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EXTINCTION AND BACKSCATTER MEASUREMENTS OF ANTARCTIC PSC'S, 1987: IMPLICATIONS FOR PARTICLE AND VAPOR REMOVAL

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Observations since 1979 of aerosol extinction at 1.0 μm by the SAM II (Stratospheric Aerosol Measurement II) sensor have shown recurring synoptic-scale, optically thin clouds in both winter polar stratospheres (McCormick et al., 1982) which are highly correlated with cold temperatures (<195K). Steele et al. (1983) initially proposed that PSC's consist of pure ice particles forming at temperatures below the frost point, but subsequent papers (Toon et al., 1986; Crutzen and Arnold, 1986) proposed a preliminary stage of binary HNO_3-H_2O particles forming at temperatures above the frost point. These authors suggested that a large fraction of the gaseous NO_x reservoir in the Antarctic stratosphere could be depleted during such a process, thereby "preconditioning" the stratosphere for halogen-catalyzed ozone destruction.

Airborne lidar observations of Arctic PSC's by Poole and McCormick (1988a) support the idea of a two-stage (Types I and II) formation process. At temperatures above the frost point (the Type I regime) the authors found a signature indicative of particles significantly larger than the ambient aerosol, but probably of limited size (radii on the order of the lidar wavelength, ≈0.7 μm) and perhaps quasi-spherical in shape. In contrast, the authors found a signature typical of larger crystalline (Type II) particles in PSC's at temperatures near the frost point. In a separate paper, Poole and McCormick (1988b) gave theoretical results from a two-stage PSC microphysical model assuming Type I particles to be solid, fixed (stoichiometric) composition nitric acid trihydrate ($HNO_3 \cdot 3H_2O$) and Type II particles to be a homogeneous mixture of pure water ice and the trihydrate. The results compared favorably with the authors' Arctic experimental data and supported the earlier estimates by Toon et al. and Crutzen and Arnold that a large fraction of the ambient HNO_3 vapor supply could be consumed in the PSC formation process. Computed particle size distributions for Antarctic PSC's suggested that Type II particles may be large enough to fall rather quickly, thereby removing the condensed HNO_3 (i.e., gaseous NO_x) from the region in which the clouds were formed. Calculated optical properties also showed a distinctive temperature dependence, with threshold temperatures for Type I and Type II PSC particle formation being sensitive indicators of the HNO_3 and H_2O vapor supplies, and enhancements in extinction and backscatter (relative to those computed for the ambient aerosol) being closely related to the number and modal size of the PSC particles.

In this paper, we examine the temperature dependence of optical properties measured in the Antarctic during 1987 at the 70-mb level (near 18 km), a level chosen to correlate our results with in situ measurements made from the NASA Ames Research Center ER-2 aircraft during the 1987 Airborne Antarctic Ozone Experiment (AAOE). Our data set consists of extinction measurements by SAM II inside the

Antarctic polar vortex from May to October 1987; and backscatter measurements by the UV-DIAL (Ultraviolet Differential Absorption Lidar) system (Browell et al., 1983) aboard the Ames DC-8 aircraft during selected AAOE flights. We will compare observed trends with results from a revised version of Poole and McCormick's model (assuming variable-composition Type I PSC's; McElroy et al., 1986; Hanson and Mauersberger, 1988), to classify the PSC observations by Type (I or II) and infer the temporal behavior of the ambient aerosol and ambient vapor mixing ratios.

