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Extreme precipitation, uncertainty and appropriate scales for assessment of climate change effect on river flooding

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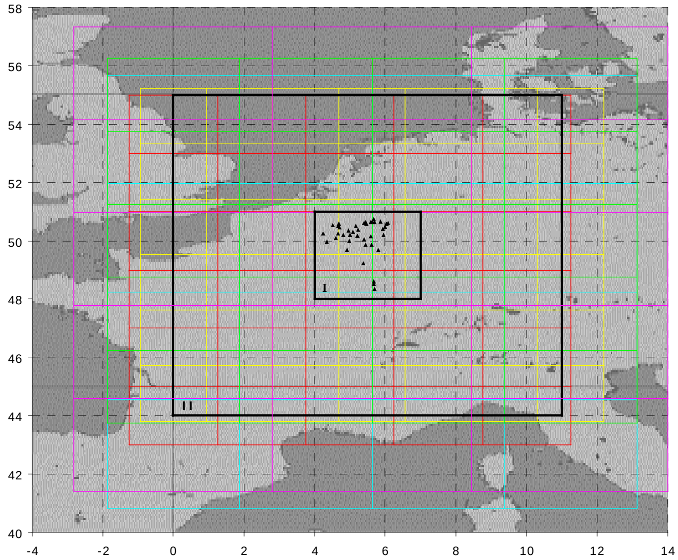
1. Introduction

River flooding is highly sensitive to the spatial and temporal distribution of precipitation. Uncertainties in precipitation may lead to large uncertainties in simulated floods, in particular in the context of climate change. Furthermore, precipitation statistics will change when going from the climate model scale (GCM) to the appropriate river basin model scale. These aspects of precipitation are quantified by assessing the 20-year return values (*RV*20) of daily precipitation under climate change at the appropriate river basin spatial scale and the associated uncertainties for a region around the Meuse basin.



2. Observed and modelled precipitation

Scale	Category	Source	Current cl. (1X) 1960	1970	1980	1990	Changed cl. (2X) 2070	2080	2090
Point(▲)	Stations	KMI,METEO F							
Areal mean		KMI,METEO F							
	Reanalysis	NCEP-NCAR							
		NASA-GEOS1							
	GCM	CGCM1							
		HadCM3							
		CSIRO9							
Appropriate		eq. (3)							

3. Return values at the appropriate scale and uncertainties

It is assumed that point and areal mean annual maximum daily precipitation P_M stems from a Gumbel extreme value distribution with probability density function

$$f(P_M) = \frac{1}{\nu}\exp\left[-\frac{P_M-\xi}{\nu} - \exp\left(-\frac{P_M-\xi}{\nu}\right)\right] \quad (1)$$

where $\xi = \mu - \gamma\nu$, $\nu = \sigma\sqrt{6}/\pi$, μ and σ are the mean and standard deviation of P_M and $\gamma \approx 0.5772$. Precipitation *RV*20 and lower and upper confidence limits (l,u) are found by fitting this Gumbel distribution to P_M

$$RV20 \pm l,u = \mu + K_{20}\sigma \pm t_{\alpha,N-1}\sqrt{\frac{\sigma^2}{N}\left(1+1.14K_{20}+1.1K_{20}^{\,2}\right)} \quad (2)$$

where $K_{20} \approx 1.86$ and $t_{\alpha,\,N\text{-}1}$ are values of the Student *t*-distribution with α the probability limit required and *N*-1 degrees of freedom.

