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Numerical Simulations of Anomalies of Precipitation and Surface Air Temperature in China in the Summer of 1997①

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ABSTRACT

The anomalies of precipitation and surface air temperature in the summer (June to August) of 1997 are simulated by use of a global spectral numerical climate model (L9R15) developed in Australia originally and modified in LASG. The purpose of this paper is to study the effect of the El Nino event that happened in that year on the anomalies. The results show that the 1997 El Nino event does have a lot of influences on the climatic anomaly in that summer, however, the effect is not the same as pointed out by statistical studies. Therefore, the effects of the El Nino events are of uncertainties. The effects of the El Nino events on the regional climate in China might be different due to the different SSTA distributions over the western and northwestern Pacific in the El Nino years. It is likely more important to pay attention to the SSTA distributive patterns and values in the Chinese adjacent oceans. Besides the El Nino event there might be other factors such as the South Asia high at the 100 hPa level which has more direct impact on the climatic anomaly in China and can be taken as another strong signal of the climatic change in the atmosphere.

Key words: Climatic anomalies, Numerical modelling, Effect of El Nino event

1. Introduction

Statistical studies demonstrated that in El Nino years the precipitation in summer in the Changjiang River and Huaihe River Basins is probably above the normal while it is possibly below the normal in the northern China and the Hetao (the Great Bend of the Huanghe River) region. The temperature in summer is usually lower than normal in East Asia, especially in Northeast China. There were 6 years with severe low temperature since 1951, and they are 1954, 1957, 1964, 1972, 1976 and 1983, which are all related to the El Nino years (see Huang et al., 1989, 1992; Xiang and Bao, 1991; Chen, 1990; Wang, 1990; Wang and Zhu, 1986). Of course, there are some different openings about the influences of El Nino on the climatic change of China. Some scientists pointed out that the influences are dependent on whether the El Nino event is in the period of development or at the stage of decaying. In the years of El Nino development the precipitation in the Changjiang River valley in summer is usually above the normal and vise versa in the years of El Nino decaying. Other scientists suggested that only in the years of El Nino decaying the precipitation in the Changjiang River valley is above the normal, such as in 1998. The above openings are evidently in contrary.

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Therefore, more observational studies are needed and the above different results are worth being verified by numerical simulations.

The 1997 El Nino event is the strongest one in the century and should have large influences on the climate in China. This event starts from May 1997 and reaches the largest strength in November and December, therefore, 1997 summer is in the stage of El Nino development, and the precipitation should be larger than normal according to most results of statistical studies. What are the distributions of the anomalies of precipitation and surface air temperature in China in the summer of 1997? If the 1997 case perfectly agrees with the statistical results, then we may conclude that the El Nino event does have typical deterministic functions on the climate of China, if not, then other questions are rising: firstly, are the observed anomalies still induced by the El Nino event? Whether do the effects have uncertainty which makes the anomalies different from that found by the statistical studies? Secondly, if the El Nino event is not the only factor, then to what extent does the El Nino event have its influence? Are there other factors influencing the anomalies in China?

In order to answer those questions, we are going to analyze the distributive patterns of the observed anomalies of precipitation and surface air temperature in the summer of 1997 first. The data are taken from the 160 surface observational stations in China in 48 years (1951–1998). And then we will simulate the anomalies by use of a numerical model in order to assess the effects of the El Nino event on the regional climatic anomalies of China and to understand the possible mechanisms.

2. Anomalies of precipitation and surface air temperature in the 1997 summer

Figures 1a, 1b, 1c and 1d are the June, July, August monthly and June–August seasonal mean anomalies of precipitation (unit: mm/d) in China in 1997 obtained from the corresponding monthly and seasonal mean of the 48 years, respectively. Fig. 1a shows that in June 1997 the precipitation in most areas of China including Northeast China, North China, East China and the west part of South China is less than normal, especially in the lower reaches of the Changjiang River, the precipitation is much smaller. Only the southwestern China, the east part of South China and the south part of East China are the areas with more precipitation. However, the areas with more precipitation are small and isolated from each other. In July 1997 (Fig. 1b) the situation is remarkably changed. The anomaly values of precipitation are much larger than those in June, the largest area with less precipitation is still located in the west part of the mid China, North China and Northeast China, however, the less precipitation area originally located in the lower reaches of the Changjiang River in June now shrinks northward. Therefore, a large area from the south of the Changjiang River to the coastal region of South China, the mid Changjiang River valley, especially the east part of the mid China between the Changjiang River and the Huanghe River, and Southwest China become the areas with large positive precipitation anomalies. The above analysis indicates that the July precipitation anomaly is much more severe than that in June and somewhat agrees with that of statistical results in the El Nino years. In August (Fig. 1c) the distribution of the precipitation anomalies is evidently changed again. The eastern coastal regions of China including most part of Northeast China, the east part of North China, East China and South China, become the area with more precipitation than normal. While a large area in the mid part of China, from the west part of North China to the upper and middle reaches of the Changjiang River, becomes the area with negative anomalies of precipitation. The anomaly values are a little smaller than that in July, but much larger than that in June. The seasonal

