Do high resolution GCMs overestimate precipitation over land?

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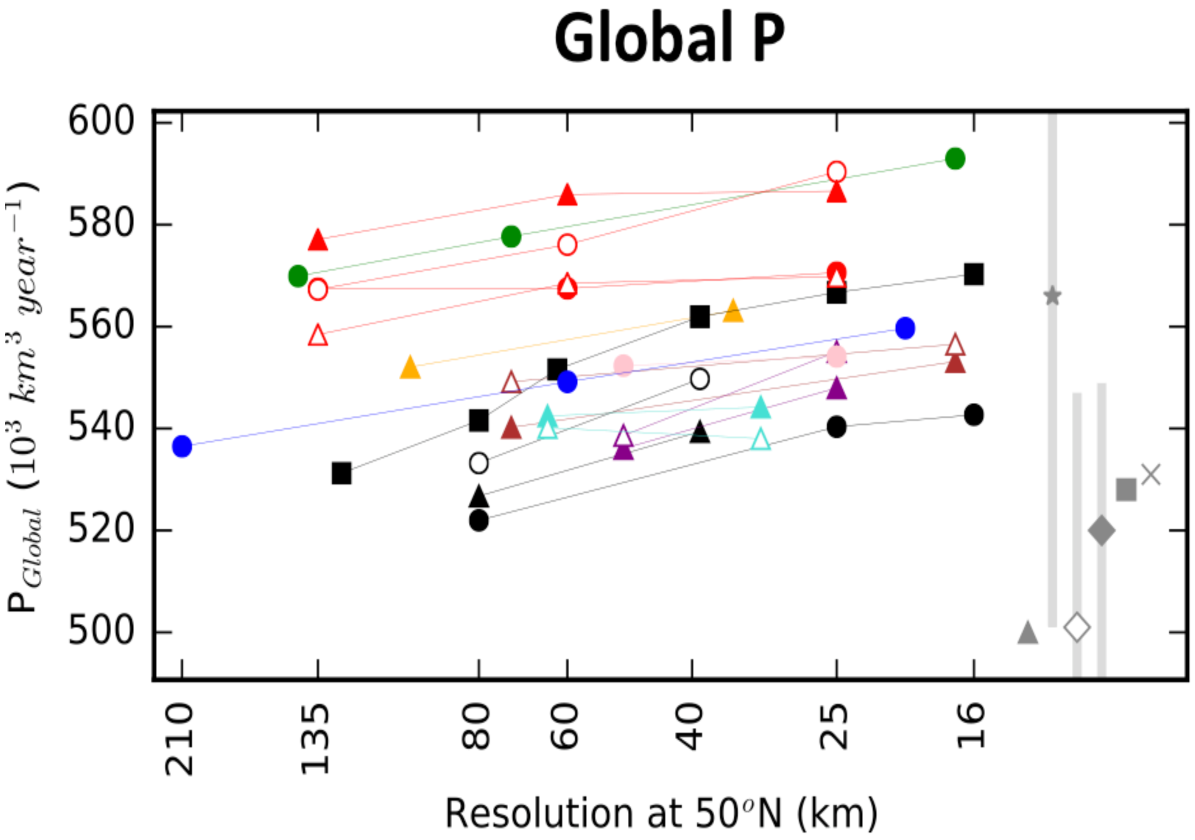
Motivation: How much does it rain?



- There is considerable uncertainty among global precipitation estimates (grey marks).
- Stephens (2012) suggested global precipitation was larger than previously thought in the light of new data from satellite CloudSat and when snowfall was accounted for.
- High resolution GCMs support the Stephens' estimate. The increase in global P even occurs in coupled experiments (CPL) suggesting that it is not an issue of the forced SST providing an infinite source of energy.

