Data assimilation methods to improve the wave predictions in the Black Sea

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1. INTRODUCTION

A better prediction of the wave conditions in the environment of the Black Sea became in the last decades an issue of increasing importance. The recent economic developments, including the last years offshore activities related to the oil and gas exploitations, enhanced substantially the marine activities, in general and the maritime traffic, in special. The objective is to increase the accuracy of the predictions by implementing some data assimilation techniques in a wave modelling system. The model considered is SWAN (Simulating Waves Nearshore) and the marine area targeted is the Black Sea. A multi-level wave prediction system SWAN based has been implemented. SWAN simulations for a 5-year interval (2004-2008) were considered. The wind fields from NCEP-CFSRv1 (Climate Forecast System Reanalysis) with a spatial resolution of 0.312° x 0.312° and a temporal resolution of 3 hours were considered for forcing the wave model.

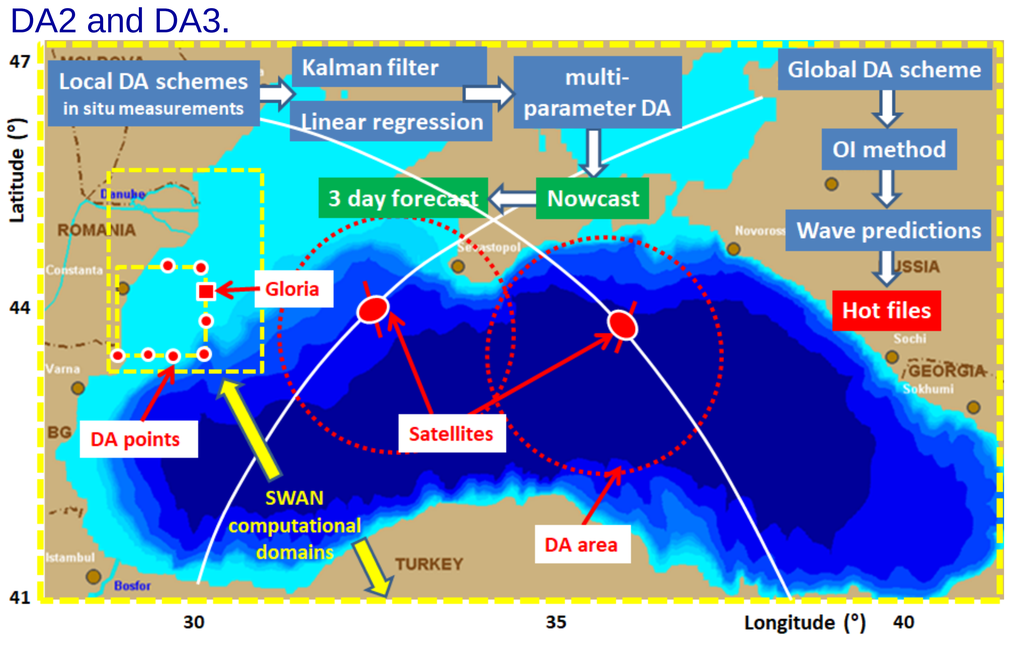
2. MATERIALS AND METHODS

An important step in increasing the reliability of the wave predictions is represented by the implementation of a Data Assimilation (DA) scheme for the entire basin of the Black Sea based on satellite data. For this purpose, an approach based on the Optimal Interpolation (OI) method has been considered. The algorithm based on OI techniques is formulated in the observational space, with the following relation (Kalnay, 2003):

$$x_a = x_b + \mathbf{P}_b\mathbf{H}^T[\mathbf{H}\mathbf{P}_b\mathbf{H}^T + \mathbf{R}]^{-1}[y - H(x_b)]$$

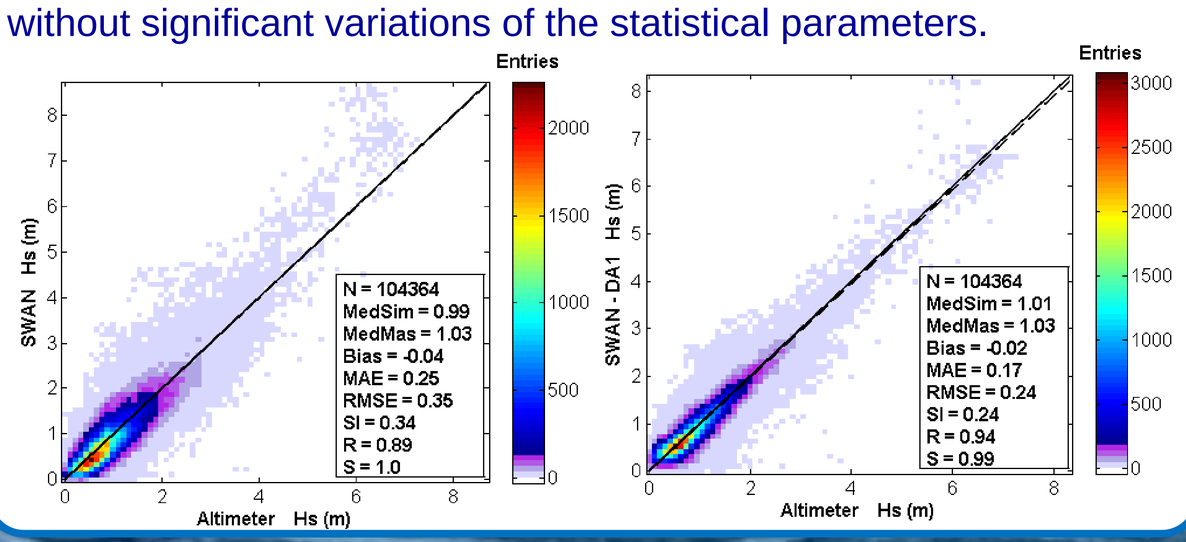
y	Observation vector	$\mathbf{R}$	Observation Error Covariance
x_b	Background vector	$\mathbf{P}_b$	Background Error Covariance
x_a	Analysis vector	$y-H(x_b)$	Innovation vector
H, $\mathbf{H}$	Forward operator, Matrix		

