CHAPTER 2

SIMULTANEOUS DATA SYSTEM FOR INSTRUMENTING THE SHELF

by

Robert L. Lowe, Douglas L. Inman and Birchard M. Brush

Scripps Institution of Oceanography, University of California

La Jolla, California 92037

ABSTRACT

A system, designed to give maximum flexibility and portability, has been developed to collect wave, current and other physical data within the dynamic environment from the surf zone to the edge of the shelf. The system consists of a radio-linked shore station, housed in a mobile van and as many as six shelf stations mounted in bottom referencing spars.

A shelf station can be deployed from a small boat with minimum diver time. The ease of deployment of the shelf stations coupled with the mobile self-contained shore station, allows the use of a modern data acquisition system, and rapid deployment of sensors, for the field study of remote coastal areas.

Each of the shelf stations is designed to accomodate as many as fifteen sensors. All simultaneous sensor outputs are digitized and transmitted by radio to the mobile shore station, where the received signals are processed and selected for recording on strip charts or digital magnetic tapes for computer analyses. Very high sampling rates and a real time system are used to insure precise time correlation between all data channels including those from separate shelf stations.

A single shelf station would transmit data from an array of wave sensors, thus providing continuous wave climate including the two dimensional wave spectra. Some different combinations of shelf station ensembles are shown.

INTRODUCTION

In order to observe more comprehensively the broad tapestry of energy translation which occurs as a result of the action of waves and currents incident to the coastlines, a multipurpose data acquisition system for instrumentation of the surf zone was developed several years ago (Koontz and Inman, 1967). This early system enabled the evaluation of the longshore transport of sand as a function of wave power (Inman, et al, 1969; Komar and Inman, 1970). Subsequently it became an important factor in the study of the mechanics of rip currents and mixing in the surf zone (Bowen and Inman, 1969; Inman, et al, 1971). Because the early system was limited in scale and resolution, it became attractive to consider a second generation data acquisition system which would increase resolution and greatly expand the capacity to achieve accurate data over much larger areas.

A project in 1971 for assimilating larger amounts of data than formerly available in the nearshore zone and on the continental shelf led to a new system; the Shore and Shore System (SAS System), which included an economical vertical spar which could be placed in varying depths of water for the purpose of relaying data to a shore station and make it available for further processing and analysis. The SAS System was designed so that it would be possible to rapidly exchange transmitting and battery modules, while using a small boat as an operational base.

Original evaluation of a design concept suitable for use as the shelf station ran the gamut from a single tethered subsurface sphere (an oscillator at certain wave periods and subject to periodic torsional rotation); consideration of a redundantly anchored subsurface sphere (again, complex because of intensive anchor placement, and the requirements necessary for accurate anchor spotting); and, surface buoyant devices (sometimes wavelength-coupled and fraught with seakeeping problems). The final choice for the shelf station was a vertical spar shape which is securely anchored to the bottom through a universal joint. This arrangement prevents vertical motion, but allows motion in the horizontal plane. Vertical sections of filament wound pipe may be added for varying depths using sexless couplings. Tests performed in the hydraulics laboratory have verified that the heave-free spar tends to rectify the prevailing current direction, and implies integration of the water column, though its surge response is still being studied.

As of August 1972, a prototype has been successfully exposed to all wave regimes and storms in 20 meters of water off Scripps Pier. The survival of the shelf station in inclement periods of weather leads to speculation that storms for the first time may be instrumented; these are occasions of compelling interest in the study of nearshore processes.

The SAS System, shown schematically in Figure 1, has the following major subassemblies: 1) a shelf station, which has a benthic power supply and a vertical spar which may accomodate various ensembles of sensors; and, 2) a shore station, which receives coded data and records it virtually simultaneously for further processing and visual assay. The most frequently used sensors, on the shelf station, have been digital wave staffs, absolute pressure sensors, and passive electronic current meters. In addition, depending upon the type of operation being used for special studies, a suspended sediment meter, thermal measuring devices, and bottom roughness profiler will utilize other data channels on the shelf station. Portions of the capability for synchronous binary counting will enhance the ability to relate underwater photography to time series, and allow individual frames of motion pictures to be correlated with data taken at the same instant.

The SAS System contains a data acquisition system using a multiple radio link, pulse code modulated (PCM) telemetry link. Up to six shelf stations each having the capacity to transmit up to 15 data channels (i.e., 15 sensor inputs) can be processed simultaneously. All sensor outputs are converted to digital (10 bit binary) before transmission to the shore station. Each shelf station operates on a different RF frequency to provide isolation between shelf station transmissions.

The van mounted shore station receives the transmitted information from the shelf stations simultaneously, processes the data to provide outputs in the form of hard copy, strip chart records, and digital tape. The digital tape provides the means for inputing the data into a computer system for detail spectral and cross spectral analysis.

