

Re-examining the relationship between climate sensitivity and the Southern Hemisphere radiation budget in CMIP models

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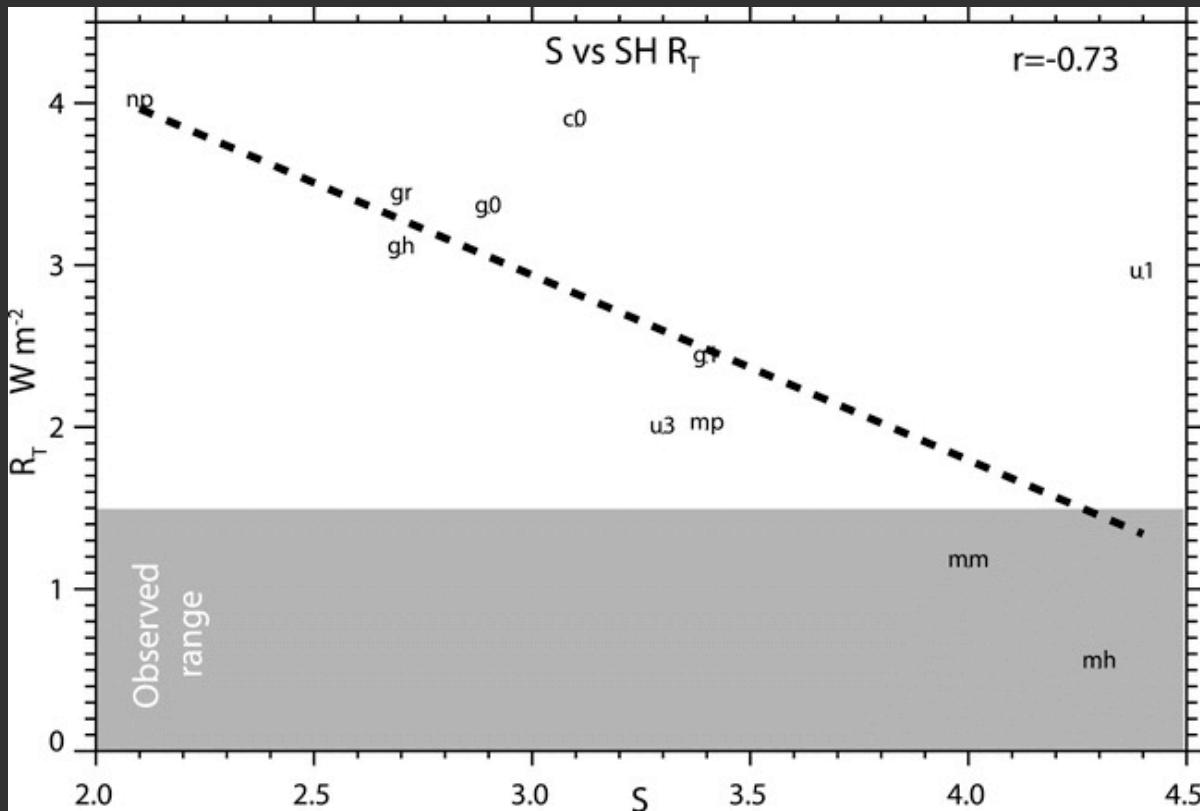
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Columbia University

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CFMIP Meeting on Cloud Processes and Climate Feedbacks
Monterey, CA
June 9, 2015

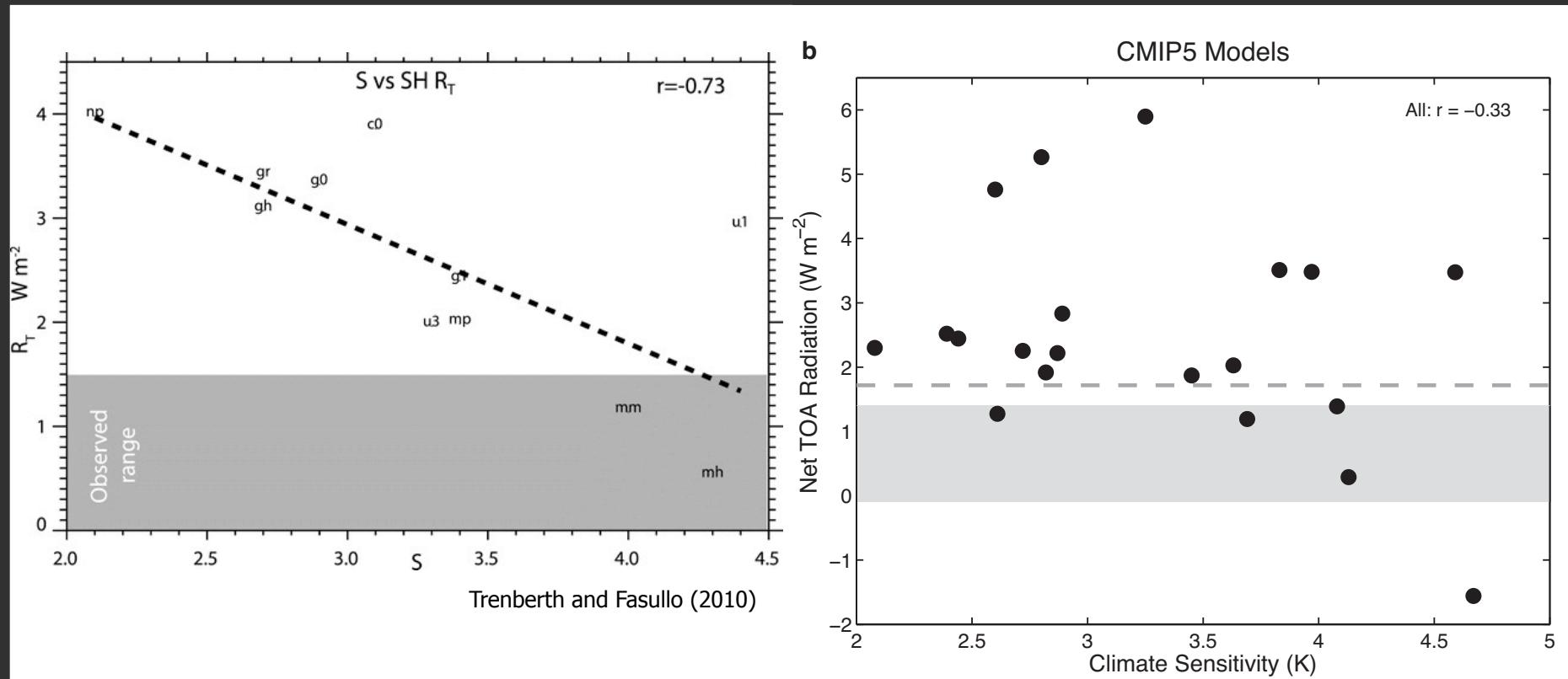
CMIP3 Models

Trenberth and Fasullo (2010)



Models with most realistic values of present-day Southern Hemisphere net TOA radiation have highest climate sensitivity.

Relationship breaks down in CMIP5 models!

