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The Morphology and Meteorology of Southern Hemisphere Spring Total Ozone Mini-Holes

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I. Introduction

On August 13 and September 2, 1986, rapid declines of total ozone in the south polar region were observed in Total Ozone Mapping Spectrometer (TOMS) data (Mark Schoeberl, personal communication). The two events were labeled mini-holes because of their rapid decline rates, and their small horizontal scales (1000-3000 km), as opposed to the long-term decline rate and planetary scale of the ozone hole. Two more mini-holes were observed on August 17 and September 5, 1987 during the Antarctic Airborne Ozone Experiment (AAOE).

The purpose of this paper is to describe the properties of mini-hole events. Both TOMS data and National Meteorological Center (NMC) meteorological analyses will be used to determine the horizontal, vertical and temporal characteristics of the mini-holes.

II. Analysis

As originally observed, the mini-holes showed horizontal spatial scales of 1000-3000 km, were usually located near the Palmer penninsula region (70°S 65°W), and produced rapid 20-30 DU reductions of the polar total ozone minimum value. Fig. 1 displays the 1987 map minimum total ozone values. These values were determined from the lowest gridded TOMS data value between 50°S and 90°S. The crosses on the figure denote days when the minimum value decreased by at least 20 DU over a single day. These sudden decreases are typical of each spring, usually occurring in August and September. The years 1979 and 1984 each had 6 mini-holes which resulted in at least a 20 DU decrease, while 1981 had only 1 mini-hole. Horizontal maps of mini-hole locations during August-September 1979 through 1987 indicate two preferential regions of intensification: 1) the Palmer penninsula (65-75°S, 60-80°W); and 2) the East Antarctica ice sheet (70-80°S, 40-100°E). The majority of mini-holes appeared over the first region.

In order to illustrate the temporal behavior of the mini-holes, the TOMS data have been band-pass filtered (half-amplitude points of 10 and 3 days). Fig. 2 shows these band-pass filtered data as a Hovmoller plot (only negative contours are plotted for ease of interpretation). The mini-holes are observed as the strong negative disturbances near 75°W on August 17 (day 16) and September 5, 1987 (day 35). It is now apparent that the mini-holes are eastward propagating disturbances which intensified in the 75°W region. In addition, the plot shows the detailed behavior of the mini-hole event of mid-August as two separate features. The first disturbance appeared on day 14 (August 15) near 120°W, moved rapidly eastward and intensified near 60°W by August 17. A second weak disturbance near 135°W appeared on August 16, intensified, and moved eastward to 60°W by August 19. The second mini-hole of September 5 can be traced from the weak disturbance mentioned previously which developed on August 16 near 135°W. This disturbance propagated completely around Antarctica at a phase speed of 10 m/s over a 17 day period and reintensified in the 65°W region.

Figs. 3 show polar stereographic projections of band-pass filtered total ozone (Fig. 3a), and band-pass filtered 100mb temperatures (Fig. 3b) on September 5, 1987. Excellent spatial correlation between these data sets is obvious. The mini-hole of September 5 is clearly identifiable in Fig. 3a as the low total ozone region which extends from the base of the Palmer penninsula (70°S, 60°W) into the region slightly west of South America. An identical feature is observed in the band-pass filtered 100mb temperatures in Fig. 3b. Thus, the total ozone field is highlyt correlated with lower stratospheric temperatures at small horizontal and short time scales. Note that the both filtered data sets show a distinct northwest-southeast tilt.

Band-pass filtered geopotential heights (not shown here) show an anti-cyclone which is closely associated with the mini-hole, but is phase shifted slightly to the west of the mini-hole on both Aug. 17 and Sep. 5. The unfilterd geopotential heights show stong northward flow in the mini-hole region. The vertical structure of the mini-hole features show a slight westward tilt with altitude for both the filtered temperatures and geopotential heights. Finally, the absolute value of Ertel's potential vorticity (Epv) shows a strong positive correlation, but with a slight phase shift of the Epv to the east of the mini-hole.