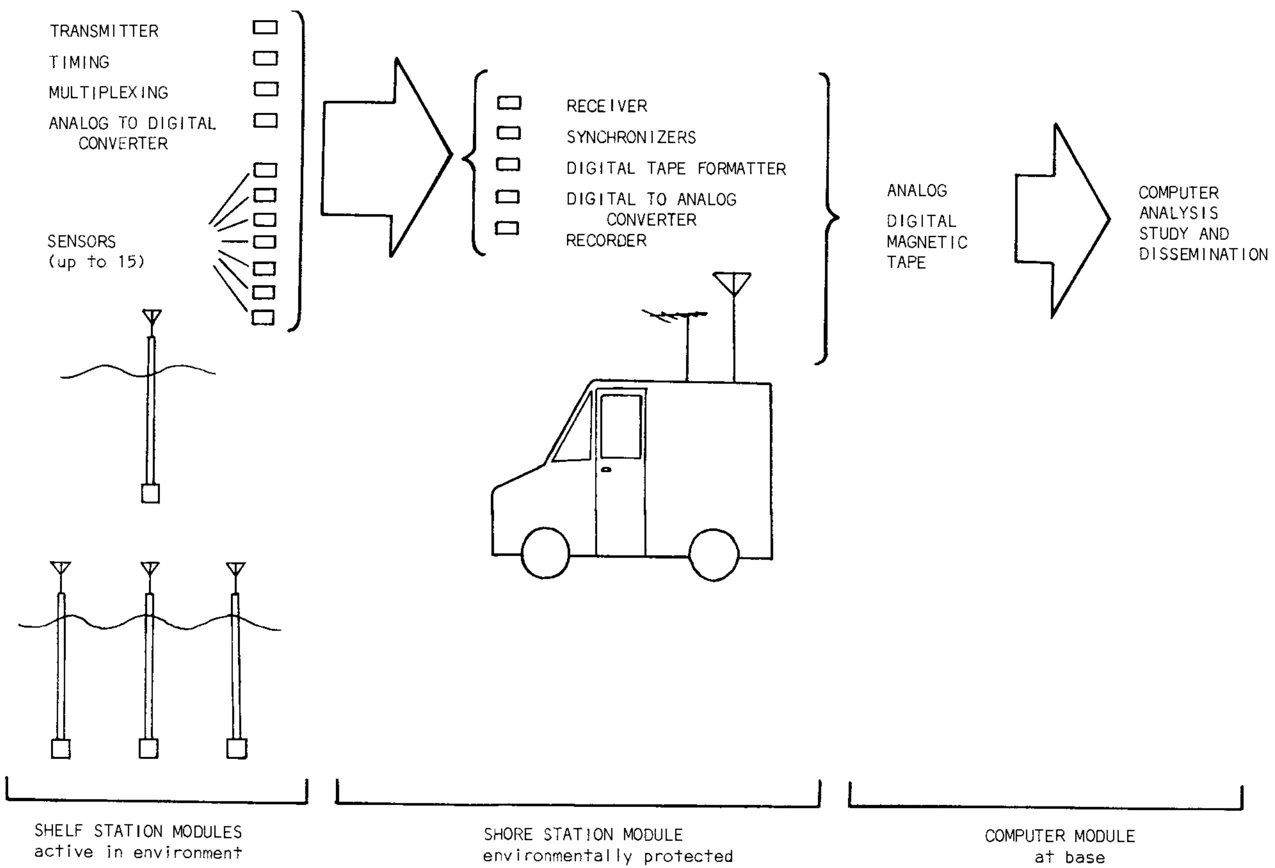

Figure 1. Schematic diagram of the shelf and shore system (SAS System). The system accepts data from six spar shelf stations, and each station will accomodate up to 15 sensors. Data is telemetered to a shore van recording station, thence to computer analysis.

In order to provide the maximum close range support, an especially modified van is capable of positioning the shore station, in the field, on coastal terrain. The component racks of the shore station are designed to be enclosed by the van and will operate from within. Major components of the SAS System are now available, and may be transported to a field location by road or on shipboard so that field conditions need not be primative as far as data acquisition is concerned. The SAS System appears to offer a versatile shelf study tool and continues to suggest itself for other applications as a basic field tool.

SHELF STATION

The shelf station consists of a vertical spar with airtight ends (Figure 2), utilizing a standard pipe size of 3.5 inches OD with a wall thickness of 0.144 inches. Standard lengths are used for modular assembly, and can be assembled to provide the desired total length. The pipe is filament wound with 75% glass and 25% epoxy resin (Table 1). In depths of water over 20 meters, the bottom sections are free-flooded.

The couplings are sexless, forged, anodized aluminum with two cadmium steel plated bolts each (Roylyn Div., Rucker Corp). These couplings are modified with a larger than standard seal to prevent loss of integrity when experiencing bending moments imposed by wave action. The sealing unit or "oreo" seal (Figure 3) consists of layers of elastomeric compound (usually neoprene with a 40 to 50 shore durometer hardness) interleaved with circular metal plates. A single axial bolt compresses the elastomer between the circular plates and exerts a bearing stress against the inside of the pipe. The pipe is bias wound (45^{o}) to tolerate the induced loop strain. When properly installed, a 3 inch oreo seal will withstand an axial load in excess of 1000 lbs by friction alone.

Two sizes are used; a 3 inch diameter seal for the top and the bottom of the shelf station, and a 2 inch diameter seal for the internal cartridges. Redundant sealing is used so that in case of damage to the shelf station spar the individual packages and circuits might be more likely to survive immersion. Where possible, transmitters, logic packages, and support modules are intentionally packaged as long slender units which will correspond to the configuration of the shelf station spar. As an alternative, the cylindrical package may be strapped alongside on the outside of the spar. A section of filament wound pipe may be cut to any desired length and sealed at each end with an oreo seal to provide additional volume with watertight integrity, including provision for watertight passage of wires and cables. The anchor assembly is shown in Figure 4: above the captive pivot pin, the positioning and trim weight platform can accept 40 lb weight modules as an aid in positioning the spar while attaching the pin. The anchor platform will accept up to six weight modules depending on the length and buoyancy of the spar. Normally, access to the lower oreo seal is only required on land, and is performed with a socket wrench and extension, through the lower clevis slot.

The univeral joint allows the spar to maintain a preferential direction without resisting. It is a standard automotive part, encased in a silicone oil filled bellows to prevent corrosion.

