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Dependence of the AGCM Climatology on the Method of Prescribing Surface Boundary Conditions and Its Climatological Implication①

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ABSTRACT

By using IAP 9L AGCM, two sets of long–term climatological integration have been performed with the two different interpolation procedures for generating the daily surface boundary conditions. One interpolation procedure is the so–called "traditional" scheme, for which the daily surface boundary conditions are obtained by linearly interpolating between the observed monthly mean values, however the observed monthly means cannot be preserved after interpolation. The other one is the "new" scheme, for which the daily surface boundary conditions are obtained by linearly interpolating between the "artificial" monthly mean values which are based on, but are different from the observed ones, after interpolating with this new scheme, not only the observed monthly mean values are preserved, the time series of the new generated daily values is also more consistent with the observation. Comparison of the model results shows that the differences of the globally or zonally averaged fields between these two integrations are quite small, and this is due to the compensating effect between the different regions. However, the differences of the two patterns (the global or regional geographical distributions), are quite significant, for example, the magnitude of the difference in the JJA mean rainfall between these two integrations can exceed 2 mm / day over Asian monsoon regions, and the difference in DJF mean surface air temperature can also exceed 2°C over this region.

The fact that the model climatology depends quite strongly on the method of prescribing the daily surface boundary conditions suggests that in order to validate the climate model or to predict the short–term climate anomalies, either the "new" interpolation scheme or the high frequency surface boundary conditions (e.g., daily or weekly data instead of the monthly data) should be introduced. Meanwhile, as for the coupled model, the daily coupling scheme between the different component climate models (e.g., atmospheric and oceanic general circulation models) is preferred in order to partly eliminate the "climate drift" problem which may appear during the course of direct coupling.

Key words: Linear interpolation, Model climatology, Atmospheric general circulation model (AGCM), Surface boundary condition

1. Introduction

As the most important surface boundary conditions for the Atmospheric General

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Circulation Model (AGCM), time dependent sea surface temperature (SST) and sea ice concentration (SIC) are used to drive the AGCM when performing climate simulations. experiments. In most models, such as the Atmospheric General Circulation Model for Institute of Atmospheric Physics (IAP AGCM), the observed monthly mean SSTs are prescribed as the values at the middle of each month, then daily SSTs are obtained by linearly interpolating between these monthly mean values. However, as pointed out by Taylor et al. (1997) and Sheng and Zwiers (1998), this traditional interpolation procedure does not preserve monthly means, i.e., the monthly means computed from the linearly interpolated time–series are not equal to the observed monthly means. At the same time, this traditional procedure has a smoothing effect and the amplitudes of the seasonal and interannual variations of the interpolated time series are damped. This would imply that with the traditional linear interpolation procedure, we cannot expect AGCMs to experience with the same boundary conditions as the observation even the observed monthly mean SST and SIC distributions are provided.

Fortunately, these deficiencies have been recognized by several researchers. Based on the observed monthly means values, Harzallah And Sadourney (1995) adopted the iterating cubic spline interpolating procedure, instead of the linear interpolation method, to achieve the conservation of the monthly means. But this procedure is quite complex and it may be difficult to be adopted to some climate models. Recently, Taylor et al.(1997) and Sheng and Zwiers(1998) have proposed a much simpler approach to preserve the monthly means. In their method, the "artificial" values which are based on the observed monthly mean values, instead of the observed monthly means themselves, are specified as mid–month values, daily values are obtained by the traditional linear interpolation between these artificial mid–month values and the month means can be preserved. At the same time, the damping of the seasonal and interannual variation of the interpolated time series can also be largely alleviated. Due to its simplicity, this method has been adopted to generate the surface boundary conditions (SSTs and SICs) used in the phase II of the Atmospheric Model Intercomparison Project (AMIP II).

It has been well known that an anomalous warming or cooling of the sea surface temperatures of the tropical oceans can have significant influence on the atmospheric general circulation (e.g., Rowntree, 1972; Wallace and Gutzler, 1981; Blackmon et al., 1983; Von Storch and Kruze, 1985; Fennessy and Shukla, 1991). The response of the atmospheric circulation to the extratropical SST anomalous has also been investigated (e.g., Palmer and Sun, 1985; Lau and Nath, 1990). Wallace and Jiang (1987) shows that the atmospheric response to extratropical SST forcing is indeed stronger than the response to tropical forcing. However, the SST anomalies in these studies are usually several degrees in magnitude, which is much stronger than the SST difference caused by the interpolation procedure. So, in this paper we will use an atmospheric GCM to demonstrate whether the SST difference due to the linear interpolation procedure will induce significant differences in the model results.

2. Surface boundary condition

In this paper, two sets of sea surface temperature (SST) and sea ice concentration (SIC) distributions are adopted as the surface boundary conditions respectively. One is the observed monthly mean SST and SIC distribution (Fiorino, 1997), and the other is the AMIP II type monthly mean SSTs and SICs which is based on, but is different from the observed one (Taylor et al.,1997).

