The Madden Julian Oscillation (MJO) in CCSM4 and CESM1(CAM5)

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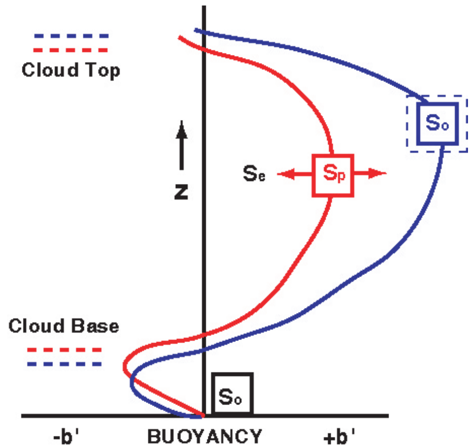
CAM Evolution

Model	**CCSM3** ***(2004)***	**CCSM3.5** ***(2007)***	**CCSM4** ***(Apr 2010)***	**CESM1(CAM5)** ***(Jun 2010)***
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4 (L26)	CAM5 (L30)
Boundary Layer	Holtslag and Boville (93)	Holtslag and Boville	Holtslag and Boville	UW *Diagnostic TKE* Park et al. (09)
Shallow Convection	Hack (94)	Hack	Hack	UW *TKE/CIN* Park et al. (09)
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.	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*	Morrison and Gettelman (08) *Double Moment* Park Macrophysics Park et al. (10)
Radiation	CAMRT (01)	CAMRT	CAMRT	RRTMG Iacono et al. (2008)
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Liu et al. (2011)
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume HOMME	Finite Volume HOMME
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2	POP2.2
Land	CLM3	CLM3.5	CLM4 – *CN*	CLM4
Sea Ice	CSIM4	CSIM4	CICE	CICE

CAM4: Physics Changes

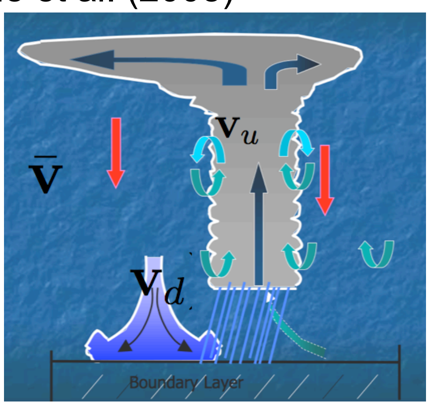


Convection Dilution

✓Reduced sensitivity to surface temp

✓Increase sensitivity to atmos. humidity

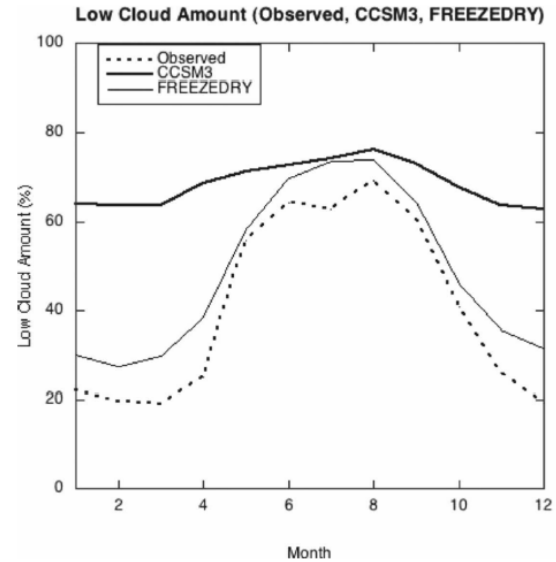
Neale et al. (2008)



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

Experiments and diagnostics

- ✓20 years (1980-1999) from a single 20th century coupled forcing experiment
    - CCSM4 (coupled) - 1 deg, L26 atmosphere/1 deg ocean
    - CCSM4 (coupled) - 2 deg, L26 atmosphere/1 deg ocean
    - CCSM3 (coupled) - T85 (~1.4deg), L26 atmosphere/1 deg ocean

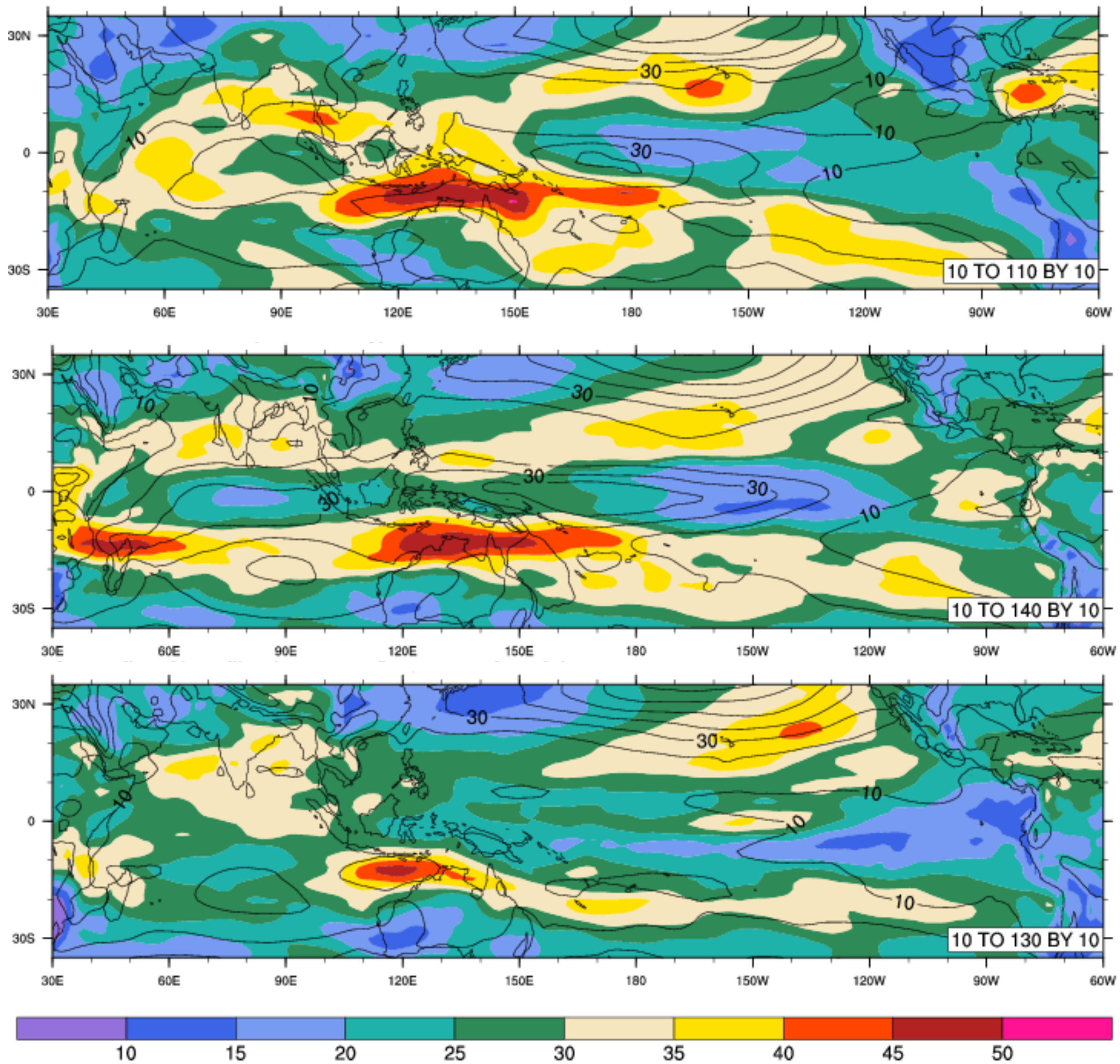
- ✓20 years (1980-1999) from a single AMIP prescribed SST experiments
    - CAM3 - 1 deg, L26 atmosphere
    - CAM4 - 1 deg, L26 atmosphere
    - CAM4 - 2 deg, L26 atmosphere
    - CAM5 - 2 deg, L30 atmosphere

- ✓Observations (daily means, 1990-1999)
    - NOAA OLR
    - NCEP winds
    - TRMM, GPCP precipitation

- ✓Diagnostics
    - Mostly using MJO-CLIVAR diagnostics package (Waliser et al. 2009, J. Clim)
      http://www.usclivar.org/mjo.php
    - NCL version available (analysis package being developed)
      http://www.ncl.ucar.edu/Applications/mjoclivar.shtml

