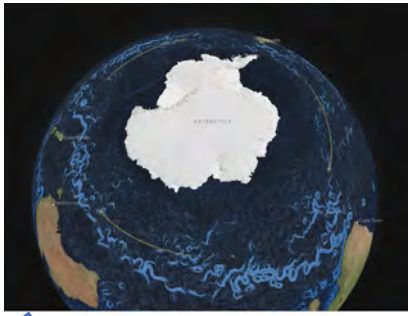
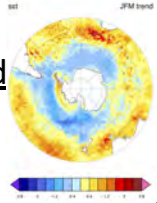
Antarctic ice cores are the paleo Southern Ocean



World revolves around the Southern Ocean

Many explanations for S.O. SST trend



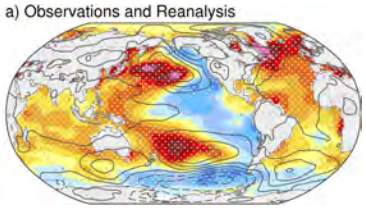
- Delayed warming/ MOC
- Modes of variability and winds
- Antarctic meltwater
- Forced wind response to ozone and/or CO2
- Negative cloud feedback

Southern Ocean

Strongly linked to ECS

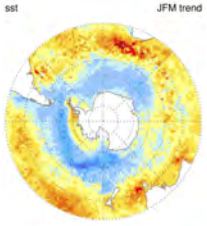
Heat uptake
Carbon uptake
Cloud feedbacks

Strongly linked to tropical Pacific

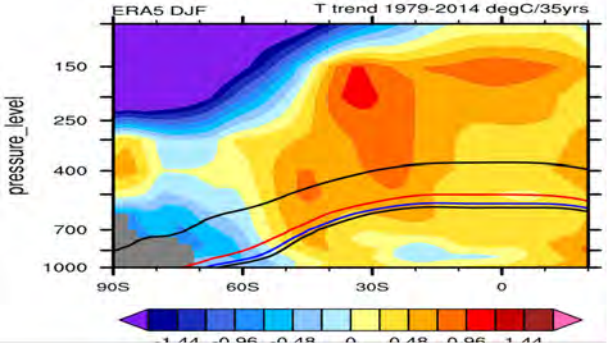


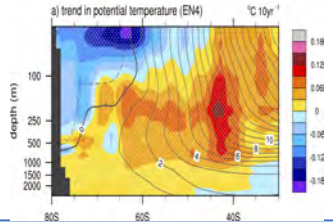
Q1: If models got the SST (& sea ice) trends in the Southern Ocean right, for the right reasons, would everything else fall into place?

