Status and Developments with CAM-CLUBB (aka CAM5.5)

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Rich Neale, Vincent Larson, Patrick Callahan, Cheryl Craig,
and contributions from many many others….

AMWG, Mini-Breck, February 8, 2016

Outline

- Coupled Simulations with CAM5.5 (in CESM1.0)
  - Efforts to improve some of the negative aspects
- Future developments and opportunities
  - High-res version of CAM5.5
  - Opportunities for high-res version of CAM-CLUBB-DEEP

Physical Parameterizations of the CAM5 Family

Physics	CAM5.3	CAM5.4	CAM5.5
Deep Convection	Zhang and McFarlane (1995)	Zhang and McFarlane (1995)	Zhang and McFarlane (1995)
Shallow Convection	Park and Bretherton (2009)	Park and Bretherton (2009)	CLUBB
PBL	Bretherton and Park (2009)	Bretherton and Park (2009)	CLUBB
Macrophysics	Park	Park	CLUBB
Microphysics	Morrison and Gettelman (MG1; 2008)	Gettelman and Morrison (MG2; 2015)	Gettelman and Morrison (MG2; 2015)
Aerosols	MAM3	MAM4	MAM4
Radiation	RRTMG	RRTMG	RRTMG

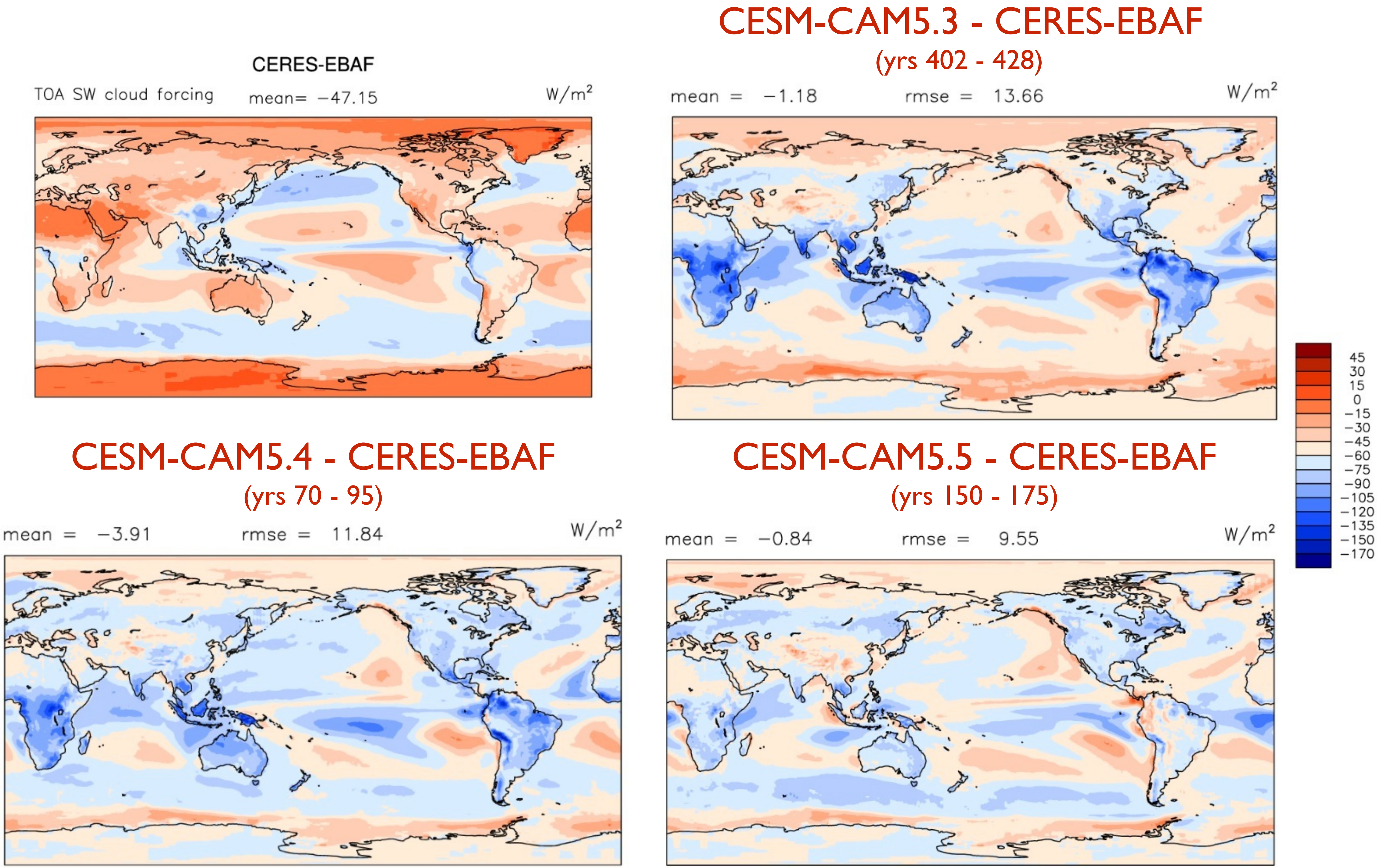
- CLUBB = Cloud Layers Unified by Bi-normals (Golaz et al. 2002)
- CLUBB is a third-order turbulence closure centered around a tri-variate double gaussian PDF to close turbulence and clouds
- CLUBB provides a "unified" parameterization of the PBL, shallow convection, and cloud macrophysics (i.e. cloud fraction, cloud liquid water)

Coupled Simulations

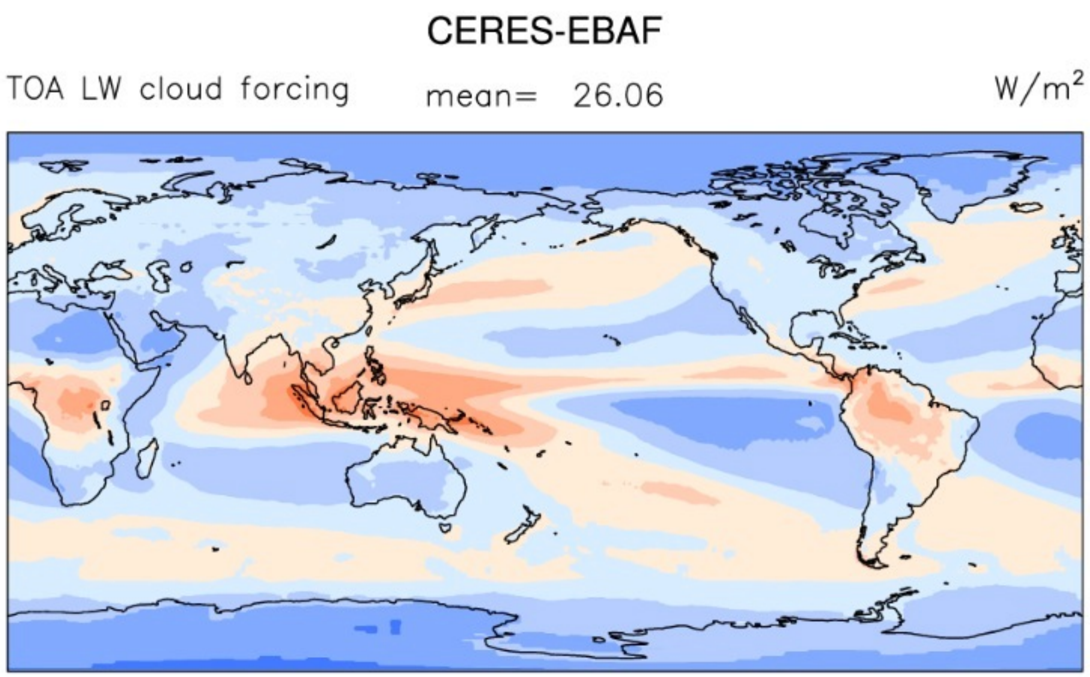
Model	Pre-industrial control (B1850)	20th Century	Reference (or performed by)
CESM-CAM5.3 (aka, LE)	✓ 2200 years	✓ 38 members	Kay et al. (2015)
CESM-CAM5.4	✓ ~120 years	Not performed	Hannay
CESM-CAM5.5	✓ 200 years	✓ 1 lonely realization	Bogenschutz

- Coupled simulations performed throughout the CAM development process
- Performed in CESM1.0
- Simulations shown in next few slides use FV-dycore and the same atmosphere & ocean resolution (f09_g16), for pre-industrial control runs

