気象庁全球モデルの気候特性(2)：熱帯の降水(英文)

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The Climate Simulated by the JMA Global Model
Part 2 : Tropical Precipitation

By

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Abstract

A 34-year simulation of the global atmospheric circulation has been performed using the Japan Meteorological Agency (JMA) global model. The simulated climate of tropical outgoing longwave radiation (OLR) and precipitation are compared with the observed climate of OLR. The seasonal mean field is generally well simulated by the model. However, several deficiencies in the simulation can be identified. 1) Convective activity around the Philippines is weak. 2) The convective area over Africa is shifted eastward and the convective area over the Amazon splits into two parts. 3) Asian monsoon precipitation extends north-eastward. 4) The area of large inter-annual variation of convective activity over the equatorial Pacific is shifted westward.

Key Words : model, climate, JMA, tropical, precipitation

1. Introduction

The main objective of the climate modeling study at the National Research Institute for Earth Science and Disaster Prevention (NIED) is to predict the posibility of a disaster based on the prediction of future climate. For this purpose, a very accurate prediction of the geographical distribution of precipitation is required. For reliable prediction of precipitation, the model is required to simulate the present climate of precipitation very accurately. Apart from this specific purpose, the accurate simulation of tropical

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precipitation is important because tropical convective heating is the major driving force of the general circulation of the earth's atmosphere, and therefore the model's deficiency in the tropical convection is likely to lead to a deficiency in the model's global climate.

In this paper, we investigate the tropical convective activity in the Japan Meteorological Agency (JMA) global model (JMA, 1993 ; Sugi *et al.*, 1990). We examine the climate of outgoing longwave radiation (OLR) as well as precipitation in the tropics simulated by the model and compare them with the observed climate of OLR.

For the verification of the simulated convective activity, we use the observed climate of OLR (Kawahara, 1990), which is derived from the NOAA satellite observation for the period of 1974-1987. The observed climate of the seasonal mean OLR (Fig. 1) is computed as the 10 year average of the seasonal mean OLR for the period 1974-85 (the data for 1978 is absent). The seasonal mean is defined as a 3 month mean : Dec-Jan-Feb for winter, Mar-Apr-May for spring, Jun-Jul-Aug for summer and Sep-Oct-Nov for autumn. The interannual variation (IAV) of OLR (Fig. 3) is the standard deviation of the seasonal mean OLR. For the computation of the intra-seasonal variation (ISV) of OLR (Fig. 5), the pentad OLR data is used. First, the climatological average is subtracted to remove the annual variation. Then, the nine pentad moving average is subtracted to remove the inter-annual variation. The ISV is defined as the standard deviation of the resultant pentad data for each season.

The simulated climate of OLR and precipitation of the JMA global model is computed using the result of a 34-year time integration of the model, as in Sugi *et al.* (1995). The same computational procedure is used for the model data as for the observed data. The averaging period is different for the model and the observed data, but we have checked that the difference due to the averaging period does not affect much the results presented in this paper.

2. Outgoing longwave radiation (OLR)

2.1 Seasonal mean

The observed and simulated climates of the seasonal mean OLR are shown in **Fig. 1** and **Fig. 2**, respectively. The areas below 220 W/m^2, which correspond to active convective areas, are shaded in both figures. Note that the contours above 240 W/m^2 are not drawn in Fig. 1. Overall agreement is good between the model climate and observed climate. However, some discrepancies can be pointed out. The active convection area over Africa in the model is shifted eastward compared to the observations in winter, spring and autumn. The convection area in the model over the Amazon splits into two parts in winter and spring. In summer, from Africa to South Asia, the belt-shaped low OLR area extends too much in the model. In the observation, there is an active convection area over the western Pacific near the Philippines, but it does not appear in the model. Instead, strong convections are concentrated in the regions near the equator such as Sumatra, Borneo and New Guinea.

2.2 Inter-annual variability (IAV)

Figs. 3 and **4** show the observed and simulated inter-annual variability (IAV) of the seasonal mean OLR. These two figures do not agree with each other. In the observation, the IAV signal associated with ENSO is evident, particularly in the winter. These signals are not seen in the OLR in the model. The largest amplitude of IAV in the model appears over the eastern Pacific at the latitude around 10°N in the winter and spring, but the amplitude is relatively small over this region in the observation.

2.3 Intra-seasonal variability (ISV)

Fig. 5 and **6** show the observed and simulated intraseasonal variability (ISV). The correspondence between the simulated and observed climates is much better than in the case of IAV. In general, the amplitude of the simulated ISV is less than that of the observed one. Note that the contour intervals are different in the two figures. In the model, there is no area where the ISV is larger than 30 W/m^2. In the observation, the large ISV areas are concentrated in the region from the Indian Ocean to the western and middle Pacific Ocean.

In winter, the large amplitude of ISV in the model is seen in the south of 20°S, while it is seen in the north of 20°S in the observation. In spring, two maxima of ISV are seen over the east Indian Ocean and New Guinea in the observation, but they are not clear in the model. In summer, over the western Pacific near the Philippines, the amplitude of ISV is large in the observation but small in the model. The wide area over the Arabian Sea is covered with large ISV in the observation, while the large ISV region in the model is concentrated in a narrow band in the north of the Arabian Sea. In autumn, areas of large ISV appear in the east Indian Ocean and around the Philippines in the observation, while the areas of large ISV in the model are shifted northward of these regions.

