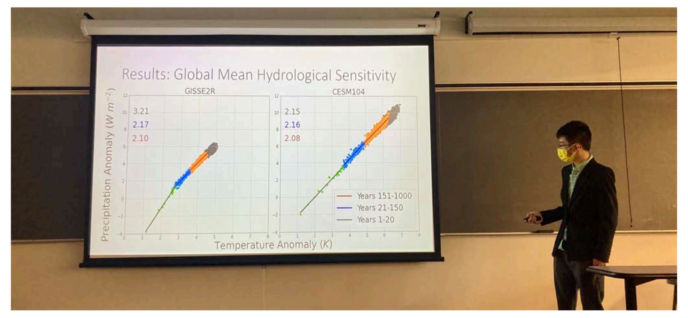
Is the forced response of precipitation timescale-dependent?



Kinen giving his senior thesis defense on this work, 6 May 2022

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The Pattern Effect: Coupling of SST Patterns, Radiative Feedbacks, and Climate Sensitivity Workshop, May 10 - May 13, 2022

Synopsis

Issue:

- The pattern effect leads to time-dependence of climate sensitivity via the multiple response timescales of TOA net radiative fluxes. Since the global-mean precipitation is in balance with the atmospheric radiative cooling (=TOA + surface fluxes) plus sensible heat flux, is its response to forcing timescale-dependent too?
- How does precipitation change in response to abrupt 4xCO2 forcing across different timescales: years 1-20, 21-150, and 151-1000?

Approach:

- Investigate with LongRunMIP simulations (Rugenstein et al., 2019)
- Abrupt 4xCO2 forcing, 1000+ year simulations, and pre-industrial control

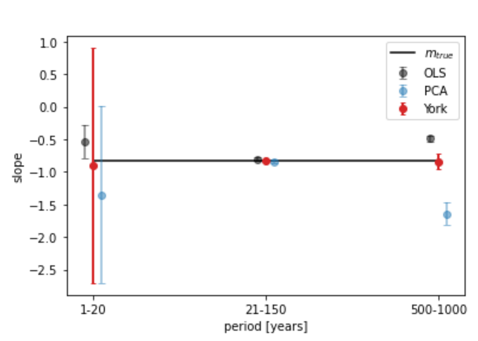
Findings:

- The hydrological sensitivity has a **less consistent trend** across time scales compared to climate sensitivity.
- Timescale dependence of climate sensitivity can be overestimated when calculated with OLS regression for 1 ensemble member because of differing bias across timescales.

Regression methods applied to TOA radiation

Slope estimates are not always unbiased; Ordinary Least Squares (OLS) regression assumes the x-variable is known exactly (Gregory et al., 2020 discuss implications for climate sensitivity) and there is no correlation between x- and y- internal variability. Can these biases affect different timescales differently?

In a test with hypothetical data (many assumptions, ask for details), the York regression method can recover slope with no bias, while OLS and PC regression (a type of Total Least Squares) cannot get the true slope within +/- 1σ for some timescales – and, the bias changes with timescale.



