Evaluating quantitative precipitation estimates and hydrological models for simulating the 2021 extreme events in Germany

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EGU General Assembly 2022

RealPEP

A B C / J geoverbund aachen bonn cologne jülich

HPSC TerrSys

CPEX-LAB

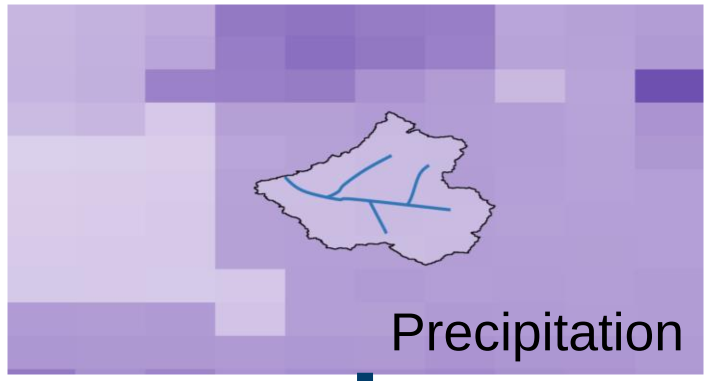
UNIVERSITÄT BONN

Mitglied der Helmholtz-Gemeinschaft

JÜLICH Forschungszentrum

1| Context and objectives

Hydrological evaluation of QPE



Precipitation estimates are biased

Hydrological model

Simulated discharge

Observed discharge

Errors in model outputs

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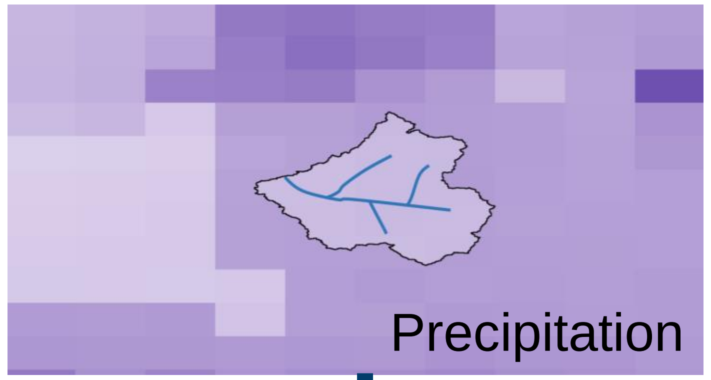

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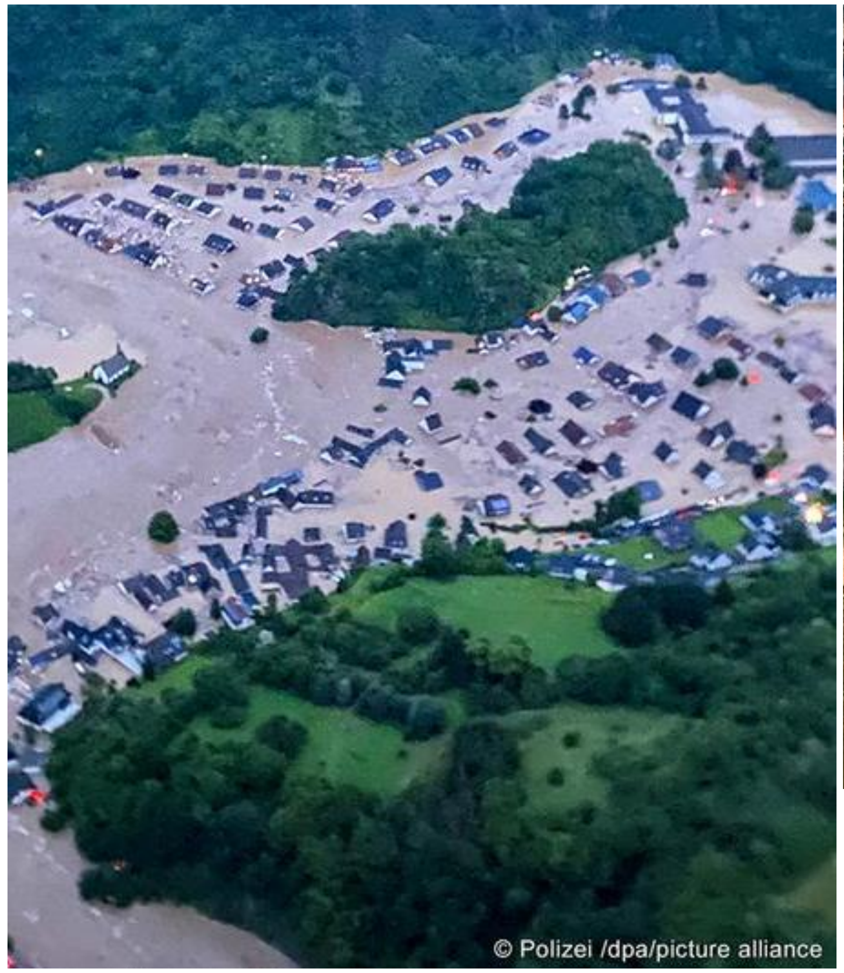
For extreme floods, accurate precipitation estimates are crucial

But event hydrographs are generally unavailable!



July 2021 events at Altenahr and Erftstadt-Blessem (source: DW.com)
>200 fatalities, up to € 5.5 Billion in insured losses

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RealPEP

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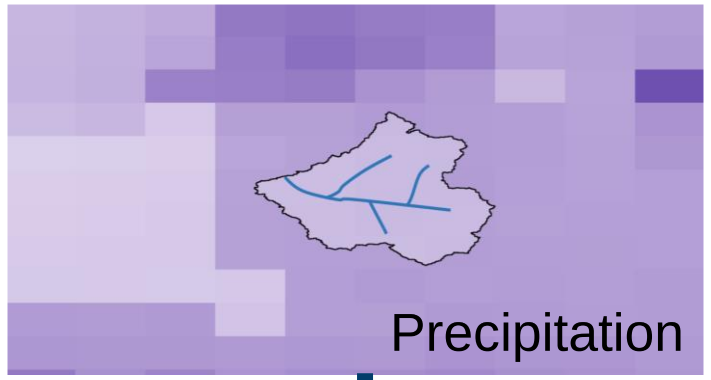

