Relationship between atmospheric blocking and thunderstorm activity over western and central Europe

Susanna Mohr[1,2] (mohr@kit.edu), Jan Wandel[1], Michael Kunz[1,2], Sina Lenggenhager[3], Olivia Martius[3,4]

[1]Institute of Meteorology and Climate Research (IMK-TRO), Karlsruhe Institute of Technology (KIT), Germany

[2]Center for Disaster Management and Risk Reduction Technology (CEDIM), Germany

[3]University of Bern, Oeschger Centre for Climate Change Research and Institute of Geography, Switzerland

[4]University of Bern, Mobiliar Lab for Natural Risks, Switzerland

Overview

Severe thunderstorms and associated hazardous weather extremes such as heavy precipitation or hail frequently cause considerable damage to buildings, crops, and automobiles in many parts of Europe and the world. Despite the high relevance to questions regarding trends of such events caused by climate change, the role of large-scale mechanisms on the persistence or the natural variability behind them is not yet well understood. For example, a first case study indicate a connection between blocking and thunderstorm activity (Piper et al., 2016).

Data basis

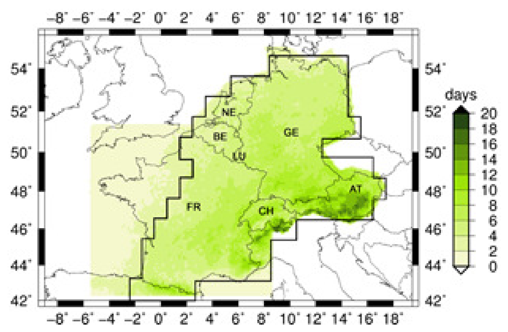

Fig. 1: Mean annual number of thunderstorm days (2001 – 2014, MJJA).

Lightning Data

- Lightning detection system BLIDS (part of EUCLID)
- Time period: **2001 – 2014 (May to August)**
- Dichotomous variable "thunderstorm day" (TD): TD is defined if at least five cloud-to-ground flashes were registered within a 10 x 10 km² grid point per day.

Blocking Data

- Based on ERA-Interim reanalysis data (1° x 1°)
- Time period: 2001 – 2014 (May to August)
- Methodology of Schwierz et al. (2004): Persistent negative upper-level potential vorticity (PV) anomalies
- Summer blocking criterion: –1 pvu

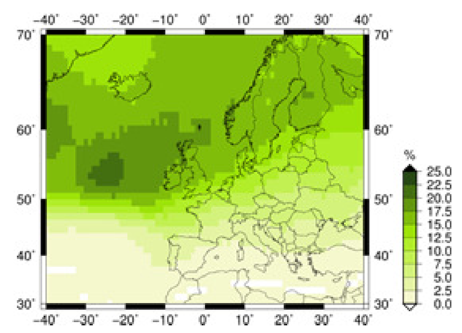

Fig. 2: Relative blocking frequency between 2001 – 2014 (MJJA).

