Category: 05

High-Resolution SAR-Based Wind Fields Over Offshore Wind Farms: Assessment of Shadowing Effects and Resulting Power Yield Reduction.

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1. Introduction

Spaceborne active microwave devices, such as Scatterometer and Synthetic Aperture Radar (SAR), apply Geophysical Model Functions (GMFs) to relate the observed Radar backscatter to sea surface roughness and associated wind speeds. However, GMFs are tuned with large footprints of SAR [1] or Scatterometer data and were initially not designed to resolve small-scale structures such as wind turbine wakes or wind gusts. SAR images contain radar backscatter values at a high spatial resolution while retaining the large coverage area. Recent direct comparisons of observations obtained by high resolution TerraSAR-X (TS-X) X-band SAR data and platform-based Doppler LiDAR installed in the German offshore Wind park Alpha Ventus (Fig ???) reveal a remarkable agreement in the investigation of small scale wind field structures [2,3]. On this foundation, the interpretation of SAR-Based wind fields to estimate the power yield potential in turbine height is possible. SAR images of the German Bight (e.g. Fig 2) regularly show pronounced wind shadows in the wake of wind turbine clusters. These often represent a reduction in wind speed of 20% and extend up to 80km downstream of the wind park. Energy yield assessments of planned are based on long-term wind statistics taken including mostly years prior to the construction of the first wind park facilities. Hence, these figures do not include the significant shadowing effects of existing clusters. With the SAR-based wind data it is possible to observe and quantify the wind shadows and thus improve energy yield estimates for existing and future wind parks.

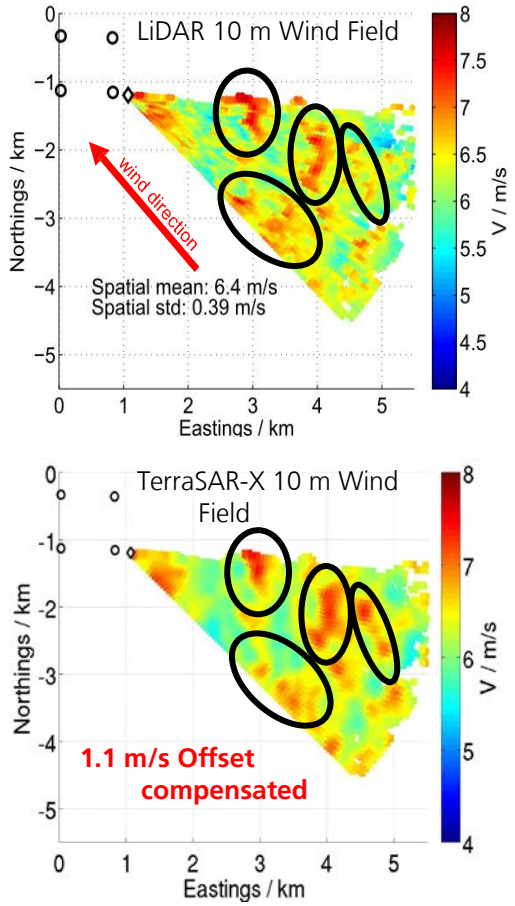

Figure 1: Comparison from Doppler LiDAR and TerraSAR-X based wind fields over Alph Ventus Wind Park (at 0.0,0.0) on Jan 22, 2015.

2. Methods

In order to statistically analyse the wind shadow extent and other properties, we calculate high resolution wind fields of the German Bight of over 400 Sentinel-1 scenes and complement the dataset with TS-X observations where available. We stack wind-speed-normalized scenes to extract average down-wind conditions and obtain an estimate for the relative wind speed reduction in the wind shadow area of the turbine cluster under investigation. This information can be used directly to better parametrize wind wake effects in power production models and in the long run help to improve models to incorporate the simulation of shadowing effects.

