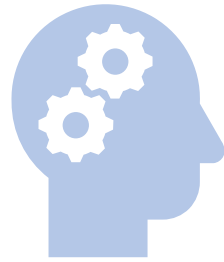


G-RUN ENSEMBLE:

A multi-forcing observation-based global runoff reanalysis using machine learning



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Correspondence: gionata.ghiggi@epfl.ch, lukas.gudmundsson@env.ethz.ch

¹Environmental Remote Sensing Laboratory, EPFL, Lausanne, Switzerland

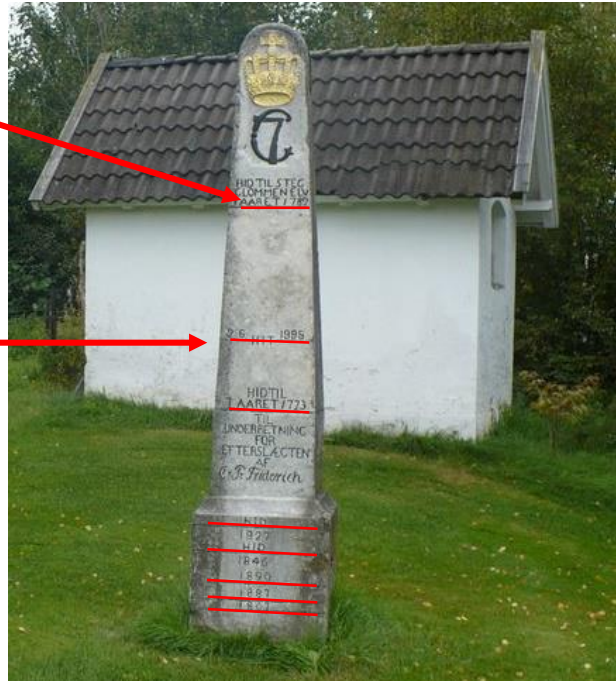
²Institute of Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

³Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA, USA

⁴Department of Geography, University of Zurich, Zurich, Switzerland

Overcoming sparse in situ observations

Local Observations



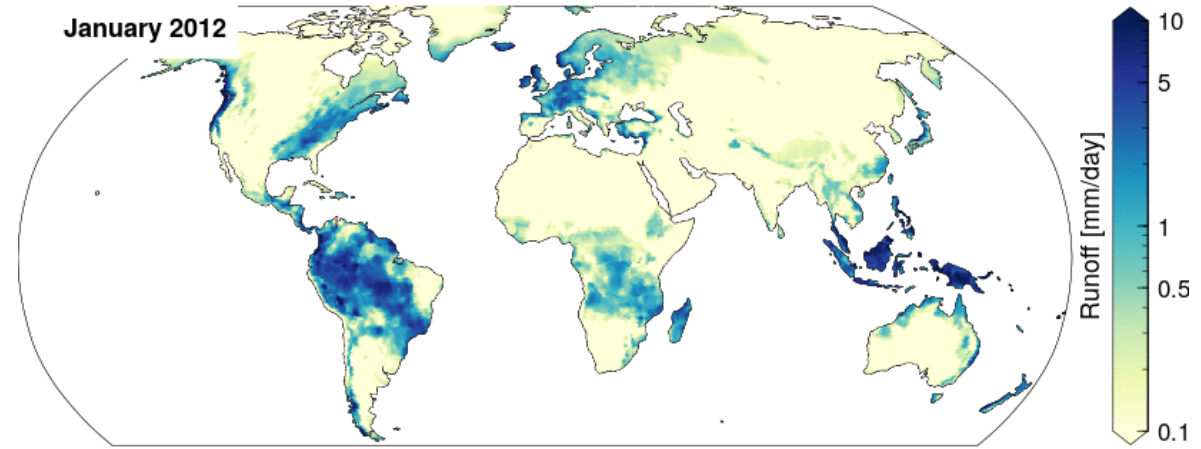
1789

1995

How?

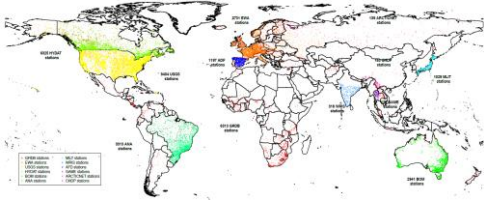


Global Estimates



Methodology

River discharge data^{1,2}



Assembled from public available data sources.

Atmospheric forcing: gridded time series of Precipitation & Temperature

Well established products available through atmospheric and climate research.

$$Q_{s,t} = f\left(\tau_n(P_{s,t}), \tau_n(T_{s,t})\right)$$

Unknown function

Random Forests are used for estimation.
Other machine learning algorithms have similar performance.

Time lag operator

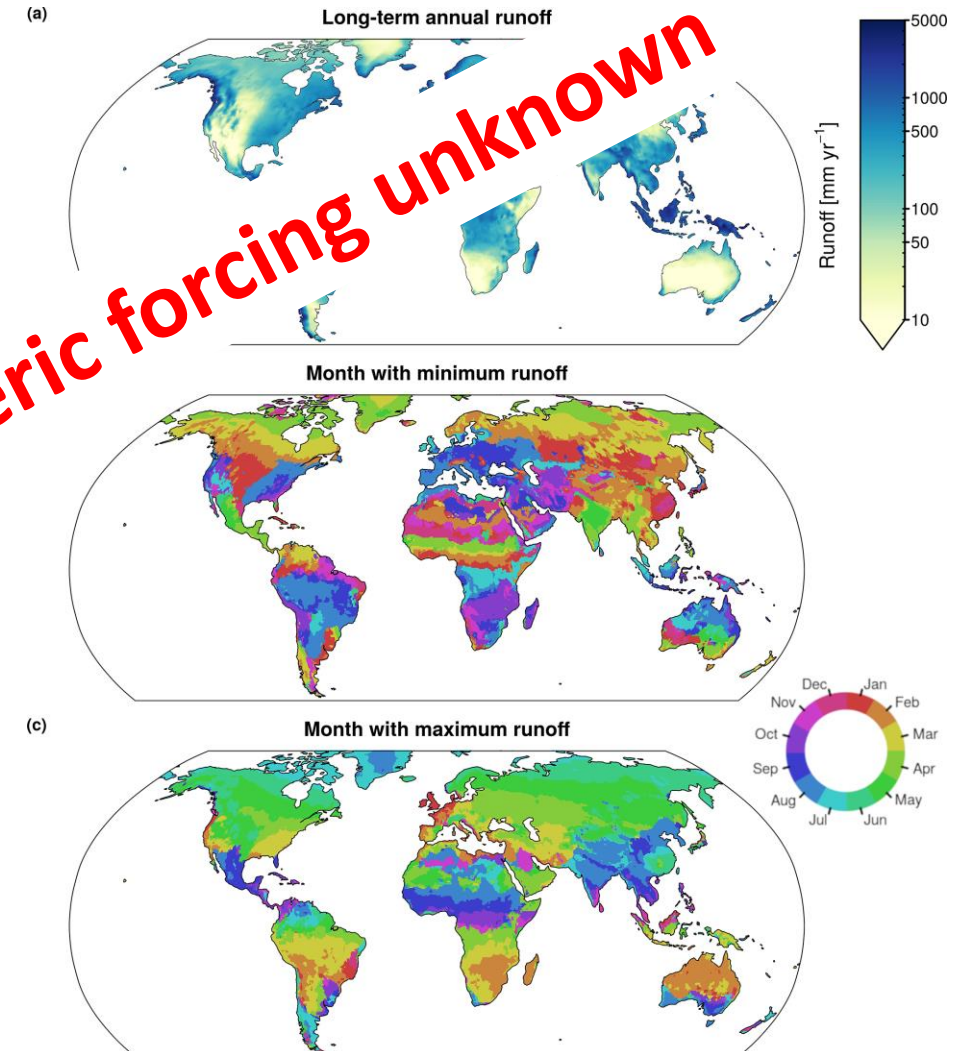
$$\tau_\lambda(X_{s,t}) = [X_{s,t}, X_{s,t-1}, \dots, X_{s,t-\lambda}]$$

Similar to approaches for phase space reconstruction of non-linear dynamics.

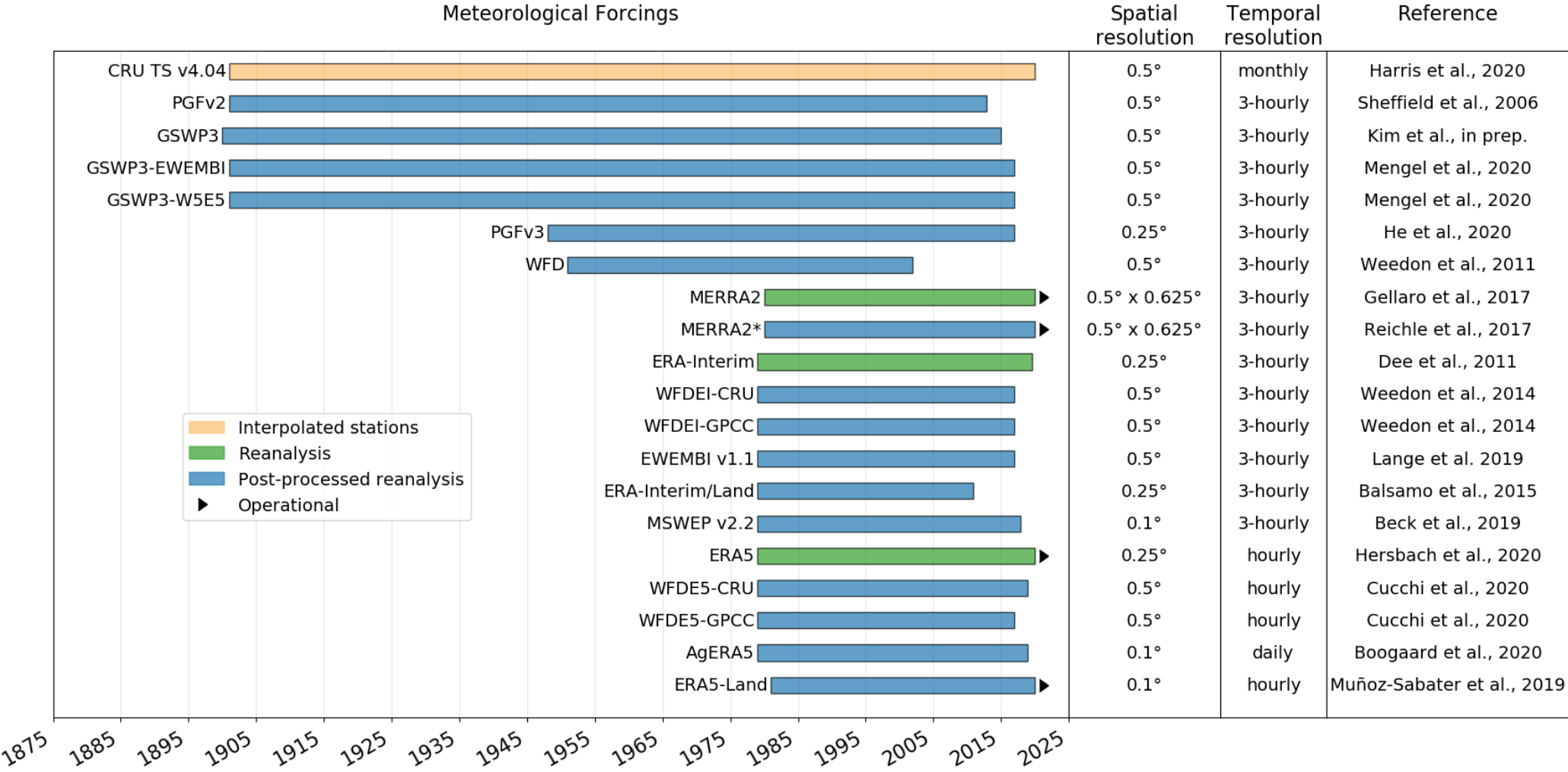
¹ [Do, Gudmundsson et al., Earth Syst. Sci. Data., 2018.](#)

² [Gudmundsson et al., Earth Syst. Sci. Data., 2018.](#)

Previous work: G-RUN – A runoff climatology



An ensemble of atmospheric forcing data



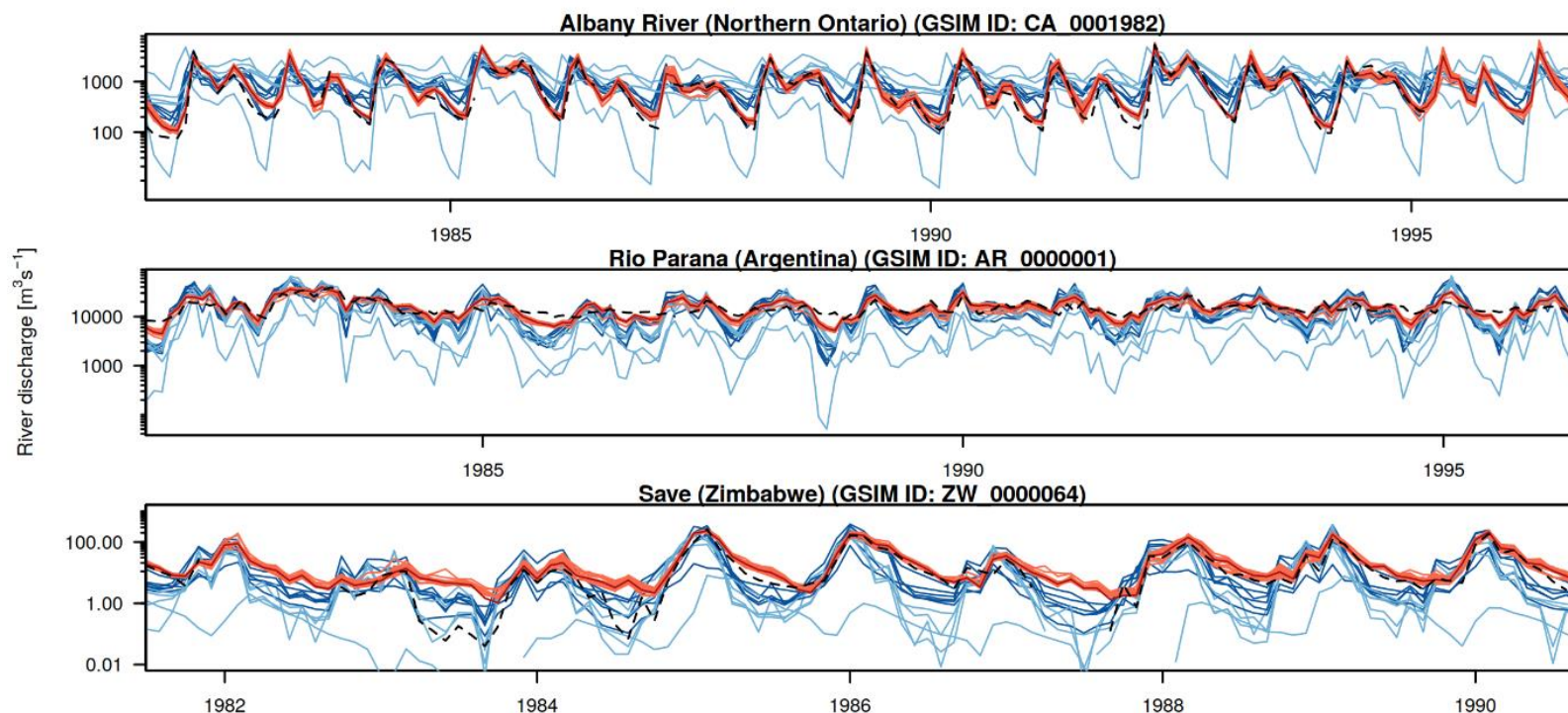
Benchmarking using river basins not used for calibration