GCMs

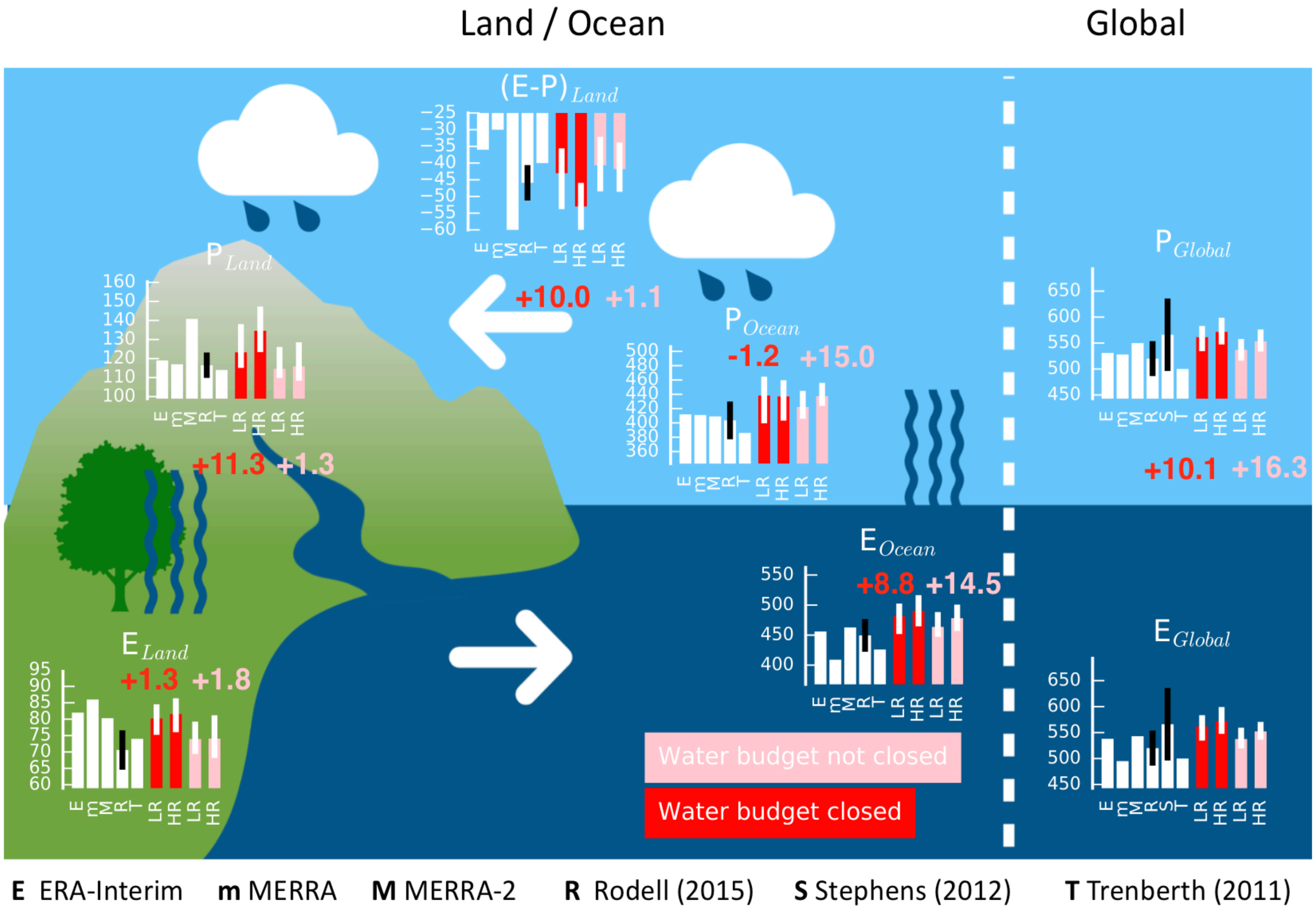
Reanalysis

Vannière et al. 2018, CD

Motivation: Hydrological cycle sensitivity to resolution

- Right side: in all models the global precipitation increase when the resolution is enhanced as we have seen before.

- Left side: Models conserving moisture (red) increase evapotranspiration over ocean, moisture transport from ocean to land, and precipitation over land. This enhancement of some water balance components are even larger in high resolution GCMs (HR) as already found by Demory et al. (2014).

