How an extreme wind atlas is made

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• Why do we need extreme wind statistics?

• Statistical background for estimation of extreme wind stats

• Development of extreme wind statistics/values
  – measured data
  – modelling

• Applications
  - wind energy
  - built environment
  - disaster management
Why do we need extreme wind statistics?

- Information on extreme winds essential in the design of wind farms – situated in areas with relatively strong winds;

- Application of REWC to obtain extreme wind statistics for wind farm position (e.g. with WAsP Eng.) for IEC 61400-1;

- Updated extreme wind statistics critical for optimal design of built environment

- Disaster management – strong wind hazard profiles for risk estimation
Statistical Approaches

Annual maxima – most widely applied:

GEV (3 types: $k < 0$, $k = 0$ (Gumbel) and $k > 0$)

Shortcomings of GEV approach:

- Only one maximum value selected per epoch (per annum)
- Data sets must be long ($\geq 20$ years)
- Cannot be used for data sets $< 10$ years

Alternative approaches to increase number of cases, e.g.:

- $r$-largest values per epoch
- Method of Independent Storms (MIS)
- Peak Over Threshold (POT)
**Mixed strong wind climates:**

- Mixed distribution method – storms from different origins to be considered separately
- Return period values from combination of set of Gumbel distributions
Estimation of Extreme Wind Statistics for South Africa
Analysis of measured data

Background Study

Prevailing macroclimatic conditions
Study Extreme Value Theory
Infrequent meteorological events

Investigate Available Wind Data

Audit
Quality Control

Description of the Strong Wind Climate

Causes of the strong winds

Analyze Wind Data

GEV method
POT method
Mixed distribution method

Investigate Exposure of Weather Stations

Assess exposure of weather stations
Develop correction factors

Develop Extreme Wind Climatology

Selection of 1:50 year quantiles
Spatial interpolation of quantiles
Uncertainties of quantiles
Maps
Modeling

- High spatial resolution possible;
- New methods continuously researched:

**Low time-resolution data (e.g. 6-hourly wind speed)**

**High time-resolution statistics (e.g. 1:50 yr 10 min wind speed)**

- Temporal variability can be missed out by smoothing effect of numerical modelling;
Selective Dynamical Downscaling Method (SDDM)

STEP 1: Identification of annual max. storms

STEP 2: Mesoscale modelling of storms:

1. Run WRF for the 72+175 cases
   * Input: CFSR data, 6 hrly, 1998 - 2010
   * 20 s time step
   * 41 vertical layers
   * Run time <=72 hrs per storm
   * 4 km resolution
   * Output: 10 min

2. The 50-year wind using the Annual Maxima Method (Gumbel distribution).
STEP 3: Post-processing procedure:

- Correction to the standard condition:
  Height: 10 m, Roughness length: 5 cm

- Microscale generalisation scheme with Linear Computational Model (LINCOM) to obtain mesoscale speedup factors from upwind orography and roughness length

Gust modelling

• E.g. Brausseur’s concept of the gust and estimation:

Basis: Modelling of air parcels deflected to the surface through turbulent eddies:

• Classical gust calculation: Wind converted to 10 min, application of turbulence model to obtain gust

SDDM Outputs:

1:50 year **10-min** wind at 10 m over roughness length = 5 cm
Horizontal resolution: 4 km
Gust estimations through modelling:
Comparison between measurements and modelling (e.g. 10 min):
Final 10 min map (Measurements + SDDM):

Upward adjustments of modelled values where necessary
WASA Phase I: 1:50 yr gust (m/s)
Wind farm planning:
Application of appropriate software (e.g. WAsP Engineering) with inputs e.g.:
- Extreme wind statistics (REWC),
- Information of the wind farm (e.g. arrangement of wind turbines),
- Environment around the proposed wind farm (e.g. surface roughness, topography and obstacles).
- IEC 61400-1 site assessment rules:

<table>
<thead>
<tr>
<th>Wind turbine class</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>S</th>
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<td>C</td>
<td>$I_{\text{ref}}$</td>
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</tbody>
</table>

$V_{\text{ref}}$: Hub-height, 10-min, 1:50 yr extreme wind

$I_{\text{ref}}$: Reference turbulence intensity at 15 m/s in a 10-min period

Checklist
- Extreme winds
- Turbulence Intensity
- Vertical wind shear
- Flow inclination
- Wake turbulence
Applications

Built environment:

Update of SABS SANS 10160-3 Wind Actions:

- Fundamental value of basic wind speed $v_{b,0}$:
  
  Intervals range from 32 m/s (green), to 44 m/s (red)
  
  - Based on measured values, but with WASA 1 modelling results considered
  
  - Details in forthcoming suite of 4 papers (SAICE journal)
Applications

Disaster management:

- Quantification of wind hazard used in the relative assessment of risk (1: lowest – 5: highest), quantitatively defined as

\[
\text{risk} = \frac{\text{hazard} \times \text{vulnerability}}{\text{capacity}}
\]

- Risk includes 4 factors defined by NDMC:
  1. Likelihood
  2. Frequency
  3. Magnitude
  4. Predictability

- Wind hazard: Wind gust > 20 m/s – damage to infrastructure possible (Kruger et al. 2016 - SAJS)

- As with loading code – wind hazard identified per local municipality to identify vulnerable local government areas:
Wind Atlas for South Africa (WASA)
Relative wind hazard (incl. of 4 factors) - seasonal:

(a) Summer (DJF)  
(b) Autumn (MAM)  
(c) Winter (JJA)  
(d) Spring (SON)  

Wind Atlas for South Africa (WASA)
Relative wind hazard (annual):
Additional information:

- WASA 1 guidelines for using extreme wind data (application of WAsP Eng.) and how to obtain the data: www.wasainfo.org

- Climatic background to strong winds & estimation of extreme wind statistics from measured data:

- Modelling approaches and results:
Additional information:

• Wind loading code:


4. **Forthcoming set of papers in Journal of the South African Institution of Civil Engineering** detailing development, application and consideration of uncertainties.

• Disaster management:


Wind Atlas for South Africa (WASA)