Satellite data for systematic validation of wave model results in the Black Sea

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Waves in the Black Sea

The Black Sea is with regard to the availability of traditional in situ wave measurements recorded by usual waverider buoys a data sparse semi-enclosed sea. The only possibility for systematic validations of wave model results in such a regional area is the use of satellite data. In the frame of the COPERNICUS Marine Evolution System for the Black Sea that requires wave predictions, the third-generation spectral wave model WAM is used. The wave forecast system for the Black Sea that runs operational (one day hindcast and five days forecast) is demonstrated based on six years' systematic comparisons with satellite data. The aim of this investigation was to answer two questions. Is the wave model able to provide a reliable description of the wave conditions in the Black Sea and are the satellite measurements suitable for validation purposes on such a regional scale ?

Along track validation

Three examples in **Figure 1** show the distribution of the computed significant wave height and of the total wave direction in selected storm situations, together with an along track validation of the model results in comparison with measured data recorded by the radar altimeter of the satellite JASON-2. Measured and modelled wave heights in those cases agree pretty well. Yearly statistics for each of the six years of the considered time period between January 2011 and December 2016 indicate a slight systematic underestimation of the satellite data by the wave model.

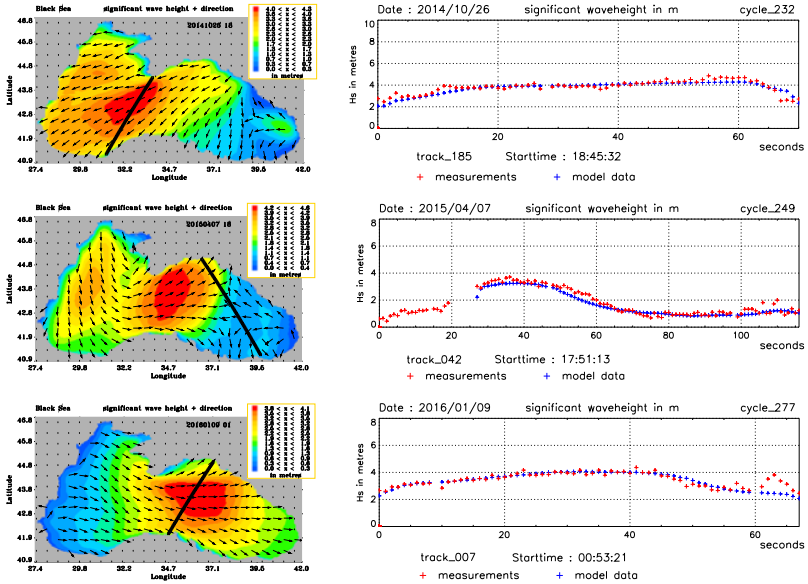

Figure 1 : Distribution of computed significant wave height and total wave direction on the left for three storm situations (26.10.2014 – 6 pm, 07.04.2015 – 6 pm and 09.01.2016 – 01 am) and time series between model data and measurements recorded by the JASON-2 radar altimeter along the corresponding satellite tracks on the right.

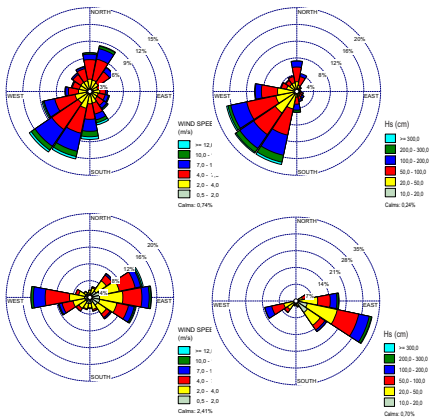

Figure 2: Wind rose for wind speed and wind direction (left:a) and wave rose for significant wave height and wave direction (right:b) in the western (top) and eastern (bottom) part of the Black Sea (in propagation direction). The wave rose in the western part shows a clear predominant wave direction in propagation direction to southwest and is more distinct here than the direction of the driving wind. That is due to the more persistent swell in the wave field. The predominant wave direction in the eastern part of the Black Sea can be detected in propagation direction to east-southeast and is more pronounced than in the western part.

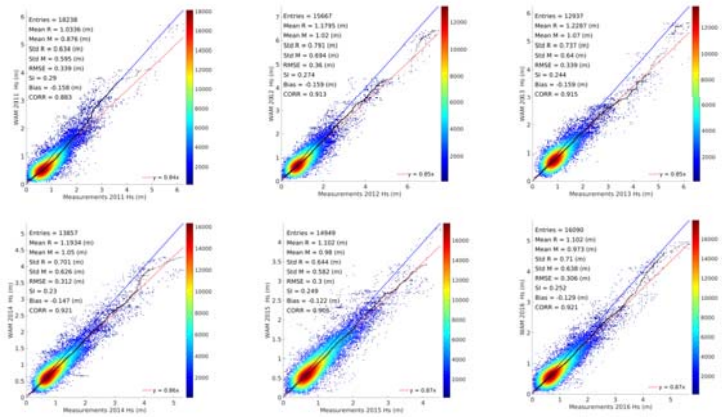

Figure 3 : QQ-Scatterplots for measured and computed significant wave heights for the last six years between January 2011 and December 2016 : QQ-plot (black crosses), 45° reference line (blue line) and least-squares best fit line (red line).

Validation statistics

The yearly statistics demonstrated in the six QQ-scatterplots including the most important statistical parameters for the six years between 2011 and 2016 in **Figure 3** prove that the wave model system provides reliable wave predictions for the Black Sea and simultaneously that the measured satellite data are of good quality and suitable for validation purposes in that area.
In general the wave heights in the Black Sea are moderate and are around 1 m only in all years. The correlation between measured and computed data is very good with values above 0.9 (except 2011: 0.88) and the bias for the significant wave heights (model – satellite measurements) is between -12 and -16 cm which denotes a slight systematic underprediction of the measurements by the wave model. In that case a future validation with buoy data (if available) is required to find out whether the satellite measurements are systematically too high in the Black Sea area or the computed wave heights are systematically too low.

The operational wave forecast results are currently presented under the following link : http://ncwms.hzg.de/ncWMS/godiva2.html. An example is given in **Figure 4**.

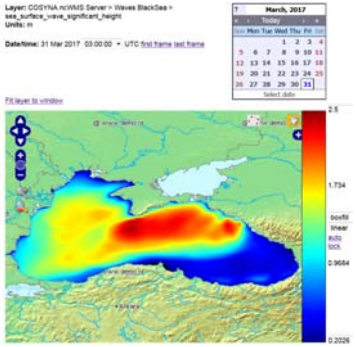

Figure 4: Distribution of the significant wave height on 31 March 2017, 03 UTC

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