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IMPACTS OF LARGE-SCALE CIRCLUATION ON CONVECTION: A 2-D CLOUD RESOLVING MODEL STUDY

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1. MOTIVATION

Stduies of impacts of large-scale circulation on convection, and the roles of convection in heat and water balances over tropical region are fundamentally important for understanding global climate changes. Heat and water budgets over warm pool (SST=29.5°C) and cold pool (SST=26°C) were analyzed based on simulations of the two-dimensional cloud resolving model. Here the sensitivity of heat and water budgets to different sizes of warm and cold pools is examined.

2. EXPERIMENT DESIGNS AND BUDGET EQUATIONS

The model has 20480-km horizontal domain, and a horizontal grid mesh of 2.5 km, and 33 vertical levels. The model also has a cyclic lateral boundary. Two experiments were carried out in this study. The ratio of the sizes of warm pool to cold pool is 1:2 in Experiment C, whereas it is 1:11 in Experiment CS. Otherwise, two experiments are identical. The model physical parameterization schemes can be referred to Sui et al. (1998) and Li et al. (1998). The initial temperature and moisture conditions were taken from observations over the western Pacific warm pool during TOGA COARE.

The equation for mass-weighted heat budget is

$$\underbrace{\frac{\partial\langle\overline{T}\rangle}{\partial t}}_{\text{TT}} = -\underbrace{\left\langle\overline{\vec{V}\bullet\nabla T}\right\rangle}_{\text{HAT}} - \underbrace{\left\langle\overline{\pi w\frac{\partial\theta}{\partial z}}\right\rangle}_{\text{VAT}} \underbrace{+H_s}_{\text{SH}} + \underbrace{\frac{1}{c_p}\left\langle\overline{Q_{cn}}\right\rangle}_{\text{CH}} + \underbrace{\frac{1}{c_p}\left\langle\overline{Q_R}\right\rangle}_{\text{RH}}. \quad (1a)$$

The equation for vertically-integrated water vapor budget is

$$\underbrace{\frac{\partial[\overline{q_v}]}{\partial t}}_{\text{TQ}} = -\underbrace{\left[\overline{\vec{V}\bullet\nabla q_v}\right]}_{\text{HAQ}} - \underbrace{\left[\overline{w\frac{\partial q_v}{\partial z}}\right]}_{\text{VAQ}} - \underbrace{\overline{P}}_{\text{P}} + \underbrace{\overline{E}}_{\text{E}}. \quad (1b)$$

Here, <()>=[()]/[1], and $[()]=\int_0^{z_T}\overline{\rho}()dz$, where z_T is the height of top model level; Overbar is the horizontal mean; T, θ, and q_v are temperature, potential temperature, and specific humidity, respectively; $\vec{V}$ and w are horizontal wind vector and vertical velocity respectively; $\overline{\rho}$ is a horizontal-mean air density; $\pi = (\frac{p}{p_o})^{\frac{R}{c_p}}$, R is the gas constant, and c_p is the specific heat of dry air at constant pressure p, and p_O=1000 mb; Q_{cn}, Q_R, H_s, P, and E are condensational heating, radiative heating, surface sensible heat, rain rate, and surface evaporation, respectively. Local temperature change (TT) is determined by horizontal (HAT) and vertical (VAT) temperature advections, surface sensible heat flux (SH), condenational heating (CH), and radiative heating (RH). Local water vapor change (TQ) is determined by horizontal (HAQ) and vertical (VAQ) moisture advections, precipitation (P), and surface evaporation (E).

3. RESULTS

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Over warm pool, the mass-weighted temperature increases faster in C (0.36°C day^{-1}) than in CS (0.17°C day^{-1}), whereas the total water vapor increases at the similar rates in both experiments (1.01 mm day^{-1} in C and 1.21 mm day^{-1} in CS) within day 7-11. The heat and water vapor budgets averaged within the same period (Table 1) show that two largest terms, VAT and CH, are almost canceled each other in both experiments in the heat budgets, though the magnitudes of both terms are smaller in C than in CS. The larger increase of temperature in C is a result of warm HAT. The magnitudes of VAQ are larger than those of P so that water vapor increases in both experiments.

Over cold pool, the mass-weighted temperatures increase (0.4°C day^{-1} in C and 0.3°C day^{-1} in CS) and the total water vapor decreases (-0.5 mm day^{-1} in C and -0.4 mm day^{-1} in CS) at the similar rates in both experiments. The budgets show that two largest terms, VAT and RH, almost offset. CH and SH explain a large part of temperature increase in both experiments. The magnitudes of VAQ are larger than those of E so that water vapor decreases in both experiments.

The heat and water vapor budgets in CS are compared with those in C1 that was carried out by Li et al. (1998). In C1, the model is imposed by the large-scale vertical velocity, zonal wind as well as horizontal temperature and moisture advections taken and derived from observations during TOGA COARE, and is integrated for selected six days when strong convection occurred. The budgets averaged within day 3-4 of the integration are shown in Table 1. The major difference between CS and C1 is that the interaction between large-scale circulations and convection is fully guaranteed in CS but it is partially allowed in C1.

The magnitude of VAT is about 0.5°C day^{-1} larger than that of CH in C1, whereas their magnitudes are similar in CS. Also the magnitude of RH is much larger in C1 than that in CS. These two differences cause warming and cooling trends in CS and C1, respectively. The magnitude of VAQ is much larger in CS than that in C1, whereas the magnitude of P is slightly larger in CS than C1. These differences cause moistening and drying in CS and C1 respectively.

Table 1 Mean heat (°C day^{-1}) and water vapor (mm day^{-1}) budgets within day 7-11 for experiments C and CS over warm and cold pools and 2-day mean heat budget in C1 from Li et al. (1998). See text for C1. Definition of each term in the table can be seen in (1).

Exp.	C	CS	C1	C	CS
Pool	warm	warm	warm	cold	cold
TT	0.36	0.17	-0.71	0.38	0.28
HAT	0.46	-0.2	-0.06	0.06	-0.02
VAT	-2.81	-6.84	-6.36	1.01	0.62
SH	0.22	0.32	0.25	0.11	0.12
CH	2.72	6.93	5.88	0.18	0.43
RH	-0.23	-0.04	-0.42	-0.98	-0.87

Exp.	C	CS	C1	C	CS
Pool	warm	warm	warm	Cold	Cold
TQ	1.1	1.21	-2.06	-0.49	-0.4
HAQ	-4.78	-8.82	-5.48	1.09	1.18
VAQ	11.92	31.0	19.91	-4.33	-3.06
P	-10.7	-27.2	-23.2	-0.69	-1.68
E	4.63	6.21	6.75	3.44	3.16

REFERENCES

Li, X., C.-H. Sui, and K.-M. Lau, 1998: Large-scale forcing and cloud-radiation interaction in the tropical deep convective regime. *J. Atmos. Sci.*, (revised).

Sui, C.-H., X. Li, K.-M. Lau, 1998: Radiative-convective processes in simulated diurnal variations of tropical oceanic convection. *J. Atmos.Sci.*, **55**, 2345-2357.