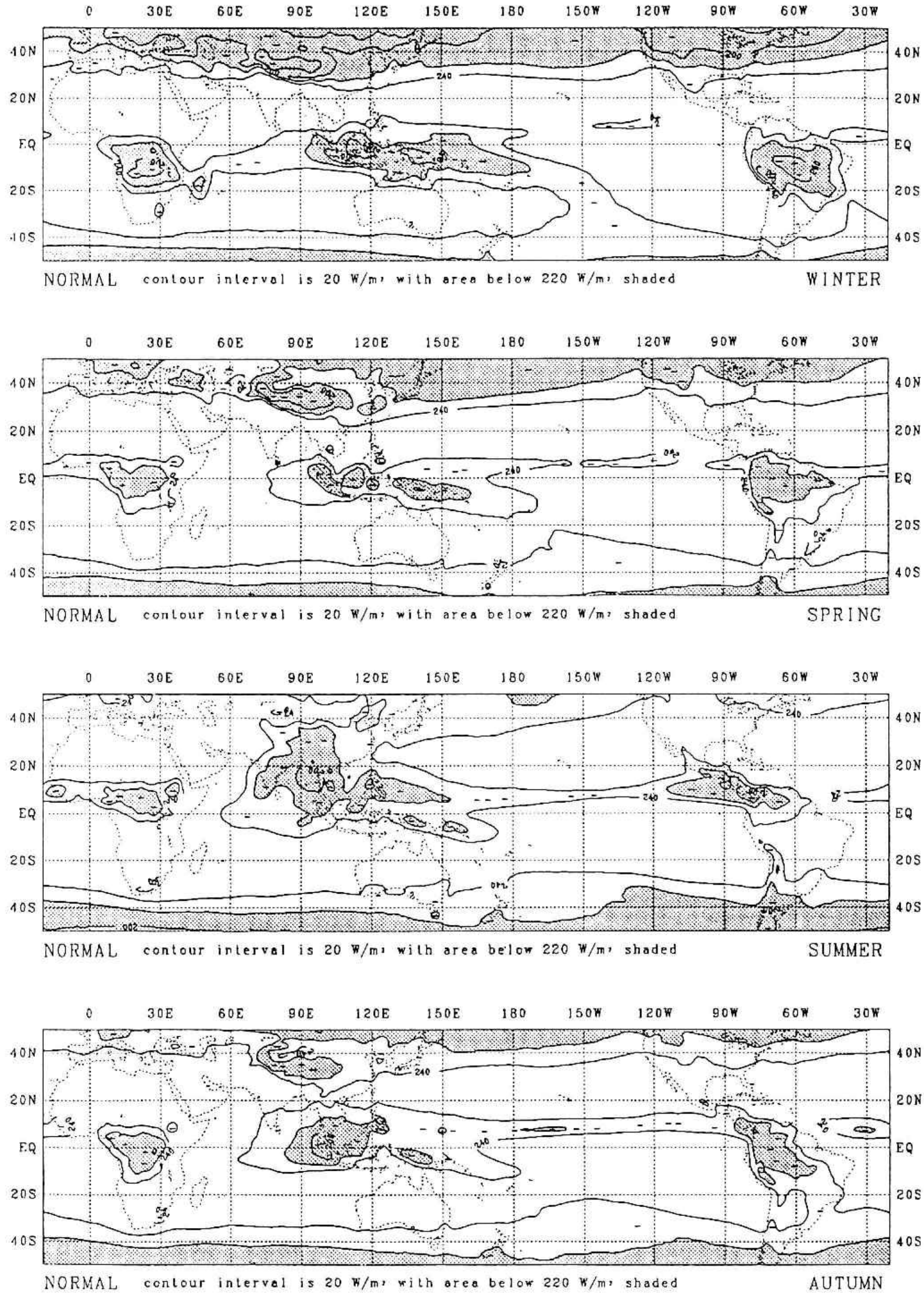

Fig. 1 Observed seasonal mean OLR (Kawahara, 1990). Contour interval is 20 W/m^2. Areas below 220 W/m^2 are shaded. Contours above 240 W/m^2 are not drawn.

