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Simulated seasonal movement of precipitation zone in rainy season over China and its change on CO_2-doubling*

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Abstract— In this paper, an investigation of simulated monthly precipitations from April to September is made. Though the precipitations are sometimes overestimated or underestimated, the geographical advance and recession of precipitation zones are well simulated by the UKMO global climate model with a simple mixed-layer ocean. Main characteristics of large-scale precipitation distribution are changed less on CO_2-doubling, but the change is significant in some regions. The change in precipitation threatens us while the dry region is imposed by rainfall defect or the wet region by abundant rainfall induced by CO_2-doubling.

Keywords: greenhouse effect; carbon dioxide change; climate simulation.

INTRODUCTION

Seasonal variation of precipitation in both geographical distribution and intensity is one of main characteristics of the climate in China, i.e., the zonal-distributed precipitation immigrates northward from spring to summer along with its intensification and recedes southward from summer to winter along with its weakening. Weather and climate in China are strongly dependent on the seasonal variation of precipitation. Therefore, agriculture, forestry and even socio-economy are also impacted by the seasonal variation of precipitation. On the basis of the simulation generated by the UKMO (UK Meterological Office) climate model, a study on monthly precipitation in a rainy season and its change on CO_2-doubling has been made to understand the climatic characteristics of precipitation.

Climatic effect due to the accumulation of carbon dioxide (CO_2) has been investigated in many studies. Most studies focus on its global greenhouse effect and several works on regional climate changes have been accomplished (Rind 1989; Cao, 1992). Zhao and Ding (Zhao, 1990) have presented comprehensive results of change in both

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temperature and precipitation in China on CO_2-doubling based on five models, mainly presenting the change of climatic averages in winter and in summer. In the present paper, the main viewpoint under study is to obtain the spacial and temporal features of the change in precipitation on CO_2-doubling. It provides a basis on which a climate impact and a response strategy can be studied, and it is very important for the policymaker in China.

MODEL AND EXPERIMENT

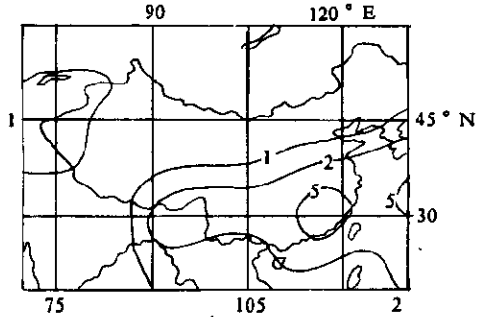
A version of the UKMO model with a regular 2.5° latitude by 3.75° longitude grid is used in the present study. The model solves the primitive equations using a finite difference scheme on $11\sigma(\sigma=p/\pi$; p is pressure; π is surface pressure) layers, which are irregularly spaced, being concentrated near the surface and the tropopause. The general circulation model (GCM) is coupled to a 50m oceanic mixed-layer and an sea-ice energy-balance model. The model includes a cloud-prediction scheme for both convective and layer clouds. The seasonal and diurnal variations of solar radiation are represented, and radiative fluxes depend on temperature, the concentrations of water vapor, carbon dioxide and ozone as well as clouds. Long-wave fluxes are calculated by the emissivity approximation. Over snow-free land the surface albedo is prescribed to vary with geographical location, with values derived from the global data on land cover and soils. Over snow-covered land, albedo increases with snow depth. The radiation scheme provides for three layer clouds (low, medium and high) and a convective tower.

The evolution of the mixed layer temperature T at each point is given by

$$\rho h c_p \frac{dT}{dt} = S + C$$

where ρ and c_p represent the density and the specific heat of seawater respectively, h is the depth, S the heat flux through the surface, and C refers to the prescribed heat convergence due to oceanic processes (advection, convection and so on). In the coupled model, sea surface temperature is updated every 5 days, based on the net surface heating from the atmosphere and the specified heat convergence.

