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"Polar Stratospheric Clouds and Background Aerosols over Dumont D'Urville"

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POLAR STRATOSPHERIC CLOUDS AND BACKGROUND AEROSOLS OVER DUMONT D'URVILLE

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1-Summary

The IROE two channel elastic backscatter lidar [1], suitable for depolarization measurements, has been operating since January 8, 1989 at the French Antarctic base of Dumont d' Urville ($66^0 40$'S, $140^0 01$'E). A continuous monitoring of the stratosphere has been performed, which permitted to measure first the evolution of the background stratospheric aerosols and later, during the Antarctic winter, Polar Stratospheric Clouds. Radiosonde were launched daily. Depolarization measurements were performed, which permitted to have indications on the crystal sizes of the PSCs. Depolarization ratios of the order of 30 to 40 % were detected, indicating large size crystals, while the temperatures, when rediosonde were available, never exceeded 193^0K. Sedimentation processes of the PSC layers were observed. Sedimentation velocities of the order of up to 500 m/h, consistent with the hypothesis of large particles were observed.

2-The Polar Ozone Lidar Experiment (POLE)

The Pole experiment was organized under an italo-french cooperation program for Antarctic research, in the frame of the Italian National Program for Antarctic Research (PNRA) and the Territoires des Terres Australes et Antarctiques Francaises (TAAF) by IROE-CNR and SA-CNRS. The first step of such a program was the installation at Dumont d' Urville of the elastic backscattering lidar designed for both tropospheric cloud and stratosperic aerosols measurements. The system, operating at 0.53 u, with a linealy polarized laser pulse and a repetition rate of 4 Hz, collects the signal on the parallel and perpendicularely polarized plane relative to the output laser radiation. Thus the depolarization induced by non spherical particles, such as ice, may be measured. Analog detection is performed by means of a 12 bit, 5MHz transient digitizer. Groups of lidar data are automatically averaged. Typically during the Polar night averaging was performed over 500 shots while 2000 shots are necessary for measurements during the Antarctic day.

Stratospheric lidar profiles have been written in a suitable way on floppy disks, an Olivetti M 28 PC was connected by means of a telephonic modem, with maximum transmission rate of 1200 bauds, to the INMARSAT system of the Dumont d' Urville base and the data were transmitted by means of electronic mail link via INMARSAT to the BITNET knot of Singapore, and hence to IROE-CNR Firenze, Italy and from here, after proper conversion to Service d' Aeronomie-CNRS Paris, France.

The system started operating on January 8, 1989. During the Antarctic summer and up to the end of april two stratospheric profiles per week ware measured. Table 1 shows the measurements timetable for the 1989 POLE experiment; also the timing for the tropospheric cloud measurements are indicated. It results that the lidar has been operating for 18 hours per day over the whole year showing a great reliability of the system.

In order to show the sensibility of the instrument in Fig.1 the profile of the aerosol extinction versus height is plotted for the case of February 2, 1988, taken when the lidar was still at Terra Nova Bay. In such figure a comparison with the SAM II satellite data has been carried out. From the analysis of the figure it results that even during the summer, and before the formation of Polar Stratospheric Clouds, with relatively low aerosol loading (background aerosol), the lidar data and the SAM II data are in good agreement.

From the beginning of June the stratospheric lidar measurements have been performed daily, when the meteorological conditions were favorable. In some particular occasions, tipicaly once per week, when PSCs were present a long sequel of measurements was carried out, with an avrage profile every 10-15 minutes and measurements lasting up to 10 hours. This was done in order to follow the PSCs evolution and to monitor possible sedimentation processes. Polar Stratospheric Clouds were detected from June to the second part of September. Here we report a first analysis of the phenomena.

