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THE IMPACT OF USING THE UPGRADE PROCESSING OF ASAR LEVEL 2 WAVE PRODUCTS IN THE ASSIMILATION SYSTEM

Lotfi Aouf⁽¹⁾, Jean-Michel Lefèvre⁽¹⁾, Danièle Hauser⁽²⁾, Bertrand Chapron⁽³⁾ and Fabrice Collard⁽⁴⁾

⁽¹⁾ *Météo-France, Division of Marine and Oceanography, Toulouse, France.*

⁽²⁾ *CETP/IPSL/Université de Versailles Saint-Quentin, Vélizy, France*

⁽³⁾ *IFREMER, Laboratoire d'Océanographie Spatiale, Brest, France.*

⁽⁴⁾ *Boost Technologies, Brest, France.*

ABSTRACT

The ASAR data provided by the upgraded level 2 wave mode have been used in the assimilation system developed at Meteo France. Two periods of last week of May and the month of July 2004 are considered for this study. The validation of upgraded level-2 wave mode with the WAM model showed the improvement of the wave parameters and their consistency. The assimilation runs have been performed with ASAR wave spectra from the new and old level-2 wave mode. Two cases of wavelength cut-off have been investigated in order to evaluate their impact on the results. Statistical analysis in comparison with altimeter Jason-1 and buoys data exhibits a positive impact for the upgraded level-2 wave mode in terms of root mean square error of significant wave height. Furthermore, the accepted ASAR wave spectra in the analysis process are well increased.

1 INTRODUCTION

Following the increase of wave observations from satellites, the assimilation approach has a considerable benefit to correct and improve numerical wave models. It also helps the understanding of physical processes at the air-sea interface. The ASAR level 2 wave mode of the satellite Envisat provides directional wave spectra limited to a certain range of wavelength. This has a considerable advantage for the correction of the sea state in particular when swell is dominant. It is now well known that such improvement on sea state prediction induces to a better description of related physical processes at the ocean surface (currents circulation and air-sea fluxes). The validation study of using the ASAR level 2 wave products (Aouf et. al 2004) has mainly indicated that the fidelity controls and the use of an accurate wavelength cut-off in the optimal interpolation (OI) procedure represent the key points for a positive impact on the wave prediction. Then, it is necessary to shed light on these points before the step forward to the operational use of ASAR wave data.

The main objective of this paper is to evaluate the impact of using the ASAR wave products retrieved from the upgraded level 2 algorithms. A second goal concerns the choice of wavelength cut-off in the assimilation and its impact on the results. In section 2, we describe the data sets used in this study and their validation in comparison with the wave model WAM. Then, section 3 presents a brief description of the assimilation system and the performed test runs. Results and comparison to independent wave data are discussed in section 4. Finally, conclusions and future works are commented in section 5.

2 VALIDATIONS OF ASAR DATA

The ASAR wave mode implemented by the European Space Agency provide the directional wave spectra, the wind speed at ocean surface and other parameters related to the quality of data. In our previous studies we have indicated that we encountered inconsistent data for low wind speed cases where the ASAR significant wave height was over estimated. It was also indicated some problems related to non-wave features for wavelength over the range of 800 meters. The upgraded algorithms answer mainly to these problems. Further, the new processing include a new estimation of the azimuth cut-off, a new estimation of non linearity wave range and wave spectra variance which is a very important information for the quality control of data. To evaluate the impact of the upgraded level-2 wave products, two sets of data were provided by Boost Technology. The first set of data concerns the last week of May 2004 and the second set starts from July 1 until 26 2004. The total of spectra for the upgraded level-2 data of July 2004 is of 58397 spectra, with a daily average of 2163 spectra. While for the old processing the total retrieved spectra is of 34432 spectra with a daily average of 1275 spectra. In the validation process we performed a comparison between wave model WAM and ASAR wave parameters. The WAM model (cycle 4) is set for the global scale with a resolution of 1 degree in latitude and longitude. A 6-hourly analyzed wind input from the ECMWF atmospheric model is used to drive the wave model. The collocation between observations and model is performed using the nearest model grid point and nearest 3-hour model synoptic time to the observations locations and time. Three parameters have been considered the low frequency wave height (H_{10}), the low frequency mean period (T_{10}) and the wind speed at the ocean surface. Fig. 1a shows the scatter plots between upgraded ASAR and WAM wave parameters, and this indicates the consistency of the retrieved wave spectra. However for the old wave mode it is clearly found that there is an overestimation of the wave height for low wind speed as illustrated in Fig. 1b. Because of the problem related to non-wave feature in old processing, the scatter plot for mean period T_{10} clearly reveals the unrealistic out of range of values (larger than 16 seconds), as illustrated in Fig. 1b. Table 1 indicates the statistical parameters for the upgraded and old processing. It is well showed that the root mean square (RMS) error of low frequency wave height, mean period and wind speed are significantly reduced to 0.6 meters, 1.3 seconds and 2.2 m/s, respectively.