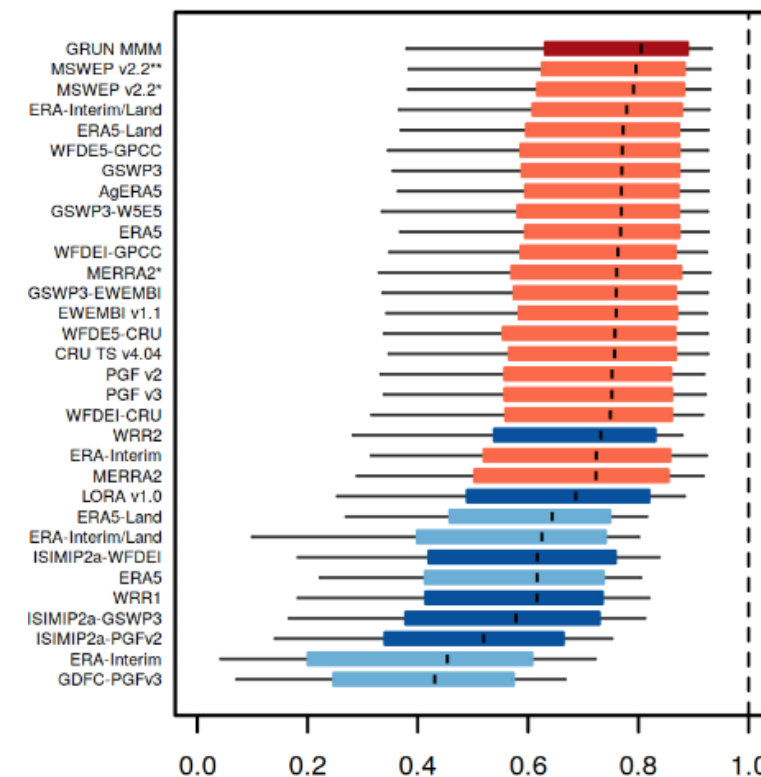
[Click the buttons !](#)



Selected river basins

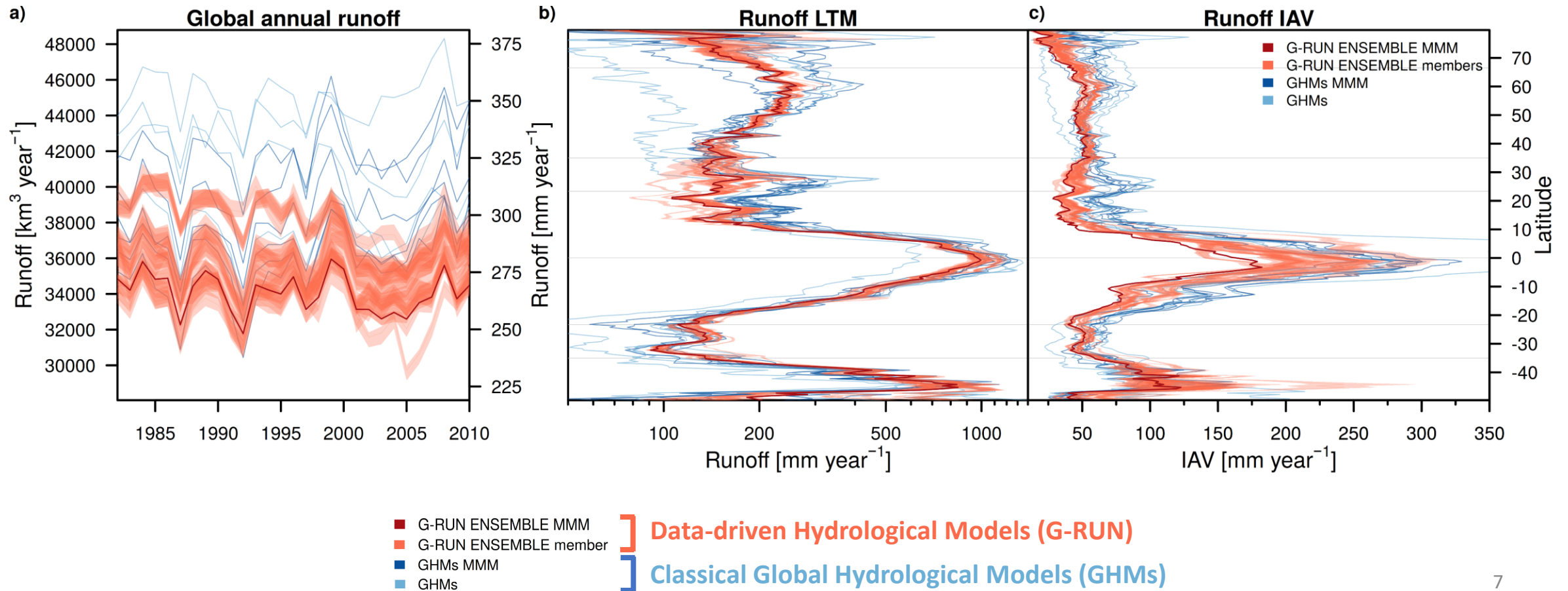


R² for 1205 large river basins

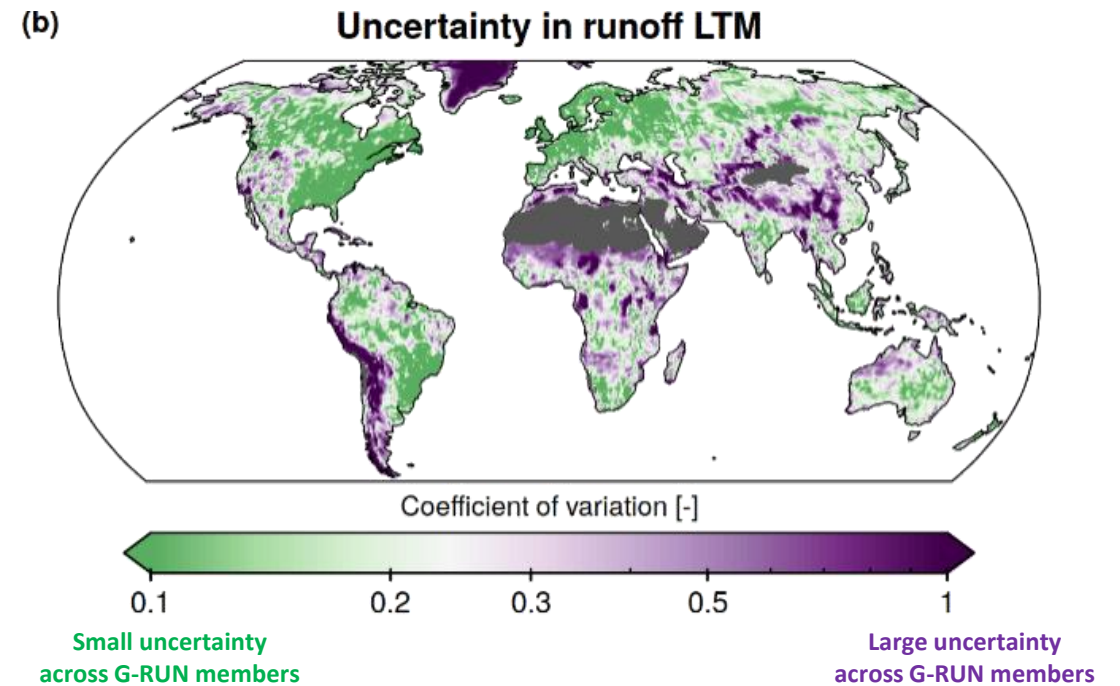
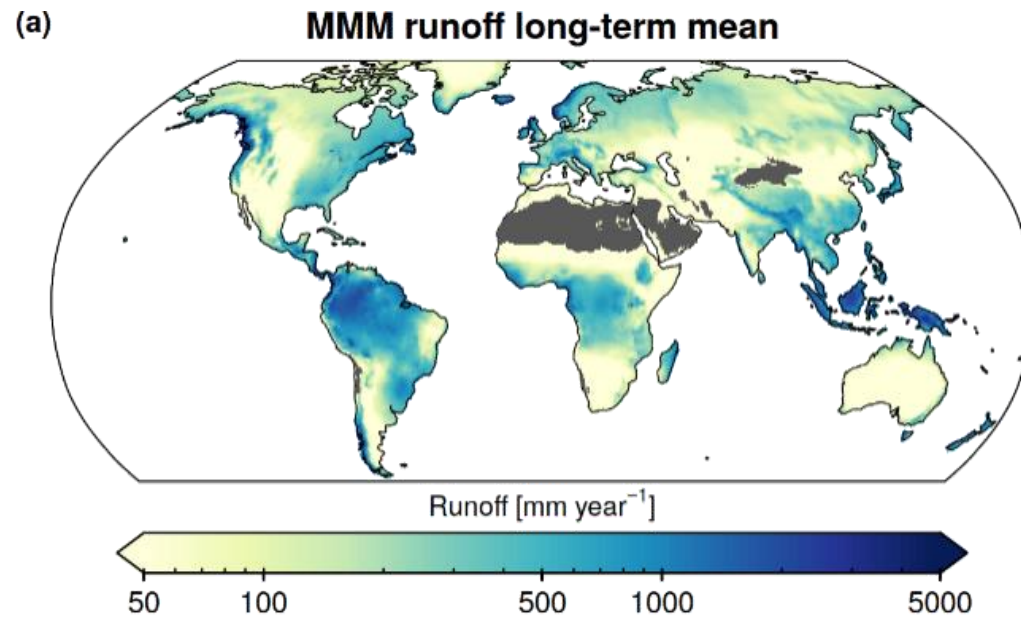


Global statistics - Runoff

- The spread between G-RUN ENSEMBLE estimates is much smaller than GHMs
- Orange shadings represent the uncertainty of each G-RUN ENSEMBLE member