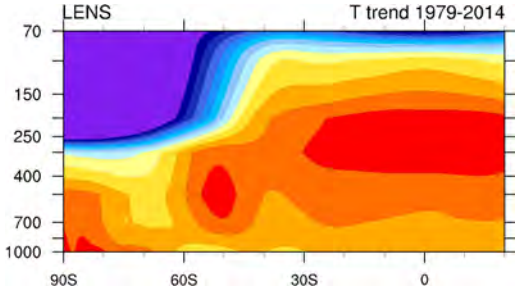
CESM1 experiments

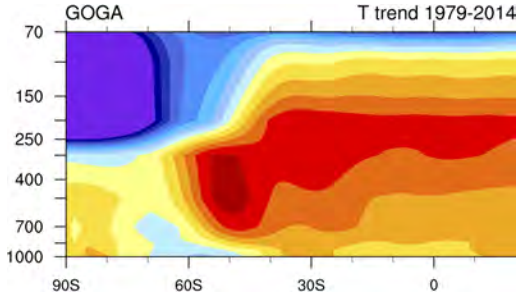


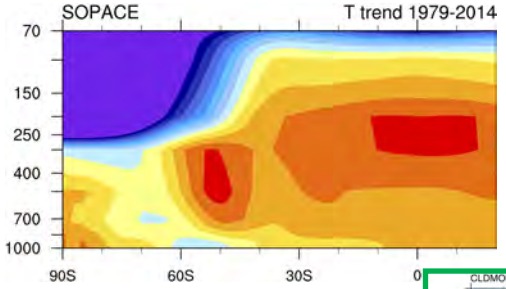
OBS & reanalysis

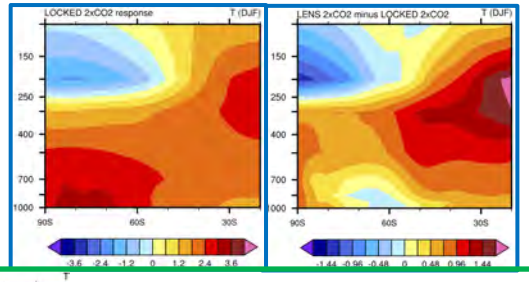


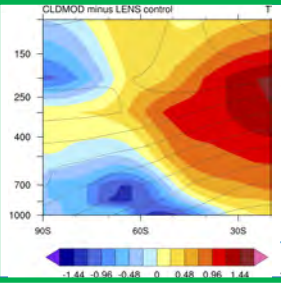












CESM1-LE climatology minus LENS climatology looks similar to the observed trend in troposphere.*

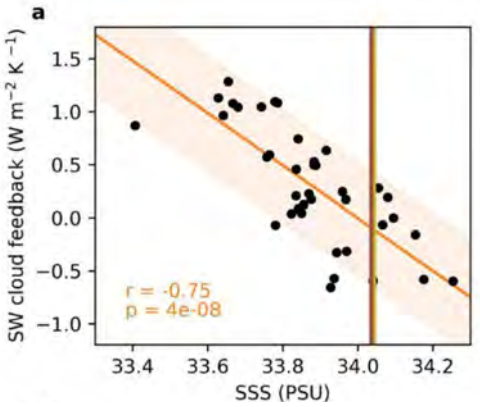
**Shows the impact of increased supercooled cloud liquid.* Kay et al., 2016; Schneider, Kay, Lenaerts 2020

Q2: What can we learn by looking in the vertical dimension (not just at SST patterns)?

Q3: What observations have been most essential to your science? What new observations or observational syntheses would you like to have?

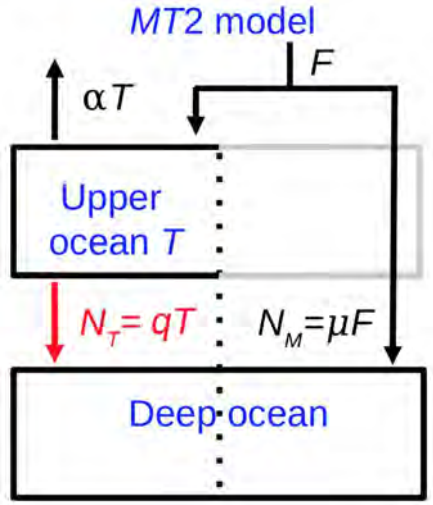
Exciting new ideas

- Importance of climatological salinity in determining Southern Ocean OHU and cloud feedbacks (Maofeng Liu's poster)



- Ts-independent component of N related to Southern Ocean OHU (Jonathan Gregory's poster)

