



Intergovernmental Oceanographic Commission

Anton Bruun Memorial Lecture

OPERATIONAL OCEANOGRAPHY— A PERSPECTIVE FROM THE PRIVATE SECTOR

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ANTON FREDERICK BRUUN

ANTON FREDERICK BRUUN was born on the 14th of December 1901 as the oldest son of a farmer, but a severe attack of polio in his childhood led him to follow an academic, rather than agrarian, career. In 1926 Bruun received a Ph.D. in zoology, having several years earlier already started working for the Danish Fishery Research Institute. This association took him on cruises in the North Atlantic where he learned from such distinguished scientists as Johannes Schmidt, C.G. Johannes Petersen and Thomas Mortensen.

Of even more importance to his later activities was his participation in the *Dana* Expedition's circumnavigation of the world in 1928-1930, during which time he acquired further knowledge of marine animal life of the sea, general oceanography and techniques in oceanic research.

In the following years Bruun devoted most of his time to study the rich *Dana* collections and to the publication of his treatise on the flying fishes of the Atlantic. In 1938 he was named curator at the Zoological Museum of the University of Copenhagen and later also acted as lecturer in oceanology.

From 1945-1946 he was the leader of the *Atlantide* Expedition to the shelf areas of West Africa. This was followed by his eminent leadership of the *Galathea* Expedition in 1950-1952, which concentrated on the benthic fauna below 3,000 m and undertook the first exploration of the deep-sea trenches, revealing a special fauna to which he gave the name "hadal".

The last decade of Bruun's life was devoted to international oceanography. He was actively involved in the establishment of bodies like SCOR, IACOMS, IABO, and the IOC and was elected IOC's first chairman in 1961.

His untimely death a few months later, on 13 December 1961, put an end to many hopes and aspirations.

In 1962, the former US Presidential yacht *Williamsburg* was converted into a research vessel and renamed Anton Bruun in honour of the great scientist. The *Anton Bruun* took part in the International Indian Ocean Expedition (1959-1965) and, in the late 1960's, circumnavigated the globe in one of the last great exploratory expeditions of modern oceanography.

THE BRUUN MEMORIAL LECTURES

This series of lectures is dedicated to the memory of the noted Danish oceanographer and first chairman of the Commission, Dr. Anton Frederick Bruun. The "Anton Bruun Memorial Lectures" were established in accordance with Resolution 19 of the Sixth Session of the IOC Assembly, in which the Commission proposed that important inter-session developments be summarized by speakers in the fields of solid earth studies, physical and chemical oceanography and meteorology, and marine biology.

TWENTIETH SESSION OF THE ASSEMBLY, 29 JUNE - 9 JULY 1999

Ocean Predictability, by John Woods. In: IOC Bruun Memorial Lectures, Paris, UNESCO, 2000. (*Technical Series*, 55).

NINETEENTH SESSION OF THE ASSEMBLY, 2 - 18 JULY 1997

Common Resources, Conflicting Uses: The Economics of Coastal Resources Management, by John A. Dixon. Sixty-five Years of the Continuous Plankton Recorder Survey: 1931-1995, by Philip C. Reid; Sonia D. Batten; Harry G. Hunt.

EIGHTEENTH SESSION OF THE ASSEMBLY, PARIS, 13 - 26 JUNE 1995

Some Results of the Tropical Ocean and Global Atmosphere (TOGA) Experiment Application of El Niño Prediction to Food Production in Peru, by Pablo Lagos; New Applied Knowledge Resulting from the TOGA Programme in all Three Oceans, by James J. O'Brien.

SEVENTEENTH SESSION OF THE ASSEMBLY, 25 FEBRUARY - 11 MARCH 1993

The Role of Marine Research, Systematic Observations and Related Capacity Building and Technology Development for Ocean and Coastal Zone Sustainable Development: The Global Ocean Observing System, by John Woods; Long-Term Systematic Environmental Monitoring and Sustainable Development: The Role of WMO and of the National Meteorological and Hydrological Services, by G.O.P. Obasi.

SIXTEENTH SESSION OF THE ASSEMBLY, 7 - 21 MARCH 1991

Modelling and Prediction in Marine Science, Opening Statement, by Manuel Murillo; Overview of the Coastal Ocean Prediction Systems Programme, by Christopher N.K. Mooers; The Barents Sea/The Physical-Biological Connection, by Egil Sakshaug; The Real-Time Numerical Forecasting System for Marine Environmental Elements in China, by Chao Jiping and Wu Huiding, In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1992. (*Technical Series*, 39).

OPERATIONAL OCEANOGRAPHY— A PERSPECTIVE FROM THE PRIVATE SECTOR

RALPH RAYNER

FUGRO GEOS, UK





DR RALPH RAYNER
Managing Director,
Fugro GEOS

Following completion of a first degree in biology, and a masters degree in underwater science and technology, Dr Rayner undertook research into the physical oceanography of the Indian Ocean Chagos Archipelago leading to award of his doctorate in 1982.

His professional career started at Wimpey Laboratories Limited in 1981, where he joined a small unit working in coastal marine science. This unit later became the marine environmental sciences division of Wimpol and, in 1990, joined the newly formed Wimpey Environmental. As a director of Wimpey Environmental, Dr Rayner was responsible for the worldwide marine, freshwater, terrestrial and atmospheric consultancy businesses of the company.

In 1994 he was responsible for the formation of Global Environmental and Ocean Sciences Limited (GEOS). GEOS was acquired by the Fugro Group in 1996, and has since grown to become a world leader in the provision of oceanographic and marine meteorological consultancy services.

Throughout his career Dr Rayner has played an active part in the marine scientific community though membership of professional associations and committees, lecturing and authorship of technical and scientific papers.

He is currently a member of the Global Ocean Observing System Steering Committee, the UK NERC Coupled Ocean-Atmosphere Processes and European Climate Steering Committee, the UK Foresight Marine Panel and the Council of the Society for Underwater Technology.

