N95- 11016

ARCTIC POLAR STRATOSPHERIC CLOUD MEASUREMENTS BY MEANS OF A FOUR WAVELENGTH DEPOLARIZATION LIDAR

L.Stefanutti*, F. Castagnoli*, M. Del Guasta*, C. Flesia', S. Godin", J.Kolenda+, H. Kneipp+, E. Kyro°, R. Matthey', M. Morandi*, P. Rairoux+, V. M. Sacco*, B. Stein+, V. Venturi*, D. Weidauer+, J. P. Wolf+, L. Woeste+, L. Zuccagnoli*

* Istituto di Ricerca sulle Onde Elettromagnetiche del CNR via Panciatichi 64, 50127 Firenze, Italy
+ Freie Universitaet Berlin,Institut f?r Experimentalphysik Arnimallee 14, 1000 Berlin 33, Germany
' Observatoire Cantonal de Neuchatel,Neuchatel,Switzerland
" Service d'Aeronomie du CNRS, Universite P. et M. Curie, Jussieu, Paris, France
° Finnish Meteorological Institute, Sodankyla, Finland

Abstract

A four wavelength depolarization backscattering lidar has been operated during the European Arctic Stratospheric Ozone Experiment (EASOE) in Sodankyl?, in the Finnish Arctic. The lidar performed measurements during the months of December 1991, January, February and March 1992. The Finnish Meteorological Institute during the same period launched regularly three Radiosondes per day, and three Ozone sondes per week. Both Mt. Pinatubo aerosols and Polar Stratospheric Clouds were measured. The use of four wavelengths, respectively at 355 nm, 532 nm, 750 nm and 850 nm permits an inversion of the lidar data to determine aerosol particle size. The depolarization technique permits the identification of Polar Stratospheric Clouds. Frequent correlation between Ozone minima and peaks in the Mt. Pinatubo aerosol maxima were detected. Measurements were carried out both within and outside the Polar Vortex.

1) Introduction

A lidar with a Nd:YAG and a Ti:Sapphire laser was installed at the Finnish Meteorological Institute [1]. The output energies for pulse and wavelengths are:

100 mJ	@	355 nm	@	10Hz
350 mJ	@	532 nm	@	10HZ
250 mJ	@	750 nm	@	4Hz
250 mJ	@	850 nm	@	4Hz

The lidar system started operation during the early days of December 1991. A stop in the campaign was decided between December 20 and January 6, 1992. During this period of inactivity, due to the very low temperatures reached, a severe damage occurred to both lasers due to the freezing of the cooling systems. This accident caused additional 5 days of stop for the Nd:YAG laser and 15 for the Ti:Sapphire laser. Since January 20, 1992 both lasers were again operational until March 15, when the experiment was ended. During this period of operation over one thousand of stratospheric profiles was recorded. On the average, about 20 days of measurements per month were possible. During one day (December 11) simultaneous measurements with the lidar LEANDRE on board of the Fokker 27 ARAT were performed when a PSC event occurred.

The adopted measurement procedure has been the following: measurements at the all 4 lidar wavelengths were performed, the measurement cycle started with the Nd:YAG and ended with the Ti:Sapphire laser. For each measurement, averaging was performed over 2000 laser shots. The measurement sequence started with the 532 nm radiation, followed by the 355 nm, 750 nm and finally the 850 nm pulses. Measurements were carried out during daytime and nighttime.

2) Experimental results

By plotting the scattering ratio of the lidar signature versus height together with the ozonesonde profiles, we observed often, as shown in Fig. 1, a strong anticorrelation between the peak of Mt. Pinatubo aerosol and the Ozone vertical distribution (March 2, 1992). This type of anticorrelation may be due either to depletion events on the Mt. Pinatubo particles, or to dynamical effects.

In order to understand in which way Pinatubo aerosol causes a depletion of the Ozone layer, an analysis of the history of the various layers must be performed. The compution of the horizontal advection is performed for each lidar profile, which together with trajectories analysis and potential vorticity helps to search a correlation between ozone concentration and air mass origin at different heights. From the analysis of the history of air parcels at 350K, 380K, 400K, 440K, 450K, 475K, 550K and 700K (case of March 2, 1992) it was observed that the layers above 440K isentropic surface, have been circulating inside the vortex or at the vortex edge (Fig.2).

