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Resource and extremes: where are we and where do we need to go? Focus on offshore mesoscale modeling

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Resource and extremes, etc.

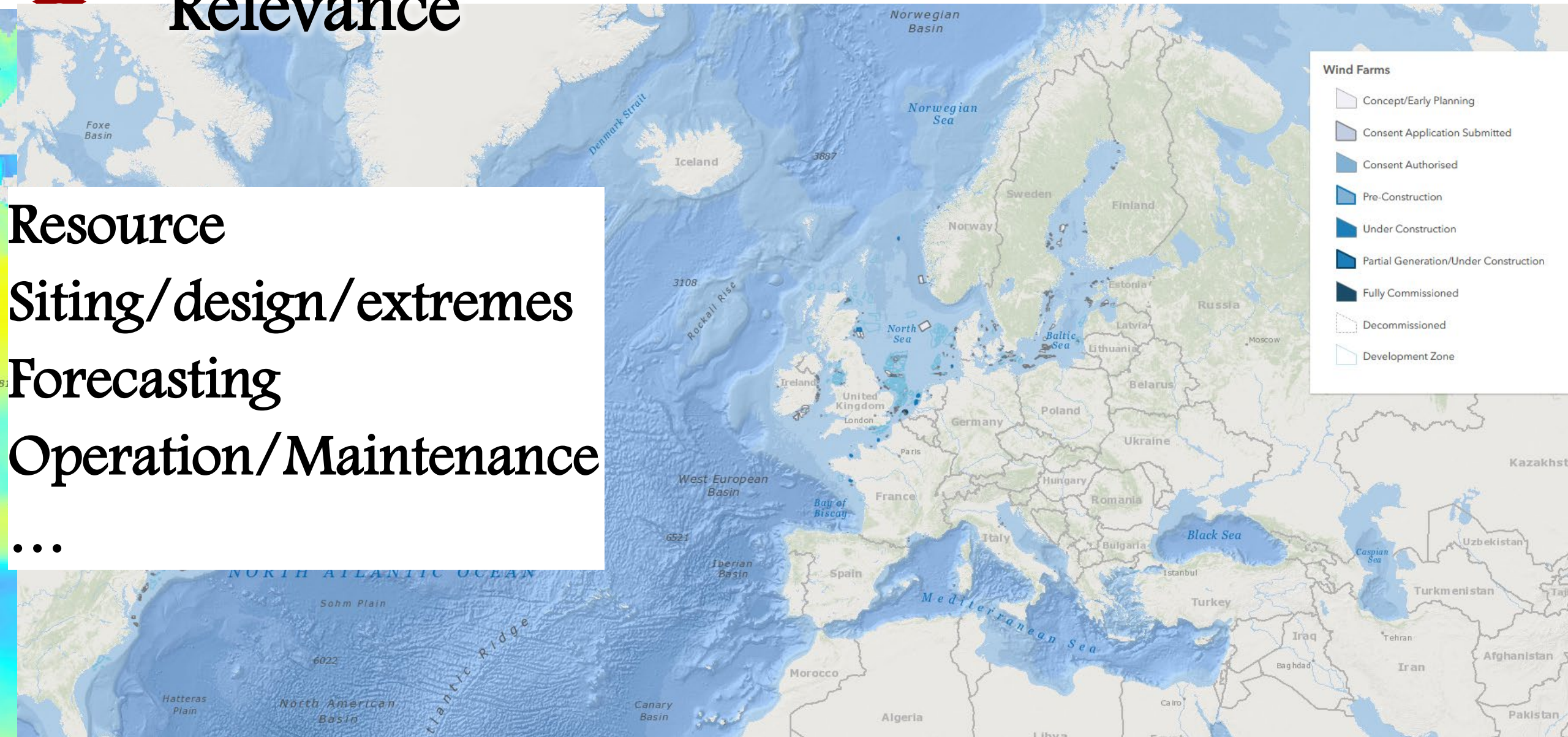# **Where are we and where do we need to go? Focus on offshore mesoscale modelling**

