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NUMERICAL SIMULATION OF THE IMPACT OF LATENT HEAT FLUX ANOMALY IN THE TROPICAL WESTERN PACIFIC ON PRECIPITATION OVER SOUTH CHINA IN JUNES

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Abstract: Based on composite analysis and numerical simulations using a regional climate model (RegCM3), this paper analyzed the impact of the LHF anomaly in the tropical western Pacific on the precipitation over the south of China in June. The results are as follows. (1) Correlation analysis shows that the SC precipitation in June is negatively correlated with the LHF of the tropical western Pacific in May and June, especially in May. The SC precipitation in June appears to negatively correlate with low-level relative vorticity in the abnormal area of LHF in the tropical western Pacific. (2) The LHF anomaly in the tropical western Pacific is a vital factor affecting the flood and drought of SC in June. A conceptual model goes like this: When the LHF in the tropical western Pacific is abnormally increased (decreased), an anomalous cyclone (anticyclone) circulation is formed at the low-level troposphere to its northwest. As a result, an anomalous northeast (southwest) air flow affects the south of China, being disadvantageous (advantageous) to the transportation of water vapor to the region. Meanwhile, there is an anomalous anticyclone (cyclone) at the low-level troposphere and an anomalous cyclone (anticyclone) circulation at the high-level troposphere in the region, which is advantageous for downdraft (updraft) there. Therefore a virtual circulation forms updraft (downdraft) in the anomalous area of LHF and downdraft (updraft) in the south of China, which finally leads to the drought (flood) in the region.

Key words: drought and flood in the south of China; tropical western Pacific; LHF anomaly; climate simulation

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1 INTRODUCTION

Being one of the areas with abundant annual rainfall in China, the coastal part of the south of China (SC, 18°–28°N) is frequently subject to damages from droughts and floods due to inhomogeneous distribution of the rain, resulting in large casualties and loss of property. A key component of the current study on synoptic dynamics[1], air-sea interactions are an important contributor to the change in weather and climate in the coastal part of SC. The western North Pacific is the region that contains the warmest sea water and stores the most energy across the world oceans, in addition to being one of the main sources of atmospheric energy in the globe[2].

2 DATA

This work uses the monthly averaged NCEP/NCAR reanalysis from 1948 to 2007 and daily rainfall data from 730 weather stations across China from 1960 to 2005 which have been conformed to the format of grids. At a horizontal resolution of 2.5°×2.5°, the former dataset includes air temperature, sea temperature, geopotential heights, relative humidity, wind fields and monthly averaged net flux of latent heat. It is available four times daily and used to drive models.

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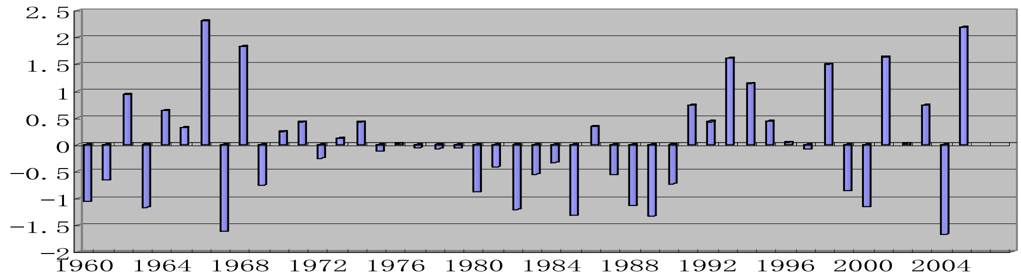
3 KEY OCEAN PARTS AFFECTING JUNE PRECIPITATION IN SC

