Shallow Clouds in Tropical Deep Convective Regimes

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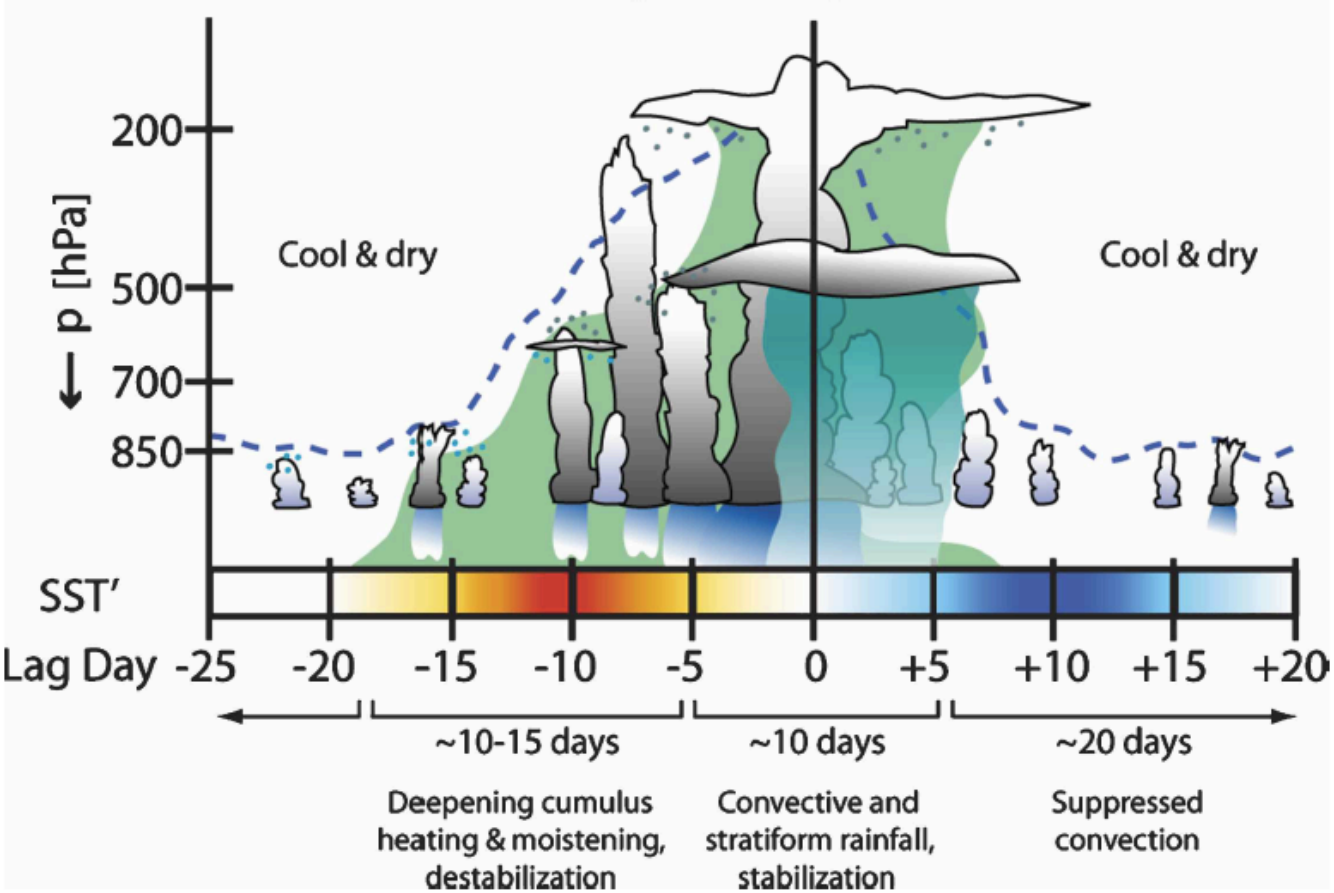
4. PNNL
5. McGill University
6. University of Washington

Hypothesized Importance of Shallow Convective Clouds in the Tropical Deep Convective Regimes:

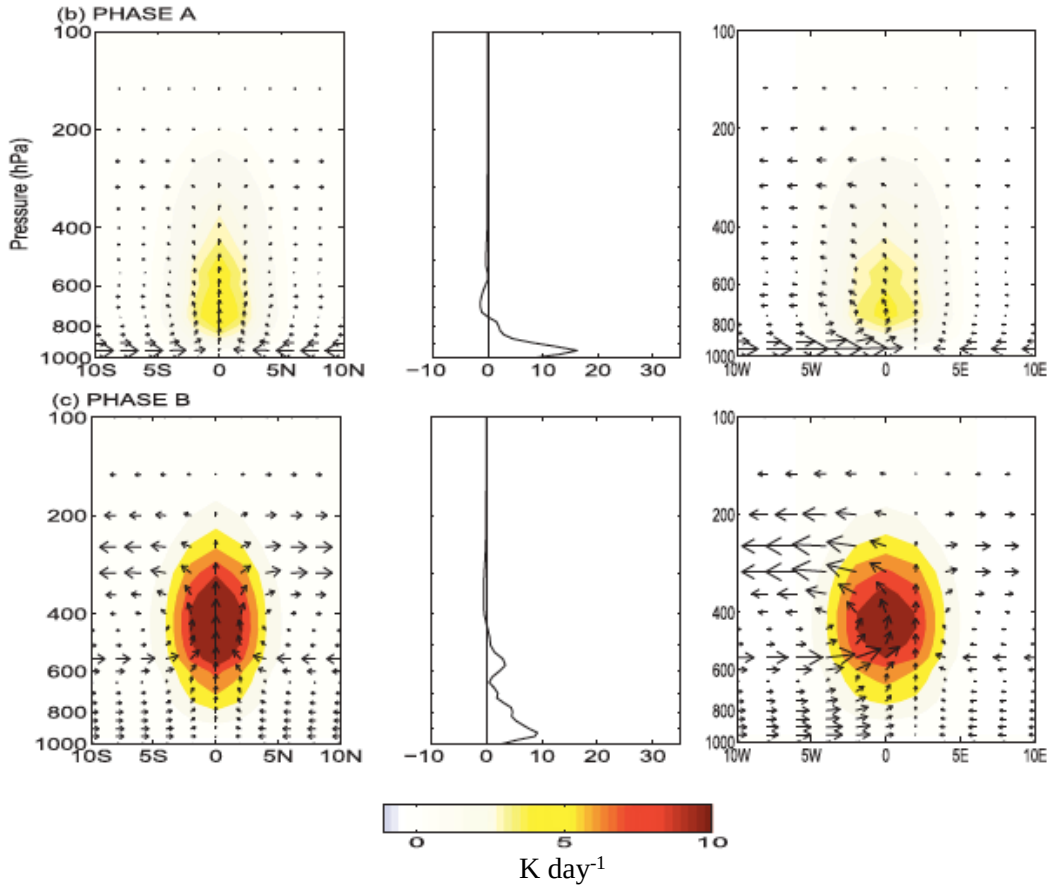
1. Moistening of the lower troposphere as a pre-condition for the development of deep convection



Benedict and Randall (2007)

