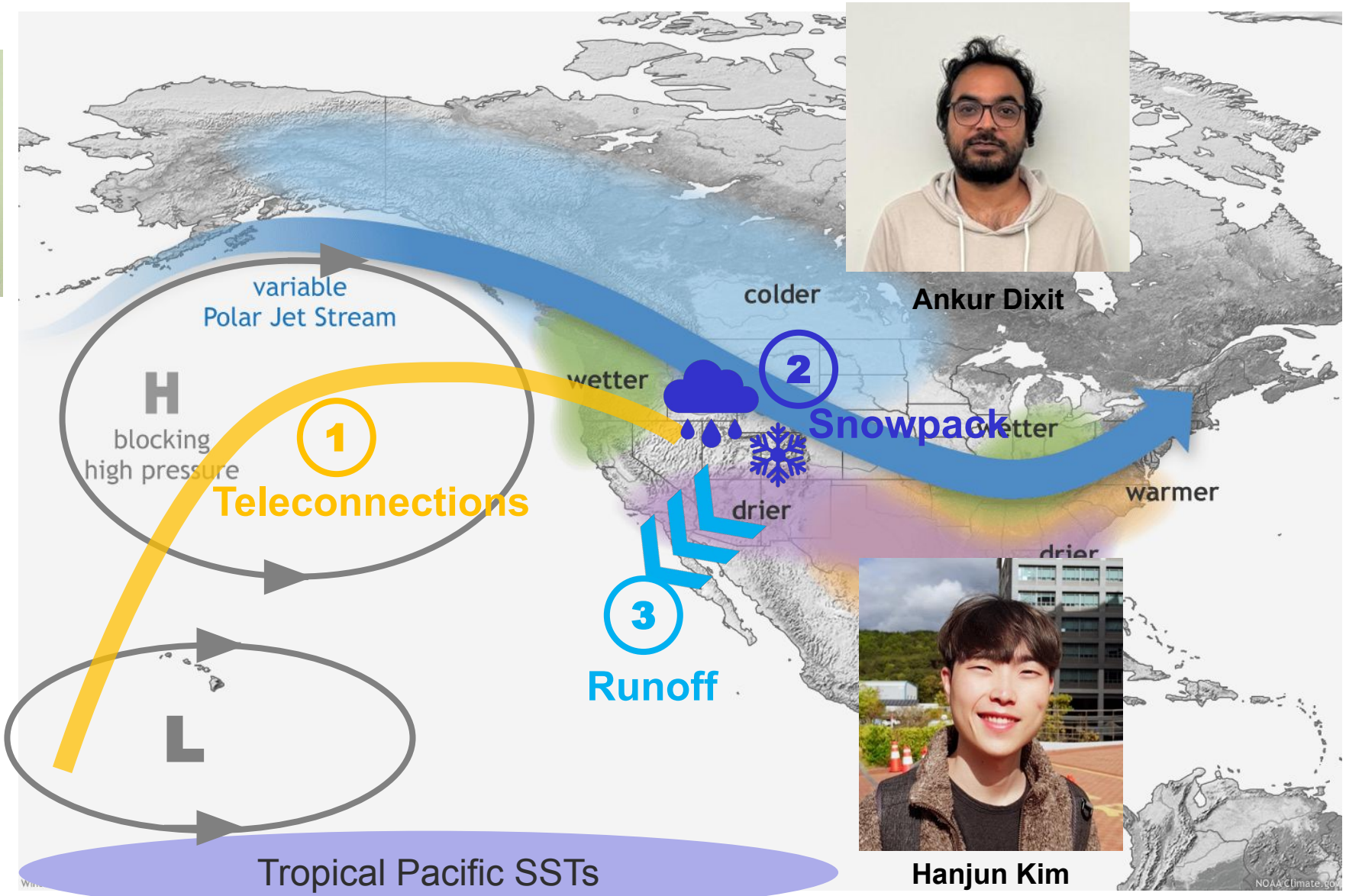
Observational constraints on runoff sensitivity of global river basins

Hanjun Kim[1], **Flavio Lehner**[1], Katie Dagon[2], David M. Lawrence[2], Samar Minallah[2], Sean Swenson[2], Andrew W. Wood[2]

[1]Earth and Atmospheric Sciences, Cornell University; [2]Climate and Global Dynamics, NCAR

Background and motivation

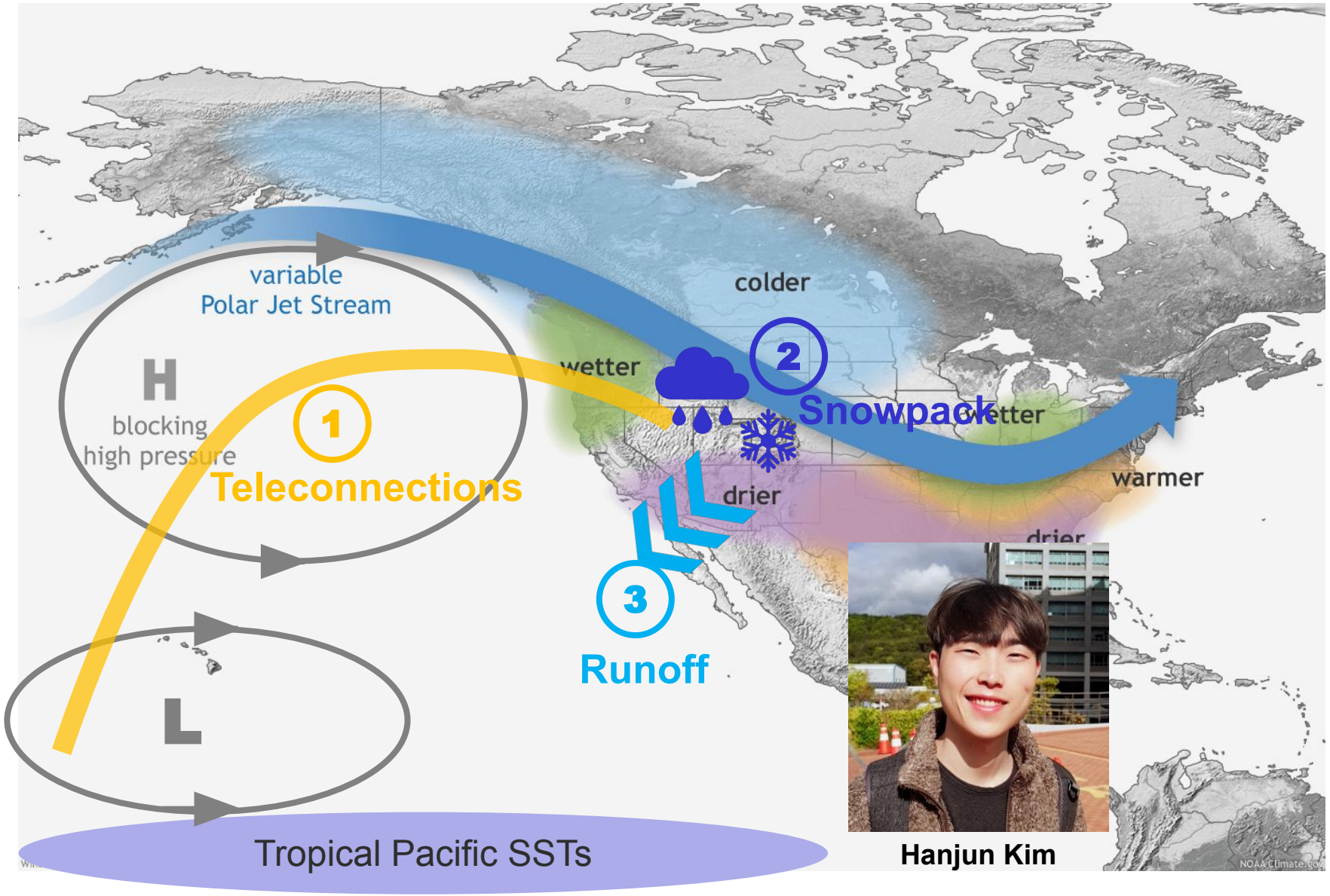
Yan-Ning Kuo



Ankur Dixit

Hanjun Kim

Background and motivation



Runoff sensitivity

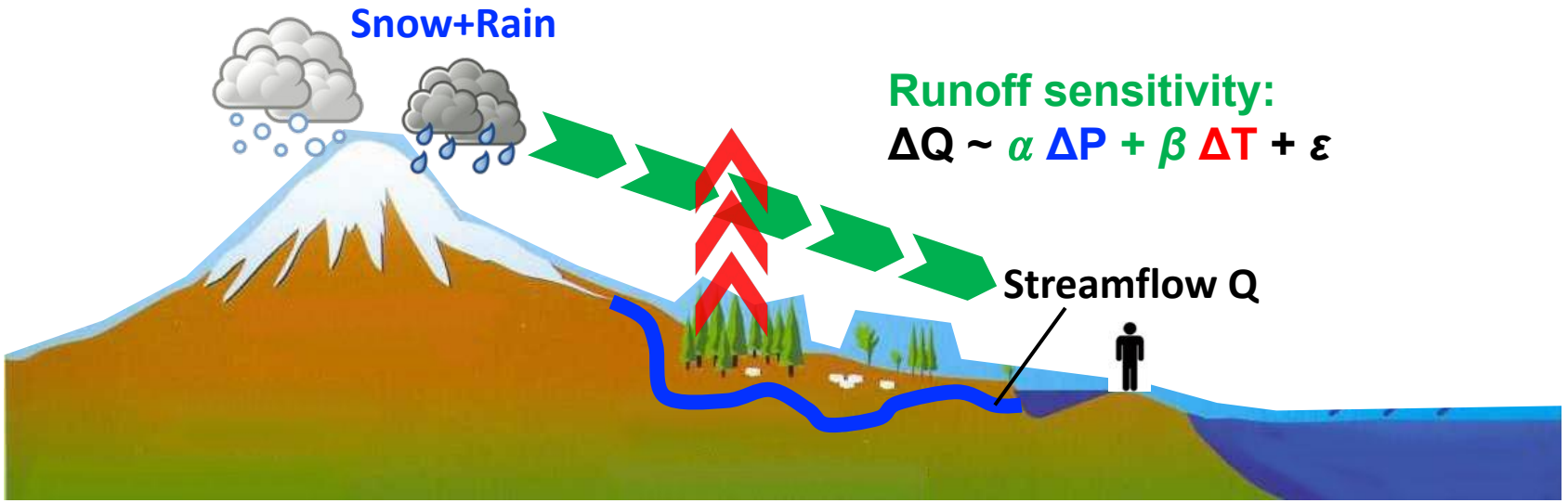
Hanjun Kim

PERSPECTIVE
https://doi.org/10.1038/s41558-019-0639-x

nature climate change

The potential to reduce uncertainty in regional runoff projections from climate models