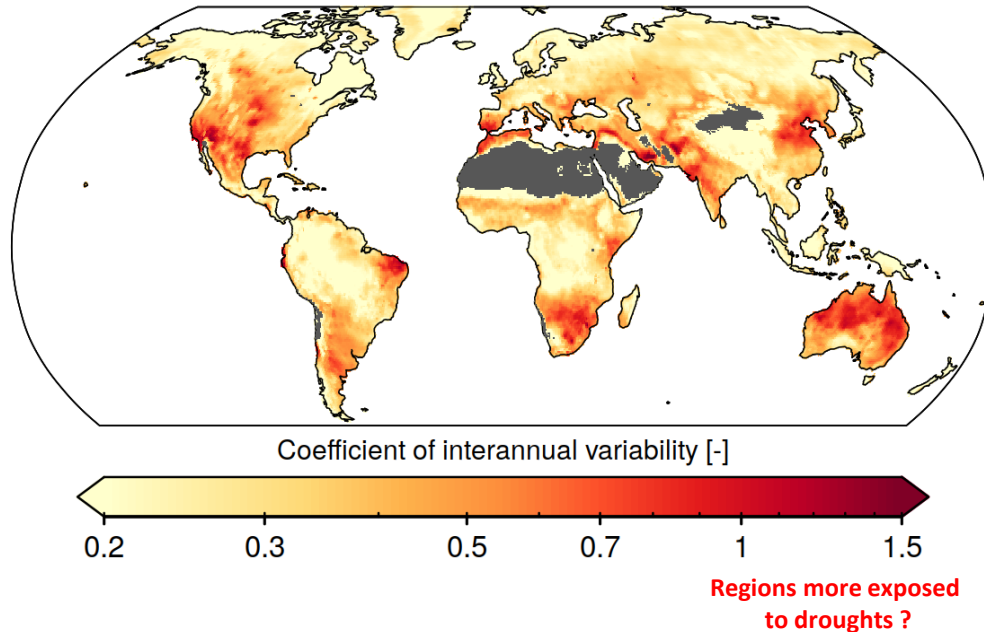


A first look at the new data – Long-term mean

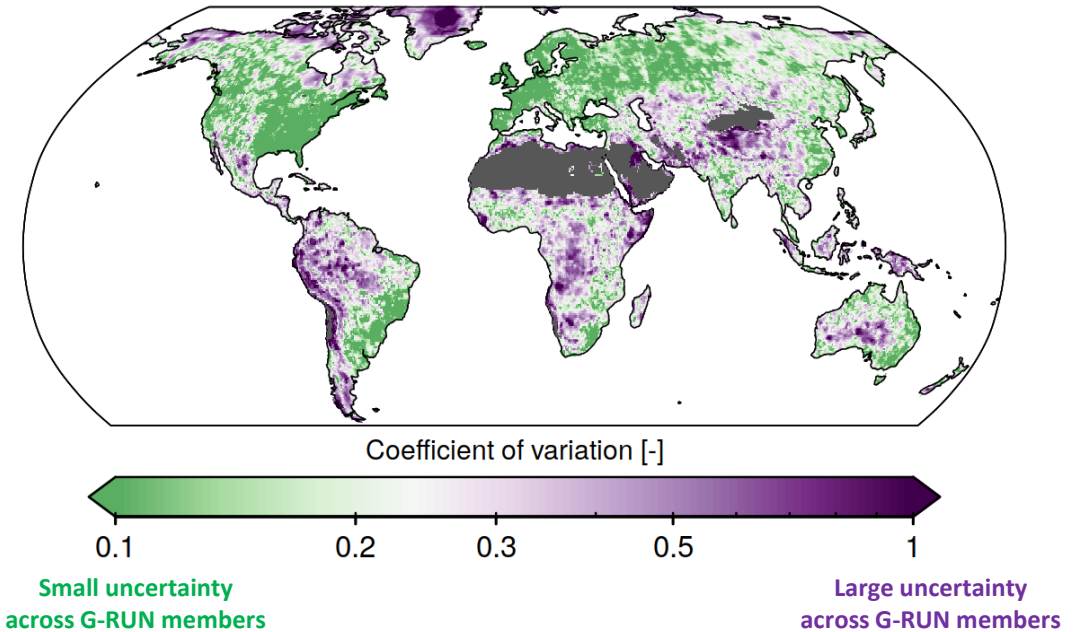


A first look at the new data – Interannual variability

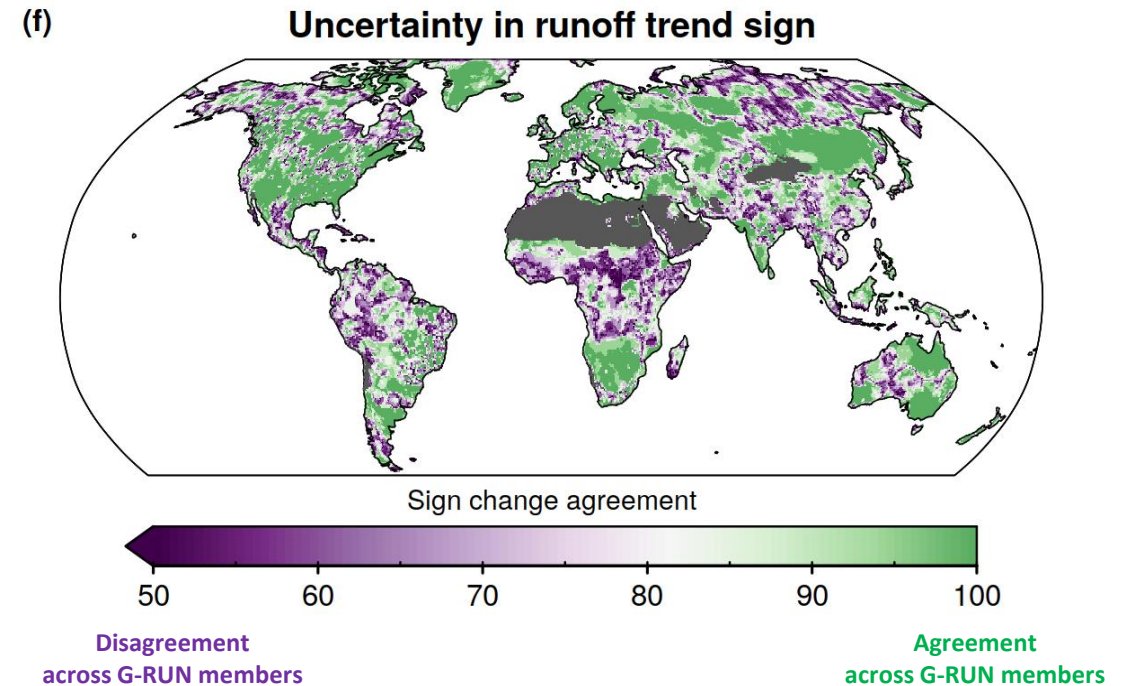
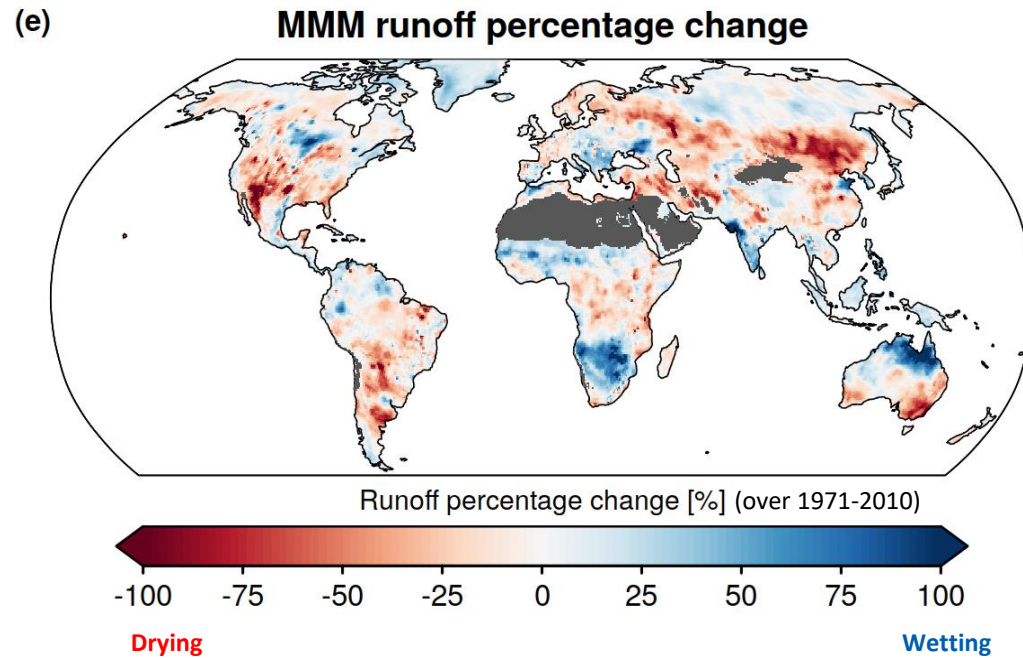
(c) **MMM runoff interannual variability**



(d) **Uncertainty in runoff IAV**



A first look at the new data – Trends



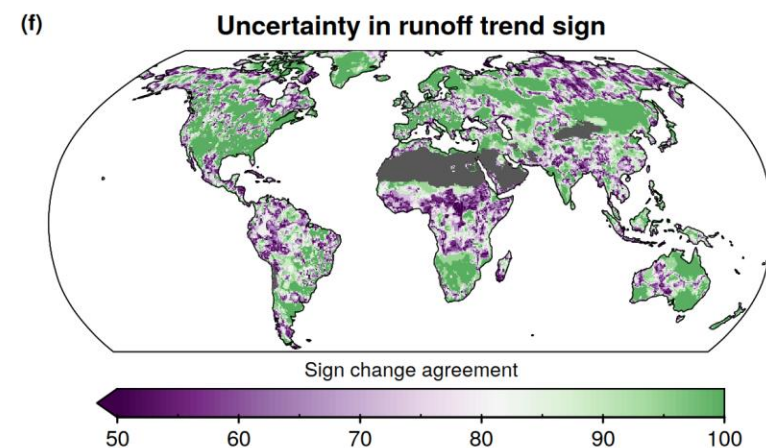
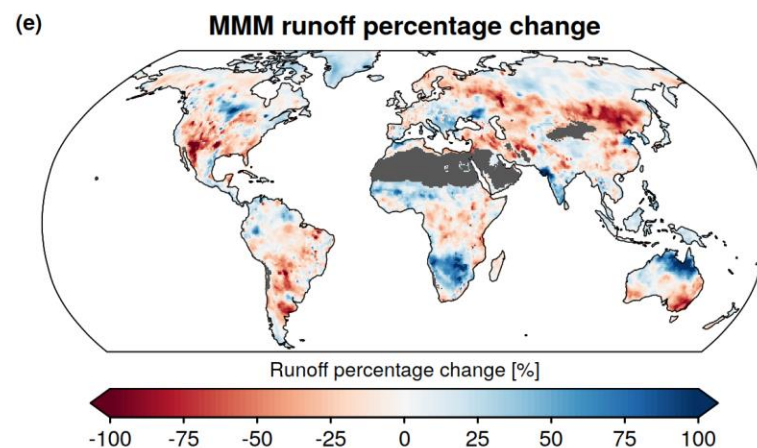
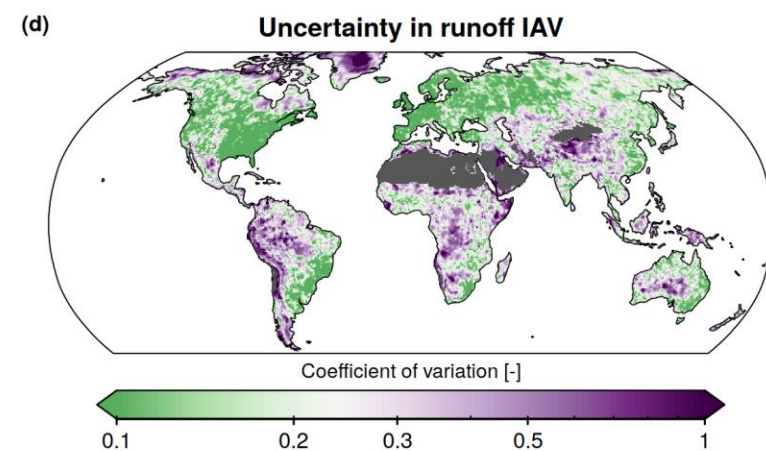
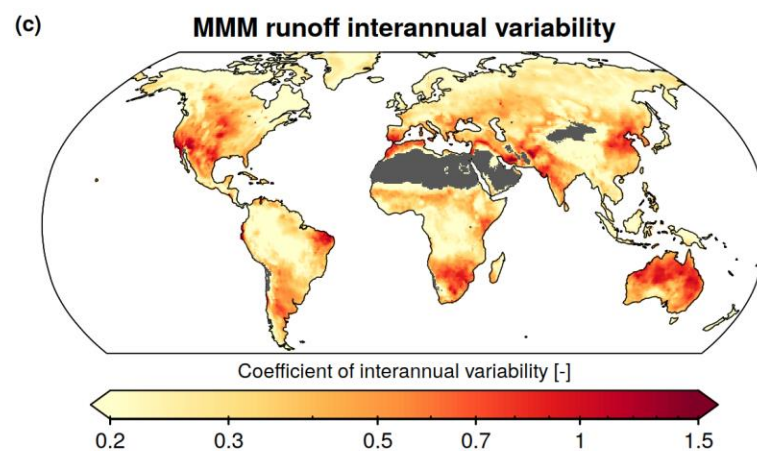
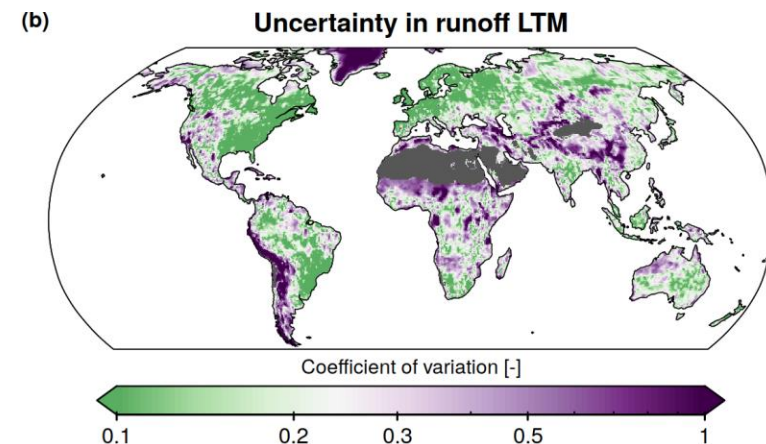
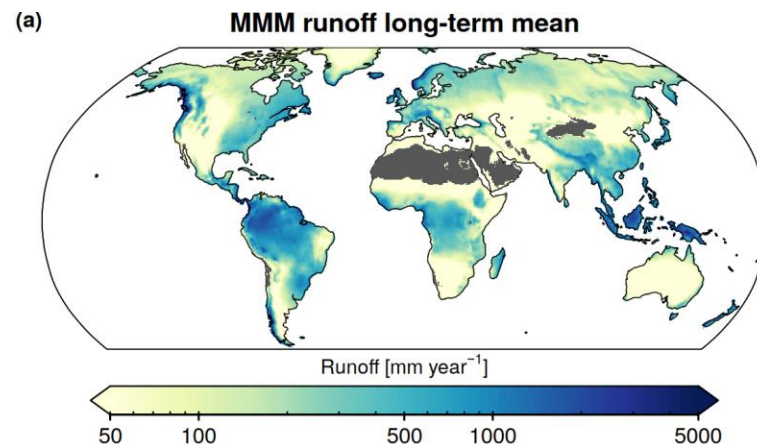
Runoff – G-RUN

Click [HERE](#) to display the GHMs runoff estimates

Click [HERE](#) to display precipitation



Find differences and correlations !



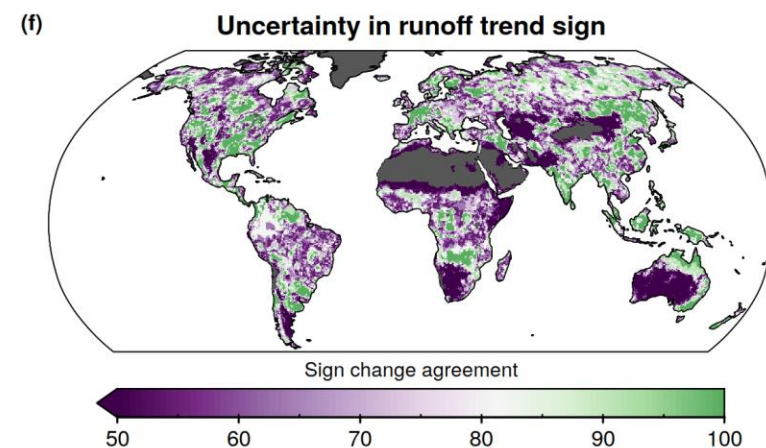
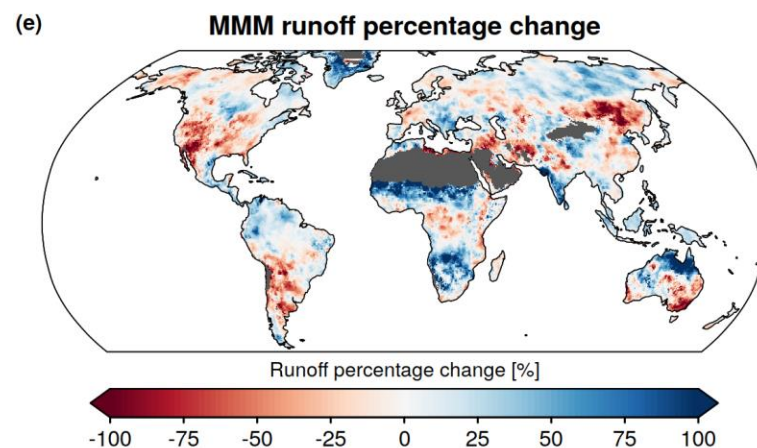
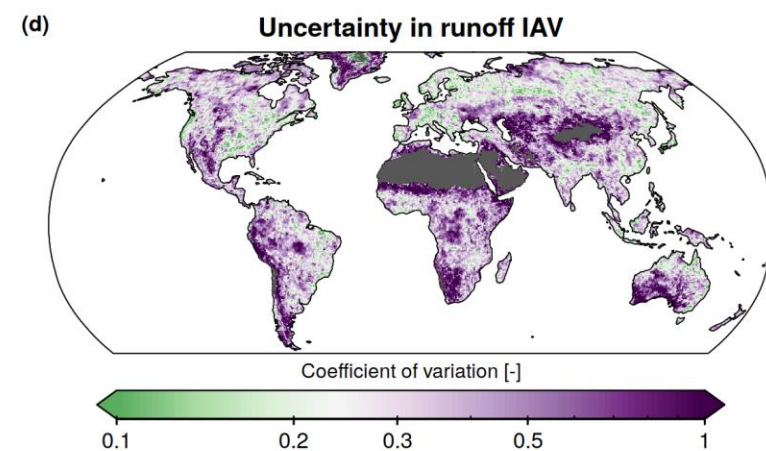
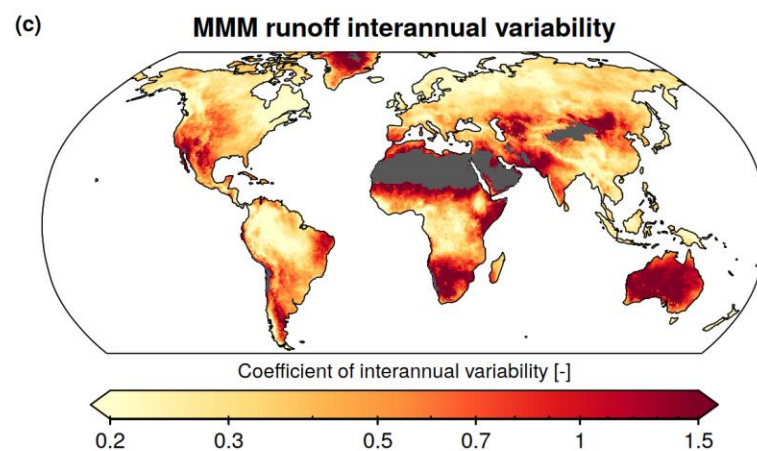
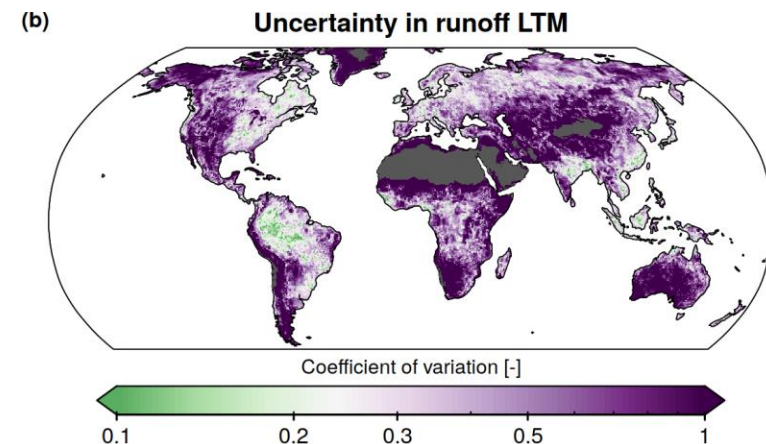
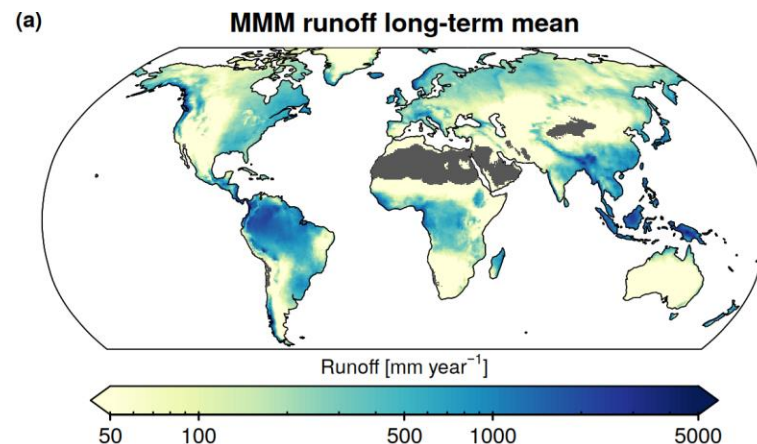
Runoff – GHMs

