# Offshore Extreme Wind Atlas Using Wind-Wave Coupled Modeling

**Larsén, Xiaoli Guo; Du, Jianting; Bolanos, Rodolfo; Imberger, Marc; Badger, Merete**

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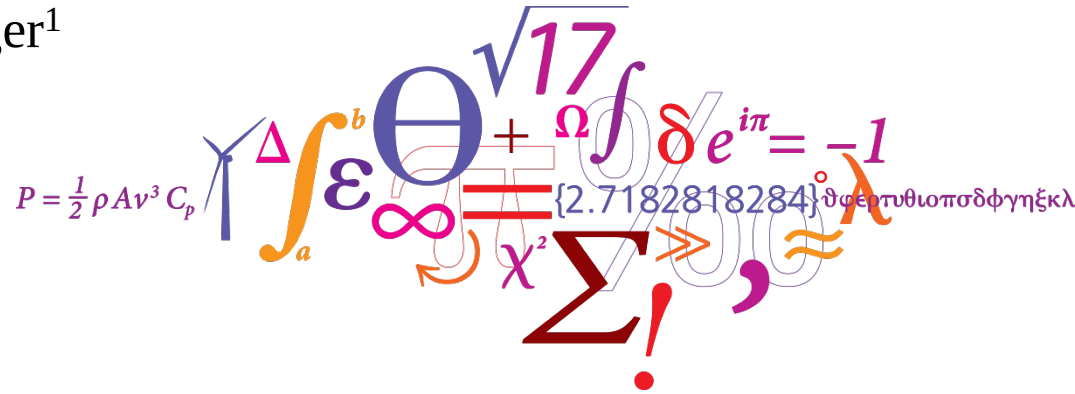
# Offshore Extreme Wind Atlas Using Wind-Wave Coupled Modeling

Xiaoli Guo Larsén[1], Jianting Du[1], Rodolfo Bolanos[2], Marc Imberger[1] and Merete Badger[1]

1. DTU; 2. DHI




DTU Wind Energy
Department of Wind Energy

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

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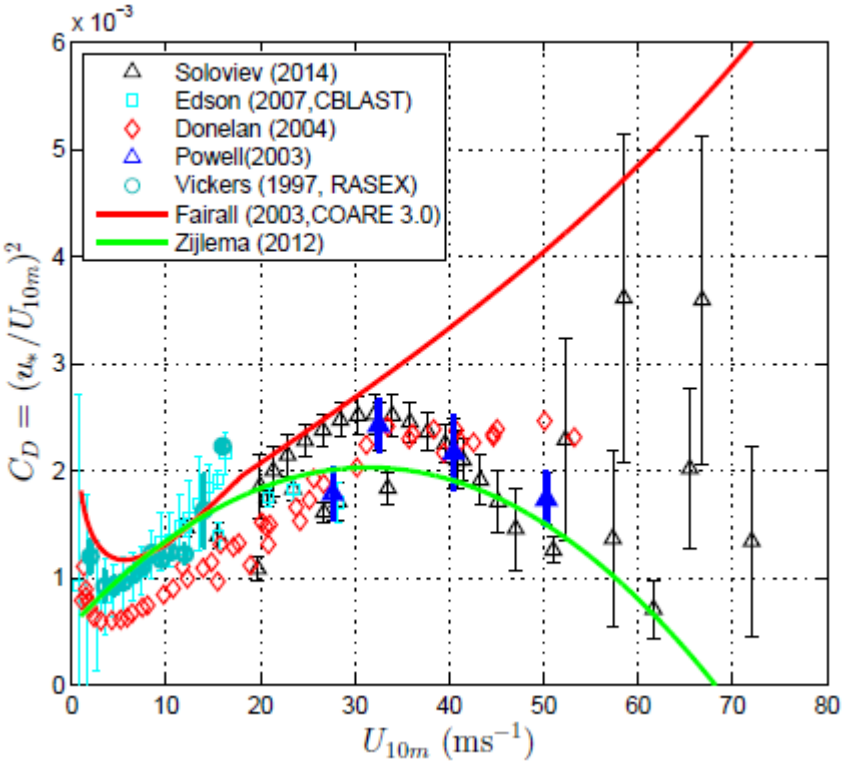
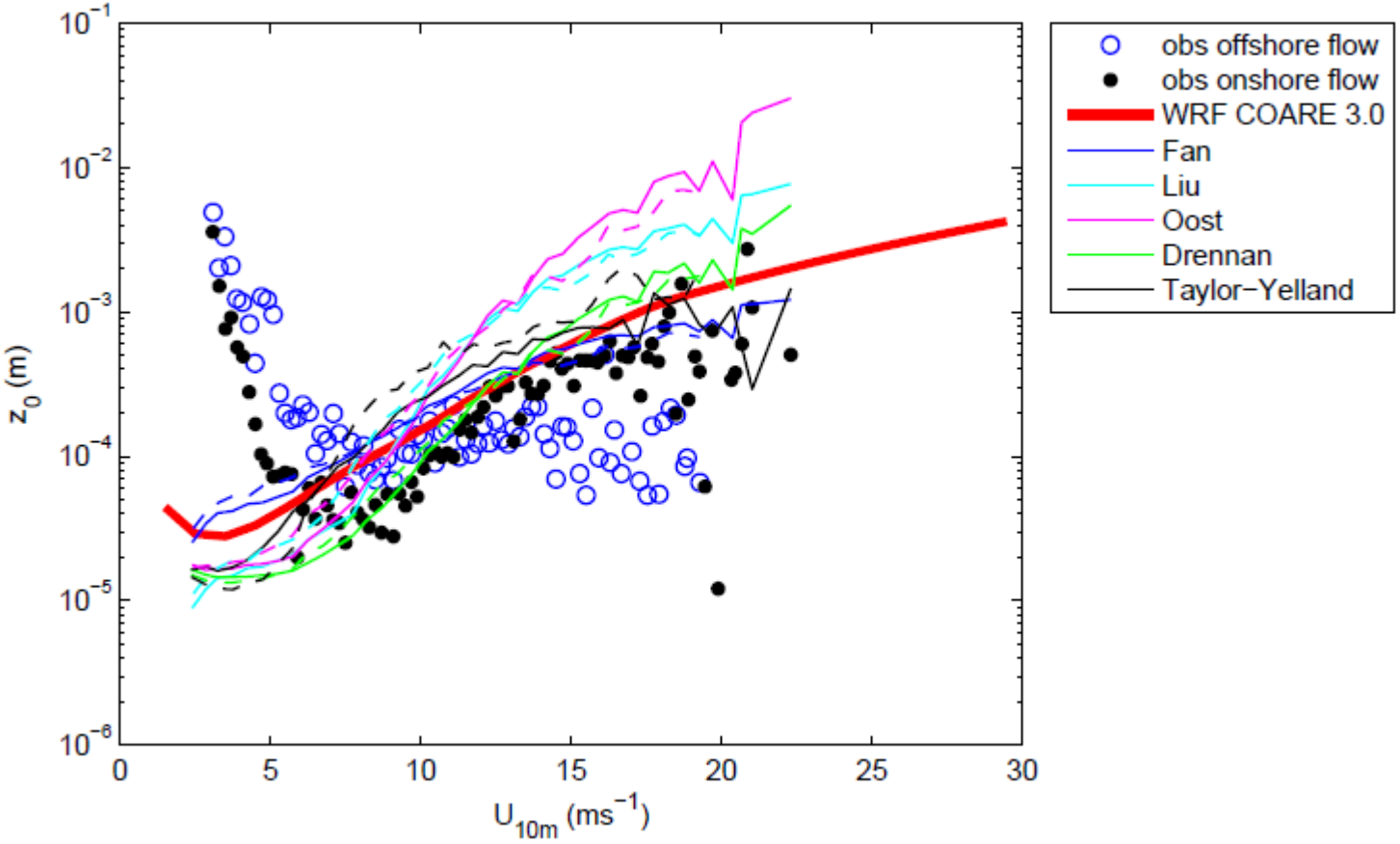


