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# Influences of environmental moisture on the development and organization of cumulus convection

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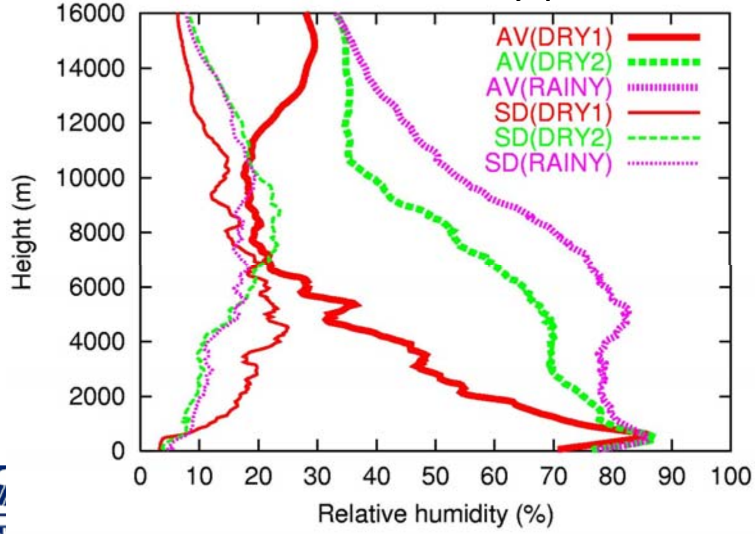
# Motivation

- Tropical convection exhibits trimodal characteristics: Cu, Cg, and Cb (Johnson et al. 1999)
- The large-scale variability of moisture in space and time significantly controls the development of cumulus convection; Cumulus activity will play a role in moistening the larger-scale atmosphere by transporting moisture.
- Mixing between cumulus and the environment is a key to understand dynamics and interactions of tropical convection across scales

# Cloud-top height of tropical cumulus

With cloud classification algorithm applied to satellite infrared data, cu-type clouds are chosen in 10 deg by 10 deg area over tropical oceanic areas.

