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Convection regimes during TWP-ICE and in the GISS SCM

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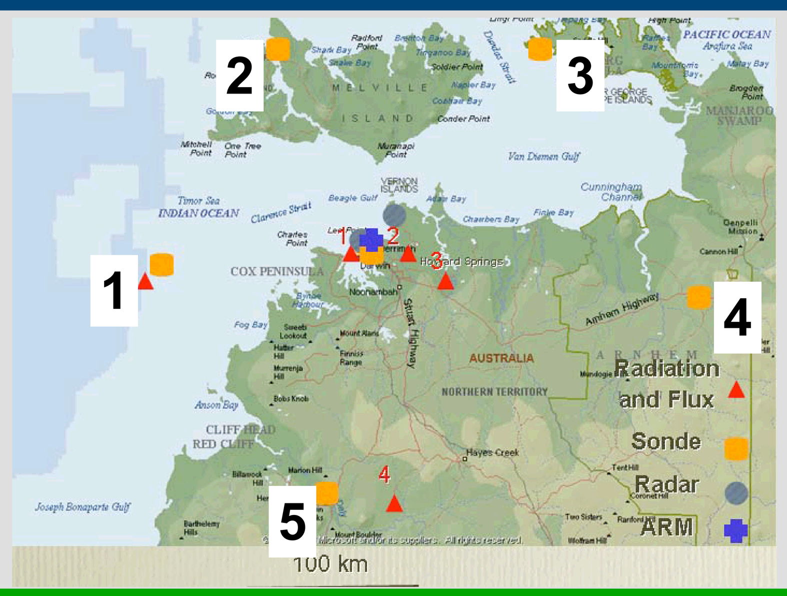
Summary: Soundings acquired during the TWP-ICE IOP at Darwin show stronger buoyancies/CAPE for the "break" period late in the IOP than for the early "active" monsoon period. Convective response to the stronger large-scale forcing neutralizes the moist stability during the "active" period; for the "break" period, sporadic moist convection under moderate forcing keeps the mid-troposphere relatively cool, and combined with the low-level heating from surface turbulent fluxes, leads to a steeper lapse rate, which generates more intense convection. The GISS SCM is able to simulate more intense deep convection for the "break" period than for the "active" period.

1. Introduction

The TWP-ICE IOP included an early "active monsoon" period with an apparent maritime style of convection, and a late "break" period with occasional intense continental convection. This IOP thus offers the opportunity to understand physical processes that cause differences in convective intensity and the ability of GCM cumulus parameterizations to simulate these differences, which are hypothesized to influence detrainment into radiatively important anvil clouds.

2. Observations



1: Ship
2: Garden Point
3: Cape Don
4: Point Stuart
5: Mount Bundy

Figure 1: Overview of the TWP-ICE array (J. Beringer: TWP-ICE surface flux stations data)

