Floods in small and medium sized catchments in the Eastern Alps simulated by RCMs from the hydrostatic to the convection-permitting scale

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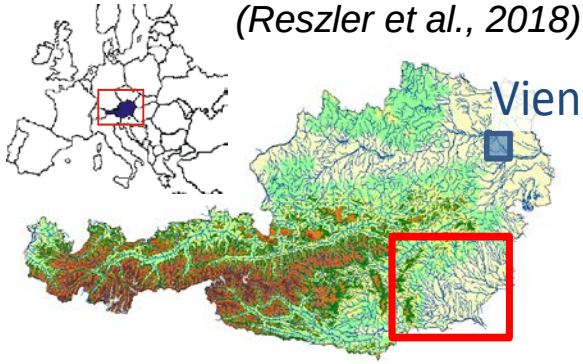
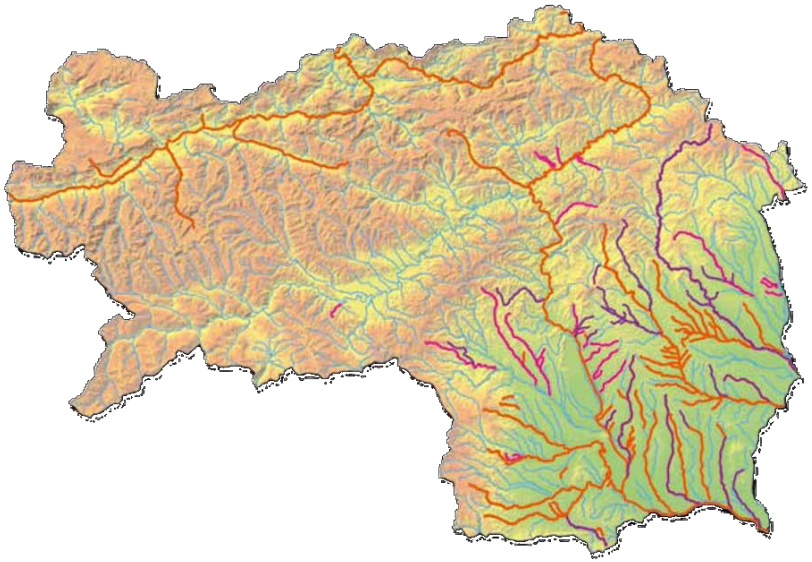
Introduction

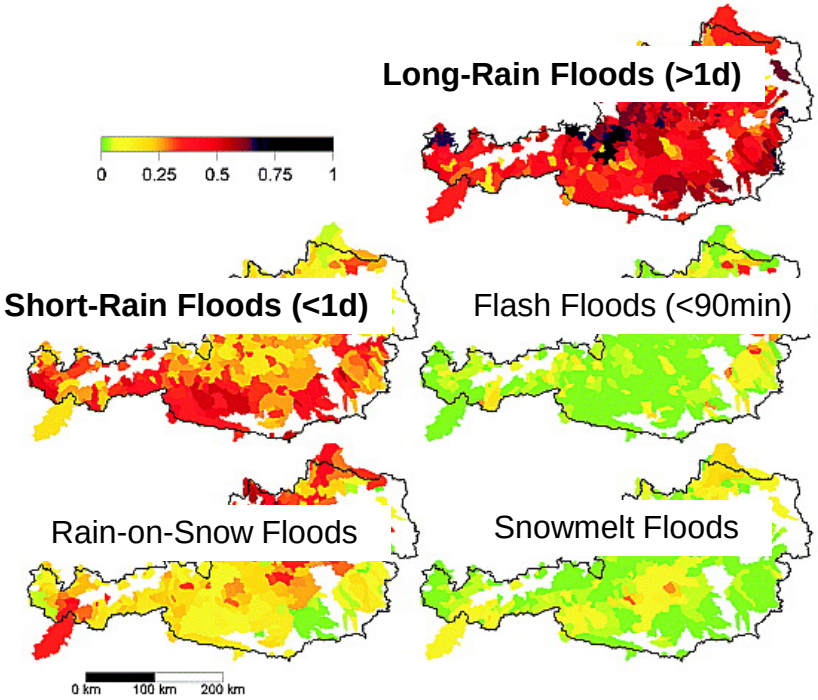
- **Styria – a land of extremes**



(Reszler et al., 2018)



(R. Hornich, Styrian Government, 2009)



1971 to 1997

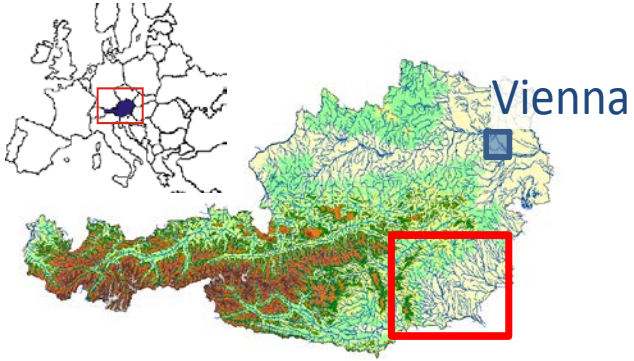
(Merz and Blöschl, 2003)

09.2014: 12 Mio €

top agrar Österreich

Introduction

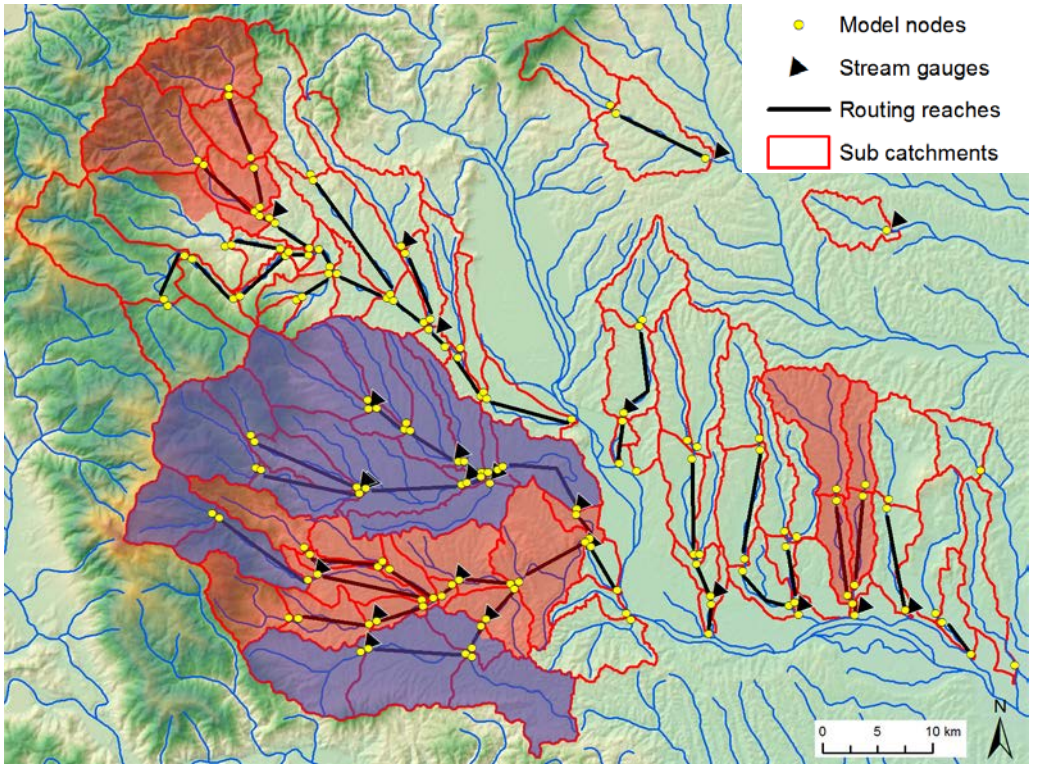
- **Operational flood forecast with KAMPUS** *(Blöschl et al., 2008)* **in Styria**
  - **Spatially distributed conceptual model; gridded 3 layer run-off model; ground and deep ground water flows; snow/snowmelt processes; evapotranspiration…**



Calibration data (2000 – 2009)

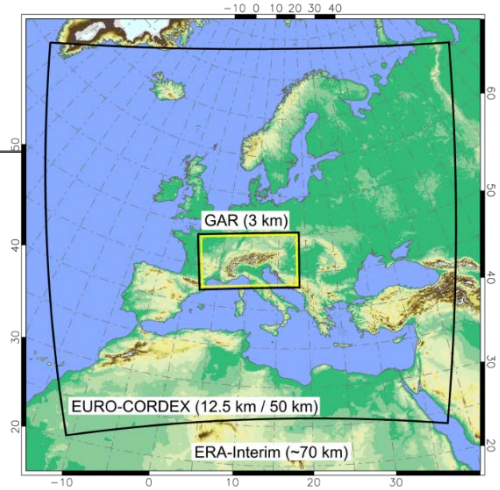
- 80 – 115 met. stations (daily)
- 40 – 60 met. stations (hourly)
  (from ZAMG and Hydrographic Service)
  1 km x 1 km grid

- ~25 stream gauges (hourly)



(Reszler et al., 2018)

Experimental setup



- **Models**

from Klaus Keuler, BTU Cottbus

ERA-Interim (~80 km)

CCLM p11 (EU 12.5 km)

CCLM p03 (GAR 3 km)

CCLM p44 (EU 50 km)

w/o bias correction

KAMPUS

from Klaus Görgen, Research Centre Juelich

WRF p44 (EU 50 km)

WRF p11 (EU 12.5 km)

