Parametric sensitivity of cloud feedbacks in CAM6

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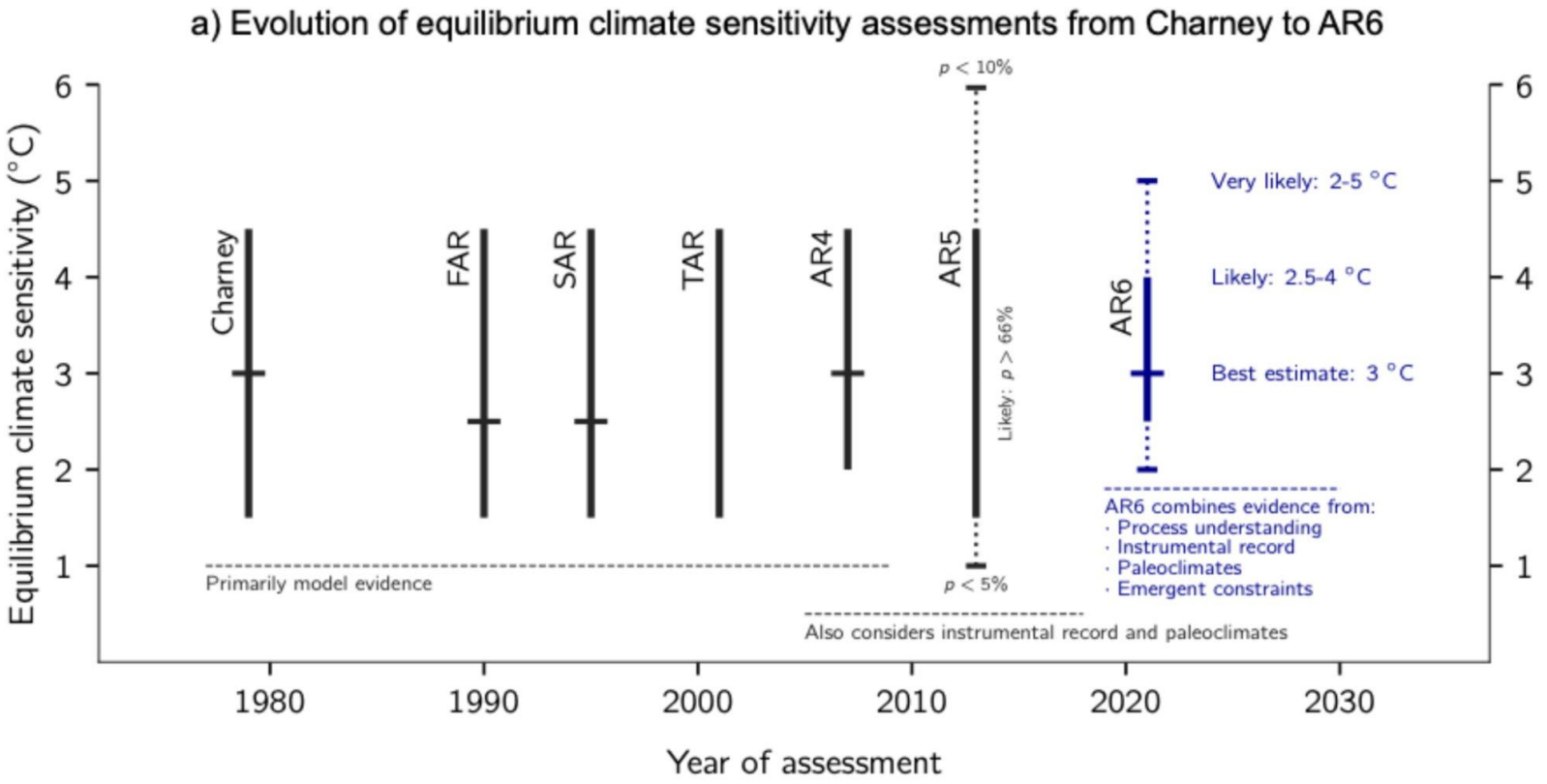
Equilibrium climate sensitivity (ECS) quantifies global warming… and is very uncertain!

- Global mean surface warming per doubling of atmospheric CO_2, at equilibrium



How does ECS relate to cloud feedbacks?

