Hail hazard and risk assessment in Europe and the relation to orographic & atmospheric characteristics

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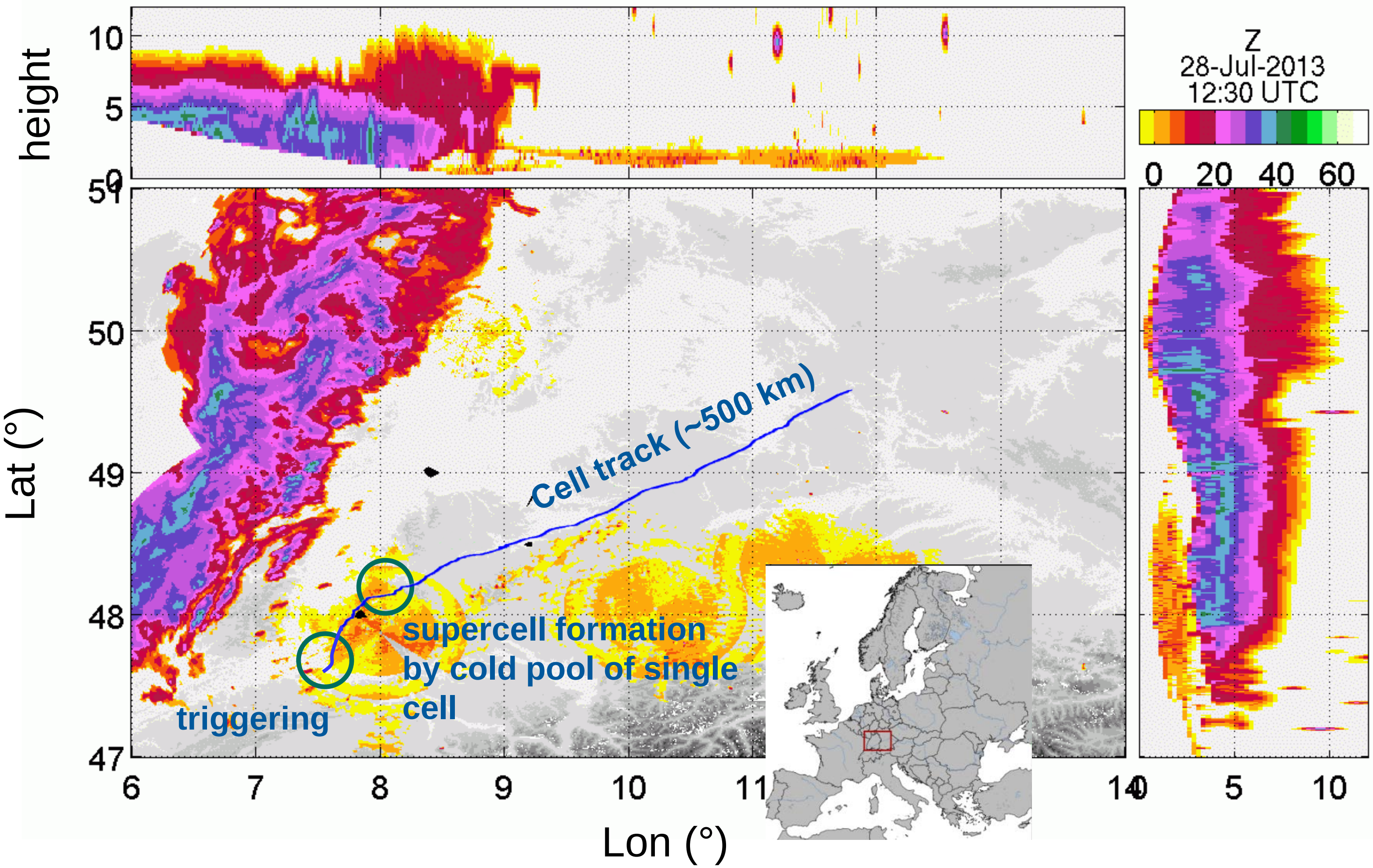
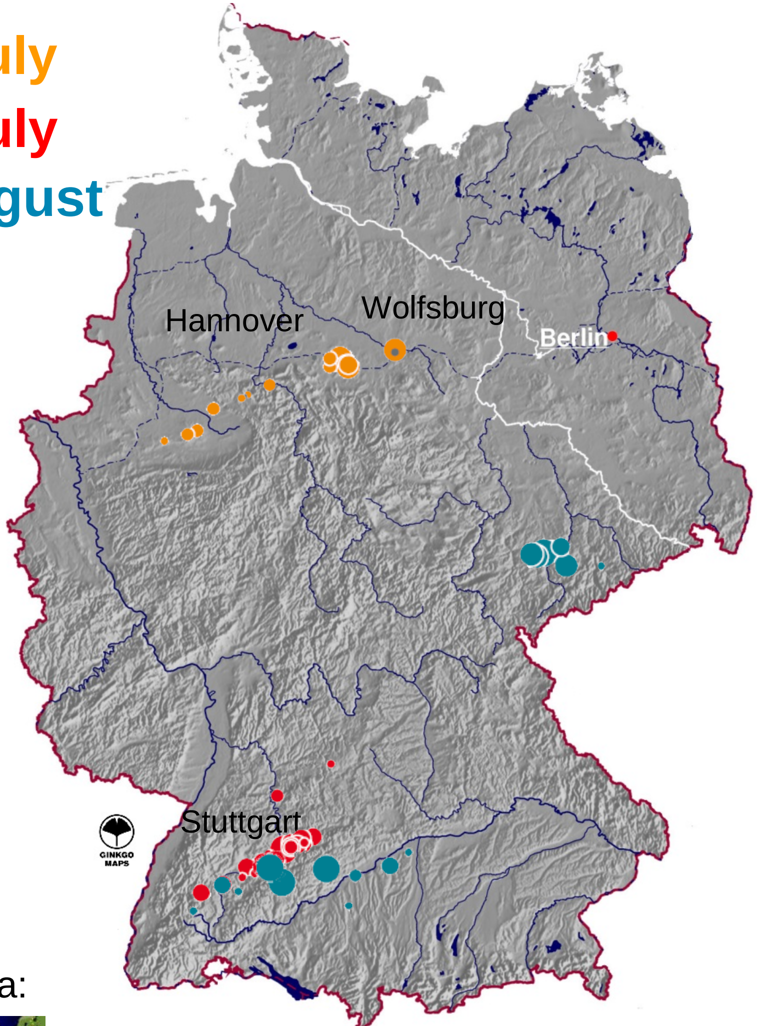
Severe hailstorms 2013: Andreas

- Radar composite (radars IMK + DWD, cell tracking TRACE3D) 28 July 2013



Severe hailstorms 2013 Germany

27 July
28 July
6 August



Data:

2-4 cm 6-7 cm > 8 cm

Total loss: $ 4.6 bn
insured loss 27/28 July: $ 3.1 bn
(Swiss Re, 2014)

