Temporal Variations in Hydrological Sensitivity

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PCMDI Earth System Model Evaluation Project

Background

An important but uncertain metric of a changing climate is the rate at which global precipitation changes per degree of warming, the hydrological sensitivity (HS). Attempts to observationally constrain HS assume that current-climate variations are informative about its greenhouse warming response. But to the extent that HS exhibits substantial temporal variations, observational constraints may be overconfident, biased, or both. So we ask:

- Does HS vary through time?
- What drives these variations?
- Are HS variations large relative to inter-model differences in "true" HS due to 4xCO_2?
- Is the HS derived from the most recent 30-years predictive of "true" HS?

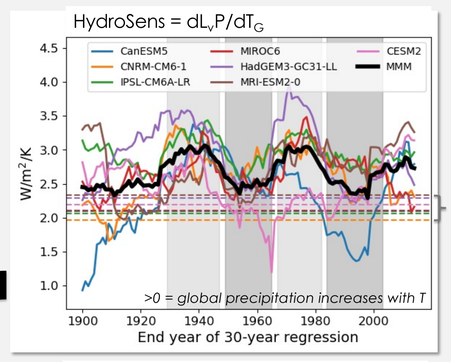
Take Home Messages

- ✓ Substantial inter-decadal HS variations occur in amip-piForcing simulations.
- ✓ These variations exceed the full inter-model spread in "true" HS from abrupt-4xCO2 simulations.
- ✓ Variations in atmospheric longwave radiative cooling – especially surface downwelling clear-sky radiation – drive variations in HS.
- ✓ HS estimated from recent trends are weakly correlated with "true" HS and are biased high, mostly because ATM-to-SFC LW cooling by clouds strengthens in recent decades.
- ✓ Linkage of HS variations to warming pattern variations remains unclear.

Methodological Details

- Take all available CMIP6 models that provided sufficient amip-piForcing experiment data over 1871-2014.
- Compute global- and annual-means, then compute anomalies relative to an 1871–1900 baseline (following Andrews et al 2018).
- Regress L_vP and ATM radiative budget terms on global mean surface air temperature anomalies over sliding 30-year windows.
- For "true" HS, do the same, but compute a single regression over the full 150-year abrupt-4xCO2 experiment.
- Sign convention: positive = more precip = more ATM cooling / less ATM heating

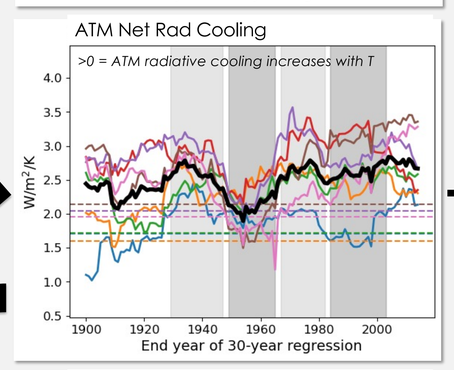
Drivers of Time-Varying Hydrological Sensitivity



←HS varies substantially through time

←In most models, the recent 30-year period implies higher HS than "true" 4xCO_2 HS

"true" HS from abrupt-4xCO2



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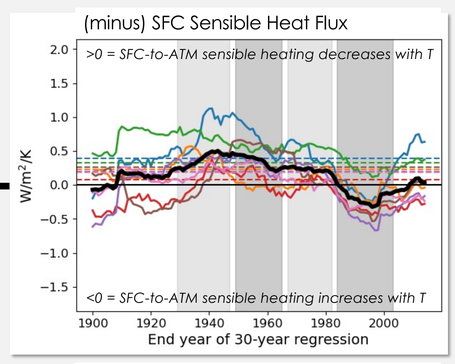

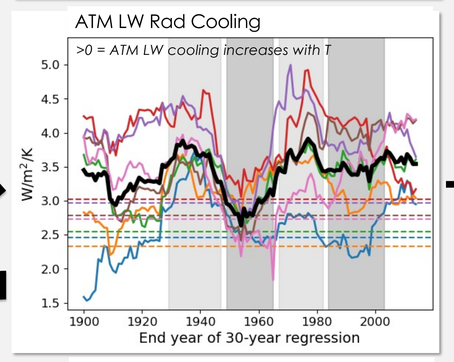

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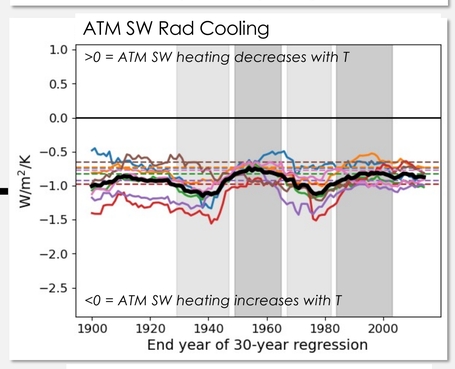