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Senior Scientist, DTU Wind Energy

MMC-Sponsored Industry Workshop: Atmospheric Science Challenges for the Wind Energy Industry, October 19-20, 2020, online

Relevance

Resource
Siting/design/extremes
Forecasting
Operation/Maintenance
…

Wind Farms

- Concept/Early Planning
- Consent Application Submitted
- Consent Authorised
- Pre-Construction
- Under Construction
- Partial Generation/Under Construction
- Fully Commissioned
- Decommissioned
- Development Zone

State-of-the-art: resources/challenges

Wind Farms

- Concept/Early Planning
- Consent Application Submitted
- Consent Authorised

Resource

Siting/design/extremes

Forecasting

Operation/Maintenance

...

- ~ Missing farms and their impact

- ~ Missing accuracy in the calculation of physical processes cross scales, e.g. coastal flow, farm wake vs. turbine wakes…
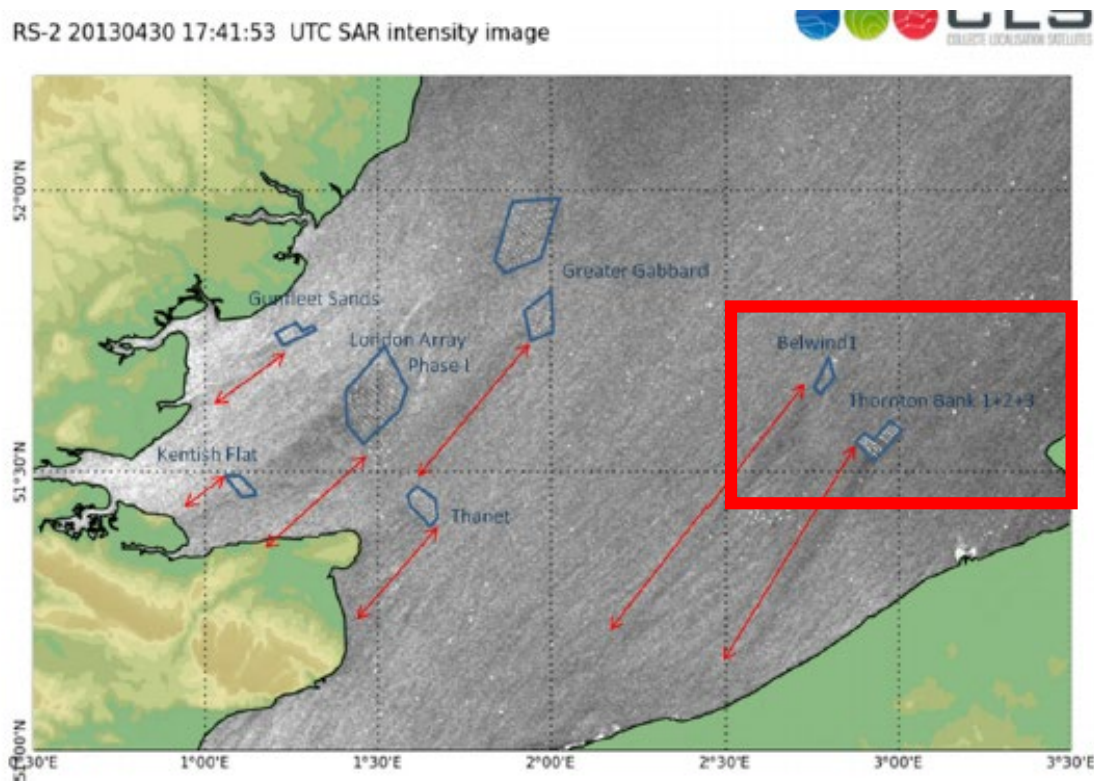
From 4coffshore.com
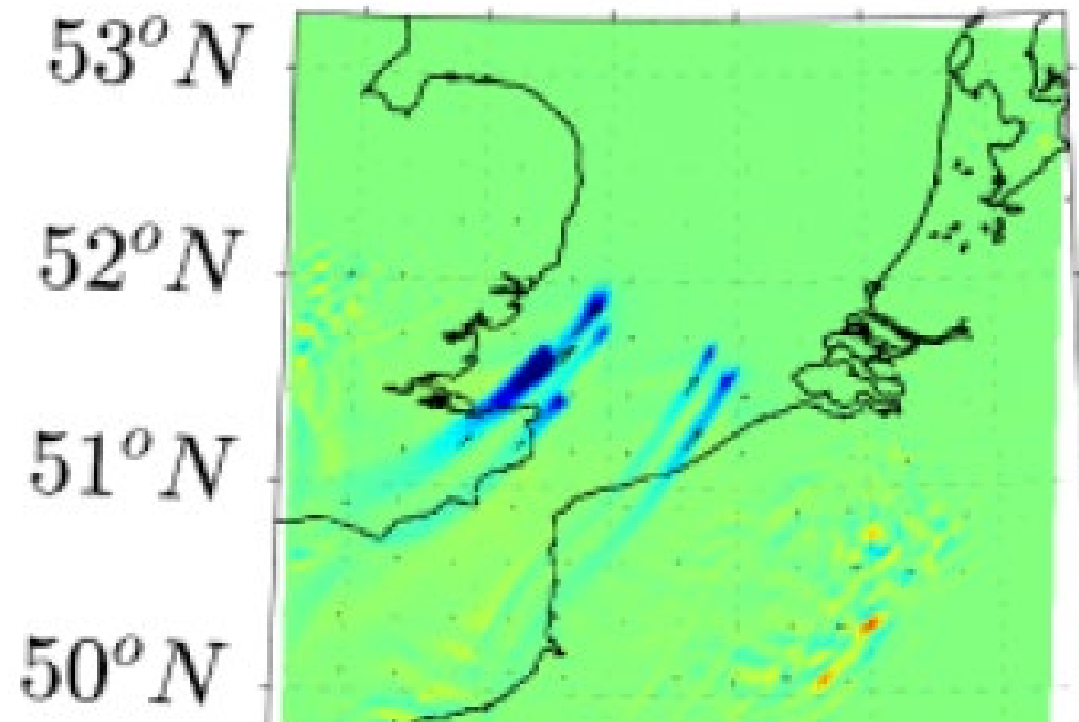
State-of-the-art: resources