Flavio Lehner[1,2,3*], Andrew W. Wood[2], Julie A. Vano[2,4], David M. Lawrence[1], Martyn P. Clark[5] and Justin S. Mankin[6,7,8]



Lehner et al. (2019, *Nature Climate Change*)

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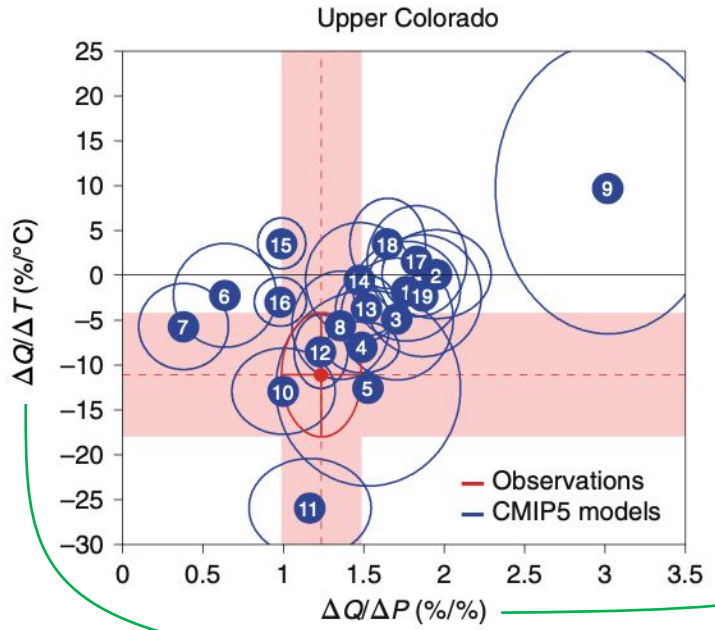

- Models have biases in their runoff sensitivity

Runoff sensitivity:

$\Delta Q \sim \alpha \Delta P + \beta \Delta T + \varepsilon$

Lehner et al. (2019, *Nature Climate Change*)

Runoff sensitivity

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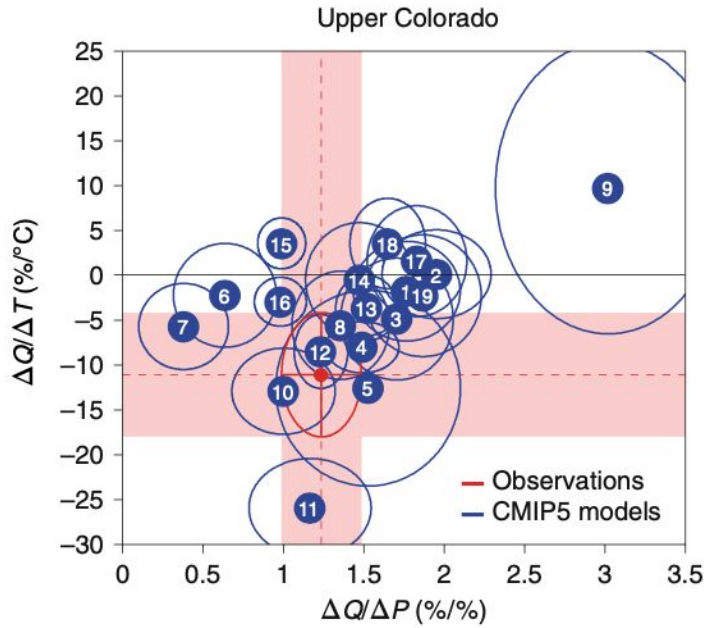

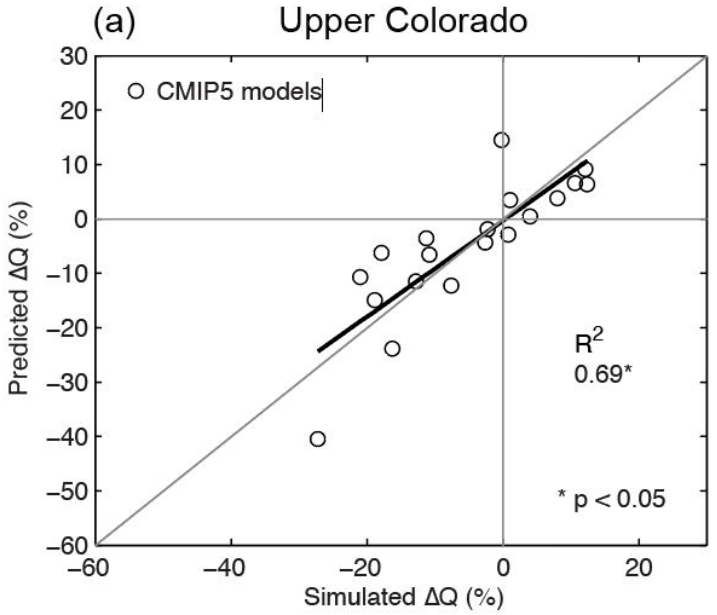

- Models have biases in their runoff sensitivity
- The sensitivities are predictive of future behavior

Lehner et al. (2019, *Nature Climate Change*)

Runoff sensitivity

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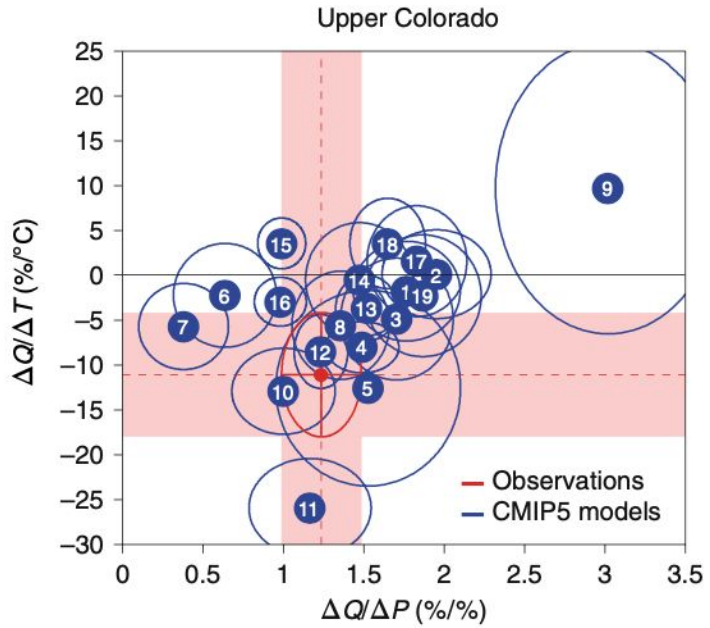