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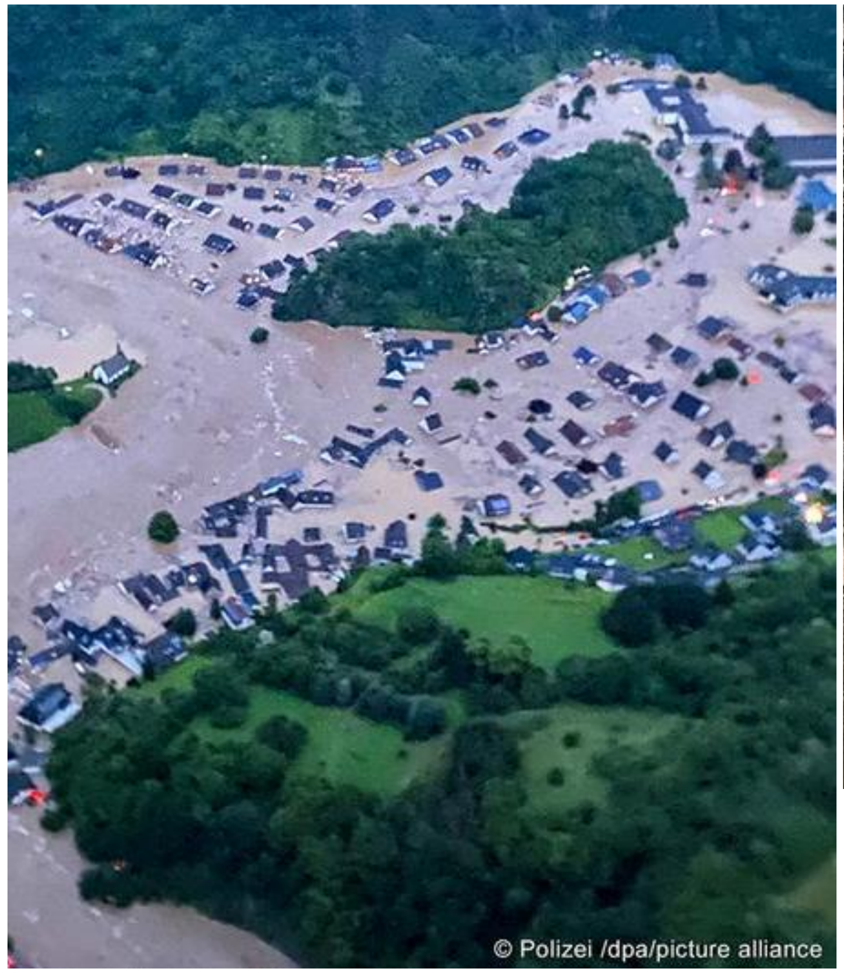

July 2021 events at Altenahr and Erftstadt-Blessem (source: DW.com)
>200 fatalities, up to € 5.5 Billion in insured losses

Given different precipitation estimates (QPE), what were the chances of exceeding the highest measured peakflow?

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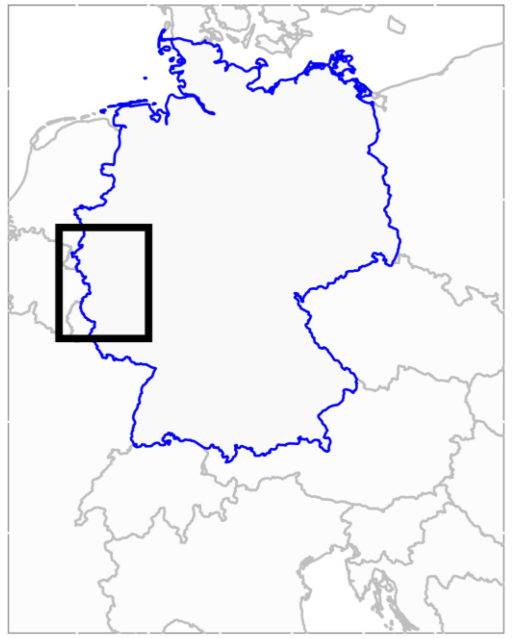
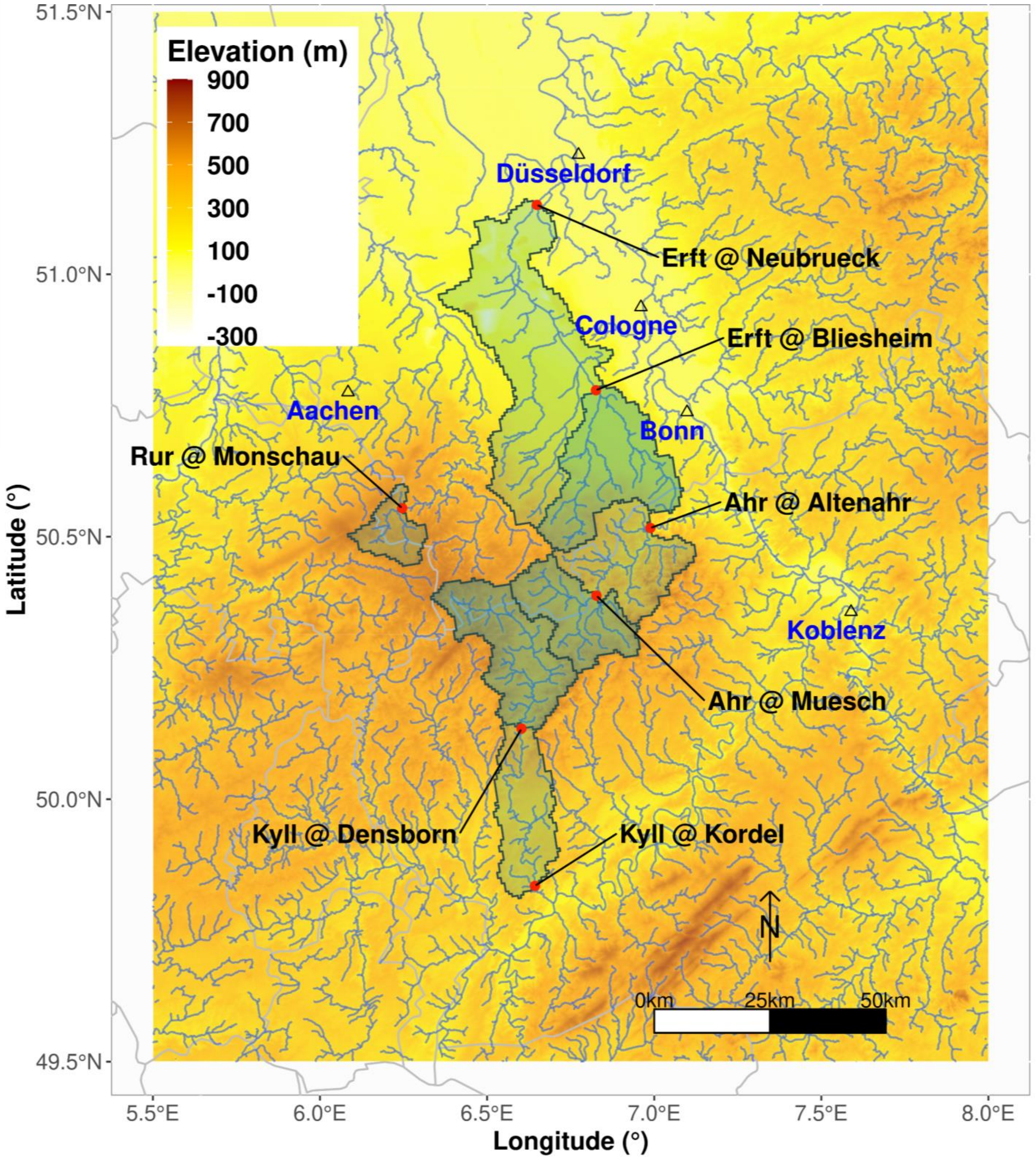
2| Catchments, models and data

