A. Ansmann
R. Neuber
P. Rairoux
U. Wandinger (Eds.)

Advances in Atmospheric Remote Sensing with Lidar

Selected Papers
of the
18th International
Laser Radar Conference
(ILRC),
Berlin, 22–26 July 1996

Springer

Polar Stratospheric Cloud Measurements by Multispectral Lidar at Sodankylä in Winter 1994/95

C. Wedekind[1], F. Immler[1], B. Mielke[1], P. Rairoux[1], B.Stein[1], L. Wöste[1], M. Del Guasta[2], M. Morandi[2], L. Stefanutti[2], F. Masci[3], V. Rizi[3], R. Matthey[4], V. Mitev[4], M. Douard[5], J.P. Wolf[5], E. Kyrö[6]

1. Freie Universität Berlin, Arnimallee 14 D-14195 Berlin
2. IROE/CNR, Via Panciatichi 64, I-50127 Firenze
3. Università l'Aquila, Via Vetoio, I-67010 Coppito L'Aquila
4. Observatoire Cantonal Neuchâtel, Rue de l'Observatoire, CH-2000 Neuchâtel
5. Université Lyon I, 43 Boulevard du 11 Novembre 1918, F-69622 Villeurbanne
6. FMI Sodankylä Observatory, FIN-99600 Sodankylä

Abstract. Lidar measurements at 4 wavelengths and two polarizations were performed during the SESAME campaign in Sodankylä, Finland (67.37N, 26.65E). Using the wavelength dependence of the particle scattering the aerosol size distribution and the refractive index of the PSC particles were retrieved. A liquid PSC with a refractive index of 1.36 could be observed. We assume that this PSC consists of ternary solution particles in contradiction to the NAT-hypothesis.

1 Introduction

Polar stratospheric clouds (PSC) play a major role in the process of Arctic and Antarctic ozone depletion due to heterogeneous chemical reactions responsible for chlorine activation, and particle sedimentation redistributing nitrogen species in the stratosphere. Therefore the phase, size and the composition of PSCs should be known. PSC can be divided into PSC type I, observed at temperatures some degrees above the ice frostpoint, and PSC type II consisting of water ice particles occurring at temperatures below the frostpoint. PSC type I can be subdivided into aspherical (type Ia) and spherical (type Ib) particles. Measurements of gas phase HNO_3 removal in presence of PSCs and laboratory studies led to the assumption that PSC type I consist of nitric acid trihydrate and the particle shape depends on the cooling rate [1].
However the explanation of PSC I based solely on the NAT-hypothesis can not explain a large amount of data [2], and other compositions like liquid supercooled ternary solutions (STS) of H_2O, HNO_3 and H_2SO_4 are discussed now [3].
Multiwavelength, 2-polarization lidar measurements give information about the size distribution, refractive index and physical state of the cloud particles.

2 Experimental Setup

The aerosol lidar used here was designed to measure the particle backscatter in a wide range of wavelengths using a Nd:YAG laser at 355, 532 and 1064 nm together with a Ti:Sapphire laser at 750 nm and simultaneous detection of all wavelengths. Two additional detection channels acquired the cross polarized signals at 532 and 750 nm. The use of a 0.15 nm (FWHM) bandwidth filter at 532 nm, reduces the Rayleigh signal contribution in the cross polarized channel to only 0.36 % by suppressing the rotational Raman lines. This allows a very high sensitivity for nonspherical particles. From the retrieved Mie backscatter coefficients at the four wavelengths we determined the aerosol size distribution of the PSC particles and their refractive index using an algorithm based on Mie theory [4].

3 Observations

On Jan. 19, 1995 we observed a PSC with a scattering ratio up to 3.5 at 532 nm in an altitude range from 19.5 to 24 km (Fig. 1). The aerosol depolarization

$$\delta = (R_s - 1) / (R_p - 1) * \delta_{mol} \qquad (1)$$

was below our detection limit of 0.36 %. This proves the presence of spherical (liquid) particles. Here δ_{mol} denotes the depolarization of the Cabannes line of the molecular atmosphere with $\delta_{mol} = 0.365$ % [5], R_s and R_p are the scattering ratios at the perpendicular and parallel detection channel. We retrieved the size distribution and the refractive index of the particles assuming a monomodal lognormal size distribution.