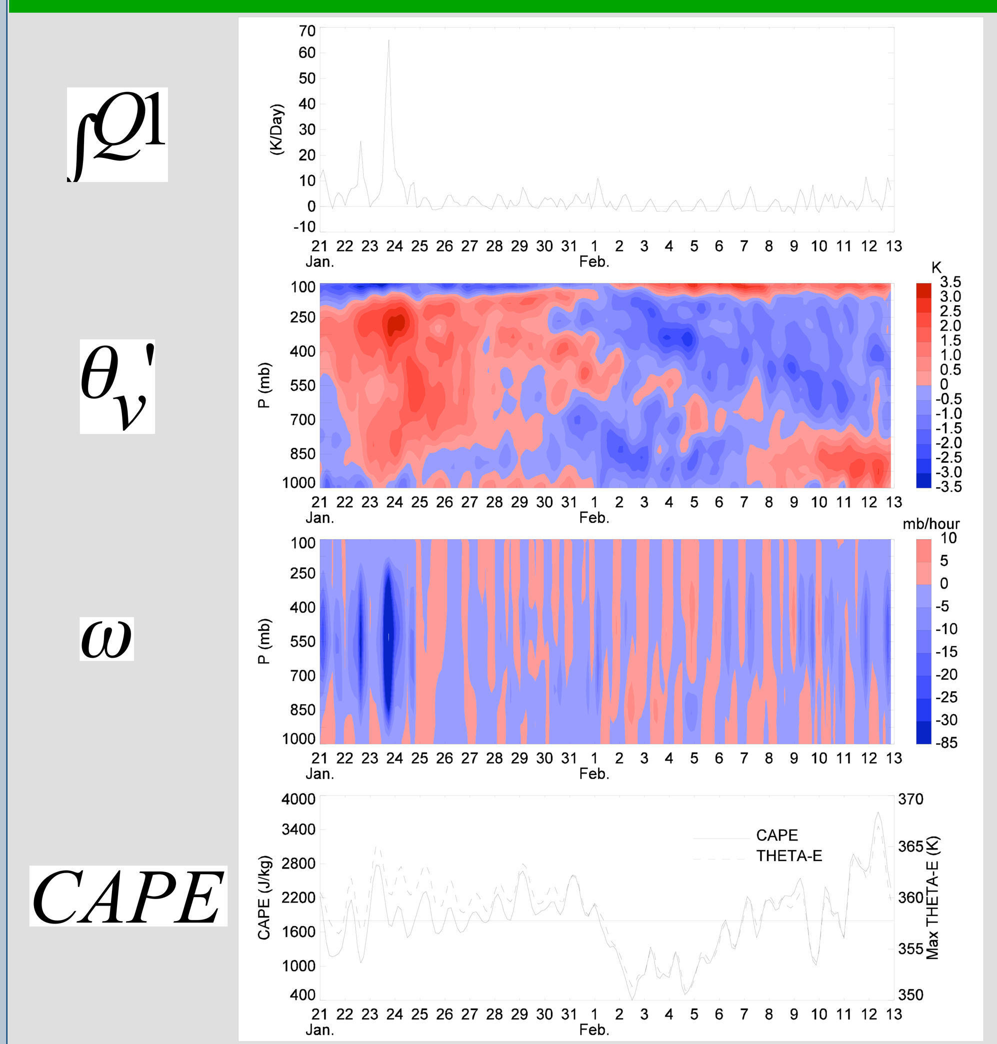


Figure 2: Evolution of integrated diabatic Heating Q1, stratification, vertical large-scale forcing, and CAPE

"Active" (1/21-1/22):
- heavy precipitation;
- strong large-scale forcing;
- near-neutral stratification;
- low-value CAPE

"Break" (2/8 – 2/12):
- moderate precipitation;
- moderate large-scale forcing;
- destabilized stratification;
- high-value CAPE

