The National Center for Atmospheric Research
sponsored by NSF
NCAR
managed by UCAR to serve the community
NESL

ENSO Modeling at NCAR

Rich Neale
NCAR

presented by
Samantha Stevenson
University of Colorado, Boulder, CO

NCAR is sponsored by the National Science Foundatio
NSF

Overview

Community Earth System Model (CESM)

✓Recent improvements to ENSO
✓Impacts across scales CCSM4 (CAM4)
✓Impact of new physics CESM1(CAM5)

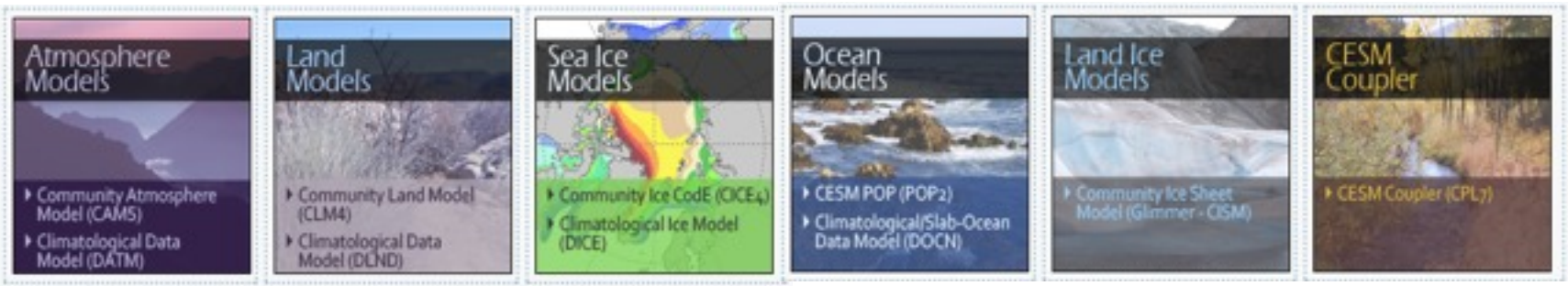
Remaining/Ongoing ENSO Challenges

✓Dealing with significant long term variability in modeled ENSO
✓Understanding the response to new cloud physics

Community Earth System Model

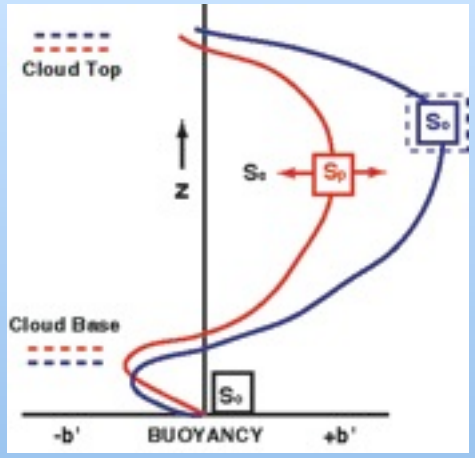
- April 1, 2010: **CCSM4.0 release**
  - ✓CAM4 deep convection modifications (Neale et al. 2011)
  - ✓Updated surface models (ice, land, ocean)

- June 25, 2010: **CESM1.0 release**
  - ✓ ocean ecosystem, interactive chemistry, WACCM, land ice, and CAM5.0 (Rasch et al. 2011)



http://www.cesm.ucar.edu/models/

CAM4: Physics Changes

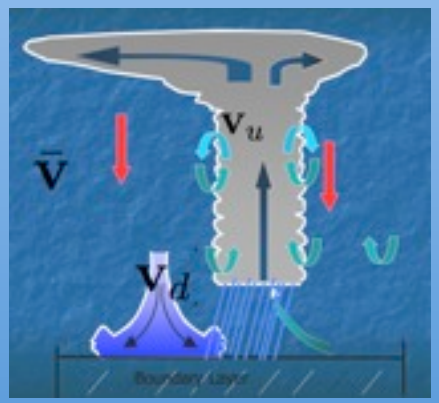


Convection Dilution

✓Reduced sensitivity to surface temp

✓Increase sensitivity to atmos. humidity

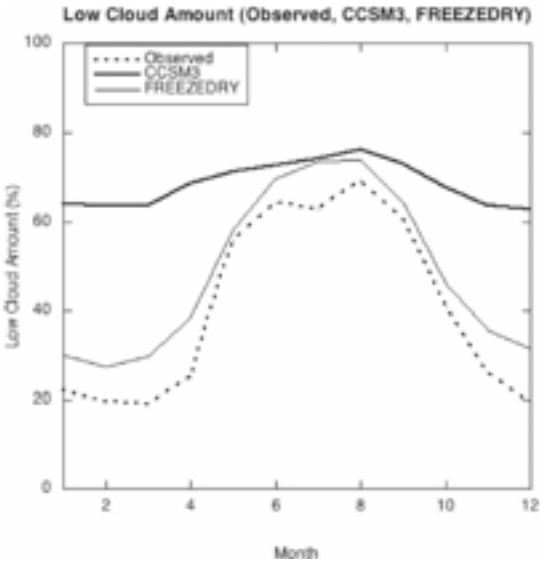
Neale et al. (2008)



Convective Momentum Transports

✓Reduce excessive surface trades

Richter and Rasch (2008)



$$f = f \times \left[\max(0.15, \min)\left(1.0, \frac{q}{0.003} \right) \right].$$

