Observational Study of Level of Neutral Buoyancy, Mass Detrainment and Convective Entrainment in Tropical Deep Convective Clouds

Michael P. Jensen[1], Dié Wang[1], Jennifer A. D'Iorio[2,*], Gina Jozef[3,4,*], Scott E. Giangrande[1], Karen L. Johnson[1], Johnny Luo[5], Mariusz Starzec[6], Gretchen Mullendore[6]

[1]Brookhaven National Laboratory [2]Pennsylvania State University [3]Colorado College
[4]University of Colorado - Boulder [5]City College of New York [5]University of North Dakota
*DOE Science Undergraduate Laboratory Internship
Corresponding author: Michael P. Jensen, mjensen@bnl.gov

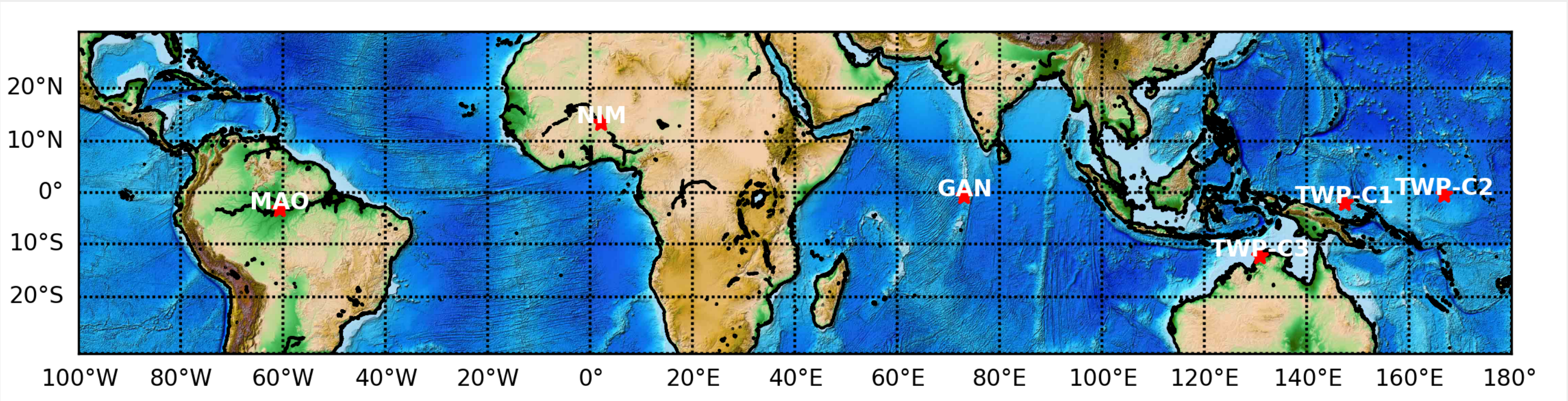
1. MOTIVATION

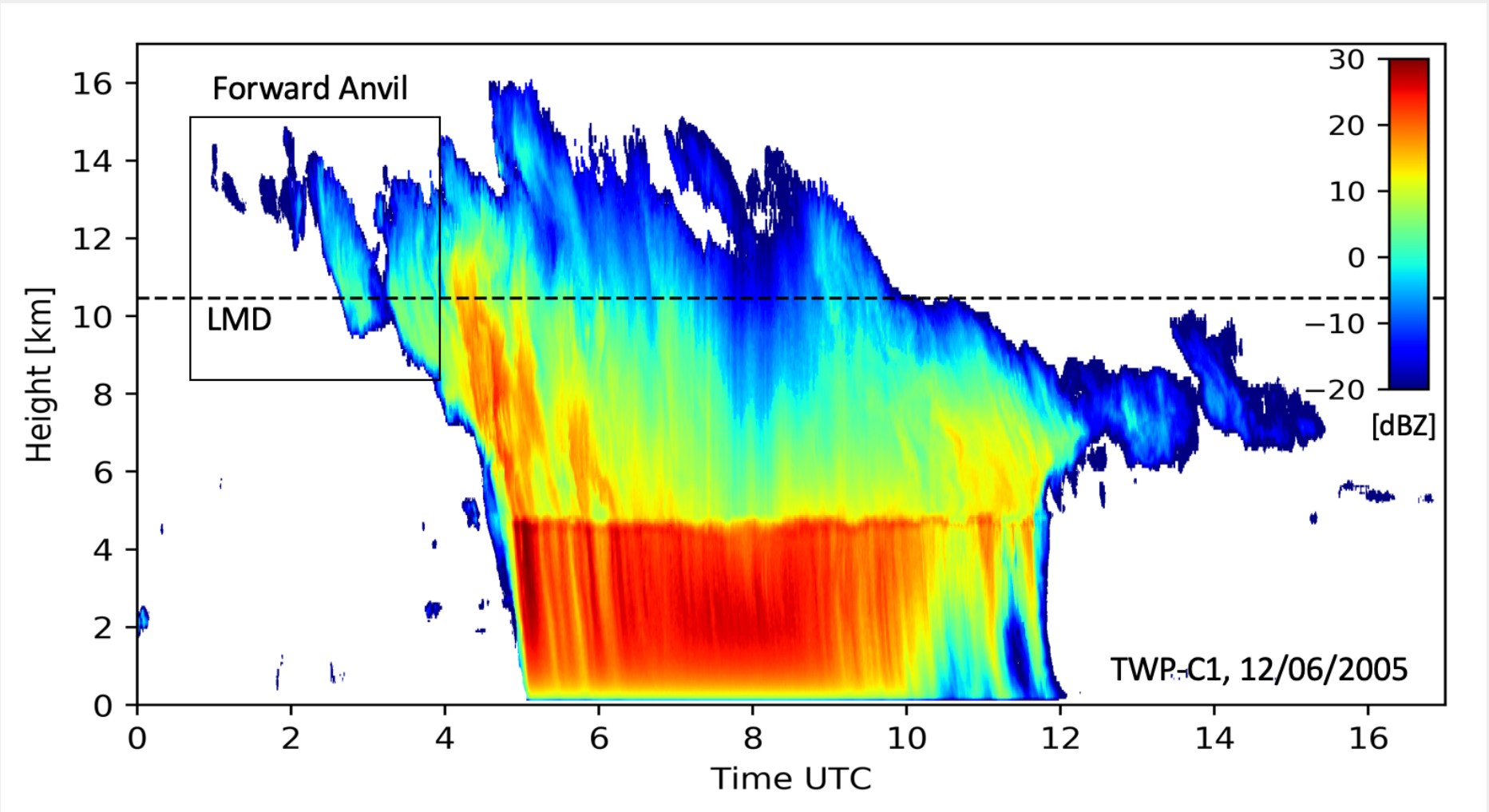
- Deep convective clouds are important driver of the global circulation enabling transport through the depth of the troposphere.
- Updraft size and strength are controlled by buoyancy and dynamical forcing, as well as the mixing of environmental air (i.e., entrainment). The rising air parcel will be impacted by mixing, water loading and nonhydrostatic pressure effects.
- As a result the rising parcel will not reach the theoretical level of neutral buoyancy, instead experiencing deceleration and neutral buoyancy at a lower level where mass is detained.
- We use ARM observations to estimate the difference between the level of neutral buoyancy (LNB; the theoretical height that a surface parcel raised above the level of free convection would reach with no mixing) and the level of maximum detrainment (LMD; cloud radar-based height of the maximum reflectivity factor in forward anvil clouds).
- We investigate how this the difference (LNB-LMD; a proxy for non-adiabatic processes) related to environmental properties.

2. DATA AND METHODS

Tropical ARM deployments:

