Resource and extremes, etc.

Challenges in mesoscale modelling for offshore wind energy

Speaker: Xiaoli Guo Larsén (xgal@dtu.dk)

Relevance

Resource

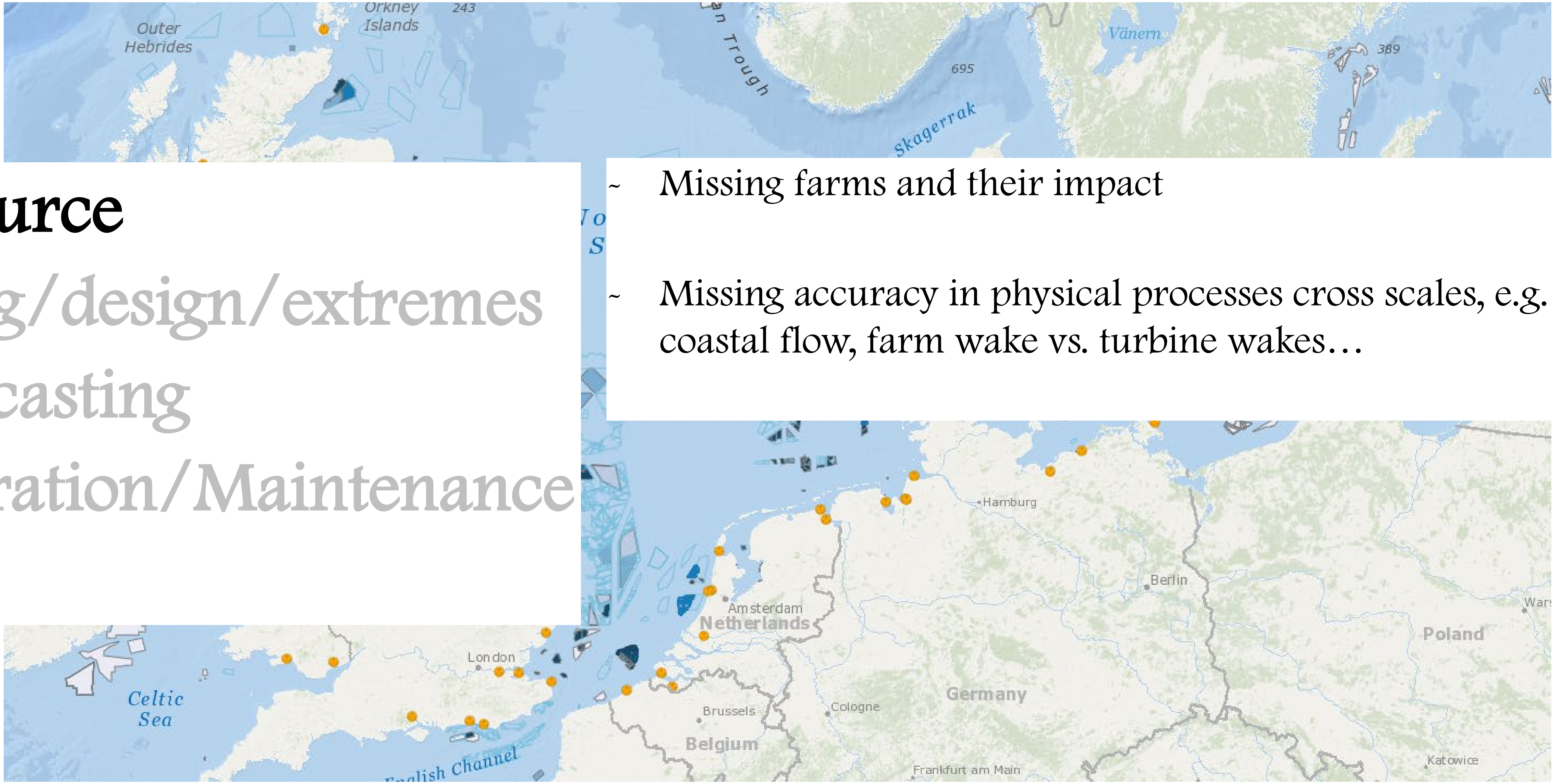
Siting/design/extremes

Forecasting

Operation/Maintenance

…

State-of-the-art: resources/challenges



Resource

Siting/design/extremes

Forecasting

Operation/Maintenance

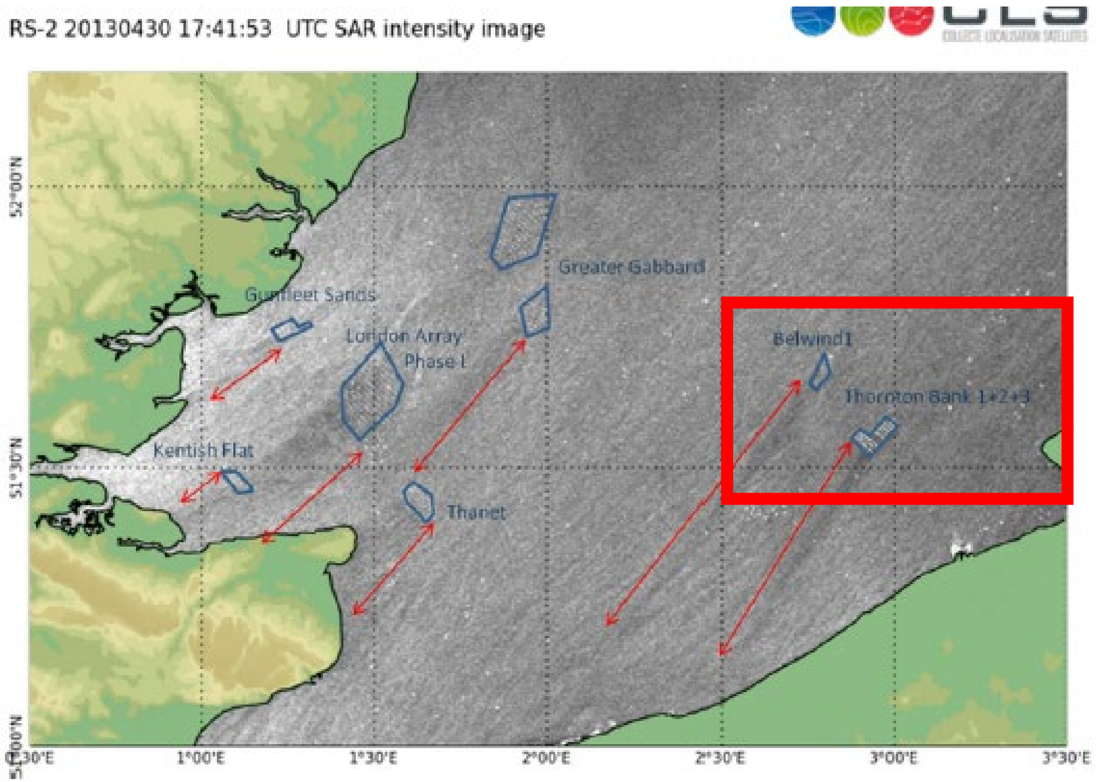
…

- Missing farms and their impact
- Missing accuracy in physical processes cross scales, e.g. coastal flow, farm wake vs. turbine wakes…

