FREEWIND KU LEUVEN

Mesoscale weather systems and their interactions with wind farms: A study for the Kattegat

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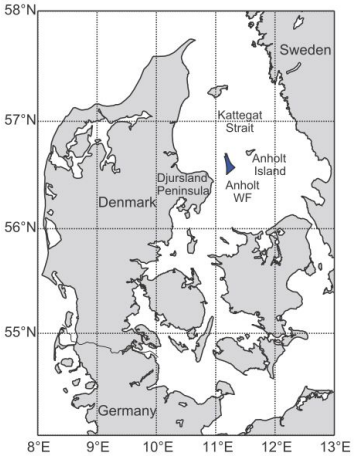
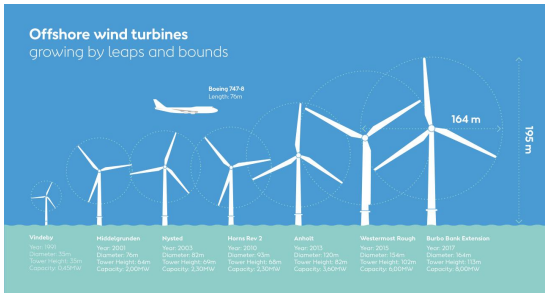
23/09/2021



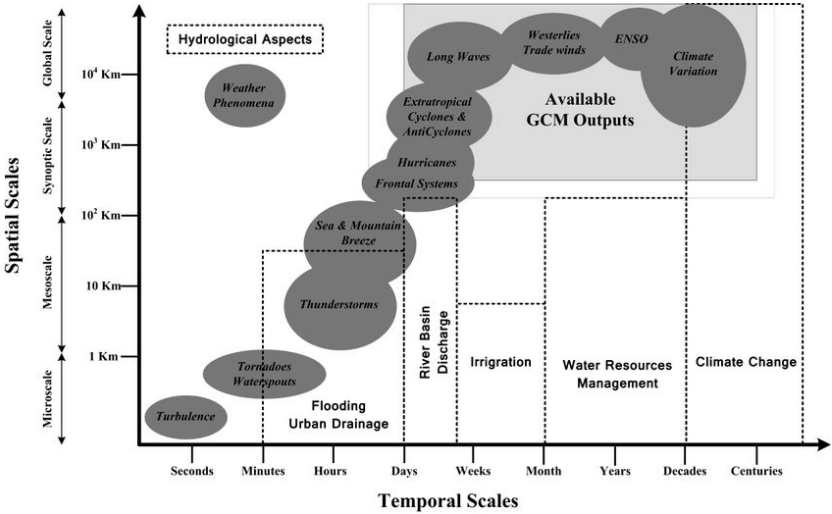
Introduction

Fast REsourcE planning and forecasting platform for the Belgian offshore WIND zones (freewind-project.eu)

Ever larger wind farms and turbines
-> stronger interaction with mesoscale systems (seabreezes, downbursts, …)



Source: orsted.com



Source: Nese and Grenci (2011)

Simulation domain

COSMO 5 CLM15

Kattegat seastrait around the Anholt wind farm

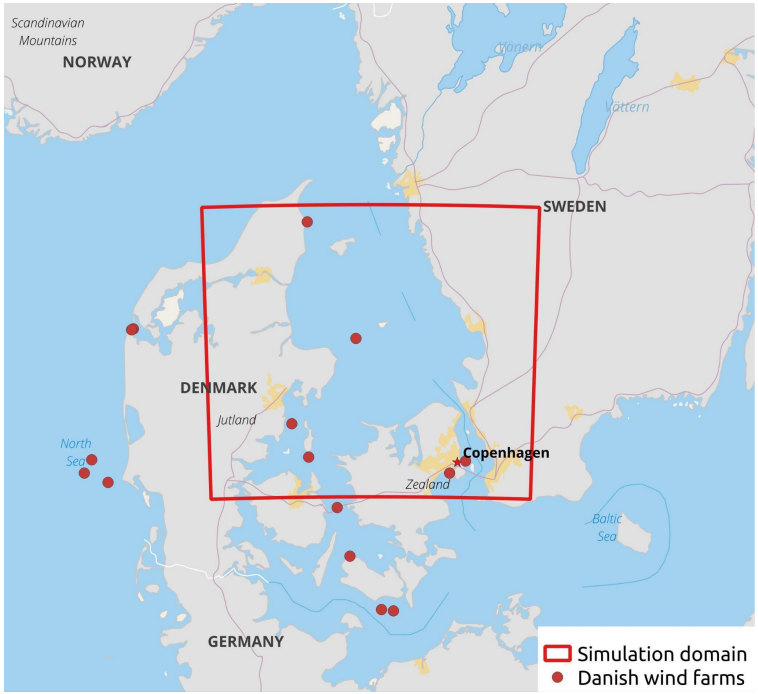
180 x 160 horizontal grid points @ 0.0135 deg resolution (≈ 1.5 km)

Tiedtke shallow convection scheme

50 height levels, with a dense spacing near the surface

Driven by ERA5 data (≈ 30 km)

Simulation period = 2013 (SCADA data of Anholt wind farm available)