3.1 *Selection of years with dry and wet Junes*

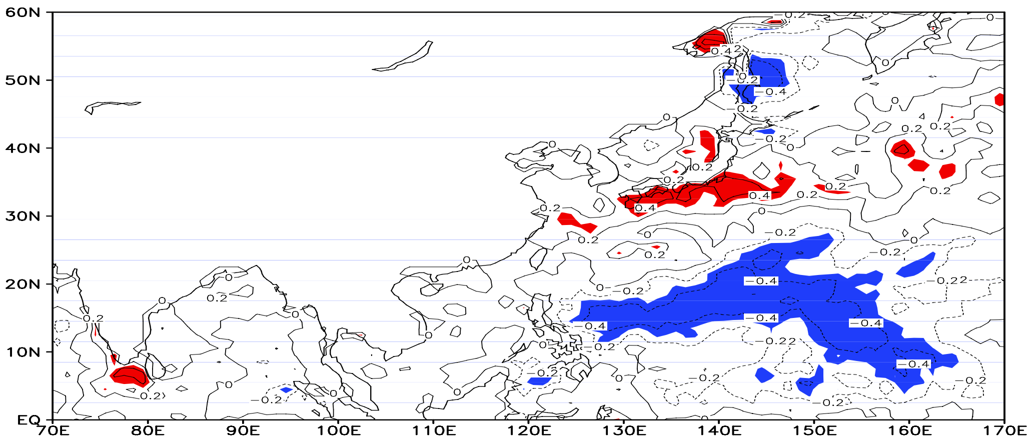
Stations within the domain outlined by 105°–120°E, 18°–28°N are selected from the 730 sites to represent the region of SC. The precipitation of Junes is averaged for these stations to determine a 46-year time series for this region. Processed with normalization, a time series of normalized June precipitation is derived for 1960 to 2005 (Fig. 1). Large year-to-year differences are found in the June precipitation in SC. From the years that are more than one time as large as the standard deviation, those with anomalously more and less June precipitation are identified. As a result, the seven years of 1966, 1968, 1993, 1994, 1998, 2001, and 2005 are determined to be the years of wet June, and the nine years of 1960, 1963, 1967, 1982, 1985, 1988, 1989, 2000, and 2004 are picked as the years of dry June, for SC.

3.2 *Definition of key areas of tropical western Pacific*

Figure 2 presents the coefficients of the correlation between the rainfall averaged over Junes from 1960 to 2005 and the flux of oceanic latent heat. The shading indicates the area that passes the 95% confidence test.



Fugure 1. Time series of standardized precipitation of SC in Junes of 1960 to 2005. The abscissa is for the year.

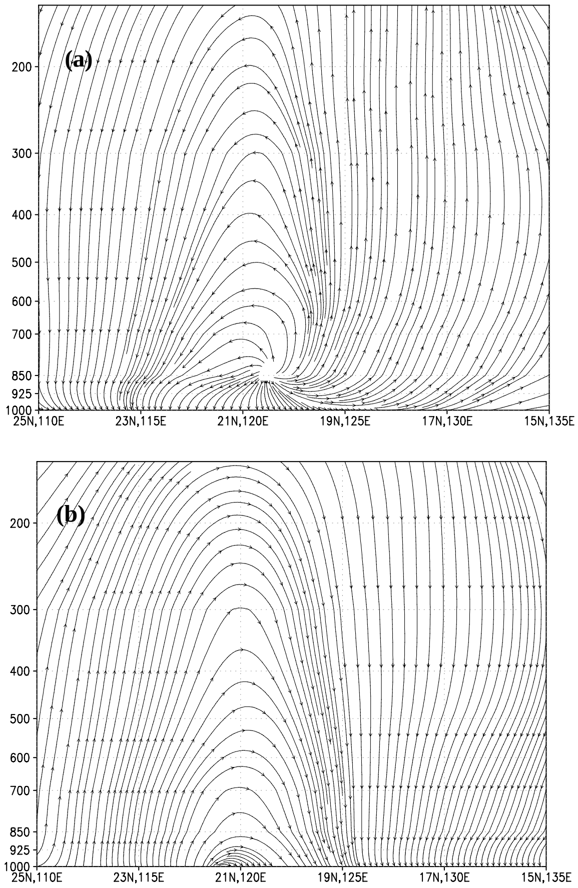


Fugure 2. Coefficients of the correlation between the rainfall averaged over Junes from 1960 to 2005 and the flux of oceanic latent heat. The shading indicates the area that passes the 95% confidence test.

