CHAPTER 7

THE MEDITERRANEAN SEA WAVE FORECASTING SYSTEM

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Abstract

We describe the sea wave forecasting system presently operational at ECMWF. After a short description of the meteorological and wave models, we address specifically the problems connected to their application to the Mediterranean Sea. We consider in particular two storms, a Mistral and an African storm, whose results provide clear indication of the present forecasting capability in this area.

Background

Following the opening to Optional Projects by the Council of the European Centre for Medium Range Weather Forecasts, Reading, U.K. (henceforth referred to as ECMWF), a project for real time forecast of the sea wave conditions has been proposed and approved by the Centre in May 1991. The aim is to make use of the daily meteorological forecast to produce a corresponding wave forecast on a global basis by means of an advanced wave model. Due to the lack of sufficient resolution the Mediterranean Sea cannot be properly represented on a global grid. Consequently a separate version of the model, with a sufficiently high spacial resolution but otherwise the same physics and numerics of the global version, has been implemented in this basin.

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In this paper we briefly describe the meteorological and wave models used for the forecast. Then we point out the problems specifically connected to the Mediterranean area. These are well illustrated by the analysis and forecast of two storms of different characteristics, a Mistral and an African storm. We conclude with an outlook on the expected future developments of the models and their effect on the actual forecast.

The meteorological and wave models

A 213 components spectral meteorological model is daily run at ECMWF on a global basis for analysis and up to days forecast (Tiedtke et al, 1988). The results are provided at 6 hour interval. Among a wide variety of products the model provides U10, the 10 m height wind, with an effective resoolution of approximately 80 km. This wind is used as input to the wave model.

The third generation WAM wave model is used for wave evaluation. The model (amply described in the literature, see e.g. The WAMDI Group, 1988 and Cavaleri et al, 1991) is based on the energy balance equation, and on the physical description of the processes that affect the growth and decay of wind waves. In the present version 300 components, 12 directions and 25 frequency bins, are considered. For each component and at each integration step the balance equation is solved at the knots of a spherical grid with 3 degree resolution, both in latitude and longitude, providing information on the two-dimensional spectrum at each grid point. For application to the Mediterranean Sea a limited area geographical grid, with 0.5 degree resolution, is used. The grid includes 930 sea points. With 0.3*10**3 CPU second for each point and each integration step, a 5 day forecast in the Mediterranean Sea requires about 100 second of CPU on a CRAY C90.

Application to the Mediterranean Sea

The main problem for a correct evaluation of wind wave conditions is the correctness of the input wind field. This is particularly true in basins with complicated geographical shape, as it is the case for the Mediterranean Sea. Limited shift of location or direction of an intense wind distribution can lead to substantial change of fetch in a certain area, and consequently to drastically different wave conditions. The practical difficulties are also increased by the presence of a complicated orography. Cavaleri et al (1991) and Dell'Osso et al (1992) have discussed the problem of an accurate description of the wind field in the Mediterranean Sea, and they have clearly shown the fundamental role of the surrounding orography in shaping the meteorological situation, in particular the wind field, inside the basin. The present resolution of the ECMWF meteorological model has been shown to be the minimum required for a proper description of the surface wind fields in the Mediterranean basin.

In the following we show different applications of the WAM model, both with analysis and forecast wind. We call attention to the fact that for a wave model there is no difference if operating in hindcast (analysis) or forecast mode. An input wind, however produced, is just an "input wind", and the wave model reacts accordingly, independently of where the wind information comes from. Given the basic characteristics and the intrinsic accuracy of a wave model, its results plainly reflect the accuracy of the input wind fields.

The wave measurements used to verify the results discussed in this paper have been obtained with the italian network of directional buoys. The network is described in a companion paper in this conference (De Boni et al, 1992).

