4.2 **Mean upper-air patterns**

The patterns of pressure and wind in the middle troposphere are less complicated in appearance than at the surface as a result of the diminished effects of the landmasses. Rather than using pressure maps at a particular height, it is convenient to depict the height of a selected pressure surface; this is termed a contour chart by analogy with topographic relief map. Figure 4.3 and 4.4 show that in the middle troposphere of the southern hemisphere there is a vast circumpolar cyclonic vortex poleward of latitude 30°S in summer and winter. The vortex is more or less symmetrical about the pole, although the low centre is towards the Ross Sea sector. Corresponding charts for the northern hemisphere also show an extensive cyclonic vortex, but one that is markedly more asymmetric with a primary centre over the eastern Canadian Arctic and a secondary one over eastern Siberia. The major troughs and ridges form what are referred to as long waves (or Rossby waves) in the upper flow. It is worth considering why the hemispheric westerlies show such large-scale waves. The key to this problem lies in the rotation of the earth and the latitudinal variation of the Coriolis parameter). It can be shown that for large-scale motion the absolute vorticity about a vertical axis $(f + \zeta)$ tends to be conserved, i.e.

$$d(f + \zeta)dt = 0$$

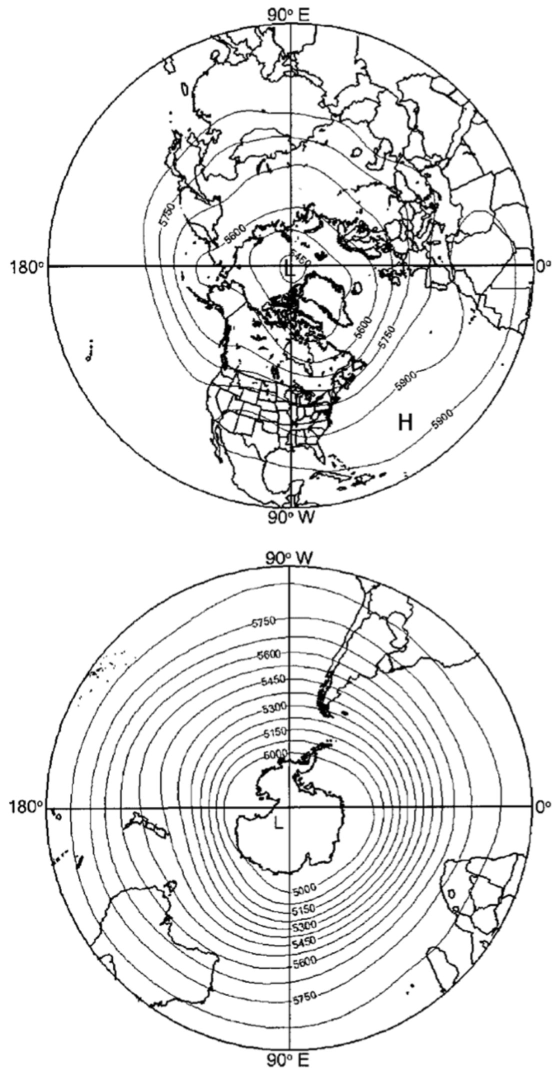


*Figure 4.3* The mean contours (gpm) of the 500-mb pressure surface in July for the northern and southern hemispheres, 1970 to 1999.

*Source*: NCEP/NCAR Reanalysis Data from the NOAA-CIRES Climate Diagnostics Center.

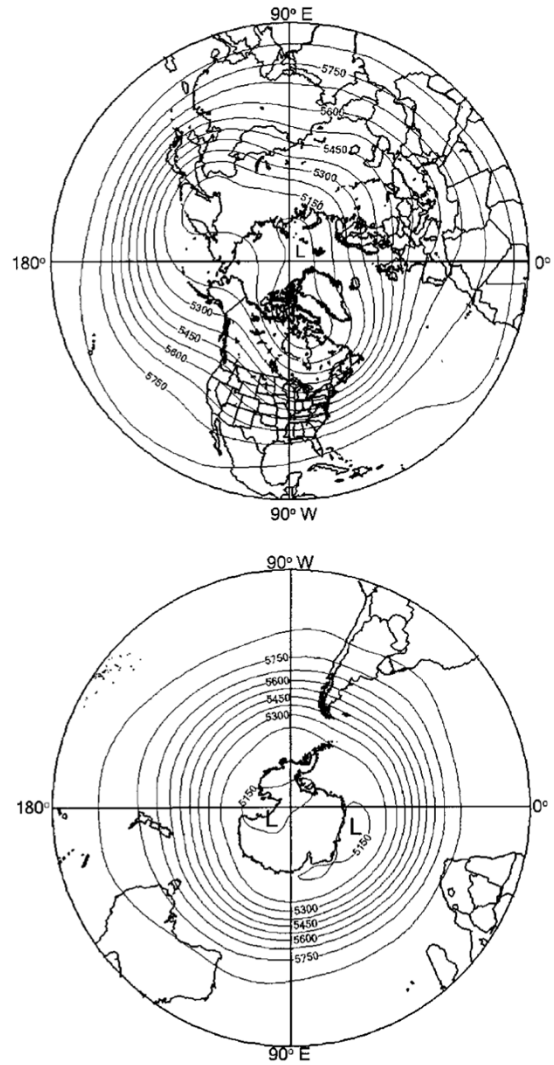


*Figure 4.4* The mean contours (gpm) of the 500-mb pressure surface in January for the northern and southern hemispheres, 1970 to 1999.

