed of sand in very shallow water. Wavelength may reach 100 meters; amplitude is about 0.5 meters.

Sandbar – 1. See bar.

2. In a river, a ridge of sand built up to or near the surface by river currents.

Satellite – 1. A celestial body orbiting another of larger size; 2. A man-made object or vehicle intended to orbit the earth, the moon, or another celestial body. 3. A man-made object or vehicle placed on geostationary orbit above the earths equator (geosynchronous, or geostationary satellite.

Satellite communications telemetry – Instrumentation installed on monitoring stations on earth and on satellites, which permits exchange of information and the rapid and accurate reception and transmission of data by radio waves.

Satellite technology – Current, advanced technology on instrumenting, launching, and positioning or orbiting satellites for communications, data telemetry, remote sensing and numerous other applications.

Satellite telemetry – See Satellite Communication Telemetry.

Saturation signal – A radio signal (or radar echo) which exceeds a certain power level fixed by the design of the receiver equipment. When a receiver or indicator is "saturated," the limit of its power output has been reached.

Scalar – Any physical quantity whose field can be described by a single numerical value at each point in space. A scalar quantity is distinguished from a vector quantity by the fact that a scalar quantity possesses only magnitude, whereas a vector quantity possesses both magnitude and direction. Thus, pressure is a scalar quantity and velocity is a vector quantity.

Scalar product – (Also called dot product, direct product, inner product.) A scalar equal to the product of the magnitudes of any two vectors and the cosine of the angle 0 between their positive directions. For two vectors A and B, the scalar product is most commonly written A • B, read "A dot B," and occasionally as (AB). If the vectors A and B have the components A_x, B_x, A_y, B_y and A_z, B_z along rectangular Cartesian x, y and z axes, respectively, then

$$\begin{aligned} A \cdot B &= A_x B_x + A_y B_y + A_z B_z \\ &= |A|\,|B| \cos\theta = AB\cos\theta. \end{aligned}$$

If a scalar product is zero, one of the vectors is zero or else the two are perpendicular.

See vector product.

Scale distortion – Falsified reproduction of scale or condition, caused by change in the waveform of the original signal. A lack of proportionality in an image or condition resulting from defects in proper scaling. .

Scale effects – Erroneous or inaccurate results obtained by improper scaling, or minor distortions amplified by the degree of scaling downward.

Scale factor – (Also called map scale, map factor.) The ratio between the distance separating two points on a map of the earth's surface at a standard latitude or latitudes) and the distance between the corresponding points on the earth's surface itself. For most map projections, this factor is a slowly varying function of latitude, and for synoptic-chart base maps it is usually of the order of 10^{-6} to 10^{-7} . The scale factor is sometimes defined as the reciprocal of the above ratio.

See conformal map.

Scaling – The reduction of a sample (as a model) in proportion to the size of the actual thing.

Scarp – See escarpment.

Scarp, beach – An almost vertical slope along the beach caused by erosion by wave action. It may vary in height from a few inches to several feet, depending on wave action and the nature and composition of the beach. (See Figure A-1.)

Scatter – 1. Same as scattering; or, sometimes used in referring to the scattered radiation.

2. The relative dispersion of points on a graph, especially with respect to a mean value, or any curve used to represent the points.

See scatter diagram, dispersion (3), spread.

Scatter angle – The angle between any given ray of scattered radiation and the incident ray.

Convention varies as to whether this angle is measured with respect to the direction in which the incident radiation was advancing or with respect to the direction from scatterer to radiation source. See relative scatter intensity, scattering.

Scattering – Dispersion and irregular spreading of water waves leading to attenuation and energy dissipation of the wave system. In reference to seismic waves, the effects of scattering on measurements of intrinsic attenuation, at frequencies that are so low that wavelengths are much larger than linear dimensions of a heterogeneity, the effects of scattering can usually be neglected for the propagation of body waves. Very low frequencies are in the domain of Rayleigh scattering, in which the energy loss in the forward direction is proportional to the inverse fourth power of frequency. At sufficiently low frequency, the medium behaves like an equivalent medium, having properties that are an average of small-scale heterogeneities. At higher frequencies, those in which the wavelength is on the order of the scale length of heterogeneities, the presence of the heterogeneities can profoundly alter the propagation of the wave field. For wavelengths much smaller than the scale length of the heterogeneities, it is possible in some situations to calculate the effect of scatterers by using ray theory. The distribution and shape of the scatterers, however, must first be known or assumed.

SCOR - Scientific Committee on Oceanic Research.

Scour – Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

SE - Solid Earth.

Sea – 1. Same as ocean (1).

2. A subdivision of an ocean (2). All seas except "inland seas" are physically interconnected parts of the earth's total salt water system. Two types are distinguished, Mediterranean and adjacent. Mediterraneans are groups of seas, collectively separated from the major water body as an individual sea. Adjacent seas are those connected individually to the larger body.

3. Same as state of the sea.

4. Sea-surface waves within their fetch; opposed to swell. See fully-developed sea.

Sea cliff – A cliff situated at the seaward edge of the coast.

Sea floor - See continental drift, ocean basins, ocean floor.

Sea-floor spreading – A hypothesis that the oceanic crust is increasing by convective upwelling of magma along the midoceanic ridges or world rift system, and a moving away of the new material at a rate of from 1 to 10 cm(o.4 to 4 in.) per year. This movement provides the source of power in the hypothesis of plate tectonics. This hypothesis supports the continental displacement hypothesis.

Sea Ice - Any ice, floating or fast, that is formed from freezing ocean water.

Sea level – 1. The average height of the sea averaged over a long time compared to tidal fluctuations; sea level can change over the years.

2. The level of the surface of the sea esp. as its mean position midway between mean high and low water.

Sea-level chart – Same as surface chart.

Sea-level pressure – The atmospheric pressure at mean sea level, either directly measured or, most commonly, empirically determined from the observed station pressure.

In regions where the earth's surface is above sea level, it is standard observational practice to reduce the observed surface pressure to the value that would exist at a point at sea level directly below if air of a temperature corresponding to that actually present at the surface were present all of the way down to sea level. In actual practice, not the current temperature but the mean temperature for the preceding twelve hours is employed. This "reduction of pressure to sea level" is responsible for many anomalies in the pressure field in mountain areas on the surface synoptic chart.

Sea level reference – See Reference sea level.

SEAN - Scientific Event Alert Network.

Sea puss – A dangerous longshore current; a rip current caused by return flow; loosely, the submerged channel or inlet through a bar caused by those currents.

Sea shock – Violent disturbance of the sea resulting from a relative shallow and powerful earthquake in the area.

Sea state – Same as state of the sea.

Seamount – An undersea, relatively isolated mountain rising from the seafloor to a height of about 1,000 m (3,300 feet). It if has a pointed summit it is called a sea peak; if it is flat-topped, it is called a guyot. The shape of most seamounts is elliptical. Only the very small ones have steep sides; large ones have gently sloping sides. These features are true for the seamounts present in every ocean. Hundreds of these mountains have been mapped, particularly in the Pacific, and it has been estimated by oceanographers that this number is only a small portion of the total. Although they are separate entities, seamounts occur in groups or chains, as do island arcs. Seamounts seem to be of volcanic origin, and may result from eruptions along crustal fissures. In most cases the volcanic cone shows signs of weathering (erosion). There may be sedimentary accretion on a seamount, or a coral reef that has used the dormant or dead volcano as a base for growth. Some seamounts, including a significant number with coral or limestone tops, are below the level of coral growth. This suggests subsidence by an unknown mechanism.

Seaquake – An earthquake that occurs beneath the ocean and that can be felt on board a ship in the vicinity of the epicenter (A submarine earthquake).

Seas – Waves caused by wind at the place and time of observation.

Seashore – The shore of a sea or ocean.

SEATAR - South-East Asian Tectonics and Resources.

Seawall – A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

See also bulkhead.

Seawaves – One of a series of waves collectively known as a sea.

Secondary instrument – An instrument whose calibration is determined by comparison with an absolute instrument.

Second-foot – A contraction of cubic foot per second (cfs), the unit of stream discharge commonly used in the United States.

Secondary shorelines – Secondary shorelines are those where the coastal region has been mainly formed by marine or biological agents, like coral reefs, barrier beaches, and marshes.

Secondary undulations – Fluctuations in water level of a basin or a semi-enclosed body of water, or on an open coastline, of lesser importance and, possibly unrelated, to the primary and more significant initial water level fluctuations caused by a tsunami.

Secondary waves – See secondary undulations above.

Secular variation – In general, a slow trend, the actual time scale implied being different for different contexts.

Sediment – Matter that settles to the bottom of the sea. Sediments were first seriously sampled by Matthew Maury, and systematically studied by the Challenger expedition (1872-1876). They are divided into two large groups, the terrigenous and the pelagic. The former is largely of terrestrial origin and consists of rock, gravel, sand, and mud - with volcanic intrusion, and coral debris. The pelagic sediments are those that "rain down" from all levels of the water and finally land on the bottom. These are the shells or skeletal remains of plankton.

Sediment plume – An elongated, usually open and mobile column or band of solid fragmented material that originates from weathering of rocks and is transported by, suspended in, or deposited by air, water, or ice, or that is accumulated by other natural agents.

SEG - Solid Earth Geophysics.

Seiche – The occasional, rhythmic rise and fall of water in enclosed lagoons or bays. It is not tidal. The phenomenon was carefully observed on Lake Constance (Switzerland) in the 16th century. The oscillation of the water is the result of a disturbance that sets up "waves." The time period of these "waves" is described by Merian's formula,

$$T = \frac{2L}{\sqrt{gh}}$$

L= length of the body water, h = depth of body water, g = gravity of body water.

The so-called wave will bounce back and forth until its energy is dissipated through friction. The seiche is dependent on the shape of the basin in which it occurs. Seiches may be generated by meteorological conditions, such as fast moving fronts, but they may be generated also by earthquakes.

Seismic – Pertaining to an earthquake or Earth vibration, including those that are artificially induced.

Seismic belt – An elongate earthquake zone, for example, circum-Pacifife, Mediterranean, Rocky Mountain.

Seismic constant – In building codes dealing with earthquake hazards, an arbitrarily set quantity of steady acceleration (in units of gravity) that a building must withstand.

Seismic data acquisition – All but the simplest seismic instruments are designed to record the time history of ground motion. For discussing such instruments, it is useful to break them down into three parts (although these may be combined in an actual instrument). First there is a sensor, which converts ground motion into some other quantity, usually an electrical one; this sensor is called a seismometer, or a geophone in exploration seismology. Next, the sensor output is modified, usually by amplifying some frequencies and suppressing others; very often such modification is done partly within the sensor itself. Third, the modified output is recorded, along with a time scale (and in most cases absolute time). With the growth, first of analog and then of digital electronics, the systems used for the signal modification and recording have increasingly often been adapted from devices built for other purposes, rather than being purely seismological inventions. It is with such seismic instrumentation that seismic data is aquired, with the exception of other types of seismic data, for example data for earthquake intensity determinations, or other field data, which is acquired by surveys.

Seismic focus - In seismology, the point within the earth that is the center of an earthquake. It is the initial rupture point of an earthquake, where strain energy is transformed into elastic wave energy. See epicenter.

Seismic moment – An earthquake parameter recently introduced in seismology is that of the seismic moment (Mo). The seismic moment is related to fundamental parameters of the faulting process resulting from earthquakes in the following way: The amplitude of every long period seismic wave is proportional to the surface area of the fault, the average displacement on the fault plane, and the rigidity of the material at the fault. The result of these three quantities is the seismic moment, Mo, which after some corrections, can be calculated from measurement of long-period seismic waves. The seismic moment is the most suitable parameter representing the size of an earthquake because, unlike magnitude obtained from surface waves, it does not saturate for larger shocks. Another advantage of the seismic moment is that it represents, in addition to the size of the earthquake, the overall deformation at the source. The seismic moment is determined by the Fourier analysis of seismic waves of such long period that the details of the rupture are smoothed out, with the effect that the entire fault may be considered to be a point-source. The periods at which the seismic moment are determined increase with the size of the fault. If the fault is based on such long-period waves, the slip from unruptured to ruptured state appears to be instantaneous. The actual pattern of the seismic radiation emitted by the instantaneous rupture is mathematically equivalent to the theoretical radiation pattern emitted by two hypothetical torque couples embedded in an unruptured elastic medium. The torque couples, rotating in opposite directions, deform the medium thus radiating elastic waves in a pattern identical with that in

which an earthquake source radiates seismic waves. The moment can be calculated from this model. Earthquake magnitudes calculated by the use of seismic moment for large historic earthquakes would be greater than the assigned Richter magnitudes. For example, the 1964 Alaskan earthquake's assigned magnitude (Ms), was 8.4 while the magnitude (Mw) based on the seismic moment was 9.2. Similarly, for the 1960 Chilean earthquake, Ms was 8.3 while Mw would be 9.2. Scientists have concluded that comparison of earthquake magnitudes obtained from surface waves and seismic moments agree quite well for earthquakes with smaller fault dimensions, but do not agree for earthquakes of larger fault dimensions.

Seismic oscillation – The act or fact of oscillating or swinging back and fourth or up and down, caused by an earthquake.

Seismic reflection profile – Profile of reflection horizons within a sediment pile obtained by using lower frequency sound waves in the manner of echo sounding.

Seismic seiche – Oscillation of the surface of a lake or landlocked sea that varies in period from a few minutes to several hours caused by an earthquake.

Seismic sea wave – Same as tsunami.

Seismic source – The point of origin or an earthquake. Two main categories of seismic sources are transient and continuous. Transient sources have a total source duration of a few minutes or less; this duration cut-off corresponds to the duration of the largest earthquakes. Continuous sources may have a distinct spectral peak (such as microseisms) and hence appear as quasi-harmonic oscillations with durations of many hours or days. The main types of seismic sources that are routinely recorded are listed below:

Transient - Earthquakes; Explosions (caused by humans); Volcanic explosions; Landslides; Extraterrestrial impacts and explosions.

Continuous - Microseisms; Atmospheric noise; Volcanic harmonic tremor; Underwater volcanic venting.

Seismic waves – A general term for all elastic waves produced by earthquakes or generated artificially by explosion. It includes both body waves and surface waves.

Seismic zone – A distinctive area or belt on the earth's surface characterized by recurrent seismic activity.

Seismic zoning - Areal delineation of seismic risk used for planning and for the assignment of building codes.

Seismicity – The measure of the amount of earthquake activity in a given region.

Seismogenic – A region is said to be seismogenic if it known historically to have produced earthquakes. A tsunami is described as seismogenic if it was generated by an earthquake.

Seismogenic zone – A belt or an area on the surface of the earth with a known history of seismic activity.

Seismograph – An instrument for recording the motions produced by an earthquake at any particular point.

Seismology – The study of earthquakes and of the structure of the Earth, by both natural and artificially generated seismic waves.

Seismometers – An instrument that detects Earth movements.