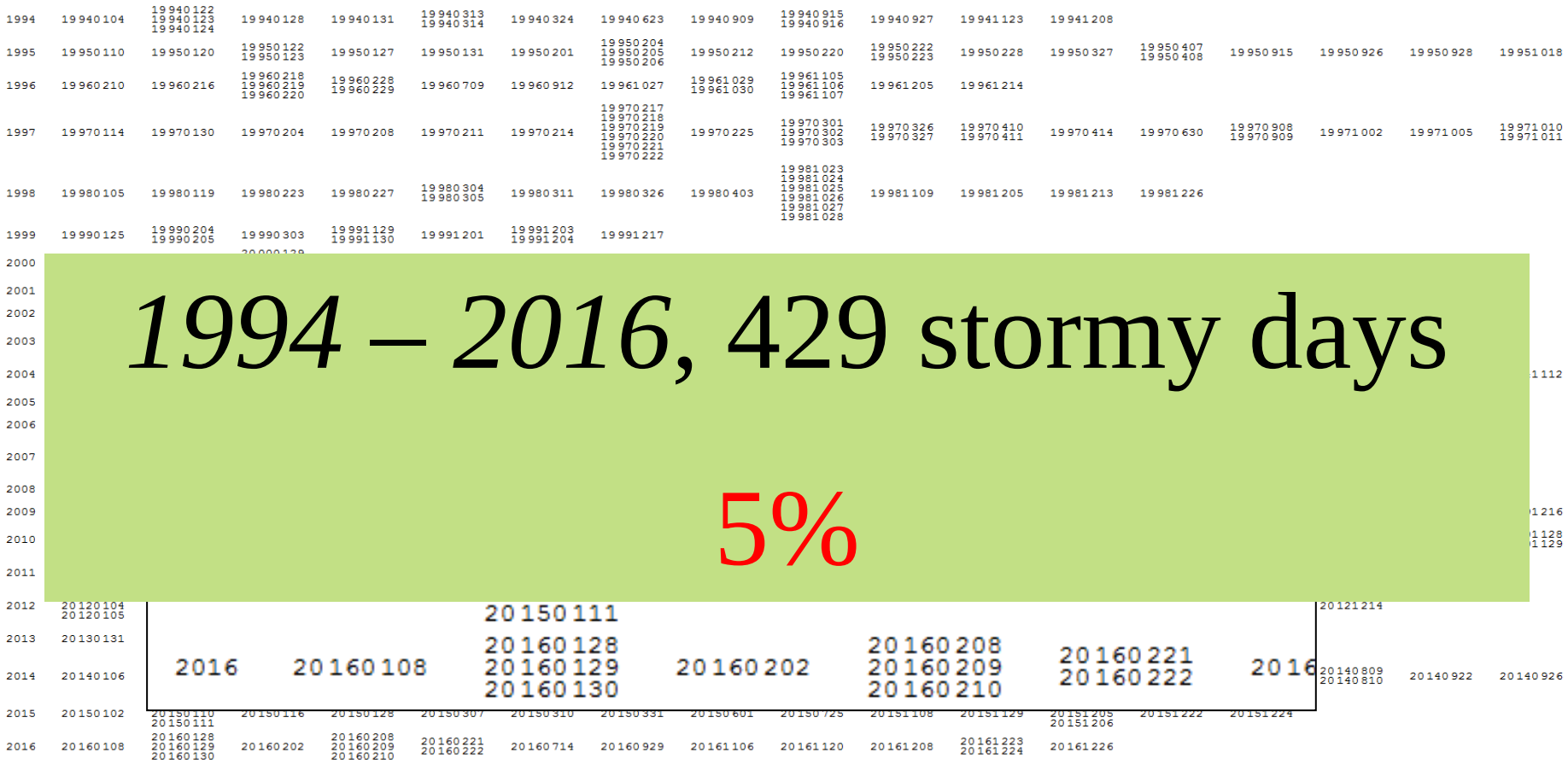
# Relevance of the study / state-of-the-art



