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Supplement of

Using the classical model for structured expert judgment to estimate extremes: a case study of discharges in the Meuse River

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S1 Introduction

This documents serves as a supplement to the article ”Using structured expert judgment to estimate extremes: a case study of discharges in the Meuse River” by Guus Rongen, Oswaldo Morales-Nápoles, and Matthijs Kok. The article describes a method to estimate extreme discharges with expert judgment, in a case study for the river Meuse. The information in this supplement presents more detailed results for the expert elicitation. Section S2 shows the questionnaire through which the expert estimates were elicited. Section S3 shows the resulting estimates for all experts and all the items. Section S4 shows the generalized extreme value (GEV) distributions that were fitted to these estimates using Bayesian inference: Section S4.1 for the tributaries, which were directly fitted to the annual maxima observations and expert estimated (Sect. S3), and Sect. S4.2 for the discharges at the downstream locations, which are a combination of the upstream tributaries, the correlations, and the fitted sum-factors. Finally, Sect. S5 contains background information on the hydrology of the Meuse catchment that was available to the experts during the elicitation.

S2 Questionnaire

Estimating Extreme Discharges for the Meuse River

You have received the questionnaire for the expert session on extreme discharges for the Meuse River. Thank you for participating in this session. In this questionnaire, you will answer 26 questions to quantify the uncertainty in extreme discharges. For this purpose, we will use Cooke's method, which involves asking calibration questions to calculate weighting factors that will be used to combine the estimates for the target questions.

We ask for your name, affiliation, and whether you agree to have this information mentioned in a publication. Please note that individual results will be stored and published anonymously, so your name cannot be linked to your answers.

1. Name: _____

2. Briefly describe your professional background/affiliation/position: _____

   _____

   _____

3. Do you consent to have this information mentioned in a publication (without it being linked to your answers)? Yes / No

The questions are structured as shown in the frame below.

X. Question name

Possibly a situation description. If you find the information provided with the question incomplete or open to interpretation, please consider this in your uncertainty estimation.

This is the question?

answer Q05	*unit*	**answer Q50**	*unit*	**answer Q95**	*unit*
5%		50%		95%	

S2.1 Weser (exercise)

In almost all questions, we ask for the discharge at a specific return period. We consider the current state of the catchment area and the current climate. For example, a question is about the discharge that is exceeded on average once every 1,000 years. In this case, imagine that the catchment area in question remains unchanged over a period of 100,000 years, as well as the climate. The discharge that is exceeded in the measurements 100 times (100 per 100,000 = on average once every 1,000) is the answer we are looking for. Of course, we do not know this answer, and we will never know it. Therefore, the uncertainty in the answer can be expressed in uncertainty bands.

A tip to achieve good uncertainty estimates is to first fill in the 5th and 95th percentiles and then the 50th percentile. This prevents you from deducing the other percentiles from your "best guess" (the 50th percentile).

Measurements for the Weser are available from November 1940 onwards.

Werra, Letzter Heller, T10

What is the discharge that is exceeded on average once every 10 years for the Werra River at Letzter Heller?

_____ m^3/s	_____ m^3/s	_____ m^3/s
5%	50%	95%

Aller, Rethem, T10

What is the discharge that is exceeded on average once every 10 years for the Aller River at Rethem?

_____ m^3/s	_____ m^3/s	_____ m^3/s
5%	50%	95%

Eder, Affoldern, T10

What is the discharge that is exceeded on average once every 10 years for the Eder River at Affoldern?

_____ m^3/s	_____ m^3/s	_____ m^3/s
5%	50%	95%

Eder, Affoldern, Max.

What is the maximum recorded discharge for the Eder River at Affoldern?

_____ m^3/s	_____ m^3/s	_____ m^3/s
5%	50%	95%

S2.2 Meuse River

T10 Discharges

What is the discharge that is exceeded on average once every 10 years for the following locations:

Tributary	**Location**	**5% [m^3/s]**	**50% [m^3/s]**	**95% [m^3/s]**
Vesdre	Chaudfontaine			
French Meuse	Chooz			
Lesse	Gendron			
Ambleve	Martinrive			
Sambre	Salzinnes			
Ourthe	Tabreux			
Semois	Membre			
Roer	Stah			
Geul	Meerssen			
Niers	Goch			

T1000 Discharges

What is the discharge that is exceeded on average once every 1000 years for the following locations:

Tributary	**Location**	**5% [m^3/s]**	**50% [m^3/s]**	**95% [m^3/s]**
Vesdre	Chaudfontaine			
French Meuse	Chooz			
Lesse	Gendron			
Ambleve	Martinrive			
Sambre	Salzinnes			
Ourthe	Tabreux			
Semois	Membre			
Roer	Stah			
Geul	Meerssen			
Niers	Goch			

Downstream Factor

What is the factor between the sum of peak discharges upstream of Borgharen, Roermond, and Gennep, and the peak discharge at this location? Keep in mind that the estimated discharges from the upstream tributaries do not cover 100% of the catchment area.

Location	**5% [-]**	**50% [-]**	**95% [-]**
Borgharen			
Roermond			
Gennep			

S2.3 Final questions

What approach did you follow to estimate the discharges (in a few sentences)?

What approach did you follow to estimate the correlations (in a few sentences)?

S3 Expert estimates

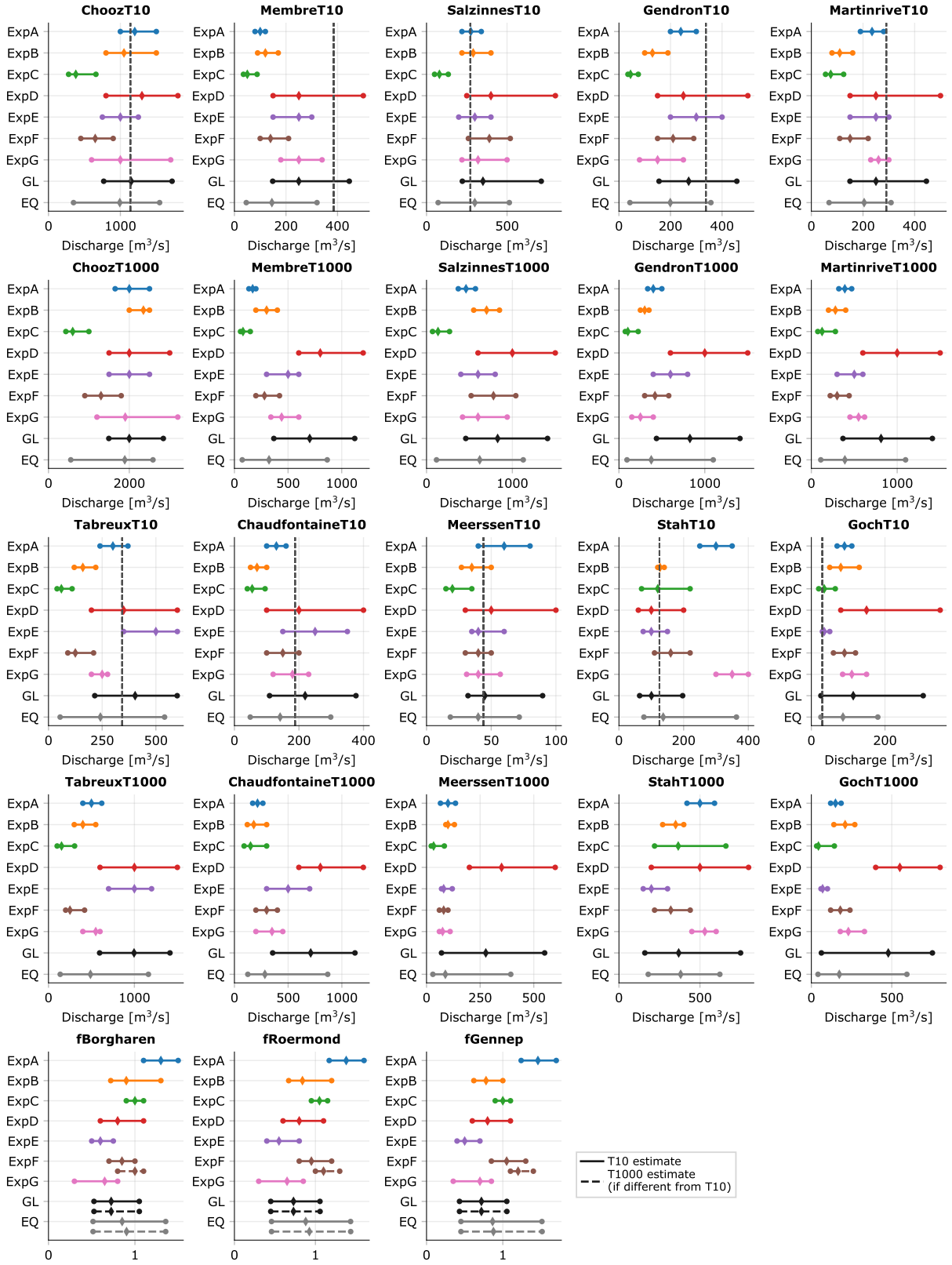

Fig. S 1 Overview of expert estimates for all items.

S4 Fitted exceedance frequency curves

This chapter shows the fitted distributions for the tributary discharges (see Section S4.1) and downstream discharges, and the factors that where . The tributary discharges are fitted to observations (see Figure 2), expert estimates, and data (see Figure 3 to Figure 11)

S4.1 Exceedance frequency curves for tributaries

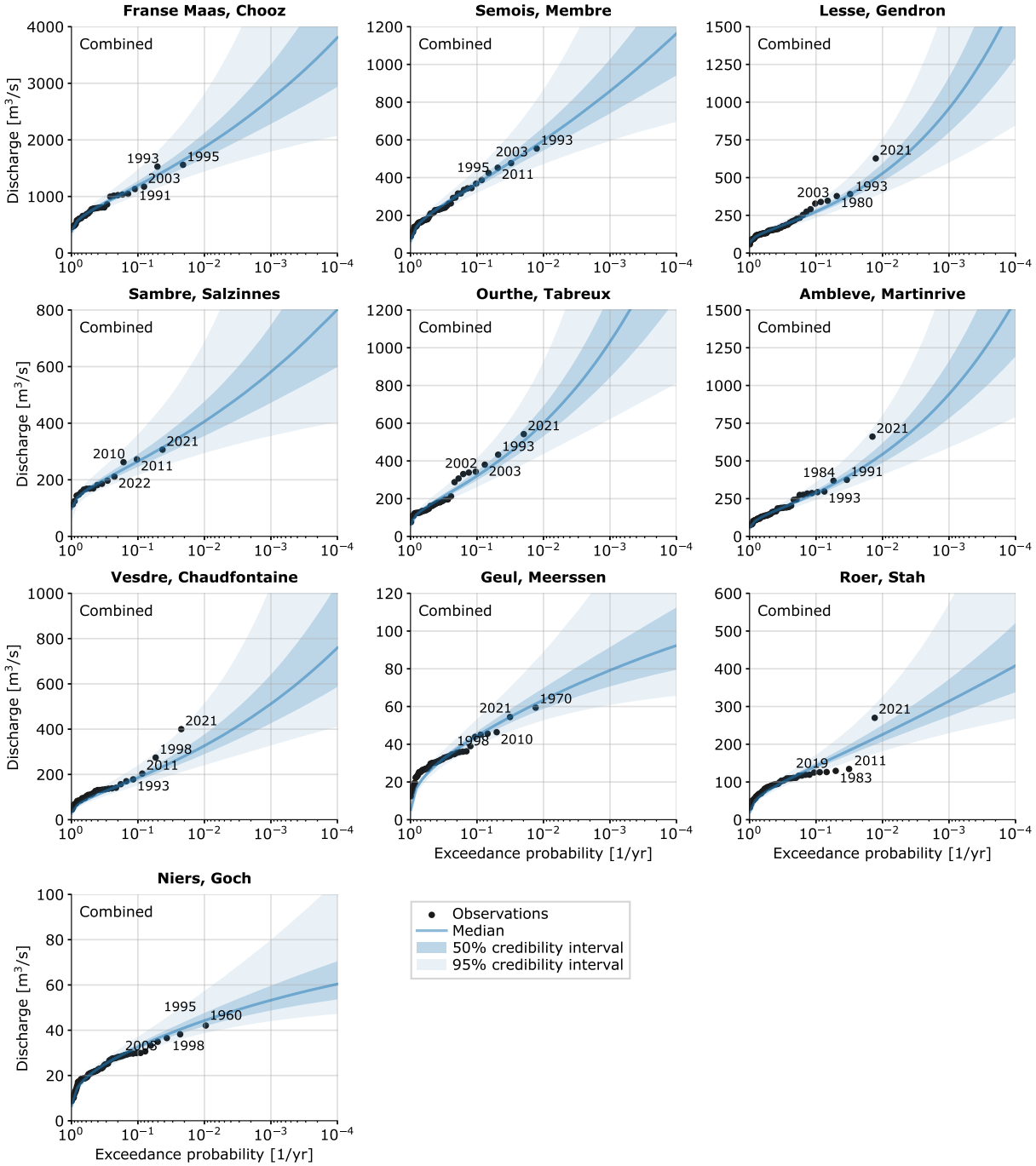

Fig. S 2 Exceedance frequency curves of tributary discharges fitted only to observed annual maxima.

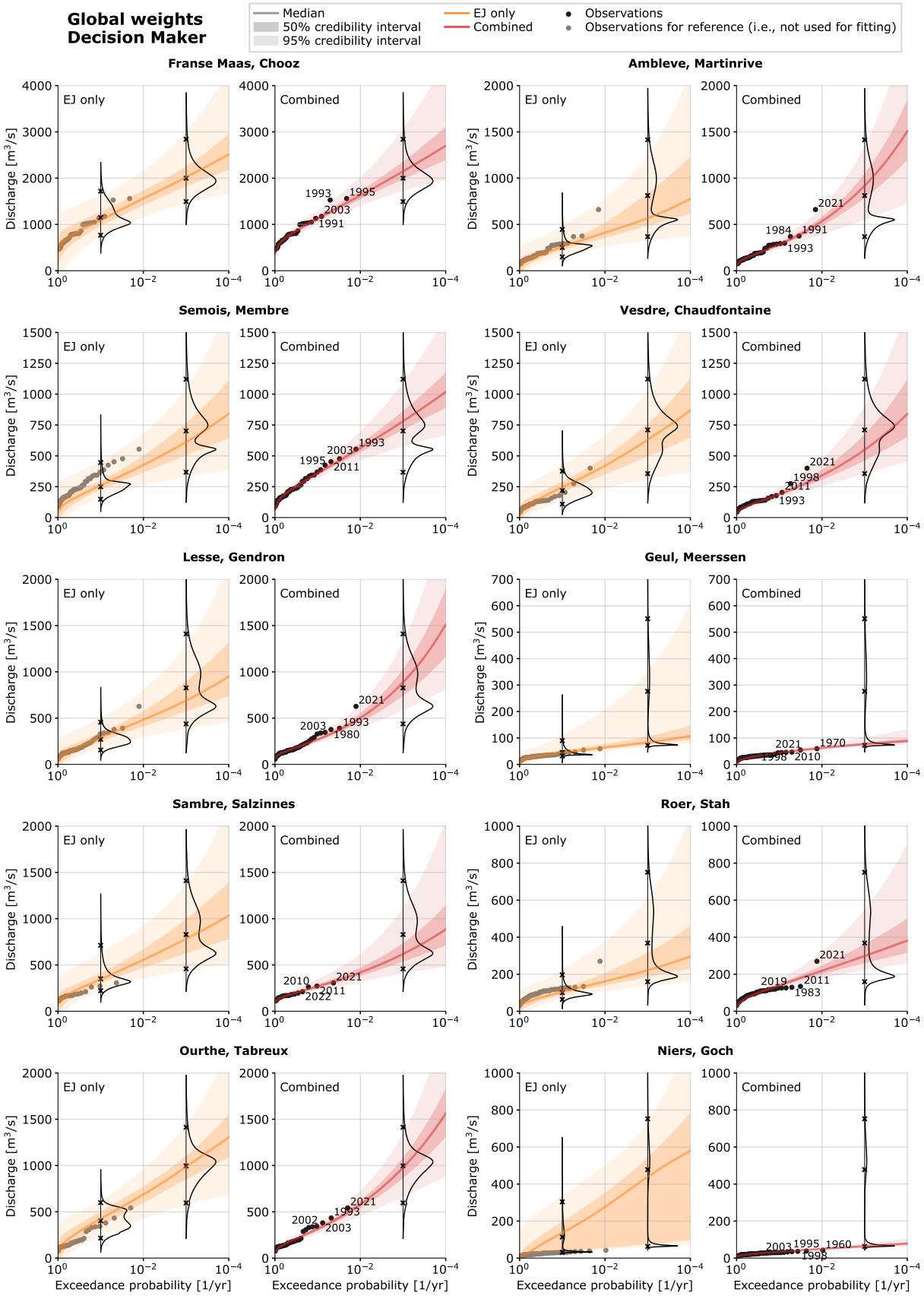

Fig. S 3 Exceedance frequency curves of tributary discharges for the global weights decision maker. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

