

Development of Drifting Buoys

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ABSTRACT

Polar orbiting satellites equipped with random access data collection and position fixing systems have made long-term remote oceanographic/meteorological observations possible by means of instrumented drifting buoys fitted with ARGOS telemetry transmitters. This paper discusses the design aspects and performance characteristics of these buoys presenting a small fraction of the considerable data set acquired. The requirements for further inclusion of certain sensors and hardware are described. Considerable potential exists for the use of drifting buoys if the cost of data acquisition and processing systems is held at a reasonable level. As yet it is in infancy and further development is required before system reliability and longevity are considered to match those for telemetry systems. A fundamental question to be answered is the extent of the buoy remaining "attached" to the local watermass when it encounters current shear, wind forcing and waves.

INTRODUCTION

Knowledge of surface currents is of fundamental importance in oceanographic activities. In research, it is directed towards improved understanding of climate, modelling and prediction of currents, and studies on exchanges of heat and momentum between the atmosphere and the ocean [11]. A prominent part of the surface layer is the gravity wave field generated by wind stress, which has a profound influence on surface currents and on their measurements. Wave motion at a given spectral wavelength, λ , decays with depth, z , as $\exp[-2\pi z/\lambda]$ and this provides a reasonable definition of surface layer depth ~ 10 m, though in oceanic storm conditions the depth of wave influence can be greater than this. Major contributing mechanisms in the current structure are tidal forcing, wind stress, Coriolis force and density gradients. Measurements of currents *in situ* are made in either Eulerian (in this flow is determined by a sensor fixed with respect to the surface of the earth), and Lagrangian in which the reference moves with a field particle and its vector displacement from a fixed point is measured as a function of time). It has been demonstrated, in several cases, that technological improve-

ments do not necessarily lead to greater accuracy of measurement unless attention is also paid to the hydrodynamic design, especially to minimizing obstruction of the flow by the sensor itself [1]. Sensors can now be said to have reached the stage of development at which the characteristics of the moving or mounting platform now represent the principal limitation in accuracy achieved in a measurement.

The design aspects and performance characteristics of NIO drifting buoys presenting a small fraction of the data set are discussed in this paper.

MATERIALS AND METHODS

Emergence of satellite-based position fixing systems has enabled Lagrangian measurements to be made worldwide with a precision in location of about 400 m. Ideal Lagrangian tracking cannot be achieved in practice, as it is impossible to follow precisely the small-scale motion of individual water particles. Assumption is made in a statistical sense that the drifter motion emulates a typical watermass [2]. Data from satellite tracked buoys are usually disregarded when drogues get detached. Most of the report on droguing of drifting buoys are aimed at improving practical aspects of performance under the adverse effects of winds, waves and currents on the surface buoys [9]. The problem is rather different and somewhat idealized, namely, knowing that the track of a drogue can never truly represent a Lagrangian path. How is the track of drogued buoys under the influence of a surface stress differ from that of a parcel of water at the depth of the drogue? The result becomes more significant to drogued meteorological buoys with more windage.

Four main considerations have been taken into account while designing such buoys: (i) satellite antenna must protrude above the ocean surface; (ii) a drag producing "drogue" of suitable dimensions attached at depth to enhance the water following capability; (iii) a minimum tension in the surface float-to-subsurface together line, so that the effect of non-uniform current distribution along the 15 m line rope is minimized; and (iv) the instrument and the entire drifting system must not only survive the harsh environment but must also operate reliably throughout.

Assuming that a drogue of a drifting buoy is in a steady flow field of surface current, the wind field and the wave field acting on the surface buoy are also steady. To first order, the sum of the forces on a drogued assembly is equal to the vector sum of the stress forces acting on the system.

$$F_1 + F_2 + F_3 + F_4 = 0 \quad \dots(1)$$

where F_1 is the force due to the wind; F_2 , the forces due to waves; F_3 , the forces due to surface currents on the buoy and upper part of the rope connecting the buoy to the drogue; and F_4 , the force due to the slippage of the drogue through the water mass [5,7,8]. Equation (1) neglects forces producing other accelerations on the drogue assembly.

