The MJO Simulation in the NCAR CAM3 with Conventional Convective Parameterization:

Closure/Trigger, Shallow Convection, and Sensitivity Tests

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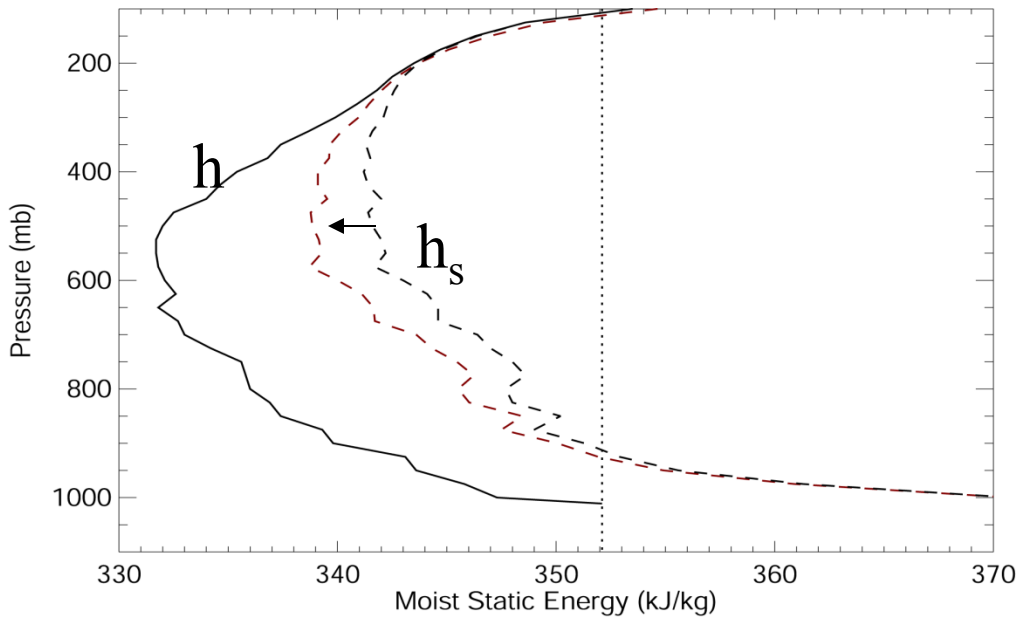
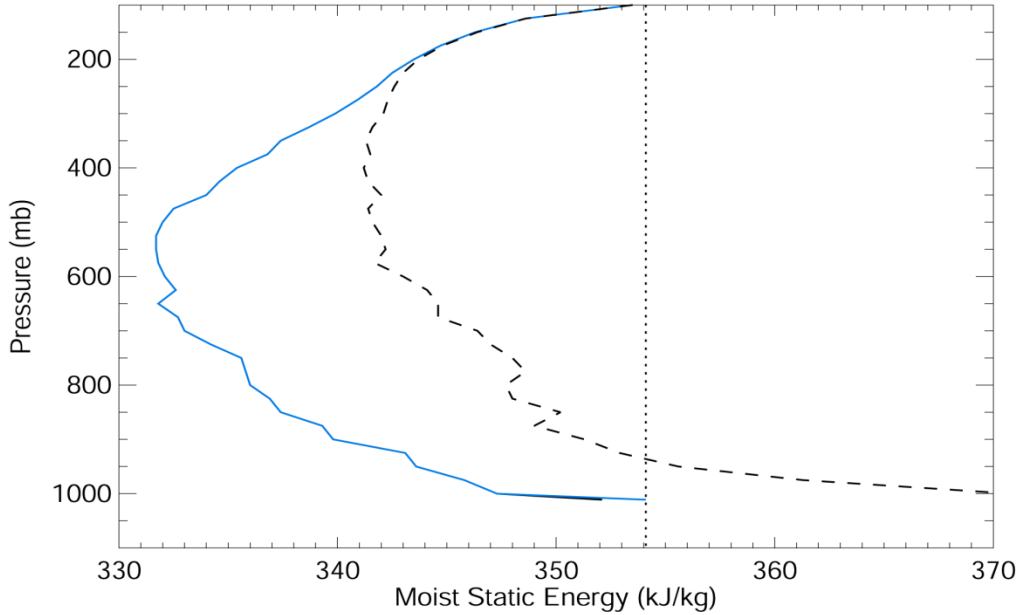
Convection Parameterization

- Zhang-McFarlane (1995) Scheme: CAPE-based closure
- Revised Zhang-McFarlane scheme (Zhang, 2002): based on CAPE change due to large-scale forcing, plus RH threshold for PBL air



Revised Z-M scheme

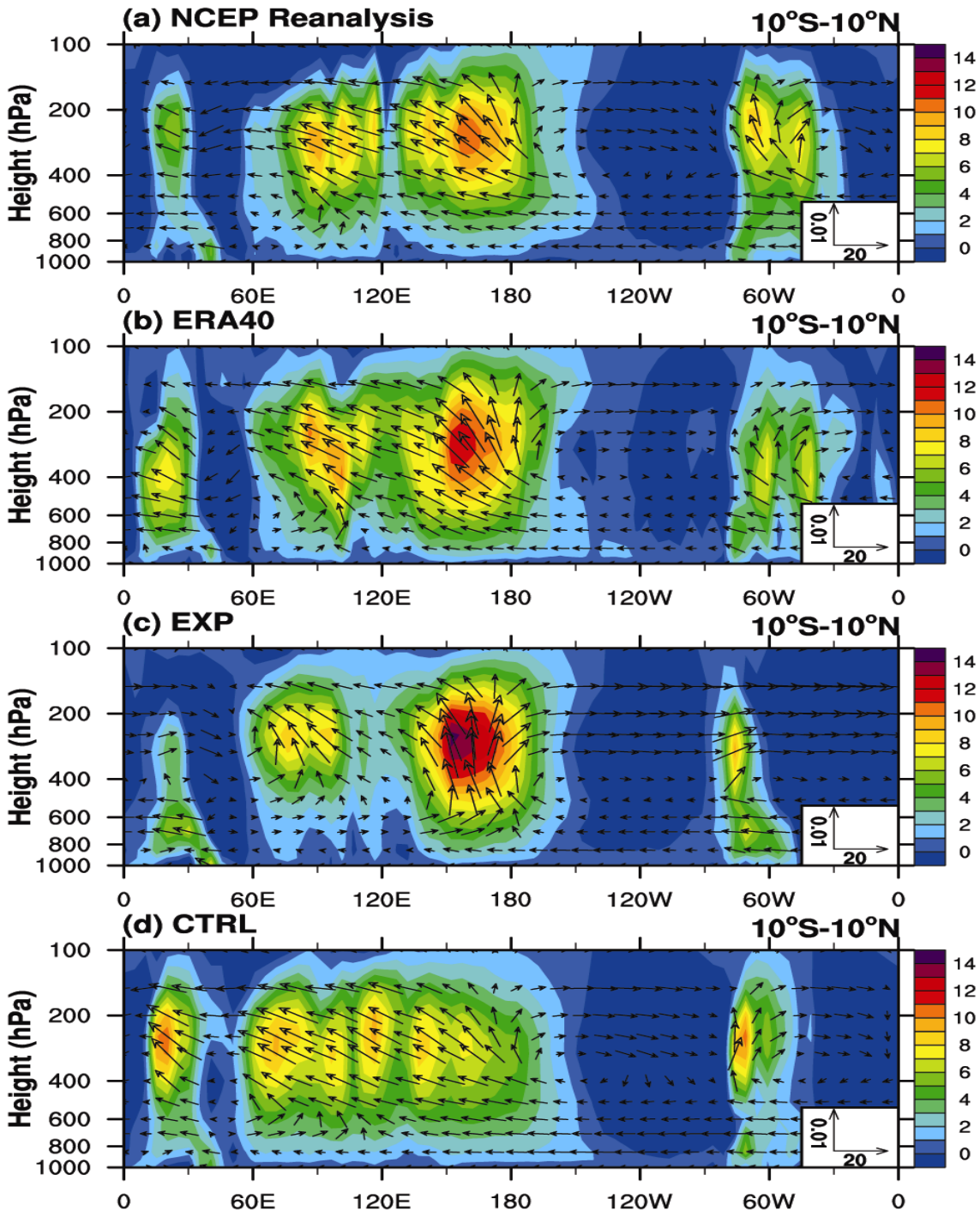
deep convection

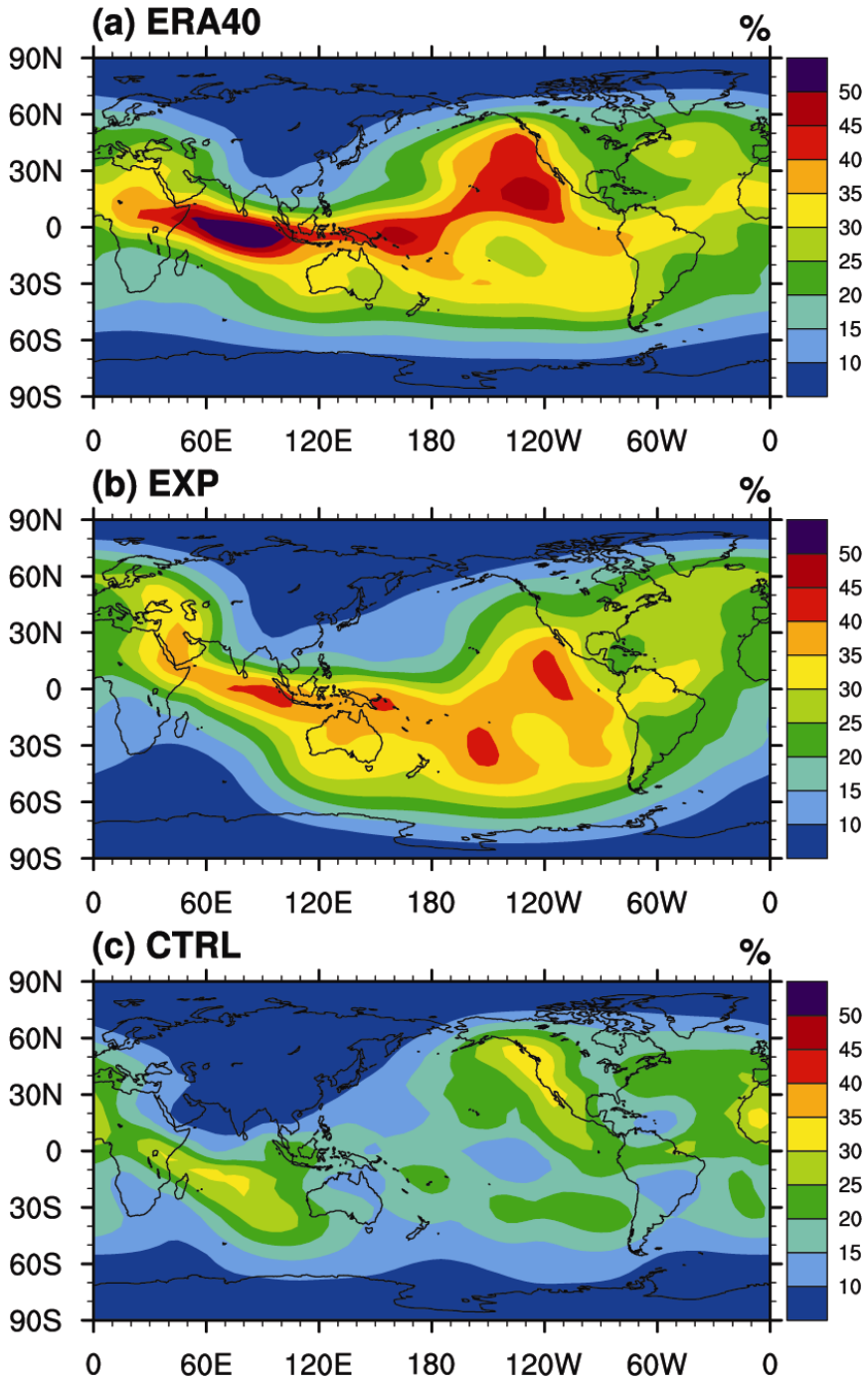


no deep convection

CAM3 Simulations

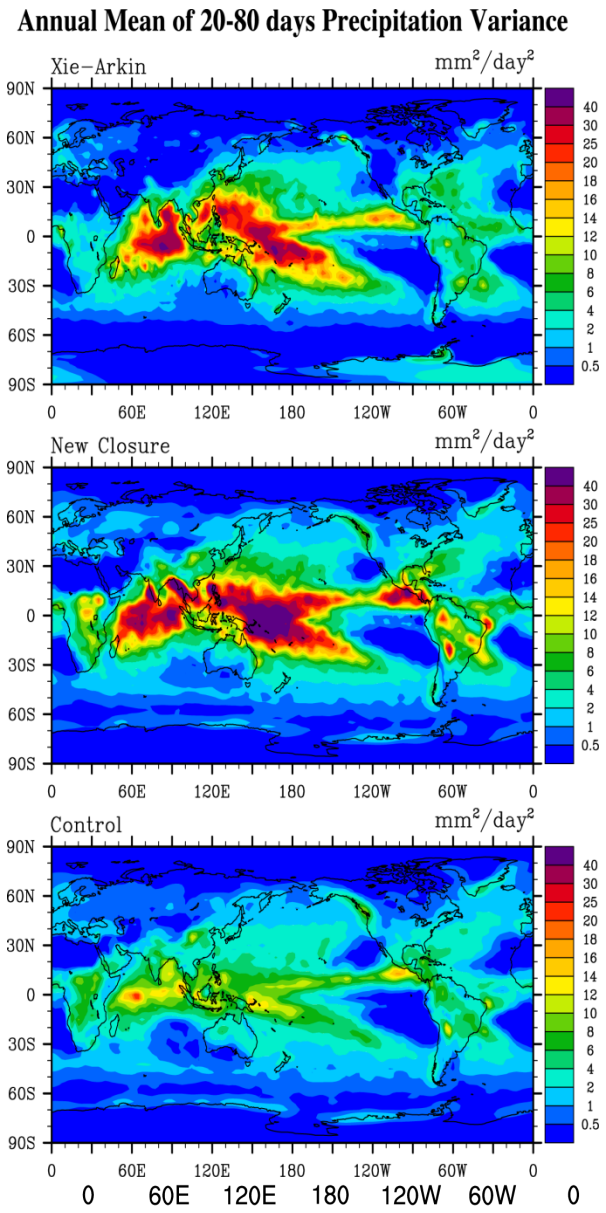
- Multi-year runs with prescribed SST


(a) NCEP Reanalysis
10°S-10°N
(b) ERA40
10°S-10°N
(c) EXP
10°S-10°N
(d) CTRL
10°S-10°N
Height (hPa)
100
200
400
600
800
1000
0
60E
120E
180
120W
60W
0
14
12
10
8
6
4
2
0
0.01
20

