SAR Wind Maps and Derived Products: New Possibilities for Offshore Wind Energy Exploitation

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SAR Wind Maps and Derived Products:

New Possibilities for Offshore Wind Energy Exploitation

Merete Badger, Tobias Ahsbahs, Ioanna Karagali, Charlotte Hasager
EU: Wind energy cover 11.6% of the EU’s electricity demand.

Denmark: Wind energy cover 44% of Denmark’s electricity demand.
Offshore wind energy capacity in Europe

4,149 offshore turbines.

Two 350 MW wind farms, to be built by 2022 offshore in the Netherlands, will be the world’s first to be built without public subsidy.
Global forecast

Global offshore wind cumulative installation forecast

Source: BNEF
Map of offshore wind farms

Courtesy: 4C Offshore
Offshore wind energy and SAR

- Mean wind conditions
- Horizontal coastal wind speed gradients
- Wind farm wake effects
- Extreme events
SAR wind data archive at DTU

View, search and download wind maps:
https://satwinds.windenergy.dtu.dk/

Image courtesy: Google Earth
SAR wind data archive at DTU

- 30,000+ ENVISAT ASAR scenes
- 100,000+ Sentinel-1 A/B SAR scenes
- Wind processing using SAROPS tool by APL/NOAA
- Processing choices:
  - GMF: CMOD5.n
  - Pol. ratio for HH: Mouche et al. (2005)
  - Wind direction input: GFS model

Wind map from Sentinel-1B, Irish Sea, May 3 2018 at 06:29 UTC
Wind speed comparisons - model

Envisat ASAR vs. GFS model

Sentinel-1A SAR vs. GFS model

Wind speed comparisons – mast

Høvsøre, Denmark

\[ R^2 = 0.97 \]
\[ y = 1.04x \]
\[ N_{\text{total}} = 256 \]
\[ \text{RMSE} = 1.70 \]
\[ \mu_x - \mu_y = -0.44 \]

\[ \mu_y = 8.77 \]

\[ R^2 = 0.98 \]
\[ y = 1.06x \]
\[ N_{\text{total}} = 85 \]
\[ \text{RMSE} = 1.37 \]
\[ \mu_x - \mu_y = -0.71 \]

\[ \mu_y = 9.03 \]
Wind speed comparisons – lidar

Figure 6. Relative wind speed nondimensionalized with the wind speed at −3000 m for from the LiDAR and the SAR for (a) the dual Doppler and (b) the sector scans.

Wind speed comparisons – lidar

10-m offshore wind atlas for Europe

Number of samples

Envisat and Sentinel-1 A/B

ASCAT

10-m offshore wind atlas for Europe

Mean wind speed

Envisat and Sentinel-1 A/B

ASCAT

Wind atlas statistics

Each grid cell:

- 0.02° latitude/longitude
- Weibull scale and shape parameters
- Wind power density

<table>
<thead>
<tr>
<th></th>
<th>Weibull-A</th>
<th>Weibull-k</th>
<th>Mean speed</th>
<th>Power density</th>
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<tr>
<td>Fitted</td>
<td>8.9 m/s</td>
<td>2.21</td>
<td>7.88 m/s</td>
<td>522 W/m²</td>
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<tr>
<td>Emergent</td>
<td>-</td>
<td>-</td>
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<td>522 W/m²</td>
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<tr>
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<td>8.9 m/s</td>
<td>2.22</td>
<td>7.89 m/s</td>
<td>522 W/m²</td>
</tr>
</tbody>
</table>

Example site in the North Sea
100-m offshore wind atlas for Europe

Mean wind speed

Envisat and Sentinel-1 A/B

ASCAT

Extrapolation of SAR wind speeds to hub height

- Based on the numerical weather prediction model WRF
- Long-term average stability correction and wind profile
- Differences between SDW and ENW can be large

\[
\left( \frac{\kappa}{u} \right) u(z) = \ln \left( \frac{z}{z_0} \right) - \langle \psi_m \rangle
\]

Global Wind Atlas

http://science.globalwindatlas.info/science.html
Conclusions

• Open access to SAR observations and derived products has eased application in the wind energy community

• SAR wind samples have reached numbers that are satisfactory for wind energy resource assessment – and new data is collected daily

• Methods for wind extrapolation from 10 m to the turbine hub height exist

• Remaining challenges:
  - Calibration consistency is crucial for wind resource estimation (Envisat vs. S-1 A/B)
  - Incidence angle dependence persists (positive wind speed bias at high incidence angles)
  - GMFs may be optimized and input wind direction inputs improved
  - Reprocessing of large image archives is computationally challenging
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Thank you