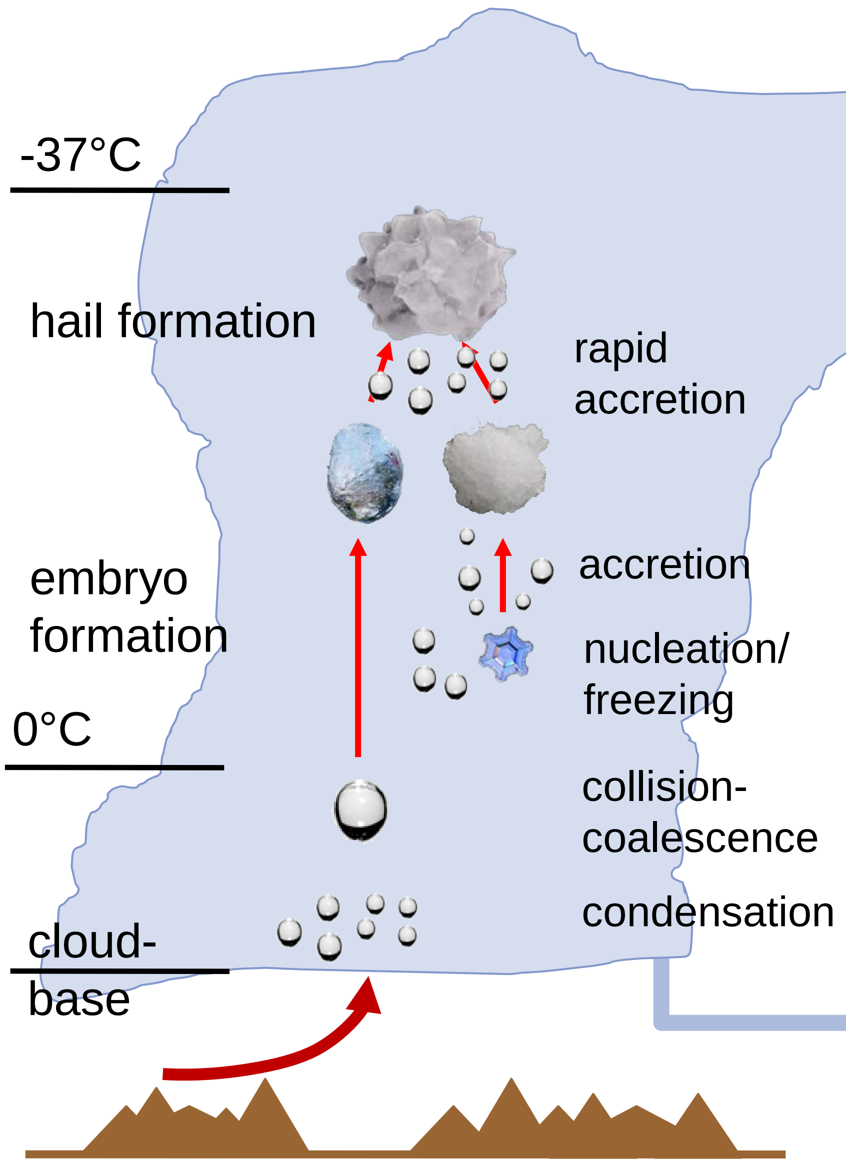
Questions…

Regional-scale hail frequency**?**

Reasons for the spatial distribution**?**

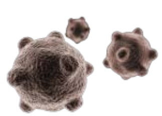
Long-term variability of hail potential**?**

Hail growth within convective clouds



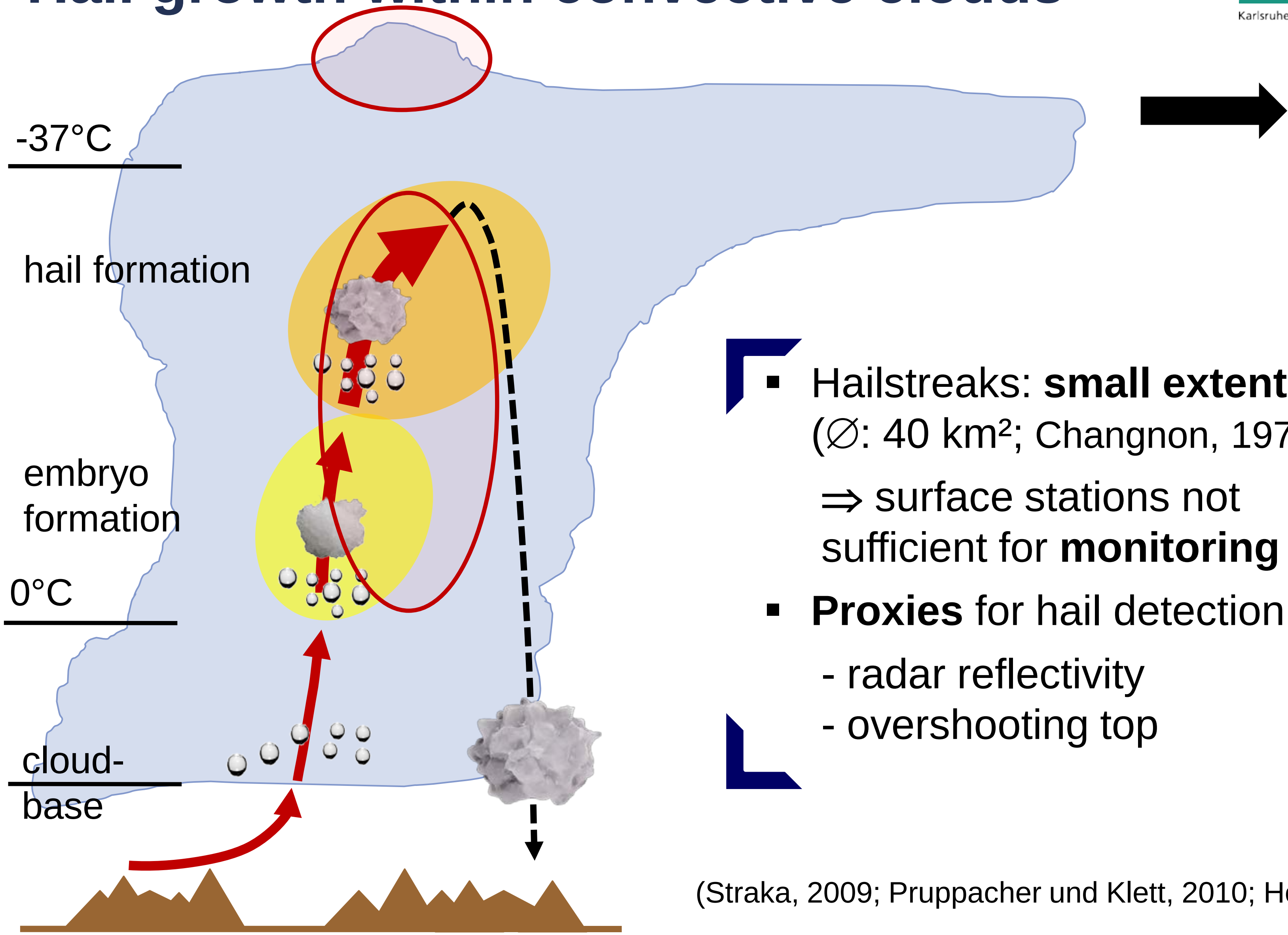
- hailstone formation by fast riming
- Riming by accretion of **supercooled droplets**: **hail embryos** (graupel, frozen drop)
- Nucleation by **IN**: ice crystal

- Raindrops
- Condensation process by cloud condensation nuclei **CCN**



(Straka, 2009; Pruppacher and Klett, 2010; Houze, 2014)

Hail growth within convective clouds



- Hailstreaks: **small extent** (∅: 40 km²; Changnon, 1970)

  ⇒ surface stations not sufficient for **monitoring**

- **Proxies** for hail detection:

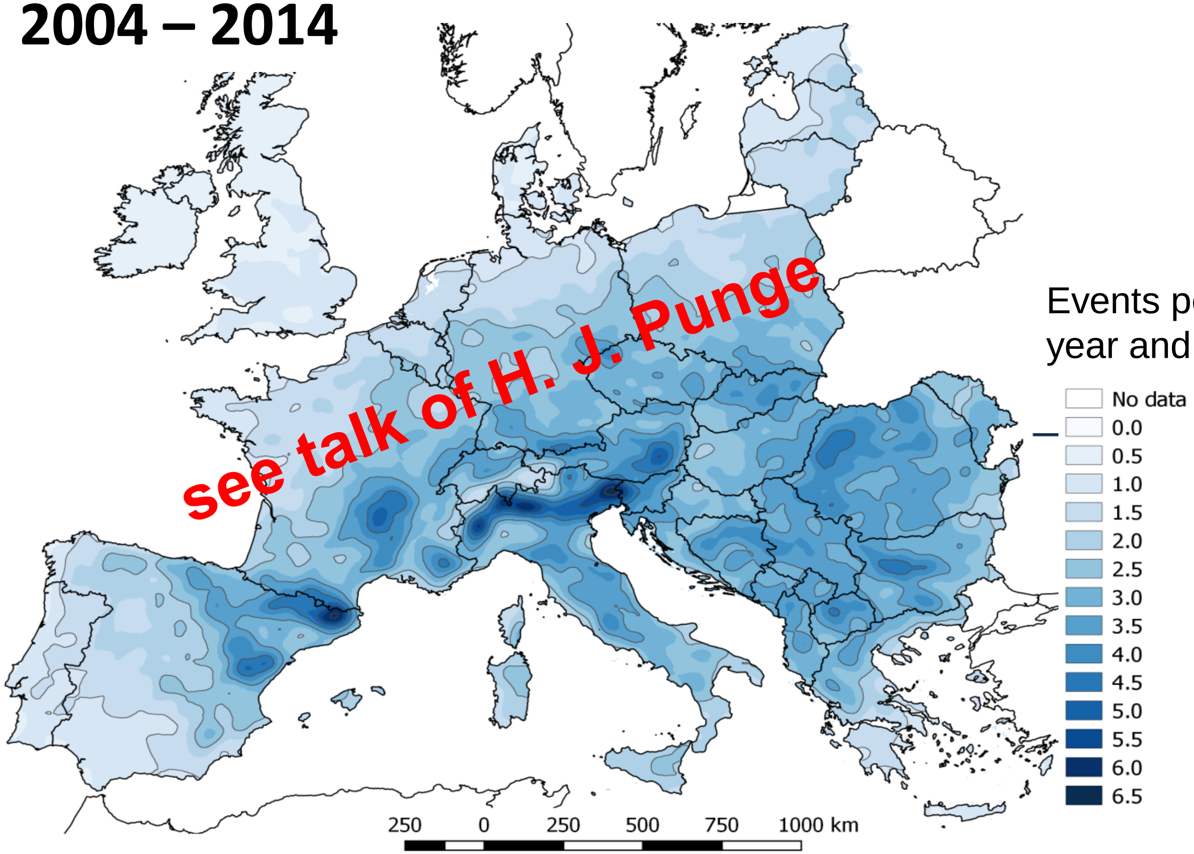
  - radar reflectivity
  - overshooting top