Shortwave Cloud Forcing Biases

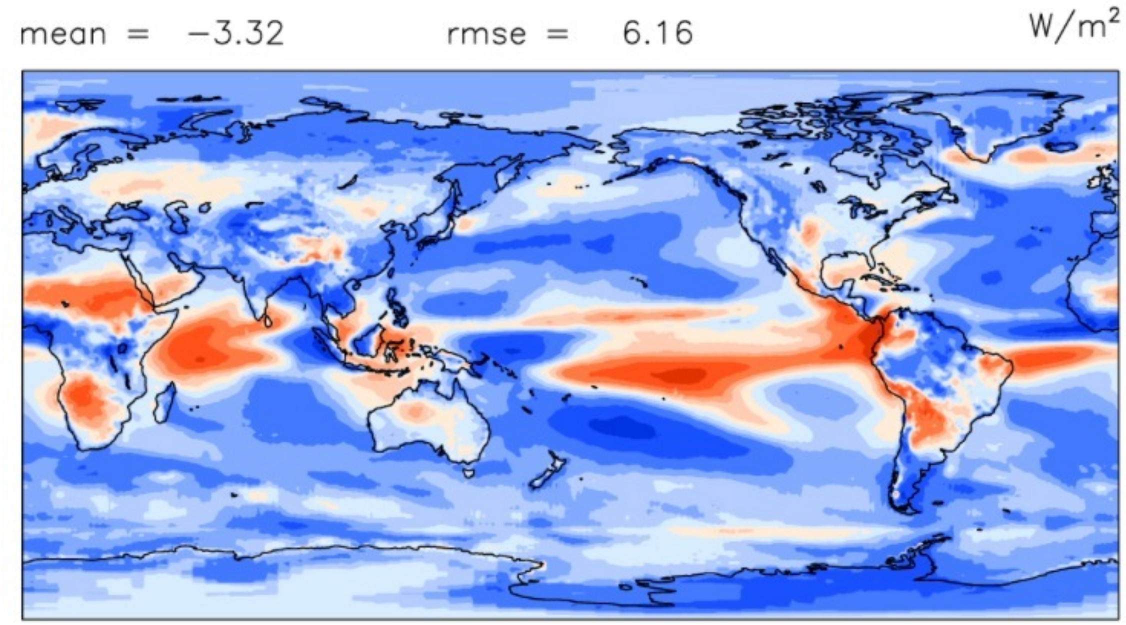


Longwave Cloud Forcing Biases



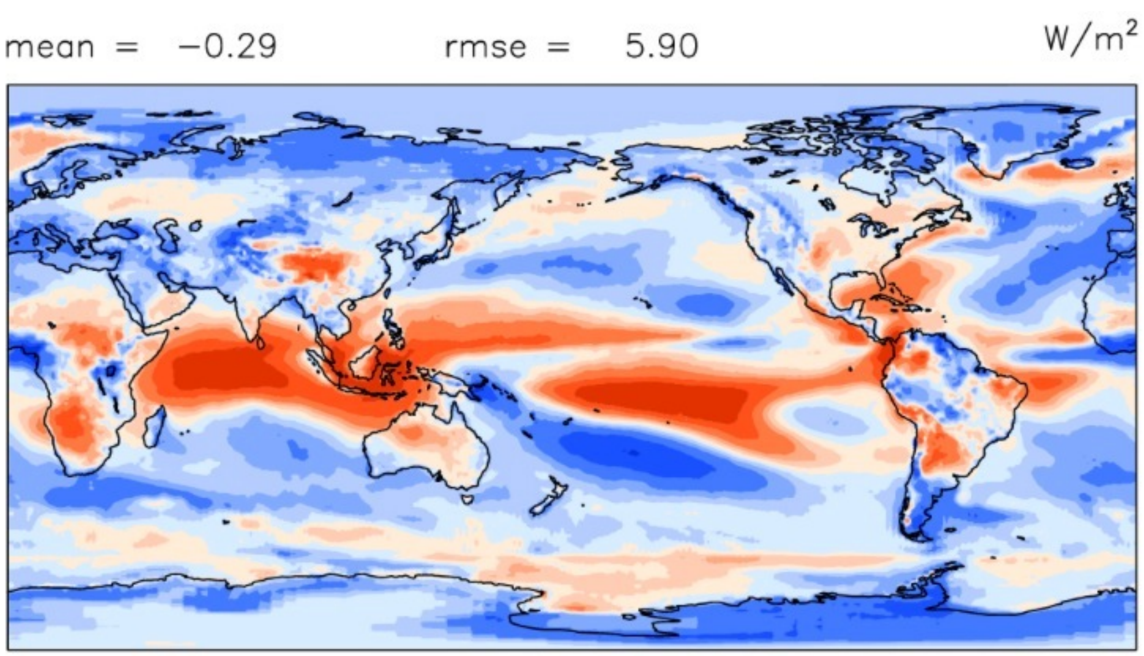
CESM-CAM5.3 - CERES-EBAF

(yrs 402 - 428)



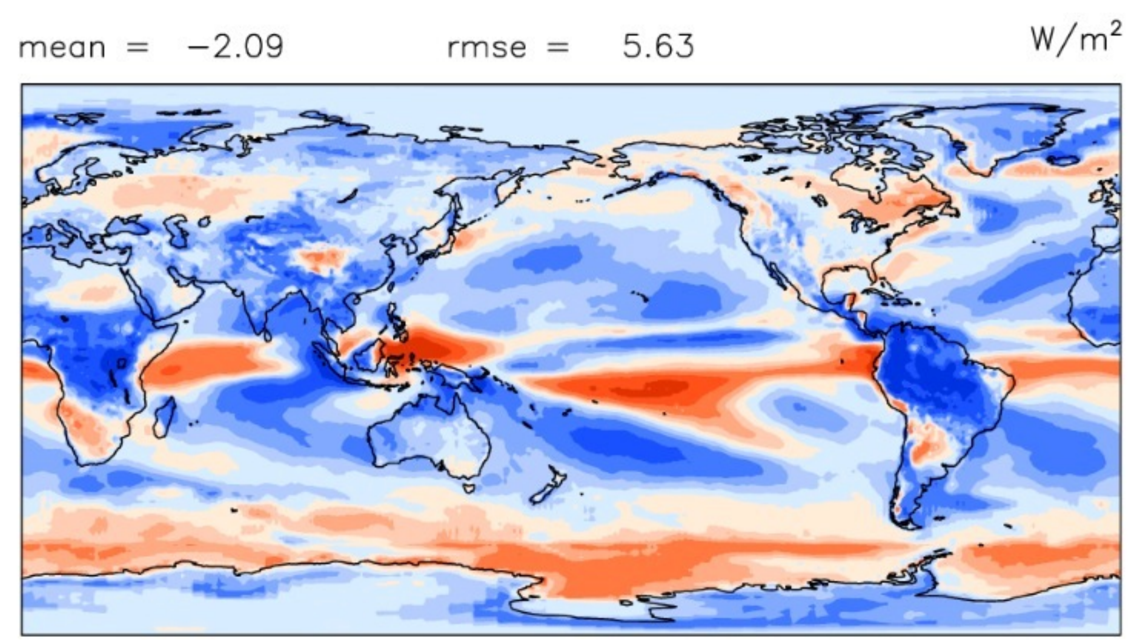
CESM-CAM5.4 - CERES-EBAF

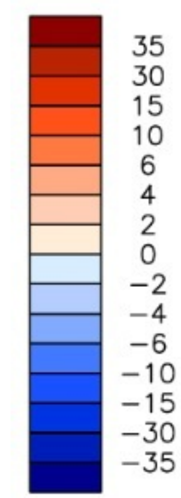
(yrs 70 - 95)



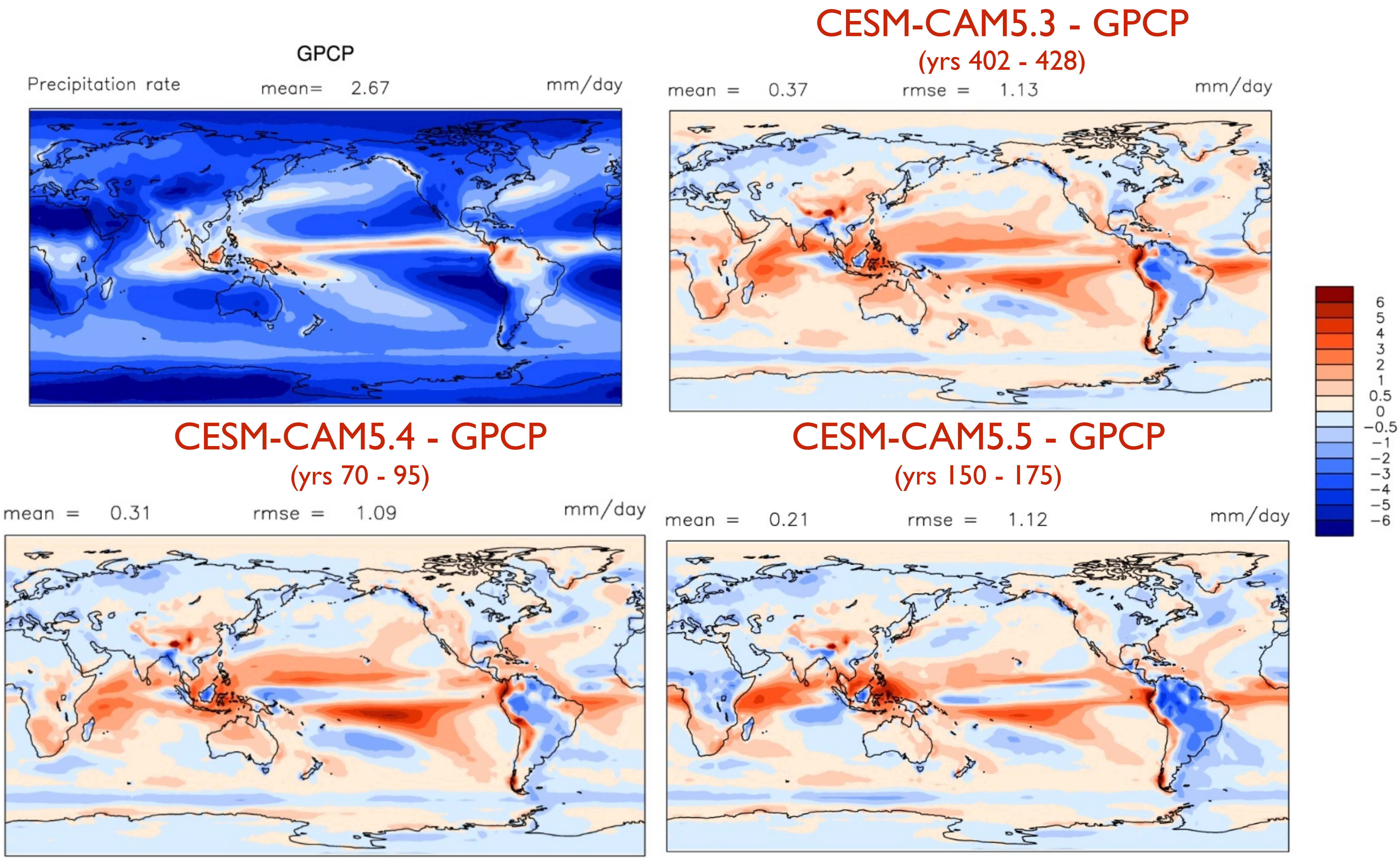
CESM-CAM5.5 - CERES-EBAF

(yrs 150 - 175)