III. Summary

Mini-holes are rapidly developing (1-5 days), small horizontal scale (1000-3000 km) features which appear in the polar total ozone field during September and October of each year. Typically, a total of 1-6 mini-holes appear each year in either the Palmer penninsula region or over the East Antarctica ice sheet. The mini-holes do not develop over these two regions, but they intensify most dramatically there (possibly associated with the local orography). The mini-holes are associated with cold pools of air in the lower stratosphere, anti-cyclonic (geopotential height highs) disturbances to their west, high potential vorticity slightly to the east, and strong northward flow. These meteorological feature are baroclinic, having a distinct westward tilt with increasing altitude.

Figure Captions

Figure 1. TOMS total ozone minimum values for the southern spring 1987. The mapped minimum is the lowest total ozone value observed in the TOMS data between latitudes 50°S to 90°. The crosses denote map minimum decreases which exceeded 20 DU in a single day (Aug. 15, Aug. 17, and Sep. 5, 1987).

Figure 2. Hovmoller plot of band-pass filtered TOMS data. Only the -5 DU, -10 DU, -20 DU, and -30 DU contours are shown for ease of interpretation. The filter has half-amplitude points of 3 and 10 days.

Figure 3. Horizontal plots of band-pass filtered TOMS total ozone (3a, 10 DU contour increment), and NMC 100 mb temperatures (3b, 1°K contour increment). The band-pass filter has half-amplitude points of 3 and 10 days. TOMS data in 3a are omitted from 20°S to 32°S.

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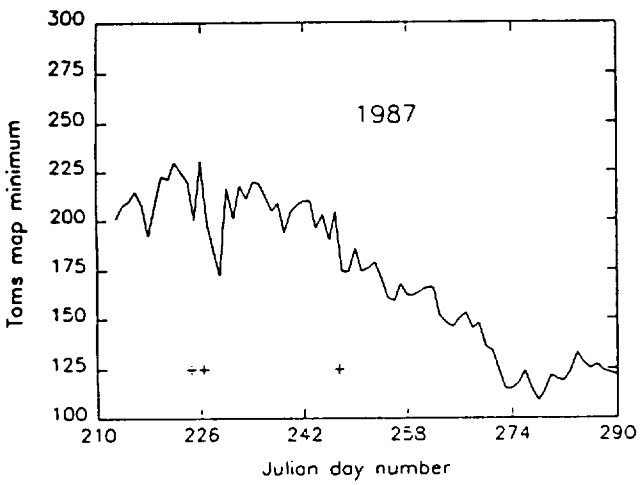
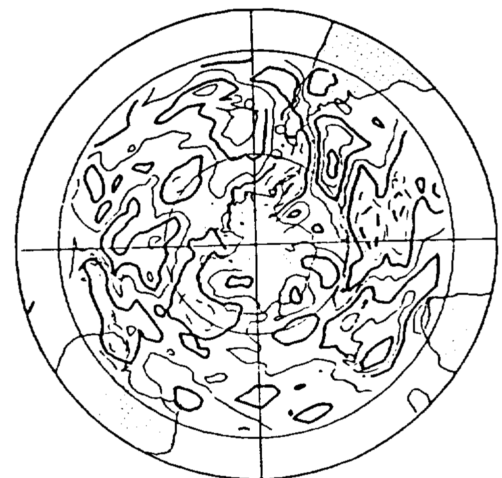


3a.

TOMS TOTAL OZONE DU 9/ 5/87



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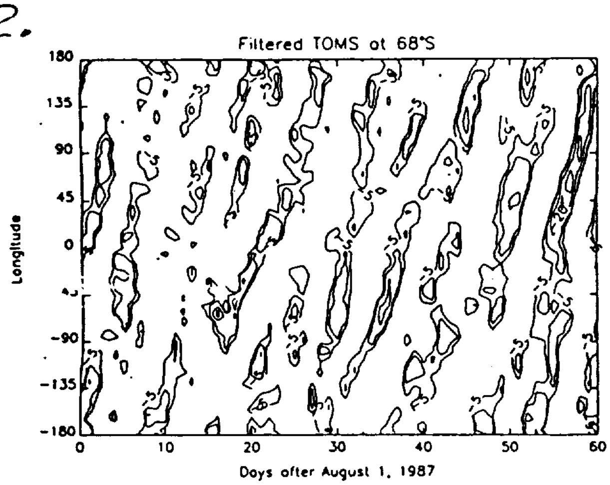

3b.

NMC 100MB TEMP. 9/ 5/87