Interreg Euregio Meuse-Rhine
EMFlood Resilience
EUROPEAN UNION European Regional Development Fund
Deltares

Estimation of discharge extremes in the Meuse basin

Application of high-resolution climate and hydrological models

Interreg Euregio Meuse-Rhine

Robert Slomp, Rita Lammersen, Niek van der Sleen (Rijkswaterstaat)

Leon van Voorst, Henk van den Brink (KNMI)

Anaïs Couasnon, Alessia Riveros, Laurène Bouaziz (Deltares)

September 12 2023

Main goals of the project

- Evaluate the use of **synthetic data** sets from climate models to calculate statistics in extreme discharge frequencies at the **sub-daily timestep** for the **main tributaries** of the Meuse

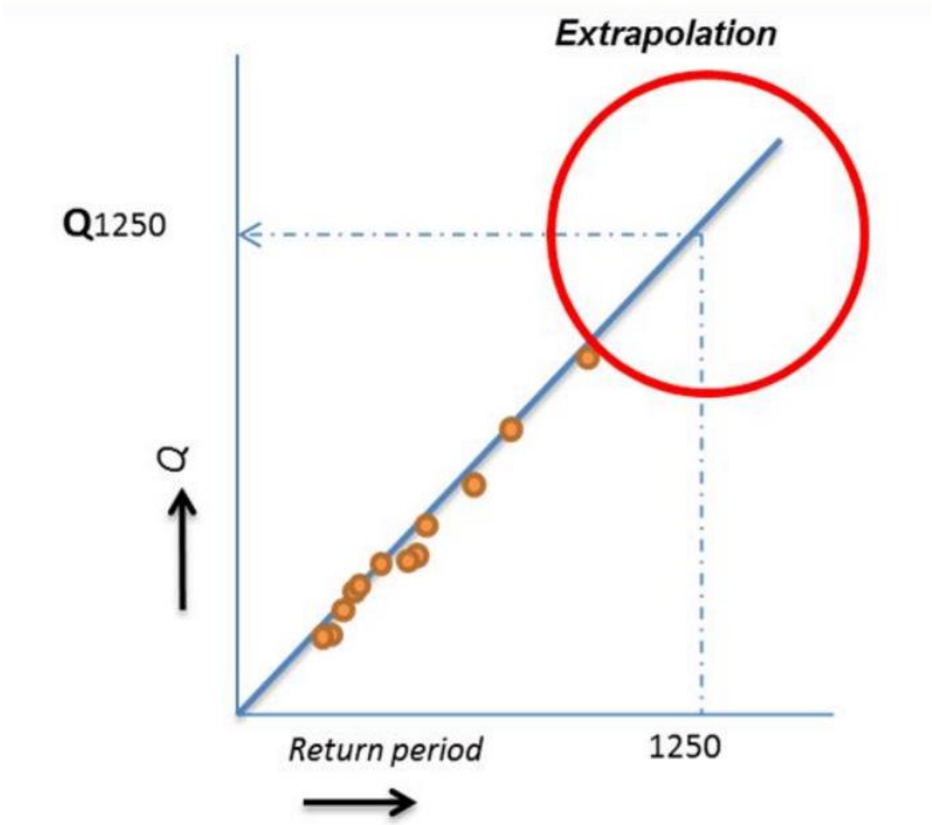
- Improve the model based on **feedback and information** of water managers in the basin

Partners

Lead partner:

Other partners:

Statistical extrapolation:

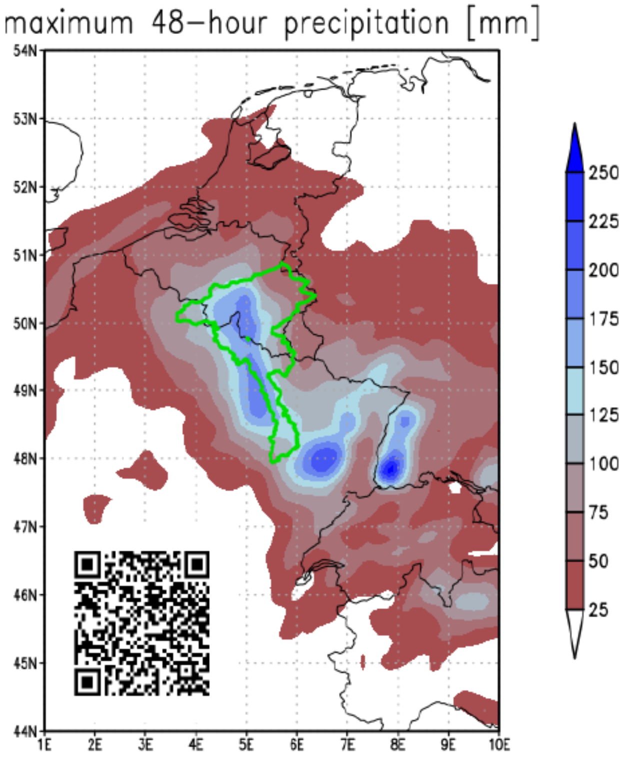


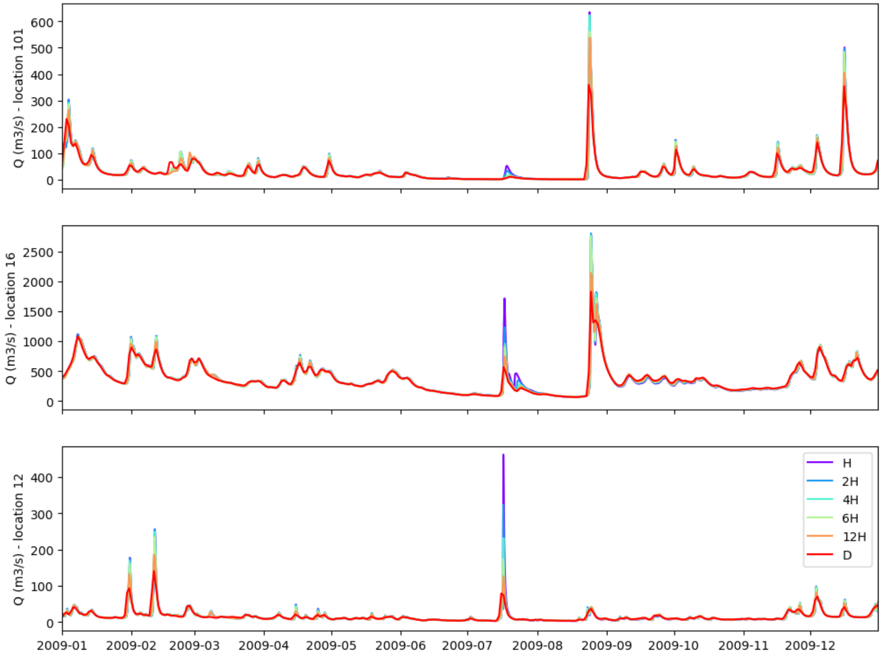
- Result depends
  - on (arbitrary) extrapolation method
  - on presence of observations

- Provides singular maximum values but no hydrograph representation

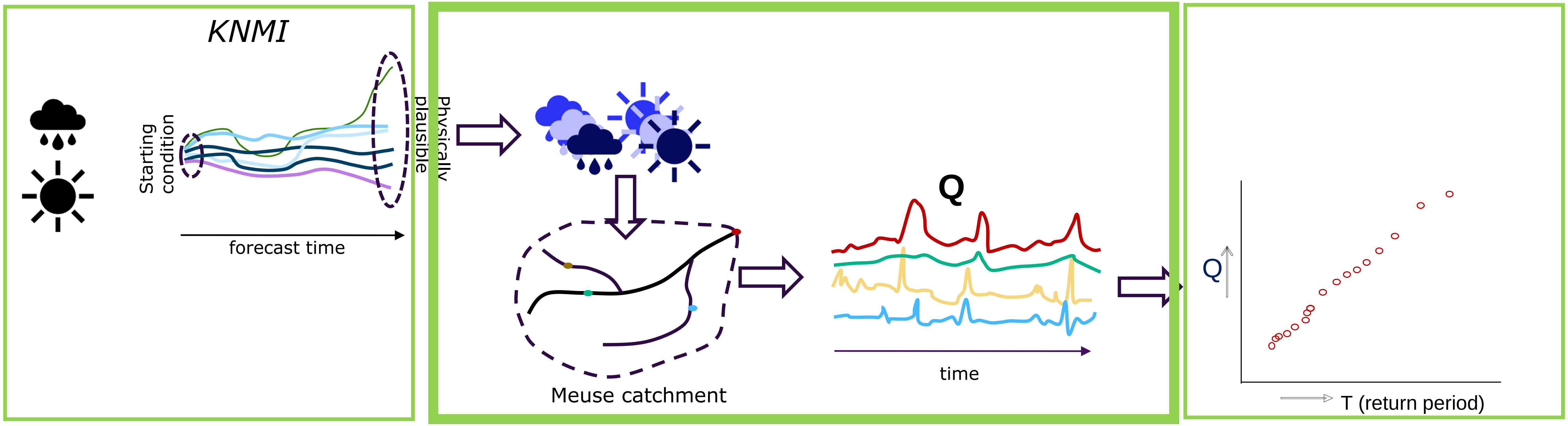
➢ Need for a longer dataset…

Intro: From synthetic meteorological data to extreme streamflow statistics





Suggested Approach

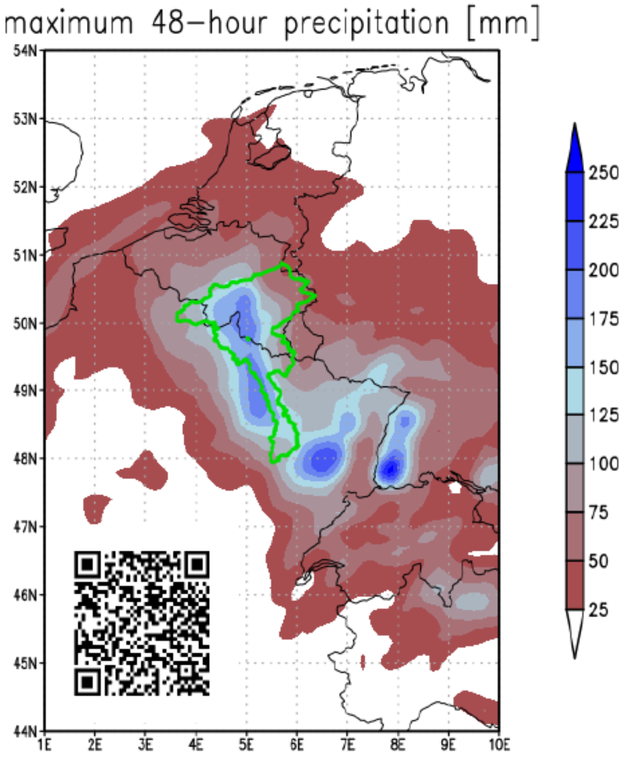


Fully automated process for efficient computing

RWS / Deltares

Datasets from KNMI → **Hydrological and hydraulic model** → **Datasets of discharges across the whole Meuse catchment** → **Postprocessing**