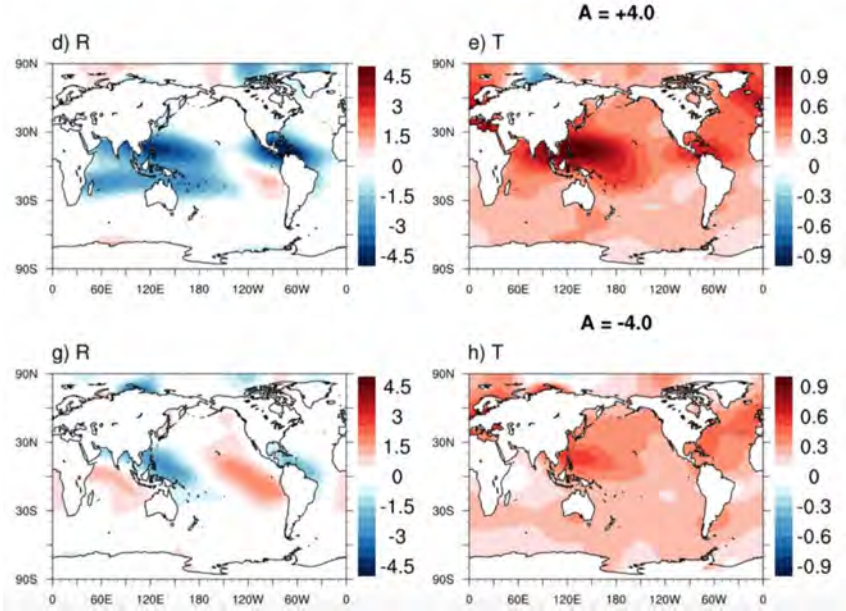
⇒ Time-dependent OHU *efficiency* γ(t). Implications for OHU *efficacy* ε ?



Wary of involved methodologies

– **Feedback formalisms** require consequential choices (qv vs. RH, local vs. global normalization, etc. etc.)

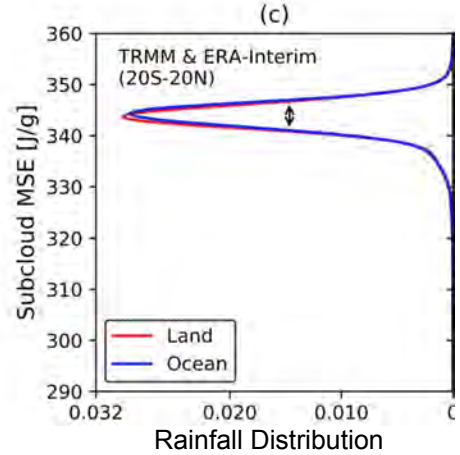
– **Green's function** approaches: Emphasize non-locality, but are they actually linear in T(x)? (Bosong Zhang's poster)



How Tropical Convection Couples High Moist Static Energy Over Land and Ocean

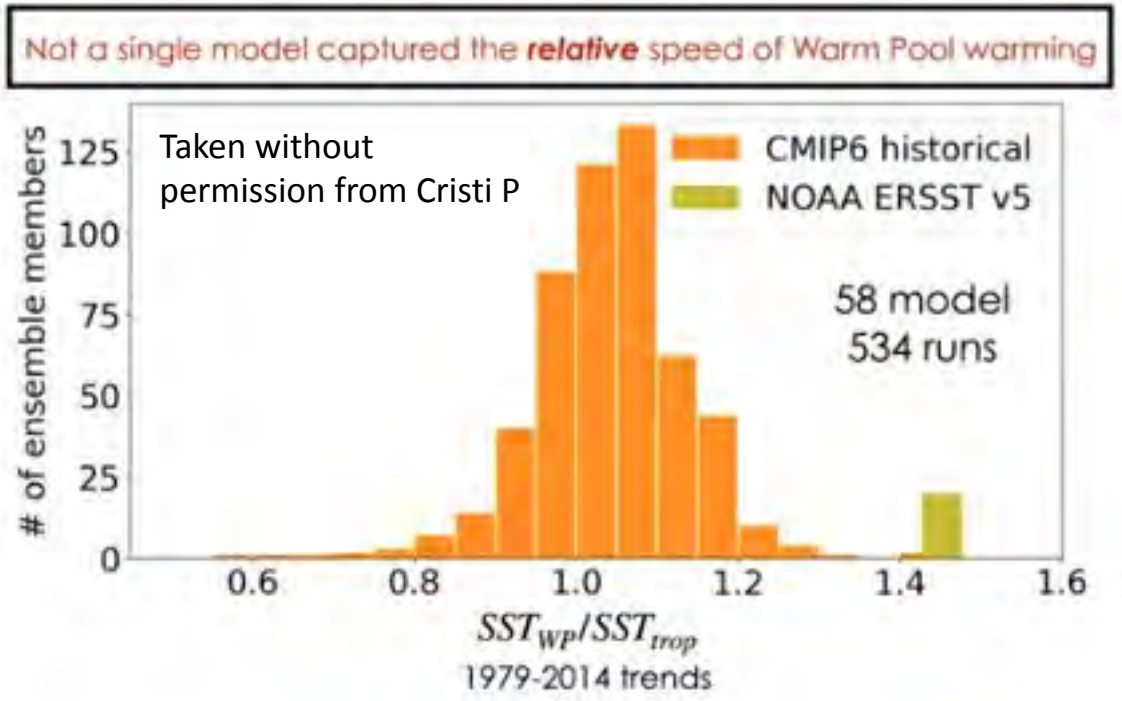
Yi Zhang[1] and Stephan Fueglistaler[1,2]