In order to separate the molecular from the aerosol component from the lidar signature the vertical temperature profiles up to at least 25 km is necessary. Most of the time these data were not available due to the launching technique of the radiosonde balloons, which caused in the cold antarctic atmosphere their explosion at altitudes between 13 and 17 kilometers. From September on a new technique was adopted which allowed to reach much higher altitudes. The stratospheric temperature up to mid July seemed to be still quite warm at 50 mBar, except for some few exceptional days. A substancial cooling of the stratosphere started at the end of July, and continued all throught the second part of September. Fig. 2 shows the temperature variation at 50 mBar as a function of time. Due to the lack of a complete temperature profiles data set for a first evaluation of the backscattering coefficient and the scattering ratio R it was necessary to make the following assumptions:

1) a summer Antarctic molecular backscattering profile obtained by averageing pressure profiles during the antarctic summer was used for a first data analysis up to the end of July.

2) from the SAM II data, obtained from M.P. McCormick, for the days 25,26,27 and 28 July 1989,(when the SAM II was measuring tangent to Dumont d' Urville) a winter atmosphere has been derived.

3) an extinction to backscatter ratio of the order of 20 has been adopted inside the PSCs, i.e. a value similar to those adopted for cirrus clouds. A first attempt to evaluate backscattering and extinction coefficient by means of the Klett [2] procedure was attempted, but the first results have not been sattisfactory.

In order to perform the calculation of the depolarization ratio a calibration of the two receiving channels and the evaluation of the system's depolarization was necessary. By exchanging the two detectors their relative gain was detrmined, and hence the system's depolarization was measured by carring out measurements during a perfect clear air day. The Depolarization ratio has been defined as the ratio between the perpendicular component of the Mie backscattered signal versus the sum of the parallel and the perpendicular component of the Mie backscattered signals.

3-Experimental results

The data presented here are only preliminary; not all lidar profiles taken during the winter and springtime campaign have been transmitted to Firenze, but only a small sample; therefore some of the following statements could be subject to modification when all the data will be availabe. The lidar profiles of the stratosphere over Dumont d' Urville did not show apparent presence of PSCs during the months of May and June 1989. This is consistent with the 50 mBar temperature, which would indicate that the station of Dumont d' Urville was up to the end of July outside the Polar Vortex. There is only one exception for the day of June 19, when the tropopause height was at 10779 m with a temperature of -77^{0}C. At that height there was a small cirrus type cloud, which could be interpreted as a PSC, extending between 11 and 12 Km with a depolarization of the order of 20-25 %. This value seems low for a cirrus cloud. On the same day SAOZ spectrometer of Pommareau and Goutail indicated a sharp variation in the vertical O_3 column. We therefore think that this might have been a PSC of type I (see Fig 1).

Polar Stratospheric Clouds were measured on the following days: July 27 and 28, August 2, 3, 18, 19, 28, 29 and 30, September 2, 9, 15, 16, 19 and 20. No PSCs were dected afterwards, and by the end of September the station was no more under the Vortex, as it appears from TOMS data of October 15 [3]. Again very low values of the vertical Ozone column were measured by SAOZ from October 18 to 22, but there was no clear indications of Polar Stratospheric Clouds.

During many days of July, August and September the sky was overcast not permitting stratospheric measurements. Abruptly very strong PSCs appeared during the days 27 and 28 July, extending between 15 and 23 km. The clouds seemd quite layered, see Fig. 2. Scattering ratios R of the order of 3 were measured. The depolarization ratio has been computed, and values between 35 and 40 % were detected. No radiosonde data were available for these days. In Table I we report the available temperatures reached at altitudes closest to the PSCs.

