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NUMERICAL SIMULATION OF SSTA IMPACTS OVER THE GLOBAL OCEAN ON THE ANOMALOUS CIRCULATION OVER EURASIA IN JANUARY 2008

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Abstract: In this paper, we discussed the features of atmospheric circulations over Eurasia as a response to sea surface temperature anomalies (SSTAs) over the tropical Indian Ocean, the equatorial Pacific, Kuroshio and the North Atlantic. Our results are shown as follows: (1) CAM3.0, driven by the combined SSTAs over the four oceanic regions, can simulate well the features of anomalous atmospheric circulations over Eurasia in January 2008, indicating that the effects of the SSTAs over these four regions were one of the key causes of the anomalous systems over Eurasia. (2) The SSTAs over each key region contributed to the intensification of blocking over the Urals Mountains and a main East Asian trough. However, the influence of the SSTAs over individual oceanic regions differed from one another in other aspects. The SSTAs over the North Atlantic had an impact on the 500-hPa anomalous height (Z500A) over the middle-high latitudes and had a somewhat smaller effect over the low latitudes. For the warm SSTAs over Kuroshio, the subtropical high was much stronger, spread farther north than usual, and had an anomalous easterly that dominated the northwest Pacific Ocean. The warm SSTAs over the tropical Indian Ocean could have caused a negative Z500A from West Asia to Middle Asia, a remarkably anomalous southwesterly from the Indian Ocean to the south of China and an anomalous anticyclone circulation over the South China Sea-Philippine Sea region. Because of the La Niña event, the winter monsoon was stronger than normal, with an anomalously cooler northerly over the southeastern coastal areas of China. (3) The combined effects of the SSTAs over the four key regions were likely more important to the atmospheric circulation anomalies of January 2008 over Eurasia than the effects of individual or partly combined SSTAs. This unique SSTA distribution possibly led to the circulation anomalies over Eurasia in January 2008, especially the atmospheric circulation anomalies over the subtropics, which were more similar to those of the winter El Niño events than to the circulation anomalies following La Niña.

Key words: January 2008 snow disaster; SSTAs; atmospheric circulation anomalies; CAM3.0; numerical simulation

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1 INTRODUCTION

In January 2008, an unprecedented disaster of long-lasting snowstorms and freezing temperature (referred to as the January 2008 snow disaster) affected the south of China. This disaster caused a great loss of both lives and property and prompted much concern from both the public and scientists[1]. Generally, a persistent weather phenomenon must be associated with a persistent atmospheric circulation. A number of studies have investigated the impact of atmospheric circulations on the January 2008 snow disaster[2, 3]. Researchers have found that a long period of anomalous atmospheric circulations over Eurasia was the direct cause for the January 2008 snow disaster. The anomalous circulations in January 2008 that affected China included the Ural Blocking High over the Ural area, the East Asian trough and the western Pacific Subtropical High, which shifted farther northward and westward than normal[2, 3]. These anomalous circulations formed a kind of cooperation referred to as a combination anomaly[4].

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It is of interest to examine how these anomalous atmospheric circulations were induced in January 2008. It is known that large-scale anomalous atmospheric circulations are induced by many factors. Sea surface temperature anomalies (SSTAs), which cause abnormal heat and evaporation, etc., are thought to play a critical role in causing atmospheric circulation anomalies. Scientists have analyzed the climatic background of the January 2008 snow disaster and have shown that the La Niña event of 2007/2008 may have contributed significantly to the snow disaster[2, 6, 7]. Scientists, moreover, found that the distribution of anomalous atmospheric circulations, temperature and precipitation over the mid- to high- latitudes of Asia in January 2008 were similar to those of the 11 boreal winters when typical La Niña event occurred (1954/1955, 1955/1956, 1964/1965, 1970/71, 1971/72, 1973/1974, 1974/1975, 1975/1976, 1988/1989, 1998/1999, 1999/2000). However, the conditions over Asia in January 2008 differed from those over the subtropical and tropical regions during these years and, instead, beared more resemblance to those of winter El Niño events[2, 4]. As the La Niña event of 2007/2008 was probably not the single cause of the atmospheric circulation anomalies over Eurasia in January 2008[5], the reasons for this unusual situation need to be studied further.