# Method for obtaining the 50-year wind

## 1. Collecting the samples:

### Selective Dynamical Downscaling Method – Storm Episodes

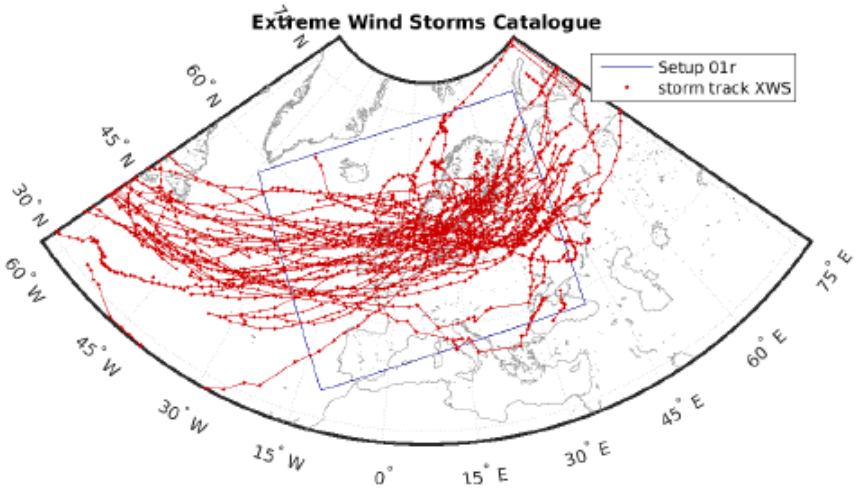



*1994 – 2016*, 429 stormy days

5%

# 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.

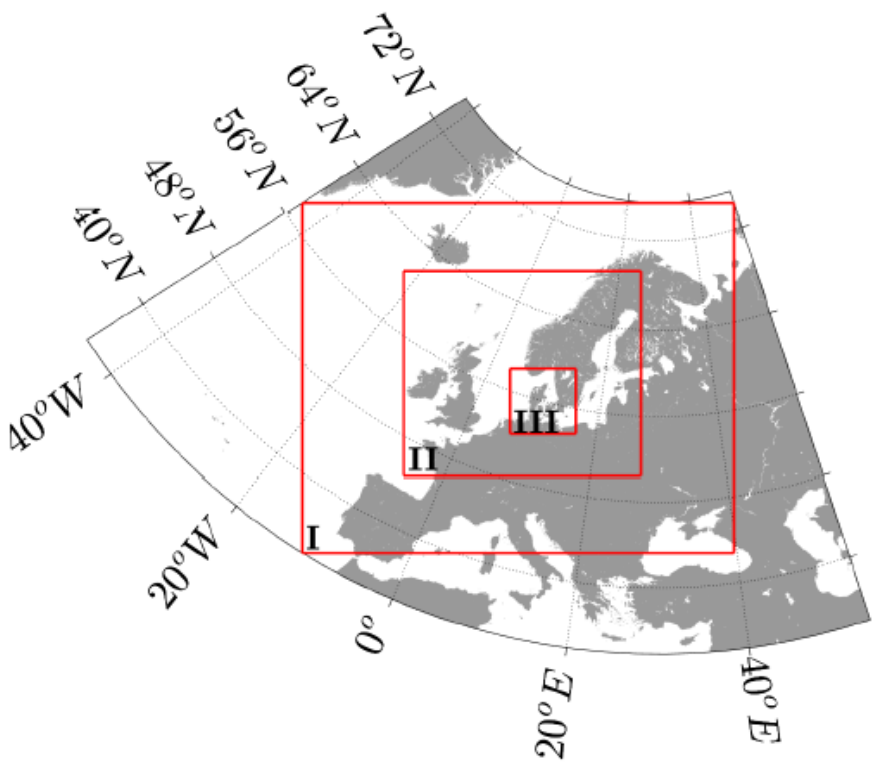
Optimalization of model setup

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**

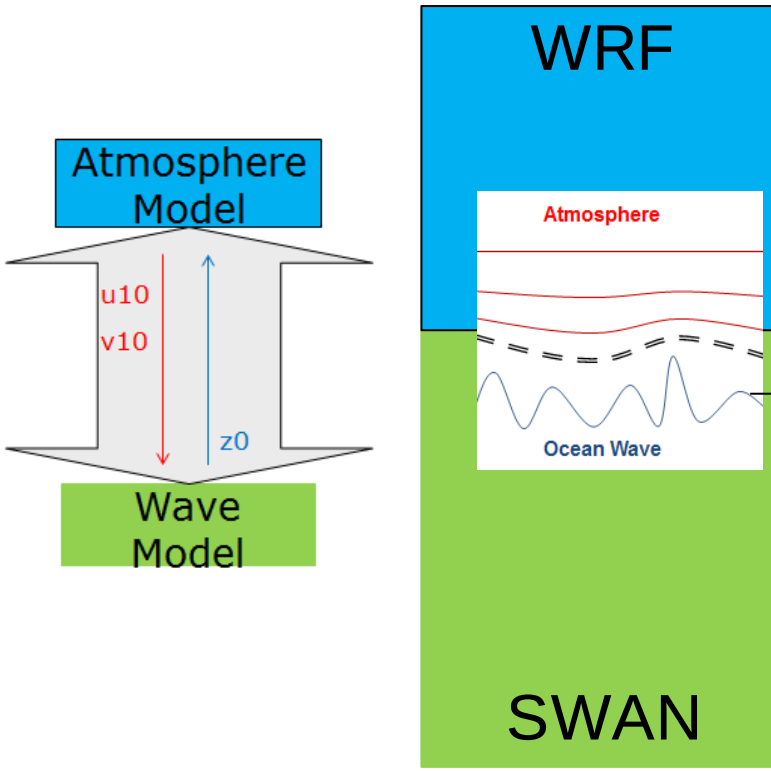
**WRF:**
**CFSR+OISST**
**77 vertical sigma levels**
**MYNN 3.0 PBL scheme**
**RRTM long and short wave radiation**
**Kain-Fritsch cumulus scheme (domain I)**
**Corine land use**

