A storm severity index based on return levels of wind speeds

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1) Introduction

- One aim of the project RAIN (Risk Assessment of Infrastructure Networks) is to asses the impact of extreme weather events on critical infrastructure
- We focus on extreme winds caused by extra-tropical cyclones during the winter season in Europe
- The design codes of critical infrastructure are usually based on the 50-year return levels of the local wind speed climatology
- Here, we show the steps towards the development of a Storm Severity Index based on exceedances of the 50-year return levels of wind speed

2) The Storm Severity Index

- A Storm Severity Index (SSI) was introduced by Leckebusch et al. (2008)
- At each time step coherent areas of wind threshold exceedances are identified and tracked in time with a nearest neighbor approach (Fig. 1)

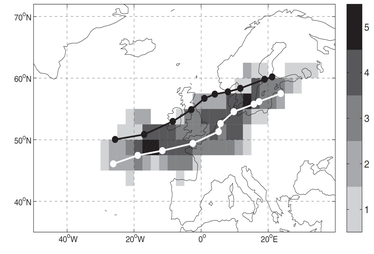


Fig. 1: Wind storm "Daria" (24.01.1990-26.01.1990). Track of wind fields exceeding the 98th percentile (white) and track of the corresponding low pressure system (black). Shading indicates the number times the wind speed exceeded the local 98th percentile (from Leckebusch et al. 2008).

- For each storm event (track) the SSI is calculated:

$$SSI = \sum_{t}^{T} \sum_{k}^{K} \left[\left(max(0, \frac{v_{k,t}}{v_{perc,k}} - 1) \right)^3 \times A_k \right]$$

where *t* refers to the time steps, *k* refers to the grid boxes and *v* is wind speed. v_{perc} is the local 98th percentile of the wind distribution and is used as the threshold

- The 98th percentile was chosen, because insured losses occur within the upper 2% of the local wind speed distribution (Klawa and Ulbrich, 2003)
- In this study, the SSI is modified by replacing the 98th percentile with the 50-year return level (v_{50yr}), in order to identify events, relevant to critical infrastructure

$$SSI_{mod} = \sum_{t}^{T} \sum_{k}^{K} \left[\left(max(0, \frac{v_{k,t}}{v_{50yr,k}} - 1) \right)^3 \times A_k \right]$$

3) Data

- For the estimation of return levels we use the three reanalysis datasets ERA40, NCEP-I and JRA-55
- The overlapping period from 1958 to 2002 is used for calculating percentiles and return levels of all datasets (Fig. 2)

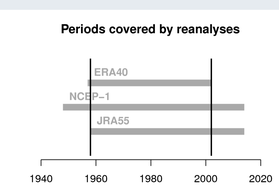


Fig. 2: Periods covered by different reanalysis datasets. Vertical lines denote the overlapping period chosen for the analysis.

4) Estimation of return levels

- The 6-hourly 10m wind fields of the three reanalyses are interpolated to a 2x2° grid
- Maximum wind speeds of the extended winter seasons (ONDJFM) are calculated
- 50-year return levels and 95% confidence intervals are estimated by fitting a Generalized Extreme Value distribution

Figure 3: 50-year return levels and 95% confidence intervals of 10m wind speeds from different reanalyses for two different grid points. Average of reanalysis return levels (blue), double standard deviation of reanalysis return levels (red) and average confidence intervals of return levels (green).

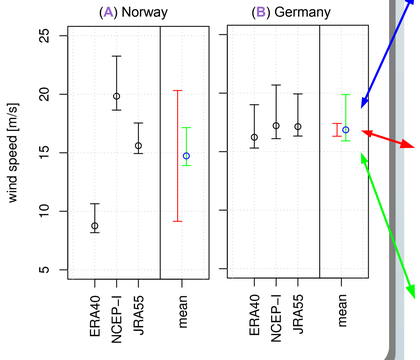
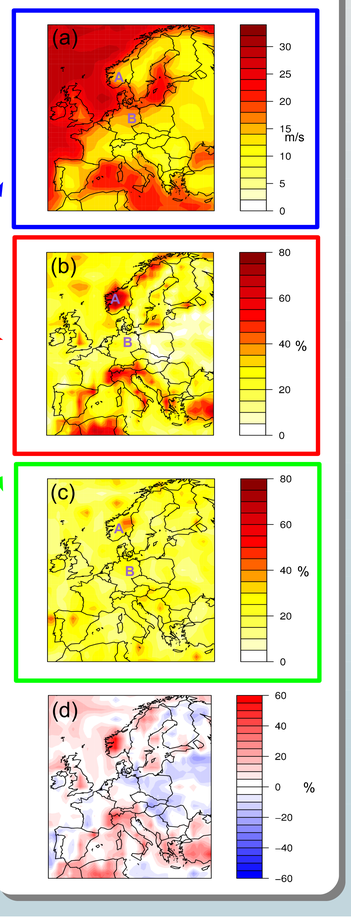


Figure 4: 50-year return levels of 10m wind speeds. (a) Average of the return levels from of three reanalyses. (b) Standard deviation between the return levels of three reanalysis datasets, as a percentage of the mean. (c) Mean 95% confidence intervals, as a percentage of the mean return level. The difference between (b) and (c) is shown in (d).



