Potsdam Institute for Climate Impact Research

PIK

Intercomparison of climate change impacts simulated by regional and global hydrological models

in eleven large river basins including quantification of uncertainties using ANOVA

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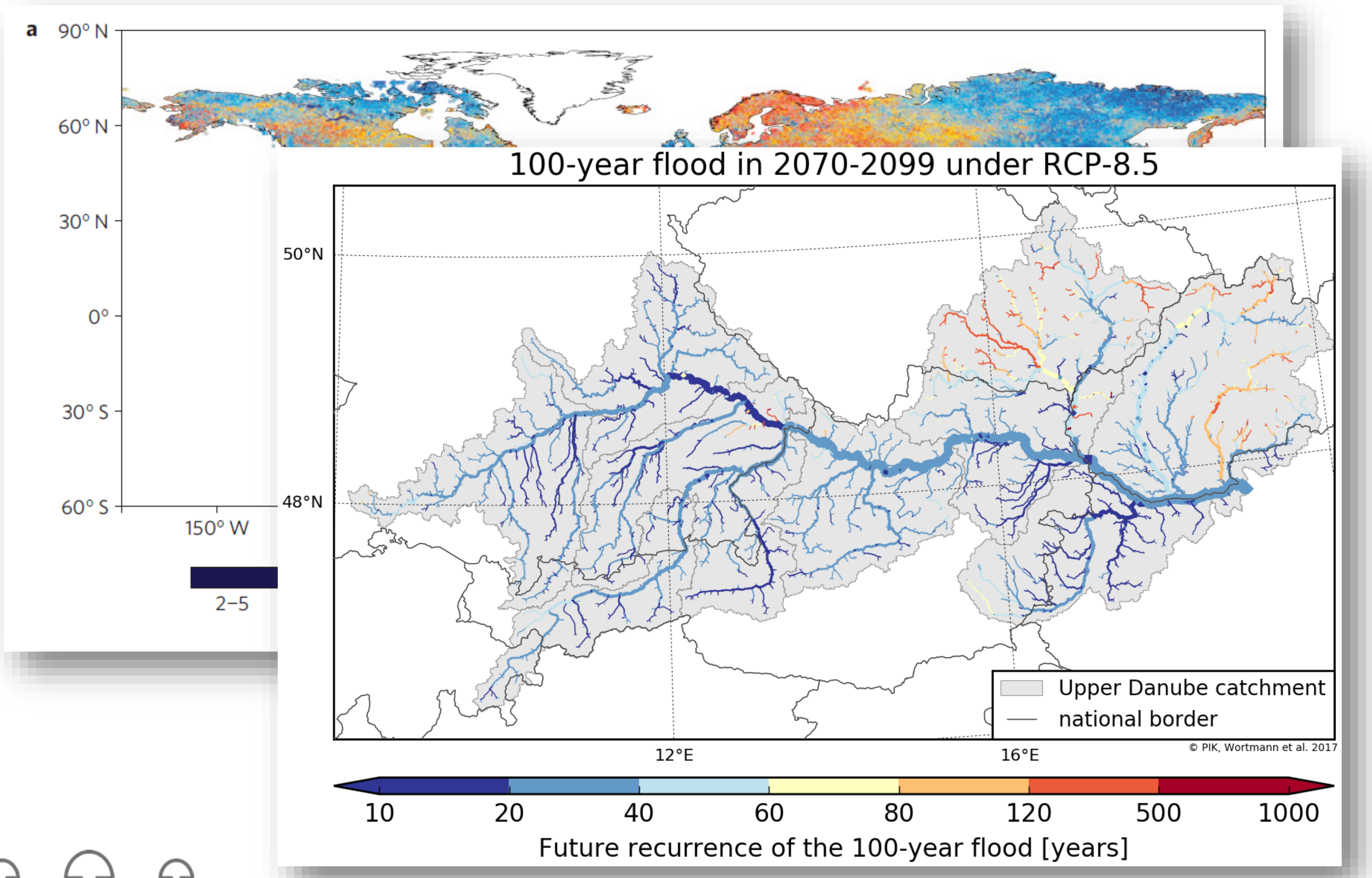
Leibniz Gemeinschaft

Potsdam Institute for Climate Impact Research

RD2 Climate Impacts & Vulnerability

Why bridging the scales?



Hattermann et al 2017, in prep.

Why bridging the scales?

- Climate change is a global phenomenon, and a global overview on climate change impacts (done by global hydrological models, GHMs) is important, and can motivate regional impact assessment.
- Climate change impacts manifest at the regional scale, where most mitigation and adaptation measures are planned and implemented, and where regional hydrological models (RHMs) are usually applied.
- It is important to investigate the consistency of the results modelled at different scales

Objectives of the study

1. To compare performance of global and regional HMs under current climate conditions considering the long-term average seasonal dynamics;
2. To compare sensitivity of simulated annual river discharge at both scales to climate variability (annual precipitation);
3. To compare simulated climate change impacts for the long-term average seasonal dynamics driven by 5 bias-corrected GCMs (data prepared by ISI-MIP); and
4. To quantify sources of uncertainty in a multi-model study using ANOVA (Analysis Of Variances): from RCP scenarios, driving GCMs and applied HMs.

The Inter-Sectoral Impact Model Intercomparison Project

- **ISIMIP is a international community effort of climate impact modelers which offers a framework and data to harmonize climate impact assessments across sectors and scales.**

5 statistically downscaled and bias-corrected GCMS for 4 RCPs

Socio-economic input
SSP scenarios

Impact models global & regional

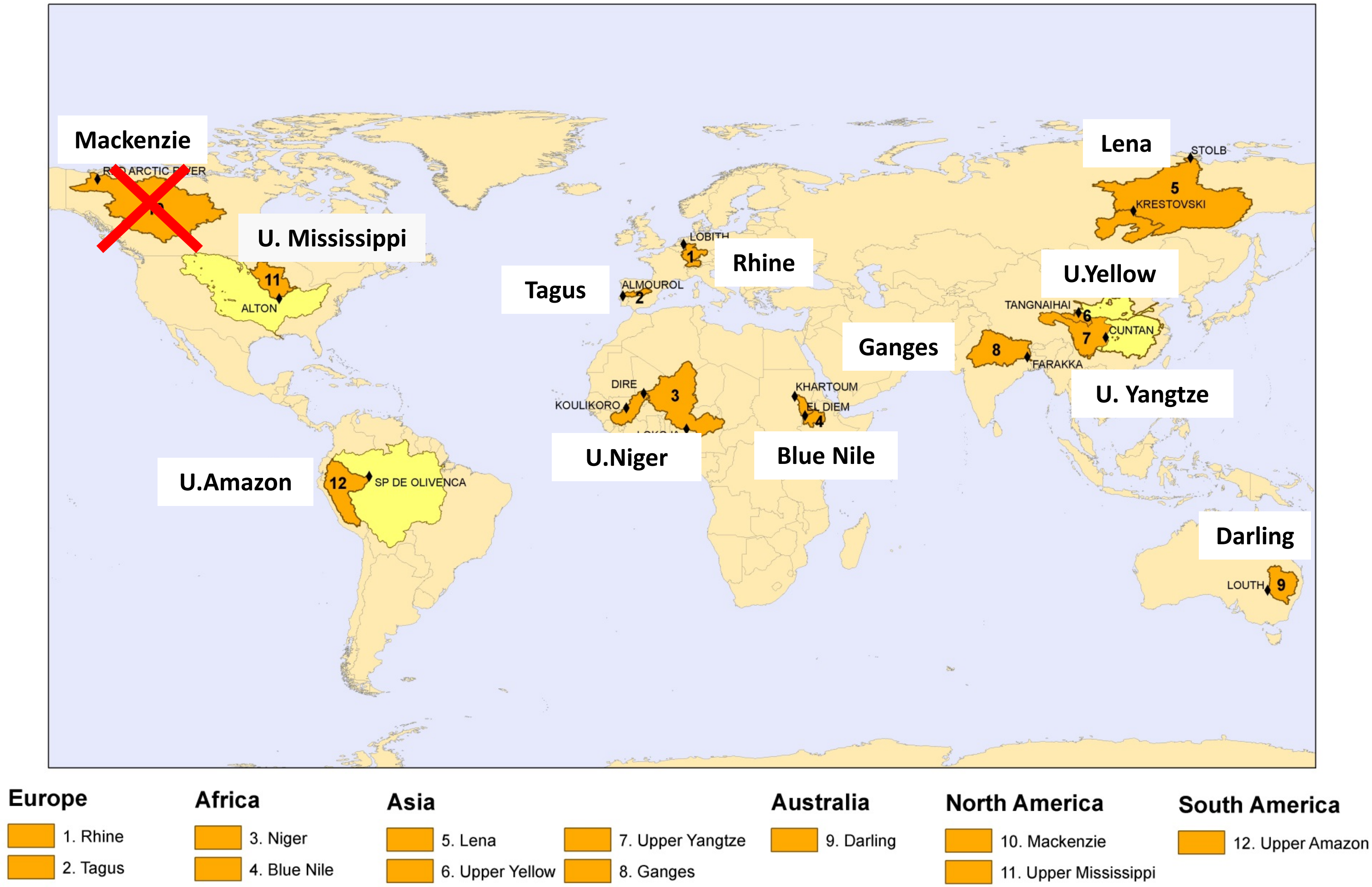
agriculture	water
biomes	Forests
coastal infrastructure	health
fisheries	energy
agro-economics	permafrost