From 4coffshore.com

State-of-the-art: resources

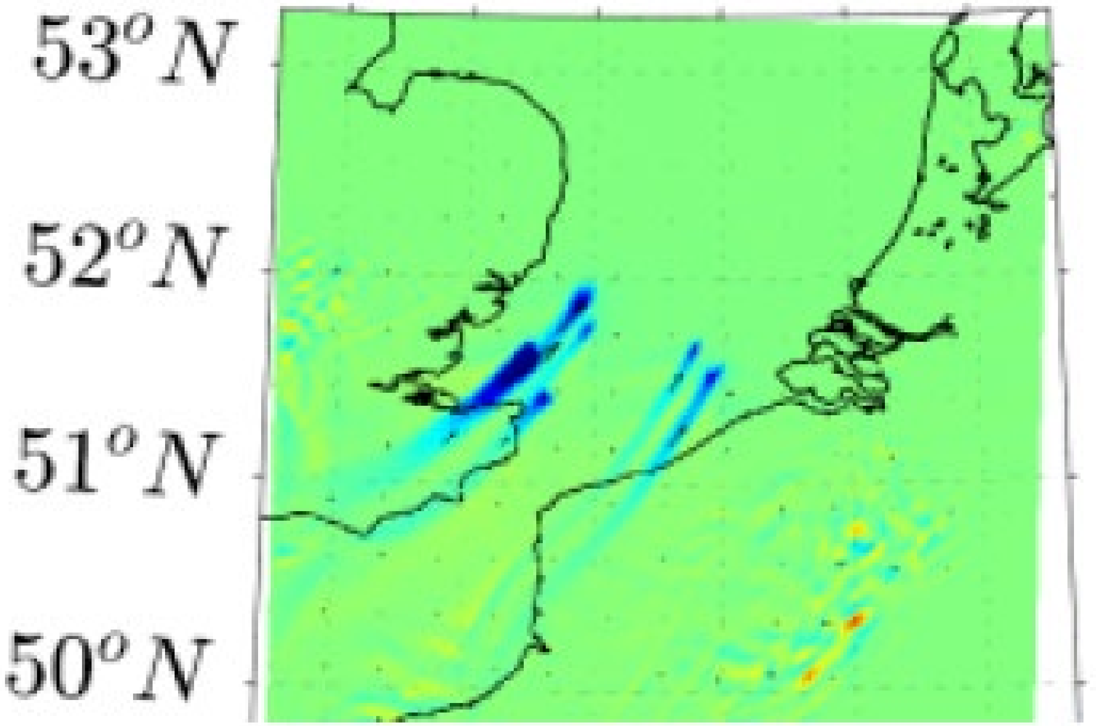
Wind farm cluster effects



Satellite SAR shows wind farm wakes

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

WRF-EWP minus WRF



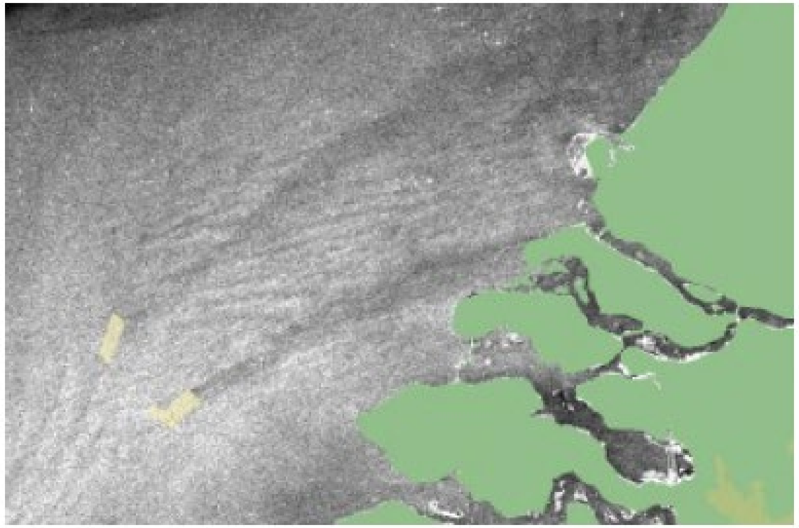
WRF shows wind farm wakes

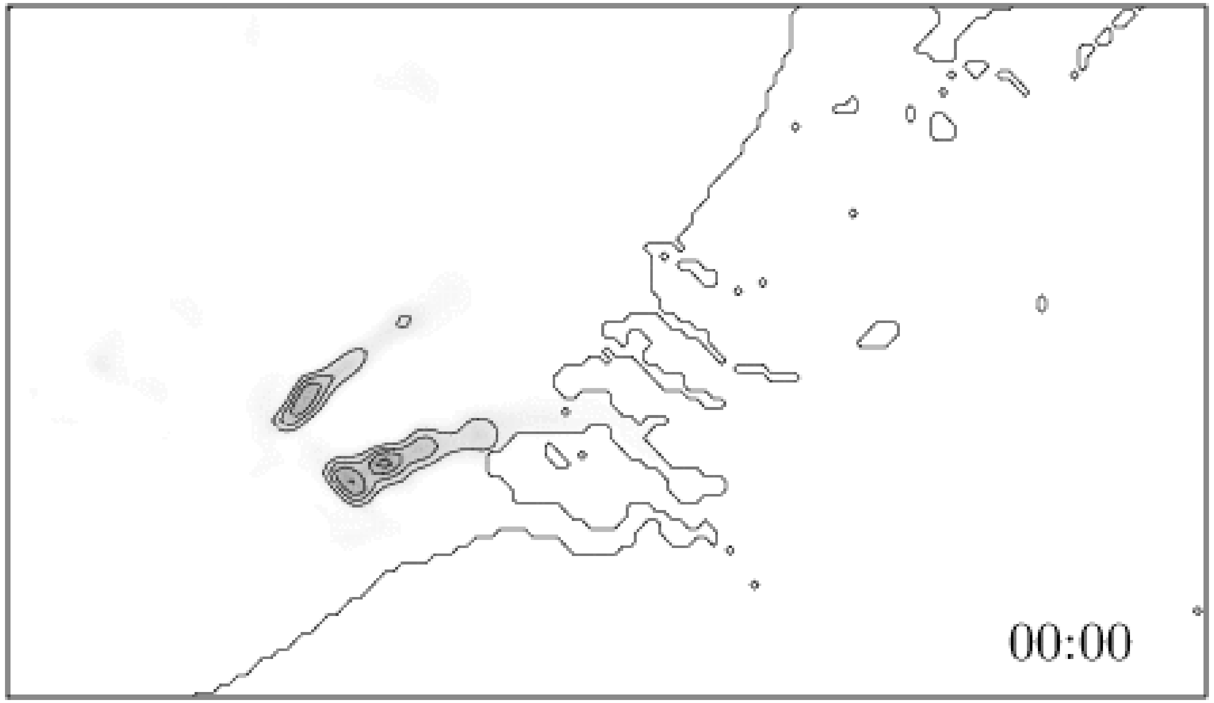
Courtesy: Du, Volker and Larsén (2018): OffshoreWake project report WP3 (the simulation is done using COAWST modeling system, mostly by Du J)