Mistral case

On 17 November 1991 (see figure 1) a strong Mistral wind was blowing across the Western Mediterranean Sea. The Mistral wind is a cold north-westerly wind that, associated to energetic flows from the Atlantic Ocean, enters the Mediterranean Sea across the Carcassone Passage, north of the Pyrenees between Spain and France. The analysis at 12 UTC 17 November 1991 is shown in figure 1a. Figure 2a shows the corresponding wave field. The peak conditions are reached on the west coast of Sardinia, with significant wave height Hs larger than 6 metre. Figure 3a compares the WAM output at Alghero, indicated with a dot (A) in figure 2a, with the data obtained from the WAVEC wave measuring buoy. The closest grid point to the measurement location was chosen for comparison. Given this approximation and the time variability of the Hs record, the comparison is quite satisfactory.

Figure 1b,c,d shows the corresponding wind fields evaluated as forecast at day N-1, N-2, N-3 respectively. Remarkably we see that the storm was well described till 3 days in advance. The associated wave forecasts stress further this point. They are shown in figure 2b,c,d. We note only a limited (a few hours) anticipation of the storm in figure 2d, with wave energy already protruding into the Tyrrhenian Sea.

Note that the actual ECMWF forecast would be much better than this. In routine operations a wave forecast uses as input the analysis wind until time 0 (beginning of the forecast), and then the wind forecast at +1d (day), +2d, etc. We have used a different tecnique. Considering p.e. the +1d wave forecast (one map of which is shown in figure 2b), for each day N of the run the input wind has been

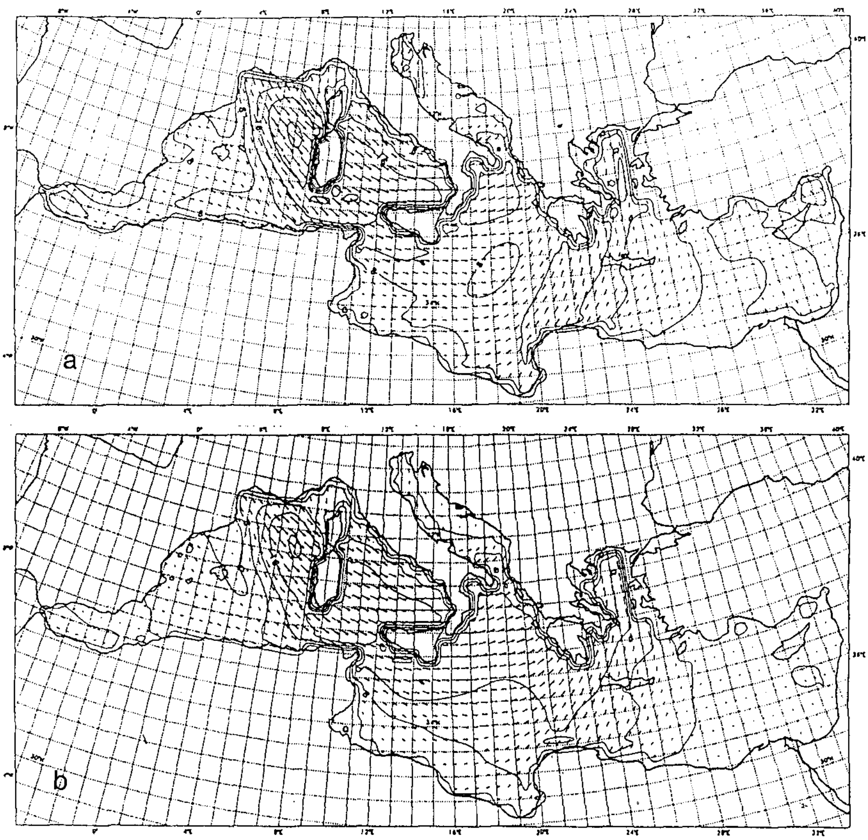

Figure 1 - Wind field on the Mediterranean Sea at 12 UTC 17 November 1991. 10 m height wind; speed is given as m/s. a) analysis, b) 1 day forecast.

given by the wind forecast produced at day N-1. So doing, the wave forecast becomes very sensitive to even small but permanent error in the wind forecast, certainly much more than in the standard routine operation. This leads to a better appreciation of the wave forecast shown in figure 2 and figure 3.

