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Using SAR Satellites to Map Wind Speed Variation Across Offshore Wind Farm Clusters

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Abstract

Offshore wind speed maps at 500m resolution are derived from freely available satellite Synthetic Aperture Radar (SAR) data. A flow chart shows the method and the results are tested against coincident offshore mast data.

Offshore Wind and SAR

Offshore wind farms are increasingly installed in clusters where external wakes from wind farms may impact other wind farms. Synthetic Aperture Radar (SAR) images from satellites can be used to derive 2D wind speed maps across offshore wind farm clusters and the Sentinel-1 mission makes SAR data freely available.

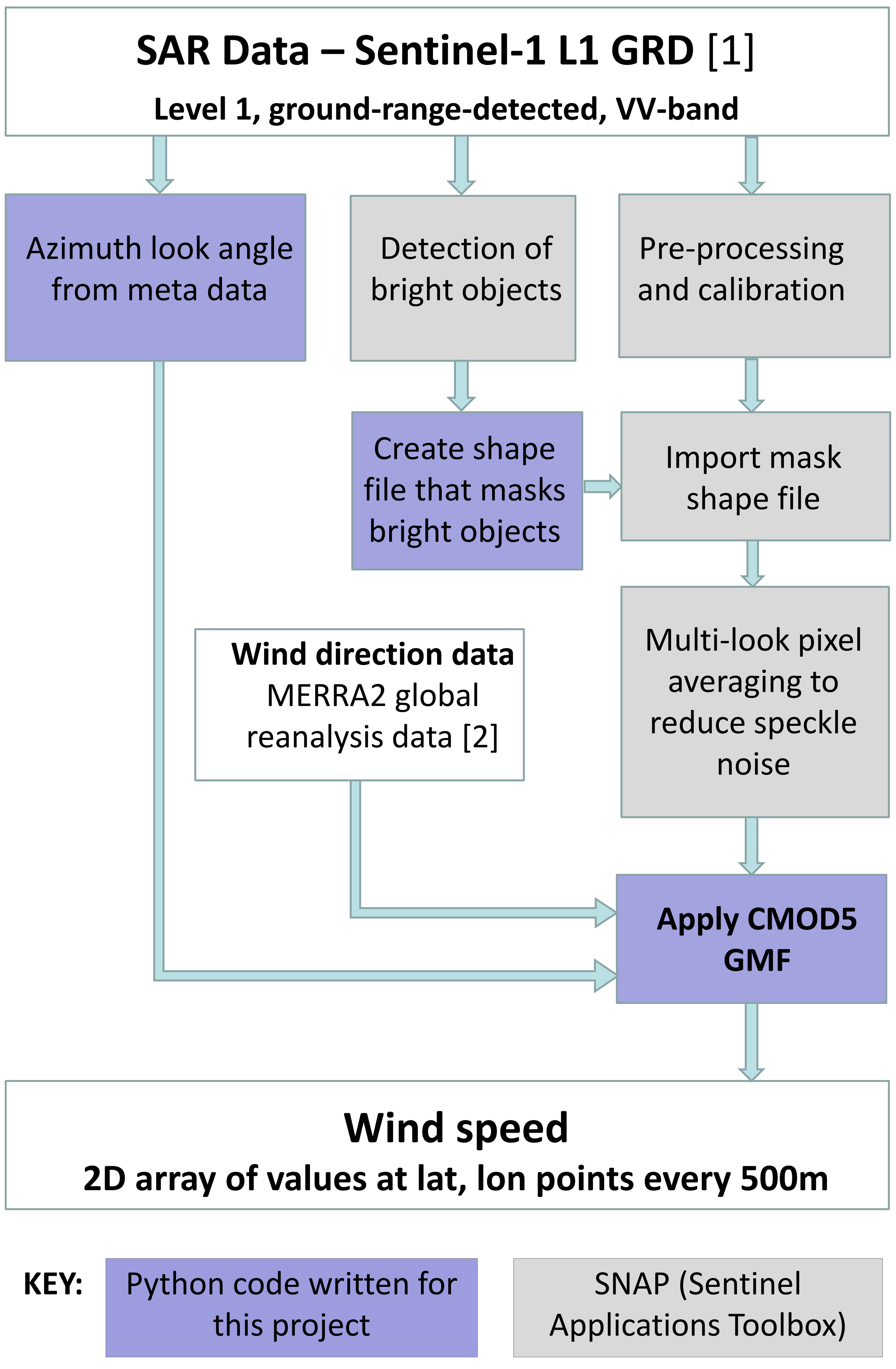
SAR backscatter from open water is affected by the centimetre scale surface roughness of the water which is affected by the wind speed. Empirically derived Geophysical Model Functions (GMF) are used to relate the calibrated radar backscatter (Sigma0) to wind speed and wind direction at 10m.

Automated Calculation of Wind Speed from SAR

The approach taken has been to make as much use as possible of the SNAP software (Sentinel Applications Toolbox) made available with Sentinel data, and to make the process as automated as possible so that many SAR scenes can be processed. Other steps were implemented in Python.

