Shallow to Deep Convective Transition of the MJO - Perspectives from Observations

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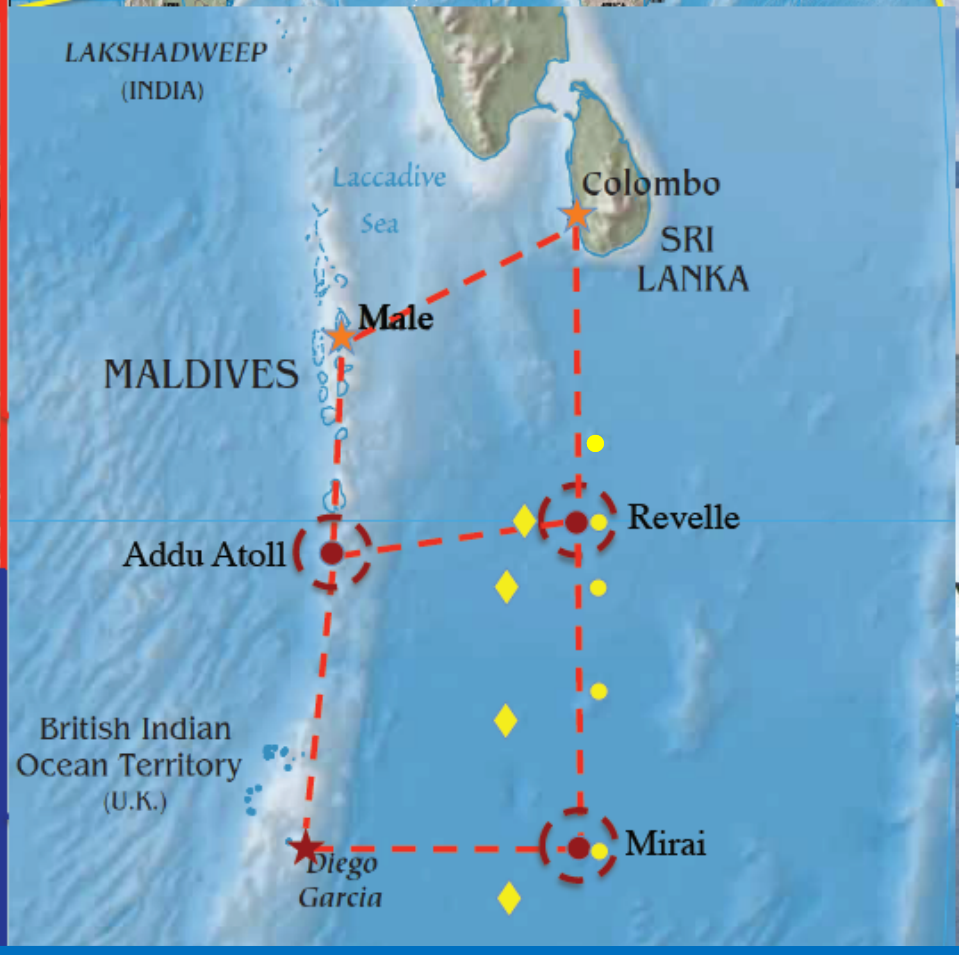
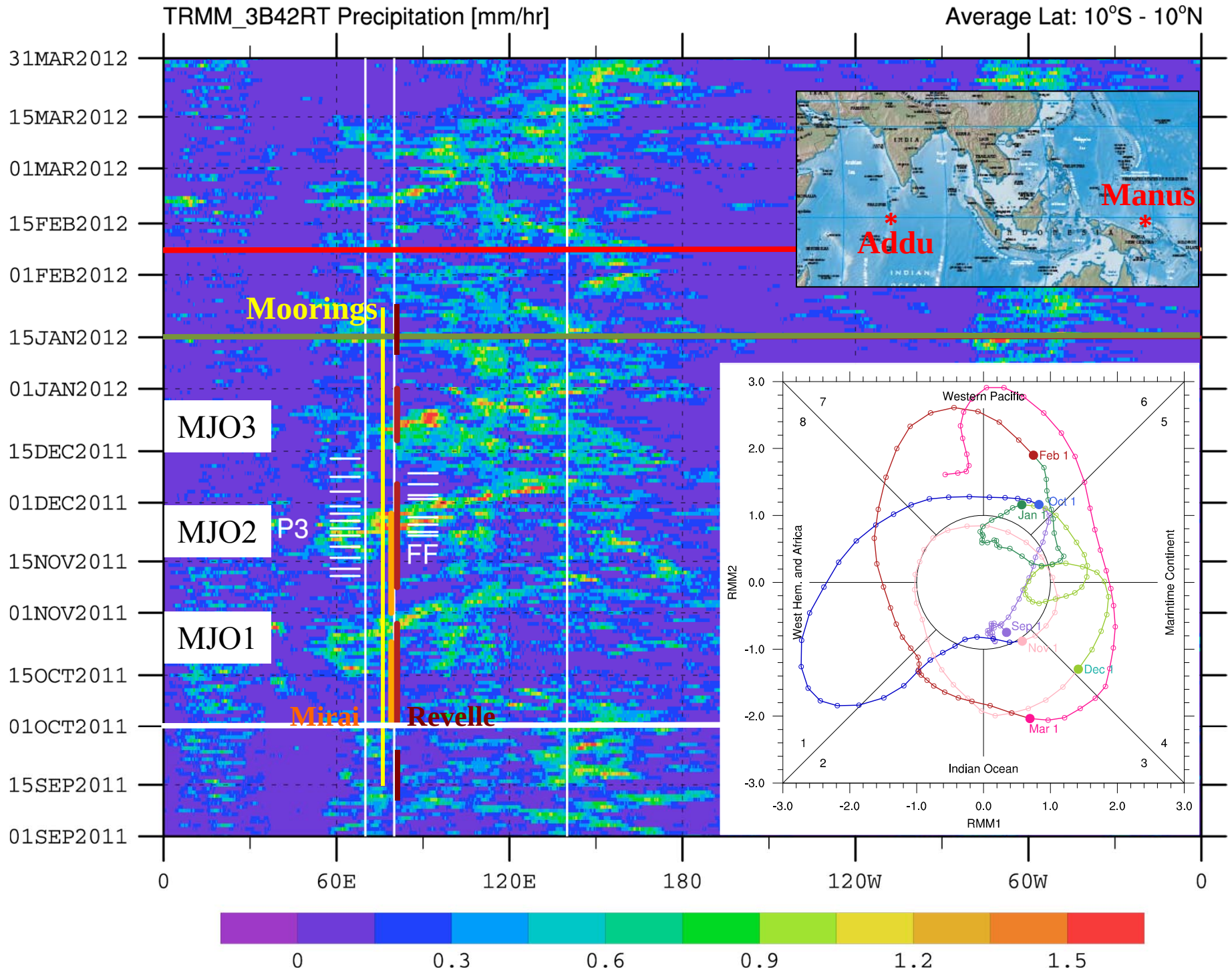
Issues:

- *Transition of cloud types vs. cloud population distribution*
- *Asymmetry in shallow to deep to shallow transitions*
- *Convective self-sustainment (moisture feedback) vs. large-scale forcing*
- *Sources of moisture: convective detrainment, local surface evaporation, large-scale advection and convergence*
- *Effects of moisture vs. other factors: vertical wind shear, temperature perturbations*

AMIE/DYNAMO Field Experiment

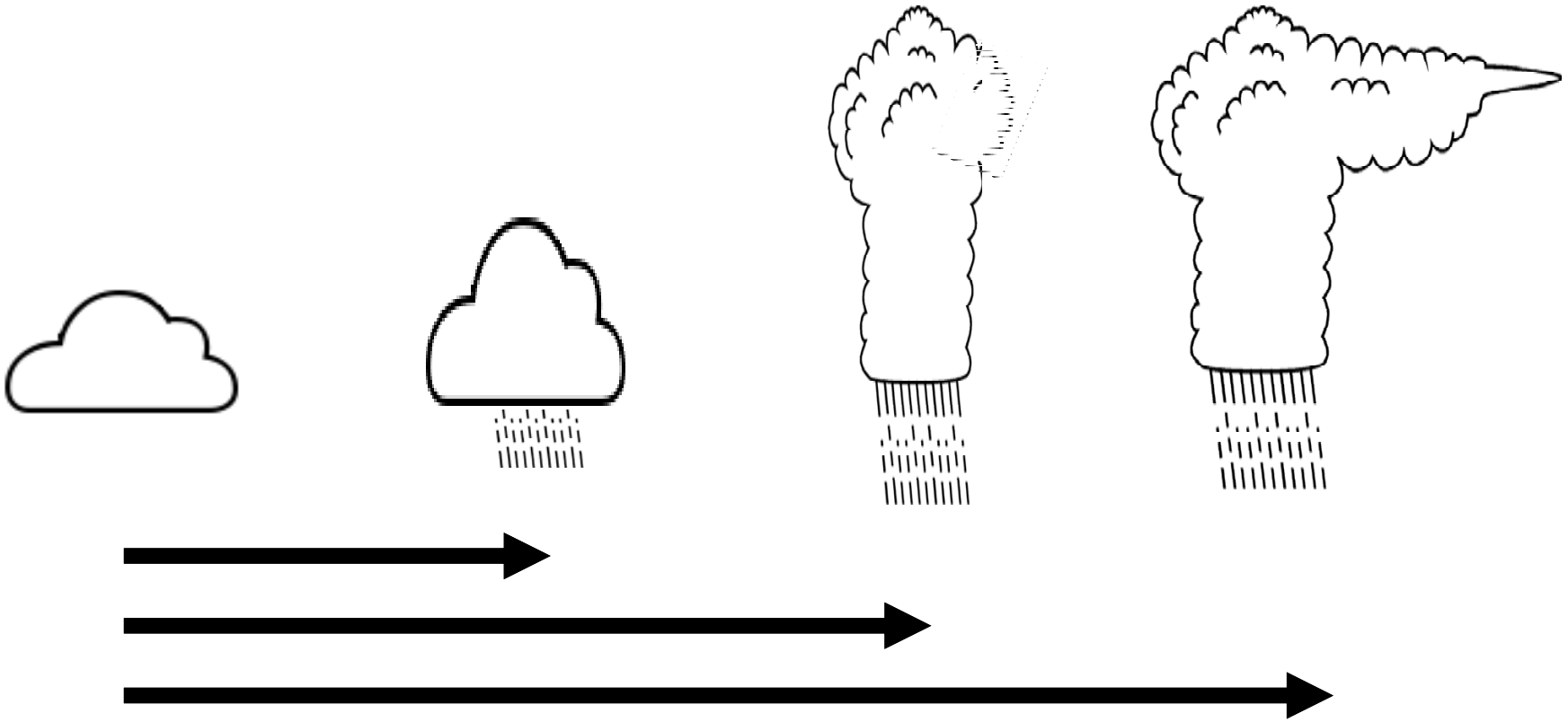


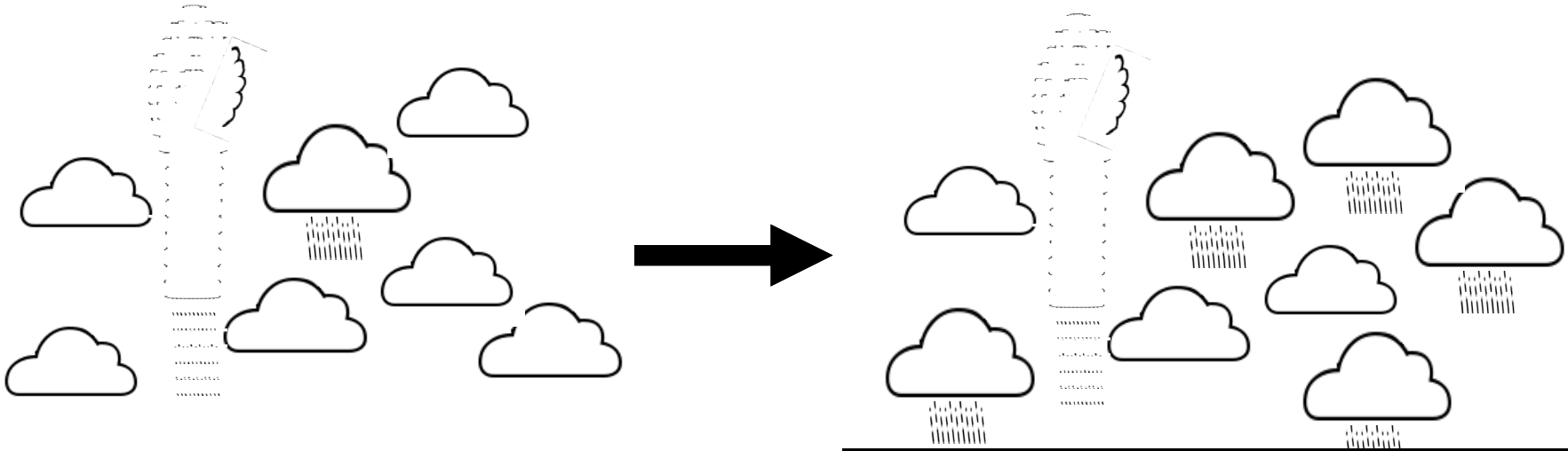

TRMM_3B42RT Precipitation [mm/hr]
Average Lat: 10°S - 10°N
31MAR2012
15MAR2012
01MAR2012
15FEB2012
01FEB2012
15JAN2012
01JAN2012
15DEC2011
01DEC2011
15NOV2011
01NOV2011
15OCT2011
01OCT2011
15SEP2011
01SEP2011
0
60E
120E
180
120W
60W
0
Moorings
MJO3
MJO2
MJO1
P3
FF
Mirai
Revelle
Addu
Manus
Western Pacific
Indian Ocean
West Hem. and Africa
Marintime Continent
RMM1
RMM2
Feb 1
Oct 1
Jan 1
Sep 1
Nov 1
Dec 1
Mar 1
0
0.3
0.6
0.9
1.2
1.5

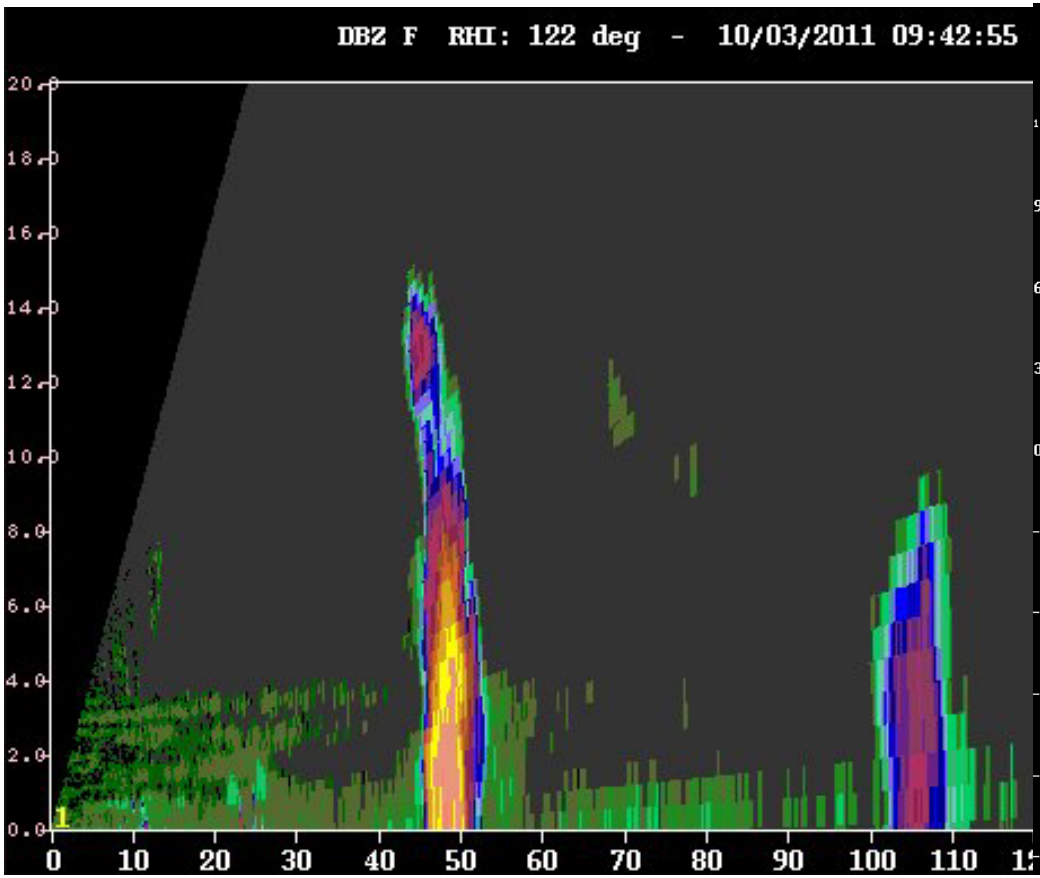
Transition of Cloud Types vs. Cloud Population Distribution