Tropical convection exhibits well-understood threshold behavior
⇒ **inherently non-linear**!



(Why) do models fail to capture observed warming patterns?

- Its partly forced and they have the wrong forcing / response to forcing?
- Insufficient natural variability? (biased cloud feedback on warming patterns)
- They do if you run them enough times?



See also Zhou et al (2016); Fueglistaler and Silvers (2021)

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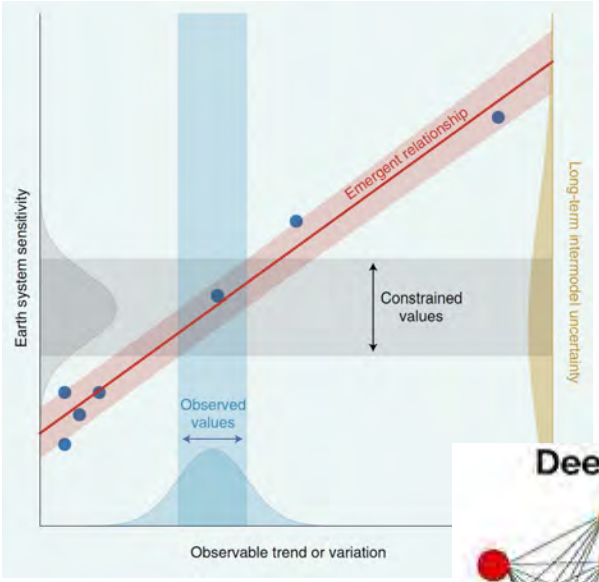
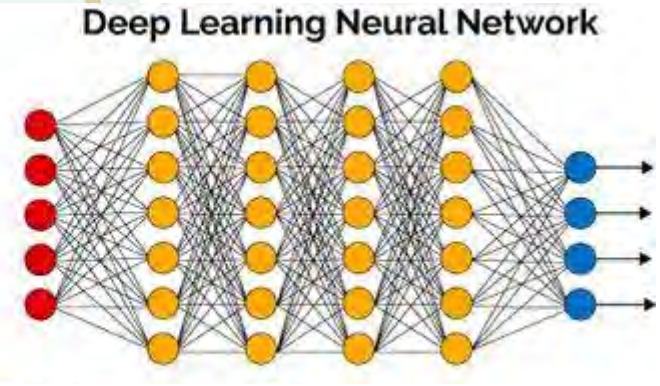
(Why) do models fail to capture observed warming patterns? …and should we trust their future warming predictions?

- Can we develop some emergent constraints on future warming patterns?
- Out of sample (Paleo) tests of GCMs
- Finding ways to disentangle forced and unforced warming patterns seems like a crucial first step
  - Job for ML?
  - Ancillary information (sub-surface, altimetry, etc)?

