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Sensitivity experiments and assessment of climatic changes in China induced by greenhouse effect

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Abstract—Climatic changes can be separated into two parts: natural changes and human activity influenced on climatic changes. The observed data could not only show the effects caused by human activity. Several simulated results as simulated by the GCMs induced by the greenhouse effects in China have been analysed. It is shown that an obvious warming of about 3–6°C in winter and 2–5°C in summer in China as simulated by the GCMs induced by doubling CO_2 have been found. There are getting drier or wetter regions in China due to doubled CO_2 as simulated by most of models. Comparing the simulated results with the observed data in China, some simulated results are able to be believed. The GCMs should be improved, especially in the regional areas.

Keywords: greenhouse effect; climatic changes; global warming.

INTRODUCTION

A warming trend of about 0.5°C of the global surface air temperature for the last 100 years have been found (Wigley, 1985). There is the similar trend in China (Zhang, 1989). Unfortunately, no evidence shows that the global warming of about 0.5°C only depended on the greenhouse effect.

Up to now only sensitivity experiments could simulate the greenhouse effect on climatic change. In this paper the results of several popular GCMs, such as GFDL(Manabe, 1987), GISS(Hansen, 1984), NCAR(Washington, 1984), OSU(Schlesinger, 1989) and UKMO(Wilson, 1987), have been used to analyse the climatic changes in China. Validation and evaluation in the parts of China for these GCMs have been given.

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METHODOLOGY

Climatic effects in China induced by doubled CO_2 as simulated by the GCMs

Similar to Kellogg's and Zhao's works (1988a and b), climatic changes in China induced by doubled CO_2 as simulated by five GCMs (as mentioned in first section) have been summarized (Fig.1)(Zhao, 1989). It is found in Fig.1 that an obvious warming of about 3–6°C for winter (DJF) and 2–5°C for summer (JJA) in China as simulated by five models have been noted. The significant warming of about 4–6°C in the northern part of China in winter are given by most of the models. The decreasing rainfall in winter in the southern part of China and in summer in the northern and central parts of China as simulated by most of models have been given. The increasing rainfall have been noticed in the northwestern and northwestern parts of China in winter and summer induced by doubled CO_2 as simulated by most of models. The dry trend are found in the southern part of China in winter and in the northern part of China in summer as simulated by most of models.

As compared by five models, there are distinguishable distributions for five models, especially for rainfall and soil moisture. Fig.2 and Fig.3 show some examples for the simulated temperature (DJF) and rainfall (JJA) in China by five models. An obvious warming of about 4–7°C in the most parts of China as simulated by the GISS and UKMO models have been noticed. A relative small warming of about 2–4°C in the most parts of China as simulated by the NCAR and OSU models have been found (Fig.2). For the simulated rainfall in China in summer, the significant different distributions for five models have been shown in Fig.3. A dry trend in the most parts of China induced by doubled CO_2 as simulated by the NCAR and GISS models have been given. But a wet trend in the most parts of China as simulated by the OSU and UKMO models have been indicated.

For comparing the changes of temperature, Fig.2 (g) and (h) show the results as simulated by the NCAR coupled atmospheric and ocean model (Washington, 1989) induced by doubled CO_2 and gradually increased CO_2 at a linear rate of 1% per year, respectively. It is found in Fig.2 (h) that a warming of about 1°C in the most parts of China induced by increase of 1% per year of CO_2 is noticed. It is much less than that induced by doubled CO_2 as simulated by the NCAR CGCM (Fig.2(g)) and AGCM coupled to a simple ocean model(Fig.2(c)).