It is shown in Fig. 2 that the June SC rainfall is negatively correlated by a one-month leg with the LHF over the ocean east of the Philippines. In other words, the latter may be one of the important reasons for the former. Thus, a key area must be somewhere in the tropical western Pacific, which is defined at 125°–145°E，10°–20°N. Besides, the precipitation is also correlated with the flux simultaneously in June (figure omitted). In Junes of the dry years, the LHF of the key area in May and June are both positively anomalous (figure omitted) and keep expanding in size. It suggests that when the LHF is significantly anomalous in the key area in May and persists in June, it may become one of the important reasons for anomalous precipitation in that year.

3.3 *Characteristics of circulation in the key area and SC in dry and wet Junes*

Profile analysis is done of the circulation (Fig. 3) at two points (110°E, 25°N for SC) and (135°E, 15 °N for the key area). In wet Junes an anomalous ascending airflow covers the whole SC and travels to the key area before becoming an anomalous descending flow there. In dry Junes, however, the anomalous ascending airflow over the key area and travels to SC before becoming an anomalous descending flow there.



Fugure 3. Local circulation of the profile for the anomalous latent heat in tropical western Pacific and SC in dry Junes (a) and wet Junes (b). Units for *u* and *v*: m/s; unit for ω: -0.01 Pa/s.

4 SIMULATIONS OF WET AND DRY JUNES IN SC

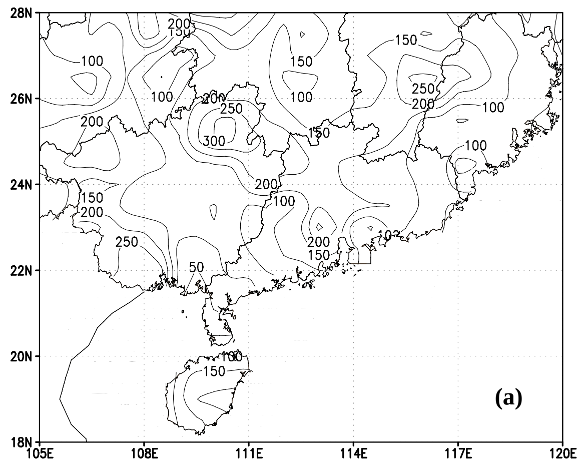
4.1 *Design of control experiment and analysis of results*

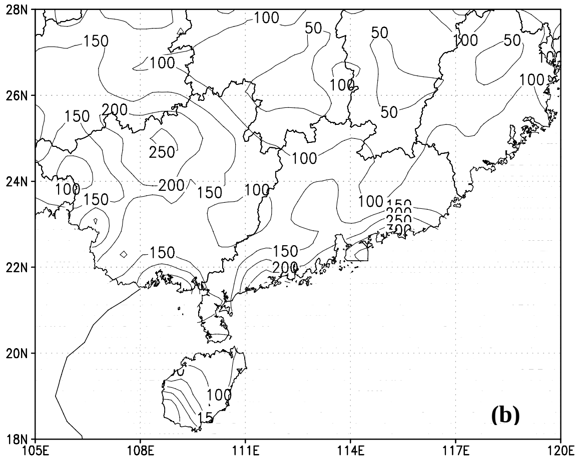
With RegCM3, a regional climate model from the International Center for Theoretic Physics, Italy, an experiment with simulations is carried out in this work. The center of the simulated domain is located at 125 °E, 22.5°N, with a horizontal resolution of 60 km, horizontal gridpoints of 70×122, 18 uneven layers in the vertical and the pressure of top layer at 52 hPa. The NCAR CCM3 scheme is used for radiation, the Zeng scheme for the parameterization of sea surface fluxes and the Holtlage scheme for the planetary boundary. The terrain used in the model is derived by interpolating the 10′×10′ data from United States Geological Survey (USGS) and the Global Land Cover Characterization data retrieved using satellite observations for the vegetation. Besides, the initial field and lateral boundary is determined with the 2.5°×2.5° reanalysis of NCEP/NCAR that is available four times daily, the Grell-AS scheme is used for cumulus parameterization, a scheme of index-based relaxation boundary is used for the lateral boundary condition that has model output once every six hours, and the OISST data from the Hadley center, updated weekly, is taken for the sea surface temperature. The model integration covers the period from 25 April to 1 July, 2004. The late April is not studied for it is set as the spin-up time of the model.