Eyring et al (2019)





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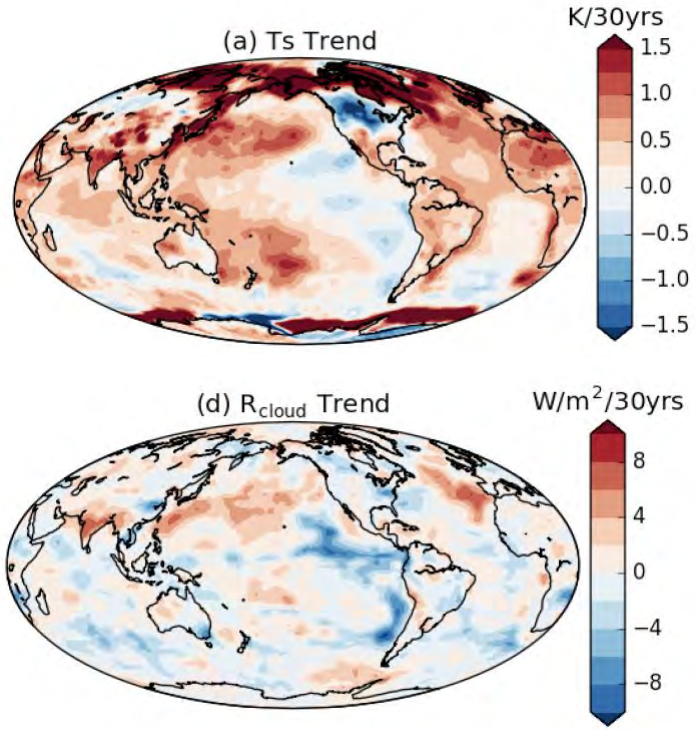
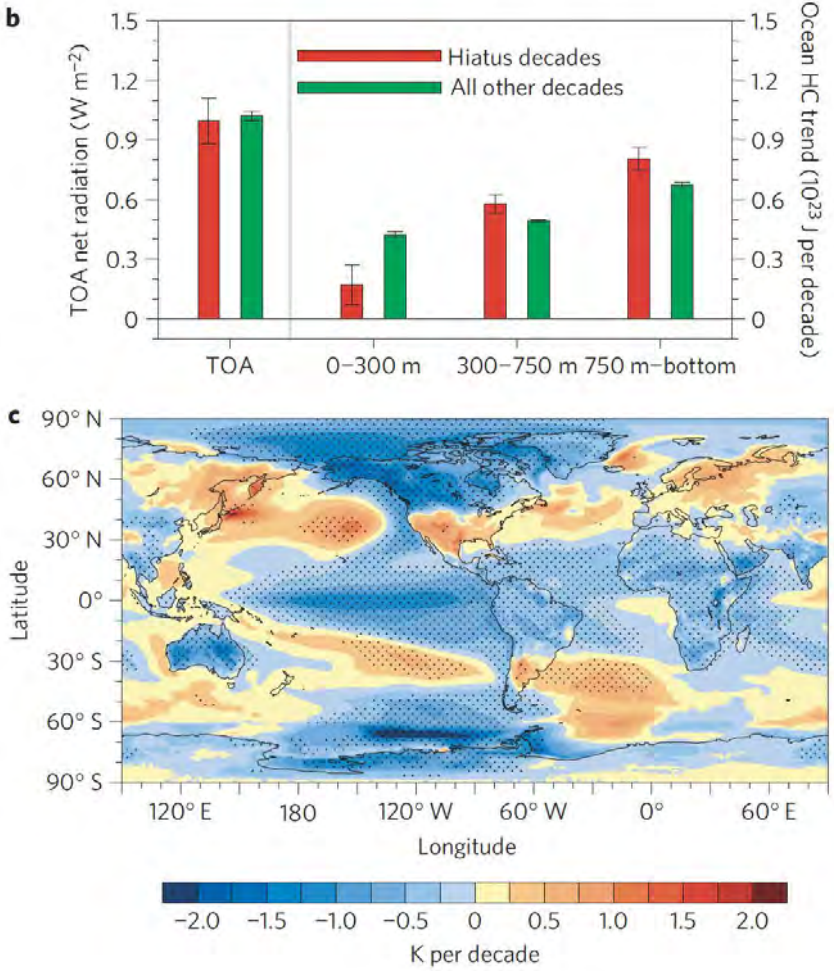
(How) are OHU and TOA feedbacks related via pattern effect?





