

CHAPTER 49

Wave Gauging Networks Worldwide — An Overview

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Abstract

Throughout the history of society's attempts to build on the beach, waves have been the principal antagonist. Engineers soon learned that to be successful, they had to understand the nature of the waves that attacked their structures. That understanding has led to many efforts to measure or estimate waves to develop a climatology useful in coastal design.

Over the past 25 years, our ability to accurately and cost-effectively measure waves has improved considerably. This has resulted in an increasing number of gauging networks worldwide. This paper is a summary of many of those networks. Information on the networks will include, where available, the type gauges used, locations of stations, additional data collected, and data distribution means.

Introduction

Because many wave gauging programs are locally installed and operated, they are known only to their operators. Only a few of the networks are associated with the World Meteorological Organization (WMO) and have their data distributed worldwide on the Global Telecommunications System (GTS). Information about the networks operated by the U.S. National Data Buoy Center (NDBC), Canadian Atmospheric Environment Service (AES), and the United Kingdom Meteorological Office was relatively easy to acquire. The smaller networks have been a challenge. That challenge has been offset, though, by the willingness of most network operators, once identified, to share information.

To most coastal scientists and engineers, the small networks are the most interesting. The large networks, often funded by the country's weather service, are well known. But most network operators — or potential operators — must operate on a much smaller scale, so there is often much more to learn from others who manage data collection efforts within similarly restrictive budgets.

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Networks

In all, information has been received or obtained about wave measurement networks in 19 countries. Information has come from personal communications, papers or other publications, and, in several cases, from a "Guide to Moored Buoys and Other Ocean Data Acquisition Systems" (Data Buoy Cooperation Panel, in publication). Programs are likely to exist in countries other than those reported in this paper, particularly in countries such as Germany, The Netherlands, People's Republic of China, Portugal, and Sweden. Unfortunately, time ran out before all leads could be followed and information produced. It is hoped that this information will be useful to anyone who operates a wave gauging network or even a single station by providing information about the alternative hardware, techniques, and approaches available. A presentation of these alternatives should also help those who are interested in collecting wave data for research or engineering purposes.

Of the information that has been received, several networks stand out. Two particular examples of those that deserve mention are the efforts by Spain to establish their national network and the international effort to define the wave climate along the coasts of the Black Sea. The Clima Maritimo is the research and development department of the Puertos del Estado, which is responsible for coordinating the activities of 27 of Spain's ports. To provide data critical to their mission, they have installed and are operating a network of 20 nondirectional and 4 directional wave buoys. In the future, they will add three more directional wave buoys, five coastal wave radars, and six to nine oceanographic buoys that will report atmospheric information, current data, and temperature and salinity profiles, as well as wave data.

The international effort on the Black Sea, called NATO-TU WAVES, is supported by Russia, Turkey, the Ukraine, Bulgaria, and Rumania. Four nondirectional and six directional stations are being established to provide data needed for wave modeling and forecasting around the perimeter of the Black Sea.

The collection of wave data is important to coastal engineers and scientists. This overview is intended to be a minor reference for use when new networks are being planned or existing networks are updated. While an attempt has been made to ensure that the stations are currently in service, it is possible that some information may no longer be current. A consistent set of symbols will be used and will follow the key provided below. For simplicity, the only symbols used on the figures will be for directional and nondirectional systems. Where the information is available, the type of gauge will be mentioned in the discussion. The presentation to follow is organized alphabetically by country, except for the network in the Black Sea, which will be listed as NATO-TU WAVES because of its international nature.

Australia

Gauging networks in Australia are operated, primarily, by the states. This decentralization made identification of networks a bit more difficult than for countries with centralized control of their programs.

Three programs have been identified, those of Queensland, New South Wales, and Western Australia. In Queensland, wave data are collected at 13 locations (Figure 1). Nondirectional data are collected using Datawell Waverider buoys and from InterOcean S4 current meters, while directional data are collected from Datawell Directional Waverider buoys. All stations in the Queensland network are shown on Figure 1 as nondirectional, although several are likely to collect directional data. Data from the Waverider buoys are transmitted to shore via radio.