In the observation precipitation for 2004 (Fig. 4a), there is a rain band that goes northwest to southeast over Guangdong and Guangxi and two centers are located in northeastern Guangxi and southern Guangdong respectively. Two centers of rainfall larger than 200 mm are over western and southwestern Guangxi respectively. In the simulations (Fig. 4b), the model is generally good at reproducing the precipitation in SC, with the rain centers close to the observation in northern and southwestern Guangxi and southern coast of Guangdong.

4.2 *Definition of key areas of tropical western Pacific*

As shown in the analysis of the correlation between the SC precipitation and LHF, the former in June is in significantly negative correlation with the latter in May. In May and June of a dry SC year, the LHF is usually positively anomalous in the key area at the same time and keeps expanding in size. Two sensitivity experiments are then designed to work further on the effect of anomalous LHF in the tropical western Pacific on the SC precipitation in June. The LHF of the key area is either increased to be twice as much as it used to be, or an LH-increasing experiment, or decreased to be 0.5 as much as it used to be, or an LH-decreasing experiment, during the computation. Other details of the experiment follow that of the control experiment.



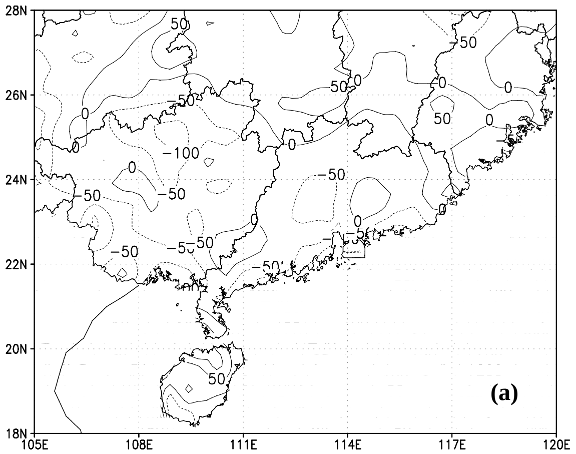


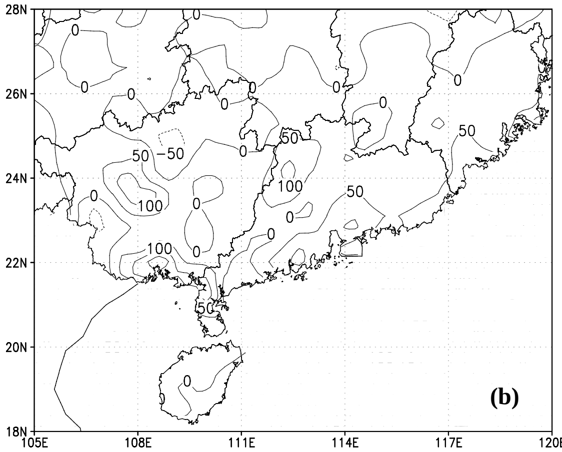
Fugure 4. Observed (a) and simulated (b) SC rainfall in June 2004. Units: mm.

