# CMIP5: Uncertainties in tropical climate and carbon uptake

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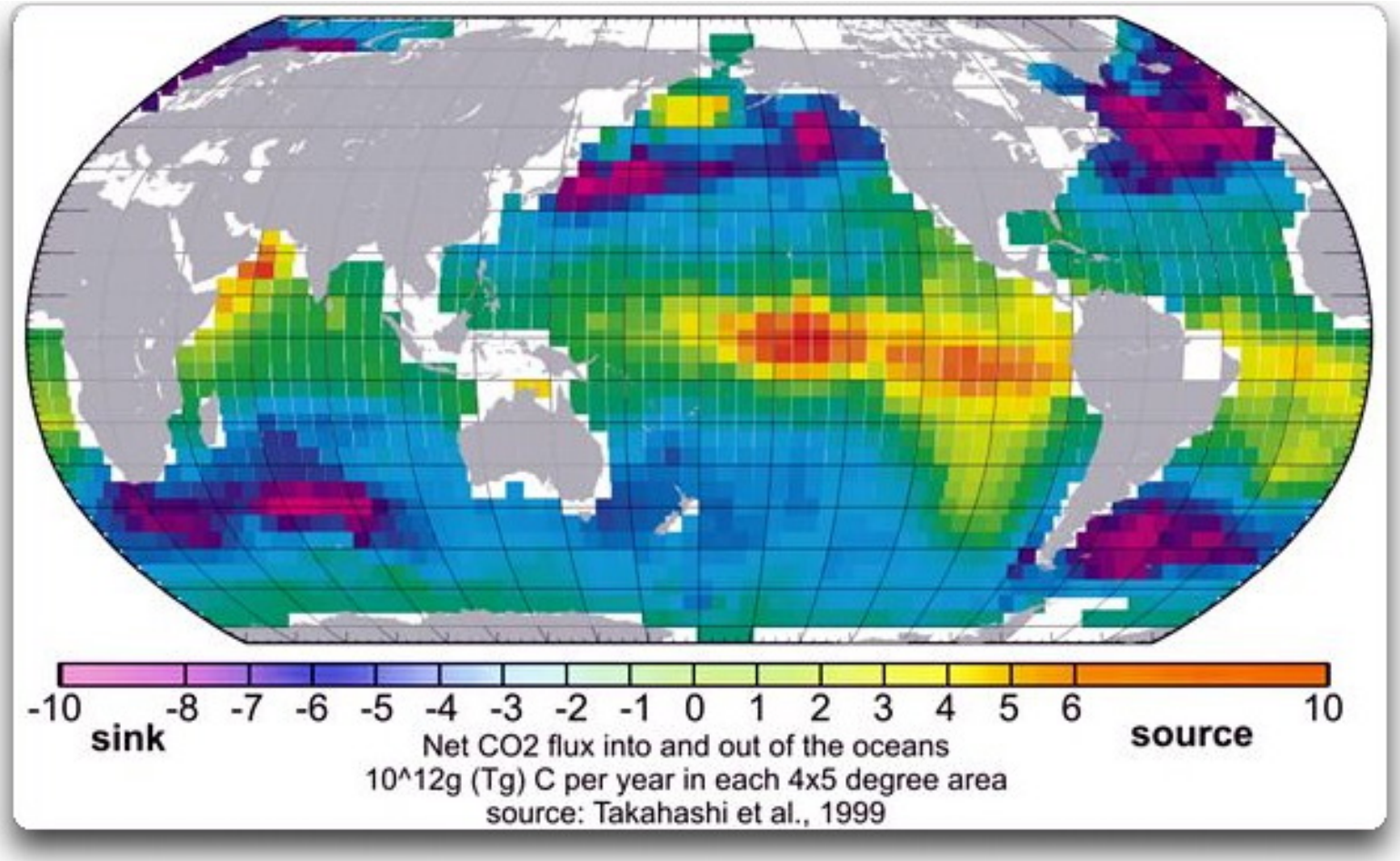
# Outline

- Biases in CMIP5 vs. CMIP3
  - Mean tropical climate
  - ENSO
- Role of resolution
  - Results from CESM1 high-resolution simulation
- Uncertainties in the 21$^{st}$ Century evolution of carbon uptake
  - CMIP5 models

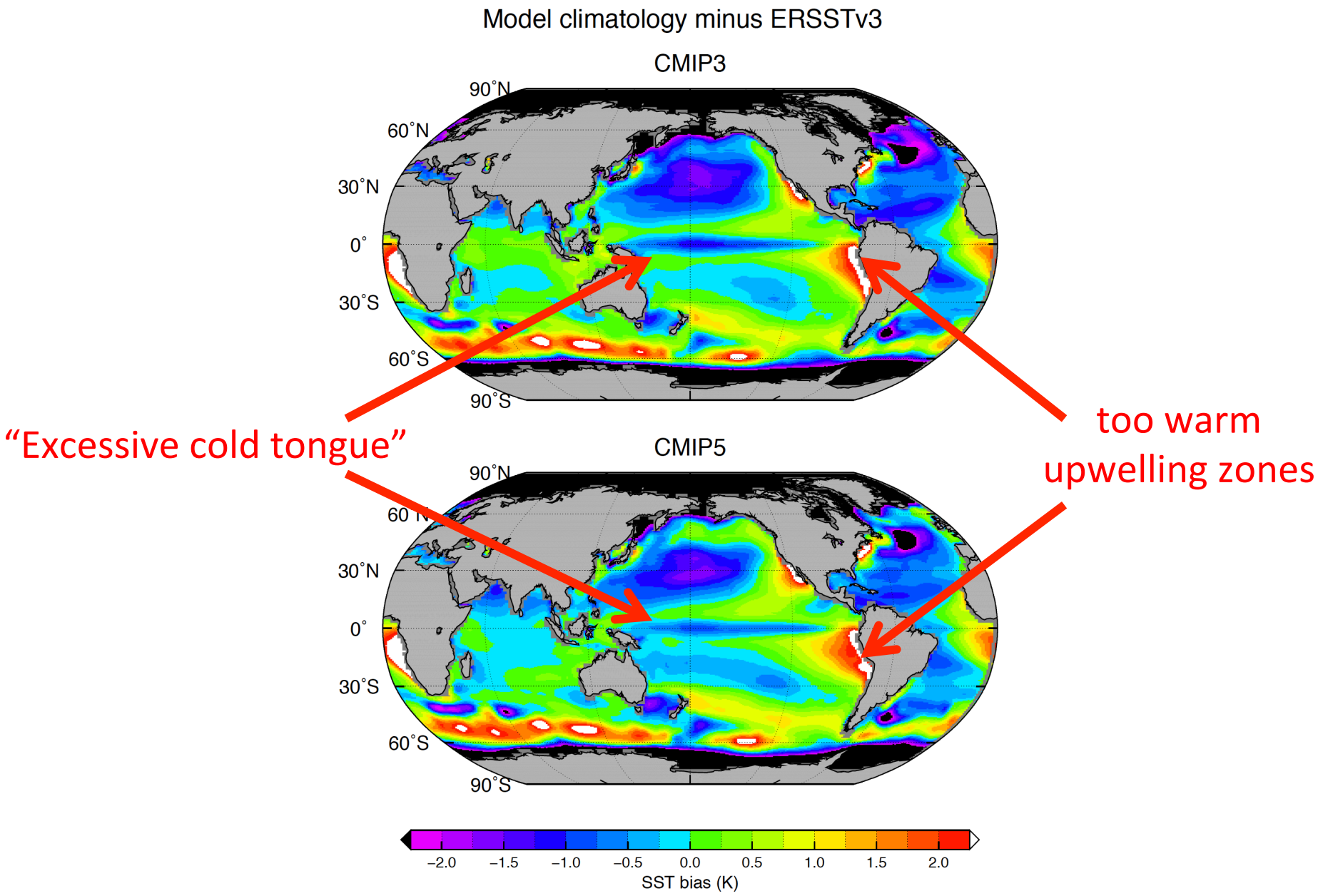
# Importance of the tropical Pacific for carbon cycle