Wind farm cluster effects

WRF-EWP minus WRF

Satellite SAR shows wind farm wakes

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

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
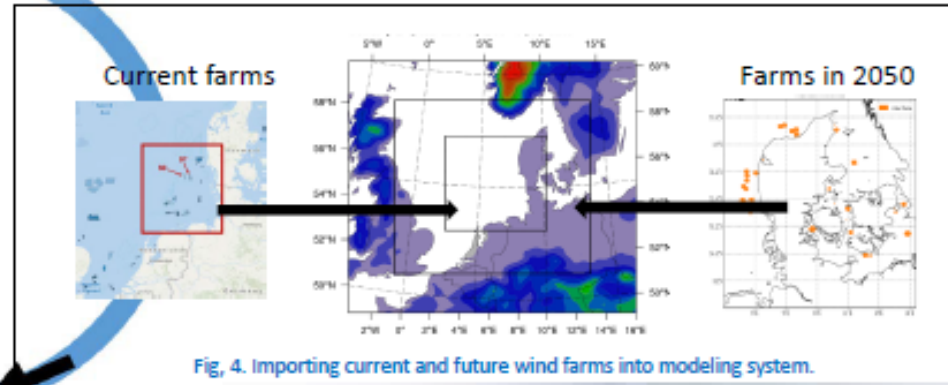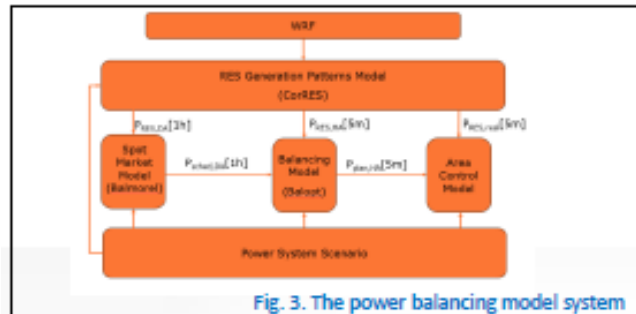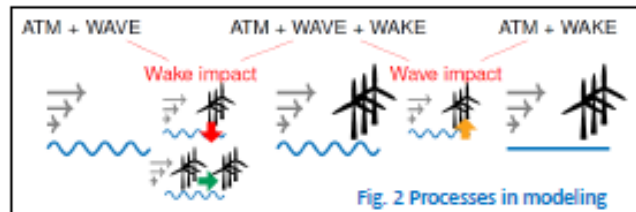
State-of-the-art: resources

Mesoscale modelling of Thornton Bank (BE) and Belwind (BE)
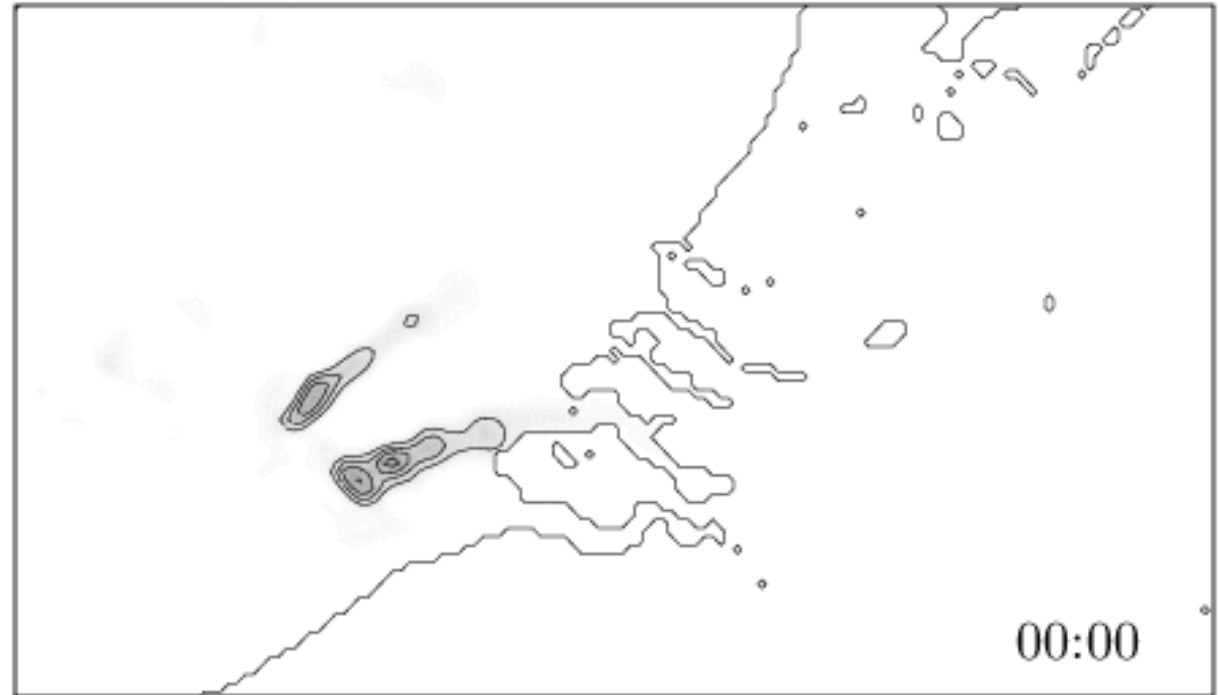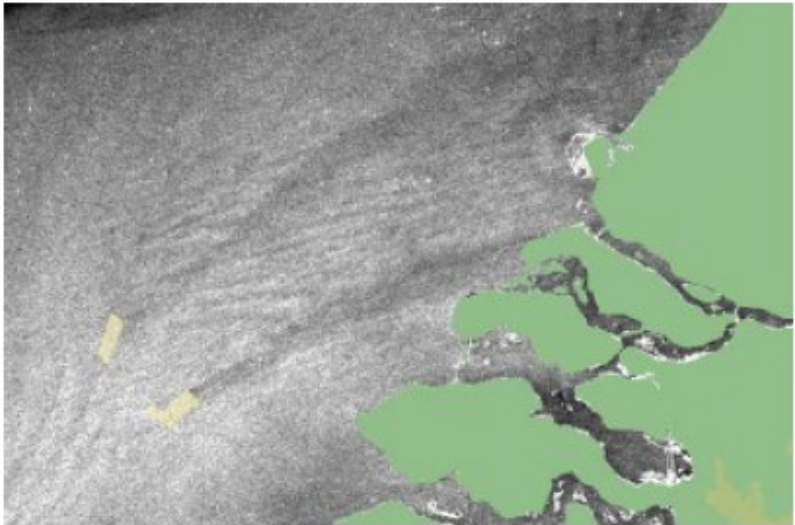
Courtesy: Patrick Volker

