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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Department of Wind Energy
Relevance of the study/state-of-the-art
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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:

Optimization 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

Momentum conservation

Kinetic Energy conservation

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


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

<table>
<thead>
<tr>
<th>Site</th>
<th>Coordinates</th>
<th>Period</th>
<th>Data length (years)</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINO1</td>
<td>6.588°E, 54.014°N</td>
<td>2004 - 2017</td>
<td>14</td>
<td>100</td>
</tr>
<tr>
<td>FINO2</td>
<td>13.1542°E, 55.007°N</td>
<td>2008 - 2017</td>
<td>10</td>
<td>102</td>
</tr>
<tr>
<td>FINO3</td>
<td>7.1583°E, 55.195°N</td>
<td>2010 - 2017</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>Høvsøre</td>
<td>8.15°E, 56.433°N</td>
<td>2005 - 2017</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>M2</td>
<td>7.875°E, 55.508°N</td>
<td>2000 - 2005</td>
<td>6</td>
<td>62</td>
</tr>
</tbody>
</table>
Method for obtaining the 50-year wind

2. For calculating the 50-year return value

**Peak-Over-Threshold Method**

\[ U_T = u_0 + A \ln(\lambda T) \]

- Applied to measurements only

**Annual Maximum Method**

\[ U_T = \alpha^{-1} \ln\left(\frac{T}{T_{BP}}\right) + \beta \]

- 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
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

<table>
<thead>
<tr>
<th>Wind turbine class</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_{ref}$ (m/s)</td>
<td>50</td>
<td>42.5</td>
<td>37.5</td>
<td>Values specified</td>
</tr>
<tr>
<td>A</td>
<td>0.16</td>
<td></td>
<td></td>
<td>by the designer</td>
</tr>
<tr>
<td>B</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.