(Straka, 2009; Pruppacher und Klett, 2010; Houze, 2014)

Hail proxy: Overshooting tops

- OTs: intrusions of convective cloud to lower stratosphere
- Indicator of very strong convective updrafts

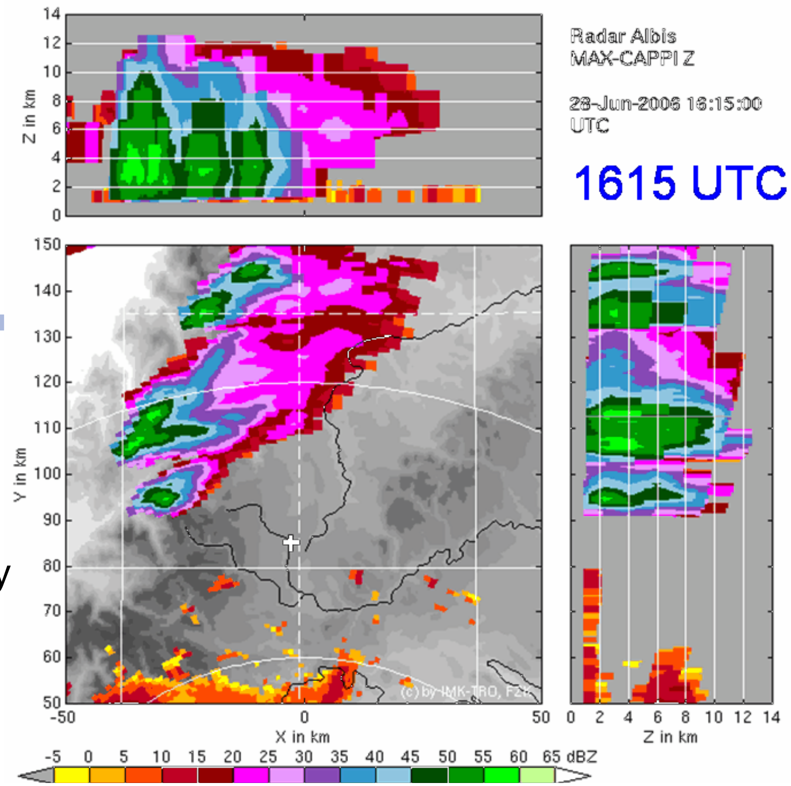
2004 – 2014



Combination **Satellite** (MSG SEVIRI) and **Reanalysis** (ERA-Interim)

Hail proxy: Radar reflectivity

- **Radar**: high spatial / temporal resolution, available for several European countries
- Dual-pol only over recent years



Methods:

- Maximum reflectivity $Z > X \text{ dBZ}$

  $Z = \int_0^\infty N(D) D^6 \, dD$ $N(D)$: number density

- Vertical extent (Waldvogel et al., 1978)

  $Y \geq H_{0^\circ \text{C}} - H_{45\,\text{dBZ}}$

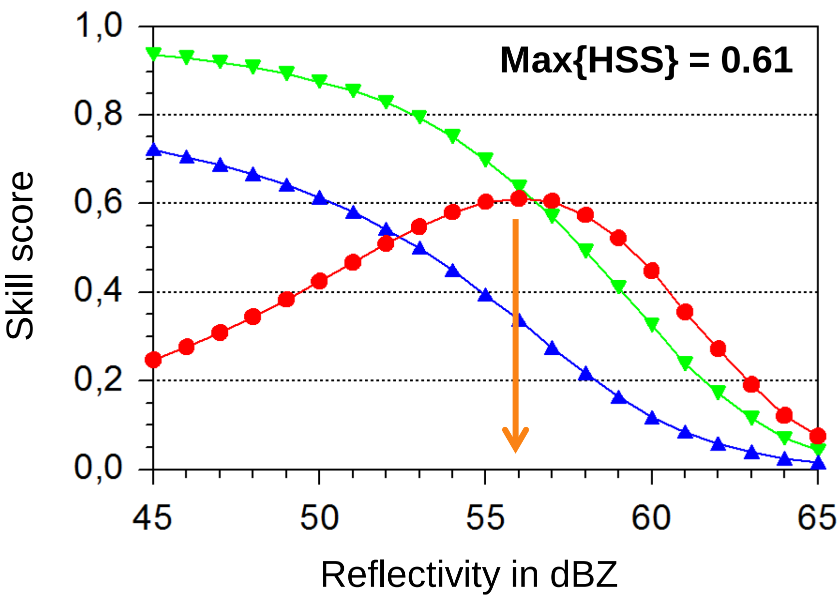
- Cell tracking (TRACE3D), advection correction
- Clutter correction (lightning), calibration (insurance)

Hail detection radar vs damage data

- Calibration: categorical verification with skill scores
- Building insurance data;summer half-year 2005 - 2011

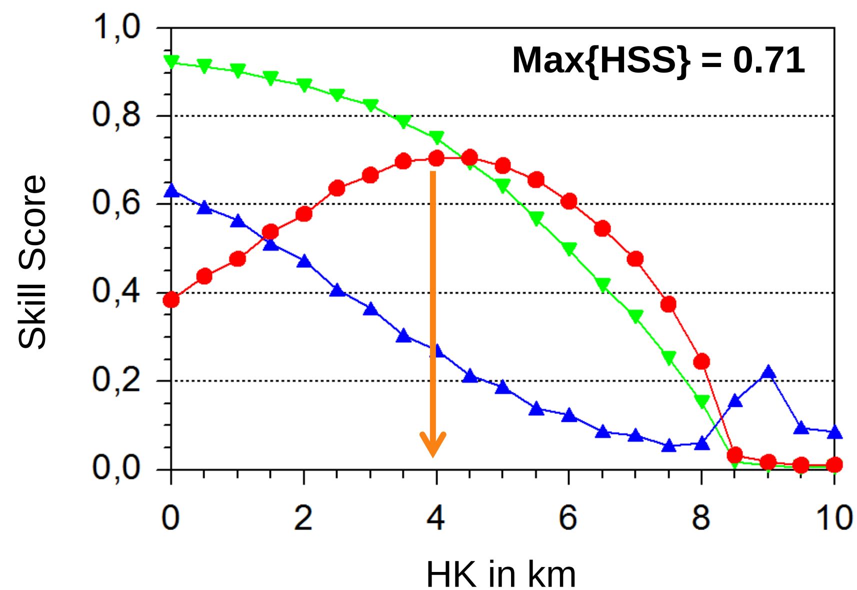
2D: threshold exceedance

$$Z > X \text{ dBZ}$$



3D: vertical extent

$$Y \geq H_{0^\circ\text{C}} - H_{45\,\text{dBZ}}$$

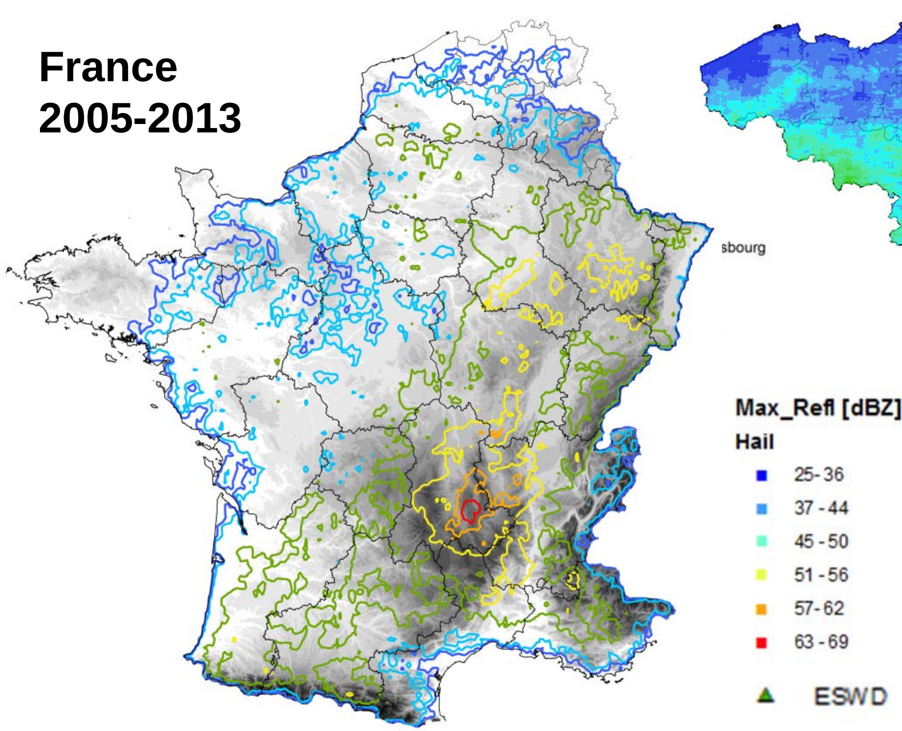


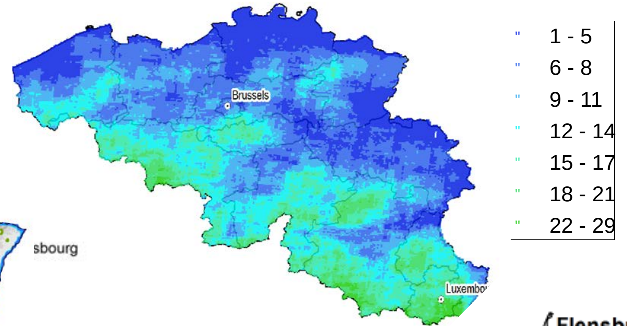
(Puskeiler and Kunz, 2016)

