THE STORMINESS AND THE WIND WAVE CLIMATE IN THE BALTIC SEA PRODUCED BY THE SWAN MODEL

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Main goals

Implementation of SWAN wave model for Baltic Sea using a high resolution grid

Validation of SWAN model by using instrumental wave measurements

Wave climate of the Baltic Sea for last 63 years
Wind data
U, V, 10 m above the ground

- NCEP-NCAR (~1.9x1.9°; 6 hours) period 1948 – 2010
- NCEP CFSR (~0.3x0.3°; 1 hour) period 1979 – 2014
Modeling tools

**SWAN** (Simulating waves nearshore) is the most widely used computer model to compute irregular waves in coastal environments, based on deep water wave conditions, wind, bottom topography, currents and tides (deep and shallow water).

**SMS** (Surface Water Modeling System) is a comprehensive environment for one-, two, and three-dimensional hydrodynamic modeling. A pre- and post-processor for surface water modeling and design, SMS includes 2D finite element, 2D finite difference, 3D finite element modeling tools.
Storm 8 Jan 2005

- $H_s \text{ max} = 8.7 \text{ m}$
- $\text{Dur} = 90 \text{ ч}$
- $W \text{ max} = 26.5 \text{ m/s}$
- $H_w \text{ max} = 6.35 \text{ m}$
- $P_k = 12.7 \text{ с}$
- $\text{Per} = 8 \text{ с}$
- $W_l = 75.7 \text{ m}$
Wave data base

- Model output wave parameters (Wave height, period, length, energy)
- Output Regular Grid 0.05° (351x251 nodes)
- Time step 3 hours
- Period 1948-2010
- Volume 600 Gb
Comparison results with other wave models
Points of wave measurements - SMHI Open Data (http://opendata-catalog.smhi.se)
Comparison with instrumental wave measurements

Graphs showing the comparison between measured and modeled significant wave heights (Hs) over different periods.
<table>
<thead>
<tr>
<th>Buoy №</th>
<th>Name</th>
<th>Period of measurements</th>
<th>R</th>
<th>RMSE</th>
<th>Bias</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Finngrundet</td>
<td>Jan-Dec 2010</td>
<td>0.83</td>
<td>0.51</td>
<td>-0.33</td>
<td>0.53</td>
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<td></td>
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<td>Nov 2010</td>
<td>0.88</td>
<td>0.64</td>
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<td>-0.20</td>
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<td>2</td>
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<td>0.39</td>
<td>0.04</td>
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<td></td>
<td></td>
<td>Jan 1992</td>
<td>0.71</td>
<td>0.59</td>
<td>0.032</td>
<td>0.61</td>
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<td></td>
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<td>May 1992</td>
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<td>0.30</td>
<td>0.02</td>
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<td>3</td>
<td>Södra Östersjön</td>
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<td>0.72</td>
<td>-0.53</td>
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<td>May 1992</td>
<td>0.83</td>
<td>0.31</td>
<td>-0.14</td>
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</table>
Calculating a number of storms in period 1948-2010

- $H_s \text{ max } = 4.4 \text{ [m]}$
- $\text{Dur } = 198 \text{ [ч]}$
- $W \text{ max } = 16.4 \text{ [м/с]}$
- $H_w \text{ max } = 1.32 \text{ [m]}$
- $P_k = 14.3\text{ [с]}$
- $\text{Per } = 8 \text{ [с]}$
- $W_l = 62.4 \text{ [м]}$

```javascript
Calculating a number of storms in period 1948-2010
```

