Trend analysis of meteorological parameter relevant to hail from soundings and reanalysis data

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Project: HARIS-CC "Hail Risk and Climate Change"

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GFZ German Research Centre for Geosciences

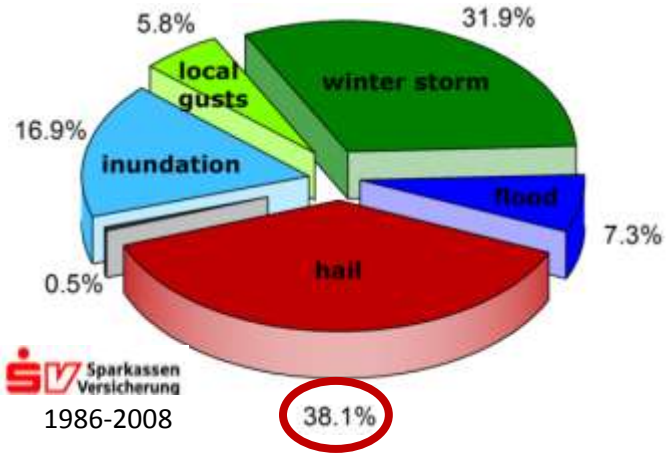
Motivation

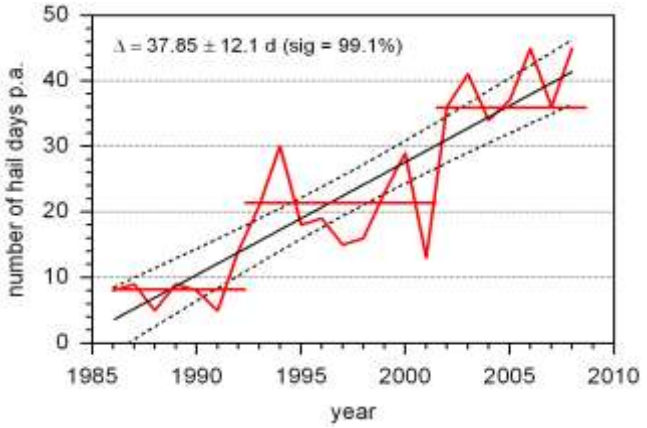
Problem: hail usually a local-scale phenomena

➡ Insurance data of buildings for Baden-Württemberg (southwest of Germany) show:

Sparkassen Versicherung

- most of the damage to buildings by natural hazards are caused by hail
- Significant increase of hail **damage** days





Scientific questions and objectives?

1. Which meteorological parameters describe hail events best?

   CAPE, Lifted Index (LI), $\Delta\theta_E$, PII, DCI, KO, K_{mod}

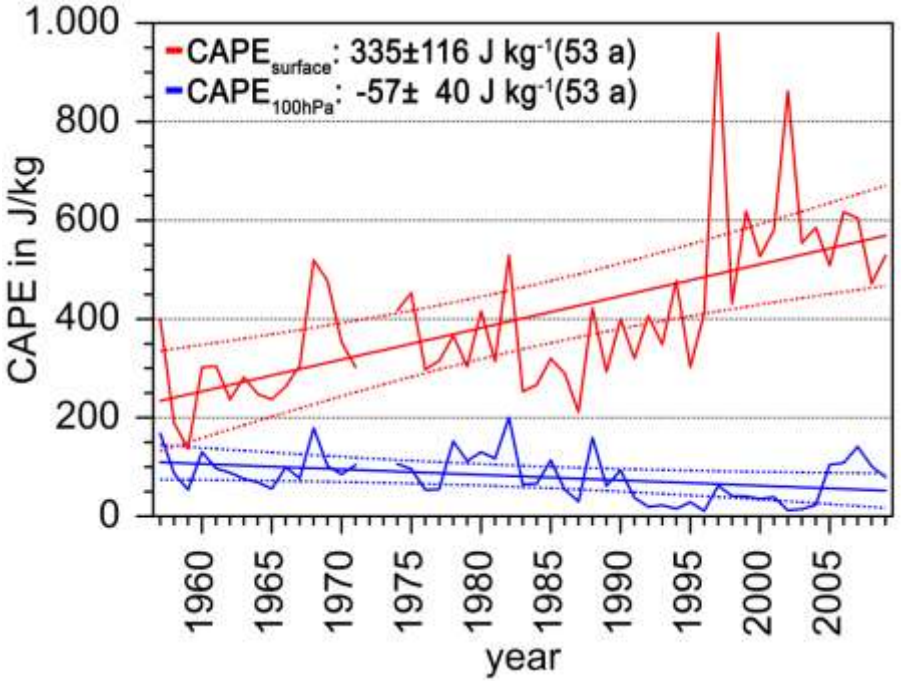
   (see Kunz, 2007; Mohr and Kunz, 2011)

