Feature-based classification of European windstorms

PhD-Project: Changes in European windstorm characteristics

Christian Passow

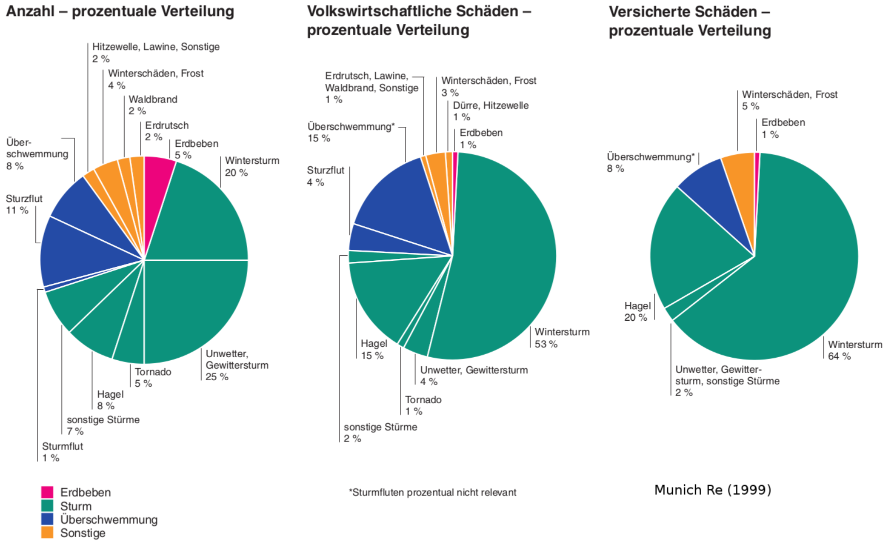
Supervisors:

Univ.-Prof. Dr. Uwe Ulbrich
Univ.-Prof. Dr. Henning Rust

Freie Universität Berlin

8th European Windstorm workshop, 2019

Windstorms



*Sturmfluten 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

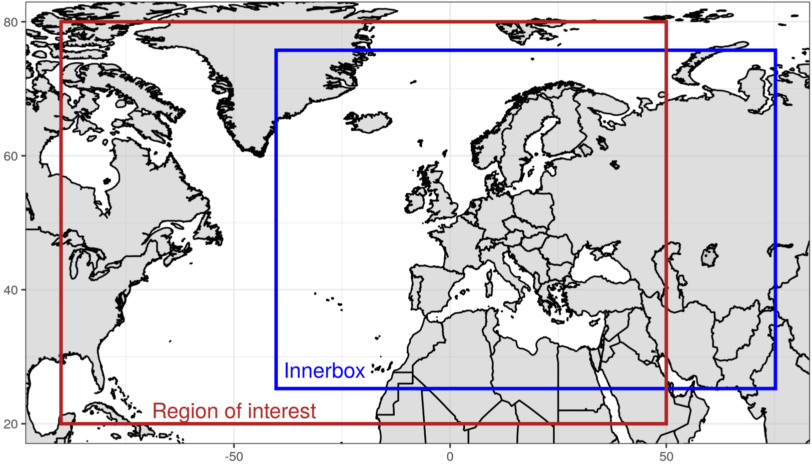
The Project

- 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

Region of interest



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 km^2
- 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:

```
                                                  Produced by tracking algorithm WTRACK revision 167, developed by Freie Universitaet Berlin-Institute of Meteorology
         DATE INDEX  SIZE     AREA     LON     LAT  RADIUS   MEANV    STDV    MINV    MAXV  LONMAX  LATMAX      SSIn       SSIs        SSIu      SSIan
Event: 199000001 Start:   1990100100 Length:  6 Area:     59.857 SSIscaled:     0.67016 SSIarea:     0.84820
  1990100100     1    57   28.164  -86.12   72.57  963.53    8.86    2.63    3.78   13.50  -90.00   72.00   0.10640      77.73     19937.1    0.13467
  1990100106     1    73   36.126  -79.38   71.46  736.21    8.81    2.17    3.91   12.70  -90.00   72.00   0.14047      71.80     23532.6    0.17778
  1990100112     1    45   22.182  -71.32   70.97  544.13    9.12    2.46    3.75   12.68  -68.62   72.00   0.03805      24.01     16481.0    0.04815
  1990100118     1    45   21.251  -73.61   72.47  635.94   10.36    3.04    3.78   15.40  -73.12   73.12   0.17330     159.20     23818.9    0.21934
  1990100200     1    42   19.132  -70.59   72.42  359.36   12.16    2.75    5.51   15.87  -69.75   73.12   0.18827     283.40     31816.9    0.23829
  1990100206     1    34   15.675  -68.05   72.71  333.61   12.38    1.47    8.51   14.63  -66.38   72.00   0.02368      47.25     25026.9    0.02997
Event: 199000016 Start:   1990100212 Length:  7 Area:    228.979 SSIscaled:     0.10309 SSIarea:     0.13047
  1990100212    16    23   31.738  170.91   27.97  450.05   14.21    0.51   13.02   14.94  169.88   28.12   0.00606      18.52     73913.2    0.00767
  1990100218    16    41   57.278  169.86   26.59  797.23   13.85    0.65   12.24   14.90  169.88   27.00   0.02800      74.67    123957.5    0.03544
  1990100300    16    36   50.836  171.00   25.37  805.76   13.00    0.41   11.99   13.52  177.75   27.00   0.00383       9.28     90646.2    0.00484
  1990100306    16    77  109.932  172.93   24.38 1649.72   12.90    0.68   11.72   14.27  178.88   29.25   0.02539      59.40    192608.5    0.03214
  1990100312    16    92  131.003  169.25   23.34 1473.76   13.04    1.07   11.66   16.57  178.88   31.50   0.02672      60.54    239772.7    0.03382
```