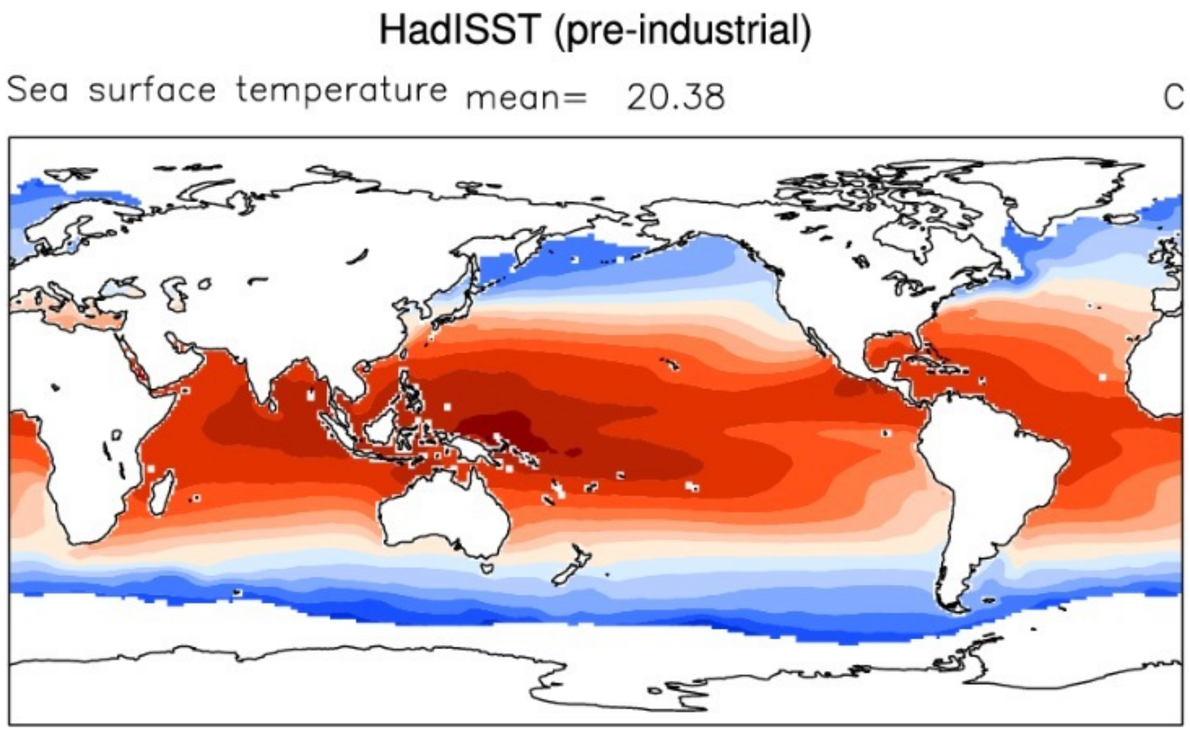




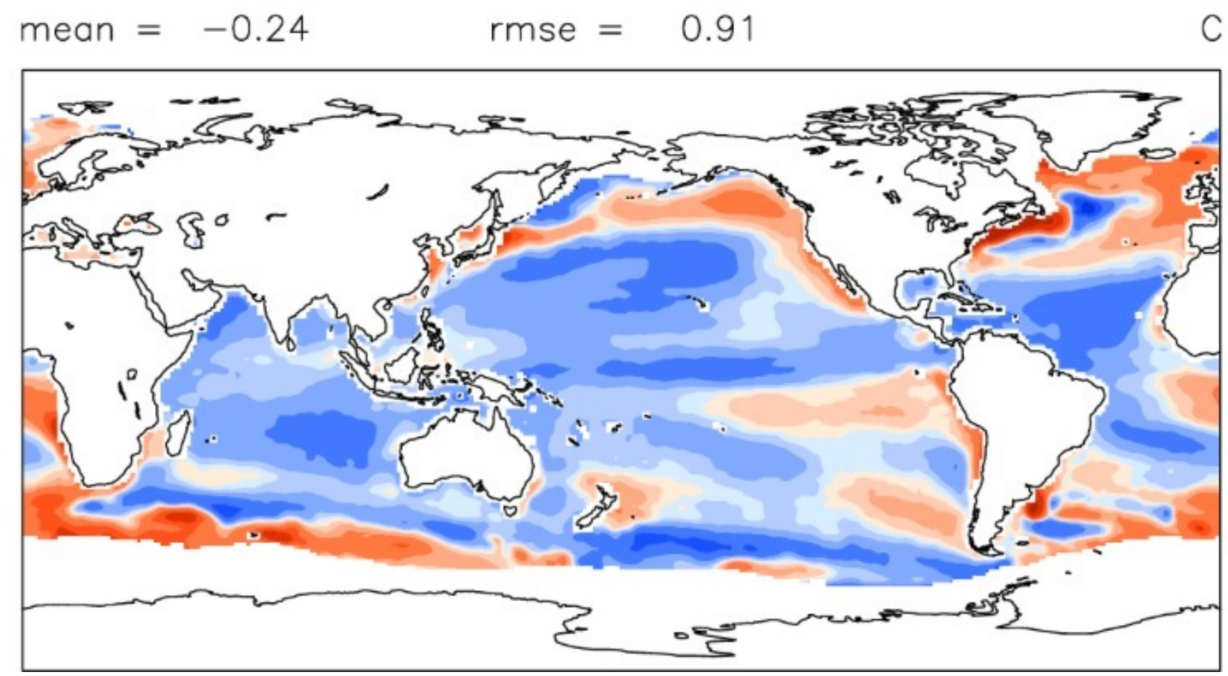
Precipitation Biases



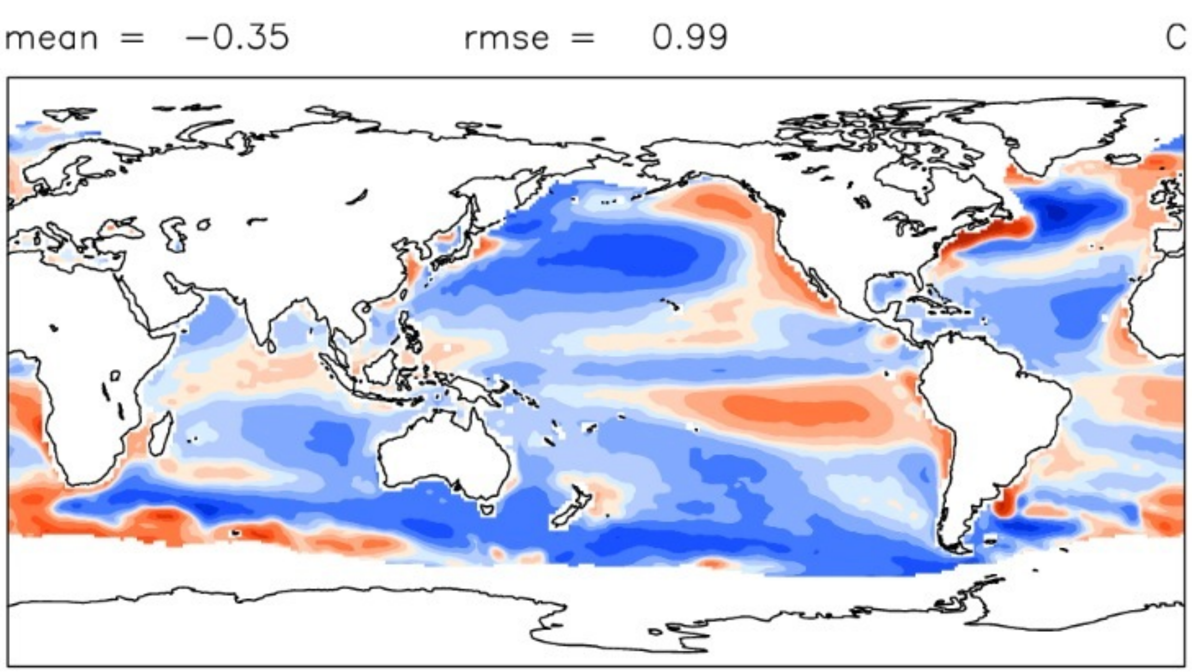
Pre-industrial SST Biases



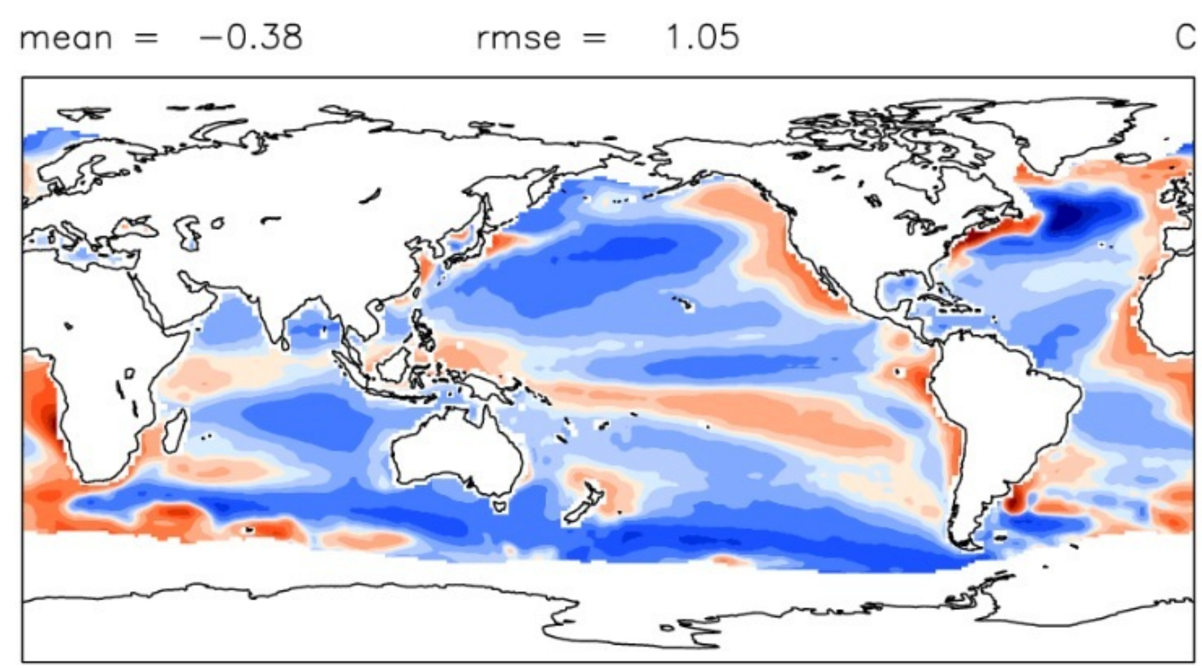
CESM-CAM5.3 - HADISST
(yrs 402 - 428)

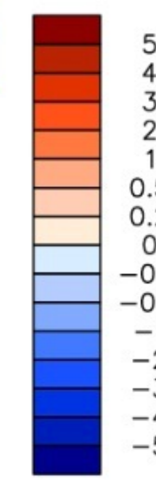


CESM-CAM5.4 - HADISST
(yrs 70 - 95)