Seismotectonics – A branch of geophysical sciences that is closely related to but not synonymous with structural geology. Whereas structural geology is concerned primarily with the geometry of rocks, seismotectonics deals not only with larger features of the earth, but also with the forces and movements that produced them. Thus seismotectonics is the study of plate tectonics, and crustal plate movements, by the use of seismic data from earthquakes ocurring along the boundaries of such crustal plates.

Semidiurnal tide – A tide having two high waters and two low waters each lunar day, with little or no diurnal inequality. This applies equally to solar tides and to atmospheric tides.

Sensing element – (Or sensor.) The component of an instrument which converts an input signal into a quantity which is measured by another part of the instrument.

Sensitivity – In instrumental terminology;, the degree to which a receiver will respond to an input of given strength. The greater the sensitivity, the weaker are the signals detected.

See threshold signal.

Sensor – The component of an instrument that converts an input signal into a quantity that can be measured by another part of the instrument.

Separation of variables – The assumption that the solution of a partial differential equation is equal to a product of functions, each being a function of only one of the independent variables. Each function then satisfies an ordinary differential equation and the original equation is said to be separable. This method has been widely applied in linear boundary value problems admitting of permanent waves as solutions.

Serial correlation – Usually same as autocorrelation, but occasionally used to designate lagged correlations between two separate series of observations, for example, the correlation between x_i and y_i+1, and in the series $x_1,x_2, \ldots$ and $y_1,y_2 \ldots ..$

Setup, wave – Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

Shadow zone – Same as diffraction zone.

Shallow focus – 1. An earthquake whose center is at earthquake or close to the surface, as distinguished from a deep focus earthquake whose center is deep in the Earth's crust.

2. An earthquake whose focus occurs at a depth of less than 50, 60, or 70km(31, 37, or 44 miles) (there is no agreement). Most earthquake activity is of this type.

Shallow water – 1. Commonly, water of such a depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-half the surface wavelength as shallow water.

See transitional zone and deep water.

2. More strictly, in hydrodynamics with regard to progressive gravity waves, water in which the depth is less than 1/25 the wavelength. Also called very shallow water.

Shallow-water wave – (Also called long wave, Lagrangian wave.) An ocean wave whose length is sufficiently large compared to the water depth (i.e., 25 or more times the depth) that the following approximation is valid:

$$c = \sqrt{gh} ,$$

where c is the wave velocity, g the acceleration of gravity, and h the water depth. Thus, the velocity of shallow-water waves is independent of wave length L. In water depths between $(1/2)L$ and $(1/25)L$ it is necessary to use the more precise expression

$$c = \sqrt{(gL/2\pi)[\tanh (2\pi h/L)]} .$$

See deep-water waves, gravity wave.

Shallow water wave theory – The part of water wave theory dealing with long waves whose length is sufficiently long compared to water depth where the waves may be treated as shallow water waves and are affected predominantly by the depth of the water in their propagation, attenuation, and energy dissipation. Tsunamis are such long waves, and so are seiches, and tides. All seldom break.

Shear – The variation (usually the directional derivative) of a vector field along a given direction in space.

Shear, or S, waves – Elastic waves characterized by distortional changes in the body through which they travel.

Shear-gravity wave – A combination of gravity waves and a Helmholtz wave on a surface of discontinuity of density and velocity. If the densities of the lower and upper layers

respectively are ρ and ρ' and the velocities U and U', the phase speed of the shear-gravity wave is

$$c = \frac{\rho U + \rho' U'}{\rho + \rho'} \pm \left[\frac{gL}{2\pi} \frac{\rho - \rho'}{\rho + \rho'} - \frac{\rho\rho' (U - U)^2}{(\rho + \rho')^2} \right]^{\frac{1}{2}}$$

where g is the acceleration of gravity and L the wave length. The motion is unstable if and only if the bracketed quantity is negative; the density difference thus contributes to stability and the velocity difference to instability.

Shearing stress – Any of the tangential components of the stress tensor.

Shear vector – The derivative of any vector in any spatial direction. The particular direction should be clear from the context.

Shear wave – 1. Same as Helmholtz wave.

2. A wave propagated in an elastic solid.

Sheet pile – See pile, sheet.

Shelf – A zone adjacent to a continent (or around an island) and extending from the low water line to a depth at which there is usually a marked increase of slope towards oceanic depths.

Shelf break – The sharp break in slope which marks the edge of the continental shelf and beginning of the continental slope.

Shelf, continental – See continental shelf.

Shelf ice – Same as ice shelf.

Shelf, insular – See insular shelf.

Shelf response – The continental shelf is a partially resonant chamber for oscillations normal to its contours, and necessarily responds greatest to excitations with length scales close to its natural modes of oscillation.

Shelf seiche – Free oscillations characterized by rhythmic rise and fall of the water level observed on the open shelf restoring equilibrium conditions which have been disturbed by an outside exciting force such as a sudden meteorological barometric fluctuation.

Shelf wave – A wave propagating on the continental shelf.

Shingle – 1. Loosely and commonly, any beach material coarser than ordinary gravel, especially and having flat or flattish pebbles.

2. Strictly and accurately, beach material of smooth, well-rounded pebbles that are roughly the same size. The spaces between pebbles are not filled with finer materials. Shingle often gives out a musical sound when stepped on.

Shoal (noun) – A detached elevation of the sea bottom, comprised of any material except rock or coral, which may endanger surface navigation.

Shoal (verb) – 1. To become shallow gradually.

2.To cause to become shallow.

3. To proceed from a greater to a lesser depth of water.

Shoaling coefficient – The ratio of the height of a wave in water of any depth to its height in deep water with the effects of refraction, friction, and percolation eliminated. Sometimes shoaling factor or depth factor.

See also energy coefficient and refraction coefficient.

Shock wave – A compressional wave formed whenever the speed of a body relative to a medium exceeds that at which the medium can transmit sound having an amplitude that exceeds the elastic limit of the medium in which it travels, and characterized by a disturbed region of small but finite thickness within which very abrupt changes occur in the pressure, temperature, density and velocity of the medium.

Shore – The narrow strip of land i immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach. (See Figure A-1.)

Shore-protective structures – Structures such as seawalls, seabreakers, dikes,groins,jetties, riprap, or concrete armor units, protecting shorelines.

Shoreface – The narrow zone seaward from the low tide shoreline covered by water over which the beach sands and gravels actively oscillate with changing wave conditions. See inshore (zone) and Figure A-1.

Shoreline – The place where land and water meet.

Short-crested wave – An ocean wave whose crest is of finite length, i.e., the type actually found in nature.

Short term prediction – A prediction issued within hours, days, or even weeks before the ocurrence of a natural disaster such as an earthquake or a tsunami.

Short wave – (Or minor wave.) In oceanography, same as deep-water wave.

Sieberg tsunami intensity scale – A descriptive tsunami intensity scale which was later modified into the Sieberg-Ambraseys tsunami intensity scale shown below.

Sieberg-Ambraseys tsunami intensity scale i. Very light. Wave so weak as to be perceptible only on tide gauge records. ii. Light. Wave noticed by those living along the shore and familiar with the sea. iii. Rather strong. Generally noticed. Flooding of gently sloping coasts. Light sailing vessels carried away on shore. Slight damage to light structures situated near the coast. In estuaries reversal of the river flow for some distance upstream. iv. Strong. Flooding of the shore to some depth. Light scouring on man-made ground. Embankments and dikes damaged. Light structures near the coast damaged. Solid structures on the coast injured. Big sailing vessels and small ships drifted inland or carried out to sea. Coasts littered with floating debris. v. Very strong. General flooding of the shore to some depth. Quay-walls and solid structures near the area damaged. Light structures destroyed. Severe scouring of cultivated land and littering of the coast with floating items and sea animals. With the exception of big ships all other type of vessels carried inland or out to sea. Big bores in estuary rivers. Harbour works damaged. People drowned. Wave accompanied by strong roar. vi. Disastrous. Partial or complete destruction of man-made structures for some distance from shore. Flooding of coasts to great depths. Big ships severely damaged. Trees uprooted or broken. Many casualties.

Signal – Any carrier of information; opposed to noise. See carrier wave.

Signal generator – An electronic instrument used for the production of electric (or radio signals with certain desired characteristics. It is useful in testing and calibration.

Signal strength – In radio, a measure of the received radio frequency power; generally expressed in decibels relative to some standard value, normally either 1 milliwatt or that power which would have resulted at the same distance under free space transmission. The term field strength is commonly used as a synonym.

Signal-to-noise ratio – The comparison between the amplitude of the seismic signal and the amplitude of noise caused by seismic unrest and (or) the seismic instruments.

Signal velocity – The speed of propagation of a hydrodynamic influence.

Significance level – See significance test.

Significance test – A test of the reliability of estimates of statistical parameters. Such tests proceed by assuming that the estimates are not significant and are those to be expected from sampling a particular population, and then, from the properties of the population, determining the probabilities of such occurrences. The hypothesis (that the estimates are not significant) is rejected only when an observational result is found to be significant, that is, when the obtained result belongs to an objectively specified unfavorable class (critical region or rejection region) having a fixed, small probability of occurrence in random samples from the hypothesized population. When the result falls in the acceptance region, it is not significant and the hypothesis cannot be rejected. The boundaries of the classes are set in such a way that the total probability (unit) is appropriately divided between them, say .95, .05 or .99, .01. The probability assigned to the critical region, commonly either .05 or .01, is called the significance level.

See chi-square test, Student's "t" test, analysis of variance.

Significant wave – A fictitious wave whose height and period are equal to the average height and period of the highest one-third of the actual waves that pass a fixed point.

Significant wave height – The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one-third of a selected number of waves, this number being determined by dividing the time of record by the significant period. Also characteristic wave height.

Significant wave period – An arbitrary period generally taken as the period of the one-third highest waves within a given group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, this is determined as the average period of the most frequently recurring of the larger well-defined waves in the record under study.

Sill – A ridge or other below sea level geological formation which separates the water of one basin from another; as, for example, the ridge at the Straits of Gibralter which separates the Mediterranean from the North Atlantic

Sill depth – (Also called threshold depth.) The maximum depth at which there is horizontal communication between an ocean basin and the open ocean.

Silt – See soil classification.

Silurian Period - The period following the Ordovician Period of the Paleozoic Era and preceding the Devonian. This time is usually given as 430 million to about 395 million years ago. The name Silurian was devised by Murchison, who chose it for the Silures, a tribe living in pre-Roman Wales. The Silurian was an age of mountain building: The events of this time raised the Scottish Highlands in Britain and the Taconic Mountains in eastern North America, and closed the proto-Atlantic Ocean, Canada, Scandinavia, and South Africa were probably equatorial landmasses, Japan and the Philippines were near the North Pole, and South America and Australia were near the South Pole. Generally speaking, the climate throughout this time was mild to tropical and the seas were shallow, a combination that encouraged the growth of calcareous invertebrates, which in turn produced vast limestone deposits.

Simple average – Same as arithmetic mean.

Simple harmonic wave – An oscillation translating with constant speed and amplitude, and represented mathematically by a trigonometric or complex exponential function. Thus,

$$A \sin\left(\frac{2\pi}{\lambda} x - \nu t + \phi\right) \text{ or } e \exp i\left(\frac{2\pi x}{\lambda} - \nu t + \phi\right)$$

represents a simple harmonic wave of amplitude A, wave length λ, frequency ν, and phase angle ϕ. In ocean wave studies, a simple harmonic progressive wave is an idealized wave characterized by constant speed of propagation and a straight crest of indefinite length.

Simple linear correlation – See correlation.

Simple wave – 1. The solution of a set of quasi-linear differential equations describing a fluid flow which possesses a family of straight-line characteristics. In such a fluid motion the dependent variables, or simple combinations thereof, are constant along the characteristics, and may be used as the basis of the integration of the equations by the method of characteristics.

2. Same as simple harmonic wave.

Single-crest wave – A solitary wave.

Sinusoidal wave – A wave generated by plotting the value of a sine function against its angular value.

Skewness – Departure from symmetry. In statistics, the coefficient of skewness γ_1 of a random variable or of a probability distribution is defined as $\gamma_1 = \mu_3/\sigma^3$, where μ_3 is the third moment about the mean and σ is the standard deviation. Where $\gamma_1 > 0$ the typical curve tails off toward the right and hence is said to be skewed to the right; when $\gamma_1 < 0$ the longer tail is on the left, and the curve is said to be skewed to the left.

Sky wave – In radio terminology, radio energy that is received after having been reflected by the ionosphere.

Slack water – The condition when a tidal current has zero speed.

Slip – A berthing space between two piers.

Slip earthquake - A type of earthquake in which the movement is mainly in a horizontal direction.

Slope – The inclined surface of any part of the Earth's surface.

Slope current – See gradient current.

Sloping beach – A beach which is inclining upwards from the edge of the sea at an angle which may vary from one or two degrees, to a much steeper gradient of thirty degrees or more depending on its configuration, and the nature of the deposits covering it, which in turn are related to coastal profile, types of debris available, wave pattern, and the rate of deposit.

Slump – The sudden downward slipping or sliding of unconsolidated material of sediments and rocks along a steep slope, behaving as a single mass, usually with a backward rotation relative to the slope along which movement takes place.

ebb tide period.

Snell's law – See refraction, index of refraction.

Socio-economic impact – The forceful and adverse effects of a natural disaster on the social and economic resources of a community.

SOFAR - Sound Fixing and Ranging, a triangulation technique based on the mode of travel of sound waves underwater. Sounds created in deep ocean waters (e.g., by an explosion or an earthquake) move great distances with little attenuation. Land-based listening stations in several different locations that receive such sound signals can then pinpoint their origin. T-phases from tsunamigenic earthquakes travel readily through the SOFAR channel.

Solar tide – A partial tide caused by the gravitational pull of the Sun on the Earth. The Earth is closer to the Sun at perihelion because the Earth's orbit is an ellipse. Perihelion occurs in winter in the Northern Hemisphere, while aphelion (the farthest distance of the Earth from the Sun) occurs in summer. (The moon also moves closer to and farther from Earth respectively, during these two seasons.) Because of both of these movements, the tidal ranges are greater in the Northern Hemisphere during the winter than they are in the summer.

See aphelion, lunar, and perihelion tide.

Solitary wave – A finite-amplitude gravity wave consisting of a single crest; under certain conditions, a permanent wave. Certain barograph traces have been taken as evidence that the solitary wave also occurs in the atmosphere.

SONAR - The acronym for Sound Navigation and Ranging, a technique used at sea for detecting and determining the position of underwater objects (e.g., sunken ships, schools of fish), and for determining the depth of the water under a ship.

Sonic energy – The energy associated with the propagation of sound waves.

Sonic wave – Same as sound wave.

