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THE TRANSMISSION PATH OF THE 500 hPa TEMPERATURE RESPONSE TO THE SOUTH CHINA SEA SST MONTHLY ABNORMALITY IN WINTER

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ABSTRACT: In view of the SSTA study mostly confined to summer, this work tries to take another look from the point of winter. Using a two-layer general circulation model (IAP–GCM Ⅱ) developed at the Institute of Atmospheric Physics of the Chinese Academy of Sciences, numerical experiments are conducted to study the transmission paths of the 500-hPa response field of temperature in association with monthly winter anomalies of SST for the South China Sea. The result shows that the response field splits into two branches in transmission when the anomaly is positive —one travels counterclockwise to the north arriving in the Qinghai-Xizang (Tibetan) Plateau via southeastern China after leaving the sea and the other goes southwards; the transmission becomes clockwise when anomaly turns negative so that it starts from the sea and passes the Bay of Thailand before, as in the case of positive anomaly, reaching the plateau. Our work has shown that the South China Sea SST is essential for the prediction of short-term climate in southeast China.

Key words: numerical experiments; SST; response

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1 INTRODUCTION

The SST is high and air-sea coupling is strong in the South China Sea (SCS). As is shown in some studies, the subtropical high intensifies and extends westward in warm SST years but weakens and goes eastward in cool SST years (Zhong, 1991). The South China Sea SST is playing a vital role in the motion of the atmosphere for China, southeast Asia and even the Northern Hemisphere. In recent years, a number of scholars have studied the SST anomalies in the area though with their focus mostly on summer (Luo and Jin, 1986; Liang, 1991). In view of it, it is of great significance to study the path of response of the 500-hPa temperature to anomalous SST in winter SCS. It is a relatively cool source over the mainland China in winter when the SCS is in the easterly monsoon south of the continental cold high and has warm SST, most probably leading to the appearance of updraft in the middle and lower layers of atmosphere over the sea. Any anomalies of SST there would certainly affect the rising airflow. In this way, it is therefore possible to probe into the transmission path of 500-hPa temperature response in association with anomalous SST in the SCS area.

2 SCHEME OF EXPERIMENTATION

The numerical model used in this work is a two-layer general circulation model (IAP-GCM Ⅱ)

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developed at the Institute of Atmospheric Physics of the Chinese Academy of Sciences. The model performs well, computes steadily and operates conveniently, as is proved by much research work. In fact, it has been successful in simulating a number of issues in atmospheric circulation and climate (Xiao and Li, 1992; Li, Liu and Xu, 1994). The current initial field is the output of steady model integration that covers 24 years and ends at 00:00 L.T. January 31. The integration is three months in the model, i.e., lasting from February 1 to April 30. The SST anomalies are added in February and the climatological mean, which comes from COADS, is used for SST in the following months. Domains selected for anomalous SST in the sea are within 110°E ~ 120°E and 6°N ~ 22°N. Four experiments are designed to address different monthly SST anomalies in winter SCS. Refer to Tab.1 for monthly anomalous parameters of SST in the experiments. Although they occur in an ideal condition of monthly anomalies, there is still a possibility that they will be present in reality. A 5-day pentad-mean treatment is applied to the integration above to obtain averages over 17 pentads, which are then studied. The 500-hPa temperature response fields in this work indicate the differences between the mean temperature field with anomalous monthly SST and the corresponding field averaged over pentads with normal monthly SST. That is the anomaly of pentad response of 500-hPa temperature.

Tab.1 Monthly SSTA in the numerical experiments

Numerical Experiments	I	II	III	IV
Monthly SST Anomalies (°C)	+3.0	+2.8	+2.0	–2.0

Set that the atmosphere is ideal over the SCS, i.e. the gradient of horizontal temperature and diabatic heating are absent and the temperature on the 500 hPa layer is assumed to be T_0. Then variations in the temperature at 500 hPa are uniquely dependent on whether the local air is diabatically rising or falling. The SST there acts as an external forcing for a heat source or sink. In winter, the SCS area is a relative heating source that brings about updraft motion over it. With normal SST forcing, however, temperature at 500 hPa over the SCS is denoted as

$$T_1 = T_0 + \Delta T_1 \tag{1}$$

where ΔT_1 is the temperature variations at 500 hPa caused by the vertical motion associated with normal SST forcing and $\Delta T_1 < 0$ for rising movement of the atmosphere. When there are monthly anomalies in SST, anomalous vertical motion should be a natural response and the local 500-hPa temperature is rewritten as