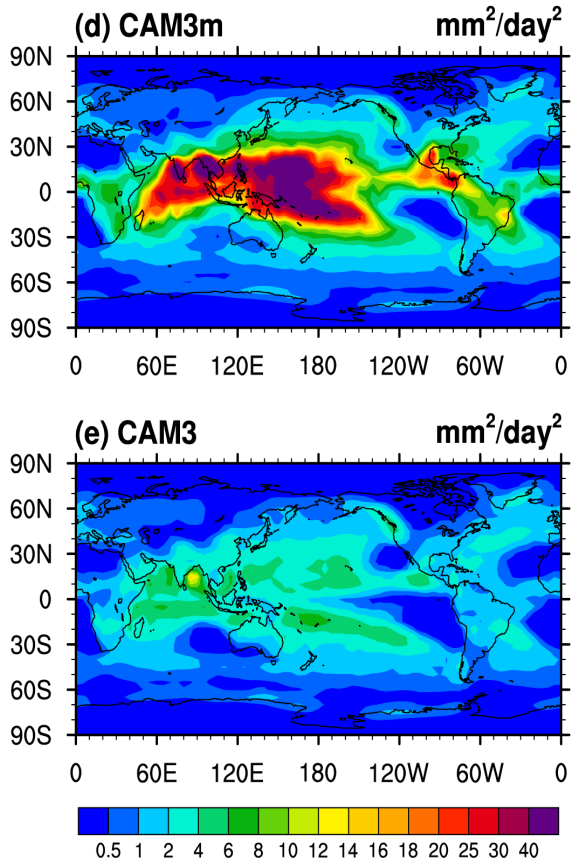


Ratio of 20-80 day variance to total variance

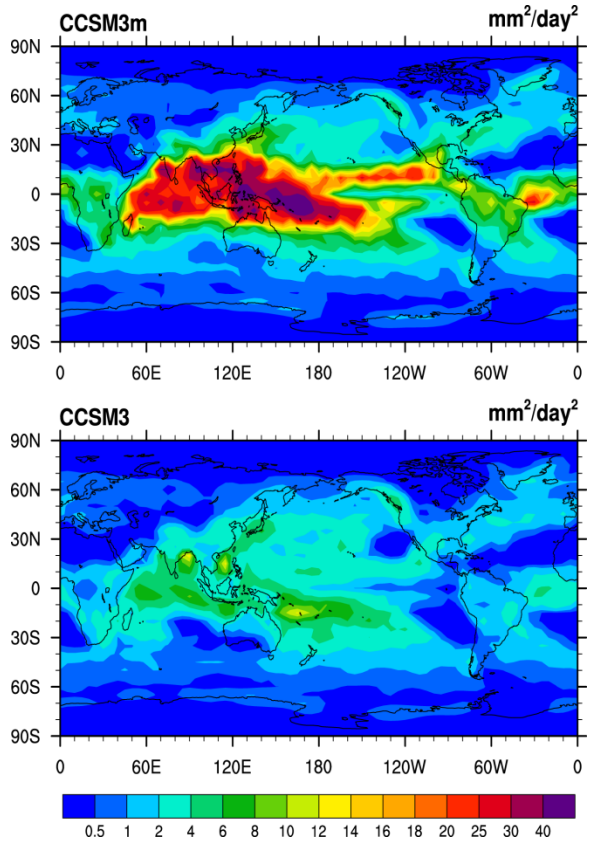
CCM3



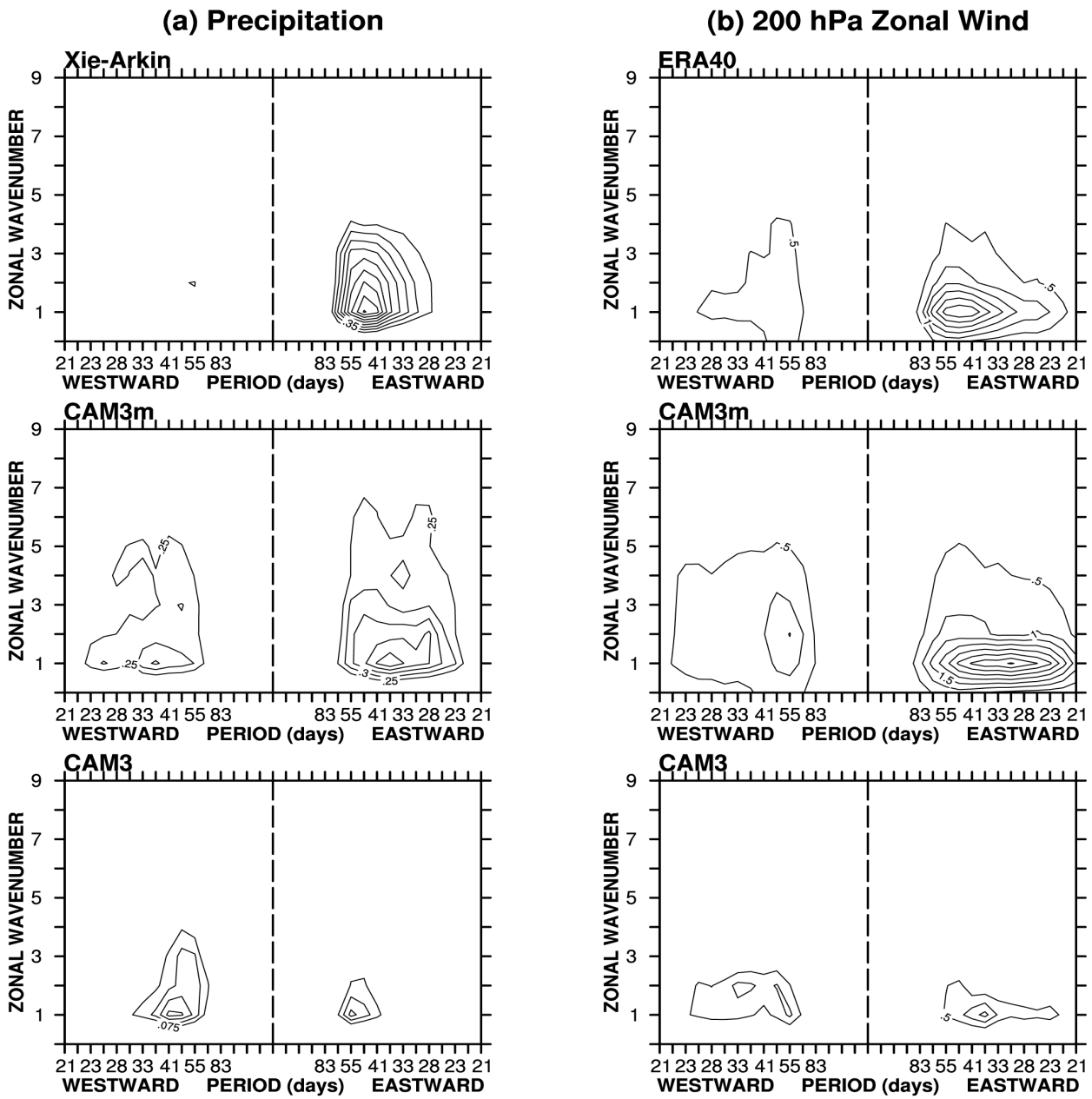
CAM3

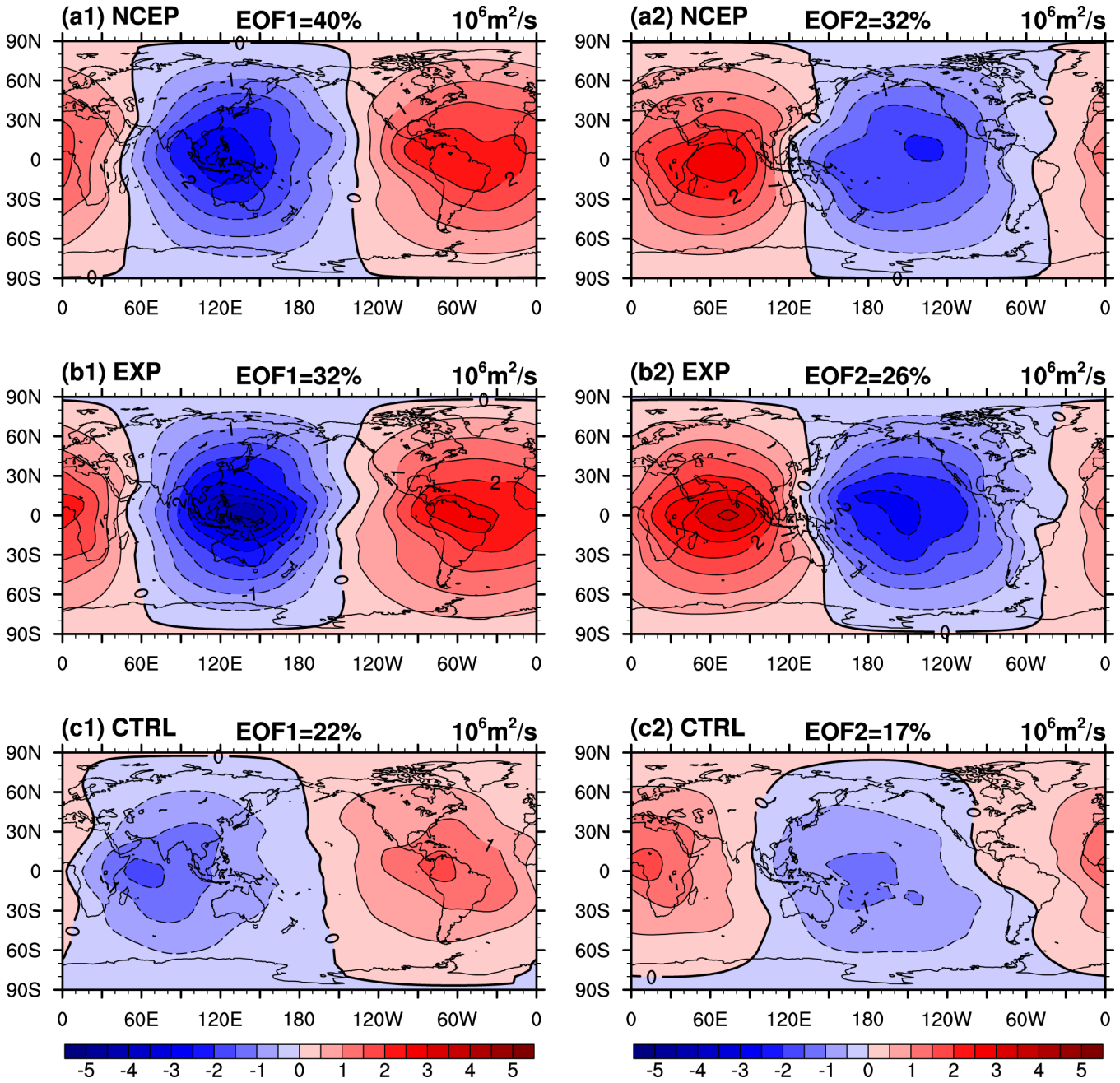


CCSM3



CAM3

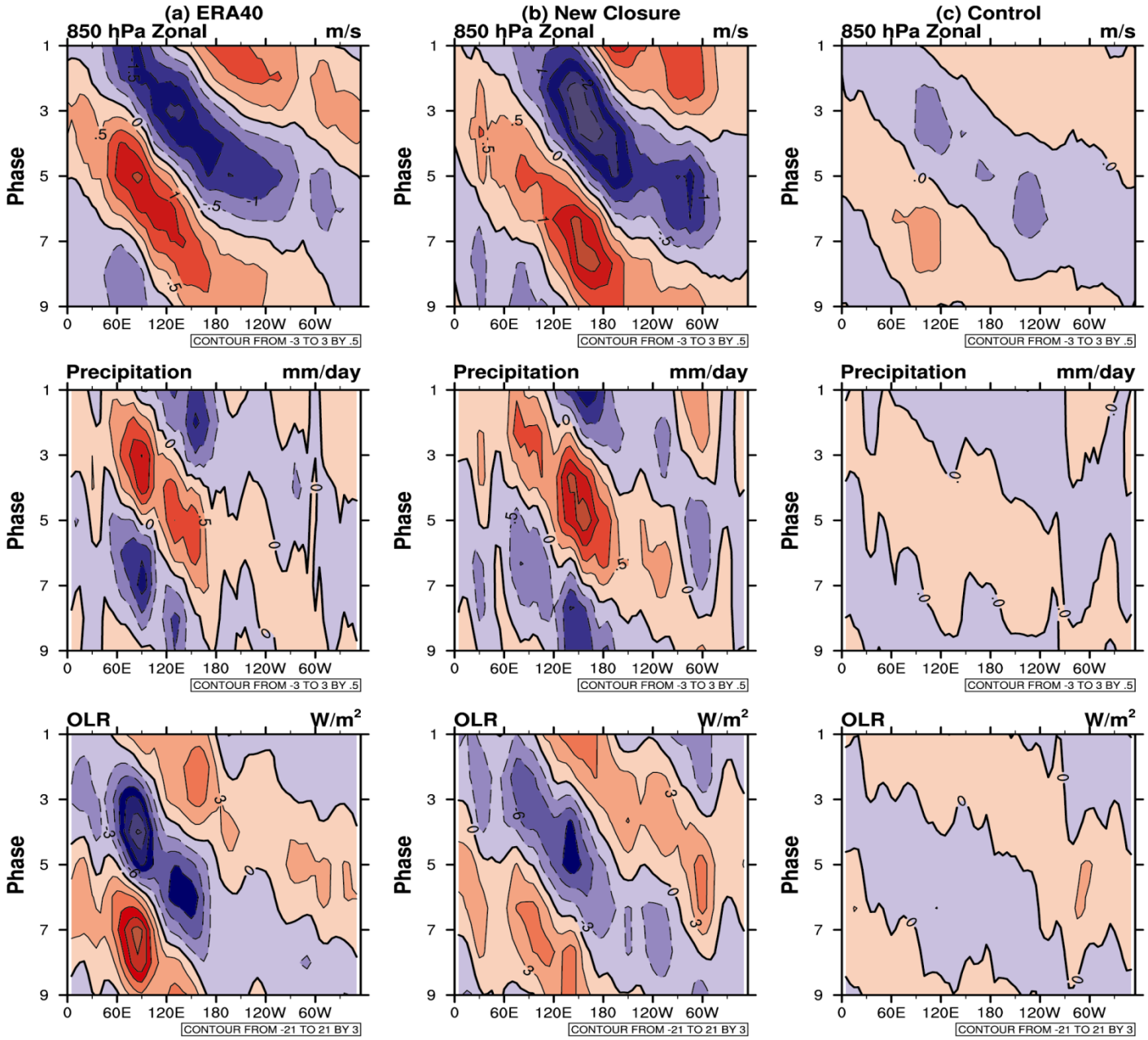

(a) Precipitation
(b) 200 hPa Zonal Wind
Xie-Arkin
ERA40
CAM3m
CAM3
ZONAL WAVENUMBER
9
7
5
3
1
