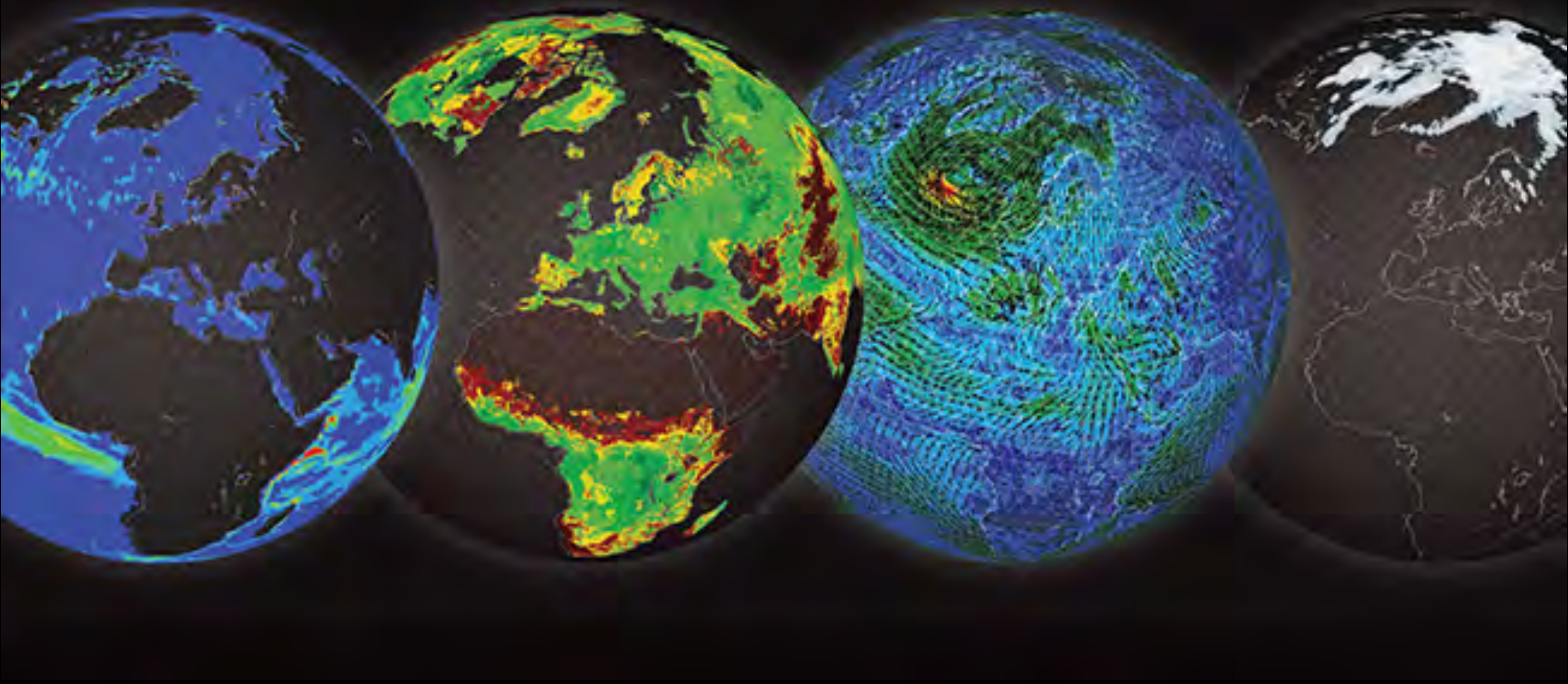
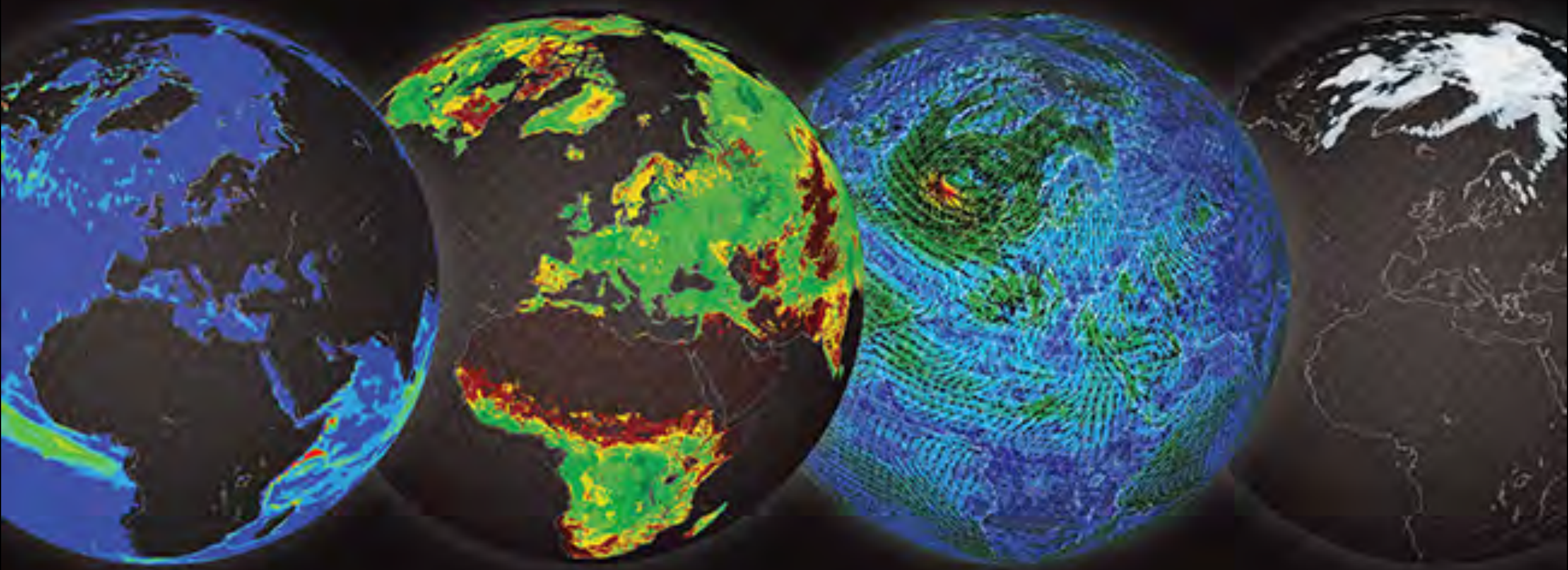
How much do cloud errors matter in coupled modelling?