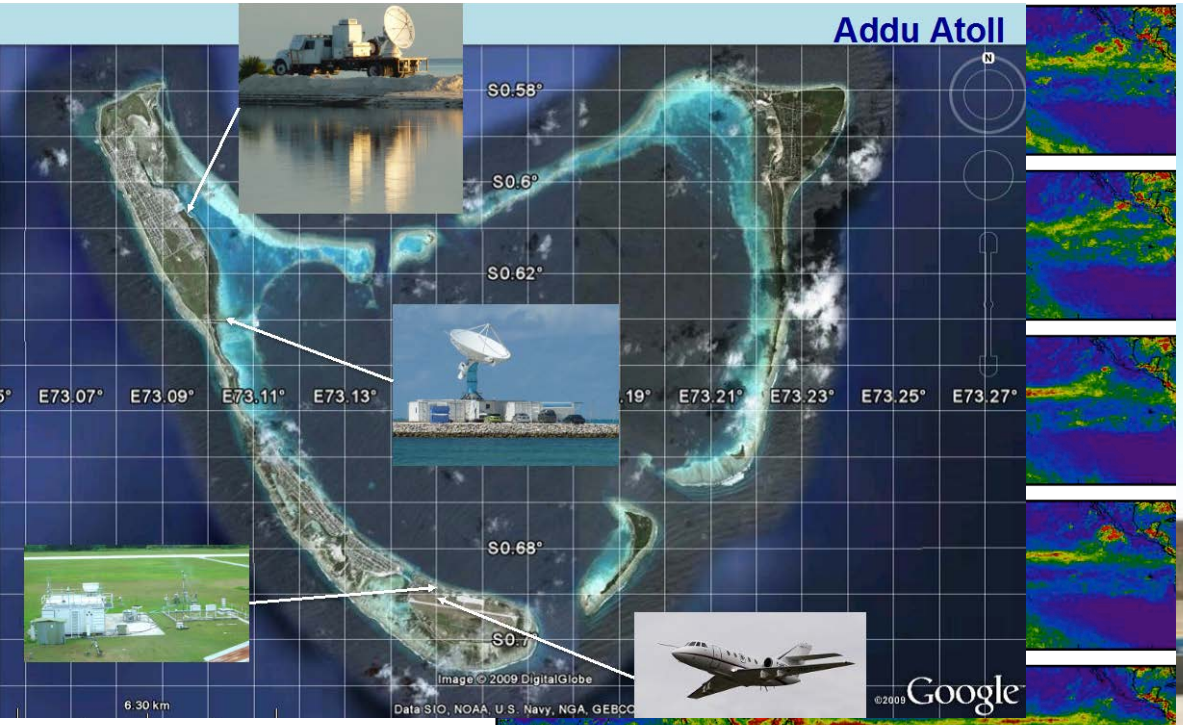
Hypothesized Importance of Shallow Convective Clouds in the Tropical Deep Convective Regimes:

1. Moistening of the lower troposphere as a pre-condition for the development of deep convection
2. Low-level heating as an effective mechanism for low-level convergence for moisture supply to deep convection



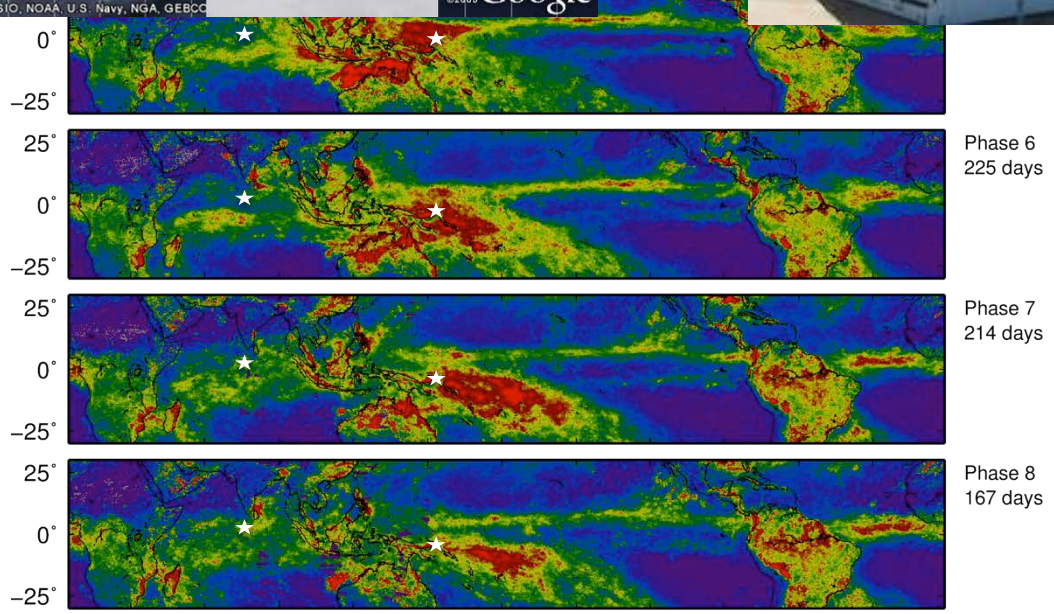
Zhang and Hagos (2009)

TRMM 3B42 Rainfall (1998–2013 Nov–Apr)



Oct 1, 2011 – Feb 8, 2012

2001 – 2014



AMIE/DYNAMO Shallow Cloud Research Activities:

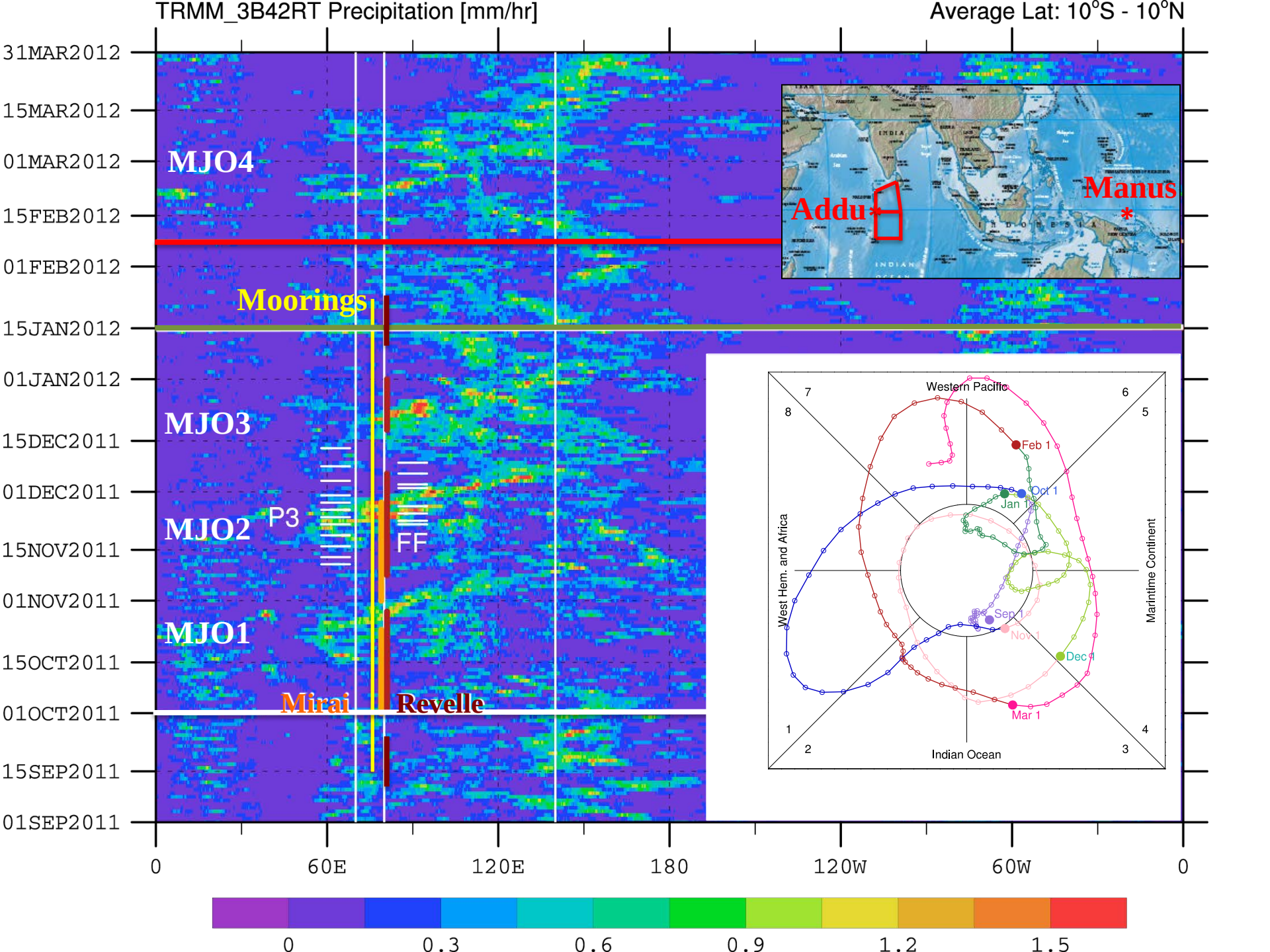
I. KAZR, S-PolKa, SMART-R comparison at Addu Atoll (October 1, 2011 – January 15 2012)

- Produce merged radar data that include non-precipitating and precipitating shallow clouds as well as deep and stratiform precipitation features;
- Calibrate Ka-band radar retrievals for (a) partition of convective-stratiform rain frequency, (b) estimate of low rain rates of shallow convection, and (c) estimate of diabatic heating profiles of shallow convection.