From the SSTAs distribution in January 2008 (figure omitted), we notice that SSTAs occurred during the La Niña event not only in the equatorial Pacific but also in other oceanic areas. Very strong negative SSTAs appeared in the equatorial central and eastern Pacific, and positive SSTAs appeared in the equatorial western Pacific to the northeast Pacific. Positive SSTAs could also be found over Kuroshio and its eastern area, over most of the tropical Indian Ocean and over the North Atlantic[2]. Studies have found that there was a significant relationship between the anomalous atmospheric circulations over Eurasia in January 2008 and the SSTAs over the global ocean[5]. The anomalous atmospheric circulations over Eurasia in January 2008 may have been due to the combined influence of the SSTAs over the tropical Pacific and the North Atlantic or the combined influence of the SSTAs over the Kuroshio and the tropical Pacific[5, 8, 9, 10]. However, most studies have focused on the influence of SSTAs over individual or partly combined oceanic areas rather than fully examining the influence of SSTAs over the four oceanic areas, that is, the equatorial Pacific, Kuroshio, the tropical Indian Ocean and the North Atlantic. In particular, there are no works that study the effects of the warm SSTAs over the tropical Indian Ocean. Therefore, we examined both the combined and individual influence of the SSTAs over the four oceanic areas. Using the NCAR Community Atmosphere Model Version 3.0 (CAM3.0), we conductd several sensitivity experiments to reveal the effects of the SSTAs over these oceanic areas on the atmospheric circulation anomalies in January 2008 over Eurasia.

2 MODEL DESCRIPTION, DATA AND EXPERIMENT DESIGN

2.1 *Model description*

The CAM3.0 uses a η-coordinate system with 26 vertical layers. The nonlinear terms and parameterized physical processes are calculated on a 128 × 64 Gaussian grid with a horizontal resolution of about 2.8125º×2.8125º. The time integral uses a semi-implicit scheme with 20 minutes for each time step. The model includes full physical processes (i.e., radiation, cloud, convection, land surface, and boundary layer). More details can be found in the model description document[11]. Many studies indicate that the CAM3.0 can preferably describe the large-scale climate characteristics over East Asia and the atmospheric response to SSTAs[12-15]. The model includes two optional ocean models: one drives the atmospheric model by taking a monthly mean SST as a boundary field (Data Ocean Model, DOM); the other model is coupled to a simple ocean model (Slab Ocean Model, SOM). The DOM was adopted in our experiments. We solely considered the impact of the SSTA on the atmosphere (i.e., we did not consider the feedback of the atmosphere to the ocean in this study).

2.2 *Data*

The NOAA Extended Reconstructed SST dataset used in this study is from January 1951 to December 2008 with a horizontal resolution of 2º×2º[16]. The NCEP/NCAR reanalysis provided monthly 850 hPa winds and 500 hPa geopotential height fields on a 2.5º lat.×2.5º long. grid for January 2008.

The horizontal distributions of normalized SSTAs from November 2007 to February 2008 (left panel) and the horizontal distributions of the normalized SSTAs of the 11 typical La Niña events from November to the following February (right panel) are shown in Fig. 1. There are notable differences between the left and right panels. There are significant warm SSTAs over Kuroshio and its eastern area, over the tropical Indian Ocean basin-wide and over the North Atlantic from November 2007 to February 2008 in the left panels of Fig.1, in addition to the SSTAs appearing over the tropical Pacific. Four regions where the absolute values of the normalized SSTAs exceed 1.0 are selected for analysis: 01—the Northwest Atlantic (40–50ºN, 320–340ºE); 02—Kuroshio (12–36ºN, 122–150ºE); 03—the tropical Indian Ocean (10ºS–10ºN, 60–100ºE);

and 04—the equatorial Pacific (10ºS–10ºN, 120–270ºE). A series of sensitivity experiments were conducted to examine the impacts of SSTAs over the above four oceanic regions (referred to as the four key regions) on the atmospheric circulation anomalies over Eurasia in January 2008.

