Future Changes in Extreme Multiple-Day Precipitation Sums for the Rhine Basin

Sarah F. Kew*, Frank Selten, Geert Lenderink and Wilco Hazeleger

Estimates of future changes in extremes of multi-day precipitation sums are critical for estimates of future discharge extremes of large river basins (major flooding events). Here we use a large ensemble of global climate model simulations to investigate summer and winter changes in extremes of 1-20 day precipitation sums over the Rhine basin, projected for the period 2071-2100 with reference to the control period 1961-1990.

1. Introduction

Global warming-induced changes in intensity and relative persistence of extreme precipitation episodes and dry spells could cause the changes in multi-day precipitation extremes to scale differently to the single-day extremes. Global climate models (GCMs) are required to supply boundary conditions and effectively impose the large scale flow and its variability on regional climate models (RCMs) and the hydrological models they drive.

- Can a GCM detect an externally forced climate signal for the Rhine basin over the noise of internal variability?
- Can a non-trivial scaling behaviour across multi-day sums be detected?

We used the Essence GCM ensemble to find out.

**ESSENCE ensemble data set** [Stael et al. 2008; GRL]

**MODEL:** ECHAM/OPYC coupled GCM
**FORCING:** SRES A1B scenario
**PERIOD:** 1901-2100
**MEMBERS:** 17

![Rhine Basin representation](image)

2. GCM vs. Observations

The GCM performs reasonably compared to up-scaled observations.

![Control period PDFs for the North Rhine region](image)

3. Quantile Changes

We present changes in extreme precipitation as a relative change ("scaling") to the 99% quantile, \( \Delta q_{99} \). Fig C shows how \( \Delta q_{99} \) depends on the summation interval, \( n \), for each region.

- **Summer JJA:**
  - Non-trivial scaling for North Rhine: \( \Delta q_{99} \) (1 day sum) \( > 0 \), but \( \Delta q_{99} \) (20 day sum) \( < 0 \)
  - Central / Alpine Rhine regions: \( \Delta q_{99} < 0 \) (all \( n \))

- **Winter DJF:**
  - \( \Delta q_{99} > 0 \), scaling close to independent of \( n \).

![Quantile Changes](image)

4. Mechanism of Change?

Quantiles are influenced by changes in the wet day frequency and rain-intensity.

- Change in mean wet day frequency dominates change in mean intensity in JJA (Fig D).
- Summer dry spells become longer, wet spells shorter (Fig E).

![Mechanism of Change](image)

5. Sensitivity to Ensemble Size

Around 240 yrs (8 members) are needed to detect the signal as significantly different from zero or the non-trivial scaling behaviour for JJA in the North Rhine (Fig F). For small ensembles, even opposing scaling behaviours can be attained [data in all quadrants of Fig G).

![Sensitivity to Ensemble Size](image)

6. Conclusions

- Currently available estimates of future discharge extremes using around 90-years (3 ensemble members) of GCM simulations risk inadequate sampling of natural variability and could mis-represent the impact of large-scale circulation changes on extreme precipitation.
- Non-trivial scaling behaviour of extremes cannot be easily captured by the commonly used "delta-change" approach, in which mean parameters are used to transform historical precipitation sequences to future time series.