**WBLM**

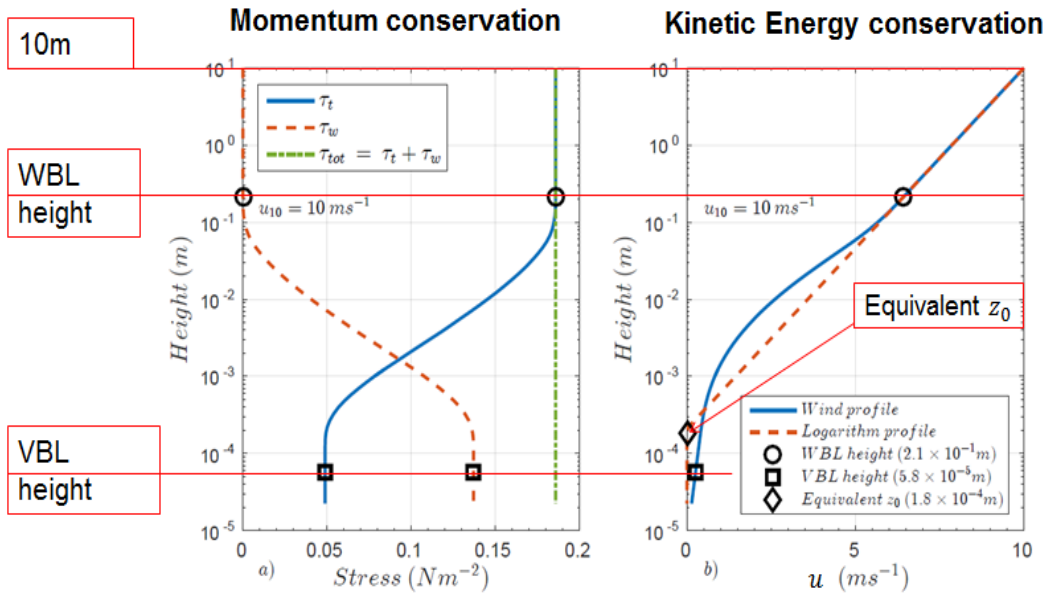
**SWAN:**
**1/8 arc-minute bathymetry data**
**Initiated 24h before the simulation**
**Close boundary for open sea**
**36 directional bins.**
**0.03 Hz < f < 10.05 Hz (KOM and WBLM)**
**0.03 Hz < f < 0.57 Hz (JANS)**

