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The effects of moisture conditions on the organization and intensity of mesoscale convective systems in near moist-neutral stability: Convection-resolving simulations of tropical cumulus

Tetsuya Takemi

Disaster Prevention Research Institute
Kyoto University

DPRI-KU

京都大学
KYOTO UNIVERSITY

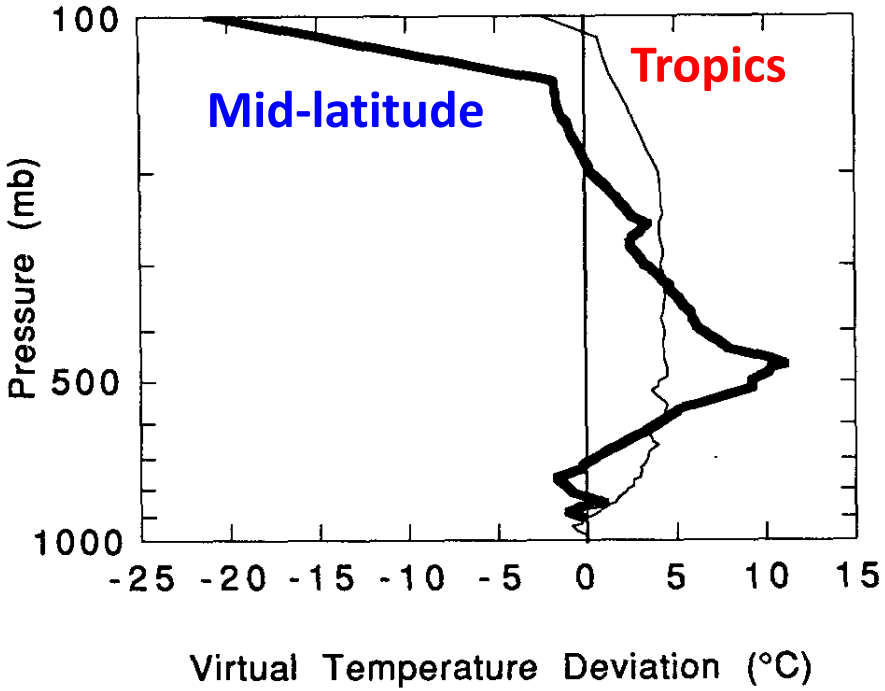
Moisture and cumulus convection

- The large-scale variability of moisture in space and time significantly controls the development of cumulus convection, while cumulus activity will play a role in moistening the larger-scale atmosphere by transporting moisture.
  - Vertical development of cumulus convection (cumulus mode: Cu, Cg, and Cb; Johnson et al. 1999) (Takemi et al. 2004)
  - Shallow to deep convection transition in MJO (Del Genio et al. 2012)
  - Congestus preconditioning (Waite & Khouider 2010)
- Tropospheric moisture is a key to understand the nature of tropical cumulus convection and their interactions across scales

Smaller buoyancy, weaker updraft in tropical cumulus clouds

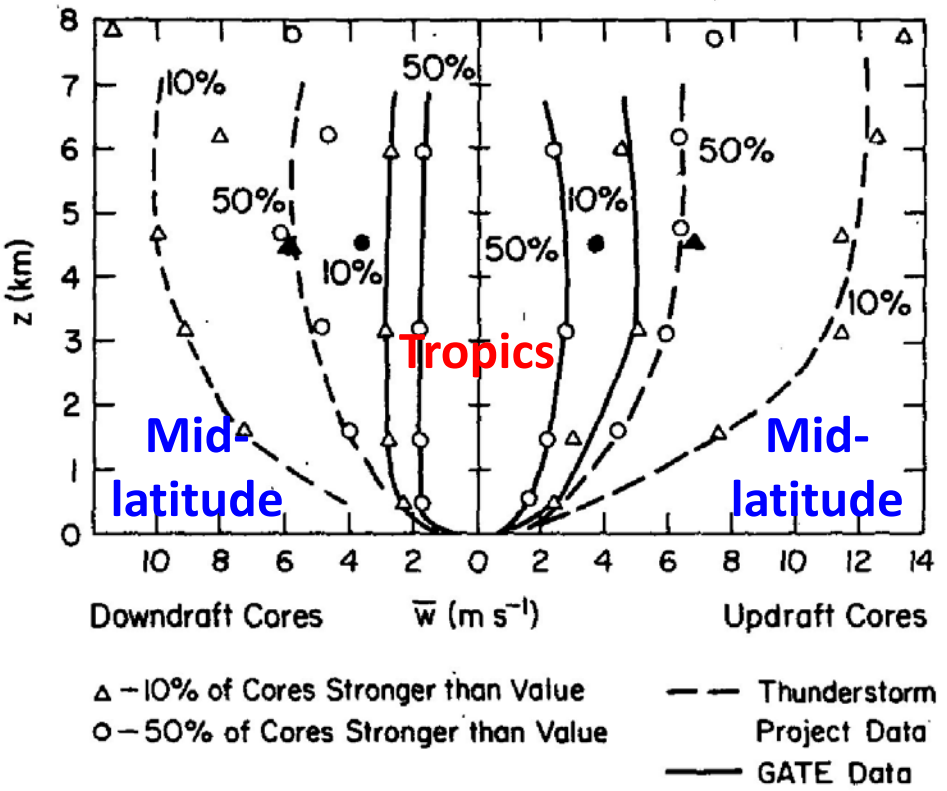
Tropical—oceanic: small buoyancy, high LNB, weak updraft
Mid-lat—continental: large buoyancy, lower LNB, strong updraft

