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On the Application of MIROS Data in Ocean-Wave Modelling

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MIROS is a microwave radar system for real-time measurement of directional ocean wave spectra and surface currents. MIROS is the only system of its kind available on a commercial basis. At the present time, several systems have been delivered and will be put into operation in the North Sea in the near future.

During the period from December 1984 until May 1985 one system has been operational from Esso's *Odin* platform in the Norwegian sector of the North Sea under contract with Esso Norge A/S. One important aspect regarding this installation is that other wave and current measurement programs have taken place in the same period; thus data for inter-comparison studies will be available.

This chapter starts with a brief description of the MIROS system which includes the most important characteristics of both hardware and software. The principles of operation are also reviewed.

The MIROS directional wave spectra contain amounts of information concerning the directional distribution of sea and swell as well as the unidirectional spectrum and total energy. A new ocean-wave model is being implemented at DNMI (the Norwegian Meteorological Institute). This model simulates the full two-dimensional (direction/frequency) wave spectrum, generated from successive windfields over the N.E. Atlantic, North Sea and Norwegian Sea. An interesting application of MIROS data is in verification and calibration of the wave model. The experience obtained investigating the applicability of MIROS data from the *Odin* installation for this purpose is the main subject of the chapter.

INTRODUCTION

Availability of directional wave information is becoming increasingly more important in several fields related to offshore activities. The present applications involve both the need for statistical information as well as real-time data and forecasts. It is of course impossible to cover all ocean areas of interest with sensors, and therefore a complete maritime weather service system will incorporate both various types of sensors and a wave model, which can be run in both a hindcast and a forecast mode. DNMI (the Norwegian Meteorological Institute) has implemented the WINCH wave model. The windfields used as input are taken from the six-hourly routine wind analysis at DNMI.

A wave model does certainly not eliminate the need for measured data. A wave model must be adapted to a certain geographical area by tuning, and problems with correct windfield estimation render the assimilation of real-time measured wave data in the model necessary, to prevent accumulated errors. Measured data will also be necessary for model verification.

MIROS measures the directional wave spectrum as well as components of the surface current. Wave data from a MIROS system seem to be well suited for the applications described.

The chapter begins with a short review of the MIROS system. Then the application of MIROS data in the maritime weather service is discussed in general terms, followed by a short description of the DNMI wave model. During the winter of 1984/85 one MIROS system was operational from Esso's *Odin* platform in the North Sea. A short description of this installation is given. In a preliminary data analysis, measured data from the MIROS *Odin* installation have been compared with DNMI model hindcast data.

THE MIROS SYSTEM

MIROS is a microwave radar system for real-time directional measurements of ocean wave height frequency spectra and surface currents. MIROS is primarily designed for operation from stationary offshore installations. The MIROS hardware consists an outdoor-mounted microwave sensor head connected by a cable assembly to an indoor-installed central processor cabinet (see Fig. 1). The sensor head is to be installed on the top of the platform building section or at another convenient location giving 50 to 100 m elevation above sea level.

The MIROS software is written in extended PASCAL.

The directional properties of MIROS depend on the actual installation geometry and the sensor head antenna beamwidth. A typical geometry gives resolution better than 30° for waves up to approximately 200 m wavelength. The resolution then gradually decreases for longer waves.

During a typical measurement sequence, observations are taken in six directions with an angular increment of 30°. This represents a 150° rotation of the antenna assembly, which is sufficient for a complete scan since the radar

