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OZONE, AEROSOLS AND POLAR STRATOSPHERIC CLOUDS MEASUREMENTS DURING THE EASOE CAMPAIGN

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ABSTRACT

Preliminary results are presented of observations obtained during the EASOE campaign, with an airborne backscatter lidar and a ground-based DIAL ozone lidar system. Although the main signature observed on the lidar signals was due to the Pinatubo cloud which erupted in June 1991, distinct PSC events were detected on several occasions by the airborne lidar often in relation with orographic wave activity over the norvegian mountains. The ozone profiles obtained in Sodankyla with the ground based lidar are locally perturbed by the presence of the volcanic cloud. After a first correction of the aerosols effect, they present however a reasonably good agreement with the ozone sondes profiles performed on the same site.

1. INTRODUCTION

The Elsa (Expériences Lidar dans la Stratosphere Arctique) experiment is a cooperative project intended to perform aerosol and ozone lidar measurements during the EASOE campaign (European Arctic Stratospheric Ozone experiment), which took place in the 1991-1992 winter in the northern arctic region. It includes several instruments located both in Kiruna (Sweden) and Sodankyla (Finland). The first instrument (Leandre) is an airborne dual wavelength (1064 and 532 nm), dual polarization lidar (Pelon et al., 1990), which allows the study of the three dimensional structure and the optical properties of polar stratospheric clouds, within a range of 500 km. Located in Kiruna, it was operated during the two intensive measurements periods, in early December 1991 and January-February 1992. The second lidar system is a ground-based multi-wavelength instrument meant to perform measurements of the ozone vertical distribution in the 5 to 40 km altitude range. For that purpose, two pairs of wavelengths are used : 289-299 nm for the measurements in the troposphere and 308-355 nm for the stratosphere. This instrument is part of the ELSA - Sodankyla project which also includes operation of a multiwavelength backscatter lidar, developed jointly by the IROE of Florence and the Freie Universitat of Berlin. The ozone lidar was operated from the end of November 1991 to the beginning of March 1992. Preliminary results obtained with these two instruments during the EASOE campaign are presented here with emphasis, in the case of the Leandre observations, on several situations where polar stratospheric clouds were present.

2. OBSERVATION OF THE PINATUBO VOLCANIC CLOUD

Right from the beginning of the lidar operation in the Arctic, the signature of the volcanic cloud of Mt. Pinatubo which erupted in June 1991 in the Philippines was clearly seen on the lidar signals. As compared to the lidar measurements made routinely at the Observatoire de Haute-Provence (44°N, 5°E), the aerosol layer is lower than at mid-latitude as is the value of the scattering ratio (see figures 1a and 1b which represent respectively the altitude of the maximum scattering ratio obtained at OHP, Sodankyla and with the Leandre instrument, and the value of this maximum, at 532 nm for the same instruments). As at mid-latitude, the volcanic cloud is generally multi-layered and presents a high day to day variability. Note that the values of the scattering ratio obtained at 355 nm with the ozone lidar located in Sodankyla were converted for the comparaison to values at

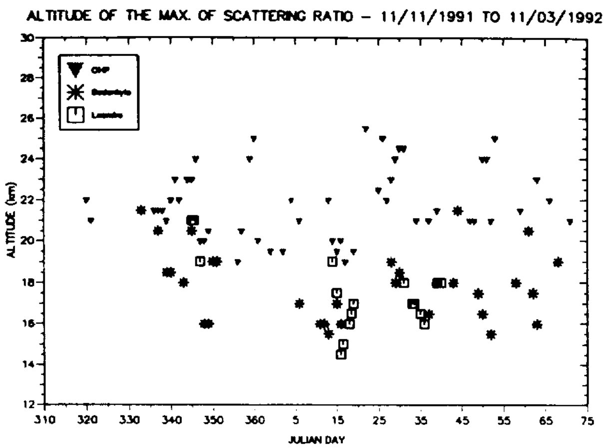

figure 1 : a. Evolution of the altitude of the maximum scattering ratio as observed at OHP, Sodankyla and with the Leandre lidar during the EASOE campaign