Buoyancy difference



(Lucas et al. 1994)

Vertical velocity difference

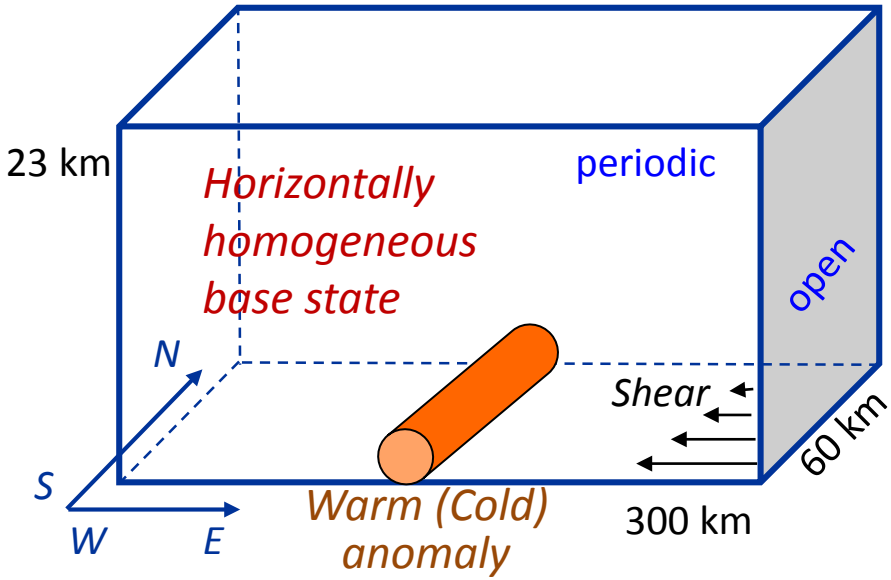


(Zipser and LeMone 1980)

More sensitive to moisture profile for tropical cumulus clouds

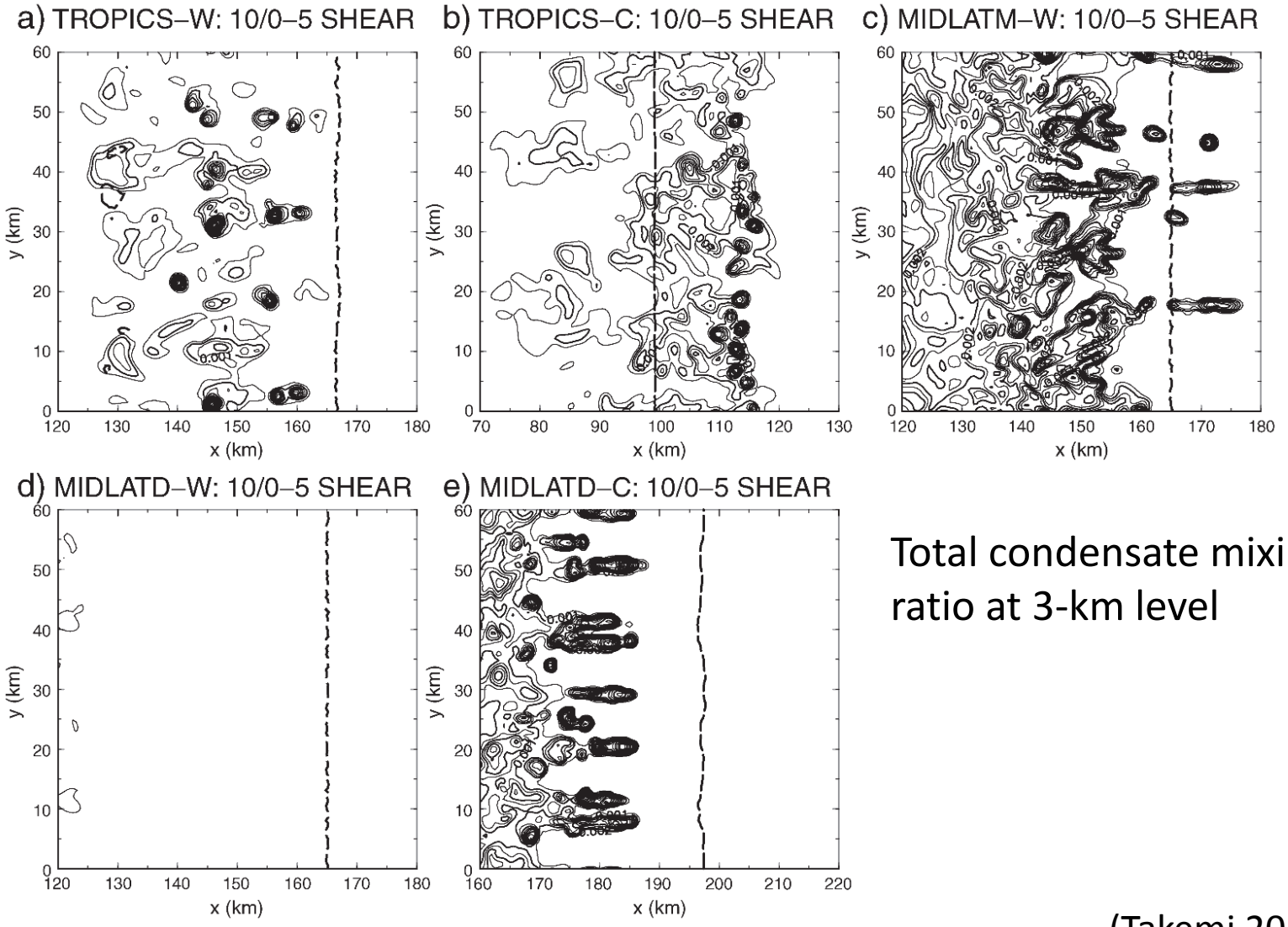
Idealized numerical experiments on tropical vs midlatitude squall lines