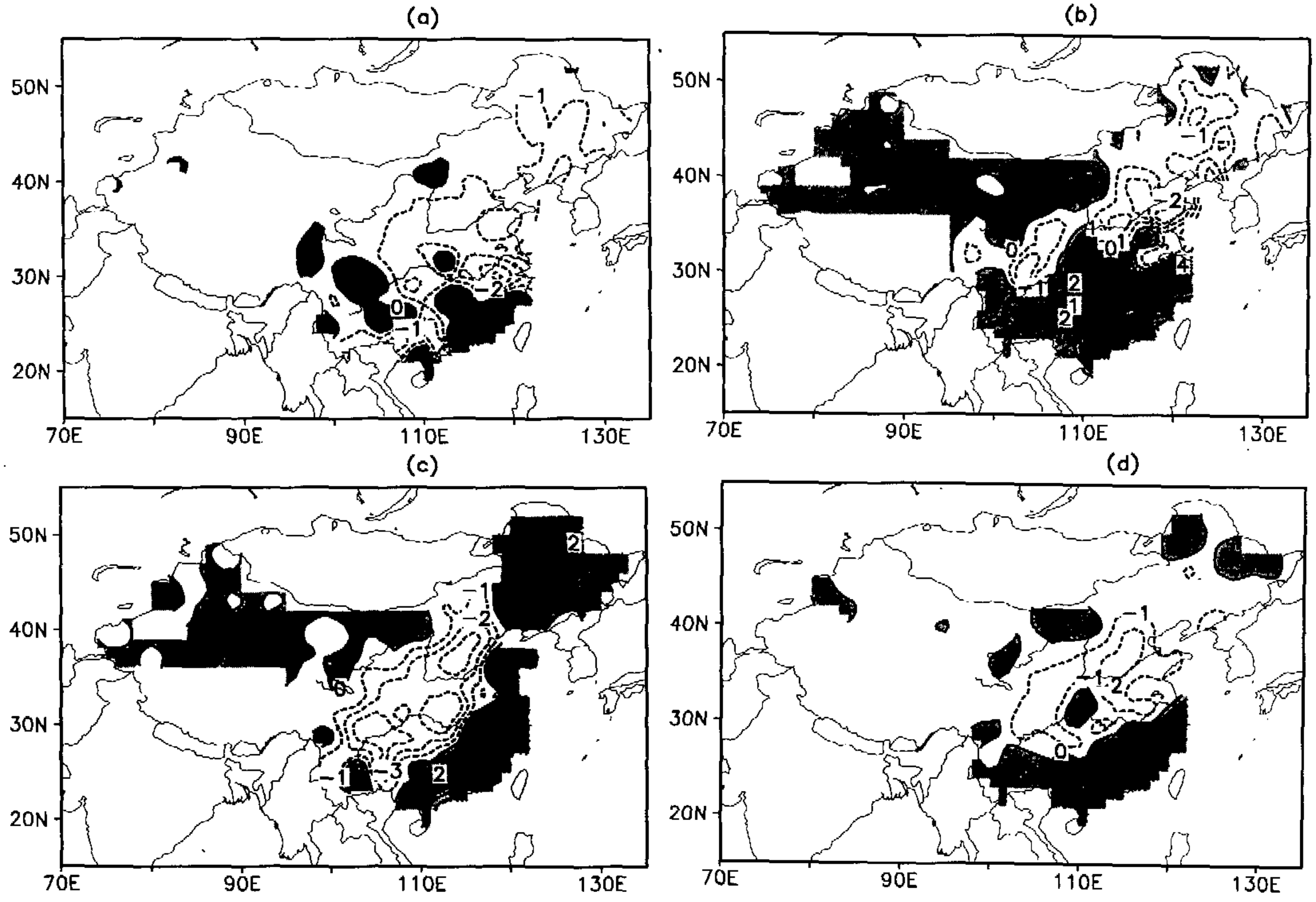

Fig. 1. June (a), July (b), August (c) and June—August seasonal mean anomalies (d) of precip- itation (mm / d) in the 1997 summer in China.

