AUTOMATED REMOTE RECORDING AND ANALYSIS OF COASTAL DATA

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ABSTRACT: A system is described for sampling coastal data from a remote central station under computer control. The data gathering network handles wave measurements from offshore buoys and nearshore pressure sensors, and velocity components from current meters and anemometers. Coastal station locations range from Hawaii to North Carolina with system interconnection through ordinary dial up telephone lines. Data are objectively edited automatically, analyzed and are available for remote display within a few minutes of the observation. Measuring instruments, system hardware, operations, and reports are described.

INTRODUCTION

The collection and rapid dissemination of climatological and environmental data by weather services became routine decades ago in the industrialized nations. A comparable capability for those features of the climate of greatest interest to coastal engineers, nearshore waves and currents and wind at the shoreline, has lagged far behind.

An early approach to a limited national capability occurred in the United Kingdom. Draper (2) describes the growth of a wave climate program in the U.K. Canada followed with an extensive system of offshore wave measurements with accelerometer buoys as described in Wilson and Baird (13). The first program of national scope in the United States was conducted by the NOAA Data Buoy Office. This involved a relatively small number of buoys in deep water, primarily for conventional weather measurements. Steele and Johnson (12) describes the wave measurement capabilities of this system. None of these systems made measurements close to shore. All of the wave data had either no directional information or such limited directional resolution that meaningful refraction analyses were not possible for a specific location. The Japanese have also developed an extensive national wave gaging program with a mix of offshore and nearshore measurements.

At a wave measurement conference in 1974, the keynote address by Professor Robert Wiegel stressed the need for acquiring a nearshore wave climatology for the United States to allow coastal engineers to make more rational design decisions. The present writers began a development program immediately to meet those needs and others we perceived for coastal data collection and analysis. The design attributes for the system were:

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(1) The ability to accept input from any sensor type that provides continuous output; (2) automatic operation of the complete data sampling, recording, validation, and analysis sequence without intervention except for maintenance; (3) recording at a central station with near real time availability of analyzed results; and (4) data link costs that would allow economical operation of the system with inputs from anywhere in the country.

Some of these goals were met in the first operational configuration as described in Seymour and Sessions (10). Significant improvements in system economics, reliability and capability were made in the next few years as described in Seymour (4). In 1979, with the acquisition of a computer dedicated to analysis, all of these goals were finally met.

The network for coastal data was designed and developed by the Nearshore Research Group at the Scripps Institution of Oceanography (SIO), under the direction of the writers. The effort received sponsorship from a variety of local, state, and federal sources. At present, it is sup-