- Investigate the sensitivity of the intensity and organization of SLs to tropical-oceanic (TOGA-COARE) and midlatitude-continental (US Great Plains) environments.
- The initial environment conditions are closely coordinated by keeping CAPE unchanged between tropical and midlatitude environments.
- The sensitivity is examined by changing:
  - vertical wind shear
  - initial disturbance
    - † warm bubble
    - † cold pool



System organization: cloud features

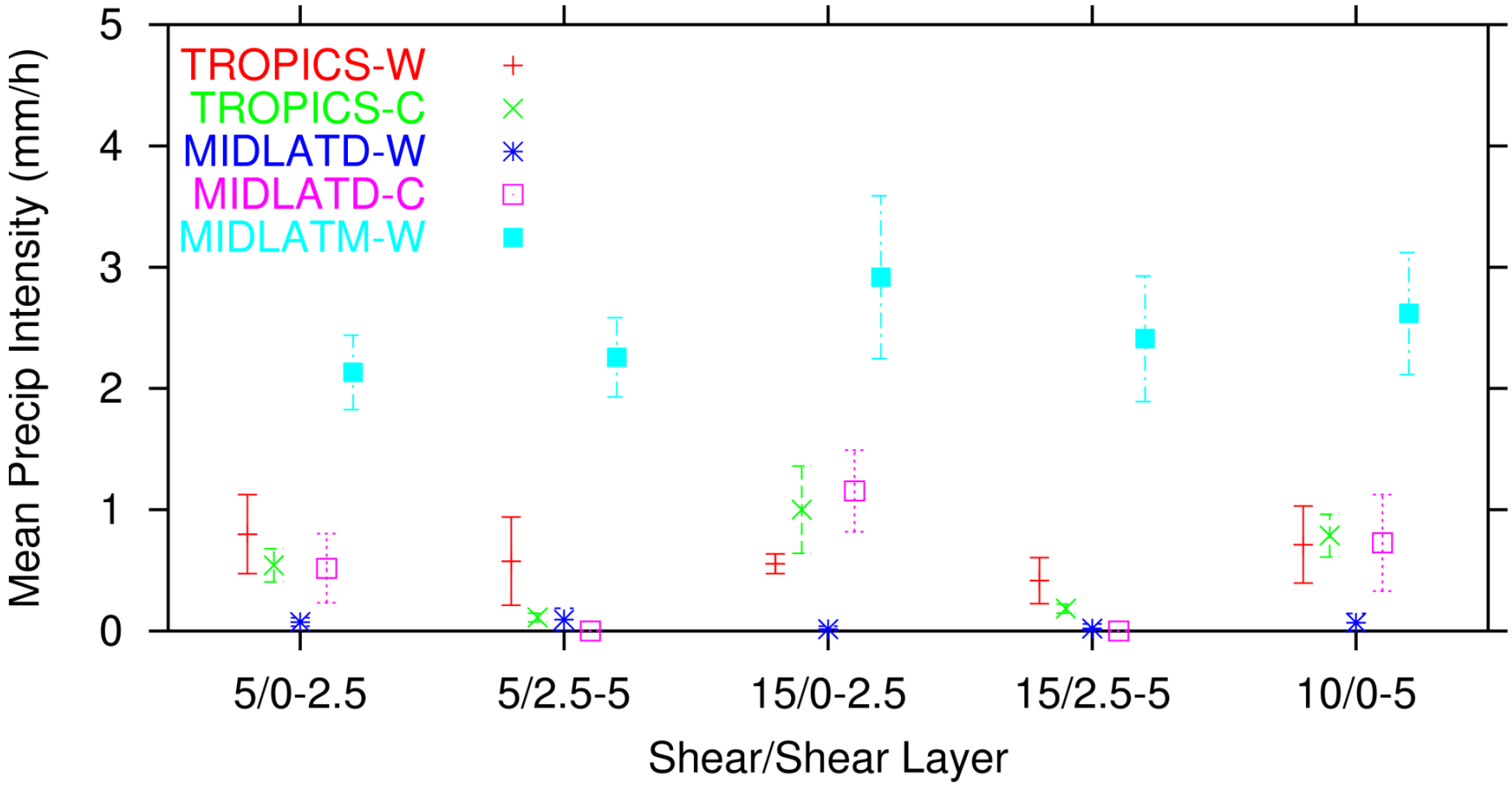
Shear case: 10 m/s /0—5 km



Total condensate mixing ratio at 3-km level

(Takemi 2014)

