Parametric sensitivity of cloud feedbacks in CAM6

Margaret L. Duffy, Brian Medeiros, Andrew Gettelman, Trude Eidhammer
NCAR

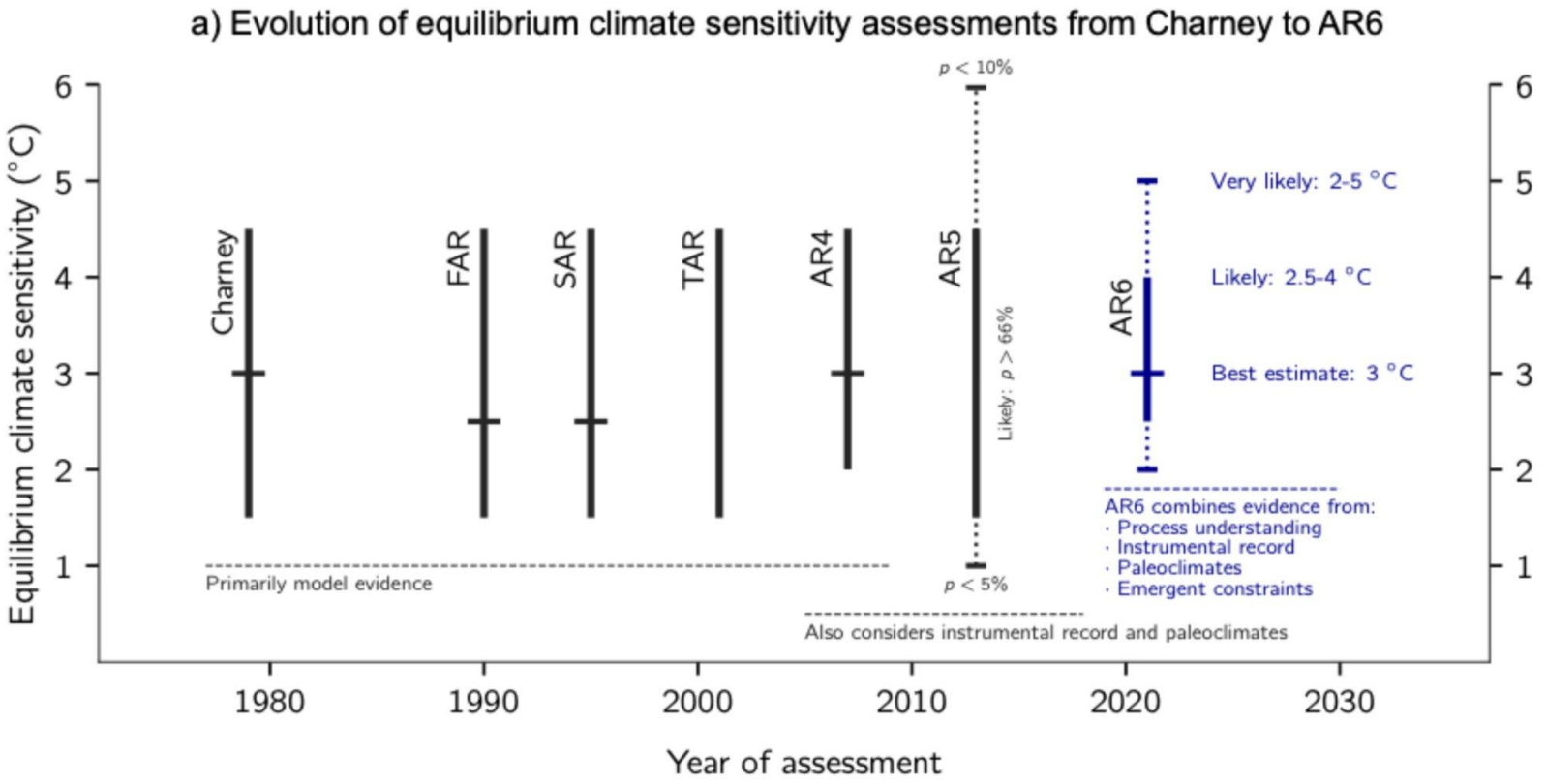
mlduffy@ucar.edu

NCAR
UCAR

MAPP
Modeling, Analysis, Predictions, and Projections

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?