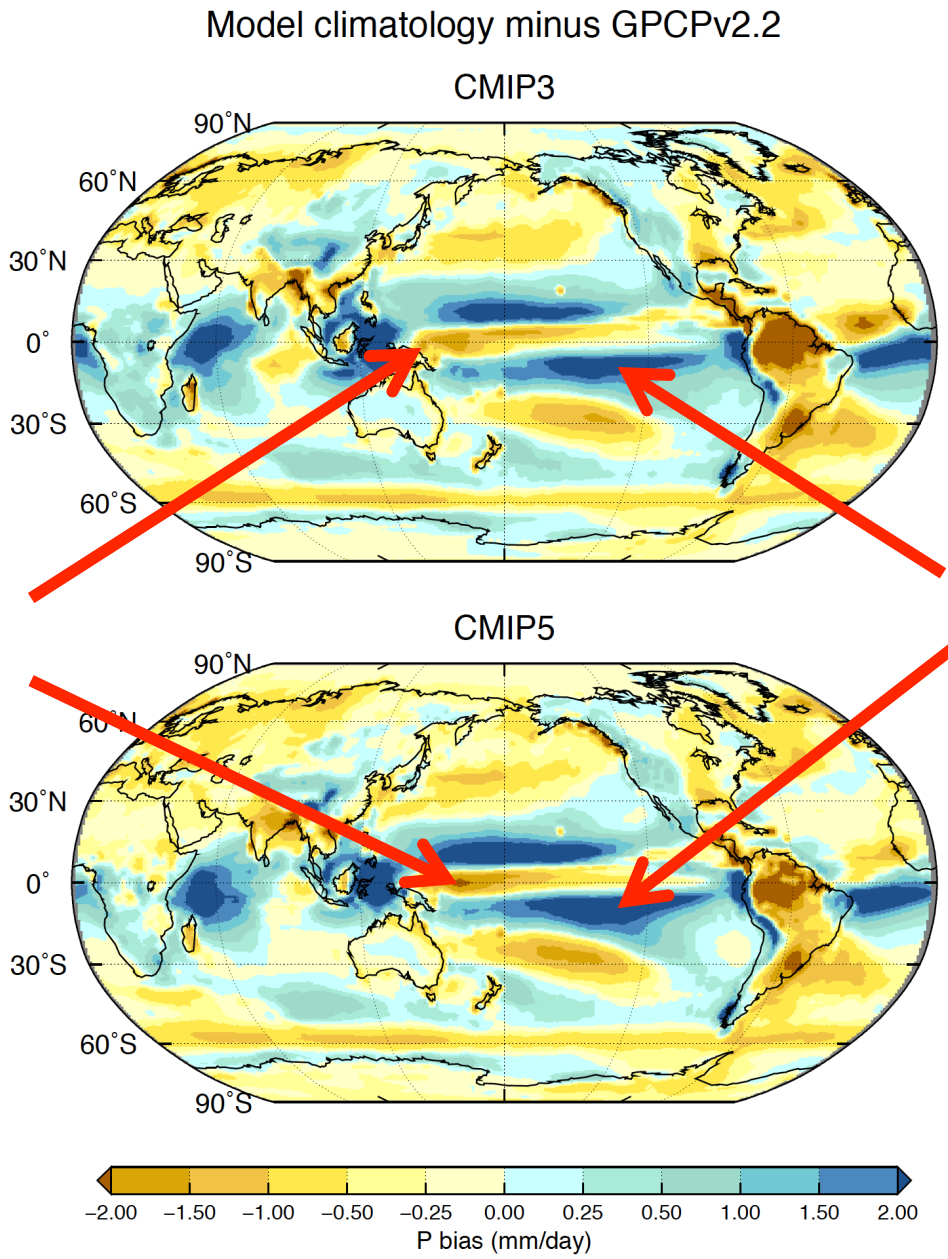

The tropical pacific is a massive source of CO2

obvious to everybody in this room ;)

# SST biases have not improved in CMIP5



# Rainfall biases have not improved in CMIP5

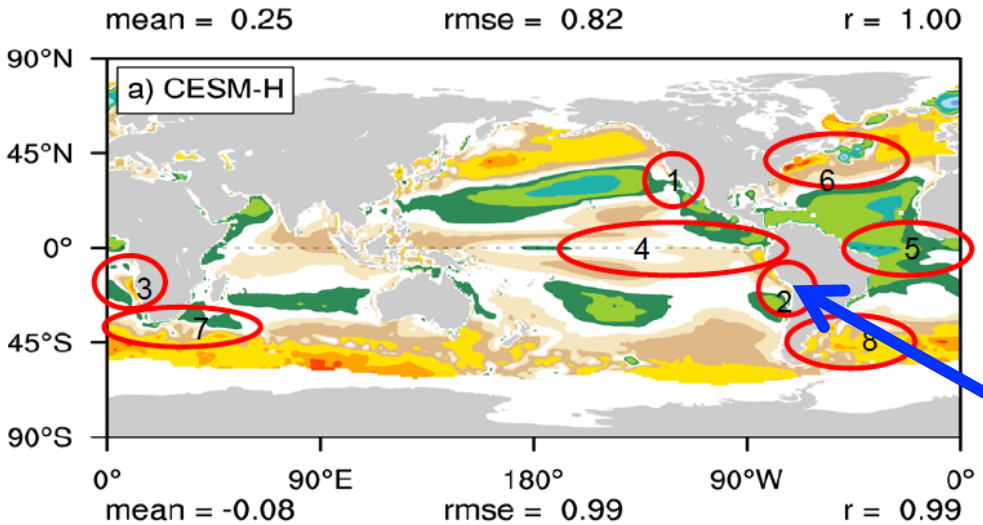



dry western equatorial Pacific

Double ITCZ bias

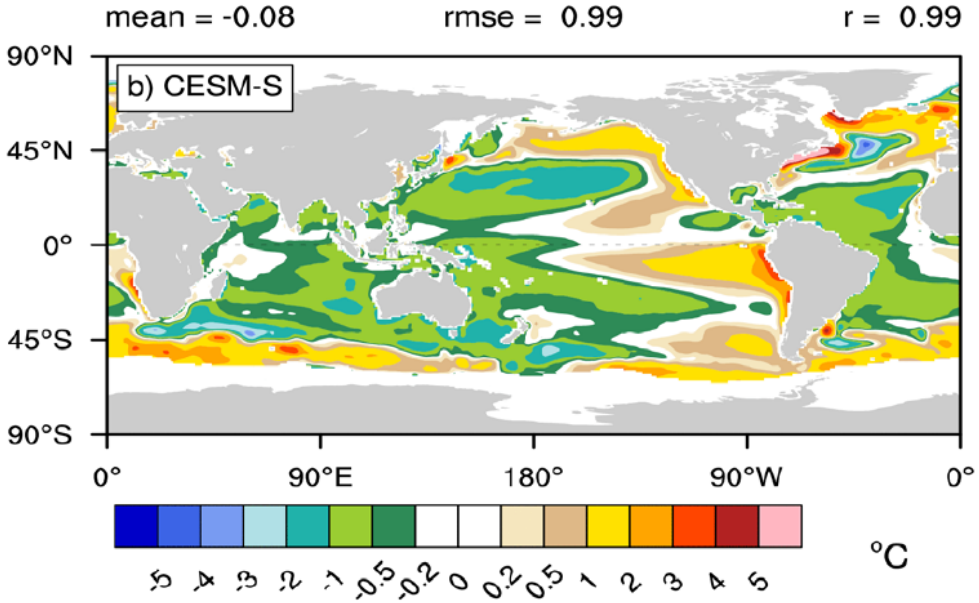
# Some of these biases maybe resolution dependent