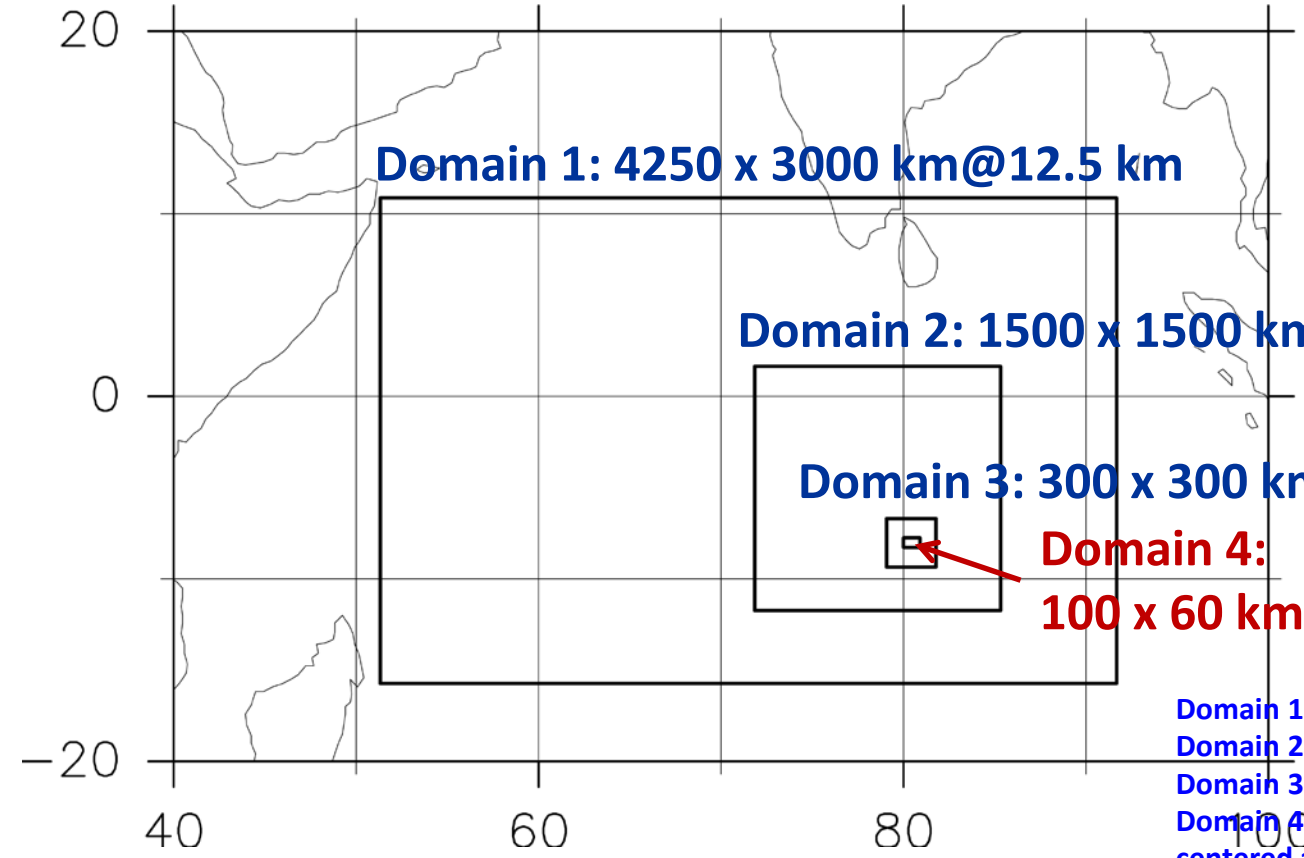
Mean precipitation intensity



(Takemi 2014)

Convection-resolving simulation of tropical cumulus during CINDY/DYNAMO

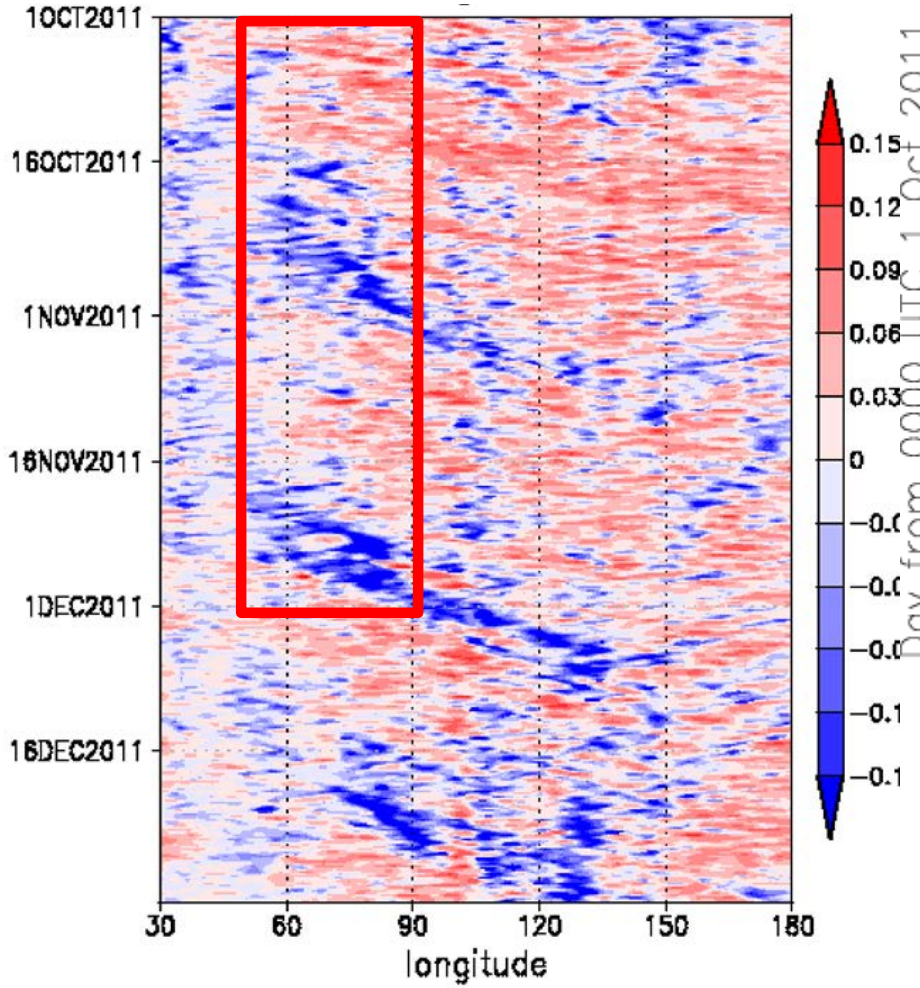
- Simulation period: 1 Oct – 1 Dec 2011
- WRF/ARW Version 3.3.1
- Domain: 1-way nested, 21 km height with 61 levels



