Serial clustering of intense European storms

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Key questions

- How well can we estimate the likelihood of multiple storms hitting a region in a given time period?
- How well can this be applied to catastrophe modelling and risk assessment?
- What are the large-scale climatic drivers of clustering?

Approach

- NCEP/NCAR reanalysis 1950-2003, Oct-Mar winters.
- Storms identified by objective tracking of relative vorticity ξ_{850} at 850 hPa.
- Storm crossings of meridians aggregated in 3-monthly transit counts.
- Quantification of the dependence of clustering on storm intensity (vorticity) and aggregation period.

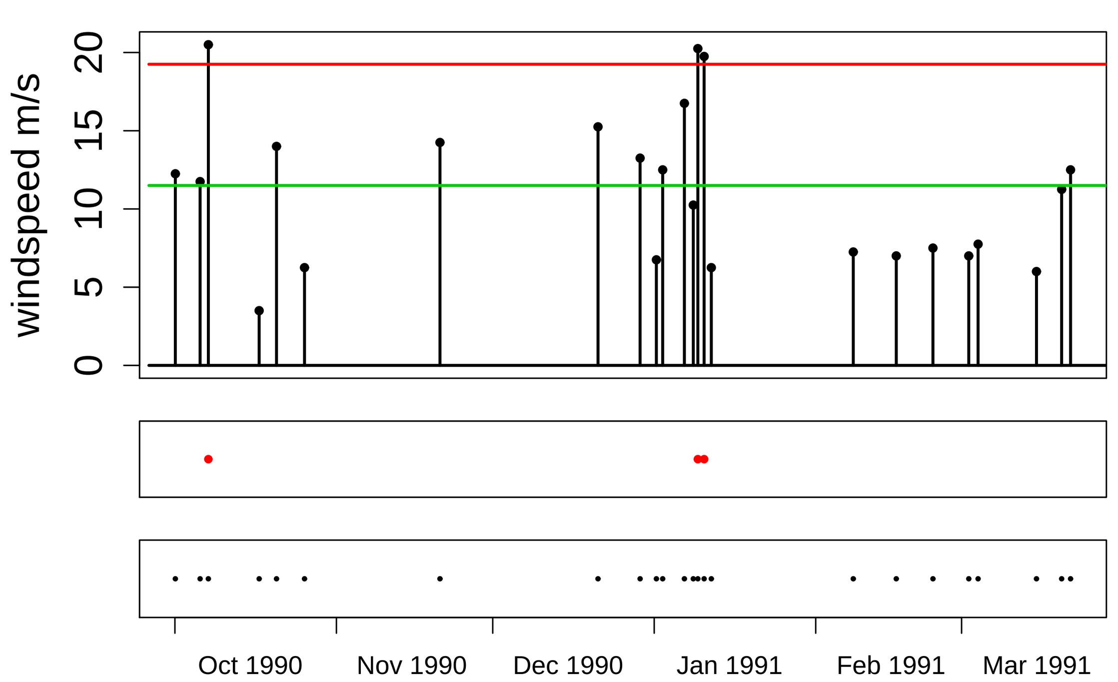
Results

Clustering:

- increases for intense storms in a large area around North Sea;
- increases for larger aggregation periods;
- is accounted for by large-scale flow (4 teleconnections);
- is captured (both trend & uncertainty) by Poisson regression.

What is clustering?

Tendency of storms to arrive in groups rather than randomly distributed in time. Below: transit times across meridian segment through Berlin, winter Oct '90-Mar '91. Transits are clustered in time both for all storms and for storms whose vorticity exceeds high thresholds (red/green lines).



(a) vorticity ξ_{850} at the moment of transit (c), for all storms. Red, green line: 50%, 90% vorticity threshold. (b) transits of storm above 90%.

Quantification of clustering

The dispersion statistics ψ measures deviation from *total randomness* in time of storm arrivals:

$$\psi = \mathbb{V}ar(Y)/\mathbb{E}(Y) - 1, \qquad (1)$$

Y is a sequence of 3-monthly storm transit counts.

$\psi = 0$: **total randomness in time**; Poisson!

$\psi > 0$: **overdispersion**, (e.g.) negative binomial.

Overdispersion means that storms cluster more than what is expected from chance. It might be modelled by a negative binomial distribution.

