The Effect of Heating Anomaly on the Asian Circulation−A GCM Experiment①

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ABSTRACT

A numerical experiment was done by using the IAP 9−Level AGCM to study the effects of radiation anomaly over East Asia on the Asian general circulation. The results show that the changes of Asian summer general circulation are remarkable in the Indian and China southwest monsoon, precipitation in India and the Yellow River and Huaihe River valley in China and area around the north Japan, the easterly anomaly of low−level zonal wind in the tropical Pacific and so on.

Key words: Asian circulation, Simulation, Monsoon, Low−frequency

I. INTRODUCTION

Asian general circulation and climate are characterized by the strong seasonal, extra−seasonal and interannual variations. Factors which may have effects on the variability of summer East Asian general circulation and climate include the tropical SST (especially the western Pacific SST), the winter and spring snow cover over the Tibetan Plateau and Eurasia, the soil moisture in spring and possibly the polar ice. On the other hand, variabilities of East Asian general circulation (monsoon) may influence the tropical ocean−air variabilities (ENSO event) (Li, 1990). Hence study on the variability and predictability of Asian general circulation is one of the major tasks of CLIVAR (Climate Variabilities and Predictabilities Program) (CLIVAR Science Plan, 1995).

There exists observational evidence that there is considerable interannual variation of the heat budget over the Tibetan Plateau and East Asian region. Figure 1 shows the interannual variation of January 850 hPa temperature during 1979−1988 over China as analysed by using the ECMWF (European Centre for Medium−Range Weather Forecast) analyses. Then, how about the effects of heating anomaly on the variability of East Asian general circulation? This problem cannot be answered only through the study of the impacts of snow cover changes because the impacts of snow cover anomaly include two aspects, one is the changes of soil moisture and evaporation due to the snow cover change ('wet effect') and the other is the anomaly of heating due to the albedo change ('dry effect'). Therefore, the motivation of this work was to study the influence of heating anomaly on the Asian general circulation, or, the dry effect of snow cover change.

Hence for the sensitivity experiment, the solar radiation over East Asia was increased by 2% during June, July and August (10°−42°N, 65°−120°E) and the integration was made from June 1 through the end of next February. The initial conditions for both the control and sensitivity experiments were taken from the previous integration of the model and SST was

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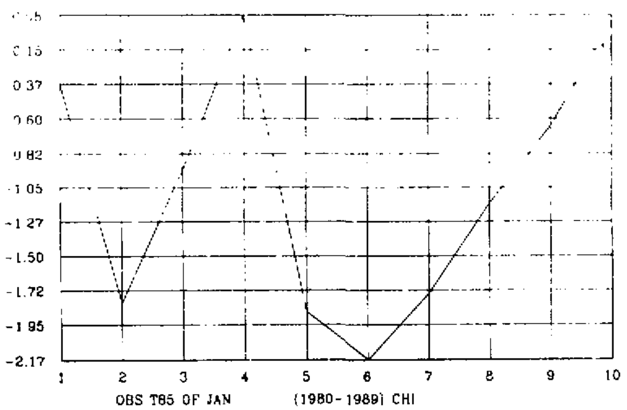


Fig.1. The observed interannual variation of January 850 hPa temperature over China during 1979–1988.

prescribed on the climatological SST. The model has been validated through climatological run, the AMIP (Atmospheric Model Intercomparison Program) run, Palaeo–climatic simulation and so on (Bi, 1994; Wang and Bi, 1996, Wang, 1994).

II. THE TEMPORAL VARIATIONS

From the seasonal variation of 10–day mean surface temperature difference (sensitivity run control run), the increase of temperature over East Asia (65°–120°E, 10°–42°N) during June, July and August is about 1.5°C and during the following period when the positive radiation anomaly was removed the temperature change is nearly zero. The changes of middle level (~375 hPa) geopotential height, the sensible heat flux and the precipitable water are similar to that of surface temperature, while the changes of precipitation, the soil moisture and the latent heat fluxes are different. The increase of precipitation begins from July until October, with low–frequency variation (Figure 2). Soil moisture decreases during June through August and after October but with small magnitude. There is also clear low–frequency variation in the change of latent heat flux. The change of latent heat flux is negative in June and July, positive from July to early September, again negative from mid–September to early November and then positive from mid–November to mid–December, and the magnitude is not so small.

We have also noticed that the low–level southwestly wind in the region (10°–26°N, 70°–100°E) is enhanced during mid–July through early September, while the change of low–level southeast wind is quite small.