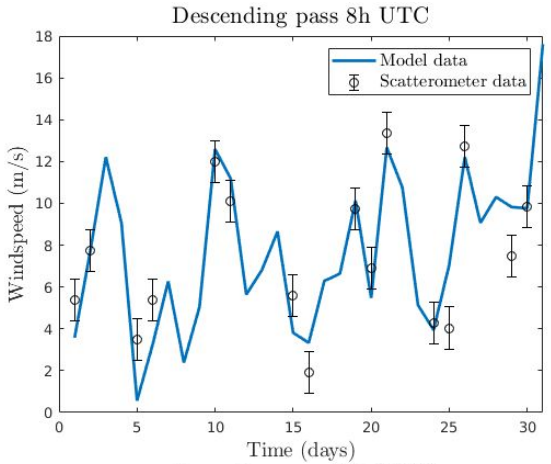
Evaluation with scatterometer data

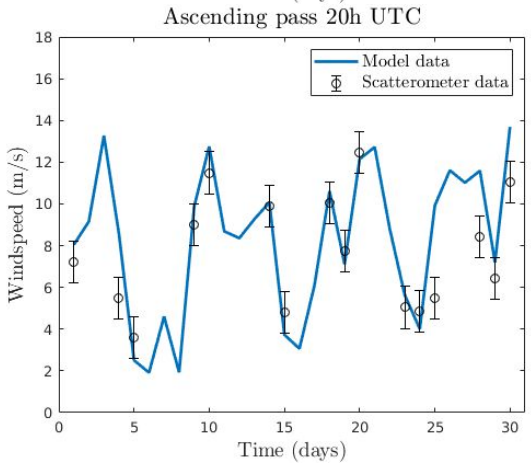
Model output regridded to scatterometer grid for comparison

RMS error = 1.7 (with spectral nudging = 1.6)

Correlation = 0.9 (with spectral nudging = 0.9)

