Impacts of climate change on flooding in the river Meuse

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Overview

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Climate change
Appropriateness
Components
Rainfall model
Results rainfall
Basin models
Results basin
Conclusions

- Climate change in the Meuse basin
- Model appropriateness
- Appropriate model components

- Rainfall modelling
- Results rainfall model
- River basin models
- Results river basin models

- Conclusions

Climate change in the Meuse basin (1)

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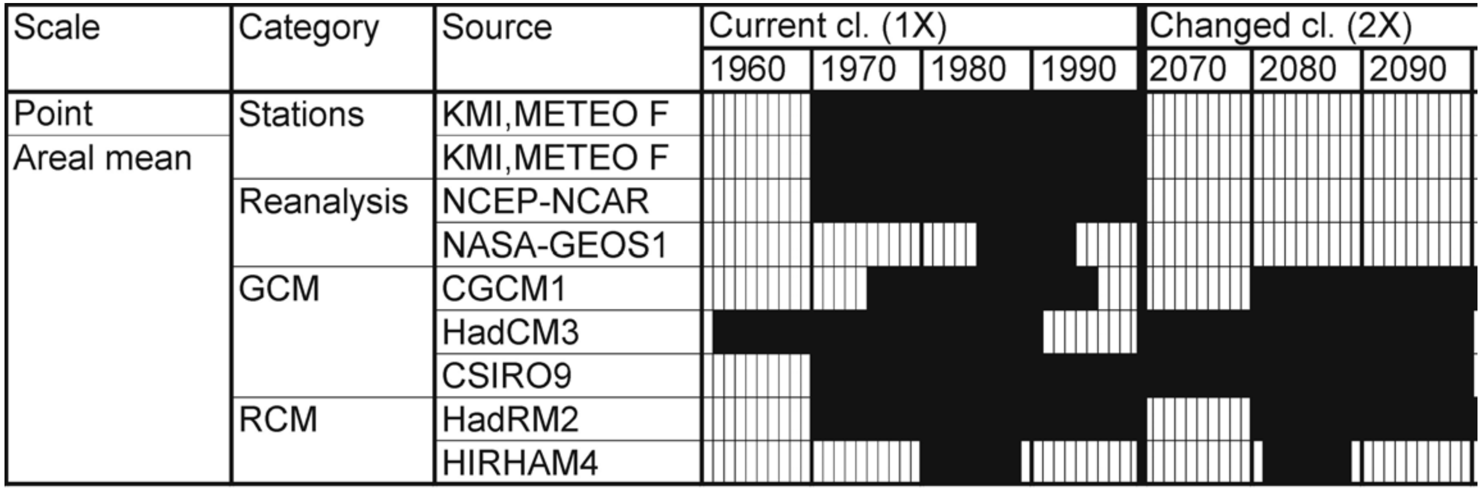
- **Rainfall (extreme values)**
- **Temperature**
- **Evapotranspiration**



Climate change in the Meuse basin (2)

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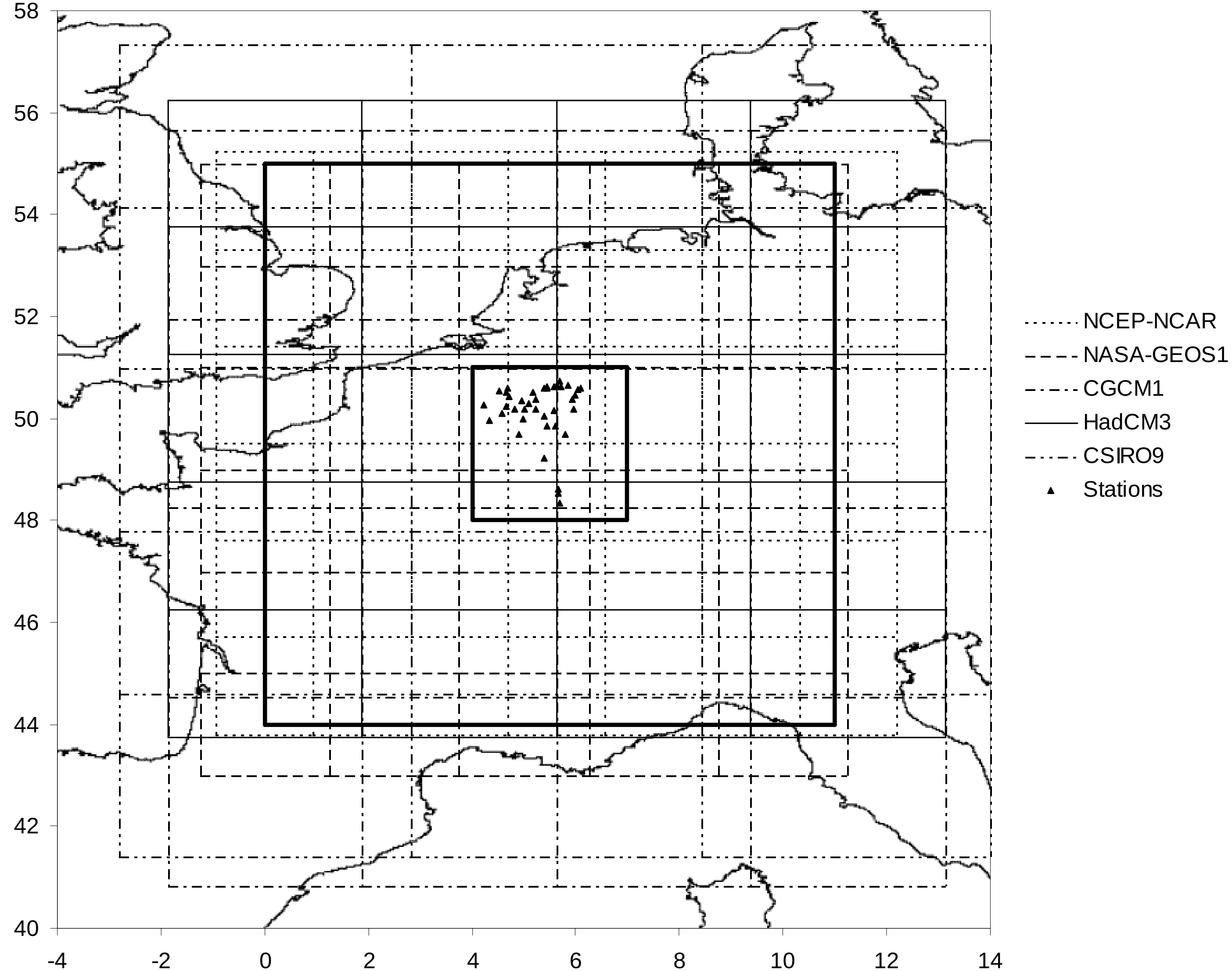

Climate change in the Meuse basin (3)

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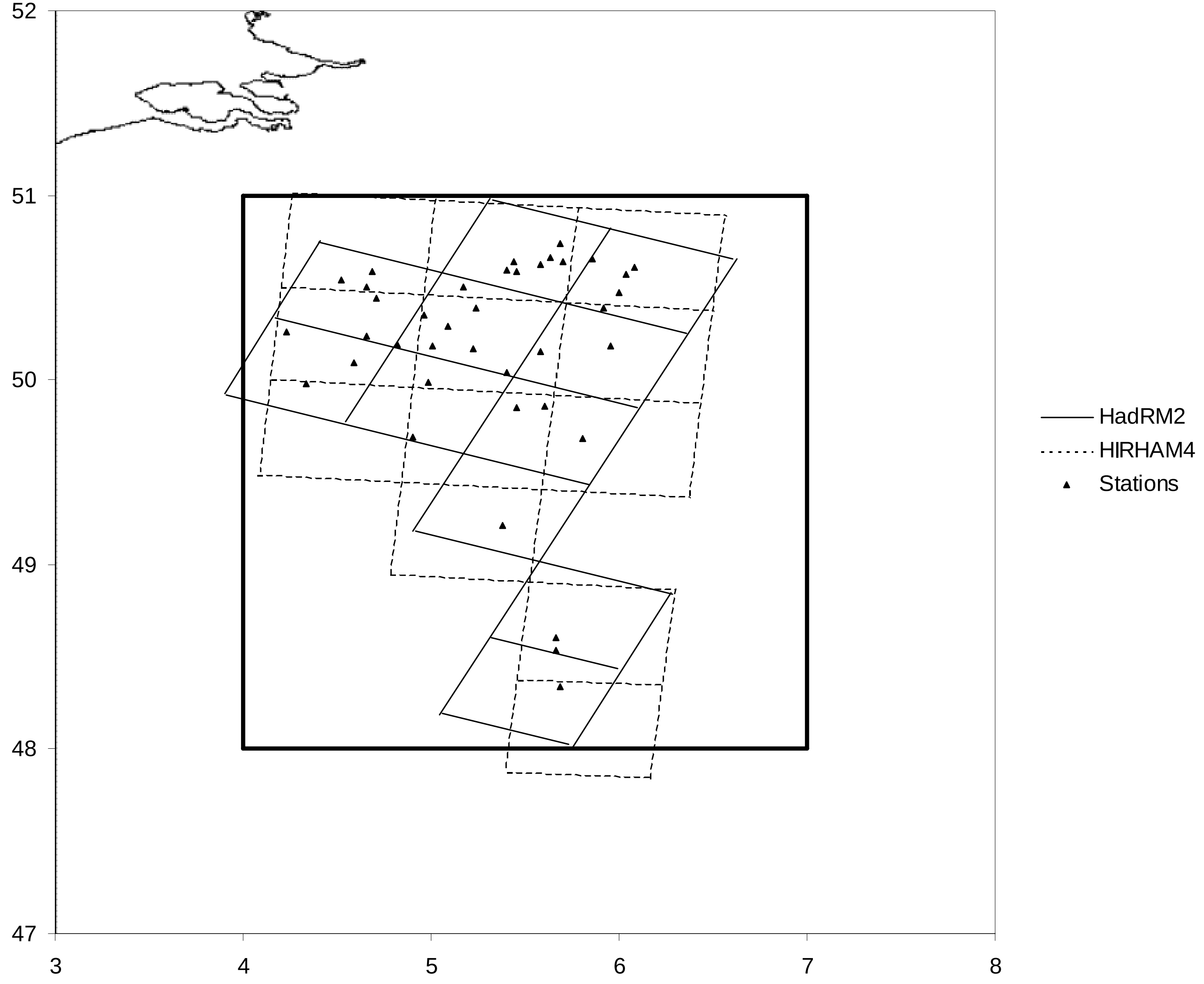