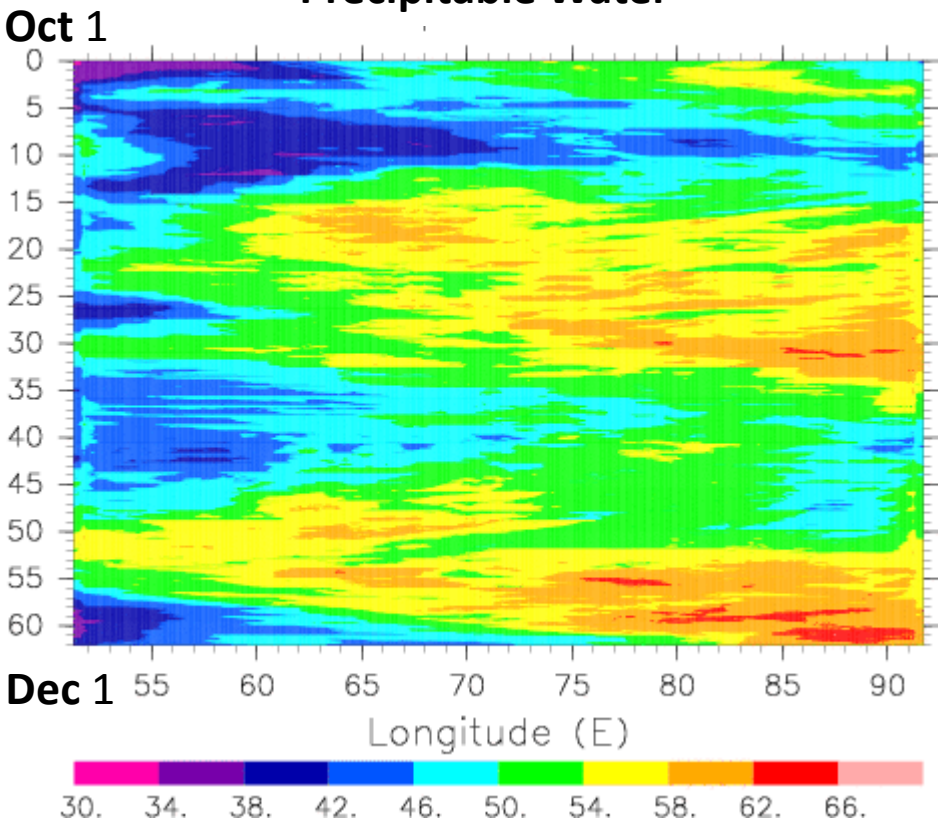
Domain 1: 51.3 E–91.7 E, 15.7 S–10.9 N
Domain 2: 71.85 E–85.32 E, 11.74 S–1.65 N
Domain 3: 79.08 E–81.77 E, 9.36 S–6.69 N
Domain 4: 80.009 E–80.908 E, 8.282 S–7.748 S; centered at Mirai Obs.

Large-scale field: Longitude-time diagram

Observed (JMA Global Analysis)
Vertical Velocity (omega)