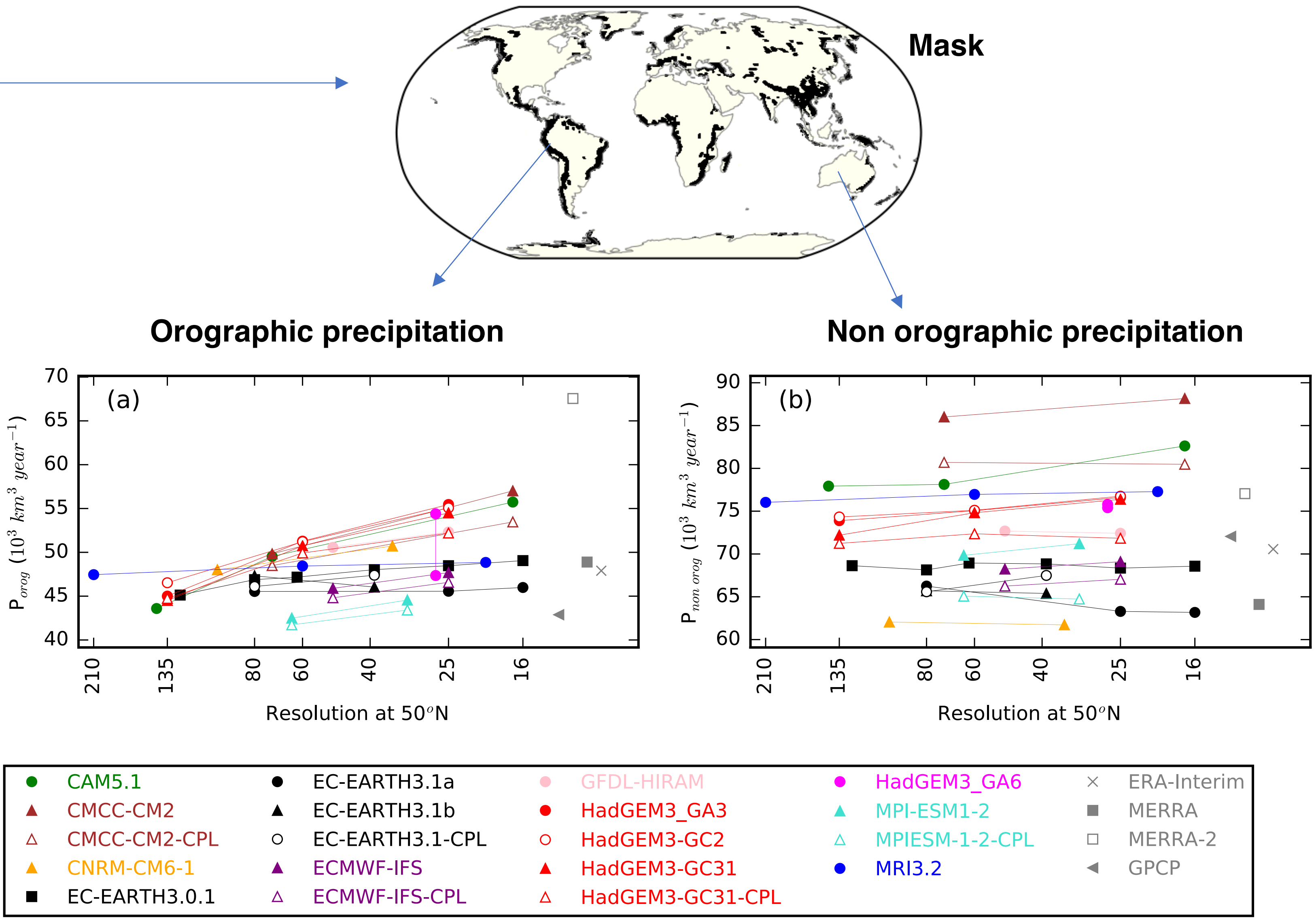


A zoom over land precipitation

- Partitioning precipitation with a mask based on orographic precipitation model of Sinclair (1994), we find that the increase of precipitation over land occurs in regions prone to orographic enhancement. In region of flat land, there is a large inter-model spread but little sensitivity to resolution.

- Do observations underestimate the amount of orographic precipitation (possibly due to the lack of gauges to correct satellite observations) OR are HR models too sensitive to orography?

- Need for an <u>independent constraint</u>: river discharge observations!



Vannière et al. 2018, CD

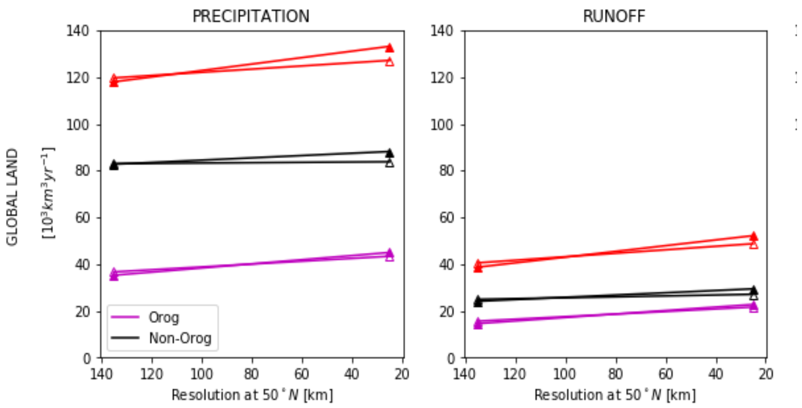
Goal

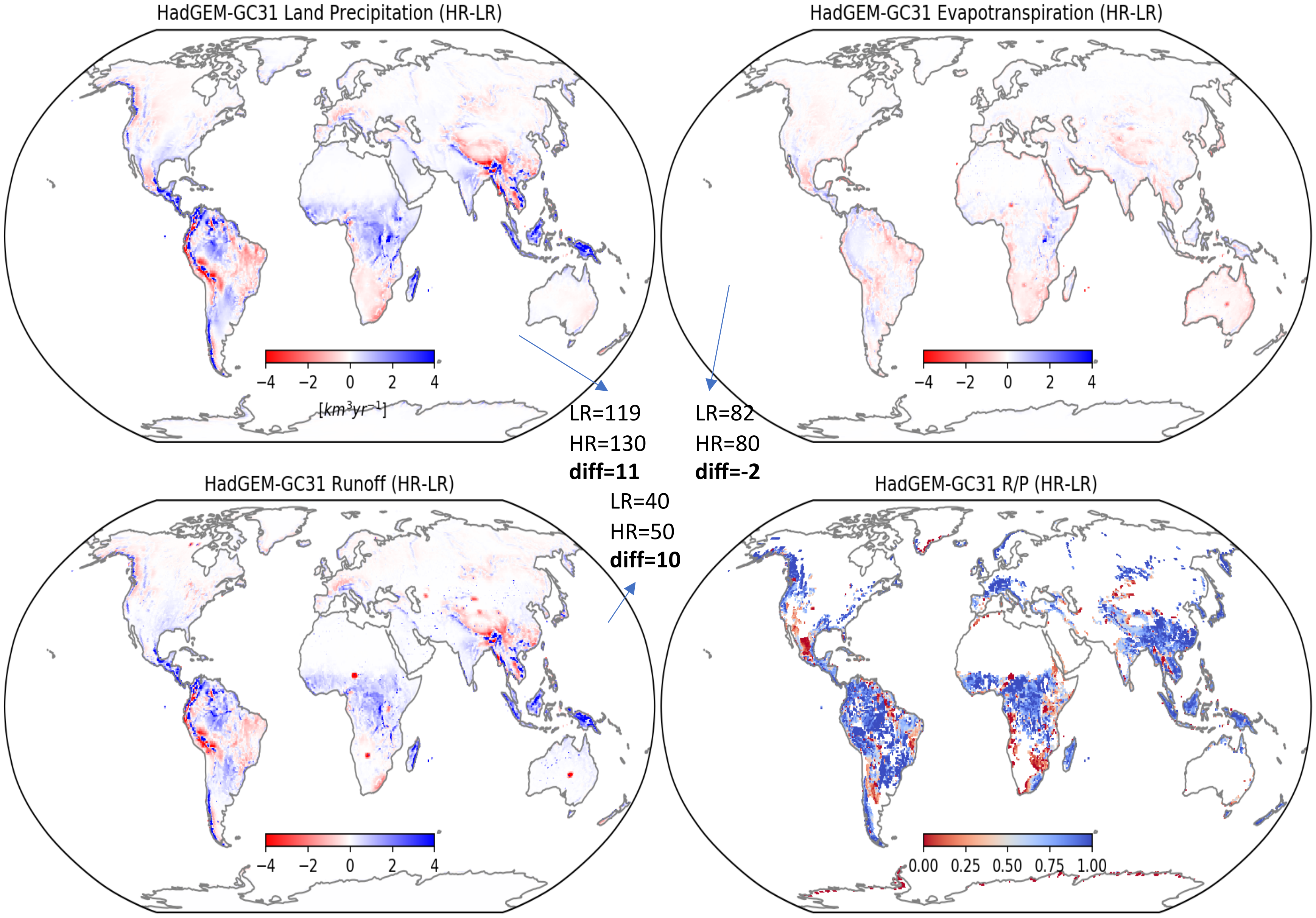
Use river discharge observations to understand HadGEM3 precipitation biases at catchment scale and globally.