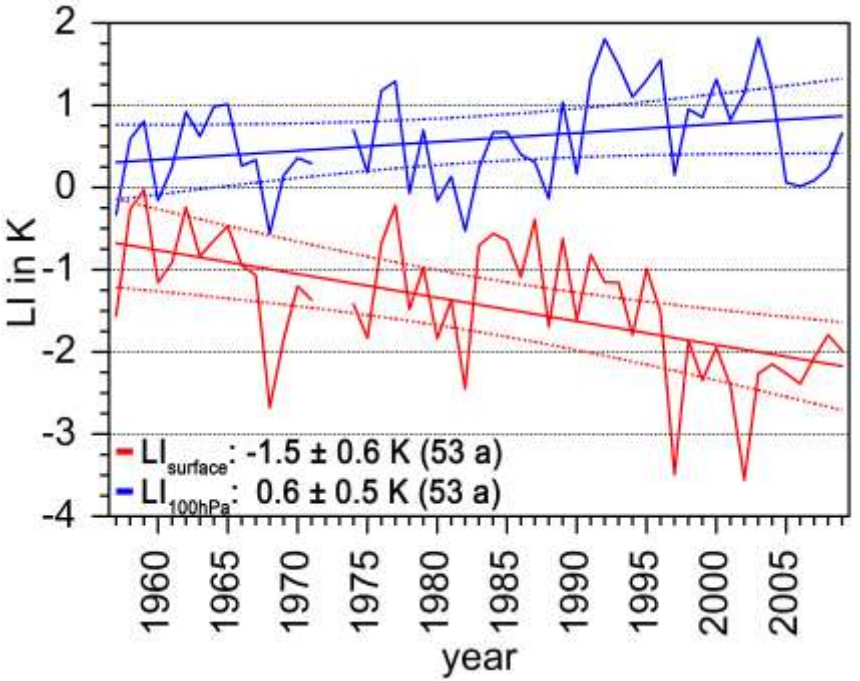
2. **How did the convective potential of the atmosphere change over past decades (Germany and Europe)?**
3. **Can RCMs reproduce the convective potential? Which trends can be derived from reanalysis data?**
4. How will the thunderstorm potential change in the future?

Trend analysis of CPs in Germany (1957-2009):

2. How did convective parameters/indices (CPs) of the atmosphere change in the past at the station of Schleswig (summer half year, 12 UTC)?

Examples: 90% percentile of **CAPE** 10% percentile of **LI**





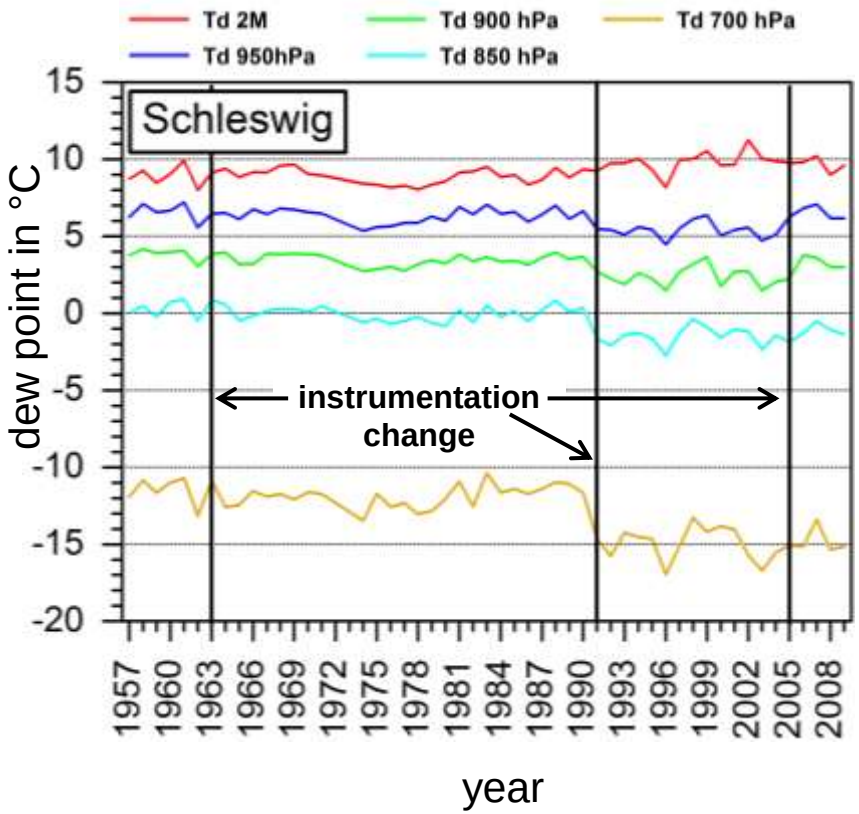
- convective potential substantially changed in the past (north Germany)
- different trend directions for various CPs

90/10% percentile means ≈ 18 days per year

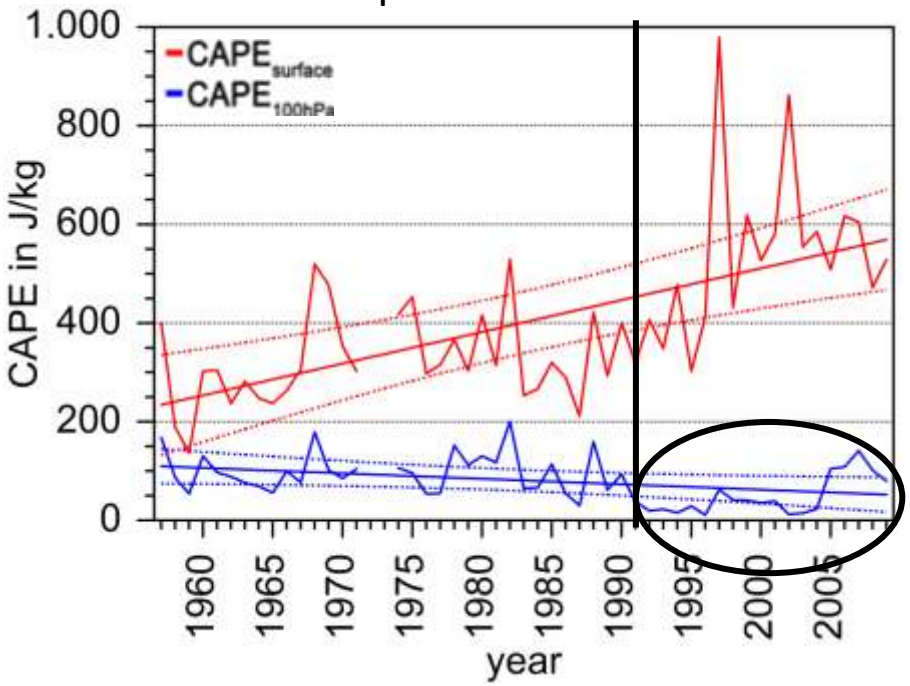
Trend analysis of CPs in Germany (1957-2009):