His work on the Foresight Marine Panel led to the formation of the UK Marine Information Council and the European Oceanographic Industry Association, both of which he currently chairs.

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OPENING REMARKS

‘Operational’: Relating to operations,
ready for action

‘Oceanography’: The scientific study and
description of the ocean



President, distinguished colleagues, ladies and gentlemen,

It is a great honour to be asked to deliver the 2001 Anton Bruun Memorial Lecture and I thank you for your kind invitation.

In giving this lecture I have the difficult task of following a succession of distinguished past speakers. In one particular respect I stand apart from them all, in that I practise the science of oceanography in a commercial environment. For most of my professional career I have been engaged in the business of applying oceanographic science to practical engineering and environmental problems for purposes of making a profit for shareholders. However, it is here that the distinction ends, since although I am responsible for a business, I remain motivated first and foremost by the science of oceanography.

In the sense of the dictionary definition, I have been practising operational oceanography for over twenty years.

Operational oceanography has frequently been compared with meteorology. In drawing such parallels, it must be remembered that the observational and modelling capacity underpinning operational meteorology has been developed over a considerable period of time and has reached a mature stage. Operational oceanography on the other hand, especially at a global scale, is still in its infancy.

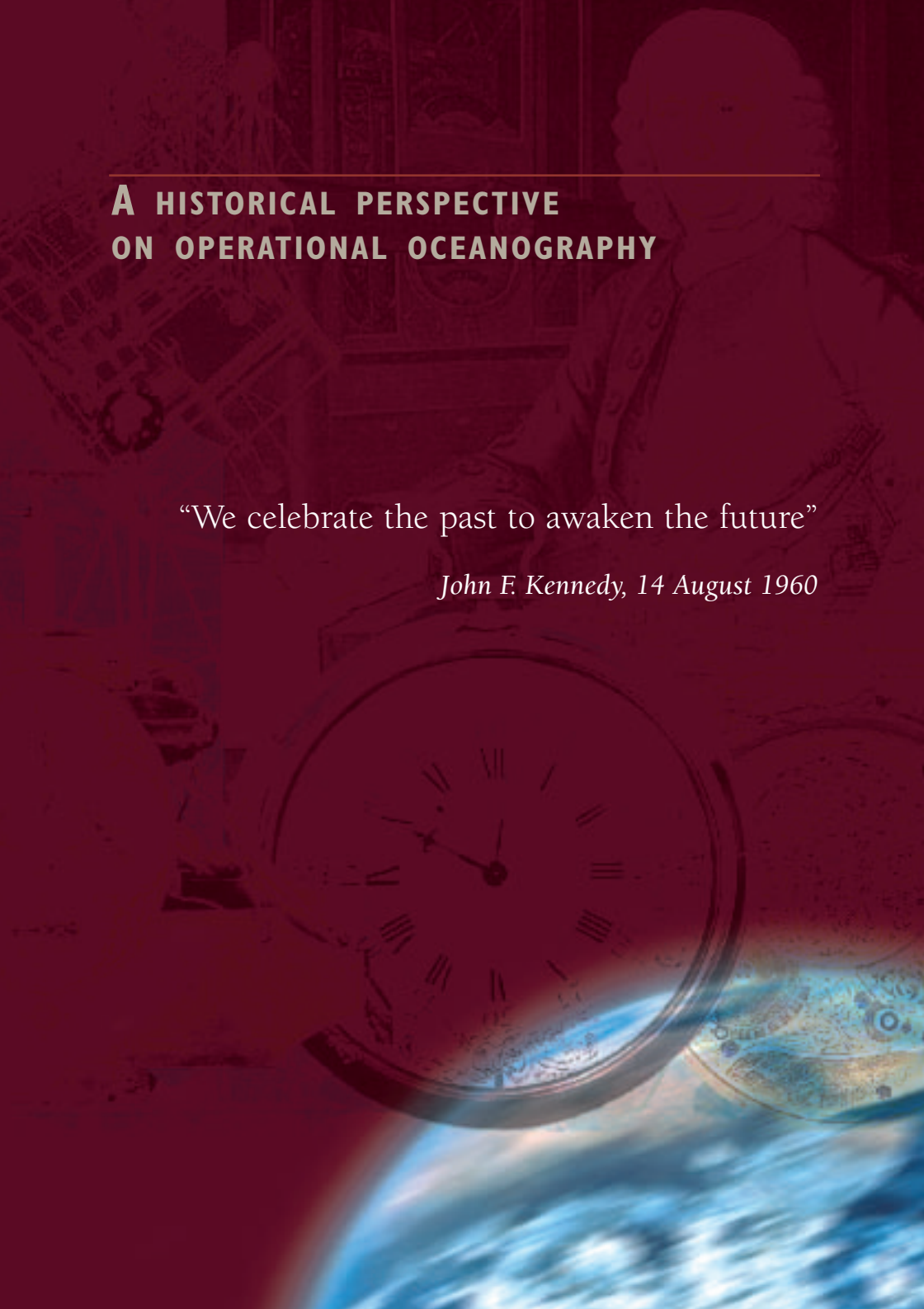
In the early stages of the development of operational meteorology the role of the private sector as a provider of data products was a minor one. But in the last few decades there has been a rapid growth in private sector activity, to the extent that commercial companies dominate the provision of data products to a large and growing range of customers.

Commercial activity in the provision of operational oceanographic data products has also advanced considerably. In contrast to the activity in meteorological services, satisfying the demands of customers has preceded the development of significant public sector capability.

The creation of global operational observing and forecasting systems analogous to those in meteorology will permit considerable enhancement of existing data products and the development of many new products, some of which will undoubtedly lead to commercial opportunities.

But the commercial market is currently much smaller than that for meteorological products and, for reasons I will return to later, it is likely that this will remain the case.

First I will set the scene with a brief excursion into the historical roots of present day oceanographic science.