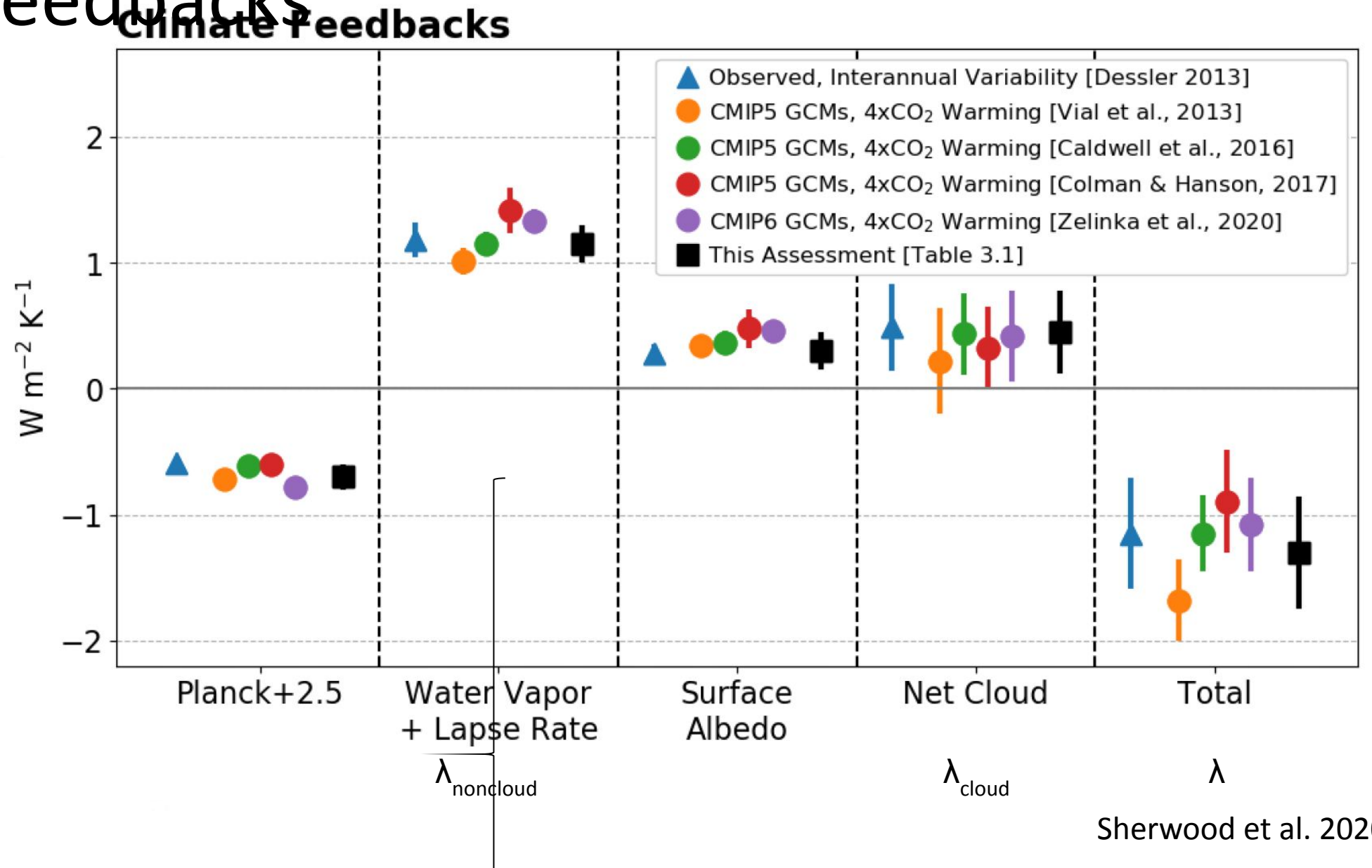
$$ECS = -\frac{\Delta F}{\lambda}$$

ΔF ← Forcing

λ ← Feedback

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

Spread in feedbacks is largely from cloud feedbacks

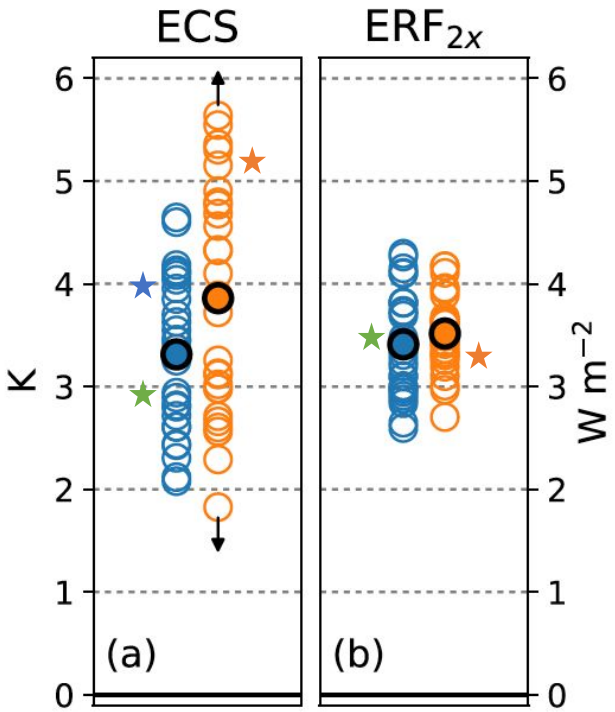


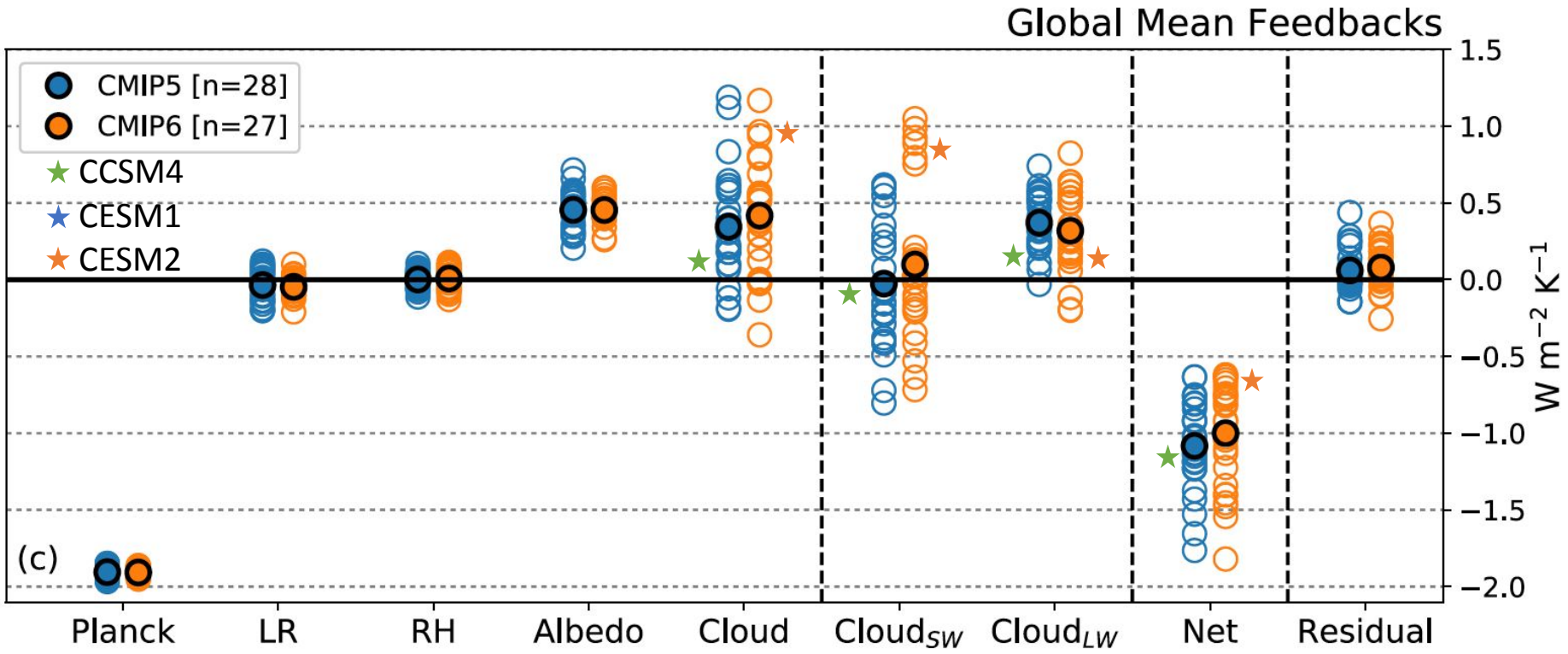
Positive/amplifying feedback

Negative/stabilizing feedback

Sherwood et al. 2020

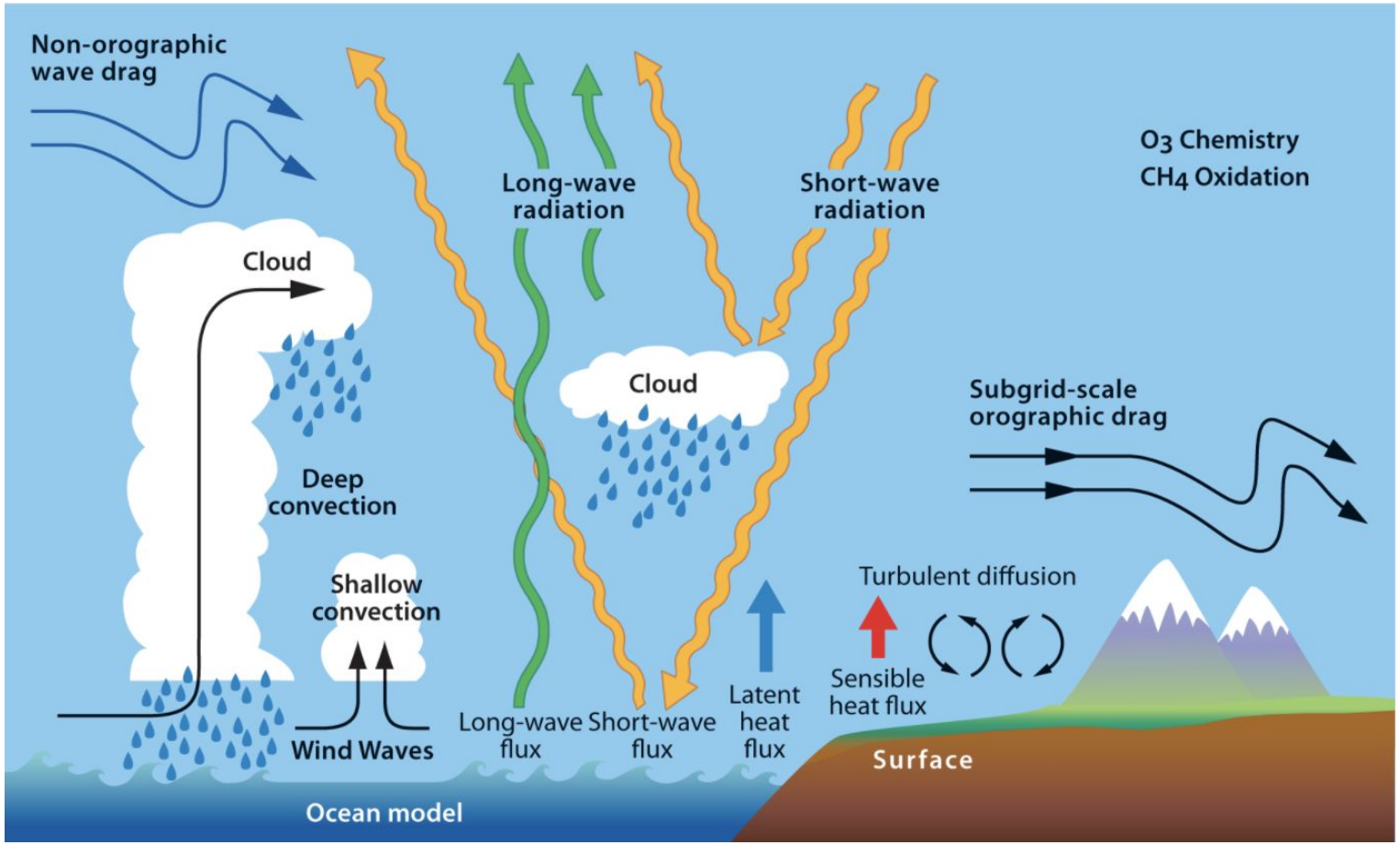
Range of ECS estimates increased from CMIP5 to CMIP6





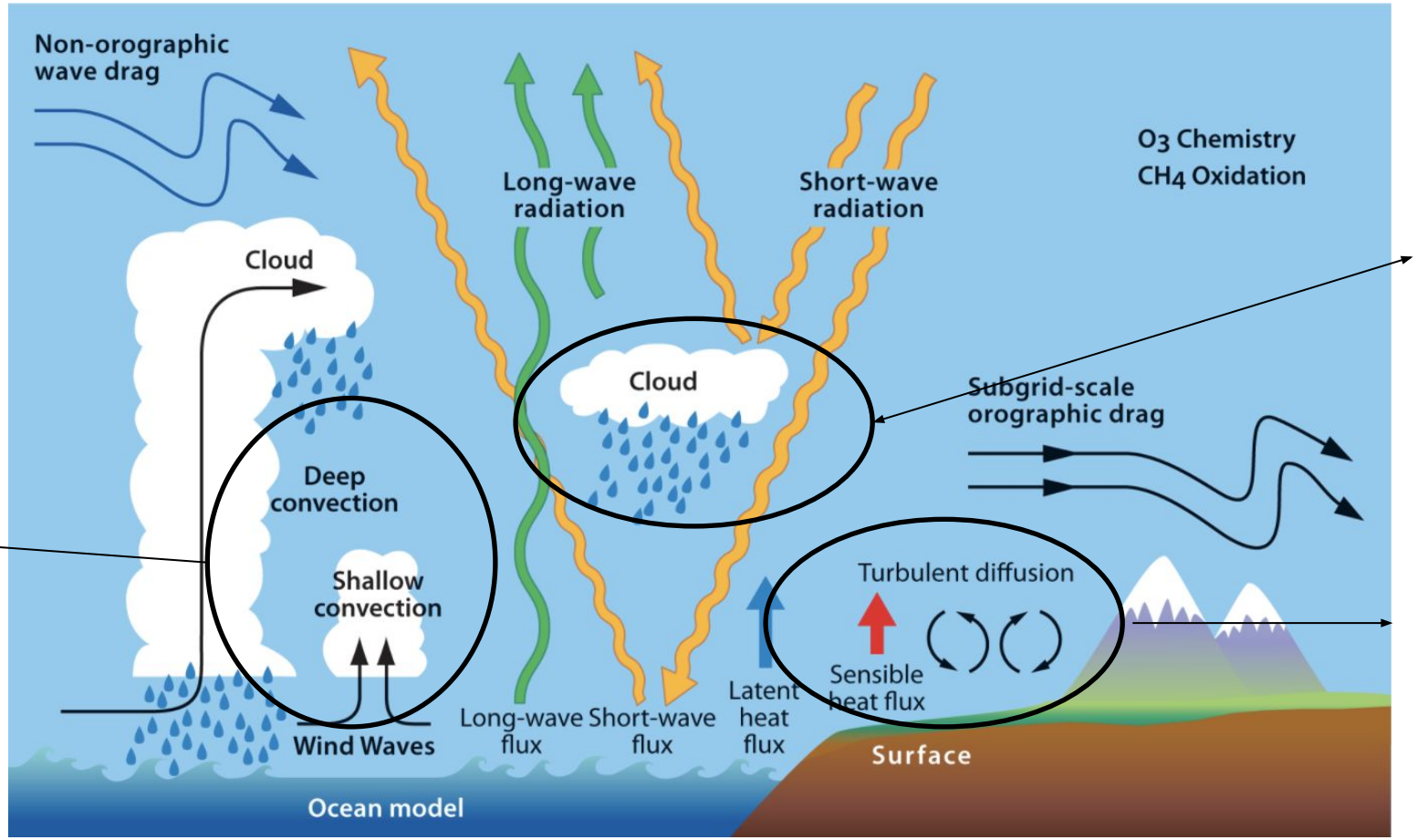
Zelinka et al. 2020

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



NCAR CESM

We vary 45 atmospheric parameters from several schemes



ZM: convection

MG3: cloud microphysics
PUMAS: more microphysics
Aerosol

CLUBB: turbulence

NCAR CESM

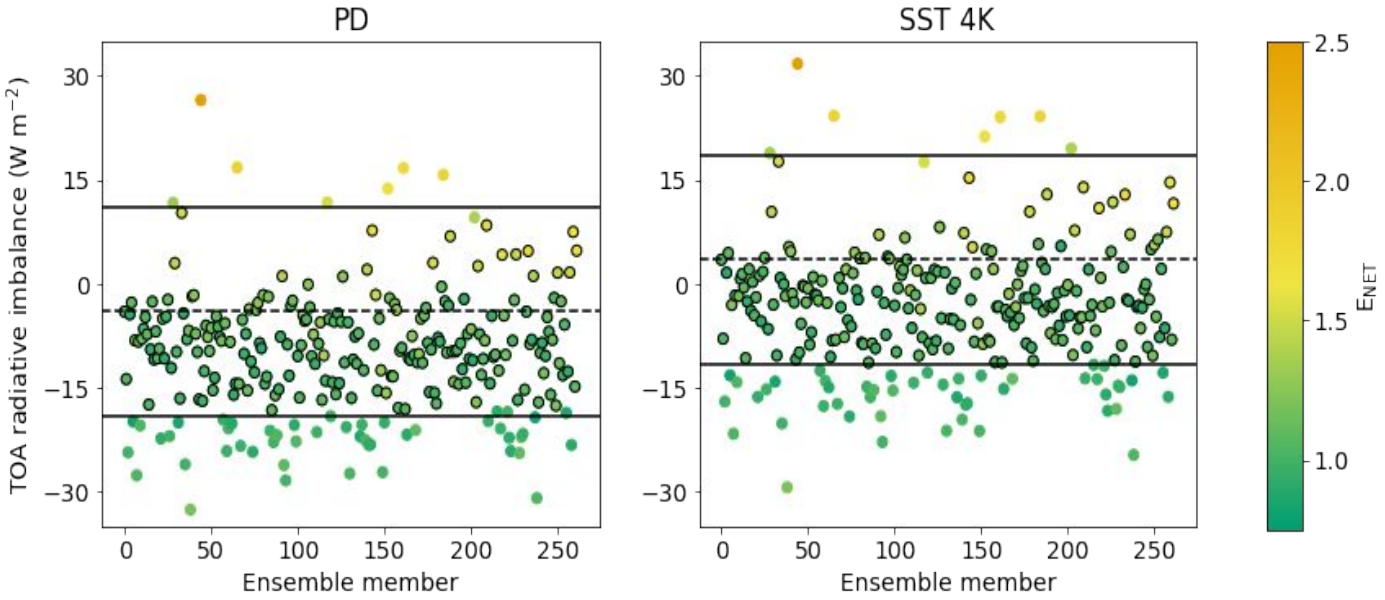
The CAM6 perturbed parameter ensemble has a large spread in cloud-radiative feedbacks