U, V and T nudged with $\alpha = 0.05$ and $p_{sn} = 850$ hPa

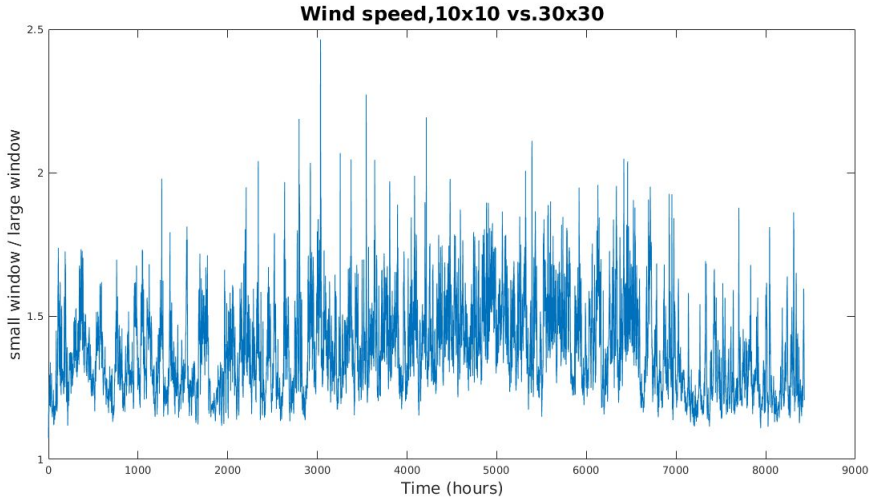


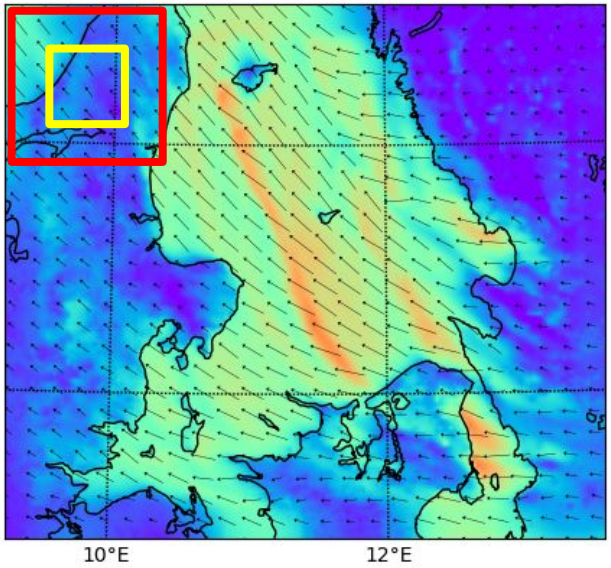


Detection local wind speed variations