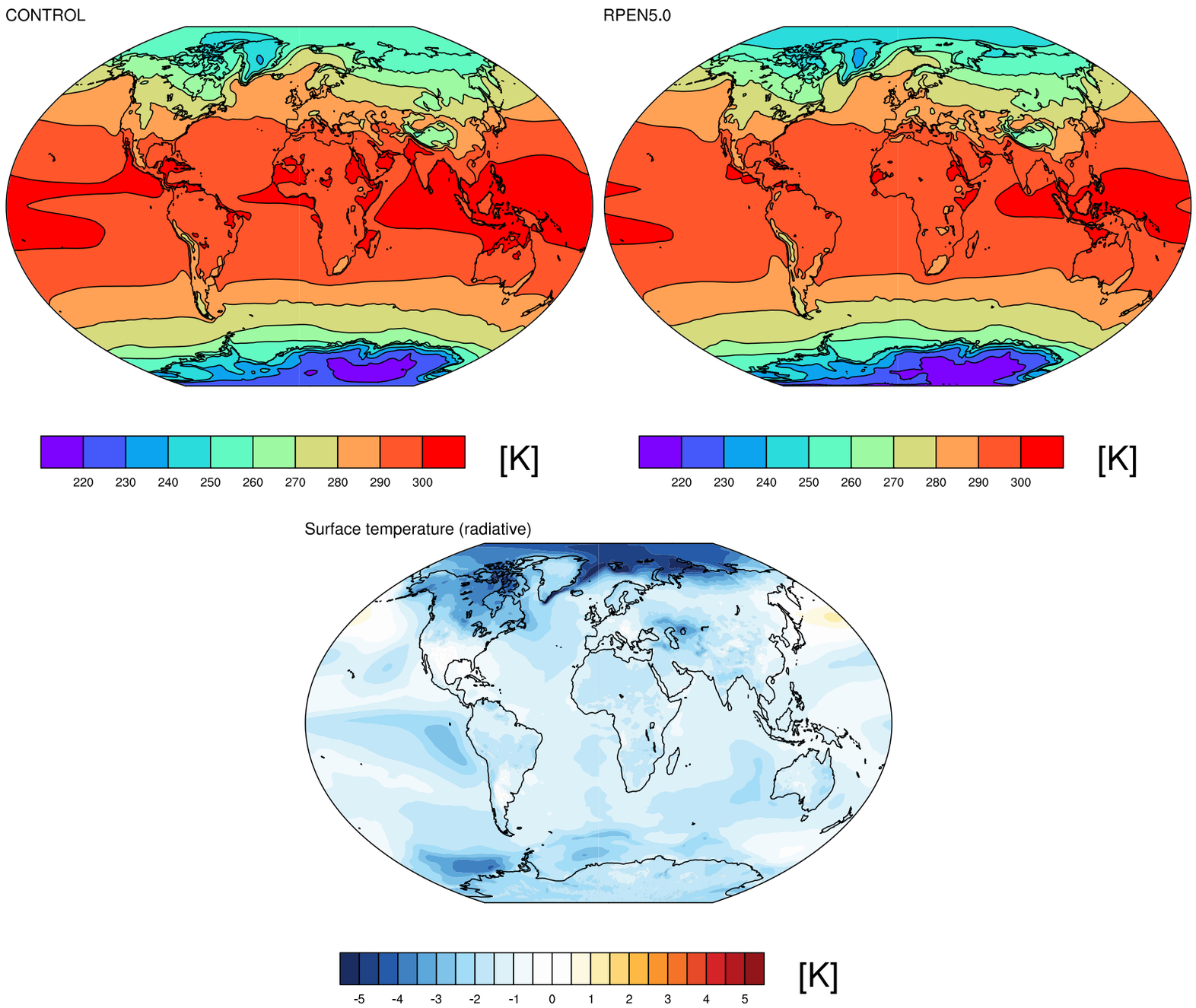
Brian Medeiros, NCAR, brianpm@ucar.edu

ECMWF Annual Seminar 2016

ocean land circulation ice

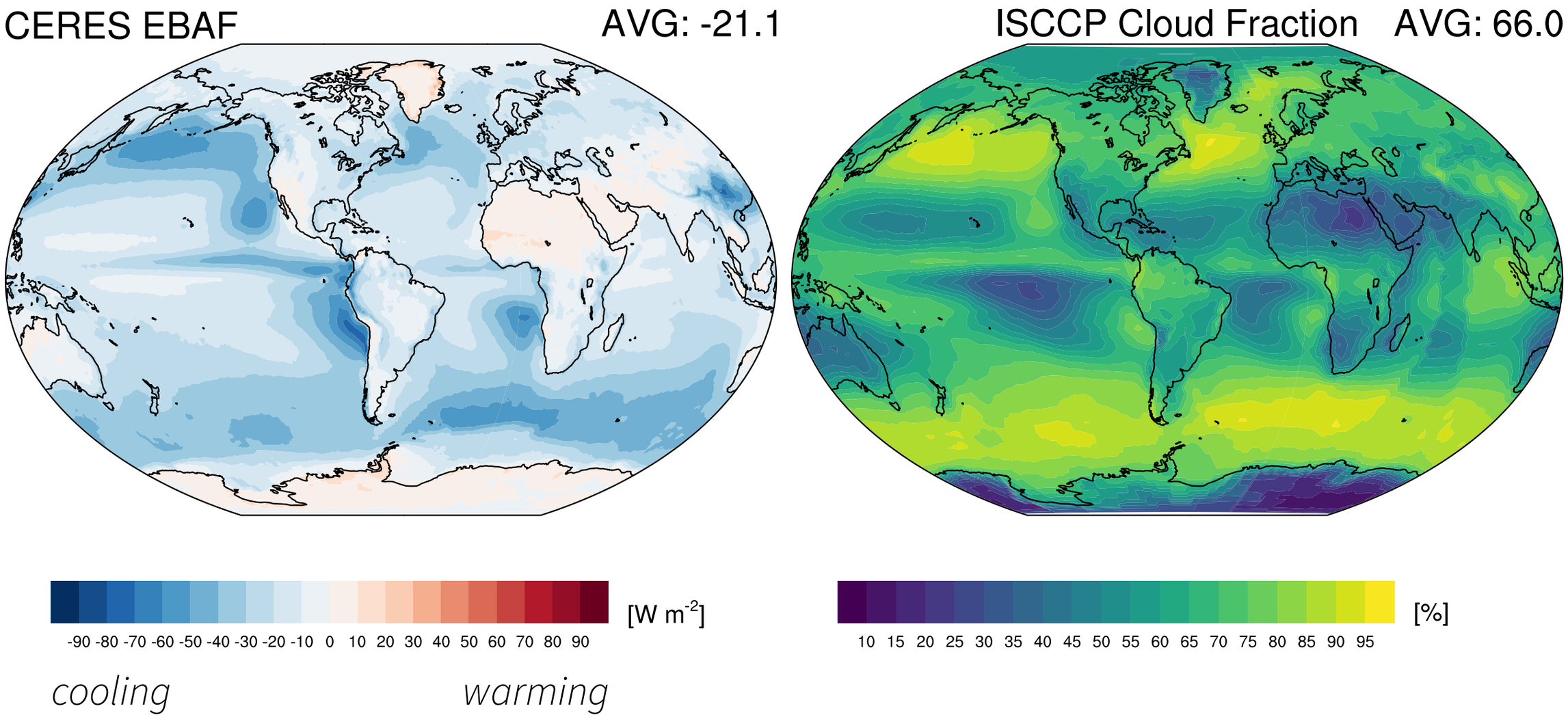


example: change a cloud parameter

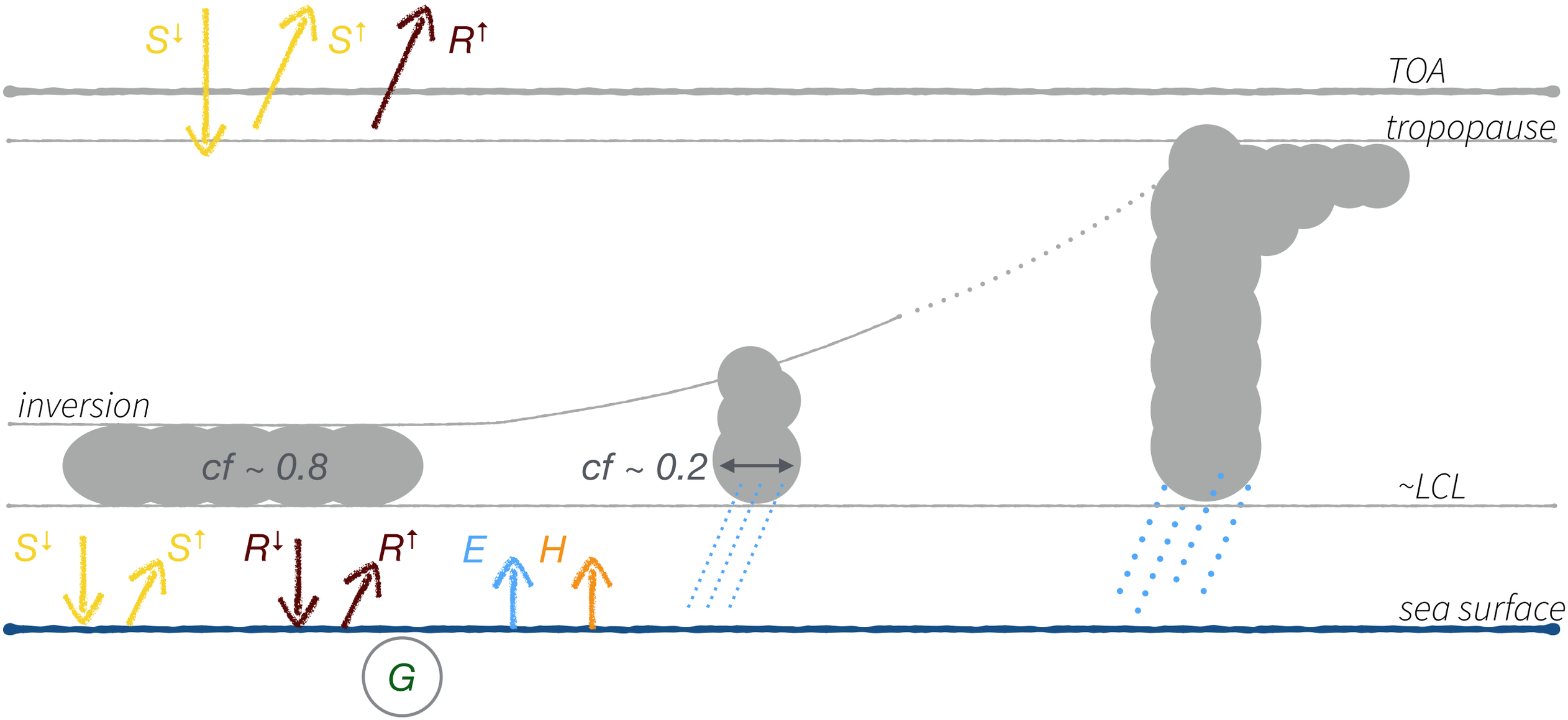


Simulations by Eleanor Middlemas

clouds from space



cloud effects: tropics as the prototype*



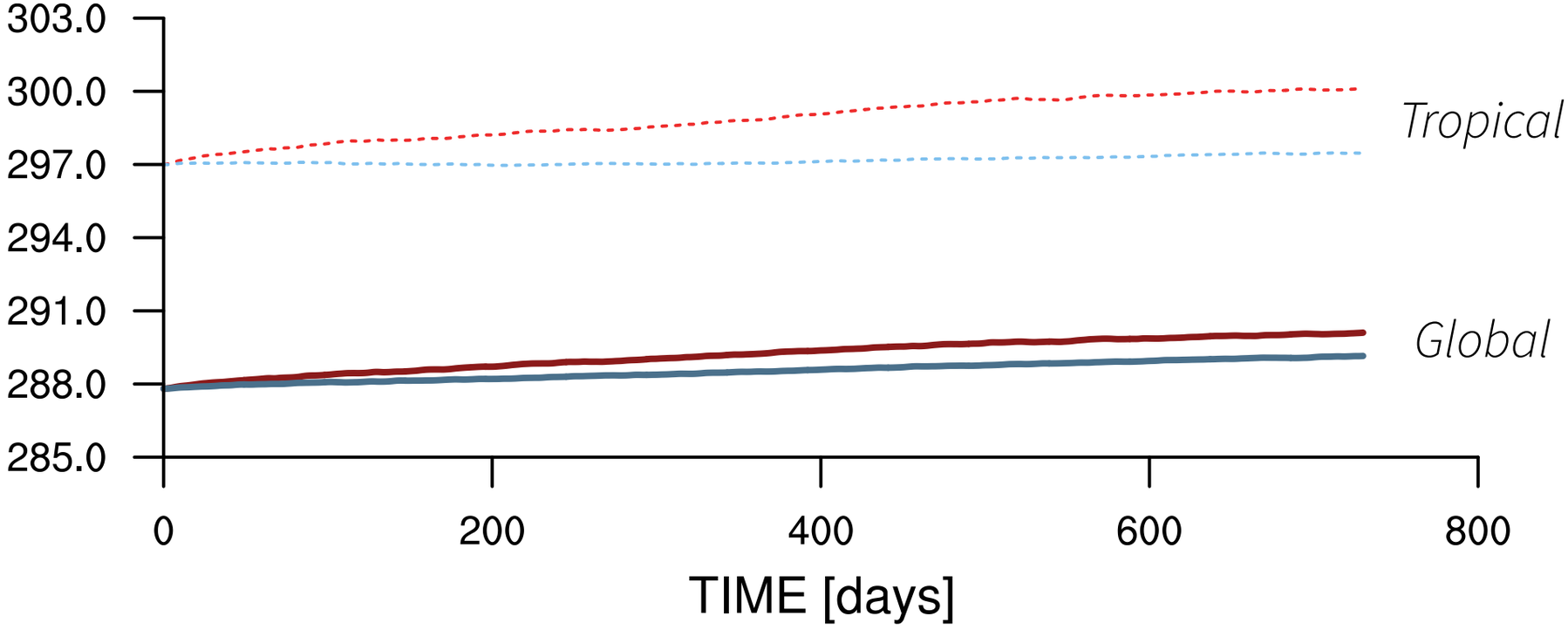
$$G = S_{\text{net}} + R_{\text{net}} - H - L_v E$$

** not drawn to scale.*

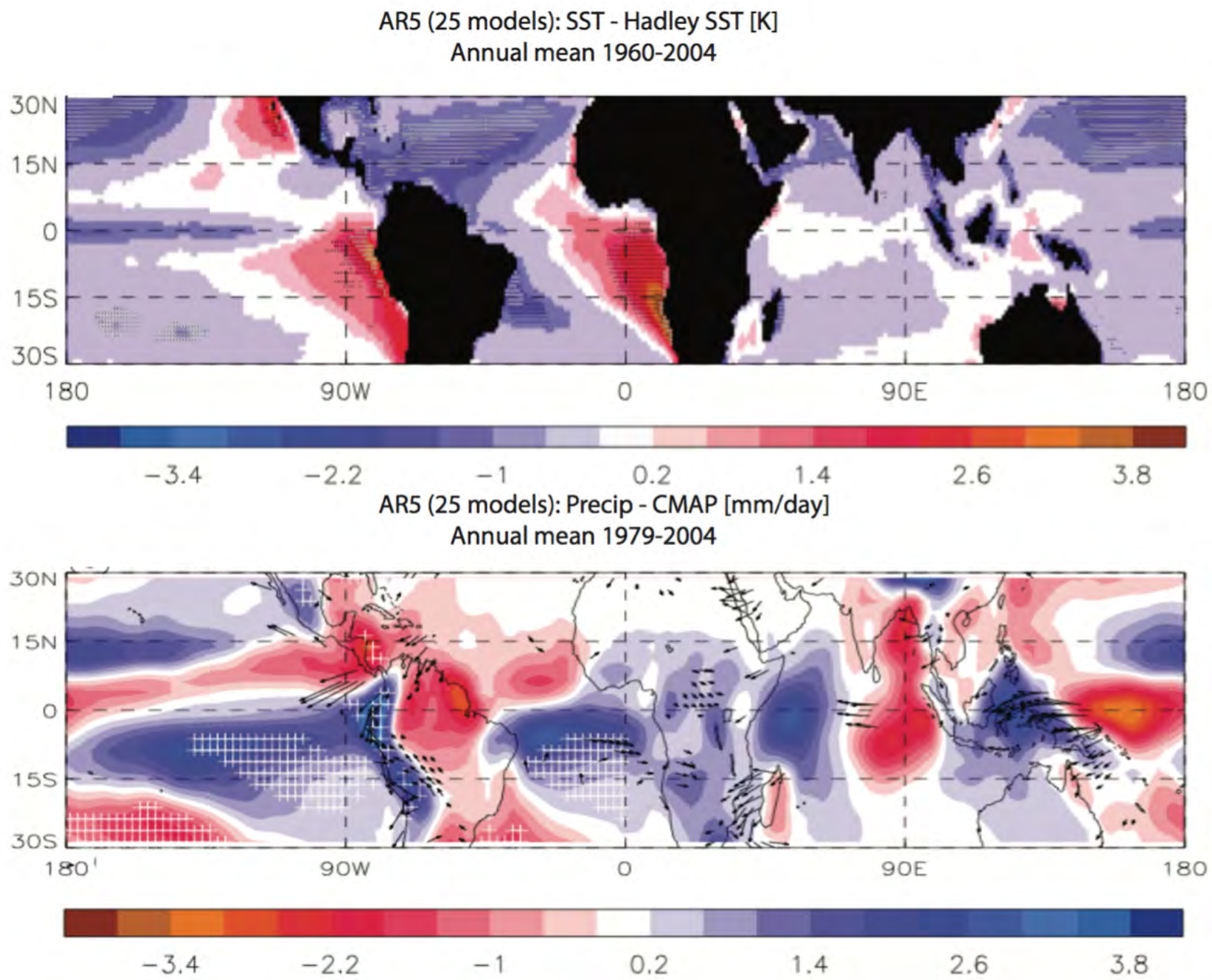
example: SST under invisible clouds

$$G = S_{\text{net}} + R_{\text{net}} - H - L_v E$$

$$c_p h \rho \frac{dT}{dt} = (\Phi_{\text{clear}} + \Phi_{\text{cloud}}) - H - L_v E$$

