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NESL

CAM4/CCSM4 Overview and Simulations

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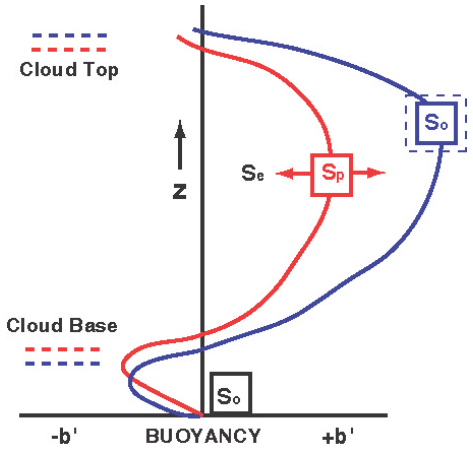
Community Earth System Model

CESM

CAM Evolution

Model	CCSM3 *(2004)*	CCSM3.5 *(2007)*	CCSM4 *(Apr 2010)*
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4 (L26)
Boundary Layer	Holtslag and Boville (93)	Holtslag and Boville	Holtslag and Boville
Shallow Convection	Hack (94)	Hack	Hack
Deep Convection	Zhang and McFarlane (95)	Zhang and McFarlane Neale et al.(08), Richter and Rasch (08) mods.	Zhang and McFarlane Neale et al., Richter and Rasch mods.
Stratiform Cloud	Rasch and Kristjansson (98) *Single Moment*	Rasch and K. *Single Moment*	Rasch and K. *Single Moment*
Radiation	CAMRT (01)	CAMRT	CAMRT
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume HOMME
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2
Land	CLM3	CLM3.5	CLM4 – *CN*
Sea Ice	CSIM4	CSIM4	CICE

CAM3 -> CAM4: Physics Changes

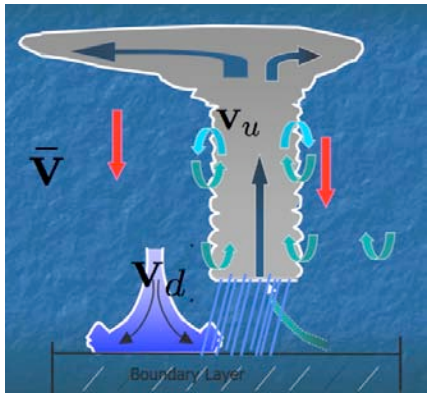


Convection Dilution

✓Reduced sensitivity to surface temp

✓Increase sensitivity to atmos. humidity

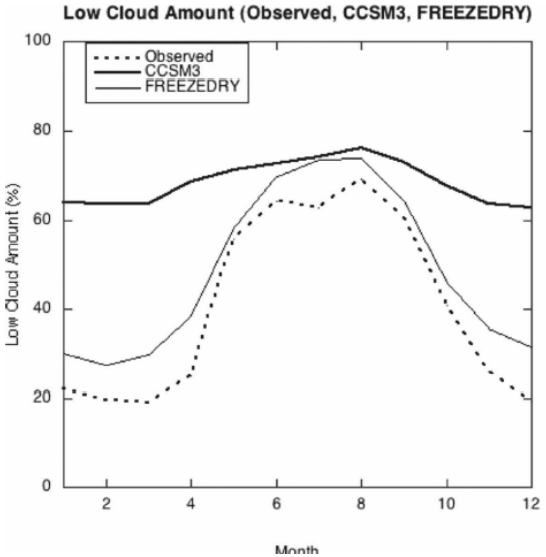
Neale et al. (2008)



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*

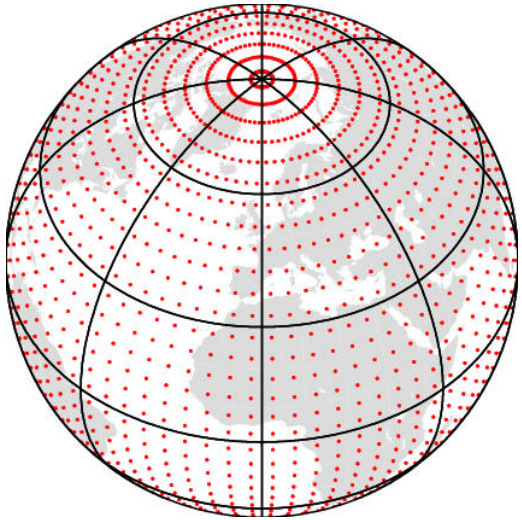
✓Reduce excessive winter-time polar low cloud

Vavrus and Waliser (2008)

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

CAM3 -> CAM4: Dynamics Changes

Default: Finite Volume (FV)



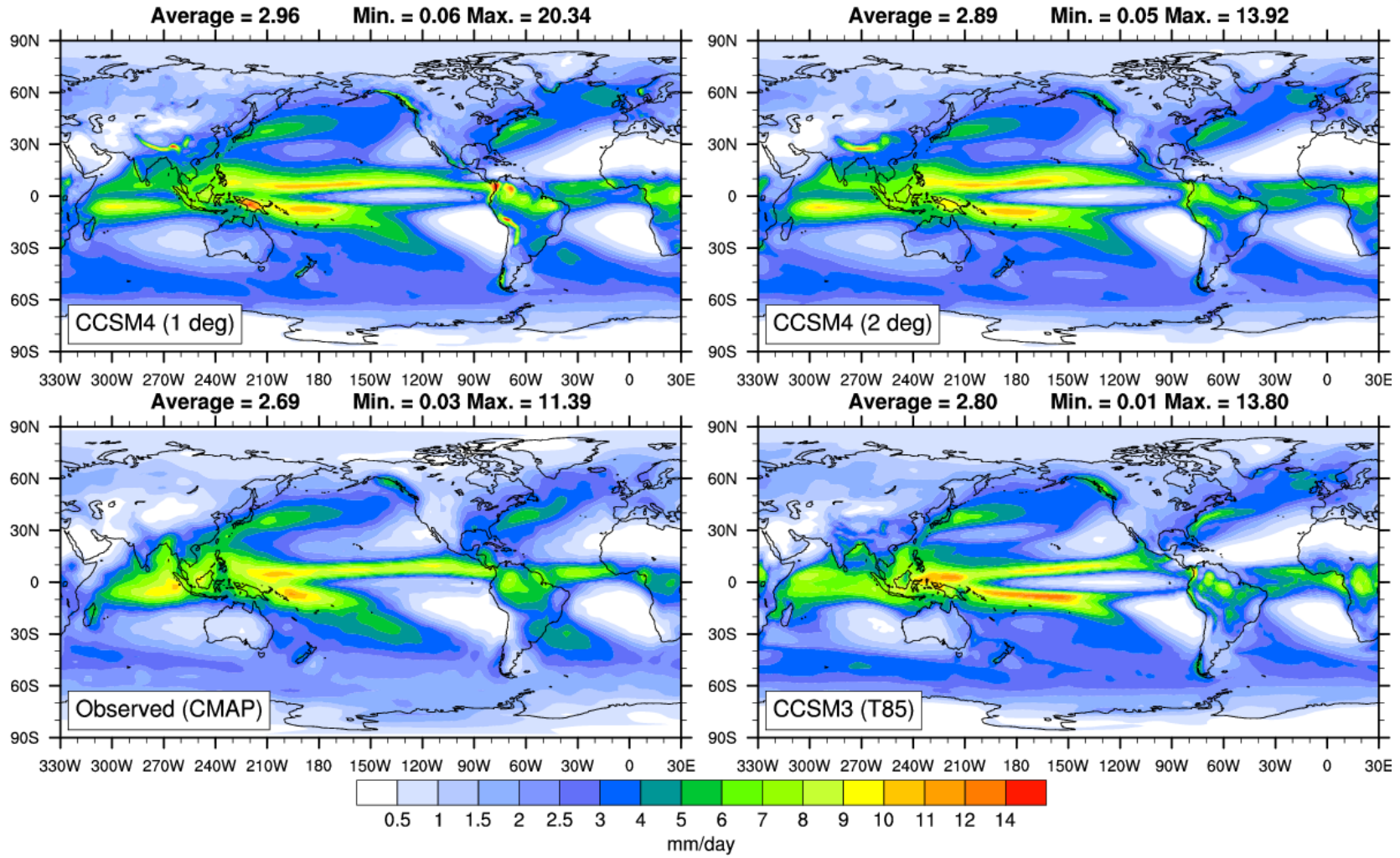
- ✓Lat-lon grid
- ✓Scaling limitations
- ✓Conserves mass and total energy
- ✓Conservative and monotonic 2D transport scheme