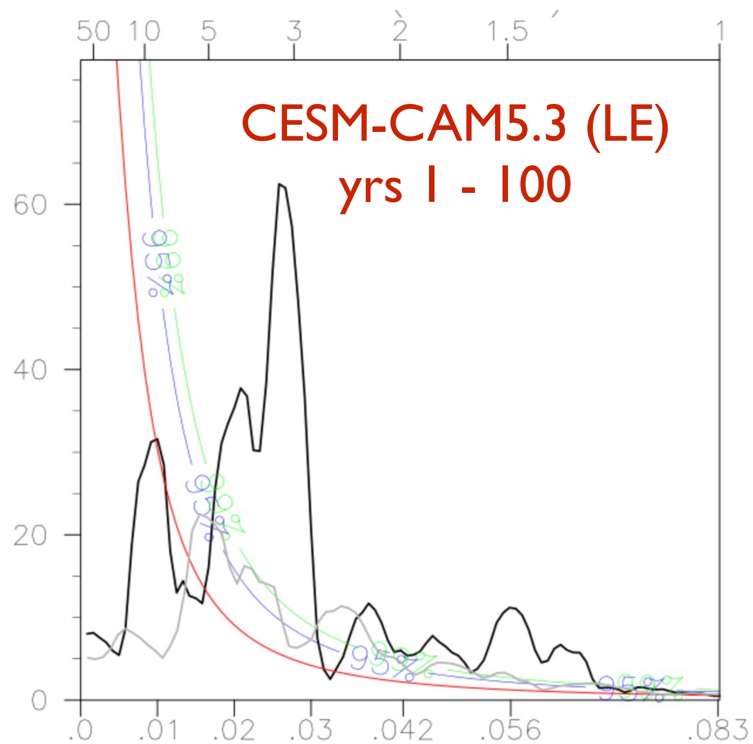
CESM-CAM5.5 - HADISST
(yrs 150 - 175)

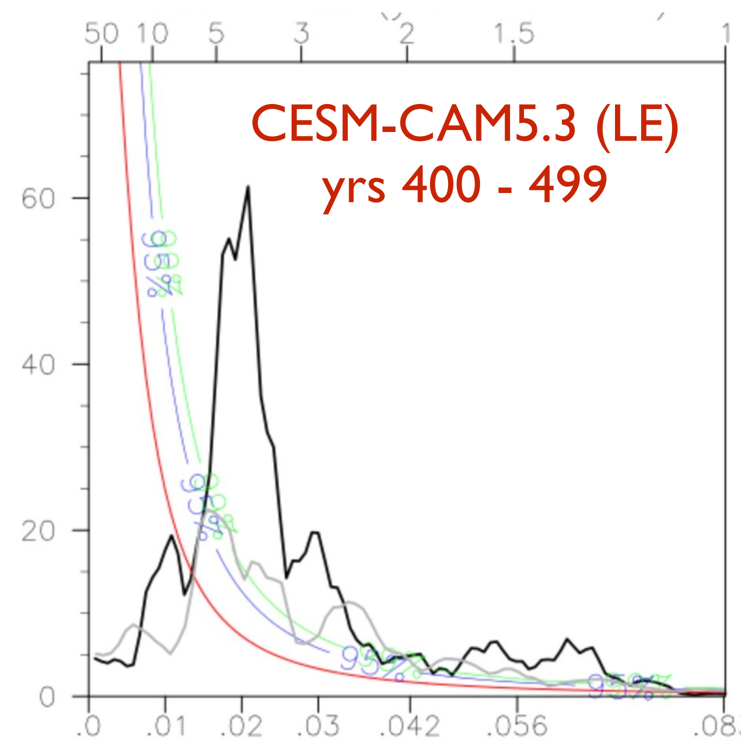


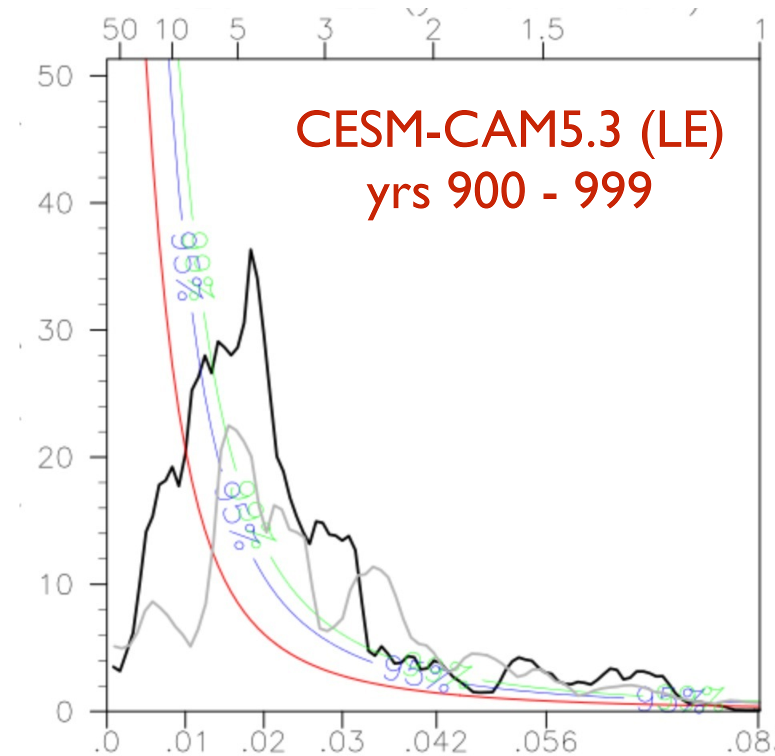


ENSO

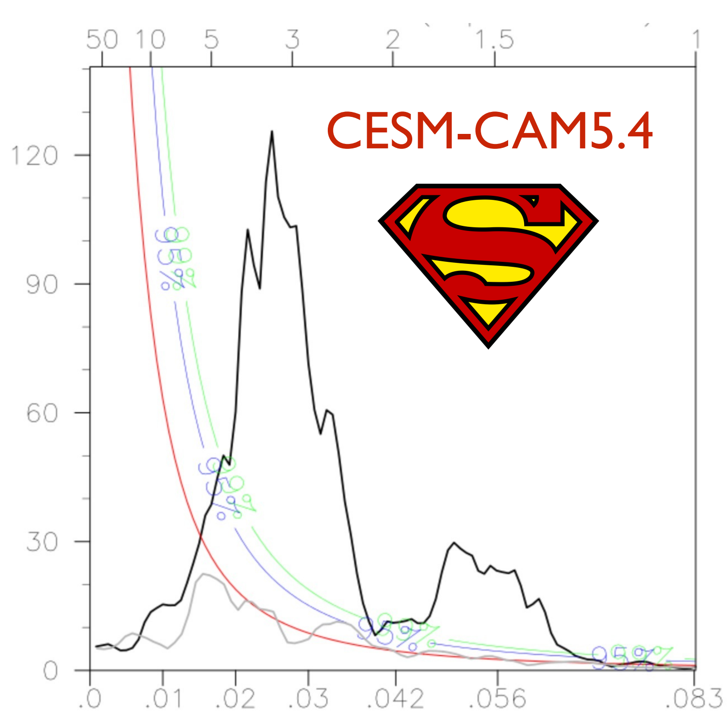
(plots by CVDP)



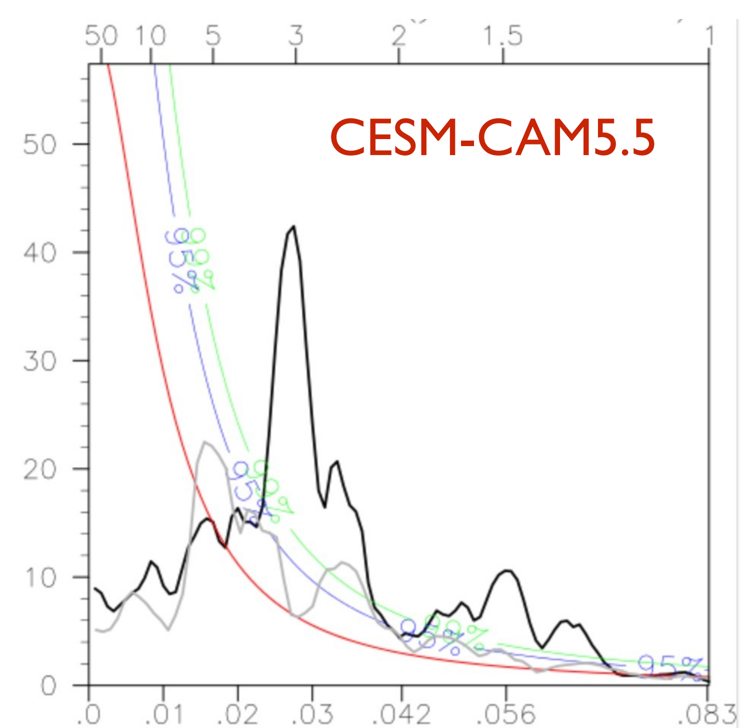




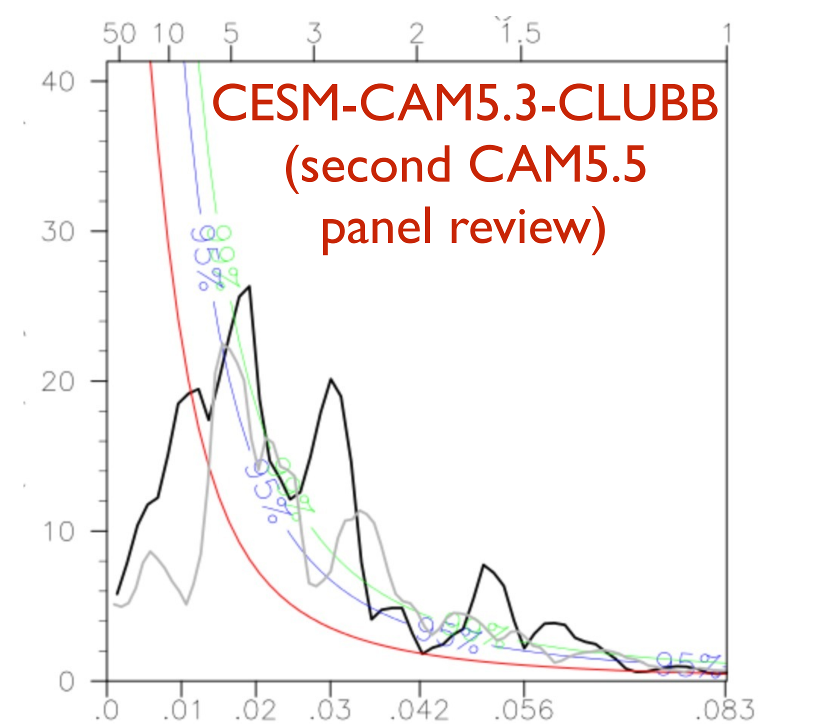
CESM-CAM5.3 (LE) ENSO periodicity and amplitude dependent on time period analyzed