African storm

A week after the Mistral case a different condition arose, characterised by an intense African storm. The main feature of African storms is a small minimum that, born over the Sahara desert, moves then northward. When entering the Mediterranean Sea the minimum rapidly intensifies, producing a very localised but deep low. The dominant characteristics of the African storms, at least for what

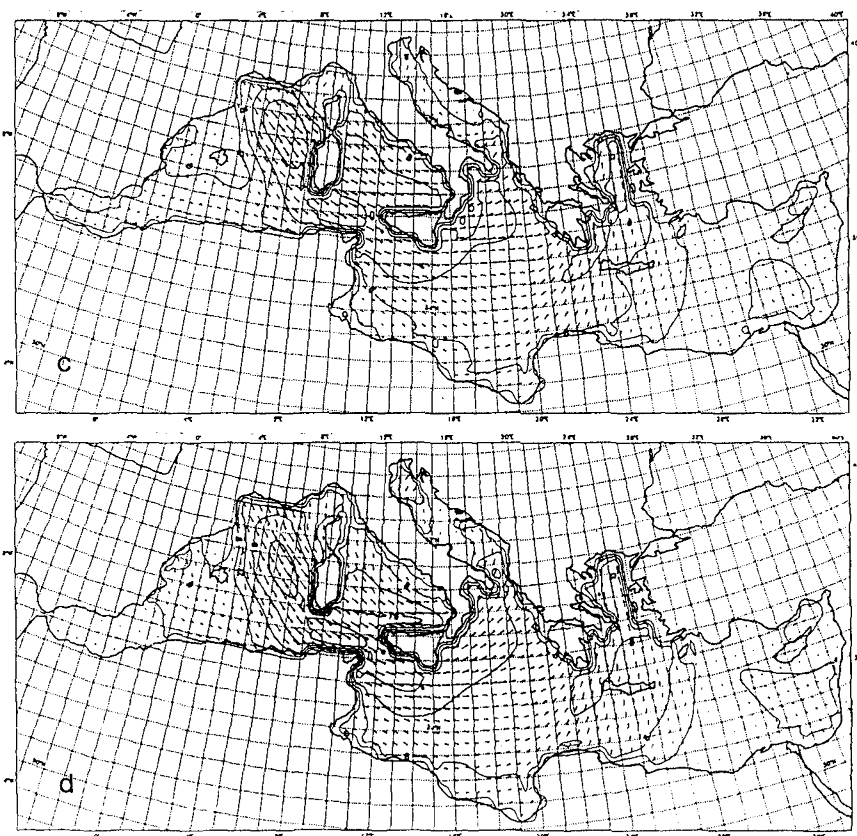

Figure 1 - (cntd) c) as b), but for 2 day forecast, d) 3 day forecast.

concerns the evaluation of wind waves, are the extremely strong winds and the large spacial and temporal gradients. Mutatis mutandis, they resamble small hurricanes.

The meteorological situation at 00 UTC 24 November 1991 is shown in figure 4a. The minimum is located on the western end of Sicily, producing a strong southerly wind on the whole Ionian Sea, south of Italy. The associated wave conditions are represented in figure 5a. Large waves, with Hs larger than 5 metre, affect the south-eastern coast of Italy.

