Temporal variability of severe convective storms connected with hail events across Europe and their relevant drivers

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Overview

Due to a lack of long-term, reliable, and consistent information about the occurrence of **severe convective storms** (SCS) in Europe – especially those **connected with hail events** – we have developed methodologies that enables to indirectly estimate thunderstorm and hail probability from numerical weather prediction or climate models. Using these two approaches, we investigated the **temporal and spatial variability** of convective predisposition and hail potential over past decades and identified **large-scale atmospheric processes** (e.g., teleconnection patterns, SST, blocking) that determine the spatio-temporal variability of SCS.

Conclusions

- **Little or no trend** in PHI and *convection-favoring* weather types for most of the grid points (1951–2010/2014); but **high annual variability** of the conditions that favor severe convective events including hail.
- Regarding weather pattern: Most regions feature **positive trends** for **thermodynamic** and **negative trends** for **dynamic** quantities: Positive trends for thermodynamic parameters, negative trends for lifting (not shown).
- Large-scale mechanism like **teleconnections** (e.g., NOA, EA) or **SST** substantially **impact** local-scale **convective activity** in Europe: e.g. increased convective activity during NAO- and EA+.
- Several simultaneous peaks in EA/SST time series and days with convection-favoring conditions.
- Areas with **blocking activity** over the **eastern North Atlantic** (reduction) and **Scandinavia influence** (increasing) **thunderstorm activity** in western/central Europe. Reasons are resulting condition for the upper flow, moisture transport and stability conditions.

Methodology

How can thunderstorm and hail probability estimated?

Proxy by Logistic hail model

Potential Hail Index (PHI):

$$\mathrm{P_{hail}} = \frac{1}{1+e^{-\mathrm{g_{hail}}(x)}}$$

$$\mathrm{g_{hail}} = \beta_0 + \beta_1 \cdot \mathrm{SLI} + \beta_2 \cdot \mathrm{T_{min}} + \beta_3 \cdot \mathrm{T_{2m}}$$

with $0 \leq p(x) \leq 1$

Moisture content: Minimum temperature in the morning

Atmospheric stability: Surface Lifted Index

Boundary condition: Surface temperature

Proxy by Objective weather types classification scheme

Convection-favoring weather type:

W – M – U – A ← 6% of all days

warm, moist, unstable, ascend

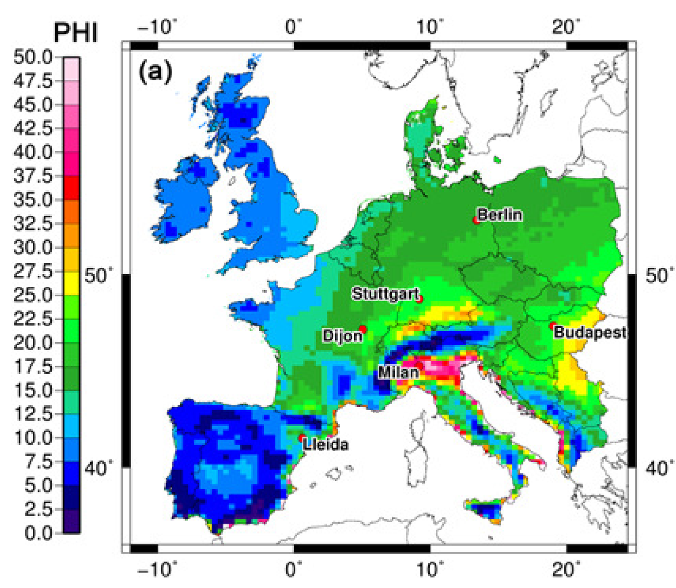

Fig. 1: Median of the annual (summer) Potential Hail Index (PHI; coastDat2, 1951–2010, JJA; Mohr et al., 2015).

