Clouds and Climate Sensitivity

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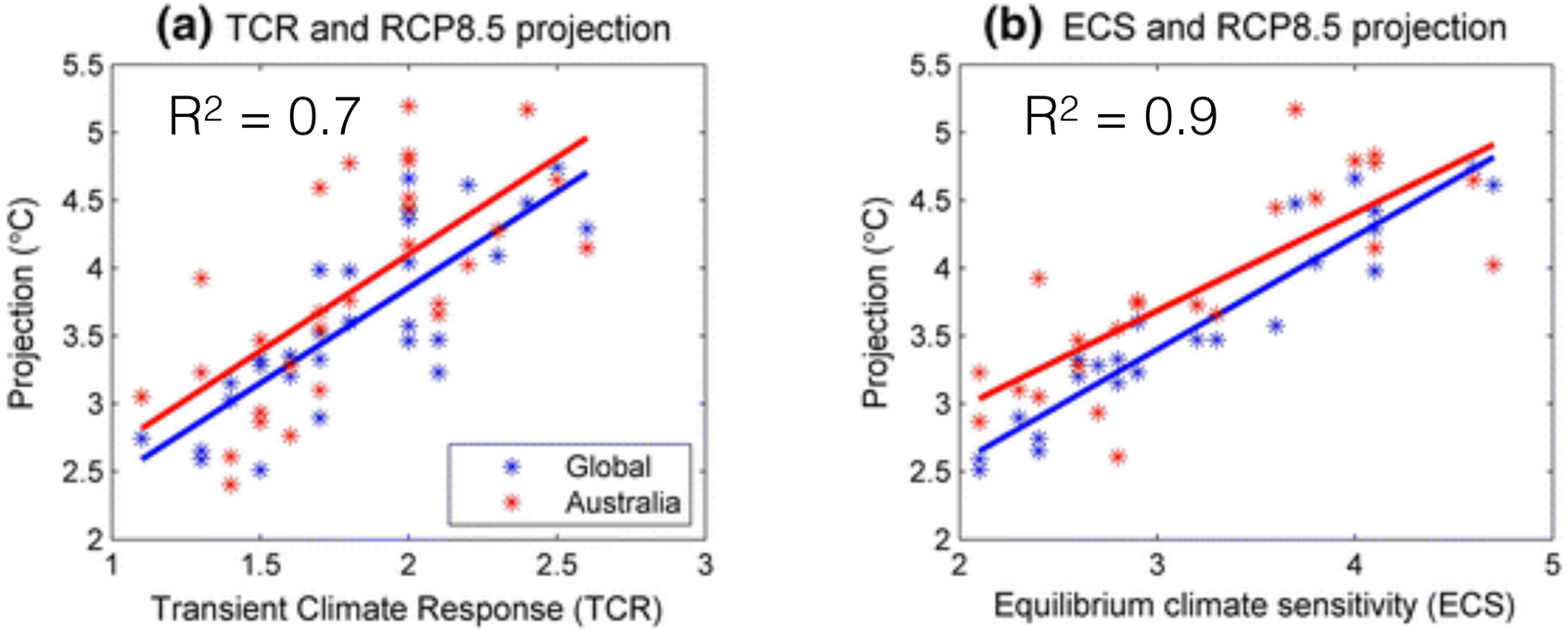
Aspen Global Change Institute, July/August 2017

Is ECS relevant?



Grose et al. 2017

- ECS* is surprisingly well correlated to 21$_{st}$-century RCP8.5 T_{surf} trend in CMIP5 model simulations (appears **better** than TCR)

*Effective sensitivity based on 150 years

Cloud feedback mechanisms.
Red (or blue) = robust

◆ = positive feedback contribution

◆ = ambiguous feedback contribution

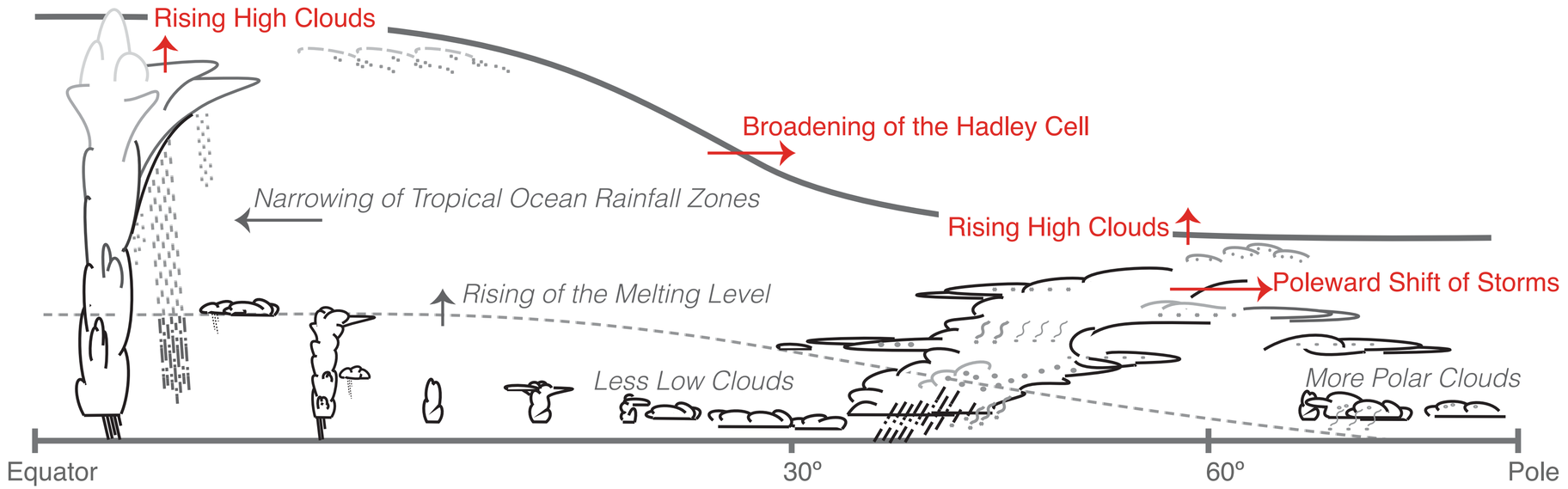


Fig. 7.11

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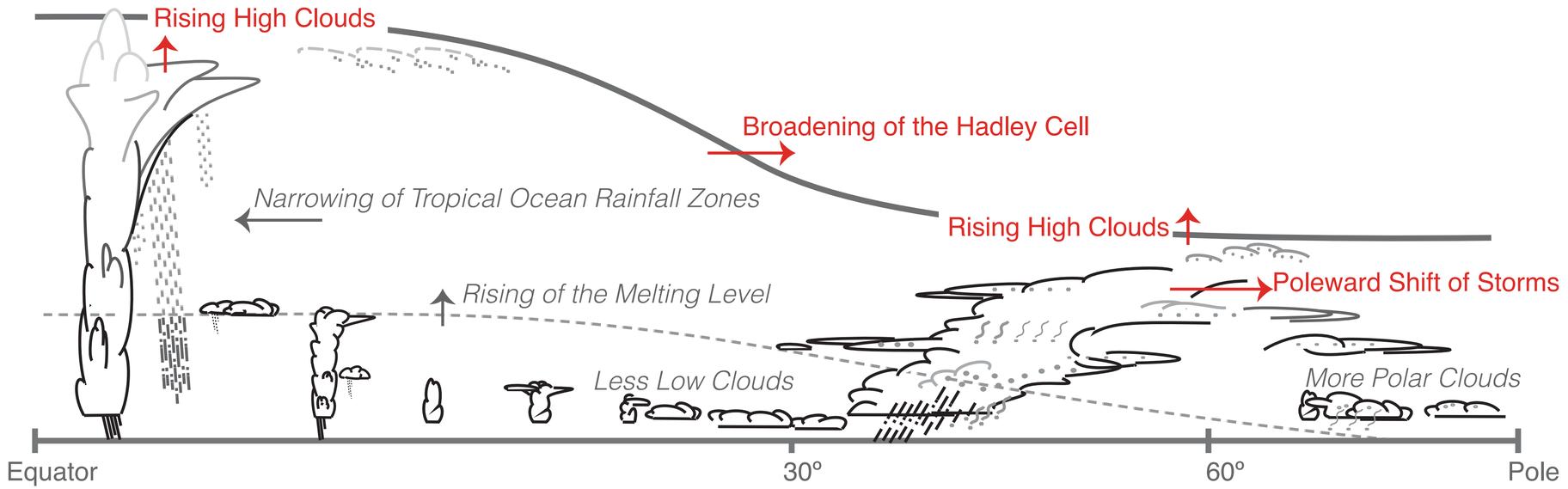


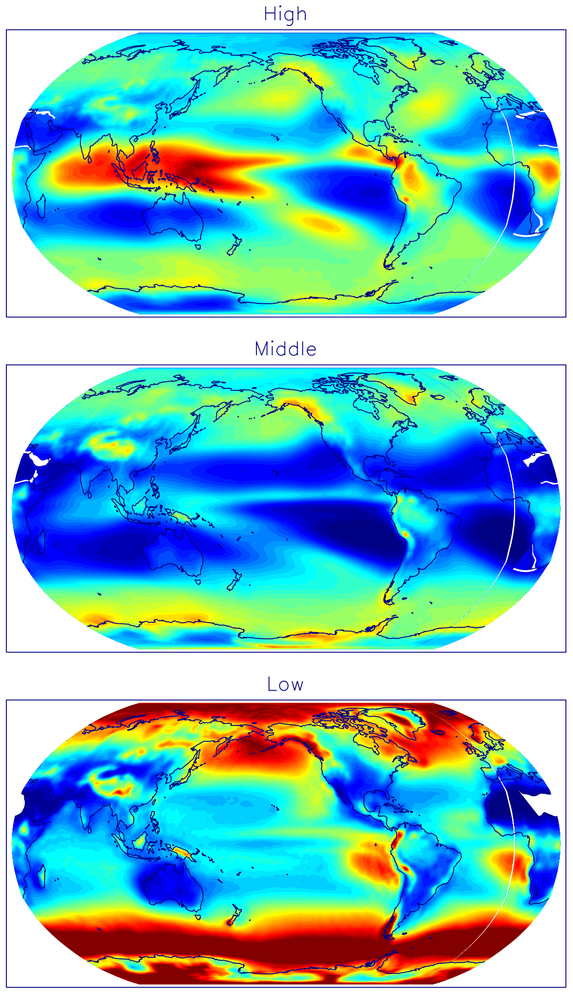
These mechanisms are tied to large-scale circulation changes that are robust and relatively well understood.