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

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



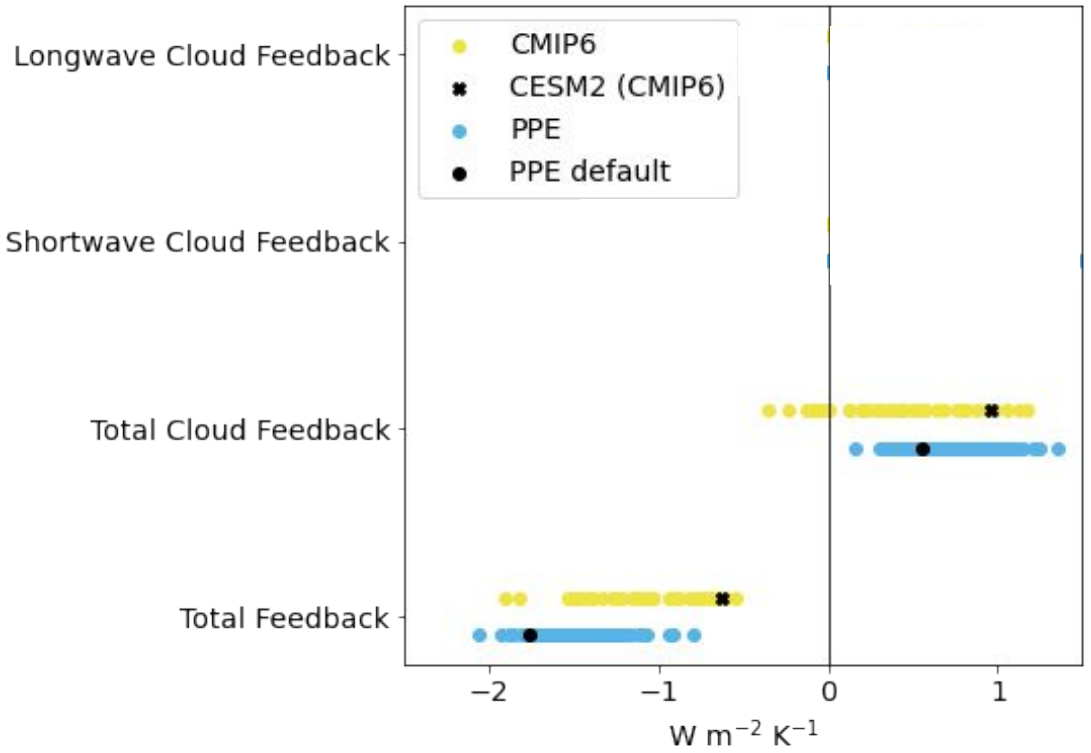
A TOA radiative imbalance of 0 W m^{-2} indicates equilibrium

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
- 206 simulations are used here

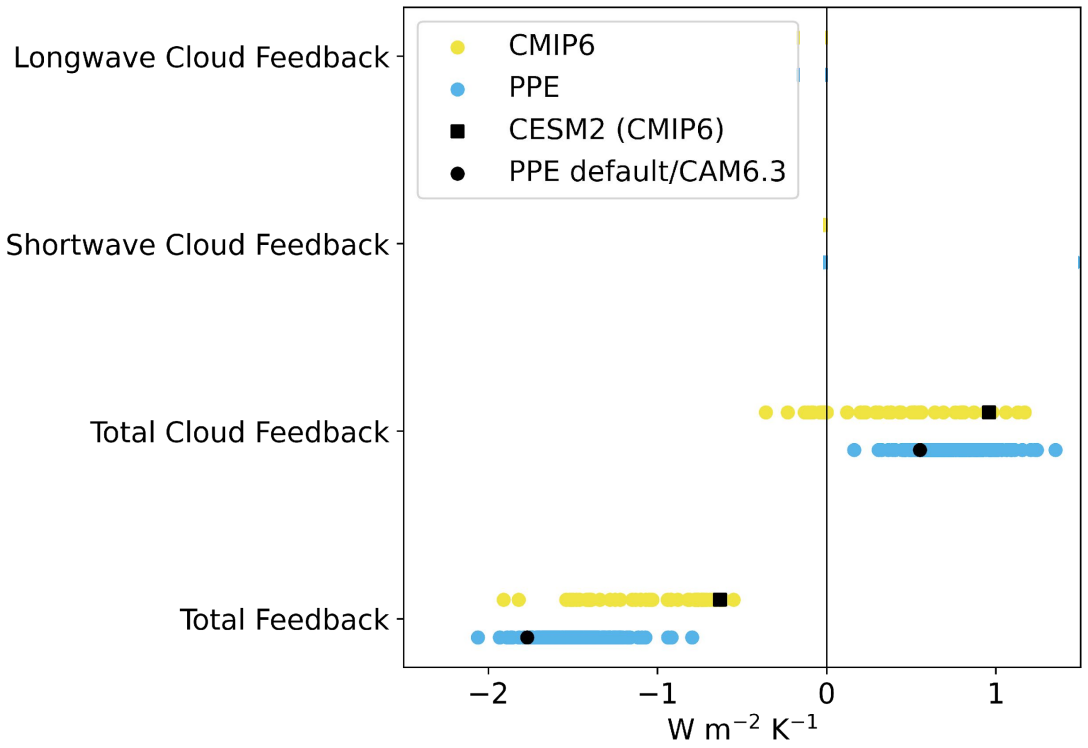
The CAM6 perturbed parameter ensemble has a large spread in cloud-radiative feedbacks



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
- 206 simulations are used here



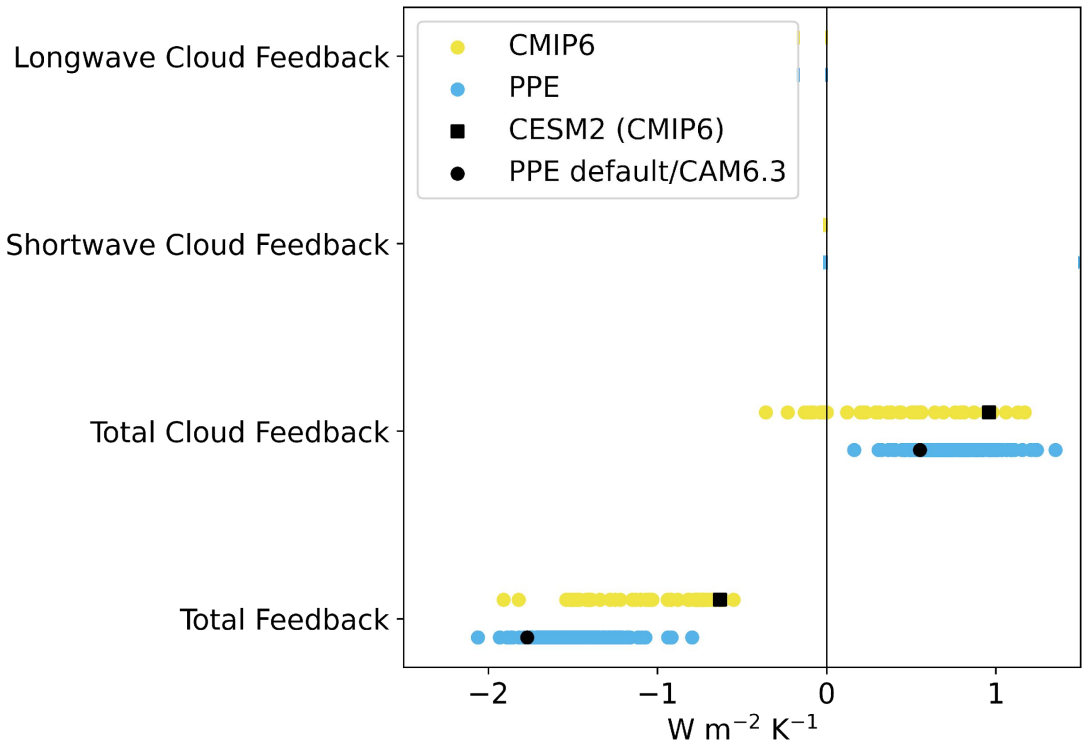
Questions

1. Why is the cloud feedback lower in the PPE default simulation than in CESM2?

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

3. Which parameters control the spread in cloud feedbacks?

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



Questions

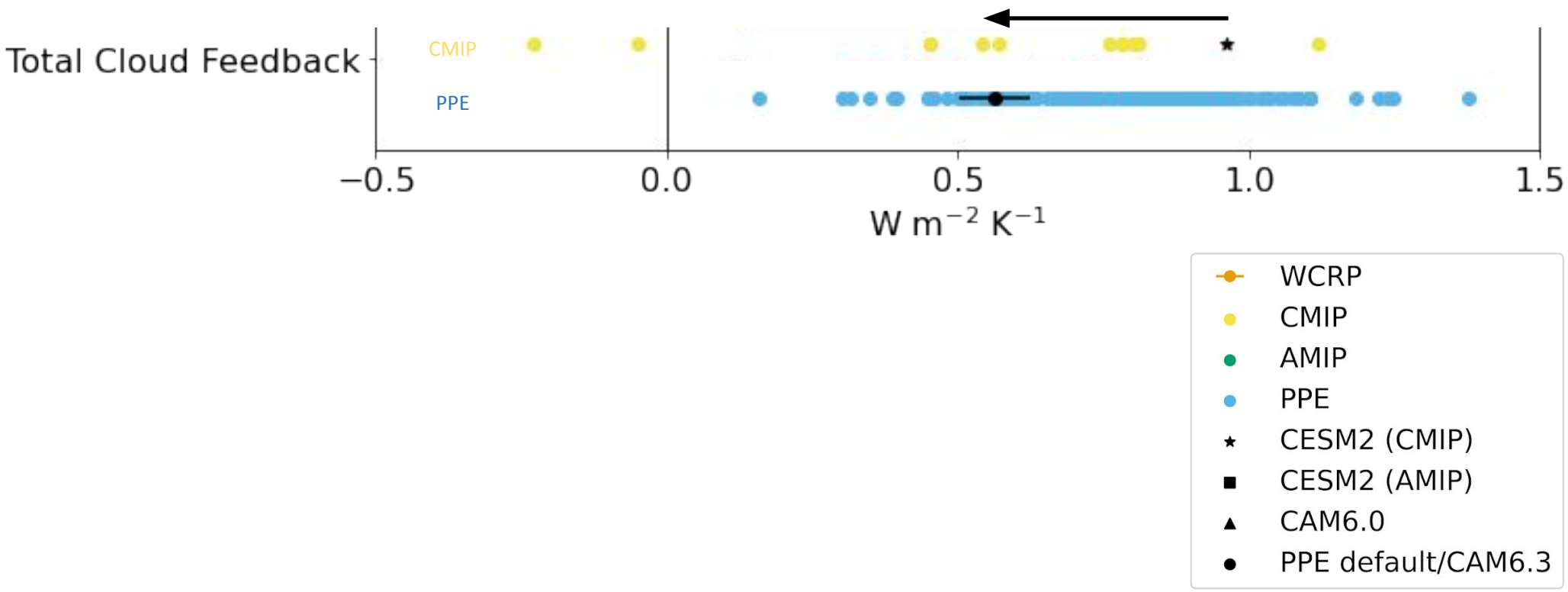
1. **Why is the cloud feedback lower in the PPE default simulation than in CESM2?**

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

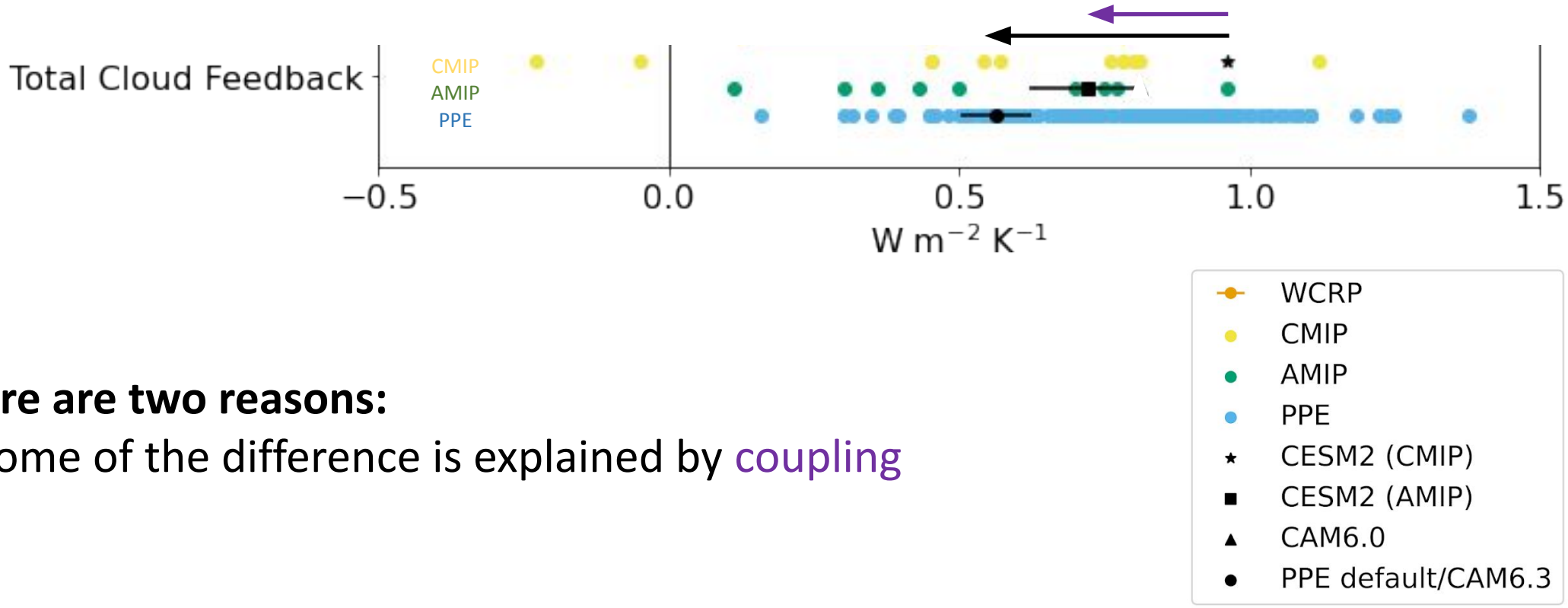
3. Which parameters control the spread in cloud feedbacks?