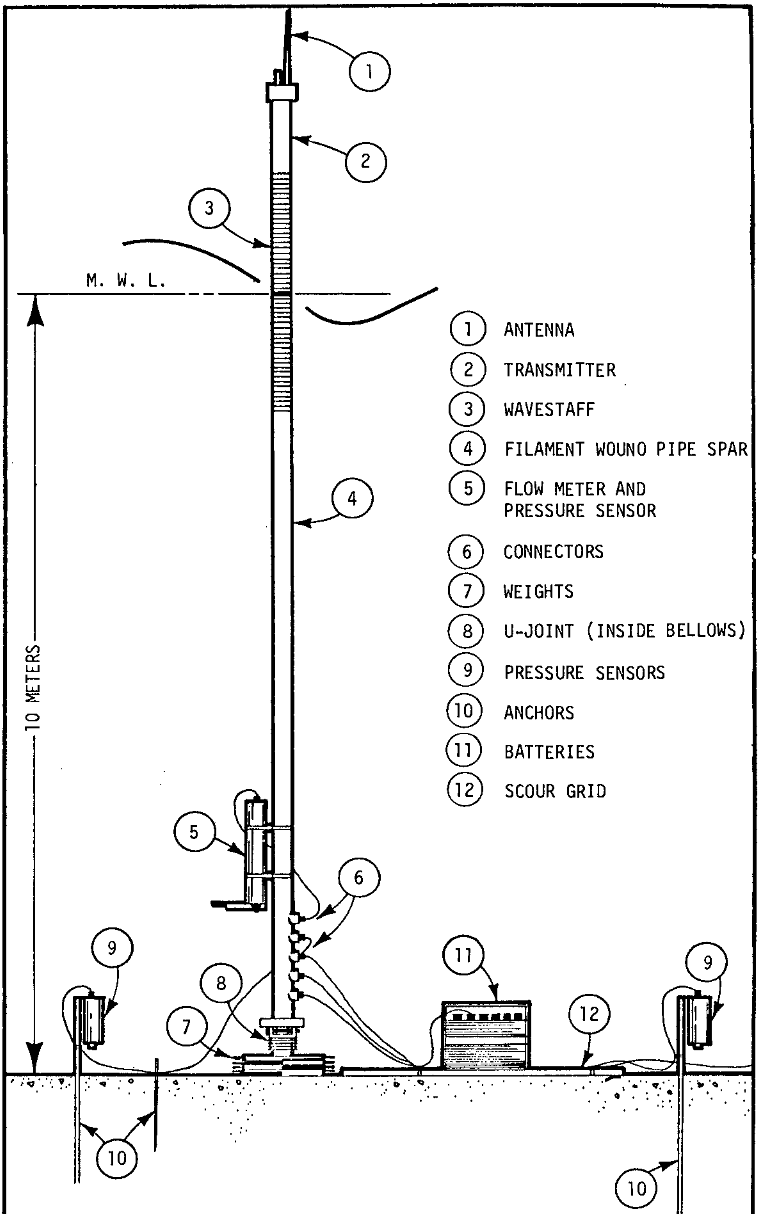

FIGURE 2. SHELF STATION

Table 1. Properties of filament wound pipe as used for the vertical buoyant section of the SAS shelf station. *

Outside Diameter	3.5 inches
Thickness of Wall	0.144 inches
Mean Radius	1.68 inches
Cross Sectional Area	1.48 in^2
Buoyancy (air filled)	3.07 lbs/foot
Weight per foot	1.2 lbs.
Section Modulus	1.195 in^3
Polar moment of Inertia	4.179 in^4
Moment of Inertia	2.098 in^4
Density	.076 lbs/in^3
Glass/Resin Ratio (weight)	3/1
Ultimate Tensile Stress	80,000 psi
Yield Stress	12-14,000 psi
Young's Modulus of Elasticity	5×10^6 psi
Poissons ratio	0.29
Expansion Coefficient	8.8×10^{-6} in/in/^oF
Conductivity	1.7 BTU/ft^2/^oF @ 50^oF
Internal (working) Pressure	120.5 psi
External (working) Pressure	69.6 psi

* Bondstrand #2000 series, Ameron Div., Brea, California

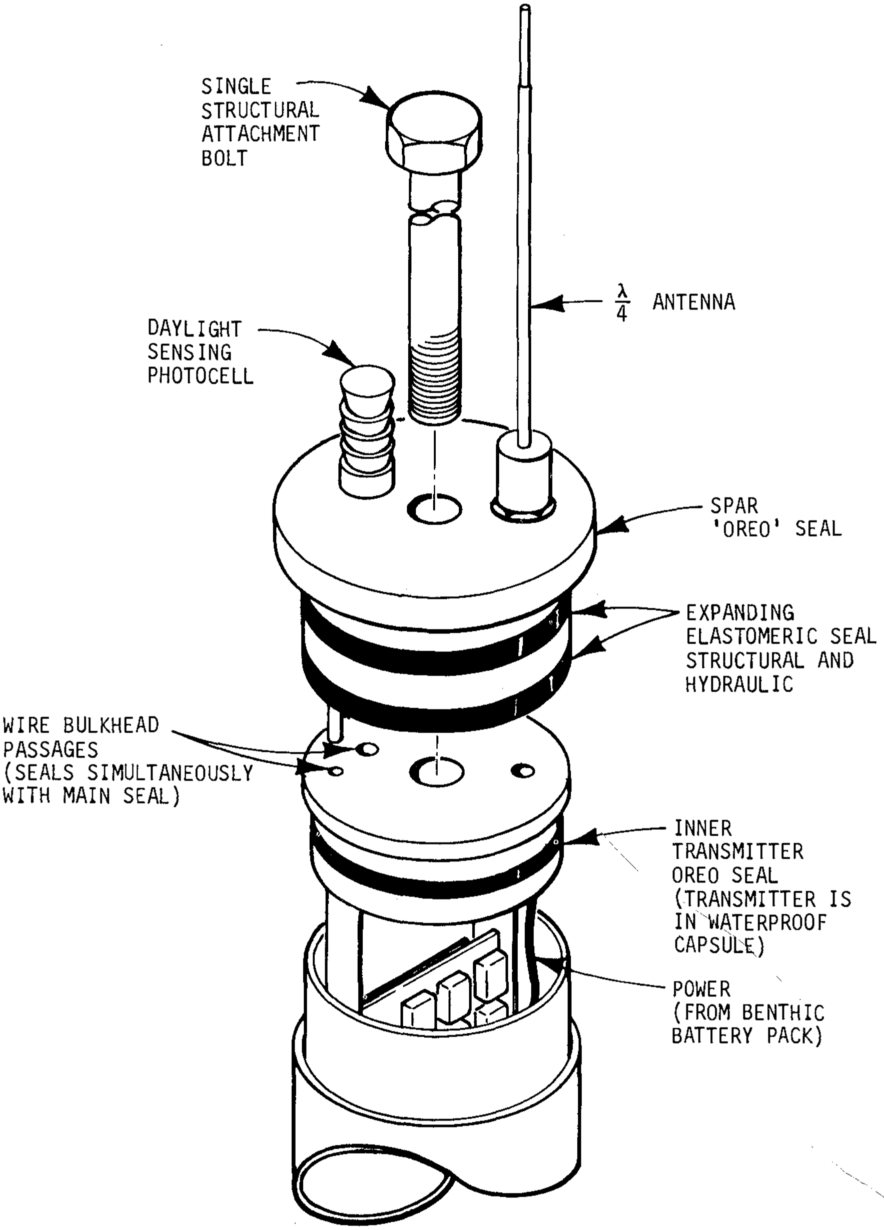

Figure 3. To facilitate rapid exchange while on station, the transmitter capsule may be removed and replaced with a centrally bolted 'oreo' seal which combines structural integrity with watertightness.