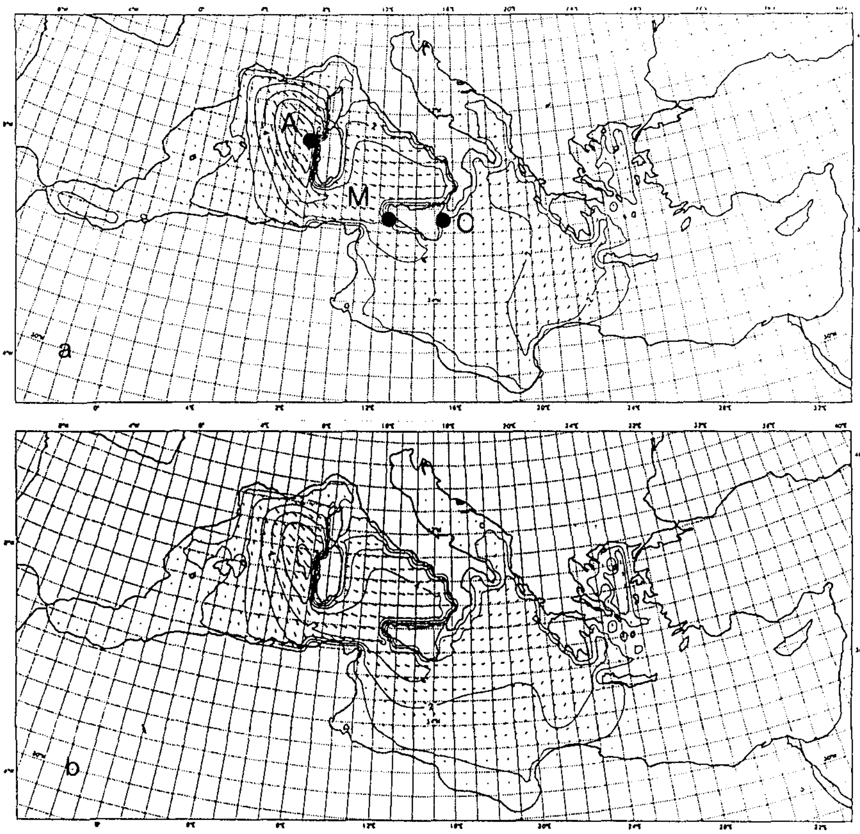

Figure 2 - Wave field on the Mediterranean Sea at 12 UTC 17 November 1991. Significant wave height, in m. a) analysis, b) 1 day forecast. The dots in a) show the position of the wave measuring stations at Alghero (A), Mazara (M), Catania

The comparison of the WAM model output with the measured Hs at Mazara and Catania (points M and C in figure 2a, respectively) reveals several interesting aspects. The underestimate of Hs at Mazara and the overestimate at Catania suggest that the analysis has misplaced the actual track of the low to the East. Also, as discussed by Dell'Osso et al (1992), the strength of these storms is often underestimated. The main reason for this is the limited resolution of the meteorological models, consequently unable to resolve the details of the storm and to correctly represent its physics. The limited dimensions of the African storms, and the substantial lack of information on the African territory where they come from, make their prediction a very difficult task. This is apparent in the 1d, 2d, 3d wind forecast in figure 4b,c,d. The storm is present, but weaker and misplaced