Based on the comparison between Eulerian current profiles and Lagrangian drift data, Reverdin *et al.* [10] concluded that the effect of wind and wave drag on the hull amounted to at the most a few centimetres per second in buoy speed. While it is difficult to quantify these effects precisely, the inferred magnitude is nonetheless consistent with the results of other studies, such as that of Kirwan *et al.* [6]. These forces are generally assumed to follow a drag law of the form

$$F = \rho \cdot C_D \cdot A \cdot |V|V/2 \quad \dots(2)$$

where ρ is the density of the surrounding fluid; A , the area; C_D , the drag coefficient; and V the relative velocity.

Schematic design of the drifter ID. No. 11350 and 11351 is shown in Fig. 1. and it consists of 40 kg surface unit, a 14m long nylon line down to drogue and a weighted 1 × 6m nylon window shade drogue (or sea anchor). The surface unit consists of a fibreglass antenna on a foam-filled fibreglass cylindrical hull and a flotation collar. Inside the cylinder is a 400 MHz transmitter that sends a 0.4s burst every 90 sec. The unit transmits to TIROS satellites, and the position is determined by Doppler shift *via* the Argos system. In the middle is the electronics unit of Tattletale datalogger operating in a low-power "DONE" mode and a signal conditioning board powered by Yuasa sealed lead acid batteries for power supply for six months life (18V, 30AH). The ballast lead weights in the bottom provide the necessary restoring moment to maintain the vertical position. The total buoyancy is around 180 kg. The temperature sensor is YSI thermilinear thermistor 44202 operating at a reference voltage of 3.2V. Two thermistors are housed in an aluminium enclosure at the bottom of the hull touching the water layer at 1m depth in case one fails. The Argos data telemetry and position location system is based on two polar orbiting satellites of the NOAA-n series. Messages transmitted at approximately 90s intervals by individual UHF beacons are received by the satellite on random access basis and positions are computed accurate to within 400m from the Doppler shift of the received carrier. Acquisition and processing times vary, but according to recent statistics, approximately 80% of all data are available to the user at the system computer within 4 h of receipt of the satellite. The Argos system is thus useful for near-real time applications, and is invaluable in providing and indication of correct position and proper operation of the instrument. The main limitations of the system are: (a) gaps in coverage due to imperfect orbit configurations, and (b) message length limited to 256 bits.

The general rules for Argos sensor data processing are: maximum message length, 256 bits; each PTT can have 1-32 sensors, and each sensor can transmit 1-32 bits (minimum 1 bit).

RESULTS AND DISCUSSION

It is seen from plot of the trajectory of the buoy ID No. 11351 in Fig. 2 that the general drift is westward during March to April and subsequently after the onset of the southwest monsoon trajectories are mainly orientated to south, south-east.