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

Current farms

Farms in 2050

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

www.offshorewake.dk

- 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., Du J. and Badger 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
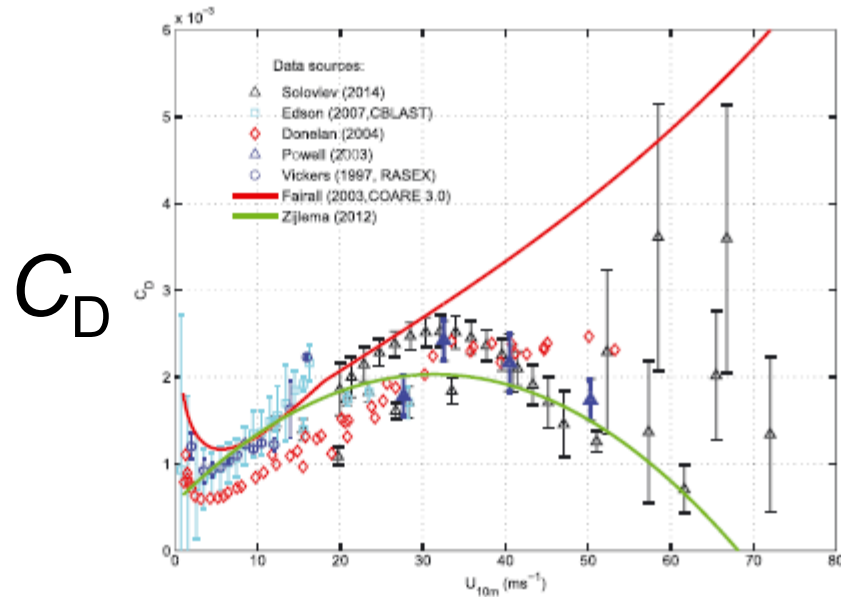
Wind speed at 10 m (m/s)

[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.