4.3 *Analysis of sensitivity experiments*

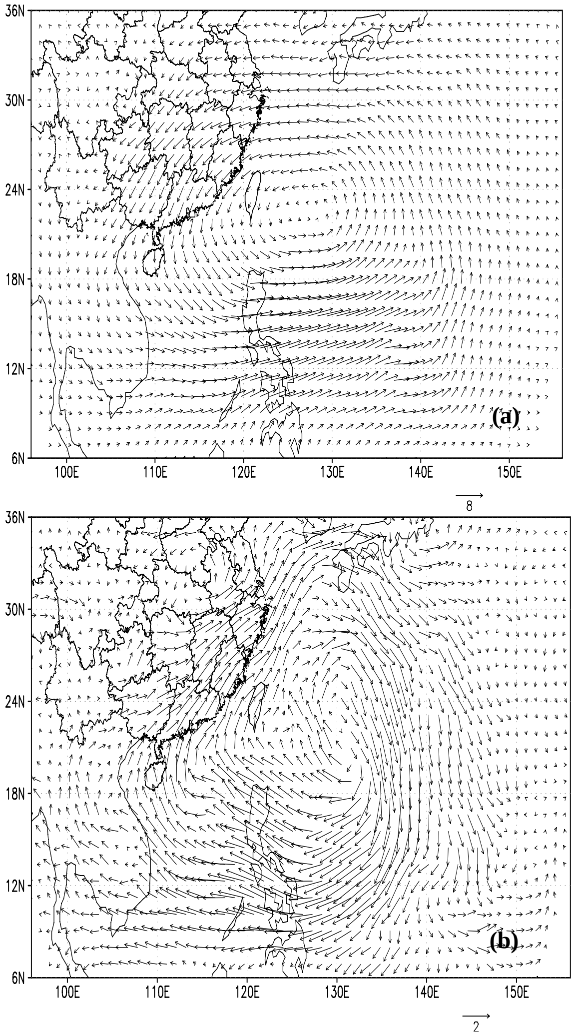
Figure 5 shows the results of sensitivity experiments minus the control. When the LHF increases in the tropical western Pacific, the rainfall decreases by 50 to 100 mm in most of SC but increases a little in the northern part of the region. When the LHF decreases anomalously, the rainfall increases in most of the region and by amounts varying from 50 to 100 mm near the rain centers, which is consistent with the analysis.

When the LHF increases in the tropical western Pacific, an anomalous anticyclonic circulation appears on the northwest side of the increasing region (Fig. 6a) and the western part of the circulation is just over SC that is marked with anomalous northeasterly wind and causes the southwesterly wind to reduce, unfavorable for the southwest monsoon to flow into SC. When the LHF decreases, an anomalous anticyclonic circulation occurs on the northwest side of the increasing region (Fig. 6b) and the western part of the circulation is just over SC that is featured by southwesterly anomalies, enhancing the southwest monsoon and being favorable for it to advance to SC.



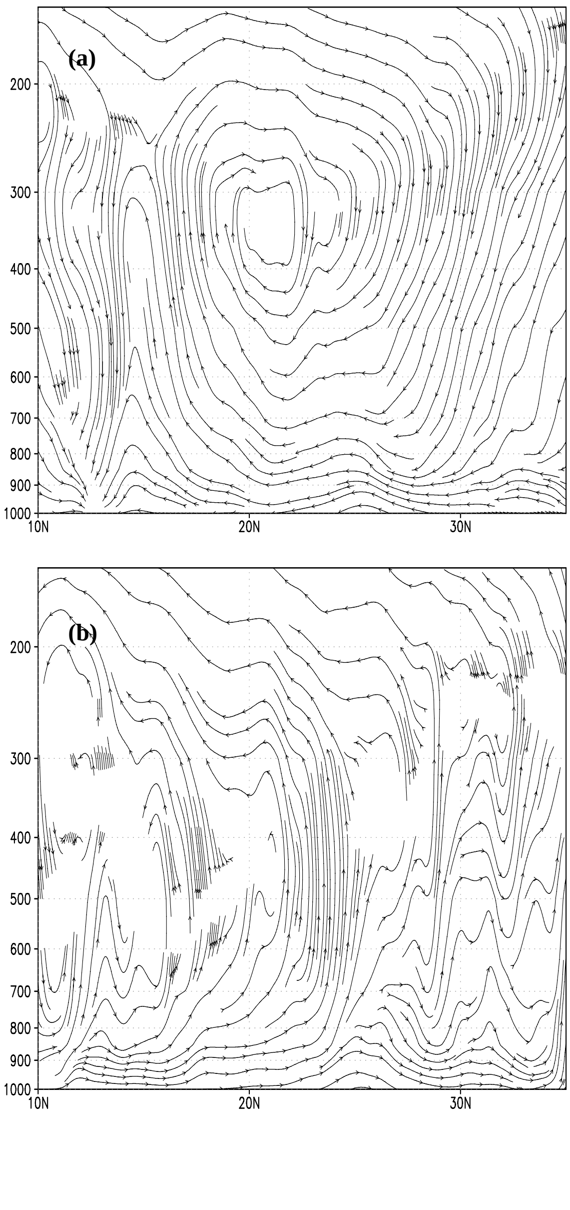


Fugure 5. Simulated precipitation by subtracting the control from the sensitivity experiment. Unit: mm. (a): increasing LH; (b): decreasing LH.