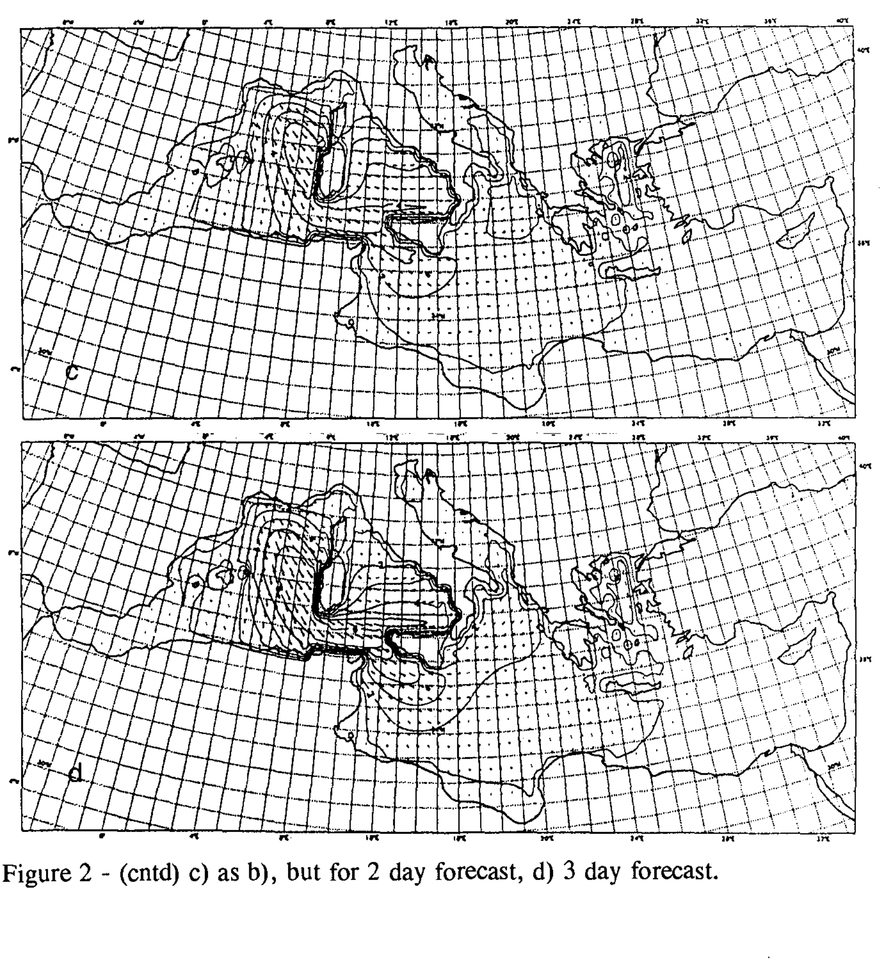

Figure 2 - (cntd) c) as b), but for 2 day forecast, d) 3 day forecast.

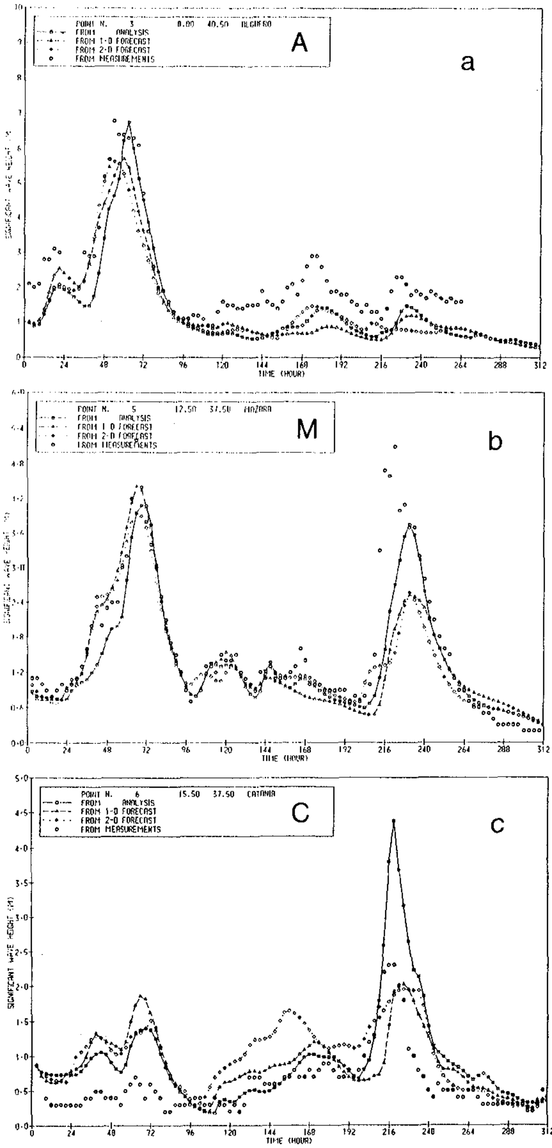

Figure 3 - Timeseries of the significant wave height (m) at the three locations shown in figure 2a. Measured data, and wave model output for analysis wind and 1 and 2 day forecast are shown.

in b, barely discernible in c, absent in d where the minimum over Sardinia has a different genesis. As previously said, the consequences of these poor forecasts are stressed by the corresponding wave forecast (shown in figure 5b,c,d). There is virtually no resamblance with the analysis field in figure 5a. This conclusion is backed by the Hs comparison in figure 3b,c. Note that the 3d forecast has not been drawn to avoid an unnecessarily large number of diagrams in the figure.

