SIMULATION OF MONTHLY CLIMATIC MEAN FIELD IN JANUARY AND JULY IN QINGHAI-XIZANG PLATEAU AND NORTHWESTERN CHINA

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ABSTRACT

In this paper, we simulate the regional climate in summer and winter in northwestern part of China and the Qinghai-Xizang Plateau with regional climate model (MM4) nested with GFDL data, and compare the simulated results with observed data and GFDL data. The results show that the regional model reproduces the regional climate systems, such as the high pressure on the plateau and the low pressure in the north of the plateau in winter, the warm-low pressure over the plateau and pressure ridge in south and north of the Qinghai-Xizang Plateau in summer. These regional climate features could not be distinguished by the GCM. The simulations of precipitation distribution are reasonable. But differences between the simulated and observed precipitation values in some places are obvious. The precipitation in south of the Qinghai-Xizang Plateau is underestimated, and in north of the Qinghai-Xizang Plateau, the precipitation is overestimated. The simulation of height field is better than temperature field.

Key words: Qinghai-Xizang Plateau, climate simulation, regional climate

I. INTRODUCTION

Drought, flood, severe cold and hot have impacts on the environment, people's life and economy. Scientists have been paying more and more attention to the global and regional climate changes due to the intensified effects of people activities on the climate. The global climate model, as an important tool to study the climate, has developed rapidly, it could catch hold of the average of global climate and be used to study the cause of climate change with sensitive experiments. However, its low resolution and inability to describe in detail the different characteristics of different regions have limited its abilities to simulate the climate of sub-continent scale, especially that of the Qinghai-Xizang Plateau with complex terrain and surface feature. It is difficult to increase the resolution with limited computer resource. In recent years, scientists have tried to use the regional climate model to study the feature of regional climate. Giorgi and Bates (1989) developed a regional climate model nested with GCM and studied the regional climate. The results show that this kind of model could catch the regional climate feature which the GCM could not distinguish, and improve the simulations of rainfall and surface temperature (Giorgi 1990; Godzun 1995).

In China, some studies in the field of regional climate simulation have been done. Qian et al. (1997) used limited area model with p-σ hybrid coordinates to simulate the climate in East Asia. He concluded that the limited area model is able to reproduce more realistic climate which the GCM could not distinguish, the simulation of climate with limited area model is better than that with the GCM. Chen and Lu (1996) simulated the monthly climatic mean field over East Asia in July 1979 using a limited area model with the FGGE Ⅲ data, she improved the process of lateral boundary and initial condition of the model developed by Yan (1987) with a 1.875°×1.875° grid. Comparing the results of simulated monthly mean values with the observed values in July of the year shows that the limited area model could be applied to study regional climatic change and its simulated results are very close to the observed climatic mean field. But resolutions of the limited area models are not high enough to resolve some climate features with complex terrain. Liu (1994) simulated the monsoon development, movement of rain belt, and activities of cyclones, precipitation and surface temperature in East Asia by using regional climate model, and the simulated results are reasonable. There are wide plateau, grassland and desert with complex orography and surface parameters in the Qinghai-Xizang Plateau and northwestern China. The climate in the area is different from that in other places. It is useful and significant to study the climate and its cause of formation in the Qinghai-Xizang Plateau and the northwestern China with high resolution model.

II. MODEL AND EXPERIMENT DESCRIPTION

The Pennsylvania State University (PSU)/the National Center for Atmospheric Research (NCAR) meteorological model MM4 (Anthes et al. 1987) with "Arakawa B" grid structure, σ vertical coordination, grid distance of 120 km and time step of 2 min is used in this paper. The MM4 used here includes horizontal and vertical diffusions, convective adjustment, large-scale stable precipitation and cumulus parameterization.

The surface is divided into crop field, grassland, watershed, desert, swamp and forest. Table 1 shows the parameters of different surface, which are constant during model integration. Figure 1 shows the orography of the model and the parameters of land surface.