# Method for obtaining the 50-year wind

## 2. Modeling the samples: the WBLM




**The Wave Boundary Layer Model**

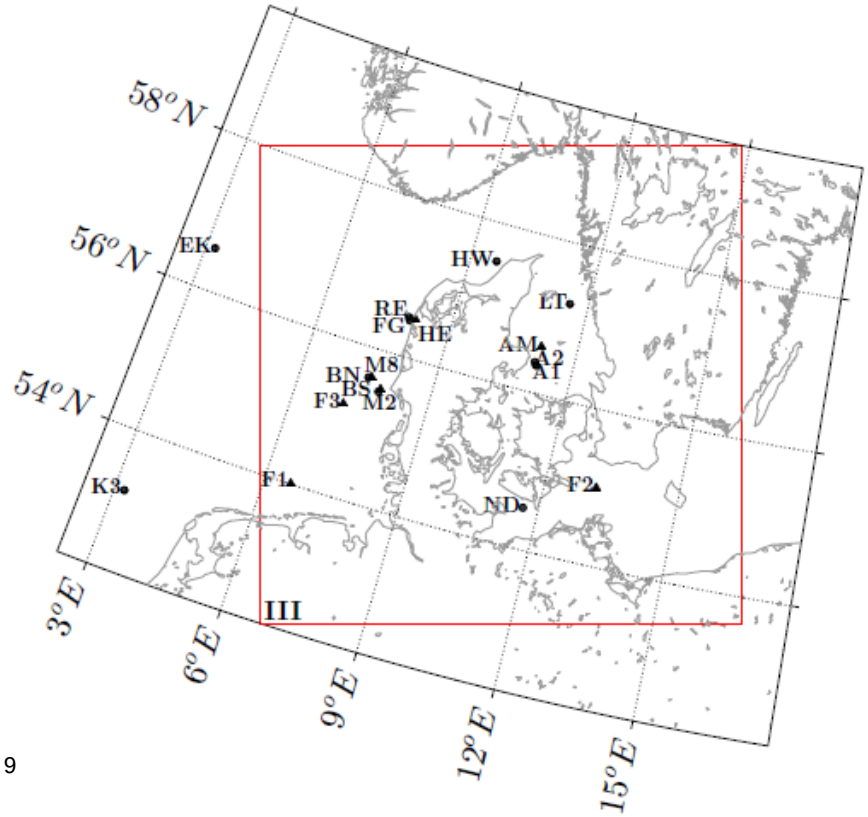


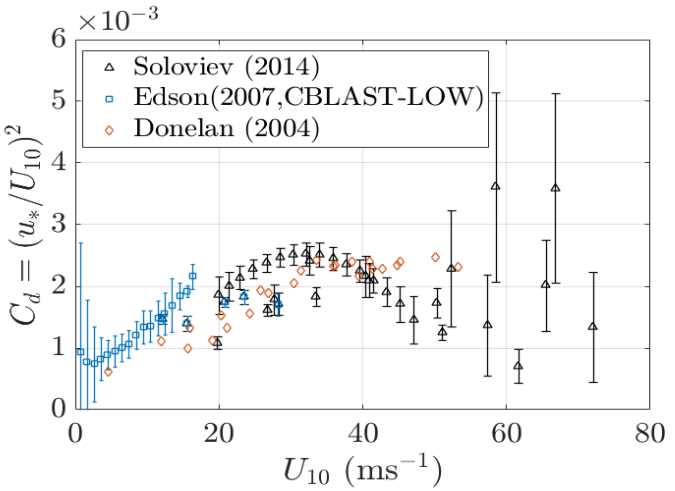

Du, J., Bolaños, R., and Larsén, X. (2017a). The use of a wave boundary layer model in SWAN. *Journal of Geophysical Research: Oceans*, pages 1063–1084.

# 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



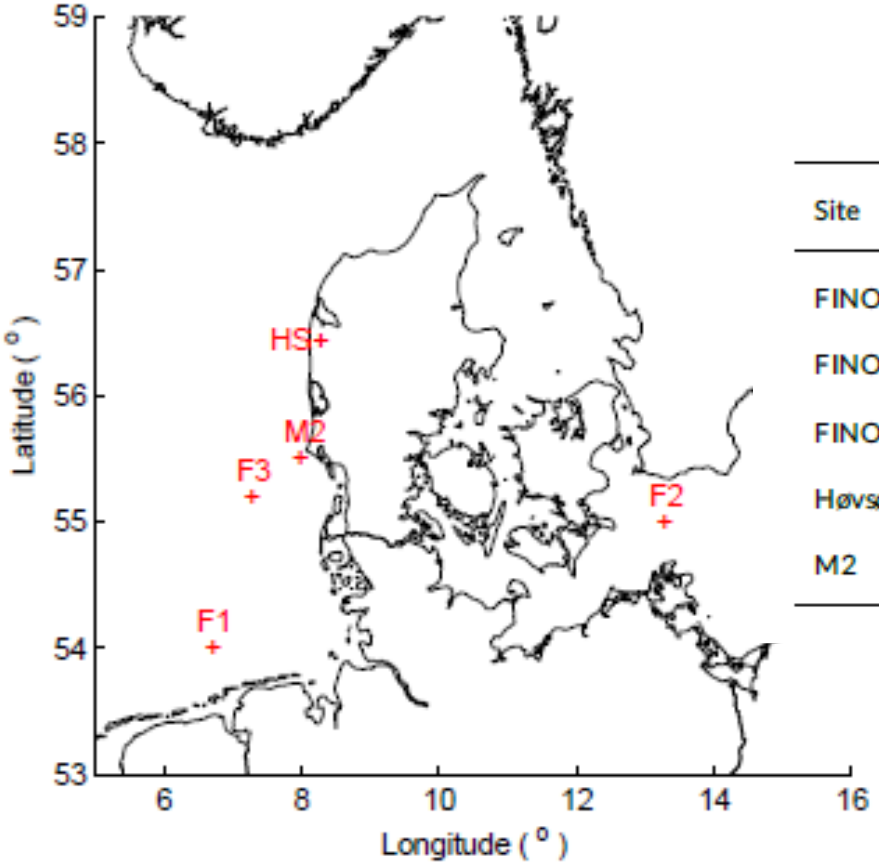

**Soloviev (2014)**: A collection of measurements from Powell (2003), Black (2007, CBLAST-Hurricane), Bell (2012), Jarosz (2007), Holthuijsen (2012)

**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

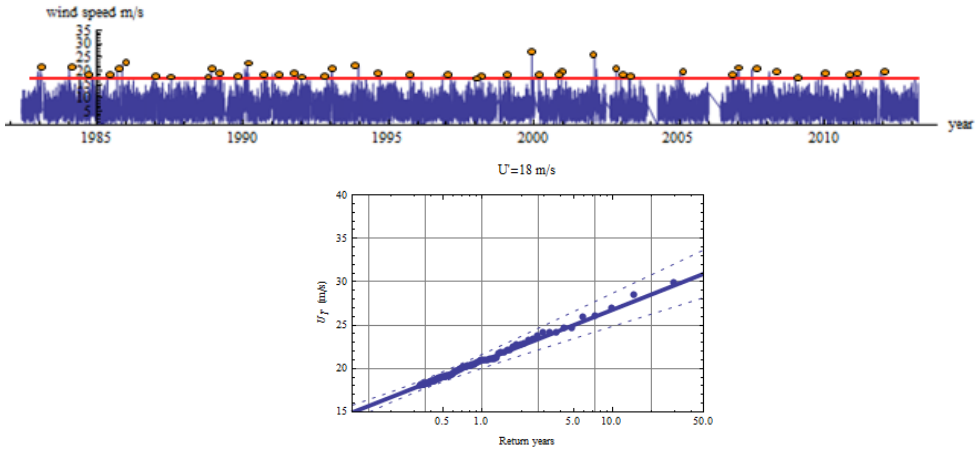



| Site | Coordinates | Period | Data length (years) | Height (m) |
|---|---|---|---|---|
| FINO1 | 6.588°E, 54.014°N | 2004 - 2017 | 14 | 100 |
| FINO2 | 13.1542°E, 55.007°N | 2008 - 2017 | 10 | 102 |
| FINO3 | 7.1583° E, 55.195°N | 2010 - 2017 | 8 | 100 |
| Høvsøre | 8.15°E, 56.433°N | 2005 - 2017 |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