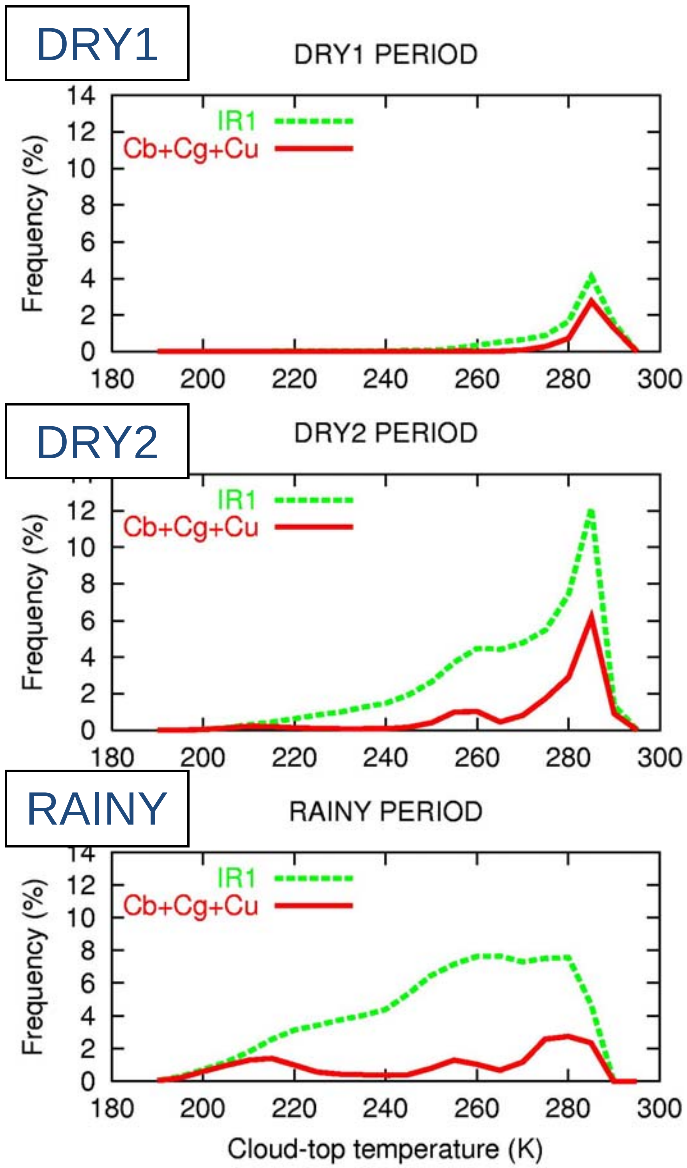
Relative humidity profile




✧Cu peak : ~ 285 K

✧Cg peak : ~ 255 K

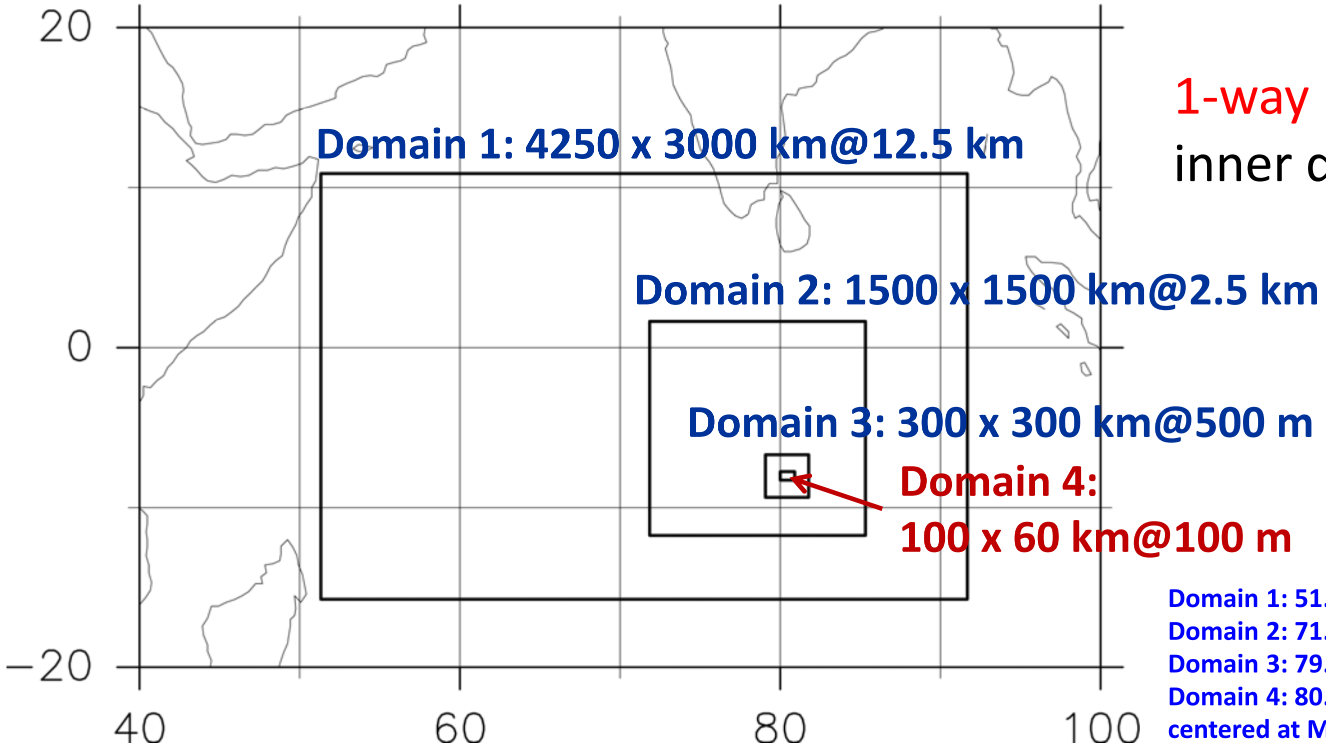
✧Cb peak : ~ 210 K




(Takemi et al. 2004)

# Purpose

- Investigate the interaction between cumulus convection and its environment over the tropical Indian Ocean
- Conduct high-resolution simulations extending two months during Oct-Nov 2011 (within the CINDY2011/ DYNAMO field observation period) with WRF/ARW v3.3.1