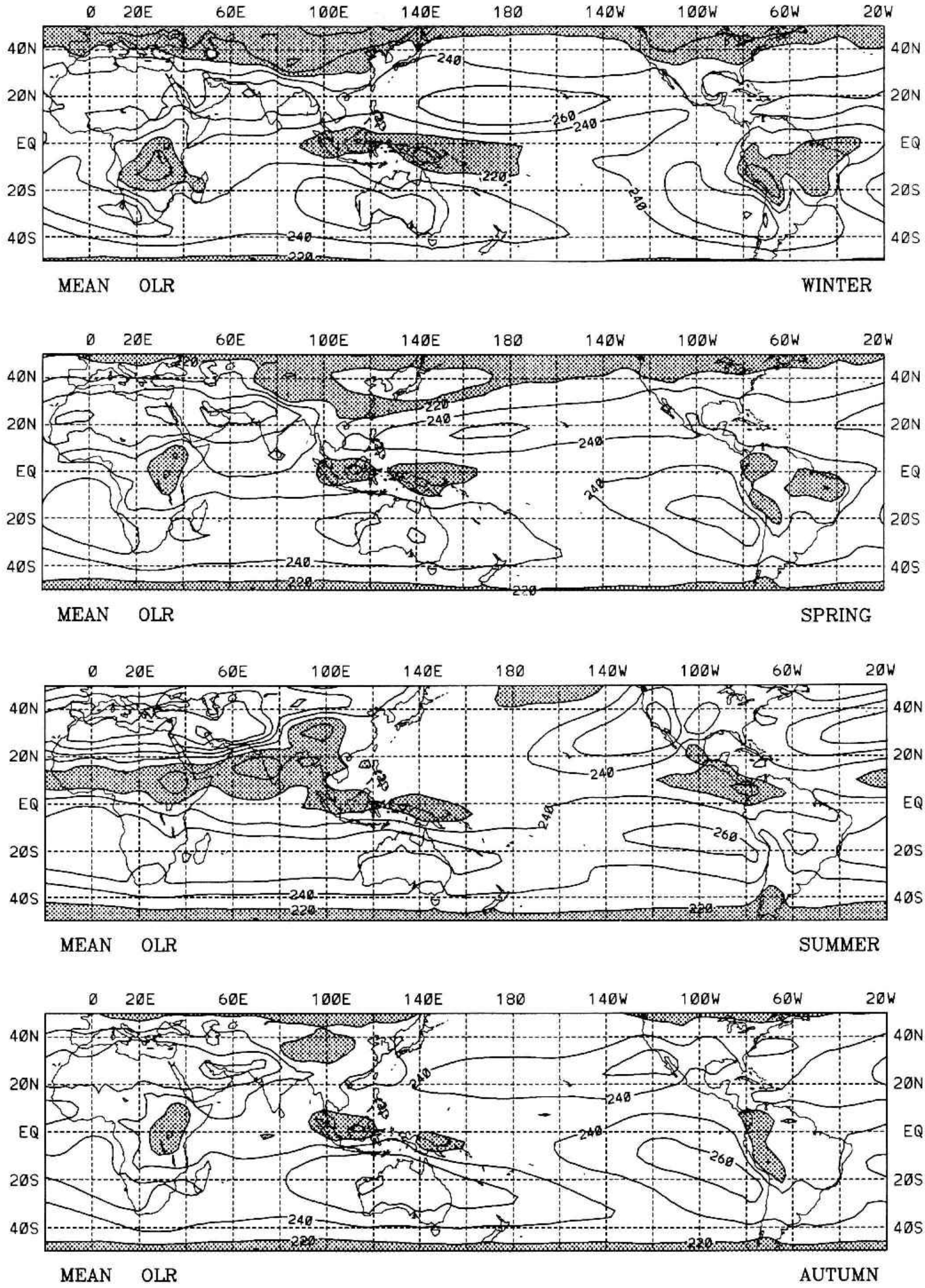

Fig. 2 Simulated seasonal mean OLR. Contour interval is 20 W/m^2. Areas below 220 W/m^2 are shaded.

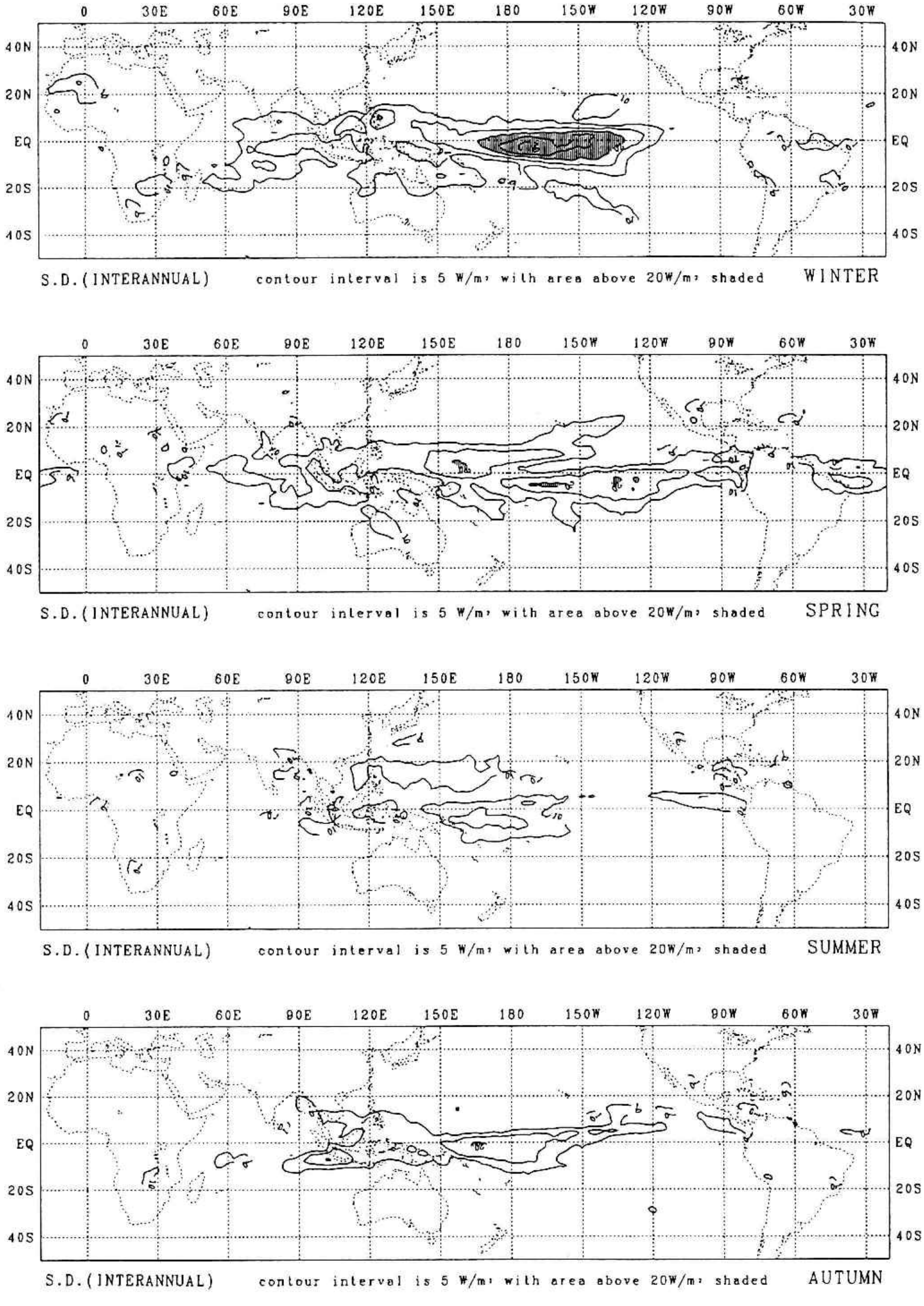

Fig. 3 Observed inter-annual variation (IAV) of the seasonal mean OLR (Kawahara, 1990). Contour interval is 5 W/m². Areas above 20 W/m² are shaded.