For the observed monthly mean SST (hereafter SST_{obs}), the model daily values can be obtained with linear interpolation procedure between these observed monthly mean values (this procedure is hereafter referred to as " traditional" scheme), and the new monthly mean SSTs (hereafter $(SST_{obs})^{new}$) can be re-generated from these daily values. Careful examination of the difference between SST_{obs} and $(SST_{obs})^{new}$ month by month shows that the monthly mean observed SST cannot be preserved after interpolation, and the maximum differences appear in August for the Northern Hemisphere, and in February for the Southern Hemisphere. Fig. 1 shows the difference between monthly-mean SST_{obs} and $(SST_{obs})^{new}$ for August and February respectively.

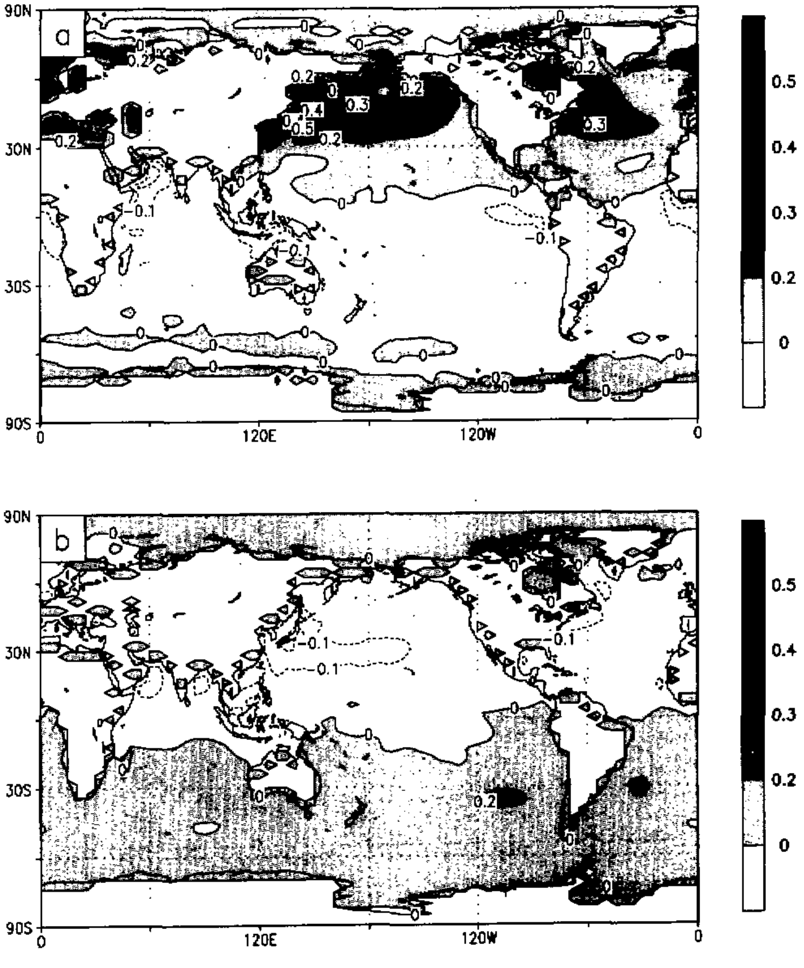

Fig. 1. The difference between the observed monthly mean and the monthly mean calculated from daily values obtained by linearly interpolating between observed monthly means for (a) August and (b) February. The contour interval is 0.1°C.

From Fig. 1a we can find that, in August, the large SST differences tend to appear off the coasts of Japan and extend eastward, and then spread over the large area of the northern Pacific Ocean. The large positive values also appear off the coast of Newfoundland, also found is in the Hudson Bay. The SST difference over these regions is typically more than a few tenths of a degree, however in some regions, the maximum SST difference can exceed 0.5°C. In the Southern Hemisphere, the SST difference is relatively small, and is always less than 0.1°C.

In February, we can find from Fig.1b that the SST difference in the Northern Hemisphere is less marked. Over the arctic region, the positive SST differences are less than 0.1°C. Over the Pacific and Atlantic Ocean, the negative SST differences, which is in the opposite sign of that in August, are also less than 0.1°C. In the mid–latitude southern Oceans, the positive SST differences are also less pronounced, and the maximum SST difference of about 0.3°C appears only in a very small region. As for the AMIP II type monthly mean SST (hereafter SST_{amip}), the model daily values can also be obtained by linearly interpolating between these " artificial" monthly mean values (this procedure is hereafter referred to as " new" scheme), and the new monthly mean SSTs (hereafter $(SST_{amip})^{new}$) can also be re–generated from these daily values. The difference between monthly mean SST_{obs} and $(SST_{amip})^{new}$ for August is shown in Fig. 2, and we can find that the difference is negligible, i.e., the observed monthly mean SST is almost preserved after interpolation with " new" scheme, and the same is true for the other months (figures not shown).