Option: HOMME-Spectral Element

Mark Taylor, DOE, NCAR-CISL

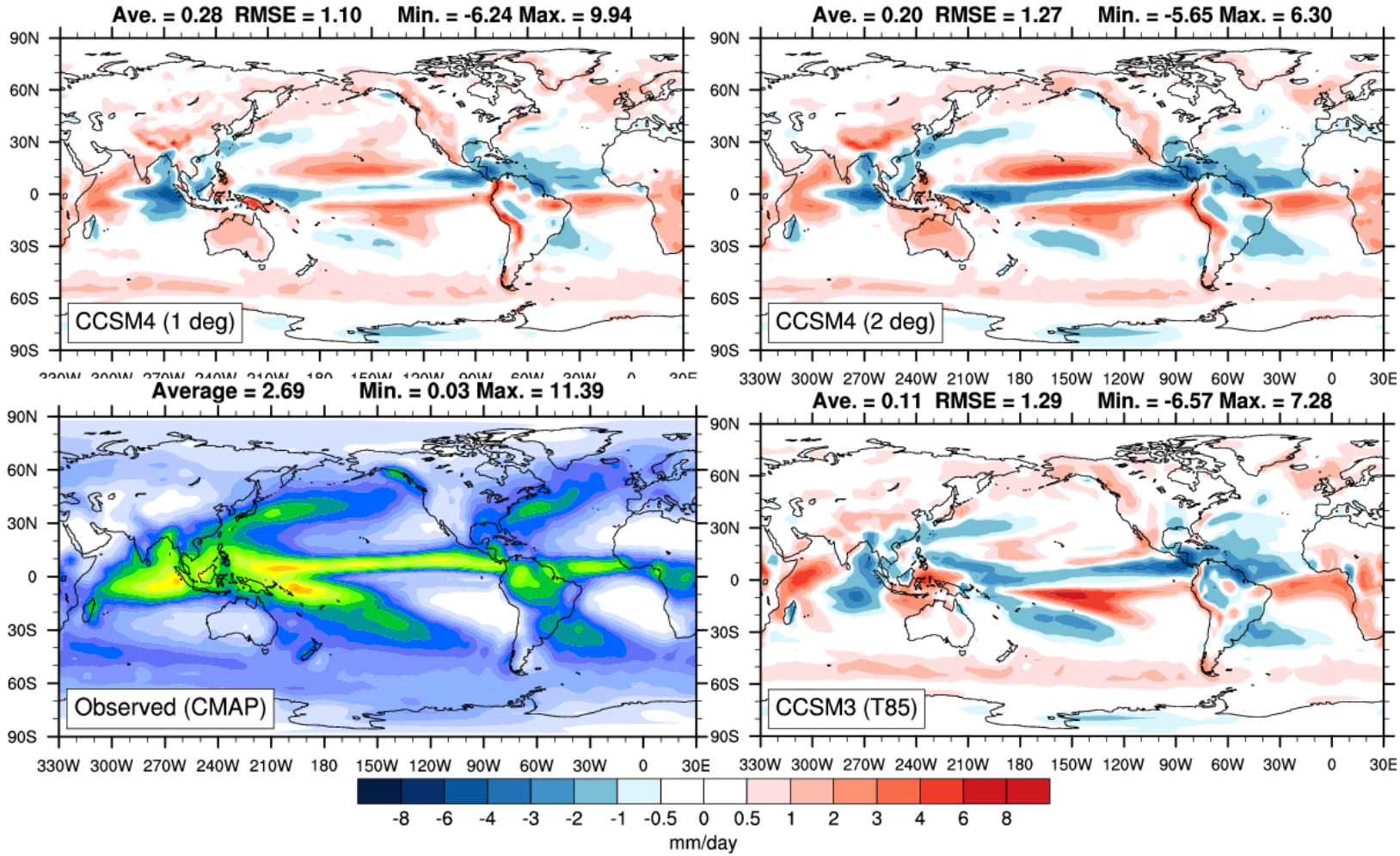
- ✓Unstructured grid (cubed sphere)
- ✓Highly scalable
- ✓Locally conserves mass and moist energy
- ✓Tracer advection modeled on FV core
- ✓Advection modeled on Eulerian core

Annual Precipitation



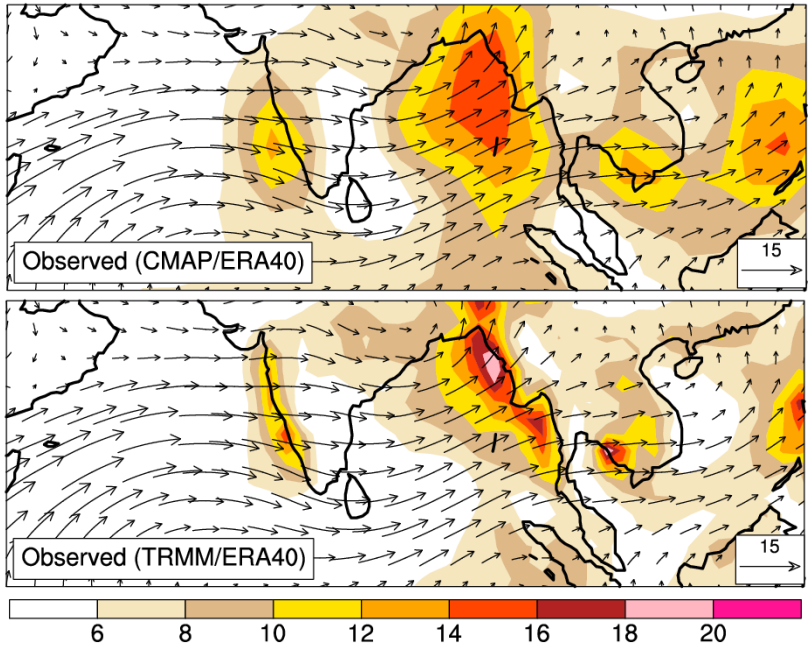
20th Century Coupled Experiments (average 1970-1999)
Observed (CMAP, average 1979-1998)