Tropical Variance

U850mb: total variance (lines) ratio of band-pass to total (colors) – m^2s^{-2}



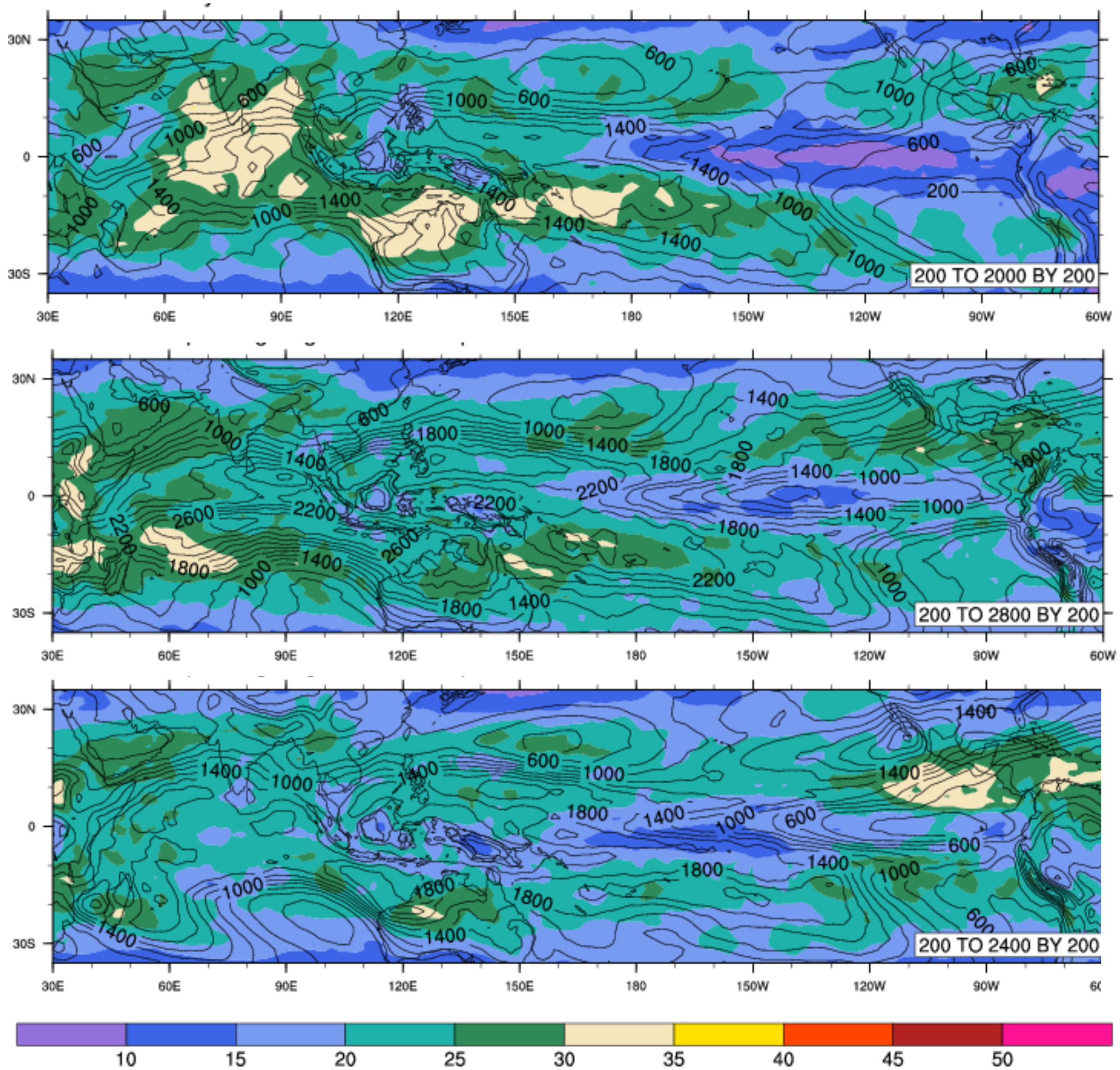
Observed

CCSM4 (1 deg)

CCSM (T85)

Tropical Variance

OLR: total daily variance (lines) ratio of band-pass to total (colors) – $(Wm^{-2})^2$



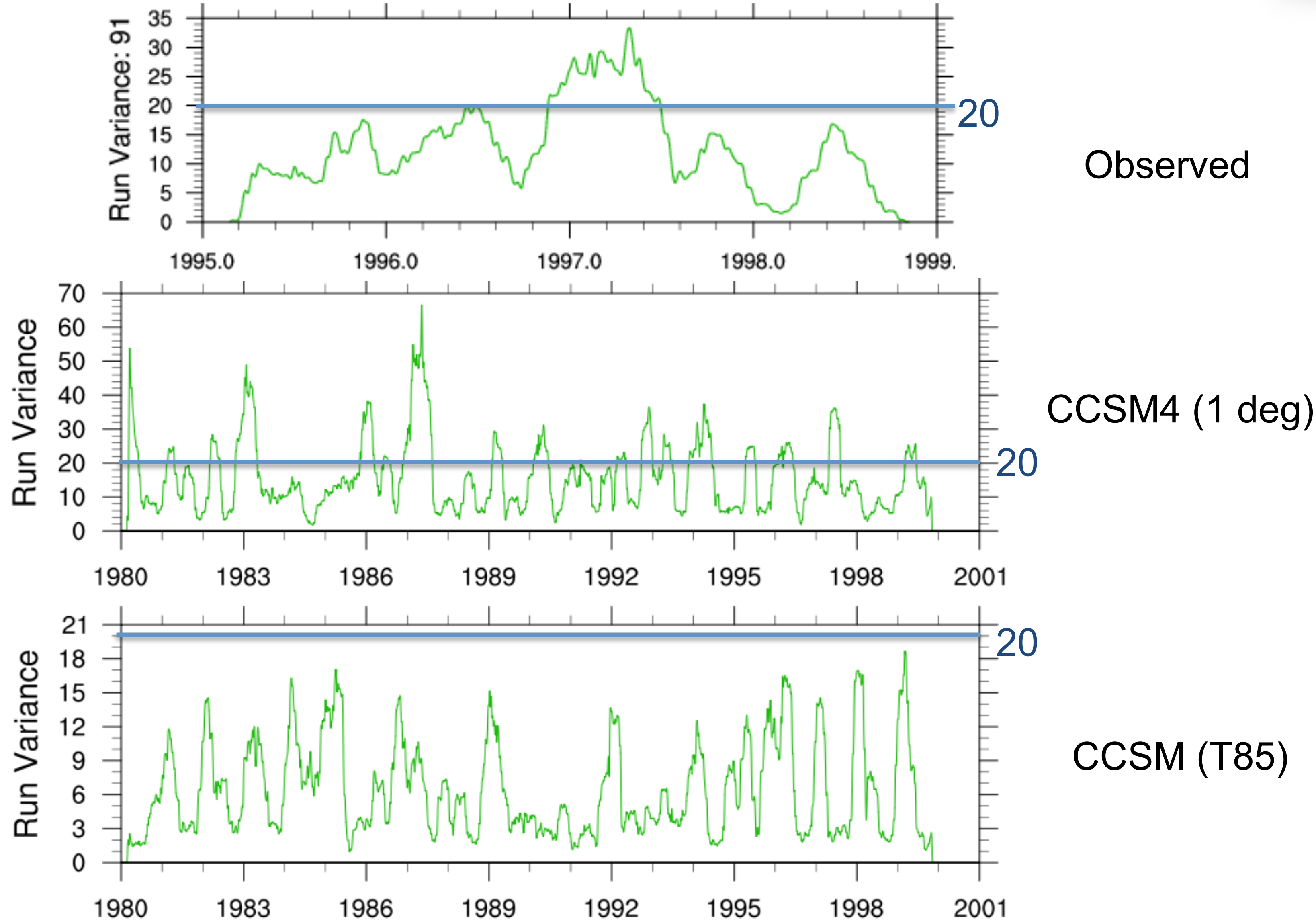
Observed

CCSM4 (1 deg)

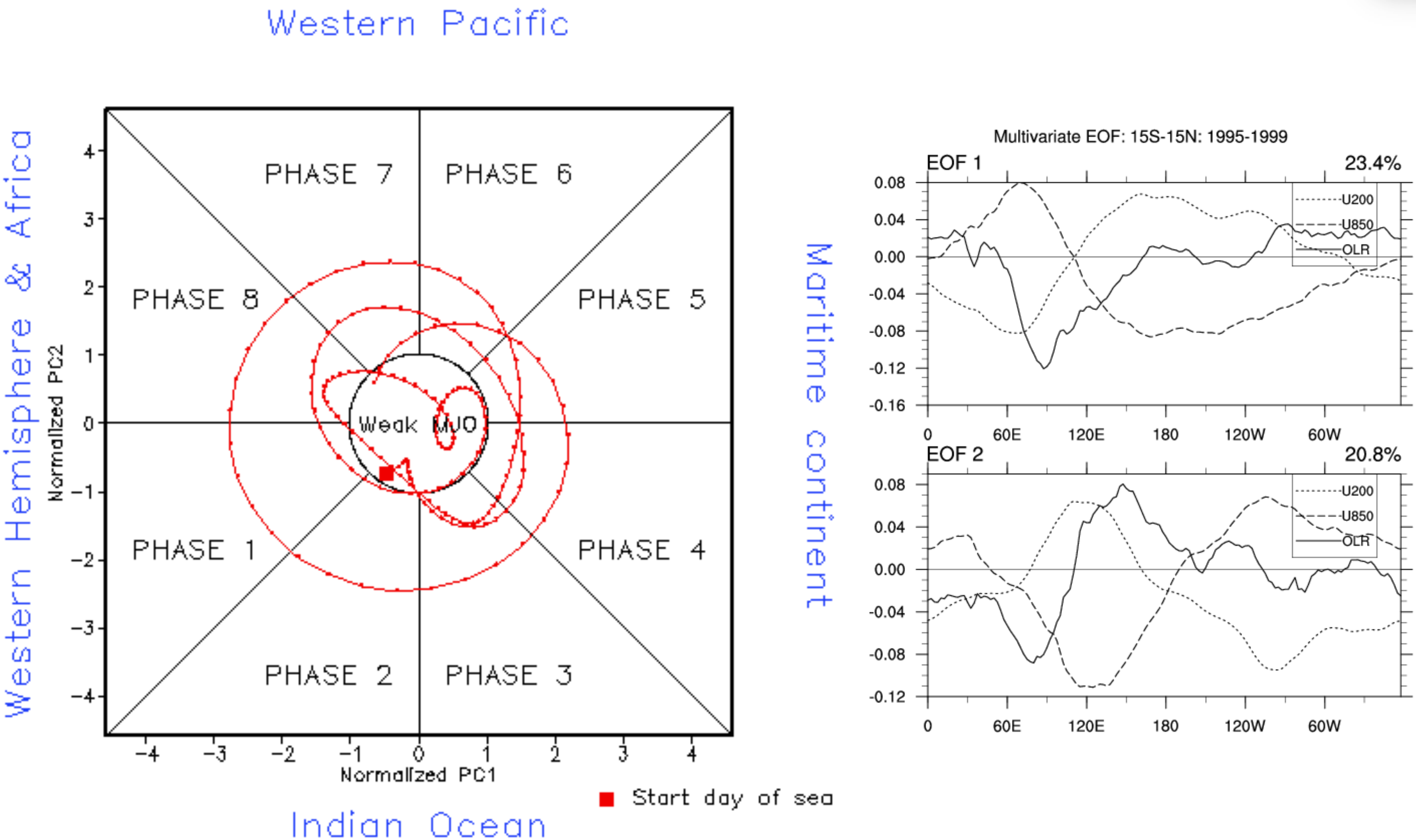
CCSM (T85)

