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The Interannual Variability and Predictability in a Global Climate Model①

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ABSTRACT

The interannual variabilities of the climatological simulation (V1) and the AMIP (Atmospheric Model Intercomparison Project) simulation (V2) by the IAP 9-Level Atmospheric General Circulation Model are studied and discussed in this paper. Based on the analysis of ratio of variability (R) of above two simulations the predictability of the model on the interannual climate variation are studied as well. Results show that V2 is bigger than V1 generally and V2 is more comparable to the real variability of the atmosphere, the major difference of V1 and V2 is in the tropics, for temperature and geopotential height the predictability is higher in the tropics while in the extra-tropics there is almost no predictability and the predictability is bigger in higher level than in lower level. The predictability for precipitation is generally low in the globe, and generally the predictability is high in the tropical eastern Pacific for the lower level. This study suggests that the possible way of increasing the model predictability is the improvement of land surface process modelling and the inclusion of the interannual variations of the land surface conditions (snow cover, albedo, soil moisture, etc.) as the forcing factor for climate modelling and prediction.

Key words: Interannual variability, Predictability, Land surface process

I. INTRODUCTION

The interannual variability of atmospheric general circulation and climate has great potential impacts on economy and people's life, especially in regions with great interannual variability like China, India, Indo-China Peninsula, Australia, Northeast Brazil, and so on. Factors which may have influence on the atmospheric interannual variability include SST, land surface conditions, and possibly the polar processes (Lau et al, 1985; Yeh et al, 1984; Meehl, 1994; Huang et al, 1992; Shukla, 1987; Tang et al, 1982). Models may behave quite differently in reproducing the atmospheric variabilities caused by various external factors and internal dynamics (Slingo et al, 1996; Sperber et al, 1995), which is a crucial problem in predicting the interannual variability of climate.

The aim of this work is to study the model reproduced interannual variability through two kinds of simulation experiments. One is the climatological simulation using the observed climatological SST as the boundary condition and another is the AMIP simulation using the interannually changed observed SST as boundary condition. The ratio of the variabilities of the two results can reasonably reflect the SST-driven model interannual variability and model predictability.

The model used in this work is the IAP 9-Level grid point AGCM with 40X50 horizontal resolution. The model was developed through IAP-SUNY (State University of New

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York) cooperative research on climate change and was modified by Bi ①(1993). The climatological run and the AMIP run were made by Bi in 1995.

II. THE INTERANNUAL VARIABILITY OF THE CLIMATOLOGICAL AND AMIP SIMULATION

For convenience, let us define *V1* and *V2* as the standard deviation of the interannual variability of climatological simulation and AMIP simulation respectively, and define R as the ratio of *V2* over *V1*. First looking at the geographical distribution of *V1* and *V2* for surface air temperature of January, the most pronounced feature is that those bigger than average *V1* and *V2* exist in the land region and that the biggest value is in the high latitude land area, while over the ocean areas the value is quite smaller. The most striking difference between *V1* and *V2* is located in the tropical eastern Pacific which is clearly the result of the large interannual variability of SST over there (Fig. 1). For the sea–level pressure of January, the biggest *V1* and *V2* exist in the northern Pacific and northern Atlantic where the edges of low pressure centres are located, and in the North Eurasia where is the edge of high pressure centre over Eurasia. Possible reason for this feature is the interannual movement and magnitude change of the pressure centre. The *V1* and *V2* in the higher latitude region is much greater than in the lower latitude region. We can also find the above features for sea–level pressure in *V1* and *V2* fields at 850 and 500 hPa geopotential height, the only pronounced difference is in the North Eurasia where the value is not so big relatively compared to the case of low level geopotential height.

For the interannual variability *V2* of zonal wind at 200 hPa of January, the value bigger than average value can be found over the tropical eastern Pacific, Northeast Africa, North Eurasia and North Atlantic and North Pacific. These changes seem to be apparently linked to the big variabilities of Walker circulation, the African–Asian monsoon system, and easterly jet over Eurasia. We do find the similar distribution in *V1* of zonal wind at 200 hPa in January, but with a smaller value compared to *V2* especially in the tropical eastern Pacific. For *V1* and *V2* of January 850 hPa water vapour mixing ratio we can find the biggest value in African–Asian–Australian monsoon region, in the tropical Eastern Pacific (for *V2* only), and in the central South America (Figure 2).

