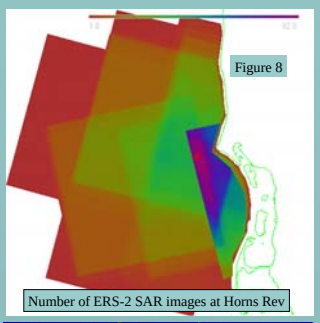
Quantitative remote sensing: Horns Rev wind farm case study

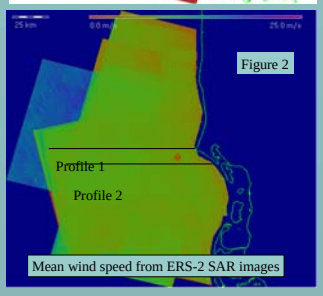
Charlotte Bay Hasager, Morten Nielsen and Merete Bruun Christiansen

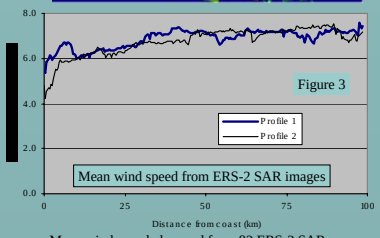
Risø National Laboratory, Wind Energy Department, P.O.Box 49, DK-4000 Roskilde, Denmark, charlotte.hasager@risoe.dk

Abstract

Observations from ERS-2 SAR and scatterometer are used to quantify wind resources near the Horns Rev wind farm located in the North Sea, Denmark. At this site a large offshore wind farm (80 2MW-turbines) is in operation. The study includes spatial analysis of wind climatology maps derived from satellite observations, as well as time series statistics from offshore meteorological observations collected within the wind farm. Focus of the case study is on the spatial variations in wind fields within the region. The overall aim is to provide quantitative estimates on offshore wind resources, and to demonstrate possibilities and limitations on the use of quantitative remote sensing for wind resource estimation. CMOD4 is used to derive wind speed from SAR. A footprint methodology for averaging wind speeds in SAR imagery for wind resource estimation is used (Hasager et al. 2004). The current study is based on 82 ERS-2 SAR scenes and several years of Quikscat scatterometer daily observations.

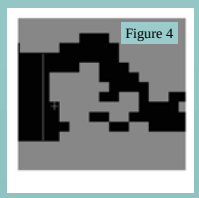




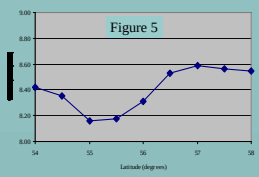


Mean wind speed observed from 82 ERS-2 SAR scenes near Horns Rev in the North Sea. The mast is indicated with a red crosshair.

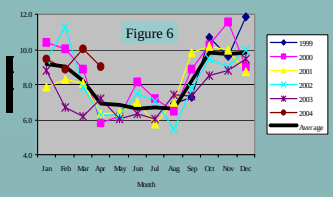
Horns Rev wind farm from http://www.hornsrev.dk/Engelsk/default_ie.htm
80 VESTAS turbines of 2 MW operating since Dec. 2002



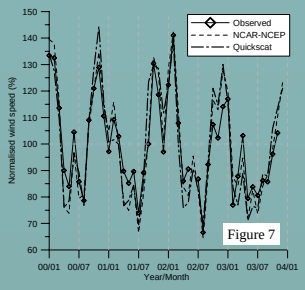
Quikscat data domain showing Denmark and interior seas. The Horns Rev mast is located at the cross. Each cell is 0.5º by 0.5º.