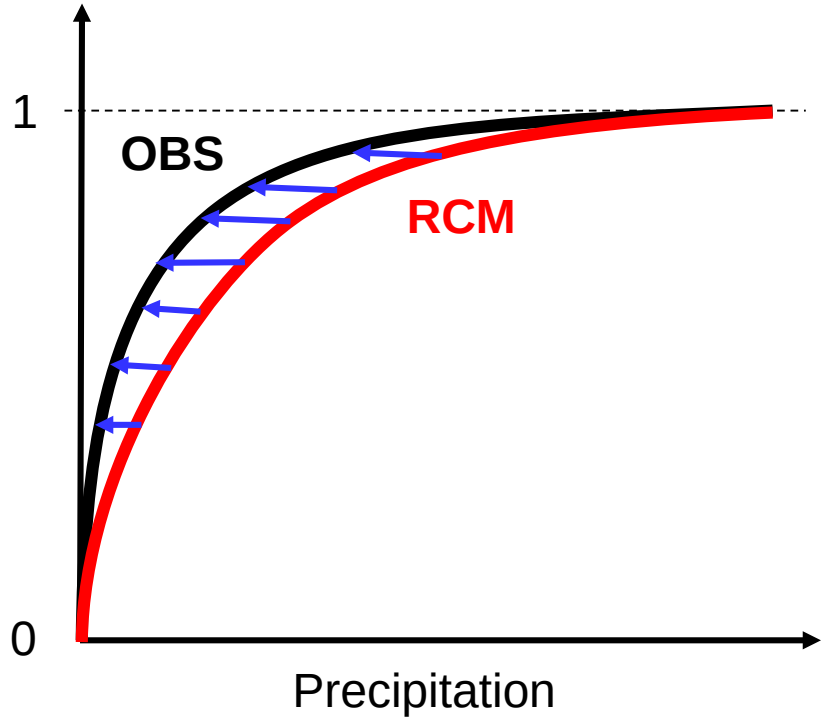
WRF p03 (GAR 3 km)

Gridded obs (1 km, 3h)

- **cosmo_090213_4.8_clm17** – EUR-11 config, but no deep convection parameterization in GAR 3 km
- WRF-ARW v3.3.1 – EUR-11 config. (WRF331A), but no deep convection parameterization in GAR 3 km
- Period: 1989 – 2010 → 22 years
- → flood statistics (**max. annual floods and return periods**; seasonality, …)

Bias correction

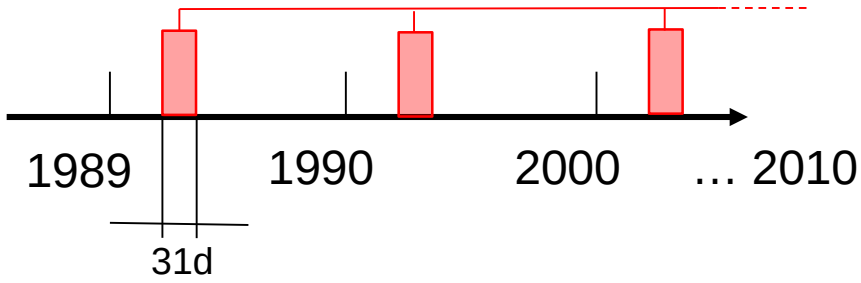
- **Bias correction via Scaled Distribution Mapping (SDM)**
  - *Switanek et al. (2017)*



Parametric Gamma-distributions

$$f(x;k,\theta) = \frac{x^{k-1}\exp\left(-x/\theta\right)}{\theta^{k}\Gamma(k)}$$

Distributions are drawn from a moving window of 31 days



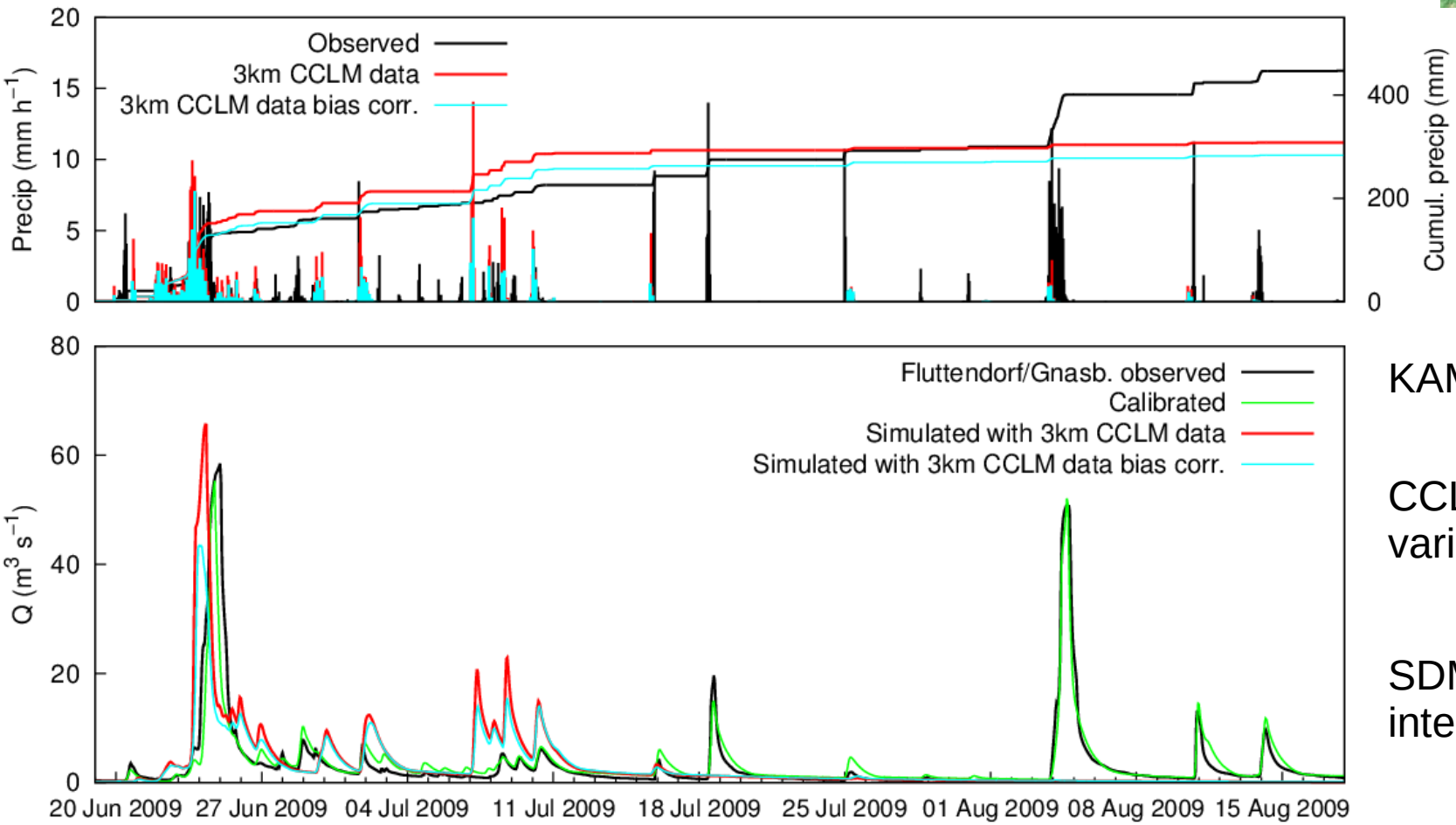
Applied to each grid cell of the observations (1 km) separately

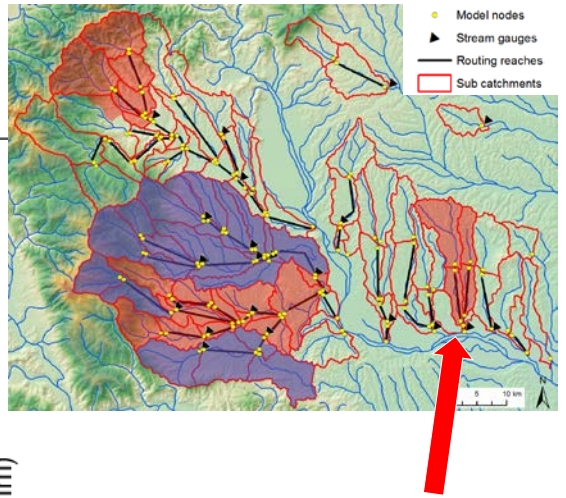
➔ works as a spatial „interpolation“ scheme, but affected by inflation/deflation problem *(Maraun, 2013; Bürger, 2014)*

