Changes in the Hail Potential Over Past and Future Decades using a Logistic Hail Model

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Problems

- Large increase of 'hail damage' in Southern Germany during the last decades.
- Significant increase of the convective potential in Central Europe during the last decades (Mohr and Kunz, 2013).
- The local-scale extent and a lack of appropriate monitoring systems hampers statistical analyses of hail probability.

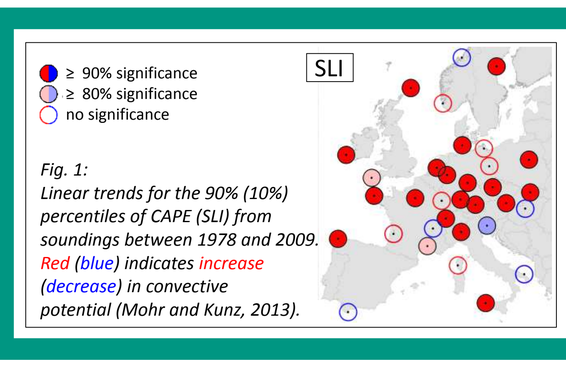


Fig. 1:
Linear trends for the 90% (10%) percentiles of CAPE (SLI) from soundings between 1978 and 2009. Red (blue) indicates increase (decrease) in convective potential (Mohr and Kunz, 2013).

Logistic Hail Model

How can the diagnostic of hail events be improved?

Method: Development / calibration of a logistic regression model using high-resolution reanalysis (CCLM-ERA40; Berg et al., 2012) and building insurance data of SV Sparkassen Versicherung for Baden-Wuerttemberg (SW Germany; 1992 – 2000).

Logistic Hail Model (LHM):

$$\mathrm{P_{hail}} = \frac{1}{1+e^{-\mathrm{g_{hail}}(x)}} \quad \text{with } 0 \le p(x) \le 1$$

$$\mathrm{g_{hail}} = \beta_0 + \beta_1 \cdot \mathrm{SLI} + \beta_2 \cdot \mathrm{T_{min}} + \beta_3 \cdot \mathrm{T_{2m}} + \beta_4 \cdot \mathrm{OWT}$$

considering:

- Surface-based Lifted Index at 12 UTC (SLI)
- Minimum near-surface temperature in the morning (T_{min})
- Near-surface temperature at 12 UTC (T_{2m})
- Hail–related and hail–unrelated weather types (OWT)

$$\text{whereas} \quad \mathrm{P_{hail}} = \begin{cases} < 0.2 & , \text{ day without hail} \\ \geq 0.2 & , \text{ day with hail} \end{cases}$$

➡ Definition of **Potential Hail Index (PHI)**

[**unit** of PHI is the count of days with hail]

Validations of LHM:

Good agreement with insured losses and hail signals derived from radar data (Puskeiler, 2013).

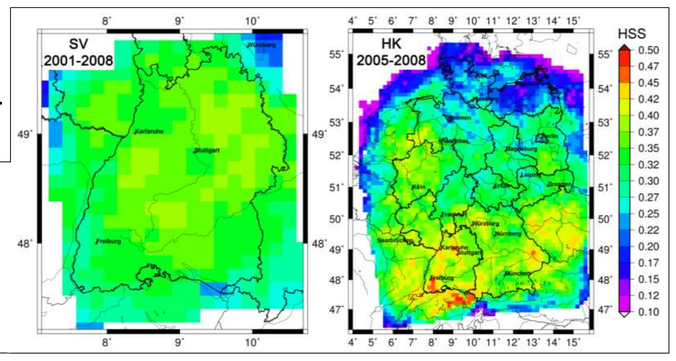
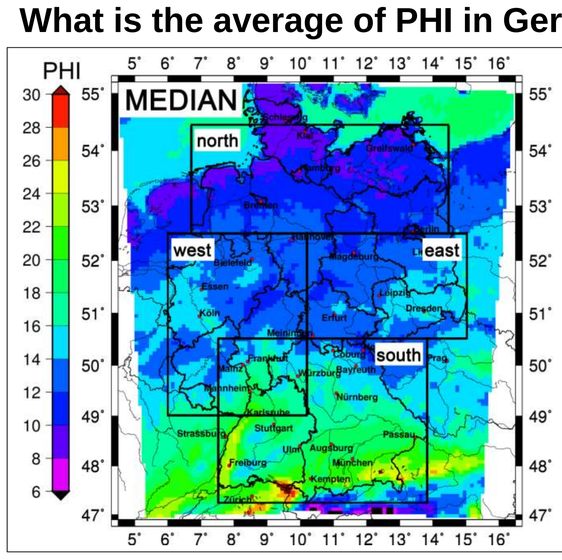


Fig. 2:
Validation of the LHM with the Heidke Skill Score (HSS) between a high-resolution regional climate model driven by ERA-Interim and insurance data (2001 – 2008; left) and hail events from radar data (2005 – 2008; right; Mohr et al. 2014a).

Climatology of PHI

What is the average of PHI in Germany?



- North-to-south gradient in the hail probability
- Largest number of potential hail days occurring in the South.

Fig. 3:
Median of the annual PHI (June to August) derived from a high-resolution regional climate model driven by ERA40 (1971 – 2000; Mohr et al. 2014a).

PHI in the Future

What changes in the hail potential can be expected in the Future?

