Climate Change due to Greenhouse Effects in China as Simulated by a Regional Climate Model[①]

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ABSTRACT

Impacts of greenhouse effects ($2 \times CO_2$) upon climate change over China as simulated by a regional climate model over China (RegCM / China) have been investigated. The model was based on RegCM2 and was nested to a global coupled ocean–atmosphere model (CSIRO $R_{21}L_9$ AOGCM model). Results of the control run ($1 \times CO_2$) indicated that simulations of surface air temperature and precipitation in China by RegCM are much better than that by the global coupled model because of a higher resolution. Results of sensitive experiment by RegCM with $2 \times CO_2$ showed that the surface air temperature over China might increase remarkably due to greenhouse effect, especially in winter season and in North China. Precipitation might also increase in most parts of China due to the CO_2 doubling.

Key words: Regional climate model, Greenhouse effect

1. Introduction

As well known, greenhouse effect caused by increase of CO_2 in the atmosphere due to human activities may has strong potential impacts on climate. Study of the effect is a hot topic in climate research today. Many investigations have been conducted on it by using general circulation models (GCMs) in the world, also in China (Wang et al., 1993; Chen et al., 1996; Song and Chen, 1996). Because of the limitation of computer ability, the resolution of GCMs is usually not high enough to give better representation on regional climate and its change. To solve the problem, regional climate model (RCM) was developed. Using of RCMs in the study of greenhouse effect began in China in the 1990s (Li and Gong, 1996; Chen and Fu, 1997). Following the recent developments of the coupled global atmosphere–ocean models, with their simulation being used as the initial and boundary conditions of RCM, and developments in computer techniques, further study on it becomes necessary.

In the research, a regional climate model over China (named RegCM / China) which is a modified version of the NCAR / RegCM2 (Giorgi et al., 1993), was one way nested into the Australian CSIRO (The Commonwealth Scientific and Industrial Research Organization)

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$R_{21}L_9$ AOGCM (named CSIRO) (Gordon and Farrell, 1997) to study the climate change due to doubled CO_2 in China.

The atmospheric component of CSIRO has a horizontal resolution of about 5.6 × 3.2 degrees (longitude × latitude) and 9 layers in the vertical direction. Oceanic component of the model is of 12 layers in the vertical. The coupled model has been run from 1881. A ten-year simulation from 1981 to 1990 was used in this research as the present climate (control run). The experiment of greenhouse gases has been run with an increase of 1% / year of the CO_2 concentration from 1991. Another ten-year simulation with about doubled CO_2 has been used as the sensitive experiment.

Domain of RegCM / China covered over China with a center at 110°E, 37.5°N. Horizontal resolution of the model is 60 × 60 km and the vertical resolution is 16 layers with 10 hPa at top. Numbers of grid points in north-south direction are 80, in east-west direction are 150 (the area is roughly as 70°–150°E, 15°–60°N).

The initial and boundary conditions of RegCM were derived from the second 5 years of both control and sensitive runs of the GCM. Both control and sensitive experiments of the RegCM have been run for 5 years respectively. CO_2 concentration in the sensitive run was changed accordingly as the GCM.

RegCM / China was linked with CSIRO by using one-way nesting skill. Boundary conditions were updated every 12 hours. The present time and sensitive experiments have been run for 5 years respectively.

2. Assessment of the simulations of surface air temperature and precipitation in China

Observation data of 35-year mean (1956–1990) in 160 standard stations of China were taken as present climate. Surface air temperature (Ts) and precipitation (Pr) as simulated by CSIRO and RegCM / China for the present time were interpolated from grids to the 160 stations respectively. Correlation coefficients between observations and simulations by the 2 models for monthly averaged temperature and precipitation is given in Fig. 1.

As shown in Fig. 1, simulations of both Ts and Pr by RegCM are improved significantly as compared to those by CSIRO. The annual mean correlation coefficient of simulated Ts rises from 0.83 to 0.92, while the precipitation from 0.48 to 0.65. Simulation of Pr by CSIRO in June, September and October did not pass 0.01 significance level (about 0.2) while the simulation by RegCM passed in all months.