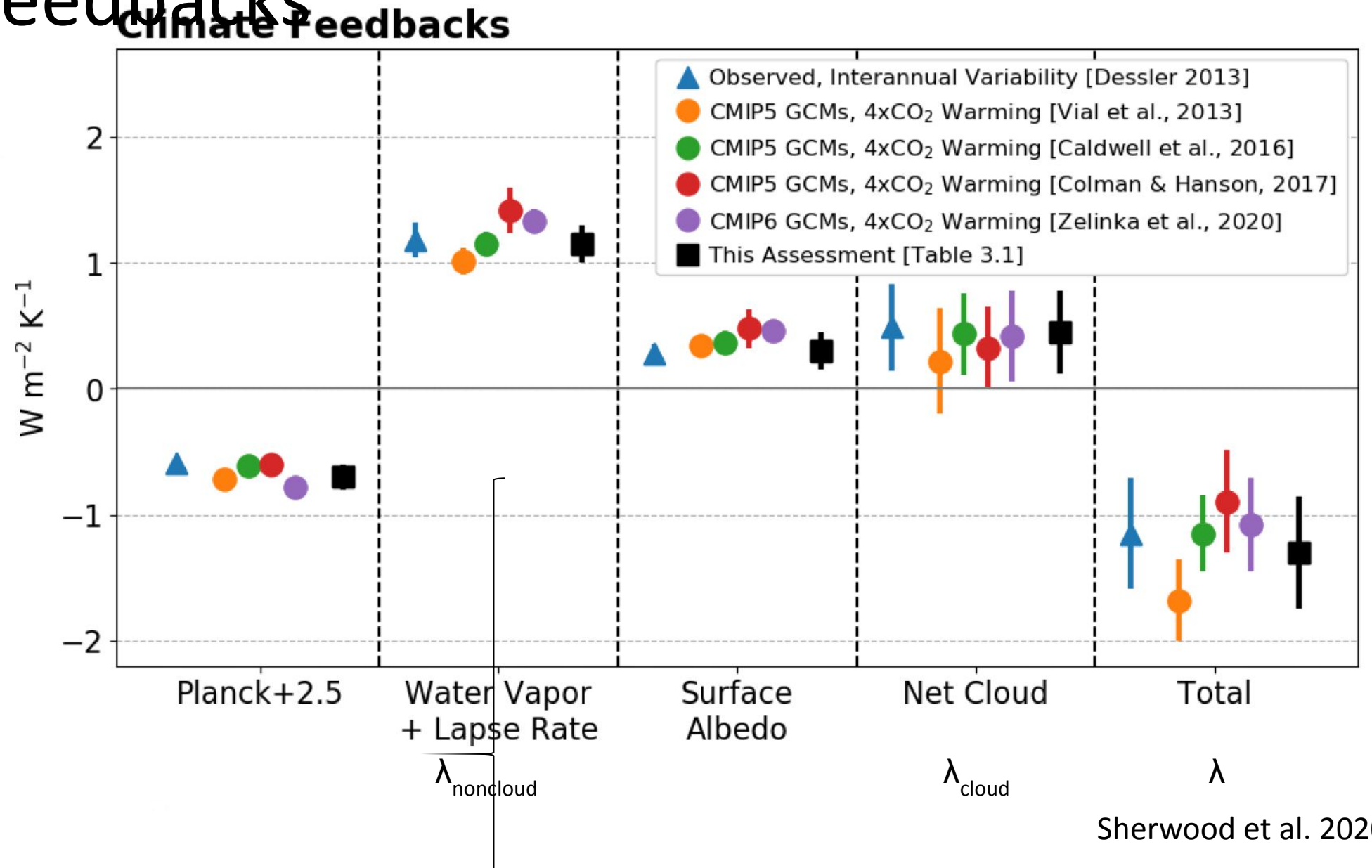
$$ECS = -\frac{\Delta F}{\lambda}$$

ΔF ← Forcing

λ ← Feedback

$$\lambda = \lambda_{\text{cloud}} + \lambda_{\text{noncloud}}$$

Spread in feedbacks is largely from cloud feedbacks

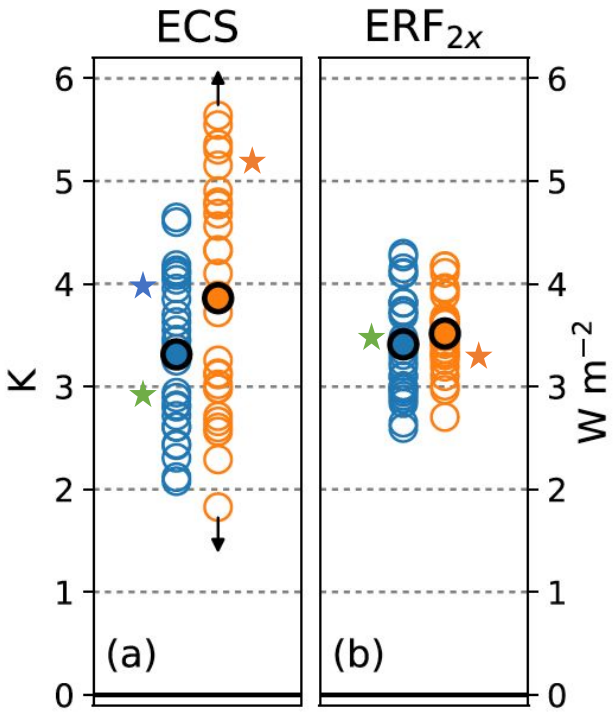


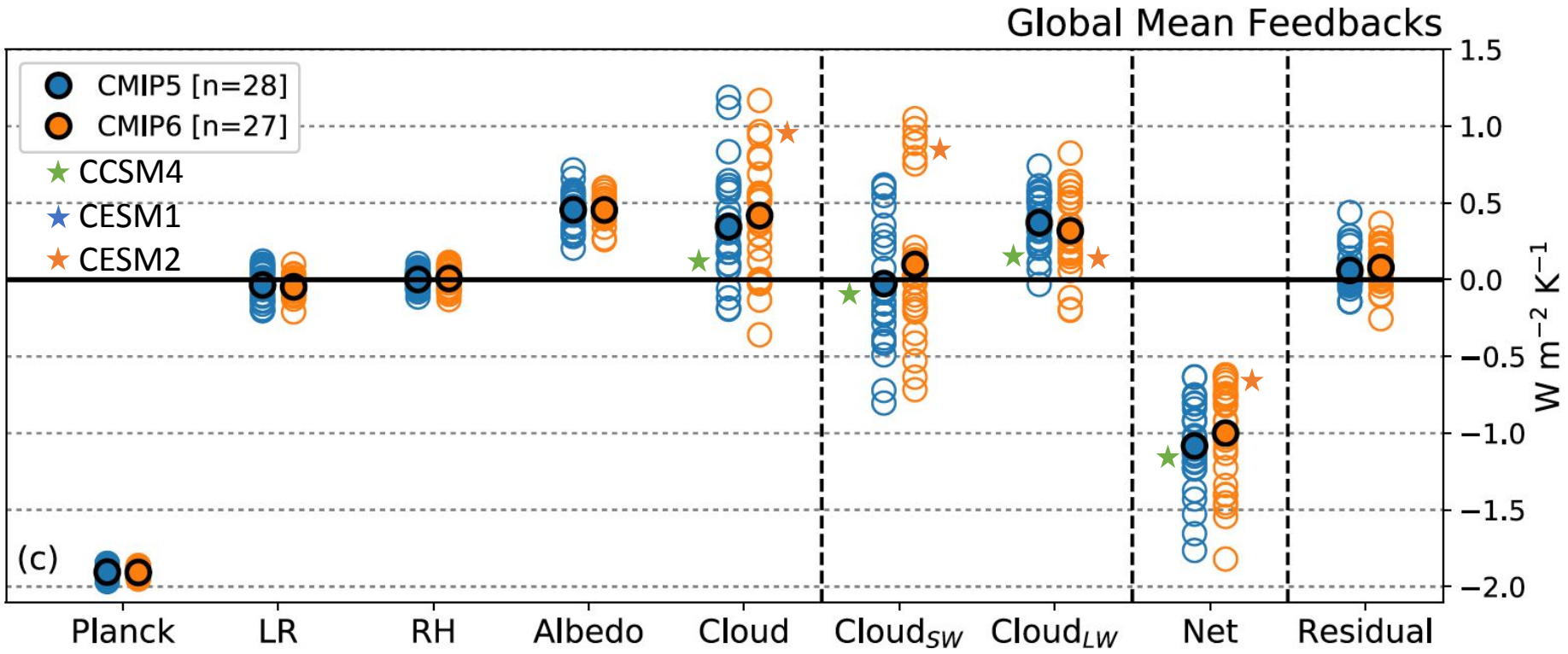
Positive/amplifying feedback

Negative/stabilizing feedback

Sherwood et al. 2020

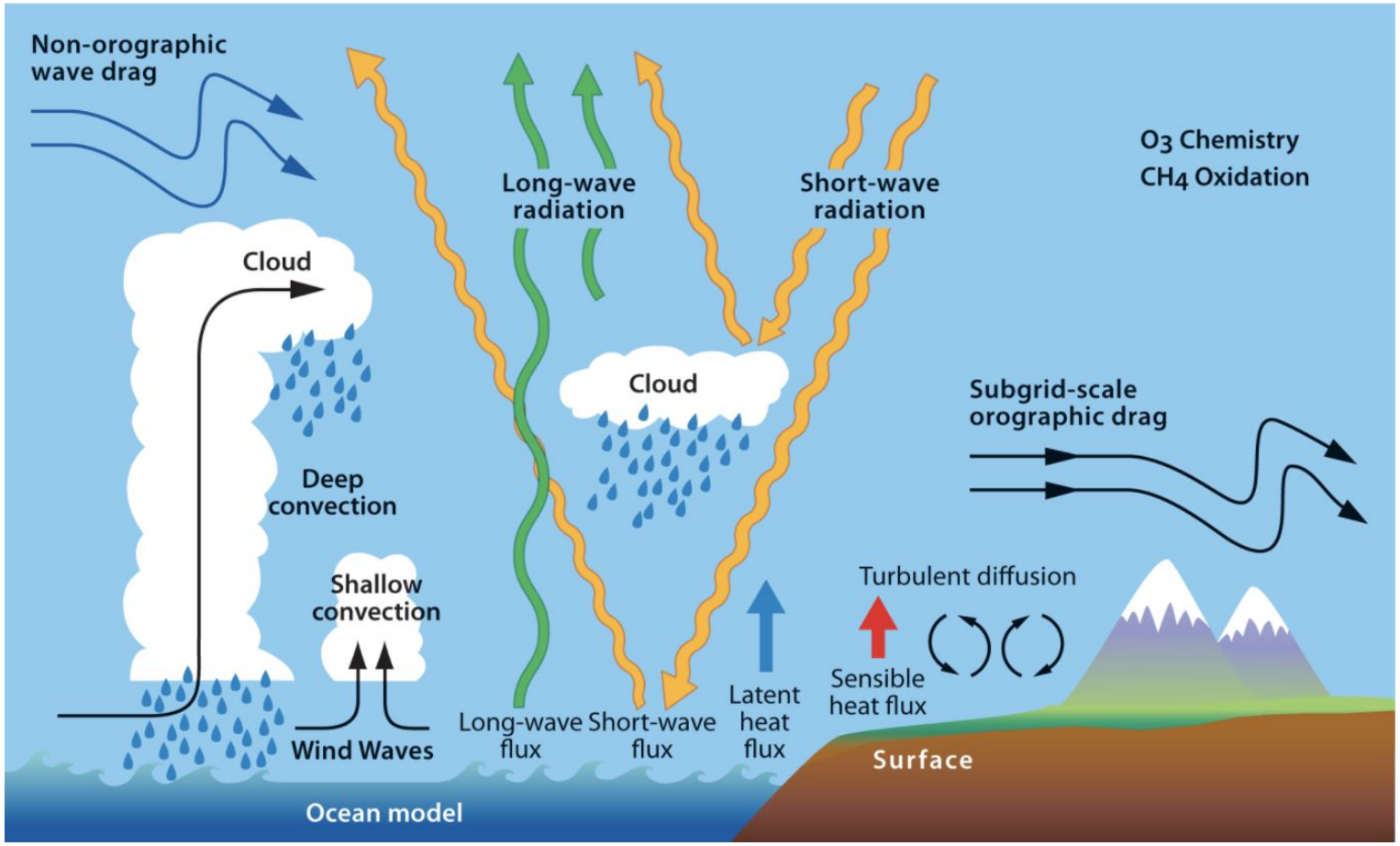
Range of ECS estimates increased from CMIP5 to CMIP6





