An Observation-Based Approach to Assess Tropical Stratocumulus and Shallow Cumulus Clouds and Feedbacks in CMIP6 and CMIP5 models

Grégory Cesana[1,2], Andrew Ackerman[2], Nina Črnivec[1,2], Robert Pincus[1] and Hélène Chepfer[3]

[1]Columbia University
[2]NASA Goddard Institute for Space Studies
[3]LMD, Sorbonne Université

Paper

Acknowledgements:
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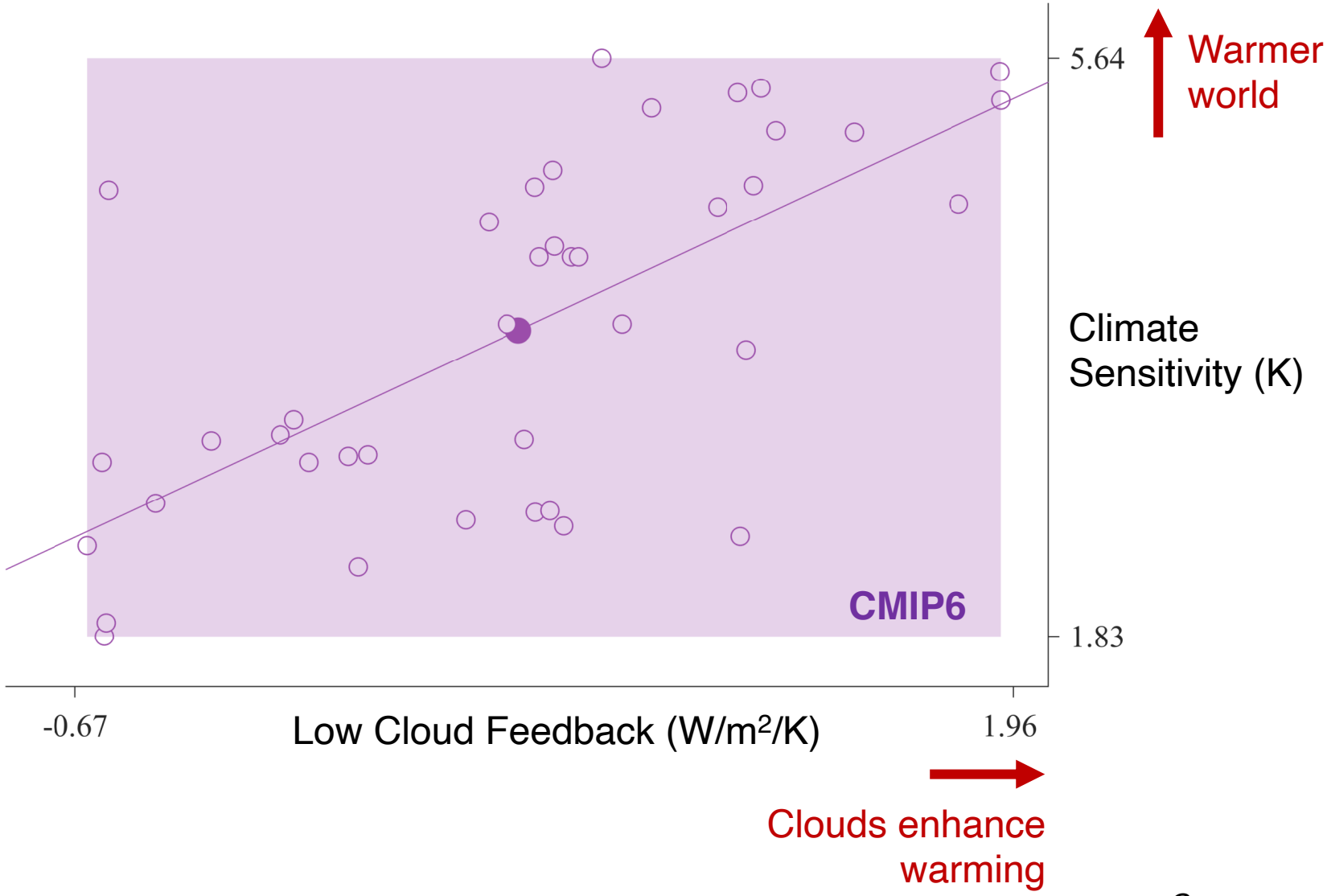
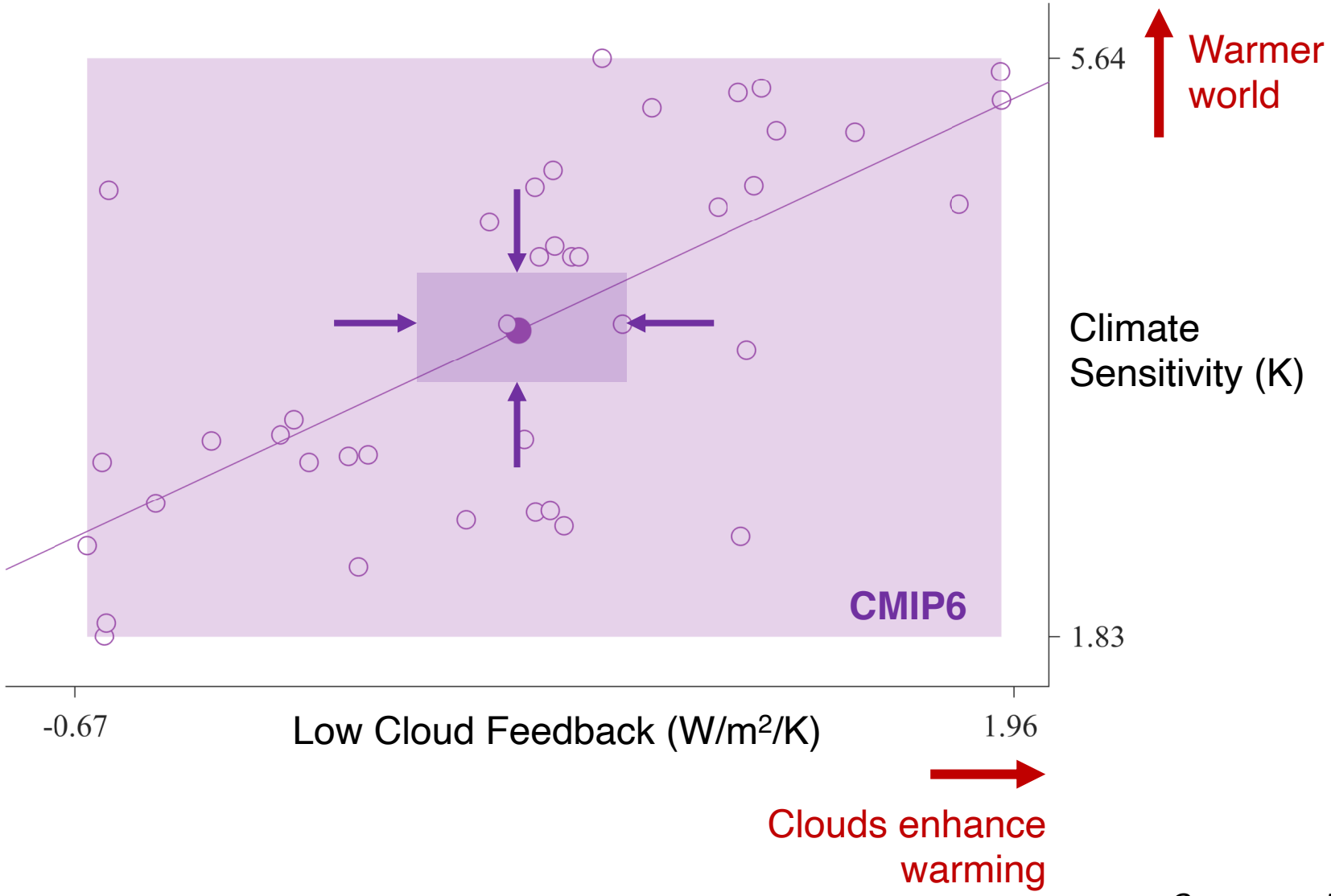
SW tropical low-cloud feedback explains part of the spread in simulated climate sensitivity