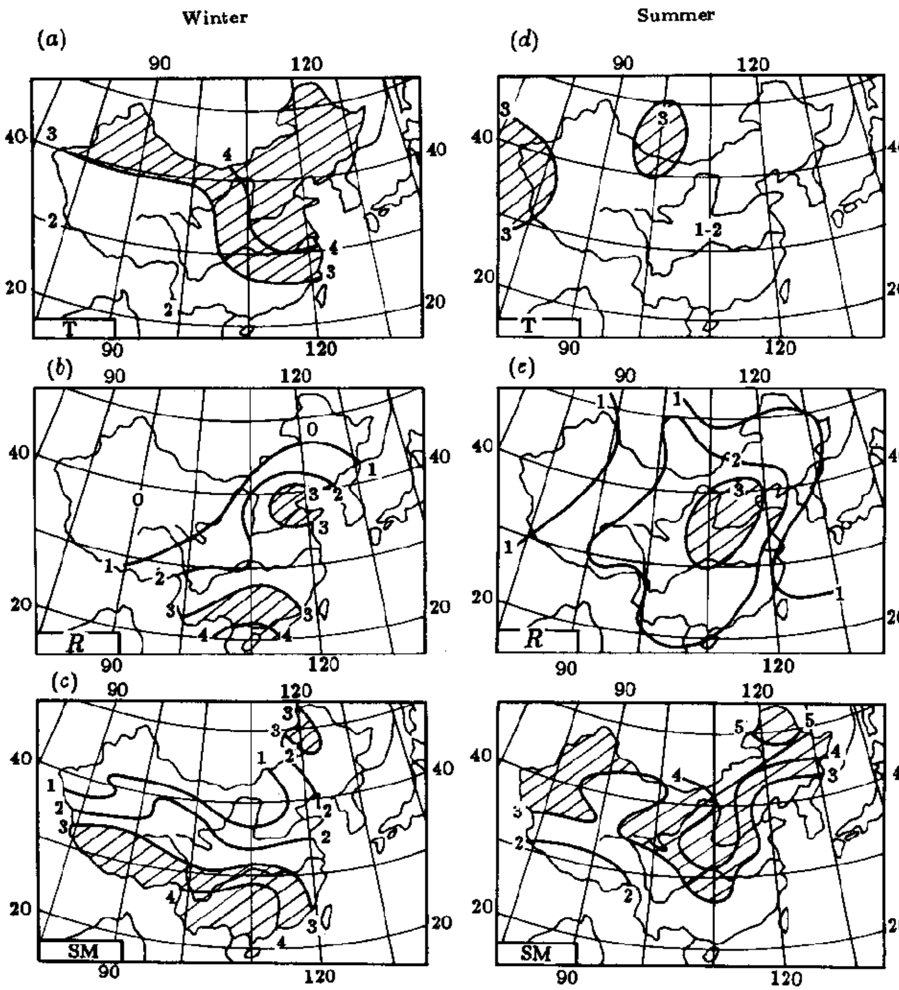

Fig.1 Summarized map as simulated by five models (GFDL, GISS, NCAR, OSU and UKMO) for $2\times CO_2-1\times CO_2$ in winter (left) and summer (right) for temperature (a), (d), rainfall (b), (e) and soil moisture (c), (f). The areas with oblique lines express that three or more of the models agree on a warming of about 4°C or more in (a) and (d); the area with oblique lines express that three or more of the models agree on the decrease of rainfall and soil moisture in (b), (e) and (c), (f). The label numbers show how many models agree on this characteristic