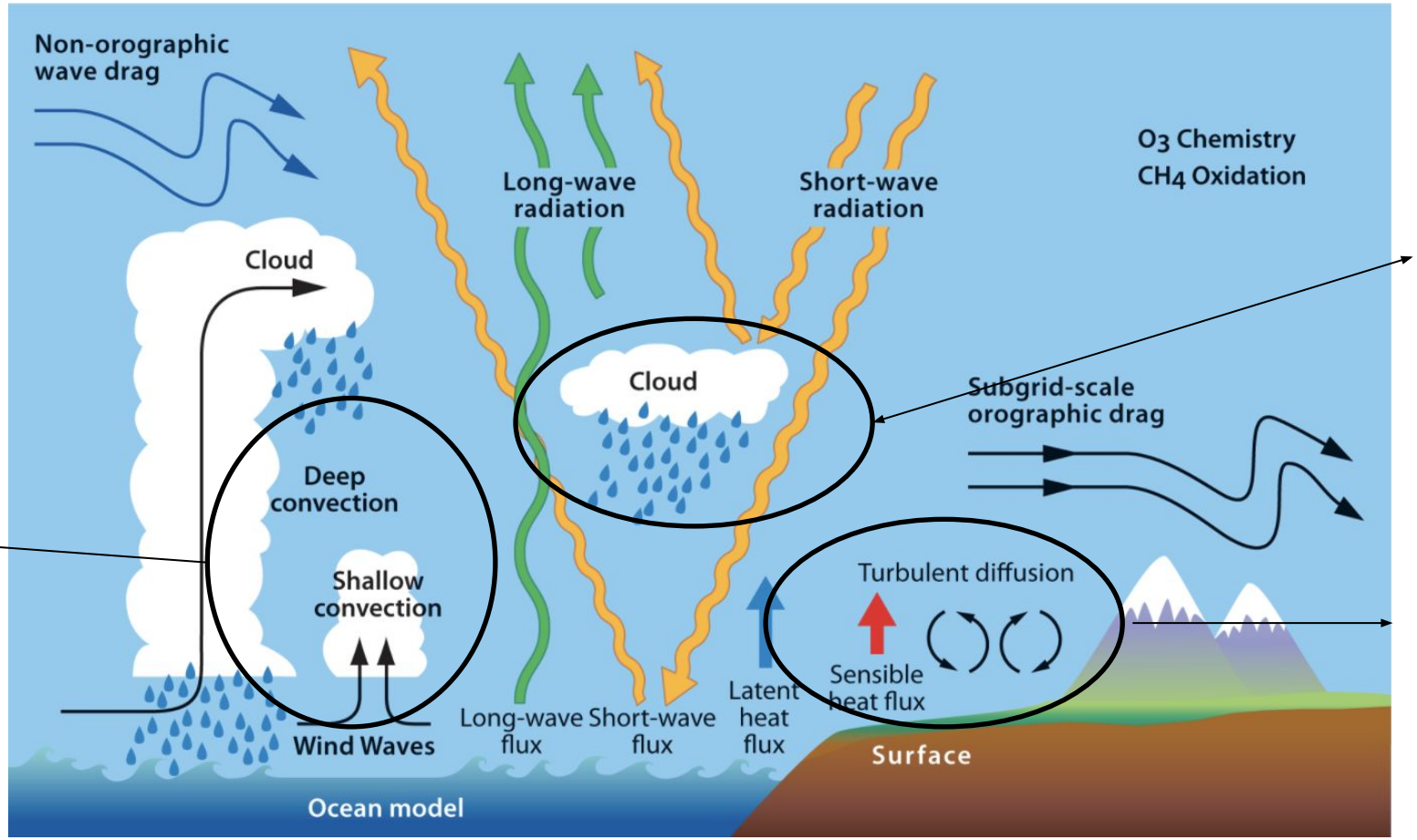
Zelinka et al. 2020

Here we focus on the influence of atmospheric **parameters** on cloud feedbacks



NCAR CESM

We vary 45 atmospheric parameters from 5 different schemes



ZM: convection

MG3: cloud microphysics
PUMAS: more microphysics
Aerosol

CLUBB: turbulence

NCAR CESM

The CAM6 perturbed parameter ensemble has a large spread in cloud-radiative feedbacks

PPE experiments

- CAM6 – atmosphere only
- 45 atmospheric parameters vary
- 3 years each
- Fixed SST
- PD: Present day simulation
- SST4K: Uniform 4K warming simulation

- 262 simulations are run

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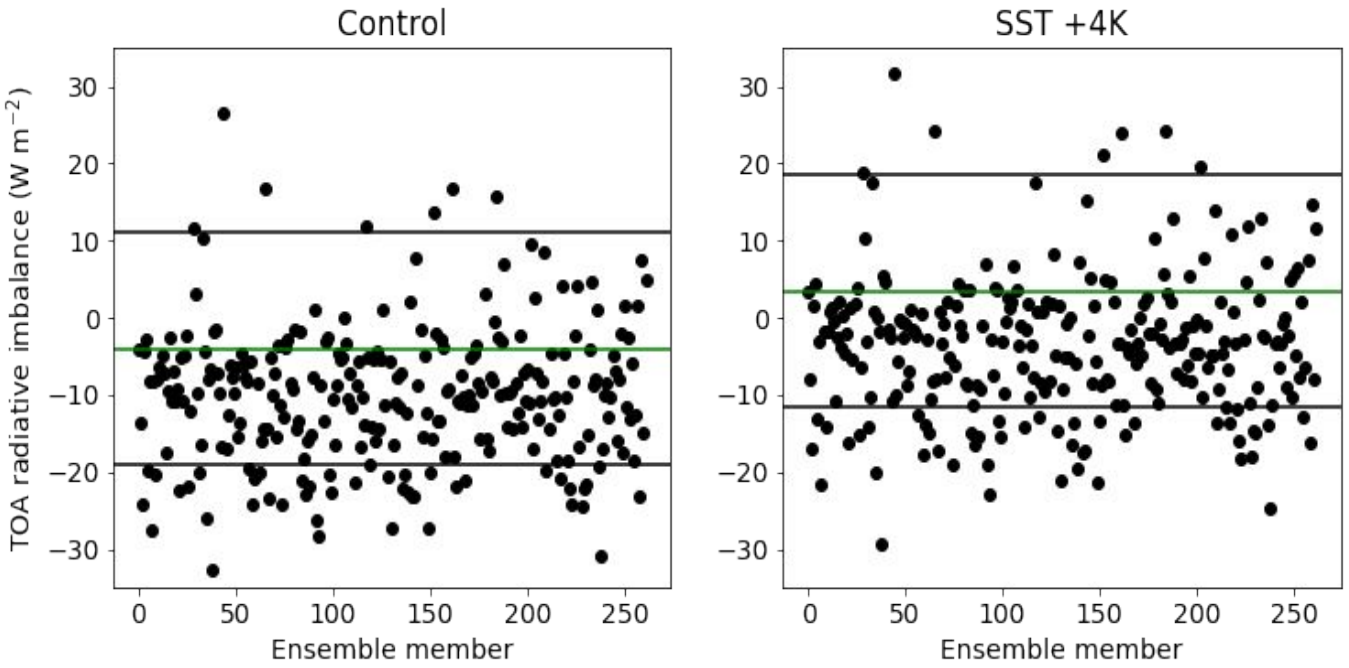

A TOA radiative imbalance of 0 W m^{-2} indicates equilibrium

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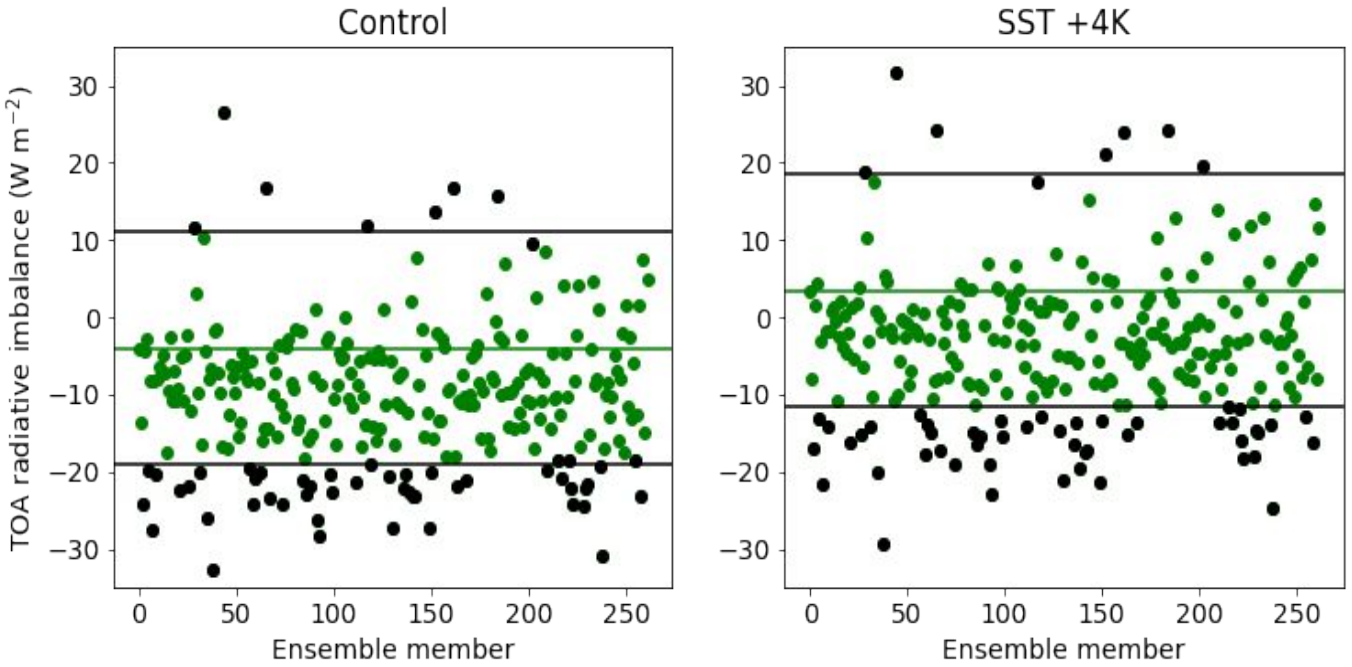

