Assessment of the Weather Research and Forecasting model using Copernicus Sentinel-3A/B altimetry-derived wind speed in coastal areas

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ABSTRACT

This work presents the capabilities of wind speed (WS) retrievals from the altimeters on-board Copernicus satellites Sentinel-3A/B (S3A/B) for the spatial validation of WS outputs from the Weather Research and Forecasting (WRF) model over the complex coastal area of the Gulf of Cádiz (GoC), Spain. In order to assess the applicability of the altimetry data for this purpose, comparisons between three different WS data sources over the GoC area were evaluated: in-situ measurements, S3A/B altimetry data at 20 Hz of posting rate and the WRF model output. Weather Research and Forecasting model outputs over the area were evaluated with in-situ data, with satisfactory results (WS bias < 0.75 m/s) over three different locations. The spatial variability of the WS derived from the WRF model was compared with the along-track altimetry-derived WS. The analysis was carried out under different wind synoptic conditions. Qualitative and quantitative results (average RMSE < 1.0 m/s) showed agreement between both data sets under low/high wind regimes, proving that the spatial coverage of satellite altimetry enables the spatial validation of high-resolution numerical weather prediction models in water-covered zones, including coastal areas.

Study area

Gulf of Cádiz, southwestern coast of the Iberian Peninsula (Fig.1), characterised by abrupt changes in the orientation of the coastline, very complex coastal topography and links between two basins with different characteristics. Such features favour the existence of a heterogeneous wind field, with topography-induced atmospheric flows strongly controlling the zonal surface circulation.

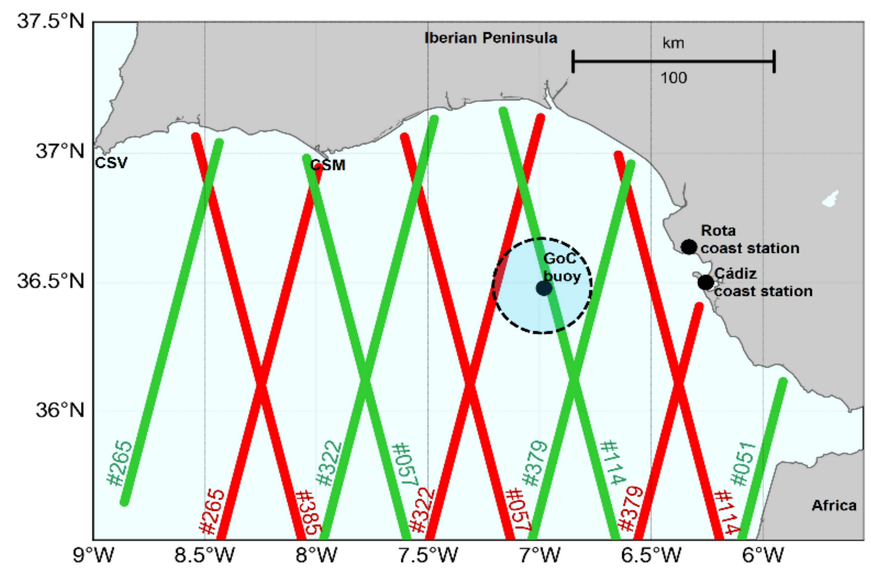

Fig.1. Study area along with the spatial distribution of the data sources: S3A tracks (red line), S3B tracks (green line), location of the moored buoy (GoC buoy) along with the 25 km radius area used to select S3A/B data for its validation (light-blue shaded area), location of the land-based meteorological stations (Cádiz coast station and Rota coast station).

WRF model wind velocity evaluation against in-situ data

Hourly WS and WD data for 2020 obtained from the WRF model simulations were compared to in-situ data from the Cádiz and Rota coast meteorological stations and the GoC buoy. The temporal variability (intensity and direction) observed in the in-situ measurements is adequately simulated by the WRF model over the three sites (Fig.2).