Sorting coefficient – A coefficient used in describing the distribution of grain sizes in a sample of unconsolidated material. It is defined as

$$S_0 = \sqrt{Q_1/Q_3}$$

where Q_1 is the diameter (in millimeters) which has 75% of the cumulative size frequency (by weight) distribution smaller than itself and 25% larger than itself, and Q_3 is that diameter having 25% smaller and 75% larger than itself.

Sound – 1. A mechanical disturbance transmitted from one point in a material medium to another, which can produce an auditory sensation. The advancing disturbance is called a sound wave; its speed of propagation, the speed of sound, is governed by the nature of the propagating medium. The complete description of any sound, from the physical viewpoint, requires specification of three quantities: the pitch (frequency); the loudness (sound intensity); and

quality (timbre, waveform). As in all other forms of propagation, sound waves may suffer reflection, refraction, scattering, and diffraction. See also sound absorption, threshold of audibility, decibel, ultrasonic, thunder, atmospheric acoustics.

2. From a psychophysical point of view, an auditory sensation resulting from the action of a sound wave upon the ear and its associated receptors.

Sound (verb) – To measure the depth of the water.

Sound wave – (Also called acoustic wave, sonic wave.) A mechanical disturbance advancing with finite velocity through an elastic medium and consisting of longitudinal displacements of the ultimate particles of the medium, i.e., consisting of compressional and rarefactional displacements parallel to the direction of advance of the disturbance; a longitudinal wave. Sound waves are small-amplitude adiabatic oscillations. The wave equation governing the motion of sound waves has the form

$$\nabla^2\phi = \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2}$$

where ∇^2 is the Laplace operator, ϕ the velocity potential, t the time, and c the speed of sound, the density variations and velocities being taken small. As so defined, this includes waves outside of the frequency limits of human hearing, which limits customarily defined sound.

Gases, liquids, and solids transmit sound waves, and the propagation velocity is characteristic of the nature and physical state of each of these media. In those cases where a steadily vibrating sound generator acts as a source of waves, one may speak of a uniform wave train; but in other cases (explosions, lightning discharges) a violent initial disturbance sends out a principal wave, followed by waves of more or less rapidly diminishing amplitude.

Sounding – The determination of the depth of the ocean. It can be done by lowering a line to the bottom or, electronically, by noting how long sound takes to travel to the bottom and return. It is an old nautical term for the measurement of the depth of a body of water.

Sounding datum – The plane to which soundings are referred.

See also chart datum.

Sounding line – A line, wire, or cord used in sounding. It is weighted at one end with a plummet (sounding lead). Also leadline.

Source – In hydrodynamics, a point, line, or area at which mass or energy is added to a system, either instantaneously or continuously. Conversely, a sink is a point where mass or energy is removed from the system.

An incompressible fluid will possess sources or sinks of mass only at points where the divergence of its velocity vector is non-zero; a source is associated with positive divergence and a sink with negative divergence (convergence). The fluid is usually assured to poss outward from a source or inward to a sink equally in all directions along radial lines. The strength of a source, e.g., the rate of mass flow of fluid unit density across a curve enclosing the source, is given by

$$Q = 2\pi r v_r$$

where r is the distance from the source and v_r the radial speed.

South American Plate - One of the larger elements of the Earth's crust. It is approximately continuous with the western and Caribbean coastlines of the South American continent. On the Pacific side it abuts the overriding Nazca Plate. On the Atlantic side, the South American Plate spreads westward from the Mid-Atlantic Ridge.

South China Sea - Part of the warm, complex ocean area at the joining of the Indian and Pacific oceans, bordered by the mainland of Asia, the Indonesian islands, Japan, and the Philippines. The area is pinched into a large gulf by Thailand. The South China Sea is a deep basin (over 5,000 m, or 15,000 feet), with the circulation of its bottom water impeded by the Bashi Sill between Taiwan and Luzon and the Karimata Sill between the China and Java seas and the Malacca Strait, the connection to the Indian Ocean. The sea is rich in sediment brought down by the Red and Mekong Rivers. The shoreline and nearshore undersea landforms of both of these exhibit the

typical structures of drowned river valleys. The major climatic feature of the South China Sea is the monsoon.

Southeast Indian Rise - A part of the mid-ocean ridge system which divides the Australian from the Antarctic Plate.

Spectral function – (Or spectrum.) The Fourier representation of a given function: that is, the Fourier transform if the given function is aperiodic; or the set of coefficients of the Fourier series if the given function is periodic. The existence of the spectral function depends on the mathematical behavior of the given function. If it exists, the spectral function will in general be a complex function, having both amplitude and phase.

See also continuous spectrum, discrete spectrum.

Spectral region – Any part of the electromagnetic spectrum that is indicated by limiting wavelengths(generally synonymous with band).

Spectrum – Amplitude and phase response as a function of frequency for the components of a wave-train.

Speed – The act or state of moving swiftly. Motion. Velocity.

Speed of sound – (Or velocity of sound.) The speed with which a sound wave advances through a medium.

The speed of sound varies widely from one medium to another and depends upon the physical state of any given medium, but this is not strongly dependent upon the frequency of the sound wave. Only in the case of ultrasonic waves does one have to take account of dispersion effects, and even then this is important only in gases. For all media, the speed of sound V is given by

$$V = \sqrt{K/\rho}$$

where K is the modulus of elasticity of the medium (for fluids, the bulk modulus) and ρ is its density. Newton, mistakenly regarding the passage of a sound wave as an isothermal process, concluded that K for fluids must be simply the pressure itself. Laplace in 1816, recognizing that the rapidity with which sonic rarefactions and compressions follow each other implied adiabaticity, showed that the effective bulk modulus K is the product of pressure times the ratio γ of the specific heat at constant pressure to that at constant volume of the medium in question. In the case of a perfect-gas medium, substitution from the equation of state gives, in all,

$$V = \sqrt{\frac{\gamma p}{\pi}} = \sqrt{\gamma R T}$$

where p is the pressure, R is the gas constant for one gram of the gas in question, and T is its absolute temperature. In air at 0°C, V is 331.4 m/sec or 1087.8 ft/sec; in water at 13°C, v is 1441 m/sec; in steel at 0°C, V is about 5000 m/sec.

See Laplacian speed of sound, Newtonian speed of sound.

Spherical coordinates – (Also called polar coordinates in space, geographical coordinates.) A system of curvilinear coordinates in which the position of a point in space is designated by its distance r from the origin or pole, called the radius vector, the angle ϕ between the radius vector and a vertically-directed polar axis called the cone angle or colatitude, and the angle θ between the plane of ϕ and a fixed meridian plane through the polar axis, called the polar angle or longitude. A constant- amplitude radius vector r confines a point to a sphere of radius r about the pole. The angles ϕ and θ serve to determine the position of the point on the sphere.

The relations between the spherical coordinates and the rectangular Cartesian coordinates (x, y, z) are: $x = r \cos \theta \sin \phi$; $y = r \sin \theta \sin \phi$; $z = r \cos \phi$.

Spherical harmonics – In analogy to harmonic functions in the plane: the solutions of the Laplace equation in spherical coordinates. Spherical surface harmonics are special sets taken over the surface of a sphere, therefore, the harmonic components are restricted to an integral number of waves over the sphere. Spherical harmonics have been applied in the study of the large-scale oscillations of the atmosphere.

Spherical symmetry – See radial symmetry.

Spherical wave – A wave whose phase-front surfaces are spheres. Such waves propagate from a point source.

Spilling breaker – See breaker.

Spit – The extension of a bar or a beach as the result of long-shore currents.

Splash – To move into a liquid and cause it to spatter.

Spontaneous – When water-saturated sediments are subjected to a sudden shock, shear, or increase in pore water pressure, the internal grain-to-grain contacts within the sediment may change. It this happens, the entire sediment mass may move or flow, similar to an avalanche.

Spread – Usually referring to the layout of recording instruments such as seismomenters, geophones, tide gauges or any other instruments where appropriate geographical separation and positioning are important for obtaining optimum signals from an environmental property which is being monitored.

Spreading – When reference is made to tsunami waves, it is the scattering and dispersion of the wave energy over a wider geographical area as the waves propagate away from the source region. The reason for this geographical spreading and reduction of wave energy with distance traveled, is the sphericity of the earth. The tsunami energy will begin converging again at a distance of 90 degrees from the source. Of course tsunami waves propagating across a large ocean undergo other changes in energy configuration due to refraction, p[rimarily, but geographical spreading is very important also, depending on the tsunami source region, the orientation of the tsunami generating area, the source dimensions, and the geometry of the system.

Spring tide – Tide near the time of syzygy, when ranges between high water and low water are greatest.

Compare neap tide, tropic tide, equatorial tide.

Stability – 1. Same as static stability.

2. A property of a steady state or a disturbance thereof which is not characterized by hydrodynamic instability. Without further specification, it is thus ambiguous whether a stable disturbance is neutral or damped.

3. A property of a finite difference equation or a system of equations, not characterized by computational instability.

Stability (ocean) – As used here, a measure of the density stratification of the ocean waters and the resistance of the ocean waters to vertical mixing.

Stable motion – A motion in which small disturbances do not grow.

Stable wave – 1. Generally, any wave that is not an unstable wave.

2. See neutral wave.

Stand – The condition of high water or low water when there is no change in the height of the tide. Compare slack water.

Stand of tide – An interval at high or low water when there is no sensible change in the height of the tide. The water level is stationary at high and low water for only an instant, but the change in level near these times is so slow that it is not usually perceptible.

See slack tide.

Standard atmosphere – 1. A hypothetical vertical distribution of atmospheric temperature, pressure, and density which, by international agreement, is taken to be representative of the atmosphere for purposes of pressure altimeter calibrations, aircraft performance calculations, aircraft and missile design, ballistic tables, etc. The air is assumed to obey the perfect gas law and the hydrostatic equation, which, taken together, relate temperature, pressure, and density variations in the vertical. It is further assumed that the air contains no water vapor, and that the acceleration of gravity does not change with height. This last assumption is tantamount to adopting a particular unit of geopotential height in place of a unit of geometric height for representing the measure of vertical displacement, for the two units are numerically equivalent in both the metric and English systems, as defined in connection with the standard atmosphere.

The current standard atmosphere is that which was adopted on November 7, 1952, by the International Civil Aeronautical Organization (ICAO), supplanting the NACA Standard Atmosphere (or U.S. Standard Atmosphere) prepared in 1925. The parametric assumptions and physical constants used in preparing the ICAO Standard Atmosphere are as follows:

(a) Zero pressure altitude corresponds to that pressure which will support a column of mercury 760 mm high. This pressure is taken to be 1.013250×10^6 dynes/cm^2, or 1013.250 mb (and is known as one standard atmosphere or one atmosphere).

(b) The gas constant for dry air is 2.8704×10^6 erg/gm/°K.

(c) The ice point at one standard atmosphere pressure is 273.16°K.

(d) The acceleration of gravity is 980.665 cm/sec^2.

(e) The temperature at zero pressure altitude is 15°C or 288.16°K.

(f) The density at zero pressure altitude is .0012250 gm/cm^3.

(g) The lapse rate of temperature in the troposphere is 6.5°C/km.

(h) The pressure altitude of the tropopause is 11 km.

(i) The temperature at the tropopause is -56.5°C.

2. A standard unit of atmospheric pressure, defined as that pressure exerted by a 760 mm column of mercury at standard gravity (980.665 cm/sec^2) at temperature 0°C.

one standard atmosphere = 760 mm Hg
= 29.9213 in Hg
= 1013.250 mb

Standard deviation – The positive square root σ of the variance σ^2.

Standard error – The standard deviation (positive square-root of the variance) of the errors associated with physical measurements of an unknown quantity, or statistical estimates of an unknown parameter or of a random variable. See root-mean-square error, regression.

Standard error of estimate – Same as root-mean-square error.

Standing wave – A wave whose nodes and antinotes remain fixed.

STAR - South Pacific Tectonics and Resources.

State of the sea – (Or sea state; also called sea.) A description of the properties of the wind-generated waves on the surface of the sea.

Static – In general, any radio interference detectable as noise in the audio state. At broadcast frequencies, most naturally- induced static is caused by non-periodic electromagnetic radiation emitted by lightning discharges acting as huge antennas (see atmospherics). Aircraft radio communication is often hindered by precipitation static due to discharges from the aircraft surfaces following autogenous electrification.

Static pressure – In engineering fluid mechanics, the pressure in a homogeneous incompressible fluid in steady flow along a level streamline at points other than the stagnation point. Thus if p is the static pressure, Bernouli's equation gives

$$p + \tfrac{1}{2}\rho V^2 = p_1$$

where ρ is the density of the fluid, V the speed, and p_1 the pressure at the stagnation point, called the total pressure. The kinetic energy per unit volume $\frac{1}{2}\rho V^2$ is also called the dynamic pressure. The static pressure is that measured by a barometer moving with the fluid.

Station – In oceanography, the geographic location at which any set of oceanographic observations was taken; also, the observations recorded at the location. The appropriate verbal phrase is "occupy a station."

See also serial station; compare ocean station, ocean weather station.

Stationary motion – Same as steady state.

Stationary time series – A time series having stable statistical properties in the following sense. Let x(t) denote the value of the variable at time t. Hold t fixed and imagine an indefinite series of repetitions of essentially the same generating

process, giving rise to a population (ensemble) of values of x(t). For a stationary time series, the ensemble probability distribution of x(t) is independent of t. When the probability distribution changes very gradually with t, the time series is called quasi-stationary.

Stationary wave – A type of wave where the wave form does not move forward by the surface moves up and down. At certain fixed points, called nodes, the water surface will remain stationary.

Statistic – Generally, a number describing some characteristic of a population or samples therefrom. Specifically, an estimate of a statistical parameter computed from a sample.

Statistical – Pertaining to or characterizing random phenomena, or referring to statistics.

Statistical dependence – See statistical independence.

Statistical independence – The relationship between two or more random variables when their joint probability density function can be expressed as the product of the individual functions,

$$F(x,y) = H(x)G(y) ;$$

and the ranges of variation of x and y are independent. Otherwise, variates are statistically dependent.

Statistical parameter – See parameter (2).

Statistical significance test – See significance test.

Statistics – The systematic analysis of random phenomena. Primarily, it is the application of probability theory to specific data, but includes special techniques and principles not subsumed under probability. Statistics is concerned with collecting and processing data, summarizing information, estimating descriptive constants (parameters), discovering empirical laws, testing hypotheses, and designing experiments in such a way that valid inferences can be drawn from empirical evidence.

Steady motion – Same as steady state.

Steady state – (Also called steady motion, stationary motion.) A fluid motion in which the velocities at every point of the field are independent of time; streamlines and trajectories are identical. Sometimes it is further assumed that all other properties of the fluid are identical. Sometimes it is further assumed that all other properties of the fluid (pressure, density;, etc.) are also independent of time. All local derivatives in the fundamental equations then vanish.

A steady-state solution to a theoretical problem suggests two further questions: how the steady state came to exist (the initial-value problem); and whether it will persist (the instability problem).