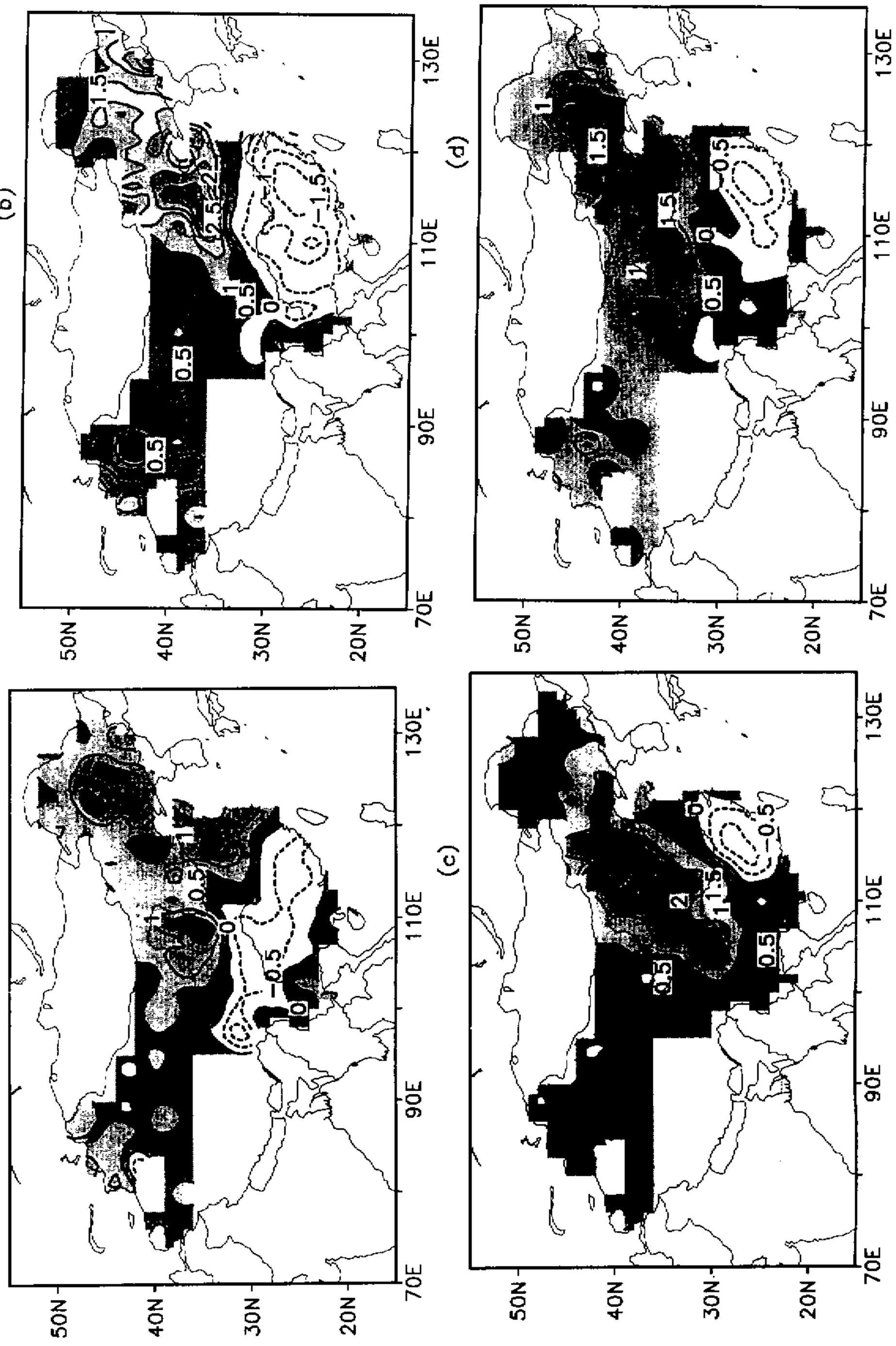

Fig. 2. June (a), July (b), August (c) and June–August seasonal mean anomalies (d) of surface air temperature (°C) in the 1997 summer in China.

(June–August) mean anomalies are shown in Fig.1d and it is seen that the distribution of anomalies is quite different from that in individual months. The precipitation is less than normal in a large area in China except for the area south of 25°N and some small regions isolated from each other.

Figures. 2a, 2b, 2c and 2d are the same as Fig. 1 but for surface air temperature (unit: oC). It is seen From Fig. 2a that in June 1997 the temperature in South China, south of 30°N, is lower than normal by a value of −0.5°C or even lower. It is higher than normal in other areas. Large positive anomalies of temperature are located in North China, Northwest China and Northeast China, as well as in the lower reaches of the Changjiang River, with a maximum value of 1.5°C or even higher. The temperature anomalies in July (Fig. 2b) are much more evident than that in June, however, the distribution of the anomalies is not much changed. The area north of 32°N is of large positive anomalies with a maximum value of more than 3°C in the middle reaches of the Huanghe River. The negative anomaly area south of 30°N in June now expands northward to 32°N and southward to the whole South China and the minimum value is lower than −1.5°C. The case is somewhat changed in August (Fig. 2c). The anomaly values are less than that in July but higher than that in June, the positive anomaly area in North China expands southwestward and the area with negative anomalies in South China shrinks. The seasonal mean anomaly distribution (Fig. 2d) shows similar characteristics as in August, but the negative anomaly area is a little larger and the maximum positive anomaly located in the middle reaches of the Huanghe River is 2°C.