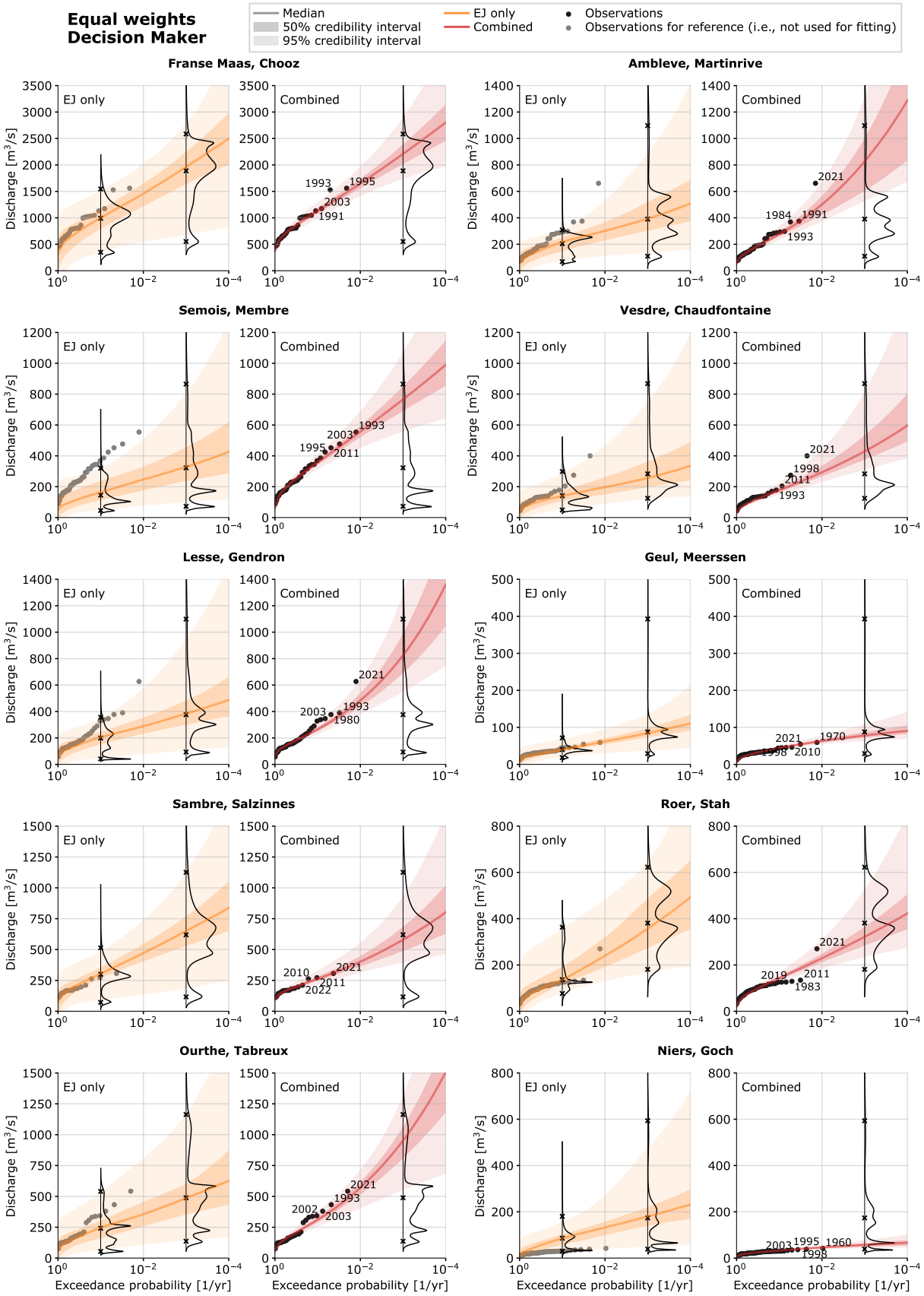

Fig. S 4 Exceedance frequency curves of tributary discharges for the equal weights decision maker. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

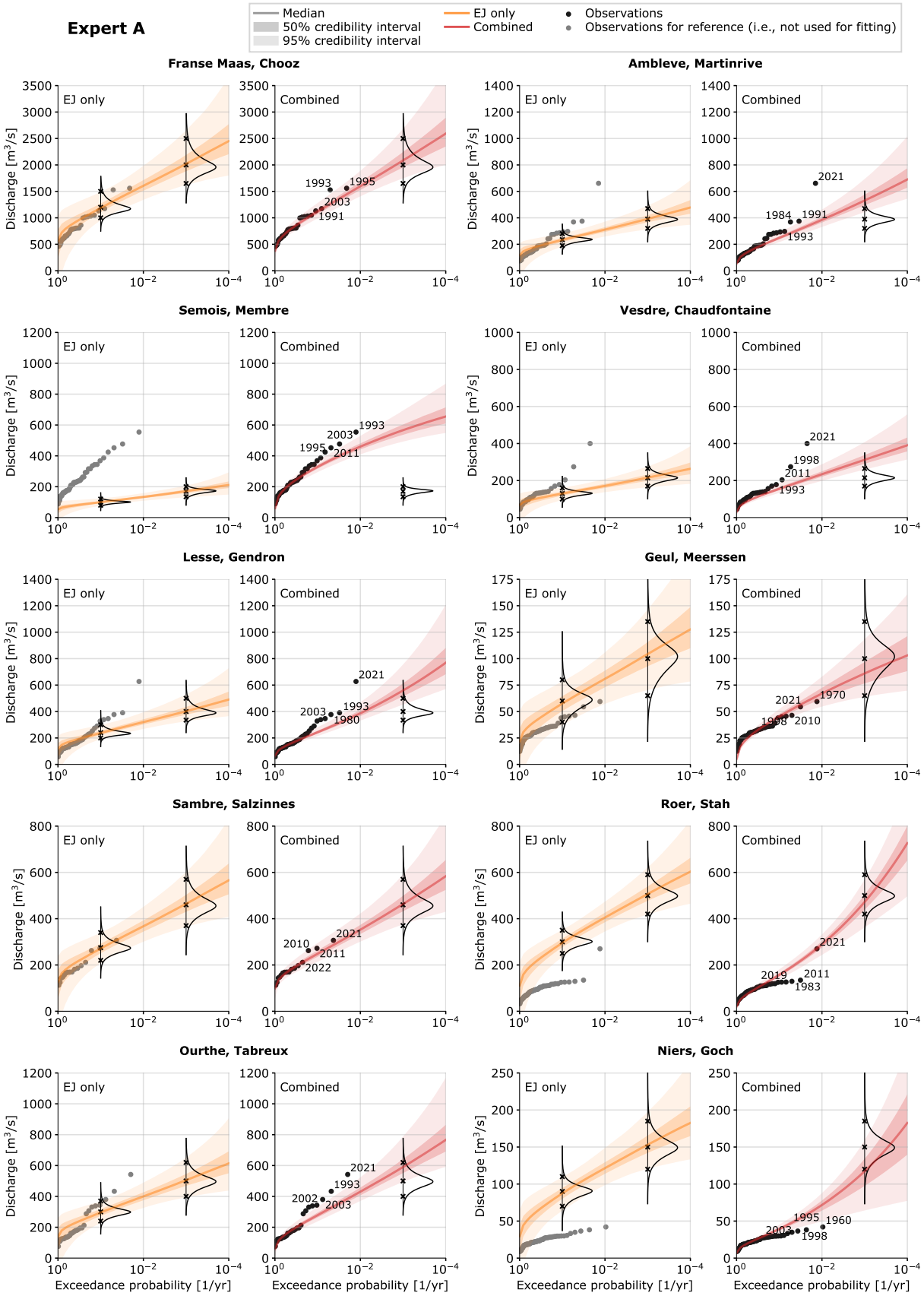

Fig. S 5 Exceedance frequency curves of tributary discharges for Expert A. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

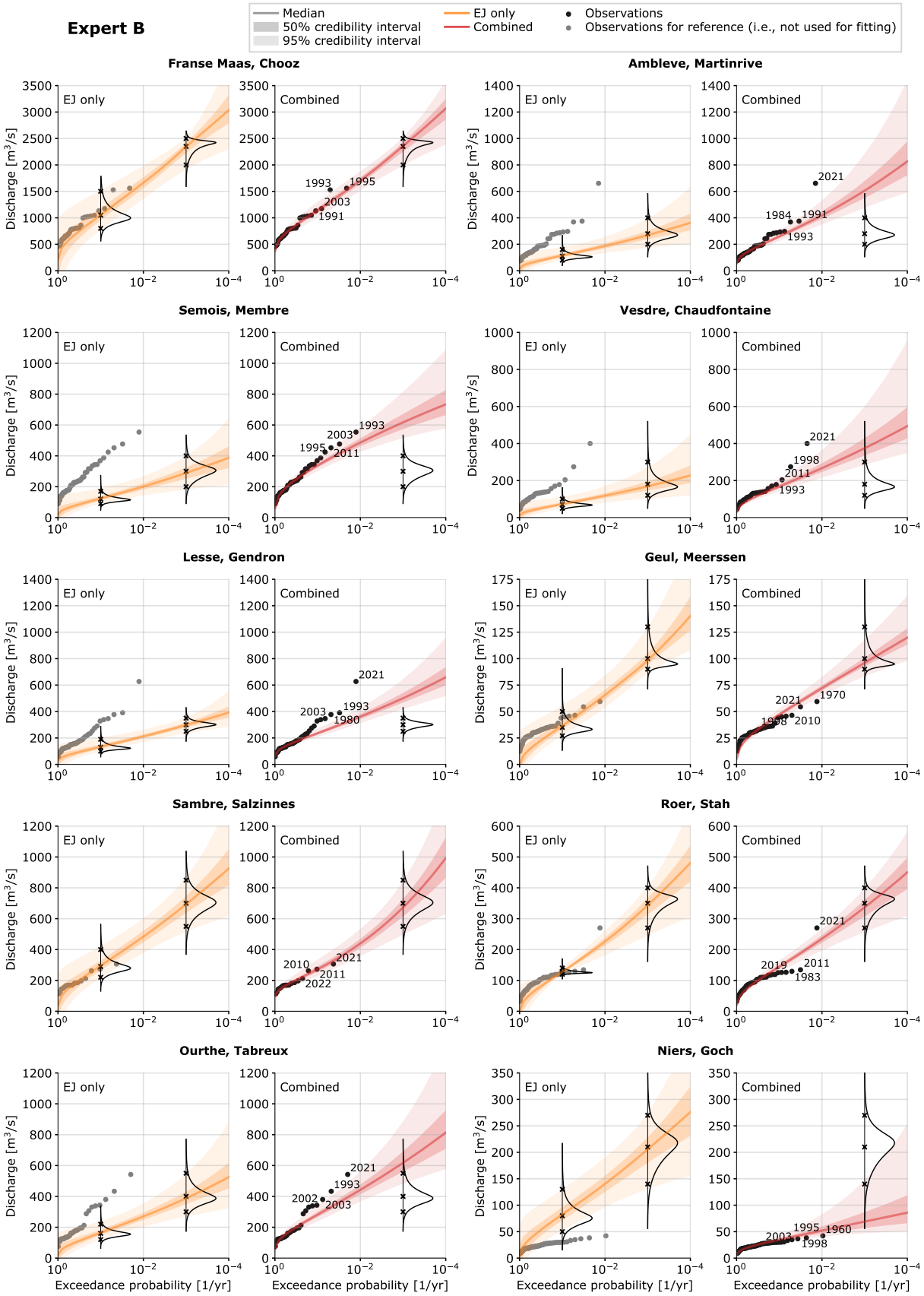

Fig. S 6 Exceedance frequency curves of tributary discharges for Expert B. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

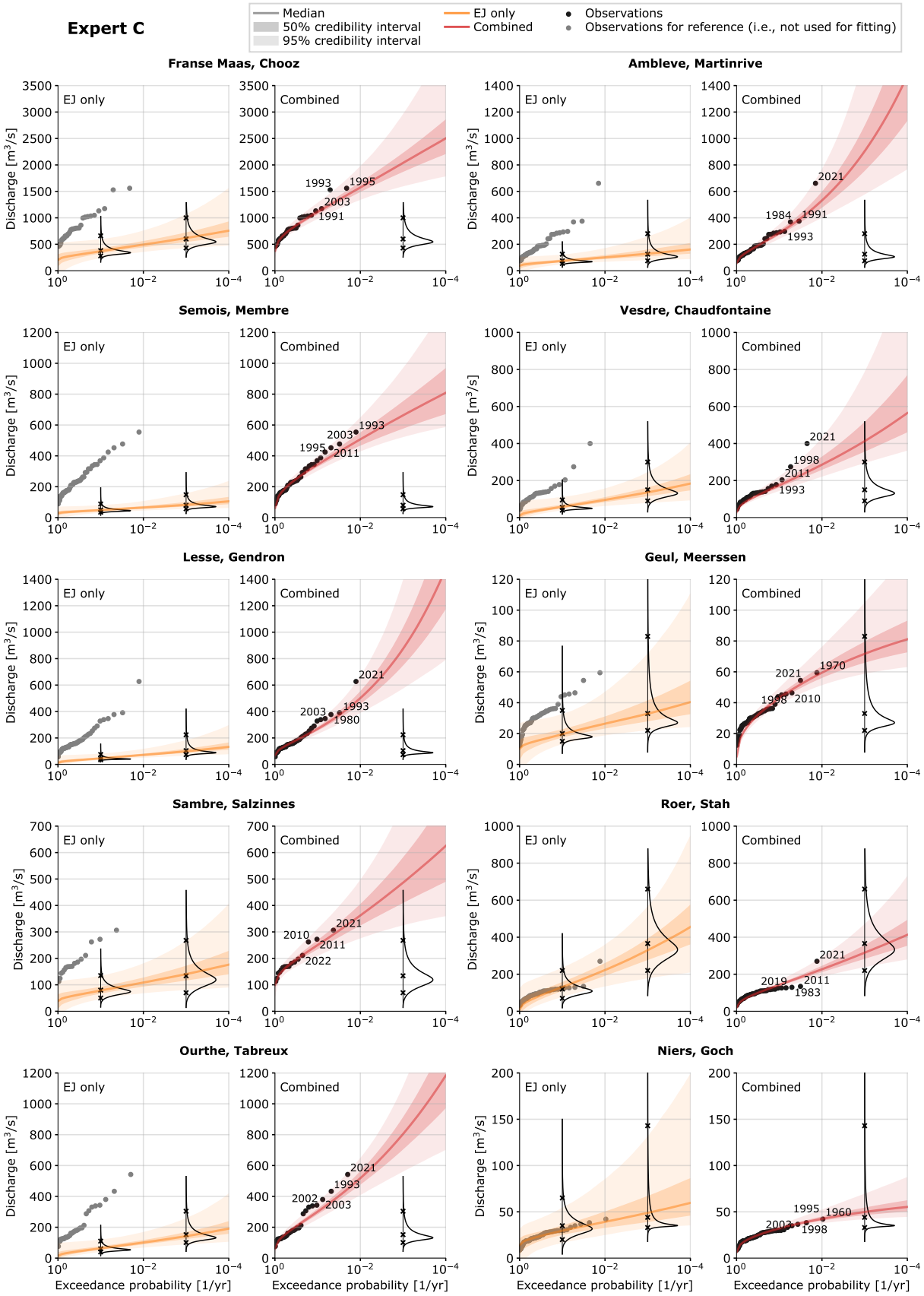

Fig. S 7 Exceedance frequency curves of tributary discharges for Expert C. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

