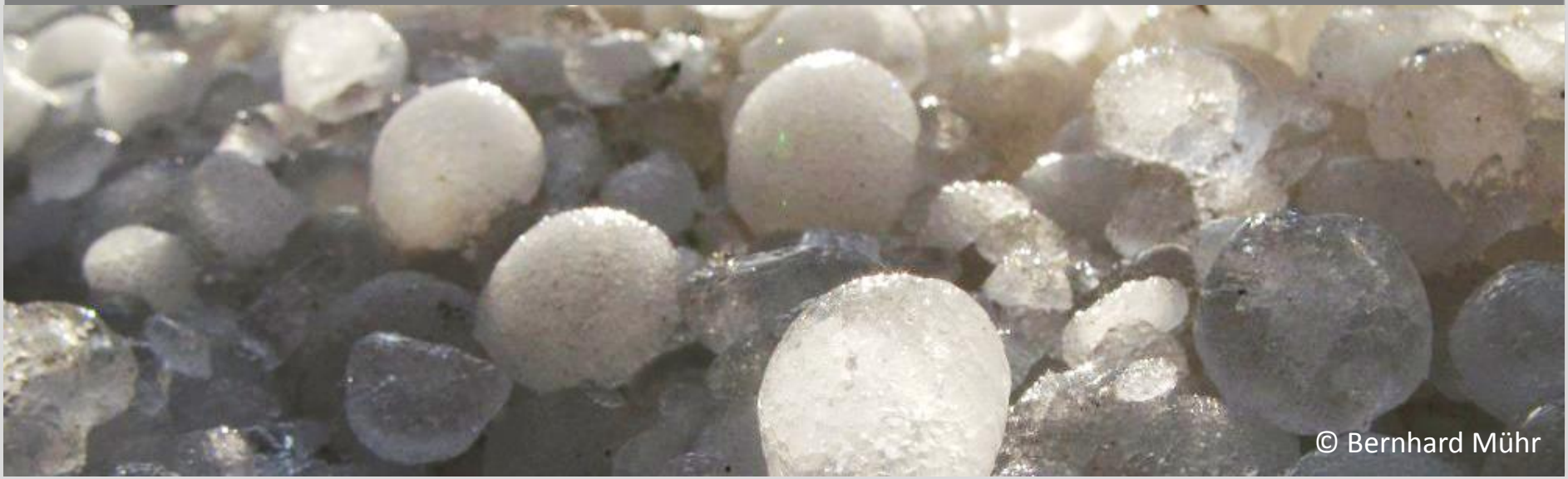
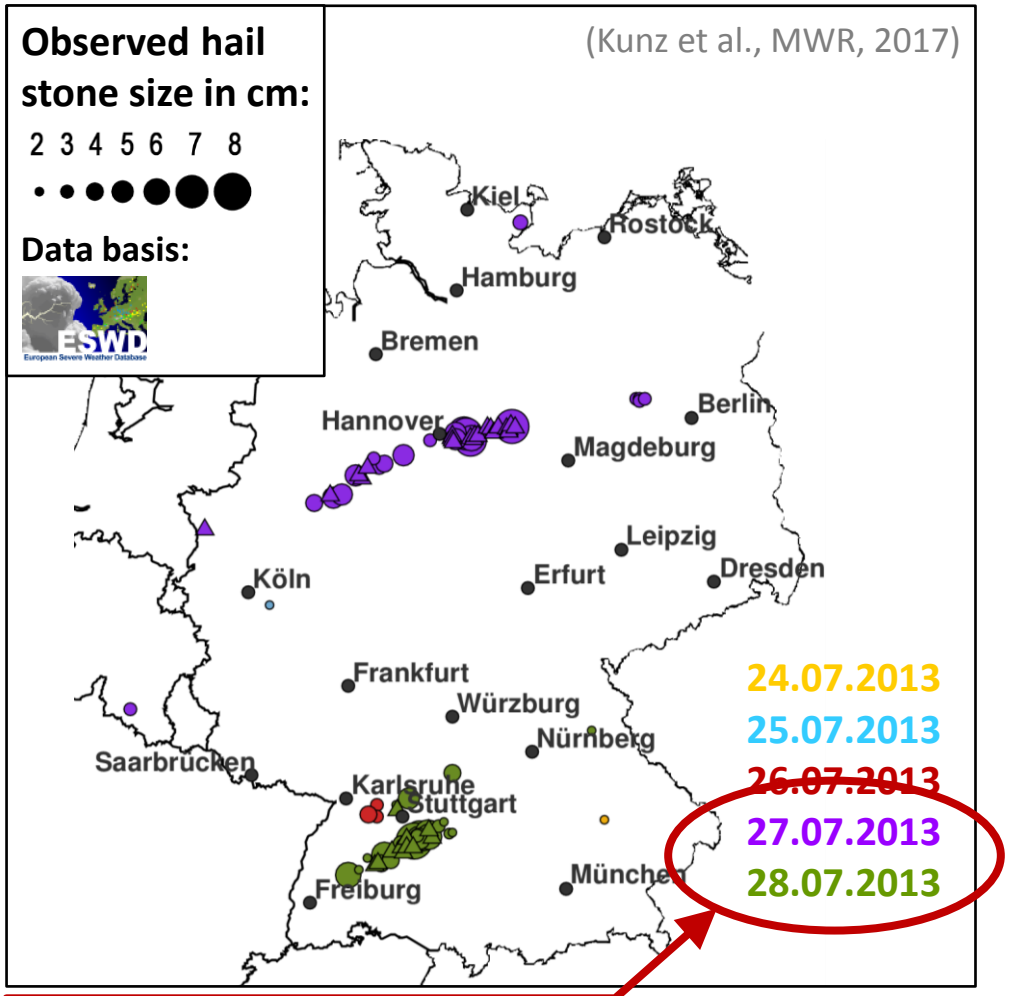
Has the hail potential over Europe changed and what are potential drivers?