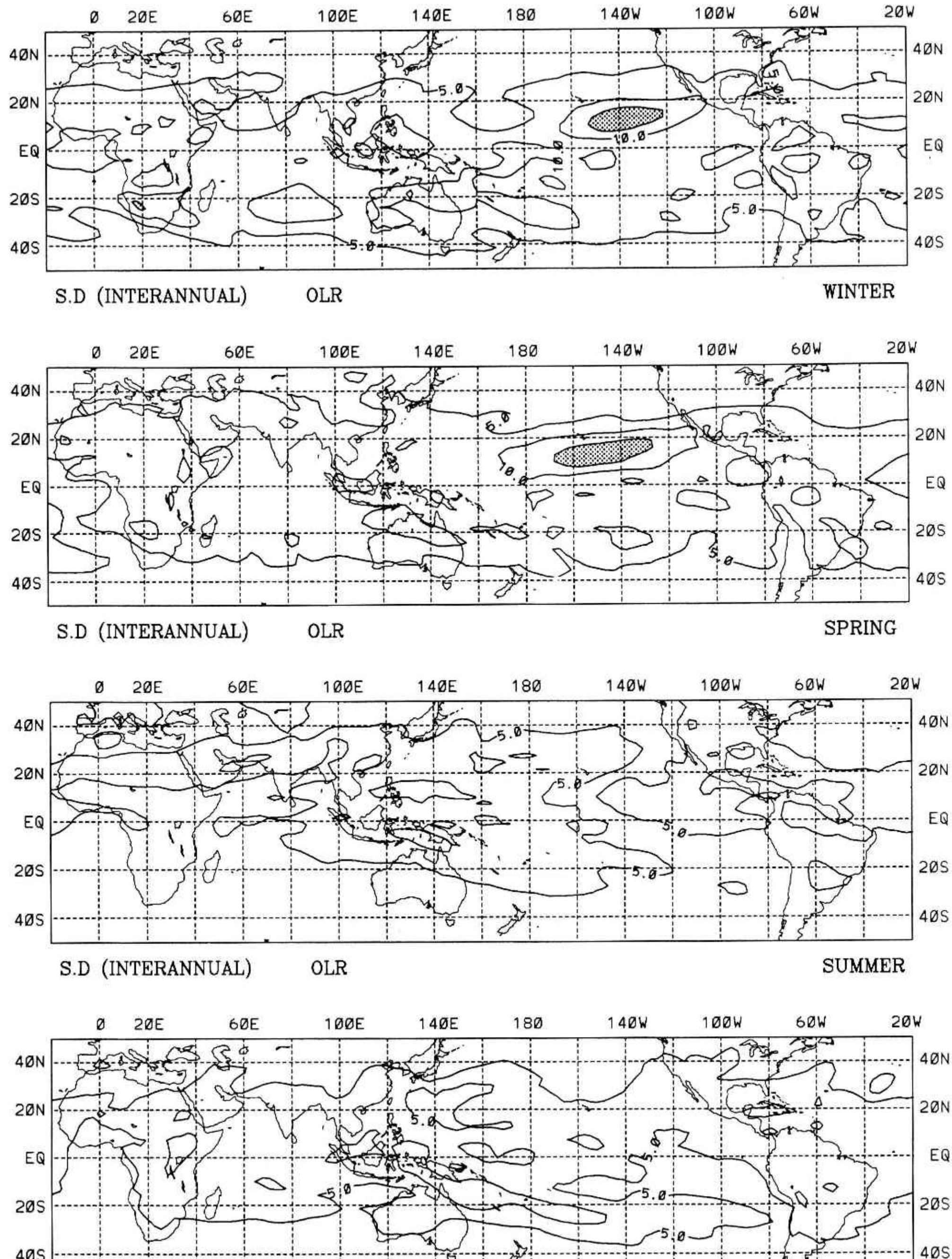

Fig. 4 Simulated inter-annual variation (IAV) of the seasonal mean OLR. Contour interval is 5 W/m^2. Areas above 15 W/m^2 are shaded.

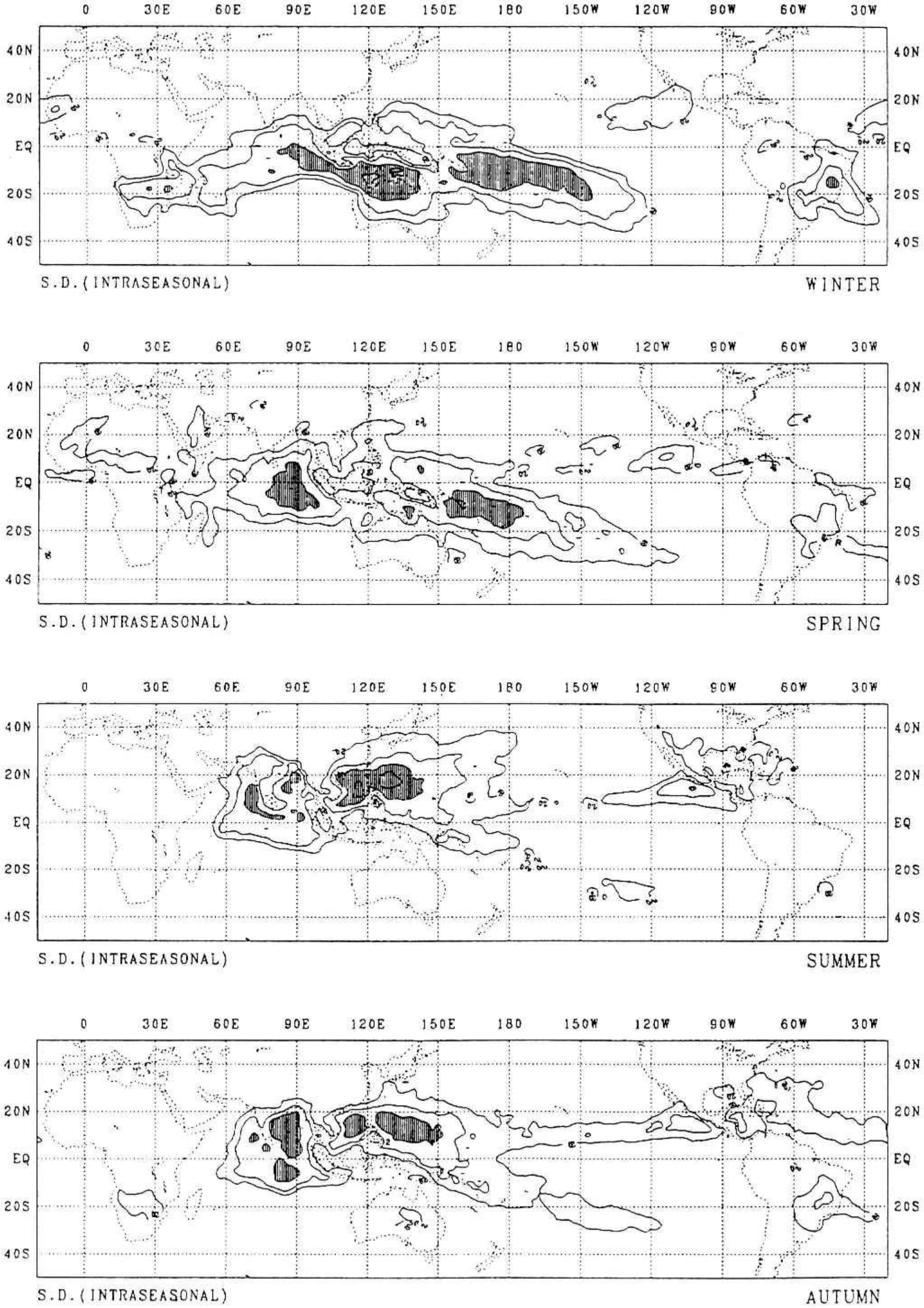

Fig. 5 Observed intra-seasonal variation of OLR (Kawahara, 1990). Contour interval is 5 W/m². Contours below 20 W/m² are not drawn. Areas above 30 W/m² are shaded.