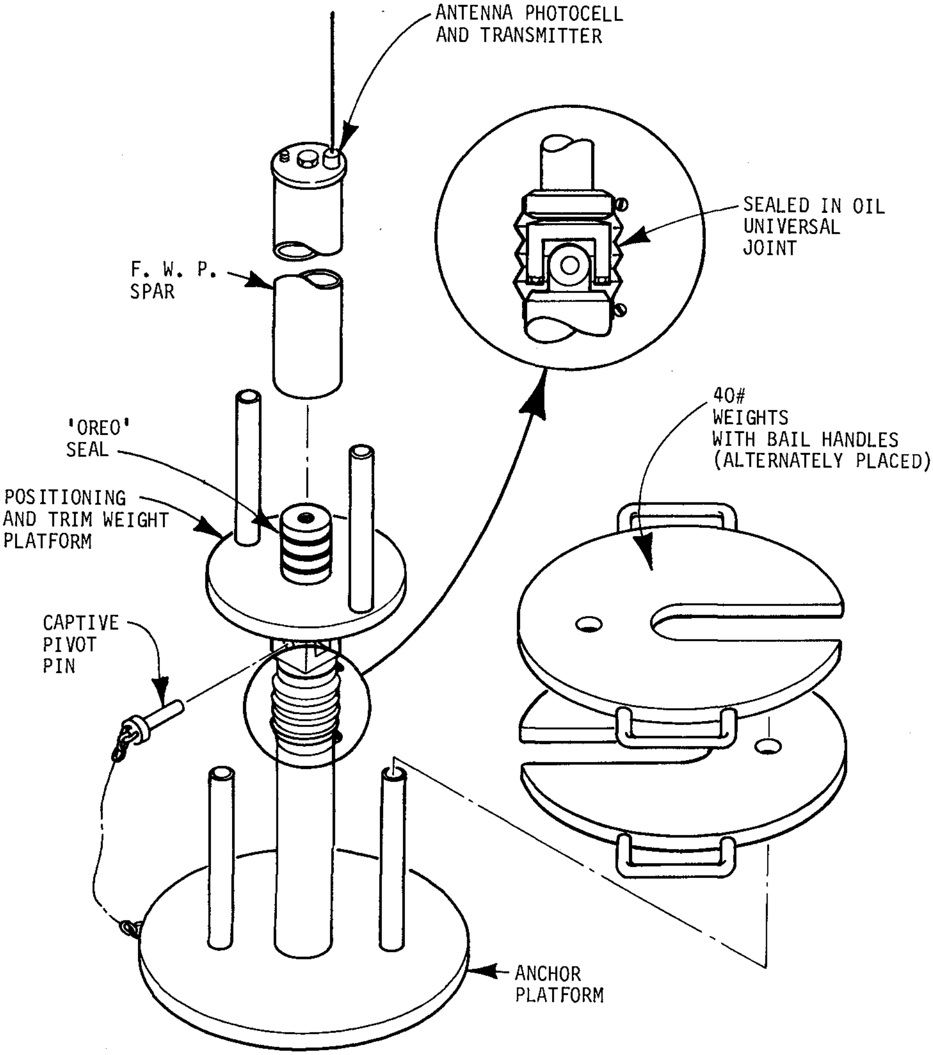

Figure 4. The lower portion of the station separates to facilitate installation and removal of components. Weights added to the trim weight platform enable the buoyant spar to be engaged to the anchor assembly.

DATA ACQUISITION AND PROCESSING

The SAS System has been designed to acquire data from a large array of sensors simultaneously. In order to accomplish this task, state-of-the-art telemetry techniques must be utilized. A completely digital data transmission scheme known as Pulse Code Modulation (PCM) is employed on six assigned UHF (ultra high frequency) frequencies within the band between 216 and 219.6 mega Hertz. Six shelf stations can therefore be operated simultaneously; each on its own UHF frequency band.

Shelf Station Electronics

Sensors can be located either within, clamped to the outside or on the bottom near the base of the shelf station. As many as 15 sensors can be accomodated by a single station. Among the most frequently used sensors are digital wave staffs, absolute pressure sensors, passive electronic current meters and accelerometers (accomodation for other sensors which might be developed in the future, whose output is in volts is assured).

A functional block diagram of the shelf station electronics is shown in Figure 5. The system is designed to accept 8 analog type sensors (e.g., pressure sensors) and 7 digital type sensors (e.g., digital wave staffs). Signals emanating from sensors having an analog format are amplified, attenuated, or offset in the signal conditioning section. Signal conditioning is necessary in order to take advantage of the entire dynamic range of the analog to digital converter. Sensors having an inherent digital format are interrogated by the digital multiplexer and their data is serially shifted into the PCM encoder.

The PCM encoder functions as a master controller establishing the sampling rates for the sensor, converting all analog signals to digital, converting parallel data into serial,and generating a unique 10 bit pattern called a frame sync word. Timing is established by dividing down a high frequency oscillator to establish bit-time or clock, word time, and frame time. From these divider outputs, the necessary timing control signals can be derived.

There are two interlocked multiplexers; one for analog data channels and one for digital data channels. The PCM format is designed to handle 16 channels; 8 analog and 7 digital and 1 frame sync word. The frame sync word is assigned the first word in the frame; and is used by the receiving equipment to identify the start of the frame. During the second word time, the first analog channel is sampled, followed by the first digital channel. Alternating between analog and digital channels continues until all input channels have been sampled. This process constitutes a total frame of data. Frame after frame of data is formatted in this fashion giving a continuous serial stream of binary data.

This serial bit stream of data consisting of a binary "1's" and "0's" is known as non-return to zero level code (NRZ-L). The NRZ-L signal turn is converted into a phase encoded signal called biphase level code (biϕ-L). In a Biϕ-L code the information (data) is contained in the clock phase (i.e., a binary "1" is represented by 0^o clock and a binary "0" by 180^o clock). It is this Biϕ-L code, after it has been filtered at approximately twice the bit rate, that is transmitted over a UHF radio channel. The selection of Biϕ-L code for transmission was motivated by one important characteristic; its

