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ENGINEERING APPLICATIONS OF DRIFTING BUOYS

Interim Report prepared by ECOR Working Group
on Engineering Applications of Drifting Buoys

(SC-82/CONF.218/COL.41)

GENERAL CONCLUSIONS AND RECOMMENDATIONS

- The oceanographic and meteorological research communities should take the lead in evolving drifting buoy systems and the international programs to encourage their use.
- ECOR should continue to be consulted in the formulation of international buoy programs so that the engineering community can be informed of future buoy programs and the environmental data which will result from them.
- Drifting meteorological buoy programs will be of major importance to engineers if these programs result in improved operational weather forecasting in offshore areas of interest.
- Drifting oceanographic buoy programs will be of importance to engineers if these programs result in improved data on mean environmental parameters and the probability and magnitude of extreme events in offshore areas of interest.
- The need exists in the engineering community for an inexpensive drifting buoy system suitable for nearshore operation with a spatial resolution of 0.2-1 km and with a minimum of several position fixes daily.
- IOC/SCOR/ECOR partnership should examine the availability of such a buoy system in consultation with buoy and satellite development engineers and the technical representative of the present ARGOS system.

1. Introduction

This interim report from the Engineering Committee on Ocean Resources' (ECOR) Working Group on Engineering Applications of Drifting Buoys (WG-EADB) is submitted to the Intergovernmental Oceanography Commission (IOC) in response to Resolution EC-XIII.10 adopted by the Thirteenth Session of the Executive Council of IOC. This resolution "requests Scientific Committee on Oceanic Research (SCOR) and ECOR to assist the Commission in defining the oceanographic applications of drifting buoys."

An initial IOC/ECOR/SCOR consultative meeting on Drifting Buoy Programs was held in London (April 1981), under the chairmanship of Dr. J. Garrett, the Chairman of SCOR's Working Group on Oceanographic Applications of Drifting Buoys (WG-66). ECOR was represented by Dr. J. Michael Hall. In response to the IOC request, ECOR requested its U.S. adhering body, the Marine Board of the National Academy of Sciences, to form an international working group under the chairmanship of Dr. J. M. Hall to address ECOR's involvement in the resolution. The working group was formed and tasked with several of the issues raised at the London meeting; it was to work in parallel with SCOR Working Group 66 on the oceanographic application of drifting buoys.

The terms of reference of the ECOR WG-EADB were selected to define the most appropriate role for ECOR in these deliberations:

- Identify selected ocean engineering areas that could benefit significantly from the application of drifting buoy technology.
- Summarize observational needs (for these applications) in terms of parameters, sampling density and duration, and geographical emphasis.
- Identify technical and operational deficiencies likely to be encountered in applying today's technology to new (engineering) applications.
- Identify logistical opportunities and constraints associated with these applications.
- Advise IOC on the probable extent of engineering programs employing drifters during the next decade, and inform the Secretariat of areas in which buoy observations made through IOC and others could provide information suitable for engineering purposes.
- Establish liaison with SCOR WG-66 and the appropriate World Meteorological Organization (WMO) Advisory Group; identify potential areas of mutual concern.

2. Membership and Method of Operation

The membership of ECOR's WG-EADB is given in Attachment A. The working group convened a meeting of international professionals associated with ocean engineering and industry at the Joint Oceanography Assembly, held in Halifax, Nova Scotia, August 13, 1982. (Attendees are listed in Attachment B.) This report is the consensus of the participants at the meeting, supplemented by submissions from corresponding members of the working group (see Attachment A). A draft of this report was subsequently distributed to the members of the WG-EADB and additional participants at the Halifax session, with a request for review and comment. The final version of this report will be reviewed by the Marine Board and submitted formally to the IOC on behalf of ECOR; the interim version is to be used as a working paper at the Twelfth IOC Assembly in Paris, in November 1982.