Divergent model responses are due to divergent changes in low cloud amount (e.g. marine stratus). Much of the mean positive feedback also comes from them + mid-level.

Fig. 7.11

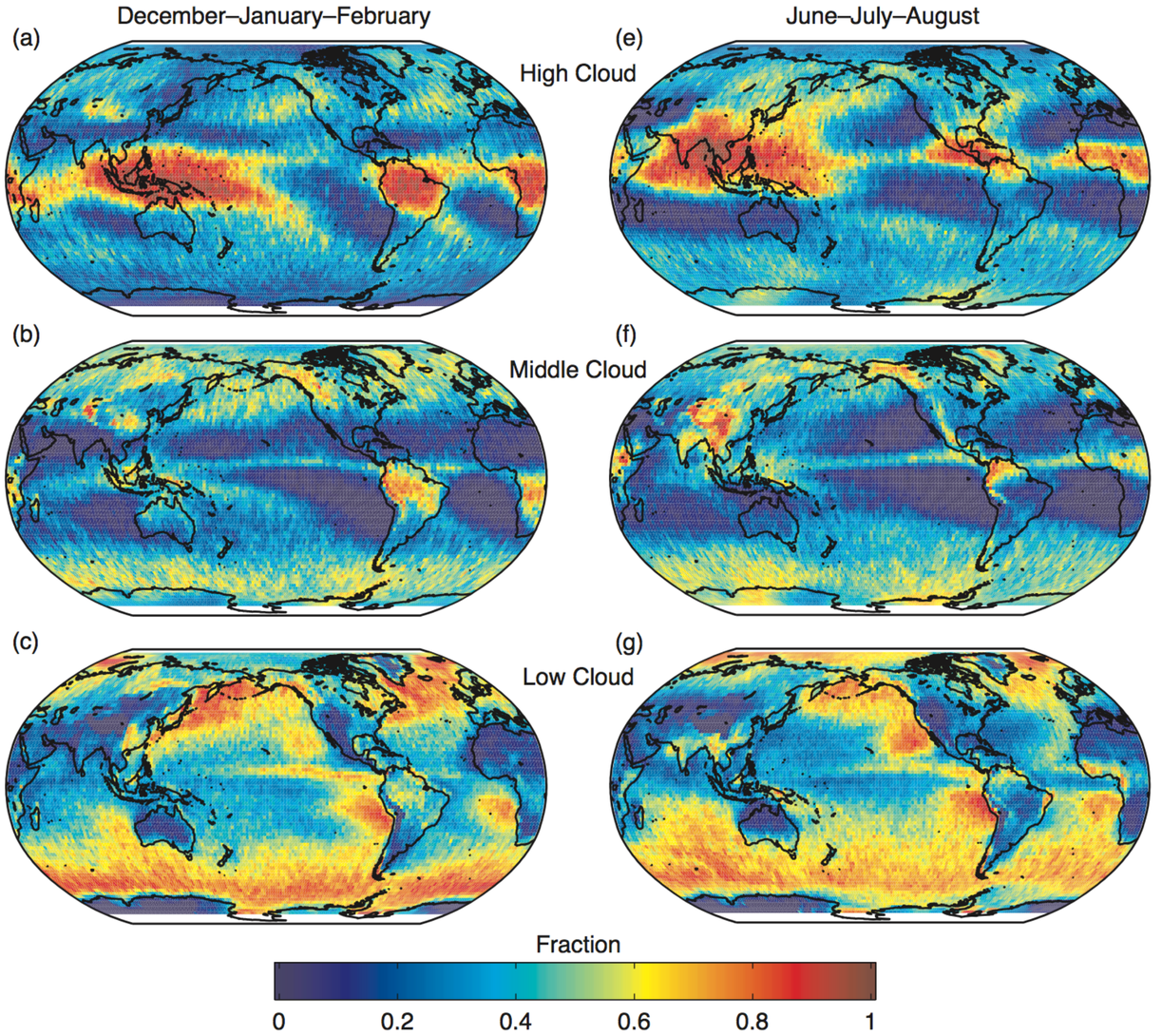
CMIP5 models

AMIP (10 models)
ANNUAL MEAN



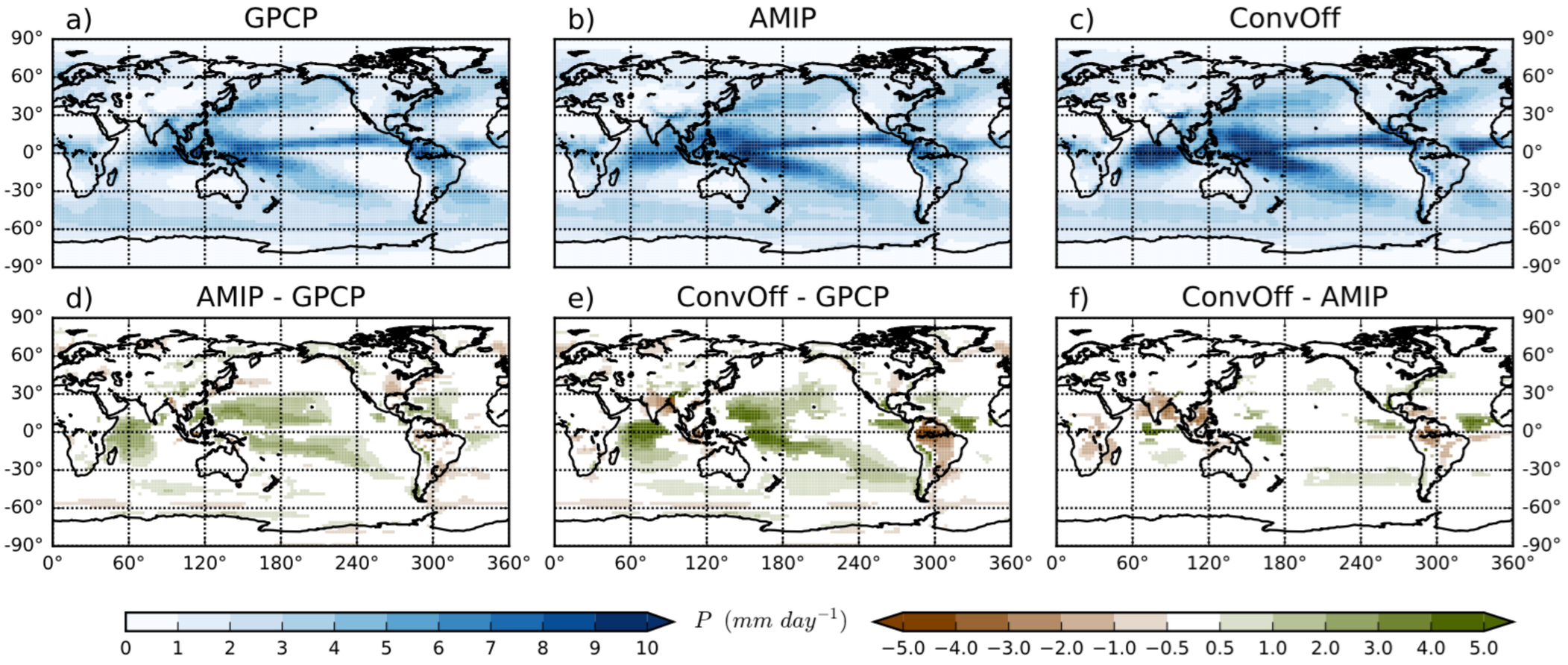
Observations

CloudSat/Calipso

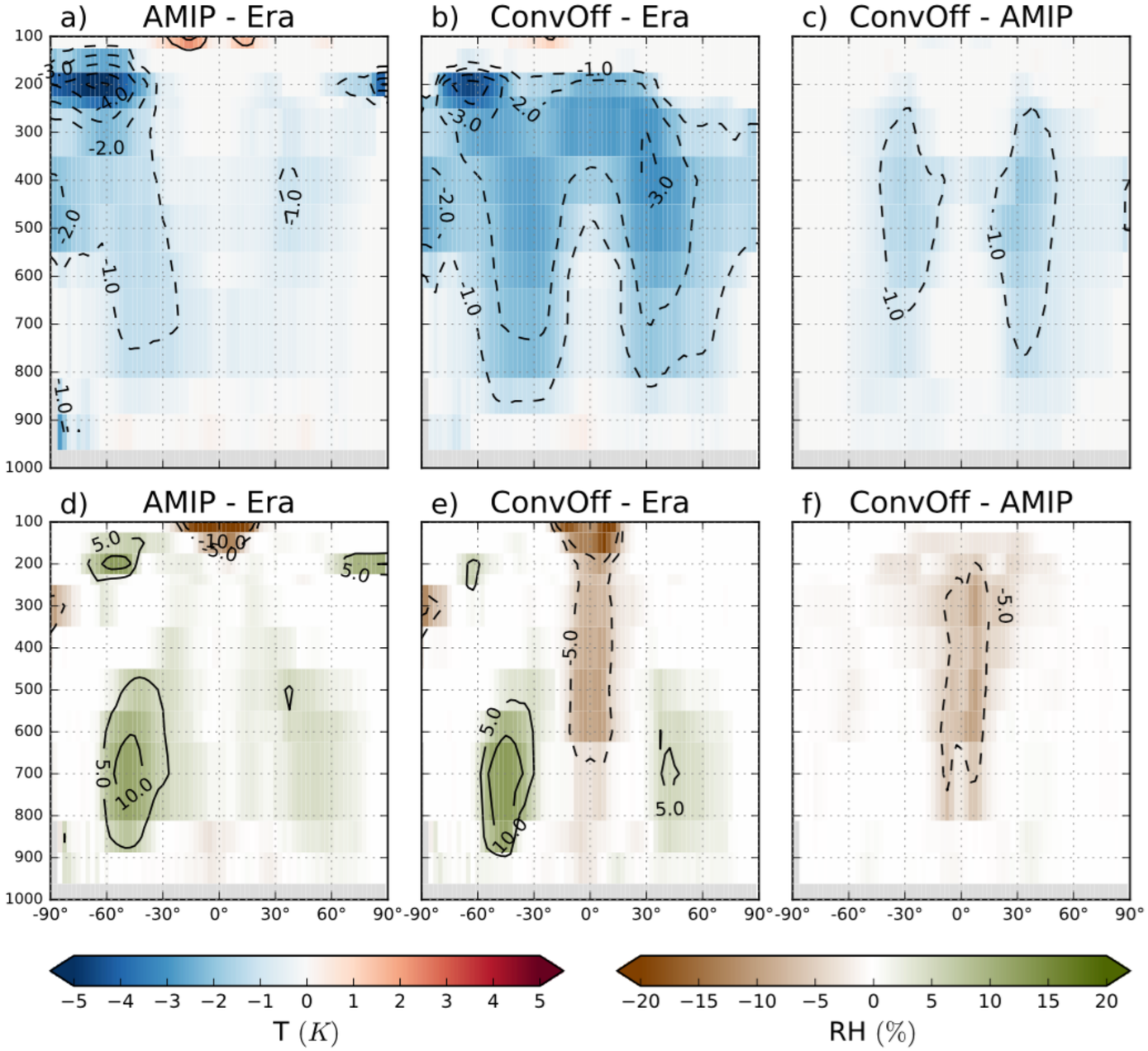