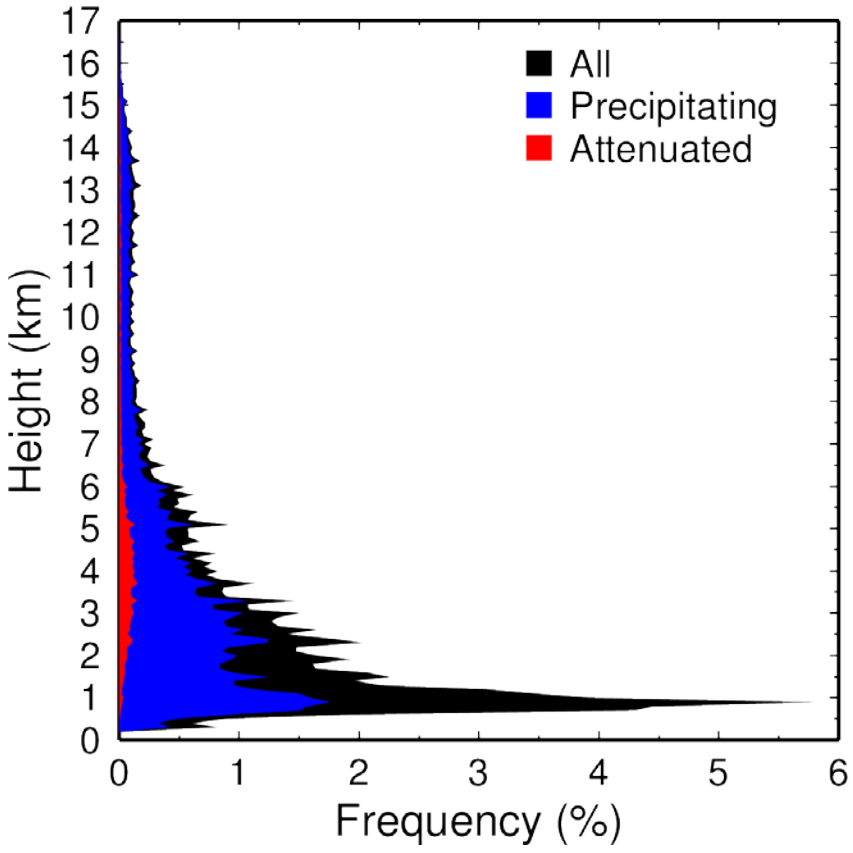
II. Detailed documentation and modeling of shallow and deep convection through the MJO events observed during the AMIE/DYNAMO field campaign.

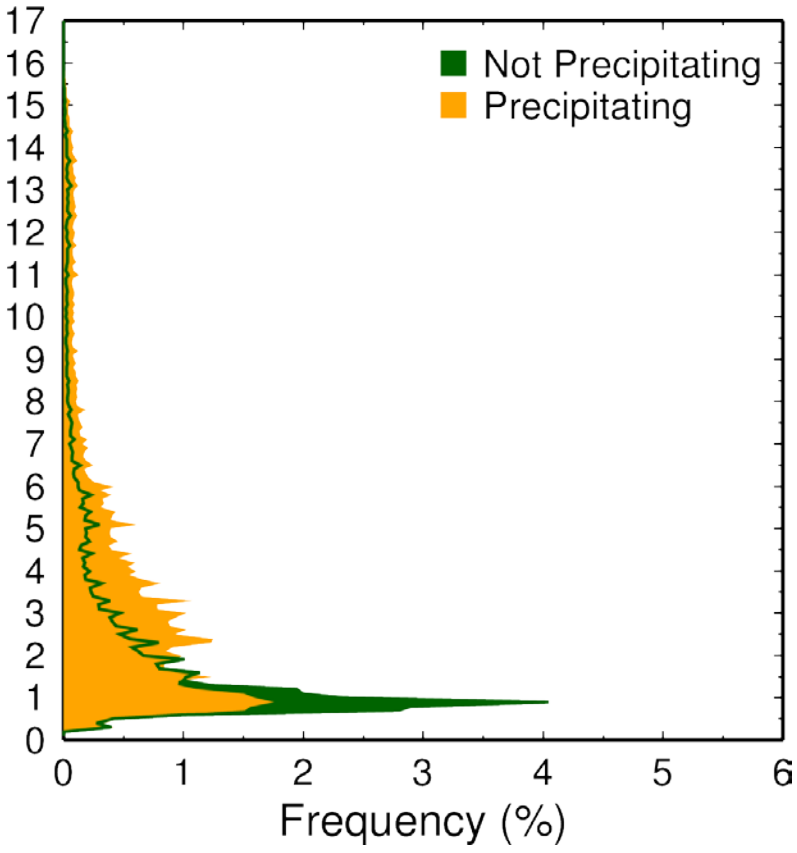
III. Statistics of MMCR/KAZR observations at Manus (2001 – present) for (a) evolution of non-precipitating and precipitating shallow convective clouds in the life cycles of various types of tropical disturbances (e.g., MJO, Kelvin waves), (b) their roles in heating and moistening the lower troposphere, and (c) their connections to the large-scale environment (temperature, humidity, winds).