Steepness – See wave steepness.

Step function – (Or stepped function.) A function that has different constant values over adjacent subintervals; thus it has discontinuities at the ends of each interval. The distribution function of a discrete variate and a histogram have this shape.

Stereographic projection – See conformal map.

Stick-slip – A jerky, sliding type of motion associated with fault movement in laboratory experiments. It may be a mechanism in shallow-focus earthquakes.

Stochastic – Conjectural; in statistical analysis, a synonym for random.

Stockpile – Sand piled on a beach foreshore to nourish downdrift beaches by natural littoral currents or forces.

See feeder beach.

Stokesian wave – Same as deep-water wave.

Stokes's theorem – The statement that if s is a surface in three dimensions having a closed curve c as its boundary, then the circulation of a vector V around c is equal to the flux of the vorticity (curl of V) through s, under certain mathematical conditions on these fields and boundaries.

$$\iint_s \mathrm{n} \cdot (\mathrm{t} \times \mathrm{V}) ds = \oint_c \mathrm{V} \cdot d\mathrm{r} ,$$

where n is the unit vector normal to s on that side of s which is arbitrarily taken as the positive side. The positive direction along c is defined as the direction along which an observer, traveling on the positive side of s, would proceed while

keeping the enclosed area to this left. dr is a vector line element of c.

For two dimensional flow in the x, y plane Stokes's theorem becomes

$$\iint_s \zeta ds = \oint \mathrm{V} \cdot dr ,$$

where ζ is the vertical component of the vorticity. This states that the circulation around a given curve per unit area enclosed by the curve is equal to the average vorticity within the area.

Stone, derrick – Stone heavy enough to require handling individual pieces by mechanical means, generally 1 ton and up.

Storm - A meteorological disturbance involving a change in atmospheric pressure, high winds, high tides, and precipitation.

Storm surge – An abnormal sudden rise of sea level along an open coast during a storm, caused primarily by onshore-wind stresses, or less frequently by atmospheric pressure reduction, resulting in water piled up against the coast.

Storm tide – (Also called storm surge, storm wave, tidal wave.) 1. An abnormal rise of the sea along a shore as the result, primarily, of the winds of a storm. Because storm surge frequently is the most dangerous aspect of a coastal storm, considerable research is currently underway to ascertain its nature and predictability.

Compare forerunner, hurricane wave, tsunami; see also tidal wave.

2. The height of a storm surge (or hurricane wave) above the astronomically predicted level of the sea.

Storm wave – 1. A wind-generated sea-surface wave of great height.

2. Same as storm surge.

See also hurricane wave.

Strait – A relatively narrow waterway between two larger bodies of water.

See also sound.

Stratification – In hydrodynamics, the state of a stratified fluid.

Stratified fluid – A fluid having density variation along the axis of gravity, usually implying upward decrease of density, i.e., a stratification characterized by static stability.

Stratum – A layer of sediment or sedimentary rock. The term is more frequently used in its plural form, strata.

Streamline flow – Same as laminar flow.

Stress – Generally, a surface force, measured per unit area. In a solid, the force per unit area that acts on or within a body. Given a vertical column of material, along any imaginary horizontal plane within the column, the material above the plane, because of its weight, exerts a force on the material below the plane. Similarly, the part of the column below the plane exerts an equal upward force; the mutual action-reaction along a surface then constitutes a stress.

Stress difference - The algebraic difference between the greatest and least principal stresses.

Stress ellipsoid - A geometric representation of a state of stress as defined by three mutually perpendicular principal stresses and their magnitudes.

Structural geology - The branch of geology concerned with the description, spatial representation, and analysis of structural features ranging from microscopic to moderate. As such, it includes studies of the forces that produce rock deformation, and of the origin and distribution of these forces. Structural features may be primary, i.e., those acquired in the genesis of a rock mass (e.g., horizontal layering), or secondary, i.e., resulting from later deformation of primary structures (e.g., folding or fracturing). Cf: tectonics.

Structural relief - The difference in elevation between the lowest and highest points of a bed or stratigraphic horizon in a specified region.

Structure - 1. The altitude and positions of rock masses of an area; the sum total of structural features resulting from processes such as folding and faulting. 2. In geomorphology, a general term for underlying rocks of a landscape.

Stress tensor – The complete set of stress components in a medium, which are written as a tensor τ_{ij}. It has nine components, one for each of the coordinate faces of an imaginary fluid element upon which the stress acts (j=x,y,z) and for each direction in which the stress is directed (i=x,y,z).

By definition, an inviscid fluid is one in which the six tangential stresses ($i \neq j$) are zero, and the three normal stresses (= j) are equal to the negative of the pressure.

Strike - 1 - The direction taken by a structural surface such as a fault or bedding plane as it intersects the horizontal; it is the compass direction of the horizontal line in an inclined plane. 2. To be aligned in a direction at right angles to the direction of dip.

Strike fault - A fault that strikes essentially parallel to the strike of the adjacent rocks. Cf: dip fault; dip joint.

Strike joint - A joint that strikes nearly parallel to the strike of the bedding of a sedimentary rock, schistosity of a schist, or gneissic structure of a gneiss. Cf: dip joint.

Strike separation - The distance between two previously adjacent beds on either side of a fault surface, measured parallel to the strike of the fault. Cf: dip separation.

Strike shift - Relative displacement of rock units parallel to the strike of a fault, but beyond the fault zone itself; partial syn. of strike slip.

Strike-shift fault - Strike-slip fault.

Strike slip - The component of movement parallel with the strike of a fault. Cf: dip slip; strike separation; strike shift.

Strike-slip fault - A fault along which the movement has been predominantly horizontal, parallel to the strike. The movement of a strike-slip fault is described by looking straight across the fault and observing in which direction the block on the opposite side has moved.

Strombolian-type eruption - See volcanic eruption, types of.

Structural - Of or relating to rock deformation or to features that result from it.

Structural feature - A feature produced by the displacement or deformation of rocks, such as a fault or fold.

Student's "t" test – (Also called t-test.) A significance test applicable to a sample mean of a sample estimate of a regression coefficient or a correlation coefficient (the latter only when the hypothetical value is zero). It is used to test an assumed value of the corresponding parameter. It is also applicable to the comparison of two (but not more than two) sample means or two regression coefficients, but not two correlation coefficients. The t-test has different formulas for different uses.

Subaqueous – Said of conditions and processes, or of features and deposits, that exist or are situated in or under water, especially fresh water, as in a lake or stream.

Subduction – The process of one crustal block descending beneath another, by folding or faulting or both. The concept was originally used by Alpine geologists.

Subduction zone – An extended region along which one crustal block descends relative to another, and along which deep oceanic trenches occur. Subduction zones are one of three kinds of boundaries (see mid-oceanic ridges; transform faults) of crust plates. During the tectonic process of two plates moving toward each other, one dips downward and is forced under the edge of the other, penetrating the earth's mantle at a rather sharp angle. The bend in the submerging plate creates an ocean trench. The downward action of this plate is responsible for deep-focus earthquake activity, and the resultant friction produces volcanoes and intrusions on the far side of the trench. Shallow focus earthquakes along subduction zones have been responsible for the generation of most destructive tsunamis in history. See also: plate tectonics.

Submarine canyon – A physiographic channel totally submerged under the sea and cut by submarine currents.

Submarine landslide – Underwater movement, under gravity, of massesbof sediment and rock material as a result of a variety of processes.

Submarine perturbations – Undersea disturbances, irregularities, and abnormal changes.

Submarine slope – The underwater inclination of the topography.

Submarine slump – See slump. Same process except occuring under the water along a submarine slope.

Submarine volcano – A volcano existing, acting, or growing under the sea.

Submarine eruption - An eruption from a volcano located on the oceanic crust of the earth. Such eruption can be extremely explosive than its continental counterpart,as a result of the contact between volcanic magma and sea water.

Submarine fans - Fan- or cone-shaped underwater features formed by the deposition of terrigenous sediments, usually found offshore from most large rivers, and extending downward on the continental shelf and slope to the abyssal plains. Such fans are accumulate by the flushing action of turbidity currents through submarine canyons.

Submergence - Inundation of land areas, either by a gradual net rise in sea level or by subsidence of the land due to isostatic changes. Also, earthquakes can cause sudden submergence of land areas.

Sub-oceanic changes – Geomorphic changes on the ocean floor resulting from earthquakes, volcanic eruptions, depositions by turbidity currents, or by slow occurring processes such as ocean floor spreading.

Subsidence – 1. Sinking or falling to the bottom, especially to flatten out so as to form a depression. 2. The dropping of dry land into the sea. This can have several causes. One might be a rise in sea level, another the collapse of an isolated guyot, or coral island. The latter may be the result of volcanic activity. If a volcanic eruption empties an underwater volcanic chamber of liquid lava, the resulting cavity may not be sufficiently strong to withstand the pressure of the surounding water mass. Thus the roof of the chamber may collapse resulting in subsidence. Subsidence may be caused also by an earthquake in a region of subduction, where one side of the crust may go up while another one may go down.

Sulawesi Sea - Also known as the Celebes Sea; a body of water that separates Sulawesi (Celebes) from the Philippine islands. It is one of several ocean deeps with known volcanic activity. The flat bottom, which has a mean depth of about 4,000 m (13,000 feet), has deep, cold, Pacific bottom water entering the area by spilling over the sill near Mindanao.

Sunda Shelf - The largest shelf area in the ocean, almost 2 million sq. km (or 0.6 million square miles) in size. It underlies part of the Java Sea. The entire area, including Malaya, Sumatra, Java, and Kalimantan (Borneo) is a vast, drowned river system. The North Sunda River flowed northeast into the South China Sea from headlands in Malaya and Kalimantan. The South Sunda River also moved from Sumatra east into what is now the Makassar Strait between Borneo and Sulawesi (Celebes). The Sunda Strait, which separates Sumatra from Java, is very shallow and probably the result of very recent seismic activity. Krakatoa, in the Sunda Strait, is the most important vocano in the area and the source of the famous 1883 tsunami, the largest tsunami of volcanic origin, in recent times.

Supersonic – At a speed greater than the local speed of sound. Current convention is to apply this to speeds in the range Mac 1 to Mach 5.

Superstructure - The upper structural layer of an orogenic belt, which is subjected to relative shallow or near surface deformation processes, as distinct from an underlying and more profoundly deformed infrastructure.

Surf – The sea-surface wave activity between the outermost line of breakers and the shore.

Surf beat – Irregular oscillations of the nearshore water level, with periods of the order of several minutes.

Surf zone – The area between the outermost breaker and the limit of wave uprush. (See Figures A-2 and A-5.)

Surface of no strain - A surface along which the original configur tion remains unchanged after deformation of the body in which the surface is contained.

Surface wave – Elastic waves that propagate along the surface of the Earth. Rayleigh waves have a retrograde elliptical particle motion; love waves are horizontally polarized shear waves.

Surf beat – Oscillations of water level near shore, associated with groups of high breakers.

See beating.

Surge – A swelling, rolling, or sweeping forward like that of a wave or series of waves (2b) A large wave or billow.

Surging breaker – See breaker.

Surging front – In Oceanography the front of a breaking wave. As it relates to tsunami, the bore often formed by a tsunami traveling in a bay or up a river

Suspended load – 1. The material moving in suspension in a fluid, being kept up by the upward components of the turbulent currents or by colloidal suspension.

2.The material collected in or computed from samples collected with a suspended load sampler. (A suspended load sampler is a sampler which attempts to secure a sample of the water with its sediment load without separating the sediment from the water.)

Where it is necessary to distinguish between the two meanings given above, the first one may be called the "true suspended load."

Swale – The depression between two beach ridges.

Swash – The rush of water up onto the beach face following the breaking of a wave. Also uprush, runup. (See Figure A-2.)

Swash channel – 1. On the open shore, a channel cut by flowing water in its return to the parent body (e.g., a rip channel).

2. A secondary channel passing through or shoreward of an inlet or river bar. (See Figure A-9.)

Swash mark – The thin wavy line of fine sand, mica scales, bits of seaweed, etc., left by the uprush when it recedes from its upward limit of movement on the beach face.

Swell – Waves that have traveled away from their generating area. These waves have a more regular pattern than sea waves.

Syncline – A troughlike fold, the core of which contains the stratigraphically younger rocks; it is concave upward.

Synoptic – In general, pertaining to or affording an overall view.

Systematic error – That part of the inaccuracy of a measuring instrument, or statistical estimate of a parameter, which is due to a single cause or small number of causes and is usually of the same sign, and hence, in principle, is correctable. In the absence of random errors, the true value is equal to the instrumental reading or statistical estimate minus the systematic error.

– T –

T phase – A seismic phase with a period of 1 sec or less, which travels through the ocean with the speed of sound in water. It is occasionally identified on the records of those earthquakes, in which a large part of the path from epicenter to station is across the deep ocean.

T wave – Earthquake T waves, in common with tsunamis, are generated by movements of the ocean floor. In the case of T waves the movement is oscillatory, while for the tsunami it more closely resembles a moving-step function. Although the oscillatory waves are not likely to indicate the magnitude and direction of permanent displacement of the ocean floor, they may find application in delimiting the lateral extent of the affected region. From the standpoint of tsunami generation this dimension is probably more diagnostic than an estimate of earthquake magnitude.

Also,earthquake T waves may find application to the tsunami warning problem by being interpreted in terms of the length or rupture. This dimension is a more direct indication of the

potential of an earthquake to generate a tsunami than is earthquake magnitude. Earthquake swarms within a confined region may be recognized as such by the repetition of their signature. The length of rupture of a major earthquake can be estimated from the duration of the high-level portion of the T phase at two or more stations. It is speculated that equivalent information may be obtained from one recording station by azimuthally tracking the incoming T waves.

Tabular iceberg – (Also called table iceberg; formerly called barrier iceberg.) An iceberg which has broken off from an ice shelf.

Newly formed tabular icebergs have nearly vertical sides and flat tops. In the Antarctic, they may be tens of miles wide, up to 100 miles long, and as much as 1000 feet thick with about 100 feet exposed above the sea surface. In the Arctic, the large icebergs of this type are called ice islands, but they are considerably smaller than the largest of the antarctic variety.

Tangential stresses – The components of the stress tensor which are tangential to the faces of the fluid element.

tau-value – The time rate of change of D-values at a fixed point defined by the relation,

$$\tau = \frac{\Delta_t D}{\Delta t}$$

where $\Delta\tau$ is the change in time and $\Delta_t D$ is the change in D-value during this time interval. Tau values are expressed in terms of feet per hour. Tau-values lines are drawn on 4-D charts and comprise the time dimension of these charts.

Taylor effect – A phenomenon investigated experimentally and theoretically by G. I. Taylor in which the relative motion of a homogeneous rotating liquid tends to be the same in all planes perpendicular to the axis of rotation. For example, if a sphere is introduced as an obstruction, the fluid flows around it as if it were a cylinder extending the entire depth of the fluid parallel to the axis of the system. It is due essentially to the presence of highly geostrophic, homogeneous conditions so that the thermal wind is zero. It occurs at very low values of the Rossby number.

