Synthetic Aperture Radar for wind energy applications: potential and challenges at high wind speeds

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Synthetic Aperture Radar for wind energy applications: potential and challenges at high wind speeds

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Offshore wind energy

Annual wind power installations 2016-2020.
Source: GWEC.

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SAR wind data archive at DTU

- 30,000+ ENVISAT ASAR scenes (2002-2011)
- 36,000+ Sentinel-1 A/B SAR scenes (2014-→)
SAR Ocean Products System (SAROPS)

- Evolved from the APL/NOAA SAR Wind Retrieval System
  [http://fermi.jhuapl.edu/](http://fermi.jhuapl.edu/)

- SAR wind retrieval in near-real-time

- NOAA covers polar seas and US coastlines (operational)
  

- DTU covers the European seas (routine)
Sentinel-1 A retrievals over the UK

October 31, 2016 at 06:06 UTC

October 27, 2016 at 17:50 UTC
Mountain gravity waves

November 6, 2006

Envisat ASAR 10-m wind speed

Cloud image
WRF wind speed


Open cells

*Envisat ASAR 10-m wind speed*

Cloud image

DTU Wind Energy, Technical University of Denmark


DTU Wind Energy, Technical University of Denmark
Boundary layer rolls
May 17 and May 25, 2011

Envisat ASAR 10-m wind speed
Svensson N., Bergström H., Sahlée E., Nilsson E., Badger M. and Rutgersson A. (2016), Offshore advection of boundary layer rolls, Submitted to BLM.
Wind resource mapping
Chain of processes

Download and pre-processing

SAR
GFS
Ice

SAROPS

Wind maps

S-WAsP

Wind resource maps
(10 m)

WRF + MOST

Wind resource maps
(100 m)

Wind retrieval
(APL/NOAA)

Wind resource assessment (DTU)

Wind resource extrapolation (DTU)

ESA OWI product
The New European Wind Atlas (NEWA)

- Envisat ASAR and Sentinel-1 A/B
- Extrapolation to different heights up to 100 m
- Extensive measurement campaigns and modeling

Coverage of the satellite based atlas in NEWA

(image courtesy Google Earth)
Preliminary 10-m atlas for Europe

*Envisat ASAR and Sentinel-1A/B combined*

DTU Wind Energy, Technical University of Denmark
Wind speed comparisons

Envisat ASAR vs. GFS model

Sentinel-1A SAR vs. GFS model

Wind class sampling

Stability:

- Stability class definition from NCEP/NCAR re-analysis data

Weightings:

- Weighting and Weibull fitting
- Population of each wind class with a SAR wind field

Advantages of wind class sampling

- Compensates for a limited number of SAR samples
- Long-term wind climatology may be obtained
- Results are directly comparable with mesoscale modeling results

Example from the UAE:

10-m mean wind speed from Envisat ASAR data (225 scenes)

10-m mean wind speed from KAMM mesoscale modeling
Long-term average wind profile

\[
\left\langle \frac{\kappa u(z)}{u_*} \right\rangle = \ln \left( \frac{z}{z_0} \right) - \langle \psi_m \rangle
\]
Wind speed extrapolated to 100 m

Conclusions

• Future wind energy developments are global and high-wind issues must be considered

• SAR wind retrievals offshore are valuable for:
  1) Model validation
  2) Wind resource mapping
  3) Wind farm wake analyses

• Strenght of SAR winds: a high spatial resolution

• Limitations of SAR winds: Lack of high-wind samples and information above the 10-m level above m.s.l.
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