ASSIMILATION OF RA-2 ALTIMETER AND ASAR DATA IN A 3G WAVE MODEL

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1. INTRODUCTION

Ocean wave data from space such as measured by Envisat satellite instruments represent a stimulating challenge for wave modellers in order to improve numerical wave analysis and forecasting. This task is also of considerable interests for a better understanding of ocean surface physical processes such as air-sea fluxes and overall energy balances. At Météo-France, we have implemented an assimilation system, based on a combination of Vorrips et al. (1997) scheme and Lionnelo et al. (1994) scheme. The assimilation procedure uses conjointly altimeter data and directional wave spectral data from an Advanced Synthetic Aperture Radar (ASAR). Such assimilation scheme aims to correct both the wind sea and swell parts of the sea-state.

In previous works (Aouf et al. 2004) it has been noticed that the low frequency wave parameters (significant wave height and mean period) from WAM model hindcast experiments where slightly overestimated compared to the ASAR level 2 products, which describe the swell systems. In spite of this, it has been showed that the assimilation of such ASAR wave spectra in the wave model has improved the estimate of the mean wave parameters in particular for swell dominant sea-states. However it still remains some difficulties related to the choice of the wavelength cut-off for ASAR wave spectra.

In other respects, the use of different sources of wave data with a spacing orbit tracks of about 200 km between Ra-2 altimeter and ASAR improves the coverage of wave observations over sea grid points, and therefore should improve the wave model analyses.

This study is a preliminary step forwards operational data assimilation of altimeter data together with ASAR data. To that end, assimilation runs using both Envisat Altimeter (RA2) data and Envisat ASAR wave spectra have been performed for a period of two months (January and February 2004). Further, different wavelengths cut-off regarding to ASAR wave spectra have been investigated for the assimilation system. In this paper, we briefly describe the assimilation system and the assimilation experiments. Then, the impact of the assimilation is evaluated using independent data sets, the Jason-1 altimeter data and NDBC buoy observations. We finally briefly give conclusions and indications about future works.

2. THE ASSIMILATION SYSTEM

Two sources of wave data from Envisat satellite have been used in this study. The Ra-2 altimeter provides the significant wave height and the wind speed near the ocean surface (10 m level), while the ASAR gives the directional wave spectra limited to a certain wavelength, depending on the wave direction (azimuth cutoff). The ASAR level 2 retrieval algorithms developed by the European Space Agency (ESA) also provides the wind speed near the sea surface, the signal to noise ratio and the normalized variance of the image, which are the key parameters for the quality control procedure before the assimilation. Note the ASAR level 2 algorithms did not use any first guess wave spectrum from a wave model.

The combined assimilation of Ra-2 altimeter and ASAR level 2 wave data is implemented in two parts. The first part of the assimilation system consists in the assimilation of data provided by the Ra-2 altimeter. This performs an optimal interpolation on the total significant wave height and the wind speed at the ocean surface. Thereafter, the wave spectra are corrected according to empirical laws (see Lionello et al. (1992)). The second part of the system concerns the assimilation of ASAR directional wave spectra. This procedure uses the partitioning principle (voorrips et al. 1997), which consists in decomposing the wave spectra in dominant wave trains describing different wave systems (swell and wind sea). Thereafter, a cross-assignment, which collects the first guess and observation partitions corresponding to the same wave system, is then applied. An optimal interpolation is performed on total energy and components of wave number of each dominant wave train (Aouf et al. 2006). Better description of the model background errors over grid points induces an effective optimal interpolation procedure. Afterwards, the analysed partitions are superposed to derive an analysed wave spectrum. To eliminate gaps between the analysed partitions, a bi-parabolic interpolation is performed.

In this study we have used the wave model WAM cycle 4 with a global implementation and a resolution of 1 degree in longitude and latitude. The wave spectrum is configured with 36 spaced directions by a step of 10 degrees and 24 frequency bins, scaled logarithmically between 0.04 to 0.39 Hz.

Note that before the assimilation of ASAR wave spectra, a quality control procedure on ASAR level 2 wave products is applied. The procedure consists in checking whether the retrieved parameters are not exceeding the defined threshold values. The considered parameters are: the signal to noise ratio, the surface wind speed and the normalized variance of the image. They must be respectively between 2-20 db, 3-17 m/s and 1-1.6, otherwise the data are rejected before the assimilation.

The numerical experiments consist at first in running the wave model WAM, driven by 6-hourly analysed ECMWF wind fields, for a spin-up period of ten days to get a realistic sea-state. Thereafter, the Ra-2 altimeter wave data and the ASAR directional wave spectra are assimilated by steps of three hours (assimilation window). The assimilation period starts from January 1 until March 4, 2004. The daily average number of data used in the assimilation procedure is 2300 for ASAR wave spectra and 2200 for Ra-2 altimeter data. The correlation length and the distance of influence of observations used in the optimal interpolation procedure are set respectively to 250 km and 600 km. Two additional runs have been performed in order to analyse the impact of the combined assimilation. The first run is a control one of the wave model without assimilation, while the second one is performed with assimilation of Ra-2 altimeter wave height only.

3. RESULTS

The impact of combined assimilation is analysed by comparing the results with the control run of the wave model without assimilation. Figures 1a, 1b show that the impact is significant and reaches 1.5 meters and 4 seconds for the significant wave height and mean wave period respectively. After a 3-day forecast period, the impact of the combined assimilation stays significant, in particular for swell dominant seas, as illustrated in figure 2. This is a definite advantage in comparison with the classical assimilation of significant wave height only.