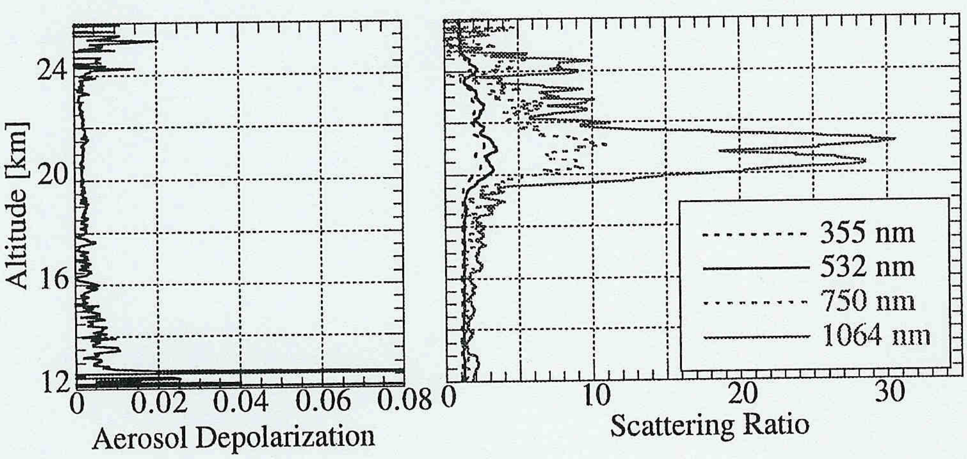

Fig 1: Aerosol depolarization and scattering ratios at 4 wavelengths for a PSC measured on Jan. 19, 1995.

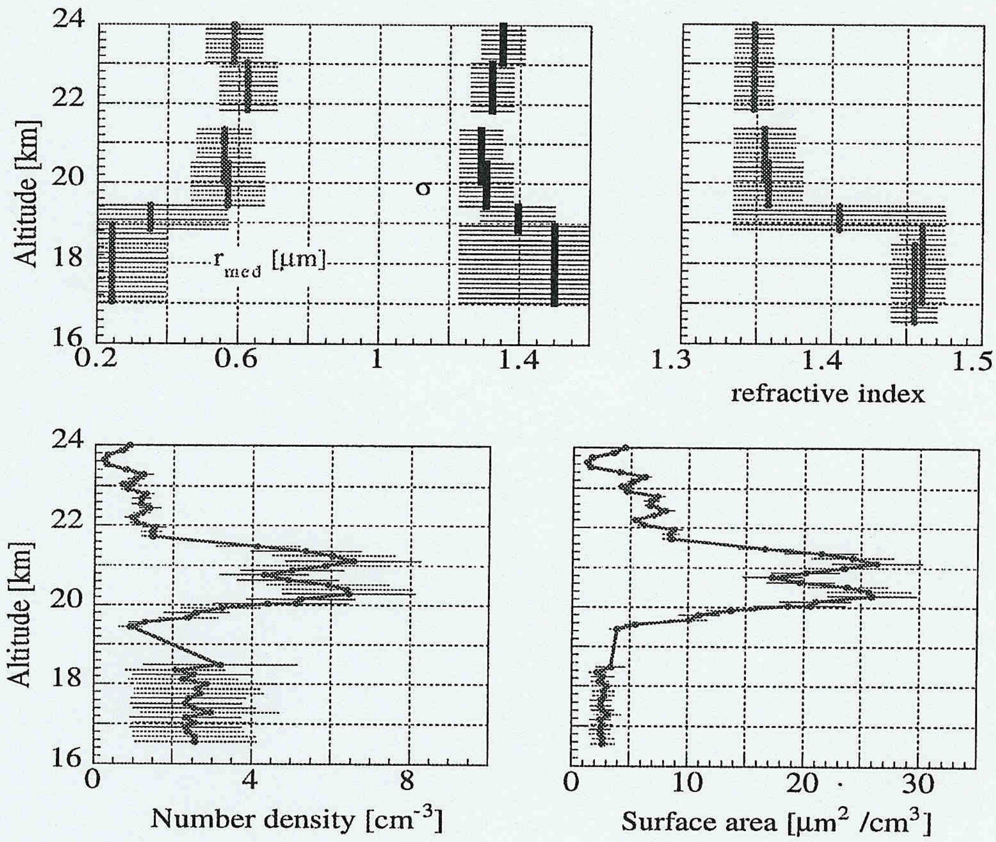

Fig 2: Parameters of the aerosol size distribution, r-median and width σ (upper left), refractive index (upper right), number density (lower left) and surface area density (lower right) for the PSC observed on Jan. 19, 1995.