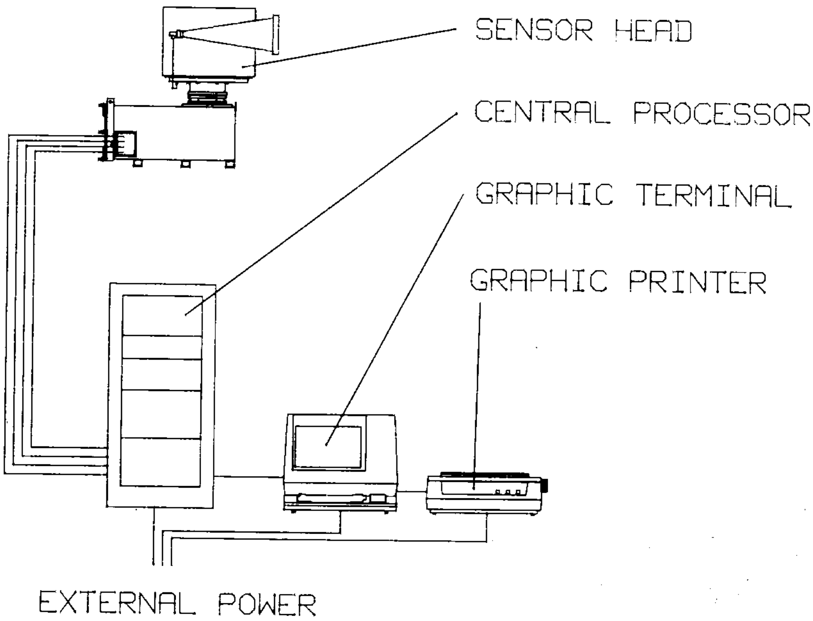

Fig. 1 The MIROS system

can observe both approaching and receding waves. A typical observation time per direction is 12 minutes, giving a total observation time of 72 minutes for a complete directional scan.

MIROS operates in two different modes, a pulse-döppler mode and a dual-frequency mode. Directional wave height–frequency spectra are measured in the pulse-döppler mode, basically obtaining spatially averaged water-particle velocity information. A wave model is applied to transform the velocity spectrum to a wave height spectrum. Surface current information is obtained by measuring the phase velocity of a gravity-wave component in the dual-frequency mode.

The output wave data format is an array with 40 equidistant frequency bands and 12 (6) directions. Presently, additional information is needed to resolve an inherent 180° ambiguity. The frequency bands range from 0.01 Hz to 0.4 Hz, and the resolution is 0.011 Hz.

APPLICATION OF MIROS DATA IN MARITIME WEATHER SERVICE

Hindcasting

For climatological purposes, numerical wave models have been used to produce time-series of wave parameters, such as:

- significant wave height,
- "peak" period, and even
- full directional/frequency spectra

at locations and times where no measurements have been available.

In order to assess model performance, reliable spectral information from measurements is compared to corresponding model spectra, in particular in the case of extremes, i.e. storms with rapidly changing wind. Results from such comparisons might lead to the reconstruction of certain algorithms within the numerical model, i.e. the simulation of wave directional relaxation in connection with rapidly propagating storms.

Nowcasting

For certain wave sensitive operations, such as diving, lifting, etc., special attention will be paid to the onset of long-period swell systems. With a real-time operating MIROS, one will have the opportunity to detect the early stage of long periodic components arriving at the location of interest, and also:

- to identify their generation area by means of their measured direction;
- in co-operation with weather forecasters (with wave models) to decide whether the phenomena are expected to be temporary or to last for a longer period of time;
- to advise operational management on the actual operation.

Forecasting

A numerical wave model used for forecasting is, in principle, the same as the one used for hindcasting, which means that there is the same need for model quality assessment and tuning (reconstruction).

Additionally, a wave model requires the definition of the sea state for a large ocean area at some initial time, t_0. In principle, this should imply the full knowledge of the spectral density function

$$F = F(f, \theta)$$

where f = frequency, and θ = partial direction, for every required grid point in a 75 (or 25) km grid network covering all ocean areas that could generate wave systems to travel towards the North Sea.

In practice, this is impossible. What a model does to define the initial sea-state field, is to let the successive windfields, as input to the model, generate the initial wave fields by a 36 (or 48) hours preceeding integration starting from zero sea state ($F = 0$ for all locations). From this initial (although artificial) sea state, the actual prognostic integration carries on for a 48- or 72-hour forecast period.

However, errors accumulate in the initial field during model run. It has been demonstrated, i.e. for closed basins like the North Sea, that assimilation of even limited amounts of real-time measurement data into the initial fields gives significant benefits to wave-forecast prognosis.

Network Requirement

Certain requirements are stated to the wave-sensoring network supplying the measured data:

- adequate directional information/resolution;
- continuous time-series provision;
- geographical coverage of certain extents, in compliance with operational marine weather service requirements.

A realistic future system will be a blend of buoy and fixed platform based (MIROS) systems. Recommendations for platform instrumentations come partly from national meteorological agencies and joint committees, i.e. the North Sea Panel.