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

State-of-the-art: resources

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





Courtesy: Patrick Volker

State-of-the-art: resources

DTU’s OffshoreWake Calcultion System: WRF+SWAN+WAKE+POWER BALANCING

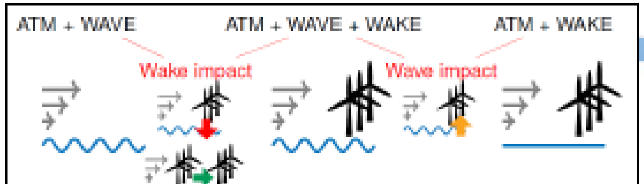


Fig. 2 Processes in modeling

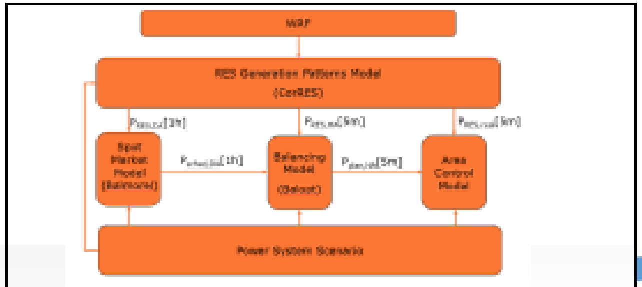
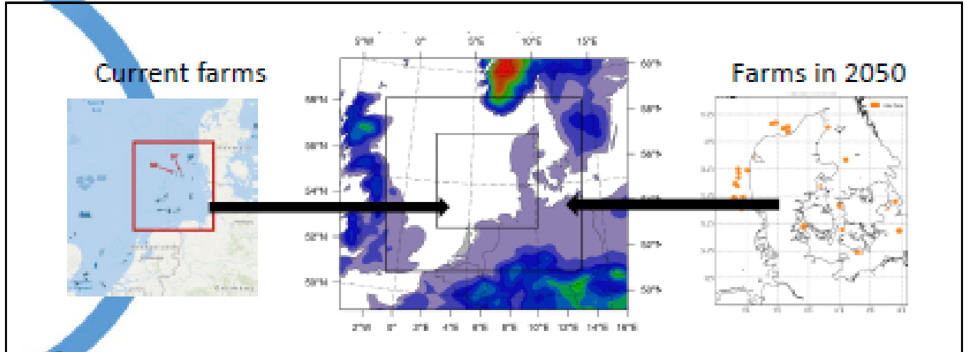