Are the time series homogenous?

summer mean of dew point (Td)



90% percentile of **CAPE**



change point in 1991
➡ influence on CPs calculated by parameters aloft

Trend analysis of CPs in Germany

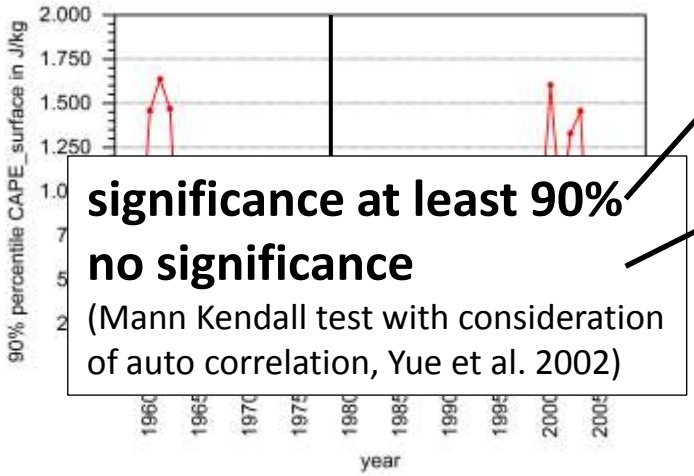
How robust are the trends to temporal shifts of the time series?

CAPE

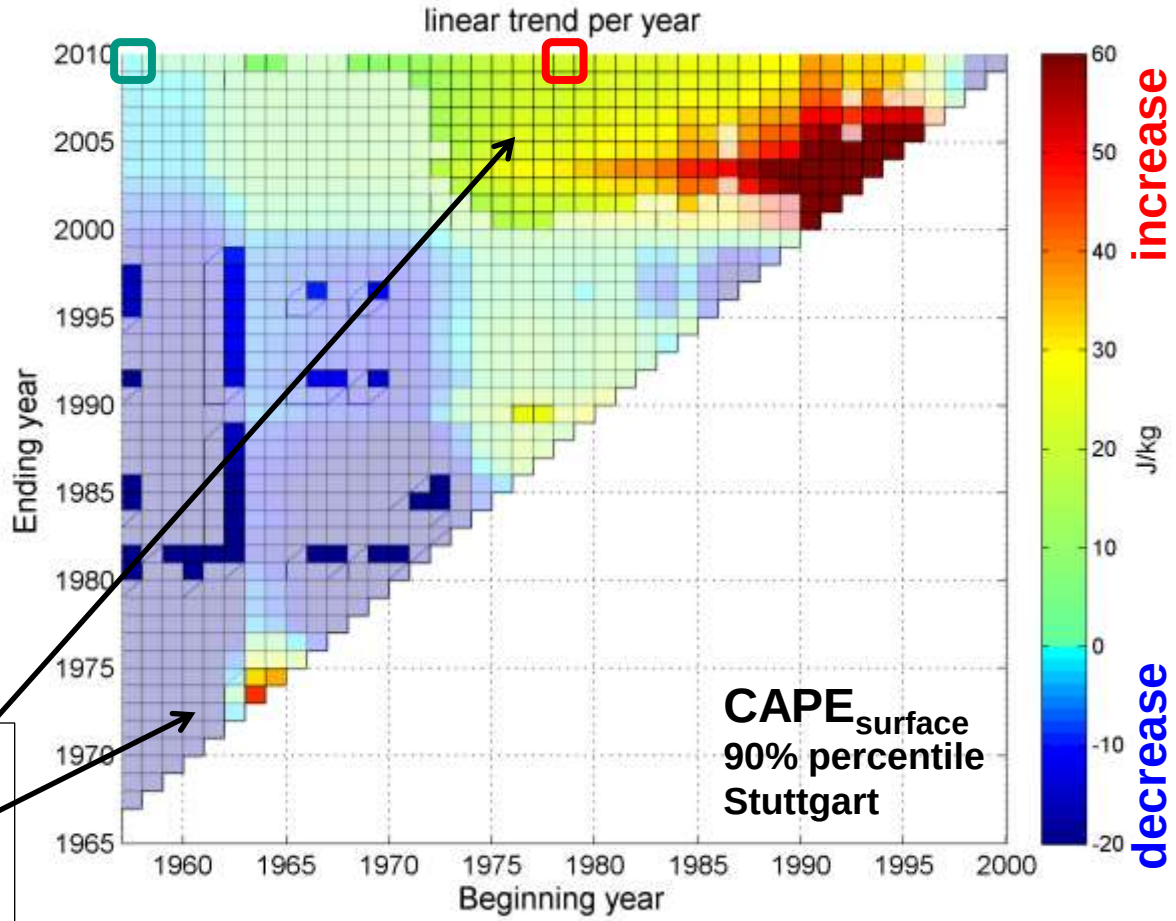
Stuttgart:

1978-2009: 671 ± 360 J/kg
(sig. 99%)

1957-2009: -14 ± 350 J/kg
(sig. 4%)



significance at least 90%
no significance
(Mann Kendall test with consideration of auto correlation, Yue et al. 2002)

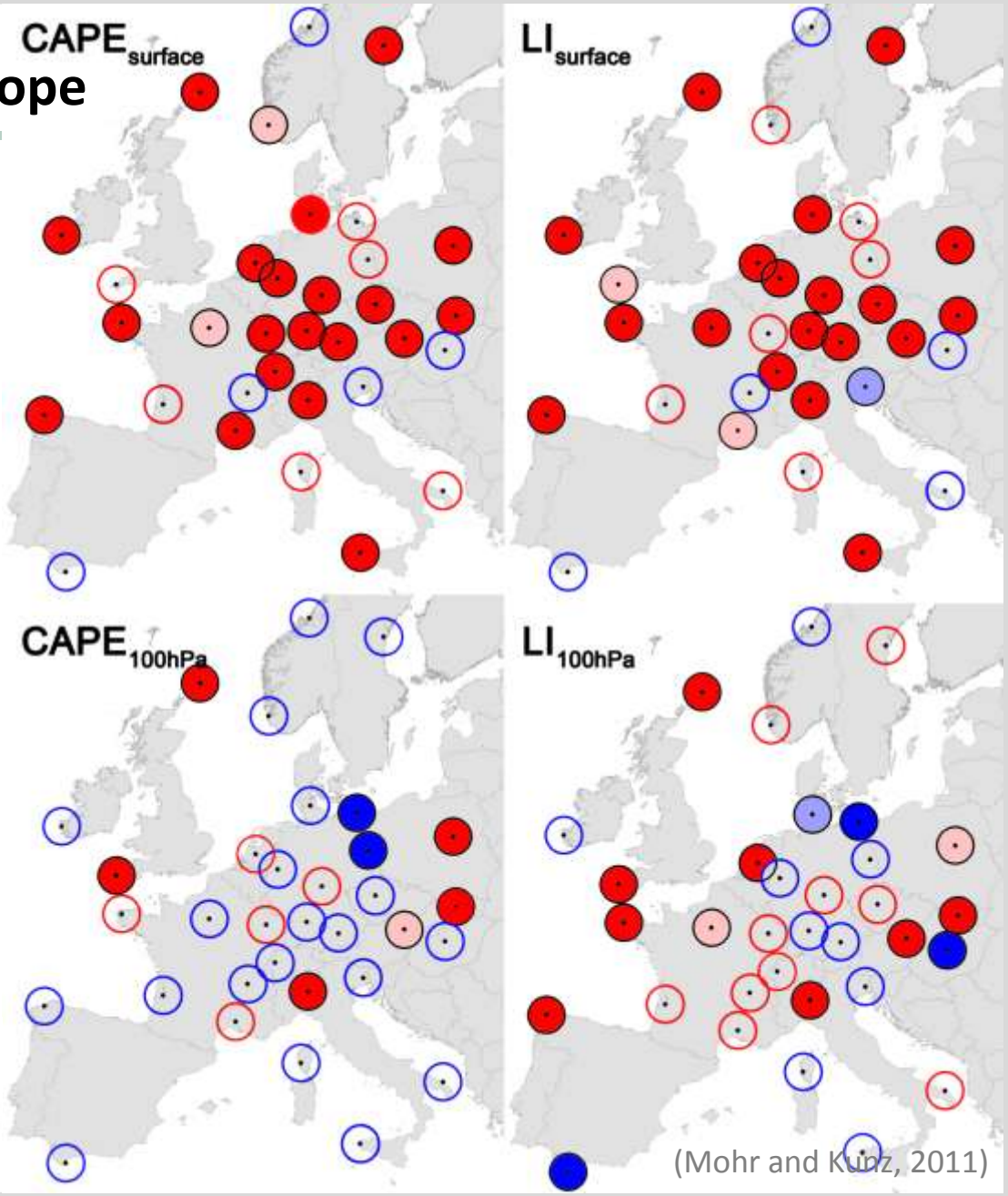


(Mohr and Kunz, 2011)

Trend analysis of CPs in Europe

2. How did the convective potential change in the past over Europe (1978-2009)?

A significant change towards higher convective potential for most CPs calculated from near-surface values ($CAPE_{surface}$, $LI_{surface}$, PII, $\Delta\theta_E$)