Methodological approach

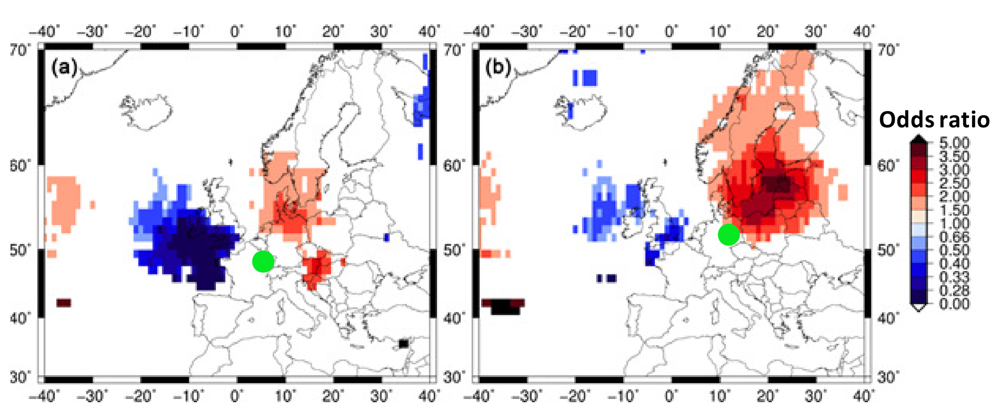

*Fig. 3: Two examples of identified areas with statistically significant **changes in the odds ratio**, where blocking affects the thunderstorm activity in the reference regions (illustrated as green point).*
*The **blue colors** indicate a **reduction** of thunderstorm days by blocking (e.g., a value of 0.5 means a decrease of the odds by 50 %) and **red colors** indicate an **increase** (e.g., a value of 2 means a doubling of the odds).*

- **Task:** Identifying relevant regions over the North Atlantic and European sector, where blocking is related to thunderstorms over Europe
- Method: **Odds Ratio** (OR) (see Mahlstein et al., 2012; Mohr et al., 2019)
- **Calculation of changes in the odds ratio** between blocking data (1° x 1° grid) and thunderstorm data (converted to the same 1° x 1° grid; resulting in 132 grid points; cf. Fig. 1 black line)

Relation between blocking & thunderstorms

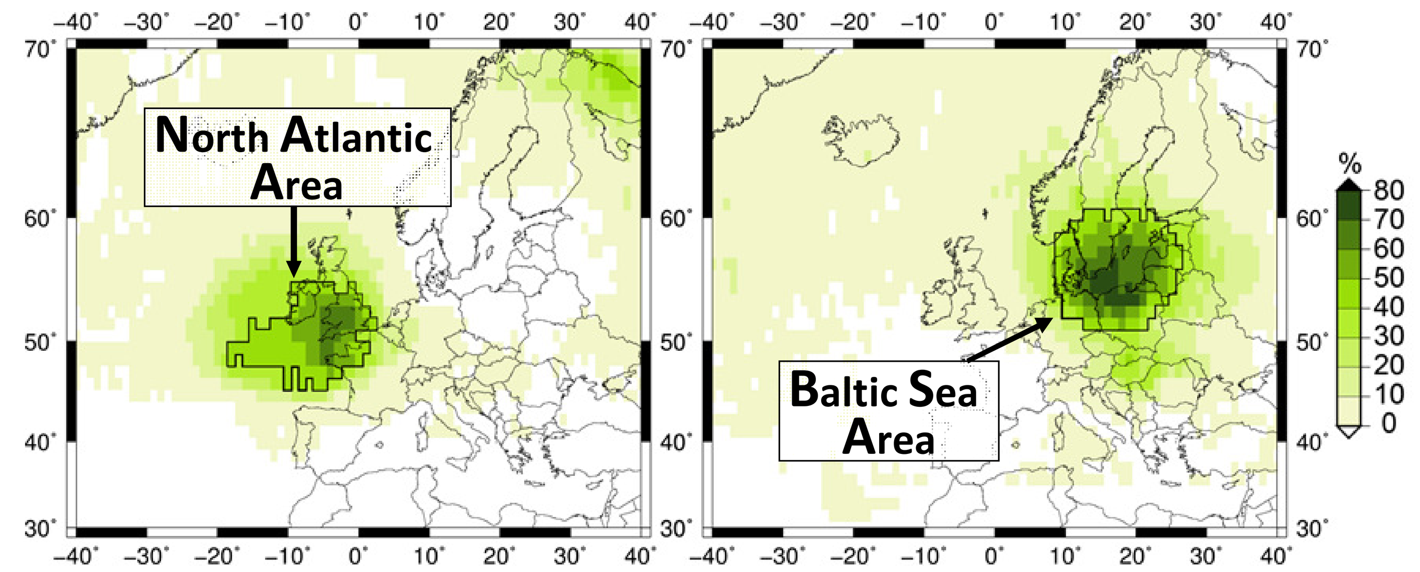

Fig. 4: Relative frequency of the 132 OR calculations quantifying how often (a) OR< 1 (blocking suppresses TDs; blue in Fig. 3) or (b) OR> 1 (blocking supports TDs; red in Fig. 3) in this region. The black lines indicate the final defined blocking area.