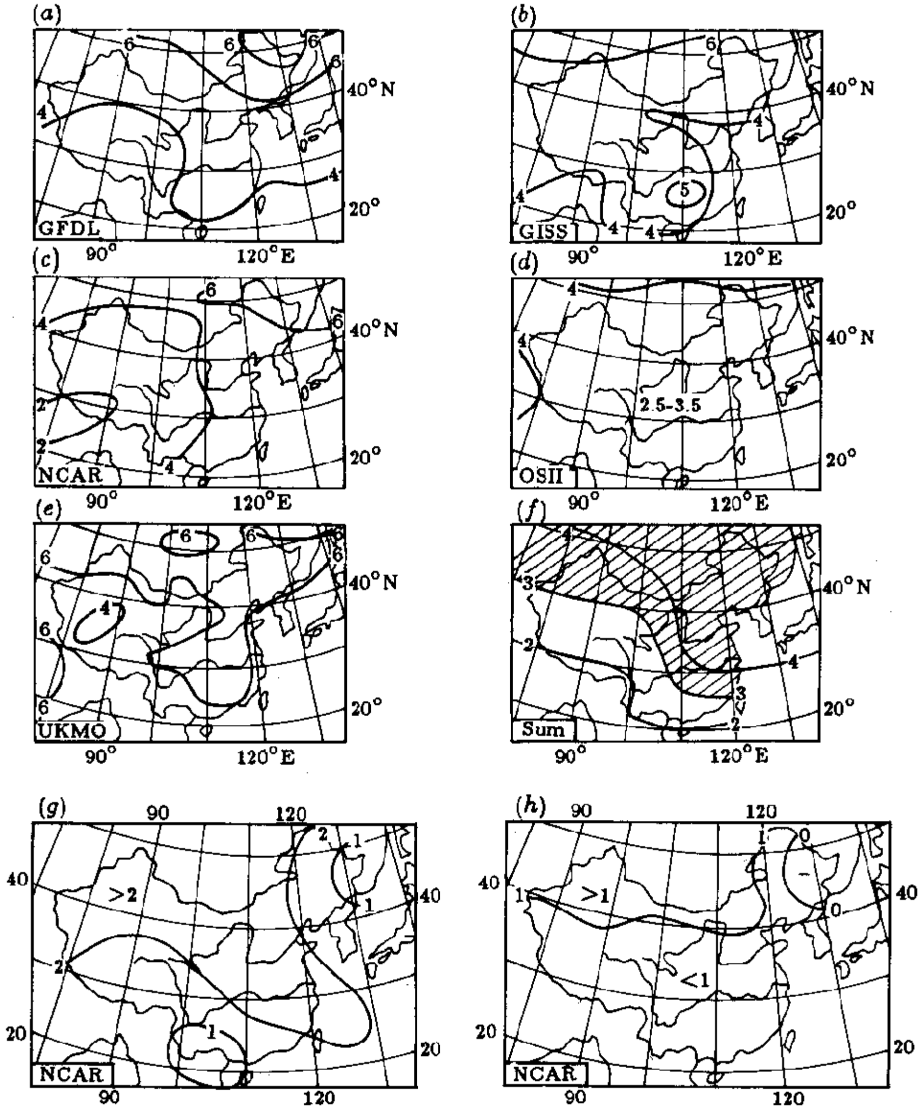

Fig.2 Differences of temperature (unit: °C) in winter in China between $2\times CO_2$ and $1\times CO_2$ as simulated by the GFDL (Manabe, 1987)(a), GISS (Hansen, 1984)(b), NCAR(Washington, 1984) (c), OSU(Schlesinger, 1989) (d), UKMO(Wilson, 1987) (e) and NCAR(Washington, 1989) (g) models. (h) is the NCAR(Washington, 1989) model induced by increase of 1% per year of CO_2. (f) is the same as to Fig.1 (a)