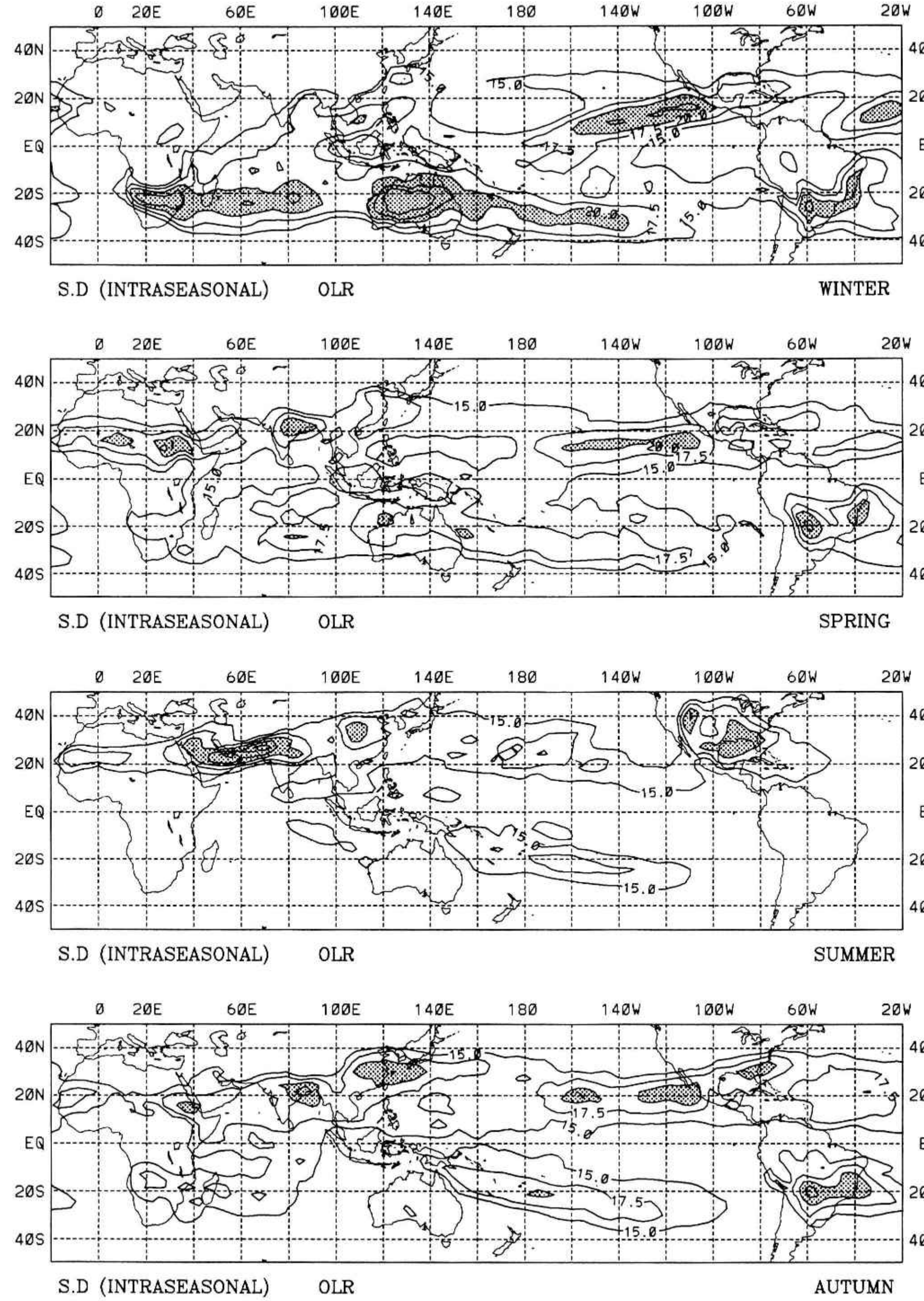

Fig. 6 Simulated intra-seasonal variations of OLR. Contour interval is 2.5 W/m^2. Contours below 15 W/m^2 are not drawn. Areas above 20 W/m^2 are shaded.