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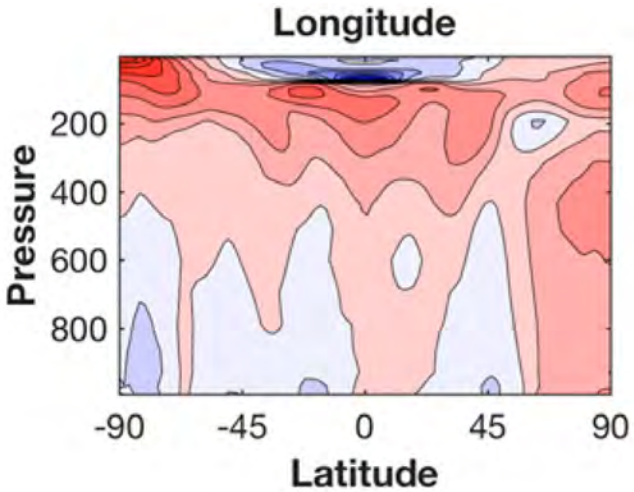
Zhou et al (2016)

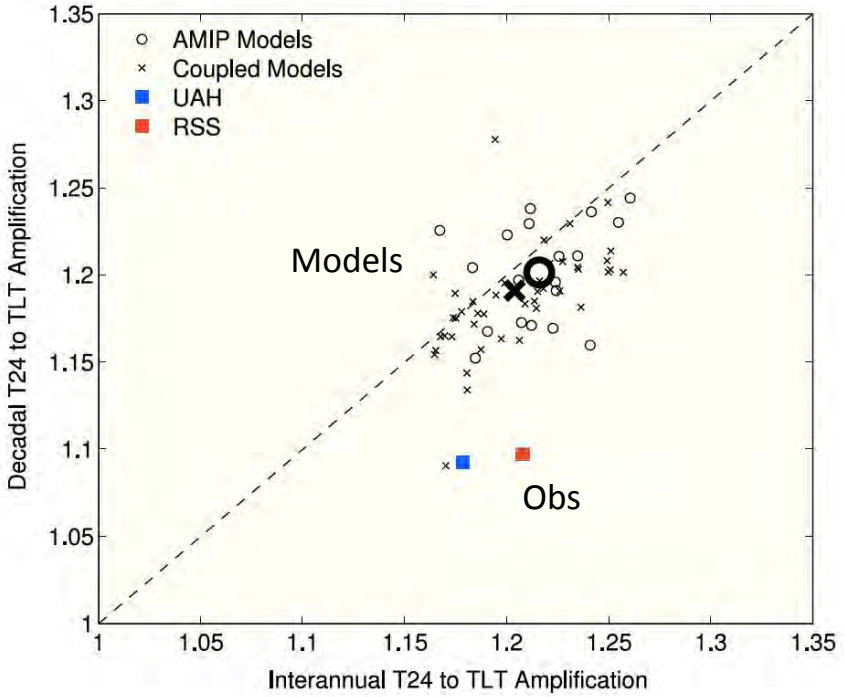
Meehl et al (2011)

Why do coupled models get too much tropical upper tropospheric warming despite simulating a weaker west-to-east warming gradient?