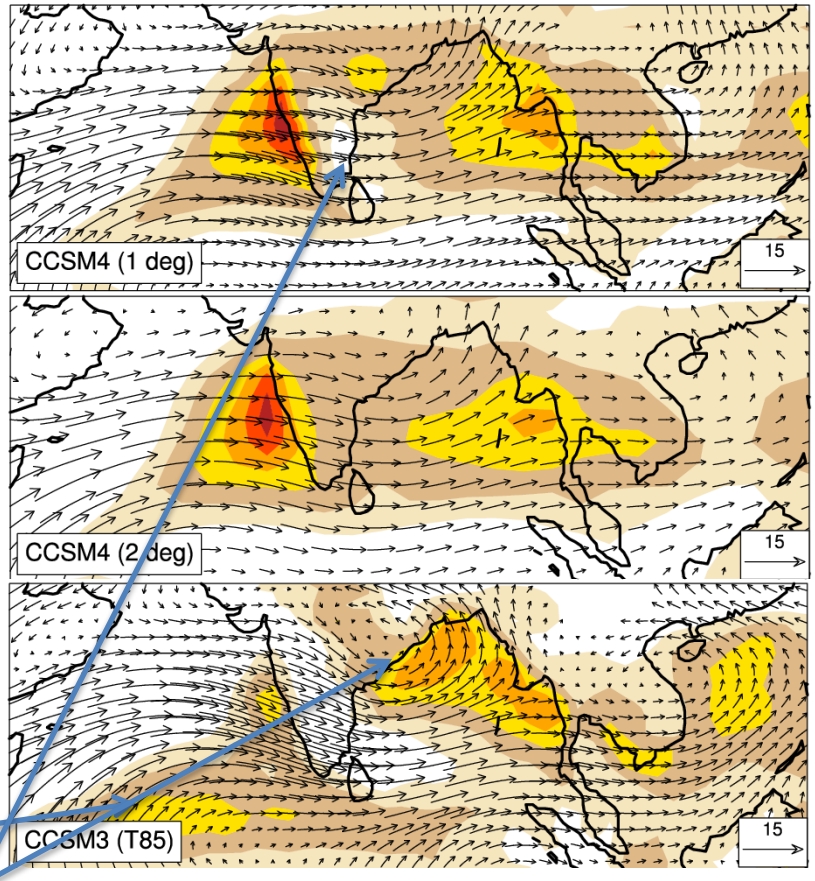
Annual Precipitation Biases



20th Century Coupled Experiments (average 1970-1999)
Observed (CMAP, average 1979-1998)

Indian/Asian Monsoon

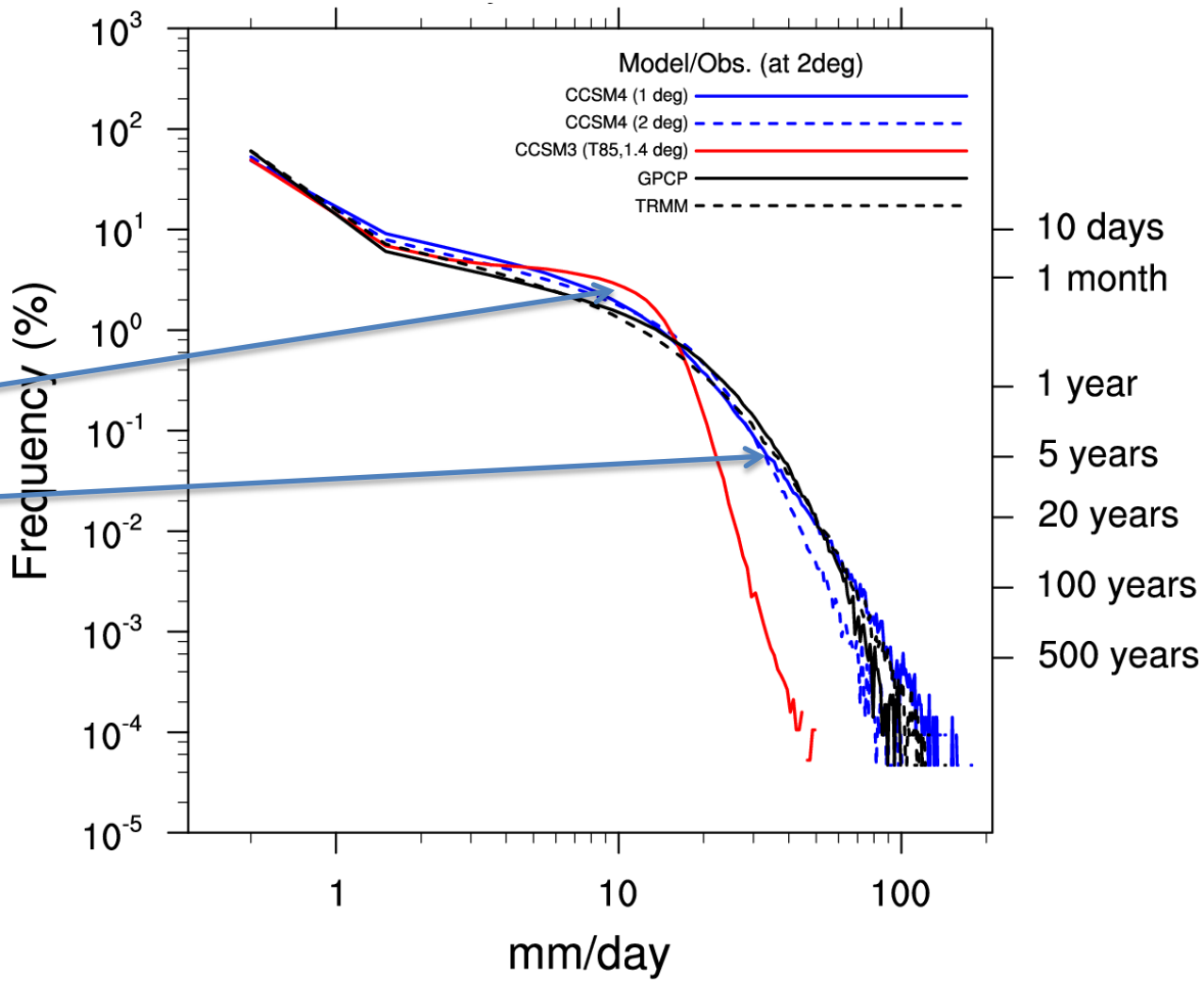




1970-1999
JJAS Average Rainfall
JJAS 850-mb winds
✓Break phase improved
✓North east Indian cycle improved
✓Higher resolution better captures orographic features (inc Indian rain shadow)

Tropical Land Precipitation PDF

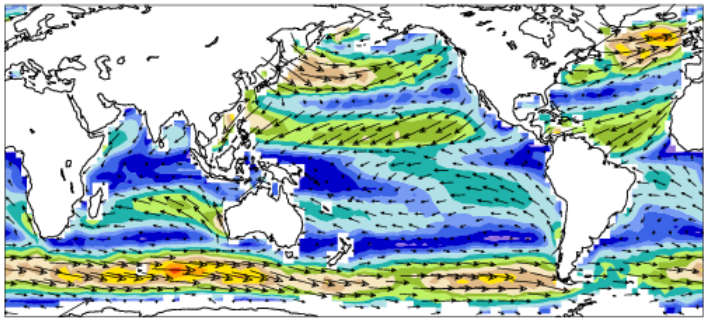
Daily rainfall averages
-20N-20S land regions
-All interpolated to 2 deg
-Model (1990-1999)
-Obs. (1998-2007)
-Reduction in moderate rainfall events
-Mean return period events of ~6 months(>25 mm/day) and greater are better reproduced
-Implications for future extreme event changes



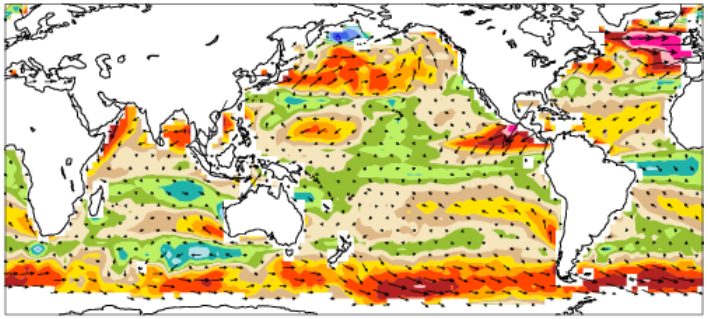
Global Surface Stress Improvements

DJF Surface Stress (1970-1999)
Direction (vectors) strength (colors)