IPCC 2013 Chapter 7

Average of 10 CFMIP SPOOKIE model runs



Maher et al. in prep

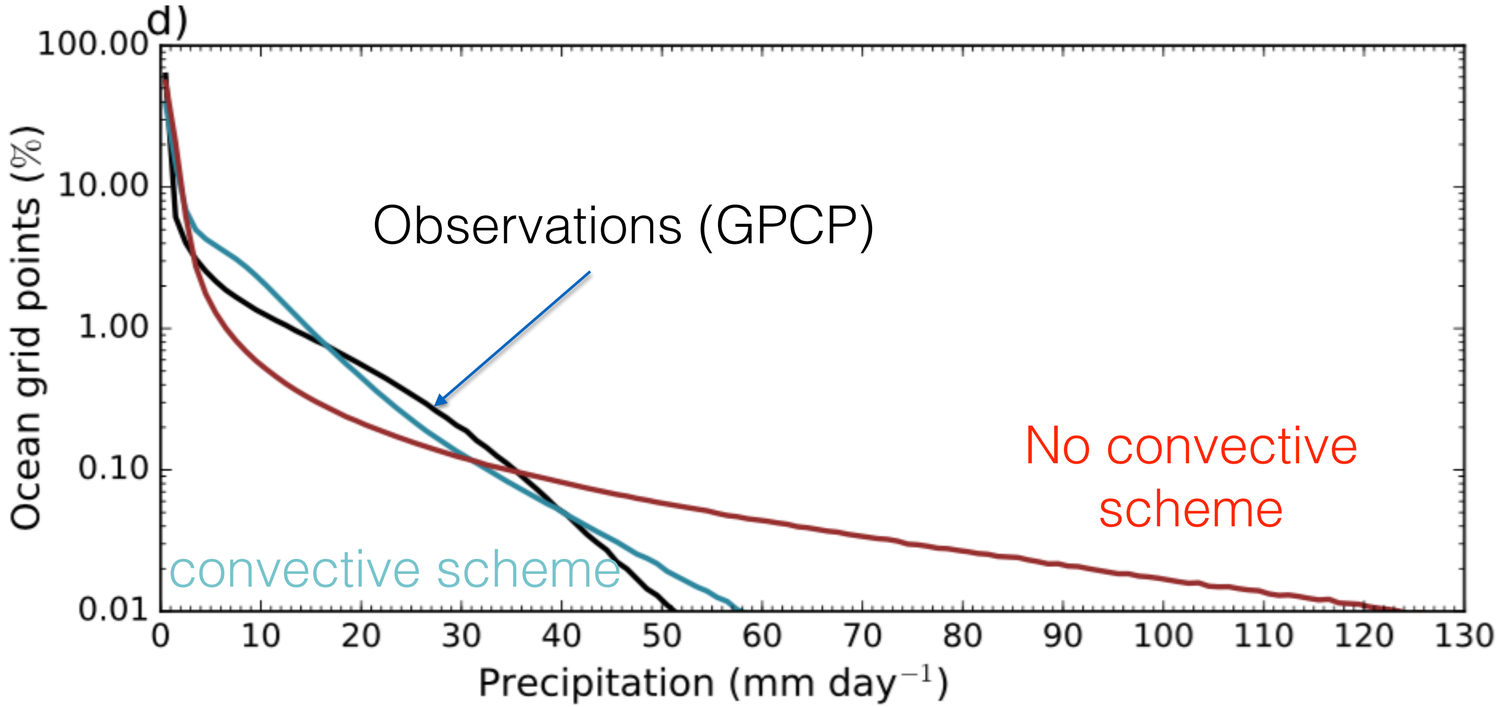


Temperature

Humidity

Maher et al. in prep

Extreme precipitation significantly affected.



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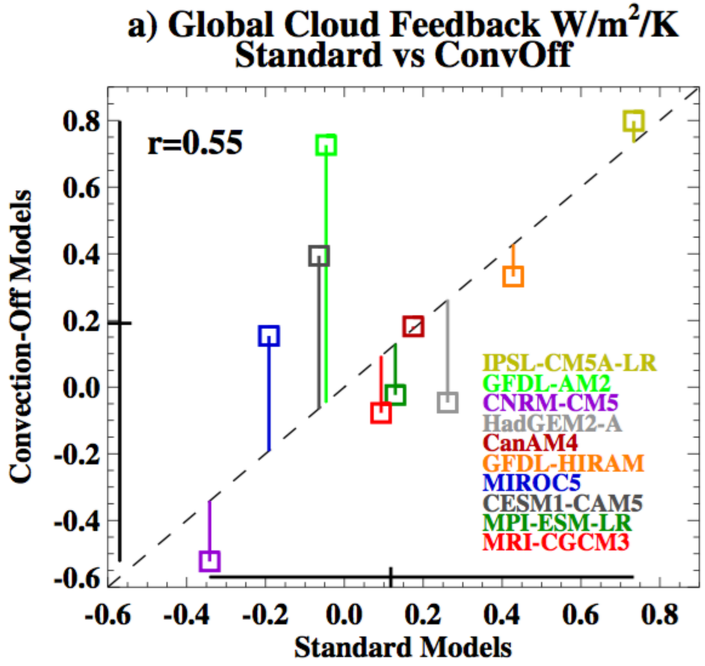
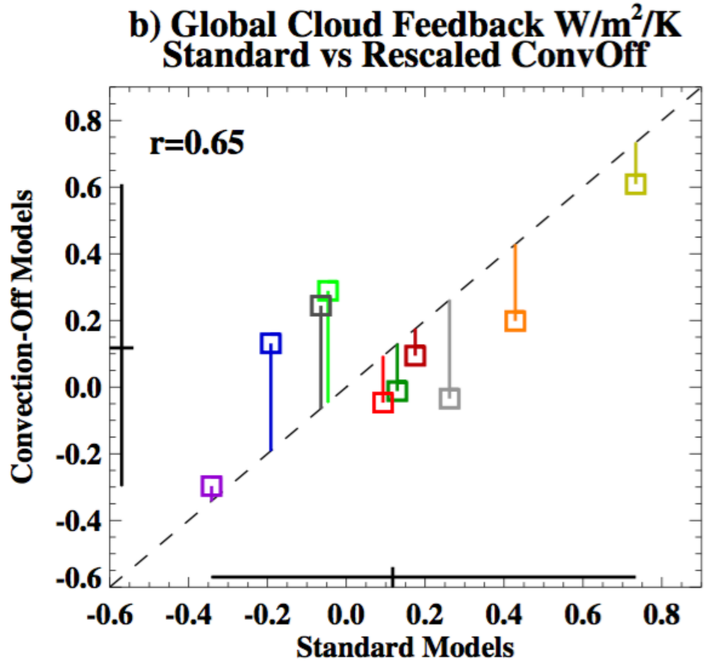
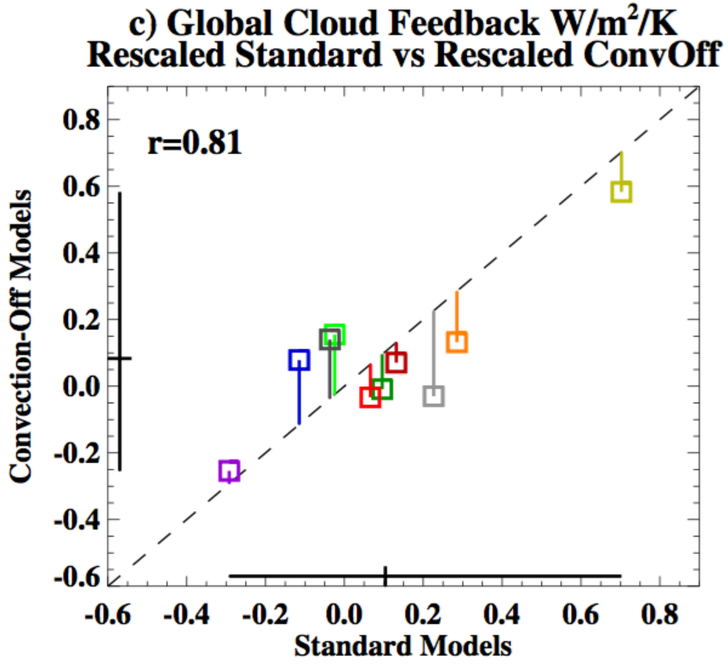