2.1 | Seven catchments

Draining the Eifel range





Humid climate, with oceanic influence

Median elevation (m)	150 – 580
Area (km^2)	140 – 1670
Mean precipitation (mm/yr)	700 – 1070
Aridity index (-)	0.52 – 0.89
Mean discharge (mm/yr)	130 – 760

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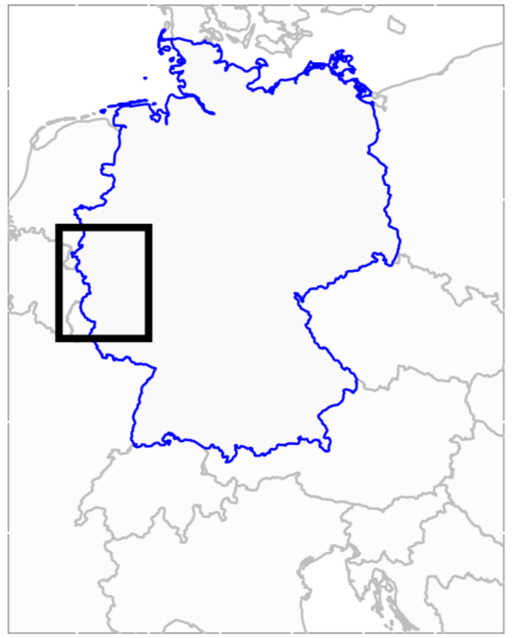

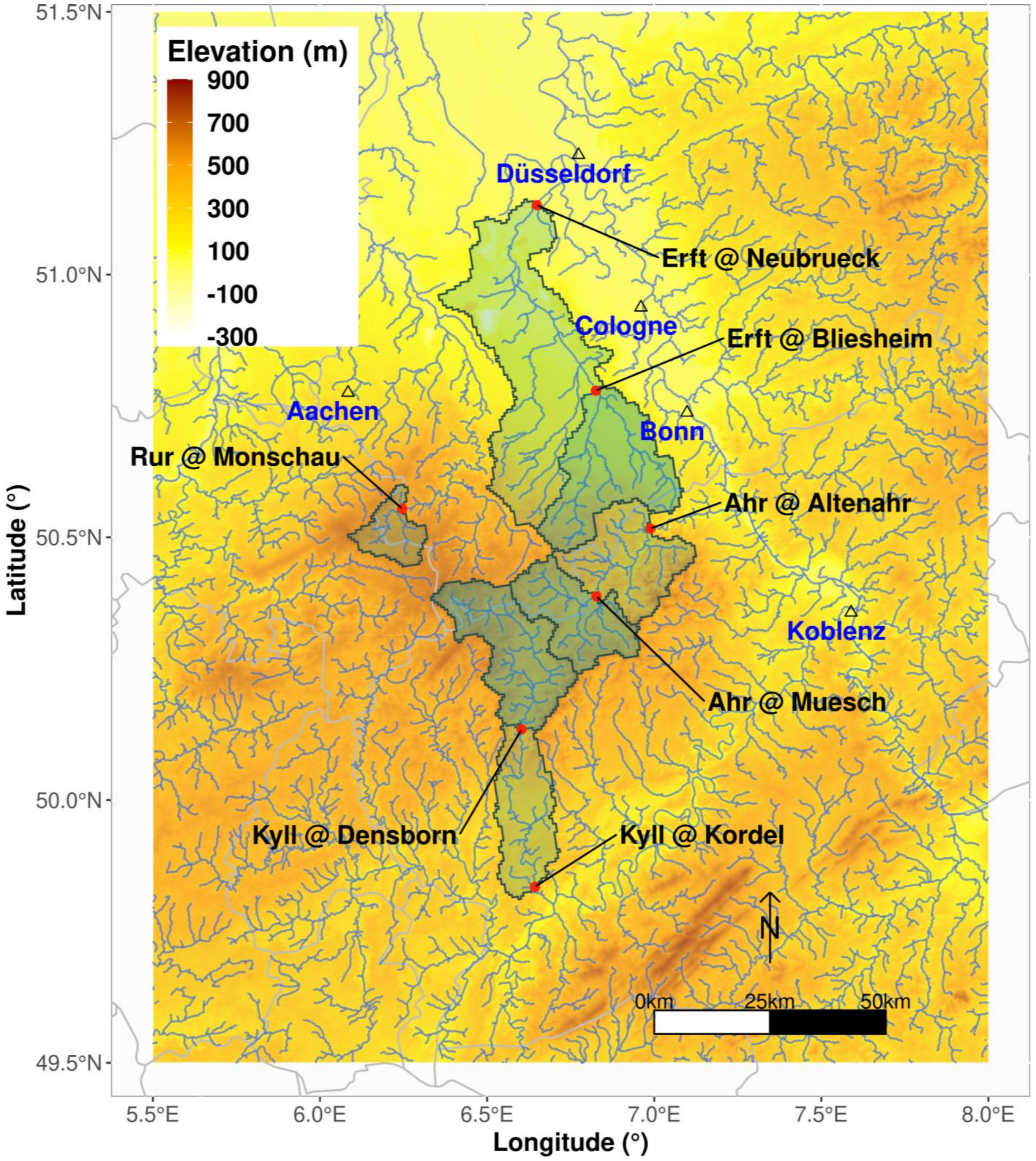

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Highest measured peakflows

Catchment	Historical peakflow (m^3/s)
Ahr @ Altenahr	236
Ahr @ Muesch	132
Erft @ Bliesheim	55.8
Erft @ Neubrueck	46.64
Kyll @ Densborn	180
Kyll @ Kordel	218
Rur @ Monschau	109.63