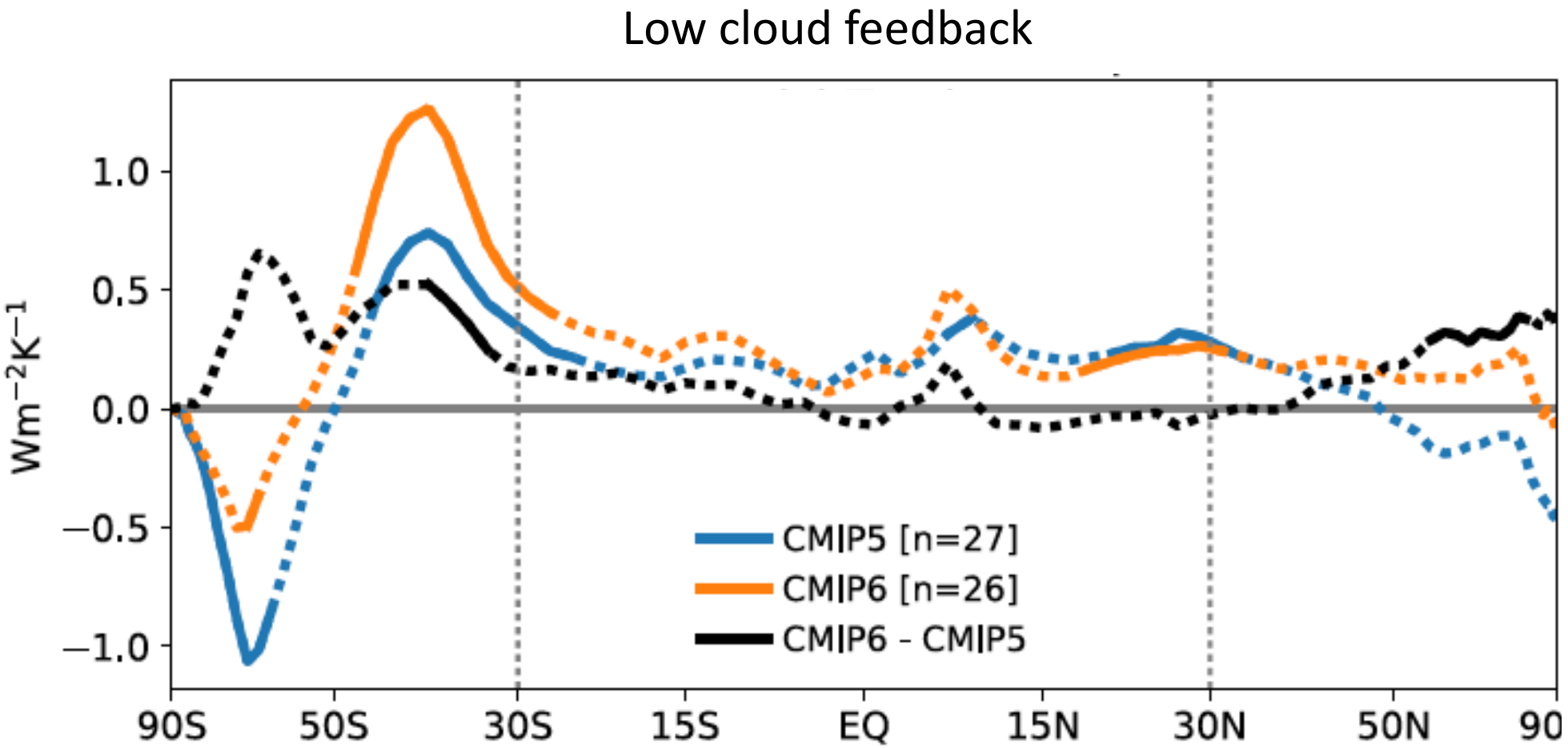
Cesana and Del Genio (2021)

Reducing the uncertainty in low-cloud feedback would reduce its contribution to the spread in ECS



Cesana and Del Genio (2021)

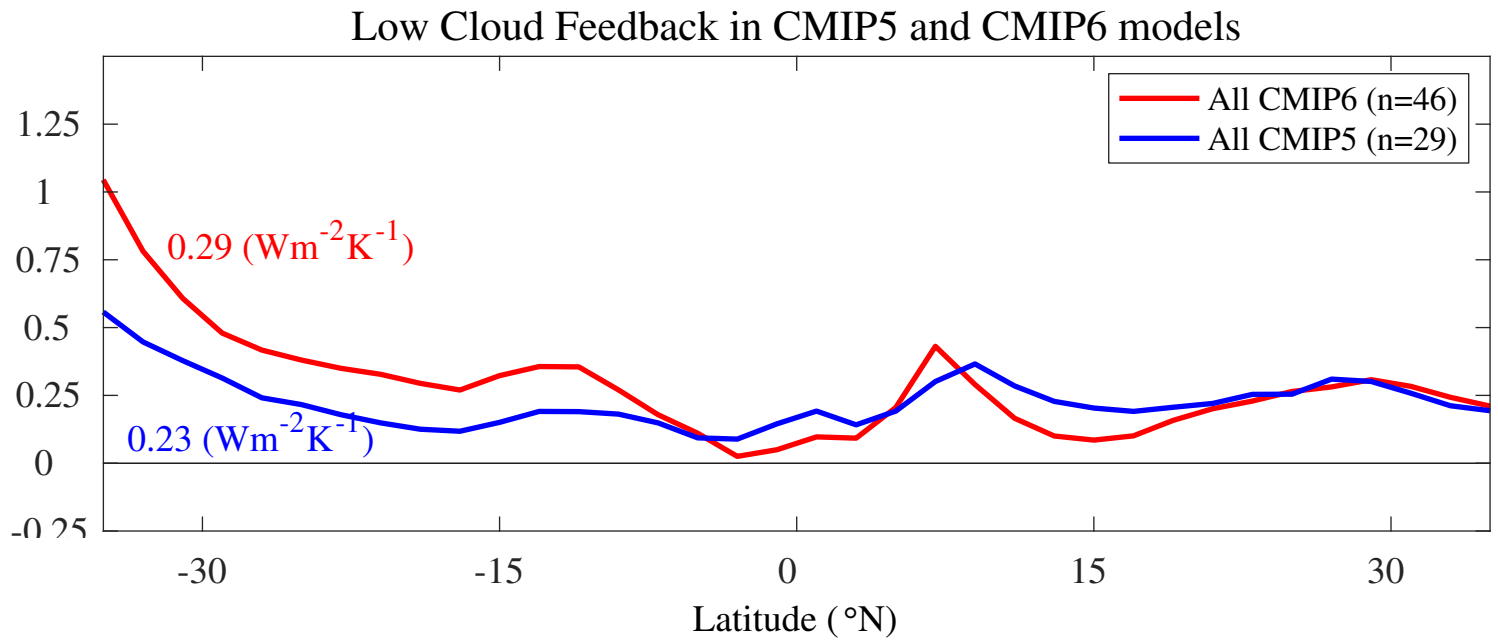
Large increase of the extratropical low-cloud feedback…



Zelinka et al. (2020)

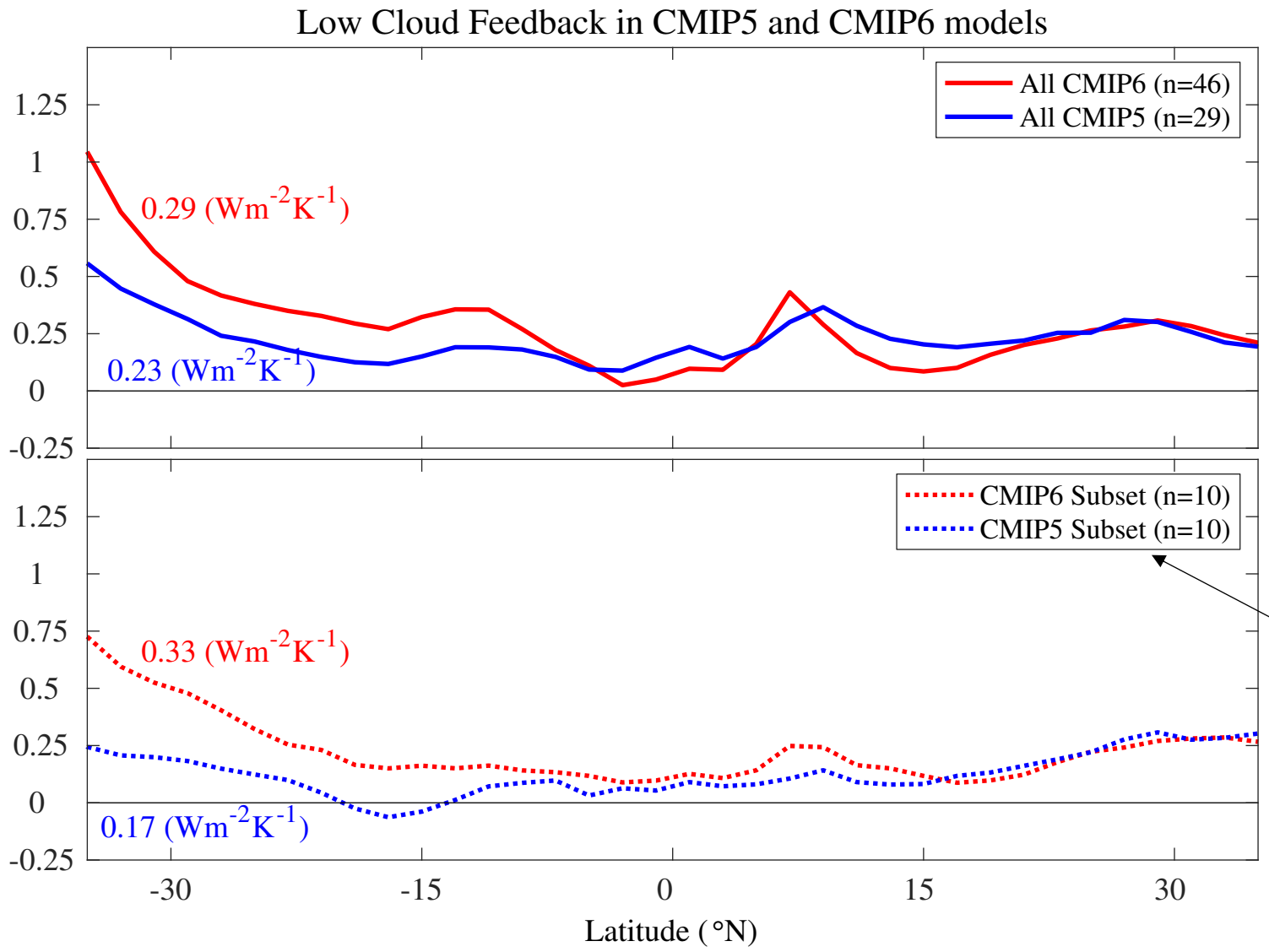
Small increase of the tropical low-cloud feedback…