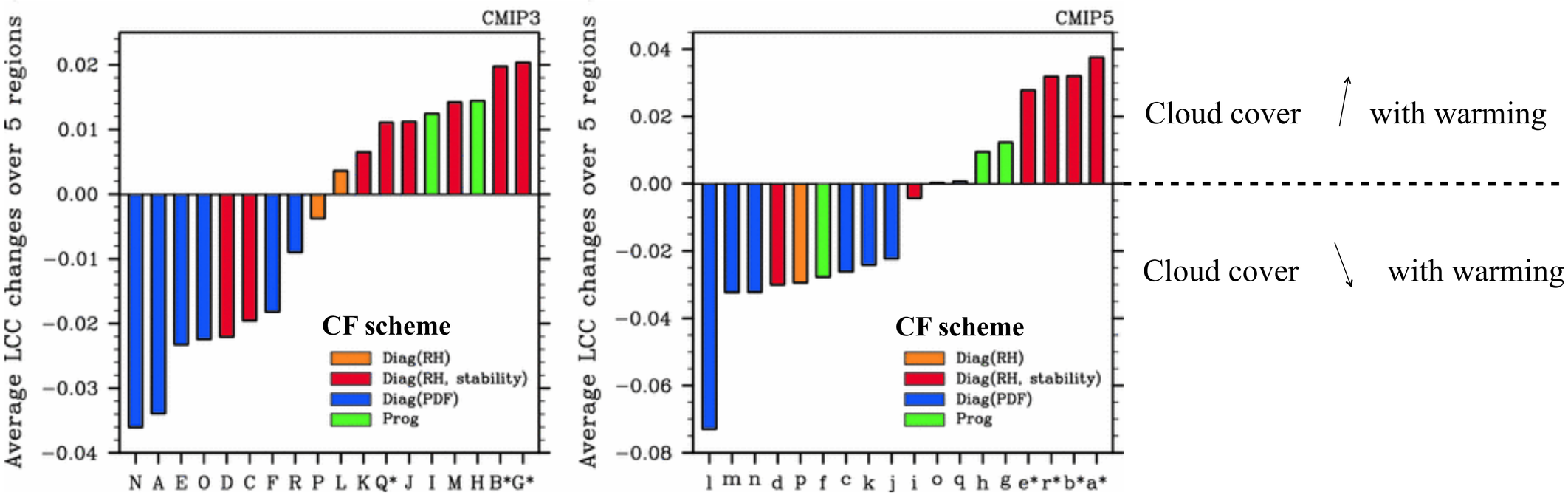




Cloud feedbacks not greatly affected either (in CFMIP).

Webb et al. 2015

Cloud response in Sc regions and stratiform cloud scheme

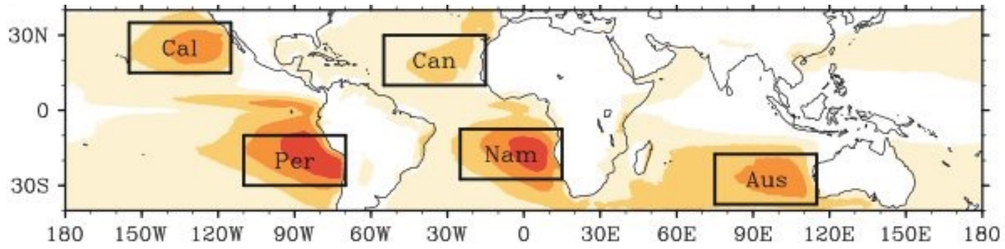


CMIP3 Models

CMIP5 Models

Qu et al. 2014

Sc regions :



Method

	qcloud	Cloud fraction
A	Diag	Diag(RH)
B	Diag	Diag(RH, stability)
C	Diag	Diag(RH, stability)
D	Prog	Diag(RH)+Sc scheme
E	Diag	Diag(RH,ω)+Sc scheme

Implement these cloud schemes in two climate models:
- CSIRO-Mk3L
- CAM4

(8 simulations / model)

- Impact on cloud feedback ?

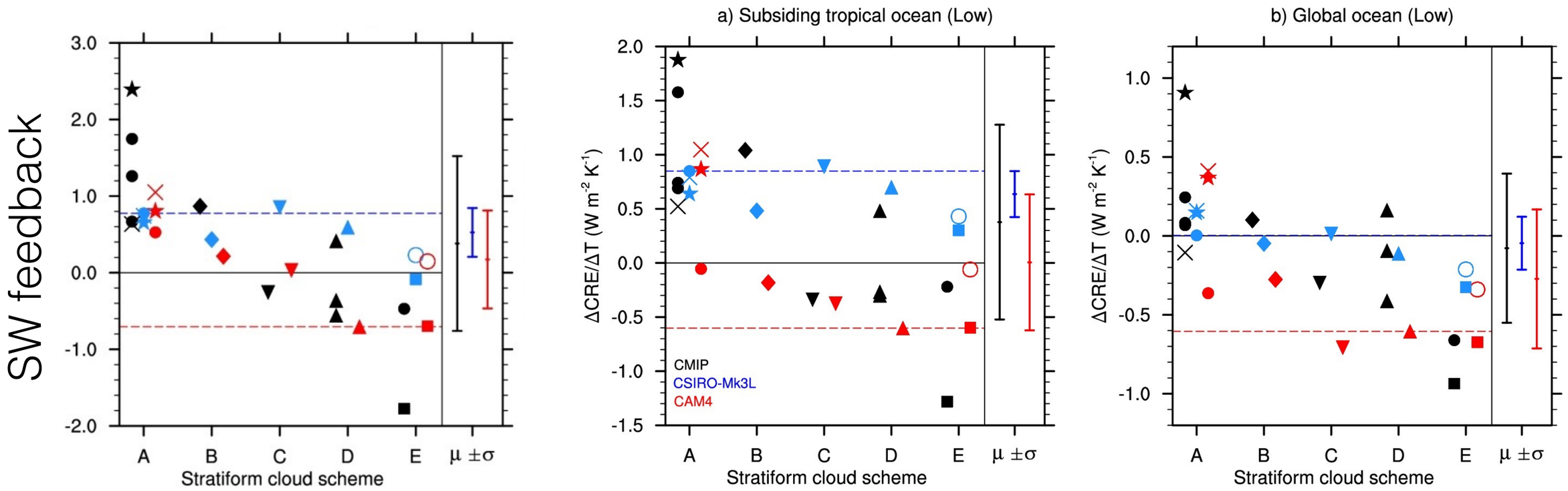
- Consistent with CMIP5 models responses ?

Cloud radiative effect change (feedback)