3 ASSIMILATION SYSTEM AND TEST RUNS

The assimilation system consists of using the partitioning principle and an optimal interpolation (OI) on mean wave parameters (energy and components of wave number) of the dominant wave trains (Aouf et al. 2006). The partitioning procedure decomposes the wave spectrum in several dominant wave trains and each one is characterized by its mean parameters (energy, period and direction). After the OI procedure, the analyzed partitions are superposed and a bi-parabolic interpolation is performed to reconstitute the analyzed wave spectrum. To reject spurious data from the analysis process, quality controls depending on the retrieved ASAR wind speed, the ratio of signal to noise and the normalized variance of image, are used in a prior procedure before assimilation. Only ASAR data satisfying the three threshold ranges of, 3 to 16 m/s for ASAR wind speed, 1 to 1.6 for normalized variance of image and 3 to 200 for ratio of signal to noise, are kept in the optimal interpolation procedure.

In this study, the assimilation of ASAR wave spectra is performed for two periods. The first period starts from May 25 until June 1, 2004, while the second period starts from July 1 until 22, 2004. The numerical experiment

consists at first in running the wave model WAM, driven by analyzed ECMWF wind fields, for ten days to get a well-developed sea. Thereafter, the ASAR directional wave spectra are assimilated in different dates by a step of three hours (assimilation window).

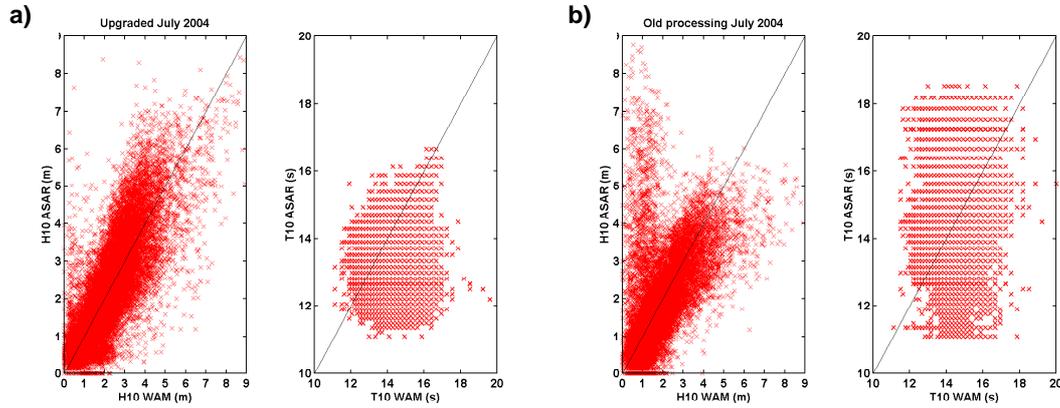


Fig.1. Scatter plots between ASAR and WAM wave parameters for July 2004. (a) : upgraded wave mode; (b) : old wave mode.

Table 1: comparison between level-2 wave mode and WAM model wave parameters for July 2004.