Low Cloud Feedback ($W/m^2/K$)



But the increase is also substantial when focusing on a fixed subset of CMIP6 and CMIP5 models

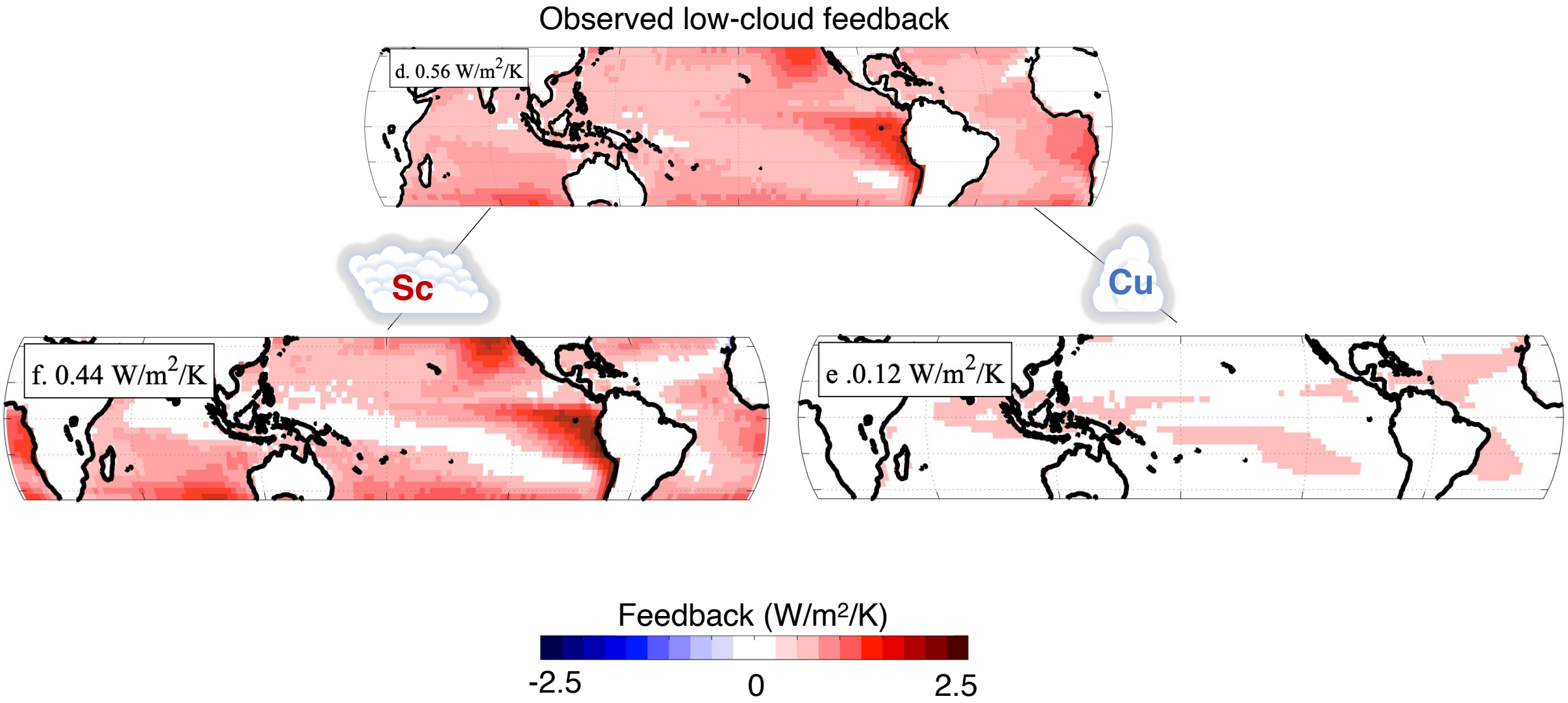
Low Cloud Feedback ($W/m^2/K$)



Same 10 modeling centers

Corresponds to the 8 main GCM families, which account for 95% of the CMIP submissions

Observationally inferred low-cloud feedback is driven by stratocumulus clouds



Cesana and Del Genio (2021)

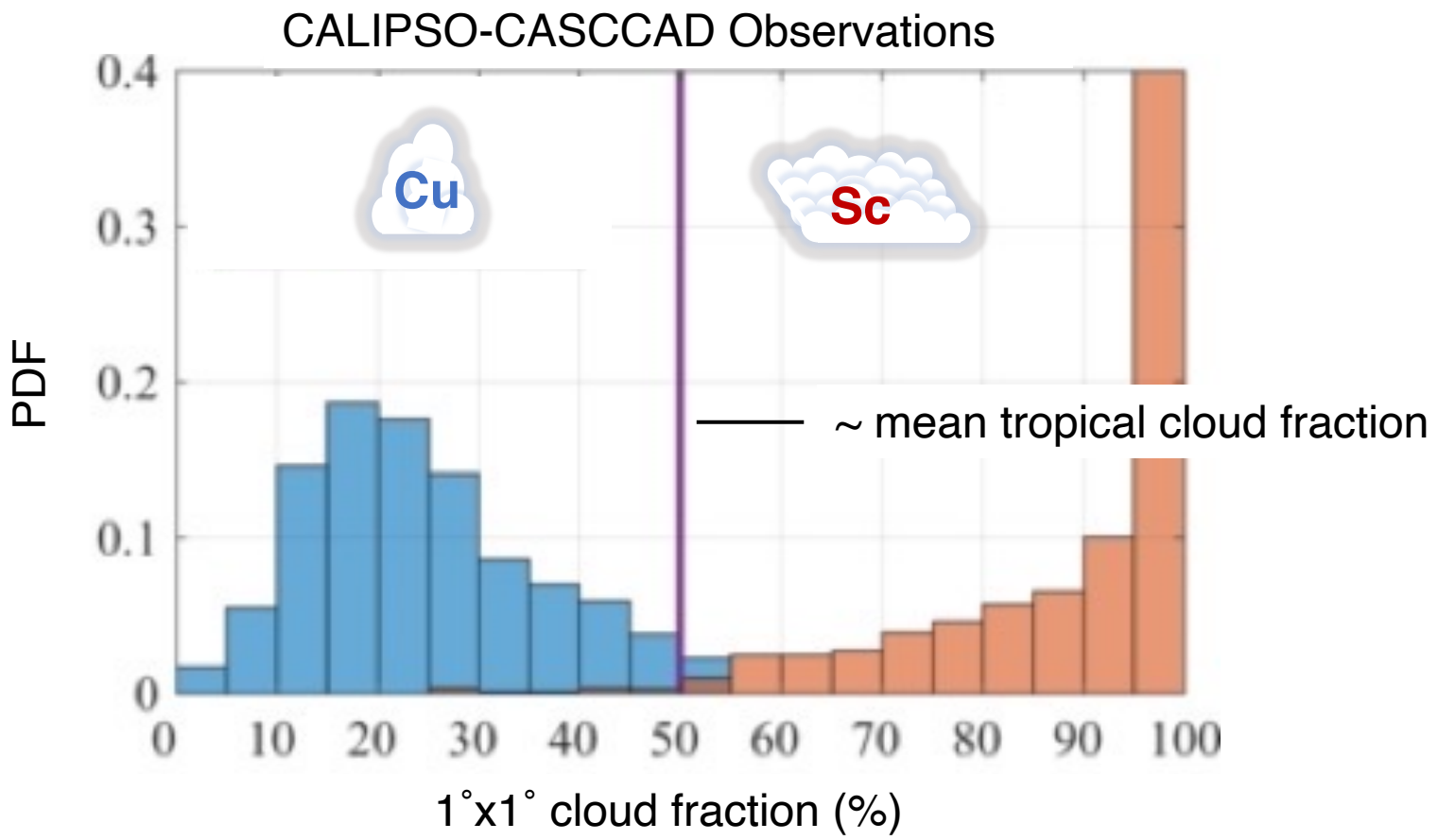
Objectives

1. Evaluate Sc and Cu in two CMIP generations

2. How changes in Sc and Cu cloud properties between CMIP generations affect low-cloud feedback

How to discriminate Sc and Cu clouds in climate models?