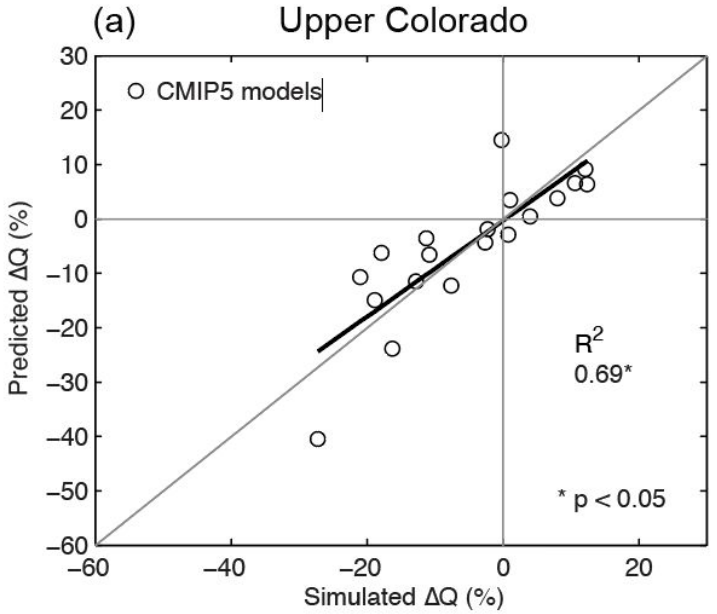

- Models have biases in their runoff sensitivity
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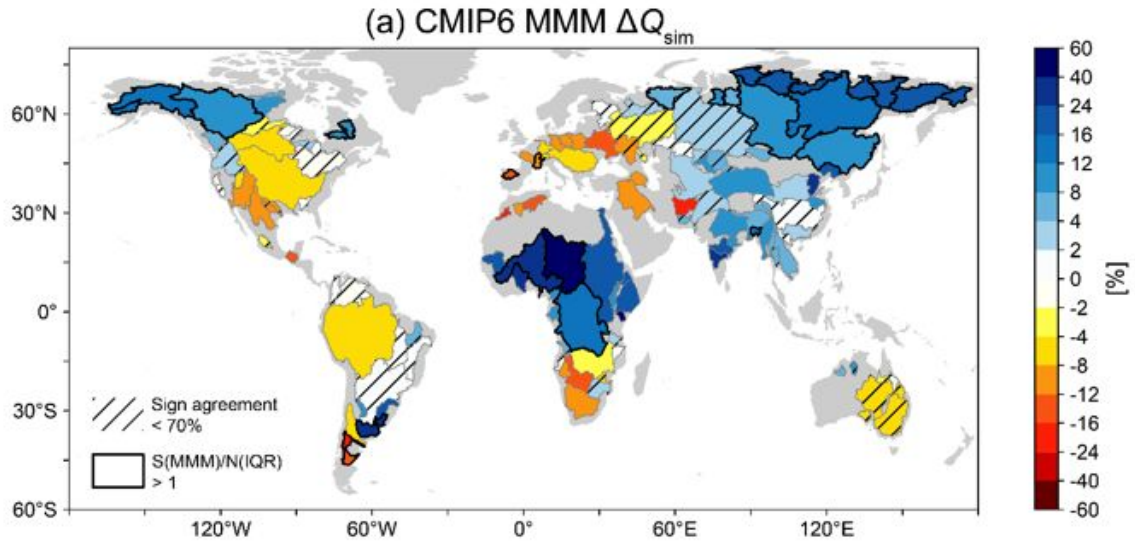
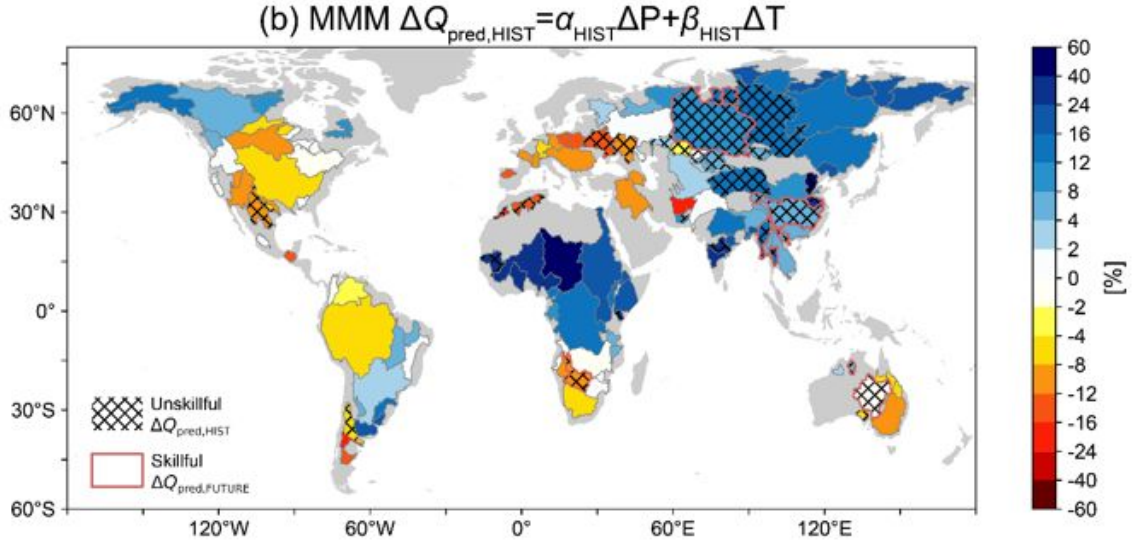
 Opportunity for an **observational constraint**

Lehner et al. (2019, *Nature Climate Change*)

Projected runoff changes



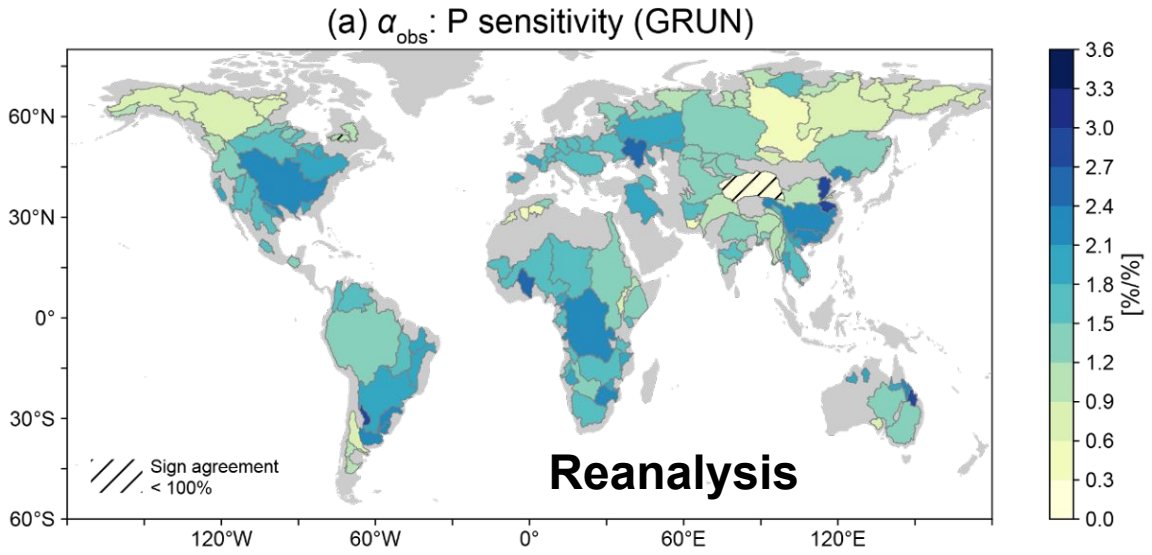
CMIP6 simulated ΔQ
(2030-2070 vs 1947-2017
under SSP2-4.5)

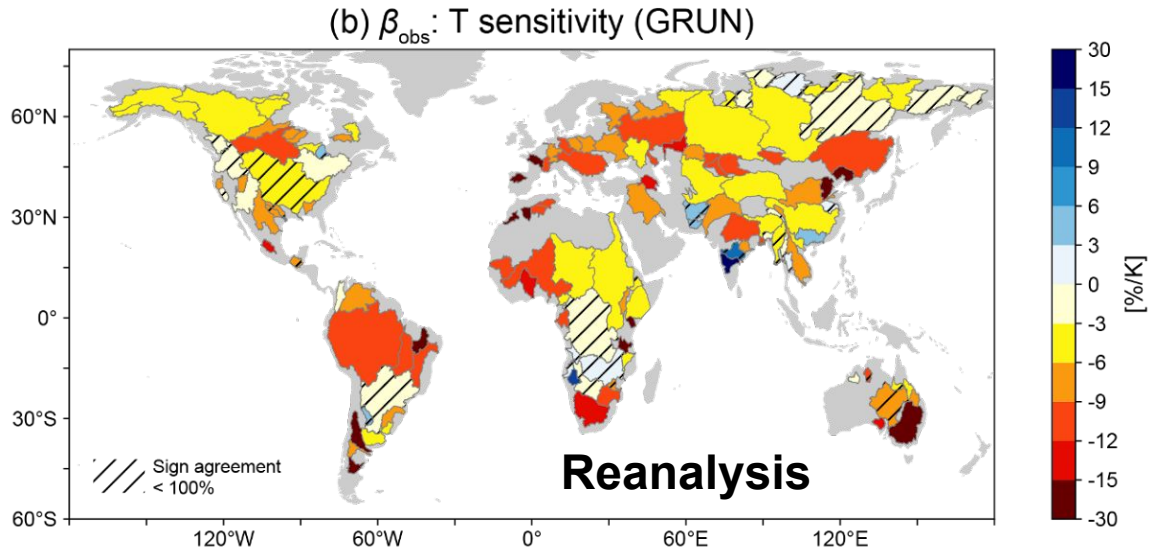


ΔQ **predicted** from ΔP and ΔT
and historical runoff sensitivity

Kim et al. (submitted)