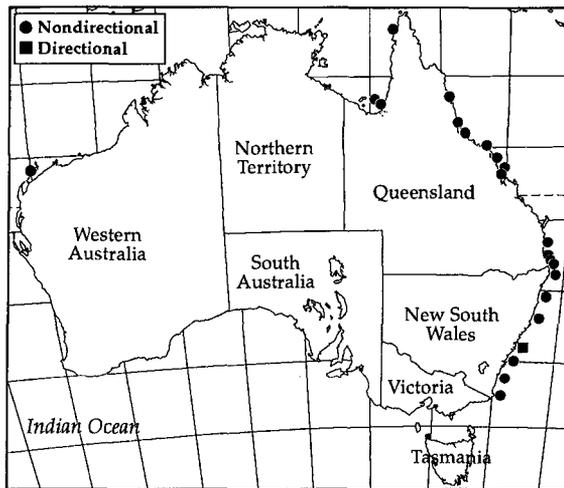


Figure 1. Australian Wave Gauging Networks

The wave data network in New South Wales presently consists of seven stations, one of which collects directional data (Figure 1). The oldest station in this network was installed in 1974; all stations have been operational since 1987. Datawell Waverider buoys are used at every station, and the data are transmitted to a shore station by radio.

There is one station in Western Australia for the past 4 years (Figure 1). A Datawell Waverider buoy is used to collect nondirectional data that are transmitted to shore by radio every 20 minutes. These data are used for "real" time ship operations.

Canada

There are two wave gauging networks in Canada. The first, and more traditional, is operated by the AES and has stations in the Atlantic and Pacific Oceans and in the Great Lakes and other major inland waters (Figure 2). The other network is operated in Quebec Province as a part of the James Bay Hydroelectric Project by the Societe d'Énergie de la Baie

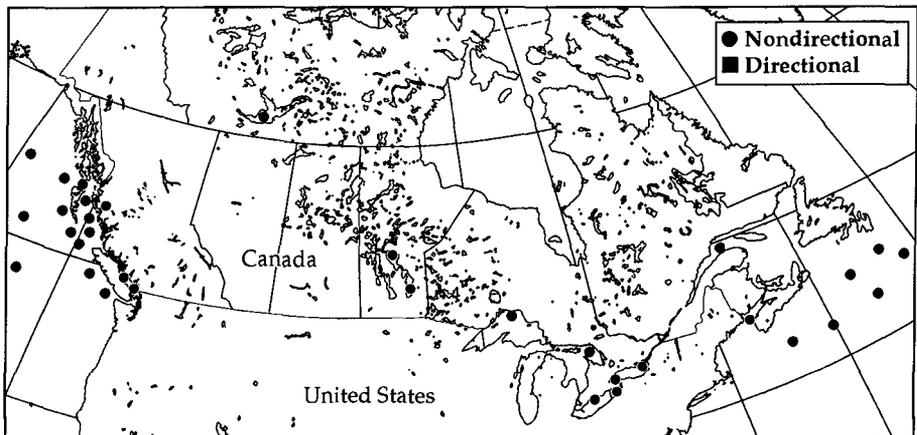


Figure 2. Canadian AES Buoy Network

James (Figure 3). The AES operates a total of 33 buoy stations, 8 in the Atlantic, 9 in the Great Lakes region, and 16 in the Pacific. The buoys in the Atlantic and Pacific consist of fifteen 3-m-diameter discus buoys in the nearshore areas and nine 6-m boat-shaped buoys offshore. In the Great Lakes region, two of the stations are occupied by 12-m-diameter discus buoys. All stations collect nondirectional wave spectral data as well as meteorological data such as wind speed and direction, pressure, and temperature. All data are transmitted hourly via the Geostationary Operational Environmental Satellite (GOES) and are available on the GTS.

In Quebec, four Endeco WaveTrack 1156 buoys are used to collect data from eight stations in the James Bay area. These buoys collect directional wave data that are transmitted hourly via an RF radio link to a base station. The buoys are deployed in a most unusual manner — by helicopter.

France

Meteo-France operates one buoy station in cooperation with the United Kingdom Meteorological Service. The buoy was developed and used by the UK Met Service and is operated by them. The station is located 300 km off the Brittany coast in 2,000 m of water. Additional information on the buoy used can be found in the section on the United Kingdom. Meteo-France plans to operate another buoy in the Bay of Biscay soon. Another plan to operate four additional stations, two in the Mediterranean Sea and two in the West Indies, is currently under study. Two directional Datawell Waverider buoys are currently deployed in the West Indies as a part of the Oceanilles project. The French Aids-to-Navigation Service (STNMTE), which operates its own network of ten wave buoys along the coast of France, assisted Meteo-France in the establishment of the stations in the West Indies (Data Buoy Cooperation Panel, in publication).