Is river flow (or runoff) a good indicator of precipitation biases?

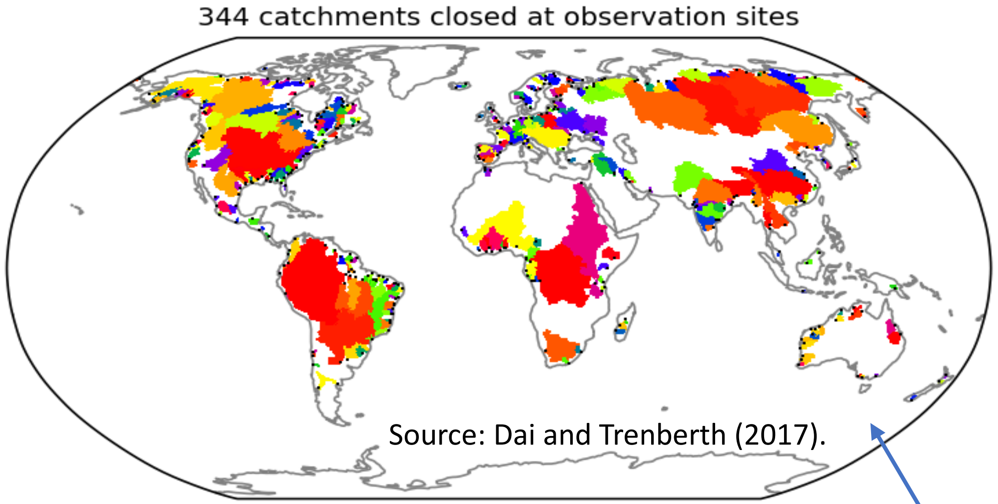
- The increase in land precipitation at HR has a slight effect on evapotranspiration but a strong impact on runoff. Land precipitation is 9% higher at HR and produces 20% more runoff.

- The absolute difference in land precipitation is 11 $[10^3 km^3 yr^{-1}]$, and 10 $[10^3 km^3 yr^{-1}]$ in runoff. It suggests the extra precipitation at HR ends mostly in rivers as it occurs over mountains where horizontal surface fluxes prevail over vertical fluxes. Then, river discharge observations can give us a good hint to infer precipitation biases at catchment scale.