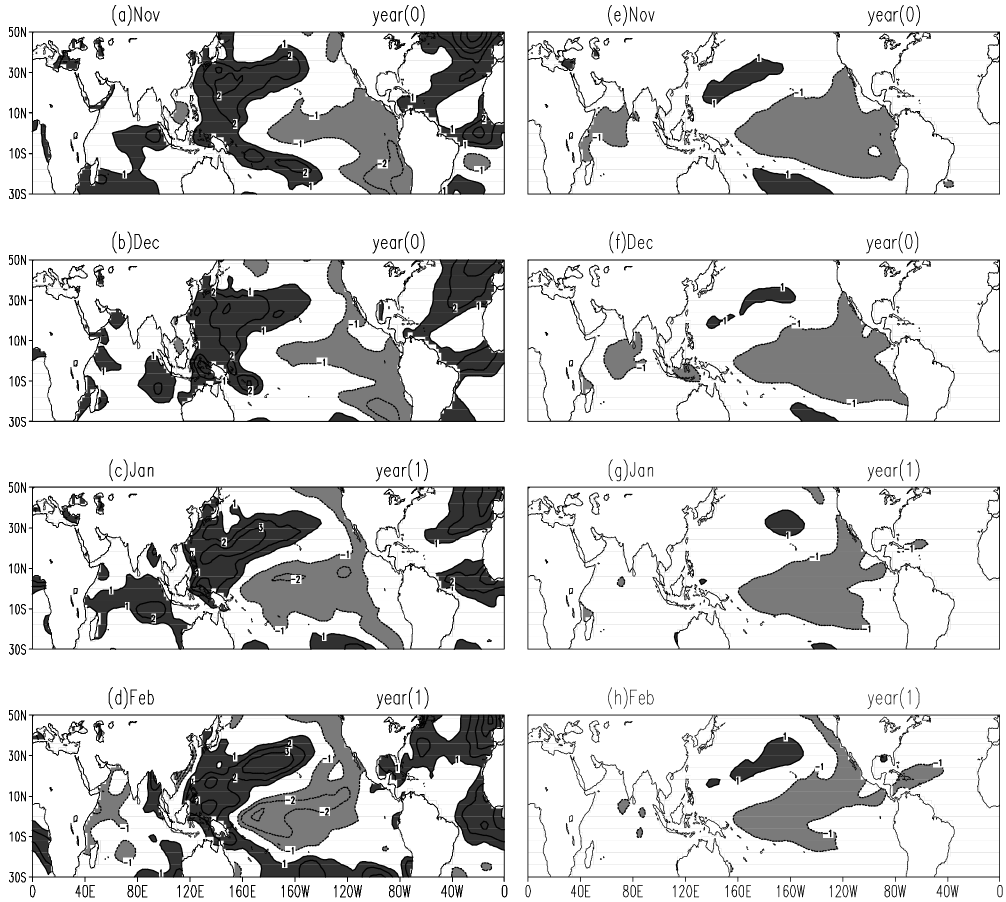

Fig.1. Normalized monthly SSTAs from November 2007 to February 2008 (left panels) and normalized SSTAs for the 11 typical La Niña events composites from November to the following February (right panels). Shaded areas denote the absolute values of normalized SSTAs exceeding 1.0.

2.3 *Experimental design*

Experiments were performed to investigate the impacts of the SSTAs over the four key regions on the atmospheric circulation anomalies of January 2008 appearing over Eurasia.

2.3.1 CONTROL EXPERIMENT (C00)

A control experiment was carried out using a seasonally varying climatological SST as the boundary field. The model was integrated for 20 years. The average of the last five years was regarded as a model climate, referred to as C00s.

2.3.2 SENSITIVITY EXPERIMENTS

(1) Series 1: This experiment focused on the combined effects of the SSTAs over the four key oceanic regions (Experiment E-1234). The observed SSTAs over the four key oceanic regions were put into the model’s boundary field together。

(2) Series 2: To discuss the impacts of the SSTAs over each oceanic region, the observed SSTAs over the North Atlantic, Kuroshio, the tropical Indian Ocean and the equatorial Pacific were put into the model individually (Experiments E-01, E-02, E-03 and E-04, respectively).

(3) Series 3: To further understand the effects of the SSTAs over each region, experiments for different combinations of oceanic regions were made: the observed SSTAs over regions 01, 02, and 03 (Experiment E-123); the observed SSTAs over regions 01, 03, and 04 (Experiment E-134); the observed SSTAs over regions 02, 03, and 04 (Experiment E-234); the observed SSTAs over regions 01, 02, and 04 (Experiment E-124).

For each of the above sensitivity experiments, the observed SSTAs from November 2007 to February 2008 were added to the monthly mean climatological SST field without changing the other parameters. Each scenario was started from five different atmospheric initial conditions (for November 1 in the 16th–20th years in the Control experiment). The integration ran for four months (from 1 November to 28 February), and we only analyzed the results in January to reduce the nonlinear error caused by the different initial conditions. The average result of the five integrations was taken as the result of the sensitivity experiments. The atmospheric circulation anomalies were obtained by subtracting results of the control experiment from those of the sensitivity experiments.

3 EXPERIMENTAL RESULTS

3.1 *Anomalous atmospheric circulations of the observation and the simulation of experiment E-1234*

The observed and simulated 500 hPa anomalous height (Z500A) and 850 hPa wind anomalies in January 2008 over Eurasia are shown in Fig. 2. The anomalous atmospheric circulations over Eurasia that probably caused the ice and snow disaster are shown in Fig.2a: the Ural blocking high with a peak centered at (70ºN, 65ºE), the transverse trough from Lake Baikal to Lake Balkhash, the negative Z500A along eastern Asia and Japan, and the northwestward, enhanced Northwest Pacific subtropical high[2,4]. In the 850 hPa anomalous wind field, significant anomalous southwesterly from the Bay of Bengal to southern China and an anomalous anticyclone flow around the South China Sea–Philippine Sea region are shown clearly in Fig. 2b. Both anomalous wind fields tend to transport abundant warm and moist air to the south of China, converging with cool air from mid- to high-latitudes along ~30ºN, as shown in Fig. 2b.