The time-step is 20 minutes in an integration. The control integration has been simulated for 14 years, and at the end of the fourth year, the anomaly integration was started with an instantaneous doubling of CO_2 concentration and thereafter it ran for 10 years. The averages calculated for the last 10 years of the experiment are presented later.



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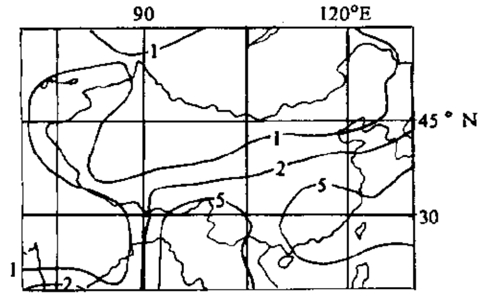

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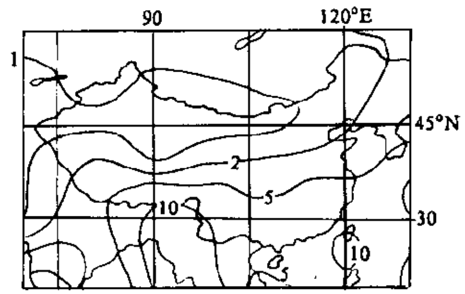

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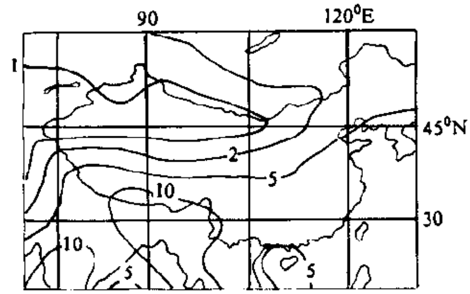

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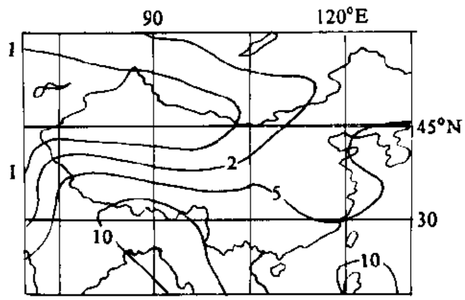

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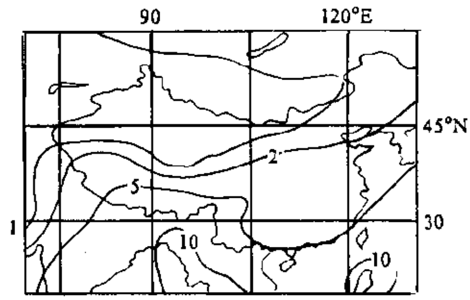

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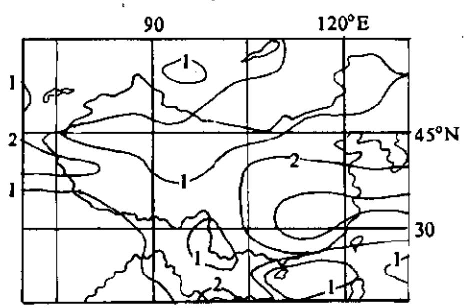

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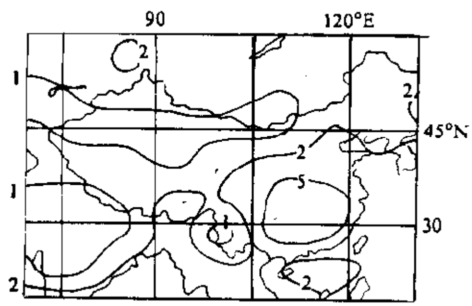