A HISTORICAL PERSPECTIVE ON OPERATIONAL OCEANOGRAPHY

“We celebrate the past to awaken the future”

John F. Kennedy, 14 August 1960

From its earliest beginnings, oceanography has been a discipline with vital practical applications and the development of marine science and technology has always been closely linked to the strategic and practical needs of government and commerce.

Although we have been attempting to predict ocean behaviour for over two thousand years, the first systematic use of marine information to create ‘operational data products’ on a significant scale lies within the activities of early chart makers. Their work underpinned world trade and played a key role in the outcome of conflicts between nations. Although the first hydrographic office was established in France in 1720, it was the British Admiralty Hydrographic Office, created in 1795, that became the dominant worldwide provider of nautical charts — an early example of a globalised marine information business.

The accuracy of the hydrographer’s work, and the effective use of hydrographic data products, depended on navigation. But the ability to accurately navigate the world’s oceans had to await the invention of a key piece of ‘marine information technology’ which emerged during the second half of the 18th century — the marine chronometer.

It is a common misconception that science leads to technology in a more or less linear fashion. Prior to the latter part of the 19th century this was certainly not the case. Few of the major industrial innovators between the mid-1700’s and the mid-1800’s were scientists. Indeed most were artisans or engineers with little or no scientific training. Their goal was not to understand how the world worked, but to make machines that worked better at a



lower cost. During this period, radical innovations were not the fruit of scientific breakthroughs but of indefatigable trial and error under the guidance of experience and a craft tradition. These were men of common sense, curiosity, energy and vast ingenuity, standing on the shoulders not of scholars but of similar practical types. This was certainly the case of the inventor who solved the longitude problem.

The story of John Harrison's invention and perfection of the world's first marine chronometer is now well known through the publication and subsequent dramatisation of *Longitude* (Sobel, 1995). He developed



the solution to the problem of determining longitude at sea, the most important scientific problem of his time, through increasing the accuracy of timekeeping. The story of his life's work, seeking to gain acceptance for his ideas, contains some interesting and important lessons about the tensions that existed between academics, politicians and industry. It is my contention that these tensions still exist.

Today's hydrographic surveying and precision marine navigation businesses are all descended from these early beginnings. The key components of the marine information business now draw on a bewildering array of technologies from elaborate swathe sonars to the satellites of the Global Positioning System. By means of atomic



clocks, global time is set to an accuracy Harrison would not have believed possible.

The origins of our ability to understand and predict the characteristics and behaviour of the oceans and the geology of the ocean floor has a shorter history than charting and navigation. Indeed, it was not until the late 19th century that oceanography began to emerge as a separate scientific discipline.

The United Kingdom can lay claim to a pivotal role in the establishment of oceanography not so much through the efforts of a single individual, but through collective endeavours. The pioneering three and a half year voyage of H.M.S. *Challenger*, which sailed from Portsmouth in the late 19th Century, covered some 68,890 miles. The many years spent working up the data and samples collected during her voyage laid much of the foundation for the many strands of present day oceanographic science and continues today.

For me, of the individuals who made early contributions to oceanography in a truly heroic style, the life and work of Fridtjof Nansen stands out as exceptional. As a scientist, explorer, politician and humanitarian Nansen applied his energy and determination to making a difference, not just in science but in society as well.

It is hard to conceive the degree of determination and conviction that lay behind the voyage of the *Fram* — locking a ship into the arctic polar ice off the coast of Siberia, confident that she would move with the then unknown circumpolar current, to emerge some three years later off Spitzbergen. All this at a time when no communication was possible once a ship was out of sight of inhabited land. Nansen, and



Voyage of H.M.S. *Challenger* (1872-1876)



Fridtjof Nansen and the first voyage of the *Fram* (1893-1896)

other key thinkers of the time, such as his friend and colleague Otto Sverdrup, gave us fundamental insights into how the oceans work; insights based on careful observation and analysis of data. Perhaps as important, Nansen demonstrated the need for inspiration, hard work, daring and adventure in achieving significant progress.

Another key contributor to the development of operational oceanography was Matthew Fontaine Maury. Maury's painstaking and methodical assessment of vessel logs created a better understanding of Atlantic Ocean currents, and especially the Gulf Stream. This was one of the first examples of a systematic



Matthew Fontaine Maury and the first charts of the Atlantic and the Gulf Stream

derivation of the circulation in an ocean basin. In adding value to this existing data set, his objective was an overtly commercial one

— to reduce the passage time of Atlantic crossings by taking advantage of the ocean environment. Maury was also a pioneer of early attempts to chart the deep ocean floor. Armed with a collection of a mere 200 deep water soundings hundreds of miles apart in the Atlantic, he produced the first chart of an entire ocean basin.

The voyage of the *Challenger* added many hundreds of soundings to Maury's collection. However, the business of determining ocean depth remained a tedious one. To measure the depth at a single deep water station and dredge a sample of the bottom was a long day's work, a day spent tossing on the waves and listening to the whine of a steam winch as it reeled in first the sounding line, then the dredge.

In today's world we now perform the same task using acoustic methods. These had their beginnings in some underwater bell ringing. In November of 1826, a Swiss mathematician, Jean Daniel Colladon, positioned an assistant in a boat on one side of Lake Geneva. A 140 pound church bell hung from the boat a few feet below the surface. As the assistant struck the bell with a hammer and simultaneously lit a flare, Colladon sat in a boat at the other side of the lake, eight miles away, listening with a 17 foot long ear trumpet. This experiment on sound propagation through water laid the foundation for acoustic methods to probe the ocean depths. Subsequent development was then driven by pressing operational needs — to detect icebergs after the sinking of the *Titanic*, and to detect submarines after the sinking of the *Lusitania* during the second world war.



The extension of acoustic techniques to map sub-surface geology was firmly rooted in the quest for academic knowledge about the formation of the ocean floor. It was the founder of the Lamont Doherty Earth Observatory, Maurice Ewing, who pioneered the use of powerful sound sources, in his case sticks of dynamite, to penetrate the buried layers of the ocean crust. His pioneering work led to the use of seismic techniques to help determine the engineering properties of the seafloor, and to prospect for offshore oil and gas.