**high resolution CESM1**




alleviated biases in the Pacific upwelling zones

**standard resolution CESM1**



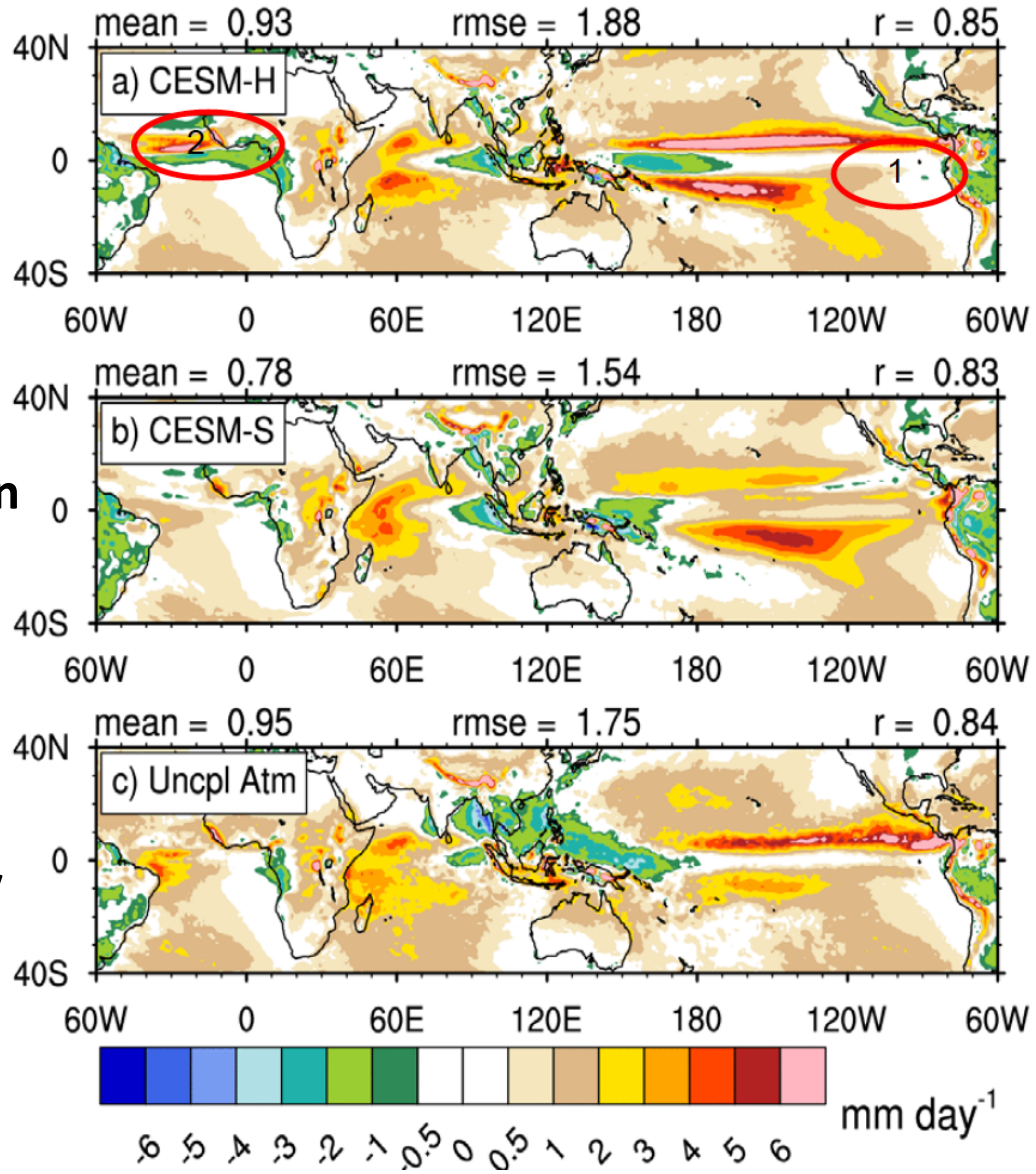

Small et al. 2014

# High ocean resolution improves double ITCZ problem

**high resolution CESM1**

**standard resolution CESM1**

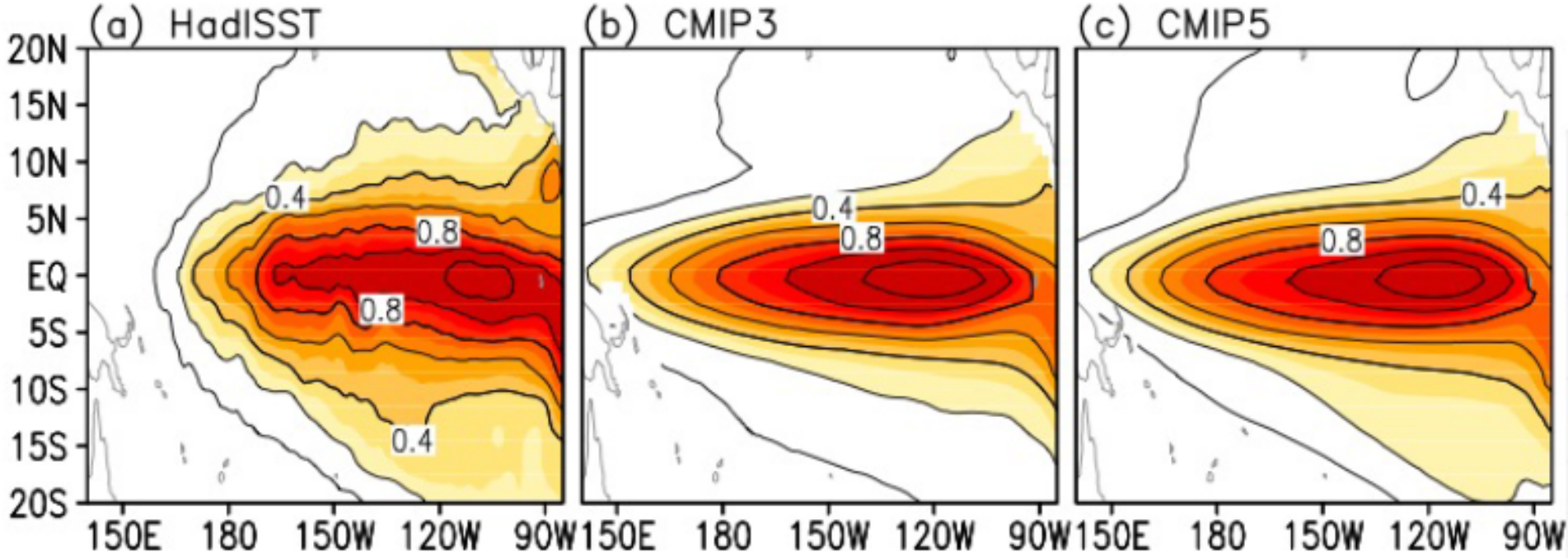
**High resolution atmosphere-only**




Small et al. 2014

# ENSO simulation has not improved either

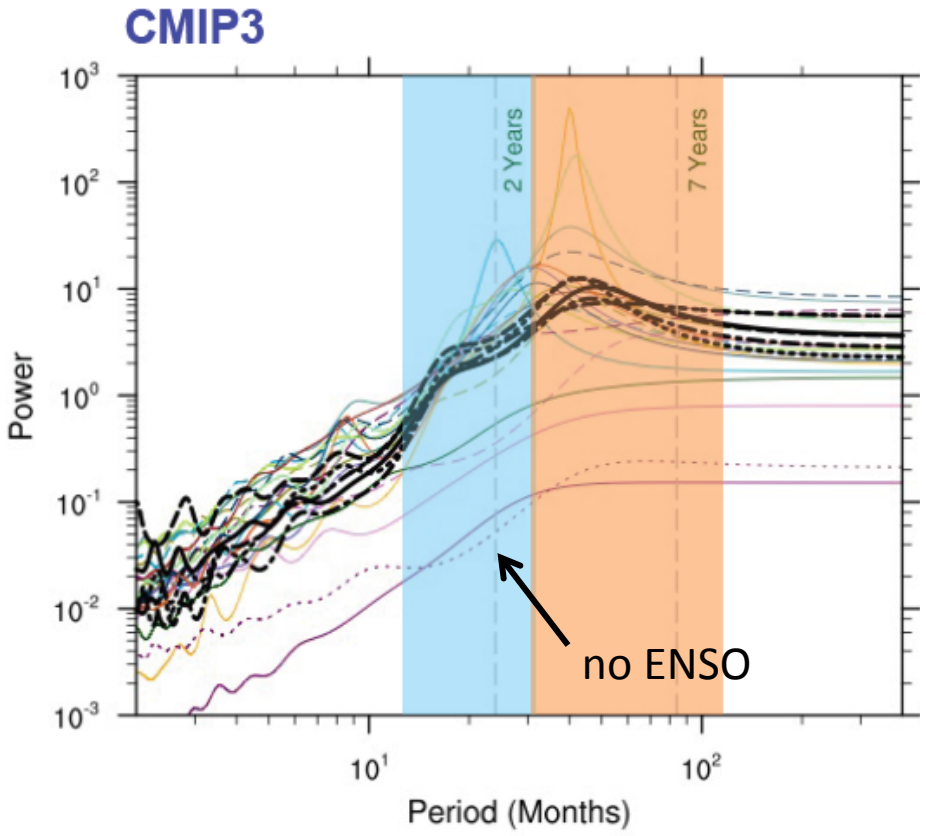
