Long-term variability of the thunderstorm and hail potential in Europe

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motivation & questions

Severe thunderstorms and associated hazardous weather events such as large hail frequently cause considerable damage in many parts of Europe. To relate single extreme hail events to the historic context, to estimate their return periods, or to quantify possible trends related to climate change, long-term statistics of those events are required. Due to the local-scale nature of hail and a lack of suitable observation systems, however, hailstorms have not been captured reliably and comprehensively for a long period of time. The essential questions are the following:

1) **Which meteorological parameters (proxies) best describe severe thunderstorm or hail events?**
2) **How has the thunderstorm/hail potential changed over past decades?**
3) **What is the role of natural climate variability?**

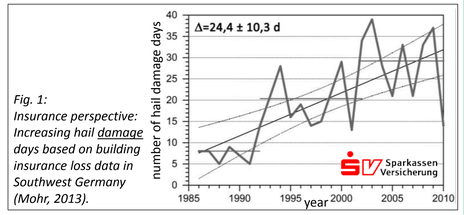

Fig. 1: Insurance perspective: Increasing hail damage days based on building insurance loss data in Southwest Germany (Mohr, 2013).

trends

Which parameters are most appropriate as proxies for severe thunderstorms and what trends can be estimated for the past?

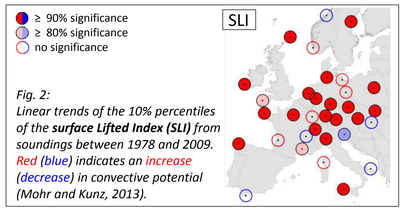

*Fig. 2: Linear trends of the 10% percentiles of the **surface Lifted Index (SLI)** from soundings between 1978 and 2009. Red (blue) indicates an increase (decrease) in convective potential (Mohr and Kunz, 2013).*

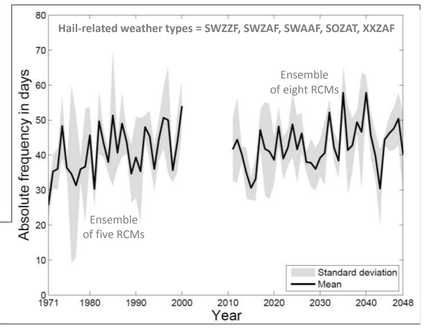

*Fig. 3: Time series of **hail-related large scale weather types** following the objective weather classifications by the German Weather Service (DWD; Kapsch et al., 2012).*

conclusions

- ✘ High annual variability of the conditions that favor severe convective events
  ➡ only a few statistically significant trends.
- ✘ Tendency of an increase of thunderstorm/hail potential over the last three decades (Western/Central Europe) making severe thunderstorms more likely. However, our analyses suggest that the potential in the fifties was similar to that nowadays.
- ✘ Despite the local-scale nature of convective storms, the ambient conditions favoring these events are mainly controlled by large-scale circulation patterns and mechanisms – such as the NAO, which shows an influence on the convective activity in some parts of Europe.

variability

How can the diagnostic of hail events improved?

Development of a logistic hail model that defines a new index estimating the potential of the atmosphere for hailstorm development per day – so-called **Potential Hail Index (PHI;** Mohr et al., 2015a,b) :

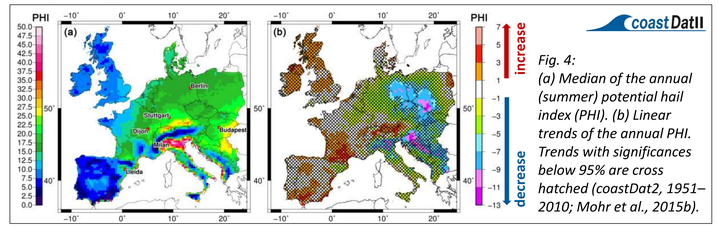

Fig. 4: (a) Median of the annual (summer) potential hail index (PHI). (b) Linear trends of the annual PHI. Trends with significances below 95% are cross hatched (coastDat2, 1951–2010; Mohr et al., 2015b).

Why are most of the trends not significant?

