NOAA Technical Report OOE3

Geostationary and Orbiting Satellites Applied to Remote Ocean Buoy Data Acquisition

Washington, D.C.
September 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Ocean Engineering

NOAA Technical Report OOE3

Geostationary and Orbiting Satellites Applied to Remote Ocean Buoy Data Acquisition

E. G. Kerut
NOAA Data Buoy Office

G. Haas
Sperry Support Services
NSTL Station, Mississippi

Washington, D.C.
September 1979

Presented at the Thirteenth International Symposium on Remote Sensing of Environment
Ann Arbor, Mich., April 23-27, 1979

U.S. DEPARTMENTOF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

Office of Ocean Engineering
Steven N. Anastasion, Director

Mention of a commercial company or product does not constitute an endoresment by the NOAA Office of Ocean Engineering. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

CONTENTS

FIGURES

GEOSTATIONARY AND ORBITING SATELLITES APPLIED TO REMOTE OCEAN BUOY DATA ACQUISITION

E. G. Kerut
NOAA Data Buoy Office, NSTL Station, Mississippi
and
G. Haas
Sperry Support Services, NSTL Station, Mississippi

ABSTRACT. A better understanding of oceanic and atmospheric climates is becoming increasingly important. Essential to the understanding and study of climate processes is the evolutionary development and implementation of a global environmental measurement/monitoring system. With the advent of geostationary and polarorbiting satellites, the technology is now available for the collection of environmental data from surface stations all over the globe. Remote sensing of oceanographic and meteorological data by space-derived measurements will provide descriptions of planetary-scale phenomena. Moored and drifting buoy systems, in conjunction with space measurement systems, will enhance and complement the data products available from individual systems.

1. INTRODUCTION

"Over the past few years many factors have been at work to emphasize the importance of climate to man: the drought in the Sahel, the severe winters of 1977 and 1978, and the growing energy-environment enigma to mention a few. These are the 'what' and 'why' questions of climate. Mounting interest in providing answers to these questions has created a more favorable 'climate' for new efforts in climate research."[1] Large numerical models that describe and predict global climatology by simulation will play a central role in climate research studies by enabling an understanding of the underlying dynamics of climate systems. Modeling studies, together with observational studies, will aid in the development of future climate observation systems and their components.

Although no single comprehensive theory exists to explain climate variability, it appears that climate is determined by an extremely complex interactive physical system comprising the global atmosphere, oceans, continents, cryosphere, and biosphere. Thus a complete definition of the climate system necessarily involves a host of variables describing the internal state of each of these components, along with certain internal factors such as the Earth's radiation budget. A major element of a climate program will be the long-term systematic observation of many of these variables, so that the causes of climatic anomalies may be better understood and their future occurrences anticipated.

The ocean has a profound effect on the weather and climate and in turn is affected by the atmosphere; the ocean acts as a heat reservoir for storing, distributing, and releasing solar energy, and also as a source of most atmospheric moisture. The role of the ocean as it affects the climate will require major study,[2] and a global monitoring system will be required to observe the spatial and temporal variations of ocean climate variables. Comprehensive data sets are needed for ocean climate diagnosis, model development and validation, process-oriented studies, and ocean-atmosphere coupling investigations. The ocean climate monitoring system is also required to ensure long-term records of temporal ocean climate variability. A future global observing/monitoring system will evolve from existing and projected observational capabilities, including satellites, buoys, ships of opportunity, island stations, and large scale spatial measurement systems not yet developed.

It is certain that remote measurement and observations from satellites will play a key role in the development of an ocean climate observing/monitoring system. Satellite oceanography is confined largely to surface and near-surface phenomena; however, the space-derived data can be appended to conventionally derived surface and subsurface measurements. It is reasonable to assume that operational observing/measurement systems will evolve which are a mix of surface and space-derived data providing improved data products over individual measurement systems. Space-derived information can be calibrated and validated by in-situ point surface measurements and can often extend the surface observations to near planetary scales.[3]

This paper presents a brief review of NOAA Data Buoy Office (NDBO) activities in the development of moored and drifting buoy systems for surface measurements used in conjunction with available satellites having surface platform position determination systems and/or data collection and relay telemetry systems. The buoy observing/measurement systems are primarily used as in situ surface measurement platforms for meteorological and oceanographic parameters. They are also valuable adjuncts to the remote sensors on board satellites, providing groundtruth data or enhancement of derived remote sensor data products.