Frequency adaptation via small values

Results

- **Precipitation and runoff in Fluttendorf (June 20 to August 15, 2009)**





Fluttendorf
119 km²

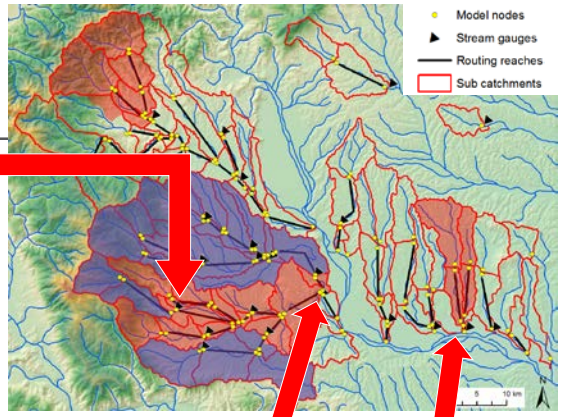
KAMPUS is well calibrated

CCLM is affected by internal variability AND biases

SDM cannot correct internal variability

Results

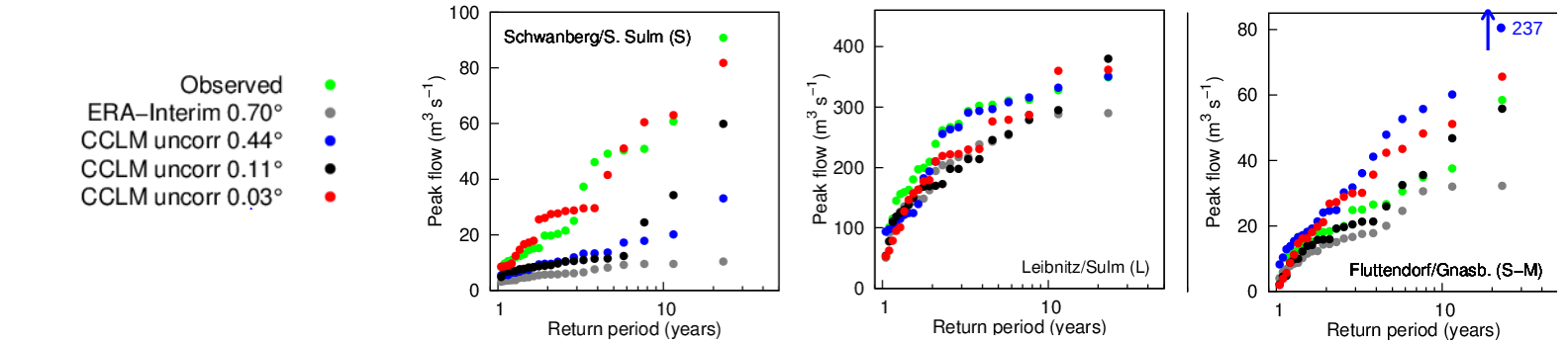
- **Flood statistics**
  (max. ann. peak flows, return periods)

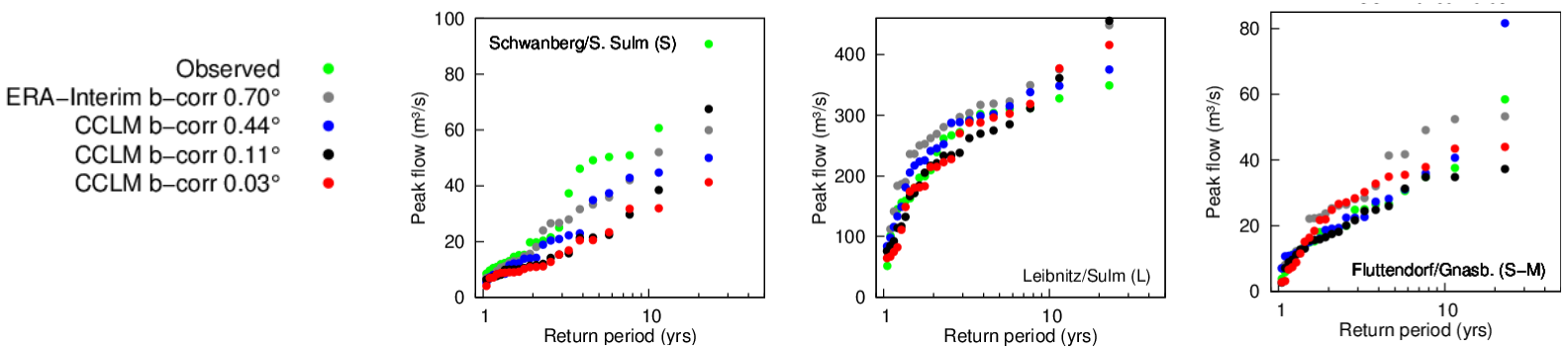


Schwanberg
75 km²

Leibnitz
1103 km²

Fluttendorf
119 km²





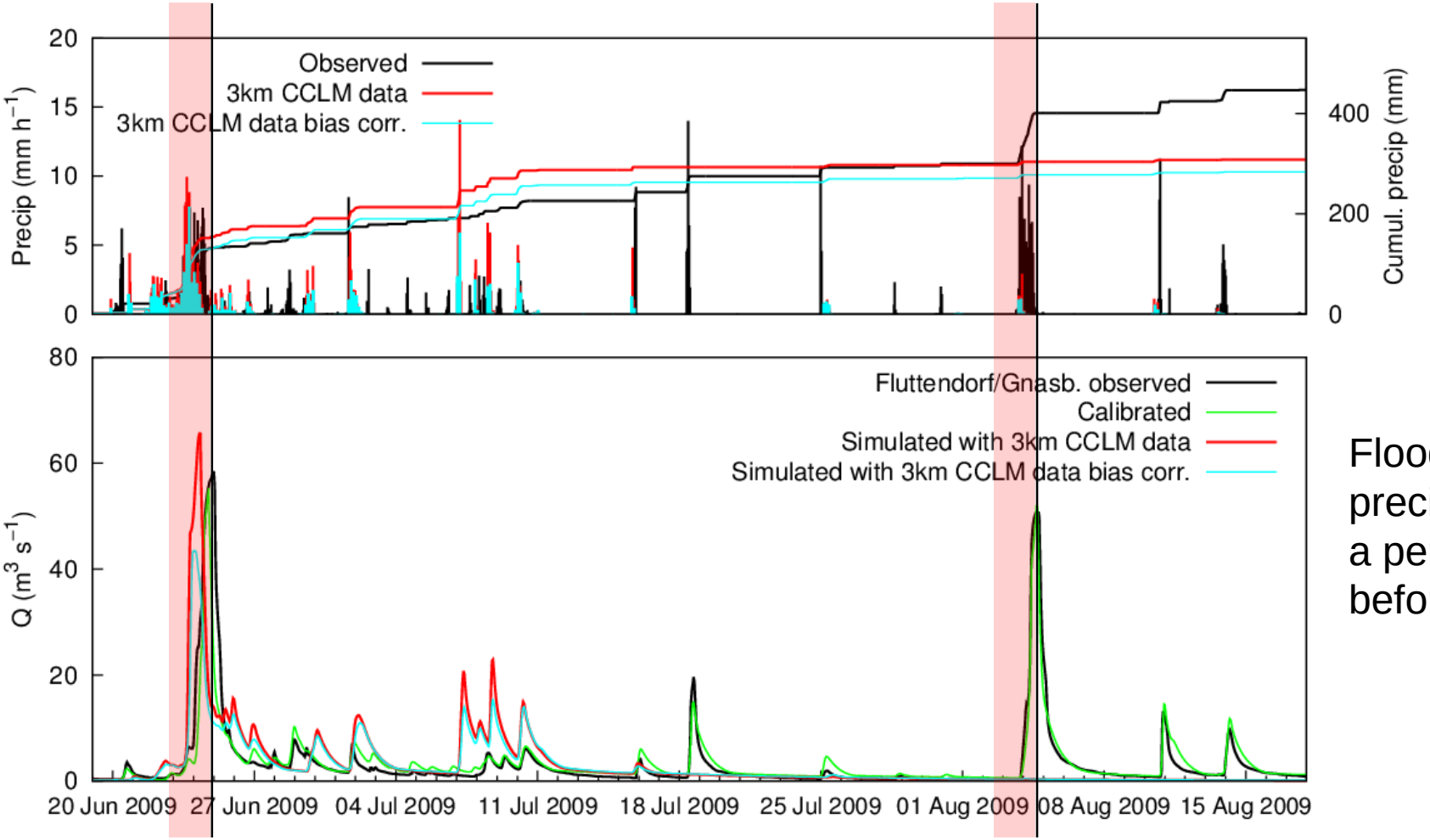
Max. annual peak flows are partly well captured, partly strongly biased

in general, a systematic behaviour is difficult to find

SDM has difficulties with peak flows

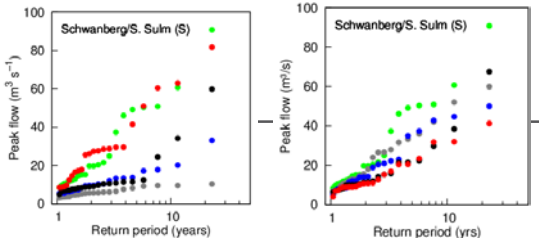
Results

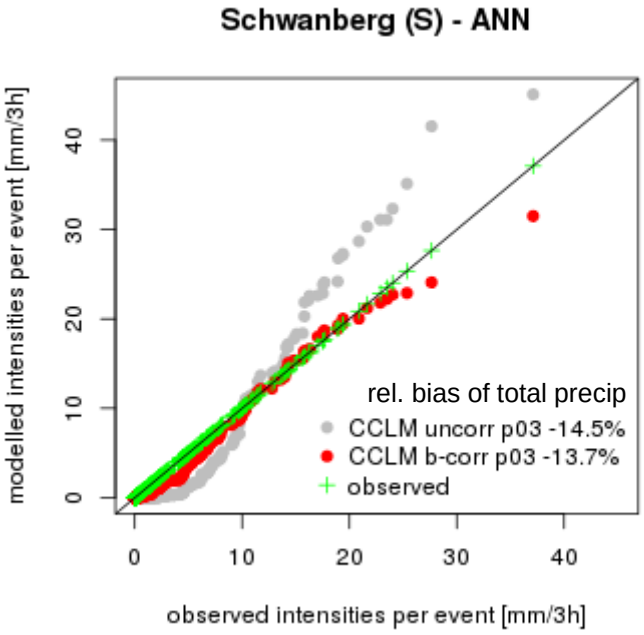
- **Temporal sequence of precipitation**