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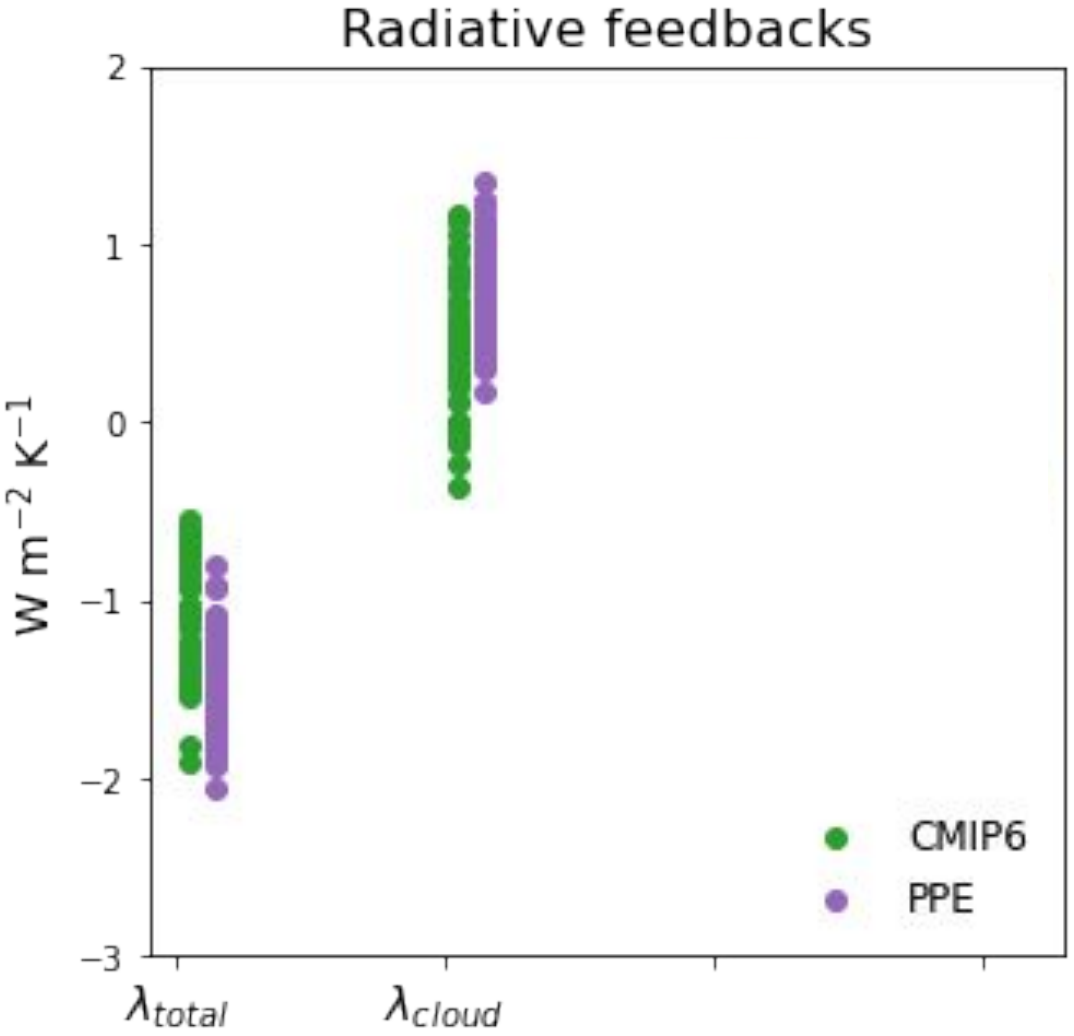

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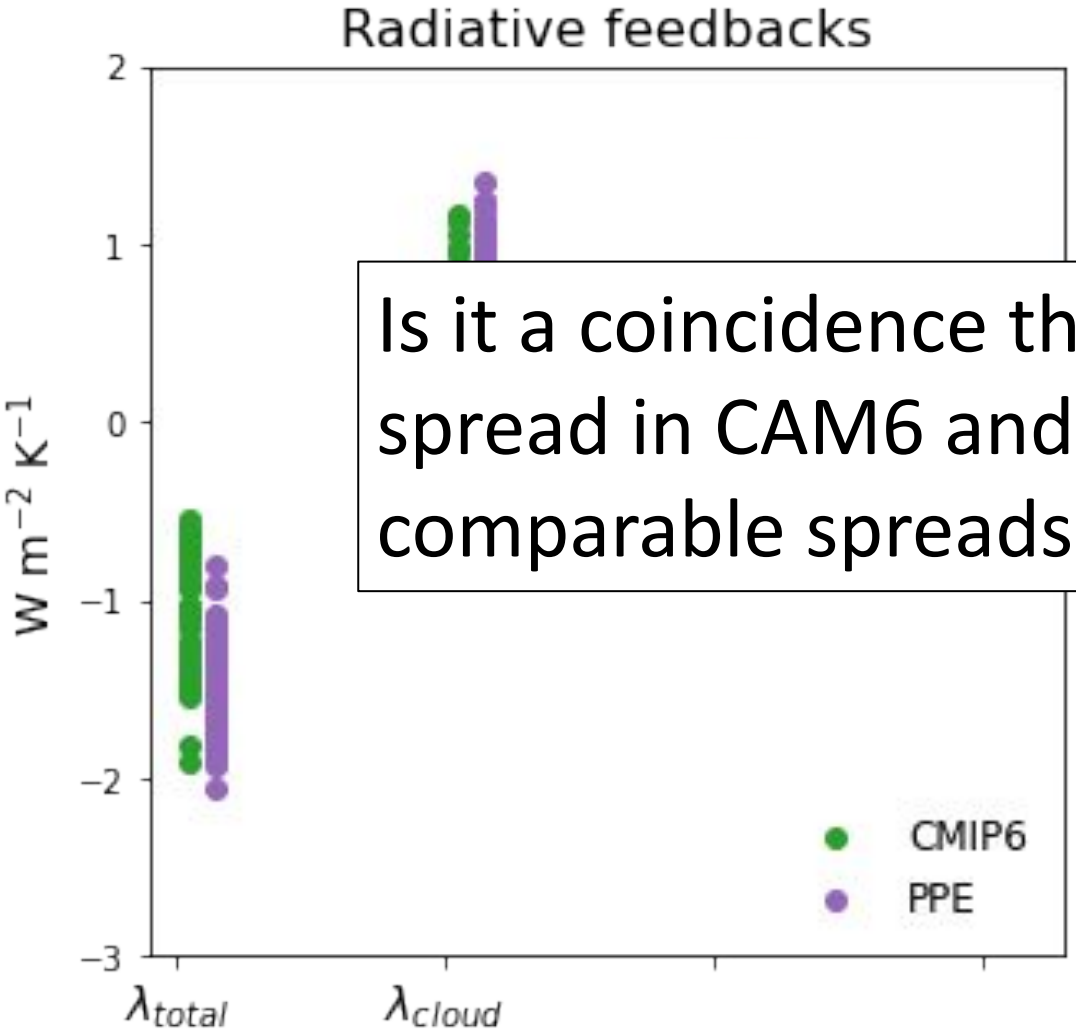

Is it a coincidence that the parametric spread in CAM6 and CMIP6 models have comparable spreads?

PPE experiments

- CAM6 – atmosphere only
- 45 atmospheric parameters vary

ulation

warming

simulation

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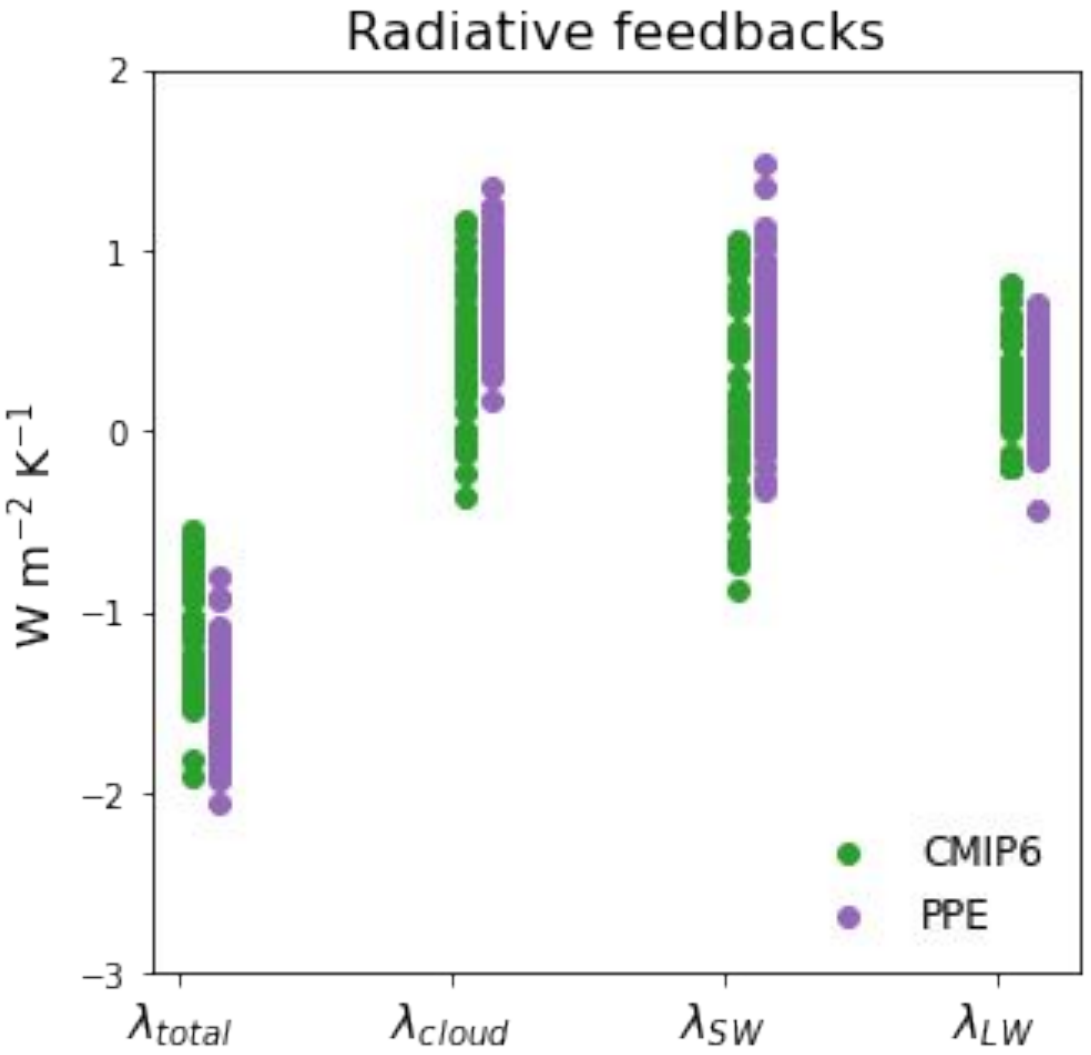
SW and LW cloud feedbacks have comparable spreads across CMIP6 and the PPE