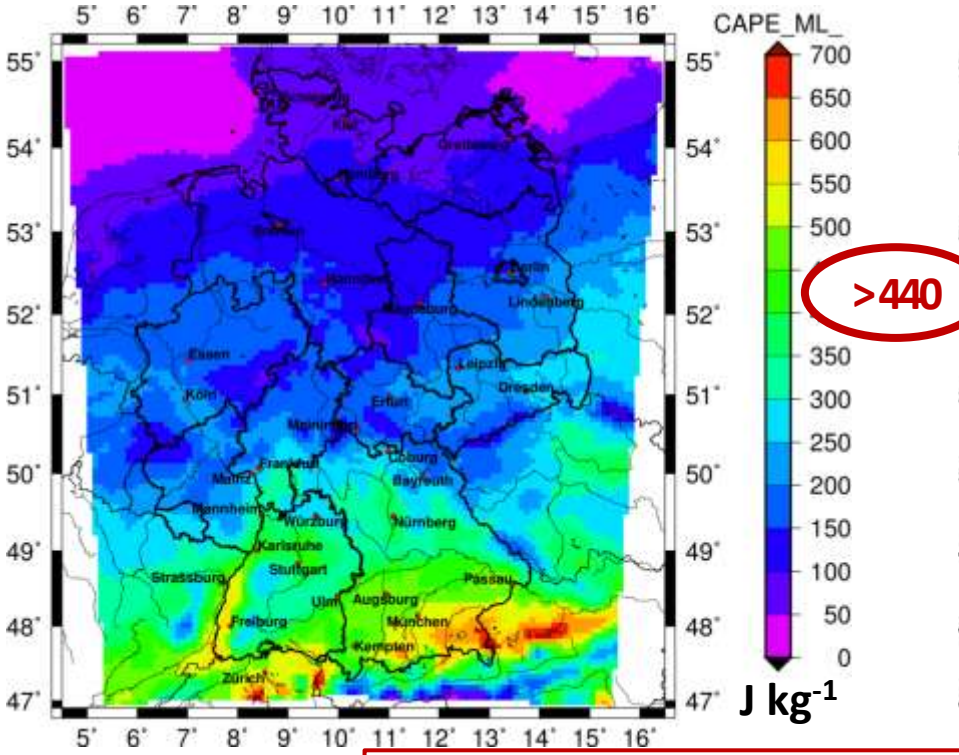


(Mohr and Kunz, 2011)

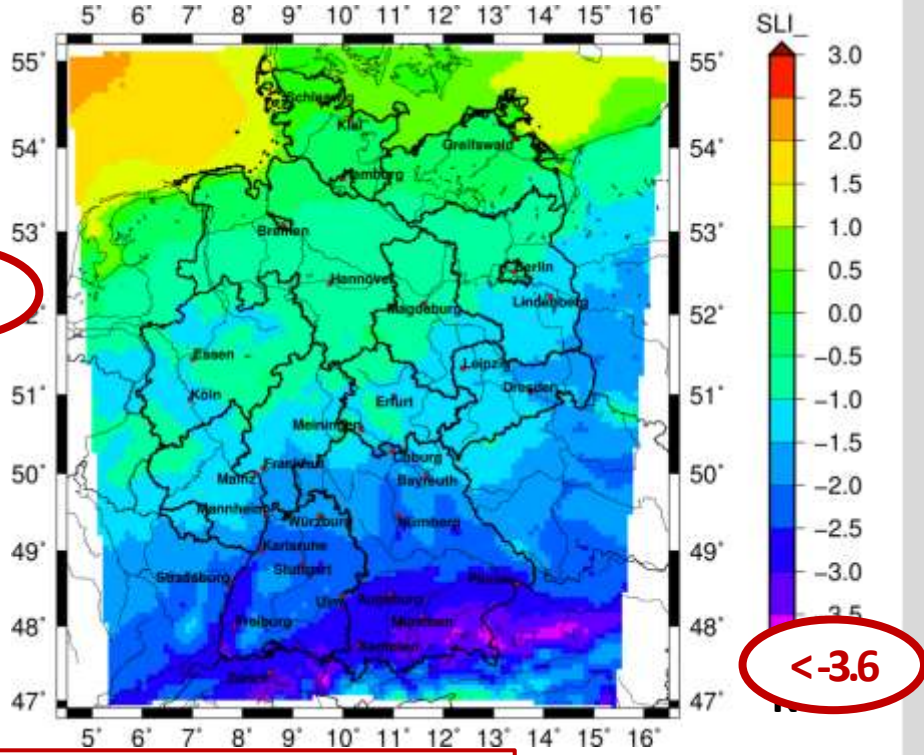
Reanalysis data from RCM (CCLM-ERA40, 7 km)

Average of 90/10%-percentiles, 1971-2000

$CAPE_{100hPa}$



$LI_{surface}$



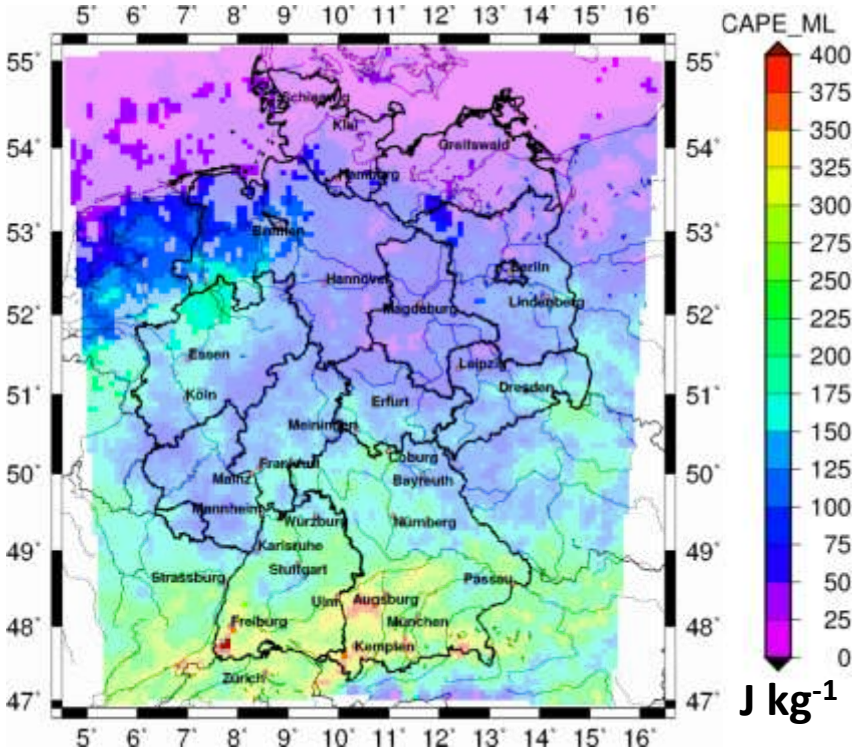
hail-relevant thresholds according to insurance data
(Mohr and Kunz, 2011)