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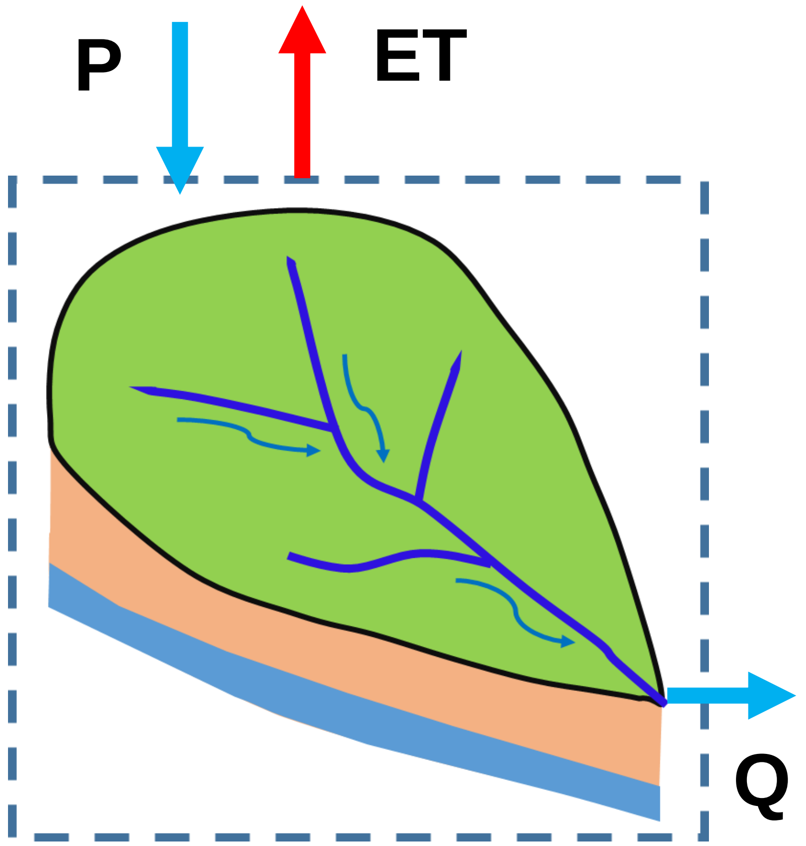
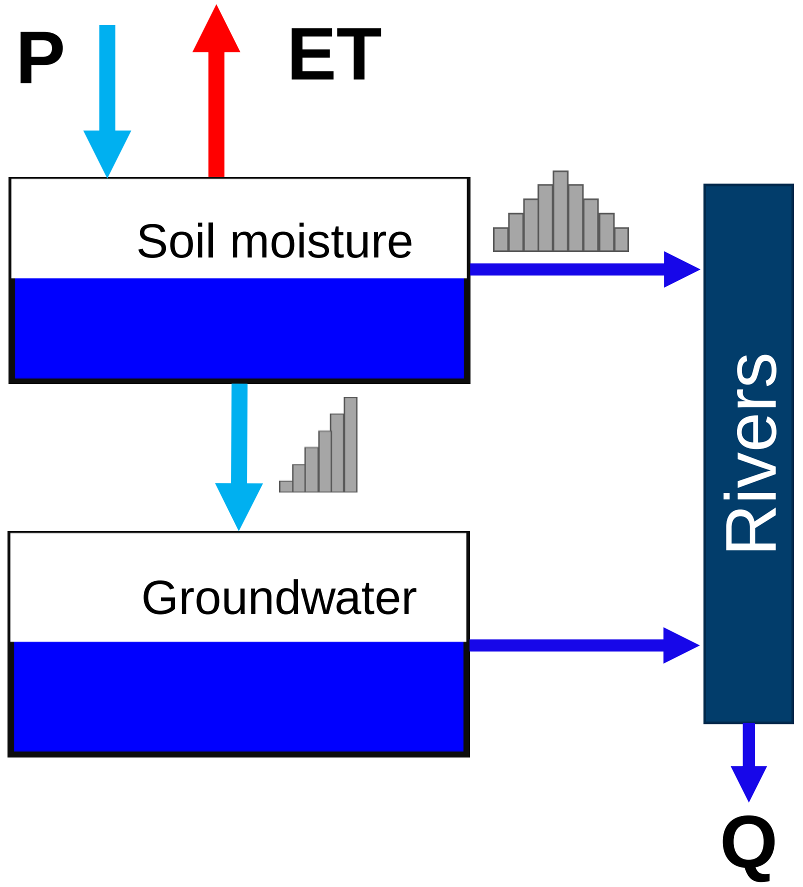
2| Catchments, models and data

2.2 | Two hourly models

GR4H





Systemic/lumped

Conceptual

12 optimal parameters, from historical observations

Runs on local computer

Ficchì et al. (2019); Kollet & Maxwell (2006)