21 23 28 33 41 55 83
83 55 41 33 28 23 21
WESTWARD
PERIOD (days)
EASTWARD
.35
.5
.25
.3
.075
1
1.5

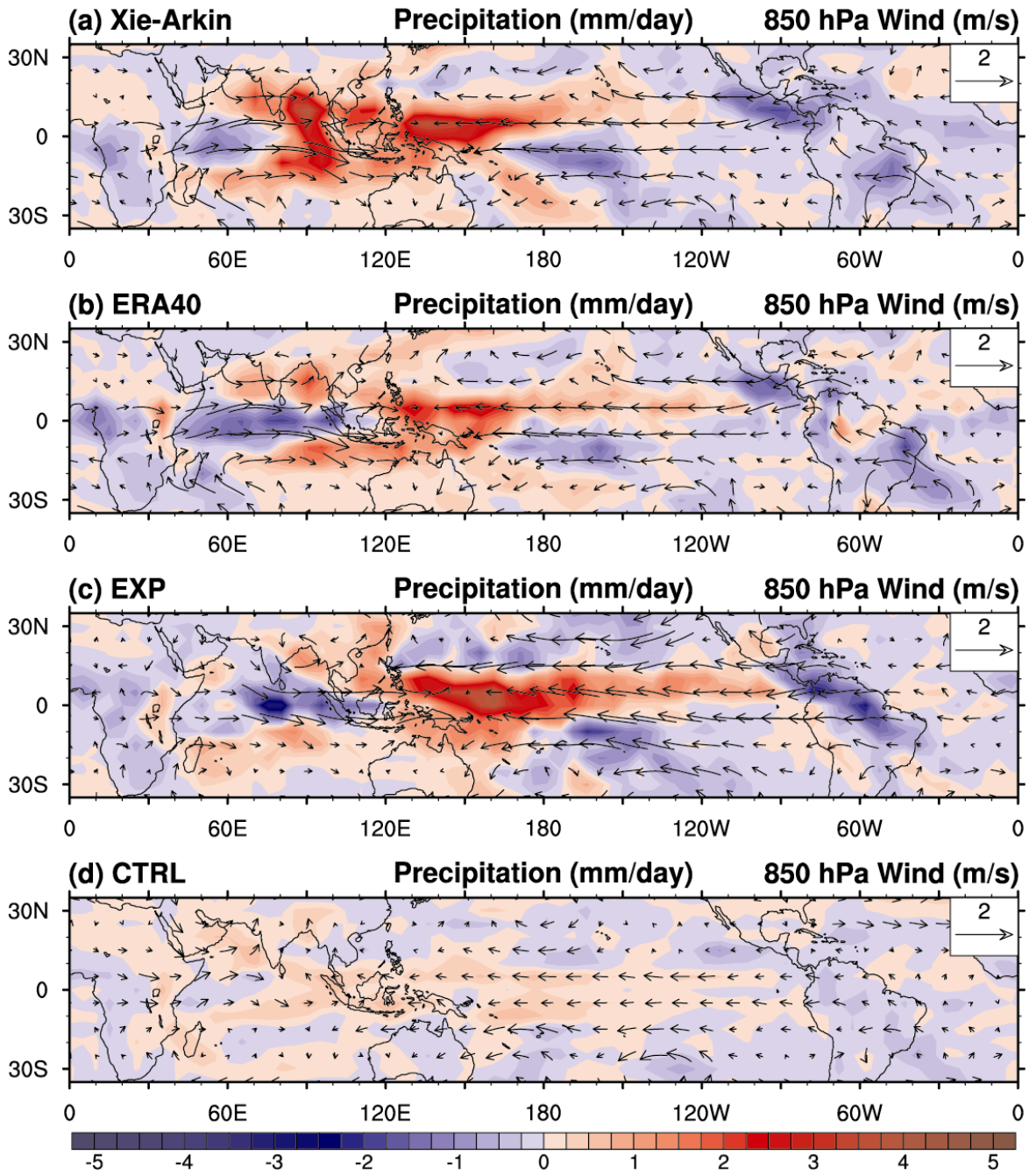

(a1) NCEP
EOF1=40%
10^6m^2/s
(a2) NCEP
EOF2=32%
10^6m^2/s
(b1) EXP
EOF1=32%
10^6m^2/s
(b2) EXP
EOF2=26%
10^6m^2/s
(c1) CTRL
EOF1=22%
10^6m^2/s
(c2) CTRL
EOF2=17%
10^6m^2/s
90N
60N
30N
0
30S
60S
90S
0
60E
120E
180
120W
60W
-5 -4 -3 -2 -1 0 1 2 3 4 5