HSS FAR POD

Hail frequency in European countries

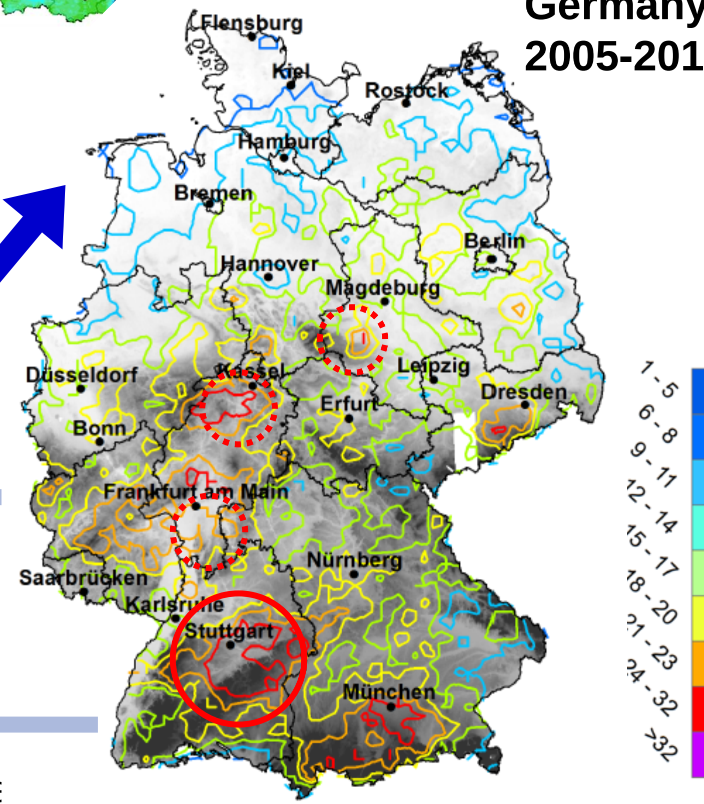
France 2005-2013





Belgium, Luxembourg 2004-2013

Germany 2005-2011



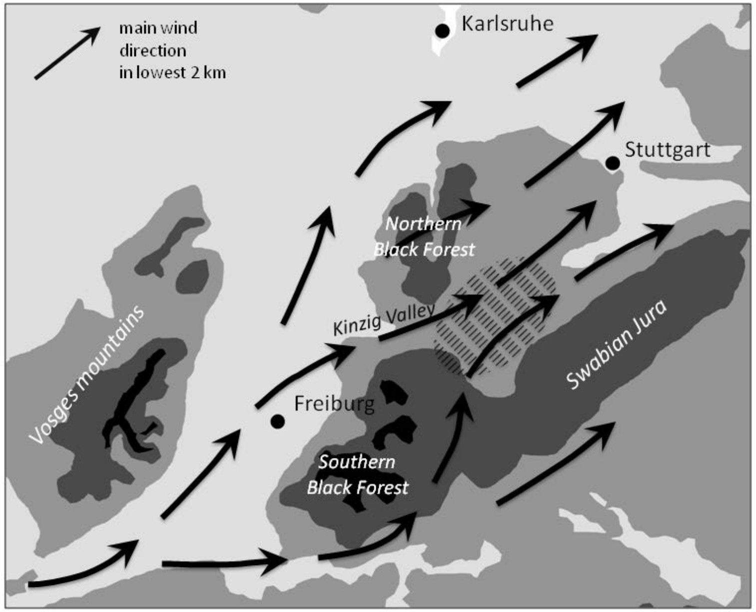
Number of days with hail signals (2D/3D radar refl.)

(Fluck et al., 2015; Kunz and Schmidberge

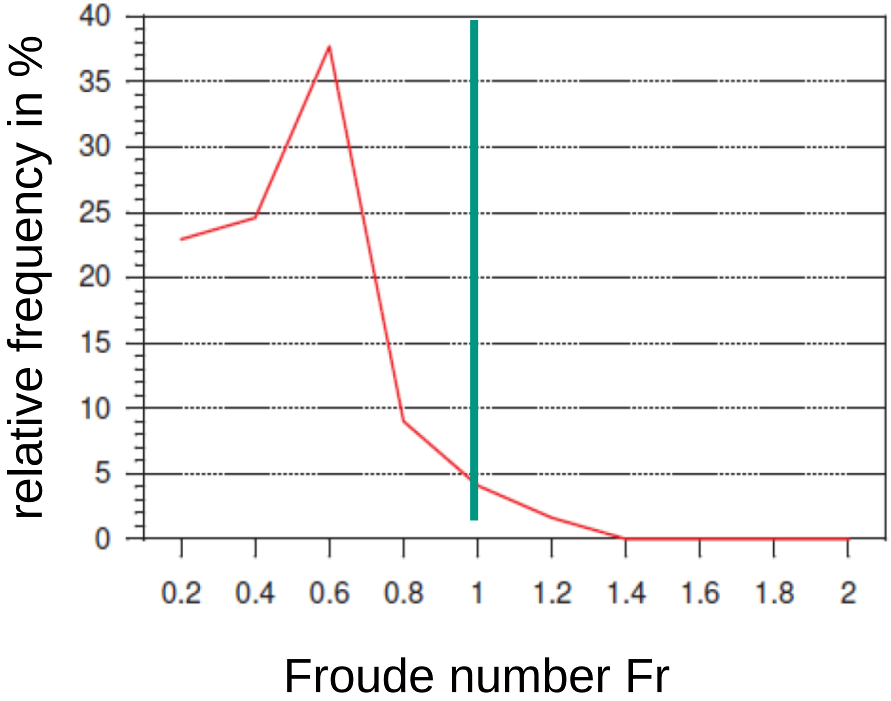
Hail probability related to orography

- **Flow dynamics**: Flow around regime, formation of low-level flow convergence

$$Fr = \frac{U}{N\,H}$$

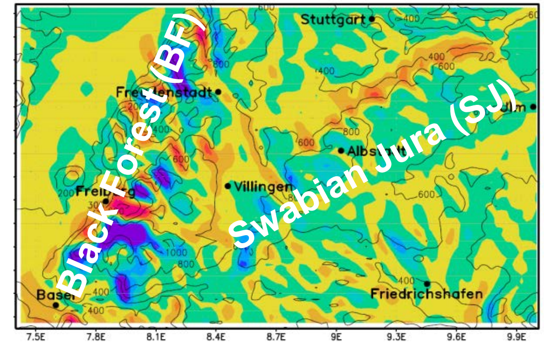


(Kunz and Puskeiler, MZ, 2010)



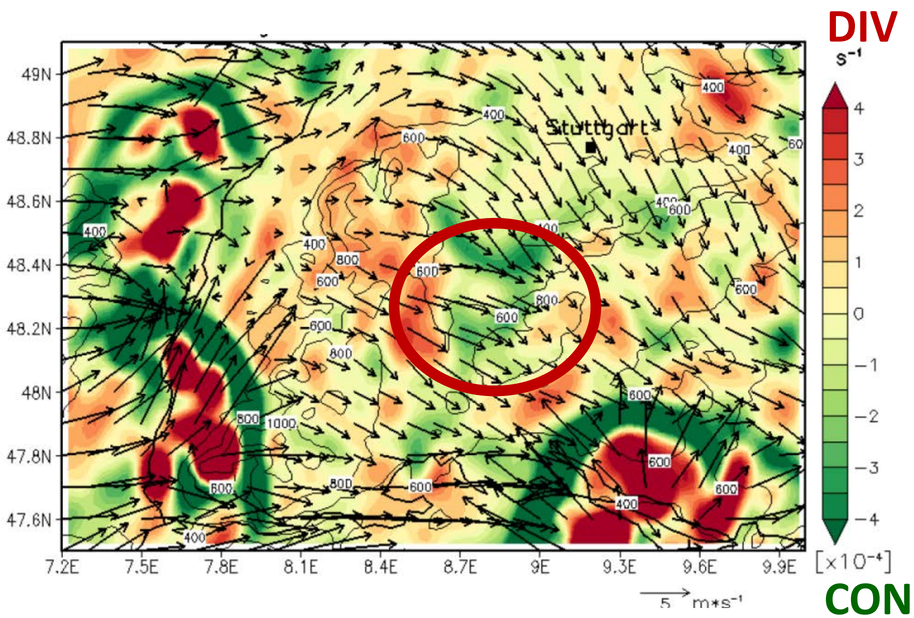
Histogram of Fr on hail days SW Ger.