	Upgraded level-2			Old Level-2		
	H ₁₀ (m)	T ₁₀ (s)	U ₁₀ (m/s)	H ₁₀ (m)	T ₁₀ (s)	U ₁₀ (m/s)
Bias	0.02	0.70	-0.43	0.10	-0.20	-1.00
RMSE	0.61	1.3	2.2	0.96	1.84	2.71

Three runs have been performed for the two period tests. The first run, called to as A, uses the ASAR wave spectra retrieved by the upgraded level-2 algorithms. However, the second run, called to as B, assimilates the ASAR wave spectra obtained from the old level2 wave mode. The third run, called to as C, is a baseline run of the wave model with no assimilation. The assimilation parameters, which are the correlation length, the distance of influence of the observations and the cross-assignment threshold value, are considered of 250 km, 600 km and 2, respectively. The key parameter in the assimilation system consists in the limit of validity of ASAR wave spectra. The frequency cut-off is considered by using the average value of peak frequency of the retrieved ASAR wave spectra. For the data of July 2004 retrieved by the upgraded level-2 wave mode, the average peak frequency is estimated at 0.09 Hz corresponding to a wavelength of 200 meters. To investigate the impact of wavelength cut-off on the assimilation, test runs have been performed for two wavelengths cut-off of 200 and 240 meters. Note that the case of wavelength cut-off of 240 meters is the average value given by the old algorithms of level-2 wave mode.

4 RESULTS

First, the comparison between the outputs from runs A and B to run C indicates the impact of the assimilation of ASAR wave spectra. It is also called the assimilation skill with respect to no assimilation case. The impact of the assimilation on significant wave height and mean period for run A is significant and reaches respectively 1.5 meters and 4 seconds on July 5, 2004 at 0:00 (UTC), as illustrated in Fig. 2a and 2b. After 3-day forecast Fig. 3a and 3b show that the impact for run A with wavelength cut-off of 200 meters stays efficient and is estimated at 1.5 seconds and 0.6 meters for mean period and low frequency wave height (H₁₀), respectively. The maximum impact is mainly

located in the intertropical and northeast Pacific Ocean areas.

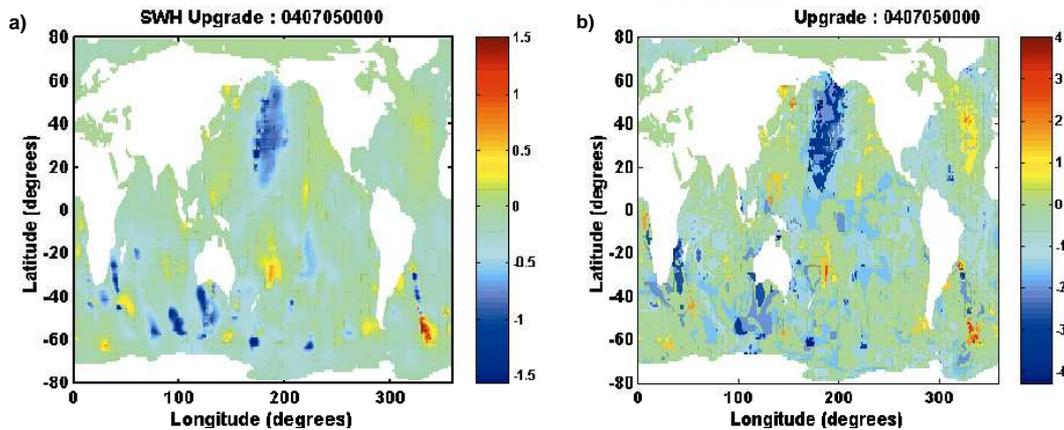


Fig. 2. Difference of wave parameters between runs A (with cut-off of 200 meters) and C on July 5, 2004 at 06:00 (UTC). (a) : Significant wave height; (b) : Mean wave period.