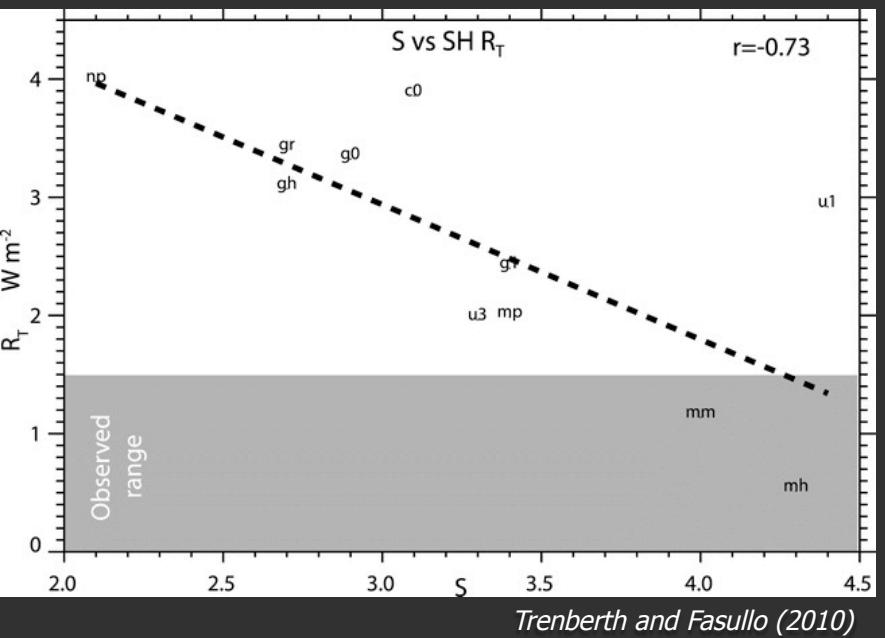


Today's Questions

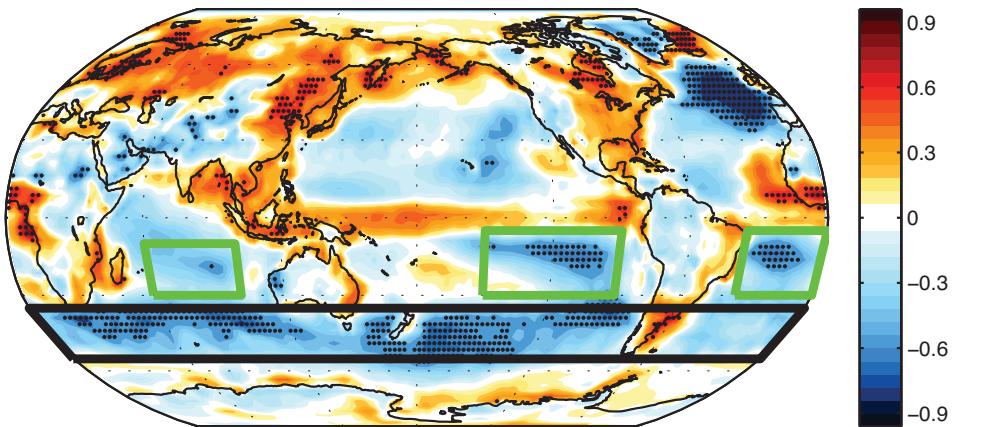
- 1) *What are the processes responsible for the relationship between climate sensitivity and present-day Southern Hemisphere radiation biases in CMIP3 models?*

- 2) *Why does this relationship break down in CMIP5 models?*

CMIP3 Models

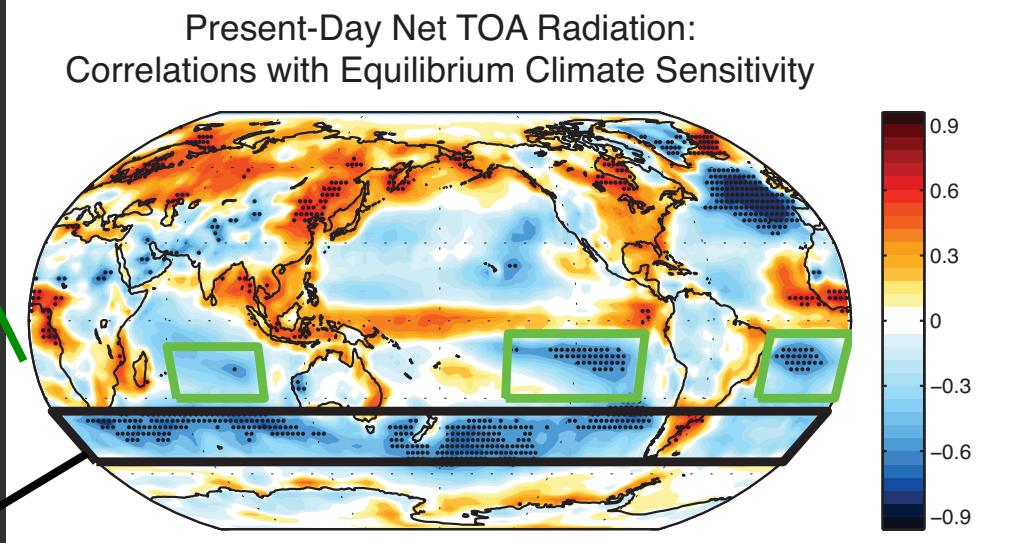
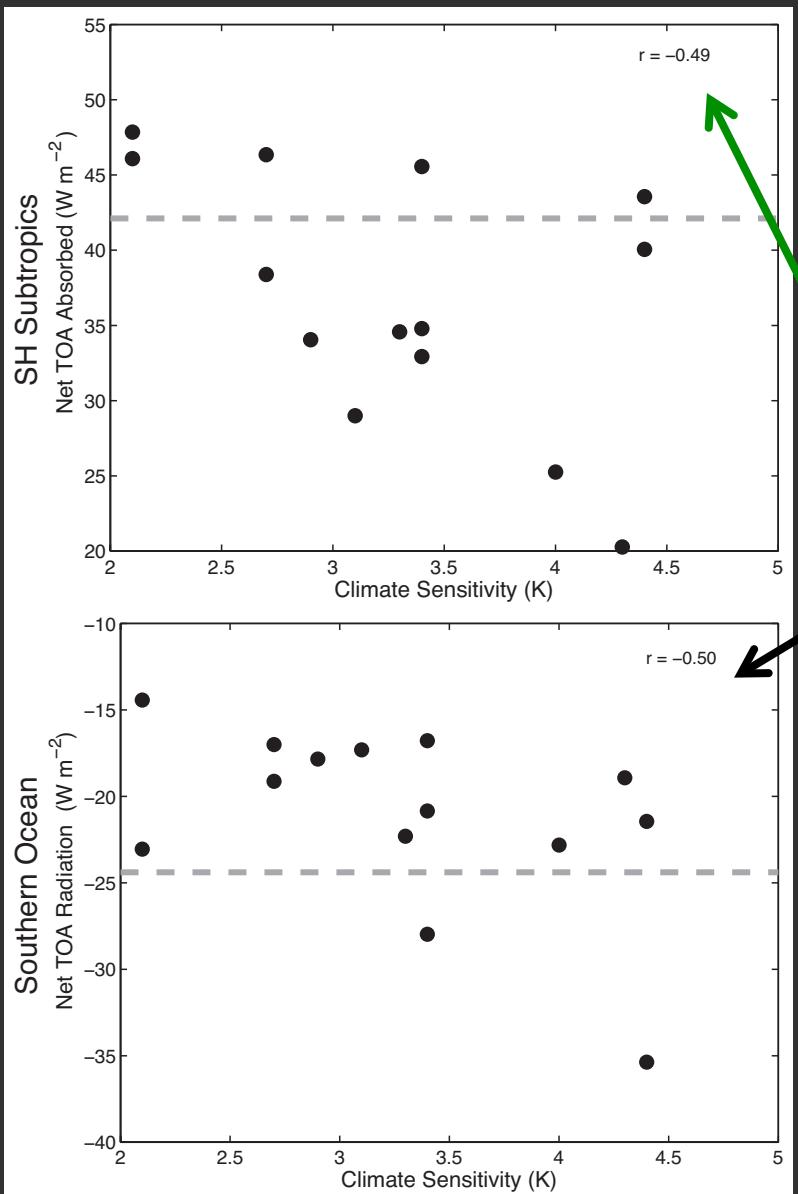