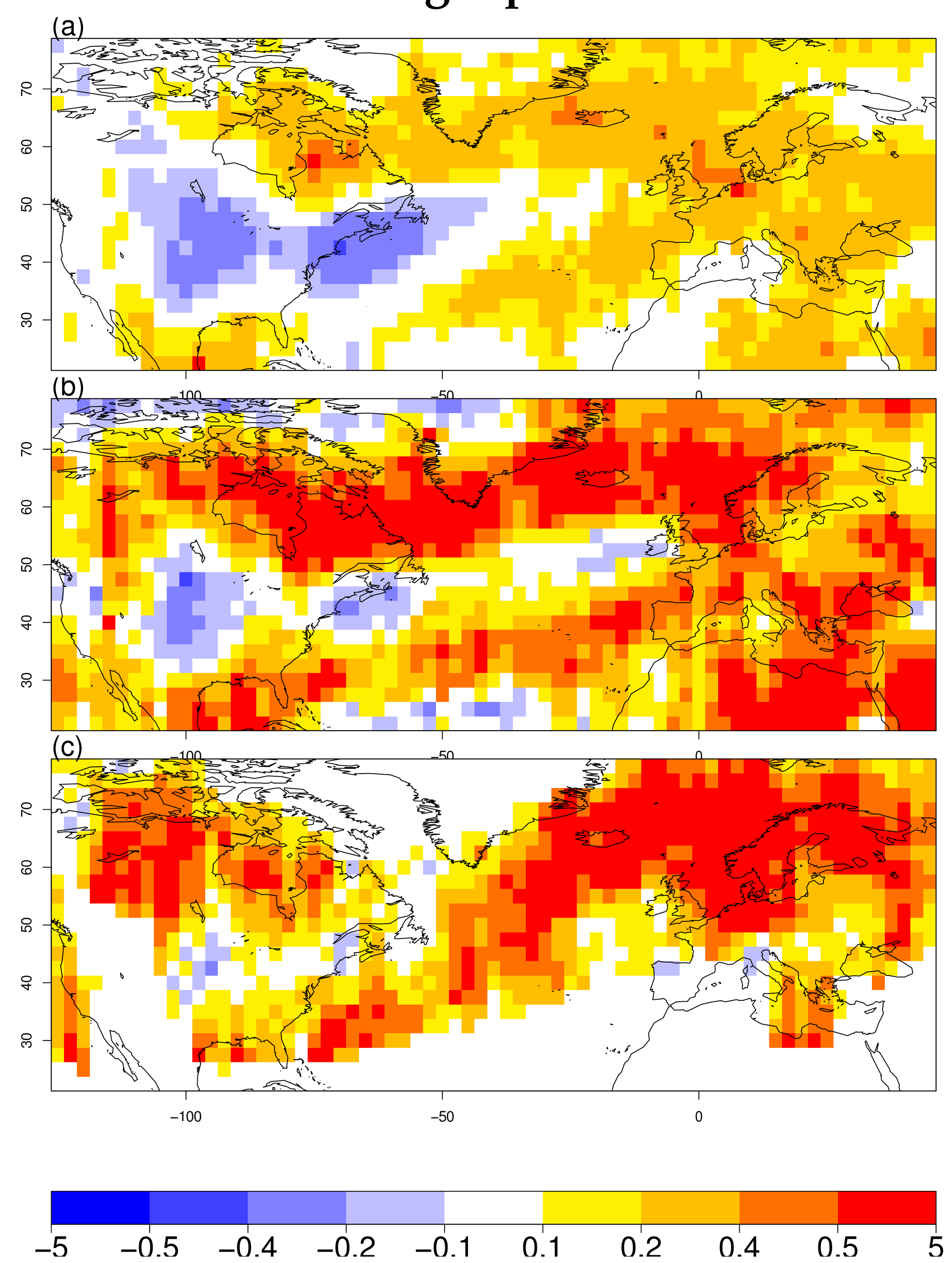
Why is dispersion relevant?

Reinsurance: typically bought for 2 events/year.
Assume to buy cover from 15% exceed. prob. level.

Dispersion	$\psi = 0$ (Poiss.)	$\psi = 0.5$ (Neg. bin.)
Prob[2 events/yr]	1.1%	2.1%
Prob[≥ 3 events/yr]	0.1%	0.8%

Eight-fold increase of probability of 3 or more CAT!! Need additional coverage?