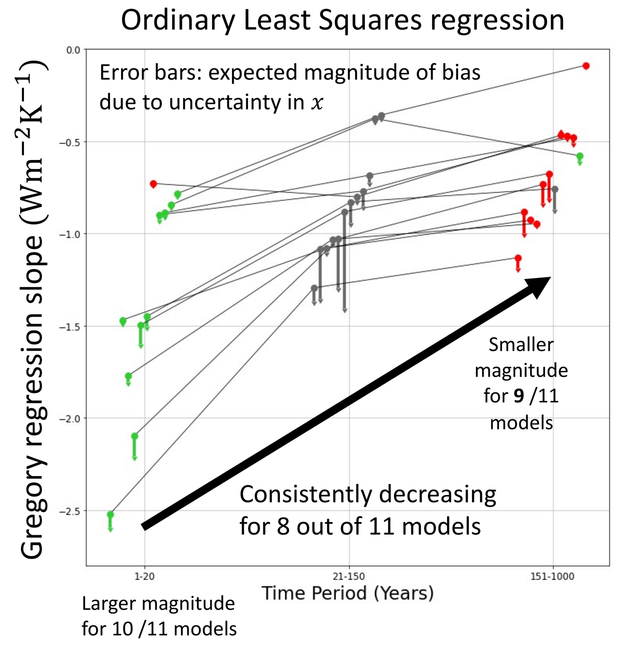
piControl, multi-model mean

$r(T, R_{TOA}) = -0.2$

$r(T, P) = 0.6$

Correlation of internal variability is larger for precip than net TOA radiation

Ordinary Least Squares regression



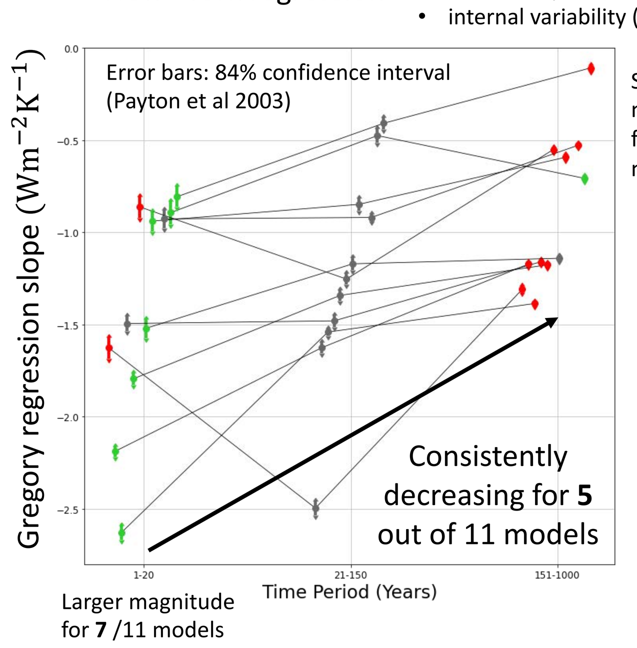
Green indicates $|m| > |m_{21-150}|$,

Red indicates $|m| < |m_{21-150}|$.

"New" York regression

Accounts for:

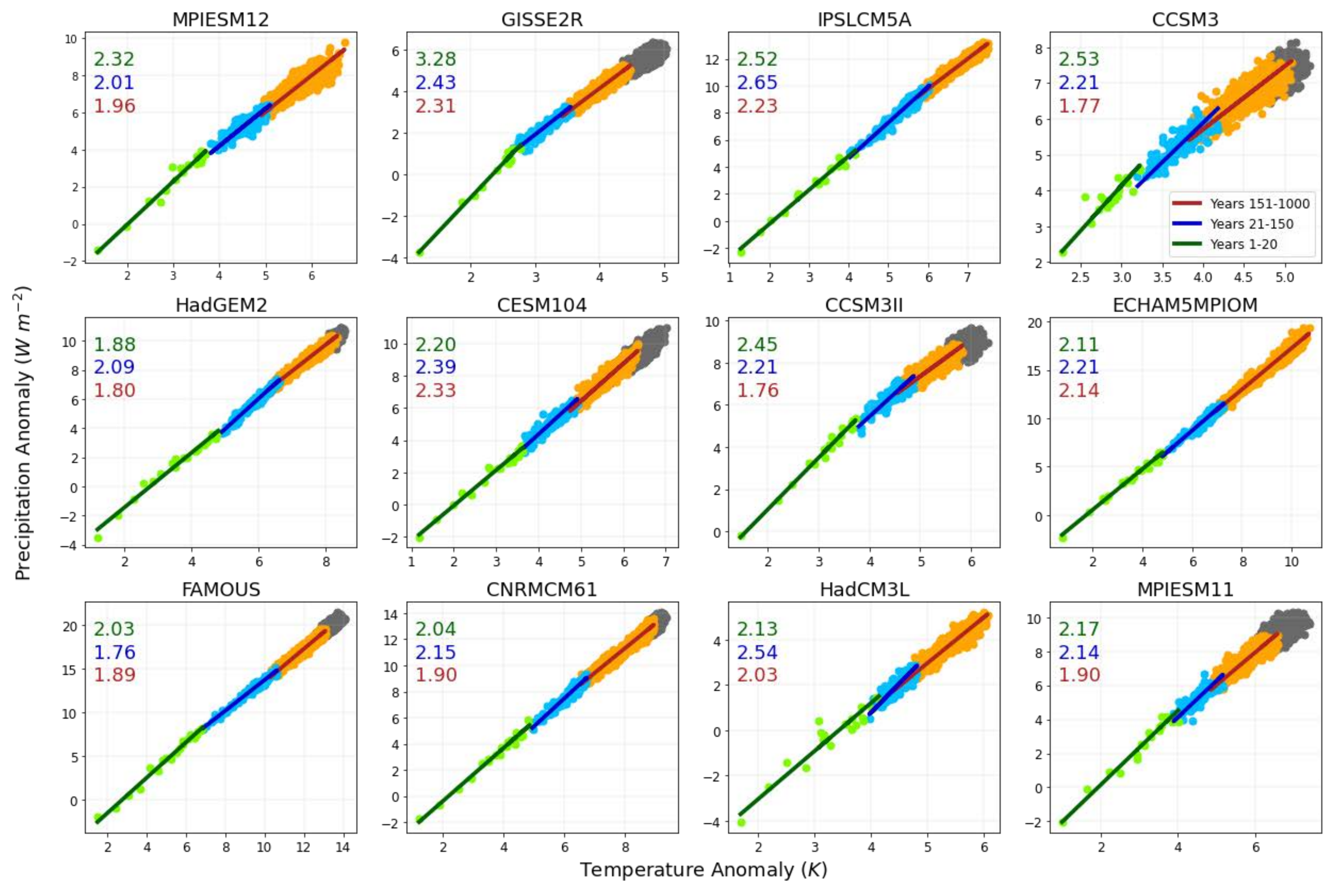
- uncertainty in x, and
- internal variability (r in piControl)