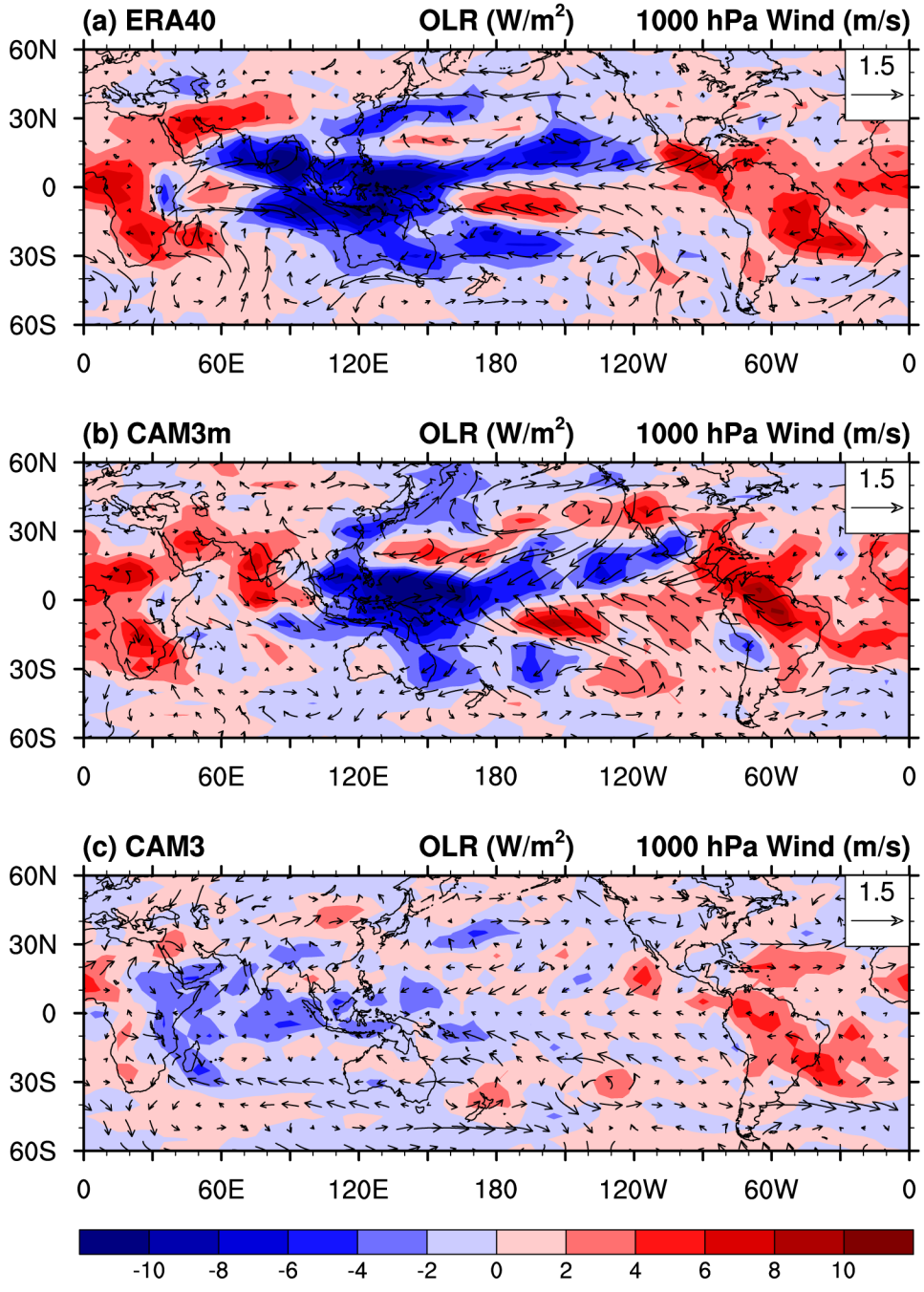
Obs

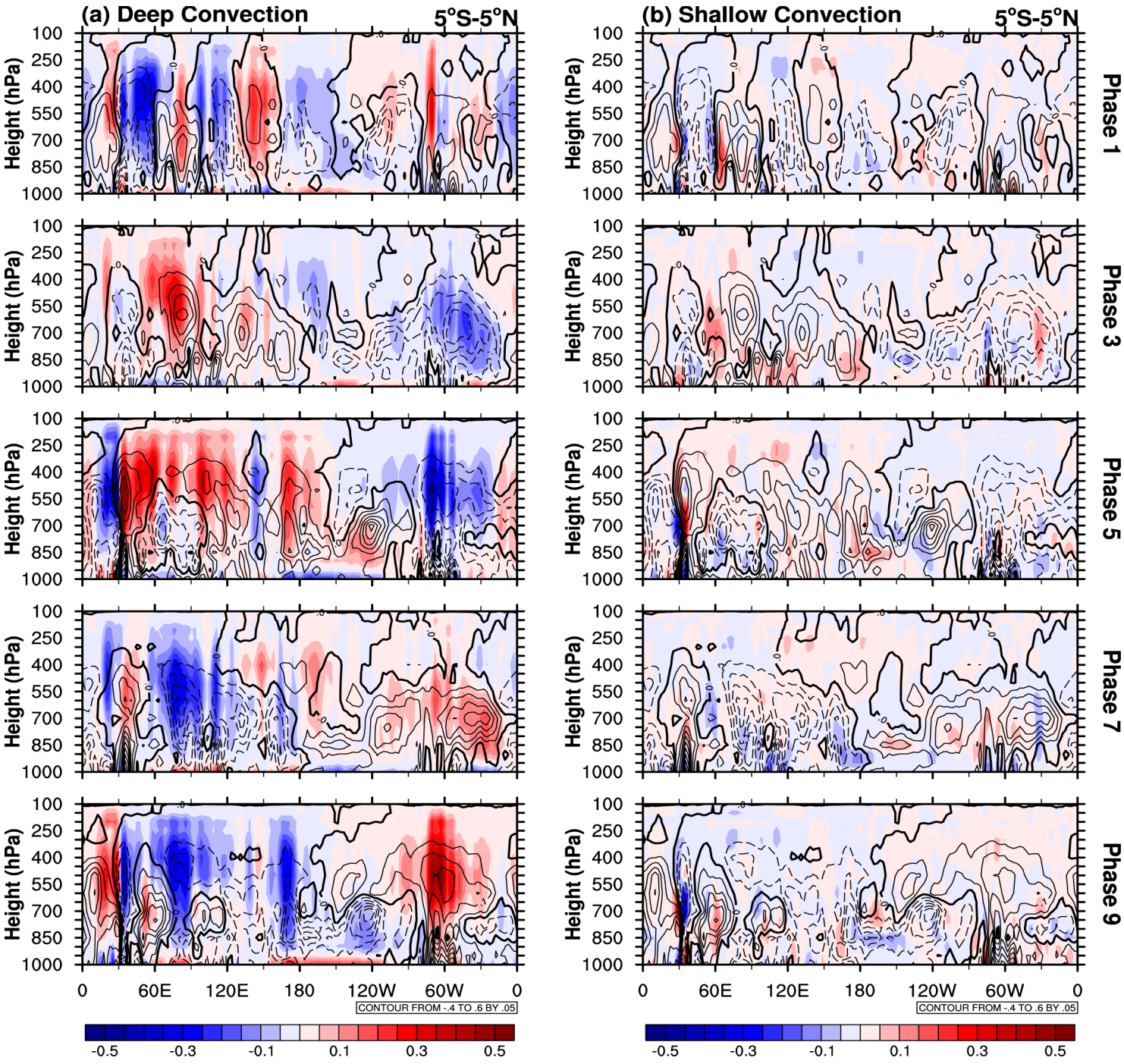
CAM3 w/ RZM

CAM3

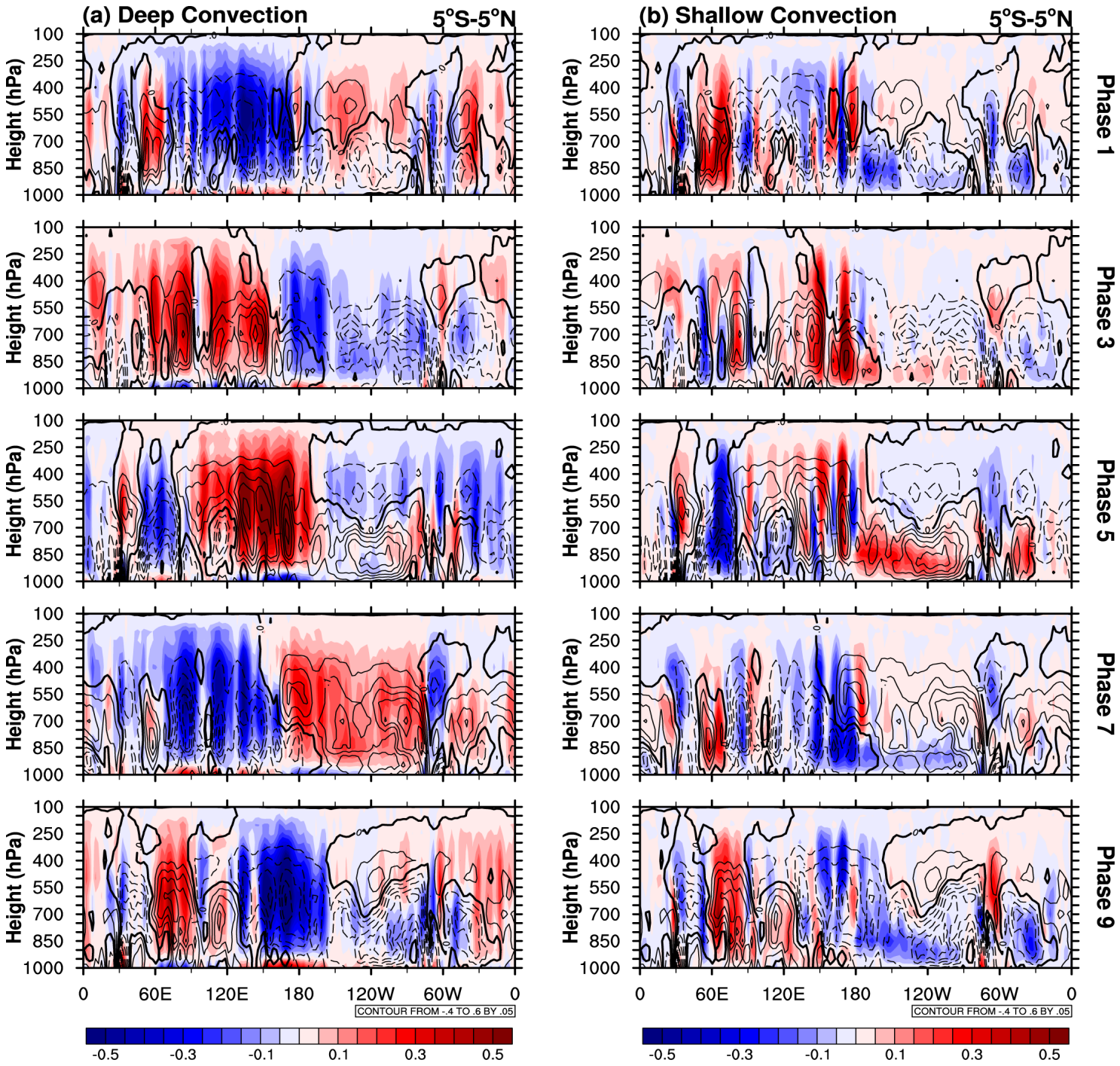



(a) Xie-Arkin
Precipitation (mm/day)
850 hPa Wind (m/s)
(b) ERA40
Precipitation (mm/day)
850 hPa Wind (m/s)
(c) EXP
Precipitation (mm/day)
850 hPa Wind (m/s)
(d) CTRL
Precipitation (mm/day)
850 hPa Wind (m/s)
30N
0
30S
0
60E
120E
180
120W
60W
0
2
-5
-4
-3
-2
-1
0
1
2
3
4
5


(a) ERA40
OLR (W/m2)
1000 hPa Wind (m/s)
1.5
60N
30N
0
30S
60S
0
60E
120E
180
120W
60W
0
(b) CAM3m
OLR (W/m2)
1000 hPa Wind (m/s)
1.5
60N
30N
0
30S
60S
0
60E
120E
180
120W
60W
0
(c) CAM3
OLR (W/m2)
1000 hPa Wind (m/s)
1.5
60N
30N
0
30S
60S
0
60E
120E
180
120W
60W
0
-10
-8
-6
-4
-2
0
2
4
6
8
10


(a) Deep Convection
5°S-5°N
(b) Shallow Convection
5°S-5°N
Height (hPa)
100
250
400
550
700
850
1000
Phase 1
Phase 3
Phase 5
Phase 7
Phase 9
0
60E
120E
180
120W
60W
0
CONTOUR FROM -.4 TO .6 BY .05
-0.5
-0.3
-0.1
0.1
0.3
0.5

CAM3
Ctrl

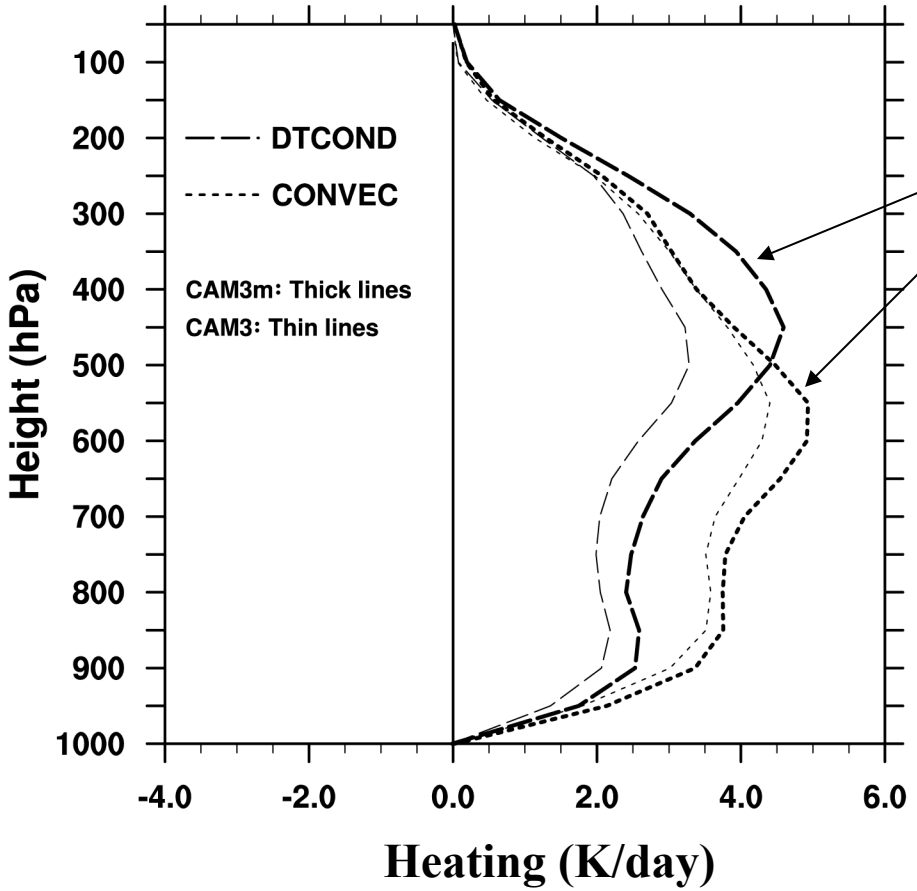

(a) Deep Convection
5°S-5°N
(b) Shallow Convection
5°S-5°N
Height (hPa)
100
250
400
550
700
850
1000
Phase 1
Phase 3
Phase 5
Phase 7
Phase 9
0
60E
120E
180
120W
60W
0
CONTOUR FROM -.4 TO .6 BY .05
-0.5
-0.3
-0.1
0.1
0.3
0.5

CAM3
Exp

Possible Reasons why MJO is or is not simulated well

- Vertical heating structure, e.g. top-heavy profile (obs and models differ)
- Relative humidity threshold (model sensitivity)
- Shallow convection preconditioning (observed, but not much obs-model comparison)