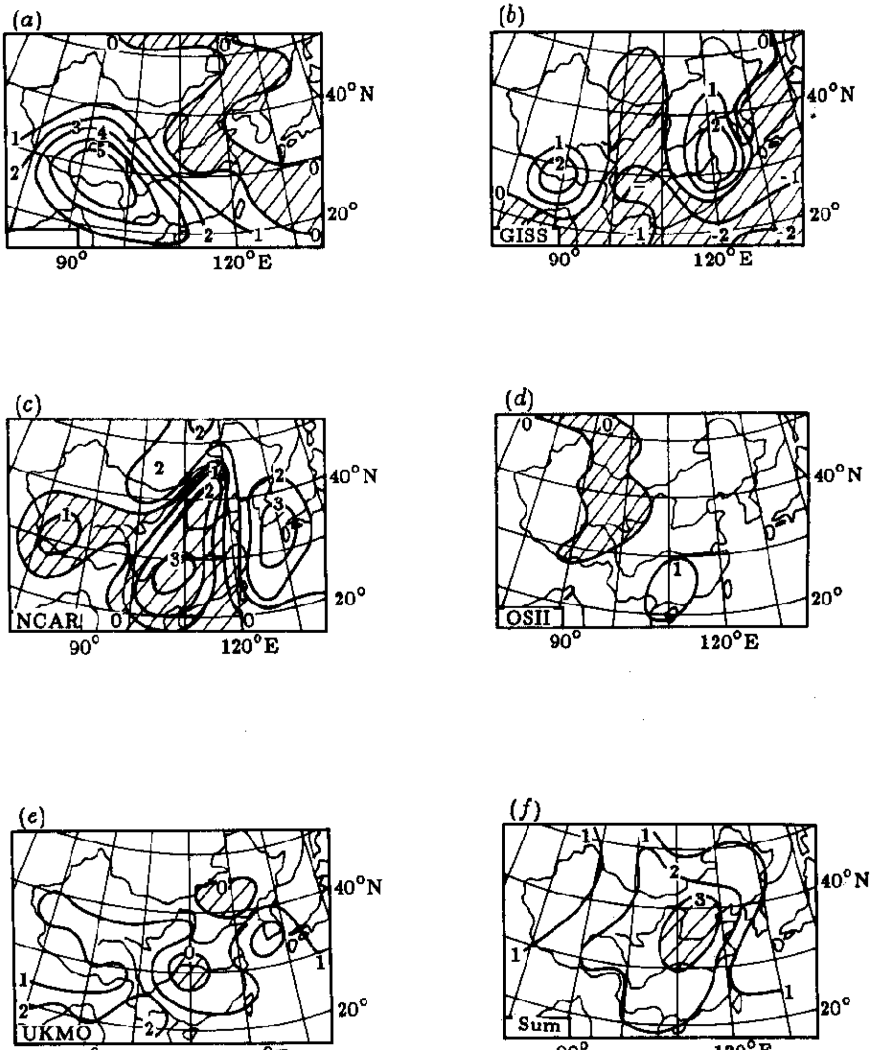

Fig.3 The same as to Fig.2, except for rainfall (unit: mm/day) in summer. (f) is the same as to Fig.1 (e)

Validation and assessment for the GCMs

Could we believe these results as simulated by GCMs and how do we evaluate these simulations? Several papers (Schlesinger, 1987; Wigley, 1988; Cess, 1988; Zhao, 1989) discussed this question in the global simulations. For evaluating the validations in the parts of China, the control simulations of surface air temperature, rainfall, runoff and soil moisture as simulated by GCMs have been compared with the observed data in China. There are about 50 grid points in the part of China as simulated by the GCMs. Therefore, it is possible to assess them.

The distributions of surface air temperature in China in winter for the control results as simulated by the GCMs and observed data is given in Fig.4. It is interesting to notice that the major characteristics of temperature with the cold northern and warm southern parts of China have been simulated by all of GCMs. It is shown in Fig.4 that there are the overestimating temperature in South China for the OSU model and the underestimating temperature in the same areas for the NCAR model.

Fig. 5 shows the distributions of rainfall in the parts of China in summer as simulated by the GCMs and the observed data. The major characteristics of rainfall in China with the dry northwestern and wet southern parts of China have been simulated by all models. Comparing the simulations with the observed data in Fig.5, the OSU model has an underestimating value and both NCAR(1984) and GFDL models have the overestimating values in the southwestern part of China. It is obviously to show in Fig.5 that the simulation of the NCAR (Washington, 1984) model is much better than the NCAR (Washington, 1977) model.

The annual mean runoff in the parts of China as simulated by the GCMs compared with the observed data is given in Fig.6. The major characteristics with the less runoff in the northeastern part of China and the more runoff in the southeastern part of China have been simulated by the GFDL–VC and OSU models. But the OSU model has an underestimated results in the parts of China and the GFDL-VC has an overestimated results in the southwestern part of China. The regions of the more runoff as simulated by the UW model move northward compared with the observed data. It is interesting to notice in Fig.6 that the distribution of the runoff as simulated by the GFDL-VC model which is a variable cloud model is better than the GFDL-FC model. The latter is a fixed cloud model (Manabe, 1987).