For July case of *V1* and *V2* of 850 hPa water vapour mixing ratio, again Asian–Australian monsoon region is of the largest value, and the mid–latitude Pacific has the largest value too, and the value over the tropical eastern Pacific is bigger than average as well (for *V2* only). Fig. 3 shows the interannual variability *V1* and *V2* for July precipitation. We can more clearly find that for both *V1* and *V2* African–Asian–Australian monsoon region has the largest variabilities. Generally speaking, the variabilities of precipitation are much bigger in the tropics than in the extra–tropics. Smaller variabilities are found in Europe, the central South America, and North Africa.

For the 200 hPa and 850 hPa *V1* of velocity geopotential of July, the biggest value is in the tropical western Pacific, while for *V2* of 200 hPa and 850 hPa velocity geopotential the central region of the biggest value extended to the west, covering the Indo–China Peninsula, South China (south to the Yangtze River) and the tropical western Pacific.

III. RATIO OF *V2* OVER *V1* (R)

Since *V2* stands for the interannual variability caused by the interannual change of

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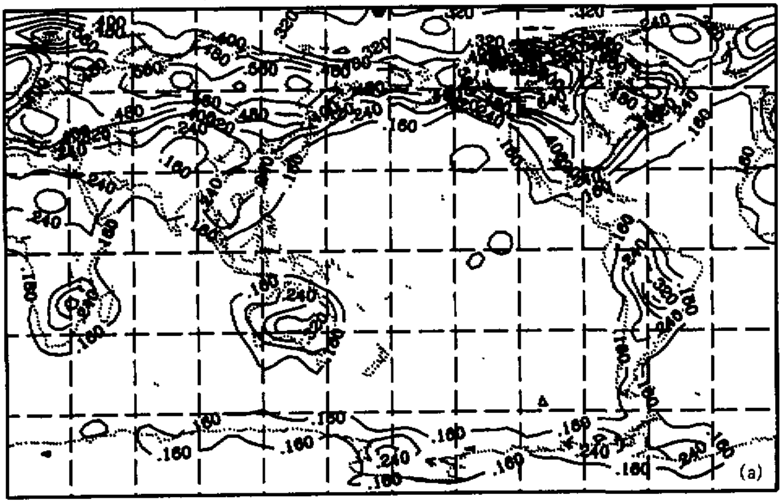
①Bi Xunqiang, 1993, The IAP 9–L AGCM and Its Climate Simulation, PhD Dissertation of the Institute of Atmospheric Physics, Chinese Academy of Sciences.



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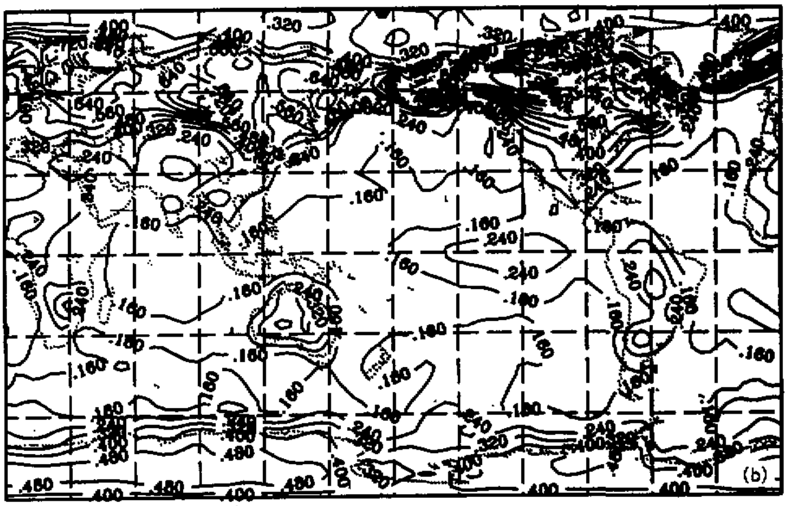


AMIP VARIABILITY OF TS FOR JAN

Fig. 1. The global distribution of *V1* (a) and *V2* (b) for surface air temperature of January (Unit: 3.5°C).