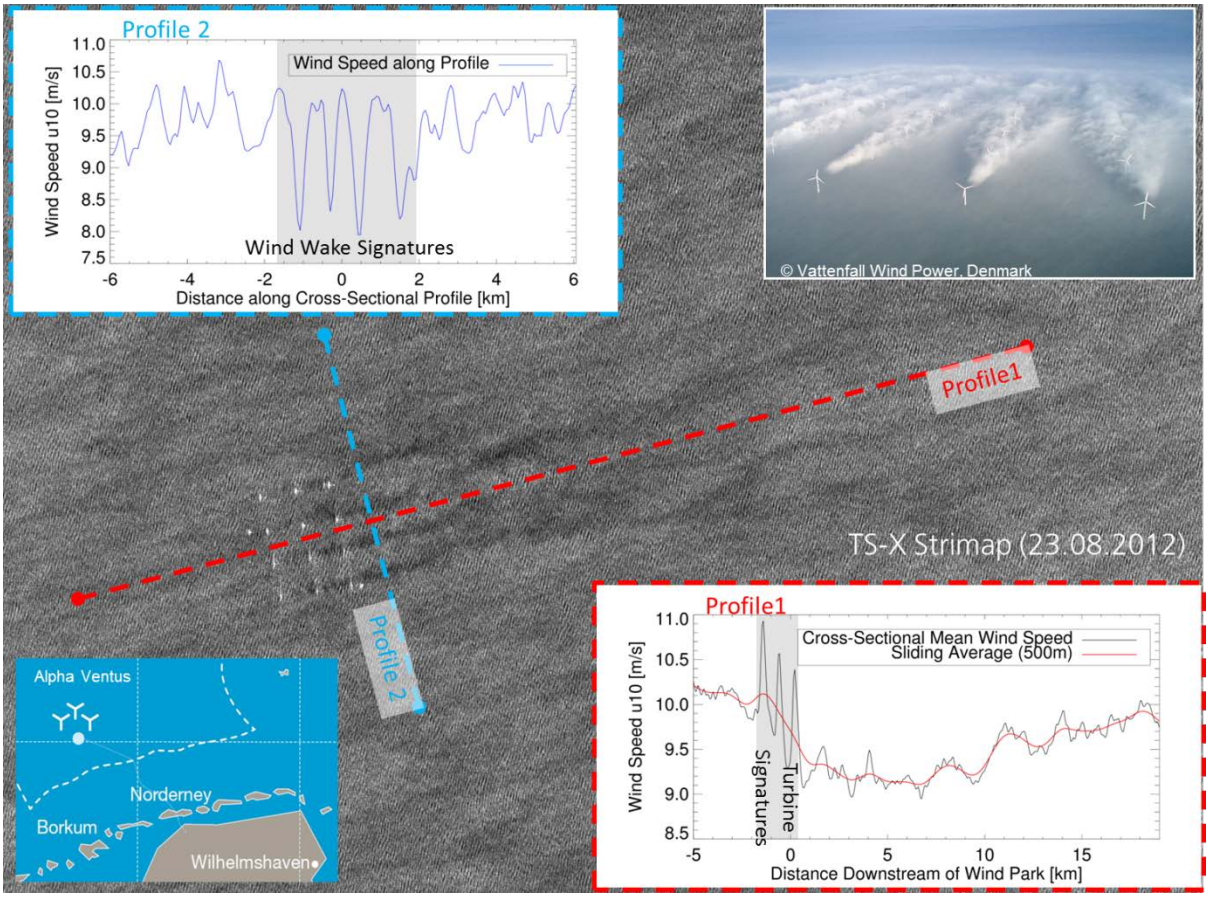

Figure 2: TerraSAR-X Image of the Alpha Ventus Wind Park (August 23, 2012). Turbulent wakes of single turbines are detectable and merge to a combined wind shadow in the far field. Relaxation to background wind speed occurs only after ~20 km downstream for the relatively small 12 turbine array.