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

1. Why is the cloud feedback lower in the PPE default simulation than in CESM2?



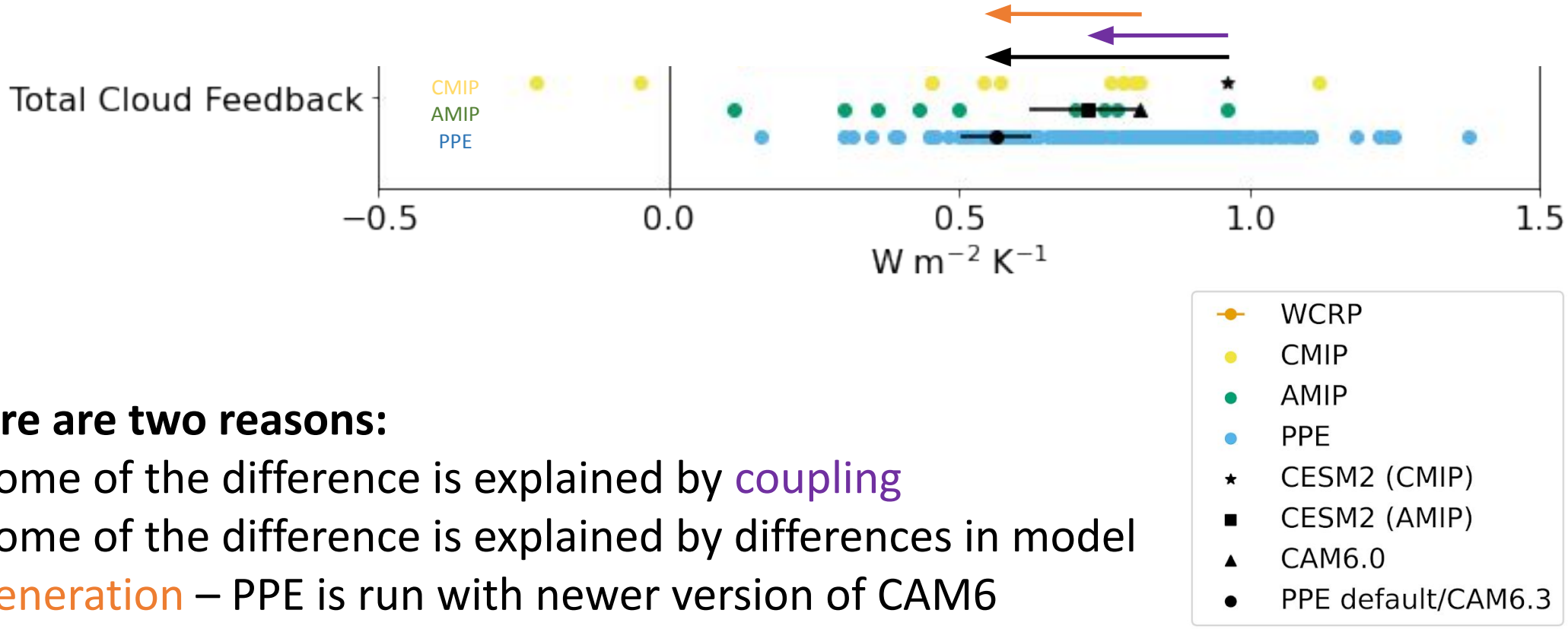
1. Why is the cloud feedback lower in the PPE default simulation than in CESM2?



There are two reasons:

- Some of the difference is explained by coupling

1. Why is the cloud feedback lower in the PPE default simulation than in CESM2?

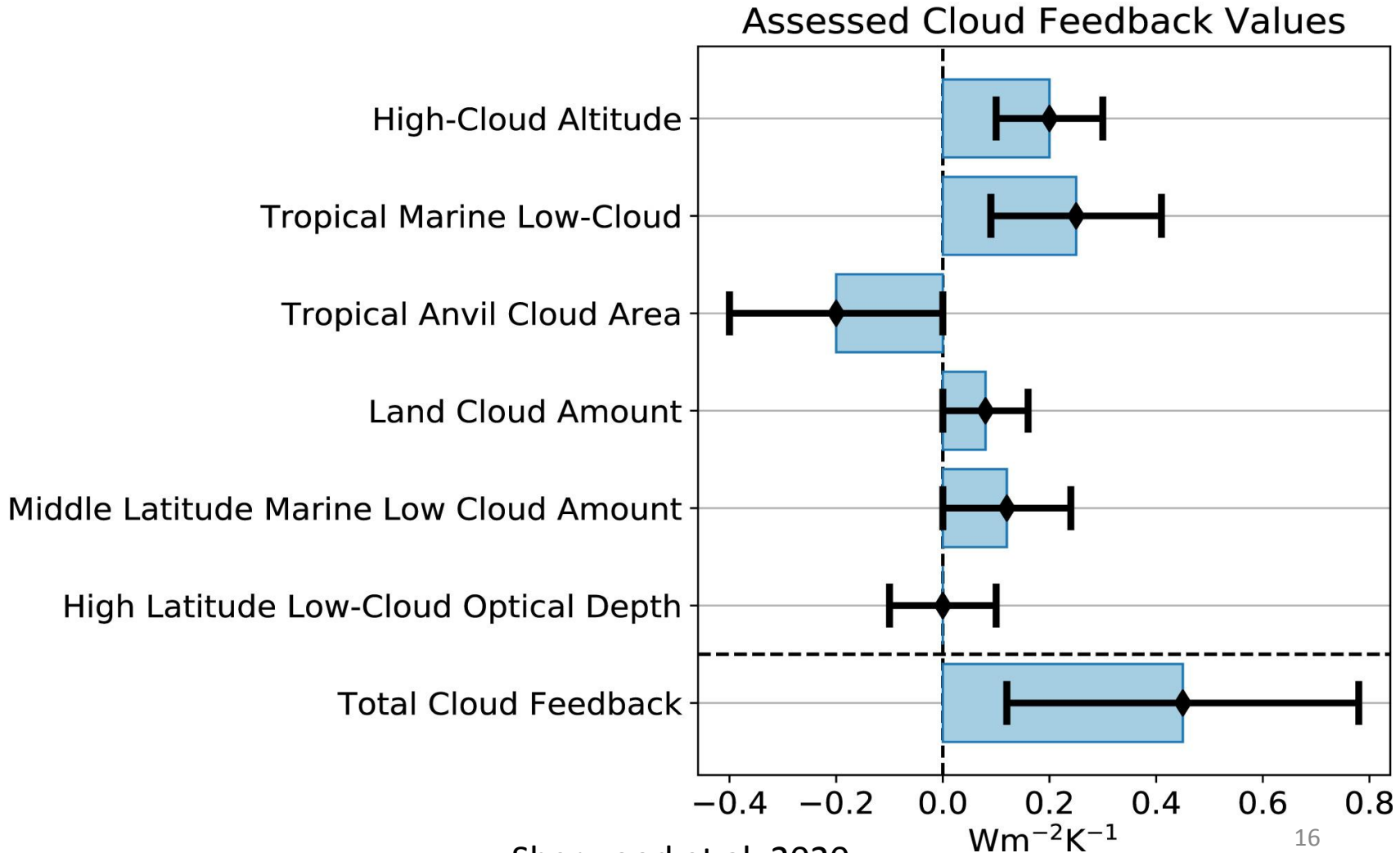


There are two reasons:

- Some of the difference is explained by coupling
- Some of the difference is explained by differences in model generation – PPE is run with newer version of CAM6 (CAM6.0 -> CAM6.3)

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

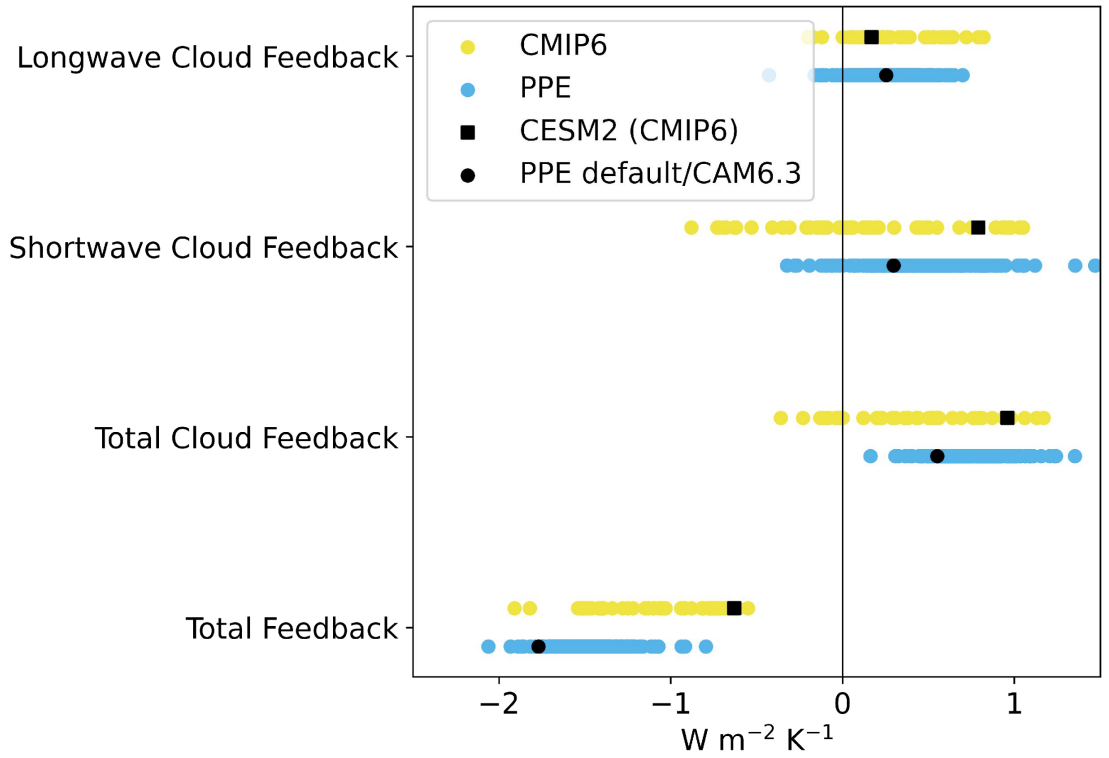
Are the same **processes** setting the spread in cloud feedbacks across both ensembles?