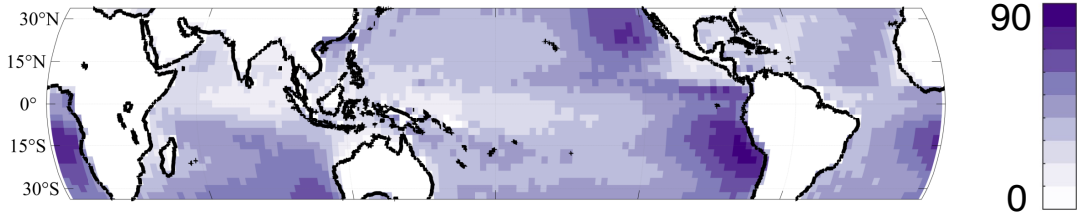
We use mean tropical cloud fraction
to distinguish **Sc** and **Cu**



Cesana, Del Genio, Chepfer (2019)

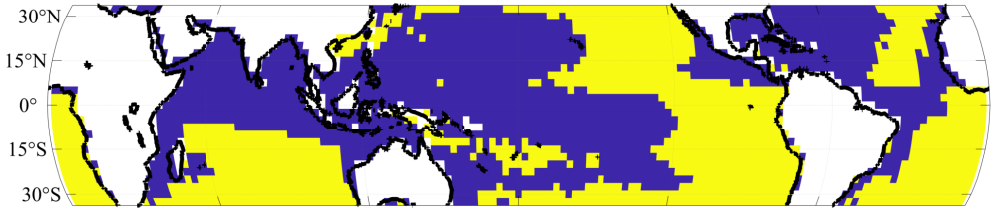
Sc and Cu are discriminated at each time step based on the tropical mean low cloud fraction

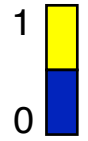
CALIPSO Low Cloud Fraction (%)



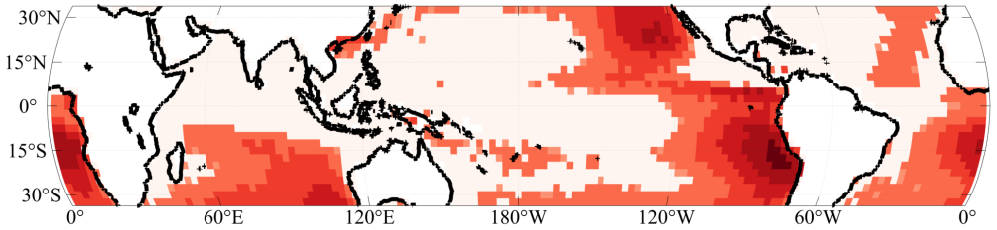
$1 \text{ where LCF} \geq \overline{LCF_{tropics}}$

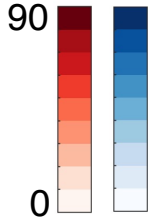
Mask



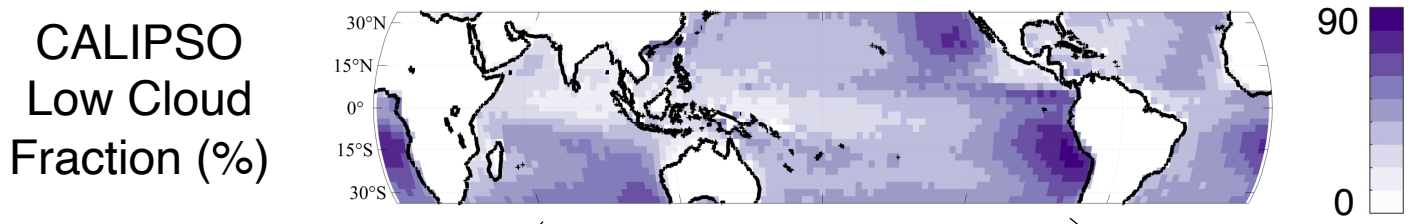


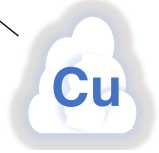
Cloud Fraction (%)





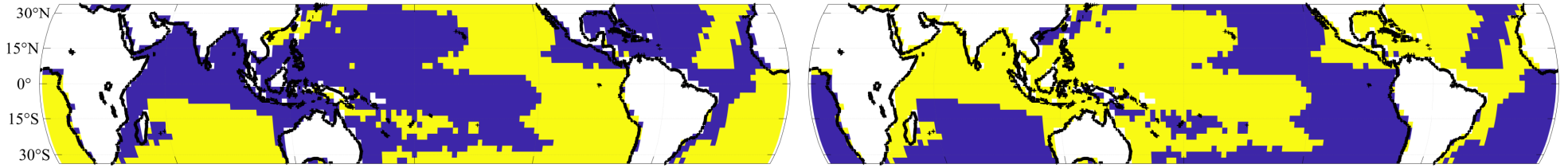
Sc and Cu are discriminated at each time step based on the tropical mean low cloud fraction

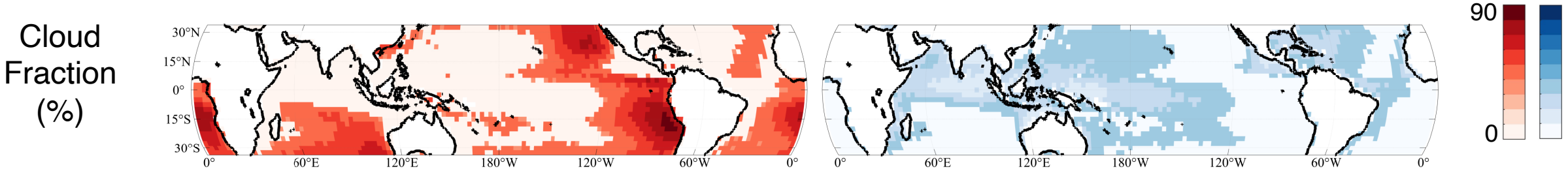




1 where LCF $\geq \overline{LCF_{tropics}}$

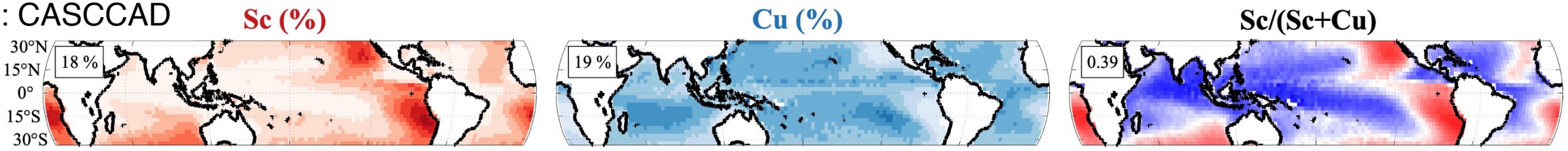
1 where LCF $< \overline{LCF_{tropics}}$



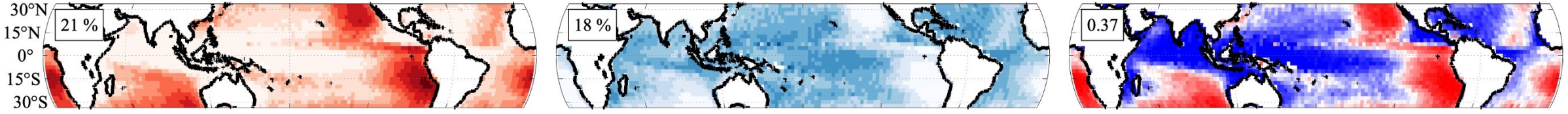


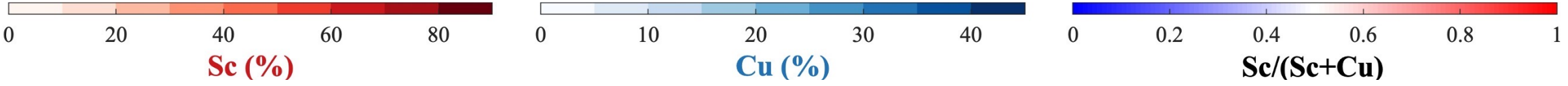
Our novel Sc-Cu discrimination method works very well with observations