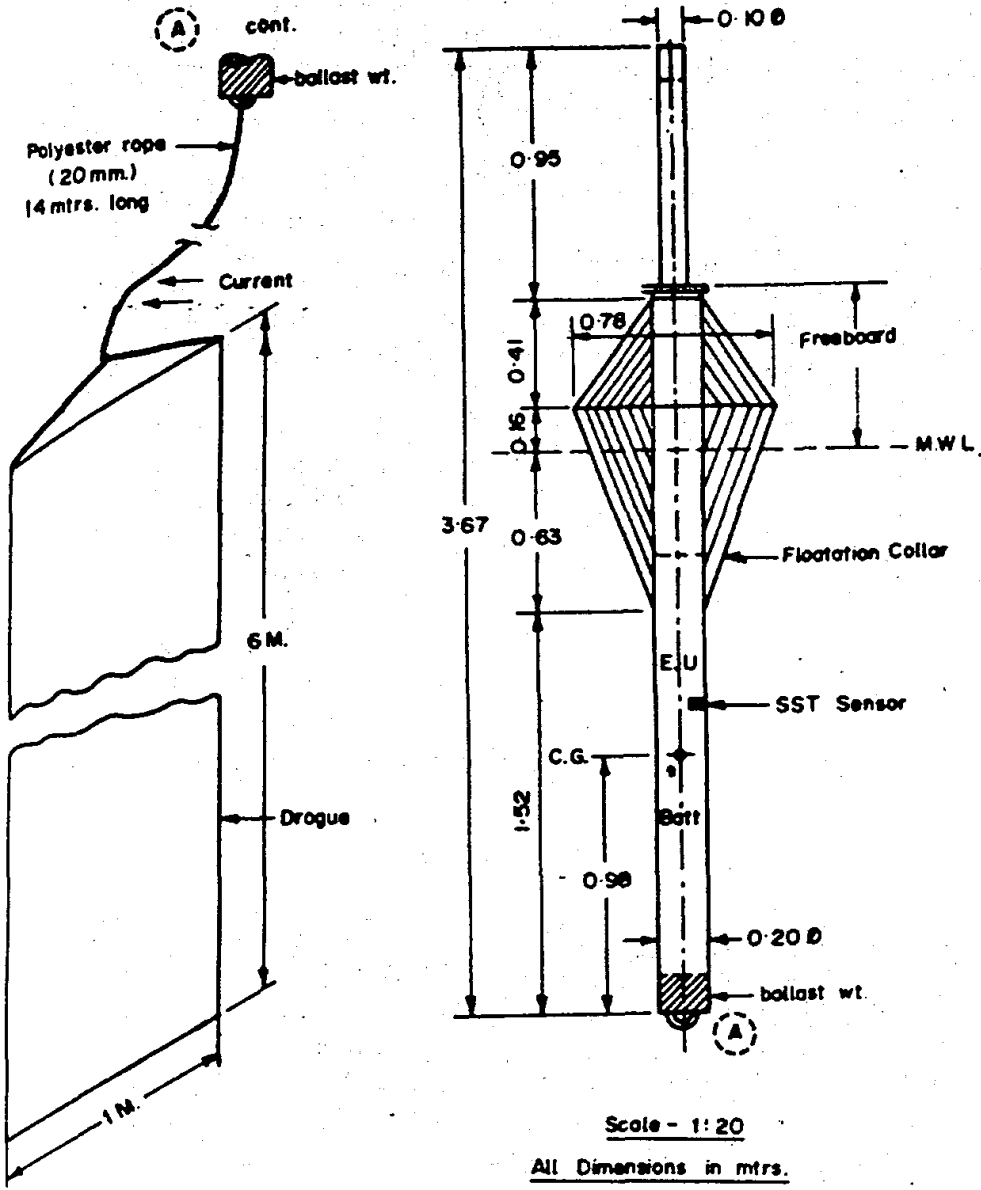


Fig. 1. — NIO drifting buoy (schematic)

There is considerable variation in the behaviour of the buoys from one deployment to the other. The Lagrangian content of the trajectories exhibits richness of time/space scale variability in the data, confirming the climatological estimates. The data covered the months March to August 1992 and included measurements of near-surface drift and upper ocean temperature. Temperature data were relatively few in number in comparison with drift data owing to the suspected thermistor damage after 45 days of deployment. So, emphasis in this paper is on near-surface flow field. The basic idea is to generate a monthly climatology of