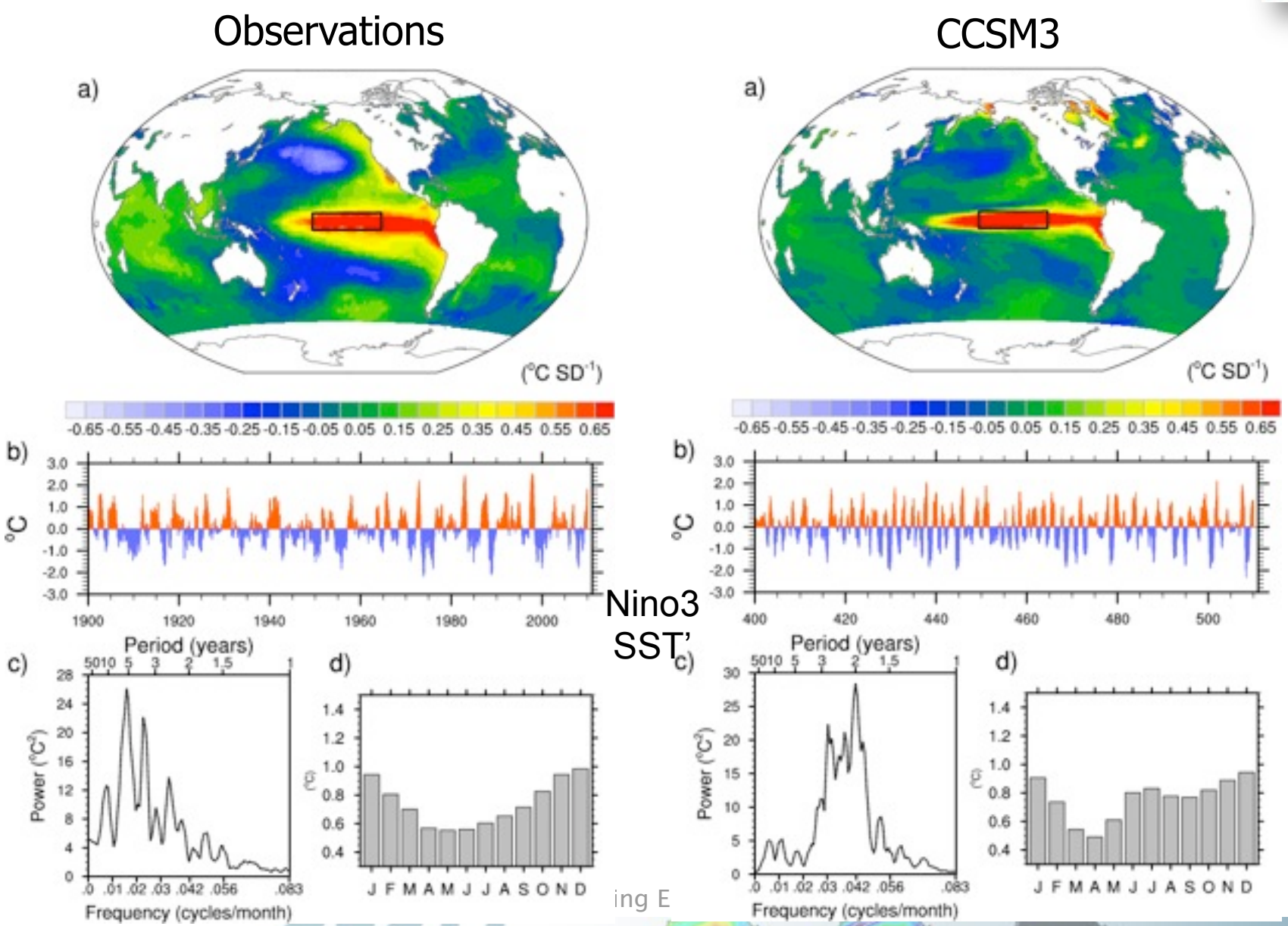
Polar Cloud *Freeze Drying*

✓Reduce excessive winter-time polar low cloud

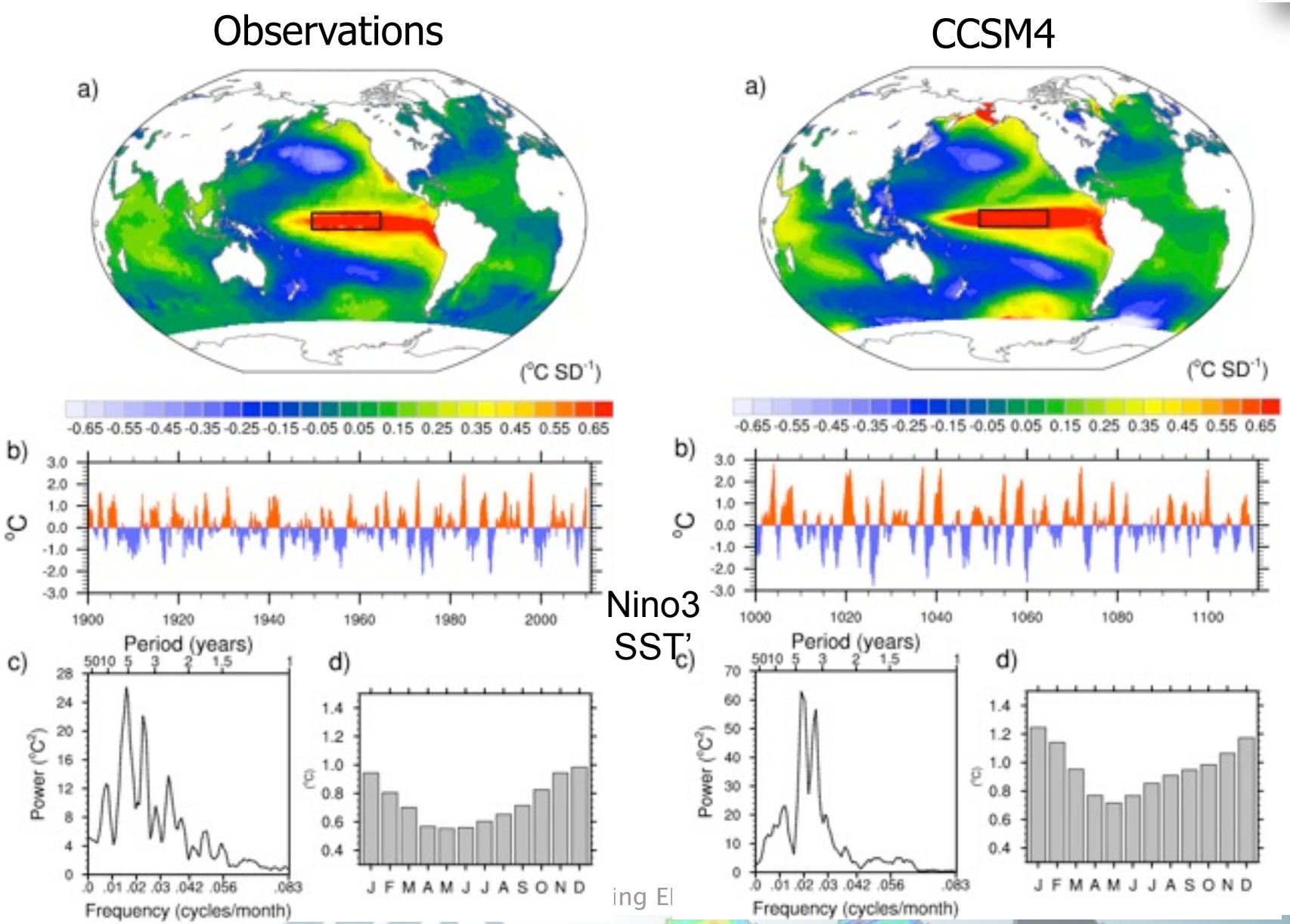
Vavrus and Waliser (2008)

- 1 deg/L26 standard version
- 2 deg/L26 + turbulent mountain stress & lower ice fall velocity (WACCM)
- T31 coupled version