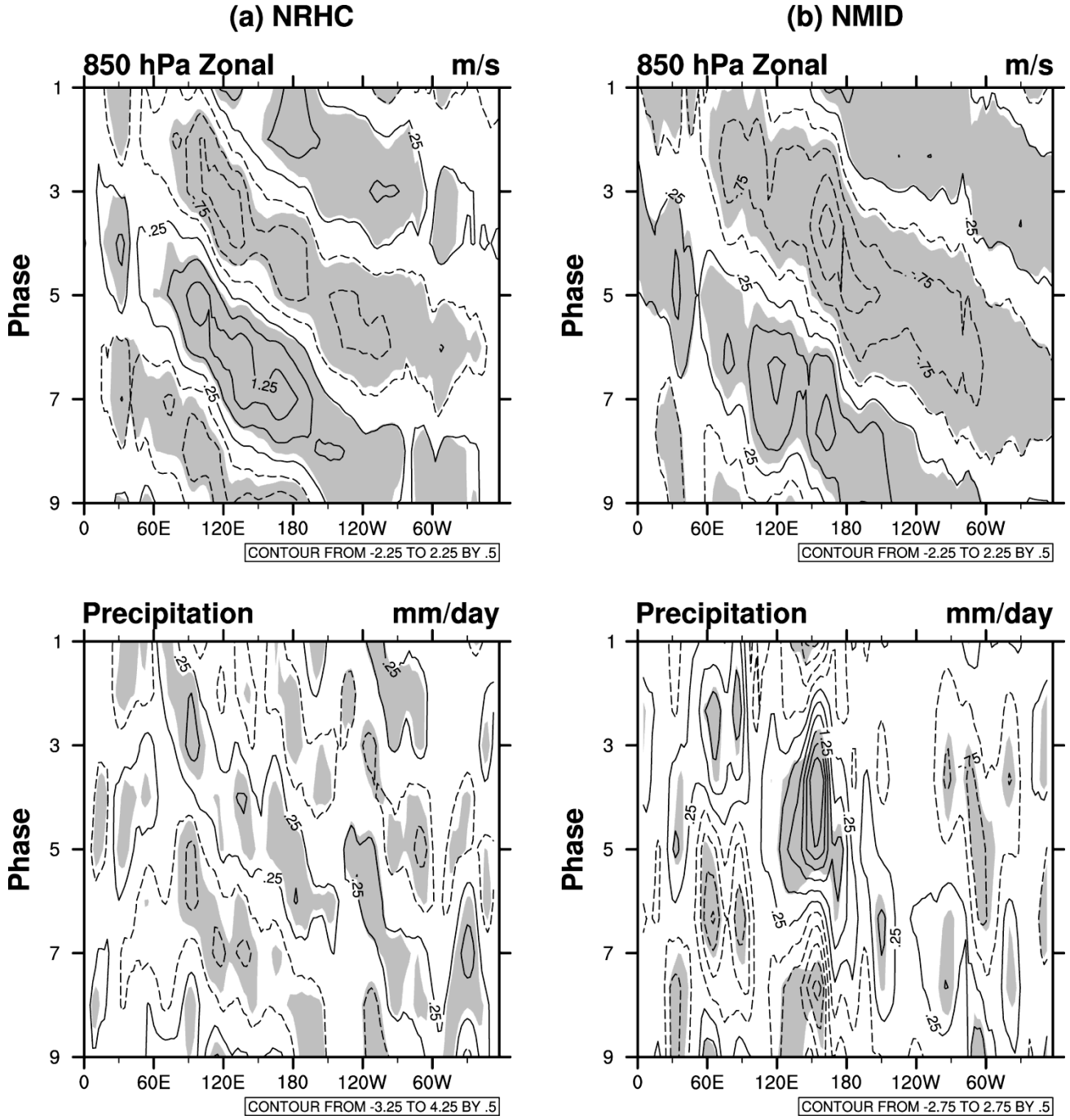
- Change of convection parameterization affects all three above



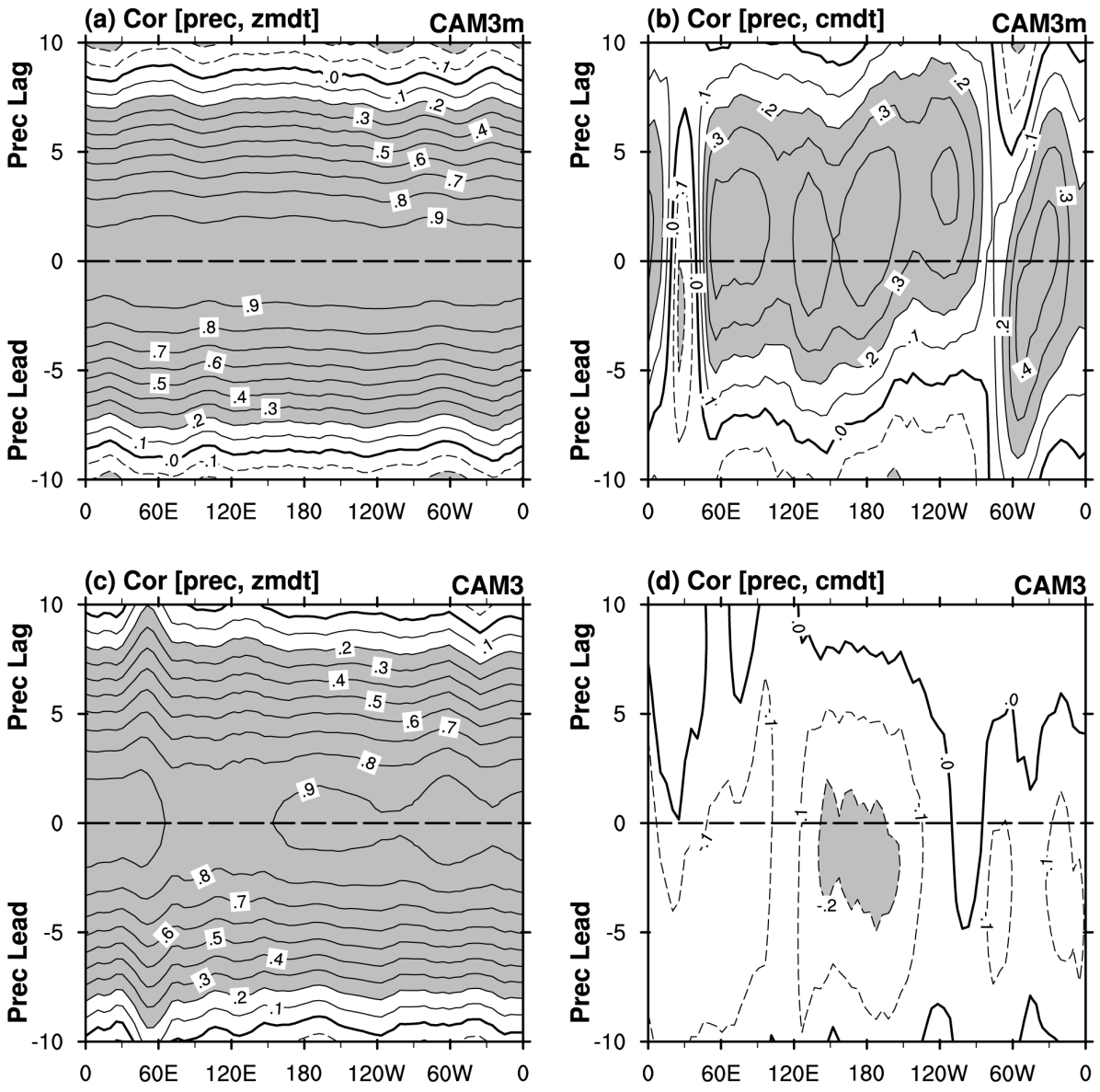
CAM3m

Averaged over
(5S, 5N) and
(155 E, 165E)

Mu and Zhang (2006, JGR)


(a) NRHC
850 hPa Zonal
m/s
Phase
1
3
5
7
9
0
60E
120E
180
120W
60W
CONTOUR FROM -2.25 TO 2.25 BY .5
(b) NMID
850 hPa Zonal
m/s
Phase
CONTOUR FROM -2.25 TO 2.25 BY .5
Precipitation
mm/day
Phase
CONTOUR FROM -3.25 TO 4.25 BY .5
Precipitation
mm/day
Phase
CONTOUR FROM -2.75 TO 2.75 BY .5

Lag corr. of deep and shallow convection



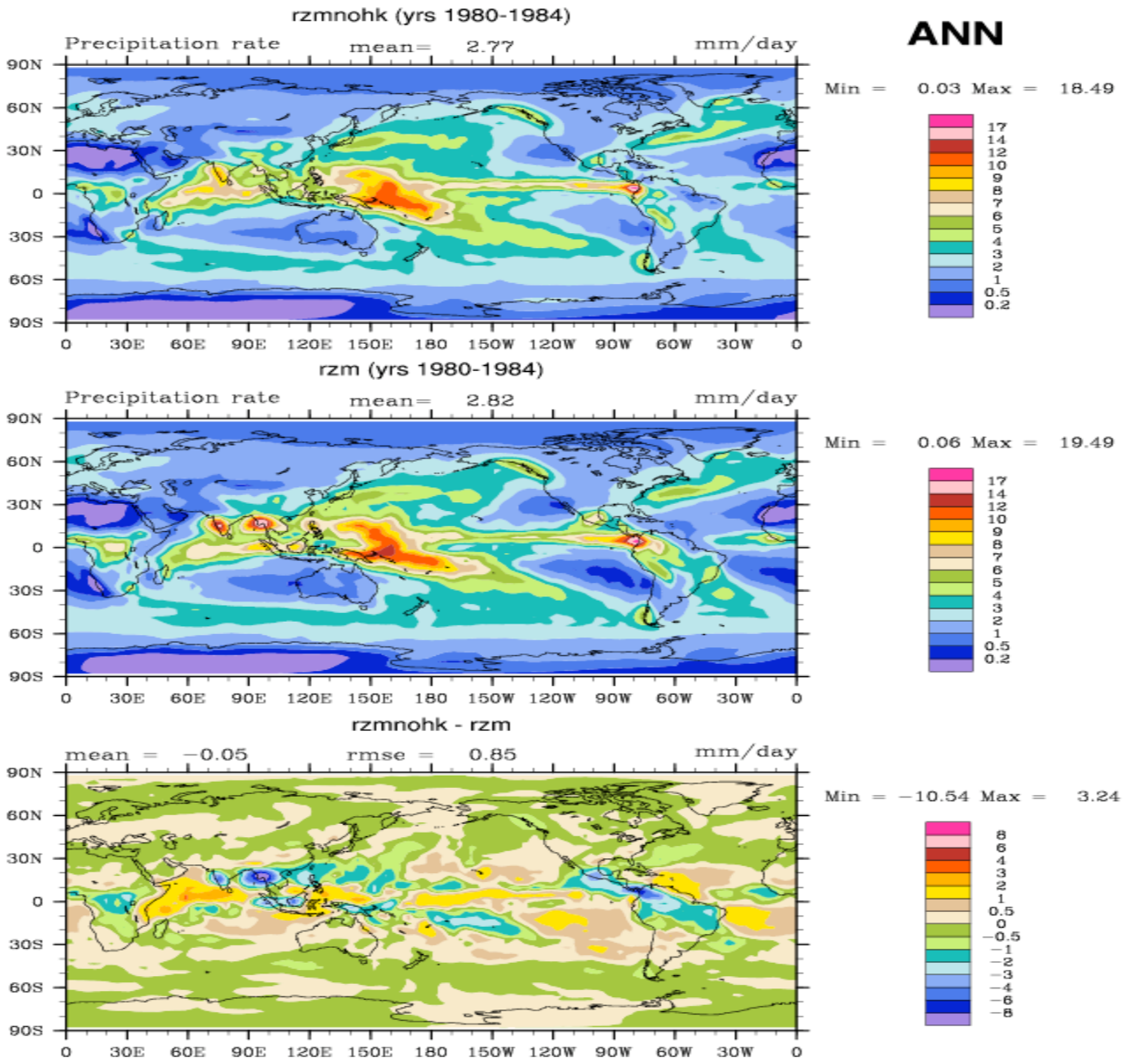
CAM3
w/ RZM

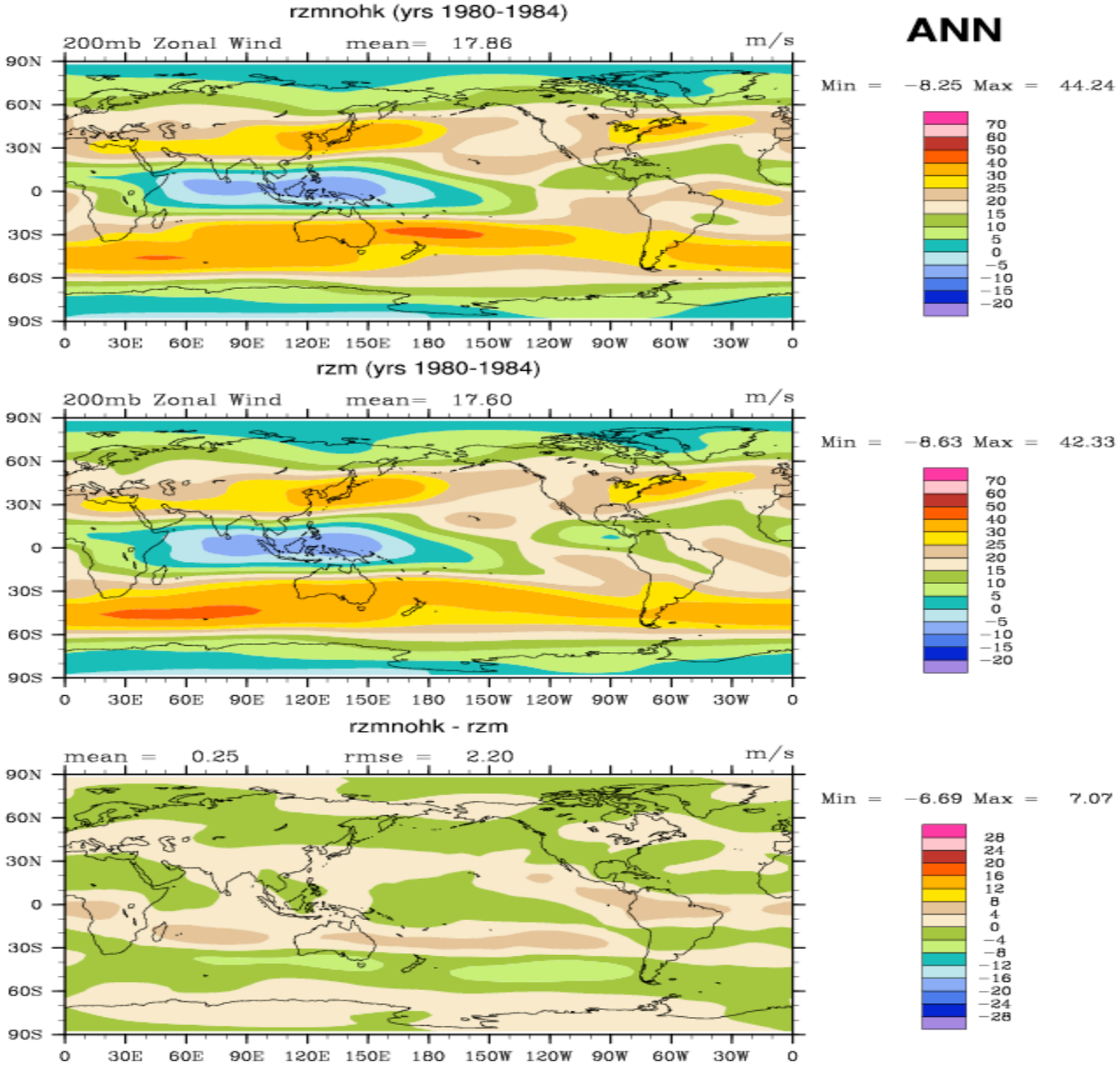
Mu and Zhang
(2008, JGR)