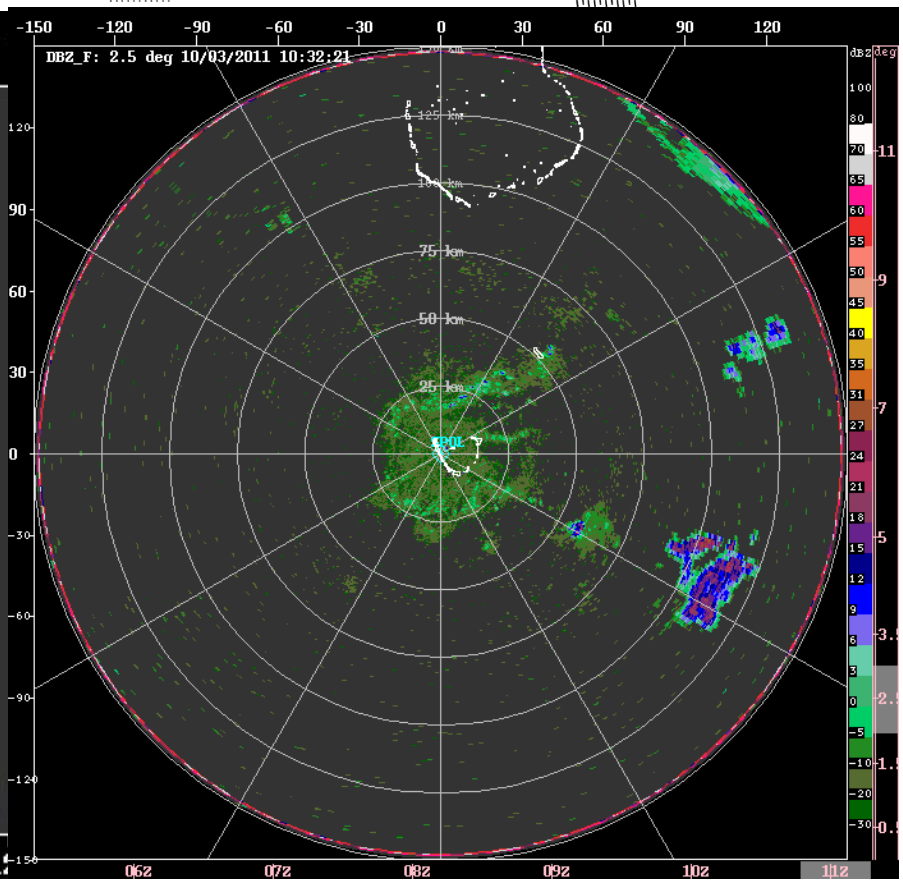
"Suppressed"

"Active"






DBZ F RHI: 122 deg - 10/03/2011 09:42:55
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
10
20
30
40
50
60
70
80
90
100
110


DBZ_F: 2.5 deg 10/03/2011 10:32:21
-150
-120
-90
-60
-30
0
30
60
90
120
75 km
50 km
25 km
dBZ
deg

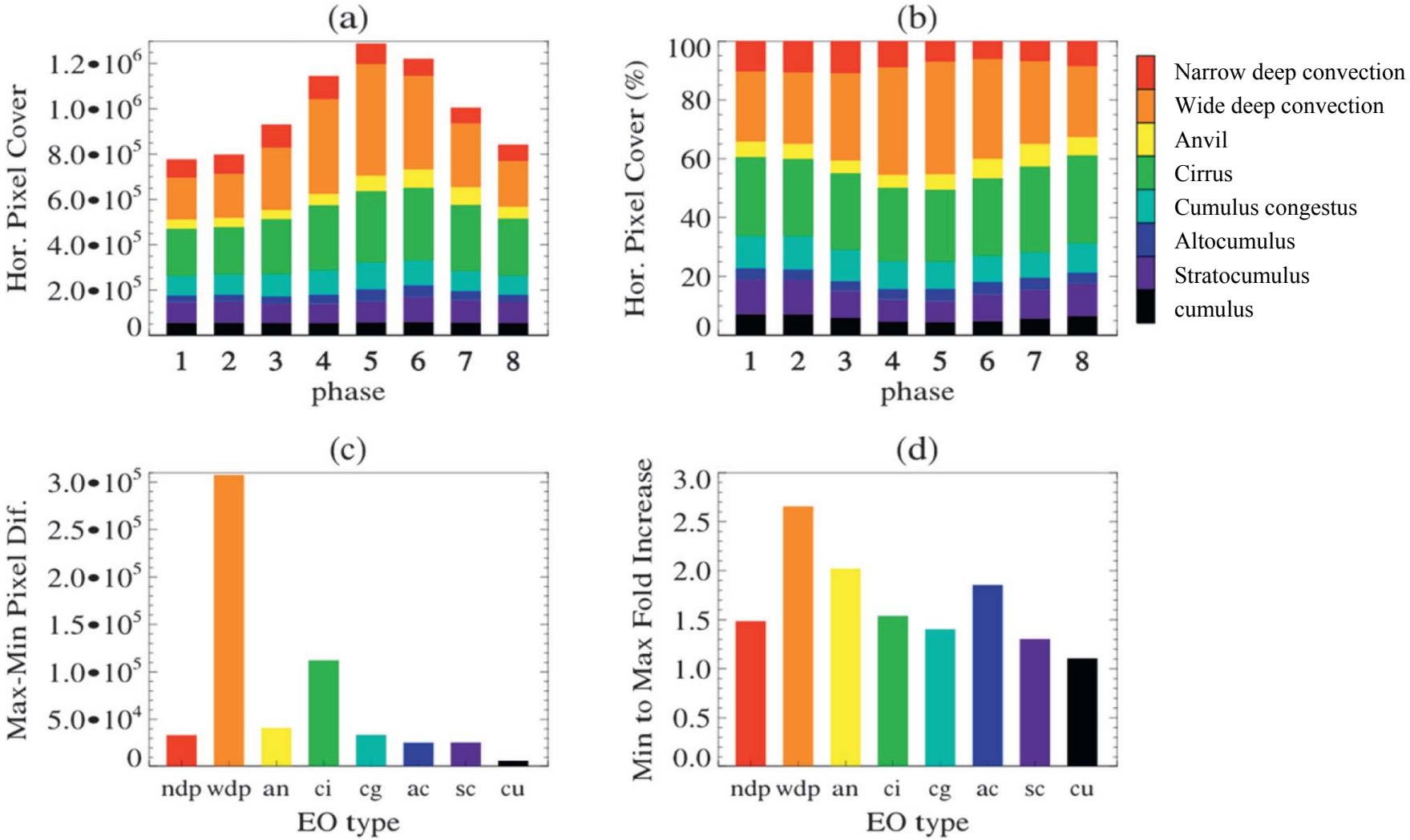
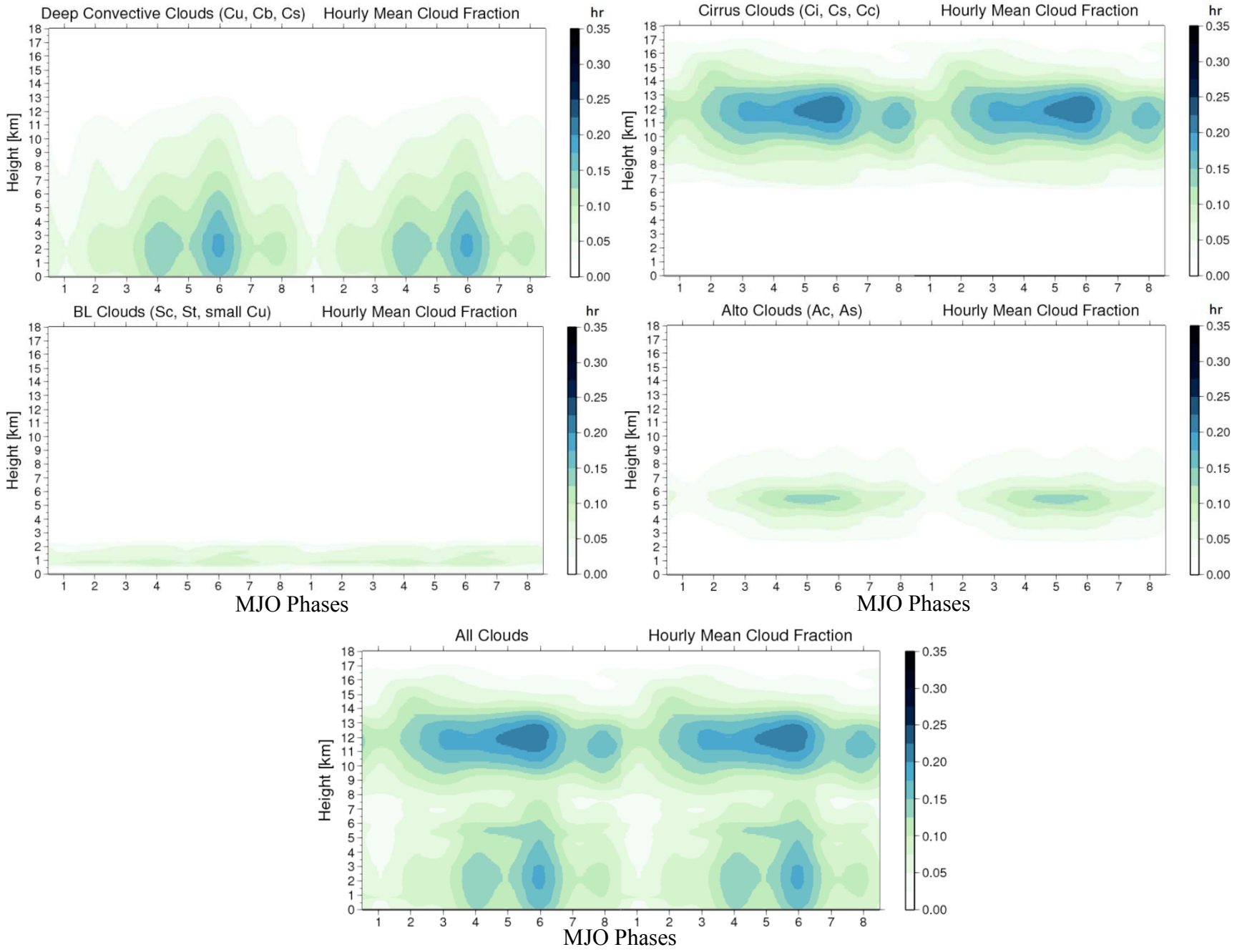


FIG. 5. (a) Total horizontal pixel cover and (b) normalized horizontal pixel cover percentage for each EO type per MJO pinwheel phase. (c) Absolute difference between the phase with maximum (max) horizontal pixel cover and the phase with minimum (min) horizontal pixel cover for each EO type. The phase with the max horizontal pixels and min horizontal pixels per EO type is as follows: narrow deep precipitating (ndp) max phase is 4 and min phase is 7; wide deep precipitating (wdp) max phase is 5 and min phase is 1; anvil (an) max phase is 6 and min phase is 3; cirrus (ci) max phase is 6 and min phase is 1; cumulus congestus (cg) max phase is 5 and min phase is 8; altocumulus (ac) max phase is 5 and min phase is 2; stratocumulus (sc) max phase is 6 and min phase is 4; and cumulus (cu) max phase is 6 and min phase is 4. (d) The fractional increase from the minimum horizontal pixels to the maximum horizontal pixels for each EO type. Riley et al. (2011)

Cloud Distributions through MJO Phases as Observed by KAZR at Manus



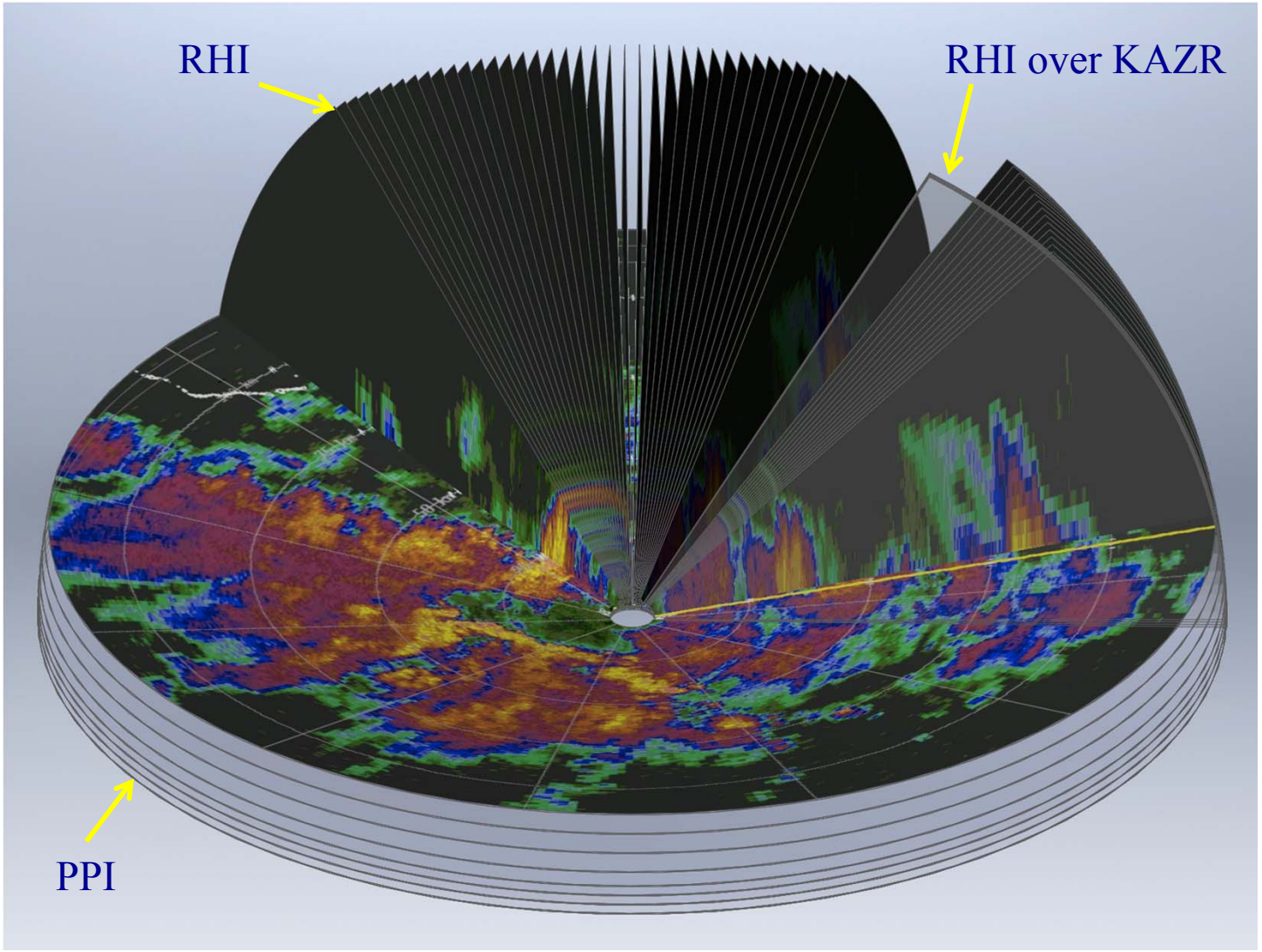
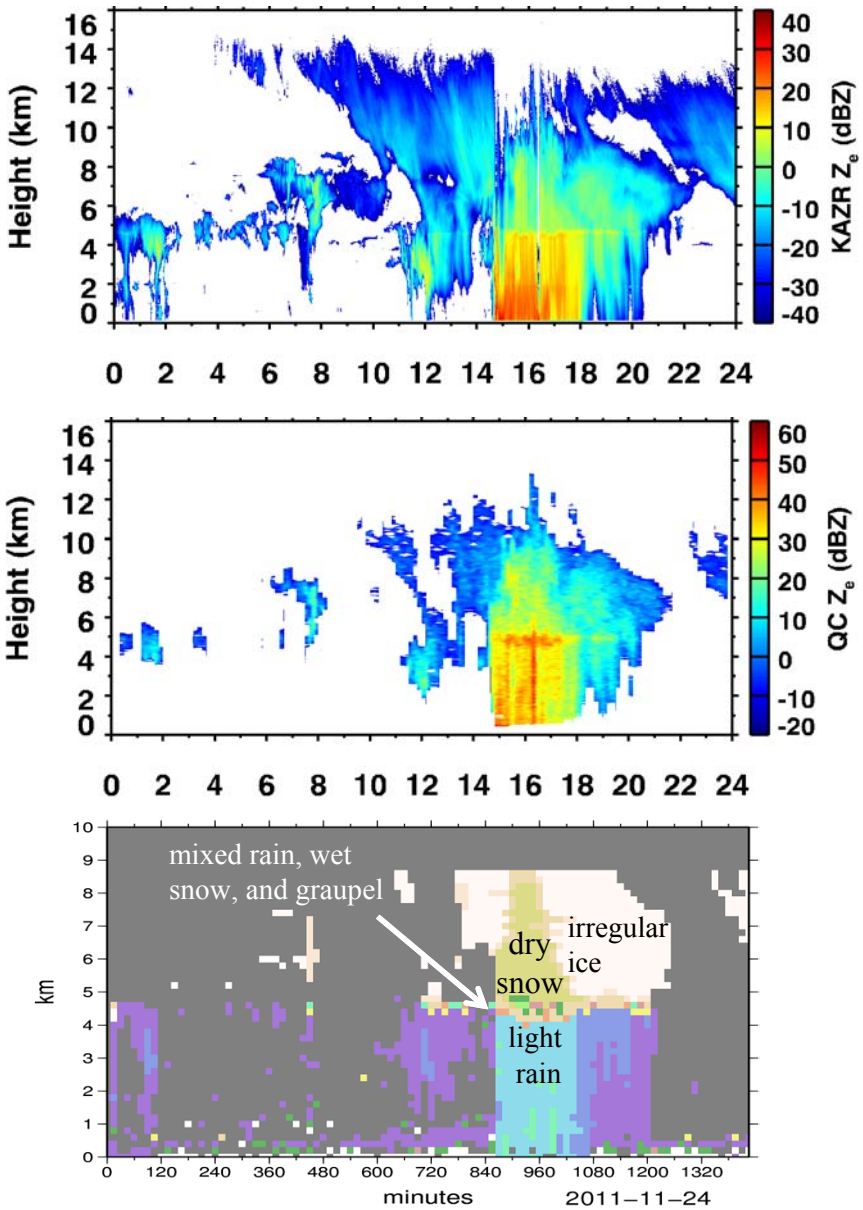