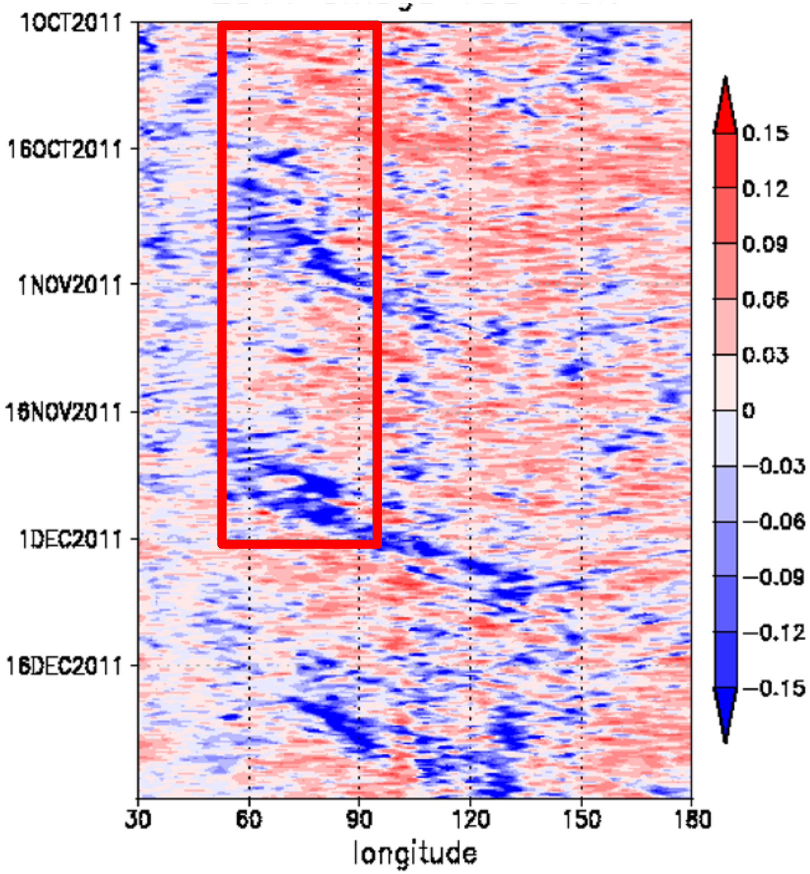



1-way nesting; no feedback from inner domains to outer domains

Domain 1: 51.3 E–91.7 E, 15.7 S–10.9 N
Domain 2: 71.85 E–85.32 E, 11.74 S–1.65 N
Domain 3: 79.08 E–81.77 E, 9.36 S–6.69 N
Domain 4: 80.009 E–80.908 E, 8.282 S–7.748 S;
centered at Mirai Obs.

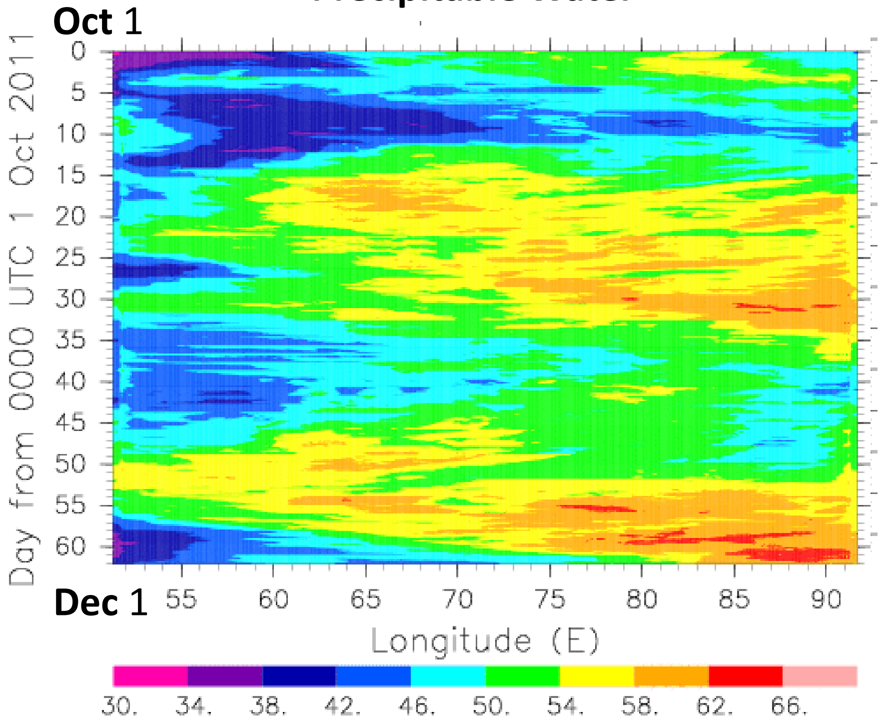
# Large-scale field: Longitude-time diagram in Oct/Nov 2011

