Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

Future Changes in Rainfall Extremes 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 (and changes in frequency of major flooding events). Here we use a large ensemble of global climate model simulations to estimate changes in extremes of 1-20 day precipitation sums over the Rhine basin, projected for the period 1971-2100 with reference to 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 precipitation sums be detected?

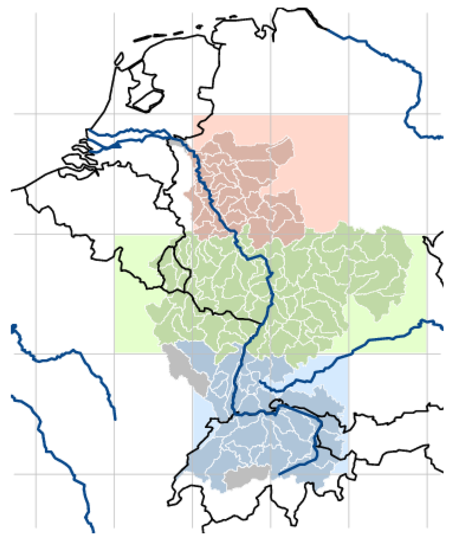


***Figure A** The Rhine Basin and Essence grid. The basin is represented by 8 cells: 2 in the North Rhine, 4 in the Central Rhine, and 2 in the Alpine Rhine region. CHR-OBS subbasins are outlined in white.*

2. GCM vs. Observations

We use the ESSENCE ensemble to explore variability and changes in extreme precipitation quantiles for the future (2070-2100) with reference to a control (1961-1991) period, for 3 regions of the Rhine basin (Fig. A), 2 seasons – DJF and JJA, and five n-day sums (n = 1, 2, 5, 10, 20).

- ESSENCE performs reasonably compared to upscaled observations (CHR-OBS) in the control period (Fig. B).

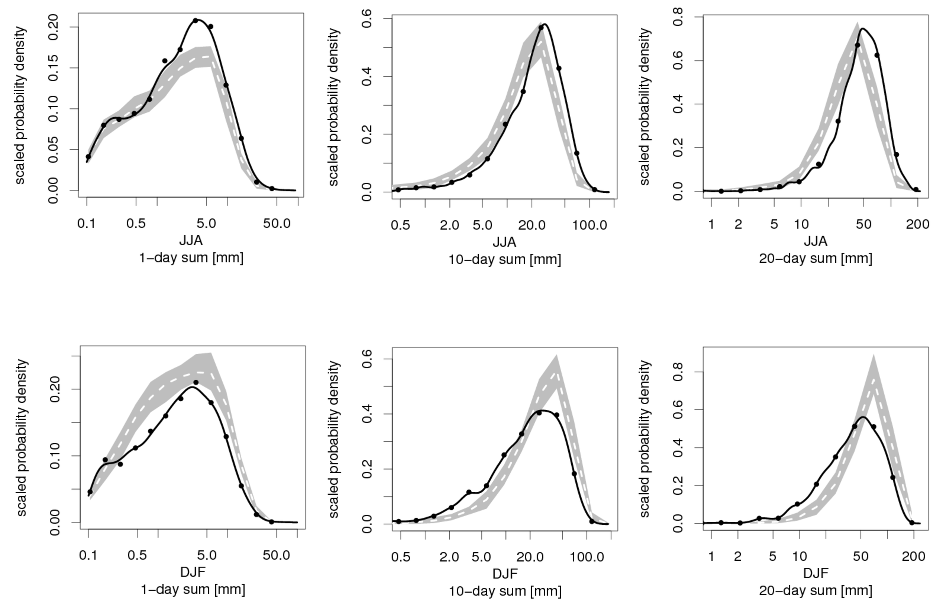


***Figure B** Probability density functions for the North Rhine region in 1961-1991, scaled by wet-period frequency, for the ESSENCE ensemble (grey envelope) and upscaled CHR-OBS area-averaged observations (black).*

ESSENCE ensemble data set [Sterl et al. 2008, GRL]

MODEL:	ECHAM5/MPI-OM coupled GCM
FORCING:	SRES A1B scenario
PERIOD:	1950-2100
MEMBERS:	17 (atmosphere only perturbations)