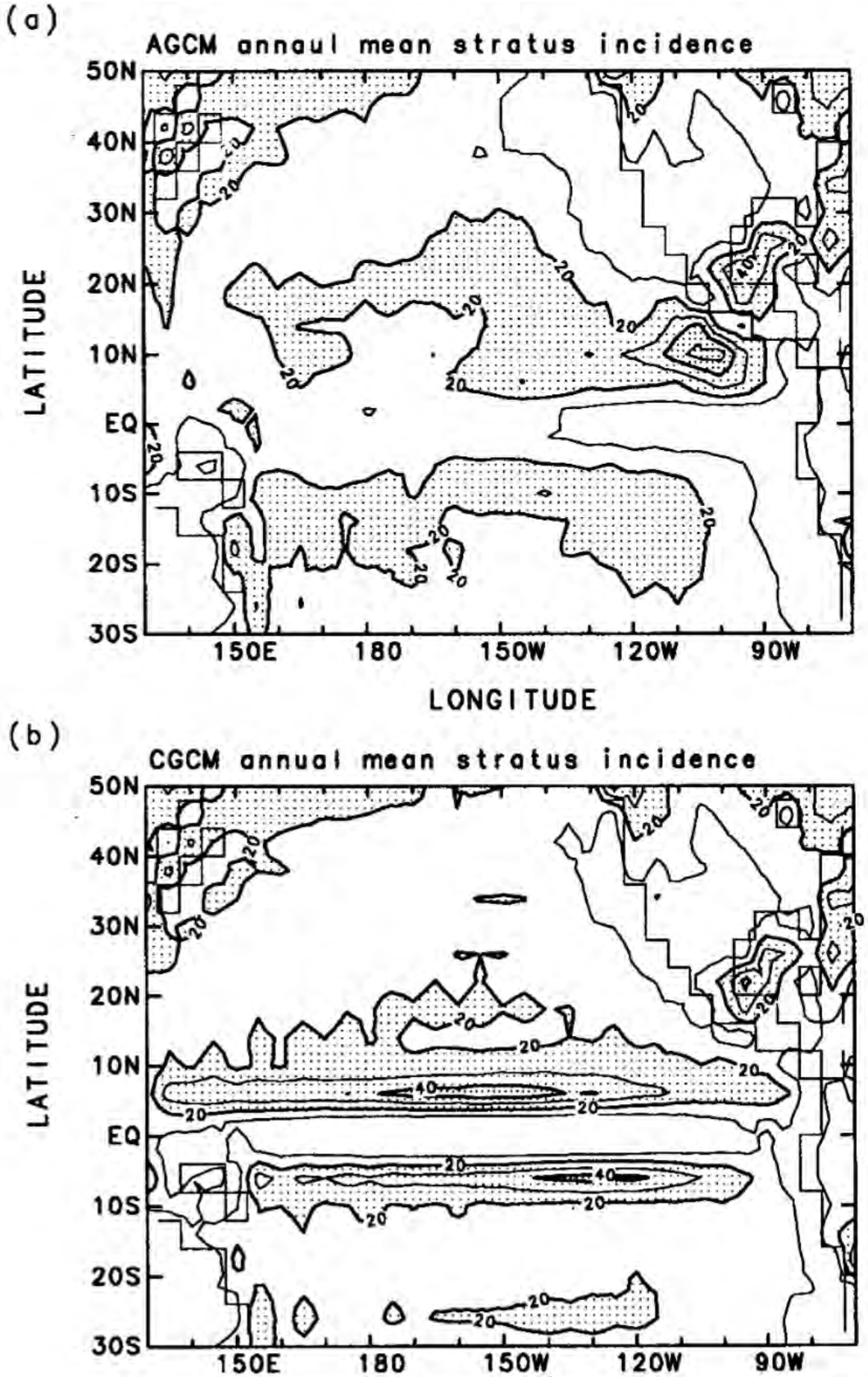


Coupled model biases

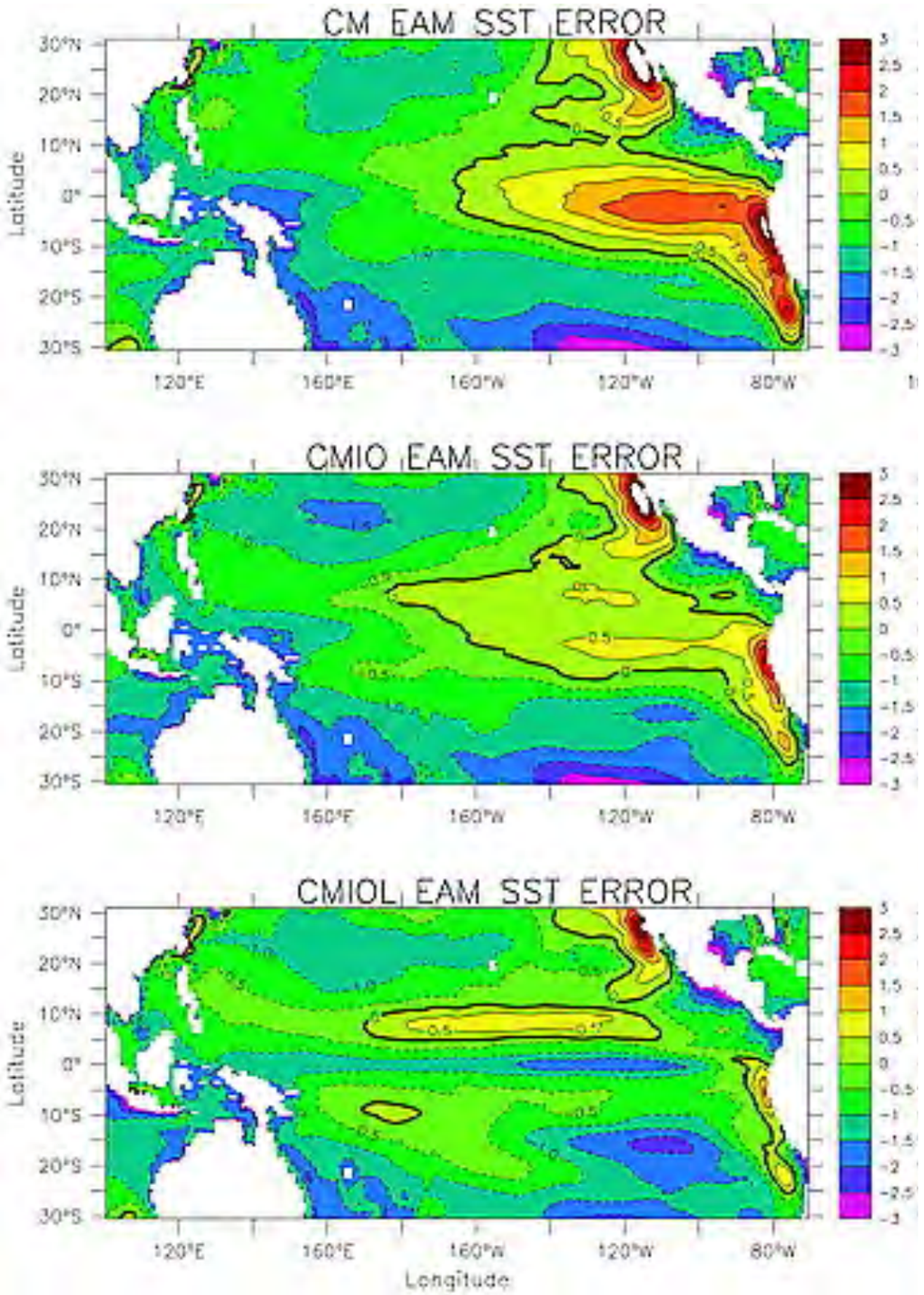


Zuidema et al. 2016

an old story



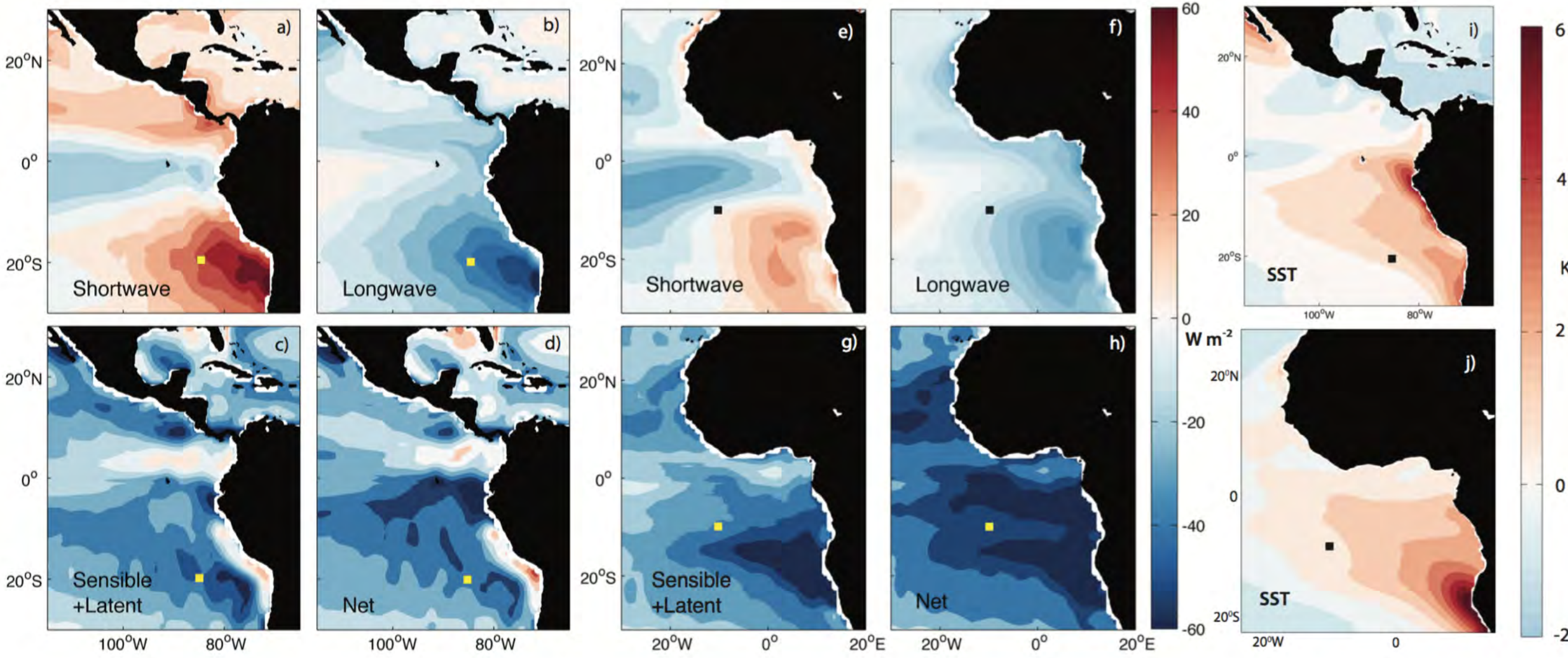
[Ma et al. 1996](#)



[Gudgel et al. 2001](#)

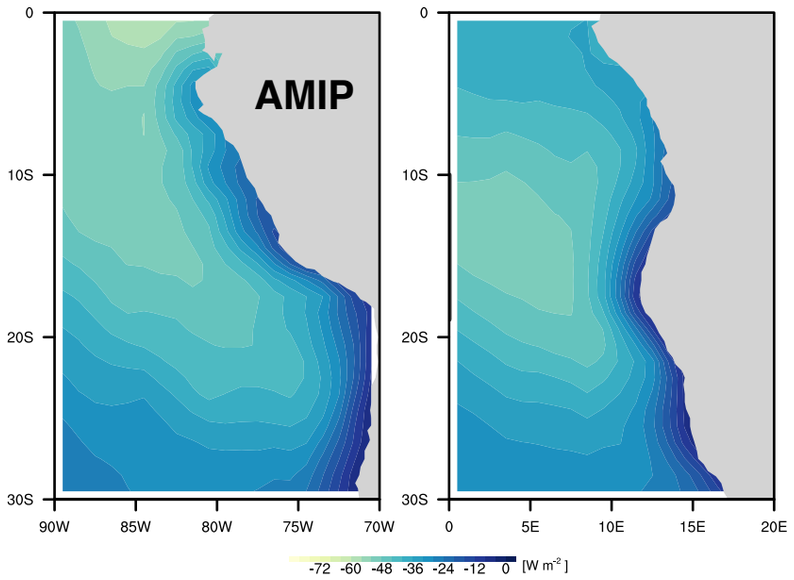
Coupled model surface flux biases

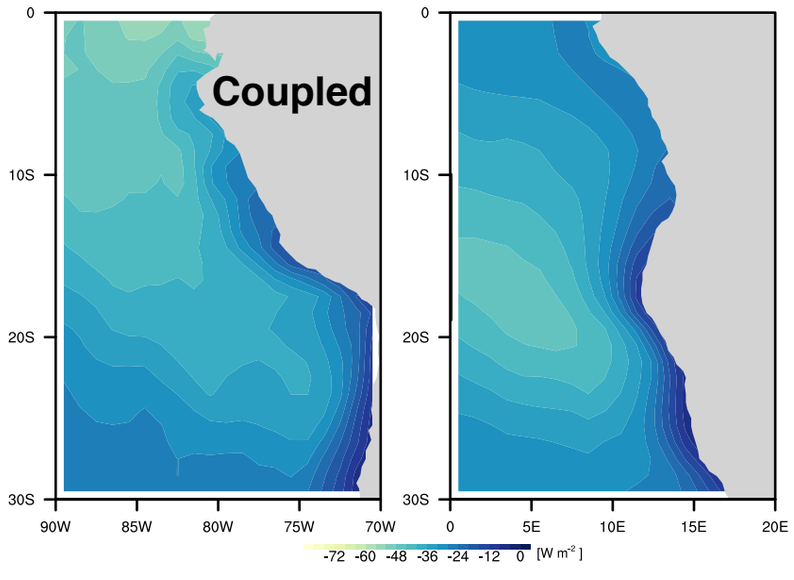
Southeast Pacific *Southeast Atlantic*

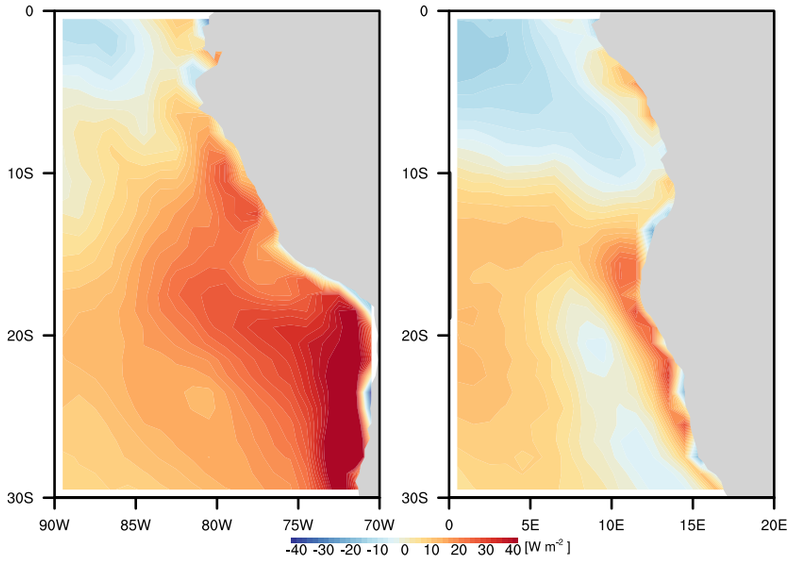


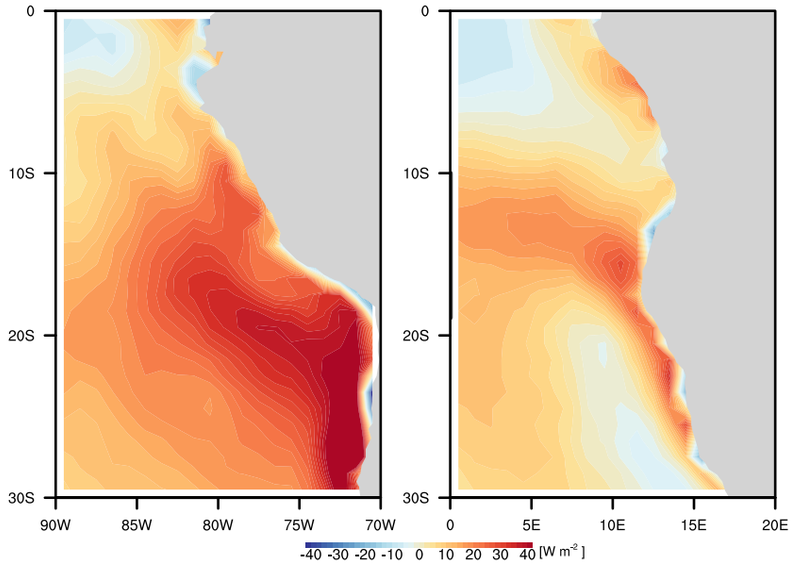
Zuidema et al. 2016

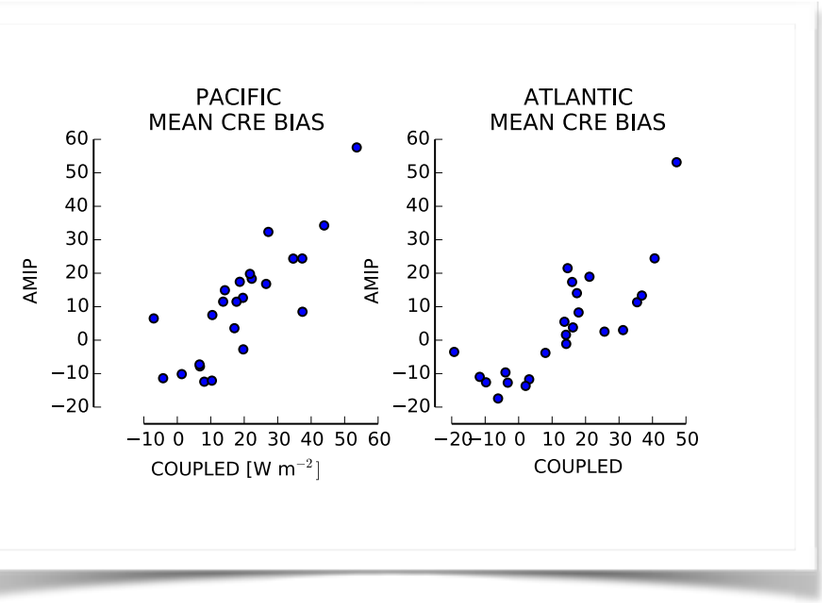
SST errors are not cloud errors







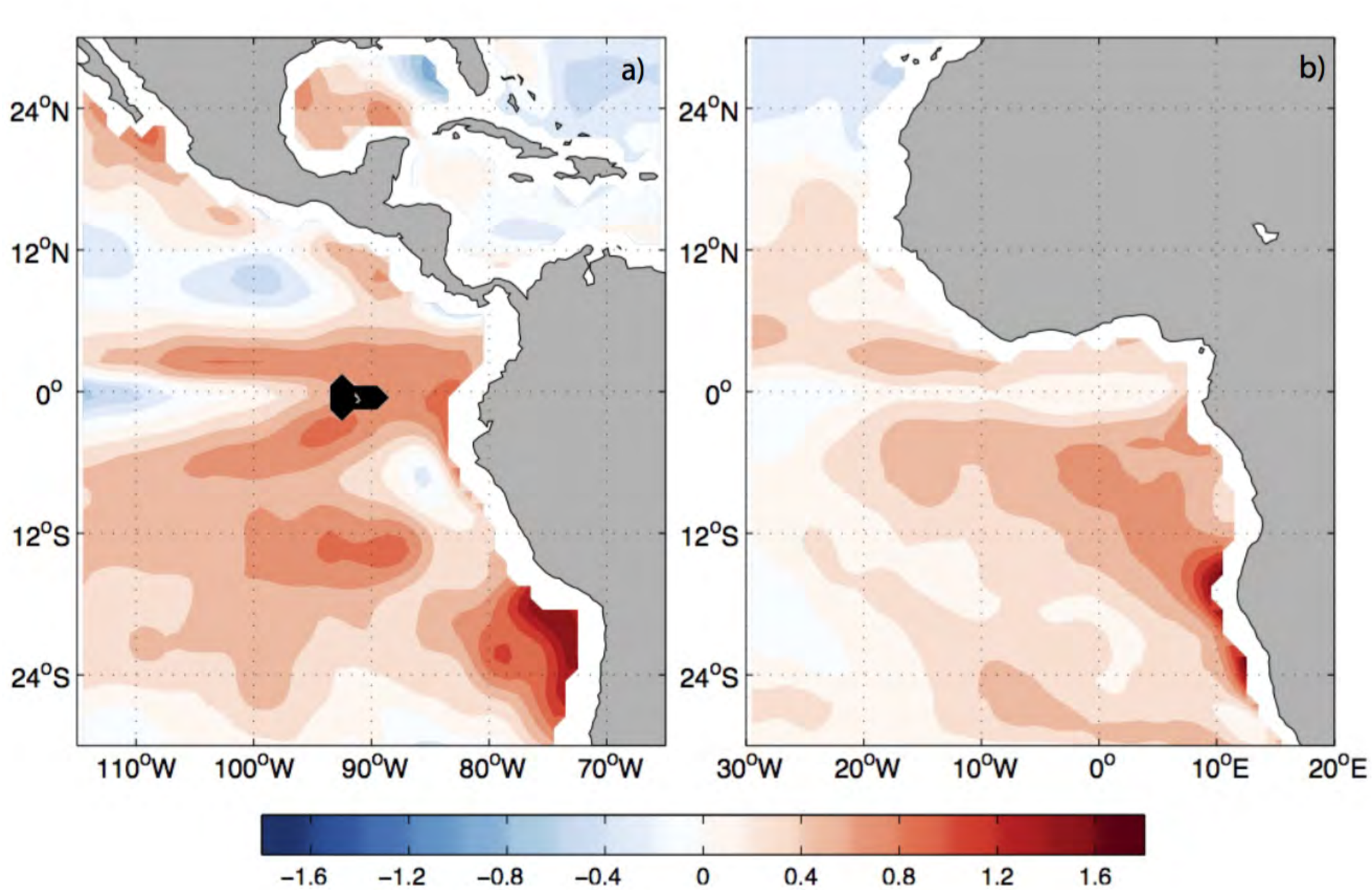




[Zuidema et al. 2016]

