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Offshore wind resource estimation using satellite images: what are the challenges?

Charlotte Bay Hasager (1), Merete Badger (1), Alexis Mouche (2), Poul Astrup (1), Ad Stoffelen (3), and Ioanna Karagali (1)

(1) Risø National Laboratory for Sustainable Energy - DTU, Wind Energy, Roskilde, Denmark (cbha@risoe.dtu.dk, +45 4677 5970), (2) CLS, France, (3) KNMI, the Netherlands

In the EU-Norsewind project (2008-2012) short for 'Northern Seas Wind Index Database' the aim is to produce state-of-the-art offshore wind atlas. The method builds on combining information from around 15 ground-based wind lidars on offshore platforms, several meteorological masts, satellite information and modeling in the area of interest - Baltic, Irish and North Sea. An advantage of lidar is observation at several heights providing wind profile information also at the height of wind turbines. The information is however only valid in the observation point. Similar situation exists for tall met-masts. Both lidar and met-mast data collection are rather costly, yet in progress in the Norsewind project in the coming 1.5 years. Meanwhile satellite information provides series of spatial snap-shots of the area of interest at limited cost. Finally meteorological modeling will tie together all information. The satellite data will be used for verification of the spatial results of the wind atlas.

At present, the Norsewind satellite image archive includes Envisat ASAR (Advanced Synthetic Aperture Radar) in wide swath mode (WSM), passive microwave SSM/I and scatterometer QuikSCAT and ASCAT images. The three different satellite remote sensing principles provide a unique opportunity to map with 1) high spatial scale though with only 300-1000 samples for each point of interest (ASAR); 2) twice daily temporal scale for 10 years at low spatial scale (QuikSCAT) and followed by ASCAT in same or better spatial scale; 3) several times per day for 20 years at low spatial scale, but wind speed only far from the coasts (SSM/I). The passive microwave SSM/I and the scatterometers are in orbit in space with the prime task of mapping ocean winds.

The challenges using satellite remote sensing in wind energy are mainly five: 1) number of samples; 2) Weibull fitting at conditional data; 3) diurnal variation; 4) 10 m versus hub-height; 5) satellite wind retrieval. Each of the challenges is addressed. Ad 1) For SSM/I and scatterometer the number of samples is sufficiently high – several thousand – yet for SAR the number is below this and in some cases only few hundred. In order to adjust for the relatively low number of samples a wind-class weighting method is applied. This is based on long-term or other available data and basically weighs the results appropriately. Ad 2) the fitting of Weibull parameters is adjusted such that missing data, e.g. at very low or high wind speeds are accounted for. Ad 3) the diurnal wind speed variation is known to vary at some coastal stations with pronounced sea-breeze. However further offshore there may be less variation. The situation is that the SAR and scatterometer satellites observe either early morning and early evening or late morning and late evening local time, dependent upon the ascending and descending paths. Using SSM/I more observational times are available as more satellites are in space in various orbits. In areas with pronounced diurnal wind speed variation the satellite-based results may be adjusted to improve the estimate. Ad 4) For scatterometer and SAR satellite ocean wind mapping is based on the physical principle of relating the normalized backscattered observed - which is a function of surface shear as short gravity and capillary waves are produced by near-instantaneous wind - and relating this empirically to wind speed at 10m. For SSM/I empirical algorithms between brightness temperatures and wind at 10m is used. In wind energy, however, winds at hub-height is more relevant, thus the wind profiles from lidar and masts (selected points) will be used to estimate hub-height winds from the satellite data (spatial domain). Ad 5) the method for wind speed retrieval using satellite data is based on empirical methods. As new high-quality offshore in-situ data series appear, e.g. in the Norsewind project, there may be room for improvement of algorithms. For SAR processing in particular, the wind direction a priori estimate from meteorological models, scatterometer and in-situ data is under investigation.

In summary, the satellite-based wind resource maps will be used for comparison to the other outputs of the Norsewind project in support of the validation of final products and will provide a detailed spatial context to the Norsewind maps.