Iceland

The Icelandic Lighthouse and Harbour Authority operates a network of stations within the Information System on Weather and Seastate for Seafarers, an automated call-up voice information system (Figure 4). Among the stations are seven Datawell Waverider buoys reporting nondirectional wave data and nine harbor installations that report wave and

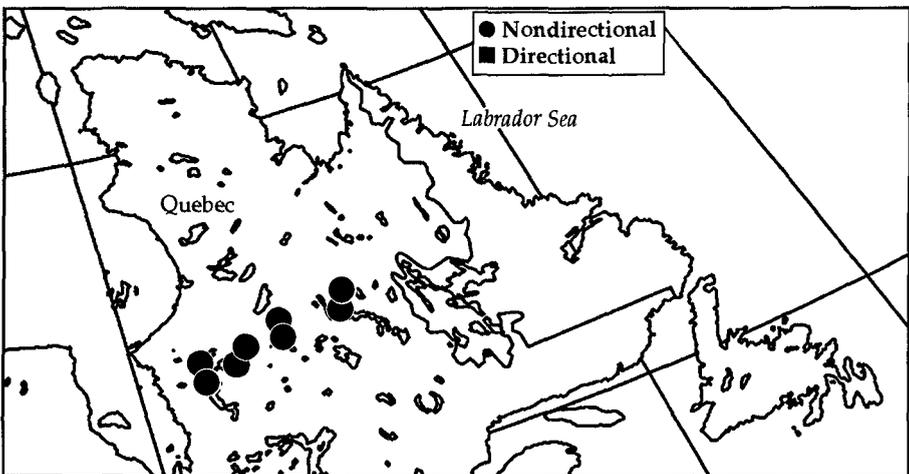


Figure 3. James Bay Hydroelectric Project Wave Gauging Network

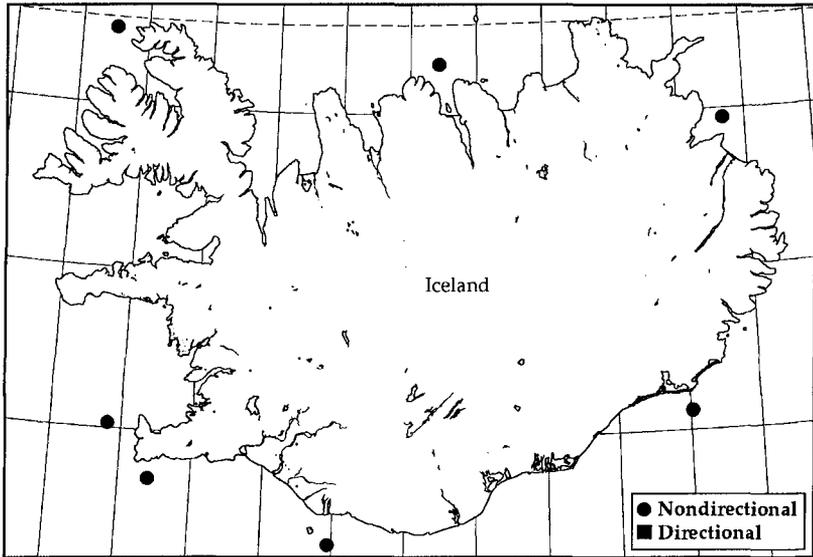


Figure 4. Icelandic Data Buoy Network

meteorological information. Another 12 automated weather stations are located on lighthouses. Waverider data are transmitted via radio link to a shore station (Data Buoy Cooperation Panel, in publication).

Israel

The Israel Meteorological Service operates a small network of directional Datawell Waverider buoys. The Waverider buoys are deployed in Haifa Bay and the ports of Asdod and Hadera. Data are received by direct radio link to a shore station (Data Buoy Cooperation Panel, in publication).

Italy

In an article in *History and Heritage of Coastal Engineering*, Professor Leopoldo Franco reports that there have been nearly 100 wave gauging stations on the Italian coast since 1974 (Franco, 1996) (Figure 5). Currently, there are 13 permanent stations. Eight of these are operated as a part of the National Wave Measurement Network. These stations are directional Datawell Wavec buoys reporting their data via polar orbiting satellites. The network is managed by the Italian Hydrographic and Tidal Service and has accomplished an average data acquisition rate of more than 90 percent since the network was established in 1989.