DNMI'S WAVE MODEL

DNMI has implemented the WINCH wave model, which was developed by Vincent Cardone of Oceanweather Inc. The model is of the discrete coupled type and operates with 15 frequency and direction bands, so that the directional resolution is 15°. The frequency bands range from 0.04 Hz to 0.239 Hz, with a ratio between adjacent bands of $3^{1/9}$.

All spectral bins are propagated individually. Growth for each spectral bin is the largest of a parametric increment and an input term of the Miles type, i.e. proportional to the energy in the band.

The parametric growth term is derived from empirical fetch-limited growth data and forces the growing wind-sea to conform with a reference spectrum that possesses the most important characteristics of the JONSWAP spectrum, which can be integrated analytically and reduces to the Pierson–Moskowitz (PM) spectrum as the sea approaches full development. Growth is scaled to the friction velocity, dimensionless energy and the PM spectrum to the wind speed at 10 m above sea level.

The high-frequency tail of the spectrum is restored to an αf^{-5} form, where α is related to the dimensionless energy. Thereafter, a directional redistribution is performed so that frequencies below the PM peak frequency are left unaltered, i.e. they propagate as swell, and frequencies above are subjected to relaxation.

The time step is 2 hours.

The grid is a nested rectangular mesh on a transverse Mercator projection, with an assumed equator along the Greenwich meridian. The grid spacing is 75 km on the fine mesh and 150 km on the coarse mesh. The integration area is shown in Fig. 2.

The windfields used as input are taken from the six-hourly routine wind analysis at DNMI.

MIROS AT ESSO'S *ODIN* PLATFORM

During the period from December 1984 until May 1985, one MIROS system has been operational from Esso's *Odin* platform in the Norwegian sector of the North Sea (Fig. 3), under a contract with Esso Norge A/S. One important aspect regarding this installation is that other wave and current measurement programs have taken place in the same period; thus data for intercomparison studies will be available.

This exercise represents the first real offshore experience with a MIROS system. Apart from some minor technical problems at the beginning, from the manufacturer's point of view the experiment has been a success.

The sensor head was installed on the lifeboat deck approximately 45 m above sea level, looking in the directions 235°, 265°, 295°, 325°, 355° and 25° relative to true north (see Fig. 4). The central processor cabinet was installed in a cable shaft at the same level in the living module. The sensor head was connected to the central processor cabinet with appoximately 50 m of cable. Mechanical installation and cabling were performed by Esso-*Odin* personnel.

Apart from periodical inspection by MIROS personnel, the system was left unattended. Data were logged on 3M ¼ inch data cassettes. One cassette has a storage capacity of 67 Mbytes. Measurements were taken every 3 hours using radar mode 3, wave spectrum and