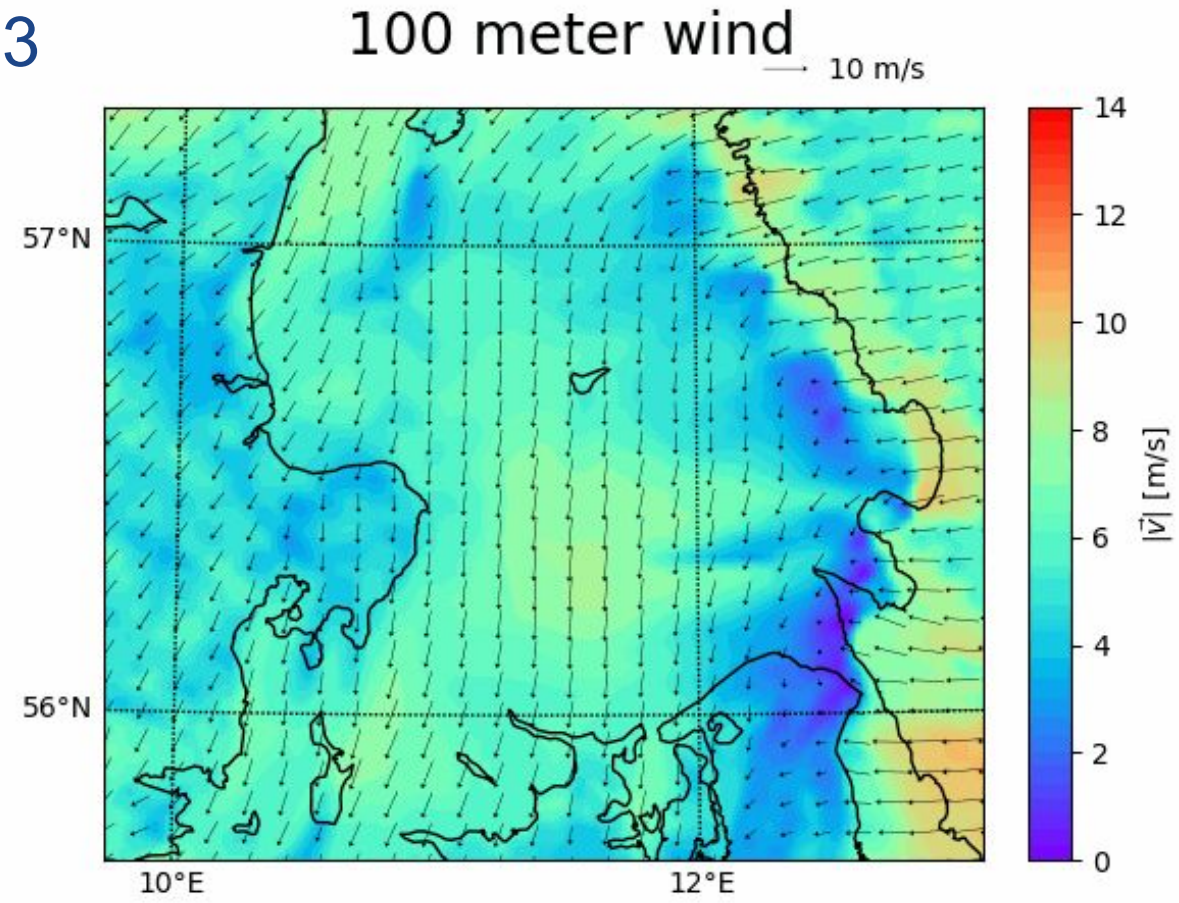
2 sliding windows: small window & large window

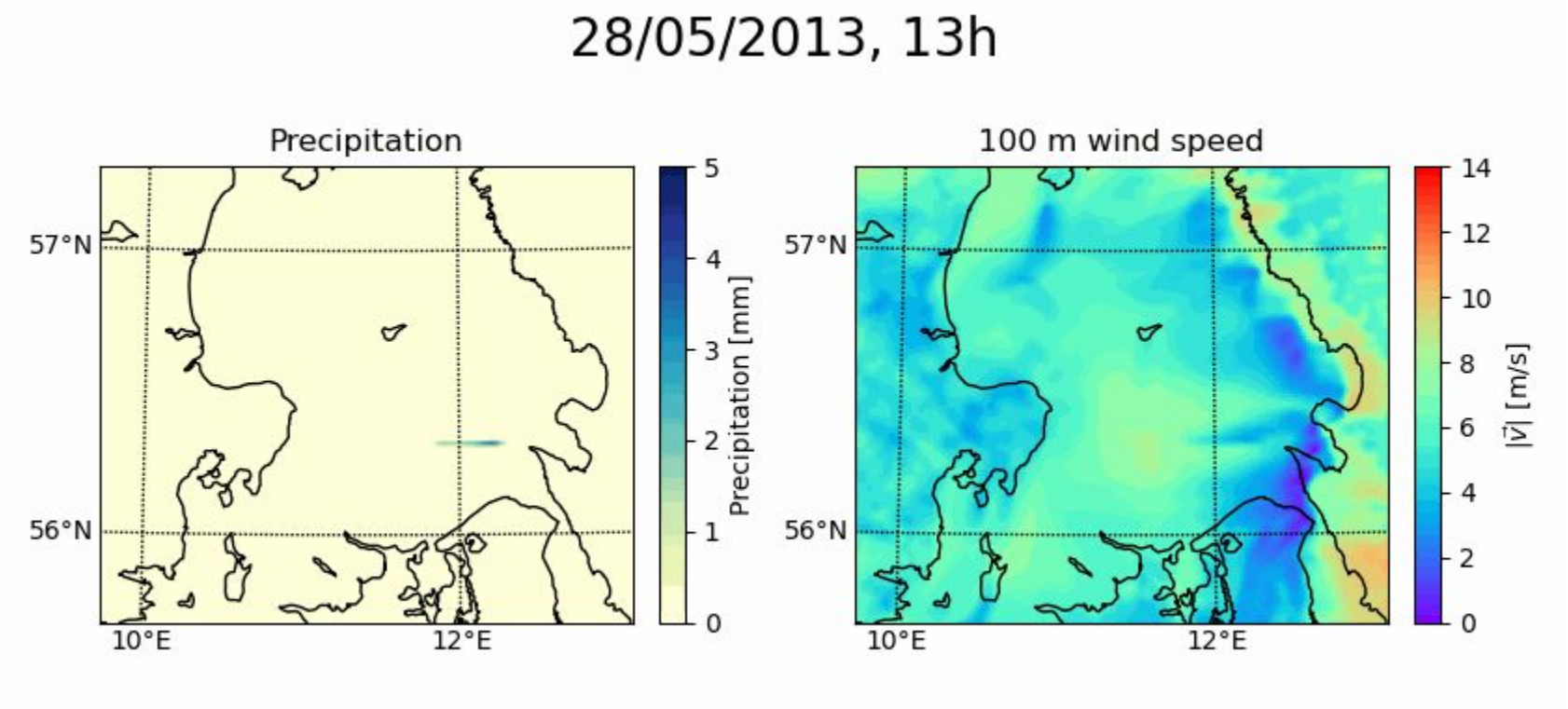
Ratio used to detect local elevated wind speed compared to background