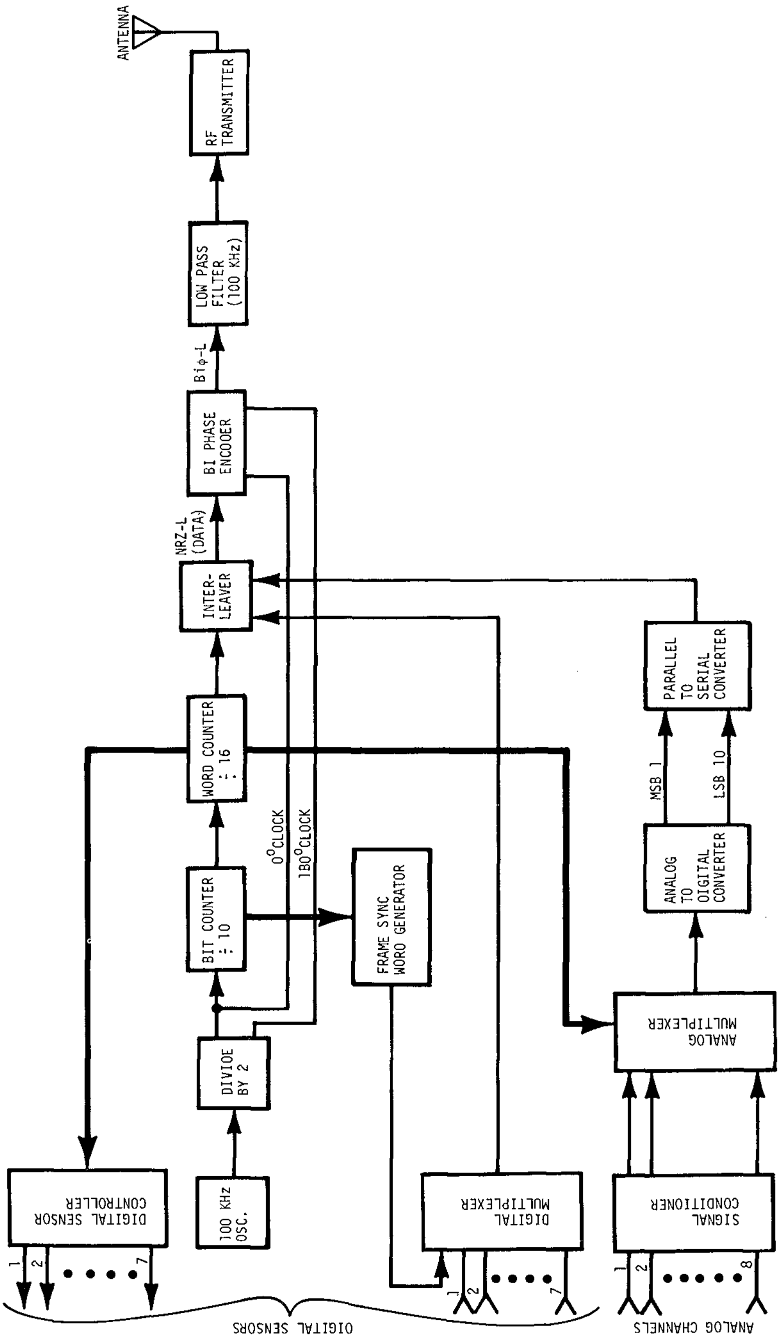

Figure 5. Up to fifteen different sensors or combinations of sensors may be accomodated by the SAS System. It is designed to accept 8 analog output sensors, and seven digital type sensors.

power spectrum density is zero at zero frequency, which is not true of other binary code types. This characteristic is important in this system for two reasons: (1) the design of the RF transmitter and receiver is much simpler because the RF system does not need dc response; and, (2) direct recording on a wide band analog tape record of the receiver output is more readily accomplished. A price must be paid for this desirable trait however; Biϕ-L code requires approximately twice the bandwidth for the same information rate than does NRZ-L. In the present system this increased bandwidth did not pose a problem.

Presently the PCM encoder is set-up to operate at 50,000 bits per second which provides a single sensor sampling rate of approximately 300 samples per second. Although the sampling process used is sequential, this high rate insures virtually simultaneous data from all 15 sensors.

Power Supply

The shelf station and its complement of sensors are powered by especially packaged lead-acid batteries. A sketch of the power pack is shown in Figure 6. Two 12 volt batteries are connected in series to provide 24 volts for operating the system. For a typical installation, 80 amp-hr rated batteries will operate a shelf station continuously for 120 hours; or slightly longer if intermittently operated.

In order to protect the battery's plates from the intrusion of sea water, a special oil mixture is used. The density of the oil is adjusted between that of the electrolyte and that of sea water. The oil allows the gas formed during battery discharge to escape, yet prevents sea water from mixing with the electrolyte.

Most installations are in water shallow enough to have intensive wave action at the bottom and thus bottom scour is a potential problem. To prevent the power pack from tumbling a grid of aluminum tubing is used to support the batteries and extend support beyond the scour pit in the immediate vicinity of the battery. The power pack is diver recoverable and reuseable. Approximately four recharge cycles can be expected.

Shore Station Electronics

The shore station of the SAS System is a complete self-contained PCM ground station. It is housed in a mobile van to allow field work to be conducted at remote sites. Four 6 foot high racks of equipment comprise the electronics of the shore station. Data outputs from the system are in two forms: 1) hard copy in the form of 8 channel strip chart records; and, 2) 9 level IBM compatible digital magnetic tapes.

A functional block diagram of the shore station electronics is shown in Figure 7. A 6 channel receiver system was custom designed to receive the RF signal transmitted by as many as six shelf stations simultaneously. The six outputs of the receiver system are in the serial encoded Biϕ-L format. All six Biϕ-L signals are directly recorded on the 7 track, wide band analog tape recorder. This process is known as predetection recording.

Along with the data, on the 7th track of the record, a precision time reference, IRIG standard time code format "B" (IRIG, 1960) is recorded. This time code uses amplitude modulation of a 1 KHz carrier to record the time of day in hours, minutes, and seconds.