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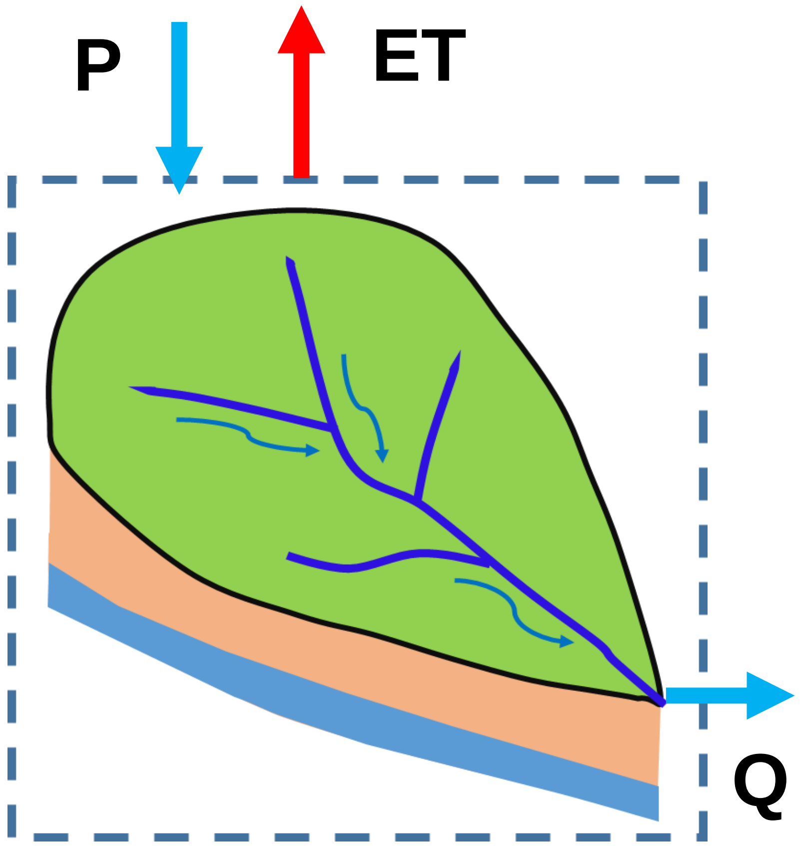

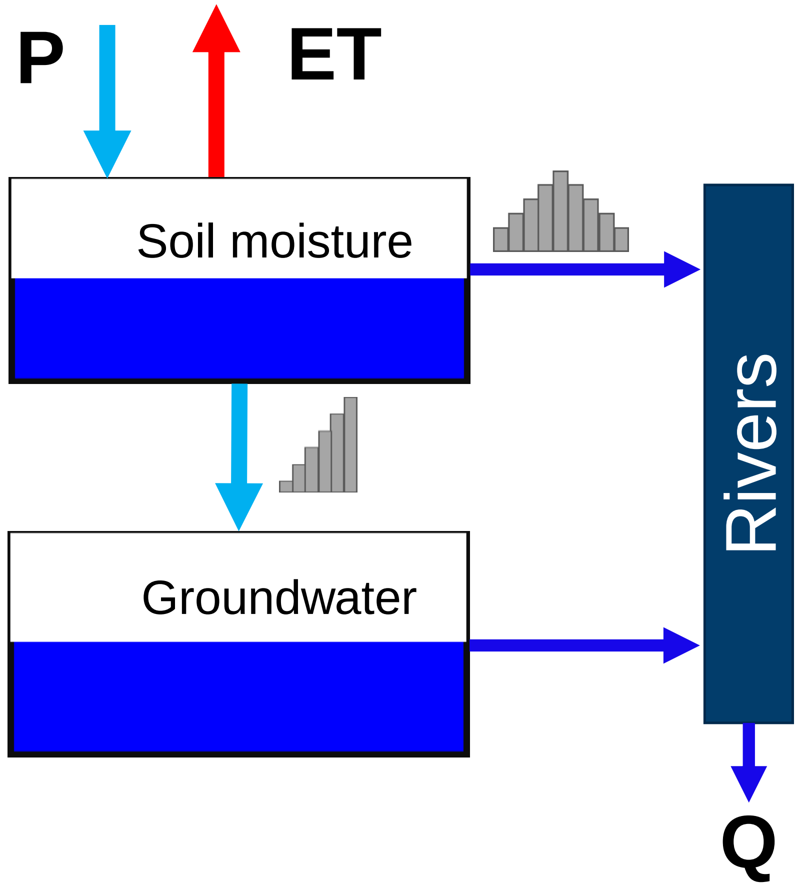

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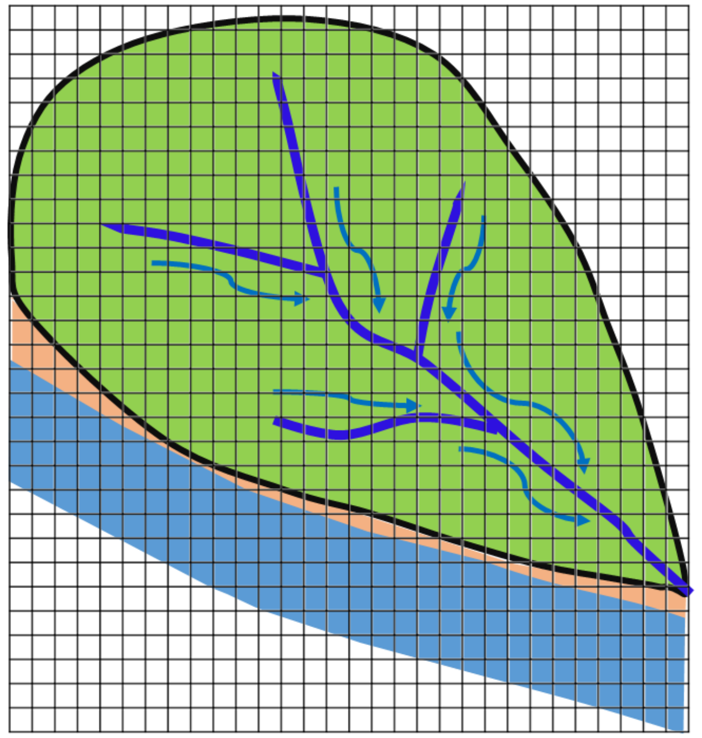
ParFlowCLM



Reductionist/distributed (611 m)

3-D Richards equation

$$\begin{cases} S_s S_w(p)\dfrac{\partial p}{\partial t} + \varphi \dfrac{\partial S_w(p)}{\partial t} = \nabla q + q_s \\ q = -k_s k_r(p)\nabla(p - z) \end{cases}$$

Kinematic wave approximation

$$\begin{cases} \dfrac{\partial h}{\partial t} = \nabla(vh) + q_s \\ S_0 = S_f \end{cases}$$

Mechanistic

Parameters from landscape properties, with 3 Manning's values

Runs on GPUs of the JUWELS HPC system (4 nodes x 512 GiB)

Ficchì et al. (2019); Kollet & Maxwell (2006)

2| Catchments, models and data

2.3 | Six QPE products for the 14.07.2021

QPE products

	Rain gauges
	RADOLAN
Horizontal reflectivity Z_h	RZH
Horizontal reflectivity Z_h+ Specific differential phase K_{DP}	RZHKDP
Specific attenuation A_H + Specific differential phase K_{DP}	RAHKDP
Specific attenuation A_V + Specific differential phase K_{DP}	RAVKDP