Taylor number – A non-dimensional number arising in problems of a rotating viscous fluid. It may be written

$$T = f^2h^4/\nu^2$$

where f is the coriolis parameter (or, for a cylindrical system, twice the rate of rotation of the system), h representative of the depth of the fluid, and ν the kinematic viscosity. The square root of the Taylor number is a rotating Reynolds number, and the fourth root is proportional to the ratio of the depth h to the depth of the Ekman layer.

Taylor series – See Taylor's theorem (1).

Taylor's theorem – 1. If all the derivatives of a function $f(x)$ are continuous in the vicinity of $x = a$, then $f(x)$ can be expressed in an infinite series (the Taylor series):

$$f(x) = f(a) + f'(x)\,(x-a) + \frac{1}{2!}f''(x)\,(x-a)^2 + \ldots + \frac{1}{n!}f^{(n)}(a)\,(x-a)^n + \cdots .$$

The case a=0 is called a Maclaurin series.

2. The theorem of G.I. Taylor in the statistical theory of atmospheric turbulence:

$$\overline{x^2} = 2\overline{u^2}\int_0^T\int_0^t R(\xi)\,d\xi dt$$

where x is the distance traveled by a particle in the time interval T, u is the fluctuation or eddy velocity of the particle, and $R(\xi)$ is the Lagrangian correlation coefficient between the particle's velocity at time t and $t + \xi$.

Tectogene – A large downbuckle of the crust in an orogenic belt.

Tectonics – 1. Study of the large scale structural features of the Earth and their causes.

2. Pertaining to the structure and deformation of the Earth's crust.

Telemeter – The measuring, transmitting, receiving, and indicating apparatus for obtaining the value of a quantity at a distance.

Telemetry – The study of the measurement of quantities at a distance.

Tele-tsunami – A tsunamic originating at a distance of more than one wave length from the point of observation.

Telemetry – A method, usually electronic, of measuring something and then transmitting the measurement to a receiving station.

Teleseism – An earthquake that is distant from the recording station.

Tendency – The local rate of change of a vector or scalar quantity with time at a given point in space. Thus, in symbols, $\partial p/\partial t$ is the pressure tendency, $\partial \zeta/\partial t$ the vorticity tendency, etc. Because of the difficulty of measuring instantaneous variations in the atmosphere, variations are usually obtained from the differences in magnitudes over a finite period of time; and the definition of tendency is frequently broadened to include the local time variations so obtained.

Tension - A force that tends to stretch a body (e.g. a string, rod, wire, etc.).

Tensor – A mathematical entity that is the general equivalent in any n-dimensional coordinate system, of a vector in two or three-dimensional coordinates. Tensors are used to describe how all the components of a quantity behave under certain transformations, just as a vector can describe a translation from one point to another in a plane or in space. An array of functions which obeys certain laws of transformation. The motivation for the use of tensors in some branches of physics is that they are invariants, not depending on the particular coordinate system employed. See also vector.

Tera - Symbol: T A prefix denoting 1012. For example, 1 terawatt (TW) = 1012 watts (W).

Terminal - A point at which a user can communicate directly with a computer both for the input and output of information. It is situated outside the computer system, often at some distance from it, and is linked to it by electric cable, telephone, or some other transmission channel. A keyboard, similar to that on a typewriter, is used to feed information to the computer. The output can either be printed out or can be displayed on a screen, as with a visual display unit. An interactive terminal is one connected to a computer, which gives an almost immediate response to an inquiry from the user. An intelligent terminal can store information and perform simple operations on it without the assistance of the computer's central processor. See also input/output, visual display unit.

Terminal effects – The behavior and effects of a tsunami just prior and upon striking a coastline.

Terrace – A horizontal or nearly horizontal natural or artificial topographic feature interrupting a steeper slope, sometimes occurring in a series.

Thalweg – In hydraulics, the line joining the deepest points of an inlet or stream channel.

Theorem - The conclusion which has been proved in the course of an argument upon the basis of certain given assumptions. A theorem must be a result of some general importance.

Theorem of parrallel axes - If Io is the moment of the inertia of an object about an axis, the moment of inertia I about a parallel axis is given by:

$$I = Io\ m\ d$$

where m is the mass of the object and d is the separation of the axes.

Three-dimensional - Having length, breadth, and depth. A three-dimensional figure (solid) can be described in a coordinate system using three variables, for example, three-dimensional Cartesian coordinates with an x-axis, y-axis, and a z-axis. Compare two-dimensional.

Three-dimensional model – Models of or relating to three dimensions; models giving the illusion of depth or varying distances - usually of an image or a pictorial representation. Modern computers with good graphics can simulate very realistically the three-dimensional results of calculations by depicting them pictorially, and in a continuous fashion, by acceleration or slow down, as needed, of the time scale of events.

Threshold value – The amount or extent of a specified measurement of space, time, or quantity of a boundary or a level point which something is true or will take place and below which it is not or will not. Also it is helpful to the

decision-making process for operational purposes to set thrshold values for certain parameters being measured before acting. For example a threshold value of 6.5 on the Richter eartqhake magnitude is set on the seismographs of the Pacific Tsunami Warning Center and an alarm is sounded. Only earthquakes with that threshold value or higher are investigated, as historically only earthquakes exceeding this magnitude threshold value are known to have produced tsunamis of any significance.

Thrust - A force tending to compress a body (e.g. a rod or bar) in one direction. Thrust acts in the opposite direction to tension.

Thrust fault – 1. A fault in which the block above the fault plane moves upward relative to the block below

2. A fault with a depth of 45 or less in which the upper block appears to have moved upward relative to the lower block. Horizontal compression rather that vertical displacement is its characteristic feature

Tidal bore – A large wave of tidal origin that will travel up some rivers and estuaries

Tidal component – Same as partial tide.

Tidal constituent – Same as partial tide.

Tidal current – Current resulting from the advance and retreat of water from a restricted body of water as the result of tidal forces.

Tidal datum – See chart datum and datum plane.

Tidal day – Same as lunar day.

Tidal disturbance – An interference or change caused by the astronomical tide.

Tidal excursion – The net horizontal distance over which a water particle moves during one tidal cycle of flood and ebb. The distances traversed during ebb and flood are rarely equal in nature, since there is usually a layered circulation in an estuary, with a net surface flow in one direction compensated by an opposite flow at depth.

Tidal flats – Marshy or muddy land areas which are covered and uncovered by the rise and fall of the tide.

Tidal flow –Flow in the form of a tidal current resulting from the advance and retreat of water from a restricted body of water as the result of astronomical tidal forces.

Tidal inlet – 1. A natural inlet maintained by tidal flow.

2. Loosely, any inlet in which the tide ebbs and flows. Also tidal outlet.

Tidal period – The interval of time between two consecutive like phases of the tide.

Tidal pool – A pool of water remaining on a beach or reef after recession of the tide.

Tidal prism – The volume of water that moves in or out of a harbor or other basin during each tidal cycle. It is usually computed as the product of the tidal range and the area of the basin at mid-tide level..

Tidal range – (Or tide range.) The difference in height between consecutive high water and low water; twice the tide amplitude.

Tidal rip – See rip.

Tidal rise – The height of tide as referred to the datum of a chart.

Tidal stream – Same as tidal current.

Tidal wave – 1. The wave motion of the tides.

2. In popular usage, any unusually high (and therefore destructive) water level along a shore. It usually refers to either a storm surge or tsunami.

Tide – The rhythmic, alternate rise and fall of the surface (or water level) of the ocean, and of bodies of water connected with the ocean such as estuaries and gulfs, occurring twice a day over most of the Earth, and resulting from the gravitational attraction of the moon (and, in lesser degrees, of the sun) acting unequally on different parts of the rotating Earth.

Tide amplitude – One-half of the difference in height between consecutive high water and low water; hence, half of the tidal range.

Tide, daily retardation of – The amount of time by which corresponding tides grow later day by day (about 50 minutes).

Tide, diurnal – A tide with one high water and one low water in a tidal day. (See Figure A-10.)

Tide, ebb – See ebb tide.

Tide, flood – See flood tide.

Tide gauge – A device for measuring the height (rise and fall) of the tide especially an instrument automatically making a continuous graphic record of tide height versus time.

Tide-well – The part of a tidal gauge which consists of a tube with a small orifice on the bottom through which water enters as the tide changes and which filters short term water level changes caused by wave action. Within the tide-well a float oscillates freely and is connected to a instrument which records in digital or analog form sea level variations with time.

Tide, mixed – See mixed tide.

Tide, neap – See neap tide.

Tide-producing force – The slight local difference between the gravitational attraction of two astronomical bodies and the centrifugal force that holds them apart. These forces are exactly equal and opposite at the center of gravity of either of the bodies, but, since gravitational attraction is inversely proportional to the square of the distance, it varies from point to point on the surface of the bodies. Therefore, gravitational attraction predominates at the surface point nearest to the other body, while centrifugal "repulsion" predominates at the surface point farthest from the other body. Hence there are two regions where tide-producing forces are at a maximum, and normally there are two tides each lunar day and solar day.

Tide range – Same as tidal range.

Tide rip – See rip.

Tide, semidiurnal – See semidiurnal tide.

Tide, slack – See slack tide.

Tide, spring – See spring tide.

Tide stations – A place where tide observations are obtained.

Tide, storm – See storm surge.

Tide tables – Annual tabulations of daily predictions of the times and heights of high water and low water at various places. Such tables are constructed from astronomical data and from the results of harmonic analysis of previous observations at the desired point. They are compiled and issued by national hydrographic authorities, for example, the U.S. Coast and Geodetic Survey. The heights in tide tables usually are measured from chart datum rather than mean sea level.

Tide constant – (Also called lag coefficient.) Generally, the time required for an instrument to indicate a given percentage of the final reading resulting from an input signal; the relaxation time of an instrument.

Time lag – The total time between the application of a signal to an instrument and the full indication of that signal within the uncertainty of the instrument.

Time section – (Also called time cross-section.) A diagram in which one coordinate is time and the other is distance (usually height, in which case it is a vertical time-section).

Compare cross section, profile time-height section.

Time sharing - A method of operation in computer systems in which a number of jobs are apparently executed simultaneously instead of one after another (as in batch processing). This is achieved by transferring each program in turn from backing store to main store and allowing it to run for a short time. Time sharing is particularly useful for programs that are controlled by users at terminals. It allows all the users to interact with the computer apparently

simultaneously, provided there are not too many of them. Compare batch processing.

Time series – The values of a variable generated successively in time.

TOGA - Tropical Oceans and the Global Atmosphere.

Tombolo – A sand or gravel bar that connects or "ties" an island to the mainland or to another island. When larger, it may be a spit or a causeway.

Ton - A unit of mass equal to 2240 pounds. It is equivalent to 1016.05 kg.

Tonga Trench - A deep depression in the floor of the southwestern Pacific Ocean. Its average depth is almost 11,000 m (33,000 feet), and it is about 1,400 km (900 miles) long. This fairly narrow, steep-walled break in the Earth's crust lies south-southwest of Samoa. A belt of volcanic and seismic activity is west of the trench. The Tonga Trench and the Kermadec Trench, with which it is almost continuous, form a line which, together with the Great Alpine Fault of New Zealand, creates a long slip-strike fault that is analogous to the fault in the Caribbean. Tsunamis are known to originate from the Tonga trench region. See crust, Kermadec Trench, plate tectonics, Puerto Rico Trench, trench.

Tonne - (metric ton) Symbol: t A unit of mass equal to 103 kilograms.

Topography – The general configuration of a land surface or any part of the Earth's surface, including its relief and the position of its natural and man-made features. This may include forests, rivers, highways,; bridges, etc. as well as contour-lines of elevation, although the term is often used to denote elevation characteristics (particularly orgraphic features) alone.

The study or process of topographic mapping.

Topological space - A non-empty set A together with a fixed collection (T) of subsets of A satisfying:

(1) 0 T, A T;

(2) if U T and V T then U V T;

(3) if U, T, where (U) is a finite or infinite collection of sets, then U, T.

The set of subsets T is called a topology for A, and the members of T are called the open sets of the topological space. Compare metric space. See also topology.

Topologically equivalent - See topology.

Topology - A branch of geometry concerned with the general properties of shapes and space. It can be thought of as the study of properties that are not changed by continuous deformations, such as stretching or twisting. A sphere and an ellipsoid are different figures in solid (Euclidean) geometry, but in topology they are considered equivalent since one can be transformed into the other by a continuous deformation. A torus, on the other hand, is not topologically equivalent to a sphere - it would not be possible to distort a sphere into a torus without breaking or joining surfaces. A torus is thus a different type of shape to a sphere. Topology studies types of shapes and their properties. Topology uses methods of higher algebra including group theory and set theory. An important notion is that of sets of points in the neighbourhood of a given point (i.e. within a certain distance of the point). An open set is a set of points such that each point in the set has a neighbourhood containing points in the set. A topological transformation occurs when there is a one-to-one correspondence between points in one figure and points in another so that open sets in one correspond to open sets in the other. If one figure can be transformed into another by such a transformation, the sets are topologically equivalent.

Torque – A force which tends to produce a rotating motion. Torque is the vector product (**F x s**) and is a vector at 90 degrees to the plane of the force and displacement.

Torsional wave - A wave motion in which the vibrations in the medium are rotatory simple harmonic motions around the direction of energy transfer.

Total derivative – The rate of change of a function of two or more variables with reference to a parameter on which these variables are dependent.

If $z = f(x, y, t)$, $x = \Phi(t)$, and $y = \theta(t)$, the total derivative of z with reference to t, written dz/dt, is given by

$$\frac{dz}{dt} = \frac{\partial f(x, y)}{\partial x}\frac{d\phi(t)}{dt} + \frac{\partial f(x, y)}{\partial y}\frac{d\theta(t)}{dt} + \frac{\partial f}{\partial t}$$

where $\frac{\partial f(x, y)}{\partial x}$ and $\frac{\partial f(x, y)}{\partial y}$ are the partial derivatives of $f(x, y)$ with respect to x and y, respectively, $\frac{d\phi(t)}{dt}$ and $\frac{d\theta(t)}{dt}$ are the total derivatives of $\phi(t)$ and $\theta(t)$, respectively, with respect to t. For a function of one variable, the partial derivative equals the total derivative. The individual derivative is the total derivative when the parameter t represents time.