Present-Day Net TOA Radiation:
Correlations with Equilibrium Climate Sensitivity



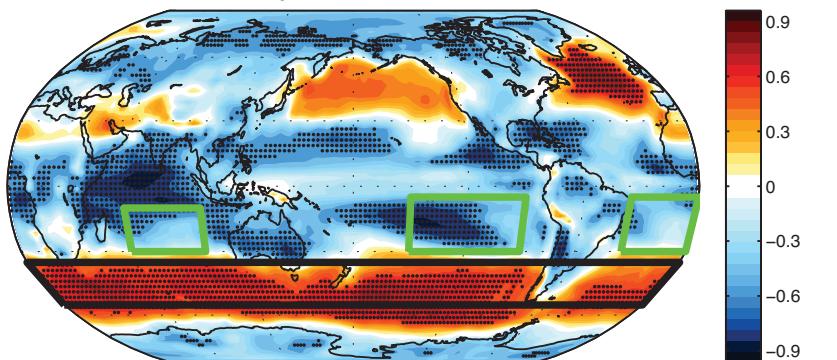
Relationship between climate sensitivity and present-day Southern Hemisphere radiation biases in CMIP3 models is not just about mid-latitudes!

CMIP3 Models

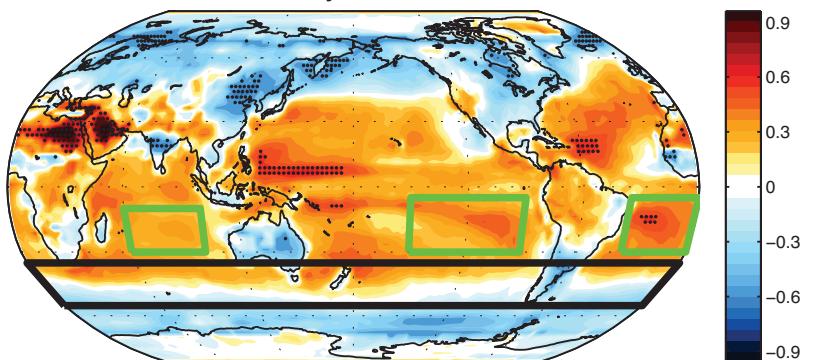


Understanding the CMIP3 Correlations

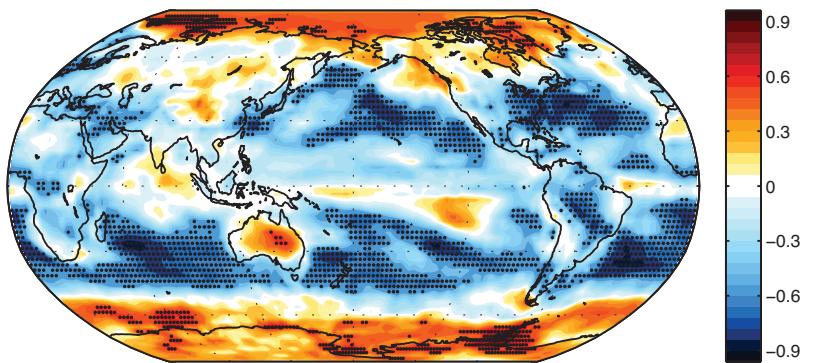
Correlations with Equilibrium Climate Sensitivity
Present-Day Total Cloud Fraction



Present-Day Cloud Albedo



2xCO₂: ΔTotal Cloud Fraction



Southern Ocean: More present-day clouds, higher climate sensitivity
(Trenberth and Fasullo 2010)

SH Subtropics: Brighter present-day clouds, higher climate sensitivity

Increased CO₂: Greater dissipation of subtropical clouds, higher climate sensitivity (Soden and Vecchi 2011)

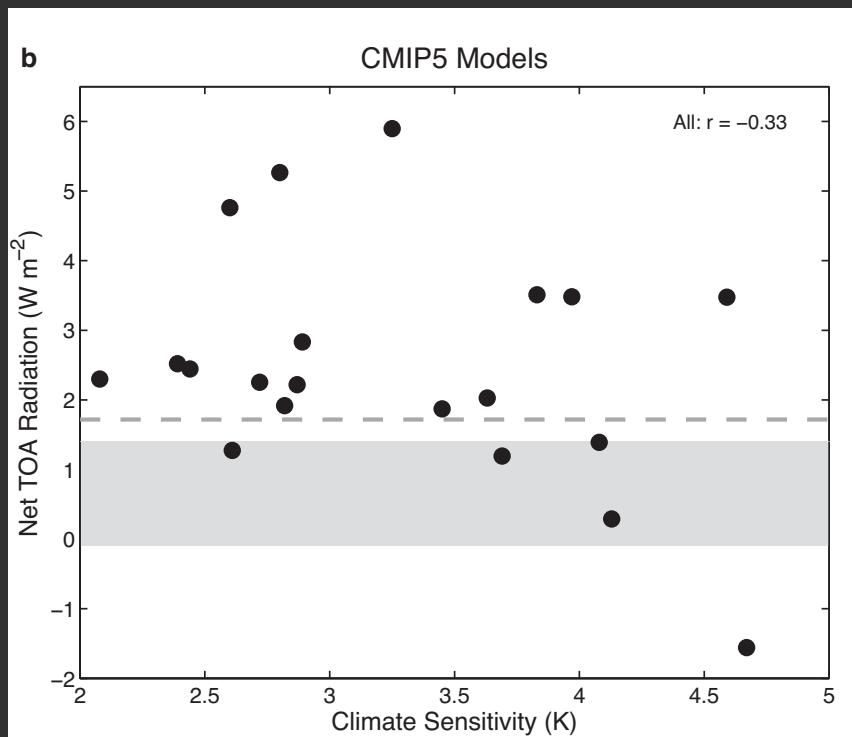
Today's Questions

1) What are the processes responsible for the relationship between climate sensitivity and present-day Southern Hemisphere radiation biases in CMIP3 models?