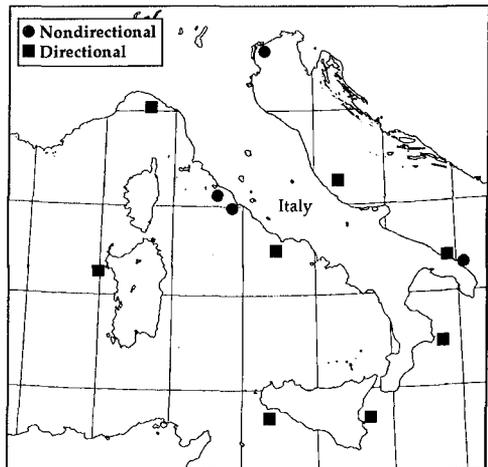


Figure 5. Permanent Wave Gauging Stations in Italy

Japan

For years, the Japanese have been leaders in coastal engineering research. Various agencies and research institutions have, therefore, operated networks of wave gauging stations. The diversity of organizations that have been involved in wave measurements has made the identification of all stations a bit difficult. Those stations that have been identified are reported here.

Japan's ocean data buoy program was initiated by the Japanese Meteorological Agency (JMA) in 1968. A total of seven 10-m-diameter discus buoys was eventually constructed. Four of these buoys remain in service, rotating among three stations (Figure 6). These buoys report data hourly via the JMA Geostationary Meteorological Satellite. Nondirectional wave data, as well as considerable meteorological data, are collected and reported. These data are published annually on CD-ROM in a report entitled "Data Report of Oceanographic Observations" available from JMA headquarters (Data Buoy Cooperation Panel, in publication).

A much more extensive network is operated and maintained by the Ports and Harbours Bureau of the Ministry of Transport. In particular, the Port and Harbour Research Institute (PHRI) operates a 42-station network of wave measurement stations called Nationwide Ocean Wave information network for Ports and HARbourS, or NOWPHAS (Figure 6). The network includes a variety of sensor types, some quite innovative. PHRI has deployed directional arrays, nondirectional buoys, measurements from towers, two acoustic meters, and a new Doppler-type wave directional meter. The Doppler meter is installed at three existing stations and one new research station.

NOWPHAS and JMA data are provided to a semi-governmental agency and from there to users. The Coastal Development Institute of Technology operates the Coastal Wave Information Center.

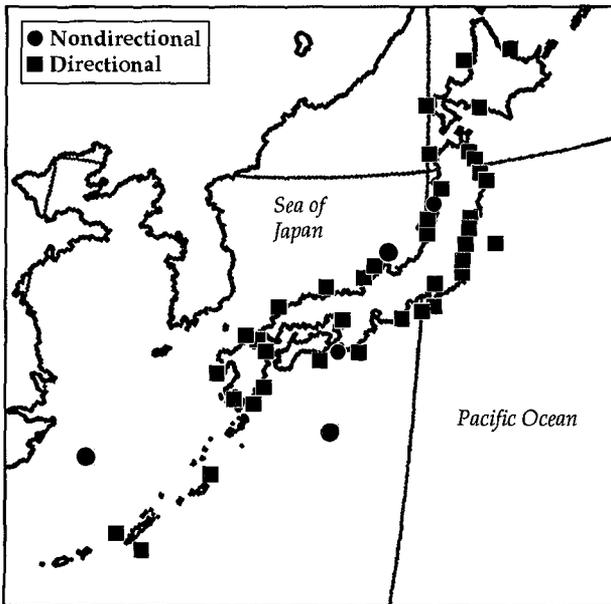


Figure 6. NOWPHAS and JMA Wave Measurement Stations

Korea

The Korean Meteorological Agency (KMA) and the Korean Maritime and Port Administration, the latter together with the PHRI in Japan, are cooperating in the establishment of a wave gauging network around the Korean peninsula. So far, the KMA has one buoy on station in the Yellow Sea—it is the northernmost buoy shown in Figure 7. The other stations are operated by the Maritime and Port Administration and include seven directional Datawell Waverider buoys and one directional pressure sensor and electromagnetic current meter (PUV) gauge—the northernmost station in the Sea of Japan. This PUV gauge is temporary and will be replaced by one of the Doppler meters being developed by the PHRI.