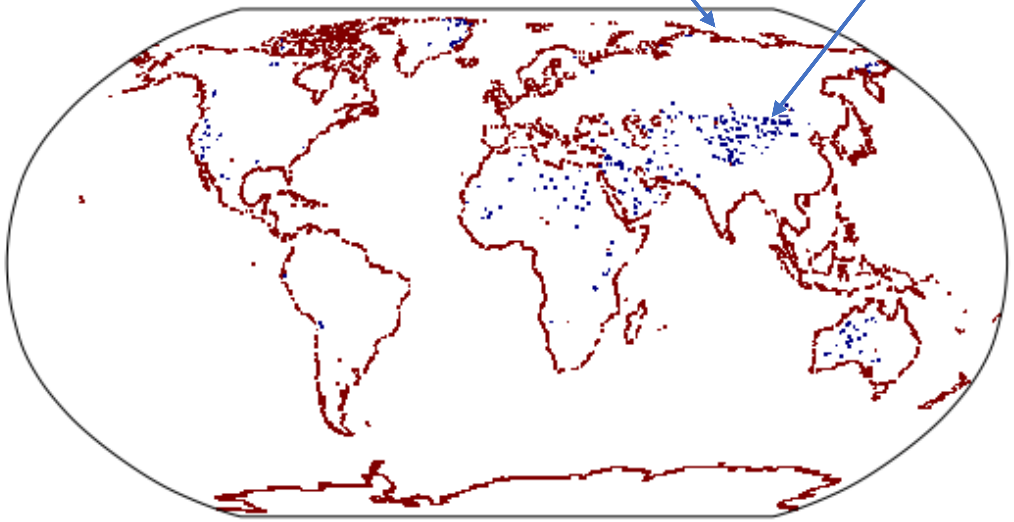




Using river flow observations to understand precipitation biases in HadGEM3



<u>Approach:</u> Combine simulated river flow with observations to estimate the discharge in coastal points and lakes.

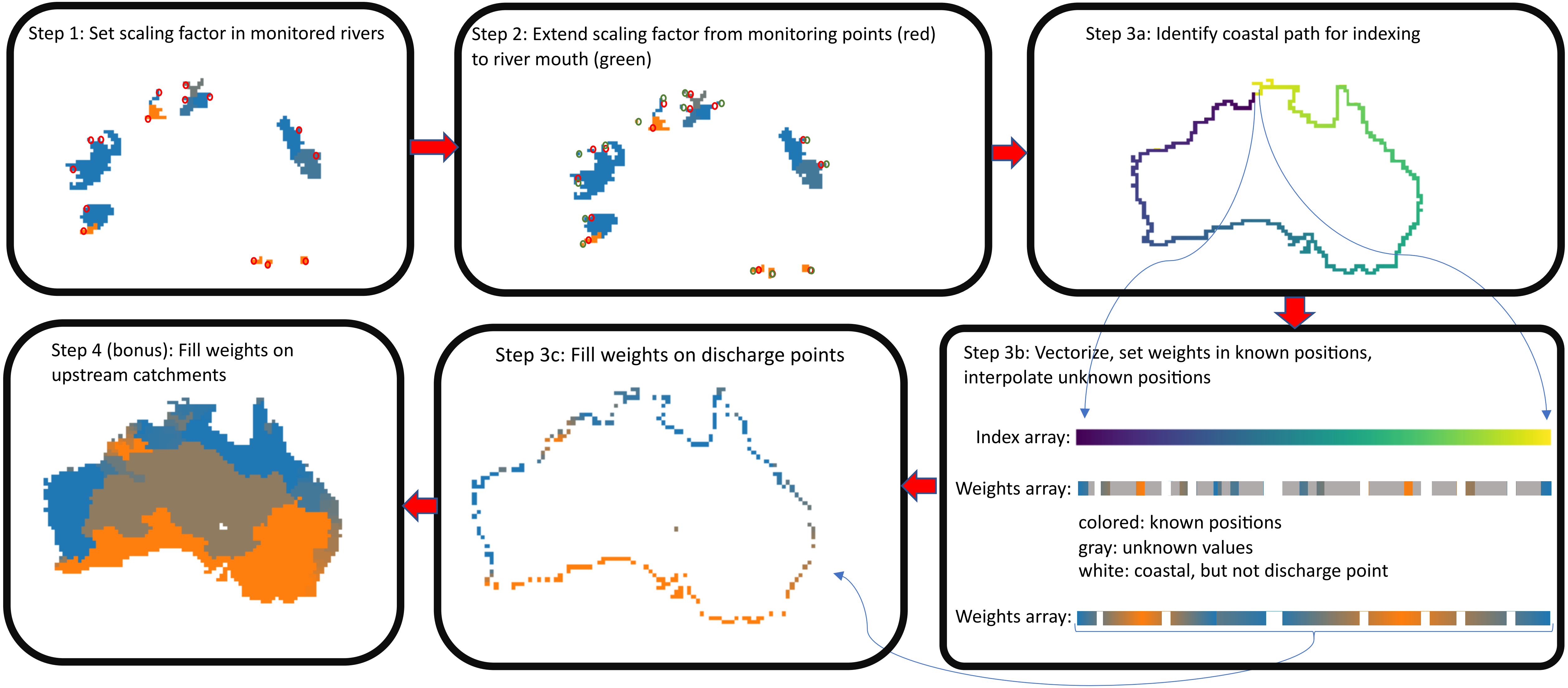


Methodology:

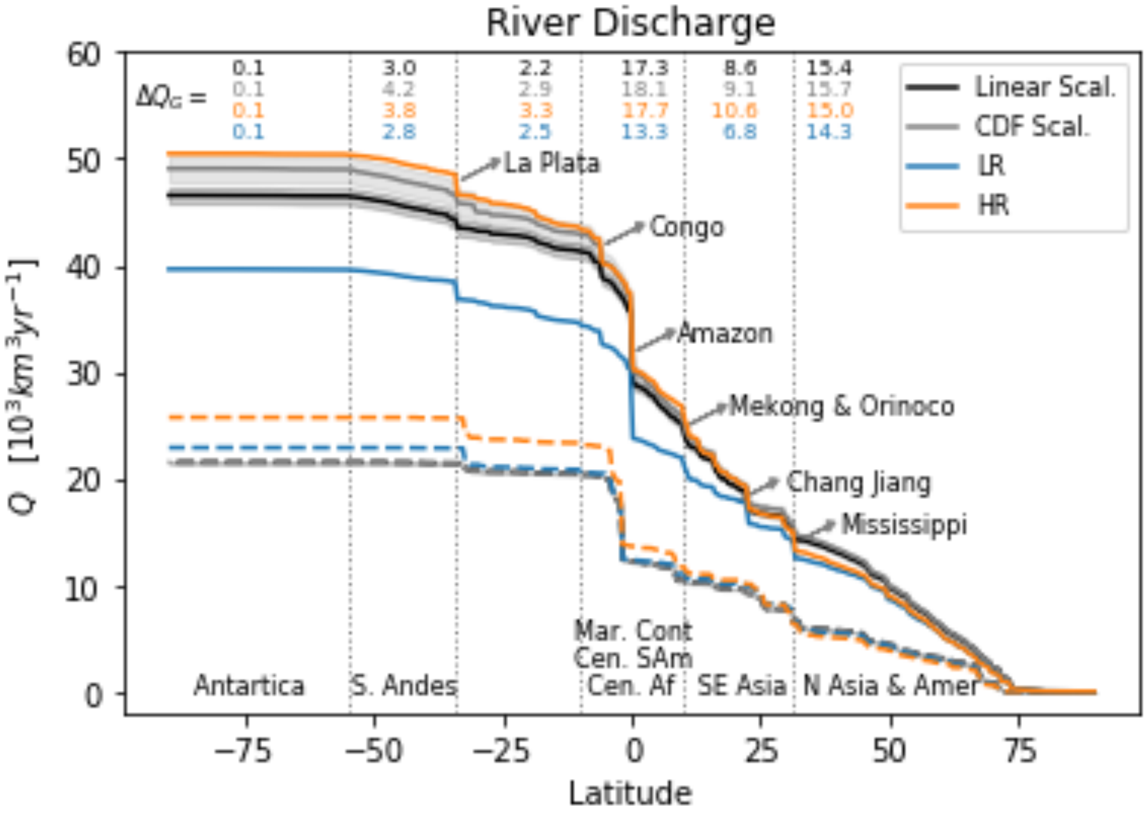
1. Run a river routing model forced by runoff at LR and HR to simulate the river discharge.
2. Estimate the bias for simulated time-series in 344 sites with observations.
3. Extrapolate the bias correction from inland monitored points to the river mouth in the coast.
4. Estimate the bias correction of each coastal point by the interpolation along the coast of the already constrained coastal points.
5. Quantify the global discharge as the sum of all coastal point and lakes.

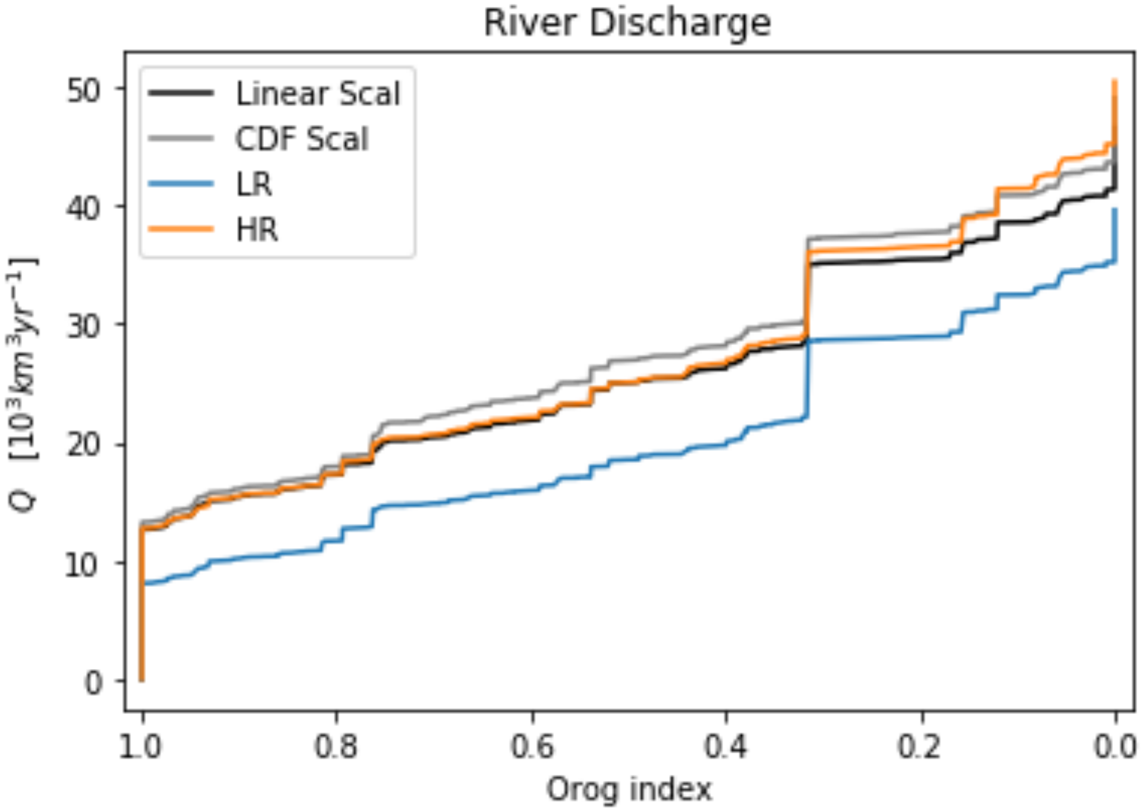
Extrapolating bias correction from monitored rivers to all discharge points (example in Australia)

We tested two different bias correction methods: linear scaling and CDF scaling.
The example shows how the linear scaling factor is extrapolated to the coast and extended along it.