2. MOORED BUOY SYSTEMS

Since June 1972, NDBO has deployed meteorological and surface oceanographic environmental reporting data buoys in various gulf and ocean regions to provide synoptic data to the National Weather Service (NWS) and to provide a data base for scientific studies. As of April 1979, 21 moored buoys were reporting environmental data operationally. These deep-ocean moored buoys measure wind speed and direction, air temperature, barometric pressure, sea-surface temperature, wave spectra and, at a limited number of sites, subsurface temperatures. Data are telemetered on an operational 3-hour synoptic basis via the SMS/GOES satellite to the National Environmental Satellite Service (NESS) and then via landline to the National Meteorological Center (NMC). Environmental data from many other sources are assimilated, and meteorological and oceanographic forecast data products are provided for dissemination to the user community. In this application, the moored buoy is used as an in situ primary data source, and SMS/GOES is used as an efficient data telemetry relay.[4]

Oceanographic satellite data are now available largely on an experimental basis. Oceanic environment parameters being measured either directly or indirectly include temperature, radiation budget, surface vector wind field, and wave height and spectra. To achieve the precision desired in the future, ancillary data will usually be required. There is every reason to mix surface and satellite data, so that space-derived information can be calibrated and validated by in situ surface measurements. Applying the concept of mixed-mode measurements can often then extend the surface in situ observations to near planetary scales.[3]

It is conceivable that, in the near future, space-derived information and surface in situ measurements from both moored and drifting buoys will be processed in an operational mode, thereby ensuring data products of greater accuracy and utility than space or surface information alone.

As part of the SEASAT-A field experiments planned during 1978, moored buoys were a principal means of in situ observation of surface winds, sea-surface temperature, air temperature, barometric pressure, and wave height and spectra for surface truth comparisons with space-derived information.[5] Prior to the SEASAT-A field experiment, aircraft flight experiments using satellite remote sensors used drifting and moored buoys as primary sea-surface temperature truth data for sensor calibration and algorithm validations.[6, 7] A part of the aircraft experiments included a study to determine the improvement in sea-surface temperature data products using a mix of space-derived information and in-situ surface measurements from drifting buoys. The study is now in progress and may lead to further refinements in experimental designs culminating in an improved sea-surface data product.

Tsunamis--seismically excited, long length ocean waves--are capable of great damage upon reaching distant shores. In principle, these waves can be measured or monitored in the open areas on a target-of-opportunity basis along a satellite subtrack using altimetric measurements. This is, however, a low-probability observation.[8] Experimental work has been in progress during the past several years using bottom-mounted pressure sensors to measure the tsunamis in mid-ocean. Real-time data telemetry, via an acoustic data link from the bottom-mounted sensor to a deep-ocean moored buoy and then to shore via satellite, has been proposed. A mix of the two measurement technologies may solve the problem of providing timely disaster warning data to coastal areas in the path of a tsunami.

The present complement of moored buoy data acquisition and telemetry electronics was determined by a series of hardware evolutions, which in turn were brought about by a continued quest for the most accurate and reliable equipment that technology could offer at realistic costs. The evolution of the data buoy hardware, together with the availability of microprocessor technology and suitable communication satellites, has permitted a fully automated, reliable approach for the acquisition of remote marine environmental data on a synoptic basis in all weather conditions. These conditions encompass a wide range of sea states, from smooth seas to severe disturbances. In addition, the measurement and reporting of environmental data are accomplished on remote ocean platforms that are relatively inaccessible for maintenance and therefore require highly reliable equipment and data-link.

2.1 Moored-Buoy Payloads

The first-generation NDBO buoy payloads were developed to meet both R&D and data-product delivery requirements. These units were designated the Engineering Evaluation Phase (EEP) payloads and were placed on 12-m discus hull buoys with 100-ton displacement for evaluation of advanced state-of-the-art sensors and buoy components. Deployment of six of the EEP buoys began in June 1972. The term "payload" as used herein refers to the buoy instrumentation, which includes onboard sensors, data processing, communications, and the power source.

A companion development to the EEP units involved the Phase I payloads, which were designed for simple, less flexible data acquisition requirements and which were originally placed on small 1.7-m diameter moored and drifting buoys. Deployment of buoys with Phase I payloads began in January 1973.

Four types of moored buoy payloads are currently being maintained and operated by NDBO: the Prototype Environmental Buoy (PEB) payload, the Phase I and Phase II payloads, and the newly developed General Purpose Buoy Payload (GSBP). Of the payloads currently deployed, eight are PEBS, two are Phase I payloads, five are Phase II payloads, and six are GSBPs.

2.2 Prototype Environmental Buoy (PEB) Payload

The PEB design was based on concepts proven during initial NDBO programs. Although originally tailored to meet the needs of the National Weather Service, its measurement capability was expanded to include surface wave data and subsurface water temperatures to 300 meters.

Figure 1 shows a 10-m diameter moored buoy. Meteorological sensors are located on the mast at the 10-m level. In addition to synoptic reporting, the onboard weather data acquisition and reporting sequence can be changed to hourly operation by command from shore for special needs (e.g., during abnormal weather disturbances). Present and previous data frames can also be acquired on demand via radio link. The onboard data acquisition and timing is controlled by a special purpose, stored-program computer. Batteries provide the power required for up to 3 years of continuous buoy operation.

This payload is equipped with a dual hf/uhf communications system. Redundant rf links were implemented to ensure an orderly transition from hf to the more reliable uhf satellite communications. Conversion to uhf communications is nearly complete. Eight 10- and 12-m hulls equipped with PEB payloads are currently in service in deep ocean areas, including the Gulf of Alaska, North Pacific, and Atlantic Ocean. All PEB's are being modified to incorporate a microprocessor system to replace the stored-program minicomputer. The PEB microprocessor system comprises two RCA 1802 microprocessors. A 2K memory microprocessor provides the communications and timing function, while a 1K memory microprocessor provides the data processor function.