Table 1. The Parameters of Different Land Surface in Summer (S) and Winter (W)

Type of land	Albedo (%)		Moisture availability (%)		Emissivity (%)		Roughness length (cm)		Heat inertia (cal cm^{-2}K^{-1}s$^{-0.5}$)	
	S	W	S	W	S	W	S	W	S	W
crop	17	23	30	60	92	92	15	5	0.04	0.04
grassland	19	23	15	30	92	92	12	10	0.03	0.04
watershed	8	8	100	100	98	98	0.0001	0.0001	0.06	0.06
desert	25	25	2	5	85	85	10	10	0.02	0.02
swamp	14	14	50	75	95	95	20	20	0.06	0.06
forest	12	12	50	50	95	95	50	50	0.05	0.05

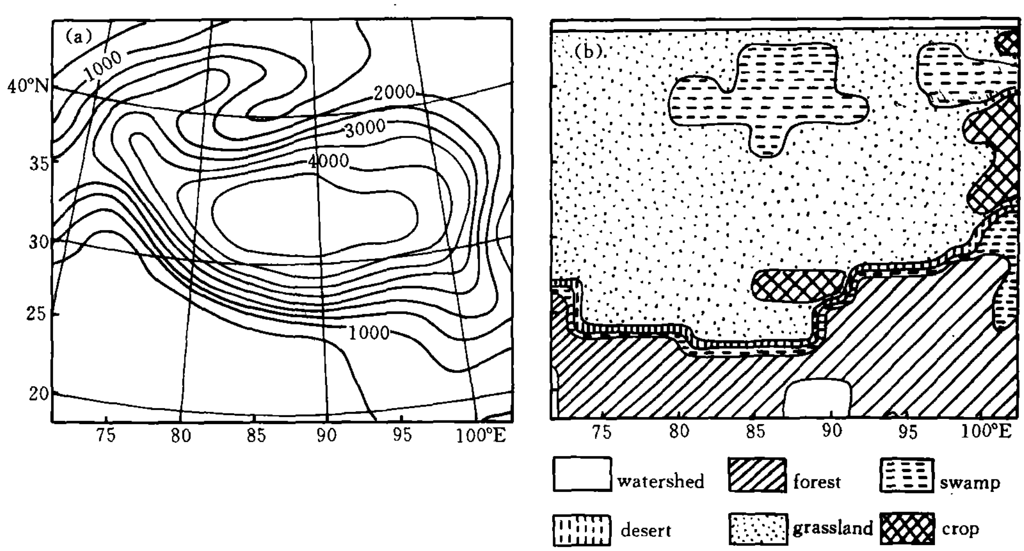


Fig. 1. The orography (unit: m) (a) and land parameters (b) of the model.

The lateral boundary condition is important to the regional climate model. The sponge lateral condition is used in this paper, which is defined as

$$\left(\frac{\partial \alpha}{\partial t}\right)_n = w(n)\left(\frac{\partial \alpha}{\partial t}\right)_{MC} + [1 - w(n)]\left(\frac{\partial \alpha}{\partial t}\right)_{LS}, \tag{1}$$

where α is any physical parameter, the subscript MC refers to the tendency of the model, the subscript LS refers to the large-scale tendency or observed tendency. n is the grid point ($n=1$ at the boundary). $w(n) = 0.0, 0.4, 0.7, 0.9$ when $n=1, 2, 3, 4$ for the "cross point" respectively. $w(n) = 0.0, 0.2, 0.55, 0.8, 0.95$ when $n=1, 2, 3, 4, 5$ for "dot point" respectively, for other grids, $w(n) = 1$.