Preliminary results:



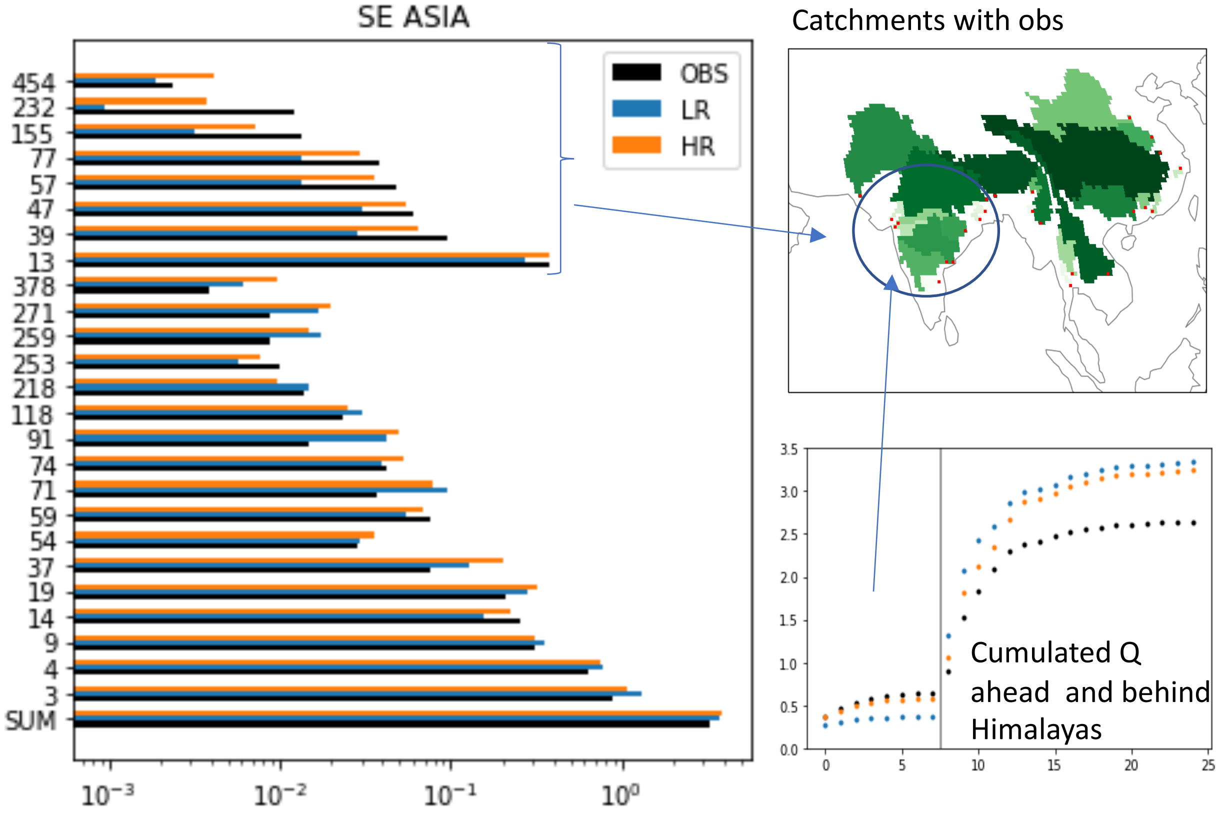


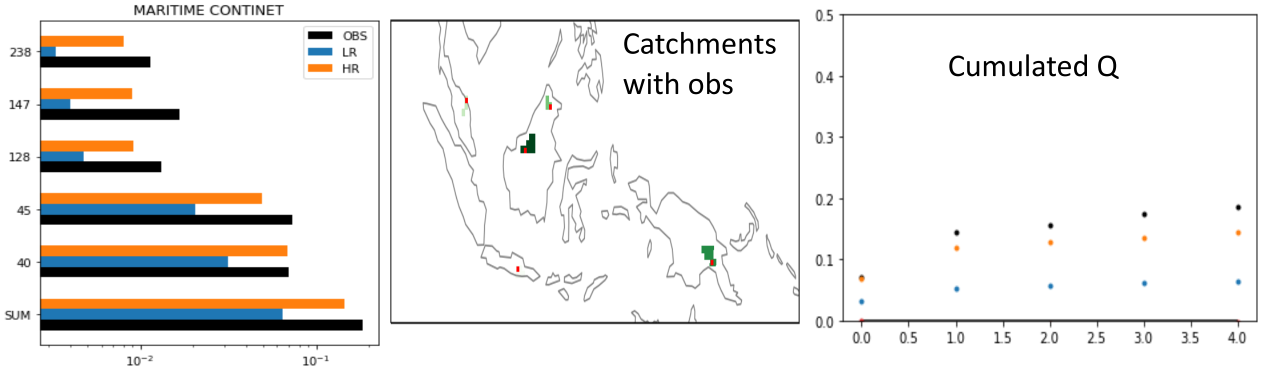
- Our estimate of global Q is 46.6 ± 0.7 using linear scaling and $49.0 \pm 1.2\ [10^3 km^3 yr^{-1}]$ using CDF scaling.
- It suggests that the real global runoff is between the original LR and HR estimation (40 and 50 respectively), but closer to HR.
- LR underestimate runoff across all latitudes.
- HR performs very well in the north hemisphere, but it overestimates in Congo and La Plata.