# Method for obtaining the 50-year wind

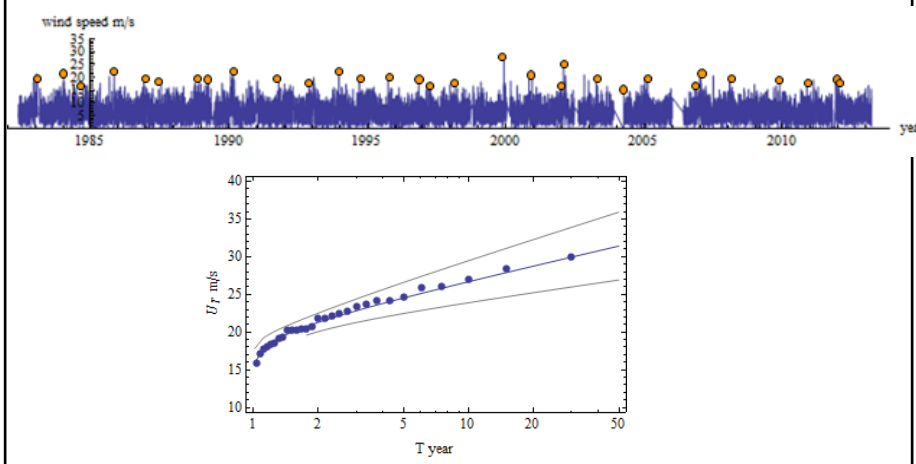
## 2. For calculating the 50-year return value

### Peak-Over-Threshold Method




$$U_T = u_0 + A\ln(\lambda T)$$

### Annual Maximum Method




$$U_T = \alpha^{-1}\ln(T/T_{BP}) + \beta$$

**Applied to measurements only**

**to both measurements and modelled data**

# Results

Questions:

Have we captured the relevant storms?

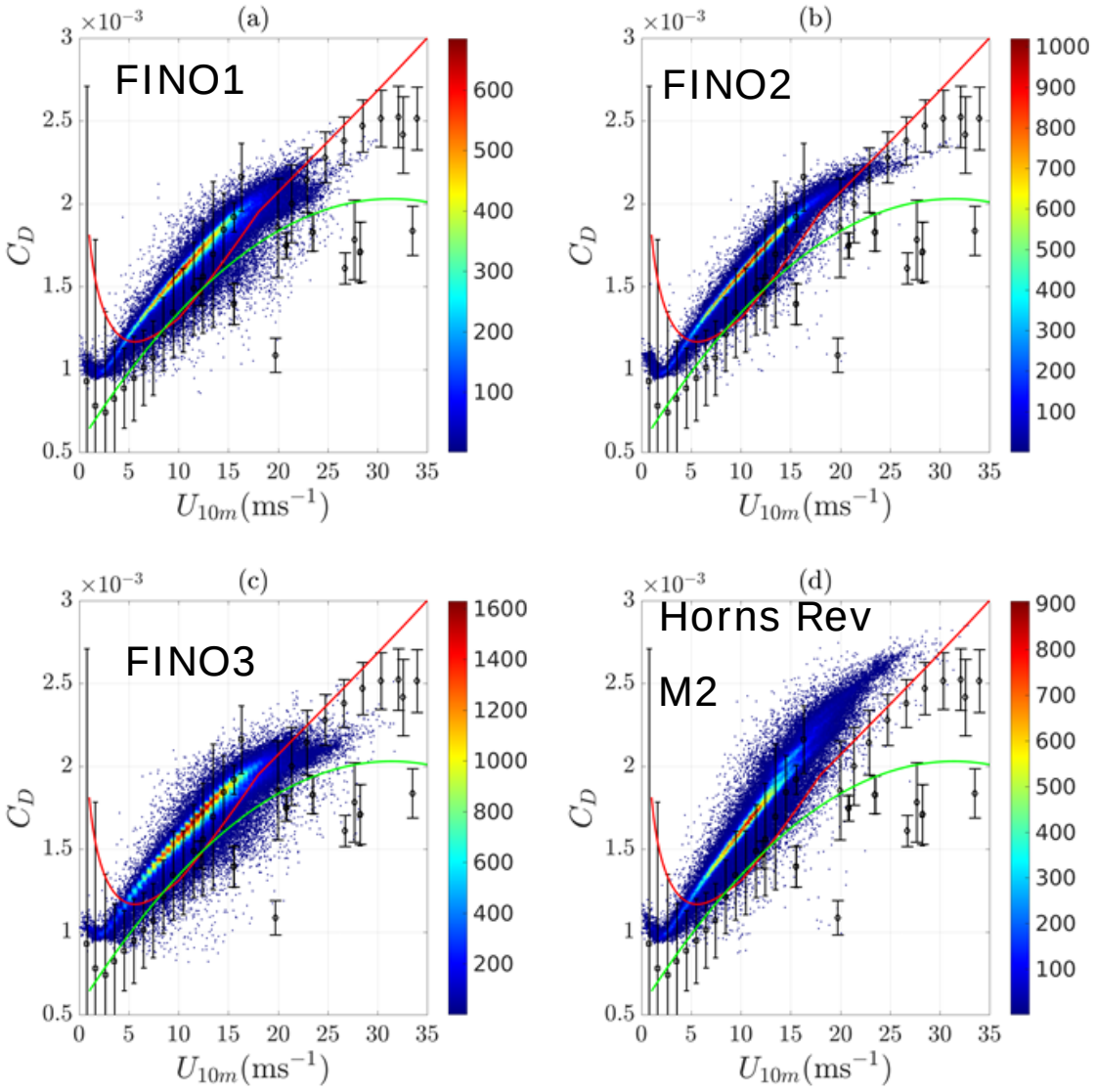
How is the general model performance?