In fact, the linear interpolation procedure is just like a filter. Under the traditional procedure, the warmest month is always too cool and the coolest month is always too warm after

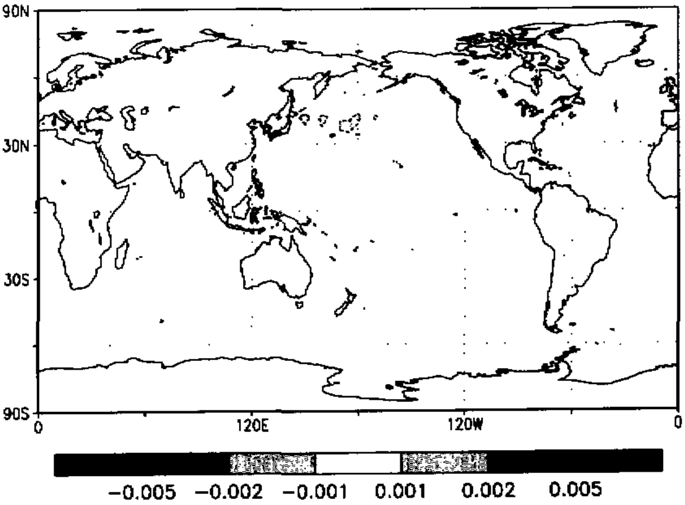

Fig. 2. The difference between the observed monthly mean and the monthly mean calculated from daily values obtained by linearly interpolating between AMIP2 type (artificial) monthly mean SST for August.

interpolation, as shown in Fig.1. So the seasonal variation of SST is always damped with the "traditional" interpolation method. However with the "new" procedure, this damping effect can be largely alleviated. Fig.3 shows the time series of the difference of daily SST values interpolated by "new" and "traditional" scheme at different locations. We can clearly find that either in the mid–latitude Pacific or in the mid–latitude Atlantic Ocean, the daily sea surface temperatures interpolated with "new" scheme are always warmer in warm seasons compared with the "traditional" scheme, and cooler in cold seasons. This indicates that the seasonal variation of the daily SST interpolated with "new" scheme is always stronger than that with "traditional" procedure, i.e., the seasonal variation of SST is more consistent with the observation after interpolation with "new" scheme.

3. Brief description of the IAP AGCM and the experimental design

The climate model used in this study is the AMIP–II version of IAP 9L AGCM which is a grid point model with horizontal resolution of 5° in longitude by 4° in latitude and 9 levels in the vertical. The model physics module includes major atmospheric processes such as convection, precipitation, cloud formation, radiation, eddy diffusion, gravity–wave drag and surface–atmosphere interaction, the more detailed description of IAP 9L AGCM can be found

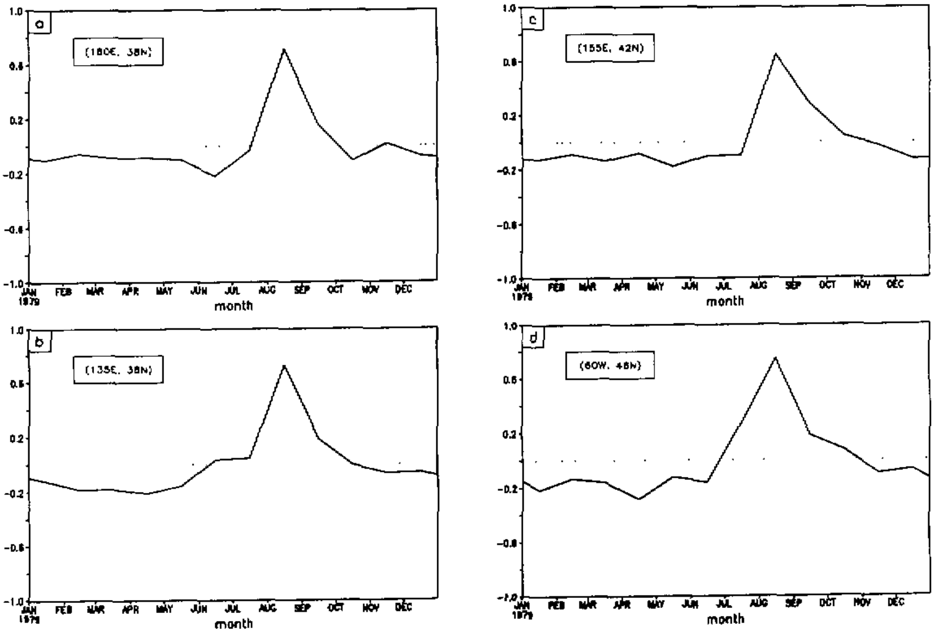

Fig. 3. Time series of the difference between the daily SST values interpolated with "new" and "traditional" interpolation procedure respectively at (a) (180°E, 38°N) (b) (135°E, 38°N) (c) (155°E, 42°N) and (d) (60°W, 46°N) for IAP AGCM.

in Liang's paper (1996). And the daily values of sea surface temperature (SST) and sea ice concentration(SIC) are obtained by linearly interpolating between the observed monthly mean values as the traditional method. As for the AMIP II version of IAP 9L AGCM, certain model parameters are reset according to the AMIP II specification (see Table 1).