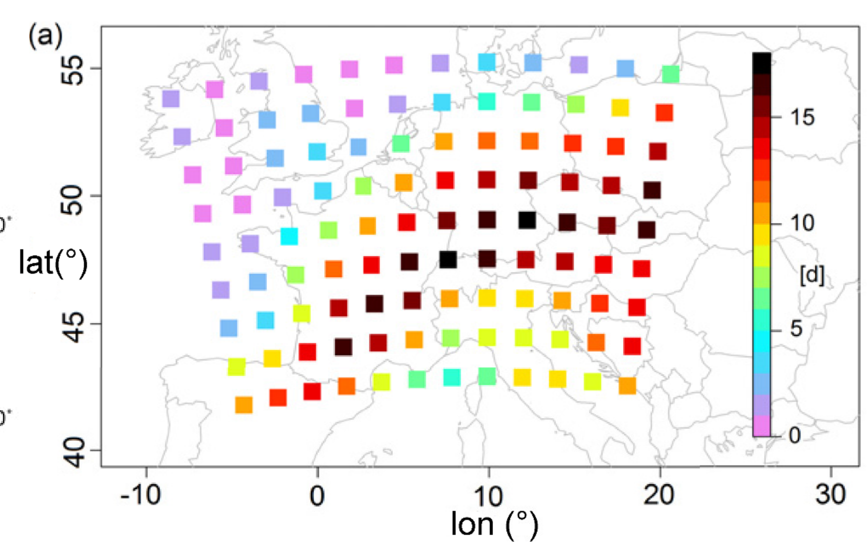

Fig. 2: (a) Mean annual frequency (days) of convection-favoring (WMUA) conditions (coastDat2, 1958–2014, SHY; Piper, 2017; Piper et al., in prep).

Variability

How is the temporal and spatial variability of convective activity and hail potential over past decades?

Convection-favoring weather types

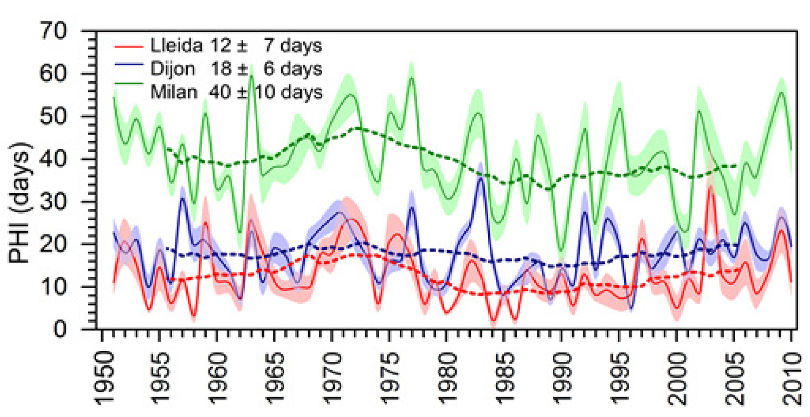

Fig. 3: Time series of the annual PHI [mean (solid) ± standard deviation (shaded)] including 11-year moving average (dashed) for different locations (3×3 grid points) around Lleida (Spain), Dijon (France), Milan (Italy; Mohr et al., 2015).

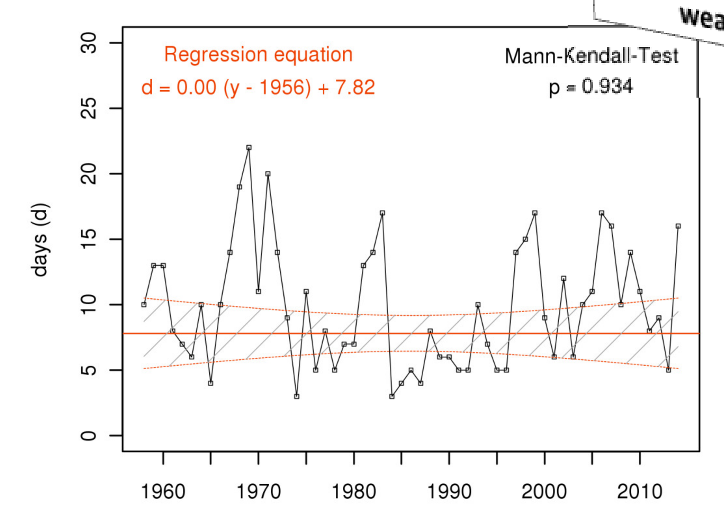

Fig. 5: Time series of convection-favoring weather patterns 1985-2014 (Germany; Piper, 2017).