Dispersion increases for intense storms and for longer periods

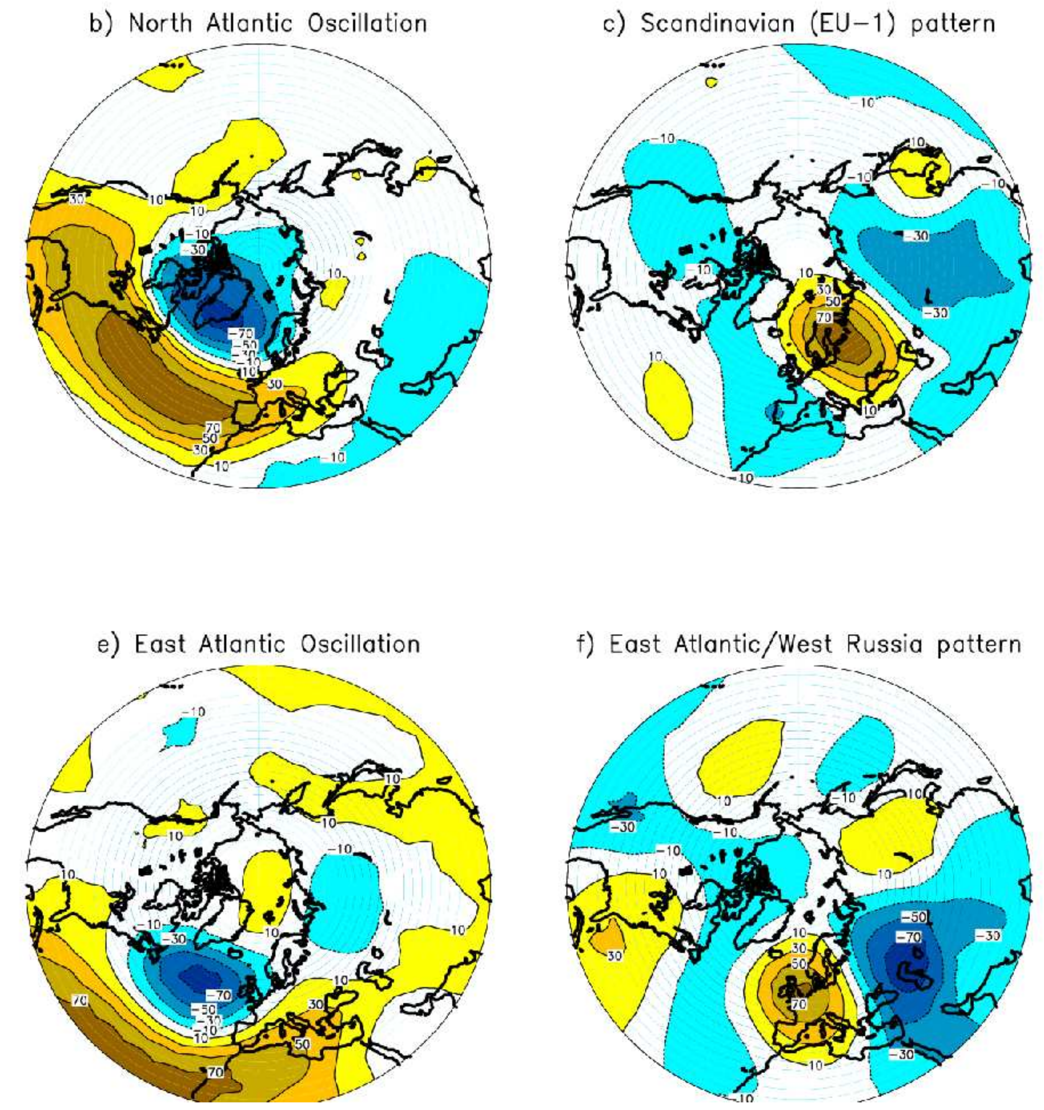


(a) Dispersion ψ for all storms. (b) Same as (a) for an 80% threshold at each gridpoint.