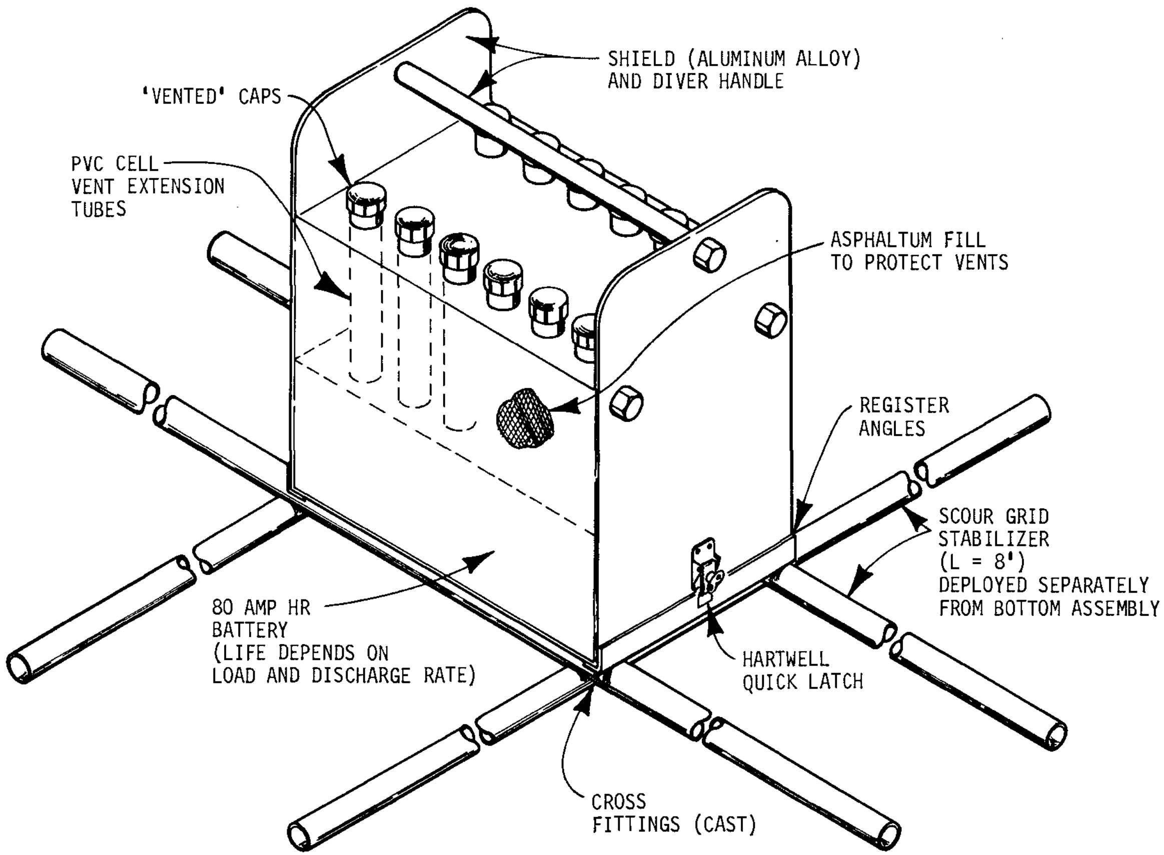

Figure 6. The benthic power pack. The necks of the cells are extended to allow the intermediate specific gravity fluid to be placed between the electrolyte and the ambient sea water. No hydrostatic pressure modifications are required with standard batteries.

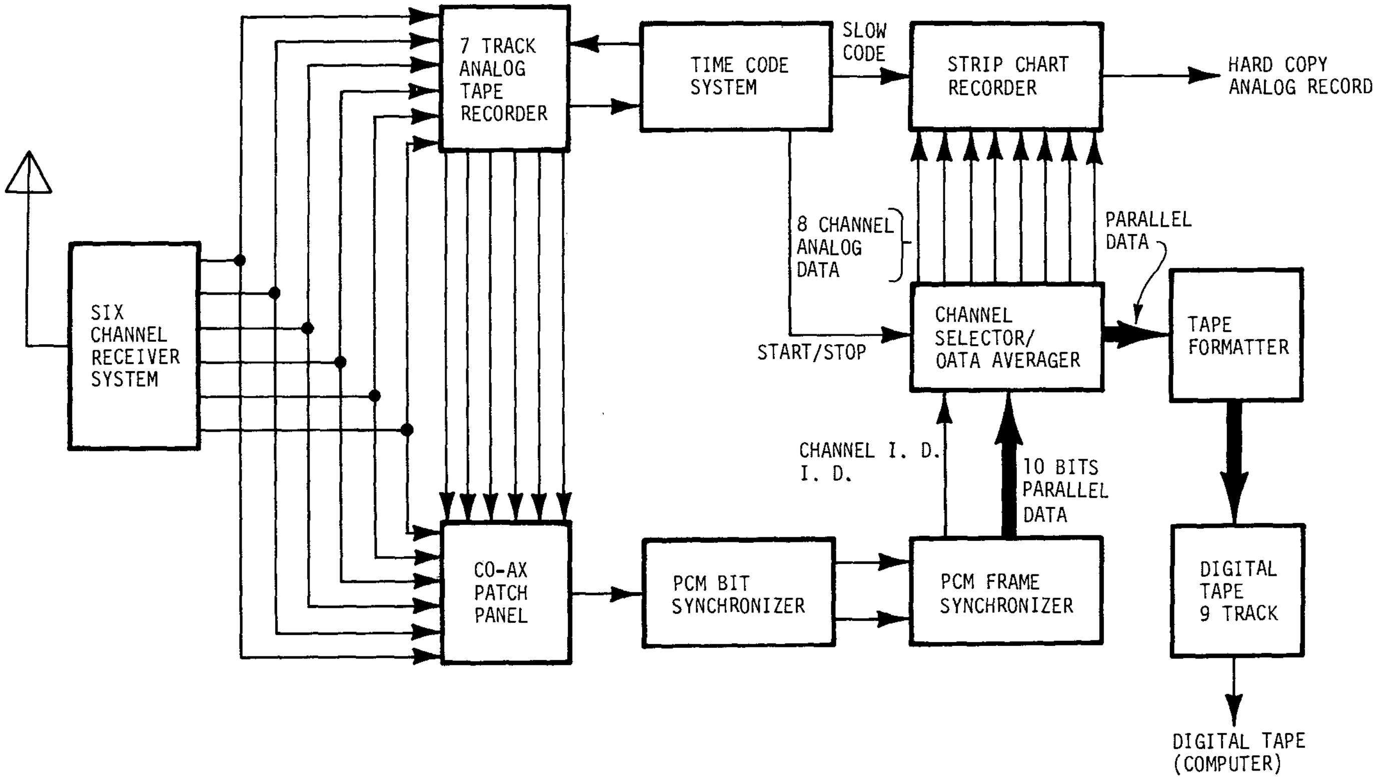

Figure 7. Functional block diagram of the shore station. The equipment is housed in a mobile van to allow data acquisition in remote areas.

Any one of the shelf stations can be selected for data reduction by the PCM system via the co-ax patch panel. The selection stations signal is applied to the PCM synchronization equipment. Synchronization must first be established with the serial Biϕ-L encoded data. A PCM bit synchronizer, using a special type of phase lock loop, produces a coherent bit rate clock. The bit synchronizer also detects and converts the serial Biϕ-L data back to NRZ-L.