The pioneering period of oceanography had its full share of heroic and adventurous characters setting out on epic voyages of discovery and, along the way, unravelling many of the secrets and mysteries of the previously unfathomable oceans. Their emphasis was more on the description of the oceans and ocean processes than on long-term observation and the ability to predict future states.

In contrast, early work in the science of meteorology was firmly rooted in the need to be able to understand climate and forecast the weather. So from its earliest beginnings it comprised the systematic analysis of long periods of relatively routine observations. Here too there were some heroic explorers. For example, the Picards who set about voyages of exploration not only in the oceans but also in the atmosphere — at one time holding the record for both the deepest descent into the oceans and the highest ascent in the atmosphere. In the main though, meteorology was founded on the analysis and use of routine, mostly land based, synoptic observations for which there was no parallel in early oceanography, except perhaps in the study of tides.



Meteorologists concentrated on determining the statistical basis of climate, and the principal features of atmospheric circulation. The advent of electronic communications, provided the basis to bring together global synoptic observations in near real-time. The digital computer permitted their use to support numerical simulations of the behaviour of the global atmosphere leading to today's forecasting capability. Add satellite observations and the spectacular increases in the speed of computers and you have the ingredients that have allowed present day meteorology to challenge the theoretical limits of atmospheric predictability.

Yet it is only in the last few decades that oceanography has similarly progressed towards routine, regular and continuous observation of the oceans coupled to operational rather than experimental ocean models. The objective has been to continuously monitor and forecast ocean behaviour on a global scale, in a manner analogous to meteorology. But so far we are way behind the meteorologists and lack much of the basic observing and communications infrastructure that they take for granted.

Operational oceanography requires a different kind of scientist compared to the early pioneers of our discipline. Largely gone are the lone, often bearded scientists of the past, with their discipline firmly based in the teamwork of seagoing oceanography.

Operational oceanography also demands a different type of teamwork. It must bring together the data from satellite observing systems and large scale automated observations at sea and permit the assimilation of these data into complex models running on



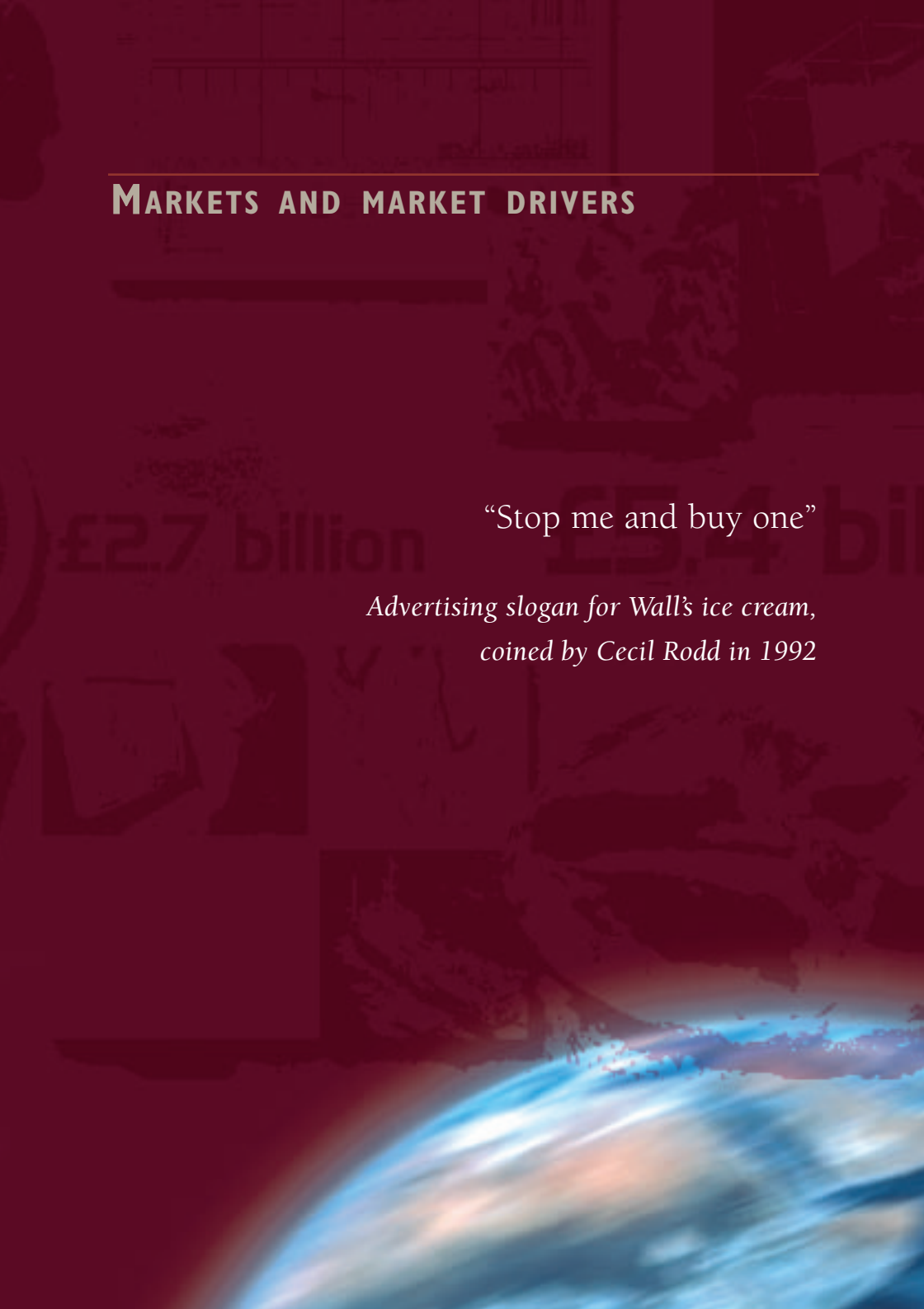
some of the world's fastest computers. This is an activity that depends not only on the technologies of instrument miniaturisation, satellite sensing systems and the means to transmit, manage and analyse vast volumes of data, but also on a very different breed of oceanographers and engineers.