- Synthesis of impacts at different levels of global warming
- Quantification of uncertainties
- Model improvement
- Cross-sectoral interactions
- Cross-scale intercomparison
- Focus topics (e.g. extreme events, adaptation)

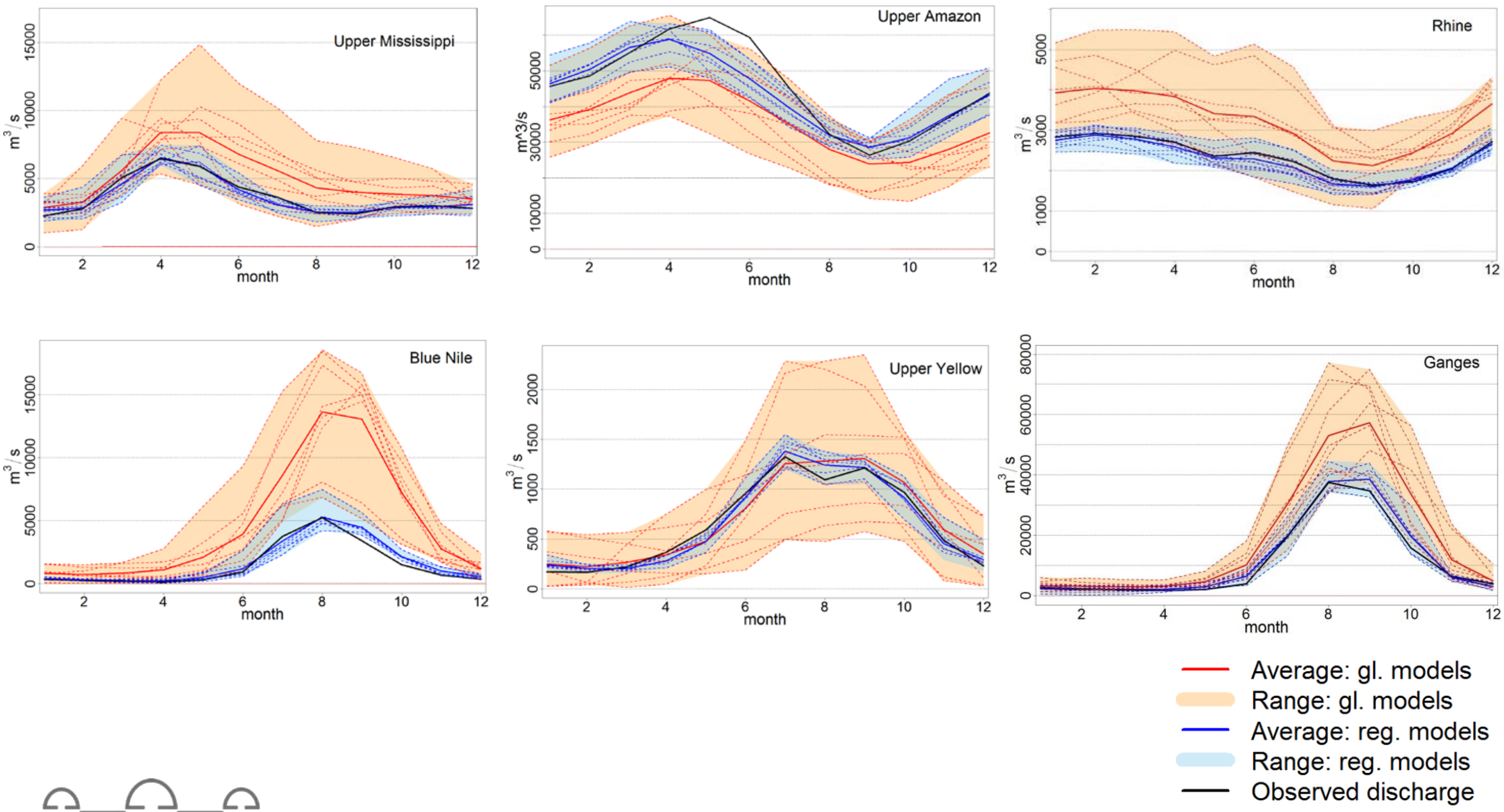
Application of GHMs and RHMs to river basins

Basin	*Rhine*	*Tagus*	*U. Niger*	*Blue Nile*	*Ganges*	*U. Yellow*	*U. Yangtze*	*Lena*	*Darling*	*U. Mississippi*	*U. Amazon*
Gauge	*Lobith*	*Almourol*	*Koulikoro*	*El Deim*	*Farakka*	*Tangnaihai*	*Cuntan*	*Stolb*	*Louth*	*Alton*	*SP Olivenca*
Drainage area, km2	*160800*	*67490*	*120000*	*238977*	*835000*	*121000*	*804859*	*2460000*	*489300*	*444185*	*990781*
Average T, deg.C	*8.7*	*14*	*26.5*	*19.4*	*21.1*	*-2*	*6.8*	*-10.2*	*19.2*	*7.3*	*21.7*
Average P, mm/yr	*1038*	*671*	*1495*	*1405*	*1173*	*506*	*768*	*384*	*590*	*967*	*2122*
Regional models											
ECOMAG								*			
HBV	* *	*	*	*	*	*	*			*	*
HYMOD	* *		*		* *	*			*	* *	*
HYPE	*	*			*			*			
mHM	*		*	*	*	*			*	*	*
SWAT			*	*			*		*	*	*
SWIM	*	*	*	*	*	*	*	*		*	*
VIC	*	*	*	*	*	*	*	*	*	*	*
WaterGAP3	*	*	*	*	*	*		*		*	*
Global Models											
CLM	*	*	*	*	*	*	*	*	*	*	*
DBH	*	*	*	*	*	*	*	*	*	*	*
H08	*	*	*	*	*	*	*	*	*	*	*
LPJmL	*	*	*	*	*	*	*	*	*	*	*
Mac-PDM.09	*	*	*	*	*	*	*	*	*	*	*
MATSIRO	*	*	*	*	*	*	*	*	*	*	*
MPI-HM	*	*	*	*	*	*	*	*	*	*	*
PCR-GLOBWB	*	*	*	*	*	*	*	*	*	*	*
WaterGAP2	*	*	*	*	*	*	*	*	*	*	*
Number of cases	17	13	15	14	16	14	12	13	12	16	15