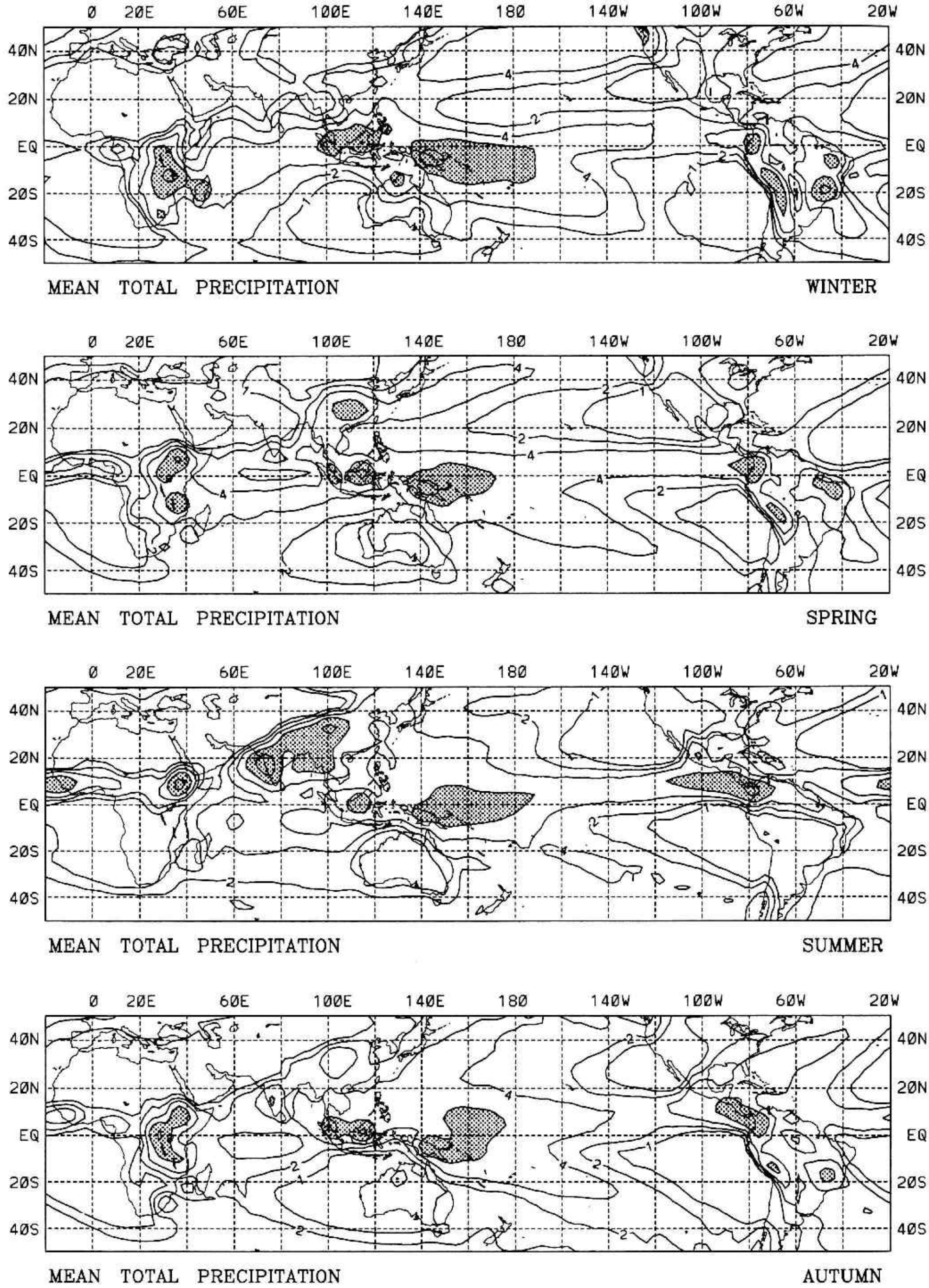

Fig. 7 Simulated seasonal mean precipitation. Contours are 1, 2, 4, 8, ... mm/day. Areas above 8 mm/day are shaded.

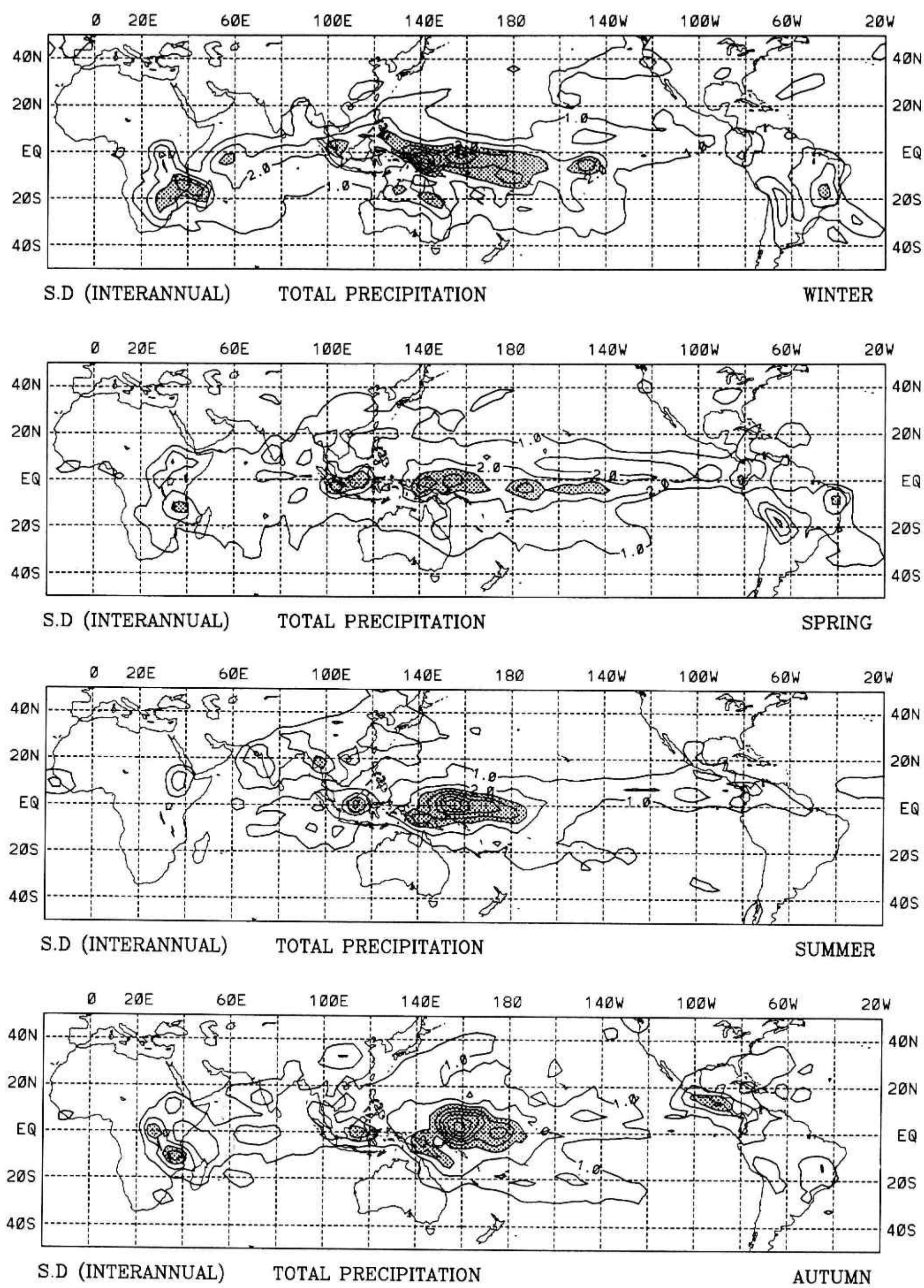

Fig. 8 Simulated inter-annual variation (IAV) of seasonal mean precipitation. Contour interval is 1 mm/day. Areas above 3 mm/day are shaded.