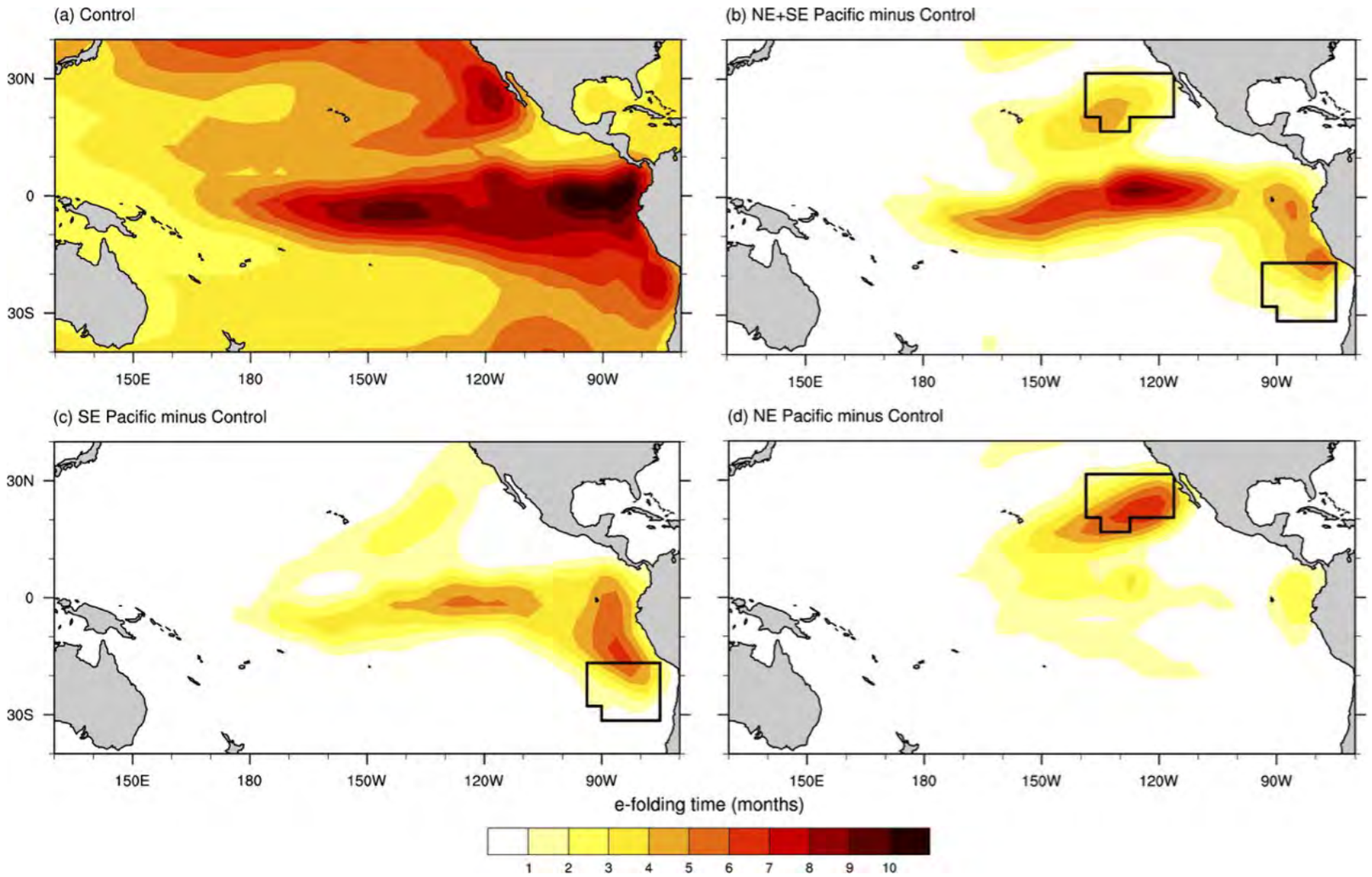
Not just clouds!

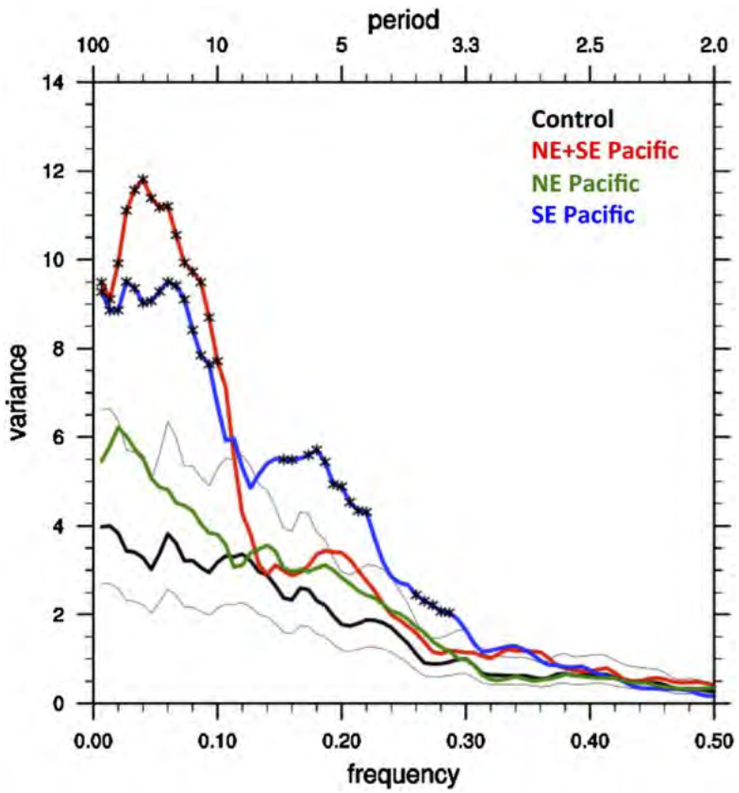
Ocean only models forced by prescribed atmosphere



Zuidema et al. 2016

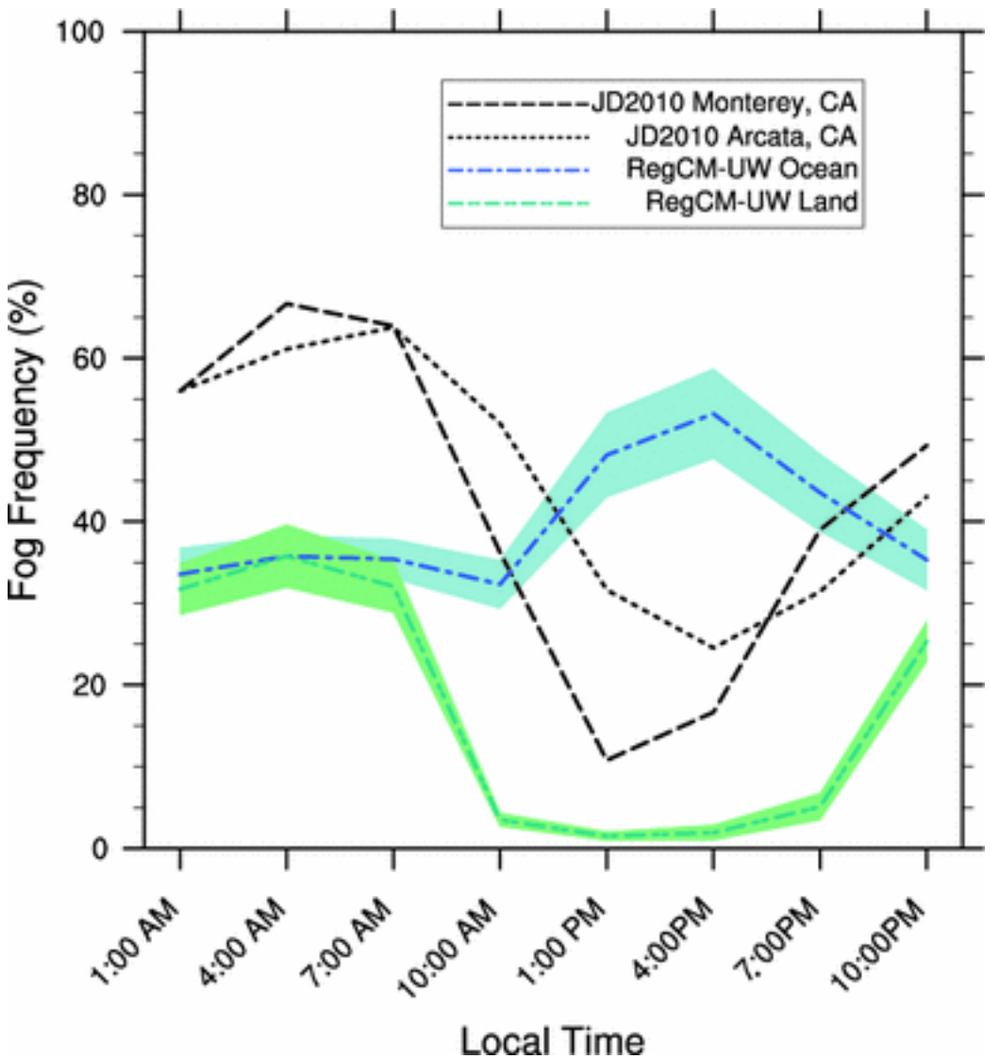
impact on SST variability





[Bellomo et al. (2014)]

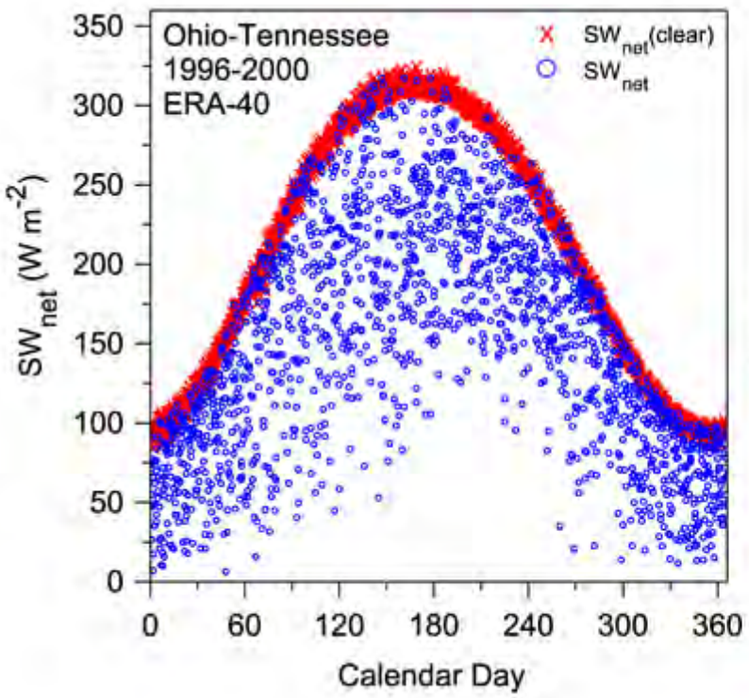
but … should I bring a jacket?