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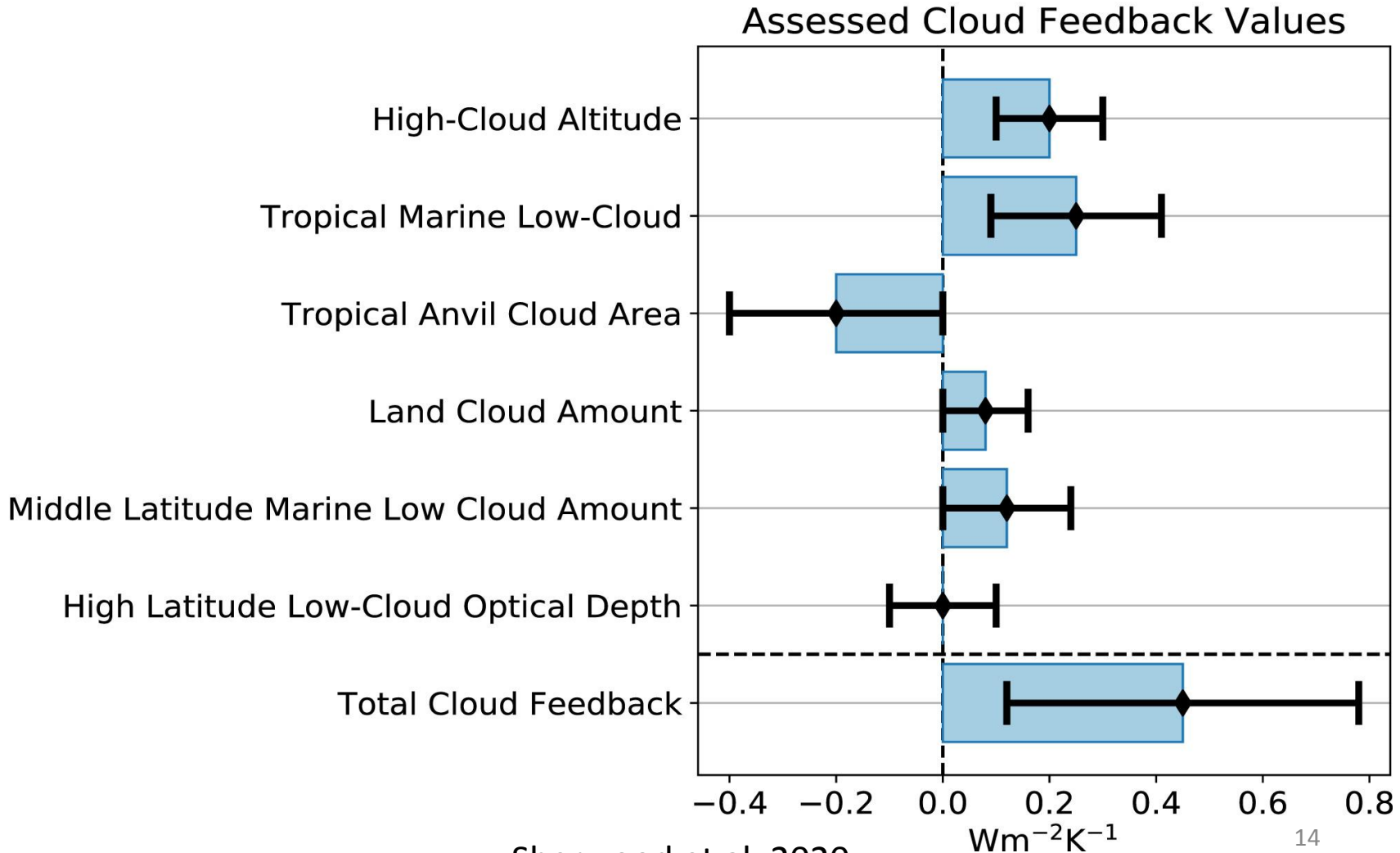
Are the same **mechanisms** setting the spread in cloud feedbacks across both ensembles?



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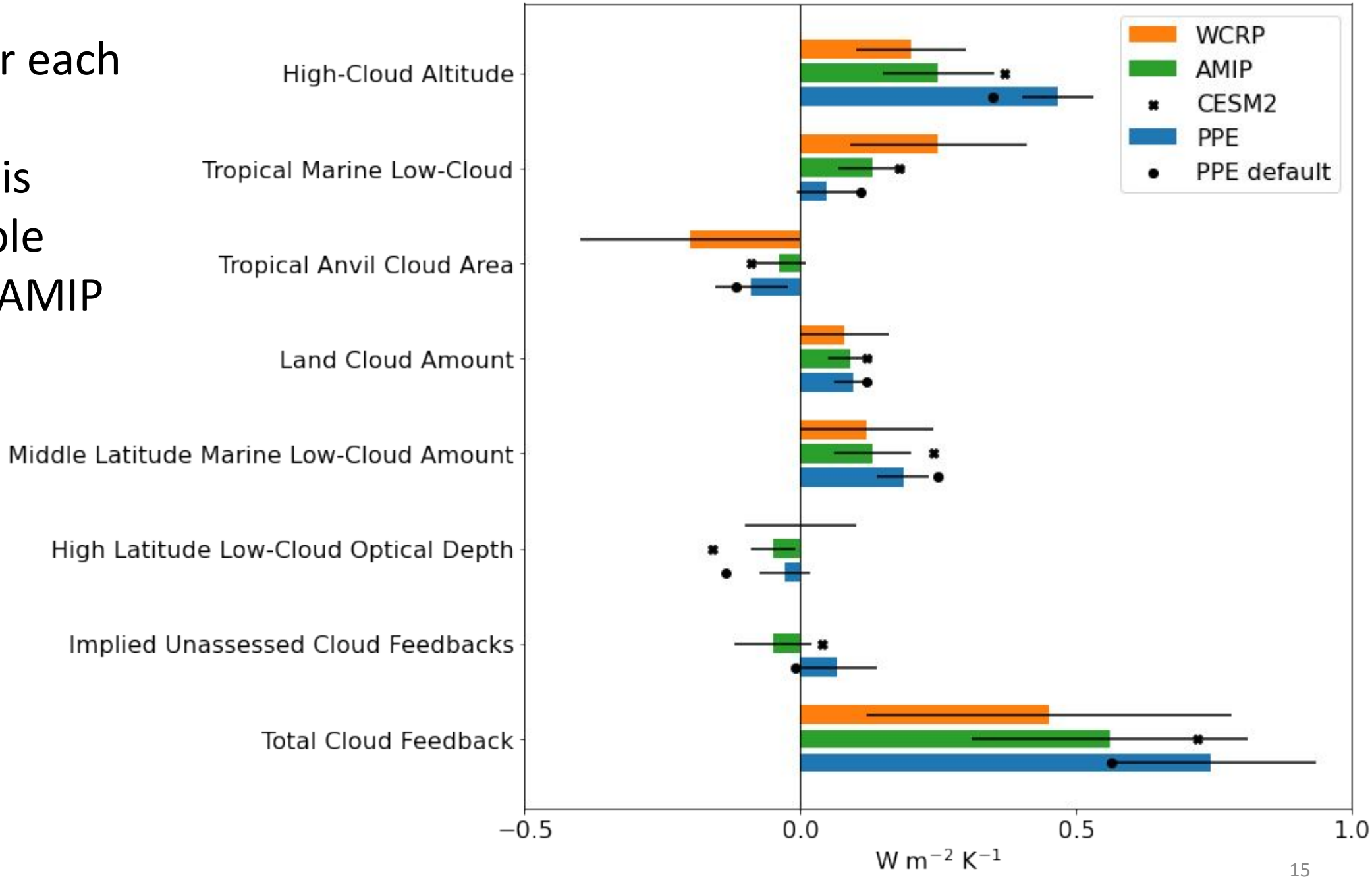
Spread for each assessed feedback is comparable between AMIP and PPE