Leading Mode of Global SST Variability

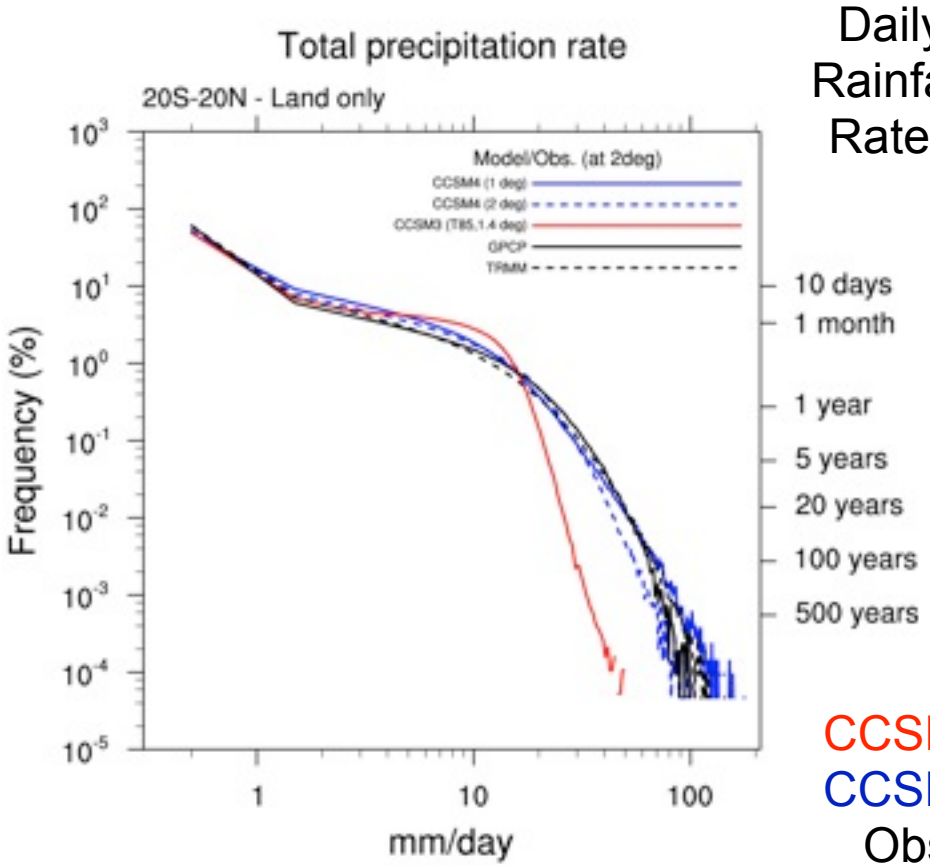


Leading Mode of Global SST Variability



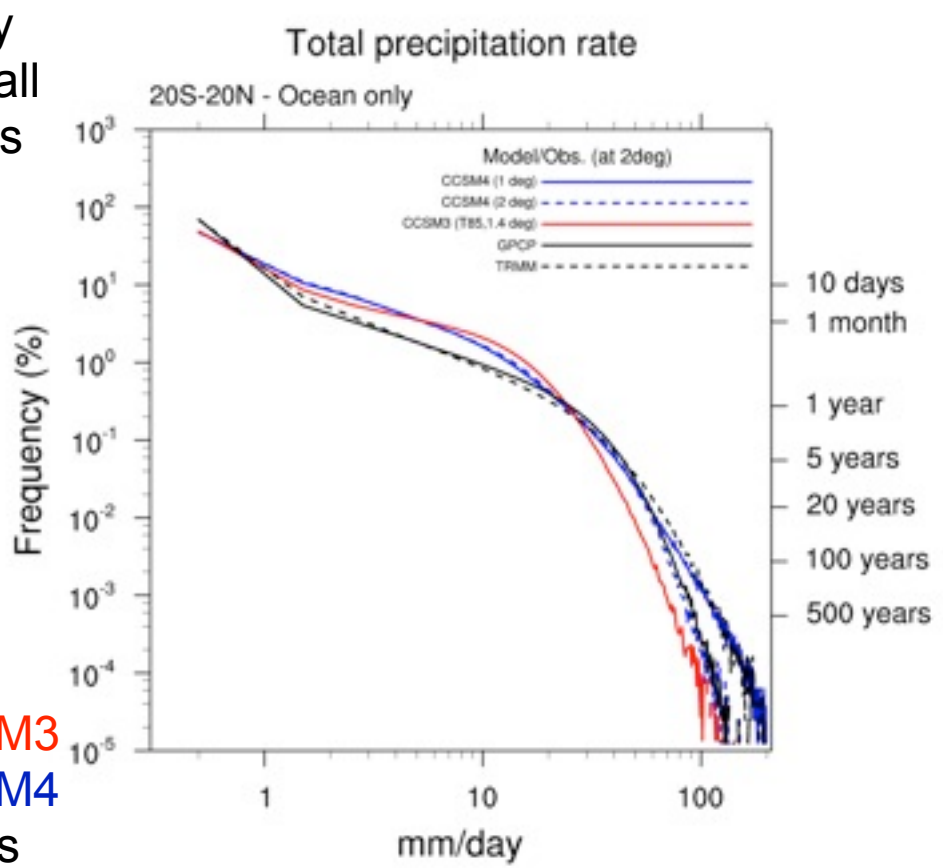
High Frequency

CAM4 has more stronger precipitation events in climate



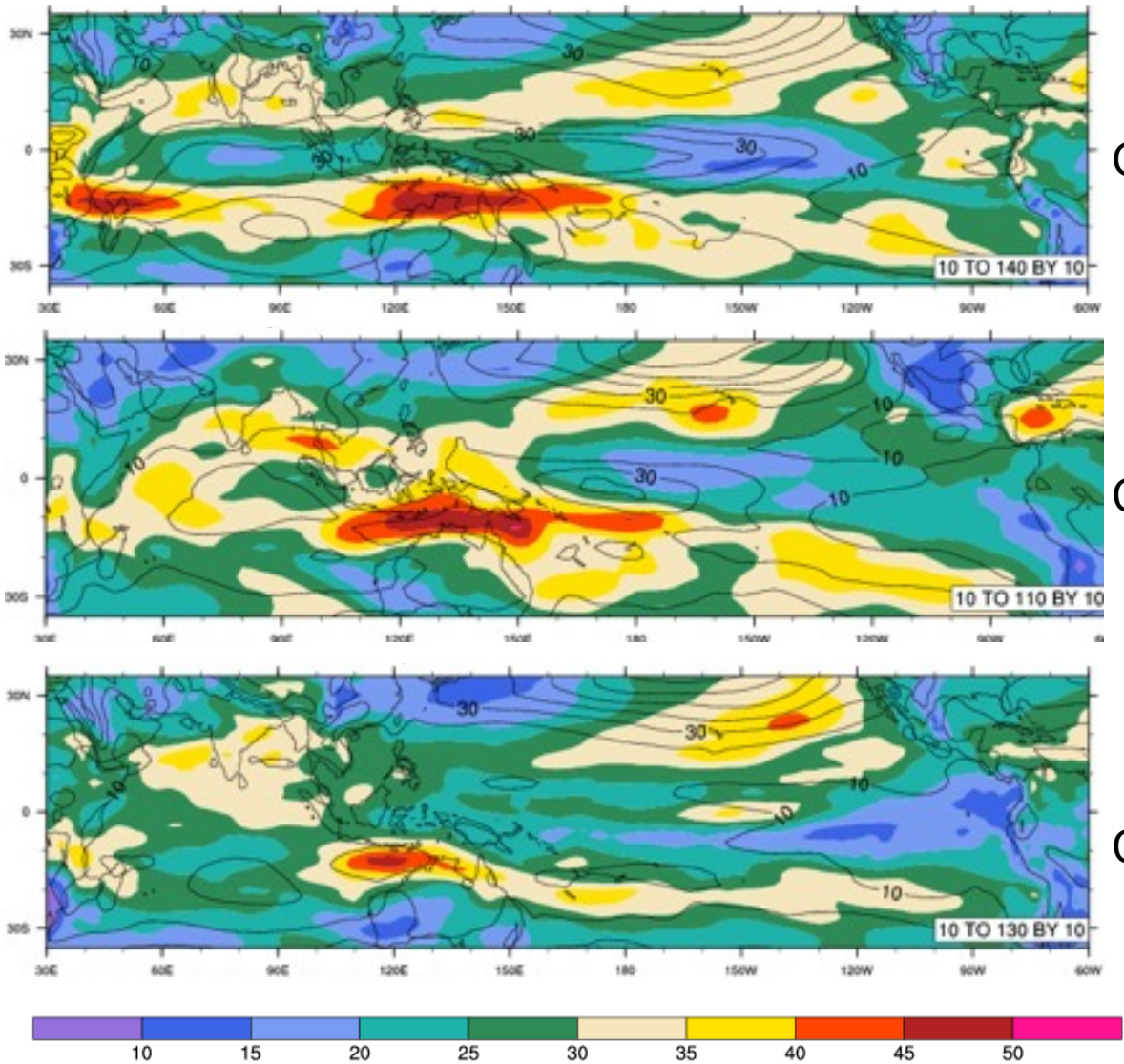
Daily Rainfall Rates

CCSM3
CCSM4
Obs



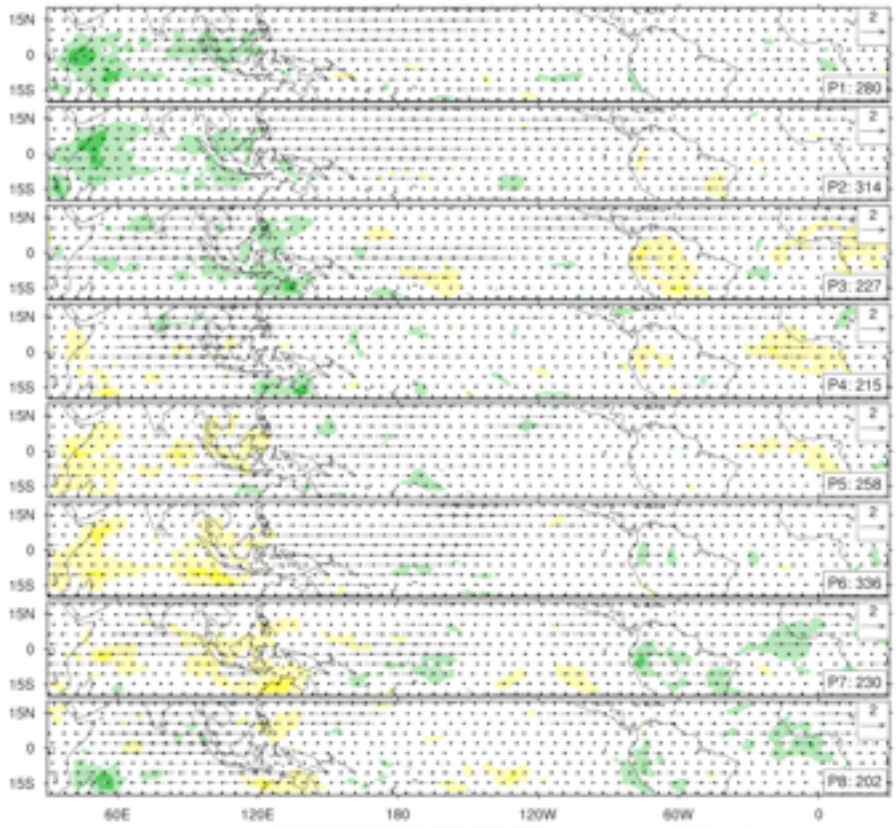
High Frequency Variance Increases

- ✓ Variance from daily zonal winds (850 mb)
- ✓Contours: full variance
- ✓Colors: intraseasonal variance (20-100 day bandpassed)
- ✓West Pacific variance improved
- ✓Role of intraseasonal variance in ENSO?