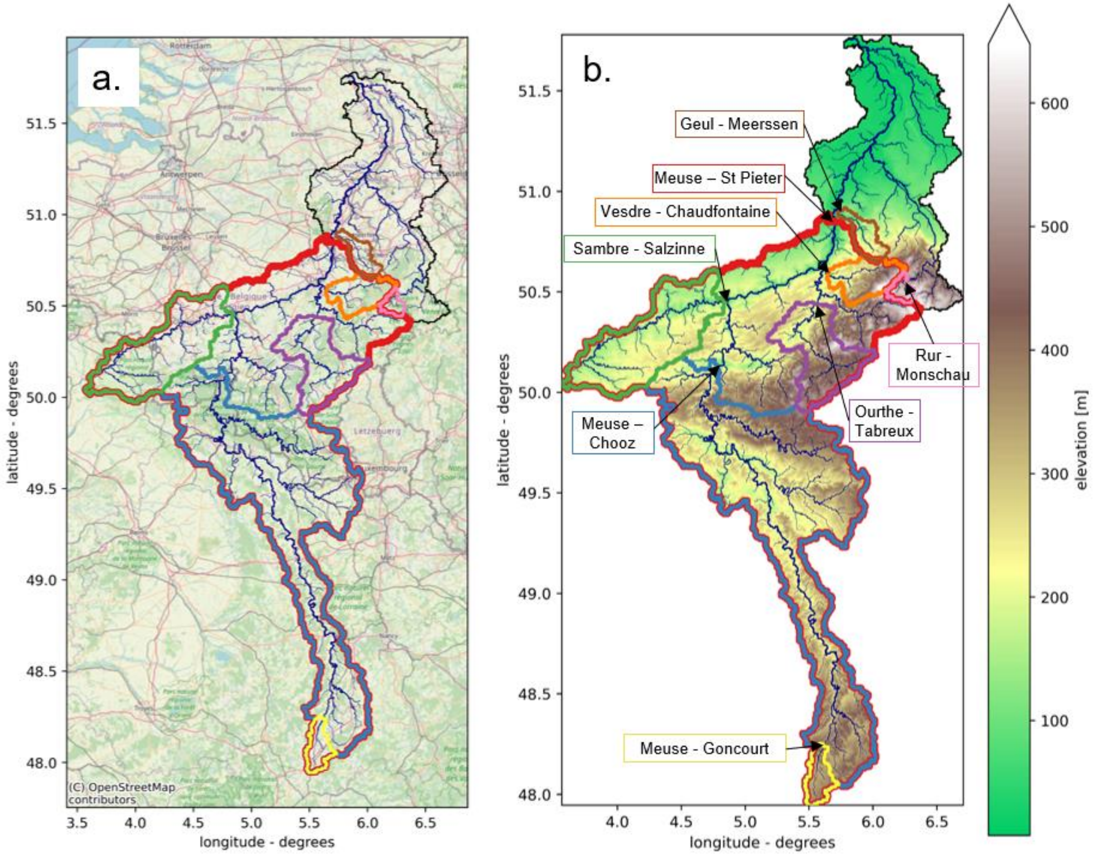
Intro: From synthetic meteorological data to extreme streamflow statistics



RACMO climate model provides:

- Longer timeseries than observations (~1100 years)
- High spatial resolution (12km x 12km)
- Hourly time resolution
- Many meteorological variables
- Ability to capture climate change

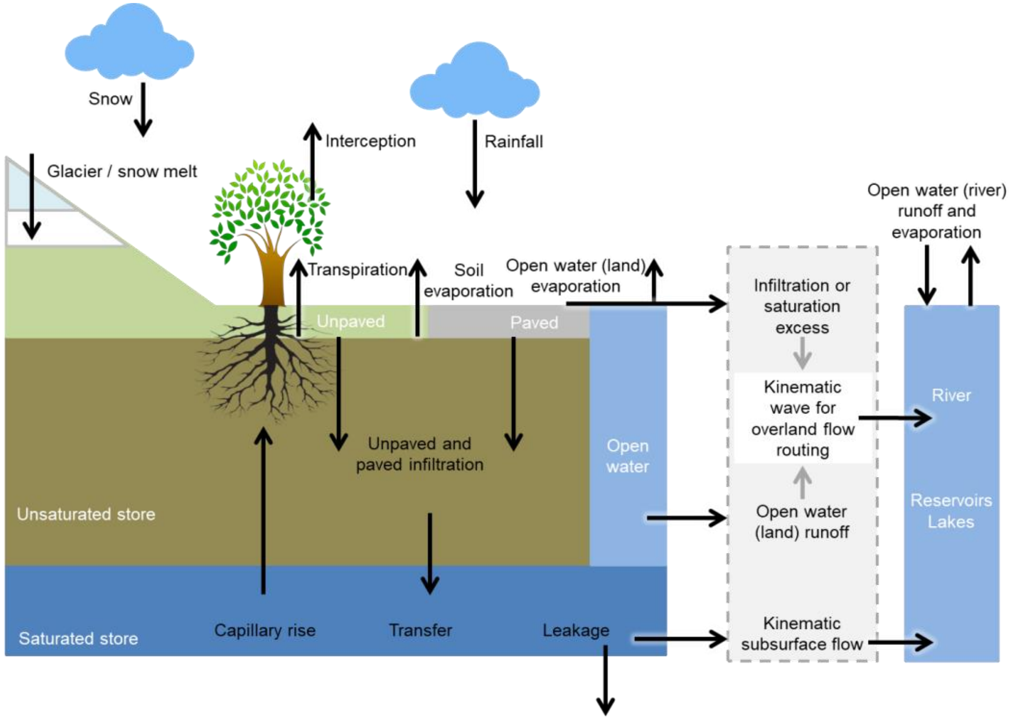
Catchment of interests



River	Location	Country	Catchment area (km^2)
Rur	Monschau	Germany	147
Geul	Hommerich	The Netherlands	151
Geul	Meerssen	The Netherlands	338
Meuse	Goncourt	France	364
Viroin	Treignes	Belgium	548
Vesdre	Chaudfontaine	Belgium	683
Ambleve	Martinrive	Belgium	1,068
Semois	Membre Pont	Belgium	1,226
Lesse	Gendron	Belgium	1,286
Ourthe	Tabreux	Belgium	1,607
Rur	Stah	Germany	2,152
Meuse	St Mihiel	France	2,551
Sambre	Salzinne	Belgium	2,842
Meuse	Chooz	France	10,120
Meuse	St Pieter	The Netherlands	21,233

Hydrological model: wflow_sbm model

- Wflow sbm is distributed hydrological modelling platform
- Open source https://github.com/Deltares/Wflow.jl
- Documented https://deltares.github.io/Wflow.jl/dev/
- Compiled executable https://download.deltares.nl/en/download/wflow/



wflow_sbm – main model components

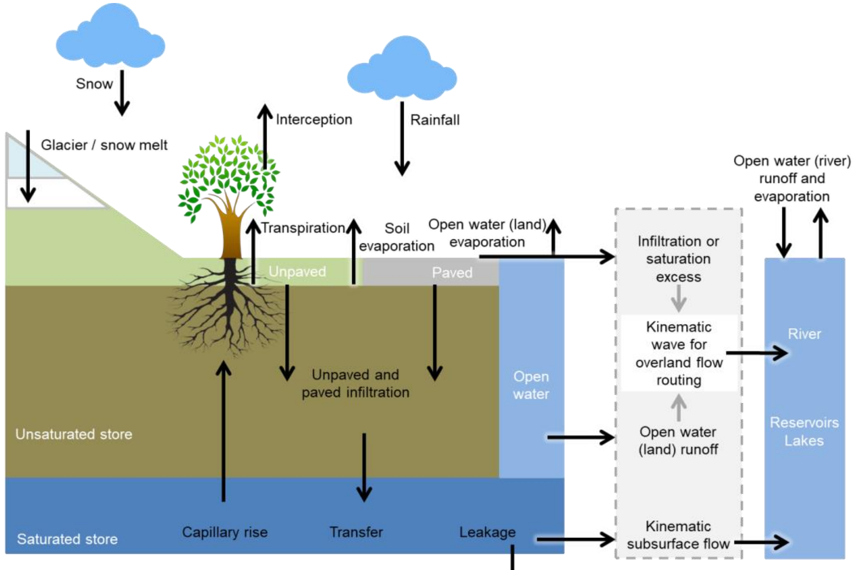
Vertical processes

- Snow (and glacier) processes
- Interception evaporation
- Infiltration into the soil (paved and unpaved areas)
- Capillary rise and recharge between the unsaturated and saturated soil layers
- Transpiration
- Soil and open water evaporation
- Deep groundwater leakage

Lateral processes

- Kinematic wave for overland, subsurface flow and river routing /
- Local inertial wave for overland flow and river routing

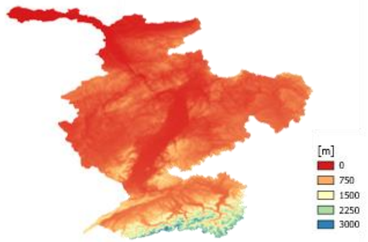
Lakes and reservoirs module



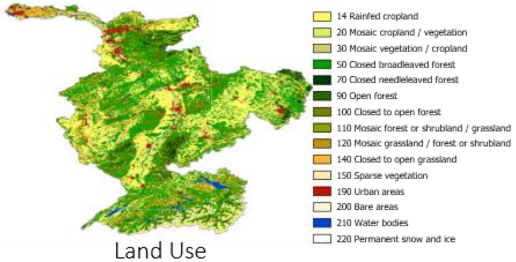
wflow_sbm model – distributed modelling

Gridded inputs

Static maps



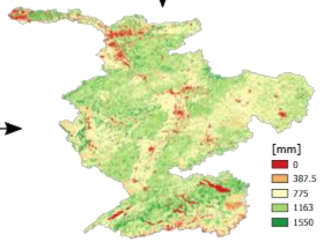
Elevation



Land Use

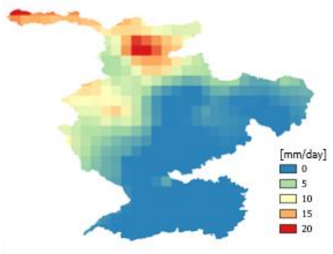
Derived parameters maps

Land Use	Rooting depth
14	750
20	750
30	750
40	1200
50	1000
60	1000
70	900
90	900
100	1200
110	1550
120	1550
130	1250
140	1200
150	200
180	750
190	100
200	0
210	0
220	0