Truth: CASCCAD

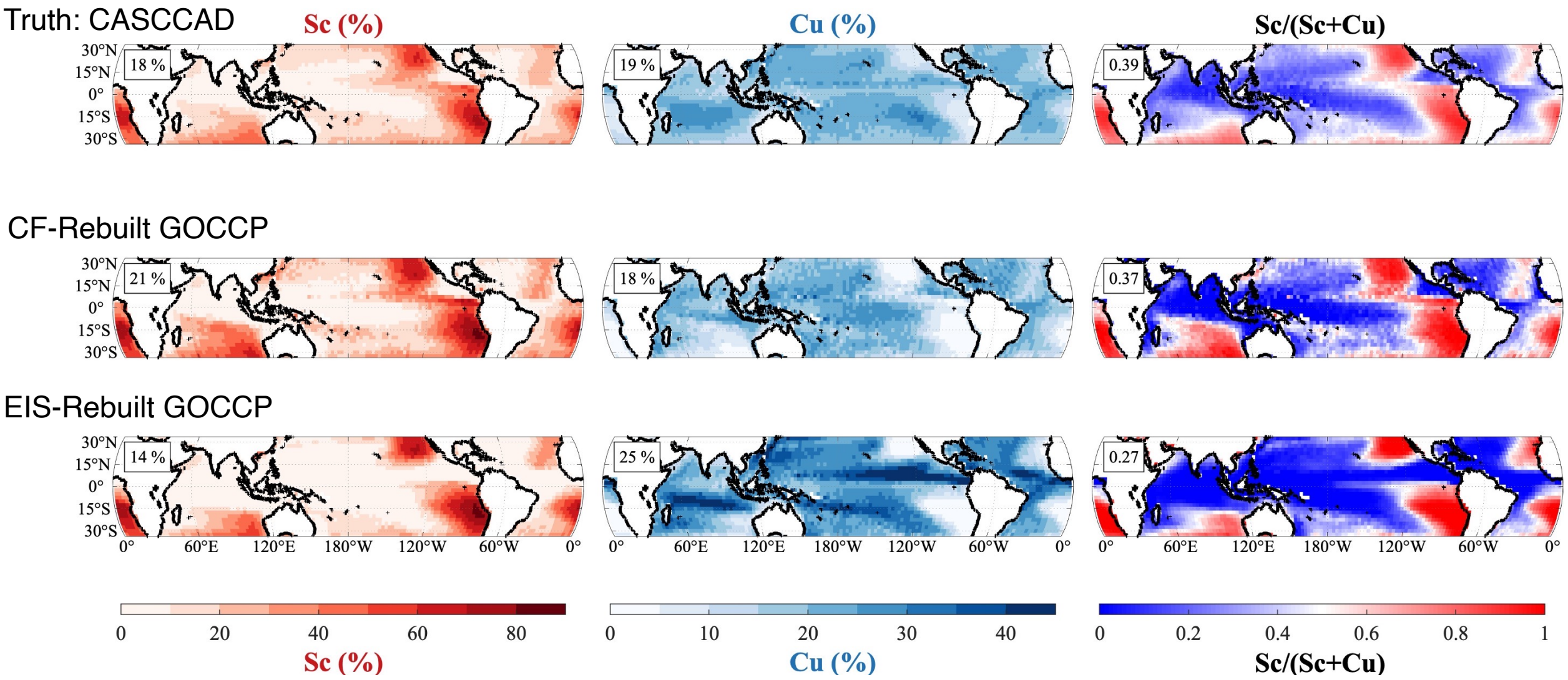


CF-Rebuilt GOCCP

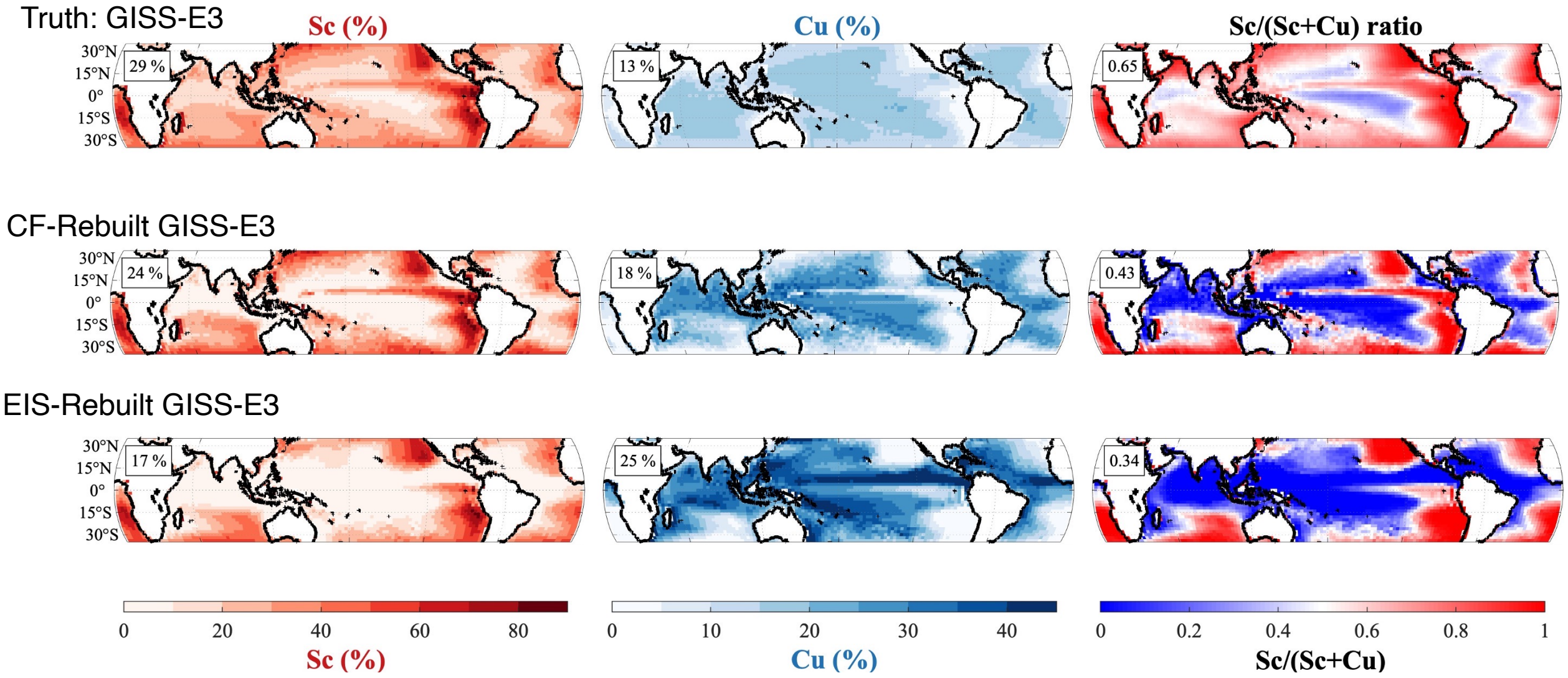




Our novel Sc-Cu discrimination method works very well with observations Better than an EIS-based method.

