Probabilistic modelling of extreme wind speeds from ensemble forecasts for the generation of pre-warnings at the RMI

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Abstract

Due to the relatively small size of ensembles, the use of simple empirical probabilities becomes inappropriate for gauging the risk of very high windspeeds. This talks discusses an application of extreme value theory to try and overcome this practical problem. An exploratory threshold method based on the General Pareto Distribution (GPD) is used to make inferences on extreme wind speeds from EPS forecast data at one grid point location. The approach taken here is manual and subjective as an objective procedure that could be automated is difficult to put in place. Ensembles and / or grid points could be pooled together to improve confidence in estimated GPD parameters.

Background

- The RMI issues
  - Warnings of high wind speeds in the short range:
    - Own web site
    - Meteoalarm
    - Shipping
    - Media
  - pre-warnings in the early medium range:
    - 'Bruxelles Environnement'
      - *Authorities must close roads through wooded areas ahead of storms (e.g. Bois de la Cambre, Forêt de Soignes);*
      - *Pre-alerts 3 to 4 days beforehand helps with the planning so as to make sure that the necessary manpower and equipment are available;*
      - *Pre-warnings are triggered automatically when a given proportion or more of EPS members exceed a prescribed threshold.*
      - *Pre-warnings are disseminated via emails and SMS.*
- This talk focuses on pre-warnings in the medium-range generated through the EPS

Limitations of the current method

- Current method essentially empirical

$$P(WSP \geq thr) = \frac{n}{N}.$$

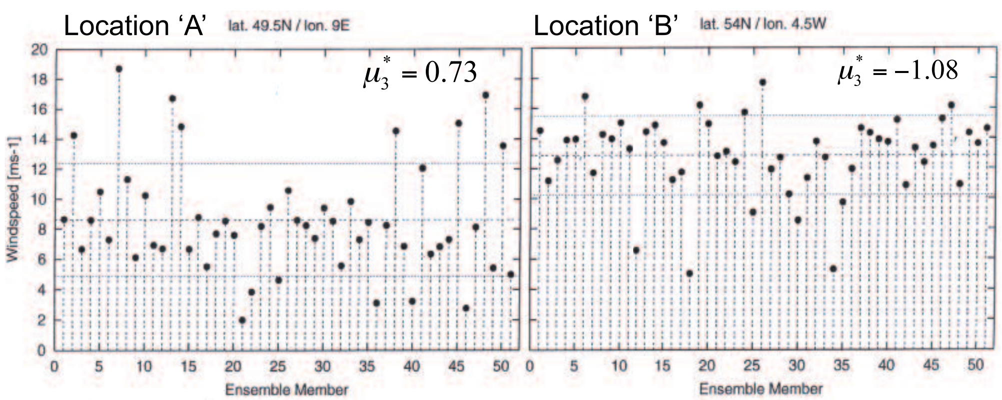
n ← number of EPS members above some threshold *thr*

N ← total number of EPS members

- Fairly small ensemble size poses a problem to estimate upper-tail probabilities when the distribution is skewed to the right.
- More in particular, probabilities collapse to zero at thresholds above the maximum of the EPS distribution:

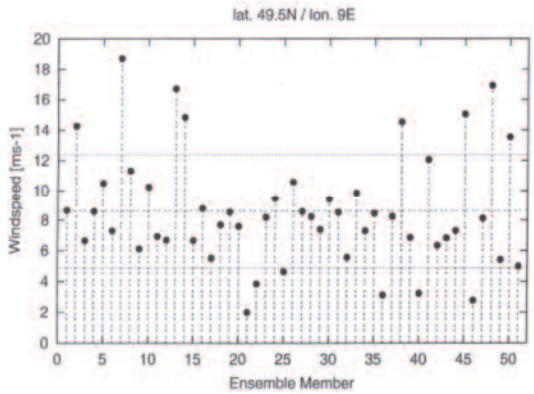
$$P(WSP > \max(wsp_1, wsp_2, ..., wsp_N) = 0.$$

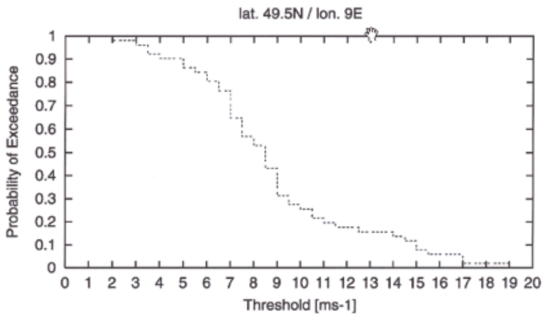
Typical EPS distributions with high wind speeds



- EPS distributions significantly asymmetric: skewed to the right at ‘A’and to the left at ‘B’
- EPS mean larger at ‘B’, but EPS maximum larger at ‘A’
- Larger spread at ‘A’ due to longer upper tail
- *P(WSP > 19 m/s) = 0*

Probability of exceeding a moving threshold





- Below *2m/s*, all points are above threshold.
- More than ½ of all EPS members fall below threshold between *6 and 10 m/s*.
- Above *19 m/s*, all points are below threshold.
- Q: How can we estimate the probability of exceeding thresholds beyond *19 m/s*?
- A: Parameterise ... but fit a GEV distribution on one sample maximum only doesn’t work.
- The generalised Pareto distribution makes use of more data in the upper tail than just the maximum.