Recovered NRZ-L data and clock is used by the frame synchronizer which is programmed to recognize and synchronize to the frame sync word generated by the PCM encoder in the shelf station. The frame synchronizer is equipped with bit and word counter identical to those in the PCM encoder, therefore when the frame sync word is detected, these counters are forced into step with the counter generating the data. Once synchronization is established all data channels can be identified by their location in the PCM frame. The frame synchronizer groups the data into 10 bit words and presents these words in parallel to the channel selector/data filter along with frame location identification.

The channel selector/data filter allows the system operator to select any eight of the possible 15 data channels to be displayed on the strip chart recorder. Each selected channel can be filtered using a running-mean digital filter which averages the data over 2^n samples where n can range between 0 and 7. The selected data channels are formatted for digital magnetic tape for later computer analyses. Most analysis involves computation of power spectrum using fast fourier techniques. This technique requires a record length 2^n where n is any positive integer. In our computer programs n is usually 12 (i.e., 4096 data points). The system allows flexibility in selecting the sampling rate which produces the 4096 data points. The operator can select a rate from as low as one sample every two seconds to as high as 16 samples per second. In order to insure simultaneous data from all 8 channels, a memory is provided in the channel selector/data filter to store the data until requested by the tape formatter.

Simultaneous samples from all six shelf stations are made possible by the serial time code recorded along with the data on the analog tape recorder. Precise control of the start time in the playback mode insures simultaneous sampling of the data. Playing the analog tape through the system while holding the start time constant, enables all shelf stations to be sampled at the same time.

Applications

The SAS System has many possible modes of operation, some of which are depicted in Figure 8. The general configuration shown in A might be used to study surface waves coupled through a thermocline, or to study the interaction of internal and surface waves. This configuration distributes sensors along the water column. 'Wave climate' can be obtained using a single shelf station as shown in B and C. Configuration B uses an array of pressure sensors placed along the bottom from which wave energy and directional spectra can be inferred by computation. Configuration C uses a passive electronic current meter to resolve direction and a pressure sensor for measuring wave energy. Finally, an array of shelf stations can be used to study larger scale phenomena such as edge waves, and the study of circulation and mixing over the shelf.

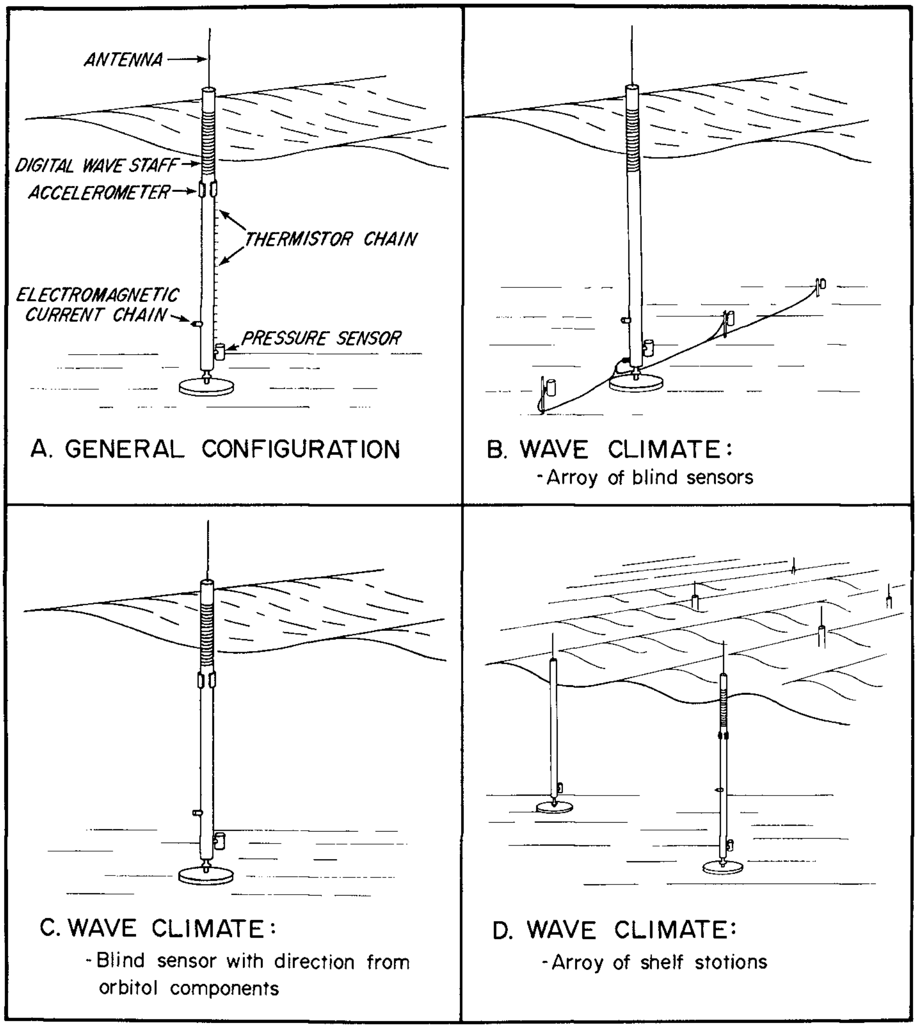

Figure 8. The shelf station is shown in four arrangements, each one of which uses common modules. Survival of prototype units have encouraged speculation that storm data may be taken continuously.