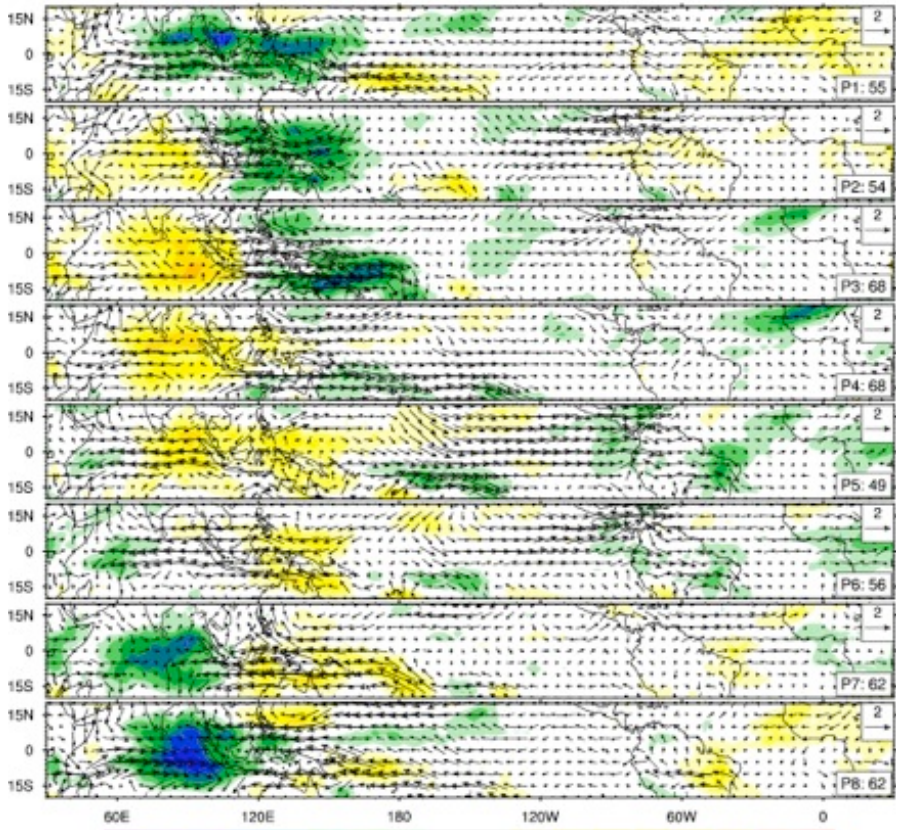


Composite Madden Julian Oscillation (MJO)

CCSM3-T85 (1980-1999)



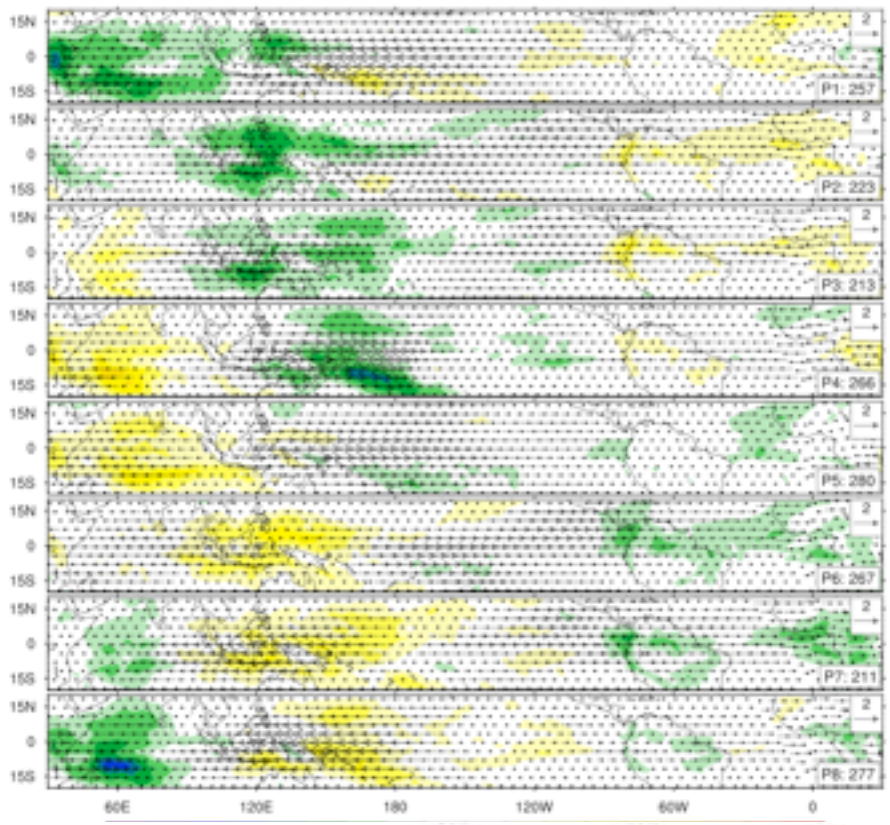
Observed (NOAA,ERA40,1995-1999)



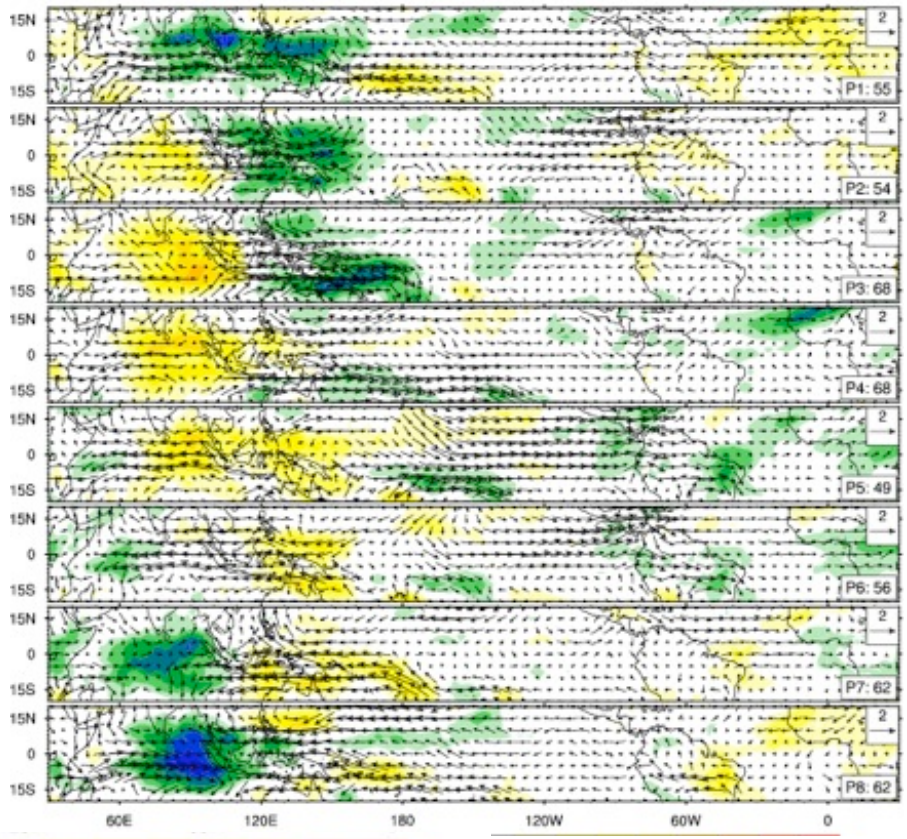
Eight phase composite of PC1 and PC2 from combined EOFs, technique from Wheeler & Hendon (2004)
20th Century coupled experiments, Winter

Composite Madden Julian Oscillation (MJO)

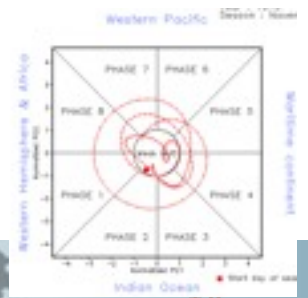
CCSM4-1 deg (1980-1999)



Observed (NOAA,ERA40,1995-1999)