*Source*: NCEP/NCAR Reanalysis Data from the NOAA-CIRES Climate Diagnostics Center.

The symbol d/dt denotes a rate of change following the motion (a total differential). Consequently, if air moves poleward so that f increases, the cyclonic vorticity tends to decrease. The curvature thus becomes anticyclonic and the current returns towards lower latitudes. If the air moves equatorward of its original latitude, f tends to decrease (Figure 4.5), requiring ζ to increase, and the resulting cyclonic curvature again deflects the current polewards. In this manner, large-scale flow tends to oscillate in a wave pattern.

C-G. Rossby related the motion of these waves to their wavelength (L) and the speed of the zonal current (U). The speed of the wave (or phase speed, c), is

$$c = U - ß\left(\frac{L}{2\pi}\right)^2$$

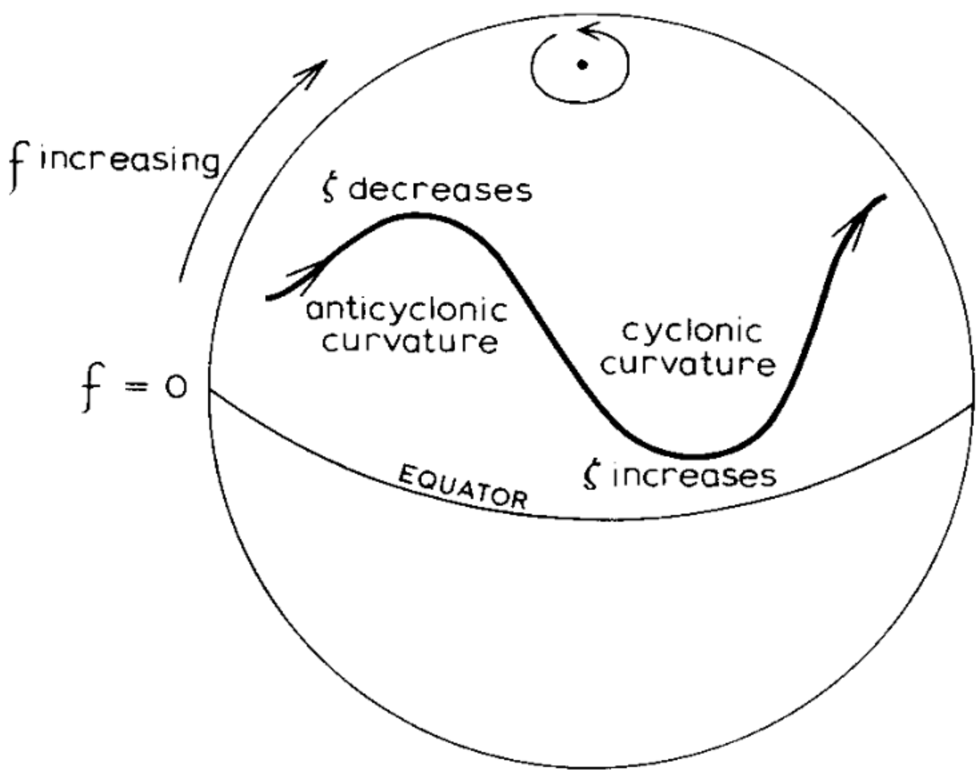


***Figure 4.5*** A schematic illustration of the mechanism of long- wave development in the tropospheric westerlies.

where ß = ∂f/∂y (i.e. the variation of the Coriolis parameter with latitude) (a local, partial differential). For stationary waves, where c = 0, L = 2 π √(U/ß). At 45° latitude, this stationary wavelength is 3120 km for a zonal velocity of 4 m s–1, increasing to 5400 km at 12 m s–1. The wavelengths at 60° latitude for zonal currents of 4 and 12 m s–1 are, respectively, 3170 and 6430 km. Long waves tend to remain stationary, or even to move westward against the current, so that $c \leq 0$. Shorter waves travel eastward with a speed close to that of the zonal current and tend to be steered by the quasi-stationary long waves.

The two major troughs at about 70°W and 150°E are thought to be induced by the combined influence on

upper-air circulation of large orographic barriers, such as the Rocky Mountains and the Tibetan Plateau, and heat sources such as warm ocean currents (in winter) or landmasses (in summer). It is noteworthy that land surfaces occupy over 50 per cent of the northern hemi- sphere between latitudes 40° and 70°N. The subtropical high-pressure belt has only one clearly distinct cell in January over the eastern Caribbean, whereas in July cells are well developed over the North Atlantic and North Pacific. In addition, the July map shows greater prominence of the subtropical high over the Sahara and southern North America. The northern hemisphere shows a marked summer to winter intensification of the mean circulation, which is explained below. In the southern hemisphere, the fact that oceans com- prise 81 per cent of the surface makes for a more zonal pattern of westerly flow. Nevertheless, asymmetries are initiated by the effects on the atmosphere of features such as the Andes, the high dome of eastern Antarctica, and ocean currents, particularly the Humboldt and Benguela currents, and the associated cold coastal upwellings.