3. Characteristics of Engineering Applications of Drifting Buoys

The Working Group discussions emphasized that the oceanographic research and meteorological communities have properly taken the lead role in determining the directions that international drifting buoy programs will take in the next decade. The environmental data from the ocean and the improved meteorological forecasting ability that will result from these programs can have significant benefit for engineering and industry in the areas of both design and operations. However, in contrast to the research interests of scientists, engineering design interests usually require both a description of mean environmental parameters and the magnitude and probable frequency of occurrence of extreme events, such as trajectories of ice islands, hurricane and severe storm conditions, water column loading, etc. In addition, operation of offshore installations requires an improved oceanographic and meteorological forecast ability for the safety of personnel, integrity of the facility, and fiscal efficiency. An additional major difference between scientific and engineering applications of drifters is the geographical area(s) of interest, with a tendency for scientists to focus on understanding open ocean processes and engineers to focus primarily on coastal and offshore continental shelf regions.

For the next decade, ocean engineering and industry will be limited to depths of less than 400 meters with the possible exceptions of Ocean Thermal Energy Conversion (OTEC) facilities, deep sea mining, and exploratory deep sea drilling. Thus, the environmental data resulting from existing and planned drifting buoy programs will benefit the industrial and engineering community in the areas of mean values of parameters and improved ability to predict weather, but generally, will not be sufficient to meet their design and operational needs. Design and operational requirements will necessitate supplemental data gathering programs, which will focus on localized geographical areas of interest and have smaller spatial and temporal scales than currently envisioned for international and national drifting buoy programs. The principal need is for site-dependent, long-term, Eulerian fields of oceanographic parameters and for time series information containing characteristics of severe events. If drifters are used for such applications, the environmental data resulting from these programs will be of interest to the scientific community and the issue of data accessibility (for nonproprietary data) may become a special problem for the attention of IOC/SCOR/ECOR in the future.

4. Current and Potential Engineering Applications of Drifting Buoys

In Section 5 of this report, the Working Group has attempted to set forth some generalized conclusions regarding engineering applications and to recommend action by appropriate international bodies. The Working Group arrived at these views by examining in detail a number of specific engineering problems thought to be representative of a larger class of applications. These problems were examined in the light of the terms of reference for the Working Group: to what extent are drifting buoys apt to be of significant benefit to engineers and how will the IOC/SCOR's use of drifters improve the overall situation, if at all.

The term drifting buoy represents a broad spectrum of Lagrangian drifters and other observational platforms from drift cards to large buoys with multiple sensors and a satellite navigation system. Noting that it could not address this entire spectrum and considering the type of drifting buoy programs under discussion by WMO and IOC for the next decade, the Working Group restricted its considerations to that class of buoy. That is an expendable, low cost (a few thousand U.S. dollars) buoy with satellite tracking. Deliberations were directed to a band of technological capabilities centered about those available on such a system but focused on the requirements for such buoys to be of utility to engineering. A more comprehensive description of the present state-of-the-art in systems of this type is available in the report of SCOR Working Group 66 (October 1982).

Meteorological buoys of this class are developed and are available from government or commercial sources at a cost of approximately $5 to $10K. However, buoys dedicated to oceanographic research are still under development and are not available commercially.

Engineering interests will generally require the same sensor capabilities as physical oceanographers with the addition of surface wave height, spectrum, etc. Additionally, if such buoys are to be used by engineers, the cost must be kept to well under $10K per buoy.

To date, usage by engineers of drifting buoys has been very limited except for the example cited in the report on Artic ice applications. Therefore, the working group has concerned itself with potential usage rather than an extensive examination on present use.

4.1 Design and Operation of Arctic Offshore Facilities

Drifting buoys (particularly those using the ARGOS satellite system) have been used quite extensively in both the Arctic and the Canadian East Coast areas, mainly to build up statistics on sea ice and iceberg movements.

In order to consider logically how drifting buoys can be used to provide data to address engineering problems, it is appropriate to consider first the types of offshore facilities either in use or likely to be used. The most common type of offshore facility used for petroleum operations is the bottom-founded fixed platform. Such platforms now exist in the form of a steel or concrete structure, or an artificial island, or hybrids. A principal design criteria for a fixed platform is that it must be able to withstand the worst environmental forces likely during its design life. However, for very extreme events, the option does exist to allow major damage to occur, as long as sufficient warning time is available to evacuate people and secure wells to avoid pollution. Mobile floating platforms such as drillships can, on the other hand, avoid the worst environmental forces by moving off location. In this case, reliable real-time detection of hazardous conditions is essential.