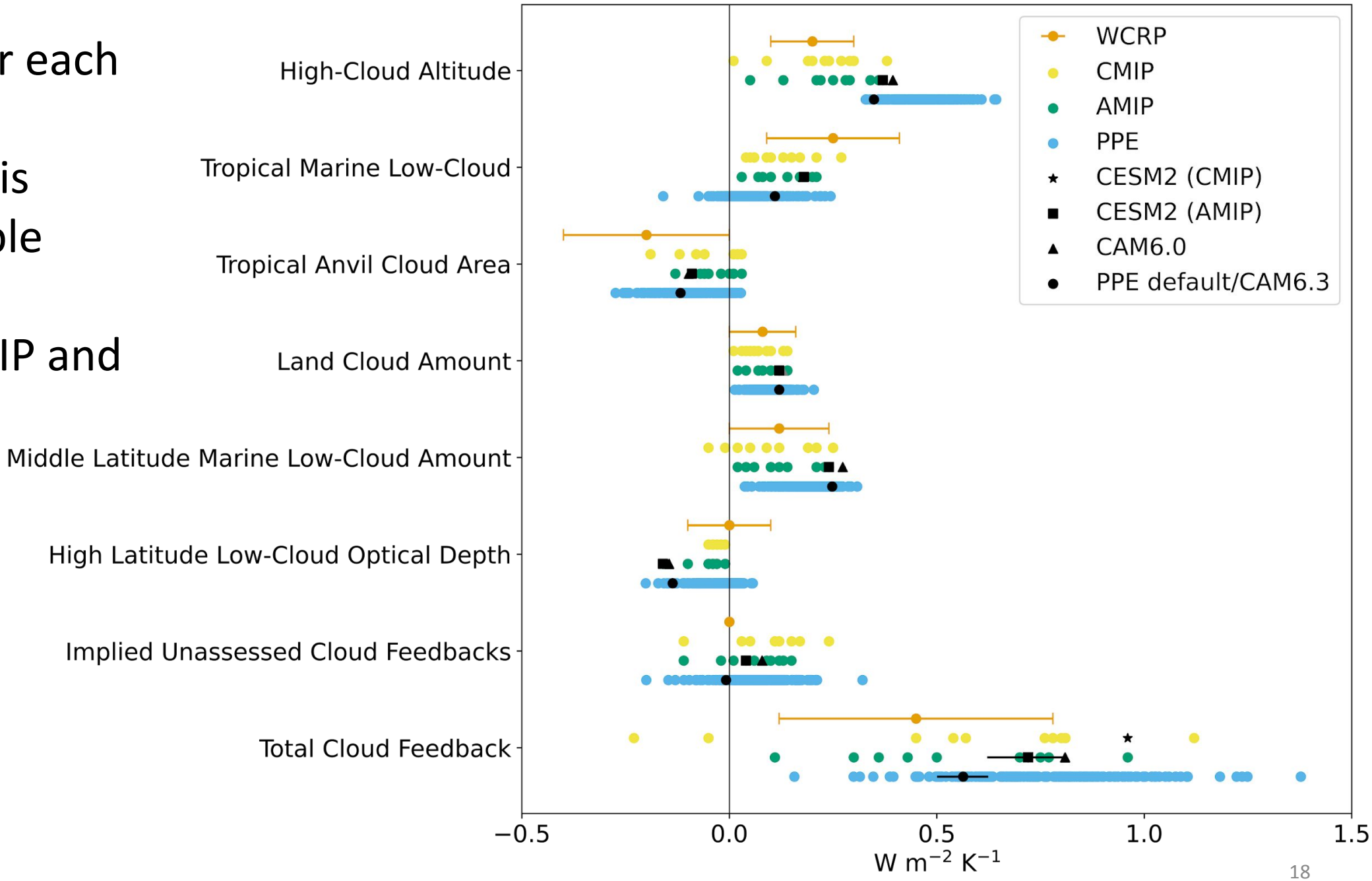
Sherwood et al. 2020

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

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

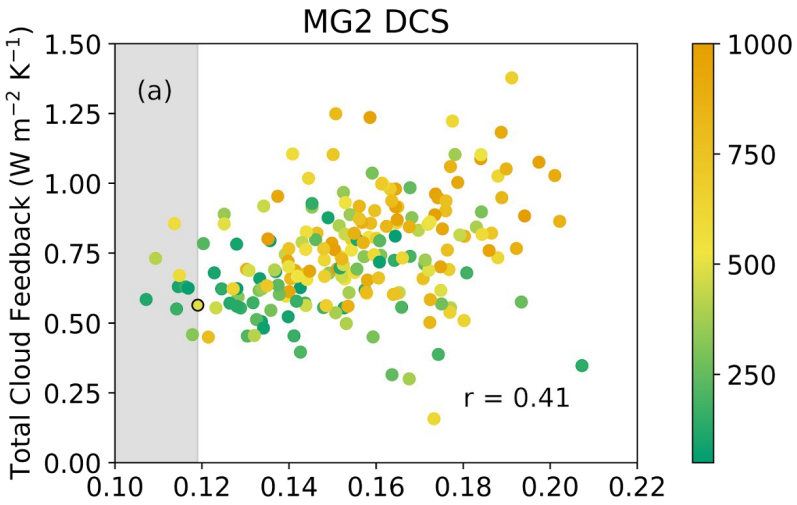


Spread for each assessed feedback is comparable between CMIP/AMIP and PPE

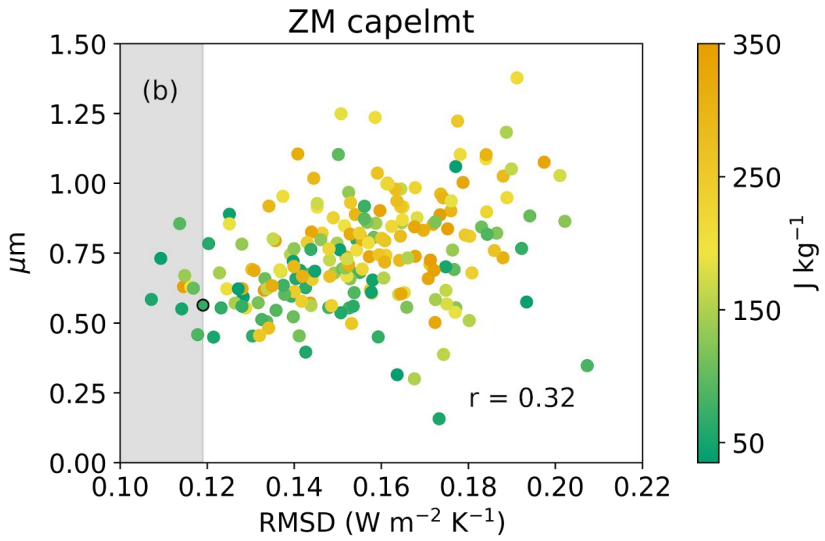


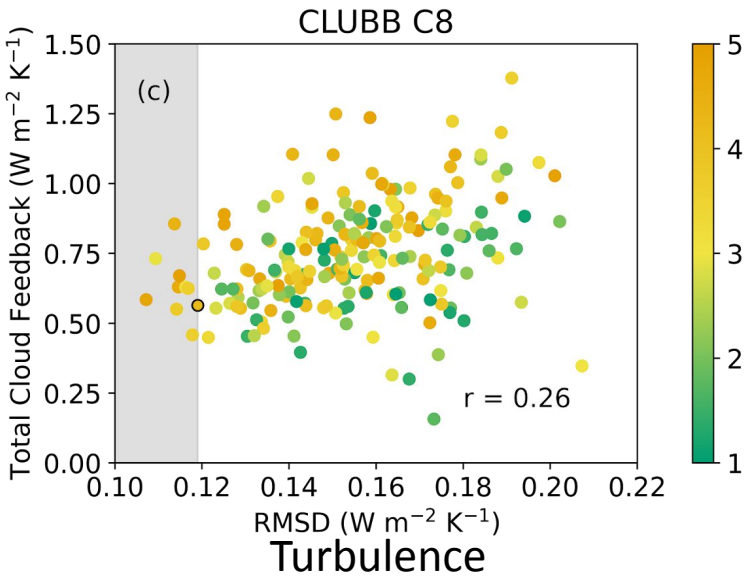
3. Which parameters control the spread?

Microphysics



Convection





Turbulence

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

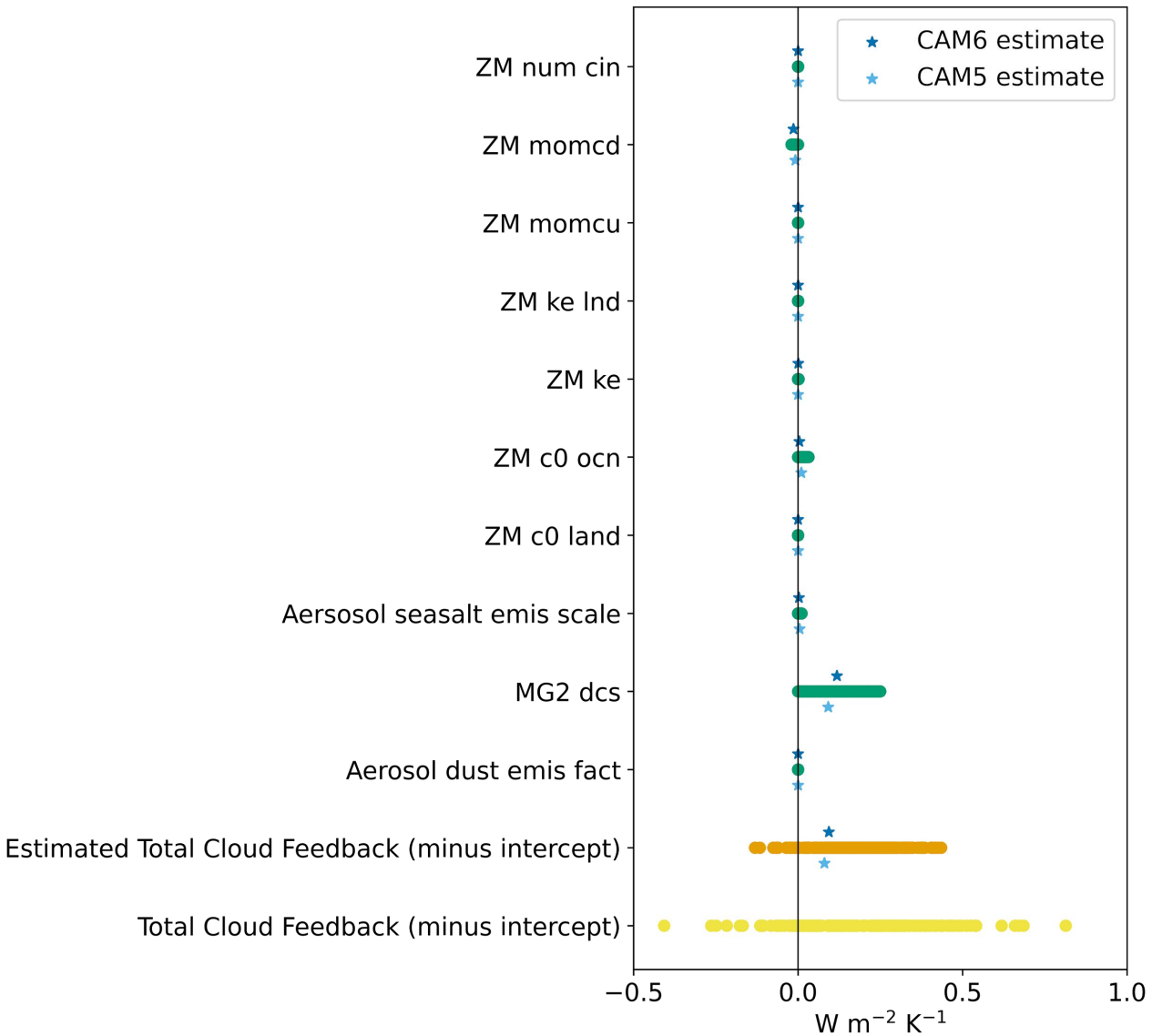
4. Are changes in parameters responsible for the increase in ECS from CAM5 to CAM6?