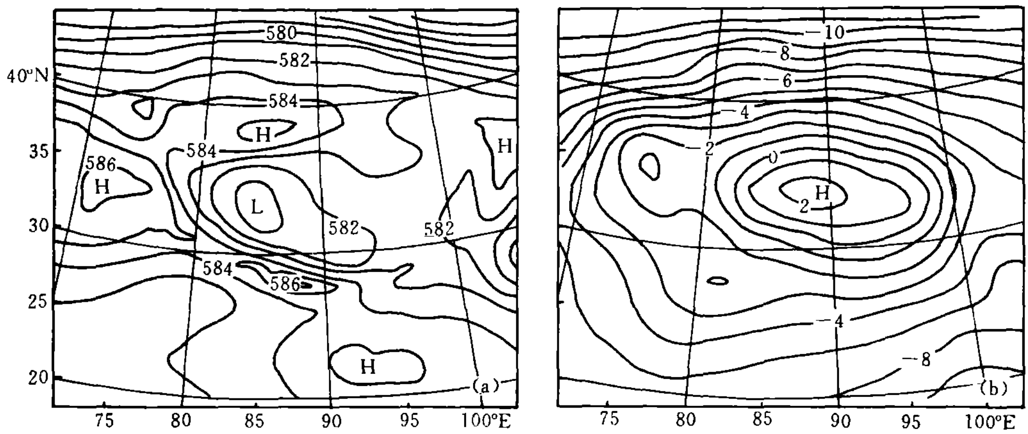
For the summer climate, we can obtain the daily climate field from June 15 to July 30 from GFDL data of monthly average in June, July and August by the linear interpolation method. The initial integration time is June 15, the integration duration is 45 d nesting every day with GFDL data. The average of simulation result in last 30 d refers to the climate of July.

In the same way, for the winter, we can obtain the daily climate fields from GFDL data for December, January and February. The initial integration time is December 15, the integration duration is 45 d. The average of simulation results in last 30 d represents the climate of January.

III. SIMULATED RESULTS

1. *Atmospheric Fields in July*

In order to investigate that how the MM4 with the boundary condition nested with GFDL data simulates the regional climate in the Qinghai-Xizang Plateau and northwestern China, the simulated results are compared with the observed climate data from 1961 to 1970 in the Qinghai-Xizang Plateau. The warm highs at 200 hPa and 300 hPa over the Qinghai-Xizang Plateau are reproduced successfully. The centers of these highs are similar



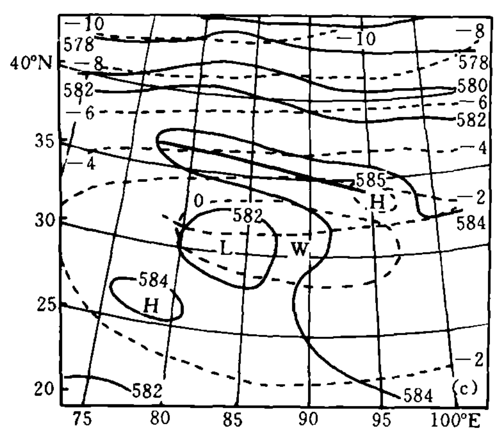


Fig. 2. Simulated mean monthly height (a), temperature (b) field of 500 hPa in July and related observed data (c).

to the observed results. Most obvious deficiencies are that the simulated temperature and pressure are higher than the observed results in the north of the Qinghai-Xizang Plateau, the gradients of temperature and pressure in this region are lower than the observed values.

Figure 2 presents mean monthly height and temperature fields of 500 hPa in July and related observed data. The warm low over the Qinghai-Xizang Plateau and the ridge lines in north and south of the Qinghai-Xizang Plateau are simulated successfully by the regional climate model. But the ridge lines in north and south of the Qinghai-Xizang Plateau are farther from the Qinghai-Xizang Plateau than the observed results, which are caused by the strong convergence over the Qinghai-Xizang Plateau at 500 hPa. The simulated height over the Qinghai-Xizang Plateau is 20 m lower than the observed, which is caused by the stronger convergence. We can see from the wind fields of 500 hPa and 700 hPa that these two ridge lines are the demarcation lines of summer monsoon in the Qinghai-Xizang Plateau and planetary westerlies.