Illustration of S-Polka scanning. Colors are S-band reflectivity at the top PPI and RHIs.

November 24, 2011



KAZR

SMART-R

S-PolKa

Courtesy of C. Long

Asymmetry in Shallow – Deep - Shallow Transitions

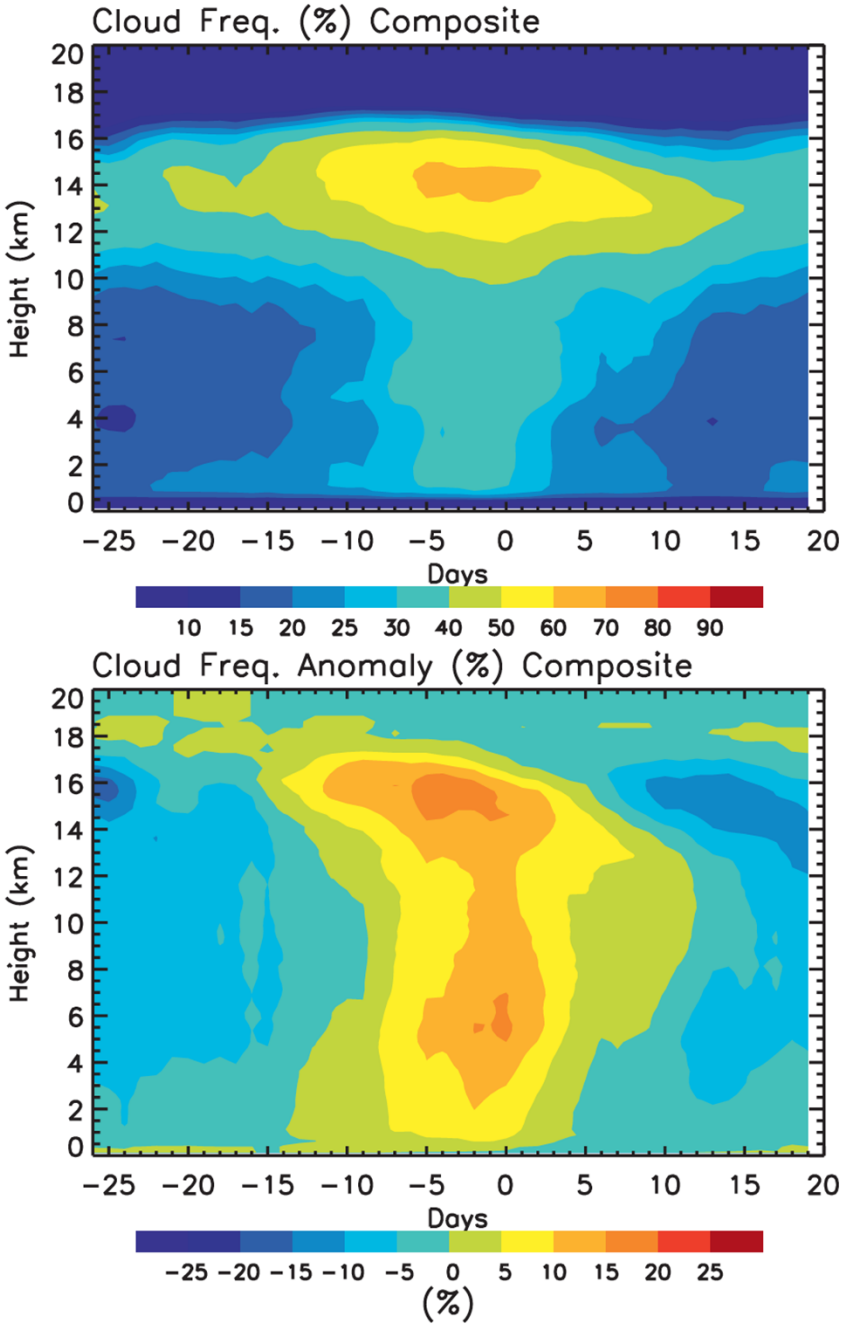


FIG. 1. MJO composite vertical profile of cloud frequency of occurrence vs lag relative to the peak for all 10 events in the domain in GEOPROF-lidar data. (top) Absolute occurrence frequencies and (bottom) anomaly relative to the longitudinal mean at each altitude.

Del Genio et al. (2012)

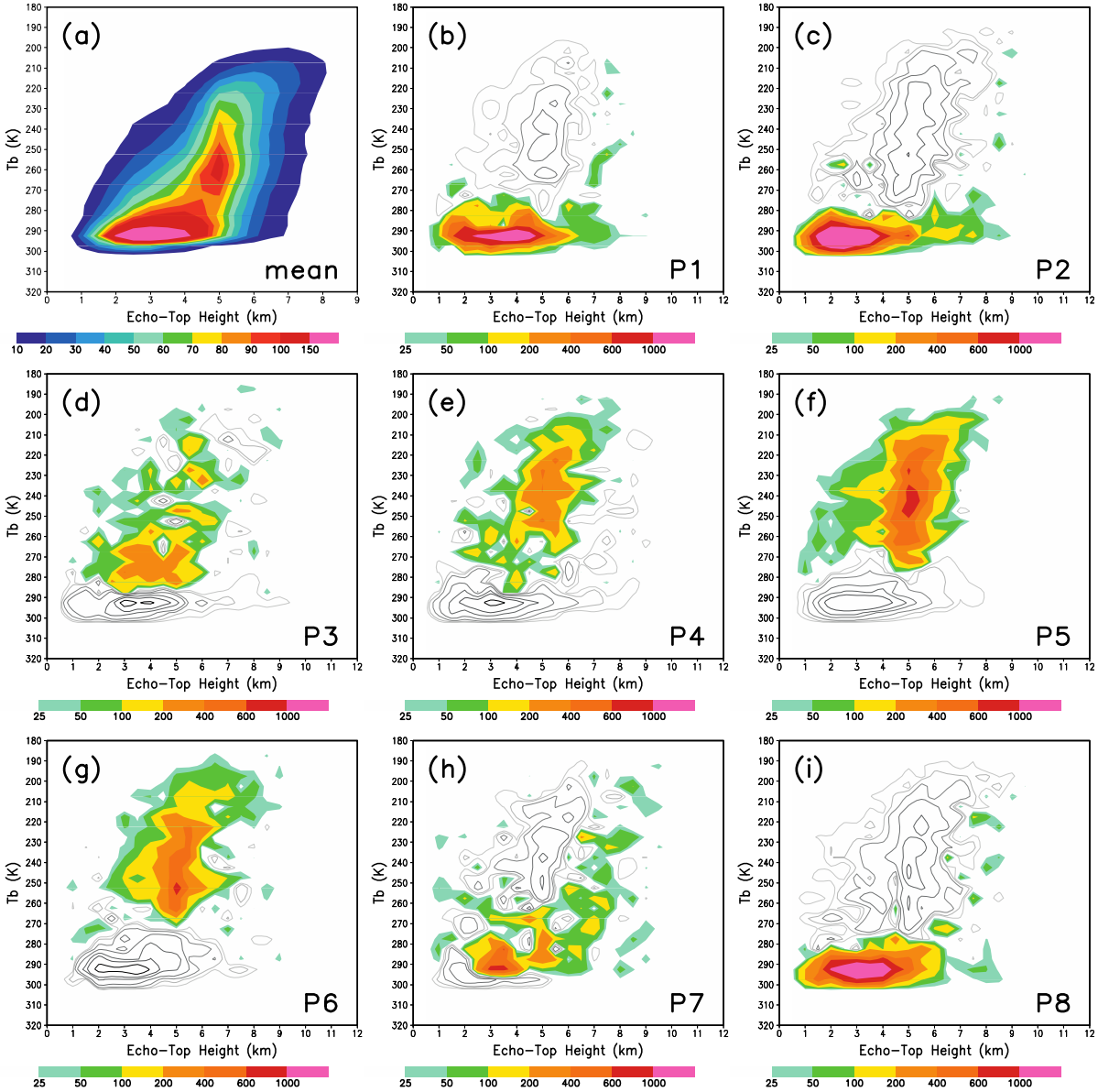
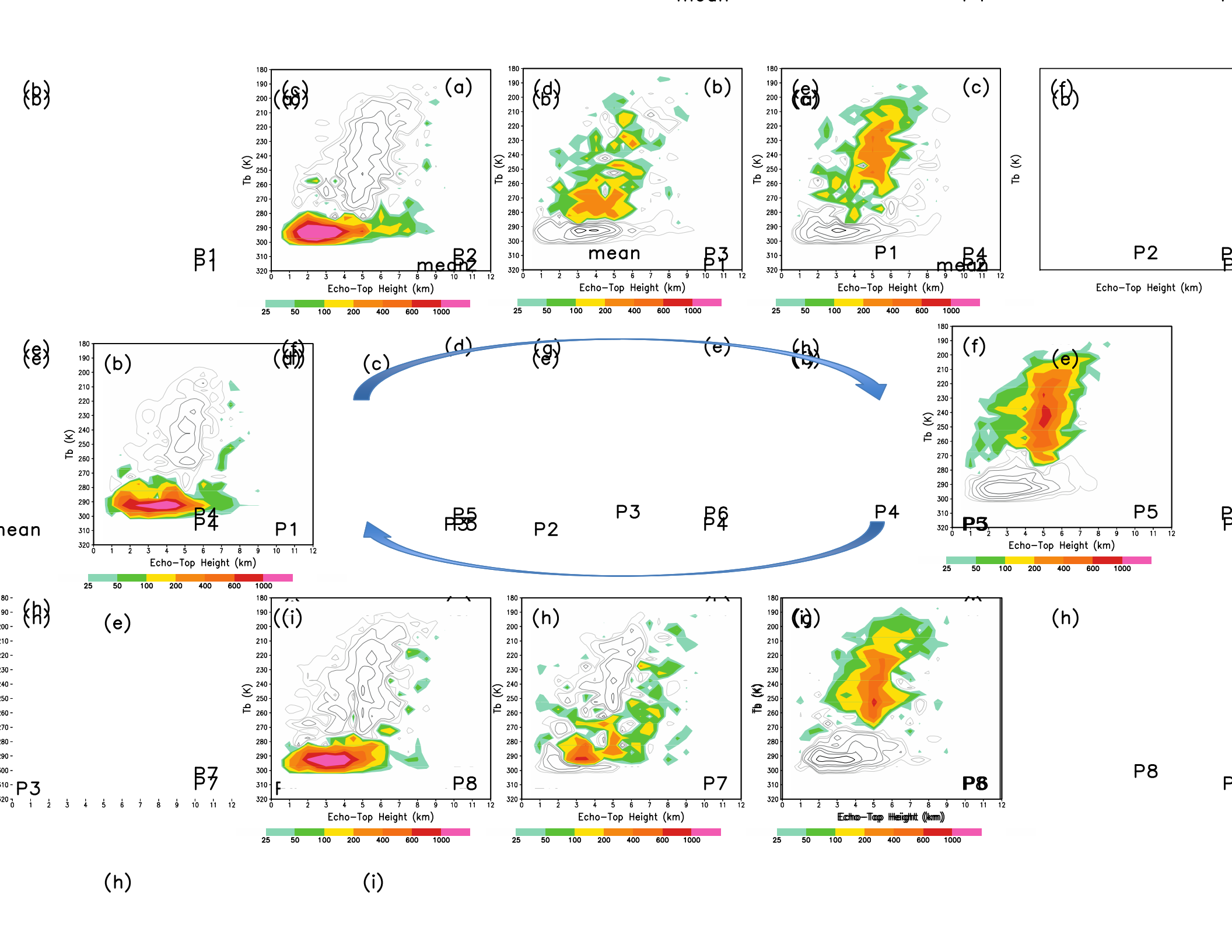
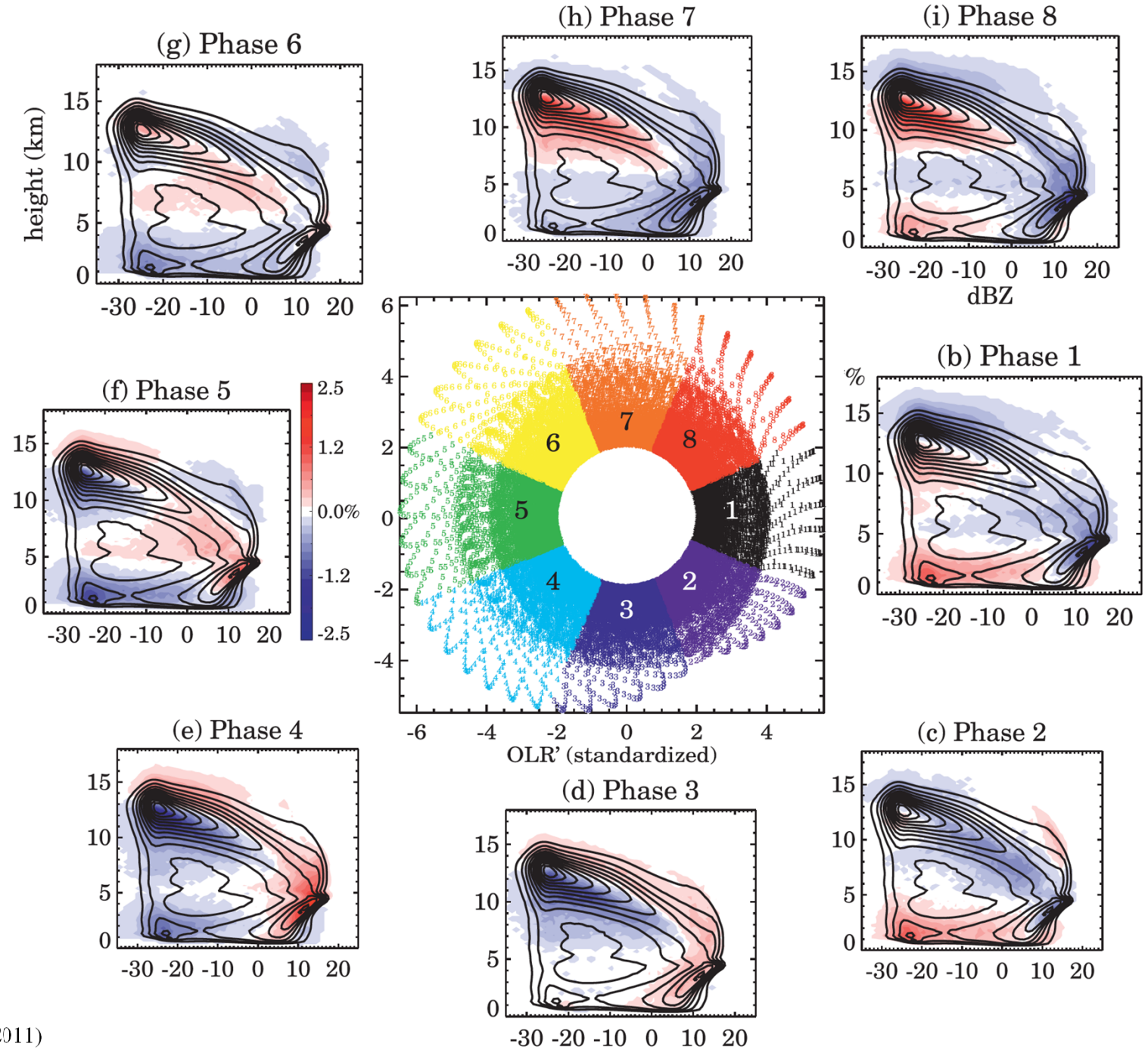