Susanna Mohr, David Piper & Michael Kunz

Institute of Meteorology and Climate Research (IMK-TRO)
Center for Disaster Management and Risk Reduction Technology (CEDIM)



A series of severe hailstorms in July 2013



27. + 28.07.2013:

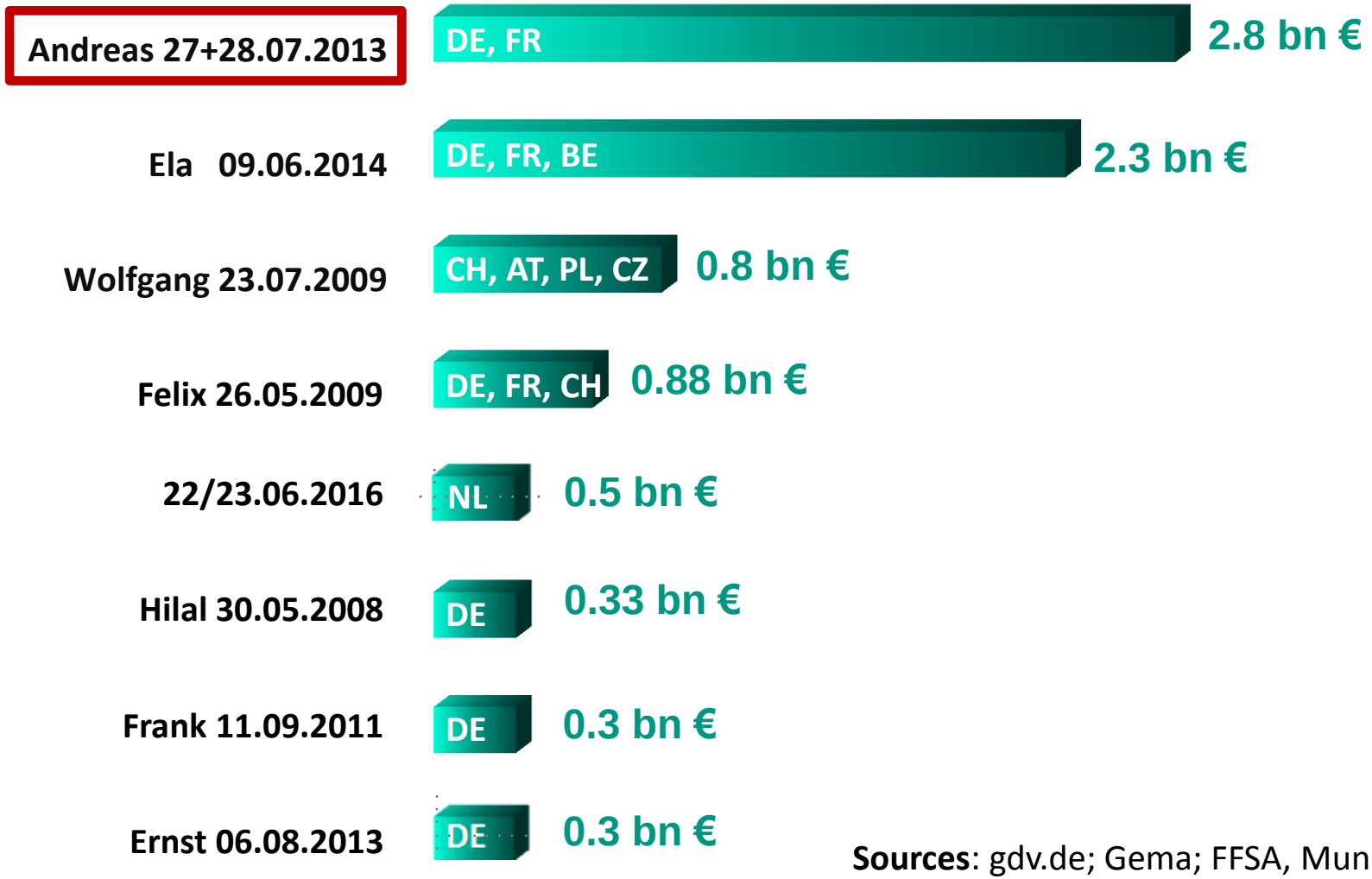
Insured loss:	2.8 bn €
Total loss:	3.6 bn €

(Munich Re, 2014)

Costliest hailstorms over Europe

Karlsruhe Institute of Technology

Insured Losses of most intense hailstorms in Western & Central Europe (last 9 years)