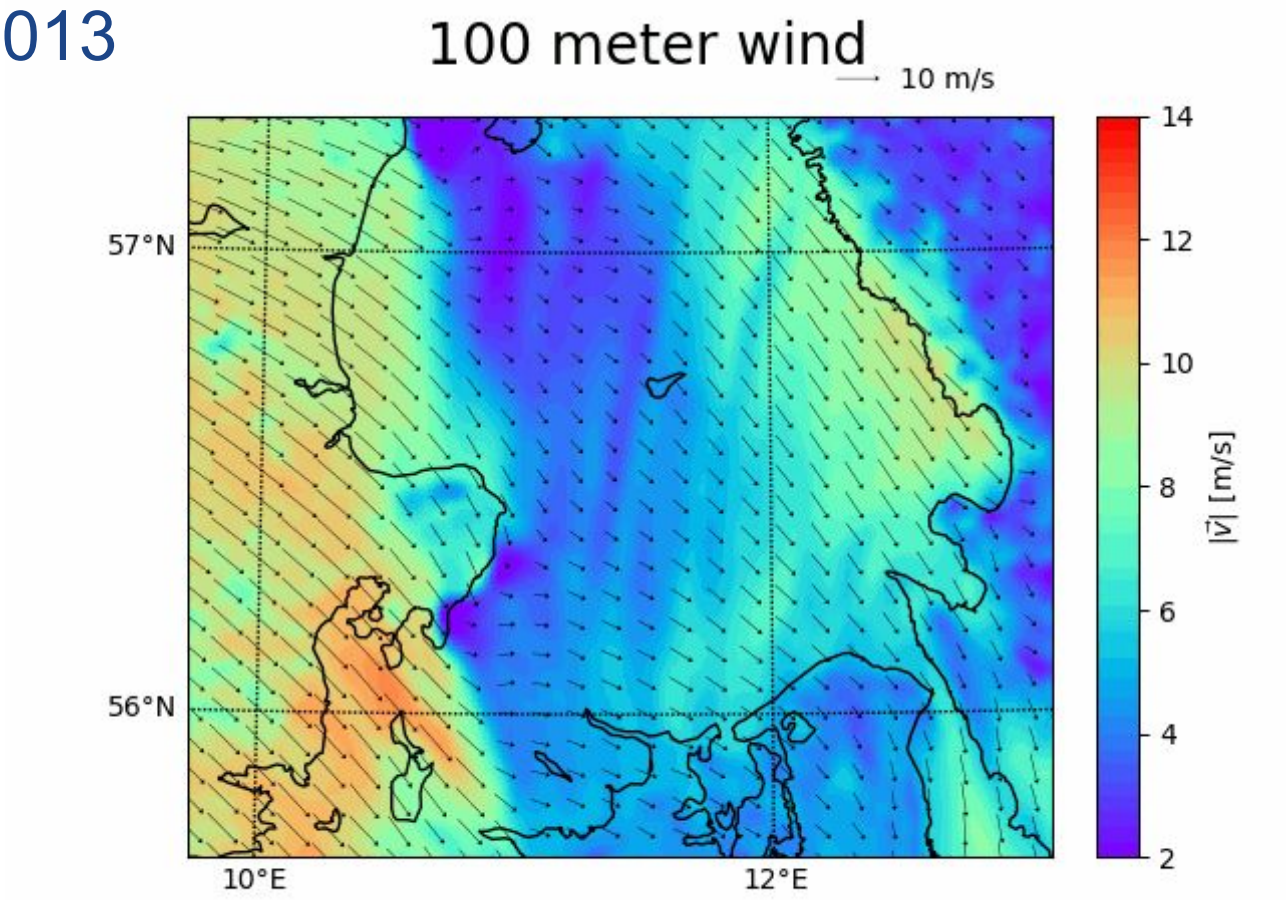


28/05/2013

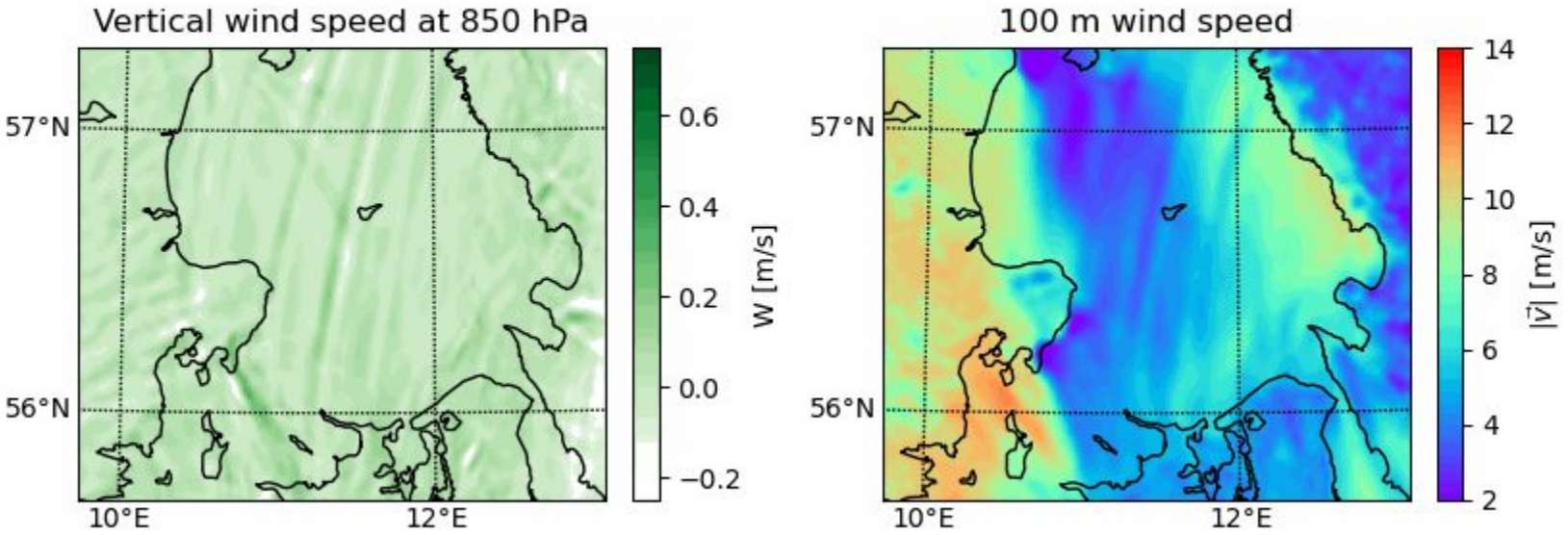



28/05/2013, 13h
Precipitation
57°N
56°N
10°E
12°E
5
4
3
2
1
0
Precipitation [mm]
100 m wind speed
57°N
56°N
10°E
12°E
14
12
10
8
6
4
2
0
$|\vec{v}|$ [m/s]

25/06/2013



25/06/2013, 17h

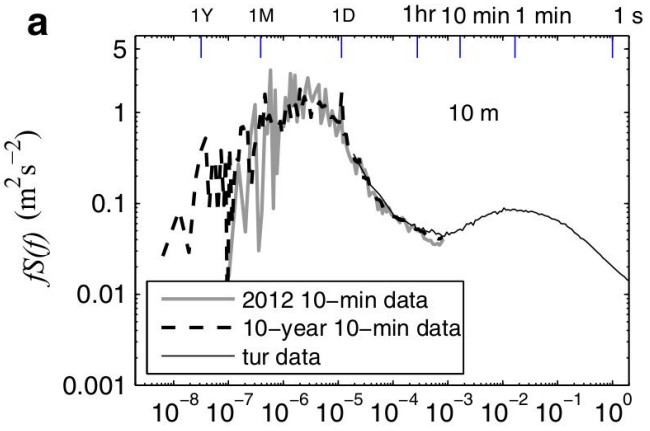


Periodogram

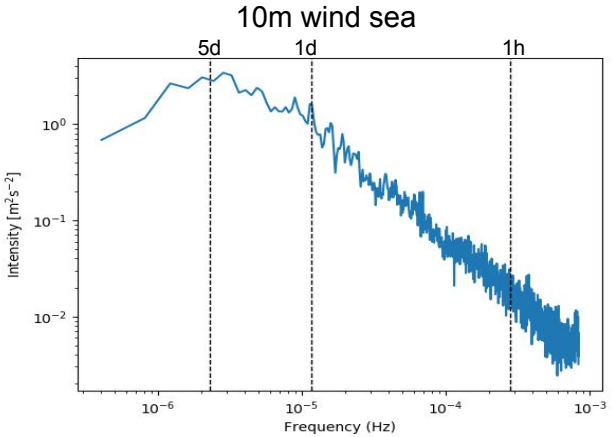
Estimate of spectral density of signal

Used for stochastic signals

Welch's method: divides signal in overlapping sections and returns the average spectrum in order to reduce noise