FIG. 5. Joint PDF of Tb and echo-top height over equatorial western Pacific: (a) mean state of the eight MJO phases and (b)–(i) difference between JPDF of each of phases 1–8 (P1–P8) and the mean state. Positive values are color shaded and negative values are in clear contours. The unit for the mean state is in 0.01% of the total occurrence counts. For P1–P8, the unit is number of counts.

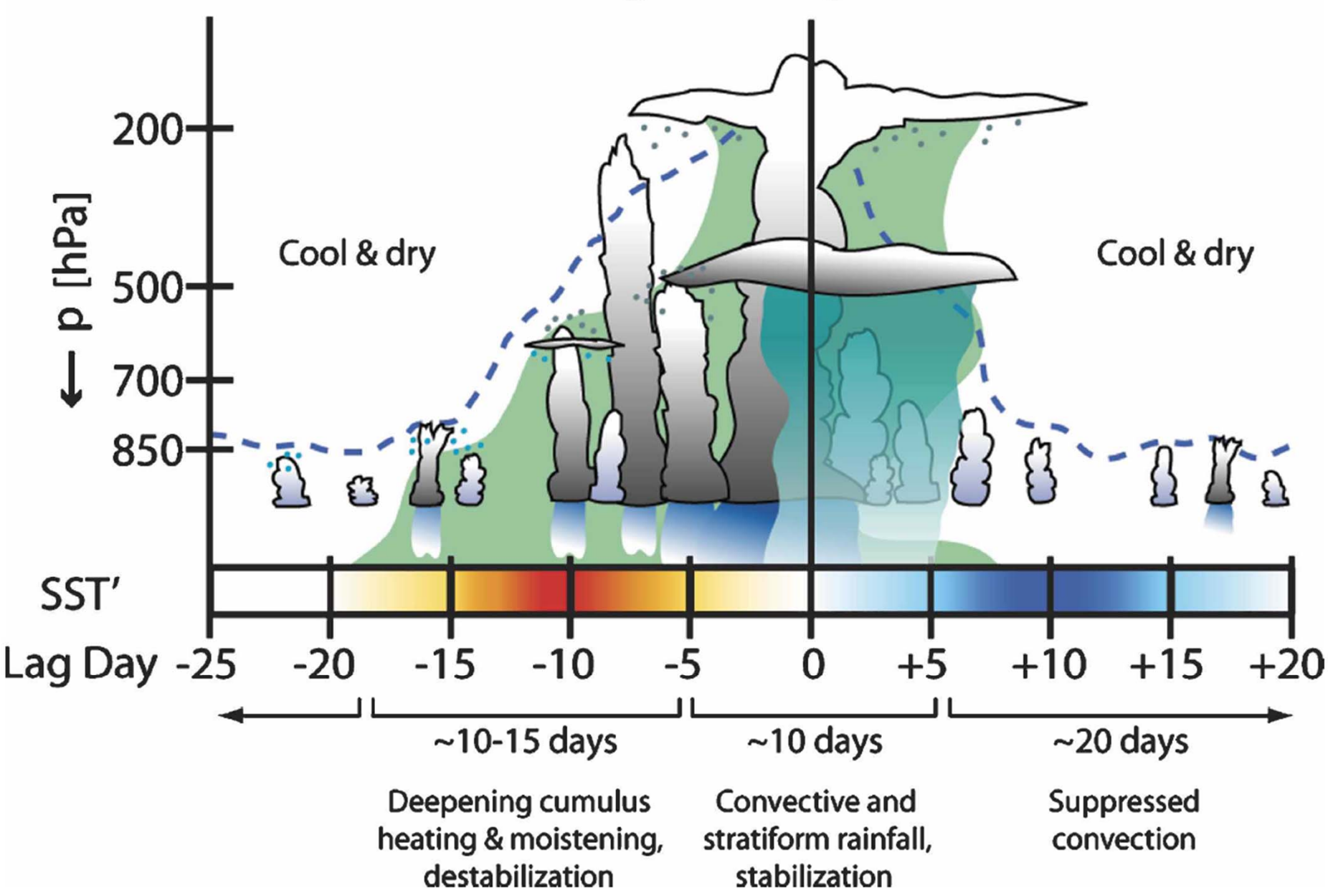
Lau and Wu (2010)


Tb (K)
Echo–Top Height (km)
25 50 100 200 400 600 1000
mean
P1
P2
P3
P4
P5
P6
P7
P8

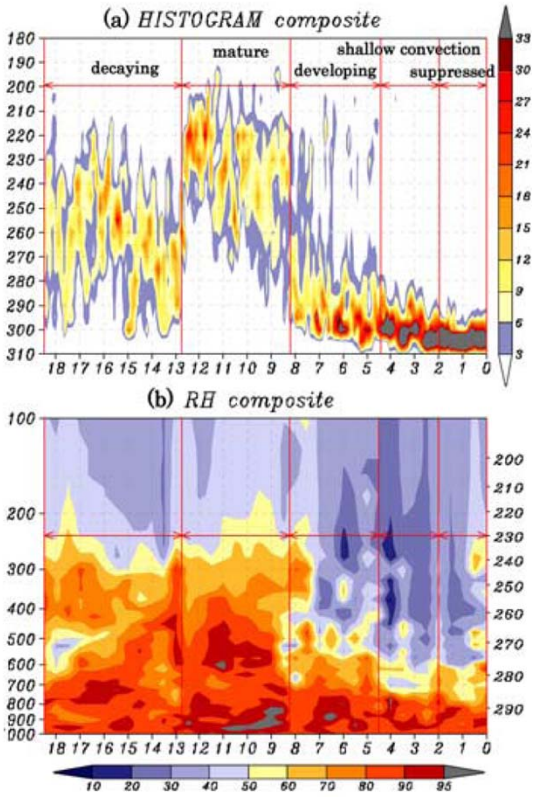


Riley et al. (2011)

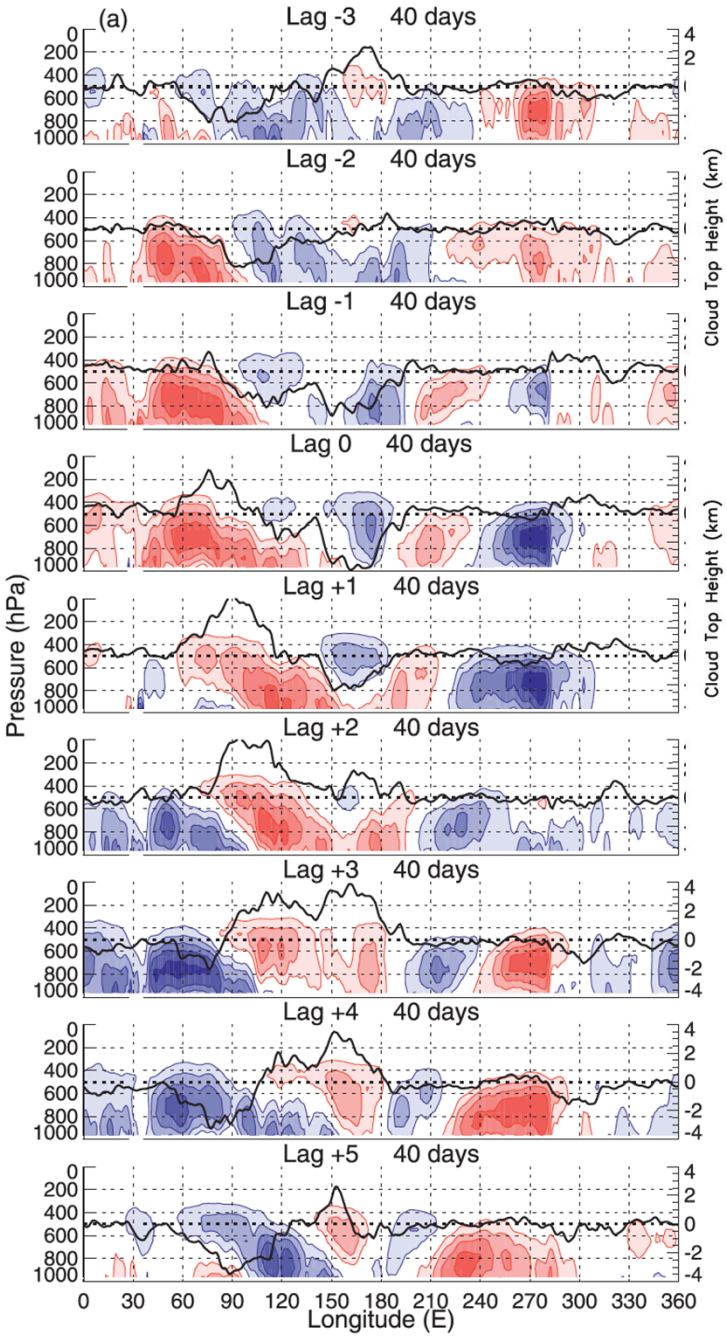
Moisture Feedback



Benedict and Randall (2007)



Kikuchi and Takayabu (2004)



Tian et al. (2010)

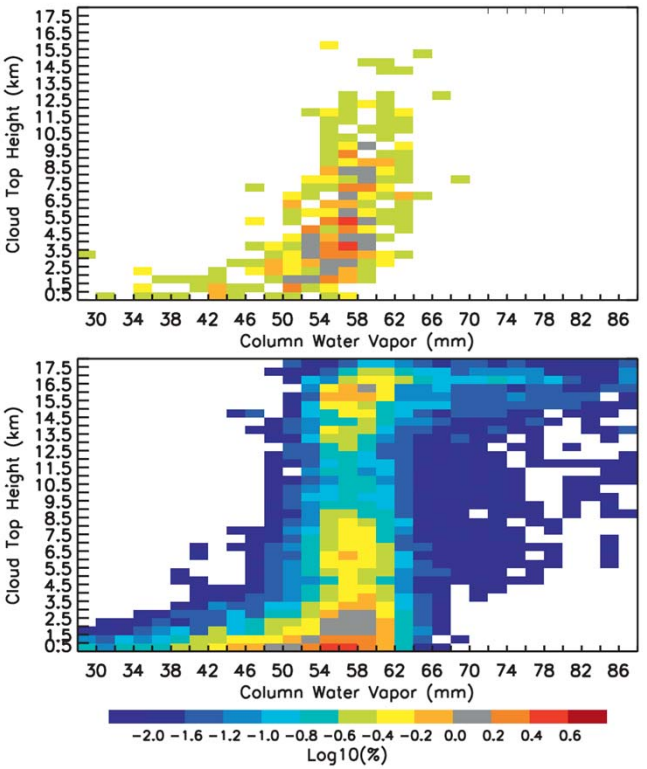
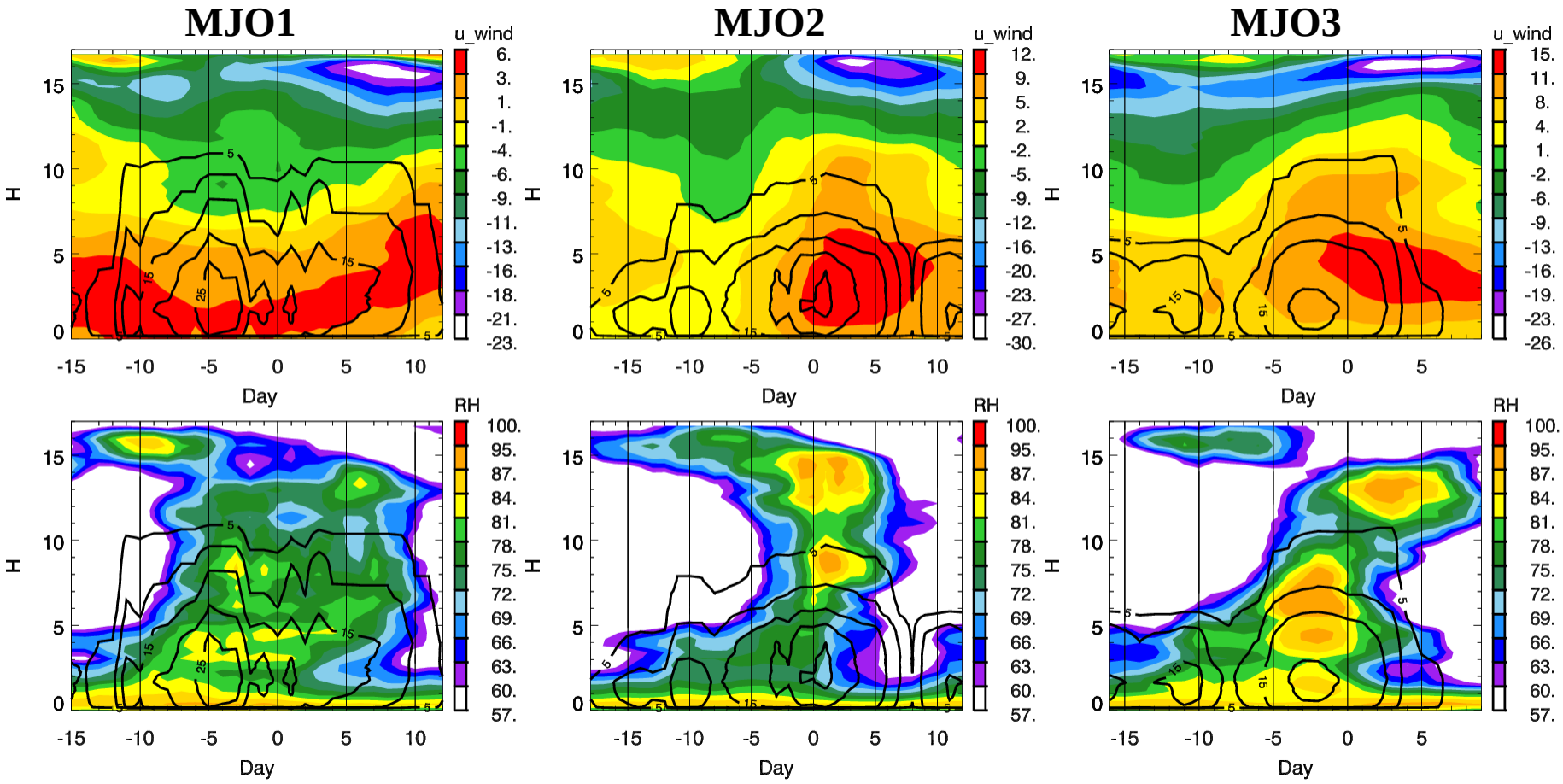