2.3 Phase I and Phase II Payloads

The Phase II payload program is an outgrowth of the Phase I payloads for small buoy systems that were developed during 1972-73. These earlier buoys were configured as spheres and as horizontal and vertical cylinders, with typical diameters ranging between 1.4 and 1.7 m. None of the small buoy systems achieved significant success with regard to survivability and operability in the open sea; however, the data acquisition payloads were quite reliable.

The Phase II payloads are second-generation payloads that are now integrated in existing 6-m boat-shaped hulls, NOMADs, shown in figure 2. (The NOMAD hulls were developed in earlier U.S. Navy programs.) Phase II payloads are also installed on the larger discus hulls. This payload provides meteorological environmental parameters and surface wave data. The onboard data processing and rf data link are very similar to that of the PEB payload, employing nonprogrammable hardware and both hf and uhf satellite communications. However, the Phase II payloads are being upgraded to an all-uhf configuration. Five Phase II payloads are in service in both deep ocean and continental shelf areas. Two buoys are still using the earlier Phase I payloads, but will receive the General Service Buoy Payload within 6 months.

2.4 General Service Buoy Payload (GSBP)

The first 15-unit production run of this advanced payload class has recently been completed. Six GSBPs are now in service onboard one 5-m discus, three NOMADs, and two 10-m hulls. Ten additional payloads will be in service by the spring of 1979, along the continental shelf, in the Great Lakes, and in deep ocean areas.

The GSBP system design draws extensively upon proven hardware and systems. For example, the entire meteorological sensor suite is identical to that used in the Phase II payload. In addition, data input ports are provided for future sensor additions, including a wave measurement system and a multi-element temperature measurement system. Buoy communications consist of a uhf-satellite transceiver with 40 watts output power, and associated electronics similar to that used on Phase II and PEB payloads.

The GSBP relies entirely on a uhf-satellite communications relay link, which eliminates the need for the large antennas required for hf systems. The GSBP features a program-controlled microprocessor instead of the nonprogrammable special-purpose computers used on earlier payloads. This element, the Intel 8080 microprocessor, acquires, digitally processes, and formats the sensor data. This microprocessor has a 3K core memory.

2.5 Future Moored Buoy Activities

A new moored buoy program is being initiated in the Great Lakes. The loss of the Great Lakes ore carrier EDMOND FITZGERALD in November 1975 prompted an