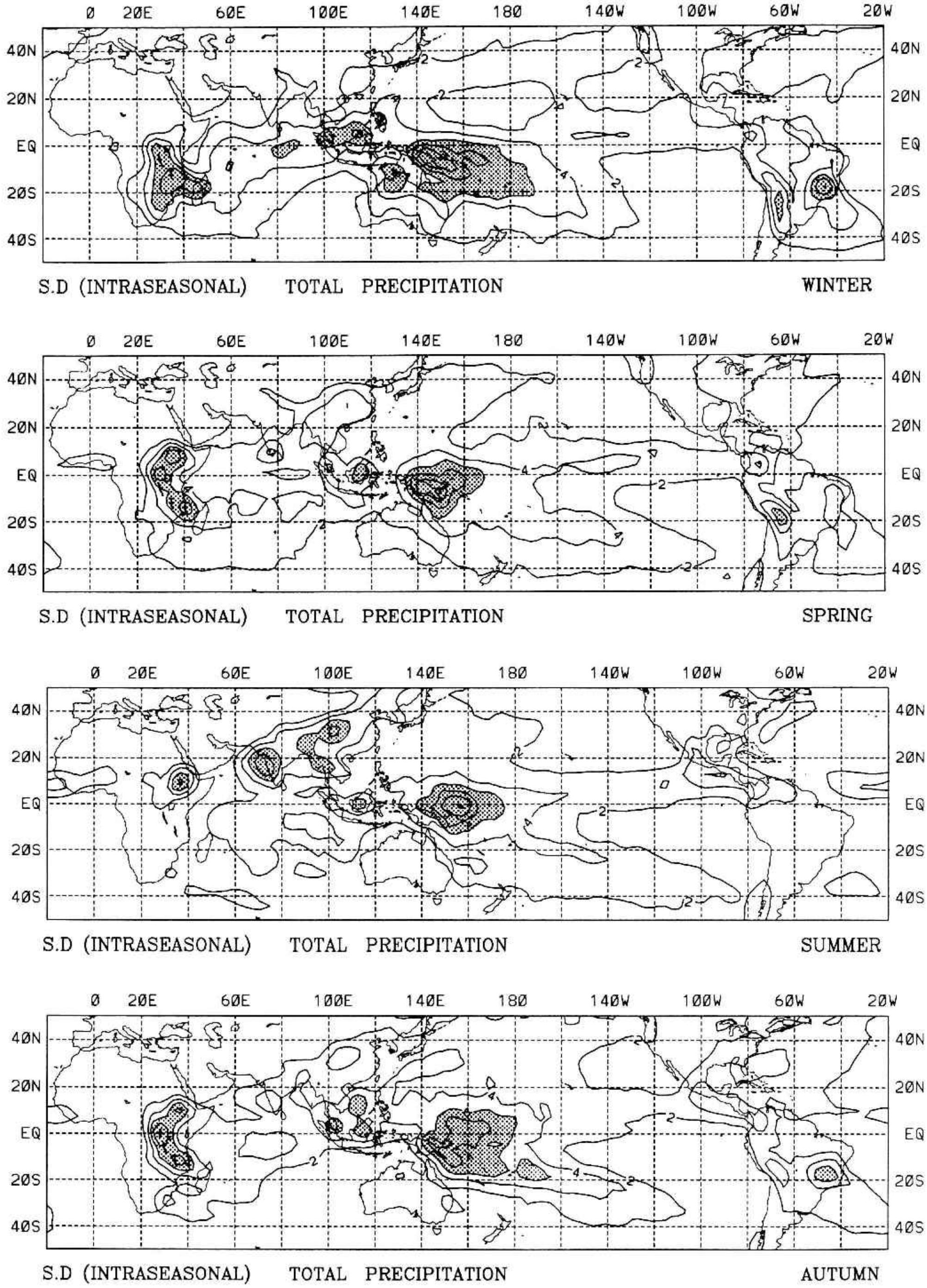

Fig. 9 Simulated intra-seasonal variation (ISV) of precipitation. Contour interval is 2 mm/day. Areas above 6 mm/day are shaded.

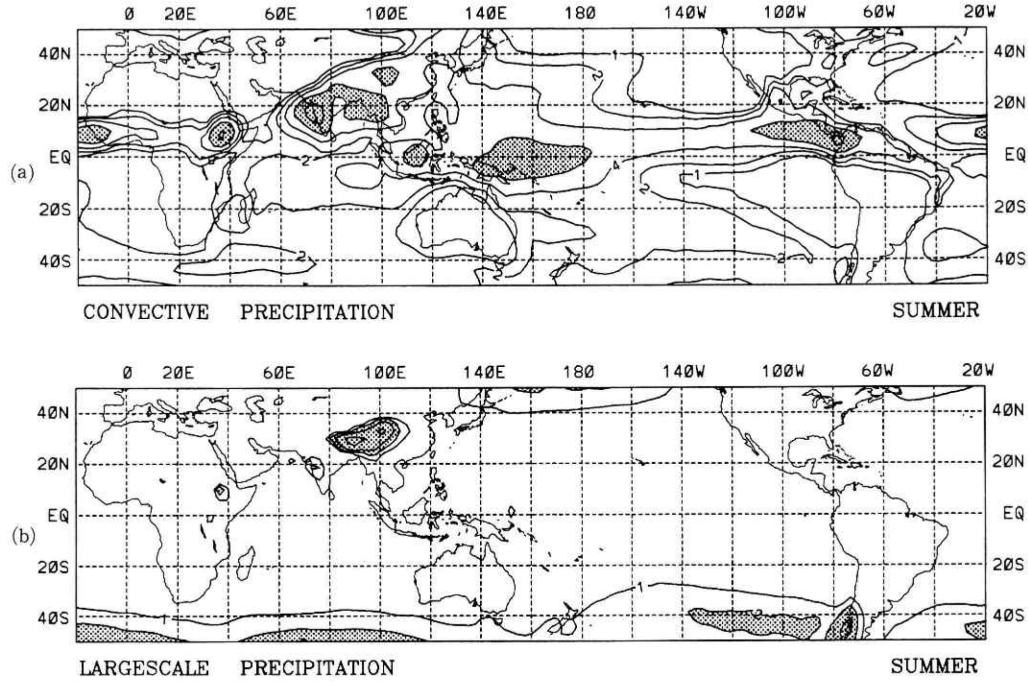

Fig. 10 Simulated convective and stable precipitation for summer. (a) Convective precipitation. (b) Stable (large scale) precipitation. Contours are 1, 2, 4, 8, ... mm/day. Areas above 2 mm/day in (a) and 8 mm/day in (b) are shaded.