- The orographic index is calculated as: $OI = \frac{Orog\_P}{Total\_P}$ for each catchment.
- The curves show that HR simulations significantly improves the simulation of catchments with very complex orography but increase the wet bias in catchments dominated by flat terrain.

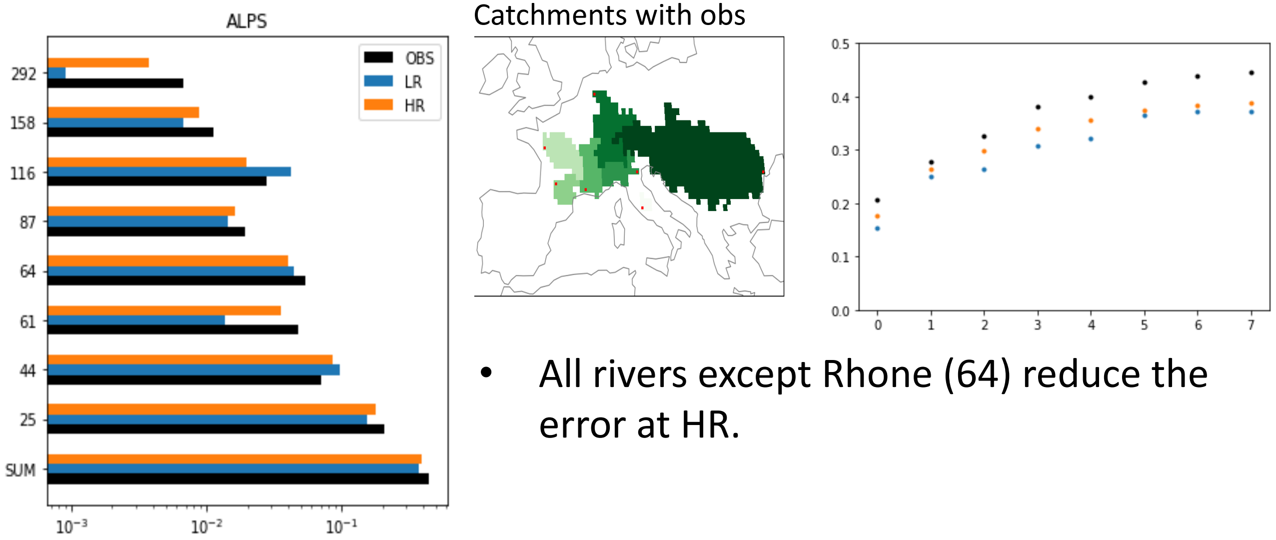
A zoom over some regions of high uncertainty

HR RAINS IN THE CORRECT PLACE!





- There is a general improvement of the simulated maritime continent water budget because of better resolved coastline and orography. It significantly improves the simulation of runoff.



- All rivers except Rhone (64) reduce the error at HR.

- In SE Asia LR performs better for the wrong reason. There is a compensation of negative biases ahead Himalayas with positive biases behind them.
- HR notably reduces the biases in Indian rivers, and slightly improves in Chinese rivers.

Concluding remarks

- The increase of models' resolution increase the orographic precipitation due to a better definition of orographic features. It leads to higher positive biases when compare with most reanalysis products except with Stephens (2012), who suggests that the lack of in-situ observations over mountains produce an underestimation of orographic precipitation in reanalysis products.

- River discharge observations are suitable to constraint precipitation at catchment scale given that: 1) it is an integrator of the water balance in the catchment, and 2) the extra precipitation at HR ends mostly in rivers as it occurs over mountains where horizontal surface fluxes prevail over vertical fluxes.

- Our estimate of global discharge is 46.6 ± 0.7 using linear scaling and 49.0 ± 1.2 $[10^3 km^3 yr^{-1}]$ using CDF scaling. It suggests that the real global runoff is between the original LR and HR estimation (40 and 50 respectively), but closer to HR.

- HR simulations significantly improves the simulation of catchments with very complex orography (e.g. Alps, Maritime Continent) but increase the wet bias in catchments dominated by flat terrain (e.g. Congo and La Plata).

- HR produces rain in the correct place leading to a more realistic spatial distribution of precipitation. It is evident in SE Asia, where HR notably improves the simulation of precipitation that falls ahead and behind Himalayas.

Acknowledgments

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