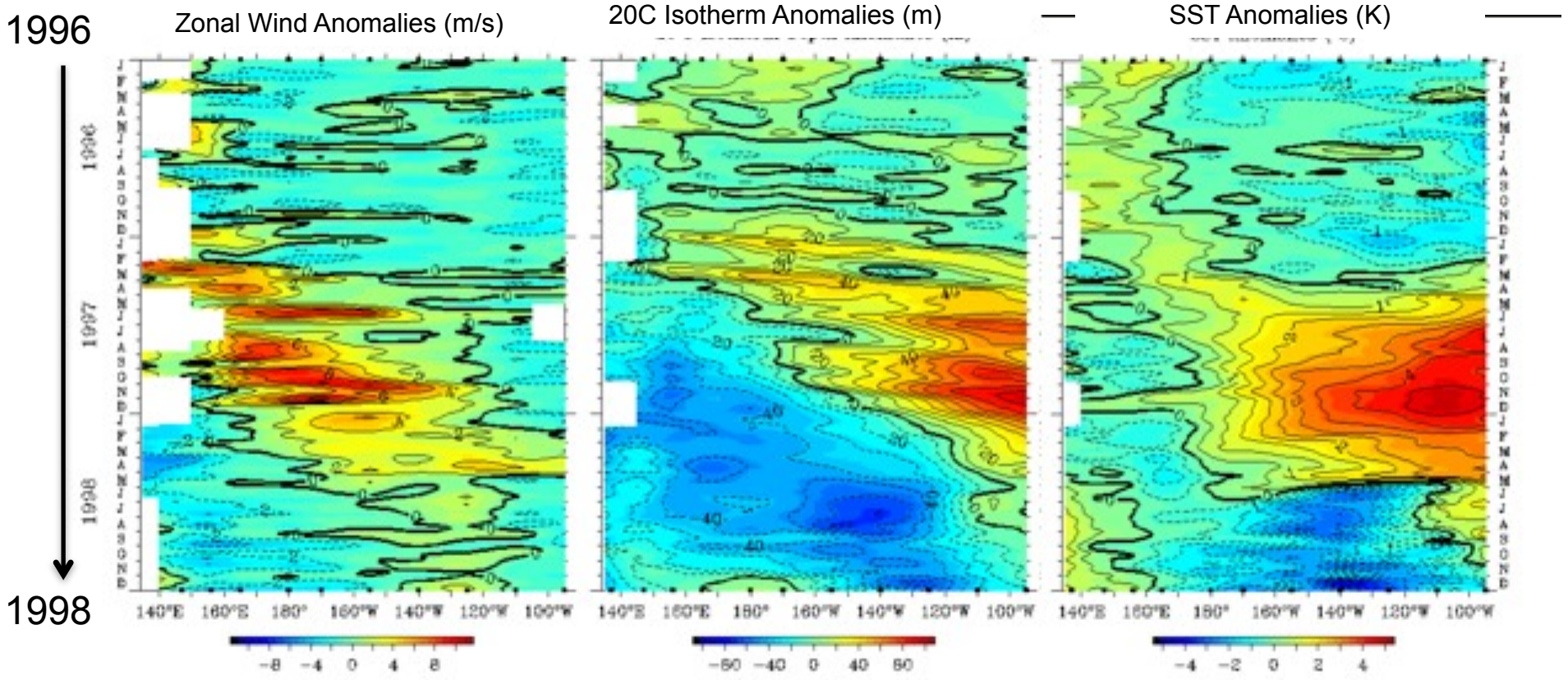


Eight phase composite of PC1 and PC2 from combined EOFs, technique from Wheeler & Hendon (2004)
20th Century coupled experiments, Winter



1997/98 ENSO

The role of intraseasonal variability/westerly wind bursts



- Convective forcing has to be strong enough to generate significant intra-seasonal activity
- Leads to ocean relevant forcing (K-waves)

Across Scales

The extension of the MJO westward may maintain and even trigger El Nino events

Westerly wind bursts (5N-5S)

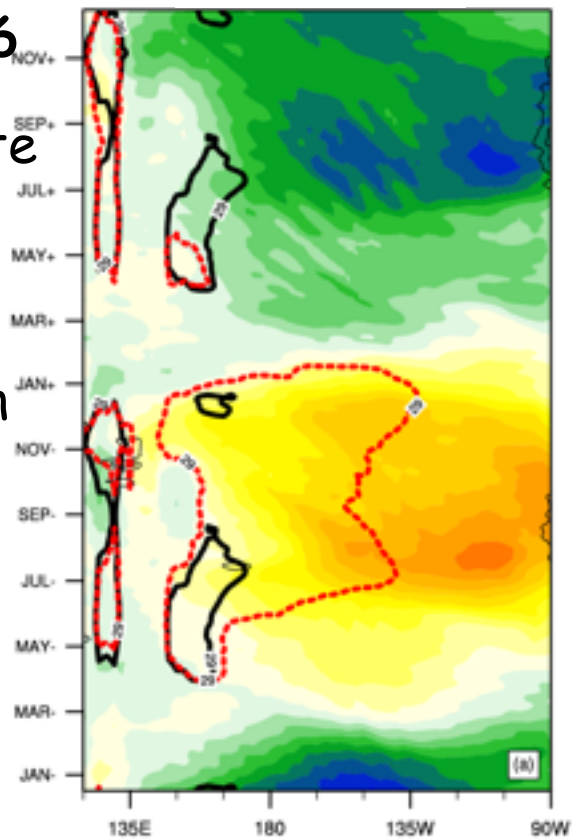
Absolute surface Westerlies (daily data) are the key

Year 85/86

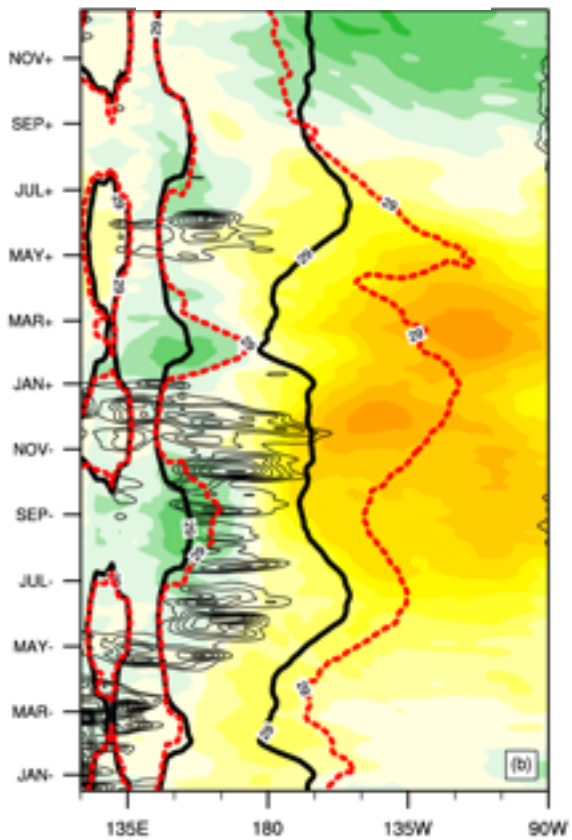
-No absolute westerlies

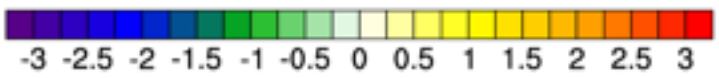
-No propagation

CCSM3



CCSM4





SSTA (K)

Year 95/96

-Absolute westerlies

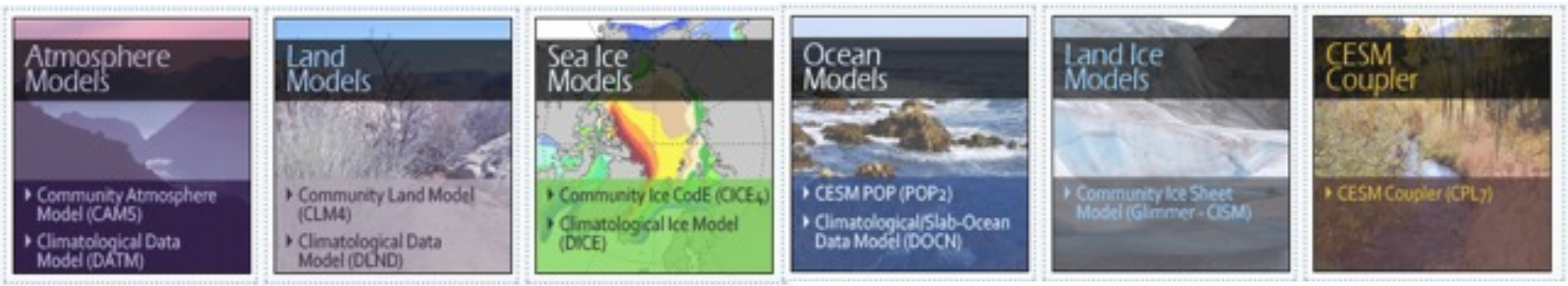
-Eastward propagation

-Indications of initiation and maintenance

Community Earth System Model

- April 1, 2010: **CCSM4.0 release**
  - ✓ CAM4 deep convection modifications (Neale et al. 2011)
  - ✓ Update surface models (ice, land, ocean)