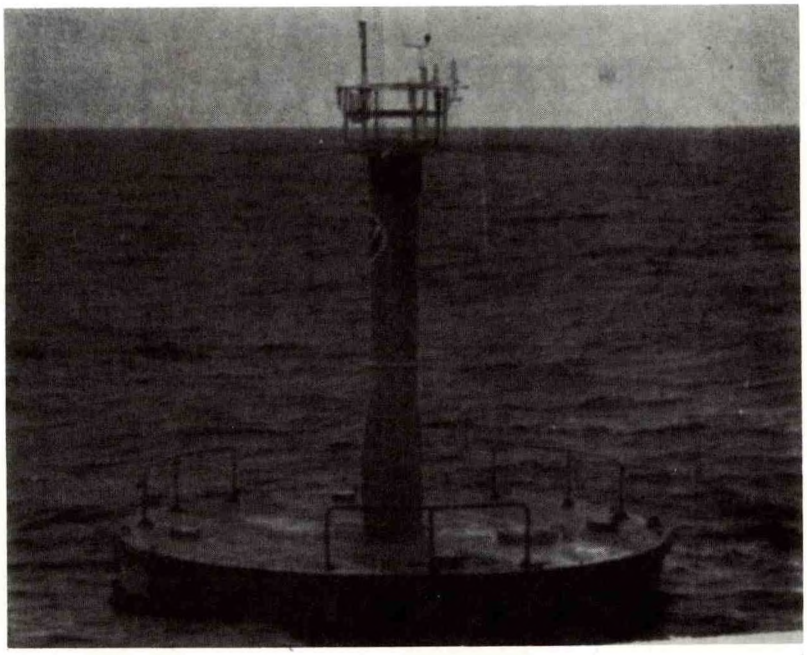

Figure 1.--10-meter discus buoy

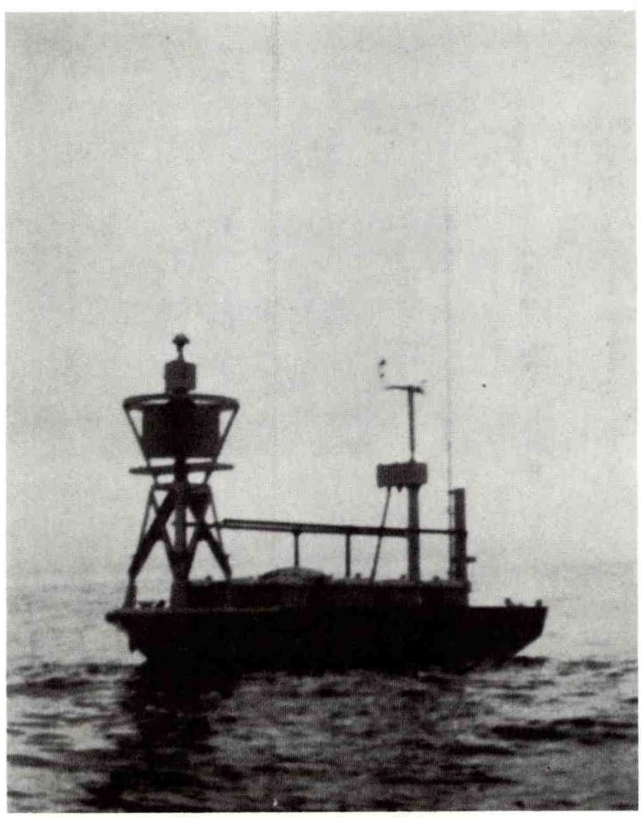

Figure 2.--NOMAD Buoy

intensive investigation of the weather forecasting capability in this area. Several deficiencies in the program were found, which led to the decision to deploy and operate a series of data buoys in the lakes. Two buoys are planned for 1979 and the remainder for 1980 and 1981. Each buoy will be equipped with a meteorological sensor suite and a wave measurement system.

3. DRIFTING BUOY SYSTEMS

With the launching of polar-orbiting satellites capable of data collection and relay, as well as position determination from suitably instrumented surface sensor platforms, impetus has been given to the development of low-cost, expendable drifting buoy systems capable of unattended operation on a global basis.

Communications and position fixing depend upon the operation of a low-cost uhf transmitter on the buoy, which sends data to a specialized electronics package on board a polar-orbiting satellite. The satellite in turn relays the data to a ground station. Relative motion between the satellite and buoy produces a Doppler effect on the frequency of the rf link. This frequency shift is processed along with the satellite orbital track to derive buoy position. Experience with position-fixing has found the accuracy to be well within 5 km rms for the NIMBUS-6 satellite.[9] The operational TIROS-N satellite is providing position-fix accuracies of about 1 km. TIROS data telemetered from a surface platform (drifting buoy) are transmitted to ground stations in the United States, then collected during each satellite pass by NESS for transmittal to France, where Service ARGOS processes the environmental parameters and determines the platform position. Data dissemination is via the Global Telecommunications Service, for timely worldwide distribution and use.

Drifting buoys have been used primarily as in situ environmental measurement systems. However, scientists are now investigating the future use of drifting buoys in conjunction with remote satellite measurements as a calibration or model validation tool, or to enhance the present satellite measurement capability. During early process-oriented experiments, drogued drifting buoys were used as Lagrangian trackers to describe near-surface currents. Position data from subsequent satellite passes were used to plot buoy trajectories or the Lagrangian measurement of surface current.[10] Much scientific and engineering work remains to relate Lagrangian and Eulerian measurements, and to verify analytically and/or experimentally Lagrangian measurement accuracies, i.e., the slippage of the drogue buoy system in the parcel of water mass to be described. However, a potentially powerful tool is available to the oceanographer to describe ocean currents over large spatial and temporal scales at a cost unattainable heretofore.

During the Global Weather Experiment[11, 12] drifting buoys deployed in the vast ocean regions of the Southern Hemisphere are measuring and reporting barometric pressure and sea-surface temperature via the TIROS-N satellite. A knowledge of these parameters is needed to infer the vertical profiles of temperature and wind from satellite data with acceptable accuracy.[13] An array of more than 200 drifting buoys has been deployed in the southern oceans to obtain surface pressure and temperature data. About 300 drifting buoys will be deployed during the two special observation periods in the 25° to 65° south zone, providing an average horizontal resolution of about 1,000 km. The Global

Weather Experiment is a good example of the environmental measurement performance results that can be achieved with a well-designed mix of surface and remote satellite data to enhance the remote sensor data product. The experiment has also been the prototype for a future operational drifting buoy network deployed in data-sparse regions, providing surface meteorological data for appropriate analysis and forecast data products. Although the experiment is still in progress, early analysis has shown the feasibility of receiving data from drifting buoys on a nonsynoptic basis within the time required for the analysis and generation of forecast data products for the Southern Hemisphere.

A significant contribution by NDBO to the Global Weather Experiment has been the development of the prototype climate drifting buoy and the development of an air-drop capability for deployment in remote areas inaccessible by ship. Figure 3 shows the air deployment of a drifting buoy.

In addition to the drifting buoys developed for climate-related programs, NDBO has developed an air-deployable ice buoy to measure/monitor environmental parameters in polar regions[14, 15] to further develop the understanding of the dynamics and thermodynamic interaction between arctic ice fields and the environment. These buoys are instrumented with barometric pressure and temperature sensors and use a uhf orbiting satellite relay data link for telemetry and position fixing. Platform position fix changes between satellite orbits provide the measure of ice movement needed to study ice dynamics.[16] Figure 4 shows an air-deployable ice buoy.

