Offshore Extreme Wind Atlas Using Wind-Wave Coupled Modeling

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Offshore Extreme Wind Atlas Using Wind-Wave Coupled Modeling

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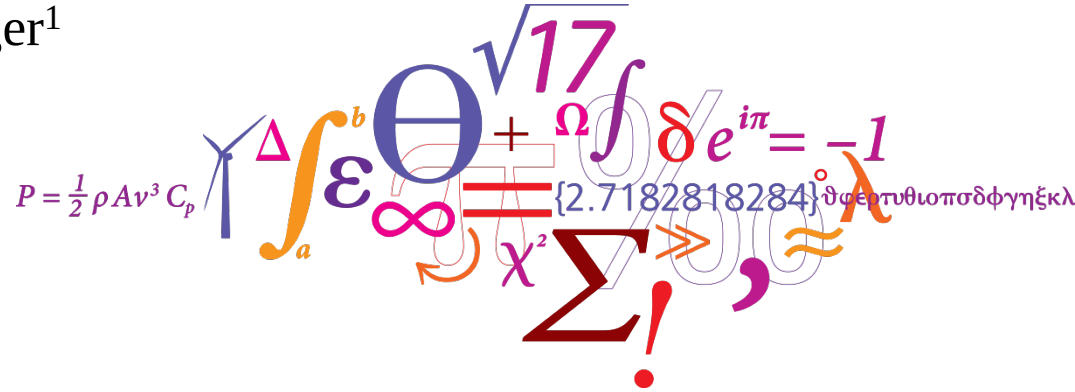
1. DTU; 2. DHI



DTU Wind Energy
Department of Wind Energy

Relevance of the study / state-of-the-art

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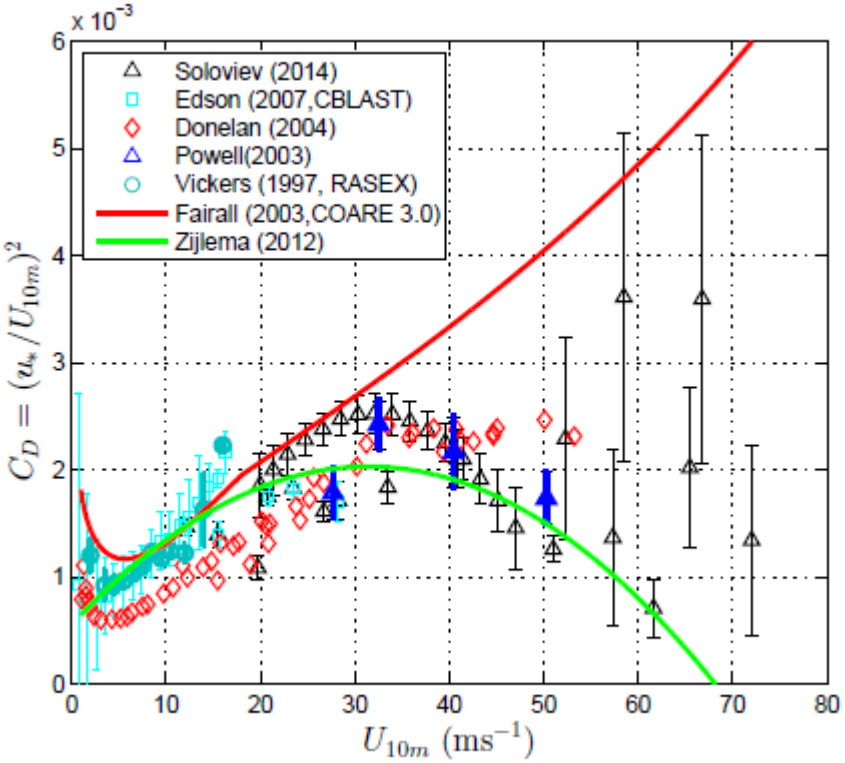
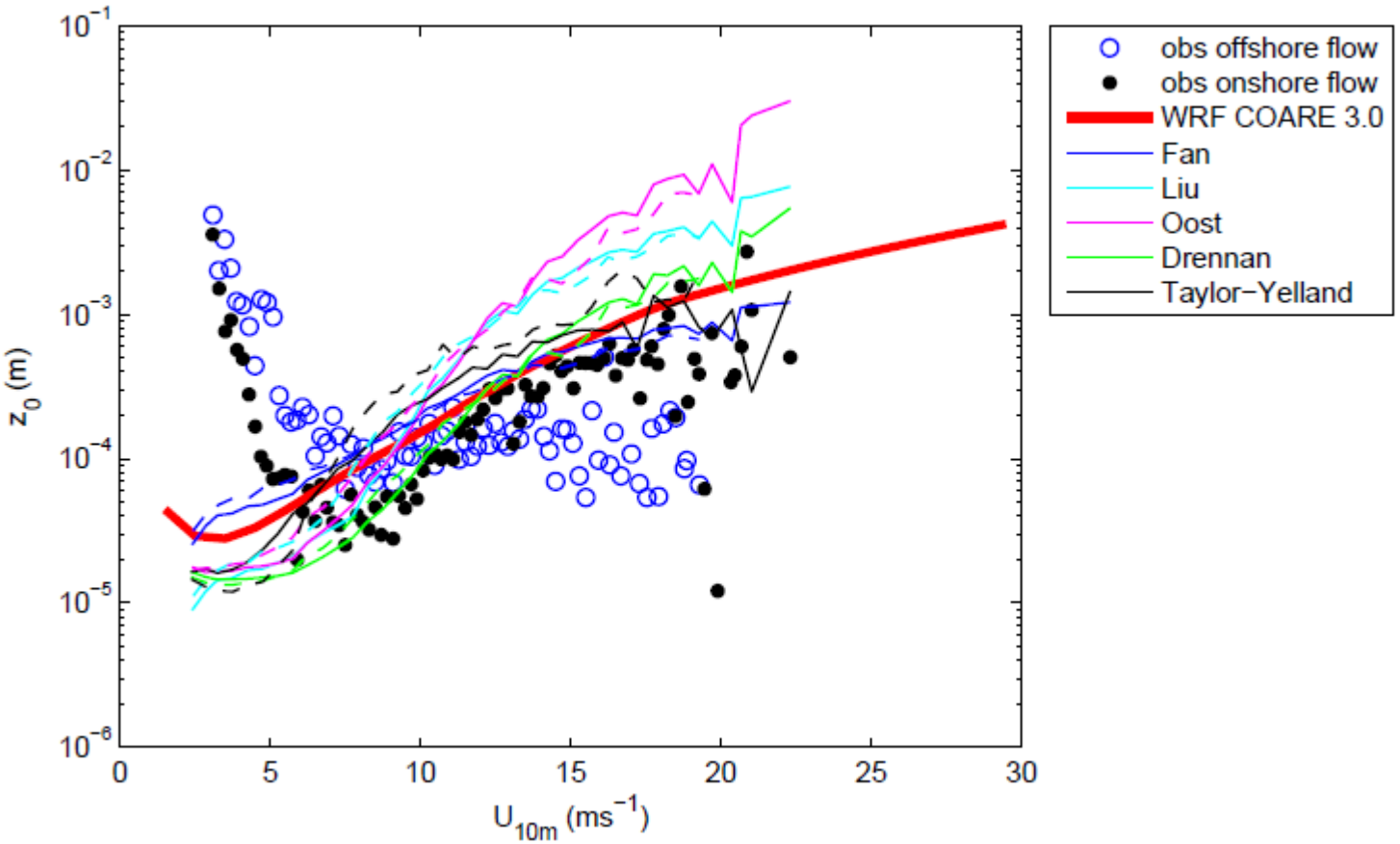