Another interesting change is the easterly anomaly of low–level zonal wind over the tropical Pacific ocean during summer, especially over the eastern Pacific. Besides, the temporal variation of zonal wind difference over the eastern Pacific has the feature of low–frequency variation.

III. THE CIRCULATION CHANGES

For the summer surface pressure change, bigger positive change located in northern mid-latitude region of the Pacific and Atlantic and negative change with smaller magnitude exists over the Eurasia and North America. A strange thing is that there is a little smaller change in the southern mid-latitudes. The geopotential height change in the middle level (~375 hPa) increases everywhere in the Northern hemisphere, with bigger change in Asia and western part of North America in the order of 8 m and smaller change over the oceans. This means that the meridionality of the general circulation in the Northern Hemisphere is enhanced (Figure 3).

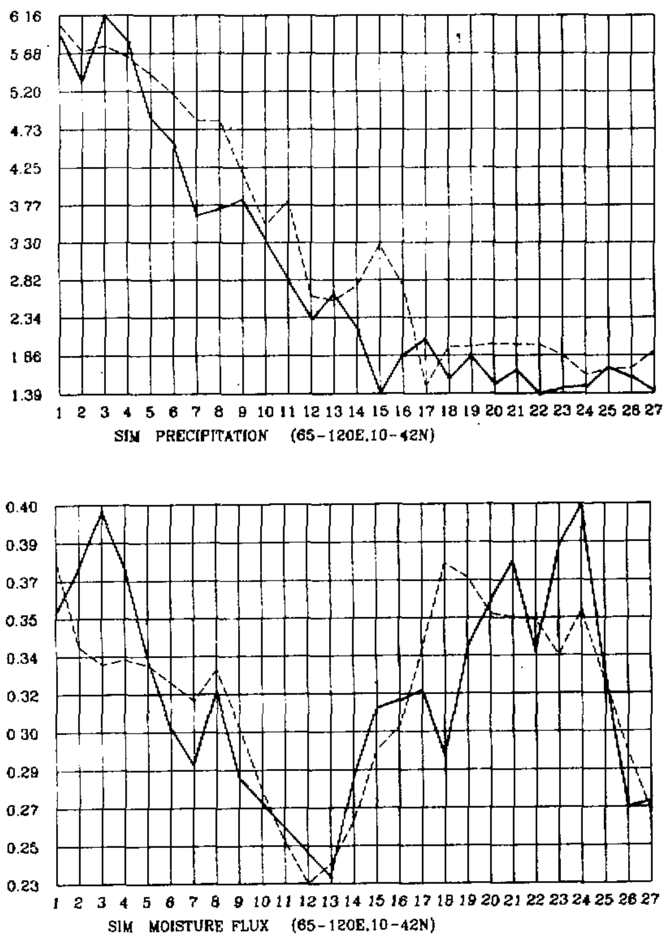


Fig. 2. The temporal variation of 10-day mean average precipitation (a) and moisture flux (b) over East Asia (10°-42°N, 65°-120°E) from June to next February. Solid line is for the control run and the dashed line is for the sensitivity run).

The most striking change in the JJA low-level (~ 975 hPa) wind field is located in the Pacific and Atlantic at the order of 3 m / s. In North Pacific the wind anomaly is easterly in central and eastern part and is clockwise around Japan. The tropical zonal wind anomaly is negative (easterly anomaly) and in North Indian ocean the anomaly of wind is also clockwise and so that the Indian monsoon is enhanced.

It seems that there is also systematic change in the cross section at 110°E of the meridional wind difference for JJA (Figure 4). One could find positive anomaly in northern mid-latitudes and southern subtropics and negative anomaly in the tropics at lower level. In the cross section at 110°E of geopotential height difference, maximum increase exists at the higher level of mid-latitudes in the Northern Hemisphere.

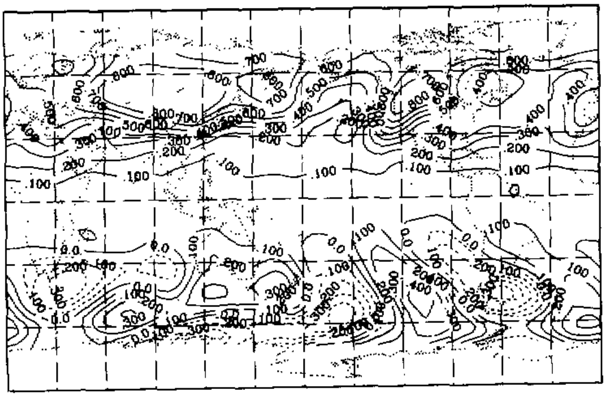


Fig.3. The global distribution of level 6 (~ 375 hPa) geopotential height changes of June, July and August mean in 10 m.