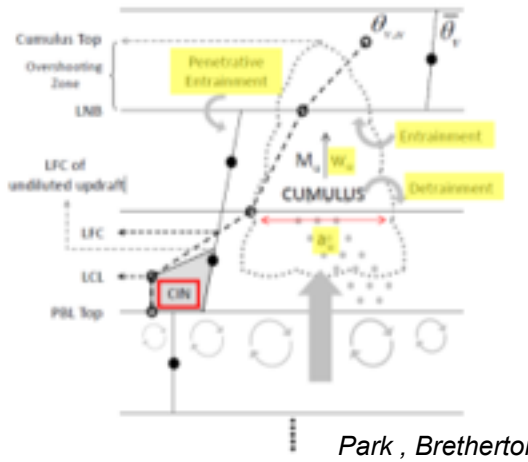
- June 25, 2010: **CESM1.0 release**
  - ✓ Ocean ecosystem, interactive chemistry, WACCM, land ice, and CAM5.0 (Rasch et al 2011)



http://www.cesm.ucar.edu/models/

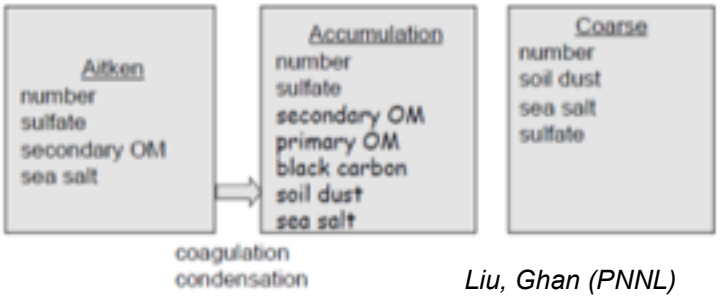
CAM5: Physics Changes
Cloud-aerosol interaction focus

UW PBL and shallow cumulus



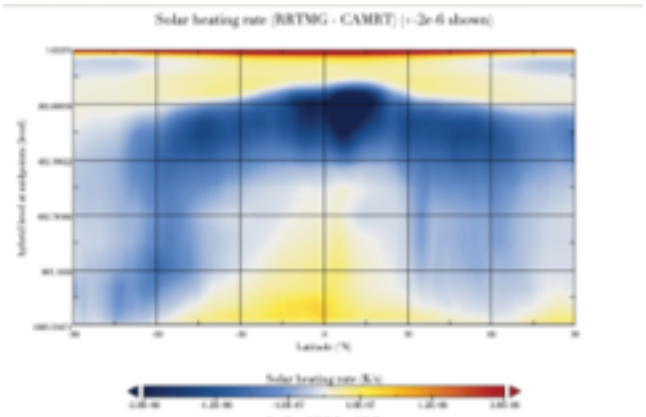
Park , Bretherton (UW)

3-mode Modal Aerosol Model (MAM)



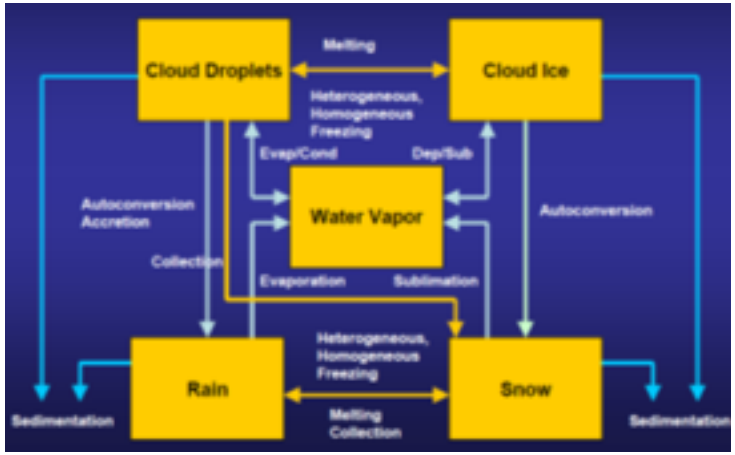
Liu, Ghan (PNNL)

Rapid Radiative Transfer Model (RRTM)



Iacono (AER), Conley (NCAR), Collins (UCB)

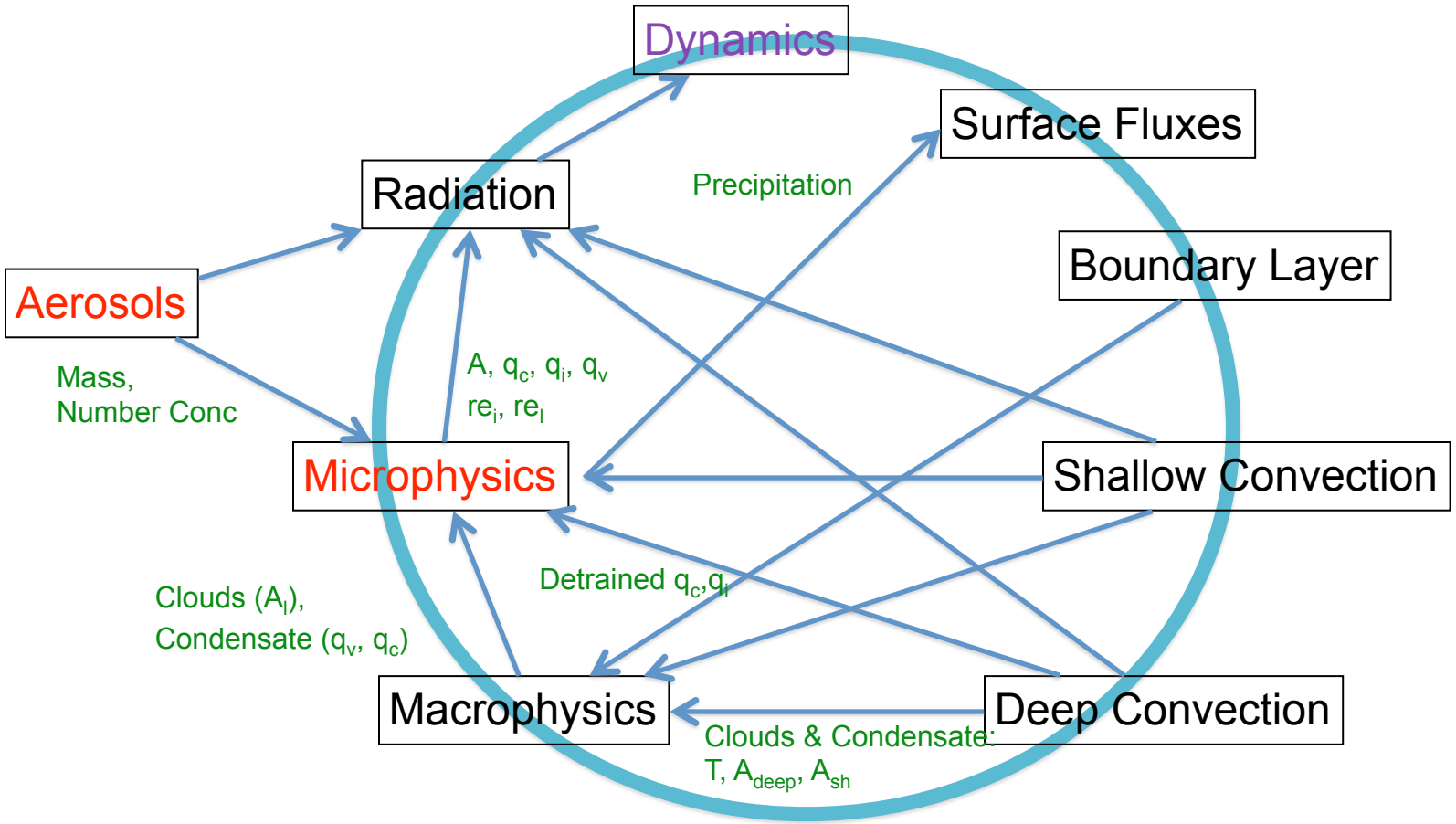
2-moment microphysics + ice cloud



Morrison, Gettleman (NCAR)