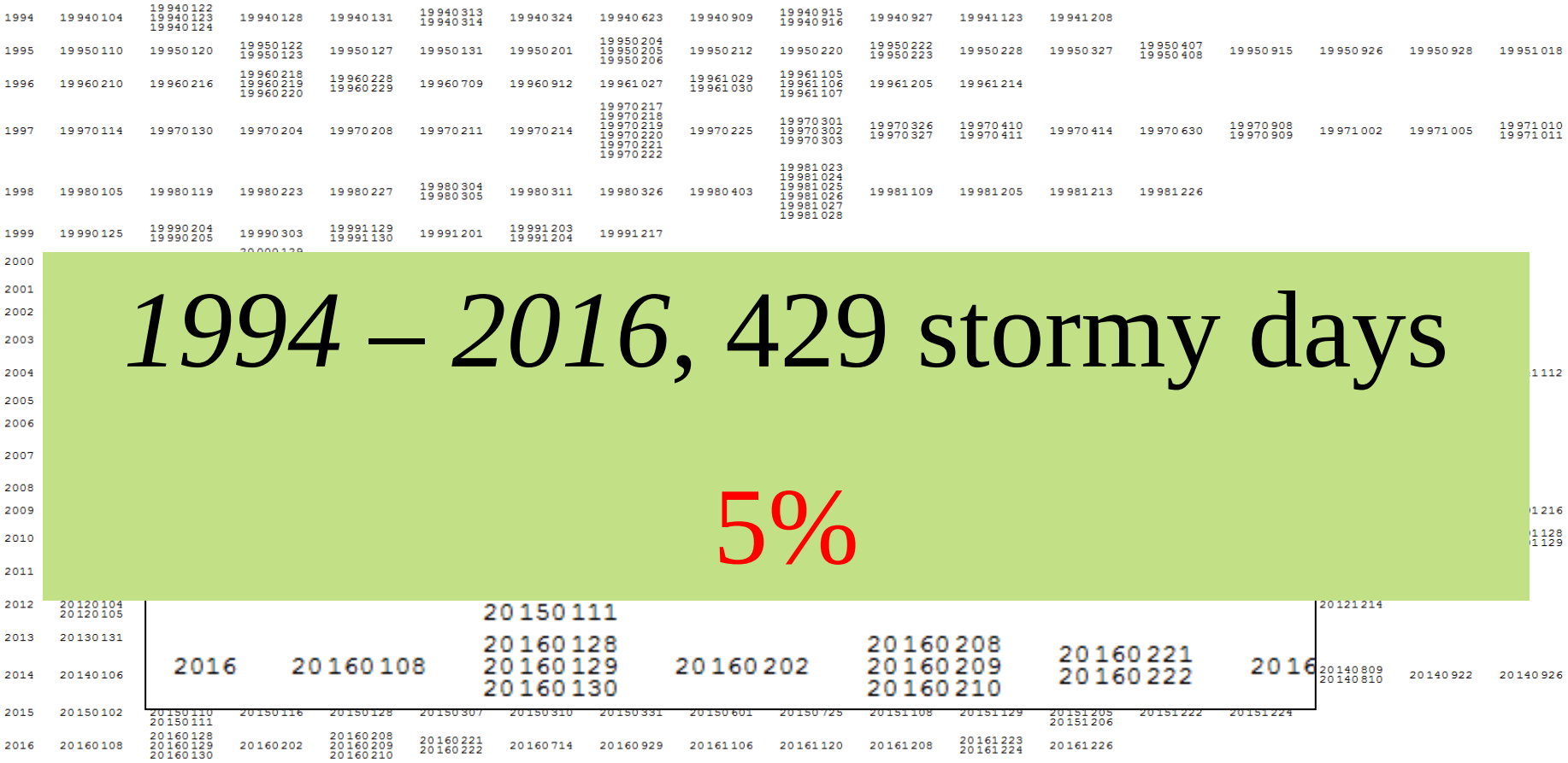
Relevance of the study / state-of-the-art