NOTE: amplitude directly related to tuning of high clouds for radiation balance

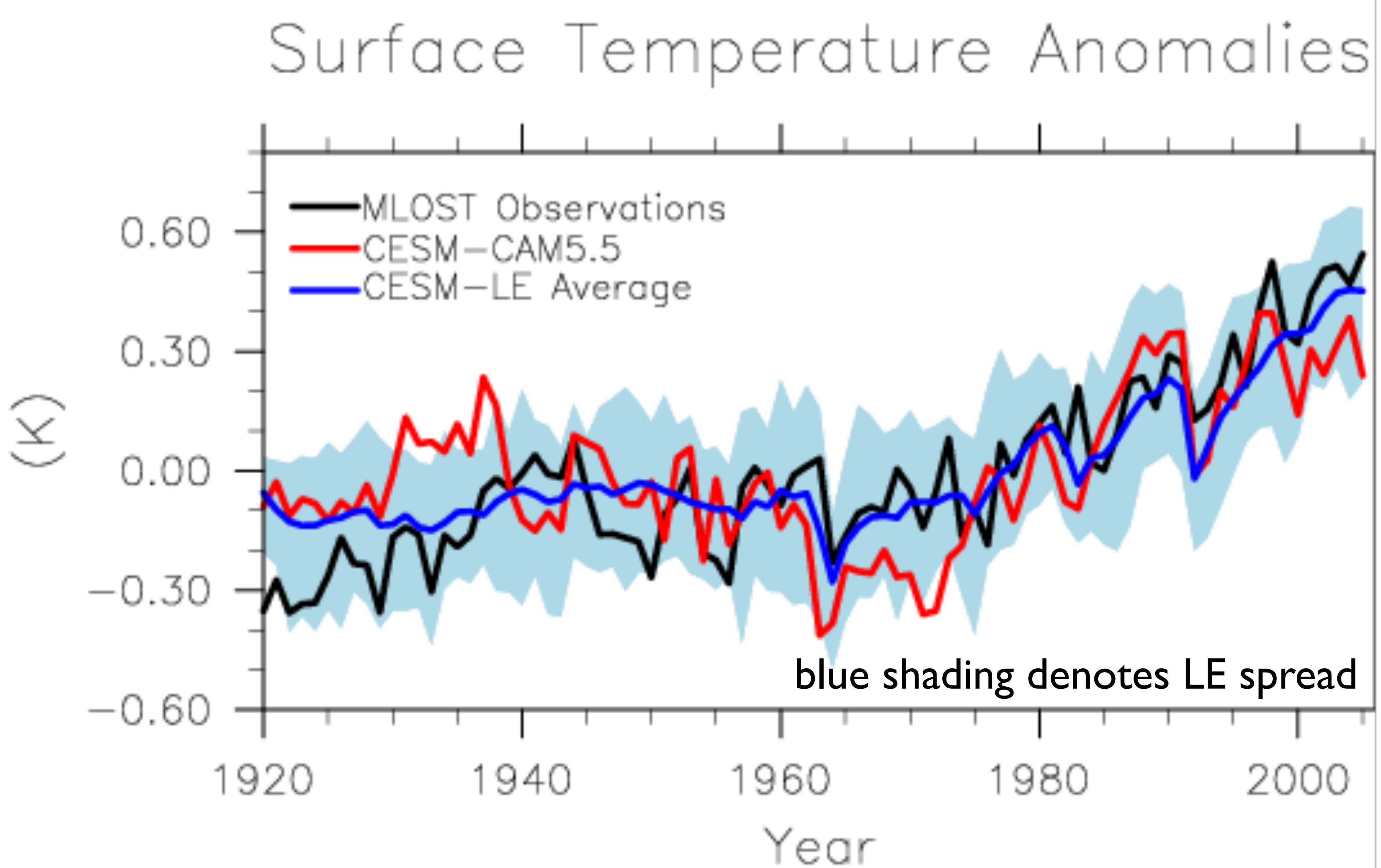


Reasonable amplitude but short periodicity



A version of CESM-CAM5.3-CLUBB had a very good period. Why?

20th Century Simulation



- CESM-CAM5.5 stays mostly within LE spread, however winds up on the cold end. Why?
  - Likely reason due to large aerosol indirect effects (AIE) due to combined increases associated with CAM5.4 (SO2 lifetime) & CLUBB
  - We have implemented Seifert and Behang (2001, SB2001) autoconversion and accretion into MG2, resulting in ~30% reduction of RFP and AIE in prescribed SST simulations

New Autoconversion Climate Impacts

- Application of SB2001 physics resulted in a -3.0 W/m2 change in RESTOM for CAM5.5
- We have tuned up CAM5.5-SB2001 simulations taking different tuning paths
- Pre-industrial coupled simulations with this development leads to SSTs colder than the standard CESM1.5 simulations (stronger cloud forcing). Tuning is ongoing.
- Goal is for a version of CAM5.5-SB2001 that simultaneously 1) reduces aerosol cloud interactions, and 2) improves upon SSTs in CESM1.5, and 3) improves Amazon precip biases?…

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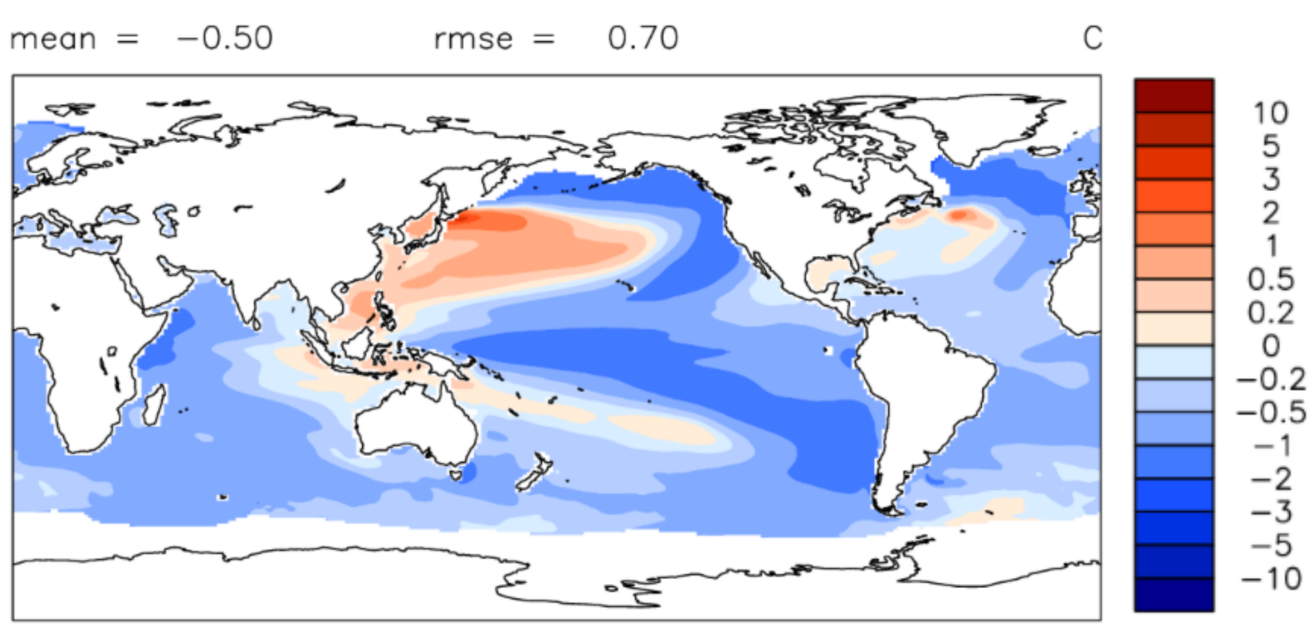
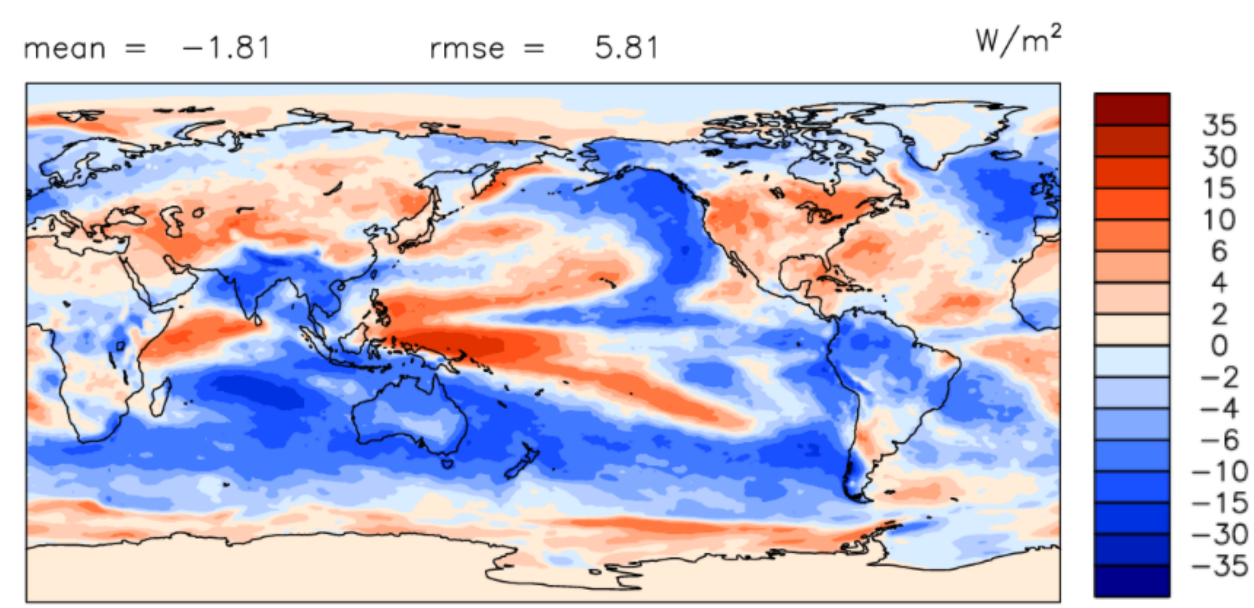
CESM1.5-SB2001 - CESM1.5 control