Correlation coefficient between the simulated annual mean Ts and observation rises from 0.90 by CSIRO to 0.94 by RegCM, while Pr from 0.63 to 0.80. The main improvement of Ts simulation by RegCM / China is that small Ts perturbation caused by small-scale topography can be simulated (figure not shown). Simulations of annual mean precipitation by the two models are given in Fig. 2. It is indicated in the figure that the most important improvement of RegCM is that the virtual rainfall center in mid-west part of China which was simulated by many GCMs (Zhao et al., 1992) as well as CSIRO was removed. The rainfall simulated by RegCM in north and northwest part of China is smaller than that by CSIRO, therefore, is closer to the observation. One reason of the improvements might be the higher resolution, and the better land process description in RegCM might be another.

The higher capacity of the simulations by RegCM indicated that the regional scale climate change scenario such as in China, as simulated by RegCM might be more reliable than that by CSIRO in a regional scale region. Therefore, only simulations by RegCM were given below.

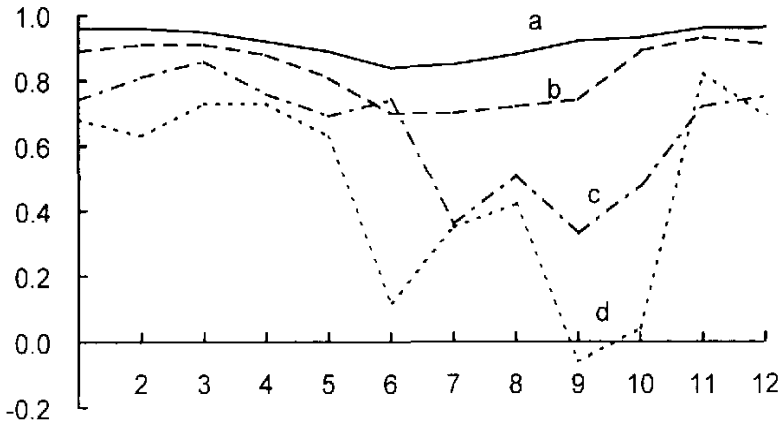

Fig. 1. Correlation coefficients of Ts and Pr between simulations and observation (a: Ts simulated by RegCM b: Ts simulated by CSIRO c: Pr simulated by RegCM d: Pr simulated by CSIRO).

3. Possible change of Ts and Pr in China due to doubled CO_2 (simulated by RegCM)

3.1 *Change of Ts*

Difference of Ts between the sensitive experiment (with doubled CO_2) and present time experiment was considered as Ts change in China due to doubled CO_2. Seasonal mean Ts in China is expected to increase in all the 4 seasons with a larger increase in winter and spring (the second row of Table 1). The change of annual mean temperature distribution in China is given in Fig. 3a. It is indicated in the figure that the increasing of Ts happens everywhere in China. It is also indicated that the increase in North China by the range from 2.5–3.0°C is a little higher than in South China with the range from 2.0–2.5°C. The average increase of Ts in China is about 2.5°C.

Table 1. Seasonal change of Ts and Pr in China due to doubled CO_2

Season	Winter	Spring	Summer	Autumn
Change of Ts (°C)	3.0	2.6	2.4	2.1
Change of Pr (%)	17	6	19	6

3.2 *Change of Pr*

The third row in Table 1 shows the change of Pr in percentage (difference between sensitive experiment and present experiment by present experiment × 100). It is indicated that Pr in China will also increase in all the seasons due to doubled CO_2. The largest increase will happen in summer, and the second largest in winter. There will be less increase in spring and autumn. Total increase in the whole area is 12%.

Figure 3b presents the distribution of annual mean Pr change in China. Similar to Ts, Pr will increase in most part of China when CO_2 is doubled. The largest area with a higher Pr