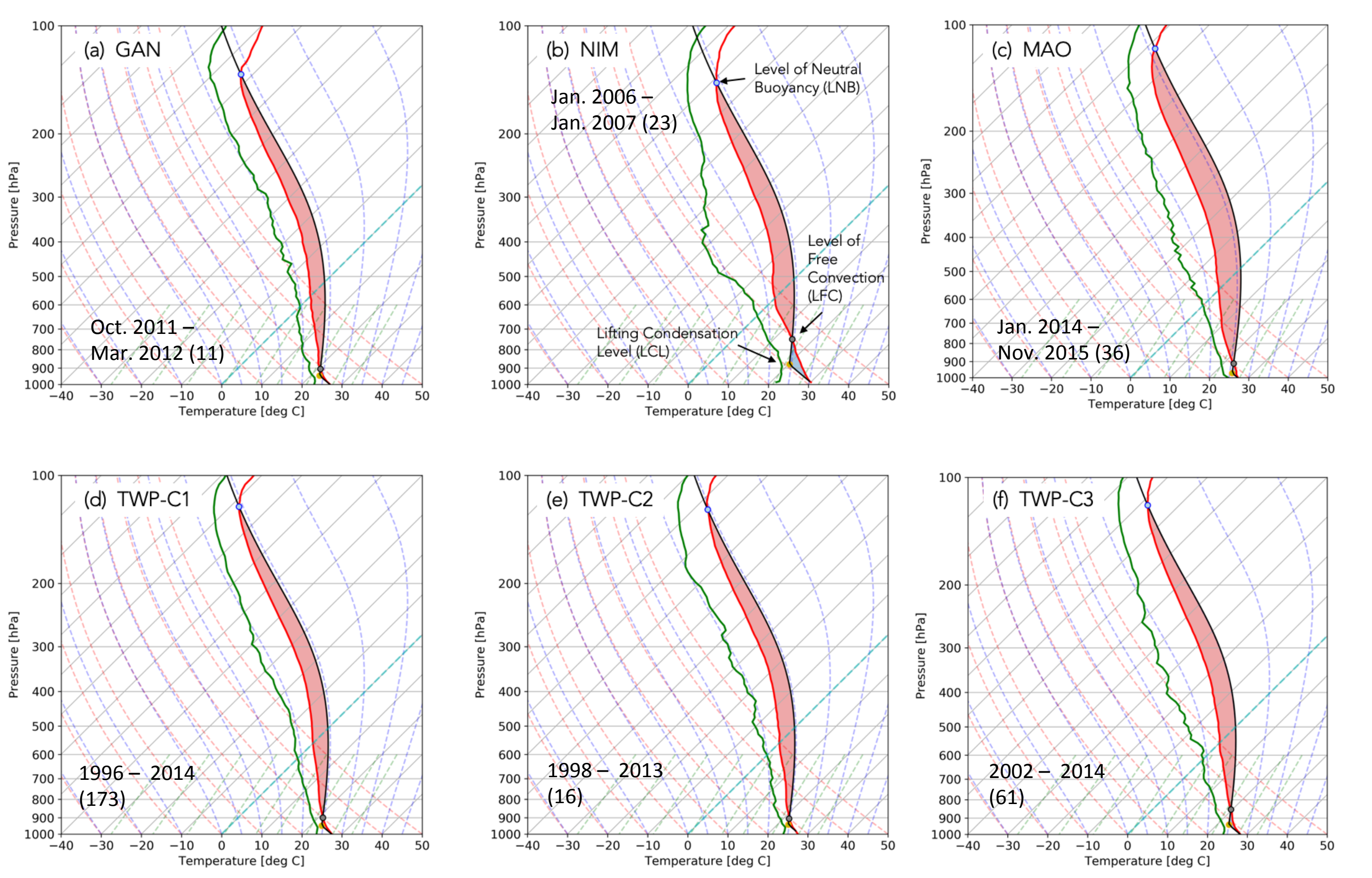
- Fixed-sites at oceanic / maritime continental locations from the Tropical Western Pacific (Manus, Nauru, Darwin)
- ARM Mobile Facility deployments to (oceanic) Gan Island, Maldives, and (continental) Niamey, Niger and Manacapuru, Brazil.





Deep convective event selection:

- Cloud-top height > 10 km observed from the ARSCL suite of VAPs
- Presence off a well defined forward anvil cloud
- Clean radiosonde launched less than 6 hr prior to the convective updraft regions