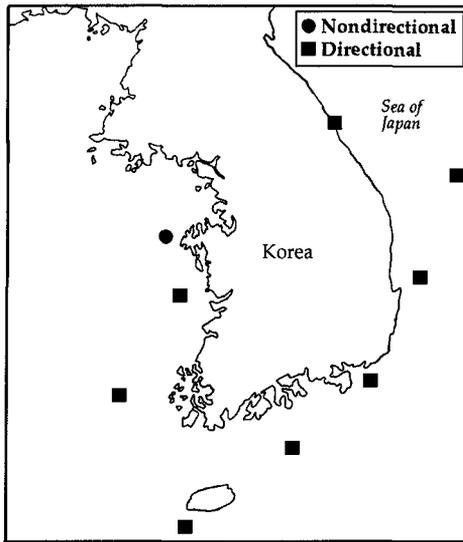


Figure 7. Korean Wave Gauging Networks

Kuwait

One directional wave station is maintained by the Hydraulics and Coastal Engineering Department of the Kuwait Institute for Scientific Research. Data are received by radio from the Endeco 1156 buoy located 6 km off the Fintas Coast in the Persian Gulf. The purpose of the station is to study deep-water waves in Kuwait's territorial waters.

NATO-TU WAVES

Bulgaria, Rumania, Russia, Turkey, and the Ukraine are cooperating in a program to better understand the wave climate affecting the Black Sea coastline and the Turkish coastline of the Mediterranean Sea. Partially funded by NATO, the program is being executed by four collaborating Turkish organizations and four institutes in the other Black Sea countries. A total of ten stations are collecting data, including six collecting directional wave data from directional Datawell Waverider buoys and four others from a Ukrainian-built wave staff that measure nondirectional waves (Figures 8 and 9). All buoy data are transmitted to shore using radio frequencies (Ozhan and Abdalla, 1993).

There is one additional station located in Turkish waters. A PUV gauge installed in conjunction with the Japanese International Corporation Agency — an installation supervised by the PHRI — is reporting directional wave data from a station at Filyos near Zongldak.

