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STRATOSPHERIC AEROSOL AND CLOUD MEASUREMENTS AT MCMURDO STATION ANTARCTICA DURING THE SPRING OF 1987.

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Measurements of stratospheric aerosols with balloonborne optical particle counters on 6 occasions at McMurdo Station (78°S) in the spring of 1986 indicated subsidence of the stratospheric sulfate layer during the time that the ozone hole was forming (Hofmann et al., 1988). Since dynamic models of ozone depletion involving upwelling in the spring polar vortex would suggest the opposite, we repeated the measurements with an increased frequency (about one sounding per week) in 1987. During 3 of the aerosol soundings in 1986, temperatures in the 15-20 km range were low enough (<-80°C) for HNO_3 to co-condense with water according to several theories of polar stratospheric cloud formation. However, particles were not observed with the characteristic size suggested by theory (≈0.5 μm). For this reason, it was proposed that polar stratospheric clouds may predominantly consist of large (≈5-50 μm) ice crystals at very low (≈10^{-4}-10^{-3} cm^{-3}) concentrations (Rosen et al., 1988). The particle counter employed would be relatively insensitive to these low concentrations. With the increased frequency of soundings in 1987, and adding additional size discrimination in the 1-2 μm region, this hypothesis could be verified if suitably low temperatures were encountered.

Between August 29 and November 6, ten 8-channel (r ≥ 0.15 to 2 μm) aerosol detectors were flown. Of these, 8 returned size distribution information to altitudes in excess of 20 km, well above the sulfate layer at 10-15 km. As in 1986, no evidence for vertical motions could be found in the aerosol profiles during the time that the ozone hole was forming (see Figure 1).

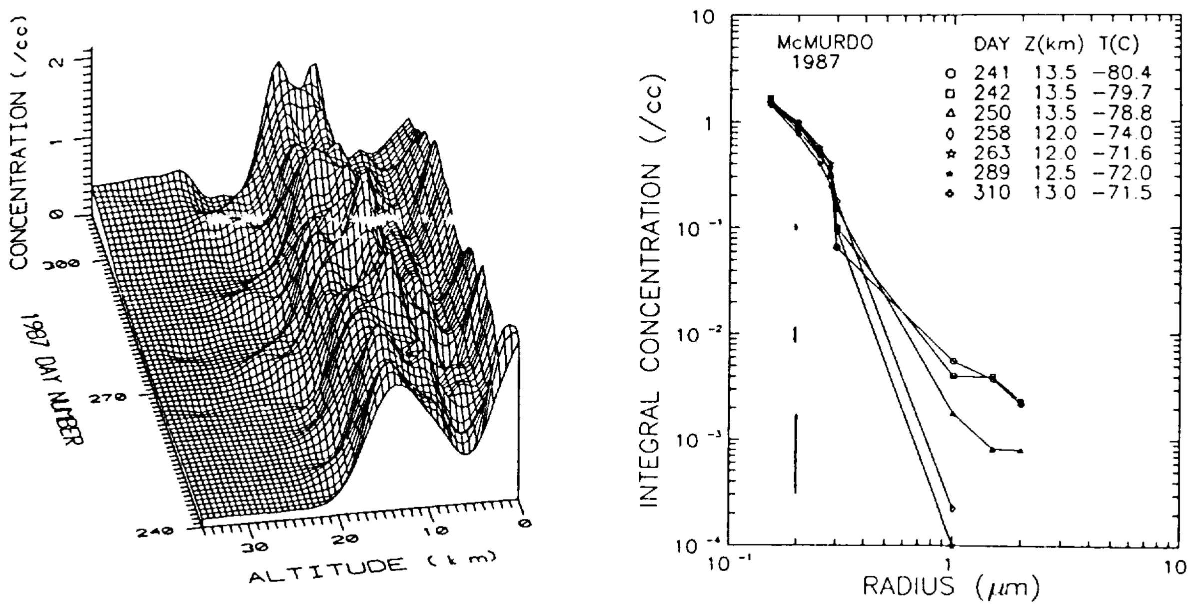

Figure 1. (Left) Time development of the aerosol concentration profile for radii greater than 0.15 μm and (Right) the size distribution (½km averages) at the stratospheric concentration maximum at McMurdo Station between August 29 and November 6, 1987. Vertical bars indicate the statistical uncertainty in the number of particles counted in ½km at the corresponding concentrations.

Size distributions in the stratospheric sulfate layer indicated the presence of large ($r \approx 1$-$2\ \mu m$) particles at concentrations of 10^{-3} - $10^{-2}\ cm^{-3}$ in late August and early September (see Figure 1). By the middle of September the large particles were absent. Although sizes greater than 2 μm could not be resolved, the size distributions are not inconsistent with concentrations in the 10^{-4} - $10^{-3}\ cm^{-3}$ range for particles of 5-10 μm size. The large particles in the sulfate layer disappeared when temperatures were in excess of about -79°C (after about September 15) except on October 5 when 1-2 μm particles were observed at concentrations as high as 0.1 cm^{-3} and temperatures as high as -74°C in the 11-13 km region (see Figure 2). This event was observed in lidar data at McMurdo (B. Morley, personal communication) with scattering ratios <3 and nacreous clouds were observed that evening.