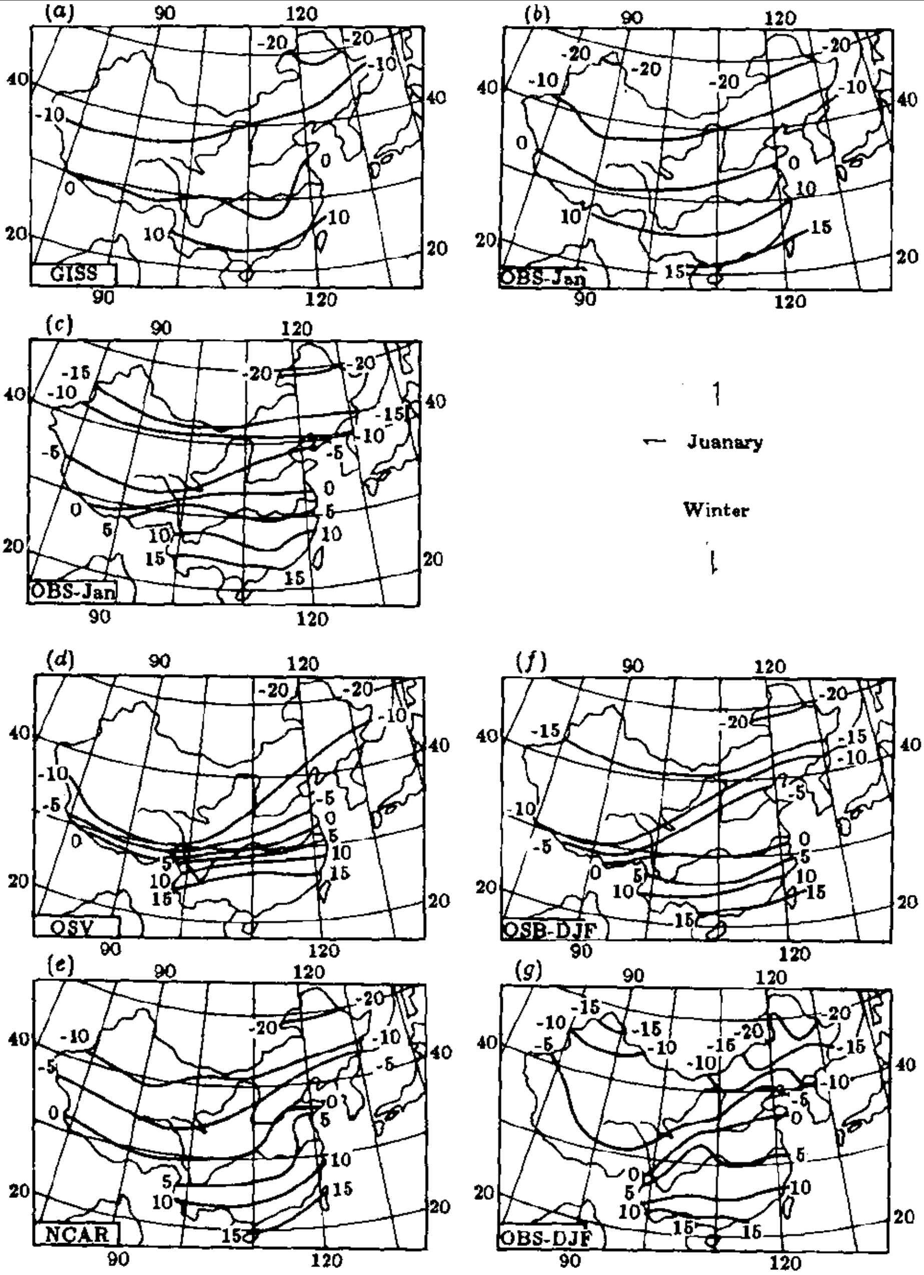

Fig.4 Distribution of temperature in January (above) and winter (bottom) in China as simulated by the GISS (Hansen, 1983) (a), OSU (Schlesinger, 1989) (d) and NCAR (Washington, 1984) (e) models. The observed data in January (b) (Crutcher, 1970), (c) (Chen, personal communication) and in winter (f) (Jenne, 1975), (g) (Chen, personal communication) are shown for comparing with the simulated data (unit:°C)