Trend analysis (CCLM-ERA40, 7 km)

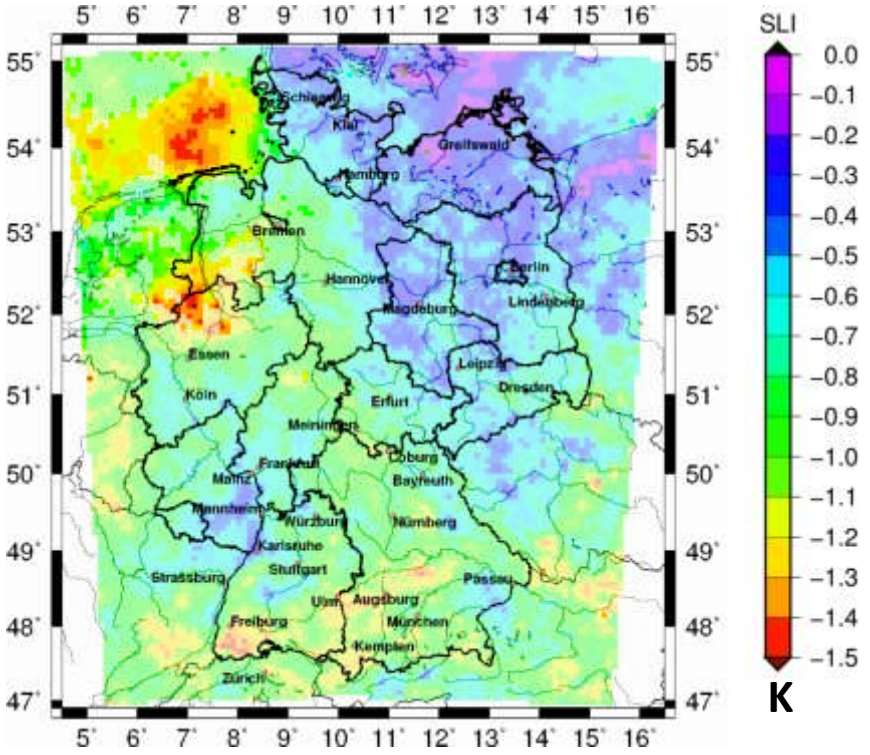
3. Which trends are derived from reanalysis data?

Trends of the 90/10% percentiles (1978-2000)

