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OZONE PROFILE MEASUREMENTS AT MCMURDO STATION ANTARCTICA DURING THE SPRING OF 1987.

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During the Antarctic spring of 1986, 33 ozone soundings were conducted from McMurdo Station. These data indicated that the springtime decrease in ozone occurred rapidly between the altitudes of 12 and 20 km. During 1987, these measurements were repeated with 50 soundings between 29 August and 9 November. Digital conversions of standard electrochemical cell ozonesondes were again employed. The ozonesonde pumps were individually calibrated for flow rate as the high altitude performance of these pumps have been in question. While these uncertainties are not large in the region of the ozone hole, they are significant at high altitude and apparently resulted in an underestimate of total ozone of about 7% (average) as compared to the Total Ozone Mapping Spectrometer (TOMS) in 1986, when the flow rate recommended by the manufacturer was used. At the upper altitudes (≈30 km) the flow rate may be overestimated by as much as 15% using recommended values (see Harder et al., "The UW Digital Ozonesonde: Characteristics and Flow Rate Calibration", poster paper, this workshop). These upper level values are used in the extrapolation, at constant mixing ratio, required to complete the sounding for total ozone.

The first sounding was on 29 August, prior to major ozone depletion, when 274 DU total ozone (25 DU extrapolated) was observed. By early October total ozone had decreased to the 150 DU range; it then increased during mid-October owing to motion of the vortex and returned to a value of 148 DU (29 DU extrapolated) on 27 October. The recommended ozonesonde flow rate would have given 137 DU (25 DU extrapolated) on 27 October. TOMS recorded 150 DU on this day over McMurdo (A. Krueger personal communication, 1988). In general, agreement with TOMS was very good except for the period 3-9 September when the soundings indicated more ozone than derived from TOMS data (see Figure 1).

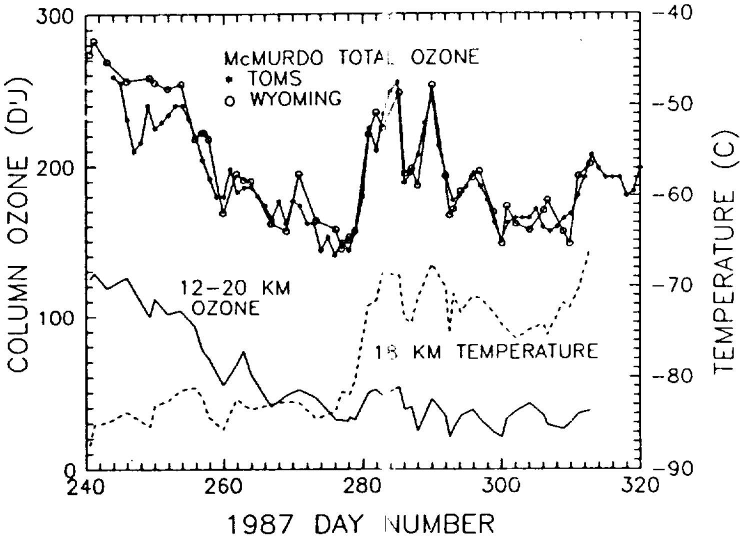

Figure 1. Total ozone at McMurdo in 1987 as determined by ozonesondes (circles) and TOMS satellite data (stars). Also shown is the 12-20 km ozone column and the 18±1 km average temperatures from the ozonesonde data.

The differences in early September are larger than can be accounted for by ozonesonde uncertainties. This apparent discrepancy may be related to the effect of high clouds on remotely sensed data at this time. Warmer temperatures at 18 km and high ozone above this altitude from about 7-24 October marked a period when McMurdo was near the edge of the ozone hole region. However, this did not affect the 12-20 km ozone column substantially (see Figure 1) where ozone fell sharply in September and remained low throughout October and early November. A major portion of the decrease (about 50 DU) occurred between 13 and 17 September (see Figure 1). The average rate of ozone mixing ratio decrease at 18 km in September was greater than in 1986 with a halflife, for an exponential decay, of 12.4 days as compared to 25 days.

The 16 km ozone partial pressure decreased from about 150 nbar in late August to about 3-5 nbar in early October representing a reduction in excess of 95% (see Figure 2). This may be compared to a minimum of about 10 nbar at McMurdo in 1986. Since the minimum ozone partial pressures in 1987 are near the background level of the electrochemical sensor under the prevailing conditions, and since some ozone may have diffused into the minimum region, the depletion may in fact have been total at some earlier time in this air mass. It may thus be difficult to determine the strength of the depletion mechanism from such measurements.

The 1987 ozone hole was also greater in vertical extent, reaching to 23 km as compared to about 20 km in 1986. The lower boundary was similar (about 12 km) with ozone depletion delayed at 12 km until about mid-September. In order to reach total ozone values as low as 105-110 DU, as reportedly observed in limited regions by TOMS, and restrict the depletion region to 12-23 km as observed in the McMurdo ozonesonde data, one would have to totally deplete ozone over that entire region. It is thus possible that the depletion extended to somewhat higher altitudes in limited regions. Again the possible effect of spatially limited dense clouds on remotely sensed ozone data needs to be investigated.