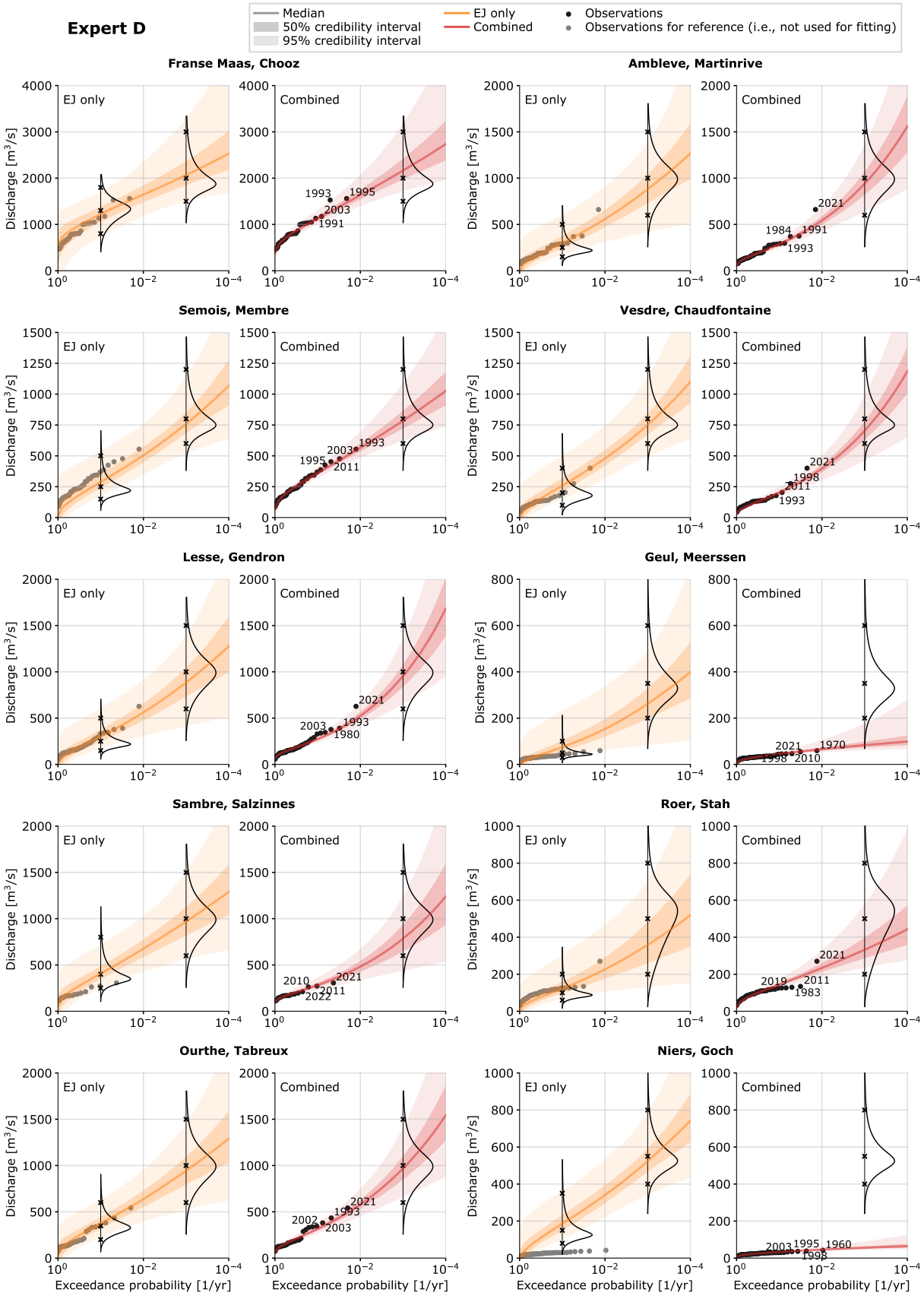

Fig. S 8 Exceedance frequency curves of tributary discharges for Expert D. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

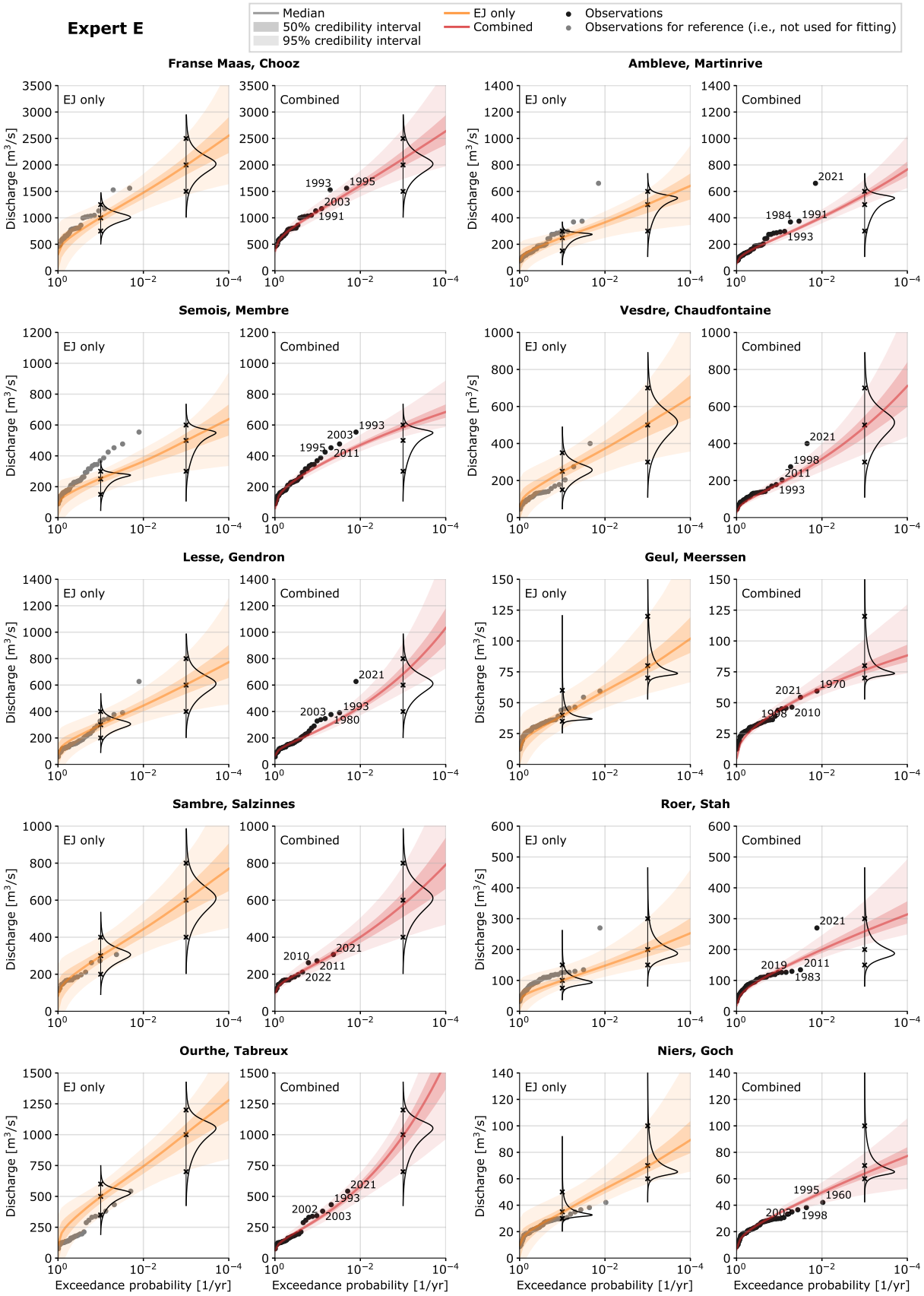

Fig. S 9 Exceedance frequency curves of tributary discharges for Expert E. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

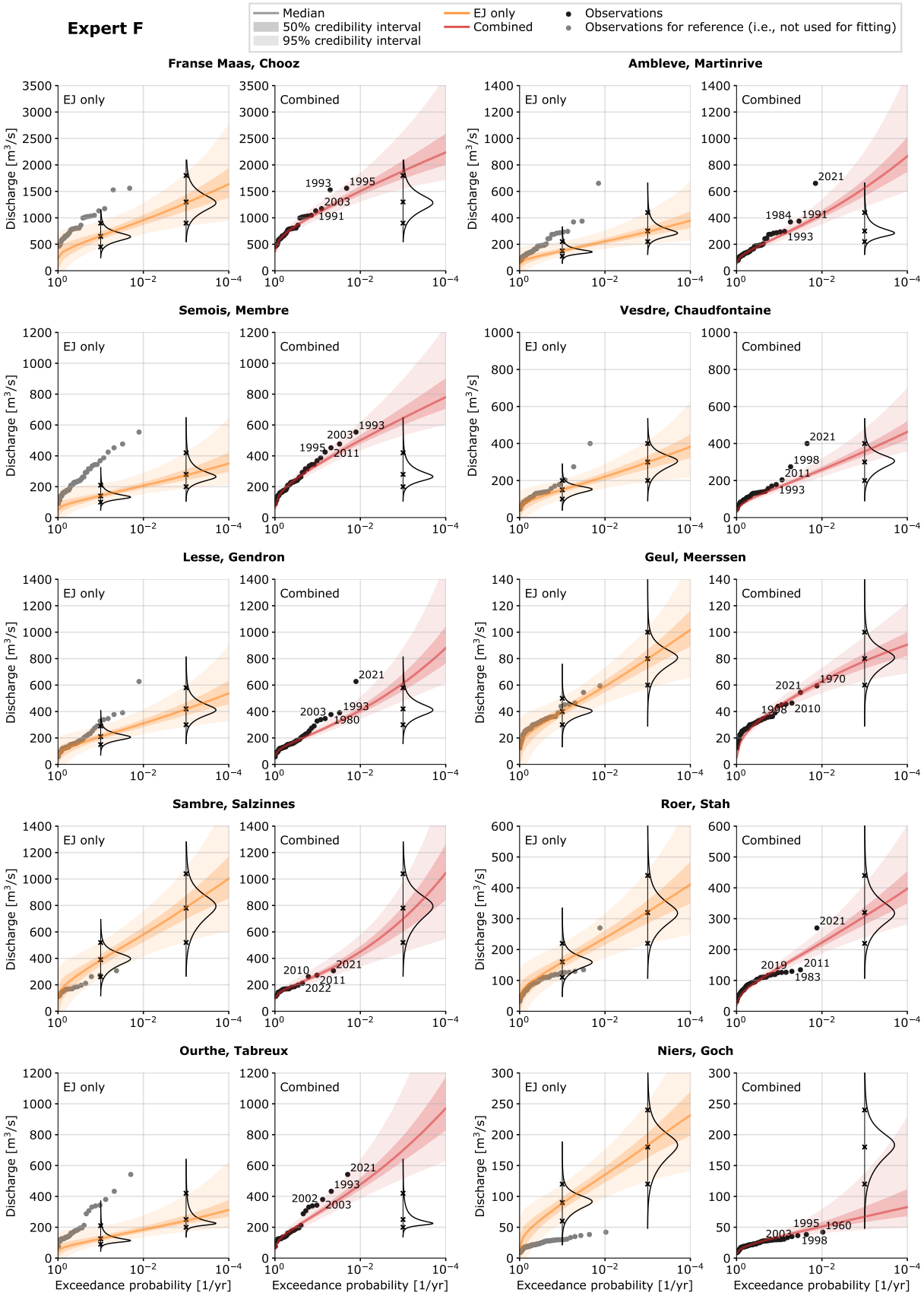

Fig. S 10 Exceedance frequency curves of tributary discharges for Expert F. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

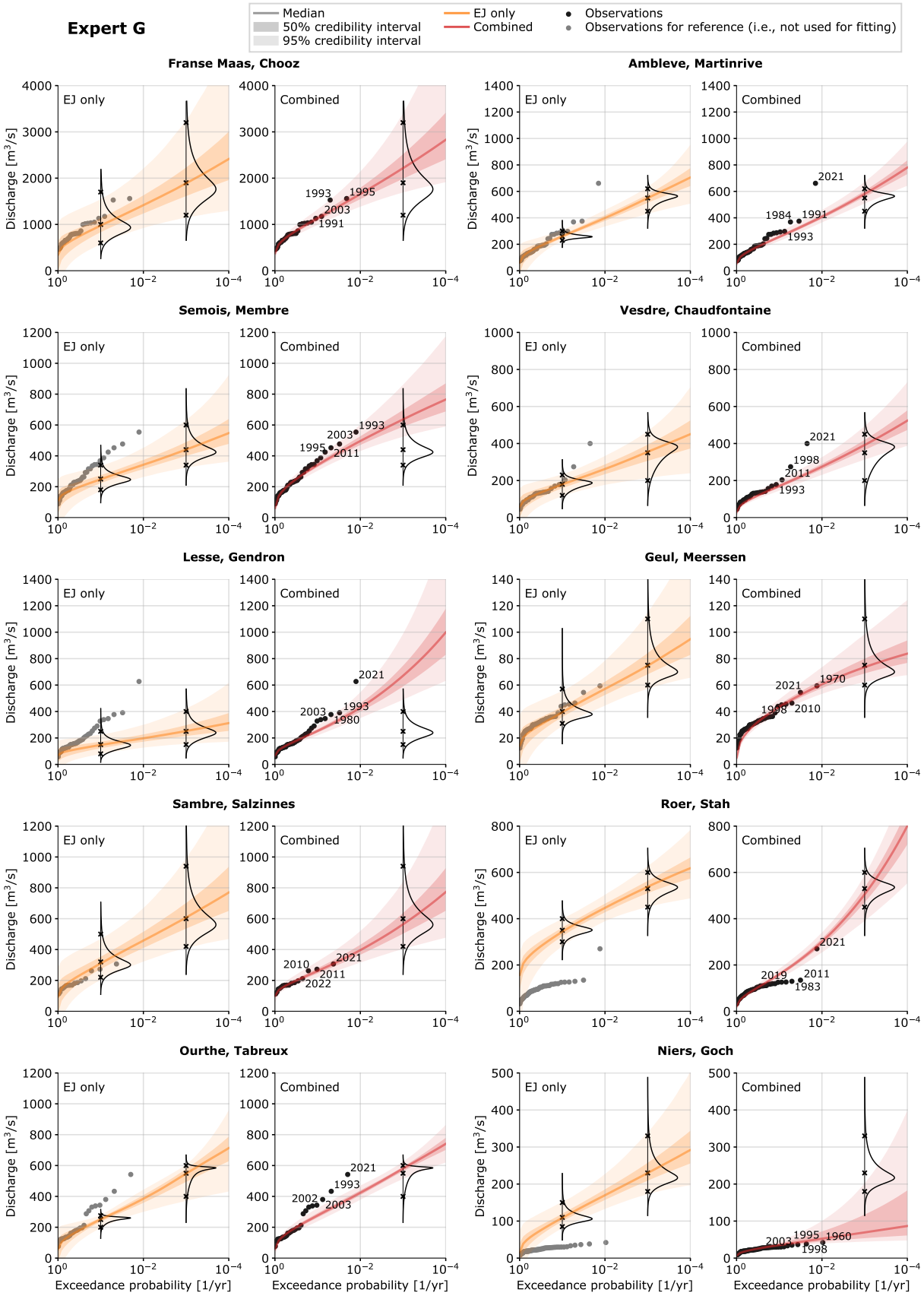

Fig. S 11 Exceedance frequency curves of tributary discharges for Expert G. Fitted to only the estimates (first and third column), and the combination between estimates and data (second and fourth column).

