

## SATELLITE RELAYED IN SITU OCEAN OBSERVATIONS

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### Abstract

Position location and data relay from unmanned ocean data platforms have come into being in the last several years by the use of satellite data relay systems. This use has arisen from the inability of conventional shipboard oceanographic observations to sample on more than a fraction of physical time and space scales of the ocean. To date, most of the satellite relayed data have been from a few highly instrumented moored platforms such as NDBO ocean weather buoys, or position information from simple surface drifters for ocean current mapping. More sophisticated drifters are planned which will take data further down into the water column. These data will be used for ocean science, weather, commercial, and naval applications. NASA will use them for verification and calibration of its own satellite observation systems. Technology improvements will be required in platform, sensor, data handling, and satellite design.

### Introduction

The course of oceanography over the last decade or two has been marked by a fundamental change in the way we view the ocean. Our concept has changed from one of a steady state ocean circulation perturbed by small scale waves to one of an ocean supporting a wide range of interacting phenomena occupying the full spectrum of time and space scales from seconds to decades and from centimeters to the size of the ocean basins. This change in perception has been accompanied by a trend away from making occasional point measurements from a single ship towards efforts to simultaneously observe the ocean over large regions for periods of years. Unfortunately, the expense of gathering observations has escalated dramatically, primarily because of the cost of the ship operations. The advent of remote sensing, data relay, and platform locating from satellites makes possible the more efficient and extensive observing systems needed to help solve the problems of modern oceanography.

Satellite remote sensing of the ocean is limited to observations which describe the ocean surface, not its interior. The presently available remote sensing of greatest utility to oceanographers is mapping of sea surface temperature and ocean color, satellite determination of the short wave radiative flux of heat through the sea surface, and inference of surface winds from cloud motion. Additional benefit results from improved characterization of weather over the ocean. Developing methods for measuring winds over the ocean and sea level height from satellites promise to dramatically expand our ability to observe important ocean processes continuously over large regions. But as important as these surface signatures are, they represent two-dimensional views of the three-dimensional ocean and, therefore, can provide only a partial picture of oceanic phenomena. Further, remote observations of the ocean are indirect and not always as easily related to quantitative in situ observations as is needed. These considerations dictate a continuing requirement for in situ observations, both to interpret the descriptions gained from remote sensing and to observe phenomena which do not have strong surface signatures.

The marine environment imposes serious constraints on observational oceanography and makes satellite data relay and positioning of great value. Because the ocean is essentially opaque to electromagnetic radiation, remote sounding (such as is employed in observing the atmosphere) and long range underwater telemetry from observing systems are not possible. The oceans are vast, essentially unpopulated domains across which transportation by vessels steaming at ten knots and costing on the order of \$10,000 per day is slow and expensive. The ocean is a hostile environment in which field operations are inefficient, maintenance of three mile long moorings is a major engineering task, and sensor survivability is limited.

Historically, oceanographers have mapped the ocean from slow moving ships or have moored

internally recording instruments and returned to recover or replace them. The emergence of satellite data relay and platform locating permits fundamentally different modes of operation which both increase the quantity and quality of some observations and permits new kinds of measurements.

#### Satellite Data Relay

In recent years the oceanographic field has become adept at deploying unmanned sensors to observe a variety of parameters over long periods of time. Data from surface buoys are either recorded internally or relayed ashore by satellite. The greater number of in situ sensors, however, are deployed below the surface, within the water column or on the bottom. Sub-surface moorings include those with strings of current meters and other point sensors, and those which are acoustic remote sensing systems themselves, such as Automatic Listening Stations for SOFAR float tracking, or active and passive acoustic arrays for acoustic tomography. Bottom mounted sensors include Ocean Bottom Seismometers and various instruments for observing the ocean's bottom boundary layer's physics, biology, and geology. All these sub-surface instruments record record their data internally, and are able to perform untended for well over a year in some cases. The disadvantages of long term deployments are:

- The inability to monitor degradation or loss of data during the course of the experiment.

- The cost of a research ship cruise to recover the data, which could exceed the value of the deployed instrument.

These factors are leading to investigations of ways to move data from deep sensors to surface transmitters for relay to shore via satellite. Thus one can foresee increased use of satellite relay of ocean data both from increased numbers of conventional surface buoys and from the transmission of sub-surface data. Users of these data will be the oceanographic and meteorological research communities as well as NASA itself for verification and ground truth of its future ocean sensing satellites which are in the planning stages now. In addition to research users, there are operational customers for satellite relayed ocean data. Presently, of course, NOAA, the Navy and Air Force, and commercial forecasters use the NDBO buoy data in their weather, oceanographic, military, and ship routing services. The largest block of Argos transmissions in 1981 was from sailboats in a transatlantic race. These users will probably deploy more ship mounted and drifting Argos transmitters in the future as their plans develop for such instruments as automated ship weather report stations,

ambient noise buoys, and in the case of the Coast Guard, a fishing boat locating system. Crude drifting buoys were employed during the recent intense meteorological observation periods of FGGE, and so may lead to routine large scale use of drifters for weather and ocean forecasting. Indeed, although the Argos system is relatively underused now, it would certainly become saturated if all the potential operational plans come to pass.