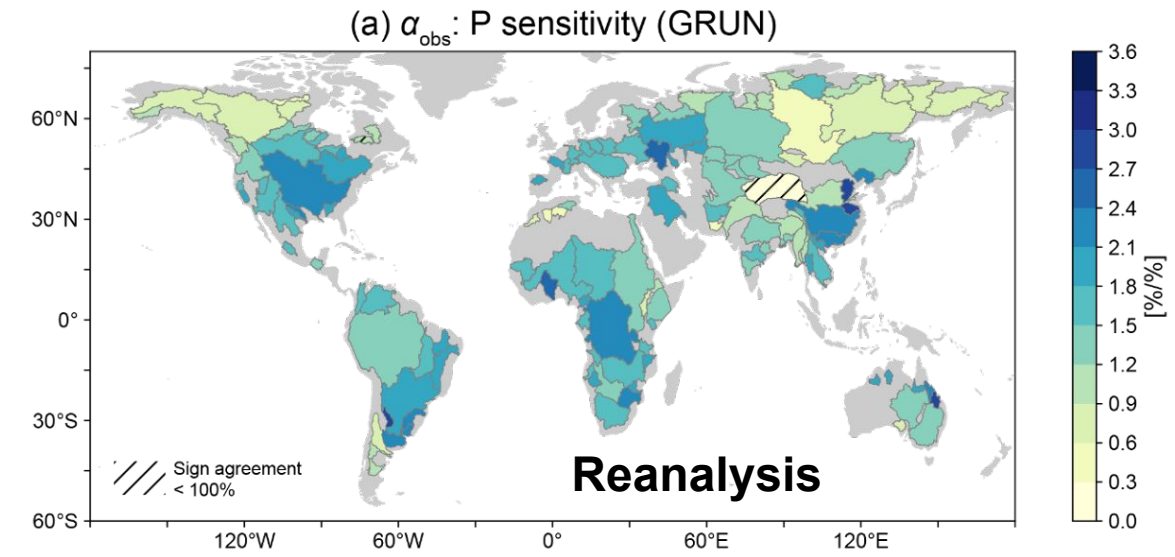
Observation-based runoff sensitivity

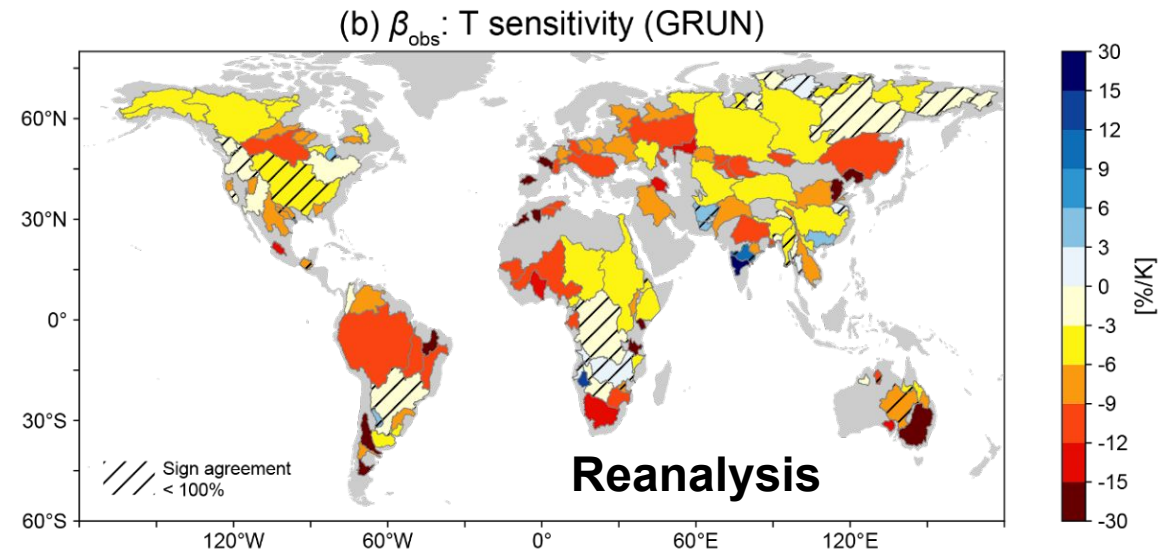


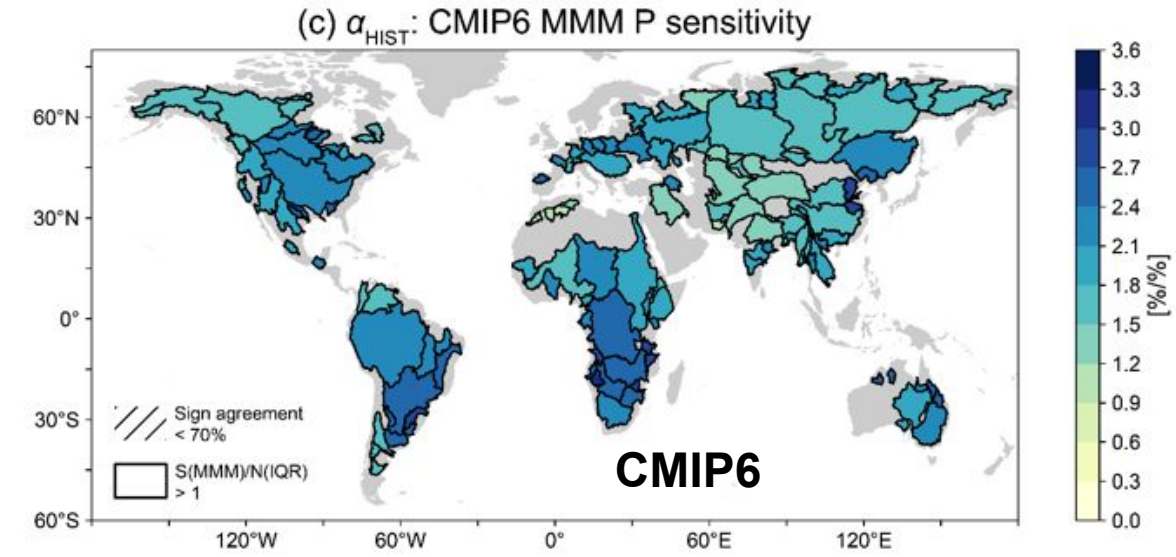


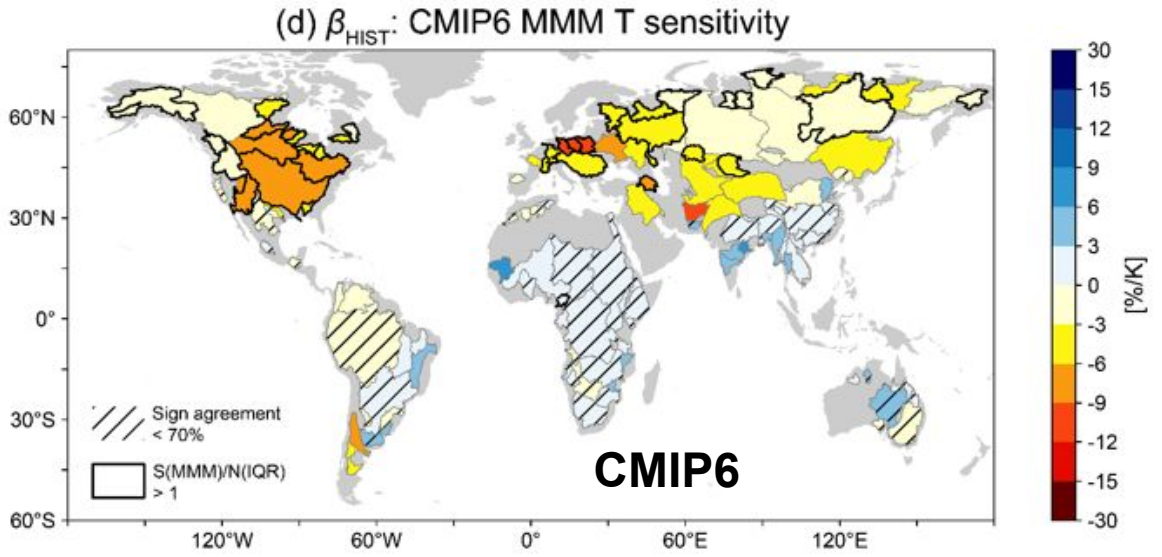
Kim et al. (submitted)

Model biases in runoff sensitivity









P sensitivity is **overestimated**

T sensitivity is **underestimated**

Kim et al. (submitted)

Applying constraint

$$\Delta Q \sim \alpha_{model}\,\Delta P + \beta_{model}\,\Delta T + \varepsilon$$

$$\Delta Q \sim \alpha_{obs}\,\Delta P + \beta_{obs}\,\Delta T + \varepsilon$$

Substitute the observed sensitivity for the model sensitivity

□ **constrained projection**

Kim et al. (submitted)

Applying constraint

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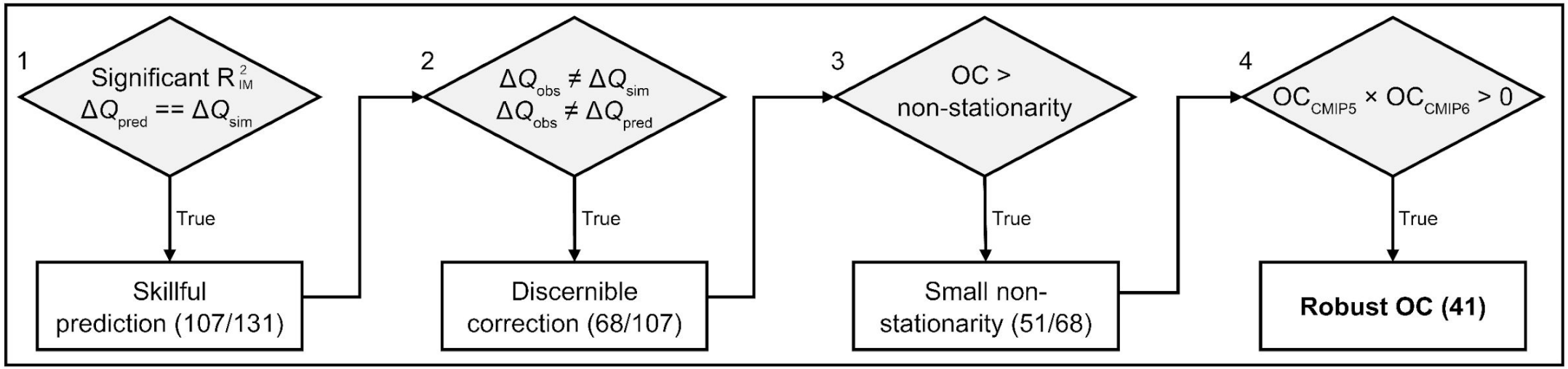
(a) Analysis to develop robust Observational Constraint ($OC = \Delta Q_{obs} - \Delta Q_{sim}$)



Can we use historical sensitivity to predict future ΔQ?