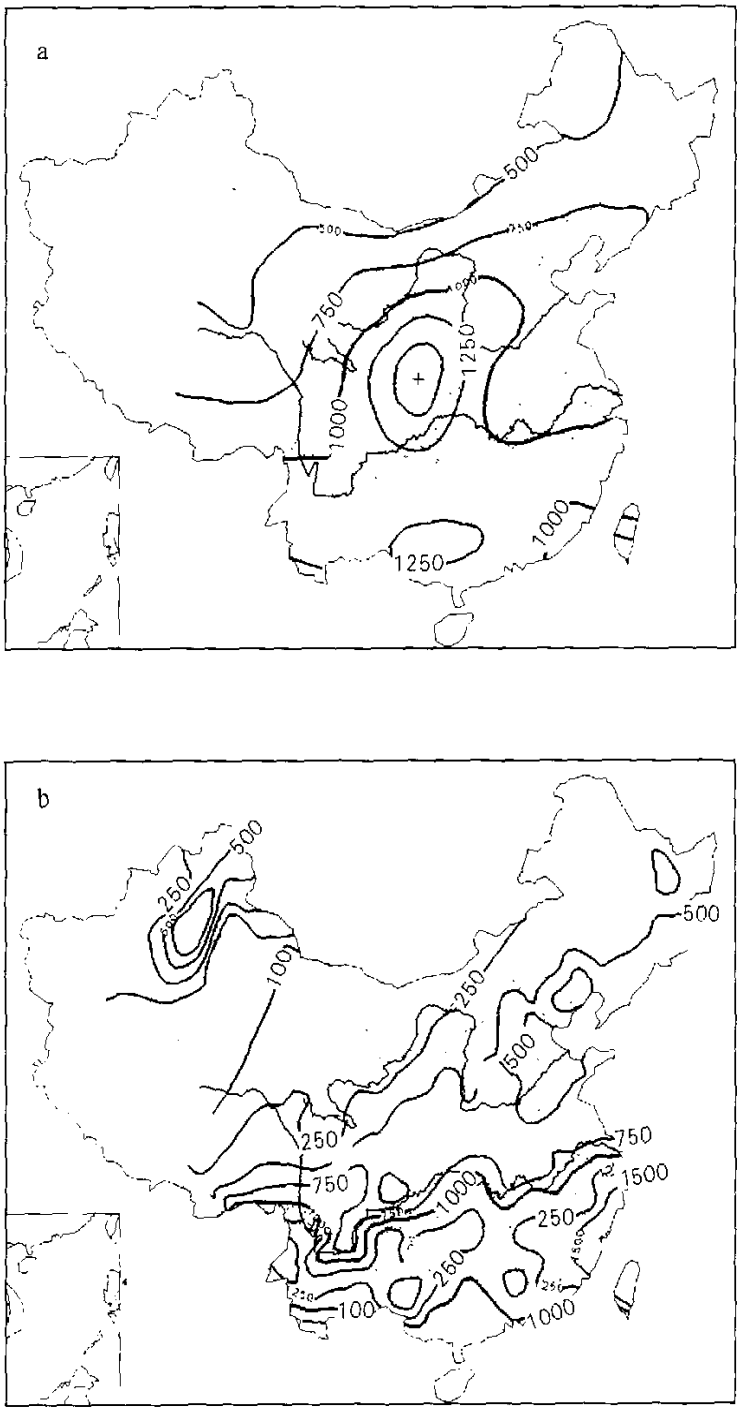

Fig. 2. Annual mean Pr in China as simulated by CSIRO (a) and RegCM (b) (unit: mm).