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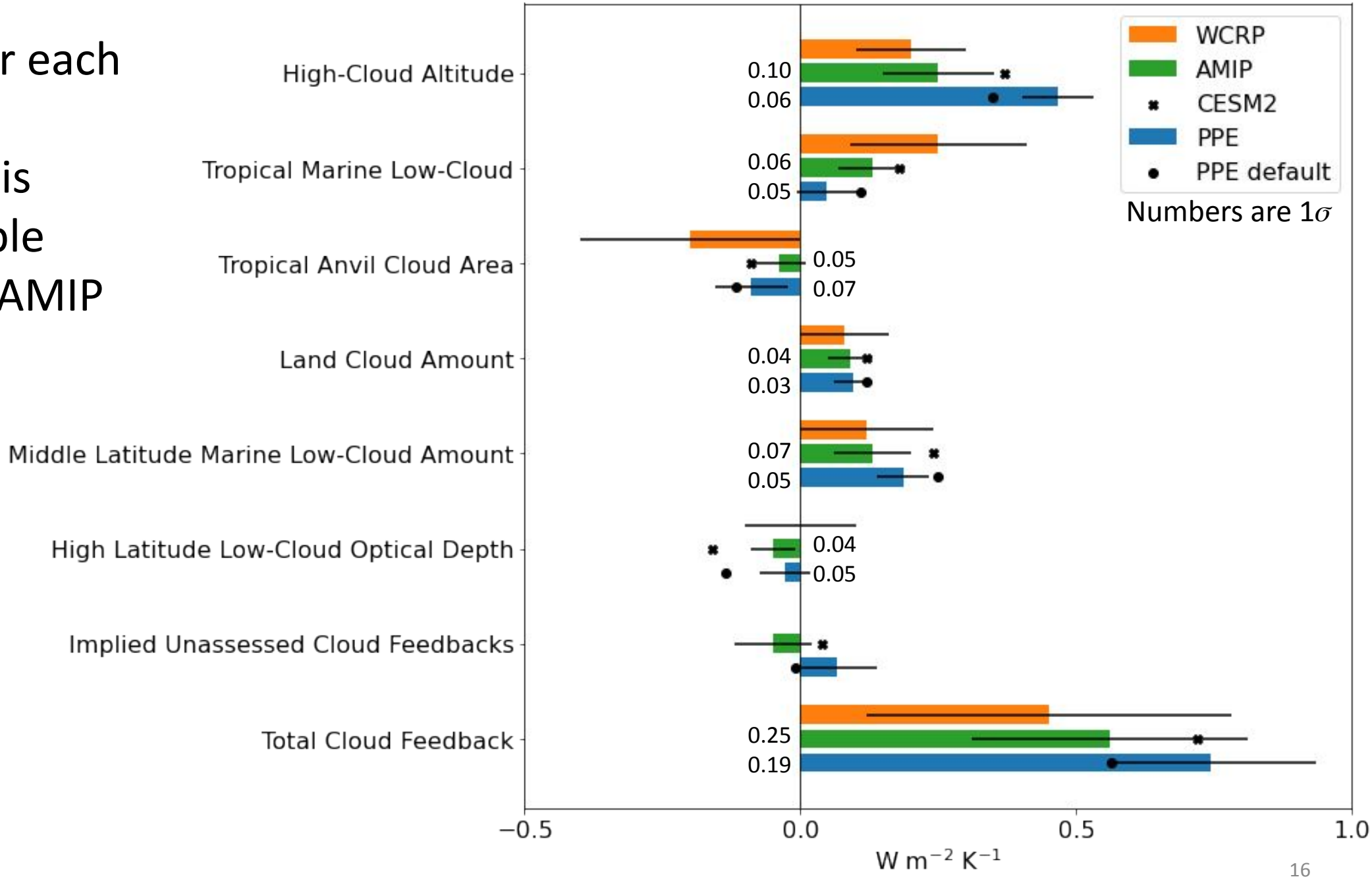
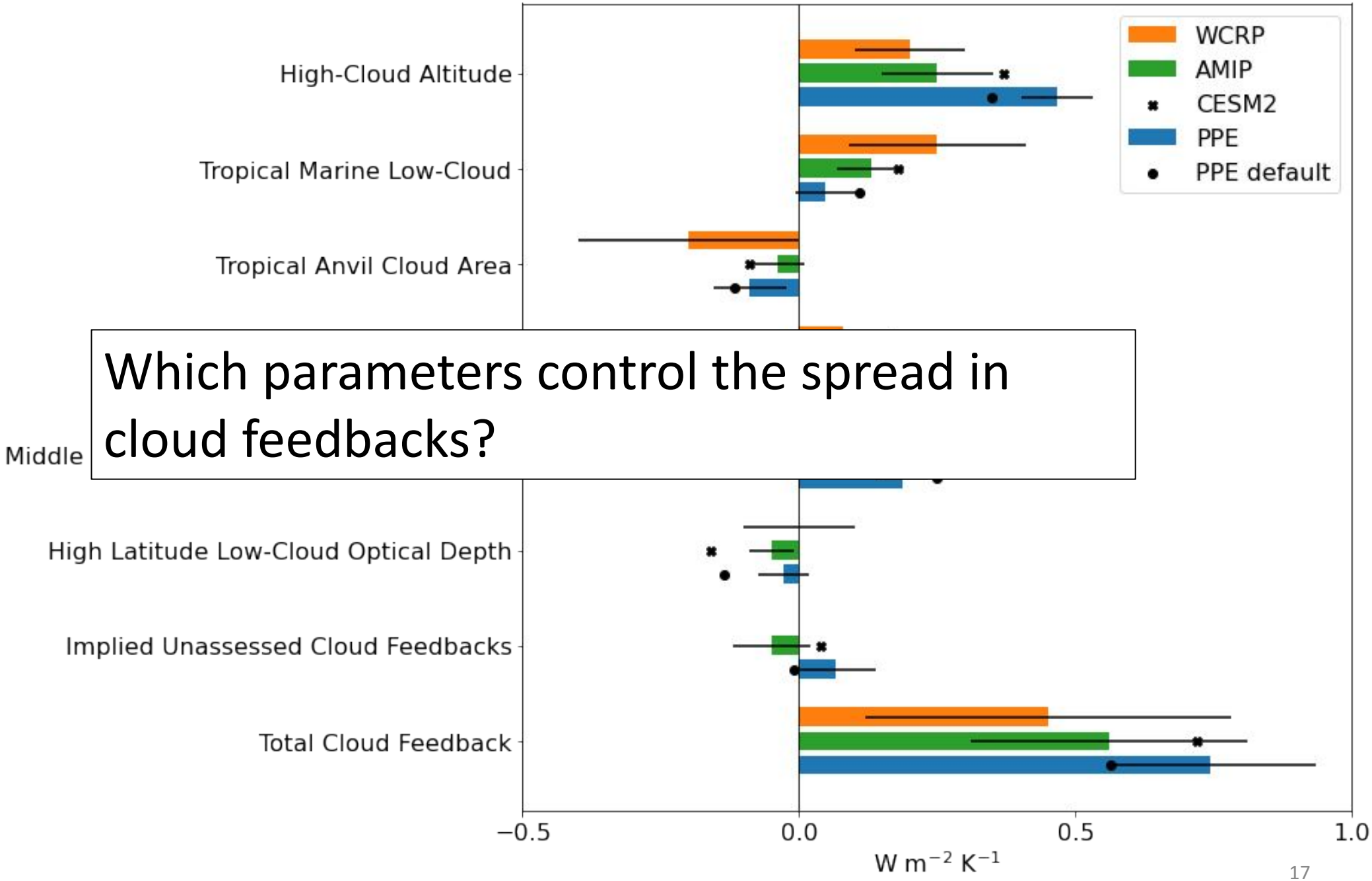
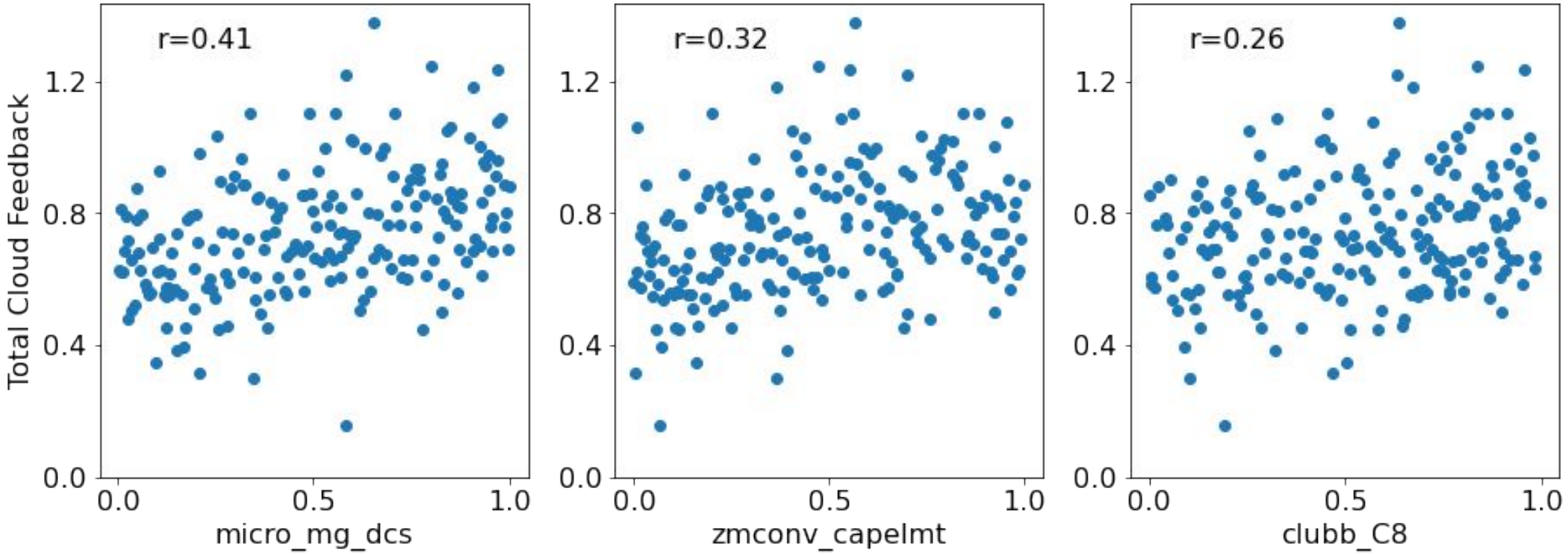




Which parameters control the spread in cloud feedbacks?