Spatial pattern of SST anomalies

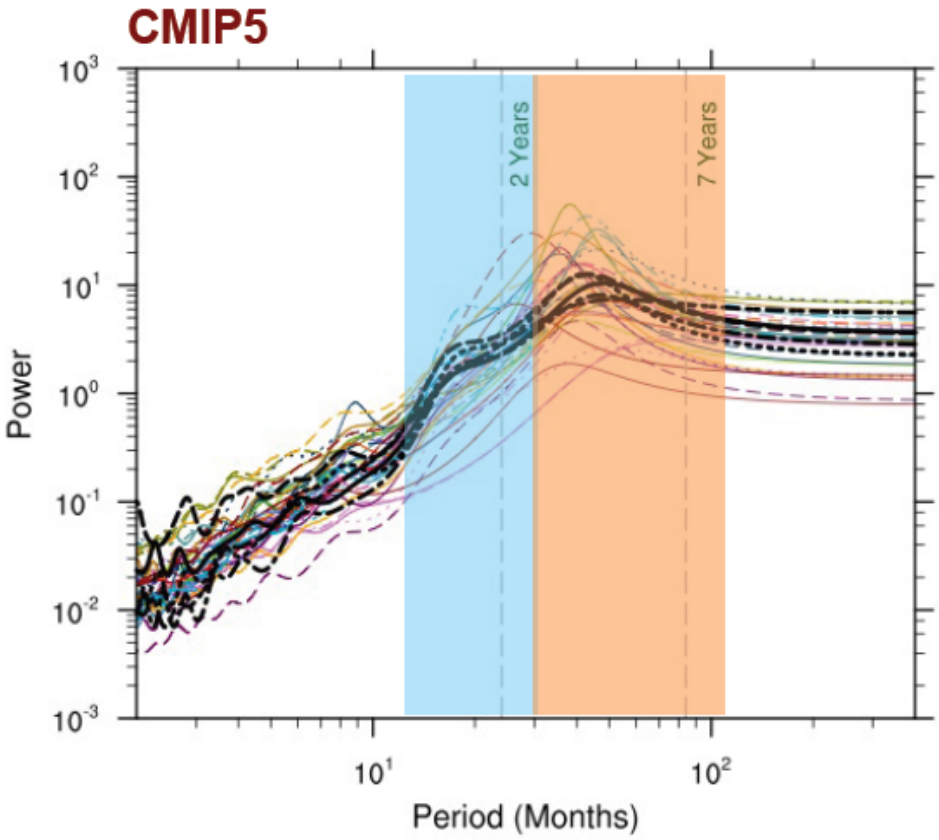



Excessive westward extension of SST anomalies still present in CMIP5

Zhang et al. 2013

# Improved Nino-3.4 spectrum



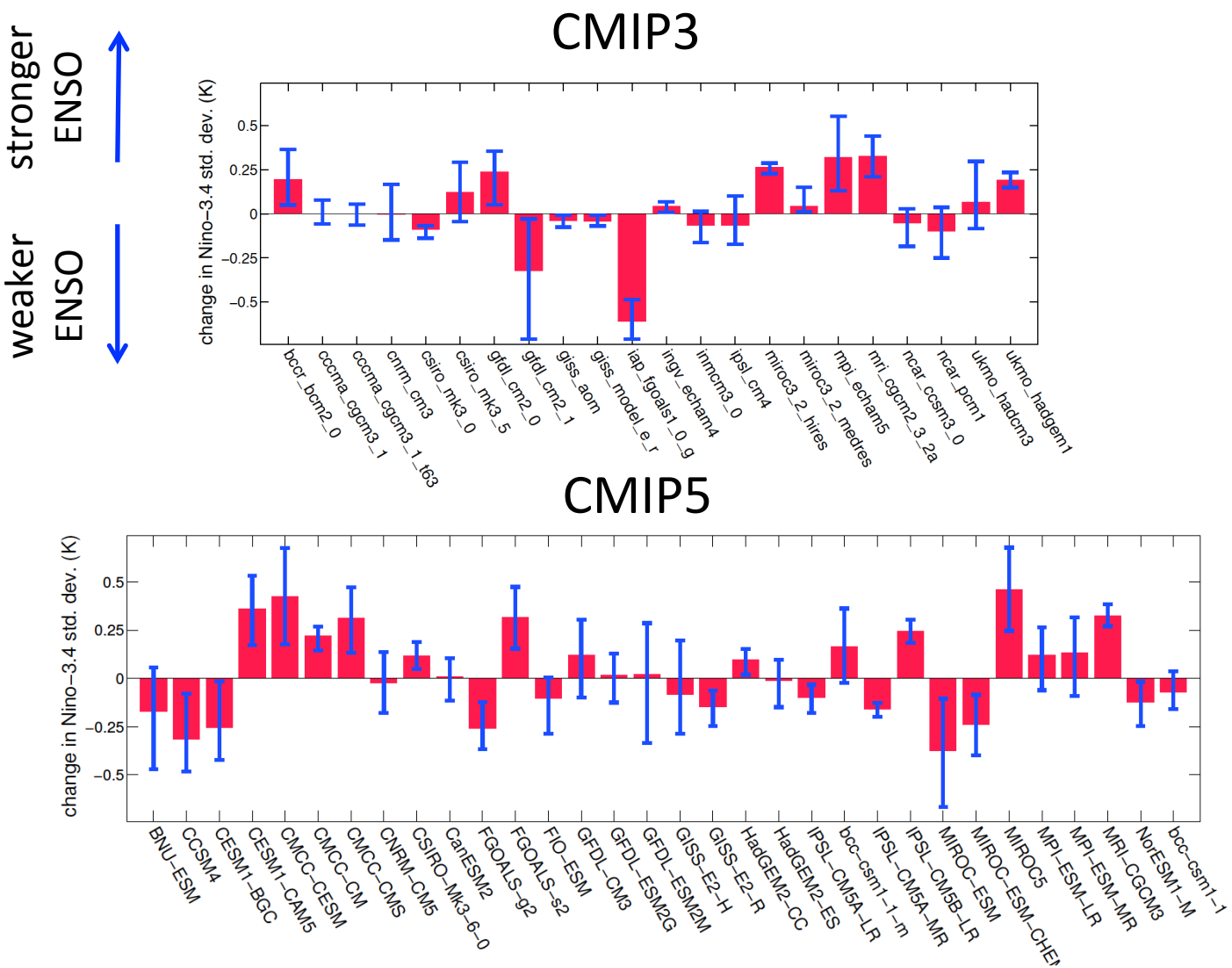




- Unrealistic sharp spectral peaks
- Some modes without ENSO

- Improved (broader) spectra in CMIP5
- No more models with no ENSO

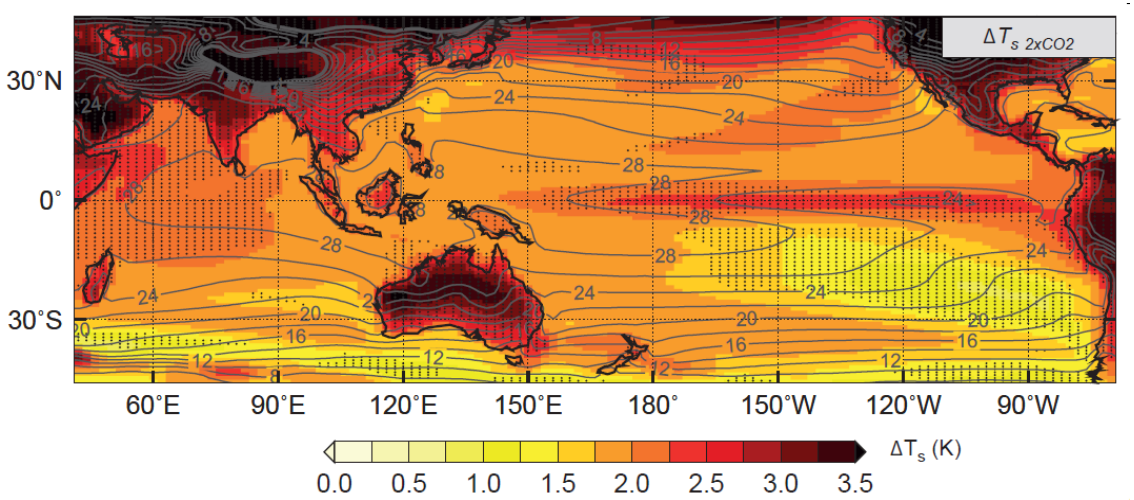
Bellenger et al. 2013