11 river basins for intercomparison

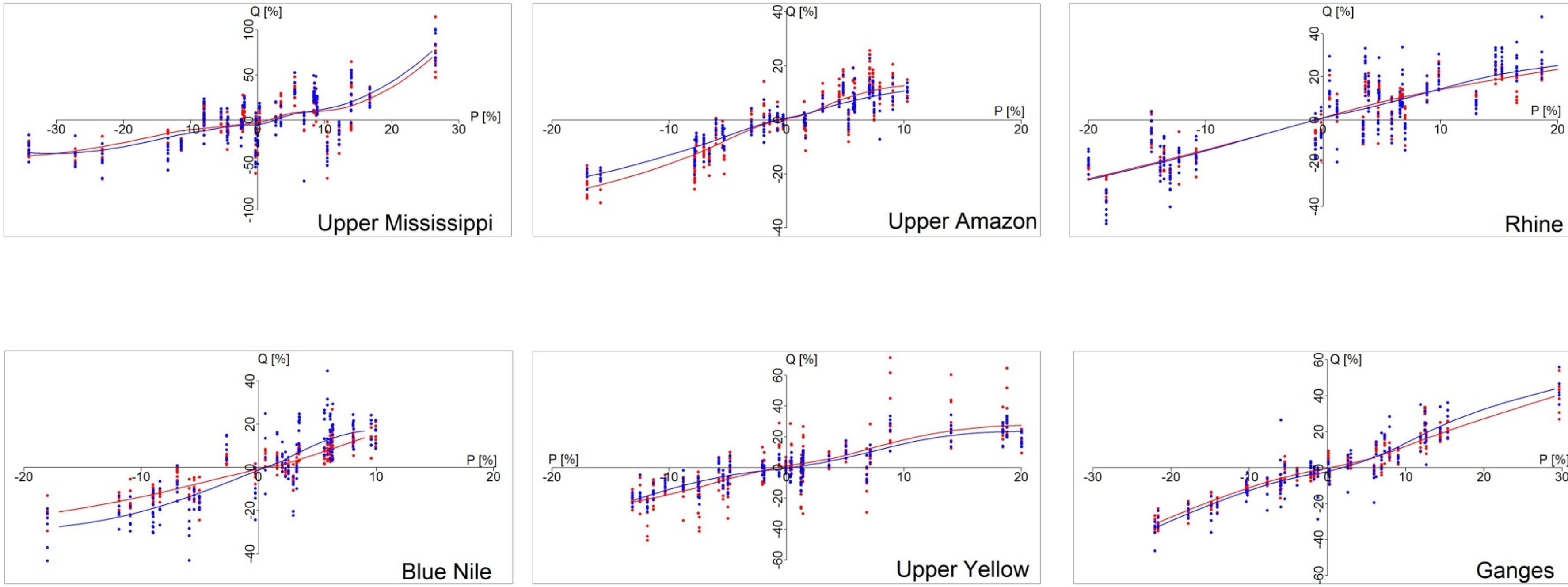


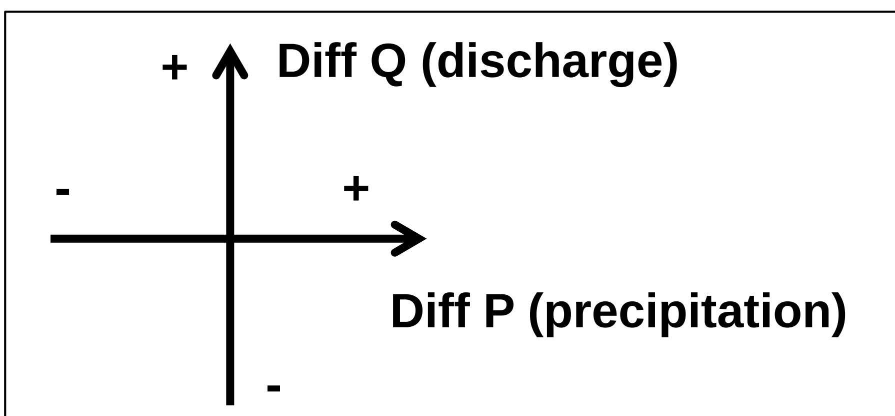
1. Comparison of model performances: long-term average seasonal discharge 1971-2000