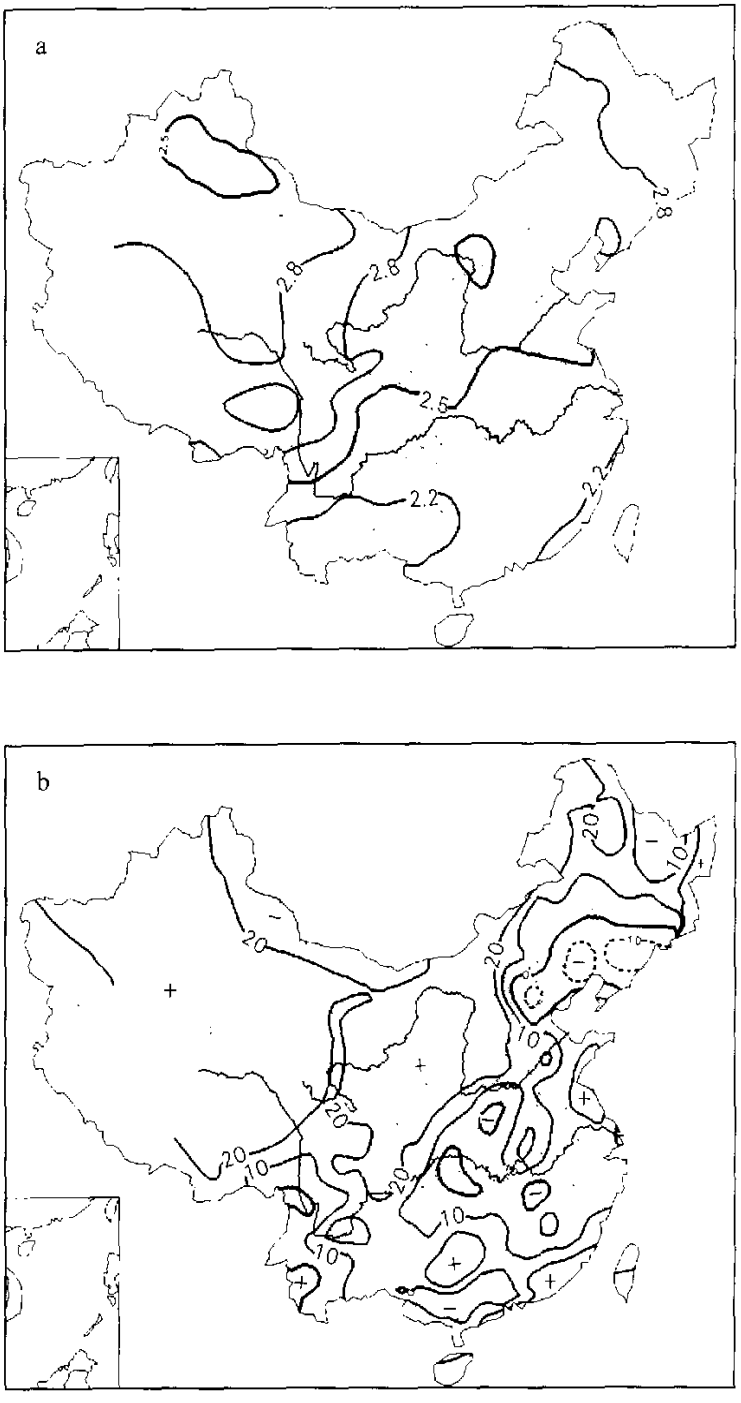

Fig. 3. Climate change in China due to doubled CO_2 as simulated by RegCM(a: change of annual mean Pr(%), b: change of annual mean Ts, unit: °C).

increasing is located in West China, which extends from west part of North China to Xinjiang with the value larger than 20%. The only area with decreasing Pr is located from the south part of Northeast to the north of North China. The Pr increase in West China in the simulation shows some coherence to the observational change (Ren et al., 2000).

4. Conclusion and discussion

(1) The climate scenario due to doubled CO_2 in China as simulated by RegCM / China should be more reliable because of its higher capability in simulating the regional climate at present as compared to the GCM.

(2) Ts in China will rise remarkably when CO_2 is doubled. The warming will be more obvious in winter and spring than in the other seasons, and in the north than in the south. Annual mean warming in China is 2.5°C. Meanwhile, Pr might also increase in most part of China with a larger increase in summer and winter, and in the west. The annual / area mean increasing is 12%.

(3) There are still a lot of uncertainties in the study of greenhouse effects in China by numerical models. Further research is needed to get more valuable conclusions.

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区域气候模式对温室效应引起的中国地区气候变化的数值模拟

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摘 要

利用基于 RegCM2 的区域气候模式并单向嵌套澳大利亚 CSIRO $R_{21}L_9$ 全球海-气耦合模式，进行了温室气体二氧化碳浓度倍增对中国气候变化影响的数值试验研究。控制试验结果表明：区域模式由于具有较高的分辨率，因而对中国区域地面气温和降水的模拟效果较全球模式有了较大提高；模式对 $2\times CO_2$ 敏感性试验结果表明了在 CO_2 浓度倍增情况下，由于温室效应，中国区域的地面气温将有明显升高，降水也将呈增加趋势。

关键词：区域气候模式，温室效应