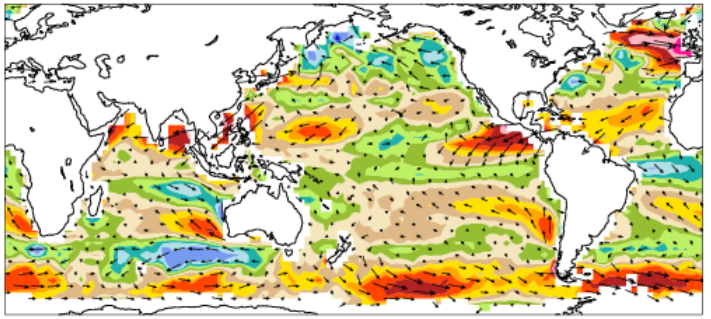
- ✓Reduced trade-wind biases (CMT)
- ✓Reduced Atlantic low strength (CCSM4, 1deg)
- ✓Greatest improvements come from including turbulent mountain drag (TMS) formulation



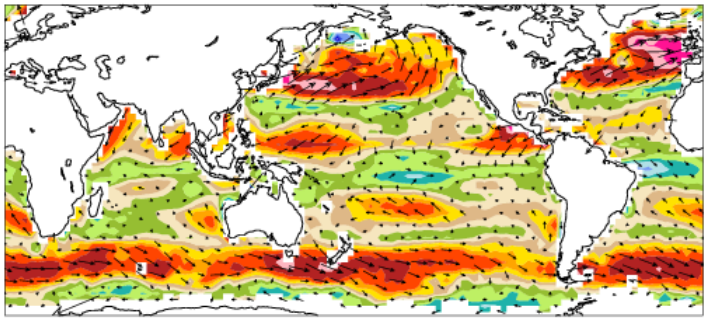
ERS



CCSM4 (1 deg)



CCSM4 (2 deg)

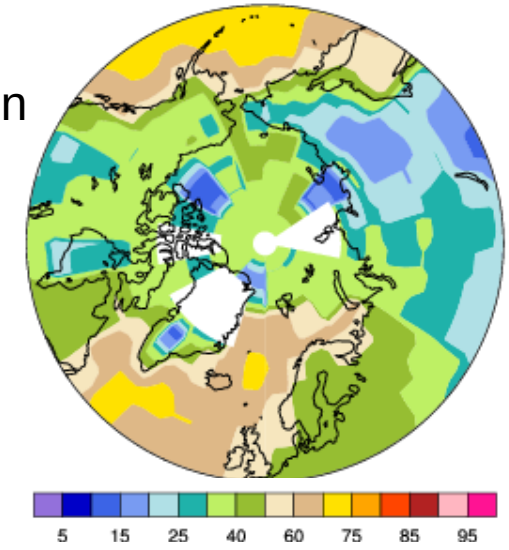


CCSM3 (T85)

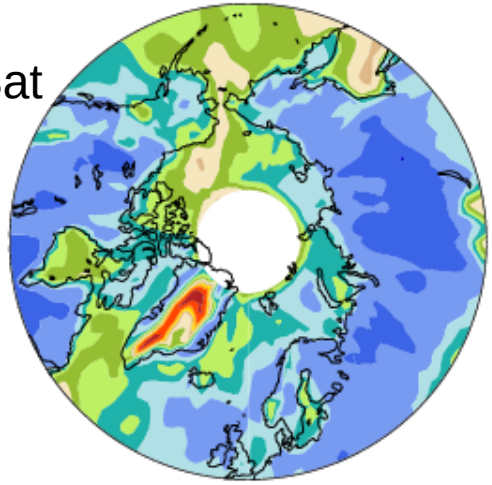
Polar Low-Cloud Improvements

Late 20th Century

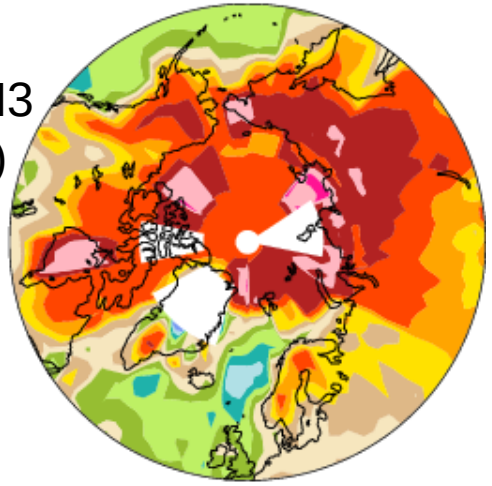
Warren



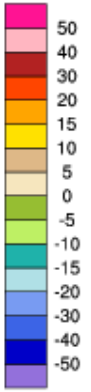
CloudSat



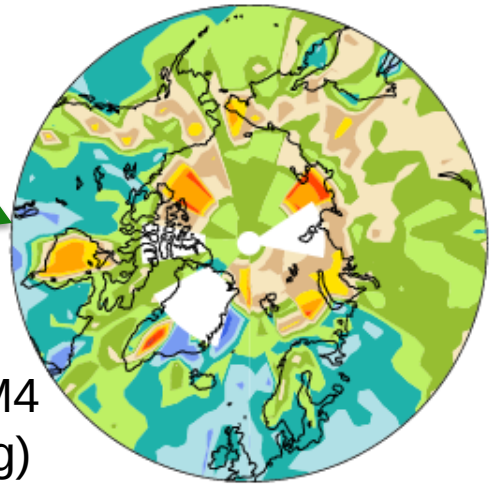
CCSM3
(T85)



Annual Polar
Cloud
Fraction (%)