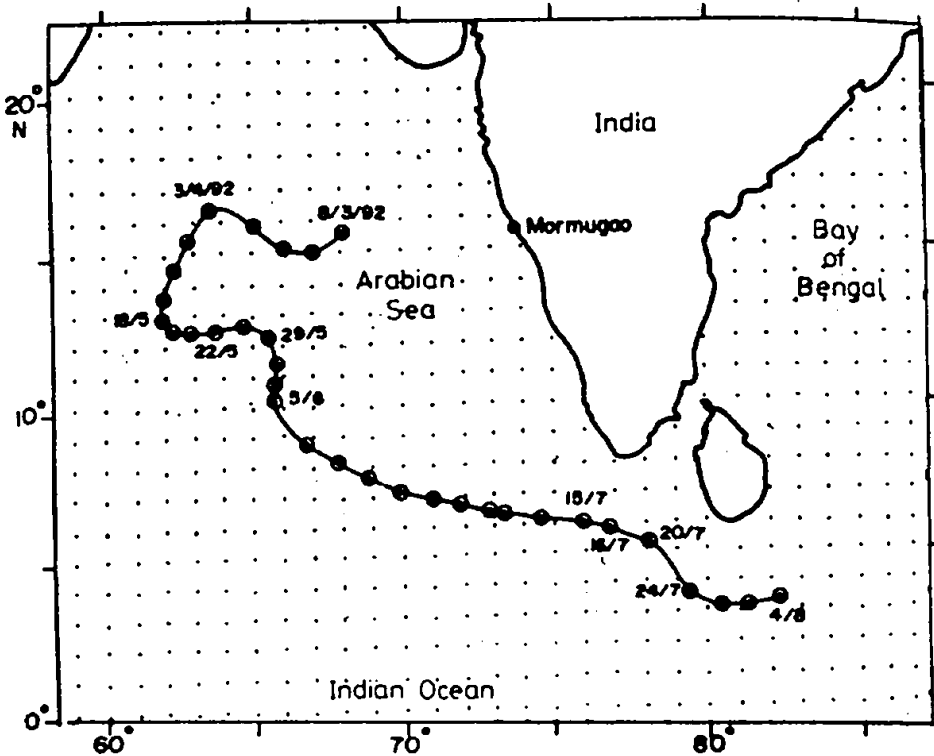


Fig. 2. — Drifting buoy ID No. 11351 trajectory

surface currents in the tropical Indian Ocean and Arabian Sea. The buoy data provided direct observations of surface currents. Although data for some of the older drifters have been described earlier, the combined data set provides considerably greater coverage in both space and time. In an attempt to establish qualitatively the representativeness of the drifter climatology and other earlier descriptions of regional circulation, the buoy data are compared with a recent compilation of drift reports by Cutler and Swallow [4].

The limited data is a shortcoming in the analysis. Despite these limitations, the tendency for windowshade drogues to “fly” in the presence of wind waves was observed during rough weather deployments. Slippage in many different current and wind regimes is manifested by poorer performing drogues exhibiting faster drifts [8]. The main discussion is directed towards a design for an ARGOS-tracked drifter that is configured so as to minimize surface wave effects [3], and present measurements of its water following character in the Arabian Sea at 15 m nominal depth in a small range of wind-wave conditions.

The differences in windage effects are consistent with the buoy designs and are small compared with the signals studied. The buoy trajectories exhibit a wealth of variability on many temporal and spatial scales. As indicated earlier, these data

are presently being analyzed using various Lagrangian and Eulerian techniques to define these scales quantitatively. Of particular interest is the design of a buoy deployment scheme sufficient to monitor the surface current and temperature fields in an operational mode. Results from these analyses will be reported later. One parameter 'tilt' and 'uplift' exhibited by the drogue in strong vertical shear brings the centre of the drogue closer to the 10 m depth. These are still not well defined due to the uncertainties in the media. The buoy is shown in Fig. 3.

A fundamental question arises as to the extent to which the buoy will remain 'locked' to the local water mass when it encounters current shear, wind forcing and waves. Each of these aspects is being examined separately. Improved estimates are proposed through the measurement of current relative to the buoy, in addition to the buoy displacement over the earth's surface (using vector measuring current meter attached near the drogue).

Programmatic considerations indicate deployment logistics, scientific sampling requirements needing the buoys to remain operational for a long time and cost as the major factors in the use of drifting buoy systems. Oceanography does not seem to have a good record in moving techniques and instruments into the commercial sector for marketing and further development. Specialized designs and the need for elaborate logistic support are among the reasons. Small potential markets and high overheads make the oceanographic measurement systems unat-



Fig. 3. — The NIO drifting buoy

tractive to the private sector. This point is being addressed as an overall deployment effort. In particular, our objectives of flexibility, modularity and broad scientific applicability, if achieved, should make it a useful tool. A combination of commercial sector production of buoys in combination with an established operational capability can ensure the availability of drifting measuring systems to the scientific community in the next decade.

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