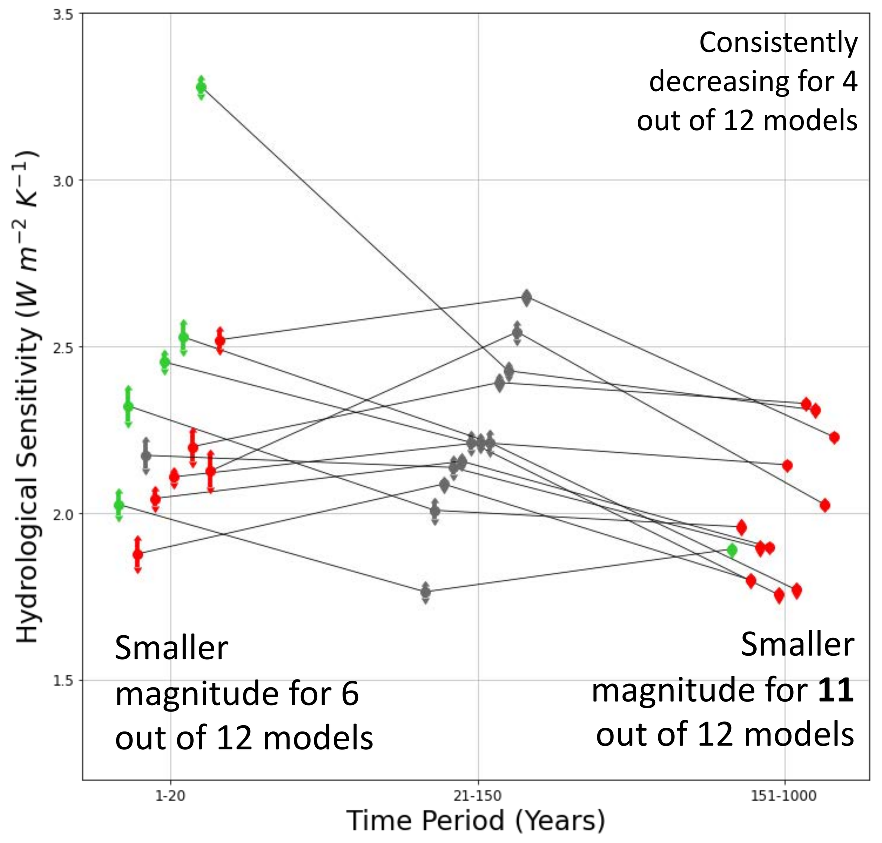
Smaller magnitude for **9** /11 models

Hydrologic Sensitivity

$$HS = \frac{L\Delta P}{\Delta T}$$



In contrast to climate sensitivity, HS for the first 20 years lack a consistent response among models compared to the next 130 years



Green indicates $|m| > |m_{21-150}|$.

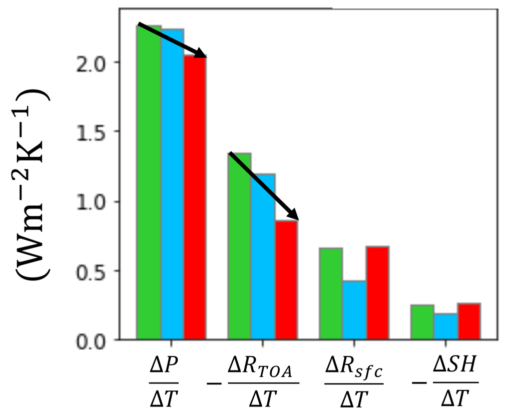
Red indicates $|m| < |m_{21-150}|$.

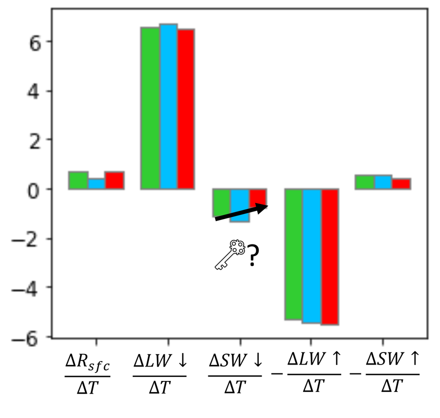
Beyond 150 years, the magnitude of HS decreases for most models

Energy budget

Years 1-20
Years 21-150
Years 151-1000

The only energy budget component changing with the right sign to explain the difference between HS and climate sensitivity seems to be downwelling shortwave radiative flux at surface