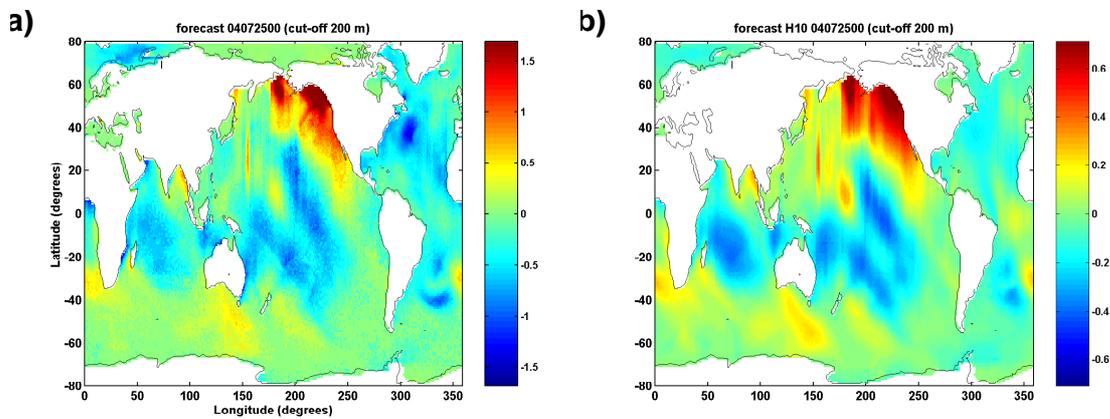


Fig. 3. The impact of run A with a wavelength cut-off of 200 meters after 3-day forecast (on July 25, 2004 at 0:00 UTC). (a) : mean period ; (b) : low frequency wave height H_{10} .

Secondly, to investigate whether the impact of using ASAR wave spectra is positive, we then compared the model results to independent wave data such as altimeter Jason-1. This concerns only significant wave height. First, the statistical analysis is performed at crossover locations between Jason-1 and ASAR orbit tracks. The procedure uses a maximum space lag between Jason-1 and ASAR orbit tracks of 120 km and a time window of 3 hours. Table 2 shows the mean bias and the root mean square (RMS) error for runs A, B and C. This indicates that the RMS errors of run A are significantly reduced to 0.49 and 0.50 meters for wavelength cut-off of 240 and 200 meters, respectively. The record of crossover data increases to 1362 for run A with a wavelength cut-off of 200 meters. Moreover, it is clearly found that for run A the RMS error of significant wave height is improved in average by more than 10 %, as illustrated in Fig. 4a and 4b. The difference between the new and old wave modes is enhanced when using a wavelength cut-off of 200 meters. Furthermore, statistical analysis at Jason-1 locations also indicates better assimilation index (see appendix) for run A, as shown in Fig. 5. Large recorded data of 16164 in July 2004 have been collected for run A when using a wavelength cut-off of 200 meters. Note that this decreases to 10813 recorded data when using a wavelength cut-off of 240 meters.

The results are also compared with buoys data from National Buoy Data Center (NDBC) of NOAA. In this way,

Fig. 6a shows the assimilation index of significant wave height at crossover between buoys and ASAR orbit tracks for the period of July 2004. We found that the correction on RMS error is more than 20 % for run A with wavelength cut-off of 200 meters, while for run B it is estimated at only 6 %. But note that in this analysis only 38 crossovers have been recorded. Furthermore, statistical parameters are computed at buoys locations for each output time. Fig. 6b shows that the assimilation index for run A with wavelength cut-off of 200 meters is more than 5 % with recorded data of 1463. However, the correction on RMS error for run B with cut-off of 200 and 240 meters is very small (less than 1%) and can be neglected.

Table 2: statistical analysis on significant wave height in comparison with the altimeter Jason-1 for July 2004

	Cut-off of 240 m				Cut-off of 200 m			
	Upgraded run A		Old level-2 run B		Upgraded run A		Old level-2 run B	
	MB (m)	RMS (m)	MB (m)	RMS (m)	MB (m)	RMS (m)	MB (m)	RMS (m)
ASSI-ASAR	0.06	0.49	0.11	0.50	0.09	0.50	0.07	0.51
NO ASSI	-0.10	0.58	-0.01	0.52	-0.06	0.56	-0.01	0.54
Records	1065		893		1362		1047	

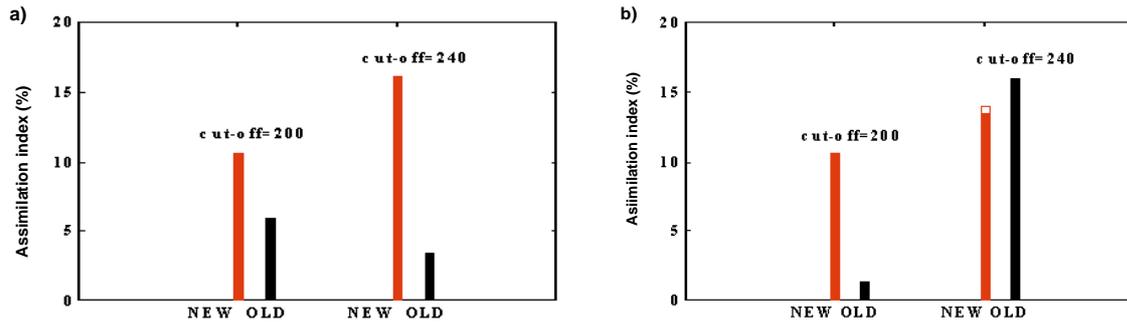


Fig. 4. Assimilation index of significant wave height at crossover of Jason-1 and ASAR orbit tracks; (a) : for July 2004; (b) : for last week of May 2004.