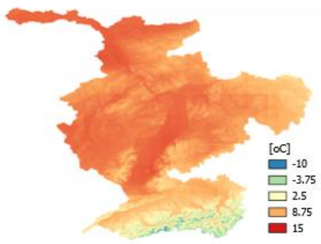


Depth of vegetation roots

Dynamic maps



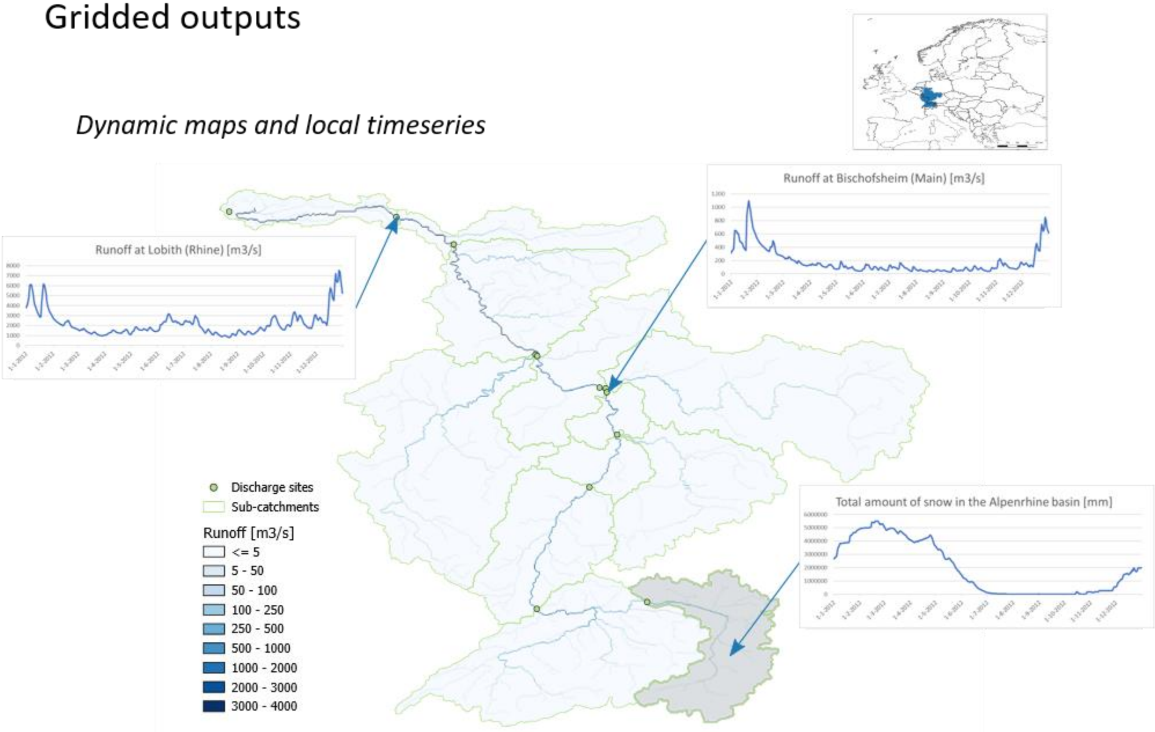
Precipitation



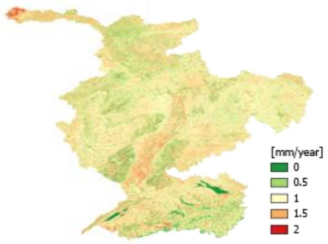
Temperature

Gridded outputs

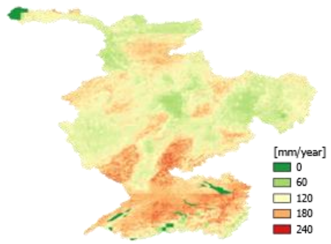
Dynamic maps and local timeseries



Statistics maps



Average evaporation



Total rainfall interception by vegetation

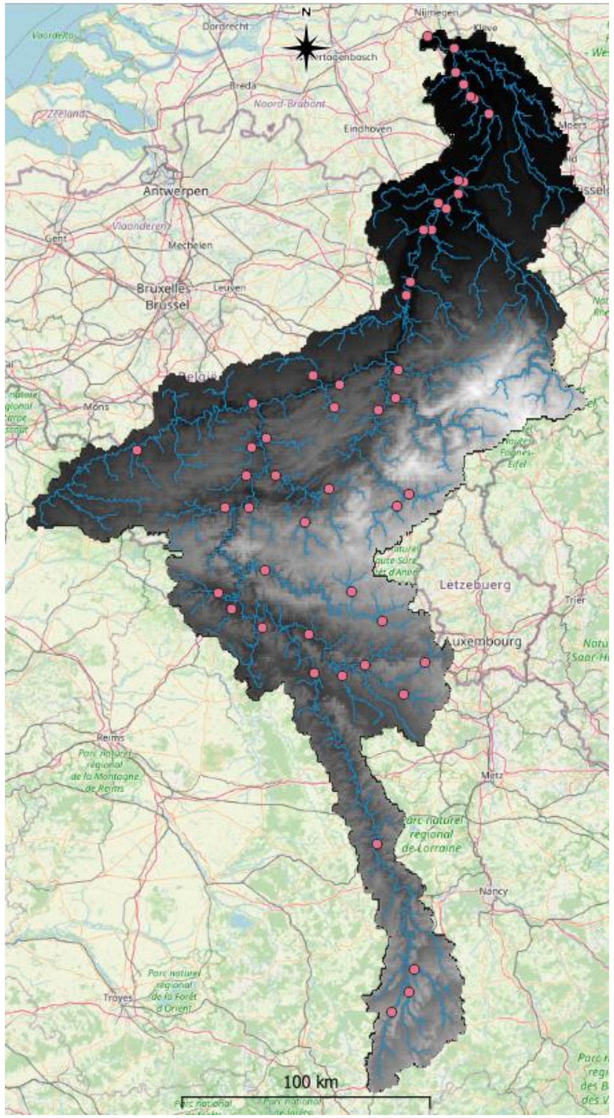
wflow_sbm model for the Meuse

- Since 2021: model set-up for the entire Meuse basin upstream of Mook
- For planning and operational purposes of Rijkswaterstaat

- Estimate model parameters from land-use and soil properties
- Includes a simple representation of reservoirs
- Model evaluation using historical data
- Different options for river routing (kinematic wave and local inertial approximation) along the river network

- Further improve model schematization within this Interreg project

Meuse model extent



Model improvements since workshop dec ’22

- **River routing**: Implementation of the local inertial approximation for river flows including a 1d representation of the floodplains
- Faster run times compared to the local inertial approximation with 1d2d representation of river flow and overbank flow into the floodplains

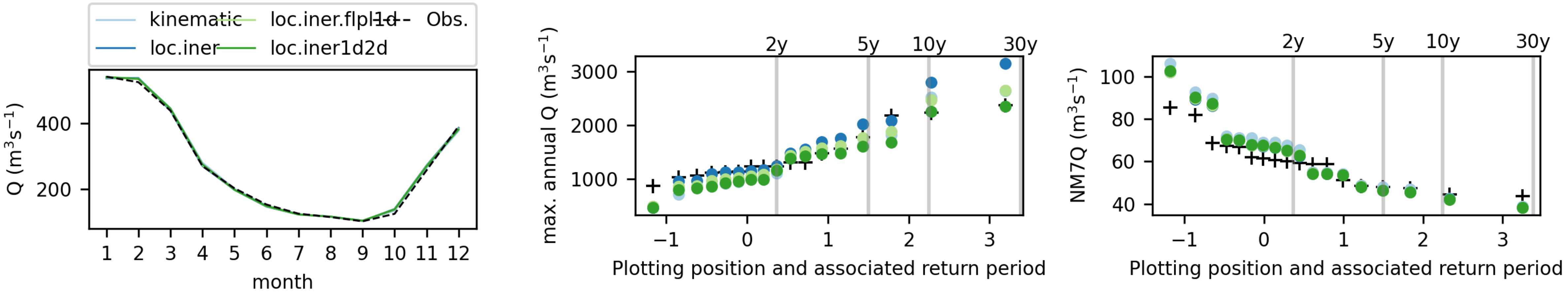
- **Manual calibration** of the **daily** model

- Integration of **optimized Geul and Rur models** as developed in the master theses work of two TU Delft students (Angela Klein and Sebastian Hartgring) into the larger Meuse model

- **Automatic calibration** of the **hourly** model (~1000 runs)

Lateral river routing after manual calibration

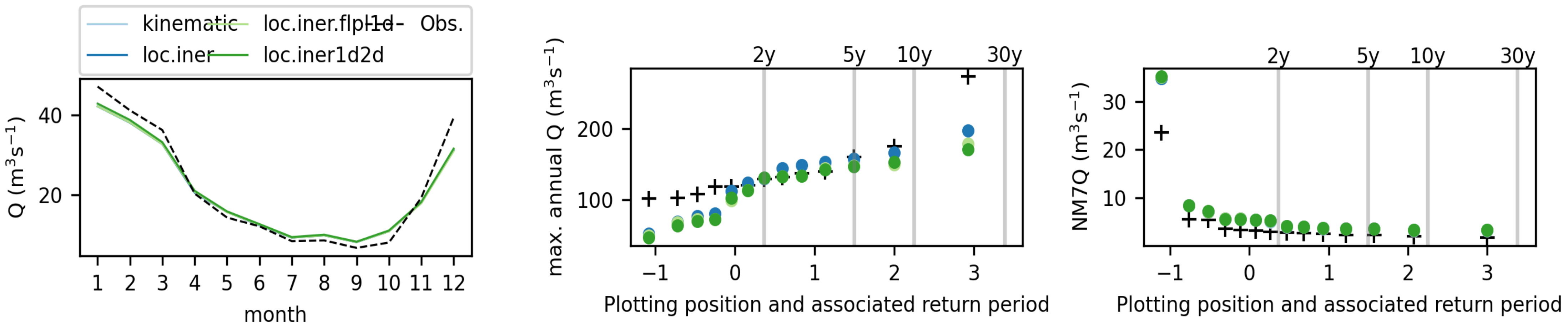
- Comparative study on different routing modules for the daily model
  - Kinematic wave
  - Local inertial 1d
  - Local inertial 1d and overbank flow to 2D floodplain schematization
  - Local inertial 1d and overbank flow to 1D floodplain schematization



Meuse at Borgharen - Flattening of the highest peaks with local inertial + floodplain routing