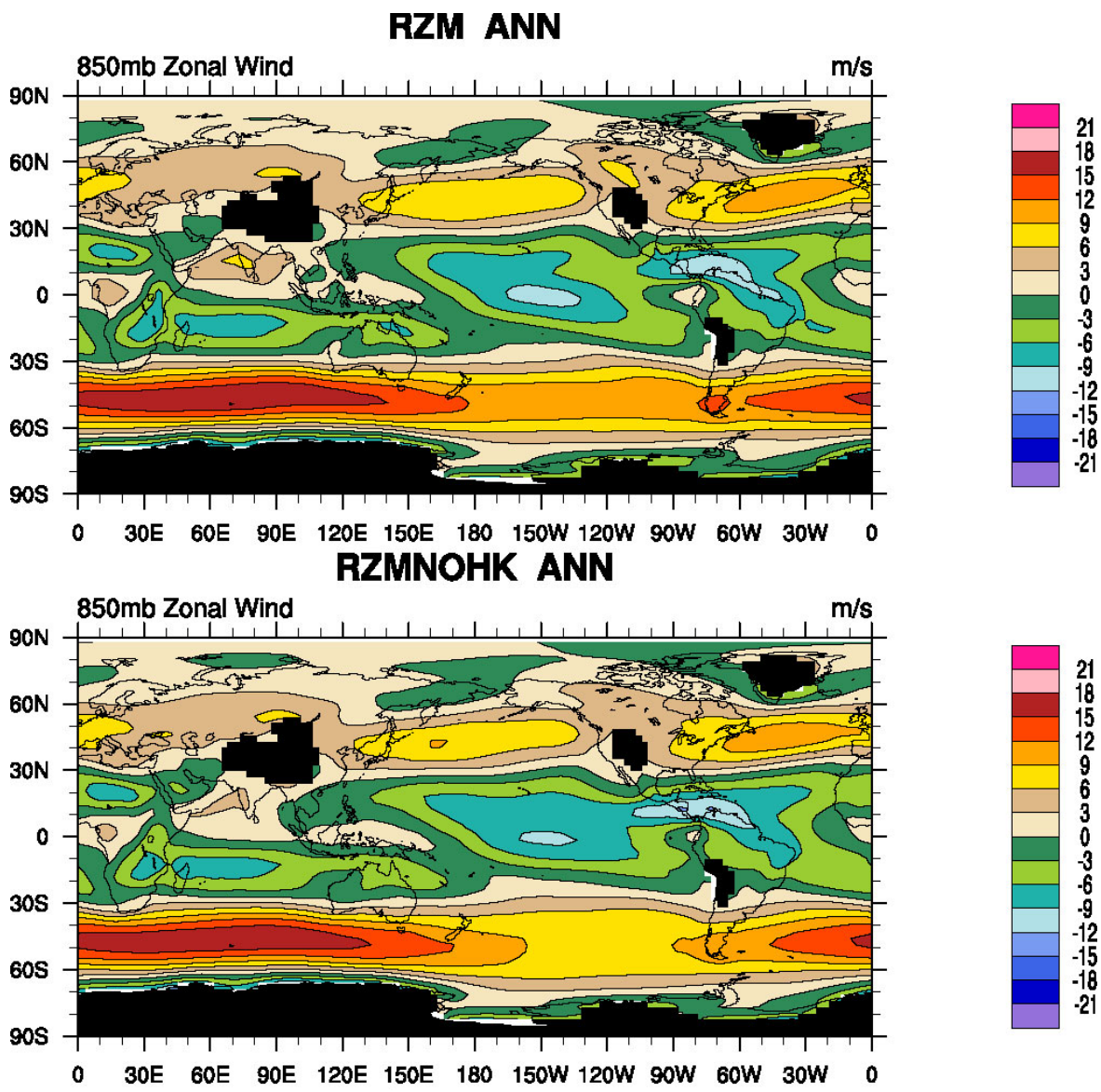
CAM3
w/ ZM

Shallow Convection Experiments

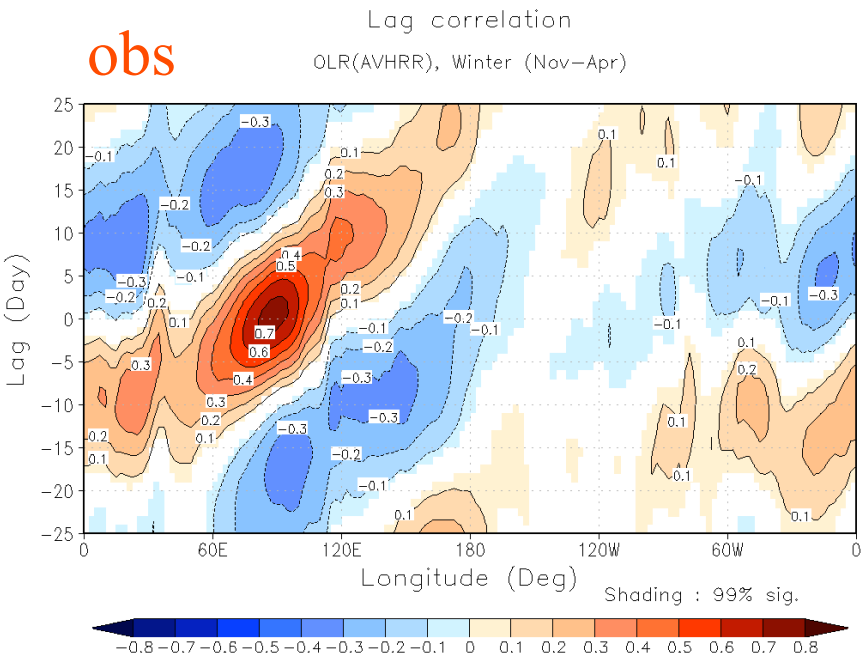
- Hack scheme is removed in tropical belt below 700 mb


rzmnohk (yrs 1980-1984)
Precipitation rate
mean= 2.77
mm/day
ANN
Min = 0.03 Max = 18.49
rzm (yrs 1980-1984)
Precipitation rate
mean= 2.82
mm/day
Min = 0.06 Max = 19.49
rzmnohk - rzm
mean = −0.05
rmse = 0.85
mm/day
Min = −10.54 Max = 3.24
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
17 14 12 10 9 8 7 6 5 4 3 2 1 0.5 0.2
8 6 4 3 2 1 0.5 0 −0.5 −1 −2 −3 −4 −6 −8

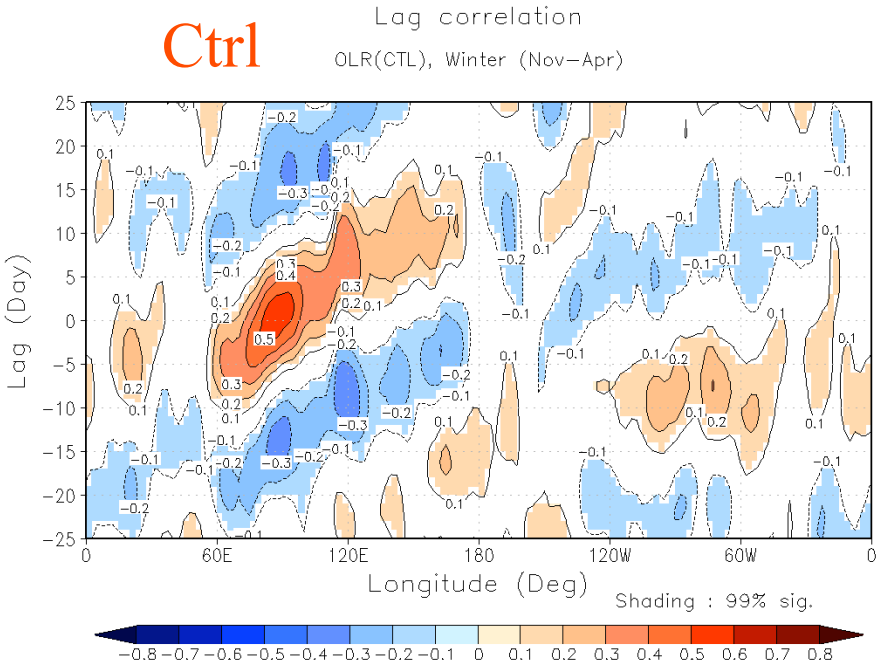

rzmnohk (yrs 1980-1984)
200mb Zonal Wind
mean= 17.86
m/s
Min = −8.25 Max = 44.24
ANN
rzm (yrs 1980-1984)
200mb Zonal Wind
mean= 17.60
m/s
Min = −8.63 Max = 42.33
rzmnohk - rzm
mean = 0.25
rmse = 2.20
m/s
Min = −6.69 Max = 7.07
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
70 60 50 40 30 25 20 15 10 5 0 −5 −10 −15 −20
28 24 20 16 12 8 4 0 −4 −8 −12 −16 −20 −24 −28


RZM ANN
850mb Zonal Wind
m/s
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
21
18
15
12
9
6
3
0
-3
-6
-9
-12
-15
-18
-21
RZMNOHK ANN
850mb Zonal Wind
m/s
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
21
18
15
12
9
6
3
0
-3
-6
-9
-12
-15
-18
-21