Hail probability vs orography

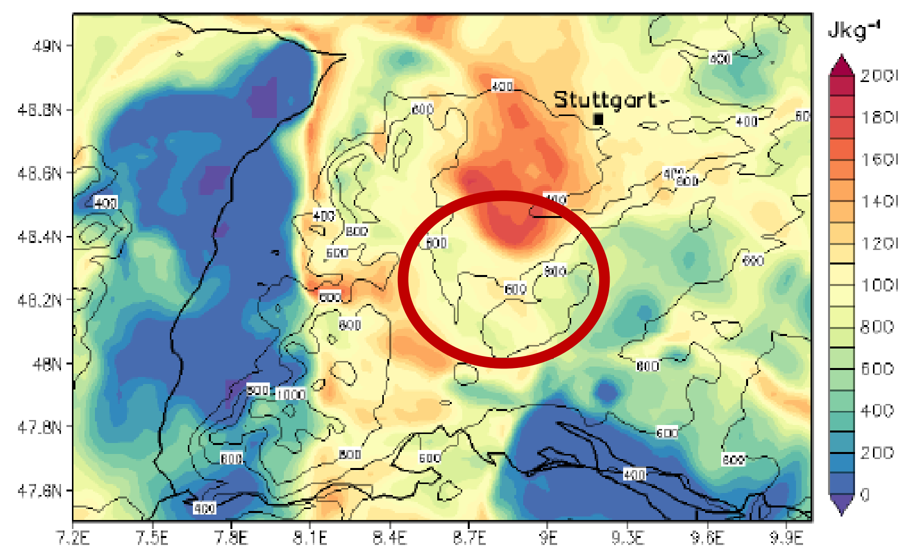


- Semi-idealized COSMO-DE simulations (2.8 km)
- Initialization with ambient conditions that favor hailstorms (Fr ~ 0.6)

Flow convergence $\nabla \cdot \vec{v_H} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = \frac{\partial |\vec{v}|}{\partial s} + \frac{|\vec{v}|}{R_n}$



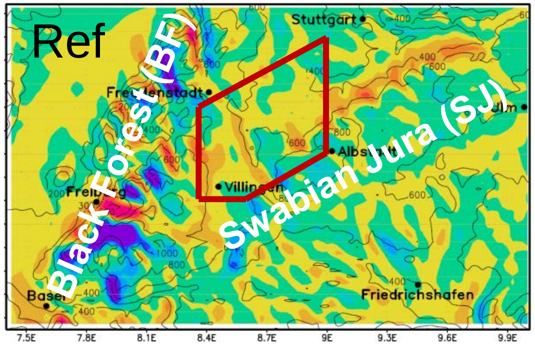
Convective available potential energy CAPE

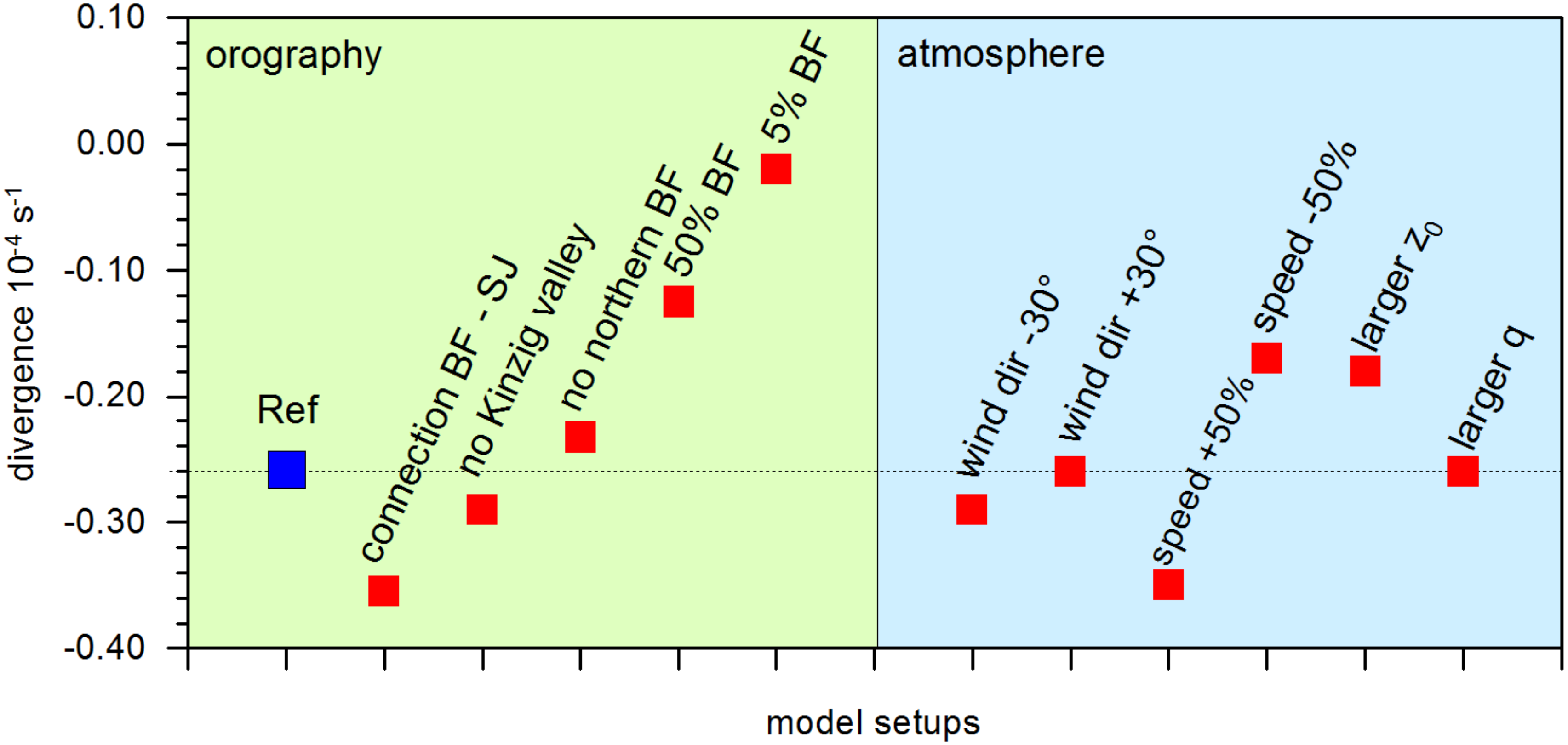


(Köbele, 2014)

Hail probability vs orography

- COSMO sensitivity studies using different model setups





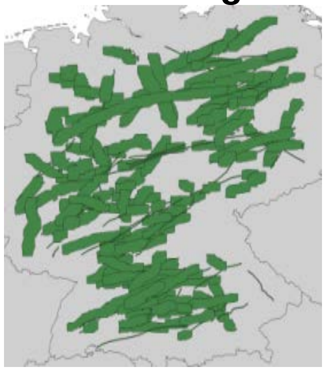
(Brombach, 2012)