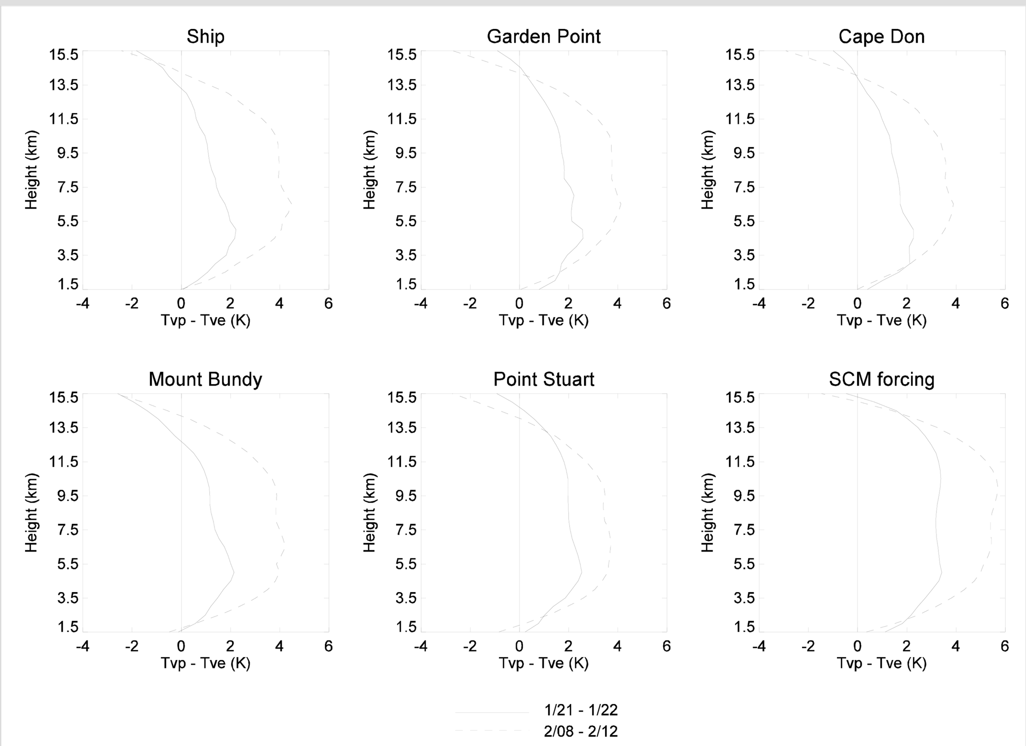


Figure 3: Buoyancy profiles for "active" (solid) and "break" (dashed) periods

"Active" monsoon period shows small buoyancies for lifted parcels over all sounding stations, while "break" period shows larger buoyancies.

"Break" period buoyancies are weaker than that for midlatitude continental convection, but extend over greater depth, resulting in larger CAPE than in typical maritime convection.

Buoyancies in SCM forcing dataset are larger and extend deeper than observed at sounding locations

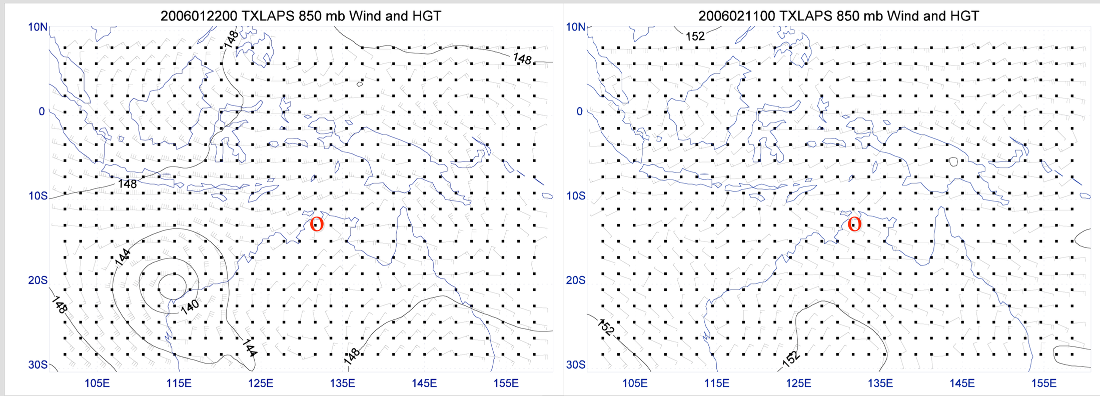


Figure 4: Circulation reverses from onshore ("active") to offshore ("break") during the IOP (data provided by BOM,AU)