Table 1. AMIP II specification for model parameters

Parameter	AMIP II specification
Earth Obliquity	23.441°
Eccentricity	0.016715
Longitude of perihelion	102.7°
Solar constant	1365 W / m^2
Carbon dioxide concentration	348 × 10^{-6}
Ozone concentration	Wang et al. (1995)

From the discussion in Section 2, we can find that even with the observed monthly mean sea surface temperature, the "traditional" interpolation procedure will provide "unrealistic" surface boundary conditions for the climate model during its integration. However, whether these SST differences due to the deficiency of interpolation procedure will induce significant influence on the model performance have not yet been investigated. So in this paper, IAP 9-Level AGCM has been integrated for 20 years under the observed monthly mean sea surface temperature distributions with the "traditional" schemes (hereafter referred to as "EXPTRD") and with the "new" scheme (hereafter referred to as "EXPNEW") respectively, in order to investigate the impact of the interpolation scheme on the model performance. During the analysis, the last 5-year model results are extracted and we only pay attention to several important climatological fields, such as precipitation, surface air temperature, outgoing longwave radiation (OLR), sea level pressure and cloudiness.

4. Impact of the interpolation procedure on the model climatology

4.1 *Globally and zonally averaged fields*

Firstly, we will try to investigate whether the difference in interpolation procedure will cause significant influence on the global averaged fields for IAP 9L AGCM. Table 2 shows the annual, summer and winter mean globally averaged fields from the integrations of IAP 9L AGCM by applying the "traditional" and "new" interpolation procedure respectively. We can find that the difference between the global averaged model resulting from "EXPNEW" and "EXPTRD" is quite small. In "EXPNEW", JJA mean precipitation, surface air temperature and outgoing longwave radiation (OLR) at TOA are 2.777 mm / day, 15.53°C and 247.95 W / m^2 respectively, and for "EXPTRD", the corresponding values are 2.777 mm / day, 15.55°C and 248.07 W / m^2, and the difference in the simulated cloudiness is only 0.1%, so the differences are negligible between the two interpolation schemes. The same is true for the annual and winter means. The above comparison results indicate that, as for the globally averaged fields, the difference due to the interpolation procedure is negligible.

In Fig. 4, we show the differences of the zonally averaged model fields between the "EXPNEW" and EXPTRD" integrations. Generally, the magnitude of the difference of JJA mean precipitation is less than that of DJF mean, especially in the low latitude regions, the maximum difference for DJF mean precipitation can reach about 0.4 mm / day near

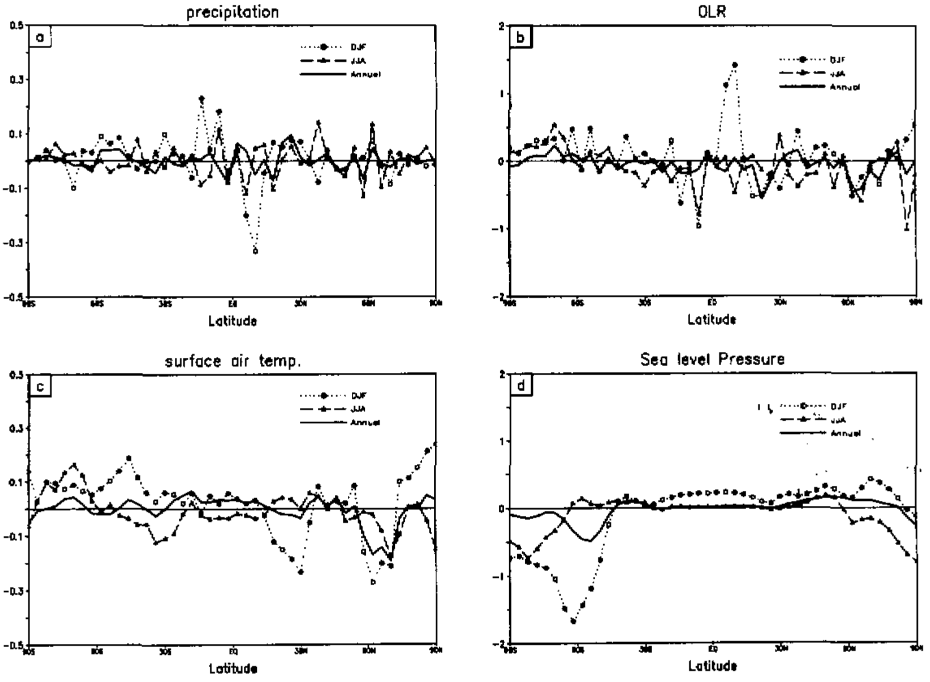

Fig. 4. Zonal averaged difference of (a) Precipitation (mm / day) (b) Outgoing long-wave radiation at the top of atmosphere (W / m^2) (c) Surface air temperature (K) and (d) Sea level pressure (hPa) between the model integrations with the "new" and "traditional" interpolation procedure for annual, summer (*JJA*) and winter (*DJF*) mean respectively.