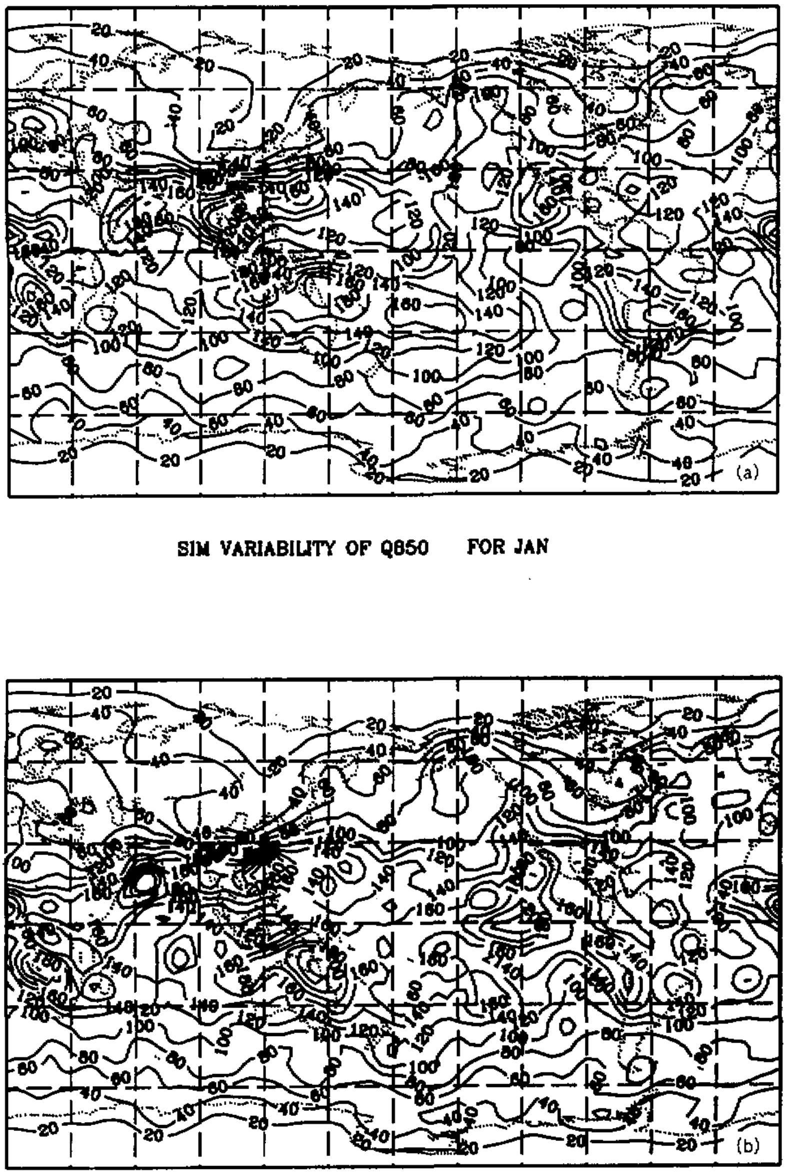


Fig. 2. Same as Figure 1, but for 850 hPa water vapor mixing ratio of January (Unit: 3.5 g / kg).