Filtered MJO Events

91-day running average of 20-100 day band pass filtered U200mb in the Northern Indo-Pacific Tropics

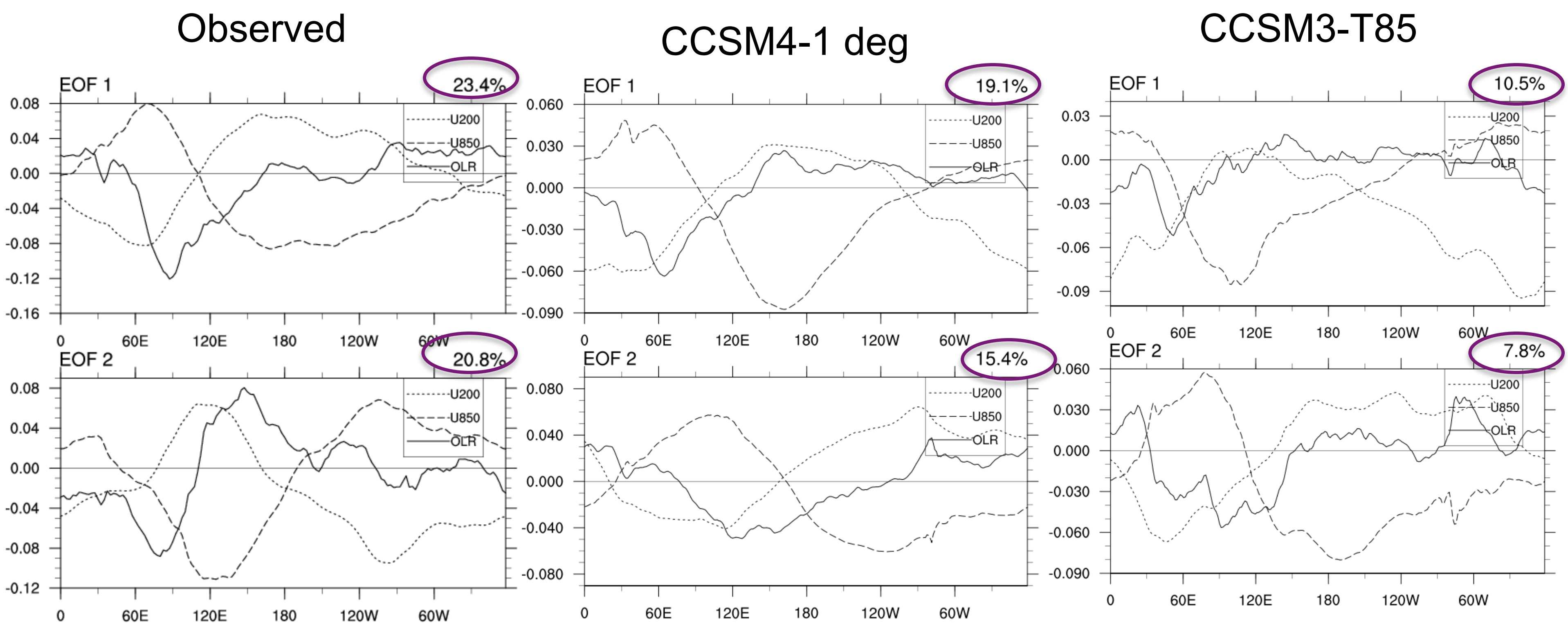


Composite Madden Julian Oscillation (MJO)



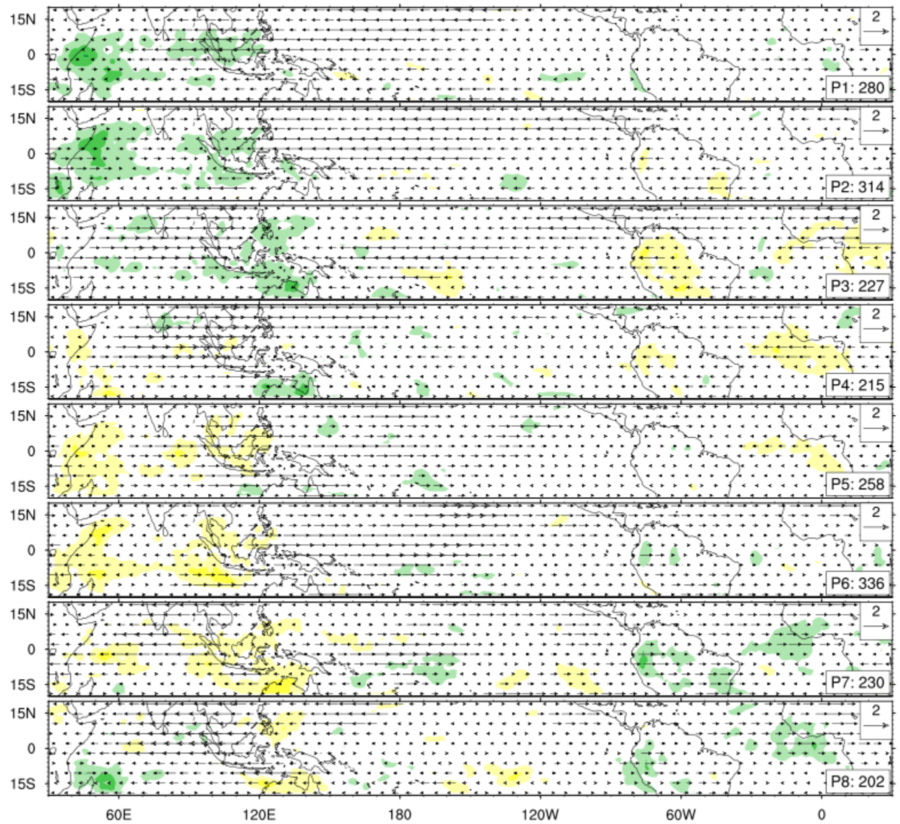
Normalized PC1 and PC2 of multivariate (OLR,U200,U850) EOF1 and EOF2 from 20-100 band pass filtered daily anomalies

Composite Madden Julian Oscillation (MJO)

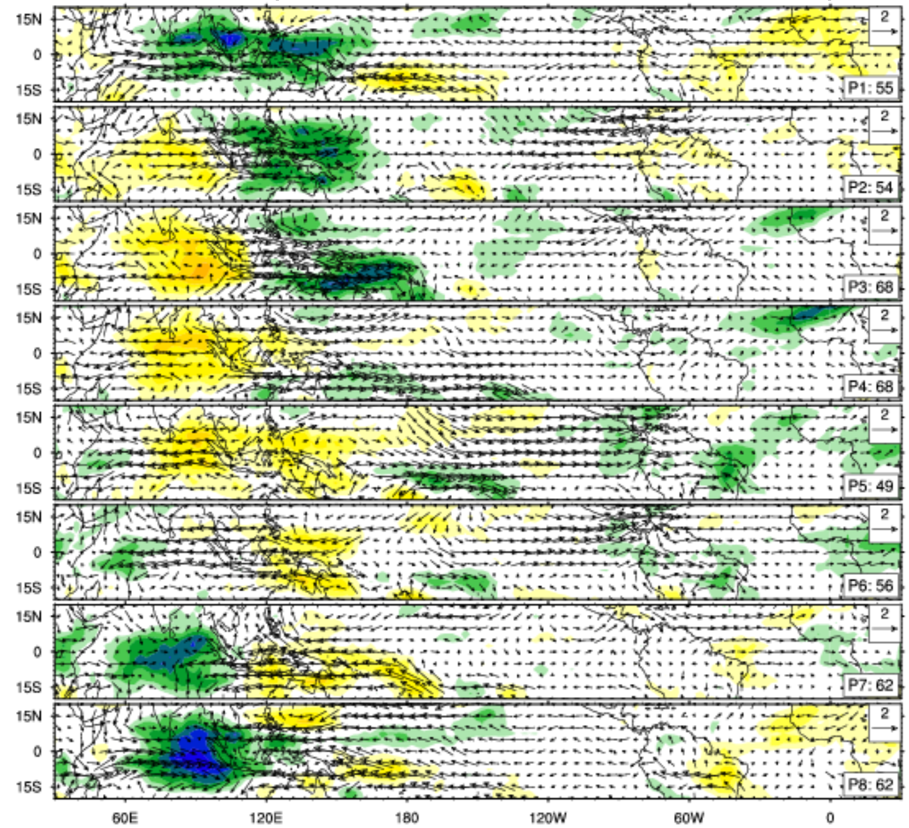


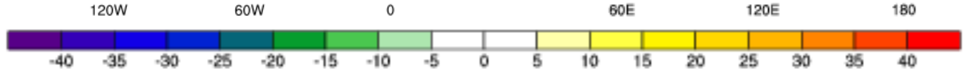
Composite Madden Julian Oscillation (MJO)

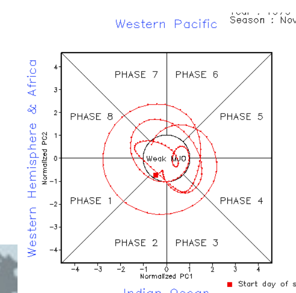
CCSM3-T85 (1980-1999)



Observed (NOAA,ERA40,1995-1999)