Temperatures are, on the whole, simulated successfully. The position of the simulated warm region over the Qinghai-Xizang Plateau is similar to the observed result, but the simulated temperatures exceed the observed values by about 2℃, which results from the simple treatment of boundary layer and radiation processes.

In addition, the regional model is also used to simulate the low over the Qinghai-Xizang Plateau, the low and high in south and north of the Qinghai-Xizang Plateau at 700 hPa respectively.

2. *Surface Climate in July*

An accurate simulation of precipitation with most regional models is difficult for a number of reasons. First, precipitation formation depends on extremely complex dynamical and microphysical processes, which are often parameterized using relatively simple formulations. Second, precipitation in many instances highly varies with spatial scale smaller than the resolutions of regional models. Finally, the prediction of precipitation is sensitive to the orograghy smoothed and moisture analysis that provides the initial conditions and the lateral boundary conditions, and moisture is often the most poorly analyzed input variable. But precipitation is very important element. So we analyze the simulated precipitation in the whole model domain in order to demonstrate that the simulation of precipitation, on the whole, is reasonable.

The Qinghai-Xizang Plateau is located in the transition zone from desert to pluvial region. There is a most abundant rain region in the world to the south, and a desert to the north of the Qinghai-Xizang Plateau. The complex orography and distribution of precipitation are resolved only by the regional model. We first present results for precipitation. Figure 3 shows the simulated and observed mean monthly accumulated precipitation in July. It can be seen from Fig. 3 that, the model reproduces quite well the major pluvial regions along the edge of the Qinghai-Xizang Plateau, e. g. in the south of the Himalayas Mountain, the Pamir Plateau, the Tianshan Mountain and the Qilian Mountain, and three precipitation maxima, e. g. (78°E, 22°N), (87°E, 27°N), (75°E, 32°N) where sharper slope causes the strong ascent of air. The minimum precipitation is also simulated by the model. But the differences between values and locations of the simulated precipitation and the observed are obvious. The precipitation simulated in model in the south of the Qinghai-Xizang Plateau is about 40% smaller than the observed values, and 20% more than the observed values in north of the Qinghai-Xizang Plateau, which are

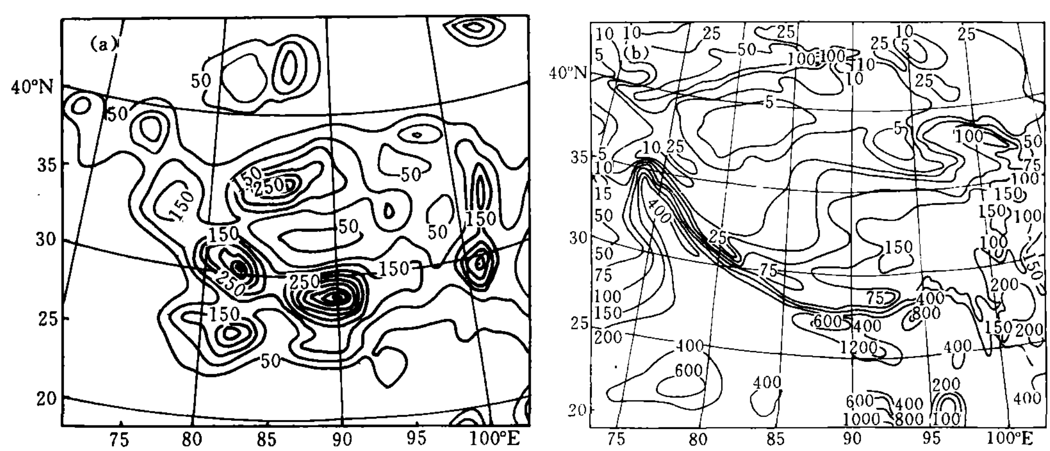


Fig. 3. Simulated (a) and observed (b) monthly mean accumulated precipitations in July (mm).