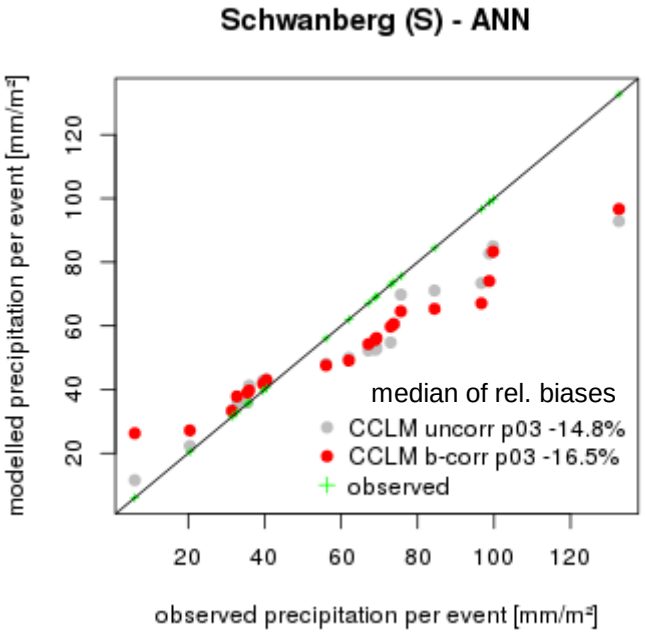


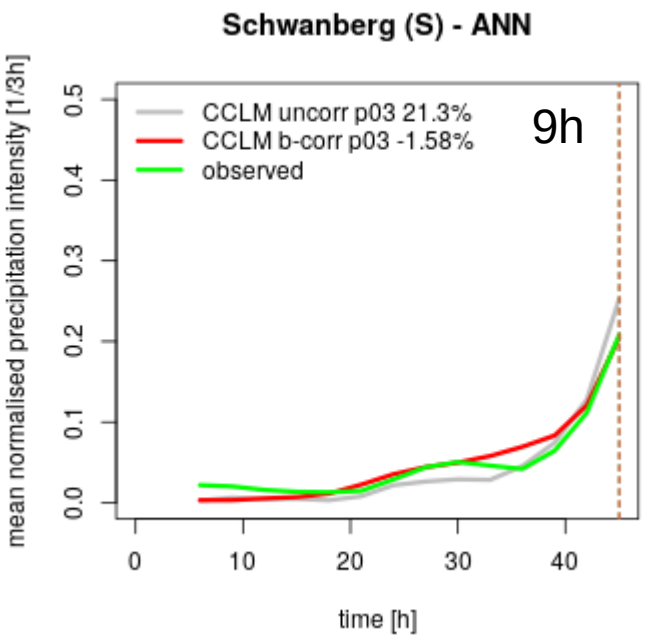
Flood event depends on precipitation fallen within a period of max 2 days before the event

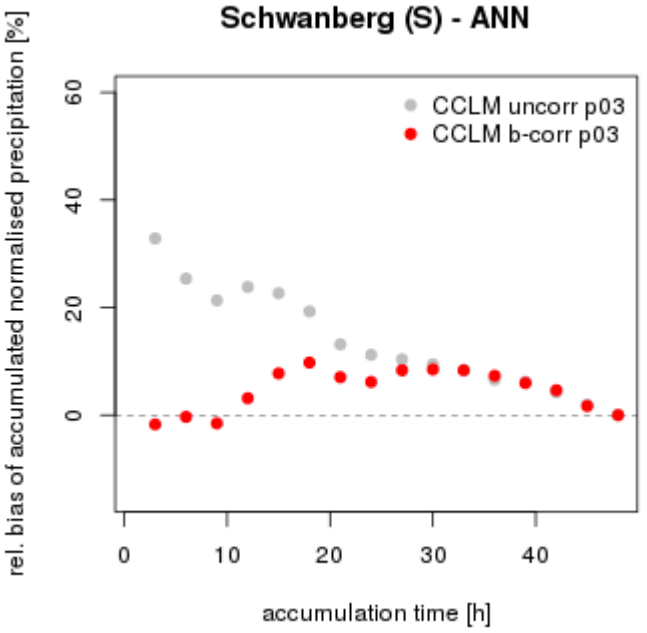
Results











Catchment is very small, reacts fast on precipitation

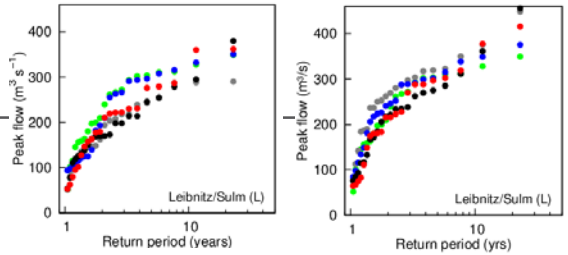
Precipitation sum <1d before the flood event is strongly overestimated, this compensates the underestimation of the precipitation amount per event

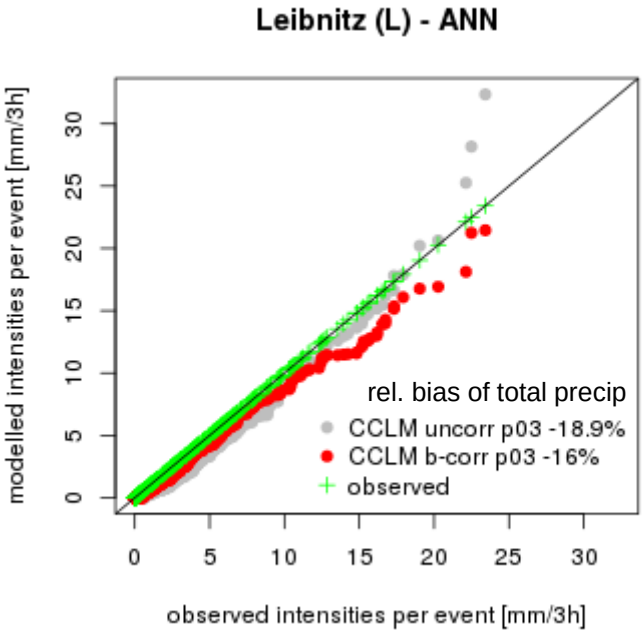
➔ Floods with raw CCLM 3 km data are well captured, but for the wrong reasons

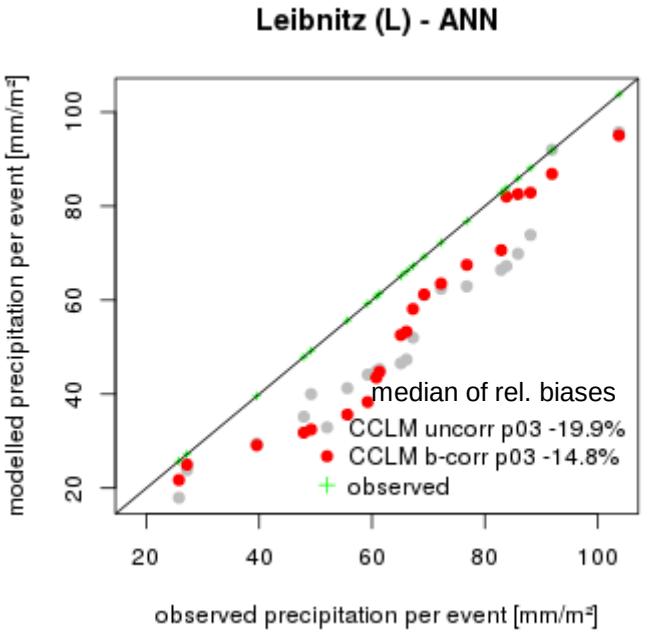
SDM partly corrects amount per event and temporal sequence

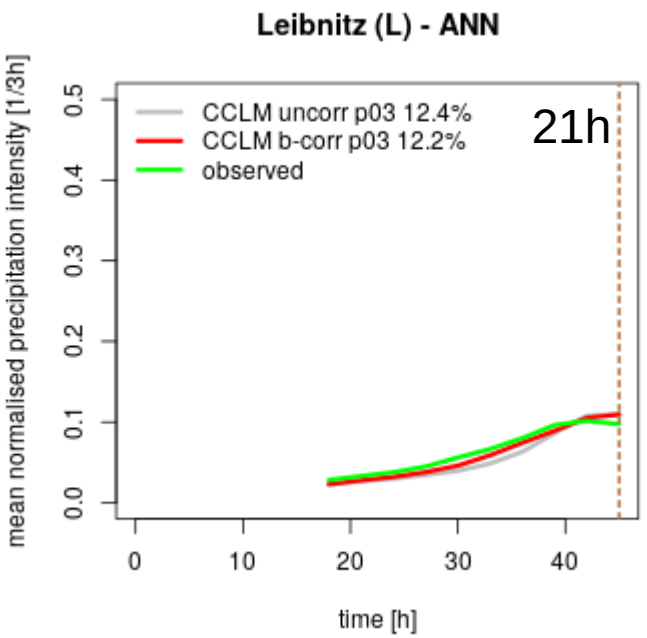
➔ Flood statistics get worse

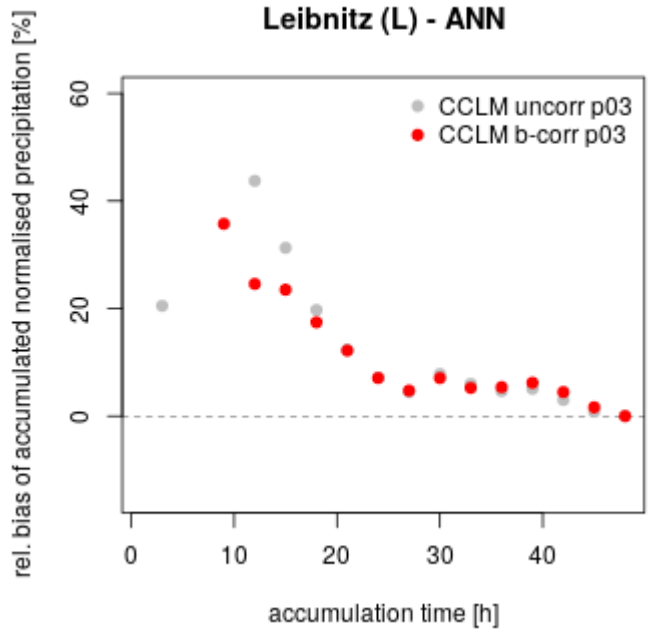
Results











Catchment reacts slower → earlier precipitation also matters

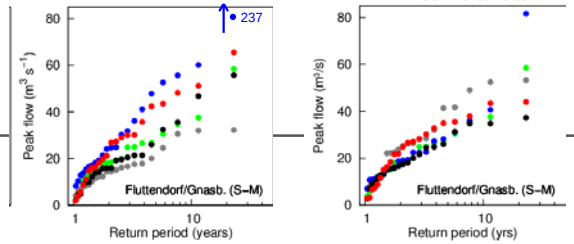
Precipitation sum <1d before the flood event is overestimated, but the underestimation of amount per event is larger