Risk Assessment: CAT-Modeling

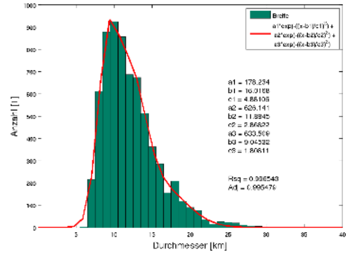
- Hail risk for the Insurance Industry

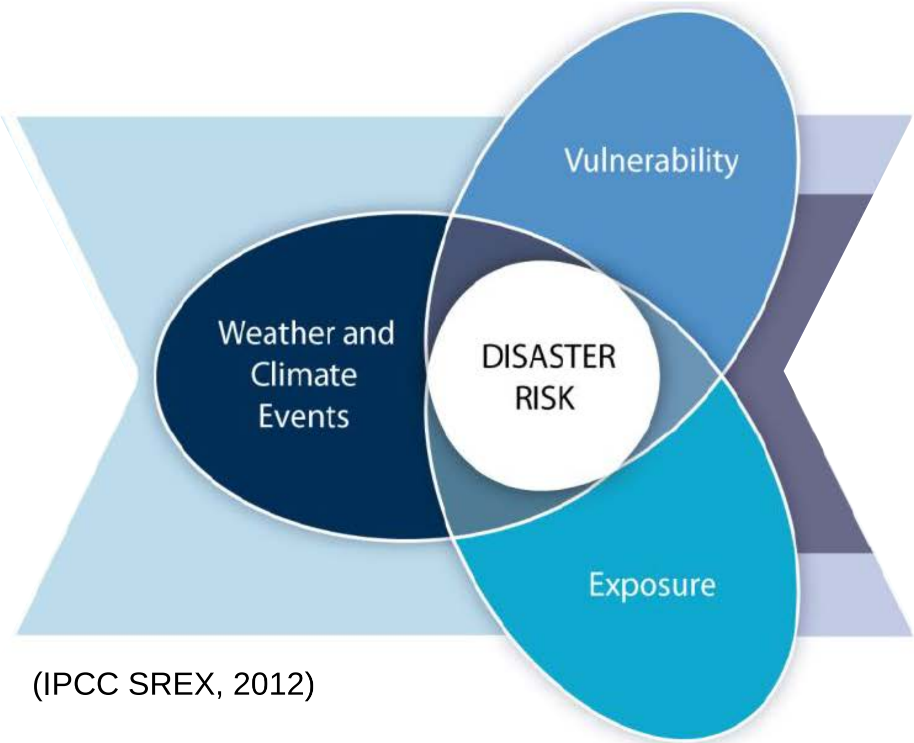
Risk = hazard x exposure x vulnerability

Event catalogue



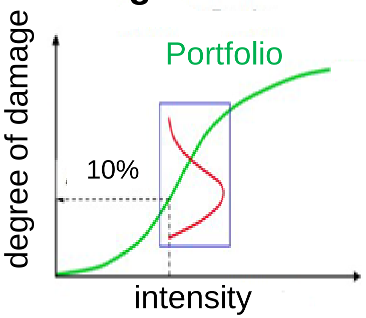
Stoch. Modeling e.g. 10 000 years



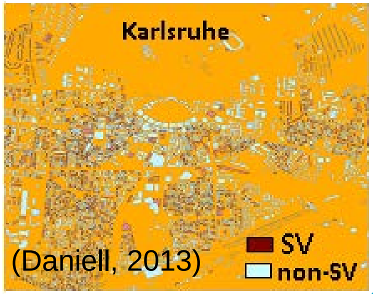


(IPCC SREX, 2012)

Damage function

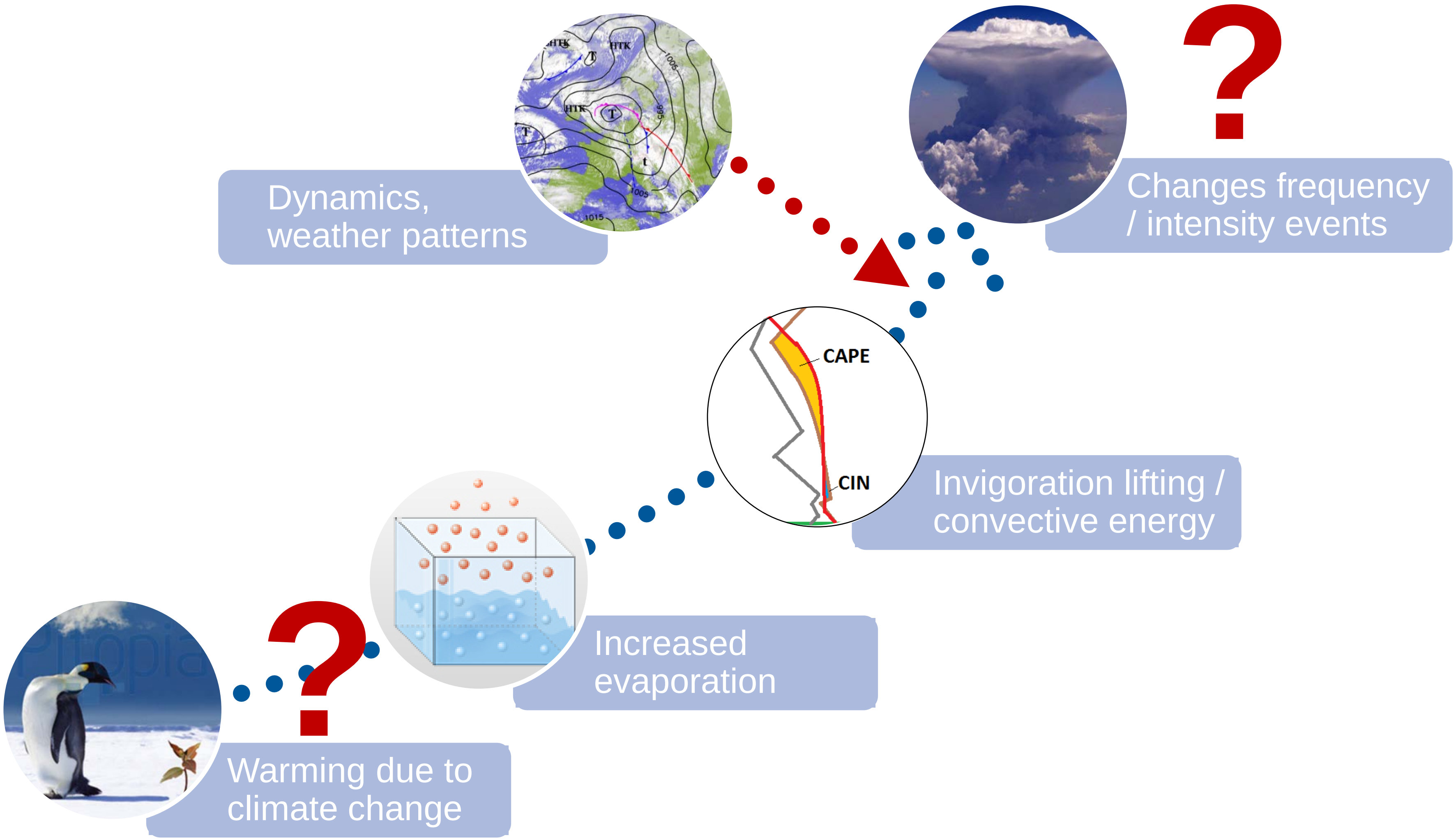


Portfolio, object data



(Daniell, 2013)

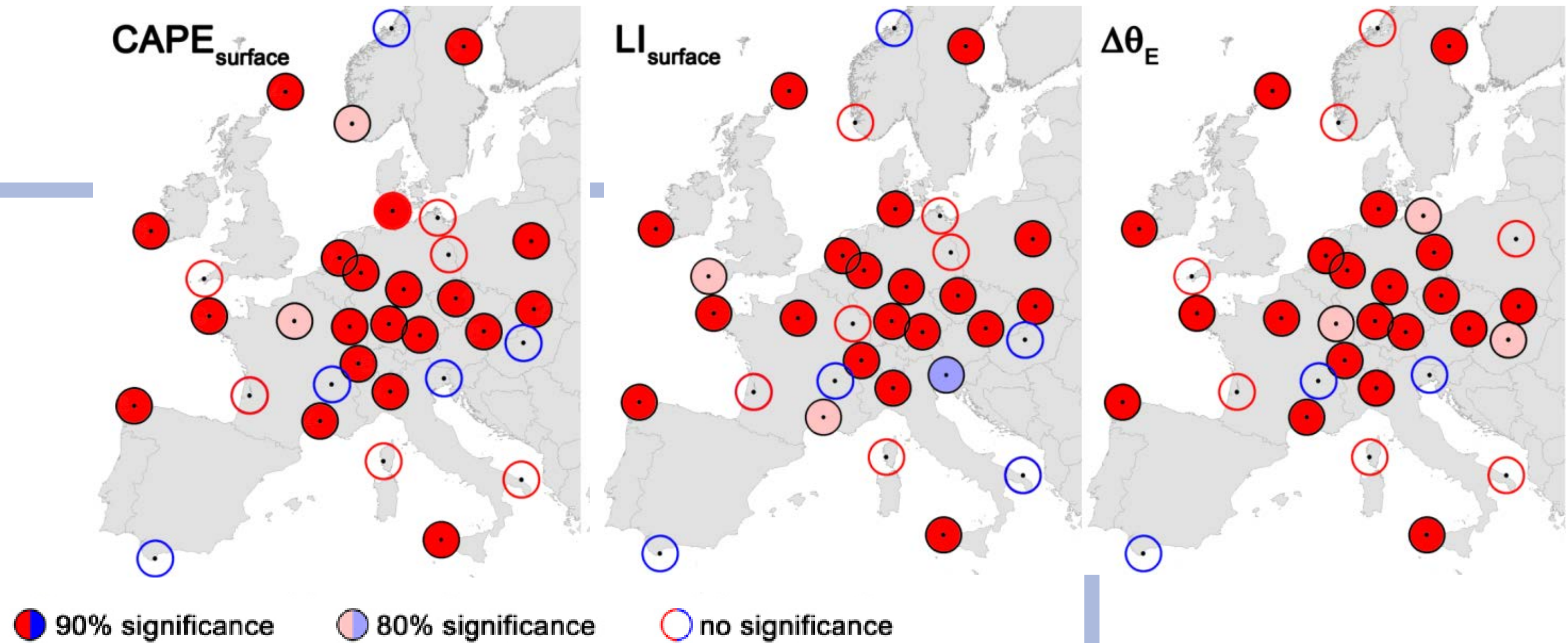
Long-term changes in hail probability



Trends Convective Parameters

- Trends 90% percentiles from radio-soundings
- Increase in convective energy caused by increase in moisture (low lev)