S4.2 Exceedance frequency curves for downstream discharges

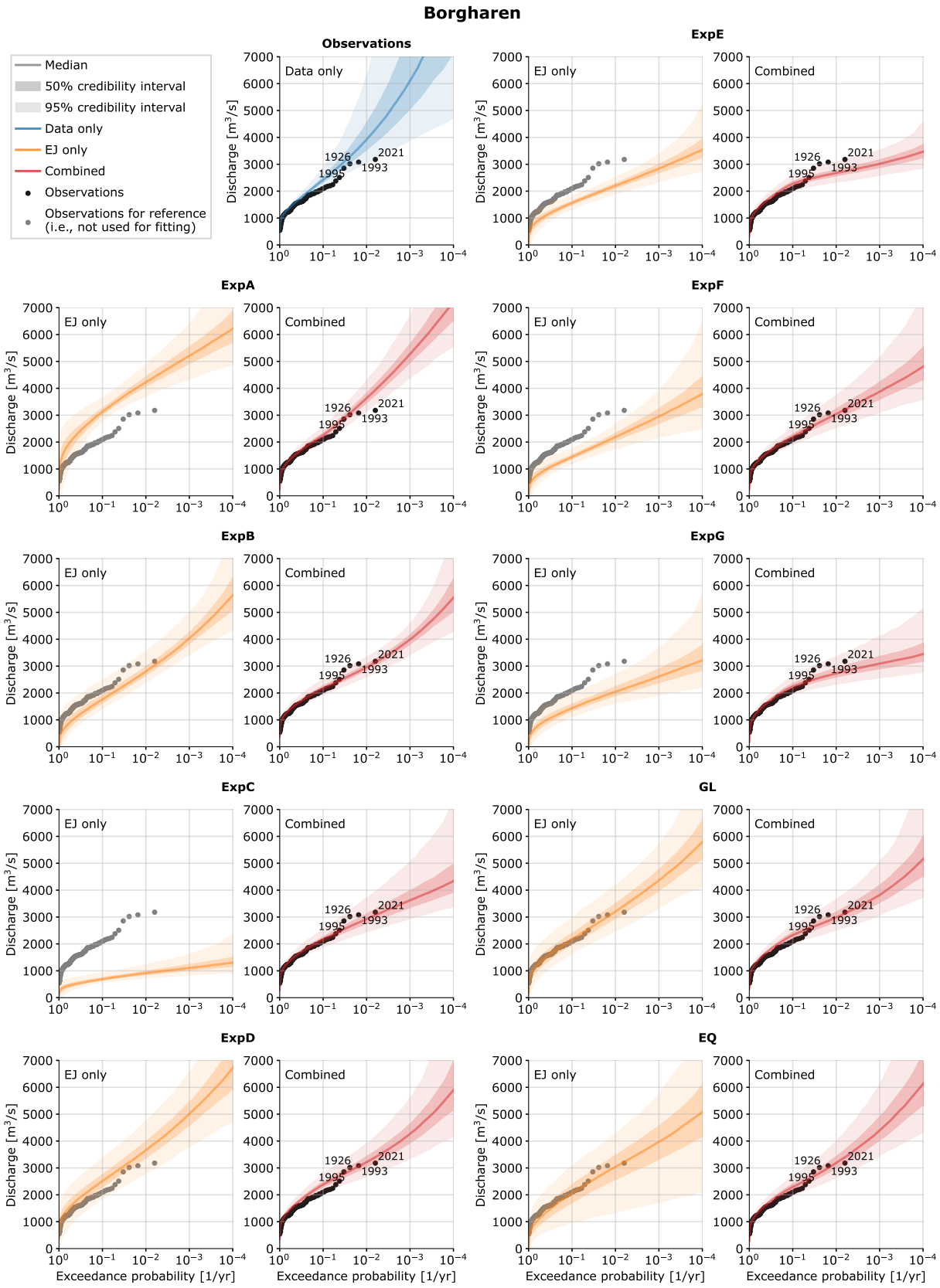

Fig. S 12 Exceedance frequency curves of the downstream discharges at Borgharen. Fitted to observations (blue), only estimates (orange), and the combination between estimates and data (red).

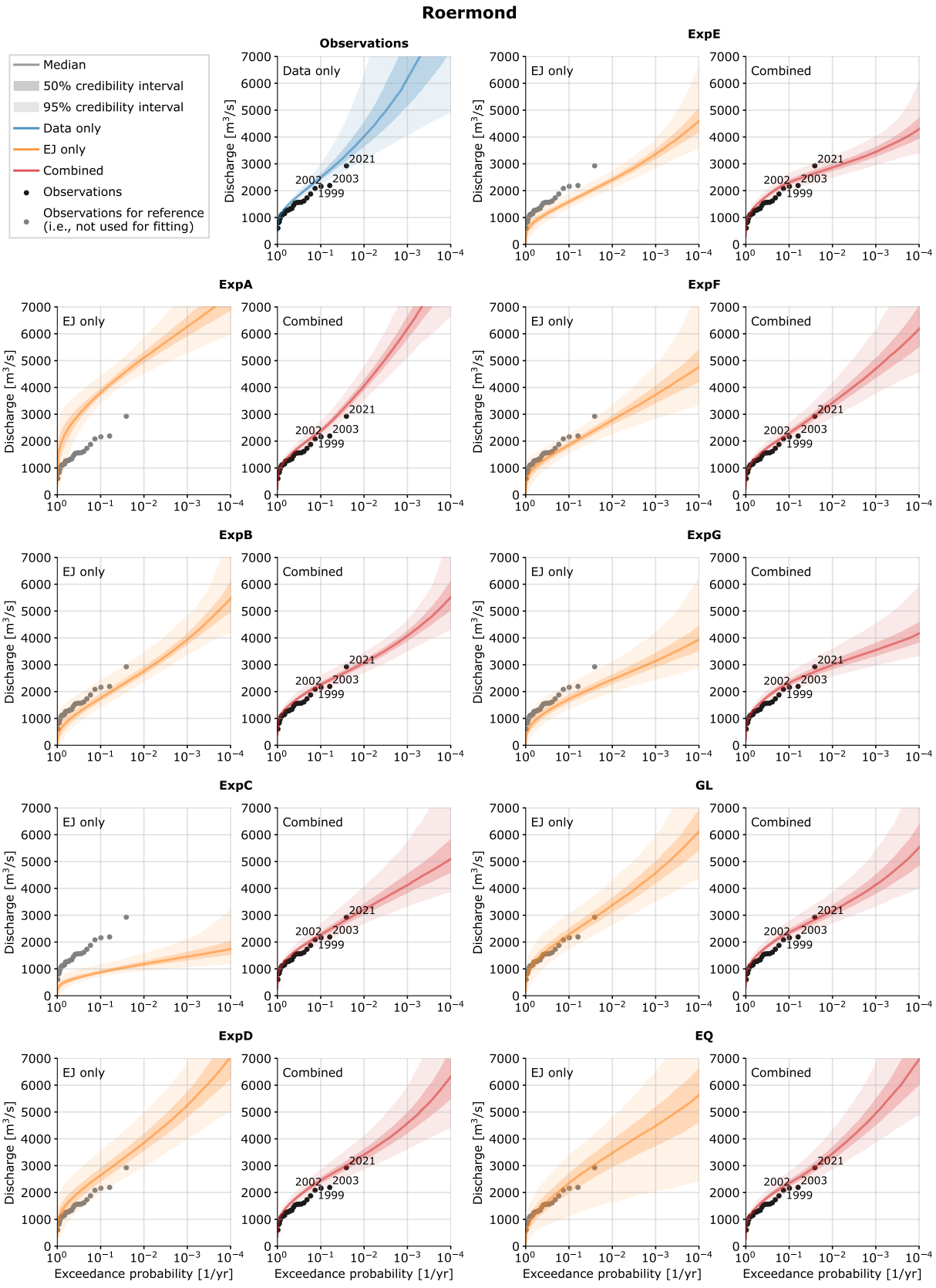

Fig. S 13 Exceedance frequency curves of the downstream discharges at Roermond. Fitted to observations (blue), only estimates (orange), and the combination between estimates and data (red).

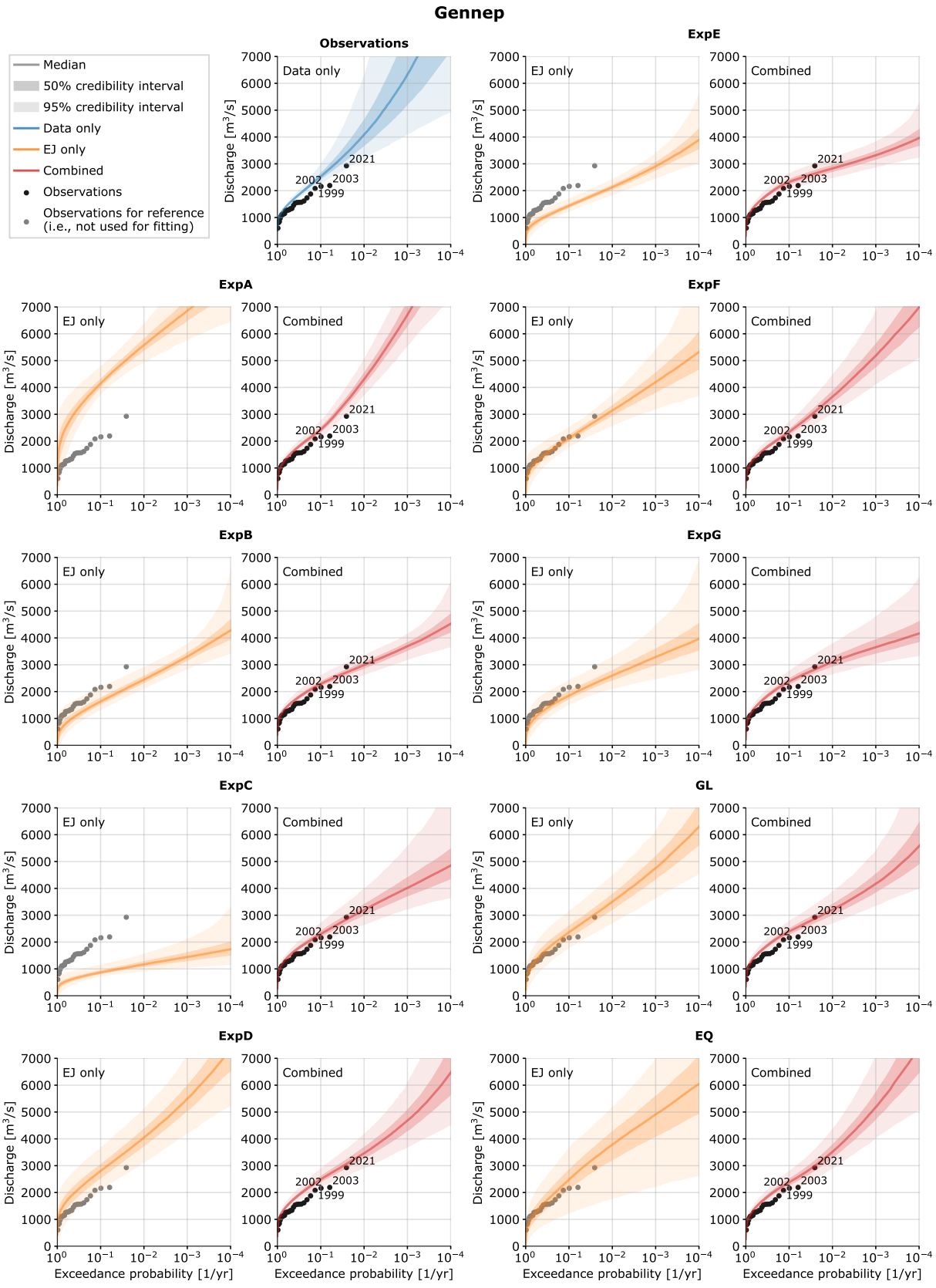

Fig. S 14 Exceedance frequency curves of the downstream discharges at Gennep. Fitted to observations (blue), only estimates (orange), and the combination between estimates and data (red).

S5 Hydrological information on the river Meuse

S5.1 Catchment overview

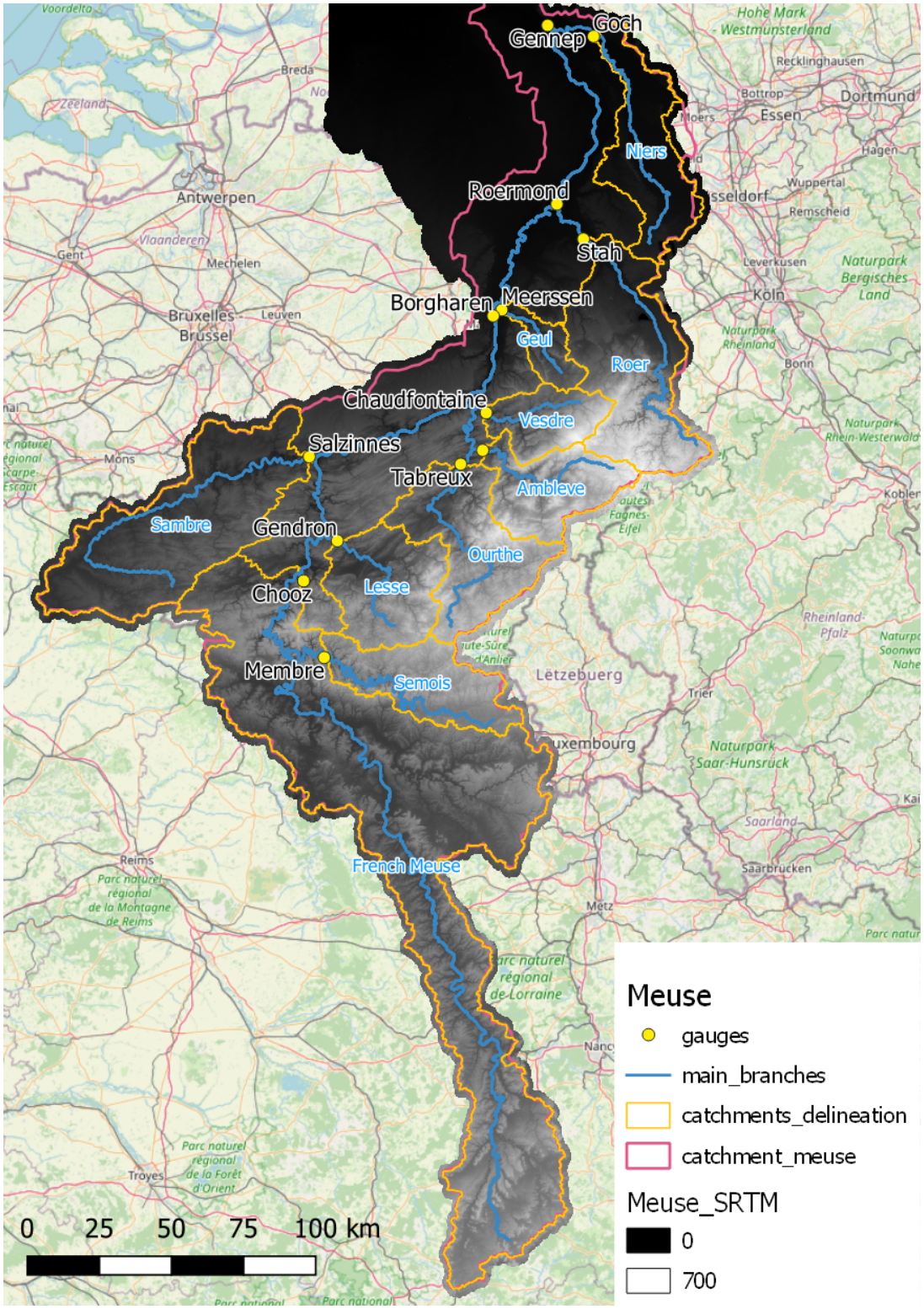

Fig. S 15 Digital elevation map of the Meuse catchment. Background map tiles: © OpenStreetMap contributors 2022. Distributed under the Open Data Commons Open Database License (ODbL) v1.0.