Climate change in the Meuse basin (4)

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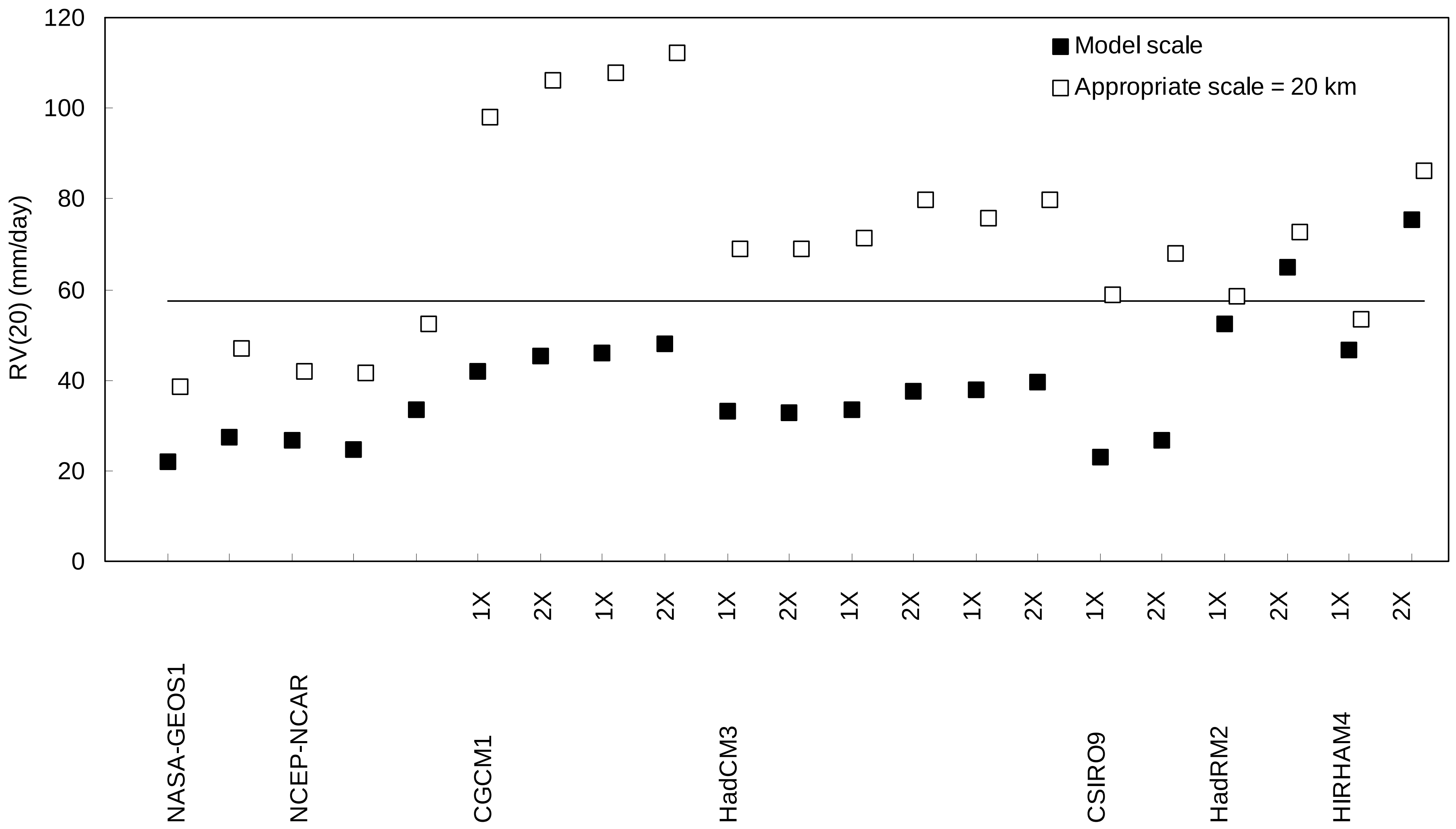
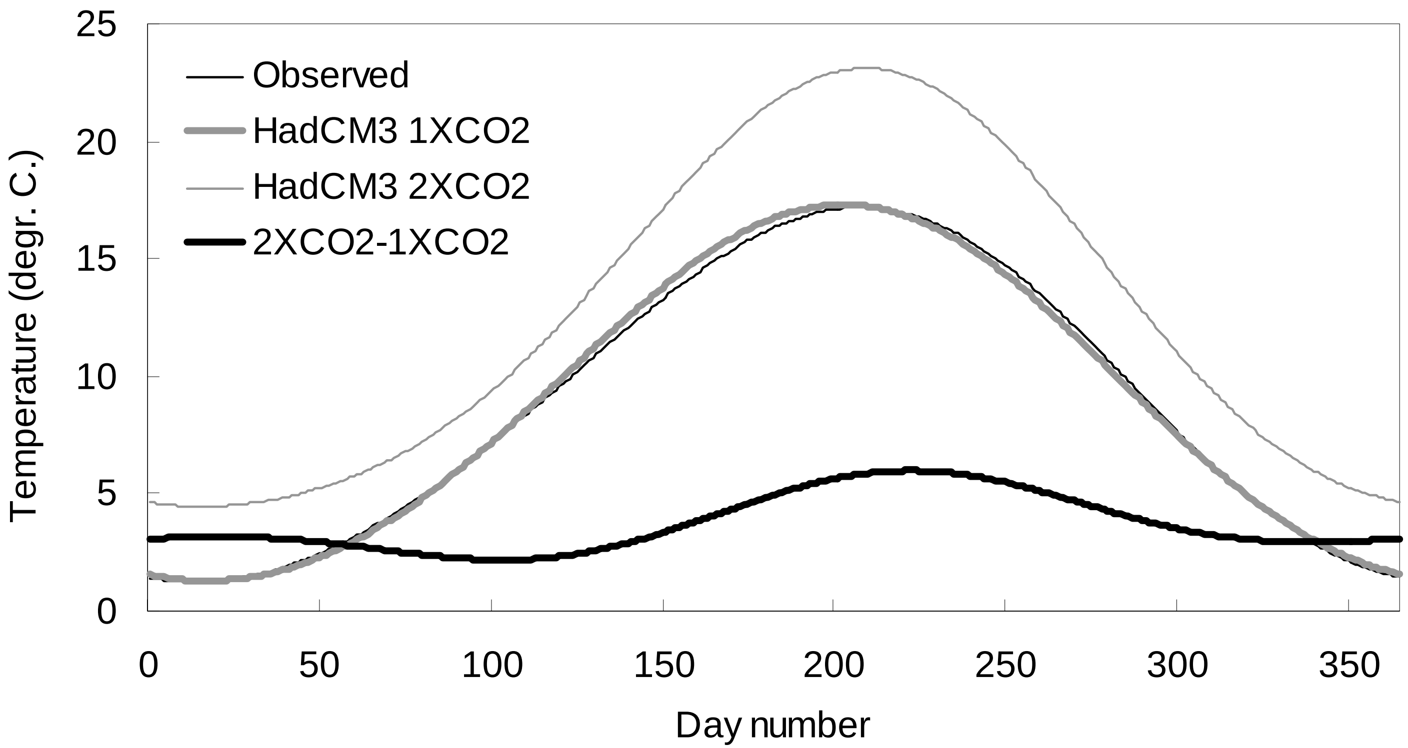


Climate change in the Meuse basin (5)



Model appropriateness (1)

- **Simple models and complex models → appropriate model dependent on research objectives, research area etc.**
  - **data and computational costs vs. required accuracy**
  - **balance of uncertainties**

  - **key processes and variables**
  - **appropriate temporal scales**
  - **appropriate spatial scales**
  - **appropriate formulations**

Model appropriateness (2)