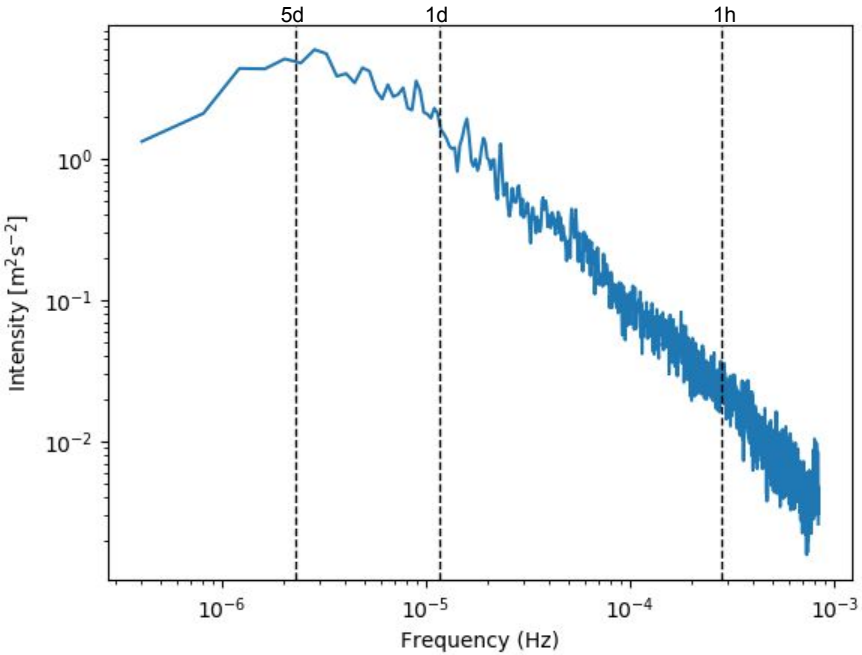


Source: Larsén et al. (2017)