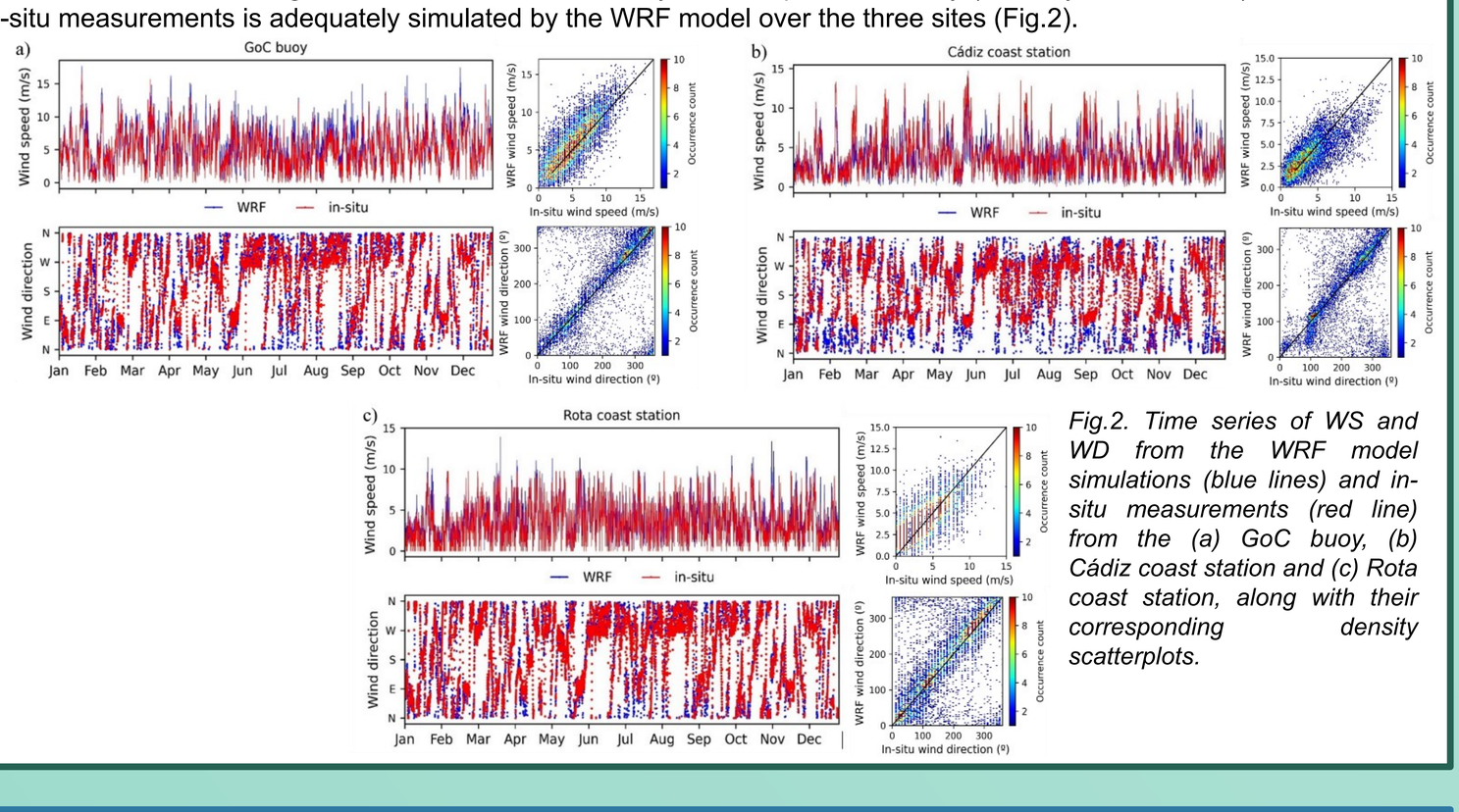

Fig.2. Time series of WS and WD from the WRF model simulations (blue lines) and in-situ measurements (red line) from the (a) GoC buoy, (b) Cádiz coast station and (c) Rota coast station, along with their corresponding density scatterplots.

Altimetry wind speed validation using in-situ data

All available WS data derived from altimetry, and corresponding to relative orbits #322 (S3A), and #114 (S3B) that matched the 25 km radius criteria, from January 6, 2020, to December 31, 2020, were compared against the moored GoC buoy. The resulting scores prove the adequate performance of the two altimeters over the study area for WS (Fig.3).