Fig. 3. The power balancing model system

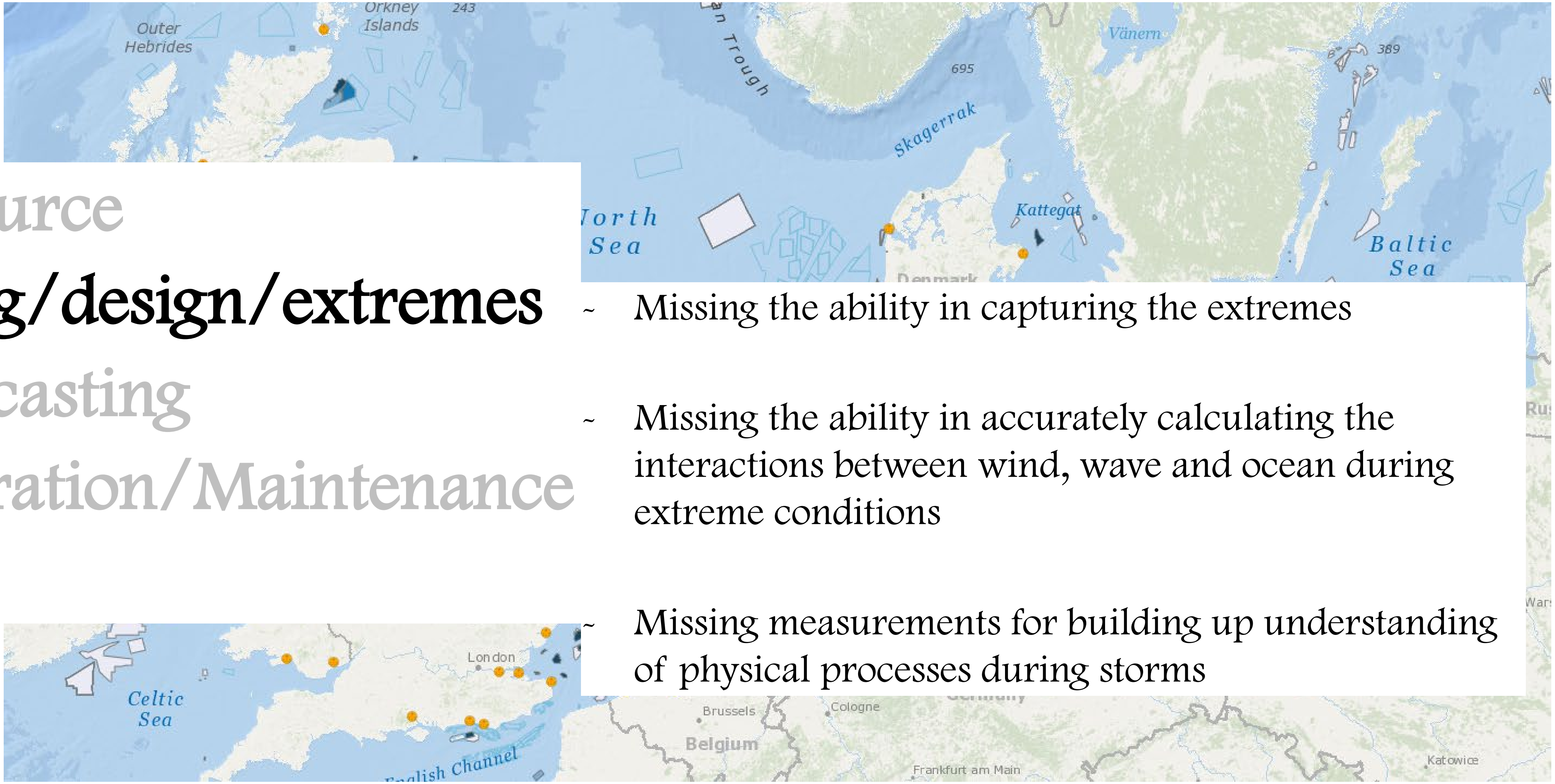


Fig, 4. Importing current and future wind farms into modeling system.

- Couple wind-wave-current-wake modeling (WRF-SWAN(WBLM)-ROMS-EWP/FITCH)[2,3]
- Power balancing model with coupled model input
- Long term modeling, using both climatologically representative year method [4] and statistical-dynamical downscaling method [1]
- For current, as well as future scenarios (2050)
- Calibration, verification and validation using measurements (SCADA at DanTysk (DT) and Sandbank (SB), numerous stations and SAR data)

Larsén X.G., Volker P., Imberger M., Fischereit J., Langor E., Hahmann A., Ahsbahs T., Duin M., Ott S., Sørensen P., Koivisto, M., Maule P., Hawkins S., Kishore A. and Du J. (2019): Calculation of wakes from offshore wind farm cluster and the introduction to the Danish power integration system. WindEurope Offshore 2019, Copenhagen.