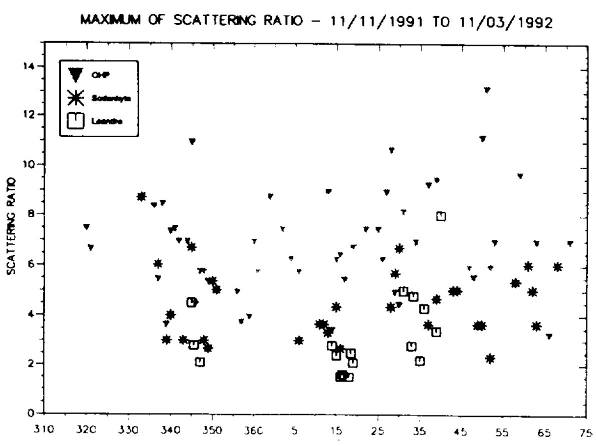

figure 1 : b. Evolution of the maximum scattering ratio as observed at OHP, Sodankyla and with the Leandre lidar during the EASOE campaign

532 nm with a conversion factor of 3, which corresponds to what is observed in average at OHP where both measurements at 532 nm and 355 nm are present.The uncertainty on this conversion factor is estimated to be on the order of ± 30 %. The average values observed at OHP are higher than in the Arctic (for both the measurements performed in Sodankyla and with the Leandre instrument) by approximately a factor of 2. Likewise, the average altitude of the aerosols layer is around 3 km higher at OHP than in the Arctic. The limited range of the airplane prevented lidar measurements of the Pinatubo cloud clearly outside and inside the vortex during the same flight. However, the observation of the aerosols layer with the airborne lidar, gave insight of its spatial heterogeneity with characteristic patterns on the order of a few kilometers. Moreover, the altitude of

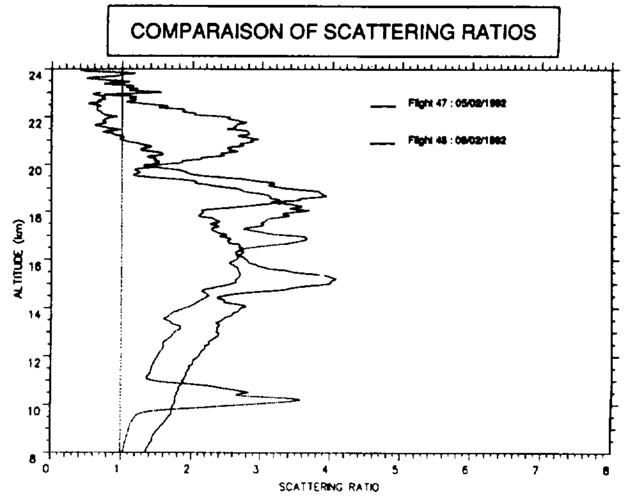

figure 2 : Comparaison of scattering ratios observed during flights with and without PSC conditions (on the 8th and the 5th of February 1992 respectively)

VOL	DATE	DIRECTION
28	10/12/1991	North : Kiruna - Hammerfest
29	11/12/1991	West : Kiruna - Narvik
30	11/12/1991	East : Kiruna - Sodankyla
31	12/12/1991	East : Kiruna - Sodankyla
32	13/12/1991	East : Kiruna - Sodankyla
33	14/01/1992	West : Kiruna - Narvik
34	15/01/1992	West : Kiruna - Narvik
35	16/01/1992	West : Kiruna - Narvik
36	16/01/1992	East : Kiruna - Sodankyla
37	18/01/1992	East : Kiruna - Sodankyla
38	18/01/1992	North : Kiruna - Hammerfest
39	19/01/1992	West : Kiruna - Narvik
40	22/01/1992	East : Kiruna - Sodankyla
42	31/01/1992	West : Kiruna - Narvik
43	01/02/1992	North : Kiruna - Hammerfest
44	02/02/1992	West : Kiruna - Narvik
45	02/02/1992	East : Kiruna - Sodankyla
46	04/02/1992	West : Kiruna - Narvik
47	05/02/1992	West : Kiruna - Narvik
48	08/02/1992	West : Kiruna - Narvik
49	09/02/1992	West : Kiruna - Narvik

table 1 : flights performed with Leandre

the aerosols layer is not constant from one flight to the other, reflecting the large scale vertical motions in the atmosphere associated with the evolution of the polar vortex on a day to day basis. Thus, a lowering of 3 km of the aerosols layer was