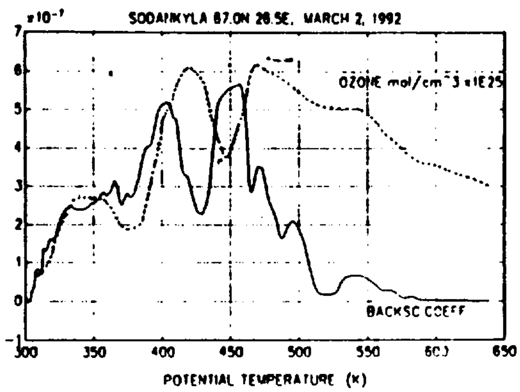
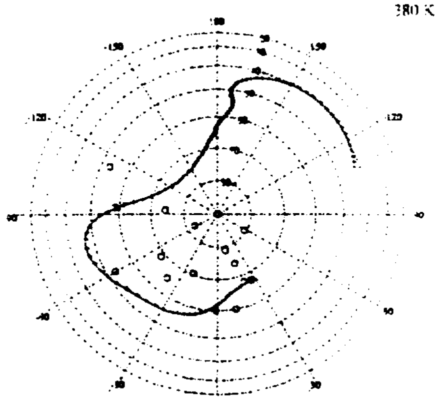
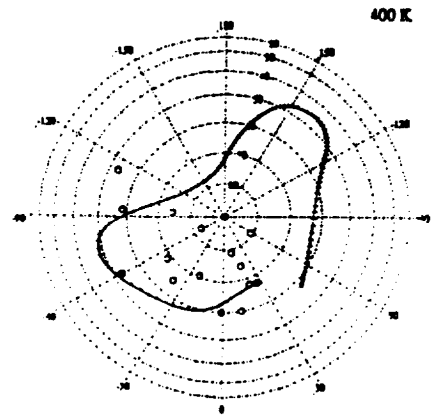


Fig. 1 Comparison between ozone number density (as obtained from Ozonesonde) and Lidar backscattering profiles , plotted versus potential temperature for March 2, 1992.

The lower trajectories, on the other hand cover a much wider latitude belt extending to the Japanese sea and outer Mongolia, i.e. well outside the vortex. Therefore it is understandable that the layering is much stronger below the 440K than above because extra vortex air is being advected there. It is possible that the layer at 18 Km (450K) coming from the edge and from inside the vortex has affected the ozone itself. It should be noted that Sodankyla station was often outside the Polar Vortex, and air masses from the mid latitude were frequent. This type of analysis will constitute part of the future work.





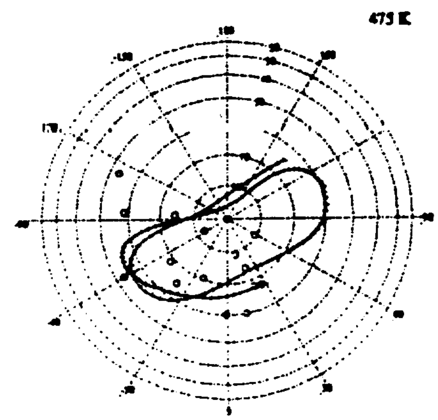


Fig. 2 : Trajectories of air parcels at different potential temperatures with final point at Sodankyla (30^{o} E) have been plotted for the case of March 2, 1992: below the 440-450 K level, airmasses origin at midlatitudes.

Fig. 3 shows, as an example, a set of measurements carried out on February 6, 1992 using the 532 nm laser radiation. The scattering ratio and the depolarization ratio versus height are plotted. One may notice that the depolarization ratio ($P_{per}/(P_{per}+P_{par})$), is very small up to 15 Km altitude, where it reaches a minimum up to the end of the Mt. Pinatubo layer. Two regions may be distinguished: a first one, up to approximately 14-16 km, with a relatively higher depolarization ratio (2%) and a second layer, from 14-16 km to the upper end of the Mt. Pinatubo layer with a depolarization ratio of the order of 1% (smaller than the depolarization expected from Rayleigh scattering).

From the results of B.P. Luo, Th. Peter and P.J. Crutzen [1] such a change in the depolarization ratio seems to be consistent with the hypothesis of the presence of Sulfuric Acid Tetrahydrate (SAT) in the lower Mt. Pinatubo layer. The change in the depolarization ratio could indicate the presence of SAT crystals in the lower stratosphere and of liquid sulfuric acid at the upper altitudes. There is a small enhancement of the depolarization ratio in the 20-23 Km region, that could be either due to noise or due to the presence of the Polar Stratospheric Cloud. Formation of cirrus clouds at the base of the Pinatubo layer was frequently observed (g.e.Fig.4).