State-of-the-art: extremes

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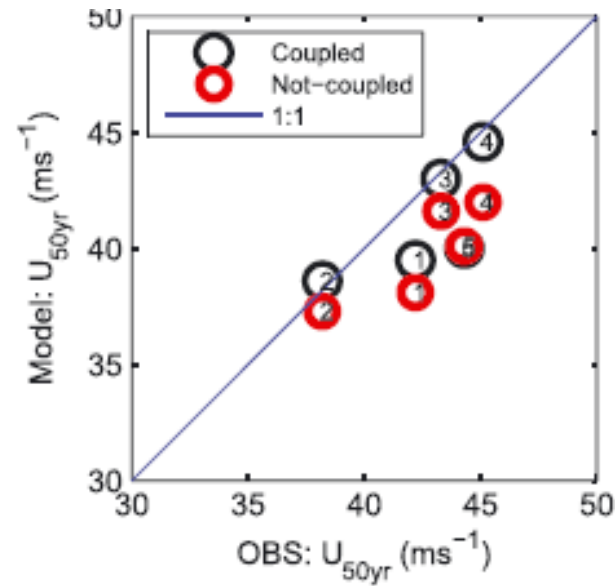2. capturing the key statistics of extremes[5,6]
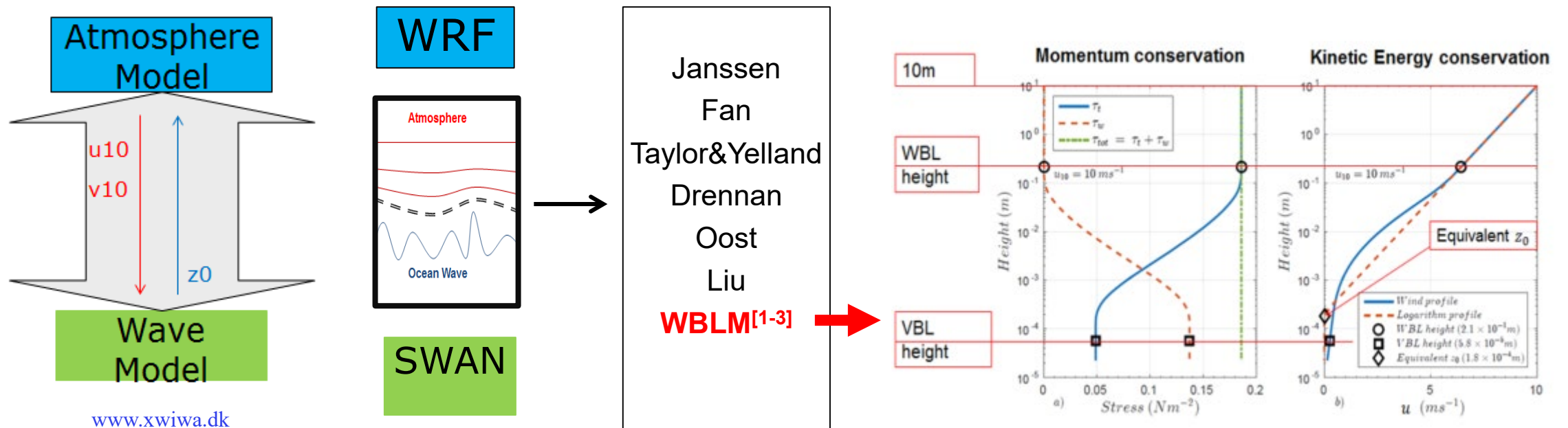
2 Du J., Bolanos R. and Larsén X. (2017) The use of a wave boundary layer model in SWAN. Journal of Geophysical Research - Ocean: DOI: 10.1002/2016JC012104, vol. 122, No 1, p42 - 62.