The sample figures show monthly ensembles of the 70-mb SAM II extinction ratio (the ratio of aerosol or PSC extinction to molecular extinction) as a function of NMC temperature at the beginning (June) and end (October) of the 1987 Antarctic winter. Both ensembles show two rather distinct clusters of points: one oriented in the near-vertical direction which depicts the change with temperature of the ambient aerosol extinction ratio; and a second cluster oriented in the near-horizontal direction whose position on the vertical scale marks a change in particle phase (i.e., PSC formation) and whose length (the extinction enhancement relative to that of the ambient aerosol) is an indicator of PSC type. Several points are of note: (1) The typical ambient aerosol extinction ratio is smaller by a factor 2-3 in October than in June, indicating a change in the ambient aerosol population due to subsidence or sedimentation (or both) over the course of the winter. We found that June values are approximated well by theoretical computations using an ambient aerosol size distribution derived from August ER-2 observations. (2) Most extinction enhancements observed in both months were of the order of 10 or smaller, signaling (by model calculations) Type I PSC's. (3) Type I PSC's occurred at 70-mb temperatures between 195-200K in June, suggesting HNO_3 and H_2O mixing ratios of 5-7 ppbv and 4-5 ppmv, respectively. These are similar to local pre-winter values measured by LIMS (Limb Infrared Monitor of the Stratosphere) in 1979 (Russell, 1986) and, for H_2O only, by SAGE II (Stratospheric Aerosol and Gas Experiment II) in 1987 (J Larsen, personal communication). (4) In contrast, Type I PSC's occurred at lower (by ≈5K) 70-mb temperatures in October, implying a marked reduction in ambient vapor mixing ratios over the winter. Our calculations suggest October mixing ratios of 1-2 ppbv for HNO_3 and ≈2 ppmv for H_2O, similar to those measured inside the vortex from the ER-2 during AAOE and (H_2O only) by SAGE II in October. We believe that the inferred changes in ambient vapor levels cannot possibly be attributed to subsidence, but must be due instead to losses via sedimentation of PSC particles.

Although our quantitative estimates are subject to uncertainties in the NMC temperatures and the saturation HNO_3 and H_2O vapor pressures used in our supporting calculations, we feel that the general trends shown here would be borne out by similar analyses using other data bases. The results strongly suggest that Antarctic PSC's act as a sink for HNO_3 and H_2O vapor, a process which, by examination of other monthly ensembles of SAM II data, appears to take place primarily during the August time frame.

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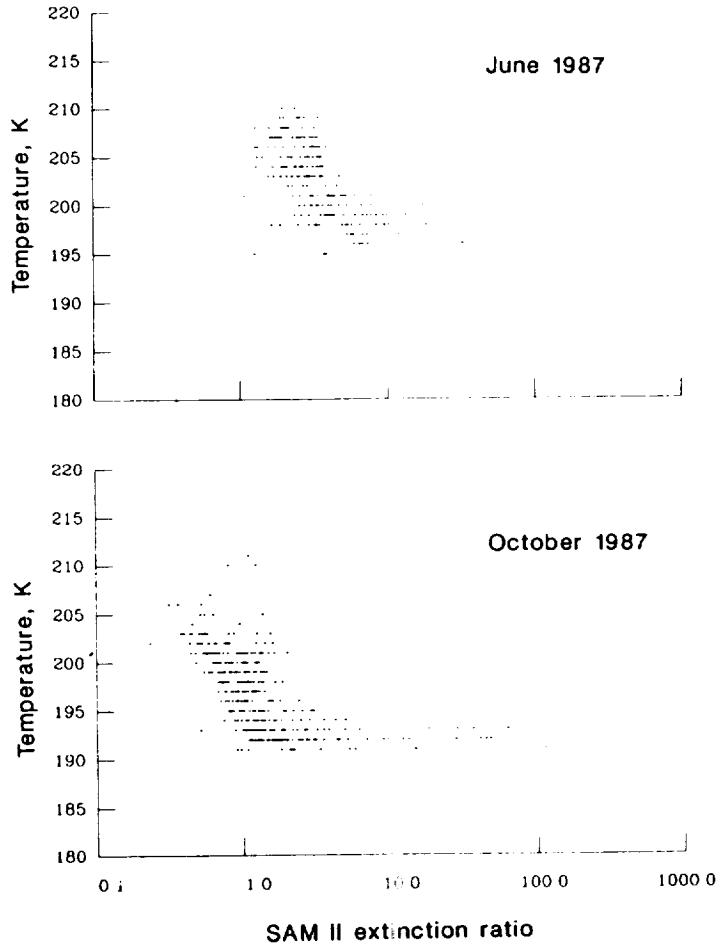

Ensembles of SAM II extinction ratio at 70 mb inside the Antarctic polar vortex, June and October 1987.