Sources: gdv.de; Gema; FFSA, Munich Re

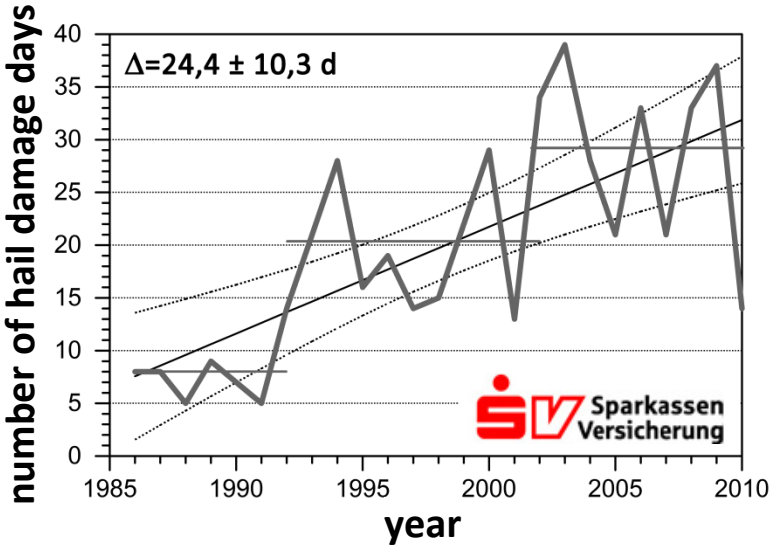
Scientific questions

1. Has the thunderstorm/hail potential over Europe changed during the past?

2. How will the thunderstorm/hail potential change in the future?

3. What are potential drivers of severe thunderstorms or hail occurrence in Europe?

Past changes (Insurance perspective)



Insurance perspective:

Increase of hail **damage** days in Southwest Germany

(Kunz et al., 2009; Mohr, 2013)

Hail detection in climate models

Development of logistic hail model:

- Determination of hail in climate models
- Combination of a number of **hail-related parameters**
- Output variable: **Potential Hail Index (PHI)** = Number of days with hail

$$p_{hail} = \frac{1}{1 + e^{-g_{hail}(x)}} \qquad \text{with } 0 \leq p(x) \leq 1$$

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

Moisture content: Minimum temperature in the morning

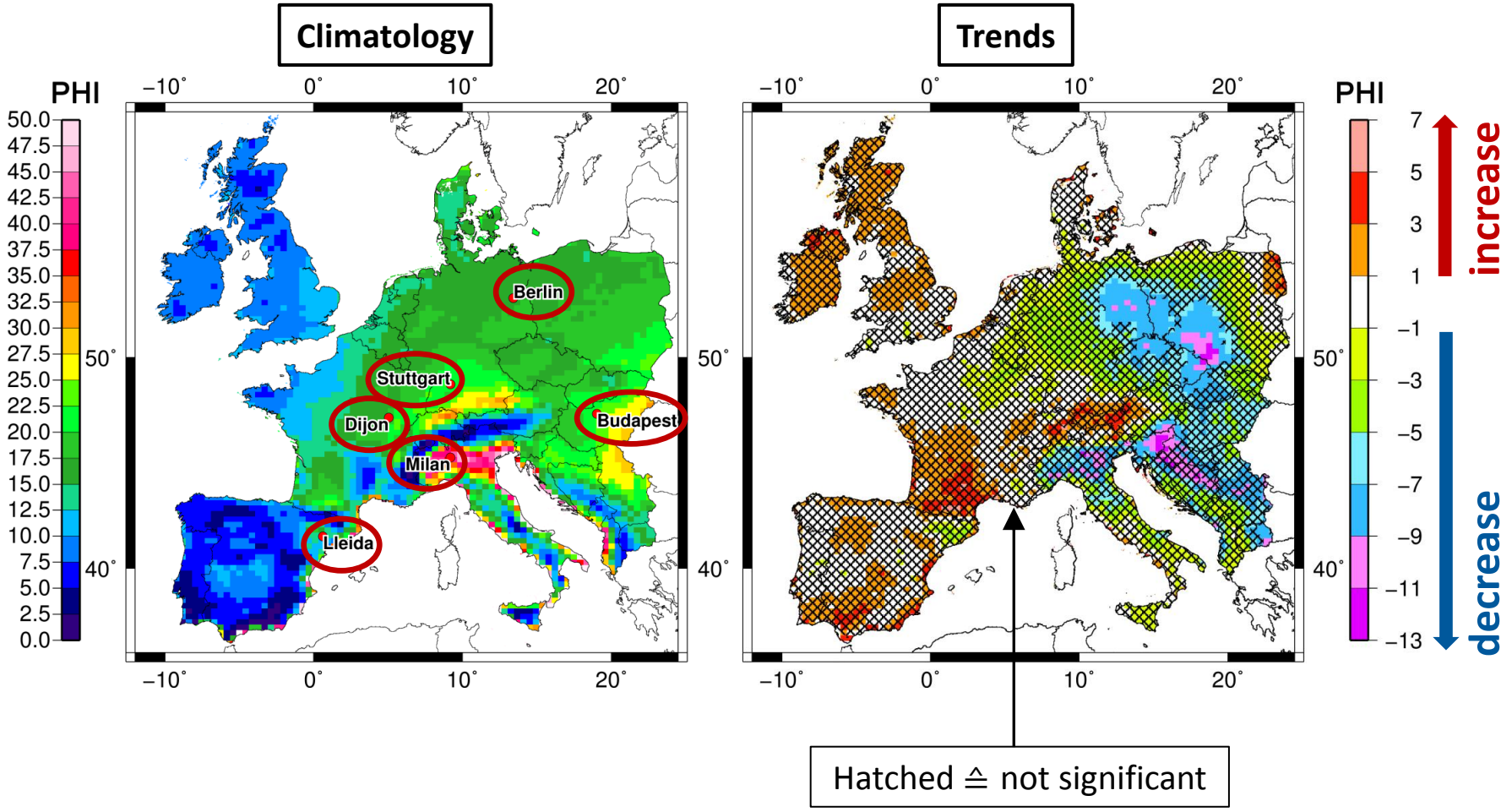
Atmospheric stability: Surface Lifted Index