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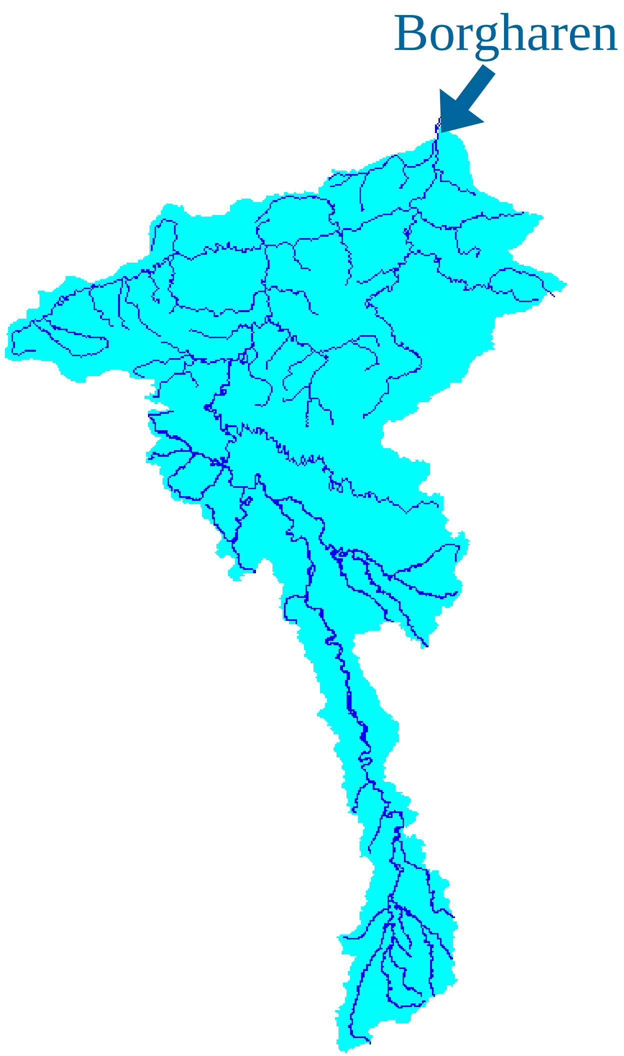
- **Appropriate model developed is a river basin model to assess impact of climate change on river flooding**
- **Research area is Meuse basin upstream of Borgharen in Belgium and France**



Appropriate model components (1)

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- Key variables
  - extreme precipitation (annual maximum)
  - temperature
  - elevation
  - soil type
  - land use type
- Appropriate temporal scale: 1 day
- Appropriate spatial scales: based on loss of variability (less extreme behaviour) with larger model scales ➔

Appropriate model components (2)

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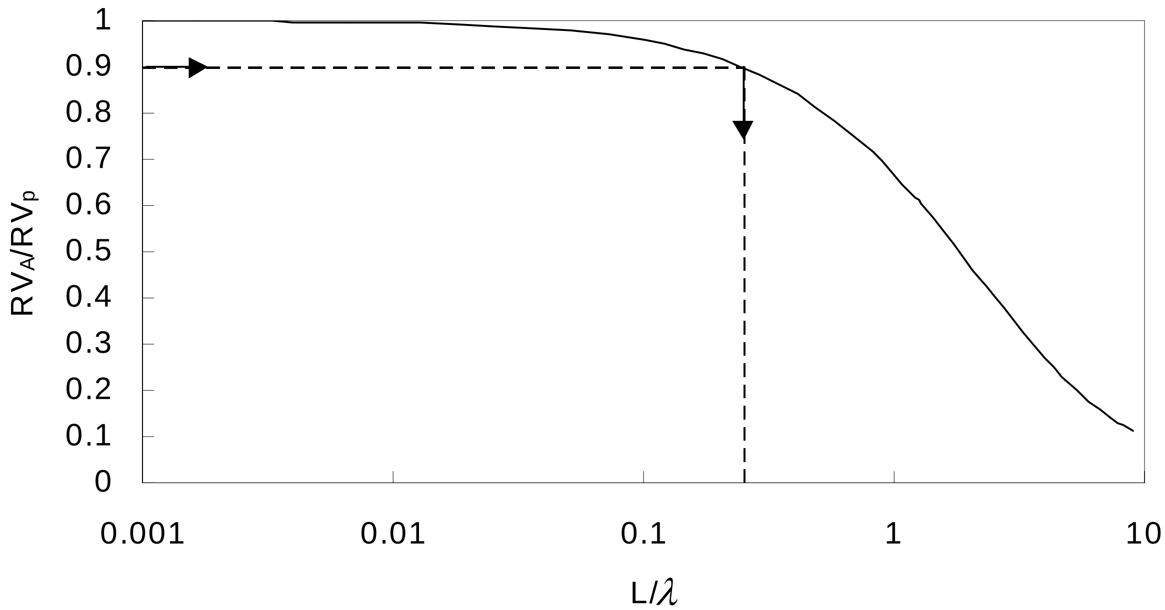

For other statistics such as variance, similar relationships dependent on correlation structure/ length λ and scale L

Appropriate model components (3)

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➔ appropriate: 10 % error in estimating statistic:

- daily average temperature (stations): ~1000 km >> extent of river basin area
- annual maximum daily precipitation (stations): ~20 km (this means for the Meuse basin upstream of Borgharen > 50 precipitation stations or model cells)
- elevation: ~0.11 km
- soil type: ~3.3 km
- land use type: ~5.3 km

➔integrated appropriate model scale (based on relative importance of separate scales for peak discharge) : ~ 10 km (150-200 sub-basins upstream of Borgharen)

- Appropriate formulations: dependent on scale (+ model used)

Rainfal modelling (1)

Requirements:

- Climate variables at appropriate scales
  - Precipitation (L = 20 km) ➔ for changed climate no GCM or RCM model data available at this scale ➔ statistical downscaling – random cascade model
  - Temperature (L >> extent of river basin area) ➔ GCM and RCM data can directly be used
- Time series of sufficient length (30 years)
- Multiple stochastic simulations (ensembles)

Rainfal modelling (2)

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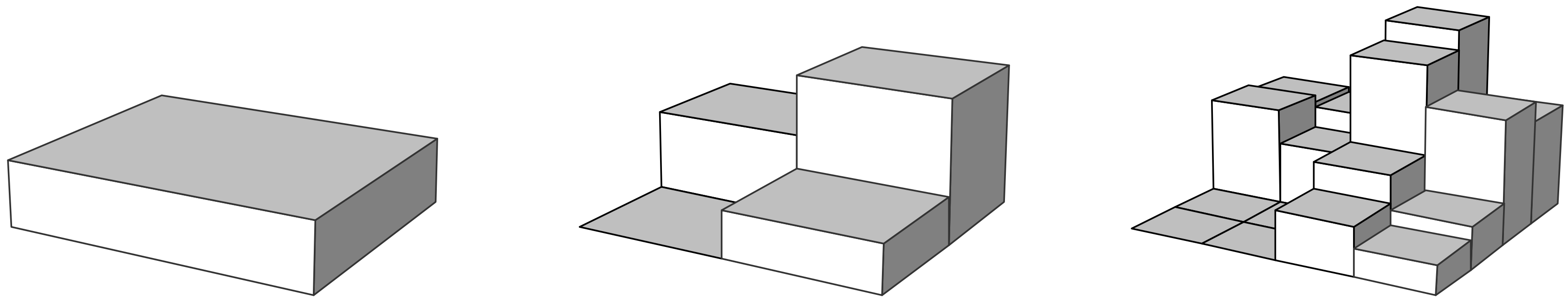
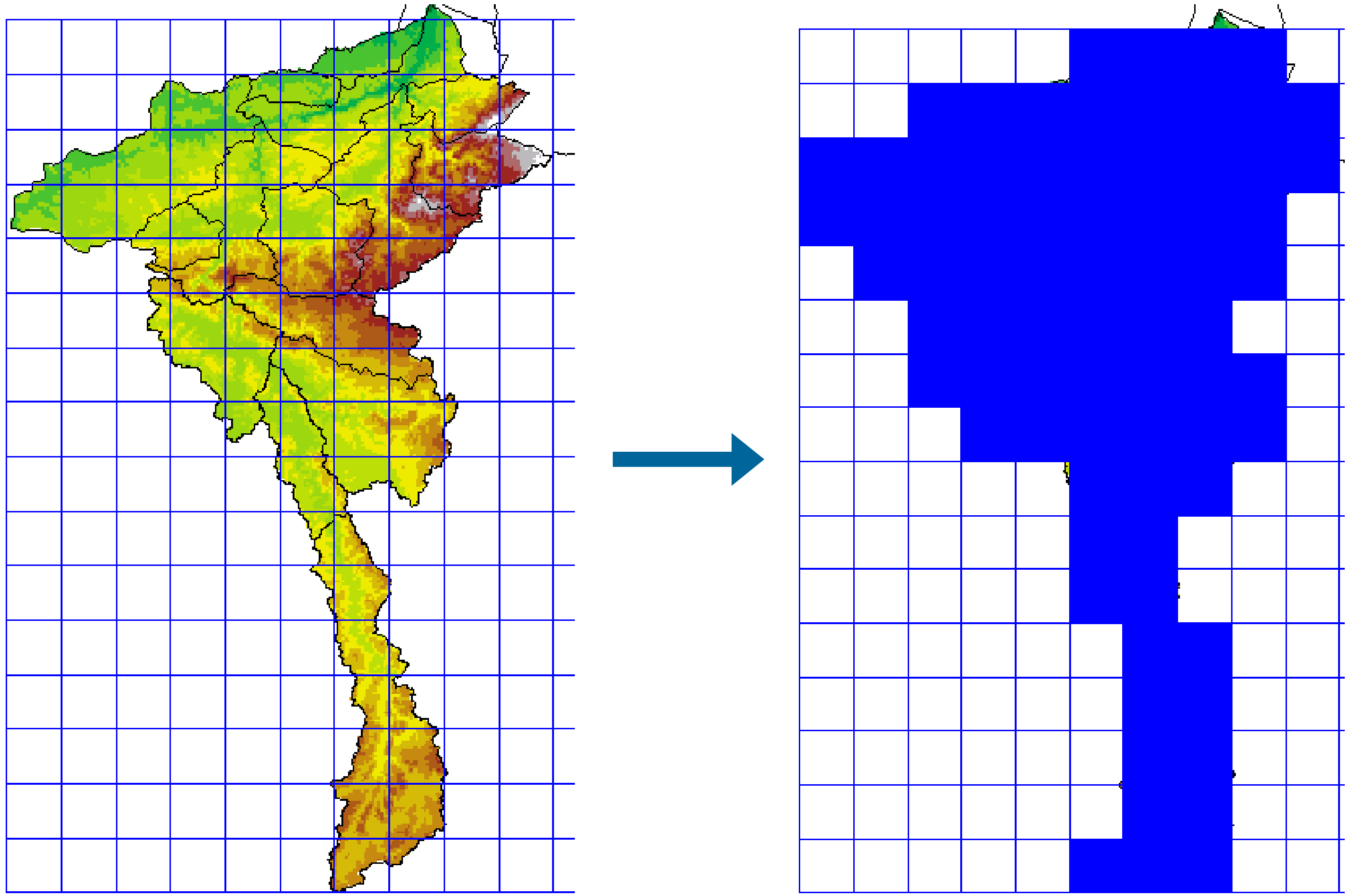
Random Cascade rainfall model (e.g. Jothityangkoon *et al.*, 2000)