It is also seen from Fig.1 and Fig.2 that the positive anomalies of precipitation normally match the negative anomalies of surface air temperature and vice versa.

The above analysis indicates that in the summer of 1997 severe climatic anomalies of precipitation and temperature took place. The distributions of the precipitation and the temperature anomalies show that generally speaking, the north part of China, north of the Changjiang River, is dryer and warmer than normal and South China is wetter and cooler. The anomaly distributive patterns are of the large scale features and not so typical as that pointed out by the statistical studies for the El Nino years, especially, the pattern of temperature anomalies is almost in opposite phase. Therefore, there must be two possibilities, one is that the anomalies of precipitation and temperature in the 1997 summer should not be only influenced by the El Nino event of that year, then to what extent does the event affect the anomalies? The another is that the anomalies are still mainly induced by the El Nino event, but its effect on the anomalies is different from that pointed out by the statistical studies. This means that the El Nino event has uncertain effect on the regional climate of China. Both possibilities need to be estimated by numerical simulations.

3. The model and the experimental schemes

Due to the large scale characteristics of the anomalies, coarse resolution numerical models may be used. The model we used is a global spectral model that was originally developed by Bourke et al. and largely improved by Wu et al. in LASG. The main improvements are the following. Firstly, the scheme of radiation is changed by use of Shi's *k*–distribution, and the diurnal variation of the solar radiation is also introduced by Shao et al. (1998); Secondly, the cloud sorts and the cloudiness are determined by the model produced moisture concentration; Thirdly, the land process of SSiB is added. With the above modifications the model has better performance than previous versions in climatic modelling. We use L9R15 to denote the model because it has a 15–wave–number rhomboidal truncation and 9 vertical σ levels. The detailed descriptions of the modifications can be found in papers written by Wu et al. (1996, 1997), Shao and Qian (1998).

In order to simulate the effect of the El Nino event in 1997 on the summer climate, two experiments are conducted. The first utilizes the multi–yearly monthly mean sea surface temperature (SST) as the model forcing and the forcing of the second experiment is the same monthly mean SST plus the corresponding monthly anomalies (SSTA) in June–August, 1997. The daily SST and SSTA are interpolated by using two adjacent monthly mean SST and SSTA data. The May 31 data created by the model itself are used as the initial fields, in such a way the bifurcation of results would be excluded and the commonly used ensemble scheme is not necessary. The two experiments are both integrated from May 31 to August 31. The first experiment is designated with CNL and the second with ANM hereafter.

4. Analysis of the model results

The L9R15 model can produce a lot of output fields such as the geopotential height, the velocity, the diabatic heating and so on. However, in order to save space, next we are going to discuss only the precipitation and the surface air temperature fields. In order to show the model performance in simulating the summer climate, the simulated and the observed June–August seasonal mean precipitation and temperature fields are given in Fig. 3 and Fig. 4, respectively, with (a) denoting the precipitation and (b) the temperature. The observations are obtained from 160 surface stations in China and averaged over 48 years.

From a comparison of Fig. 3a with Fig. 4a we can see that the main pattern of precipitation in China is not fairly simulated except for South China. It is seen that the observed largest precipitation is in the South China coastal area and the smallest precipitation happens over Northwest China including most desert areas. However, the simulated large precipitation area is only located in South China and Southwest China, the main precipitation zone along the east coastal area is missing. So the lower reaches of the Changjiang River become a relatively less–precipitation area, and the model–produced precipitation amount is somewhat too small in the south of the Changjiang River. Such discrepancies perhaps result from the systematic errors of the model in the simulation of precipitation in individual months, and it is found that the model cannot correctly simulate the June and July precipitations in East China. Comparatively speaking, the August simulation is better.

As far as the temperature field is concerned, we can see from Fig. 3b and Fig. 4b that the basic distribution simulated by the model resembles the observation very well. The simulated highest temperature area is located in the southeast part of China with the seasonal mean temperature above 20°C. The lowest temperature is undoubtedly over the Tibetan Plateau area, and the northeast part of China is a relatively low–temperature region, too. All those features agree with the observed ones. However the simulated distribution of the temperature is too simple to describe the local characteristics, the model cannot resolve the small low–temperature region in the west part of Northeast China and the high–temperature regions in the desert area of Northwest China as shown in Fig. 4b. Besides, the simulated temperatures in the southeast part of China are about 4°C lower than the observed ones on an average. Those discrepancies might be partly caused by the coarse horizontal resolution of the model.

