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Research papers

Performance of global and regional nested meteorological models

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ABSTRACT

We discuss the performance of two global meteorological models in a difficult enclosed sea area and the possible improvements using two respectively nested high resolution local models. Each of the four sets of wind fields has been used to drive the same wave model. The performances are judged on the base of measured, buoys and satellites, wind and wave data. The analysis shows clearly the general benefits of a higher resolution. However, it also highlights the sensitivity of the nested models to apparently minor changes in the input information from the global models and their consequent possibility of larger errors, particularly in complex meteorological situations.

1. The problem to be discussed

Global meteorological models have done much progresses in the last two decades, expanding the range of reliable forecast from two or three days to almost one week. The statistics available from, e.g., the European Centre for Medium-Range Weather Forecasts (ECMWF, Reading, U.K., see www.ecmwf.int, Figs. 1 and 2) provide a clear evidence in this respect. The time history of the related improvements has been nicely described by Arakawa (2001).

Having good results in time implies also better ones in space, and indeed the single person at a given location can reliably look, in general, to the expected meteorological conditions in the next few days. In most of the cases (for the sake of general discussion we purposely ignore some special ones, typically of very strong storms) the evolution of the weather systems is correctly forecast.

All this holds by and large in the open ocean and consequently on the coastal areas exposed to the direction most of the storms come from. Still with much improvement in time, things become more delicate when we focus on areas, possibly enclosed, of smaller dimensions, characterized by a relevant orography and strong gradients of the meteorological conditions. Contrarily to the ocean, in these cases a small shift of the meteorological pattern, and of the wind field in particular, may change completely the ensuing wave conditions. The natural solution is to move to nested, higher resolution modelling capable to cope with the smaller local geographical details not visible at the global scale. However, the sensitivity of the local specific conditions to even limited changes in the local scale pattern implies that small errors in the parent model may lead to serious ones in the nested model. This is often area dependent, due to the local orography and possibly to the presence of the sea. A typical area in this respect is the Mediterranean Sea. The largest enclosed basin in the world, spanning almost 43 degrees in longitude and more than 15 degrees in latitude, at the border between the hot African climate and the much colder climate of Europe, the Mediterranean is not always the balmy area often advertised in touristic pamphlets. When a severe storm hits the area, it is often intensified by the heat exchange with the local warm waters. A particularly critical area is the Catalan coast (see Fig. 3), at the west border of the basin. Shielded on its back by mountains in the direction most of the storms come from, open to the consequent effects from the North and the South, exposed to the occasional large waves from the eastern sectors, the Catalan coast is a real challenge. This is further complicated by the interaction of waves with currents, typically flowing from North-East.

Within the framework of the Field-AC project (see the Acknowledgements for the full definition) much attention has been put on this area, in particular during the early Spring of 2011 when a 40 days extensive measurement campaign provided valuable data for the verification of the model results. The main purpose of this paper is to analyse and discuss the accuracy of the simulations in the area obtained with two highly qualified global meteorological models and their respective nested models focused with high resolution on the area of interest. Waves are a key

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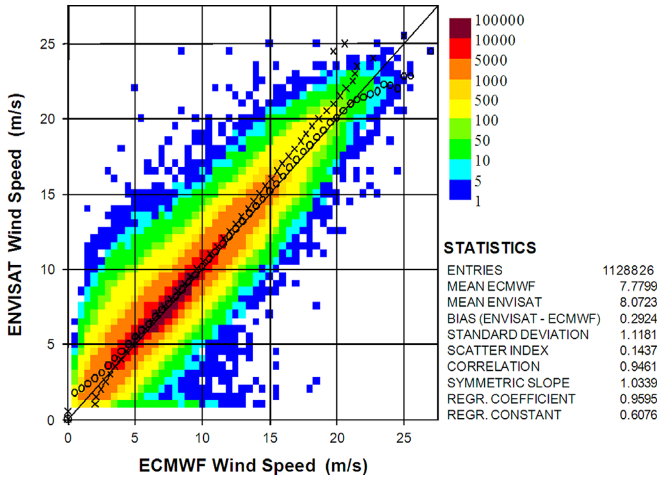

Fig. 1. Scatter diagram of the distribution of the global ECMWF wind speeds versus the corresponding ENVISAT measured data (see www.ecmwf.int).