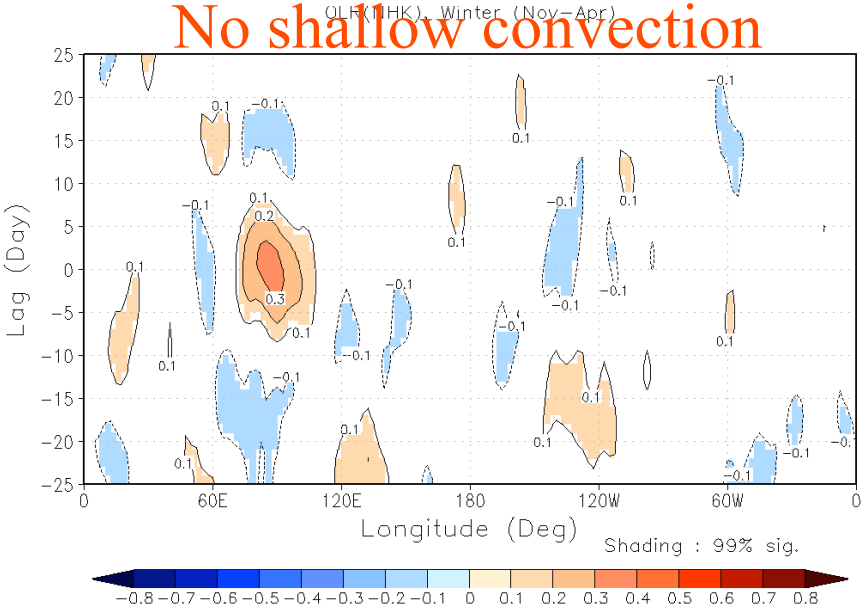
obs



Ctrl



No shallow convection

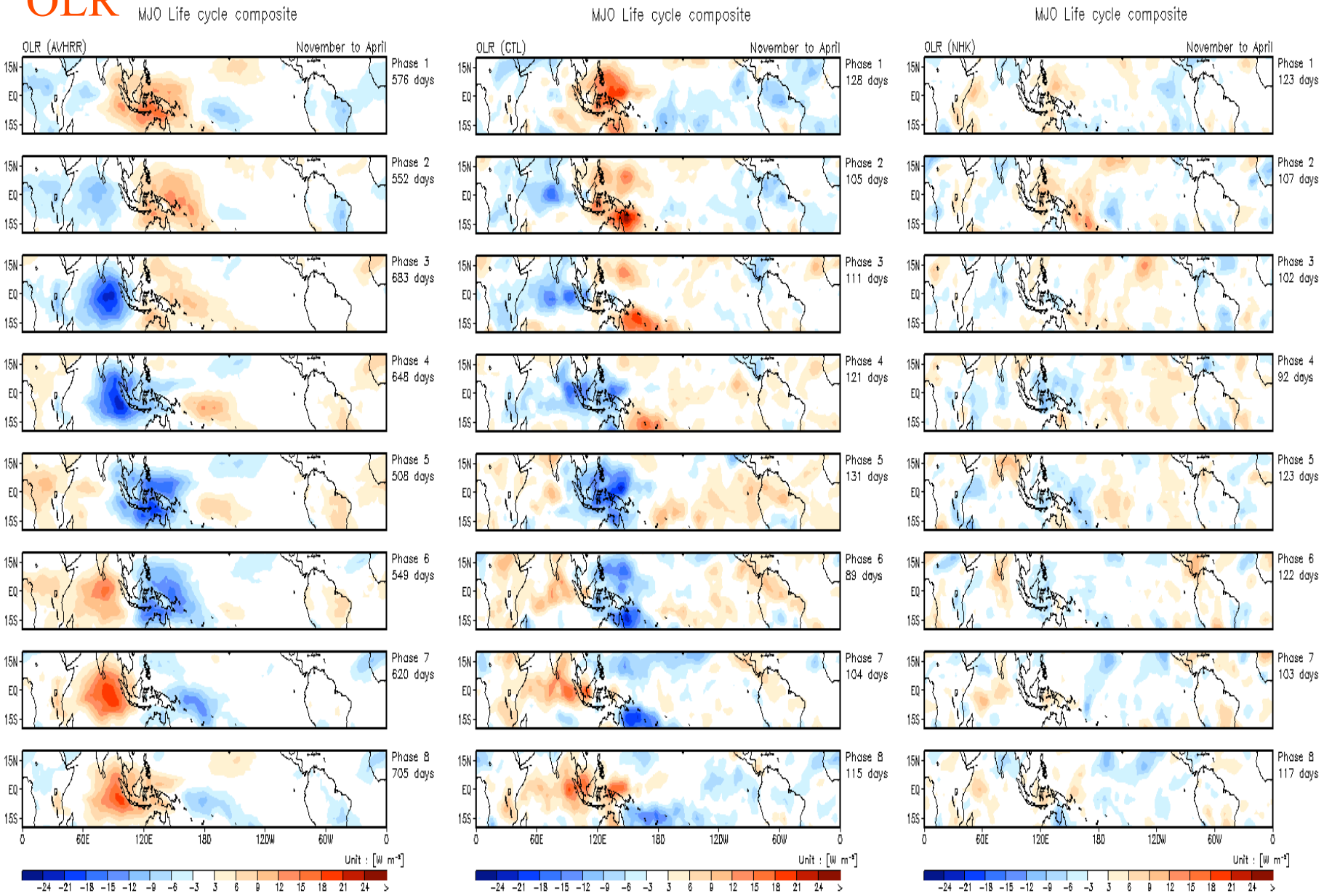


Obs

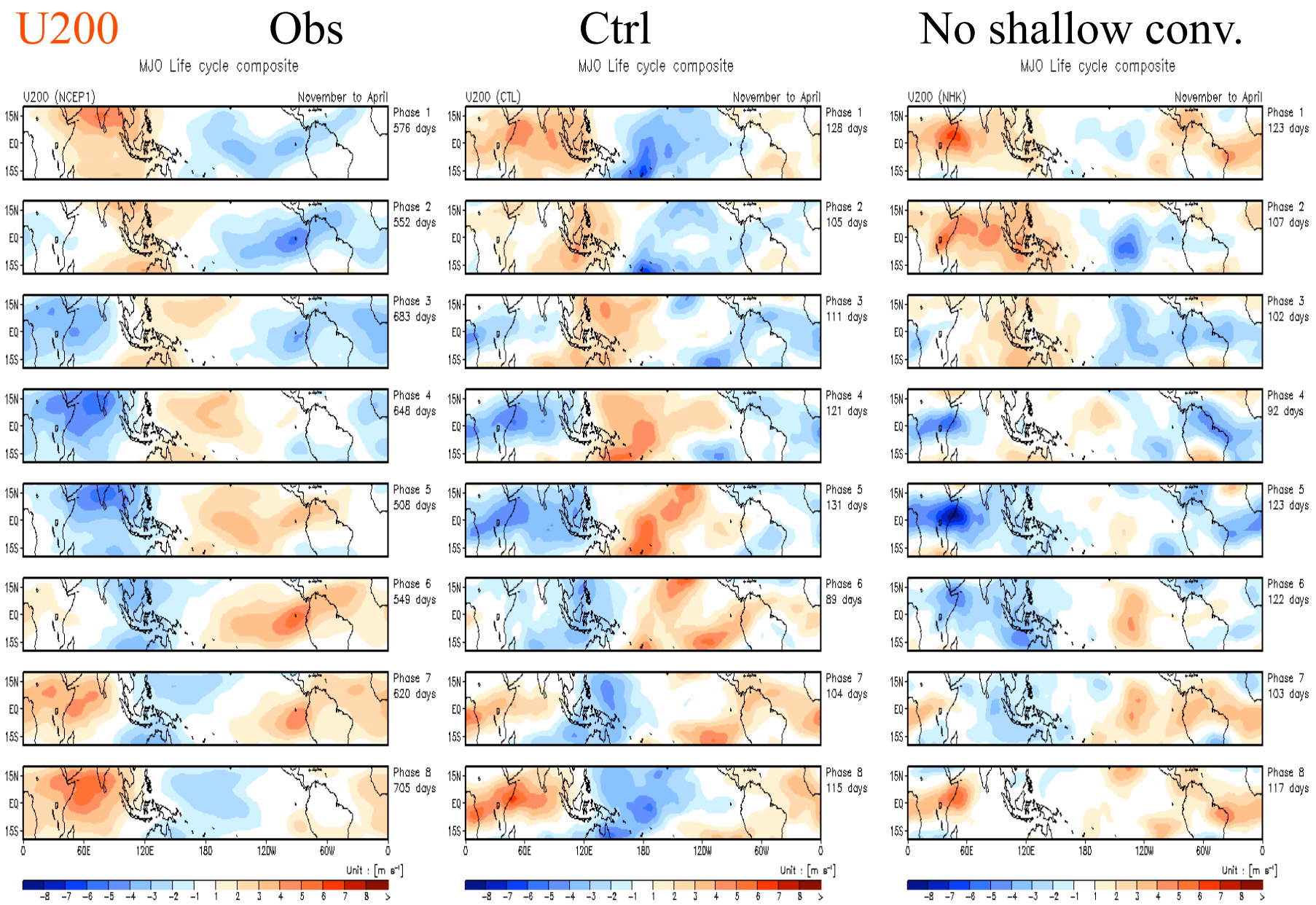
Ctrl

No shallow conv.