Hattermann et al. 2017, Climatic Change

2. Sensitivity of simulated annual discharge to annual precipitation: anomalies in Q versus anomalies in P



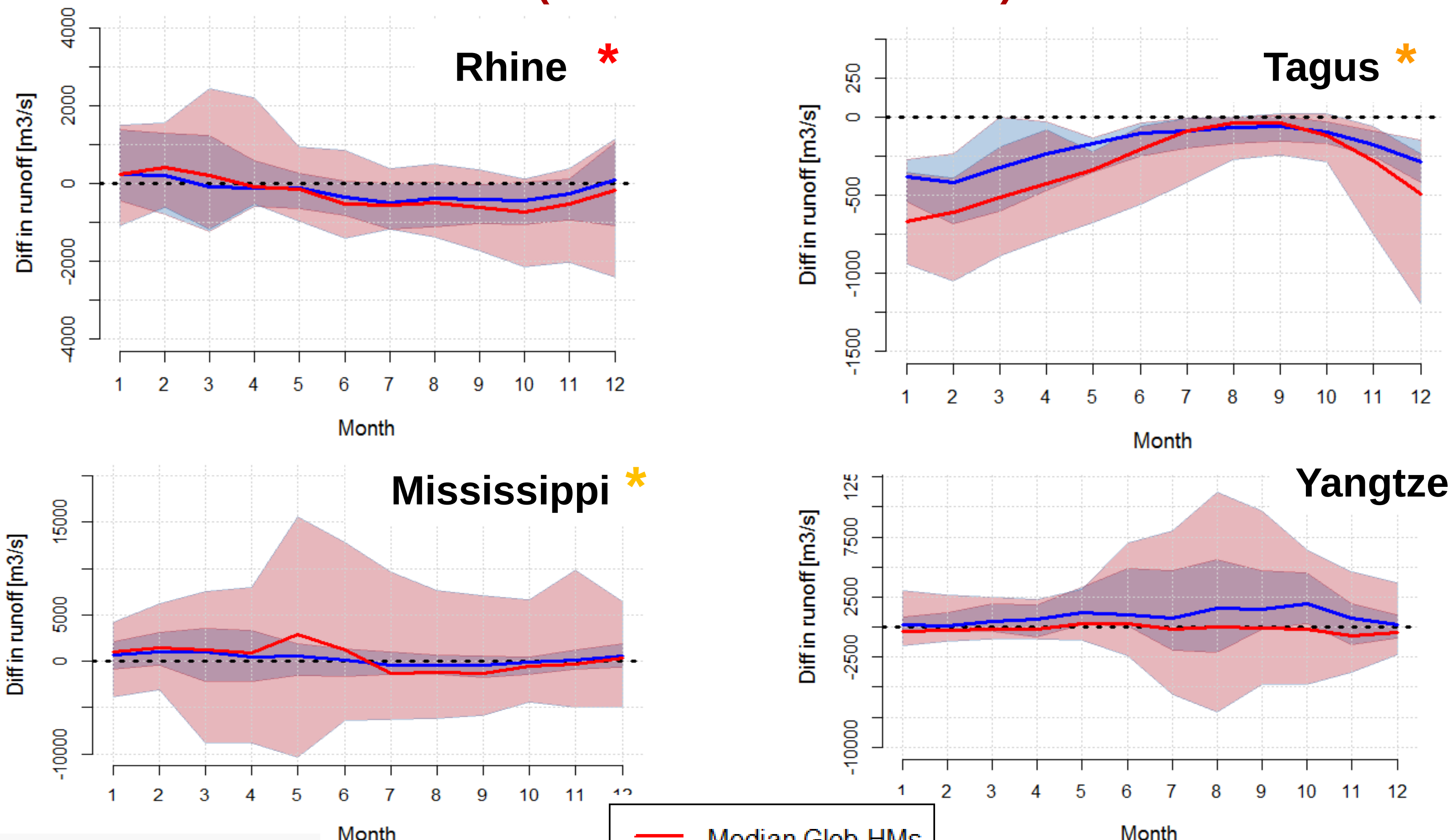


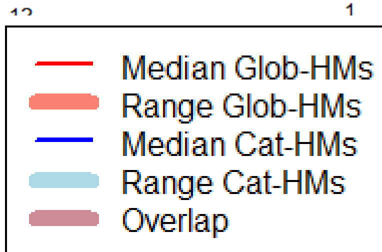
Period: 1971-2000

Hattermann et al. 2017, Climatic Change

3. Changes in long-term average seasonal runoff simulated by GHMs and RHMs: medians and ranges

(2071-2100 to 1971-2000)



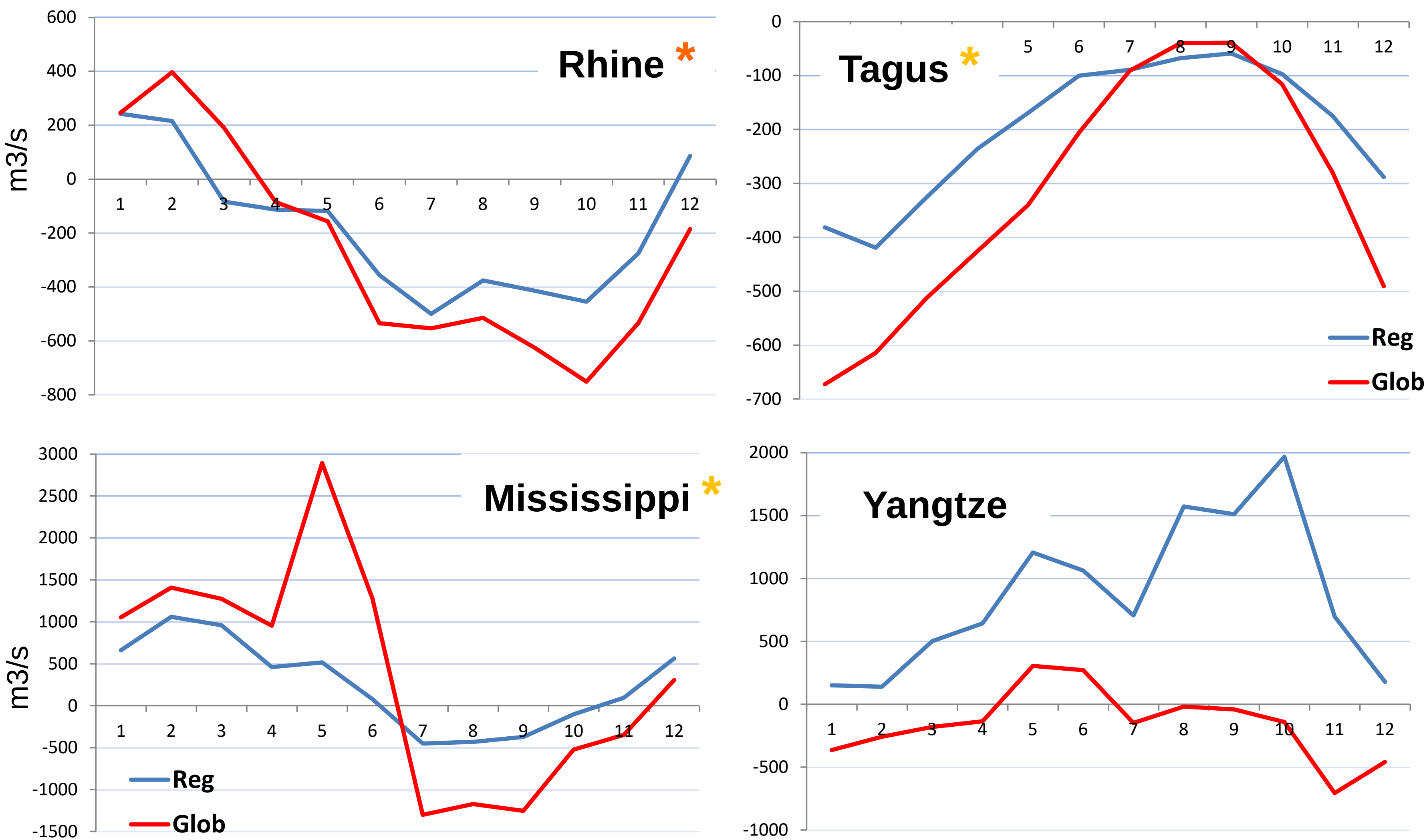


* similar (2 crit.)

* similar (1 crit.)