Boundary condition: Surface temperature

(Mohr et al., JGR 2015a; GRL 2015b)

Past changes (Meteorological perspective)

Hail potential (PHI) in Europe (1951 – 2010, JJA):

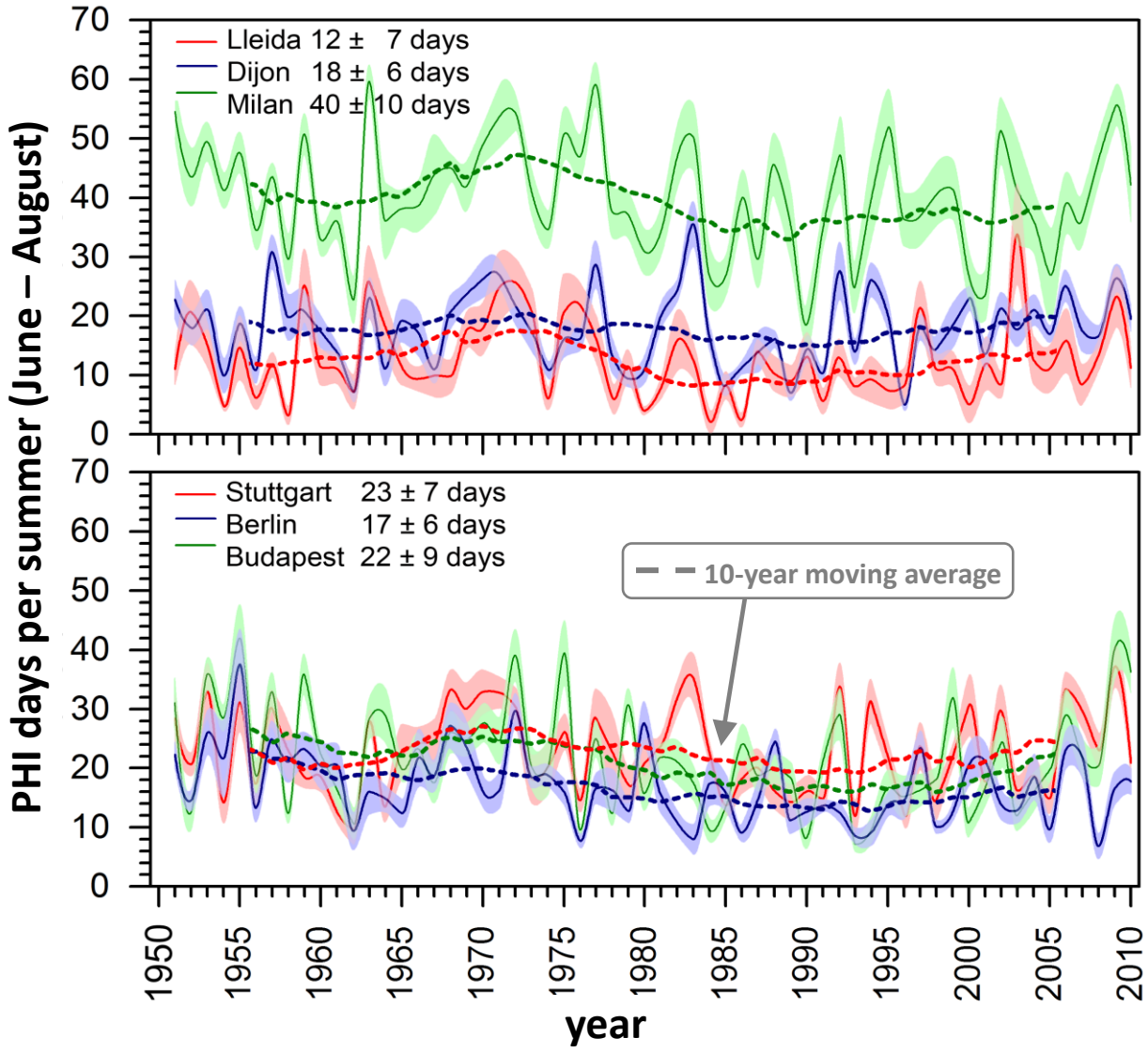


coastDatII

Downscaled **Reanalysis** run driven by **NCEP/NCAR 1**

(Mohr et al., GRL, 2015b)