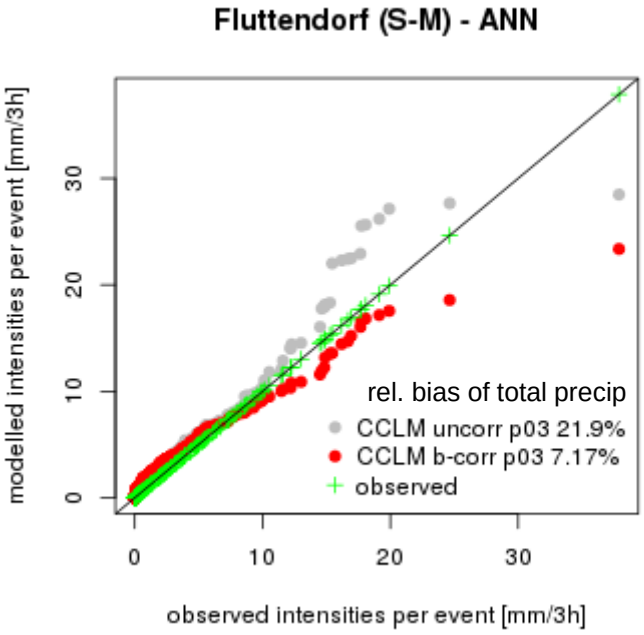
➔ Floods with raw CCLM 3 km data remain underestimated

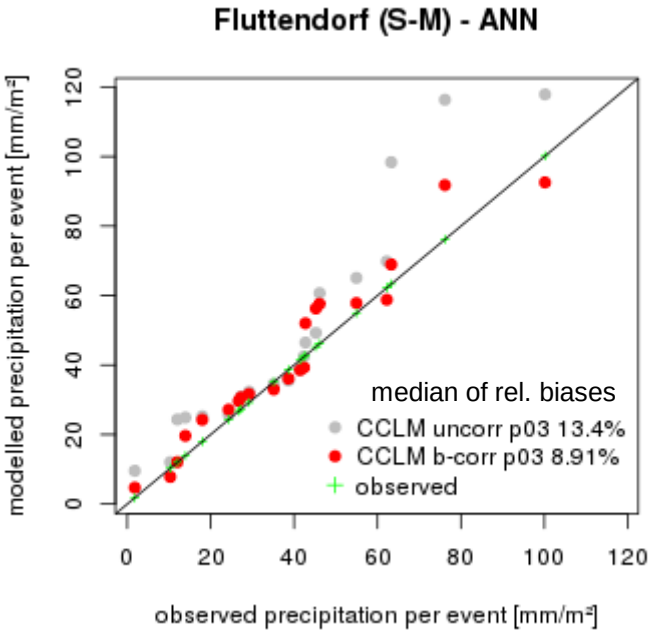
SDM slightly improves amount per event, but keeps overestimations <1d alive

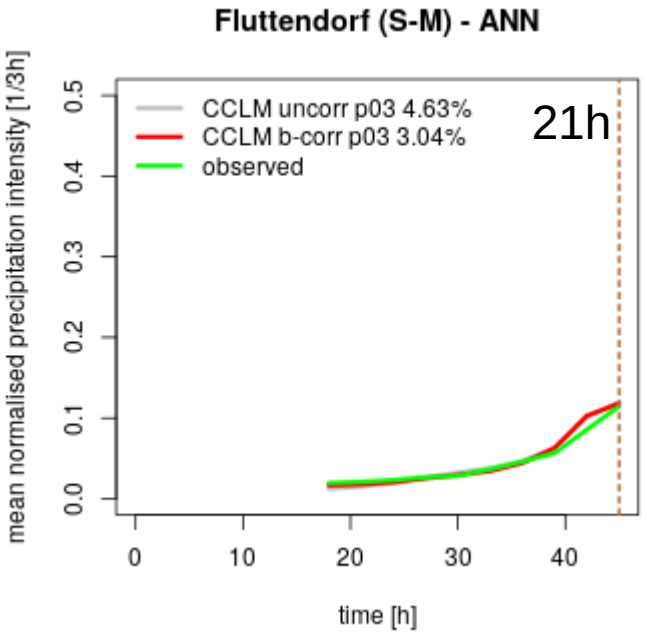
➔ Flood statistics are improved

Results







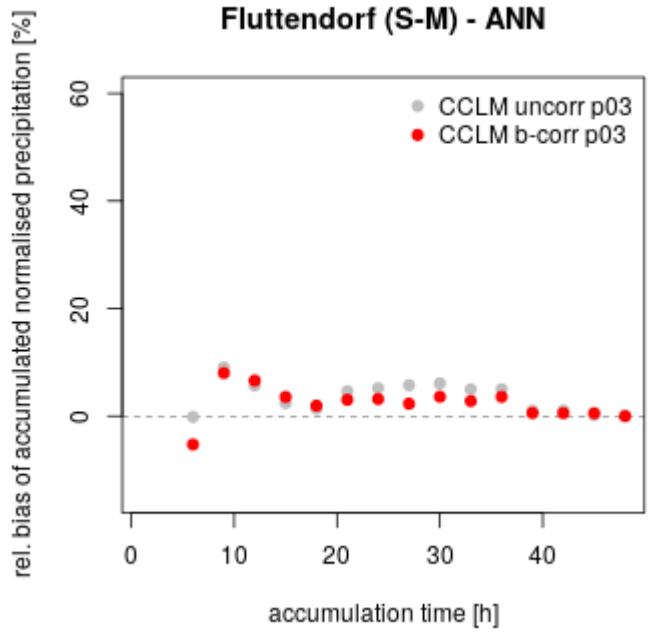


precipitation amount per event are overestimated
amount <1d is well captured

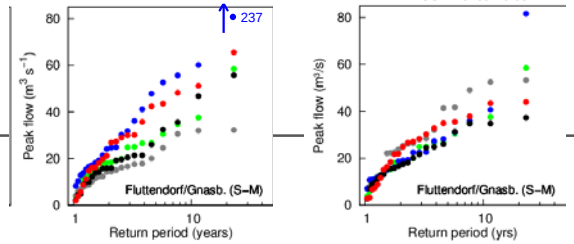
➔ Floods are overestimated with raw CCLM 3 km data

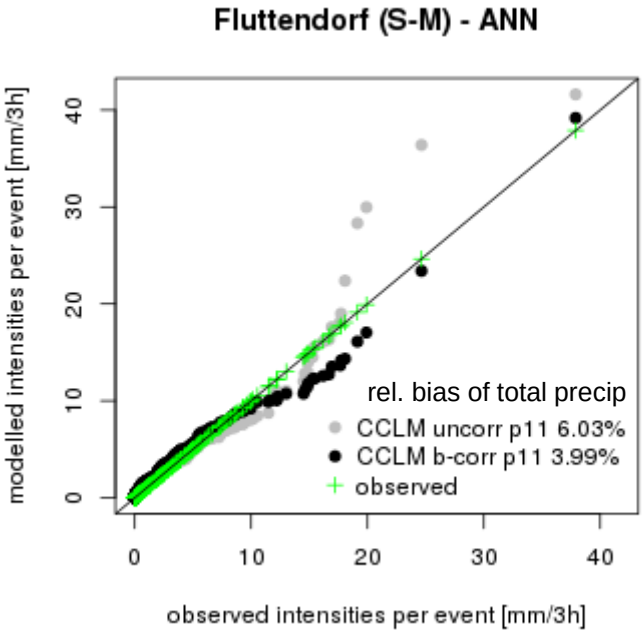
SDM corrects amounts per event and leaves temporal sequence unchanged