3 CONCLUDING REMARKS

The validation of upgraded level-2 wave mode has showed a significant improvement in terms of mean wave parameters in comparison with WAM model. The quality control procedure was successfully performed and avoided including corrupted data in the assimilation system. In average more than 60 % of upgraded level-2 wave spectra with cut-off of 200 meters were accepted in the analysis process.

The assimilation of upgraded ASAR level-2 wave mode exhibits a significant impact on wave parameters (wave height, mean period and H_{10}). The use of wavelength cut-off of 200 meters enhances the impact, which stays efficient after 3-day forecast. The validation of the results with altimeter Jason-1 and buoys data clearly shows a positive and significant impact in terms of RMS error of wave height. It has been demonstrated that the peak frequency of ASAR wave spectra is a good indicator for estimating the cut-off. The use of fixed wavelength cut-off of 200 meters was an optimal choice and it is highly recommended for the upgraded data. Work is in progress for

taking into account a variable cut-off in the assimilation system.

Longer validation and assimilation period is needed to assess our results and prepare the system to operational mode. In the context of future works, improvements are expected when using conjointly upgraded ASAR level-2 wave spectra and altimeter RA-2 data.

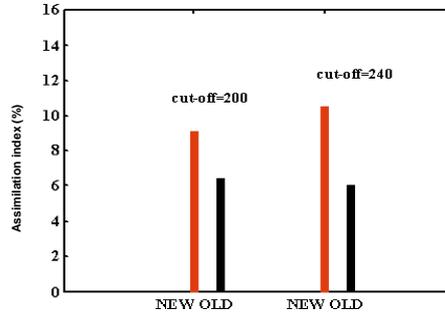


Fig. 5. Assimilation index of significant wave height at Jason-1 orbit tracks for July 2004

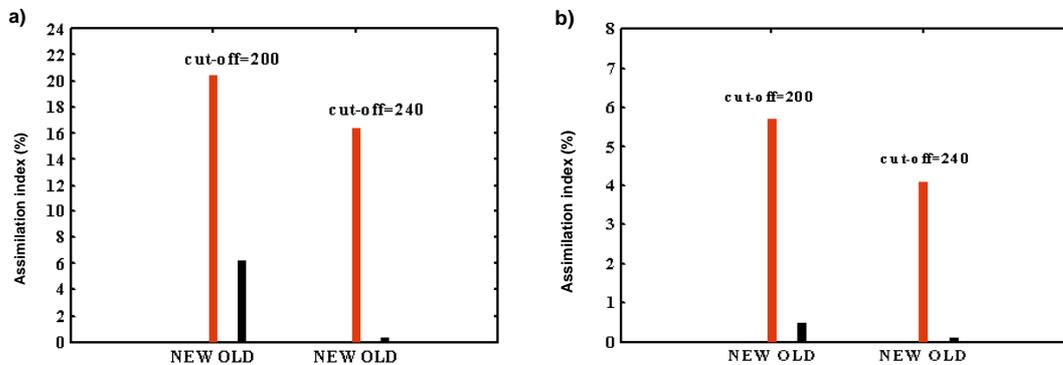


Fig. 6. Assimilation index of significant wave height for the period of July 2004. (a) : at crossovers of buoys and ASAR orbit tracks (38 records); (b) : at buoys locations with recorded data of 1463 and 1398 for cut-off of 200 and 240 meters, respectively.

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APPENDIX

The assimilation index indicates the percentage of correction on RMS error of wave parameters:

$$AI = \frac{RMSN - RMSA}{RMSN} * 100(\%)$$

where RMSN is the RMS error of wave parameters for the run with assimilation. While RMSA is the root mean square error error for the run with no assimilation.

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