# Models still do not agree whether ENSO will become stronger or weaker

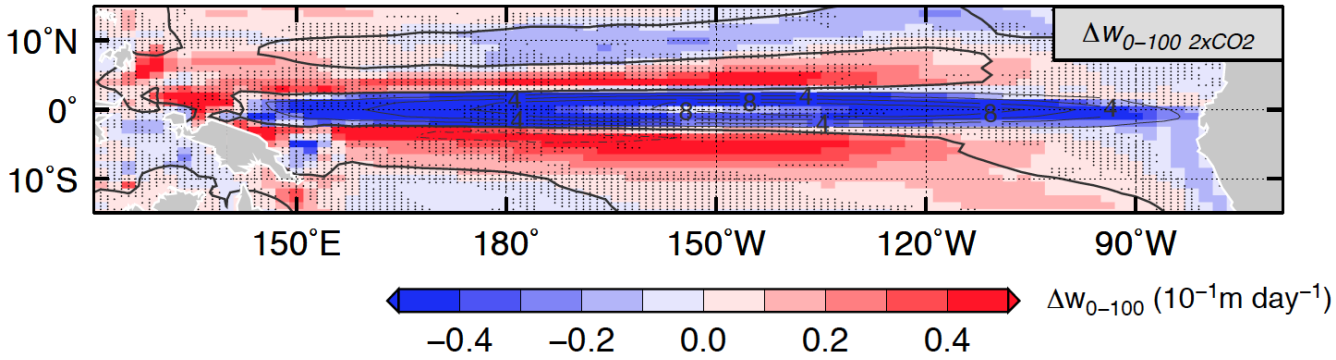


# But models agree about the mean climate response of the equatorial Pacific

Enhanced equatorial warming

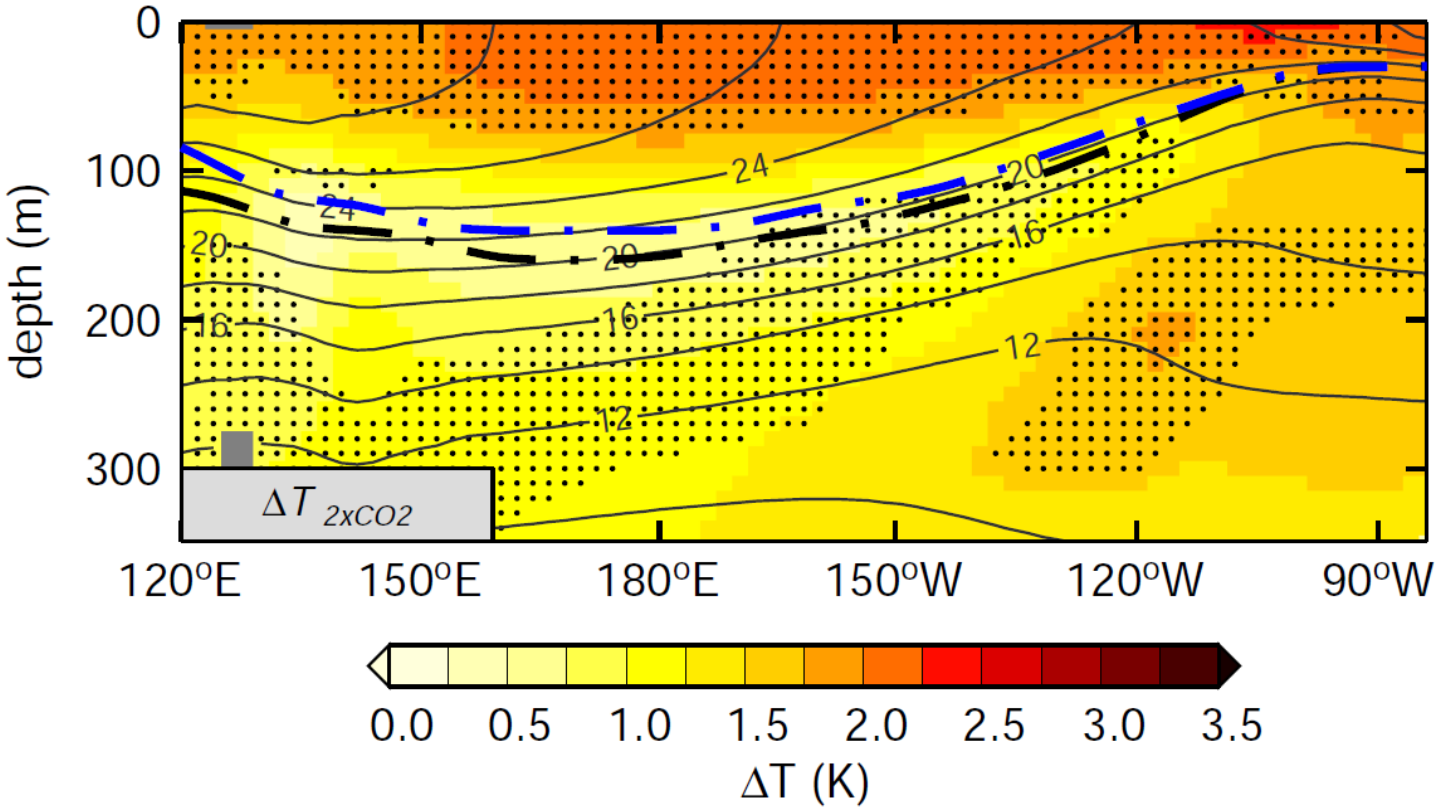



weaker upwelling




Vecchi and Soden 2007; DiNezio et al. 2009

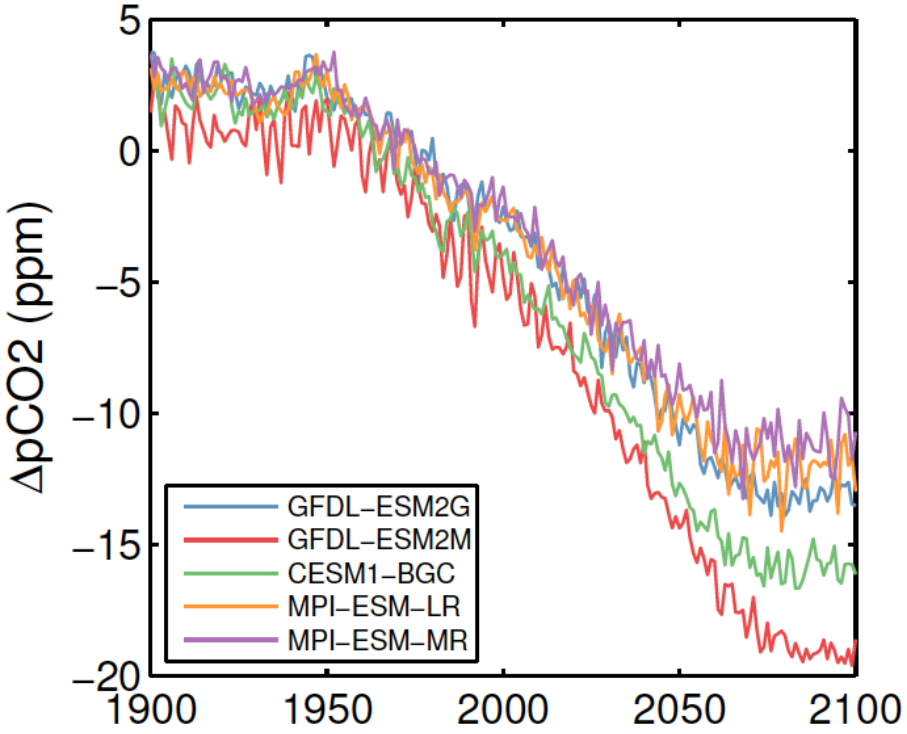
# And a sharper equatorial thermocline

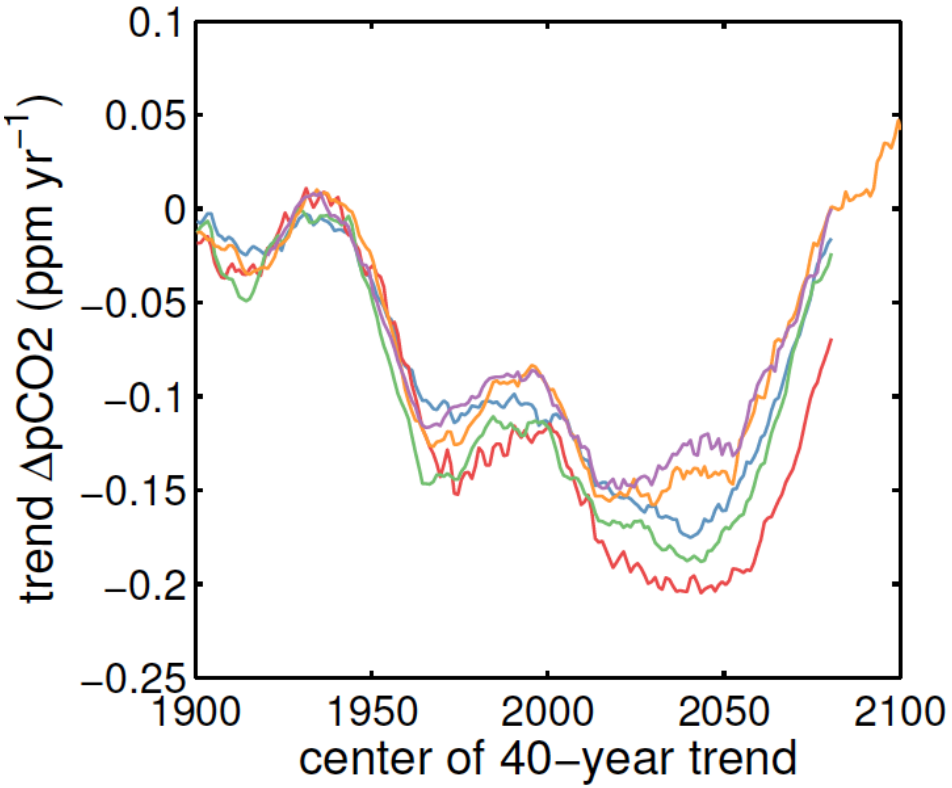



Dash-dotted black (blue) line is the thermocline in the control (2xCO2) climate.