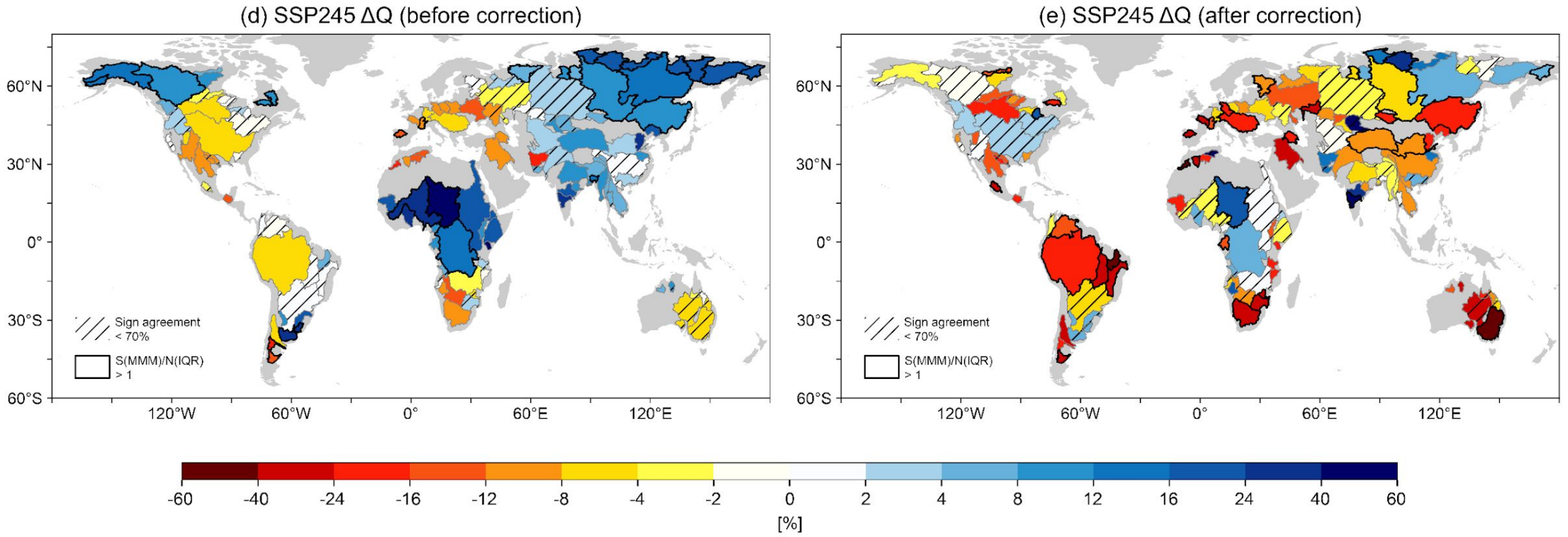
Is the observationally constrained ΔQ actually different from the simulated ΔQ?

If sensitivities themselves change in the future, is that change smaller than the constraint?

Does this all hold in CMIP5 *and* CMIP6?

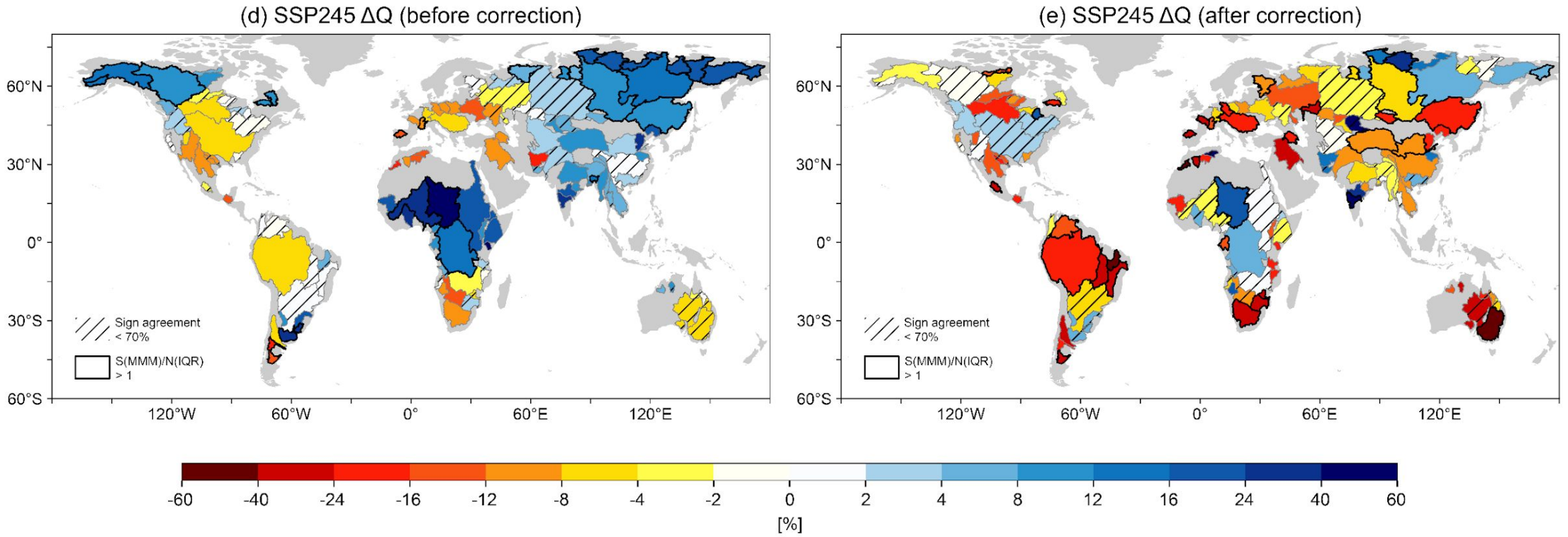
Kim et al. (submitted)

Effect from constraint



Kim et al. (submitted)

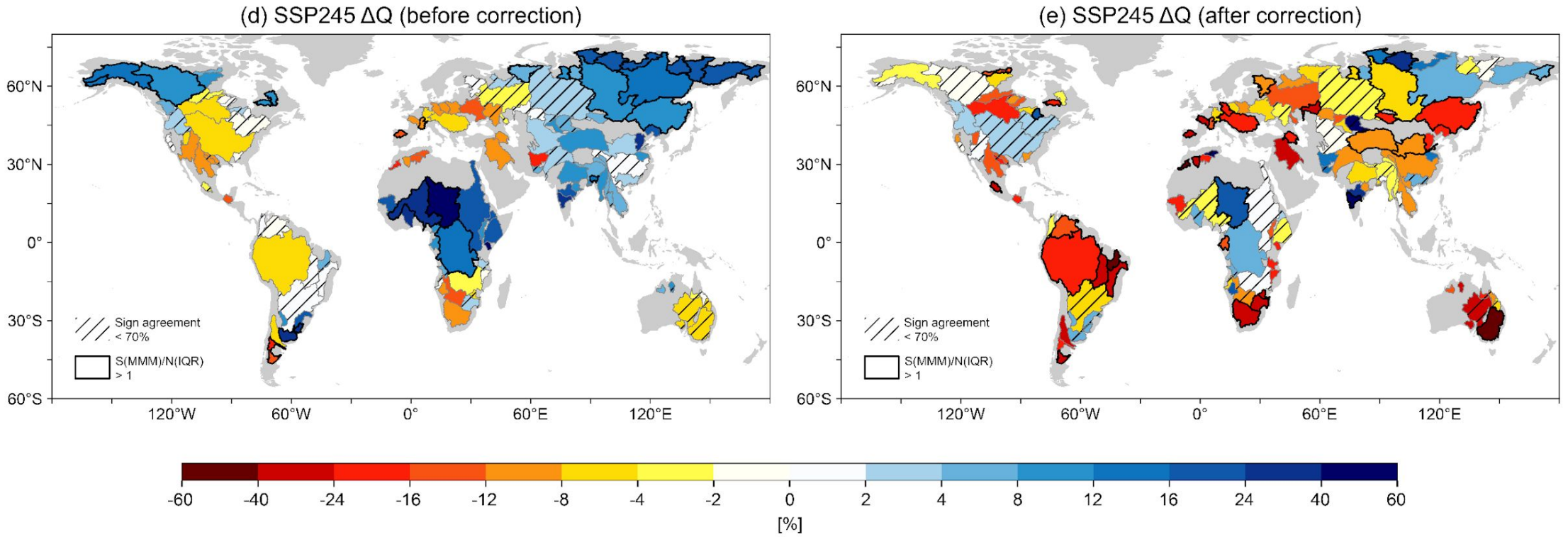
Effect from constraint



- **Robust constraints** possible in 41 out of 131 global river basins
- In many basins, projections get corrected downwards (**less runoff**)
- Models **underestimate temperature sensitivity**
- **Root causes** still unclear

Kim et al. (submitted)

