CHAPTER 140

THE ITALIAN WAVES MEASUREMENT NETWORK

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1. INTRODUCTION

The Rete Ondametrica Nazionale (RON) - the Italian Wave Measurement Network - is a system for recording directional wave motions along the Italian coasts, operational since 1st July 1989. The network includes eight wavec directional wave Datawell buoys and the corresponding land-based receiving stations.
Following an international tender, the Ministry of Public Works appointed TEI SpA for the design and management for the network and for data processing. Following the reorganization of the National Technical Services, the responsibility for the network and its activities has been transferred to the Italian Hydrographic and Tidal Service ("Servizio Idrografico e Mareografico, (SIM)"- under the aegis of the "Presidenza del Consiglio dei Ministri" (President of the Ministries Council), a special parliamentary body.
After three years of continuous operations (1989-1992), it is now possible to make a preliminary general account of the venture, analysing in particular the following aspects:

- Reliability of the technical solutions and efficiency of the network management system;
- Scientific and technological applications of statistical data;
- Use of the data in wind-waves numerical modelling for the Mediterranean Sea;.
- Prospectives of development and follows-up.

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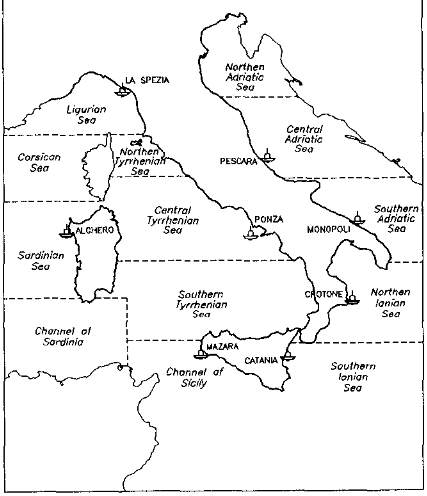
2. TECHNICAL DESCRIPTION

The Italian Wave Measurement Network (henceforth referred to as RON) includes eight stations, whose position is shown in Fig. 1.
The choice of the locations has been done with the aim of:
a) monitoring the sea conditions in areas of intense wave activity;
b) optimizing the distribution of wave measurement around Italy, given the already existing instruments (see Fig. 1).

Preliminary activity started in early 1989 and the network became operational on 1st July, 1989. In this section we give a compact description of the measuring instruments, of the network and of the data processing.

Fig. 1 – Measuring Stations Location



MEASURING INSTRUMENTS

Each station (see Fig. 2) includes a Wavec buoy, manufactured by Datawell, and a receiving station. The buoy has been amply described in the literature and we give here only a very compact description of it (see e-g, Manual of direc receiver, Manual of wavec buoy from Datawell B.V. Haarlem).
The buoy, moored using a flexible system that allows maximum freedom of movements, is of the surface following type.

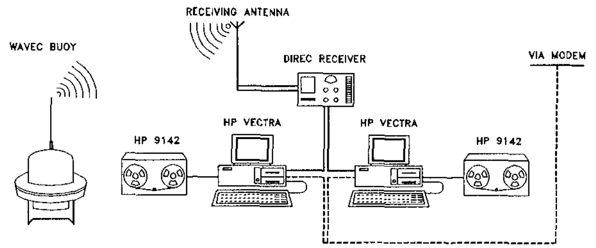


Fig. 2 – Measuring Station Configuration

Vertical acceleration, pitch and roll of the buoy, and relative components of the earth magnetic field are measured and used to deduce the heave and slopes (in North and South direction) of the local sea surface.
Each parameter is sampled at 128 Hz frequency and the data are continuously transmitted by radio to the receiving station located on the main land.
Each buoy is located far enough from the main land to allow full representativeness of open sea conditions.
The mooring depth varies from 80 to 100 m. The buoys are powered by self-contained batteries, with an authonomy of 10 months.
The system for the acquisition and processing of data, of which the Direc receiver is an integral part, is made up of two AT compatible HP Vectra ES 12 Personal Computers.
The PCs are connected by means of serial ports to the MAIN and UAX gates of the Direc; the second serial port is connected to a telephone modem used for tele-servicing and real-time remote control. Through the MAIN computer, it is possible to program the Direc receiver for the functions of sampling time, time, type of data output from the AUX port (monitor, real-time, CQ), and the Hs above which the system must sample continously. This PC is also used to store the processed data, and the directional spectra are displayed every 30 minutes, as well as a set of data on the functioning characteristics of the buoy such as tilt, platform offset, compass offset, battery voltage, and water temperature, and a report on the quality of the signals received in the previous half-hour.
As already noted, the AUX PC is used only for the acquisition of data (monitor, real or CQ) sent from the AUX port of the Direc receiver. To minimize the risk of loss of data due to hardware failures in the two computers, each day the data recorded on the hard disk are downloaded to the streaming tape as a sequential file, and then at the end of the month both the physical copy on the hard disk and the daily recordings on tape for each computer are saved.
A detailed description of the network organization and all the technicalities involved is given by Rusconi et al (1990, 1992).