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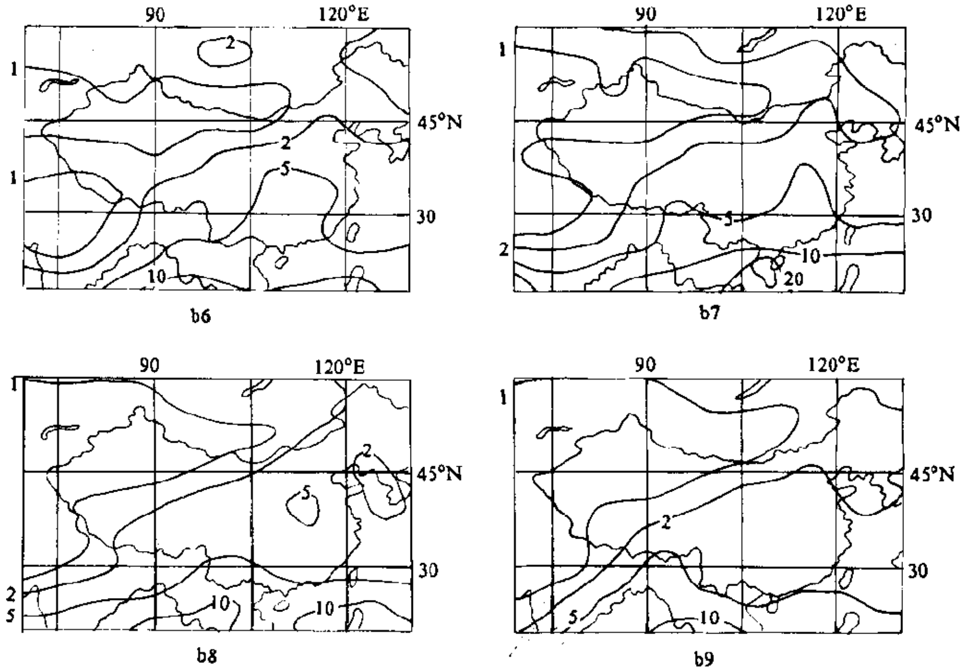

Fig 1 Precipitation in April (a4, b4), May (a5, b5), June (a6, b6), July (a7,b7), August (a8,b8), September (a9, b9), where a represents Shea's observation; b. UKMO simulation

SEASONAL VARIATION IN THE CLIMATE MODEL

In order to validate the model, we compare the control simulation with observation (Shea, 1986; CMB, 1981). The simulated patterns of monthly precipitation from April to September are in general agreement with observation, though the amount of the precipitation rate (mm/d) and its geographic distribution are slightly different from observations.

Precipitation zone in April locates in the southeastern part of China and it concentrates in south China in May, while it is a pre-rainy season in south China. The simulated precipitation zone has a north bias at about 1° latitude from observation. The rainfall zone in June immigrates northwards a great deal, i.e., over the middle and lower Yangtze River appears Meiyu (Chinese name for a heavy rainy season in summer) whose extending northwards and intensifying are simulated by the UKMO model quite well. Thought the precipitation in southwest China caused by the indian monsoon is underestimated (Fig. 1 b6), precipitation in July extends to the area between Yellow River and the Huaihe River and even to north China, but the precipitation over most parts is underestimated. The precipitation in August beings to recede southward (Fig. 1a8 and 1b8). The recession process is well simulated in comparison with observations, but the simulated recession is rapider than the observed. In September the contour of 5mm/d moves southward up to the coast of South China Sea, however, the precipitation in southwestern China and Tibet is underestimated. Comparing Fig. 1a9 with Fig. 1b9, we can see that the simulated precipitation pattern is in general agreement with the observed.

Fig. 2 presents the simulated variation in precipitation over the middle and lower Yangtze River(27 – 33° N, 110 – 122° E) and over north China (34 – 41° N, 105 – 118° E). The precipitation in winter over both areas is sparse but abundant in summer, this basic characteristics are well simulated by the climate model. Simulated precipitation peaks placing in June and in August over both Yangtze River and north China areas, are quite coincided with observations.