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

Clustering - Method

K-Means clustering

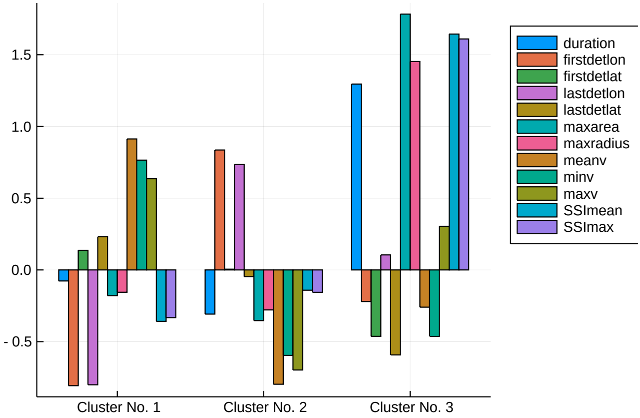
1. *k* random centroids (initialization)
2. Observations are assigned to nearest centroid (assignments)
   - Squared Euclidean distance
3. New centroids by averaging cluster members (updating)
4. Repeat 2-3 until assignments do not change anymore

Setting

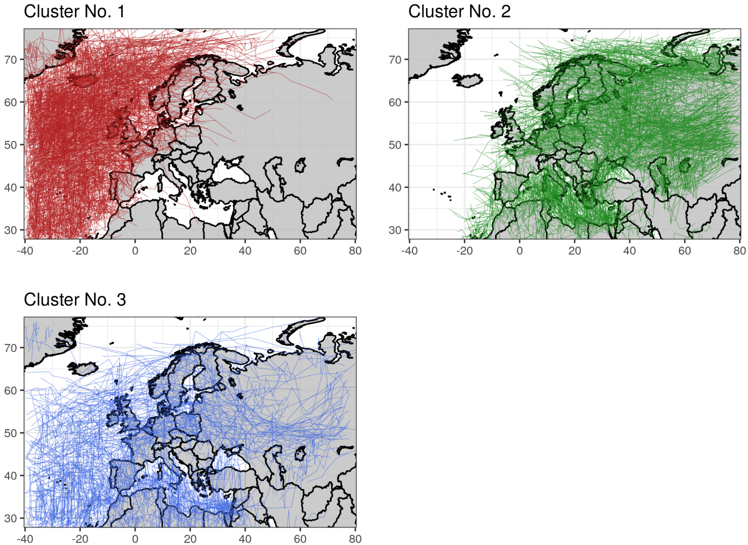
- *k* varies from 2-10
- Ensemble approach (50 member ensemble)
- Best-fit

Freie Universität Berlin

Clustering - Results



Clustering - Results



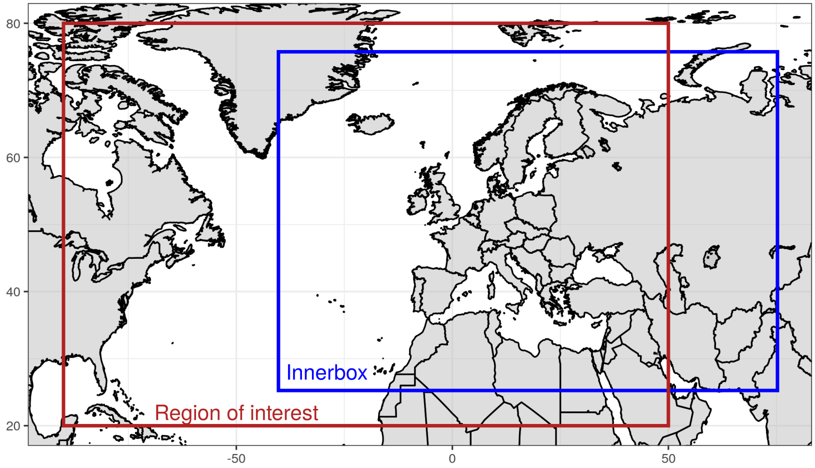
Clustering - Results

k	Ave. wind speeds [m/s]			Peak [m/s]	Dur. [h]	Area	N	SSI
	Mean	Minim.	Maxim.					
1	17.33	10.35	24.41	38.3	39	422	1420	0.24
2	11.03	5.54	18.41	27.65	35	347	1485	0.40
3	13.11	6.07	23.06	35.75	65	1400	437	1.72