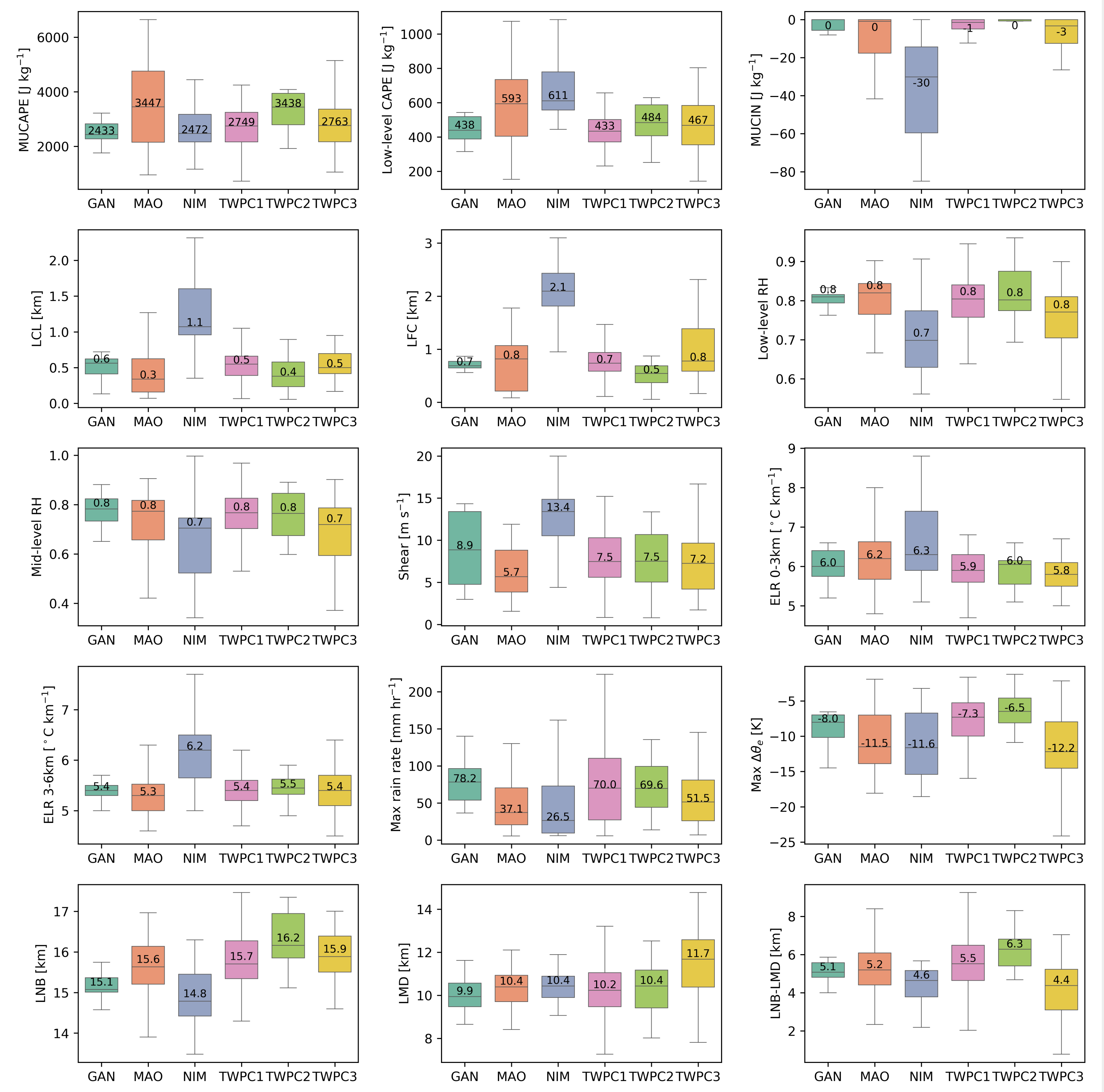


A proxy for bulk convective entrainment rate (LNB-LMD), following Mullendore et al. (2009) and Takahashi et al. (2017):