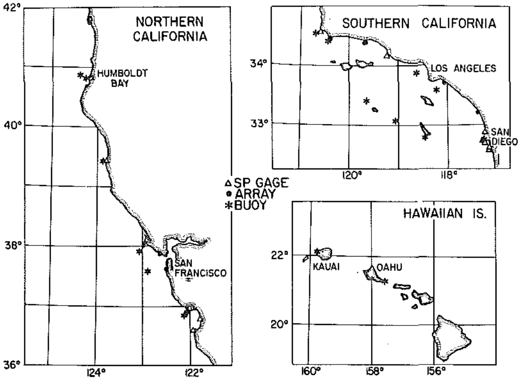

FIG. 1.—Wave Network Station Locations in California and Hawaii

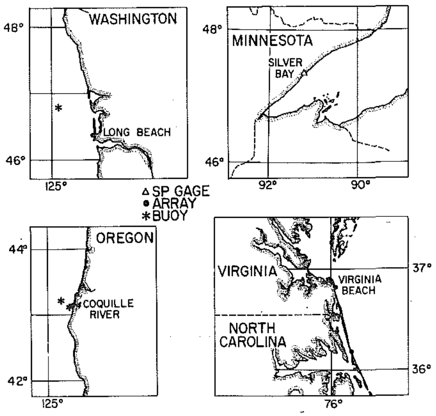

FIG. 2.—Other Wave Network Station Locations

ported jointly by the U.S. Army Corps of Engineers (USACE) and the California Department of Boating and Waterways (CBW). One of the attributes of the system is rapid dissemination of data. At the end of the first month of operation in 1975, a monthly report was issued showing spectra and other wave parameters from the first operational station at Imperial Beach, California. Every month since then, analyzed data have been reported to a large group of users, including government agencies and private engineering and consulting firms. In addition, data are summarized at the end of each year as described in one of the following sections. The system has been used to record wave energy in deep water, wave energy and direction in shallow water, long period waves in harbors and on coastal shelves, currents and wind. Figs. 1 and 2 show the locations of the stations that have been, or are now, connected to the network. The following sections describe the design and operational characteristics of the system hardware, the analytical techniques, including the automatic editing capability, and the data dissemination methods.

DATA GATHERING AND RECORDING

The system is based upon burst, rather than continuous, sampling. The sampling frequency is field selectable from several hertz to cycles per minute. For ocean gravity waves, the sampling frequency is typically set at 1 Hz. In certain limited fetch applications, such as inland waters, this is increased to 2 Hz. For infragravity waves, the signals are lowpass filtered as described later and sampled typically at 0.125 Hz. Current meters and anemometer outputs are averaged over 5–15 min intervals and sampled at the same rate.

Since most of the time series are fourier transformed to obtain spectral characteristics, the sample size is set by powers of two. Standard sample sizes are 1,024 and 2,048. A 1,024 point sample at 1 Hz yields approximately 17 min of data. A 2,048 point sample at 0.125 Hz covers about 4 hr and 33 min. In the standard mode of operation, every instrument attached to the network is interrogated once every 6 hr. Certain critical stations are polled every 3 hr. Three hour data intervals obviously precludes the 4+ hr sample time used for infragravity waves and certain current and wind measurements.

A block diagram of the coastal data system is shown in Fig. 3. Sensor signals are fed to a weather-proofed enclosure mounted on shore close to the measurement site. The shore station contains the data conversion and storage capability, the control and power systems, and the telephone interfaces. Signals from as many as eight input channels are converted to a frequency in the kilohertz range and simultaneously counted for the sample period with digital counters. The resulting 15 bit digital number corresponding to the value of each channel is loaded into a digital buffer memory of appropriate length. A full buffer expells the oldest words on a first in first out basis. The memory buffer, therefore, always contains the most recent data set and each channel buffer contains data collected in precise synchrony. Data from all of the shore stations are acquired by a computer based central station located at Scripps Institution of Oceanography, La Jolla, California.