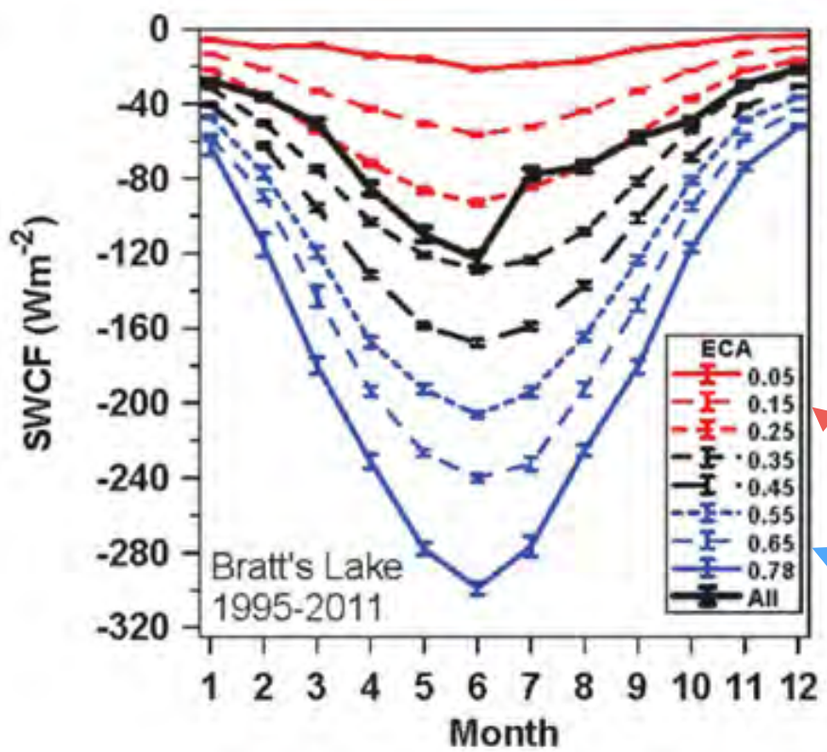


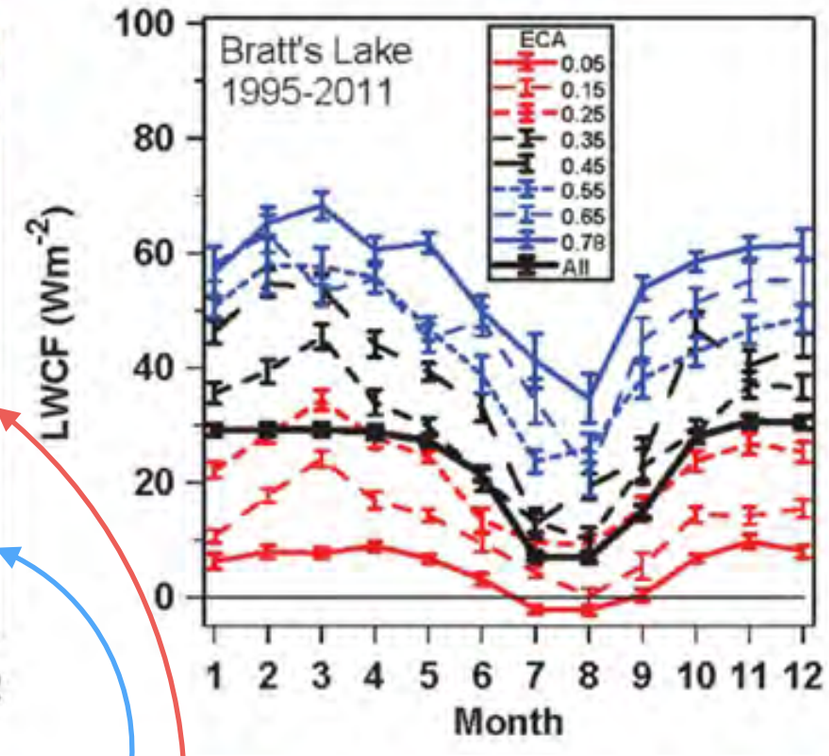
O'Brien et al 2013

land surface energy budget

$$F_{\text{net}} = S_{\text{net}} + R_{\text{net}} = H + L_v E + G$$





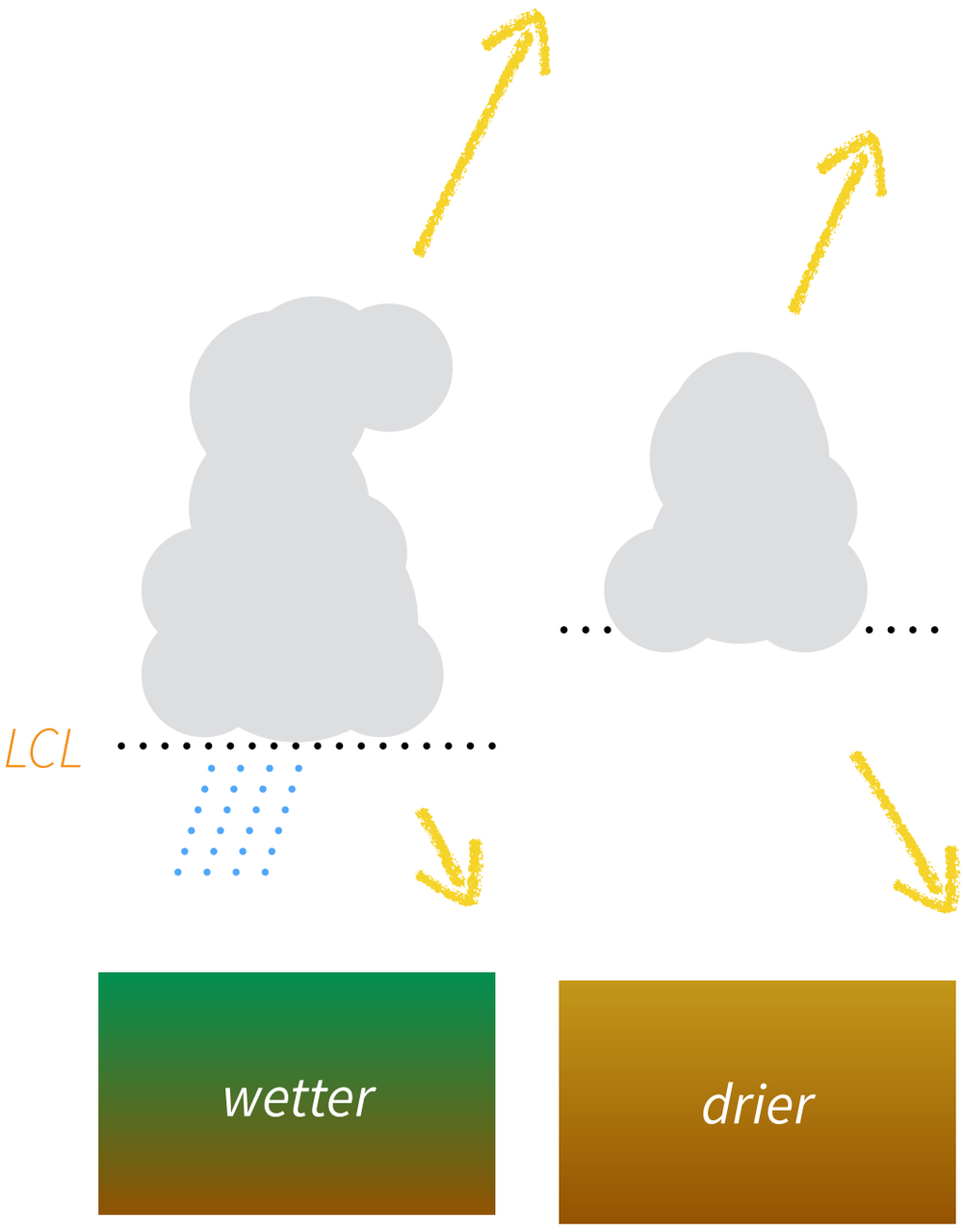


cloudy

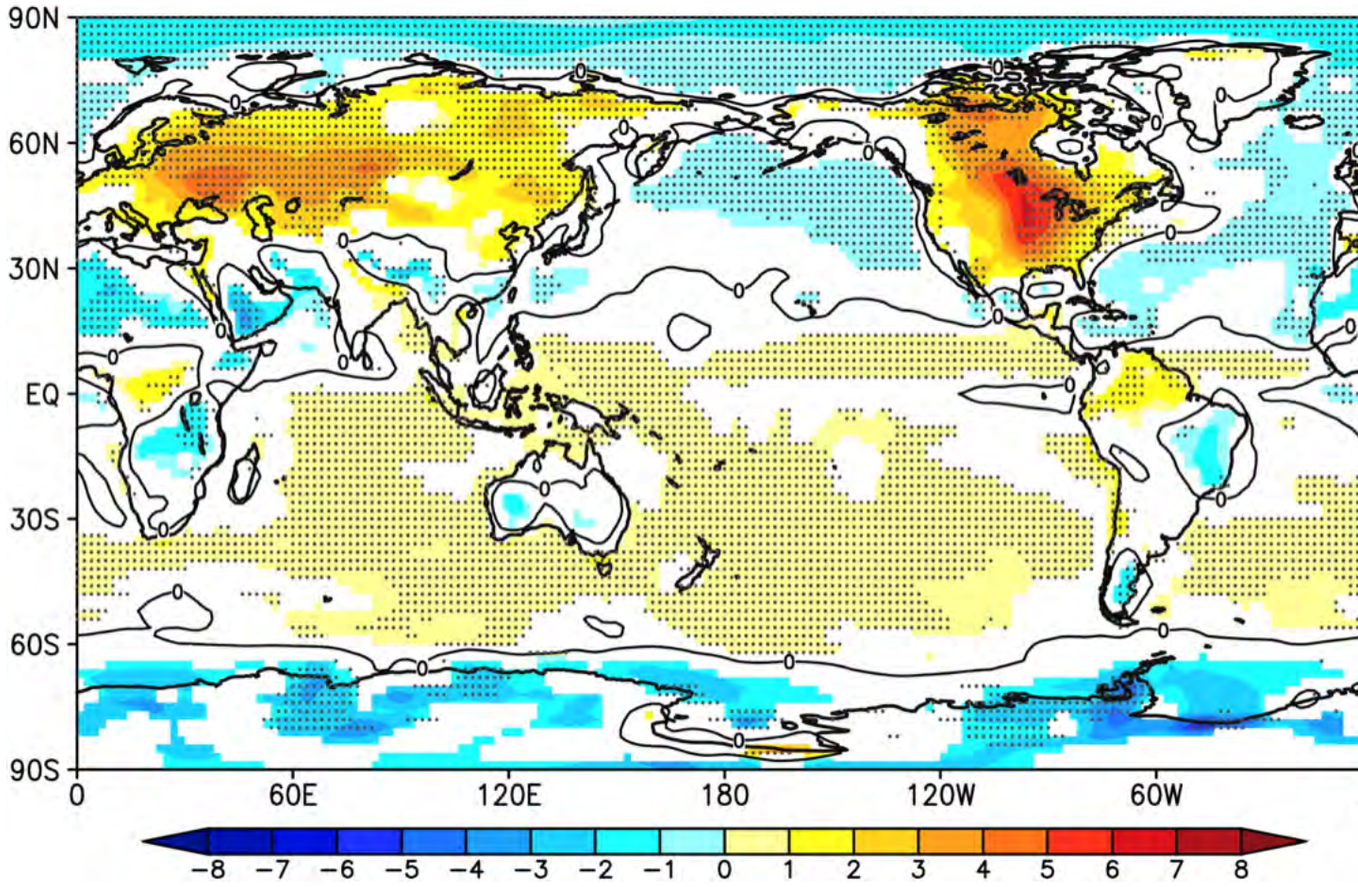
clear

[Betts (2009)](#) [Betts et al. 2015](#)

land-cloud coupling



2m T bias



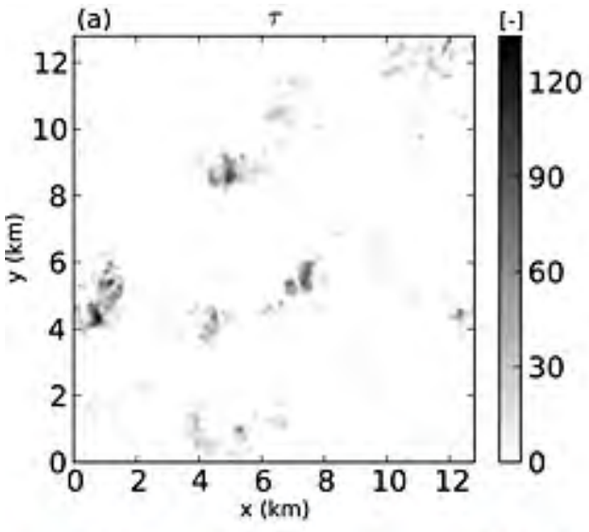
Depends on RH

$$p_{\mathrm{LCL}} = p_0 \left(\frac{T_0 - T_d}{223.15} + 1 \right)^{-\frac{7}{2}}$$