Offshore harbours may be designed as fixed platforms. In addition to surviving ice conditions and severe storms, they have to be configured so that ships can gain access through whatever ice conditions may prevail. Potential blockage of entrances and exits by ice rubble is an issue of special concern. In areas prone to sea ice and icebergs, an additional major design issue arises from the effects of ice forces. These design forces are of major importance in the case of fixed platforms because they cannot tactically avoid extreme conditions.

Various data are required for a selected area in order to predict design ice forces. These include data on such features as ice thicknesses, ice masses, ice velocities, ice strength, etc. Designing for extreme ice features, such as icebergs off the East Coast or ice islands in the Beaufort Sea, requires data which can be gathered in part by drifting buoys. Design and operational considerations for large ice masses require the probabilities of collision by features having various levels of kinetic energy. For this kind of assessment, track statistics for extreme ice features can be acquired using drifting buoy technology. Also, drifting buoy stations can be used to provide statistics on velocities which are needed to predict kinetic energies.

For ice features characteristic of extensive ice fields, information on strain rates in the field is important; these are also a function of ice velocity.

In some cases it is believed that forces on structures may be limited by the surrounding pack ice. In this regard, one important parameter which cannot be satisfactorily measured is the in-situ ice stress in pack ice. Drifting buoys with in-situ stress sensors through the ice sheet would be of significant benefit to this area of application. Development of a reliable stress sensor which could operate remotely is presently the limiting factor, but various people are attempting to address this difficult problem.

As mentioned above, for harbour design the issue of ice rubble build-up is critical. To predict ice rubble formation, data on fine-scale ice movement are very important. Such data would require drifting buoy arrays with relatively high spatial resolution and reporting characteristic suitable for the time scales involved. These systems are not known to be readily available.

For mobile systems such as drillships which are being used for exploration, detection of hazardous ice conditions is essential. At present, aerial reconnaissance and a variety of radar systems are used extensively to detect ice and icebergs. Drifting buoys could also be used to keep track of the ice edge and to tag such features as icebergs (which may have been judged as being too large to tow). Environmental data from ice buoys used for such purposes may well enhance the surface meteorological coverage in some limited ocean areas.

Floating production systems envisioned for the future will be even more sensitive to proper detection of ice hazards, and extensive ice hazard detection systems will be needed (including drifting buoys).

4.2 Design and Operation of North Sea Offshore Facilities

In European waters where licensing is carried out for offshore drilling and production, operators first consider needed environmental data. Data are required for all phases of the program: exploration, installation, and operation. Sea state and wind data on an annual basis are required for planning installations and carrying out day-to-day operations. For detailed design of offshore structures more specific data are required for each location, including seabed data for foundations. Subsequent to the assessment of data requirements, the availability of data from weather ships, government agencies, and commercial services is appraised. In some cases these data are judged adequate, but must be extended for specific locations and for design purposes.

During installations, significant activity such as heavy lifts are planned for fine weather windows (summer months) and are not likely to be carried out during bad or poor weather because of high risk and cost.

In general, these dollar contracts are now based on a fixed price for several lifts within a program that includes a margin for waiting on weather. For offshore installations it is generally the wind forces which are most critical in operations "windows" and the availability of improved weather predictions will have a commensurate benefit to the operator.

Data for specific locations have been gathered by data buoys and these are typically evaluated for design purposes. As drilling in the North Sea has now been active since the mid-sixties, more data have been gathered and initial design criteria have been revised. For new offshore areas to be explored, drifting buoys can be used to provide routine operations data and to fulfill some specific event/time requirements. Their use, however, will be for very limited areal extent and limited periods.