Chen et al. (2021)

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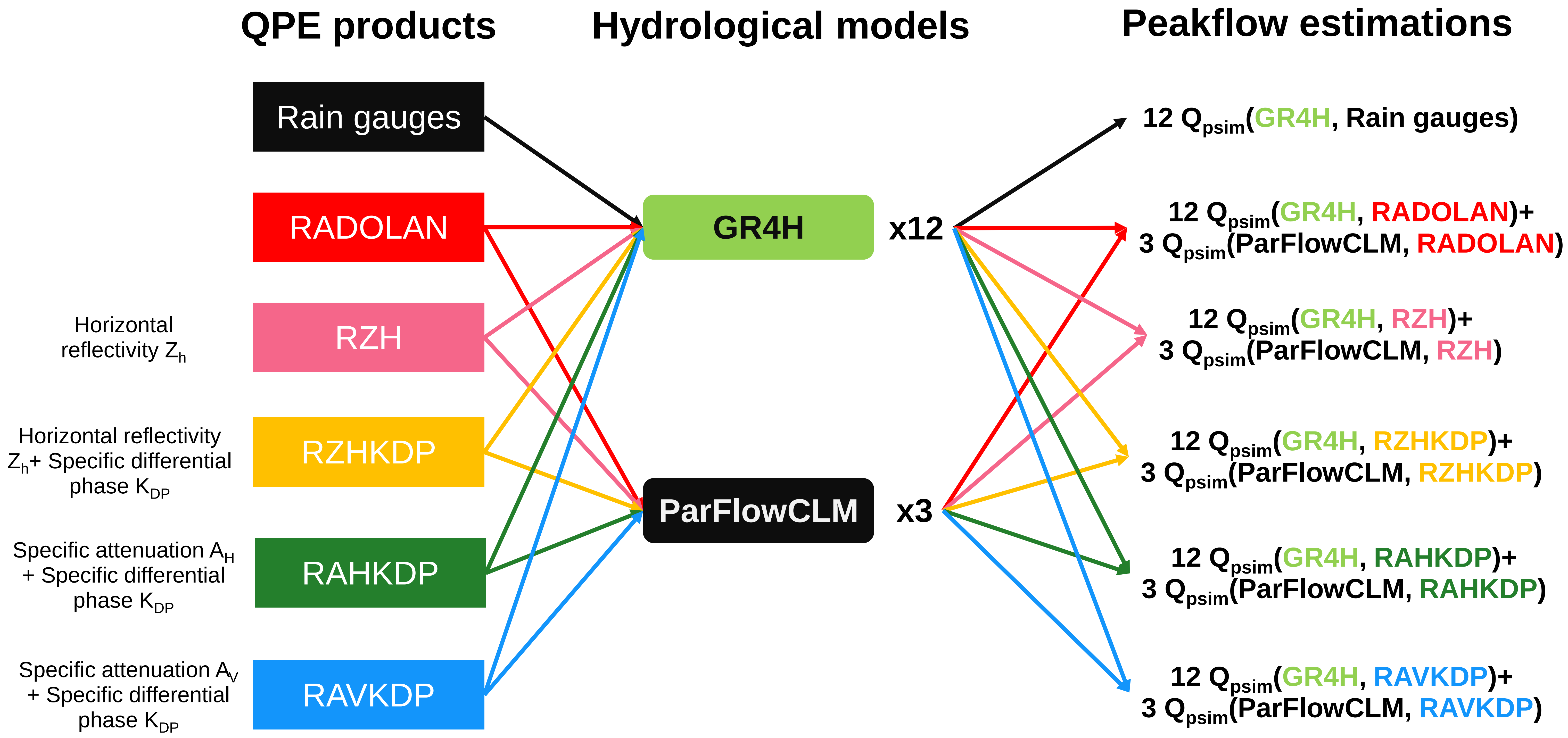