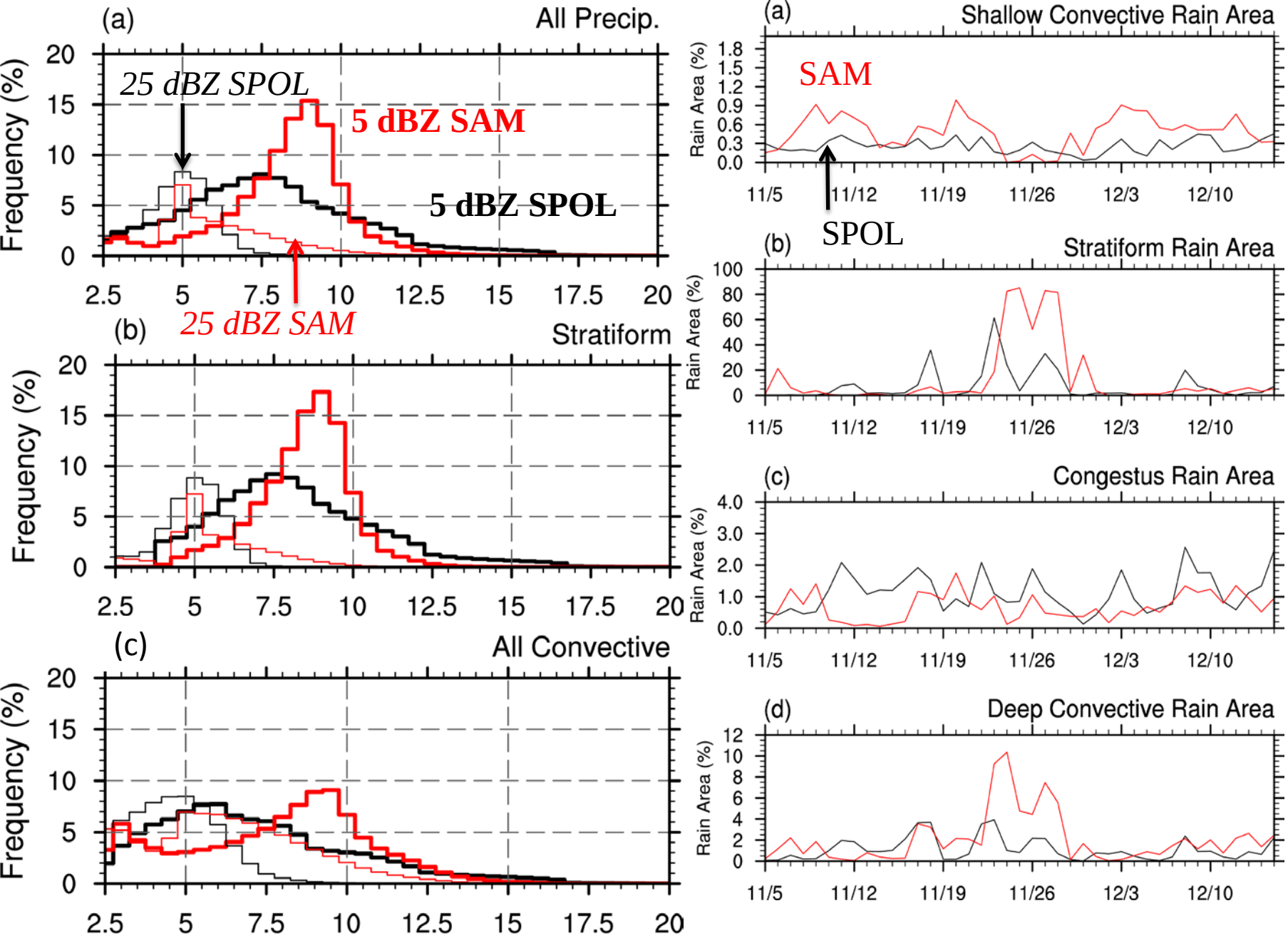
IV. Assessment of numerical models in their ability of producing shallow convective clouds in the tropical deep convective regimes.


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
MJO4
MJO3
MJO2
MJO1
Moorings
P3
FF
Mirai
Revelle
Addu
Manus
INDIA
INDONESIA
INDIAN OCEAN
Western Pacific
Indian Ocean
West Hem. and Africa
Maritime Continent
Feb 1
Oct 1
Jan 1
Sep 1
Nov 1
Dec 1
Mar 1
1
2
3
4
5
6
7
8
0
0.3
0.6
0.9
1.2
1.5

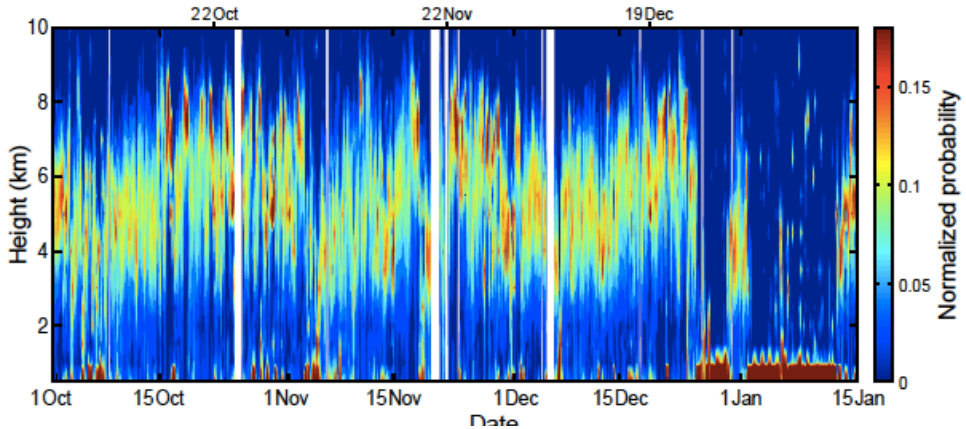
Frequencies of KAZR echo top height at Gan



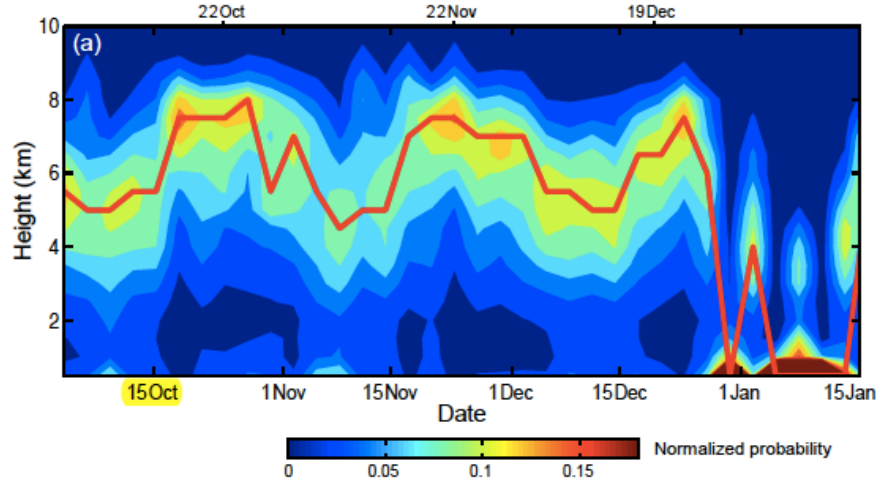




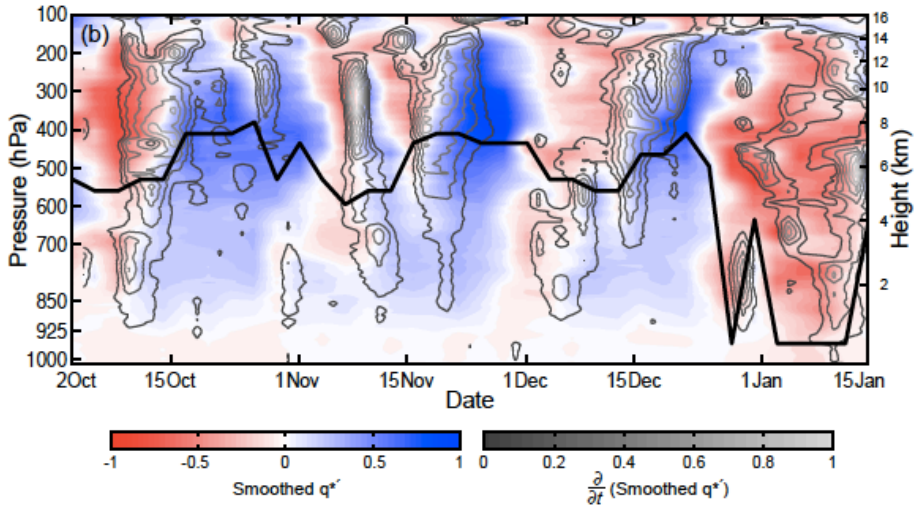
See Poster of Matt Janiga Today (MJO)