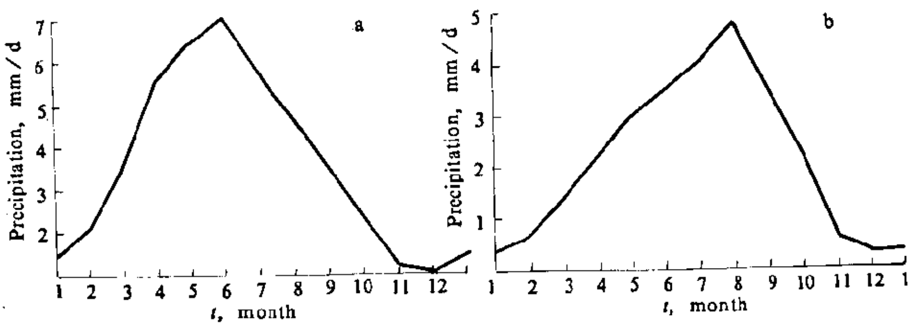

Fig. 2 Seasonal variation of precipitation

a. Over the middle and lower Yangtze River, 27 – 33° N, 110 – 122° E;

b. Over north China, 34 – 41° N, 105 – 118° E

PRECIPITATION CHANGE ON CO_2-DOUBLING

When the CO_2 concentration in the atmosphere is doubled, the precipitation zones are changed, but the basic characteristics of seasonal variation of the geographical distribution in precipitation are not changed greatly, i. e., latitudinal precipitation zones immigrate northwards from spring to summer, then recede southward from summer to autumn. As to different parts of China the precipitation amount is changed greatly, when CO_2 is doubled. Fig. 3 depicts the change in precipitation from April to September due to CO_2-doubling. We denote the difference between the doubled experiment ($2 \times CO_2$) and the control experiment ($1 \times CO_2$) as ($2 \times CO_2 - 1 \times CO_2$) .

The $(2\times CO_2-1\times CO_2)$ precipitation difference distribution in April is divided into two parts, the eastern part of China, which is an agriculture and high-level developing area, whereas precipitation decreases, and the western part of China, which is a low-level developing area, whereas precipitation increases. It is critical for the growth of crops, such as wheat, rape, broad bean, in the eastern part of China in April, if short of rainfall. The precipitation increases with lowering of a latitude in broad area, south to the Yangtze River in May. The increase of precipitation may attribute to subtropical high in the western Pacific, which moves northwestward to China on CO_2-doubling earlier than $1\times CO_2$ case. The pattern of $(2\times CO_2-1\times CO_2)$