- Temporal rainfall model for occurrence and amount
- Spatial rainfall model based on discrete random cascade with use of 'cascade generators'



Rainfal modelling (3)

Model grid (76 cells)



Rainfal modelling (4)

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	Precipitation	Temperature	Potential ET
Calibration	Stations (39) 1970-1984	Stations (12) 1970-1984	Stations (8) 1970-1984
Validation	Stations 1985-1996	Stations 1985-1996	Stations 1985-1996
Current climate	Random C. (76) 30 years	Stations 1967-1996	Stations 1967-1996
Changed climate	Random C. 30 years	Stations+change 1967-1996	Stations+change 1967-1996

Results rainfall (1) | current 10 years

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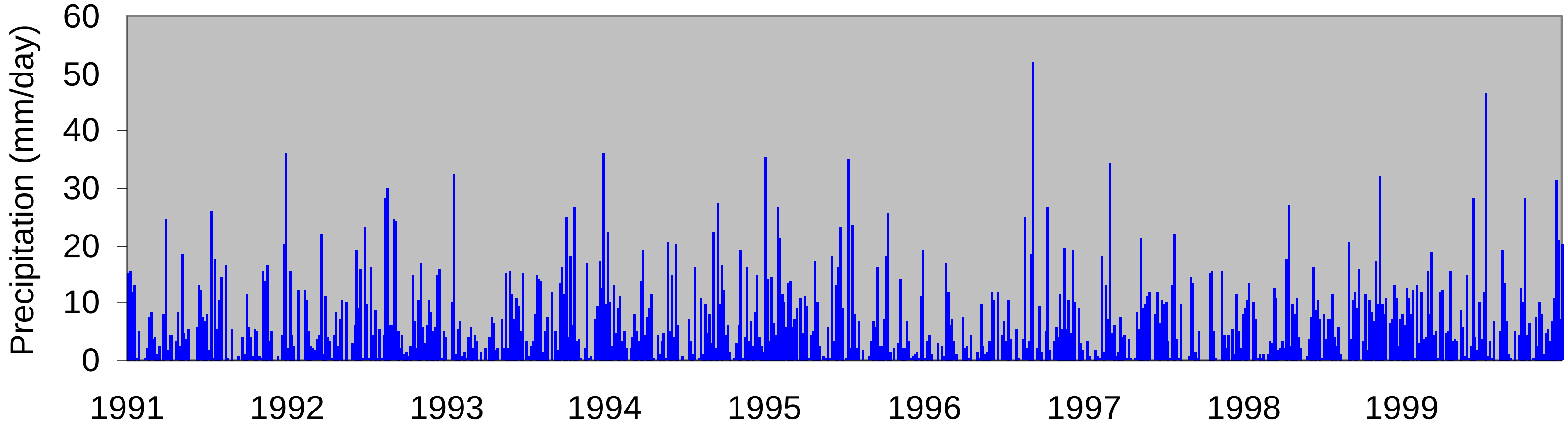
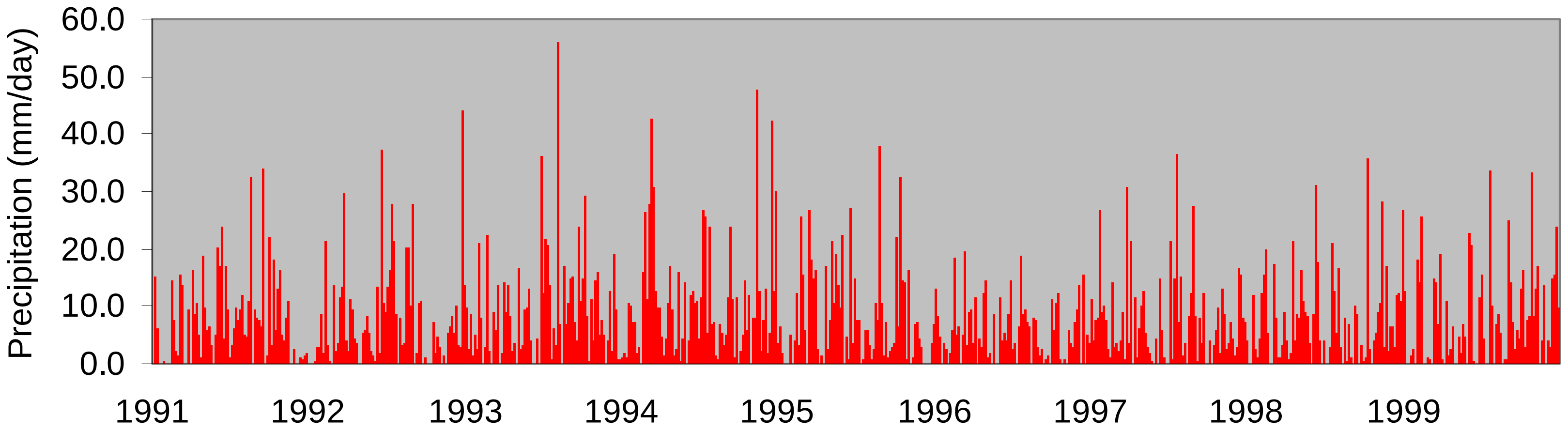
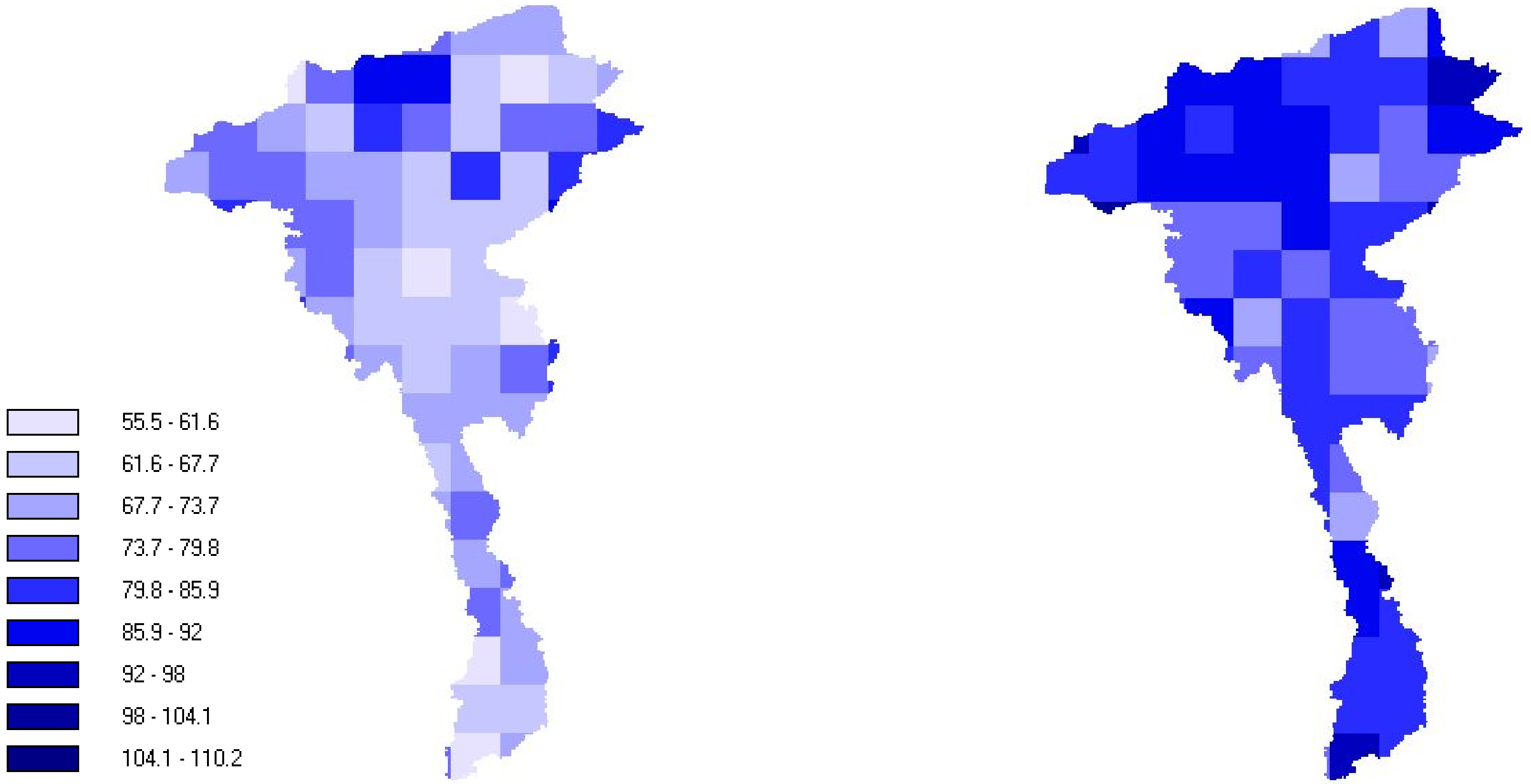
- **Observed (~20 km)**