Method for obtaining the 50-year wind

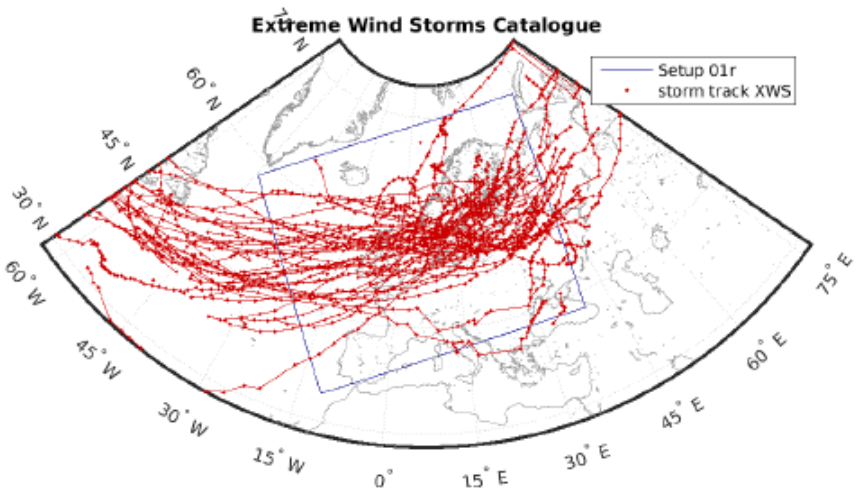
1. Collecting the samples:

Selective Dynamical Downscaling Method – Storm Episodes



Method for obtaining the 50-year wind

2. Modeling the samples:



Imberger M. 2017: Modeling rough weather over the North Sea – using COWAST for offshore wind energy applications. DTU Wind Energy-M-0149, Master thesis.

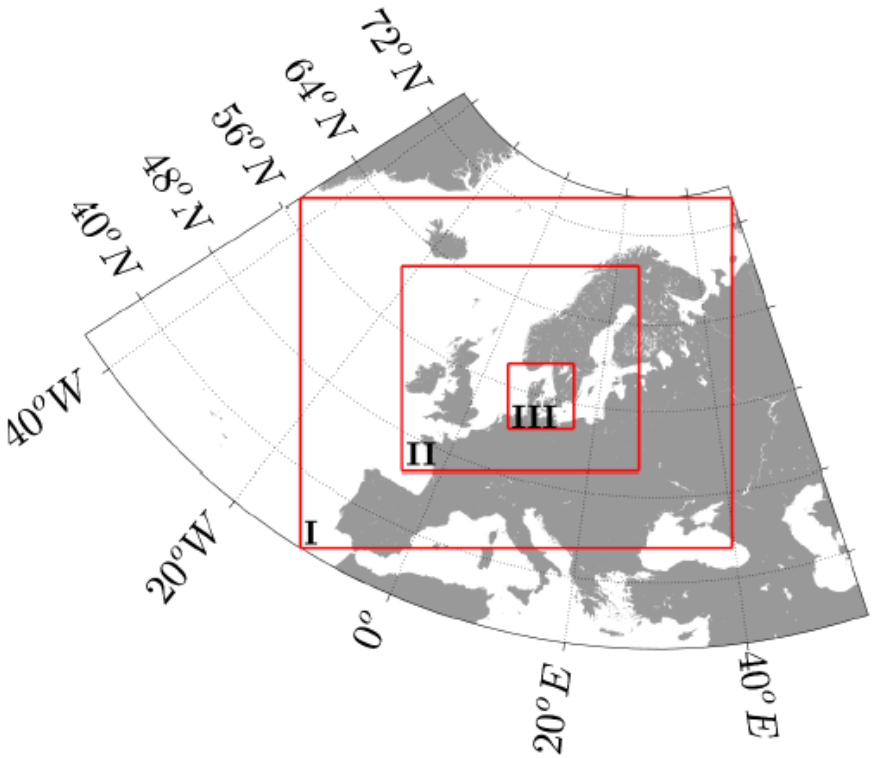
Optimalization of model setup

With consideration of:

1) Domain size
2) Domain location
3) Initial time
4) Simulation length
5) Spinning up time
6) Resolution

Method for obtaining the 50-year wind

2. Modeling the samples:



Two-way online
Nested 18-6-2km
36 hours for each run

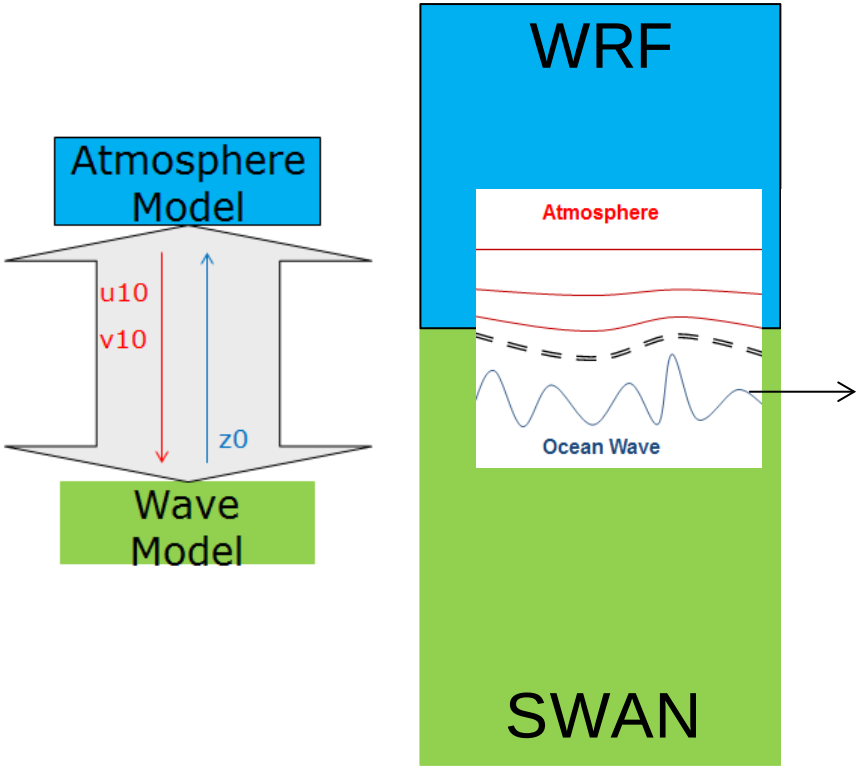
WRF:
CFSR+OISST
77 vertical sigma levels
MYNN 3.0 PBL scheme
RRTM long and short wave radiation
Kain-Fritsch cumulus scheme (domain I)
Corine land use