State-of-the-art: extremes/challenges



Resource

Siting/design/extremes

Forecasting

Operation/Maintenance

…

- Missing the ability in capturing the extremes
- Missing the ability in accurately calculating the interactions between wind, wave and ocean during extreme conditions
- Missing measurements for building up understanding of physical processes during storms

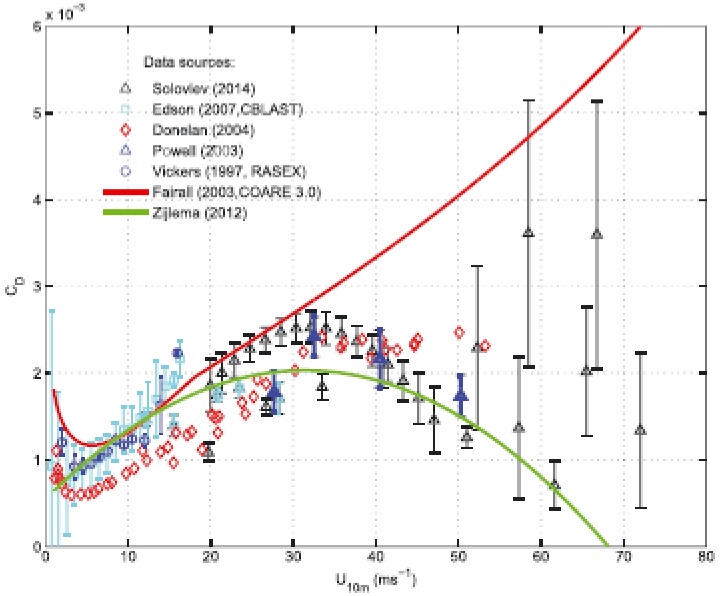
From 4coffshore.com

State-of-the-art: extremes/challenges

Our efforts target at:

1. capturing the storms – wind and waves[1,2,3,4,5]
2. capturing the key statistics of extremes[5,6]

C_D



Wind speed at 10 m (m/s)

[1] Larsén X., Du J. Bolanos R., Badger M., Kelly M. and Larsen S. Estimation of offshore extreme wind from wind-wave coupled modeling, Wind Energy DOI:10.1002/we.2339, vol 22, Issue 8.

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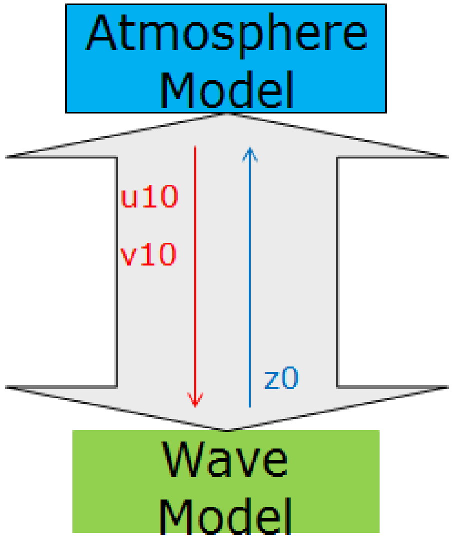
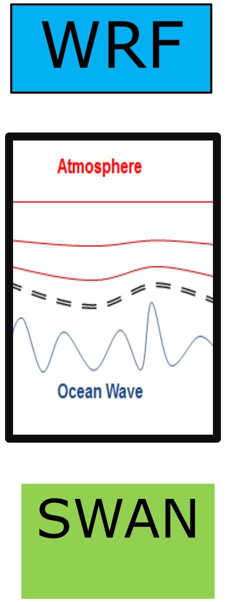
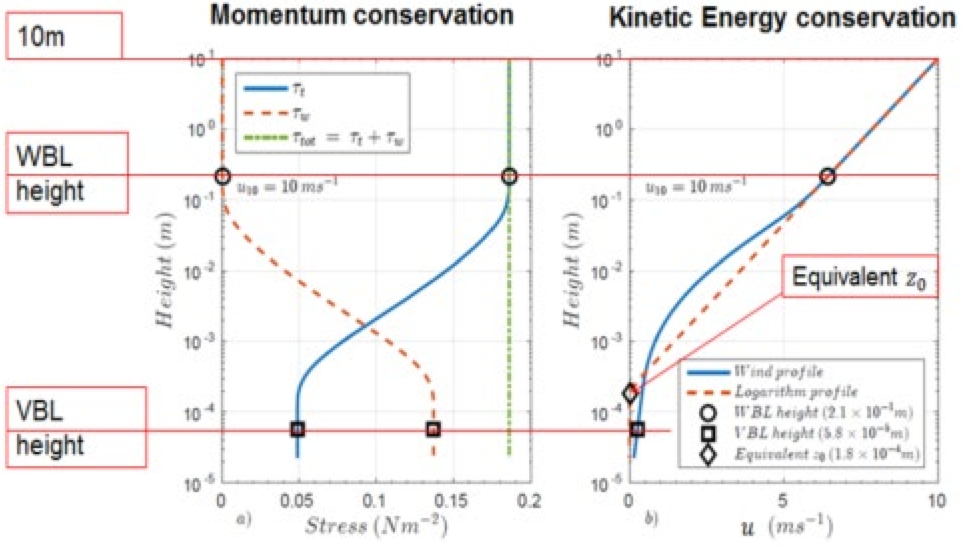


www.xwiwa.dk

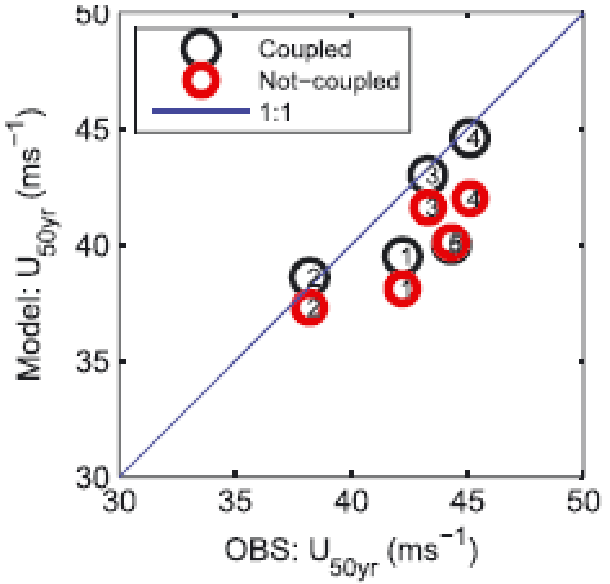


Janssen
Fan
Taylor&Yelland
Drennan
Oost
Liu
WBLM[1-3]