From the above discussion we may conclude that the coarse resolution model such as L9R15 cannot reproduce the detailed structures of the climatic elements very well, therefore, if one wants to simulate the detailed mean regional climate, models with more high resolution

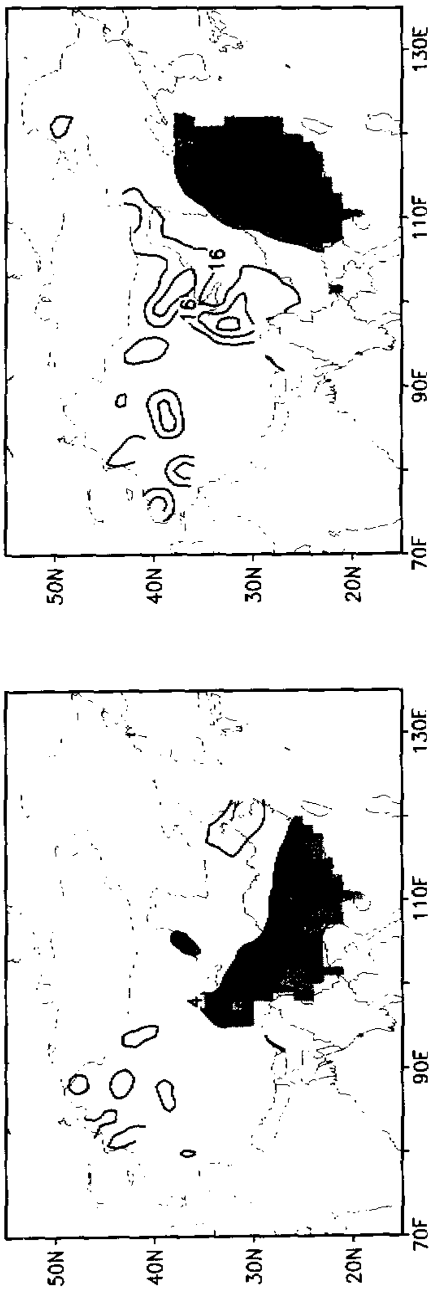

Fig. 3. Simulated June–August seasonal mean precipitation (a, in mm / d) and surface air temperature (b, in °C).

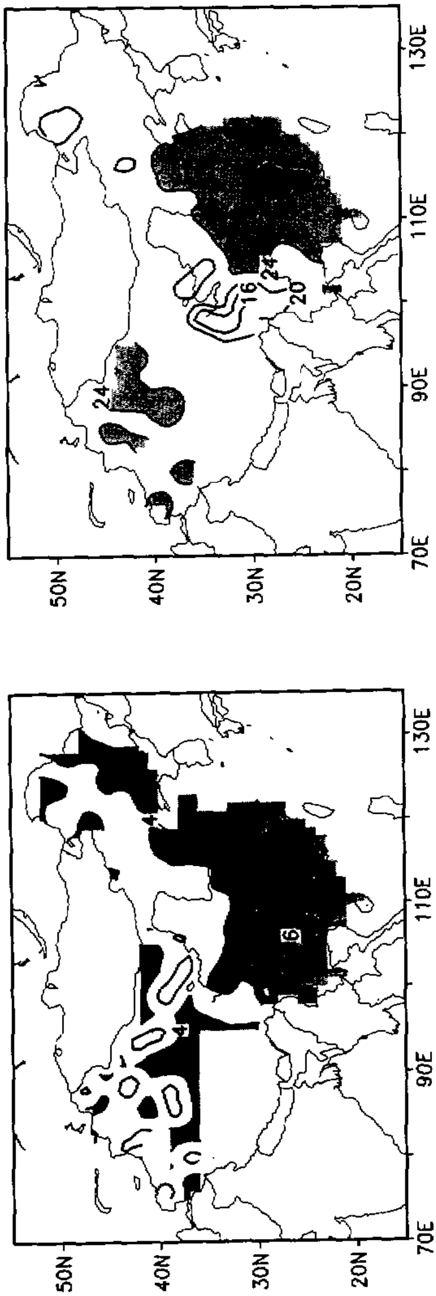

Fig. 4. Observed June–August seasonal mean precipitation (a, in mm / d) and surface air temperature (b, in °C).

should be used. However, the anomaly distributions in the 1997 summer are of large scale features, so L9R15 might be used for the simulations of anomalies.

Figures 5 and 6 are the differences of precipitation and temperature between the two experiments of CNL and ANM, respectively, for June (a), July (b), August (c) and June–August seasonal (d) means. Those differences are taken as the anomalies. The climate drift of the model L9R15 may be partly removed in such a way.