DATA PROCESSING

The combined analysis of heave, pitch and roll of the sea surface at a given location, pioneered by Longuet-Higgins et al (1962), provides estimates of:

a) the one-dimensional wave frequency spectrum E(f), and related quantity as significant wave heights Hs, mean and peak period Tm and Tp respectively;

b) directional distribution of energy at each frequency represented by mean direction $\theta(f)$, second mean direction $\theta_2(f)$, skewness and kurtosis, and the deduced mean spectral direction θm.

MANAGEMENT

The degree of reliability of the technical solutions adopted and the efficiency of the Network Management System set is demonstrated by the percentage of valid data which, for each recording station, is supplied every three months to the SIM (Table 1).

TABLE 1 - % OF COLLECTED DATA IN THE FIRST THREE YEARS

	S 89	A 89	W 90	S 90	S 90	A 90	W 91	S 91	E 91	A 91	W 92	TOT
La Spezia	91,30	99,70	86,00	96,40	96,70	93,30	97,10	95,40	94,20	95,40	91,10	94,24
Alghero	94,80	98,90	96,70	95,90	98,50	94,60	97,10	86,70	99,70	93,60	98,80	95,92
Pescara	95,60	100,00	99,90	93,30	89,80	85,20	93,50	96,10	96,70	93,30	99,90	94,85
Monopoli	99,00	96,10	89,90	99,00	98,90	96,30	96,30	99,90	96,00	86,00	97,50	95,90
Ponza	95,90	94,00	86,20	97,50	98,60	90,80	85,10	99,30	98,80	98,80	90,40	94,13
Crotone	96,20	99,70	96,50	85,00	96,70	95,00	99,90	92,00	96,60	92,50	95,50	95,05
Catania	89,80	86,40	85,40	89,80	97,80	96,10	95,70	98,40	94,80	91,20	92,90	92,57
Mazara d.V.	93,30	99,50	86,80	94,60	95,00	85,20	88,80	93,50	88,30	99,60	95,50	92,74
Totali	94,49	96,79	90,93	93,94	96,50	92,06	94,19	95,16	95,64	93,80	95,18	94,42

The following considerations can be made:

- the global reliability of 94,4% is considerably above the minimum limit of 85% required by the SIM;
- this degree of reliability, following a preliminary phase, has been maintained at a level more or less constant thanks to the Management System and to the use of the Argos satellite. This service started in 1990, and it is used for remote control of the position of the buoys;
- no substantial variations of reliability have been noted with the seasons (2% lower than the mean value), which confirms that the technological choice was correct and that reliability depends only to a limited extent on weather conditions;
- loss of data is basically the result of fishing activities: it is a random event more frequent in certain southern areas.

Two activities of considerable technological importance have been implemented to guarantee these reliability levels:

- connection of all the buoys to the Argos satellite in order to check the positioning of the measuring system;
- a star-shaped telecommunications connection via modem between the peripheral recording stations and the central interrogation system.

A permanent Assistance Service has been organized for the RON network to fully exploit these technological supports. It has the twin tasks of an immediate intervention and both a preventive and ordinary maintenance.

PREVENTIVE AND ORDINARY MAINTENANCE

These activities comprise:

- Downloading to streaming tape and monthly checking of data.
- processing and checking of the quality of the data received (the task of TEI Data Processing Centre), which issues a monthly bulletin, for use by the Assistance Service, on the quality of functioning of the sensors and the percentage of valid data. These activities provide a concise statistical picture of the functioning of the equipment and make it possible to establish in advance the ordinary and special maintenance interventions required.
- Maintenance support activities, for each peripheral site corresponding to a wave gauge station, carried out by two local operators: one for the sea parte, providing immediate nautical intervention in the event of equipment breakdowns; the other for the land part, having the task of carrying out preventive maintenance and the monthly downloading of data.
- Monthly checks on the state of the wave gauge equipment, the relative photographic documentation, underwater inspections to check the moorings, and the preparation of a service report to be delivered to the Data Processing Centre.
- Monthly checks of the equipment on land, with an evaluation of the degree of wear of components such as processors, aerials, cables, ecc.
- Calibration of the wave meters taken out of service for maintenance, using the "Ferris Wheel" system and preparation of the relative certificates.