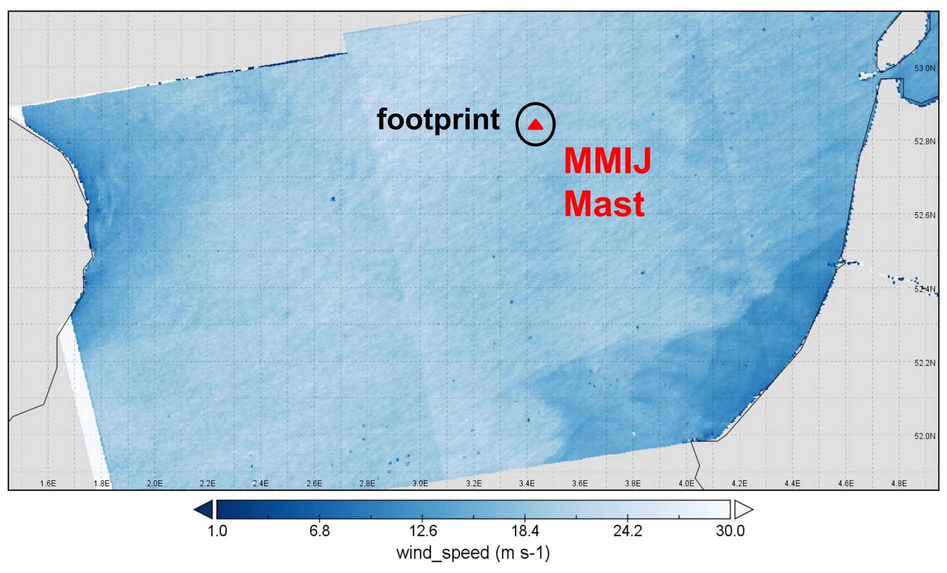
The SNAP wind field estimation tool wasn't used because it didn't provide high enough spatial resolution.

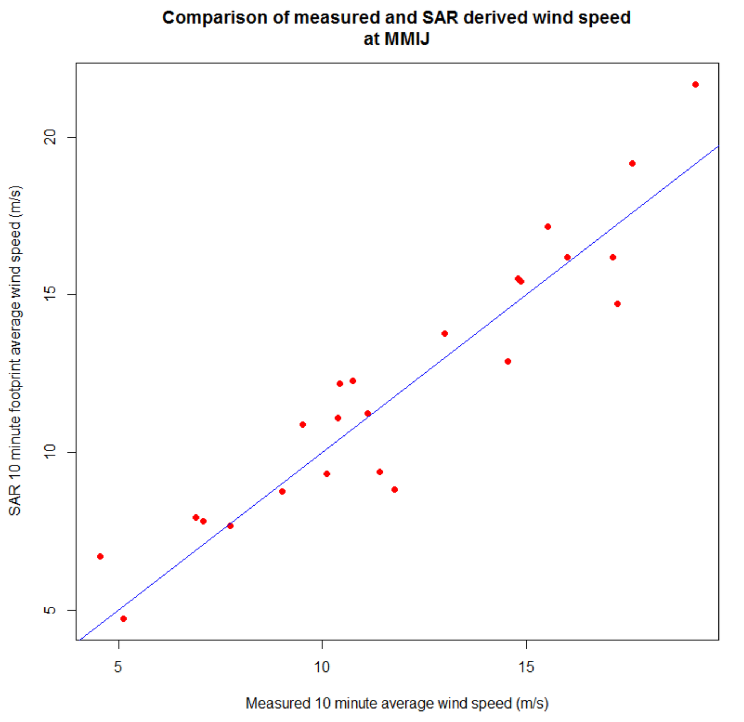
The flowchart below outlines the resulting method.



Verifying the Results

Wind speed maps were derived from 25 Sentinel-1 SAR scenes coincident with data available at Met Mast Ijmuiden (MMIJ). The 10 minute average wind speed at 10m was derived from mast data for the 10 minutes centred on the time of the SAR image. In order to compare time series mast data at one point (the mast) with spatial wind speed data taken at one time (SAR) it was assumed that the wind flow holds to Taylor's frozen turbulence hypothesis. The distance covered by the 10 minute average wind speed in 10 minutes was used as the diameter of a footprint centred on the mast , following the method used by Li and Lehner [3].**The average SAR wind speed in the footprint was compared to the 10 minute average mast wind speed.**





The results of plotting the SAR wind speed against the mast wind speed show a strong, linear correlation with a Pearson's r value of 0.93. To test the sensitivity of the results to the quality of the wind direction input, the SAR wind speed was also derived using the wind direction from MMIJ mast. The linear correlation was stronger, with a Pearson's r value of 0.96. Although this is a stronger correlation, it is clear that the difference between the SAR derived wind speed and the wind speed measured by the mast arises from more than just the wind direction input. This is a useful result as generally when applying this method mast data will not be available, but MERRA-2 will be.

Applications

The purpose of this work has been to provide wind field data for further investigation of the external wakes from offshore wind farms in clusters. Even with measurements, it is not straight forward to measure velocity deficit. There are often underlying wind speed changes across scenes, for example from offshore and onshore wind speed gradients.

Hasager et al [4] have developed a method to combine results from many SAR scenes to overcome this issue and this type of approach lends itself to the increased availability of SAR data arising from the Sentinel-1 mission and use of this or a similar method to process many scenes.

Acknowledgements

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Presenting: Thurs 9.30am - Remote Sensing in Resource Assessment