3. Changes in Intensity

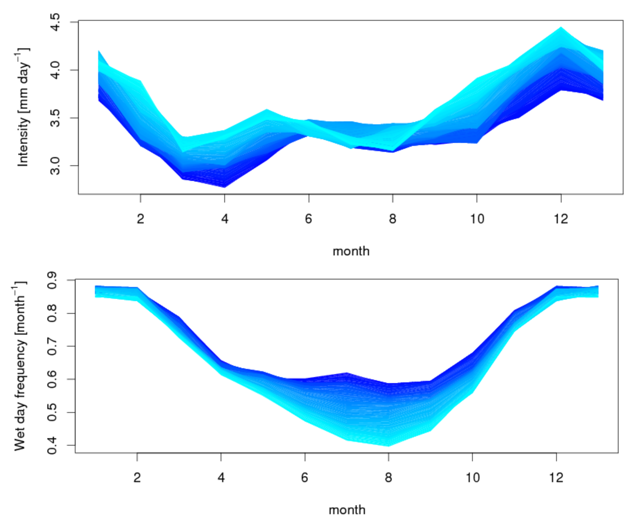


***Figure C** Seasonal changes for the North Rhine region in intensity (top) and wet-day frequency (bottom) from the beginning (blue) to end (cyan) of the ESSENCE period. A sliding window of 21 years is applied.*

4. Extreme-Quantile Changes

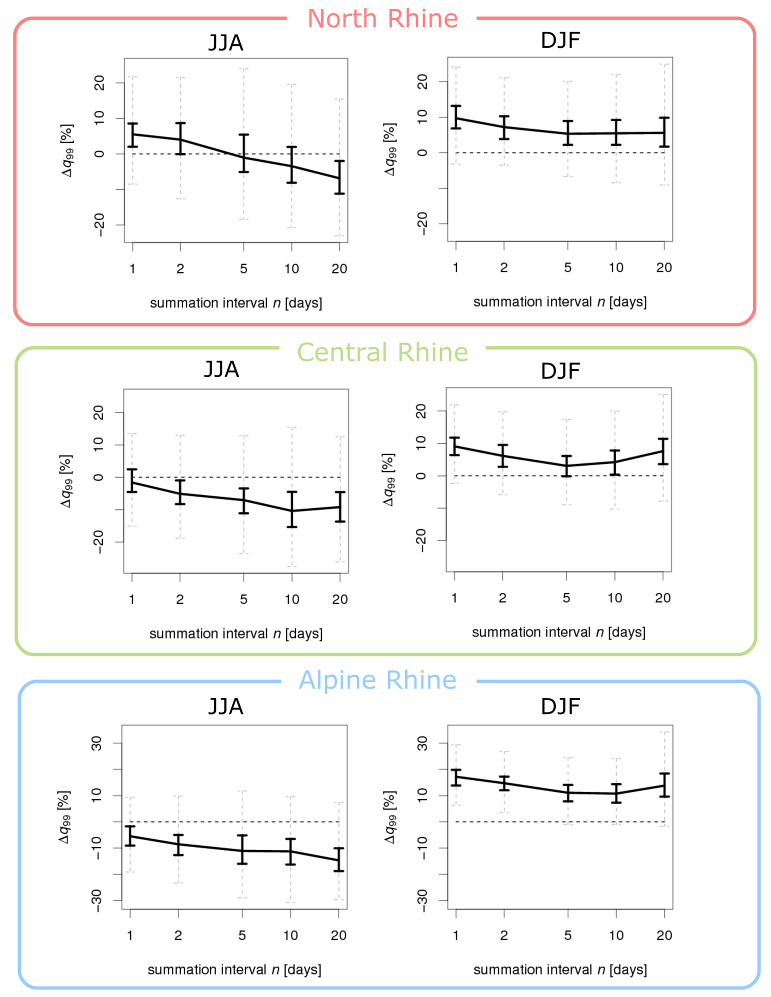


***Figure D** The projected changes of the 99% quantile in 1-20 day precipitation sums expected by 2070-2100 with reference to 1961-1991. Error bars indicate 95% confidence intervals given by bootstrapping (1000 samples) on 17 ensemble members (black) or 1 run (grey).*

Summer: Non-trivial scaling for North Rhine

- Δq (1 day sum) positive, Δq (20-day sum) negative
- Central/Alpine regions negative changes