**Observed (JMA Global Analysis)**
**Vertical Velocity (omega)**




**Simulated**

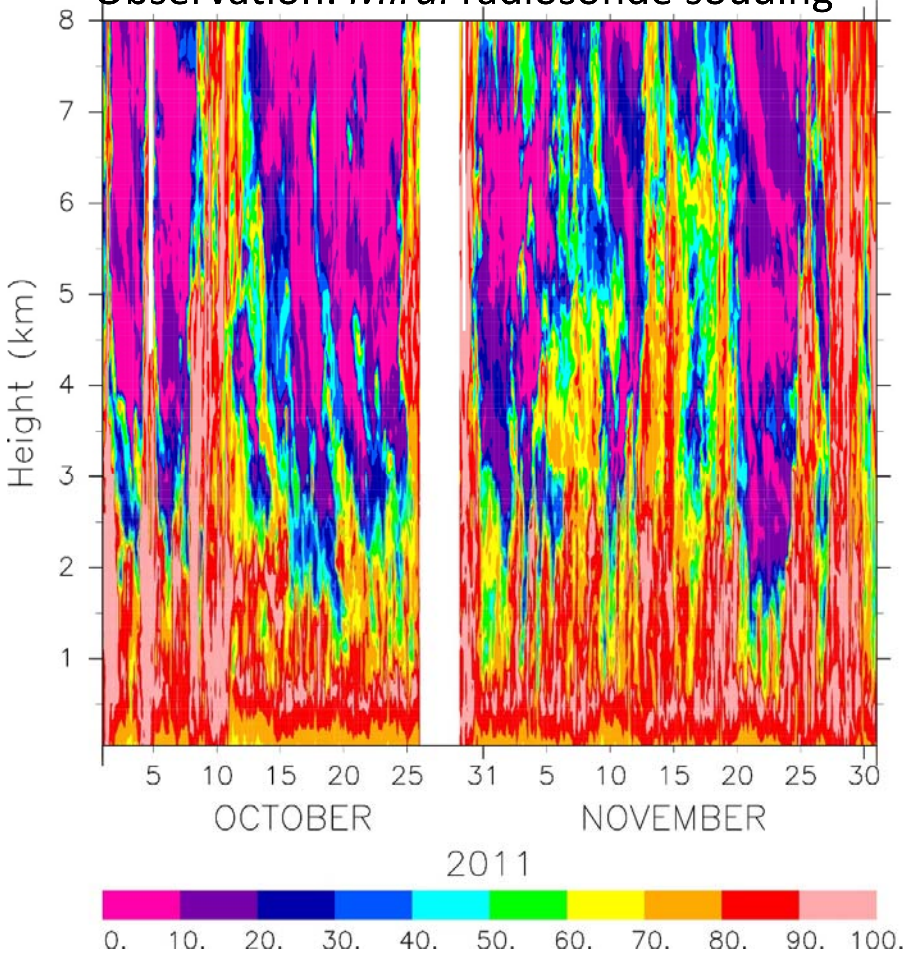
**Precipitable Water**



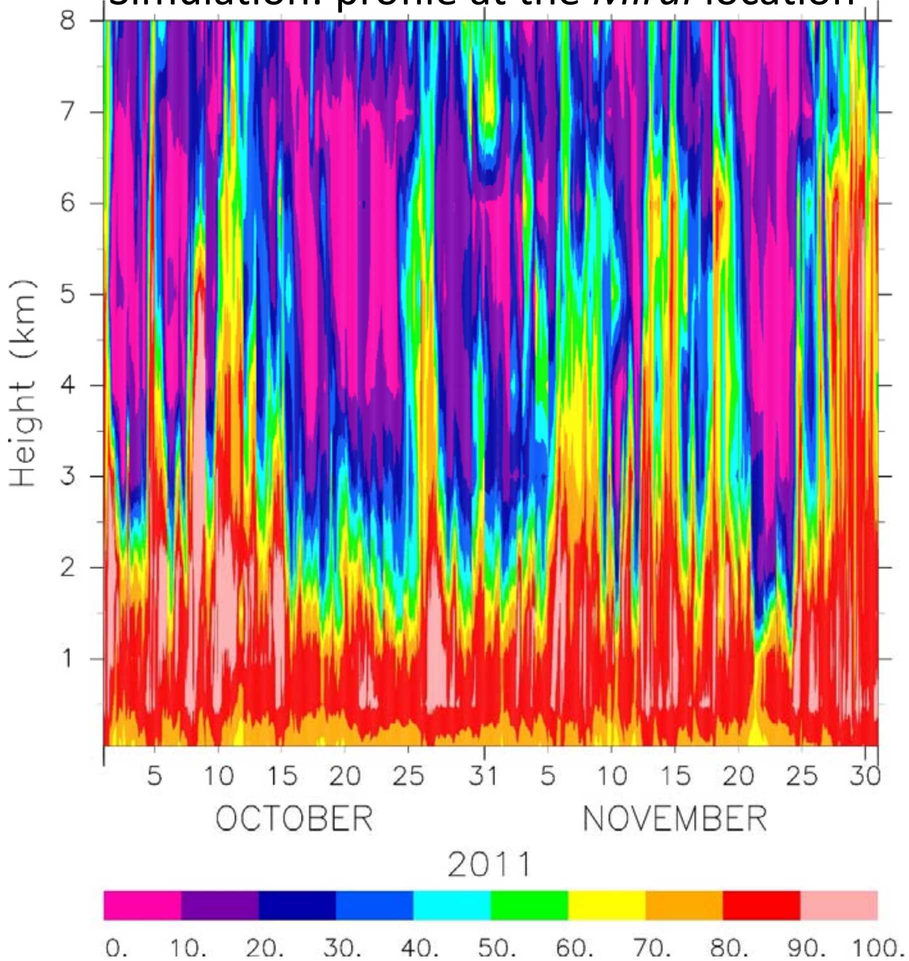
# Comparison with observations: humidity variation