Physical process interaction in a GCM

Community Atmosphere Model (CAM) Version 5



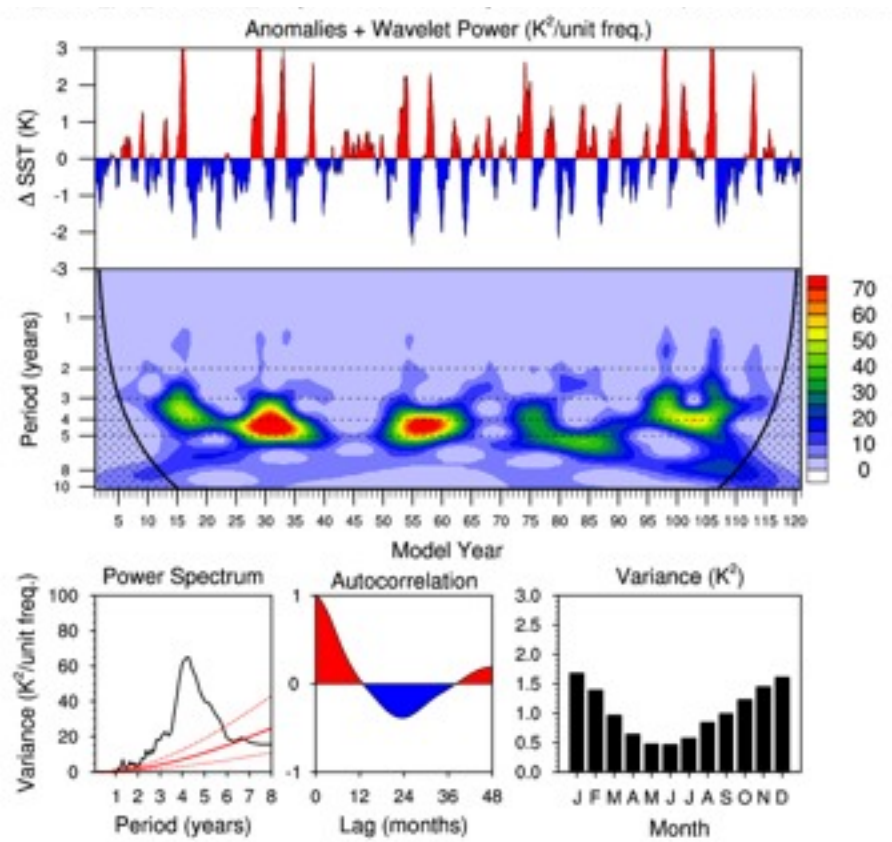
A = cloud fraction, q=H_2O, re=effective radius (size), T=temperature

(i)ce, (l)iquid, (v)apor

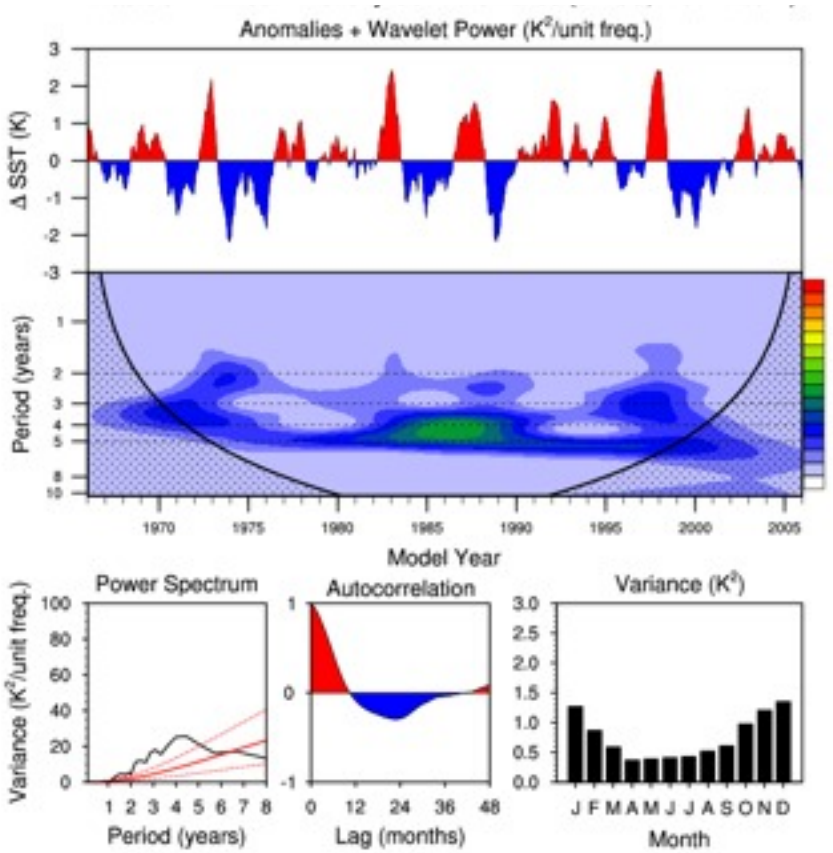
CAM5: Reduced Amplitude ENSO

How robust is this?
How easy is to diagnose?

CESM1(CAM5)

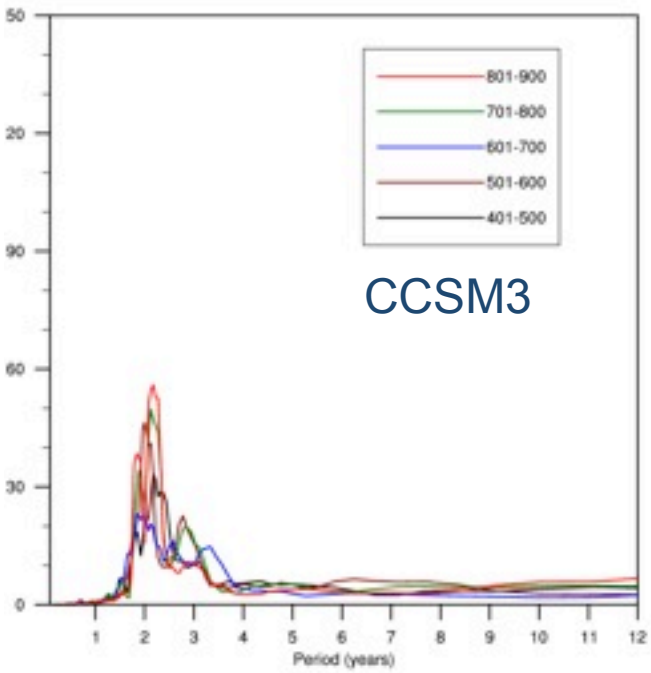


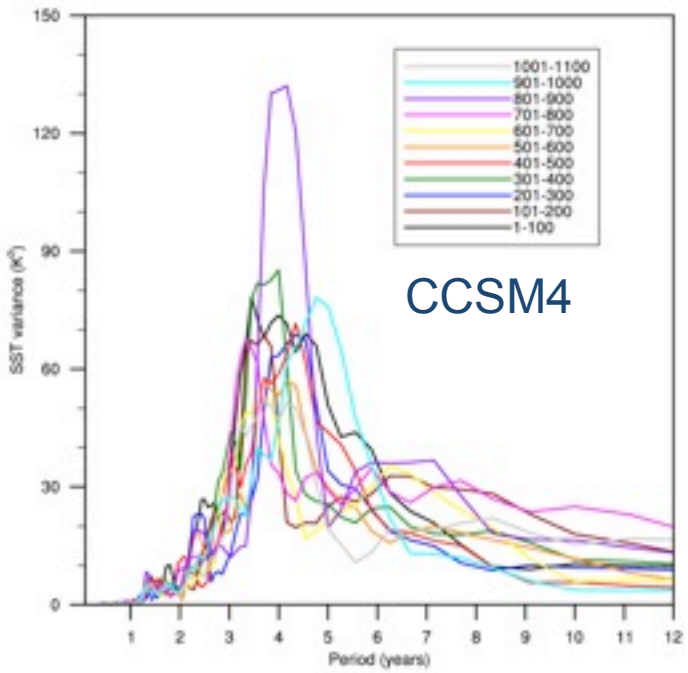
Observed (Reynolds)