Click [HERE](#) to display the G-RUN runoff estimates

Click [HERE](#) to display precipitation



Find differences and correlations !



G-RUN – R²_{ANOM}

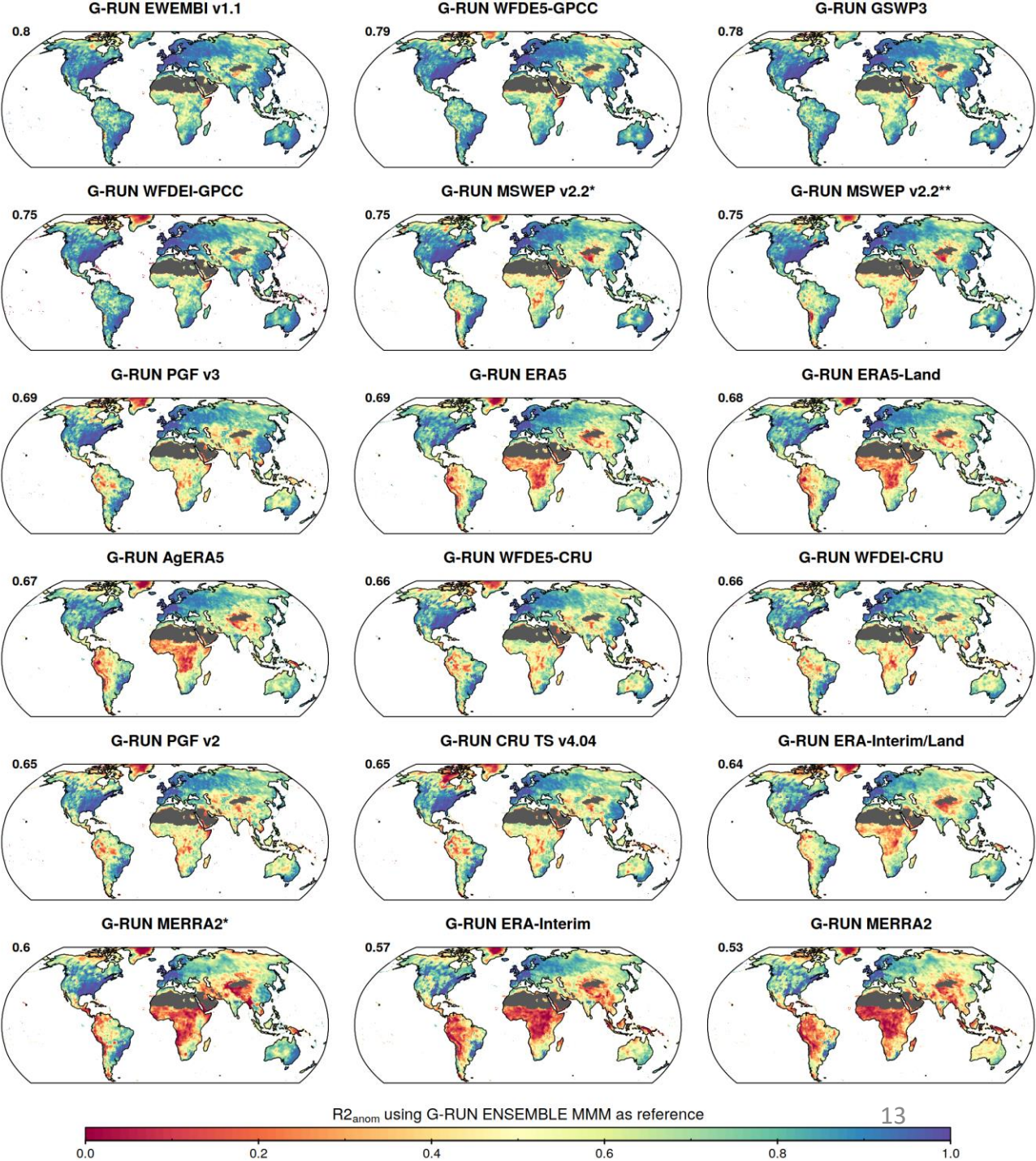
→ Differences across G-RUN ENSEMBLE members

BIAS

R²

R²_{ANOM}

G-RUN ENSEMBLE MMM
is used as reference



GHMs – R2

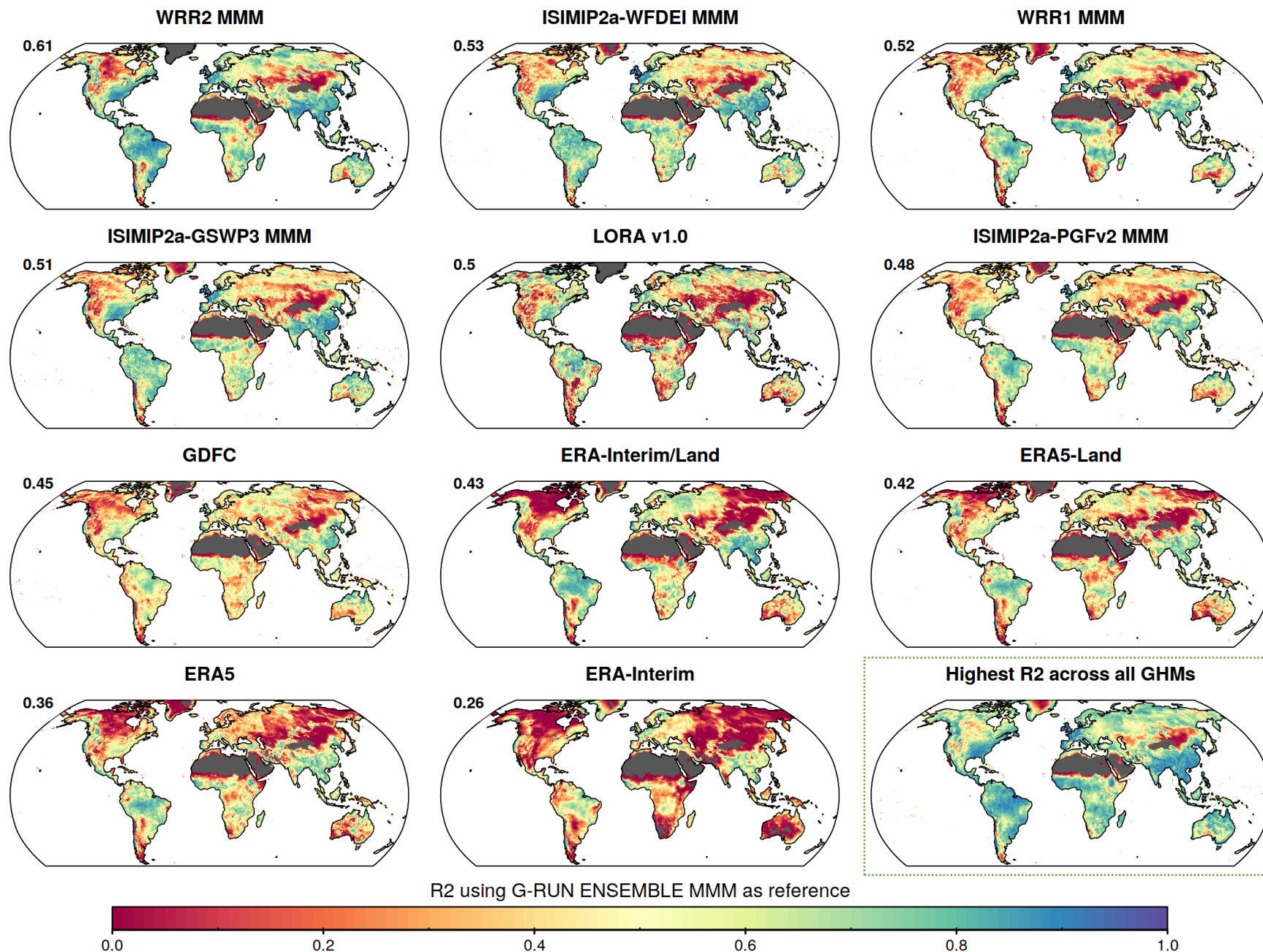
→ Differences across GHMs

BIAS

R^2

R^2_{ANOM}

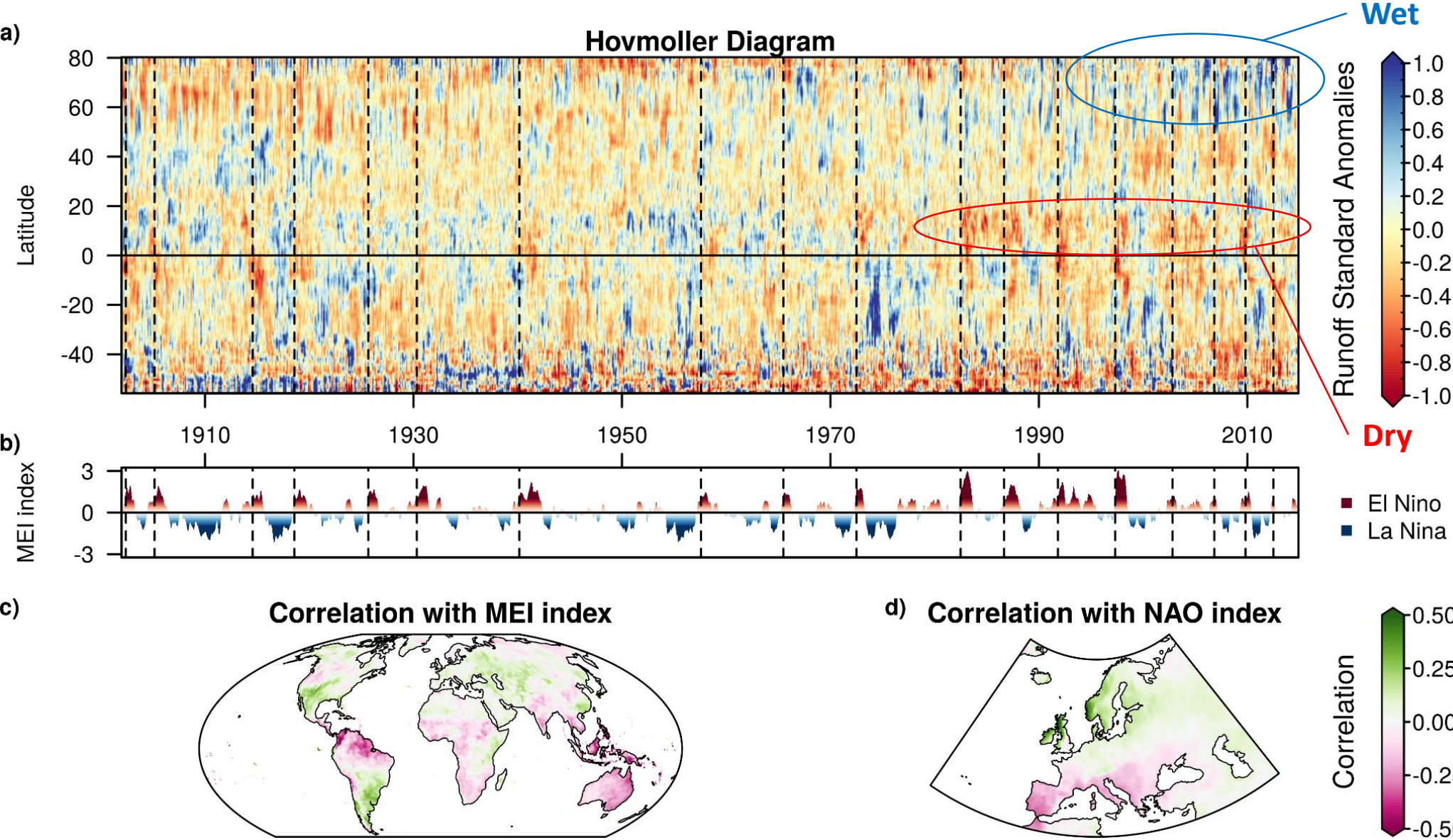
G-RUN ENSEMBLE MMM
is used as reference



The dynamics differ from G-RUN ENSEMBLE

The dynamics agree with G-RUN ENSEMBLE

Shed light on freshwater dynamics



Summing up G-RUN ENSEMBLE

- ✓ Data-driven runoff modelling at large scales
- ✓ Century-long global runoff reconstructions
- ✓ Performs on average better than classical GHMs
- ✓ Quality of runoff simulations depends on accuracy of forcing data
- ✓ GHMs are much more sensitive to bias in forcing data
- ✓ The multi-forcing nature of the ensemble helps to quantify uncertainties related to the quality of atmospheric data
- ✓ Allows for:
 - Robust and reliable water resources assessments
 - Evaluation, calibration and refinement of GHMs
 - Climate change attribution studies