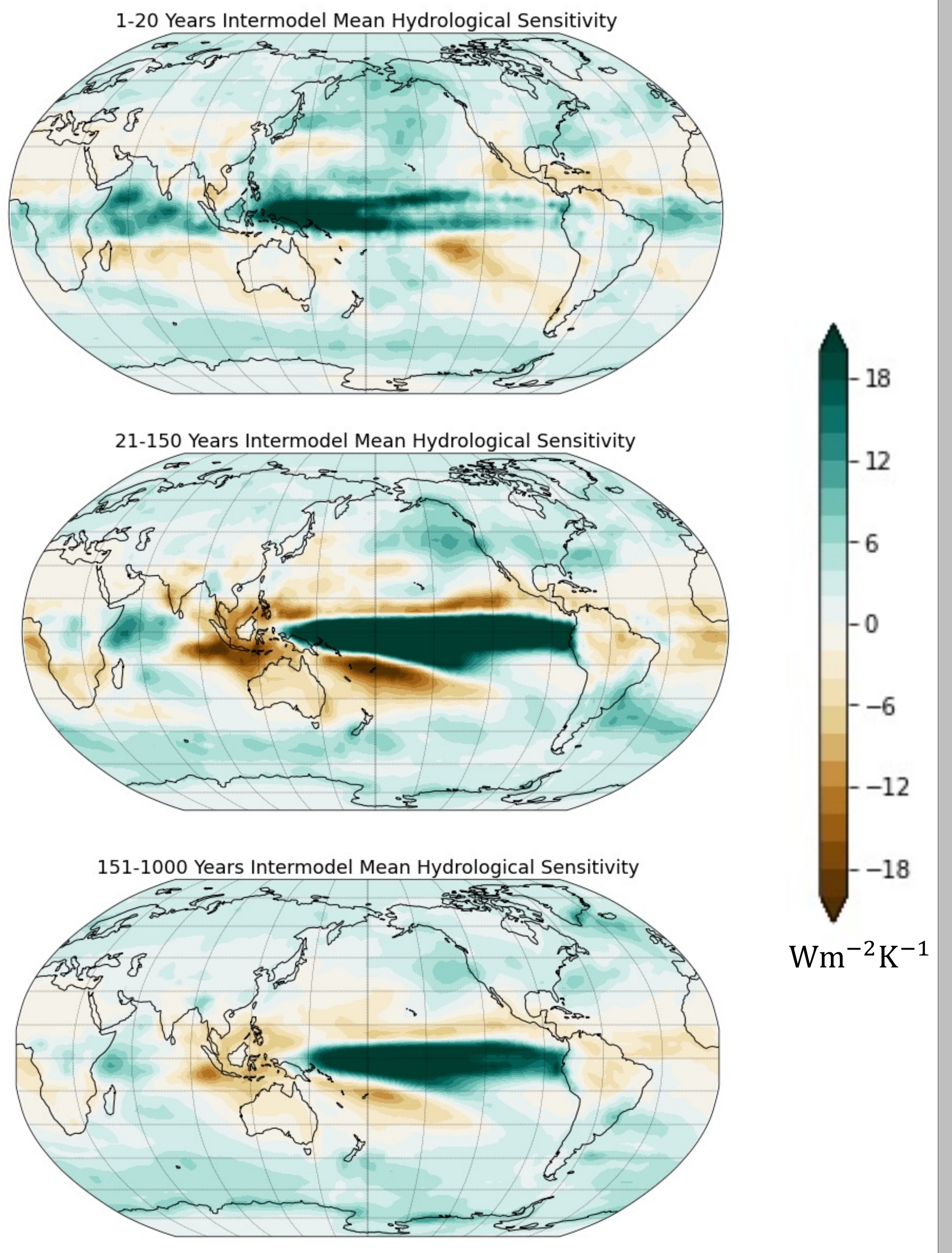




Spatial Patterns in Hydrological Sensitivity

Several regions have reversals in sign of the precip response from years 1-20 to years 21-150

Between years 21-150 and 151-1000, the sign of the precip response generally remains the same, but magnitude of moistening and drying both decrease



References and Acknowledgements

Kao (senior thesis; in review) / Kao and Pendergrass (in prep.)

References

- York. "Least squares fitting of a straight line with correlated errors." Earth and Planetary Science Letters (1968)
- Mahon. "The New "York" regression: Application of an improved statistical method to geochemistry." International Geology Review (1996)
- Rugenstein et al. "LongRunMIP: motivation and design for a large collection of millennial-length AOGCM simulations." *Bulletin of the American Meteorological Society* (2019)
- Gregory et al. "How accurately can the climate sensitivity to CO2 be estimated from historical climate change?" *Climate Dynamics* (2020)
- Payton et al. "Overlapping confidence intervals or standard error intervals: what do they mean in terms of statistical significance?." *Journal of Insect Science* 3.1 (2003).

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