Soundings: 1978-2009



- Percentiles estimated from pdf (Gamma / Weibull distrib.)
- Eliminate of autocorrelation: trend-free pre-whitening

(Mohr and Kunz, ARE, 2013)

Logistic Hail Modelling

Logistic regression

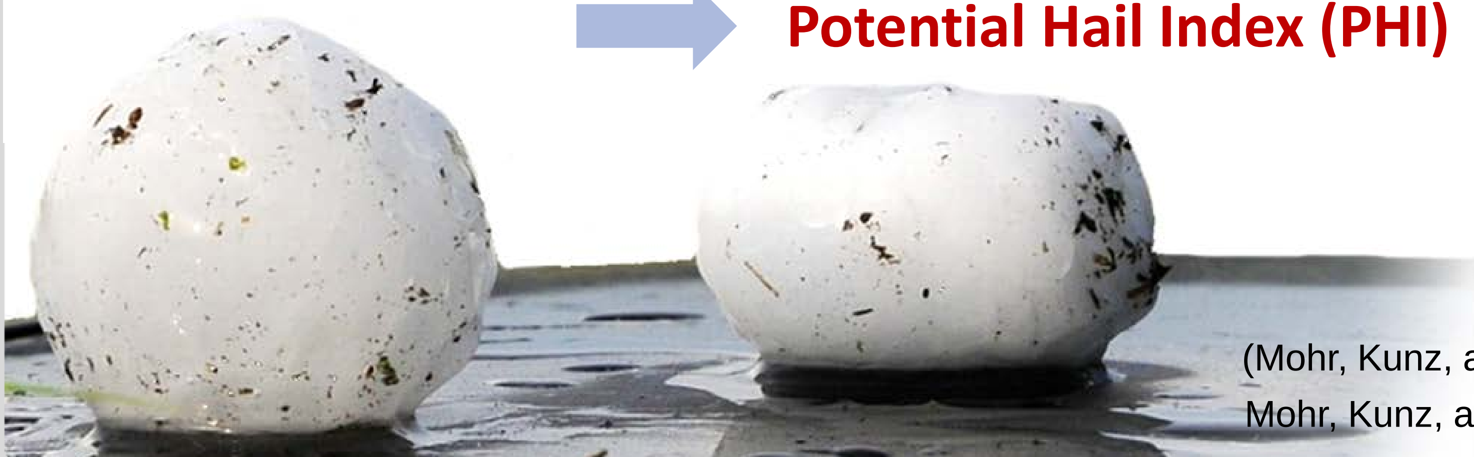
$$p_{\text{hail}}(x) = \frac{1}{1+e^{-g(x)}} \quad \text{mit} \quad 0 \le p_{\text{hail}}(x) \le 1$$

Logistic Hail Model LHM

$$g_{\text{hail}} = \beta_0 + \beta_1 \cdot \boxed{\text{SLI}} + \beta_2 \cdot \boxed{T_{\text{min}}} + \beta_3 \cdot \boxed{T_{2m}} + \beta_4 \cdot \boxed{\text{oWL}}$$

SLI: Lifted Index
T_{min}: Min. Temp. 2 m
T_{2m}: 12 UTC Temp. 2 m
oWL: objective weather patterns

→ **Potential Hail Index (PHI)**

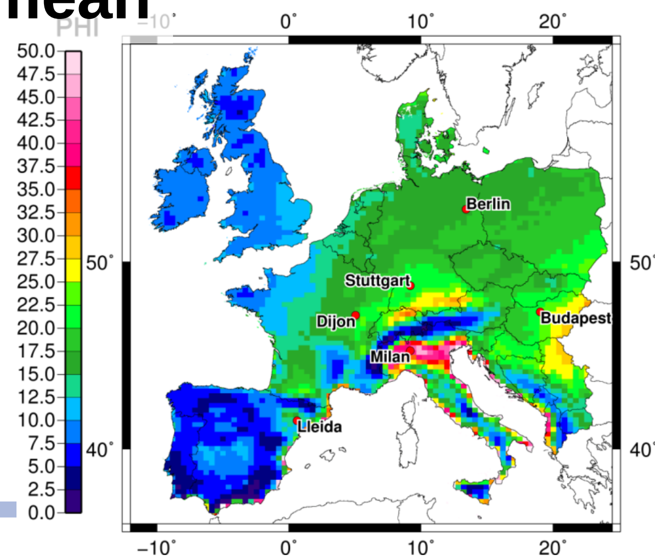


(Mohr, Kunz, and Geyer, GRL, 2015
Mohr, Kunz, and Keuler, JGR, 2015)

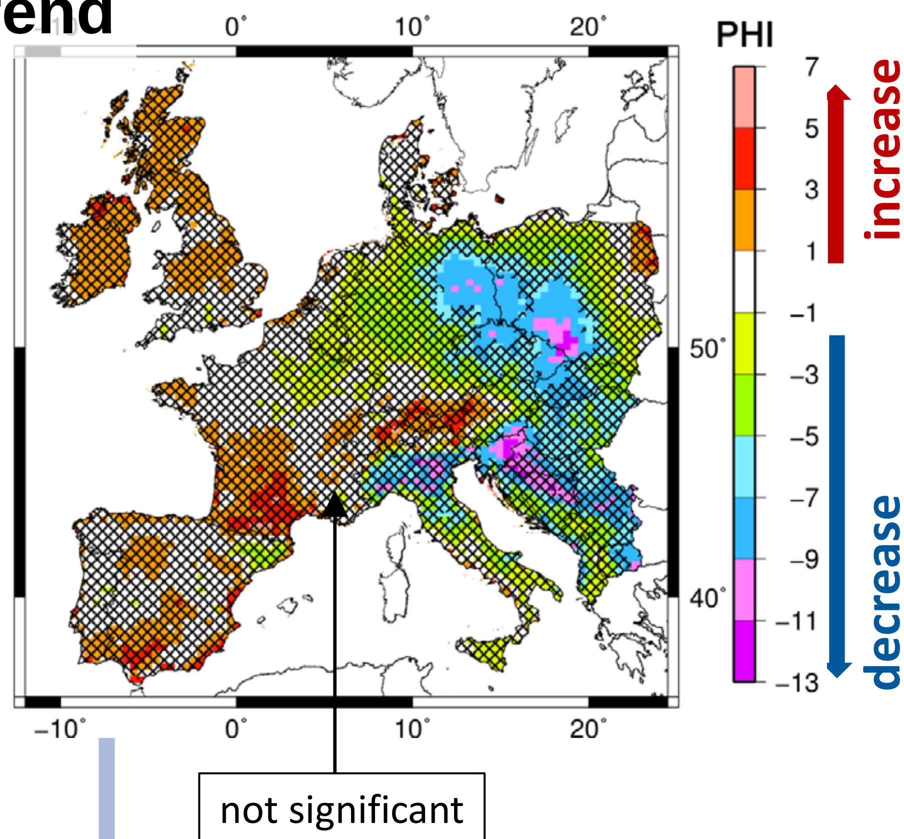
Hail potential in Europe (1951-2010)

- Combination of various meteorological parameters relevant for thunderstorm / hail: Potential Hail Index PHI

mean



trend



1951-2000

coastDatII

Reanalysis, driven by
NCEP–NCAR 1 (@ HZG)

(Mohr, Kunz and Geyer, GRL, 2015)

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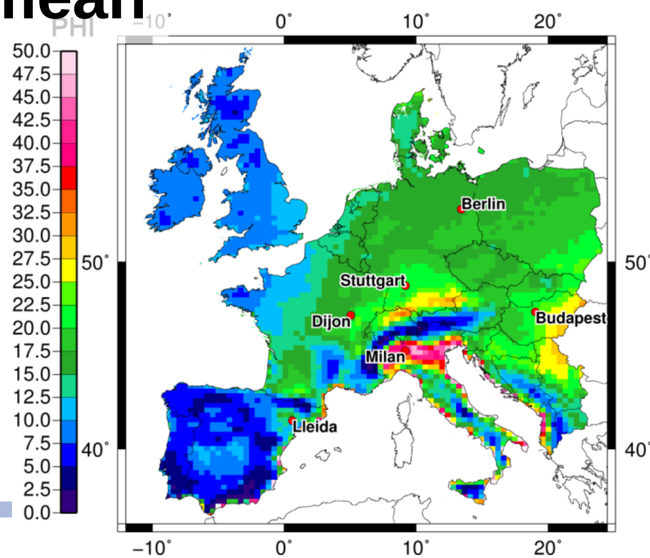