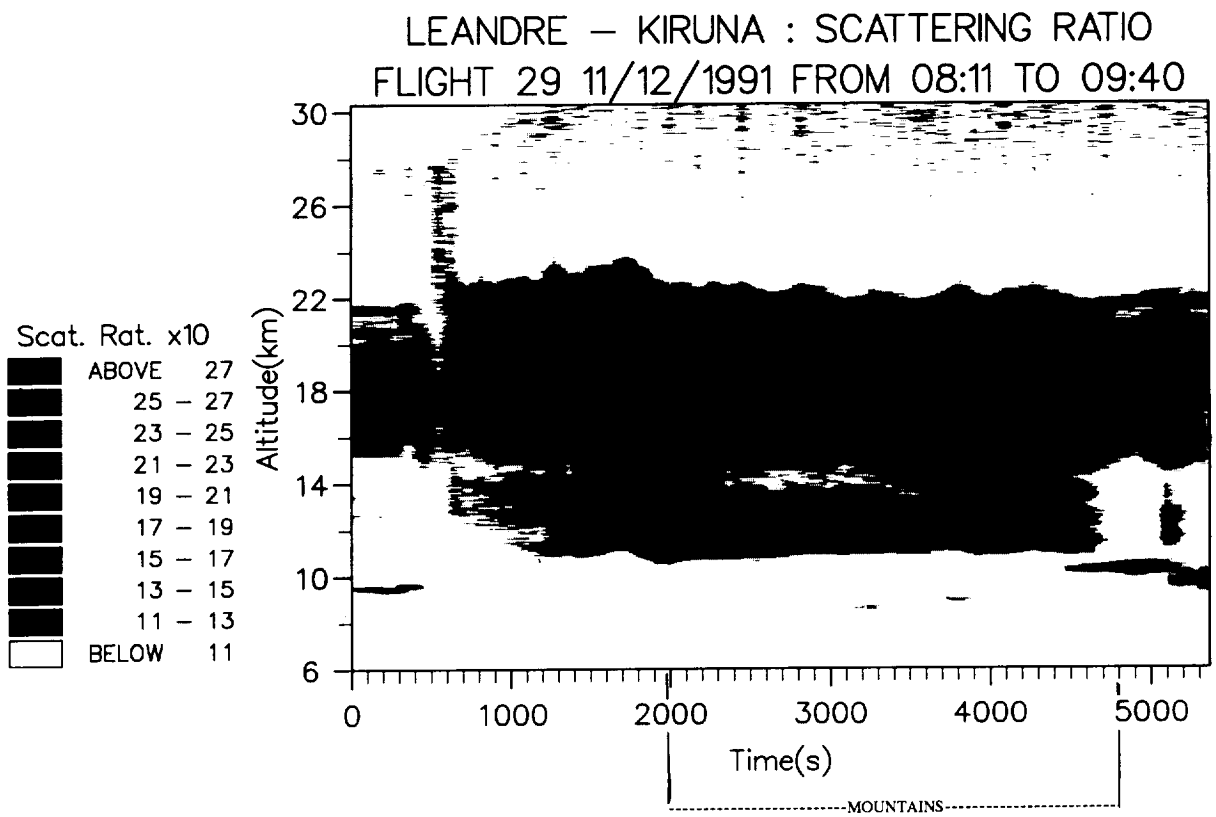

figure 3 : Evolution of the scattering ratio during the flight of December 11th 1991

observed between the 15th and the 16th of January, in a period when the polar vortex was close to Scandinavia.

3. PSC OBSERVATION WITH THE ELSA-LEANDRE EXPERIMENT

21 flights were performed with the Leandre instruments during the EASOE campaign (table 1). Although the Pinatubo cloud was present during each measurement, on several flights the aerosols observed by the lidar presented sharper structures and additional layers above the main cloud as represented in figure 2 which shows a comparison of scattering ratios obtained during two flights with and without PSC conditions (on the 8th and the 5th of February respectively). These features were generally characterized by an important short scale variability, as for the flight of December 11th, which was westward from Kiruna to Narvik and the North Sea. Starting from Kiruna, one could observe right upon the overflight of the mountains located close to the norvegian border, large scale oscillations in the scattering layer and the occurence of a more intense layer at 22km (figure 3). According to the European meteorological center analysis, the temperature was close to PSC conditions at 50 hPa and especially 30 hPa. Due to the presence of the

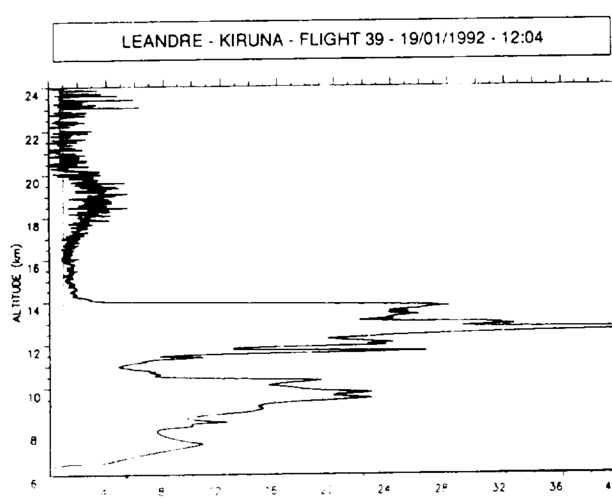

figure 4 : Vertical profile of the scattering ratio measured during the flight of January 19th 1992

mountain, one would expect the development of orographic waves inducing on the one hand patterns in the aerosols layers and on the other hand adiabatic cooling in the ascending motions which can lower the temperature below the critical point of formation of polar stratospheric clouds.