Relative humidity

Observation: *Mirai* radiosonde souding

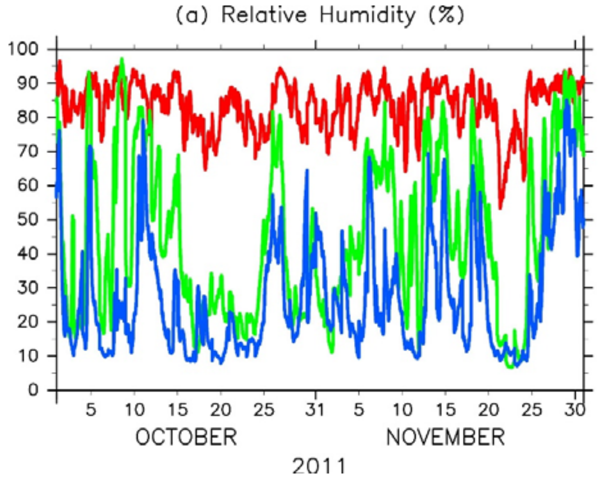



Simulation: profile at the *Mirai* location

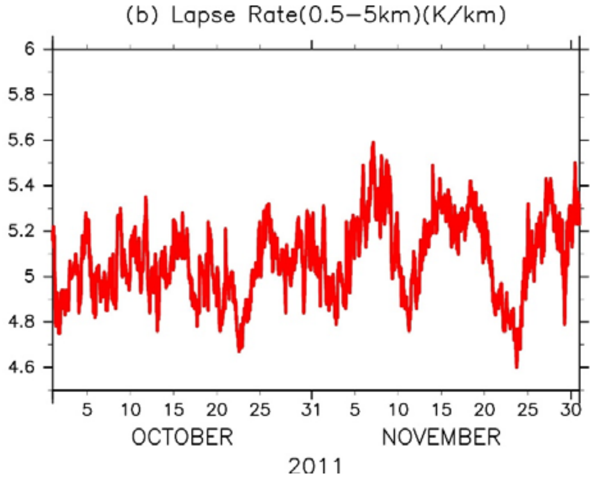


# Tropospheric humidity, stability, and cloud cover in Domain 4

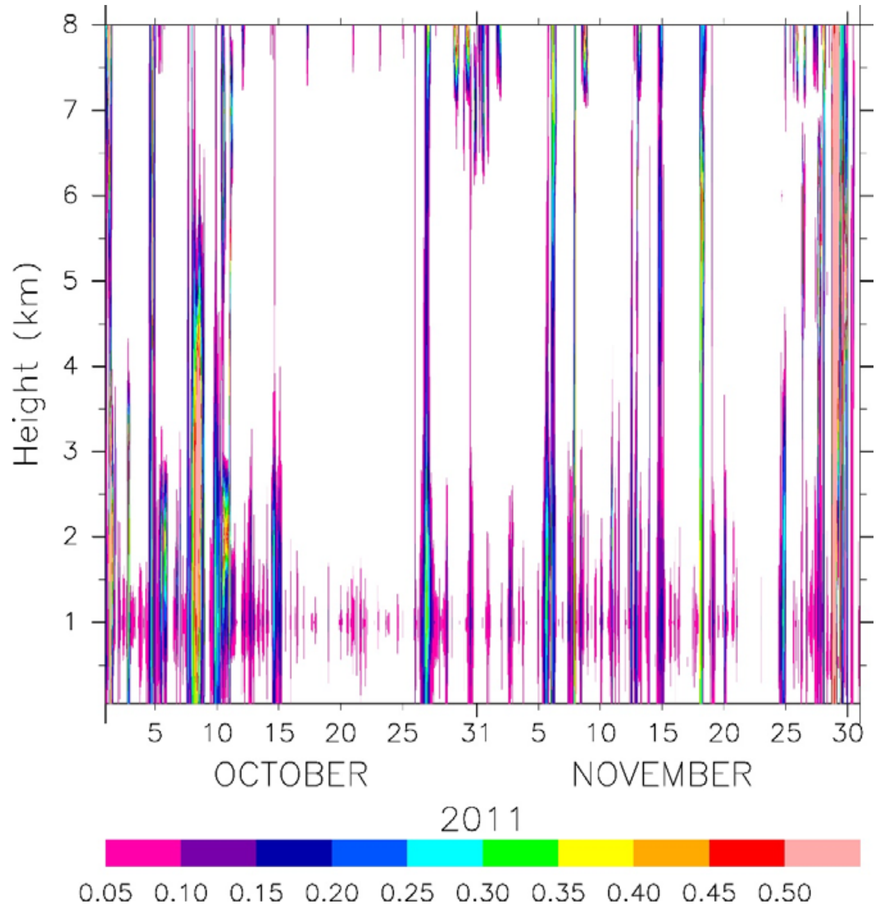
Domain-mean relative humidity:
at low-levels (0-2 km, red),
middle-levels (2-6 km, green),
and upper-levels (6-10 km, blue)




Domain-mean lapse rate
in the lower troposphere
(0.5-5 km)