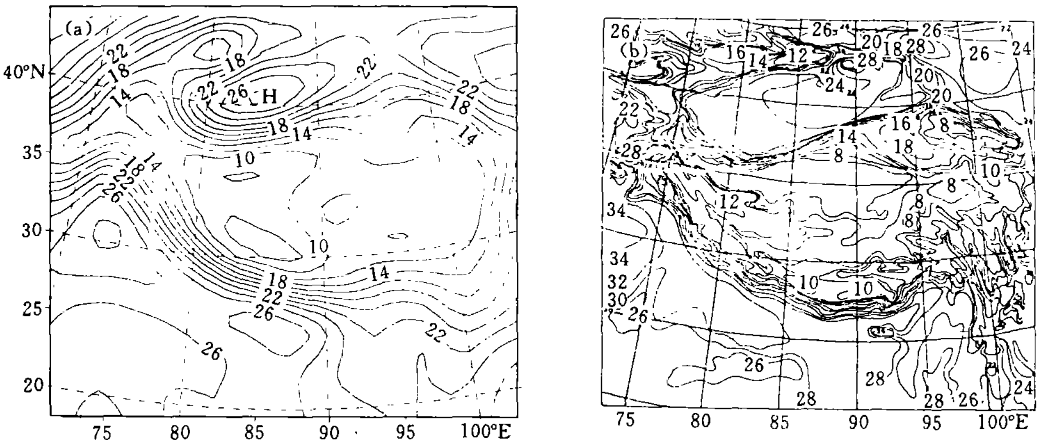


Fig. 4. Simulated (a) and observed (b) mean surface temperature fields in July (°C).

thought to be mainly caused by the smoothing process of orography which reduces the orographic slope, especially in the Himalayas Mountain.

The second important variable of near surface climate is near surface air temperature. Figure 4 shows the mean simulated surface temperature field in July together with the observed field. Obviously, the model reproduces the gross features of the observed field rather fairly, for example, the cold regions over the Qinghai-Xizang Plateau and the Tianshan Mountain, the warm regions in Taklimakan desert and its eastern area.

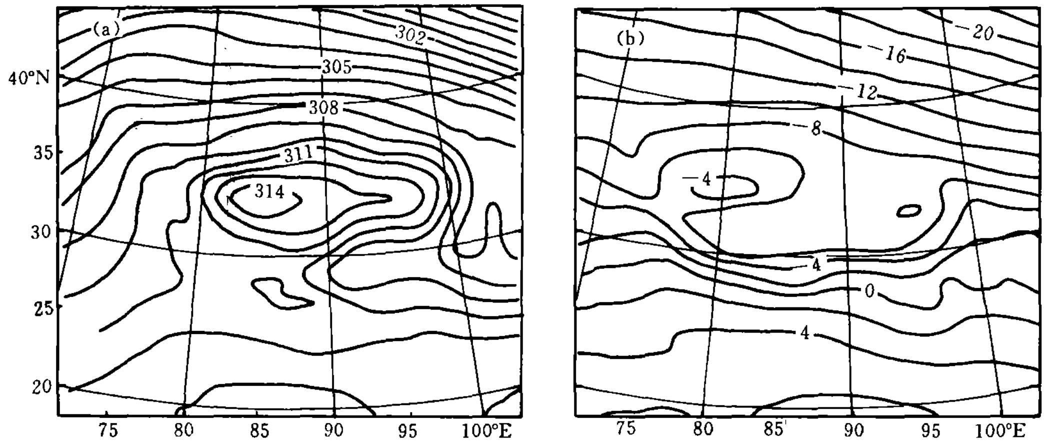
3. *Atmospheric Fields in January*

The features of height and temperature in January are relatively simple, so Fig. 5 presents the mean monthly 700 hPa height and temperature together with the observed fields in January. The difference between the simulated feature and the observed one is rather small. The model reproduces the high over the Qinghai-Xizang Plateau and the low in the south and east of the Qinghai-Xizang Plateau, but the simulation of the small high near Jiuquan is not ideal.