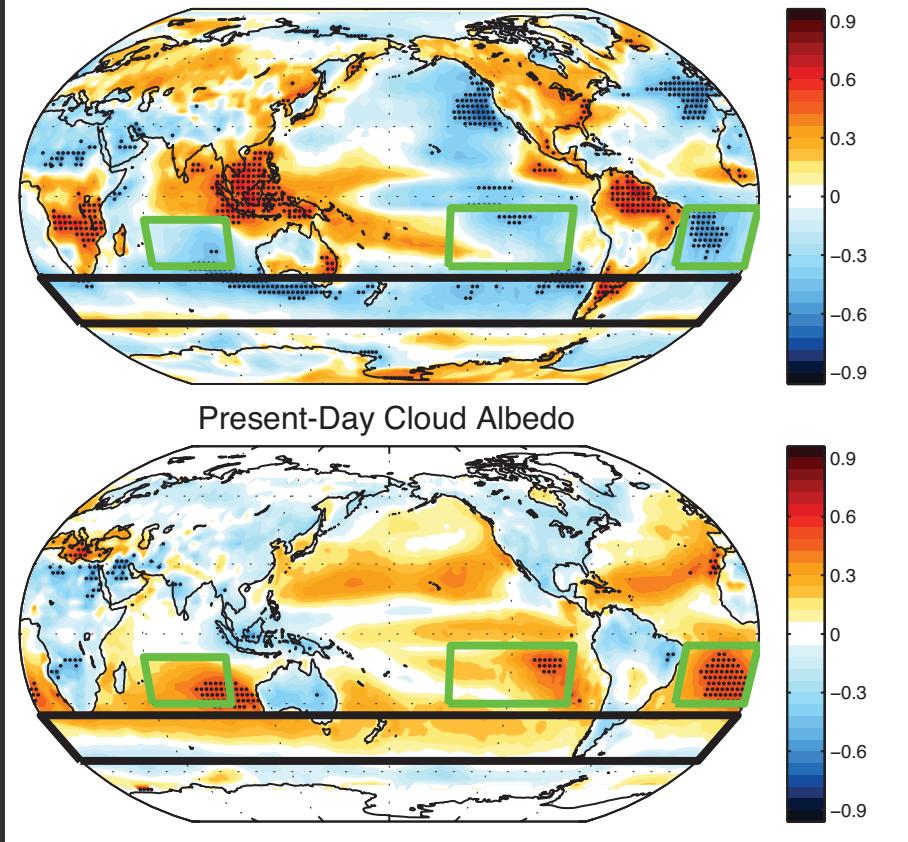
- With increased CO₂, dissipation of brighter present-day subtropical clouds contributes to greater global-mean surface temperature warming.
- Processes linking present-day Southern Ocean cloud biases with climate sensitivity remain unclear.

2) Why does this relationship break down in CMIP5 models?

CMIP5 Models



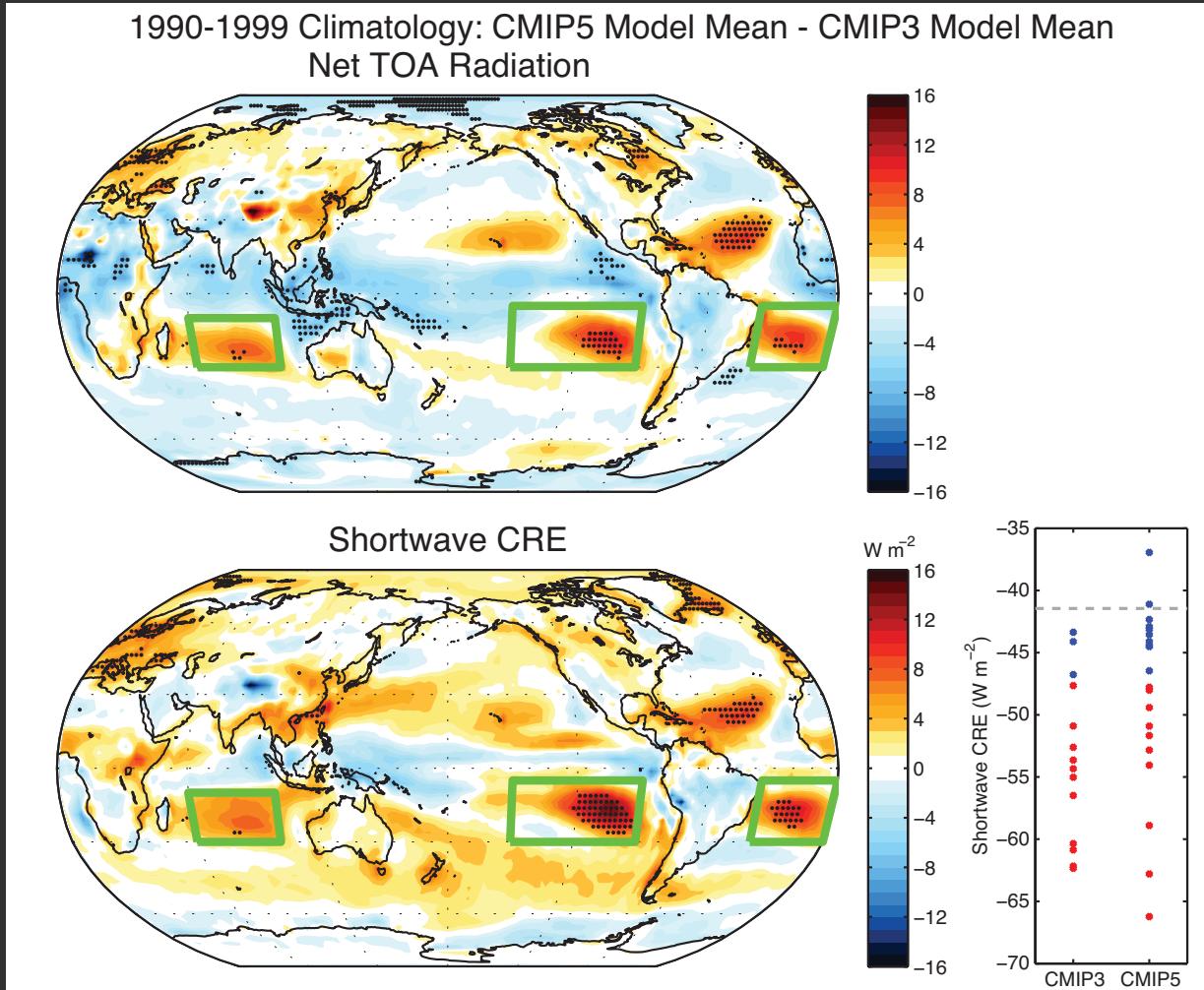
Correlations with Equilibrium Climate Sensitivity
Present-Day Net TOA Radiation



Subtropical correlations remain robust in CMIP5 models.