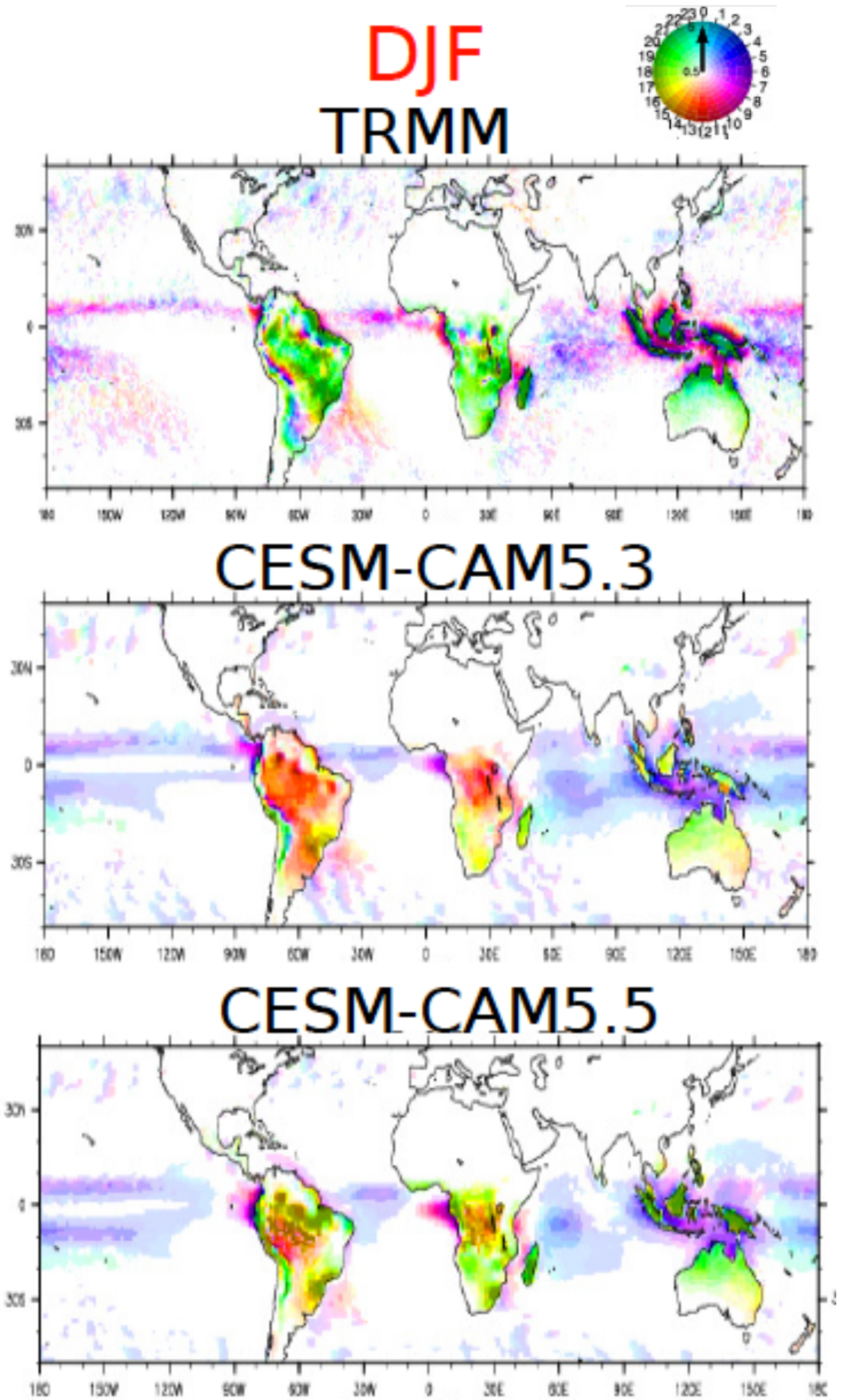
SST differences



SWCF differences



Amazon Precipitation Biases



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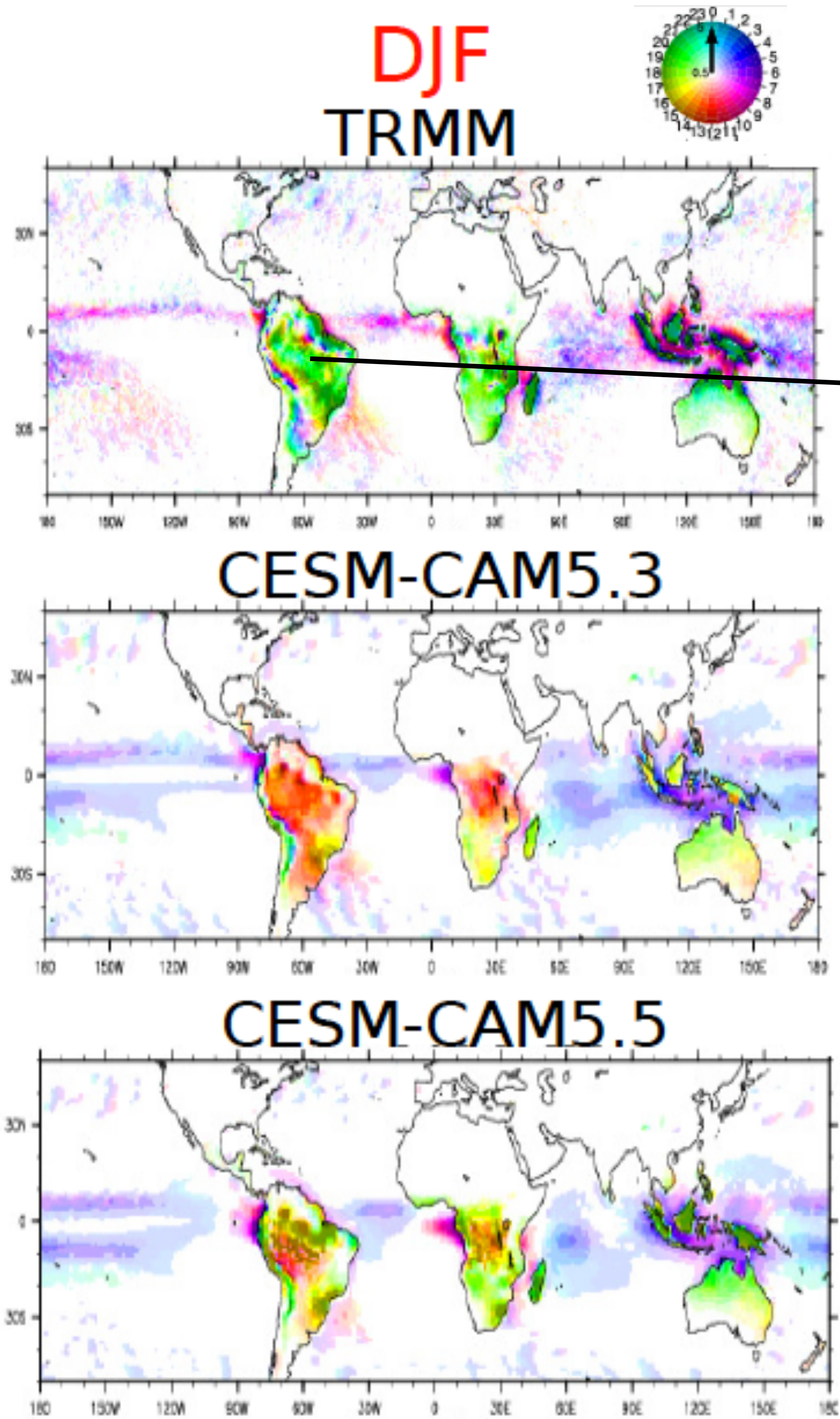
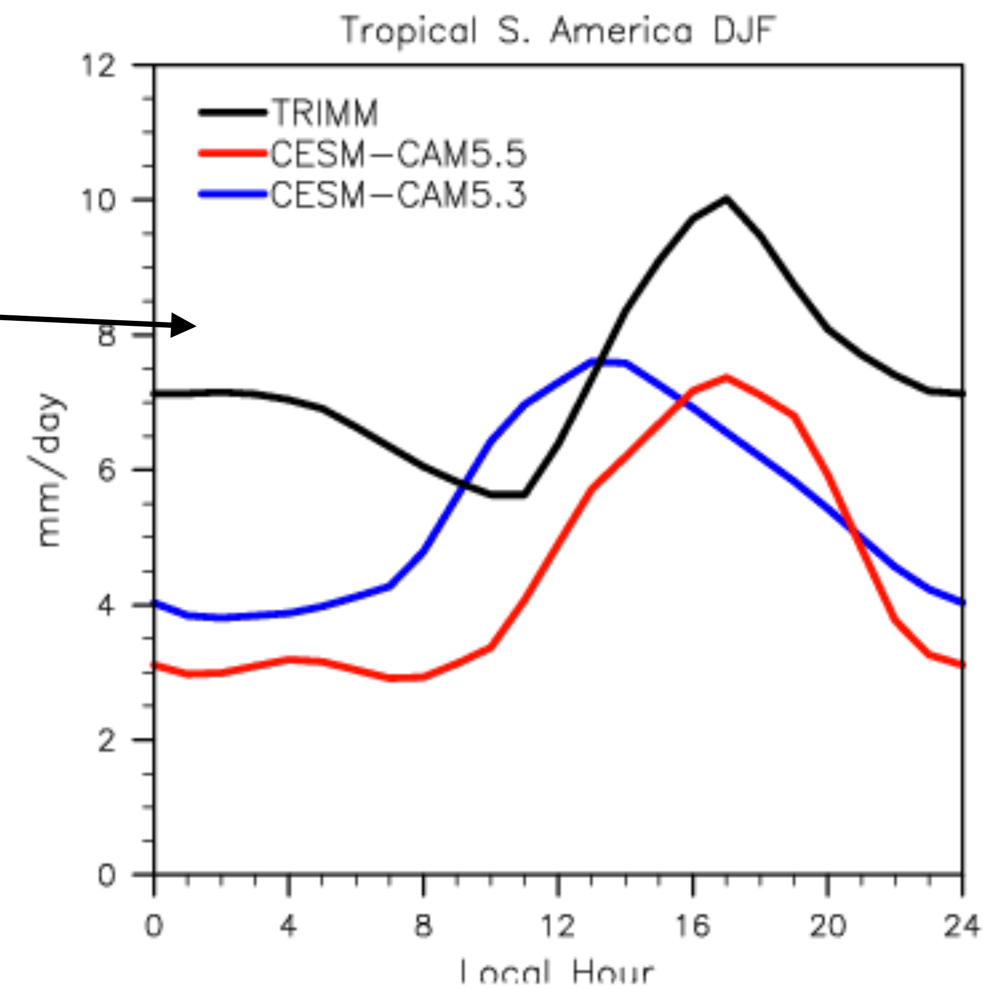