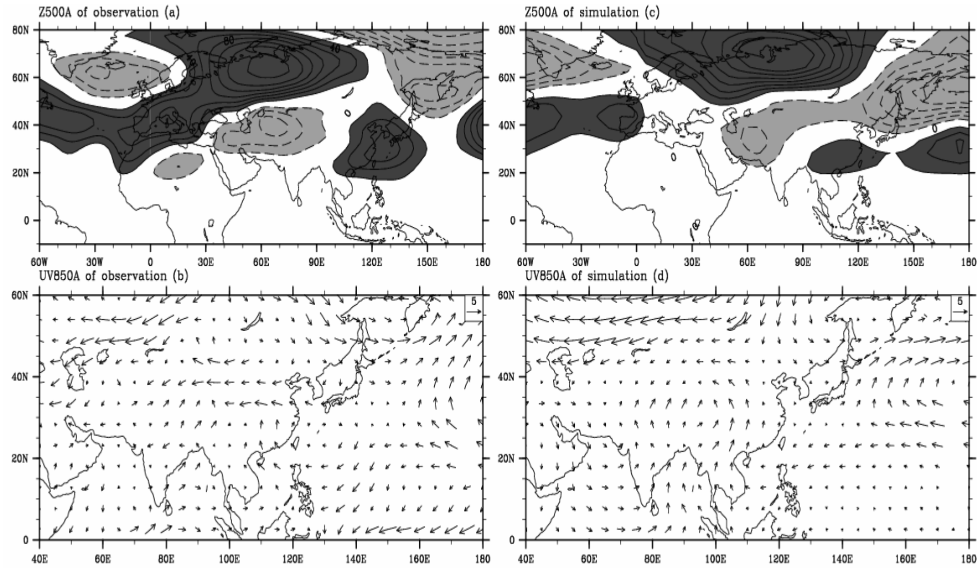

Fig. 2. Observed (a, b) and simulated (c, d) anomalous atmosphere circulations in January 2008 over Eurasia. (a) and (c) Z500A (dark areas: exceeding 20 gpm; light areas: below –20 gpm; at intervals of 20 gpm); (b) and (d) 850 hPa anomalous wind field (unit: m s^{-1})

The simulated Z500A and 850 hPa anomalous winds of E-1234 are shown in Figs. 2c & 2d. The positive Z500A with a maximum value of 120 gpm in Fig. 2c located around the north of Asia is similar to the observation in Fig. 2a. The simulated maximum value, located at (70ºN, 80ºE), is shifted farther eastward than the observation. The simulated negative Z500A around the south of Lake Balkhash, with a maximum value of -40 gpm at (28ºN, 75ºE), coincides with the observation. However, the amplitude of the model simulation is much weaker than the observation, having only a maximum value of -60 gpm. The simulated positive Z500A over the Philippine Sea indicates that the Northwest Pacific subtropical high is similar to that of the observations but is weaker in magnitude. The simulated negative Z500A along East Asia and Japan that enhanced East Asian trough coincides with that in the observation. The simulated anomalous northwesterly from the mid- to high-latitudes to the south of China and the anomalous southwesterly from the Bay of Bengal to the south of China, as well as the easterly from the tropical western Pacific, are roughly reproduced (Fig. 2d). An anomalous anticyclone circulation located over the South China Sea-Philippine Sea region is simulated in Fig. 2d and is somewhat weaker than the observation.

The CAM3.0, driven by the combined SSTAs over the four oceanic regions, is able to well simulate the features of the anomalous atmospheric circulations over Eurasia in January 2008, indicating that the impacts of the SSTAs over the four regions is a key cause to forming the several anomalous atmospheric circulation systems over Eurasia during that time. The atmospheric circulation anomalies may have been caused by the timely superposition and interweaving of the SSTAs over the four key ocean regions. In the following subsection, we investigate the effects of the SSTAs over individual key regions on the atmospheric circulation anomalies in January 2008 over Eurasia.

3.2 *Results of experiments E-01, E-02, E-03, and E-04*

The simulated Z500A of E-01, E-02, E-03 and E-04 are shown in Fig. 3. The enhanced blocking over North Asia, with a maximum value of 80 gpm at (65ºN, 60ºE) and notable negative Z500A along the coastal areas of East Asia, are shown in Fig. 3a. The results suggest that the SSTAs over North Asia have an impact on the intensity of the blocking high over the Ural Mountains, and the East Asian trough and the atmospheric circulation anomalies played a role in transporting cold air to the south of China along a northwestern or eastern route. In the simulated Z500A field of E-02 (Fig. 3b), there is a blocking high over the Ural Mountains with a maximum value of 40 gpm. Moreover, an enhanced East Asian trough and significant positive Z500A located north of the Philippine Sea are simulated. Thus, on the effect of the warm SSTAs over Kuroshio, the subtropical high is much stronger and spreads farther north than normal, in addition to the blocking high being over the Ural Mountains and the East Asian trough being deeper than normal. In the simulated Z500A field of E-03 (Fig. 3c), there is notable positive Z500A to the west of the Ural Mountains, representing enhanced blocking activity over the sector, and negative Z500A along the coast of East Asia, suggesting a deeper East Asian trough. In addition, due to the effect of the warm SSTAs over the tropical Indian Ocean, negative Z500A over India and Central Asia is simulated in Fig. 3c inducing the continuous activity of cold air in China along the western route. The anomalous westerly over the Bay of Bengal is also simulated in Fig. 3c, enhancing the trough in the southern branch of the westerly[2]. Fig. 3d shows the simulated Z500A field of E-04. There is a wide range of positive Z500A at (60ºN, 85ºE) with a peak value of 60 gpm. A negative Z500A region is located along the coastal areas of East Asia, suggesting a stronger East Asian trough than normal. There is no significant Z500A over the Philippine Sea and the South China Sea. These results are similar to those of the previous analysis concerning the winter atmospheric circulations based on the 8 strong and 12 weak La Niña events[17]. Thus, the E-04 simulation captures the main characteristics of the atmospheric circulation anomalies of the La Niña winter composites.

