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Knowledge about the long-term average wind climate offshore is essential for wind energy planning and other applications in the marine environment where in situ measurements are costly and sparse. Inter-calibration of satellite sensors is essential for achieving the best possible accuracy on wind speed retrievals and resource estimation. We propose a method for inter-calibration of Synthetic Aperture Radar (SAR) observations from different European sensors prior to wind retrieval processing.

Envisat delivered SAR observations during 2002-12 and the two follow-up missions Sentinel-1 A/B were launched in 2014 and 2016, respectively. The Technical University of Denmark performs wind retrieval processing routinely for all three SAR sensors over the Europeans seas using the geophysical model function CMOD5.n. The wind maps are available at https://satwinds.windenergy.dtu.dk/.

Comparisons of the retrieved SAR wind speeds against collocated wind speed data from ocean buys and numerical modeling lead to very different mean biases on the wind speed from sensor to sensor. Likewise, simulations of the Normalized Radar Cross Section (NRCS) from the model wind speeds through application of CMOD5.n in forward mode show residuals with respect to the observed NRCS. These residuals vary according to the SAR sensor and scanning mode and an almost linear increase occurs in the range direction. Further, the residuals vary over the lifetime of the SAR sensors. Based on linear fitting, we calculate corrections of NRCS for each sensor, mode, radar incidence angle, and month. We apply the corrections to the observed NRCS and this leads to a significant reduction of the NRCS residuals, especially for high incidence angles.

The wind retrieval processing is repeated with the corrected NRCS input and we compare once again with buoy observations of the wind speed. For Envisat, the mean bias is reduced from 0.92 m s^{-1} to only 0.20 m s^{-1} and the RMSE from 2.37 m s^{-1} to 1.90 m s^{-1}. For Sentinel-1 A, we see a reduction of the mean bias from 0.16 m s^{-1} to -0.06 m s^{-1} and for Sentinel-1 B, the bias is reduced from 0.17 m s^{-1} to 0.09 m s^{-1}. RMSE is almost unchanged for both Sentinel-1 A and B.There is generally a good agreement between observations from these two sensors except for the first few months of Sentinel-1 A acquisitions obtained during the commissioning phase. These observations were excluded from further analysis. Improvements on the wind speed accuracy are reflected in our estimations of the wind resource at the ocean buoy locations. For 10 out of the twelve buoys considered in our analysis, we find that differences between the wind power densities estimated from SAR and the buoy wind speeds decrease after inter-calibration. The average deviation from the buoy observations is 20% before and 8% after inter-calibration.

The inter-calibration method presented here can be applied to observations from any kind of SAR sensor. This gives users of the SAR observations the possibility of creating more consistent time series of wind speed and thereby more accurate wind resource estimates. Potentially, such time series could be extended to include SAR observations from third party missions; thereby increasing

the sampling density. The inter-calibration method may be refined in the future to also take wind speed and directions as well as the thermal stratification of the atmosphere into account.

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