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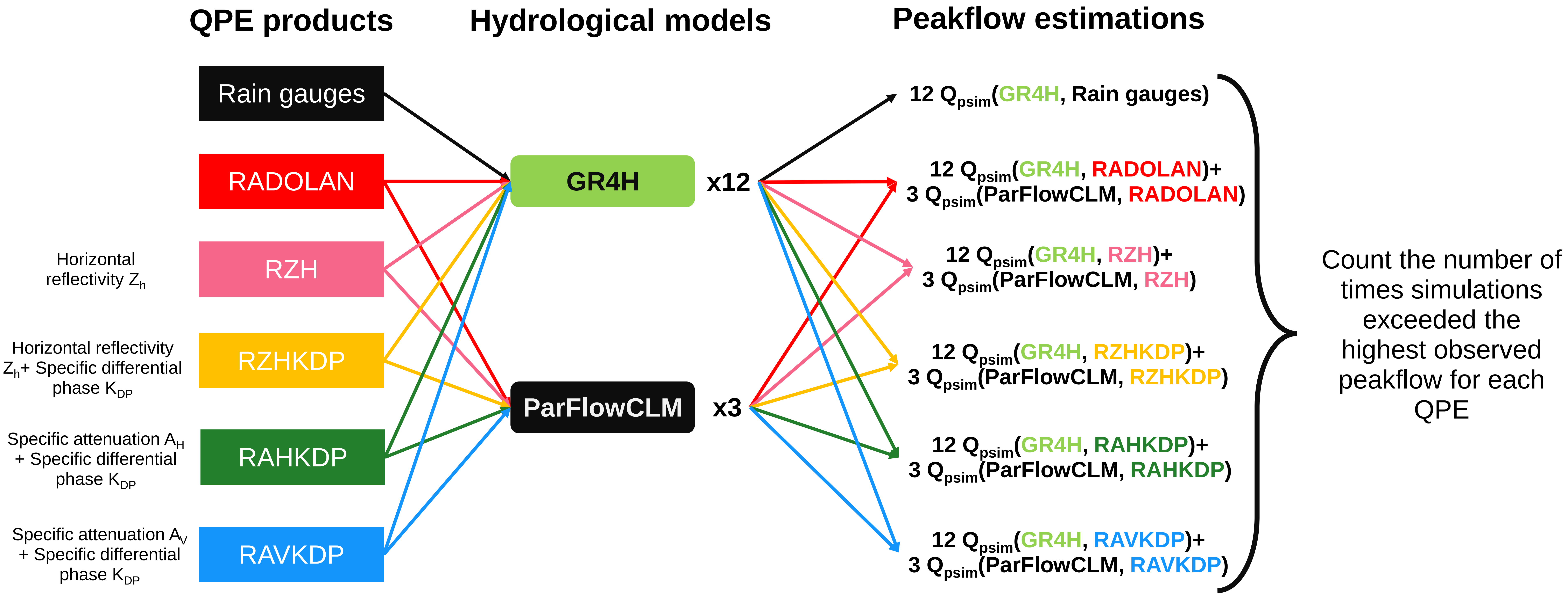
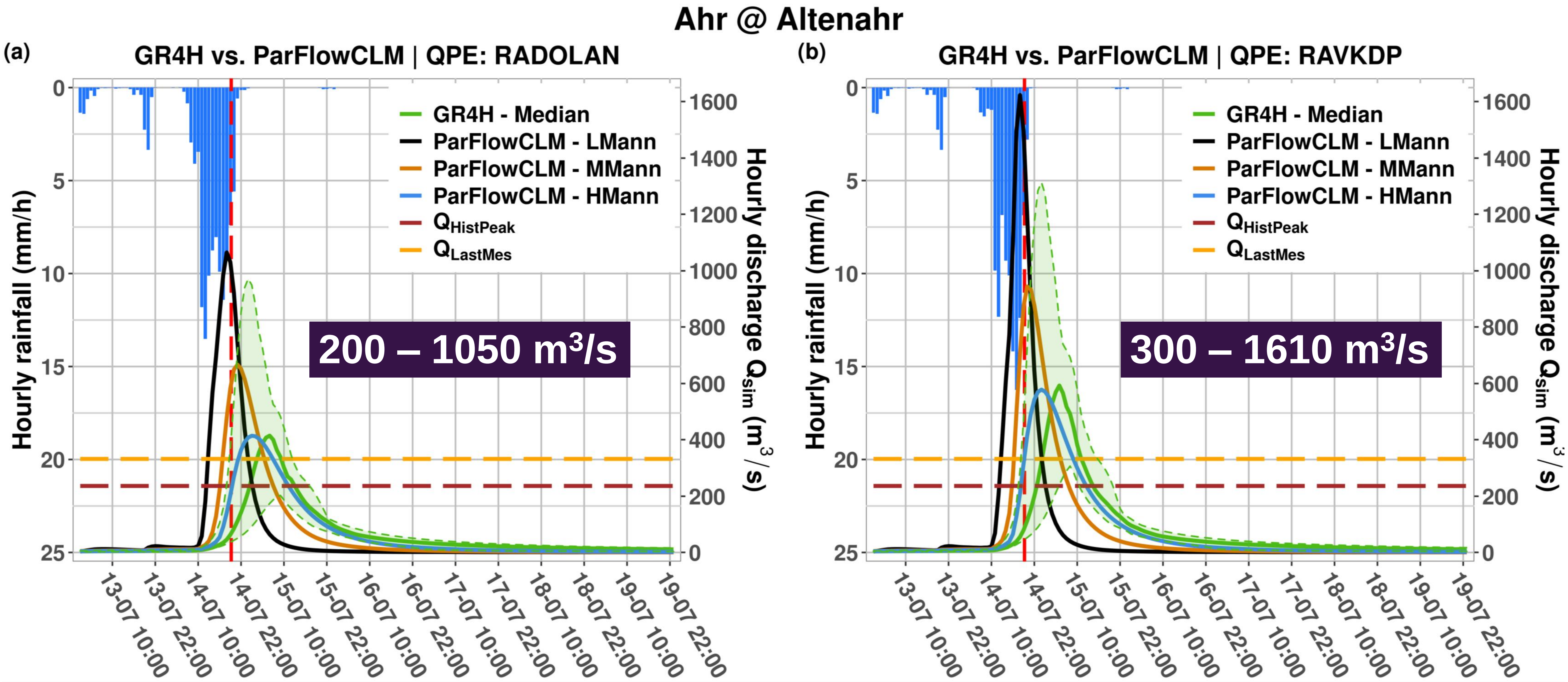


Chen et al. (2021)

3| Results

3.1 | Result 1: Uncertainty in peakflow estimation



High uncertainty in estimated peakflows

A combination of uncertainties from model parameters and input QPE

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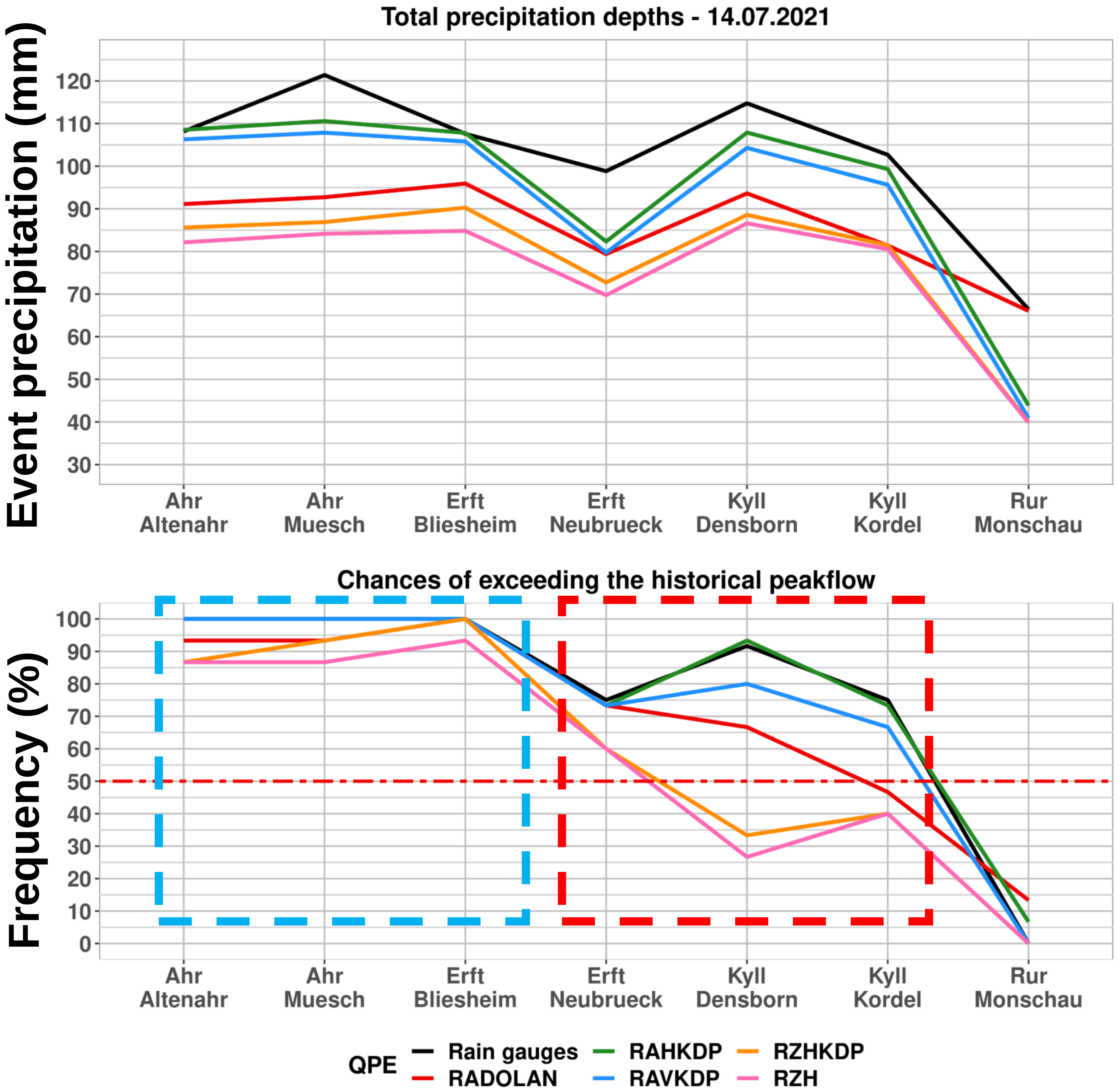
3| Results

