5. Longtitude-time cross sections*

In this chapter, longitude-time cross sections (Hovmöller diagrams) at selected latitudes are shown. Data used in this chapter are based on the "10-day means" data given in Chapter 4 both for the simulation and the observation. In each small figure, the ordinate denotes month and the abscissa, longitude from 0°E to the east. The 12 years are divided into four 3 years, for which respective figures are given. The first small figure shows the period from March of the first year to February of the fourth year. The second one shows the period from March of the fourth year to February of the seventh year and so on. The 12-year means are also shown except for anomalies of geopotential height (section 5.2).

5.1 Deviation of geopotential height from the zonal mean

The deviation of geopotential height at 300 mb from the zonal mean at 70°N, 50°N, 30°N, 30°S, 50°S and 70°S are shown in Figs. 5.1.1 — 5.1.18, together with the 12-year mean fields and observed 6-year mean fields. The contour interval is 50 g.p.m. and negative values are shaded for all maps.

At 70°N, a trough is located around 120°E in winter and slowly moves westward. During spring the trough slowly moves eastward. During summer waves are generally weak. The ridges are found at 0°E in early winter and at 30°W in winter. Another strong ridge appears around 150°W in January. Overall features are similar to the observation. In the observation, the seasonal shift of the trough in the eastern hemisphere is small and the trough at 80°W is persistent throughout the year.

At 50°N, troughs are located around 150°E and 80°W during most of the period. The troughs are deep in winter. A quick change of geopotential height is sometimes seen in winter around the dateline. Accordance with the observation is fairly good at 50°N.

At 30°N, troughs are located around 100°E and 110°W in winter and at 150°W in summer. Both the trough at 100°E and the ridge at 140°E in winter are too conspicuous compared with the observation.

At 30°S, waves are weak and a moderate ridge is situated around 30°E and a trough around 100°W in October. Accordance with the observation is not good. The trough that is

---

*This chapter is prepared by K. Yamazaki, Forecast Research Division.

observed at 150–170°W in the Southern Hemisphere winter is quite weak in the simulation.

At 50°S, the wavenumber one pattern dominates except in the summer months. The conspicuous ridge at 170°E in the Southern Hemisphere fall is not simulated well. At 70°S, the wavenumber one pattern also dominates throughout the year. The locations of trough and ridge do not show large seasonal changes. Accordance with the observation is fairly good at 70° S.

5.2 Anomalies of geopotenial height

The anomalies of geopotential height from the 12-year means at the same latitudes as in the previous section are shown in Figs. 5.2.1 — 5.2.6. The contour interval is 50 g.p.m. and negative values are shaded. At 70° N, anomalies have planetary scales and frequently the whole region has the same sign of anomaly. No preferable direction of anomaly movement is found. At 50°N, anomalies seem to occur in a random manner. Persistence of anomalies is less compared with that at 70°N. At 30°N and 30°S, anomalies are small and spotty. The feature of anomalies at 50°S is similar to that at 50°N. At 70°S, anomalies have planetary scales and the whole region frequently shows the same sign, as it happens at 70°N. Persistence is high and sometimes anomaly lasts for a few months for the whole region.

5.3 Zonal wind at the equator

The zonal winds at the equator, 200 mb and 900 mb (850 mb for observation) are shown in Figs. 5.3.1 — 5.3.6 with the 12-year means and the 6-year mean observation. The contour interval is 5 m s^{-1} in Figs. 5.3.1 — 5.3.3 and 2.5 m s^{-1} in Figs. 5.3.4 — 5.3.6. Easterlies are shaded. Most of the regions have easterlies. At 200 mb, westerlies are found in the section between 180° W and 120° W. This westerly region extends eastward in May and June. At the same time the region extends westward. Another westerly region appears around 30° W during the Northern Hemisphere winter. Intensity of easterlies during the Northern Hemisphere summer over the Indian Ocean and western Pacific is not sufficient compared with the observation.

At 900 mb, westerlies are found in the narrow section at 90° W during the period from September to January. Other westerlies are located at 10° E during the whole year except winter, 30–90° E in May – July and around 120° E in November and December. Westerlies over the Indian Ocean are much stronger in the observation (Fig. 5.3.6). Both observation and simulation show a large vertical westerly shear over the eastern Pacific.

Interannual variations are small in the tropics. Many observational studies show dominant

40 to 60-day osillations in these fields. However, the model does not simulate such intraseasonal oscillations (Tokioka and Yamazaki, 1986).

5.4 Meridional wind

The meridional winds at 800 mb of 30°N, 900 mb of 0°N and 800 mb of 30°S are shown in Figs. 5.4.1 — 5.4.9 with the 12-year means and the 6-year mean observation. The level of observations is 850 mb. The contour interval is 2.5 m s^{-1} and the shading indicates northerly winds.

At 30°N (Figs. 5.4.1 — 5.4.2), there are three regions where the large positive values (southerlies) are located just east of the large negative values (northerlies). These regions correspond to the three major troughs. Their locations are around 120° E (east of China), 120° W (west of Mexico) and 0° E (Algeria). The intensity of the first and the second pair is strong in winter, while that of the third weakens in winter. The third one is associated with the thermal low over the Sahara desert. The first pair shows the seasonal change in intensity and location. There is no counterpart in the observation (Fig. 5.4.3). The strong winter northerly at 100–120° E in the simulation reflects the strong anticyclonic flow around the Tibetan Plateau. In the observation, the northerly is located at 120–140° E and its intensity is not high.

Figs. 5.4.4 and 5.4.5 show the cross equatorial flow at 900 mb. The largest cross equatorial flow is calculated at 40° E (the east coast of Africa) and the second one at 60° W (over Brazil). The former is the so-called Somali jet associated with the Indian monsoon. Both flows show large seasonal changes. Overall features accord with the observation (Fig. 5.4.6).