From Fig. 5a it is found that in June the simulated general characteristics of the precipitation anomalies are partly similar to those of the observed ones (Fig. 1a), the negative anomalies are located in North China, the east part of West China and South China, while the positive anomalies are in Northeast China and along the Changjiang River and the Huaihe River valleys. The detailed distribution is quite different from the observed one. Especially in the coastal region of South China and the east part of Northeast China, the anomalies are out of phase. Moreover, the regions along the Changjiang River and Huaihe River should be the areas with negative anomalies, but the model gets positive anomalies. Besides, the amount of simulated precipitation anomalies is much smaller than the observed one. However, the simulated pattern is comparable with the typical one of the El Nino years. In July (Fig. 5b) the simulated positive anomalies of precipitation are mainly located in the west part of South China and the lower reaches of the Changjiang River, while the negative anomalies are in other regions. The July simulation is better than the June simulation. However, the positive anomaly area is too small compared with the observed one (Fig. 1b). The simulated August anomalies (Fig. 5c) are most different from the observed ones except for South China, the east part of Northeast China and the east coastal areas. The observed negative anomalies west of 110°E (Fig. 1c) are reproduced as positive ones and totally in opposite phase. The distribution of the simulated seasonal mean anomalies (Fig. 5d) shows similar characteristics to that in June and July. That is, the west part of South China, Southwest China, the lower reaches of the Huanghe River and the Changjing River and the east part of Northeast China are the positive anomaly areas. While most areas of North China, the west part of Northeast China, the upper and the middle reaches of the Huanghe River are the areas with negative anomalies of precipitation. Compared with Fig. 1d it is found that the anomaly distributions of the observed and simulated precipitation are basically similar except for the east part of South China where the simulated anomaly is negative while the observed one is positive and the lower reaches of the Changjiang River where the simulated one is positive while the observed one is negative.

From the above analysis we can find that the simulated June and June–August seasonal mean anomalies of precipitation are quite typical to the statistical situation of the El Nino years. The July simulation is fair, the simulated pattern of anomaly is generally similar to the observed one, with some discrepancies in the east part of South China, the lower and middle reaches of the Changjiang River, where the simulated and observed anomalies are out of phase. The August simulation is the worst. The large area west of 110°E with observed negative anomalies is roughly reproduced as the positive anomaly area. It is only right in East China including the east part of Northeast China, North China and the southeast coastal area.

The simulated temperature anomalies are shown in Fig. 6. Fig. 6a shows that in June the positive anomalies are mainly located in two areas, one is East China along the coast and the other is North China and Northeast China. The negative anomalies are located over Southwest China, the upper reaches of the Changjiang River and the Huanghe River. Compared