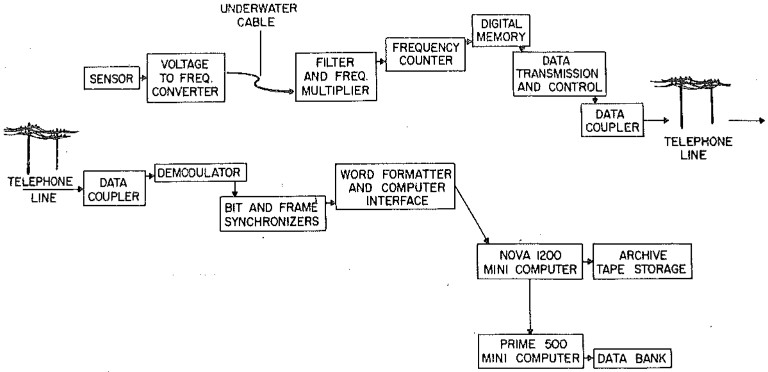

FIG. 3.—Block Diagram of Coastal Data Information System

At present times, the central station initiates a telephone call to the shore station using an autodialer and normal dial up telephone lines. The shore station responds by answering the telephone call request, and locking the most current 1,024 or 2,048 words in memory of each channel. All the data stored in the shore station are then sent in a special 1,200 Baud synchronous format to a digital data receiver connected to the control computer. A typical four channel station with 1,024 samples per channel transmits all data in slightly over one minute and then disconnects itself from the telephone line. The 15 bit digital data words that represent the observations are transferred to the control computer, a NOVA 1200, where station specific descriptive and chronological information is automatically added as a header label to each data stream. The amended record is written on magnetic tape for raw data storage. As raw data flows into the computer system, they are subjected to signal quality checks to determine conformity with expected standards. A quality check failure triggers a retry call, which causes an immediate retransmission of the original data from the shore station. This protocol is used to correct transmission errors. The chronological history of each calling event, along with primary data statistics, are logged to a printing terminal. This information forms a permanent record useful for quick status checks and as an aid in trouble shooting. The same raw data stream is sent simultaneously to a larger mini computer for quasi-real time analysis. Statistics of the analyzed data are stored on disk files. These two computers are connected with a bi-directional serial link, which allows data and command flow in both directions. Using this capability, the data acquisition computer can be remotely accessed via the larger multiuser computer. Several programs have been developed to make functions such as test calls, status check, and raw statistics from the data acquisition computer available from remote terminals.

In the standard call-up mode, the system may interrogate up to 100 individual shore stations in a programmed sequence. Each station can consist of up to eight channels with a total maximum memory capacity of 8,192 words of data per station. Individual channels may, however, contain up to 2,048 samples. A multi-tasking program allows several different groups of shore stations to be interrogated at different intervals under computer control. This method is used to gather wave data from selected stations at 3 hr intervals for relay to the National Weather Service as described later.

DATA ANALYSIS

The massive daily influx of data into the network, up to 6,500,000 bits per day, coupled with the need for real-time analysis and timely data reporting, dictates the need for an automated data quality assurance scheme. To meet these requirements, an editing program was designed to examine the data following their acceptance into the processing computer. The editor is programmed to objectively recognize certain classes of anomalies, correct some of the more obvious ones and reject others as bad data. Daily summaries and monthly statistics are compiled on the frequency and type of data rejections.

The types of errors recognized are:

1. Spikes.—Spikes are considered the most frequent cause for data rejection. They are most often caused by electronic noise of one source or another and in a sense are the easiest fault to detect. The editor calculates the standard deviation of the series and labels as a spike any value that is more than five times the standard deviation from the mean. Spikes are replaced with the previous value in the time series; however, the occurrence of more than 1% of the number of data points as spikes will cause the time series to be rejected.
2. Flat spots.—A series for which, on more than N separate occasions, M successive points were found to have an identical value is considered to be unacceptable.
3. Mean shift exceedence.—Bad data are sometimes characterized by a significant mean shift between successive groupings of data points. The editor subdivides the series into N subseries, calculates the mean for each subset, and intercompares successive means. A difference in the means greater than a predetermined threshold will cause the series to be rejected. The threshold level and length of subseries depends on the type and station location.
4. Absence of zero crossing.—A wave time series that does not cross the zero mean level for a specified number of points is considered unacceptable. This condition must be adjusted (dynamically) for a low energy, low period time series since an inflection point in the tidal range may mask a zero crossing occurrence.
5. Maximum and minimum wave height exceedence.—An exceedence test is made to verify that recorded wave heights do not exceed an established expected maximum wave height for the station. As well, the editor verifies that the recorded wave height is greater than some minimum threshold.
6. Filtering.—Where necessary, the editor filters a wave time series and removes the tidal component. This is done so that the energy in the tidal band does not leak into higher frequencies and mask the lower level energy bands found in the infragravity portion of the spectrum.

7. Intercomparisons.—In the case of the four sensor directional slope array, comparisons are performed between the individual sensor variances. Differences greater than preset thresholds will cause the odd sensor to be excluded from the directional analysis process. More than one deviating sensor will reject the record for directional processing purposes.