WBLM

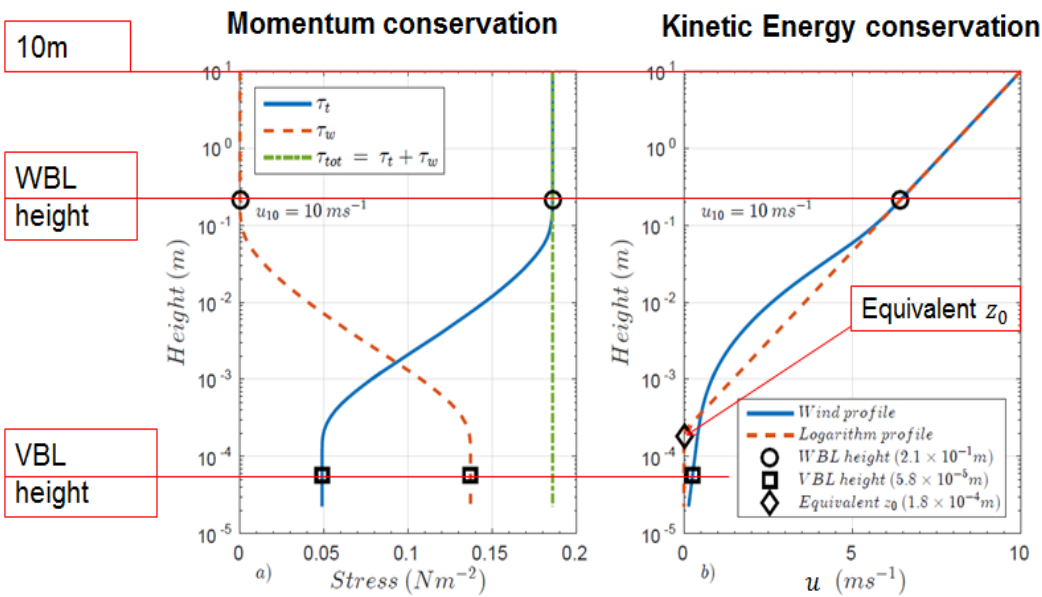
SWAN:
1/8 arc-minute bathymetry data
Initiated 24h before the simulation
Close boundary for open sea
36 directional bins.
0.03 Hz < f < 10.05 Hz (KOM and WBLM)
0.03 Hz < f < 0.57 Hz (JANS)

