Squalls Identification

1. Introduction
   1. Squalls definition
   2. Background and Objectives

2. Use of Satellite Altimeter data
   1. Verification
   2. Forward speed and event duration
   3. Foot print and Averaging interval

3. Extreme Value Analysis

4. Examples
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Introduction – Squalls definition
Introduction - Background

• Violent short-lived winds
  ➢ Significant impact on shipping and port industry
    • Moored / weathervaning ships
    • Crane operation
    • Human safety

• Measurements are scarce (squalls are short and local)

• Numerical models struggle to capture them (physics / resolution)

• Satellite data has a global coverage over extended period
  ➢ Valid solution to fill the gap
  ➢ Compensates for length of time with spatial coverage
Satellite data - Verification

Compare exceedance with available in situ data and identify threshold selection for squall isolation.
Satellite data - Verification

Compare exceedance with available in situ data and identify threshold selection for squall isolation

![Wind Speed vs Probability of Exceedance Graph](image)

- Altimeter
- Meas1
- Meas2
- Meas3

\[ U_{\text{lim}} = 13 \text{m/s} \]
Satellite data - Verification

Use satellite imagery to check the location and time of extreme satellite data samples

GOES-12 optical satellite data for event on 22-Feb-2009 at 12:00 UTC. The arrow indicates the altimeter measurement location.
Extreme Value Analysis

• Based on the Cumulative Frequency Distribution method

• Assumes homogeneity of the population
  ➢ Need to properly select the data threshold

• Uses the Weibull distribution

• Check sensitivity of results to various parameters:
  • Event duration
  • Estimated Time averaging period
  • Data threshold
  ➢ Confirm that the method is stable

➢ Validate against Guidelines for locations with squalls where they are available
Example – Ghana

Ta = 10 min
Te = 10 min
U_{lim} = 9.5 \text{ m/s}
Example – Brazil

Ta = 12 min
Te = 30 min
Ulim = 13 m/s
Hindcast validation

1. Global Validation
   1. Maps
   2. Taylor diagrams

2. Point Validation

3. Event Validation
   1. Scatterometer Overlay
   2. Altimeter Latitude
Root Mean Square Deviation between CFSSR/ERA5 wind speed input and Satellite observations

RMSE between model and Altimeter
Taylor diagram of model vs Altimeter for U10

Annual Wind Speed for the area between -60°N and 60°N
Point Validation - model vs Altimeter
Altimeter vs Model, Hm0
Conclusion

• **Squalls:**
  • A way of extracting very specific information out of a satellite database
  • Data is suitable for preliminary design
  • Limitations
  • Future plans include verifying results in squall areas where measurements are available.

• **Global validation**
  • General statistics about model quality

• **Event validation**
  • Case base verification of model performance
Thank You

Questions?
Satellite data – Forward speed

Use satellite imagery to estimate the forward speed and event duration.

GOES-12 Water vapor image on 22-Feb-2009 at 06:00 UTC (left panel) and 15:00 UTC (right panel).
Satellite data – Time Averaging

Satellite averages over space but for design we need a time average (Ta) - and we need to know what that time is.

Actual Sampling situation
Satellite data – Time Averaging

So we compute $T_a = \frac{L}{V}$ with:
- $V=$ forward speed of the squall
- $L=$ footprint of the Satellite

Fictional Sampling situation

Satellite

Sea Surface

Squall event

V

T0

T1 = T0 + $T_a$

Sea Surface
Conclusion

• **Important input data:**
  - Altimeter data
  - Averaging time \((T_a)\), from forward speed and footprint
  - Event duration \((T_e)\), from altimeter data and satellite imagery
  - Selection Threshold

• **Data is suitable for preliminary design**

• **Limitations**

• **Future plans include verifying results in squall areas where measurements are available.**
Results of the sensitivity analysis in Ghana