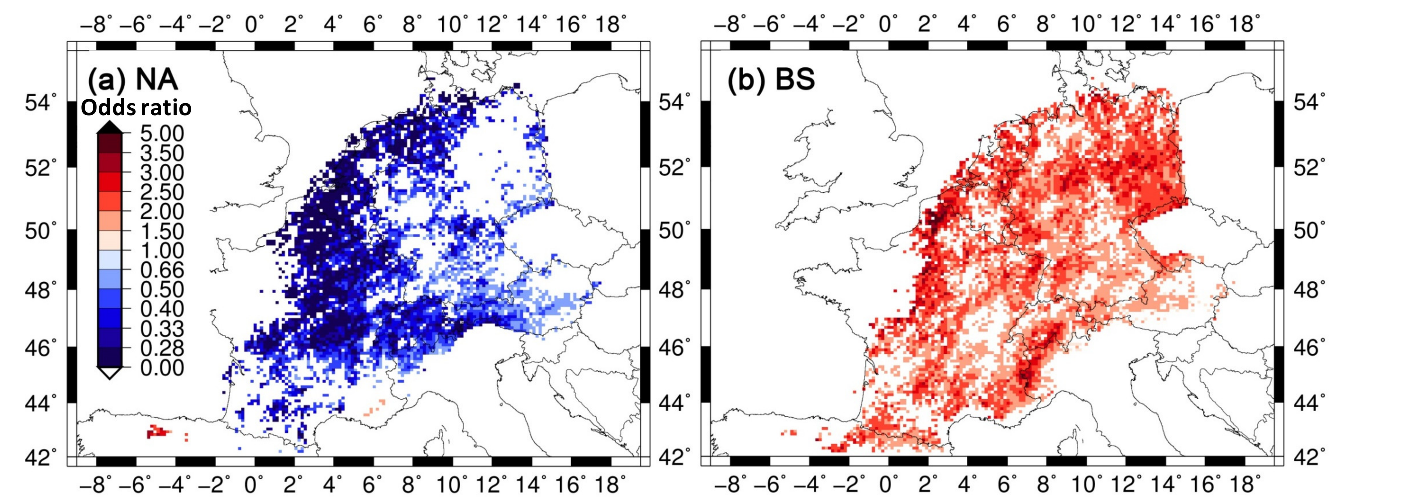

*Fig. 5: Changes in the odds ratio, where blocking in an areas (a) over the eastern part of the **North Atlantic (NA)** or (b) over the **Baltic Sea (BS)** influences the thunderstorm activity over western and central Europe. The **blue colors** indicate a **reduction of thunderstorm days by blocking** (e.g., a value of 0.5 means a decrease of the odds by 50 %) and **red colors indicate an increase** (e.g., a value of 2 means a doubling of the odds).*

Conclusions

- Two regimes were identified, where blocking affects the probability of thunderstorm days over western and central Europe. One is located over the eastern part of the **North Atlantic (*convection-inhibiting conditions*)** and one over the **Baltic Sea (*convection-favoring conditions*)**.
- The anticyclonic circulation of a blocking ridge over the eastern part of the North Atlantic leads in **northerly to northwesterly advection of dry and stable air masses** on the eastern flank of the block.
  In contrast, the **southerly to southwesterly advection of warm, moist and unstable air masses** from the Mediterranean on the western flank of a blocking system over the Baltic Sea results in preferably convection-favoring conditions (cf., Piper et al., 2019).
- Both blocking situations are **generally associated with weak vertical wind speeds at mid-tropospheric levels** and weak wind shear. As a consequence, thunderstorms related to atmospheric blocking over the Baltic Sea tend to be **on average less organized**.
  However, days with high wind shear values between 20 and 30 m/s are also observed during blocking over the Baltic Sea (around 10 %).