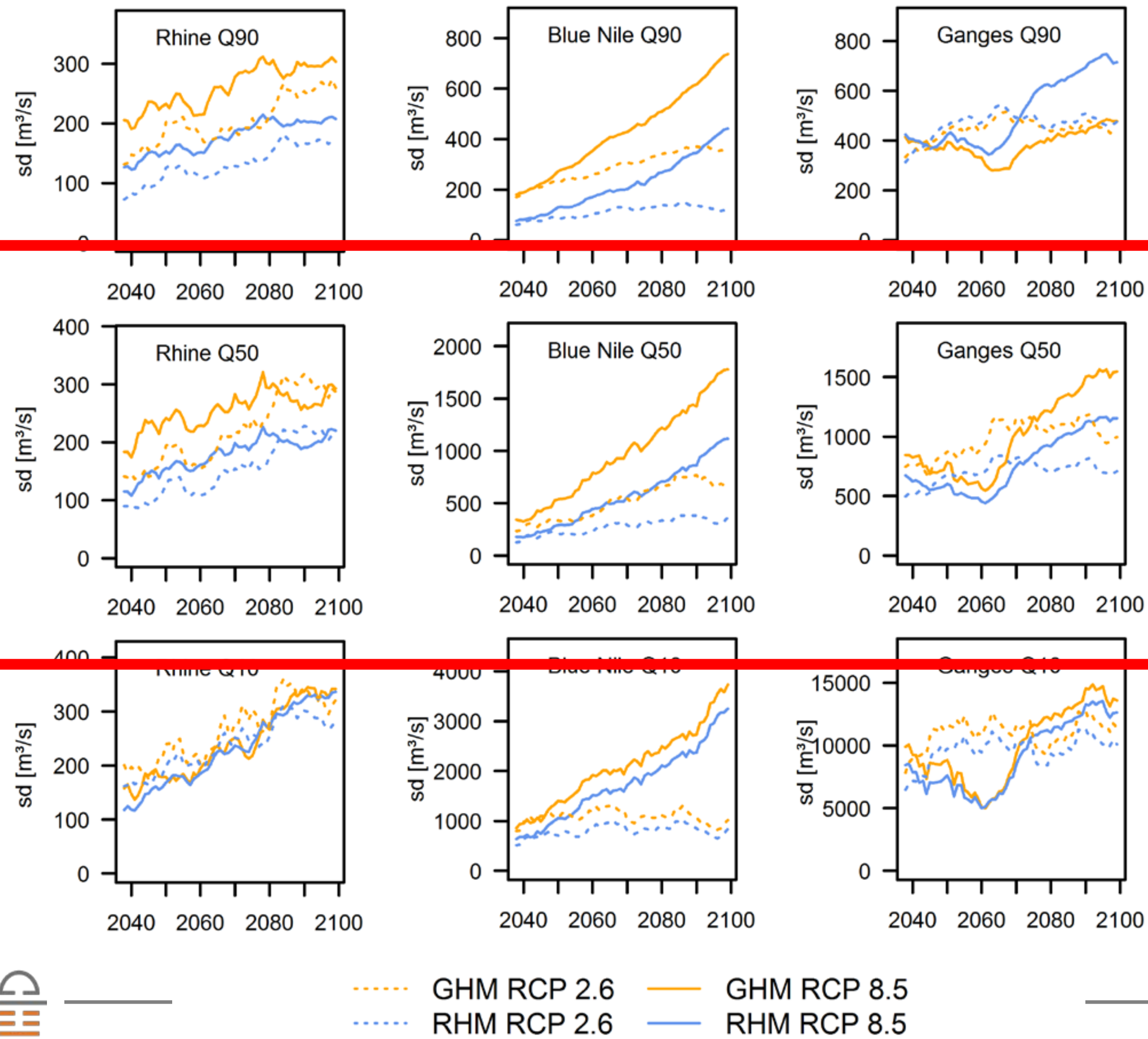
Hattermann et al. 2017, Climatic Change

3. Changes in long-term average seasonal runoff simulated by GHMs & RHMs: comparison of medians only



Differences in change signals:
Rhine 45%, Tagus 59%, Mississippi 51%, Yangtze: 861 & -156 m3/s

Increase of uncertainty with time



Hattermann et al. 2017, Envr. Res. Letters, submitted

ANOVA: Theoretical background

- ANOVA can be used for variances (sum of squares) decomposition

$$SST = \underbrace{SS_{Hyd} + SS_{Gcm} + SS_{Rcp}}_{\text{main effects}} + \underbrace{SS_{HydGcm} + SS_{HydRcp} + SS_{RcpGcm} + SS_{HydRcpGcm}}_{\text{Interaction effects}}$$

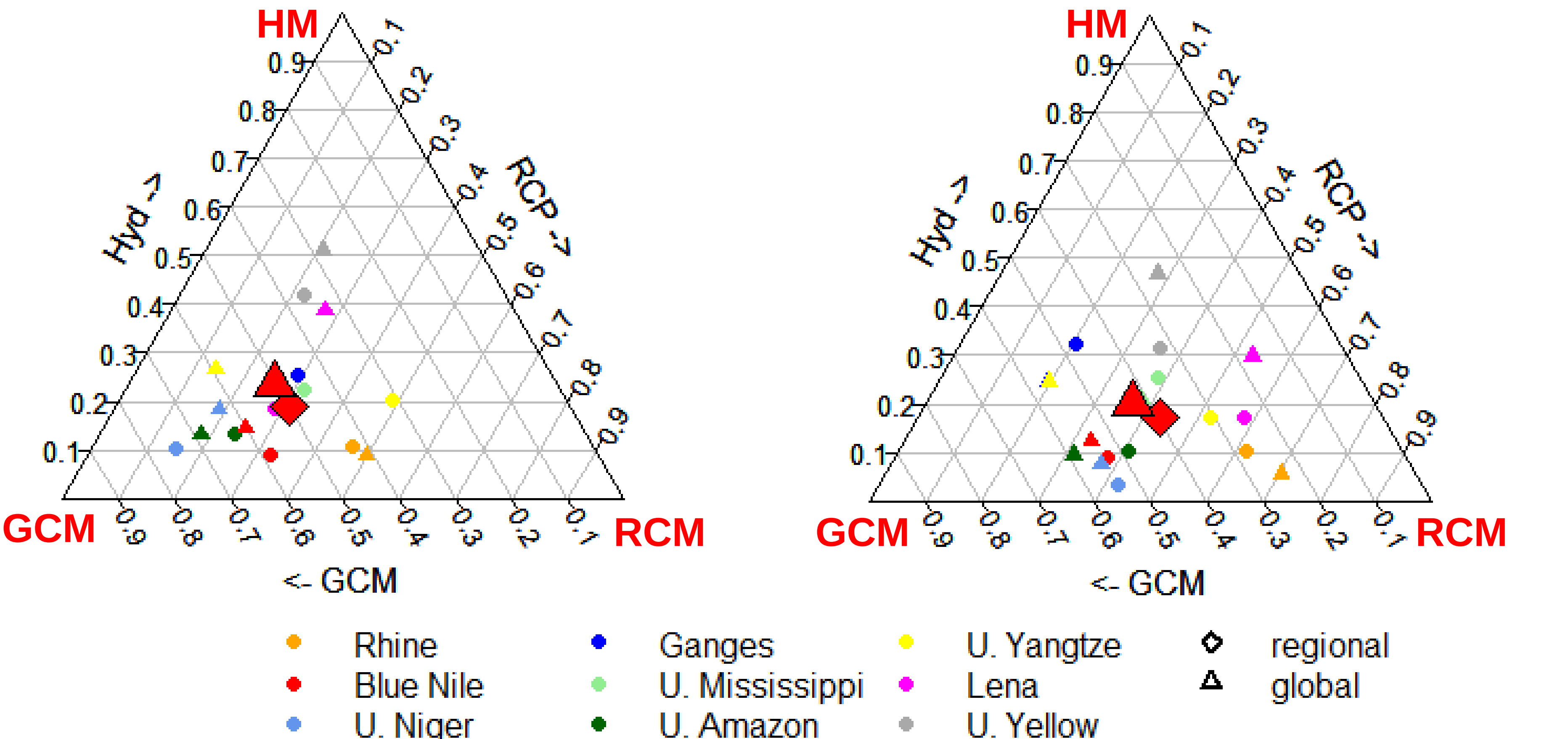
- main effects: describe direct effect e.g. the relationship between RCPs vs. temperature increase
- interaction terms: describe nonlinear behavior: if they have high contribution then one effects are depended on the value of another factor
- finaly contribution of each factor can be calculated as: $\frac{SS_{factor}}{SST}$