Table 2. The global averaged climatological fields with the traditional and new interpolation schemes for the observed monthly mean sea surface temperatures

Variable	Annual mean		Summer (JJA mean)		Winter (DJF mean)	
	EXPNEW	EXPTRD	EXPNEW	EXPTRD	EXPNEW	EXPTRD
Precipitation (mm / day)	2.748	2.747	2.777	2.777	2.710	2.703
Surface air Temperature(°C)	13.64	13.64	15.53	15.55	12.11	12.10
Outgoing longwave radiation at TOA(W / m^2)	245.13	245.20	247.95	248.07	242.83	242.78
Cloudiness (%)	0.569	0.568	0.565	0.564	0.572	0.571

10°N and 0.2 mm / day near 15°S (Fig. 4a). We can also find that the zonal mean precipitation difference is nearly in opposite sign between the JJA and DJF means, and the magnitude of the annual mean precipitation difference between the "EXPNEW" and EXPTRD" integrations is usually less than 0.1 mm / day due to the compensating effect between summer and winter seasons. From Fig. 4b we can find that the difference of the zonally averaged TOA outgoing longwave radiation is in good negative correlation with the precipitation difference. The OLR difference is also relatively large for DJF means compared with JJA means, and the maximum OLR difference with the magnitude of about 1.5 W / m^2 appears near 10°N for the DJF means, which coincides with the maximum precipitation difference shown in Fig.4a.

Fig. 4c shows the zonally averaged difference in surface air temperature for JJA, DJF and annual mean respectively. Generally, in winter months (DJF for the Northern Hemisphere and JJA for the Southern Hemisphere), surface air temperature is cooler in "EXPNEW" compared with "EXPTRD" except in polar regions, and in summer months, surface air temperature is warmer in "EXPNEW" compared with "EXPTRD" except in high latitudes. This is consistent with the conclusion given in Section 2 that the warm months are usually too cool and the cool months are usually too warm for the traditional interpolation procedure due to its smoothing effect. In both hemispheres, the signs of the temperature difference for the JJA and DJF means are opposite, and the amplitude of the difference is generally larger for DJF means compared with the JJA means. And the maximum difference can reach about −0.3°C in 60°N and 0.3°C in north pole for DJF means.

The difference of zonal mean sea level pressure is generally negligible between 45°S to 45°N (Fig. 4d). However in high latitudes, especially in southern high latitudes, the difference between the "EXPNEW" and "EXPTRD" becomes a little larger. The maximum difference appears near 60°S, where the zonal averaged DJF mean sea level pressure for "EXPNEW" is about 1.75 hPa lower than that for "EXPTRD".

In summary, in terms of the zonally averaged fields, there does exist some difference between the "EXPNEW" and "EXPTRD", although the magnitude of the difference is not so large. And in some latitudes, the difference between the "EXPNEW" and "EXPTRD" may be negligible.

4.2 *Global geographical distributions*

In this section, we will compare the global distributions of several climatological fields between the "EXPNEW" and "EXPTRD". Firstly, we can find from Fig. 5 that the difference in sea level pressure is generally negligible over low latitudes, and a little larger in middle and high latitudes with the maximum difference of about 2 hPa.

For DJF means (Fig. 5a), the sea level pressure in "EXPNEW" is higher than in "EXPTRD" over northern middle and high latitudes, and lower in the Southern Hemisphere 45°S polarward. As for JJA means (Fig. 5b), the difference of sea level pressure turns to be negative over the northern polar regions compared with the DJF means, however, around the latitudinal band of 60°S, the simulated JJA mean sea level pressure in "EXPNEW" is higher than that in "EXPTRD". Generally, the amplitude of the difference is larger for DJF means than for JJA means.

Fig. 6 shows the difference of outgoing longwave radiation (OLR) at the top of atmosphere (TOA), we can find that the regions with relative large OLR differences were confined between 30°S to 30°N, and the difference is negligible over higher latitudes in both hemispheres. For boreal winter (DJF means), the maximum positive difference with magnitude of more than 3 W / m^2 appears over the maritime continent, and large regions with negative