Sc Regions

Tropics

Globe



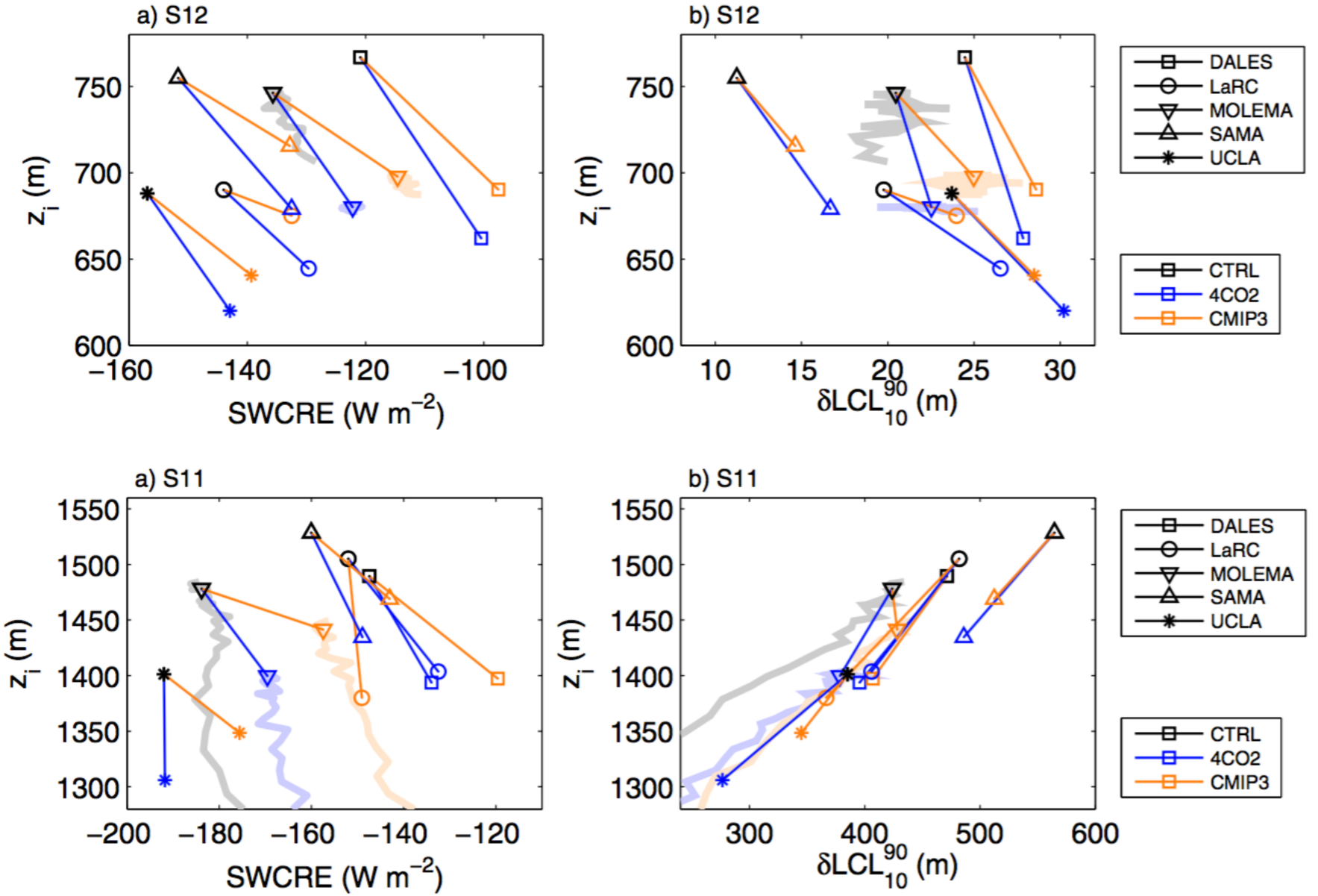
Geoffroy et al. 2017

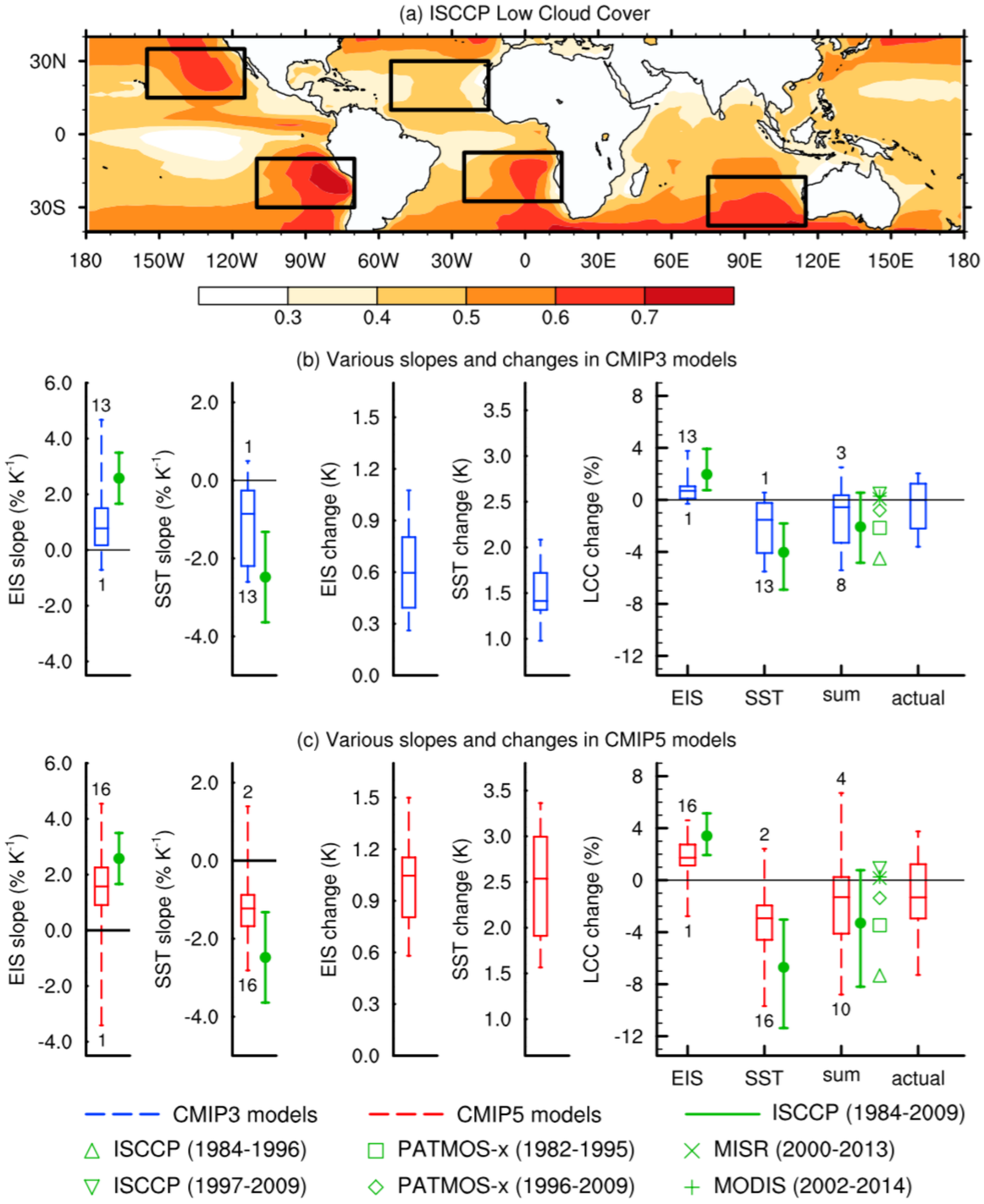
~ half of spread is captured by cloud scheme changes

Process (LES) models driven by warming-like environmental changes

..show relatively consistent reductions in cloud cover

Blossey et al. 2016



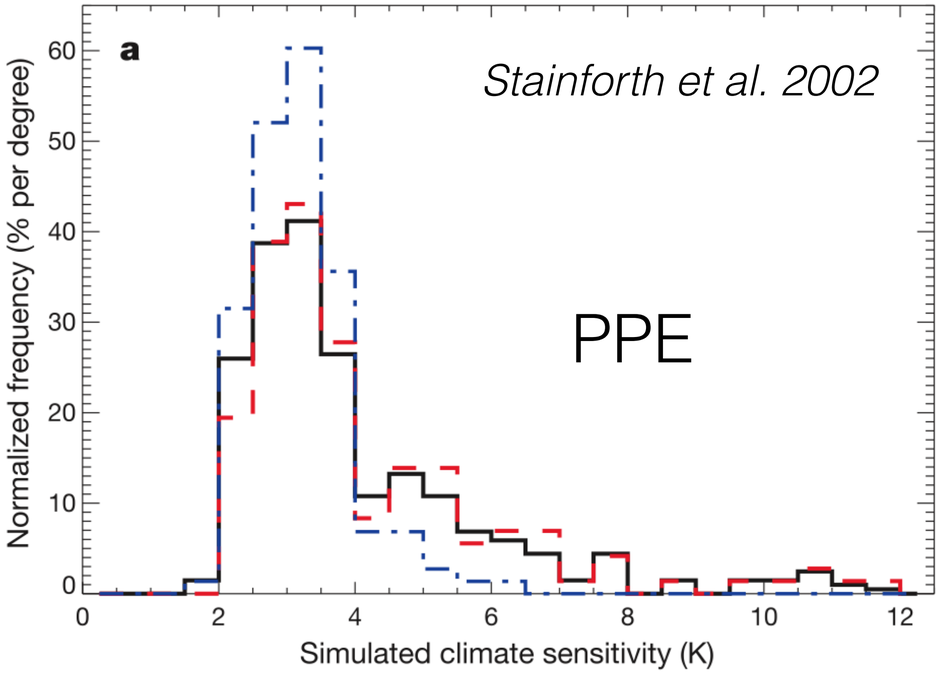


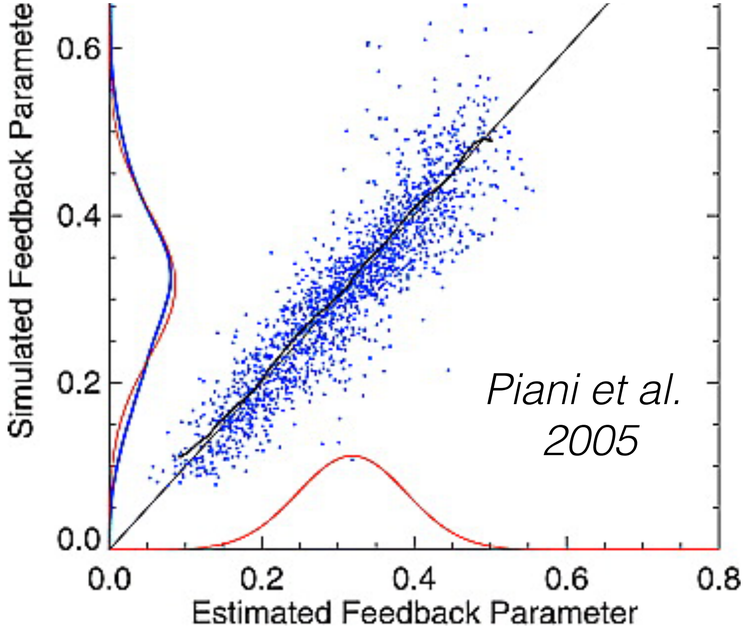
Decomposition of low-cloud responses into EIS (inversion strength) and SST parts

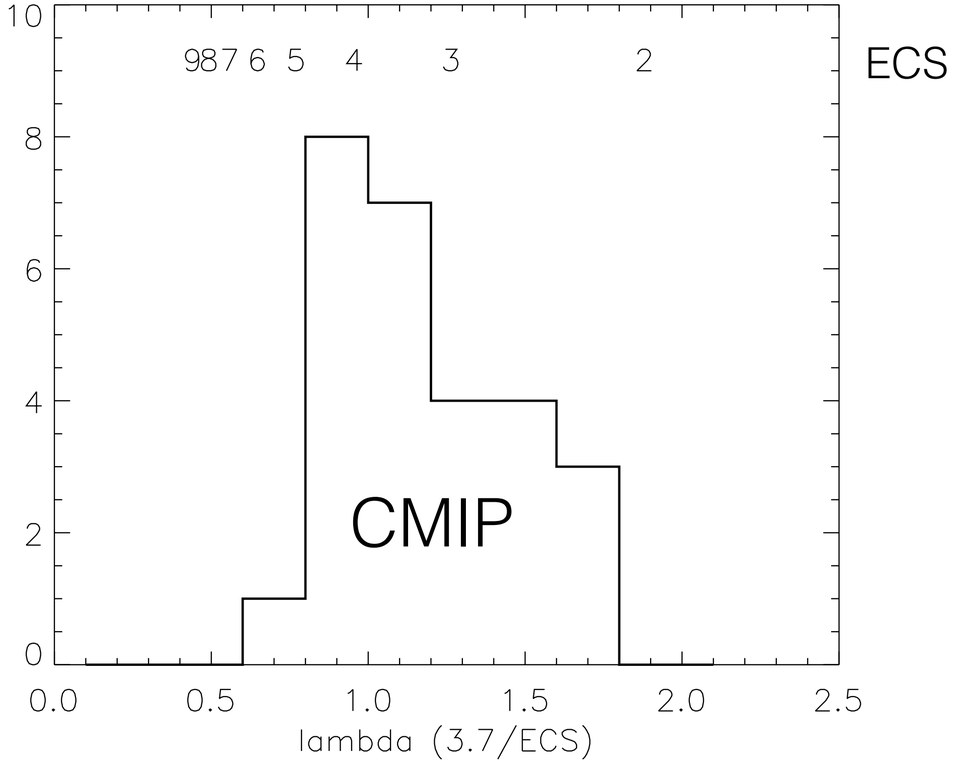
SST part responsible for most model spread