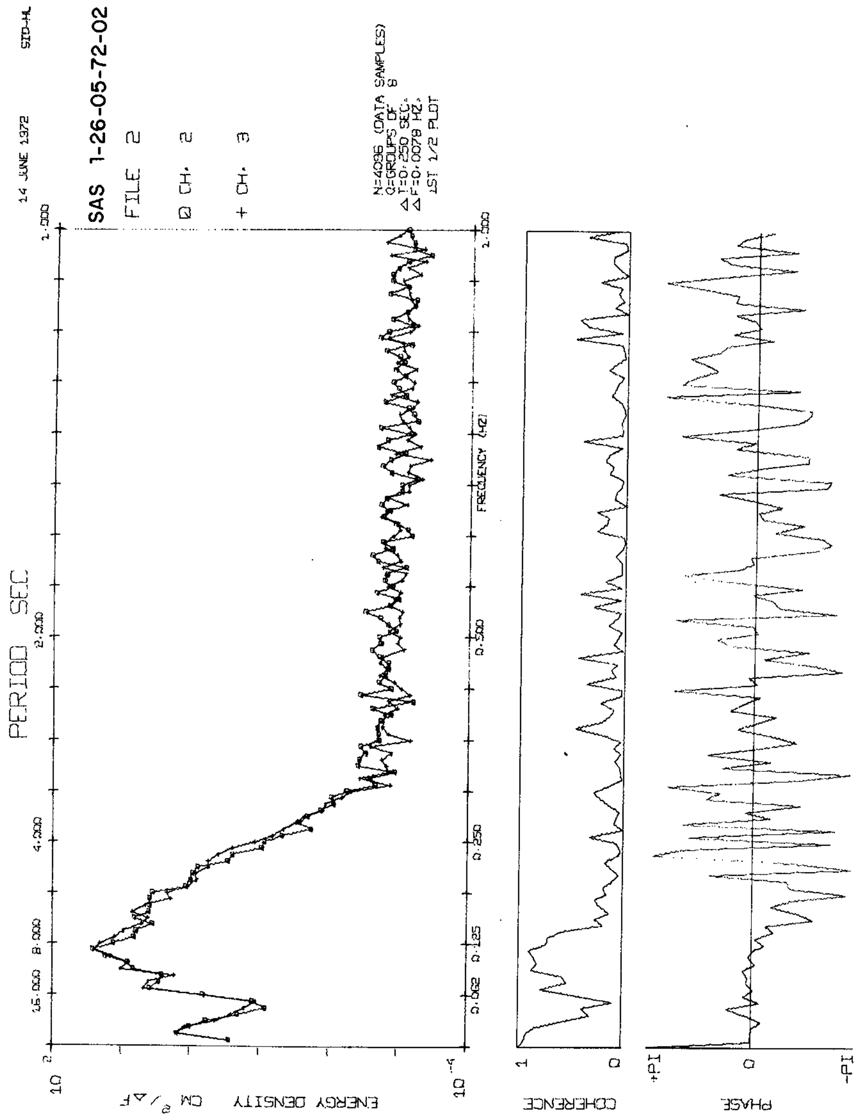

Figure 9. A typical energy density spectra presented by computer analysis. Perfection of this technique has led to new insights into the driving processes of the nearshore zone.

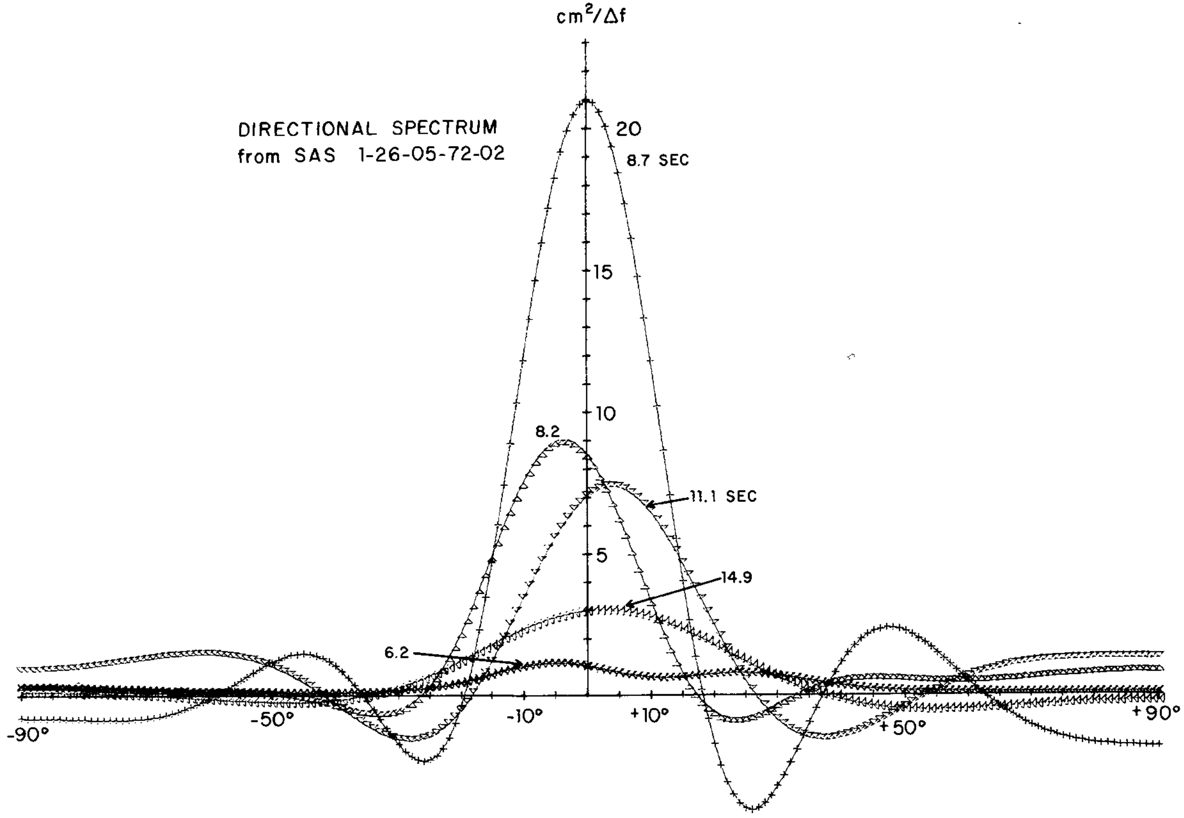

Figure 10. A directional spectrum plotted from the analytical results of SAS 1-26-05-72-02. In such plots as this the synoptic collection of data contributes to unifying theories.

The use of the SAS System is exemplified in a wave climate study. For this study a shelf station was deployed in 10 meters of water along with a four element pressure sensor array. The array was placed parallel with the beach and with a spacing of 30 meters, 60 meters, 30 meters (1-2-1). Figure 9 shows the energy spectra computed from 4096 data samples. Sampling rates for all sensors was 4 samples per second. The maximum energy occurs at a wave period of 8.7 seconds. The directions of various wave periods were computed, and are shown in Figure 10. Note that the direction of the waves is frequency dependent varying from -5 degrees for the wave of 8.2 seconds and less through 0 degrees for the 8.7 second wave to +5 degrees for the longer period wave of 11.1 seconds and greater.

Work is continuing on software for computing the directional spectra from the array data. The example given here represents preliminary results from this effort.

SUMMARY

The SAS System provides a nontraditional approach to simultaneity of measurement from large sensor arrays. Each record provides background for other measurements, and for cross-spectral analysis between various measurements. Synoptic collection of data is essential for a comprehensive and unifying study of the dynamic environment of the nearshore area.

ACKNOWLEDGMENTS

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