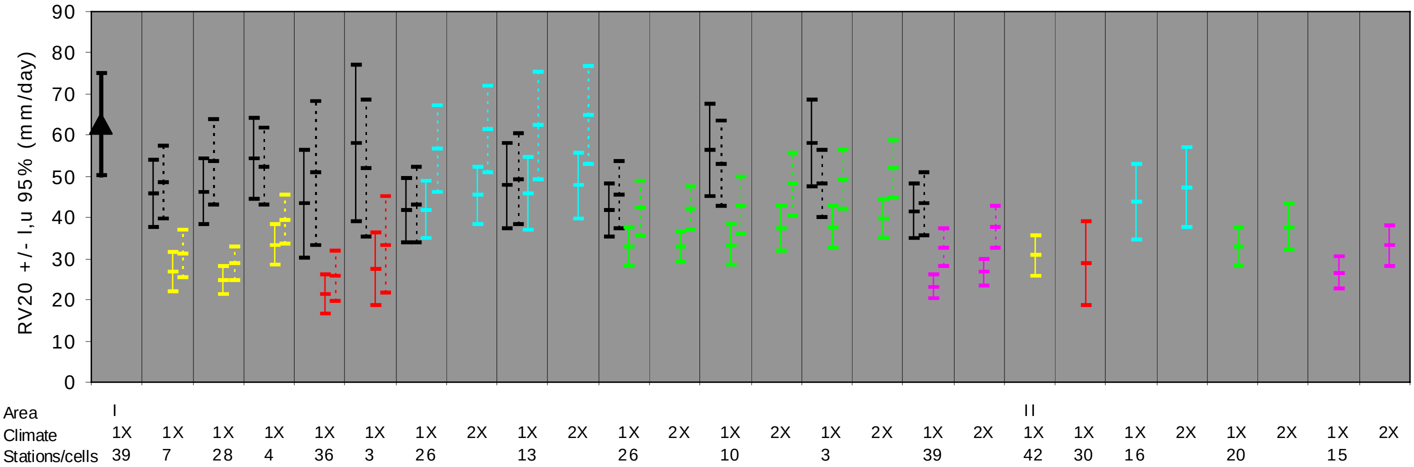
Areal mean station *RV*20 is calculated by simply averaging of station time series and by using the approach of Sivapalan and Blöschl (1998, *J. Hydrol.*, **204**, 150-167). This approach modified for daily precipitation assumes two relations

$$\nu_A = \nu_p \frac{\kappa^2}{1-0.17\ln\kappa^{-2}} \qquad \xi_A = \xi_p\kappa^2\left[0.39+0.61\left(\kappa^{-2}\right)^{0.8}\right] \quad (3)$$

where *p* refers to point values, *A* to areal mean values and κ^2 is the expected value of the correlation coefficient between any two points. In this way generalised Gumbel parameters as a function of precipitation spatial correlation structure and area (through κ^2) are obtained.

Eq. (3) is used to assess *RV*20 at the appropriate river basin scale (assumed 20 km). The additional uncertainty added by this reduction downscaling methodology is unknown (6), but is supposed to be relatively small. The uncertainty in *RV*20 at the appropriate spatial river basin scale under climate change is assessed in 6 steps (no. 1-6).

4. Results and conclusions



- The spatial variability of station *RV*20 is large.
- Areal mean station *RV*20 calculated by averaging and eq. (3) are comparable and therefore it is reasonable to use the reduction methodology.
- For area I differences between areal mean station and model *RV*20 are large (~40 %). Only CGCM1 performs well (~5 %).
- For area II similar conclusions apply. NASA-GEOS1, NCEP-NCAR, HadCM3 and CSIRO9 underestimate *RV*20 (~40 %) and CGCM1 *RV*20 is comparable to observations. It seems that reanalysis data are not well suited to validate GCM extreme precipitation data.
- For area I *RV*20 increases for 5 out of 6 grid boxes with climate change (5-10 %).
- For area II there is a difference in increase of mean *RV*20 between CGCM1 (~8 %), HadCM3 (~16 %) and CSIRO9 (~25 %). Spatial variability of *RV*20 slightly decreases with climate change in CGCM1 and HadCM3 (2-10 %), but increases in CSIRO9.
- There are considerable differences between model and appropriate scale *RV*20 (20-40 %) and therefore it seems to be necessary to use *RV*20 at appropriate scales.
- The uncertainty of *RV*20 with climate change amounted up to 30-40 % and is significantly larger than the simulated change (15 %).