$$T_2 = T_0 + \Delta T_2 \tag{2}$$

where ΔT_2 is the temperature variations at 500 hPa caused by the vertical motion associated with abnormal SST forcing and likewise $\Delta T_2 < 0$ for rising movement of the atmosphere. As changes have taken place in the atmospheric vertical motion over the region relative to the normal situation, similar changes are also recorded in the 500-hPa temperature, which is denoted as

$$\Delta T = T_2 - T_1 = (T_0 + \Delta T_2) - (T_0 + \Delta T_1) = \Delta T_2 - \Delta T_1 \tag{3}$$

ΔT here is the anomaly of response field of 500-hPa atmospheric temperature.

When the SST is positively anomalous in the South China Sea area, the atmosphere rises more vigorously than normal, making $\Delta T < 0$. It is indicated that there is relative rising motion there. On the contrary, when the SST is negatively anomalous in the area, the atmosphere rises more weakly than normal or even falls, making $\Delta T > 0$. It is indicated that there is relatively falling motion there. It is thus possible to have a qualitative determination of the vertical atmospheric motion by looking into the 500-hPa temperature response anomalies available through numerical experiments. Of course, the feedback of the atmosphere to the ocean is also an effect to consider as the real anomalies of the 500-hPa-temperature response are subject to other factors in addition to the relatively vertical motion, unlike the ideal atmosphere discussed above. It is nonetheless feasible, in view of the temporal scale in this work, to address the issue of the path of response of 500-hPa temperature to the monthly SST anomalies in the South China Sea using the qualitative analysis presented above.

3 ANALYSIS OF EXPERIMENT RESULTS

Computations for the only first few pentads in the numerical experiments are studied, considering that we are interested in the paths of the 500-hPa temperature in response to the monthly South China Sea SST anomalies in winter.

3.1 *Experiment with positive SST anomalies*

Let's look at the experimental result of Exp.I. From the anomalous field of the first pentad, it is understood that a negative response anomaly is in the central and southern parts of the sea with the central intensity of –0.02°C while positive anomalies are over the southeast China and Indonesia with central intensity of +0.08°C and +0.02°C respectively. The small values indicate that it takes time for the response anomaly to appear. In spite of it, it reveals the presence of relative rising movement over the South China Sea area in contrast to relative falling movement over the southeast China and Indonesia (Fig.1a). In the second pentad, as shown in Fig.1b, there is an increase in the anomaly of temperature response at 500 hPa in southeast China with the central intensity growing from +0.08°C to +0.15°C while a negative response anomaly over the region of the Tibetan Plateau has a counterpart of –0.05°C. By this time, the latitudinal circle of 30°N in the Northern Hemisphere has triggered weak wavetrain of response. In the meantime, the positive anomaly has increased its response in the plateau area with the center intensifying from +0.02°C to +0.05°C. On 500 hPa in the third pentad, the plateau starts to be controlled by a +0.09°C anomaly of temperature response. Apart from it, there is a positive response anomaly of +0.9°C on 30°N in the eastern Pacific against a negative response anomaly of –1.8°C on the western coast of North America. When the Tibetan Plateau in eastern Asia and Rocky Mountains in North America, two key areas influencing the global climate, begin to response, the whole world will be imprinted. Generally, the response is not remarkable in the Southern Hemisphere (Fig.1c). On 500 hPa in the fourth pentad, the wavetrain continues to grow in amplitude in the temperature response in the Northern Hemisphere with the largest positive anomaly in northern Europe at +4.0°C. The wave train further increases in amplitude in the subsequent fifth and sixth pentads till reaching a steady state and completing a full circle of response around the Northern Hemisphere, with an obvious wavenumber of 2 on the latitude circle. Local response begins to appear in the middle and high latitudes of the Southern Hemisphere that develops to the size and intensity similar to that in the Northern Hemisphere (All figures omitted).