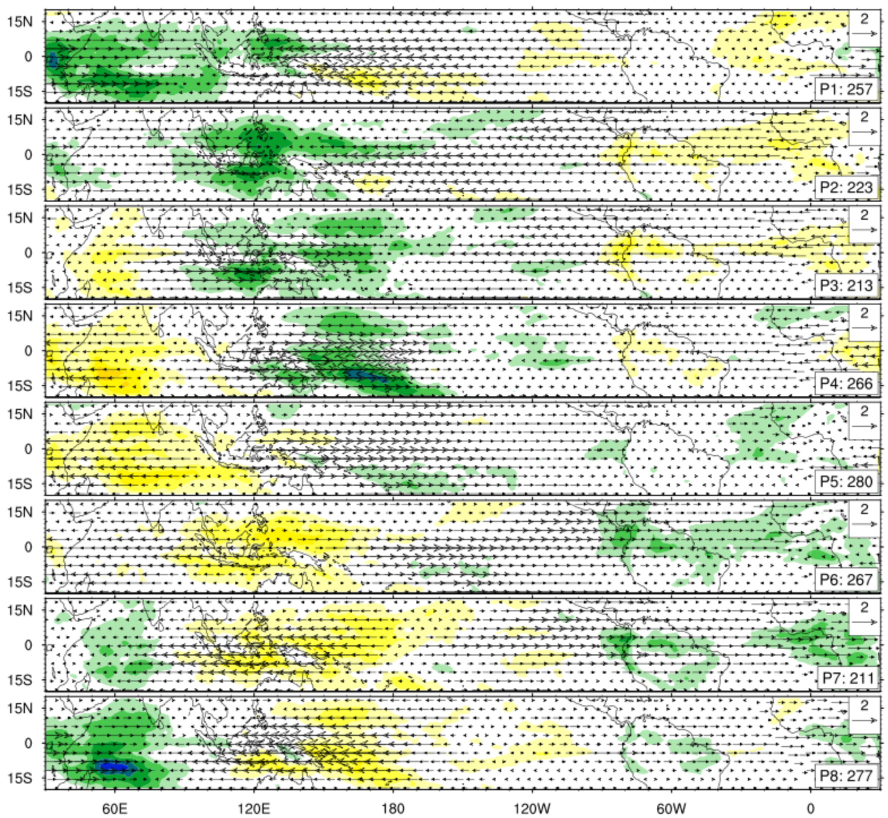




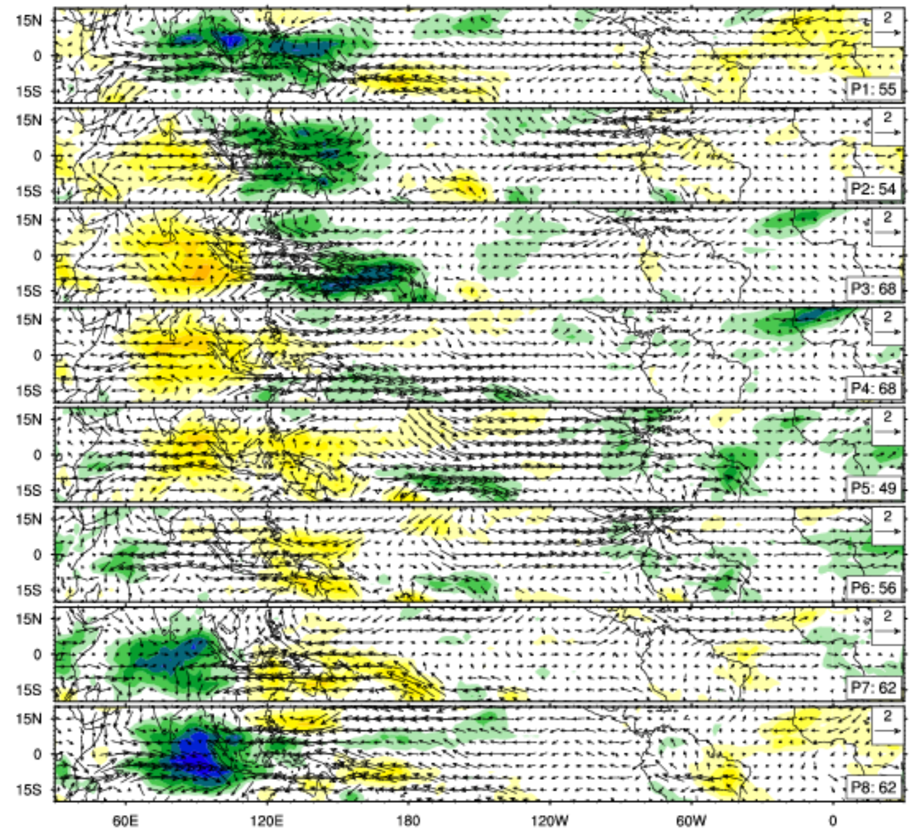
Eight phase composite of PC1 and PC2 from combined EOFs.
20th Century coupled experiments, Winter

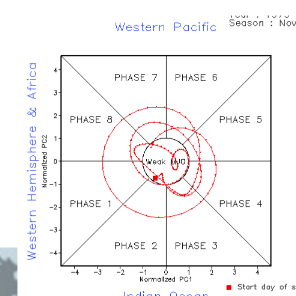
Composite Madden Julian Oscillation (MJO)

CCSM4-1 deg (1980-1999)



Observed (NOAA,ERA40,1995-1999)

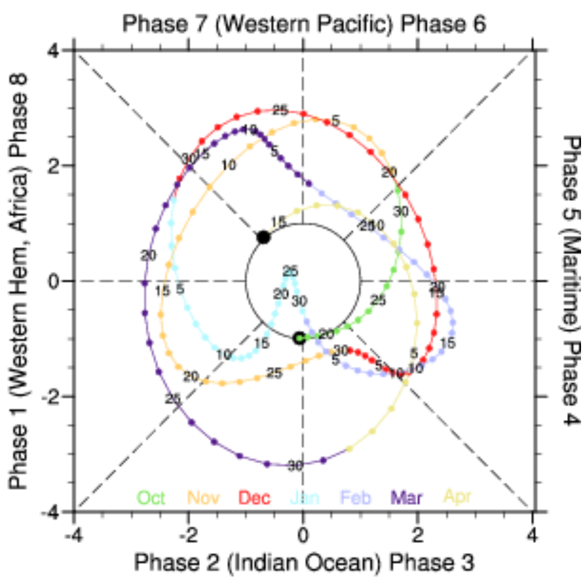




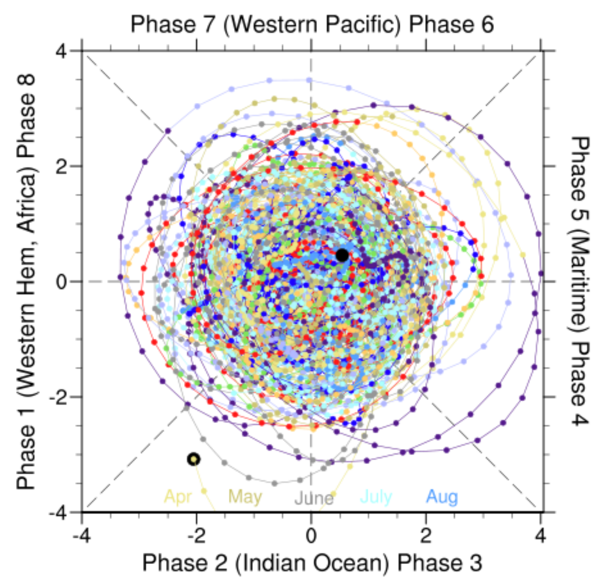
Eight phase composite of PC1 and PC2 from combined EOFs.
20th Century coupled experiments, Winter

Typical MJO Events

Observed
(1996/97)

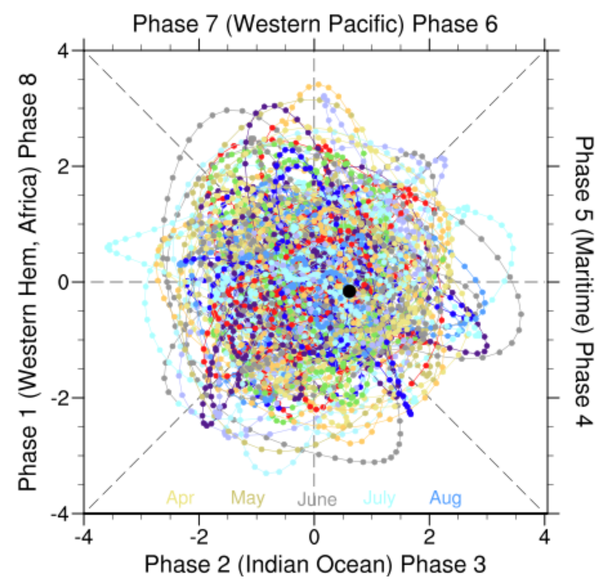


CCSM4-1 deg
(5 years)