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

Question 2:

How is the general model performance?

# Results

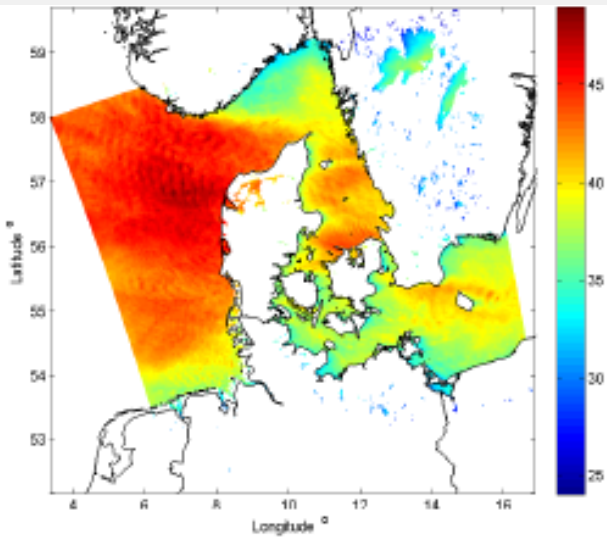

(a)
FINO1
(b)
FINO2
(c)
FINO3
(d)
Horns Rev
M2
$\times 10^{-3}$
$C_D$
$U_{10m}(\mathrm{ms}^{-1})$

Question 3:

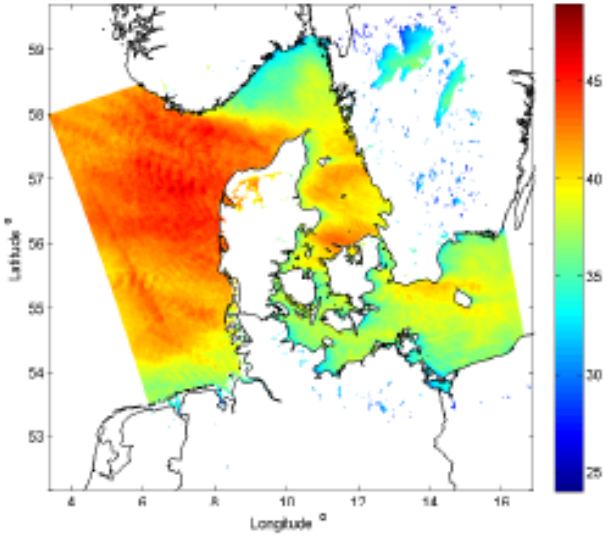
How is the estimate of U50?