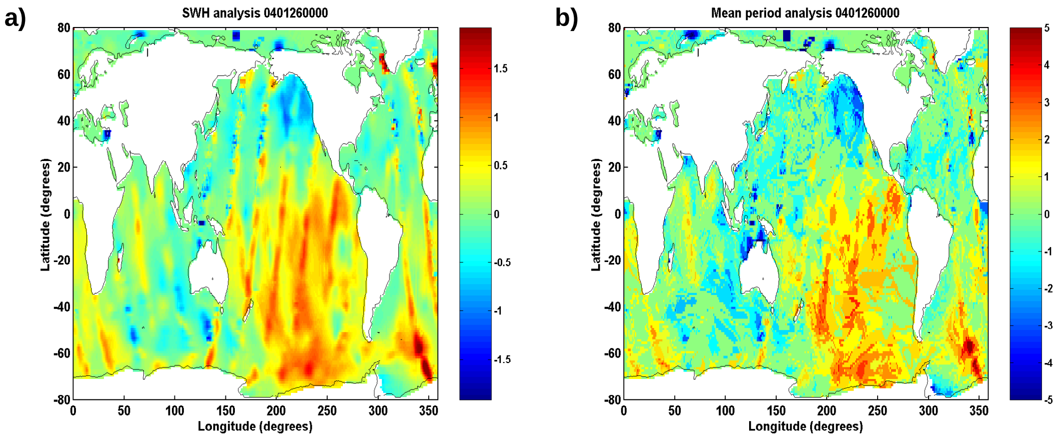

Figure 1 : Difference between wave parameters for runs with and without combined assimilation on 26 January 2004 at 0:00 UTC; (a): significant wave height; (b): mean wave period.

To evaluate the performance of the combined assimilation, the results are compared with independent wave data such as the significant wave height provided by Jason-1 altimeter. The statistical analysis at crossovers orbit tracks of Jason-1 and Envisat has indicated a relevant improvement in terms of root mean square (RMS) error. The RMS error of significant wave height is reduced in average by 25 %. In other respects, statistical analysis at all Jason-1 locations has been performed and showed that the correction induced by the combined assimilation is well propagated over all sea grid points. This reveals that the reduction of the RMS error of the significant wave height is about 10 %.
One of the most interesting results of this study concerns the impact duration in the forecast period. After the end of the assimilation period the comparison with significant wave heights from Jason-1 shows that the impact of combined assimilation decreases much less rapidly than the one of RA-2 wave height assimilation alone, as illustrated in figure 3. After 12 hours in the forecast period, the only assimilation of Ra-2 altimeter wave height is completely damped, while for the combined assimilation the impact is still significant.

Furthermore, the results of combined assimilation are compared with NDBC buoys data, which are mainly located in east and west coasts of North America. The statistical analysis is performed at buoys locations. We found that the RMS error of significant wave height and mean period are significantly reduced in average by 8% and 6 %, respectively.

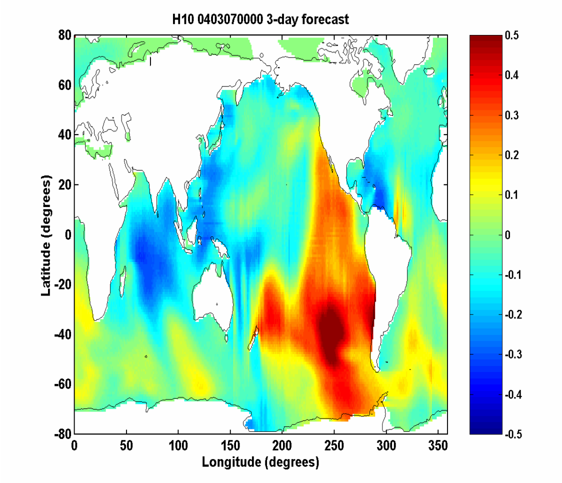

Fig. 2 : Difference (in meters) of significant wave heights between runs with and without combined assimilation on 7 March 2004 at 0:00 UTC, for a 3-day forecast.

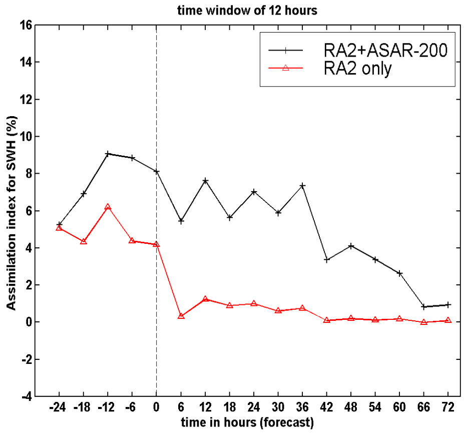

Fig. 3 : variation of the reduction of RMS error of significant wave height in the forecast period (comparison with all Jason-1 altimeter wave height). Black and red lines indicate respectively the combined assimilation (wavelength cut-off of 200 meters) and the only assimilation of Ra-2 altimeter wave height.

4. CONCLUSIONS

The combined assimilation of Ra-2 altimeter and ASAR wave data improves significantly the quality of wave model analyses and short term forecasts. The impact of the assimilation system on mean wave parameters is significant and stays efficient longer in the forecast period (more than 3 days). The validation of the results with independent wave data (Jason-1 and buoys) has indicated a positive impact in terms of RMS errors. The assimilation system should be set up for a continuous assimilation runs with comparisons with independent wave data in order to be validated for operational use. Work is on going to improve the assimilation system by considering a variable wavelength cut-off for the ASAR wave spectra. Recently, the ASAR level 2 retrieval algorithms have been upgraded and the validation of the new wave products shows a better quality of ASAR wave spectra. Consequently, additional runs will be performed in order to analyse the impact of upgraded ASAR wave spectra for the combined assimilation system.

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