AIRBORNE LIDAR STRATOSPHERIC OZONE AND AEROSOL INVESTIGATIONS

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Research Objectives:

The objectives of this research are to investigate the distribution of ozone (O_3) and aerosols across the polar regions during the winter and spring periods and to relate these observations to chemical and dynamical processes that can contribute to the chemical perturbation of the polar stratosphere and the possible destruction of O_3. The distribution and characteristics of stratospheric aerosols and polar stratospheric clouds (PSCs) are required to understand heterogeneous chemical processes that can lead to O_3 depletion, and observations of O_3 variations are important in the direct detection of O_3 depletion and in tracing atmospheric dynamics. An airborne Differential Absorption Lidar (DIAL) system is operated in a zenith mode from the NASA DC-8 aircraft to obtain data on the large-scale spatial variability of O_3 and aerosols/PSC's in the lower stratosphere from about 11-23 km for O_3 and 11-28 km for aerosols. The variability of O_3 and aerosols/PSCs is studied in relation to chemical processes that can produce O_3 depletion and to dynamics in the lower stratosphere that transport gases and aerosols inside the vortex and in some cases, across the edge of the vortex.

Progress and Results:

The airborne DIAL system successfully measured O_3 and aerosol/PSCs distributions in the lower stratosphere during the development of the O_3 hole over Antarctica as part of the 1987 Airborne Antarctic Ozone Experiment (AAOE) and during the 1989 Airborne Arctic Stratospheric Experiment (AASE). The DIAL system was configured to transmit simultaneously four laser wavelengths (301, 311, 600, and 1064 nm) for DIAL measurements of O_3 and for multiple wavelength aerosol backscatter measurements. During the AAOE a total of 13 long-range flights on the NASA DC-8 aircraft were conducted between August 28 to September 29, 1987. Large-scale cross sections of O_3 distributions were obtained with the airborne DIAL system during the formation of the O_3 hole in the polar vortex over Antarctica. DIAL measurements showed that the primary region of O_3 depletion was between 15-22 km inside the polar vortex. Over the period of the AAOE, the average O_3 concentration at high latitude (>75°S) decreased by more than 50 percent. Polar stratospheric clouds were detected in thin layers up to an altitude of ≈21 km in regions of low temperatures (typically $\leq$195 K). Many of the PSC's were found to be very large in vertical and horizontal extent. Some of the larger PSC's extended over 5 km in altitude with considerable vertical structure. The horizontal extent of the larger PSC's was greater than 10 degrees in latitude (>1000 km). The PSC's are associated with the heterogeneous chemistry that converts nonreactive chlorine gases into reactive forms that can catalytically destroy O_3. The data provided by the airborne DIAL system during the AAOE have been used in numerous collaborative studies of the chemistry and dynamics of the O_3 hole, and they are reported in the special AAOE issue of the Journal of Geophysical Research.

The Airborne Arctic Stratospheric Experiment was conducted from Stavanger, Norway, between January 2 to February 15, 1989, to investigate the conditions leading to possible O_3 destruction in the wintertime Arctic stratosphere. The airborne DIAL system was operated from the DC-8 in long-range flights over the Arctic. In addition to the O_3 and multiple-wavelength aerosol backscatter measurements made during the AAOE, simultaneous aerosol depolarization measurements were made at 622 and 1064 nm. Large-scale distributions of O_3 and PSC's were measured with the DIAL system on 18 flights into the polar vortex. The O_3 distribution clearly indicated the edge of the polar vortex, and it was also an effective tracer for dynamical processes. The primary O_3 layer inside the vortex extended from 14-23 km with a peak at about 18 km. PSCs were observed on almost all missions between January 6-February 3 in regions of low temperatures (188-195 K) between 15-26 km. Two types of PSCs thought to be nitric acid trihydrate were observed. Water ice PSCs were observed in limited regions having even lower temperatures (<188 K). There was no coincident correlation between the presence of PSCs and variations in the O_3 concentration. Ozone data obtained on the last two AASE flights indicated large regions of reduced O_3 concentrations which were spatially correlated with the chemically perturbed region inside the vortex. Investigations are still in progress to determine if this O_3 decrease was due to chemistry or a large-scale warming of this region of the vortex. The chemical perturbation of the Arctic stratosphere was found to be very similar to the conditions found during the 1987 AAOE. Airborne DIAL O_3 and aerosol/PSC data are being used in many ongoing investigations related to the dynamics of the polar vortex, characteristics of the PSCs, and the development of the chemically perturbed conditions during the Arctic winter.

Journal Publications:

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Kinne, S., O. B. Toon, G. C. Toon, C. B. Farmer, E. V. Browell, and M. P. McCormick, Infrared measurements of the size and composition of particles in polar stratospheric clouds with the JPL MARK-IV interferometer, In press, J. Geophys. Res., 94, Aug, 1989

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