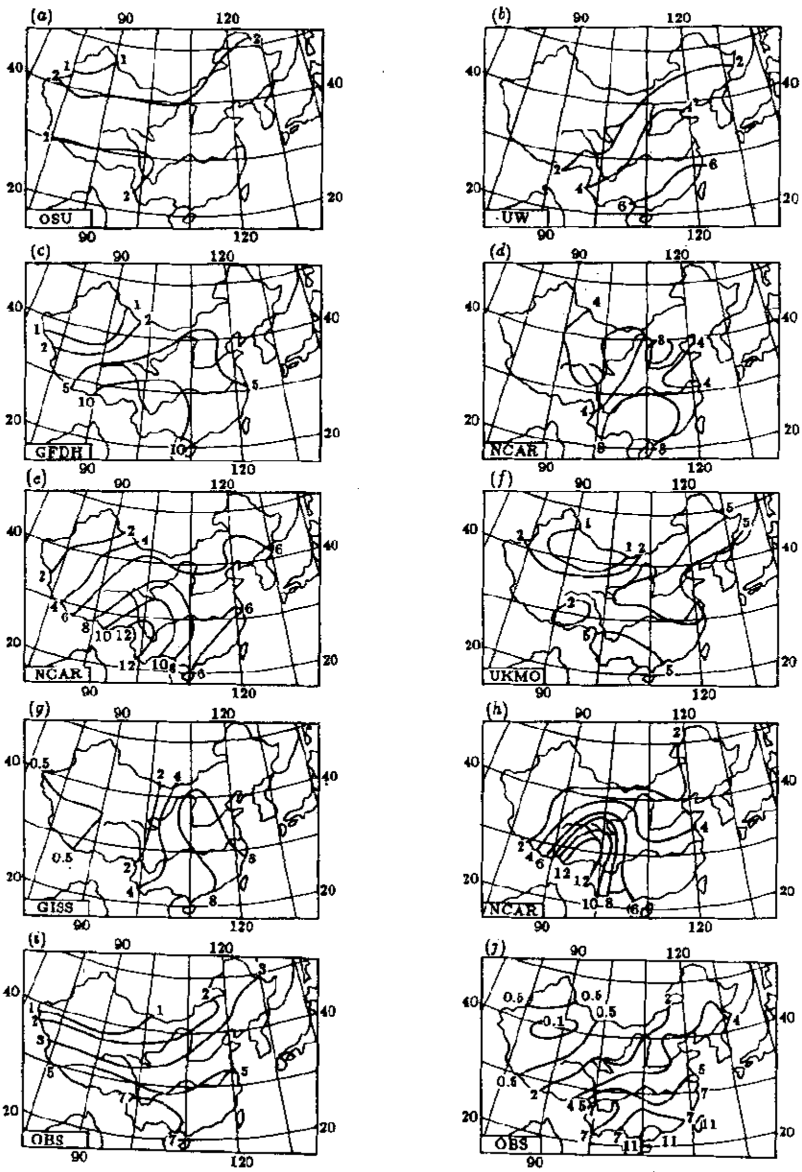

Fig.5 Distribution of rainfall in summer in China as simulated by the OSU (Schlesinger, 1989) (a), UW (Kutzbach, 1988) (b), GFDL (Keshavamurty, 1982) (c), NCAR (Washington, 1977) (d), NCAR (Washington, 1984) (e), UKMO (Wilson, 1987) (f), GISS (Hansen, 1983) (g) and NCAR (Washington 1989) (h). (i) and (j) are the observed data from Jaeger (1976) and Chen (personal communication) (unit: mm/day)