Conclusions and outlook

The tests carried out until now suggest that in most of the cases the T213 spectral

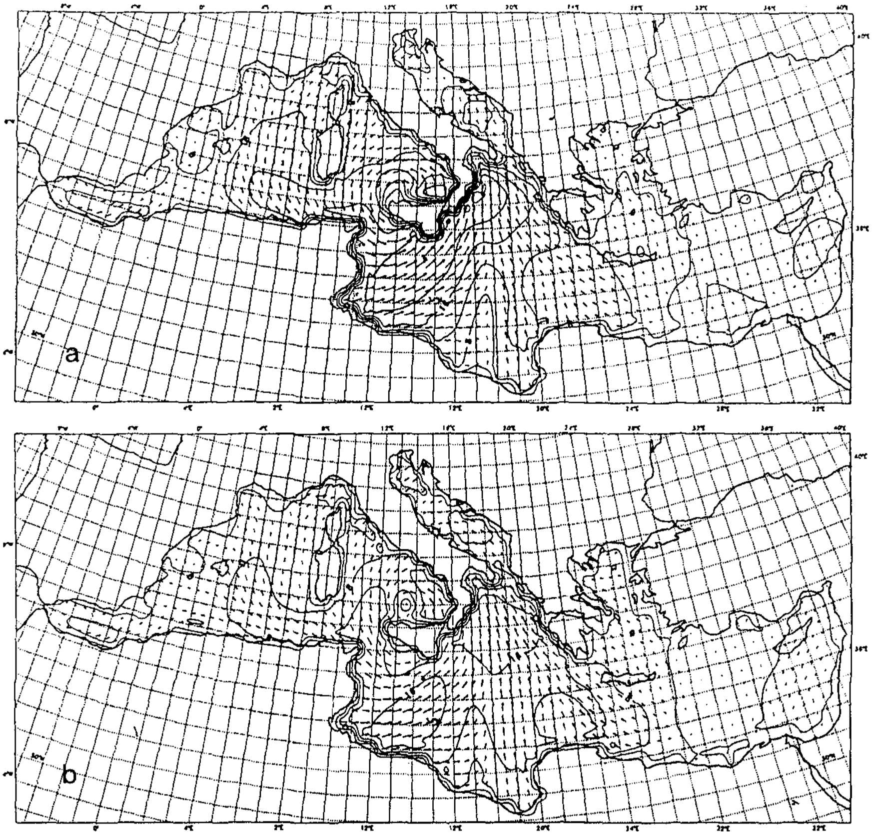

Figure 4 - As figure 1, but at 00 UTC 24 November 1991.

meterological model presently used at ECMWF provides acceptable surface winds on the Mediterranean Sea. This is true for extended storms with a well defined shape and distribution. It is not the case for small storms, e.g. the African storms, whose structure cannot be resolved in the present resolution of the meteorological model. A similar argument holds for the predictability of the storms, with the further point that the western storms are well documented from several days in advance, while in practice the African storms are not detected by the scarse and scattered meteorological network present on the North-African continent.