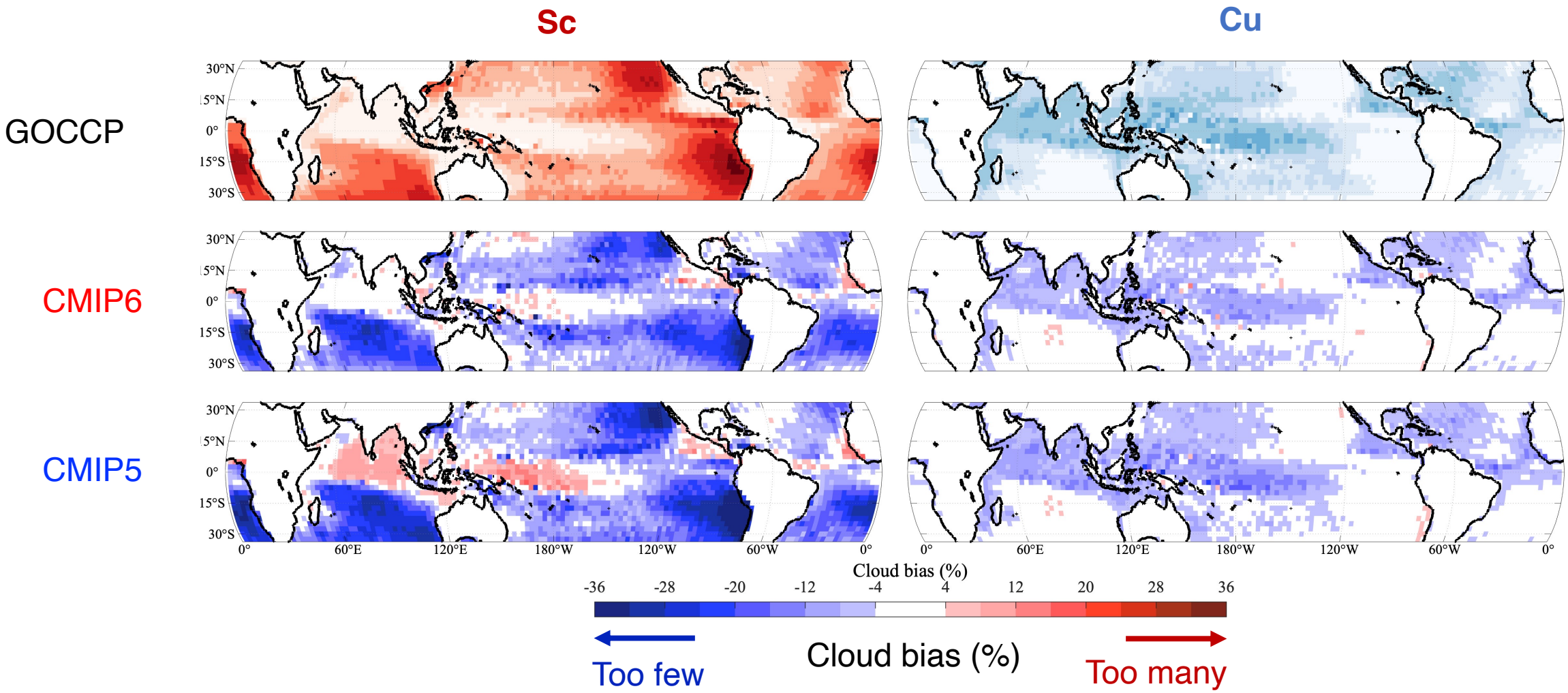


Our novel Sc-Cu discrimination method also works in GISS-E3 model

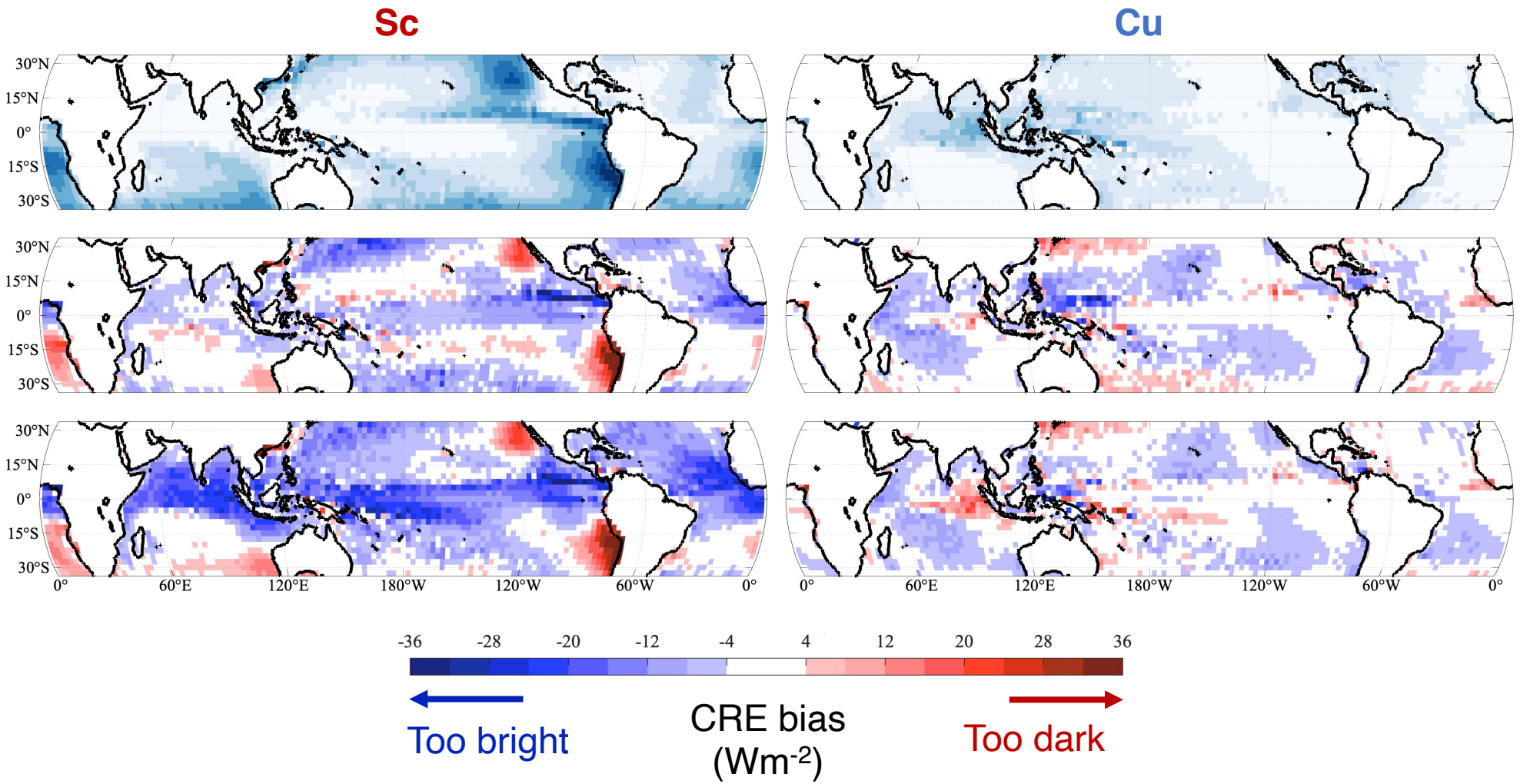


1. Evaluate Sc and Cu in two CMIP generations

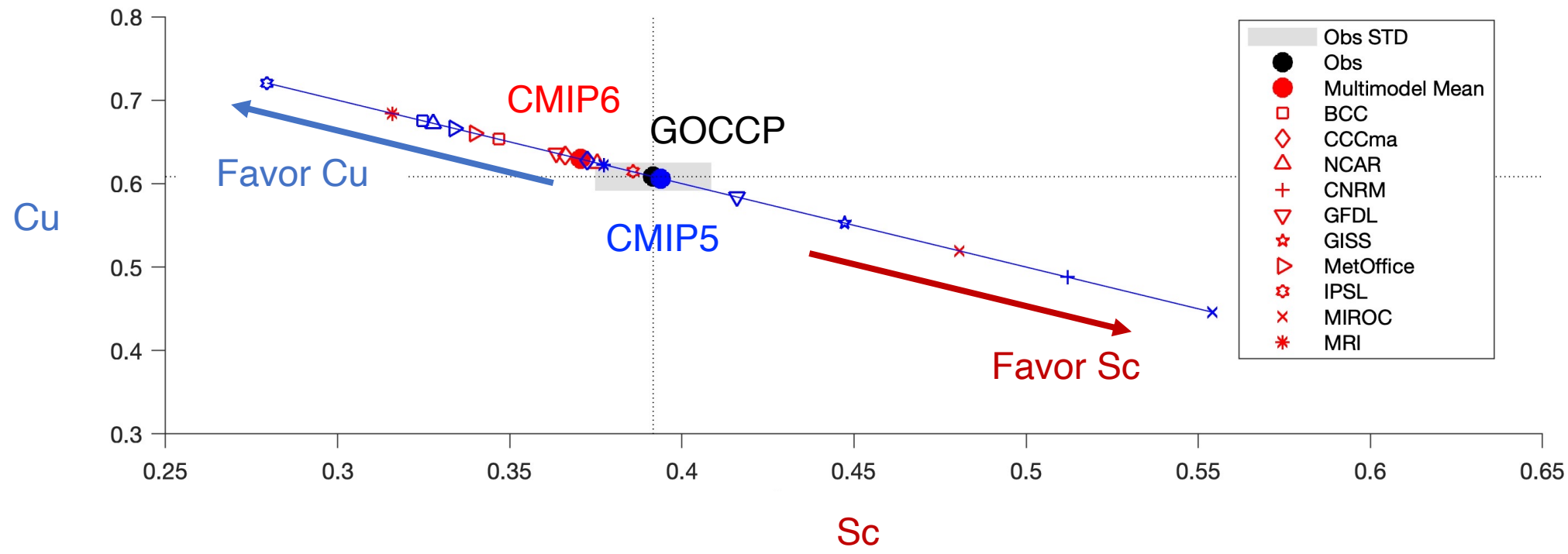
CMIP6 models collectively underestimate both Sc and Cu, especially over the Sc decks



Their SW radiative effect also improved, yet too bright overall

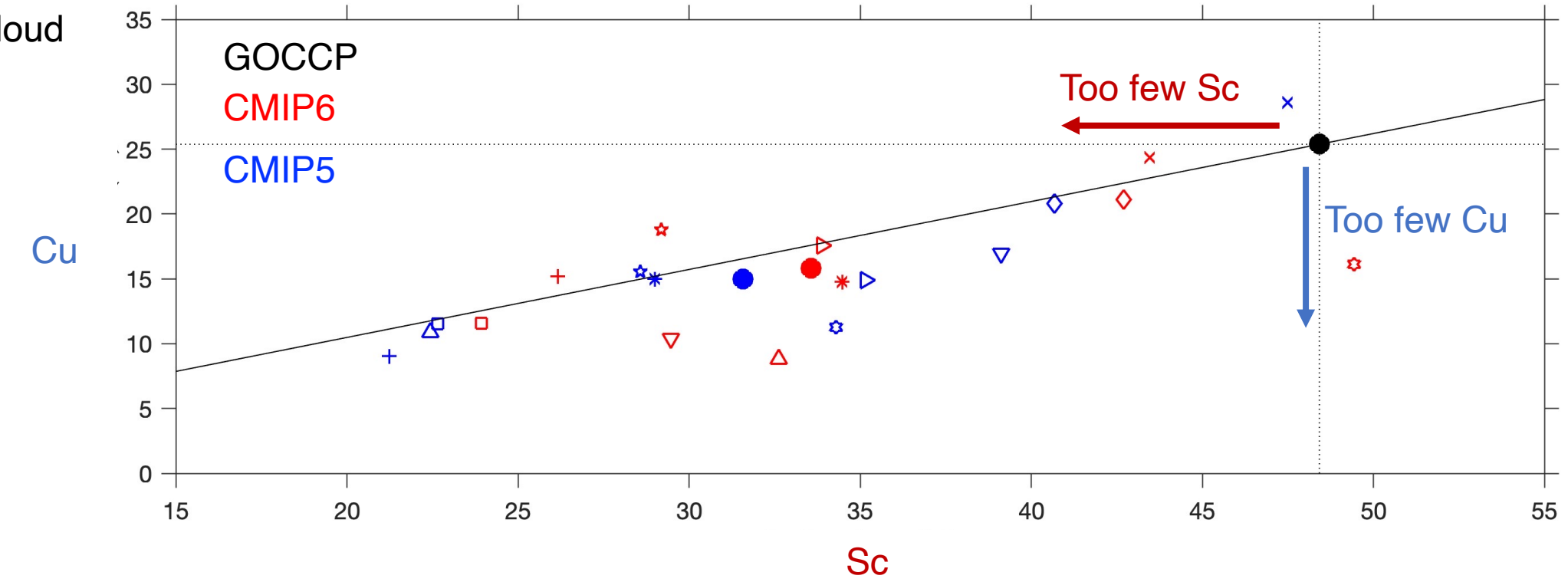


Most CMIP models favor Cu over Sc regime frequency…



Almost all CMIP models underestimate Both Sc and Cu in-regime cloud fraction

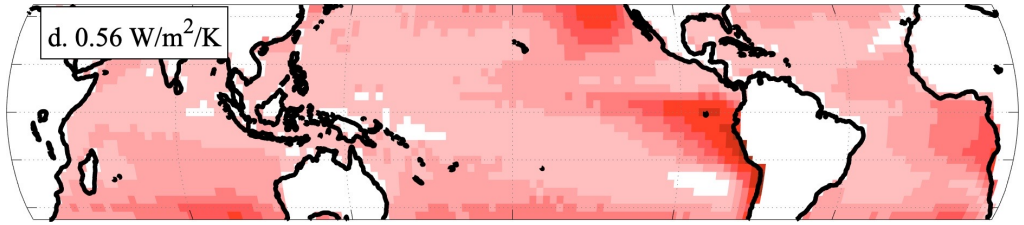
In-regime Cloud Cover (%)

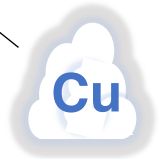


2. How changes in Sc and Cu cloud properties between CMIP generations affect low-cloud feedback

How to characterize Sc and Cu feedbacks?
We weight the low cloud feedback by the Sc and Cu cloud fractions:

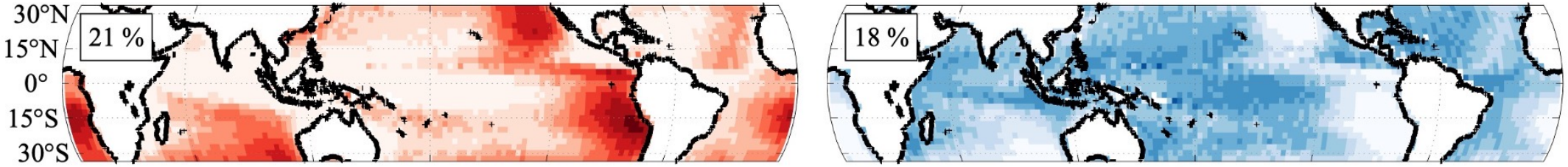
CASCCAD Low Cloud Feedback



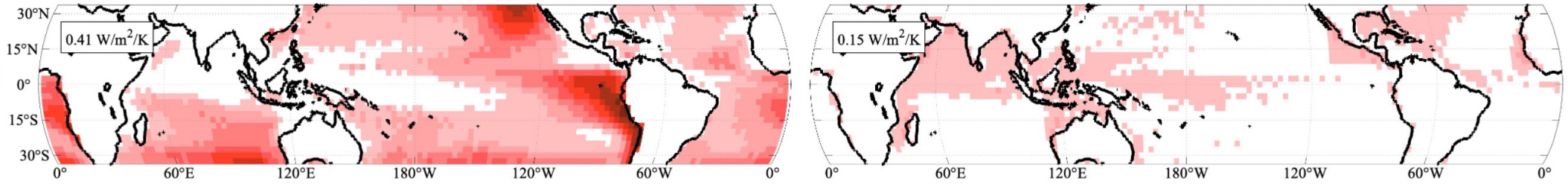


$$Feedback_{Sc\ or\ Cu} = Feedback_{Low} \times CF_{Sc\ or\ Cu}$$

CF



Rebuilt Feedback



How to characterize Sc and Cu feedbacks?
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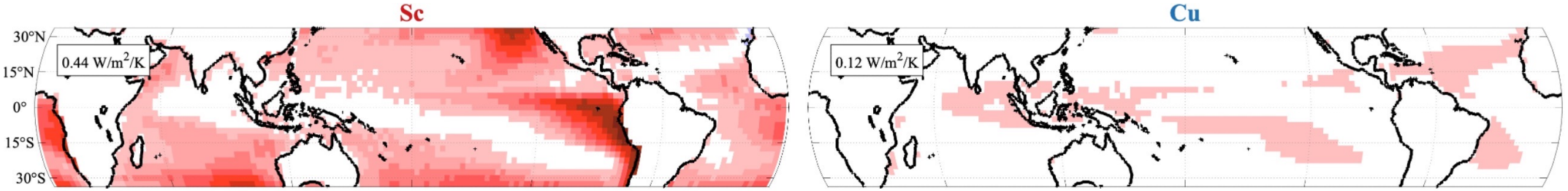
Truth: CASCCAD



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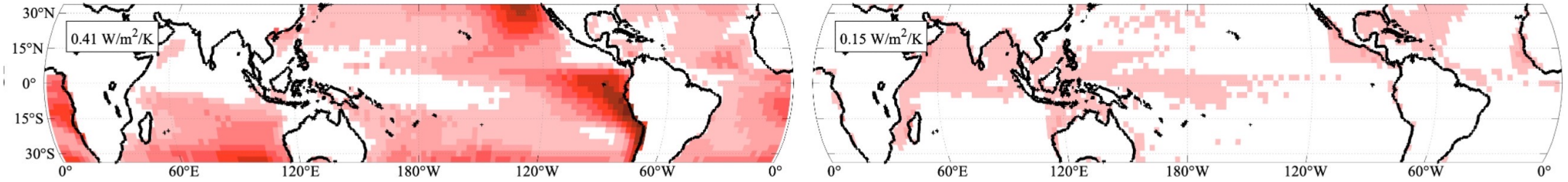
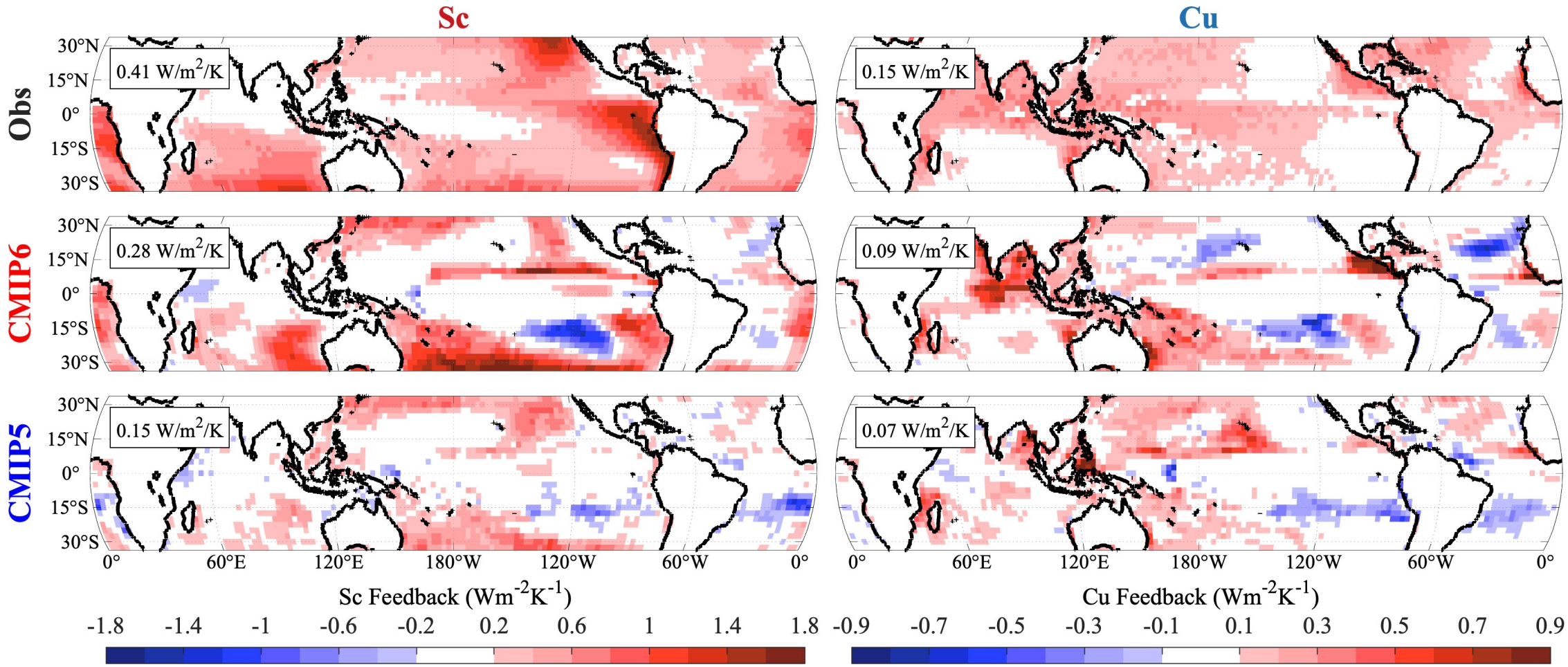
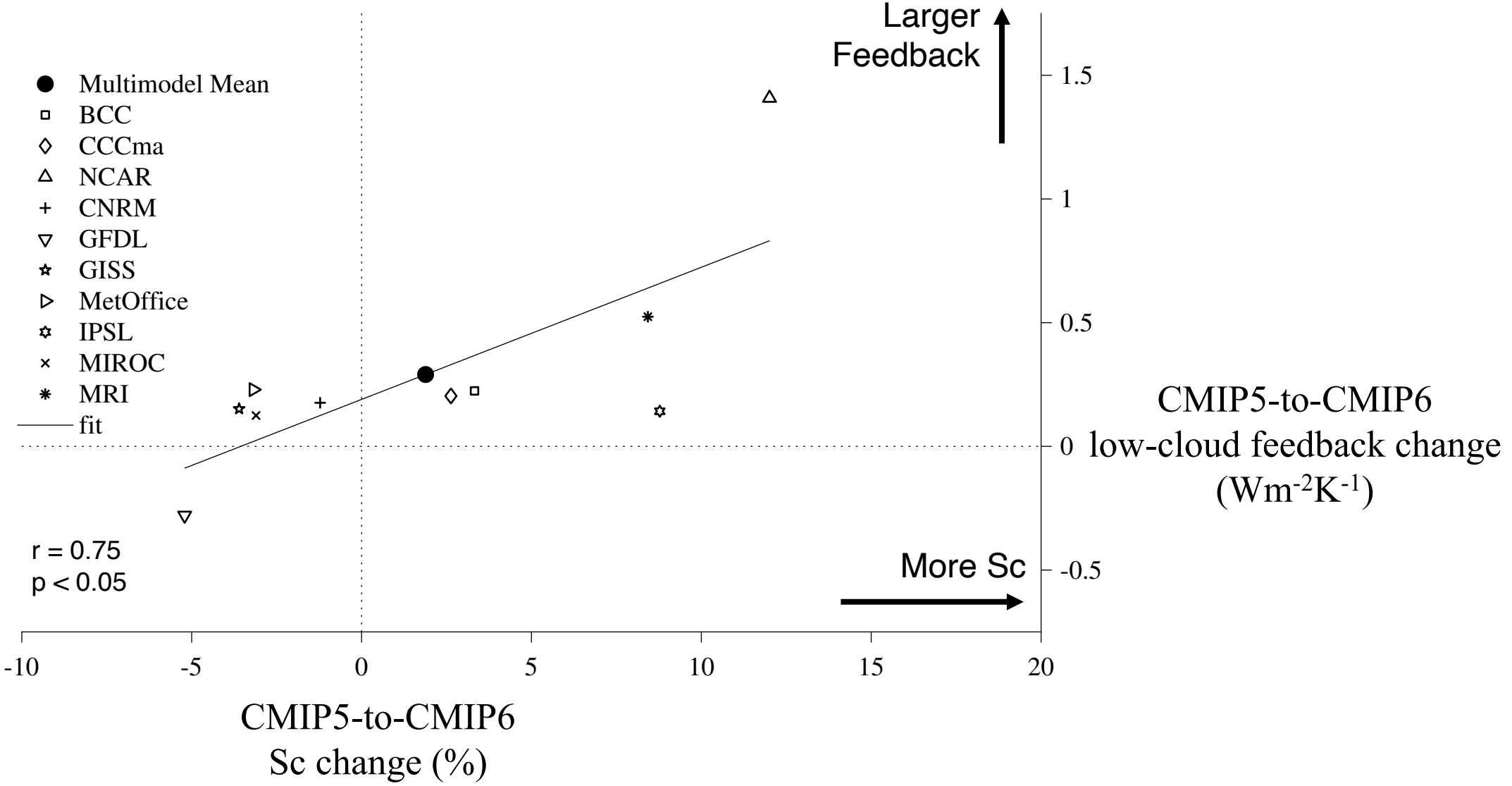