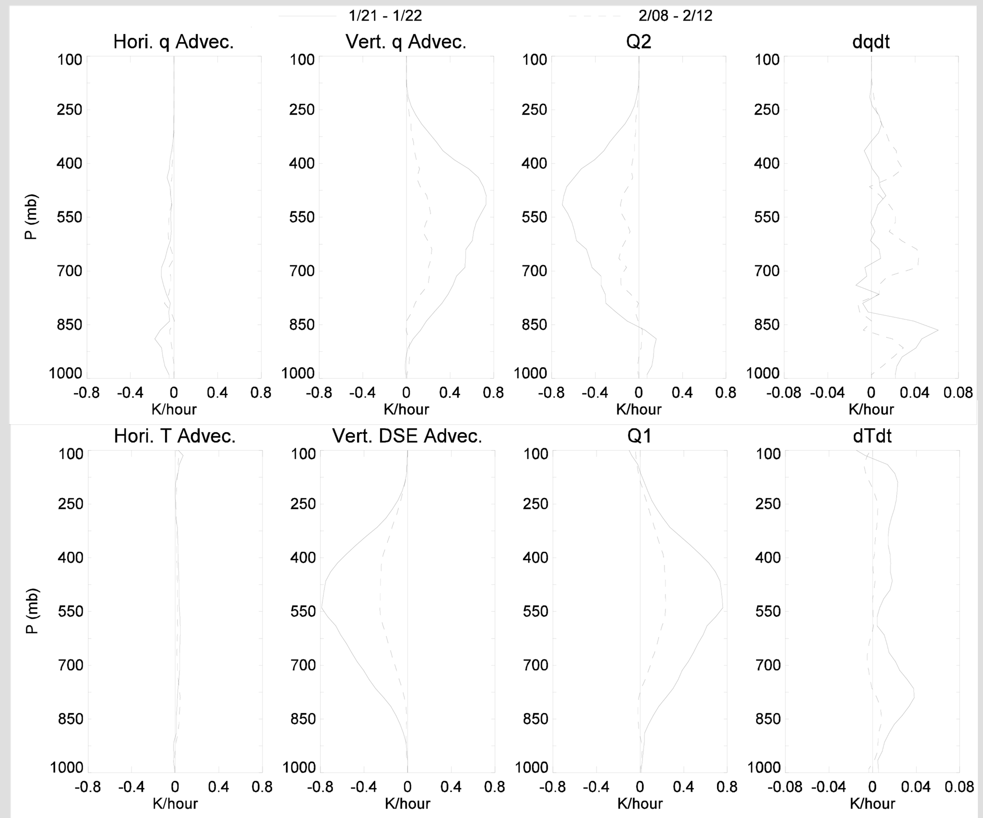


Figure 5: Water vapor mixing ratio (upper panels) and dry static energy (low panels) budgets for "active" and "break" periods

Large-scale adiabatic cooling and moistening balances diabatic heating and drying (primarily through convection events) during both periods.

For the "active" monsoon period, the magnitudes of moistening/drying and cooling/heating are much larger due to the stronger vertical large-scale forcing. The convective response to the strong vertical forcing results in a near-neutral moist stability.

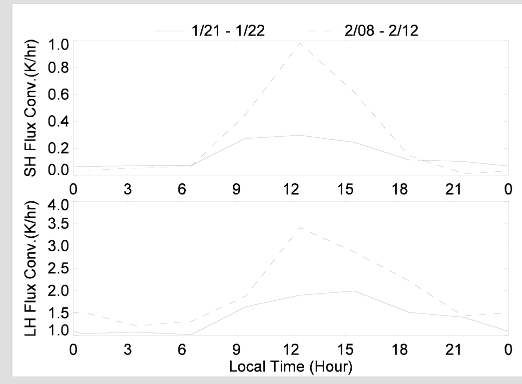


Figure 6: Heating rate from surface fluxes for "active" and "break" periods

For the "break" period, the magnitudes of moistening/drying and cooling/heating are small relative to the "active" period; the upper troposphere is cooler; during this period, the TWP-ICE region is under the influence of the warm trade south-easterly on the north side of the subtropical high; the warmer low-level air seems to be caused by the larger surface flux (7K/day from SH; 47K/day from LH). The relatively steeper lapse rate results in larger buoyancies/CAPE.