- 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



Summary

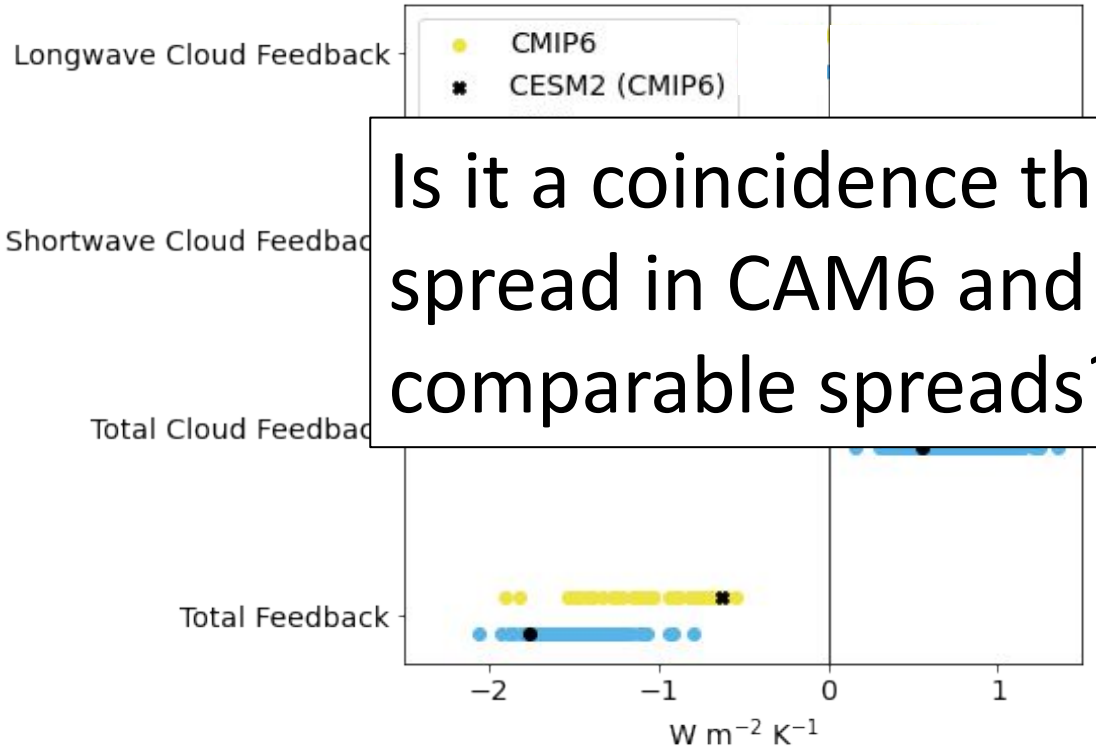
1. Why is the cloud feedback lower in the PPE default simulation than in CESM2?
   Coupling and newer generation of CAM6 in the PPE
2. Is it a coincidence that the parametric spread in CAM6 and CMIP6 models have comparable spreads?
   Similar spreads across individual assessed feedbacks suggests it's NOT a coincidence
3. Which parameters control the spread in cloud feedbacks?
   One microphysics parameter, one convection parameter, one turbulence parameter
4. Are changes in parameters responsible for the increase in ECS from CAM5 to CAM6?
   No

NCAR
UCAR

Margaret L. Duffy
mlduffy@ucar.edu

MAPP
Modeling, Analysis, Predictions, and Projections

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



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

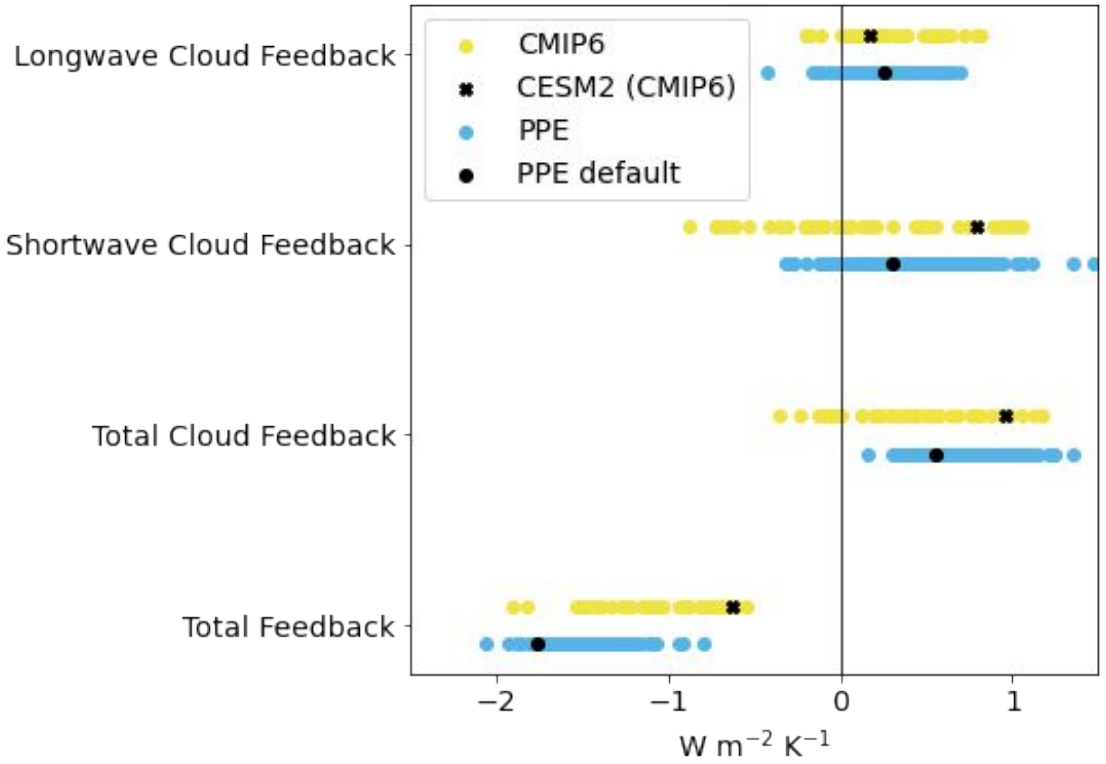
warming

simulation

- 262 simulations are run
- 206 simulations are used here

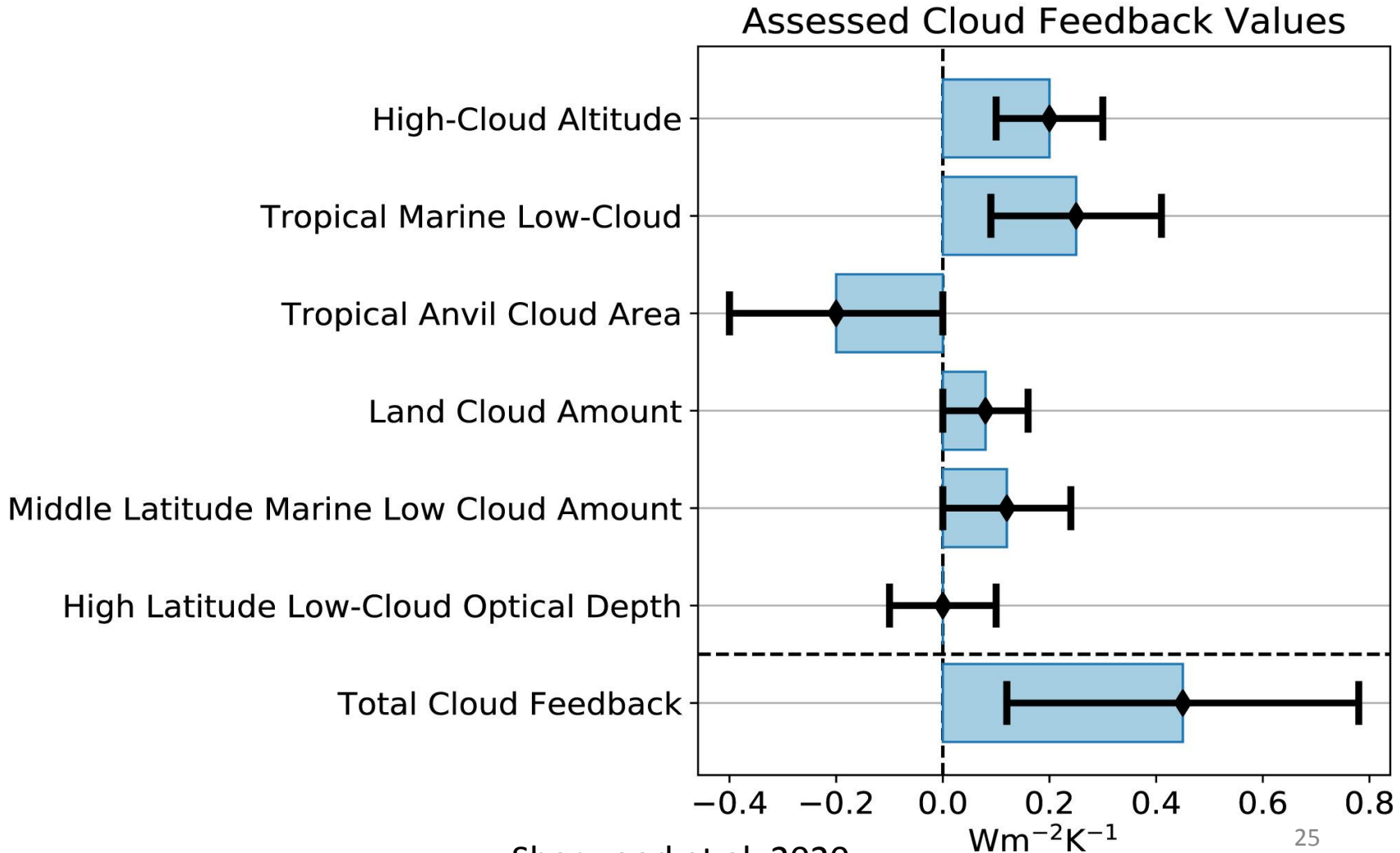
Is it a coincidence that the parametric spread in CAM6 and CMIP6 models have comparable spreads?

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



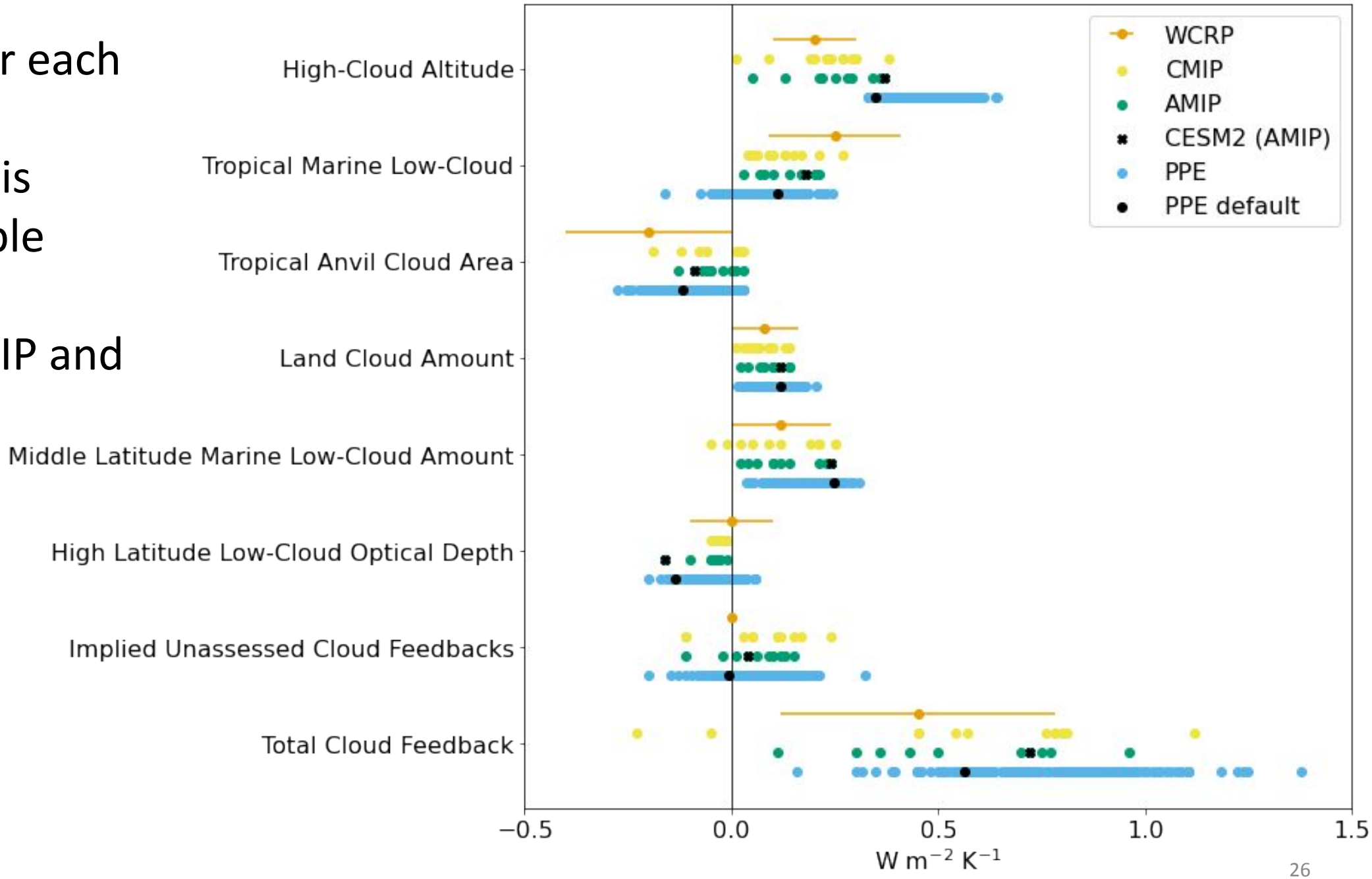
Is it a coincidence that the parametric spread in CAM6 and CMIP6 models have comparable spreads?