Effect from constraint



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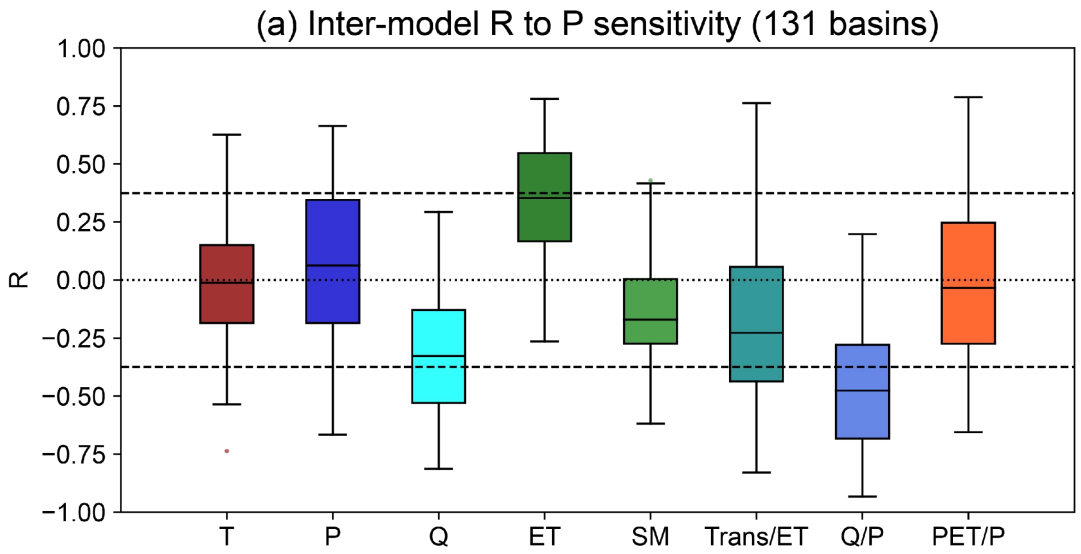
Article https://doi.org

Future global streamflow declines are probably more severe than previously estimated

Wang et al. (2023, *Nature Water*)

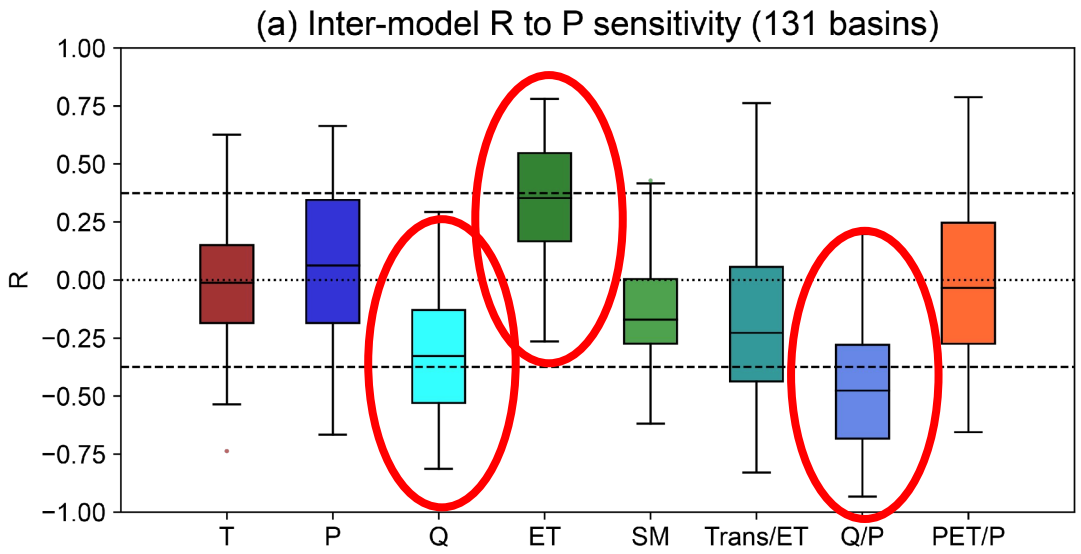
Kim et al. (submitted)

Search for root causes



Kim et al. (submitted)

Search for root causes



Kim et al. (submitted)

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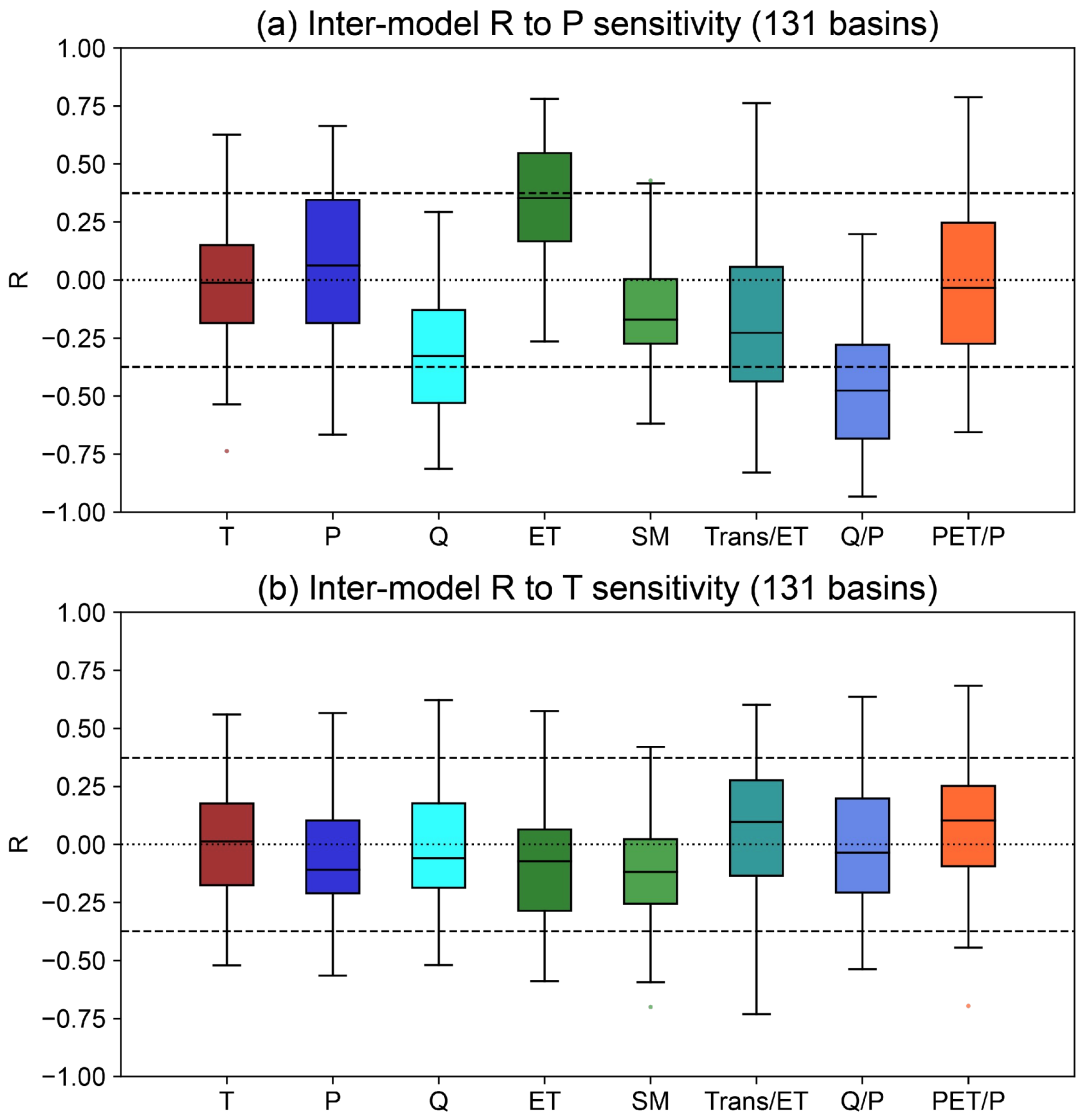

Kim et al. (submitted)

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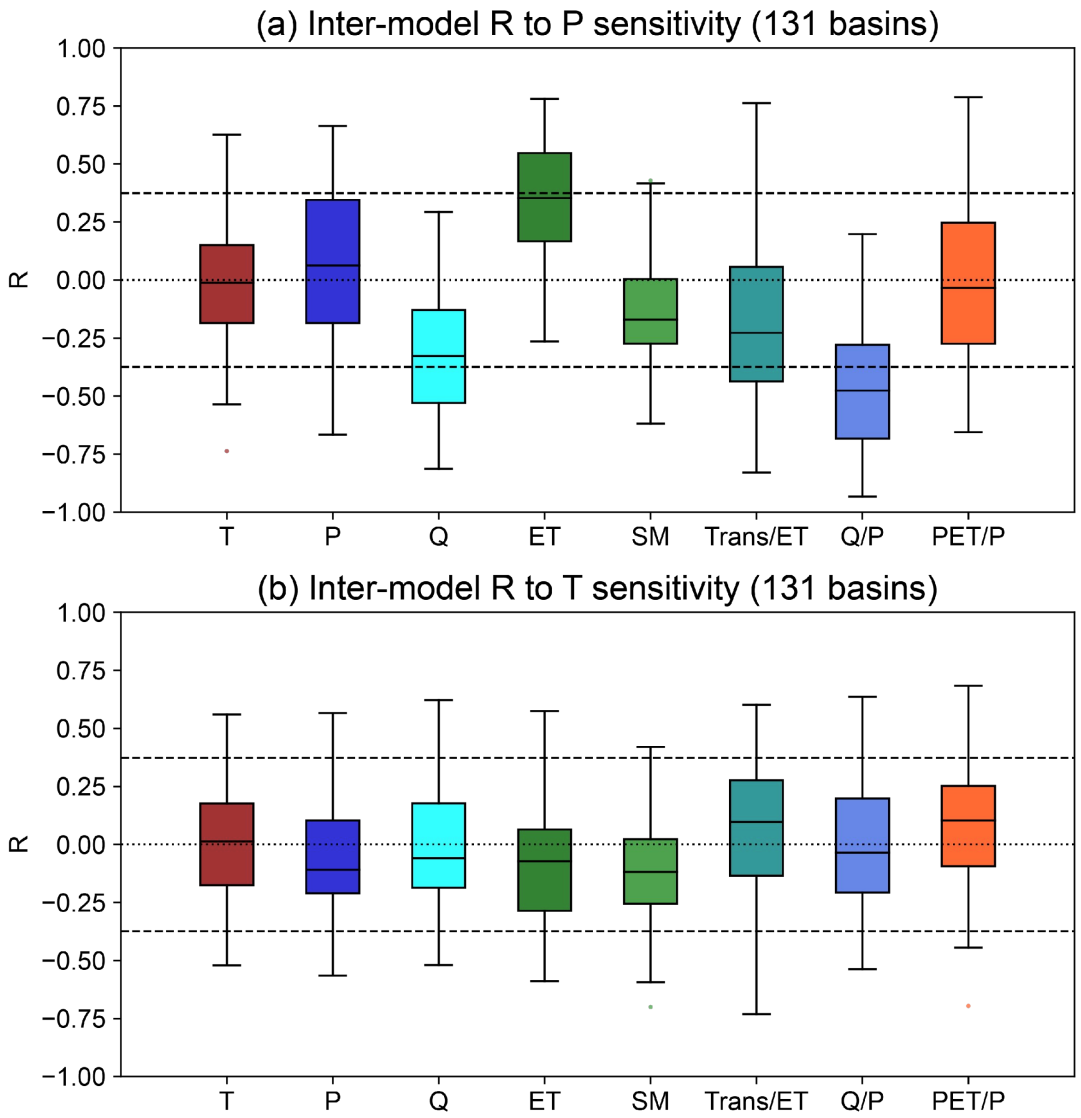