3. Precipitation

3.1 Seasonal mean

The observed and simulated seasonal mean OLR (Fig. 1 and 2) and simulated precipitation fields (**Fig. 7**) agree with each other qualitatively. The discrepancies between the observed and simulated OLR, such as the eastward shift of simulated African precipitation and the split of simulated Amazon precipitation are even more evident in Fig. 7. Concentration of simulated precipitation towards the equator over the western Pacific in summer is also evident.

3.2 Inter-annual variability (IAV)

Different from the simulated OLR (Fig. 4), the simulated precipitation (**Fig. 8**) shows a large IAV over the western to central equatorial Pacific. The simulated maximum IAV of precipitation is located west of the date line compared to the observed maximum IAV of OLR located east of the data line. The amplitude of the IAV of observed OLR in the winter is much larger than the other seasons, while the amplitudes of IAV of the simulated precipitation are not so different among the seasons.

3.3 Intra-seasonal variability (ISV)

The ISV of the observed OLR (Fig. 5) is large over the eastern Indian Ocean and western Pacific, and it is relatively weak over other convectively active regions such as Africa or Central and South America. In contrast, the areas of large ISV of simulated precipitation (**Fig. 9**) almost coincide with those of large mean precipitation (Fig. 7), although the largest ISV is concentrated in the western Pacific region. Particularly, in the summer and autumn the large ISV in the observed OLR is located around the Philippines, while that of simulated precipitation is located over the equator, east of New Guinea. This seems to suggest that the rain-producing tropical disturbances are not active around the Philippines in the model in these seasons.

4. Discussion and conclusions

The geographical distributions of seasonal mean OLR and precipitation agree well with that of the observed OLR. The convective activity in the tropics is generally well simulated by the model. However, there are some discrepancies between the simulation and the observation. Four major deficiencies of the simulation can be pointed out as follows :

1) The active convection region observed in the summer around the Philippines is not simulated well in the model. The weak convective activity over this region may be due

to the lack of active tropical disturbances in the model. On the other hand, convection is active over the equatorial regions in the model. We are not sure, at present, whether the lack of disturbances around the Philippines is a result or a cause of the concentration of convective activity over the equatorial regions in the model. Also, the weak convective activity around the Philippines in the model seems to be closely related to the strong south-westerly monsoon flow along the east coast of the Asian continent and weak westerly flow over the South China Sea (Fig. 3(b) of Sugi *et al.* 1995).

2) The active convection region over Africa in the model is shifted to the east of the observed position, and the convection region over the Amazon is split into two parts in the model. These findings indicate that the active convections over the inland regions are not simulated well in the model. This may be related to the land surface processes in the model. The land surface may be too dry over these regions to supply sufficient moisture for active convective precipitation. The diurnal cycle may not be strong enough to produce much convective precipitation over these regions in the model.

3) The region of the simulated south-east Asian monsoon precipitation extends too far north-eastward, with too much precipitation over the east area of the Tibetan Plateau. The lack of rain producing disturbances in the southern part of the monsoon region may be responsible for this. **Fig. 10** shows the simulated seasonal mean precipitation by convection and large scale condensation (stable precipitation). It is clear from this figure that the large portion of the inland precipitation is produced by stable precipitation, which is mainly maintained by a stable monsoon flow and orographic effect.

4) The region of the large IAV of precipitation over the equatorial Pacific in the model is located considerably to the west of that of the observed OLR, and it shows much less seasonal variation in intensity as compared to the observation. This seems to be closely related to the model's tendency of concentration of precipitation over the western equatorial Pacific. Also, it may be related to the weak convective activity around the Philippines in the model as mentioned above.

Generally, the distribution of the seasonal mean OLR is fairly well simulated by the model, but the variability of OLR is not well simulated, particularly in the inter-annual time scale. Because the OLR is very sensitive to clouds, the simulation of OLR depends on the simulation of clouds in the model. The accurate simulation of clouds is generally difficult, and it is likely that clouds are not well simulated in the JMA global model. Therefore, the disagreement between the simulated and the observed OLR does not necessarily mean that the convective activity in the model is different from the observation. The relationship between the convective precipitation and OLR in the model may be different from that of the observed. Ideally, observed precipitation climate should be used instead of OLR for verification of simulated precipitation climate. However, the data for the IAV and ISV of precipitation is not sufficient at present. More observed data is desirable to improve the observed precipitation climatology.

In order to cure the above-mentioned deficiencies in the simulation, further study on the possible causes of such deficiencies is necessary. Particularly, the sensitivity of the simulation to the parameterization scheme of cumulus convection needs to be examined. The activity of tropical disturbances with short time scales also needs to be examined to improve the climate of the tropical precipitation of the model.

5. Acknowledgments

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気象庁全球モデルの気候特性(2)：熱帯の降水

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要　旨

気象庁全球モデルを用いて全球大気大循環の34年間の変化のシミュレーションを行い，シミュレートされた熱帯の外向きの長波放射量(OLR)と降水量を観測されたOLRと比較した．季節平均場は，モデルによって大体良好に再現されている．しかし，次のような，いくつかの欠点が認められる．1) モデルでは，熱帯太平洋北西部での対流活動が弱い．2) アフリカの対流活動域が実際より東にずれている．また，アマゾンの対流活動域が東西に分かれている．3) アジアモンスーンの降水域が北東方向に伸びている．4) 熱帯太平洋の年々変動の大きな領域が実際と比べて西にずれている．

キーワード：モデル (model)，気候 (climate)，気象庁 (JMA)，熱帯 (tropical)，降水 (precipitation)