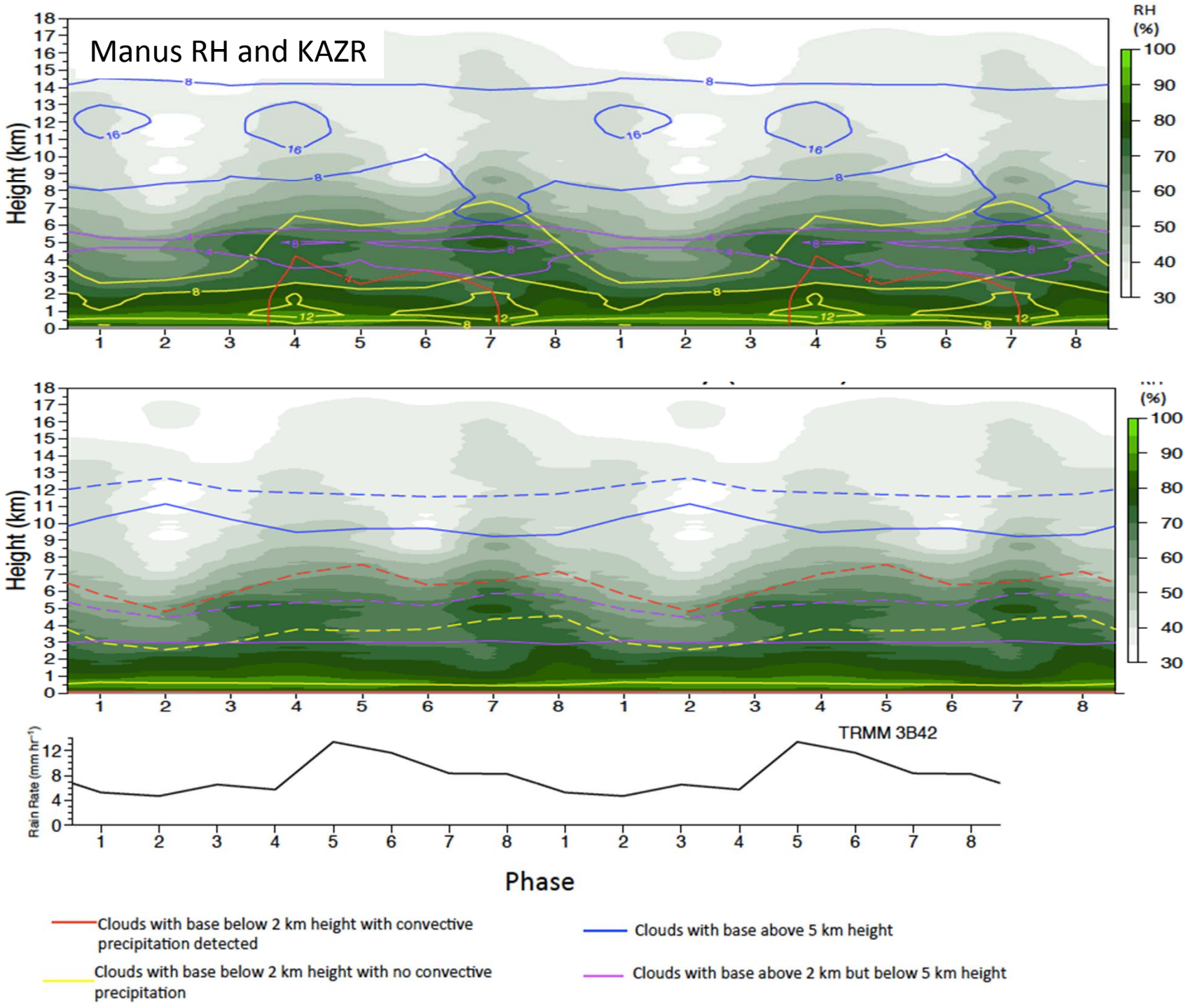
FIG. 4. Joint pdf of relative occurrence frequency (on a logarithmic scale) of convective cloud-top height and column water vapor for the MJO shallow–deep transition region (defined as lag -14 to lag -10 days). (top) Individual points in the pdf represent the 5˚N–10˚S mean convective cloud-top height and mean column water vapor for a given satellite pass through the region. (bottom) Individual points in the pdf represent single-satellite footprints containing a convective cloud.

Del Genio et al. (2012)

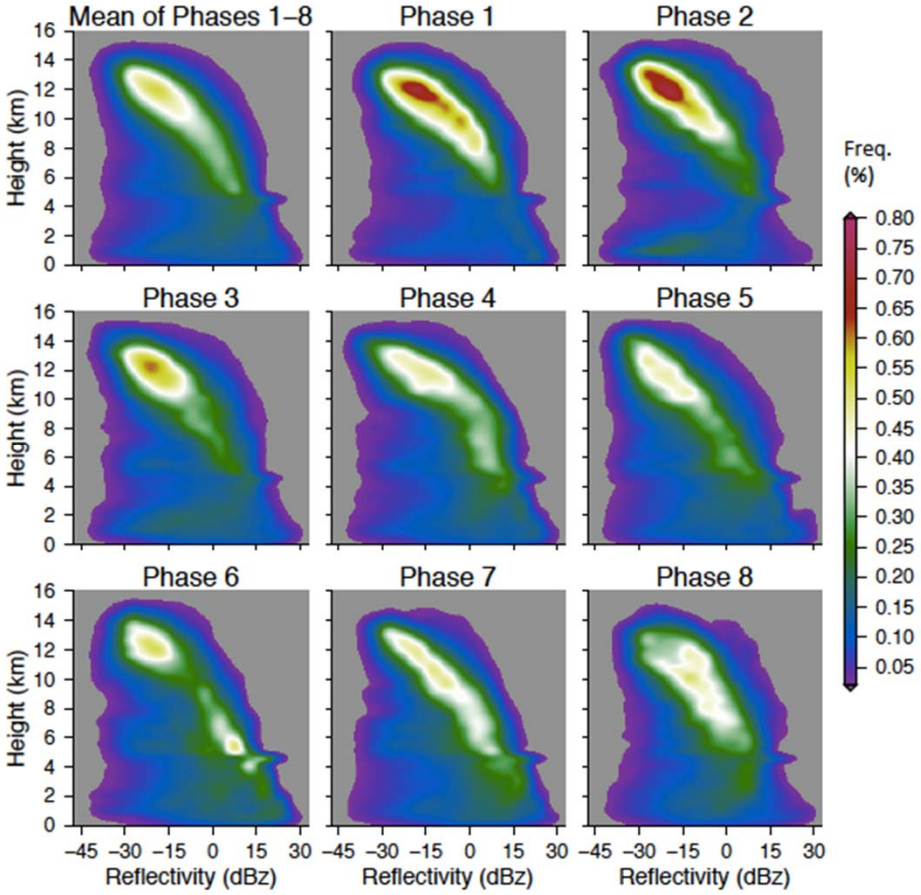
RH, U and precipitating cloud fraction of MJO at Gan
(Day 0: Maximum column precipitable water)



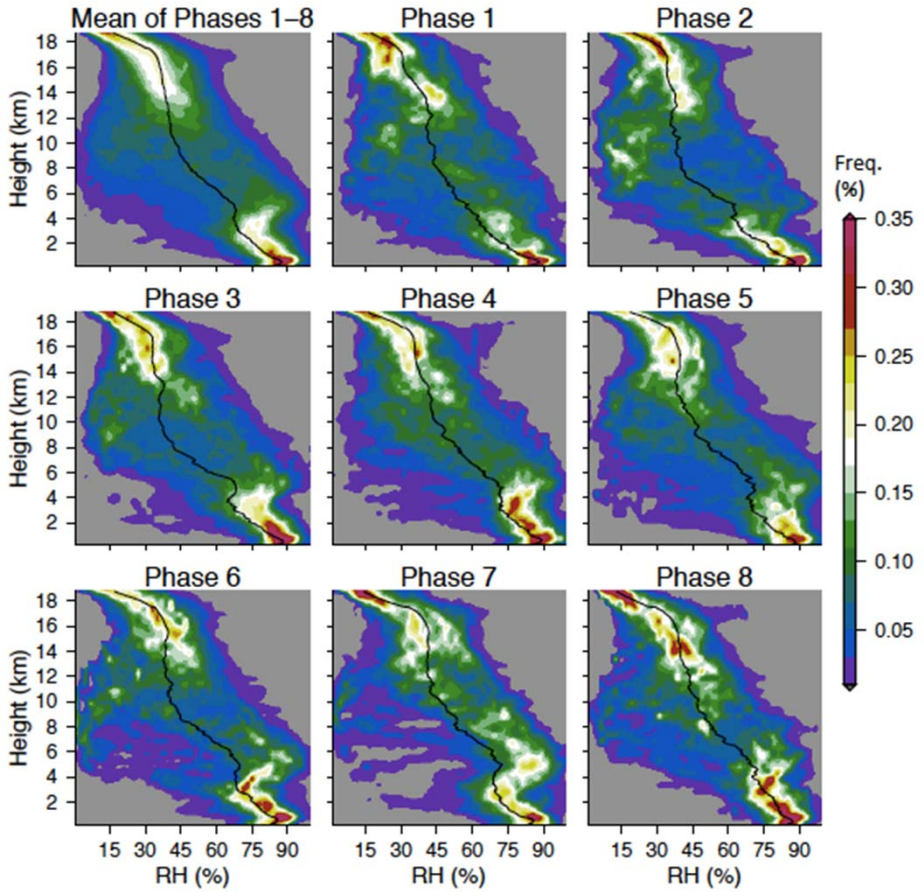
Courtesy of M. Deng


Manus RH and KAZR
Height (km)
RH (%)
TRMM 3B42
Rain Rate (mm hr⁻¹)
Phase
Clouds with base below 2 km height with convective precipitation detected
Clouds with base above 5 km height
Clouds with base below 2 km height with no convective precipitation
Clouds with base above 2 km but below 5 km height

