Topic 6: Convective Indices in Regional Climate Models (KIT-IMK)

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motivation

Severe thunderstorms and associated extreme events such as hail represent a substantial hazard potential for buildings, crops, and critical infrastructure. In the last decades, damage caused by severe hailstorms has increased significantly in Central Europe. In southwest Germany, more than 40% of all damage to buildings by natural hazards is associated with large hail (1986-2008, Kunz 2009).
Within the frame of the project **HARIS-CC („HAil RISk and Climate Change“)** it is examined whether an indication is found that extreme events connected to severe thunderstorms have been increasing in the number or intensity over the past decades (Mohr and Kunz, 2012) and which changes will be expected in the future. Because thunderstorms are not captured uniquely and entirely by observations, the trend analyses rely on several proxies like convective indices and parameters (CPs) quantifying the thunderstorm potential of the atmosphere.

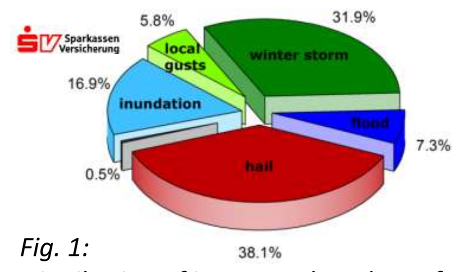


Fig. 1: Distribution of insurance loss data of damaged buildings (SV Sparkassen Versicherung, 1986-2008).

data base

High resolution **regional climate data** of IMK-TRO, KIT, Germany (Berg et al., 2012):

- COSMO 4.8 with double nesting:
  First nesting: 0.44° (~ 50km), RK 360s
  Second nesting: 0.0625° (~ 7km), RK70s
- Driven with reanalysis data ERA40 (CE40) and different global climate models (GCM): ECHAM5 (CE5) Run1-3 (R1,R2,R3) & CCCam3 (CC3)
- Area: Germany, period: 1971-2000 (C20), 2021-2050 with A1B scenario (A1B)
- Summer half year (SHJ, April-September), 12 UTC

Radiosoundings in Germany (DWD) and Europe (IGRA):

- 1957/78-2009, SHJ, 12UTC
- DWD: Schleswig, Greifswald, Lindenberg, Essen, Meiningen, Stuttgart, Munich

validation

Can regional climate models (RCM) reproduce the convective potential?

mixed layer Convective Available Potential Energy (**$CAPE_{ML}$**): $CAPE = R_d \int_{LFC}^{EL} (T'_v - T_v)\, d\ln p$

Surface Lifted Index (**SLI**): $SLI = T_{500} - T'_{S\rightarrow 500}$

Fig 2: The x-axis shows the mean of a set of radiosoundings (RS). The y-axis describes the difference ($CAPE_{100}$ of RS minus $CAPE_{ML}$ of CE40 for Stuttgart and all seven German stations. Dots (triangles) indicate the average (the standard deviation, std) of the difference of CAPE between soundings and CE40 data.