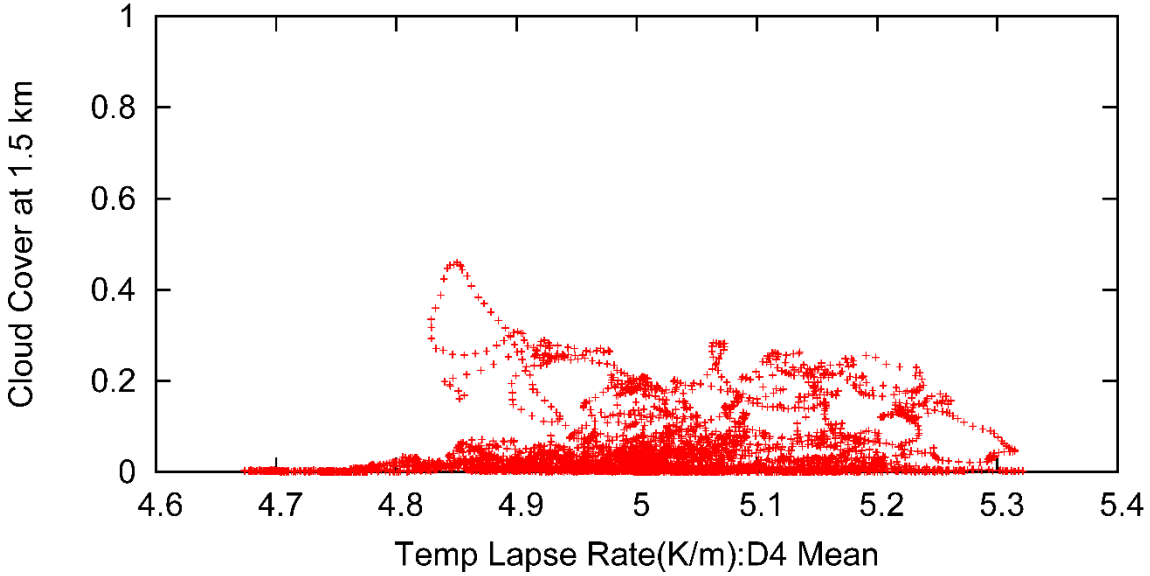
Simulated
Precipitable Water



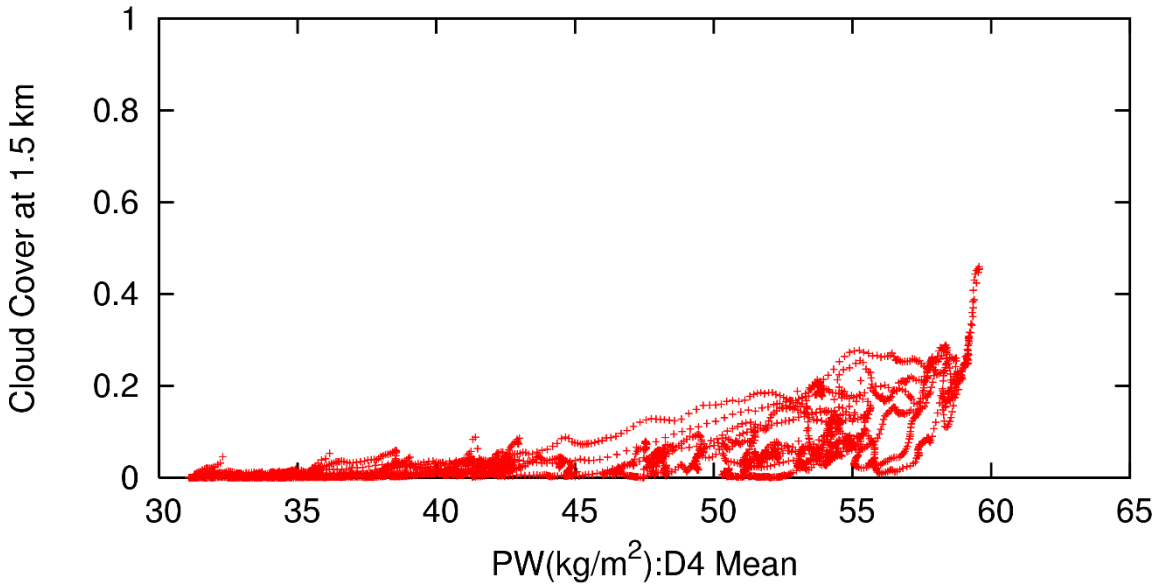
Cloud cover & lapse rate/PW in Domain 4

Nov 2011

Tropospheric temperature lapse rate versus low-level cloud amount



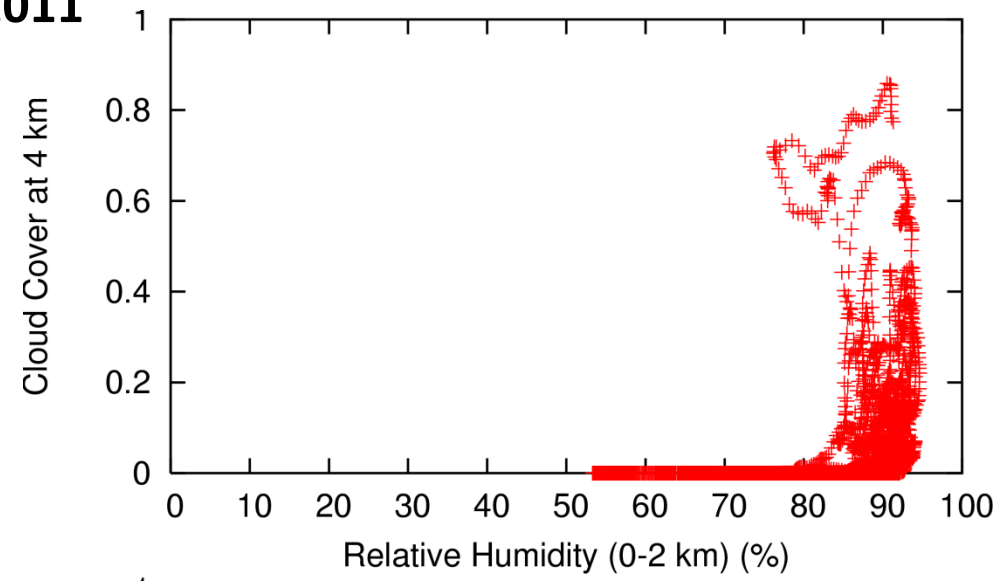
Precipitable water versus low-level cloud amount