Hattermann et al. 2017, Envr. Res. Letters, submitted

ANOVA: Total uncertainty contribution considering different scenario settings

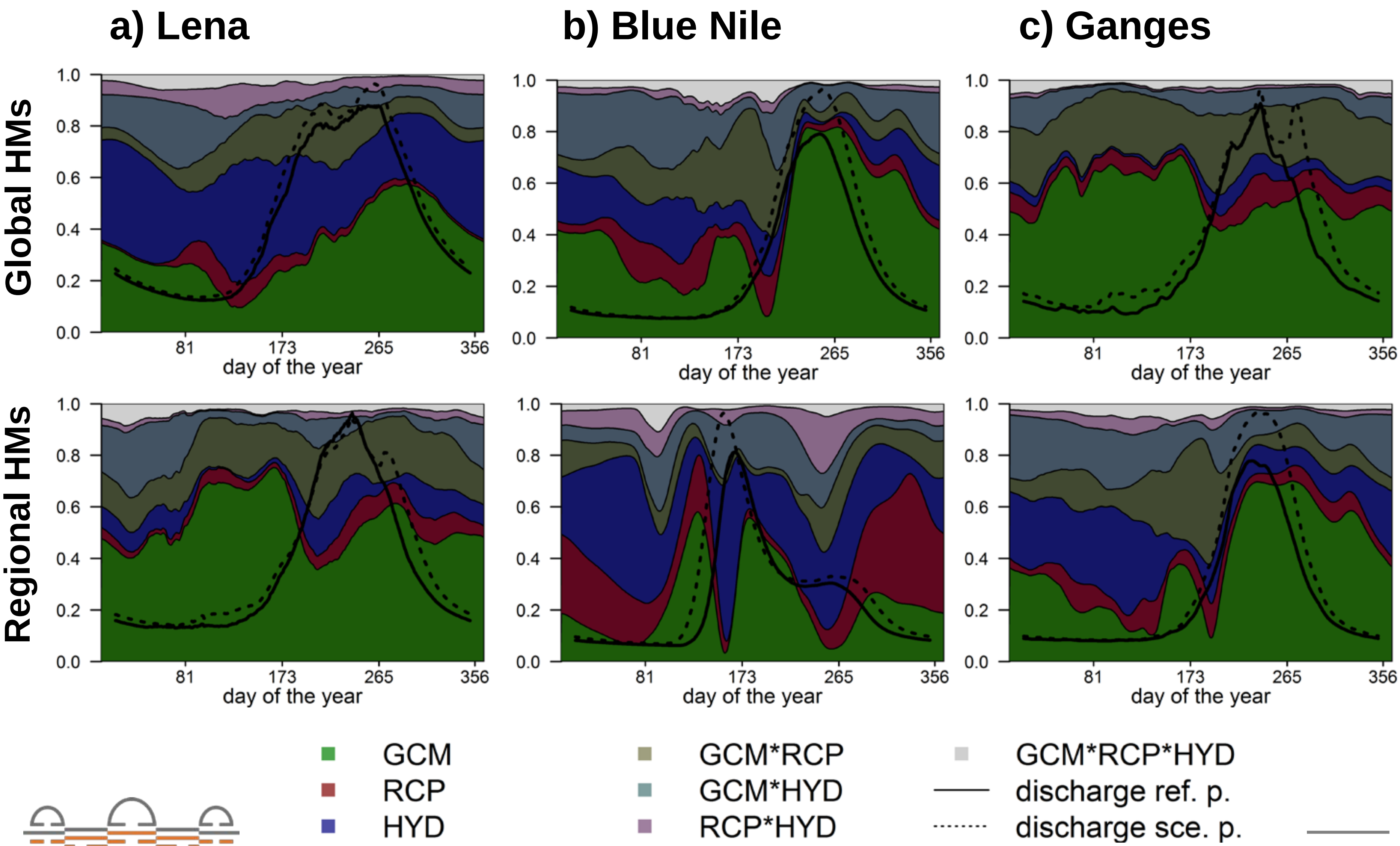
Small difference in scenario temperature increase
RCP2.6 and RCP4.5 considered

Large difference in scenario temperature increase
RCP2.6 and RCP8.5 considered



Hattermann et al. Climatic Change (2017)
Hattermann et al . Env. Res. Leters (2017, submitted)

ANOVA: Daily uncertainty contribution



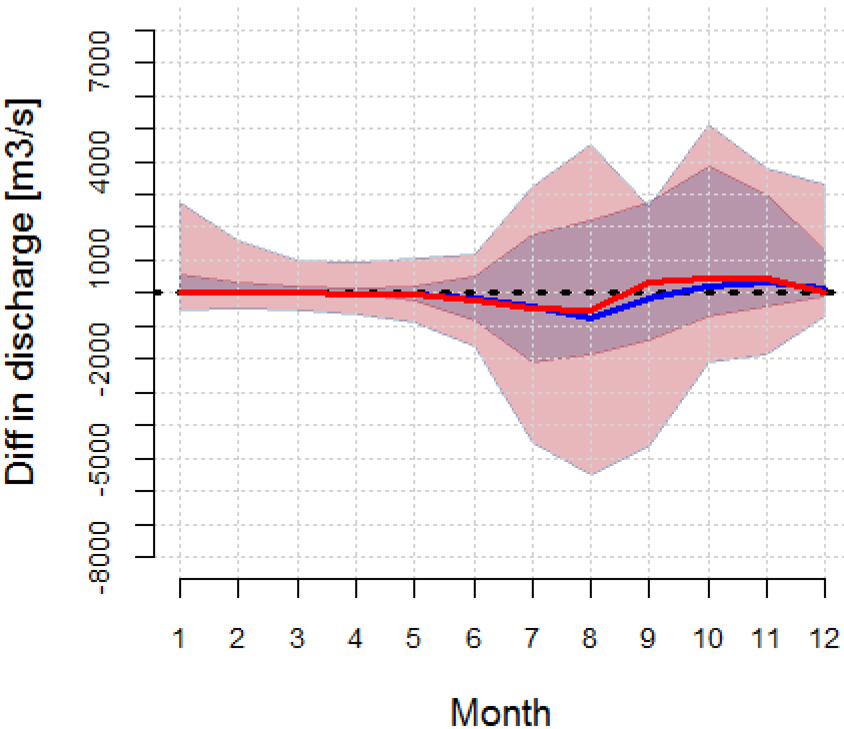
Hattermann et al. 2017, Envr. Res. Letters, submitted

ANOVA: Significance of impacts (F-test)

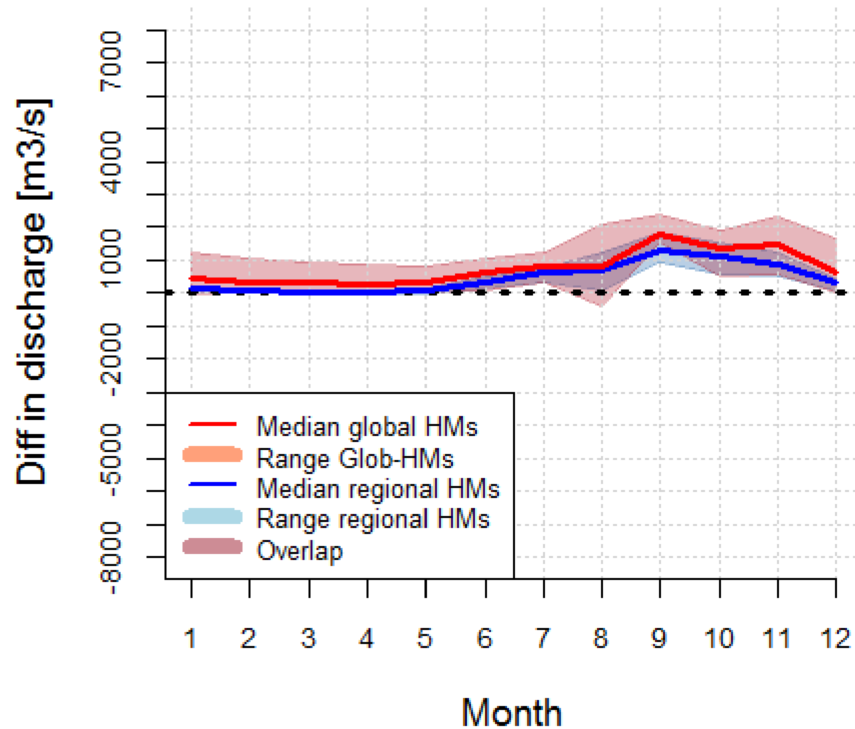
Example: CC impacts in the Niger basin until 2100 (RCP8.5)

