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# DOES THE TROPICAL ATMOSPHERE SUPPORT LARGE-SCALE RADIATIVE-CONVECTIVE OVERTURNING?

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## 1. Introduction

Some recent modelling studies (Raymond 2000, 2001, Lee et al. 2001) propose that the tropical atmosphere has negative effective static stability due to the contribution of the radiative heating. It means that the tropical atmosphere supports large-scale radiative-convective overturning. They propose that some important tropical phenomena, including the Hadley circulation and the Madden-Julian Oscillation, are driven by such large-scale radiative-convective overturning. This hypothesis has not been tested in observation.

The purpose of current study is to test this hypothesis using the observed heat budgets from four different sounding arrays during the Global Atmosphere Research Program (GARP) Atlantic Tropical Experiment (GATE) and the Tropical Ocean Global Atmosphere (TOGA) Coupled Ocean Atmosphere Response Experiment (COARE).

## 2. Data and Method

The heat budgets from the following four sounding arrays are used: (1) the Outer Sounding Array (COARE-OSA) during TOGA COARE calculated by us using the constrained variational analysis method (Zhang and Lin 1997), (2) the Borneo sounding array (COARE-BORNEO) during TOGA COARE calculated by us, (3) the Intensive Flux Array (COARE-IFA) during TOGA COARE calculated by Lin and Hohnson (1996), and (4) the GATE sounding array calculated by Esbensen and Ooyama of Oregon State University.

We also use the longwave and shortwave radiative heating profiles calculated by Qian and Cess (2002, manuscript in preparation) using realistic cloud profiles and the CCM3 column radiation model.

The method of analysis include linear correlation, linear regression, and cross-spectrum.

## 3. Effective static stability of the tropical atmosphere

Observation from the four arrays (Fig. 1) show that the effective static stability is positive throughout the free troposphere. Decomposition in the frequency domain (not shown) also shows that the effective static stability is positive at almost all subseasonal time scales. This means that the the tropical atmosphere does not support the large-scale radiative-convective overturning.

Although having a positive sign, the effective static stability is significantly smaller than the dry static stability and reduces to nearly zero (neutral) in the upper troposphere.

## 4. Role of the radiative heating

Fig. 2 shows that the effective static stability is reduced mainly by the convective heating, not the radiative heating. The radiative heating is not highly coherent with either the adiabatic cooling or the convective heating. The contribution of radiative heating is more significant for longer time scale but its phase is not well opposite to that of the adiabatic cooling (not shown). Furthermore, the radiative heating is not uniformly distributed in the troposphere. It is dominated by longwave cloud top cooling and cloud base warming.

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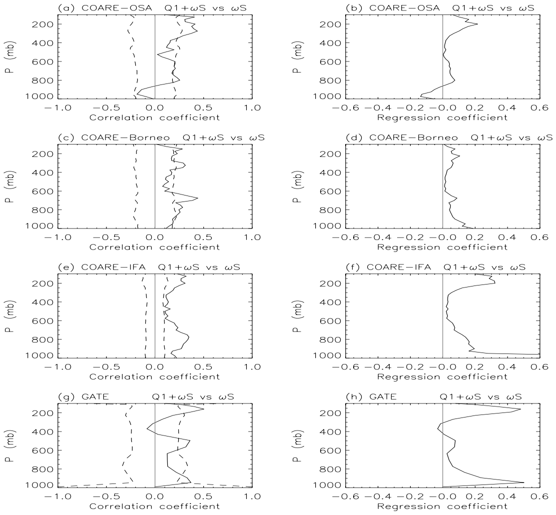

Figure 1: The linear correlation coefficient between $Q_1 + \omega S$ and $\omega S$ for (a) COARE-OSA, (c) COARE-Borneo, (e) COARE-IFA, and (g) GATE. The dashed lines are the correlation corresponding to the 95/The corresponding linear regression coefficients are shown in (b), (d), (f), and (h).

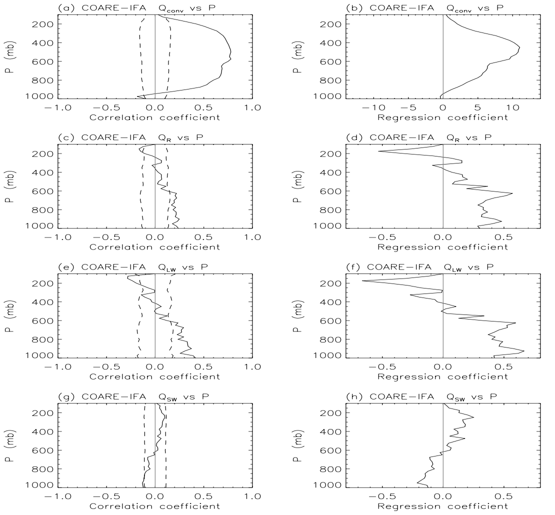

Figure 2: As for Fig. 1 except for between $Q_{conv}$ and precipitation (a, b), between $Q_R$ and precipitation (c, d), between $Q_{LW}$ and precipitation (e, f), and between $Q_{SW}$ and precipitation (g, h).