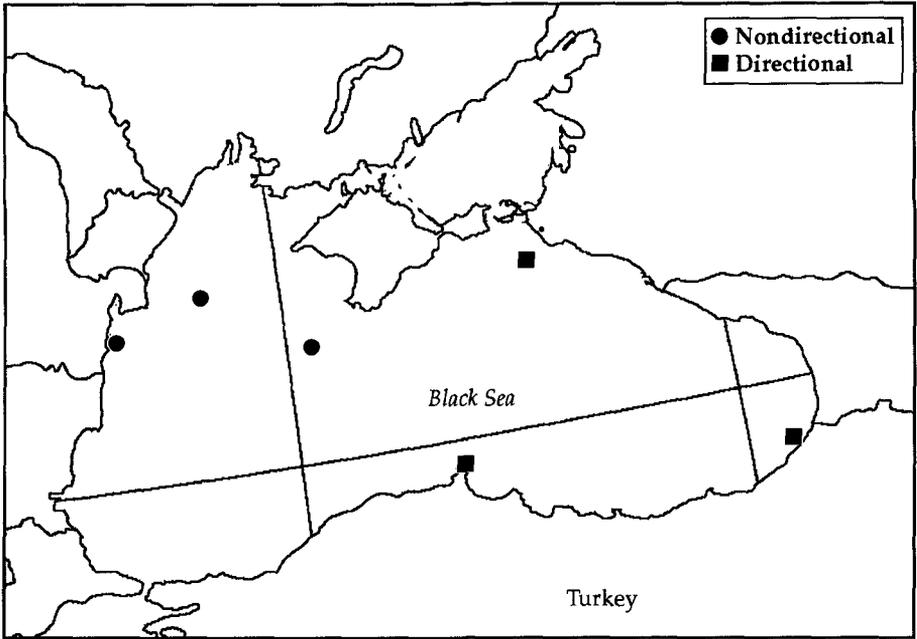


Figure 8. NATO-TU WAVES Black Sea Network

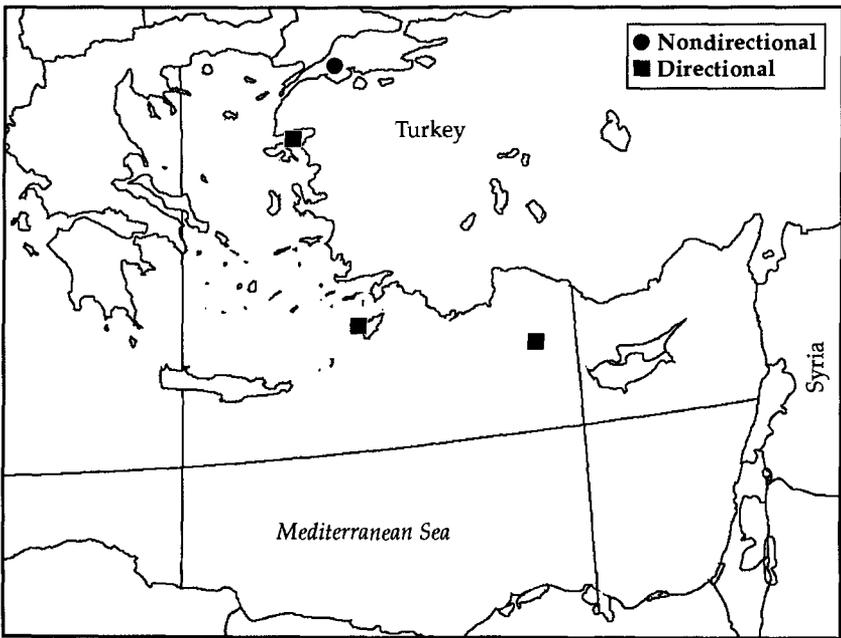


Figure 9. NATO-TU WAVES Mediterranean Sea Network

Spain

Clima Maritimo, the research department of the Puertos del Estado, is in the process of installing 21 nondirectional and 4 directional wave buoys (Figures 10 and 11). An additional four nondirectional stations are operated by other organizations. The scalar buoys are Datawell Waveriders, while the directional buoys are Seatex WaveScans. The data are collected to support the operation of Spain's harbors. Additional directional buoy stations and shore-based wave radars are planned for the future (Ruiz de Elvira, et al., date unknown).

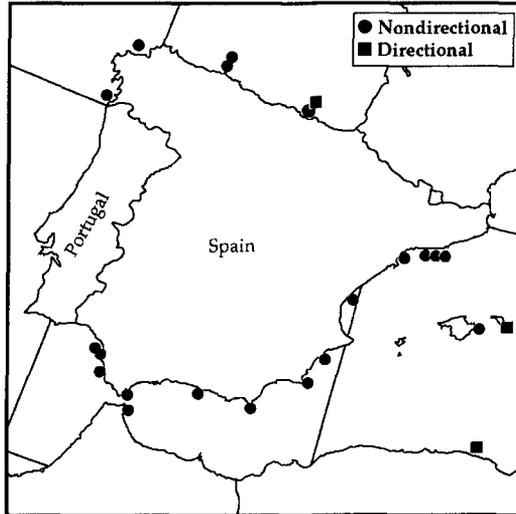


Figure 10. Spain's Coastal Wave Gauging Network

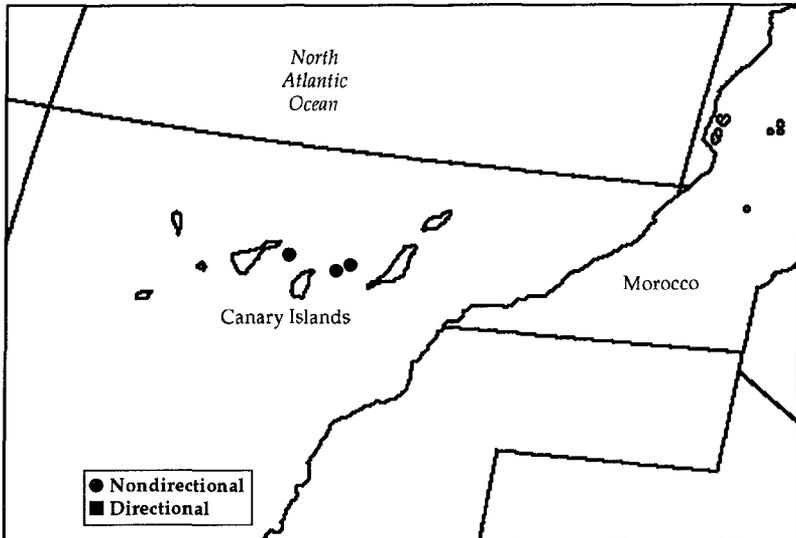


Figure 11. Spanish Wave Data Collection in the Canary Islands

Sri Lanka

An Endeco directional wave buoy has been operating offshore Galle on Sri Lanka's southwestern coast for 8 years. It was installed by the Sri Lanka Hydraulic Institute for the Coast Conservation Department.