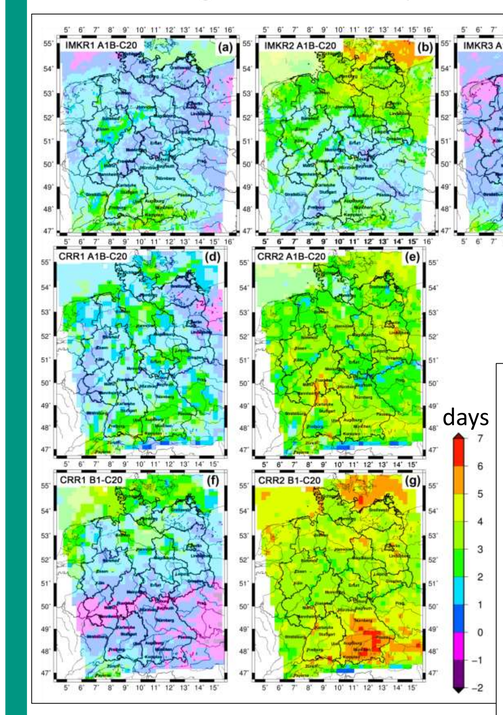


Fig. 4:
Difference of mean PHI for the CCLM-IMK (a-c) and CCLM-CR runs (d-g) between future and past (2021 – 2050 compared with 1971 – 2000). Trends with significance below 95% are brightened (Mohr et al., 2014a).

- The potential for hail events will increase in the future, but only in the northwest and south of Germany statistically significantly.

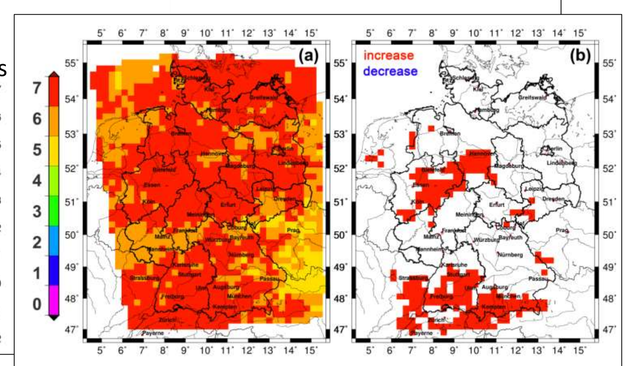


Fig. 5:
Overview of changes in PHI between 2021 – 2050 and 1971 – 2000 represented by an ensemble of seven climate simulations: (a) Number of runs showing an increase and (b) changes when at least five of the seven runs show a significant increase (or decrease) according to the Wilcoxon rank-sum test (Mohr et al., 2014a).

PHI in Europe

What is climatology of PHI in Europe?

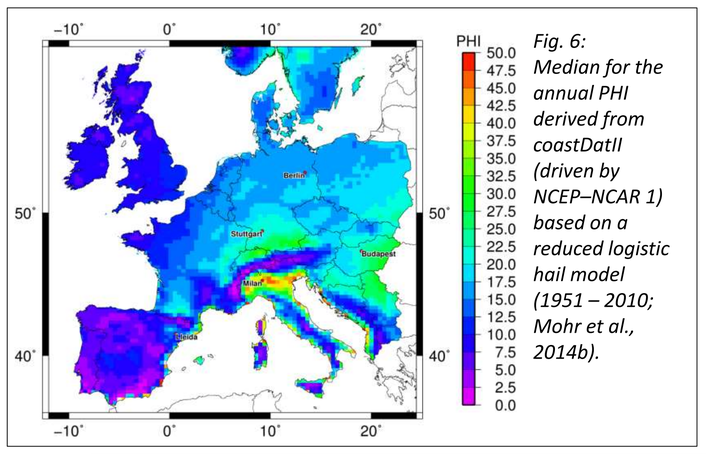


Fig. 6:
Median for the annual PHI derived from coastDatII (driven by NCEP–NCAR 1) based on a reduced logistic hail model (1951 – 2010; Mohr et al., 2014b).

- Results of a reduced logistic hail model confirm several hail relevant regions known from literature.
- PHI shows high annual variability and with a periodicity around 35 – 40 years.

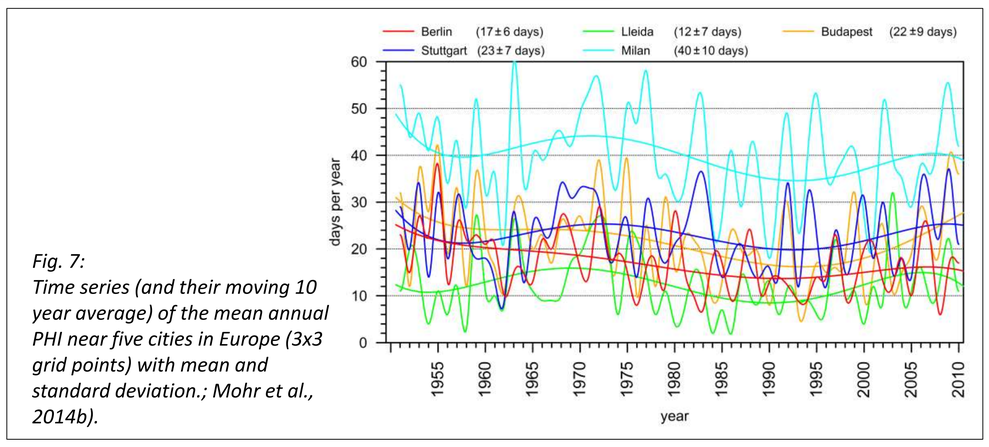


Fig. 7:
Time series (and their moving 10 year average) of the mean annual PHI near five cities in Europe (3x3 grid points) with mean and standard deviation.; Mohr et al., 2014b).

Conclusions

- Improvement of hail diagnostic by development of a logistic hail model and development of a new index: **Potential Hail Index (PHI)**.
- Climatology of PHI shows a markedly north-to-south gradient with the highest hail potential occurring in Southern Germany.
- Increasing hail potential in the future, but only in the northwest and south of Germany statistically significant.
- A modified version of the logistic hail model identifies well-known hail regions in Europa.

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