The edited data are subjected immediately to routine analyses. For both gravity and infragravity waves, the time series are fourier transformed and energy spectra calculated. Spectral values are grouped into period bins and summed to produce the variance. Significant wave height is calculated from the variance, and the period band containing the maximum energy in the spectrum is identified. In the case of gravity waves, this information can be condensed to a single line of printer output, as

TABLE 1.—Typical Tabular Output for Wave Energy from Monthly Report

PACIFICA ARRAY, ENERGY
JAN 1981

LOCAL DAY/TIME	SIG. HT (CM.)	TOT. EN (CM. SQ)	PERCENT ENERGY IN BAND (TOTAL ENERGY INCLUDES RANGE 2048–4 SECS) BAND PERIOD LIMITS (SECS)								
			22+	22–18	18–16	16–14	14–12	12–10	10–08	8–6	6–4
1 0413	127.5	1015.3	3.5	2.0	27.4	16.0	5.7	27.1	10.8	5.7	2.2
1 1016	142.7	1273.1	2.5	1.2	29.9	19.0	8.3	22.9	10.6	4.5	1.5
1 1614	132.5	1096.5	1.8	0.8	24.4	32.0	11.9	14.1	6.9	5.9	2.7
1 2211	106.0	702.4	2.9	3.6	9.3	37.3	18.2	12.3	10.4	4.5	2.0
2 0415	149.2	1391.8	2.3	1.5	15.2	36.2	30.8	4.7	4.0	3.0	2.8
2 1614	178.8	1998.7	2.4	0.8	13.6	35.6	28.7	9.0	4.0	5.2	1.2
2 2212	162.3	1645.6	2.2	0.6	6.4	39.5	30.4	7.6	5.2	5.4	3.2
3 0418	207.7	2696.1	2.0	0.4	3.2	16.3	26.8	13.0	14.2	13.9	10.6
3 1014	175.8	1932.7	1.8	0.4	3.4	17.3	25.6	14.8	13.7	12.9	10.5
3 1618	167.5	1754.4	1.7	0.5	1.7	13.2	21.9	18.8	19.6	14.0	9.0
3 2215	162.0	1640.1	1.2	0.5	1.3	6.9	28.0	21.4	23.8	10.8	6.5
4 0411	139.6	1218.1	1.6	1.3	1.7	6.5	39.8	16.1	16.1	10.3	7.1
4 1014	134.1	1123.2	2.1	2.5	4.6	10.8	17.2	16.8	25.3	15.3	5.9
4 1615	179.4	2010.7	2.1	0.8	5.9	21.8	14.6	16.8	16.8	14.6	7.0
4 2215	205.9	2650.4	2.3	1.3	5.7	26.8	22.0	13.4	11.7	12.3	4.9
5 0505	201.4	2535.5	2.6	2.5	15.4	29.2	17.1	10.1	7.3	9.3	6.9
5 1014	217.6	2959.6	2.4	4.7	15.6	29.8	21.6	12.7	4.4	6.1	3.3
5 2309	180.6	2038.9	2.1	0.7	7.2	41.2	24.1	10.3	5.9	5.8	3.0
6 0413	180.0	2024.9	2.2	0.6	14.1	28.6	27.6	14.1	4.7	6.1	2.5
6 1615	297.7	5537.8	2.6	2.3	24.8	38.6	8.4	4.0	7.8	8.7	3.2
6 2216	331.3	6861.6	3.6	0.7	13.2	45.5	11.5	9.2	6.0	7.5	3.2
7 0413	284.4	5056.8	3.0	0.7	8.0	44.1	14.8	9.4	6.8	10.3	3.3
7 1113	275.6	4745.8	2.1	0.5	1.4	26.3	50.4	7.4	5.1	5.8	1.5
7 1618	250.8	3930.1	3.0	0.4	2.5	9.4	56.0	14.0	4.9	7.6	2.7
7 2214	254.8	4058.5	2.1	0.1	1.1	11.8	41.9	26.8	6.8	7.0	2.7
8 0413	168.2	1768.7	2.0	2.4	0.5	6.8	31.1	26.4	18.4	9.9	2.9
8 1014	180.9	2044.7	2.8	8.3	22.7	4.5	15.5	26.1	10.2	6.9	3.3
8 1514	190.8	2274.3	3.3	1.4	28.8	15.9	20.3	12.3	8.8	7.7	2.0
8 2117	212.4	2820.8	2.9	1.6	9.3	48.8	10.0	10.3	5.8	9.0	2.7
9 0414	330.0	6806.2	4.0	2.2	13.1	27.3	18.4	12.6	9.0	9.7	4.1
9 0916	350.2	7665.8	5.2	31.4	3.3	13.0	16.1	8.1	14.3	5.4	3.7
9 2209	451.1	12721.0	5.4	4.4	27.3	17.6	8.6	6.9	13.8	8.5	7.9
10 0316	343.6	7378.3	2.8	1.9	16.7	30.0	17.2	14.0	6.5	7.8	3.5

