Ocean wave analysis and use of surface wind observations over the oceans

Jean-Raymond Bidlot and Peter Janssen

ECMWF
Shinfield Park, Reading, UK

ECMWF has been running operational wave models since June 1992. Two-way coupling between the wave model and the atmospheric model was introduced in June 1998 with benefits to both wave model (via high temporal wind field resolution) and atmospheric model (via wave dependent surface roughness). The wave model is now an integral part of the analysis and forecasting system at ECMWF.

Reanalysis wind and wave data have been used in many applications, quite often in coastal areas however, hence future reanalyses will benefit from an increase in horizontal resolution. Note that the resolution increase should also occur in the atmospheric model because low resolution models tend to poorly represent coastal wind fields.

The quality of ocean wave analysis is intrinsically linked to the quality of the forcing wind fields. Nevertheless, wave observations can be used to improve the quality of the wave analysis. Currently, there are two types of space-borne global observations. Radar altimeters on board earth observing satellites yield among other things wave height observations. The first two such missions were short lived (Seasat 1978, Geosat 1985-1986), however the missions that followed proved very successful (ERS-1 1991-1996, Topex 1992-2002, ERS-2 1995-, GFO 2000-, Jason 2002-, ENVISAT 2002-). Note however that a wave model predicts the evolution of the wave spectrum. Wave height is connected to the total energy, which is proportional to the integral of the wave spectrum. Hence some assumptions are required to go from analysed wave height to analysed spectrum. SAR/ASAR ocean mode data are the second source of global wave observations (ERS-1 and 2 SAR and ENVISAT ASAR). SAR does not unfortunately observe the full two-dimensional wave spectrum. Furthermore, in practice SAR wave spectra are retrieved using a model first guess. For these reasons, the impact of SAR assimilation is much reduced than originally hoped. Finally, in-situ observations, usually from buoys reporting wave observations have a relatively limited geographical coverage. They are usually kept for verification purposes only.

The wave model data analysis is based on an optimal interpolation scheme for wave height as originally developed by Lionello et al. 1992. The scheme was extended to assimilate wave systems as derived from SAR wave spectra. It is not yet directly coupled to the atmospheric scheme.

In ERA-40 both ERS-1 and ERS-2 data were used. An extensive comparison with buoy data and Topex altimeter data was carried (http://www.knmi.nl/waveatlas). From the different comparisons, it was shown that ERA-40 surface winds tend to be too low. This negative bias is also reflected in the waves. Since the end of ERA-40, much progress has been made in trying to remove these underestimations. Validation of the pre-interim analysis configurations indicates that the quality of the surface winds has much improved. Furthermore, some of the latest changes to the wave model have been found to be extremely beneficial, especially when predicting quantities that relate to how wave energy is distributed across the frequency spectrum (Janssen et al. 2005).

When ERA-40 was produced, ERS-1 and 2 data that had been received in near real time (NRT) were used. Unfortunately, between December 1991 and May 1993 low quality ERS-1 altimeter data were wrongly assimilated. Because of this adverse use of the data and also because of some other known problems with the NRT ERS data, we have reprocessed OPR ERS-1 and 2 data obtained from ESA. OPR ERS-1 and 2 have never been used by our data assimilation system. As a first check on their quality, we have run them passively through a long stand alone wave model hindcast based on the latest operational wave model version. A comprehensive buoy data set was collocated with the altimeter data and the model counterparts. Triple collocation techniques were used to infer relative biases and error estimates for each data set. Using these estimates in our data assimilation scheme show promising results in improving the quality of the wave model analysis, hence of the future reanalysis.

For more recent years, ENVISAT and Jason data can be used. NRT ENVISAT altimeter data are already of good quality. Note that some orbits are missing, especially in early days of the mission due to NRT transmission problems. Access to off-line data could prove useful. Using the same triple collocation technique, it was found that both data sets could benefit from a small reduction in wave height.

The quality of the wave analysis depends critically on the quality of the winds. During ERA-40, a better use of surface wind observations could have been achieved. For example, because of the lack of information in the current data structure, in-situ surface wind data over the ocean are not reported with the actual height of the observations or whether or not the observations have been adjusted to a reference height. Such information is currently supplied by using a default height (25m for ship, 10m for all other sources) or, if known, by providing the actual anemometer height (from a list kept at ECMWF). During ERA-40, several technical problems prevented the proper use of the anemometer height list for a large portion of the reanalysis. Furthermore only data reported as ship were adjusted. It was not realised then that some buoy data are available both as ship and drifting buoys because of the blend of ECMWF and NCEP data sets. The scheme now works for drifting buoy data as well.

There is a need to sort out in-situ observations over the oceans to avoid unnecessary duplications. Finally, it is unfortunate that potentially very valuable data from moored buoys are mixed with other type of data of the same nature (e.g. with ship and fixed platforms or with drifting buoys). This is reflected by the relatively large error assigned to these data. A separate data type should be created (moored buoys) and a bit of data mining should take place to bring all these data to ECMWF.

References:

Janssen P., J.-R. Bidlot, S. Abdalla and H. Hersbach, 2005: Progress in ocean wave forecasting at ECMWF. ECMWF Tech. Memo. 478. ECMWF, Reading, United Kingdom.

Lionello P., H. Günther and P.A.E.M. Janssen, 1992: Assimilation of altimeter data in a global third generation wave model. J. Geophys. Res. C97, 14453-144474.