Fugure 6. 850-hPa wind field by subtracting the control from the sensitivity experiment. Units: mm. (a): increasing LH; (b): decreasing LH.

With the increase of the LHF in the tropical western Pacific, anomalously descending flow appears in the region of SC (Fig. 7a). It is known from the analysis of 850-hPa anomalous circulation field in the increasing-LH experiment that increased LHF triggers anomalous circulation at 850 hPa and SC is prevalent with anomalous northeasterly as it is at the western side of the circulation, weakening the Southwest Monsoon. Besides, the airflow is anomalously descending and the falling branch of the vertical circulation strengthens in the region. Such combination of anomalous northeasterly with vertical descending motion causes less rain to appear. When the LHF decreases, anomalously ascending flow appears in the region (Fig. 7b). It is known from the analysis of 850-hPa anomalous circulation field in the decreasing-LH experiment that decreased LHF triggers anomalous circulation at 850 hPa at the northwest and SC is with anomalous southwesterly as it is on the western side of the circulation, strengthening the Southwest Monsoon. Besides, the airflow is anomalously ascending and the rising branch of the vertical circulation strengthens in the region. Such combination of anomalous southwesterly with vertical ascending motion causes more rain to appear.



Fugure 7. Meridional circulation over East Asia (averaged over 110°-120°E) determined by subtracting the control from the sensitivity experiments. Unit of v: m/s; unit of ω: -0.01 Pa/s. (a): increasing LH; (b): decreasing LH.

It is known from the vertically integrated water vapor flux (figure omitted) that the increase of the flux in the tropical western Pacific is accompanied by anomalous more transport of water vapor to the region of SC.

It is also known from the cross section of anomalous LHF of the tropical western Pacific and local circulation of SC, which is determined by subtracting the control from the sensitivity experiment, that when the former increases, there is anomalously ascending motion in the region and the airflow becomes descending when it comes to SC, turning the whole region into anomalously descending. Besides, there is an anti-cyclonic anomalous circulation between the two regions. When the flux is anomalously decreasing, the region is of anomalous descending where the airflow moves to SC on lower levels and anomalous ascending motion appears there, favorable for precipitation to occur in the region. There are clockwise circulation anomalies over the two regions.

5 CONCLUSIONS AND DISCUSSION

Through statistical analysis and the simulating experiment using the regional climate model RegCM3, this work studies the effect of anomalous latent heat in the tropical western Pacific on the wetness of June in SC:

(1) As shown in correlation analysis, the June precipitation in SC is negatively correlated with the LHF in the tropical western Pacific in both May and June, and a more significant lagging correlation is found between them in May.

(2) The LHF anomalies in the key area of tropical western Pacific are an important factor for the wetness of June in SC. Its conceptual model works as follows. The flux is anomalously high in May and June and an anomalous cyclonic circulation appears at the lower levels of the troposphere to the northwest and SC is on the west side of it and prevalent with northeasterly anomalies, unfavorable for the Southwest Monsoon to head to this region to reduce water vapor. Besides, an anomalous cyclonic circulation is at the upper levels of the troposphere in SC, accompanied by an anomalous anticyclonic circulation at the lower levels, favorable for anomalous descending motion to form in the region to contribute to the ascending of an anomalous latent heat and the descending of an anomalous vertical circulation that descends in SC. The precipitation is thus reduced to cause droughts to occur. When the LHF is anomalously decreasing in May and June, an anomalous anticyclonic circulation

appears to the north, with SC located to the west side of the circulation that strengthens the southwesterly airflow and favors the transport of water vapor. At the time, anomalous vertical circulation occurs that descends over the area LHF in the tropical western Pacific and ascends over the region of SC, causing floods there.

(3) The anomalous LHF in the key area of the tropical western Pacific is just one of the factors responsible for the wetness of SC. The causation is complicated[18-20], the Qinghai-Tibet Plateau, Southern Hemisphere circulation and monsoon variation also play some role in the precipitation of this region. How they act together to contribute to the wetness of SC is a subject that needs more study from a number of aspects.

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