How reliable is the Peak-over-threshold extreme wind assessment method? 

On the Peak-Over-Threshold (POT) Extreme Wind estimation as applied at DTU Wind Energy - Recently implemented in WAsP Engineering 

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How reliable is the Peak-over-threshold extreme wind assessment method?

On the Peak-Over-Threshold (POT) Extreme Wind estimation as applied at DTU Wind Energy
- Recently implemented in WAsP Engineering -

Ole Rathmann, Xiaoli Larsén,
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DTU Wind Energy, Denmark
Extreme Wind Prediction - background

• For wind turbine selection, typically the 50-year extreme wind is required

• Annual Max. method ¹): Based on Ann.max wind speeds distribution.
  – Requires typically 10Y+ of data
  – Gumbel double-log distribution is used for extrapolating to 50 Y.

• POT (Peak Over Threshold) ²): Based on individual storm winds distribution
  – Potentially, shorter time series should be usable
  – 1000$ Q: How short time series could be used without excessive uncertainty?


²) Abild J. Application of the wind atlas method to extremes of wind climatology.
POT - Basics

- Based on Peak-wind speeds of individual storms
- Considers the exceedance rate $R$ over a threshold (how many per year?)
  - Use $\text{Min}(U_{\text{Ann.Max}})$ as reference threshold
- How does $R$ decrease with increasing threshold?

Storms discriminated by
- Lower speed threshold
- Max. storm duration
- Min. storm separation

Exceedance rate $R$
- Exponential decay
- Extrapolation to a certain return-time to get e.g. $U_{50}$
- Quality control from statistical test (Poisson statistics)
POT – Demonstration – 4 test cases

- Indication of the reliability of the POT-method from 4 test cases

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Type</th>
<th>Height</th>
<th>Time series length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jylex</td>
<td>Denmark</td>
<td>Inland</td>
<td>24.0 m</td>
<td>16 years</td>
</tr>
<tr>
<td>Sprogoe</td>
<td>Denmark</td>
<td>Off-shore</td>
<td>70.0 m</td>
<td>22 years</td>
</tr>
<tr>
<td>Abu Darag</td>
<td>Egypt/Red Sea</td>
<td>Subtropical high</td>
<td>24.5 m</td>
<td>12 years</td>
</tr>
<tr>
<td>Bloemenfontein</td>
<td>South Africa</td>
<td>Continental</td>
<td>10.0 m</td>
<td>17 years</td>
</tr>
</tbody>
</table>

- Various time series lengths (full length; 6, 7 or 8y; 3y; 2y)
- Compared to ann.max method (full time series length)
POT – Demonstration – 4 test cases (A)

- Indication of the reliability of the POT-method from 4 test cases
  - Uncertainties deduced from Poisson-deduced statistics

POT – Demonstration – 4 test cases (B)

• Indication of the reliability of the POT-method from 4 test cases
POT – Demonstration – 4 test cases (C)

- Indication of the reliability of the POT-method from 4 test cases
POT – Demonstration – 4 test cases (D)

• Indication of the reliability of the POT-method from 4 test cases
POT and Terrain effects

Beware!

• POT may be influenced by terrain effects when predicting 50-year winds at turbine sites by high-wind data from a met-tower:
  – A certain measured “storm wind-peak” may not be a storm wind peak when transformed from mast site to a “predicted” wind turbine site
  – What seems to be a low or moderate wind at mast site may become a “storm wind” when transformed to a predicted wind turbine site.

• Special measures must be exercised to ensure that all relevant high-wind data are transformed to wind turbine sites for the POT-extreme wind estimation there.
Short term data – why do predictions fail? What to do about it?

- Short term data: 1 or a few years
  - Normally represents short-term fluctuations quite well: 10 min. recording interval or better assumed.

- Long term year-to-year variance CANNOT be represented
  - E.g., for a single year: is this a high, average or low year ???
  - Unless you combine with a long term reference data set

- Long-term model wind data from reanalysis data + Mesoscale-model may be used
  - Model data (1h ) have an insufficient representation of the dynamics at relatively high frequency
  - Impact of the high frequency dynamics must be corrected for
Model-data high frequency dynamics issue
How to handle this?

- Power spectrum
  - Model data 32Y
  - Measured data 1Y
  - Both generalized
    (terrain cleansed)
- Hybrid spectrum
  - Low freq.: model l.t. data
  - High freq.: meas. s.t. data
- Relation between power spectrum and predicted $T_0$-extreme wind
- Spectral correction procedure$^4$:
  - Use model- and hybrid spectra $+$ $U_{max}$ equation to correct $U_{max}$ for all years of l.t. data series.
  - Use set of corrected $U_{max}$ in combination with Ann.max method

\[
\overline{U}_{max}(T_0) = \overline{U} + \sigma \sqrt{2 \ln \left( \frac{1}{2\pi} \sqrt{\frac{m_2}{m_0}T_0} \right)}, \sigma = \sqrt{m_0}
\]

AnnMax – POT - Spectral Correction

- Spectral correction applied to off-shore data: Horns Rev@45m
  - Involves *terrain effects cleansing* and *terrain effects inclusion*
  - Compared to POT and Annual Max

The "Spectral correction" needs further validation

Spectral correction:
- Model data: 32 years (1979-2011)
  - CFSR-ReAn. Data (NCEP)
- Obs.data: 1 year (2001/2005-06)
Conclusion

• POT compares well with the annual Max. method
  – Same time series length: same result as Ann.Max. – but with somewhat lower uncertainty
  – Short time series:
    o Agrees largely with l.t. Ann.Max. – but with higher uncertainty, as expected
    o No or slightly negative bias
    o Cannot take long-term variability into account – unless long term reference data are somehow included (trivial)

• Spectral correction is a promising method to combine a short measured time series with long-term wind data derived from re-analysis data set by mesoscale models
  – Being validated at DTU Wind Energy against a number of cases
    • for implementation in WAsP Engineering.
Acknowledgements

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- Sprogoe: Storebaelt A/S *(Great Belt Bridge)*
- Jylex: DTU Wind Energy *(former Risoe)*
- Horns Rev: DONG Energy and Vattenfall
- Abu Darag: Wind Atlas for the Gulf of Suez / Egyptian NREA & DTU Wind Energy *(former Risoe)*
- Bloemenfontein: South African Weather Service
Spectral correction – work flow

1. Long-term Global Reanalysis Data
   - Mesoscale model

2. Long-term On-site Reanalysis data
   - Consistent Generalization (mesoscale-terrain cleansing)

3. Short-term On-site Measured data
   - Generalization (terrain cleansing)

4. Spectral Correction Model and Hybrid spectra

5. Standard condition
   - Extreme Wind Climate
     (extreme wind time series)

6. “Application” (terrain effects inclusion)
7. On-site Extreme Wind Climate
   (extreme wind time series)

8. On-site 50Y-wind