3. SCM Results

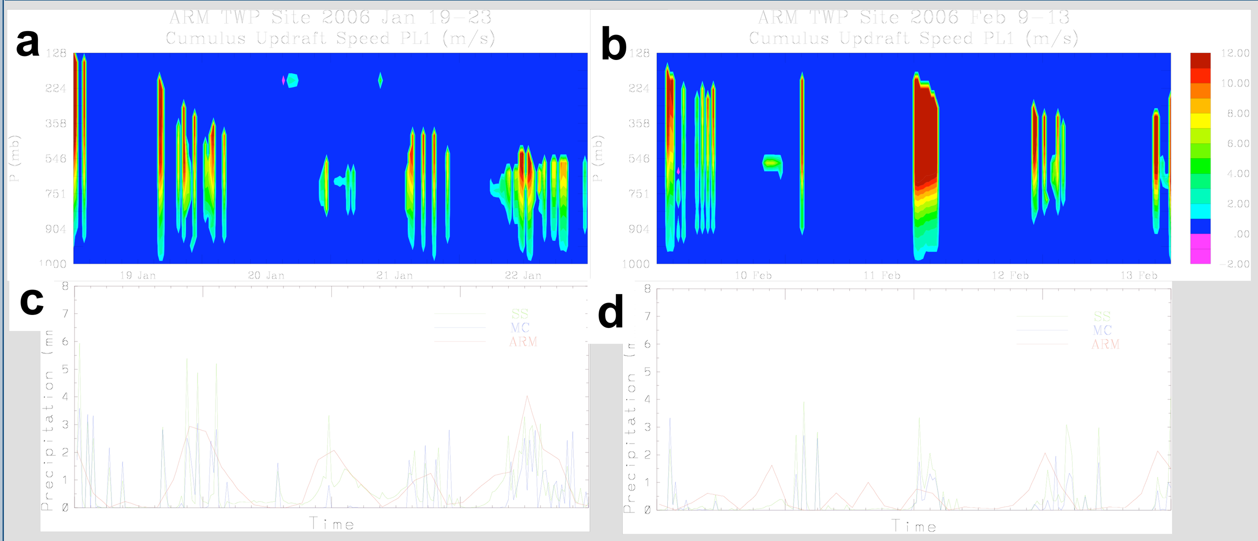


Figure 7: Pressure-time cross-sections of cumulus updraft speed for a) "active", b) "break" period; evolution of precipitation for c) "active", d) break" period (red = observed, 3-hr total; blue/green = SCM convective/stratiform, 30-min timestep)

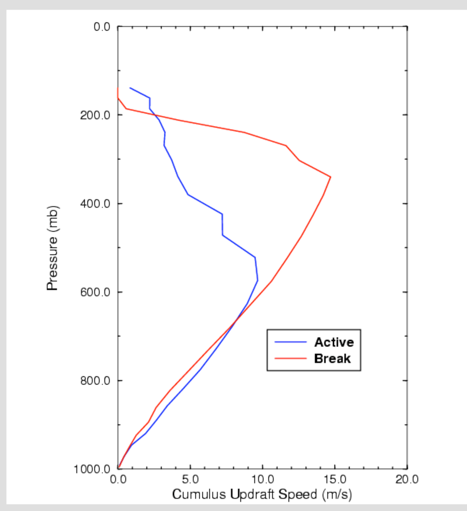


Figure 8: Mean deep convective updraft speed for "active" and "break" periods

In general, the SCM shows some difference in updraft speed between "active" and "break" periods but not for all events; magnitude may be affected by an overestimate of the SCM forcing driving the model.

The SCM is able to capture the stronger intensity of deep convection during the "break" period; timing is poor when the large-scale forcing is weak.

Considerable stratiform anvil rainfall is simulated (50% or more of total – probably too much).

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