<table>
<thead>
<tr>
<th>Storm Duration (Te)</th>
<th>2.5 min</th>
<th>5 min</th>
<th>10 min</th>
<th>20 min</th>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td>29.5</td>
<td>28.7</td>
<td>27.8</td>
<td>26.9</td>
<td>26.4</td>
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<tr>
<td></td>
<td>2.7%</td>
<td>-0.2%</td>
<td>-3.2%</td>
<td>-6.7%</td>
<td>-8.9%</td>
</tr>
<tr>
<td>10 min</td>
<td>30.4</td>
<td>29.6</td>
<td>28.7</td>
<td>27.8</td>
<td>27.2</td>
</tr>
<tr>
<td></td>
<td>5.7%</td>
<td>3.0%</td>
<td>0.0%</td>
<td>-3.4%</td>
<td>-5.5%</td>
</tr>
<tr>
<td>20 min</td>
<td>31.5</td>
<td>30.6</td>
<td>29.7</td>
<td>28.7</td>
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<tr>
<td></td>
<td>8.8%</td>
<td>6.1%</td>
<td>3.3%</td>
<td>-0.1%</td>
<td>-2.1%</td>
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</tbody>
</table>

Sensitivity Analysis of 100yr 10-minute average wind speed to estimated Storm Duration and Time Averaging offshore Ghana, value in [m/s] and percentage of variation.
Results of the satellite imagery checks in Brazil

<table>
<thead>
<tr>
<th>Event number</th>
<th>date</th>
<th>time [UTC]</th>
<th>$U_{10}$ [m/s]</th>
<th>Conv. Clouds</th>
<th>Synoptic Situation</th>
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<tbody>
<tr>
<td>e1</td>
<td>9-apr-2010</td>
<td>13:21</td>
<td>25.4</td>
<td>Yes</td>
<td>Frontal trough</td>
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<tr>
<td>e2</td>
<td>22-feb-2009</td>
<td>12:29</td>
<td>21.5</td>
<td>Yes</td>
<td>ITCZ</td>
</tr>
<tr>
<td>e3</td>
<td>17-dec-2014</td>
<td>07:31</td>
<td>18.4</td>
<td>Yes</td>
<td>Frontal trough</td>
</tr>
<tr>
<td>e4</td>
<td>18-nov-2014</td>
<td>08:56</td>
<td>17.8</td>
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<td>e5</td>
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<td>01-jun-2004</td>
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</table>

Top 10 events near Sergipe

<table>
<thead>
<tr>
<th>Event number</th>
<th>Estim. Event Dimension [km]</th>
<th>V [m/s]</th>
<th>$T_a$ [min]</th>
<th>$T_e$ [min]</th>
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</thead>
<tbody>
<tr>
<td>e1</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>e2</td>
<td>35</td>
<td>5</td>
<td>28</td>
<td>117</td>
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<tr>
<td>e3</td>
<td>40</td>
<td>5</td>
<td>14</td>
<td>67</td>
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<tr>
<td>e4</td>
<td>30</td>
<td>7</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>e5</td>
<td>30</td>
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<td>10</td>
<td>36</td>
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<tr>
<td>e6</td>
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</tr>
<tr>
<td>e7</td>
<td>40</td>
<td>-</td>
<td>-</td>
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<tr>
<td>e8</td>
<td>11</td>
<td>7</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>e9</td>
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<td>10</td>
</tr>
<tr>
<td>e10</td>
<td>11</td>
<td>10</td>
<td>13</td>
<td>17</td>
</tr>
</tbody>
</table>

Average: 24 [m/s], 7, 12, 36

Information extracted from optical imagery for top 10 events near Sergipe
References for validity of the Satellite data under 25m/s

Calibration and Cross Validation of a Global Wind and Wave Database of Altimeter, Radiometer, and Scatterometer Measurements
I. R. Young, E. Sanina, and A. V. Babanin Department of Infrastructure Engineering, University of Melbourne, Parkville, Victoria, Australia
https://journals.ametsoc.org/doi/full/10.1175/JTECH-D-16-0145.1

33 years of globally calibrated wave height and wind speed data based on altimeter observations
Agustinus Ribal & Ian R. Young
Scientific Data 6, Article number: 77 (2019)
https://www.nature.com/articles/s41597-019-0083-9
STD between model and Altimeter
Mean error between CFSR/ERA5 wind speed input and IMOS Satellite observations

Mean error Model vs Altimeter
Taylor diagram of model vs buoys for Hm0
Taylor diagram of model vs buoys for Tm02
Scatterometer Overlay Model at 12h, Scat at 13h40