Temperature Response to
W. Pacific warming
Dong et al (2019)

Upper tropospheric Warming Amplification



Po-Chedley and Fu (2012)

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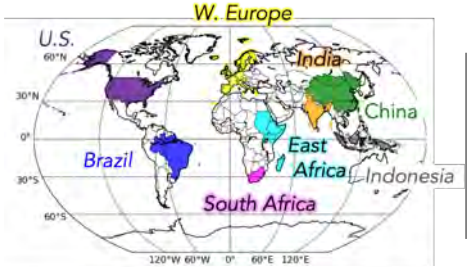
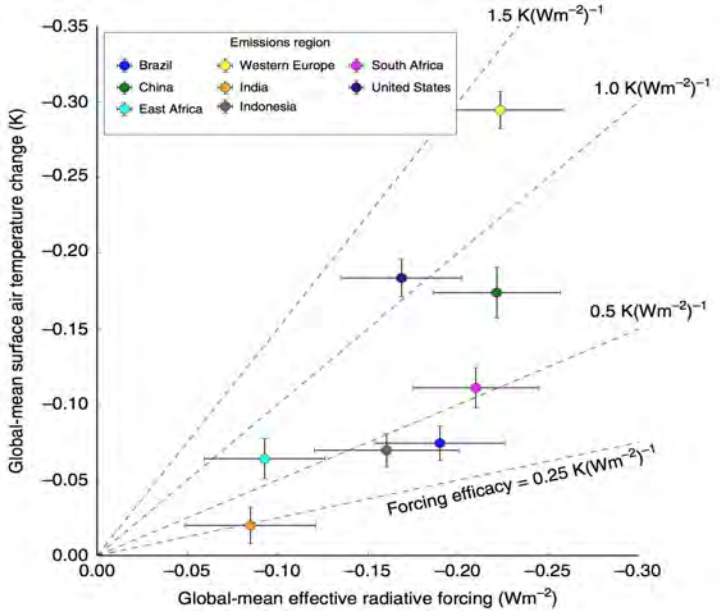
Is the SST pattern the only thing that matters for a “pattern effect” on decadal to multidecadal timescales?

- Land surface temperatures?
- Spatial pattern of heterogeneous anthropogenic radiative forcings (including atmospheric adjustments)? How heterogeneous is heterogeneous enough?
- Patterns of heterogeneous natural forcing that might be correlated with large-scale shifts in the climate system? (desert dust, wildfire, ocean DMS)



Total emissions Δ in each region
= China year 2000 emissions
22.4 Tg sulfate precursor
1.61 Tg black carbon
4.03 Tg organic carbon

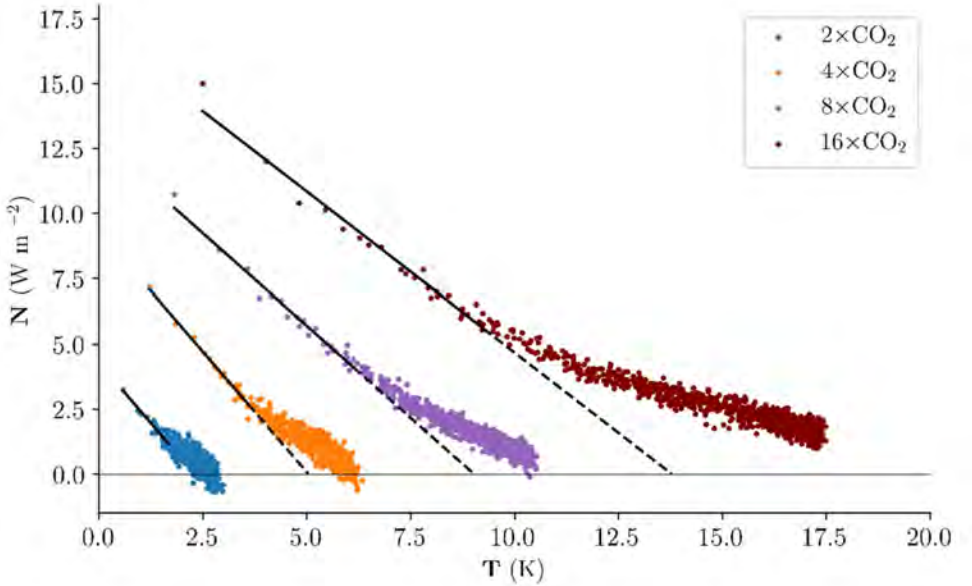


Geeta Persad | The University of Texas at Austin | geeta.persad@jsg.utexas.edu

Persad and Caldeira (2018)

What is the utility of understanding purely CO2-driven feedbacks if we think the feedbacks behave differently in response to other forcings/depend on what else is happening in the earth system?