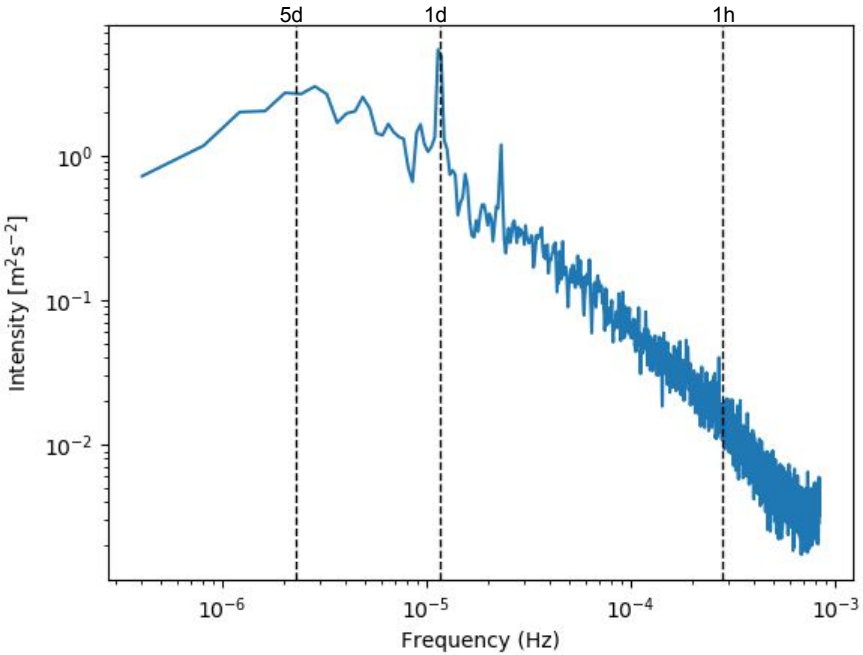


100m wind periodogram

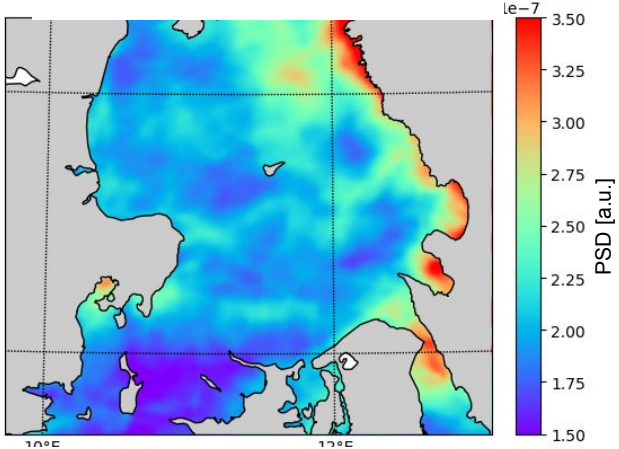
100m wind sea



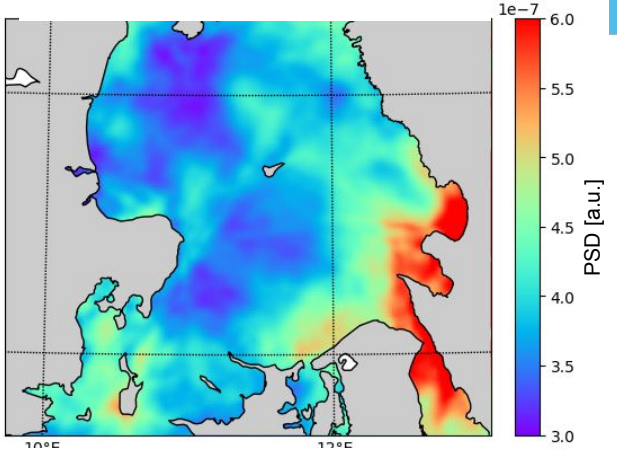
100m wind land



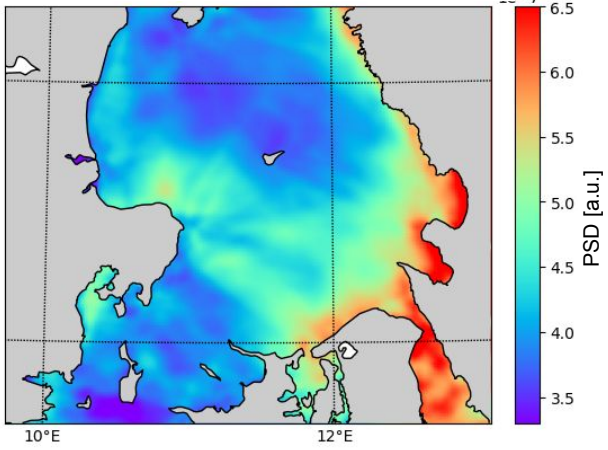
8h to 12h, Jan, Feb, Mar



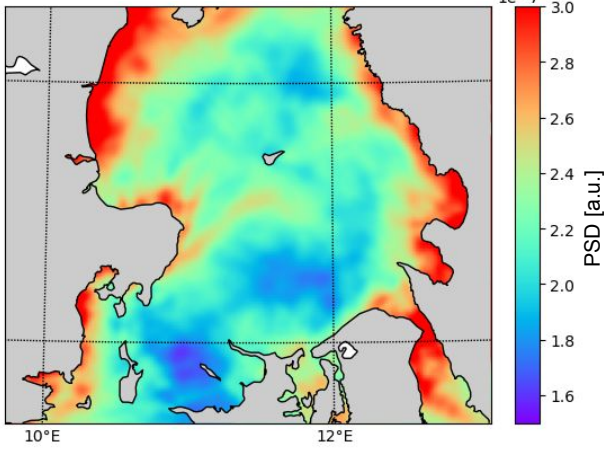
8h to 12h, Apr, May, Jun



8h to 12h, Jul, Aug, Sept



8h to 12h, Oct, Nov, Dec



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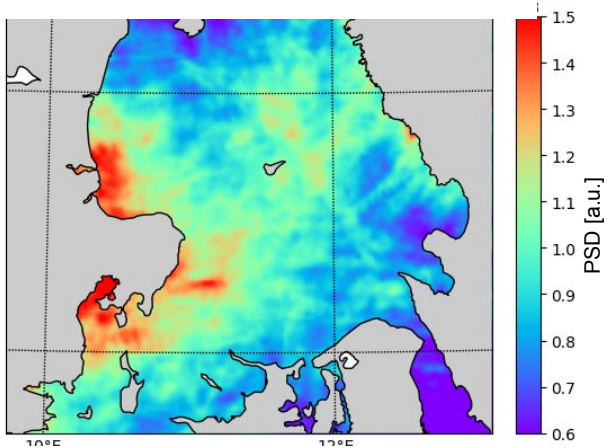
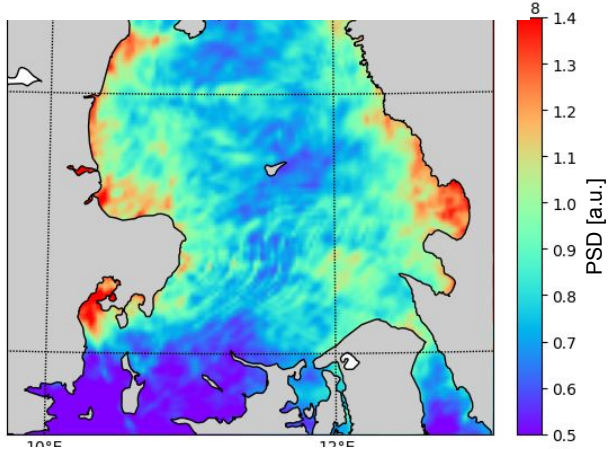
30 min to 1h, Jan, Feb, Mar