So what are the drivers for the World Ocean Circulation Experiment, large scale data assimilation programmes such as GODAE and ultimately the creation of a truly global capacity in long-term monitoring and forecasting of the oceans?

MARKETS AND MARKET DRIVERS

“Stop me and buy one”

*Advertising slogan for Wall's ice cream,
coined by Cecil Rodd in 1992*



Although the scientific parallels between operational meteorology and oceanography are enticing, there are important differences in the drivers for their development and the commercial markets for their respective data products.

The early drivers for operational meteorology are self-evident — understanding climate, and forecasting the weather, has always had a vital impact on human affairs. The requirement for a corresponding level of understanding of the ocean environment is more recent.

Granted there have been long standing historical reasons to understand the marine environment from the standpoint of maritime trade and naval operations. However apart from the demands of submarine warfare many of the requirements in this area are more associated with marine meteorology than with oceanography.

The more recent need for comprehensive long-term monitoring and prediction of the physics, chemistry and biology of the oceans has been driven partly by the requirements of coastal management and partly the growing exploitation and sometimes conflicting or unsustainable use of ocean resources. But even these probably cannot justify an investment in global observation and forecasting of the oceans on a scale equivalent to that in operational meteorology.

There is another significant driver for the development of operational oceanography and that is the need to gain a better understanding of the role of the oceans in short and long-term

climate perturbations. Since the societal impact of such changes, whether natural or anthropogenic, is likely to be large this undoubtedly does merit significant public investment.

Improved prediction of climate change and the ability to respond to strategic concerns associated with global use of ocean resources thus form the primary justification for establishing a Global Ocean Observing System (GOOS). Putting a value on such needs is extremely difficult, since this is not a 'market' in the established commercial sense.

It is clear though that the oceans provide vast benefits. In a recent study the total value of the services drawn from the marine environment was estimated at \$18 trillion *per annum* (Costanza et al. 1997). Knowing enough about the oceans to exploit these benefits in a sustainable and environmentally acceptable way, increasingly requires that we manage the marine environment to the same degree as the land. Achieving this depends on the acquisition and utilisation of large volumes of marine information to support the management process. If you add to this the need to understand the pivotal role of the oceans in controlling climate then you have a very convincing argument for investment in GOOS. This is the argument that needs to be put to politicians for a Global Ocean Observing System to become a reality.

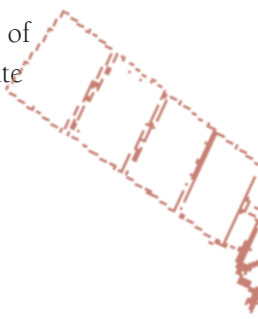
Unfortunately, in the early stages of establishing a case for GOOS rather more spurious justifications were frequently proposed — based on the projected value of marketable



operational data products. In my view these served only to undermine rather than strengthen the case for GOOS and created false expectations about the level of commercial opportunity.

It is necessary to take great care when evaluating and predicting the size of markets. In the case of the marine information sector there has frequently been confusion between the value of activities underpinned by marine information and the value of the primary market for marine information products and services. There has also been a tendency towards the view that if you can create a new or improved data product someone will be willing to buy it and perhaps pay a price directly related to the benefits that will accrue from its use. In practise, the market for data and data products is a highly competitive and a highly discretionary one, where most of the potential customers are very conservative in their purchasing.

The confusion between what might be sold and what can be sold has led to gross overestimates of the commercial value of operational data products. We have seen many examples of products seeking a market as opposed to markets requiring a product. For example, in the early phases of the development of earth observation satellites it was predicted that sales of satellite earth observation data would reach \$1,350 million by 2000 (Anon, 1999). Latest estimates for 2000 indicate that actual sales were of the order of \$300 million and that most of these were sales from one part of the public sector to another. The marine information sector too has had its share of wildly optimistic projections of market size.



So what is the current volume of commercial activity in sales of operational oceanographic data products? How will it develop in the future?

Let us start by estimating the total volume of commercial activity in the marine environment in terms of expenditure by sector. If we add together all of this expenditure including offshore oil and gas production, shipping revenues and naval expenditure we reach a total of about \$1 trillion. This is the approximate value of global maritime activity.

The value of marine information products and services that underpin this economic activity is a much smaller number estimated at about \$4 billion with a projected growth, in real terms, to \$8 billion by 2015 (Rayner et al., 1999). The marine information products and services business is currently dominated by sales of survey and geophysical data products, information about the topography and geology of the oceans, rather than sales of what we would define as operational oceanographic products.

Although the fastest rates of market growth are expected in information systems, consultancy and forecasting the projected total size of the market is modest rather than spectacular.

Now let's focus on the commercial value of operational oceanographic products and compare this with the value of corresponding activity in operational meteorology.

Undoubtedly the implementation of a full ocean observing and forecasting system as envisaged in the plans for GOOS will lead




to improved ocean information in support of commercial needs. However, this market is currently small, and while it can be further developed with enhanced and new products, it is unlikely to reach a scale equivalent to that of operational meteorology.

The commercial market for operational meteorological products is valued at in excess of \$1 billion per annum. It comprises sales of forecast products to a very wide range of specialist customer groups such as utilities, the media, recreation, transport, commodities and trade and also includes a very large public demand for meteorological information.

In contrast, the market for marine forecast information is much smaller with total sales in the order of \$70 million per annum. The reason for this large difference does not relate to the levels of maturity of the fields of operational meteorology and oceanography but to fundamental differences in need and demand for operational data products.

Commercial demands for operational oceanographic data products fall into a relatively narrow range of customer requirements. This is hardly surprising, as the bulk of commercial activity takes place on land and the human population lives on land, only venturing to sea in search of resources, to transport goods, to wage war or to spend leisure time. The principle commercial markets for operational oceanographic data products are therefore confined to the oil and gas industry, the shipping industry, the coastal management sector, fisheries and the leisure industry.