As part of an evolving national and international global ocean climate measurement/monitoring system, air-sea interaction parameters such as air-sea temperature differences, vector surface wind field, and exchange of latent and sensible heat are important measurands for climatological research.[13] Satellite sea-surface temperature measurements in conjunction with buoy surface and subsurface temperature in situ measurements will be important in quantifying the heat content of the upper layers of the ocean. Wind measurements from moored and drifting buoys may be essential in the calibration and validation of remote satellite measurements and may be required for data enhancement in the development of an operational ocean climate monitoring system. NDBO has initiated development activities to provide the needed environmental measurement/monitoring capability in response to anticipated climate-related experimental needs.

3.1 Drifting Buoy Payloads

A Buoy Transmit Terminal (BTT) was designed to operate on small data collection platforms and in concert with the onboard NIMBUS-6 polar-orbiting satellite Random Access Measurement System (RAMS). NIMBUS-6 was launched in June 1975. In general, RAMS provides the capability for data collection and location determination for a large number of austere platform configurations. The BTT is particularly applicable to scientific programs, allowing nonreal-time or asynoptic reporting of low volume data from low cost drifting buoys.

Platform position is derived from the relative motion between the platform and the satellite, which can be measured by Doppler frequency shift patterns. All measurements and processing are centrally located, either in the satellite

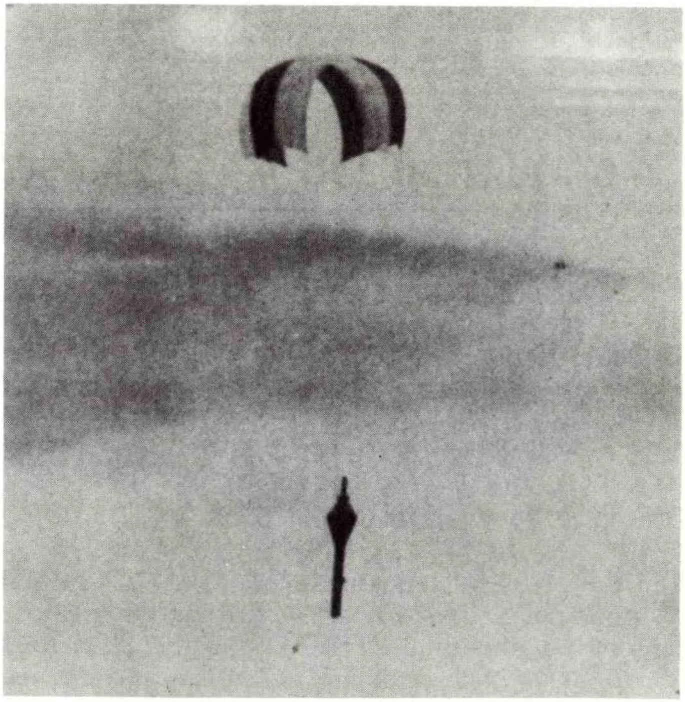

Figure 3.--Air drop of drifting buoy

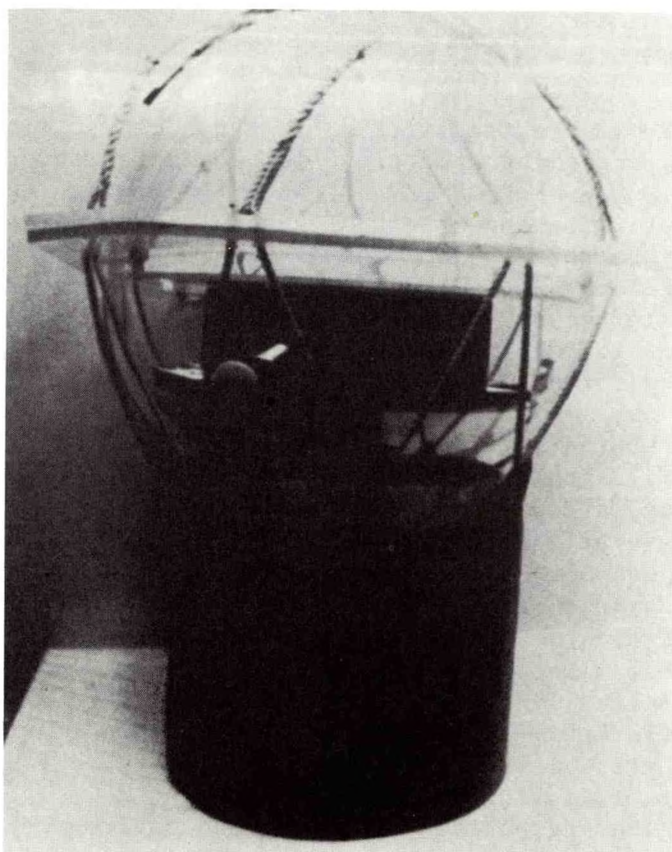

Figure 4.--Air-deployable ice buoy

itself or at the Earth tracking station, thereby enabling the use of relatively simple systems on the small platforms. The location accuracy for buoy applications is specified at 5 km rms, which has been verified by extensive testing and deployments.[9]

The BTT comprises two major functional subsystems -- a digital logic section and a solid-state transmitter. The digital section interfaces with the sensor data, converts and formats the data into a proper transmission format, and encodes the data for phase shift keying transmission. The transmitter consists of a stable oscillator circuit, a multiplier/phase shift keying circuit, and a power amplifier circuit. Prominent BTT characteristics include a power output of 2.4 watts, flexible sensor input interface options, data rates of 100 bits per second, and 300 milliwatts average power. It is packaged to fit within a 10.2-cm-diameter, 53.3-cm-long pipe.