Republic of China

A network of four directional stations is being established by the Central Weather Bureau around Taiwan. At least two, and probably all, of the stations are now in place. The current plan is to have Endeco 1156 WaveTrack buoys measuring directional waves at Bytougau at the northern tip of the island, Tonchiyu in the middle of the Taiwan Strait, Shaoliucho off Kaohsiung Harbor, and Chengkung on the southeastern coast facing the Pacific Ocean. Each of these stations reports by UHF to shore. Ultimately, the plan is to have a network of more than 20 stations ringing the island, including underwater ultrasonic wave gauges, shallow-water observation piles, buoys, and shore-based radars.

United Kingdom

The United Kingdom Meteorology Office has established a network of nondirectional data buoys off the British Isles in both relatively shallow water and in deep water off the continental shelf (Figure 12). Two types of buoys are used. Nearshore, a 2.5-m-diameter toroidal buoy transmits data via a VHF radio link to shore. Offshore, a new purpose-built buoy of less than 3-m-diameter (so it can be transported over public roads without special precautions) has been installed at four of the open-ocean locations. These buoys report via METEOSAT or GOES, and the data are distributed on the GTS (Bentley and Jones, 1993).

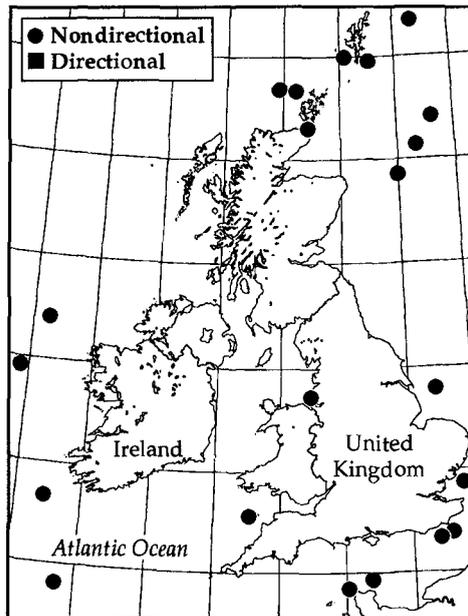


Figure 12. Wave Data Collection Off the British Isles

United States

Two agencies operate extensive networks of wave data collection stations in the United States, NDBC of the National Weather Service (NWS) and the U.S. Army Waterways Experiment Station Coastal Engineering Research Center (CERC). While buoys are the primary means of wave data collection for NDBC, laser wave systems are used on several Atlantic offshore platforms in the Coastal-Marine Automated Network. Buoys used by NDBC include the large 10- and 12-m discus buoys, 6-m boat-shaped hulls, 3-m-diameter discus buoys, and, on occasion, 2.4-m discus buoys. All NDBC's discus buoys are capable of collecting directional wave data, although those data are only collected at special locations. NWS sponsors many of the stations, but CERC, the Minerals Management Service, and the National Aeronautics and Space Administration fund a number of stations operated by NDBC as well. CERC is the primary sponsor of directional wave data from this network. In addition to wave data, NDBC buoys collect a full range of meteorological data and, occasionally, oceanographic data as well. All data are transmitted hourly from the buoys via GOES to the NWS Telecommunications Gateway and are distributed worldwide on the GTS (Figure 13).

While CERC operates wave gauging stations primarily in support of coastal projects, and therefore for short periods of time, they do fund or operate a network of relatively permanent stations (Figure 14). The principal operator of many of these stations is the Scripps Institution of Oceanography, University of California at San Diego. The Prototype Measurement and Analysis Branch of CERC operates the others. Their nondirectional stations are most often Waverider buoys; directional stations can be either PUV gauges or multiple pressure sensor arrays, including a linear array at the CERC Field Research Facility in Duck, NC. These data are usually either transmitted to shore by radio or cable where they are collected periodically by telephone connection (U.S. Army Corps of Engineers, Waterways Experiment Station, July 1996).