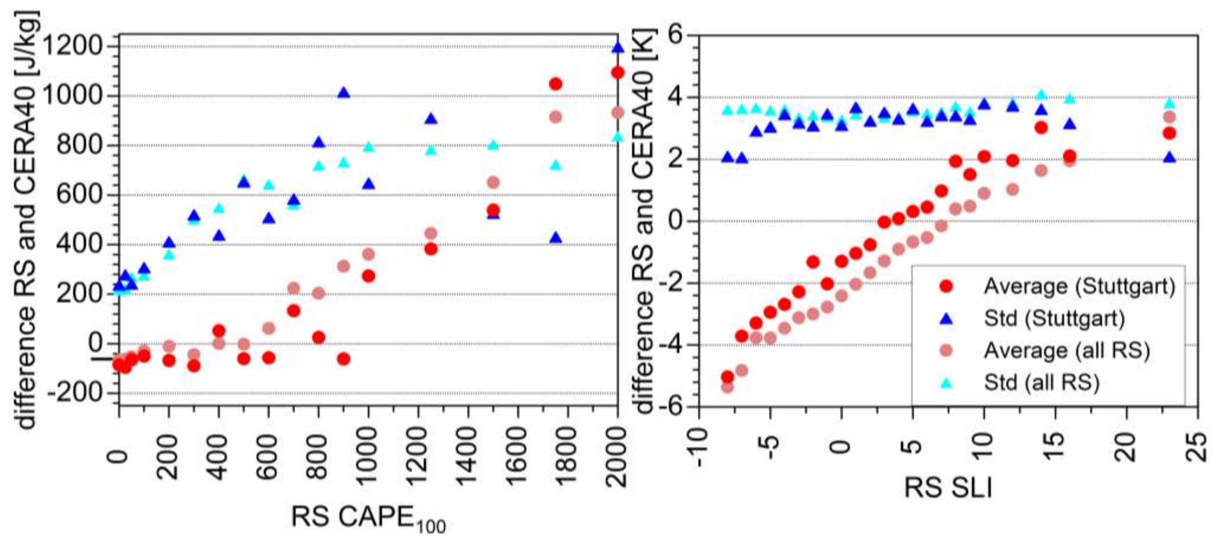
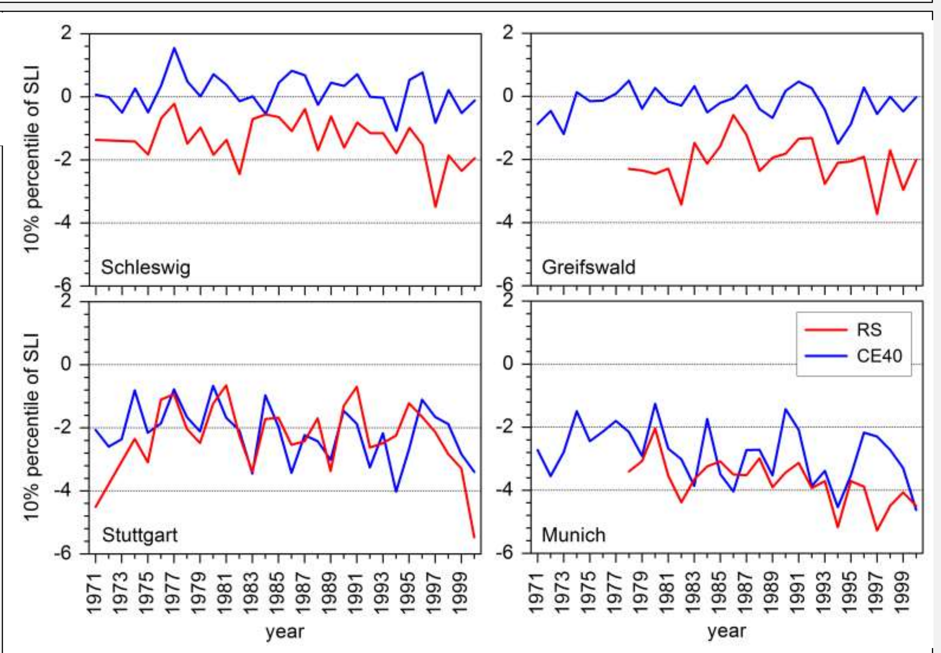


Fig 3: The yearly 10% percentile (SHJ) of SLI for four Germans sounding stations (RS) and their adjacent grid points (3x3) from reanalysis data CE40.



- CCLM simulation driven by ERA40 can reproduce the convective situation at the right time, but underestimates convective strength. The differences increase linearly with higher values.
- Whereas over southern Germany the convective potential is well reproduced, it is underestimated over the northern parts.

climatology

How does the climatology of extreme CPs looks like in the past?