S-Pol 20 dBZ echotop height



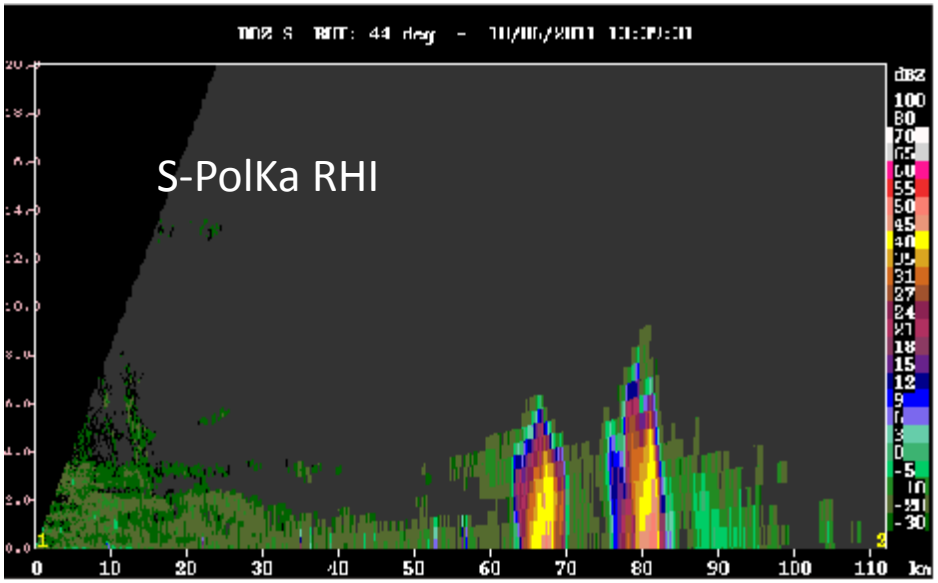
3-day running mean

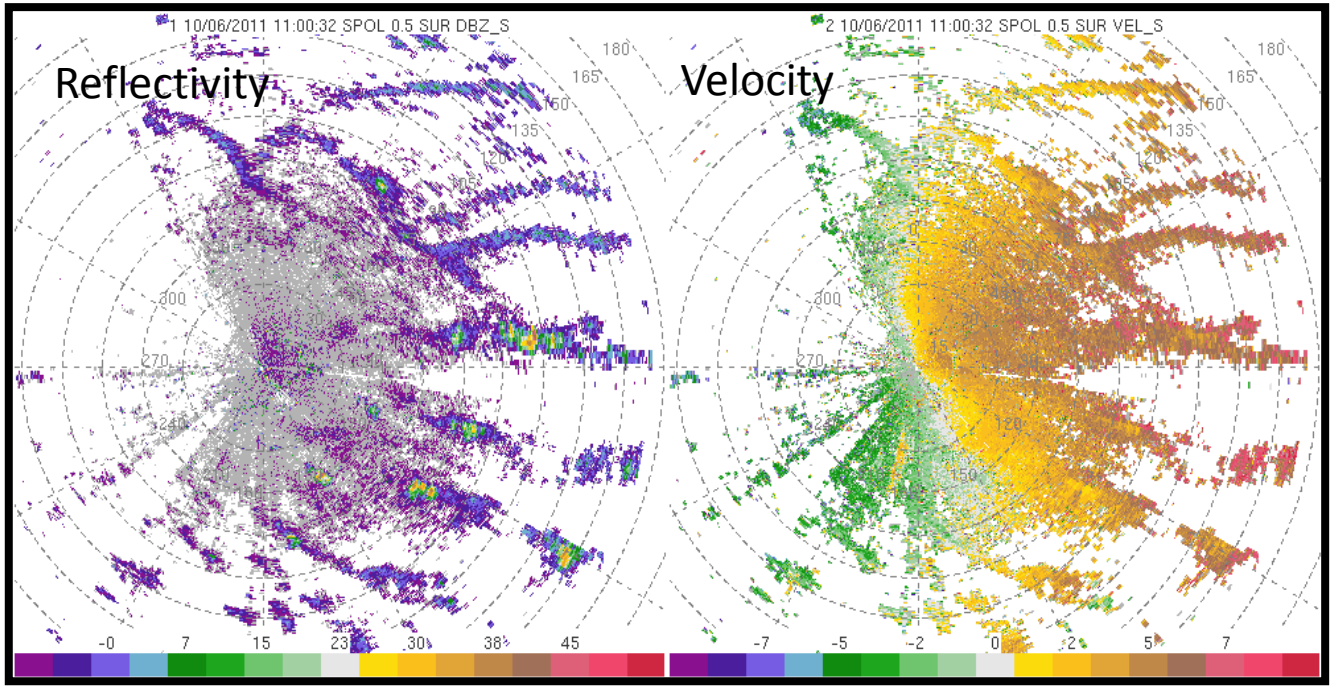


Smoothed humidity and its positive tendency (moistening)

Powell and Houze 2013

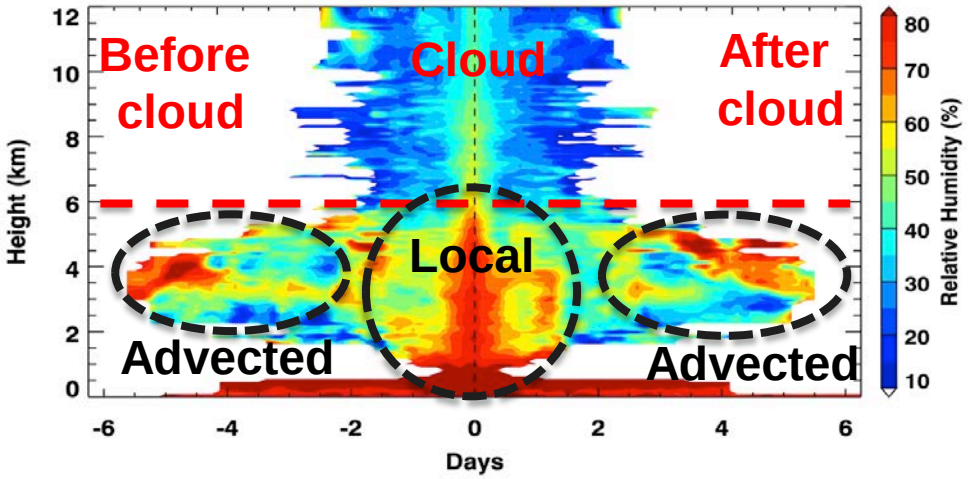
- During suppressed periods of AMIE/DYNAMO, non-precipitating clouds organized into lines oriented along the wind
- Shallow precipitating clouds began to form cold pools, which began to initiate deeper convection (ice processes) along gust fronts and removed these parallel line features





(Angela Rowe and Robert Houze, Jr.)

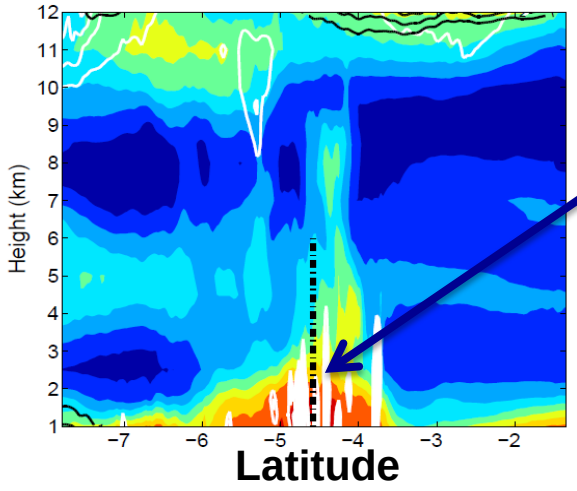
Mechanisms of Moistening in MJO



TOP: Observation
Composite RH with respect to timing of local clouds from AMIE/DYNAMO measurements at Gan

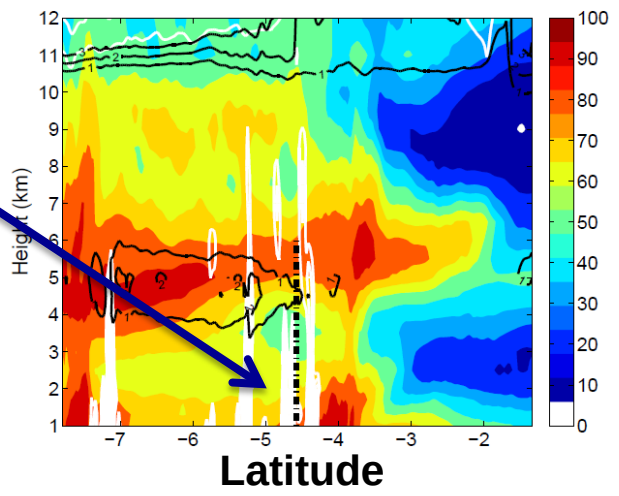
Bottom: RCPM simulation
Meridional cross-section of RH (shaded) , cloud (white contour) and meridional wind (black contours).