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
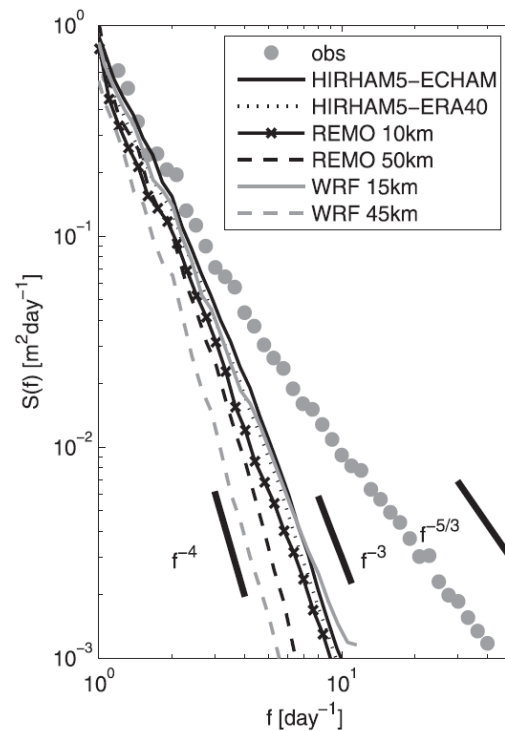