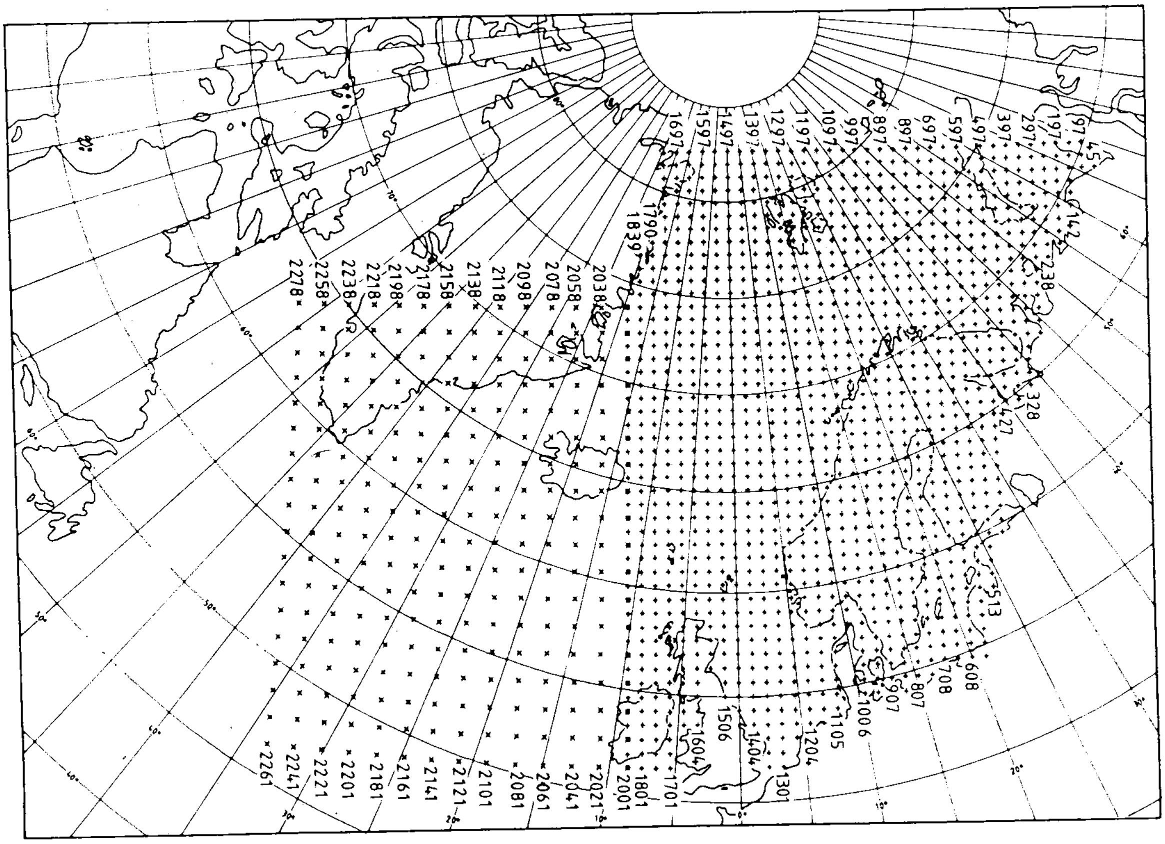

Fig. 2 DNMI model integration area

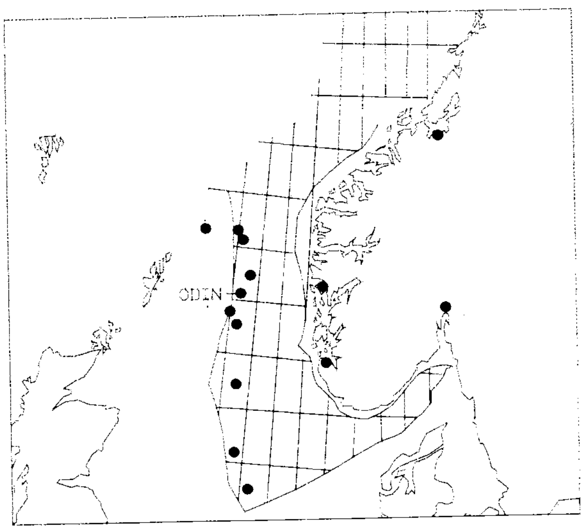

Fig. 3 The location of the *Odin* platform

surface current simultaneously. Both raw data (time-series) and processed data were logged; therefore one data cassette has sufficient capacity for approximately 75 days of operation. Esso-*Odin* personnel were instructed to change tape cassettes.

In the first part of the measurement period, the distance to the radar footprint was selected to be 487.5 m, giving a grazing angle close to 5°. Although the optimum for directional resolution (wide footprint), this low angle turned out to give shadowing problems under high wave conditions. The distance to the footprint was therefore reduced to 337.5 m, giving a grazing angle of about 8°, which is now considered sufficient for most conditions. Improved directional resolution must therefore be obtained by mounting the sensor head higher above sea level.

After completion of the measurement period, the MIROS equipment was dismantled and