Method for obtaining the 50-year wind

2. Modeling the samples: the WBLM



The Wave Boundary Layer Model

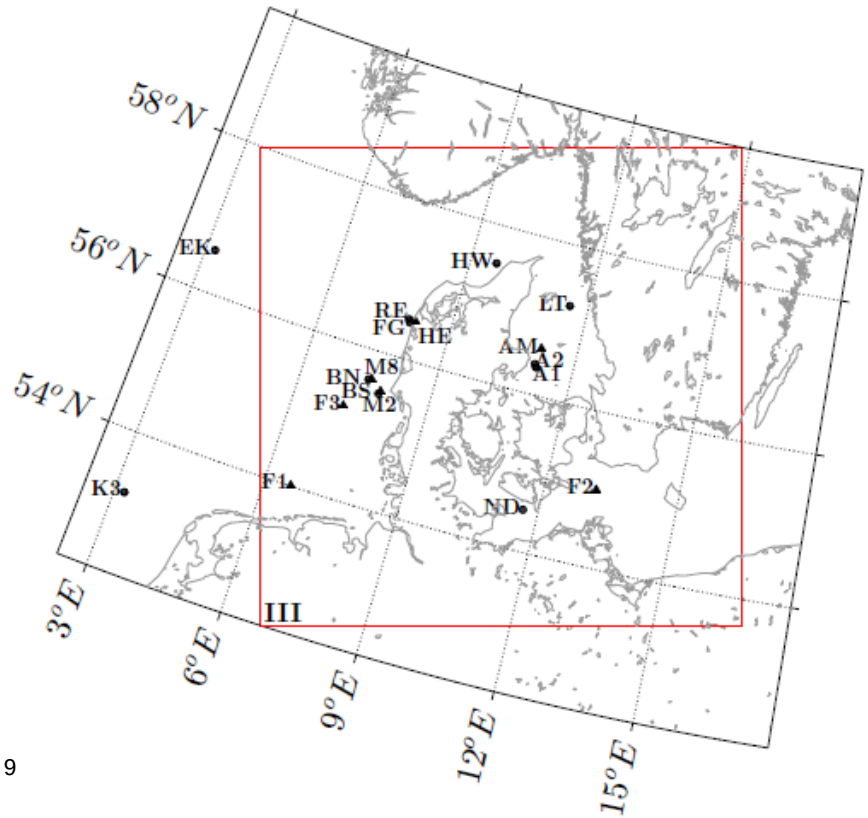


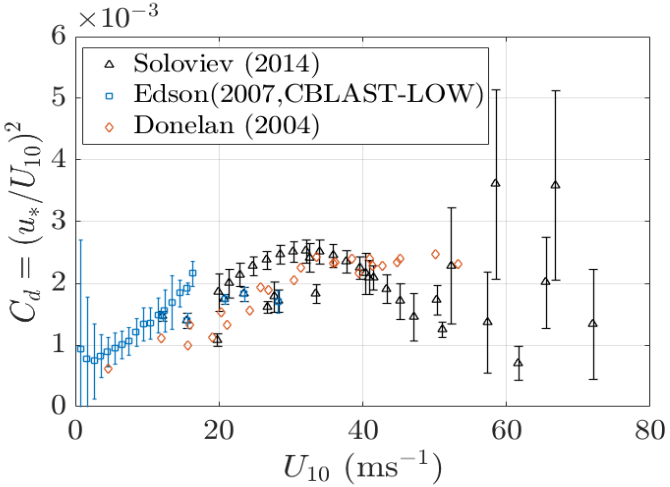
Du, J., Bolaños, R., and Larsén, X. (2017a). The use of a wave boundary layer model in SWAN. *Journal of Geophysical Research: Oceans*, pages 1063–1084.

Method for obtaining the 50-year wind

3. Validation of the modeling: general validation

- Point measurements (mast, buoy, lidar)
- Satellite data (SAR, Quikscat, cloud images)
- The literature





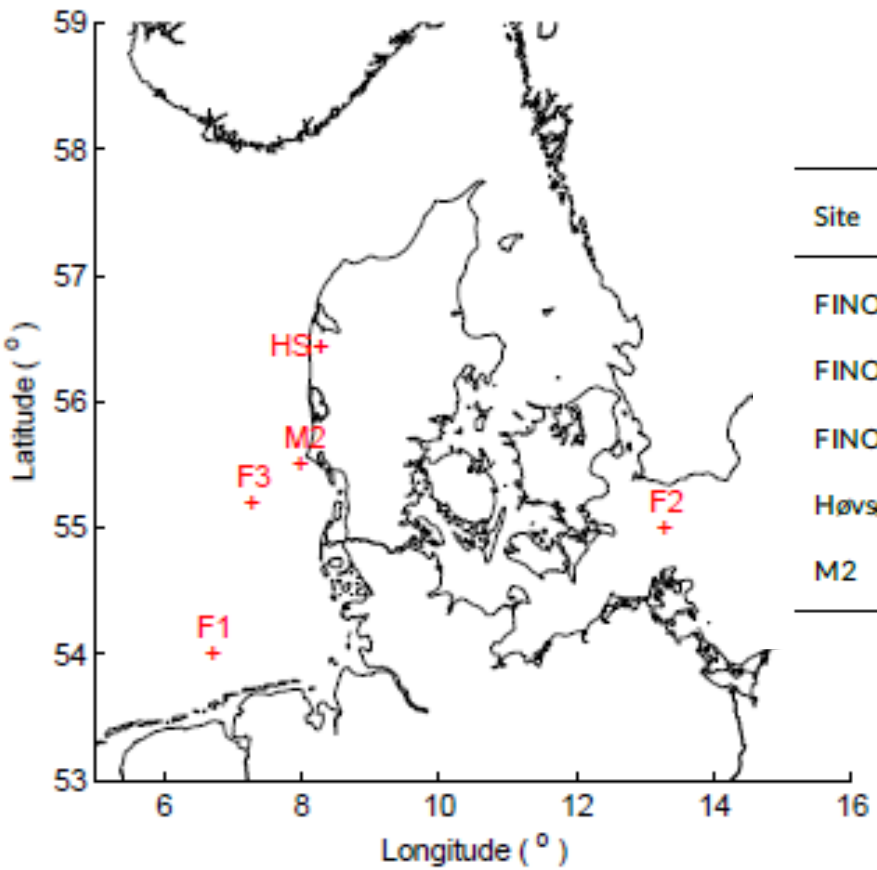
Soloviev (2014): A collection of measurements from Powell (2003), Black (2007, CBLAST-Hurricane), Bell (2012), Jarosz (2007), Holthuijsen (2012)

Edson (2007): CBLAST-LOW

Donelan (2004): Laboratory measurements in a wave tank (15m long x 1m wide x 1m high)

Method for obtaining the 50-year wind

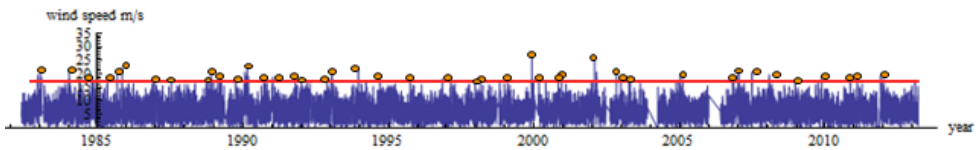
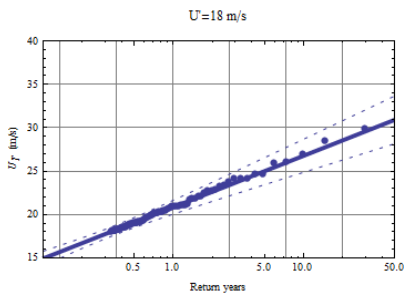
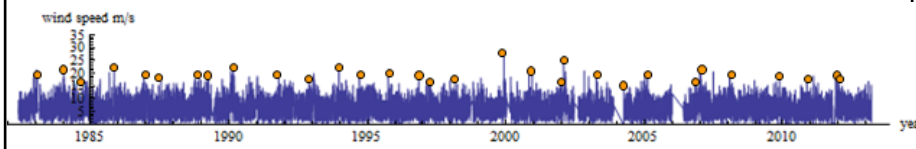
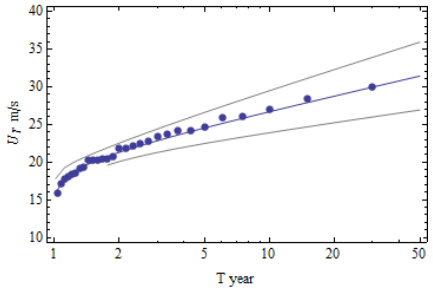
3. Validation of the modeling: U50