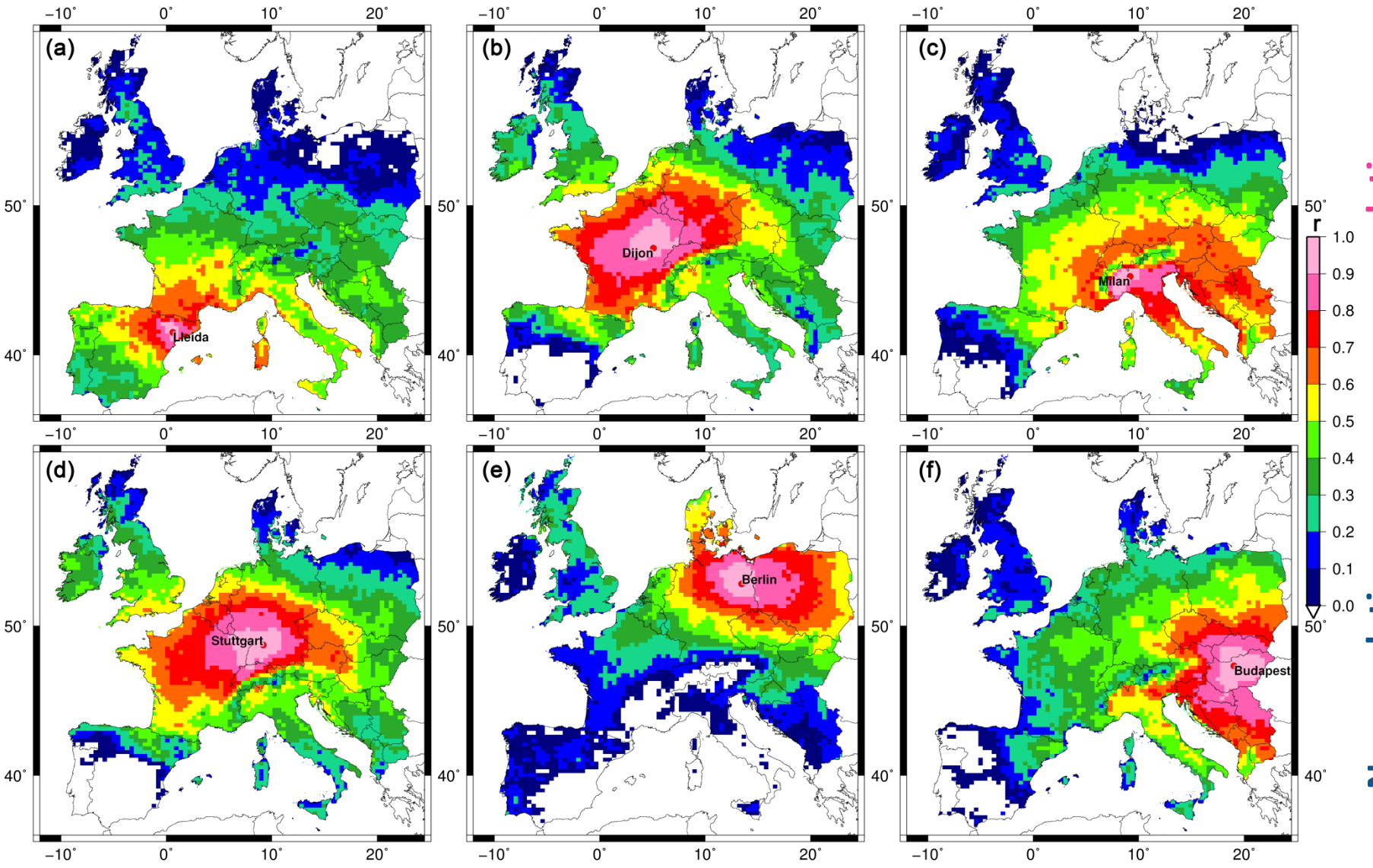
Past changes (Meteorological perspective)



PHI
1951 – 2010
JJA

(Mohr et al., GRL, 2015b)