DiNezio *et al.* 2009

# Do any of these processes play a role in the evolution of CO2 uptake during the 21st Century?

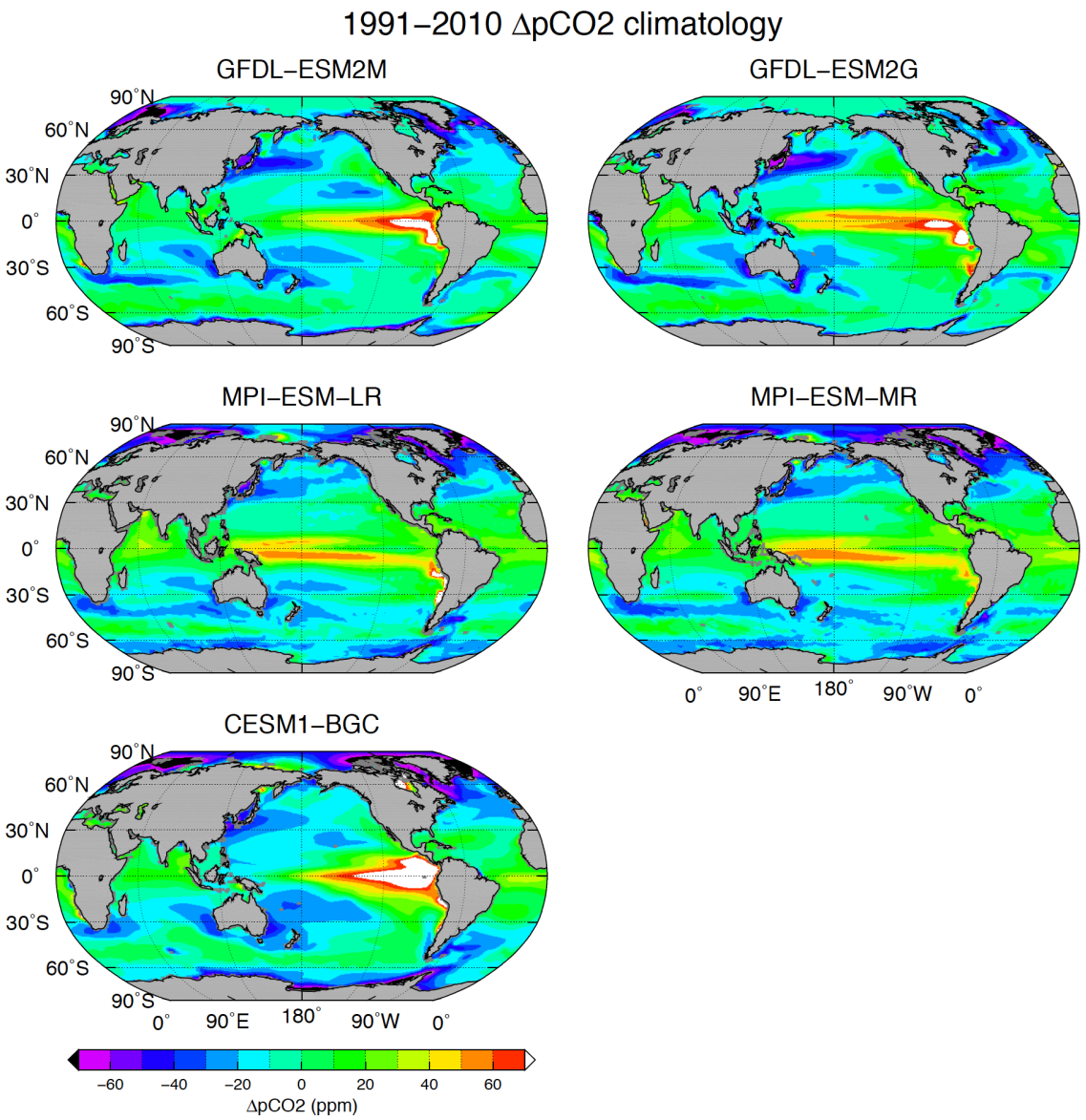


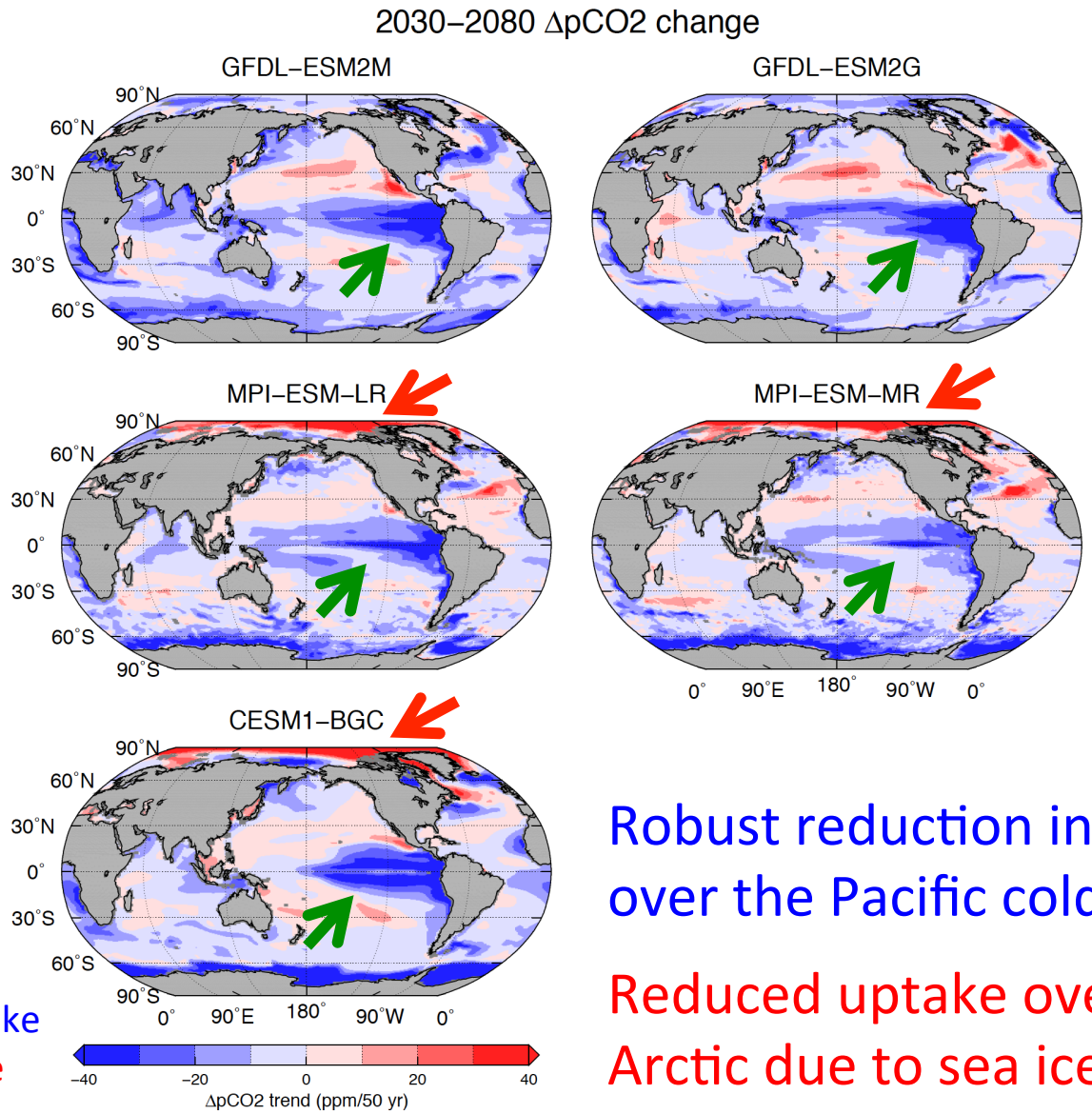

Large spread among the models after year 2000

All models simulate accelerations and decelerations in carbon uptake, hummm….