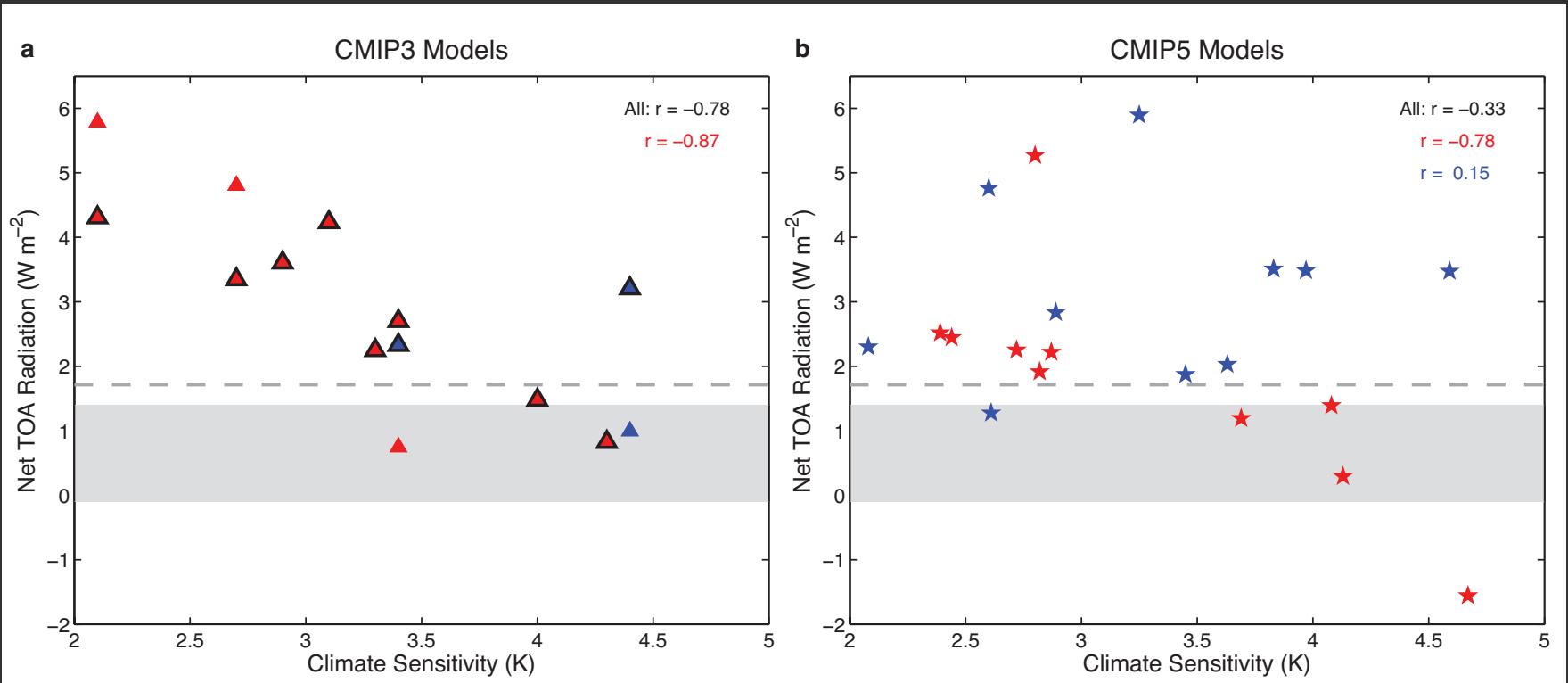
Southern Ocean (and thus hemispheric mean) correlations do not.

What's different in CMIP5 models?



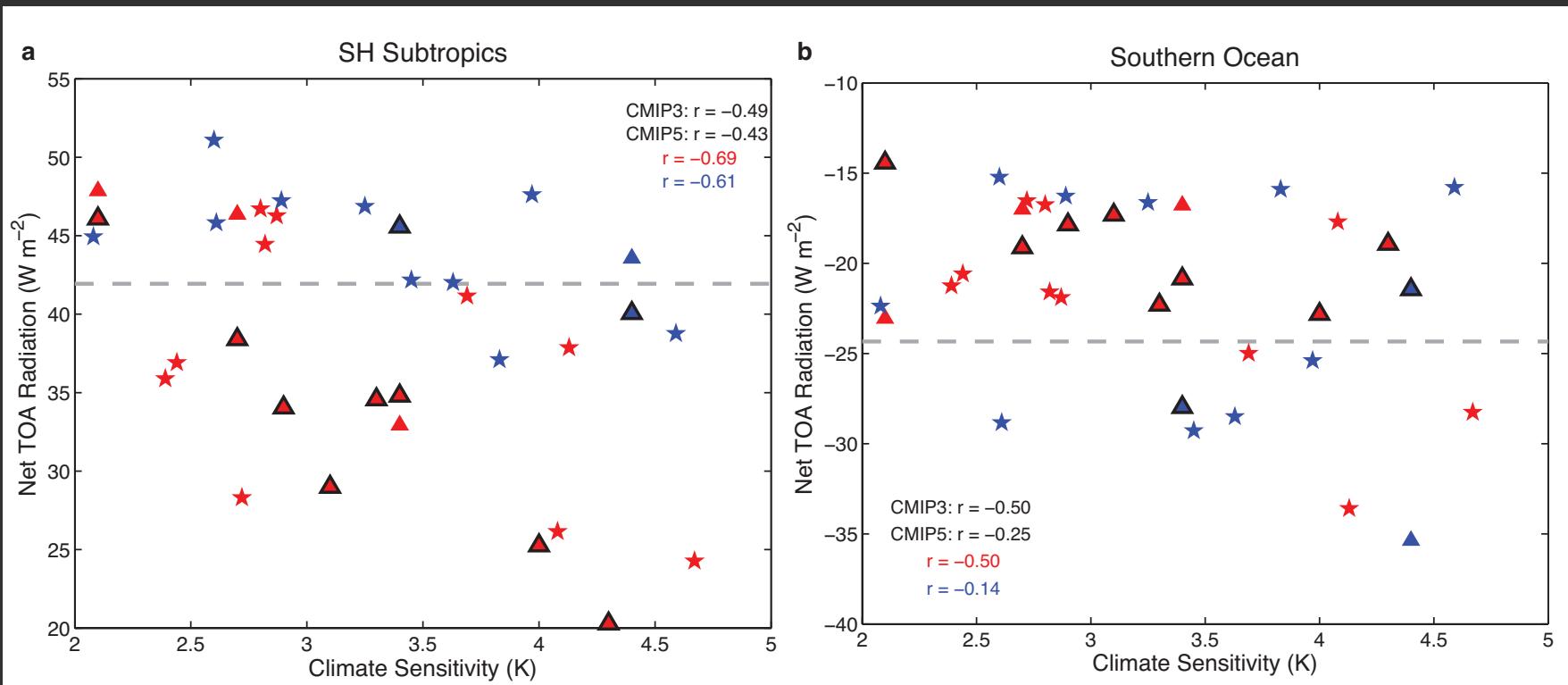
Largest improvements in net radiation and shortwave cloud-radiative effect occurred over SH subtropical regions, not Southern Ocean.

Subsetting CMIP Models by Subtropical Biases



Relationship between climate sensitivity and present-day SH net radiation biases is unique to models with large present-day biases in the **subtropics**.

