Feature-based classification of European windstorms
PhD-Project: Changes in European windstorm characteristics

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Windstorms

**Anzahl – prozentuale Verteilung**
- Hitzewelle, Lawine, Sonstige: 2%
- Winterschäden, Frost: 4%
- Waldbrand: 2%
- Erdbeben: 5%
- Sturzflut: 11%
- Überschwemmung: 8%
- Tornado: 5%
- Hagel: 8%
- Unwetter, Gewittersturm: 25%
- sonstige Stürme: 7%

**Volkswirtschaftliche Schäden – prozentuale Verteilung**
- Winterschäden, Frost: 3%
- Dürre, Hitzewelle: 1%
- Überschwemmung*: 15%
- Erdbeben: 1%
- Sturzflut: 4%
- Unwetter, Gewittersturm: 4%
- Tornado: 1%
- Hagel: 15%
- sonstige Stürme: 2%

**Versicherte Schäden – prozentuale Verteilung**
- Winterschäden, Frost: 5%
- Überschwemmung*: 8%
- Erdbeben: 1%
- Hagel: 1%
- Unwetter, Gewittersturm, sonstige Stürme: 2%
- Wintersturm: 20%
- Wintersturm: 64%

*Sturzfluten prozentual nicht relevant

Munich Re (1999)
Understanding windstorms

In conclusion:

Understanding atmospheric drivers behind windstorms of high socio-economical importance

- Statistically sound risk assessment and management
- Improvement of forecast systems
- More robust information on future risks of windstorms due to climate change
State of the art

Pinto et al. (2009)

- Extreme cyclones occur more frequently during strong positive NAO phase

Donat et al. (2010)

- Westerly flow regimes and positive NAO phase associated with the majority of storm days

Walz et al. (2018)

- Drivers may change depending on the region of interest. NAO alone is not sufficient to assess winter windstorm hazard

Wild et al. (2015)

- Meridional temperature gradient between North American continent and western Atlantic SSTs is positively correlated to windstorm frequency over North Atlantic and Europe
The Project

- Past studies focused primarily on "more statistical" characteristics, e.g. . . .
  - Inter-annual variability
  - Serial clustering
  - Occurrence
  - Trends
- Only a few studies focus on the basic windstorm characteristics such as . . .
  - Intensity
  - Duration
  - Spatial extension
  - Shape

Aim:

1. Quantification of these characteristics
2. Identification and understanding of key parameters determining these characteristics
Quantification of windstorm characteristics

- Clustering windstorms based on basic features
- Summary statistics
- Storm tracks
Data & tracking

ERA5:
- Fifth generation ECMWF atmospheric reanalysis of the global climate
- Horizontal resolution: 0.25° x 0.25°
- Period: 1981-2017, extended winter ONDJFM
- Temporal resolution: 6 hours

Tracking:
- WTRACK algorithm (Kruschke, 2014)
  - Exceedence of local climatological 98th percentile
  - Nearest-Neighbor search
  - Storm duration of > 24h and area of > 150,000 km²
- Boundary: full grid
- Innerbox: EURO-CORDEX region (40.25°W–75.25°E, 25.25°N–75.75°N)
Clustering - Preparing the data

Raw WTRACK output:

<table>
<thead>
<tr>
<th>DATE INDEX</th>
<th>INDEX</th>
<th>SIZE</th>
<th>AREA [km²]</th>
<th>LAT</th>
<th>RADIUS [km]</th>
<th>MEANV [m/s]</th>
<th>STDV</th>
<th>MINV [m/s]</th>
<th>MAXV [m/s]</th>
<th>LONMAX</th>
<th>LATMAX [°]</th>
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Event: 1999000016 Start: 1999010012 Length: 7 Area: 228.979 SSIscaled: 8.13047

Feature table:

- Duration [h]
- First and last sighting (lon,lat)
- Maximal area and radius [km]
- Mean, minimum and maximum wind speed [m/s]
- Mean and maximum SSI

Feature-based classification, Windstorm workshop 2019
Clustering - Method

K-Means clustering
1. $k$ random centroids (initialization)
2. Observations are assigned to nearest centroid (assignments)
   ▶ Squared Euclidean distance
3. New centroids by averaging cluster members (updating)
4. Repeat 2-3 until assignments do not change anymore

Setting
▶ $k$ varies from 2-10
▶ Ensemble approach (50 member ensemble)
▶ Best-fit
Clustering - Results

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Clustering - Results

Cluster No. 1

Cluster No. 2

Cluster No. 3
### Clustering - Results

<table>
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<th>$k$</th>
<th>Ave. wind speeds [m/s]</th>
<th>Peak [m/s]</th>
<th>Dur. [h]</th>
<th>Area</th>
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</table>
Identification of key parameters (coming soon)

- Classification task
- Supervised learning algorithms: Decision trees, GLMs, ...
Challenges - How to represent the field?

Region of interest

Innerbox
Challenges - How to represent the field?

Feature-based classification, Windstorm workshop 2019
Challenges - Overlap

Feature-based classification, Windstorm workshop 2019
Summary

- Clusters suggest different types of windstorms
- Tracks are neither separated in space nor time
- Designing the right data set for the task is no trivial matter
- Better differentiation through careful selection of meteorological fields and areas