2 Du J., Bolanos R. and Larsén X. (2017) The use of a wave boundary layer model in SWAN. Journal of Geophysical Research - Ocean: DOI: 10.1002/2016JC012104, vol. 122, No 1, p42 - 62.
3. Du. J., Bolanos R., Larsén X. and Kelly M. 2019: Wave boundary layer in SWAN revisited. Ocean Science, ISSN 1812-0784, https://www.ocean-sci-discuss.net/os-2018-90/.
4. Larsén X., Du J., Bolanos R. and Larsen S. 2017: On the impact of wind on the development of wave field during storm Britta. Ocean Dynamics 67:1407-1427, DOI 10.1007/s10236-017-1100-1.
5. Imberger M., Larsén X., Davis N. and Du J. 2020: Approaches toward improving the modelling of mid-latitude cyclones entering at the lateral boundary corner in the limited area model WRF, Quarterly Journal of the Royal Meteorological Society. DOI:10.1002/qj.3843.

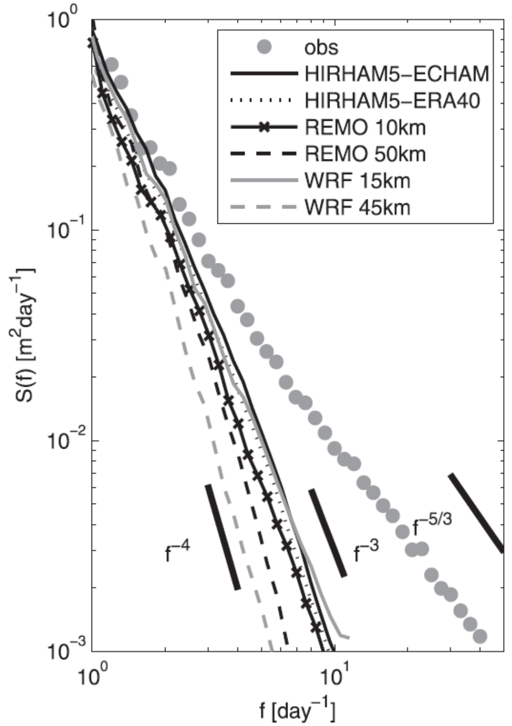
State-of-the-art: extremes



1. FINO1
2. FINO2
3. FINO3
4. Høvsøre
5. Horns Rev

[1] Larsén X., Du J. Bolanos R., Badger M., Kelly M. and Larsen S. Estimation of offshore extreme wind from wind-wave coupled modeling, Wind Energy DOI:10.1002/we.2339, vol 22, Issue 8.

State-of-the-art: extremes



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$$\overline{u}_{max} = \overline{U}_{max} - \overline{U} = \sqrt{m_0}\sqrt{2\ln\left(\frac{1}{2\pi}\sqrt{\frac{m_2}{m_0}}T_0\right)}.$$

$$m_j = 2\int_0^\infty \varphi^2(\omega)\omega^j S(\omega)\,d\omega,$$

6. Larsén X., Ott S., Badger J., Hahmann A. N. and Mann J. 2012: Recipes for correcting the impact of effective mesoscale resolution on the estimation of extreme winds. *Journal of applied meteorology and climatology*, Doi:10.1175/JAMC-D-11.090, vol 51, No. 3, p521-533.