1. FINO1
2. FINO2
3. FINO3
4. Høvsøre
5. Horns Rev

[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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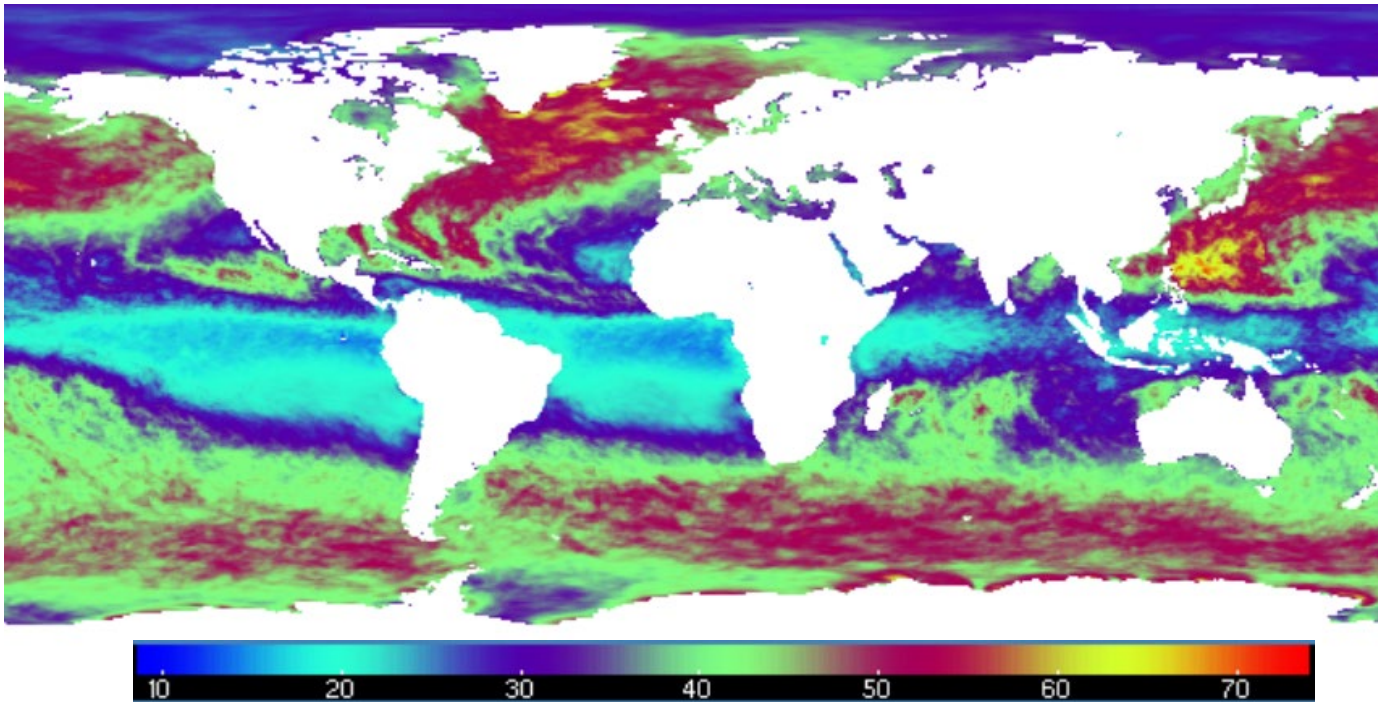
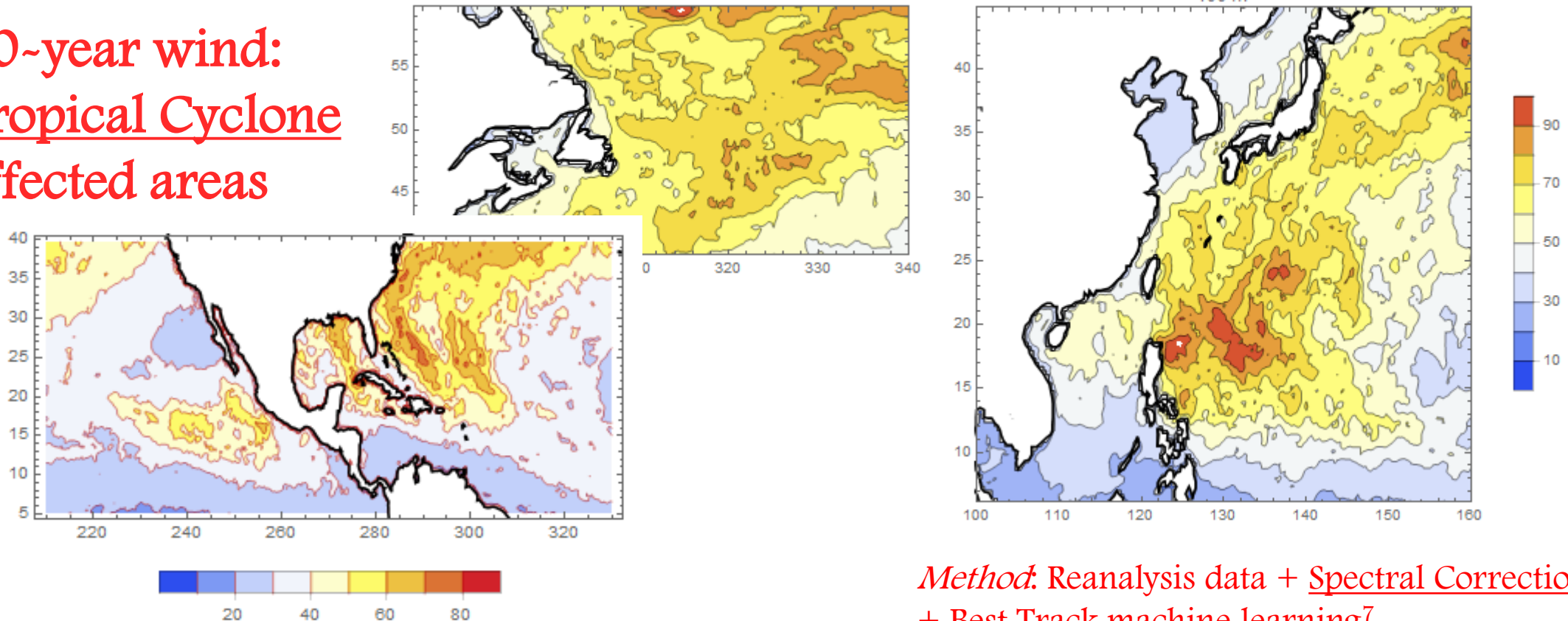

50-year wind at 10 m, 50 m, <u>100 m</u>, 150 m globally

From our GASP project (*ps. data are also available over land at a spatial resolution of 250 m*).

State-of-the-art: extremes

Our efforts target at:

1. capturing the storms – wind and waves[1,2,3,4,5]
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.