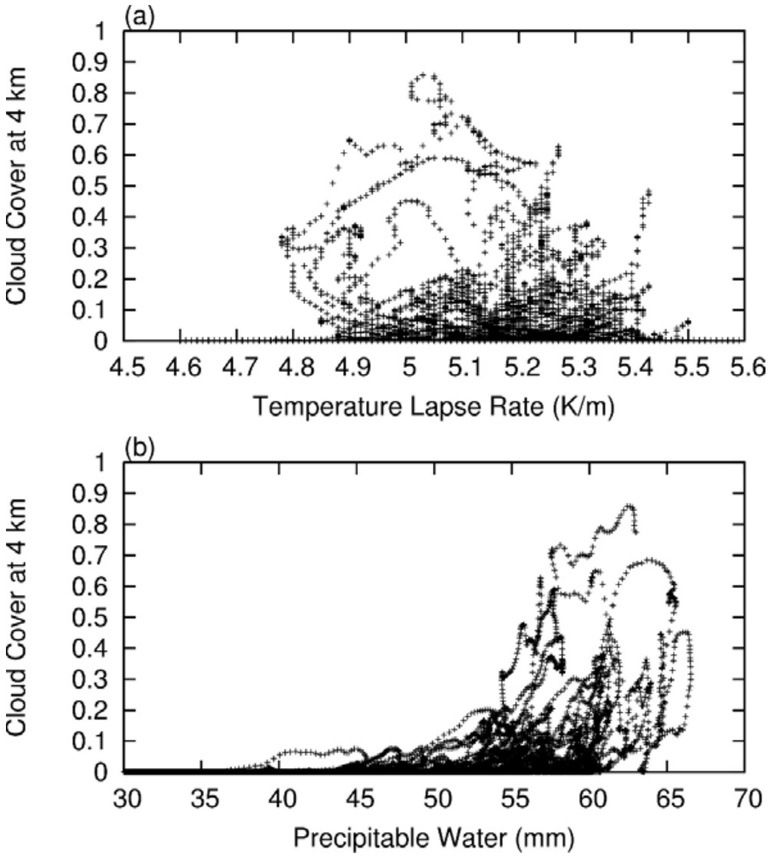

Time-height section of cloud cover

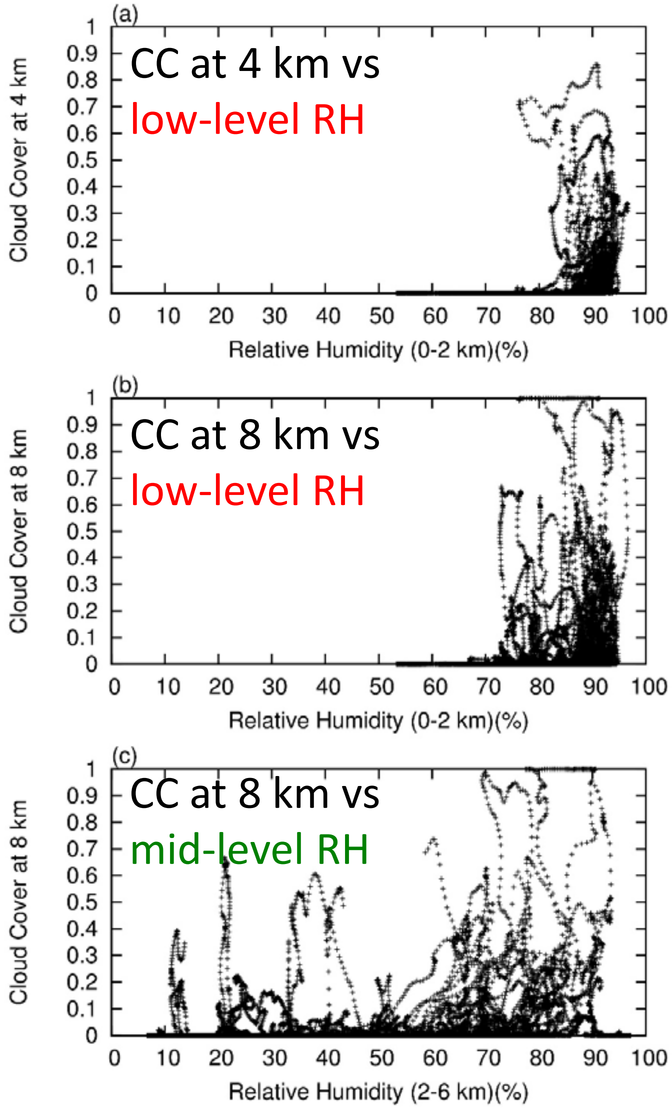


# Cloud cover versus lapse rate/humidity

Tropospheric temperature lapse rate versus mid-level cloud amount

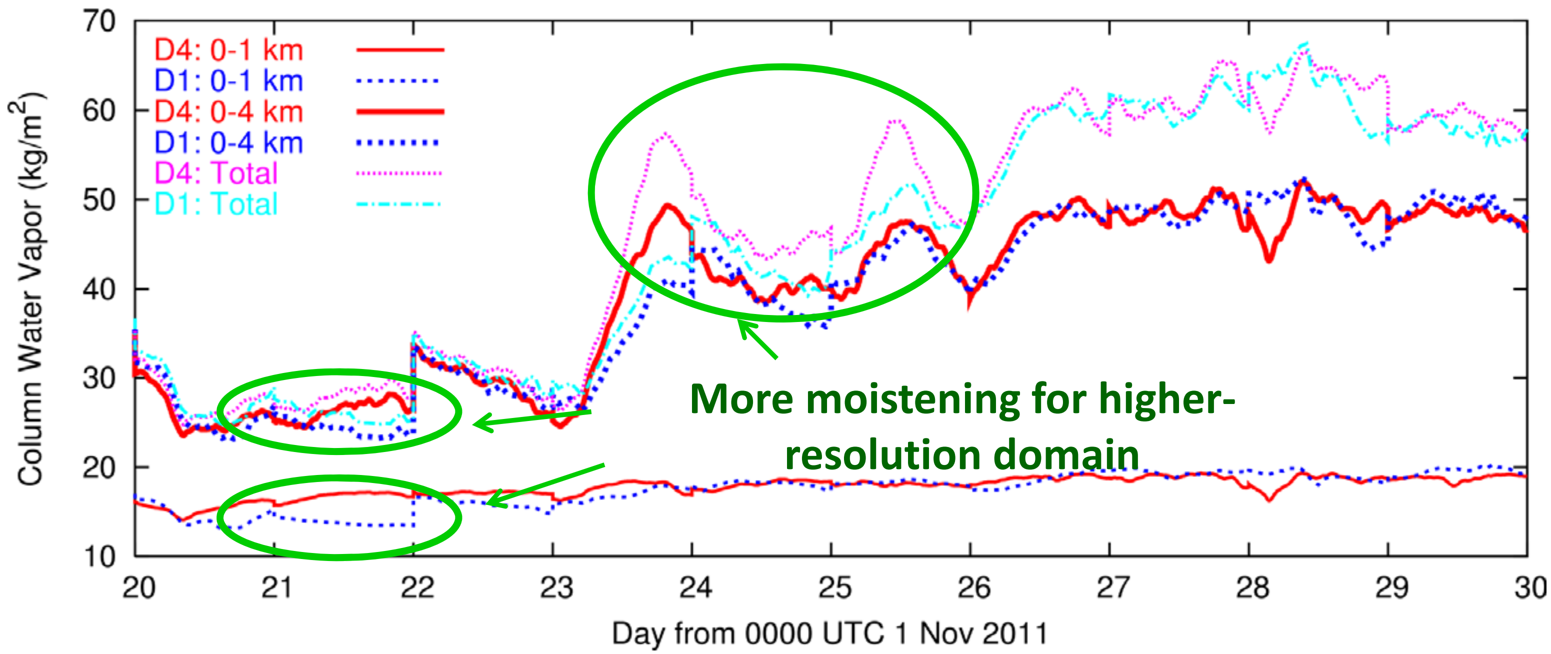
Precipitable water versus mid-level cloud amount