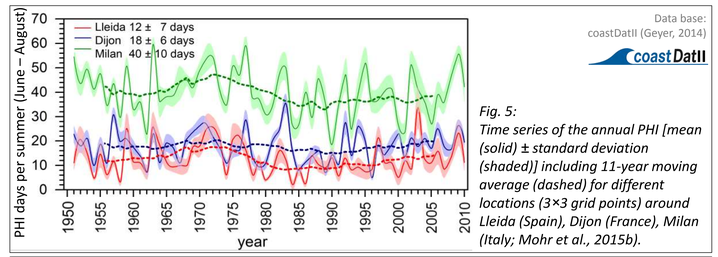

Fig. 5: Time series of the annual PHI [mean (solid) ± standard deviation (shaded)] including 11-year moving average (dashed) for different locations (3×3 grid points) around Lleida (Spain), Dijon (France), Milan (Italy; Mohr et al., 2015b).

Data base:
NOAA-CIRES 20CR v2c
(Compo et al., 2011)

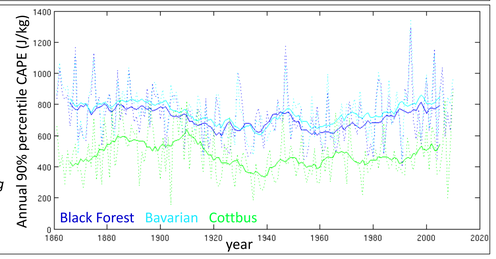

Fig. 6: Time series of the 90% percentile of the summer half year convective available potential energy (CAPE) including 10-year moving average for different locations in Germany (Speidel, 2016).

large-scale relations

Can large-scale correlations in the hail potential be identified among different locations – despite the local-scale characteristics of convective events?

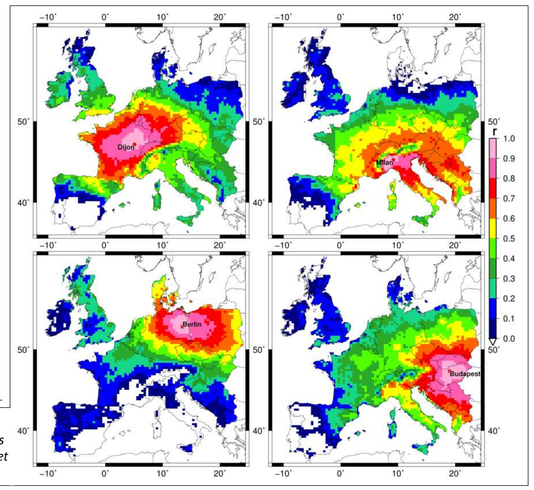

Fig. 7: Correlation coefficient between the time series of the annual PHI at four different locations (3×3 grid points) and all other grid points (Mohr et al., 2015b).

Is the thunderstorm activity related to teleconnections?

Dimensionless value:

$$D = \frac{[\text{Rel. frequency (thunderstorm day with NAO < -1)}] - [\text{Rel. frequency (all thunderstorm days)}]}{[\text{Rel. frequency (all thunderstorm days)}]}$$

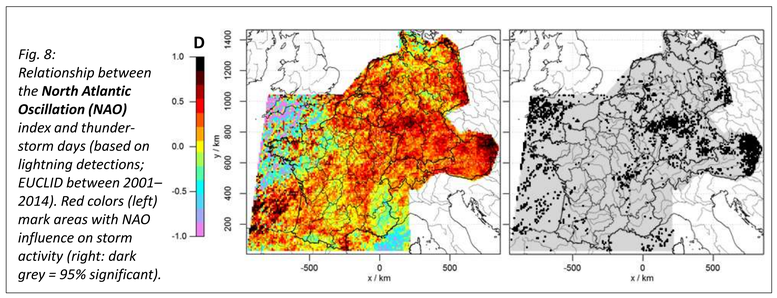

*Fig. 8: Relationship between the **North Atlantic Oscillation (NAO)** index and thunderstorm days (based on lightning detections; EUCLID between 2001–2014). Red colors (left) mark areas with NAO influence on storm activity (right: dark grey = 95% significant).*

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