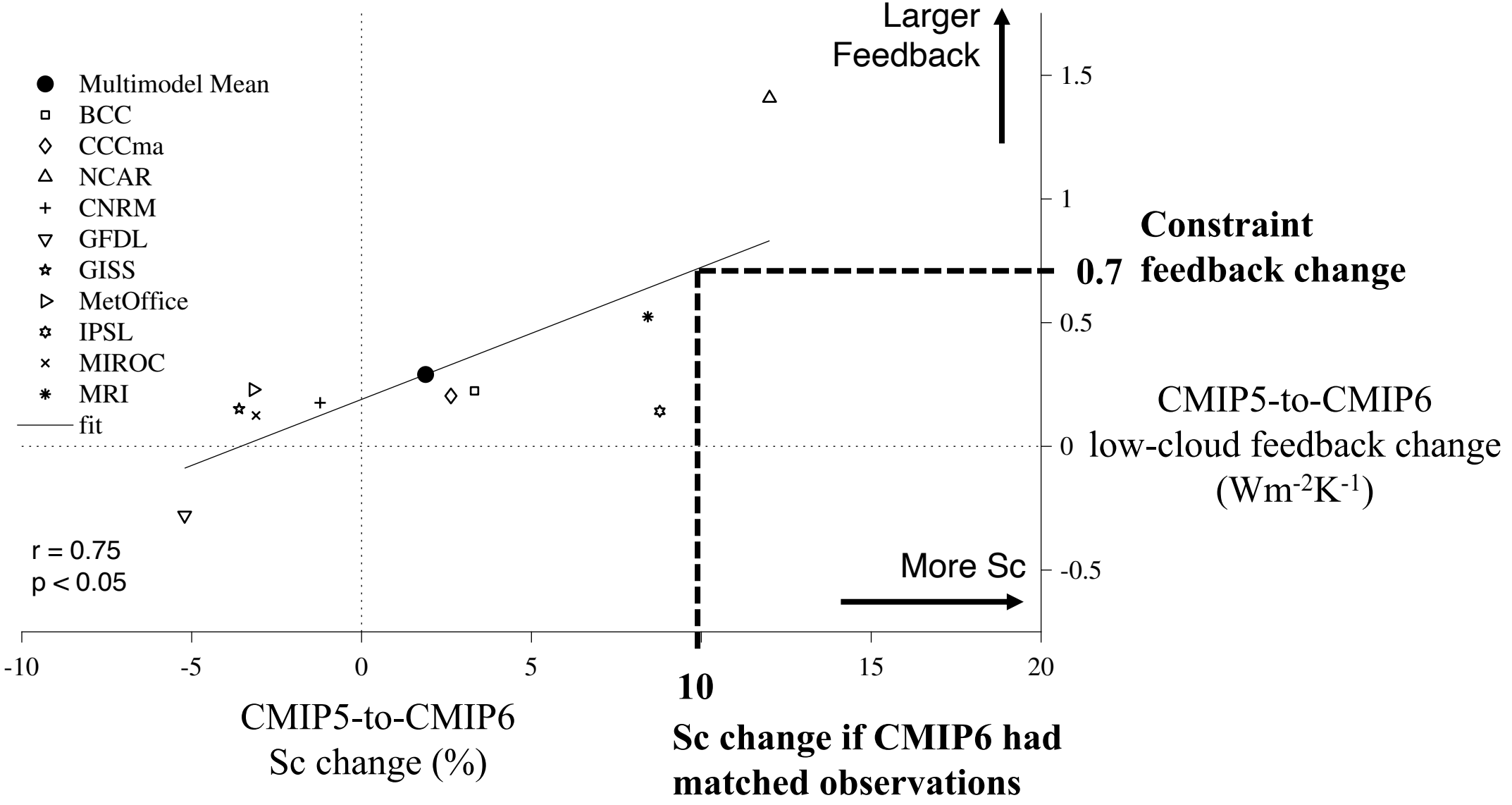
CMIP6 models substantially improved their depiction of Sc cloud feedback



Increased Sc between CMIP generations is correlated with increased low-cloud feedback

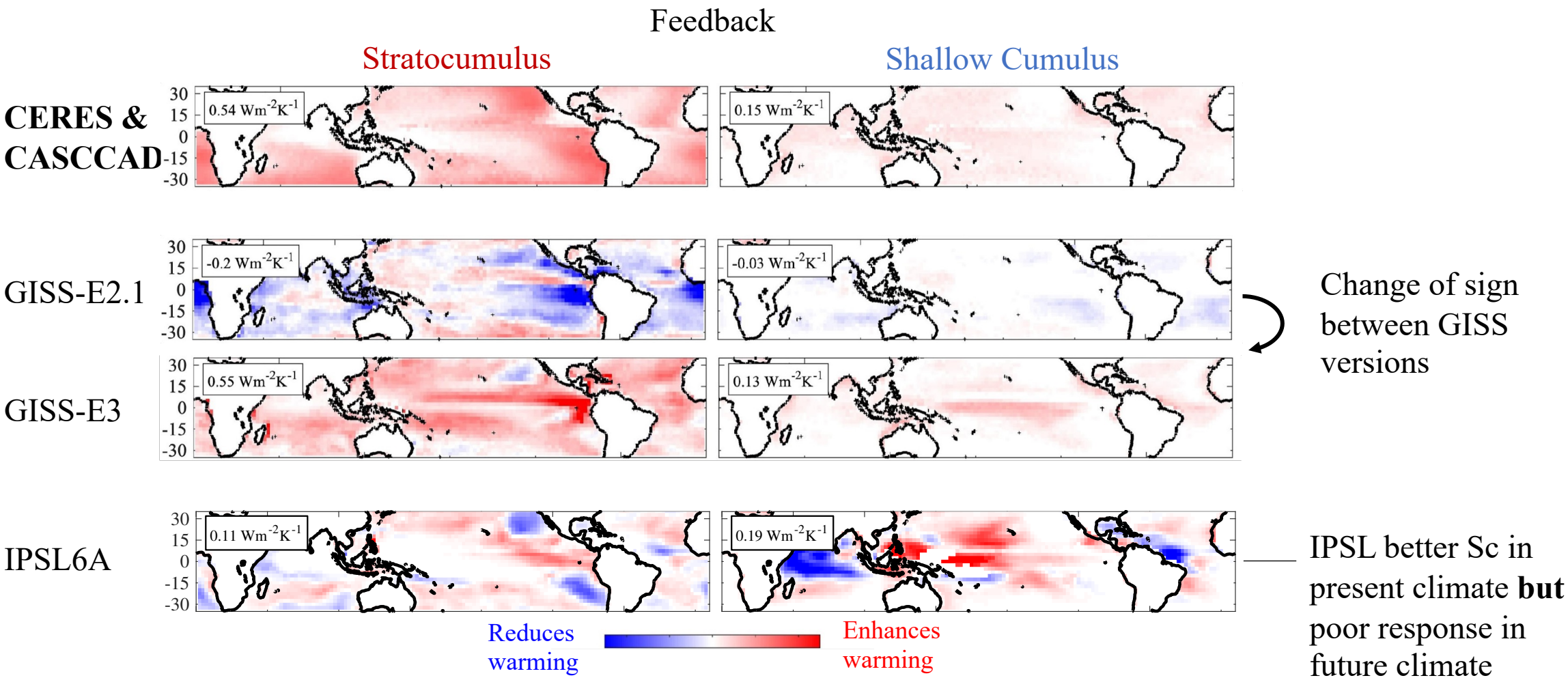


If the mean CMIP6 Sc had matched the observations, Their mean low-cloud feedback would have been twice as large



Future climate:

We will incorporate constraints on how clouds respond to climate change in our development process by using unique expertise of observational cloud feedbacks



Summary

- Large-scale cloud fraction can be used to distinguish Sc and Cu cloud amount and feedback in observations and simulations.
- CMIP6 models better simulate Sc and Cu cloud amount, pattern, SW radiative effect, and feedback.
- More Sc partly explain increased low-cloud feedback in CMIP6.

Paper

Acknowledgements:
This work was supported by NOAA MAPP, NASA MAP and CloudSat-CALIPSO Recompete.