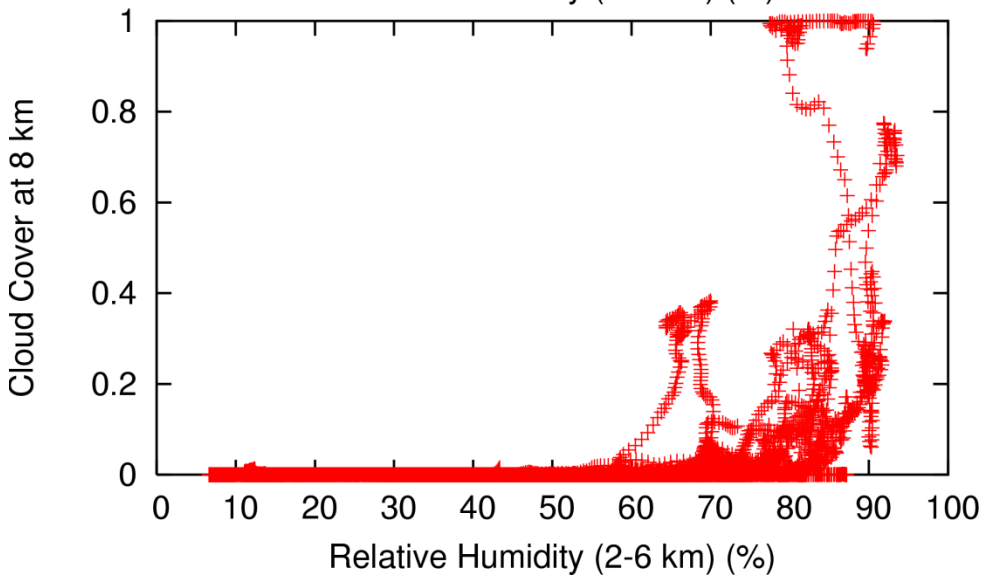
Cloud cover & humidity in Domain 4

Nov 2011

Low-level RH versus mid-level cloud amount

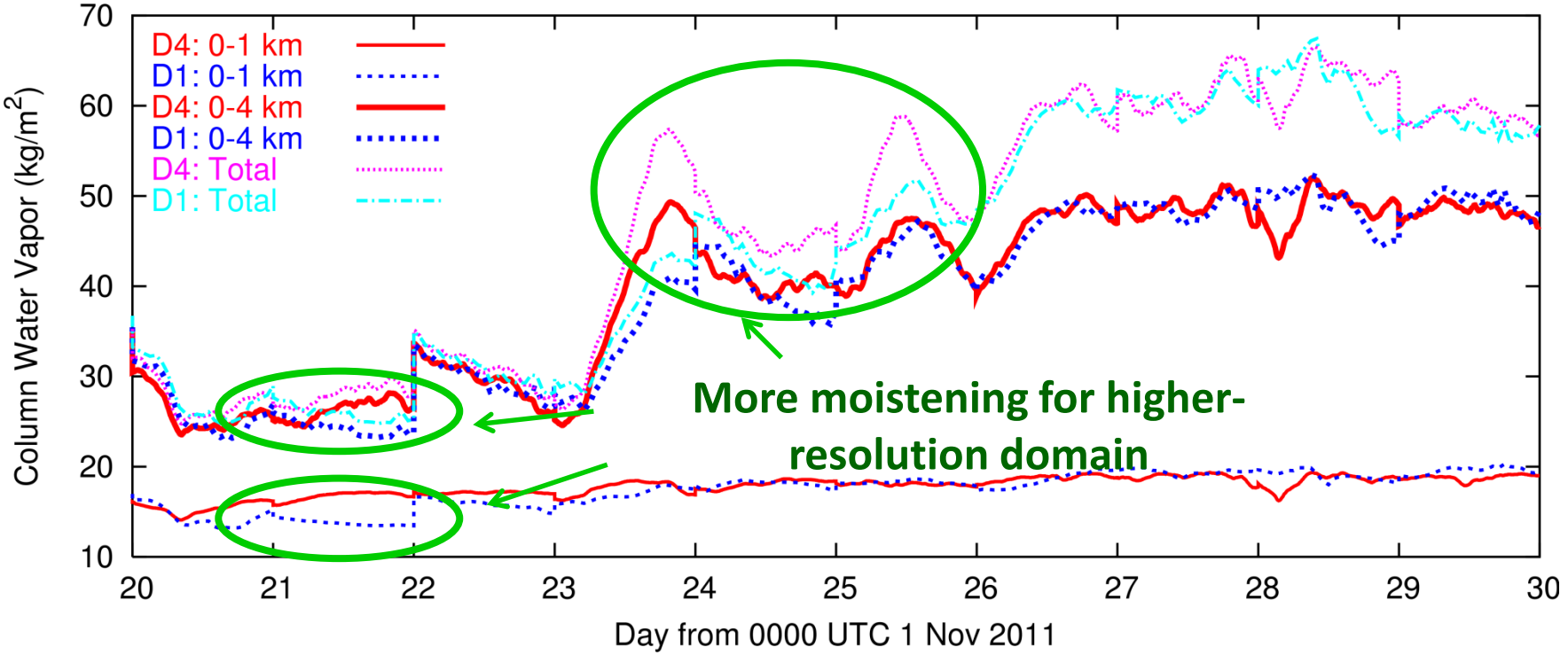


Mid-level RH versus upper-level cloud amount



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)