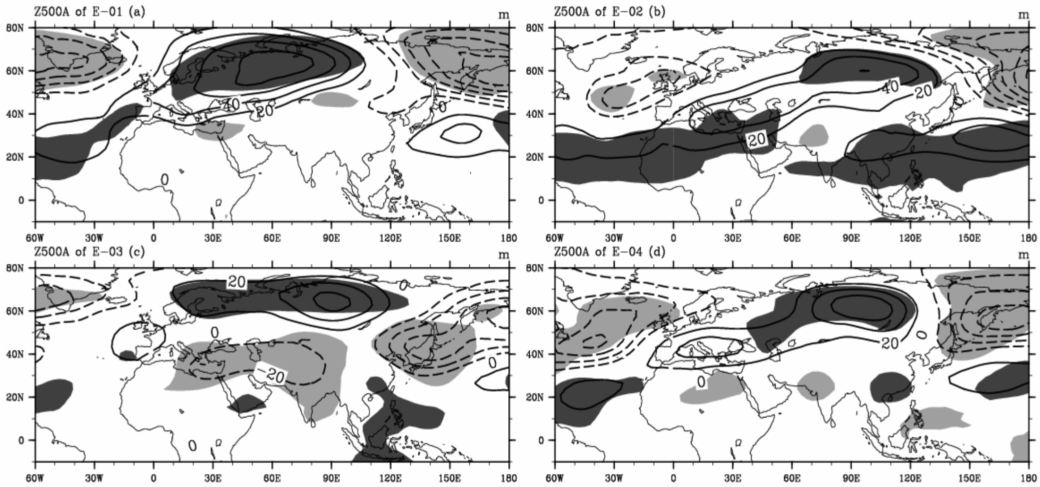

Fig. 3. Simulated Z500A of (a) E-01, (b) E-02, (c) E-03, (d) and E-04 (interval: 20 gpm) (shaded areas indicate that the Z500A is significant above the 90% confidence level.)

The 850 hPa anomalous wind fields of E-01, E-02, E-03 and E-04 are shown in Fig. 4. As seen in Fig. 4a, there is notable anomalous northwesterly from the mid- to high- latitudes to South China, but no significant anomalous winds over the low latitudes. In experiment E-02, an anomalous anticyclone circulation is located over the east of Kuroshio, and notable anomalous easterly is located from southeastern China to the South China Sea (Fig. 4b). An anomalous anticyclone circulation is also simulated around the Ural Mountains in Fig. 4b. In experiment E-03, notable anomalous northwesterly over the mid- to high- latitudes and an anomalous cyclone wind flow around Japan are simulated (Fig. 4c). At low latitudes, anomalous anticyclone circulation appears over the South China Sea–Philippine Sea and remarkable southwesterly is located from the tropical Indian Ocean to South China (Fig. 4c). Both the southwesterly and the anomalous anticyclone circulation over the Philippine Sea transport warm and moist airflows to South China which are the necessary conditions for the January 2008 snow disaster. In the simulated wind field of E-04, an anomalous northerly controls the mid- to high-latitudes of East Asia, and weak anomalous easterly controls the southeastern coastal areas. These anomalies indicate a strong East Asian winter monsoon, which favors a southward outbreak of extreme cold air to South China (Fig. 4d). An anomalous cyclonic circulation is also simulated over 10–15ºN in Fig. 4d.