30 min to 1h, Apr, May, Jun



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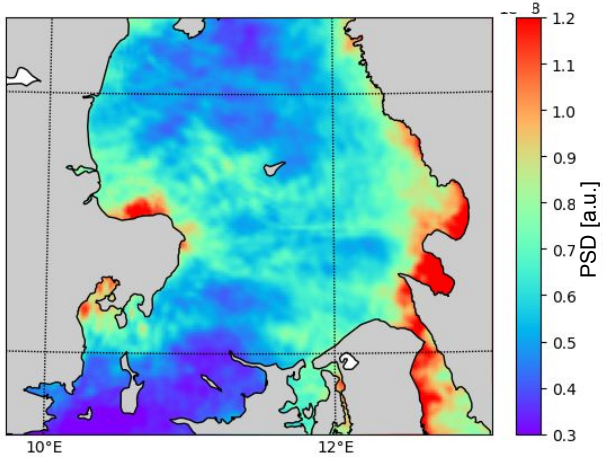

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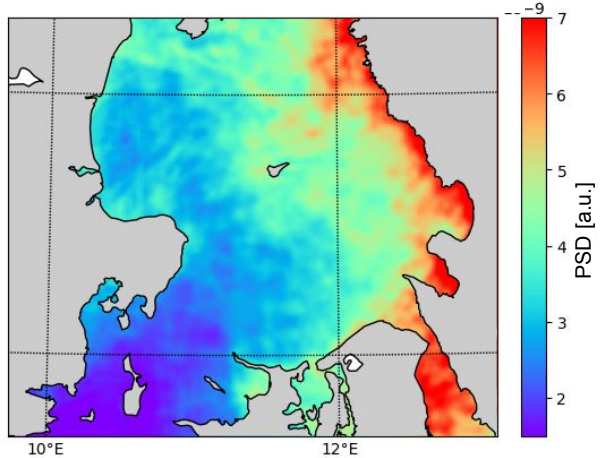


Wind farm parametrization of Fitch et al. (2012)

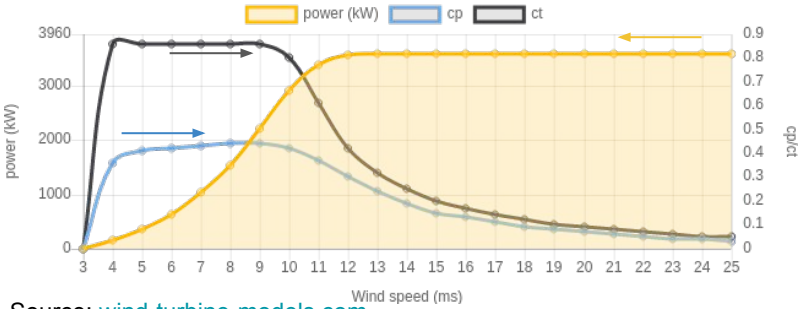
Elevated momentum sink + generation of turbulent kinetic energy

$$C_{\mathrm{T}} = C_{\mathrm{P}} + C_{\mathrm{TKE}}$$

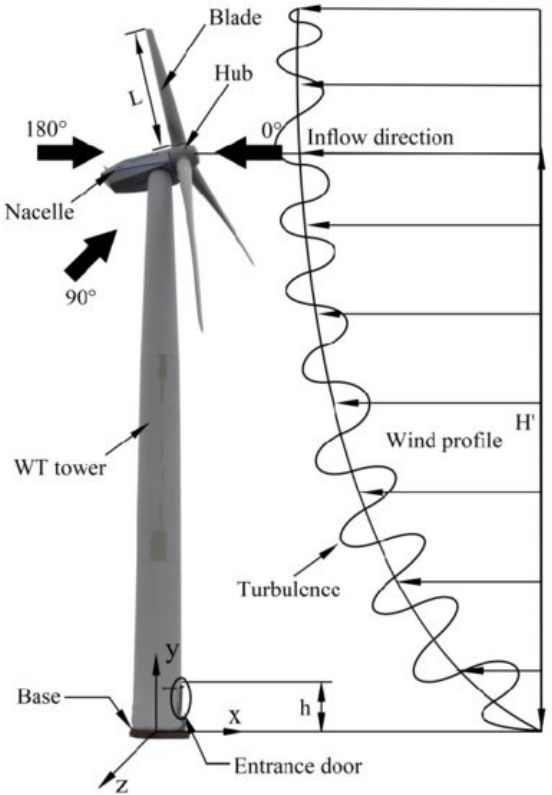
C_T = fraction of kinetic energy taken from wind

C_P = fraction of kinetic energy converted in electrical energy

C_{TKE} = fraction of kinetic energy converted to turbulent kinetic energy



Source: wind-turbine-models.com



Source: Dai et al. (2017)

Conclusions and outlook

Model output compares well with scatterometer data

Examine different mesoscale weather systems

Study the effects of mesoscale systems on the wind speed variability using periodograms

Evaluate with SCADA data

Compare wind speeds with/without wind farm

Implement a seabreeze filter (Steele et al. 2015)

Expanding run to 2010-2020

Thank you for your attention!
Any questions?

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