Analyzing the Unforced Pattern Effect Using a Modified Energy Balance Framework

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Motivation

Evaluating the model performance is essential to understand the reliability of model-estimated climate feedbacks and climate sensitivity.

Climate Feedback: $\lambda = \frac{\Delta R - \Delta F}{\Delta T_S}$

However, there are several issues in the traditional energy balance framework, including the pattern effect.

Dessler et al. (2018): $\theta = \frac{\Delta R - \Delta F}{\Delta T_A}$

ΔT_A is the 500hPa tropical temperature.

The goal of this poster is to analyze the short-term climate feedbacks in models using two frameworks, especially focus on the impacts of unforced pattern effect.

Data

Observation:
- CERES EBAF Ed4.1 and ERA5 reanalysis
- March 2000 to October 2017

Model:
- 26 models in CMIP6 pre-industrial control run
- **Divided into several 18-year segments** to be consistent with the observations
- For each model, there are ~27 estimates of feedback from individual 18-year segments.
- Abrupt4xCO2 runs are also analyzed

Climate feedback decomposition:
- Radiative kernels from Huang et al. (2017)
- Feedback is estimated by regressing TOA flux anomaly against global average surface temperature anomaly

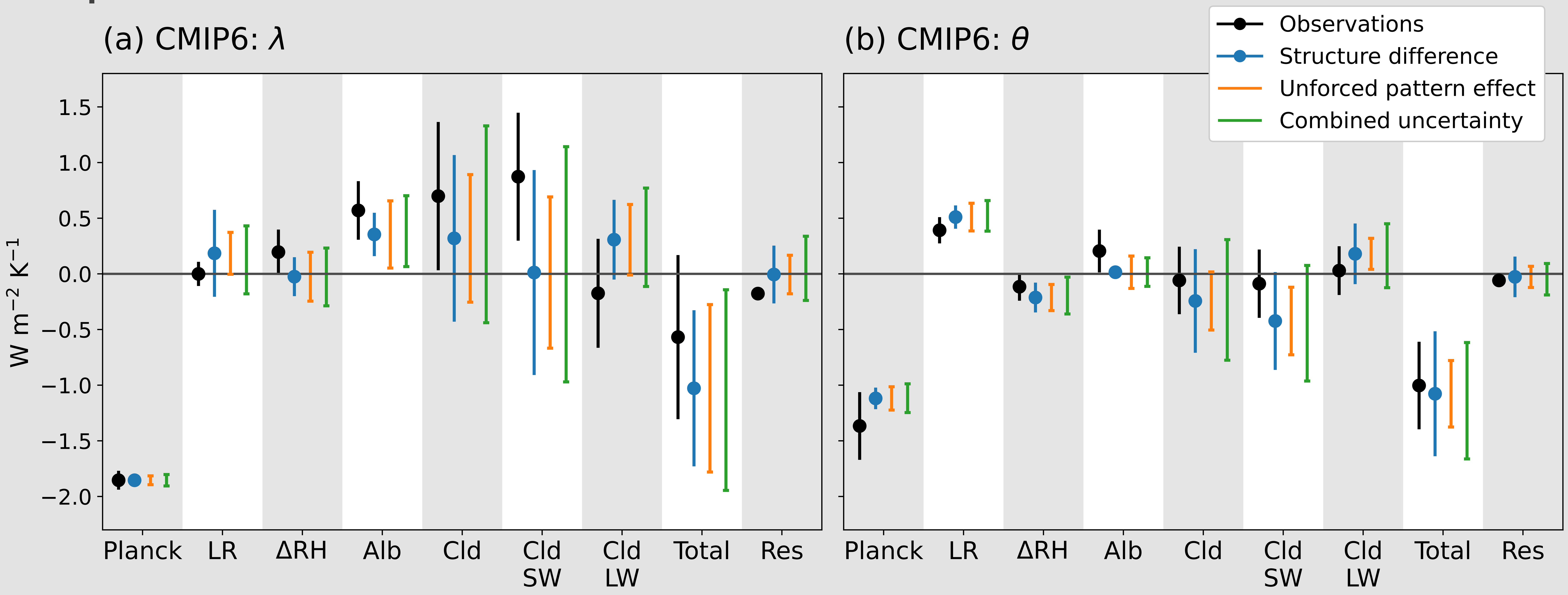
Sources of uncertainty in model

Structure difference
The differences in model parameterizations
*(±1.645*standard deviation)*

Unforced pattern effect
The pattern effect due to unforced variability
(avg of model spread, excluding max and min values)