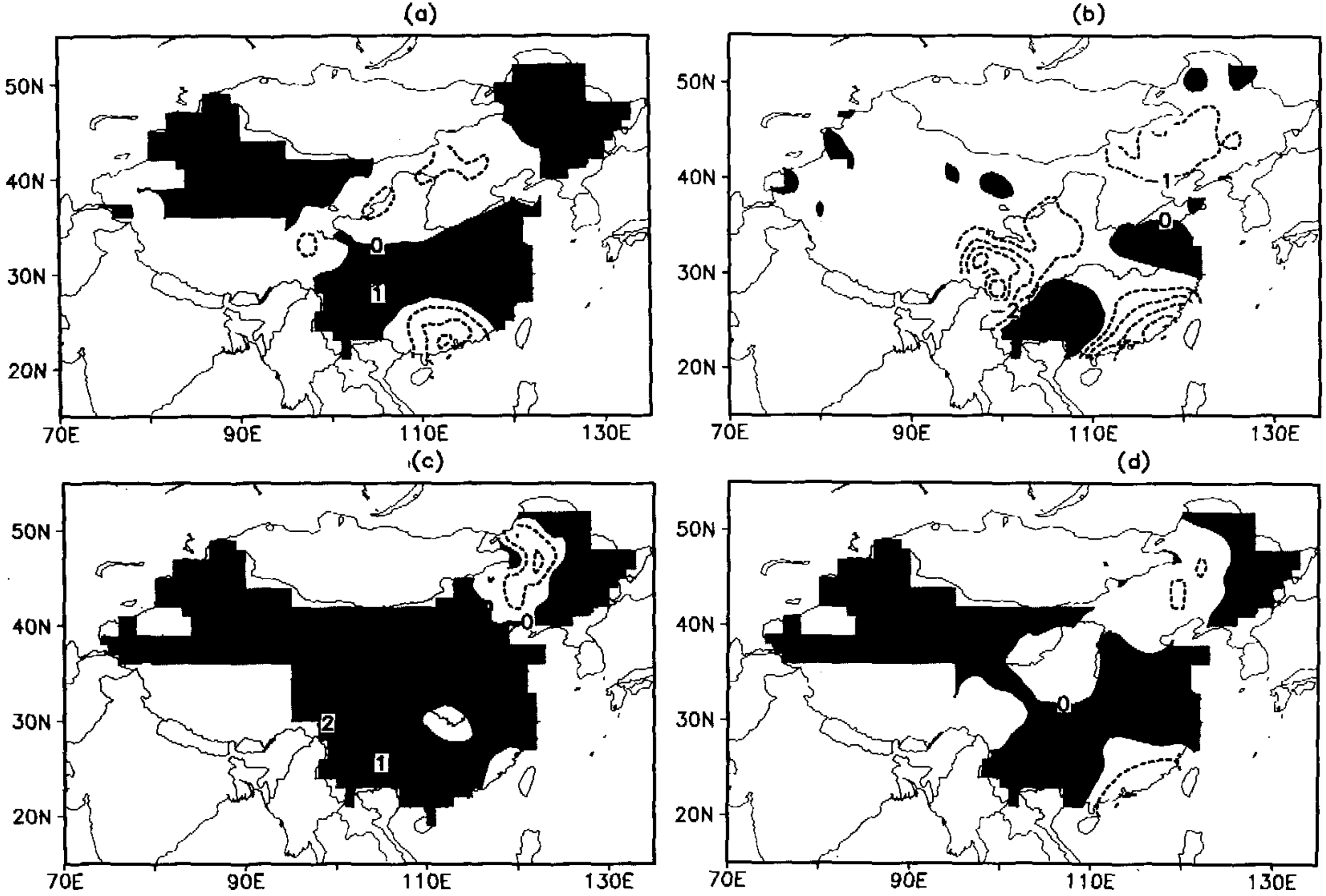

Fig. 5 Simulated June (a), July (b), August (c) and June–August seasonal mean anomalies (d) of precipitation (mm / d) in the 1997 summer in China.

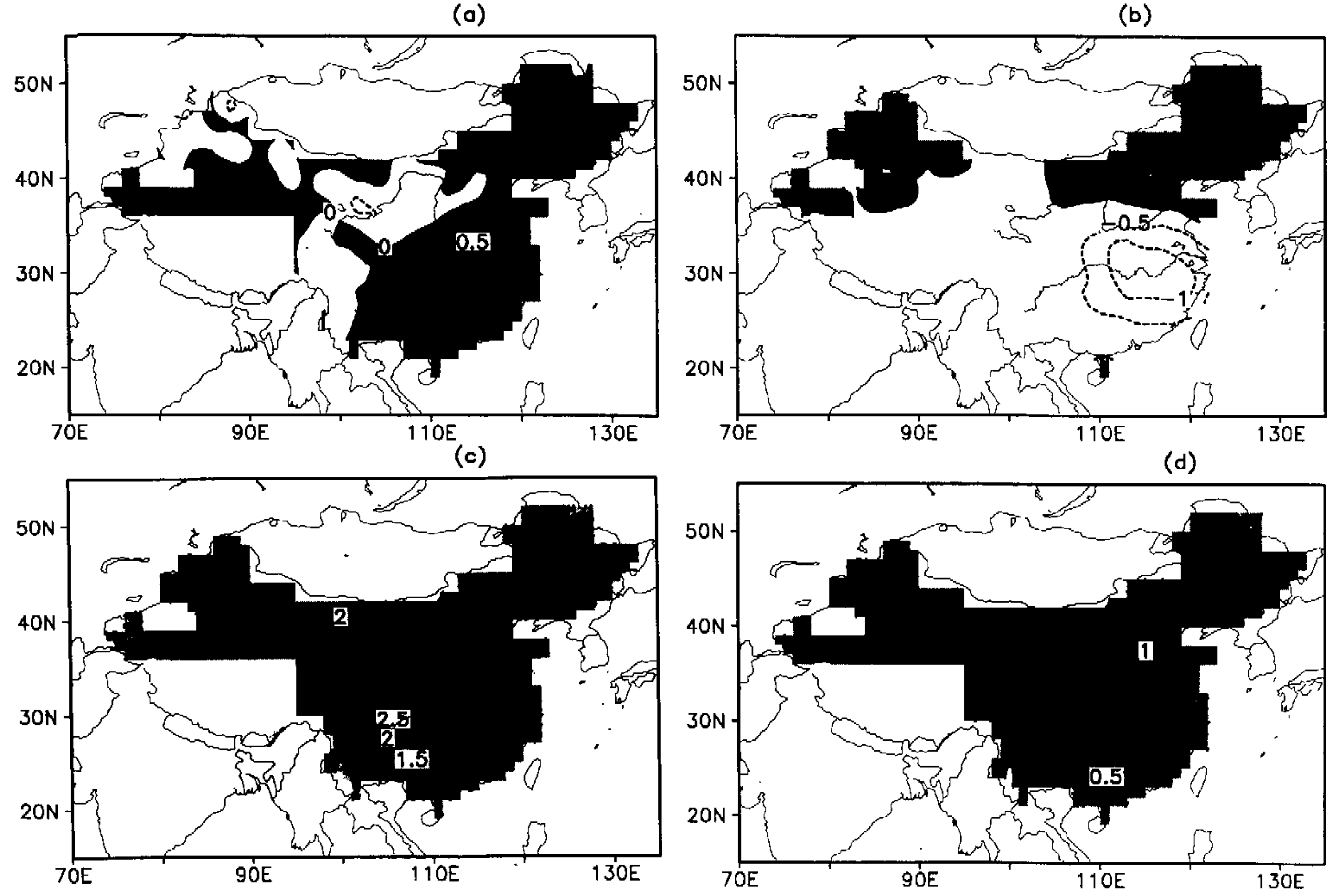

Fig. 6. Simulated June (a), July (b), August (c) and June–August seasonal mean anomalies (d) of surface air temperature (°C) in 1997 summer in China