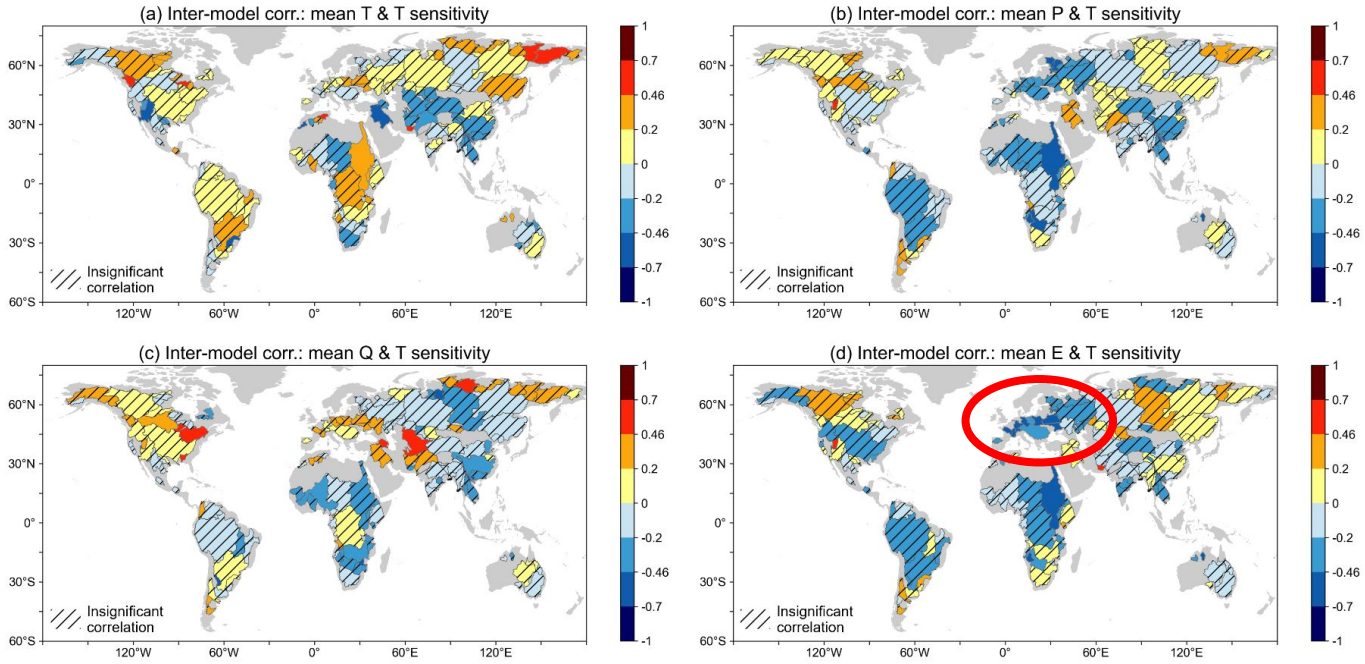

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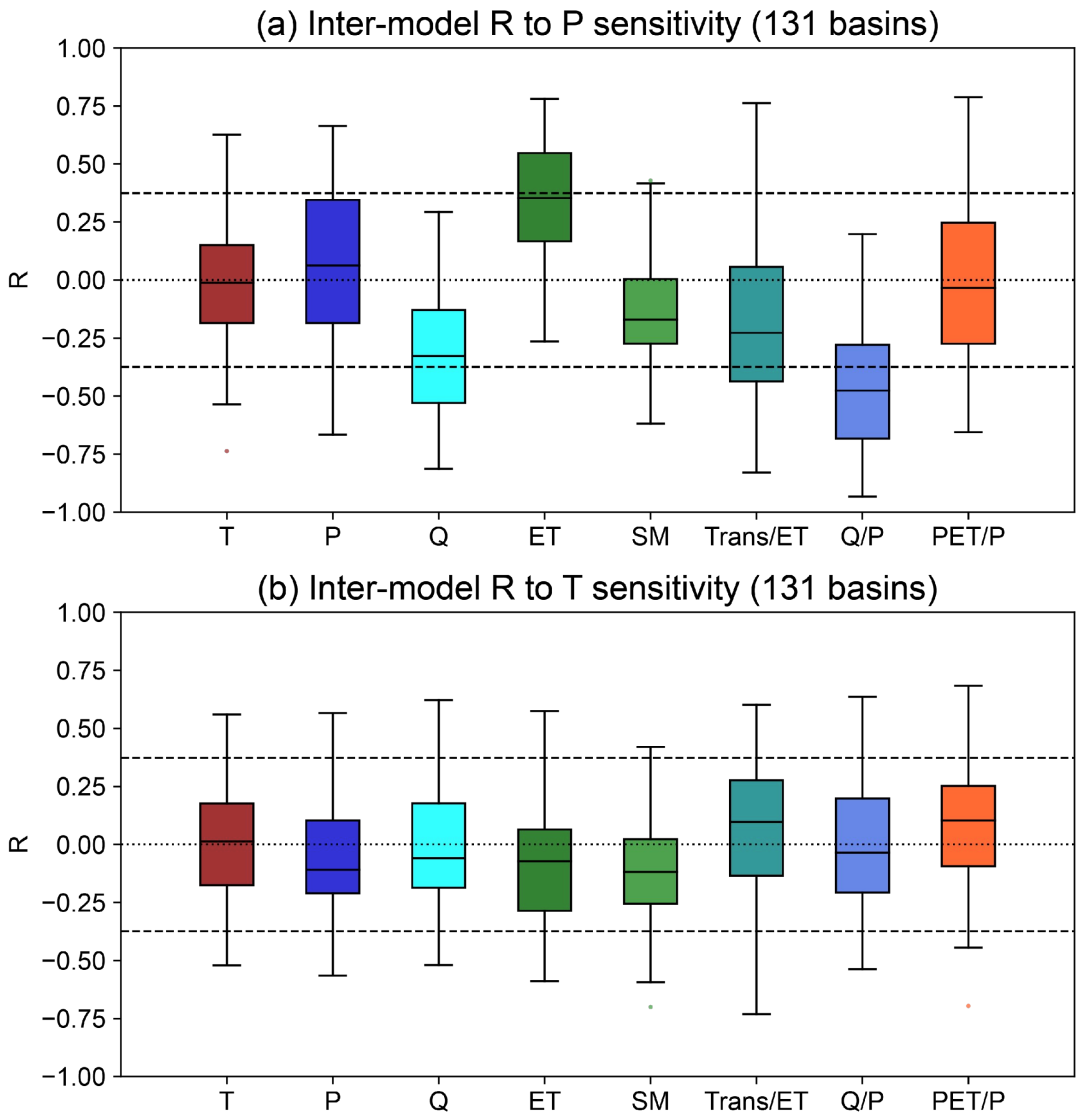
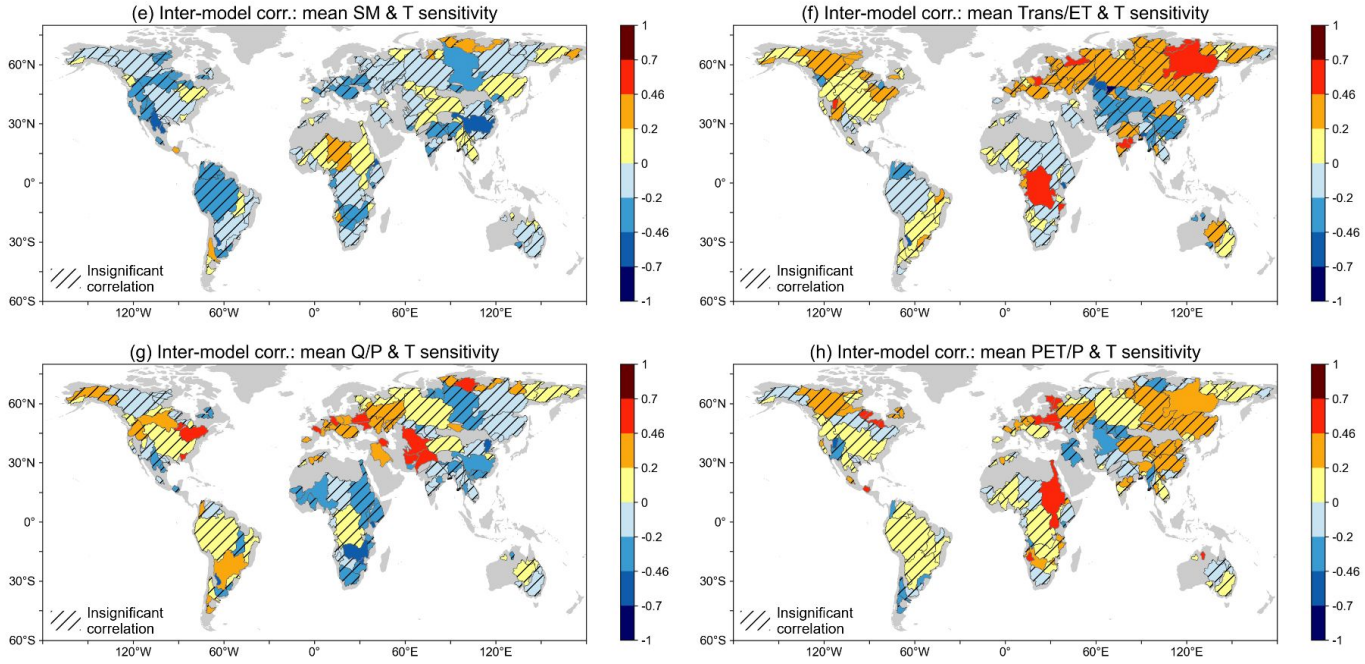