Supplementary material

Model ability to predict at ungauged cells

Two cross-validation experiments:

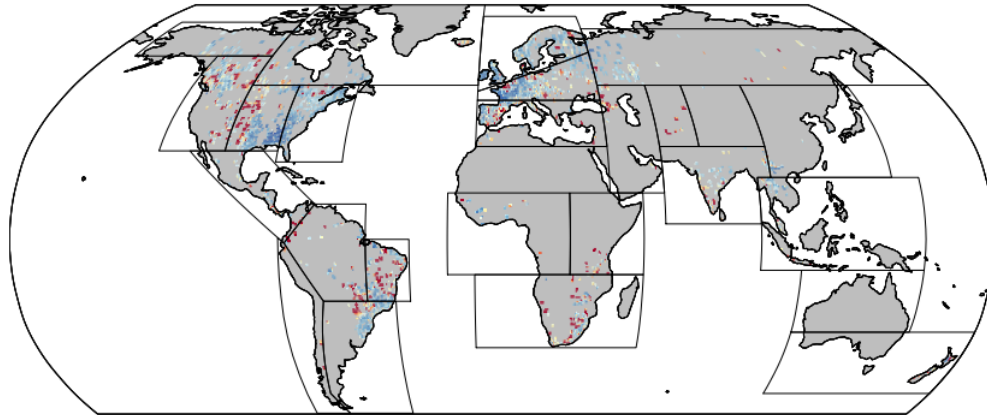
- **CV-SREX** omits observations over entire sub-continental SREX regions
- **CV-SPACE** omits randomly 10% of the grid cells



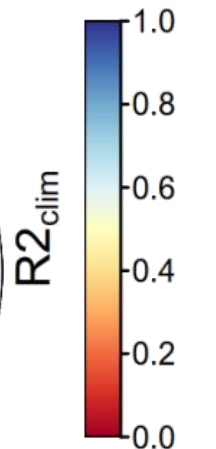
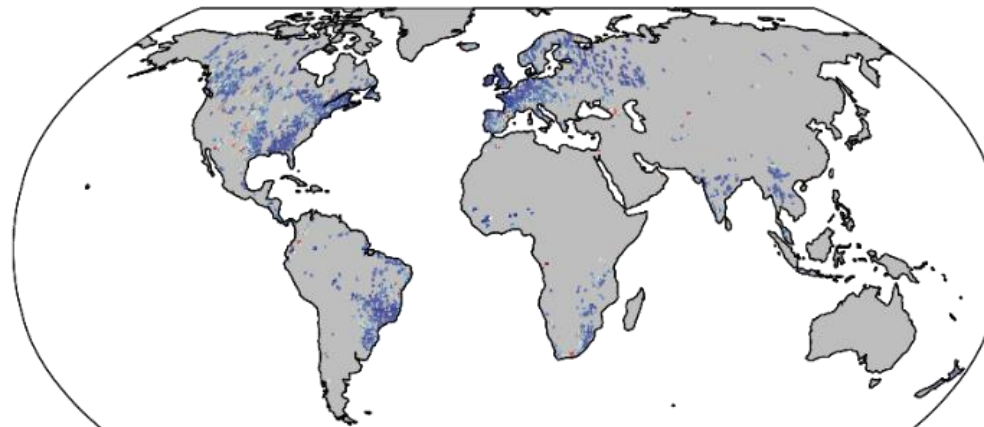
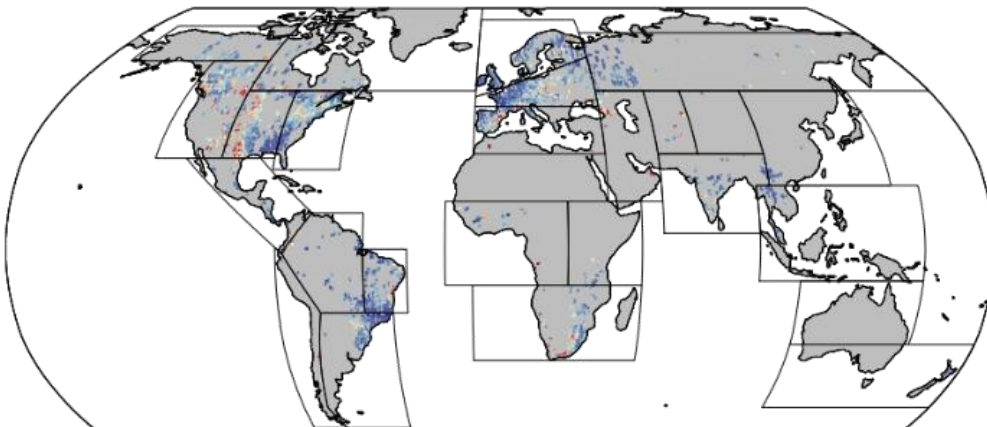
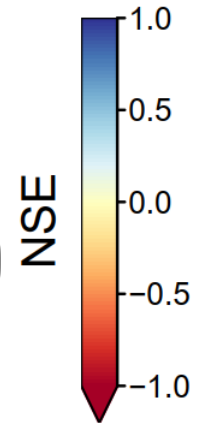
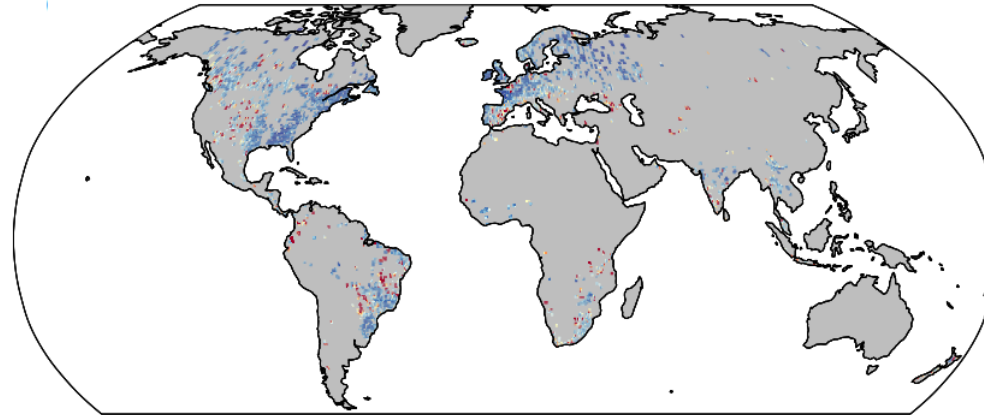
Test extrapolation ability

Proxy of G-RUN accuracy

CV - SREX

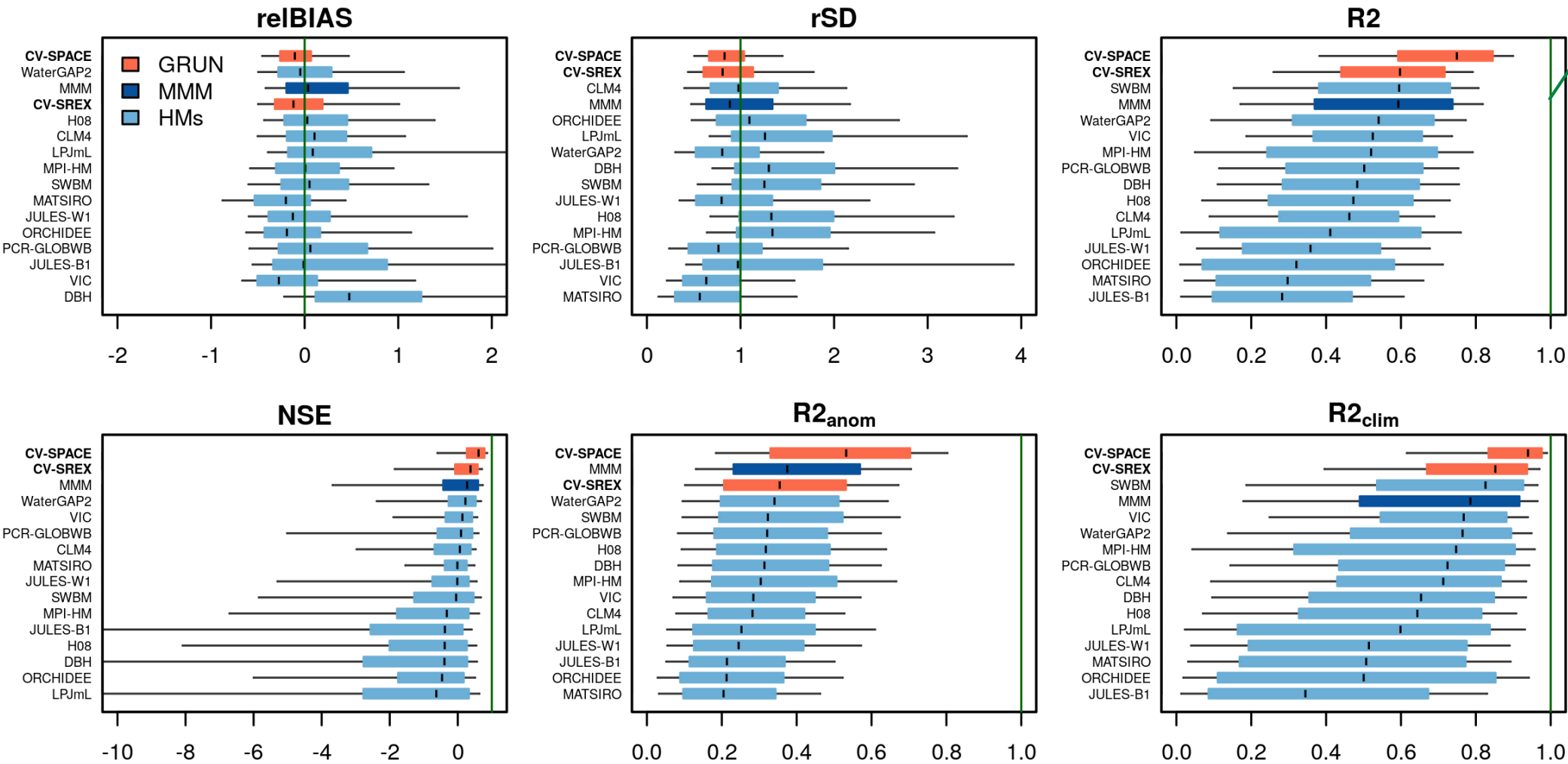


CV - SPACE



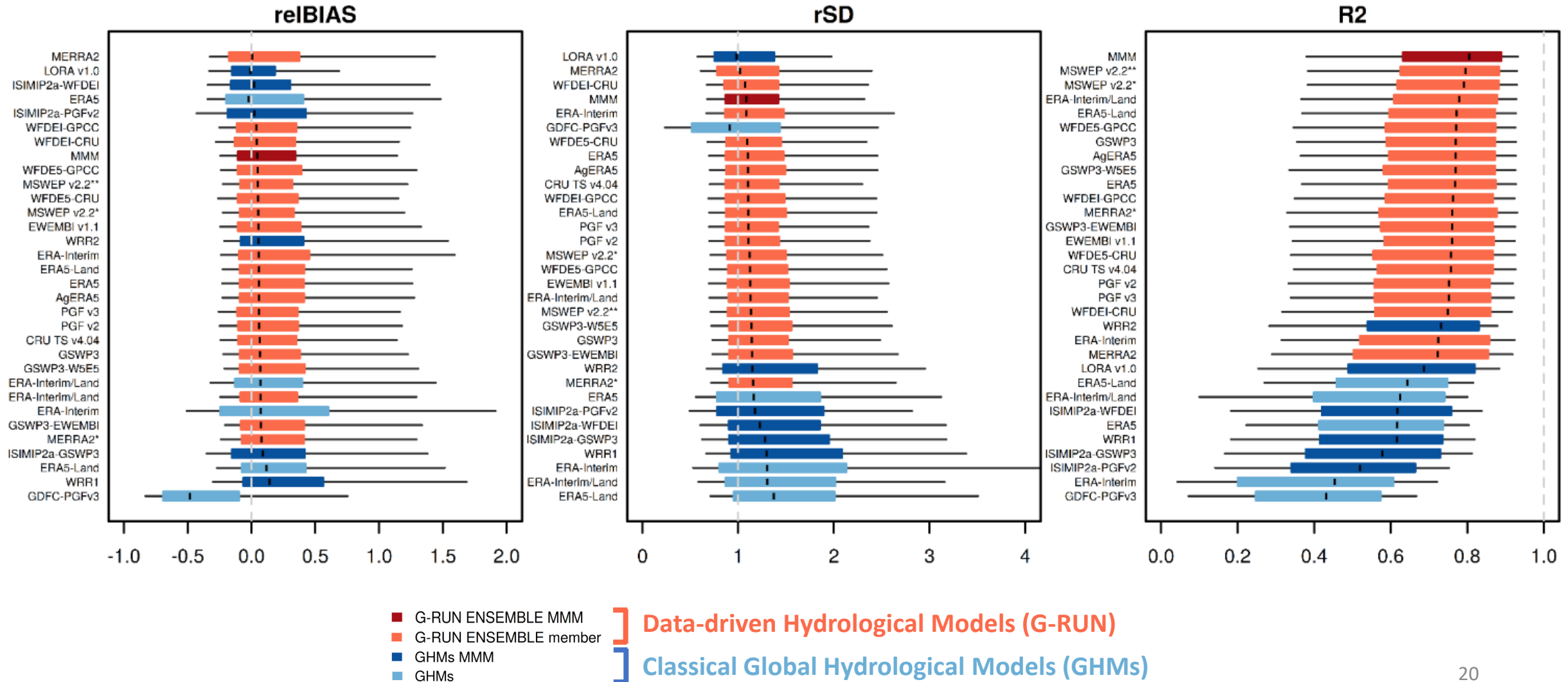
Same forcing (GSWP3) – Different GHMs

Optimal Skill



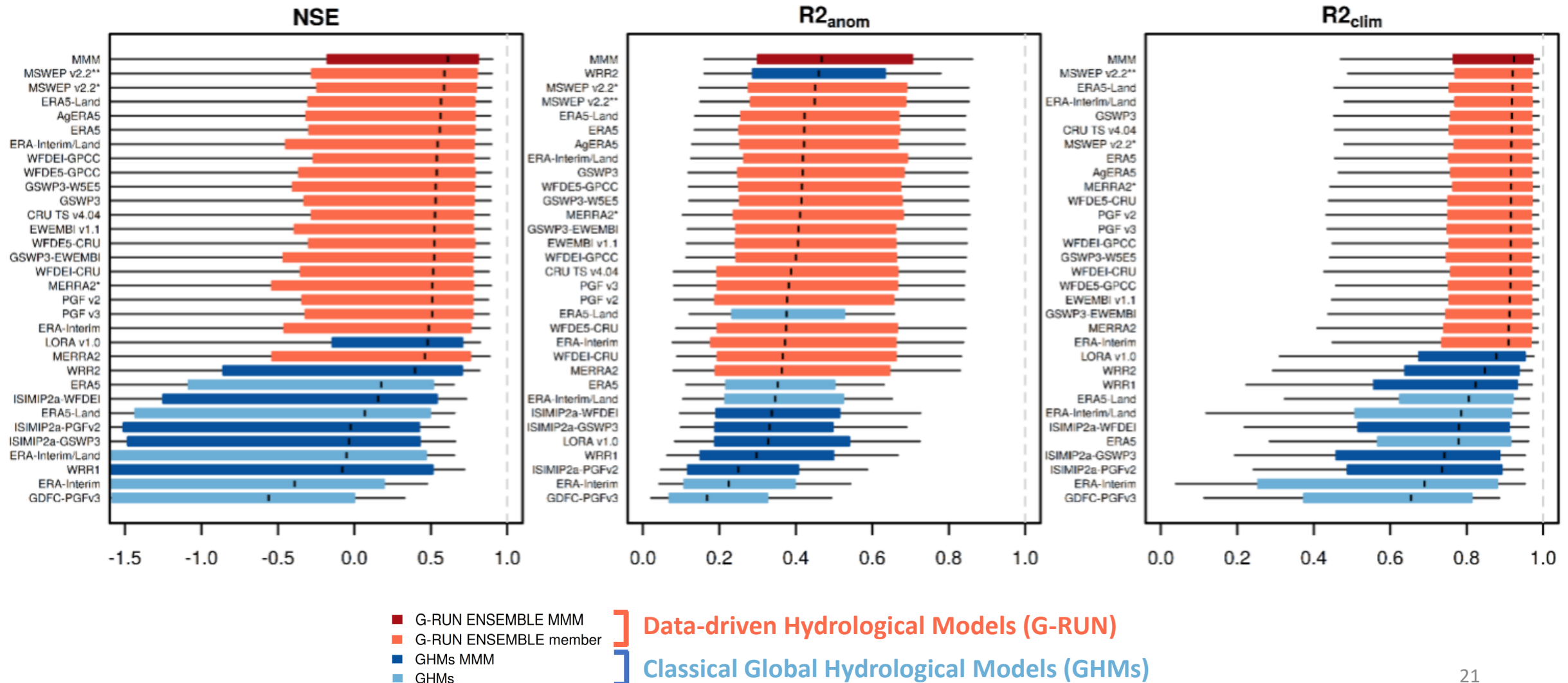
Benchmarking using river basins not used for calibration