Potential hail Index

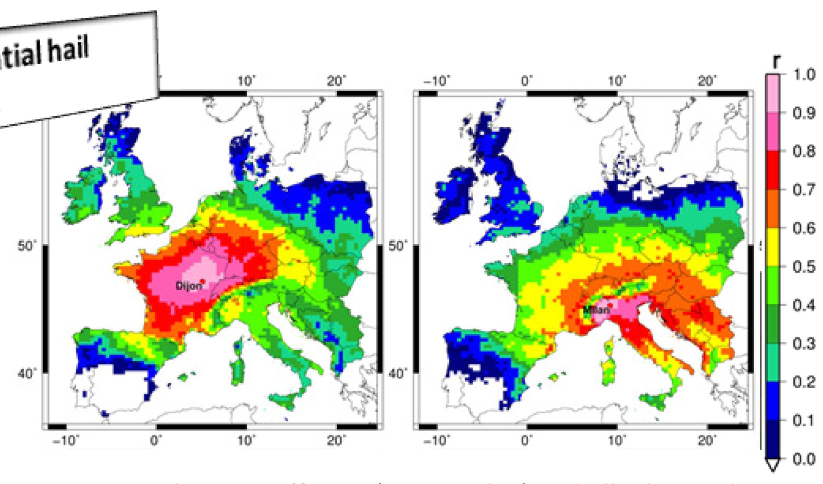

Fig. 4: Correlation coefficient (Dijon, Milan) and all other grid points (Mohr et al., 2015).

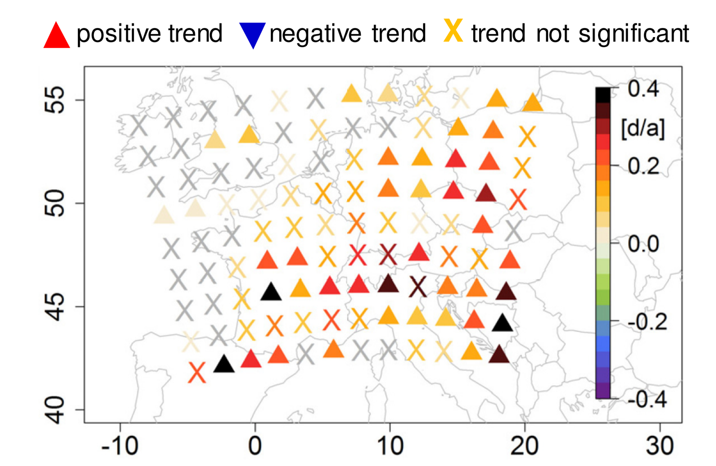

Fig. 6: Regional trends of convection-favoring weather patterns during the 30-years period 1985–2014 (Piper, 2017).

Relevant drivers

What are the large-scale atmospheric processes influencing the temporal and spatial variability?