In general terms the meteorological and wave predictability is expected to improve in the future, both for the increase of resolution of the models, and for the large

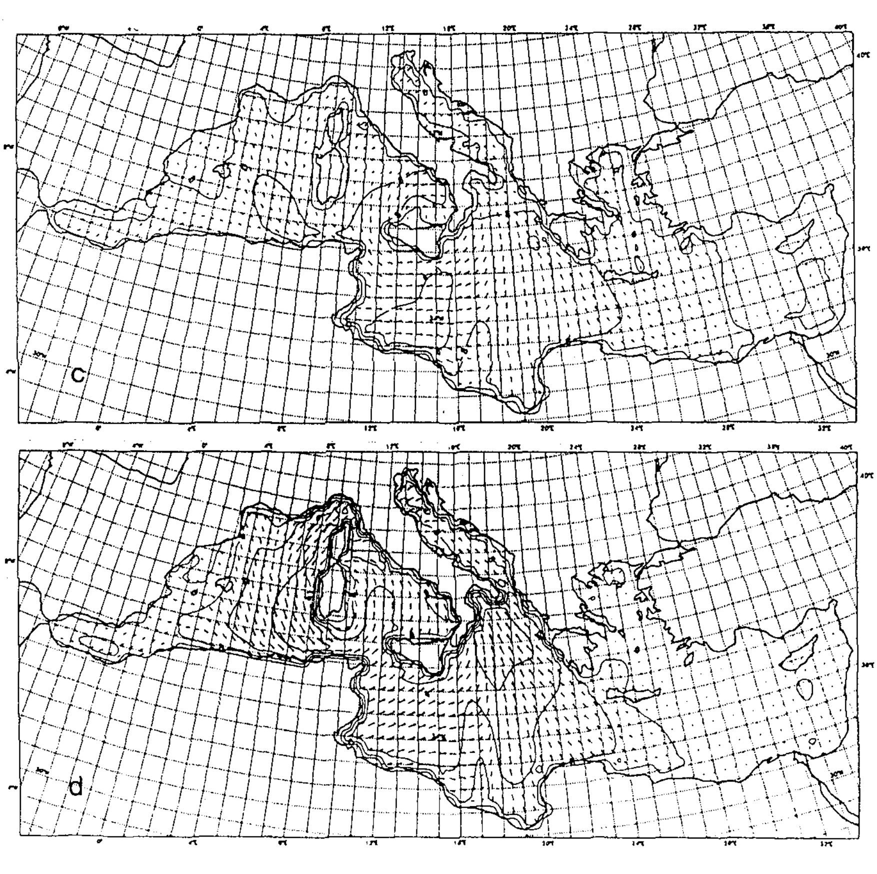

Figure 4 - (cntd).

amount of information provided by the satellite like ERS-1. However, once more the argument is much weaker for the African storms, because of the lack of sufficient information (the ERS-1 scatterometer and altimeter provide estimates of the wind distribution only on the sea). It is true that a better definition of the global meterological situation will help in detecting the conditions that are at the origin of the African storms. However, the surface observations, providing the truth for the short term accurate forecasts, will still be missing. Similar conditions are found in many parts of the world (Bengtsson, 1991). If the general forecast, and the one on the Mediterranean Sea in particular, is to be substantially improved in the near future, this problem will have to be addressed with will and decision.