These preventive activities make it possible to guarantee replacements with a maximum delay of 48 hours for the breakdown of any component on land, and a similar facility within 48-72 hours of notification for incidents involving a wave gauge buoy at sea, using personnel and tenders available on site.

ALARMS MANAGEMENT

This activity consists of:

- Checking of daily reports supplied via modem by the Argos service, concerning the correct positioning of each buoy.

  If a buoy is found a drift out of its area of action (which is calculated on the basis of the length of the mooring cable), its movement is continuously tracked and repeated via telex or modem to the centre, where the specialist control team will forward the required instructions to the people on site in order to rapidly recover the buoy and to ensure that it is immediately repositioned or replaced.

  This system, based on equipment for the transmission of signals to the Argos satellite, is installed on the wave gauge buoy. It has produced excellent results and it is certainly one of the reasons that has guaranteed the high percentages for recorded data.

- Daily activation of the automatic interrogation procedure of the peripheral stations, making it possible to check at any moment the functioning of the individual stations/components and to transfer concise wave data.

4. RESULTS

The availability of large quantities of data allows some basic analysis of the wave conditions around Italy, both for basic physical problems as for engineering applications.

A) Wave climate

From the statistical point of view, a number of specific analyses are usually carried out for each station concerning:

- the statistical distribution of Hs;
- the combined distributions (Hs, Tm), (Hs, θm);
- the seasonal variability of the above distributions.

Fig. 3 shows, in synoptic form, the directional distribution of the wave height, evaluated on all the data so far collected.

Fig. 4 shows the distribution functions p(Hs) relative to all the data recorded for the various stations.

Fig. 3 – Directional distribution of wave heights

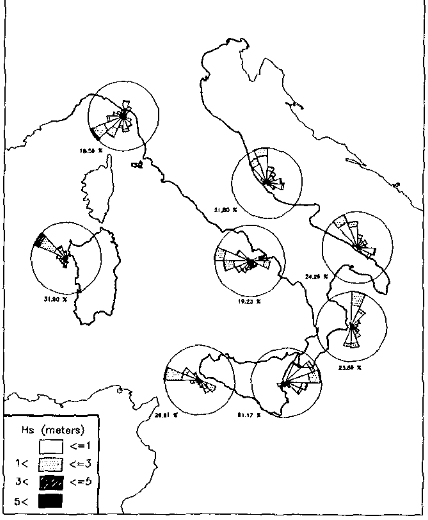
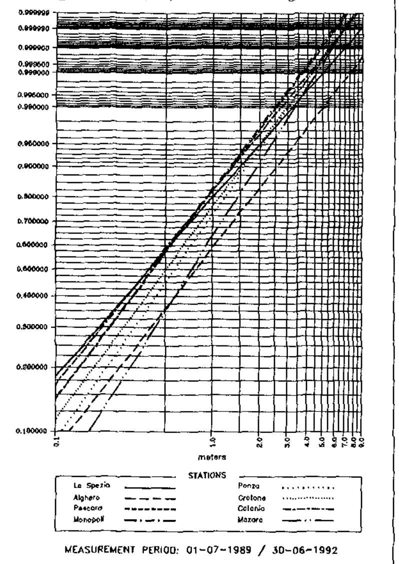


Fig. 4 – P(Hs) Weibull Diagram



The figure highlights the various energy levels corresponding to the different sites, and also the existence of different slopes for the various curves. These distributions cannot be considered conclusive because three years of data are by far a too short period for the deduced statistics to be significant. Besides, the data show a clear yearly variability that depends on the general meteorological pattern of the period. Hence the above statistics should be considered with much care. Because the data collection is continuing, updated statistics will be published as soon as available.

B) Extreme waves analysis

A further consideration more concerned with engineering is the selection of the extreme events recorded in the three year period under consideration. Table 2 shows, for the various stations, the maximum values of Hs, Tp, Tz and the correponding mean direction evaluated during the most violent storms at each station.

Undoubtedly the area most exposed to wave motion is the west coast of Sardinia: for this station, in correspondance with the storm of 20th December 1991, a significant wave height of 8.92 m has been recorded.