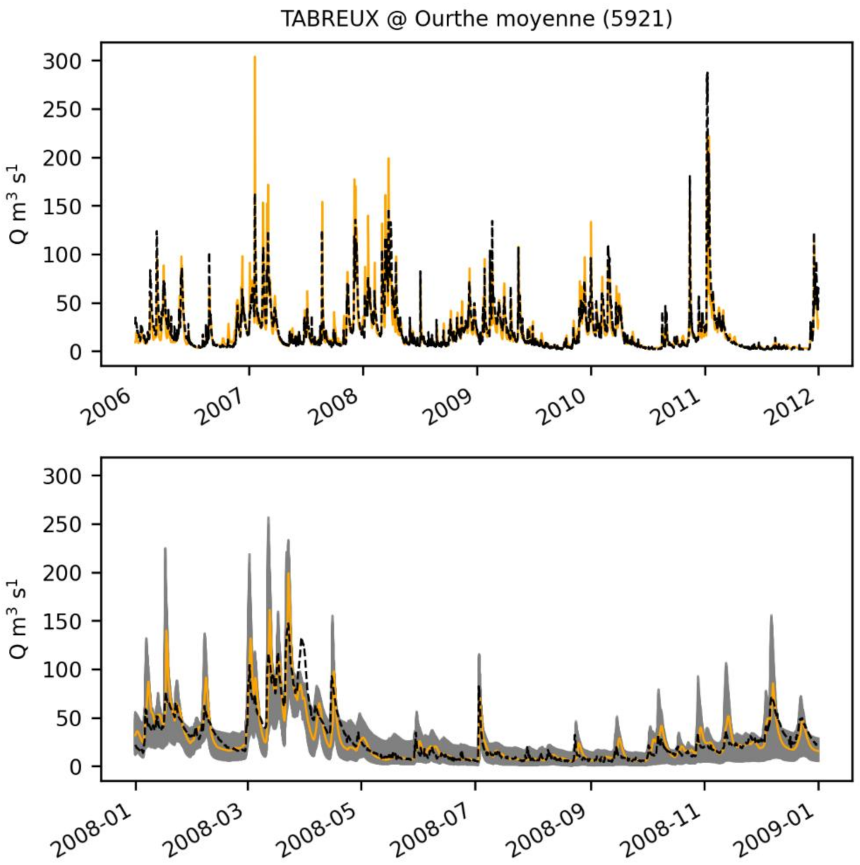
Lateral river routing after manual calibration

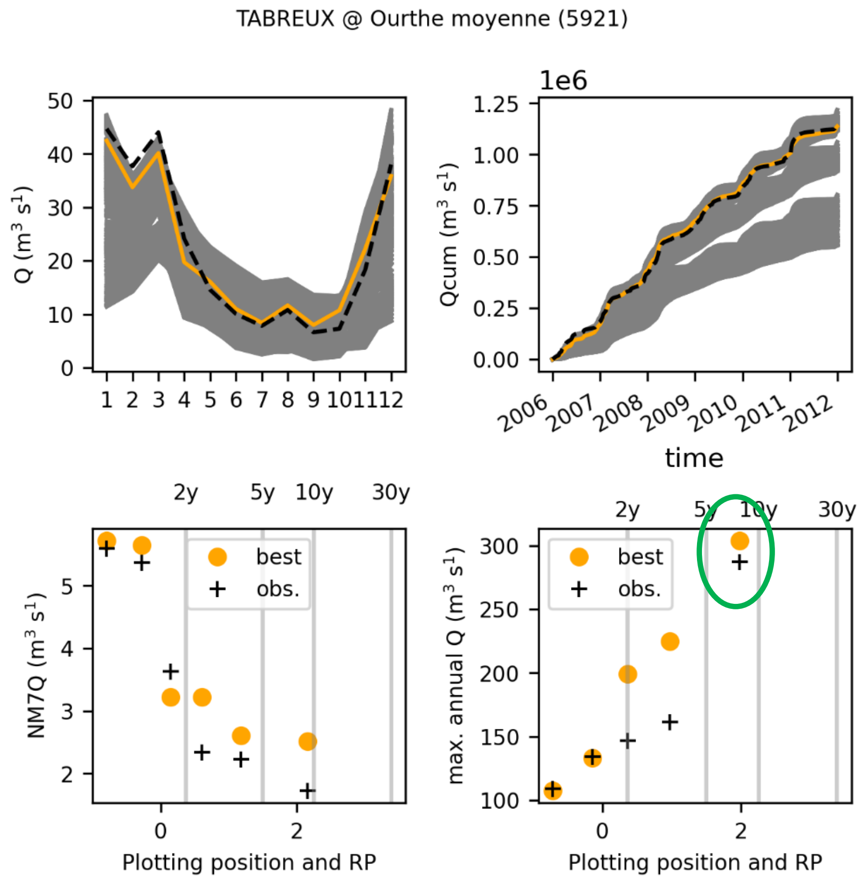
- Comparative study on different routing modules for the daily model
  - Kinematic wave
  - Local inertial 1d
  - Local inertial 1d and overbank flow to 2D floodplain schematization
  - Local inertial 1d and overbank flow to 1D floodplain schematization



Ourthe at Tabreux – Minor differences between different routing options in steeper catchments

Calibration of the hourly model ~1000 runs





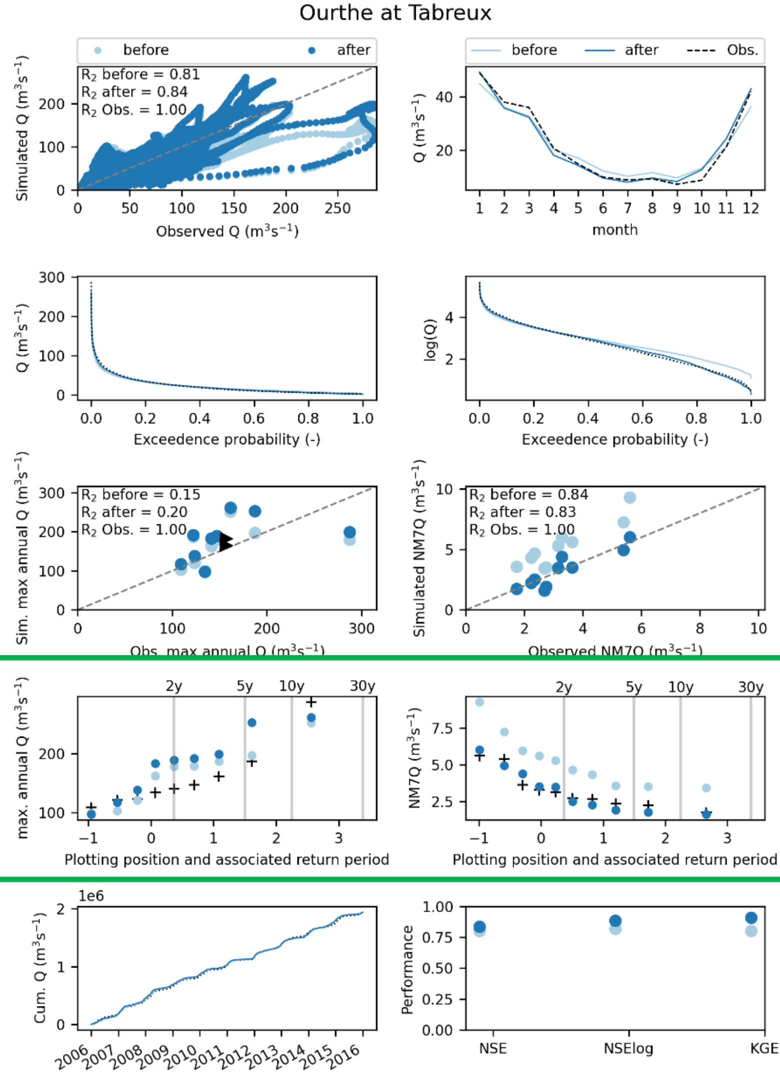
Selection based on a multi-criteria analysis, using: NSE, NSE_logQ, NSE_regime, NSE_cum, NSE_nm7q

Model performance – use the hourly model at daily time step

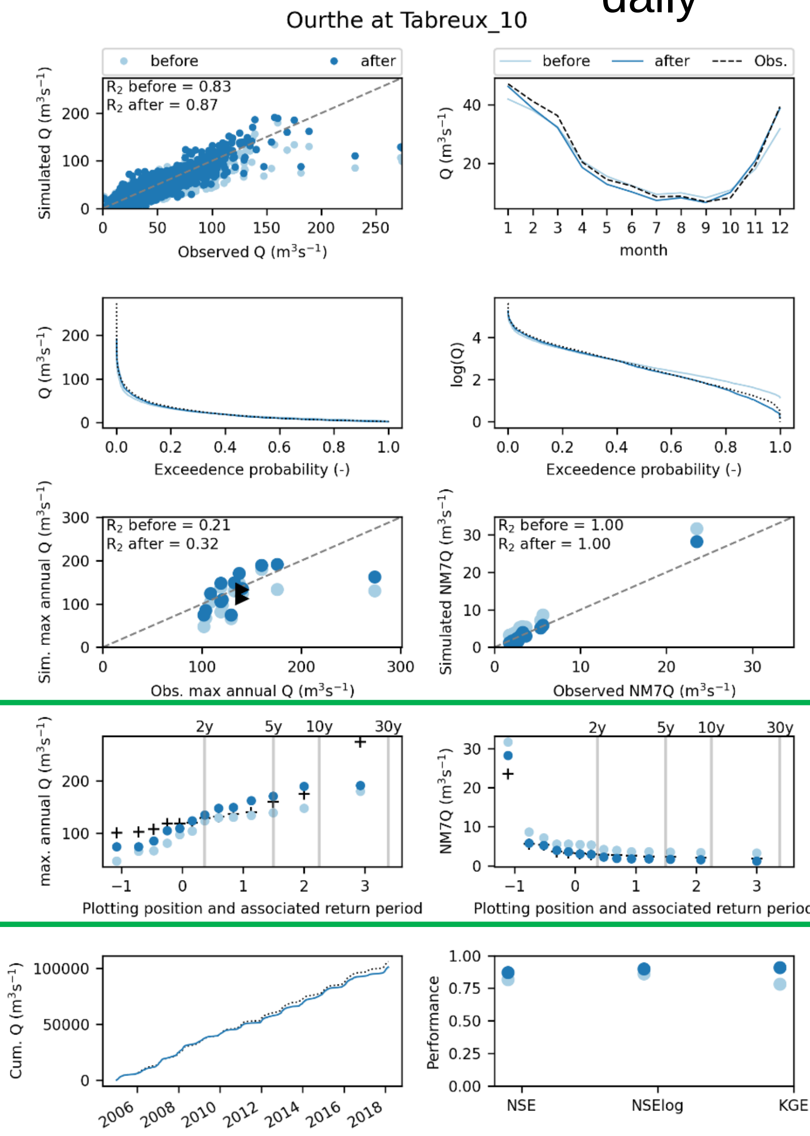
- Relatively small differences at the daily time step before and after calibration,
- in contrast to relatively large improvement at hourly time step