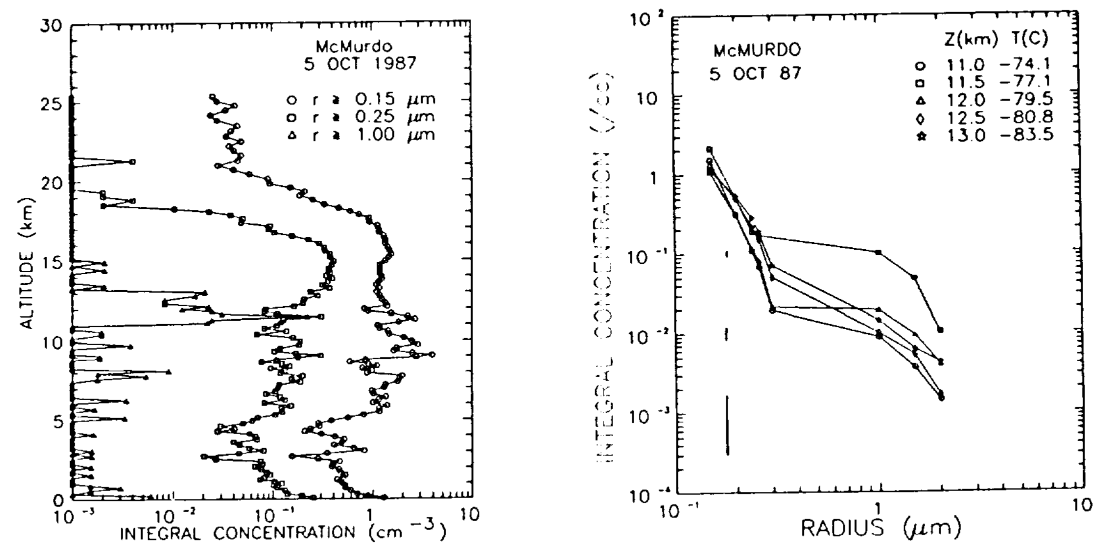

Figure 2. (Left) Aerosol concentration profiles and (Right) the associated size distribution (½km averages) at McMurdo on October 5, 1987. Vertical bars indicate the statistical uncertainty in the number of particles counted in the ½km at the corresponding concentrations.

An unusual event was observed in the 17-20 km region on August 29 when temperatures from -85° to -87°C were encountered. Both the small particle (0.15-0.3 μm) and large particle (1-2 μm) modes were enhanced with concentrations ranging from 10-80 cm^{-3} for $r \geq 0.15\ \mu m$ and 0.1-2.0 cm^{-3} for $r \geq 1\ \mu m$. Malfunction of the instrument above 20 km prevented observation of the top of this apparent cloud. A pronounced twilight reddening of the sky indicated clouds at altitudes in the 20 km region that evening. A successful sounding 22 hours later under similar temperature conditions did not reveal unusual particle concentrations in this altitude range. Twilight observations could not be made owing to cloud cover that evening. The McMurdo lidar was not operating during this period. A measurement of the total aerosol concentration (condensation nuclei, $r \geq 0.01\ \mu m$) 47 hours later with about 2°C higher temperatures indicated concentrations of about 10-15 cm^{-3} in this altitude range. Although the measurement on August 29 could not be confirmed, inverse correlations in the two size modes and the shape of the size distributions are physically reasonable. The small particle mode indicated a mass of about 50 ppb ($\rho = 1.2$) while that in the large particle mode suggested a lower limit (having no size resolution above 2 μm) of about 0.35 ppm ($\rho = 1$). These numbers translate into about 12 ppbv HNO_3 for a 50% HNO_3 aerosol in the small particle mode and about 0.55 ppmv for water in the large particle mode.

Measurements of condensation nuclei (CN) were conducted on 7 occasions in 1987. In 1986 a pronounced layer of CN (≈50 cm^{-3}) was observed on all 3 soundings just above the ozone hole (≈22-24 km). No CN measurements were made prior to ozone hole formation in 1986 so it was not known if this unusual CN layer formed during the polar winter or at the time of ozone hole formation. In 1987 a successful CN sounding was conducted on August 31, before major ozone depletion had begun. While CN concentrations were relatively high (≈ 10-20 cm^{-3}) in the 20-25 km region, no distinct layer of ≈50 cm^{-3} was observed. However, by mid-October the layer had developed with concentrations as high as 100 cm^{-3} from 20-23 km (see Figure 3). It thus appears that this phenomenon is related to photochemistry. Temperatures in the region of the CN layer of -60° to -70°C again indicates that the composition of these small particles must be a sulfuric acid - water mixture similar to the sulfate layer. While their connection to the ozone hole phenomenon remains a mystery, they suggest unusual photochemistry, possibly related to OCS conversion to H_2SO_4, taking place in the springtime polar vortex.

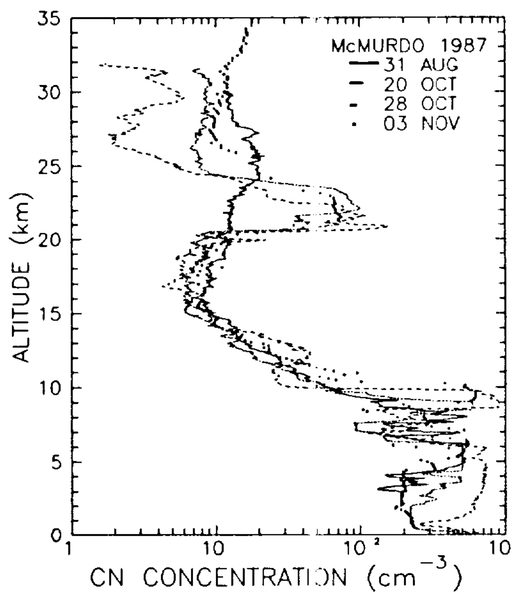

Figure 3. Condensation nuclei profiles before (August 31) and after (October 20, 28, November 3) formation of the ozone hole at McMurdo in 1987.

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