Teleconnections: North. Hemisphere

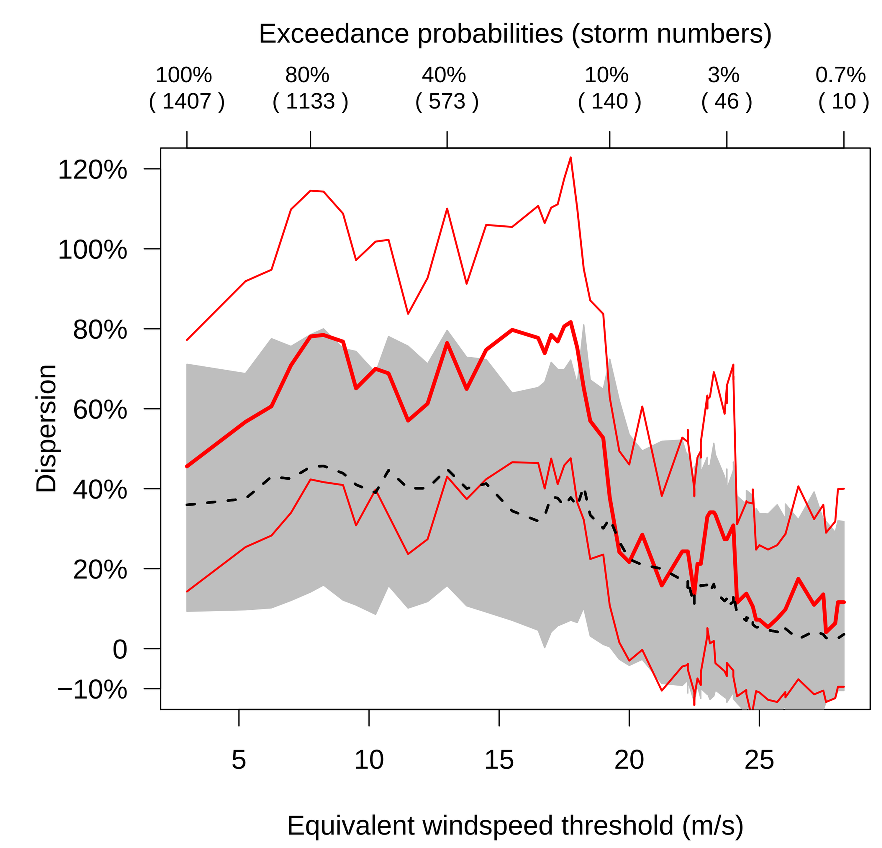
Aim: analyse effect of large scale atmospheric flow on storm transits.

Data: standardised daily teleconnection indices for NH (Climate Prediction Center, Rotated Principal Component Analysis of geopotential height anomalies).