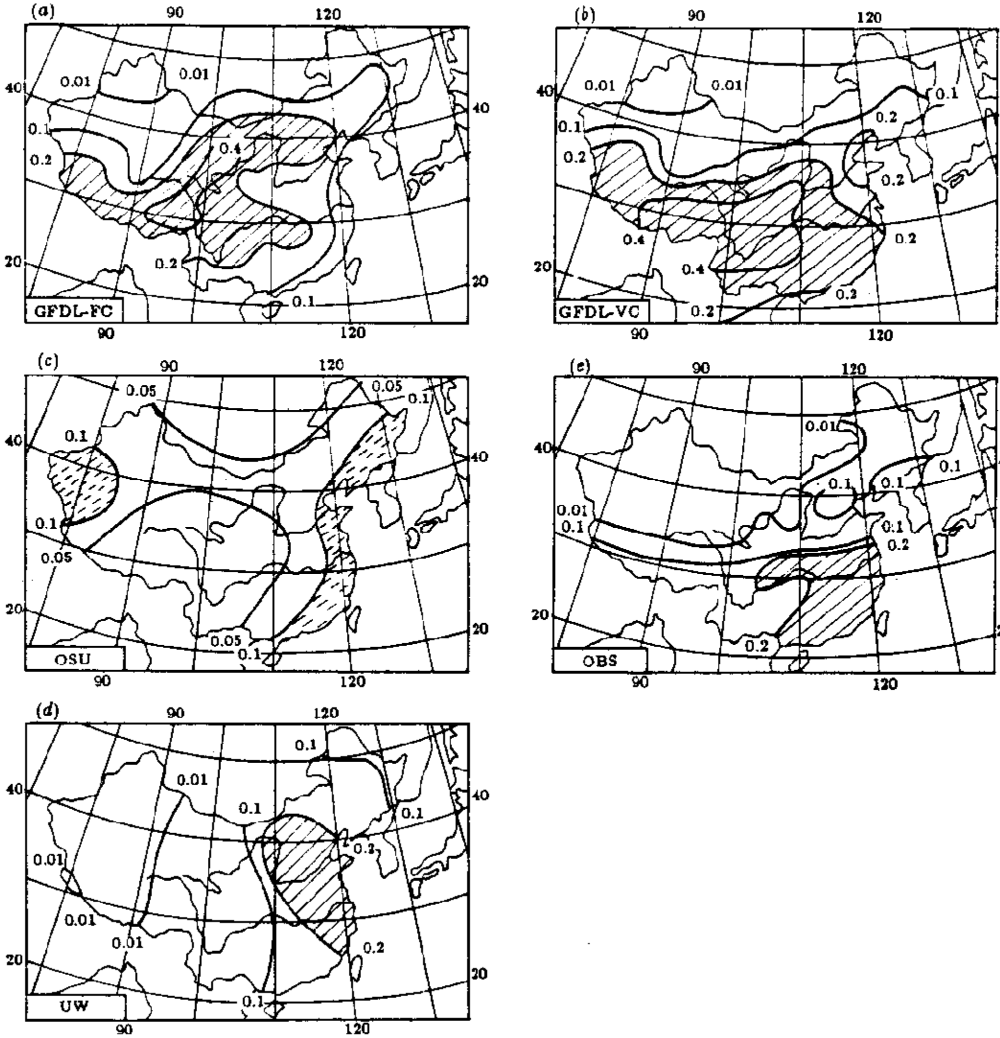

Fig.6 Distribution of annual mean runoff in China as simulated by the GFDL-FC (a) and GFDL-VC (b) (Manabe, 1987), OSU (Schlesinger, 1989) (c) and UW (Gallimore, 1988) (d). (e) is the observed data form Lvovitch and Ovchinnikov(1964) (unit: cm/day)