This brings me to another important issue and that is the distinction between users of operational oceanographic data and customers who operate in, or make use of the marine environment.





USERS AND CUSTOMERS

‘User’: Person who uses

‘Customer’: A buyer

‘Customise’: Make in such a way as to suit specified individual requirements

Chambers Dictionary, 1999

The terms user and customer are often used interchangeably, whereas strictly they have quite different meanings. A customer is someone or some organisation that purchases something. A user is someone of some organisation that makes use of something.

This distinction is critical. Customers for operational oceanography want to know how the marine environment influences their activities in terms of cost, safety and compliance with statutory obligations. They generally have no direct interest, or capability, in operational oceanography or the use of operational oceanographic information. Commercial oceanographic service providers add value to data and knowledge and customise it to meet a specific demand.

An example of this is in the installation of the ‘topside’ of a gas production facility in what is known in the oil and gas industry as a ‘floatover’. The operation of marrying this rather large and heavy installation with the submarine structure used to support it is a particularly delicate one. The organisation conducting this operation



has no internal capability in operational oceanography. To cost effectively and safely complete the operation it clearly requires some highly specific help in understanding and predicting the marine environment. It would be of little use to provide the engineers responsible for this operation with a large quantity of generalised operational oceanographic data. What they require is a highly specific tailoring of the available information and the assurance that observations and forecasts are as accurate as possible.

To get this information they turn to a commercial oceanographic service provider who uses available data and knowledge to support the planning of the operation and the installation itself. This is a complex task. In the planning stage, the commercial service provider must evaluate climatological information in the context of each phase of the installation operation. Working with the installation contractor, the provider must determine the statistical risk associated with different start dates for the project and differing plans for the installation operation.

During the installation itself, the oceanographic provider must operate the real-time and forecast systems needed to make critical decisions about when to proceed with particular tasks. In the case of a 'floatover', this involves real-time monitoring of the motion of the barge carrying the topside and predicting the response of the whole system to the prevailing and forecast meteorological and oceanographic conditions. Both real-time measurements and model predictions have to consider the response of the barge to long period waves of a specific critical wavelength that may occur from more than one direction at the same time. This example highlights the difference between a user and a customer. Users are ocean



information specialists who add value to data and knowledge in the context of a particular customer's needs.

Generally speaking, commercial organisations do not choose to engage in activities that are outside their core business, preferring to use specialist consultants and contractors to meet their needs.

Some further examples will serve to illustrate the types of operational products currently being purchased by customers. My examples are drawn from the oil and gas sector, as this is currently the largest customer for operational oceanographic services.

Many marine activities, and especially those of the offshore oil and gas industry, require knowledge of meteorological and oceanographic conditions if they are to be conducted safely and effectively. This requirement has led to the development of real-time metocean monitoring systems in several of the world's major offshore oil and gas basins.

An example is the Shell Metnet system, which acquires real-time metocean data from over twenty offshore installations in the North Sea. These data undergo rigorous quality control before being used to support a variety of offshore operations as well as providing data to support offshore weather and seastate forecasting.

Similar installations exist in other regions such as the South China Sea and the Gulf of Mexico.

The data from monitoring systems of this type is used to build up data archives, which in many cases now exceed 20 years in duration. These



archival data sets are used as one of the principal inputs to the derivation of statistical operating criteria and the environmental criteria used to support the design of new installations or modifications to existing structures.

In some cases these systems cater for integrated provision of real-time data and forecasts distributed via a customer Intranet or via the Internet.

In the most advanced systems, digital libraries are also integrated to permit immediate access to environmental design information and operational metocean statistics.

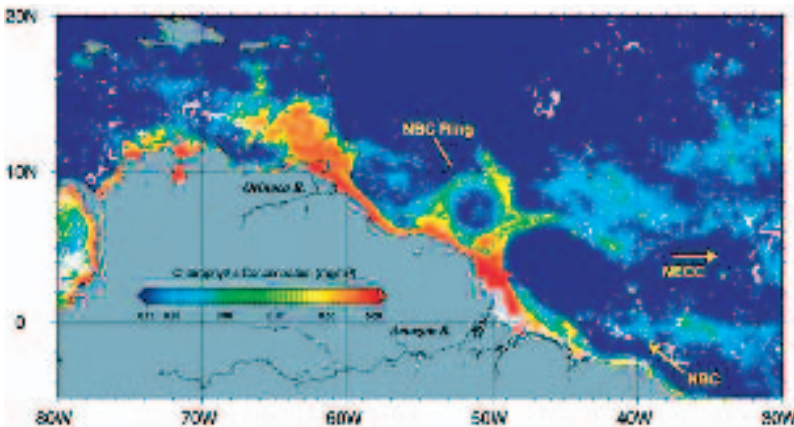
A further example is forecasting of currents for engineering applications. In the absence of fully developed global and regional operational models, the forecasting of non-tidal currents must rely on novel use of existing observations.

For example, in a current forecasting system used in support of deepwater drilling on the European continental slope, the analysis of real-time local observations is coupled with trend analysis of long-term time histories. This provides a means of forecasting both the deterministic tidal component of the current and the likely development of the slope current and provides a forecast product sufficient for most operational needs.

Satellite observations play an increasingly important role in ocean forecasting systems. For example, Seawifs images like this one showing a retroflection eddy breaking off the North




Brazil Current can be used along with satellite altimetry data to help predict the path and intensity of such features.



The reason for the high level of interest in these eddies is that they propagate towards the Caribbean where they may cross an area of active offshore exploration. These are dynamic features capable of generating surface currents of over a metre per second. If they cross an active drilling site they would cause considerable problems as the drill rigs being used cannot operate under such conditions. By combining air dropped drifters and satellite altimetry, a forecast product can be generated which permits forecasting of the track of each eddy.