# Results

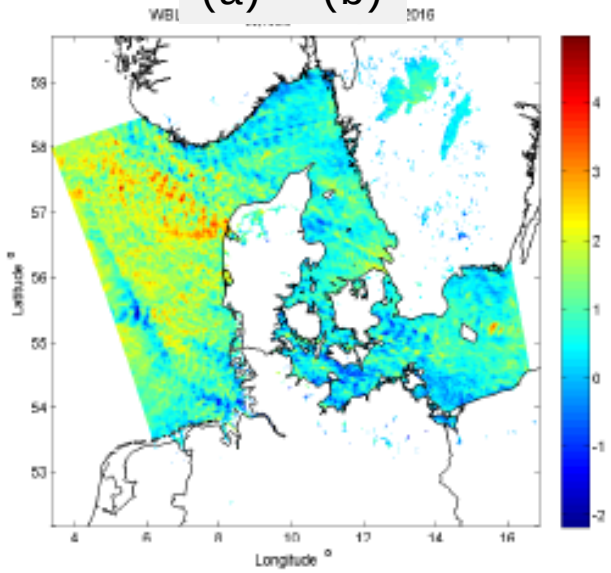
(a) U50 at 100 m, coupled



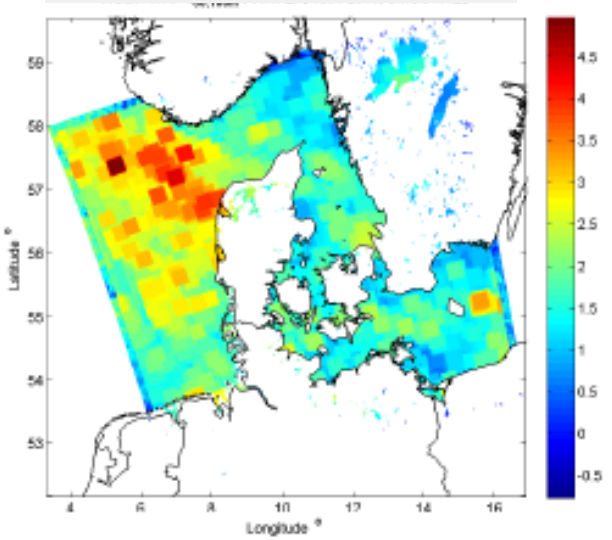

(b) U50 at 100 m, not-coupled



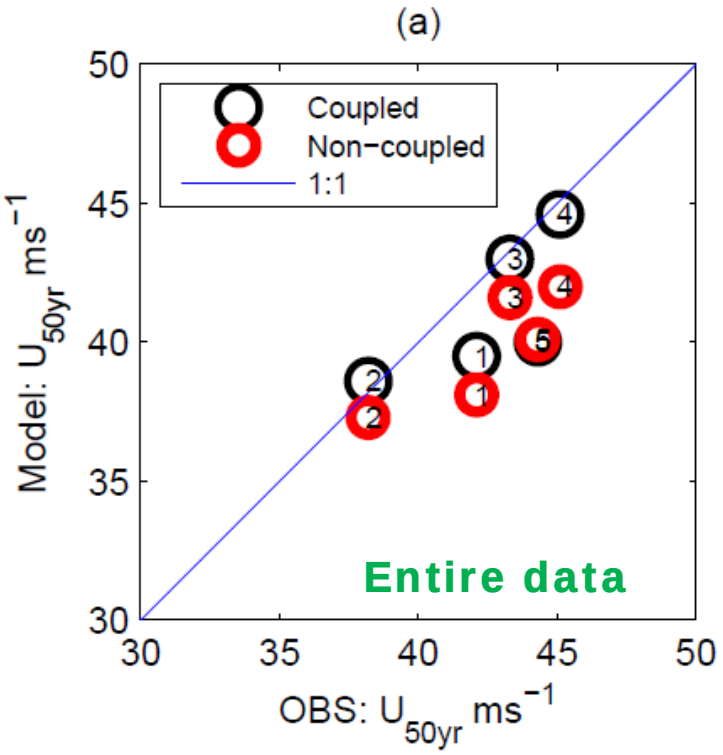

(a) – (b)




(a) – (b), smoothed



# Results



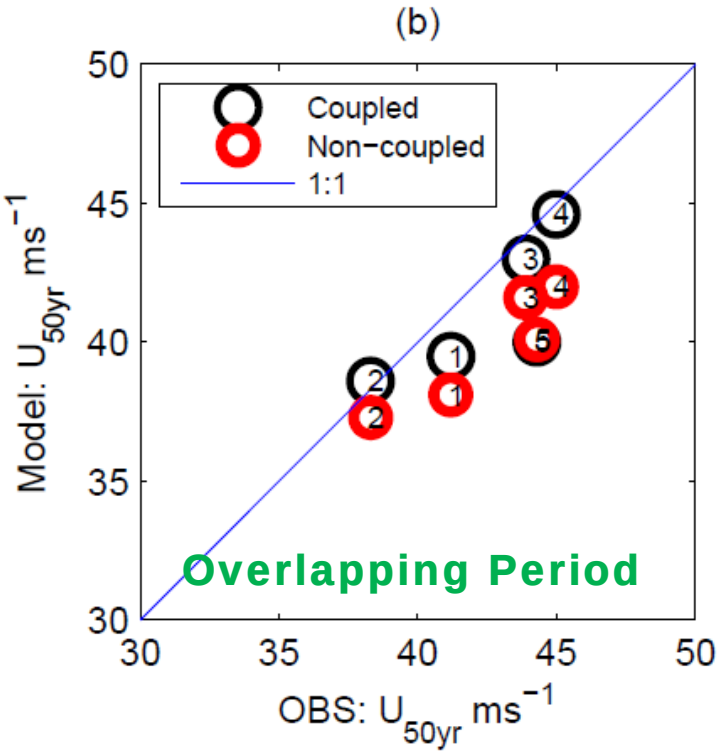




**Table 1 – Basic parameters for wind turbine classes[2]**

| 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

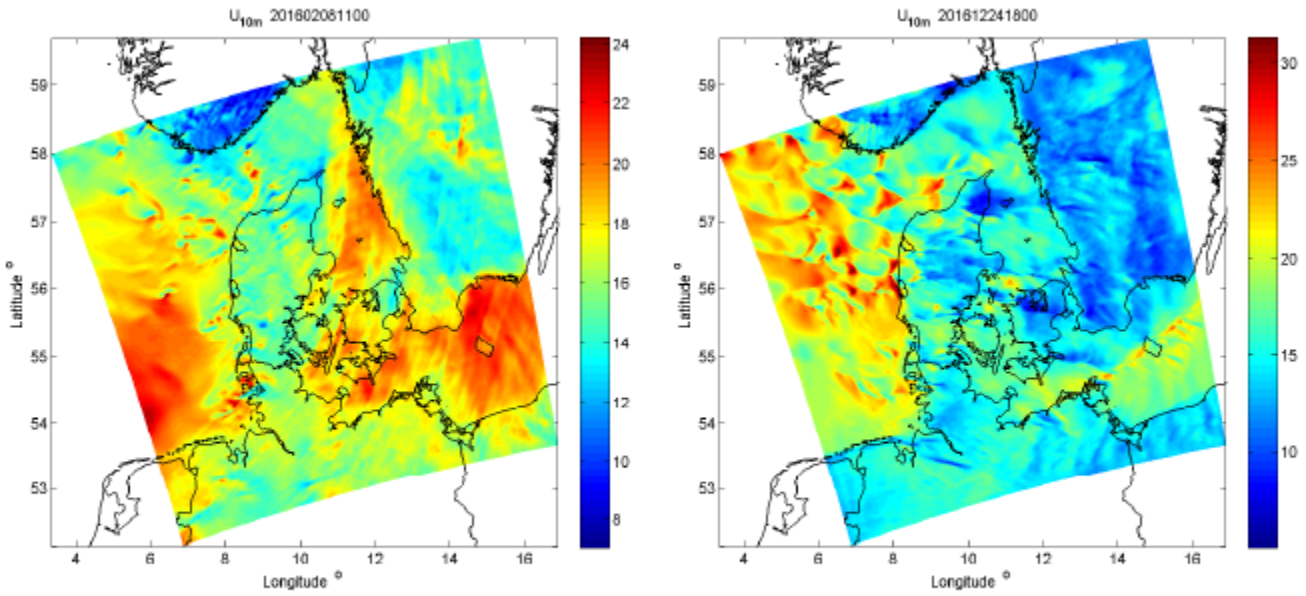



**FIGURE 8** Examples of the wind fields in the presence of open cells: 2016-02-08 11:00 and 2016-12-24 18:00.