shown in Table 1, which shows a portion of a monthly wave data report. Infragravity waves, because of a greater number of period bands, requires two lines per sample interval.

As described later, certain of the nearshore wave measurement stations employ four wave gages in an array for directional measurements. Higgins et al. (3) describe the analytical method used to extract wave directionality from measurements of sea surface slope components at the array. Routine analyses of wave direction involve calculation of a spectrum of the longshore component of shoreward-directed radiation stress that, with the energy spectrum obtained as described earlier, allows the estimation of an apparent arrival direction for each band of periods. Summing the radiation stress components over all frequencies yields total *Sxy*. From this, and the total energy, a significant angle of arrival for all the wave energy can be estimated. These data are collapsed to a sin-

TABLE 2.—Typical Tabular Output for Wave Direction From Monthly Report

SANTA CRUZ HARBOR ARRAY, DIRECTION
JAN 1981

LOCAL	SIG. ANG	TOT. SXY	ANGULAR DISTRIBUTION IN PERIOD BANDS (ANGLES IN DEGREES) BAND PERIOD LIMITS (SECS)								
DAY/TIME	(DEG)	(CM. SQ)	22+	22–18	18–16	16–14	14–12	12–10	10–8	8–6	6–4
1 0410	24.6	−1.2		70.0	28.8	26.2	25.1	22.9	24.5	23.6	16.3
1 1013	26.9	7.5		32.4	22.9	28.3	31.6	29.1	23.3	24.8	27.3
1 1708	22.0	−7.9		93.6	18.6	23.1	24.7	21.3	21.3	25.7	20.6
1 2308	25.6	3.6		13.2	14.5	32.7	27.3	28.1	21.9	22.4	21.3
2 0412	26.9	8.1		11.9	20.9	27.7	30.1	24.3	26.0	24.9	25.4
2 1611	29.8	28.9		19.6	18.9	34.9	24.7	32.2	24.4	29.2	27.2
2 2210	29.9	28.7		7.0	24.4	31.6	37.1	23.3	25.3	29.1	27.2
3 0415	28.9	36.8		17.4	25.8	26.2	33.3	29.7	28.4	28.3	26.6
3 1011	27.1	25.1		85.2	20.2	25.9	34.0	22.4	25.1	25.4	27.8
3 2212	28.4	21.7		31.1	30.0	36.9	34.5	29.3	25.3	20.0	21.1
4 0508	27.4	9.6		35.9	2.1	26.7	26.9	28.2	25.1	28.7	31.7
4 1011	27.9	10.9		23.1	25.3	22.5	32.9	24.6	27.0	29.5	30.1
4 1613	29.3	22.7		30.5	35.6	37.0	27.4	32.1	26.9	27.6	22.9
4 2312	31.9	78.5		29.0	30.4	27.6	38.5	29.1	28.1	29.9	29.5
5 0411	30.0	27.1		27.0	26.7	30.5	32.0	25.5	29.7	34.7	29.4
5 1011	33.4	87.6		24.3	35.8	27.3	37.4	26.8	28.4	30.8	29.3
5 1613	27.8	18.6		19.3	23.9	29.2	27.7	24.4	32.2	28.6	29.6