- **Modelled (20 km)**



Results rainfall (2) | modelled 100-year extreme rain



Current
20 km scale

Changed
20 km scale

Results rainfall (3) | modelled extreme values

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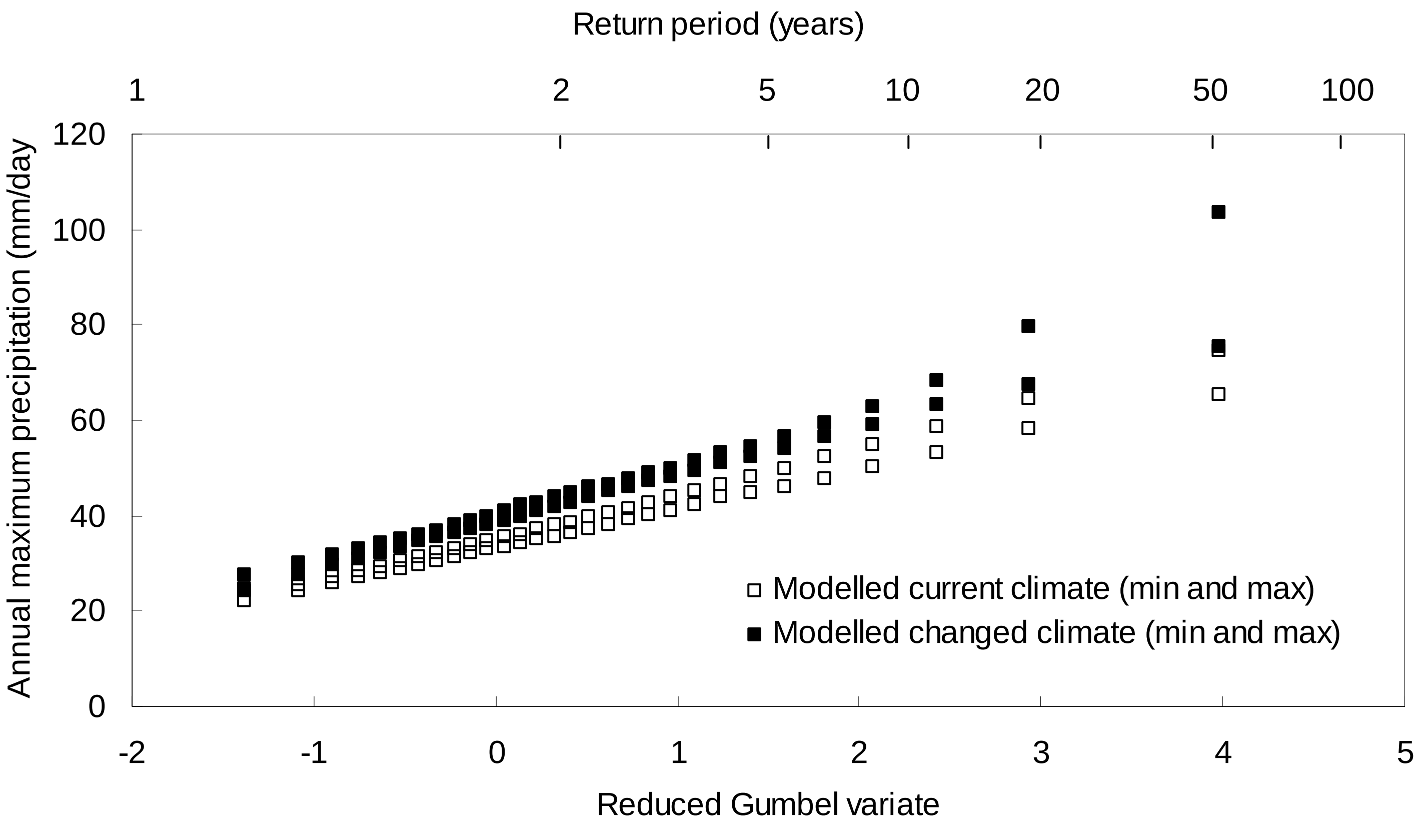

Results rainfall (4) | summary

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Appropriate scale statistics (20 km)		Current climate		Changed climate	
		Observed	Modelled	GCMs/ RCMs	Modelled
Average	(mm/day)	2.6	2.7-2.9	2.9	2.7-3.1
Standard deviation	(mm/day)	5.0	5.1-5.3	5.9	5.7-6.1
Wet day frequency	(-)	0.63	0.45-0.46	0.49	0.38-0.40
Spatial correlation length	(km)	324	332-349	389	382-404
Temporal corr. cf. (lag-1)	(-)	0.26	0.23-0.25	0.23	0.24-0.26
Return value (20-year)	(mm/day)	57.5	57.3-63.2	68.8	67.8-77.6
Return value (100-year)	(mm/day)	72.1	70.6-78.7	84.8	83.1-98.4
Five-day 100-year RV	(mm/day)	130	122-134	142	138-157
Ten-day 100-year RV	(mm/day)	174	165-173	190	182-206

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River basin models (1)

- River basin model developed within existing flexible modelling framework HBV (SMHI, Sweden)

- Impact assessment with appropriate model and two additional models:
  - 1 sub-basin (HBV-1) ~145 km
  - 15 sub-basins (HBV-15) ~37 km
  - 118 sub-basins (HBV-118) ~13 km

River basin models (2)

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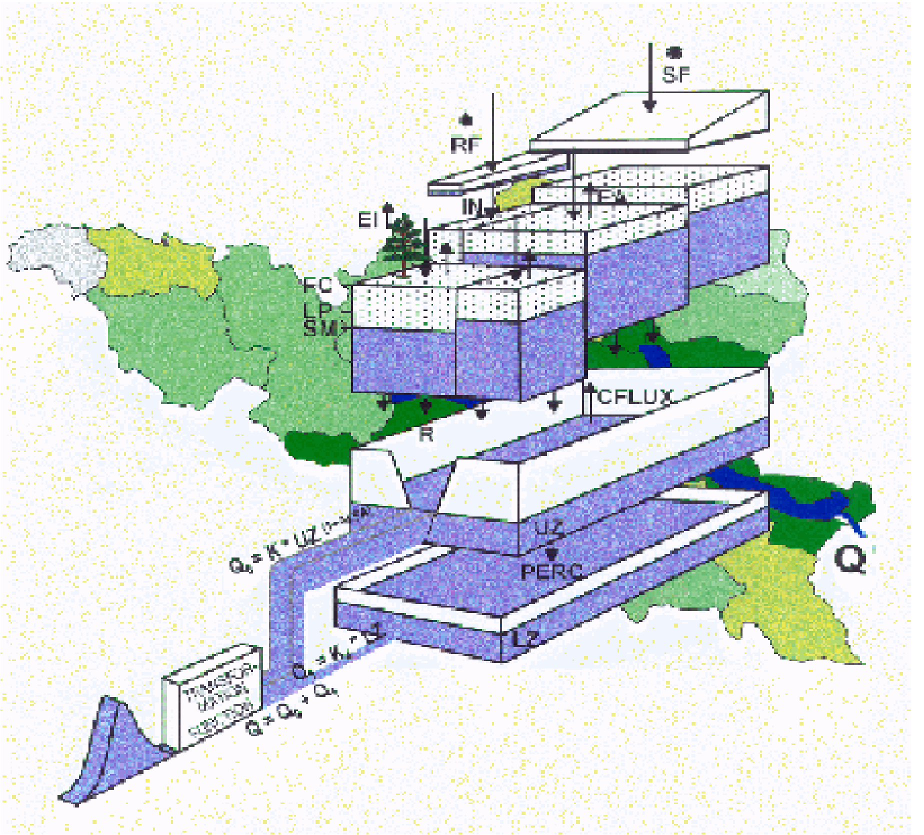
HBV model: components

- Precipitation (rain + snow)
- Soil moisture
- Quick runoff
- Base flow
- Transformation of runoff
- River routing



Calibration:

- Discharge data
- Relations HBV parameters and physical characteristics (e.g. infiltration capacity and soil type)

River basin models (3)