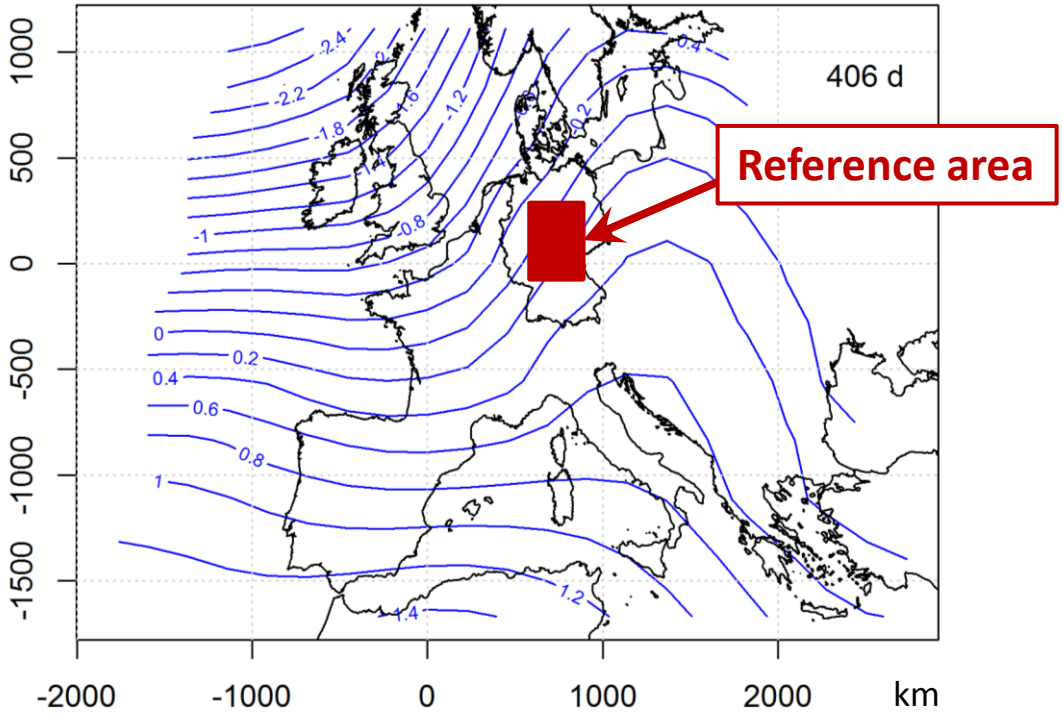
Mechanism: Large-scale relation of PHI

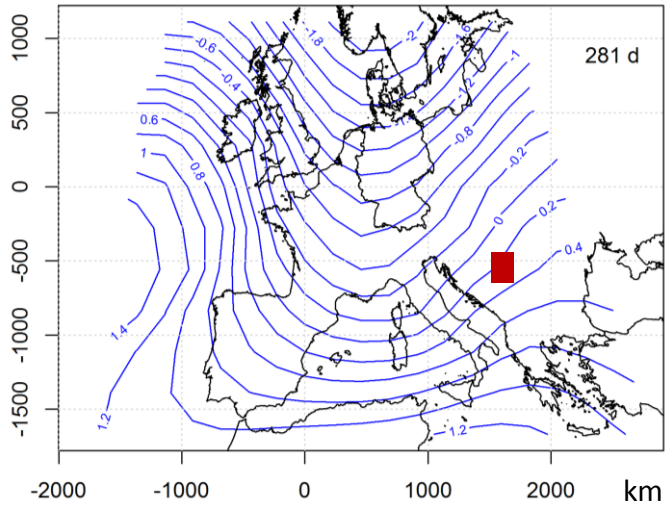


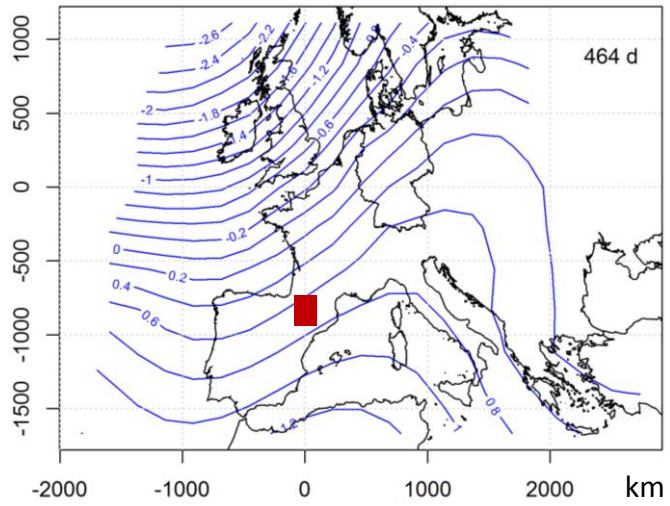
(Mohr et al., GRL, 2015b)

Relation to large-scale circulation pattern

Impact of upper-level flow (500 hPa) on thunderstorm activity:







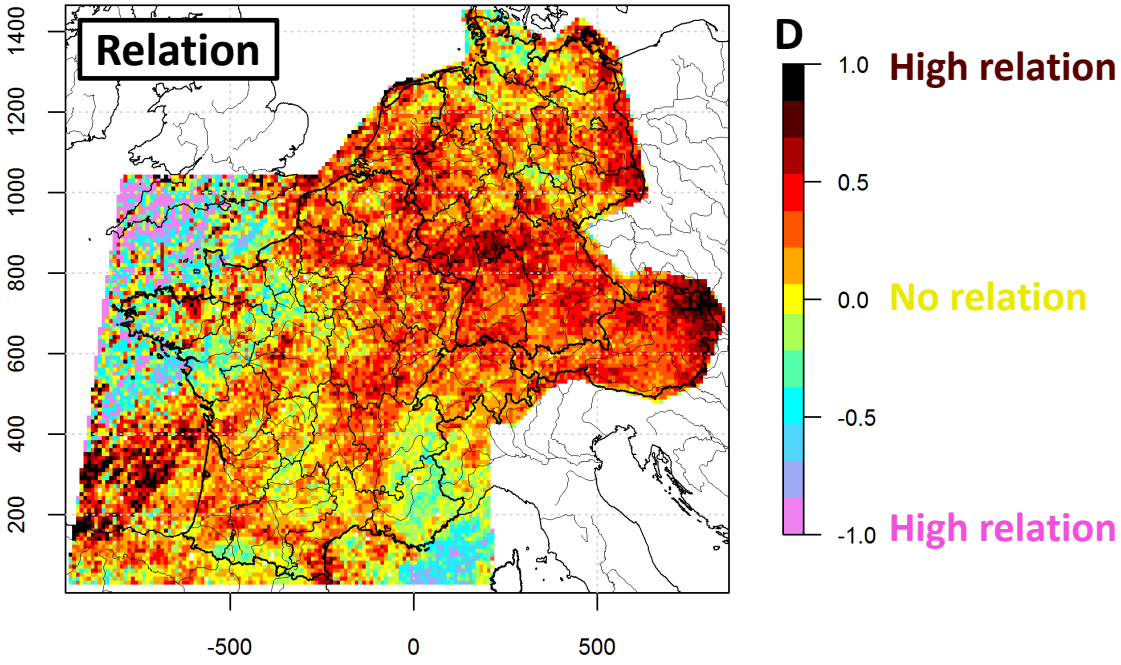
Primary (70 – 90 %) SW flow situation

Method: Principal component analysis (T-Mode) with *oblimin*-rotation
Input data (1958 – 2014), SHY: NCEP-NCAR1: Geopotential at 500 hPa, 12UTC

(Piper, PhD thesis, 2017)

Relation to teleconnections

North Atlantic Oscillation (NAO) vs. Thunderstorm days (TD):



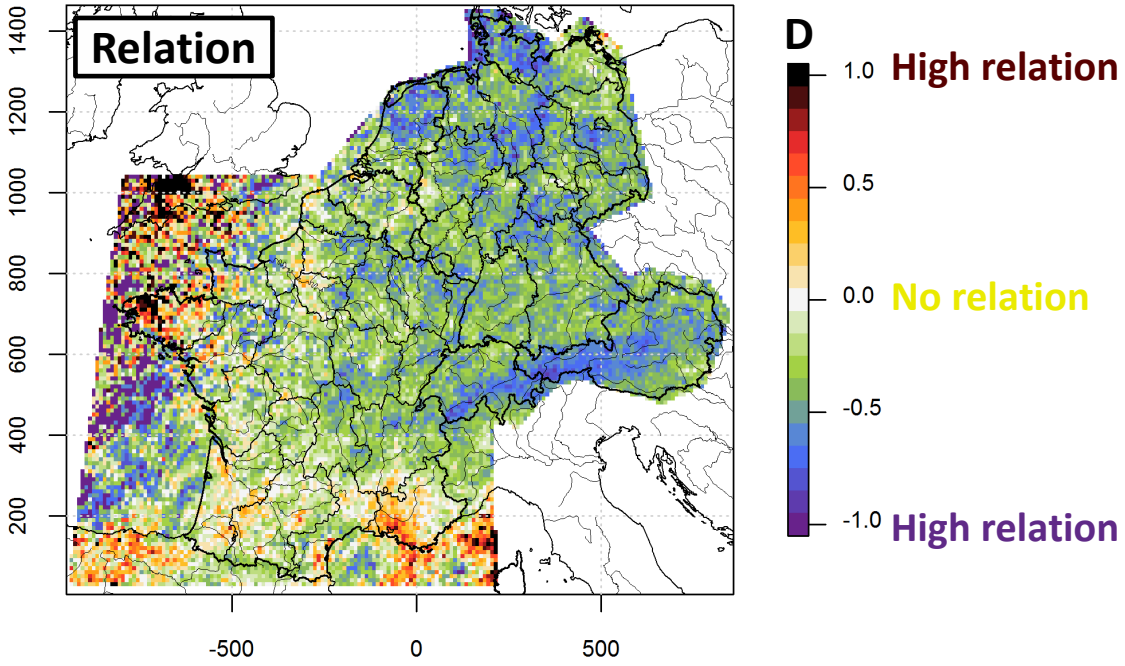
Negative phase of NAO ➡ Favoring thunderstorm days

$$D = \frac{\text{Rel. frequency(TD with NAO } < -1) - \text{Rel. frequency(TD)}}{\text{Rel. frequency(TD)}}$$

(Piper and Kunz, NHESSD, 2017)

Relation to teleconnections

East Atlantic Pattern (EA) vs. Thunderstorm days (TD):