(a) Local convection



Transition from shallow to deep convection occurs here after 6 hours

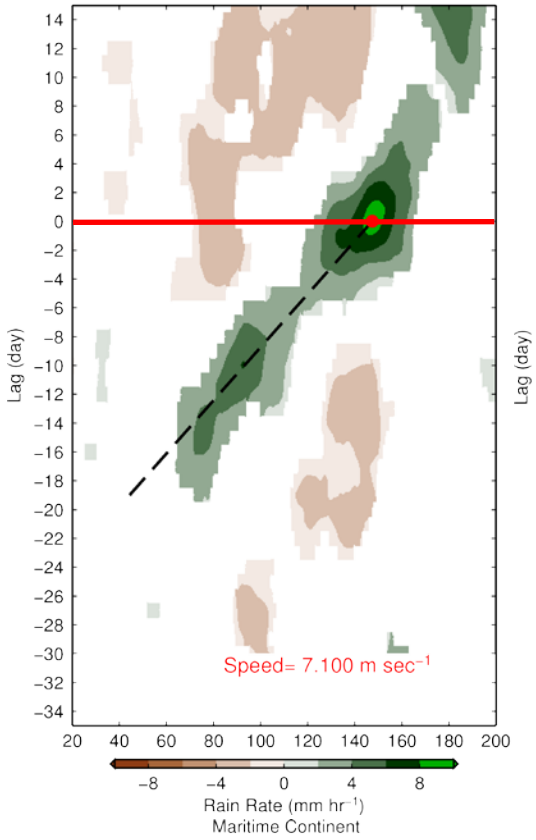
(b) Mid-tropospheric advection

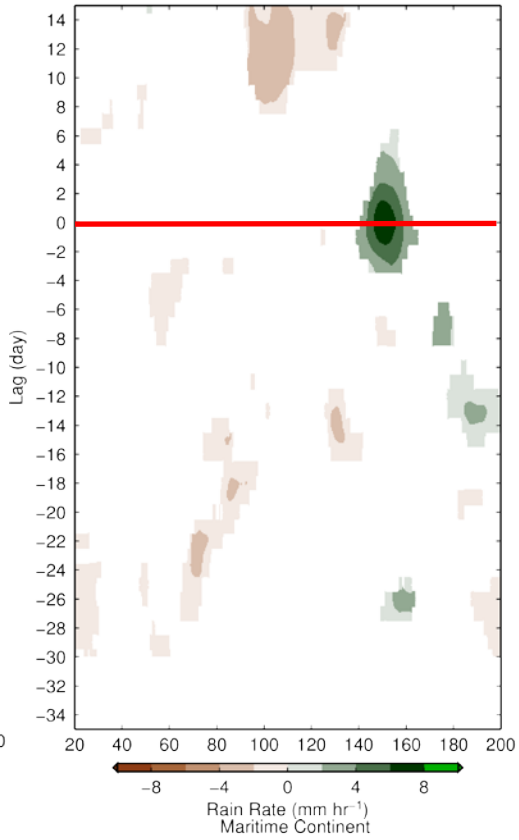


See Poster of Samson Hagos Today (MJO)