$\mathbf{P}_b\mathbf{H}^T[\mathbf{H}\mathbf{P}_b\mathbf{H}^T+\mathbf{R}]^{-1}$ is the weight matrix (Kalman gain matrix), $\mathbf{H}\mathbf{P}_b\mathbf{H}^T$ is the background-error covariance between the observation locations, and $\mathbf{P}_b\mathbf{H}^T$ is the error covariance between observation and grid locations. The horizontal correlation is $C_h=\exp(-s_h/L_{max})$ where s_h is the distance between two locations (observation and a grid point) and L_{max} is the correlation length of the prediction errors for H_s (Lionello et al., 1992). Three different values were tested L_{max}=4, L_{max}=3.2° and L_{max}=2, and the schemes are denoted as DA1, DA2 and DA3.



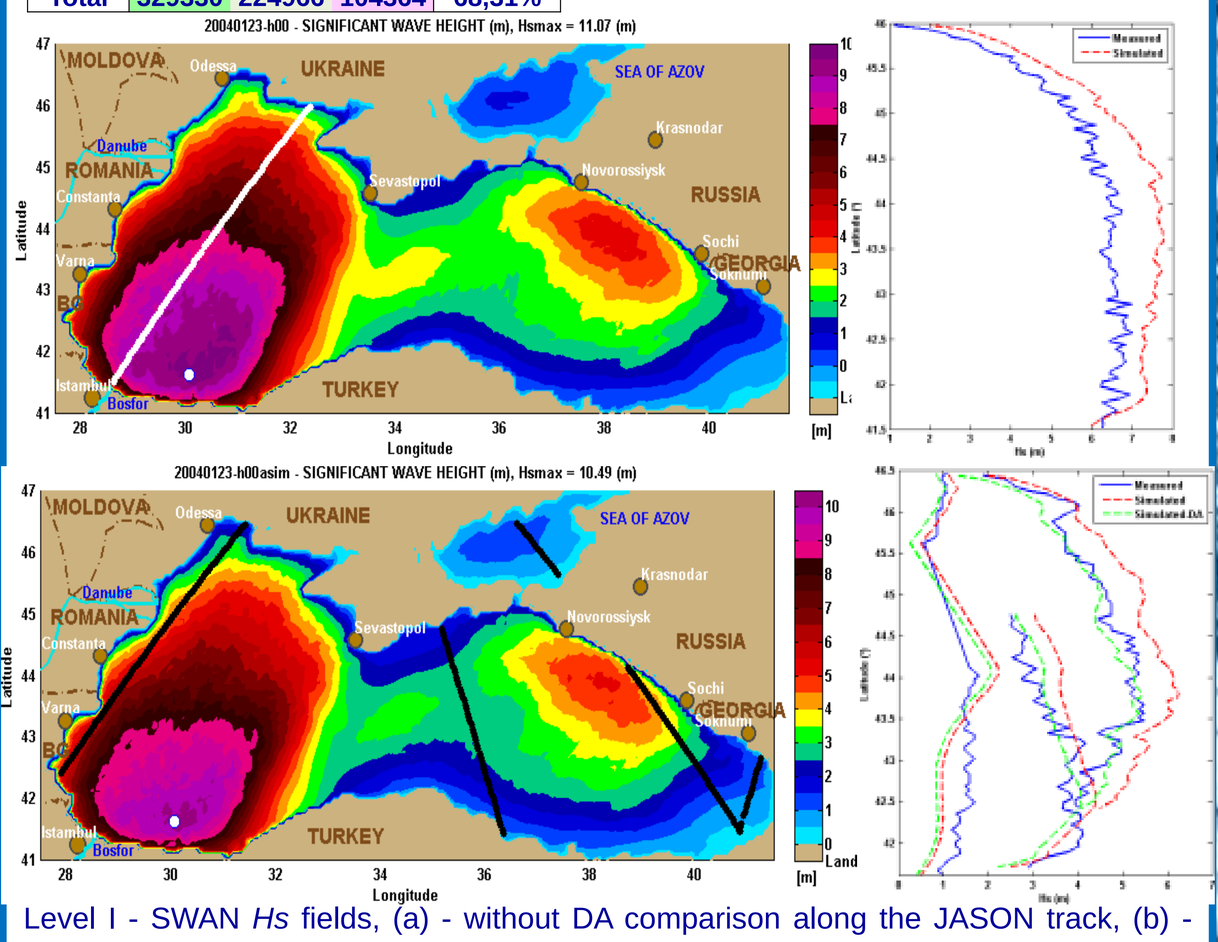
3. RESULTS

The statistical results show that the OI method induces a significant improvement of the statistical parameters. The change of L_{max} is without significant variations of the statistical parameters.

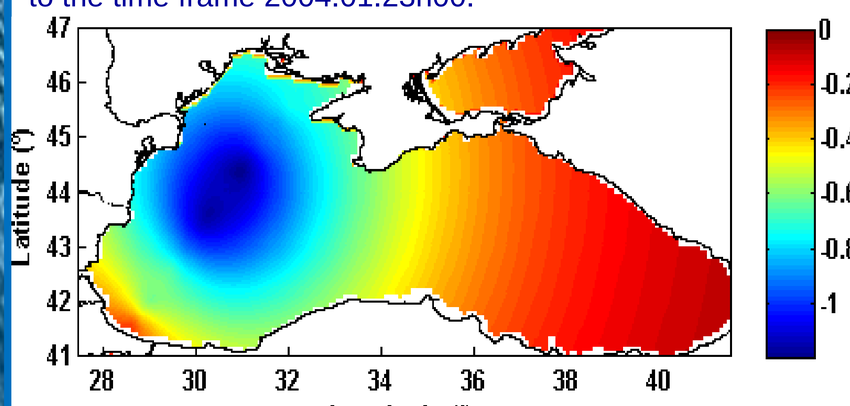


Sat/ Year	Total	Assim	Valid	Assim /Total
2004	71154	40941	30213	57,54%
2005	75798	49384	26414	65,15%
2006	54736	43953	10783	80,30%