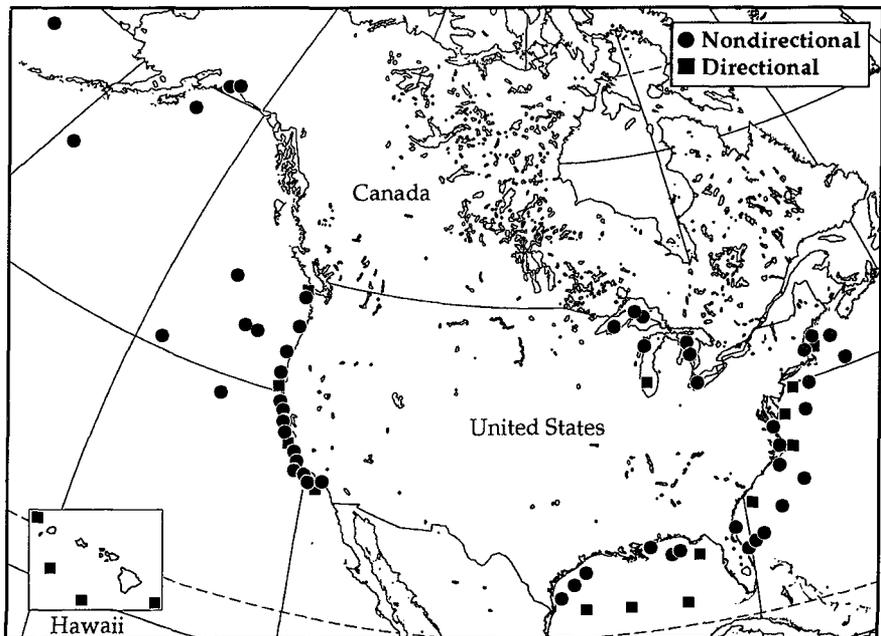


Figure 13. NDBC Wave Gauging Network

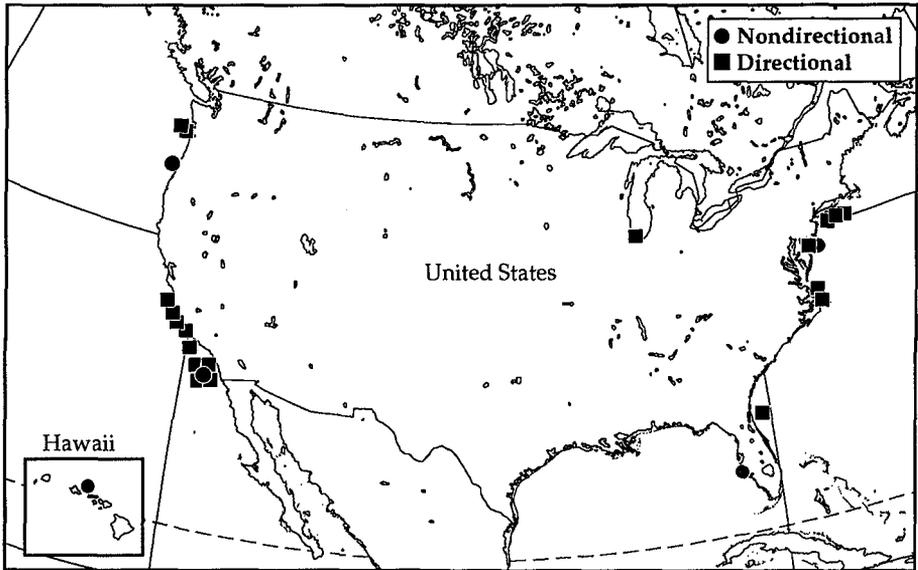


Figure 14. CERC Wave Gauging Network

Archival

Unfortunately, much of the wave data collected around the world is not archived outside the organizations that collect them. In the United States, for example, the National Oceanographic Data Center accepts all quality-controlled wave data collected, if they are sent to them. All NDBC data are archived in this way, but data collected in other agencies' programs are not always archived. So, someone searching for wave data often has to seek out a variety of sources. Internationally, there is no organization that exists to archive wave data from around the world. With proper coordination and cooperation, it is possible that this state could be corrected. The Intergovernmental Oceanographic Commission (IOC) and the WMO worked together to establish the Marine Environmental Data Service (MEDS) in Canada as the Responsible National Oceanographic Data Centre (RNODC) for drifting buoy data. All drifting buoy data transmitted on the GTS are archived by MEDS and are available to anyone who needs them. Possibly the same thing could be done for wave data and an RNODC established for them. It would seem that the IOC and WMO would have an interest in such a center.

Conclusion

Wave data are being collected by at least 19 countries around the world. This paper has attempted to summarize the programs the author could discover. Too many may have gone undetected. This is an indication that the results of many wave gauging efforts go unrecognized by others in the field, and valuable data lie unused after their initial purpose is served. These data do not decrease in value with time. It appears that the time has come for an international effort to provide an archive for wave data.

Acknowledgments

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