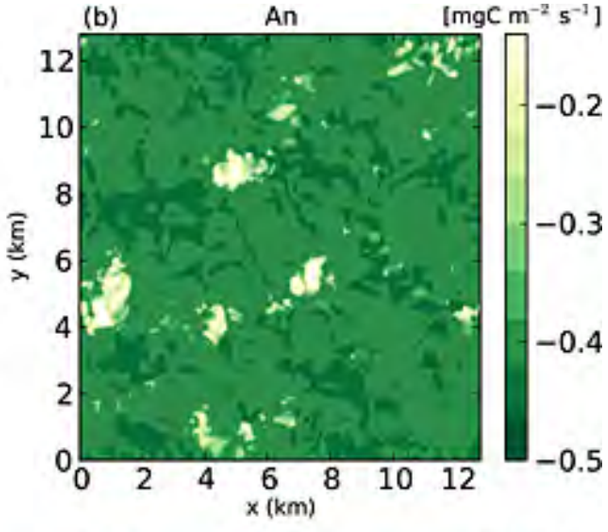
Ma et al. 2012

Cloud-Vegetation/Carbon interaction

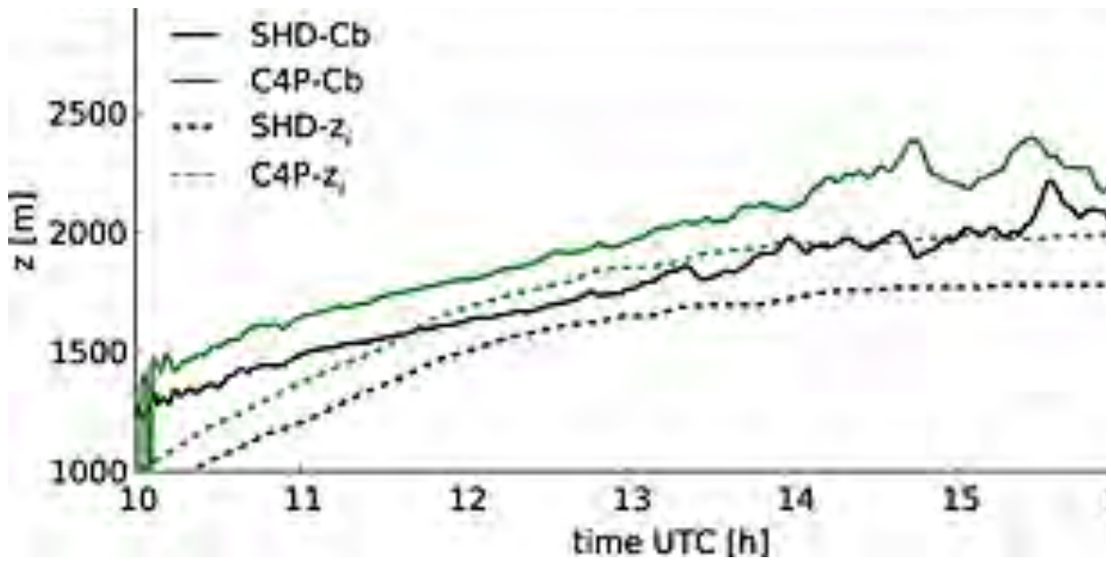
Cloud

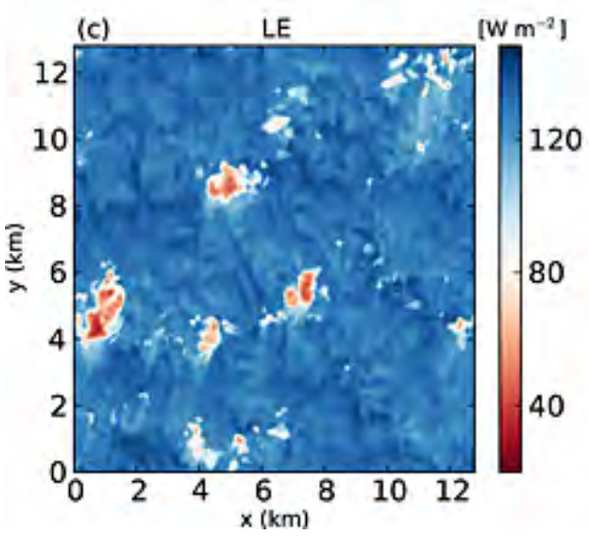


CO2 flux

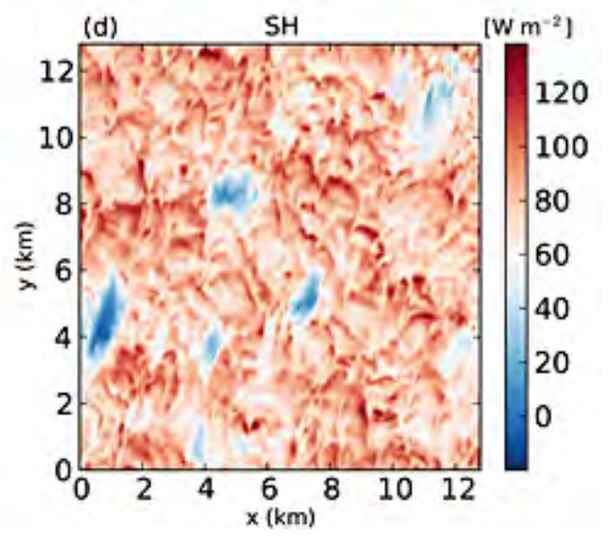


C3 vs. C4 grass





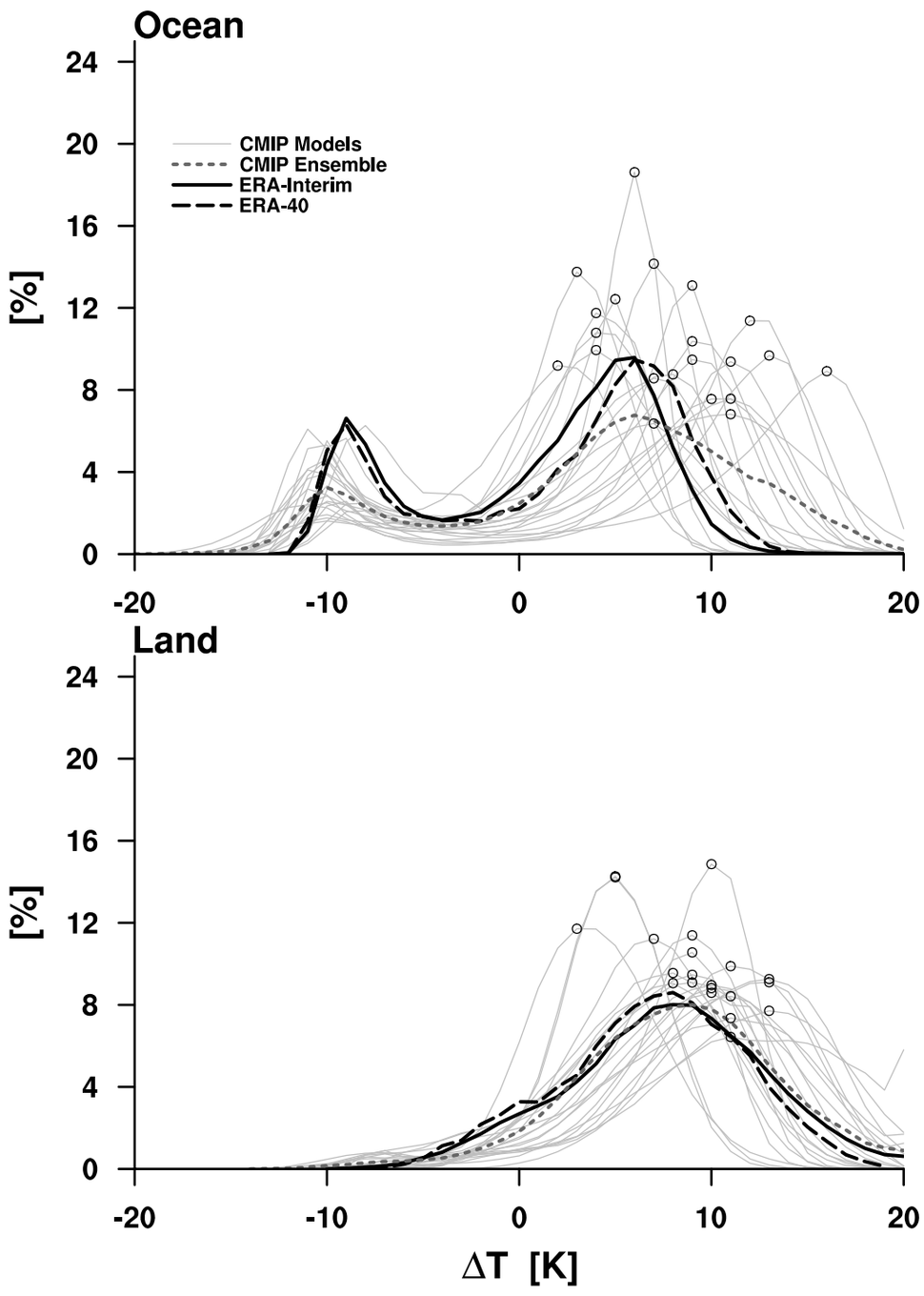
Latent



Sensible

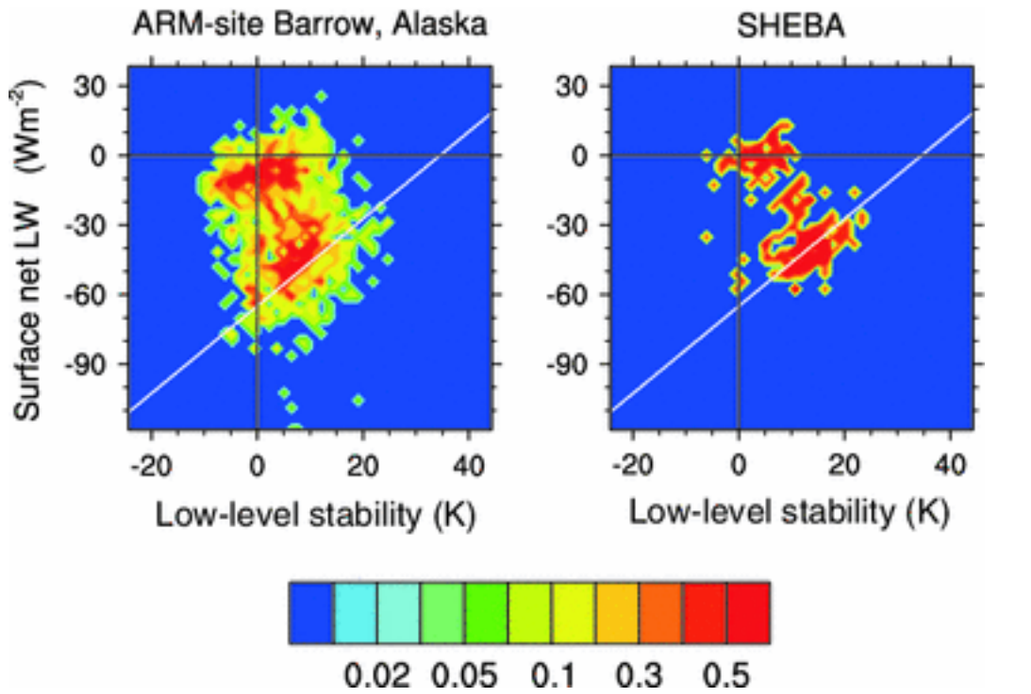
[Vila-Guerau de Arellano 2014]