It can be seen from the temperature field, there are warm regions in east side and west side of the Qinghai-Xizang Plateau and an obvious low area over the Qinghai-Xizang Plateau, which are similar to the observed pattern.

4. *Surface Climate in January*

Because there is little precipitation in winter in the Qinghai-Xizang Plateau and northwestern China, we discuss only the simulation of near surface air temperature in January (Fig. 6). We can see from Fig. 6 that the model reproduces successfully the cold region in the Qinghai-Xizang Plateau, the warm region in Taklimakan desert, but the simulated temperatures near the Tianshan Mountain are higher than the observed values, which are thought to be caused by the orography smoothing. The smoothing of orography decreases the altitude of surface. In same reason, the simulated temperature gradients near the south edge of the Qinghai-Xizang Plateau are smaller than the observed values.



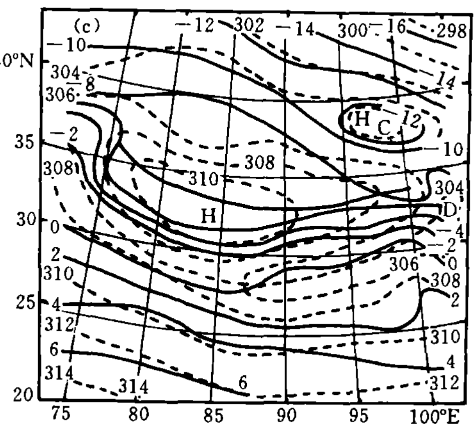


Fig. 5. Simulated mean monthly height (a) and temperature (b) of 700 hPa together with the observed fields (c) in January.

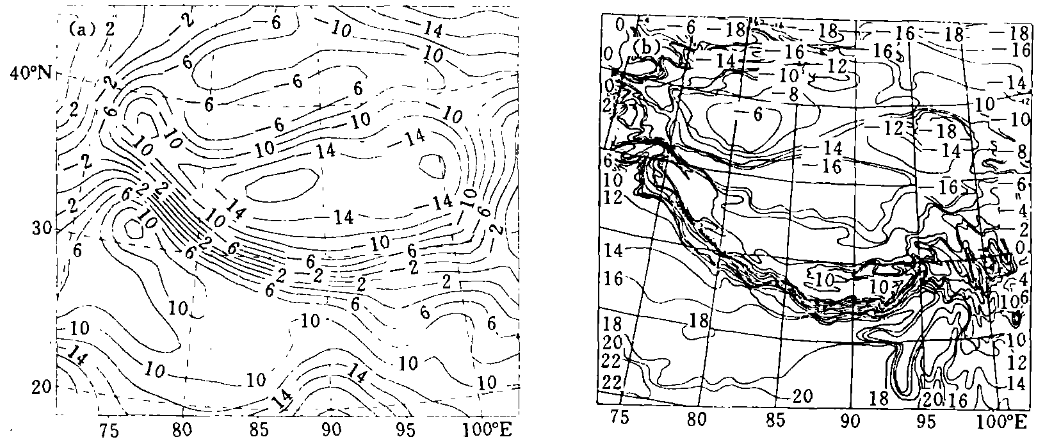


Fig. 6. Simulated (a) and observed (b) near surface air temperatures in January.

IV. CORRELATION ANALYSIS

In order to analyze the simulation results further, the mean square deviation (*RMSE*) and standard deviation (*SIDE*) are used here, which are defined as

$$RMSE = \left\{ \frac{\sum_{i=1}^{N} [A_M(i,j) - A_S(i,j)]^2}{N} \right\}^{0.5}, \tag{2}$$

$$SIDE = \left\{ \frac{\sum_{i=1}^{N} [A_M(i,j) - \overline{A_M(i,j)} - A_S(i,j) + \overline{A_S(i,j)}]^2}{N} \right\}^{0.5}, \tag{3}$$

where $A_S(i, j)$, $A_M(i, j)$ are simulated and observed parameters respectively, $\overline{A_S(i,j)}$, $\overline{A_M(i,j)}$ are their average values in a constant layer in the model domain, i, j are the horizontal grid point indexes, N is the total number of grid points.