Environmental conditions during blocking

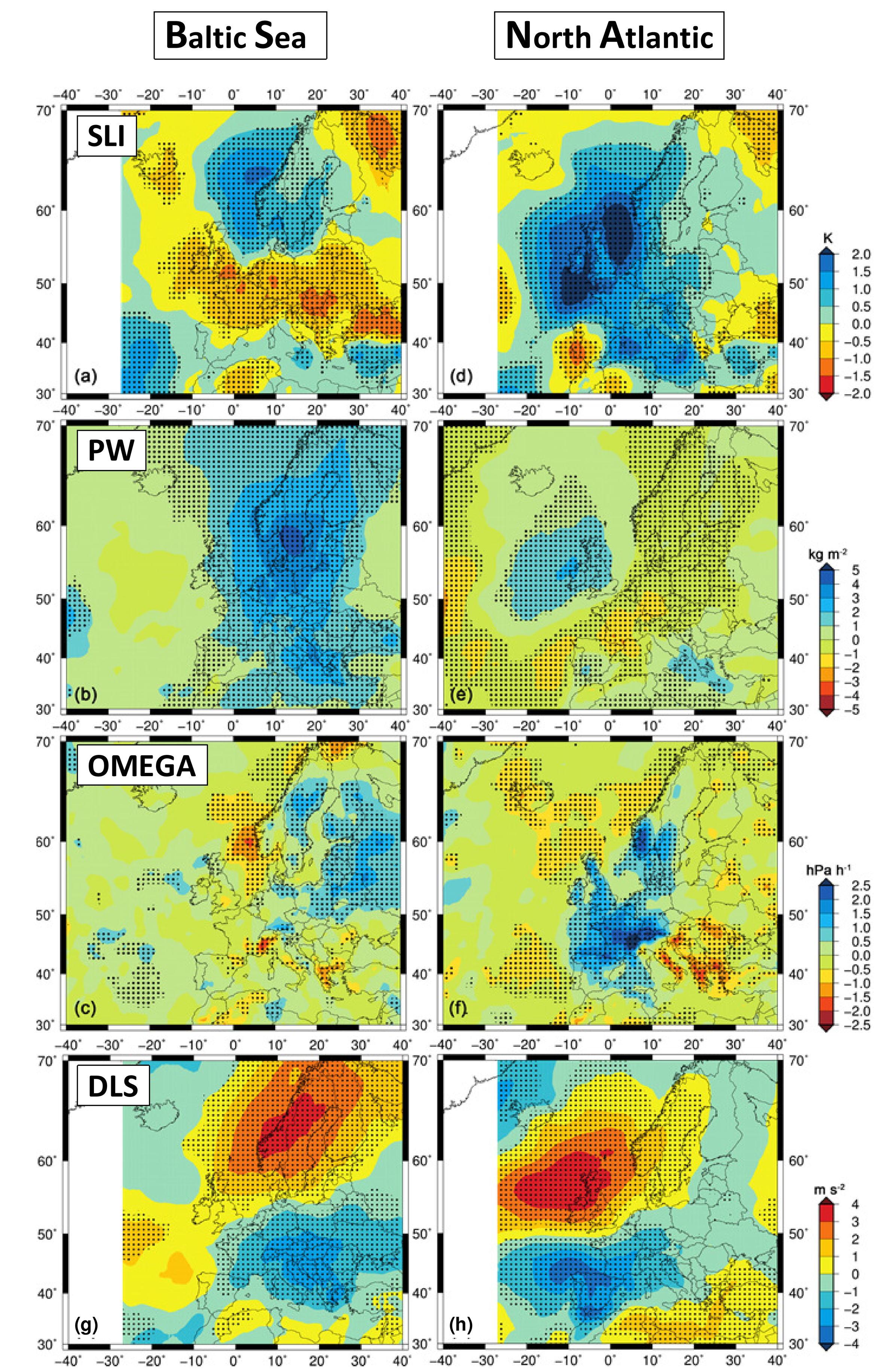

*Fig. 6: **Anomaly composites** during blocking over the Baltic Sea (left) and over the North Atlantic (right) for **(a,d) surface-based Lifted Index (SLI)**, **(b,e) precipitable water (PW)**, **(c,f) vertical motion** at 500 hPa (**OMEGA**), **(g,h) deep layer wind shear** between 950 hPa and 500 hPa (**DLS**) with respect to the **reference period (1981 – 2010**; including statistical significance in black dots).*

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