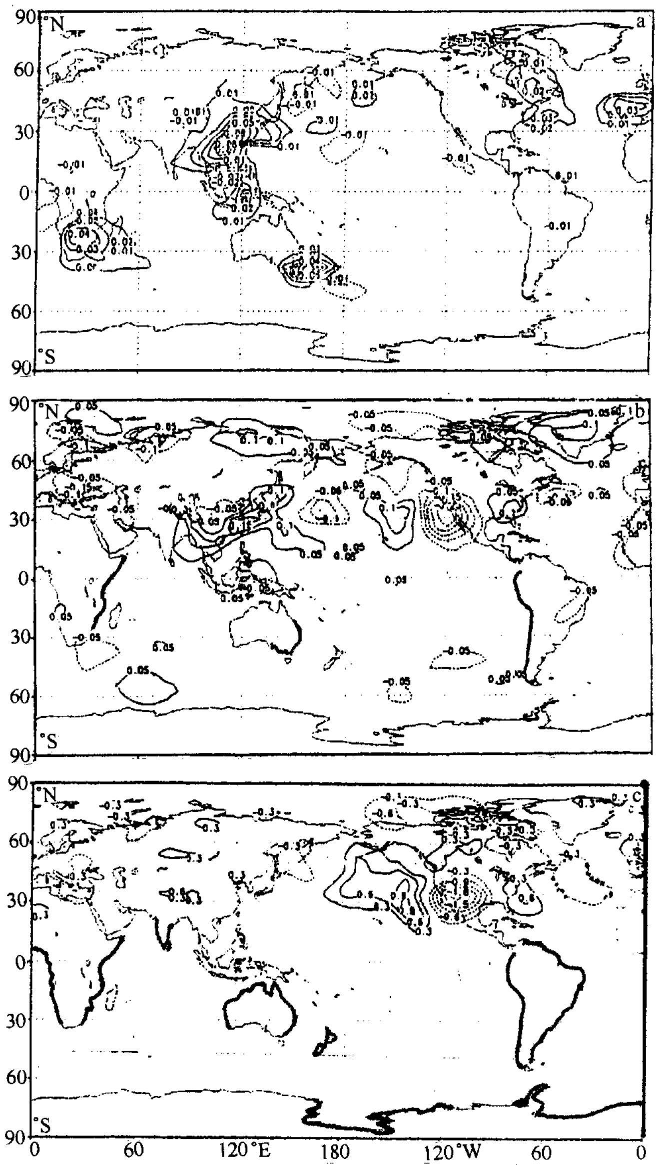

Fig.1 Anomaly field (°C) of pentad-mean temperature response at 500 hPa in Exp.I. (a) first pentad; (b) second pentad; (c) third pentad

It is then concluded that when the South China Sea SST is positive in winter the atmospheric response to it will transmit to both south and north, transmissions on the former path being eventually dissipated and those on the latter path moving counterclockwise first to southeastern China and then to the Tibetan Plateau. As this very anomalous SST changes the inherent rhythm of index cycles in the atmosphere, significant global response wavetrains appear in the middle and high latitudes in both hemispheres (Zhang, Wang and Zuo, 1999).

Exp.II and Exp.III produce results similar to Exp.I and the 500-hPa temperature to monthly SST in the sea follows roughly the same path. It shows that the result of the current results of the numerical experiments are convincing and no more description will be given here for them (All figures omitted).

3.2 *Experiment with negative SST anomalies*

Being different from the previous three experiments, Exp.IV gives a negative SST anomaly for the South China Sea. In the figure of the first-pentad anomalies, the anomaly is positive for the 500-hPa temperature response in the sea with the center of +0.01°C. In the mean time, there have been positive anomalies over the Bay of Thailand and Bay of Bengal through the Tibetan Plateau while the response in the Southern Hemisphere is not as obvious (Fig.2a). In the second pentad, however, the anomaly becomes negative in the response of the 500-hPa temperature field over the Bay of Bengal while remaining positive and even increasing with the center of +0.06°C over the plateau (Fig.2b). It is then seen that in the South China Sea a negative SST anomaly is associated with positive anomaly of temperature response at 500 hPa that transmits clockwise from the sea via the Bay of Bengal to the Tibetan Plateau.