Teleconnections

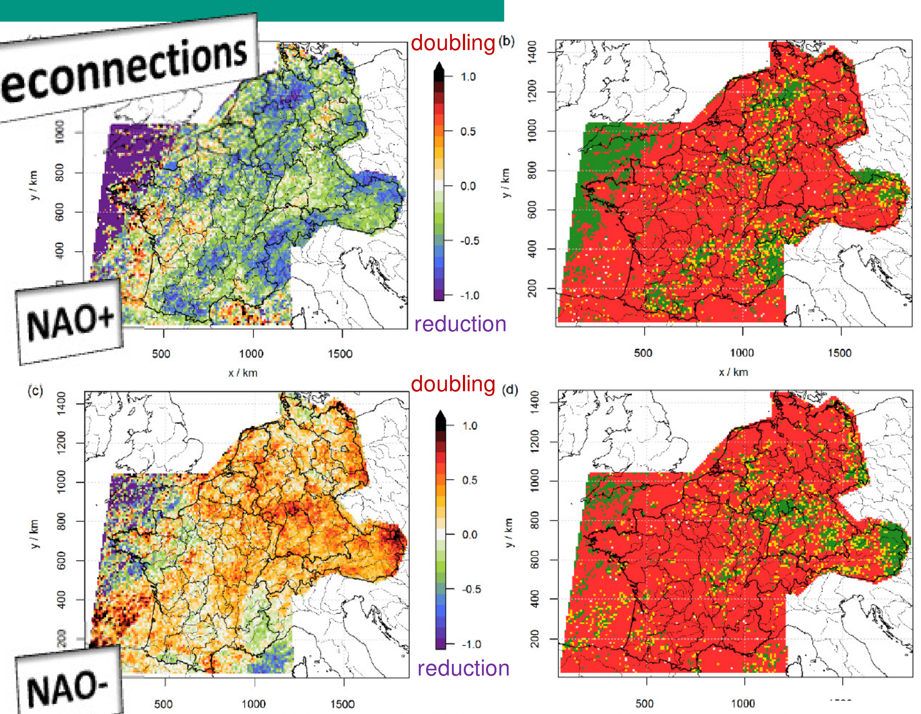

Fig. 7: Relationship between the North Atlantic Oscillation (NAO) index and thunderstorm days (based on lightning detections; EUCLID between 2001–2014). Presented is the relative deviation of the monthly number of thunderstorm days (anomaly) calculated with respect to months with an North Atlantic Oscillation (NAO) index greater than +1 (NAO+) and less than -1 (NAO-; left) and results from a bootstrap significance test (right; Piper and Kunz, 2017).

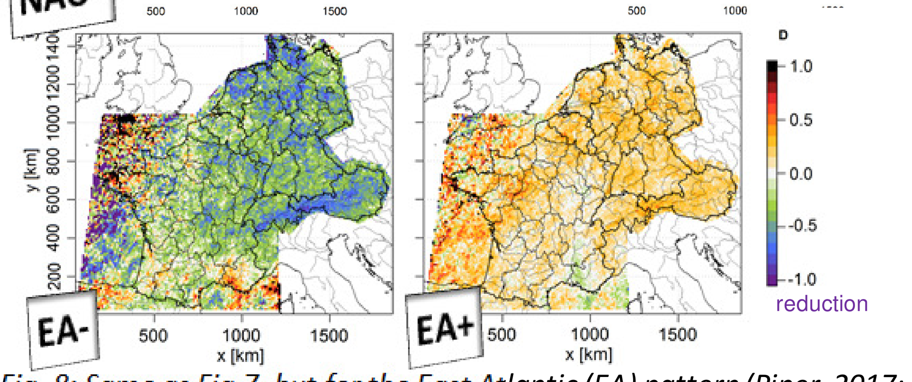

Fig. 8: Same as Fig.7, but for the East Atlantic (EA) pattern (Piper, 2017; Piper et al., in prep).