Total differential – The total differential of a function $f = f(x_1, x_2, \ldots x_n)$ of n variables is defined by the equation

$$df = \frac{\partial f}{\partial x_1}dx_1 + \frac{\partial f}{\partial x_2}dx_2 + \cdots + \frac{\partial f}{\partial x_n}$$

whether or not $x_1, x_2, \ldots,$ and x_n are independent of each other. $\frac{\partial f}{\partial x_1}$, $\frac{\partial f}{\partial x_2}$, $\cdots$, and $\frac{\partial f}{\partial x_n}$ denote the partial derivatives of f with respect to $x_1, x_2, \ldots,$ and x_n, respectively. The total differential df represents the change in f associated with simultaneous infinitesimal changes in $x_1, x_2, \ldots,$ and x_n, given by dx_1, $dx_2, \ldots,$ and dx_n,, respectively, to the order of $dx_1, dx_2, \ldots, dx_n$.

Total potential energy – See potential energy, internal energy.

Total pressure – (Also called stagnation pressure.) The sum of the static pressure and the dynamic pressure when these concepts are applicable. Since this is the pressure at the stagnation point of a streamline, it is measured by an ideal Pitot tube directed exactly upstream. The total pressure satisfies the hydrostatic equation.

Total variance – See regression.

Total vorticity – Usually, the magnitude of the vorticity vector, all components included, as opposed to the vertical (component of the) vorticity.

Training wall – A wall or jetty to direct current flow.

Trajectory – (or path.) A curve in space tracing the points successively occupied by a particle in motion. At any given instant the velocity vector of the particle is tangent to the trajectory. In steady-state flow, the trajectories and streamlines of the fluid parcels are identical. Otherwise, the curvature of the trajectory K_T is related to the curvature of the streamline K_s by Blaton's formula,

$$K_T = K_S - \frac{1}{V}\frac{\partial \Psi}{\partial t}$$

where V is the parcel speed and $\partial\psi/\partial t$ is the local change of the wind direction. The curvatures and wind change are positive for the cyclonic sense of flow.

Transducer – A device for converting energy from one form to another. Transfer – See interaction, energy transfer, conduction, mixing, exchange coefficients, transport.

Transfinite - A trnsfinite number is a cardinal or ordinal number that is not an integer.

Transfinite induction - A process by which we may reason that if some proposition is true for the first element of a well-ordered set S, and if the proposition is true for a given element it is also true for the next element, then the proposition is true for every element of S.

Transform fault – A break in the crust of the Earth. Faulting characteristic of mid- ocean ridges running perpendicular to the axis of the ridge. The line of the ridge is displaced (offset) by the fault.

Transformation – A change in structure, appearance or character, conversion, alteration or shift. In general, any function or mapping that changes one quantity into another.

Transformation of Coordinates - 1. Changing the position of the reference axis in a coordinate system by translation, rotation, or both, usually to simplify the equation of a curve. 2. Changing

the type of coordinate system in which a geometrical figure is described.

Transient – Varying in time, as opposed to steady state.

Transient problem – Same as initial-value problem.

Transient response – A sudden brief disturbance or reaction of a system to an outside force.

Transient wave – wave varying in time, but relatively of short existence.

Transitional flow – A flow in which the viscous and Reynolds stresses are of approximately equal magnitude. It is transitional between laminar flow and turbulent flow.

See laminar boundary layer, turbulent boundary layer.

Transitional zone (transitional water) – In regard to progressive gravity waves, water whose depth is less than 1/2 but more than 1/25 the wavelength. Often called shallow water.

Translatory wave – Same as wave of translation.

Transmission – An act, process or instance of transmitting. The passage of radio signals or electrical signals. Transmitting and receiving stations of a telecommunication system. In reference to tsunamis, transmission may include data signals from the seismic or tidal networks of the varying operating tsunamis warning systems, and verbal warning messages.

Transmission loss – A general term for the reduction of power in a transmitted radio signal resulting from any or all of such effects as range attenuation, precipitation attenuation, multipath transmission, etc.

Transmitter – A device used for the generation of signals of any type and form which are to be transmitted. In radio radar, it is that portion of the equipment which includes electronic circuits designed to generate, amplify, and shape the radio frequency energy which is delivered to the antenna where it is radiated out into space.

See receiver.

Transponder – A device which relays electrical signals not necessarily in the same form or on the same frequency as received. It is used in some types of rawin systems to overcome the decrease of target signal strength due to range attenuation. The transponder, in such systems, consists of a transmitter and a receiver so designed that upon receiving a pulse of energy from the ground radar, it will generate a new pulse on a different frequency, and transmit it back to the ground station.

Transport – 1. Same as flux.

2. The process by which a substance or quantity is carried past a fixed point, or across a fixed plane. In meteorology and oceanography, such quantities are: heat, momentum, mass, dissolved impurities, suspended particles, etc.

Transverse wave – (Also called distortional wave.) A wave in which the direction of propagation of the wave is normal to the displacements of the medium, e.g., a vibrating string. The gravity wave in which fluid parcels move in circular orbits is an example of a mixed transverse-longitudinal wave. The Rossby wave is also mixed, except in the case of zero current speed, when it is a transverse wave.

Compare longitudinal wave.

Trapped mode – A certain frequency of water waves entrapped selectively by a semienclosed basin beacause of its characteristic dimensions, depth, orientation, and its natural modes of oscillation.

Trapped wave – A wave of certain frequency entrapped selectively by a semienclosed basin because of its particular properties and characteristics.

Travel time – The time required for a wave train to travel from its source to a point of observation. In reference to tsunami, the time required, usually, for the first tsunami wave arrival at a given point on a coastline.

Travel time chart – In seismology, chart empirically devised to record the surface focus shocks of earthquakes using time as one axis and distance (degree) as the other. For tsunami science, a chart showing isochrones of calculated tsunami travel from the origin of the tsunami

source outwards toward terminal points on distant coastlines.

Tremor – A minor earthquake, especially a foreshock or an aftershock.

Trench – A long, narrow, characteristically very deep and asymmetrical depression of the sea floor, with relatively steep sides.
A deep ocean trench represents a maximum relief feature found on the earth's surface which may extend for hundreds of kilometers. A trench marks the boundary between major oceanic and continental plates where subduction may be taking place as oceanic crust sinks underneath the continental crust because of its greater density.

Triangular mesh – A grid of triangular spaces in a network of meshes used in tsunami numerical modeling studies.

Triassic Period - Segment of the Mesozoic Era that follows the Permian and precedes the Jurassic Period. It lasted from about 225 million to 190 million years ago and was named for the three subdivisions of the period as recorded in rock formations: Lower, Middle, Upper. The Middle corresponds to the notably marine part of the Triassic. The rock is sandstone and mudstone; it is found on all continents and is the residue of sedimentation in a hot climate. The landmass during the Triassic was a single supercontinent, Pangaea. The Atlantic Ocean opened at the end of the Triassic.

Triple scalar product – The scalar $A \cdot (B \times C)$ written (ABC) or [ABC], where A, B, and C are any three vectors. The dot denotes a scalar product and the cross a vector product. When A, B, and C are written in terms of their components along the x, y, and z axes of the rectangular Cartesian coordinates, i.e., $A = a_1\mathrm{i} + a_2\mathrm{j} + a_3\mathrm{k}$, $B = b_1\mathrm{i} + b_2\mathrm{j} + b_3\mathrm{k}$ and $C = c_1\mathrm{i} + c_2\mathrm{j} + c_3\mathrm{k}$, the triple scalar product is the determinant.

$$(ABC) = (CAB) = (BCA) = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix}.$$

Any cyclic change among the vectors in a triple product does not alter its value.

Trochoidal wave – A theoretical, progressive oscillatory wave first proposed by Gerstner in 1802 to describe the surface profile and particle orbits of finite amplitude, nonsinusoidal waves. The wave form is that of a prolate cycloid or trochoid, and the fluid particle motion is rotational as opposed to the usual irrotational particle motion for waves generated by normal forces. See irrotational wave.

Tropic tide – Tide occurring when the moon is near maximum declination; the diurnal inequality is then at a maximum.

Compare equatorial tide, spring tide, neap tide.

Trough - An undersea depression that is U-shaped rather than V-shaped like a trench or canyon, which it otherwise resembles; also, an atmospheric low about which winds circulate. See canyon, trench.

Trough of wave – The lowest part of a wave form between successive crests. Also that part of a wave below stillwater level. (See Figure A-3.)

Truncation error – 1. The error resulting from the approximation of a derivative or differential by a finite difference. The magnitude of the error is always reduced by reducing the interval over which the finite difference is taken; but for a given interval some approximations may be much superior to others.

2. The error resulting from the analysis of a partial set of data in place of the complete or infinite set.

Tsunami – A series of travelling waves of extremely long length and period, generated by disturbances associated with earthquakes occurring below or near the ocean floor. (Also called seismic sea wave and, popularly, tidal wave.) An ocean wave produced by a submarine earthquake, landslide, or volcanic eruption. These waves may reach enormous dimensions and have sufficient energy to travel across entire oceans. They proceed as ordinary gravity waves with a period between 15 and 60 minutes. Tsunamis steepen and increase in height on approaching shallow water, inundating low-lying areas; and where local submarine topography causes extreme steeping, they may break and cause great damage. Tsunamis have no connection with tides; the popular name is entirely misleading.

Tsunami Communication Plan - The primary purpose of the Communication Plan for the Tsunami Warning System is to serve as the communications operating manual for the Pacific Tsunami Warning Center (PTWC) and for participants of the Tsunami Warning System (TWS) of the Pacific. The Plan lists each country's tidal and seismological stations with preferred methods of communications between those stations and the Pacific Tsunami Warning Center. The Plan also lists the dissemination agencies in each country which receive tsunami watch and warning bulletins and communications methods by which the bulletins are sent from PTWC to those agencies.A secondary purpose of the Communication Plan is to provide a general overview of the operational procedures of the Tsunami Warning System and of the nature of tsunamis. The Plan discusses the general nature of tsunamis, the operation of the Tsunami Warning System, the communication methods and procedures for data acquisition from seismological and tidal stations, and the dissemination of information to participating agencies. Finally the Plan discusses the U.S., Alaska and West Coast Regional Warning System, giving criteria under which Watches and Warnings are issued and the recipients of those messages.

Tsunami damage – Loss or harm caused by a destructive tsunami. More specifically, the damage caused directly by tsunamis can be summarized into the following: 1) deaths and injuries; 2) houses destroyed, partly destroyed, inundated , flooded, or burned; 3) other property damage and loss; 4) boats washed away, damaged or destroyed; 5) lumber washed away; 6) marine installations destroyed, and; 7) damage to public utilities such as railroads, roads, electric power plants, water supply installations, etc. Indirect secondary tsunami damage can be: 1) Damage by fire of houses, boats, oil tanks,, gas stations, and other facilities; 2) environmental pollution caused by drifting materials, oil, or other substances; 3) outbreak of disease of epidemic proportions which could be serious in densely populated areas.

Tsunami data acquisition – Obtaining useful and relevant seismic or tidal data necessary for the evaluation of a potentially destructive tsunami prior to the issuance of tsunami informational bulletin, or a watch or a warning by an operational tsunami warning center. Collection of such relevant geophysical and oceanic data for research purposes in understanding the tsunami phenomenon.

Tsunami detectability – Discovery or determination of the existence, presence, or fact of tsunami.

Tsunami dispersion – Scattering of tsunami energy as it travels across a body of water.

Tsunami dummy message - Test message issued by The Pacific Tsunami Warning Center (PTWC) at unannounced times on a monthly basis to determine delays in disseminating tsunami information, to test the operation of the warning system by the evaluation of two-way communications with interactive personnel response, and to keep communication operating personnel familiar with the pocedures for handling message traffic pertaining to the Tsunami Warning System.

Tsunami effect – The result, consequence, or outcome in the aftermath of a tsunami disaster.

Tsunami evaluation – The appraisal and assessment of a generated tsunami and its probable potential destructive effects upon striking coastal areas.

Tsunami generation – Tsunamis are generated primarily by tectonic dislocations under the sea which are caused by shallow focus earthquakes along areas of subduction. The upthrusted and downthrusted crustal blocks impart potential energy into the overlying water mass with drastic changes in the sea level over the affected region. The energy imparted into the water mass results in tsunami generation which is energy radiating away from the source region in the form of long period waves.

Tsunami hazard – The danger of tsunami on life and property.

Tsunami impact – Although infrequent, tsunamis are among the most terrifying and complex physical phenomena and have been responsible for great loss of life and extensive destruction to property. Because of their destructiveness, tsunamis have important impact on the human,

social and economic sectors of societies. Historical records show that enormous destruction of coastal communities throughout the world has taken place and that the socio economic impact of tsunamis in the past has been enormous. In the Pacific Ocean where the majority of these waves have been generated, the historic record shows tremendous destruction with extensive loss of life and property. In Japan, which has one of the most populated coastal regions in the world and a long history of earthquake activity, tsunamic have destroyed entire coastal populations. There is a history of tsunami destruction also in Alaska, in the Hawaiian Islands, and in South America, although records for these areas are not extensive. The last major Pacific-wide tsunami occurred in 1960. Others also occurred but their effects were localized.

Tsunami Information Bulletin - A message issued to advise participants of the occurrence of a major earthquake in the Pacific or near-Pacific area, with the evaluation that a potentially destructive tsunami was not generated. If the evaluation indicates the possible generation of a non-destructive tsunami, an investigation will be initiated by the Pacific Tsunami Warning Center (PTWC) and additional Tsunami Information Bulletins will be issued until the investigation is concluded.

Tsunami magnitude – The measurement of the overall physical size of a tsunami. Tsunami magnitude is defined by:

$$m = log_2 H \quad or \quad H = 2.0^m$$

as revised by Iida, Cox, and Pararas-Carayannis (1967), where H is the maximum run-up height or amplitude on a coastline near the generating area. Other tsunami magnitude scales have been proposed based, also, on tsunami maximum run-up height.

Tsunami observation – Notice, observation or measurement of sea level fluctuation at a particular point in time caused by the incidence of a tsunami on a specific point on a coast.

Tsunami period – The amount of time that a tsunami wave takes to complete a cycle. The average tsunami period ranges from 20 minutes to 2 hours.

Tsunami preparedness – Readiness of plans, methods, procedures and actions taken by government officials and the general public for the purpose of minimizing potential risk and mitigating the effects of future tsunamis.

Tsunami prone – Anomalously receptive to damage or destruction by tsunamis.

Tsunami Propagation - Tsunamis travel outward in all directions from the generating area, with the direction of the main energy propagation generally being orthogonal to the direction of the earthquake fracture zone. Their speed depends on the depth of water, so that the waves undergo accelerations and decelerations in passing over an ocean bottom of varying depth. In the deep and open ocean, they travel at speeds of 500 to 1,000 kilometers per hour (300 to 600 miles per hour). The distance between successive crests can be as much as 500 to 650 kilometers (300 to 400 miles); however, in the open ocean, the height of the waves may be no more than 30 to 60 centimeters (1 or 2 feet), and the waves pass unnoticed. Variations in tsunami propagation result when the propagation impulse is stronger in one direction than in others because of the orientation or dimensions of the generating area and where regional topographic features modify both the wave form and rate of advance.Specifically tsunami waves undergo a process of wave refraction throughout their travel, as though they were shallow water waves. Tsunamis are unique in that the waveform extends through the entire water column from sea surface to the ocean bottom. It is this characteristic that accounts for the great amount of energy transmitted by a tsunami.