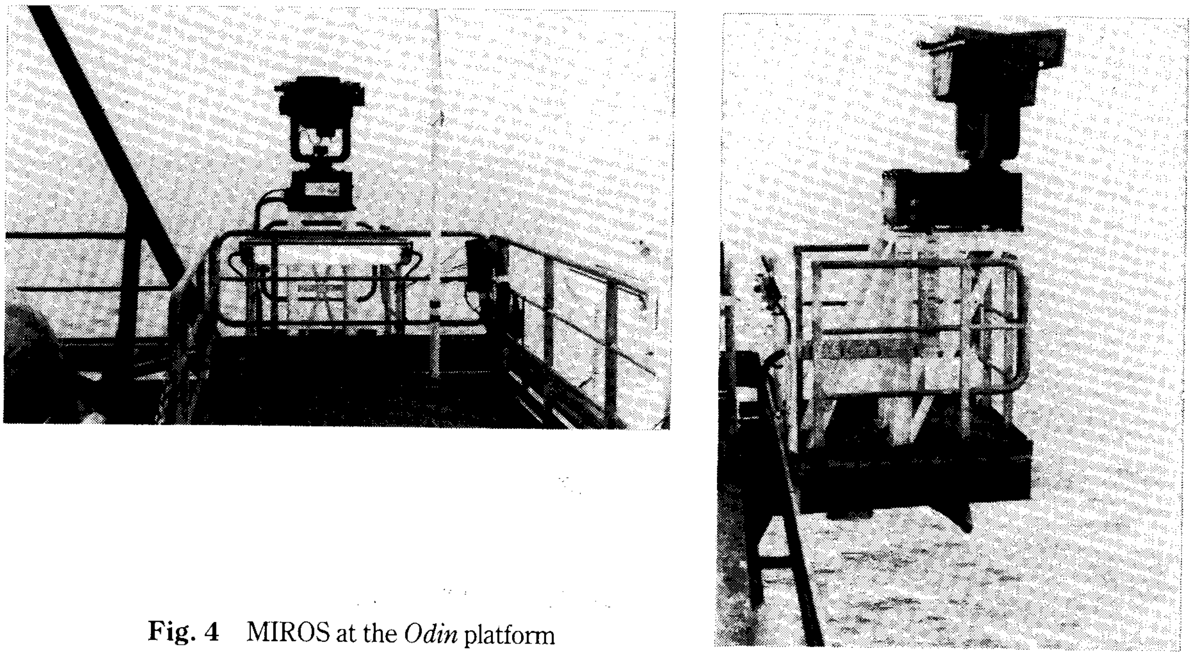

Fig. 4 MIROS at the *Odin* platform

shipped back to MIROS A/S. Having spent more than 6 months in the North Sea, the equipment was found to be in excellent condition. No significant traces of corrosion could be observed.

COMPARISON OF MEASURED AND MODEL DATA FOR SELECTED TIME PERIODS

Unfortunately, measured data from other sensors were not available at the time of writing. For this reason only model data have been compared with the MIROS data. We have selected three different periods, 6–23 February 1985, 26–31 March 1985, and 15–28 April 1985, thus covering three major storms during the measurement period. For the first period, detailed model spectra are available, while for the two last periods model output of wind speed and direction, significant wave height, peak period and peak direction are available. We have data from MIROS measurements every three hours for all periods.

The Esso *Odin* platform is located at 60.127° N and 2.166° E. The closest DNMI model gridpoint is 59.72° N and 2.67° E, which is approximately 53 km away (see Figs. 2 and 3).

Data have been compared with respect to significant wave height, spectral peak period and peak direction. In general, with respect to long-term trends, the model data are in good agreement with the measured data. For given spectrum shapes, i.e. multipeaked frequency spectra and directional distributions with high spread, parameters such as peak period and peak direction are very sensitive to small changes in the energy distribution. Some of the deviations between the model and measured data may be attributed to this fact. However, to give proper explanations in all situations one must look more into the details of the two-dimensional spectra and include more information, i.e. measured wind data.

In the present case, model data together with a simple trend analysis are used to resolve the inherent 180° ambiguity in the individual MIROS measurements.

Only a very limited set of data can, for obvious reasons, be shown here. Figures 5, 6 and 7 show the temporal progression for the significant wave height, peak period and peak direction respectively for the period 15–22 April 1985.

