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MEASUREMENTS OF STRATOSPHERIC AEROSOLS WITH A COMBINED RAYLEIGH/RAMAN DIAL LIDAR

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ABSTRACT

Improvements made to the NASA/Goddard Space Flight Center DIAL Ozone lidar system have extended its atmospheric aerosol measuring capabilities. Since the addition of two Raman scattering channels, aerosol scattering ratio (ASR), aerosol backscatter as well as aerosol extinction can now be measured. This paper reports results obtained during several intercomparison campaigns at world-wide locations. The results track the evolution of the Mt. Pinatubo aerosol cloud from 1991 to 1994.

INTRODUCTION

Since the eruption of the Philippine volcano, Mt. Pinatubo, in June 1991, large concentrations of sulfate aerosols have been present in the earth's stratosphere. Because of the problems associated with making accurate lidar measurements of other atmospheric constituents in the presence of high aerosol loadings, modifications were made to NASA's Stratospheric Ozone Lidar Trailer Experiment, enabling ozone to be measured in the presence of large aerosol loadings (McGee et al, 1993). As a result, the system is now also capable of making improved measurements of both aerosol backscatter and aerosol extinction at 308 and 351nm.

Before February 1992, the GSFC lidar operated strictly as a Rayleigh DIAL system, the chief measurable quantity being ozone. Data was collected at the on-line ozone wavelength, 308nm, and at the reference wavelength near 350 nm. Since that time, the system has been modified so that it now also collects data from the inelastic Raman scattering returns off molecular Nitrogen at 332 and 382nm. The present system is capable of simultaneously collecting data at 308, 332, 351 and 382nm in the 10 to 45 km altitude range, the region of the atmosphere most effected by the Mt. Pinatubo eruption.

RESULTS

The NASA/GSFC lidar system first observed the Pinatubo cloud in September 1991 while operating at NASA/GSFC in Greenbelt, Maryland (38.9N,-76.7E). From September 1991 to January 1992, the GSFC lidar system acquired data at GSFC when conditions permitted. Figure 1 shows monthly average profiles of ASR at 353nm for that time period. Since the system was only acquiring Rayleigh data at that time, the profiles in figure 1 were computed using the Klett inversion technique. The assumed lidar ratio was taken as 20, a best estimate from recently published results

Figure 1: ASR at 351nm from the GSFC Lidar
Data acquired at NASA/GSFC, 9/91-1/92

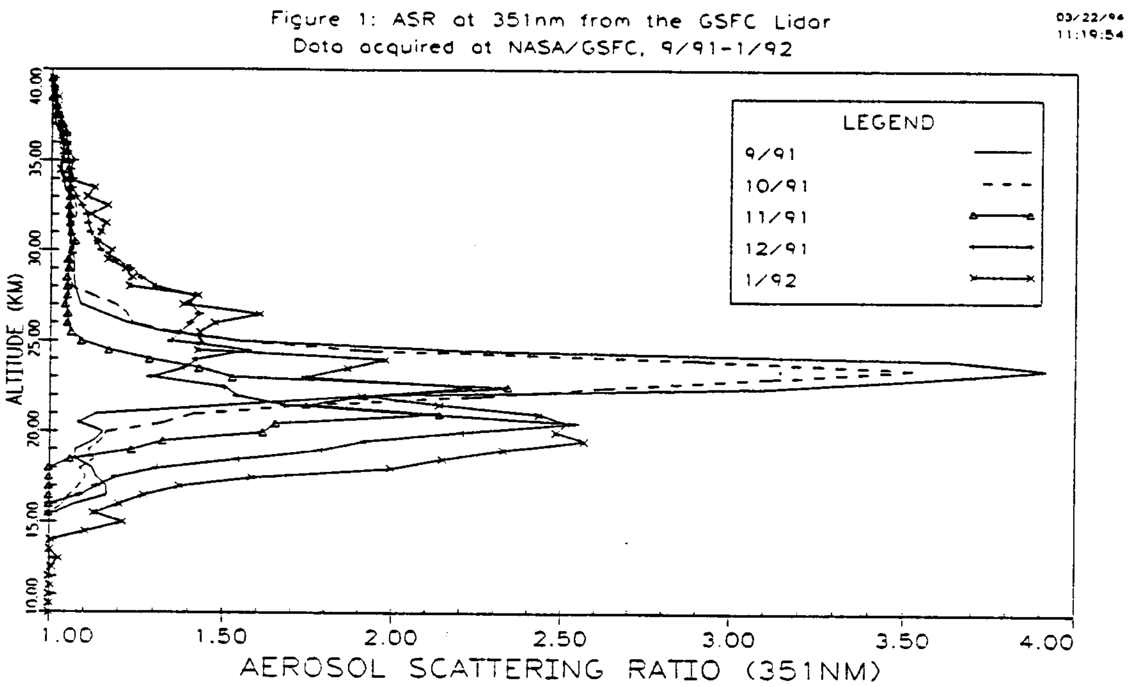
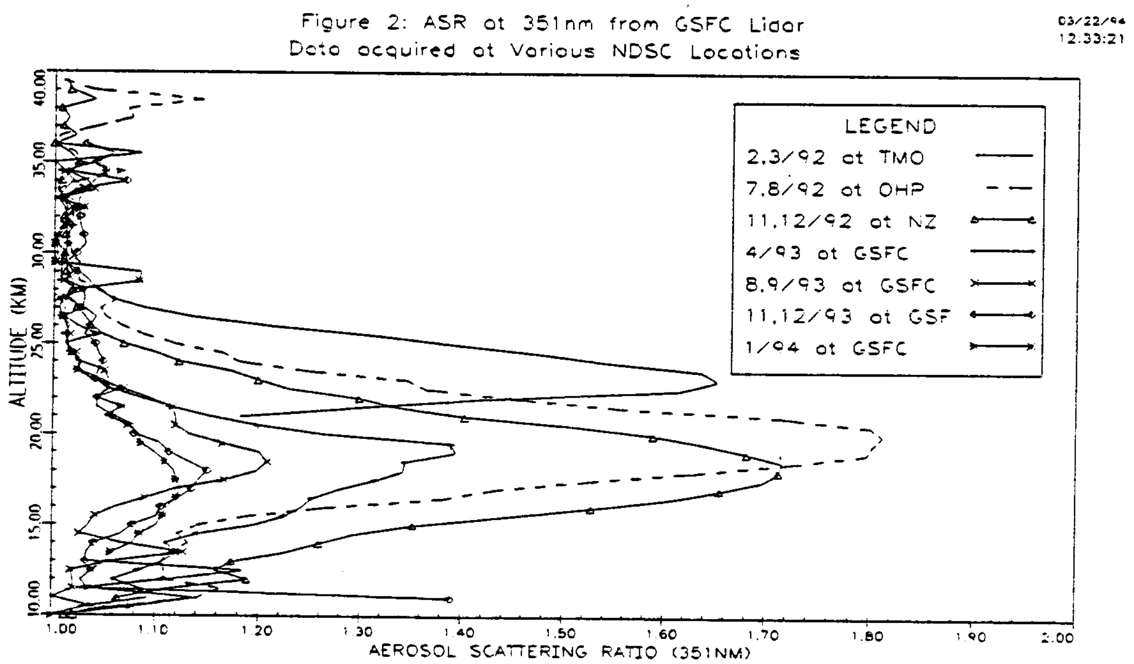