# Some models show pronounced biases in ΔpCO2 over the tropical Pacific



# But all of them project reduced outgassing over the tropical Pacific



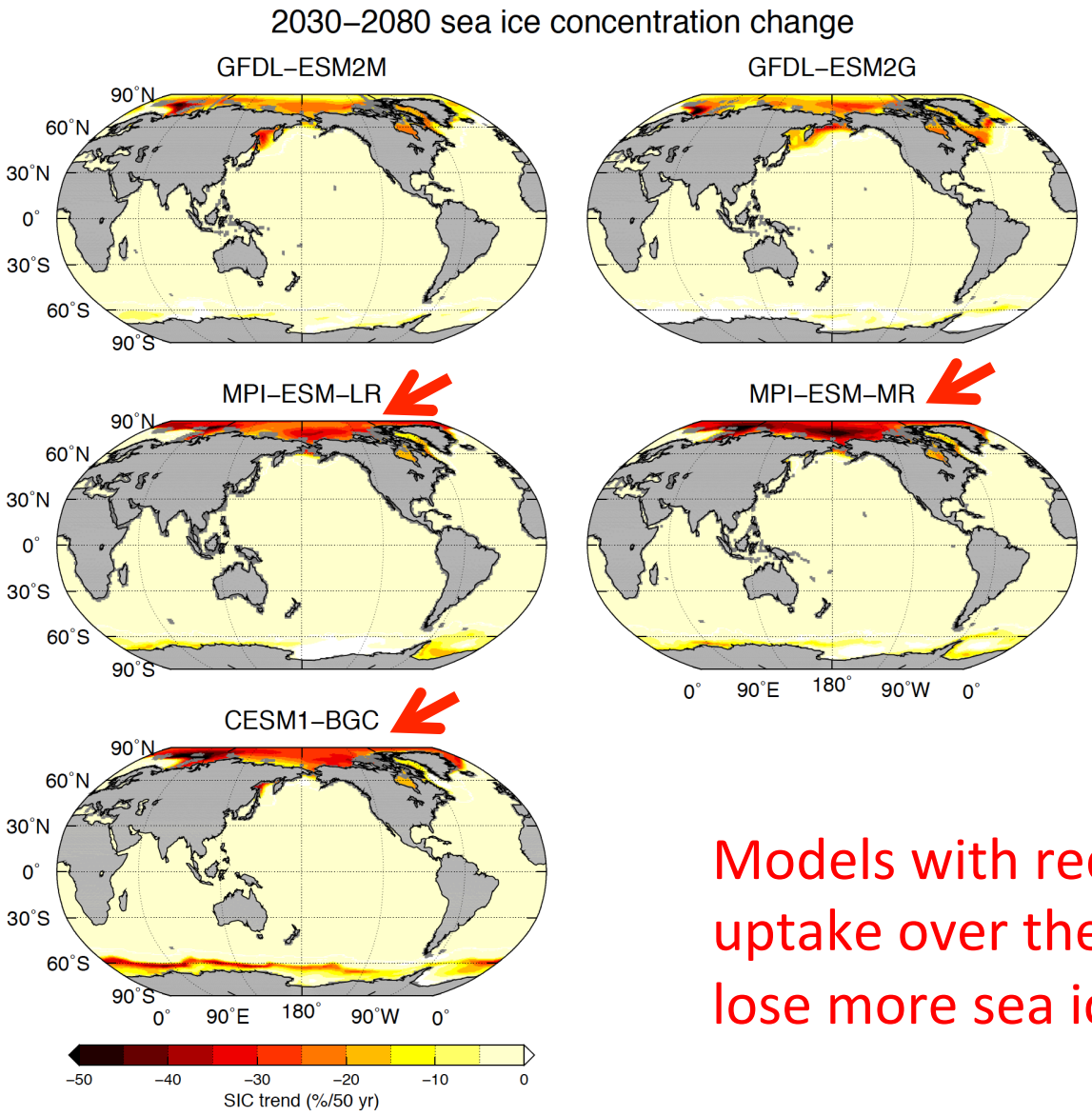

Blue: enhanced uptake

Red: reduced uptake

Robust reduction in outgassing over the Pacific cold tongue

Reduced uptake over the Arctic due to sea ice loss?