- Use the hourly calibration for both daily and hourly timestep

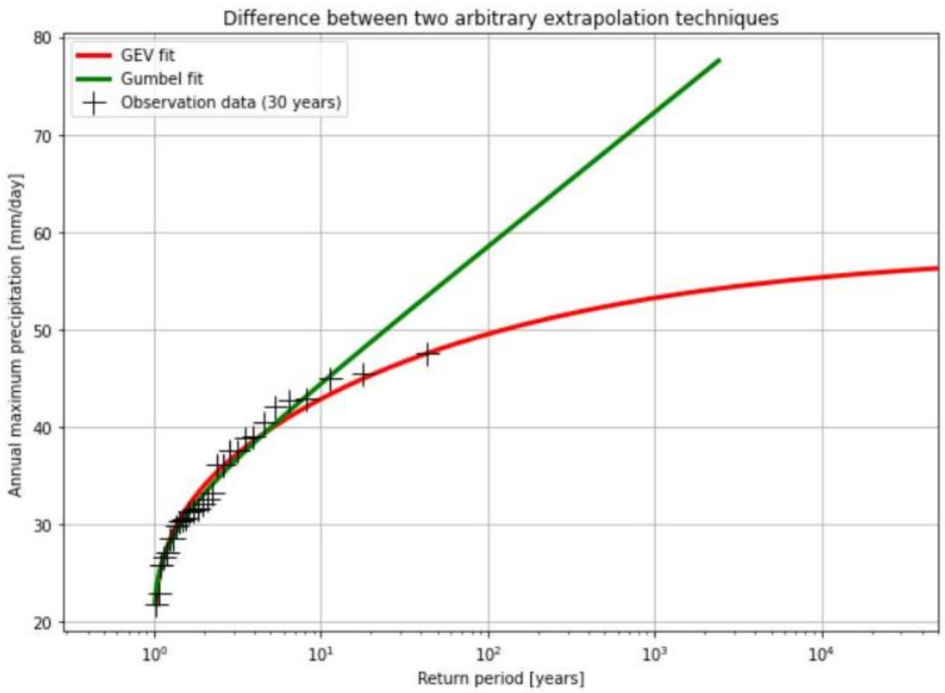
hourly

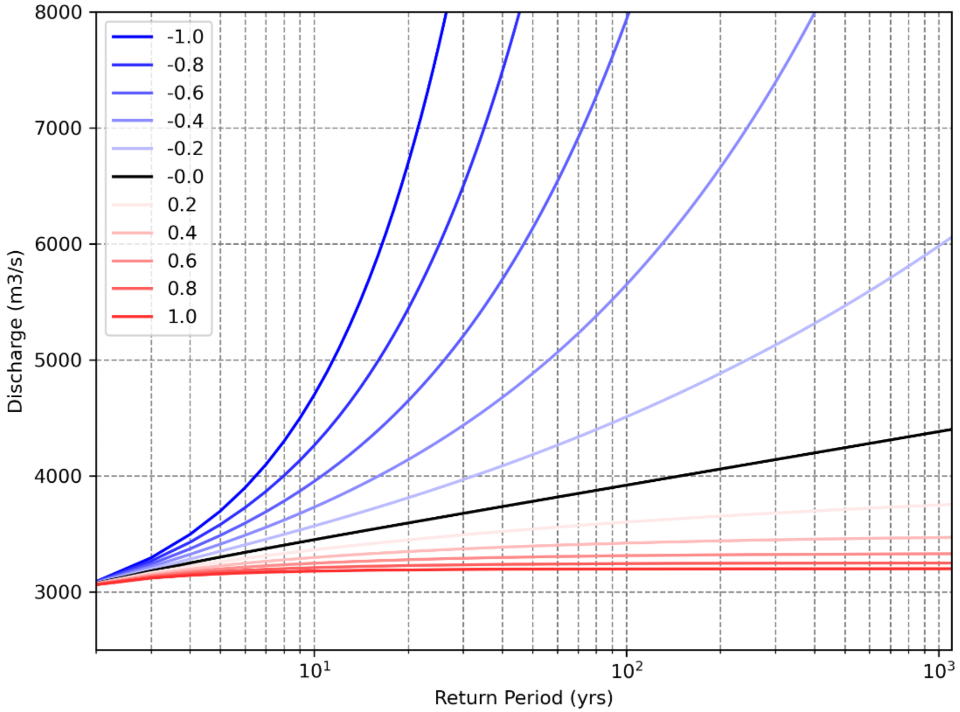


daily

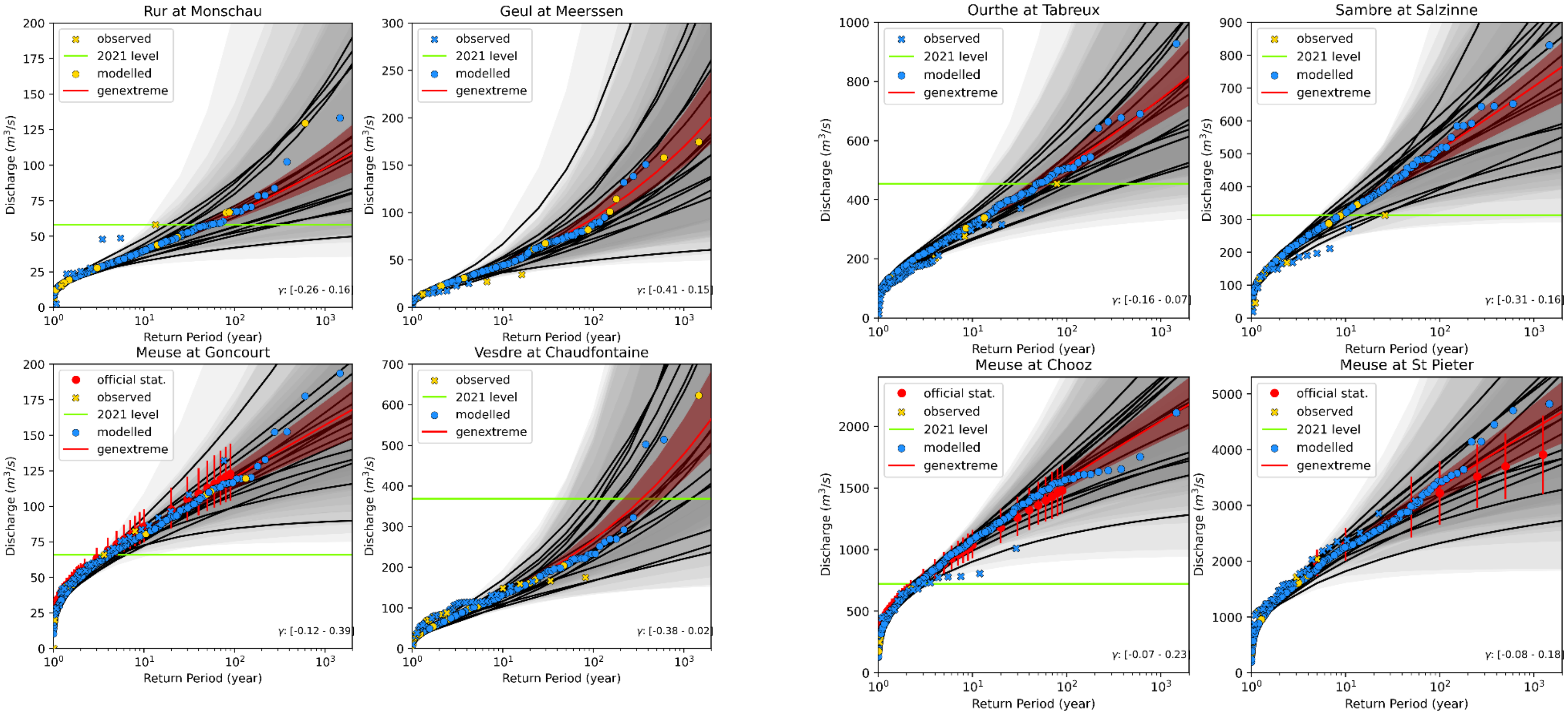


Extreme value analysis (GEV)