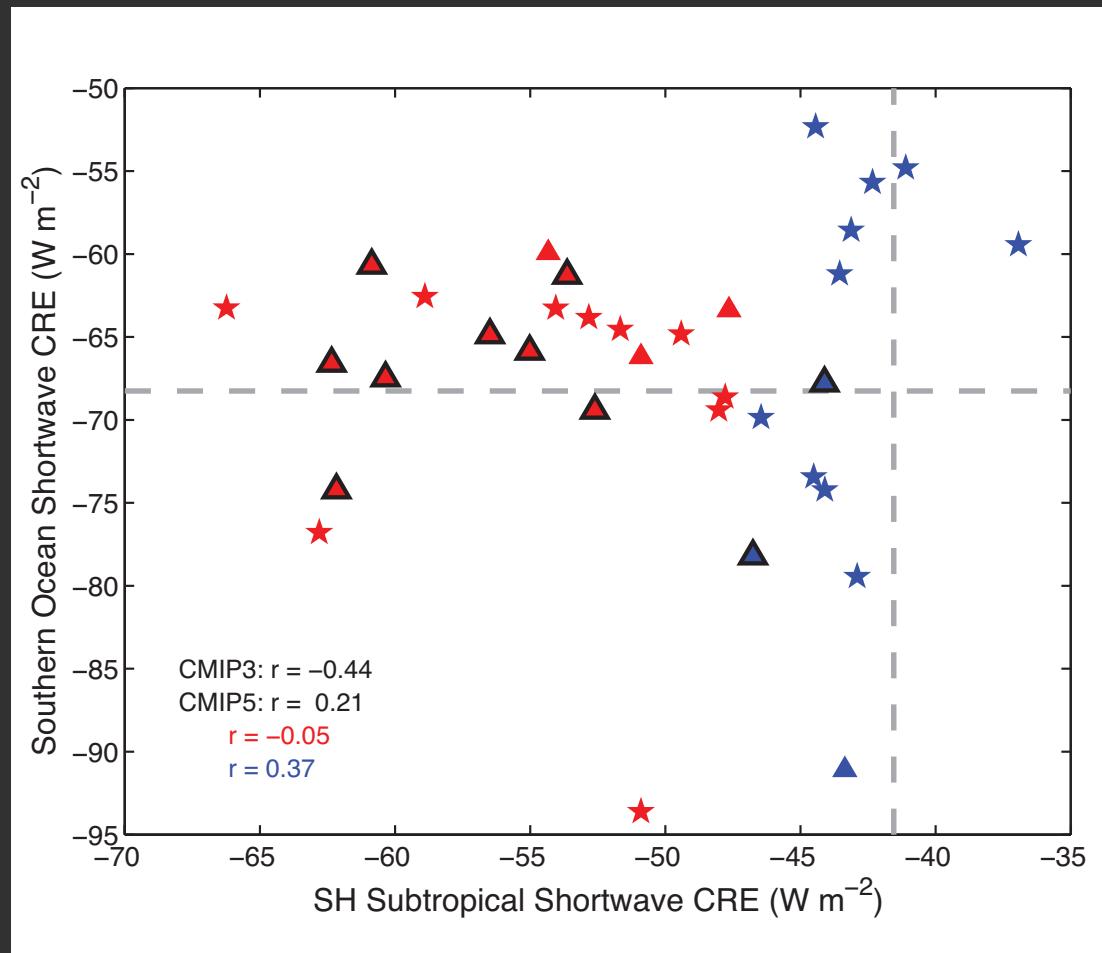
Subsetting CMIP Models by Subtropical Biases



Subtropical correlations occur in both subsets of models.

Southern Ocean correlations only occur in models with large present-day biases in the **subtropics**.

Present-Day Shortwave CRE Biases: Southern Ocean vs. SH Subtropics

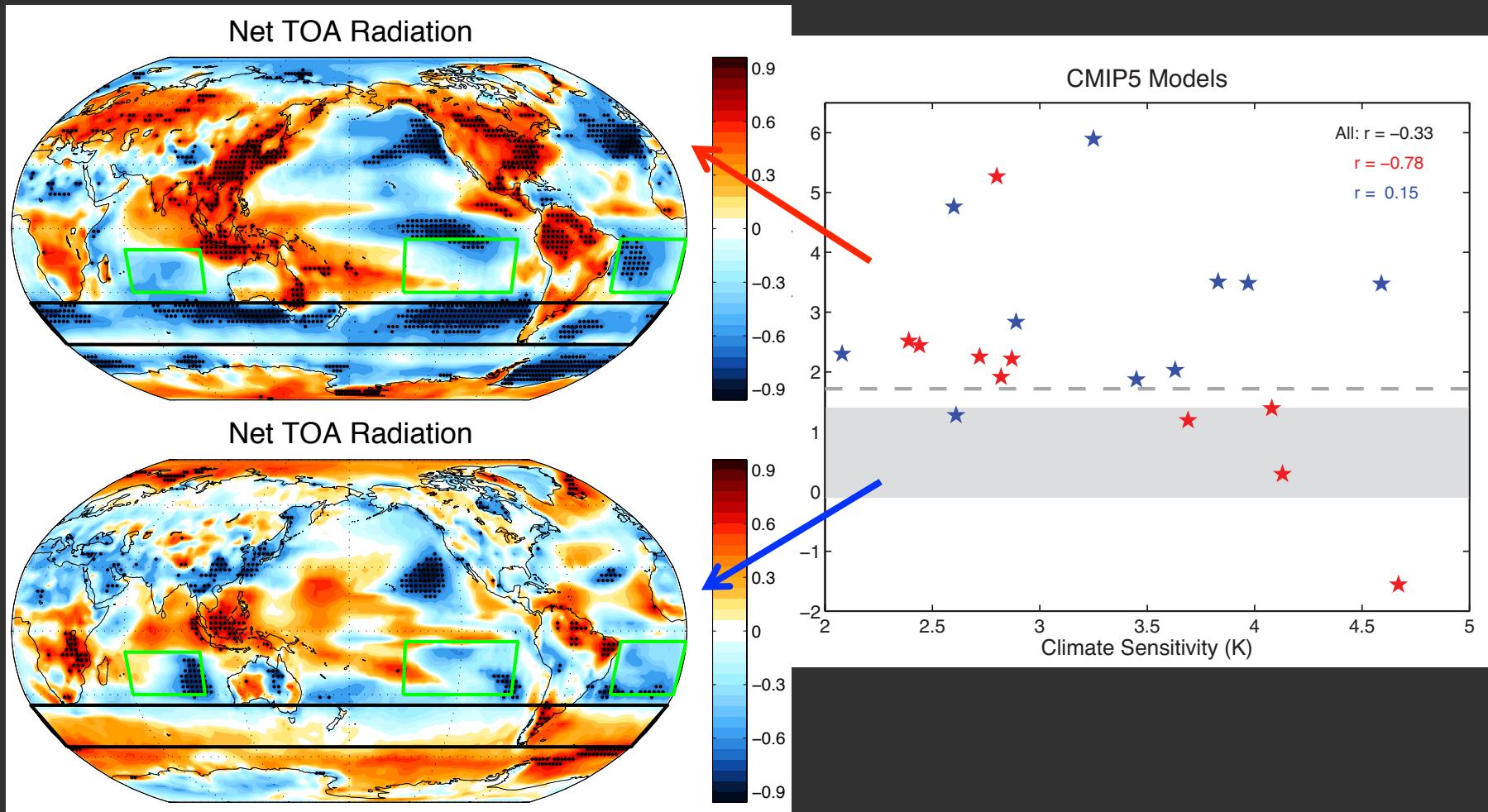


Trade-off in CMIP models between representation
of subtropical clouds and Southern Ocean clouds

Conclusions

- Trenberth and Fasullo (2010) found a relationship between climate sensitivity and present-day net radiation biases in the Southern Hemisphere in CMIP3 models.
 - With increased CO₂, dissipation of brighter present-day subtropical clouds contributes to greater global-mean surface temperature warming.
 - Physical linkages between Southern Ocean biases and climate sensitivity are not readily apparent.
- The subtropical relationship remains robust in both CMIP3 and CMIP5 models.
- The Southern Ocean relationship appears to be an artifact of models with large subtropical radiation biases, which include almost all CMIP3 models but only a fraction of CMIP5 models.