- On human timescales, multiple forcings will always be varying in tandem
- Even on paleo timescales, CO2 forcing happens on a background of other earth system changes
- Just because CO2 drives the global-mean, doesn't mean it drives the anomalies from the global-mean



Rohrschneider et al. (2019)

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Ways forward. Some random thoughts

Piers Forster (University of Leeds)

1. Defining types of pattern effect(s)

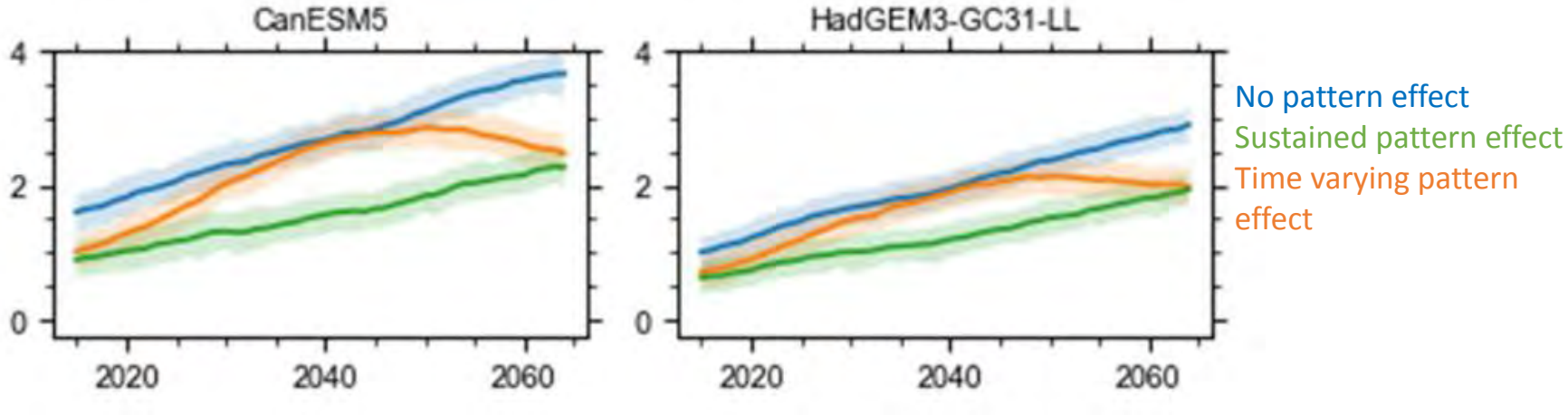
- timescales
- patterns
- variables
- **processes**

Ways forward. Some random thoughts

Piers Forster (University of Leeds)

2. Can we set bounds?

- Zhou et al. (2021) committed warming
- Could current pattern effect grow?



Lawrence Jackson, emulation of ESMs under SSP245 adding historic pattern effect onto AMIP runs

Ways forward. Some random thoughts

Piers Forster (University of Leeds)

3. Historic pattern effect might not exist or matter

- Address uncertainties in observations and models
- What is appropriate reference state?
- Are there compensating effects for lambda in ocean?

Ways forward. Some random thoughts

Piers Forster (University of Leeds)

4. Design clever model experiments

- Green functions useful but remember it's a coupled problem
- Testable hypothesis for a "pattern effect" MIP
- Role of forcing under examined?
- emergent constraints/paleo constraints or process tests for pattern effects
- Chip away at problem starting with what we know best, e.g. southern ocean?

- **High resolution models for clouds/ocean mixing**
- **Testing and rejecting simple physical models of pattern effect**
- **AMIP like but wind nudging: so keep the coupling…**