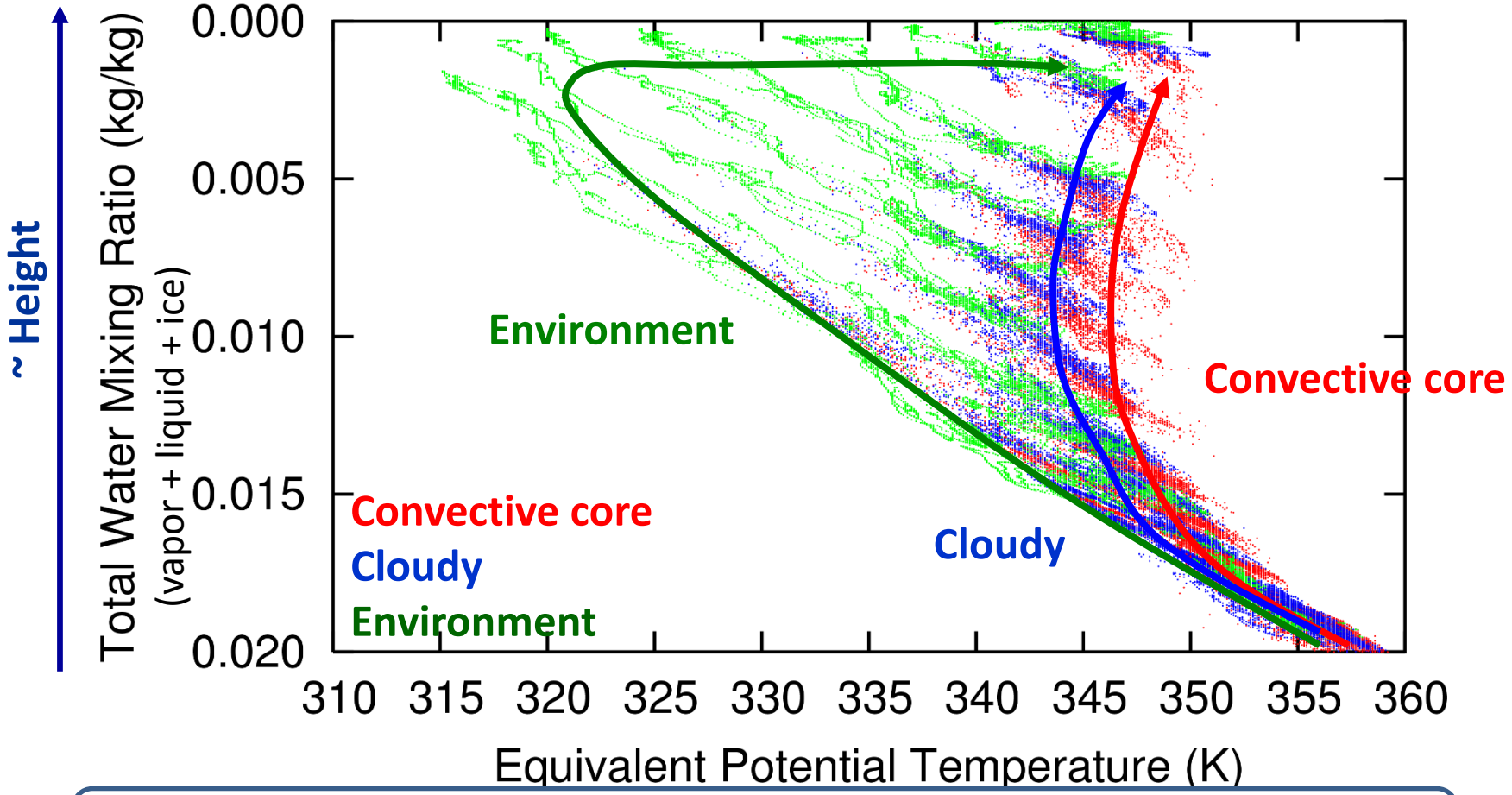
: Total layer (Precip water) (Domain 4)

: Total layer (Precip water) (Domain 1)

Thermodynamic properties of air parcels

Analysis for the period of 20-30 Nov 2011

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



θ_e of convective cores does not largely change with total water content. ➡ Existence of undiluted air parcels

Summary

- The vertical development of cumulus clouds are closely related to the relative humidity of the environment at levels lower than the cloud-top height.
- Higher moisture content is seen in the finest-resolution domain than the corresponding area within the coarsest-resolution domain; suggesting moistening by cumulus clouds.
- Convective cores with stronger updrafts are less diluted with the environment, which contributes to moistening the atmosphere.

Takemi, 2015: Relationship between cumulus activity and environmental moisture during the CINDY2011/DYNAMO field experiment as revealed from convection-resolving simulations. *under review*