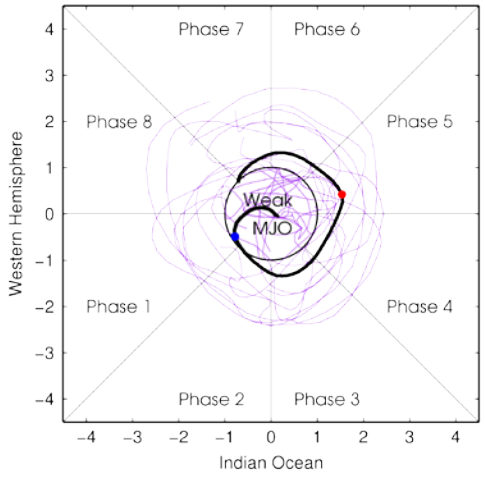
MJO

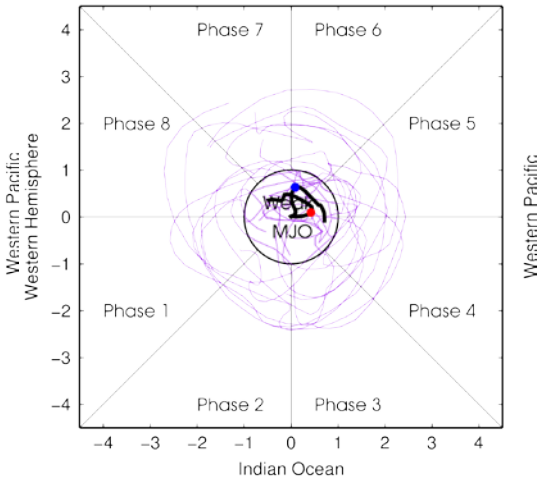
Non-MJO

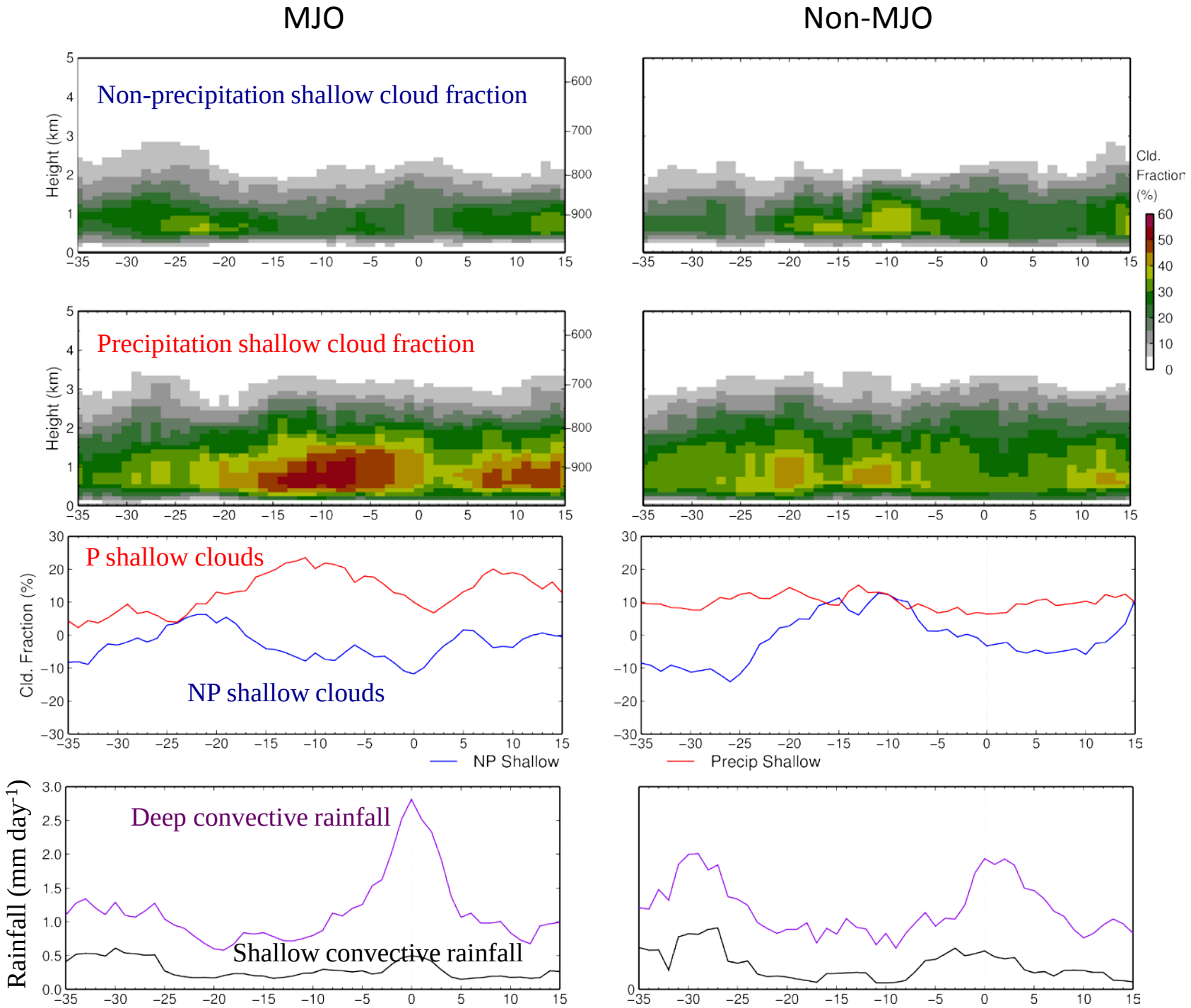

Lag (day)
Speed= 7.100 m sec^{-1}
Rain Rate (mm hr^{-1})
Maritime Continent


Lag (day)
Rain Rate (mm hr^{-1})
Maritime Continent

Manus
INDIA
INDONESIA
INDIAN OCEAN


Phase 7
Phase 6
Phase 8
Phase 5
Phase 1
Phase 4
Phase 2
Phase 3
Weak MJO
Western Hemisphere
Indian Ocean


Phase 7
Phase 6
Phase 8
Phase 5
Phase 1
Phase 4
Phase 2
Phase 3
MJO
Western Pacific
Western Hemisphere
Indian Ocean
Western Pacific

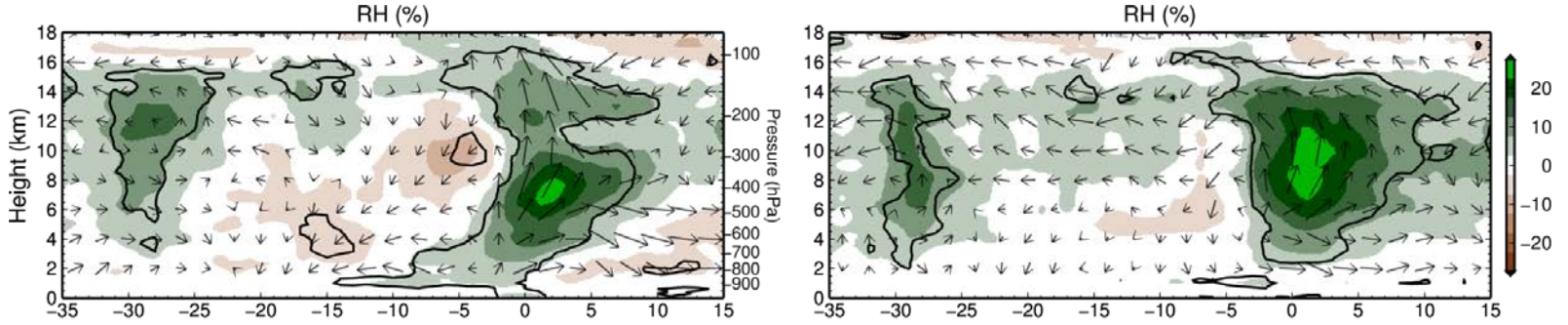

MJO
Non-MJO
Non-precipitation shallow cloud fraction
Precipitation shallow cloud fraction
Height (km)
Cld. Fraction (%)
P shallow clouds
NP shallow clouds
NP Shallow
Precip Shallow
Deep convective rainfall
Shallow convective rainfall
Rainfall (mm day-1)