# Layer moisture content: 20-30 Nov

Domain 4 versus Domain-4 area within Domain 1




: 0-1 km layer (Domain 4)

: 0-1 km layer (Domain-4 area within Domain 4)

: 0-4 km layer (Domain 4)

: 0-4 km layer (Domain-4 area within Domain 4)

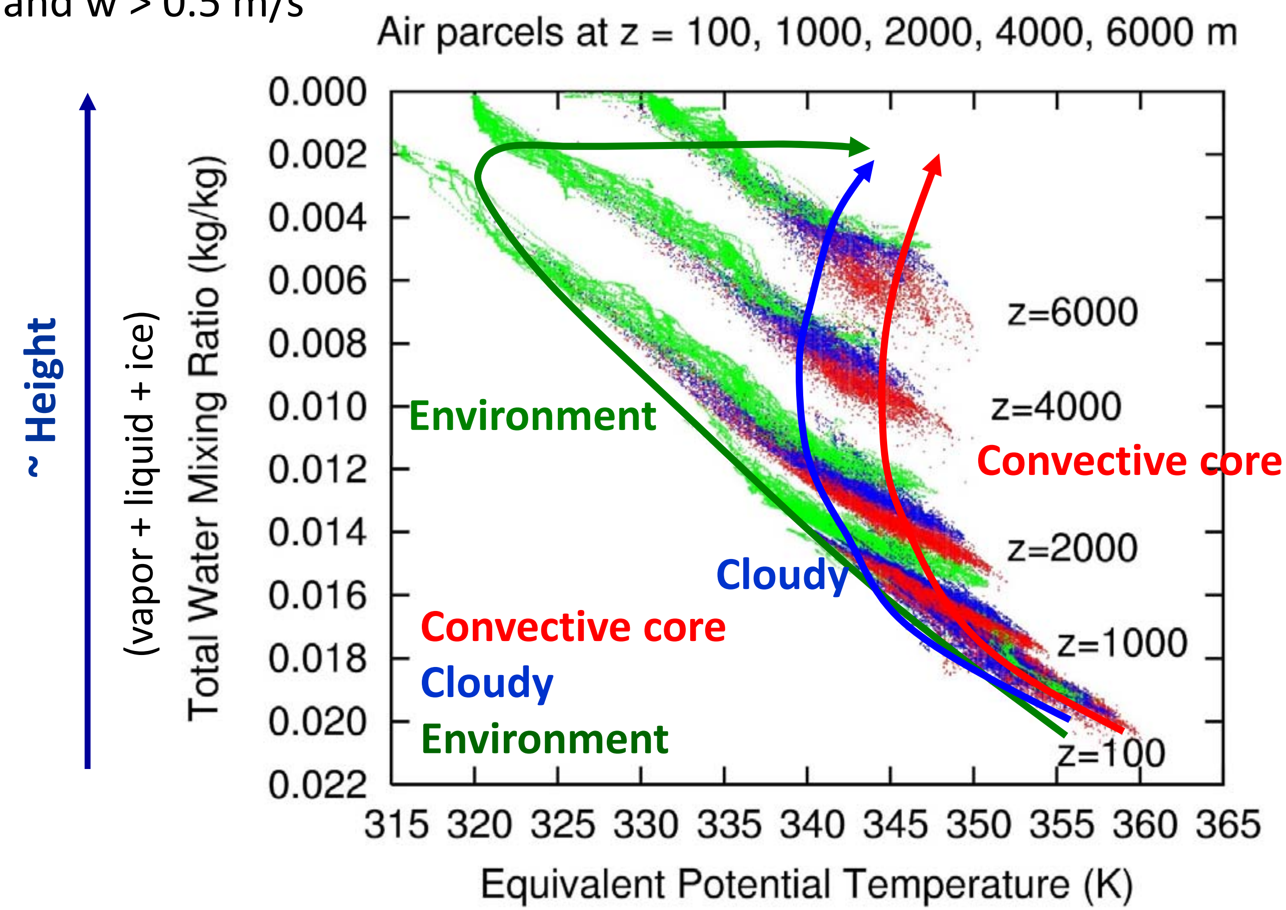
: Total layer (Precip water) (Domain 4)