BACK

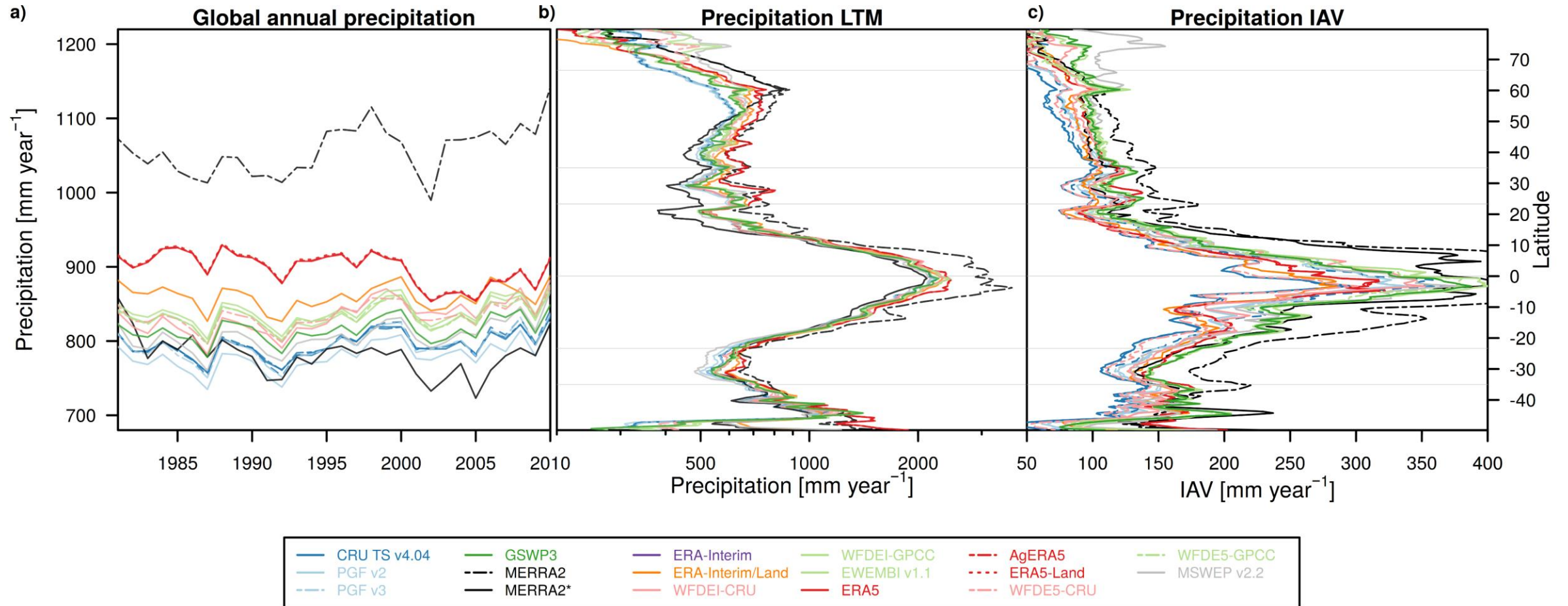


Benchmarking using river basins not used for calibration

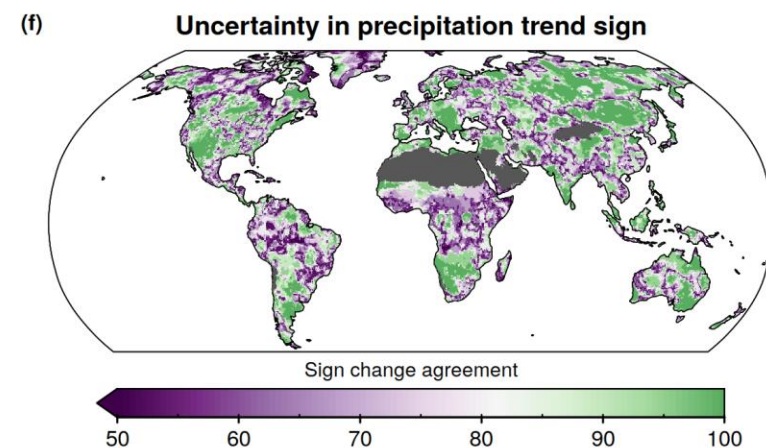
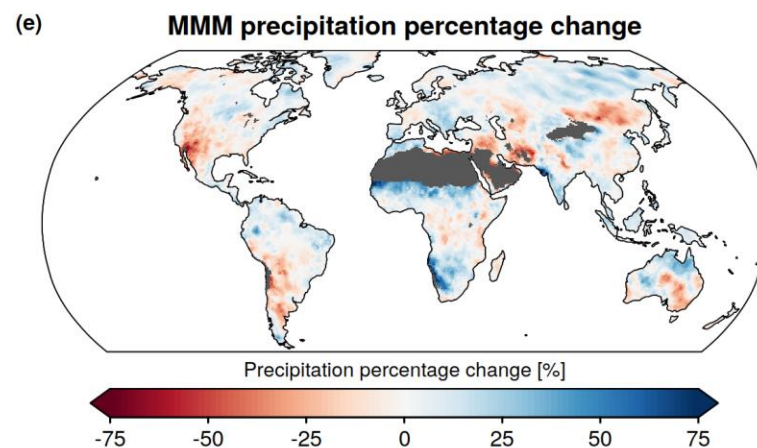
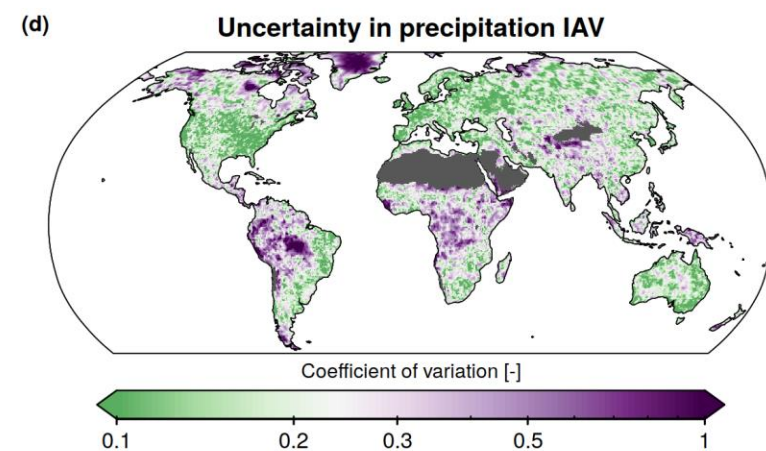
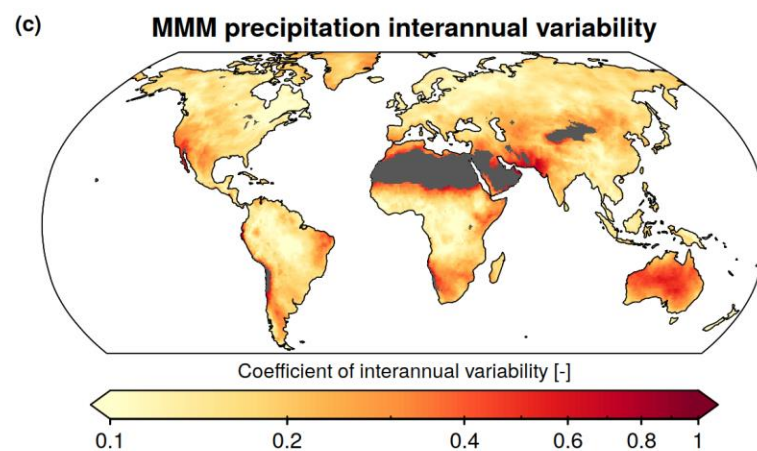
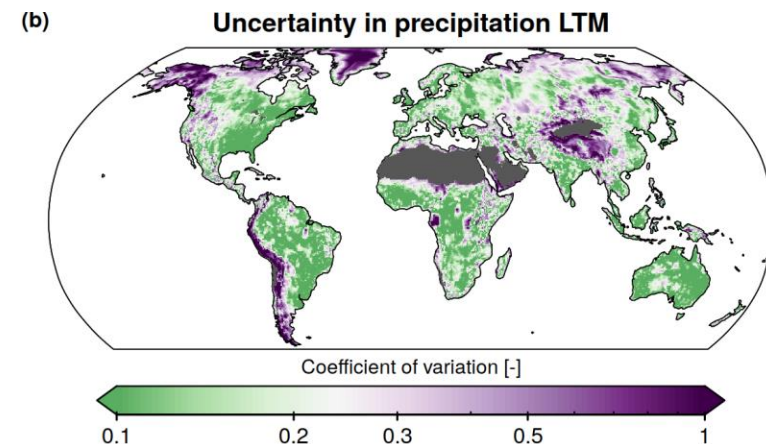
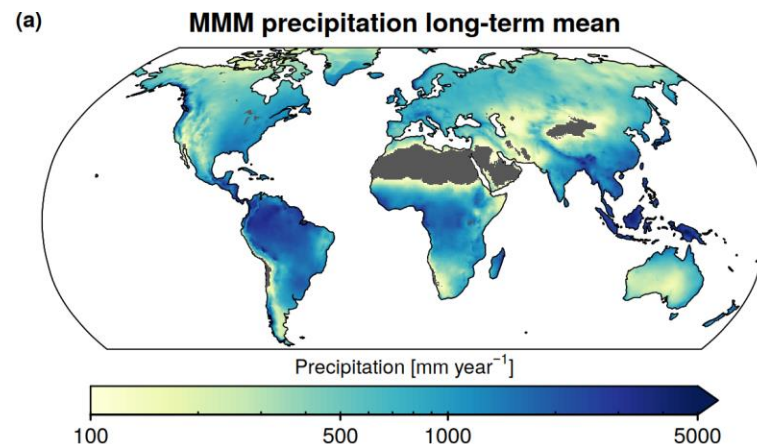
BACK