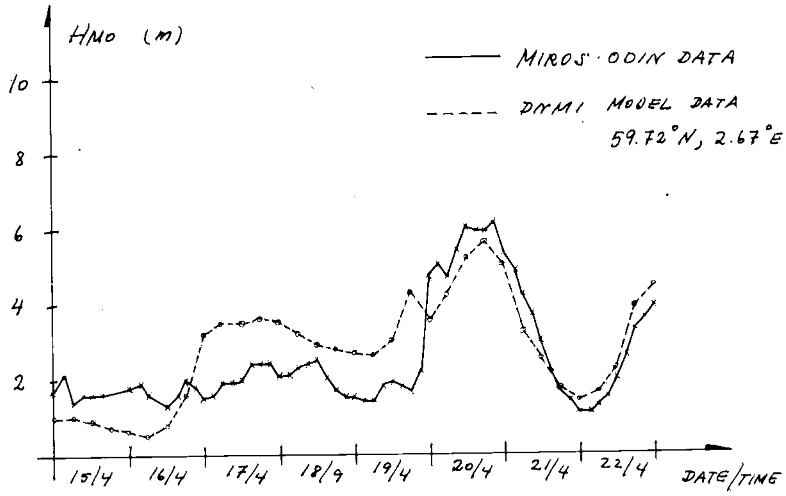

Fig. 5 Significant wave height comparison

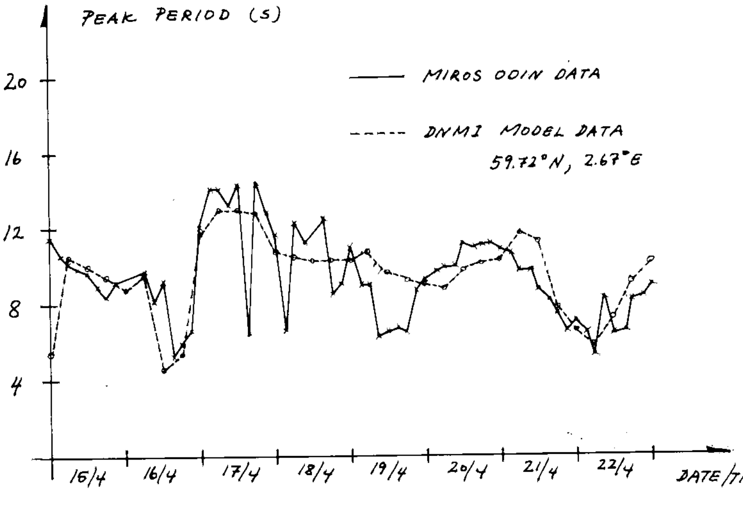

Fig. 6 Peak period comparison

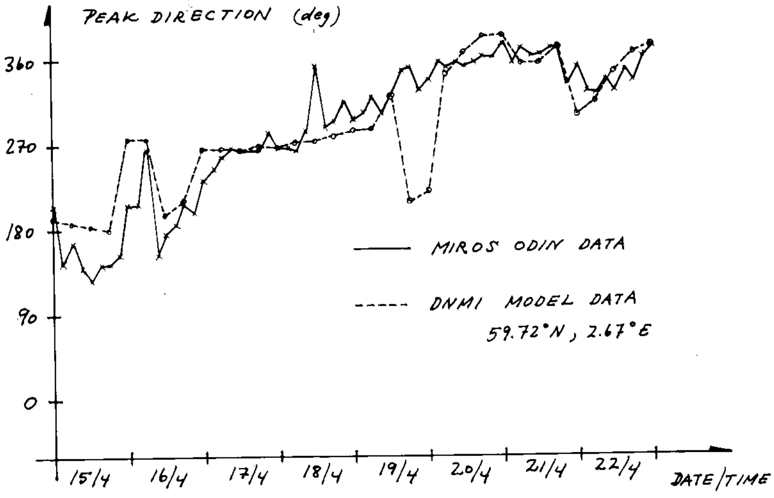

Fig. 7 Peak direction comparison

CONCLUSIONS

In general, model data show good agreement with the measured data. The MIROS data are considered well suited for calibration/verification of the DNMI wave model. In the longer term, we foresee a network of automatic MIROS systems at convenient locations in the North Sea, reporting two-dimensional real-time wave information to DNMI via telephone connections.

The Esso-*Odin* experiment has supplied MIROS A/S with valuable experience with respect to systems offshore operation. The MIROS type of system undoubtedly represents the future in routine measurements of high-quality two-dimensional wave spectra. We consider the measurement principles applied in the MIROS system to be verified. However, we look forward to being able to perform data comparison with the reference sensors, as soon as the data becomes available.

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