2. Horizontal distributions of monthly mean quantities (II) : year-to-year variation*

In this chapter the ensemble averages, the standard deviations of the monthly averages and the deviations of each year from the ensemble averages are shown for January, April, July and October, together with the observed values, for the sea-level pressure, the geopotential height at 300 mb, the temperature at 800 mb, the velocity potential at 200 mb and the precipitation. The notation "Y13", for example, indicates the 13th year of the model atmosphere. The maps of ensemble averages are the same as shown in Chapter 1.

2.1 Sea level pressure

The ensemble average and the standard deviation of the monthly mean sea-level pressure of the model atmosphere and the deviations of each year from the ensemble average are shown in Fig. 2.1.1. — Fig. 2.4.4, together with the climate values of the monthly mean sea-level pressure and the standard deviation for January, April, July and October. The climate values are based on the ECMWF analyses for the period from 1980 to 1984. The contour interval of the lefthand panels in Fig. 2.1.1, Fig. 2.2.1, Fig. 2.3.1 and Fig. 2.4.1 is 4 mb. The area over 1020 mb is shaded and the area below 1000 mb is dotted. The contour interval of the righthand panels in the same figure is 2 mb, and the area over 6 mb is shaded. The contour interval in the rest of the figures is 4 mb and the negative area is shaded.

The ensemble average for January (the upper left panel of Fig. 2.1.1) is slightly different from the map presented in Tokioka *et al.* (1985) in polar regions, where the standard deviation is large (the upper right panel of Fig.2.1.1). Although distributions of the standard deviation are different in details between the model and the observed climate, the values are comparable between them except over Antarctica, where the model gives less variation than the observed climate.

In model January (the upper right of Fig. 2.1.1) the maximum standard deviation in the Northern Hemisphere is found at the Gulf of Alaska. Maxima are also found over the northeastern part of the Atlantic Ocean and the southeastern part of the Tibetan Plateau. In the devitation maps of each year (Fig. 2.1.2 — Fig. 2.1.4), north-south seesaw patterns are also

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evident (*e.g.* Y13, Y03, Y10 and Y12). The north-south seesaw patterns are commonly found in April, July and October, although their amplitude are less than that in January.

2.2 Geopotential height at 300 mb

The ensemble average and the standard deviation of the monthly mean geopotential height at 300 mb of the model atmosphere and the deviations of each year from the ensemble average are shown in Fig. 2.5.1 — Fig. 2.8.4, together with the climate values of the monthly mean geopotential height at 300 mb and the standard deviation for January, April, July and October. The climate values are based on the ECMWF analyses. The contour interval of the lefthand panels in Fig. 2.5.1, Fig. 2.6.1, Fig. 2.7.1 and Fig. 2.8.1 is 20 g.p.m. The contour interval of the righthand panels in the same figures is 20 g.p.m., and the area over 60 g.p.m. is shaded. The contour interval in the rest of the figures is 20 g.p.m. The negative area is shaded.

The model has succeeded in reproducing basic characteristics in both the monthly mean geopotential height and its standard deviation. However, the standard deviation in the model is systematically less than the climate value. The tendency is clear in relatively high latitudes, especially in April and October. This can also be confirmed in the latitude-height cross section (Fig. 3.6.1 and Fig. 3.6.2). In the deviation maps of each year for each month, wavy patterns are conspicuous at this level compared with those in the sea level pressure.

2.3 Temperature at 800 mb

The ensemble average and the standard deviation of the monthly mean temperature at 800 mb of the model atmosphere and the deviations of each year from the ensemble average are shown in Fig. 2.9.1 — Fig. 2.12.4, together with the climate values of the monthly mean temperature at 800 mb and the standard deviation for January, April, July and October. The climate values are based on the ECMWF analyses. The contour interval of the lefthand panels in Fig. 2.9.1, Fig.2.10.1, Fig. 2.11.1 and Fig. 2.12.1 is 5℃. The contour interval of the right hand panels in the same figures is 1℃, and the area over 3℃ is shaded. The contour interval in the rest of the figures is 1℃. The negative area is shaded.

The ensemble average of the model is below the climate value in polar regions, especially in July as pointed out by Kitoh and Tokioka (1986). The standard deviation of the model is less than the climate value, especially in high latitudes of the Northern Hemisphere in January. The deviation maps in Fig. 2.9.2 — Fig. 2.12.4 have good correspondence with those of the sea level pressure in Fig. 2.1.2 — Fig. 2.4.4.