Kim et al. (submitted)

Next steps

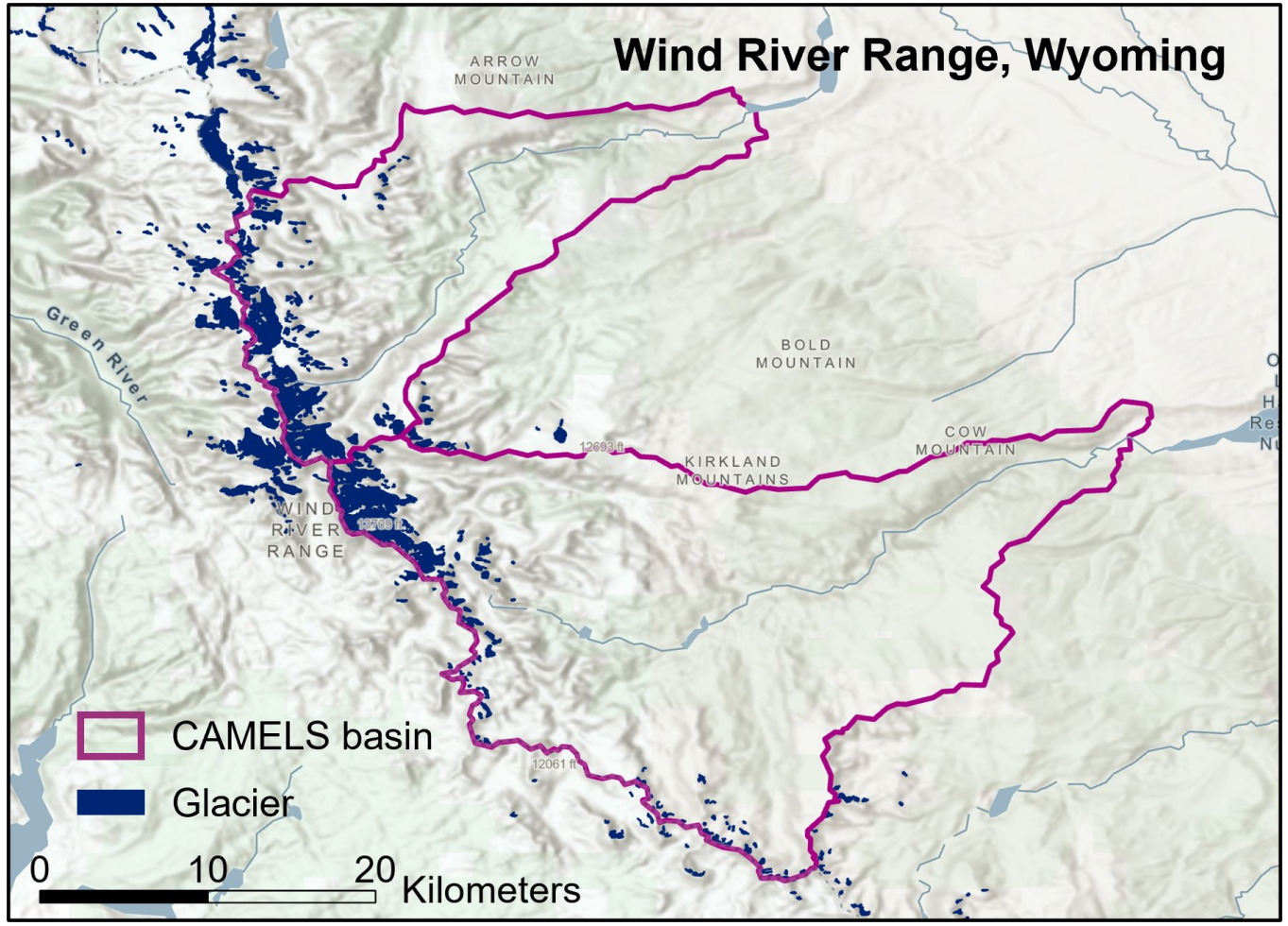
Hanjun Kim and **Nate Collier:**

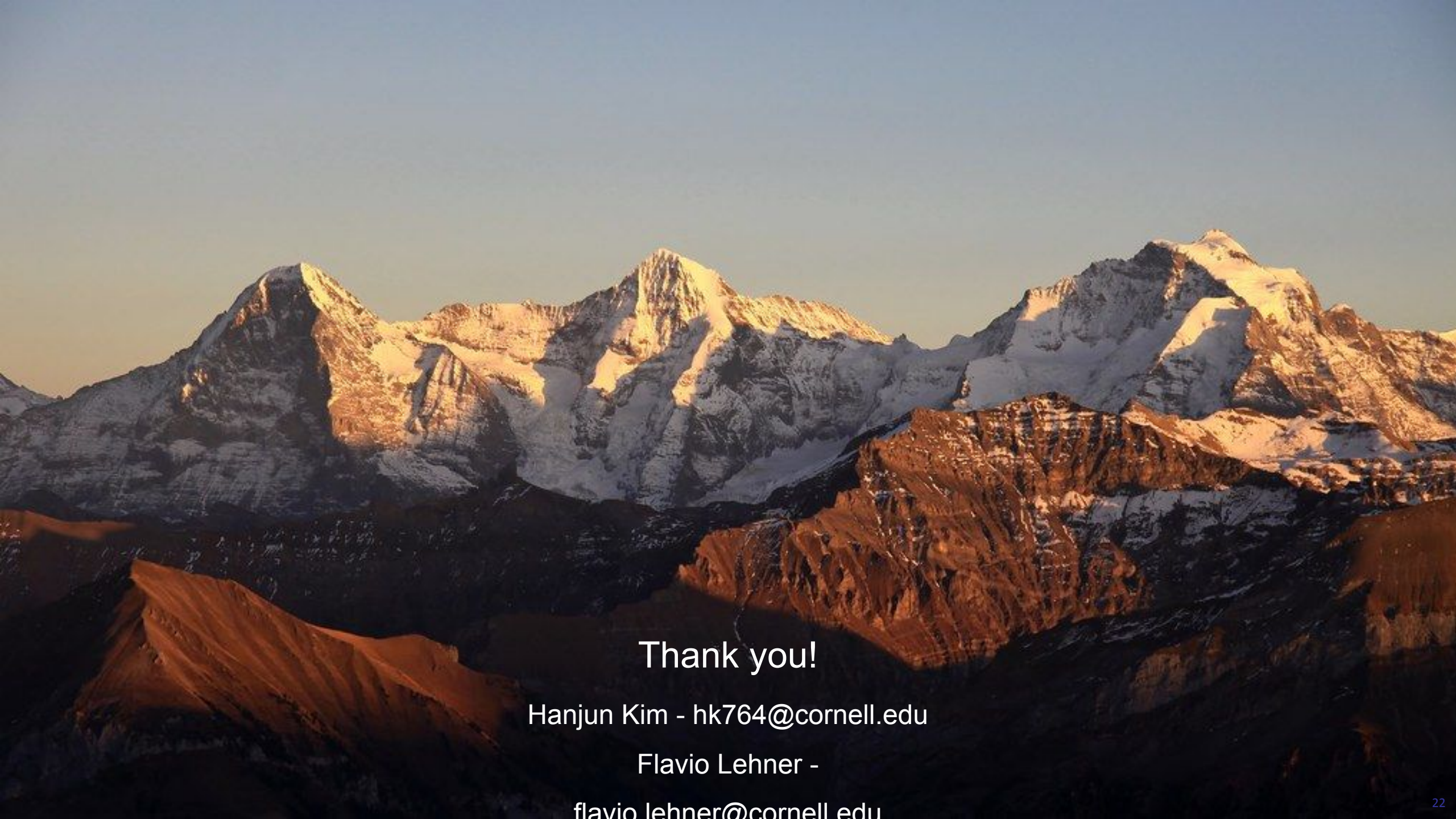
- Implementing runoff sensitivity into diagnostics packages (NOAA MDTF and DOE ILAMB)

Samar Minallah, Sean Swenson, Andy Wood:

- Looking at runoff-generating processes in CLM at smaller spatial scales (CAMELS catchments)

Opportunities to leverage CLM and CESM2 **PPEs**




Thank you!
Hanjun Kim - hk764@cornell.edu
Flavio Lehner -
flavio.lehner@cornell.edu

Extra slides

Systematic shift in ENSO teleconnections

Kuo, Lehner et al. (in press, *Nature Geoscience*)