Result: Impact chain with only one GCM as input leads to significant changes (F-test)

5 GCMs considered



1 GCM considered



Hattermann et al. 2017, Envr. Res. Letters, submitted

Conclusions I

- **Performance of regional models for seasonal dynamics is much better than that of global models.**
- **Sensitivities of simulated annual river discharges at both scales to annual precipitation are quite similar.**
- **Distribution of uncertainty sources differs between basins and variables (Q10, MF, Q90). The results with RHMs for all 12 basins in case of MF can be summarized as follows:**

  - the highest contribution comes from GCMs (54%),

  - it is followed by RCPs (30%), and

  - the smallest from HMs (16%).

Conclusions II

- In most cases even the direction of change is difficult to define (very large min/max corridors, especially for GHMs)
- However, also small changes in temperature (-> Paris agreement) lead to significant impacts on hydrology,
- but in many cases we just don‘t know the direction of the impact, and this is due to GCM related uncertainty

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Many thanks!

to all model groups for providing data and cooperation,
and to the ISI-MIP coordination team for their support

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In this issue (16 articles)

Conclusions III

- It can be concluded that the results of the single impact models should be always treated with precaution.
- Though a good preformance of a HM under current conditions does not guarantee ist reliability in simulated CC impacts, especially for far future, an improvement of model performance is needed (e.g. stage II of model calibration for RHMs in ISI-MIP is planned)
- A large uncertainty related to GCMs, especially in some regions (African basins, Amazon, Darling in Australia), is a problem which requires further efforts of climate modellers.

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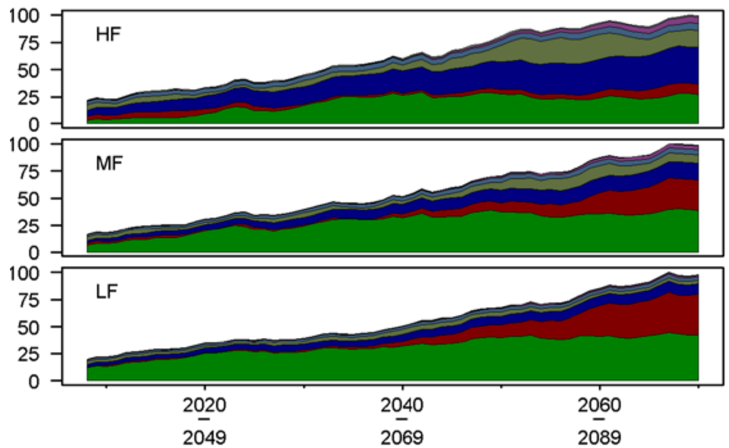
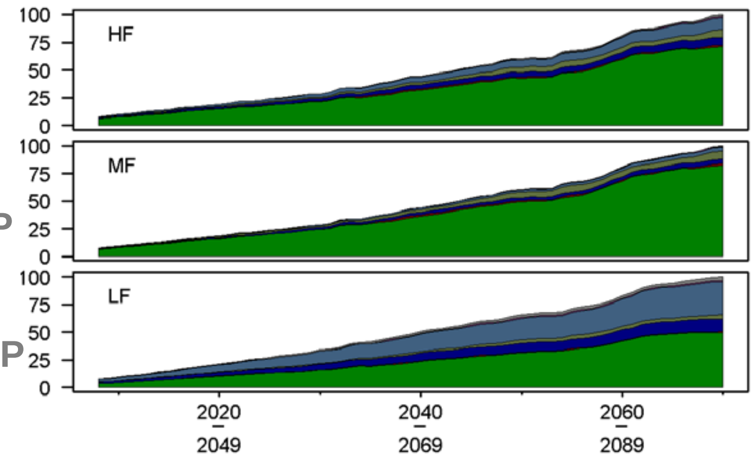
4. Sources of uncertainty: 4 examples (RHMs only)