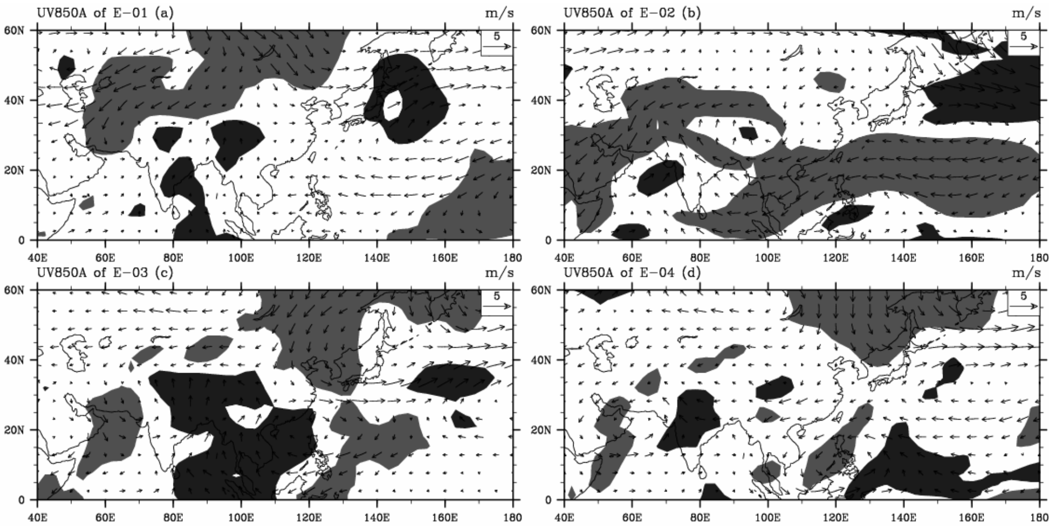

Fig. 4. Same as Fig. 3, but for wind anomalies at 850 hPa (unit: m s^{-1}) (shaded areas indicate that either zonal or meridional wind is significant above the 90% confidence level.)

These results indicate that the SSTAs over each oceanic region contribute to the intensification of blocking over the Urals Mountains and the East Asian trough. However, the influence of the SSTAs differs from one oceanic region to another in some aspects. The SSTAs over the North Atlantic have an impact on the Z500A over mid- to high- latitudes and almost have no effect over low latitudes (Figs.3a & 4a). Due to the effect of the warm SSTAs over Kuroshio there are a stronger subtropical high that spreads farther north than normal and an anomalous easterly that dominates the northwest Pacific Ocean (Figs. 3c & 4c). The warm SSTAs over the tropical Indian Ocean may have caused the notable negative Z500A from West Asia to Central Asia, as well as the remarkable anomalous southwesterly from the tropical Indian Ocean to South China and anomalous anticyclone circulation over the South China Sea-Philippine Sea region (Figs. 3c & 4c), which do not appear in the other three figures. The impacts of the La Niña event include the enhanced Ural blocking and intensely developed East Asian trough, as well as the strong anomalous northerly over the mid- to high- latitudes of East Asia (Figs. 3d & 4d). These results suggest that due to the effect of the La Niña event the winter monsoon is stronger than usual, with anomalous cool northerly over the southeastern coastal areas of China.

3.3 *Results of experiments E-123, E-134, E-234, and E-124*

The simulated Z500A and 850 hPa anomalous winds of experiment E-123 are shown in Figs. 5a & 5b. In E-123, we considered the impacts of the SSTAs over the tropical Indian Ocean, Kuroshio and the North Atlantic on the atmospheric circulations without considering the effects of the SSTAs over the tropical Pacific. The large differences between E-123 and E-1234 highlight the strength of the Z500A around the Ural Mountains and the East Asian trough, which are much weaker than in E-1234. These mean that the La Niña event has an important impact on blocking intensification over the Urals and the East Asian trough.

The results of sensitivity experiment E-134, which did not consider the effects of the SSTAs over Kuroshio, are shown in Figs. 5b & 6b. The positive Z500A over the western Pacific of E-134 is much weaker compared to that of E-1234, suggesting the warm SSTAs over Kuroshio take a significant role in causing the western Pacific subtropical high, which is stronger and farther northward. The warm SSTAs over Kuroshio play an active role in causing the conditions in the subtropics similar to those in winter during El Niño events. Also, the negative Z500A from Japan to East China in Fig. 5b is much weaker than in E-1234. This indicates that the warm SSTAs over Kuroshio have an impact on the intensification of the East Asian trough. The 850 hPa anomalous winds of E-134 are similar to those of E-1234, but with slight modifications.

Ignoring the effects of the warm SSTAs over the

North Atlantic, the blocking over the Urals and the negative Z500A along East Asia in Fig. 5c are much weaker than those in E-1234. There is no remarkable difference in the simulated 850 hPa wind anomalies between E-234 and E-1234, except for weak anomalous northerly located at the mid- to high-latitudes in Fig. 6c. Results indicate that the SSTAs over the North Atlantic have a significant effect on the blocking over the Urals and the East Asian trough and almost have no effect at low latitudes.