2007	60070	41750	18320	69,50%
2008	67572	48938	18634	72,42%
Total	329330	224966	104364	68,31%

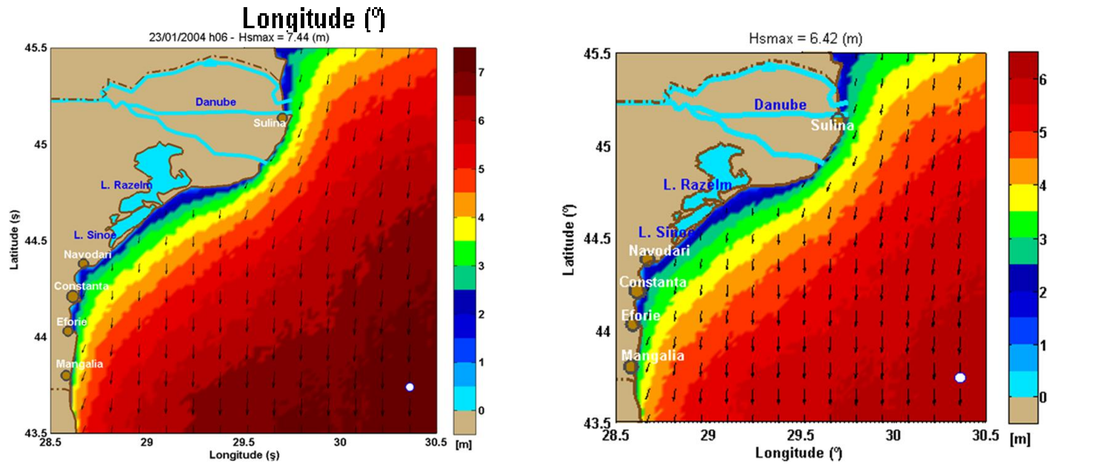
For assimilation data coming from 4 satellites (ERS-2, JASON-1, JASON-2, GFO) are used, two other satellites (ENVISAT and TOPEX) are used for validations.



Level I - SWAN *Hs* fields, (a) - without DA comparison along the JASON track, (b) - with DA1 scheme comparisons along the ENVISAT and TOPEX tracks, corresponding to the time frame 2004.01.23h00.



Hs scalar fields, differences significant wave height with DA against significant wave height without DA; Results for the time frame 2004.01.123-h00.



Level II - Significant wave height scalar fields (H_s) and mean wave direction before (left side) and after (right side) applying the DA scheme, corresponding to the time frames 23/01/2004 h06.

4. CONCLUDING REMARKS

The results show that the data assimilation approaches implemented lead to a significant enhancement of the reliability of the numerical wave predictions.

Acknowledgments

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