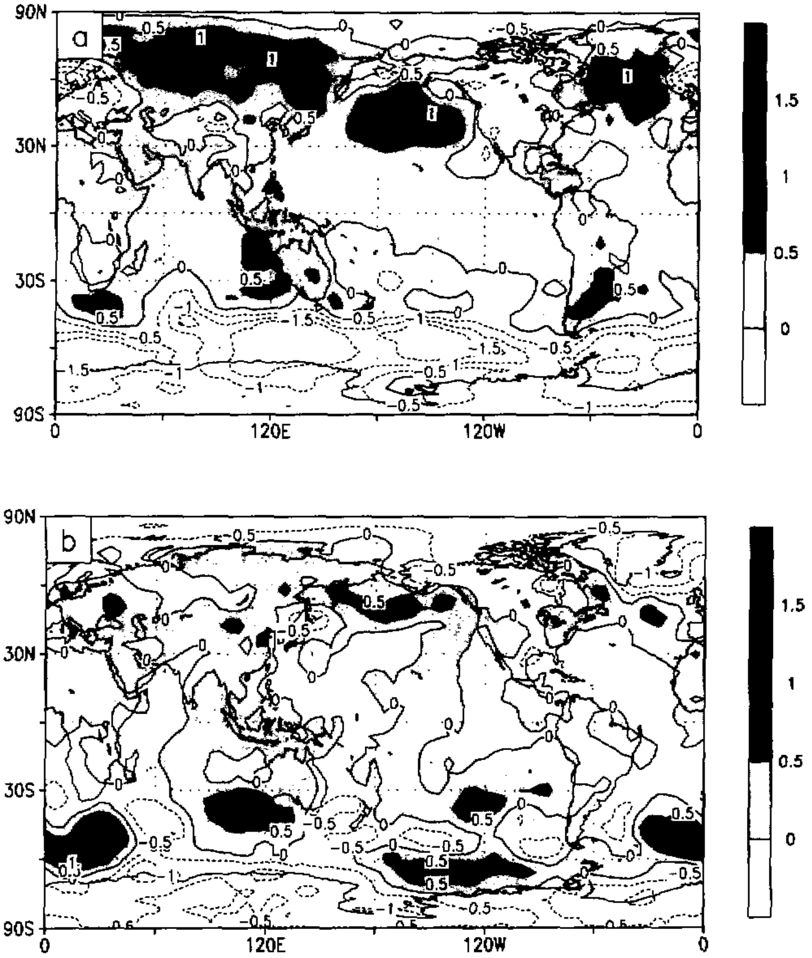

Fig. 5. The difference of sea level pressure (hPa) for (a) Winter (DJF) and (b) Summer (JJA) respectively between the model integrations with new and traditional interpolation procedures. Difference greater than 0 is shaded.

OLR differences spread from the western tropical Pacific to the date line, with the maximum negative difference exceeding −4 W / m^2 (Fig. 6a). As for JJA means (Fig. 6b), the OLR difference is generally negative over most part of the maritime continent and the western Pacific, however in the vicinity of the date line, the OLR difference turns to be weak positive which is *strongly negative for DJF means. Around the vicinity of Mexico, the positive OLR differences* more than 2 W / m^2 were found both for DJF and JJA means.

Next, we will compare the simulated JJA and DJF mean precipitation and surface air temperatures between the "EXPNEW" and "EXPTRD" over three different regions. Fig. 7

gives the differences over Asian monsoon region, and we can see from Fig. 7a that the difference of summer monsoon precipitation is remarkable between "EXPNEW" and "EXPTRD". The JJA mean precipitation in "EXPNEW" is more than 2 mm/day larger than that for "EXPTRD" over the lower reaches of the Yangtze River basin and the area between the Yangtze River and the Yellow River. Over most part of the southern China and northeastern China, the simulated JJA mean precipitation is generally weaker in "EXPNEW" than in "EXPTRD", with the maximum difference exceeding 2 mm/day. The excess JJA mean precipitation can also be found in the Bay of Bengal and the western coast of India for "EXPNEW". As for the DJF means (Fig. 7b), the difference of precipitation over the Eurasian continent is negligible, the major differences appear in Japan and its surrounding regions and in the low latitudes as well. However, compared with the difference of JJA means, the magnitude is generally weaker for DJF means, especially over the Eurasian continent.

The differences of DJF and JJA mean surface air temperatures between the two integrations are shown in Fig. 7c and Fig. 7d, and we can find that both DJF and JJA mean surface air temperatures are colder in "EXPNEW" than in "EXPTRD" over the large part of China.

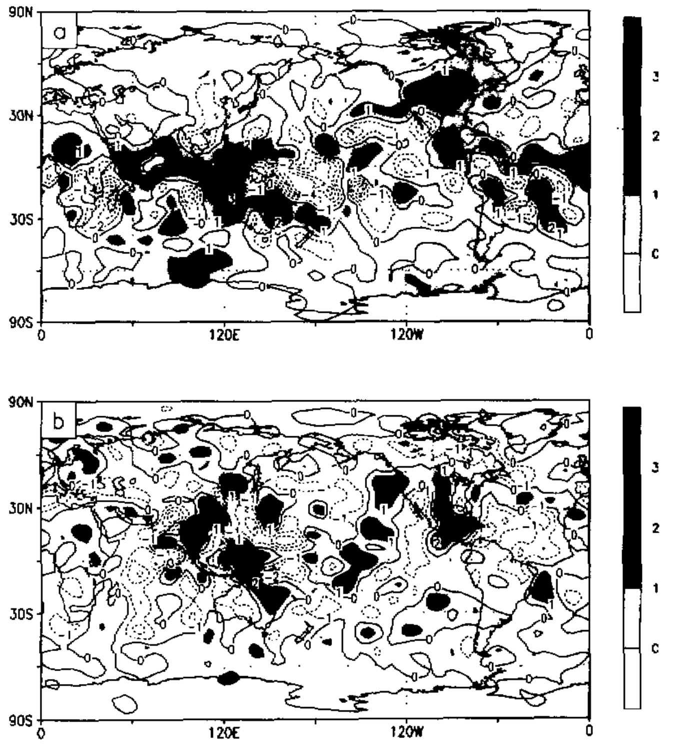

Fig. 6. The difference of outgoing longwave radiation at TOA (W/m^2) for (a) Winter (DJF) and (b) Summer (JJA) respectively between the model integrations with new and traditional interpolation procedures. Difference greater than 0 is shaded.