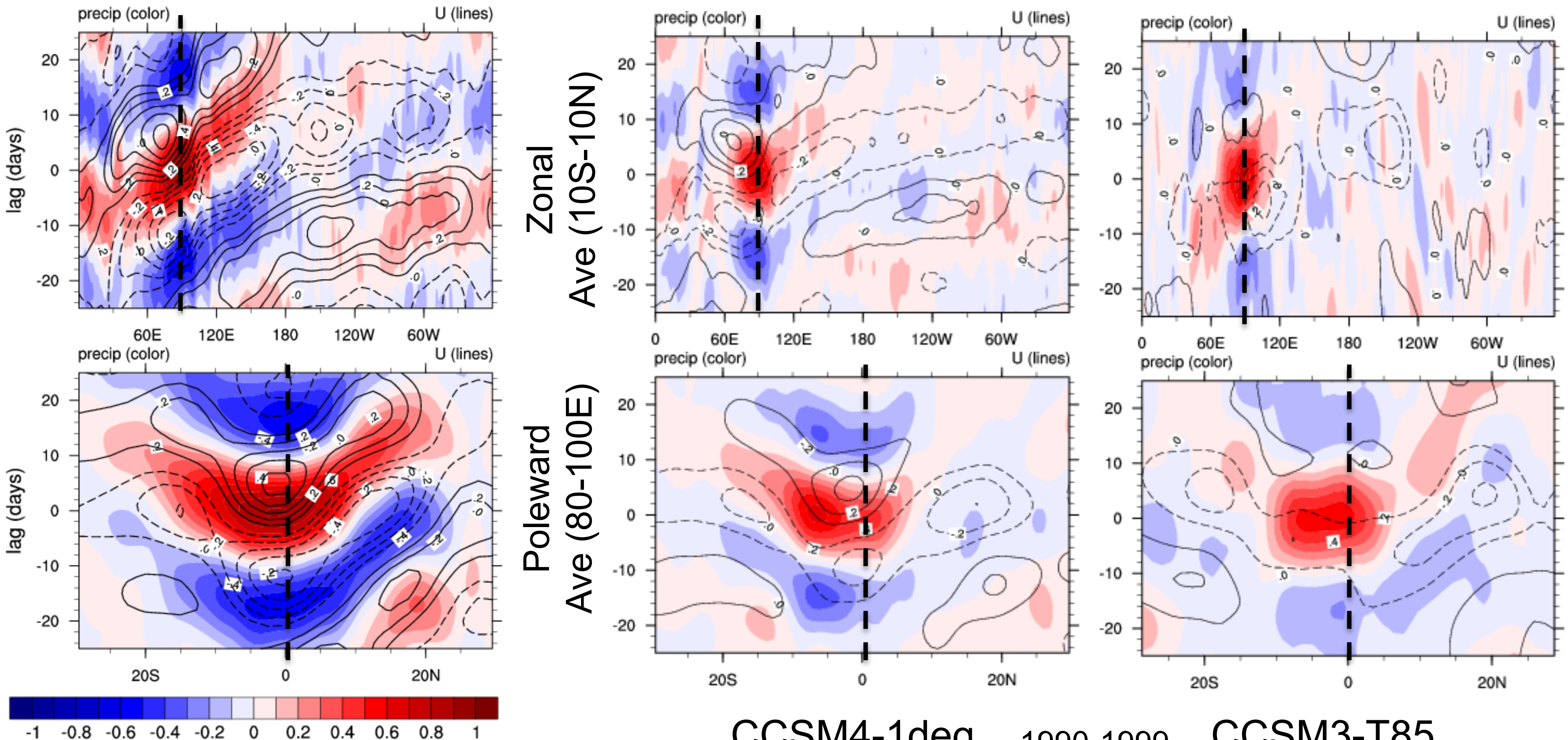
More persistent orbits

CCSM3-T85
(5 years)



Few persistent orbits

Lag Correlations



CCSM4-1deg 1990-1999 CCSM3-T85

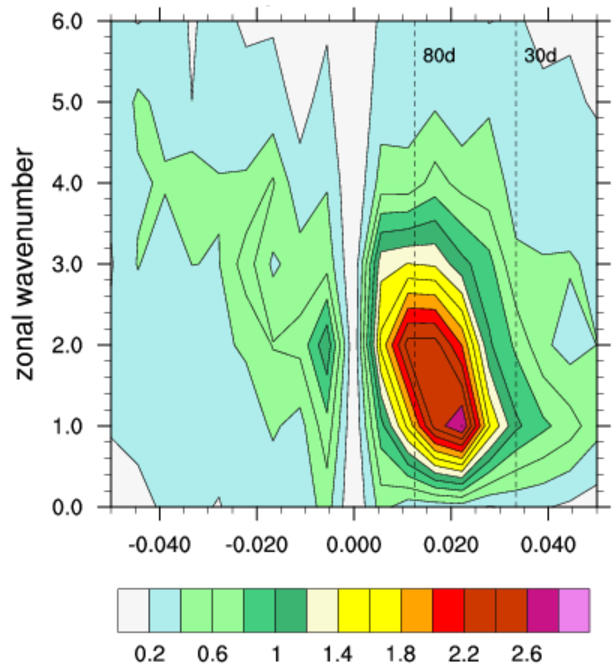
Observed (GPCP,ERA40) 1996-2005

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

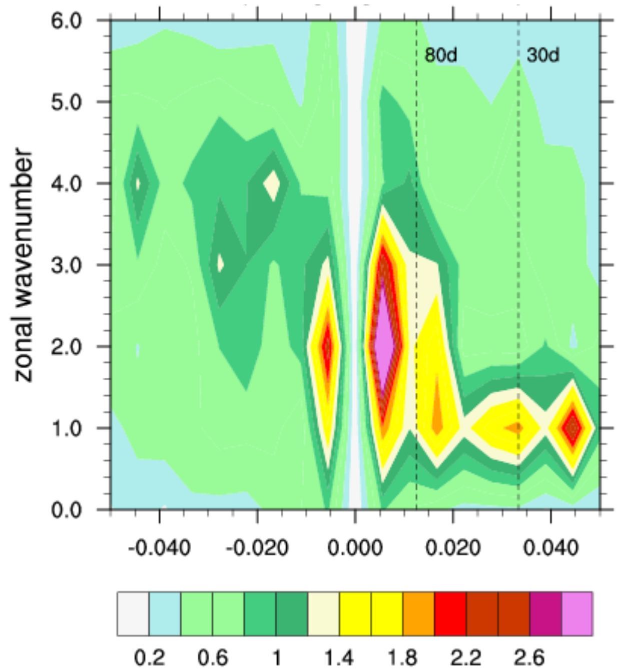
MJO Phase Speed

OLR wavenumber-frequency decomposition

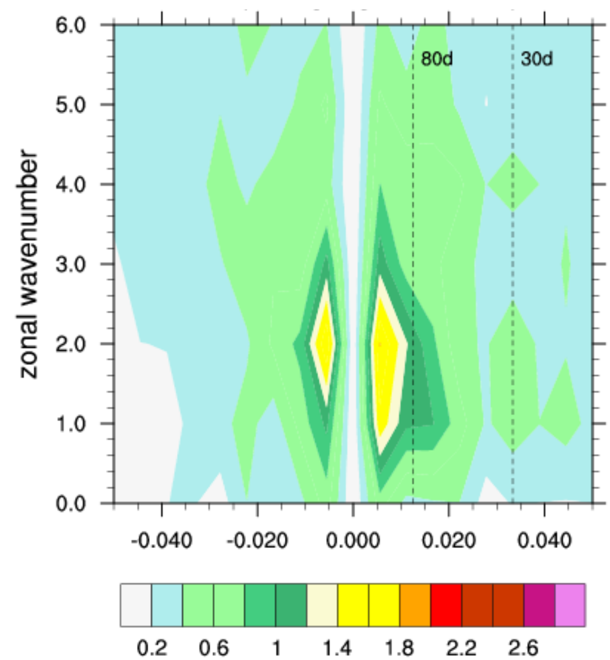
Observed
(1980-2005)



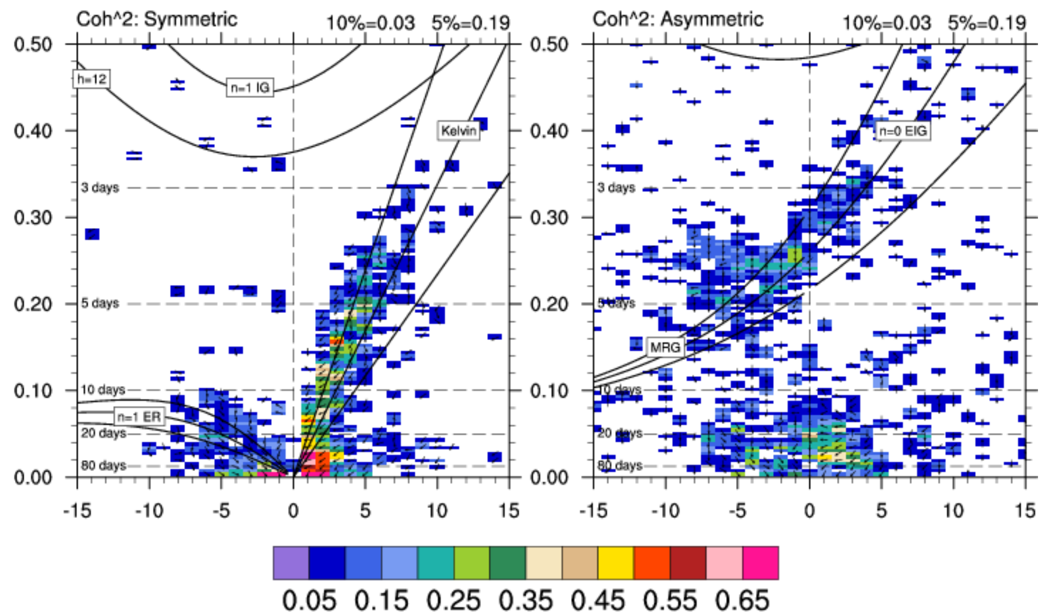
CCSM4-1 deg
(1980-1999)



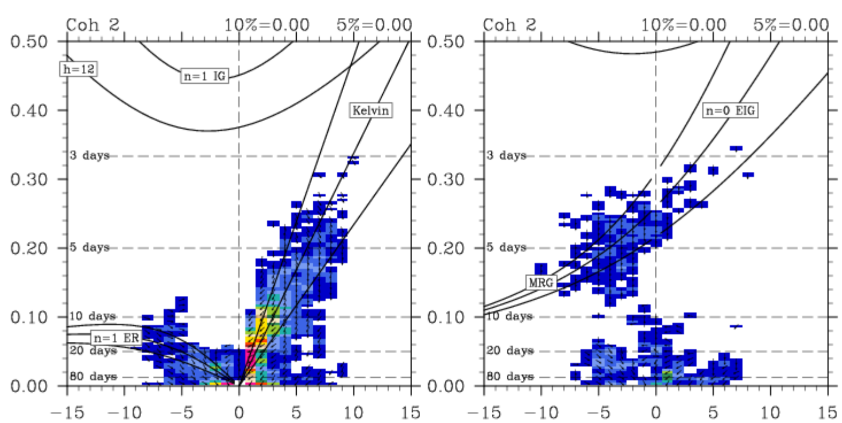
CCSM3-T85
(1980-1999)



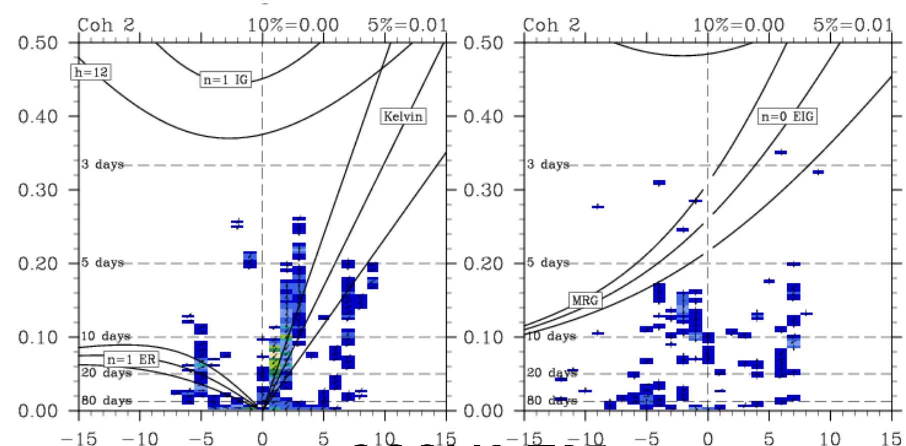
Wavenumber -frequency of coherent multivariate structures