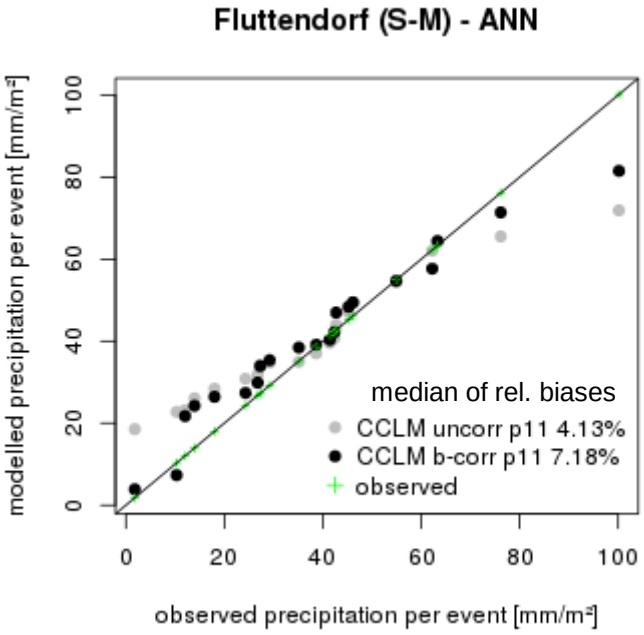
➔ Floods are better represented

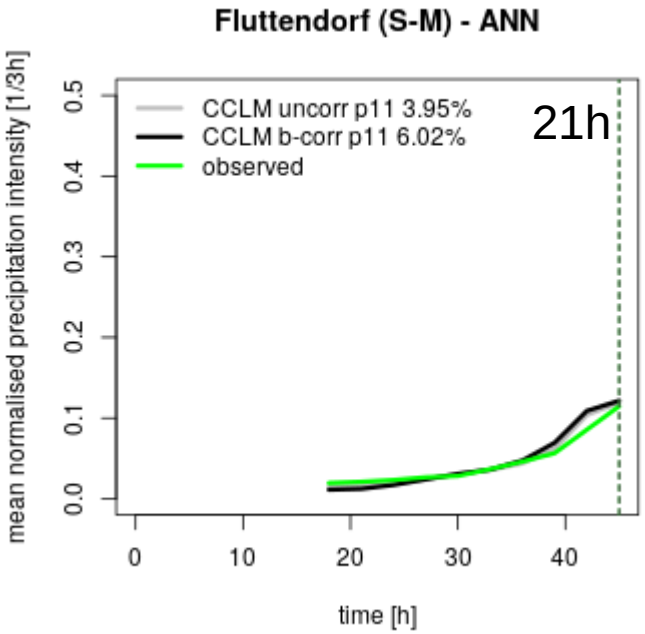


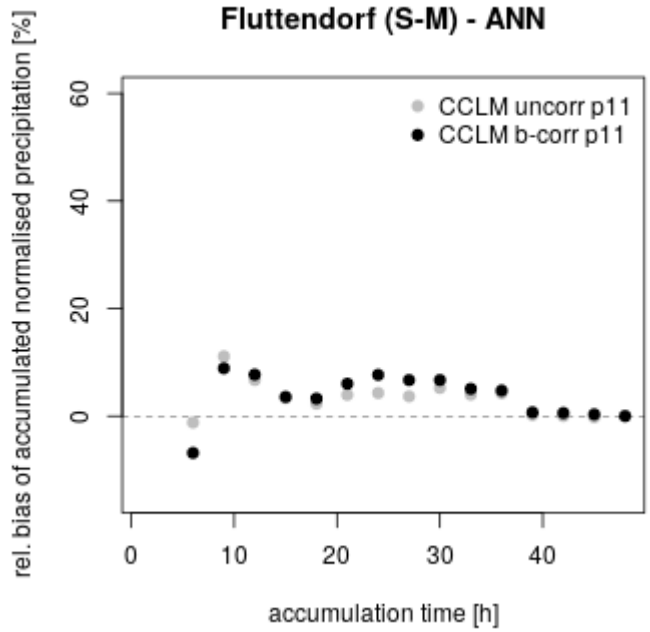
Results











Intensities, precipitation amount per event, and temporal sequence (<1d) is quite well represented

➔ Floods are well captured in raw CCLM 12.5 km data

SDM has minor effects

➔ Floods are still well captured

Conclusions

- All RCM/flood model combinations perform differently well in different catchments (3 km grid spacing does not outperform the rest)
  - reason: interplay between the precipitation per event and its temporal sequence on a sub-daily scale per event is not well captured
  - in most cases, when the wright is done, it's done for the wrong reasons
  - rises questions for climate change applications
- Significant biases have been detected,
  but there is also high sensitivity of floods for such biases
  - bias correction is a requirement,
    however it should be able to take into account spatial and temporal variability (a sub-daily scale)
    ➔ "process-informed" bias correction *(Maraun et al., 2017)*
- *Accepted for publication in*

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Convection-permitting regional climate simulations for representing floods in small and medium sized catchments in the Eastern Alps

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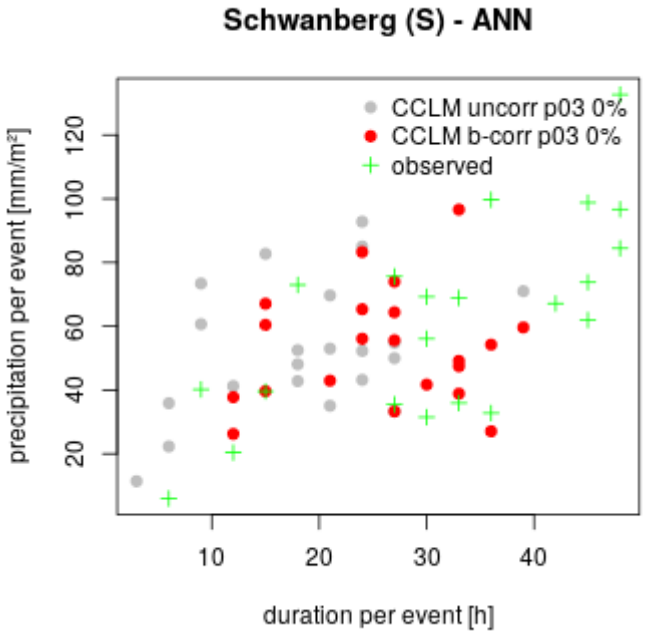
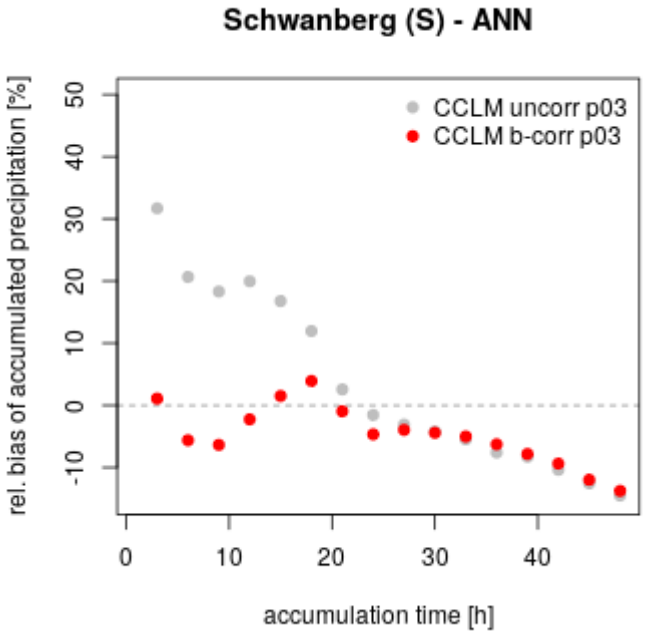
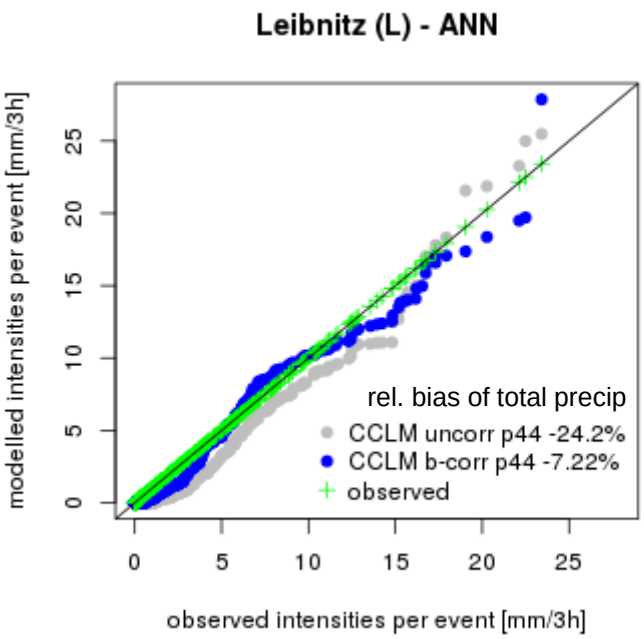
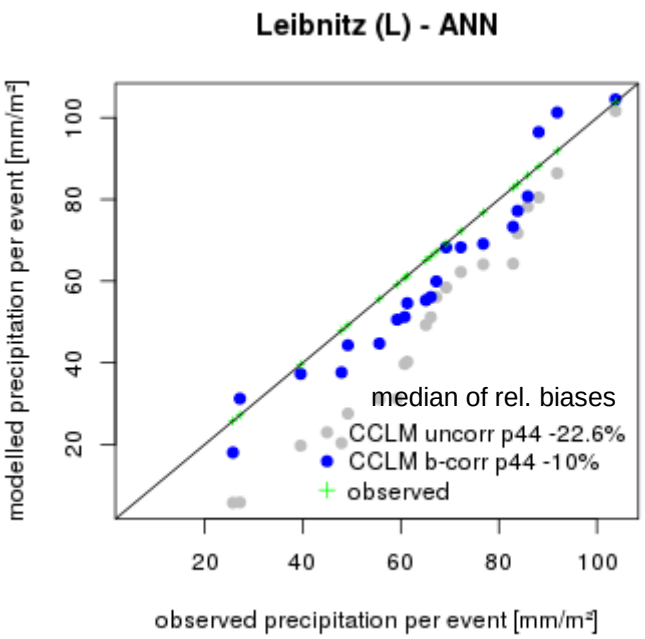
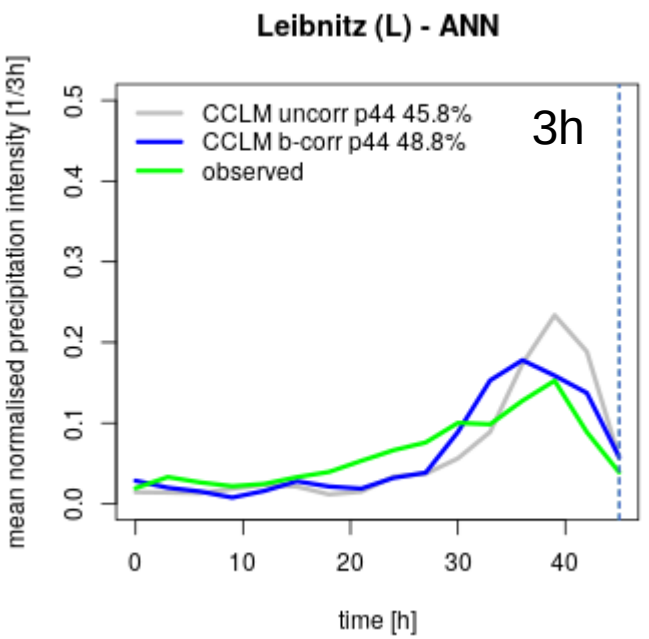