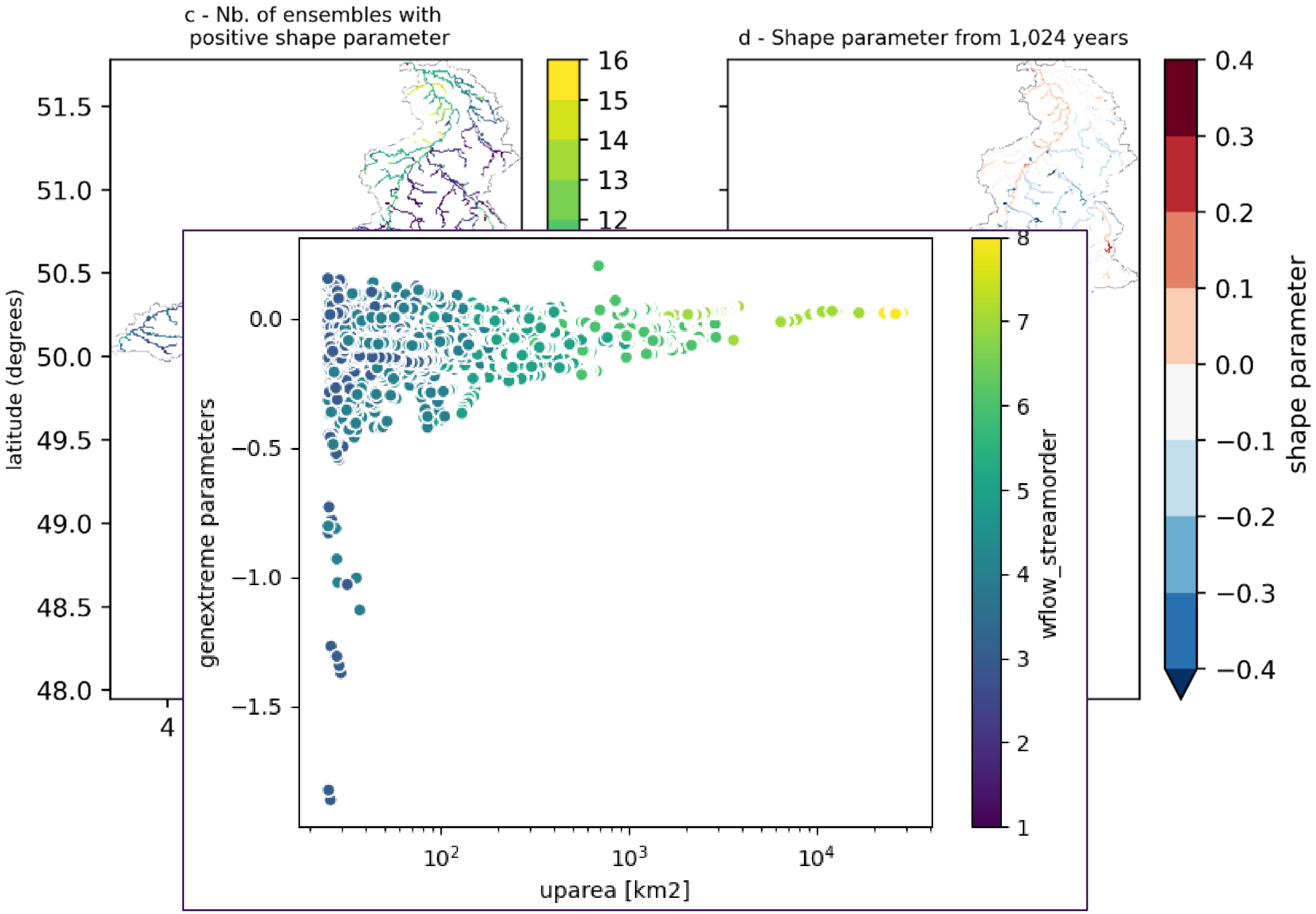


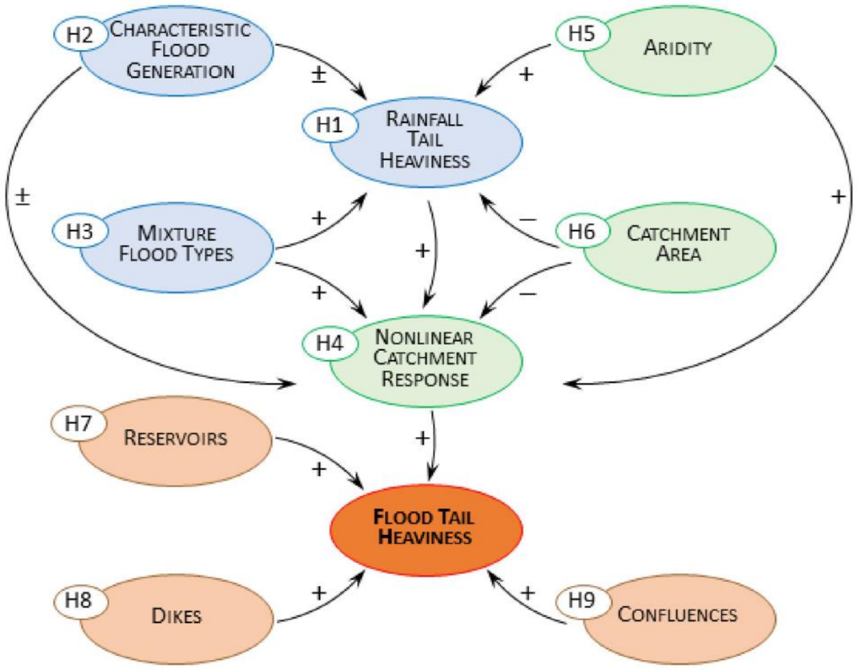


Daily time step: extreme value analysis (GEV)



Daily time step: extreme value analysis (GEV)



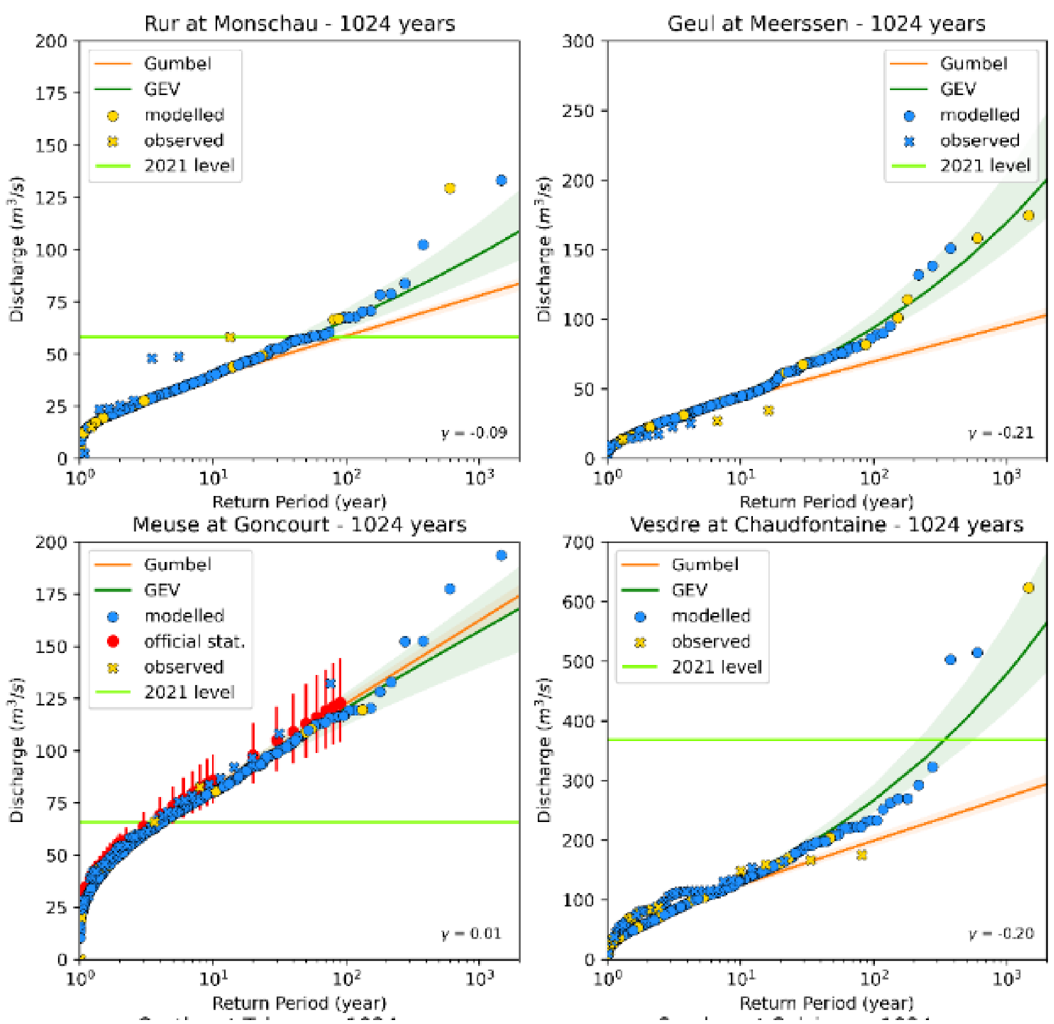


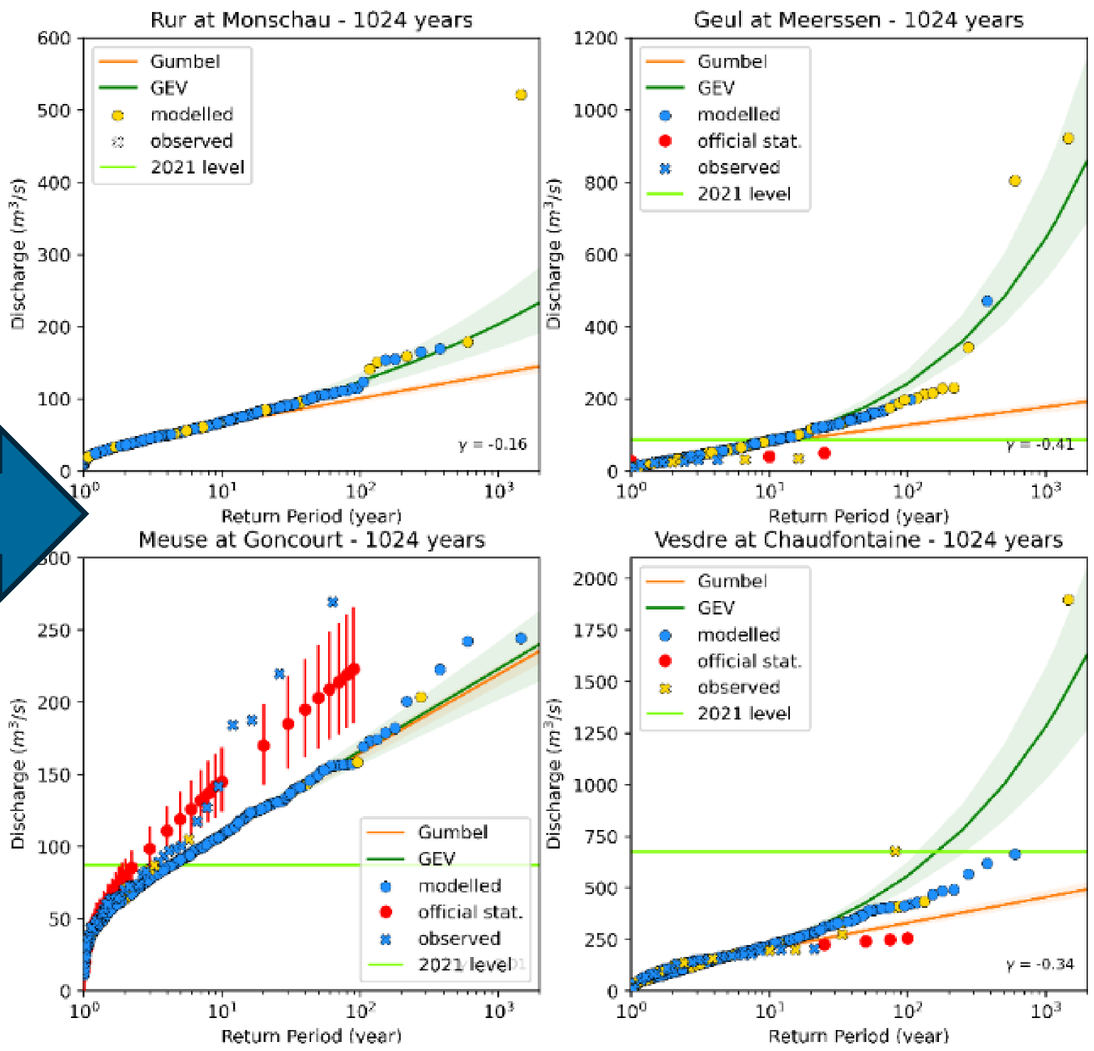
Merz et al. (2022). Understanding Heavy Tails of Flood Peak Distributions 10.1029/2021WR030506

Interreg
Euregio Meuse-Rhine
EMFlood Resilience
EUROPEAN UNION
European Regional Development Fund