$CAPE_{100hPa}$



$LI_{surface}$

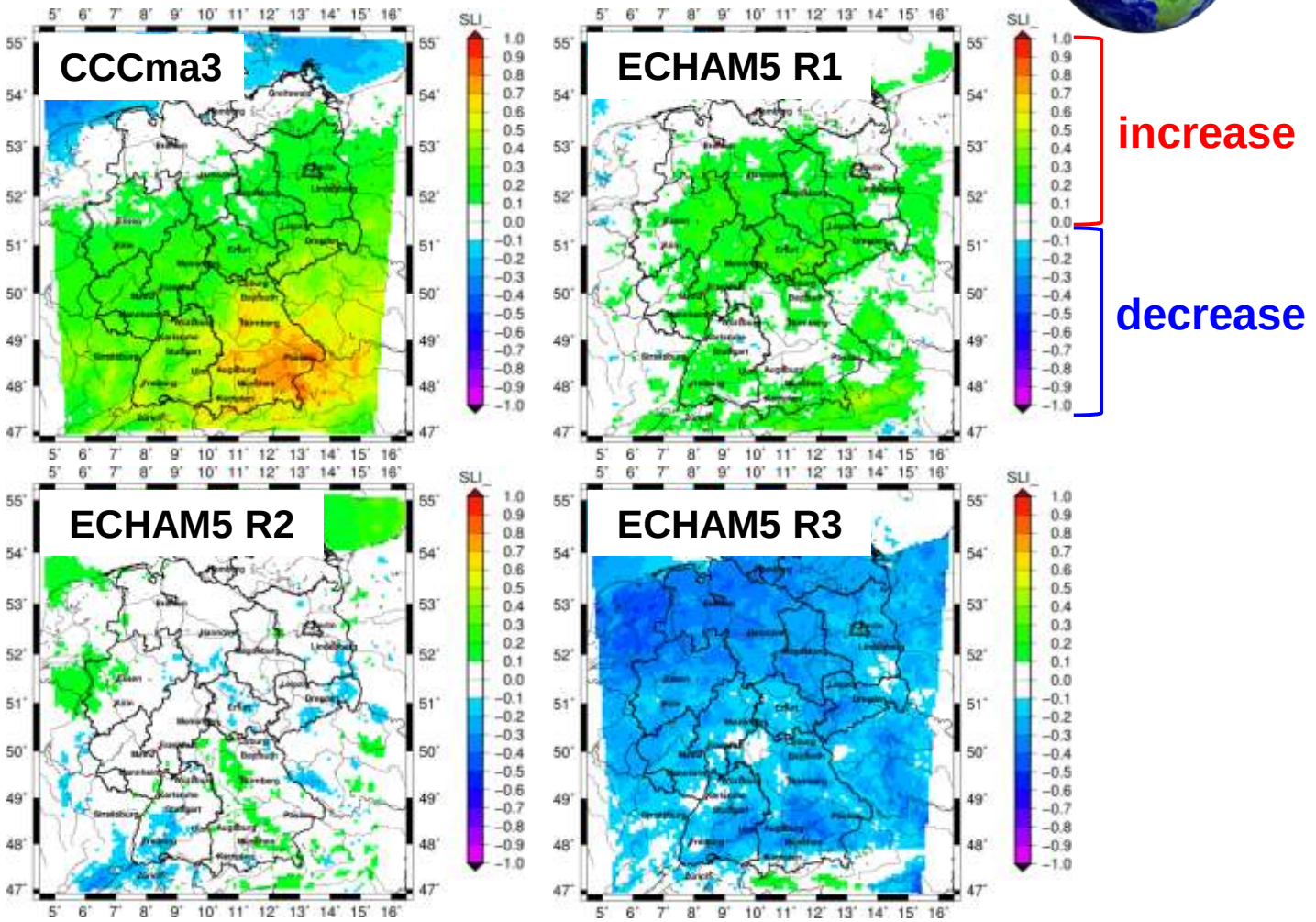


primarily a positive trend (but with low statistical significance)

Outlook…

4. Expected changes in the future (differences: C20 - A1B)?

$LI_{surface}$ (10% perc.)



C20: 1971-2000
A1B: 2021-2050

Conclusions

- Changes in the instrumentation are a crucial issue for trend analysis.
  - ➡ Particularly convective parameters that relay on moisture at higher levels affected.
- Convective parameters calculated from near-surface temp/humidity in general show an increase in the thunderstorm potential over the last 30 years in Germany.
- Most parts of Europe show an increase in the thunderstorm potential.
- The average 90% percentiles of the convective parameters of reanalysis data exceed the threshold for hail potential in south Germany.
- Reanalysis data show an increase in the convective potential for severe events (low statistical significance).
- Reason for the increase: increase of moisture at lower levels ➡ higher convective energy

Thanks for your attention!
Questions?

Mohr, S. and M. Kunz, 2011:
Trend analysis of convective indices relevant for hail events in Germany. *Atmos. Res.* In preparation.

Kunz, M., Sander, J., Kottmeier, C., 2009: Recent trends of thunderstorm and hailstorm frequency and their relation to atmospheric characteristics in southwest Germany. *Int. J. Climatol.* **29 (15)**, 2283–2297.

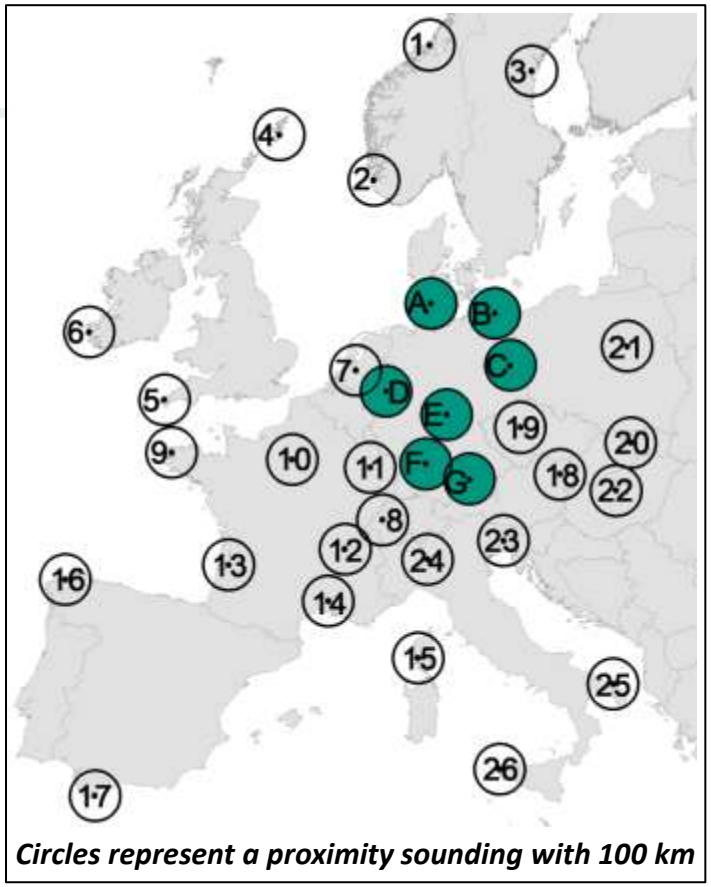
Kunz, M., 2007: The skill of convective parameters and indices to predict isolated and severe thunderstorms. *Nat. Hazards Earth Syst. Sci.* **7**, 327–342.