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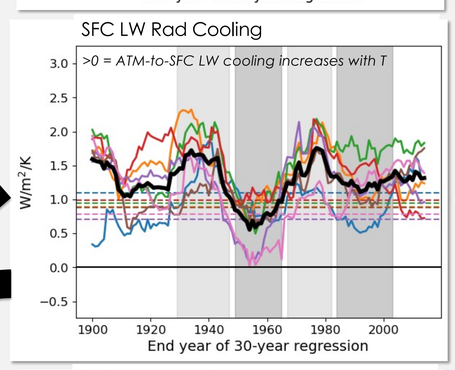

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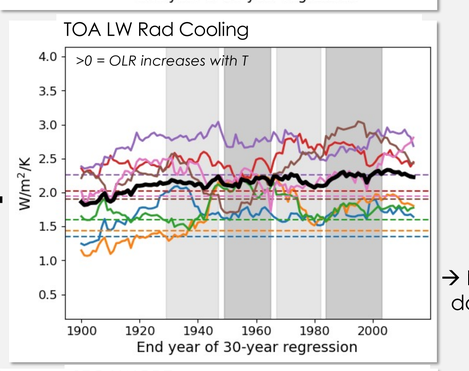

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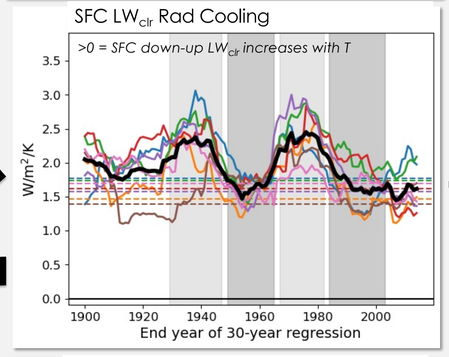

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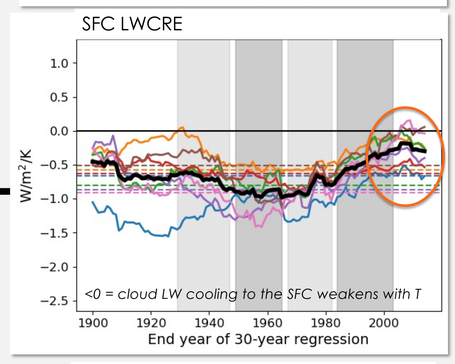
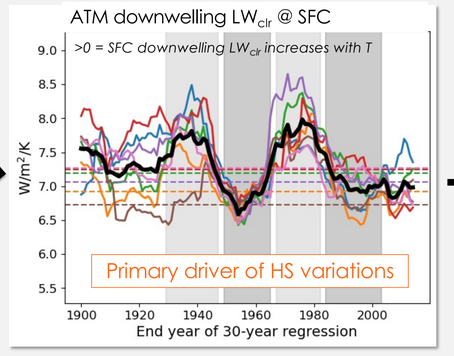


← Causes recent periods to deviate from "true" HS



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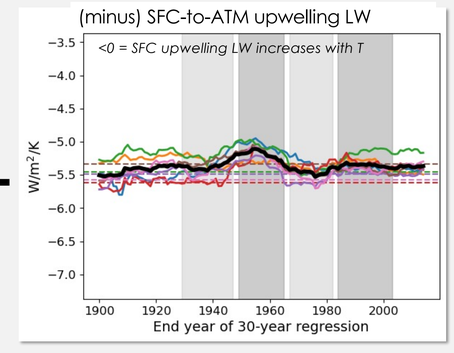
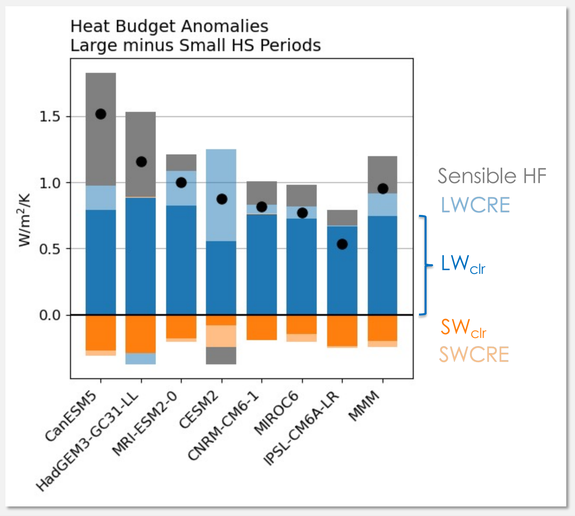