Observed (NOAA,ERA40) 1996-2005



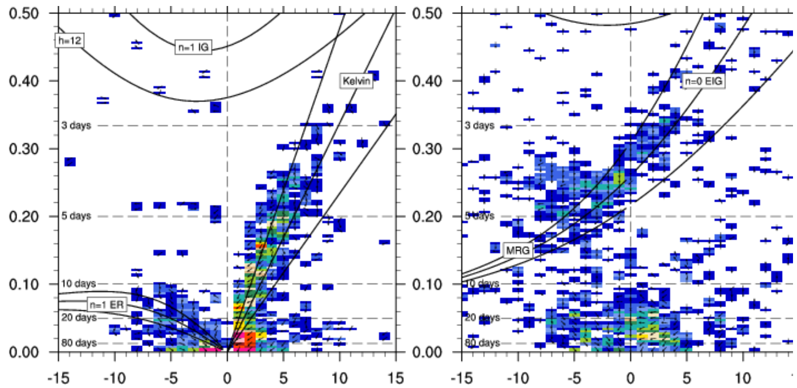
CCSM4-1deg



CCSM3-T85

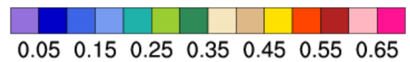
1990-1999

Cross-spectra: coherence-squared and phase relationships in wavenumber-frequency space (between OLR and 850-mb zonal wind)

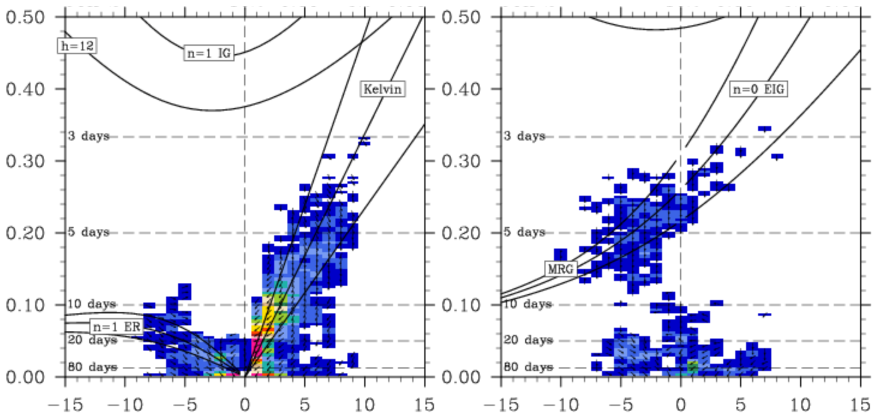


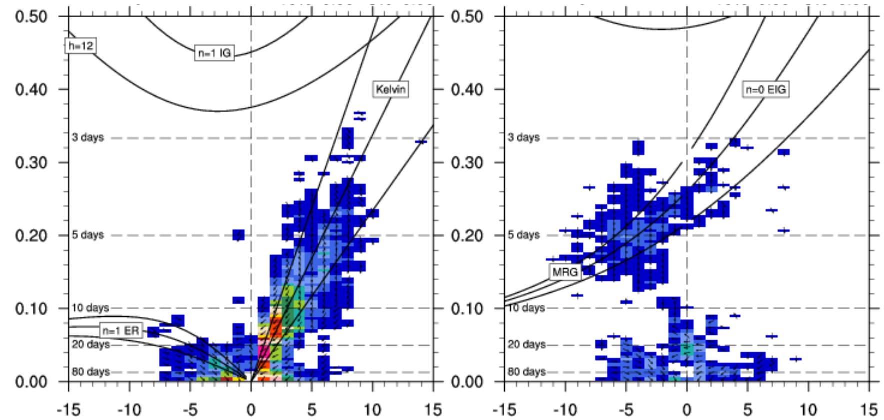
Observed
(NOAA, NCEP)
1996-2005

CCSM4-1 deg



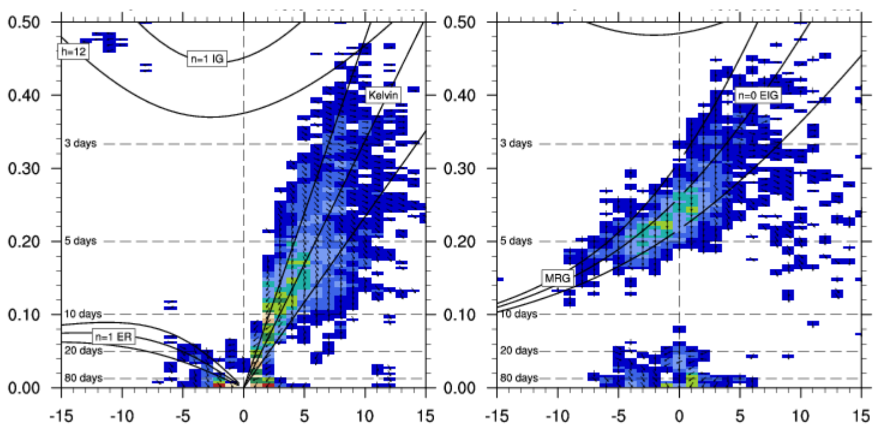
CAM4-1 deg

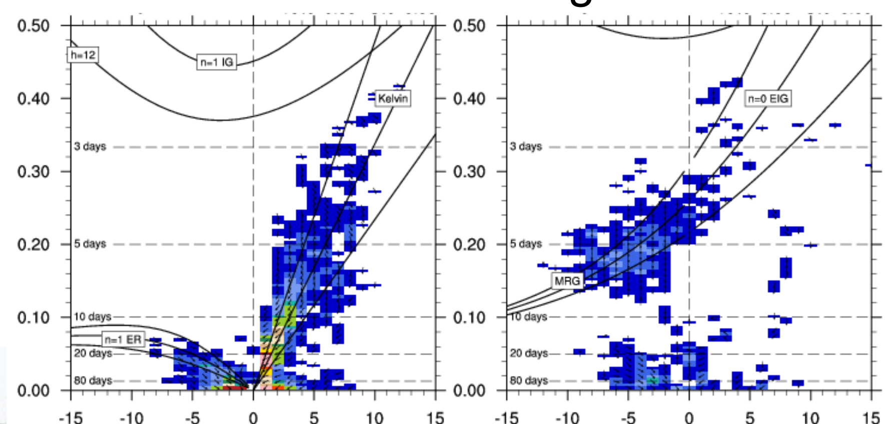




CAM5-2 deg

CAM4-2 deg





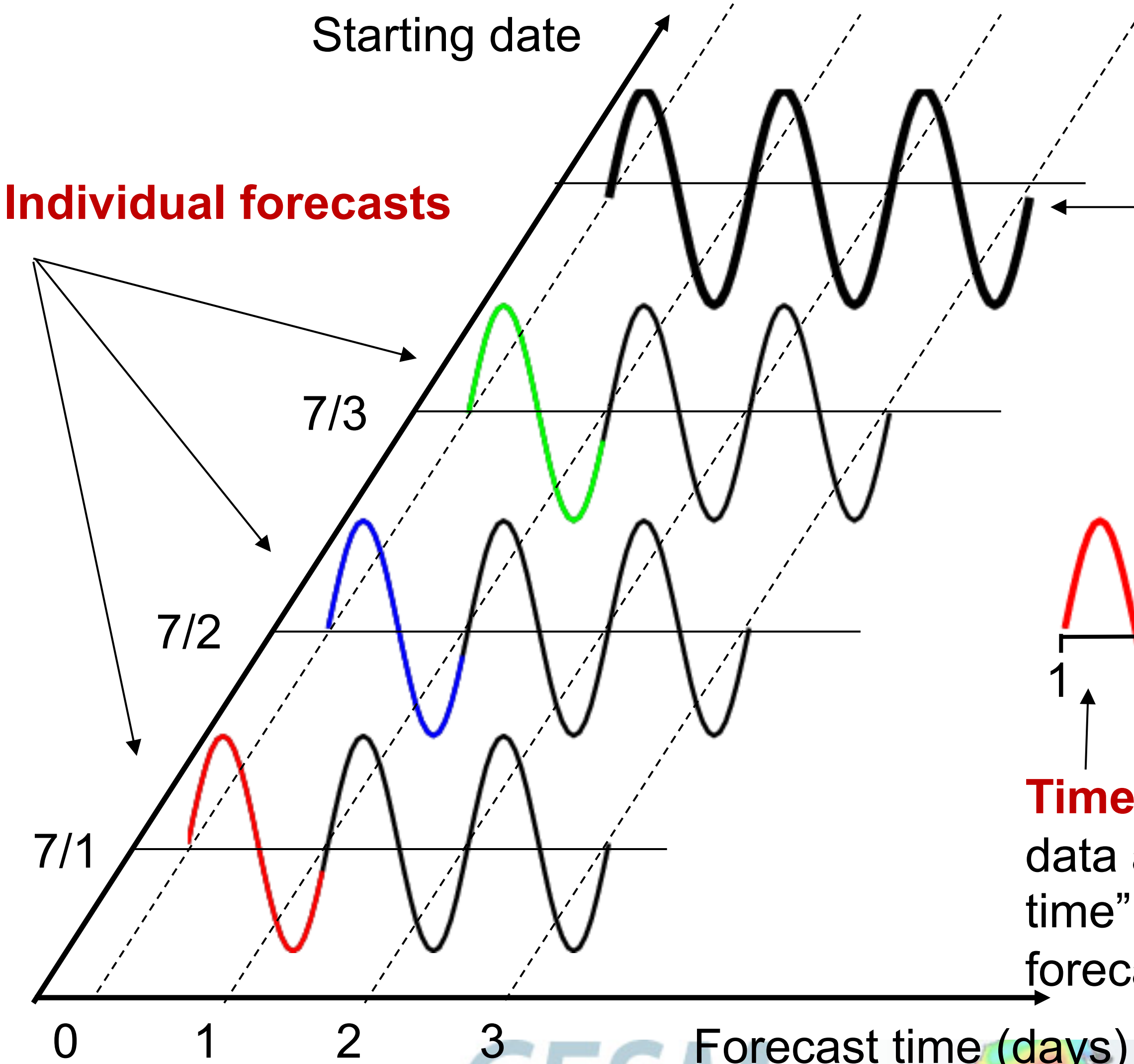
Summary

✓Significant changes to deep convection in CCSM4 (CMT and parcel dilution)
✓Tropical variance increased at most time and space scales in CCSM4
✓Tropical U850mb variance improved; OLR variance too strong
✓Intraseasonal variance is a larger fraction of total variance
✓Multivariate MJO-type structures explain greater fraction of variance
✓Propagating strength of structures much greater
✓Wavenumber-frequency distribution of variance stringer in 'MJO phase space'