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```javascript
Calculating a number of storms in period 1948-2010
```
Number of storms ($H_s > 2m$) in a year

![Graph showing the number of storms per year from 1960 to 2010. The graph displays a trend with peaks and troughs, indicating variations in storm frequency over the years.](image-url)
Black Sea Number of storms (Swh>2 m)
For period 1948 - 2010
Number of storms in a season
Model results with Forcing NCEP CFSR

Buoy "Finngrundet" 2010

Significant wave height, Hs (m)

November

b

NCEP/NCAR

Hs simulated (m)

Hs measured (m)

y = 0.74x - 0.12
R² = 0.78

NCEP/CFSR

Hs simulated (m)

Hs measured (m)

y = 1.12x - 0.09
R² = 0.91
## Statistical Analysis

<table>
<thead>
<tr>
<th>Reanalysis</th>
<th>Mechanism of wave generation</th>
<th>R</th>
<th>Bias</th>
<th>RMSE</th>
<th>SI</th>
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</thead>
<tbody>
<tr>
<td><strong>Finngrundet buoy (30.6 m) 18.67° N, 61.00° E - November 2010</strong></td>
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<tr>
<td>NCAR</td>
<td>GEN3/ 1 hour</td>
<td>0.884</td>
<td>-0.498</td>
<td>0.645</td>
<td>0.447</td>
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<td>GEN3/ 15 min</td>
<td><strong>0.953</strong></td>
<td>0.083</td>
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<td>0.047</td>
<td>0.344</td>
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<td>GEN3/1 hour</td>
<td>0.878</td>
<td>-0.047</td>
<td>0.459</td>
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<td>GEN2/ 1 hour</td>
<td>0.950</td>
<td>0.069</td>
<td>0.291</td>
<td>0.202</td>
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<tr>
<td>CFSR</td>
<td>GEN1/1 hour</td>
<td>0.949</td>
<td><strong>-0.025</strong></td>
<td><strong>0.274</strong></td>
<td><strong>0.189</strong></td>
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<tr>
<td><strong>Sodra Ostersjon buoy (111.7 m) 18.78° N, 55.92° E - November 2010</strong></td>
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<tr>
<td>NCAR</td>
<td>GEN3/ 1 hour</td>
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<td>-0.730</td>
<td>0.889</td>
<td>0.487</td>
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<tr>
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<td>GEN3/ 15 min</td>
<td><strong>0.967</strong></td>
<td><strong>-0.003</strong></td>
<td><strong>0.272</strong></td>
<td><strong>0.149</strong></td>
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<tr>
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<td>GEN3/ 30 min</td>
<td>0.959</td>
<td>-0.060</td>
<td>0.303</td>
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<tr>
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<td>GEN3/1 hour</td>
<td>0.920</td>
<td>-0.180</td>
<td>0.443</td>
<td>0.243</td>
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<tr>
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<td>GEN2/ 1 hour</td>
<td>0.943</td>
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<td>0.194</td>
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<tr>
<td>CFSR</td>
<td>GEN1/1 hour</td>
<td>0.946</td>
<td>-0.157</td>
<td>0.367</td>
<td>0.201</td>
</tr>
</tbody>
</table>
No cheating. Coefficients is default

GEN3
  KOMEN cds2=0.5e-5
WCAPping Janssen cds1=0.5
delta=1 QUADruple iquad=8
Cnl4=5e7
BREaking constant alpha=1.0
gamma=0.73
FRICITION JONSWAP 0.038
TRIAD trfac=0.10 cutfr=2.5
Where the wave models tested and calibrated?
Weather stations around the Barents sea
Conclusions

The SWAN wave model was implemented for the Baltic Sea using a high resolution grid.

Validation of SWAN model by using instrumental wave measurements shows, that for NCEP/NCAR forcing correlation is 0.8-0.9 and RMSE – 0.3-0.5 m for NCEP/CFSR forcing correlation is 0.9-0.95 and RMSE – 0.3-0.4 m.

Wave database was made (grid 0.05° (351x251 nodes, time step 3 hours, period 1948-2010).

The numbers of storms is grooving, for last 60 years trend is positive.
THANK YOU FOR YOUR ATTENTION!

For collaboration: stasocean@gmail.com

Our wave data base is available for your investigations!