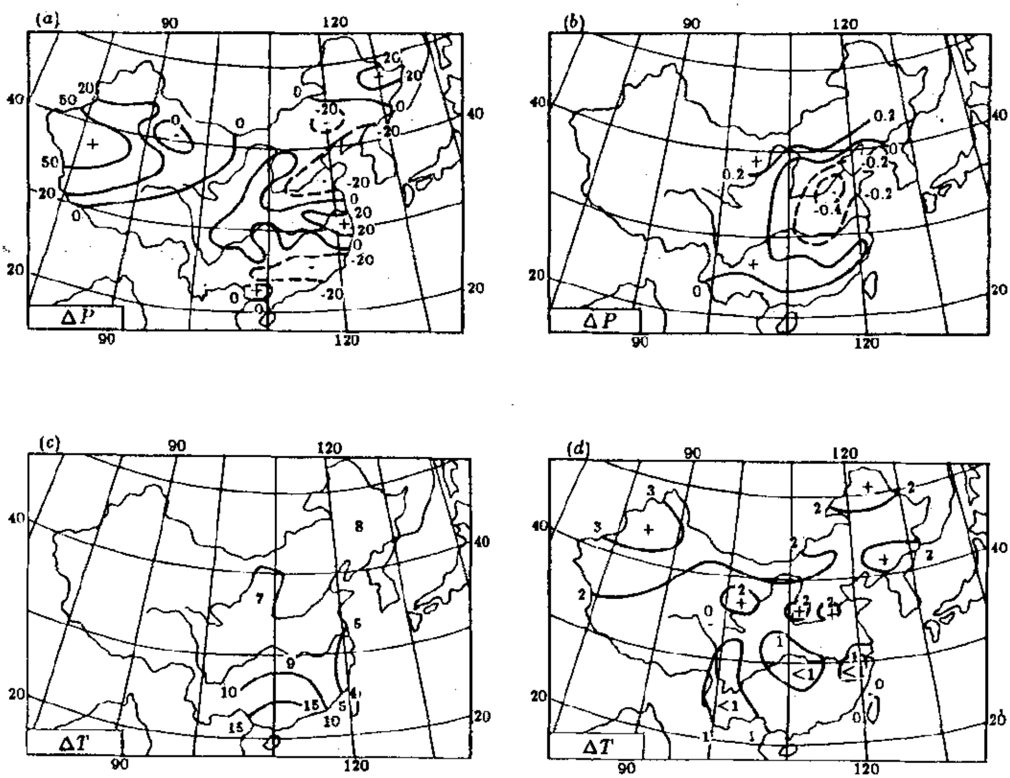

Fig.7 (a) is percentage of anomalies of rainfall in China in summer between 1986 and 1989 (Zhang, 1990); (b) is differences of grades of rainfall in summer in China (Zeng, 1983); the positive values express wetter and negative drier. The bottom pictures are the differences of temperature in China between present time and 18000 B.P. (c) and 1986–1989 and 1956–1985 (d, Zang, 1990) (unit: °C)

The validation of the results in China induced by doubled CO_2 as simulated by the GCMs were also tested by means of compared with the paleoclimate and climate at present time. Several examples are shown in Fig.7. The difference of temperature of 18000 B.P. (Ice Age) minus present time in China (Zhao, 1990) is given in Fig.7 (c). The ranges of Changes of temperature in Fig.7(c) are about 4–15°C. Fig.7(d) (Zhang, 1990) shows the differences of temperature in January in China between 1986–1989 and 1956–1985. An obvious warming of about 1–2°C in the most parts of China during 1986 and 1989 has been found in Fig.7(d), especially in the northern part of China. Therefore, a warming of about 2–6°C in the most parts of China has occurred in the historical and present time.

It is interesting to compare Fig.7(a) (Zhang, 1990) and (b) (Zeng, 1983) with Fig.1 (e). Fig.7 (a) gives the percentages of differences of rainfall in China between 1986–1989 and 1956–1985. Fig.7 (b) shows the averaged changes of grades of rainfall in summer in China for the last 500 years when it was getting warmer in winter. It is shown in Fig.7 (a), (b) and Fig.1 (e) that the distributions of difference of rainfall in the present time and historical warming time are similar to that of doubled CO_2, such as drier in the central part of China and wetter in the northwestern and northeastern parts of China.

As we know, the reasons of climate changes in China in several periods are very different. "Analogous method" are used in this section.

SUMMERY AND DISCUSSION

An obvious warming in China induced by doubled CO_2 as simulated by the GCMs has been noticed. There are getting drier or wetter in some parts of China induced by doubled CO_2 as simulated by the GCMs.

The results of the control experiments as simulated by the GCMs were compared with the observed data in the parts of China. It is shown that the most characteristics for temperature, rainfall and runoff in China have been simulated by the GCMs well. But the simulated values in some parts of China as simulated by some models are overestimating or underestimating results. The improved GCMs and the regional climatic model in part of China should be investigated in future.

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