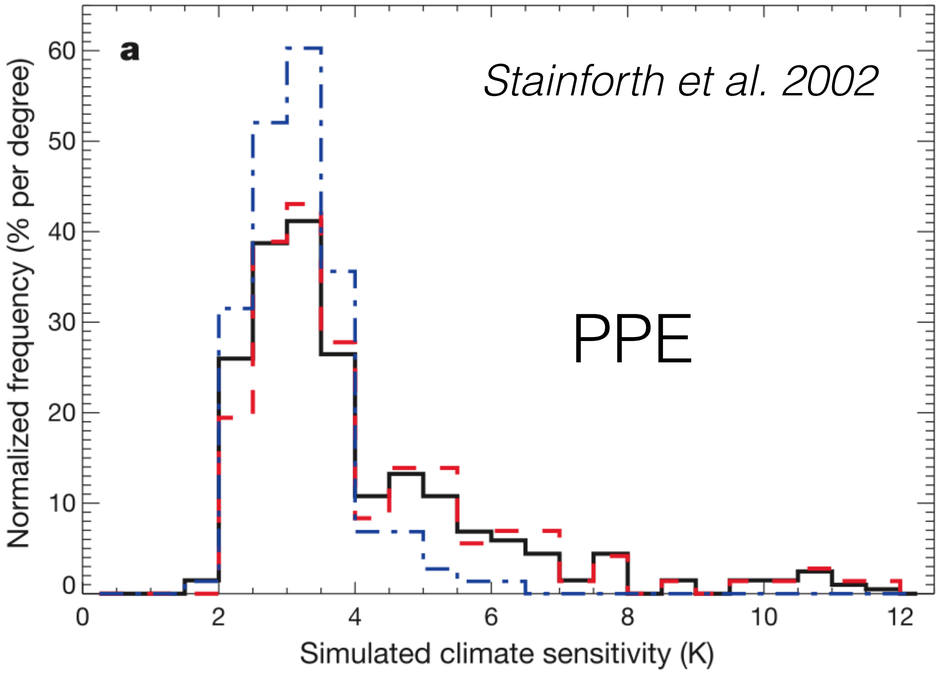
Observational constraints point to the response giving positive feedback

Qu et al. 2015 (and others)


a
Stainforth et al. 2002
PPE
Normalized frequency (% per degree)
Simulated climate sensitivity (K)


Piani et al.
2005
Simulated Feedback Paramete
Estimated Feedback Parameter


ECS
CMIP
lambda (3.7/ECS)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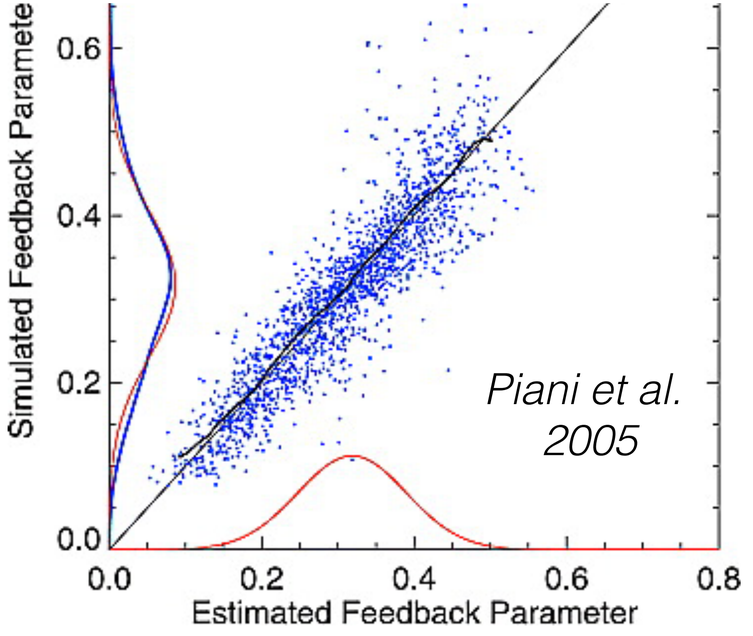
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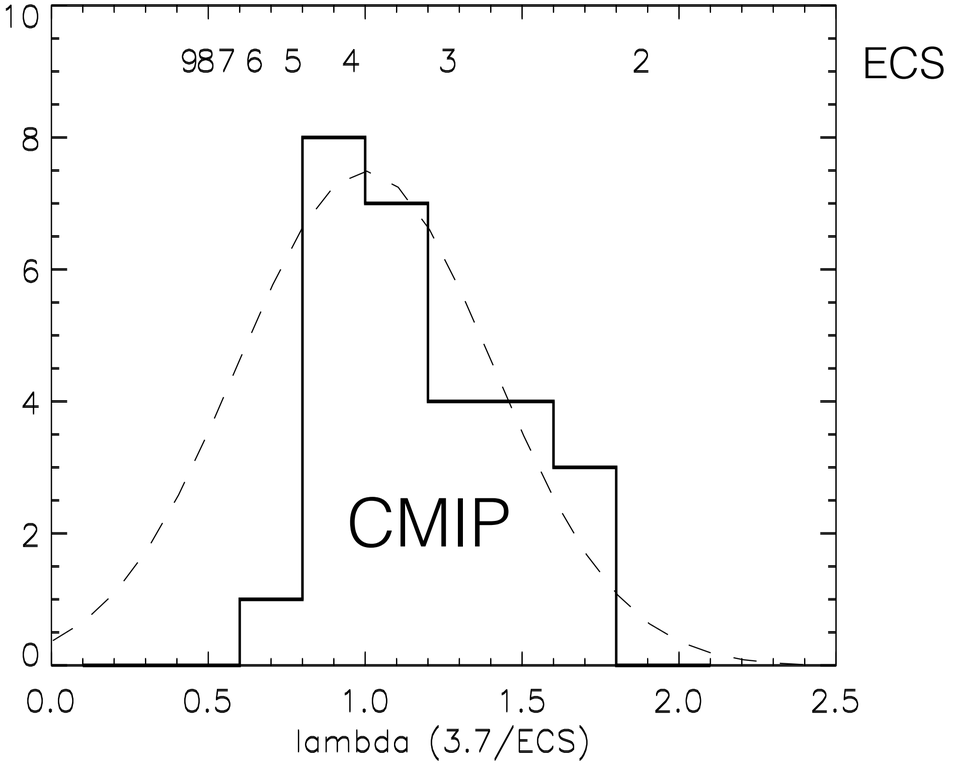
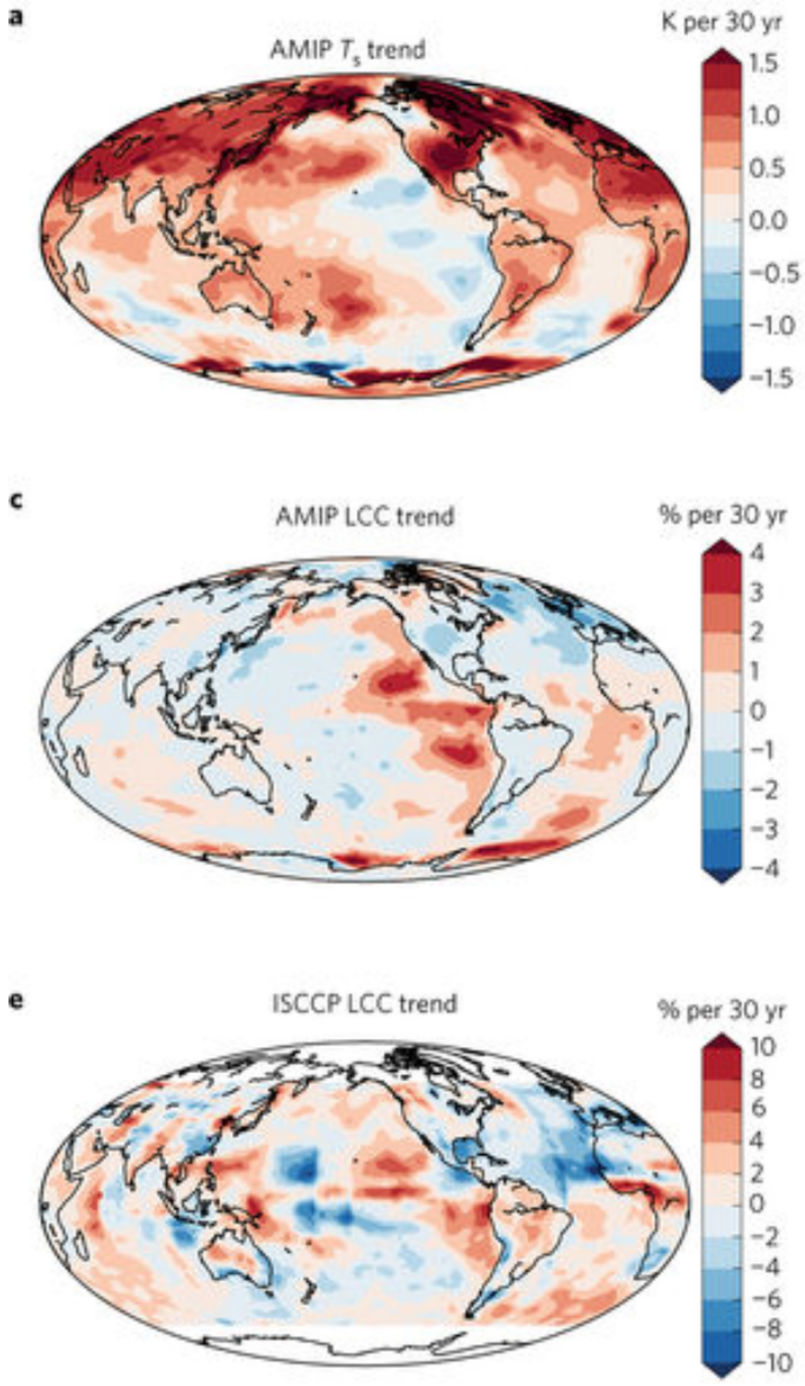

ECS
CMIP
lambda (3.7/ECS)

4. Key constraints on CS

- **Theory+models** (ECS ≤ 1.5°C would require strong cloud responses never seen in any realistic model; absent any cloud amount change, ECS~2.5°C)

- **Historical climate warming** (seems to contradict high or extremely low ECS/TCR; big uncertainty in ΔF from aerosols)

- **Palaeoclimate changes** (generally support GCM ECS range; multiple epochs available, but big uncertainties in both ΔT_{surf} and ΔF for all of them.)