Freeze-drying

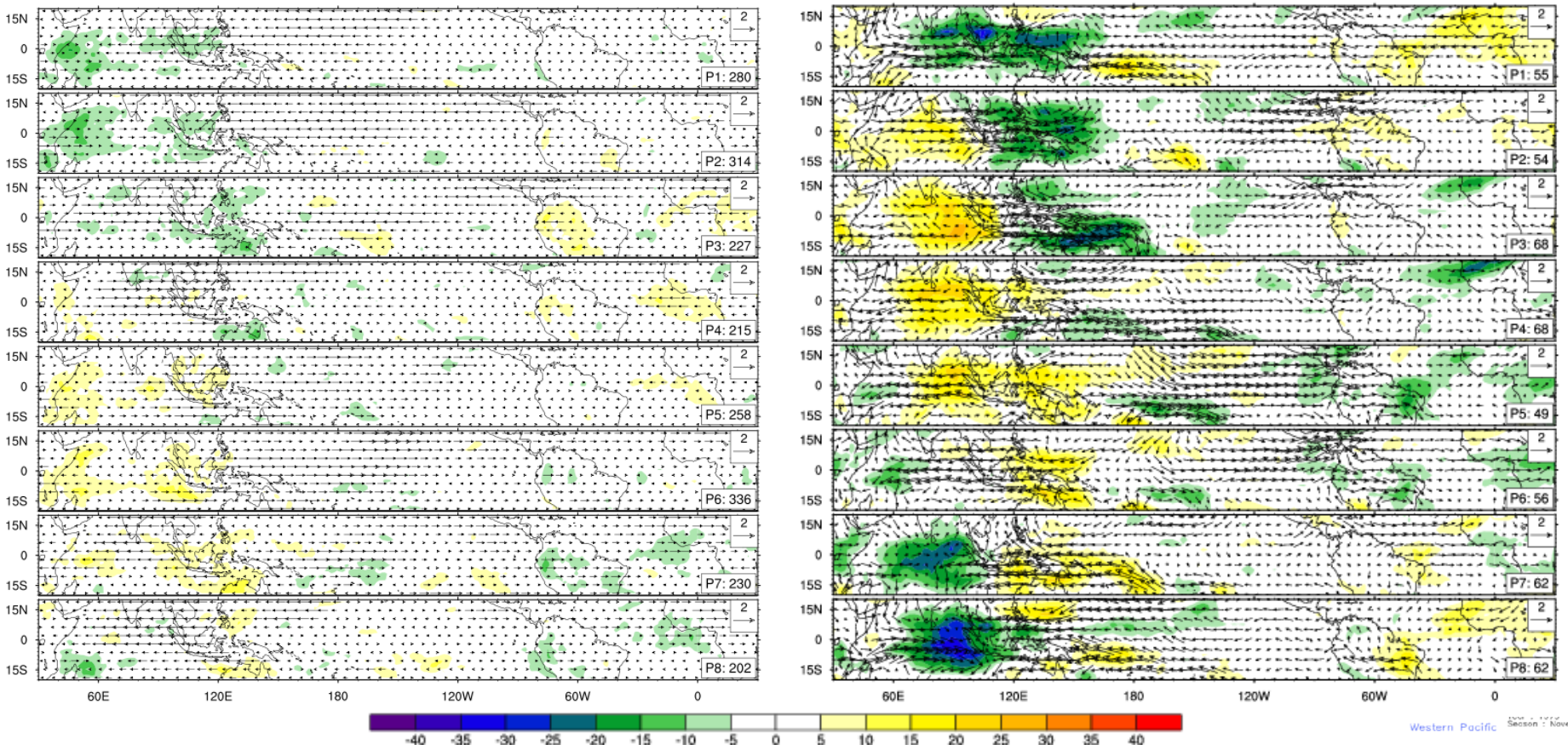


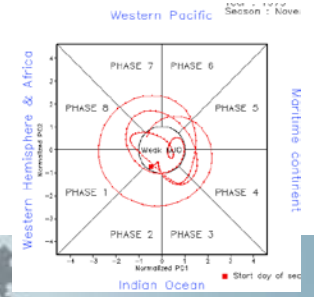
CCSM4
(1 deg)

Composite Madden Julian Oscillation (MJO)

CCSM3-T85 (1980-1999)

Observed (NOAA,ERA40,1995-1999)



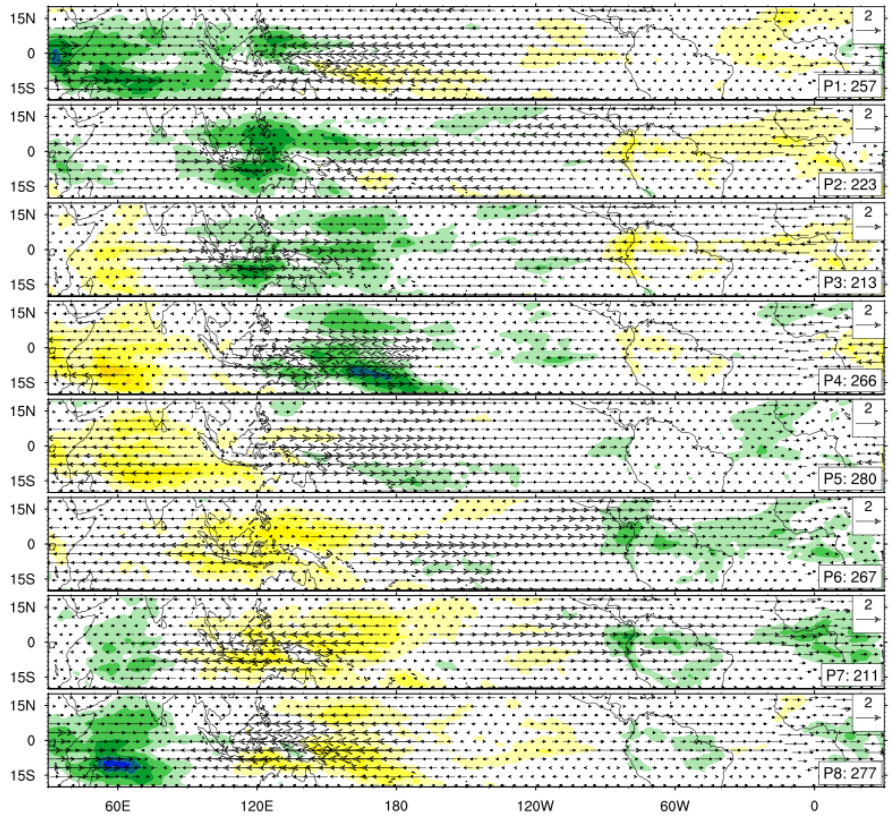


Eight phase composite of PC1 and PC2 from combined EOFs.
20th Century coupled experiments

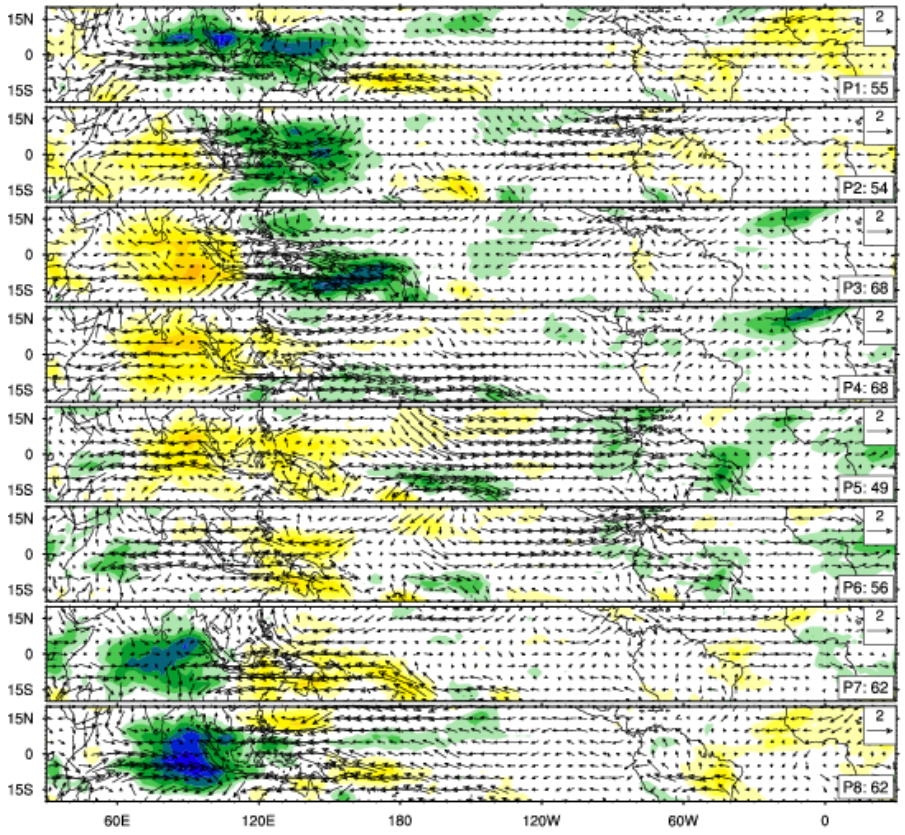
Community Earth System Model

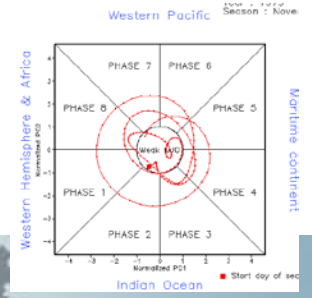
Composite Madden Julian Oscillation (MJO)

CCSM4-1 deg (1980-1999)



Observed (NOAA,ERA40,1995-1999)