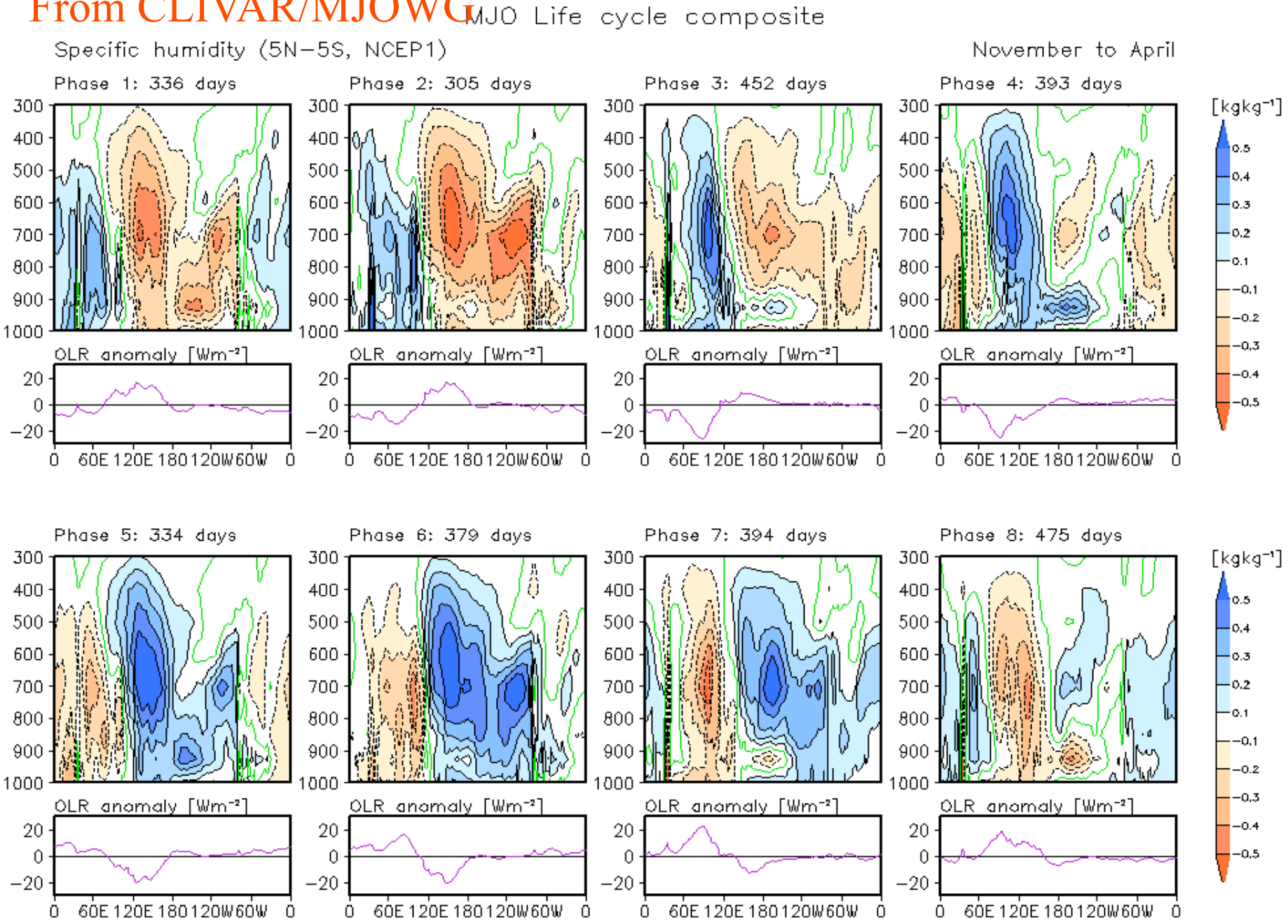
OLR

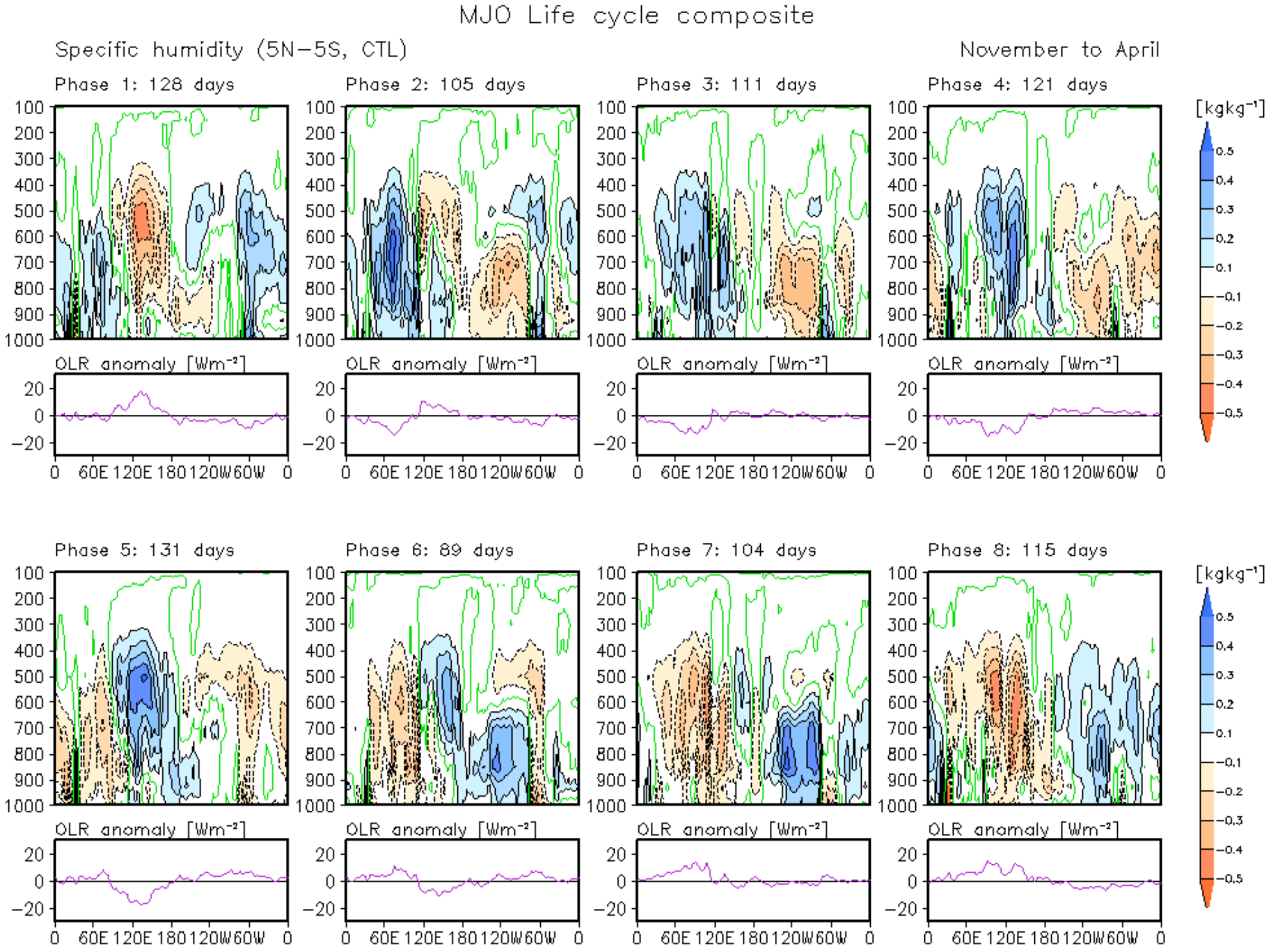


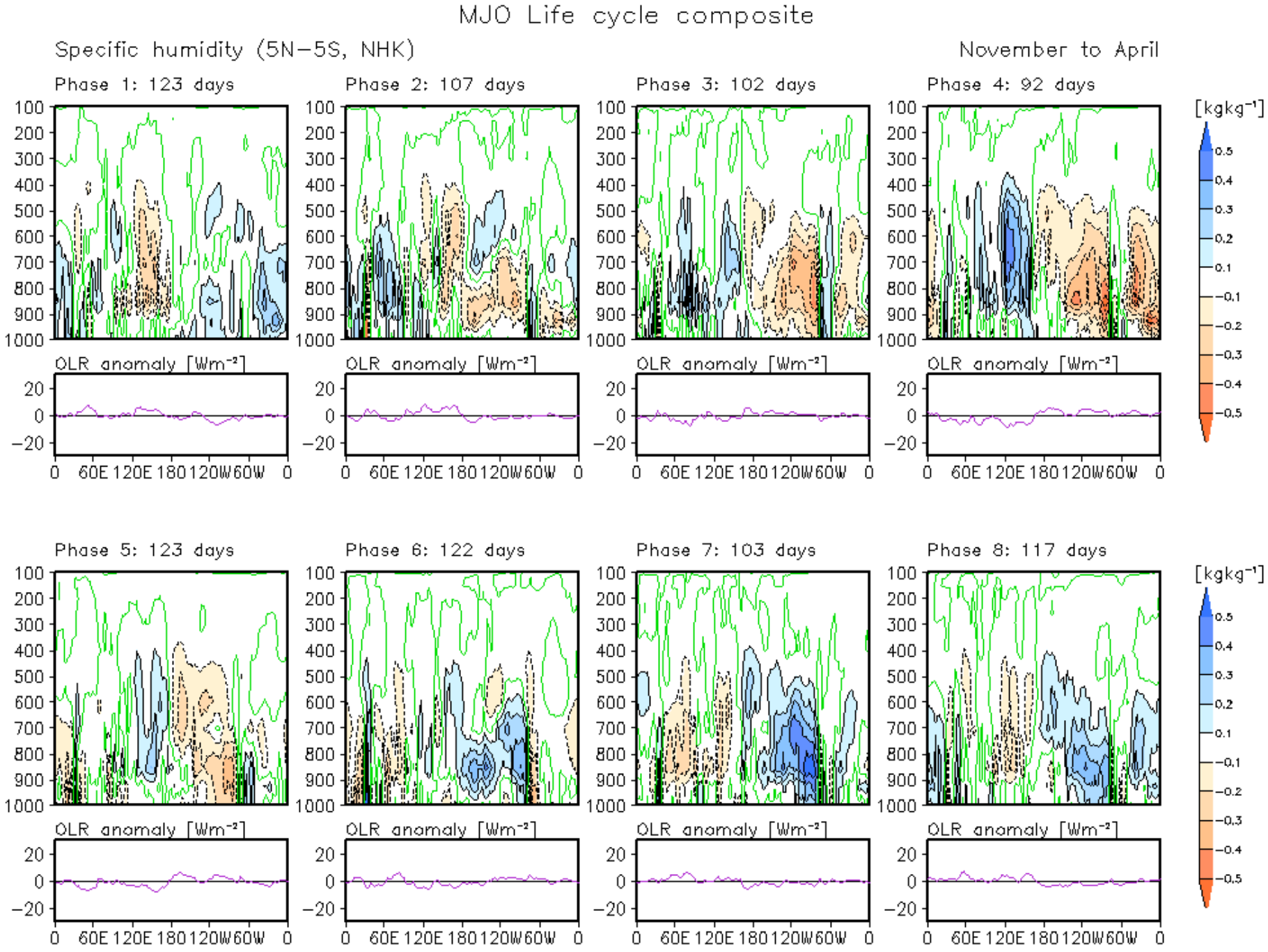
U200

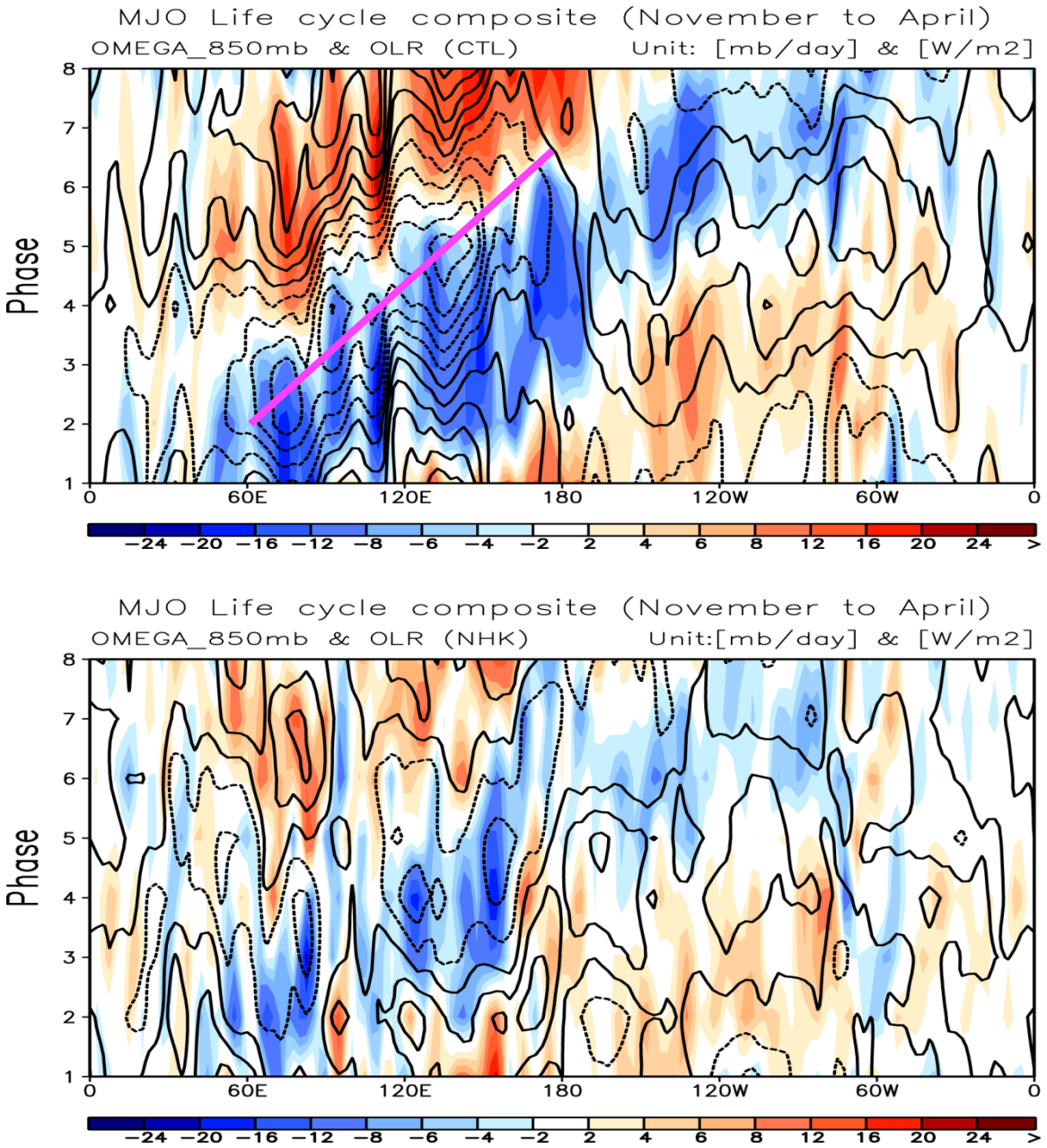

Obs
Ctrl
No shallow conv.
MJO Life cycle composite
MJO Life cycle composite
MJO Life cycle composite
U200 (NCEP1)
November to April
U200 (CTL)
November to April
U200 (NHK)
November to April
Phase 1 576 days
Phase 2 552 days
Phase 3 683 days
Phase 4 648 days
Phase 5 508 days
Phase 6 549 days
Phase 7 620 days
Phase 8 705 days
Phase 1 128 days
Phase 2 105 days
Phase 3 111 days
Phase 4 121 days
Phase 5 131 days
Phase 6 89 days
Phase 7 104 days
Phase 8 115 days
Phase 1 123 days
Phase 2 107 days
Phase 3 102 days
Phase 4 92 days
Phase 5 123 days
Phase 6 122 days
Phase 7 103 days
Phase 8 117 days
15N
EQ
15S
0
60E
120E
180
120W
60W
Unit : [m s-1]
-8 -7 -6 -5 -4 -3 -2 -1 1 2 3 4 5 6 7 8 >
Unit : [m s-1]
-8 -7 -6 -5 -4 -3 -2 -1 1 2 3 4 5 6 7 8 >
Unit : [m s-1]
-8 -7 -6 -5 -4 -3 -2 -1 1 2 3 4 5 6 7 8 >

From CLIVAR/MJOWG




MJO Life cycle composite
Specific humidity (5N−5S, CTL)
November to April
Phase 1: 128 days
Phase 2: 105 days
Phase 3: 111 days
Phase 4: 121 days
Phase 5: 131 days
Phase 6: 89 days
Phase 7: 104 days
Phase 8: 115 days
[kgkg⁻¹]
0.5
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.3
−0.4
−0.5
100
200
300
400
500
600
700
800
900
1000
OLR anomaly [Wm⁻²]
20
0
−20
0 60E 120E 180 120W 60W 0


MJO Life cycle composite
Specific humidity (5N−5S, NHK)
November to April
Phase 1: 123 days
Phase 2: 107 days
Phase 3: 102 days
Phase 4: 92 days
Phase 5: 123 days
Phase 6: 122 days
Phase 7: 103 days
Phase 8: 117 days
[kgkg⁻¹]
OLR anomaly [Wm⁻²]
100
200
300
400
500
600
700
800
900
1000
20
0
−20
0
60E
120E
180
120W
60W
0.5
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.3
−0.4
−0.5


MJO Life cycle composite (November to April)
OMEGA_850mb & OLR (CTL)
Unit: [mb/day] & [W/m2]
Phase
1
2
3
4
5
6
7
8
0
60E
120E
180
120W
60W
0
−24 −20 −16 −12 −8 −6 −4 −2 2 4 6 8 12 16 20 24 >
MJO Life cycle composite (November to April)
OMEGA_850mb & OLR (NHK)
Unit:[mb/day] & [W/m2]
Phase
1
2
3
4
5
6
7
8
0
60E
120E
180
120W
60W
0
−24 −20 −16 −12 −8 −6 −4 −2 2 4 6 8 12 16 20 24 >

Summary

- NCAR model CAM3 has very weak MJO.
- When the convection scheme was revised to use a large-scale forcing-based (instead of CAPE-based) closure, realistic MJO was simulated (Zhang and Mu 2005, J. Climate).
- Interaction of deep and shallow convection plays a key role in MJO simulation (Zhang and Song 2009)

Summary (cont'd)

- Improving deep convection can lead to improved shallow convection simulation.
- Without shallow convection, MJO simulation is poor even with the "right" deep convection parameterization.
- Shallow convection moistens lower troposphere and provides low-level mass/ moisture convergence ahead of deep convection for MJO.