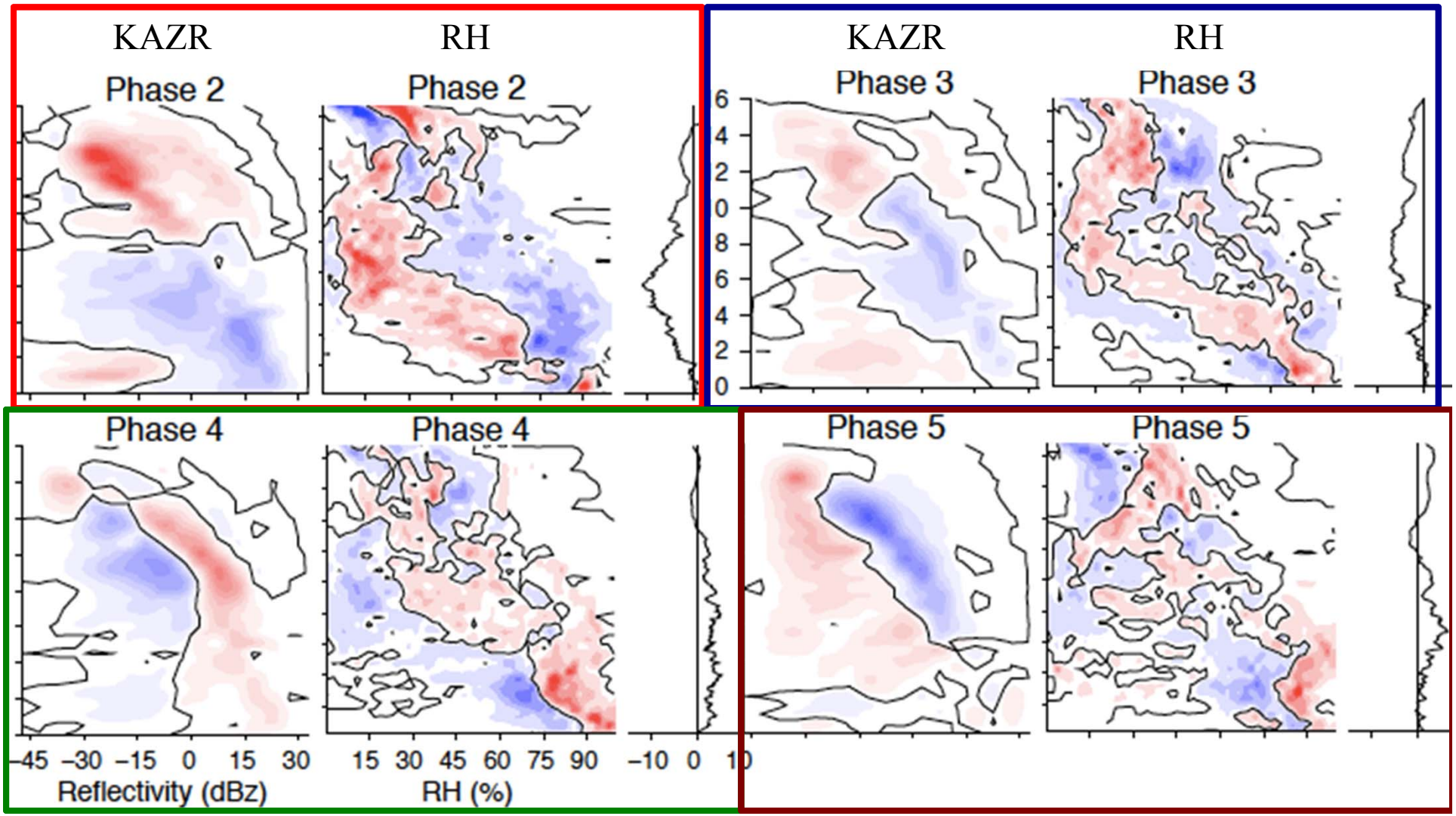
Manus KAZR

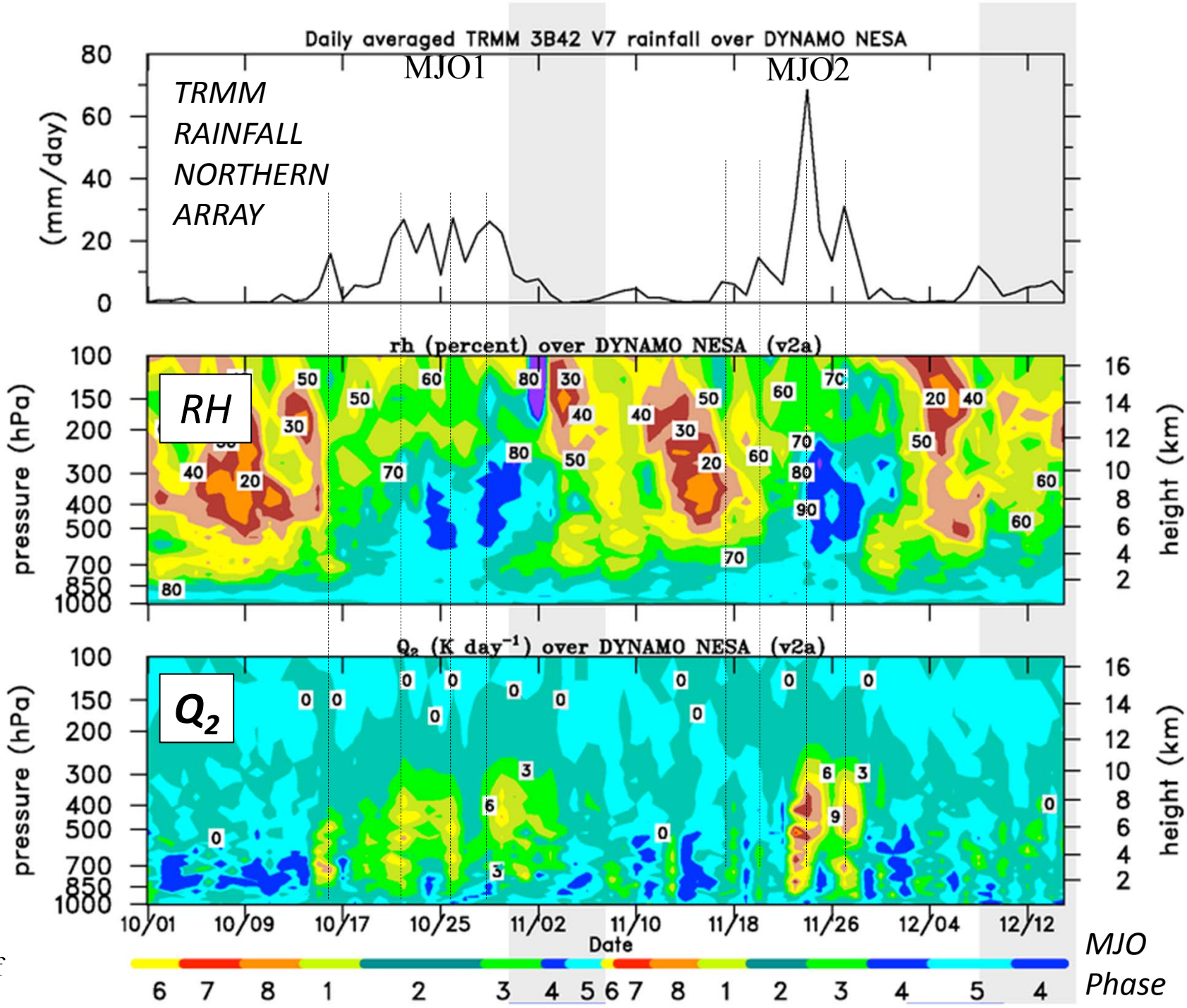


Manus RH

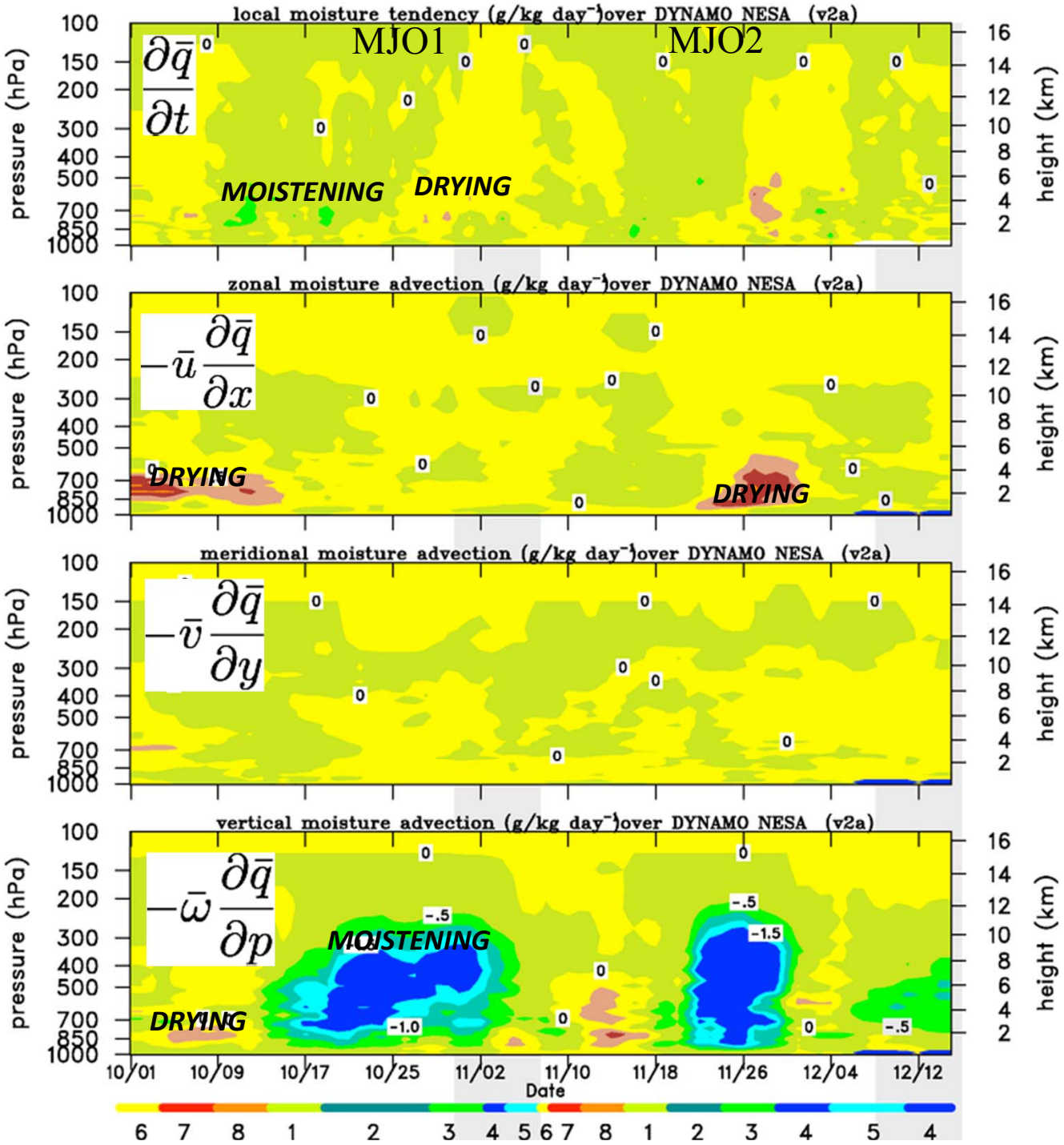


Manus: Deviations from the Mean PDF



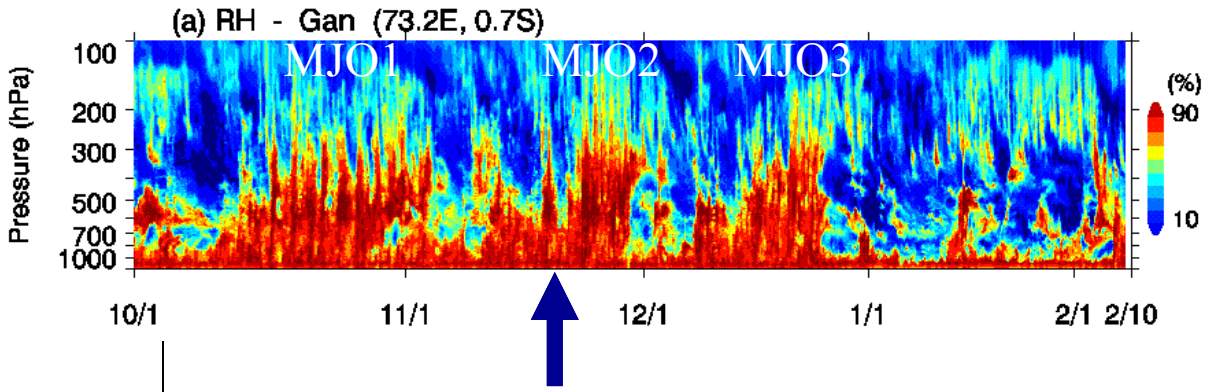


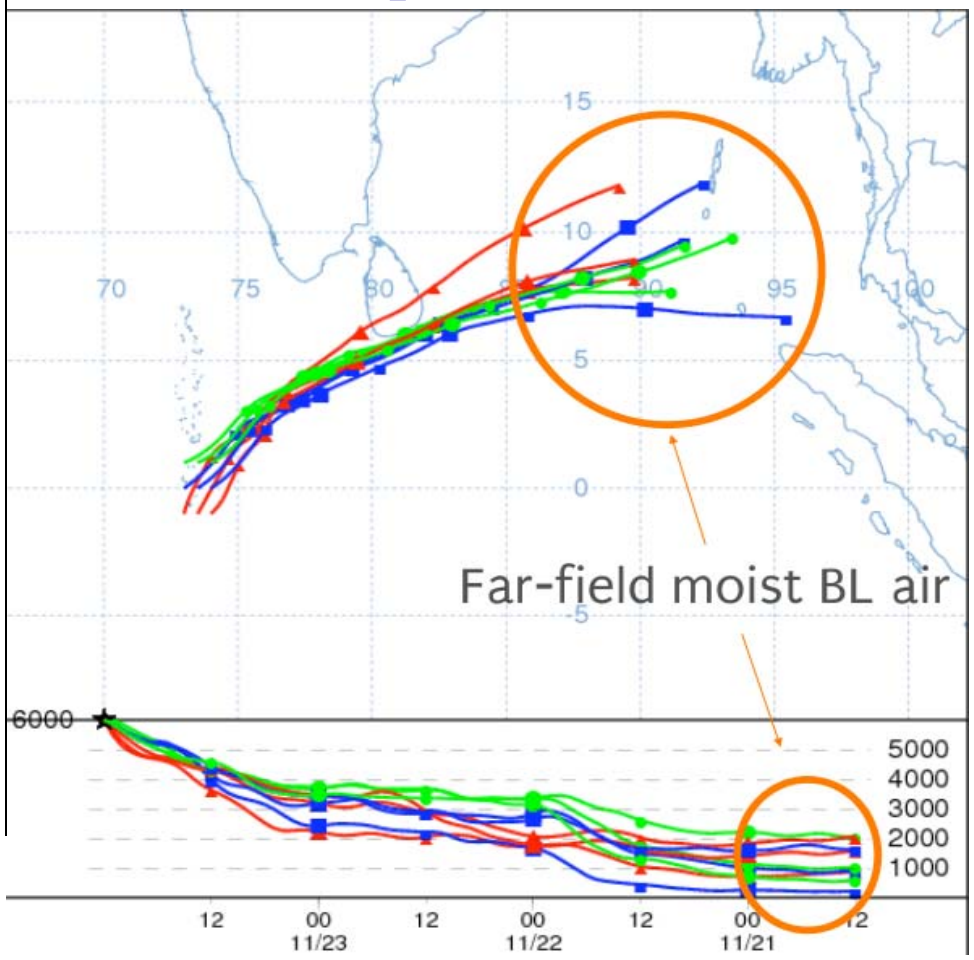
Courtesy of
R. Johnson



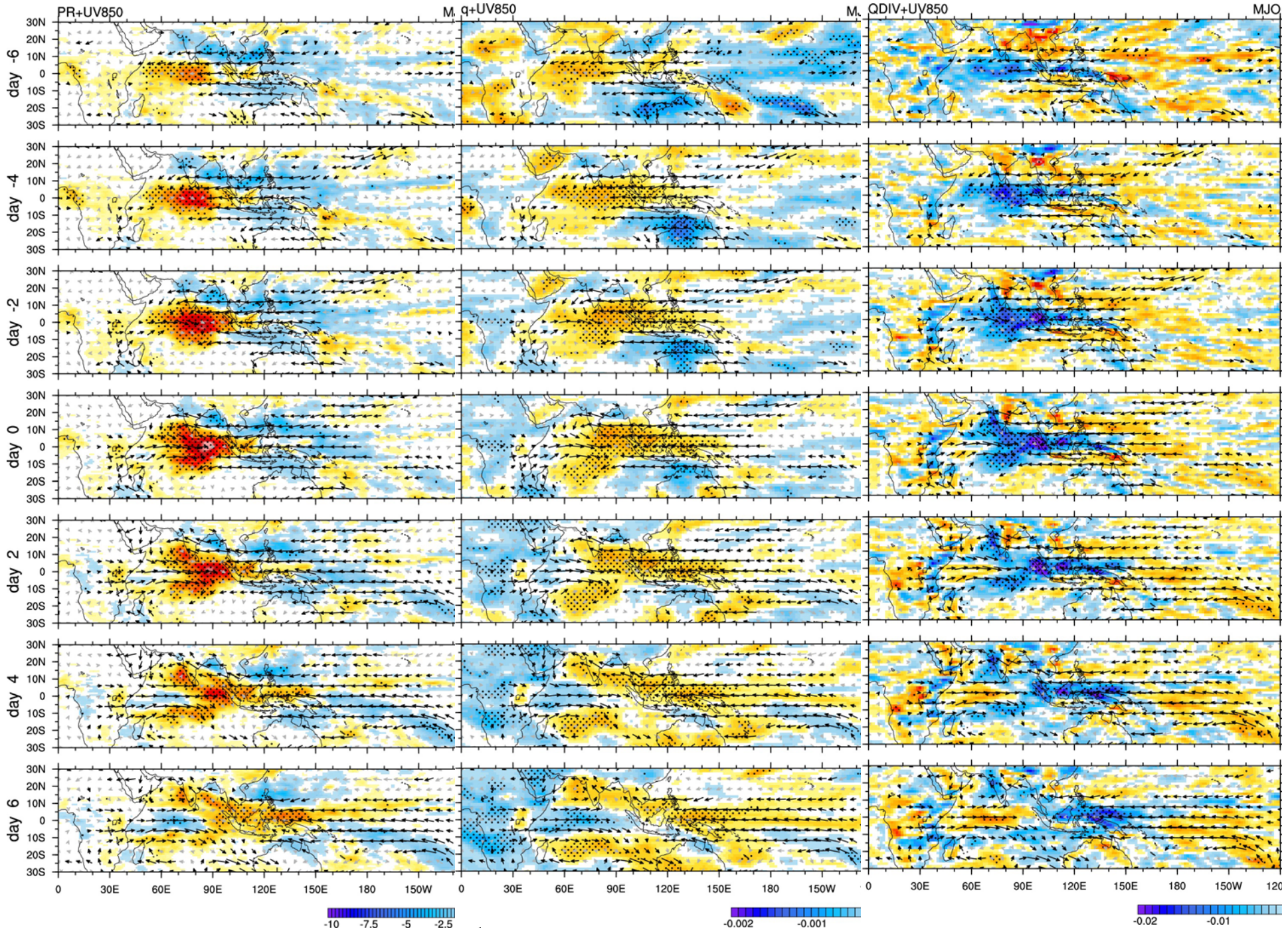
Courtesy of
R. Johnson

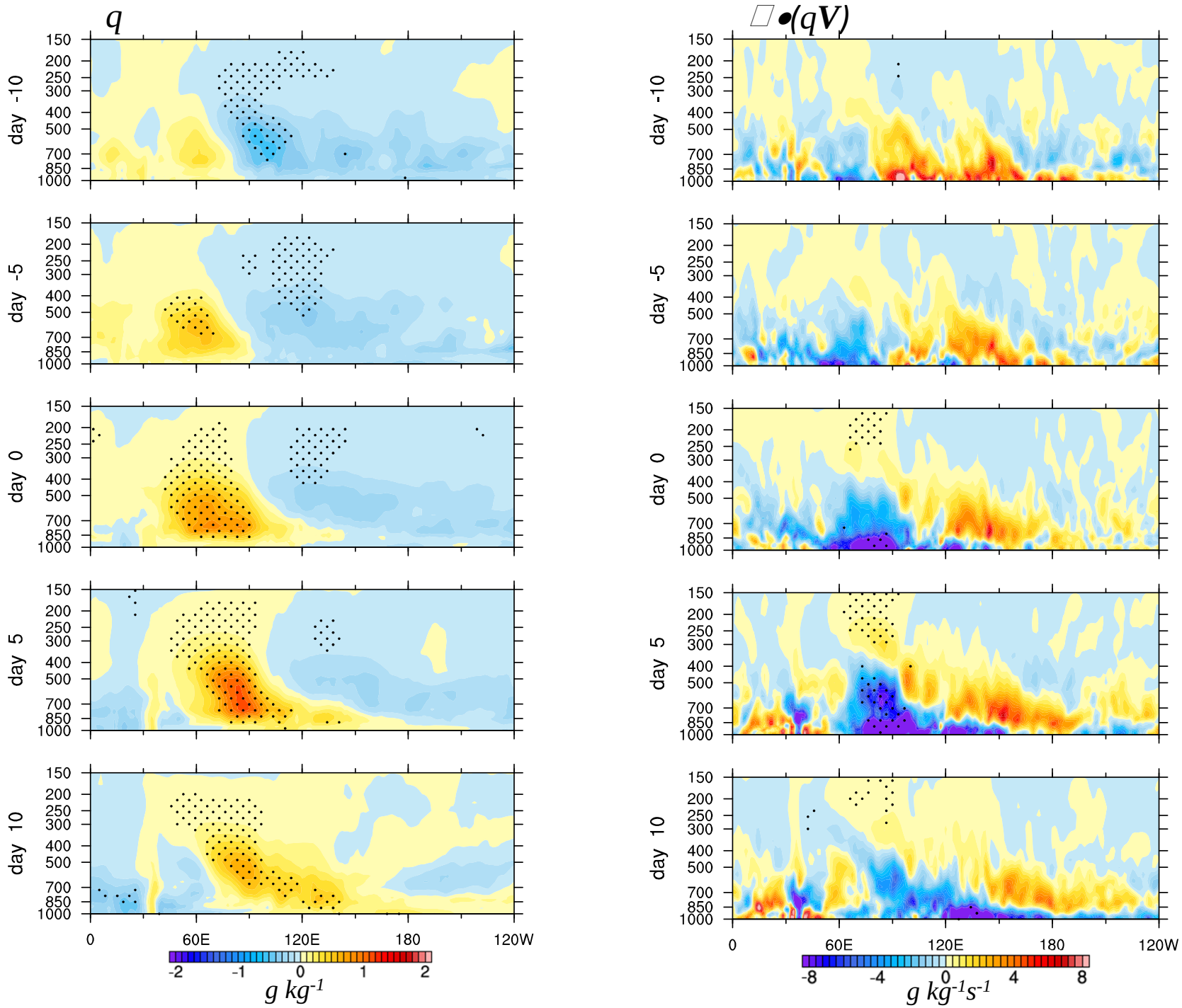
Large-Scale Forcing

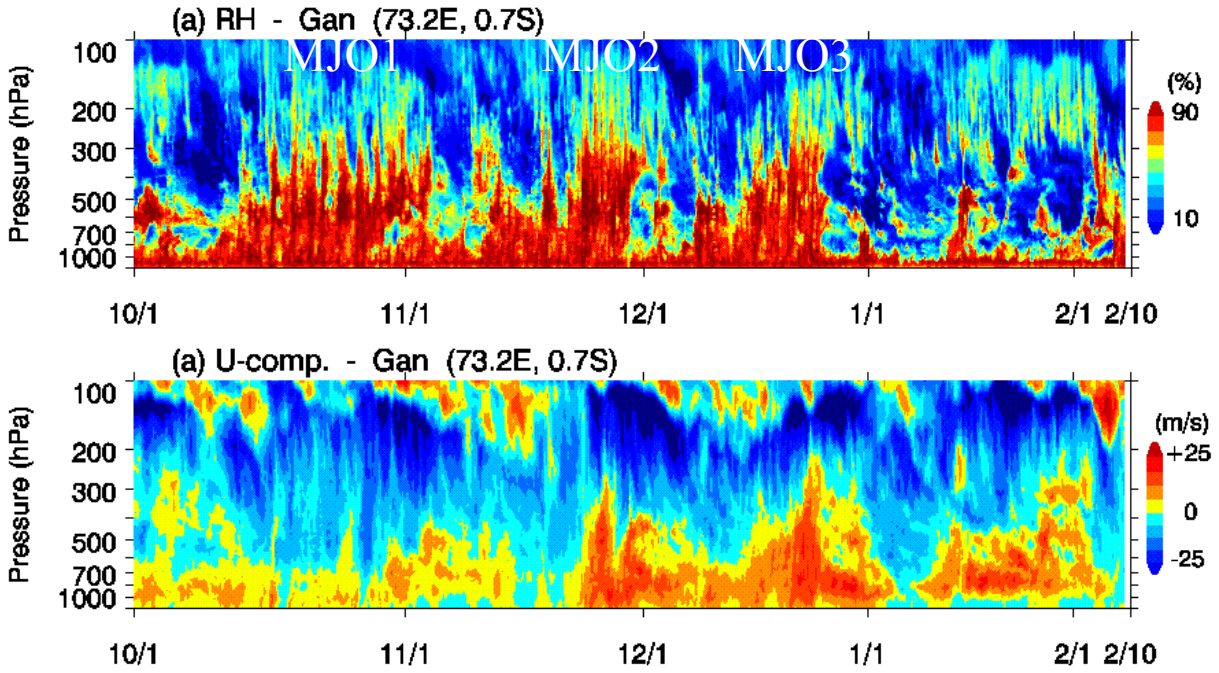




Courtesy of
S. Powell

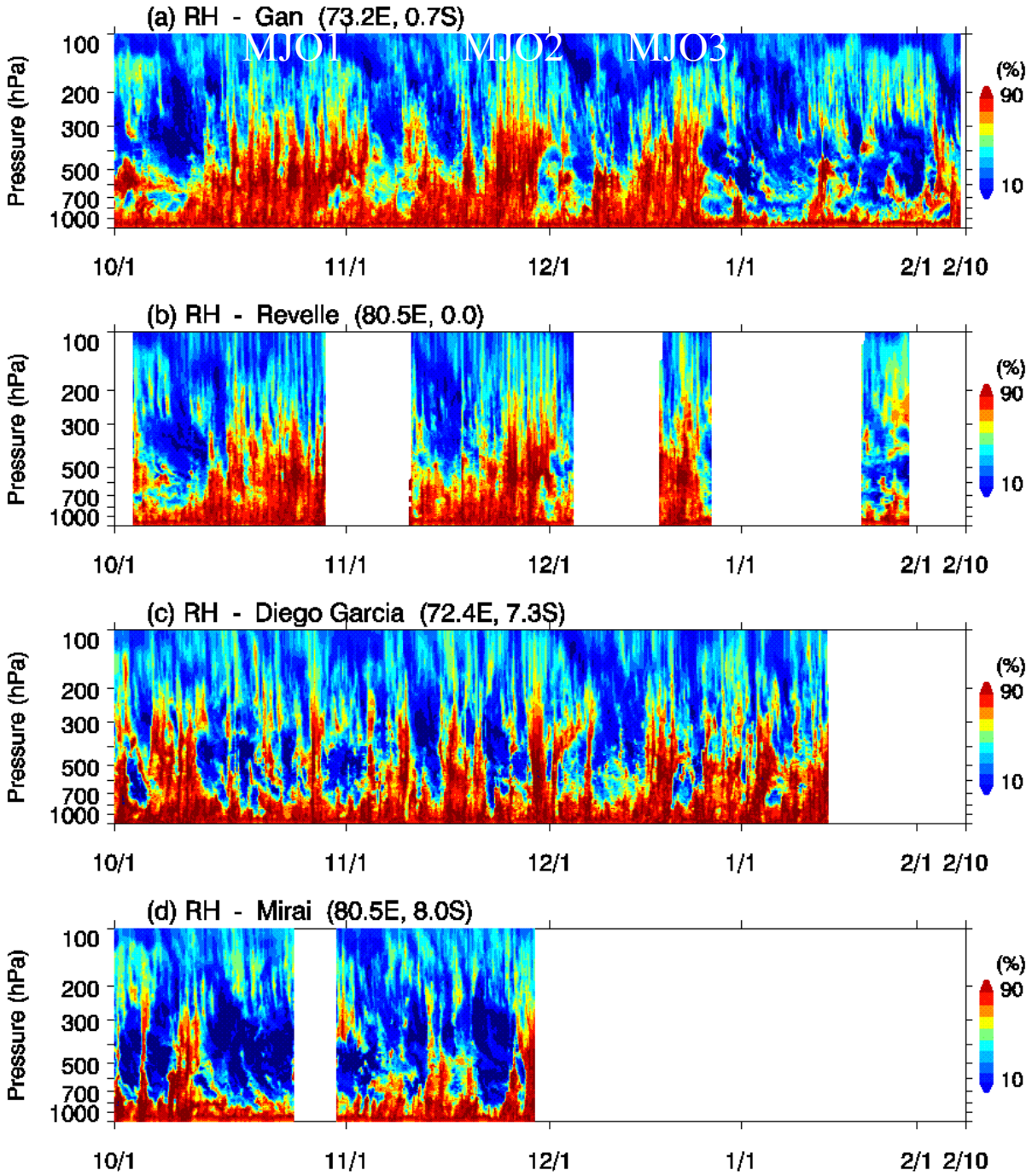

PR+UV850
q+UV850
QDIV+UV850
MJO
day -6
day -4
day -2
day 0
day 2
day 4
day 6
30N
20N
10N
0
10S
20S
30S
0
30E
60E
90E
120E
150E
180
150W
-10
-7.5
-5
-2.5
-0.002
-0.001
-0.02
-0.01

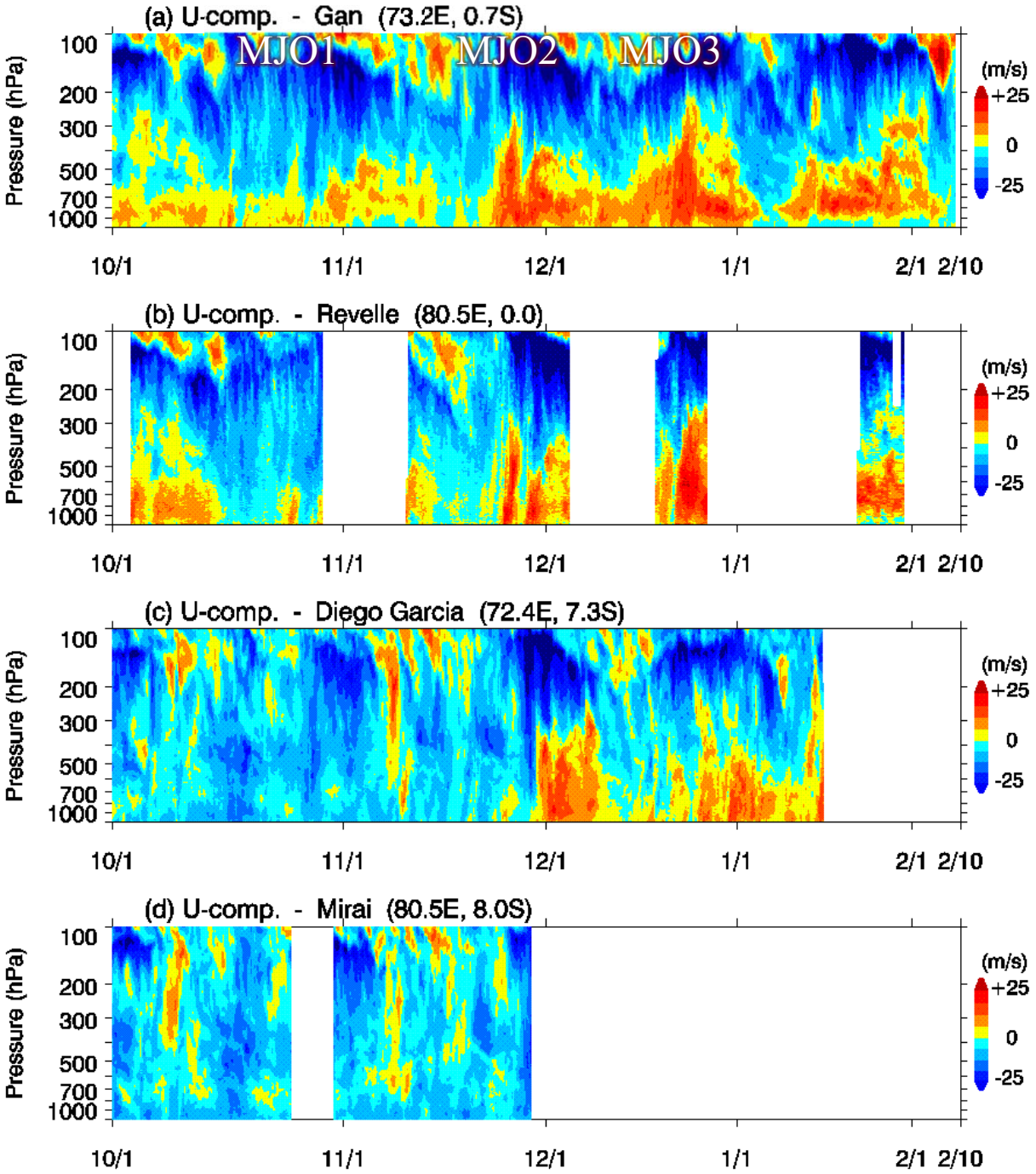

q
day -10
day -5
day 0
day 5
day 10
150
200
250
300
400
500
700
850
1000
0
60E
120E
180
120W
-2
-1
0
1
2
g kg-1
∇•(qV)
-8
-4
0
4
8
g kg-1s-1


(a) RH - Gan (73.2E, 0.7S)
MJO1
MJO2
MJO3
Pressure (hPa)
100
200
300
500
700
1000
(%)
90
10
10/1
11/1
12/1
1/1
2/1
2/10
(a) U-comp. - Gan (73.2E, 0.7S)
Pressure (hPa)
100
200
300
500
700
1000
(m/s)
+25
0
-25
10/1
11/1
12/1
1/1
2/1
2/10

Scientific Questions :

