Examining field measurements during the December 2012 storm in the North Sea

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Storm 14-15 December 2012

- Central North Sea
- Maximum Significant Wave Height 12m
- Spectral Peak Period 13s
- Nineteen rogue waves measured over eight platforms
  - \( \eta/H_s \geq 1.25 \)
  - \( H/H_s \geq 2 \)
Results

Strong correlation between deviation from second-order crest statistics and wind speed

![Graph showing correlation with wind speed](image-url)
Conclusions

1. Severe steep storm 14-15 December 2012
2. Significant departure from second-order crest elevation distribution during periods with large wind speed and sea-state steepness
3. Some departure from standard wave height distributions during periods with large wind speed and sea-state steepness
4. Results are independent of sensor location and the measurement device
Platforms

Eight fixed platforms with Saab wave radars
One FPSO with a directional waverider buoy
Storm

![Graph showing storm wave height (Hs) and wind speed (U) over time (days). The graph includes curves for Hs (solid red), U (solid black), Hs_hindcast (dashed red), and U_hindcast (dashed black). The x-axis represents time in days, ranging from -1 to 1, and the y-axis represents value, ranging from 0 to 35.]
Storm

Steep sea states around the peak of the storm
Storm

Strong winds around the peak of the storm
Wave Profiles

\[ \eta = 10.9 \text{m} \]
\[ H_s = 7.7 \text{m} \]
\[ \frac{\eta}{H_s} = 1.42 \]

\[ \eta = 14.1 \text{m} \]
\[ H_s = 10.2 \text{m} \]
\[ \frac{\eta}{H_s} = 1.38 \]
Wave Profiles

\[ \eta_{12.0m} \]
\[ Hs_{9.2m} \]
\[ \eta/Hs_{1.31} \]

\[ \eta_{15.9m} \]
\[ Hs_{12.4m} \]
\[ \eta/Hs_{1.29} \]
Crest Statistics: entire storm

No significant deviation from second order theory
Wave Height Statistics: entire storm

No significant deviation from standard wave height distributions
Crest Statistics

Crest distributions for nine hour windows at different points in the storm

\begin{figure}
\centering
\includegraphics[width=\textwidth]{crest_distributions.png}
\caption{Distribution of crest heights for different time periods during the storm.}
\end{figure}
Crest Statistics

Ratio of empirical crest elevations to second order theory

![Graph showing the ratio of empirical crest elevations to second order theory over time. The graph includes lines for different values and scales, such as \(C_{10^{-3}}/F_{10^{-3}}\), \(C_{10^{-4}}/F_{10^{-4}}\), \(S1 \times 10\), \(Ur1 \times 100\), and \(U (m/s) \times 0.01\). The x-axis represents time in days, and the y-axis represents value. The graph highlights changes in the ratios over time.]
Correlation with Wind Speed

Correlation between deviation of crest elevation from second order theory and wind speed
Correlation with Sea State Steepness

\[
\frac{(S - S_{\text{min}})}{(S_{\text{max}} - S_{\text{min}})} \quad \frac{(R - R_{\text{min}})}{(R_{\text{max}} - R_{\text{min}})}
\]
Crest Statistics

Crest distributions conditional on wind speed

\[ \eta / H_s \]

- Rayleigh
- Forristall
- 12hrs Before U>25m/s
- 12hrs U>25m/s
- 12hrs After U>25m/s
Wave Height Statistics

Wave height distributions conditional on wind speed

![Wave height distribution graph](image)
Upwave and Downwave Sensors

The effect of sensor location

![Graph showing the effect of sensor location on wave height](image)

- Rayleigh
- Forristall
- Unsheltered
- Sheltered
- All

\[ \eta / H_s \]
Radar and Buoy Measurements

Comparison between wave heights measured by the buoy and the radars

![Graph showing comparison between wave heights measured by the buoy and the radars with different models: Rayleigh, Forristall, Boccotti, Fixed, and Anasuria. The graph plots the probability density function (P) against the ratio of wave height (H) to significant wave height (Hs).]
Conclusions

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Wave Profiles

Average shape consistent with focussed wave events

![Wave Profiles Graph](image_url)
Ratio

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>1.0</td>
</tr>
<tr>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Legend:
- $H_{10^{-3}}/B_{10^{-3}}$
- $H_{10^{-4}}/B_{10^{-4}}$
- $S1 \times 10$
- $U_{r1} \times 100$
- $U (m/s) \times 0.01$
Wind speed
Correlation Hs

\[
\frac{(H_s - H_{s\text{ min}})}{(H_{s\text{ max}} - H_{s\text{ min}})} \quad \frac{(R - R_{\text{min}})}{(R_{\text{max}} - R_{\text{min}})}
\]
Correlation Ur

\[
\frac{(R - R_{\text{min}})}{(R_{\text{max}} - R_{\text{min}})} \times \frac{(Ur - Ur_{\text{min}})}{(Ur_{\text{max}} - Ur_{\text{min}})}
\]