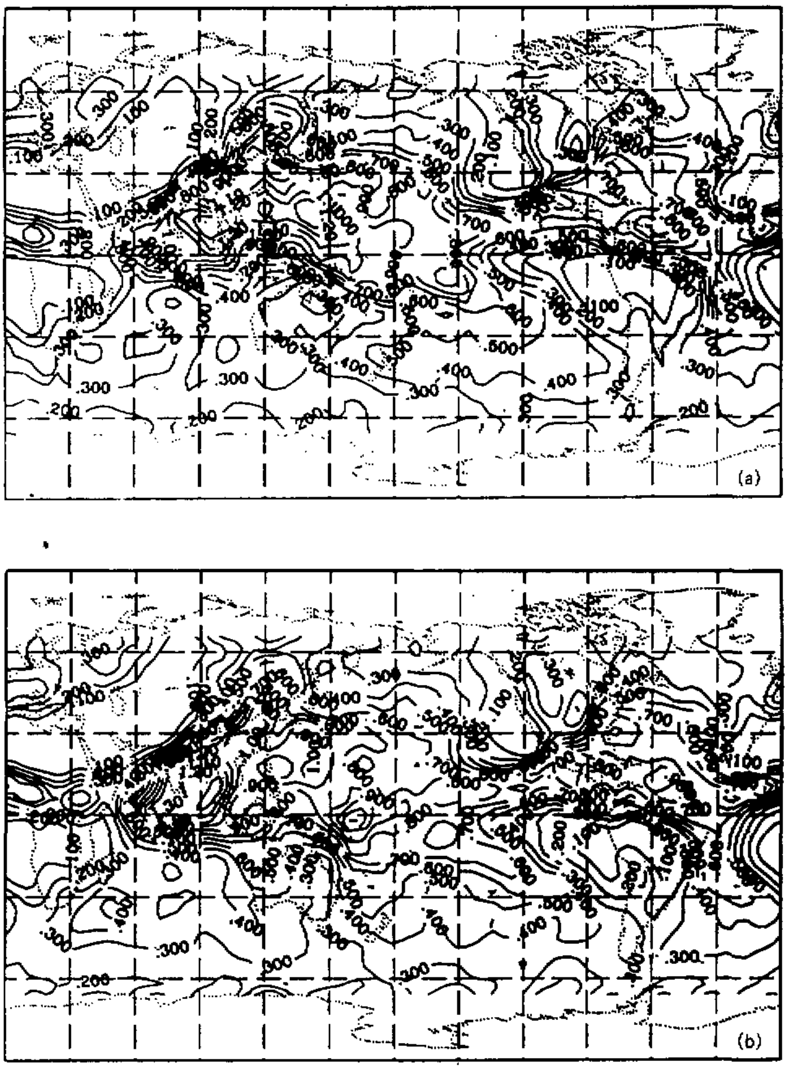
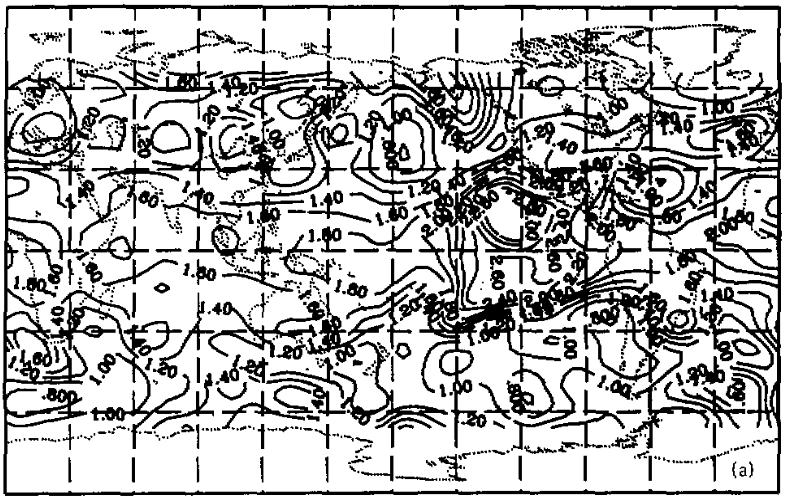


Fig. 3. Same as Figure 1 , but for precipitation of July (Unit: 3.5 mm / day).

global SST and internal dynamics of the atmosphere and *VI* for that caused by the internal dynamics only (the only difference from year to year is the difference of initial conditions of the atmosphere), the ratio R could no doubt mean the interannual signal (model predictability) caused by the interannual variation of global SST.