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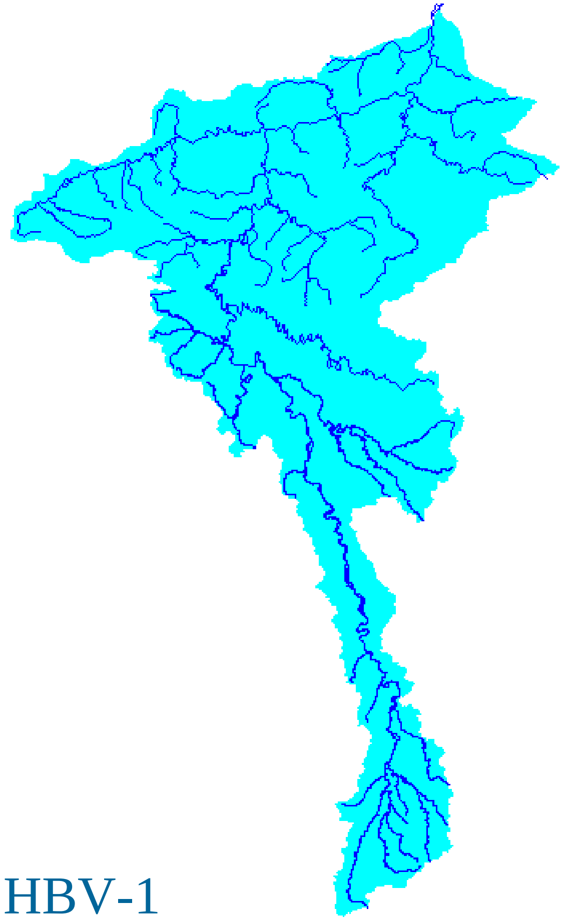
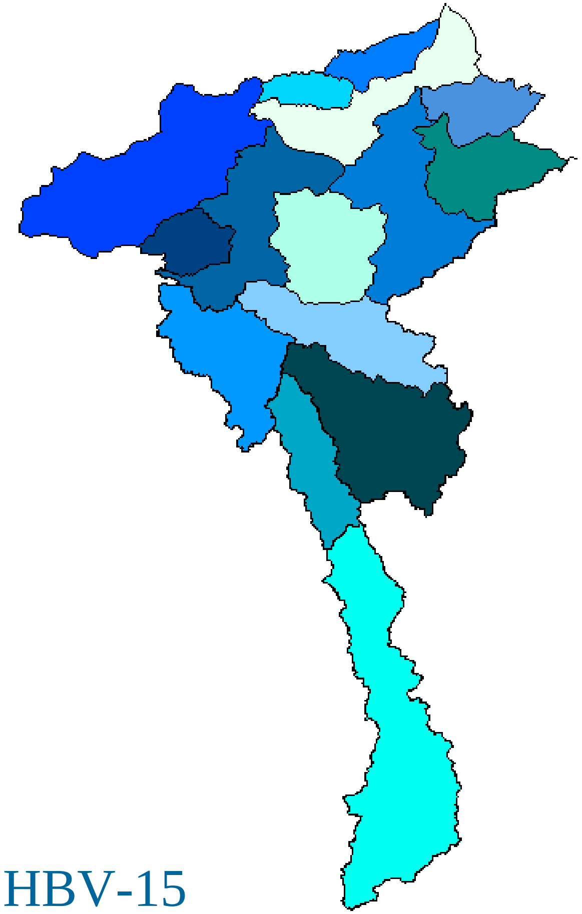
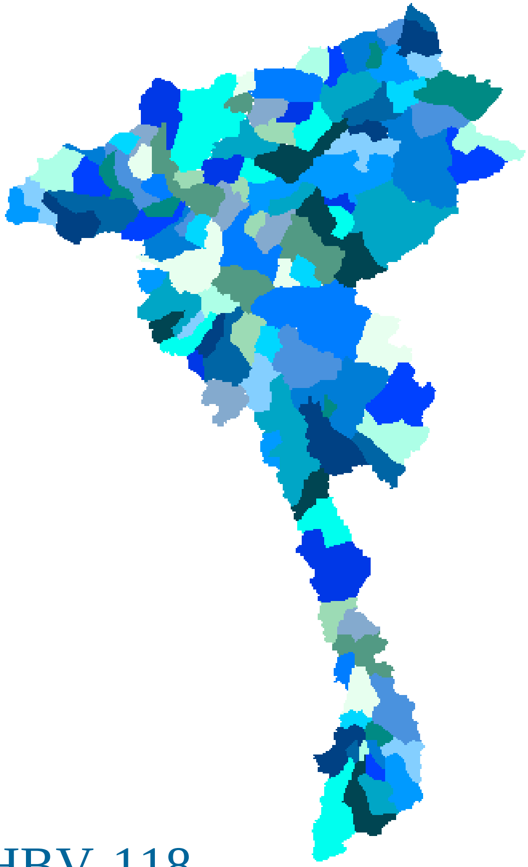


HBV-1



HBV-15



HBV-118

Results river basin (1) | calibration

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- **Results basin**
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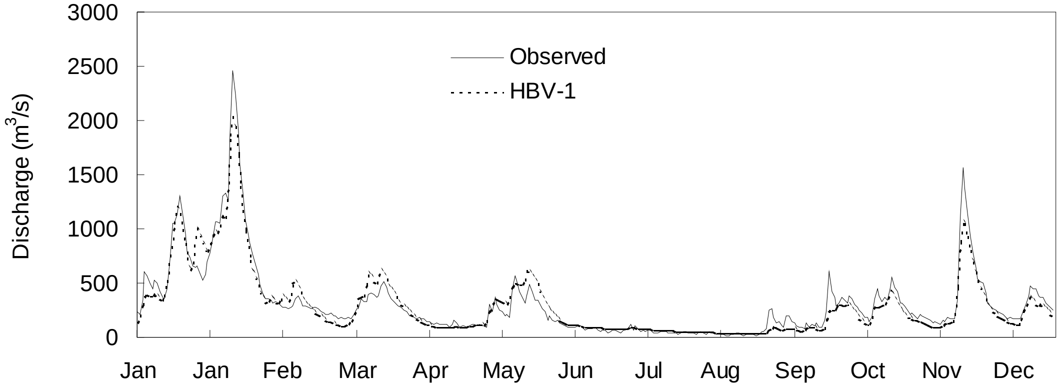
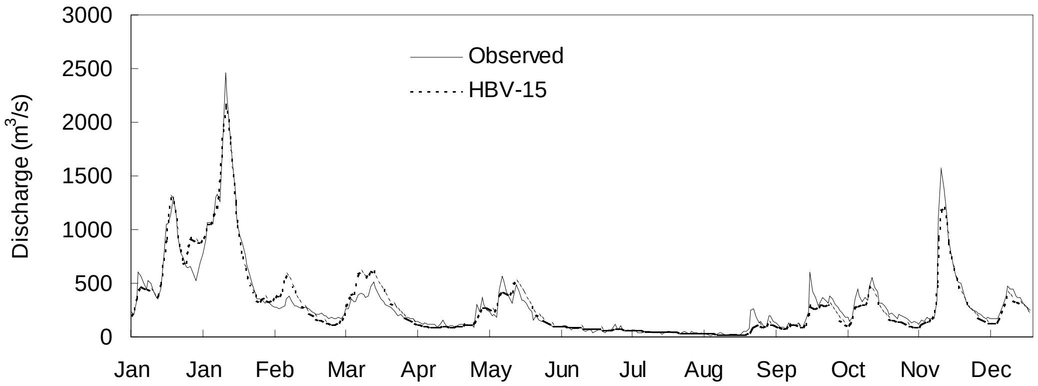
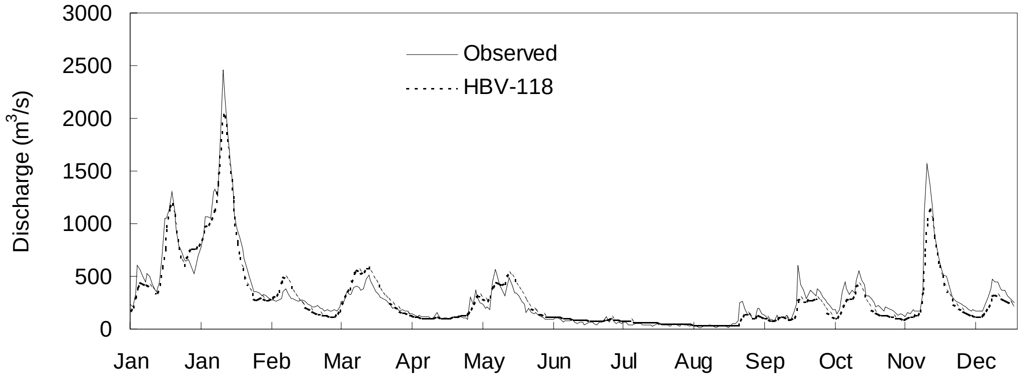
daily discharge at Borgharen