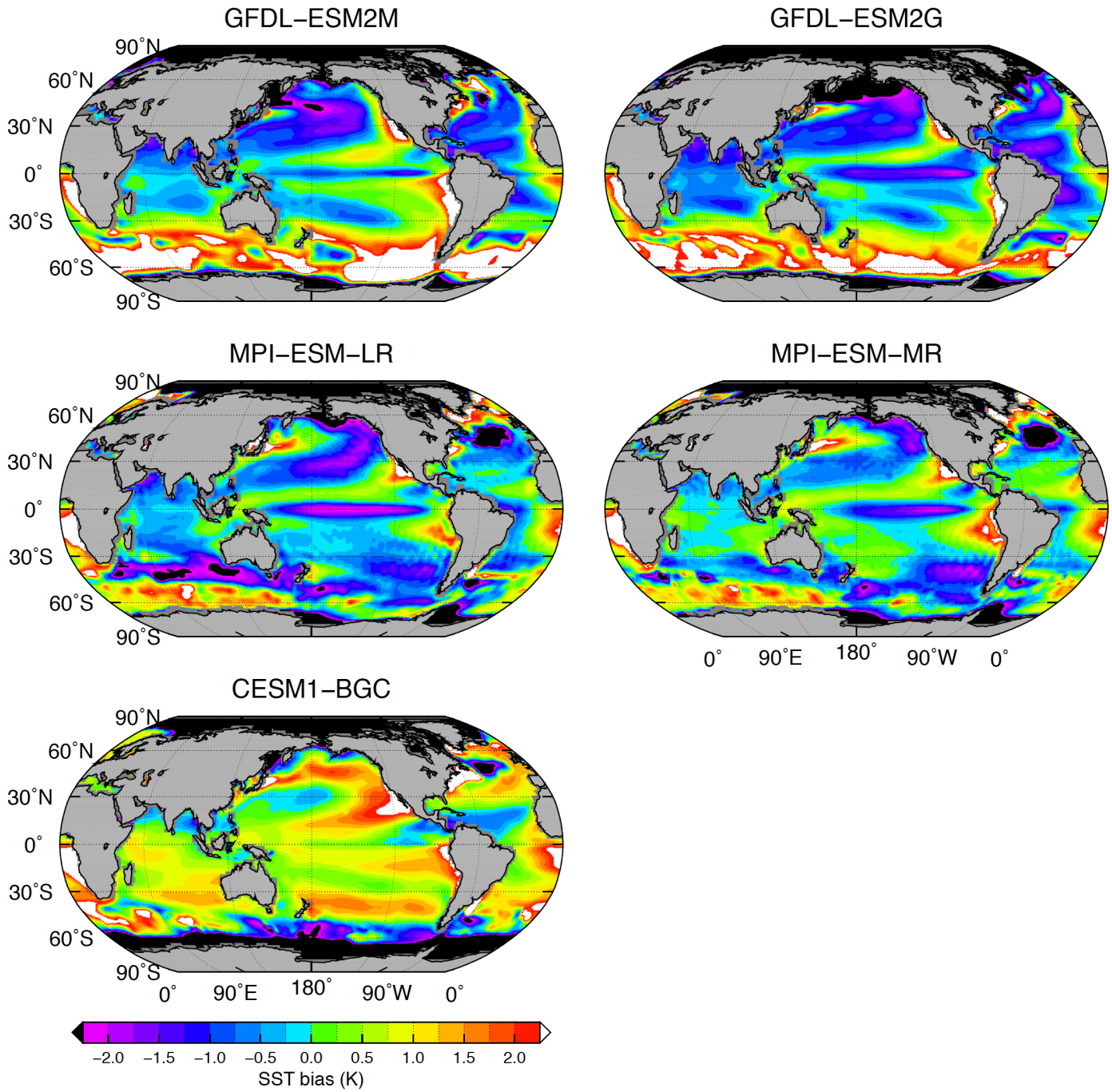
# Arctic sea ice loss could be a source of model spread:

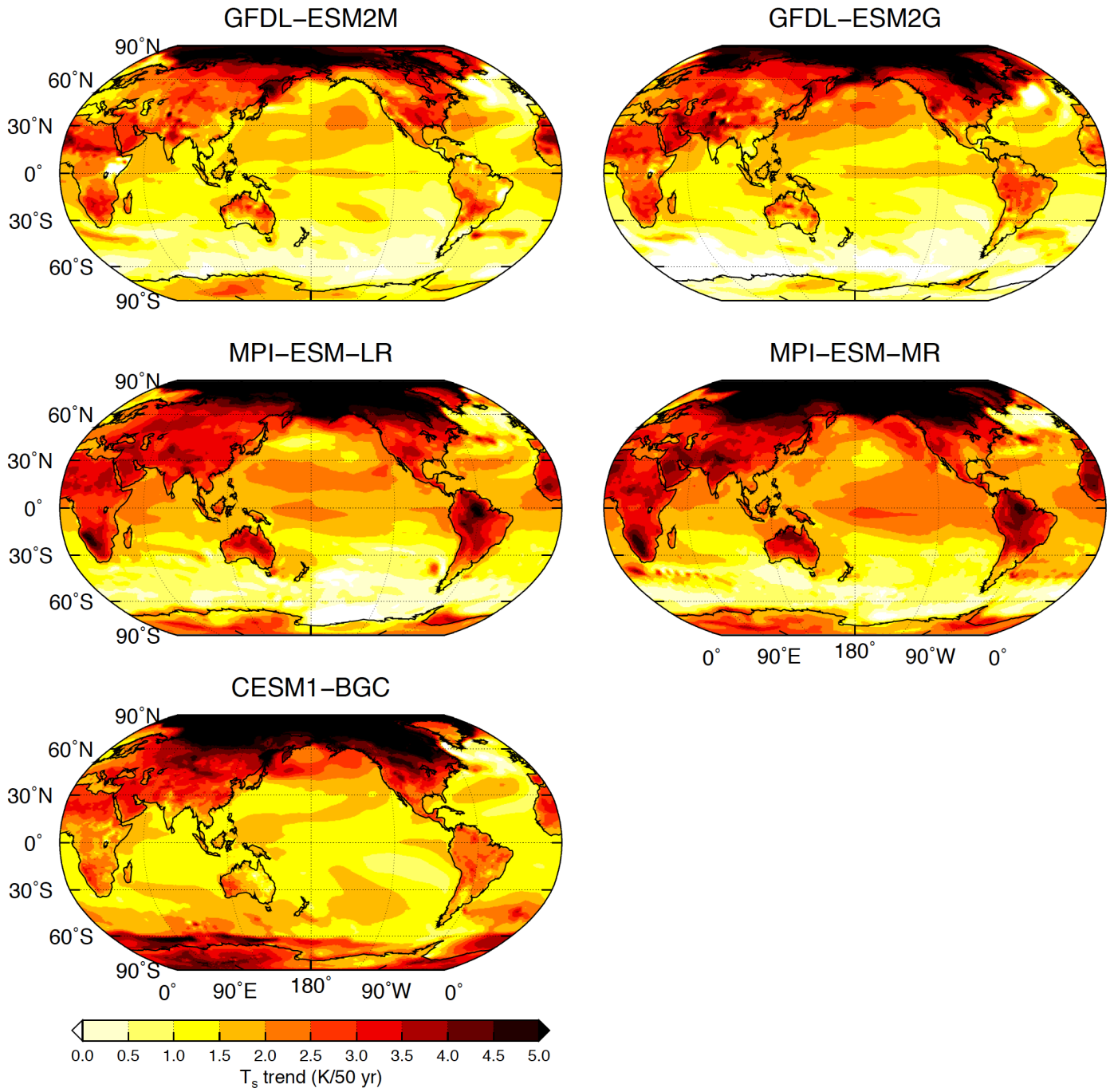



Models with reduced CO2 uptake over the Arctic also lose more sea ice

# Conclusions

- Not much improvement in the simulation of tropical climate from CMIP3 to CMIP5
- Ocean resolution may play a role improving warm biases in upwelling zones
- Uncertainties in the 21$^{st}$ Century evolution of carbon uptake:
  - Interplay of aerosols and GHGs?
  - Robust reduction in outgassing over the Pacific cold tongue
  - Arctic sea ice loss could be a source of model spread


SST bias
GFDL–ESM2M
GFDL–ESM2G
MPI–ESM–LR
MPI–ESM–MR
CESM1–BGC
90°N
60°N
30°N
0°
30°S
60°S
90°S
0°
90°E
180°
90°W
0°
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
SST bias (K)


2030–2080 surface temperature change
GFDL–ESM2M
GFDL–ESM2G
MPI–ESM–LR
MPI–ESM–MR
CESM1–BGC
90°N
60°N
30°N
0°
30°S
60°S
90°S
0°
90°E
180°
90°W
0°
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
T_s trend (K/50 yr)