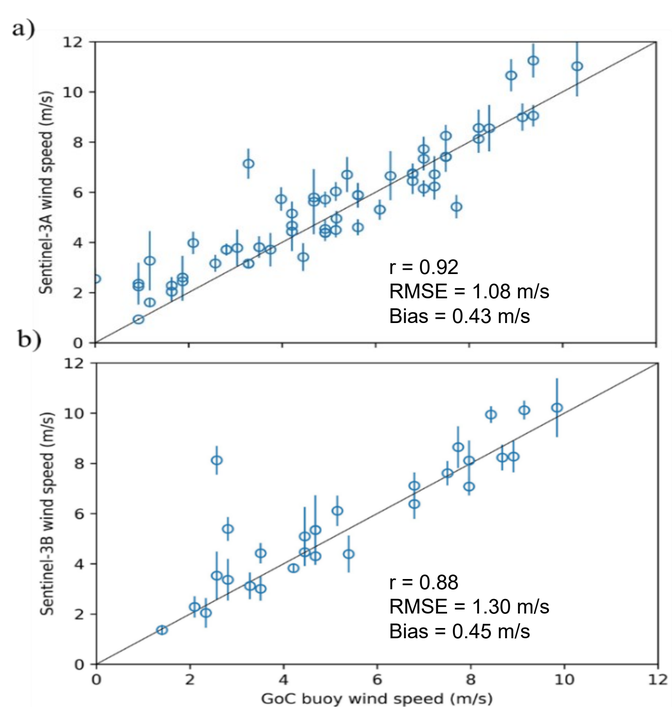

Fig.3. Scatterplot of the WS comparison among S3A (a)/S3B (b) and in-situ measurements from the GoC buoy.

WRF model spatial assessment using altimetry data

The innovative use of altimetry WS for the spatial validation of WS from the WRF model over the study area was carried out through quantitative comparisons using WS retrievals from S3A and S3B altimeters, using data up to 5 km from land, where other sensors such as the scatterometters cannot provide useful data for validating the model. With this aim, the model outputs were linearly interpolated over the positions of the satellite track measurements for 2020. Although satellite tracks do not cover the entire WRF domain area, the results prove that using along-track WS from altimetry enables the estimation of the correlation coefficient and RMSE spatial maps for the area, which facilitate the assessment of the WRF model performance over the study area (Fig.4).