First, looking at the circulation shown by the geopotential height at 200 hPa, 500 hPa and sea-level pressure (Fig. 4), we can find that higher value appears in the whole tropics and R is very small elsewhere at 200 hPa in July. In January higher R value concentrates in the



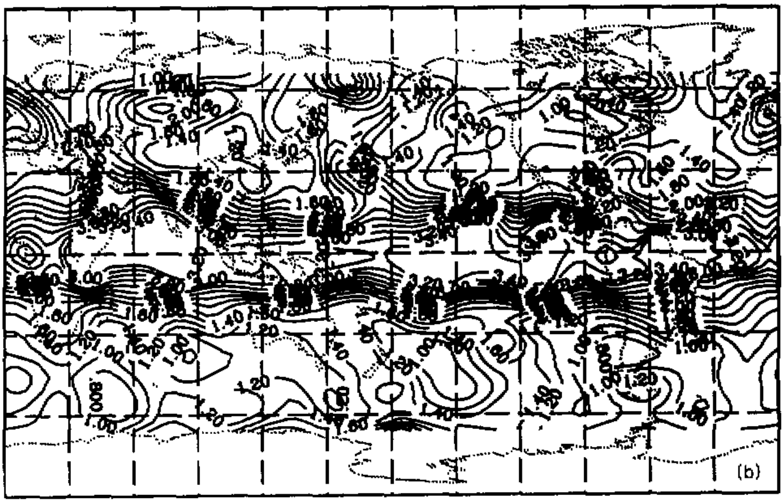


Fig. 4. The global distribution of ratio R (*V2* / *V1*) for 200 hPa geopotential height in January (a) and July (b).

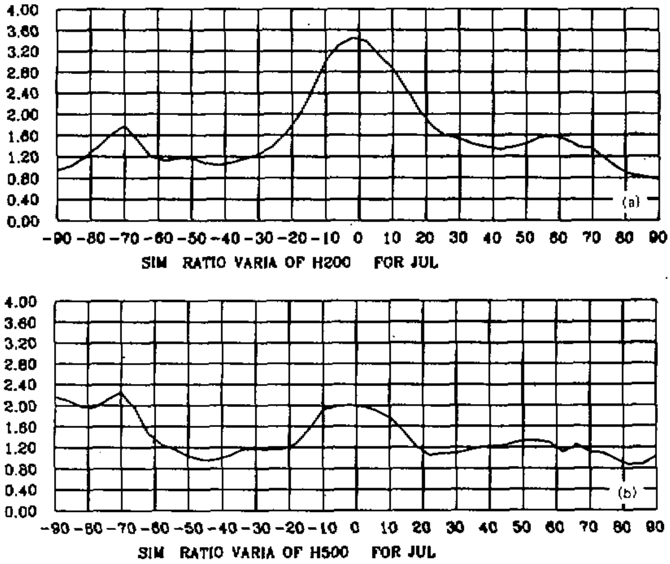


Fig. 5. The latitudinal distribution of R for geopotential height at 200 hPa (a) and 500 hPa (b) for July.

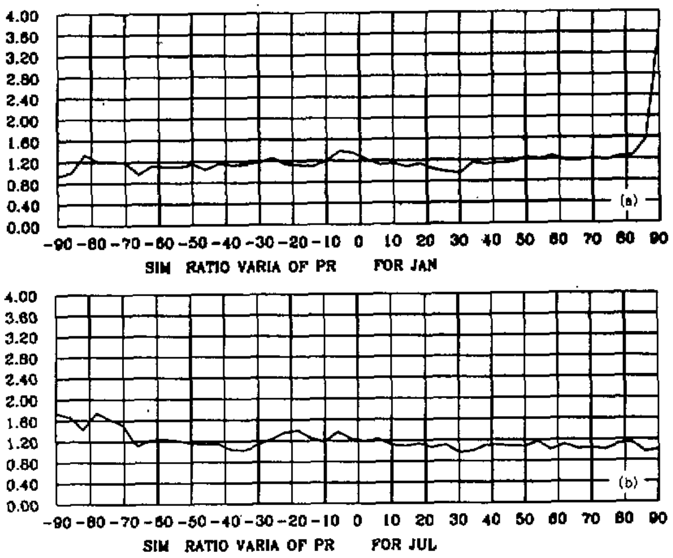


Fig. 6. The latitudinal distribution of R for the precipitation of January (a) and July (b).

tropical eastern Pacific although generally the value in the whole tropics is greater than in the extra-tropics. At 500 hPa, the distribution of R is similar to that of 200 hPa for July, and for January the high value of R is located in the tropical eastern Pacific and the tropical Indian ocean. For the sea-level pressure, higher R value is located in the tropical eastern Pacific for July and in both tropical Eastern Pacific and tropical Indian ocean for January. From the latitudinal distribution we can find that R bigger than 1.6 only exists in the tropics for geopotential height and sea-level pressure, and that R is much bigger at 200 hPa than at 500 hPa in the tropics (Fig. 5).