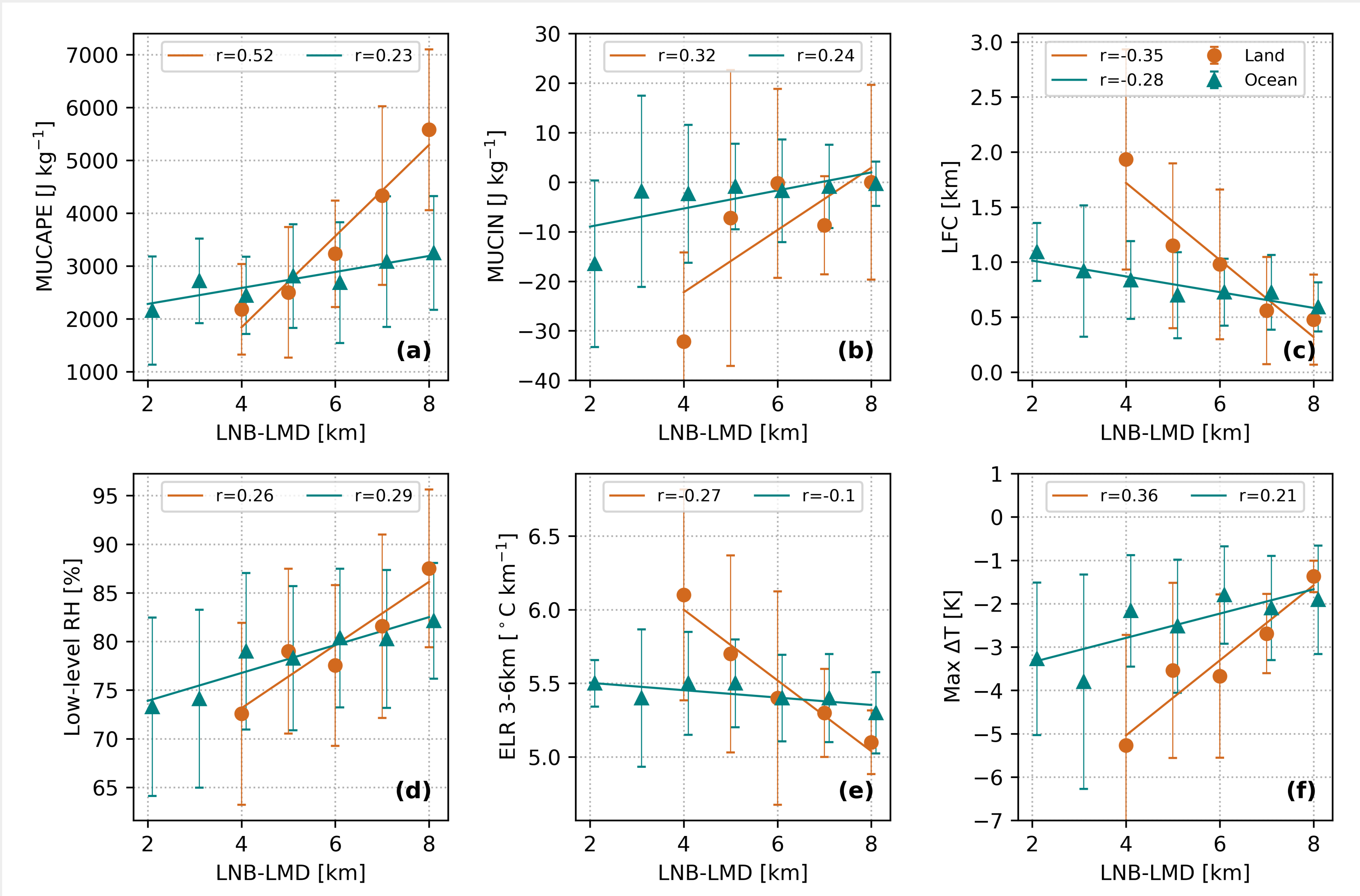
- Level of neural buoyancy (LNB, estimated from radiosondes using parcel theory): assuming air parcel experiences undiluted ascent in a pseudoadiabatic process.
- Level of maximum detrainment (LMD, cloud radar-based height of the maximum reflectivity factor in forward anvil)

3. ENVIRONMENTAL THERMODYNAMIC PARAMETERS

- Most unstable convective available potential energy (MUCAPE), level of free convection (LFC), lifting condensation level (LCL), low-level CAPE (LFC to 4 km above), convective inhibition (CIN), low-level relative humidity (RH, 0-5 km), wind shear (0-5 km), environmental lapse rate (ELR, 0-3 km and 3-6 km), from pre-storm radiosondes.(Jensen et al. 2015)
- Maximum rainfall rate during the convective cell passages from surface rain gauges.
- Surface cold pool properties, e.g., maximum temperature (*T*) and specific humidity (*q*) drops within 30 min around the maximum rain rate, from surface measurements.

