Is the forced response of precipitation timescale-dependent?

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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, it 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?

Hydrologic Sensitivity

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

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

Energy budget

The only energy budget component changing with the right sign to explain the difference between HS and climate sensitivity appears to be the downward shortwave radiation 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 andAcknowledgements

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

References

- Payton et al., \textit{Regression methods applied to TOA radiation} (2003)
- Potthoff et al., \textit{Beyond overlapping confidence intervals or standard error intervals: what do they mean in terms of statistical significance?} Journal of Vertebrate Paleontology (2000)
- Payton et al., \textit{The pattern effect: Coupling of SST Patterns, Radiative Feedbacks, and Climate Sensitivity Workshop, May 10 - May 13, 2022}

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