3.2 Operations with TIROS-N

A BTT has also been developed to operate with the TIROS-N satellite, which was launched in 1978 and with future NOAA-A polar orbiters. The prominent performance characteristics are similar to the units developed to operate with NIMBUS, except for changes in bit rate, transmitter frequency, and frame-message format. All BTT's developed to date for the TIROS-N will be used in the Global Weather Experiment and are installed on board TIROS meteorological drifters. TIROS-N BTT's are also scheduled for drift detector application on moored buoys.

4. DATA FLOW

Data from moored buoys are transmitted, in sequence, to either the east or west GOES satellite, depending upon elevation angle geometry. In general, all satellite transmissions are aimed at achieving the highest buoy-to satellite elevation angle to minimize the effect of sea-multipath during periods of buoy motion. A secondary factor in selecting either the east or west GOES is the achievement of a balanced traffic load. These factors have resulted in an overall system wherein buoys in the North Atlantic region use the east GOES and buoys in the Pacific region and Gulf of Mexico use the west GOES. Figure 5 shows the data flow for NDBO moored buoys.

Onboard data acquisition begins 20 min before the synoptic hours (i.e., 0000, 0300, 0600, ..., GMT). From 9 minutes before the synoptic hour, until nearly 20 min after the hour, all buoys transmit their environmental data, each buoy at a programmed time slot to either the east or west GOES. Each buoy is provided an opportunity to report via a self-initiate, automatically pretimed mode. The primary objective at the NMC dissemination center is to place synoptic data on-line to NWS by 20 minutes after the synoptic hour. In the event the self-timed report is either missed or fails to meet minimum data quality criteria, the message is automatically requested again, during the 20- to 40-min period following the synoptic hour. In general, three interrogations are programmed in the attempt to achieve a satisfactory message reply. If the message cannot be acquired by 40 min following the synoptic hour, the message is disseminated the following hour. During periods of heightened environmental conditions of disturbances, buoys can be interrogated to provide data in either near real time or in the same sequence during the synoptic hour, while providing data hourly as opposed to every 3 hours.

4.1 Data Processing

Following the transmission of data from the buoy to the satellite, the data are immediately relayed from the satellite to a NESS Command and Data Acquisition (CDA) station at Wallops Island, Va. At the CDA, the data are received, detected, identified, and checked for quality with regard to parity and proper message heading and termination. From the CDA, the data are transmitted over a 9600-baud landline to the NESS World Weather Building at Suitland, Md. Here, the data are placed in dissemination queues for simultaneous transmission to NMC and NDBO data processing facilities.

At NMC, the data are further processed and scaled into engineering units. Data quality refinements are implemented using boundary value limits and time rate-of-change limits. Similar analyses and processing are done at NDBO with a view toward changing onboard acquisition modes via interrogation commands. Landline communication between NDBO and NMC computers are maintained to ensure that final data dissemination is limited to valid data.

4.2 Data Base Systems

NDBO maintains both information and archival data base systems. The information data base provides the necessary integrity for the buoy processing programs at both NMC and NDBO. The data base program is maintained at NDBO in a disc storage file. Computer-to-computer wireline transfer is used to maintain and update the disc data base at NMC. Also, archival data base systems are maintained from which 7- and 9-track magnetic tapes are generated. Once a month, tapes are sent to the National Climatic Center (NCC) and the National Oceanographic Data Center (NODC) for archival and meteorological and oceanographic data base analyses.

4.3 Data Flow for Drifting Buoys

The major acquisition, processing, and dissemination function for buoys using the NIMBUS and TIROS series satellites parallels those described for the moored buoy systems. The major difference between the two systems is that the drifting buoys cannot provide synoptic data, but rather provide data about every 6 hours depending upon buoy latitude. The TIROS-6 polar-orbiting satellite successfully launched in October 1978 collects drifting buoy sensor data and determines buoy position by measuring the frequency shift of the buoy transmission during the time the buoy is in view of the satellite. All the data are collected at the CDA stations in Gilmore, Alaska, and Wallops Island, Va. The received and detected data are then sent to the spacecraft operational control center in Suitland, Md., for preliminary processing. The data are then transmitted to the Centre National d'Etudes Spatiales (CNES), an agency of the French Government in Toulouse, where they are processed by Service ARGOS and disseminated worldwide over the Global Telecommunications Service. Figure 6 shows the data flow for NDBO drifting buoys.