Site	Coordinates	Period	Data length (years)	Height (m)
FINO1	6.588°E, 54.014°N	2004 - 2017	14	100
FINO2	13.1542°E, 55.007°N	2008 - 2017	10	102
FINO3	7.1583°E, 55.195°N	2010 - 2017	8	100
Høvsøre	8.15°E, 56.433°N	2005 - 2017	13	100
M2	7.875°E, 55.508°N	2000 - 2005	6	62

Method for obtaining the 50-year wind

2. For calculating the 50-year return value

Peak-Over-Threshold Method	Annual Maximum Method
  $U_T = u_0 + A\ln(\lambda T)$	  $U_T = \alpha^{-1}\ln(T/T_{BP}) + \beta$
Applied to measurements only	**to both measurements and modelled data**

Results

Questions:

Have we captured the relevant storms?

How is the general model performance?

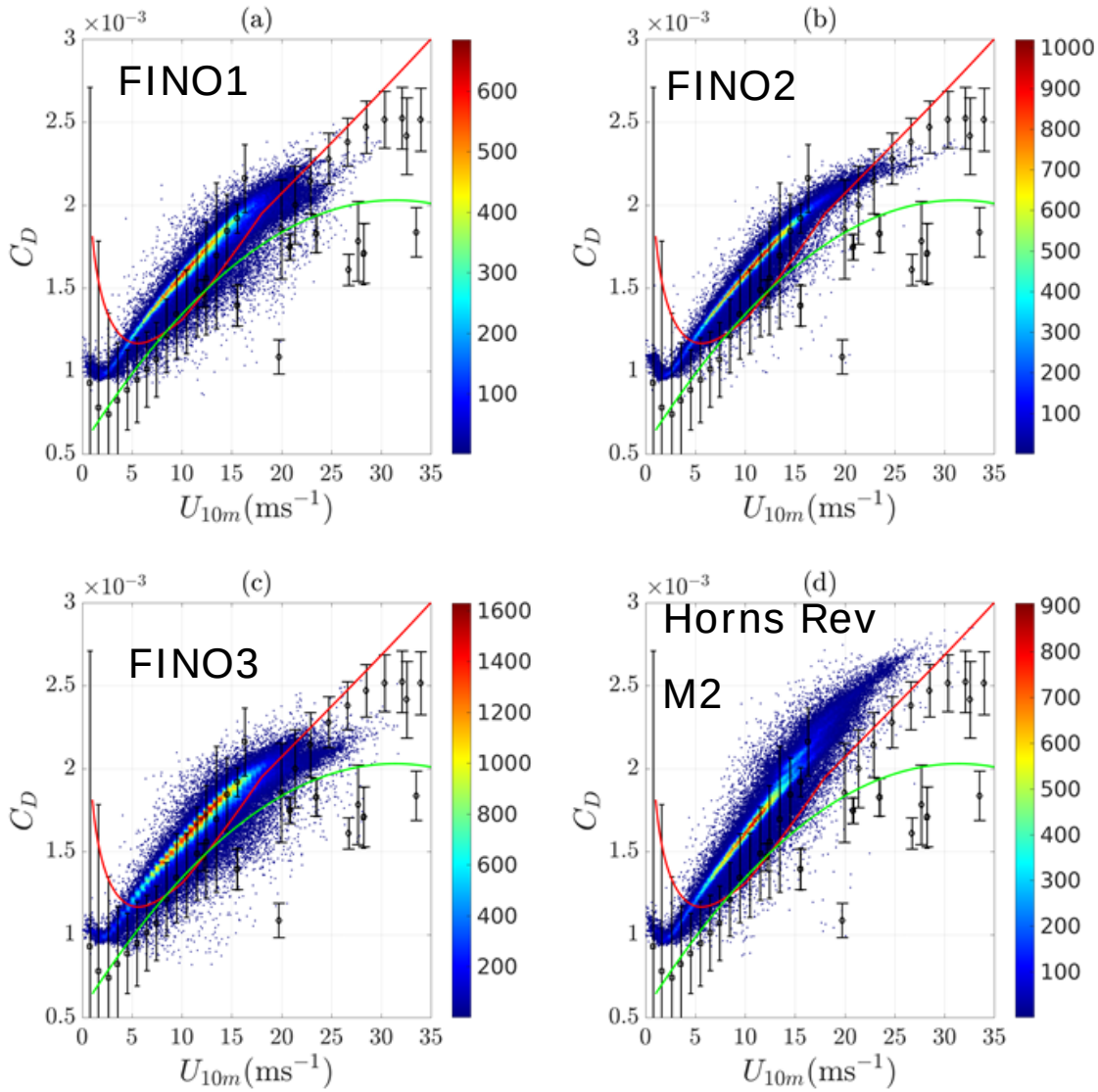
How is the estimate of U50, coupled vs not-coupled?

Results

Question 2:

How is the general model performance?