S5.2 Land use

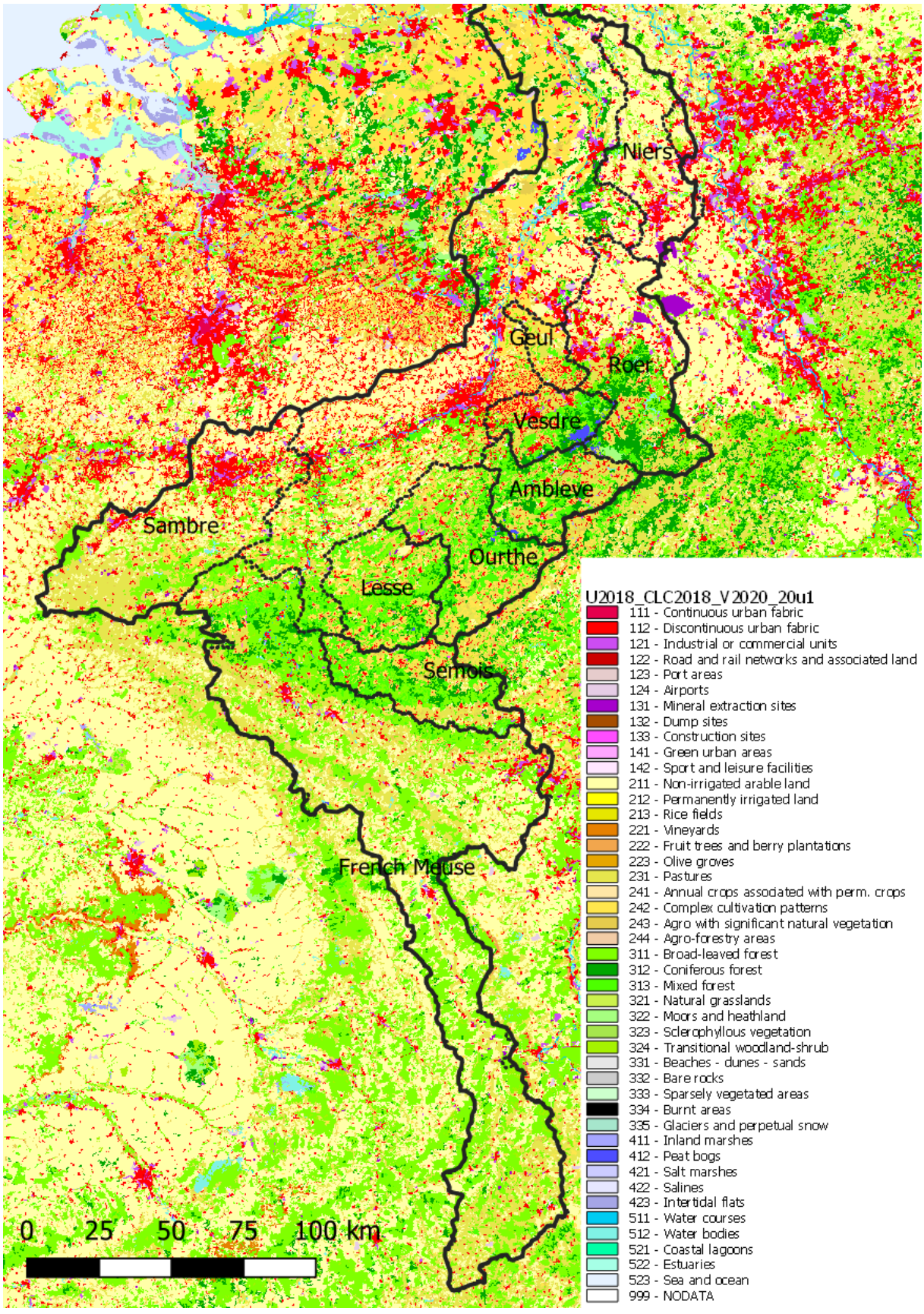

Fig. S 16 Land use in the Meuse catchment

S5.3 River profiles and time of concentration

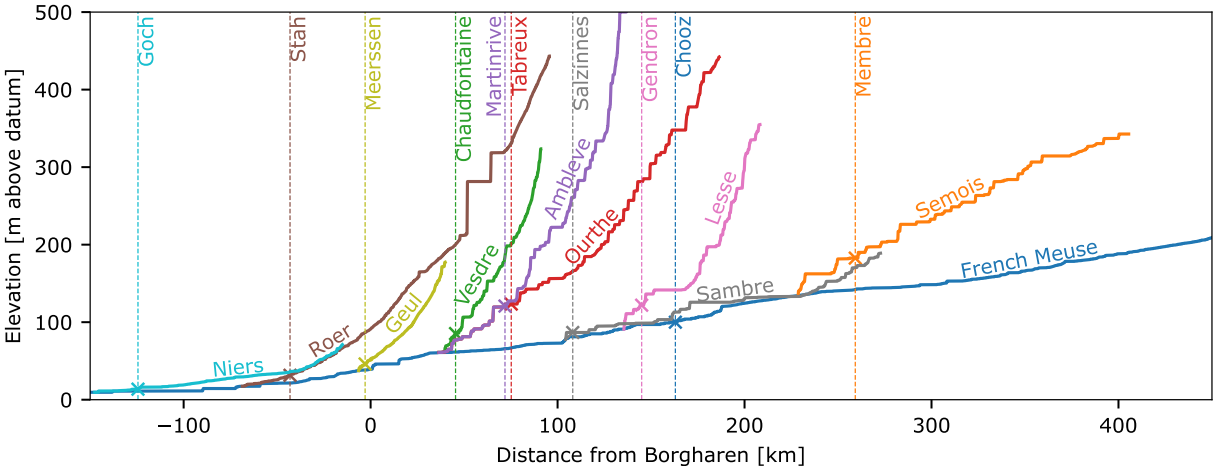

Fig. S 17 Vertical profile of the considered tributaries.

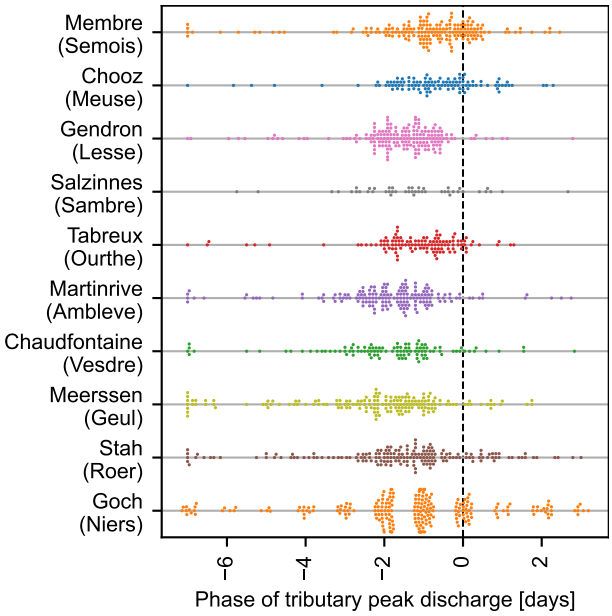

Fig. S 18 Time difference between peak discharge on tributary and the peak discharge at Borgharen.

S5.4 Characteristics of subcatchments

S5.4.1 Area

Note that the confluence of the Semois is upstream of Chooz. The percentages of Semois in the table below are included in the percentages and area for Chooz. You don't have to take this into account for your estimates, just make them for Chooz or Membre, considering all of the upstream area.

Table S 1 Areas in the Meuse catchment

station	river	area	percent Borgharen	percent Roermond	percent Gennep
Chaudfontaine	Vesdre	688.6	3.2	2.7	2.4
Chooz	French Meuse	10161.6	47.7	40.6	36.1
Gendron	Lesse	1281.1	6.0	5.1	4.5
Martinrive	Ambleve	1065.9	5.0	4.3	3.8
Salzinnes	Sambre	2875.4	13.5	11.5	10.2
Tabreux	Ourthe	1609.1	7.5	6.4	5.7
Membre	Semois	1225.7	5.7	4.9	4.4
Stah	Roer	2096.7		8.4	7.4
Meerssen	Geul	338.7		1.4	1.2
Goch	Niers	1265.6			4.5
Sum		**21382.7**	**82.9**	**80.3**	**75.9**
Borgharen remainder	Meuse	3641.0	17.1		
Roermond remainder	Meuse	4940.3		19.7	
Gennep remainder	Meuse	6788.1			24.1
Borgharen	Meuse	21322.7			
Roermond	Meuse	25057.4			
Gennep	Meuse	28170.8			

S5.4.2 Soil composition

Table S 2 Soil composition percentages in the Meuse catchment

		topsoil			subsoil		
station	river	sand	silt	clay	sand	silt	clay
Chaudfontaine	Vesdre	41	24	35	40	26	33
Chooz	French Meuse	46	26	28	41	21	26
Gendron	Lesse	39	25	35	38	27	33
Martinrive	Ambleve	38	25	36	38	28	34
Salzinnes	Sambre	50	21	26	44	21	26
Tabreux	Ourthe	39	26	35	37	28	32
Membre	Semois	50	21	30	48	22	29
Stah	Roer	50	22	27	47	22	26
Meerssen	Geul	53	21	26	48	20	26
Goch	Niers	63	19	18	59	15	21

S5.4.3 Land use

Table S 3 Land use percentage in the Meuse catchment

station	river	paved	agriculture	forest & grassland	marshes	waterbodies
Chaudfontaine	Vesdre	18.9	31.0	44.7	5.0	0.4
Chooz	French Meuse	5.0	52.2	42.4	0.1	0.3
Gendron	Lesse	5.8	38.6	55.5	0.1	0.0
Martinrive	Ambleve	8.0	42.8	48.0	1.0	0.3
Salzinnes	Sambre	17.0	64.3	18.3	0.1	0.3
Tabreux	Ourthe	6.3	48.0	45.4	0.3	0.0
Membre	Semois	5.7	38.0	56.2	0.0	0.0
Stah	Roer	18.1	47.0	33.6	0.4	0.9
Meerssen	Geul	17.3	69.1	13.6	0.0	0.0
Goch	Niers	22.2	68.2	8.7	0.0	0.9
Borgharen remainder	None	20.8	58.4	19.9	0.0	0.8
Roermond remainder	None	22.2	57.3	19.1	0.0	1.4
Gennep remainder	None	20.5	59.0	19.1	0.1	1.3

S5.5 Precipitation statistics

The precipitation statistics are derived from ”E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations”. Three characteristics are displayed to provide insight in the precipitation:

- The average daily precipitation, per month and catchment.
- The average precipitation sum per year, per catchment.
- Intensity duration frequency curves.

S5.5.1 Average daily precipitation per month and catchment

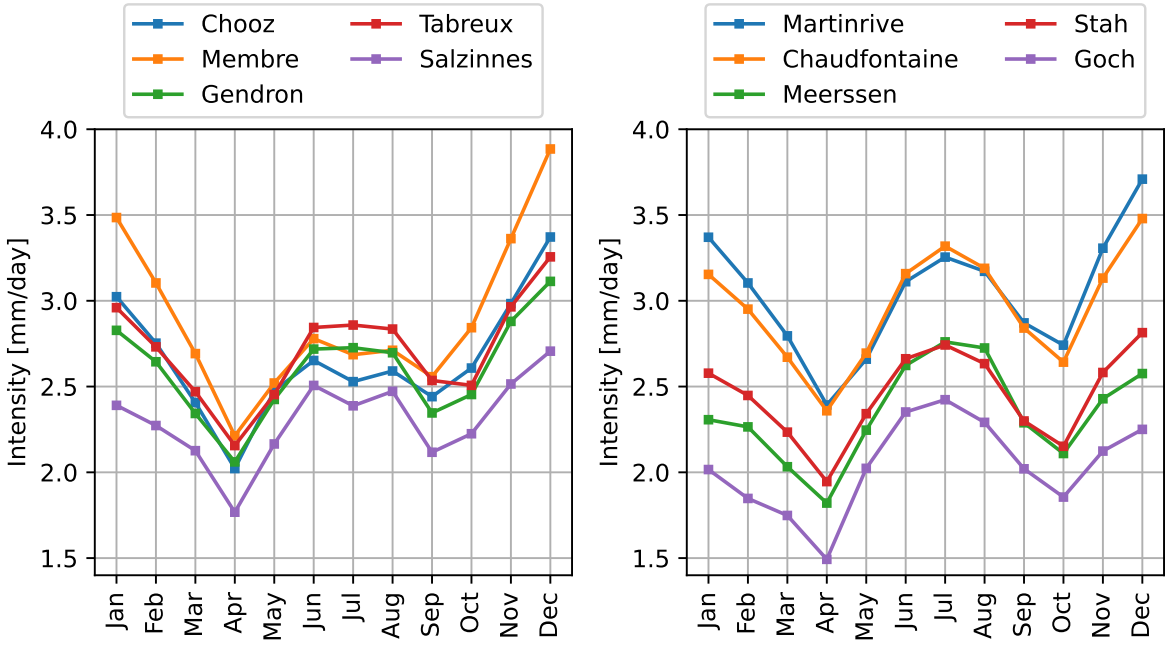

Fig. S 19 Average daily precipitation sum per month, for different subcatchments of the Meuse

S5.5.2 Yearly precipitation sum per subcatchment

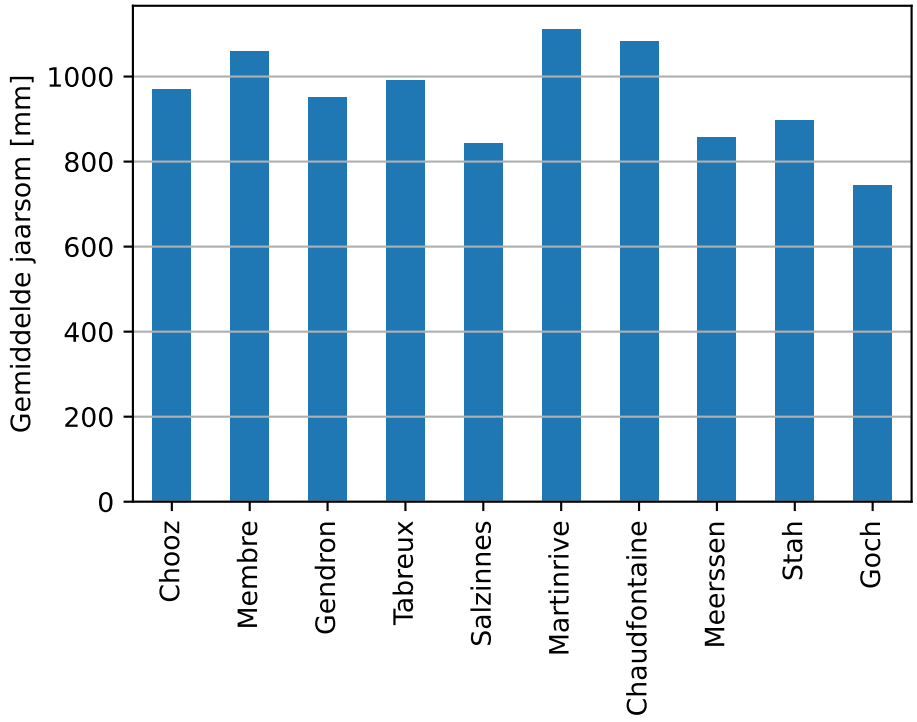

Fig. S 20 Average precipitation sum per year, for the different sub catchments of the Meuse