At 850 hPa, R for zonal wind of July is greater than 1.6 only in the central and eastern tropical Pacific, while the R value for meridinal wind of July is less than 1.6 everywhere over the globe. Region with value higher than 2.0 is the tropics (20°N-20°S) for 200 hPa temperature and only the tropical eastern Pacific for 850 hPa temperature. For precipitation the value of R at any latitude is about 1.2 on the average and there is no region with value higher than 1.6 excluding the tropical eastern Pacific Fig. 6).

IV. CONCLUDING REMARKS

The study on the interannual variability of the model climate is very important in validating the model's abilities in the interannual predictability. From above studies on climatological run and the AMIP run for 13 years we find that the AMIP variability is more realistic compared to the variability of the control run. Areas with large *V1* and *V2* for surface temperature concentrate over the land and *V2* has larger value over the tropical eastern Pacific as well. For the precipitation largest value of *V1* and *V2* is located in monsoon regions like African-Asian-Australian monsoon region, Northeast Brazil and West America. For the geopotential height, the *V1* and *V2* are larger in mid-and -high latitudes than in the tropics, with centres of largest value in North Pacific, North Atlantic and North Eurasia.

The studies on the model predictability on the interannual variability of climate through analysis on the ratio (R) of variability of AMIP run over that of the climatological run show that meaningful predictability exists only on the tropics for geopotential height and temperature at 200 hPa and 500 hPa. For some variables the R is pronounced only at the tropical eastern Pacific and for the precipitation there is almost no region where the value of R is greater than 1.6. The reason for the high R value in the tropical eastern Pacific and the whole tropics for some variables is the large signal for interannual variation over the tropical Pacific (ENSO cycle) and possibly the changes of zonal circulation cell of the atmosphere in the tropics related to the ENSO cycle.

The current studies, although tentative, gave strong implications for the improvement of model predictability. The possible way to increase the predictability is to improve the description on land surface processes and to take the interannual variation of land surface conditions (snow cover, albedo, soil moisture, sea ice, etc.) into account. It is necessary to make better and more detailed routine observation on the snow cover, soil moisture, sea ice, surface albedo, and on some meteorological variables in regions of interest, in order to increase the reliability and accuracy of the current experimental and operational climate prediction systems for seasonal to interannual time scales in our country.

REFERENCES

Huang S. S., et al, (1992), The effects of the Arctic sea ice on the variations of general circulation and climate, *Acta Meteorologica Sinica*, **6**: 1-14 (in Chinese).

Lau N. C., (1985), Modelling the seasonal dependence of atmospheric response to observed El Ninos 1962-1976, *Mon. Wea. Rev.*, **113**: 1970–1996.

Meehl G. A., (1994), Influences of the land surface in Asian summer monsoon: External conditions versus internal feedback, *J. of Climate*, **7**: 1033–1049.

Shukla J. and Mooley D. A., (1987), Empirical prediction of summer monsoon rainfall over India, *Mon. Wea. Rev.*, **115**: 695–703.

Slingo J. M., et al, (1996), Intraseasonal oscillation in 15 Atmospheric General Circulation Models: Results from an AMIP diagnostic subproject, *Climate Dynamics*, **12**: 325–357.

Sperber K. R. and Palmer T. N., (1995), Interannual tropical rainfall variability in General Circulation Model simulations associated with the AMIP, To be published in J. Climate.

Tang M. C., et al, (1982), The thermal model for long range rainfall prediction, *Acta Meteorologica Sinica*, **40**: 62–71 (in Chinese).

Yeh T. C., et al, (1984), The effect of soil moisture on the short–term climate and hydrology change–A numerical experiment, *Mon. Wea. Rev.*, **112**: 474–490.