Global statistics - Precipitation



Precipitation

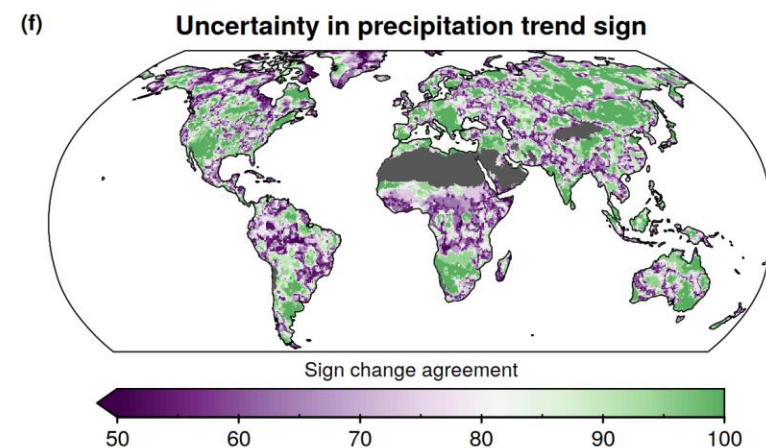
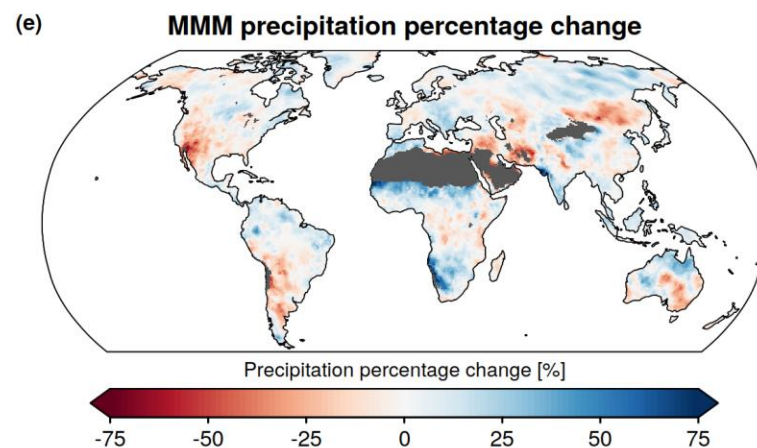
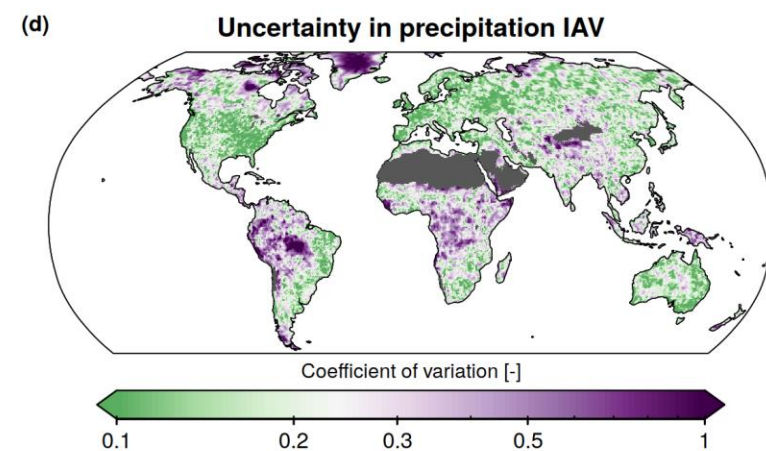
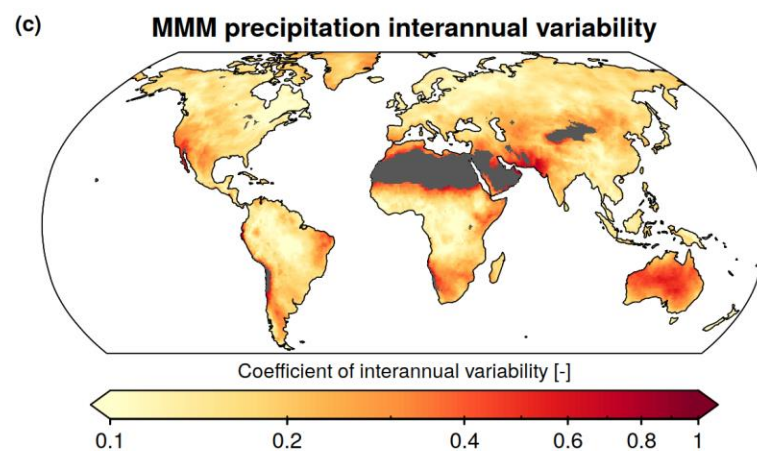
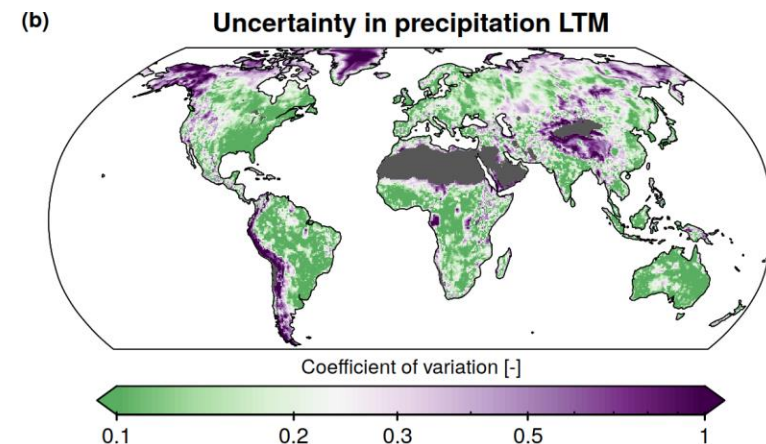
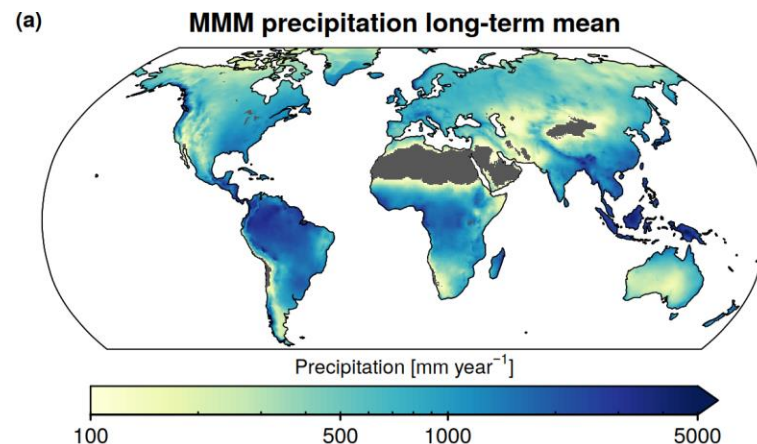


Click [HERE](#) to display G-RUN runoff



**Find differences
and correlations !**

Precipitation

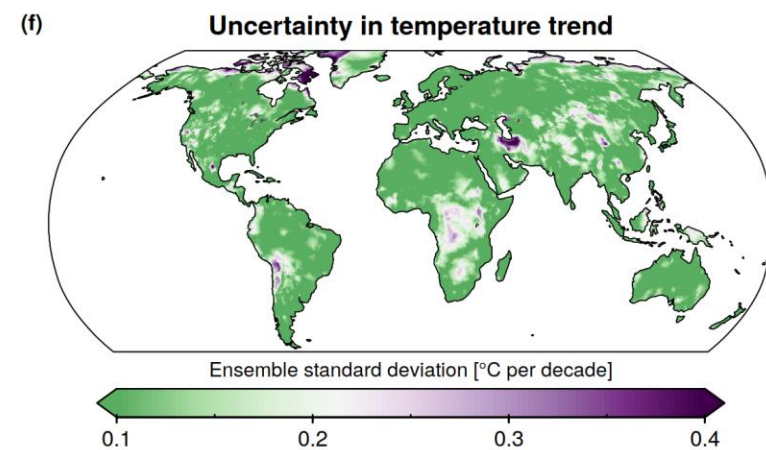
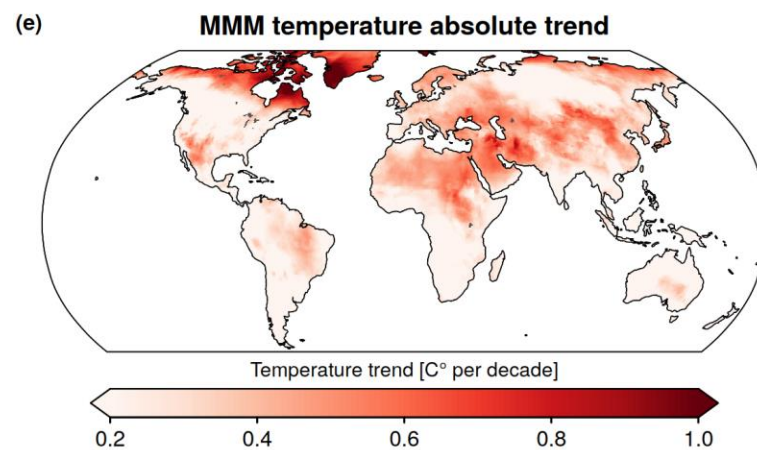
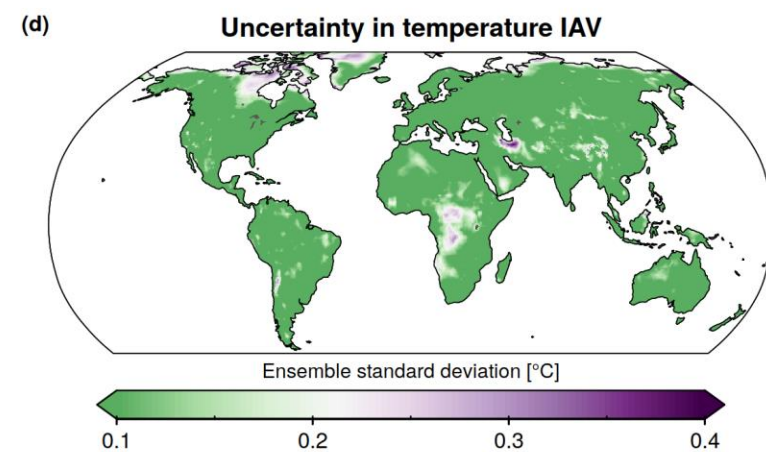
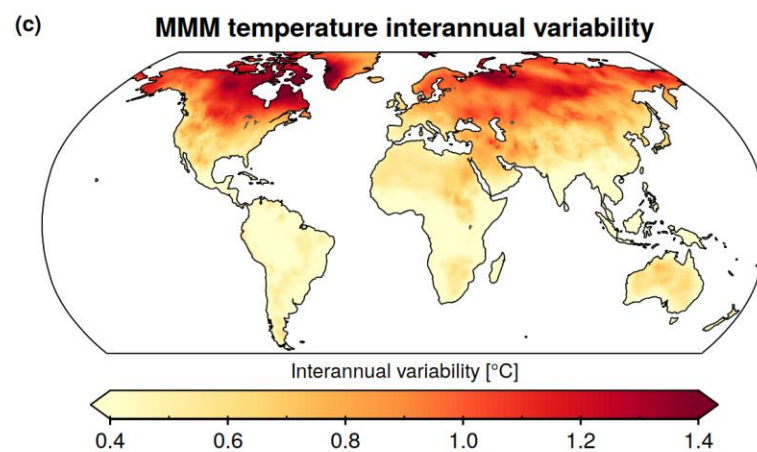
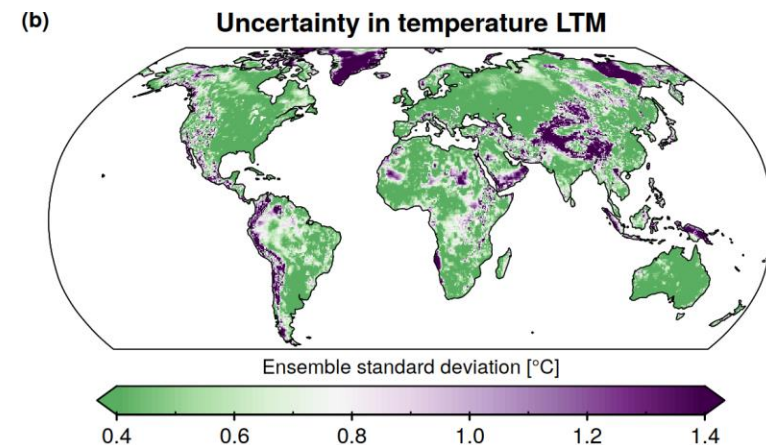
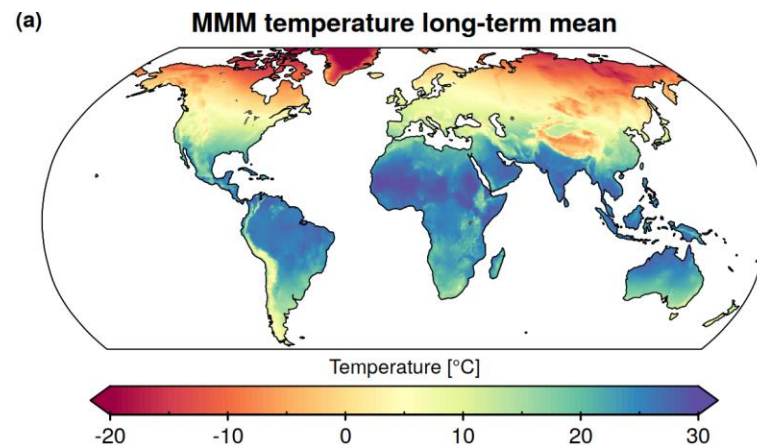