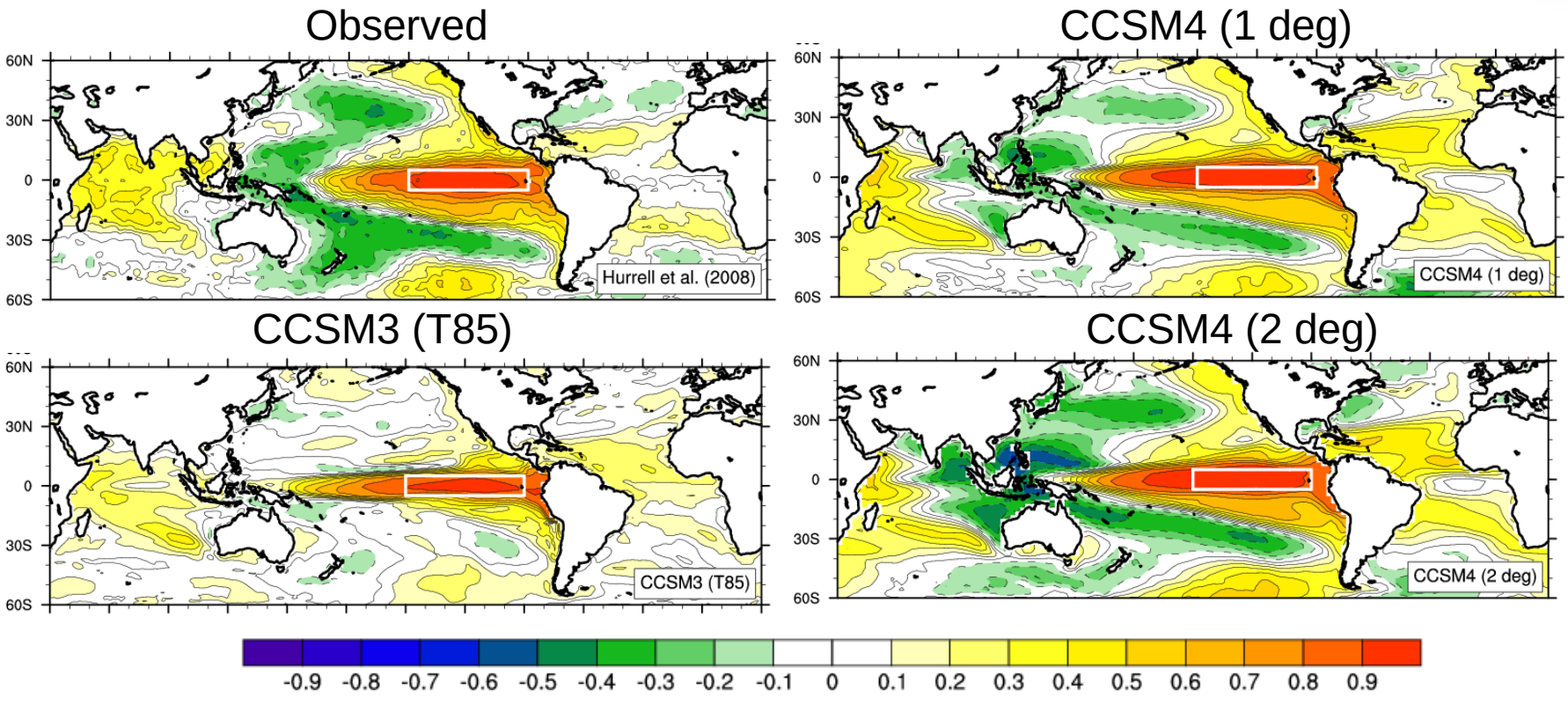




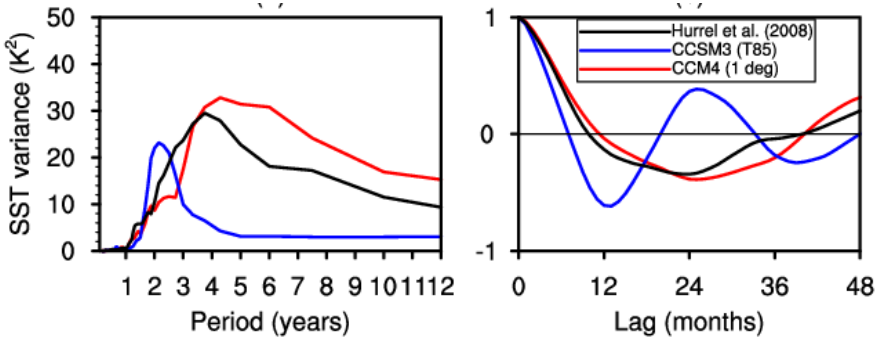
Eight phase composite of PC1 and PC2 from combined EOFs.
20th Century coupled experiments

Community Earth System Model

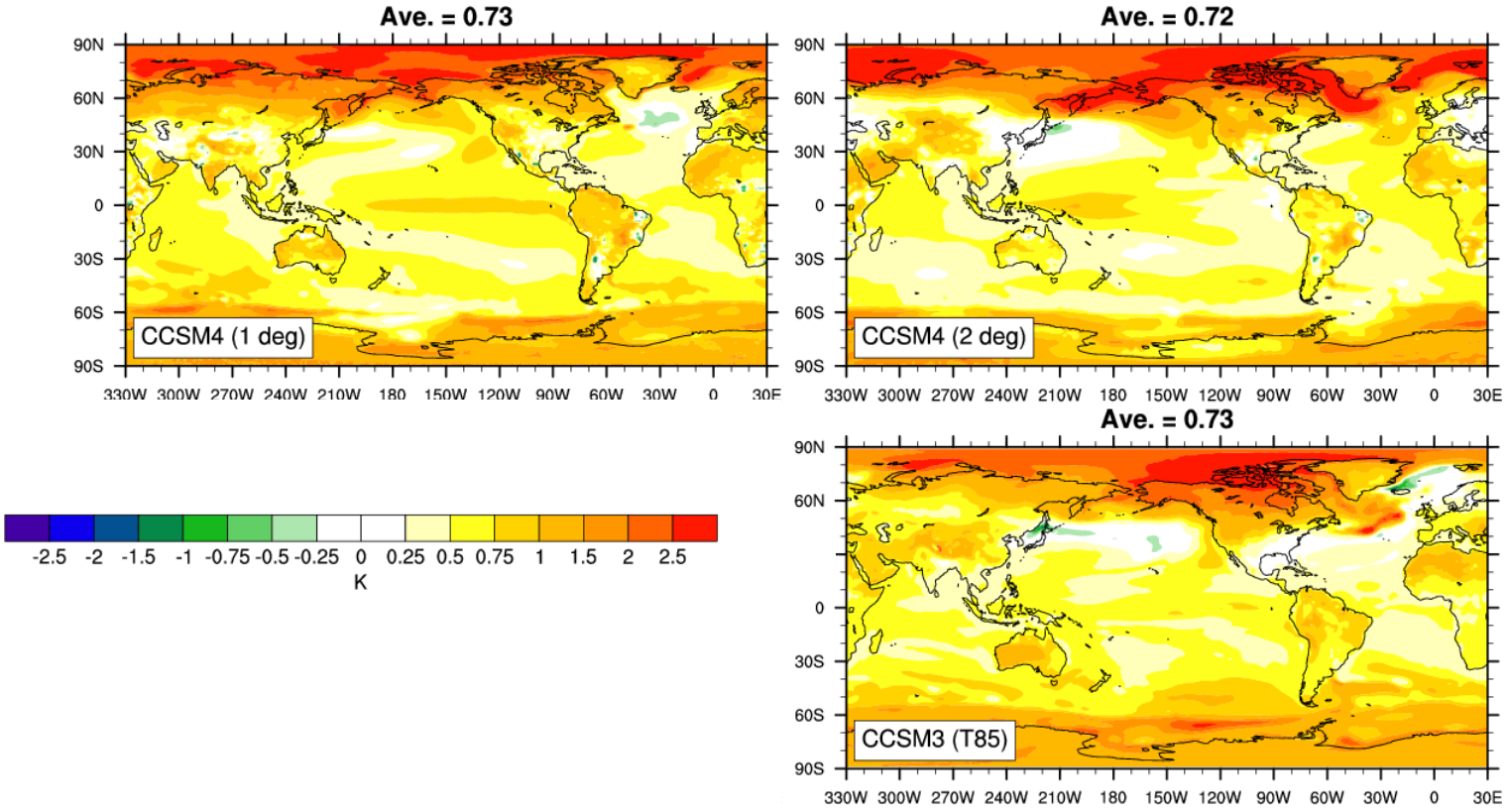
Global ENSO Response



Zero-lag correlation of nino3 SST anomalies (white box) with global SST anomalies. 20th Century simulations (1900-1999)