4.3 Hurricanes and Severe Storms as Special Design Problems

In contrast to the general applications of drifting buoys in areas such as the North Sea, a limited application exists in the Gulf of Mexico where much more needed environmental data are available. The currents generated by hurricanes and severe storms can be an important factor in the design of oil production platforms in the Gulf of Mexico. Current speeds over 2 m/sec have been measured from offshore platforms in a storm which was below hurricane strength. The technical difficulties in making measurements in a hurricane are severe, but they can be overcome. Because of their rarity and small spatial scales, the approach to observation which relies on instrumented fixed platforms is inadequate; the probability of obtaining observations in a short time period (a few years) is unacceptably low. With respect to gathering data, exceptional luck is needed for any particular installation to experience the strongest effects of a storm, hence drifting buoys offer an attractive alternative means of acquiring such data.

Hurricanes have a typical life span of about a week; far too short a time period in which to install fixed measurement stations. Even 24 hours before storm passage, its probable position can be estimated only to within 200 km, and the radius of maximum wind is only about 40 km. Thus for a high probability of making measurements near a storm center, instruments need to be developed that either can be deployed in small numbers from hurricane hunter aircraft or are cheap enough so that an array (about a dozen) could be deployed 24-36 hours before anticipated storm passage. It may be possible to develop drifting buoys which satisfy either of these criteria. Were such systems available, they would be of significant benefit in the Gulf of Mexico and might well find use in other locations where relatively small, intense storms affect offshore design considerations.

The peak conditions in a hurricane are of less than eight hours duration. The stock FGGE drifting buoy is not adequate with satellite tracking with 3 or 4 fixes per day. For the coastal areas of most interest, the position fixing characteristics of a system such as Loran-C navigation offer a reasonable solution. The fixes could be stored, transmitted by satellite, or relayed over other radio channels. These approaches are now under investigation. Problems with the mechanical integrity of the buoy, drogue, and antenna under hurricane conditions also require investigation.

4.4 Measurement of Atmospheric Particulates

A development program is currently underway in the United States to use drifting buoys to map the distribution of airborne particulates contained in both dry fallout and precipitation. Those particulates which are radioactive will be measured and reported in near-real time by a gamma ray spectrometer on the drifting buoy. Changes in atmospheric particulate concentrations will be monitored and correlated with atmospheric parameters such as air temperature and barometric pressure as part of the program. Technology development programs now underway for other purposes are focusing on improved capabilities to measure wind speed and direction, air temperature, and subsurface temperature. The developments will be incorporated into the proposed drifting buoy design. The buoy hull design is a modification of those used by the United States in the Global Weather experiment, i.e., a spar with a conical floatation collar. The ARGOS satellite system will be employed for positioning and data transmission. Plans for deployment of these systems are not yet developed, but a representative example is a meridional array of 12 buoys with 100 km spacing in the deep ocean. Clearly, should these systems be applied on the scales now envisioned, they can contribute significantly to operational meteorological arrays in large, data sparse oceanic areas.

4.5 Drifting Buoys and OTEC

The ocean thermal energy conversion (OTEC) process utilizes the temperature difference between warm surface waters and cold deep waters to drive a condensing power cycle. The principal components of an OTEC plant will consist of a structure (land-based, shelf-mounted, floating, or propelled), a warm water intake, a cold water intake, and a discharge. Although the exact configuration depends upon the plant type, the thermal gradient requirement of about 20 C^{o} necessitates the extension of a cold water pipe to a depth of about 500-1000 m for most potential OTEC sites. The fate of the "used" waters will depend upon whether the warm and cold water discharges are separate or mixed. However, most likely the discharges will be designed so as to achieve a state of neutral buoyancy near the pycnocline which, for promising OTEC sites, is on the order of 100 m in depth.

This condensed picture of the OTEC process is sufficient to suggest two key applications of ocean current information: (1) to measure the currents and shear that will be responsible for hydrodynamic forces on the OTEC structure and intake/discharge pipes; and (2) to indicate the direction and dispersion that will be responsible for supplying intake and diluting waters and for carrying the discharge(s) away.