Results river basin (2) | calibration

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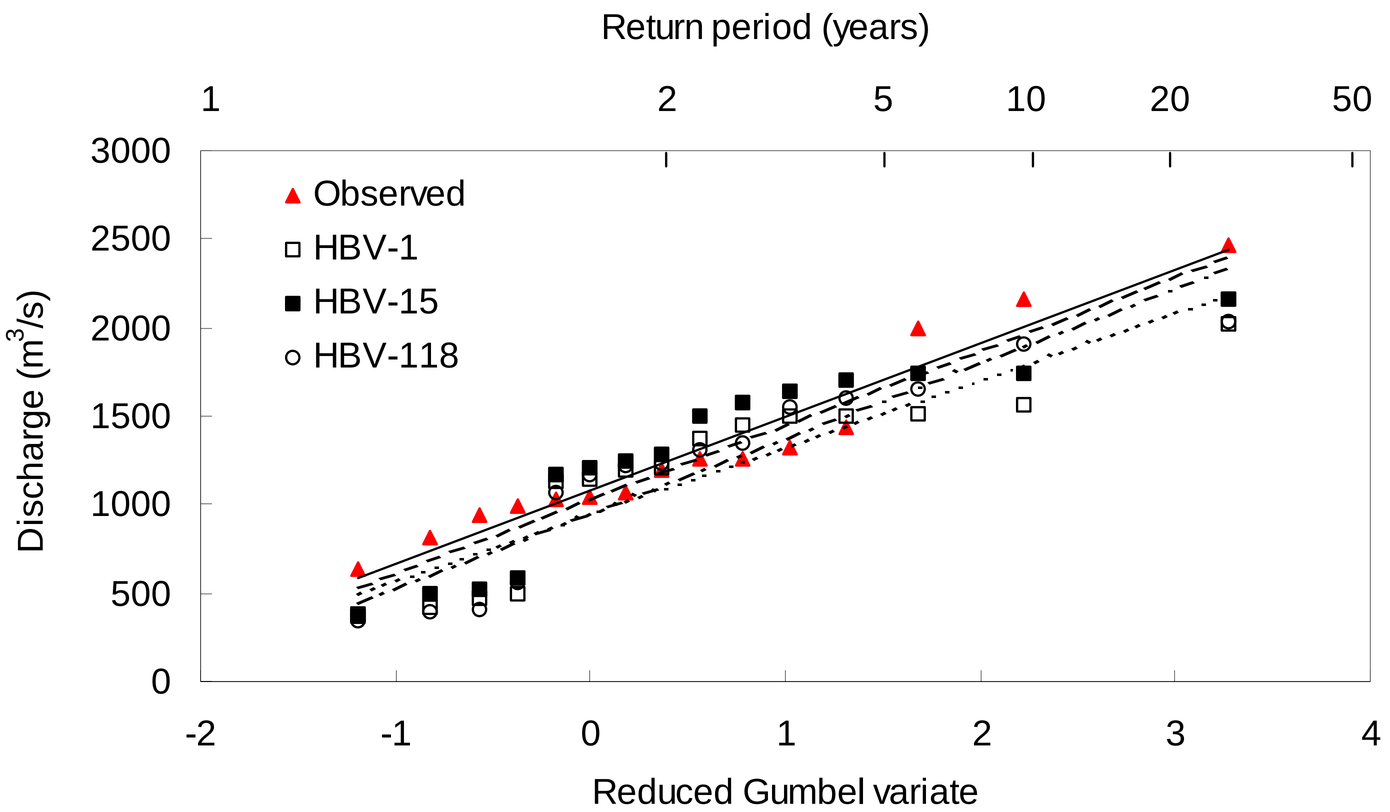
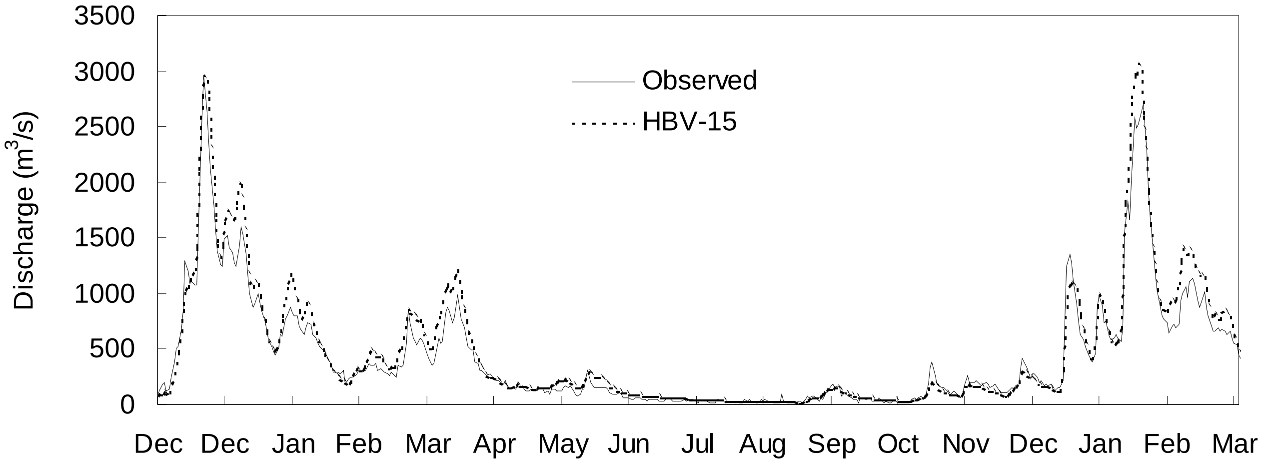
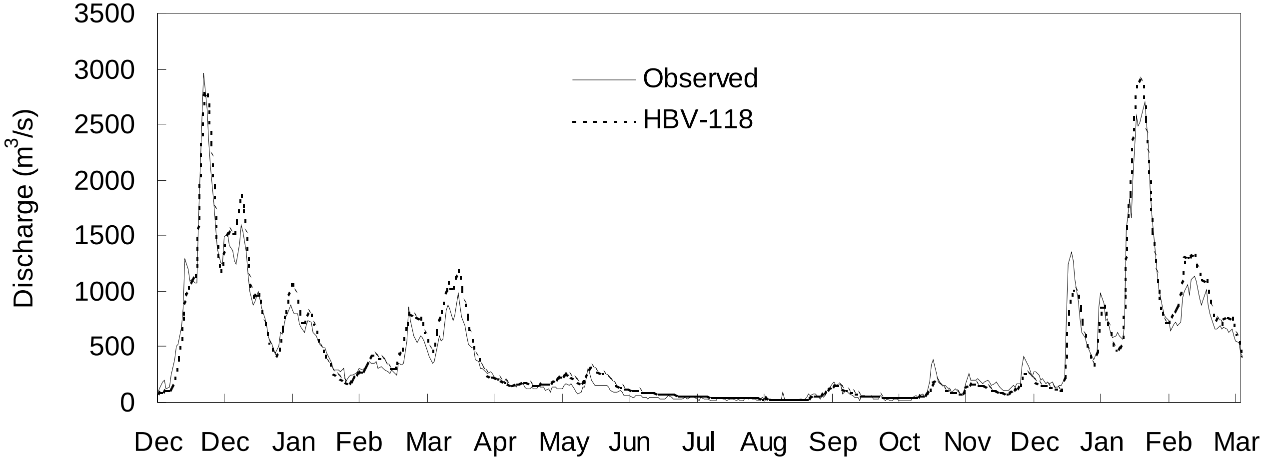


Results river basin (3) | validation





Results river basin (4) | current climate

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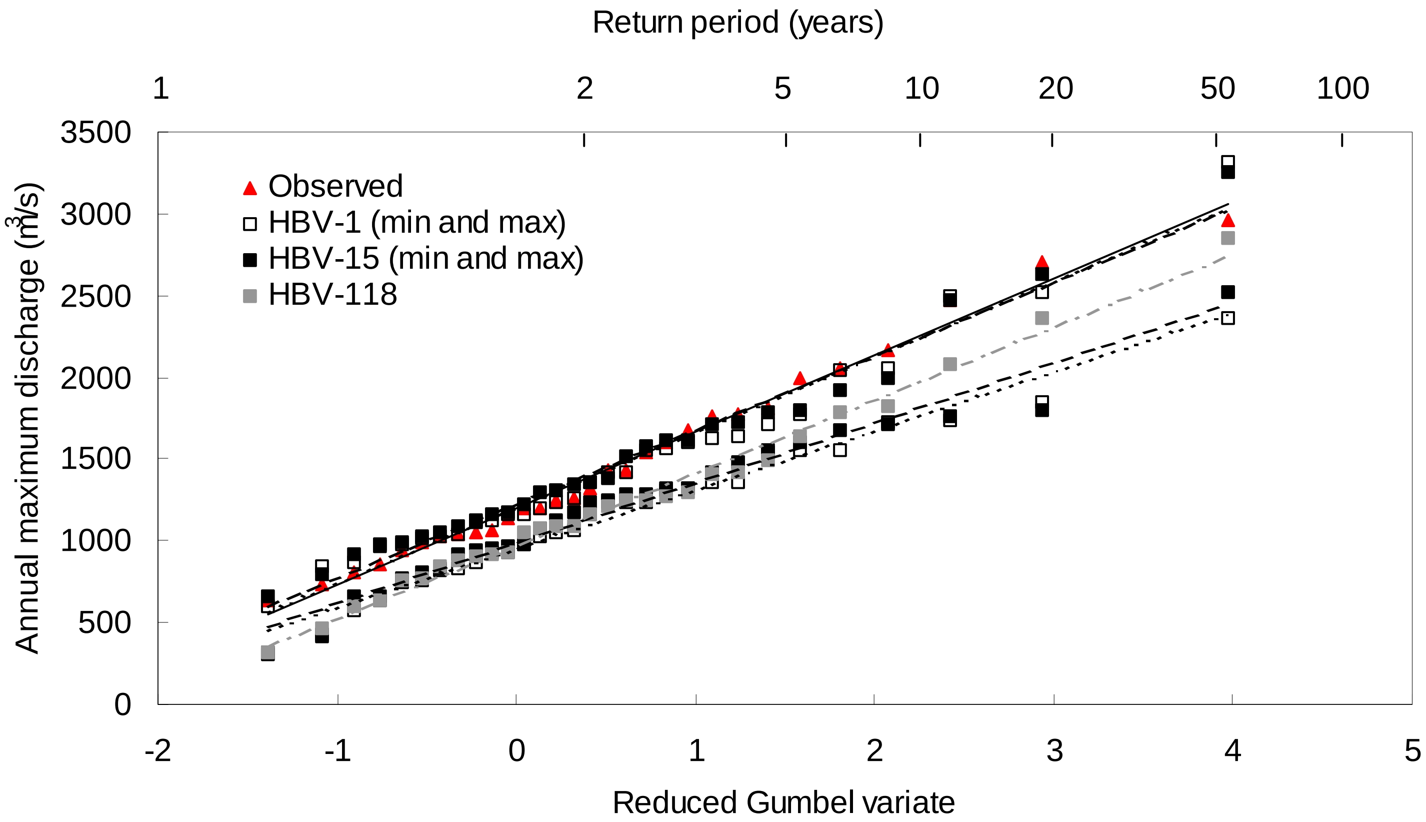