There are two generally used systems for the relay of unmanned in situ oceanographic observations to shore in near real time: through geostationary satellites and through the polar orbiting Argos system. The geostationary satellites can relay large data volumes but do not have the ability to locate the data transmission source. They are more suited therefore, to sophisticated, moored buoy applications such as is now being done in weather forecasting with the large NDBO buoys off the U.S. coast, or for some of the sophisticated ocean moorings now under consideration in the ocean science community. On the other hand, the Argos system aboard the NOAA polar orbiters does have an inherent transmitter location capability but a quite small data capacity (32-256 sensor data bits per transmission). It is well suited to simple surface drifting buoys where location, for surface current analysis, is the prime goal and the volume of observed data, such as temperature or drogue tension, is low.

#### Future needs

The techniques for using GOES and Argos for in situ data relay are well understood. Moreover, at present, both systems are operating at well below capacity. The outlook for better exploiting satellite data location and relay depends on the development of cost-effective technology in in situ and spaceborne hardware and software. There are a number of potential ocean science needs which could be better met by the Argos system, and would considerably increase its current usage. This in turn would help lower the unit cost of the buoy transmitters and the data processing costs. Future ocean circulation studies will require larger arrays of the currently used "dumb" surface drifters as well as transponders for acoustically tracked deep drifters. Studies of ocean-atmosphere interaction will require drifting surface buoys able to take a suite of measurements in the mixed layers of both the ocean and marine boundary layer. Some of these drifters will generate more data than the nominal capacity of the Argos system. For all this to happen, ocean and space technology must provide some of the following:

- Cheaper buoy transmitters. The transmitter is the largest part of the cost of a simple expendable drifter for surface current measurement. This type of buoy must be deployed in large numbers, but is not affordable for most research programs unless the unit cost is lower. Perhaps with low cost oscillators taking advantage of the ocean's stable temperature regime, the transmitters can be made cheap enough for large scale buys associated with longer production runs. Commonality with search and rescue transmitters or emergency location beacons seems possible. For more sophisticated moored buoys, the transmitter represents only a small fraction of the cost, and thus its cost is less critical.

- Advanced buoy sensors. Present drifting buoys are usually limited to a sea temperature thermistor and air pressure transducer. More sophisticated buoys for detailed air-sea interaction studies will need low power consuming, reliable, buoy-compatible instruments for measuring surface wind vectors, heat flux, near surface current profile, mixed layer temperature profile, salinity, etc.

- Data transmission. Data compaction and transmission techniques are needed to match the limited Argos data capacity. The limited viewing time of a polar orbiting satellite and the shared access required limits the number of data words per transmission. Cote (1982) has simulated the capability of the present Argos system to handle data transmissions from combinations of ocean science experiments likely to be conducted toward the end of this decade. With only moderately high data rate (10 kBIT/day) drifters involved, an Argos would saturate in its ability to relay error free data. In addition, that study only accounted for a limited number of non-ocean science "background" transmissions. With the operational plans noted earlier, there may be many more of them. This problem may be alleviated by "smart" transmission of different data in different bursts or by the addition of capacity to the Argos system when it becomes saturated.

- Improved buoy hulls. Hulls will need the power and accommodation to carry the new sensors that are foreseen. They will also need to accurately represent the surface or near surface currents through better form or drogue design.

- Improved mooring technology. Deep measurements must be de-coupled from the effects of surface buoy mooring motion. This may be done, for instance, through mooring design or, by a pop-up system, or by acoustic transmission to the surface.

## Conclusions

The present Argos and GOES systems provide an excellent service for relay of data from unmanned in situ ocean sensors. They are operating well below capacity now primarily because of the cost of data transmitters and data retrieval. If technology can help reduce these costs it is likely that the usage and benefit from at least the Argos system would dramatically increase. Additionally, there is a demand for more sophisticated ocean science measurements using the Argos system if the buoy observation and data transmission problems can be solved. In a study for NASA of potential ocean science questions that could be better addressed through the use of spaceborne data relay, Davis, et al (1982) concluded that science and economic trends in oceanography make satellite data relay and platform locating essential for continued progress in the field, and that development of the in situ ocean measurement technology necessary for full utilization of it should be continued.

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## References

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