5 2212	30.2	23.4		109.3	25.5	26.9	32.7	28.8	31.1	32.2	34.7
6 0410	31.2	49.2		40.0	20.6	30.7	34.8	25.9	27.7	29.4	27.5
6 1713	29.1	35.8		18.8	28.3	34.6	25.0	26.4	29.7	25.5	27.9
6 2213	29.4	74.6		70.0	21.6	27.4	34.1	26.4	30.6	26.2	28.7
7 0510	28.4	36.5		49.6	21.4	28.1	32.5	27.1	28.0	28.9	33.4
7 1013	26.0	18.5		48.7	27.5	22.7	32.4	27.3	26.6	29.0	30.5
7 1615	29.4	80.4		37.5	27.9	39.1	27.6	27.5	31.5	27.6	27.9
7 2212	31.2	62.3		17.5	24.3	26.1	33.9	30.2	29.5	34.0	28.3
8 0411	29.8	44.5		14.2	32.9	31.9	31.2	24.6	30.5	33.0	33.3
8 1011	28.2	16.9		35.9	42.3	14.6	36.2	27.5	26.6	27.2	31.9
8 1614	25.5	2.7		14.4	23.6	25.5	23.3	25.3	28.9	27.0	29.5
8 2114	29.7	28.7		22.7	25.9	38.7	26.4	29.7	25.1	26.8	33.5
9 0411	29.2	90.0		31.5	21.2	27.5	34.4	24.8	27.2	27.4	30.6
9 0913	29.2	80.6		28.0	19.4	23.3	37.6	27.0	26.0	24.8	29.3
9 1513	29.1	148.5		27.7	24.6	29.3	37.5	29.3	28.4	27.4	29.3
9 2206	26.4	27.8		31.7	22.5	24.1	29.6	26.6	29.2	29.0	33.4

gle line of print for ease of display on computer terminals or in reports. A typical example is shown in Table 2.

For wind and current data, the routine analysis is performed in the time domain. Data are sorted into directional bins within which the intensity is averaged over time in the bin to produce a mean speed for the reporting period. Concurrent with the sorting task the highest speed episode is identified along with its direction. The condensed output line includes the peak velocity and the averaged bin velocities with the percent time during which data were present in a directional sector. The graphical presentation shown in Fig. 4 depicts the daily distribution of mean velocities.

At the end of each calendar year, additional routine analyses are performed on wave data to highlight seasonal and annual statistics. Among these are: (1) Cumulative exceedence probabilities for heights and periods, presented in both tables and plots; (2) plots of the seasonal probability of exceeding certain wave heights; (3) plots of daily maxima in sea and swell heights, separated by seasons; (4) joint distribution function of height and period, presented in tables and in a 3-D plot; (5) plots of distribution functions of net longshore transport and cumulative