- **In Norway, Italy, and Turkey the standard deviation between the reanalysis return levels is large, compared to the confidence intervals**
- **In Central and Eastern Europe the differences between reanalysis return levels are relatively small**

5) Example cases of return level exceedances

- The maximum wind speeds during the winter storms "Kyrill" and "Lothar and Martin" are calculated from NCEP-I reanalysis (Fig. 5)
- The 98th percentiles are exceeded in large parts of Europe

- **Exceedances of the 50-year return level agree well with the areas, where the largest damages were reported**
  - → **"Lothar" and "Martin" had major impacts in France and severely affected the energy system**
  - → **"Kyrill" mainly affected Central Europe with high impacts on the transportation system**

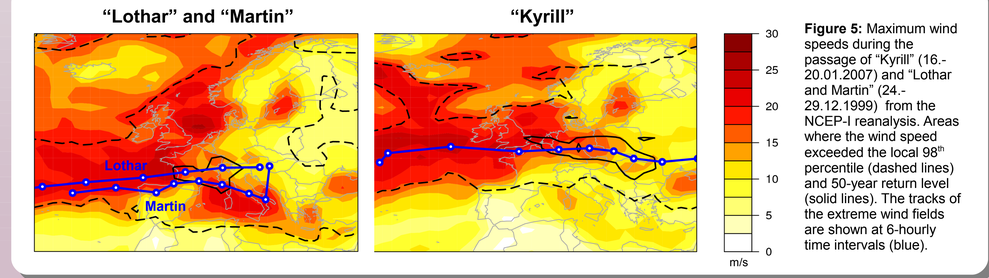


Figure 5: Maximum wind speeds during the passage of "Kyrill" (16.-20.01.2007) and "Lothar and Martin" (24.-29.12.1999) from the NCEP-I reanalysis. Areas where the wind speed exceeded the local 98th percentile (dashed lines) and 50-year return level (solid lines). The tracks of the extreme wind fields are shown at 6-hourly time intervals (blue).

6) Annual statistics of extreme windstorms

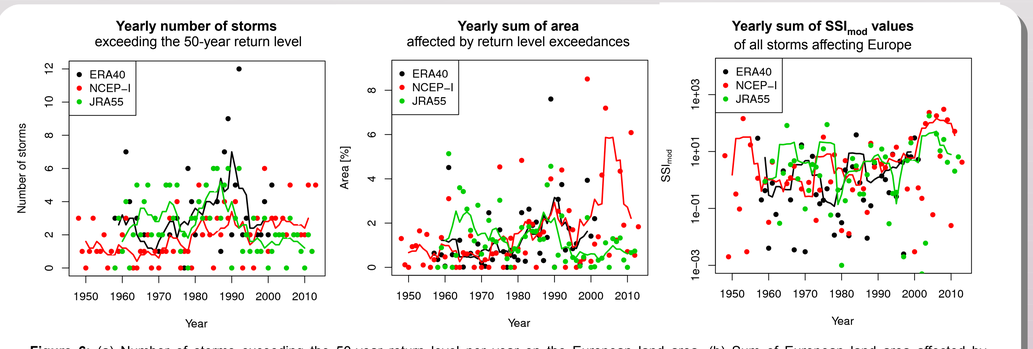


Figure 6: (a) Number of storms exceeding the 50-year return level per year on the European land area. (b) Sum of European land area affected by exceedances of the 50-year return level per year, given as the percentage of the whole European land area. (c) Sum of the SSI_{mod} values of all storms, which affect Europe by exceeding the 50-year return level per year. Solid lines are 5-year running means.

- **On average 2.5 storms exceed the 50-year return level in Europe per year**
- **On average 140.000 km2 of European landmass are affected by exceedances of the 50-year return level per year**
- **The severity of extreme storms shows a high interannual variability**

References:

- G. C. Leckebusch, D. Renggli, U. Ulbrich, Development and application of an objective storm severity measure for the Northeast Atlantic region, Meteorologische Zeitschrift, Vol. 17, No. 5, 2008
- Klawa, M., & Ulbrich, U. (2003). A model for the estimation of storm losses and the identification of severe winter storms in Germany. Natural Hazards and Earth System Science, 3(6), 725-732.

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