Winter: Positive changes all regions,

Scaling independent of n to within a few percent

5. Changes in Persistence

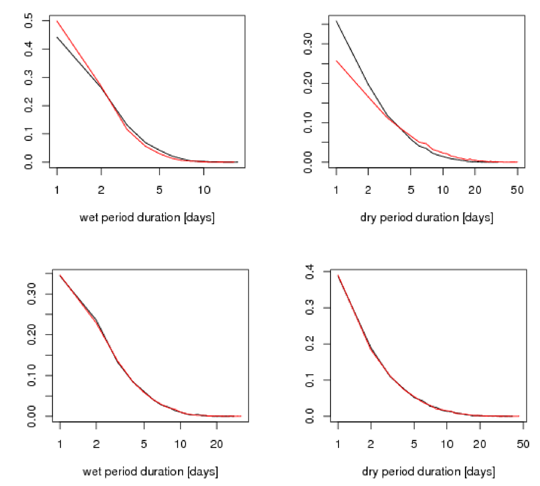
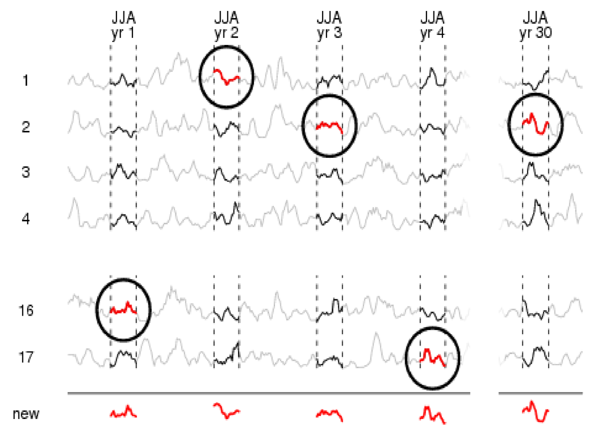


***Figure E** The probability density functions of wet period (left) and dry period (right) durations, for the control (black) and future (red) time slices in the summer (top) and winter (bottom) in the North Rhine region.*

6. Sensitivity to ensemble size

Bootstrapping (Fig. F) is used to estimate confidence intervals of the change in the 99% quantiles for a range of ensemble sizes (Fig. G).

***Figure F** New 30-yr combinations are generated by, for each year in turn, randomly selecting a seasonal segment from one of the 17 runs. A 3-member ensemble, is simulated as a collection of 3 such randomly generated sequences. Quantiles are estimated from the pool of n-day sums within each simulated ensemble.*



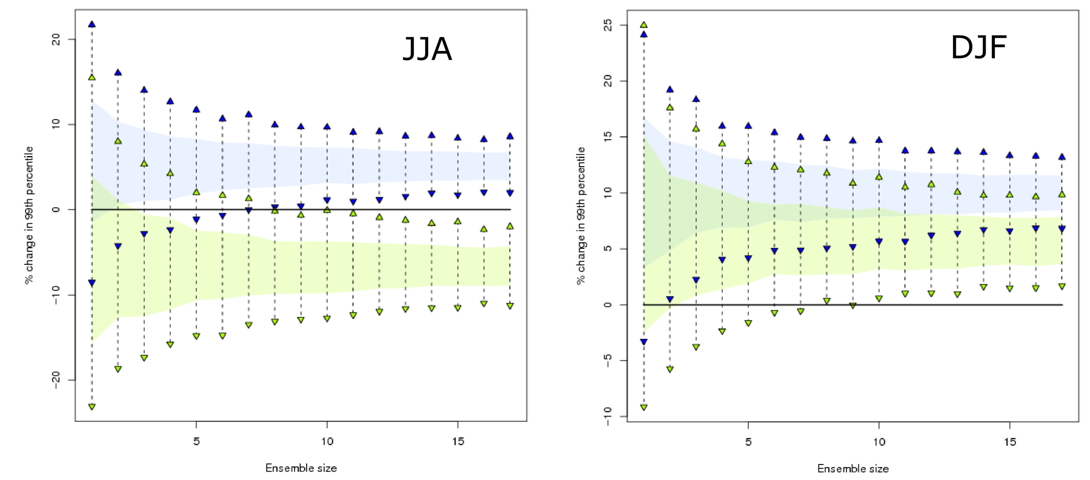


***Figure G** The 68% (shading) and 95% (arrows) confidence intervals, generated from 1000 samples, are shown for the change in 99% quantiles in 1-day sums (blue) and 20-day sums (green) for JJA (left) and DJF (right) for the North Rhine region.*

Around 240 yrs (8 members) or more are needed to detect the signal as significantly different from zero (n = 20, JJA/DJF) or the scaling behaviour for the North Rhine (JJA).

7. Conclusions

- Currently available estimates of future discharge extremes using around 90-yrs (3 members) risk inadequate sampling of natural variability and could mis-represent the large-scale circulation impact on extreme precipitation.
- Non-trivial scaling behaviour has implications for the "delta change" approach used to transform historical precipitation sequences to future timeseries.

* Royal Netherlands Meteorological Institute. PO Box 201, 3730 AE De Bilt, The Netherlands, E-mail: sarah.kew@knmi.nl