TABLE I

day	height	temperature (^{0}C)
06/19 (170)	10779	-77.5
07/11 (192)	16561	-76.8
07/16 (197)	17158	-78.0
07/17 (198)	18998	-80.1
07/18 (199)	14006	-74.4
08/18 (230)	22661	-80.0
08/20 (232)	15551	-72.7
08/28 (240)	15735	-70.1
08/30 (242)	10549	-81.1
09/15 (258)	15541	-76.7

From Table I it may be assumed that for the case of July 27 and 28 the most probable temperature, at the height of the PSCs could have been of the order of -80^{0}C. From the 3 dimensional plot of fig.3 sedimentation processes may be observed. By following the time evolution of one layer, one may deduce a sedimentation velocity of about 150 m/h, which, combined with the depolarization data (Fig. 4) could indicate particles sizes of several tens or hundred of microm. Such depolarization ratios in fact are of the same order of magnitude of those encontered in the case of cirrus clouds. This first conclusion might be in contraddiction with the hypothesis of a stratospheric temperature of -80^{0}C, which should correspond to the formation of PSCs of type I [4]. Dinamical processes might be responsible of transport of PSCs of type II from colder regions inside the polar vortex, or it may be assumed that under particular temperature conditions $HNO_3.3H_2O$ crystals, forming the PSCs of type I, may grow to large sizes. No evaluation of stratospheric circulation has jet been made.

Good examples of simultaneous presence of PSCs of Type I, II and cirrus clouds are shown in the measurements of August 3, 1989. Here we may note the presence of a cirrus cloud between 7 and 10.5 km, with a depolarization ratio of 35-40%, and two Stratospheric Clouds, respectively between 18 and 20.5 km and between 23 and 25 km (Fig.5,6,7,8 and 9). Fig. 5 and 6 shows the 3 dimensional presentation, with and without the lower cloud. From Fig. 5 the capability of the lidar to penetrate the cloud appears evident. From Fig. 8 the sedimentation process of the upper layer may be clearly seen. Fig. 7 shows the depolarization ratio for the 3 clouds and the backscattering coefficient. As the signal is normalized before the cirrus cloud, the values referred to the two PSCs are affected by large error. The stability of the depolarization ratio in the cirrus may be noticed and the indication of a much larger depolarization ratio for the high PSC compared to the lower one. Fig 8 and 9 show the depolarization ratio and the backscattering coefficient for the two PSCs. In this case the lidar profile was normalized after the cirrus cloud. The values here appear correct. The two figures refer to measurements carried out at different times. The lower layer presents a very low depolarization ratio, which is not measurable, indicating the presence of very small particles, while the upper layer presents a depolarization ratio between 10 and 20%. Further it is possible to identify a strong sedimentation process for the upper layer, of about 1 km in two hours. This also denotes the presence of very large particles. The cloud bottom of the lower layer instead tends to lift with time.

During the second part of august and in september PSCs appeared at lower altitudes, between 9 and 14 km. Very high scattering ratios have been reached as in the case of september 19 and 20, with values of the order of 4.5, and depolarization ratios of the order of 25%. In Fig. 10 one of such examples is shown. The lowering of the PSCs layer is consistent with the SAM II observations of the past years [5]. The clouds appeared to be much thicker than in the previous months and much more homogeneous. There was no clear evidence of PSCs after September 20.

Comparison between Lidar and SAOZ measurements

SAOZ is a visible spectrometer capable of measuring the vertical column of Ozone and NO_2. The system developed by Pommareau and Goutail has been operating at Dumont d' Urville since 1988. A description of the instrument and of the results are given in [6]. Fig. 10 shows the evolution of the total vertical Ozone column during the antarctic winter up to September 15. The vertical red lines indicate lidar measurements and presence of PSCs. It may be noticed that, during the Antarctic winter, before the return of the sun, there seems to be a correlation between the presence of Polar Stratospheric Clouds and sharp variations of the Ozone Vertical column. As not all the lidar data are available, it is still premature to drow any conclusions, but for the cases of June, late July and early August it may be suspected that in the formation of PSCs of type I during the Polar Night there might be conversion of NO_2 in NO_3 with destruction of Ozone and the formation of N_2O_5 and hence, by reaction with water to HNO_3 [7,8,9]. A different interpretation may be suggested: Stolarski proposed that the strong differences in the measurement of Ozone at low zenithal angles between TOMS and SAOZ could be due not only to the effect of scattering on the TOMS instrument, but also to such effect on the SAOZ instrument especially in the presence of PSCs in the lower stratosphere.