Results river basin (5) | current + changed climate

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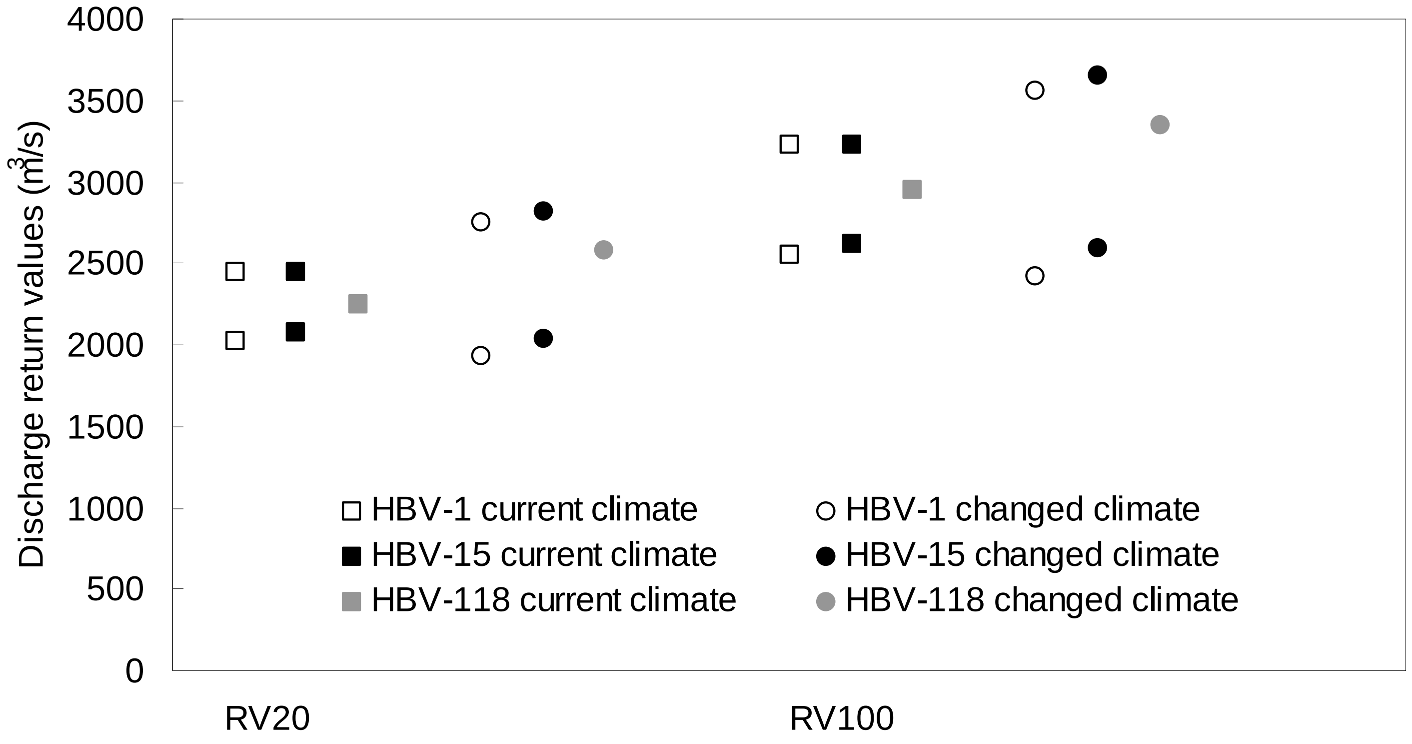
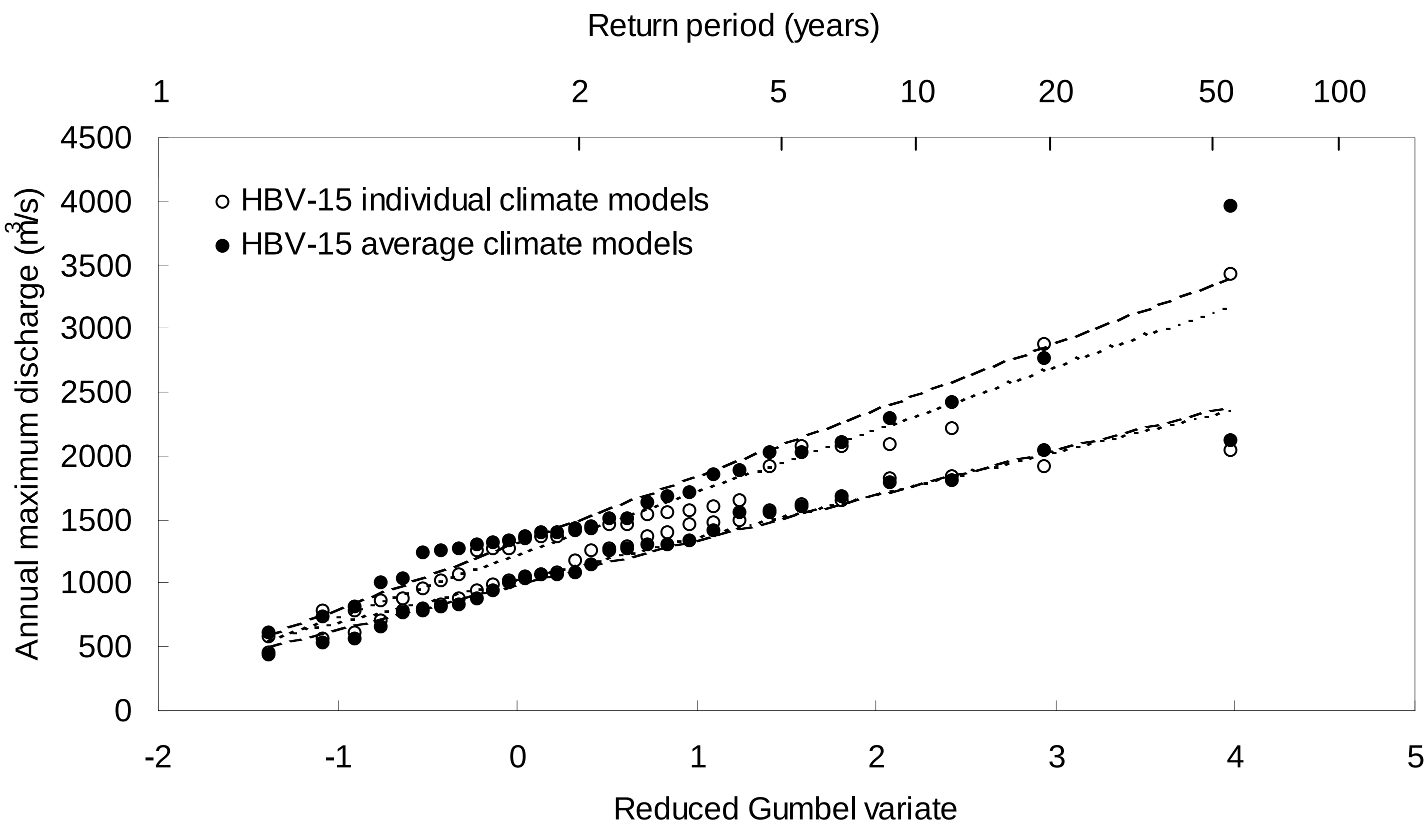


Results river basin (6) | uncertainty



Conclusions (1)

- Appropriate spatial scale for daily precipitation is about 20 km
- Other appropriate scales vary between 100 m – 1000 km
- Appropriate model scale is about 10 km; 150-200 sub-basins for the Meuse basin (daily time scale)
- Usefulness of model appropriateness procedure
  - ability to assess appropriate scales before model construction and integrate them into a model scale
  - provision of a framework for decisions about reduction or expansion of data networks and needs

Conclusions (2)

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- Rainfall model simulates a realistic climate; all relevant observed statistics are correctly reproduced, except the wet day frequency
- Most important effects of climate change on precipitation are increases in variability (14 %), extreme values (18 %) and spatial correlation (13 %)
- Rainfall model is able to reproduce these changes at 20 km scale

- Average and extreme Meuse discharge behaviour well reproduced by three hydrological models
- Models results become somewhat better with increasing model complexity, differences between HBV-15 and HBV-118 small (additional discharge data may improve HBV-118)

Conclusions (3)

- Extreme discharge is underestimated when using synthetic rainfall due to ‘point’ character observed rainfall
- Small decrease of average discharge (~5 %) and increase in extreme discharge and variability (5-10 %) with climate change

- Main uncertainties are related to precipitation and extrapolation, model structure and parameter uncertainties are less important
- Trade-off between spatial and temporal accuracy
- Uncertainty in river flooding with climate change larger than change, however climate changes are systematic changes rather than random ones