High values of the scattering ratio were also observed at lower altitudes, above the tropopause level as during the flight of January 19th (figure 4). They correspond to scattering ratio of up to 9 at 532 nm, well above the values (2 to 4) usually measured for the Pinatubo cloud in the Arctic regions. These clouds were located between 12 and 14 km, right above the tropopause which was around 10 km altitude, according to the radiosonde data from Sodankyla. Such layer, which presents a very high spatial and temporal variability corresponds probably to nacreous clouds as visually observed from the ground on several occasion during the same day.

4. OZONE LIDAR MEASUREMENTS IN SODANKYLA

Throughout the EASOE campaign, the stratospheric ozone lidar measurements were highly locally perturbed by the presence of the Pinatubo cloud. Indeed, with such an aerosol loading, it is no more possible to neglect the differential term related to the aerosol scattering as for pre-volcanic conditions. The contribution of aerosols in the differential lidar equation is controlled by the three following parameters :

- the spectral dependance of the aerosols extinction coefficient, usually modelized by the so-called angstroem coefficient (parameter m)
- the spectral dependance of the aerosols backscattering coefficient (parameter p)
- the backscatter to extinction ratio of the off-line wavelength (C)

Sensitivity studies show that the aerosol correction is mostly controlled by the value of the parameter p, while the value of the backscatter to extinction ratio is the least significant. Detailed studies using Mie calculations to infer the value of these different parameters from parallel measurement of aerosols size distribution [Jäger and Hofmann, 1991) are underway. Meanwhile, preliminary ozone profiles are obtained using values of 0 and 0.6 for the parameters m et p respectively. These values correspond approximately to a lognormal size distribution of mean radius 0.2 μm and standard deviation 0.16 μm, a typical size distribution of the Pinatubo aerosols measured during the arctic campaign (Larsen 1992). The ozone profiles show this way on average a rather good agreement with the ozonosonde measurements performed on the same site as seen on the 13th and 16th of January (figure 5). Such results are of course preliminary. The next step will be to take advantage of the multiwavelength backscatter measurements (355, 532, 750 and 850 nm) performed at the same location in order to infer for each day the vertical profile of the parameters used in the aerosols correction to retrieve, with an acceptable precision, the correct structures on the ozone profile.

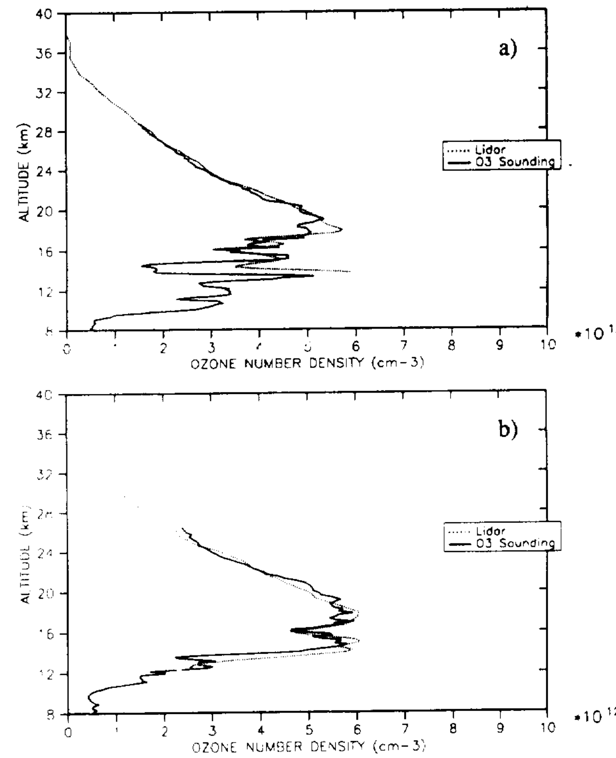

figure 5 : Comparaison of ozone profiles obtained by lidar and ozonosondes
a) lidar profile from the 01/12/92 (9:30 pm), ozonosonde from the 01/13/92 (12 pm)
b) lidar profile from the 01/16/92 (6 pm), ozonosonde from the 01/15/92 (12 pm)

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