Figure 2: ASR at 351nm from GSFC Lidar
Data acquired at Various NDSC Locations



(Ansmann et al, 1992, Ferrare et al, 1992). The aerosol peak can be seen to decrease in magnitude and fall in altitude over time showing the gradual fall-out of the larger aerosol particles.

During February and March 1992, the instrument was deployed to JPL's Table Mountain Observatory in Wrightwood, California (34.4N,-117.7E) as part of an Upper Atmosphere Research Satellite (UARS) and Network for the Detection of Stratospheric Change (NDSC) intercomparison and validation campaign. Figure 2 shows the average ASR profile at 351nm for the entire Feb./March 1992 campaign. The ASR peak has continued to fall in both magnitude and with altitude, again showing continued fall-out of the larger, volcanic, aerosol particles. The ASR curves shown in figure 2 were computed using a combined Rayleigh/Raman Lidar technique. If the concentration of aerosols can be assumed to be negligible at altitudes above 35km, then the ratio of 351nm (Rayleigh) to 382nm (Raman) signal will give ASR directly. The significant advantage of this technique is that no relationship between aerosol extinction and backscatter need be assumed, which is not the case in the more common inversion methods of analysis.

Later in 1992 the Goddard system was again deployed, this time to Southern France (43.9N,5.7E) at the Observatoire de Haute Provence (OHP) to again participate in a UARS/NDSC intercomparison and validation exercise. The results are also included in figure 2 showing an average profile of ASR at 351nm for July and August 1992.

From France the lidar trailer was immediately transported to yet another UARS/NDSC intercomparison site in Lauder, New Zealand (45.0S,169.7E). An average profile of ASR at 351nm for this time, computed using the Rayleigh/Raman lidar technique, is also shown in figure 2.

During 1993 through February 1994, the system acquired data at NASA/GSFC when conditions permitted. Some monthly average profiles of ASR at 351nm are also shown in figure 2.

Other aerosol quantities can also now be measured by the GSFC lidar. The sum of aerosol extinction, 351 plus 382nm, can be solved for directly from the 382nm signal return. If an aerosol wavelength dependence is assumed, data at 351nm alone can be computed. If molecular backscatter or rather atmospheric density is known, aerosol backscatter can be easily computed from ASR data. With measured profiles of aerosol extinction and backscatter, an altitude dependent profile of the lidar ratio can also be extracted. All these developments assume that no other constituents contribute, which is not the case when considering the 308,322nm pair as ozone becomes important. Since the NASA/GSFC system measures ozone, aerosol information at 308nm can be extracted, however the uncertainty is inherently larger due to the added error introduced by ozone extinction.

CONCLUSION

Data which utilizes the dual Rayleigh/Raman capability of the GSFC lidar system has been presented. Results obtained from 1991 to 1994 are reported, characterizing aerosol concentrations at several global-wide sites and tracking the fall out of the Pinatubo aerosol cloud.

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