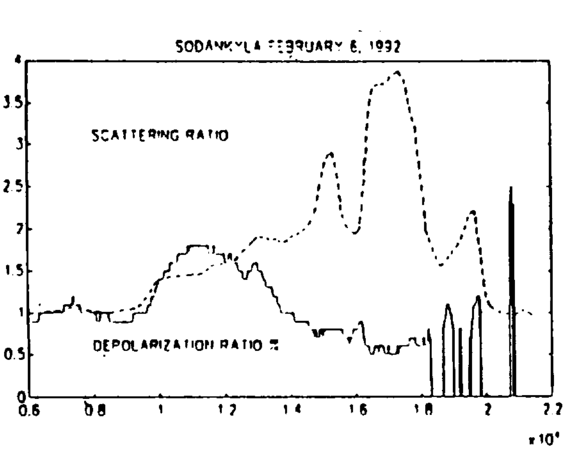


Fig. 3 Backscattering ratio and depolarization ratio versus height as obtained by lidar are shown. X axis is heigth in meters, depolarization scale is in %, backscattering scale is arbitrary. The measurement was performed at 532 nm on February 6, 1992.

Fig. 4 shows an example of two plots of the backscattering ratio versus height, plotted for the 532 nm and the 750 nm wavelength. Note that the scattering ratio at 750 nm is about twice the one at 532 nm.

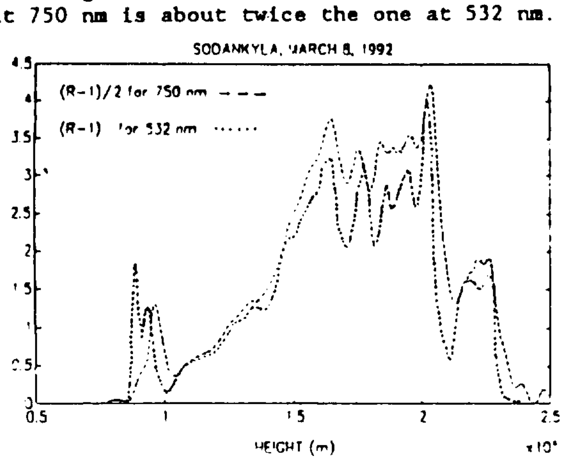


Fig. 4 The ratios $\beta_{Mie}/\beta_{Rayleigh}$ for two wavelengths are plotted on the same graph. This is the case of March 8, 1992.(Scaling of plots increases readability).

Depending on their heights, the aerosol layers show different wavelength behaviours (Fig 5). Most of the measurements in the main Mt. Pinatubo layer below 20 km show a larger increase in backscatter cross section from green to uv than in higher layers. These higher layers could include mountain wave induced polar stratospheric clouds. It may be noticed that the measurements carried out around 17 Km in the Pinatubo layer with different wavelengths clearly follow the same pattern, consistent with scattering by spherical particles of uniform size distribution. The measurements carried out at 21 Km show a different behavior and could be interpreted as Polar Stratospheric Clouds.

Mie scattering programs have been run, assuming the presence of spherical particles with refractive index corresponding to a 75% solution of sulfuric acid. These programs can vary automatically standard deviation and median particle radius of a log normal size distribution in order to obtain a correspondence with the experimental values.

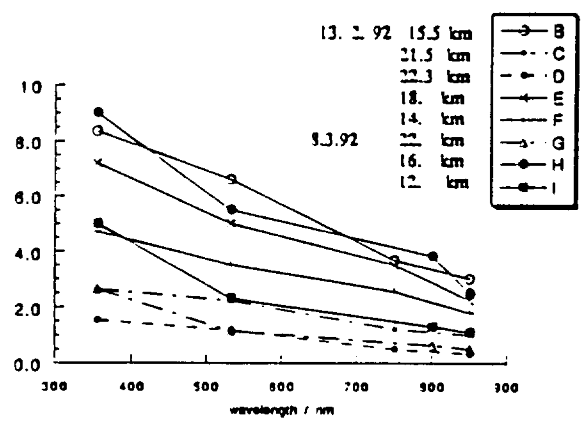


Fig.5: wavelength dependency of backscattering coefficient as measured by means of lidar in different layers, showing size distribution changes. Measurements carried out on March 8, 1992 and February 13, 1992 have been plotted. B units are 10^{-9} cm^{-1} sr^{-1}.

Fig. 6, obtained by plotting on a three-dimensional graph the backscattering coefficient versus wavelength and median particle radius rm, for a log normal distribution of particles with standard deviation of 20-30% r, allows to derive a first approximation to mean particle radius. Particles between 0.2 and 0.5 Îm of mean radius were detected this way in the typical Mt. Pinatubo aerosol layer.