Results


(a)
FINO1
(b)
FINO2
(c)
FINO3
(d)
Horns Rev
M2
$\times 10^{-3}$
C_D
$U_{10m}(\mathrm{ms}^{-1})$

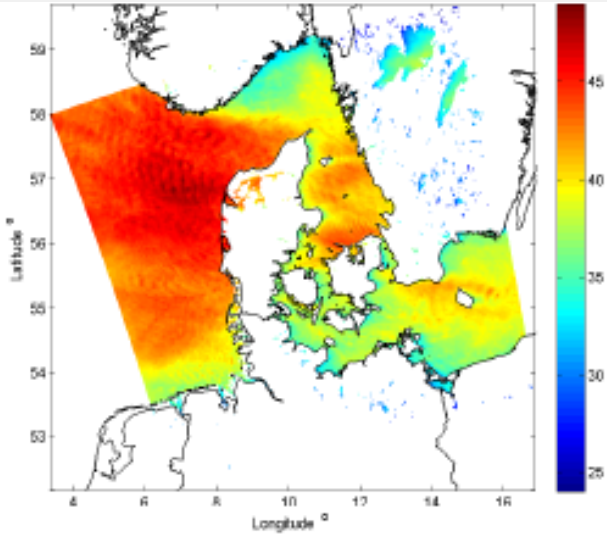
Results

Question 3:

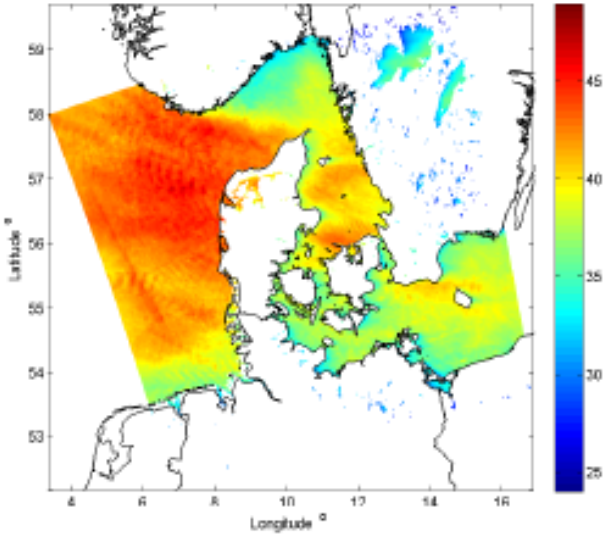
How is the estimate of U50?

Results

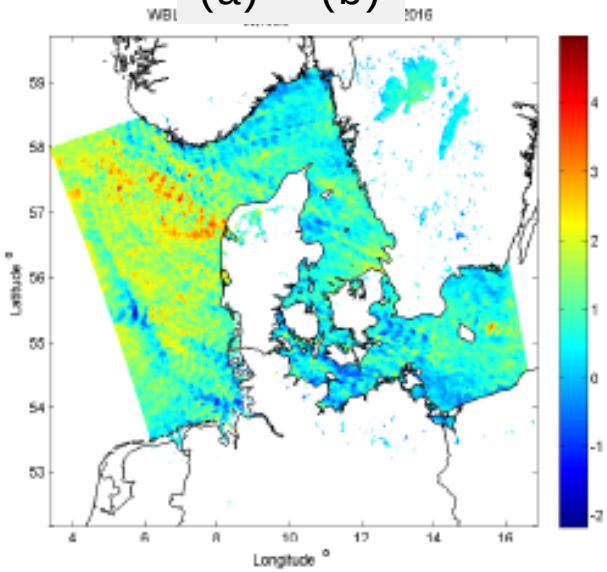
(a) U50 at 100 m, coupled



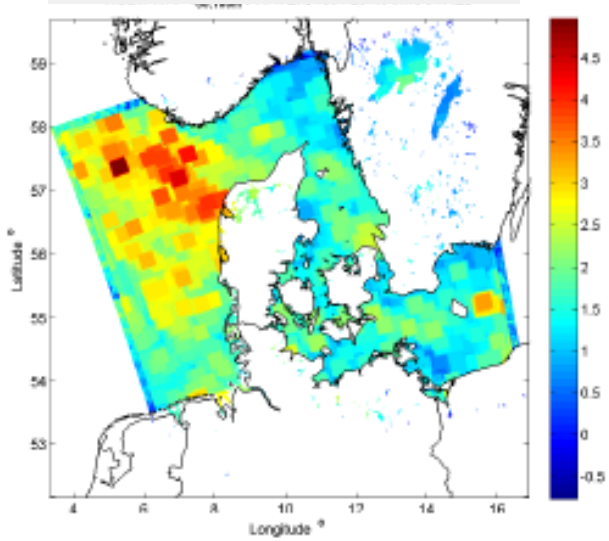
(b) U50 at 100 m, not-coupled



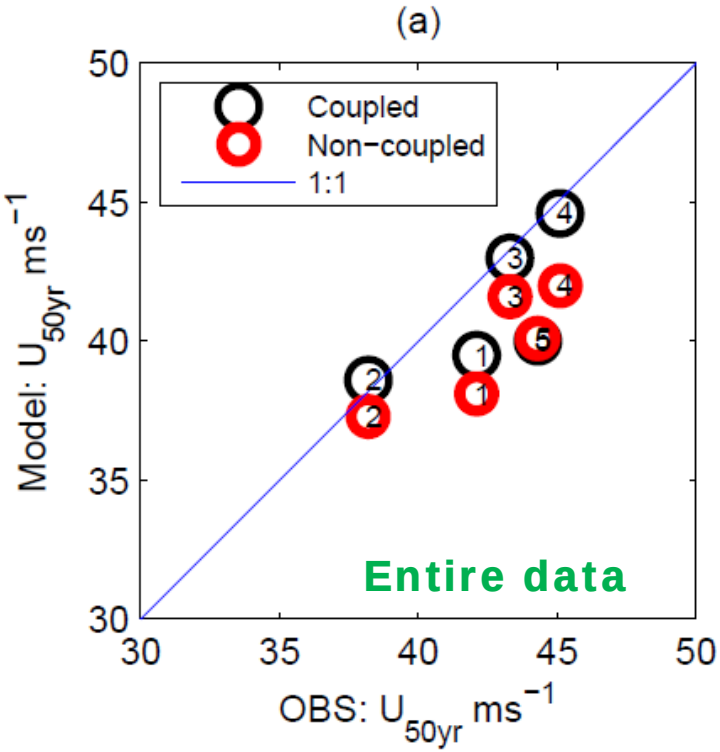
(a) – (b)