with the observation it is evident that the anomalies in North China and Northeast China, the southwest part of China and the upper reaches of the Changjiang River are basically consistent with the observation and the others are almost out of phase (see Fig. 2a), especially in South China. In July (Fig. 6b) the simulated anomalies are positive in North China and Northeast China north of 40°N, and negative south of 40°N. Such a distribution is basically similar to the observation (Fig. 2b). However, the area with positive anomalies is too small, while the area with negative anomalies is too large. The distribution of the simulated August anomalies of the surface air temperature (Fig. 6c) is the best and quite similar to the observation (Fig. 2c) with positive anomalies in the whole China. The maximum center of the positive anomaly is located in North China with values of more than 3°C. This center is consistent with the observation (Fig. 2c). However, the observed negative anomalies in the small coastal area of East China and South China are not reproduced. Fig. 6d shows the most similar distributive pattern of the seasonal mean anomalies to that in August. The simulated maximum positive anomaly in North China exceeds 1°C. Comparing Fig. 6d with Fig. 2d it is found that most positive anomaly areas are the same, but with a big discrepancy in South China where the observed anomalies are negative with a center value lower than −1°C while the model produces positive anomalies.

Besides the above shortcomings of simulation, a comparison of Fig. 6 with Fig. 5 reveals that the simulated anomalies of precipitation and surface air temperature do not fairly match each other as it is in observation.

The above analysis indicates that the simulation qualities of the individual monthly anomalies of precipitation and temperature are different in different months. The simulations of the temperature anomalies are much better than those of the precipitation anomalies. It may demonstrate the different mechanisms of the anomalies in individual months as well as between the precipitation and the temperature anomalies.

5. Discussions and brief conclusions

The observed distributions of the anomalies are not so typical as those found by statistical studies which mean that the El Nino event might have influences on the anomalies in different months to different extent and in different types. In some El Nino years the effect results in more precipitation in the Changjiang River valley and lower temperature in East Asia. While in other El Nino years the effect is different, even opposite such as in the 1997 summer, that is, in North China and Northeast China the precipitation is less and the temperature is higher than normal, and in South China the case is reverse. The reason is possibly that the effect of the El Nino event is determined not only by the SSTA over the middle and the eastern equatorial Pacific, but also by the SSTA over the western and northwestern Pacific, especially by the SSTA over the adjacent oceanic areas of China. In different El Nino years, the SSTA pattern in the middle and eastern equatorial Pacific may be generally the same, but in the oceans adjacent to China the SSTA patterns may be quite different. It is those differences in SSTA patterns that produce different effects of El Nino and La Nina events on the regional climate of China. Moreover, even in the El Nino years, the distributive patterns of the SSTA in the great oceans such as the Pacific, the Atlantic and the Indian Oceans are not always the same. Therefore, in order to predict the climatic anomalies in China better, it is more necessary to pay our attention to the SSTA patterns in the oceans adjacent to China.

The general similarities of the simulated anomalies of precipitation and surface air temperature to the observed ones indicate that the anomalies of precipitation and temperature, especially the anomalies of temperature, in China in the 1997 summer are basically caused by the 1997 El Nino event, because we used the real time monthly mean SSTA as the model forcing.

The disagreements between the simulated and the observed anomalies reveal two causes. One is the systematic error of the model we used due to its coarse resolution and some non–adequate dynamical and physical parameterization schemes. However, the general capacity of the model has been proved fair, so those systematic errors would not be very serious. The other cause , therefore, is that there are other factors which simultaneously influence the climatic anomaly in China. We have already found that the South Asia high (SAH) at the 100 hPa level has quite important impacts on precipitation and temperature. The SAH can also be considered as a strong signal of climate anomaly in China.

The above analysis and discussion lead to conclusions that the L9R15 model has certain capacity to simulate the large–scale climatic anomalies. But the performance of simulating the mean precipitation pattern is not very ideal. Therefore, for more detailed climatic changes, especially for more detailed mean climatic patterns, it is necessary to use higher resolution models or the nested regional climate models.

The large–scale characteristics of the simulated climatic anomaly, especially the temperature anomaly, in the 1997 summer are basically similar to the observed ones, hence, we may infer that the climatic anomaly still results from the 1997 El Nino event. The impact of the event is different in individual months. Moreover, it is very possible that the effect of the El Nino event on the regional climate in China is not certainly the same as that pointed out by the statistical studies, because the effect of the El Nino event is determined not only by the SSTA over the middle and eastern equatorial Pacific, but also by the SSTA over the western and northwestern Pacific, especially by the SSTA over the adjacent oceanic areas of China. We need to do more researches to understand the impact mechanisms of the El Nino event.

Besides the model errors in simulation, there must be other factors responsible for the anomalies in different months, too.

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