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

Badger, Merete; Larsén, Xiaoli Guo; Hasager, Charlotte Bay; Ahsbahs, Tobias Torben; Hahmann, Andrea N.; Pena Diaz, Alfredo; Badger, Jake

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

Merete Badger

Xiaoli Guo Larsén
Charlotte Hasager
Tobias Ahsbahs
Andrea Hahmann
Alfredo Peña
Jake Badger

DTU Wind Energy
Department of Wind Energy
Offshore wind energy

Annual wind power installations 2016-2020.
Source: GWEC.
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
  
  \[\text{http://fermi.jhuapl.edu/}\]

- 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

DTU Wind Energy, Technical University of Denmark


Open cells

Envisat ASAR 10-m wind speed

Cloud image

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

DTU Wind Energy, Technical University of Denmark
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

Wind class sampling

Weightings:
- <=0.5 %
- =1.0 %
- =2.0 %
- =3.0 %

Stability:

Wind class definition from NCEP/NCAR re-analysis data

Population of each wind class with a SAR wind field

Weighting and Weibull fitting

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

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

a. 100 m ENW from SAR

b. 100 m SDW from SAR

Without stability correction  With stability correction

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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