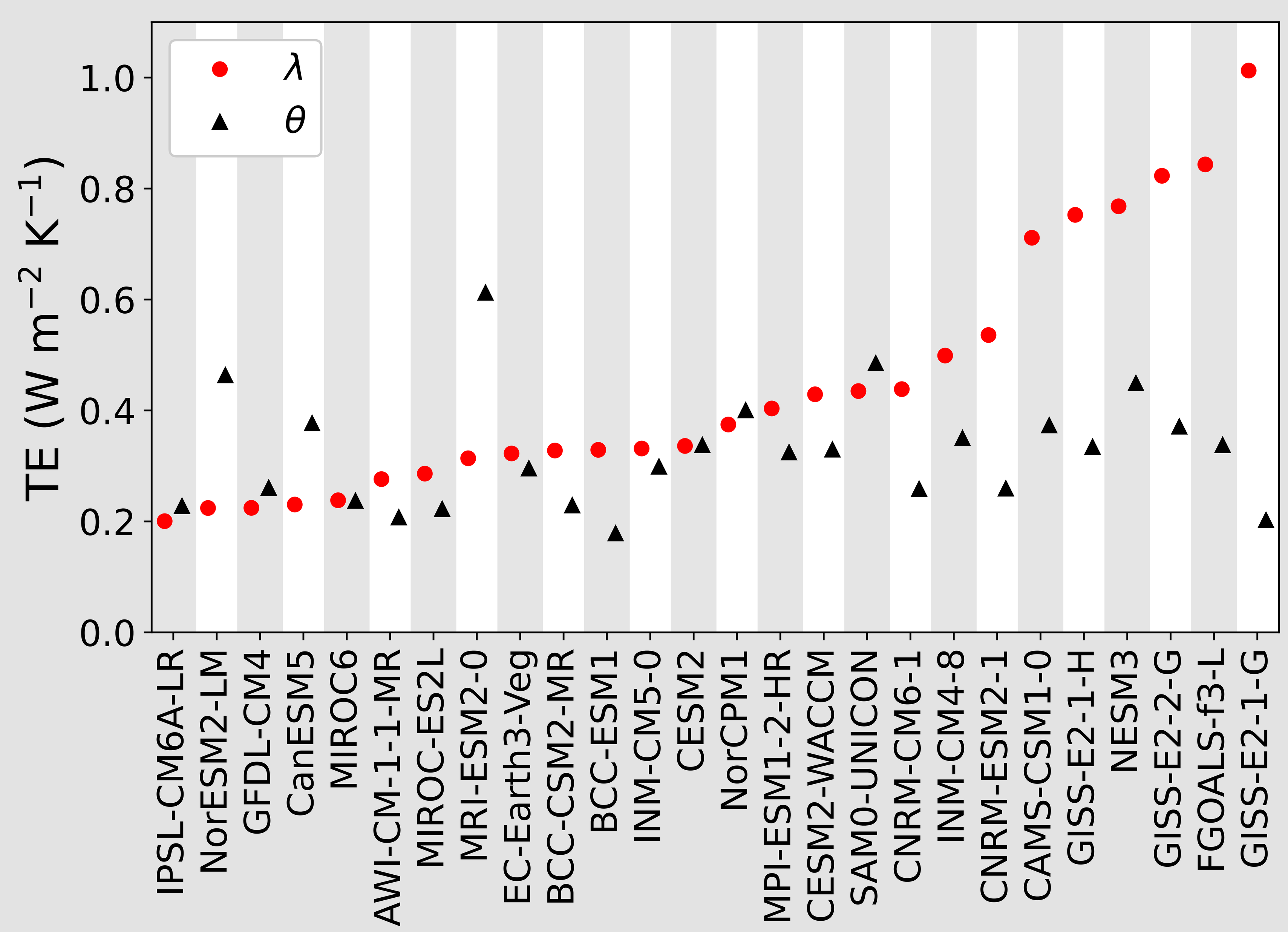
Combined uncertainty
(5% – 95% range of all 18-year feedbacks from all models)

Comparisons of λ and θ frameworks



- The uncertainty in the observed feedbacks are smaller in the θ framework
- The spread among the CMIP6 models is smaller in the θ framework
- The spread among the 18-year segments of individual models is smaller in the θ framework, implying that the unforced variability has less impacts on the 500-hPa temperature.

Model evaluation



Quantify the model performance by the differences between observed and modelled feedbacks:

$$TE = \sqrt{\sum_i \left(\lambda_{i,obs} - \lambda_{i,model}\right)^2}$$

i = Planck, lapse rate, ΔRH, albedo, cloud

- CMIP6 ensemble average TE is 28% smaller in θ framework
- 70% of the models (18 of 26) have smaller TE value in θ framework

Concluding remarks

- Unforced pattern effect is not negligible. Both uncertainties are important when comparing to observed short-term climate feedbacks
- The modified framework provides a more robust way of comparing short-term climate feedbacks, with both smaller structural differences and smaller unforced pattern effect.

Check more information at:

Chao, L.-W., & Dessler, A. E. (2021). An Assessment of Climate Feedbacks in Observations and Climate Models Using Different Energy Balance Frameworks. *Journal of Climate*, 34(24), 9763-9773.

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