Which parameters control the spread?

Scheme	Parameter	Correlation
Microphysics	Ice-snow autoconversion size threshold	0.41
Convection	Triggering threshold for convection	0.32
Turbulence	Skewness coefficient	0.26



Microphysics Convection Turbulence

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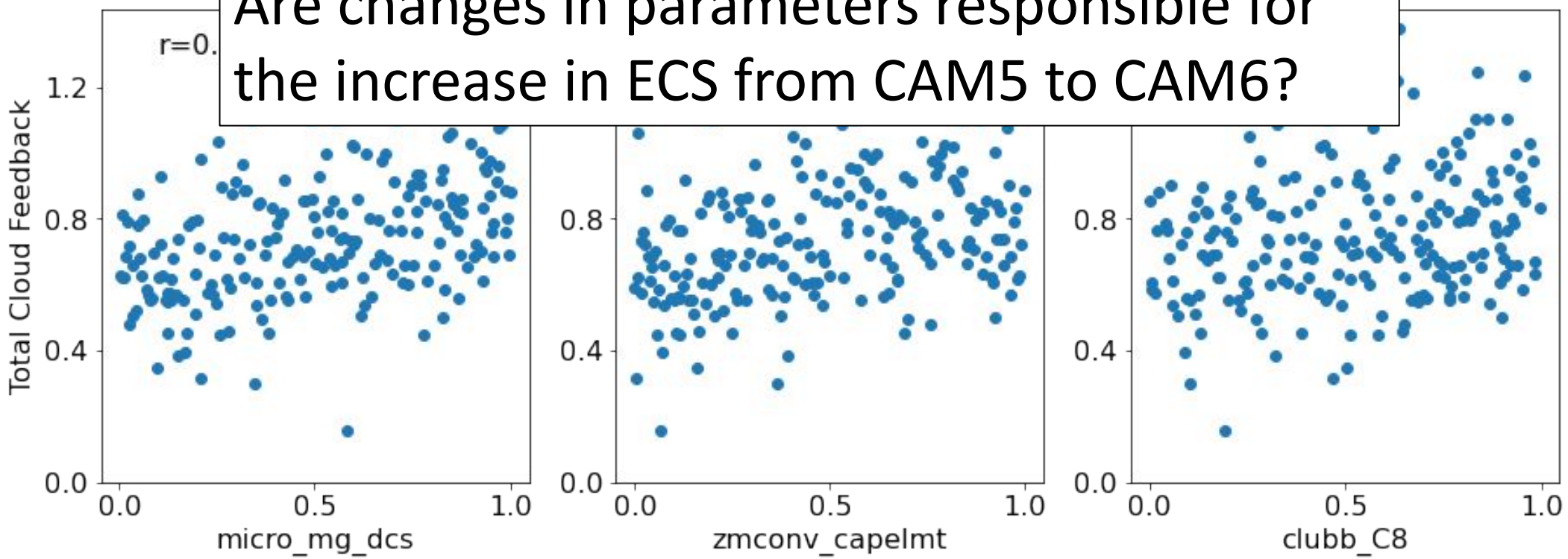
Are changes in parameters responsible for the increase in ECS from CAM5 to CAM6?



Microphysics Convection Turbulence

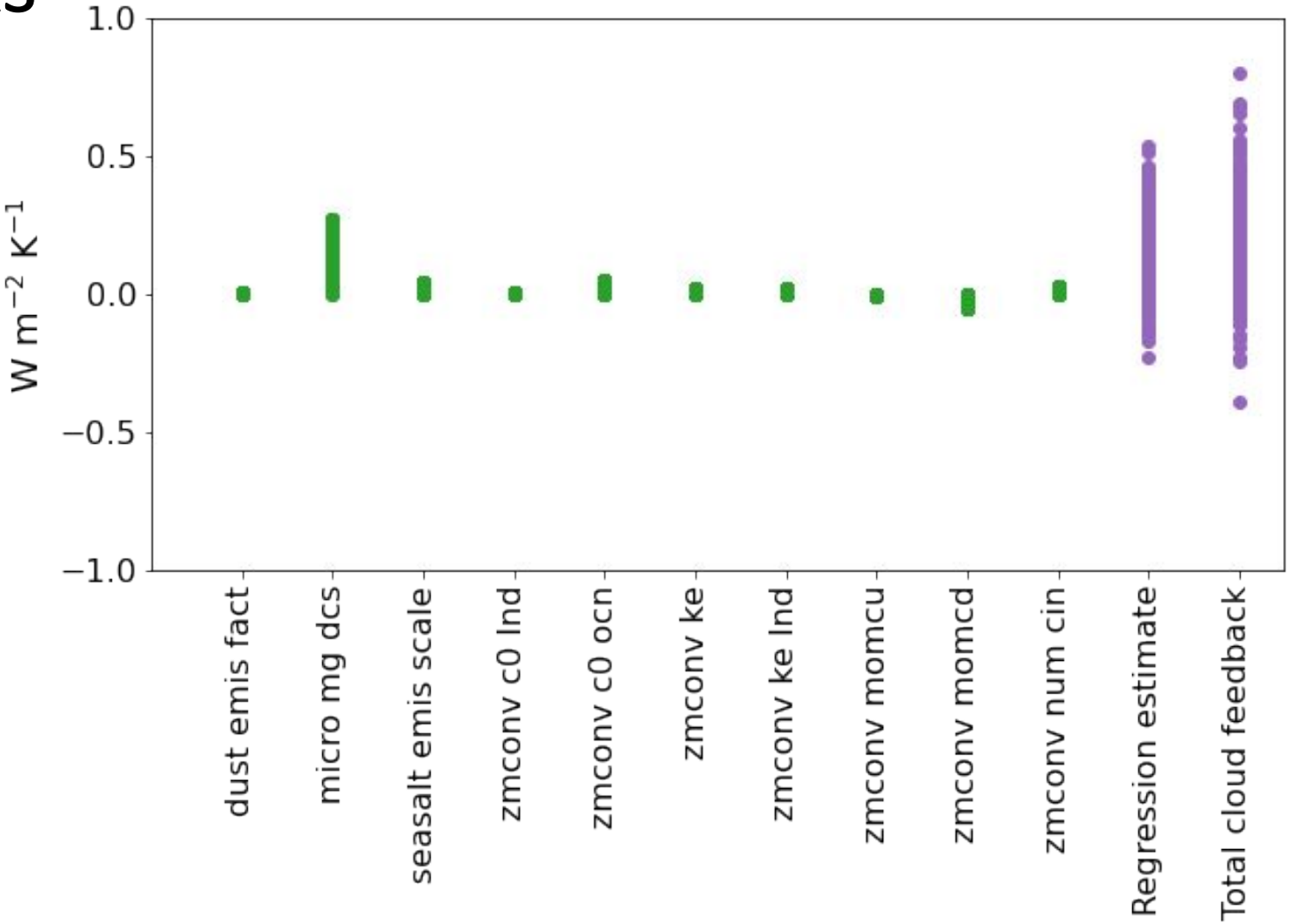
Are changes in parameters responsible for the increase in ECS from CAM5 to CAM6?

- We use the PPE to build a model for feedbacks as a function of parameter

$$\lambda \approx \sum_{i=1}^{45} a_i p_i$$

λ feedback
i parameter index (1-45)
a_i regression coefficient
p_i parameter value

Changes in parameter values from CAM5 to CAM6 are **not** responsible for the change in cloud feedbacks