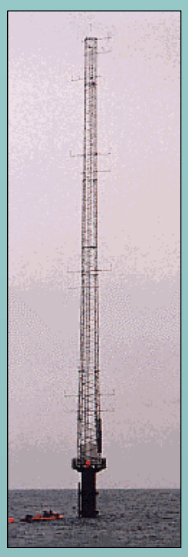
Average wind speed at 54º to 59º degree latitude along 7.5º degree longitude measured by Quikscat August 1999 to April 2004 from CERSAT at IFREMER

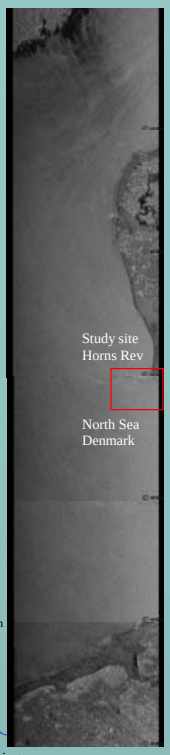


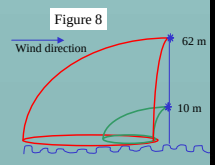
Monthly average wind speed near Horns Rev measured by Quikscat August 1999 to April 2004 from CERSAT at IFREMER.



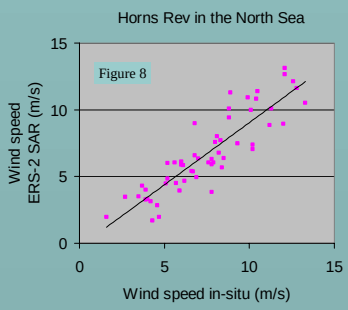
Monthly mean wind speeds calculated from observed data at the Horns Rev mast, the NCAR-NCEP data set and Quickscat satellite images. Data are normalized by the mean value from each data set for the period 2000-2003 and expressed as a percentage. Courtesy: Rebecca Barthelmie







Sketch of footprint for area-averaging



CMOD4				
Linear regression	R2	SE	N	
y=0.932x-0.276	**0.784**	**1.33**	**56**	**(SAR streak direction)**
y=0.930x-0.516	0.881	0.90	56	(in-situ direction)

Summary

•ERS-2 SAR images can be used to derive offshore wind speeds and the SAR-based wind speed maps compare well to in-situ data using footprint averaging (Hasager et al. 2004, *IJRS*) (figure 7-8).

•Wind statistic analysis from ERS-2 SAR and QuikSCAT show significant spatial variations (Hasager et al. 2004, *EWEC*) (figures 1-3)

•Seasonal and interannual variations in wind speed are mapped with good accuracy from QuikSCAT compared to in-situ data (Hasager et al. 2004, *EWEC*) (figures 4-7)

•The number of samples needed in order to assess wind resource statistics are identified (Barthelmie et al. 2003, Pryor et al. 2004)

Acknowledgements

ESA EO-1356 Cat. 1 project (Offshore wind resources from ERS SAR wind speed maps) satellite scenes,
STVF SAT-WIND project funding, and
Elsam Engineering for wind farm meteorological data.

References

Hasager, C. B., Dellwik, E., Nielsen, M., Furevik, B. 2004. Validation of ERS-2 SAR offshore wind-speed maps in the North Sea. *International Journal of Remote Sensing*, vol. 25, accepted (available as on-line preview article)

Hasager, C.B., Christiansen, M.B. 2004 Coastal wind mapping from satellite SAR: possibilities and limitations. In: *Fourth Study Conference on BALTEX. Conference Proceedings*. Ed. Hans-Jürg Isemer. 24-28 May 2004, Gudhjem, Denmark, p 21-22. Available at http://www.gkss.de/baltex/baltex_frame_builder.html

Hasager, C.B., Barthelmie, R.J., Christiansen, M.B., Nielsen, M., Pryor, S.C. 2004 Quantifying offshore wind resources from satellite wind maps: study area the North Sea. In: *Proceedings of the European Wind Energy Conference and Exhibition 2004* (EWEC 2004), London (UK), 22-25 Nov. 2004. 10 p. (accepted, to appear)

Barthelmie, R. J.; Pryor, S. C. 2003 Can Satellite Sampling of Offshore Wind Speeds Realistically Represent Wind Speed Distributions. *Journal of Applied Meteorology*, *42*, 83-94

Pryor, S.C., Nielsen, M.; Barthelmie, R.J.; Mann, J. 2004 Can satellite sampling of offshore wind speeds realistically represent wind speed distributions? Part II Quantifying uncertainties associated with distribution fitting methods. *J. of Applied Meteorology*, 43, 739-750