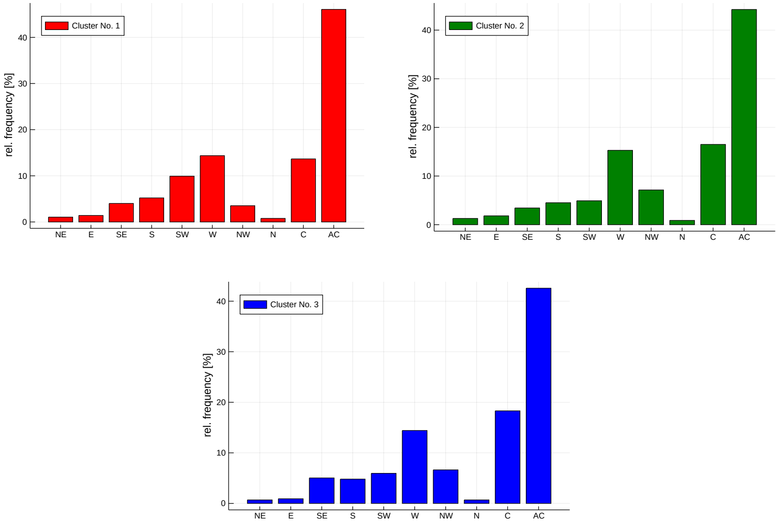
Identification of key parameters (coming soon)

- Classification task
- Supervised learning algorithms: Decision trees, GLMs, . . .

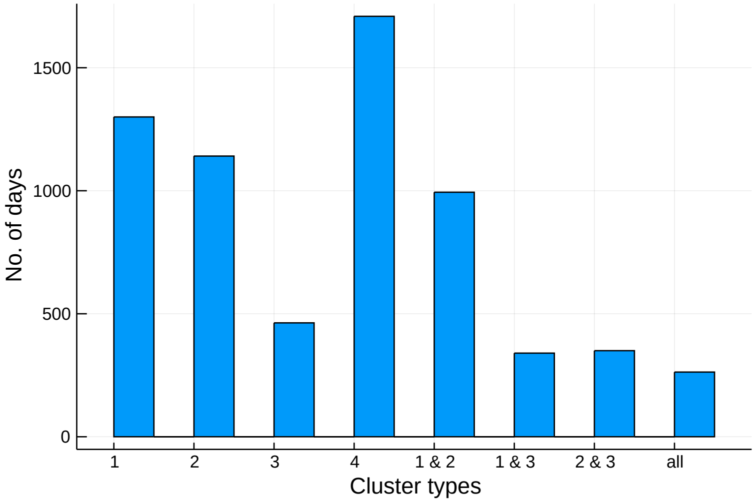
Challenges - How to represent th field?



Challenges - How to represent th field?



Challenges - Overlap



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

References I

Donat, M. G., Leckebusch, G. C., Pinto, J. G., and Ulbrich, U. Examination of wind storms over Central Europe with respect to circulation weather types and NAO phases. *International Journal of Climatology*, 30(9): 1289–1300, 2010. ISSN 08998418. doi: 10.1002/joc.1982.

Kruschke, T. *Winter wind storms: Identification, verification of decadal predictions, and regionalization*. PhD thesis, Institute of Meteorology, Freie Universität Berlin, 2014.

Pinto, J. G., Zacharias, S., Fink, A. H., Leckebusch, G. C., and Ulbrich, U. Factors contributing to the development of extreme North Atlantic cyclones and their relationship with the NAO. *Climate Dynamics*, 32(5): 711–737, apr 2009. ISSN 0930-7575. doi: 10.1007/s00382-008-0396-4. URL `http://link.springer.com/10.1007/s00382-008-0396-4`.

References II

Walz, M. A., Befort, D. J., Kirchner-Bossi, N. O., Ulbrich, U., and Leckebusch, G. C. Modelling serial clustering and inter-annual variability of European winter windstorms based on large-scale drivers. *International Journal of Climatology*, 38(7):3044–3057, jun 2018. ISSN 08998418. doi: 10.1002/joc.5481. URL `http://doi.wiley.com/10.1002/joc.5481`.

Wild, S., Befort, D. J., and Leckebusch, G. C. Was the Extreme Storm Season in Winter 2013/14 Over the North Atlantic and the United Kingdom Triggered by Changes in the West Pacific Warm Pool? *Bulletin of the American Meteorological Society*, 96(12):S29–S34, 2015. doi: 10.1175/BAMS-D-15-00118.1.