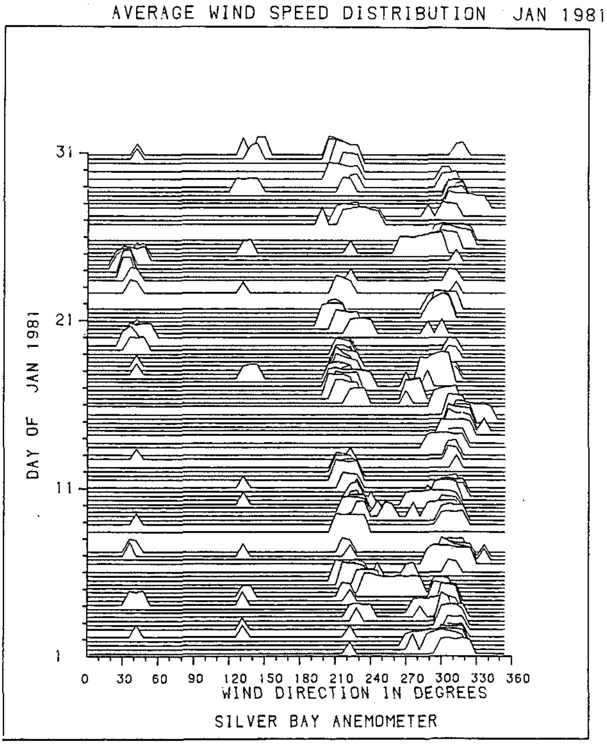

FIG. 4.—Typical Tabular Output for Daily Distribution of Mean Velocities from Monthly Report

transport; (6) plots of daily estimates of longshore transport values; and (7) plots of cumulative (net) longshore transport. A typical annual report is Seymour et al. (11).

In addition to routine analyses, the data base has been used to make special studies. These have included a number of investigations of longshore transport of sediment by waves. Among these are Dean et al. (1), Seymour et al. (7), Seymour and Gable (8), Seymour and Higgins (9), and Seymour and Castel (6).

MEASURING INSTRUMENTS

The coastal data system has been designed with the flexibility to accommodate measurements from many types of sensors. For nearshore wave observations, in water depths of less than 15 m, the primary instrument utilized is a submerged pressure sensor as shown in Fig. 5. This sensor is based on a commercially available semiconductor strain gage pressure transducer. The transducer, together with electronic circuitry, which converts the low level direct current transducer output to a variable frequency signal, are housed in a plastic pressure case. A plastic underwater connector mates with an underwater cable, which carries the signal ashore and supplies power to the sensor. This sensor is usually bottom mounted on a tripod frame made of steel pipe. For reliability, the connectors used are of the type that must be connected or disconnected out of sea water. Therefore, sufficient cable is stored in a service loop to allow a diver to bring a sensor housing to the surface for replacing the instrument.

An array of four of these sensors configured in a square shape six

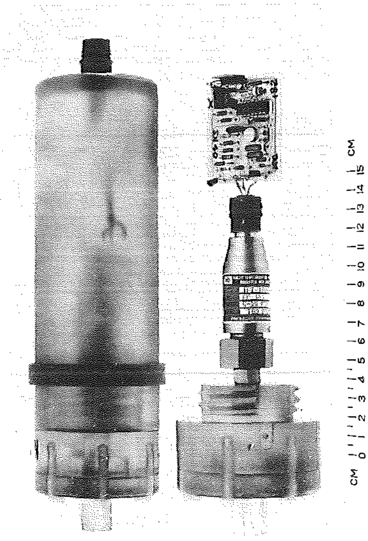

FIG. 5.—Pressure Sensor and Enclosure

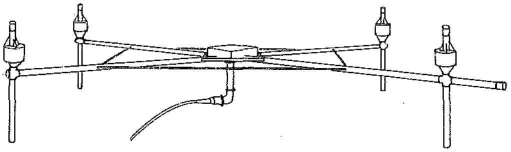

FIG. 6.—Array for Measuring Wave Direction

meters on a side has been developed to produce a directional array as shown in Fig. 6. In this configuration, all four signals are simultaneously sent ashore via a specially designed armored underwater multiconductor cable. This cable is laid along the sea floor to the beach, where it is trenched below the surface. The development of this cable, with effective abrasion resistance, waterblocking integrity, tensile strength, and resistance to cutting has greatly enhanced system reliability. Even in areas with extremely energetic surf zones, the cable has demonstrated maintenance free operation for periods exceeding 5 yr. Exceeding a critical density for a given cable diameter results in a configuration that will rapidly bury itself in the local sediment under the scouring action of waves. This results in further protection of the cable from both environmental forces and vandalism. Details of this directional array are described in Seymour and Higgins (9).