Tsunami risk – Exposure to loss, or injury caused by the tsunami hazard.

Tsunami safety rules – * All earthquakes do not cause tsunamis, but many do. When you hear that an earthquake has occurred, stand by for a tsunami emergency.

* An earthquake in your area is a natural tsunami warning. Do not stay in low-lying coastal areas after a local earthquake.

* A tsunami is not a single wave, but a series of waves. Stay out of danger areas until an "all-clear" is issued by competent authority.

* Approaching tsunamis are sometimes heralded by a noticeable rise or fall of coastal water. This is nature's tsunami warning and should be heeded.

* A small tsunami at one beach can be a giant a few miles away. Don't let the modest size of one make you lose respect for all.

* All tsunamis - like hurricanes - are potentially dangerous, even though they may not damage every coastline they strike.

* Never go down to the beach to watch for a tsunami. When you see the wave you are too close to escape it.

* Sooner or later, tsunamis visit every coastline of the Pacific. Warnings apply to you if you live in any Pacific coastal area.

* During a tsunami emergency, your local police and other emergency organizations will try to save your life. Give them your fullest cooperation.

* Stay tuned to radio, television, or NOAA Weather Radio during a tsunami emergency - bulletins from these media can help save your life.

Tsunami source – Point or area of tsunami origin, usually the site of an earthquake, volcanic eruption, or landslide that have affected the sea floor or a body of water.

Tsunami Termination - Upon reaching shoaler water, the speed of the advancing tsunami wave diminishes, its wave length decreases, and its height may increase greatly, owing to the piling up of water. Configuration of the coastline, shape of the ocean floor, and character of the advancing waves play an important role in the destruction brought by tsunamis along any coast, whether near the generating area or thousands of kilometers from it. At present, detection of tsunamis is possible only near shore where the shoaling effect can be observed. The first visible indication of an approaching tsunami is often a recession of water caused by the trough preceding an advancing wave. Any withdrawal of the sea, therefore, should be considered a warning of an approaching wave. A rise in water level also may be the first event. Under certain conditions, the crest of an advancing wave can overtake the preceding trough while some distance offshore. This causes the wave to proceed shoreward as a bore -- a wave with a churning front. The force and destructive effects of tsunamis should not be underestimated. At some places, the advancing turbulent front is the most destructive part of the wave. Where the rise is quiet, the outflow of water to the sea between crests may be rapid and destructive, sweeping all before it and undermining roads, buildings, and other works of man with its swift currents. Ships, unless moved away from shore, can be thrown against breakwaters, wharfs, and other craft, or washed ashore and left grounded during withdrawals of the sea. In the shallow waters of bays and harbors, a tsunami frequently will initiate seiching. If the tsunami period is related closely to that of the bay, the seiche is amplified by the succeeding waves. Under these circumstances, maximum wave activity often is observed much later than the arrival of the first wave. A tsunami is not one wave, but a series of waves. The time that elapses between passage of successive wave crests at a given point usually is from 10 to 45 minutes. Oscillations of destructive proportions may continue for several hours, and several days may pass before the sea returns to its normal state.

Tsunami Warning Bulletin - A message issued to all participants in the Tsunami Warning System in the Pacific on a Pacific-wide basis after confirmation has been received that a tsunami has been generated that poses a threat to the population in part or all of the Pacific. A Tsunami Warning will be followed by additional bulletins with updated information until the Tsunami Warning is cancelled.

Tsunami warning exercises – Training for the purpose of developing skills or putting into action, plans, procedures and methods that will mitigate the damaging effects and loss of life from a future and potentially damaging tsunami.

Tsunami watch bulletin - A message issued initially using only seismic information to alert all participants of the probability of a tsunami and advise that a tsunami investigation is

underway. The area placed in Tsunami Watch status will encompass a 6-hour tsunami travel-time from the earthquake epicenter. Those areas within a 3-hour tsunami travel-time of the epicenter will be designated for possible urgent action. A Tsunami Watch will be followed by additional bulletins until it is either upgraded to a Tsunami Warning or the Tsunami Watch is cancelled.

Tsunami zoning – See Tsunami zonation.

Tsunamic – Having features analogous to those of a tsunami or description of a tsunami.

Tsunamicity – The propensity of a specified region to generate tsunamis.

Tsunamigenic – Having the demonstrated or potential capability to generate a tsunami.

Tsunamigram – Recording of a tsunami made by an instrument such as a tidal gauge.

Tsunamimeter – Instrument used for measuring some parameter of a tsunami.

Tsunamist – One devoted to studying or researching tsunami or phenomena associated with tsunami.

Tsunami zonation – Designation of distinctive zones along coastal areas with varying degrees of tsunami risk and vulnerability for the purpose of disaster preparedness, planning, construction codes, or public evacuation.

Tsushima current – A warm, northward-flowing ocean current following the western coast of Japan. The Tsushima current branches off on the left-hand side of the Kuroshio flowing north into the Japan Sea.

Turbidity flow – A type of bottom current on continental slopes and rises caused when a sediment-covered submarine slope becomes structurally unstable and begins to collapse under its own weight or stirred into suspension in the overlying water. The sediment in suspension creates a water mass of higher density generating a current which flows downslope gaining speed. Turbidity currents flush out and erode submarine canyons, building up the flanks with natural levees and supply the sediments which fill the abysall plains.

Turbulence – A flow of water in which the motion of individual particles appears irregular and confused. A state of fluid flow in which the instantaneous velocities exhibit irregular and apparently random fluctuations so that in practice only statistical properties can be recognized and subjected to analysis. The situation is, in fact, analogous to that accepted unreservedly in the field of molecular physics. These fluctuations often constitute major deformations of the flow and are capable of transporting momentum, energy, and suspended matter at rates far in excess of the rate of transport by the molecular processes of diffusion and conduction in a non-turbulent or laminar flow.

See eddy.

Turbulent boundary layer – The layer in which the Reynolds stresses are much larger than the viscous stresses. When the Reynolds number is sufficiently high, there is a turbulent layer adjacent to the laminar boundary layer.

Turbulent diffusion – (Or eddy diffusion.) The diffusion of a conservative property by eddies in a turbulent flow.

See also eddy diffusivity.

Turbulent energy – Same as eddy kinetic energy.

Turbulent flow – A fluid flow characterized by turbulence.

See eddy, laminar flow, transitional flow.

Turbulent flux – Same as eddy flux.

Turbulent shear stresses – Same as Reynolds stresses.

Turnover frequency – Same as Nyquist frequency.

Twisting term – (Also called tilting term, tipping term.) The term in the vorticity equation which represents the generation of vertical vorticity by the twisting of horizontal vorticity into the vertical through the agency of shear in the vertical velocity. In symbols this term is

$$\left(\frac{\partial u}{\partial z}\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\frac{\partial w}{\partial x}\right)$$

where u, v, w are the velocity components along the coordinate directions x, y, z, respectively.

Typhoon – A severe tropical cyclone in the western Pacific. (Also spelled typhoon.) A severe tropical cyclone in the western Pacific. The name is derived either from Cantonese t'ai fung (a "great wind"), from Arabic tufan (smoke), or from Greek typhoon (a monster). Aristotle used typhoon for a wind-containing cloud (Meteorologica, III, 1). For a more complete discussion, see tropical cyclone.

– U–

UHF – Abbreviation for ultra high frequency.

See radio frequency band.

Ultra high frequency – (Abbreviated UHF.)

See radio frequency band.

Ultrasonic – Pertaining to sound waves whose frequencies lie above the upper limit of audibility, i.e., above about 20,000 cycles per second.

UN - United Nations

Uncertainty – In physical sciences, the standard deviation of a sufficiently large number of measurement.

Underwater gradient – The slope of the sea bottom.

See also slope.

Undulation – A continuously propagated motion to and fro, in any fluid or elastic medium, with no permanent translation of the particles themselves.

UNEP - UN Environment Programme

UNESCO - United Nations Educational, Scientific and Cultural Organization

Unexplained variance – Same as residual variance.

Uniform slope – Constant upward or downward slant or inclination or degree of slant.

Unit normal distribution – A normal distribution such that the mean $\mu = 0$ and standard deviation $\sigma = 1$; hence, the probability density function $f(x)$ is given by

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$$

This density function and its definite integral (usually between 0 and arbitrary upper limits) have been extensively tabulated.

Universal gravitational constant – See gravitation.

Unstable wave – A wave motion whose amplitude increases with time or whose total energy increases at the expense of its environment.

Uplift – A structurally high area in the crust produced by positive movements that raise or upthrust the rocks, as in a dome or arch.

Upper mantle – The zone of the earth immediately underneath the crust of the earth marked on its upper boundary by the Mohorovicic discontinuity, extending to a depth of 400 km and characterized by regional dissimilarities in seismic velocity profile. Because of a combination of inadequate and sometimes conflicting data, both from seismology and from laboratory experiments, there is no full consensus about the nature of the Upper Mantle. The petrological models that have been proposed start from the plausible assumption that the composition of the primitive mantle must have been such that it yields a basaltic magma upon melting and then predict the mineral assemblages formed by the remaining residue as a function of depth or pressure from laboratory experiments. As early as 1922, Goldschmidt proposed an Earth consisting of a 120-km thick silicate layer on top of an eclogite mantle. D.L. Anderson argues that the volume of the lunar crust, which represents 10% of the moon, contrasts significantly with the 0.5% found for the Earth. If the Earth's mantle is as well differentiated as that of the Moon, this would result in a basalt layer with a thickness of several hundred kilometers.

Uprush – The rush of water up onto the beach following the breaking of a wave. Also swash, runup. (See Figure A-2.)

Upstream – In the direction from which a fluid is flowing.

Upthrust – A nongeological term sometimes applied to uplifted block of crust or mountains; not synonymous with overthrust.

Upwarping – The upward warping or uplift of a regional area of the Earth's crust, usually as the result of the release of isostatic pressure; e.g., melting of an ice sheet.

URSI - International Union of Radio Science.

USGS - United States Geological Survey

UT - Universal Time

– V–

Valley, sea – A submarine depression of broad valley form without the steep side slopes which characterize a canyon.

Valley, submarine – A prolongation of a land valley into or across a continental or insular shelf, which generally gives evidence of having been formed by stream erosion.

Variability – Mathematically, same as spread (1).

Variability of waves – 1/ The variation of heights and periods between individual waves within a wave train. (wave trains are not composed of waves of equal height and period, but rather of heights and periods which vary in a statistical manner.

2. The variation in direction of propagation of waves leaving the generating area.

3. The variation in height along the crest, usually called "variation along the wave."

Variable – Something which can assume different values or states. See dependent variable, independent variable, random variable.

Variance – A measure of variability (or spread). It is denoted by σ^2 and defined as the mean- square deviation from the mean that is, the mean of the squares of the differences between individual values of x and the mean value μ.

$$\sigma^2 \equiv E[(x - \upsilon)^2] \equiv E(x^2) - \upsilon^2$$

where E denotes expected value. The positive square root σ of the variance is called the standard deviation.

An unbiased estimate s^2 of the variance σ^2 is obtained from n independent observations $x_1, x_2, \ldots, x_n$ and their sample $\bar{x}$ average as follows:

$$s^2 = [\sum_{i=1}^{n} (x_i - \bar{x})^2]/(n - 1)$$

and the positive square root s of s^2 is taken as an estimate of the standard deviation σ.

Variance ratio – Same as F-ratio.

Variance reduction – See regression.

Variate – Same as random variable.

Variation – 1. The range within which values of a variable lie, as in the diurnal or annual variation.

2. Same as declination.

Vector – Any quantity, such as force, velocity, or acceleration, which has both magnitude and direction at each point in space, as opposed to a scalar which has magnitude only. Such a quantity may be represented geometrically by an arrow of length proportional to its magnitude, pointing in the assigned direction. A unit vector is a vector of unit length; in particular, the three unit vectors along the positive x, y and z axes of rectangular Cartesian coordinates are denoted, respectively, by i, j and k. Any vector A can be represented in terms of its components a_1, a_2, and a_3 along the coordinate axes x, y and z, respectively; e.g., $\mathrm{A} = a_1\mathrm{i} + a_2\mathrm{j} + a_3\mathrm{k}$. A vector drawn from a fixed origin to a given point (x, y, z) is called a position vector and is usually symbolized by r; in rectangular Cartesian coordinates

$$\mathrm{r} = x\mathrm{i} + y\mathrm{j} + z\mathrm{k}.$$

Equations written in vector form are valid in any coordinate system. Mathematically, a vector is a single-row or -column array of functions obeying certain laws of transformation.

See scalar product, vector product, tensor, Helmholtz's theorem.

Vector product – (Also called cross product, outer product.) A vector whose magnitude is equal to

the product of the magnitudes of any two given vectors and the sine of the angle between their positive directions. For two vectors A and B, the vector product is often written A × B (read "A cross B"), and defines a vector perpendicular to both A and B and so directed that a right-hand rotation about A × B through an angle of not more than 180° carries A into B. The magnitude of A × B is equal to twice the area of the triangle of which A and B are coterminous sides. If the vector product is zero, one of the vectors is zero or else the two are parallel. When A and B are written in terms of their components along the x, y and z axes of the rectangular Cartesian coordinates, i.e.,

$$A = a_1 i + a_2 j + a_3 k,$$

$$B = b_1 i + b_2 j + b_3 k,$$

then the vector product is the determinant

$$A \times B = -B \times A = \begin{vmatrix} i & j & k \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}.$$

See scalar product.

Velocity – The time rate of change of a position vector; that is, a change of position expressed in terms of speed and direction. If R is the position vector of a given point in space and t is time, the velocity, V, is given by,

$$V = \frac{dR}{dt}.$$

See also relative velocity, absolute velocity.

Velocity currents – Fast moving circulatory patterns of water masses caused or influenced by conditions in particular locals affected by tidal forces, winds or tsunami.

Velocity of waves – The speed at which an individual wave advances.

See wave celerity.

Velocity potential – A scalar function whose gradient is equal to the velocity vector V of an irrotational flow. If $\phi(x, y, z)$ is the velocity potential,

$$V = -\nabla\phi.$$

If the flow is also non-divergent, the velocity potential satisfies the Laplace equation

$$\nabla^2\phi = 0.$$

If a velocity potential exists, it is simpler to describe the motion by means of the potential rather than the vector velocity, since the former is a single scalar function whereas the latter is a set of three scalar functions.

The velocity is everywhere normal to the surfaces of constant velocity potential. In two-dimensional incompressible flow, the relations among the velocity, the velocity potential, and the stream function ψ are

$$\frac{\partial\psi}{\partial x} = -\frac{\partial\phi}{\partial y} = v, \quad \frac{\partial\psi}{\partial y} = \frac{\partial\phi}{\partial x} = -u.$$

See acceleration potential, potential.