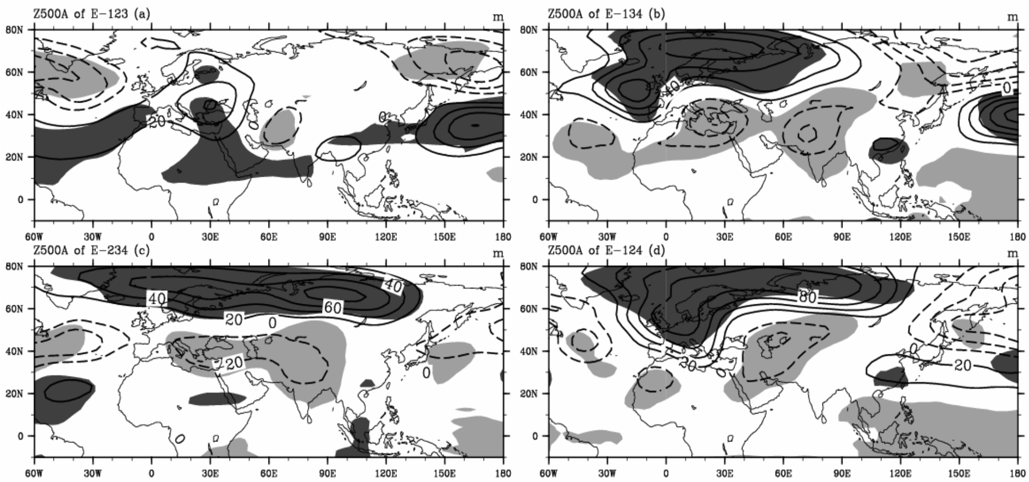

Fig. 5. Same as Fig. 3 but for the results of (a) E-123, (b) E-134, (c) E-234 and (d) E-124

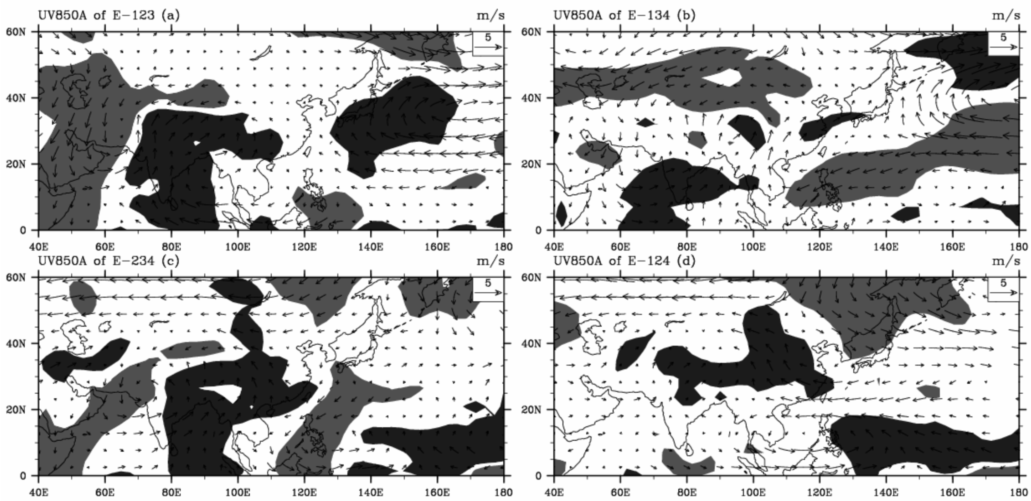

Fig. 6. Same as Fig. 4, but for the results of (a) E-123, (b) E-134, (c) E-234 and (d) E-124

Without the effect of the warm SSTAs over the tropical Indian Ocean, the distribution of Z500A in E-124 (Fig. 5d) is similar to that in E-1234. However, the simulated southwesterly anomalies at 850 hPa from the Bay of Bengal shown in Fig. 6d are much weaker than in E-1234. Also, the anomalous anticyclone circulation over the South China Sea-Philippine Sea region does not appear in Fig. 6d, but is established in E-1234. These results suggest that the warm SSTAs over the tropical Indian Ocean contribute to the transportation of warm and wet air from the tropical Indian Ocean and the western Pacific to South China.

By comparing the effects of the SSTAs over the different oceanic areas on the anomalous atmospheric circulations, we notice that the anomalous atmospheric circulations in E-1234 are in closer agreement with observations than the other experiments. All of the SSTAs over the four selected regional waters have notable contributions to the anomalous atmospheric circulations in January 2008 over Eurasia. However, the combined effects of the SSTAs over the four key regions are likely to be more important to the atmospheric circulation anomalies in January 2008 over Eurasia than the effects of individual or partly-combined SSTAs. Finally, we must note that the results of E-1234 are not simply a superposition of the results of E-01, E-02, E-03, E-04, but rather demonstrate a nonlinear effect of the combined SSTAs over the four key oceanic regions. This unusual SSTAs distribution possibly leads to the unique circulation anomalies over Eurasia in January 2008.