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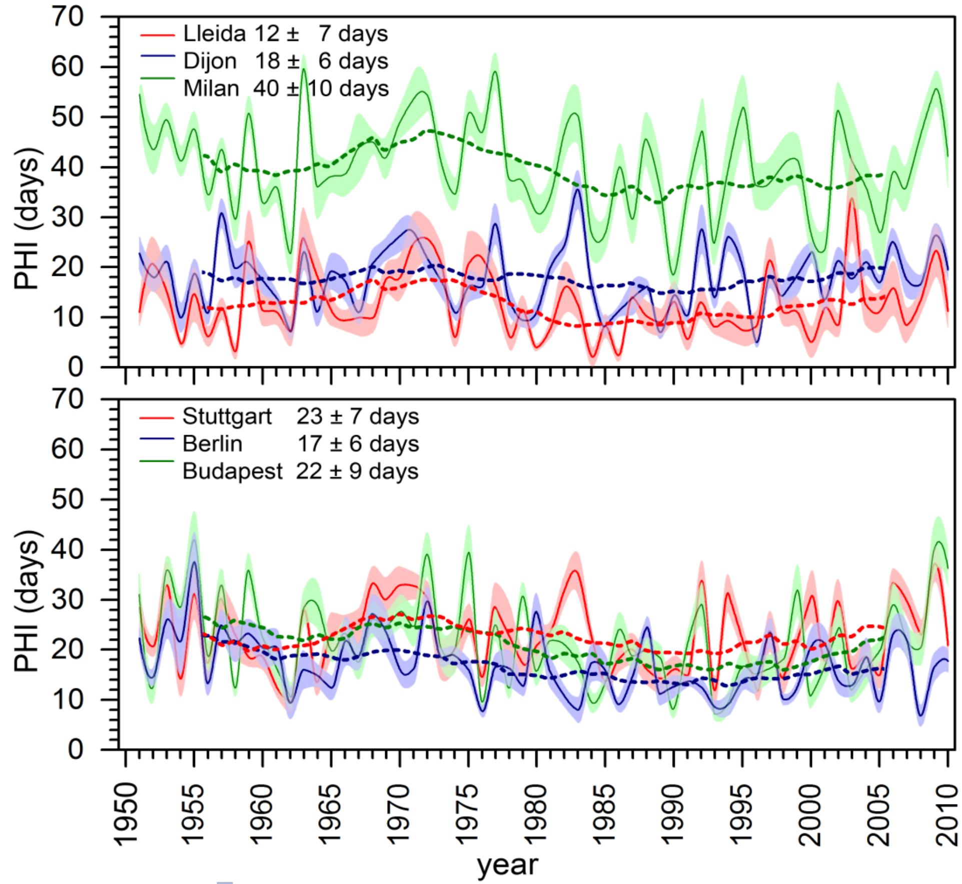
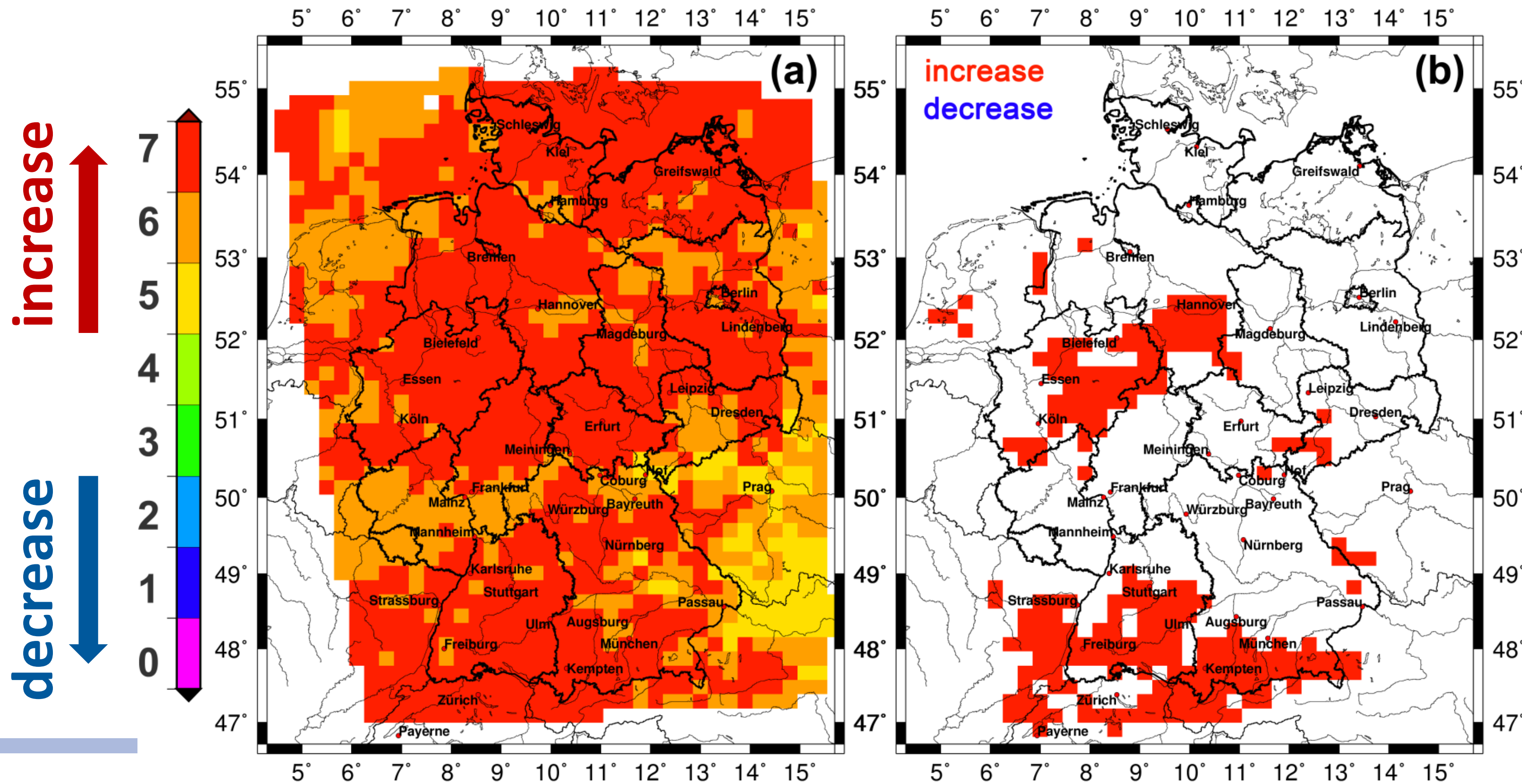


(Mohr, Kunz and Geyer, GRL, 2015)

PHI in the future (Germany)



2021-2050 vs 1971-2000

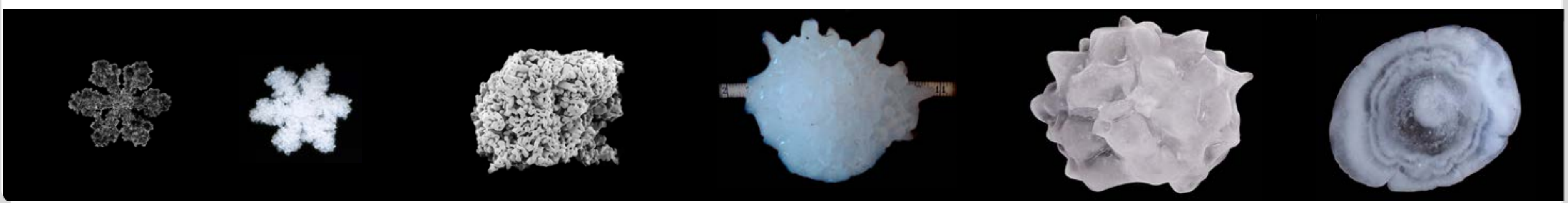
Mini-Ensemble based on **7 RCMs**

different SRES, realizations, RCMs

(Mohr, Kunz and Keuler, JGR, 2015)

Conclusions

- Large **damage potential** associated with hail in Europe
- **Hail hazard assessment** from remote sensing instruments:
  - robust and physically plausible
  - OT approach: consistent for larger areas
  - Radar-derived signals: detailed estimates
- Hail signals: **high spatial variability** related to
  - overall climatology (→ stability)
  - (low) mountains (→ preferred location downstream)
- **Hail potential** has been increased over past decades, (slight) increase in the future; trends statistically not significant




2nd European Hail Workshop
19-21 April 2017, University of Bern, Switzerland
(c) Bern Tourismus

…Thank you