TABLE 2: EXTREME VALUES COLLECTED IN THE FIRST THREE YEARS OF MEASUREMENT

STATION	Hs(m)	TP(s)	TM(s)	MeanDir(ºN)
La Spezia	6.60	11.10	8.00	60
Alghero	8.92	12.50	9.50	135
Pescara	5.10	9.10	6.00	170
Monopoli	4.40	9.10	7.00	233
Ponza	5.70	12.50	5.40	94
Crotone	5.60	11.10	8.10	302
Catania	5.20	11.10	8.10	275
Mazara	5.50	12.50	8.30	105

5. APPLICATION TO NUMERICAL MODELLING

One of the most interesting applications for the data collected by the wave gauge network is the validation of numerical models for the calculation of wave motion.

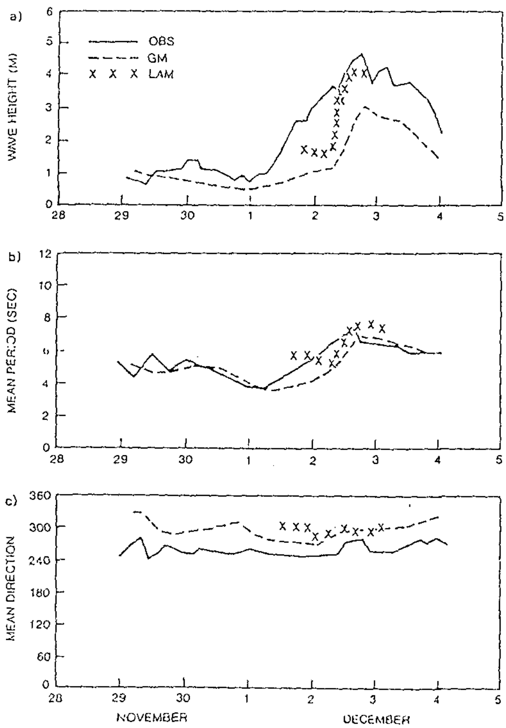
Models at various levels of complexity have been repeatedly applied in the Mediterranean Sea, and the results improve as the approach becomes more sophisticated. Presently one of the most advanced model is WAM, the product of the coordinated work of a large group of specialists in the field (WAMDI Group, 1988). This model has been repeatedly applied in the Mediterranean basin (Cavaleri et al., 1991).

The main result has been to assess the difficulty of correctly representing the field of surface wind in the basin, and consequently the wave field associated with it. An error of 20% in wind speed leads to an error of the significant wave height Hs of 30-40%, and consequently to an error of 70-100% for the energy of the wave motion, which is the variable of most practical interest in engineering applications. Errors of this level are unacceptable!!. We must recognize, however, that different meteorological models, with different solutions, give wind fields that can differ well over 20%. It is also very difficult to thoroughly test a wind model, as the complicated orography of the basin, particularly along the Italian coasts, can affect the local wind field in a drastic way and the stations of interest are located on the coast.

This makes any comparison between a detailed item of measured data (typically wind speed and direction) and the results of a meteorological model of limited significance, when the latter cannot take orographical details into account.

The solution, although neither complete nor definitive, may come from an analysis of the results of the wave field. The conditions of wave motion in a given location represent an effect, integrated in time and space, of the wind field on the entire basin. The recorded wave conditions provide therefore a validation of the combined meteorological and wave models.

Because the performance of a wave model is not affected by the geometry of the surrounding orography, particularly in areas like the Mediterranean Sea, recorded wave data, combined with the models results, can provide useful indications

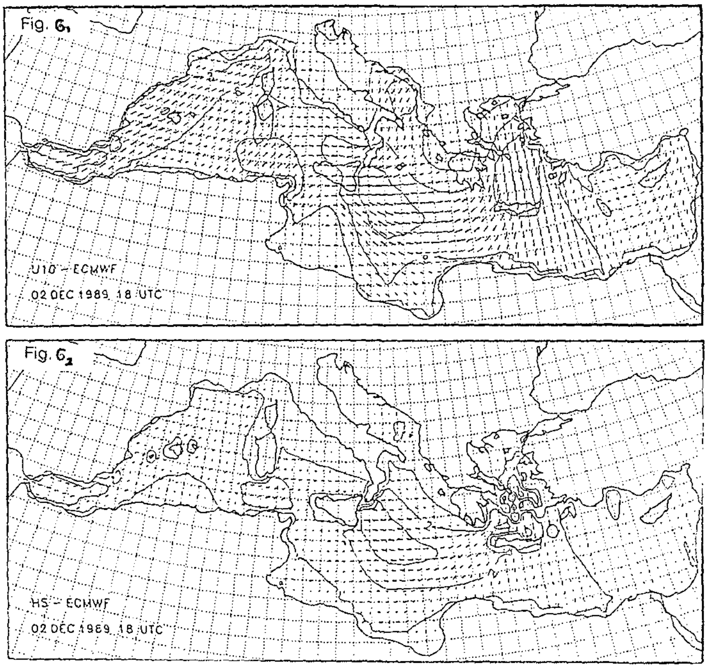


[Fig. 5 Comparison between recorded and computed wave heights by using the ECMWF (GM) and LAM models] on the accuracy of the input wind fields.