Conclusions

From this first winter campaign at Dumont d' Urville it results that lidar is a powerful and reliable tool to investigate the Antarctic stratosphere. The main limitations encountered were determined by the frequent presence of lower tropospheric clouds, which inhibited stratospheric measurements. The depolarization measurement seem extreemely interesting; a more detailed analysis of the relation between particle sizes and depolarization effect should be studied. To this end the work carried out by Flesia [10], for the inversion by means of a stochastic procedure of the lidar equation, should be of great interest. The aim of such a method, which should include the case of non spherical particles, is the determination of the particles mean size and concentration if two separate parameter are given, as for instance the two measurements in the two different polarizations.

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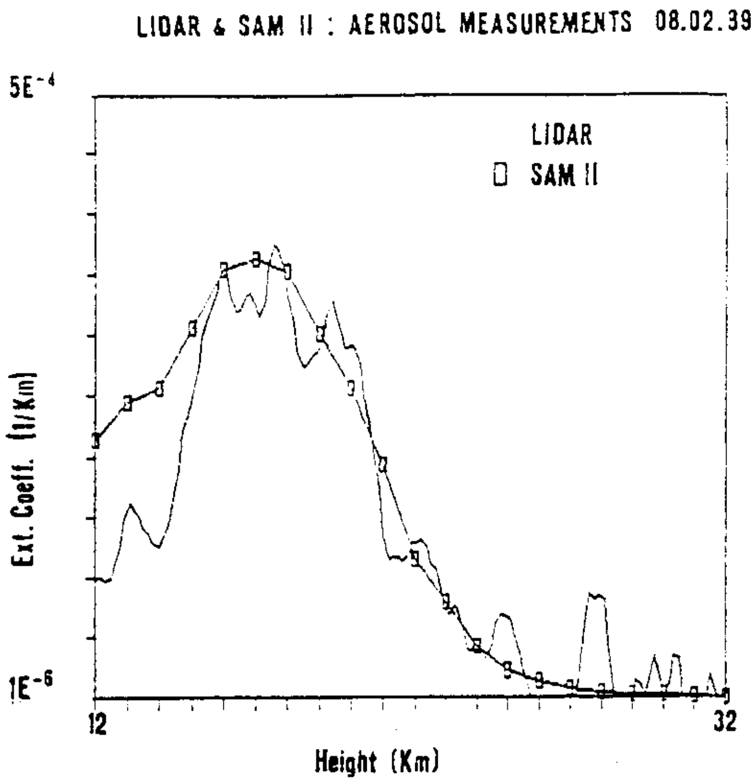

LIDAR & SAM II : AEROSOL MEASUREMENTS 08.02.39
5E-4
LIDAR
SAM II
Ext. Coeff. (1/Km)
1E-6
12
32
Height (Km)

