H13E-1026: Spatio-temporal variability of extreme hydro-meteorological events over Germany

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1. Abstract

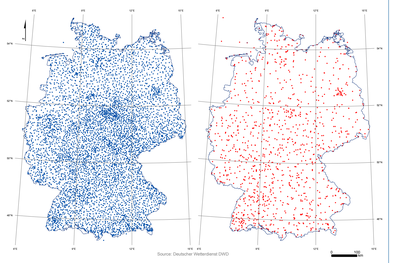
Extreme climatic and hydrologic events are the major cause of Great Natural Disasters according to the United Nations. In 2008 overall losses due to flood and drought related events amounted to US$ 570 bn (Munich RE). Discharge regimes of river basins as well as top-soil moisture patterns are expected to be altered due to possible effects of climate change. For planning and water resources management, it is fundamental to estimate the probability of occurrence of extreme hydro-meteorological events as well as its intensity. Predictions of climatic variables such as temperature and precipitation are currently done with GCM and RCM for global and regional scales, respectively.

2. Research Questions

1. Are current RCMs able to reproduce the spatio-temporal variability of extreme events that were observed during the past decades?
2. Can these RCM simulations be used for reliable regional hydrologic projections?

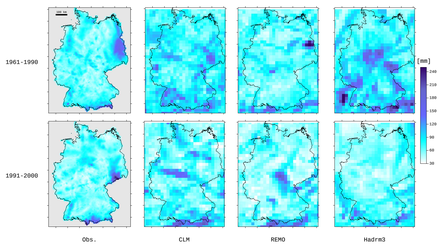
3. Study Area and Data

- **Domain**: Germany, 357 000 km^2
- **Period**: 1961-2000
- **Observations**
  - German Meteorological Service [1]
  - Daily precipitation and temperature
  - Interpolated with external drift Kriging using locally estimated variograms
- **Regional Climate Models**
  - CLM, REMO, Hadrm3 [2]
  - Driven by ERA-40 reanalysis [3]
  - Resolution 25 km, aggregated to daily values
- **Extreme statistics**
  - Maximum daily precipitation
  - Maximum annual precipitation
  - Number of heavy rain days per year greater than a threshold
  - Precipitation and temperature above and below a threshold value
  - Minimum air temperature in winter
  - Maximum daily precipitation in summer
  - Extreme circulation patterns (wetness index)
  - Dimensionality

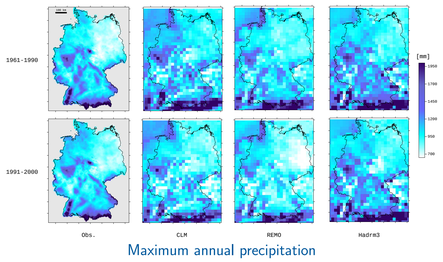


Location of precipitation (blue) and temperature(red) stations operated by DWD 1961-2010

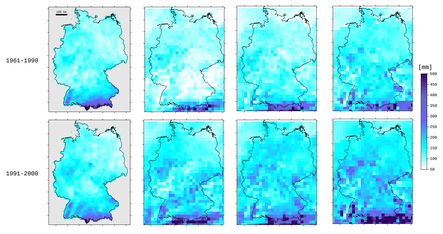
4. Precipitation



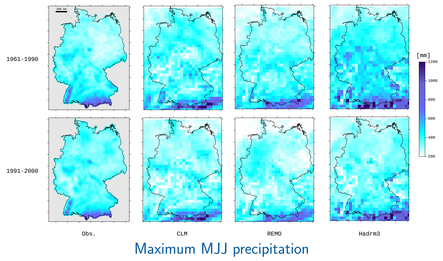
Maximum daily precipitation



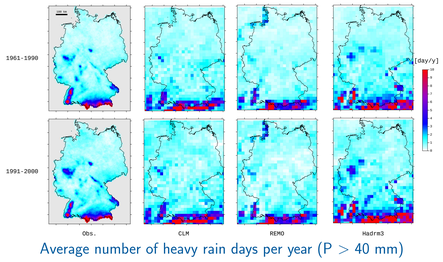
Maximum annual precipitation



Minimum MJJ precipitation

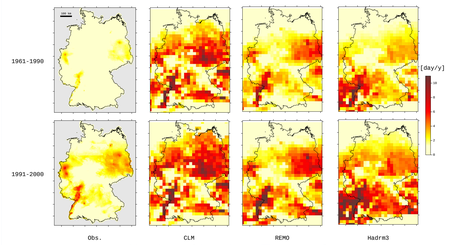


Maximum MJJ precipitation

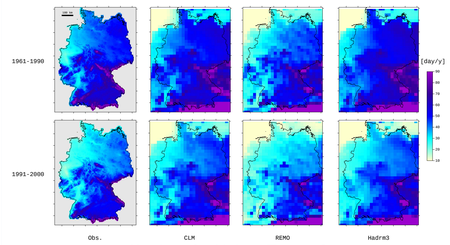


Average number of heavy rain days per year ($P > 40$ mm)

