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
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**

<table>
<thead>
<tr>
<th>Year</th>
<th>Stormy Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>19940104</td>
</tr>
<tr>
<td>1995</td>
<td>19950119</td>
</tr>
<tr>
<td>1996</td>
<td>19960210</td>
</tr>
<tr>
<td>1997</td>
<td>19970714</td>
</tr>
<tr>
<td>1998</td>
<td>19980105</td>
</tr>
<tr>
<td>1999</td>
<td>19990125</td>
</tr>
<tr>
<td>2000</td>
<td>20001211</td>
</tr>
<tr>
<td>2001</td>
<td>20011219</td>
</tr>
<tr>
<td>2002</td>
<td>20021215</td>
</tr>
<tr>
<td>2003</td>
<td>20031217</td>
</tr>
<tr>
<td>2004</td>
<td>20041221</td>
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<tr>
<td>2005</td>
<td>20051218</td>
</tr>
<tr>
<td>2006</td>
<td>20061210</td>
</tr>
<tr>
<td>2007</td>
<td>20071210</td>
</tr>
<tr>
<td>2008</td>
<td>20081210</td>
</tr>
<tr>
<td>2009</td>
<td>20091210</td>
</tr>
<tr>
<td>2010</td>
<td>20101210</td>
</tr>
<tr>
<td>2011</td>
<td>20111210</td>
</tr>
<tr>
<td>2012</td>
<td>20121210</td>
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<tr>
<td>2013</td>
<td>20131210</td>
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<tr>
<td>2014</td>
<td>20141210</td>
</tr>
<tr>
<td>2015</td>
<td>20151210</td>
</tr>
<tr>
<td>2016</td>
<td>20161210</td>
</tr>
</tbody>
</table>

**1994 – 2016, 429 stormy days**

5%
Method for obtaining the 50-year wind

2. Modeling the samples:

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

\textbf{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

\textbf{WBLM}

\textbf{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

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**

![Graph showing wind speed distribution over years]

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

Applied to measurements only

**Annual Maximum Method**

![Graph showing wind speed distribution over years]

\[ U_T = a^{-1} \ln(T/T_{BP}) + \beta \]

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?
Results

Question 2:

How is the general model performance?
Results

![Graphs showing the relationship between CD and U10m for FINO1, FINO2, FINO3, Horns Rev, and M2.](image)
Question 3:
How is the estimate of $U_{50}$?
Results

(a) U50 at 100 m, coupled

(b) U50 at 100 m, not-coupled

(a) – (b)

(a) – (b), smoothed
Results

![Graphs showing wind turbine data](image)

### Entire data

- **Coupled**
- **Non-coupled**

1: FINO 1
2: FINO 2
3: FINO 3
4: Høvsøre
5: Horns Rev M2

![Graphs showing wind turbine data](image)

### Overlapping Period

![Graphs showing wind turbine data](image)

### 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 by the designer</td>
</tr>
<tr>
<td>A</td>
<td>0.16</td>
<td></td>
<td></td>
<td></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>
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.