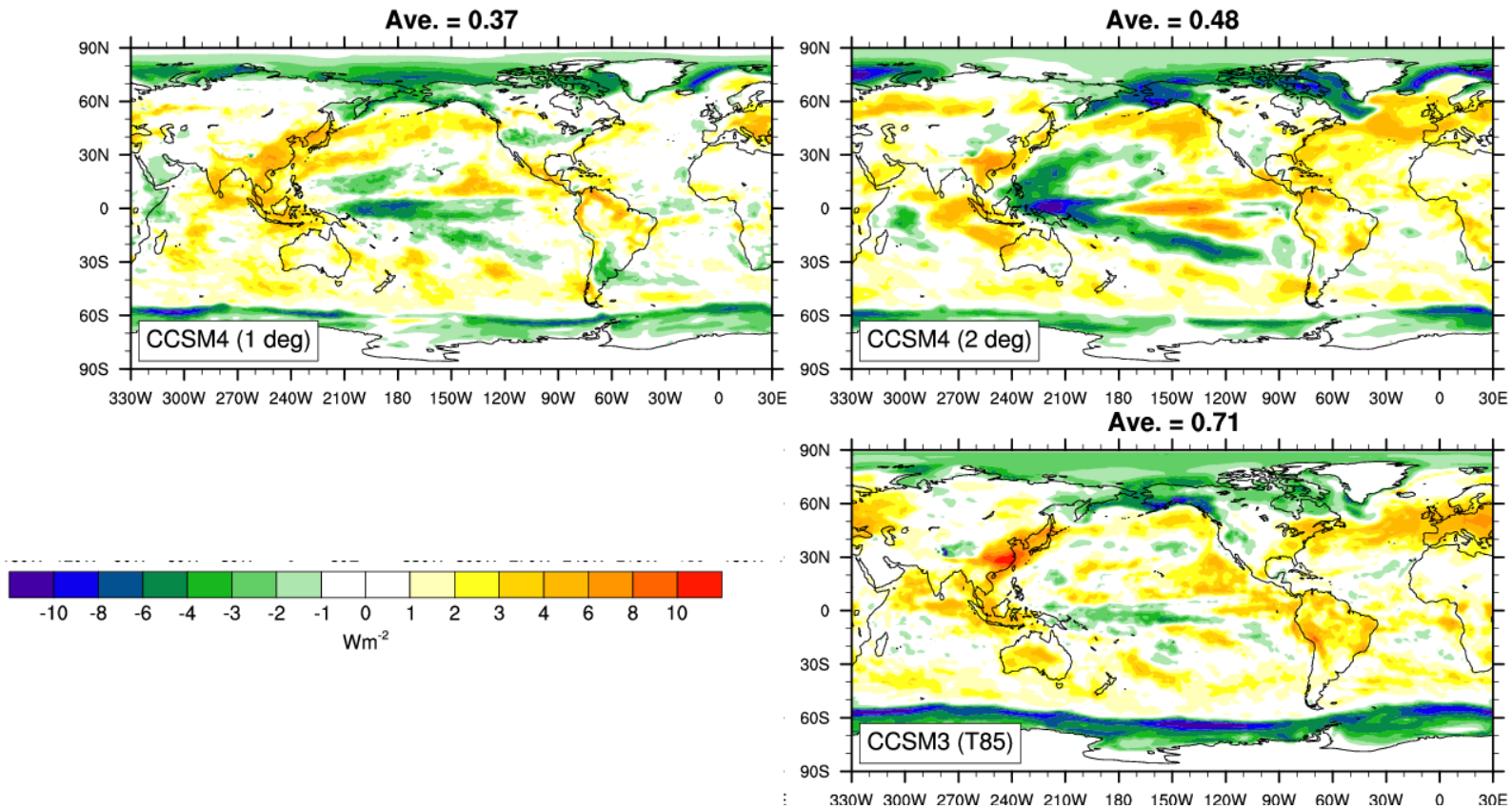


20th Century Climate Change



Surface temperature changes over the 20th Century (1970-1999 minus 1850)
CCSM3 and CCSM4: warming somewhat strong
CESM1-CAM5: warming somewhat weak

20th Century Climate Change

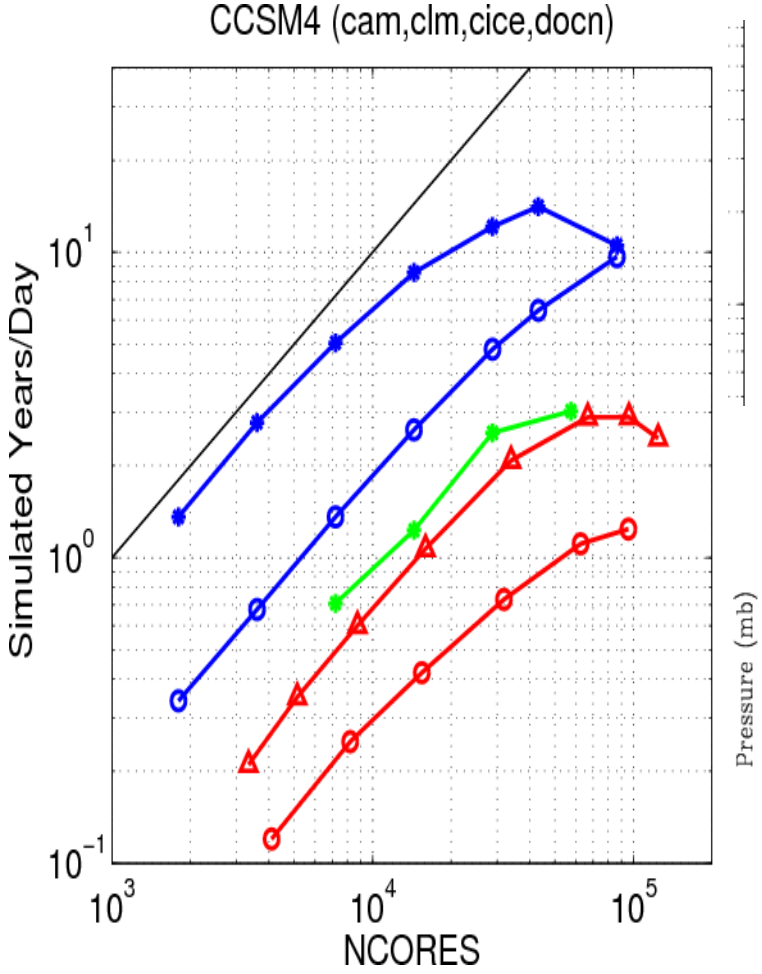


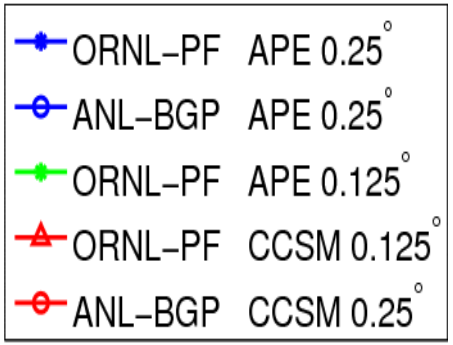
Short wave cloud forcing over the 20th Century (1970-1999 minus 1850)
CCSM3 and CCSM4: low-cloud feedbacks are positive (warming)
Amplified signals at 1 deg. compared to 2 deg.