Currents within the upper mixed layer of the ocean are typically variable in both space and time, being influenced by such factors as wind stress, tides, and major ocean currents. Variability also exists beneath the mixed layer but to a lesser degree unless boundaries (e.g., the seabed) are present. With the upper mixed layer being on the order of 100 m, some indication is provided of the vertical resolution that would be of interest regarding hydrodynamic forces. The upper 100 m will have to be well defined whereas the water column beneath the mixed layer (to about 1000 m) will need less resolution. Once a site is decided upon, the information needed is Eulerian in nature. However, if there is some question as to the selection of an exact location for a site, drifting buoys could provide some helpful information for selecting a site of low current and shear.

Probably the biggest use of drifting buoys for OTEC application relates to the advection and dispersion of ocean waters in the upper surface layer, near the bottom of the mixed layer, and near the cold water intake. Lagrangian information is needed here since it is of interest to define the source of the intake waters and the fate of the discharge waters. The spatial and temporal resolution required will probably be on the order of tens (perhaps 50) of kilometers in the horizontal, and several complete tidal cycles (e.g., several days) in time.

4.6 Pollution Monitoring in Coastal Waters

In recent years legislation and international activity to limit or prevent the dumping of waste materials in the ocean have been a regular occurrence. Large quantities of sewage sludge, the product of primary and/or secondary treatment by municipal plants, are typically transported by barge to dump sites from 12 to 100 miles offshore. On the Pacific coast of the United States, specifically Southern California, deepwater near shore allows disposal of effluent water and sewage sludge through pipelines laid on the bottom. These pipelines terminate at depths where stable density layers of ocean water insure that waste materials would not return to beaches or contaminate surface waters. In many cases these practices continue or have been moved farther offshore and curtailed to some degree.

During the decade between 1972 and 1982 increased scientific and engineering attention has been given to understanding the physics, chemistry, and biology of such dumpsites and their environs. Study has been prompted by the desire to understand and separate the true environmental effects of ocean dumping from public perceptions which might be based on inaccurate information.

In examining the potential of a particular ocean site to serve as a sink for sewage sludge, it is necessary to understand the physics of the water motion. Current patterns are influenced directly by the wind and directly or indirectly by permanent circulation features such as the Gulf Stream. Currents at any specific site will vary with depth and with the season of the year.

An attractive method of understanding water motion entails the use of drifting buoys. These buoys typically employ a surface element used to transmit signals to determine position and a drogue set at a specified depth below the surface at which water motion information is sought. Trajectories of drifter buoys released in past studies of dispersion phenomena at dump sites demonstrate drastic differences in current patterns within intervals as short as 60 days. Position determination in experiments such as these have been obtained both by radio direction finding from nearby shore stations and by satellite observation (ARGOS). The frequency of observation by radio direction finding is dependent on radio reception that can limit reliable position fixing to once every four or five days. Satellite position fixing was more reliable, providing a reliable position fix every day.

Experiments to date have shown, at least in a preliminary way, the feasibility of using drifting buoys to understand the trajectories of water particles in two dimensions (at the depth of the drogue). The experiments also demonstrate the need for position fixes more often than those available from the ARGOS satellite system due to the highly variable conditions driven by wind, by seasonal temperature, and by mean circulation features such as the Gulf Stream. This means that for engineering design purposes an extensive drifting buoy study would be required to provide reliable data on which to base transport, diffusion, and dispersion calculations. The systems developed for this purpose would characteristically produce greater spatial and temporal resolution than systems such as ARGOS and would be used in arrays of relatively limited areal extent.

Another potential use of drifting buoys would be to track the movement of materials injected from barges or ships. These buoys would be emplaced at the time and location that an injection was made with the intent of tracking the path of the waste material. An important, but difficult, engineering project would be to design a drifting buoy that would remain associated with the waste material while at the same time incorporating the ability to conveniently and accurately determine its position in three dimensions.

5. Conclusion and Recommendations

The Working Group noted with great interest the emerging programs of the WMO and IOC to employ drifting buoys in weather prediction, climate monitoring, and oceanographic research.