The emerging capability in global and basin scale oceanographic forecast models offers a number of exciting opportunities. My own organisation is seeking to develop these opportunities through collaboration with a research





centre active in the field of operational model development. In a joint venture between Fugro GEOS and the Nansen Environmental and Remote Sensing Center called 'Ocean Numerics' we are seeking to apply research models to practical marine information needs, initially in large-scale hindcast studies. This involves the development of nested model systems that are being used to generate long-term hindcasts of the European continental slope and more recently the shelf and slope off West Africa. Output from these hindcasts is used to support the derivation of design and operating criteria for deepwater oil and gas fields.

Of course what we really want to be able to do is to provide good quality forecasts of 'ocean weather'. The objective of 'Ocean Numerics' is to provide the bridge between research into operational ocean forecast techniques and their use to satisfy the needs of commercial customers.

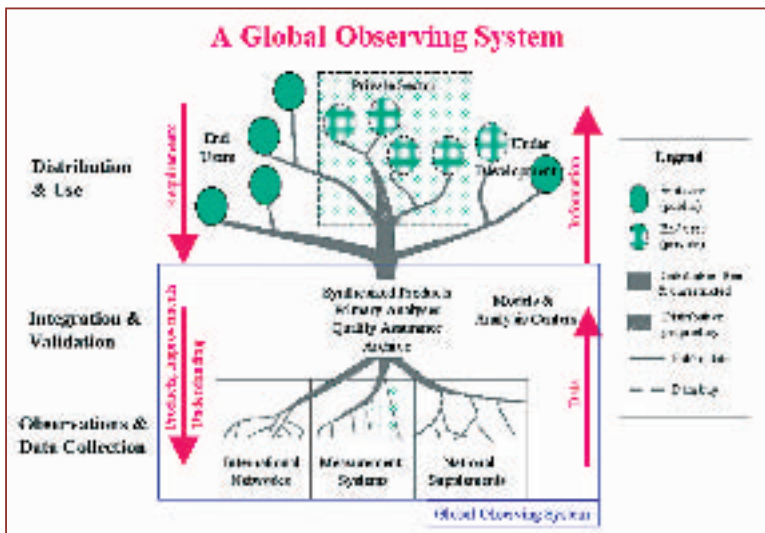
In this endeavour we are building on the work of many organisations and individuals. In particular we aim to commercially develop the outcome of a large European research initiative called Topaz.

The objective of the Topaz project is to create a pre-operational capability in basin scale oceanographic forecasting. 'Ocean Numerics' is the vehicle to then launch a fully fledged commercial forecasting service.

This interplay between public and private sector organisations provides an example of how commercial providers might draw on

GOOS products to generate value added products. This is neatly summarised in this 'tree and root' schematic of how a global observing system should be structured:

In this diagram we see how the public and private sector might interact. The public sector provides a stream of synoptic marine observations, perhaps with private contributions, and creates global scale model outputs. The private sector adds value to meet the needs of specific customer groups.



THE FUTURE

Synthesized Products
Primary Analyses
Quality Assurance
Archive

Models &
Analysis Centers

International
Networks

“Making predictions is very difficult,
particularly about the future”

Global Observing System


Nils Bohr

It is probable that private sector providers will remain the principal conduit through which improved oceanographic knowledge, information and data will be applied to the needs of commercial customers. This is because private sector providers will probably always be better able to customise information and knowledge to satisfy specialised niche demands and to marry oceanographic products with other data in such a way that they serve very specific customer needs. Because of their organisational structure, they are better at customer handholding and at specialisation. They are also better able to provide the other skills and infrastructure that inevitably accompany commercial activity.

There are some in the meteorological industry who foresee that operational meteorology will become a wholly private sector activity. The arguments that they use could equally be applied to operational oceanography. But my view is that this is very unlikely to happen in either case. The strategic needs for both operational meteorology and operational oceanography are just too great to place them entirely in private hands. Equally, the infrastructure necessary to support global observations and modelling will probably never stand up to a commercial measure of return on investment.

The private sector may be able to tailor products to specific market niches more effectively than its public sector counterparts. However, it is doubtful that the private sector will ever be in a position to support the research base needed to underpin the continual development of global operational oceanography. With this in mind I would like to conclude by turning to the





fostering of scientific progress, innovation and the development of new commercial products and services. In today's world this is a far more complex process than it was during the era of the industrial revolution. Science, technology and commerce are now intricately linked, and steered by incredibly complex political, social and cultural factors operating on a global basis.

As the frontiers of technology move ever closer to the frontiers of science, policy makers are increasingly seeking to form a direct link between scientific research and its commercial exploitation. Policy makers, at least in some countries, are also driving large parts of the public and university research base towards behaving more like businesses. Stronger linkages between academic research and industrial exploitation are clearly desirable. However, there is a danger that a naive and over prescriptive approach, or one which excessively blurs the functional boundaries between government, academia and industry, will impair the flow of new ideas that will underpin future wealth creation.

Central to the success of the marine information business is a strong curiosity and strategic research base with good links to industry to bring together those creating new ideas with those who understand market needs. A policy and cultural framework that encourages and fosters this process is a necessity.

In short, what is needed are links that encourage the wheels of commerce to turn.

Rather than being a linear process, the process of ‘technology transfer’ can be likened to a spoked wheel with all of the various participants around the rim and with the spokes representing the linkages between them. The participants include government and government policy makers, government agencies, research organisations and public and private research scientists and engineers, educators and educational establishments, industry and industrial scientists and engineers, users and customers. Unless the wheel is constructed and balanced properly, it will not move forward. Progress requires that participants have the right aims, with each fulfilling an appropriate role, and each having the correct linkages and partnerships with the others.

As we stand in the midst of the information revolution we are already seeing a rapid acceleration in the ways in which marine information is captured, distributed and utilised on a global scale. Like the early pioneers in our field, none of us has the foresight to see exactly where this process will lead us or precisely what commercial opportunities it may create but hopefully it will lead to an improved capacity to manage and protect the marine environment and to a globally enhanced quality of life.