State-of-the-art: extremes

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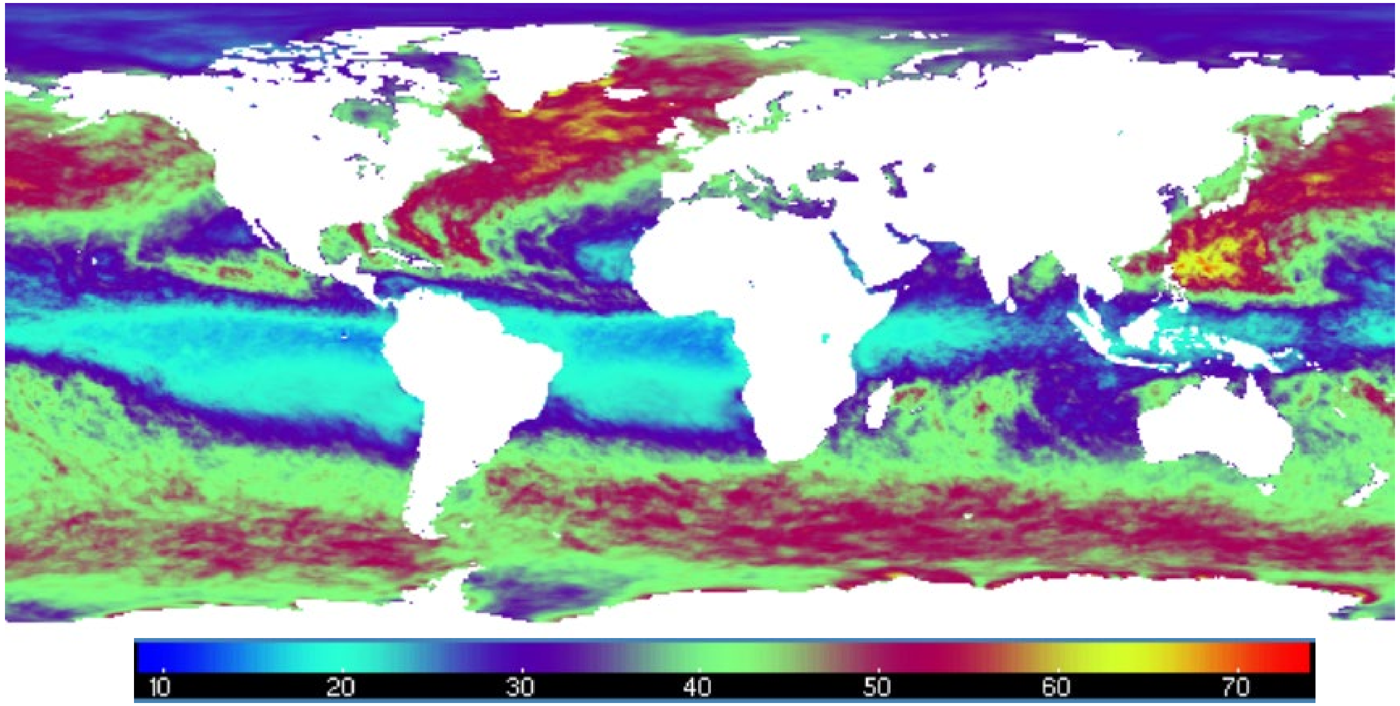

From our GASP project

50-year wind at 10 m, 50 m, 100 m, 150 m globally

State-of-the-art: extremes

Our efforts target at:

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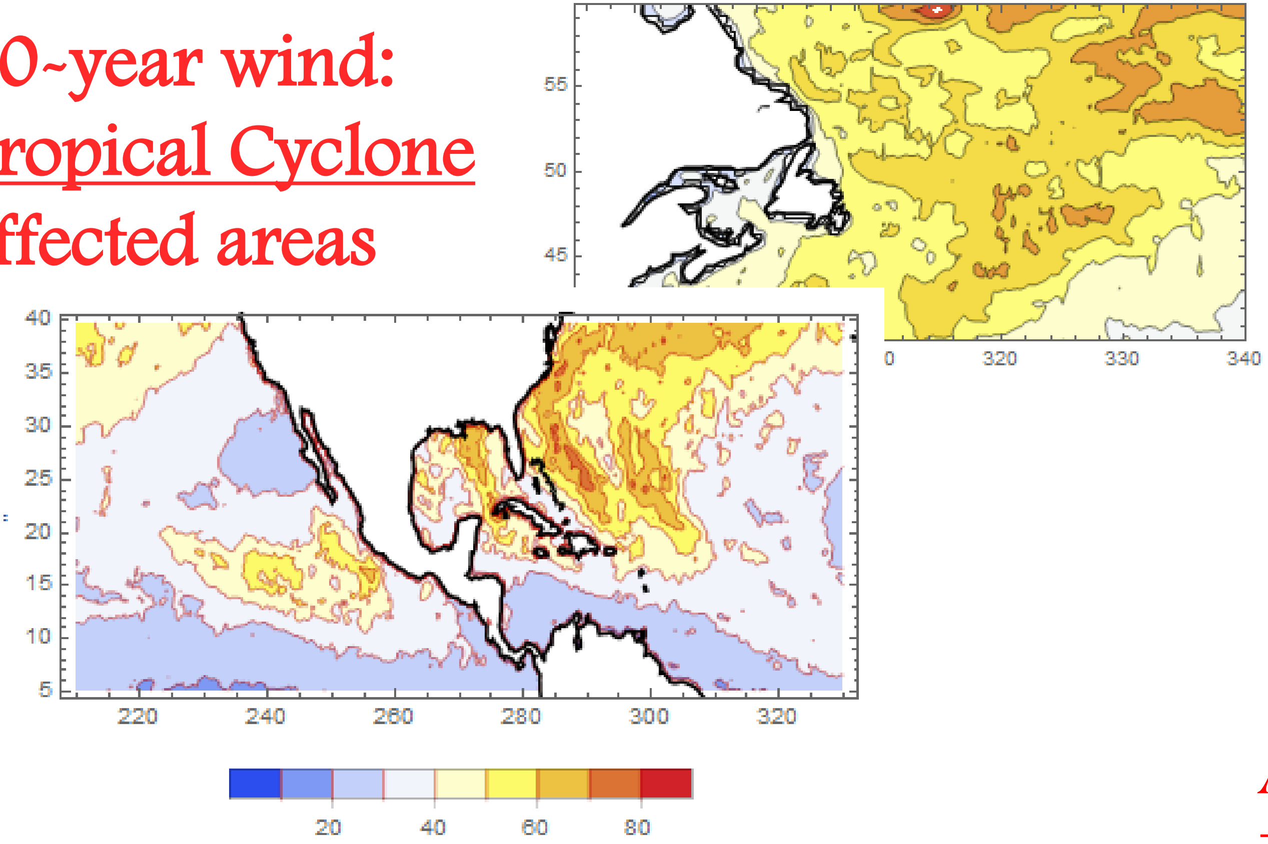
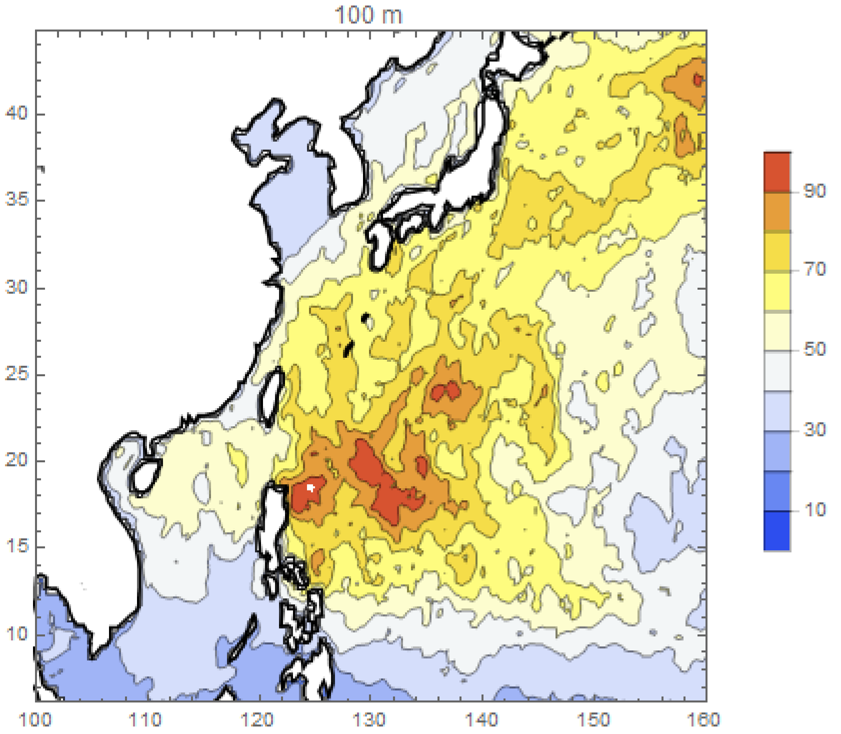
2. capturing the key statistics of extremes[6,7]