Fig 1

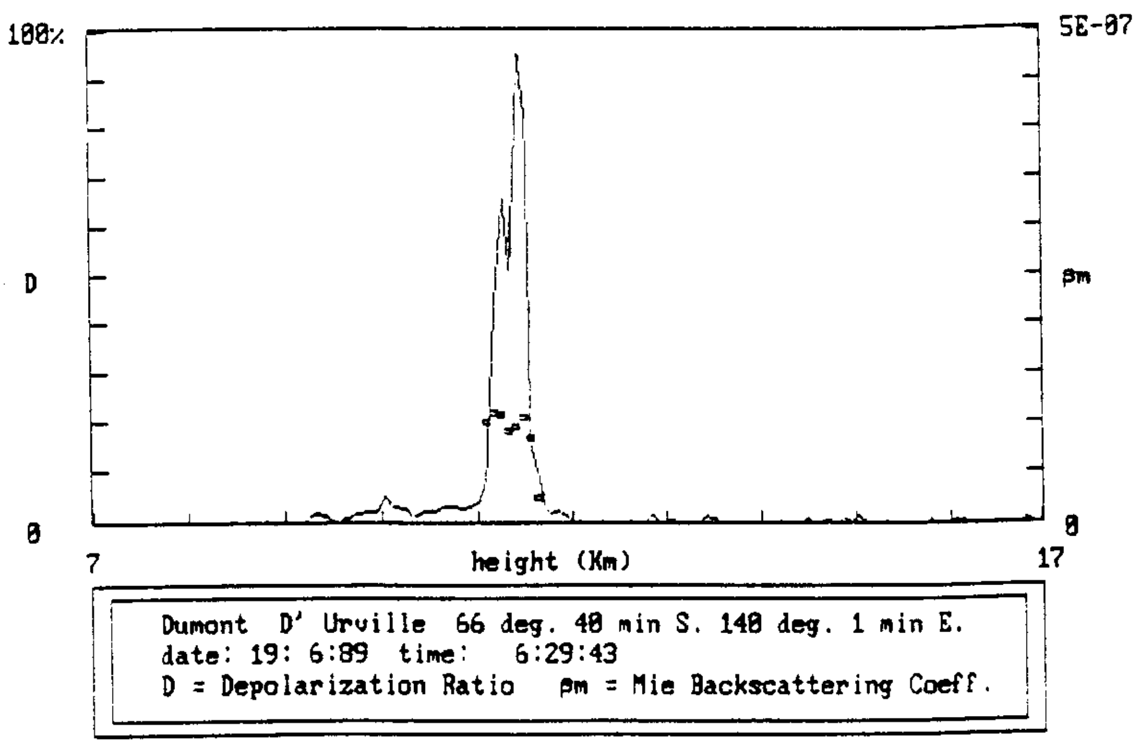
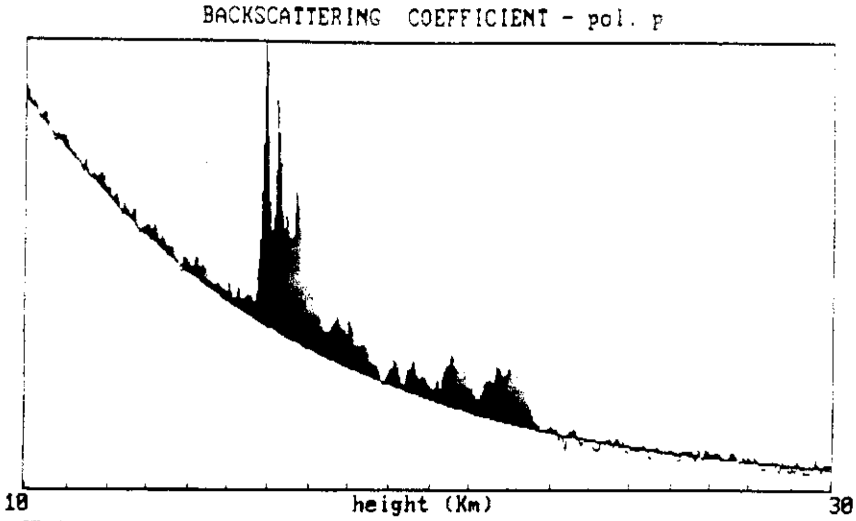

100%
5E-07
D
βm
0
0
7
height (Km)
17
Dumont D' Urville 66 deg. 40 min S. 140 deg. 1 min E.
date: 19: 6:89 time: 6:29:43
D = Depolarization Ratio βm = Mie Backscattering Coeff.