4 DISCUSSION

Many studies have discussed the mechanisms by which the SSTAs caused the formation of anomalous atmospheric circulations over Eurasia in winter. Studies have shown that SSTAs over the tropical eastern Pacific can initiate western Pacific and Pacific-North American (PNA) teleconnections that affect the East Asian and even global climate[12, 18, 19]. The forcing of the remote El Niño/Southern Oscillation (ENSO) through such an atmospheric teleconnection on the atmospheric circulation over Eurasia is no doubt an essential cause. Furthermore, scientists have found that the SSTAs over extratropical regions such as Kuroshio and the Atlantic also had important effects on the atmospheric circulation anomalies over East Asia. When the warm SSTA appeared over Kuroshio from November to December, there would be a 500 hPa pressure trough over Europe in January[9, 20, 21]. Warm SSTAs over Kuroshio also led to a higher geopotential height and a more northward western Pacific subtropical high than normal over the coast of East Asia. SSTAs over the Northwest Atlantic initiated the Eurasian pattern (EU) teleconnection, and they would have led to a positive Z500A persisting over the Ural Mountains due to the effect of warm SSTAs over the Northwest Atlantic[5, 22, 23, 24].

Previous studies have mostly focused on the mechanisms of SSTAs over the tropical Pacific, the Northwest Atlantic and Kuroshio and their effects on the atmospheric circulations over Eurasia in January 2008[5, 8, 9, 10]. However, few studies have addressed the issue of how SSTAs over the tropical Indian Ocean affected the atmospheric circulations in winter. This paper addresses this issue. The Indian Ocean basin-wide mode index (IOBMI, as defined in Yang and Liu[25], with a monthly SSTA averaged over 20ºS–20ºN, 40–110ºE), was used as the indicator for basin-wide warming or cooling events occurring in the tropical Indian Ocean. From 1978–2000 there were five years when basin-wide warming SSTAs appeared over the tropical Indian Ocean in winter (the IOBMI > 0.7 standard deviation): 1978, 1983, 1988, 1991 and 1998. We make a composite of the 850 hPa wind anomalies for the five warm events (figure omitted). The notable easterly anomalies over the equatorial Indian Ocean in the figure indicate the weakness of the Indo-Pacific Walker circulation and the suppressed convection over the Maritime Continent. Finally, an anomalous anticyclone circulation, which transports warm and moist air from the tropical northwestern Pacific, is prominent in the South China Sea-Philippine Sea region, being a Rossby wave response to the negative anomalous rainfall caused by the suppressed convection[26, 27]. Furthermore, the strong land-sea thermal contrast is favorable to the formation of an anomalous southwesterly flow from the Bay of Bengal to South China. These results suggest that the warm SSTAs over the tropical Indian Ocean in January 2008 contribute to the transport of warm and moist air from the Indian Ocean, the Bay of Bengal and the tropical northwest Pacific to South China.

5 SUMMARIES

In this study, we discussed the atmospheric circulation anomalies over Eurasia as a response to SSTAs over the tropical Indian Ocean, the equatorial Pacific, Kuroshio and the North Atlantic in January 2008. The results show the following:

(1) The combined effect of the SSTAs over the four oceanic regions is the key cause for the anomalous atmospheric circulations over Eurasia in January 2008. Under the combined influence of these SSTAs over the four oceanic regions, experiment E-1234 showed the best simulation of the anomalous atmospheric circulations over Eurasia in January 2008.

(2) The SSTAs over each key region contribute to the intensification of blocking over the Urals Mountains and the East Asian trough. However, the influence of the SSTAs differs from one oceanic region to another in some respects. The SSTAs over the North Atlantic have impacts on the Z500A over mid- to high-latitudes and almost no effect on the Z500A over the low latitudes. Due to the effect of the warm SSTAs over Kuroshio there are a subtropical high, which is much stronger and spreads farther north than usual, and a dominating anomalous easterly over the northwest Pacific Ocean. The warm SSTAs over the tropical Indian Ocean may cause the negative Z500A from West Asia to Middle Asia, the remarkable anomalous southwesterly from the tropical Indian Ocean to South China and the anomalous anticyclone circulation over the South China Sea-Philippine Sea region. The impacts of the La Niña event included a winter monsoon that is stronger than normal and an anomalous cool northerly over the southeastern coastal areas of China.

(3) The combined effect of the SSTAs over the four key regions is more important to the atmospheric circulation anomalies over Eurasia in January 2008 than the effects of individual or partly combined SSTAs. It is possible that the unusual SSTAs distribution leads to the unique circulation anomalies over Eurasia in January 2008, especially the atmospheric circulation anomalies over the subtropics which are similar to those of winter El Niño events but different from the circulation anomalies in response to the La Niña events.

The CAM3.0 used in this study properly simulated the responses of the atmospheric circulation anomalies to the SSTAs over the four key regions. However, the present findings suggest that coupled ocean-atmosphere processes are crucial in the monsoon regions, where the atmospheric feedback on SST is important. It is necessary to consider coupled atmosphere-ocean interactions using CGCM (Coupled Ocean- atmosphere General Circulation Model) to confirm the conclusions in this study and to improve the understanding of the effects of the SSTAs on the atmospheric circulation anomalies in January 2008. In addition to the SST forcing, soil moisture and snow cover may have contributed to the formation of the atmospheric circulation anomalies, and these factors should also be studied in the future.

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