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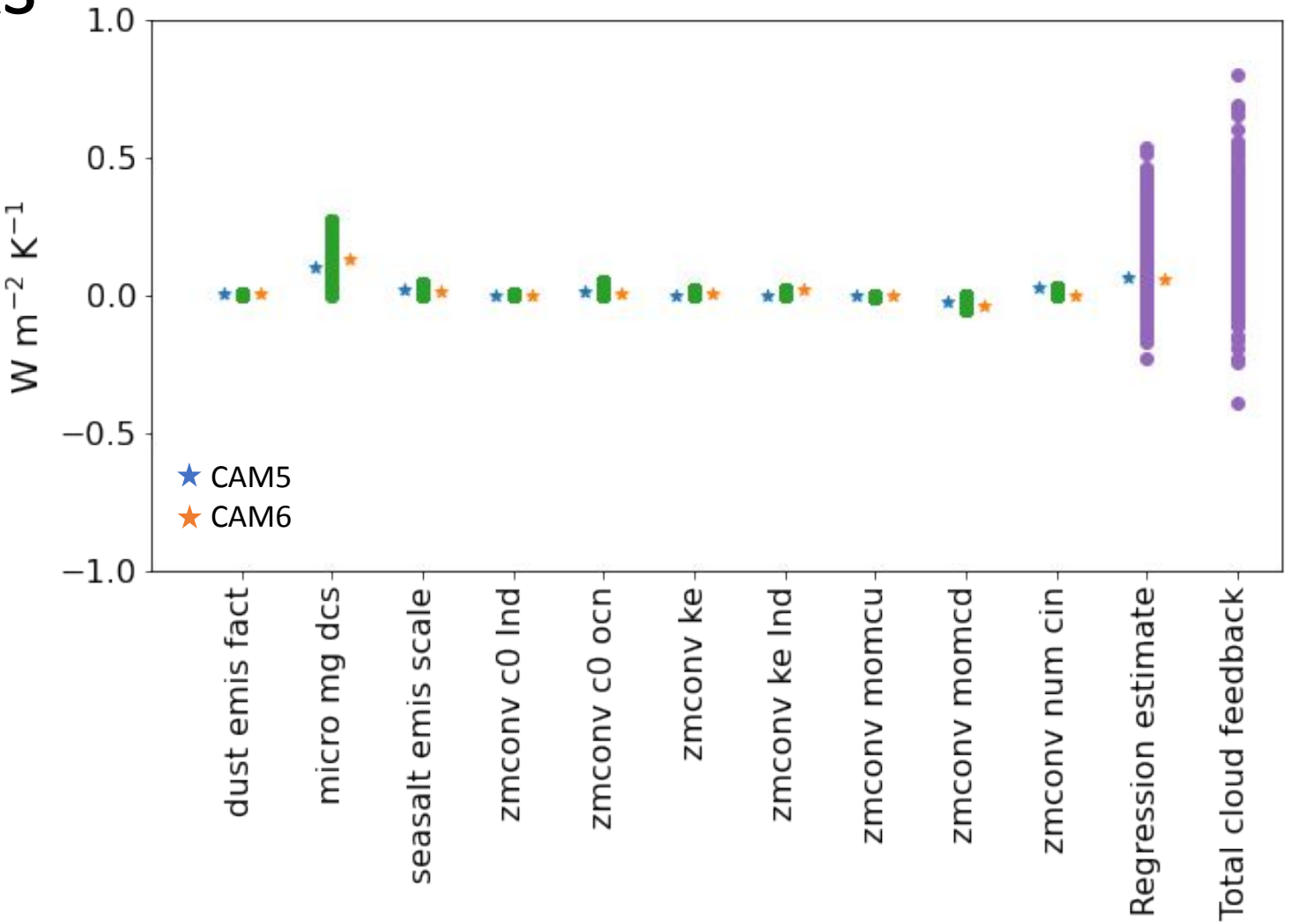

Summary

- Is it a coincidence that the parametric spread in CAM6 and CMIP6 models have comparable spreads?
  - Similar spreads across individual assessed feedbacks suggests it's NOT a coincidence
- Which parameters control the spread in cloud feedbacks?
  - One microphysics parameter, one convection parameter, one turbulence parameter
- Are changes in parameters responsible for the increase in ECS from CAM5 to CAM6?
  - No

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Spread in ECS has increased from the previous model generation

$$ECS = -\frac{\Delta F}{\lambda}$$

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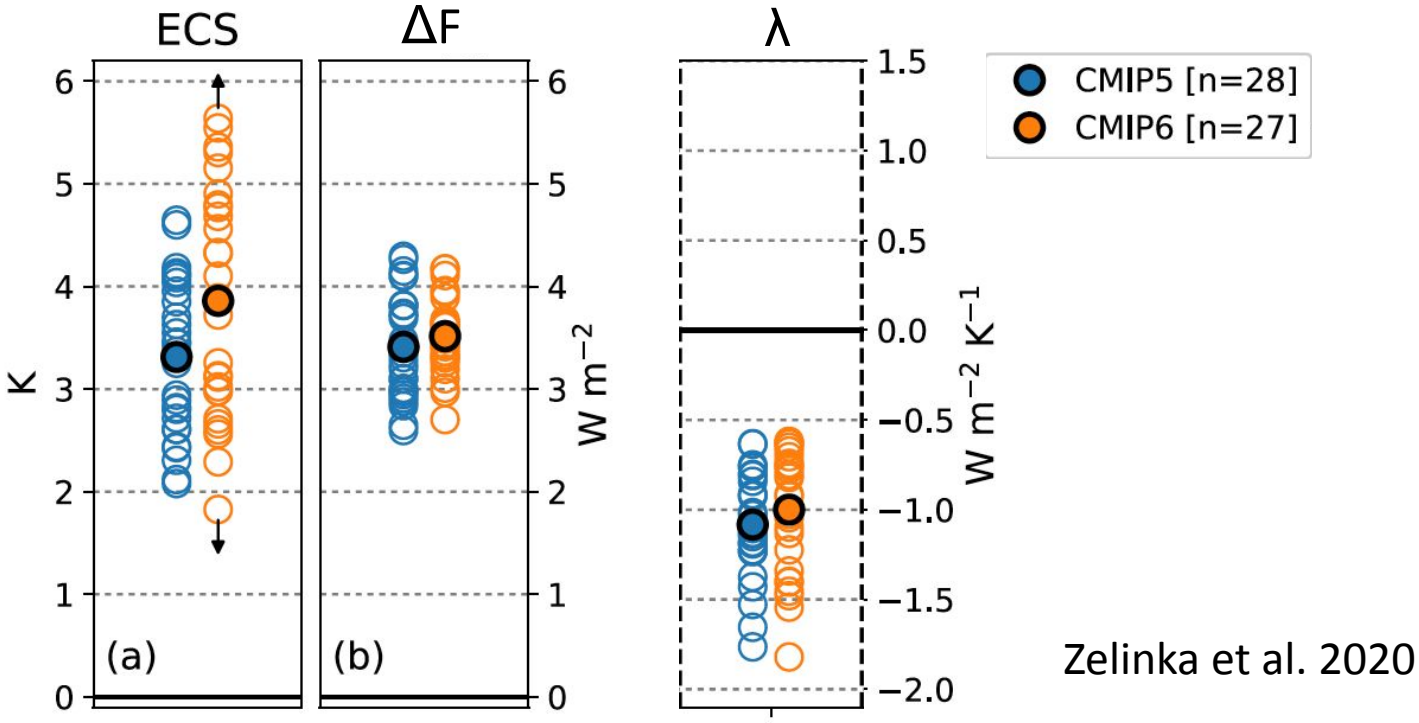
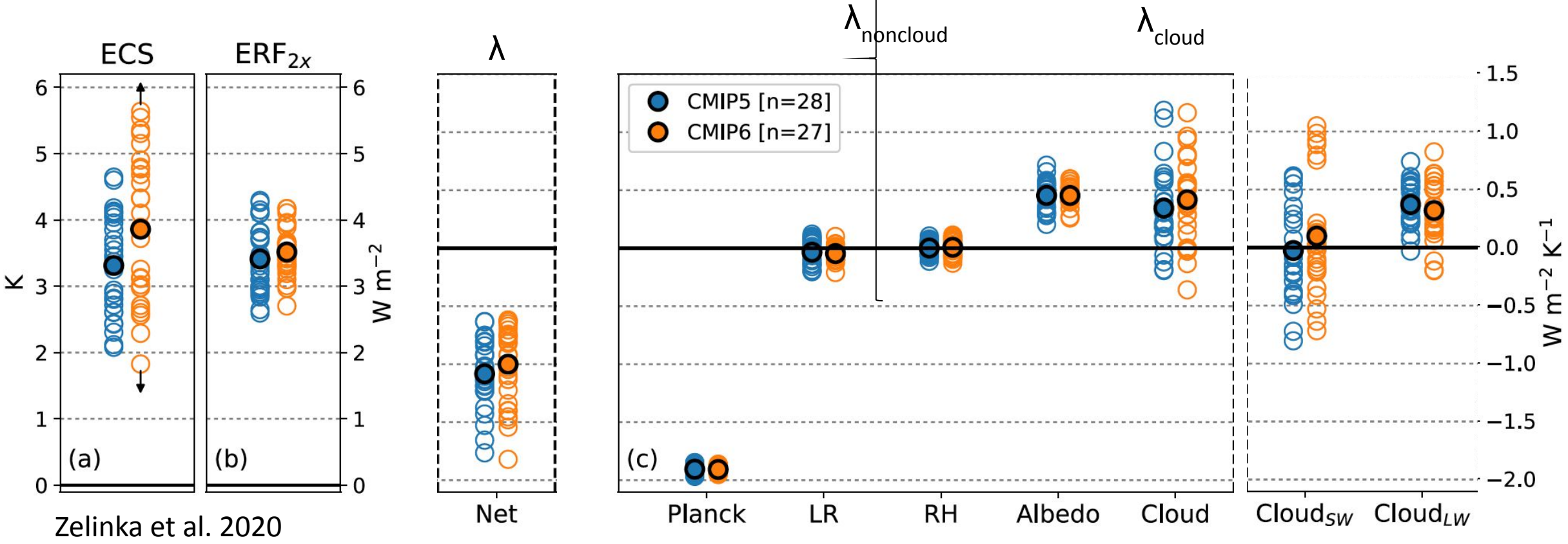


Zelinka et al. 2020

Cloud feedbacks can be partitioned in shortwave and longwave cloud feedbacks



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