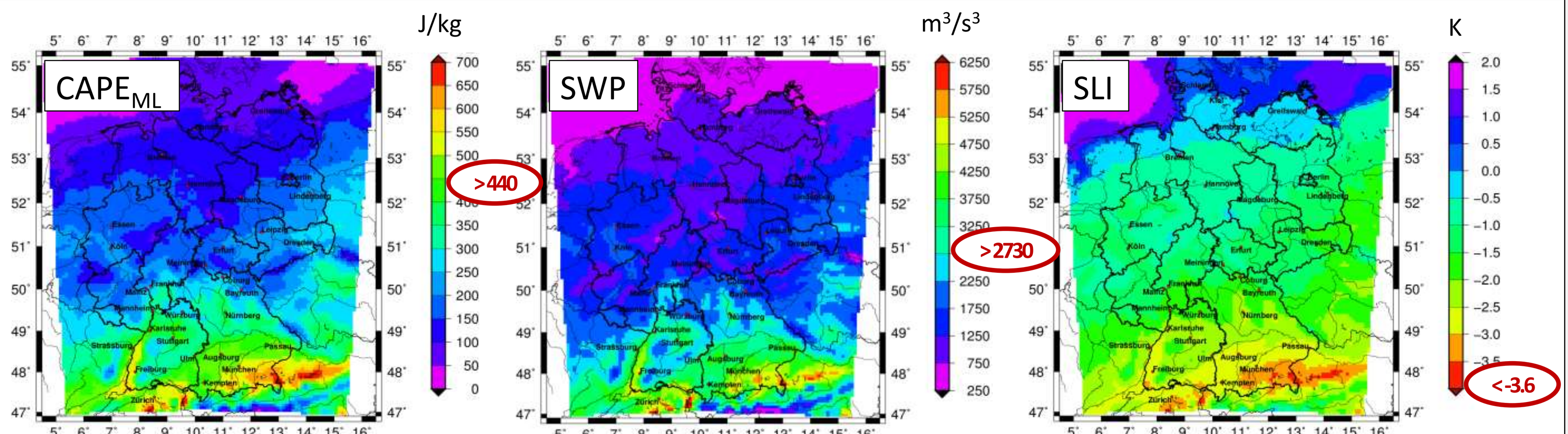


*Fig 4: The average of the annual 90% percentile of $CAPE_{ML}$ (left) and SWP (Severe Weather Parameter=$CAPE_{ML}$*WSh05[1], Craven et al., 2002, middle) and the annual 10% percentile of SLI (right) in regional reanalysis data CE40 (C20) and their hail-relevant thresholds (red) according to building insurance data*

- Grid points representative for larger areas.
- North-to-south gradient, with high values in Southern Germany.
- Hail-relevant thresholds of the CPs according to insurance data (Kunz, 2007; Mohr and Kunz, 2012) are exceeded for the extremes in the south.

1) WSh05 = magnitude of the vector difference between the winds at the surface and 500hPa level

trend analysis 1978-2000

Which trends are derived from reanalysis data?