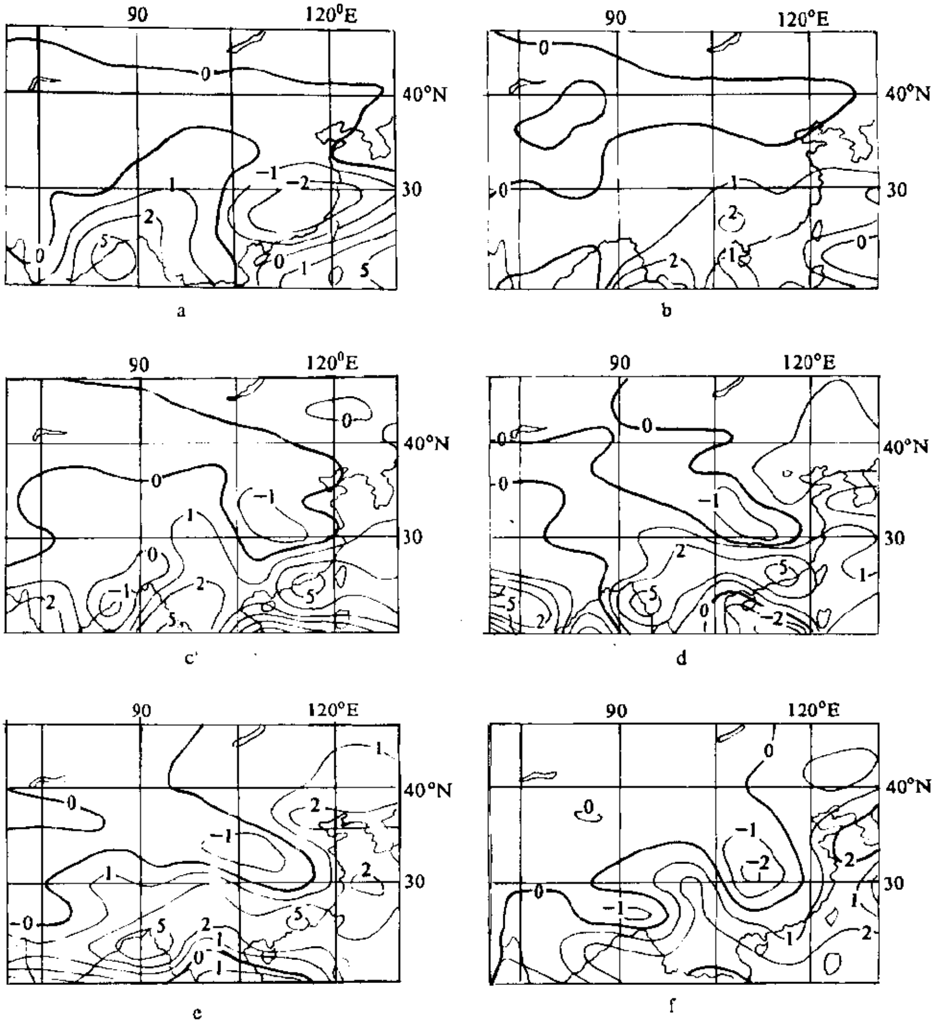

Fig. 3 Change in precipitation in April (a), May(b), June(c), July(d), August(e), September (f) on CO_2-doubling

precipitation difference in June is in the other way, i.e., the precipitation in south China increases, but decreases in north China and the Yangtze River; particularly the decrease of precipitation along the Yangtze River influences agriculture seriously. The precipitation in Guangdong and Fujian provinces increases greatly, it may be due to the invasion of typhoon on CO_2-doubling earlier than in $1 \times CO_2$ case. The $(2 \times CO_2 - 1 \times CO_2)$ precipitation distribution is similar in July and in August, i.e., precipitation increase over most of China, but decreases from northwest China to the upper Yangtze River valley. It causes serious drought on CO_2-doubling, because these areas are usually short of precipitation. The rain defect extends southward in September when CO_2 concentration is doubled, and it means the special rainy season vanishes in September over around Sichuan Province, the southern part of Shanxi Province and the eastern part of Gansu Province. The season is called the Huaxiqiuyu in Chinese (the rainy season over west China in Autumn).

CONCLUSIONS

The conclusions drawn from above work are as follows:

1. The simulated seasonal variation in precipitation for present climate is in broad agreement with observations, particularly, in respect to the large-scale distribution pattern in precipitation. For a local region, the discrepancy between the simulated and the observed precipitations sometimes is significant.

2. The change of the seasonal movement of precipitation zones is quite little changed when CO_2 is doubled, and it may attribute to that $2 \times CO_2$ radiation forcing is not strong enough to change the main characteristics of precipitation zones. Some parts of China become drier and others become wetter due to CO_2-doubling. It warns us that if it is imposed by rainfall defect due to CO_2-doubling, some dry parts of China at present-day, for example, over northwest China, become persistent droughty. As a result, the $2 \times CO_2$ climate threatens the human-being and the environment. Conversely, where the precipitation becomes abundant on CO_2-doubling, there will suffer from a terrific flood, for example, in south China.

3. The simulation of the change in precipitation in some regions on CO_2-doubling varies from one model to another (Zhao, 1988), because the change in precipitation stems from some factors, such as evaporation at the surface, cloud-feedback, radiation forcing, which are changed by CO_2 increase. Particularly, it is influenced by both global circulation and regional circulation. These factors and the related physical processes and parameterisations are formulated in different considerations in models. However, by studying the change in precipitation on CO_2-doubling, we can estimate at least the order-of-magnitude of the change and find out a dangerous signal.

Nevertheless, the knowledge we obtain from studies on CO_2 greenhouse effect is undoubtedly useful for the environmental protection and response strategies.

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