Wave height background errors simulation and forecasting via stochastic methods in deep and intermediate waters

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The forecast of the significant wave height is valuable in numerous coastal and offshore investigations and activities. This is currently accomplished numerically via the state of the art third generation deterministic wave models that solve the wave energy balance equation. In recent years, data assimilation and artificial neural network techniques have been used in a number of wave height forecast improvement efforts. In this work we present the application of linear and non-linear stochastic techniques to show that WAM background errors can be reasonably predicted by using a limited number of buoy observations and improve thus its forecasting robustness. Re-run of the wave model is not required.

The first assessment, conducted in the Aegean Sea, refers to the improvement of the significant wave height prediction in deep water. The results were checked against four pilot-study monitoring stations. These stations are located in the open sea near the Athos peninsula and offshore Lesvos, Mykonos and Santorini islands. The assessment had a two-fold scope. First, a study was conducted in a time domain fashion employing these four locations and using four stochastic models whose explanatory variables are the WAM prediction and the measured wave height at previous steps. Two bivariate linear models, a trivariate linear model and two versions of a non-linear bivariate model were usedwith results shown in Fig.1.

	R^2 Athos	R^2 Lesvos	R^2 Mykonos	R^2 Santorini
WAM	***0.781***	***0.713***	***0.722***	***0.676***
S. Model 1	**0.920**	**0.892**	**0.927**	**0.906**
S. Model 2	**0.865**	**0.813**	**0.860**	**0.820**
S. Model 3	**0.924**	**0.895**	**0.931**	**0.911**
S. Model 4a	**0.929**	**0.897**	**0.936**	**0.909**
S. Model 4b	**0.929**	**0.898**	**0.935**	**0.908**

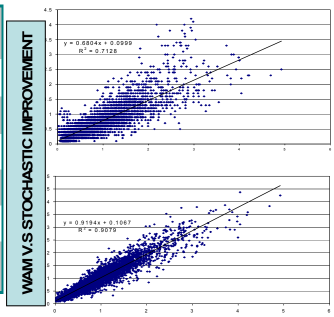

Figure 1: The improvement of the coefficient of determination in all stations using four stochastic models. An example of the improvement in Lesvos island: Scatter plot diagram

These four models result in a significant forecast improvement, irrespectively of the application time period and of the location of the prediction. It is remarkable that this is accomplished via the same pattern of weighting factors in the equations. More specifically, the coefficients of determination, which show the model adequacy, increased from approximately 0.7 (WAM) to over 0.9, suggesting that this method may be suitable for operational use. The stochastic models improvement reduced with the increase of lead time and approaches WAM predictability after 72 hours (Fig 2)

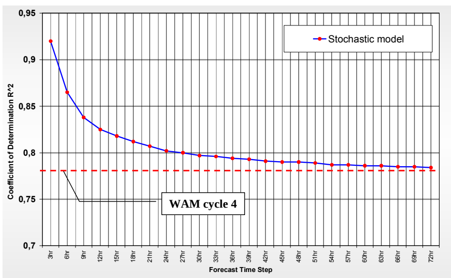

Figure 2: Coefficient of determination decay v.s. lead time

The second part of the Aegean application consists of a space-wise study including spatial stochastic modeling and wave information transfer aiming at expanding the improvement described above in space and especially in coastal regions. To accomplish this, the wind speed and direction effects were included. We found that wind information can help to improve the said prediction in time and space without using measurements or satellite observations, except for a calibration period. The applied stochastic methods show a somehow limited but steady improvement. This is due to the complexity of the Aegean Sea with its numerous islands and complicated shoreline.

To avoid this peculiarity of the Aegean Sea, further examination was conducted in two locations of the Indian Ocean again via stochastic techniques. WAM cycle 4 without assimilation schemes together with the same data from two buoys were used. The scope was to improve the 9 hrs time step wave forecast at the second location which lies in intermediate waters. For this purpose, data of the first location, which lies 900 Km offshore India peninsula, along with the prediction of the WAM model represent the explanatory variables of the non linear stochastic method. Intermediate buoy data were used for validation. A non linear transformation in the stochastic models which is related to the swell content optimizes the improvement of the wave height prediction in intermediate waters using the offshore measurement. The improvement of the wave height prediction is remarkable (Fig.3).

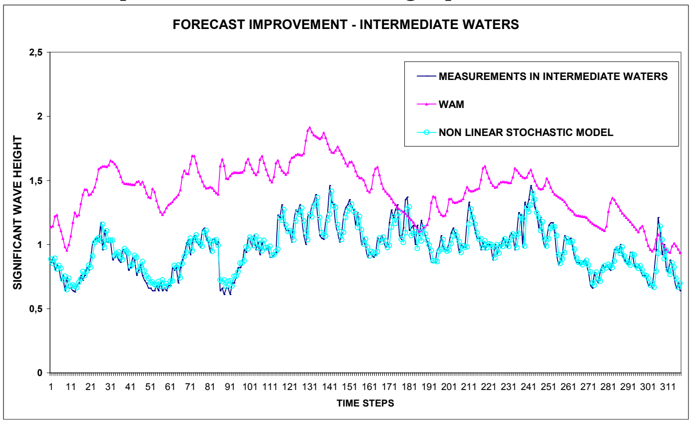

Figure 3: Wave height time series in Indian Ocean intermediate waters. WAM v.s. buoy and stochastic model

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