Table 2 shows the correlation coefficient, mean square deviation and standard deviation of height and temperature fields from 100 hPa to 700 hPa and surface. It can be seen from the table that the simulated results in January are better than those in July. The correlation coefficients of height and temperature in January are greater than 0.90, but for the summer these values are 0.70 and 0.54 respectively. The standard deviations of height and temperature of 700 hPa in January are 15.3 m and 1.1℃, but for July, these values are 16.0 m and 2.3℃. The differences of these parameters listed in the table between January and July are mainly due to two reasons. First, the heating process of land in summer in the Qinghai-Xizang Plateau is strong, but in winter, the action of land to atmosphere is relatively weak. Second, the climate fields in summer in the Qinghai-Xizang Plateau are complex with more mesoscale weather systems which the GFDL data can not resolve, but in winter the climate field is simple.

Comparing the *RMSE* and *SIDE* in different layers, we can see that the *RMSE* and *SIDE* increase as the pressure decreases. The model top is at 100 hPa, which causes the obvious simulated errors in 100 hPa.

The correlation coefficients of air temperature near surface are large, the distribution of simulated air temperatures near surface is similar to the observed field.

Table 2. The Correlation Coefficient (*COR*), Mean Square Deviation (*RMSE*) and Standard Deviation (*SIDE*) of Height (*H*) and Temperature (*T*) Fields of Surface and from 100 hPa to 700 hPa in January and July

	100 hPa		200 hPa		300 hPa		500 hPa		700 hPa		Surface	
	July	Jan.	July	Jan.	July	Jan.	July	Jan.	July	Jan.	July	Jan.
COR (*H*)	0.70	0.99	0.76	0.99	0.79	0.99	0.85	0.99	0.84	0.99	—	—
COR (*T*)	0.54	0.94	0.90	0.89	0.64	0.98	0.67	0.99	0.68	0.99	0.91	0.95
RMSE (*H*)	94.2	116.0	73.0	40.3	51.2	35.2	25.8	29.0	16.0	15.3	—	—
RMSE (*T*)	5.3	2.4	1.5	1.4	3.2	1.6	2.5	1.2	2.3	1.1	3.4	3.2
SIDE (*H*)	150.2	143.3	87.4	72.0	53.0	53.8	31.2	37.4	18.3	25.3	—	—
SIDE (*T*)	9.0	17.3	2.8	1.8	3.8	2.4	3.0	1.7	2.6	1.3	4.6	4.4

V. CONCLUSION

In this paper, we have simulated the regional climates in summer and winter in northwestern China and the Qinghai-Xizang Plateau with regional climate model (MM4) nested with GFDL data, and compared the simulated data with the observed data and GFDL data. The results show that regional model reproduces the regional climate, such as the high pressure on the plateau and the low pressure in the north of the plateau in winter, the warm-low pressure on the plateau and pressure ridge in southern and northern sides in summer. These regional climate features could not be resolved by GCM. The simulations of precipitation distribution are reasonable. But differences between the simulated precipitation values and the observed values in other places are obvious. The precipitation in south of the Qinghai-Xizang Plateau is underestimated, and in the north the precipitation is overestimated. The simulation of height field is better than temperature field.

The results demonstrate that the MM4 nested with observed field can simulate the climate feature in summer and winter in the Qinghai-Xizang Plateau with complex terrian, which is the base of simulation of climate in this area with the model nested with GCM.

In addition, the simple treatment of radiation and land process introduces obvious simulation errors. It is necessary to use the advanced regional model to improve the simulation.

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