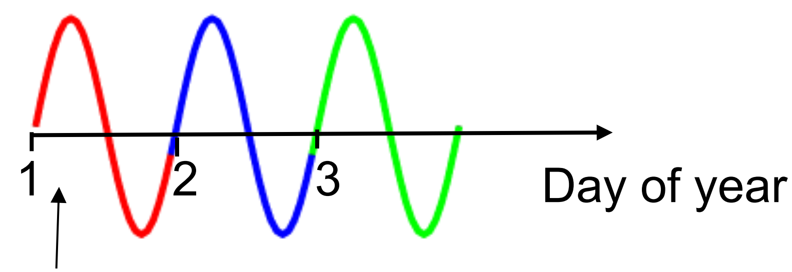
✓Prescribed SST (CAM) experiments have weaker response (=SPCAM?)
✓Resolution (2 deg -> 1 deg, CAM) buys you a stronger MJO
✓CAM5 is weaker than CAM4 (2 deg) – sacrificial tuning of deep convection!
✓CAPT forecasts shows CAM3 convective spin-up response is destructive for maintaining initialized propagation

✓More analysis needed
✓CCSM4 1 deg: MOAR (Mother of all Runs!) integration with extensive high frequency (24,6,3-hrly) output for 1850-2100; full daily atmosphere budgets

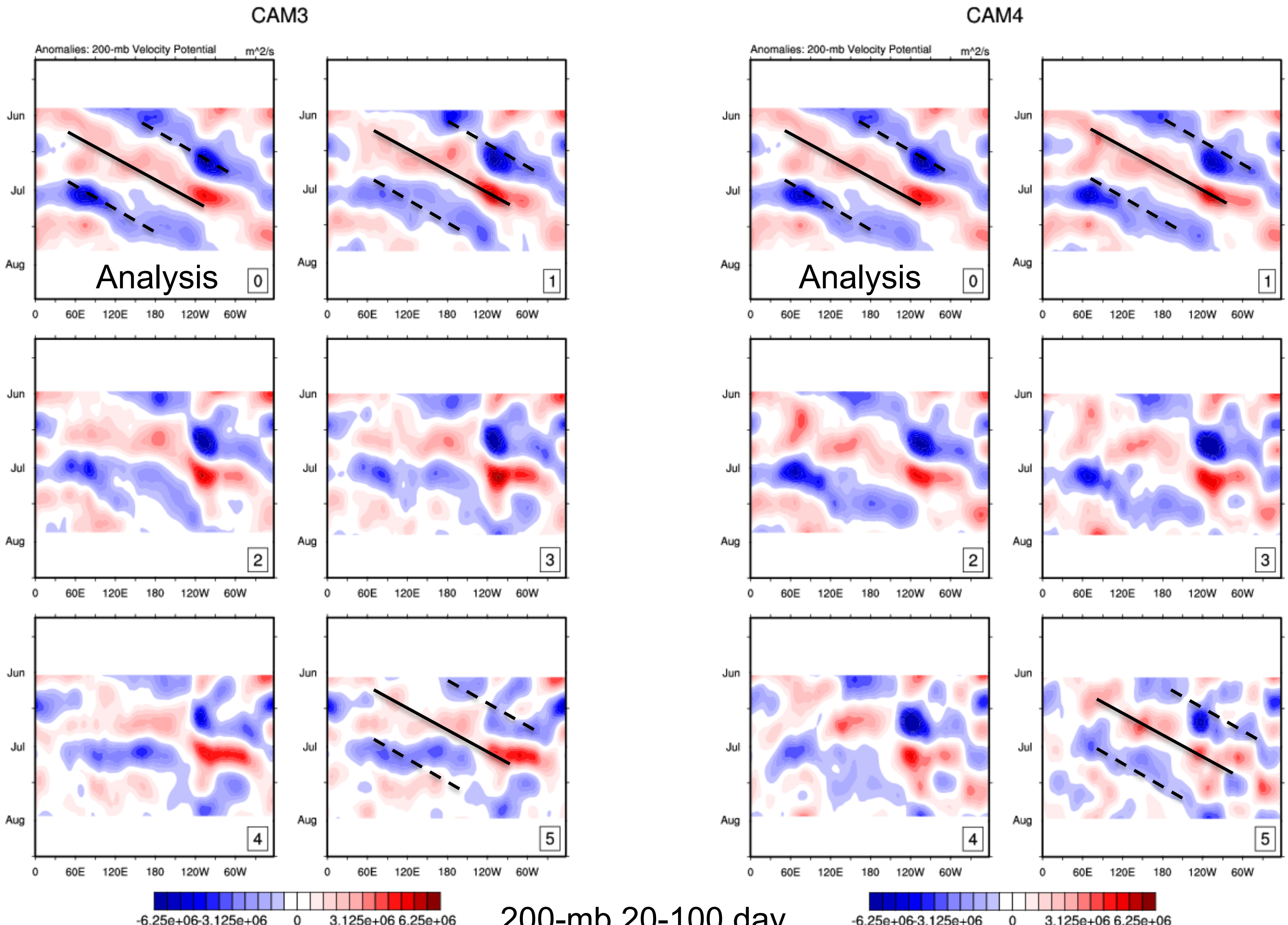
Ensemble mean forecast and timeseries forecast



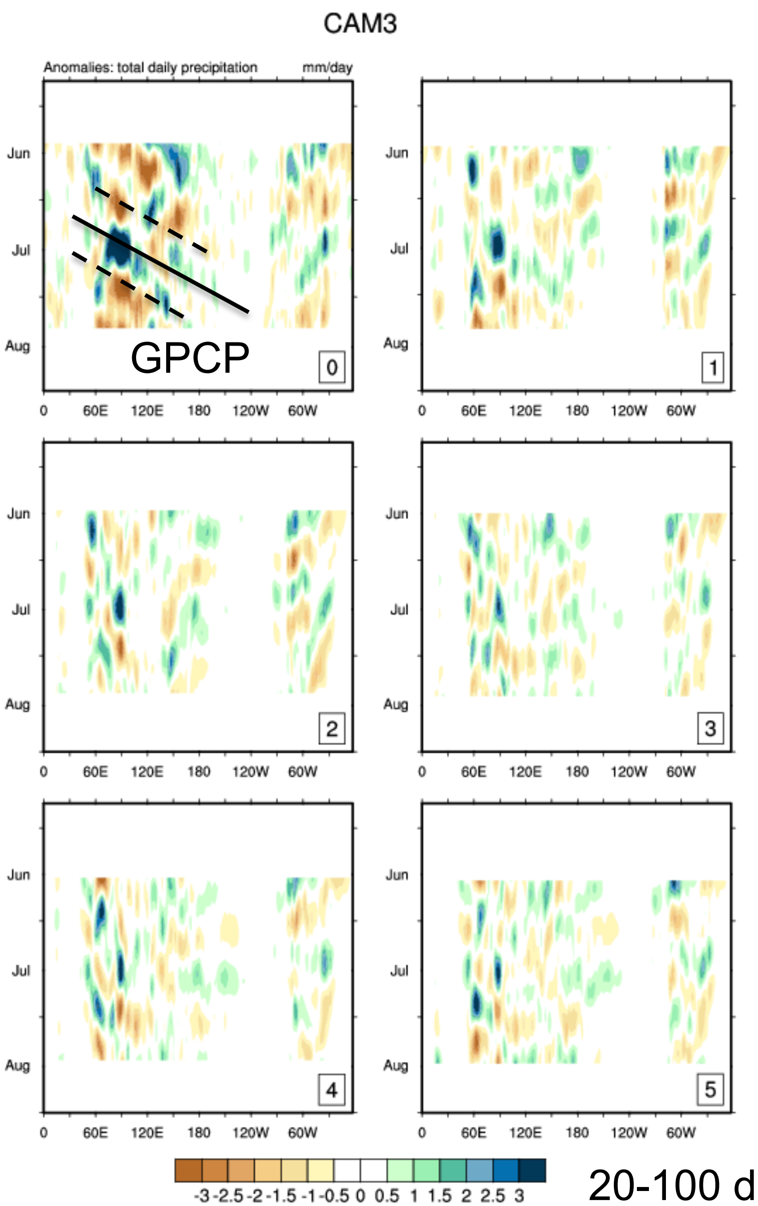
Ensemble mean forecast: average data at the same "forecast time"