Remaining ENSO Challenges

Understanding amplitude variance



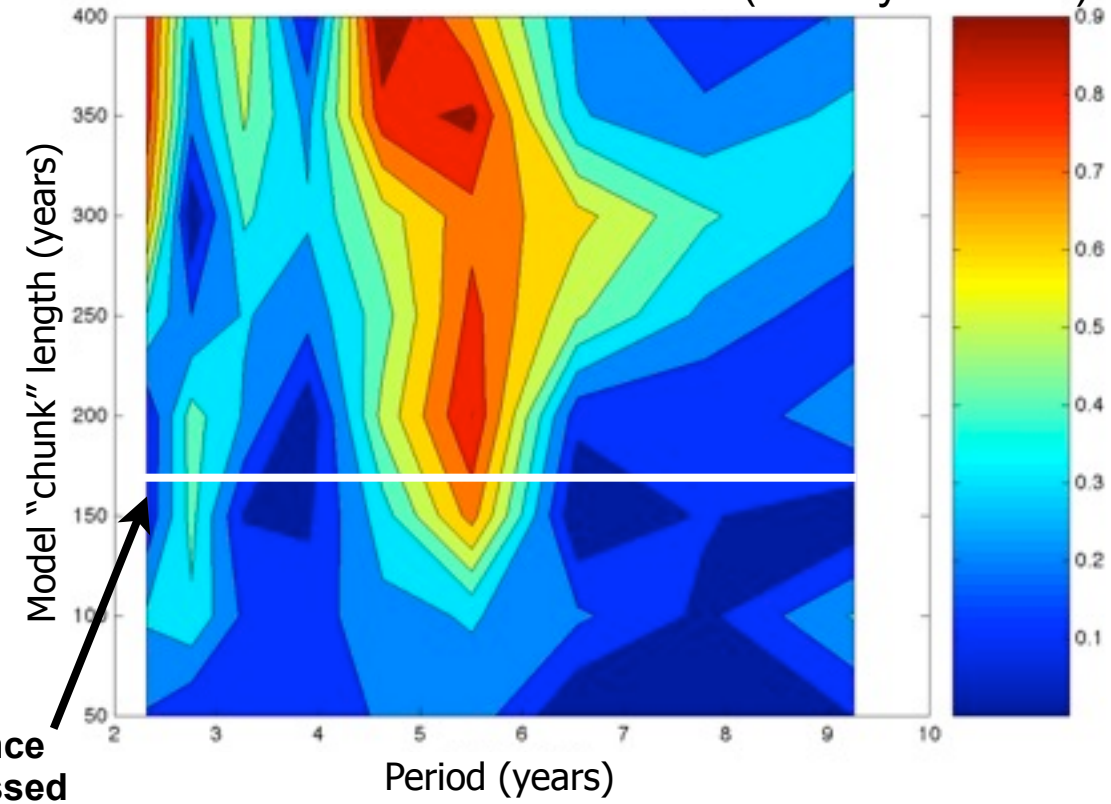


- ✓CCSM4 was a significant improvement in terms of ENSO phase
- ✓However, there is significant inter-centennial variations in amplitude
- ✓Only 100 years or so (really <50 yrs!) of good SST observations
- ✓Difficult to capture “typical” model variability in a couple of centuries

Remaining ENSO Challenges

Understanding amplitude variance

NINO4 SST: 1990 vs. ~2030AD (1000 yr control)



1: different
0: same

90% significance threshold crossed

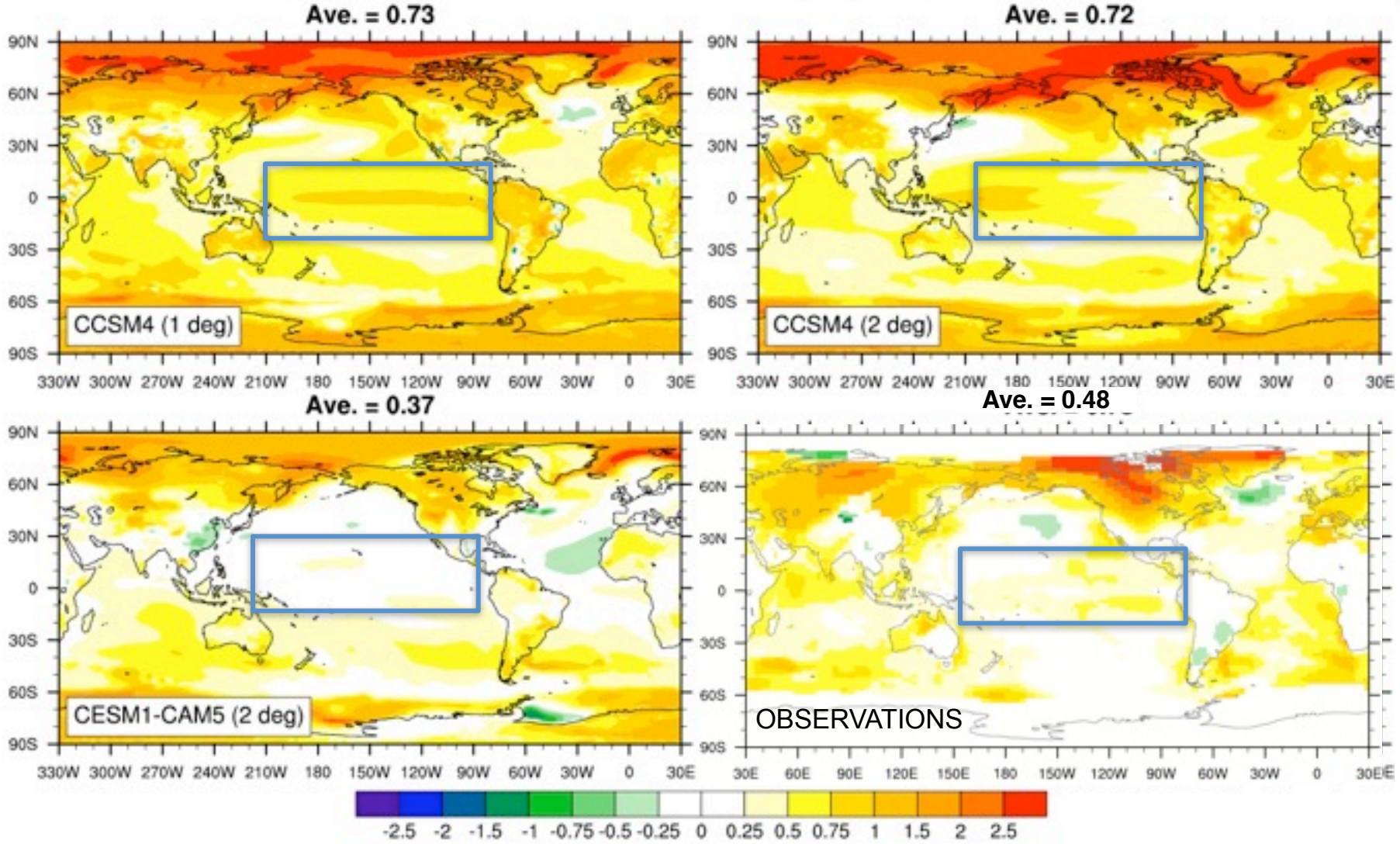
Stevenson et al. (2010) J. Clim.
Stevenson et al. (2011), in prep.

✓ Tests of statistical significance for NINO4 SST time series for CCSM3.5 355 vs. 455 ppm CO2: >150 years of model time needed

✓ Similar results are expected for CCSM4

Changing Model Response

New physics in CAM5 leads to changing response in Pacific



Weaker 20th C warming in CESM1.0 (CAM5) – ENSO region?

Summary

The role of increased variance from the atmosphere

✓Large impact of changes to convection parameterization (CCSM4)
✓Explicit linkage from moisture sensitivity to the dynamics

Multi-scale impacts

✓CCSM4 major improvements to ENSO
- ✓Local impacts (extreme events, diurnal cycle)
- ✓Variability impacts (tropical waves, MJO)
- ✓Interannual impacts (El Nino and global teleconnections)

Future Challenges

✓How do we deal with the long time-scale variability in ENSO magnitude?
✓Diagnosing the changing nature of future climate and ENSO due to additional physical interactions

Thankyou!

Questions: Rich Neale (rneale@ucar.edu)