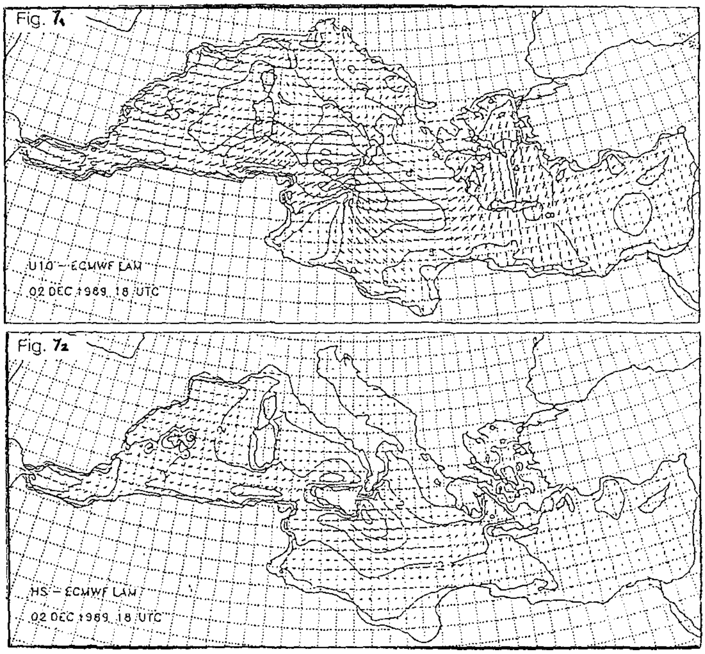
The Mediterranean Sea is characterized, as well as by large-scale events, also by events of a smaller scale, and yet extremely violent. An example is provided by the storm that hit the Malta area on 2nd December 1989 during the meeting between Presidents Bush and Gorbachov. A detailed study of this event has been made by Dell'Osso et al. (1992). The storm was characterized by the development of a deep pressure on the Ionian Sea, characterized by very strong winds with an extremely high spatial gradient. Results of the computation of the wave field by the WAM model have been compared with the experimental data recorded at Catania (Fig. 5). While the direction of the field is correct, there is a considerable underestimate of the wave height, a strong suggestion that the wind has been underestimated.

This led to repeating the meteorological simulation with a finer mesh (40 km, compared with the 125 km resolution of the global model of the ECMWF).

The results, in terms of wind and wave fields, are shown in Fig. 6). There is a strong increase and concentration of the wind in the area of Capo Passero, with a consequent increase of the wave height in the Catania area. Fig. 7 shows the obvious consequent improvement in the wave model results.



[Fig. 6 Windfield (6_1) computed by ECMWF model and associated waves field (6_2)



[Fig. 7 Windfield (7_1) computed by ECMWF model and associated high resolution waves field (7_2) computed by LAM model]

In general, the results of the modelling exercise indicate that a resolution of 125 km, such as that in the operative model of ECMWF until the end of September 1991, is not sufficient to provide the necessary accuracy of the wind field. A 70 km resolution, as that corresponding to the new model of ECMWF (T213), seams the minimum required for a sufficient seems reliability of the wave model results.

6. PRESENT SITUATION AND FUTURE DEVELOPMENTS

In view of the high reliability of the RON System, the Hydrographic and Tidal Service has decided to proceed with the monitoring activities for three more years, appointing once more TEI for the management of the project.
To improve the system the following additional activities have been added:

- connection in real-time of the existing eight stations with the central station at TEI in Milan;
- transfer of the data to a workstation located at the Rome Centre of the Hydrographic and Tidal Service;

- display of the recorded data, in real-time, using the RAI (Italian Broadcasting Corporation) Televideo Service.

Future expected activities include:

- the extension of the present network to four more stations;
- the distribution of the wave data collected and analysed in real time to the GTS - This will allow the assimilation of the wave data in the present Mediterranean Sea wave forecasting system (Cavaleri and Bertotti, 1992) with a consequent improvement of the wave forecast in the basin.

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