S5.5.3 Intensity-duration-frequency curves per subcatchment

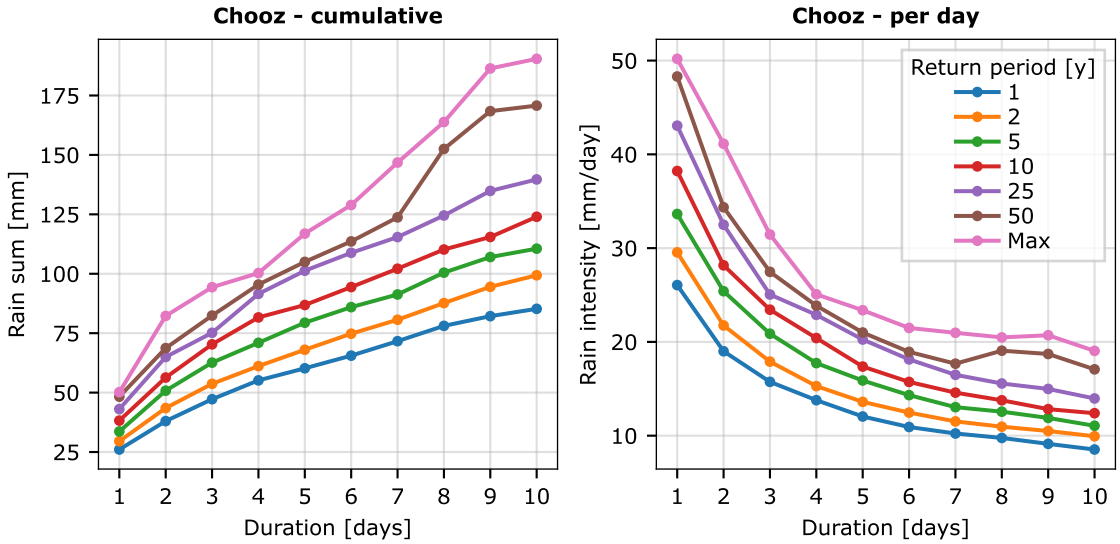

Fig. S 21 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the French Meuse

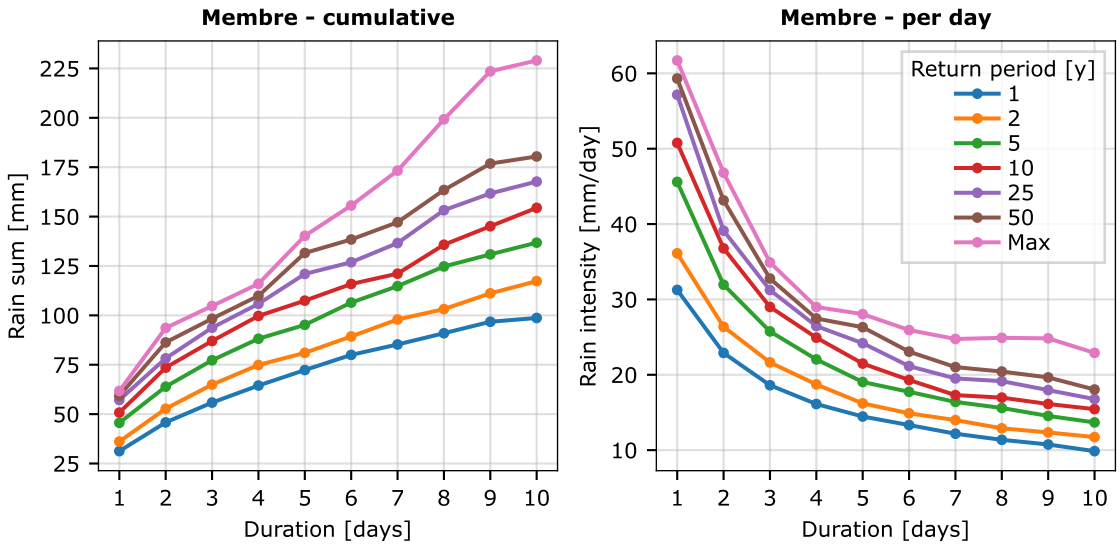

Fig. S 22 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Semois

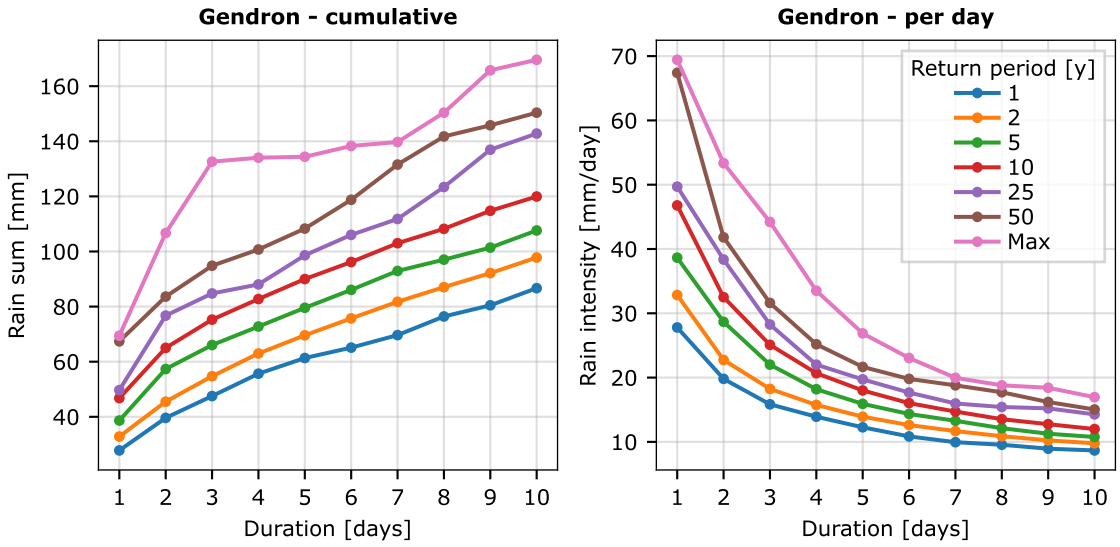

Fig. S 23 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Lesse

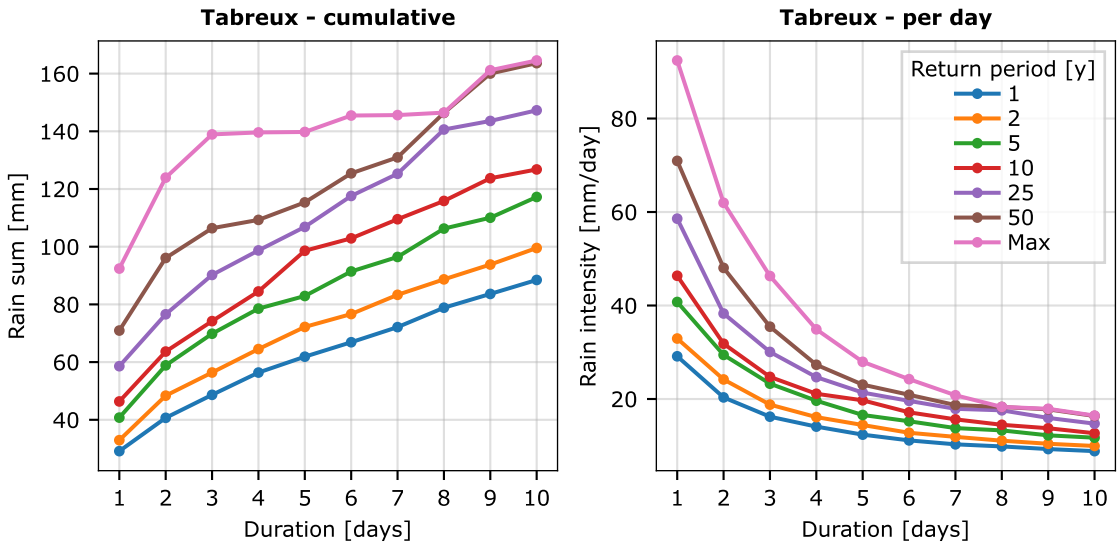

Fig. S 24 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Ourthe

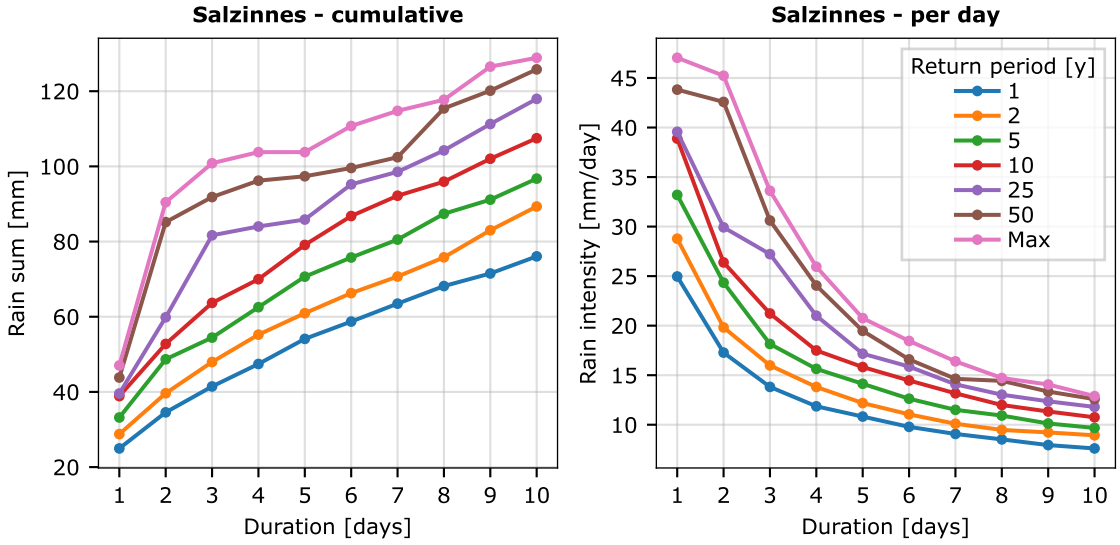

Fig. S 25 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Sambre

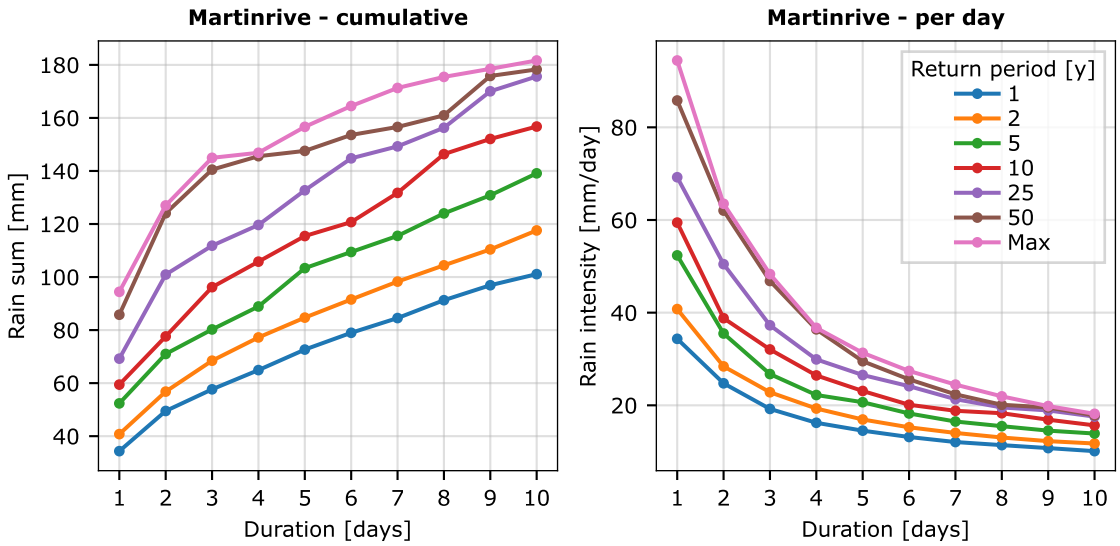

Fig. S 26 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Ambleve

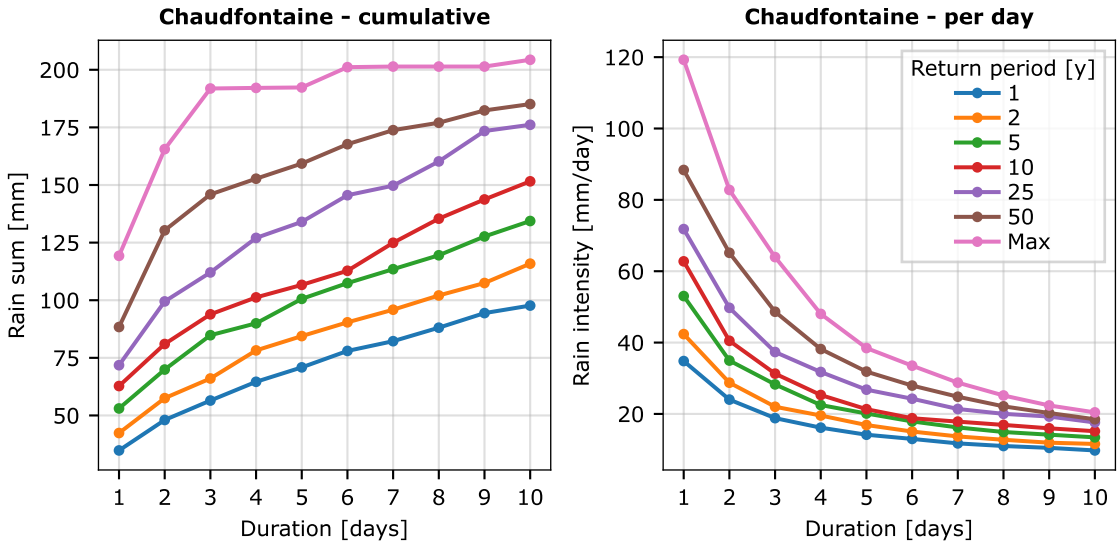

Fig. S 27 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Vesdre

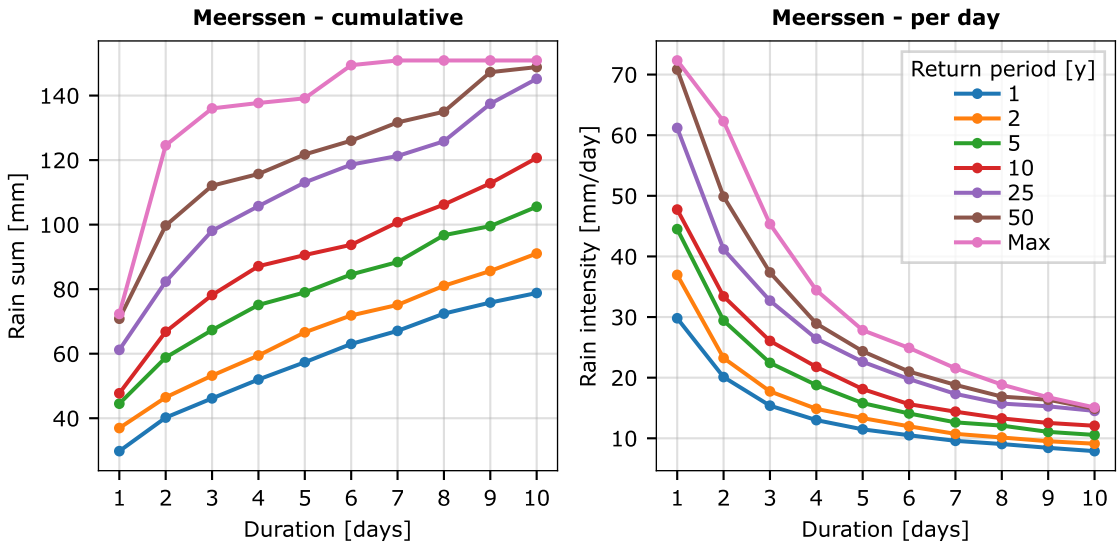

Fig. S 28 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Geul

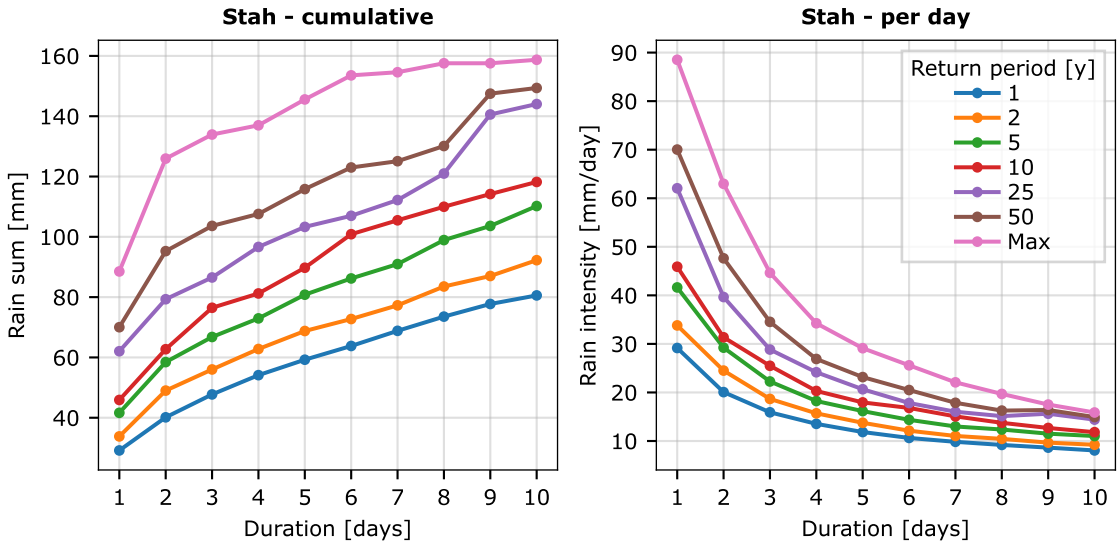

Fig. S 29 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Roer

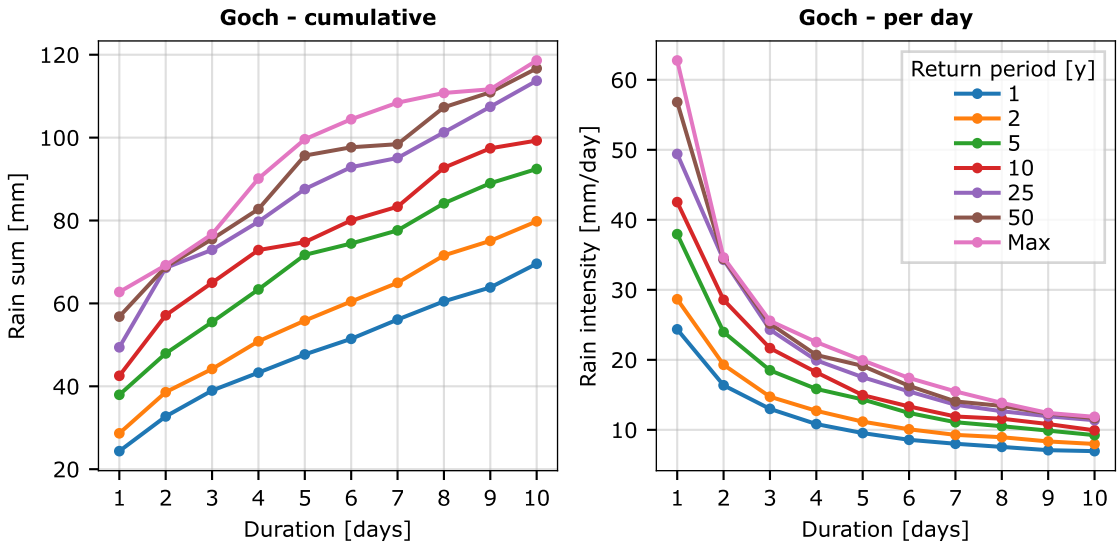

Fig. S 30 Intensity (left) en precipitation sum (right) for different durations and return periods, for the catchment of the Niers