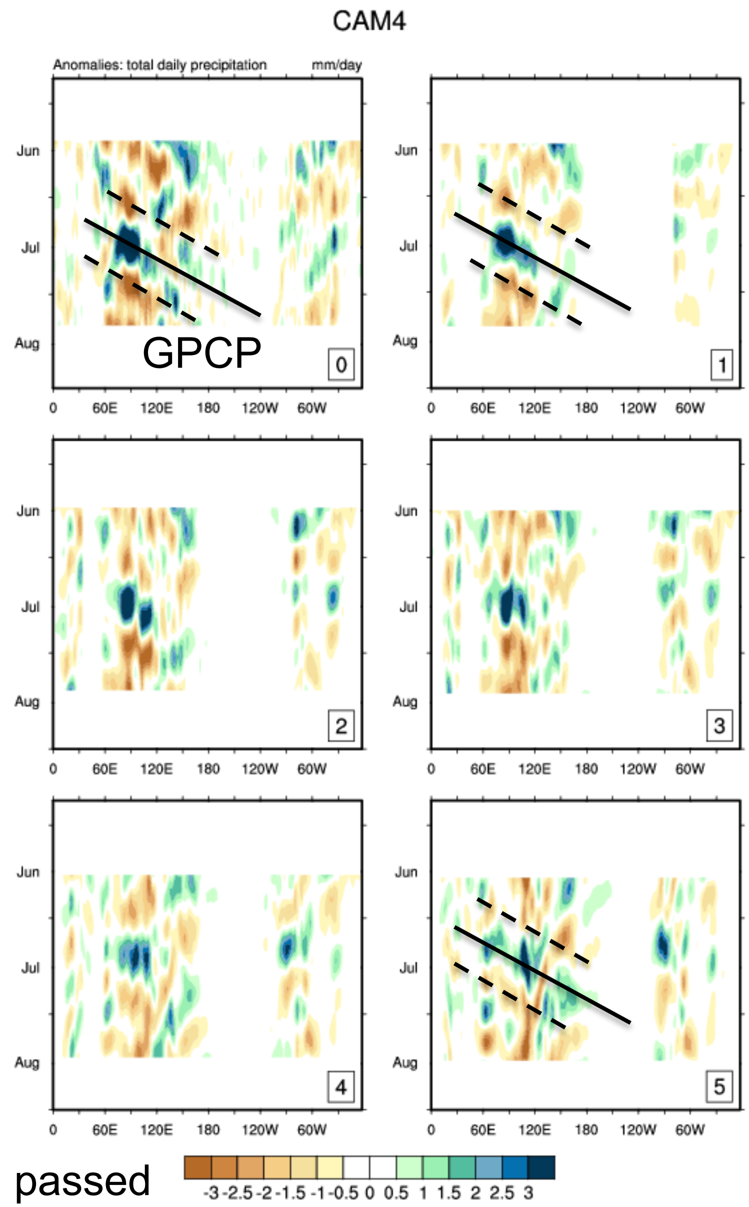


Timeseries forecast: concatenate data at the same "forecast time" (hours 0-24) from individual forecasts

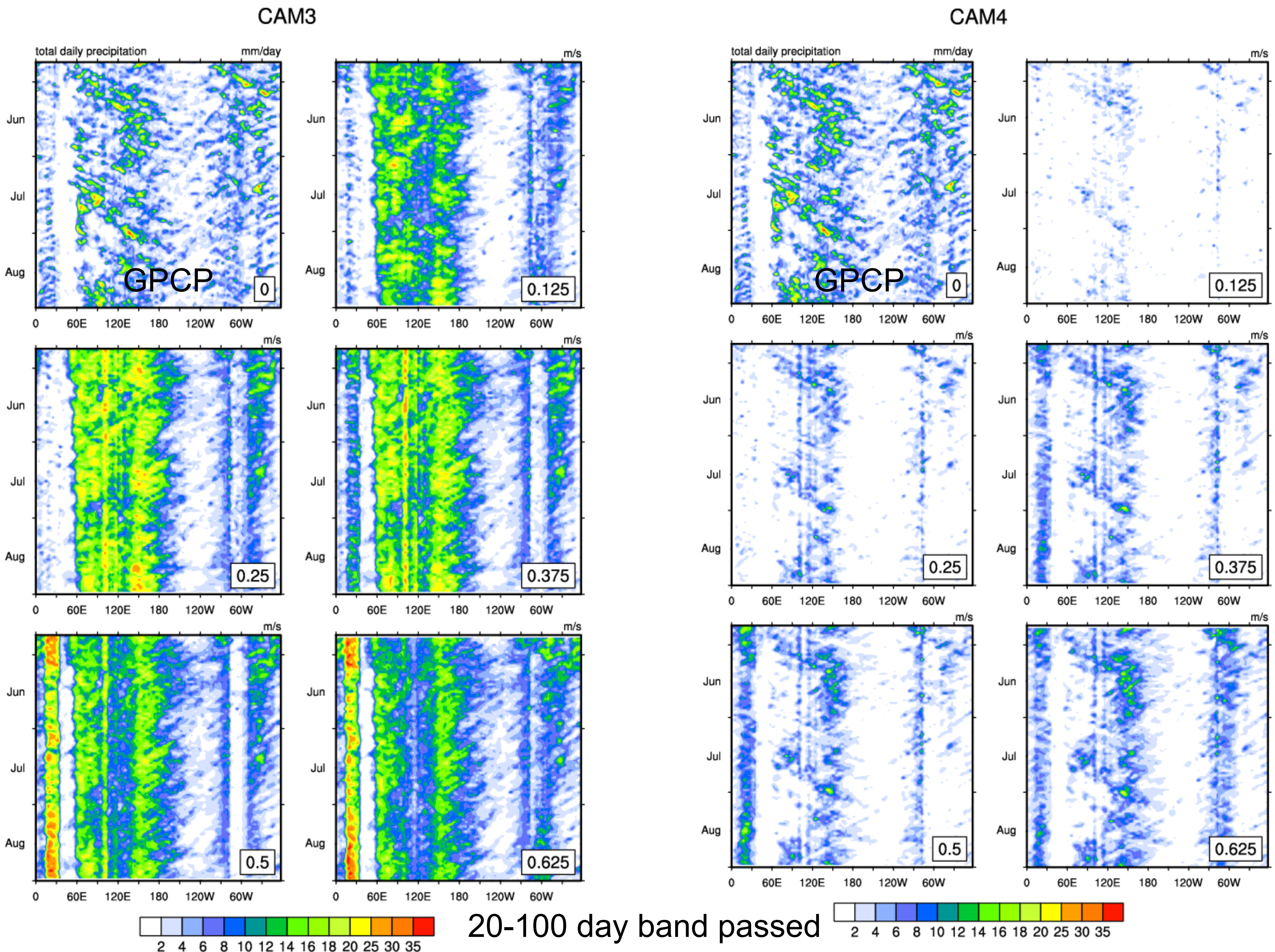


200-mb 20-100 day
band passed
Velocity Potential
(anoms. 10N-10S , m^2/s)





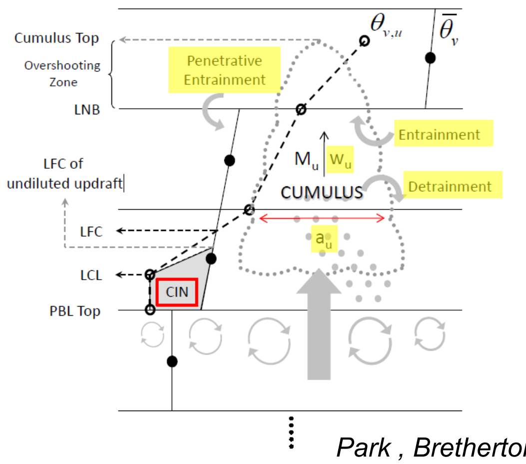
20-100 day band passed Precipitation (anoms. 10N-10S, mm/day)



20-100 day band passed Precipitation (10N-10S, mm/day)

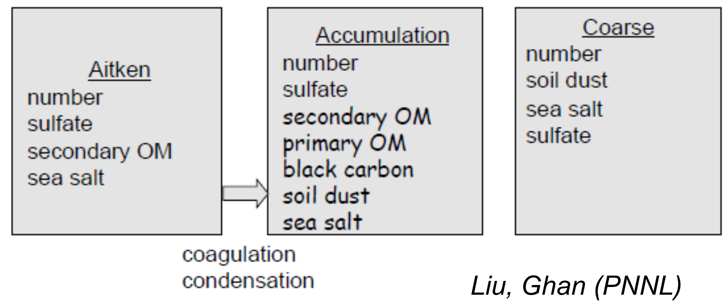
CAM5: Physics Changes

UW PBL and shallow cumulus



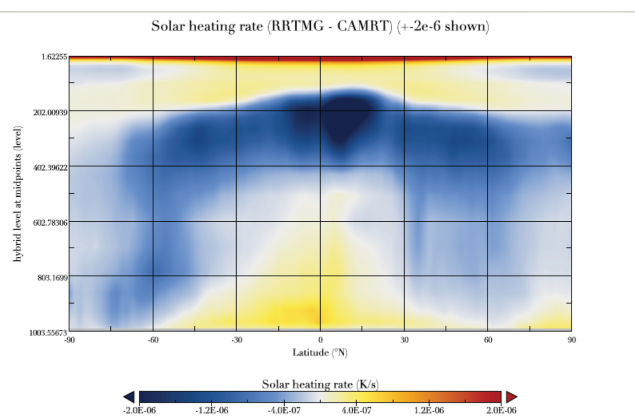
Park , Bretherton (UW)

3-mode Modal Aerosol Model (MAM)



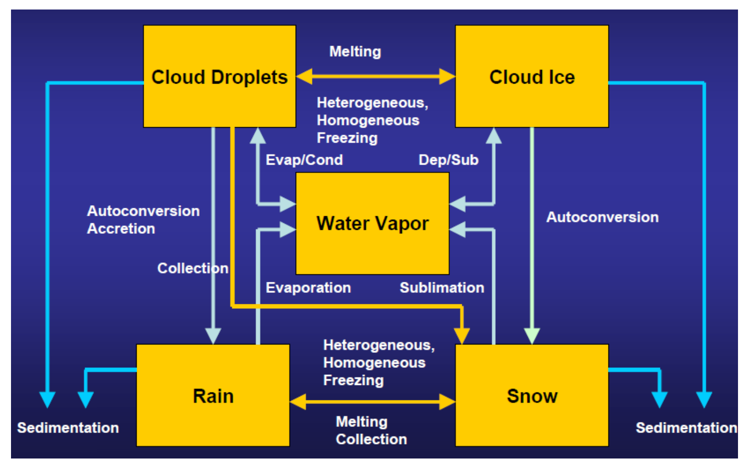
Liu, Ghan (PNNL)

Rapid Radiative Transfer Model (RRTM)



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

2-moment microphysics



Morrison, Gettleman (NCAR)