REFERENCES

- Anon. *Space applications and programmes*. In: Tenth report of the UK House of Commons Select Committee on Trade and Industry, 1999
- Costanza et al. The value of the world's ecosystem services and natural capital, *Nature*, Volume 387, 15 May 1997
- Rayner et al. *The Greenwich Project - A Marine Information Strategy for the United Kingdom*. UK Department of Trade and Industry publication 4071/10K/05/99/NP, URN 99/668
- Sobel, Dava, '*Longitude*' — *The true story of the lone genius who solved the greatest scientific problem of his time*. New York, Walker, 1995. 184 pp.

FIFTEENTH SESSION OF THE ASSEMBLY, PARIS, 4 - 19 JULY 1989

Impact of New Technology on Marine Scientific Research, Opening Statement, by Manuel Murillo; Submersibles and Remotely-Operated Vehicles at the Service of Oceanological Research, by B. Grandvaux; The Shape of the Ocean Floor, by Anthony S. Laughton; Observing Change in the Global Ocean: the View from Space, by D. James Baker. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1991. (*Technical Series*, 36).

FOURTEENTH SESSION OF THE ASSEMBLY, PARIS, 17 MARCH - 1 APRIL 1987

Recent Advances in Selected Areas of Ocean Sciences in the Regions of the Caribbean, Indian Ocean and the Western Pacific, Opening Statement, by M.A. Martin-Sané; The Scientific Basis for the Assessment of Marine Pollution in the Caribbean Sea and Adjacent Regions: the CARIPOL Experience, by Jorge E. Corredor; Monsoon and Currents in the Indian Ocean, by Michèle Fieux; Sea-level Changes, Environments, Tectonics, Marine Resources and Phosphorites, by Peter J. Cook. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1988. (*Technical Series*, 34).

THIRTEENTH SESSION OF THE ASSEMBLY, PARIS, 12 - 18 MARCH 1985

Past and Future Perspectives of the Commission, Opening Statement, by M.A. Martin-Sané; On the Benefits of Ocean Studies, by W.S. Wooster; What Steps Should Be Taken to Meet the Challenges of the Future in Ocean Services and Technology and in the Identification of Disturbances Caused by Men? by S. Z. Qasim; How Can the International Scientific Community Work Together in the Era of an Emerging Ocean Regime to Help all Partners to Achieve a Better Understanding of Ocean Phenomena and their Impact on Man? by A. Yankov.

TWELFTH SESSION OF THE ASSEMBLY, PARIS, 3 - 19 NOVEMBER 1982

Ocean Science for the Year 2000, Opening Statement, by Neil J. Campbell; Future Research on the Ocean Floor and What Lies Beneath it, by M. Talwani; Future in Physical Oceanography and Climate, by K. Hasselmann; Future Research in Ocean Chemistry, by D. Dyrssen; Future Research Biological Oceanography, by M.V. Angel. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1984. (*Technical Series*, 28).

ELEVENTH SESSION OF THE ASSEMBLY, PARIS, 22 OCTOBER - 3 NOVEMBER 1979

Marine Environment and Resources in the Ocean, Opening Statement, by Neil J. Campbell; Non-Living Marine Resources, by E. Seibold; Ocean Energy, by Kenzo Takano; A Short-term Climatic Change: A Physical Oceanographer's Point of View, by J.S. Godfrey; Living Marine Resources, by D.H. Cushing. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1980. (*Technical Series*, 21).

TENTH SESSION OF THE ASSEMBLY, PARIS, 27 OCTOBER - 10 NOVEMBER 1977

The Importance and Application of Satellite and Remotely Sensed Data to Oceanography, Opening Statement, by Agustín Ayala-Castañares; Past, Present and Future Capabilities of Satellites Relative to the Needs of Ocean Sciences, by John R. Apel; Remote Sensing of the Ocean in the USSR, by Boris Nelepo; Interaction of Electromagnetic Waves and Oceanic Waves, by Werner Alpers; Determination of Oceanic Tides from Space, by D.E. Cartwright. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1978. (*Technical Series*, 19).

NINTH SESSION OF THE ASSEMBLY, PARIS, 22 OCTOBER - 4 NOVEMBER 1975

Co-operative Study of the Kuroshio and Adjacent Regions (CSK), Opening Statement, by H.U. Roll; Co-operative Study of the Kuroshio and Adjacent Regions (CSK), by Ken Sugawara; Accuracy of the Determination of Nutrient Elements in Sea Water by Using CSK Standard Solutions, by Mitsuko Ambe; Dynamics of the Kuroshio Current: Experimental and Theoretical Studies from South of Kyushu to the Izu-ogasawara Ridge, by Allan R. Robinson; The Dynamics and Thermohaline Structure of the Waters of the Kuroshio and Adjacent Regions, by Vladimir G. Kort. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1976. (*Technical Series*, 15).

EIGHTH SESSION OF THE ASSEMBLY, PARIS, 5 - 17 NOVEMBER 1973

Tropical Atlantic, from the Guinean Trawling Survey and the International Co-operative Investigations of the Tropical Atlantic (ICITA) to the Present day; Introduction, by T. Austin; The Equatorial Undercurrent in the Atlantic, by K. Voigt; Plankton of the Tropical Atlantic, by J. Krey; Fishery Resources of the Tropical Easter-Central Atlantic Ocean: Exploration, Utilization and Management since 1960, by F. Williams; Some Results of the Eastern Atlantic Continental Margin Programme, by K.O. Emery. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1974. (*Technical Series*, 11).

SEVENTH SESSION OF THE ASSEMBLY, PARIS, 26 OCTOBER - 6 NOVEMBER 1971

The Biology of the Indian Ocean, by G.F. Humphrey; Recent Meteorological Results from the International Indian Ocean Expedition, by C.S. Ramage; A Review of Recent Physical Oceanographic Work in the Indian Ocean, by J.C. Swallow. In: IOC. Bruun Memorial Lectures, Paris, UNESCO, 1972. (*Technical Series*, 10).

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