In section 4 selected ocean engineering areas have been identified that could benefit significantly from the application of drifting buoy technology. Observational parameters needed are typically the same as those of the oceanographic and meteorological community with one major exception: data on waves (height, spectrum, etc.). Operational deficiencies are primarily centered on the question of geographic area of interest. While technical deficiencies are related to the engineering need for smaller spatial scale and shorter temporal scale than envisioned for oceanographic research and meteorology.

There was a strong consensus among working group members that the meteorological program was of particular, but qualified, significance to oceanic and offshore engineering. It was concluded that, if the drifting meteorological buoy program can be used for improved operational forecasting in offshore areas, the result will be of major importance to engineers. This result could be obtained in either of two ways: (1) the improvement in quality and extension in duration of reliable weather forecasts for a given region (based, presumably, on improved global data sets), and (2) the availability of higher density observations within an operational region that can be used by weather forecasting contractors who support engineering in that area. The implication of these statements is that, while engineering interests cannot be expected to employ general meteorological arrays for their own purposes, they will benefit directly or indirectly from those of the WMO and IOC. However, the benefits will be most direct if these arrays are capable of providing high density observation within regions of interest.

Oceanographic arrays such as those under consideration by the IOC will produce less direct benefits, but can provide improved knowledge of mean environmental parameters for design and operation of facilities provided buoys are located within regions of interest. It is recommended that the IOC take note of these needs in planning for future buoy programs. In doing so, the IOC should note that existing areas of extensive engineering field operations offer excellent logistical opportunities for support of local arrays.

The Working Group reviewed the terms of reference of SCOR Working Group 66 and, in the light of potential benefit to ECOR's constituents cited above, recommends that the oceanographic research community take the lead in evolving buoy systems and international programs to encourage their use. ECOR is ready to assist in the continued definition of related program requirements. In that regard, the Working Group noted two procedural matters: (1) engineering interests represented by ECOR, peripheral to these programs but not typically involved, have no satisfactory means of staying informed of international planning activities of this type, (2) special attention must be paid to ranging for optimal use by engineers of broad scale buoy array data and for routing of data from limited buoy arrays used for engineering into real time and archival networks such as the Global Telecommunications System (GTS) or Integrated Global Ocean Station System (IGOSS).

It is therefore recommended that ECOR be consulted in the formulation of buoy programs, as has been the case during the last two years. While this report, and the companion report from SCOR, go far towards formulating requirements, much work remains to be done.

The Working Group formed to prepare this report is representative of a community of primarily commercial and industrial engineers concerned with engineering applications in the ocean. It was decided that ECOR's primary focus should be in that direction. A somewhat distinct community of engineers concerned with the development of buoy systems and their satellite components have not yet been significantly involved in the deliberations of ECOR or SCOR. The active participation of this community will be necessary in formulating drifting buoy programs, particularly at the stage where technology transfer to some participating countries becomes desirable.

One major technological deficiency can be generalized from the engineering problems examined by the Working Group. It was concluded that the need exists for a buoy system suitable for general applications by a user group whose needs are typically nearshore, of spatial resolution that calls for 0.2-1 km position accuracy, and of temporal resolution that requires positioning no less than several times daily. Furthermore, if such buoys, and their logistics and data processing, can be made relatively inexpensive, it is reasonable to expect them to be used in significant numbers in the years ahead. Such a system would be manifested as localized high-density arrays nested within the broad ocean basin scale arrays needed for other programs, and of finite operational duration. Nonetheless, they would constitute a considerable improvement in the observational system(s) on which progress in oceanography will depend in the coming decades. The Working Group recommends that the IOC/SCOR/ECOR consultative partnership examine the availability of such a system in consultation with buoy and satellite development engineers and technical representatives of the present ARGOS system. The fostering of a system specialized to these requirements is potentially the most directly beneficial action to the interests represented by the present ECOR Working Group.

Attachment A

ECOR's Working Group on Engineering
Applications of Drifting Buoys

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ECOR's Working Session on Engineering
Applications of Drifting Buoys

Halifax, Nova Scotia
(Joint Oceanographic Assembly)
August 13, 1982

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