Data sets (12 UTC, summer half year):

Soundings:

- **Germany** (7 stations, A-G)
  - 1957-2009: Schleswig and Stuttgart
    53 years
  - 1978-2009: five other station
    32 years

- Europe (1-26)
  - 1978-2009
    32 years



Circles represent a proximity sounding with 100 km

Reanalysis data:

- CCLM-ERA40 (IMK-TRO, KIT, Germany):
  - COSMO_CLM_4.8_clm7, double nesting
  - driven with ERA40 (ECMWF)
  - high resolution of 0.0625° (~7 km)
  - area: Germany
  - period: 1971-2000

Trend analysis of CPs in Germany (1978-2009):

2. How did the convective potential change in the last 32 years in Germany?

Index 90% percentile (i.e.18 days)	Schleswig	Greifswald	Lindenberg	Essen	Meiningen	Stuttgart	Munich
$CAPE_{surface}$		X	X				
$CAPE_{100hPa}$	X			X	X	X	X
$LI_{surface}$		X	X				
LI_{100hPa}	X		X	X	X	X	X
Showalter			X	X	X	X	X
KO-Index	X			X			X
$DCI_{surface}$	X	X					
DCI_{100hPa}	X		X	X	X	X	X
K_{mod}	X	X		X		X	X
Pot.Inst.Index	X			X		X	
$\Delta\theta_E$			X				
SWISS12	X	X	X	X		X	

(Mohr and Kunz, 2011)

meteorological parameter	Schleswig	Greifswald	Lindenberg	Essen	Meiningen	Stuttgart	Munich
$temp_{surface\ to\ 500\ hPa}$		X					
$moisture_{surface}$			X				
$moisture_{950hPa\ to\ 700hPa}$		X			X	X	X
$moisture_{500hPa}$							

decrease in stability

increase in stability

90% significance

80% significance

no significance

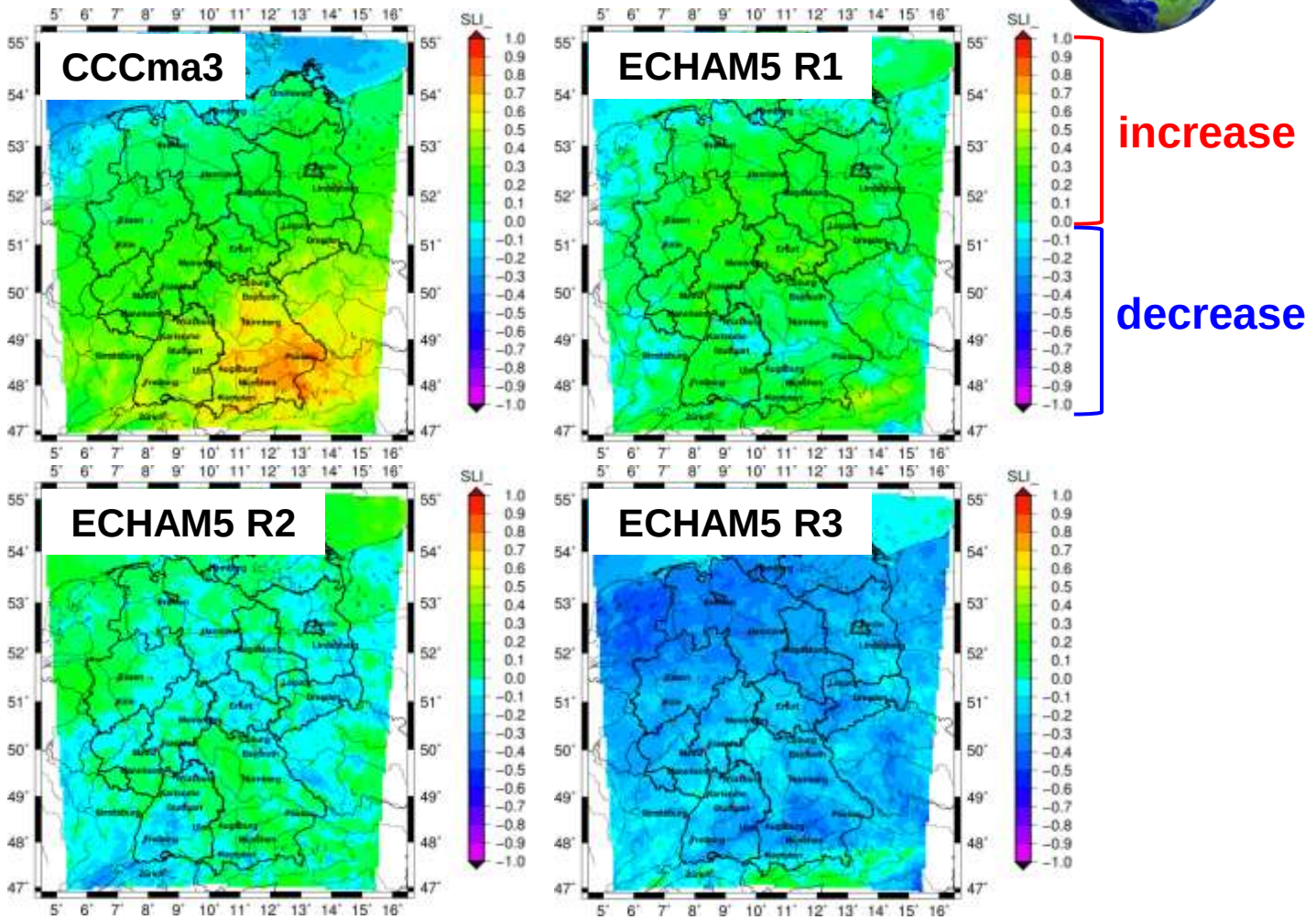
XXX *calculation from near-surface values*

XXX *calculation with layers aloft*

Outlook…

5. Expected changes in the future ?

C20 - A1B



C20: 1971-2000
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