3.2 | Result 2: Chances of having a record-breaking peakflow



Radar-based products underestimated the total event precipitation

This was limited thanks to using polarimetric variables

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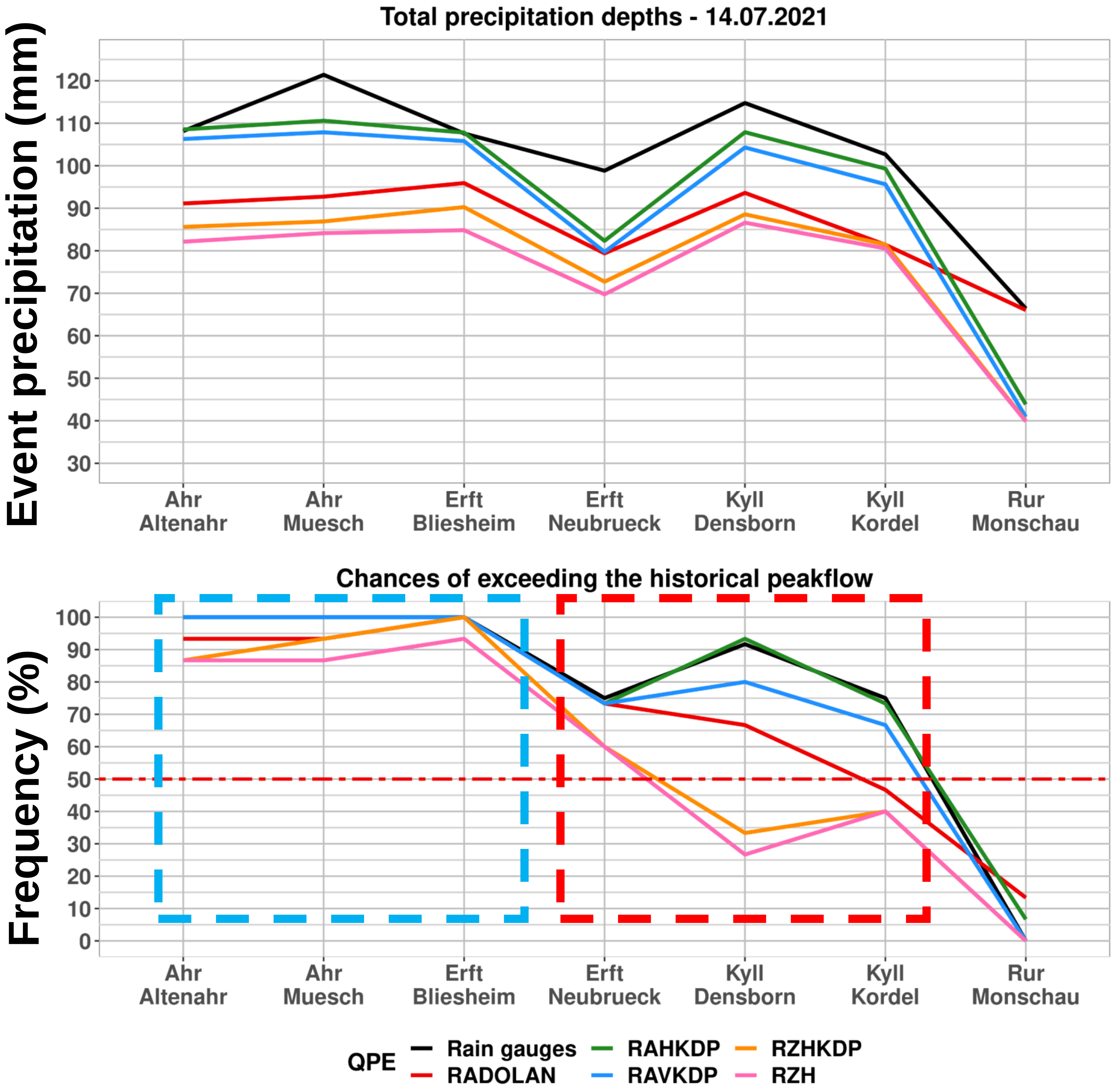

Radar-based products underestimated the total event precipitation

This was limited thanks to using polarimetric variables

The effect of the QPE on the (simulated) severity of the event varied among catchments

1. Very high chances no matter what QPE product is used
2. Very low chances for the Rur @ Monschau
3. High dependency on QPE for the remaining catchments

Thank you for your attention!
Questions?

Contact: m.saadi@fz-juelich.de

RealPEP

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Natural Hazards and Earth System Sciences

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Status: this preprint is currently under review for the journal NHESS.

How uncertain are precipitation and peakflow estimates for the July 2021 flooding event?

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References

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