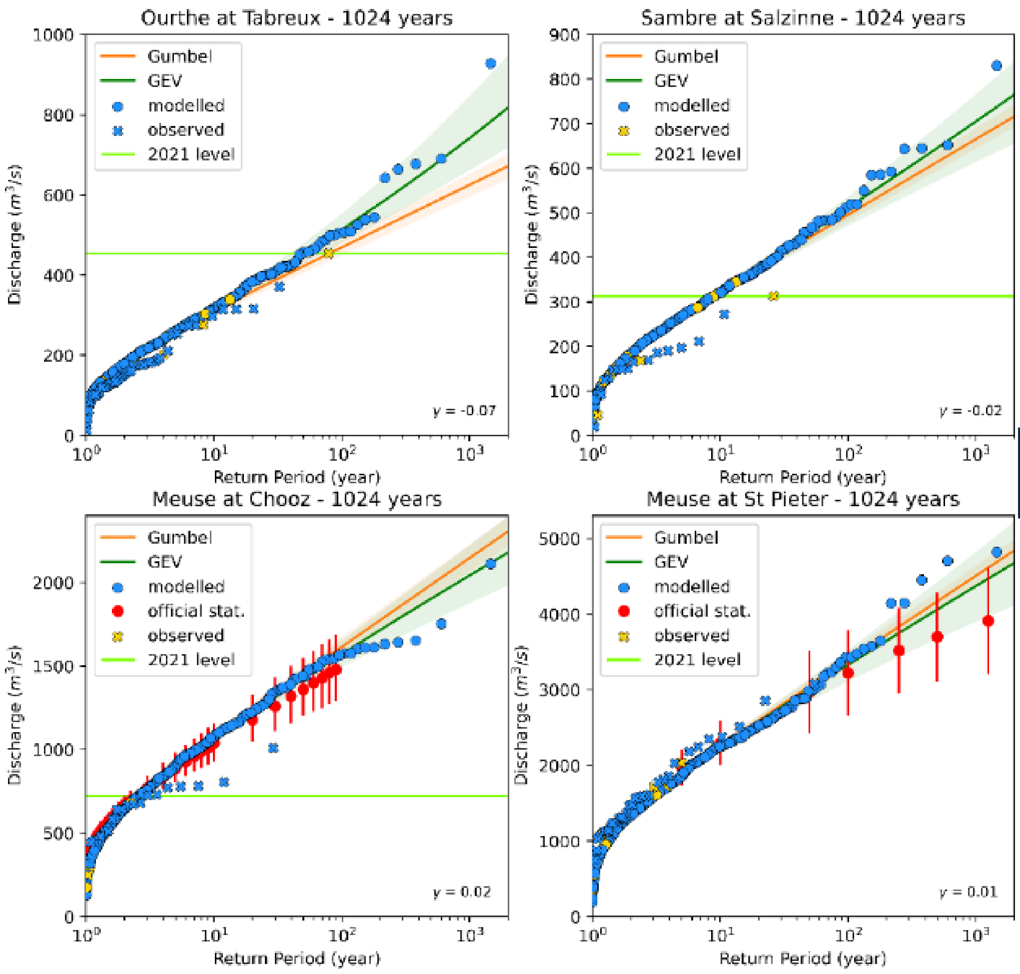
Deltares

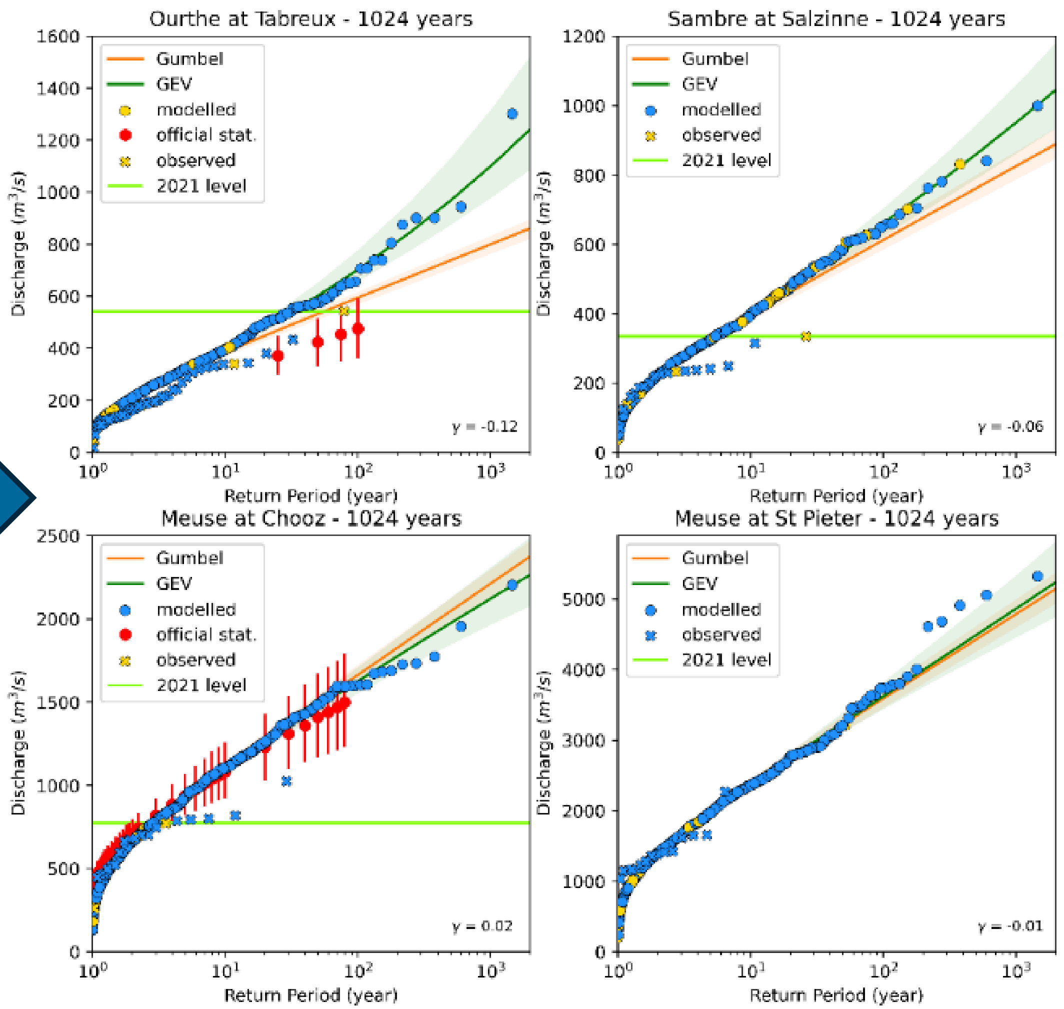
Hourly time step: extreme value analysis (GEV)





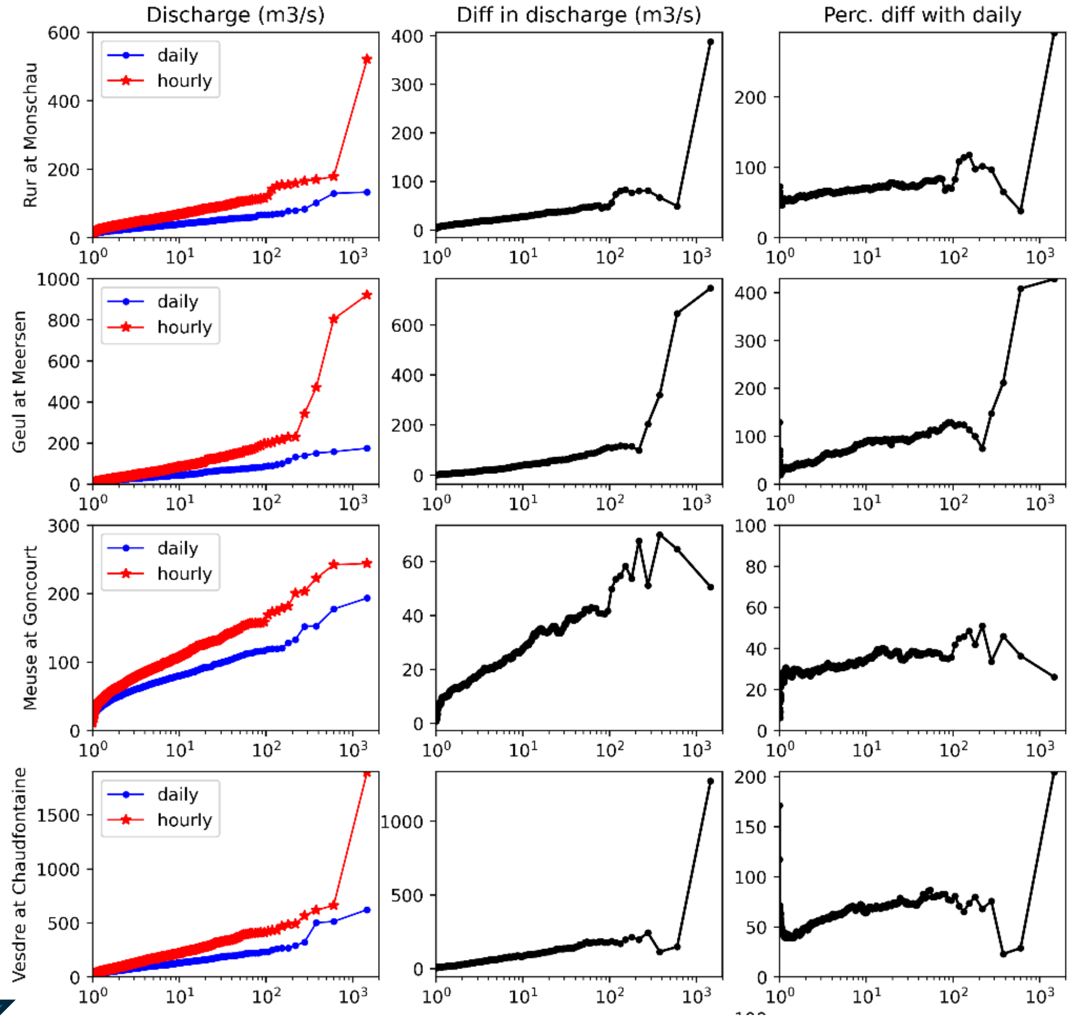
Hourly time step: extreme value analysis (GEV)