: Total layer (Precip water) (Domain 1)

# Thermodynamic properties of air parcels

Analysis for the period of 1 Oct-1 Dec 2011

Convective core : qw > 0.05 g/kg and w > 0.5 m/s




$\theta_e$ of **convective cores** does not largely change with total water content.

Existence of undiluted, cloud-core air parcels

Environmental moistening

# Future work: thermodynamic control for warm-season MCSs

Locations of the occurrence of quasi-stationary convective clusters (QSCCs) in warm season in Japan

The importance of low- to middle-level relative humidity for the occurrence of QSCCs

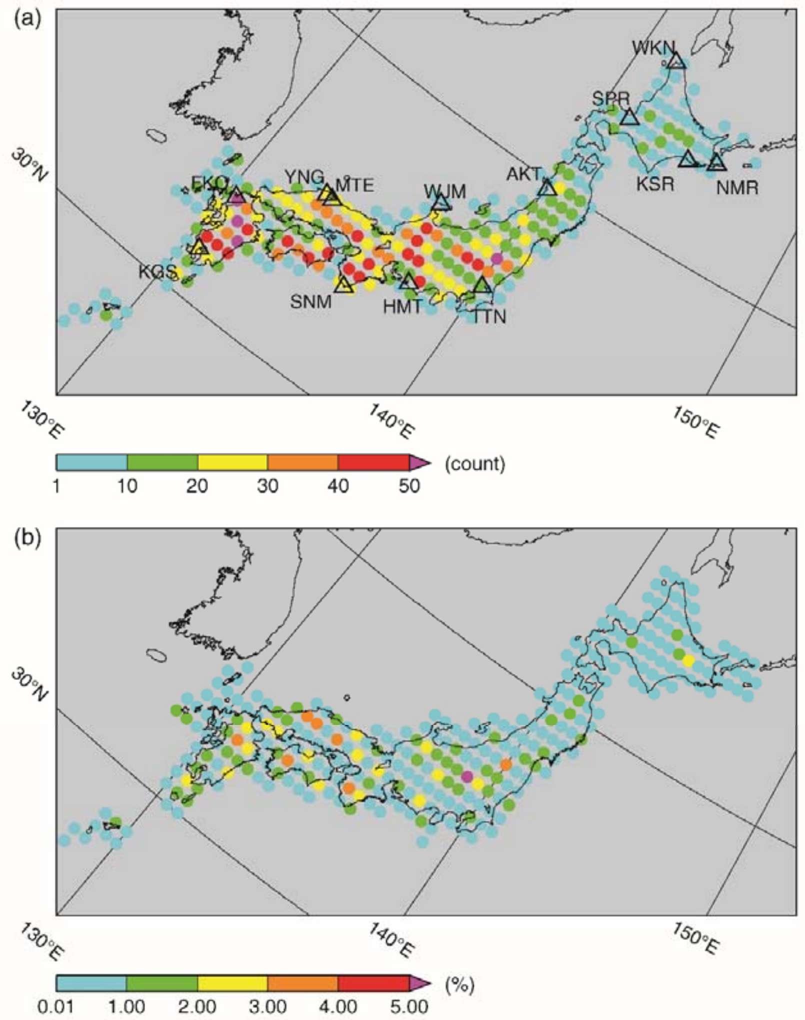



**Figure 6.** (a) The frequency of QSCCs evaluated over 50 km² areas, and (b) the percentage of rainfall produced by QSCCs relative to the total rainfall during the warm season. In (a) the locations of the radiosonde sites are indicated by triangles.

(Unuma and Takemi 2016, QJ)

# Summary

- This study investigated the relationship between cumulus convection and environmental moisture in the tropical Indian Ocean during CINDY/DYNAMO by conducting convection-resolving simulations at the 100-m grid.
- The cloud cover exceeding a middle level sharply increases with the increase in precipitable water vapor over 55 mm. The increase in lower-layer relative humidity results in the increase in cloud cover above the humid layer.
- The existence of updraft cores less is demonstrated; contributes to the environmental moistening. The updraft cores play a key role in the inter-relationship between cumulus convection and its environment, and are regarded as having a preconditioning influence for the convective initiation of MJO.

Takemi, T., 2015: Relationship between cumulus activity and environmental moisture during the CINDY2011/DYNAMO field experiment as revealed from convection-resolving simulations. *J. Meteor. Soc. Japan*, **93A**, 41-58, doi:10.2151/jmsj.2015-035

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