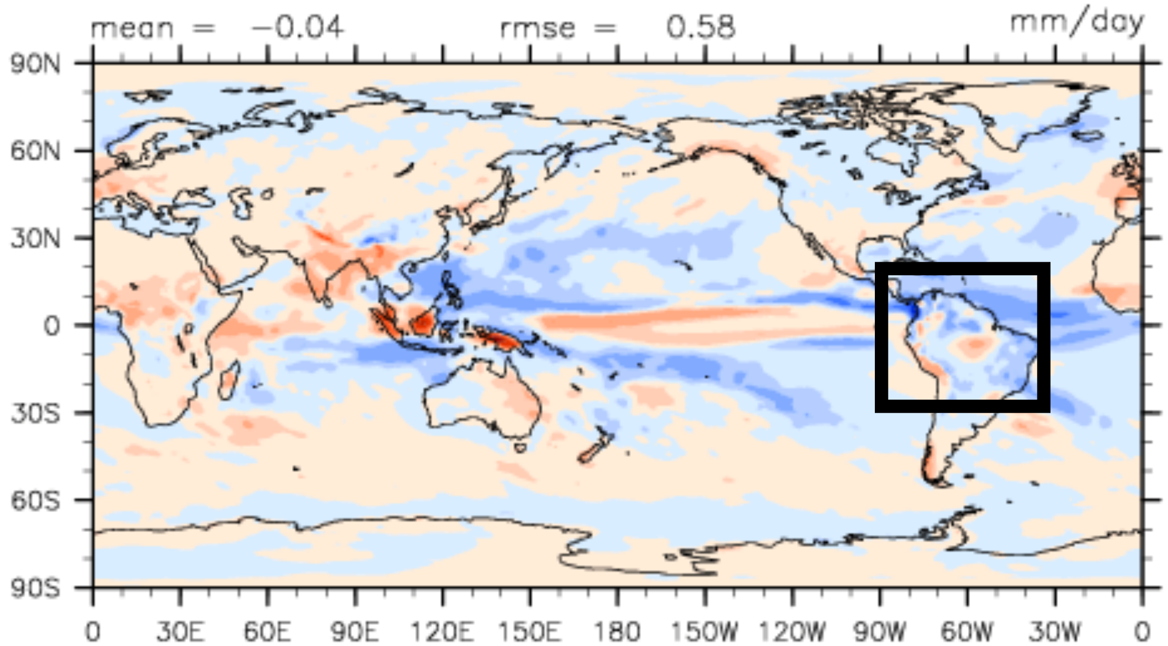
CAM5.5 has better timing

All versions underestimate intensity

CAM5.3 & CAM5.4 rain longer

Amazon Precipitation Biases
Coupled Vs. Prescribed SSTs

CAM5.5 - CAM5.4

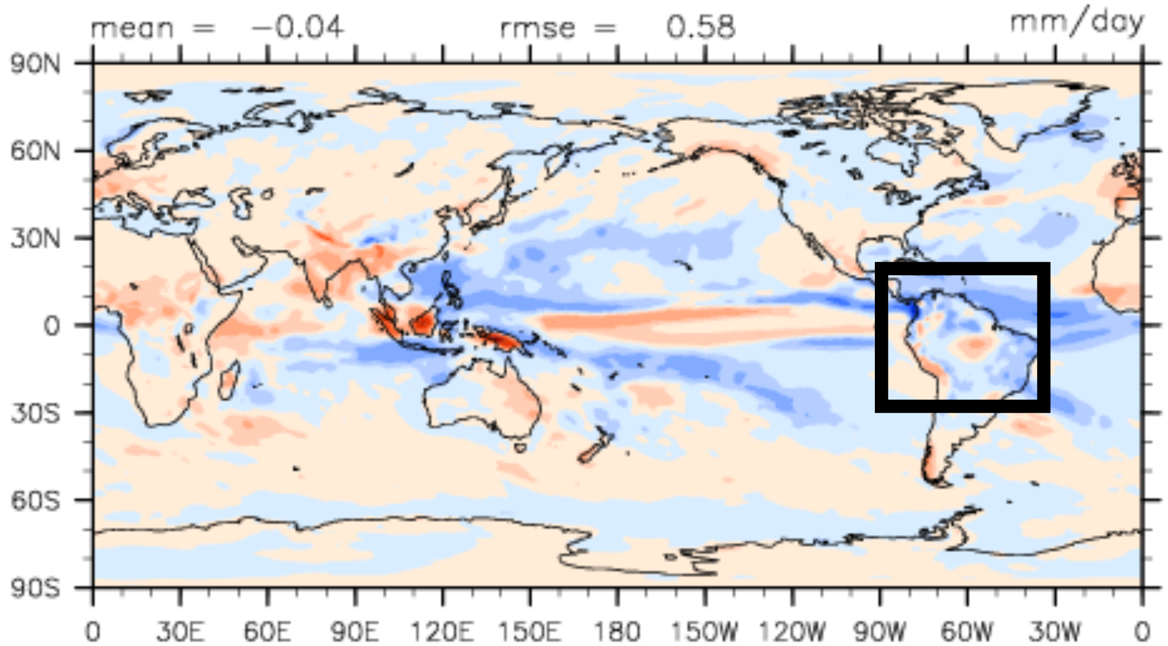


With climatological prescribed SSTs, CAM5.5 is not much worse than CAM5.4

Amazon Precipitation Biases

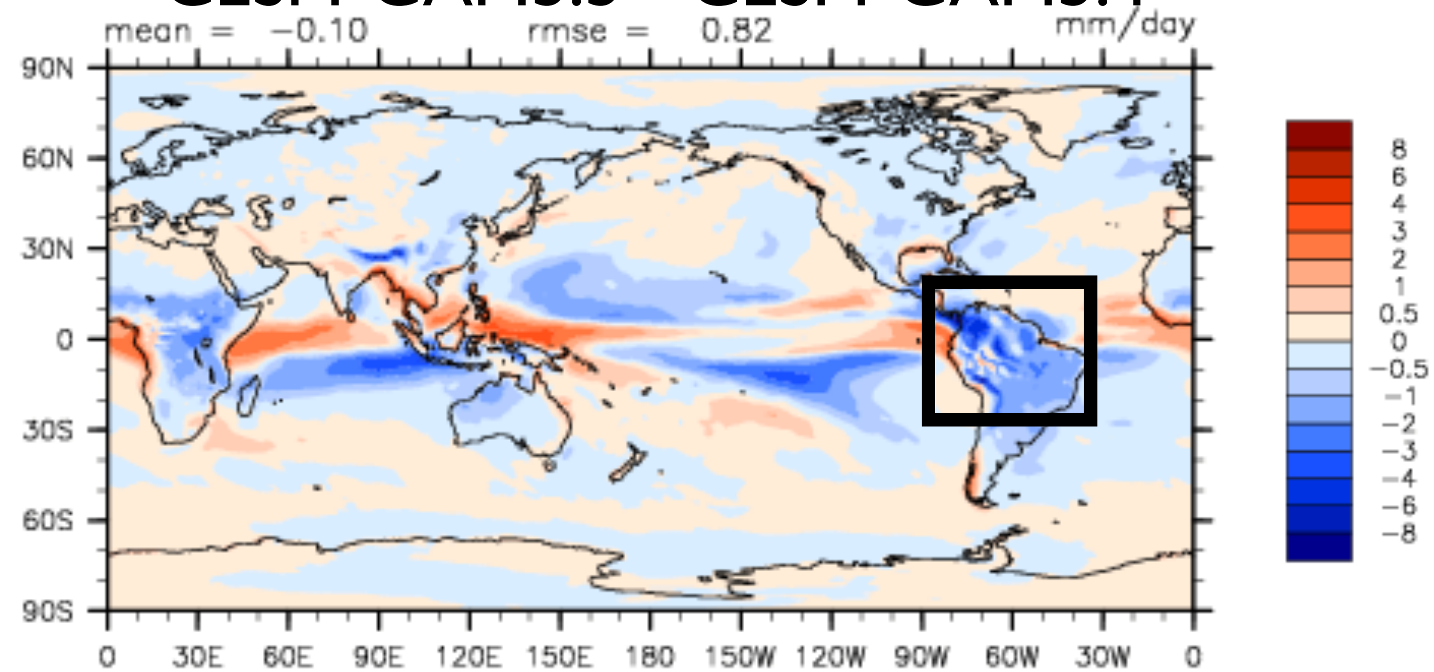
Coupled Vs. Prescribed SSTs

CAM5.5 - CAM5.4



With climatological prescribed SSTs, CAM5.5 is not much worse than CAM5.4

CESM-CAM5.5 - CESM-CAM5.4

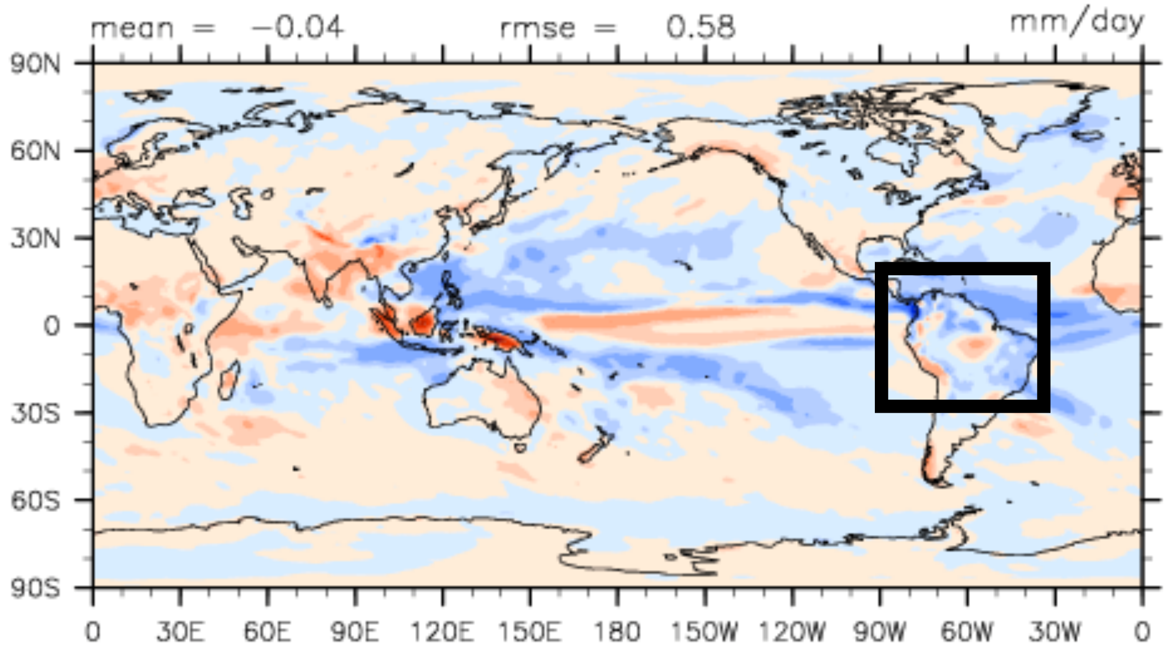


Coupled Mode: HUGE difference

Amazon Precipitation Biases

Coupled Vs. Prescribed SSTs

CAM5.5 - CAM5.4



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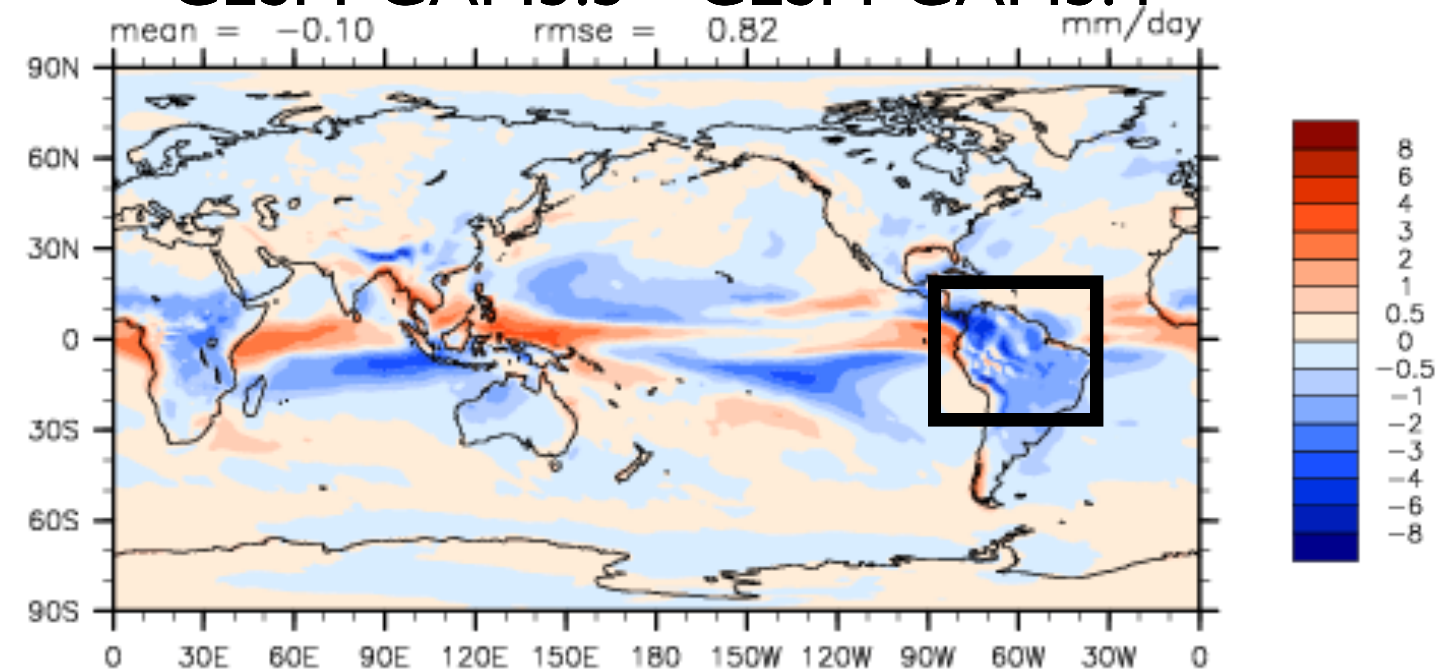
WHY?

Any relation to SST differences?
(Martins et. al 2015)
What about seasonality?

CESM-CAM5.5 - CESM-CAM5.4



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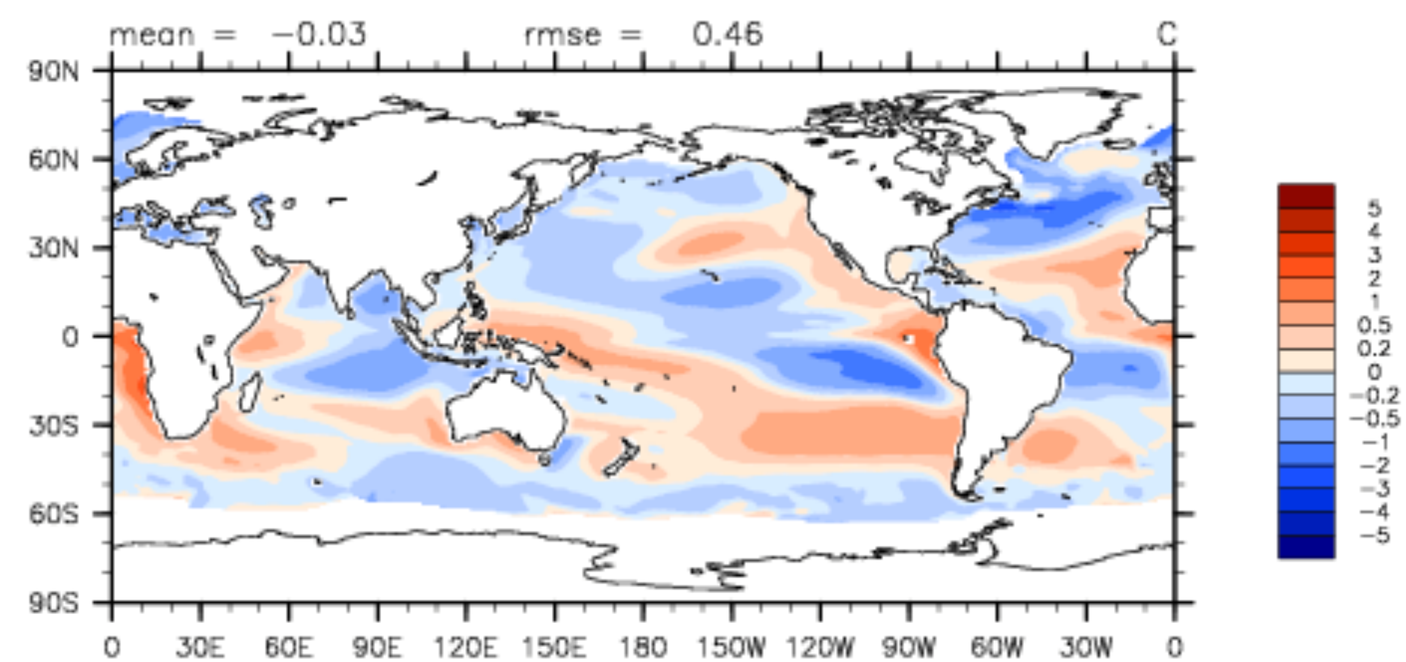

High Resolution CAM5.5

- Preliminary high-resolution (ne120) simulations of CAM5.5 have begun (thanks Patrick Callaghan)
- Untuned simulations resulted in reduction of cloud forcing over tropical pacific
- Setting zmconv_c0_ocn to CAM5.3 tuning levels for ne120 ameliorates the problem and leads to acceptable initial simulations for the mean state climatology (only a two years so far)

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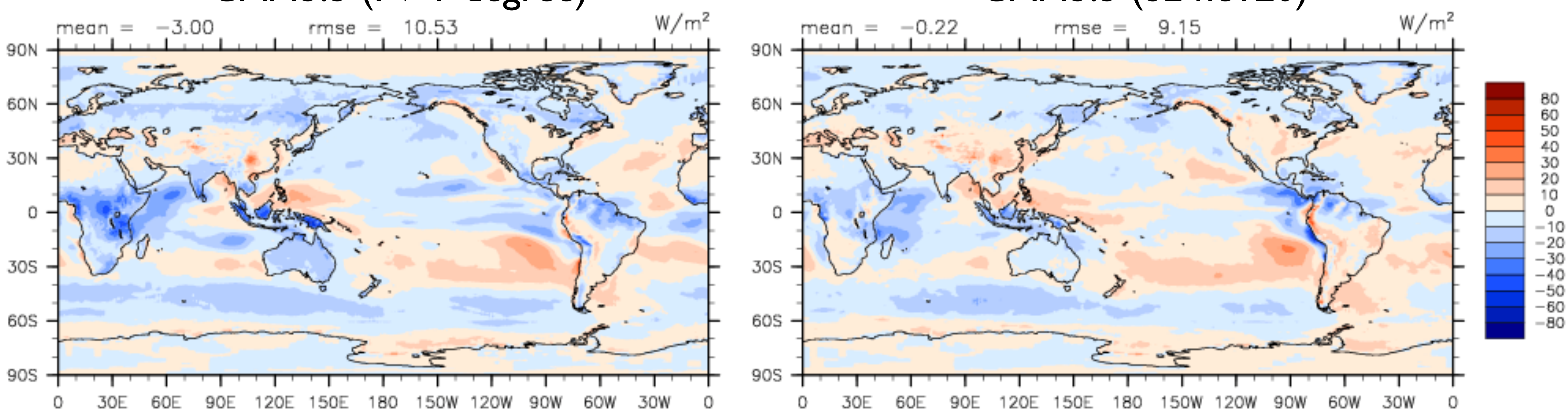