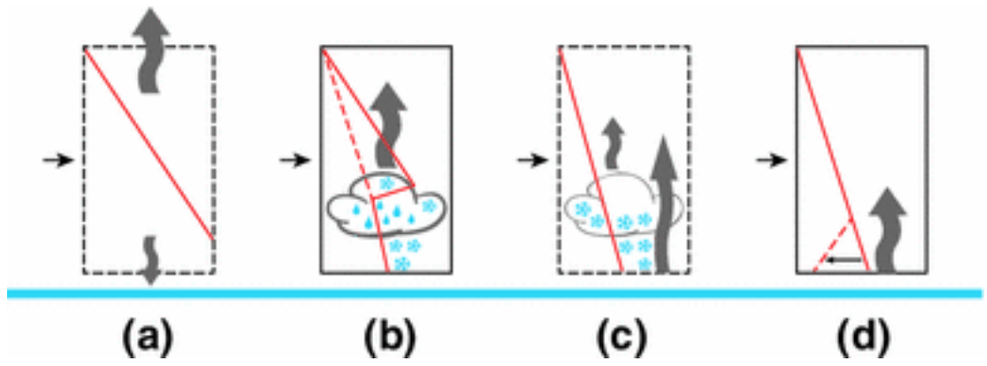
Cloud-Ice interaction



Medeiros et al. 2011

$$F_{\text{net}} = S_{\text{net}} + R_{\text{net}} = H + L_v E + G$$





Pithan et al. 2014

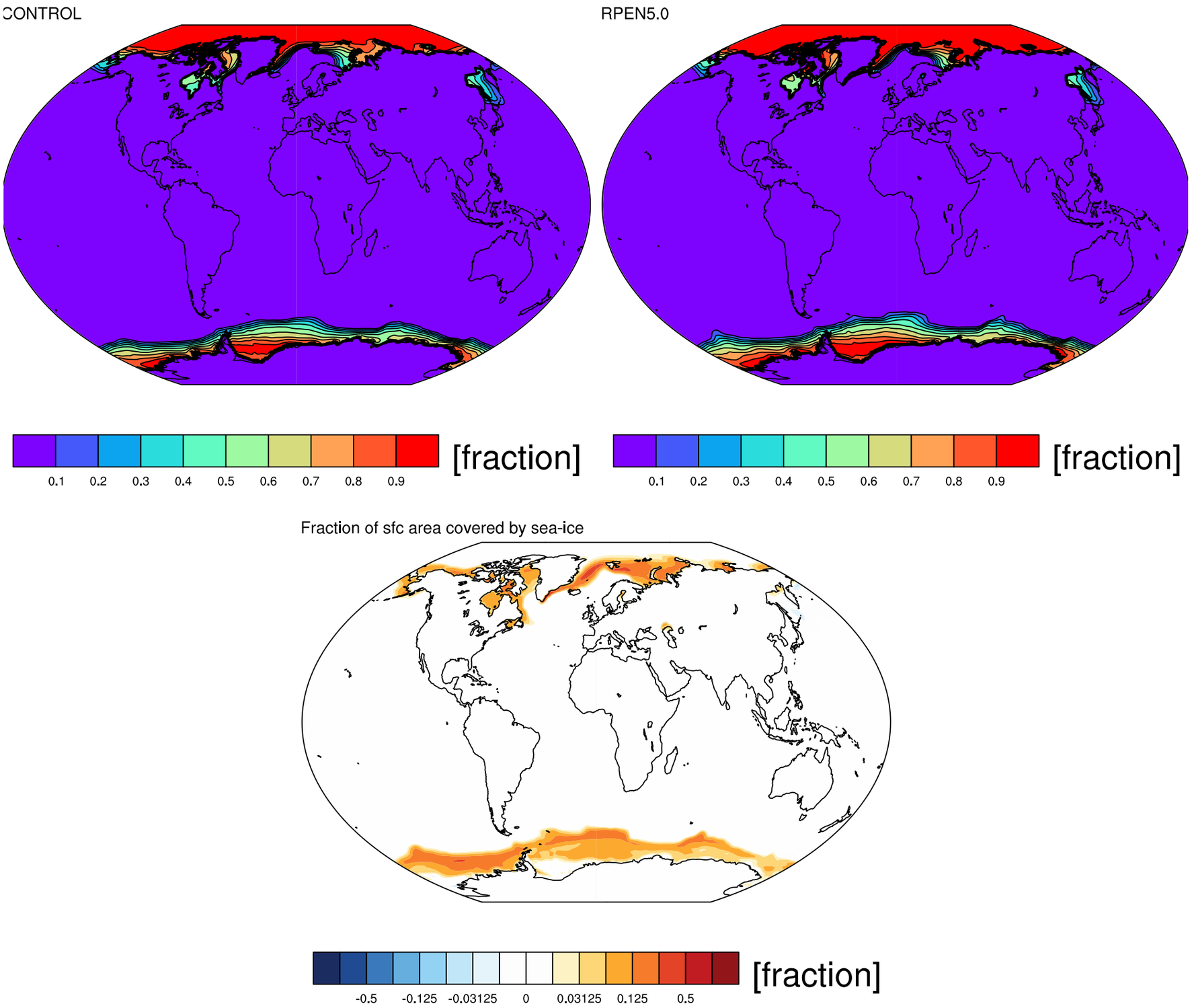
See also

Morrison et al. 2012

Persson 2012

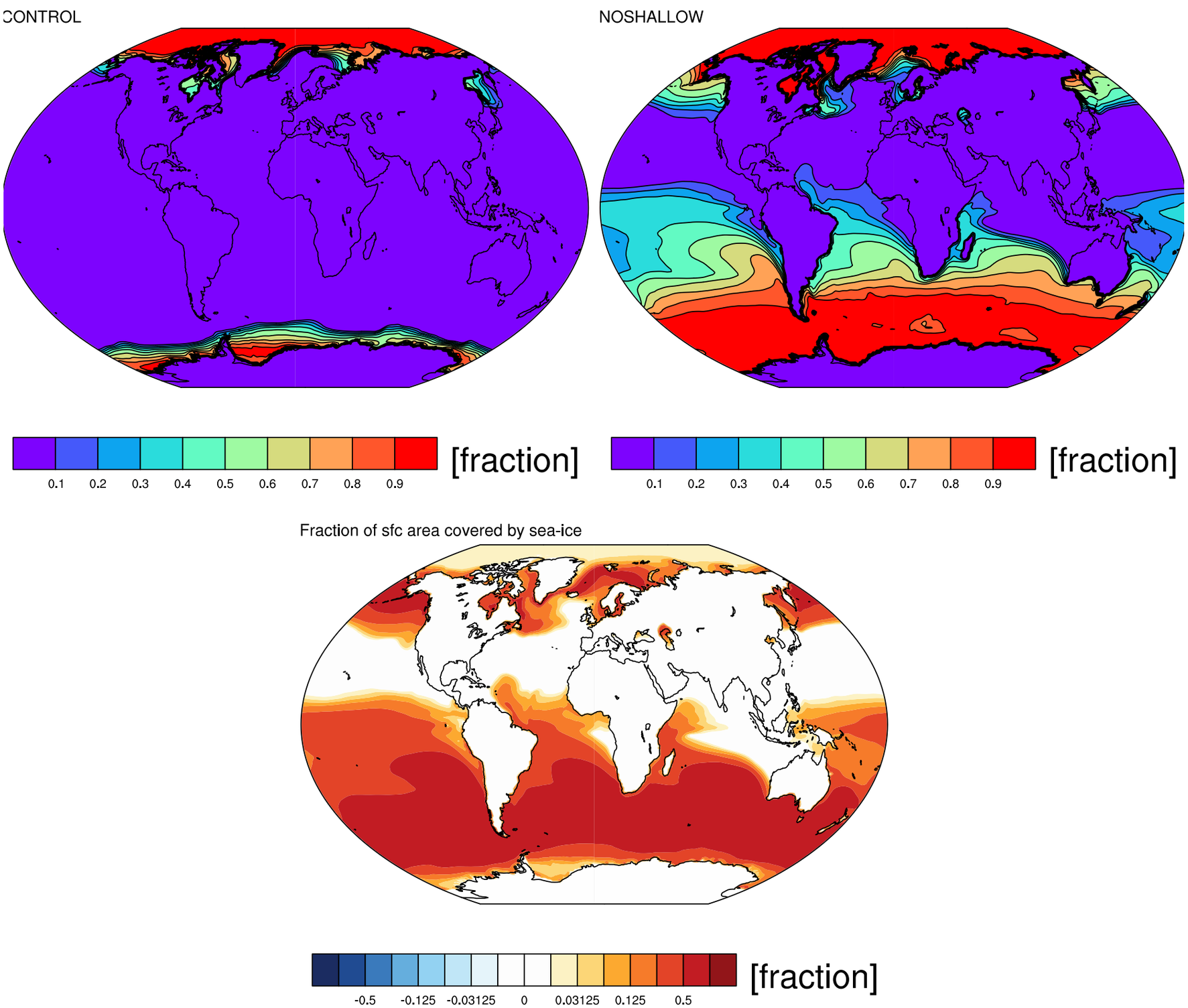
Curry et al. 1996

Our example again



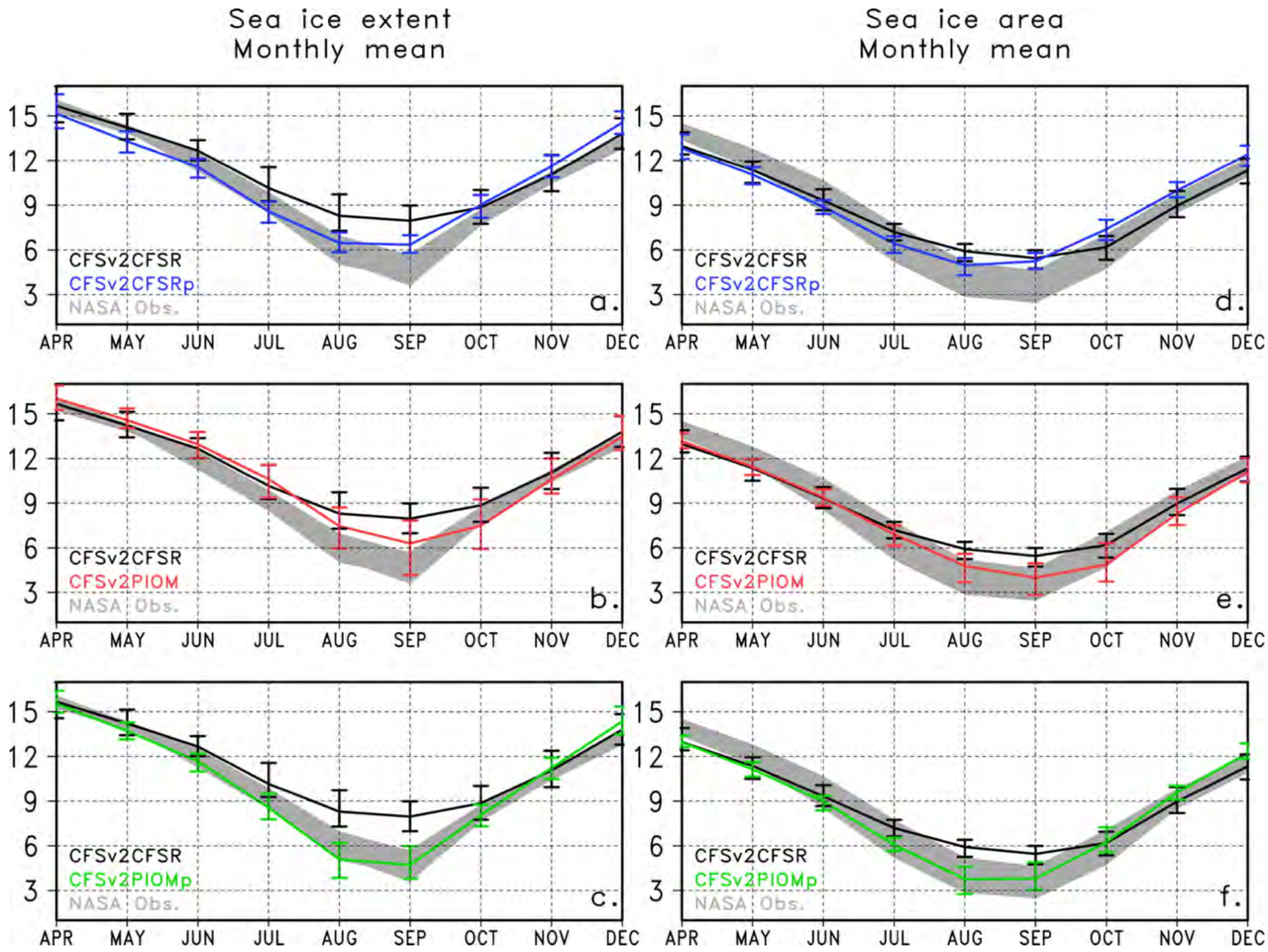
Simulations by Eleanor Middlemas

No shallow convection



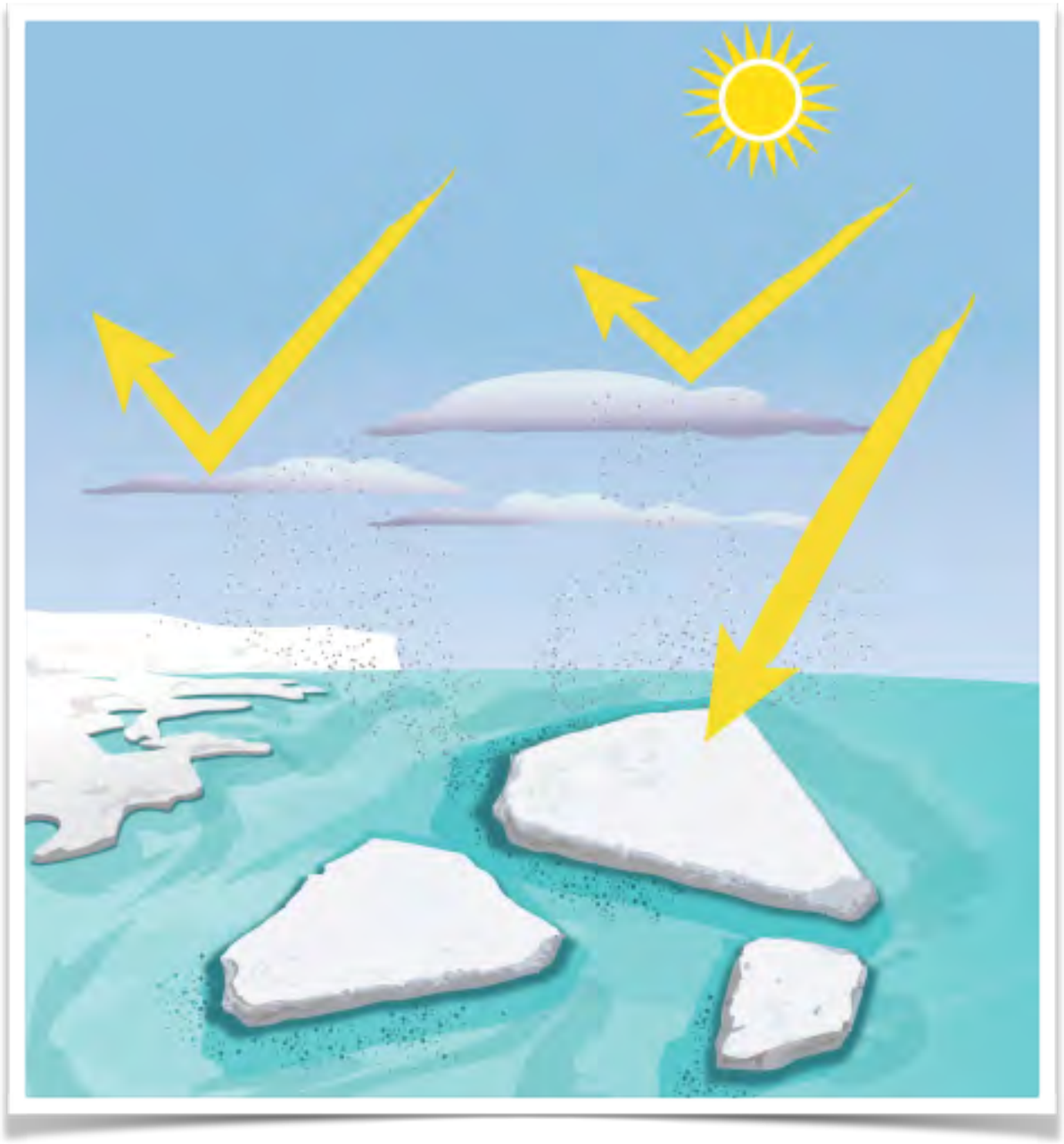
Simulations by Eleanor Middlemas

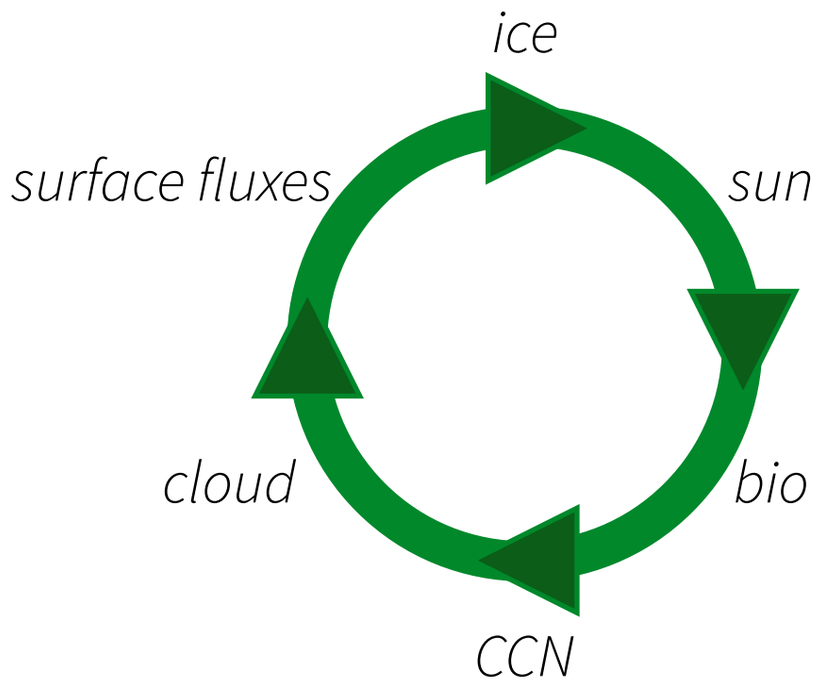
Seasonal Prediction



Collow et al. 2015

Cloud-Ice-Biogeochemical interactions





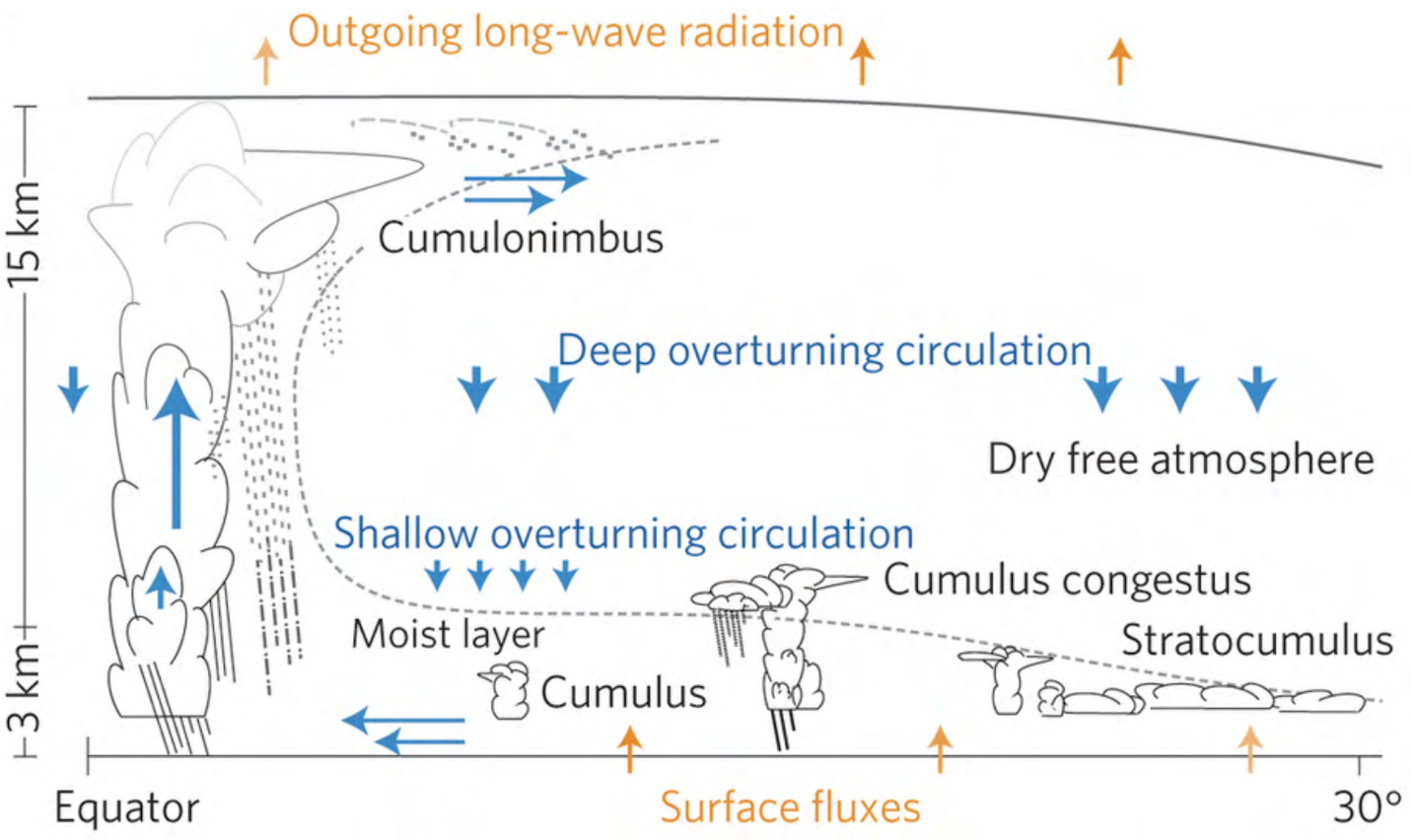
"CLAW" Hypothesis might be important in Arctic.