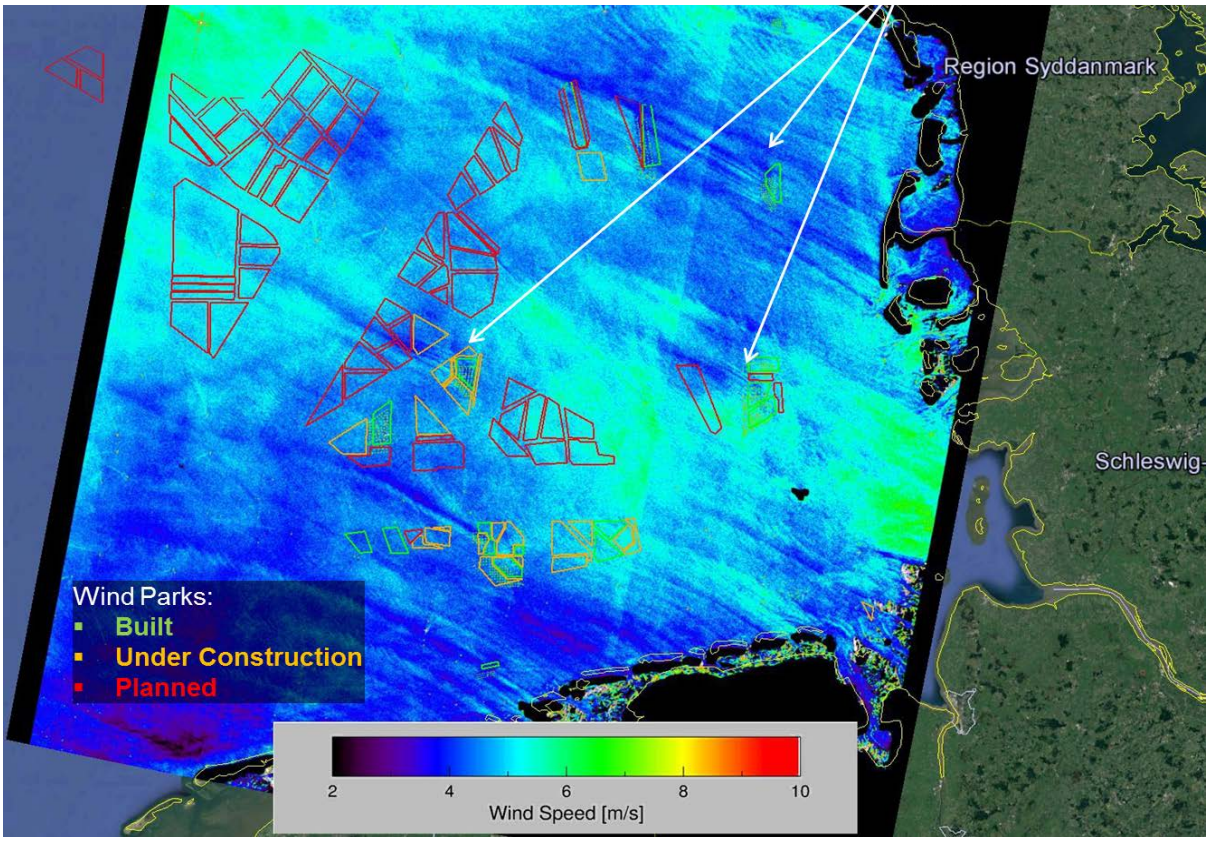

Figure 3: Sentinel-1 wind field of the German Bight (June 5, 2015). Wind shadows of existing wind parks (green outline) are visible up to 10 km downstream and would have a major effect on future facilities (orange and red outlines).

3. References

[1] X.-M. Li and S. Lehner, “Algorithm for Sea Surface Wind Retrieval From TerraSAR-X and TanDEM-X Data,” IEEE Transactions on Geoscience and Remote Sensing, vol. Early Access Online, 2013.

[2] S. Jacobsen, S. Lehner, J. Hieronimus, J. Schneemann, and M. Kühn, “Joint Offshore Wind Field Monitoring with Spaceborne SAR and Platform-based Doppler Lidar Measurements.,” in International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, 2015.

[3] J. Schneemann, J. Hieronimus, S. Jacobsen, S. Lehner, and M. Kühn, “Offshore wind farm flow measured by complementary remote sensing techniques: radar satellite TerraSAR-X and lidar windscanners,” in Journal of Physics: Conference Series, 2015, vol. 625, p. 012015.