

Measuring wind from space for offshore wind energy applications

Hasager, Charlotte Bay

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Measuring wind from space for offshore wind energy applications

Prof. Charlotte Hasager

Denmark

Sea Tech, 13 October 2020, virtual live

Content

Introduction

Earth Observations

- Cluster effects between offshore wind farms
- Offshore wind ressources

Wind lidar

Conclusions



- A department in the Technical University of Denmark
- Founded in 1979 in Denmark
- 250 employees
- Largest wind energy research institute in the world
- Research, Education, Scientific Advice
- Organized in 3 divisions:
 - o Wind Energy System
 - Wind Turbine Technology
 - Structures, Material and Components



Wind energy electricity in % in Europe

Source: Wind Europe 2029

https://windeurope.org/wpcontent/uploads/files/aboutwind/statistics/WindEurope-Annual-Statistics-2019.pdf





Europe now has a total installed offshore wind capacity of 22 GW

Offhore wind energy vision Europe

Our energy, our future

How offshore wind will help Europe go carbon-neutral

Source:

Wind Europe 2019 https://windeurope.org/wpcontent/uploads/files/aboutwind/reports/WindEurope-Our-Energy-Our-Future.pdf





Wind power generation



Østerild Test Centre – Prototype Wind Turbines (since 2012)

7 Wind Turbines – Max. 16 MW each – Max. height 250 m

DTU Wind I

2015





Wind farm wakes







Source: Bastankhah, M. and Porté-Agel, F. 2014, Renewable Energy, <u>https://doi.org/10.1016/j.renene.2014.01.002</u>

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L07 K07 EO3 FOR E07 D06 BOG Photo by: Bel Air Aviation Denmark - Heli

Acknowledgement to Ørsted A/S.

Hasager, C.B., Nygaard, N. G., Volker, P. J. H., Karagali, I., Andersen, S. J., Badger, J. (2017): Wind Farm Wake: The 2016 Horns Rev Photo Case Energies 10(3), 317

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FUGA : Wake model for large offshore wind farms

Windfarm wake view



http://www.wasp.dk/fuga

Ott, S., & Nielsen, M. (2014). Developments of the offshore wind turbine wake model Fuga. DTU Wind Energy. DTU Wind Energy E, No. 0046



Earth Observations

Applications for offshore wind energy

• Mean wind conditions



• Horizontal coastal wind speed gradients

• Wind farm wake effects



Model validation





Satellite wind maps

• We add Synthetic Aperture Radar satellite wind maps to the analysis





Satellite SAR wind data archive at DTU

Contact: Merete Badger, mebc@dtu.dk

Log in Register





Cluster effects



Northern European offshore wind farms







Satellite SAR shows wind farm wakes

RADARSAT-2 from Data and Products © MacDonald, Dettewiler and Associates Ltd

WRF-EWP minus WRF



WRF shows wind farm wakes

Courtesy: Du, Volker and Larsén (2018): OffshoreWake project report WP3 (the simulation is done using COAWST modeling system, mostly by Du J)

Hasager, C. B., Vincent, P., Badger, J., Badger, M., Di Bella, A., Pena Diaz, A., ... Volker, P. (2015). Using Satellite SAR to Characterize the Wind Flow around Offshore Wind Farms. Energies, 8(6), 5413-5439. DOI:10.3390/en8065413



Mesoscale modelling of Thornton Bank (BE) and Belwind (BE)



Courtesy: Patrick Volker



Offshore wind resources



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Global Wind Atlas 3.0 released

Wind energy Energy

DTO WING Energy

🌶 in

WEDNESDAY 23 OCT 19 | By Charlotte Hede Linde

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Model validation – compex flows around islands



Hasager, C.B., Badger, M. Nawri, N., Furevik, B.R., Petersen, G. N., Björnsson, H., Clausen, N.-E. (2015): Mapping offshore winds around Iceland using satellite Synthetic Aperture Radar and mesoscale model simulations. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, <u>10.1109/JSTARS.2015.2443981</u>.



Ahsbahs, T., Badger, M., Volker, P., Hansen, K.S., Hasager, C.B. 2018 Applications of satellite winds for the offshore wind farm site Anholt. *Wind Energy Science* <u>https://doi.org/10.5194/wes-2018-2</u>

Anholt Offshore Wind Farm





Source: Ørsted

Anholt wind farm



Acknowledgement to Ørsted A/S.

Ahsbahs, T., Badger, M., Volker, P., Hansen, K.S., Hasager, C.B. 2018 Applications of satellite winds for the offshore wind farm site Anholt. *Wind Energy Science* <u>https://doi.org/10.5194/wes-2018-2</u>



US East Coast: SAR vs. WRF

Ahsbahs, T., Maclaurin, G., Draxl, C., Jackson, C. R., Monaldo, F., and Badger, M. 2020 US East Coast synthetic aperture radar wind atlas for offshore wind energy, Wind Energ. Sci., 5, 1191–1210, https://doi.org/10.5194/wes-5-1191-2020





Vertical profile



https://www.researchgate.net/figure/Stability-variation-curves-of-the-logarithmic-wind-profiles_fig1_277995087

Wind speed extrapolation from 10 m to hub-height



Badger, M., Peña. A., Hahmann, A.N., Mouche, A., Hasager, C.B. (2016) Extrapolating satellite winds to turbine operating heights. *Journal of Applied Meteorology and Climatology*, doi:10.1175/JAMC–D–15–0197.1



a) Envisat ASAR and
Sentinel-1 combined
mean wind speed
(m s⁻¹) at 10 m
height (a),

b)number of samples

c) mean wind speed at 100 m a.m.s.l. including long-term stability correction for extrapolation

d) and difference on wind speed at 100 m height based on longterm stability correction minus neutral wind profile assumption

Hasager et al. 2020 Europe's offshore wind resource assessed with synthetic aperture radar, ASCAT and WRF, Wind Energ. Sci., 5, 375–390, https://doi.org/10.5194/wes-5-375-2020

PO

[m

WRF New European Wind Atlas



Mean wind speed at 100 m height for 1989 to 2018 with 3 km resolution

Hasager et al. 2020 Europe's offshore wind resource assessed with synthetic aperture radar, ASCAT and WRF, Wind Energ. Sci., 5, 375–390, https://doi.org/10.5194/wes-5-375-2020

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Wind lidar

Measure winds at several heights including hub-height





Wind lidar at offshore platforms



https://www.researchgate.net/figure/Photograph-of-selected-lidars-on-platform_fig3_259502414



Conclusions

- Wind farm wake and cluster effects
- Observe with satellite SAR (models: FUGA and WRF)
- Offshore wind resources
- Observe wind satellite SAR (model: WRF)
- Recommendation:
- To observe offshore wind spatially using satellite SAR and at height using wind lidar