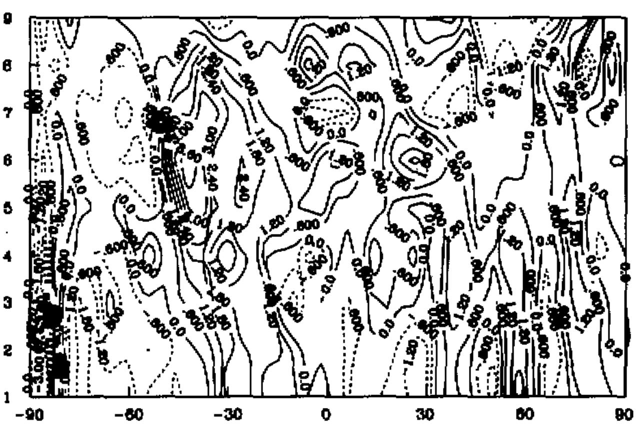
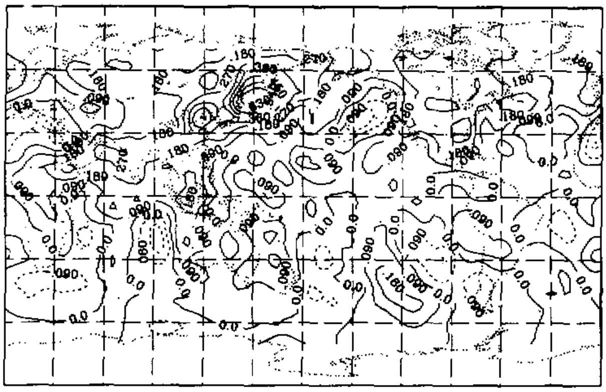


Fig.4. The cross section of meridional wind difference at 110°E for JJA in m / s.



SIM PRECIPITABLE W DIFF FOR JJA

Fig.5. The global distribution of JJA precipitable water changes in mm / day.

In the Figure of cross section at 2°N of level 2(~ 375 hPa) zonal wind difference, one can find that difference in the eastern Pacific change is quasi-periodically in a low-frequency and this fact is especially clear in 150–90°W. Another example is level 6 geopotential height difference which has the low-frequency variation in all latitudes on 2°N. Low-frequency feature exists in the tropical sea-level pressure change over the Pacific as well.

V. THE CHANGE OF ASIAN CLIMATE

The temperature increase for JJA is concentrated in Eurasia and North America with maximum value of 3.5°C. We can find that major regions of precipitation increase for JJA are India, the Yellow River–Huaihe River valley in China (including the south part of Liaoning province) and area around North Japan in the order of 10%. Since the southeast monsoon is weakened, the precipitation in the region south to the Yangtze River decreases. There are almost no changes of precipitation in other parts of Eurasian continent, but changes over the central and western tropical Pacific are quite remarkable.

VI. CONCLUDING REMARKS

This sensitivity experiment done by using the IAP 9–Level AGCM shows that there are remarkable changes of the Asian and Pacific general circulation and climate when the radiation is enhanced over East Asia. Major changes of JJA are:

a) enhancement of Indian summer monsoon and rainfall,

b) increase of precipitation over the Yellow River–Huaihe River valley and the area around North Japan,

c) enhancement of low–level southwest wind in East Asia,

d) easterly anomaly of low–level zonal wind over the tropical Pacific,

e) the circulation changes in the tropics having the feature of low–frequency variation.

The above results are far from conclusions before more work of observational analyses and more numerical experiments using different climate models are done. This work also has the strong implication for the 'dry effect' of negative snow cover anomaly over East Asia, since the decrease of snow cover will decrease the surface albedo and hence increase the radiation absorbed. This 'dry' effect is about opposite to the 'wet' effect of the snow cover decrease because the decrease of snow cover will decrease water vapour evaporation and accordingly the precipitation (weak monsoon). Another implication is that the changes of surface temperature or soil moisture will change the surface sensible or latent heat flux (heat source), and the East Asian general circulation and monsoon accordingly.

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