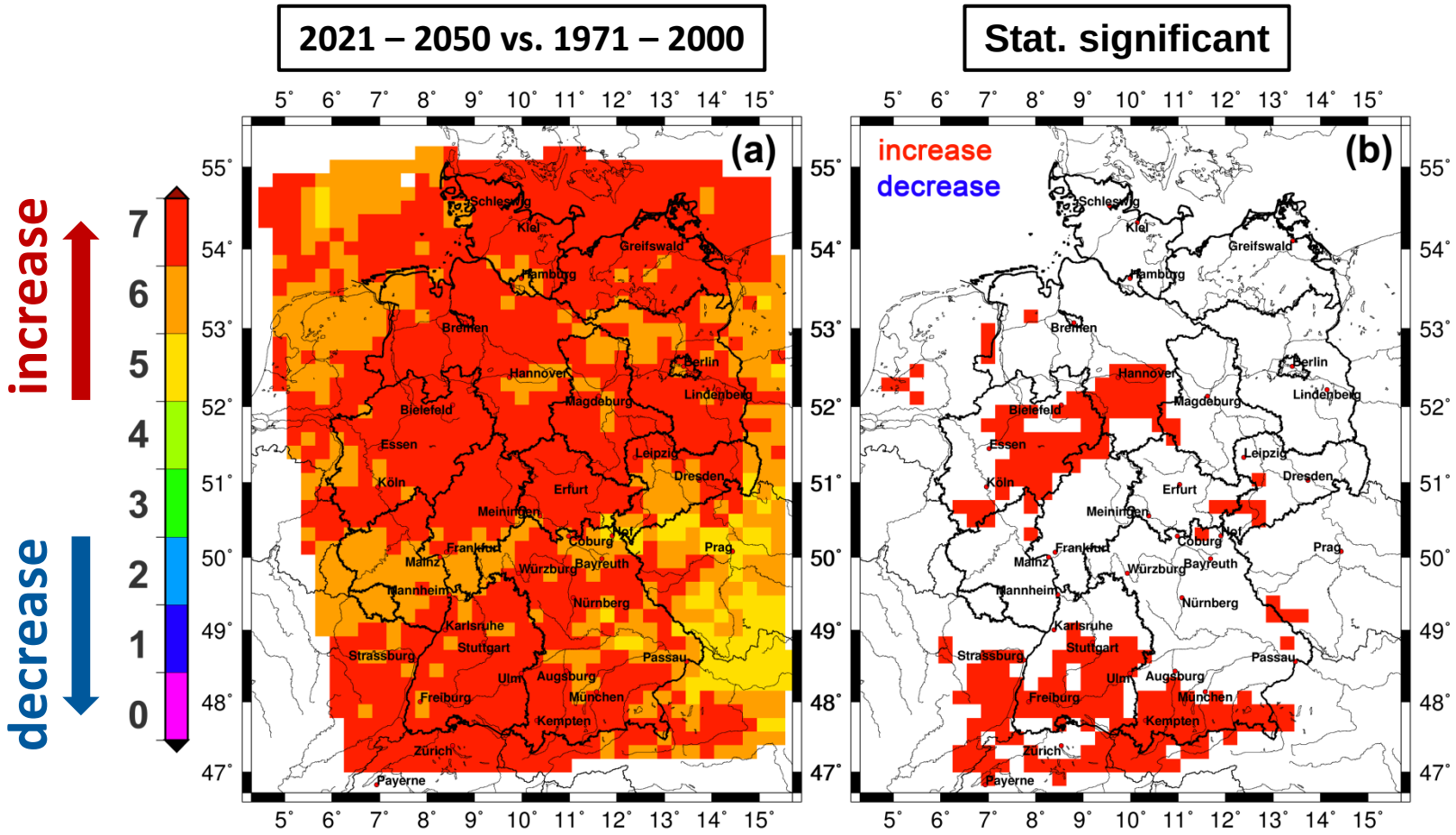
Negative phase of EA ➡ Reducing thunderstorm days

$$D = \frac{\text{Rel. frequency(TD with EA < - 0.5)} - \text{Rel. frequency(TD)}}{\text{Rel. frequency(TD)}}$$

(Piper, PhD thesis, 2017)

Future changes

Hail potential (PHI) in the future (Germany):



Stiftung Umwelt und Schadenvorsorge

(Mohr et al., 2015a)

Take-home message…

- Large **damage potential** on vulnerable regions associated with hailstorms
- High spatial and **temporal variability** of the hail probability
  ➡ A few statistically significant trends
- Tendency of an **increase** of thunderstorm/hail potential over the **last two/three decades** (central Europe), but …
- ... analyses suggest that the potential in the fifties was similar to that nowadays.
- **Relation** to large-scale circulation pattern (SW flow) and teleconnections (NAO, EA)

Mohr, S. and Kunz, M. (2013): Recent trends and variabilities of convective parameters relevant for hail events in Germany and Europe. Atmos. Res., 123, 211–228.

Mohr, S. (2013): Änderung des Gewitter- und Hagelpotentials im Klimawandel. Wissenschaftliche Berichte des Instituts für Meteorologie und Klimaforschung des Karlsruher Instituts für Technologie, Vol. 58, Karlsruhe, Germany.

Mohr, S., Kunz, M. and Keuler, K. (2015a): Changes in the Hail Potential Over Past and Future Decades: Using a Logistic Hail Model. J. Geophys. Res. Atmos., 120, 3939–3956.

Mohr, S., Kunz, M. and Geyer, B. (2015b): Hail Potential in Europe based on a regional climate model hindcast. Geophys. Res. Lett. (Submitted).

Kunz, M., Blahak, U., Schmidberger, M., Handwerker, J., Punge, H.J., Mohr, S., Fluck, E. and Bedka, K.M. (2015): The severe hailstorm in Germany on 28 July 2013: Characteristics, impacts, and meteorological conditions. Mon. Weather Rev. (Submitted).

Piper D. and Kunz, M (2017): Spatio-temporal variability of lightning activity in Europe and the relation to the North Atlantic Oscillation teleconnection pattern Nat. Hazards Earth Syst. Sci. Discuss., doi: 10.5194/nhess-2017-35.

Piper, D. (2017): Langzeitliche Variabilität hochreichender Konvektion in Europa. Phd Thesis at Institute for Meteorology and Climate Research (IMK-TRO), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany (In preparation).