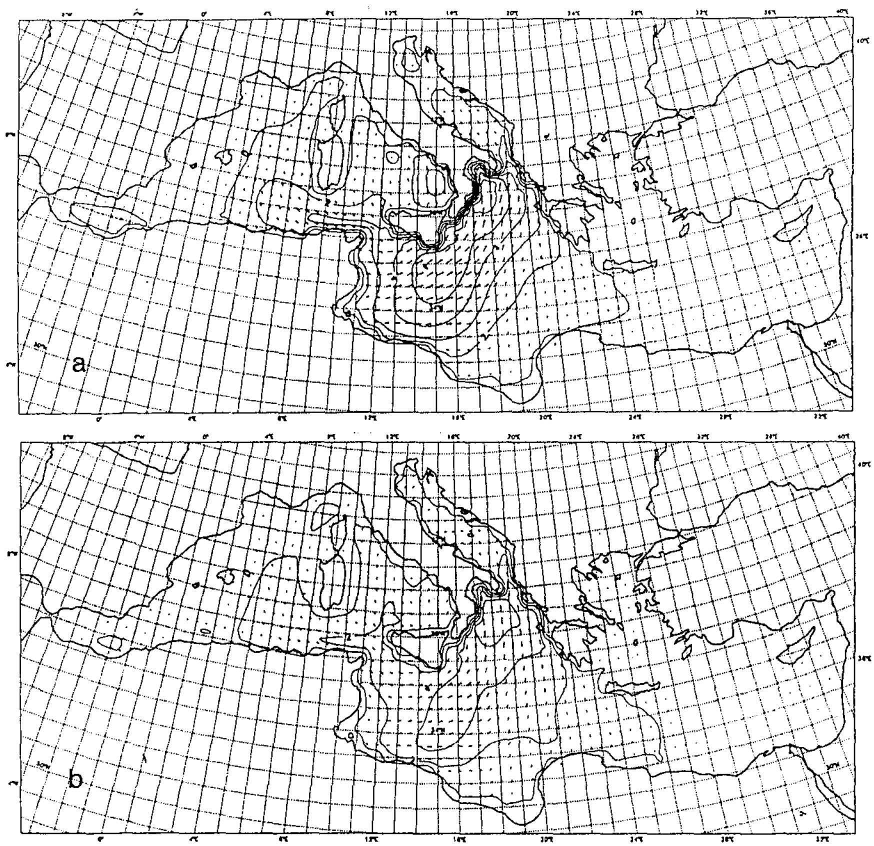

Figure 5 - As figure 2, but at 00 UTC 24 November 1991.

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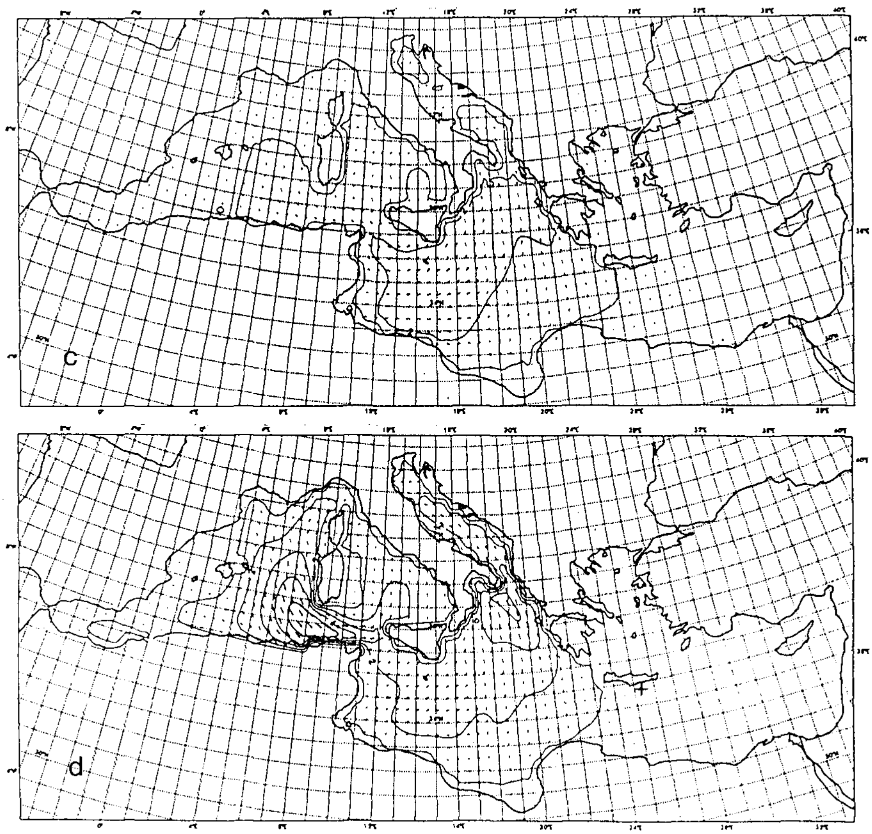

Figure 5 - (cntd).

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