Also impact on ice sheets & sea level, Van Tricht et al 2016

Orellana et al. 2011

Arrigo et al. 2012

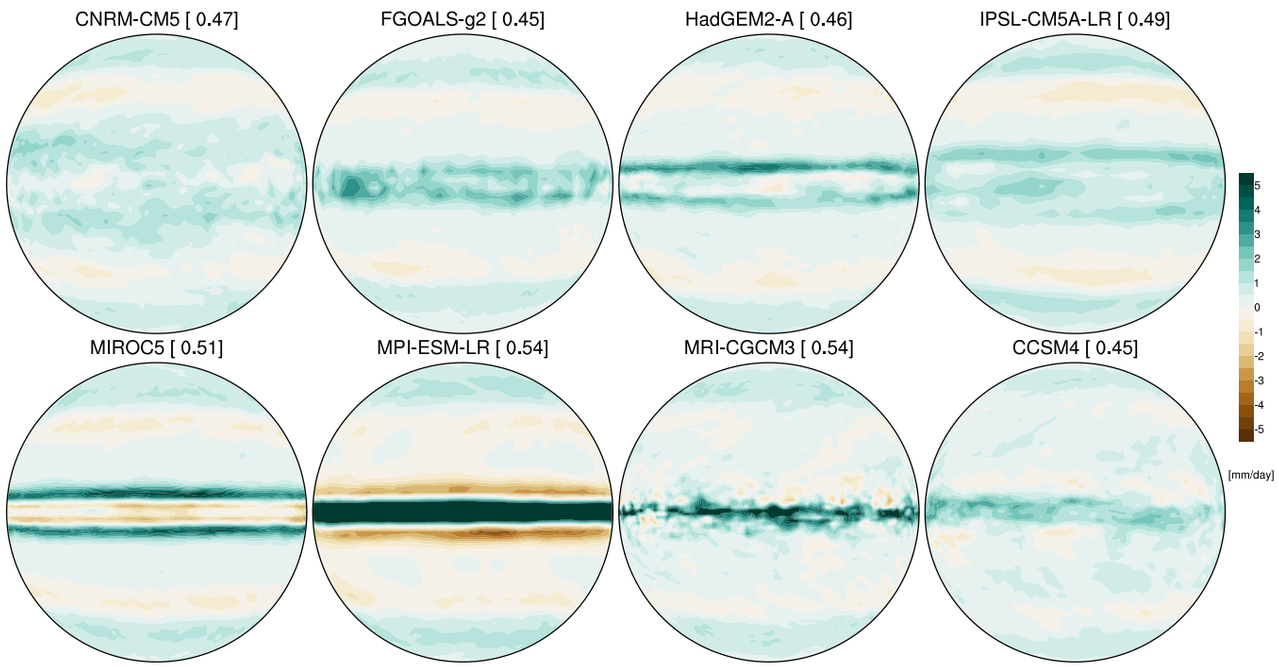
clouds & circulation



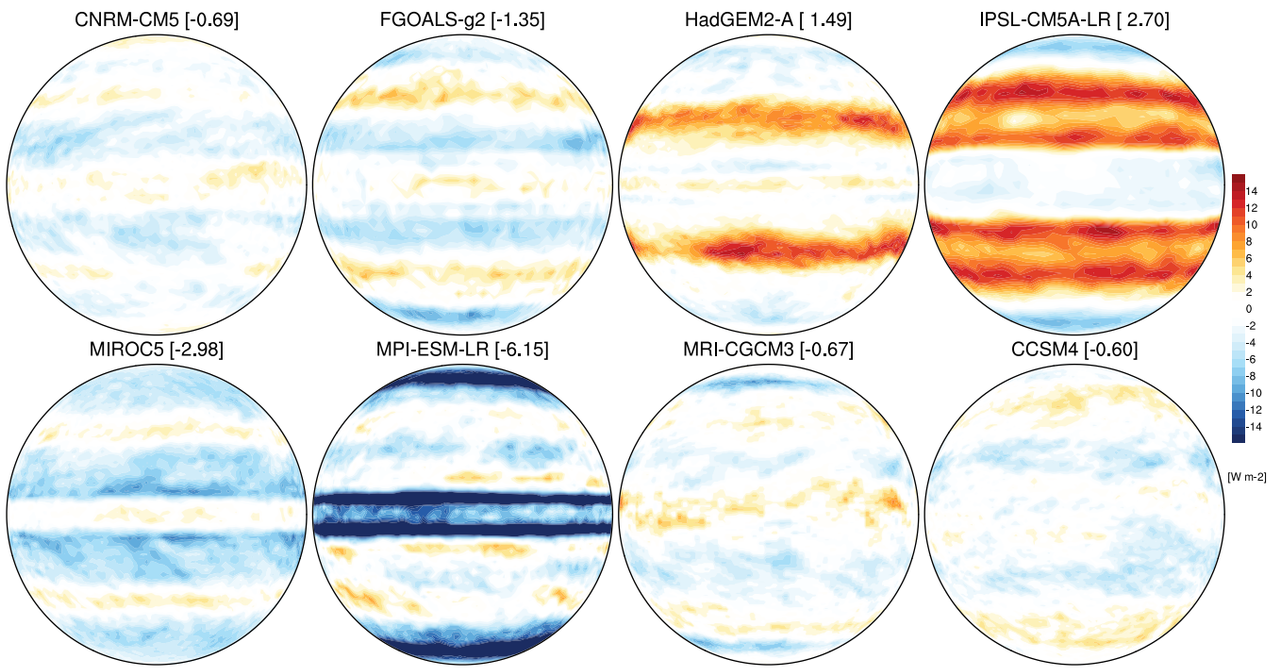
Early GCMs had no cloud-circulation coupling, but cloud effects have become more sophisticated with each model generation. Fundamental understanding of cloud-circulation coupling remains an open research frontier.

Hunt et al. 1980
Wetherald & Manabe 1988
Randall et al. 2003
Bony et al. 2015

long term climate



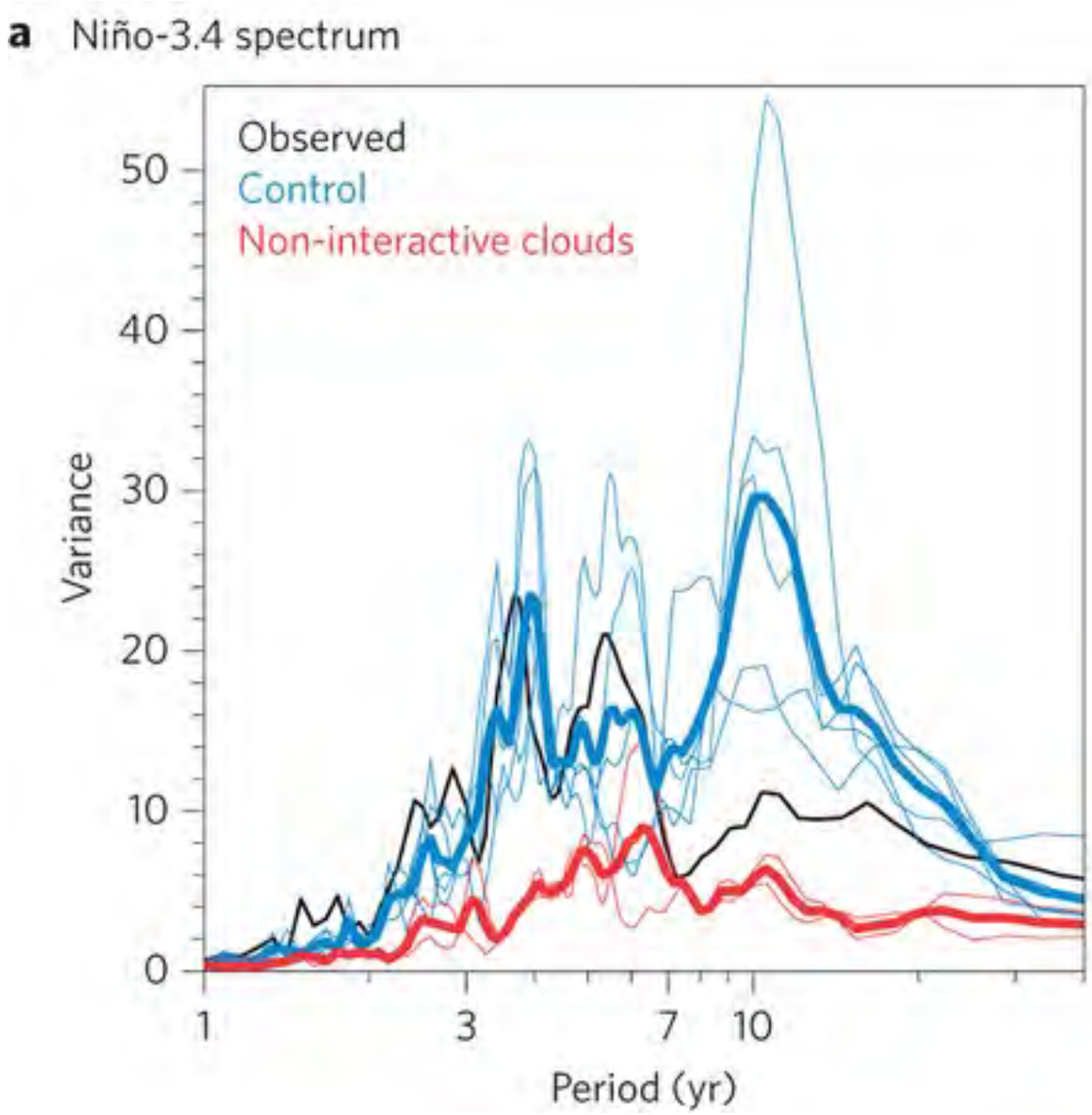
Change in precipitation with surface warming.

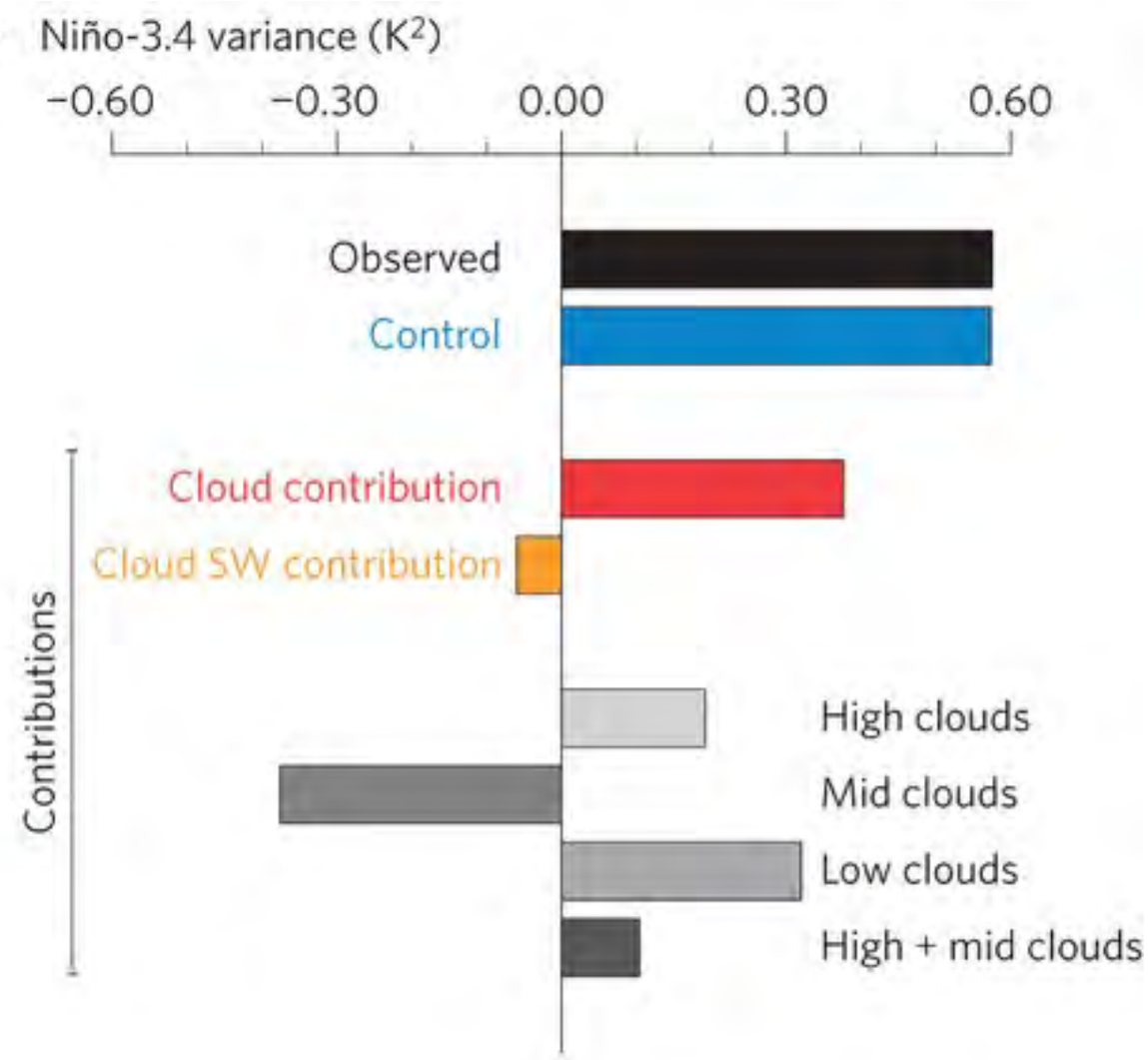


Change in TOA CRE with surface warming.

Medeiros et al. 2015; Stevens & Bony 2015

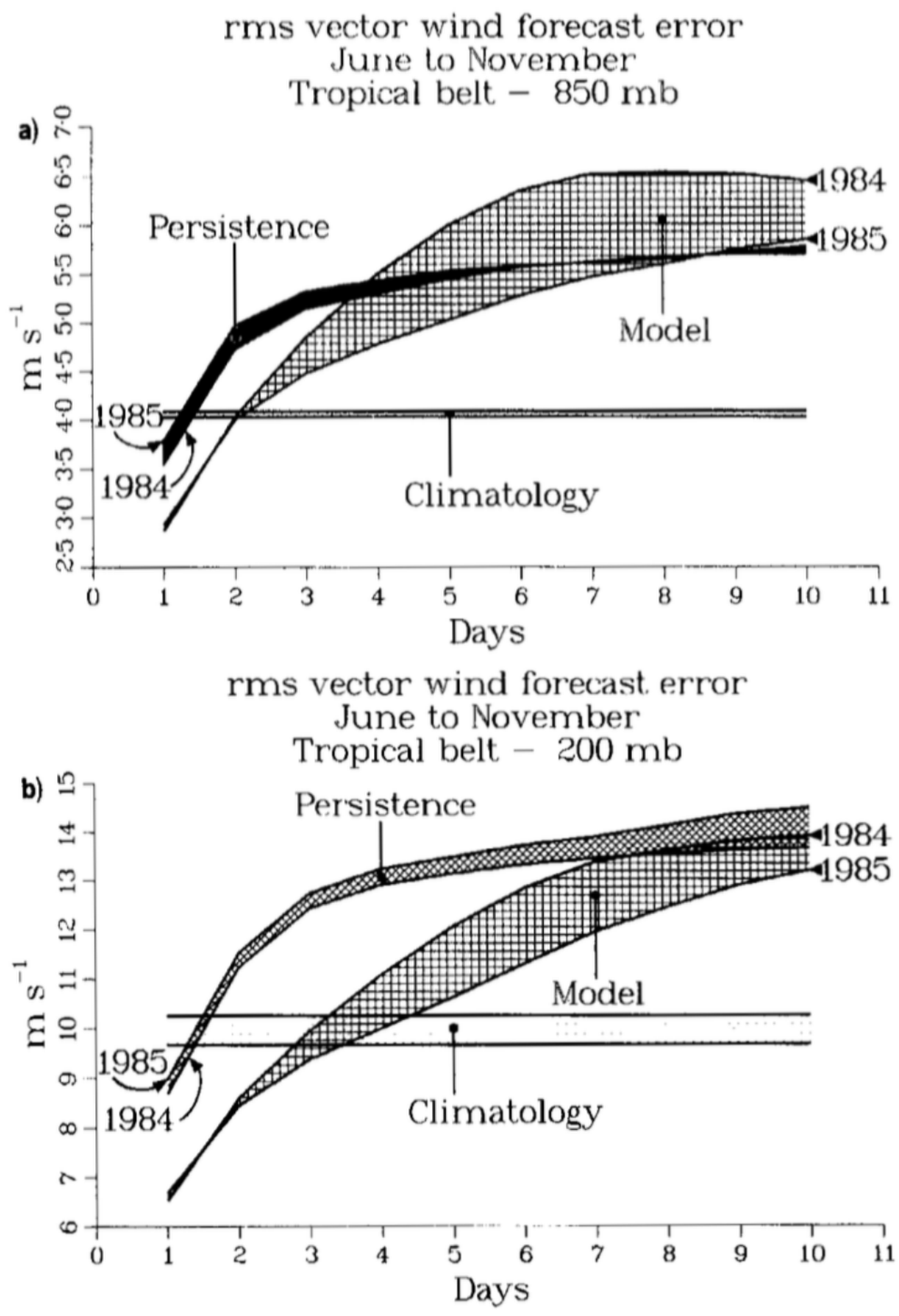
climate variability





Radel et al (2015)

short term prediction



Tiedtke et al. (1988)

summary

Cloud errors matter for coupled modelling

- But it is hard to quantify how much.

Clouds couple to other components through surface energy budget

- And interact with vertical structure and circulation.

Clouds are relevant for prediction across time scales

- Yet they remain crudely parameterized in most classes of models.