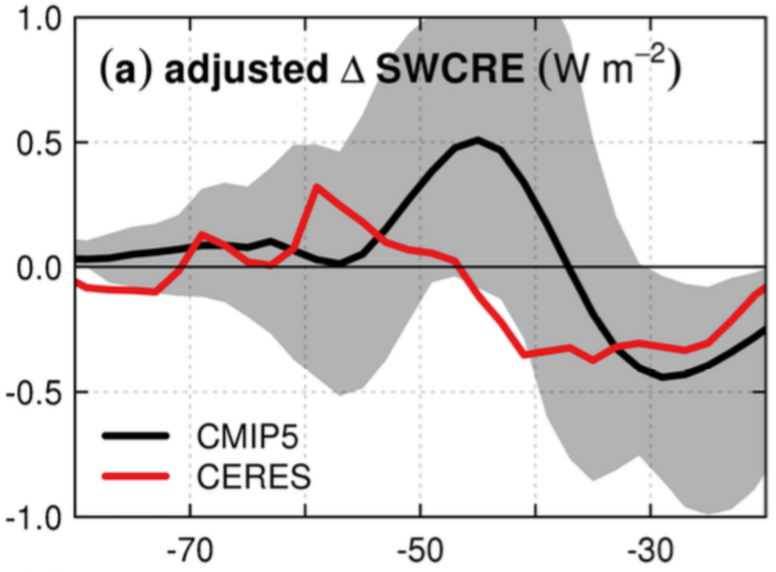


Cloud cooling triggered by temporary dSST pattern since 1980 has masked warming

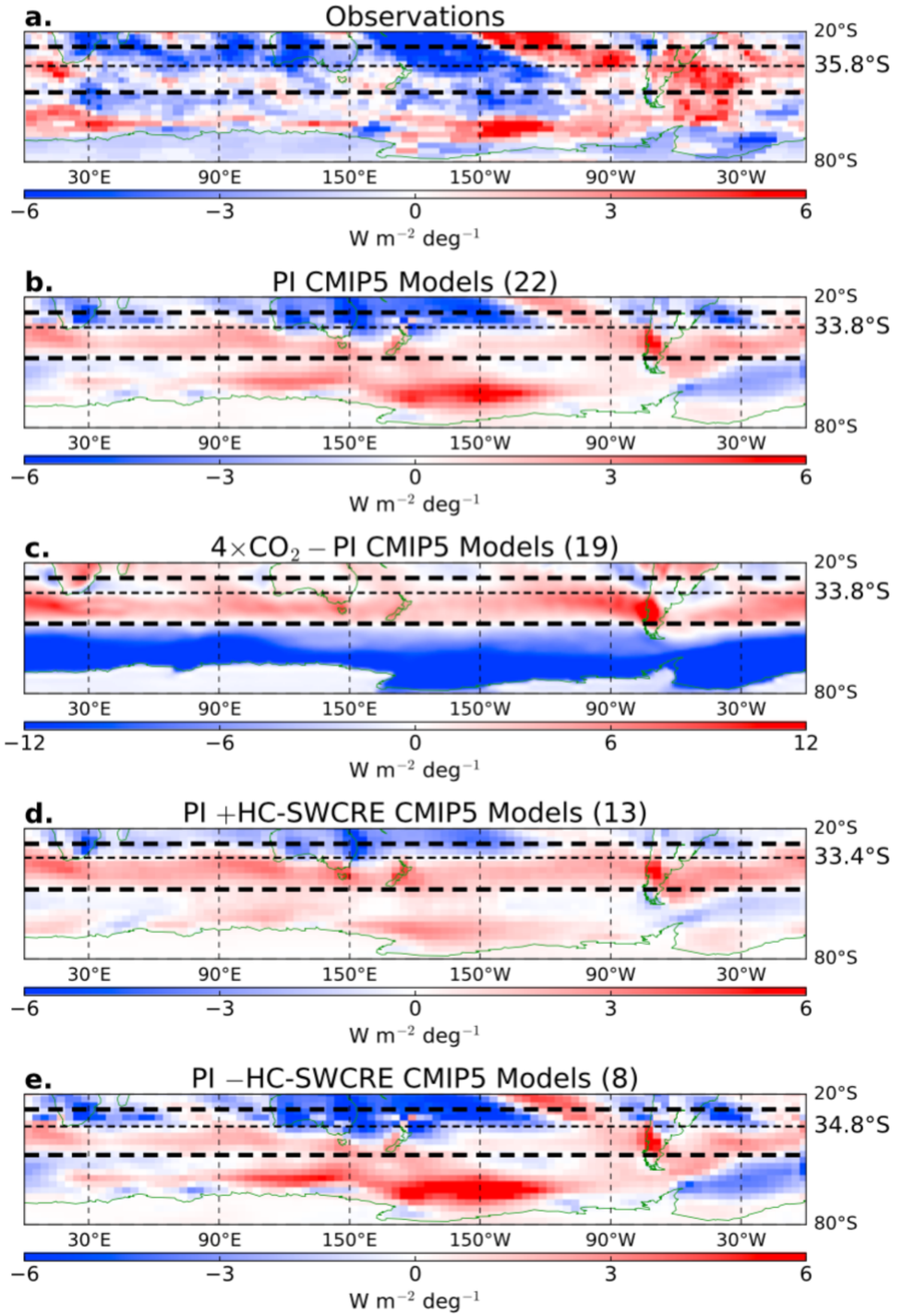
Zhou, Zelinka + Klein 2016

Relation of cloud amount to zonal shifts shows some systematic flaws in low-cloud cover

Ceppi and Hartmann 2015



Lipat et al. 2017



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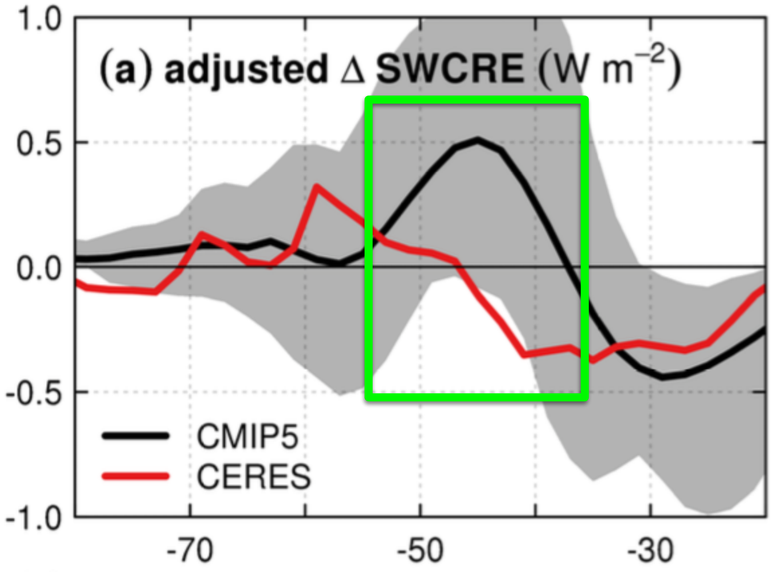

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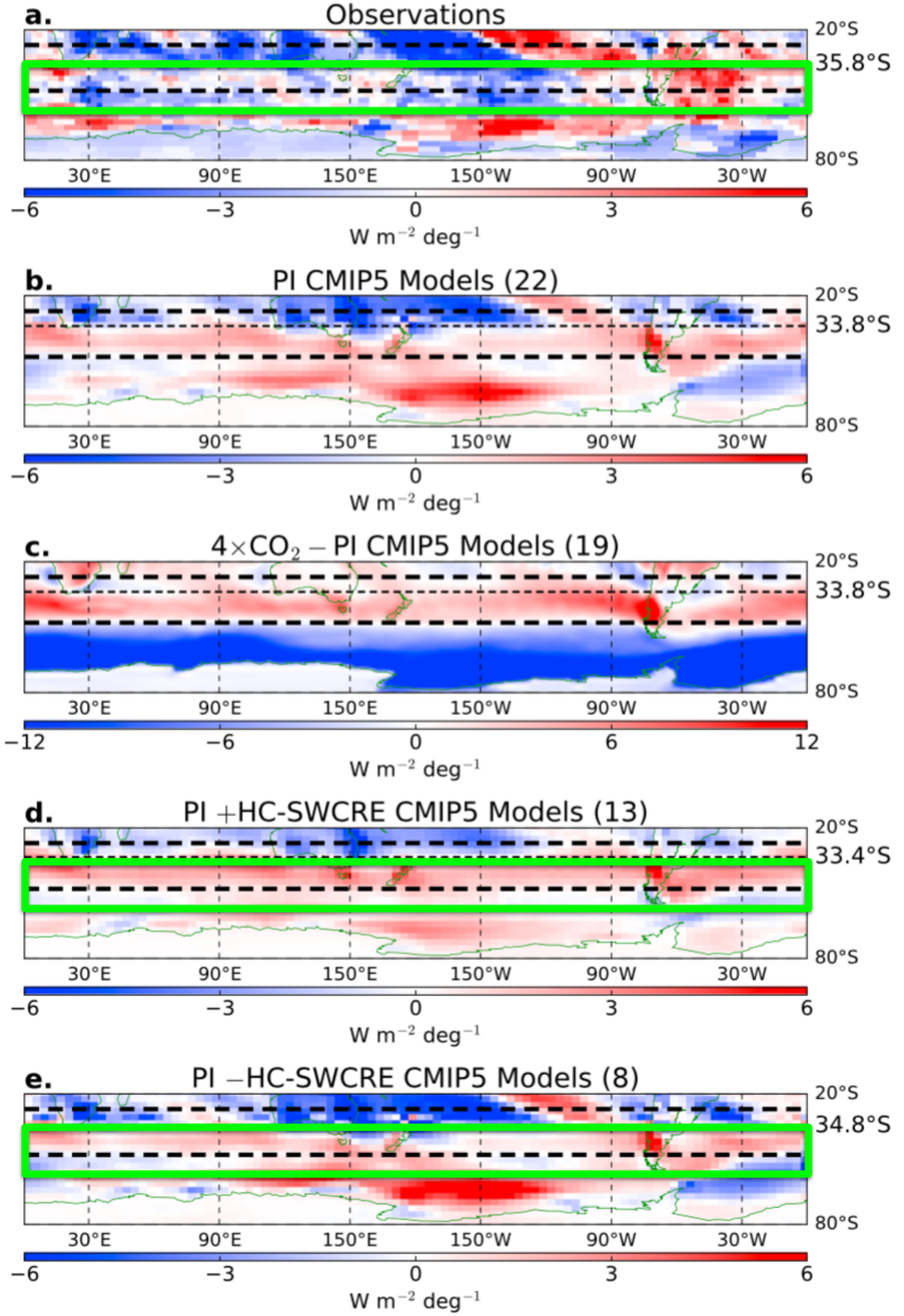

Imagine….