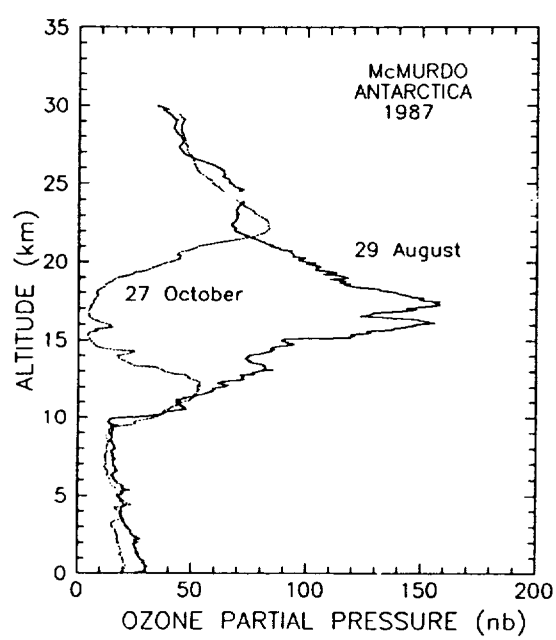

Figure 2. Comparison of ozonesonde profiles before (29 August) and after (27 October) development of the 1987 ozone hole at McMurdo.

The large variability observed in ozone profiles in the hole region in October 1986 was again observed in 1987 mainly in the 7-24 October period when McMurdo was farthest from the center of the hole. This suggests that most of these ozone layers are probably associated with the walls of the ozone cavity or polar vortex region. On September 20, reductions in ozone in ≈1 km layers in the 12-18 km region were correlated with reductions in temperature. The latter were near the frost point for water (see Rosen et al., "Balloonborne Antarctic Water Vapor Measurements and their Impact on PSC Theories," this workshop) and cloud formation may have played a role. However, on this occasion the associated ozone variations appear to be the result of adiabatic mixing in 1-2 km thick layers and are probably related to mountain generated waves and the formation of nacreous clouds which were observed at this time. Major nacreous cloud events were observed at McMurdo on 17 September in 1986 and on 20 September and 5 October in 1987.

Other than on the somewhat rare occasions associated with mountain lee waves, temperature and ozone mixing ratio profiles showed no evidence for general vertical motions with constant mixing ratio during the formation of the ozone hole (see Figure 3). The dominant depletion mechanism appears to begin in the 20 km altitude region and creates ozone mixing ratios which decrease with altitude in the hole region suggesting a local sink rather than transport of ozone out of the region. Small regions of vertical motion, as associated with the unusual temperature profile of 20 September may be important in ozone variations in the lower stratosphere especially after mid-September.

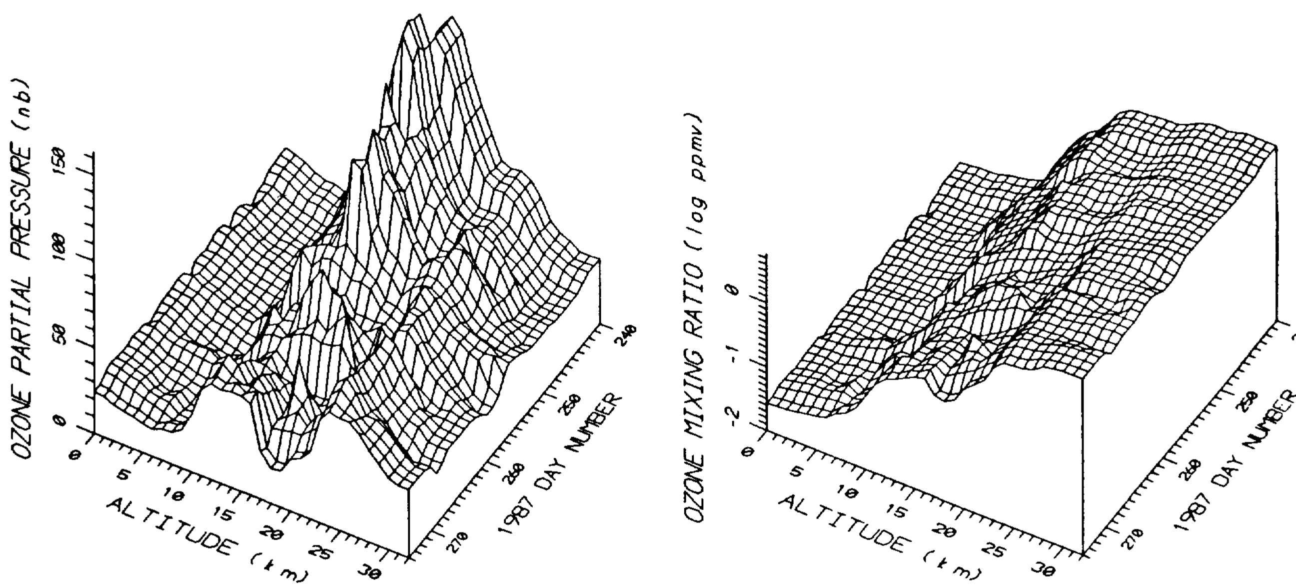

Figure 3. Three-dimensional ozone partial pressure and mixing ratio surfaces versus time and altitude constructed from 18 soundings during the 29 August to 30 September 1987 period at McMurdo.

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