S5.6 Precipitation and hydrographs

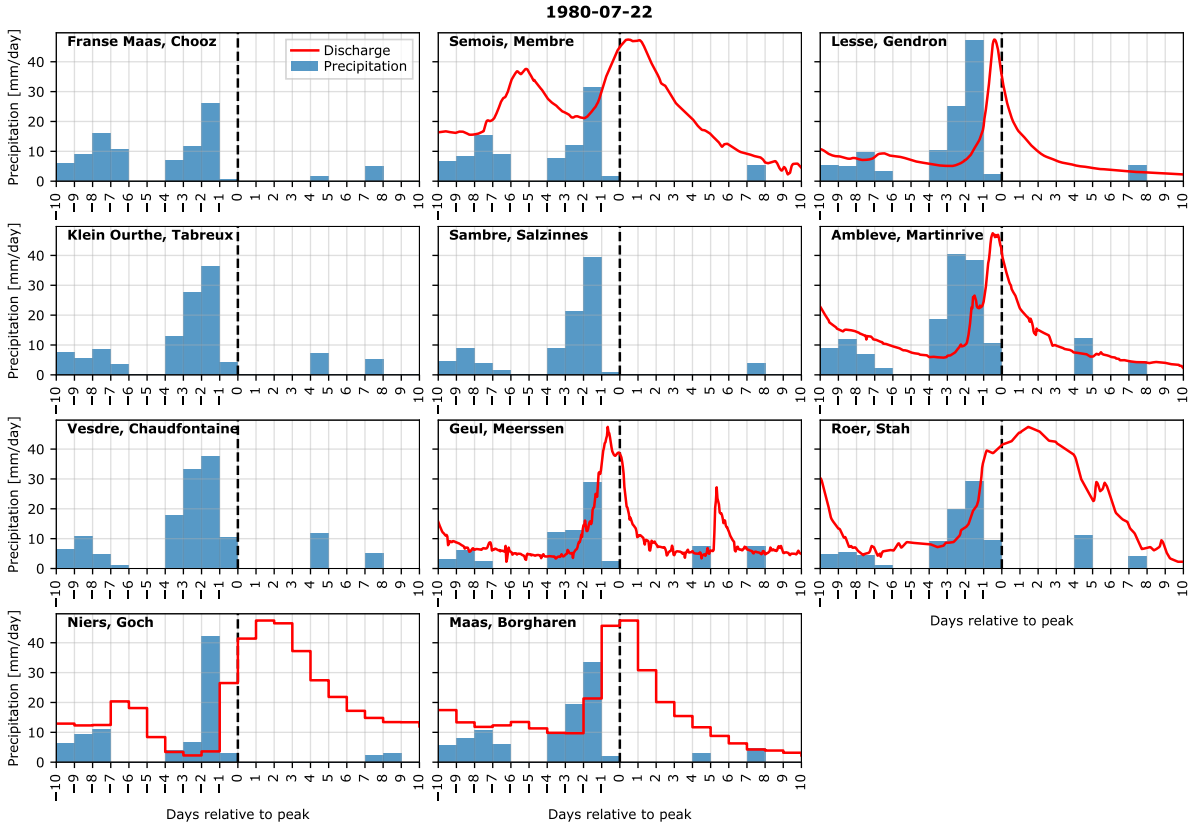

Fig. S 31 Precipitation and hydrographs for the 1980-07-22 high discharge event on the Meuse

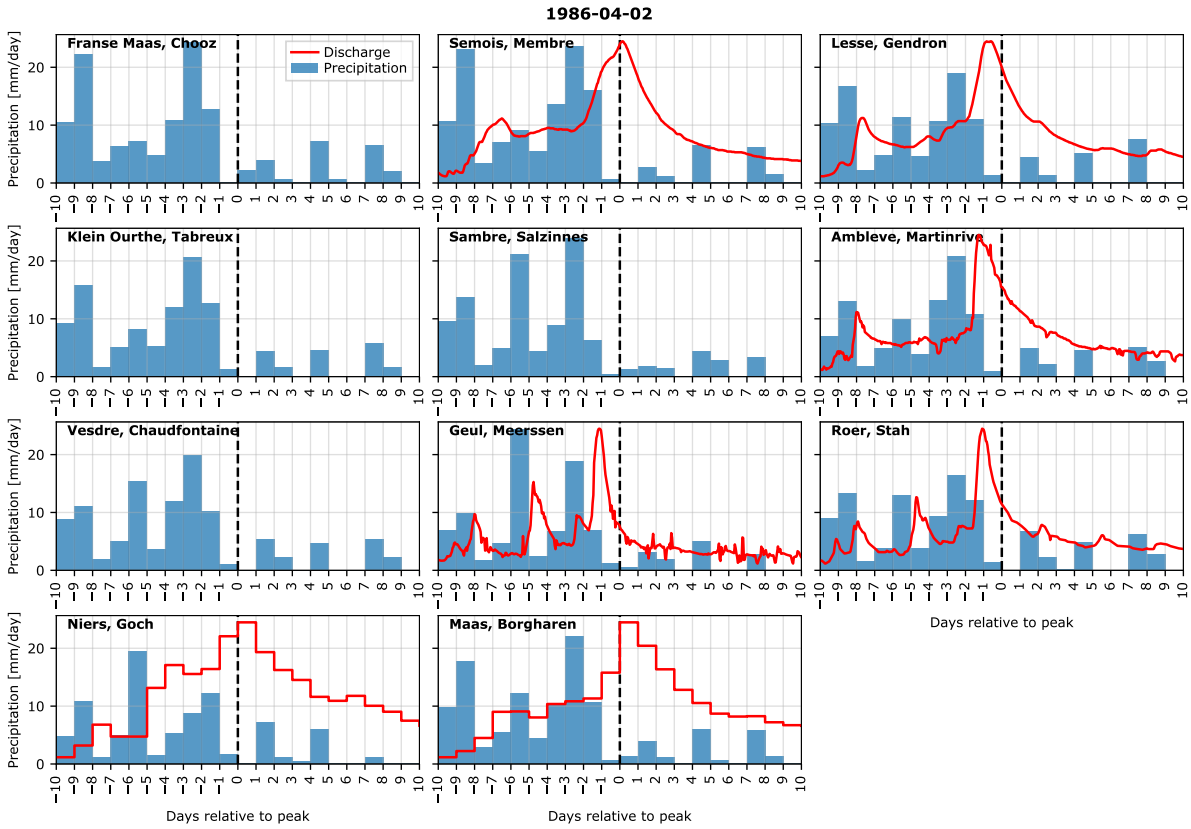

Fig. S 32 Precipitation and hydrographs for the 1986-04-02 high discharge event on the Meuse

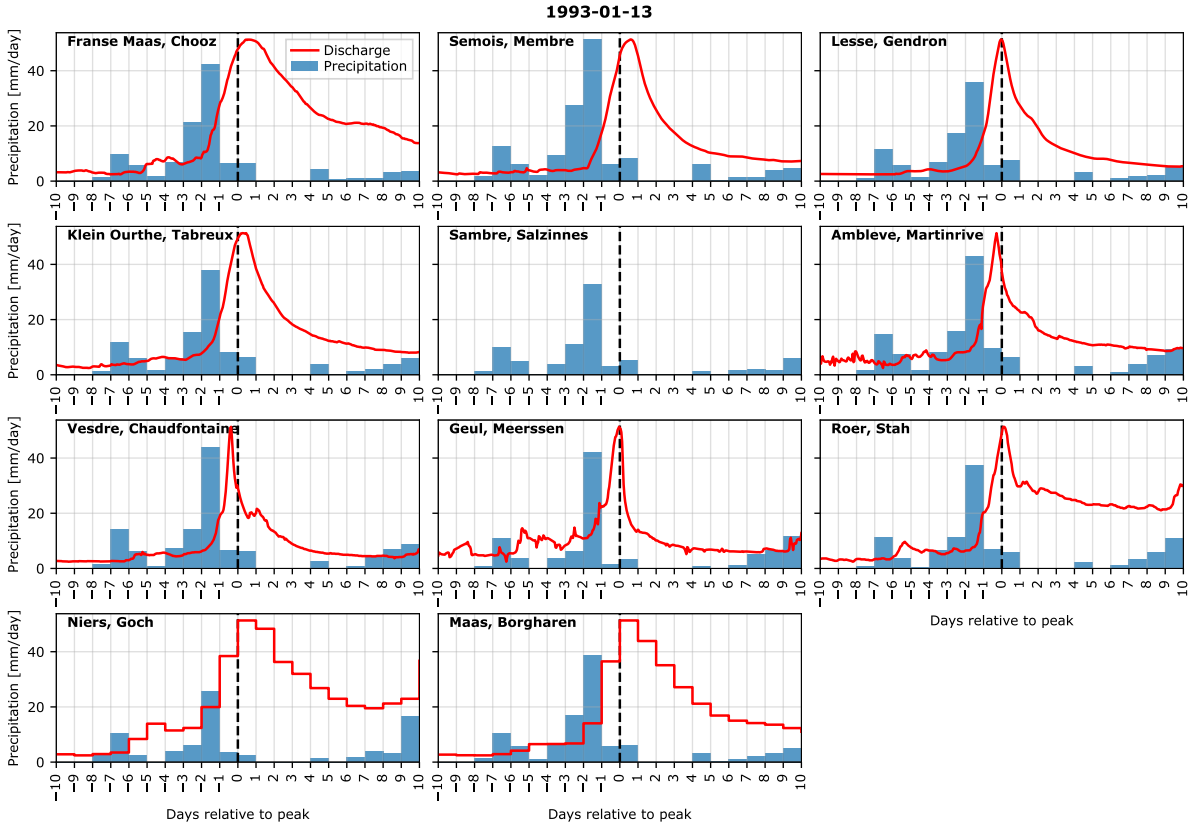

Fig. S 33 Precipitation and hydrographs for the 1993-01-13 high discharge event on the Meuse

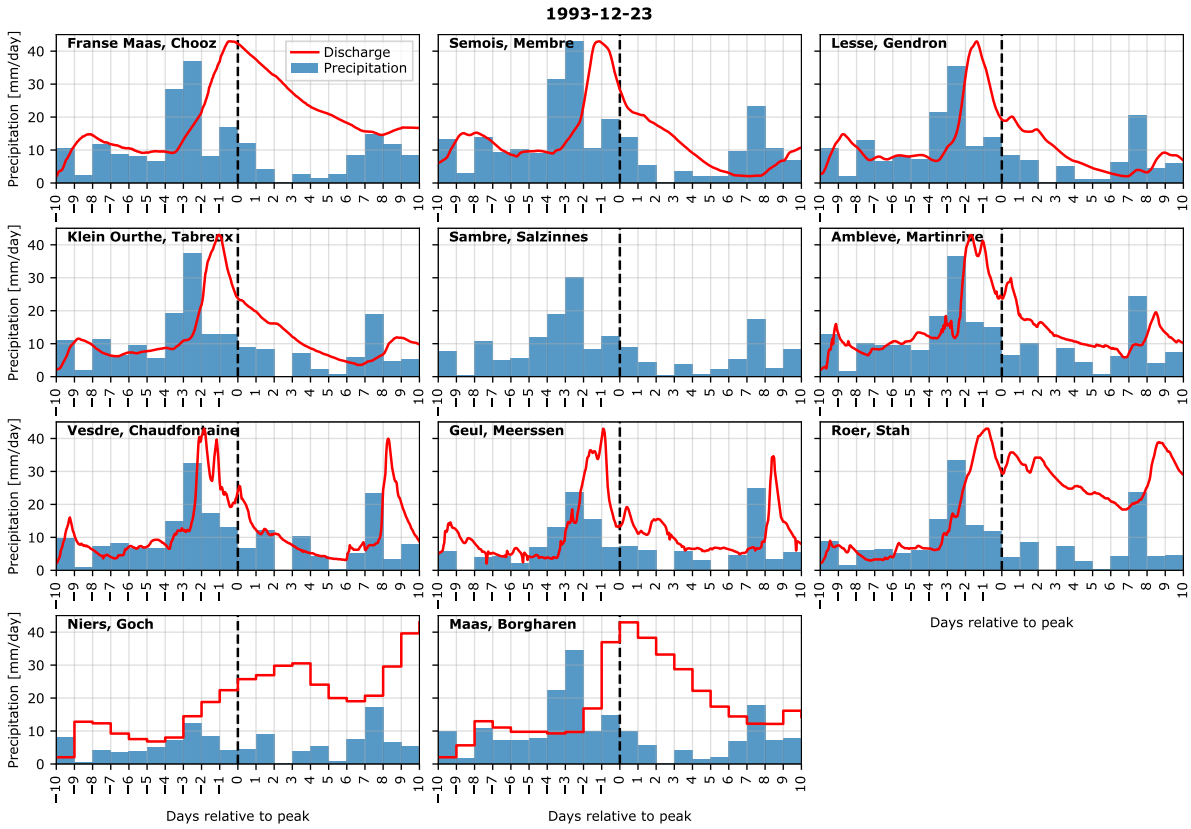

Fig. S 34 Precipitation and hydrographs for the 1993-12-23 high discharge event on the Meuse

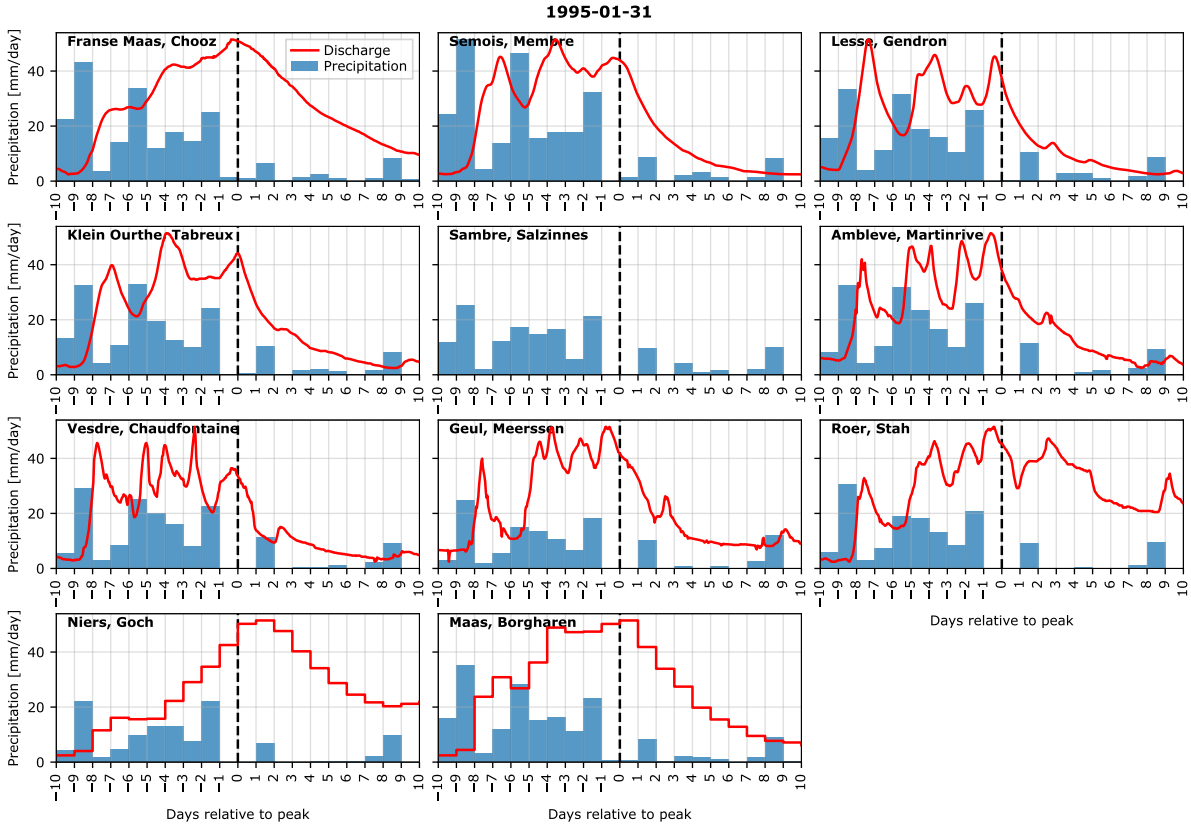

Fig. S 35 Precipitation and hydrographs for the 1995-01-31 high discharge event on the Meuse