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- An alternative universe where scientists had not figured out how to parameterize clouds, so set them to a constant distribution in space.

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- What would they conclude about ECS from models?

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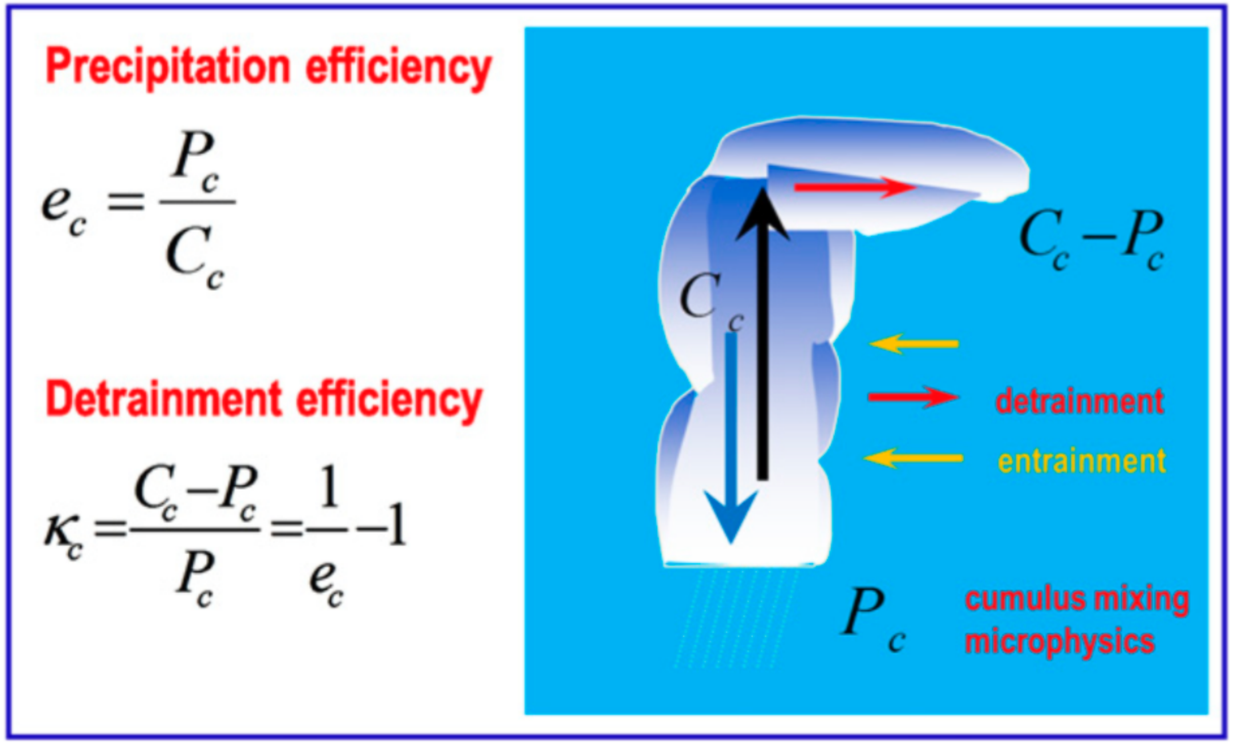
- An alternative universe where scientists had not figured out how to parameterize clouds, so set them to a constant distribution in space.

- What would they conclude about ECS from models?
- What would they conclude about ECS from the historical record?

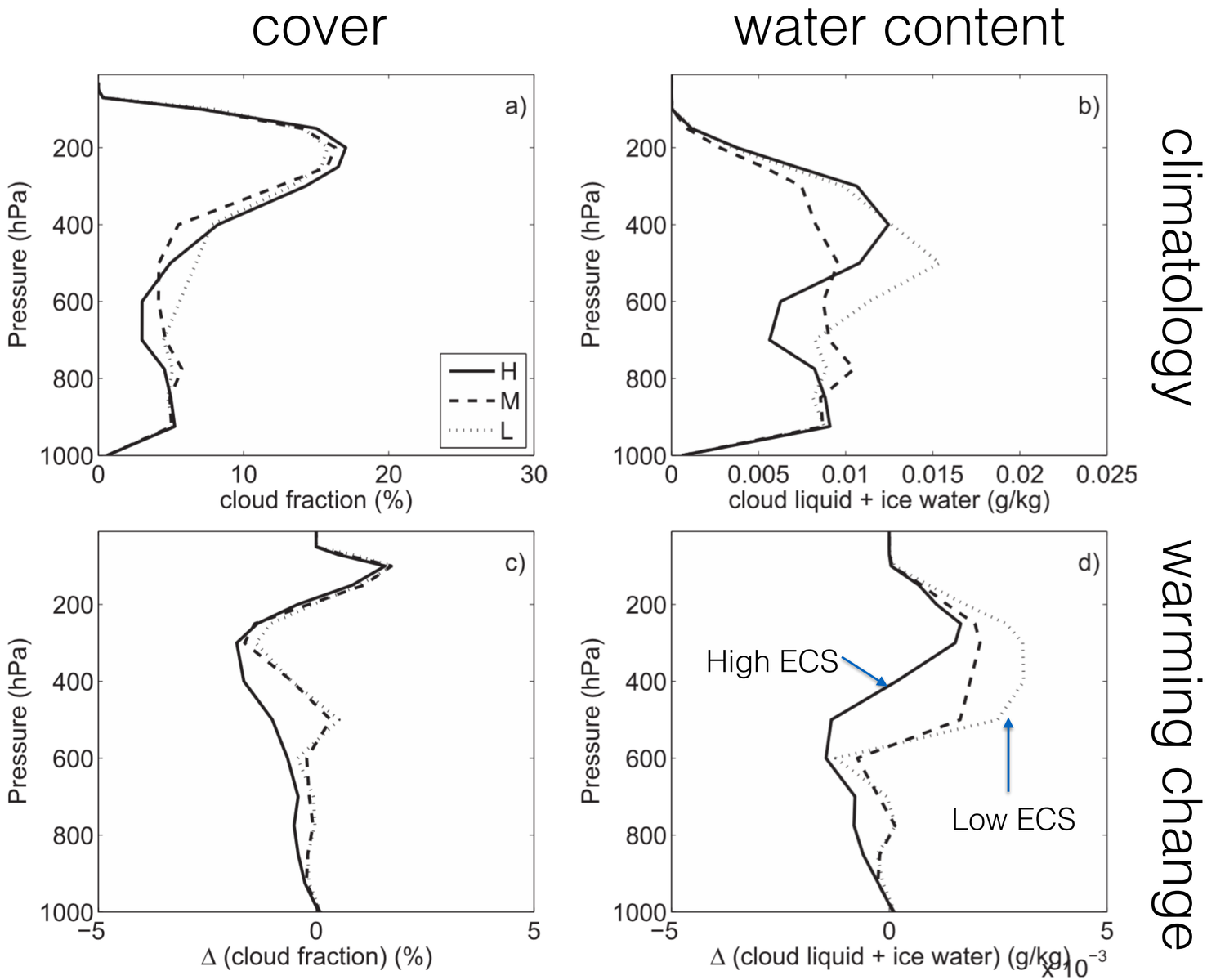
Tuning the sensitivity

- Zhao et al. changed the way precipitation efficiency depends on condensed water amount in GFDL model.
- This enabled them to dial in various climate sensitivities.
- Changes did not obey published “emergent constraints.”



Zhao et al. 2016

- Zhao et al. feedback variations come from <u>mid-high</u> clouds
- CMIP3+5 spreads mainly come from low clouds
- Degree of freedom missing in CMIP??



Other new dimensions

- *Tan et al. 2016*: GCMs produce spurious negative cloud feedback at high latitudes due to lack of supercooled liquid.

- *Gettelman et al. 2016*: strength of cloud feedback depends on aerosol load.

- Convective memory, organization (e.g. *Mapes and Neale 2011*), coupling to boundary layer (*Grandpeix and Lafore 2010, Bechtold et al. 2014*)

New developments

WCRP Assessment on Climate Sensitivity (Leads: Steven Sherwood and Mark Webb)

Purpose:

1) To make thorough assessment of climate sensitivity, clarifying the nature and limitations of key evidence.

2) To assess the likelihood of very low or high ECS (effective climate sensitivity) and to provide robust 5-95% confidence ranges for ECS.

3) To highlight future research directions most likely to yield stronger constraints.

Outputs:

Review paper of about 20 pages, to be submitted for publication in 2018.

Documentation and ideally code allowing the community to reproduce/test/build on results.

Conclusions

- Understanding of low clouds is progressing and increasingly points to + feedback from them (adding to + feed from high clouds).

- Convective parameterisations may not be that important for mean-state biases and spread. Key role for cloud and boundary-layer schemes (or, oversimplistic convective schemes?) Important role for mechanism-denial / COOKIE experiments.

- There are important physical degrees of freedom not captured (much) in existing CMIP ensembles, and CMIP spread is not necessarily meaningful. Current CMIP does not span the space of reasonable models.

- This affects “emergent constraints,” and any use of models that implicitly regards them as a representative sample.

- —> Important role for model complexity in exposing possible omissions