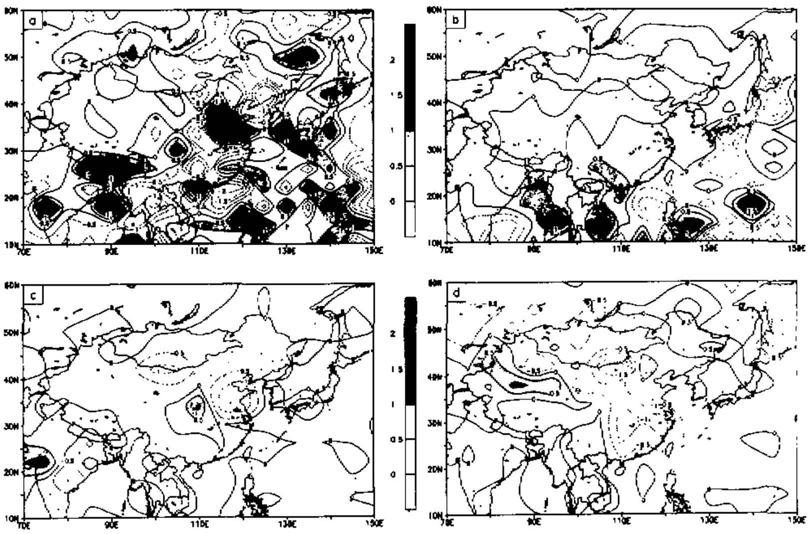

Fig. 7. Difference between the model results with new and traditional interpolation procedures for (a) JJA and (b) DJF mean precipitation (mm / day), and (c) JJA and (d) DJF mean surface air temperature (°C) over Asian region.

For DJF means, the maximum negative anomaly appears in the inner Mongolia with magnitude exceeding 2°C, and the positive temperature anomalies are located around the Tibetan Plateau, with the maximum difference of about 1°C. Unlike the precipitation, the magnitude of the temperature difference for JJA mean is smaller than that for DJF mean (Fig. 7c,d). In correspondence with the positive precipitation difference shown in Fig. 7a, relatively large negative difference of the JJA mean surface air temperature is found between the Yangtze River and the Yellow River basin with its maximum exceeding 1°C. In summary, the comparison results from Fig.7 show that, over Asian monsoon regions, both the precipitation and surface air temperature are all quite sensitive to the interpolation procedures used to generate the model surface boundary conditions.

In Fig. 8 we show the difference of the precipitation and surface air temperature between the "EXPNEW" and "EXPTRD" over the North American region. From Fig. 8a we can find that the JJA mean precipitation differences are quite marked over most part of the North American region, especially over the low latitude regions, the amplitude of difference can exceed 2 mm / day. Around the vicinity of Bermuda, there also exists large positive difference of JJA mean precipitation. Compared with the JJA means, the difference of the DJF mean precipitation is less marked in middle and high latitudes, but is of the same order in low latitudes (Fig. 8b).

Distinct from the precipitation, the differences of surface air temperature are negligible over tropical regions for both JJA and DJF means, and the magnitude of the difference is generally larger for DJF means than for JJA means (Figs. 8c,d). Over large part of North American continent, the model simulated DJF mean surface air temperature is more than

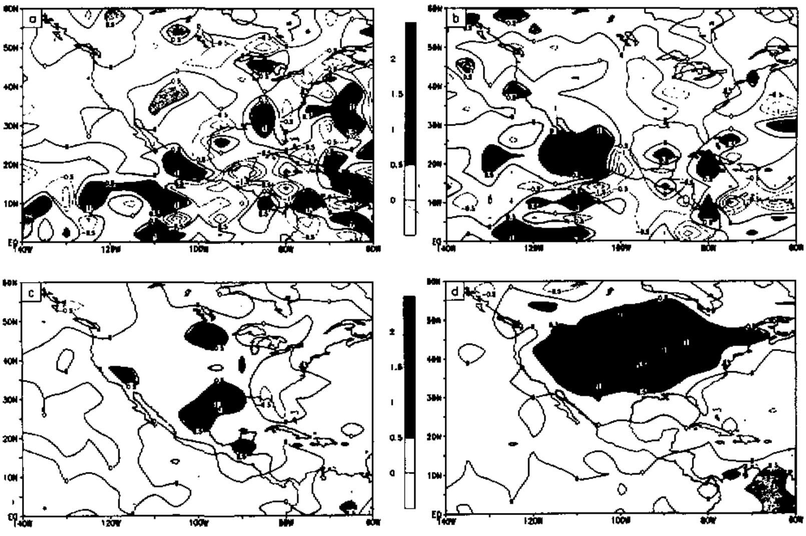

Fig. 8. As Fig. 7, but for North American region.

1°C higher in "EXPNEW" than in "EXPTRD", and the maximum difference can exceed 1.5°C. As for JJA mean (Fig. 8c), the temperature difference is less than 0.5°C over the most part of North America except in the small region around Houston, where the maximum positive difference can also exceed 1.5°C. There also exists negative difference for JJA mean surface air temperature over the eastern coast of North America,, i.e., the simulated surface air temperature in "EXPNEW" is colder than that in "EXPTRD". However for DJF means, the differences are all positive over almost the whole North American continent.

As for the African region, we can find from Fig. 9 that the differences of precipitation between "EXPNEW" and "EXPTRD" are all remarkable for both JJA and DJF means.