- *What is the cloud population distribution in a given large-scale environment and how does it vary when its large-scale environment changes?*
- *How different are the factors governing a shallow to deep convective transition from those governing a deep to shallow transition?*
- *To what extent a shallow to deep convective transition can be managed by convective clouds themselves (self-sustainment), and to what extent external large-scale influences are needed? What are those external large-scale influences?*
- *What are other essential factors for transitions of cloud population distributions in addition to moisture?*
- *Shallow-deep convective transition = isolated-organized convective transition?*


(a) RH - Gan (73.2E, 0.7S)
MJO1
MJO2
MJO3
(b) RH - Revelle (80.5E, 0.0)
(c) RH - Diego Garcia (72.4E, 7.3S)
(d) RH - Mirai (80.5E, 8.0S)
Pressure (hPa)
100
200
300
500
700
1000
(%)
90
10
10/1
11/1
12/1
1/1
2/1
2/10


(a) U-comp. - Gan (73.2E, 0.7S)
MJO1
MJO2
MJO3
(b) U-comp. - Revelle (80.5E, 0.0)
(c) U-comp. - Diego Garcia (72.4E, 7.3S)
(d) U-comp. - Mirai (80.5E, 8.0S)
Pressure (hPa)
100
200
300
500
700
1000
10/1
11/1
12/1
1/1
2/1
2/10
(m/s)
+25
0
-25