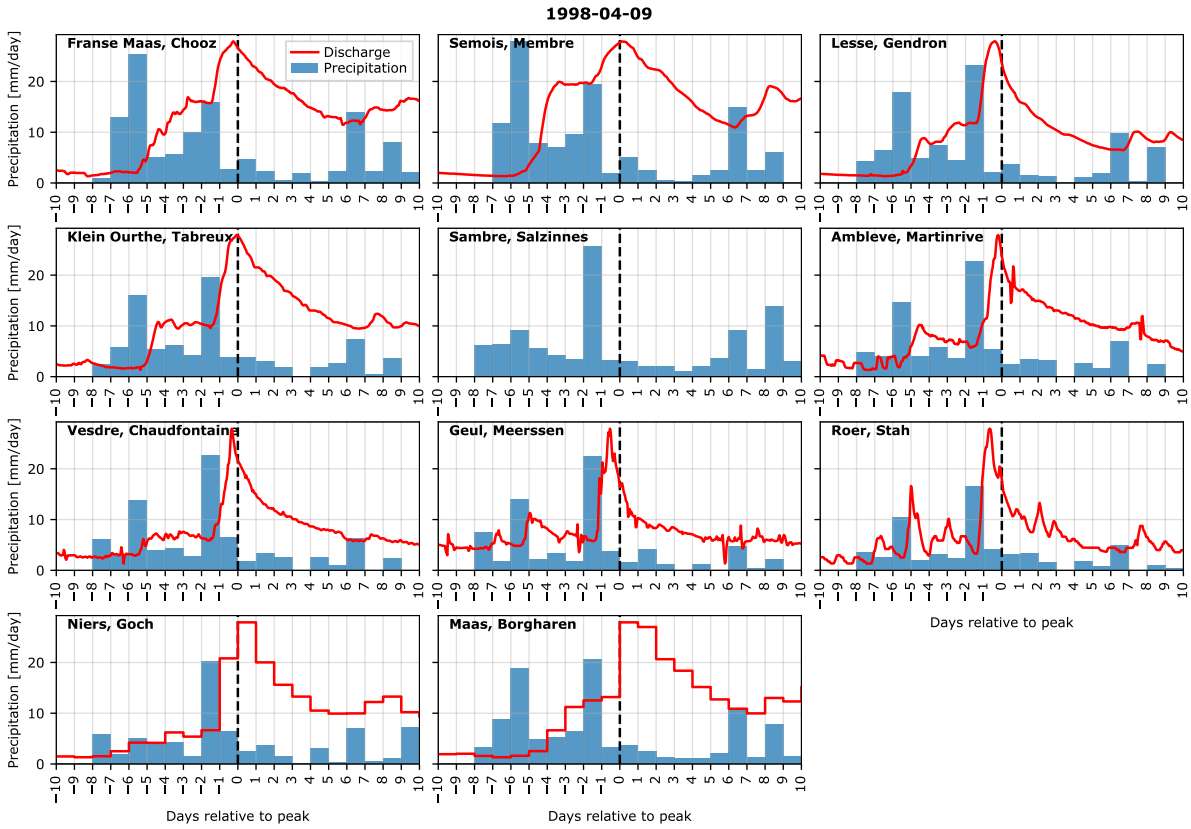

Fig. S 36 Precipitation and hydrographs for the 1998-04-09 high discharge event on the Meuse

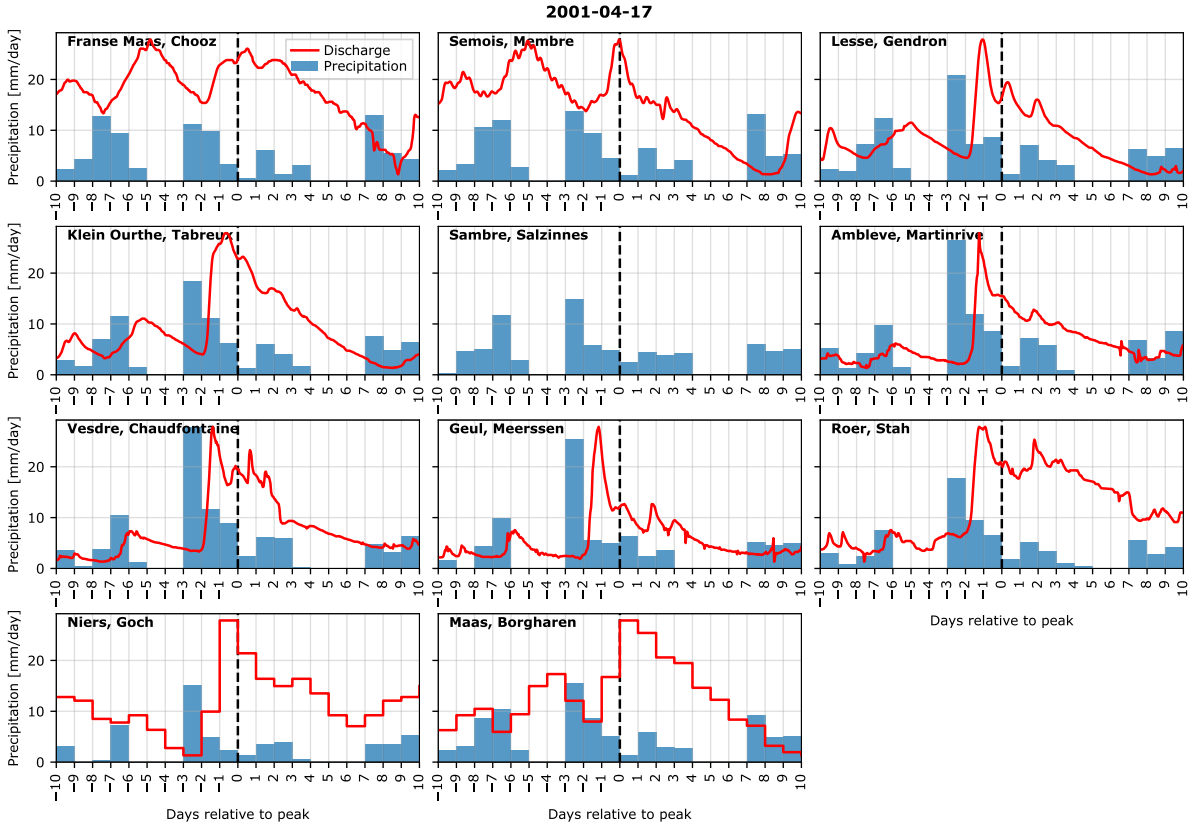

Fig. S 37 Precipitation and hydrographs for the 2001-04-17 high discharge event on the Meuse

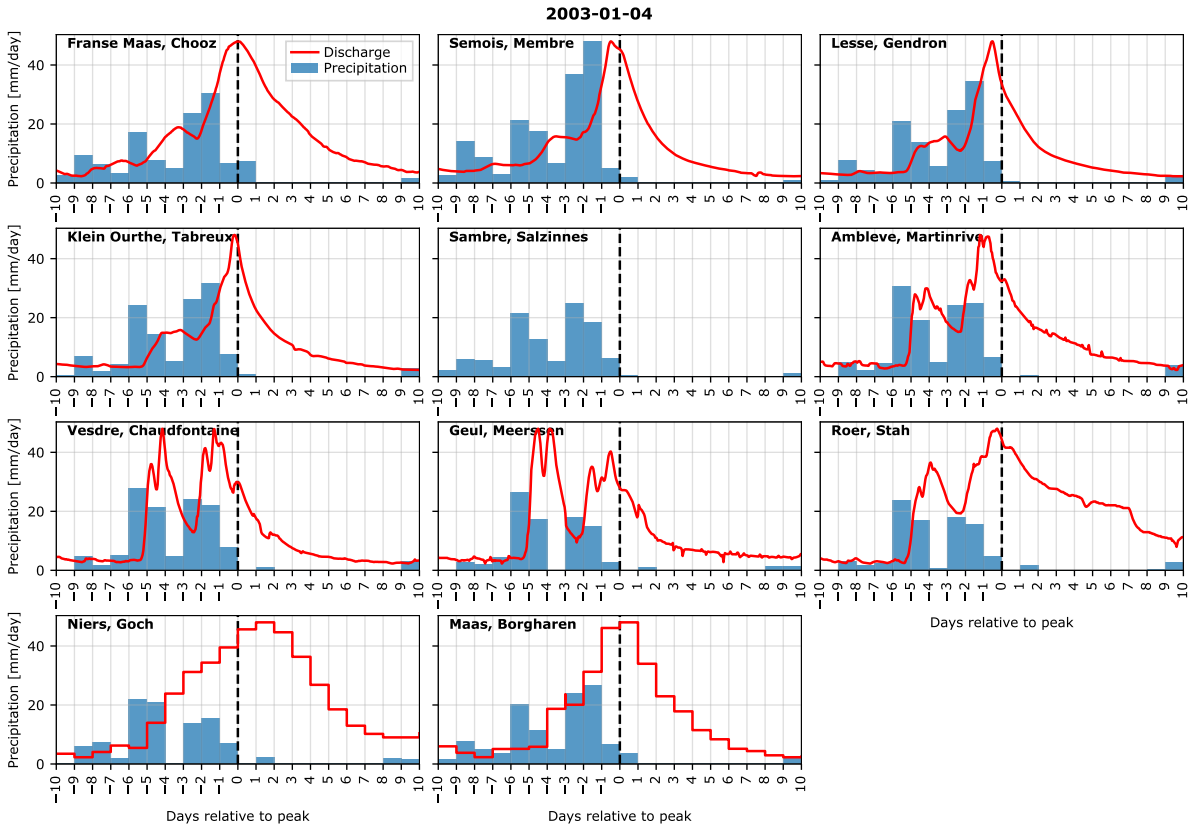

Fig. S 38 Precipitation and hydrographs for the 2003-01-04 high discharge event on the Meuse

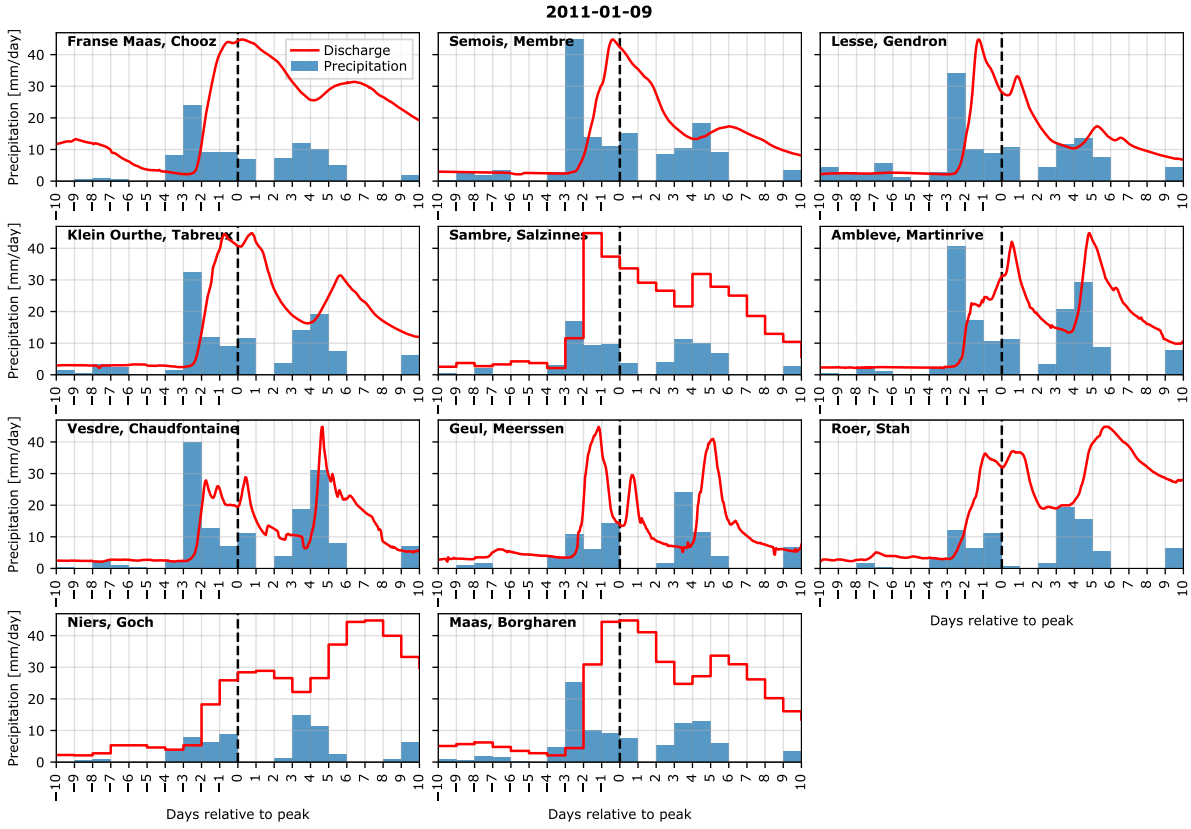

Fig. S 39 Precipitation and hydrographs for the 2011-01-09 high discharge event on the Meuse

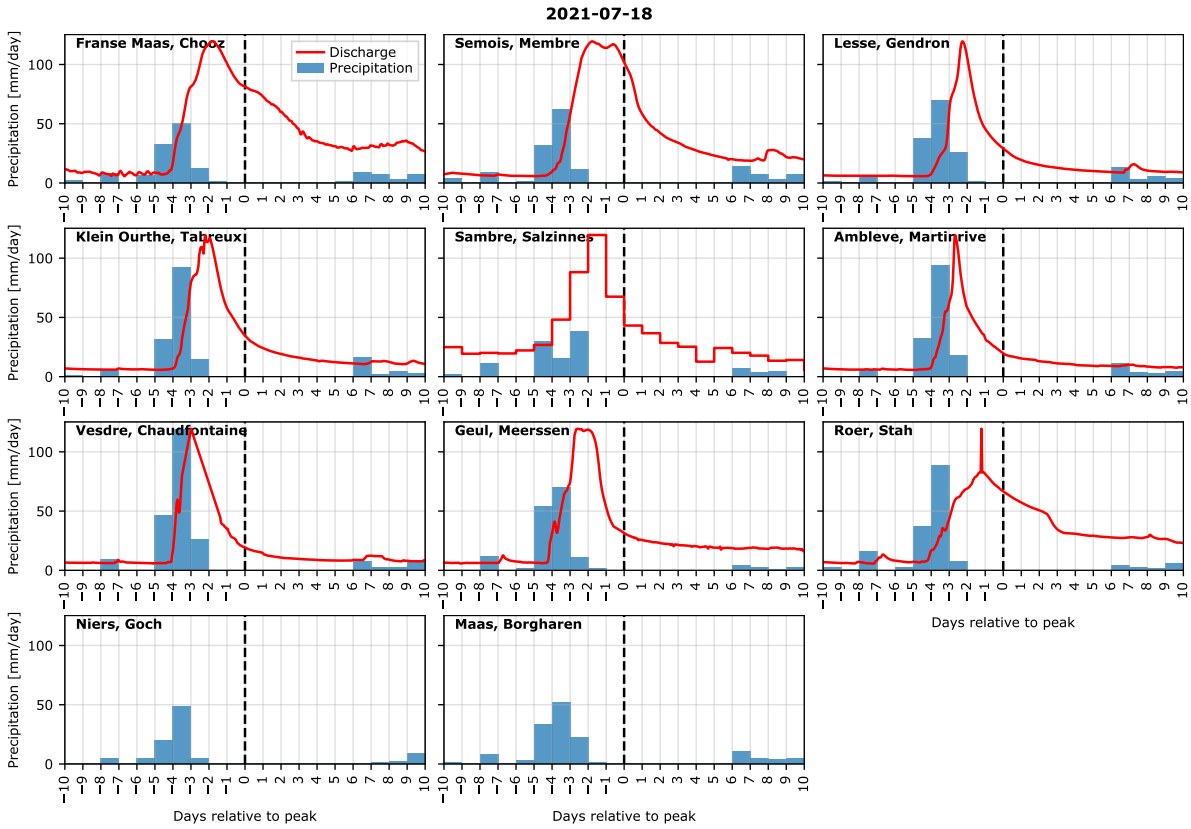

Fig. S 40 Precipitation and hydrographs for the 2021-07-18 high discharge event on the Meuse