The Generalised Pareto Distribution (GPD)

- Model for the distribution of excesses above high thresholds (Pickands, 1975)
- The probability to exceed any value above a sufficiently high threshold u is:

$$P(X > u + x \mid X > u) \approx \left[1 + \xi \frac{x}{\sigma}\right]^{-1/\xi}.$$

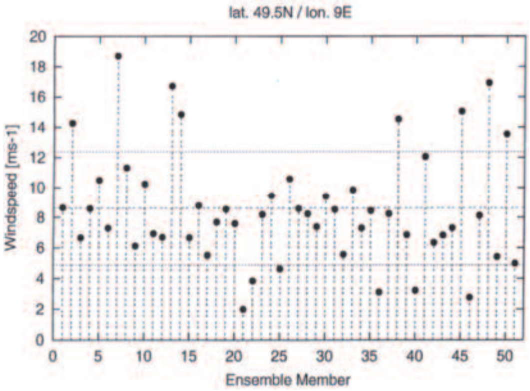
- The maximum exceedance x_e is:

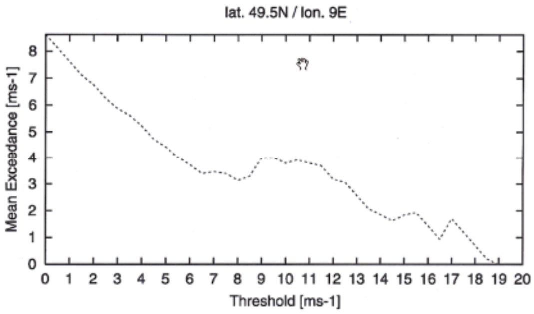
$$x_e = -\frac{\sigma}{\xi}.$$

- The mean exceedance over u is a linear function of u, provided $\xi < 1$:

$$E(X - u \mid X > u) = \frac{\sigma + \xi u}{1 - \xi}.$$

Mean residual life plot

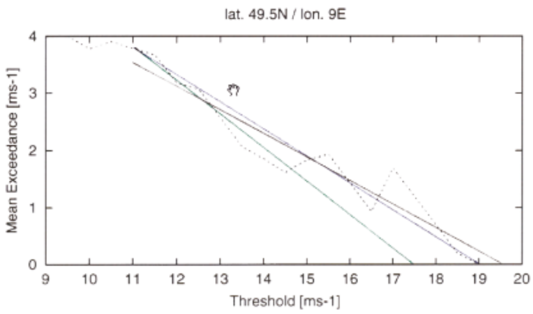




- The *mean exceedance* (*ME*) is the mean distance between the threshold *u* and the points above.
- For $u = 0\ m/s$, *ME* corresponds to the sample mean *8.6 m/s*.
- For $u \geq 19\ m/s$, $ME = 0\ m/s$.
- The decrease towards zero is not monotonic:
  - Linear below *6 m/s*
  - Nonlinear between *6* and *11 m/s* with local max at $u \approx 9\ m/s$
  - Linear behaviour returns above *11 m/s* ... but variability increases because of the small number of EPS members remaining above the threshold.

Estimation of the GDP parameters

Linear fit



- GPD assumed valid at thresholds above *11 m/s*.
- 3 straight lines:
  - Red: simple linear fit;
  - Green: linear fit discounts points 'too far' in the tail;
  - Blue: mean slope between *11* and *19 m/s*.

$$E(X - u \mid X > u) \approx a u + b$$

$$\hat{\xi} = \frac{a}{1 + a}$$

$$\hat{\sigma} = \frac{b}{1 + a}$$

$$\hat{x}_e = -\frac{\hat{\sigma}}{\hat{\xi}}$$

$$\hat{u}_e = u + \hat{x}_e = u - \frac{\hat{\sigma}}{\hat{\xi}}$$

GPD parameter and probability estimates

Fit	Red	Green	Blue
$\hat{\xi}$	*-0.7*	*-1.4*	*-0.9*
$\hat{\sigma}$	*13.8 m/s*	*24.8 m/s*	*17.1 m/s*
$\hat{x}_e$	*19.6 m/s*	*17.5 m/s*	*19.0 m/s*
$\hat{u}_e$	*30.6 m/s*	*28.5 m/s*	*30.0 m/s*
$P(X > 25\,m/s)$	*0.03*	*0.06*	*0.04*

Observed wind speed was *25 m/s*

Conclusions and suggestions for future work

- An exploratory threshold method based on the GPD has been used to make inferences on extreme wind speeds from EPS forecast data at one grid point location.
- The approach taken is manual and subjective
  - Linearity does not necessarily guarantee that the GPD model is valid. Was *11 m/s* a sufficiently high threshold?
  - Uncertainty increases at higher thresholds as exceedances gets scarce.
- An objective procedure that could be automated is difficult to put in place.
  - Method of moments and maximum-likelihood estimation only work for restricted ranges of ξ.
  - Look at alternative estimation techniques, e.g. based on the principle of maximum entropy or other Bayesian methods.
- The small EPS size is an issue
  - High uncertainty on parameter values
  - Look at how successive EPS runs can be pooled together.
  - Look at how grid points over a region can be pooled together
    - Loss of spatial resolution
    - Non-independence of events at neighbouring grid points needs to be taken care of.
- GPD value: is it worth bothering?
  - Results from the GPD should be compared with tail probabilities obtained from standard Weibull fits.