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

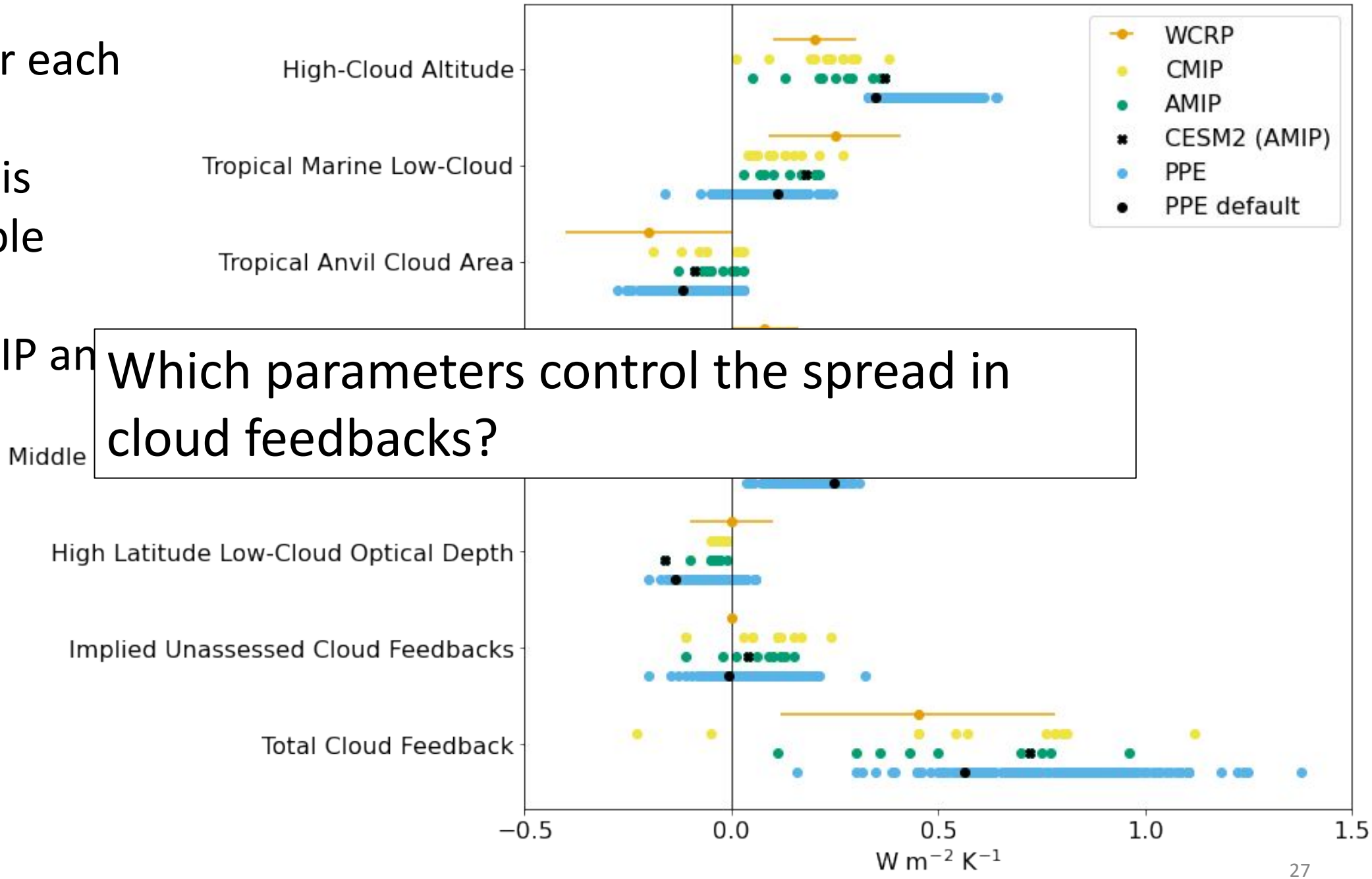


Sherwood et al. 2020

Spread for each assessed feedback is comparable between CMIP/AMIP and PPE



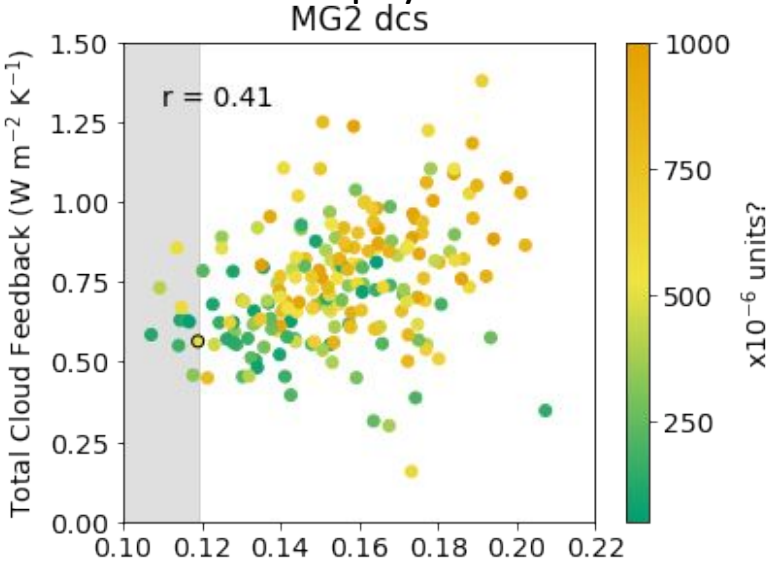
Spread for each assessed feedback is comparable between CMIP/AMIP an PPE



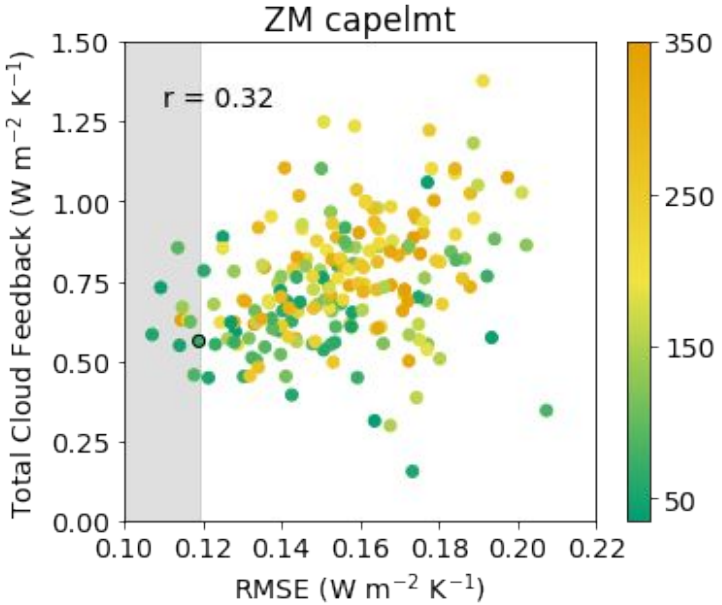
Which parameters control the spread in cloud feedbacks?

Which parameters control the spread?

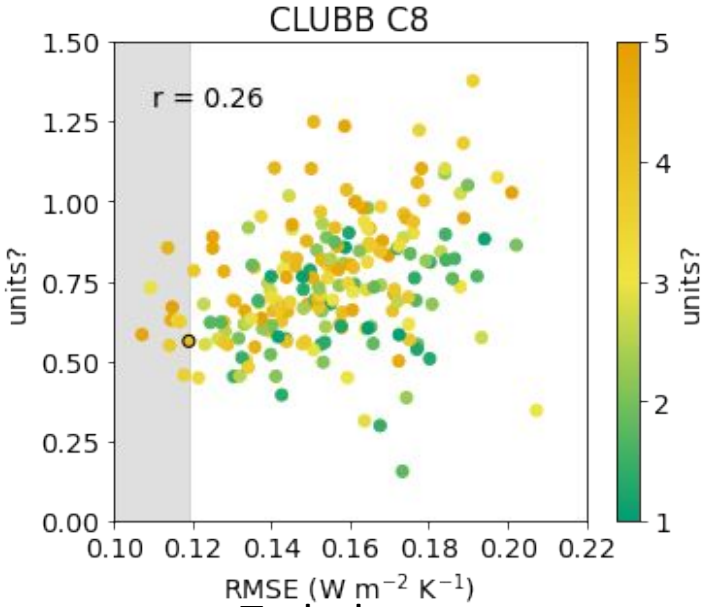
Microphysics



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



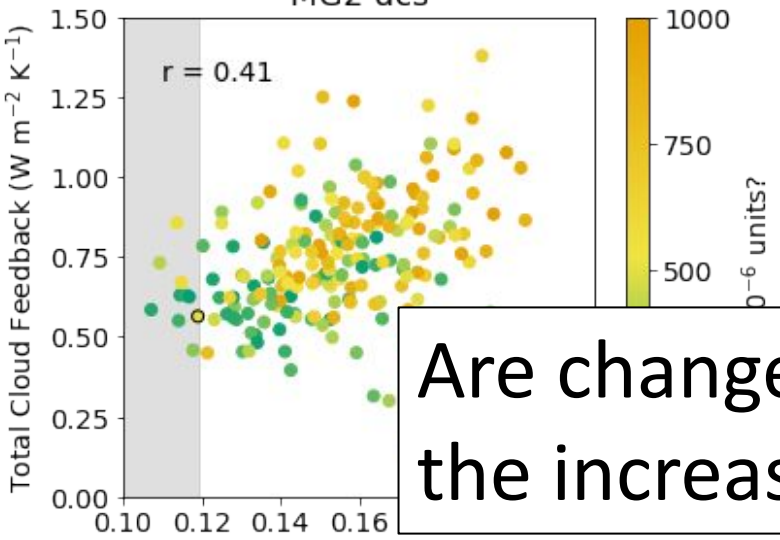
Convection



Turbulence

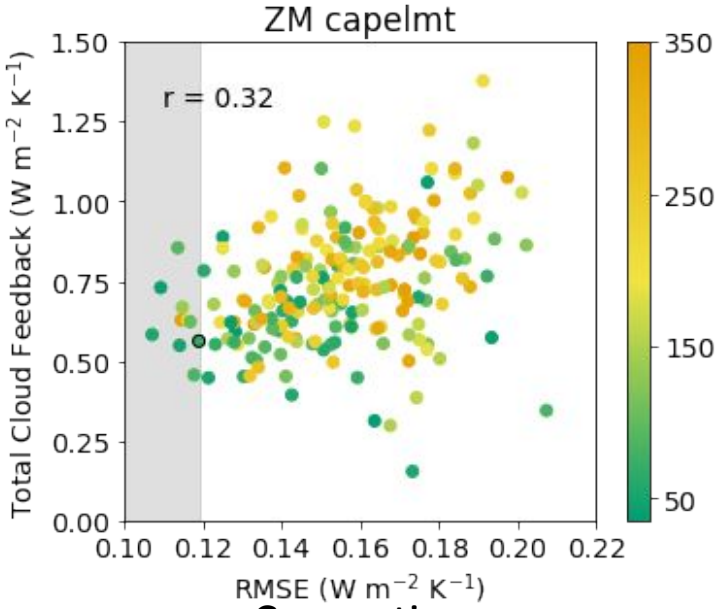
Which parameters control the spread?