CAM/HOMME Dycore

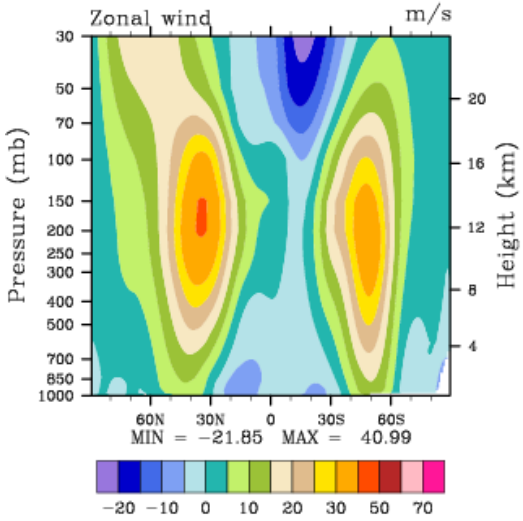
Cubed-sphere grid overcomes dynamical core scalability problems inherent with lat/lon grid

Work of Mark Taylor (SciDAC), Jim Edwards (IBM), Brian Eaton(CSEG)

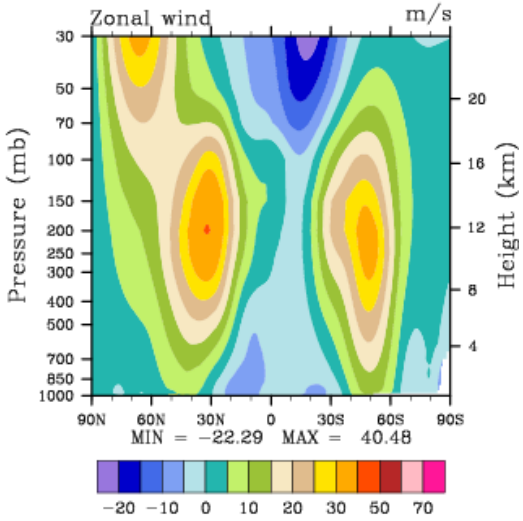




CAM4-HOMME (1 deg)



CAM4-FV (1 deg)



CAM4/CCSM4 Summary

✓CAM4 major component changes

a. Convective momentum transports
b. Convective buoyant parcel dilution
c. ‘Freeze drying’ of polar low-cloud
d. Finite volume dynamical core
e. Option of HOMME spectral-element dynamical core

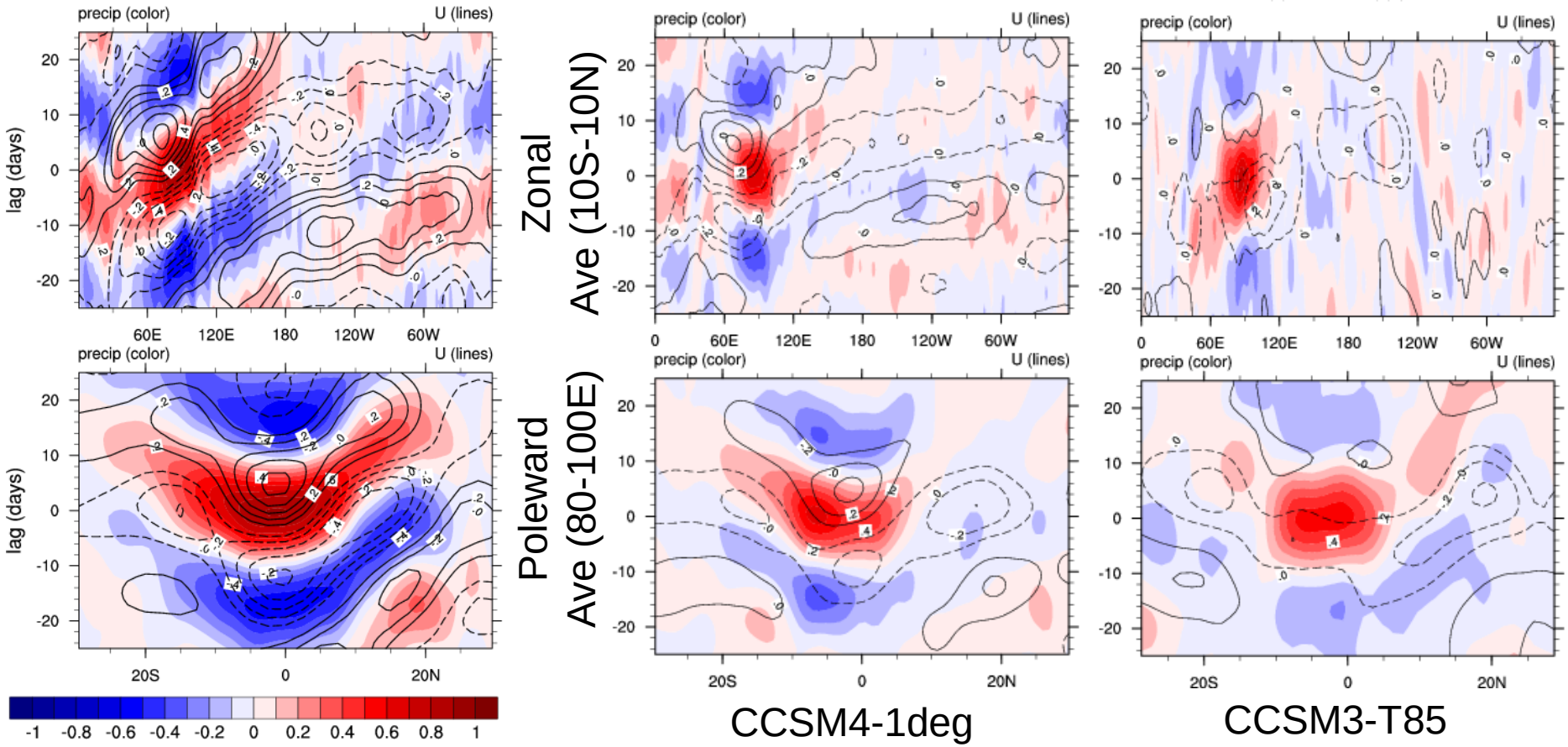
✓ Translates to mostly tropical atmosphere climate improvements

- ✓ Reduced strong bias in surface stresses (sub-tropical, mid-latitude)
- ✓ Improved mean precipitation simulation and local feature
- ✓ More frequent extreme precipitation events over land
- ✓ Stronger modes of tropical variability (esp. MJO)
- ✓ Reduced winter-time polar cloud excess
- ✓ Improved transport properties (WACCM, CAM-chem)

✓ More realistic coupled modes of variability

- ✓ El Nino period 2->3-5 years
- ✓ Realistic global teleconnection patterns

Intraseasonal Variability



Observed
(GPCP,ERA40)
1996-2005

CCSM4-1deg

CCSM3-T85

1990-1999

Lag correlation of 20-100 day band pass filtered precipitation and 850-mb zonal wind with 90E region (top) and equator (bottom)