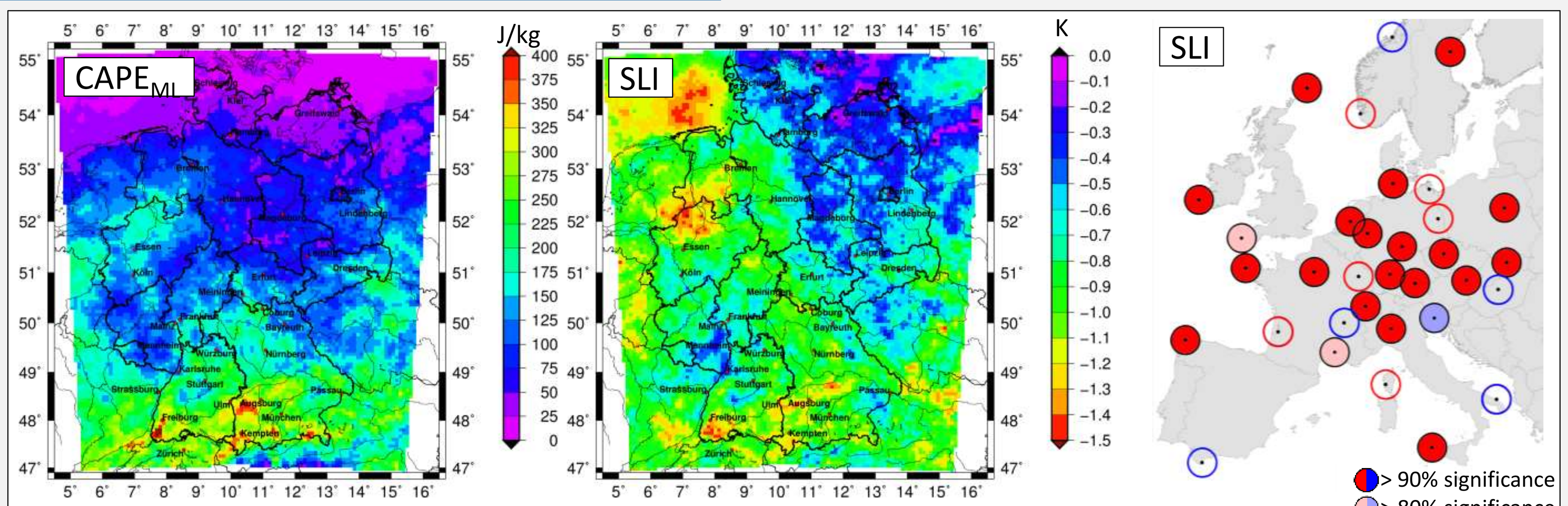


Fig 5: Linear trends for the 90% percentiles of $CAPE_{ML}$ (left) and 10% percentiles SLI (middle) from 1978-2000 in CE40 and for the 10% percentiles SLI (right) from 1978-2009 in soundings. For the letter, red (blue) means increase (decrease) in convective potential.

- All analyses show an increase in the convective potential.
- The results are consistent with trends derived from soundings stations (see Mohr and Kunz, 2012).

climate control runs C20 / future scenarios A1B

What are the difference between the RCM simulations during C20 and which changes can be expected in the future?

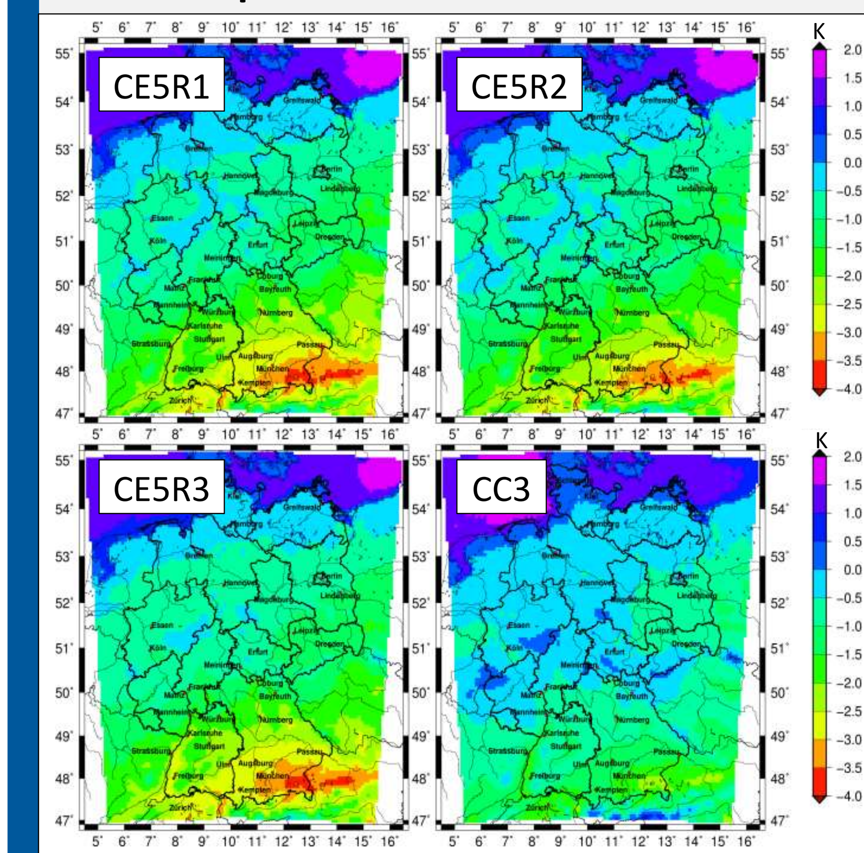


*Fig 6: Same as Fig. 4 for the **SLI** for CCLM simulations driven by different GCM (ECHAM5-CE5: Run 1-3, CCCam3-CC3) for C20.*