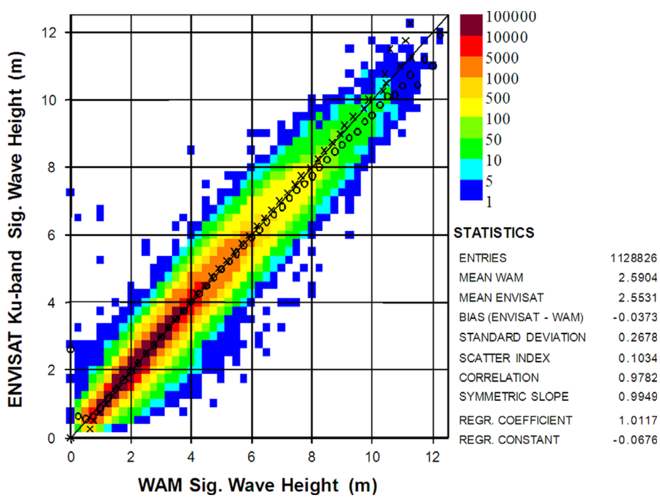

Fig. 2. Scatter diagram of the distribution of the global ECMWF significant wave heights versus the corresponding ENVISAT measured data (see www.ecmwf.int).

information to judge the quality of the input wind fields. Each one of the considered wind sources is regularly followed in daily applications by a wave model. However, the various centres do not use always the same model. Therefore, had we used the directly available wave information, we could not have derived any objective judgement on the performance of the meteorological models. We have followed a different route. We have used the four different wind sets (two parents and two sons) to drive the same wave model with the same resolution. In this way the wave results, taking the wave model reliability into account, provide direct and comparable information on the input wind fields.

We have structured the paper as follows. After a short description (Section 2) of the area and the measurement campaign, and (Section 3) of the models used for this test, in Section 4 we discuss several aspects of the results. Our target, and this is our present main aim, is to show the possible differences between father- and son-models and how the latter ones can quickly react to even small differences in the input from the global models. We summarise and discuss our conclusions in the final Section 5.

2. The Mediterranean Sea—The Catalan coast

The Mediterranean Sea is distributed between 6° West and 36.5° East in longitude and 30° and 46° North in latitude. However, the distribution of the protruding peninsulas (Italy and Greece) plus the large number of islands (Corsica, Sardinia, Sicily, Crete and Cyprus to mention only the largest ones) split the overall basin in a number of sub-basins. Fig. 3 shows the western part of the Mediterranean Sea, the area of interest being the one shadowed on the left side of the area where also a number of small dots (buoy and measurement locations) are visible. In this part of the Mediterranean Sea deep water conditions hold everywhere with the exception of a narrow continental shelf and the slightly protruding Ebro delta (in front of the most southerly dot). Barcelona (circled dot) is slightly more to the North.

The measurement campaign we are concerned with lasted from March 11 till April 18, 2011. It began with the only stormy period (March 12 to 18) characterized by a low pressure system that moved from the Canary Islands to the south-west part of the Iberian peninsula. This situation led to moderate to strong E-NE (> 10 m/s) and significant precipitation affecting the Catalan coast (March 12). This is where we will focus our attention. Basically, beside the mentioned buoys, we have used also altimeter (significant wave height) and scatterometer data (wind speed and direction). The buoys were moored at different distance from the coast, from 1 km to completely offshore, depth varying from 24 to fully deep conditions. The data shown in this paper derives from the Barcelona buoy (circled dot in Fig. 3), on 68 m depth. For the wave conditions in the considered period this corresponds to deep water conditions. This allowed focusing only on the large scale situation, avoiding the further variable of shallow water effects. Besides the buoy data, we have used the wind information provided by the ASCAT scatterometer. For wave height we have used the data provided by the Jason and ENVISAT altimeters. Within the accuracy of the available coordinates, the closest wave grid point was about 2 km East of the buoy. Because in the period of interest the wind was always blowing towards or at most (see later Fig. 9) parallel to the coast, the distance is considered small enough for a direct comparison. Also the possible diagonal advection of some wave energy along the coast (the case of Fig. 9) was not a problem because of the octave advection scheme used in the WAM model (see Cavaleri and Sclavo (1998)). Also for wind the closest sea grid point was chosen for comparison. Contrarily to waves, wind could be bi-linearly interpolated, but interpolation with data from land points is not recommended for comparison with data recoded at sea, albeit close to the coast.

3. The meteorological and wave models

For our modelling comparison we have selected the models used at two of the best meteorological centres in the world, namely the National Center for Environmental Prediction (NOAA Center for Weather and Climate Prediction—NCEP) and ECMWF. Both the centres run global models. The NCEP results are available at 0.5° resolution, the ECMWF ones at 16 km resolution (T1279 spectral truncation). For both the models the analysis and forecast data is available at 6-h interval. WRF, a high resolution non-hydrostatic meteorological model (Skamarock and Kemp, 2008), has been nested in the NCEP model with 12 km resolution. COSMO, another non-hydrostatic model (Bonavita et al., 2010) has been nested in the ECMWF model with 7 km resolution. Both the son-models cover the whole Mediterranean Sea. All these models are amply described in the literature. The basic time and space resolutions we have used are summarized in Table 1. Both the local models cover with ample margins the area of interest, and in particular the coasts of the Mediterranean Sea. WRF and COSMO work in forecast mode. Our wind fields have been assembled as a sequence of 1 to 24 h forecasts, each starting at 00 UTC of the various sequential days. For a fair comparison, one day forecast fields have been considered also for NCEP and ECMWF.