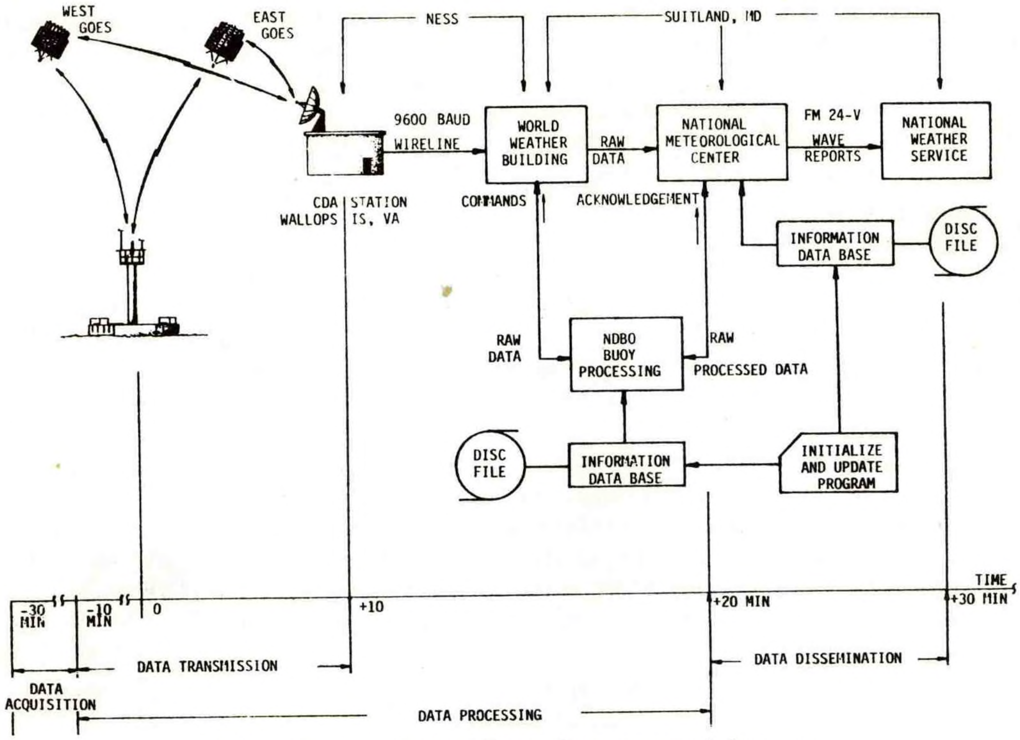

Figure 5.--Data flow for moored buoys

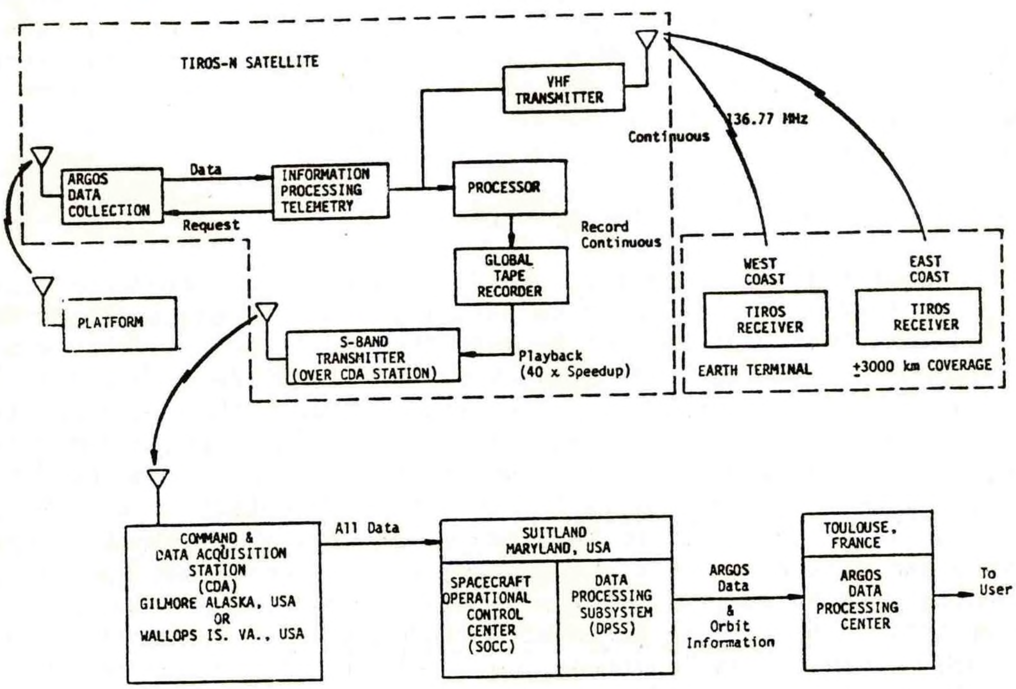

Figure 6.--Data flow for drifting buoys

5. CONCLUSION

The utility of satellite application for environmental data telemetry and dissemination has been demonstrated during the past several years. During 1978, environmental moored data buoys acquired and disseminated more than 2,500 synoptic weather messages per buoy from a complement of about 15 buoys. In addition, 25,000 wave spectra reports were disseminated in 1978 from 10 buoys equipped with wave data systems. During 1979, about 25 moored buoys will be on station, all equipped with wave data systems. Satellite data telemetry has allowed the reliable delivery of high-quality data from various remote and often hostile ocean areas. These data buoys are having major impact by providing environmental data for:

- o Improved weather forecasting
- o An initial data base for evolving climate monitoring programs
- o Ocean climate monitoring studies
- o Remote satellite measurement/monitoring systems
- o Environmental base line data for energy source assessment.