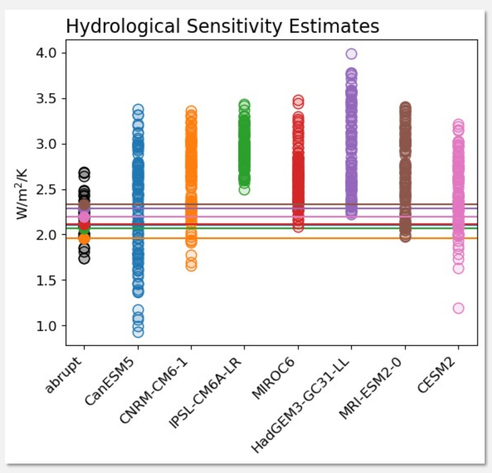
Clear-sky LW Radiative Cooling Rate as a Key Driver

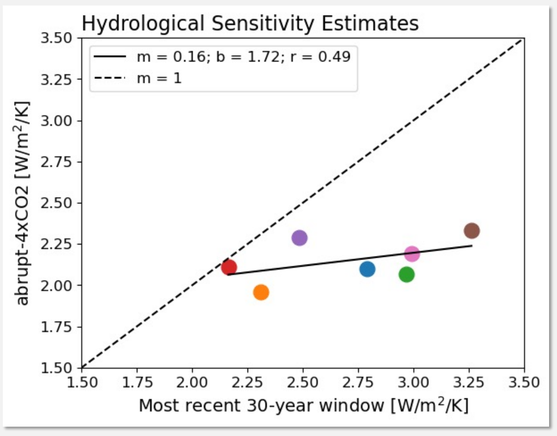


Periods with large hydrological sensitivity exhibit large temperature-mediated increase in clear-sky atmospheric longwave cooling.

Other budget terms can make comparable contribution, depending on model.

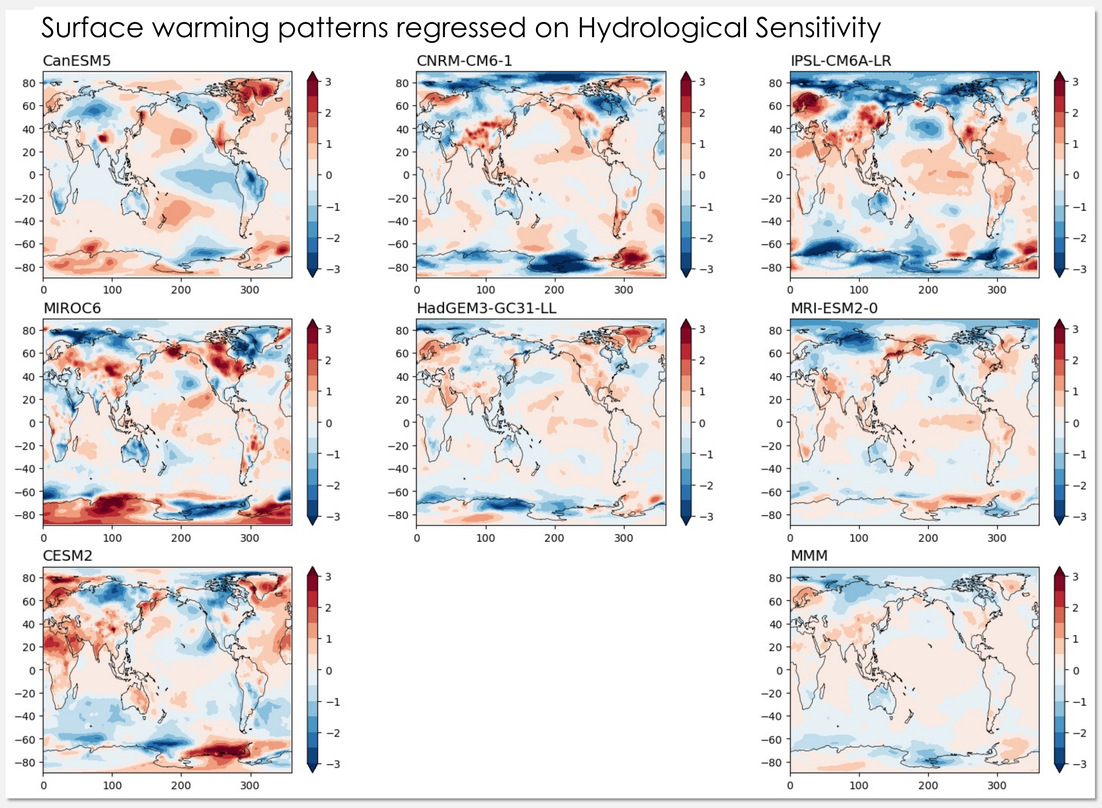
Time-Varying Hydrological Sensitivity in Context





- Inter-decadal HS variations within models exceed the full inter-model spread in "true" HS.
- Many models show little or no overlap between amip-piForcing HS distribution and "truth".
- Weak correlation exists between recent-period HS and "true" HS.

Dependence on Warming Patterns



Warming patterns during periods with higher-than-average hydrological sensitivity show little agreement among models.

More work is needed to understand what drives variations in the ATM heat budget and HS, and how these are related to the TOA radiative budget and ECS (or not).

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