Rhine

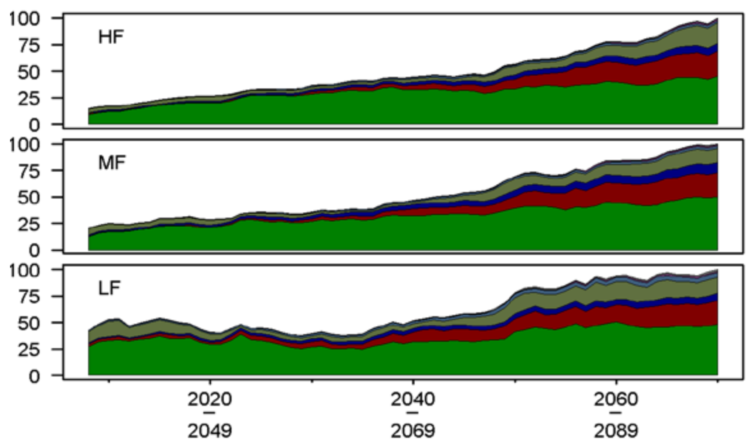


GCM+HM
GCM+RCP
GCM+RCP

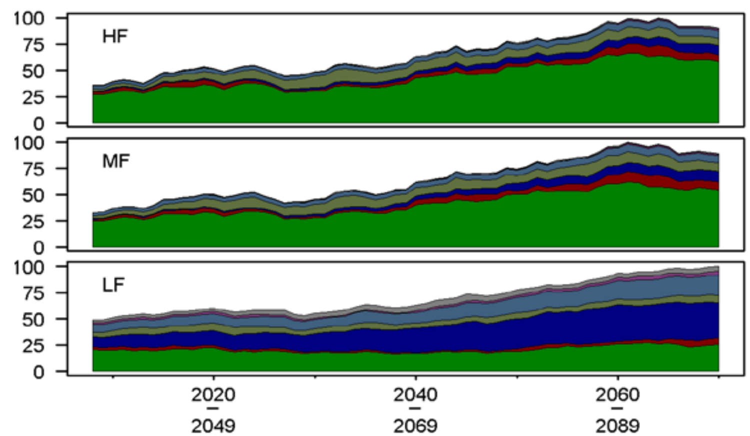
Niger: GCM prevails



Amazon: GCM & RCP



Ganges



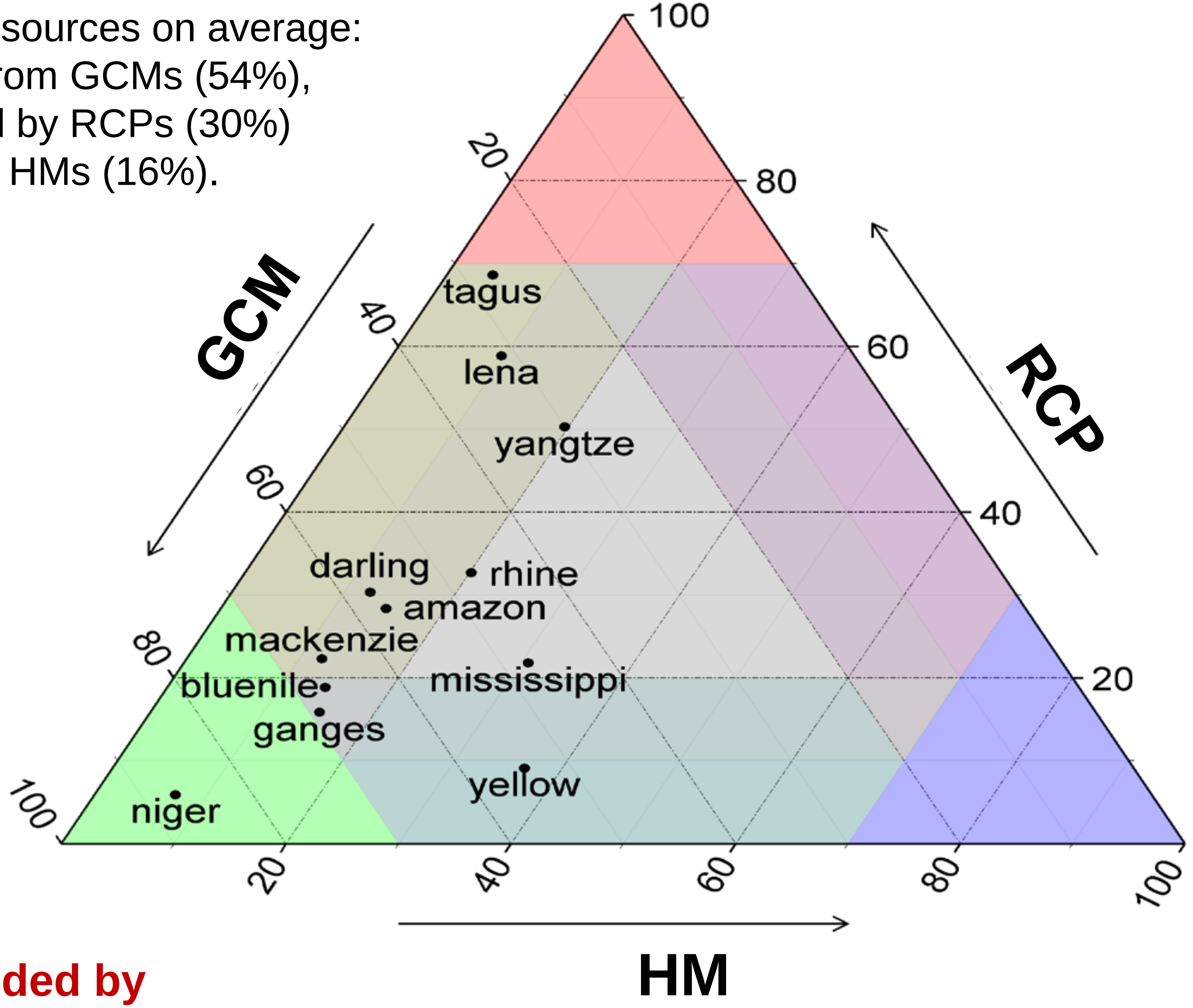
GCM
GCM
GCM+HM

GCM RCP HM

Vetter et al., Climatic Change, in review

4. Triangle of uncertainty (only for RHMs): where are the basins placed?

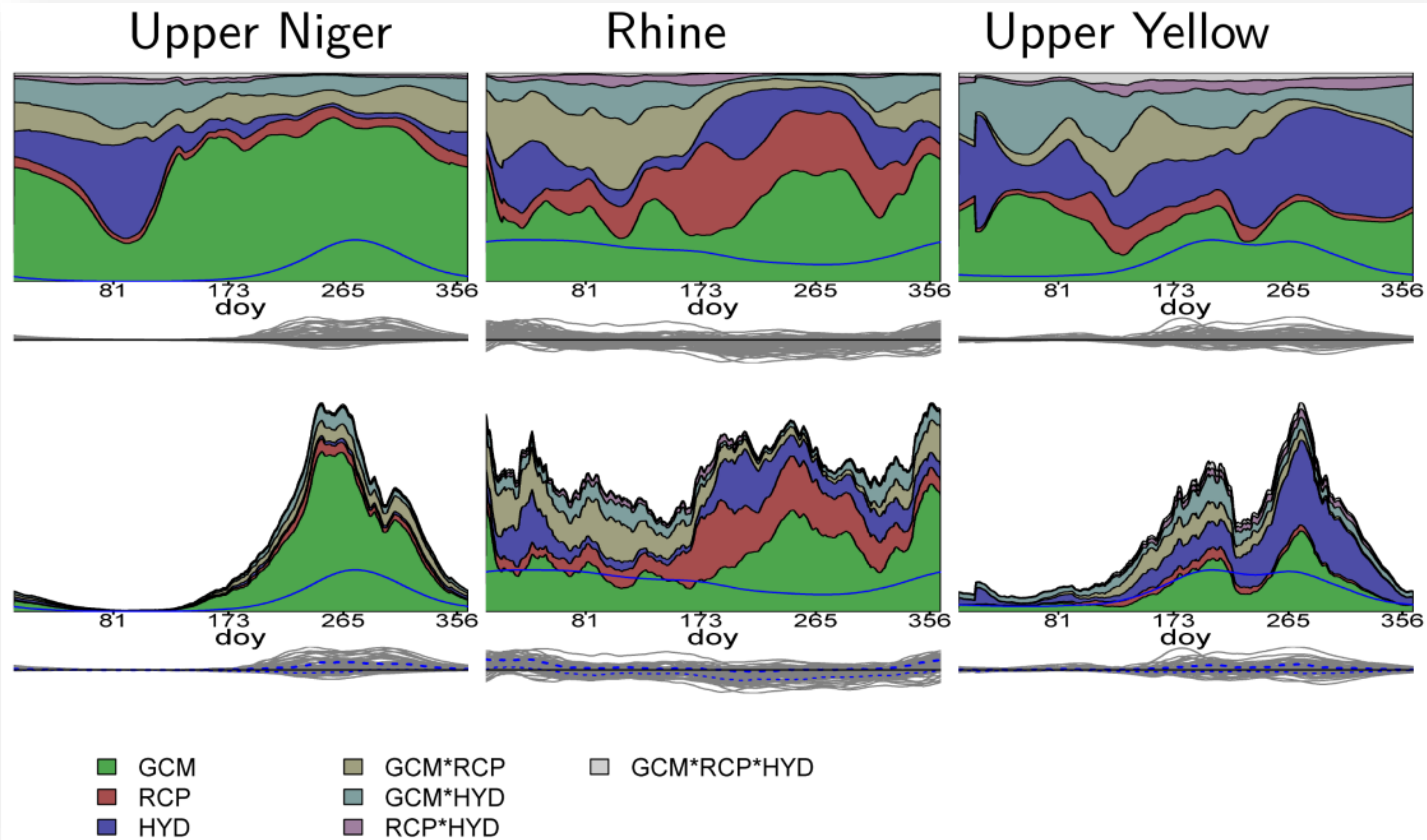
Uncertainty sources on average:
highest from GCMs (54%),
followed by RCPs (30%)
and HMs (16%).



To be extended by including also GHMs

Vetter et al., Climatic Change, in review

Quantification of uncertainty sources using ANOVA



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Vetter, T., Huang, S., Aich, V., Yang, T., Wang, X., Krysanova, V., and Hattermann, F.: Multi-model climate impact assessment and intercomparison for three large-scale river basins on three continents, Earth Syst. Dynam., 6, 17-43, doi:10.5194/esd-6-17-2015, 2015.