The launch of polar-orbiting satellites capable of data collection and relay and position determination from surface platforms has provided a global environmental measurement/monitoring capability at economy scales unachievable before. Lagrangian drifting buoys are potentially a unique tool for the global measurement of surface and deep ocean currents over large spatial and temporal scales. During the Global Weather Experiment, drifting buoy surface measurements are being used as an ancillary data source to infer vertical profiles of temperature and wind from remote satellite measurements.

Improving the measurement/monitoring capabilities on a global basis will lead to a better understanding of our oceanic and atmospheric climates. With the aid of the data and experience from the Global Weather Experiment, it will be possible to design an evolving composite global observing system for routine long range weather prediction, thereby providing the knowledge needed to reduce global vulnerability to climate variations.[17]

REFERENCES

1. "Elements of the Research Strategy for United States Climate Program," Report of the Climate Dynamics Panel to the U.S. Committee for the Global Atmospheric Research Program Assembly of Mathematical and Physical Sciences, National Research Council; National Academy of Sciences, Washington, D.C., 1978, p. v.

2. "The Ocean's Role in Climate Prediction," A Report of Workshops conducted by the Study Panel on Ocean Atmosphere Interaction Under the Auspices of the Ocean Sciences Committee of the Ocean Affairs Board, Commission on Natural Resources, National Research Council; National Academy of Sciences, Washington, D.C., 1974.

3. Apel, John R., "Ocean Science from Space," EOS, Vol. 57, No. 9, September 1976.

4. McCall, J.C., Rainnie, W.O., Jr., and Kozak, R.P., "Ocean Data Acquisition and Telemetry Applied to NDBO Buoys," NOAA Data Buoy Office, November 1978.

5. "NOAA SEASAT-A Catalog of Potential Platforms for In Situ Data Collection," NOAA SEASAT-A Project, Washington, D.C., March 1978.

6. Shemdin, O.H., Inman, D.L., Blue, J.E., "West Coast Experiment Test Plan," Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, January 24, 1977.

7. SEASAT LOG, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, No. 2., January 25, 1979.

8. Apel, J.E., and Siry, J.W., "A Synopsis of SEASAT-A Scientific Contributions," SEASAT-A Scientific Contributions, NASA, Washington, D.C., July 1974.

9. Kerut, E.G., Angelico, J.F., Livingston, T.L., and Harris, J.E., "Telemetry from Drifting Buoys via the NIMBUS-6 Satellite," International Conference on Communications - IEEE, June 1976.

10. Molinari, R. L., "Buoy Tracking of Ocean Currents," Advan. Astronaut Sci., 30, 431, 1974.

11. Global Atmospheric Research Programme (GARP), "The First GARP Global Experiment Objectives and Plans," GARP Publication Series No. 11, March 1973.

12. "Plan for U.S. Participation in the Global Atmospheric Research Program," U.S. Committee for the Global Atmospheric Research Program, Division of Physical Sciences, National Research Council, National Academy of Sciences, Washington, D.C., 1969.

13. Global Atmospheric Research Programme (GARP), "Summary of Implementation Operations Plan," Volume No. 1, April 1978.

14. Brown, W.P., and Kerut, E.G., "Air-Droppable RAMS (ADRAMS) Buoy," Proceedings of OCEANS '76 IEEE/MTS, September 1976.

15. Maykut, G.A., Thorndike, A.S., and Untersteiner, N., "AIDJEX Scientific Plan," AIDJEX Bulletin No. 15, August 1972. Arctic Ice Dynamics Joint Experiment, Division of Marine Resources, Univ. of Washington, Seattle, WA.

16. AIDJEX Bulletin No. 40, June 1978. Arctic Ice Dynamics Joint Experiment, Division of Marine Resources, Univ. of Washington, Seattle, WA.

17. "International Perspectives on the Study of Climate and Society," Report of the International Workshop on Climate Issues, Climate Research Board, Assembly of Mathematical and Physical Sciences, National Research Council, National Academy of Sciences, Washington, D.C., 1978.

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Departmen Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic im of natural and technological changes in the environment and to monitor and predict the state of the solid E the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications:

PROFESSIONAL PAPERS — Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS — Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS — Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS — Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS — Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS — Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

Information on availability of NOAA publications can be obtained from:

ENVIRONMENTAL SCIENCE INFORMATION CENTER (D822)
ENVIRONMENTAL DATA AND INFORMATION SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

6009 Executive Boulevard
Rockville, MD 20852

NOAA--S/T 79-227