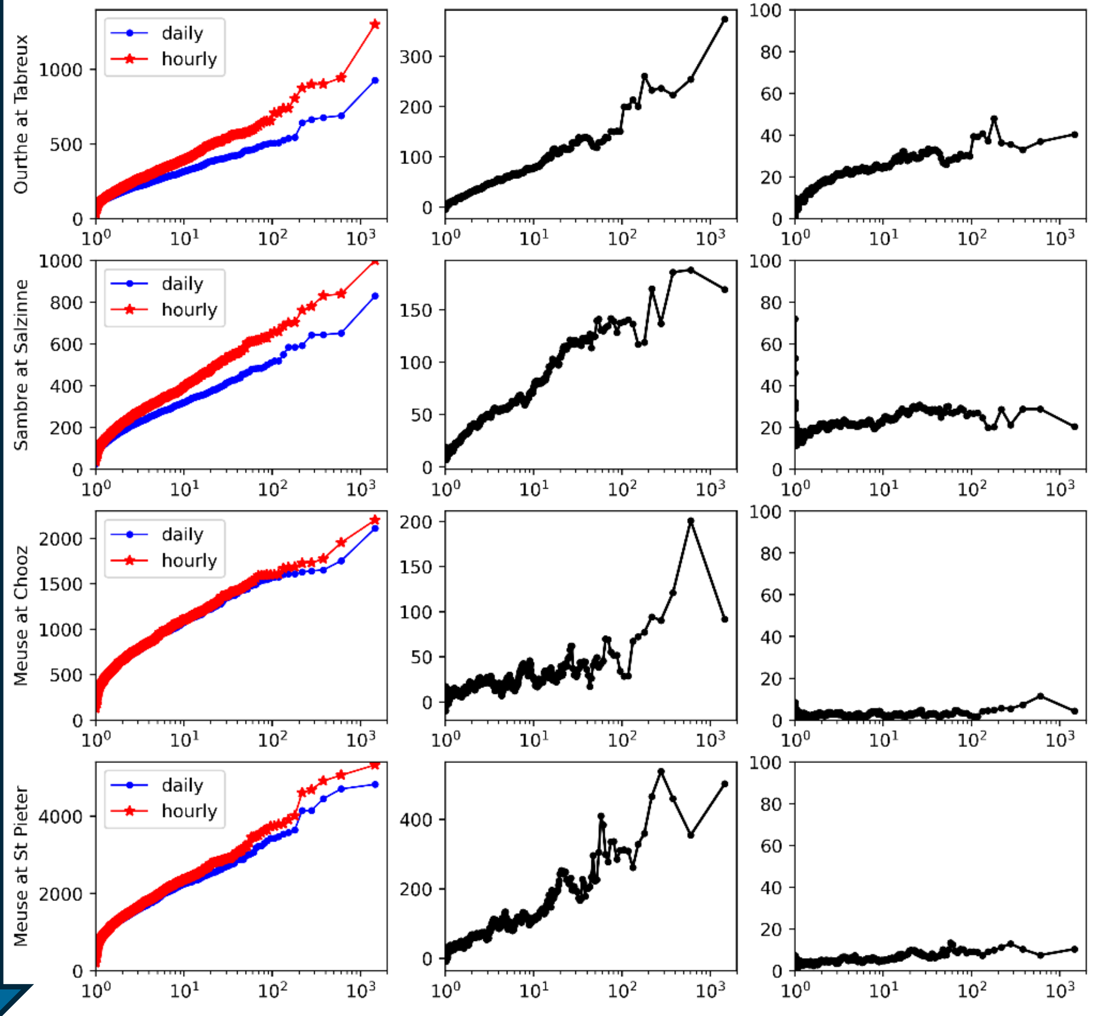


Difference in time step

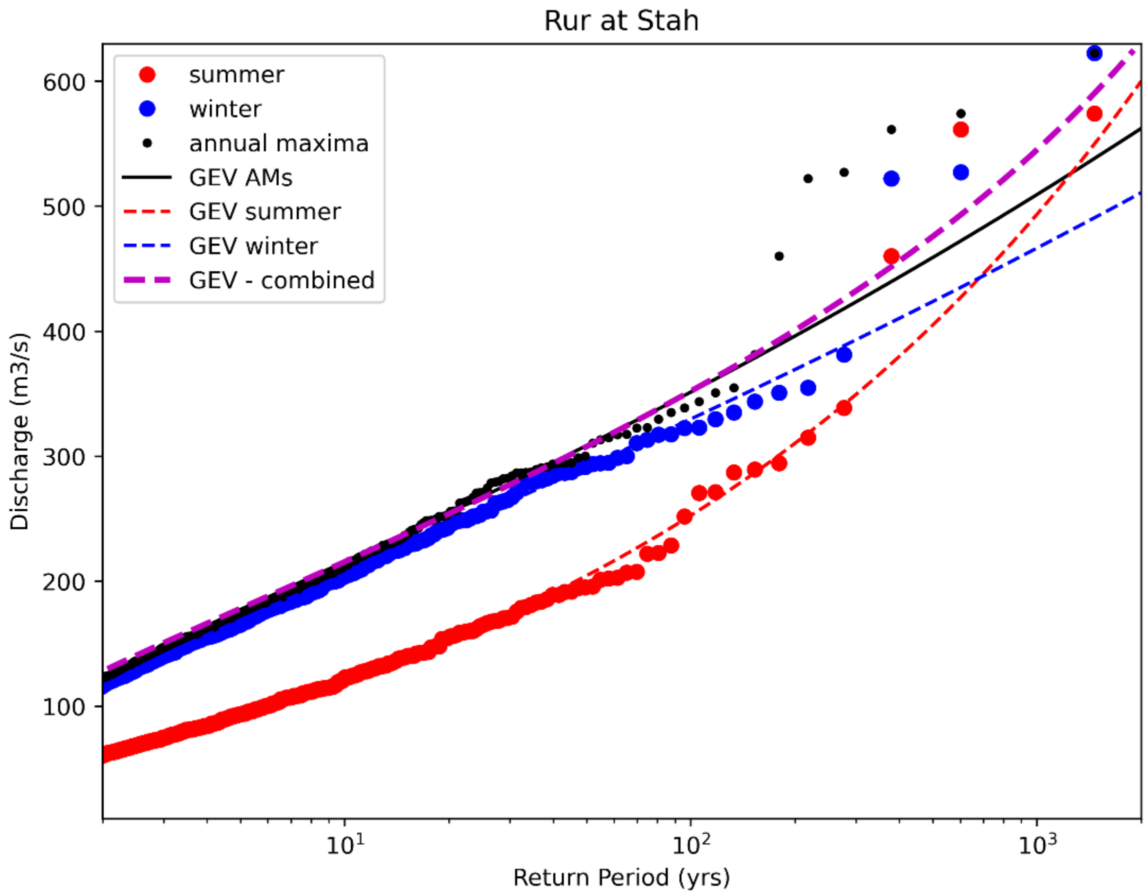
Catchment area



Catchment area

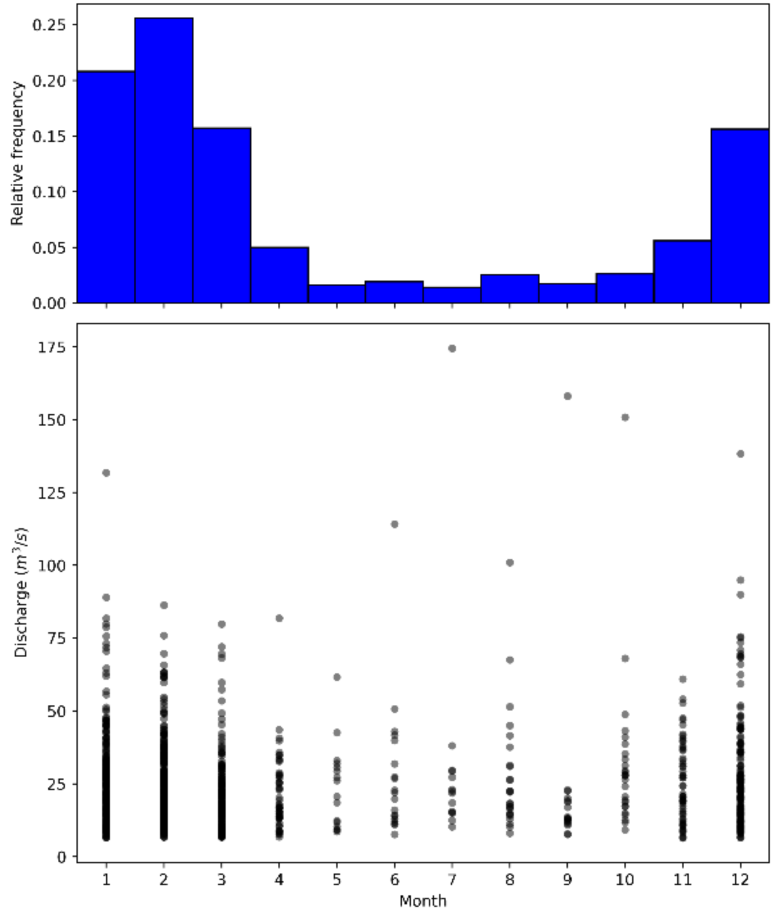


Importance of seasonality?

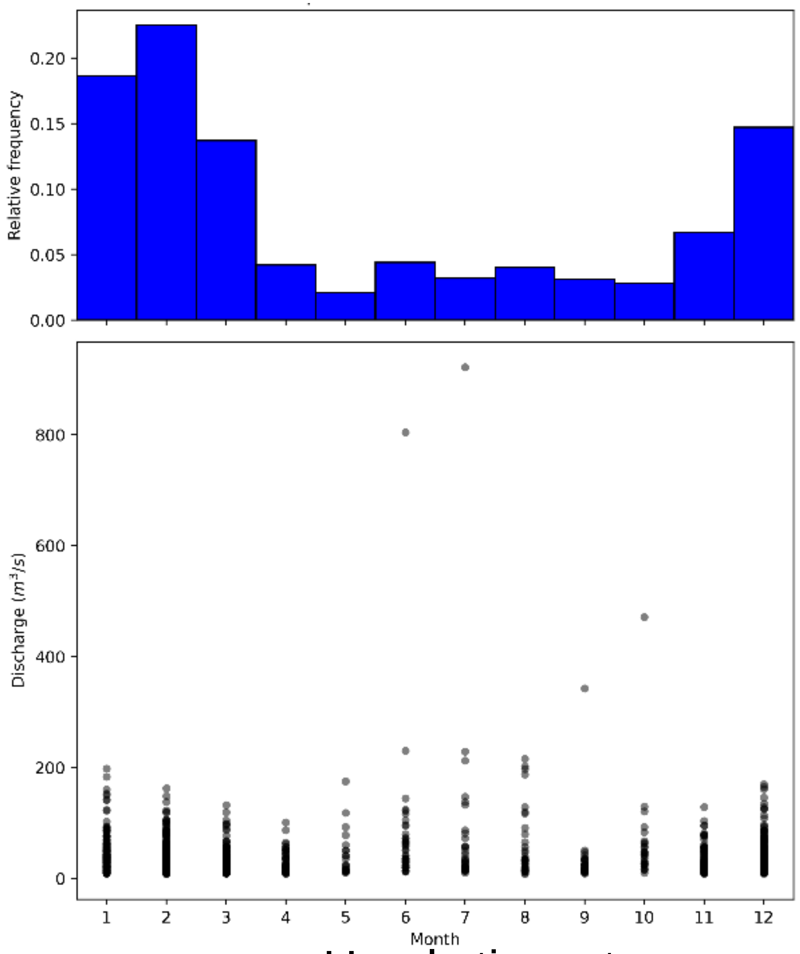


Importance of seasonality?...and time step!

Geul at Meerssen – top 1000 events



Daily time step



Hourly time step

Conclusions

- Current methodology, physics-based, has several advantages when generating extreme discharge (as opposed to purely statistical)
  - Results reflect interactions between weather, landscape and rainfall processes. Other July 2021-like events?
  - Distributed model allows for synthetic discharge time series everywhere in the catchment
- Extreme discharge behaviour
  - Natural variability in the current climate is large.
  - Convergence of shape parameter – heavy tail of the discharge distribution
  - Summer extremes can be important in extreme discharges. Steep and small catchment show heavy tails of flood peaks distribution (shape parameters)
  - Hourly time step is important for small and steep catchments
- Time series can be useful for other applications (low flow, spatial dependence). Or methodology to assess impact of change