Schwanberg (S) - ANN
CCLM uncorr p03 0%
CCLM b-corr p03 0%
observed
precipitation per event [mm/m²]
20
40
60
80
100
120
10
20
30
40
duration per event [h]


Schwanberg (S) - ANN
CCLM uncorr p03
CCLM b-corr p03
rel. bias of accumulated precipitation [%]
-10
0
10
20
30
40
50
0
10
20
30
40
accumulation time [h]

Results





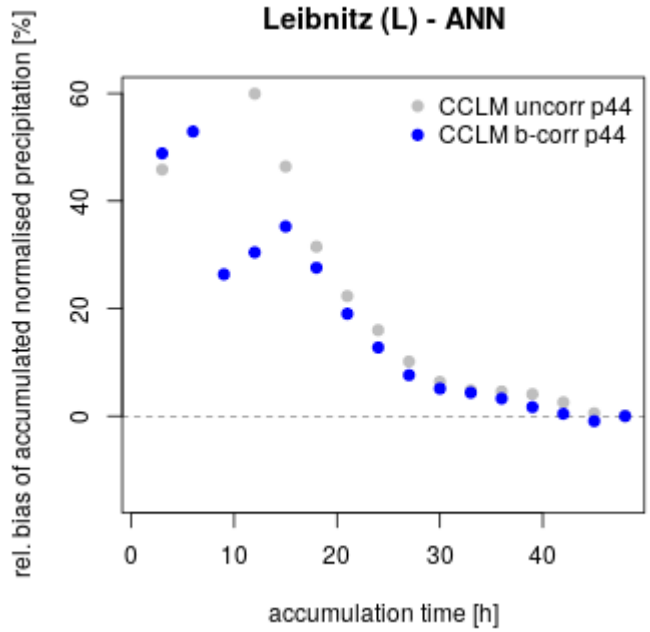


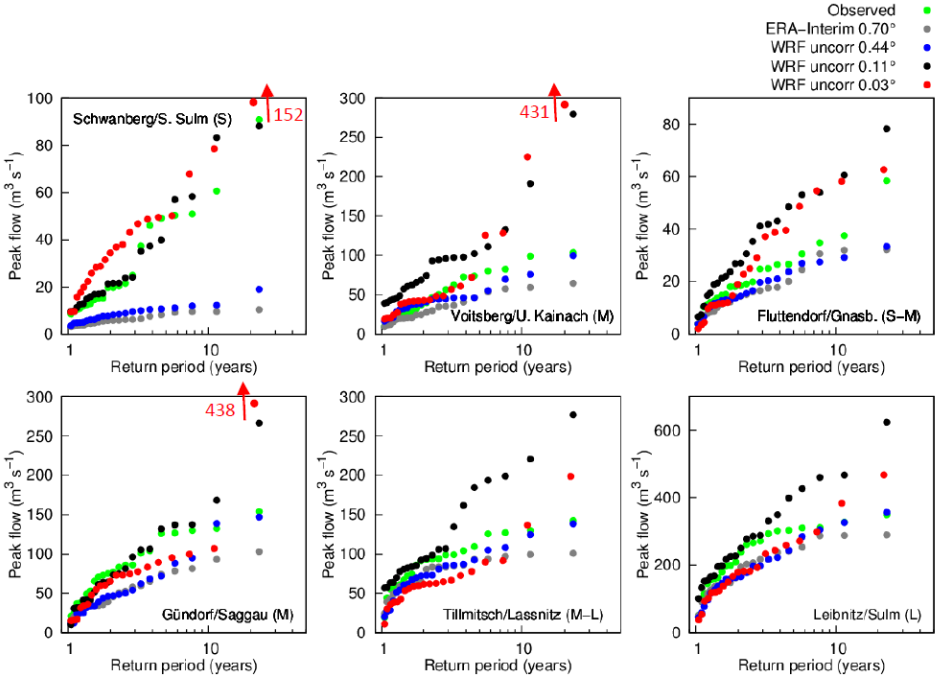
Precipitation sum ~24h before the flood event is strongly overestimated, this compensates the underestimation of the precipitation amount per event

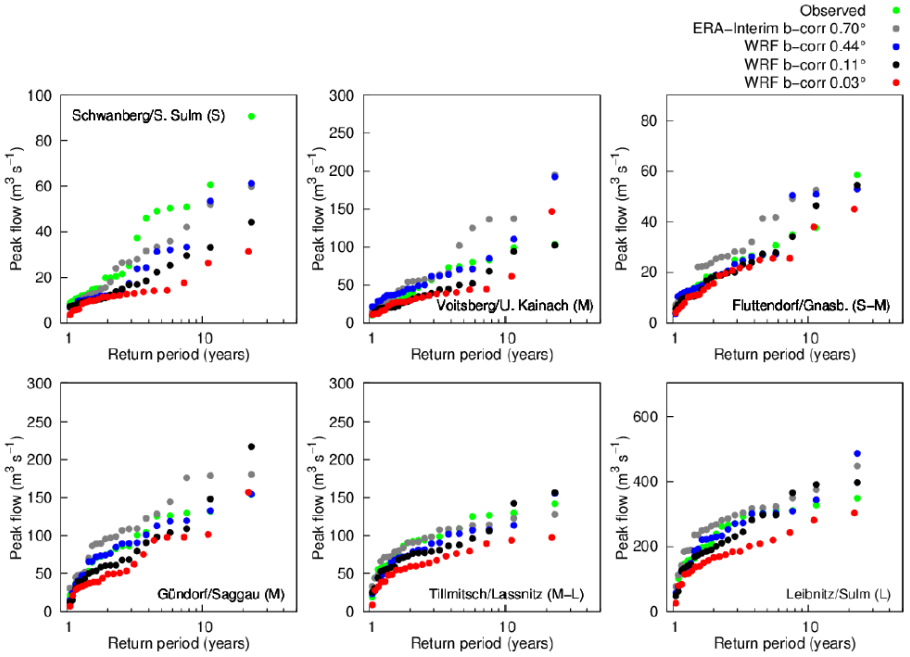
➔ Floods with raw CCLM 3 km data are well captured, but for the wrong reasons