Subsetting CMIP Models by Subtropical Biases

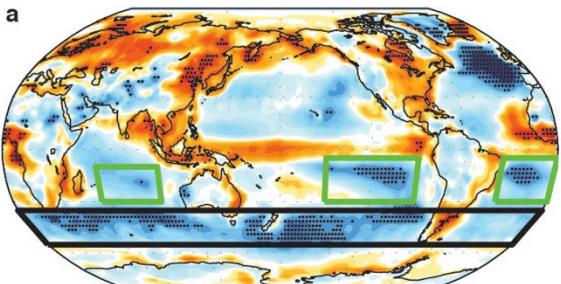


Relationship between climate sensitivity and present-day SH net radiation biases is unique to models with large present-day biases in the **subtropics**.

1990-1999 Climatology: Correlations with Equilibrium Climate Sensitivity

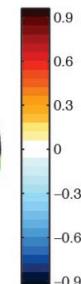
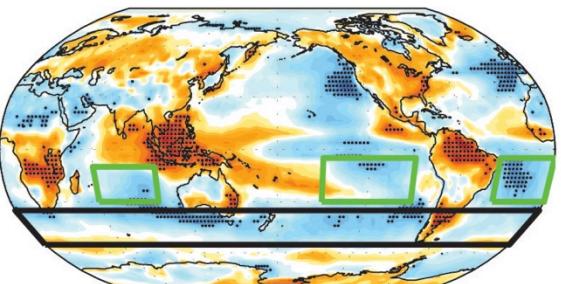
CMIP3 Models

Net TOA Radiation

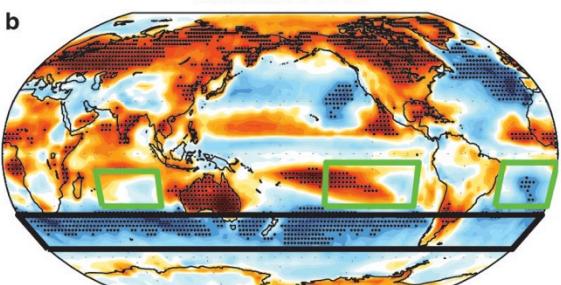


CMIP5 Models

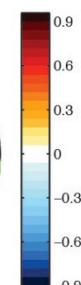
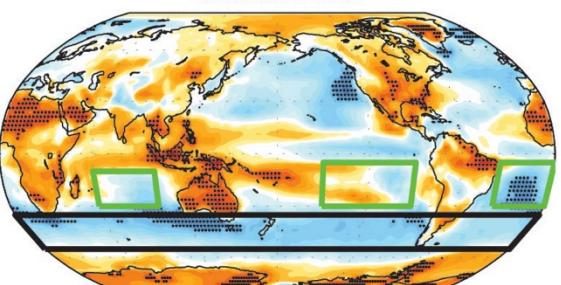
Net TOA Radiation



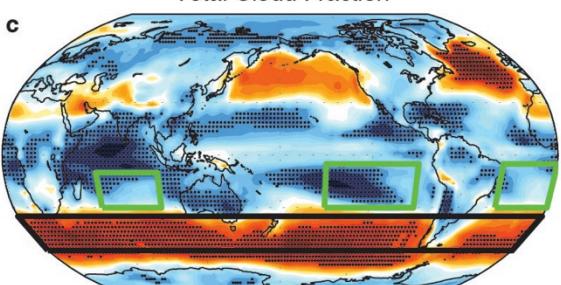
Shortwave CRE



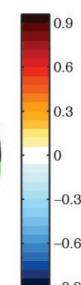
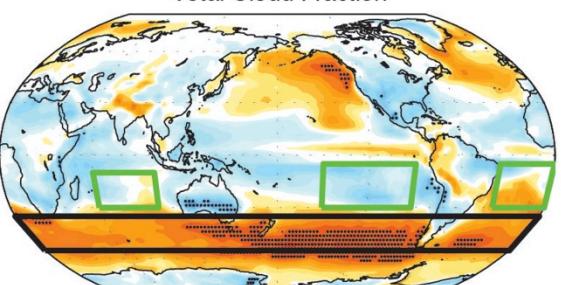
Shortwave CRE



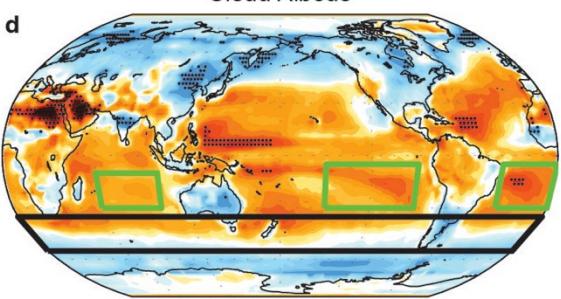
Total Cloud Fraction



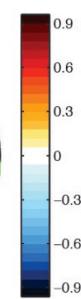
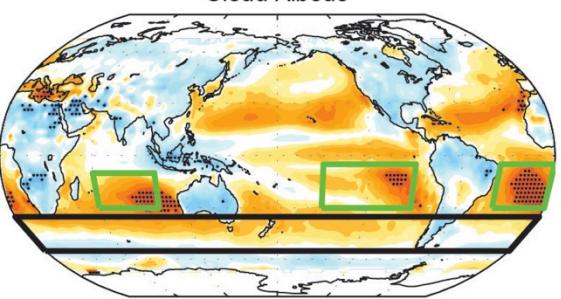
Total Cloud Fraction