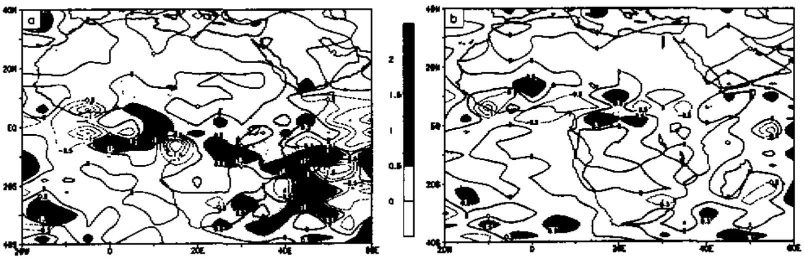

Fig. 9. Difference of (a) JJA and (b) DJF mean precipitation (mm / day) between the model results with new and traditional interpolation procedures for African region.

Especially for the winter season (DJF means), the difference between the two experiments can exceed 2 mm / day in magnitude. However, the differences of surface air temperature over African region are not significant for both JJA and DJF means, and the magnitude is generally less than 0.5°C (figures not shown).

5. Conclusion and discussions

Based on the observed monthly mean surface boundary conditions (i.e., SST and SIC distributions), two sets of long-term climatological integrations for IAP 9L AGCM (i.e., "EXPNEW" and "EXPTRD") have been performed, with the two different interpolation procedures respectively to generate the daily surface boundary conditions. Comparison shows that both the two simulations of the globally averaged fields by using "EXPNEW" and "EXPTRD" are almost the same, and this may be ascribed to the small differences of the globally mean SST between these two integrations. Meanwhile, the differences of zonally averaged fields between these two integrations are also not so significant. However, as for the global and regional geographical distributions, the differences can be quite significant, especially for the model simulated precipitation and surface air temperature distributions over several monsoon regions. For example, the maximum difference of JJA mean precipitation can exceed 2 mm / day in Asian and American monsoon regions, and the largest temperature difference can exceed 2°C for DJF means in Asian region. And this may imply that the small differences in the zonally averaged fields are actually due to the compensating effect between the different regions in the same latitude band.

The large differences of the geographical distribution of model results found in the aforementioned experiments may suggest the significant impact of the method for prescribing the daily surface boundary conditions on the model climatology. Furthermore, this conclusion is climatologically important in the following aspects:

1) Model validation

Usually, validating the atmospheric general circulation model, one always drives the AGCMs to reach equilibrium state with the "traditional" interpolation procedure to obtain the daily surface boundary conditions, and then compare the model climatology with the observed climatology. During the course of model development, all the model parameters may be "tuned" in order to assure that the AGCM climatology agrees well with the observation to the largest extent.

However, with the "traditional" interpolation procedure, the observed monthly mean values cannot be preserved and this would imply that the AGCM does not experience with the same surface boundary conditions as the observation. Therefore, suppose that the AGCM is perfect, the deviation of the model surface boundary conditions from the observations originated from the "traditional" interpolation procedure will actually lead the model to reach an equilibrium state which is different from the observation. So, unless the "new" interpolation procedure is adopted, the conclusion drawn from the model validation by using the "traditional" interpolation procedure might be doubtful, and even misleading. The same is true for the validation of oceanic general circulation models (OGCMs), in which the observed monthly mean wind stress forcing and heat fluxes are used in the upper boundary conditions.

2) Coupling between the component climate models

For the coupled climate models, the atmospheric and oceanic components can be coupled either daily or monthly. When direct coupling scheme is used without fluxes correction technique, many of the coupled models may suffer seriously from the climate drifts during the long term coupling integrations.

As for those models with the monthly coupling scheme, the distributions of the sea surface temperature calculated from the oceanic component are passed to the atmospheric component monthly, then the daily sea surface temperature distribution for the AGCM is usually obtained by the aforementioned " traditional" interpolation scheme. As discussed above, the monthly mean sea surface temperature cannot be preserved after this " traditional" scheme, and its annual and interannual variabilities are also damped. This will definitely induce an imbalance between the atmospheric and oceanic component of the coupled model, and this small initial imbalance might evolve into considerable " climate drift" after the long term coupling integration due to the nonlinear interactions within the coupled system.

So, the daily coupling scheme between the atmospheric and oceanic component models is preferred in order to partly eliminate the " climate drift" during the coupling integration. As for those who insist on the monthly coupling scheme, the above mentioned " new" interpolation procedure may better be adopted.

3) Short–term climate predictions

As for the short term climate prediction by using AGCM, the monthly mean sea surface temperature anomalies (SSTA) are usually served as an essential predictor (e.g. Zeng, 1994; Lin et al., 1998). However, due to the deficiency of the " traditional" interpolation procedure, not only the amplitude, but also the seasonal and interannual variations of the SSTA will be distorted after interpolation. Therefore, the response of the climate model to the monthly mean SSTA by the " traditional" scheme will also be distorted, and this might reduce the prediction skill and would likely induce more uncertainties during the assessment of the climate prediction system. Even for the prediction of climate anomalies, the influence of the interpolation procedure on the prediction will still exist, because the response of the climate model to the sea surface temperature is nonlinear.

In summary, in order to obtain the more realistic prediction product, either the " new" interpolation procedure together with the monthly mean data, or the high frequency sea surface temperature anomaly (daily or weekly) is needed.

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