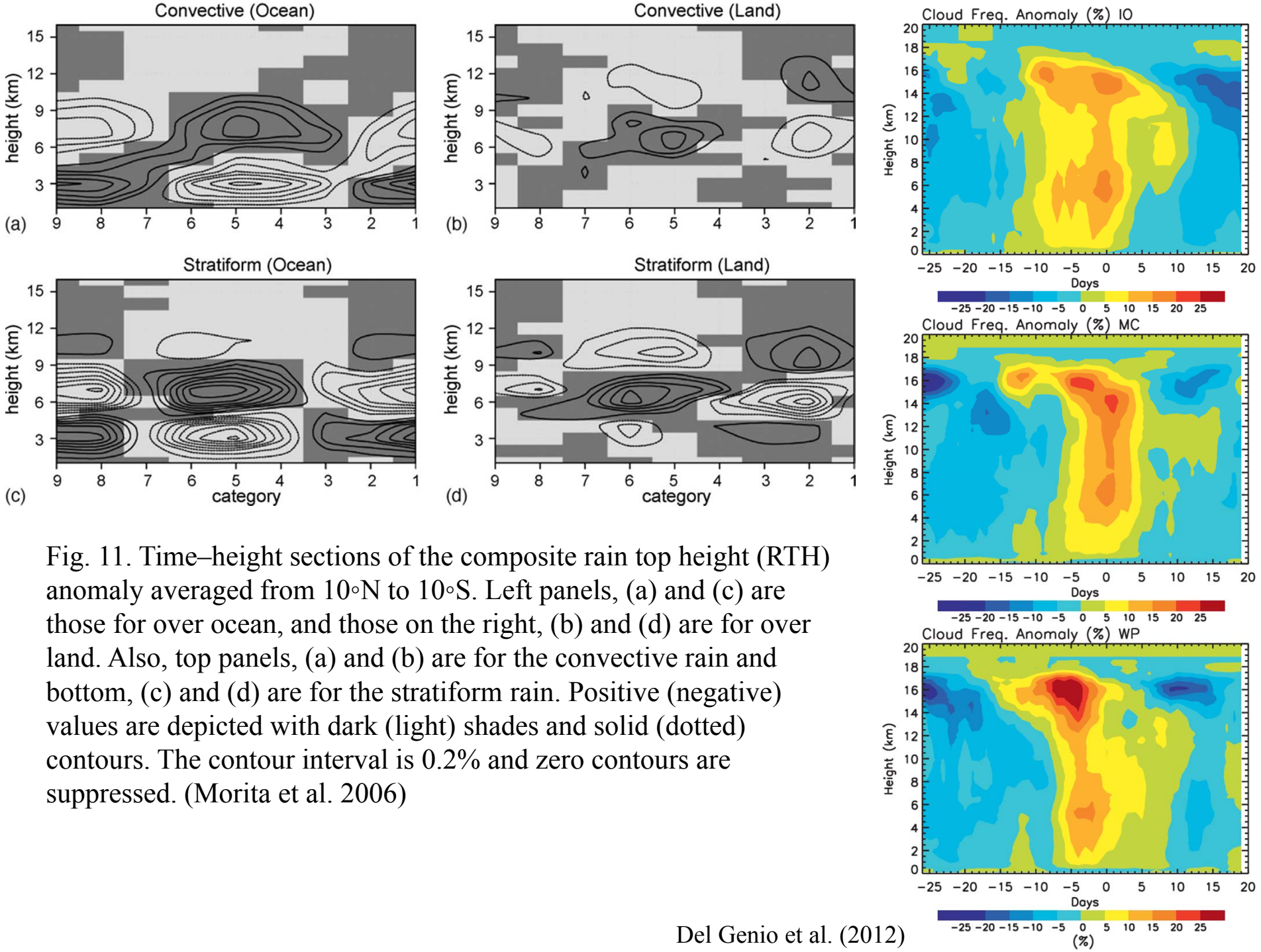


Fig. 11. Time–height sections of the composite rain top height (RTH) anomaly averaged from 10◦N to 10◦S. Left panels, (a) and (c) are those for over ocean, and those on the right, (b) and (d) are for over land. Also, top panels, (a) and (b) are for the convective rain and bottom, (c) and (d) are for the stratiform rain. Positive (negative) values are depicted with dark (light) shades and solid (dotted) contours. The contour interval is 0.2% and zero contours are suppressed. (Morita et al. 2006)

Del Genio et al. (2012)

Moisture Feedback

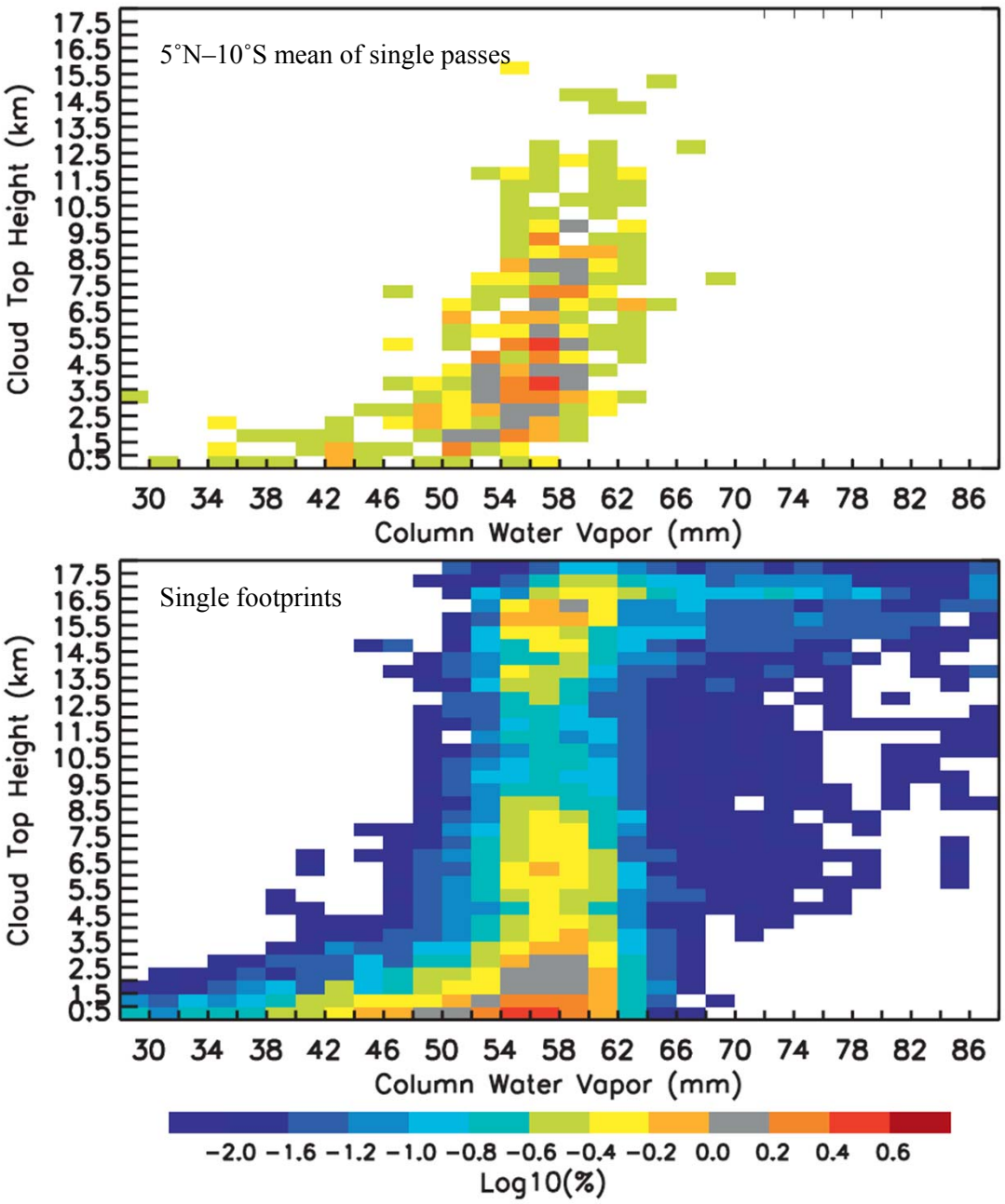
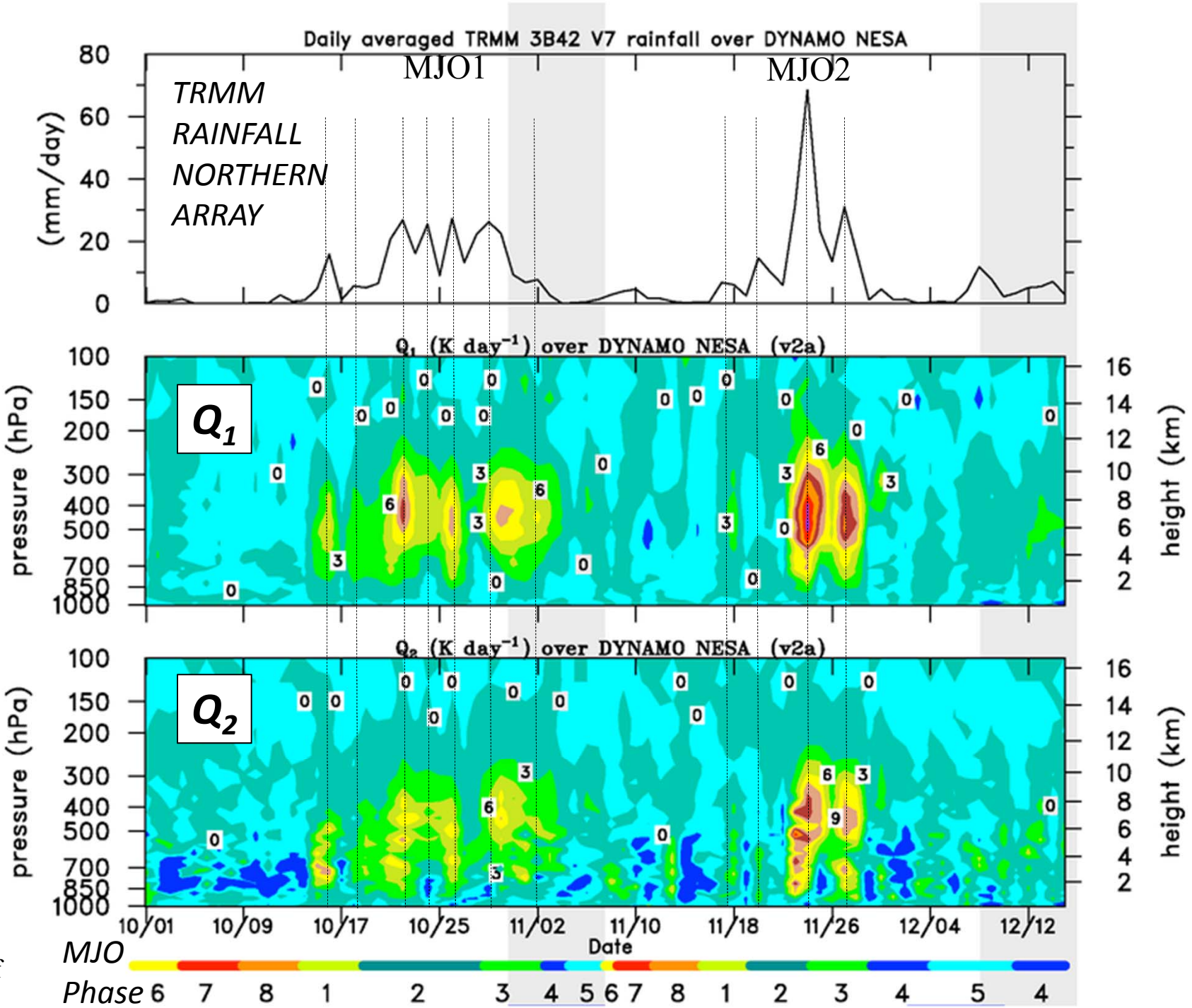
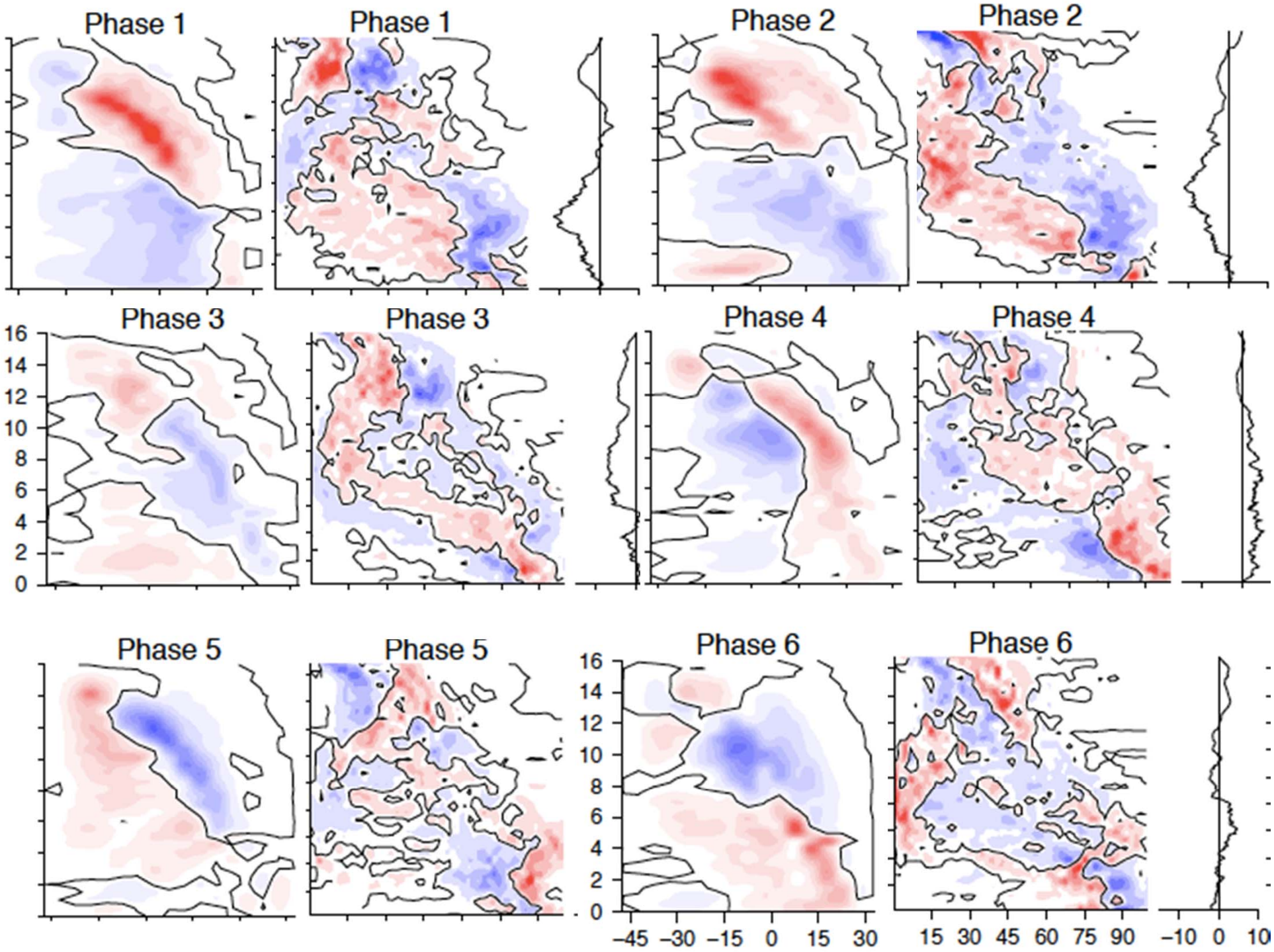


FIG. 4. Joint pdf of relative occurrence frequency (on a logarithmic scale) of convective cloud-top height and column water vapor for the MJO shallow–deep transition region (defined as lag -14 to lag -10 days). (top) Individual points in the pdf represent the 5˚N–10˚S mean convective cloud-top height and mean column water vapor for a given satellite pass through the region. (bottom) Individual points in the pdf represent single-satellite footprints containing a convective cloud.

Del Genio et al. (2012)



Courtesy of
R. Johnson


Phase 1
Phase 1
Phase 2
Phase 2
Phase 3
Phase 3
Phase 4
Phase 4
Phase 5
Phase 5
Phase 6
Phase 6
16
14
12
10
8
6
4
2
0
−45 −30 −15 0 15 30
15 30 45 60 75 90
−10 0 10