Shortwave Cloud Forcing Biases (CERES-EBAF)

CAM5.5 (FV 1-degree) CAM5.5 (SE ne120)



Opportunities for Next Generation CAM

- Running CAM5.5 high resolution requires tuning ZM to reconcile the tropics
- How about by-passing the traditional deep convective parameterization?
- Guo et al. (2015) and Thayer-Calder et al. (2015) both show that CLUBB can produce reasonable climatology when run as a deep convective parameterization
    - One parameterization to handle all turbulence and cloud transports, coupled to one microphysics scheme
- Short term development: Possibility of a version of CAM-CLUBB-DEEP for CAM6 to be supported for prescribed SST experiments (i.e. high res, variable mesh simulations)
- Longer term development: Version of CAM-CLUBB-DEEP that would be validated in coupled mode for next generation version of CAM

Summary

- Efforts are ongoing to help ameliorate some of the issues with CESM1.5 simulations:
  - Aerosol cloud interactions that are too strong
  - Sea surface temperatures that are too cold
  - Amazon precipitation biases
- New autoconversion/accretion, in conjunction with new tunings, may help to fix some (maybe all?) problems in one fell swoop
- Efforts to develop benchmark simulations for CAM-CLUBB-DEEP are underway
  - Version of CAM with one unified cloud/turbulence/convection parameterization and one microphysics scheme that is scale aware and scale insensitive