2.4 Velocity potential at 200 mb

The ensemble average and the standard deviation of the monthly mean velocity potential at 200 mb of the model atmosphere and the deviations of each year from the ensemble average are shown in Fig. 2.13.1 — Fig. 2.16.4, together with the climate values of the monthly mean velocity potential at 200 mb and the standard deviation for January, April, July and October. The climate values are based on the ECMWF analyses for the period from 1980 to 1984. The contour interval of the lefthand panels in Fig. 2.13.1, Fig. 2.14.1, Fig. 2.15.1 and Fig. 2.16.1 is 10^6 m^2 s^{-1}. The contour interval of the righthand panels in the same figures is 2.5×10^5 m^2 s^{-1}, and the area over 10×10^5 m^2 s^{-1} is shaded. The contour interval in the rest of the figures is 2.0×10^5 m^2 s^{-1}. The negative area is shaded.

The model has succeeded in reproducing basic characteristics in the monthly mean velocity potential at 200 mb (the left panels in Fig. 2.13.1, Fig. 2.14.1, Fig. 2.15.1 and Fig. 2.16.1). However, there are large differences in the standard deviation (the righthand panels in Fig. 2.13.1, Fig. 2.14.1, Fig.2.15.1 and Fig. 2.16.1). The maximum value in the model is about $\frac{1}{3}$ to $\frac{1}{4}$ of the corresponding climate value. Besides that, the distributions of the maxima are very different between the model and the climate. The year-to-year variation in the sea-surface temperature is not considered in the present model. Neglecting this variation seems to be the most responsible for the difference. The intra-seasonal variations are not simulated well in the present model (Tokioka and Yamazaki, 1986). This may also be responsible for the underevaluation of the standard deviation.

The underevaluation of the standard deviation is found in almost all variables, as mentioned so far. However, the velocity potential field seems to be one of the quantities most sensitive to neglecting the year-to-year variation in the sea surface temperature.

In Fig. 2.15.1′ are shown the same quantities as are shown in the lower panels of Fig. 2.15.1 but for the data analyzed at NMC for the period from 1979 to 1983. This figure is added to demonstrate large differences in the standard deviation of the velocity potential between the two data sources. The monthly mean field in Fig. 2.15.1′ is very close to that in Fig. 2.15.1. However, the standard deviation in Fig. 2.15.1′ is about half of that in Fig. 2.15.1, although similarity exists in the location of peaks between them.

2.5 Precipitation

The ensemble average and the standard deviation of the monthly mean precipitation of the model atmosphere and the deviations of each year from the ensemble average are shown in Fig. 2.17.1 — Fig. 2.20.4, together with the climate values of the monthly mean precipitation for January, April, July and October. The climate values are based on the data compiled by Shutz and Gates (1971, 1972, 1973, 1974). Contours of 1, 2, 5, 7.5 and 10 mm day^{-1} are shown. In the lefthand panels of Fig. 2.17.1, Fig. 2.18.1, Fig. 2.19.1 and Fig. 2.20.1, the area over 5 mm day^{-1} is shaded and the area below 1 mm day^{-1} is dotted. The contour interval of the righthand panel in the same figures is 1 mm day^{-1}, and the area over 2 mm day^{-1} is shaded. The contour interval in the rest of the figures is 1mm day^{-1}. The negative area is shaded.

The model has reproduced well the basic climatological characteristics in the monthly mean precipitation in low latitudes. However, the present model gives excessive precipitation over the continents, especially in the summer hemisphere. Although the climatological standard deviation of the monthly mean precipitation is currently not available, it is highly probable that the standard deviation in the present model is much less than the actual value, as in the velocity potential at 200 mb. However, the maximum standard deviation in Jaunuary is as much as 4 mm day^{-1} over the equatorial Indian Ocean. In the present model, northerlies are too strong near the surfarce along the eastern coast of China, while easteries are also too strong in the southern periphery of the Tibetan Plateau (Fig. 1.6.1). This anticyclonic flow is cold and dry, and thus enhances evaporation in the Bay of Bengal and precipitation over the equatorial Indian Ocean (Tokioka *et al.*, 1985). The large standard deviation in this area is closely connected with the interannual change of the Siberian high, as confirmed by comparing the maps of the sea level pressure deviations (Fig. 2.1.2 — Fig. 2.1.4) with those of the precipitation deviations (Fig. 2.17.2 — Fig. 2.17.4).