(a) – (b), smoothed



Results



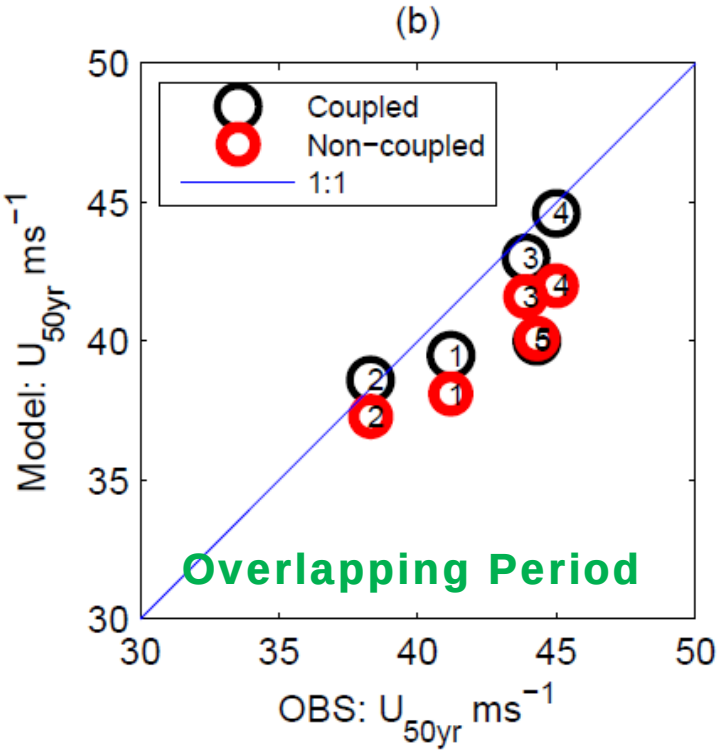


Table 1 – Basic parameters for wind turbine classes[2]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values
A	I_{ref} (-)	0,16			specified
B	I_{ref} (-)	0,14			by the
C	I_{ref} (-)	0,12			designer

1: FINO 1

2: FINO 2

3: FINO 3

4: Høvsøre

5: Horns Rev M2

Summary

- Selective dynamical downscaling method is efficient and reliable
- The WRF-WBLM-SWAN model improves strong wind calculation in comparison with WRF-alone

Acknowledgement

The Danish ForskEL project X-WIWA (www.xwiwa.dk)

The EU CEASELESS project

Sub materials

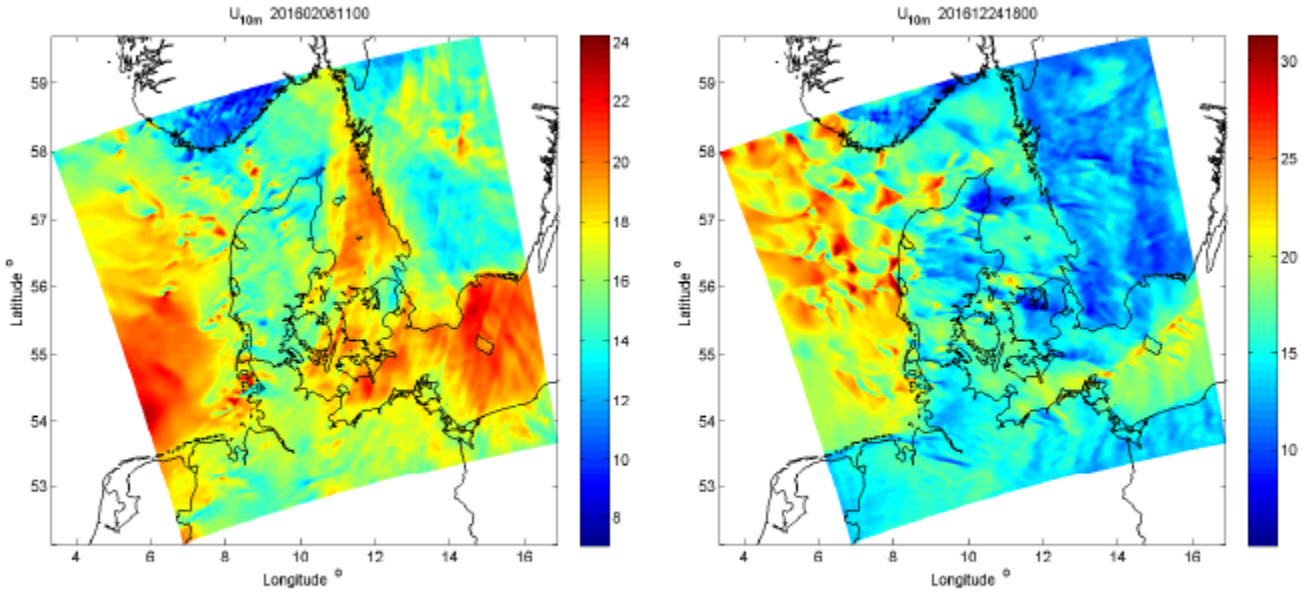


FIGURE 8 Examples of the wind fields in the presence of open cells: 2016-02-08 11:00 and 2016-12-24 18:00.