Cloud Albedo



Cloud Albedo



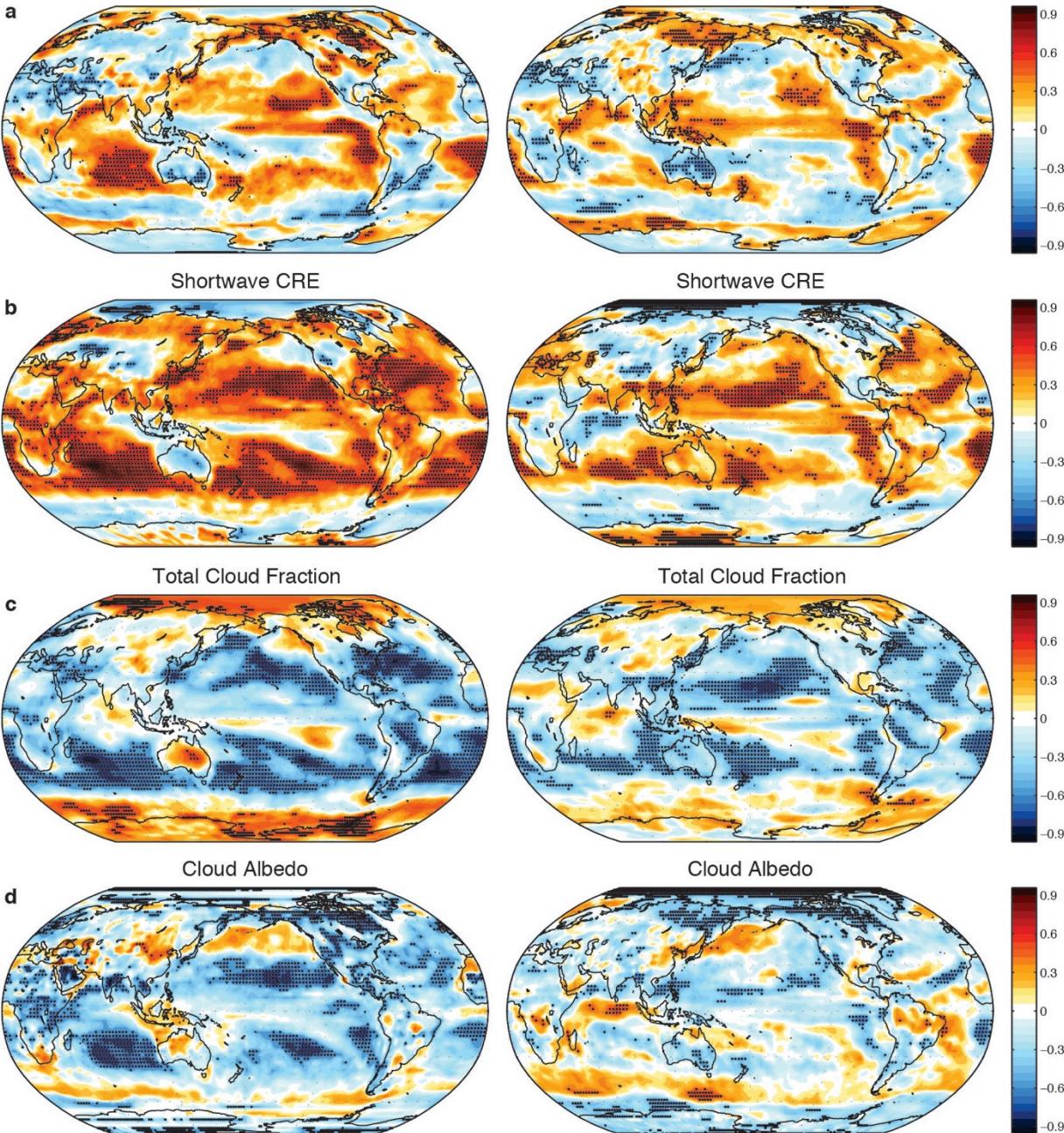
2xCO₂ Response: Correlations with Equilibrium Climate Sensitivity

CMIP3 Models

Net TOA Radiation

CMIP5 Models

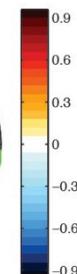
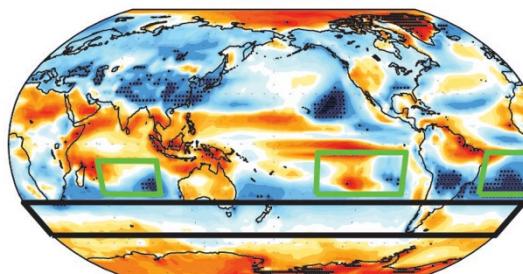
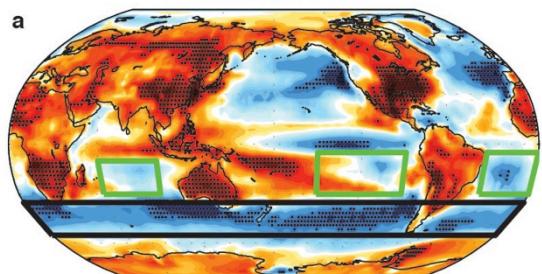
Net TOA Radiation



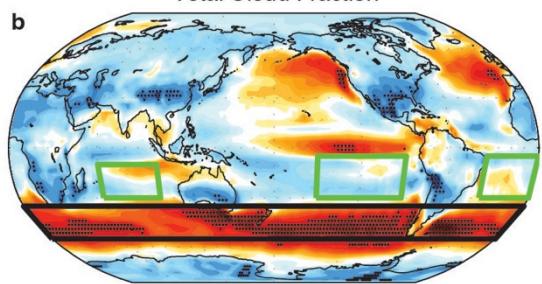
More Subtropically Biased CMIP5 Models Less Subtropically Biased CMIP5 Models

1990-1999 Climatology: Correlations with Equilibrium Climate Sensitivity

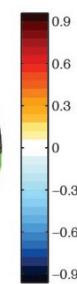
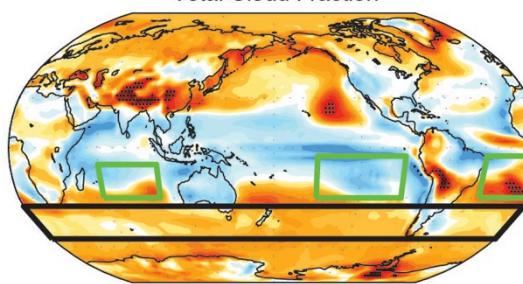
Shortwave CRE



Total Cloud Fraction

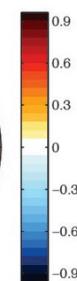
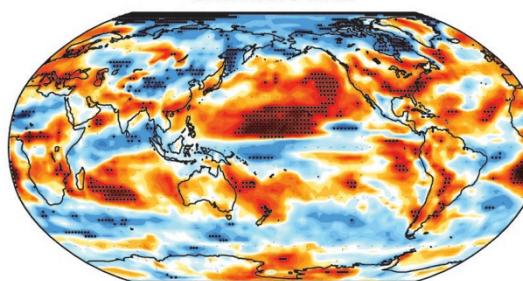
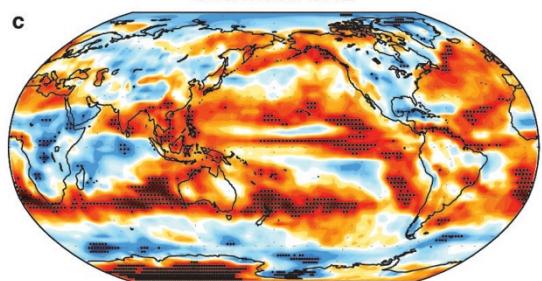


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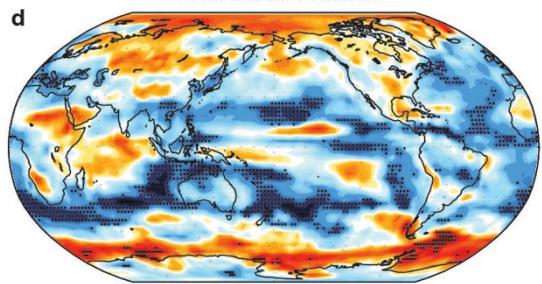


2xCO₂ Response: Correlations with Equilibrium Climate Sensitivity

Shortwave CRE



Total Cloud Fraction



Total Cloud Fraction

