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The Breakup of the Southern Hemisphere Spring Polar Ozone and Temperature Minimums from 1979 to 1987

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I. Introduction

During the late southern hemisphere (SH) spring, the total ozone field has a broad scale polar minimum surrounded by a circumpolar maximum located at 40-60°S. During the spring polar vortex breakup or final warming, the ozone minimum increases, and is usually displaced off of the pole into the western hemisphere as the circumpolar ozone maximum intrudes onto the pole. The polar ozone minimum rapidly fills prior to the breakup.

Recently, it has been suggested that the October Antarctic ozone depletion may be influencing the timing of the polar vortex breakup (Kiehl et al., 1988). The breakup timing change would result from the reduced heating of the polar lower stratosphere because of the depleted lower stratospheric ozone mixing ratios. Since the vortex would be colder, zonal mean winds would be stronger, and these stronger zonal winds would inhibit the vertical propagation of waves into the stratosphere. The net effect is that the colder vortex is stabilized against erosion by Rossby waves, resulting in a delayed polar vortex breakup.

The purpose of this study is to quantify the observations of the polar vortex breakup. The data used in this study consist of Total Ozone Mapping Spectrometer (TOMS) data, and National Meteorological Center (NMC) analyses. The final warming is diagnosed using the difference between zonal means at 80° and 50°S for temperature, ozone, and layer mean temperature. The polar vortex breakup can also be diagnosed by the onset of weak zonal mean zonal winds (i.e. $\bar{u}$, overbar denotes a zonal average) at 60°S.

II. Analysis

The polar vortex begins to erode in September at the high stratospheric altitudes; this is subsequently followed by irreversible erosion at lower levels later in the season as the jet descends. The final 100 mb breakup usually occurs in late-November (Farrara and Mechoso, 1986). The final warming during 1987 is illustrated in Fig. 1a using NMC $\bar{u}$ at 60°S and 100 mb (short dash), $\bar{T}$(80°S)-$\bar{T}$(50°S) (hereafter referred to as the temperature difference) at 100 mb (solid), and the 80°-50°S 100-150 mb layer mean temperature difference (long dash). Weak zonal winds (i.e. winds less than 20m/s) appear on December 12, 1987, the 100 mb temperature difference reverses on December 9, 1987, and the 150-100 mb layer mean temperature difference reverses on December 6, 1987. The higher levels have breakup dates which are earlier (e.g. the 10 mb 80°-50°S temperature difference reverses on October 3, 1987). Figure 1b displays the ozone hole breakup using the zonal mean 80°-50°S total ozone difference (solid) and the the polar map minimum total ozone values (dashed). The rapid breakup in late-November is accompanied by an increase of total ozone values in the polar minimum. Other years show similar evolution with time.

The breakup dates of the polar ozone minimum for all years 1979-1987 are shown in Fig. 2 using the 80°-50°S zonal mean total ozone differences (solid), 100 mb temperature difference (long dash), and 100 mb zonal mean wind (short dash). The figure shows a general trend toward later final warmings. However, the earliest 100 mb warming took place in 1986. Note also the excellent correlation between the 100 mb temperature and the total ozone differences. Comparisons at other stratospheric levels are inconclusive because of the large interannual variance of the breakdown date and the fact that total ozone reflects lower stratospheric processes.

Finally, Fig. 3 shows a plot of the breakdown date (from the 100 mb temperature difference) versus the total ozone October map minimum value. Generally, the figure reveals reduced ozone in October is associated with a later breakdown date. Although this trend is significant at the 95% confidence interval, at higher altitudes, the trend is not significant at the 95% C.I.

Individual plots of TOMS total ozone data for late November (not shown here) indicate that the ozone minimum is remaining intact for a longer period in the later years of the TOMS data set (i.e. 1985, 1986, 1987) than the earlier years (i.e. 1979, 1980, 1981, and 1982).

III. Summary and Conclusions

Computations of the polar vortex breakdown date using NMC meteorological data and TOMS total ozone data indicate that the breakdown is occurring later in the spring in the lowest portion of the stratosphere. At altitudes above 100 mb, the large interannual variance of the breakdown date renders any trend determination of the breakdown date difficult. Individual plots of TOMS total ozone indicate that the total ozone minimum remains intact for a longer period of time than is observed in earlier years.

References

Farrara, John D., and Carlos R. Mechoso, An Observational Study of the Final Warming and Polar Vortex Disappearance During the Southern Hemisphere Spring, Geophys. Res. Lett., 13, 1232-1235, 1986

Kiehl, J.T., Byron A. Boville, and Bruce P. Briegleb, Response of a General Circulation Model to a Prescribed Antarctic Ozone Hole, submitted to Nature, 1988.

Figure Captions

Figure 1. Spring 1987 line plots of: a) NMC 80°-50°S 100 mb temperature difference (solid), NMC 80°-50°S zonal mean 100-150 mb layer mean temperature difference (long dash), and zonal mean zonal wind at 60°S (short dash); and b) TOMS total ozone 80°-50°S difference (solid), and TOMS total ozone map minimums (short dash).