At 30°S (Figs. 5.4.7 and 5.4.8), the northerly-southerly pairs are calculated at 20° E (west coast of Africa) and 70° W (over the Andes). The third weak pair appears at 120° E (Australia) in summer. It is noted that all the troughs are strong in summer. These pairs are caused by summer thermal lows over the continents, i.e., Africa, South America and Australia. The simulation agrees with the observation (Fig. 5.4.9) at 30° S.

5.5 Total diabatic heating rate

Total diabatic heating rate for the total air column at 70° N, 50° N, 30° N, 0° N, 30° S, 50° S and 70° S are shown in Figs. 5.5.1 — 5.5.14 with the 12-year means. The contour interval is 50 W m^{-2} and negative values are shaded.

In high latitudes (70° N and 70° S), the values are mostly negative except in the region over the warm sea in winter such as the Barents Sea (50° E, 70° N), the Norwegian Sea (10° E, 70° N) and the Ross Sea (180° E, 70° S). The seasonal change of these positive areas is closely related to that of the sea ice extent. At 50° N, large positive values are found to the east of the Asian continent and to the east of the North American continent where cold air passes over the warm ocean. The model also calculates the positive heating over the summer continent. At 30° N, large positive heating are calculated over the summer continent and east of the continent in winter. Positive heatings over the central Pacific in summer are caused by excessive precipitation there. At the equator, negative heating over the eastern Pacific is the persistent feature, which is related to the low sea surface temperature there. The very noisy feature of the heating in low latitudes is due to the intermittency of precipitation in low latitudes. At 30° S, three strong positive heatings in summer are located over the continents, i.e., Africa (30°E), Australia (120–150°E) and South America (50–70°W). A fourth positive heating area is found over the South Pacific. The seasonal change at 50° S is quite small, because most areas are over the ocean at this latitude.

Acknowledgements

The authors thank Dr. M. Aihara, head of the Forecast Reseach Division, Mr. T. Yoshida, the former head of the same Division, and all the members of the Division for their encouragements throughout this work. We also thank Miss H. Imai for her assistance.

The numerical time integration of the model was made on the HITAC M-200H computer of the MRI.

References

Arakawa, A. and W. H. Schubert, 1974: Interaction of a cumulus ensemble with the large-scale environment, Part I. *J. Atmos. Sci.*, 31, 674-701.

Hsu, C.-P. F. and J. M. Wallace, 1976: The global distribution of the annual and semiannual cycles in sea level pressure. *Mon. Wea. Rev.*, 104, 1597-1601.

Katayama, A., 1972: A simplified scheme for computing radiative transfer in the troposphere. *Tech. Report* No. 6, Department of Meteorology, University of California, Los Angeles, 77 pp.

——————, 1978: Parameterization of planetary boundary layer in atmospheric general circulation models. *Kisyo Kenkyu Note*, Meteor. Soc. Japan, No. 134, 153-200. (jn Japanese)

Kitoh, A. and T. Tokioka, 1986: A simulation of the tropospheric general circulation with the MRI atmospheric general circulation model. Part II: The July performance. *Pap. Met. Geophys.* , 37, 145-168.

Kushnir, Y. and S. Esbensen, 1985: Subseasonal variability in the OSU atmospheric general circulation model: Northern hemisphere winter. *Report* No. 62, Climate Research Institute, Oregon State University, 61 pp.

Lau, N.-C., 1981: A diagnostic study of recurrent meteorological anomalies appearing in a 15-year simulation with a GFDL general circulation model. *Mon. Wea. Rev.*, 109, 2287-2311.

——————, 1985: Modeling the seasonal dependence of the atmospheric response to observed El Ninos in 1962-76. *Mon. Wea. Rev.*, 113, 1970-1996.

Manabe, S. and D. G. Hahn, 1981: Simulation of atmospheric variability. *Mon. Wea. Rev.*, 109, 2260-2286.

Randall, D. A., 1976: The interaction of the planetary boundary layer with large-scale circulations. Ph. D. dissertation, The University of California, Los Angeles, 247 pp.

Schutz, C. and W. L. Gates, 1971: Global climatic data for surface, 800 mb, 400 mb: Jaunuary. Advanced Research Projects Agency, Rep. R-915-ARPA, Rand Corporation, Santa Monica, 173 pp.

—————— and ——————, 1972: Global climatic data for surface, 800 mb, 400 mb: July.

Advanced Research Projects Agency, Rep. R-1029-ARPA, Rand Corporation, Santa Monica, 180 pp.

——— and ———, 1973: Global climatic data for surface, 800 mb, 400 mb: April. Advanced Research Projects Agency, Rep. R-1317-ARPA, Rand Corporation, Santa Monica, 192 pp.

——— and ———, 1974: Global climatic data for surface, 800 mb, 400 mb: October. Advanced Research Projects Agency, Rep. R-1425-ARPA, Rand Corporation, Santa Monica, 192 pp.

Tokioka, T., K. Yamazaki, I. Yagai and A. Kitoh, 1984: A description of the Meteorological Research Institute atmospheric general circulation model (the MRI·GCM-I). *Tech. Report* No. 13, MRI, 249 pp.

———, A Kitoh, I. Yagai and K. Yamazaki, 1985: A simulation of the tropospheric general circulation with the MRI atmospheric general circulation model. Part I: The January performance. *J. Met. Soc. Japan*, 63, 749-778.

——— and K. Yamazaki, 1986: Absence of dominant 30-60 day oscillations in the MRI·GCM-I. *Workshop on 40 day mode and ENSO*, Meteor. Res. Rep. 86-1, April, 1986. Geophysical Inst., Univ. of Tokyo, 41-52.