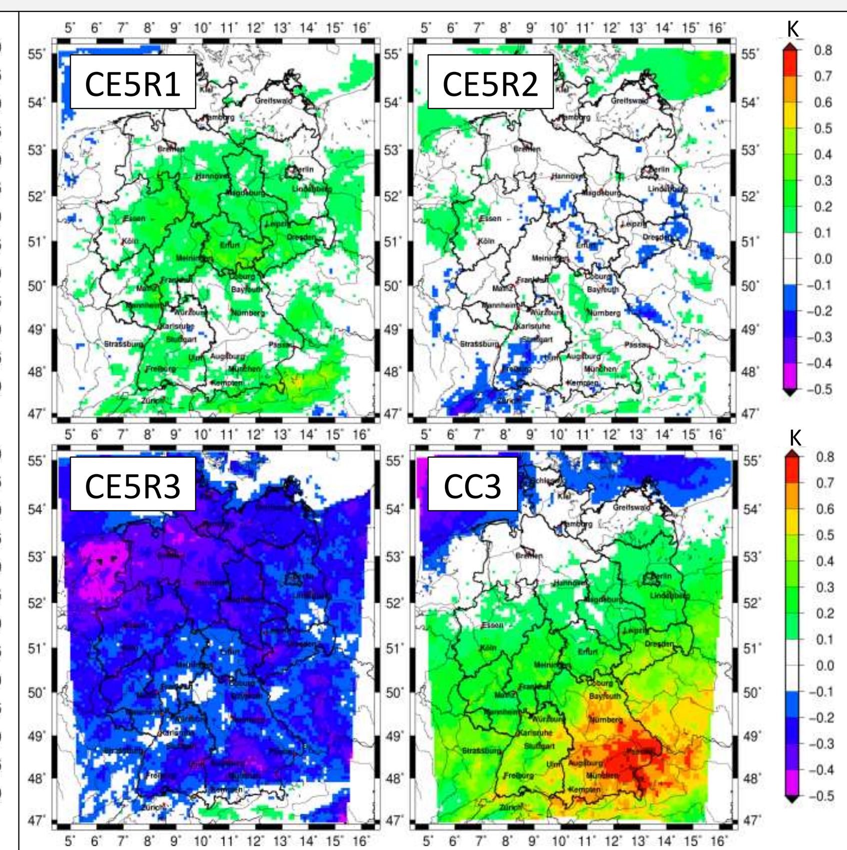


*Fig 7: Difference of the average 10% percentile of the **SLI** between C20 and A1B for various simulations. Red means an increase, violet a decrease of thunderstorm potential.*

- RCM simulations driven by ECHAM5 reproduce the middle stability of CE40 (see Fig. 4, right)
- Simulation driven by CC3 overestimates the stability. The reasons are the corresponding temperature and moisture fields.
- The expected changes in the future are inconsistent.

conclusions

- CCLM simulations are able to reproduce the convective potential for extreme events in Germany. However, highly instable conditions are underestimated, particularly in the north.
- Reanalysis data shows an increase in the convective potential for extreme events due to the increase in near-surface moisture (low statistical significance). This agrees well with the analyses of sounding data.
- Trends in the future are highly variable and not reliable. Larger ensembles of RCMs are required.

Berg, P., Wagner, S., Kunstmann, H. & Schädler, G., 2012: High resolution RCM simulations for Germany: Part I – validation. Clim. Dyn., submitted.

Craven, J. P., Brooks, H. E. & Hart, J. A., 2002: Baseline climatology of sounding derived parameters associated with deep, moist convection. Preprints, 21st Conf. on Severe Local Storms, San Antonio, TX, Amer. Meteor. Soc., 643-646.

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Mohr, S. & M. Kunz, 2012: Recent trends and variabilities of convective parameters relevant for hail events in Germany and Europe. Atmos. Res., submitted.