Click [HERE](#) to display GHMs runoff



**Find differences
and correlations !**

Temperature

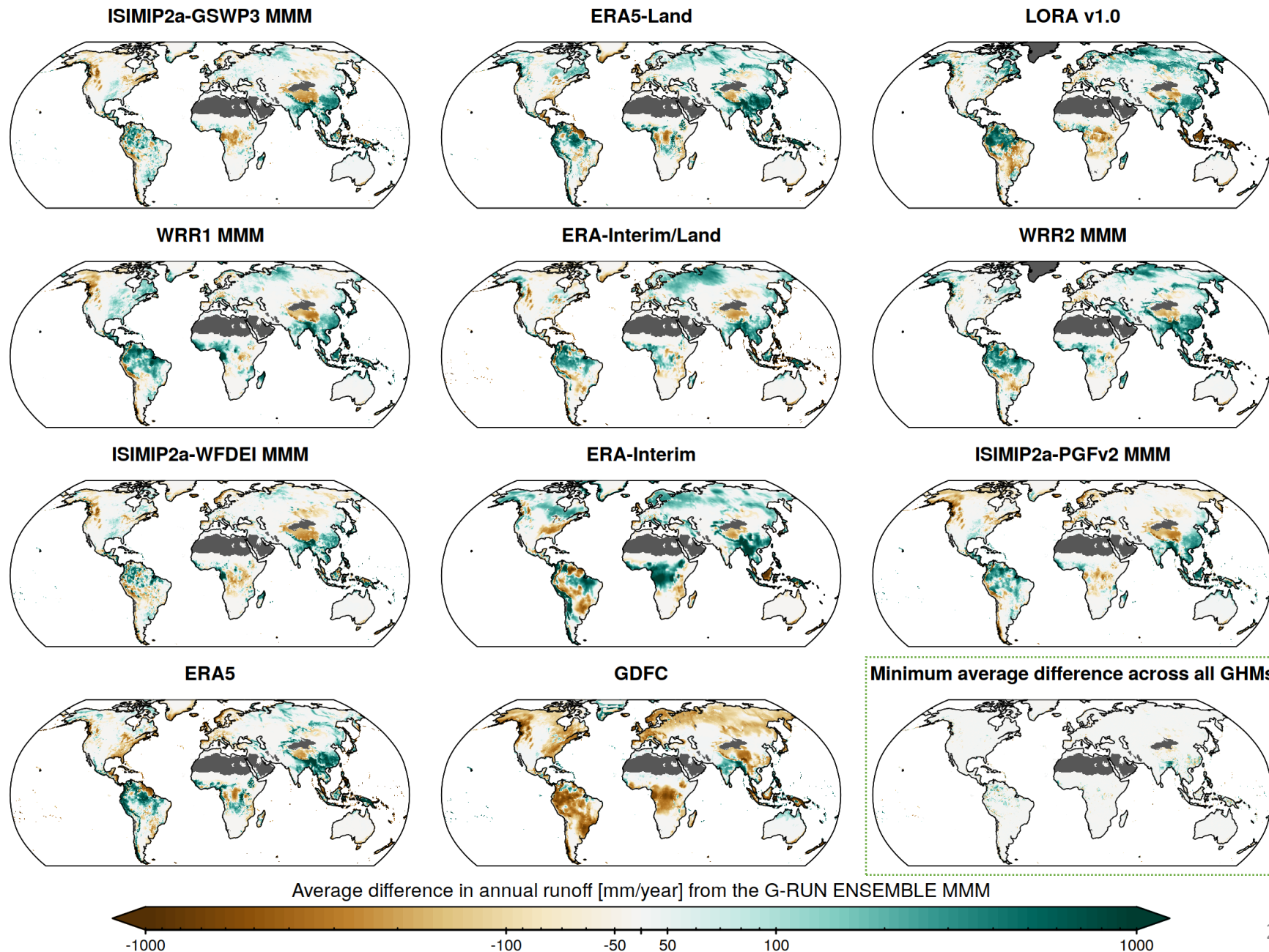


GHMs – BIAS

→ Differences across GHMs

Back

G-RUN ENSEMBLE MMM
is used as reference

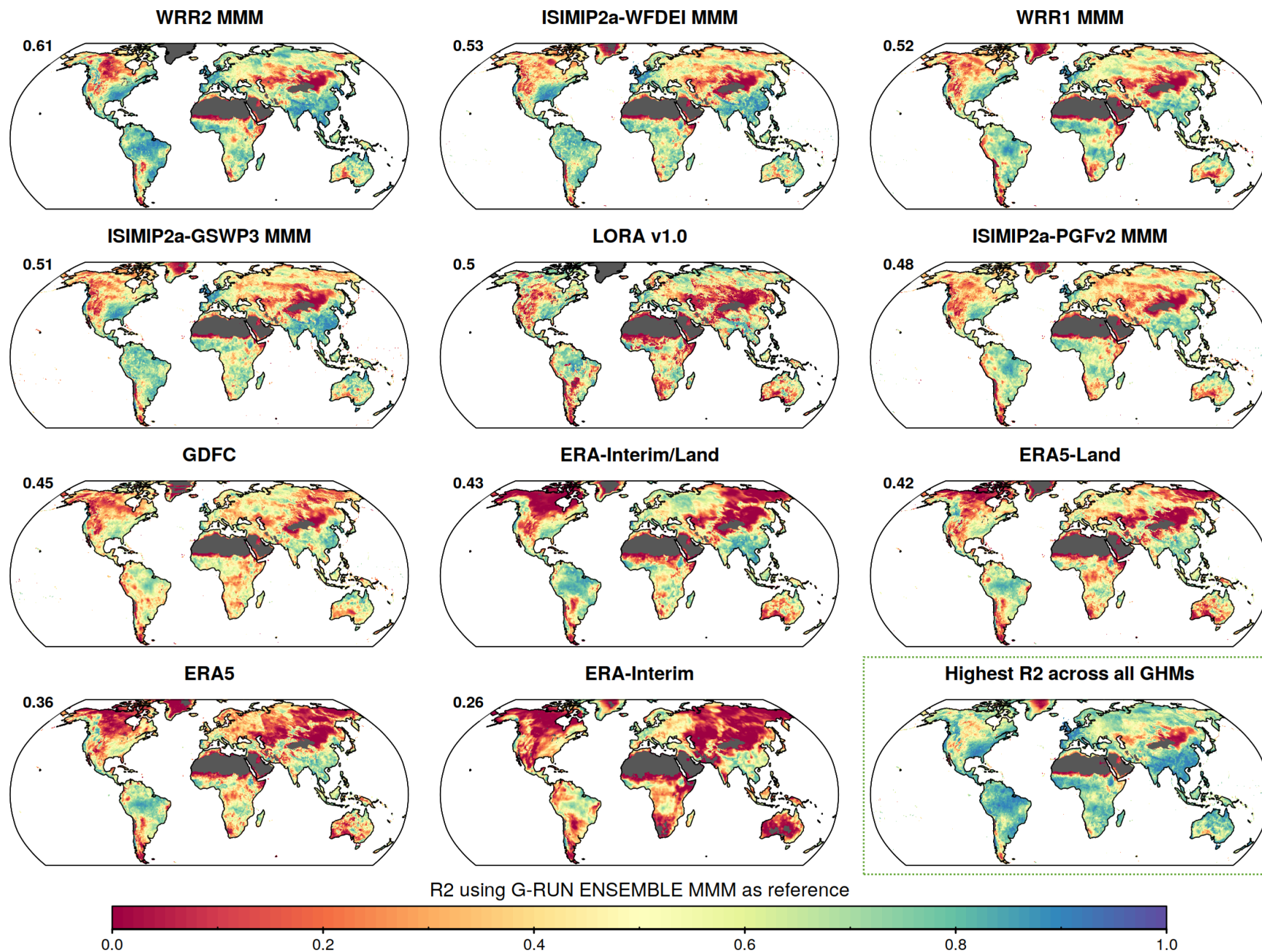


GHMs – R2

→ Differences across GHMs

Back

G-RUN ENSEMBLE MMM
is used as reference

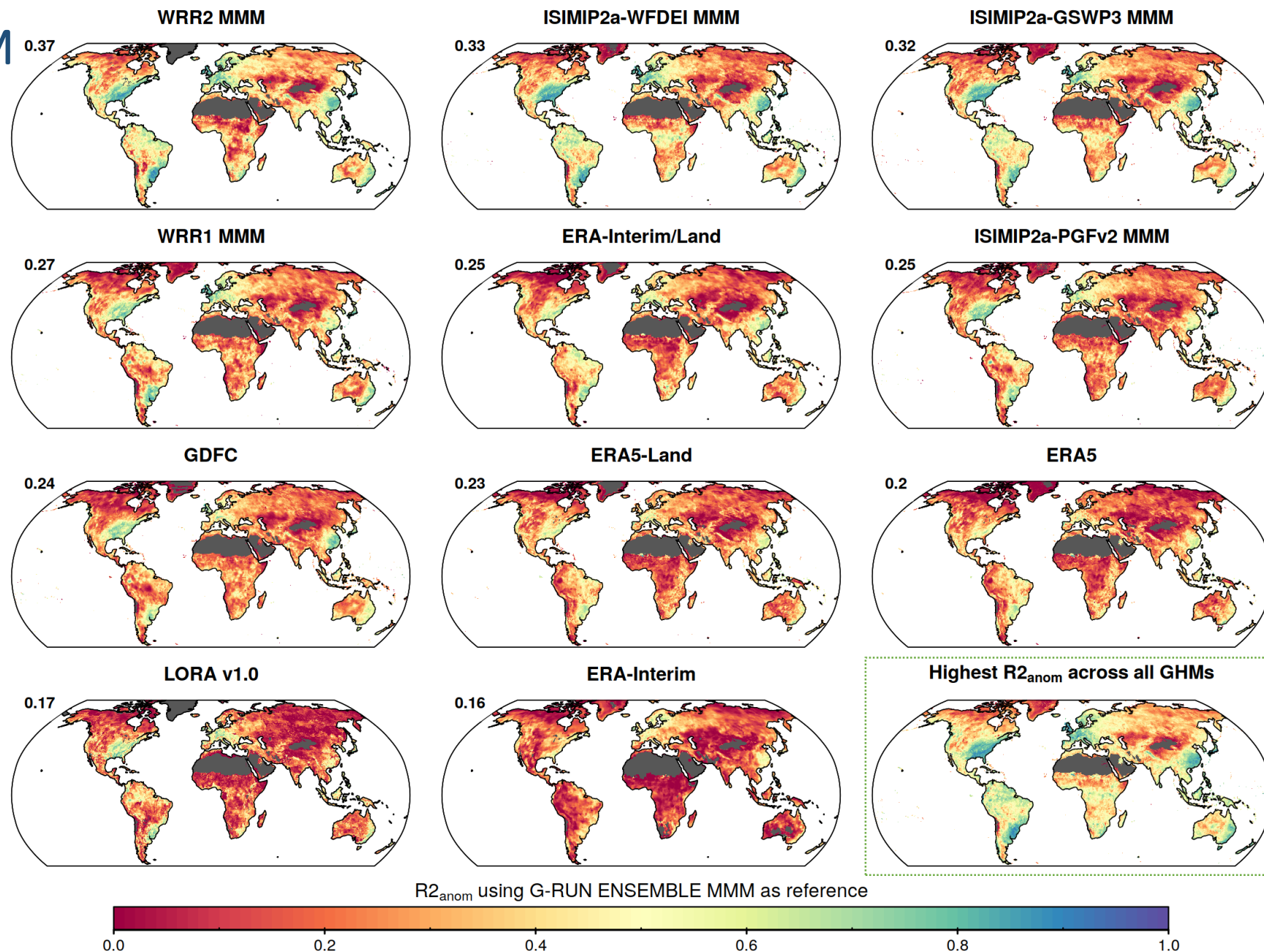


GHMs – R^2_{ANOM}

→ Differences across GHMs

Back

G-RUN ENSEMBLE MMM
is used as reference

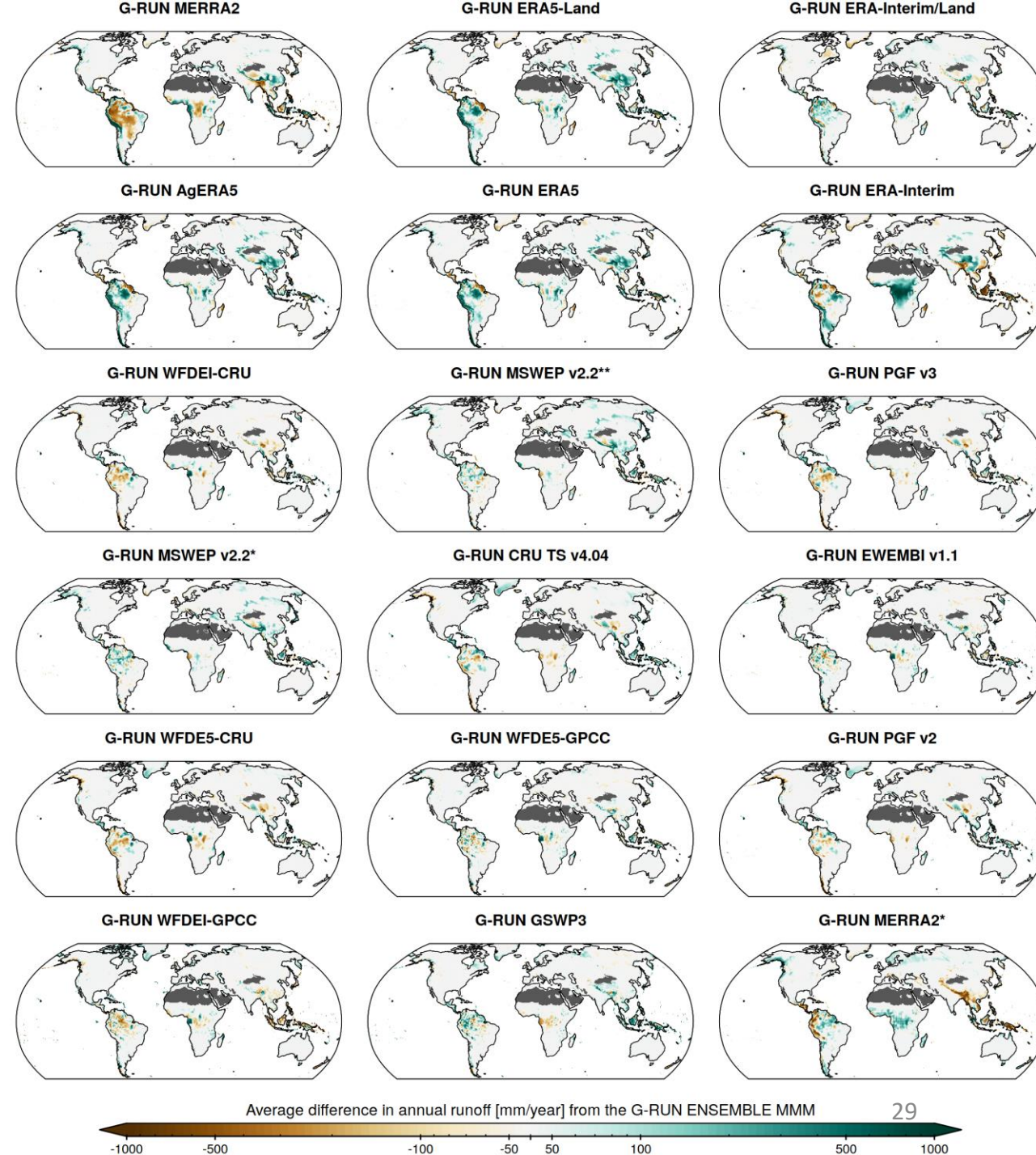


G-RUN – BIAS

→ Differences across G-RUN ENSEMBLE members

Back

G-RUN ENSEMBLE MMM
is used as reference

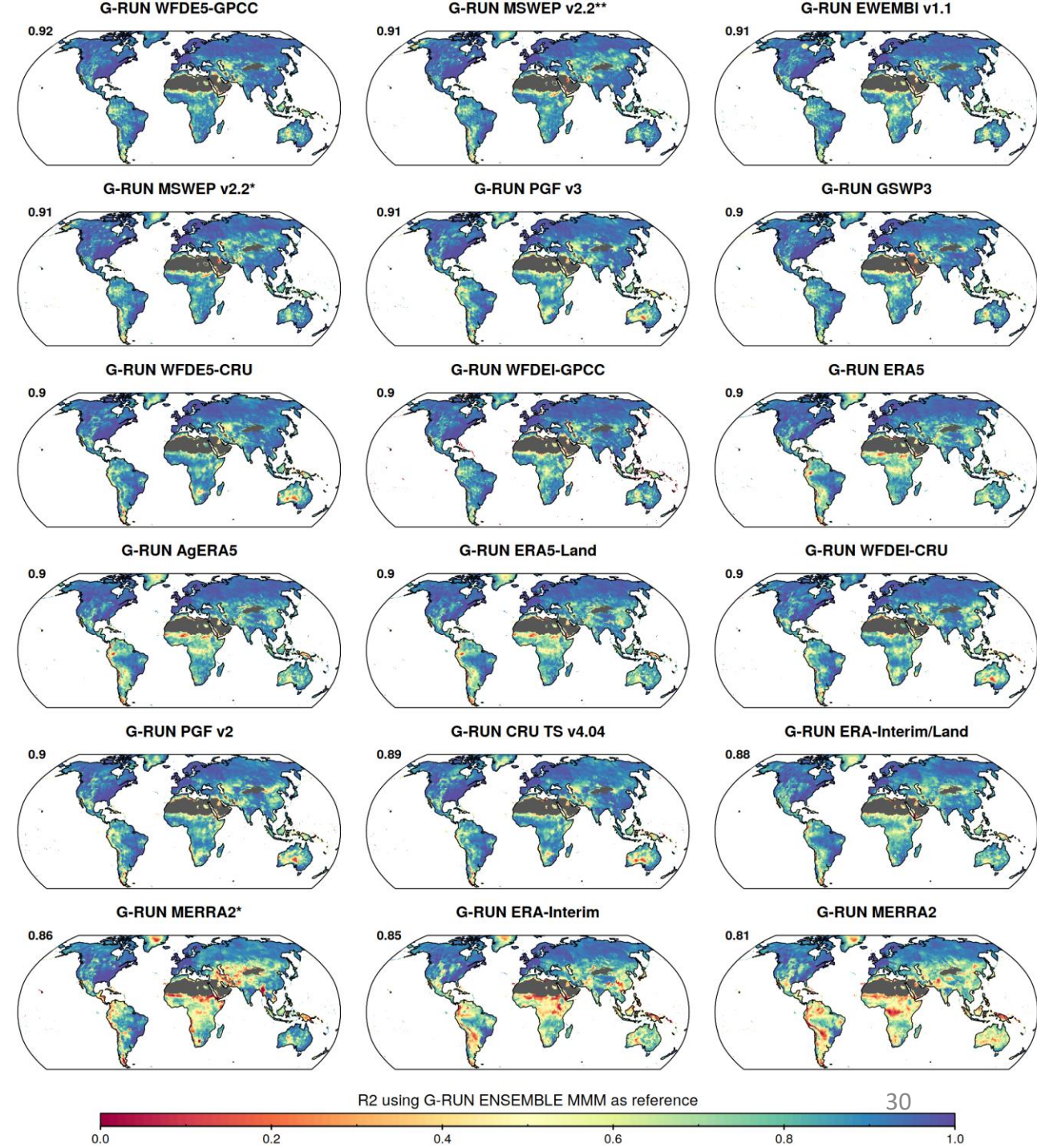


G-RUN – R2

→ Differences across G-RUN ENSEMBLE members

Back

G-RUN ENSEMBLE MMM
is used as reference



G-RUN – R2_{ANOM}

→ Differences across G-RUN ENSEMBLE members

Back

G-RUN ENSEMBLE MMM
is used as reference