Our algorithm scans size distributions with refractive indices from 1.33 to 1.53, median radii from 0.05 to 1 μm and σ from 1.2 to 1.9. Within the PSC, only particles with refractive indices between 1.33 and 1.38 yield backscatter coefficients that match the measured values within our experimental error limit of ± 10 %. Because the refractive index of water is 1.33, this result indicates a high water content of the particles as it would be expected for STS. The median radius of the particles was retrieved to (0.6±0.1) μm and the width of the size distribution was σ = 1.35±0.04. Although the real size distribution might be multimodal the description by monomodal parameters is a good approximation since the smaller particle mode (typical r_{med} < 0.1 μm) yield only a small contribution to the optical signal [6]. The surface area density of the PSC was determined to approximatly 20 $\mu m^2 / cm^3$. Below the PSC we found refractive indices between 1.42 and 1.46, and a median radius of (0.25±0.15) μm. This result is typical for sulfuric acid background aerosol.

The local radio sounding (Fig. 3) shows that the temperature drops below the condensation temperature of NAT at 15 km altitude, but no PSC could be observed in the altitude range from 15 up to 19 km. At 19 km the temperature is below the temperature range where formation of supercooled ternary solution particles (STS) is very efficient. This is assumed 3-4 K below T_{NAT}. The existence temperatures used here were calculated using an arctic LIMS profile for the nitric acid content and a water vapor mixing ratio of 5 ppm.

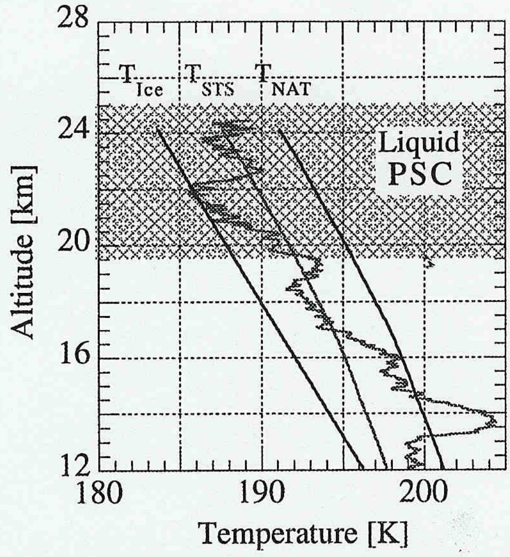

Fig 3: Local temperatures for Sodankylä at 19/01/95 and existence temperatures for NAT, STS and ice

4 Conclusion

The PSC observation presented in this paper can not be explained with the assumption of NAT particles. The altitude range of the liquid PSC corresponds much better with the height, where the temperature is below the formation temperature for liquid ternary solutions. The refractive index shows a high water content of the observed PSC as expected for STS particles.

Acknowledgements

This work was supported by the European communities DG XII under contract No. EV5V-CT-0355

References

1. Toon, O.B., E.V. Browell, S.Kinne, J.Jordan: An Analysis of Lidar Observations of Polar Stratospheric Clouds. Geophys. Res. Lett. **17** (1990) 393 - 396
2. Toon, O.B., M.A. Tolbert: Spectroscopic Evidence against Nitric Acid Trihydrate in Polar Stratospheric Clouds. Nature **375** (1995) 218-221
3. Carslaw, K.S., B.P. Luo, S.L. Clegg, T. Peter, P. Brimblecombe and P.J. Crutzen: Stratospheric aerosol growth and HNO_3 uptake by liquid particles. Geophys. Res. Lett. (1994) **21**, 2479-2482
4. Stein, B.: M del Guasta, J. Kolenda, M.Morandi, P. Rairoux, L. Stefanutti, J.P.Wolf and L. Wöste, Stratospheric aerosol size distributions from multispectral lidar measurements at Sodankylä during EASOE. Geophys. Res. Lett. **21**, (1994) 1311-1314
5. Young, A.T.: Revised depolarization corrections for atmospheric extinction. Applied Optics **19** (1980) 3427 -3428
6. Rizi, V. et al.: A comparison of LIDAR observations of PSC at Sodankyla (Finland) during SESAME and box model results of particle evolution, submitted to Journal of Atm. Sci.