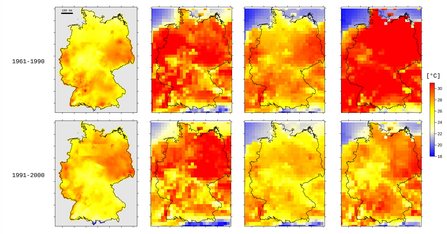
5. Temperature



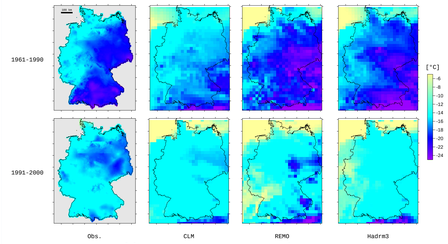
Number of hot days, T > 25 °C



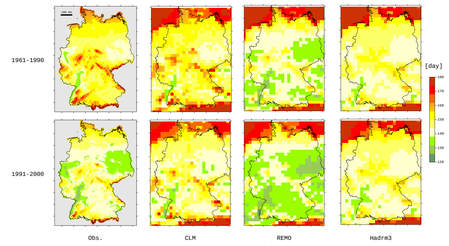
Number of cold days, T < 0 °C



Maximum temperature in July

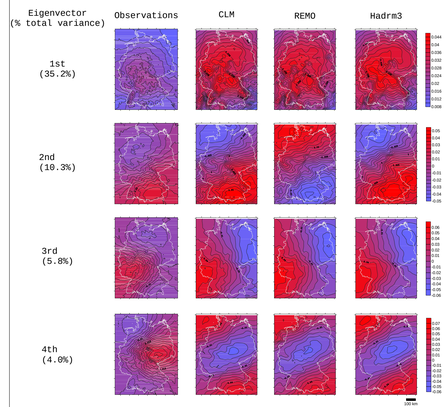


Minimum temperature in January

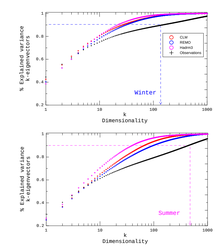


Average number of days to reach 100 Growing Degree Days

6. EOF of precipitation anomalies



First four Empirical Orthogonal Functions (EOF)



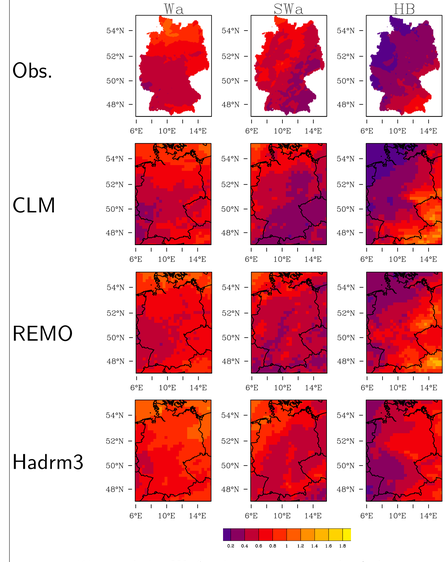
Dimensionality $\nu(k)$ of the precipitation anomalies

$$\nu(k) = \frac{\sum_{i=1}^{k} \lambda_i}{\sum_{i=1}^{m} \lambda_i}$$

λ_i ith eigenvalue

m dimension of the correlation matrix of precipitation anomalies

7. Extreme Circulation Patterns



Wetness index W_k for three extreme dry circulation patterns

- **Circulation Patterns**:
  1. Wa: West anticyclonic
  2. SWa: Southwest anticyclonic
  3. HB: British Isles high

$$W_k = \frac{\frac{1}{P} \sum_{t \in \mathrm{CP}^t = k} p^t}{\frac{1}{N} \sum_{t} 1_{\mathrm{CP}^t = k}}$$

P Total precipitation

N Number of days in a given period

$1_{\mathrm{CP}=k}$ Indicator function equal 1 if $\mathrm{CP}^t = k$ otherwise equal 0.

CP^t Synoptic circulation pattern based on Hess and Brezowsky (1969)

8. Conclusions

- All tested RCMs did not exhibit enough skill to predict extreme events
- Weather anomalies (magnitude and timing) were not resolved by RCMs
- Precipitation bias is a great issue with the evaluated RCMs
- RCM outputs can not be used directly for hydrologic impact analysis.

References

[1] DWD, http://www.dwd.de/.

[2] ENSEMBLES, http://ensembles-eu.metoffice.com/.

[3] ERA, http://www.ecmwf.int/products/data/archive/descriptions/e4/index.html.

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