4 QUALITATIVE INTERPRETATION OF RESPONSE PATHS

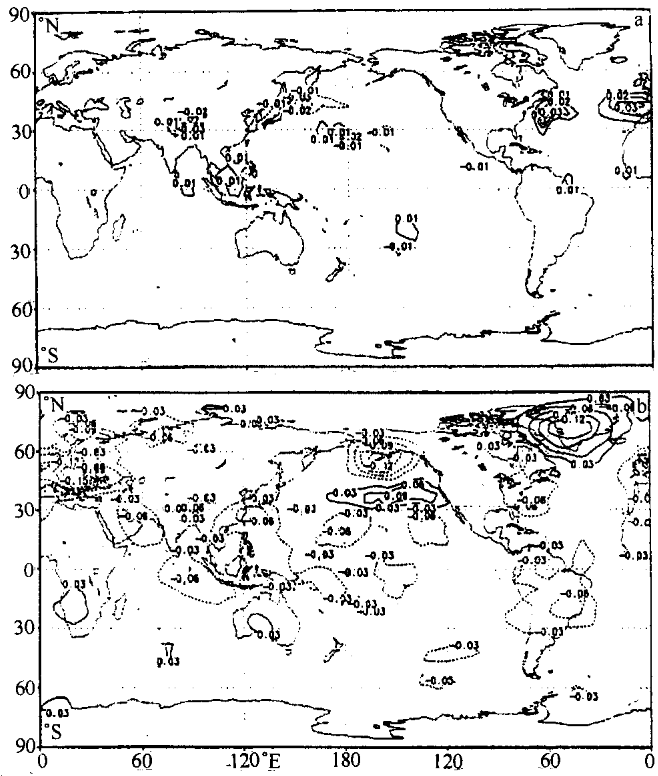

Fig.2 Anomaly field (°C) of pentad-mean temperature response at 500 hPa in Exp.IV. (a) first pentad; (b) second pentad

Let's then make a qualitative interpretation of the response paths in the experiments. Examining the geopotential fields from 850 hPa to 500 hPa obtained, we find that the fields are similar to the climotological fields of winter (All figures omitted). The ridgeline of the 500-hPa subtropical high is near 15°N and steady and anti-cyclones are active over both the Philippine Islands and the Indochina Peninsula. The South China Sea area is just between the two centers in a saddle-like pressure zone. A southerly wind prevails in the eastern part of the sea and a northerly wind in the western part. For the 850-hPa geopotential field, however, the westerly is separated into a southern and a northern branch off the western edge of the plateau and forms a return flow off the eastern one. Anti-cyclones are located in the Pearl River Mouth, southern Ryukyu Islands and western India Peninsula, and there is a saddle-like pressure field in the Bay of Bengal and a southerly wind in the Indochina Peninsula (Refer to Figs.1a and 1b in C.M.B., 1975). When the South China Sea SST is positively anomalous, the atmosphere is strengthened in the rising motion, i.e. relative updraft is taking place. At the time, subject to the southerly and northerly respectively in the eastern and western parts of the saddle-like field at 500 hPa, two branches, each flowing southward and northward, are formed. The southward branch crosses the equator and sinks relatively over Indonesia while the northward branch sinks relatively over southeastern China. They are displayed as positive anomalies of response on 500 hPa. With the strengthening of sinking motion of the atmosphere in southeastern China, the height of the layer in which the air sinks will lower. It makes the low-level environmental field a factor to consider. At this time, return flows appear over the eastern part of the plateau at 850 hPa, advecting the relative sinking movement on to the plateau. A positive anomaly of temperature would then be brought as the plateau is about as high as the 500-hPa isobaric surface in relation to the sea level.

When the SST is negatively anomalous over the South China Sea, the atmosphere would sink over there, weakening the rising movement and lowering the layer in which it is happening and thus making it more susceptible to low-level environment. Due to its location in southern side of the anti-cyclone over the Pearl River Mouth at 850 hPa, a northeasterly wind prevails. Subject to its advection, the positive anomaly transmits to the Bay of Thailand before entering the Tibetan Plateau through the 850-hPa southerly advection over the Indochina Peninsula. It is then shown as a positive anomaly in the 500 hPa temperature.

For the last point, it is clear from experimental results that there is close relationship between positive anomaly in winter over the South China Sea and short-term climatic changes in southeastern China. The SST of the sea is, therefore, an important factor to consider in the prediction of short-term climate for winter in southeastern China.

5 CONCLUDING REMARKS

a. When the SST is positively anomalous in winter over the South China Sea, temperature responses to it by showing two branches of southward and northward transmission at 500 hPa. The northern branch goes counterclockwise past the sea and southeastern China before arriving in the plateau. The southern branch crosses the equator and reaches Indonesia.

b. When the SST is negatively anomalous in winter over the South China Sea, temperature responses to it by showing a clockwise path of transmission at 500 hPa, which travels from the sea via the Bay of Thailand to get northward to the plateau.

The conclusions above are obtained only after qualitative study of relevant numerical experiments without any detailed dynamical verification. Limitations are bound to occur, which is just what we need to do more about in future.

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