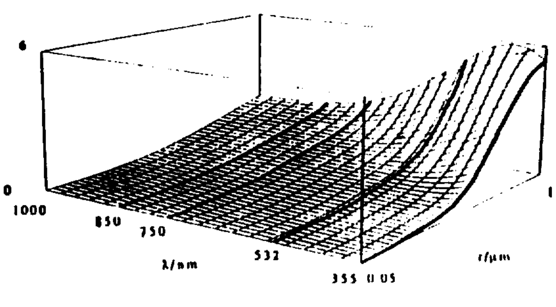


Fig. 6 The backscattering coefficient as a function of wavelength and particle mean radius, for spherical particles with n-1.4+0i and standard deviation of 20% of the mean radius, is plotted. From pictures like this and from experimental backscattering coefficients, the aerosol particle size can be evaluated.

For the upper 20-24 km layers often no fit could be obtained using refractive indexes up to n-1.4+0i, being necessary to use a higher refractive index, more typical of NAT particles (n-1.5+0i). In this case the result gave in this case particles of mean radii of the order of 0.18 Îm.

The evaluated mean radius, standard deviation and concentration of the stratospheric aerosols for the case of February 13, 1992 are shown in Fig.7.

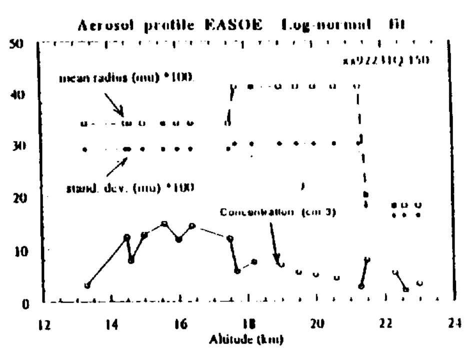


Fig. 7 Mean particle radius, width of log-normal distribution and concentration of the stratospheric aerosols versus height for March 13, 1992.

3) Conclusions

A preliminary analysis of the data obtained using the 4 wavelength depolarization lidar during the EASOE campaign in Sodankylä is carried out. Frequent anticorrelation between aerosol maxima layers and ozone minima were observed. Cirrus clouds have been regularly forming at the lower edge of the Mt. Pinatubo aerosol layer.

A first evaluation of particle size of the volcanic aerosol was possible by means of the 4 wavelength data. Polar Stratospheric Clouds were observed only a few times. Often the observation of PSCs covered only a very short time interval: changes in the depolarization ratio have been observed often only for few minutes. Unfortunately the system was not operating during the coldest period of the campaign, between Christmas time and New Year, when PSC II formation conditions existed in the Stratosphere. During our observations only small scale NAT clouds have been detected. This can be deduced by the backscattering and depolarization ratio obtained, which indicates for PSCs, at 532 nm, typical values characteristic for Type Ib clouds [3,4] (relatively low scattering ratios and depolarization ratios of the order of several percent). Finally the systematic change in depolarization ratio inside the Mt. Pinatubo layer could be interpreted as due to the presence of SAT particles in the lower layers, below 16 km.

4) Acknowledgements

This program was supported by the Italian Special Program on Electro-optical Technologies (TEO) and by the Commission of the European Communities.

5) Bibliography

[1] L. Stefanutti, F.Castagnoli, M.Del Guasta, M.Morandi, V.M. Sacco, V.Venturi, L.Zuccagnoli, J.Kolenda, H.Kneipp, P.Rairoux, B.Stein, D.Weidauer, J.P.Wolff : "A Four-Wavelength Depolarization Backscattering LIDAR for Polar Stratospheric Cloud Monitoring", Appl. Phys. B, B54 (1992) in press.

[2] B.P. Luo, Th. Peter, P.J. Crutzen: "Homogeneous Freezing of Sulforic Acid Droplets under Stratospheric Conditions", EASOE Workshop on Stratospheric Aerosols and PSCs, L'Aquila, Italy, 19-20 May, 1992.

[3] L. Stefanutti, M.Morandi, M. Del Guasta: "Polar Stratospheric Cloud Observations over the Antarctic Continent at Dumont d' Urville", J. Goephys. Res. 96(D7), 12,975-12,987, 1991.

[4] O.B. Toon et al.: "An analysis of lidar observations of polar stratospheric clouds", J. Geophys. Res. Lett., 17(4), 393, 1990.