Figure 2. Polar vortex breakup dates (Julian day) versus year as diagnosed from: a) 100 mb 80°-50° temperature differences (long dash), b) total ozone 80°-50°S zonal mean difference (solid), and 100 mb zonal winds (short dash).

Figure 3. Breakdown date from the 80°-50°S 100mb temperature gradient plotted against the TOMS October average map minimum.

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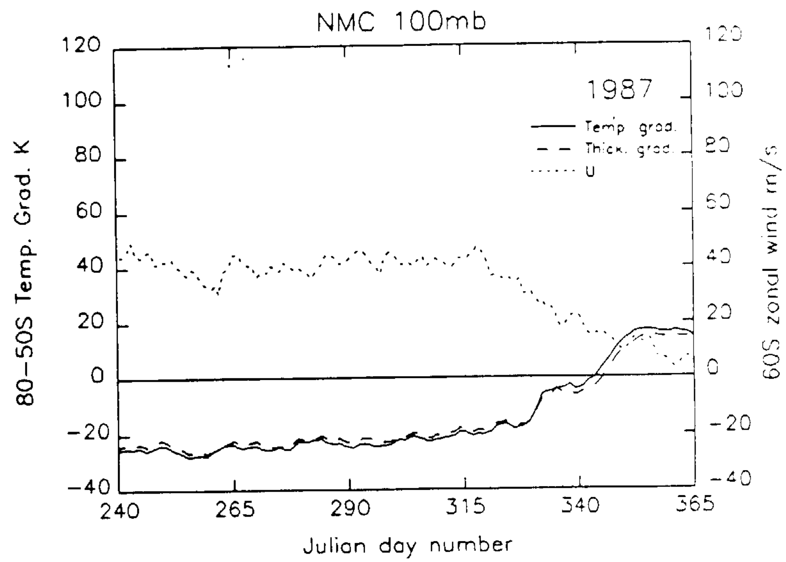

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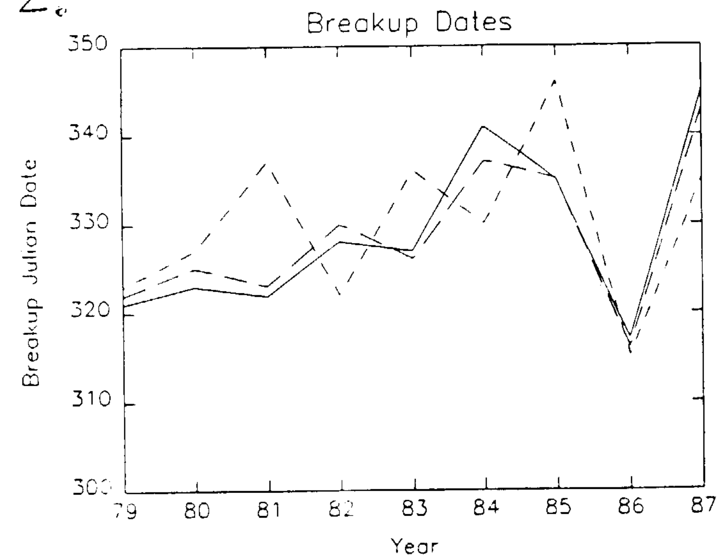

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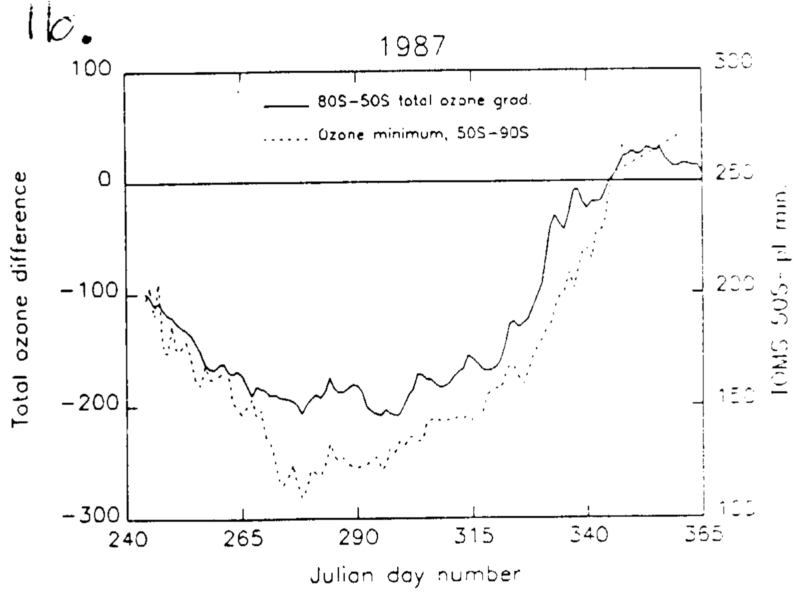

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