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1 Motivation and objectives

This work is part of the national project RIMA: Towards MAritime RIsk reduction using High-resolution modelling, which is focused on the nowadays poorly estimated wind and wave risks associated to maritime and harbour activities.

The main aim of the RIMA project is to improve risk assessment and to reduce vulnerability of maritime structures under given wind/wave/current conditions. To allow a dynamic definition of risk, wind and wave induced risks are to be calculated as a function of climatology, type of maritime activity and domain geometry. Altogether is to be used to assess the sheltering potential of natural ‘refuge’ areas under different conditions. The goals of the RIMA project are to be achieved using high-resolution calculations of wind, wave, and current fields and their interaction at local scale to achieve accurate calculations at the harbour scale.

At the time being, risk evaluations suffer from limited accuracy, limited resolution in spatial scales and limited prediction horizons. This is affecting the economical efficiency and environmental management of maritime activities, one of which, the maritime transport, is steadily increasing. Indeed, 90% of external trade and about 2/3 of internal trade in the European Union is maritime (Cortés 2003). In Spain, about 85% of import trade and 75% of export trade is at some time related to harbours (Nombela and Trujillo 1999). The volume of traded goods doubled in the last 25 years and increased by a factor of 100 in the last 50-60 years (Coto and Inglada 1999). Passenger traffic in the 1990-2000 decade was about 160 million people, confirming the growing pressure of use of the maritime coastal region. Likewise, the coastal zones are supporting most EU and Spanish populations, their economic activities and their increasing multiple uses (Klein et al. 2001).

Wind, wave and current predictions play a key role in forecasting maritime hazard situations, and its associated port and coastal management. The NW Mediterranean is especially sensitive because there are a large number of uses and resources which require a particular accuracy in maritime predictions. In particular, the ports of Barcelona and Tarragona, on the Spanish NW Mediterranean, are of relevant importance handling each one 51 and 36 million tonnes of goods during 2007 (Puertos del Estado 2008).

It is globally accepted that wave predictions are much more accurate than wind predictions. In fact, wave models are widely used to validate wind models, and in recent times many of the improvements achieved in wave modelling relied on the improvement of the surface wind fields (Komen et al. 1994). For this reason, and within RIMA, the Meteorological Service of Catalonia (SMC) is working on the improvement of the wind fields for input to the wave models. Following the area of expertise of the Maritime Engineering Laboratory (LIM), in this work the focus will be on understanding wave conditions and improving wave modelling in the Catalan Coast.

From the range of wave models likely to be used in coastal areas, the phase-resolving and phase-averaging models are limited by the computational power but also, and more importantly, because generation processes cannot be included in the calculations. Spectral models, instead, resolve the amount of energy (or action density) at each grid point. Spectral wave models are being used in a broad range of spatial scales from local to regional and global scales. The accuracy being obtained is quite good (4% bias and 0.11 scatter index from the global wave model being run by the ECMWF), although there are situations/regions where spectral wave modelling is known to be inaccurate, i.e. during peak and extreme conditions, in enclosed basins such as the Mediterranean Sea, fetch-limited regions, etc. (Cavaleri et al. 2007).

In the region of study, the predictability of wave operational forecasts is known to be limited because of the usual offshore winds and double peaked wave spectra, and the existing complex coastal orography (Cavaleri and Sclavo 2006; Sánchez-Arcilla et al. 2008). Because Cavaleri and Bertotti (2004) described decreasing model errors with higher resolution models in semi-enclosed basins, regional wave predictions were expected to improve when increasing the resolution of wind and wave models during storm conditions. Indeed, Signell et al. (2005) indicated that in semi enclosed basins where the orography plays a substantial role, high resolution models provide stronger and more accurate wind speeds overall, which would reduce the generally observed wave height under-predictions. Additionally, Komen et al. (1994) stated that wave growth is affected significantly by both the temporal and the spatial variability of the wind fields.

Bolaños (2004) assessed the improvement of the predictions when using higher resolution wind and wave models in the region of study. However, their results were poor due to the inadequate wind nesting strategy used. For operational purposes, Bolaños et al. (2007) compared the performance of two wave models. The results were not conclusive in terms of choosing one model over the other: one predicted the integrated spectral parameters better, but the other one predicted the spectral shape better. Their results pointed to the importance of improving the predictions of both the integrated parameters and the shape of the spectra. Also, they highlighted the importance of increasing the spatial resolution of the wind and wave models especially during fetch-limited conditions.

For this reason, and as a previous but essential step to improve regional wave modelling, the first objective of this work was to describe wind and wave conditions in the region of study from the observations taken at an instrumental transect set perpendicular to Tarragona's coastline. The observations along the transect would be used to assess the performance of the operational wave model. The following objective of this work was to assess the performance of high resolution wind and wave models in predicting a specific fetch-limited wave storm. Finally, the last objective of this study was to assess the importance and effect of the wind input into the wave model during the selected fetch-limited growth wave storm.

To summarize, the main objectives and particular goals of this work were:

- To provide a detailed description of several wave storms registered along an instrumented transect perpendicular to Tarragona's harbour coastline.
  - To study the shape of the energy spectra.
  - To analyze the integrated parameters time series.
- To assess the performance of the operational wave model and identify possible sources of error in terms of the evolution of the time series and the shape of the energy spectra. Using:
  - Visual analysis.
  - Statistical analysis.
- To assess the improvement achieved when using higher resolution wind and wave models.
- To assess the sensitivity of the wave model to different wind fields in properly predicting the observed wave conditions, using:
  - Observed wind fields.
  - Predicted wind fields.
  - Enhanced wind fields.

Each one of these objectives was addressed independently in a separate chapter. Altogether, the aim was to increase the knowledge of wave processes, to improve wave models performance and ultimately, to improve wave predictions in the region of study.