MJO

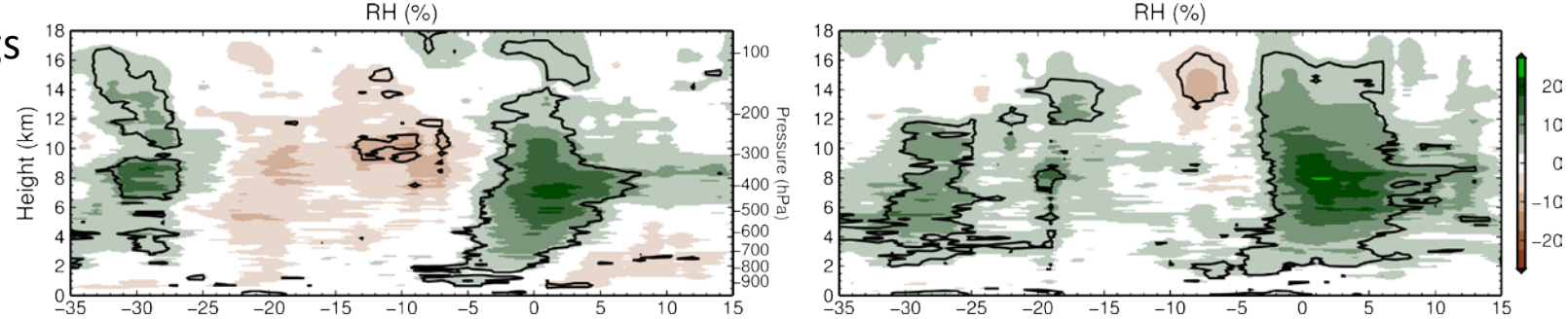
Non-MJO

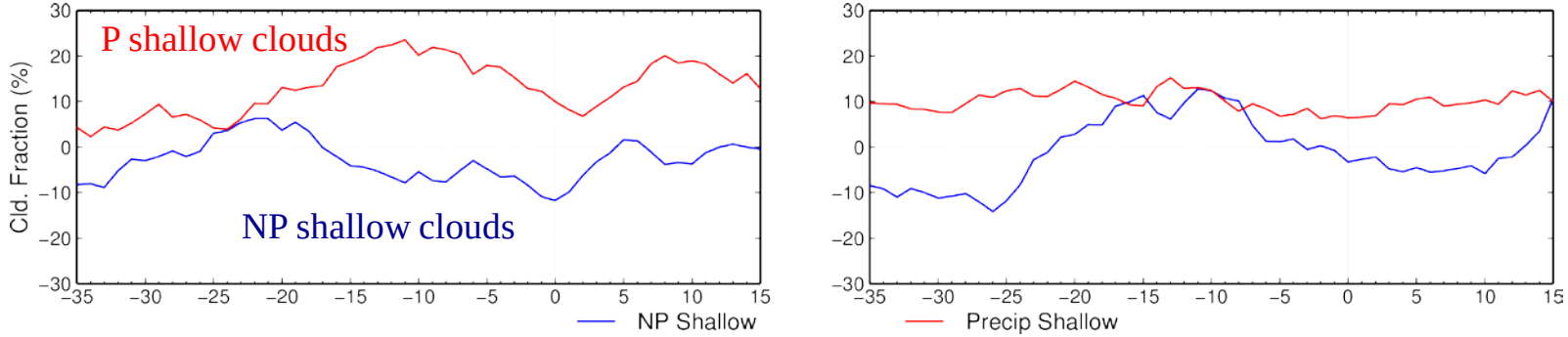
11 UTC

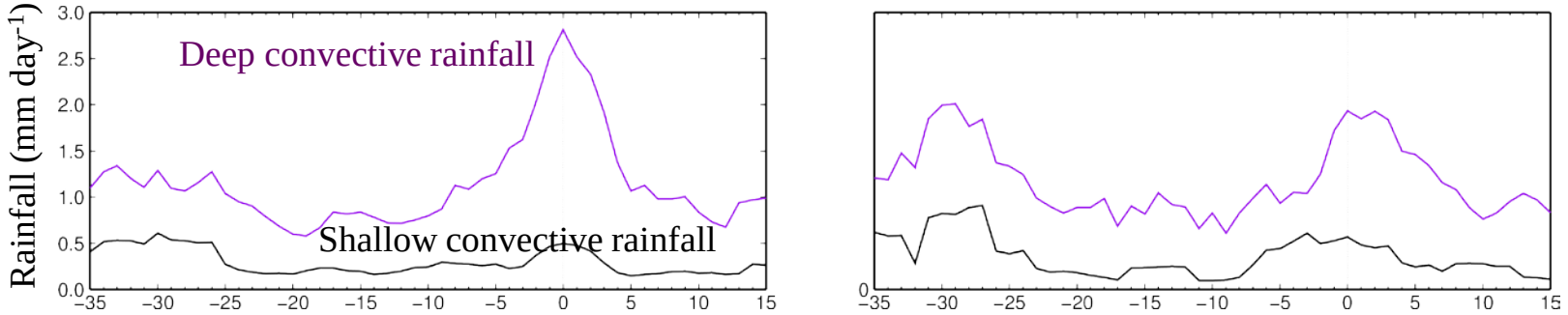
ECMWF



Soundings





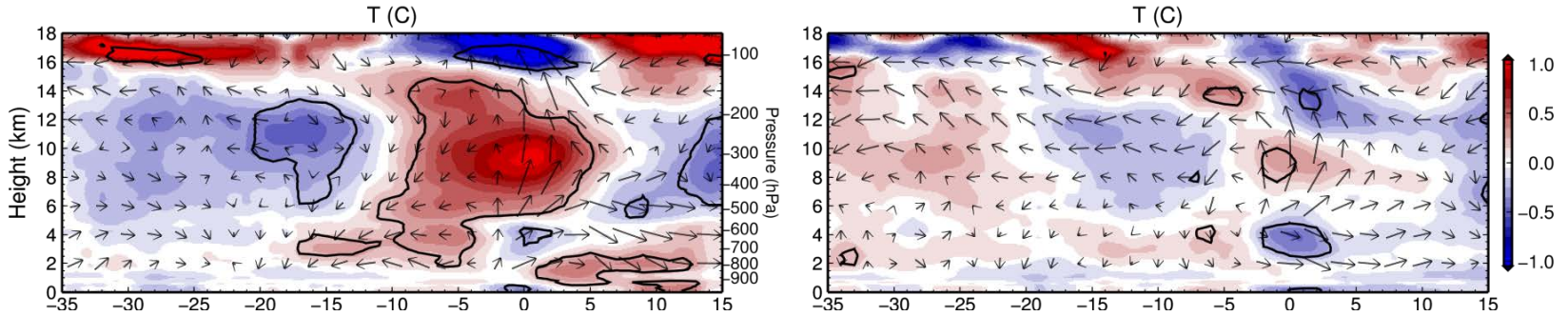


MJO

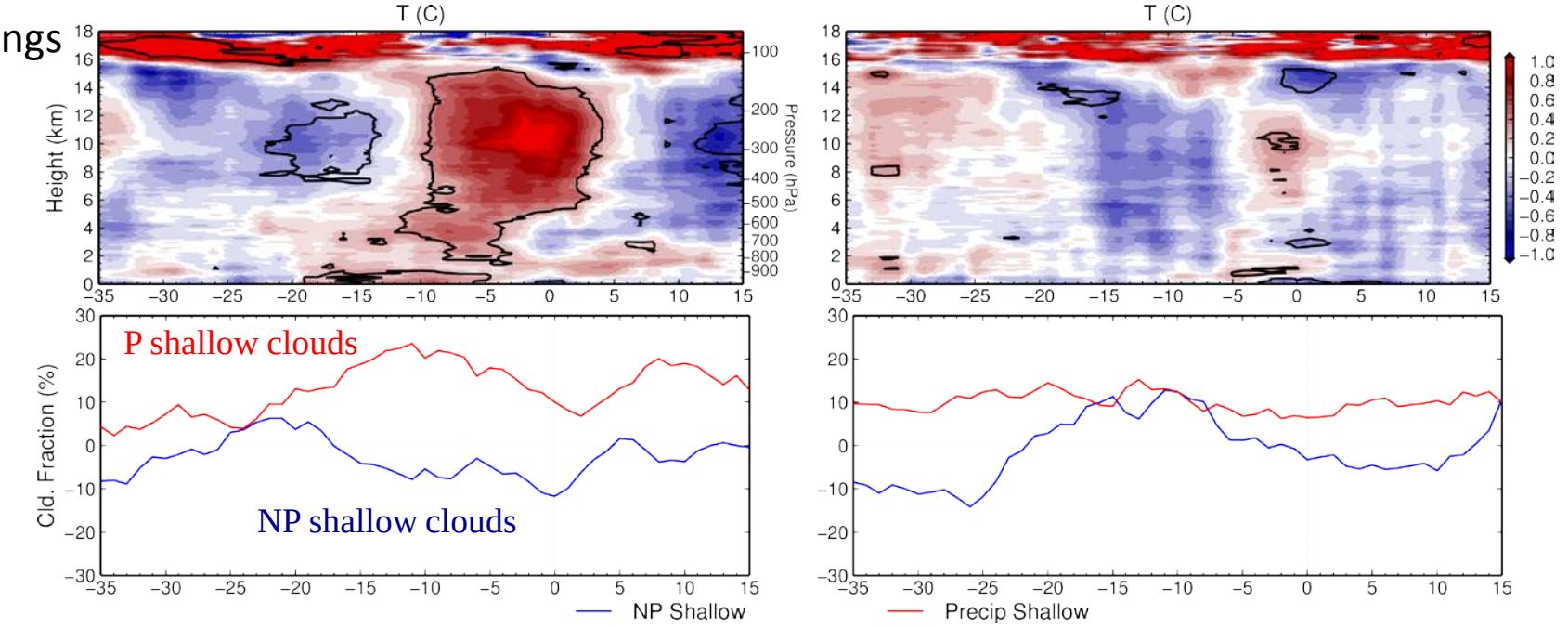
Non-MJO

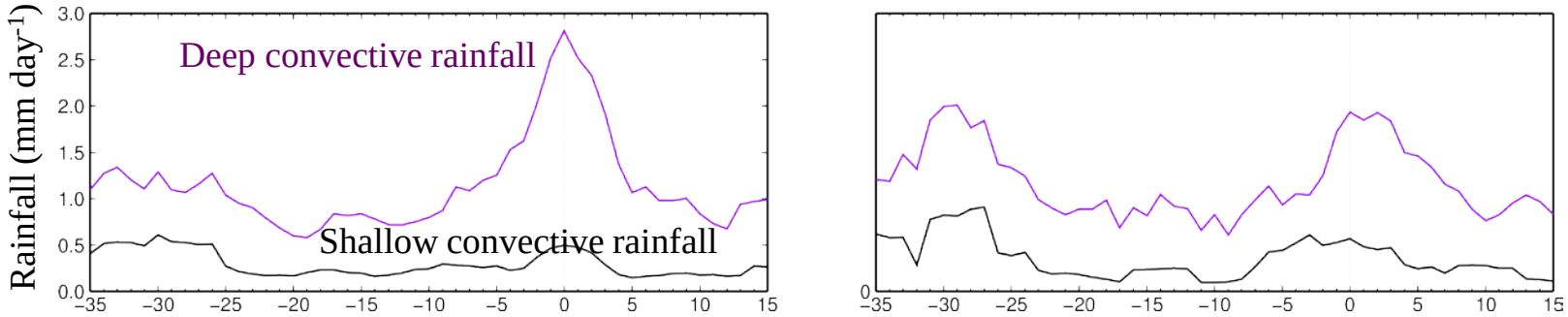
11 UTC

ECMWF



Soundings





Summary:

- Unimodal cloud distributions from KAZR and S-Pol.
- Cloud-permitting models have difficulties reproducing the observed fraction of shallow cloud (insufficient grid spacing)
- The role of shallow clouds in moistening the lower troposphere: The jury is still out!