When deep water wave data are required, Datawell Waverider buoys are anchored in ocean depths up to 200 m. Heave information from the output of a stabilized accelerometer mounted in the spherical shaped hull is radioed to a receiving site up to 50 km away. The frequency output of a standard Waverider receiver is signal conditioned in a fashion similar to the pressure sensors and stored in a standard shore station.

Electromagnetic current velocity sensors have been interfaced to the coastal data system. This is accomplished by converting the standard direct current output to a frequency proportional to each component of velocity. These values from each axis are simultaneously counted for the selected averaging period and stored in memory in the shore station. The resulting values provide a pair of vectored, averaged components of current velocity.

Wind data provided from propeller-vane type sensors are accommodated by the system. The sensor configuration in this system requires that the propeller drive a direct current generator and the vane be attached to a sine/cosine potentiometer. The output from the generator is then routed through the sine/cosine potentiometer to produce two output components of wind velocity. These wind velocity components are then converted to frequency modulated signals and processed in a similar manner to the current velocity described earlier. These results are also stored in memory in the shore station.

DATA DISSEMINATION

Under certain conditions, engineers need to have very rapid access to environmental data. To meet these needs for wave data, the system is arranged to allow any user with a computer terminal capable of remote accessing by telephone to obtain analyzed wave data within a few minutes of the time of the final measurement in the record. A friendly computer program has been developed that allows users who are unfamiliar with computer operations to call up tabular and plotted data with relative ease.

In addition to looking at data from a single station for a single day, the user can ask for multiple stations on a single day, with overplotted spectra, for example. Also, the data from one station for many days can be displayed, allowing visualization of the passage of a storm. All of the wave data since the program inception in 1975 are available in analyzed form for immediate retrieval.

Analyzed wave data summaries from selected stations are rapidly forwarded to the National Weather Service (NWS) shortly after acquisition. This near real time data is placed in a special disk file by the processing computer and then automatically sent via telephone line to a local computer operated by the NWS as part of their data distribution network. These data are then immediately available to selected weather stations in their network. Data are also teletyped to the very high frequency (VHF) radio system operated by NWS which broadcasts weather information to the public. This outlet provides very recent measured wave conditions to the marine community on offshore conditions. These data are also used by NWS marine forecasters in the preparation of sea and swell forecasts.

For many uses, direct computer access can be undesirable or unnecessary. Archive tapes of unanalyzed wave measurements are maintained at the USACE Coastal Engineering Research Center and copies can be made available to users under certain conditions. Monthly and annual wave data reports are supplied routinely at no charge by the project to public clients and university libraries. Private clients may subscribe for the cost of publishing and distribution.

SUMMARY AND CONCLUSIONS

The coastal data network has evolved with a number of attributes that, when taken together, appear to provide a unique capability. Among the more significant features are: (1) The ability to accept instrument inputs of almost any type; (2) readily field-programmable sampling rates and intervals; (3) low cost direct dial data retrieval; (4) highly reliable wave measurement instruments; (5) automatic data editing; (6) ability to measure nearshore wave direction; (7) real time data analysis and display; and (8) all analyses routinely published and distributed.

Although the operation of the system has been successful, some problems and shortcomings remain. The loss rate of the offshore buoys, apparently due principally to marine vandals, has been disappointingly high. This has introduced increased costs and lost data. At present, no commercial system has been demonstrated to measure wave direction in deep water with sufficient accuracy to allow meaningful refraction into the beach. The electromagnetic current meters require cleaning at approximately 1 mo intervals as opposed to the pressure sensors that operate without maintenance for over 5 yr. The data retrieval system is totally dependent upon local phone and power services remaining operational. For example, nearly all the wave data from the November 1982 hurricane in Hawaii were lost because of telephone service disruption caused by the high winds.

The system has demonstrated that coastal data can be reliably and economically collected, analyzed, and disseminated by an automatic computer-controlled network with reporting stations as far apart as 10,000 km.

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