Changes in winter cyclone vertical structure with increasing CO_2

Eun-Pa Lim and Ian Simmonds
School of Earth Sciences
The University of Melbourne
Victoria 3010, Australia
E-mail: eplim@earthsci.unimelb.edu.au

In a warmer globe caused by increasing CO_2, it is expected that lower topospheric baroclinicity will decrease while upper tropospheric baroclinicity increases (Zhang and Wang 1997). In order to find out how these different patterns of baroclinicity change in the troposphere affect extratropical cyclones, we investigate the 'vertical organization' of extratropical cyclones with NCEP-DOE reanalysis-II winter (DJF in the NH, JJA in the SH) data (1979-2000) and CSIRO MARK2 atmosphere-ocean coupled GCM data produced according to IPCC IS92a scenario (Wu et al. 1999). For an appropriate comparison between these data sets, we base our analysis on 22 years from the NCEP2, CSIRO Mark2 control run, and the transient 2xCO_2 and 3xCO_2 runs.

The Melbourne University cyclone finding and tracking scheme (Simmonds and Keay 2000) is used to detect cyclones at mean sea level (msl), 925, 850, 700, 600 and 500 hPa geopotential heights (hereafter Z*pressure*). The vertical organization over surface cyclones is determined in a series of steps: First, we find the location and time of maximum depth of a surface cyclone. In a circle of 4° latitude radius centered on the location and the time found, we search for the vertical extension of the cyclone at the next data level. This tracking is continued to Z500.

We find from our "vertical tracking" that about 41% and 36% of surface extratropical cyclones have well organized vertical structure in that they can be traced all the way to Z500 in winter in the NH and SH, respectively. Furthermore, this percentage has increased over our 22 years of observational record (Figure 1), but only the trend in the SH is significantly different from zero at the 99% confidence level (c.l.).

The surface cyclone features show clear differences according to whether or not surface cyclones are vertically well organized. The surface cyclones having a Z500 cyclone partner are more intense, larger and deeper than those ending their connection at Z700 or lower. Moreover, the mslp-Z500 coupled cyclones have about twice the lifespan of the others (not shown).

When surface cyclones experience their deepest stages, the average distance between Z500 and mslp cyclone centers is about 388 km and 384 km in winter in the NH and SH, respectively. This distance has reduced for the last two decades, and these decreases are -1.74 and -1.96 km per annum (99% c.l.) in the NH and SH (Figure 2). It might imply that cyclones have become more barotropic at the full development stage over the last 22 years.

About 43% and 50% of the control model cyclones have vertically well organized structure up to Z500 in the NH and SH, respectively (Table 1). With increasing CO_2, the ratio of cyclones having well organized vertical structure increases, and the mean separation of msl-Z500 pairs is seen to decrease.

In conclusion, the results of vertical organization of cyclones in the CSIRO simulations are consistent with those in NCEP2. Therefore, some of present changes in cyclone vertical structure seem to be following the patterns possibly cyclones experience in the warmer world.

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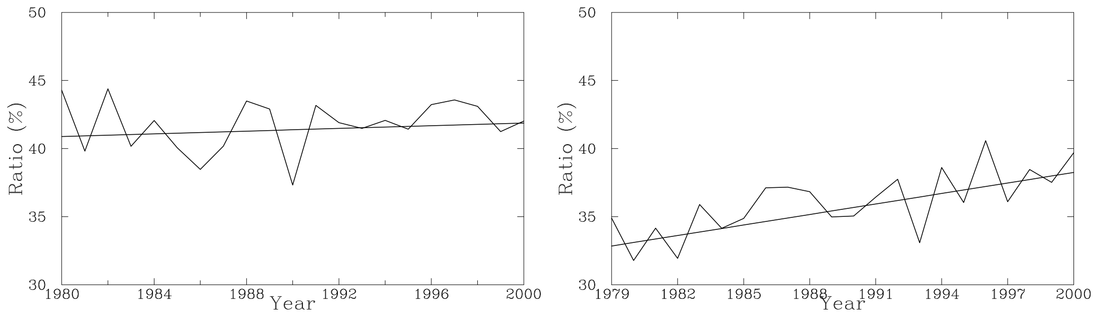
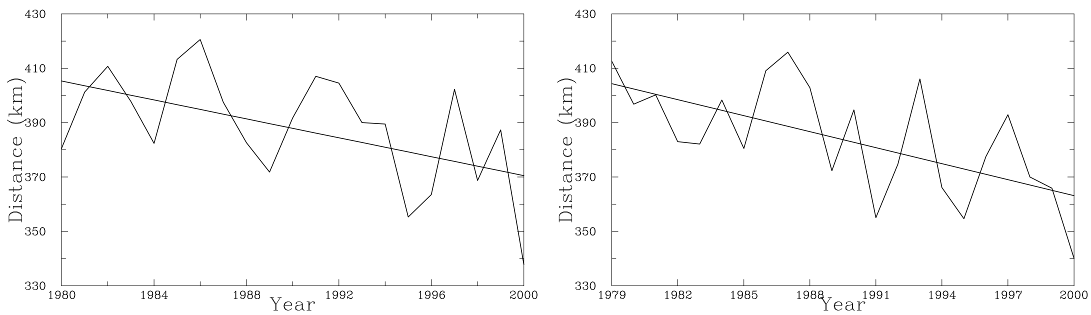


(a) (b)

Figure 1: Time series of the ratio of the number of well-organized cyclones to the entire mslp extratropical cyclones in winter seasons in 1979-2000. (a) NH and (b) SH



(a) (b)

Figure 2: Time series of the average distance between coupled Z500 and mslp cyclone centers. (a) NH and (b) SH

		CONT	$2xCO_2$	$3xCO_2$
Ratio	NH	42.6	43.3	45.1
(%)	SH	49.8	50.8	51.6
Distance	NH	505.7	494.1	485.8
(km)	SH	450.0	441.7	428.5

Table 1: Changes of vertically well structured cyclones according to CO_2 concentration in the control run (CONT) and transient runs ($2xCO_2$, $3xCO_2$).