Trends in 500 hPa cyclone characteristics and baroclinicity in the Southern Hemisphere winter in 1979-2004

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Extratropical cyclones comprise daily weather patterns in the mid and high latitudes and redistribute energy, momentum and moisture across the globe. Therefore, it is important to understand the responses of these extratropical cyclones to recent changes in climate. In this study, we will examine the trends in 500 hPa level cyclone frequency, intensity, and scale over the last 26 years with updated NCEP-DOE reanalysis II data up to 2004. 500 hPa geopotential height (Z500) June-July-August data are used with the application of the Melbourne University cyclone finding and tracking scheme to detect Z500 cyclone tracks (Keable et al. 2002).

Figure 1 shows that Z500 cyclones have increased in their number and intensity in 1979-2004, and their trends are statistically significant at the 95% confidence level. In particular, it is noted that the positive trend of Z500 cyclone frequency is contributed by the increases in the late 1990s and the early 2000s (Figure 1 (a)). On the contrary, the scale of Z500 cyclones experienced sudden reduction in the same period despite the positive trend up to the mid 1990s (Figure 1 (b)). For these interesting changes, one of the causative mechanisms might be found in the change of the static stability measured by the square of the the Brunt-Väisälä frequency (N^2) at the 500 hPa level. Figure 2 (a) shows that the static stability between the 300 and 700 hPa levels has significantly decreased in the mid and high latitudes, and the decrease has accelerated in the last decade (Figure 2 (b)). According to the baroclinic instability theory in Charney's model (Pedlosky 1987), the critical horizontal wavelength of the order of the deformation radius for baroclinic energy release depends on the vertical scale of the disturbance. In the case that the vertical scale of a disturbance, h, is greater than the density scale height, H, the critical horizontal wavelength of the disturbance, L, is determined by

$$L = \frac{\mathrm{NH}}{f} \quad (1)$$

where f is the Coriolis parameter. As h is greater than H over most of the SH extratropics at the 500 hPa level (not shown), reduction in N would correspond to the reduction in cyclone scale. At the same time, baroclinicity is inversely proportional to N (Hoskins and Valdes 1990), so this reduction would play a role in enhancing the baroclinicity at this level and contribute to the increase in Z500 cyclone frequency. Such crucial role of the static stability in determining the wavelength of baroclinic wave was shown in the model experiment of Stanley and Gall (1977). On the other hand, the increase of cyclone intensity shown in Figure 1 (c) is consistent with the result of Keable et al. (2002) and also suggest that the change shown in their study has continued in the late 1990s and the early 2000s.

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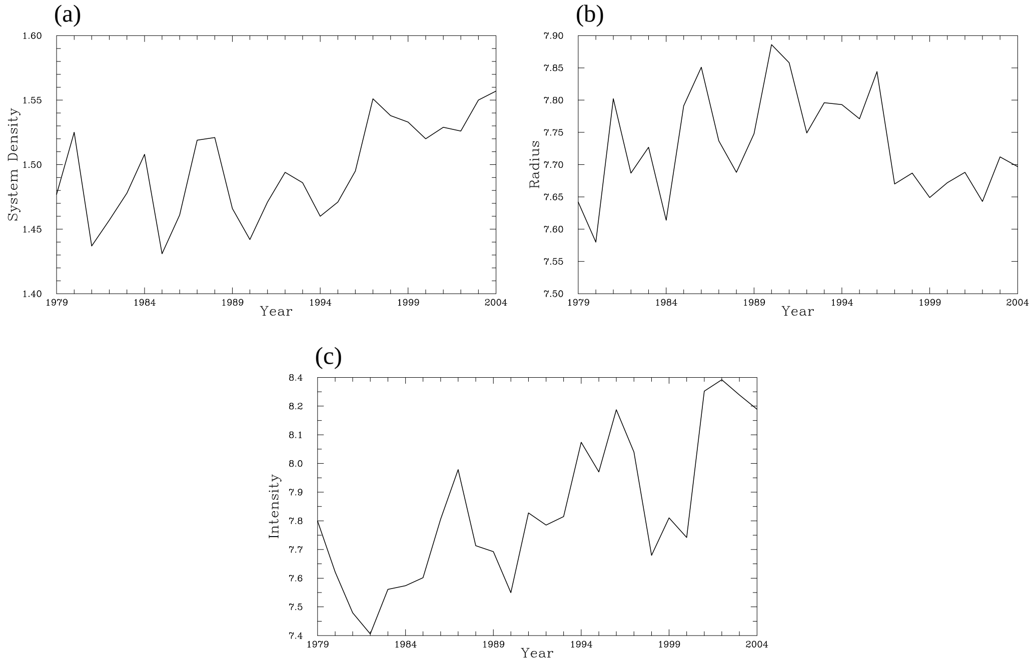

Figure 1: Time series of SH winter zonal averages of Z500 cyclone properties (a) system density (the number of cyclones over in 10^3 (° lat)^2), (b) radius (° lat), and (c) intensity (m (° lat)$^{-2}$).

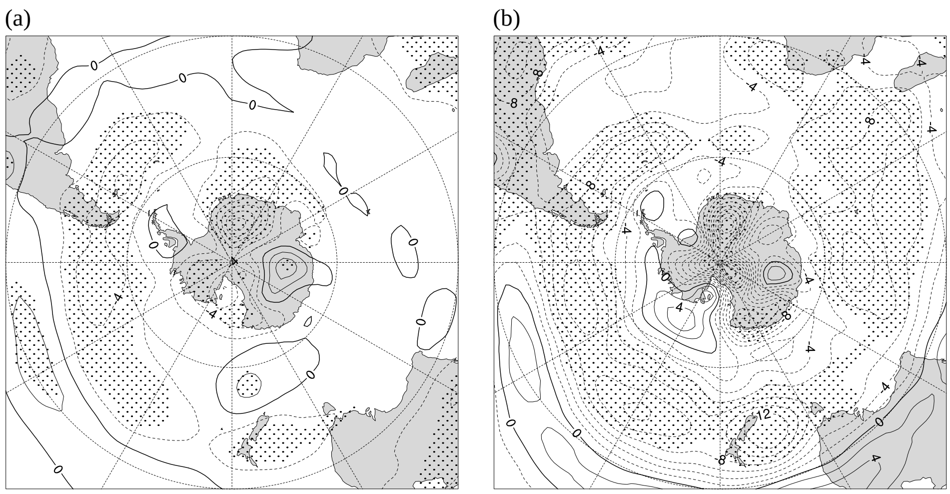

Figure 2: Trend of N^2 at the 500 hPa level in (a) 1979-2004 and (b) 1991-2004. The contour interval is 2×10^{-6} s^{-2} decade^{-1}.