Microphysics

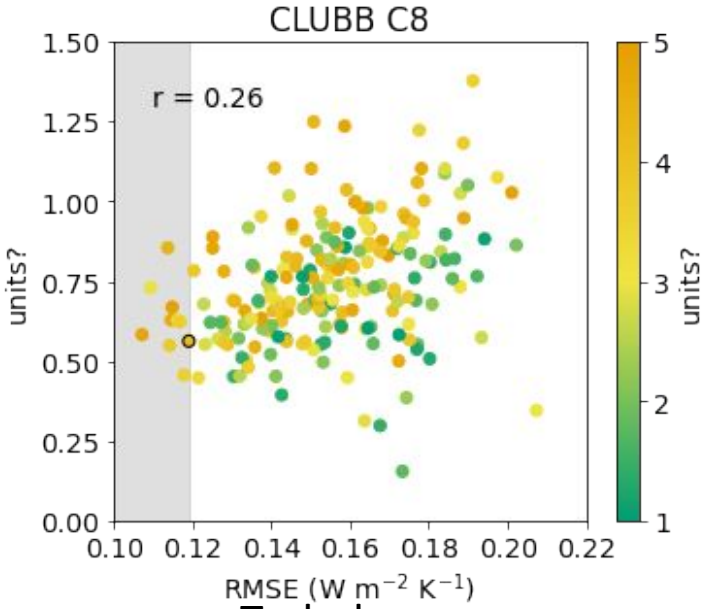


Scheme	Parameter
Microphysics	Ice-snow autoconversion size threshold
Convection	Triggering threshold for convection

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



Convection



Turbulence

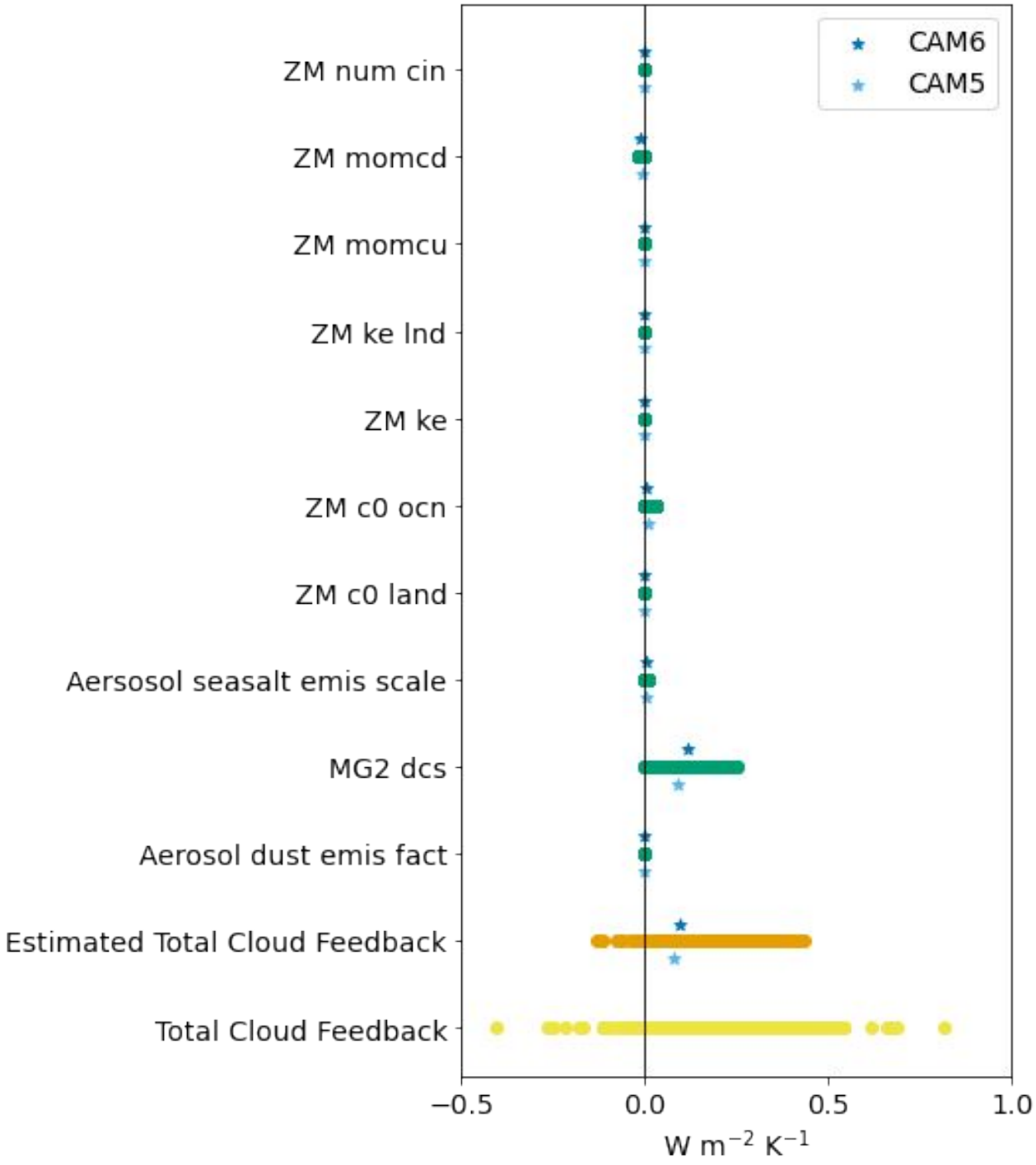
Are changes in parameters responsible for the increase in ECS from CAM5 to CAM6?

- 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



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

NCAR
UCAR

Margaret L. Duffy
mlduffy@ucar.edu

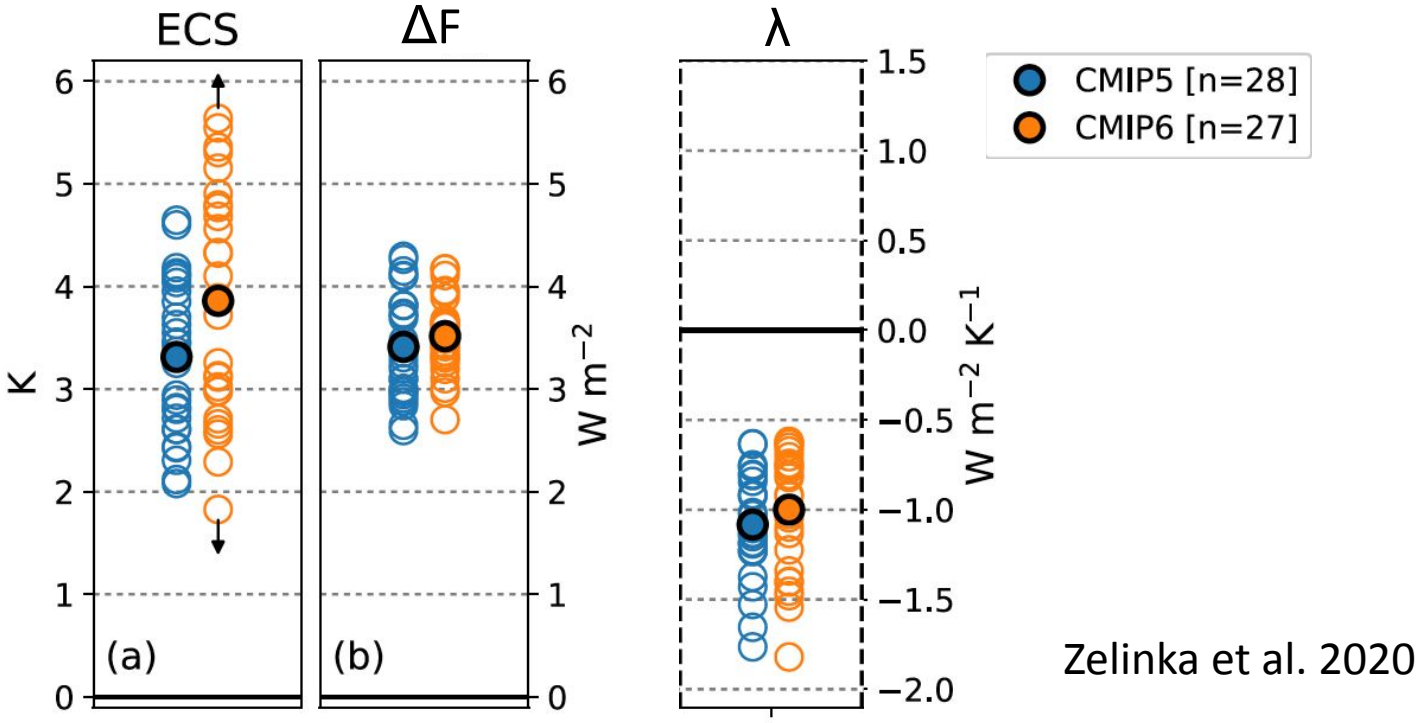
MAPP
Modeling, Analysis, Predictions, and Projections

Spread in ECS has increased from the previous model generation

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

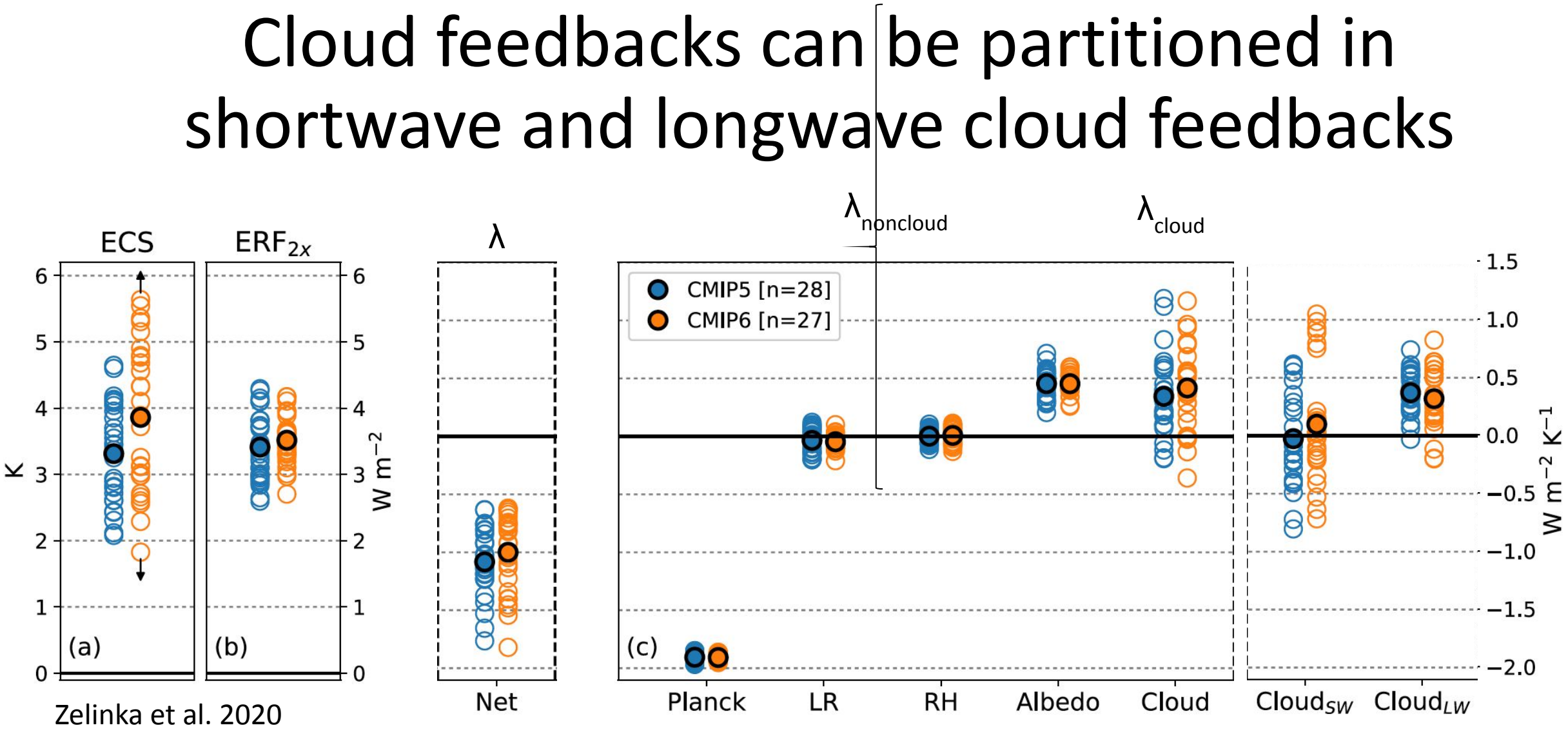
ΔF ← Forcing

λ ← Feedback



Zelinka et al. 2020

Cloud feedbacks can be partitioned in shortwave and longwave cloud feedbacks



Zelinka et al. 2020