Sea surface temperature

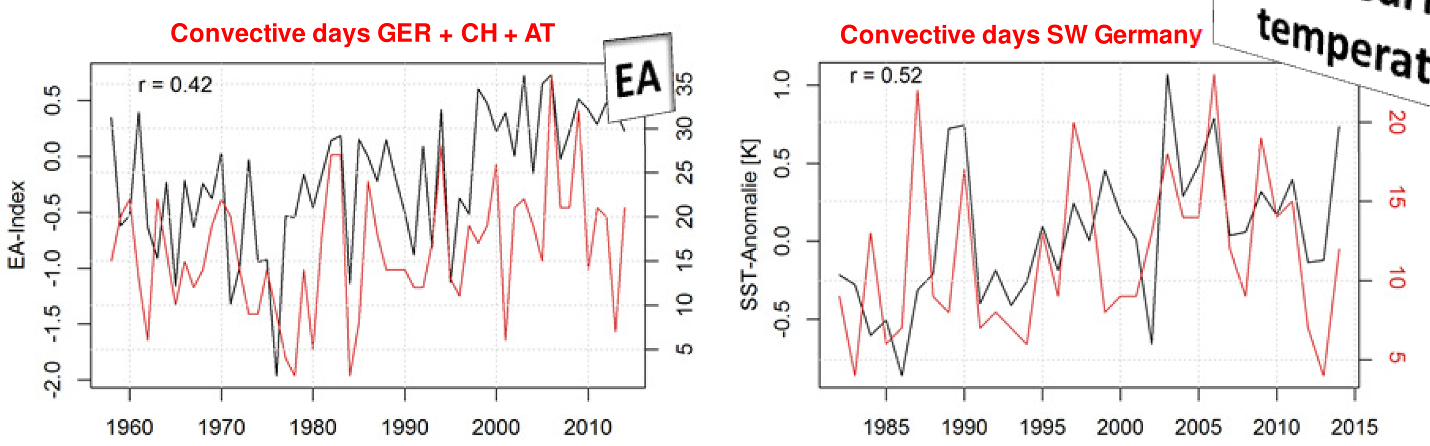

Fig. 9: Time series of convection-favoring weather patterns for different areas and annually averaged EA-Index (left) and sea surface temperature (SST) over the Bay of Biscay (right; Piper, 2017; Piper et al., in prep).

Atmospheric blocking

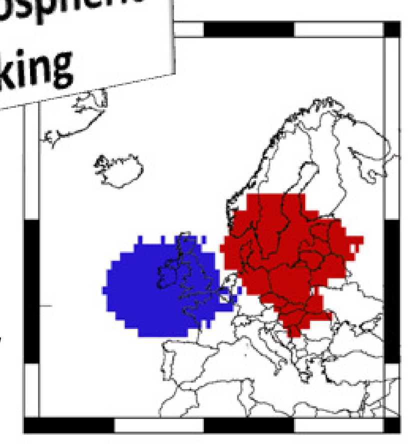

Fig. 10: Relevant areas, where the occurrence of blocking influence the thunderstorm days (BLUE = reduction; RED = increasing) in certain parts of western and central Europe (see Fig. 11; Mohr et al., in prep).

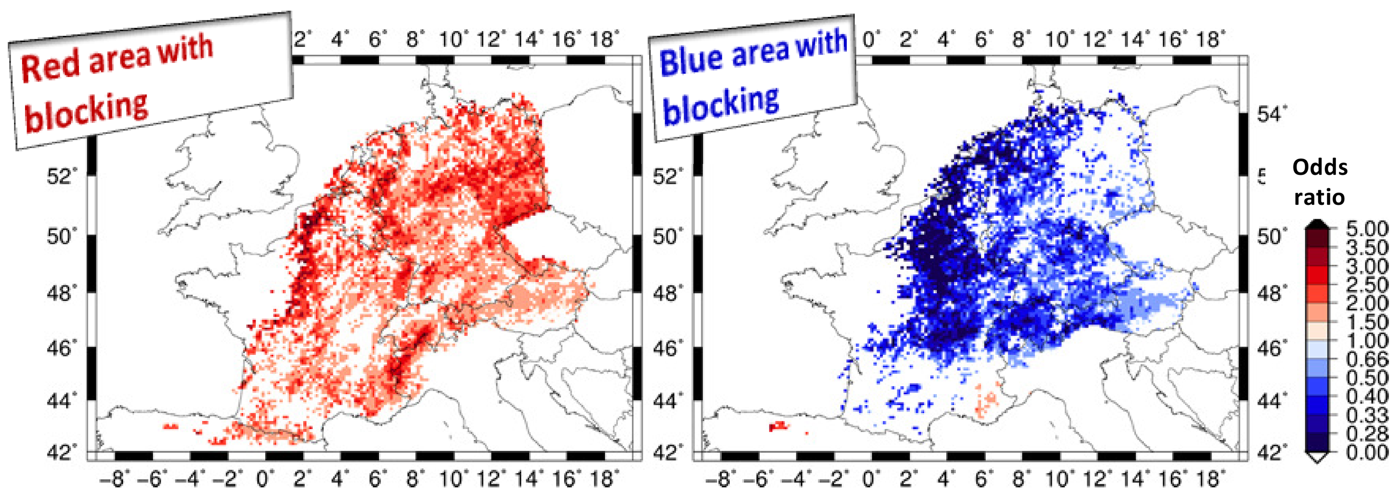

Fig. 11: Areas with statistically significant changes in the **odds** of thunderstorm days (2001–2014, MJJA) in dependency of blocking activity in the both identified area in Figure 10. The blue colors indicate a **reduction** (e.g., a value of 0.5 means a reduction of the odds by 50 %), one means no change, and the red colors indicate an **increase** (e.g., a value of 2 means a doubling of the odds; Mohr et al., in prep).

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