Bao, J. and B. Stevens, 2021: The elements of the thermodynamic structure of the tropical atmosphere. J. Meteor. Soc. Japan, 99, 1483-1499.
Special Edition on DYAMOND: The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains
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Plain Language Summary: The two foundations of the tropical atmosphere are that the horizontal temperature in the free troposphere is homogeneous, and the vertical structure follows a moist-adiabatic lapse rate. This study uses simulations from global storm-resolving models to investigate the accuracy of these ideas. Our results show that horizontally the density temperature appears to be homogeneous, but only in the mid- and lower troposphere. Vertically, the tropical atmosphere in saturated convective regions tends to be isentropic (condensed water remaining in the updraft) below the freezing level and pseudo-adiabatic (condensed water/rain falling immediately upon formation) above. However, the tropical mean temperature is substantially colder than that in saturated convective regions because of the impact of entrainment, a process that the saturated air mixes with dry environment, in the lower troposphere.

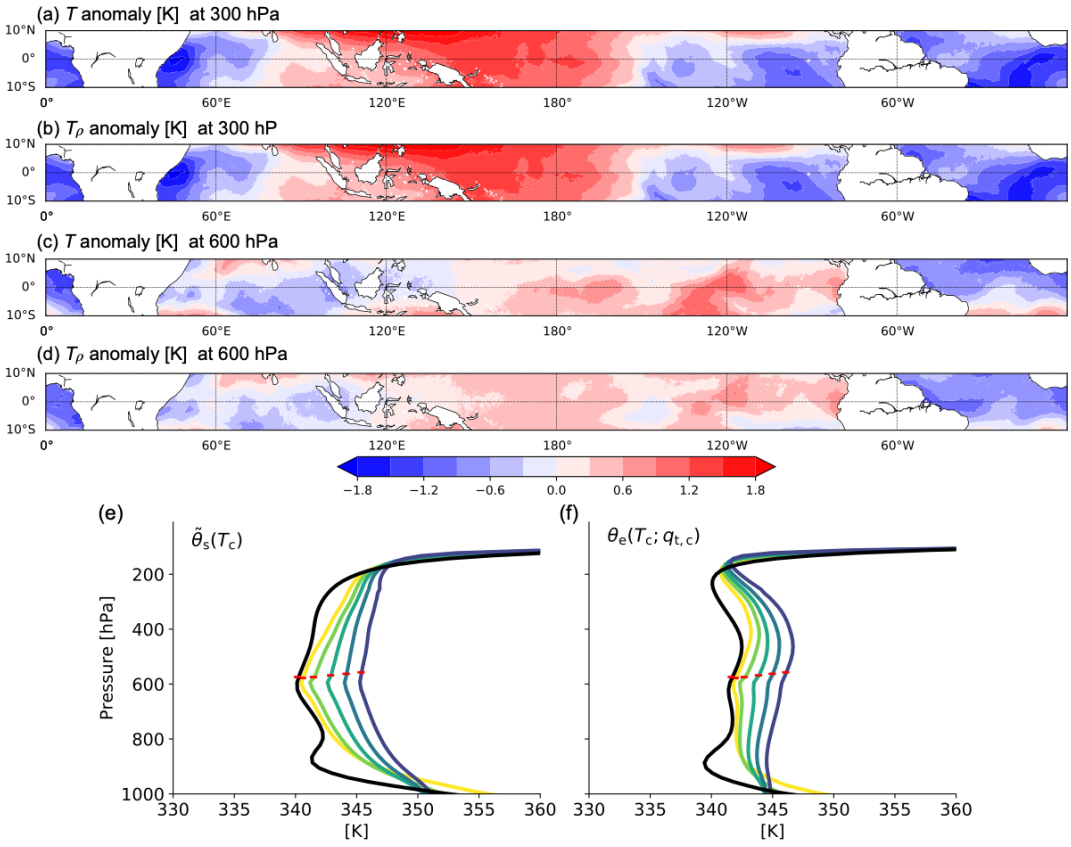

Figure (a-d) The mean spatial distribution of temperature (T) and the density temperature (T_ρ) anomaly (relative to the domain-mean value) at 300 hPa and 600 hPa over the 10-day period. (e,f) Mean profiles of $\theta_s(T_c)$ and $\theta_e(T_c; q_{t,c})$ averaged over all grid points (black) and extremely humid grid points (colors from yellow to blue correspond to the 90th, 99th, 99.9th, 99.99th and 99.999th percentile of PW). Freezing levels are marked in red.

Highlights:

- Horizontally the density temperature appears to be homogeneous, but only in the mid- and lower troposphere (between 400 hPa and 800 hPa). Therefore, water vapor plays an important role in the horizontal absolute temperature distribution.
- The tropical atmosphere in saturated convective regions tends to adopt a thermal structure that is isentropic below the zero-degree isotherm and pseudo-adiabatic above.
- The tropical mean temperature is substantially colder, and is set by the bulk of convection which is affected by entrainment in the lower troposphere.