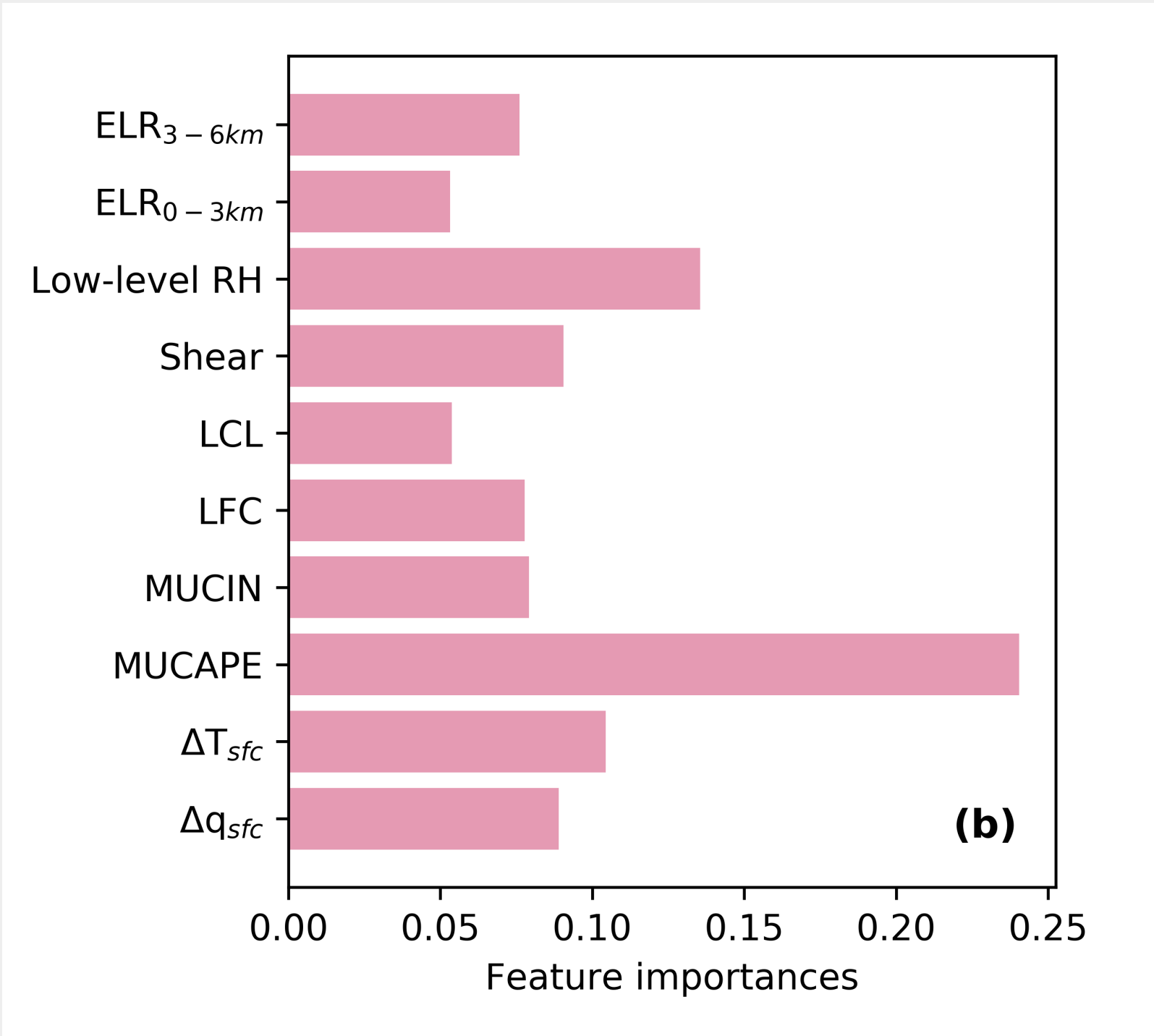


- Oceanic convective events demonstrate a 'skinny' CAPE profile, smaller low-level CAPE and higher LNB ~ 16 km, more moist environment (RH ~ 80%).
- Continental cases have much steeper ELRs associated with higher CIN; larger wind shear; stronger cold pools.
- Oceanic deep convective clouds may experience more dilution (larger LNB-LMD).



4. RELATING ENVIRONMENTAL PARAMETERS TO LNB-LMD

- Consider LNB-LMD represents a proxy for effective bulk entrainment rate.
- Entrainment tends to be more efficient for the events having larger CAPE (higher LFC/LCL) and higher low-level RH -> corresponds to the buoyancy term that contributes to the production of turbulent kinetic energy (e.g., Jensen & Del Genio, 2006).
- CIN negatively contributes to the buoyancy -> A condition, having larger CIN (steeper ELR) before the convection occurs, tends to be less favorable for air to entrain into the updrafts.
- Stronger cold pools -> generated by stronger downdrafts -> are associated with intense updrafts that are less affected by the entrained air.
- Continental cases (NIM, MAO) show higher correlations over all, compared to oceanic counterparts (GAN, TWP).



- Feature importance from Random Forest regression algorithm.
- CAPE and low-level RH have highest feature importance scores, indicating that they contribute the most to the deep convection dilution.

REFERENCES Jensen, M. P. & A. D. Del Genio, 2006: *J. Climate*, doi:10.1175/JCLI3722.1; Jensen, M. P. et al., 2015: *Atmos. Meas. Tech.*, doi:10.5194/amt-8-421-2015; Mullendore, G. L. et al. 2009: *J. Geophys. Res.*, doi:10.1029/2008JD011431;Takahashi et al., 2017: *J. Geophys. Res.*, doi:10.1002/2016JD025969.