SDM only corrects temporal sequence

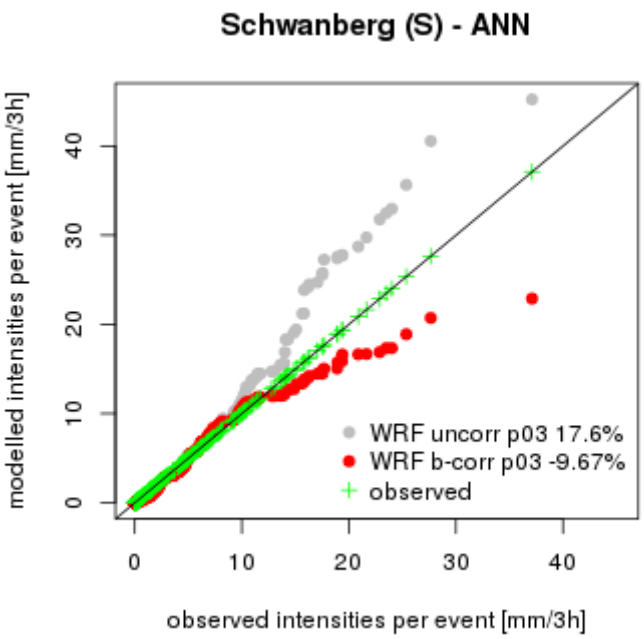
➔ Flood statistics get worse

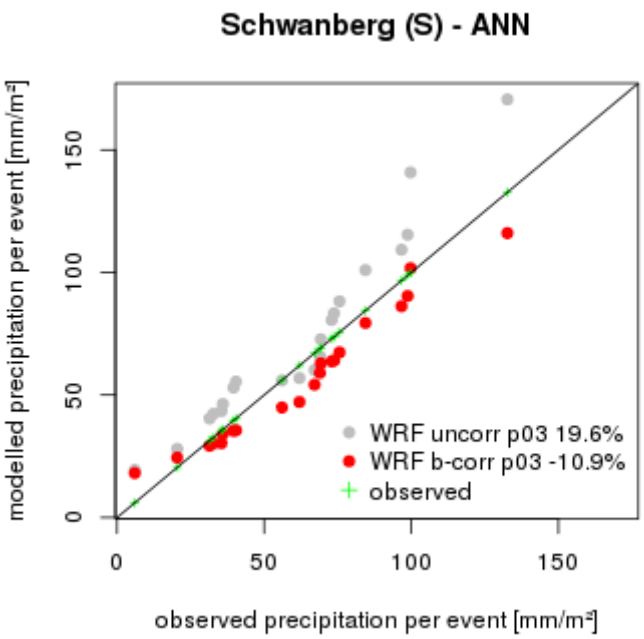


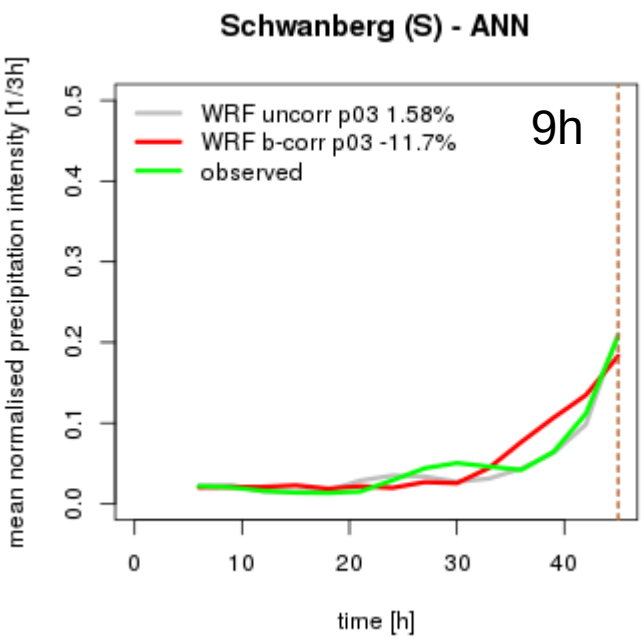

Observed
ERA–Interim 0.70°
WRF uncorr 0.44°
WRF uncorr 0.11°
WRF uncorr 0.03°
Schwanberg/S. Sulm (S)
152
Voitsberg/U. Kainach (M)
431
Fluttendorf/Gnasb. (S–M)
Gündorf/Saggau (M)
438
Tillmitsch/Lassnitz (M–L)
Leibnitz/Sulm (L)
Peak flow (m3 s–1)
Return period (years)


Observed
ERA–Interim b–corr 0.70°
WRF b–corr 0.44°
WRF b–corr 0.11°
WRF b–corr 0.03°
Schwanberg/S. Sulm (S)
Voitsberg/U. Kainach (M)
Fluttendorf/Gnasb. (S–M)
Gündorf/Saggau (M)
Tillmitsch/Lassnitz (M–L)
Leibnitz/Sulm (L)
Peak flow (m3 s–1)
Return period (years)

Results





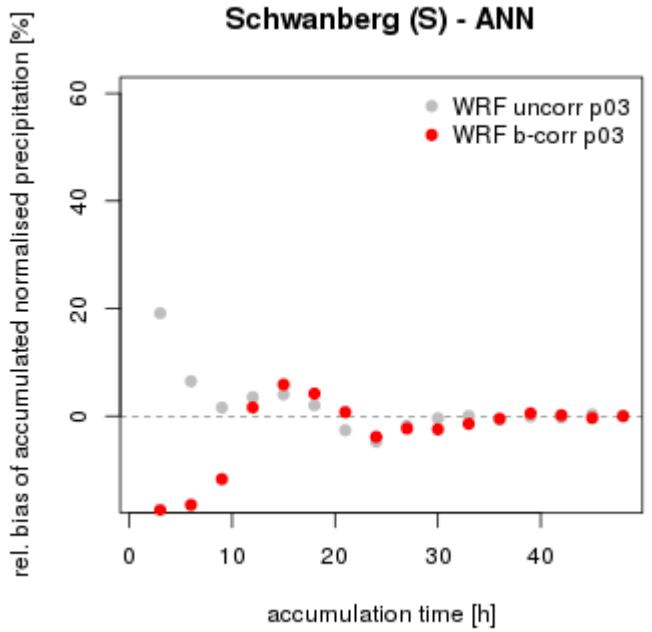


Intensities and precip amount per event are overestimated, but temporal sequence is well represented

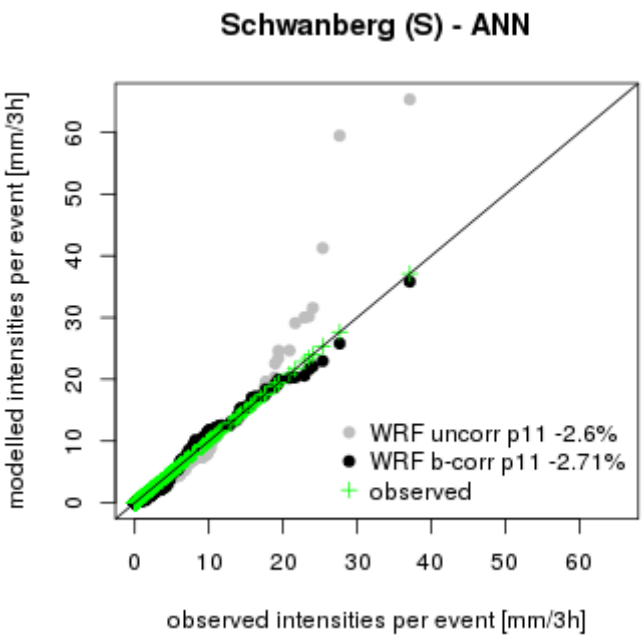
➔ Floods with raw WRF 3 km data are overestimated

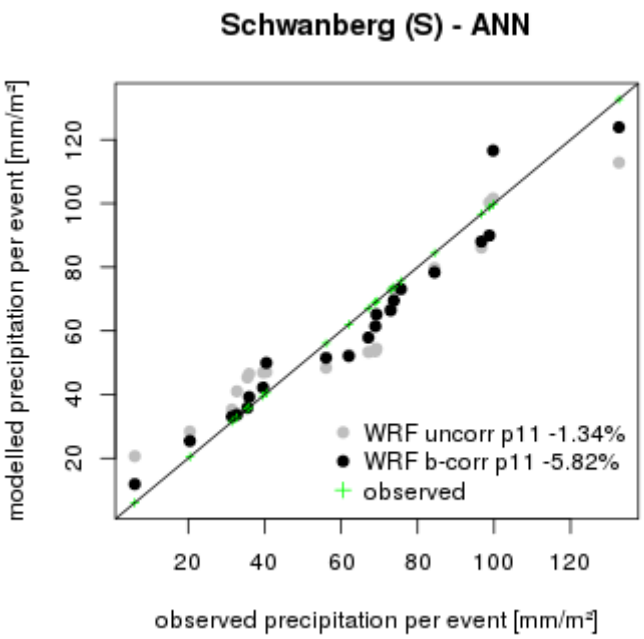
SDM overcorrects intensities, amounts per events, and degrades temporal sequence for last 9 hours before the events

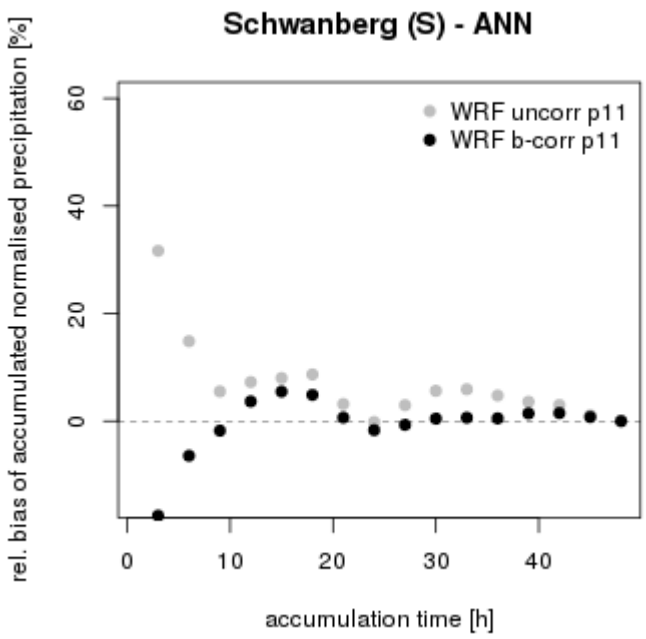
➔ Floods are not generated anymore



Results





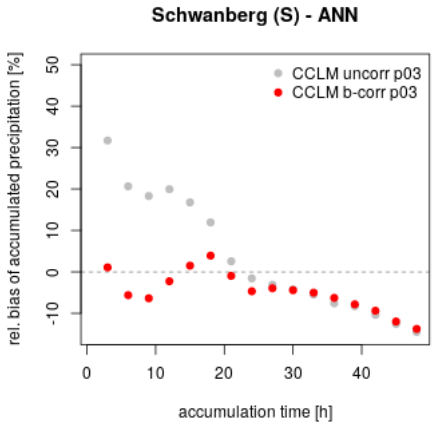


Intensities, precipitation amount per event are well represented and temporal sequence only shows a slight overestimation

➔ Floods are slightly overestimated in raw WRF 12.5 km data

SDM has some minor effects on intensities and amount per event, but degrades temporal sequence for last until 21 hours before the event

➔ Floods are underestimated


Schwanberg (S) - ANN
CCLM uncorr p03
CCLM b-corr p03
rel. bias of accumulated precipitation [%]
-10
0
10
20
30
40
50
0
10
20
30
40
accumulation time [h]