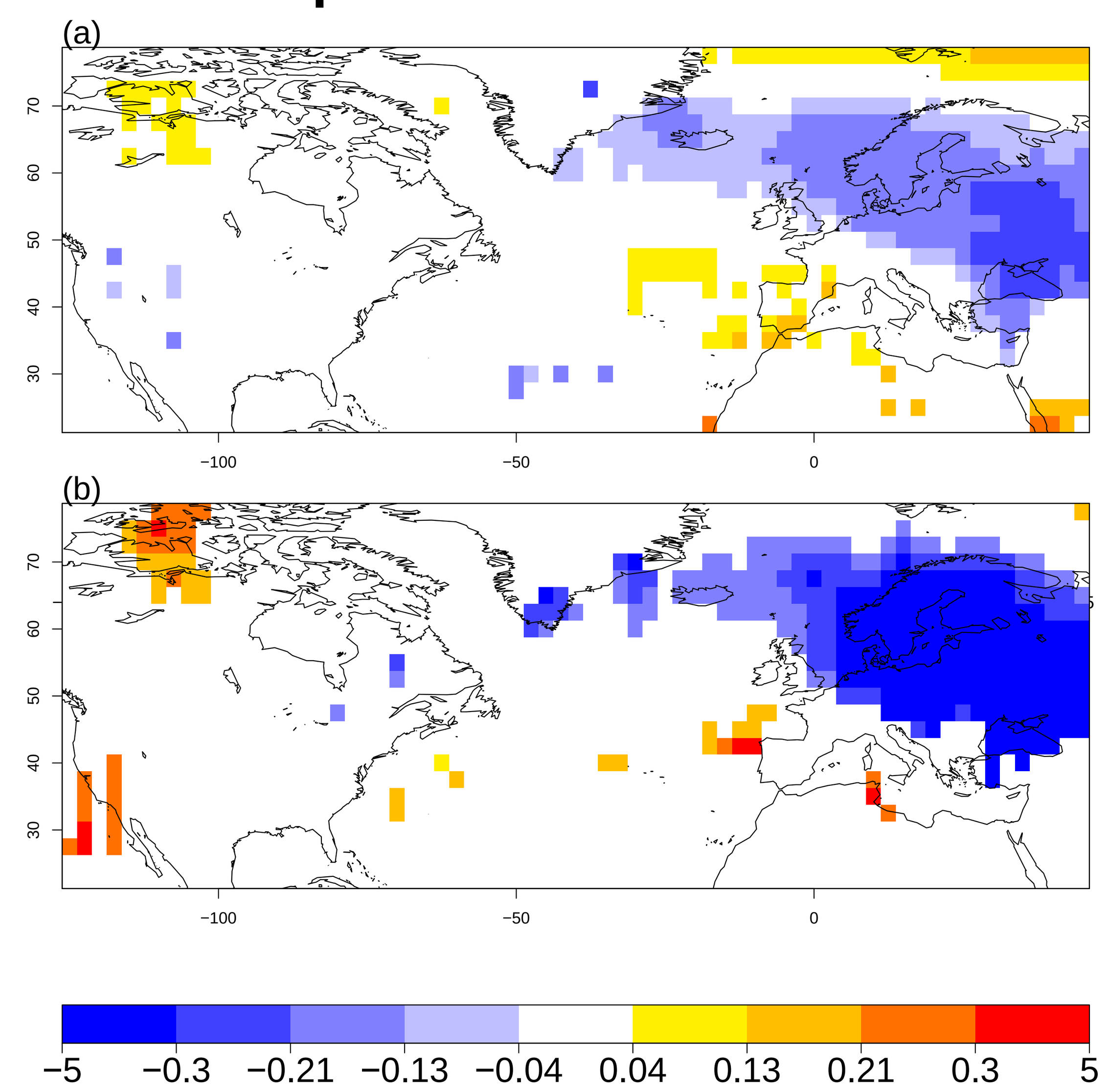
Teleconnections explain clustering

- Method: Poisson regression (stochastic model).
- 4 indices needed to capture overdispersion: North Atlantic Oscill., East Atlantic pattern, Scandinavian patt., East Atlantic/West Russia patt.
- These teleconnections affect storm transit rates in large coherent regions.



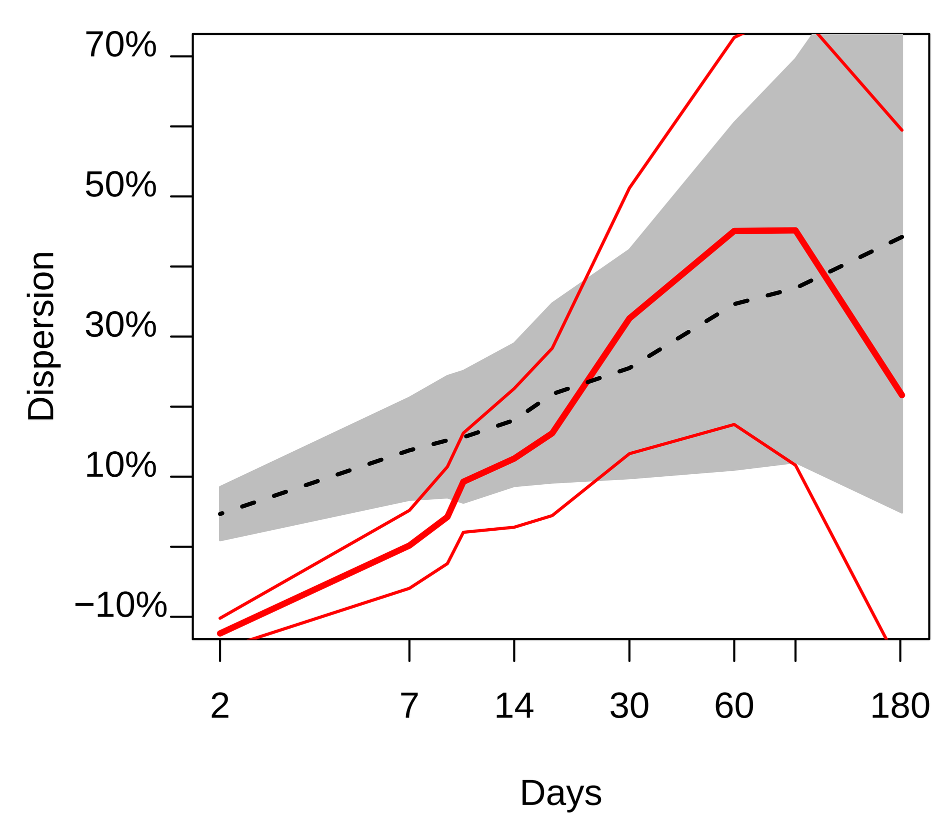
Dispersion as a function of vorticity threshold for a gridpoint near Berlin. Dispersion increases with threshold up to about 80%. Top axis: threshold (%) and corresp. total number of storms. Bottom: rough measure of windspeed equivalent to vorticity threshold. Solid red: ψ and 90% conf. interval for data. Dashed+grey: ψ and 90% c.i. as captured by Poisson model.

Scand. patt.: all vs. intense storms



Regression coefficient of Scandinavian patt. for intensity threshold of (a) 0% and (v) 80%. Strong negative effect over North and East Europe: transits are inhibited when index for Scandinavian patt. is positive. Relation to blocking?

Below: dispersion as a function of aggregation period (days) for all storms, Berlin gridpoint (as above). Dispersion increases with aggr. period up to 90 days, large uncertainty for 180 days (Oct-Mar winter).



Solid red/dashed+grey: as above.