Velocity pressure – Same as dynamic pressure.

Velocity profile – See profile, logarithmic velocity profile, power-law profile.

Vertical displacement – The relative vertical movement of the crust along the two sides of a fault, as measured in any specific direction. The term also designates the specific distance of such movement. Syn: dislocation.

Vertical force – Energy exerted on the vertical plane by a moving crustal block.

Vertical mode – Motion or trend in the vertical direction.

Vertical section – In general, any graph of the vertical distribution of a quantity with respect to either time or space.

See cross section, time section, time-height section, profile.

Vertical time-section – See time section.

Vertical vorticity – The vertical component of the vorticity vector.

See vorticity.

Very high frequency – (Abbreviated VHF.)

See radio frequency band.

Very low frequency – (Abbreviated VLF.)

See radio frequency band.

VHF – Abbreviation for very high frequency.

See radio frequency band.

Vibrotron pressure transducer –

Viscosity – Resistance to flow.

VLF – Abbreviation for very low frequency.

See radio frequency band.

Volcanic ash – Fine pyroclastic material (less than 4.0mm (o.16in) in diameter; less than 0.25mm (0.01 in.) diameter for fine ash). The term usually refers to the unconsolidated material but is sometimes also used for its consolidated counterpart or tuff.

Volcanic domes - structures formed by the extrusion of different types of lava to the earth's surface. They can be of two types:

A) Broad dome-shaped structures of basaltic origin formed by high temperature, low viscosity lavas and,

B) Steep-sided domes formed by more viscous rhyolitic types of lava that are pushed upward by extremely high gas pressures. Such lavas may fill up a volcanic crater and flow out laterally, or under extreme paroxysmal conditions may be puched directly into the air forming steep-sided domes of volcanic ash.

Volcanic eruption – The sudden and often violent flare-up, emission, or explosion of a volcano associated with the discharge of gases, lava, and various pyroclastic materials.

Volcanic explosion – A violent and explosive type of volcanic eruption varying in intensity from the mildest (Hawaiian-type eruption, characterized by emission of large quantities of very fluid basaltic magma from which gases readily escape along with subordinate pyroclastic material), to the Plinian-type eruption which is extremely violent and results in the emission of extremely viscous gas-filled magma that is blasted out of the vent at nearly twice the velocity of sound, ejecting tremendous amounts of pyroclastic material. There are other types of explosive volcanic eruptions. The Vulcanian-type which is characterized by viscous lava, large quantities of pyrochastic material (ash, blocks), and ash clouds. Another type is the Pelecan-type of eruption which is explosive and resembles the same features as with the Plinian, esp. vast amounts of pyrochastic material. Its uniqueness is defined by the presence of a nue'e ardente (glowing cloud), which is associated with the growth of a volcanic dome.

Volcanic focus - The apparent or assumed center of activity beneath a volcano, or a volcanic region.

Volcanic gases - Compounds and elements that were previously dissolved in the magma while under great pressure, and which are released as volatiles during a volcanic eruption. The gases are released when pressure is decreased as the magma reaches the surface. Most common constituents of the gases are water vapor and carbon dioxide; other constituents include sulfur dioxide, hydrogen sulfide, hydrogen chloride, and nitrogen as a free element. In addition tto its dependence on viscosity and composition of the lava, the explosiveness of a volcanic eruption is to a large degree determined by the proportion of gaseous material in the magma

Volcanism – The process by which magma and its associated gases rise into the crust and are extruded onto the Earth's surface and into the atmosphere.

Volcano – A vent in the planetary crust from which molten or hot rock and steam issue.

Vortex – In its most general use, any flow possessing vorticity. More often the term refers to a flow with closed streamlines, or to the idealized case in which all vorticity is concentrated in a vortex filament.

Vortex line – A curve tangent at every point of a field to the vorticity vector at that point.

Vortex street – (Also called Karman vortex street, vortex trail, vortex train.) Two parallel rows of alternately-placed vortices along the wave of an obstacle in a fluid of moderate Reynolds number. Fluid drag can be calculated from the motion of these vortices, which are stable only for a certain

ratio of the width of the street to the distance between vortices along the street.

Vorticity – A vector measure of local rotation in a fluid flow, defined mathematically as the curl of the velocity vector,

$$q = \nabla \times V$$

where q is the vorticity, V the velocity, and ∇ the del-operator. Some English authors define vorticity as one-half of this quantity. The vorticity component normal to a small plane element is the limit of the circulation per unit area as the area of the element approaches zero (see Stokes's theorem).

The vorticity of a solid rotation is twice the angular velocity vector.

See also relative vorticity, absolute vorticity, geostrophic vorticity, ; compare deformation, divergence.

– W–

Warp – A slight flexure or bend of the Earth's crust, either upward or downward, usually on a broad or regional scale.

Warning – Severe tsunami has been reported or is imminent - take necessary precautions. See Tsunami Warning.

Warning bulletin – See Tsunami Warning Bulletin.

Warning cancellation – Nullification of the warning bulletin which was issued issued when a tsunami was originally detected, but later it was determined that the tsunami threat had passed or would not materialize. See Tsunami Warning Cancellation.

Watch bulletin – Bulletin issued to alert the public of the possibility of a tsunami. See Tsunami Watch Bulletin.

Watch cancellation – Nullification of the watch bulletin when determined that the possibility of a damaging tsunami does not exist. See Tsunami Watch Cancellation.

Water edge – The boundary or boarder between a body of water and dry land.

Water elevation – A height which water reaches.

Water front – Land with buildings, or a section of a town fronting or abutting on a body of water.

Water mass – A vaguely homogeneous body of water having its source in a particular region of the ocean. It is usually identified by its T-S curve or chemical content, and usually consists of a mixture of several water types. The corresponding meteorological concept is air mass. The terms water mass and water type have been used loosely and interchangeably in oceanographic literature.

Waterline – A juncture of land and sea. This line migrates, changing with the tide or other fluctuation on the water level. Where waves are present on the beach, this line is also known as the limit of backrush. (Approximately the intersection of the land with the stillwater level.)

Water table – The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfirmed ground water at which the pressure is equal to that of the atmosphere.

Watt – A unit of power equal to one joule per second or 10^7 ergs per second.

Wave – 1. Very generally, any pattern with some roughly identifiable periodicity in time and/or space.

2. More specifically, a disturbance propagated by virtue of periodic motions (oscillations) of the particles of the medium. At any point in the medium, the displacement of a particle is a function of time; while at any instant, the displacement is a function of location within the medium.

Waves may be considered in terms of (a) total energy and impressed forces (see free wave, forced wave, stable wave, unstable wave, damped wave, neutral wave, inertia wave); (b) the type of force (see gravity wave, capillary wave, tide, expansion wave, compression wave); (c) the way that the medium's particles oscillate (see longitudinal wave, transverse wave); (d) the apparent relative motion of wave and medium (see progressive wave, standing wave, stationary

wave); (e) the portion of the medium affected by the wave (see external wave, internal wave, surface wave); and (f) the manner in which the waves are detected (see sound wave). The study of water-surface waves has bred its own special terminology (see deep-water wave, shallow-water wave, wind wave, sea, swell, tidal wave, tsunami, seiche).

3. Most specifically, a simple harmonic wave.

4. Popularly used as a synonym for "surge" or "influx," as in tidal wave (storm surge), heat wave, cold wave.

Wave action – Activity or disturbance of water level caused by wave.

Wave amplitude – See amplitude.

Wave attenuation – The decrease in the wave form or height with distance from its origin.

Wave basin – An enclosure within which wave activity is observed.

Wave breaking – See Breaker.

Wave celerity – Same as wave velocity.

Wave crest – The highest part of a wave. A point of maximum displacement of a wave above a mean value.

Wave crest length – See crest length, wave.

Wave, cycloidal – See cycloidal wave.

Wave cut – Carved or cut away by the action of lake or sea waves, assisted by their currents. The term is widely used in regard to marine cut features.

Wave decay – See decay of waves.

Wave direction – The direction from which a wave approaches.

Wave flume – An enclosed channel of water used to study the propagation and characteristics of water waves.

Wave force – The exceptional strength or energy of wave motion.

Wave frequency – See frequency.

Wave front – Same as phase front.

Wave gauge – Instrument for measuring wave activity

Wave generator – A machine that can generate various types of waves by mechanical means within a wave block, wave flume or any other enclosure containing liquid.

Wave height – Twice the wave amplitude. The height of a water-surface wave is generally taken as the height difference between the wave crest and the preceeding trough.

Wave generation – See generation of waves.

Wave, gravity – See gravity wave.

Wave group – A series of waves in which the wave direction, wave length, and wave height vary only slightly. See also group velocity.

Wave height – The vertical distance between a crest and the preceding trough.

See also significant wave height.

Wave height coefficient – The ratio of the wave height at a selected pint to the deepwater wave height. The refraction coefficient multiplied by the shoaling factor.

Wave hindcasting – See hindcasting, wave.

Wave, irrotational – See irrotational wave.

Wave measurements – Measurements of wave heights over a period of time

Wave, monochromatic – See monochromatic wave.

Wave-meter – An instrument that measures wave heights.

Wave motion – The oscillatory motion of the particles of a medium caused by the passage of a wave, produced by forces external to the medium, but propagated through the medium by internal forces. Wave motion per se involves no net

translation of the medium. Various types of oscillations are found in natural wave motions. Among the simplest are the linear oscillation perpendicular to the direction of propagation of a transverse wave, and the orbital motion produced by the passage of a progressive gravity wave.

See wave equation.

Wave number – The reciprocal of wave length; the number of waves per unit distance in the direction of propagation; or, frequently, 2π times this quantity. Thus, in the simple harmonic component sin $k(x - ct)$, the wave number is ambiguously k or $k/2\pi$.

Compare angular wave-number.

Wave of oscillation – (Or oscillatory wave.) A wave that results in no mean displacement of the particles of the fluid in the direction of motion of the wave, in contrast to a wave of translation.

Wave of translation – (Or translatory wave.) A wave which is accompanied by substantial net movement of the fluid in the direction of wave motion, although the wave propagates more rapidly than the fluid. Flood waves in rivers are translatory waves.

Compare longitudinal wave.

Wave, oscillatory – See oscillatory wave.

Wave period – The time required for successive wave crests to pass by a fixed point. See period.

Wave pole – (Also called wave staff.) A device for measuring sea-surface waves. It consists of a weighted pole below which a disk is suspended at a depth sufficiently deep for the wave motion associated with deep-water waves to be negligible. The pole will then remain nearly as if anchored to the bottom, and wave height and period can be ascertained by observing or recording the length of the pole that extends above the surface.

See wave recorder.

Wave pressure – Hydrostatic or dynamic force exerted on a surface by wave action.

Wave profile – Two-dimensional analog diagram of wave activity.

Wave, progressive – See progressive wave.

Wave propagation – The transmission of waves through the water.

Wave ray – See orthogonal.

Wave recorder – An instrument for recording ocean waves. Most wave recorders are designed for recording wind waves, that is waves of periods up to about 25 seconds, but some are designed to record waves of longer periods such as tsunamis or tides (see tide gage).

Wave, reflected – That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.

Wave refraction – The change in direction of waves which occurs when one portion of the wave reaches shallow water and is slowed down while the other portion is in deep water and moving relatively fast.

Wave setup – See setup, wave.

Wave, sinusoidal – An oscillatory wave having the form of a sinusoid.

Wave, solitary – See solitary wave.

Wave spectrum – 1. In ocean wave studies, a graph showing the distribution of wave heights with respect to frequency in a wave record.

2. See spectrum (2).

Wave speed – Same as phase speed.

Wave staff – Same as wave pole.

Wave, standing – See standing wave.

Wave steepness – Of a water-surface wave, the ratio of wave height to wave length.

Wave system – 1. In ocean wave studies, a group of waves having the same height, direction, and length. Ocean surface waves are generally composed of a number of superimposed wave systems.

2. See wave train.

Wave tank – Large artificial enclosure containing a liquid used for the study wave generation, propagation and terminal characteristics.

Wave train – A limited series of waves caused by a periodic disturbance of short duration.

Wave, trochoidal – See trochoidal wave.

Wave trough – The lowest part of a wave between two successive crests.

Wave-type disturbance – Same as wave disturbance (2).

Wave variability – See variability of waves.

Wave velocity – The velocity or speed at which the wave form proceeds. It is equal to the wavelength divided by the wave period. Same as phase speed. With reference to water-surface waves, however, the terms wave velocity and wave celerity seem to be preferred.

Wave, wind – See wind waves.

Waveform – The pictorial representation of the shape of a wave showing the amplitude variation as a function of time; a wave as it might be displayed on a cathode-ray tube.

Wavelength – 1. The horizontal distance between similar points on two successive waves measured perpendicular to the crest.

2. The average distance between maxima or minima of a periodic or oscillating wave disturbance.

Waves, internal – See internal waves.

WCRP - World Climate Research Program.

WDC - World Data Centre.

Weber number – A non-dimensional number relating to the effect of surface tension in a fluid system.

$$W = U^2 L\rho/\sigma$$

where U is a characteristic velocity, L a characteristic length, ρ density, and σ the surface tension. It is important in some problems of the action of the wind on a water surface.

Weir jetty – An updrift jetty with a low section or weir over which littoral drift moves into a predredged deposition basin which is dredged periodically.

WESTPAC - IOC Regional Committee for the Western Pacific.

Wharf – A structure built on the shore of a harbor, river, or canal, so that vessels may lie alongside to receive and discharge cargo and passengers.

Wind chop – See chop.

Wind setup – 1. The vertical rise in the stillwater level in the leeward side of a body of water caused by wind stresses on the surface of the water.

2.The difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water.

3.Synonymous with wind tide and storm surge. Storm surge is usually reserved for use on the ocean and large bodies of water. Wind setup is usually reserved for use on reservoirs and smaller bodies of water. (See Figure A-11.)

Wind tide – See wind setup, storm surge.

Wind wave – A wave resulting from the action of wind on a water surface. While the wind is acting on it, it is a sea, thereafter, a swell.

WMC - World Meteorological Center.

WMO - World Meteorological Organization.

WOCE - World Ocean Circulation Experiment.

Work – A form of energy arising from the motion of a system against a force, and existing only in the process of energy conversion. Many forms of work (electrical, chemical, etc.) may be defined by analogy with mechanical work, but in meteorology the most frequently useful mathematical expression is that for the work per unit mass W done by a gaseous system in a given reversible process from thermodynamic state s_1 to state s_2:

$$W = \int_{s_1}^{s_2} p\,d\alpha$$

where p is the pressure of the system and its specific volume. The amount of work done will be a function of the particular process as well as of the initial and final states.

Wrench fault – A strike-slip fault, or one in which the movement is chiefly horizontal.

WWSSN - World Wide Standard Seismic Network.

WWW - World Weather Watch.

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