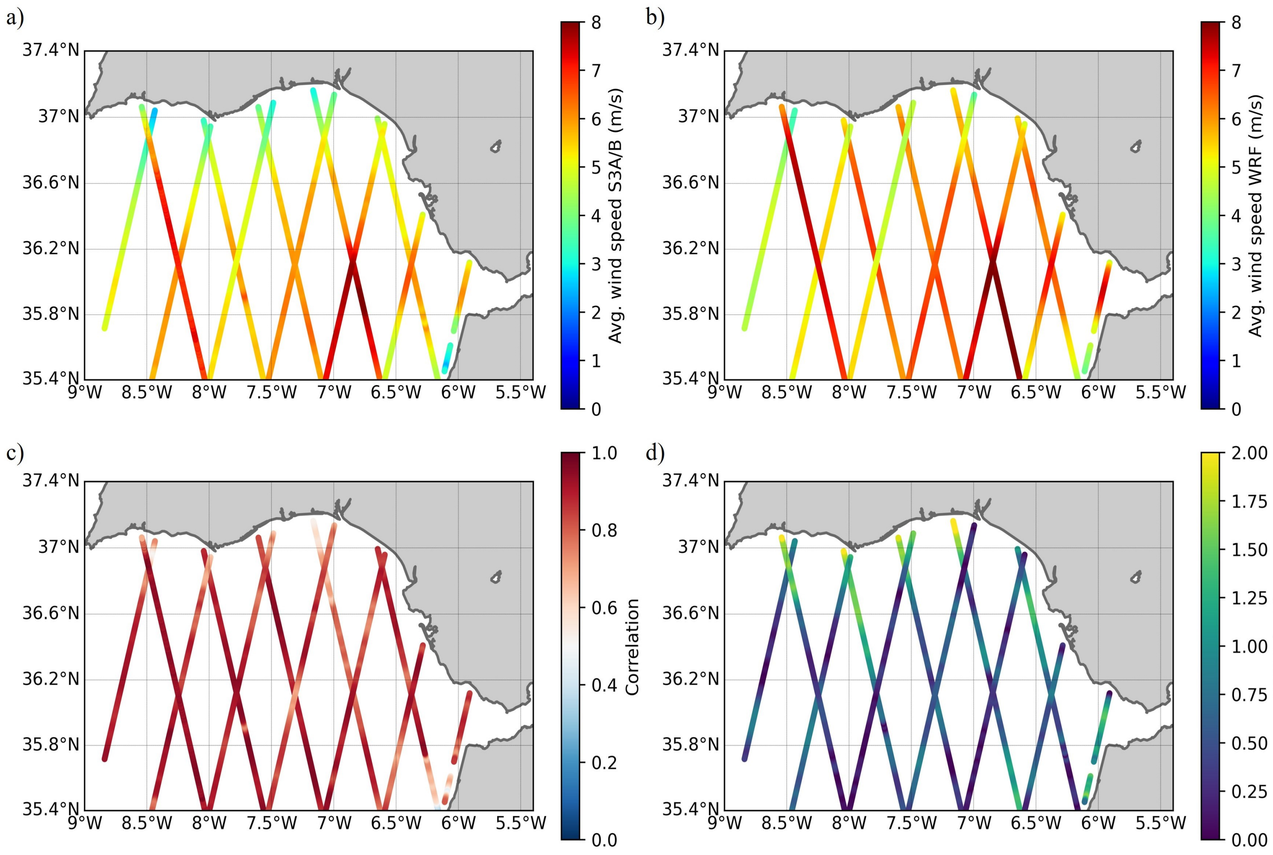

Fig.4. Average WS from S3A/B (a) and WRF (b); spatial distribution of the r Pearson's parameter (c) and RMSE (d) from the comparison among WS data from the WRF model and S3A/B tracks over the study area.

Observability of spatial variability

The wind field over the GoC is characterised by its high spatial variability and high-intensity events. Fig.5 shows an example of the capabilities of using altimetry data for validating the WRF model under complex conditions, specifically, under an extreme easterly wind event.

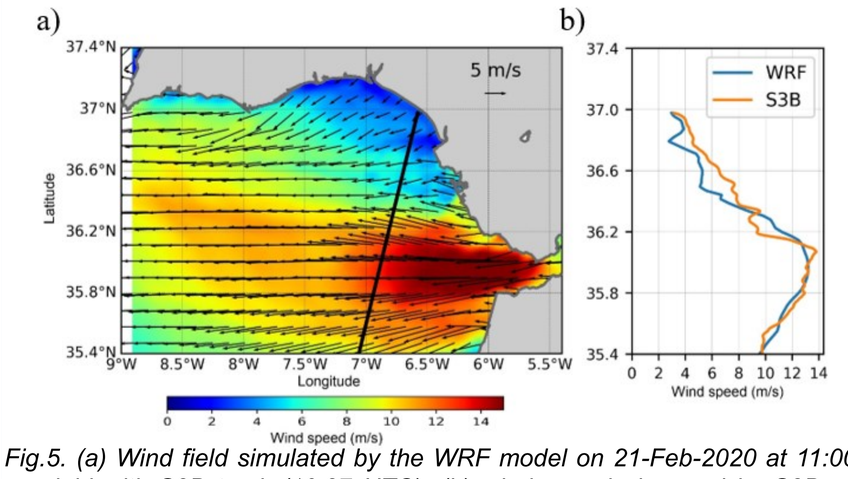

Fig.5. (a) Wind field simulated by the WRF model on 21-Feb-2020 at 11:00 UTC overlaid with S3B track (10:37 UTC); (b) wind speed observed by S3B overlaid with interpolated WRF model data for the same time and positions.

Conclusions and limitations

This study aims to foster the use of altimetry data for the improvement of knowledge of wind speed and sea surface circulation over complex areas where the availability of in-situ measurements is limited or inexistent. We have shown how the spatial coverage of satellite altimetry enables the spatial validation of high-resolution NWP models in water-covered surfaces, including coastal areas, a feature that sets altimetry as a complementary data source to improve the study and prediction of the wind in coastal areas together with some of the current systems, such as scatterometers, high frequency radars and SAR wind fields. However, it is important to note the limitations related to the fact that altimetry measurements are instantaneous and events of time scales shorter than the time resolution of the model may lead to mismatches. Moreover, perpendicular to the track, the altimeters do not measure the variability in scales smaller than the across track footprint length. In this sense, it is important to highlight the need for continues improvement of satellite altimetry and model outputs in the coastal fringe in order to obtain realistic geophysical parameters in these areas.

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