50-year wind: Tropical Cyclone affected areas





Method: Reanalysis data + Spectral Correction Method + Best Track machine learning[7]

[7] Larsén X. and Ott S. 2020: Extreme winds in tropical cyclone affected water areas, DTU Wind Energy E-Report-0206, draft.

Knowledge gap and future outlook

Accuracy

- Developing/collecting/using measurements with good target
- Understanding physical processes
- Combining physical and statistical approaches

Acknowledgement

Thanks to the contributions from colleagues (see names in publications) and support from projects: GASP, OffshoreWake (www.offshorewake.dk), X-WIWA (www.xwiwa.dk), WASA etc.

Appendix

State-of-the-art: extremes/challenges

Our efforts target at:

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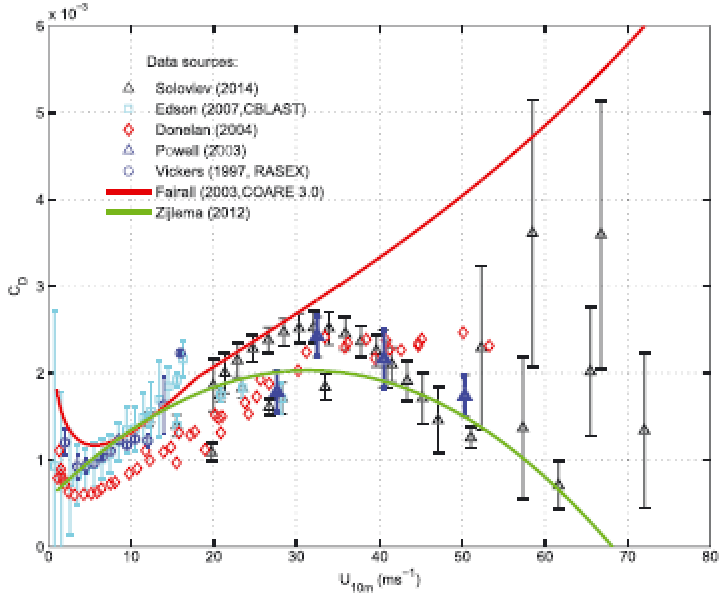
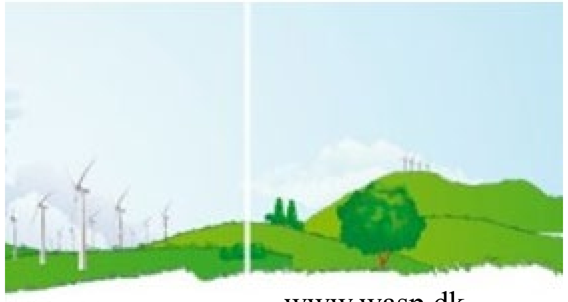


FIGURE 1 Drag coefficient C_D as a function of wind speed at 10 m height (U_{10m}), from aggregated measurements and literature (symbols). Zijlema is a simplified functional relation $C_D(U_{10m})$ for all measurements[10]; Fairall is a based on Equations 1 and 2, with Charnock coefficient α_{Ch} calibrated using measurements from COARE[16] [Colour figure can be viewed at wileyonlinelibrary.com]



www.wasp.dk

[1] Larsén X., Du J. Bolanos R., Badger M., Kelly M. and Larsen S. Estimation of offshore extreme wind from wind-wave coupled modeling, Wind Energy DOI:10.1002/we.2339, vol 22, Issue 8.