Fig 2



Dumont D' Urville 66 deg. 40 min S. 140 deg. 1 min E.
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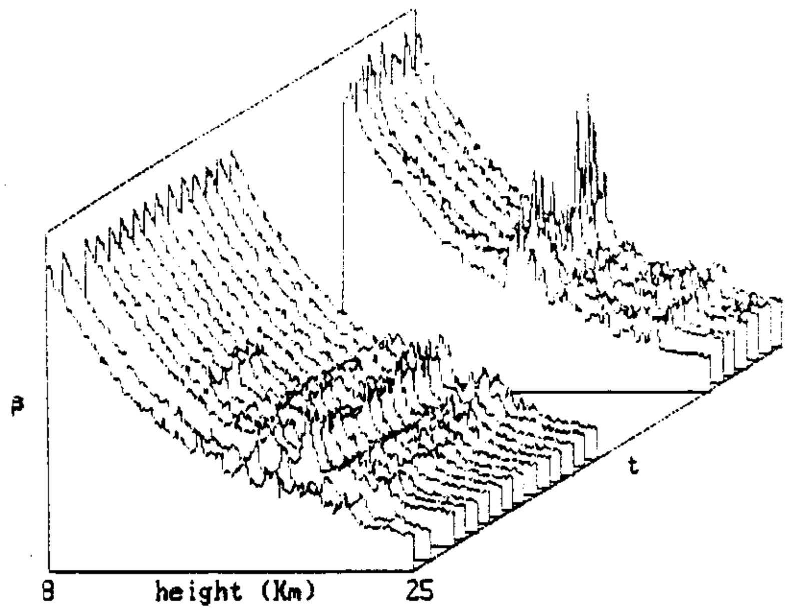
int. backscatt. 4.317157E-04 from 10 to 25 Km.

Fig 3



BACKSCATTERING TEMPORAL EVOLUTION
Dumont d' Urville 66°. 40' S 140°. 1' E
date 27:7:89 time from 21h:23m to 7h:40m

Fig 4

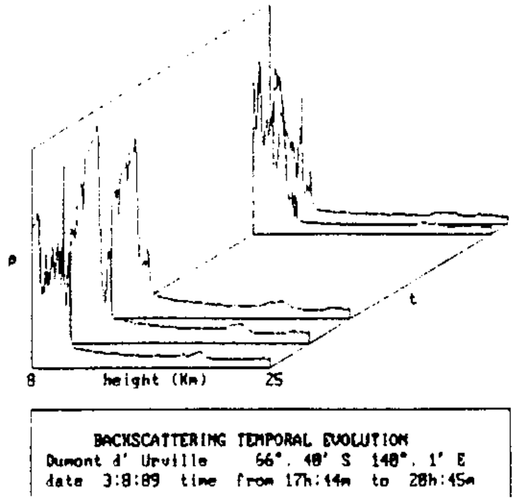


Fig 5

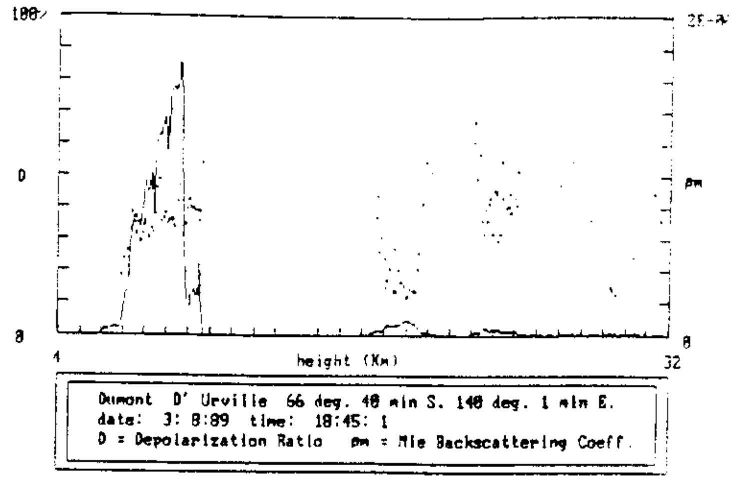


Fig 7

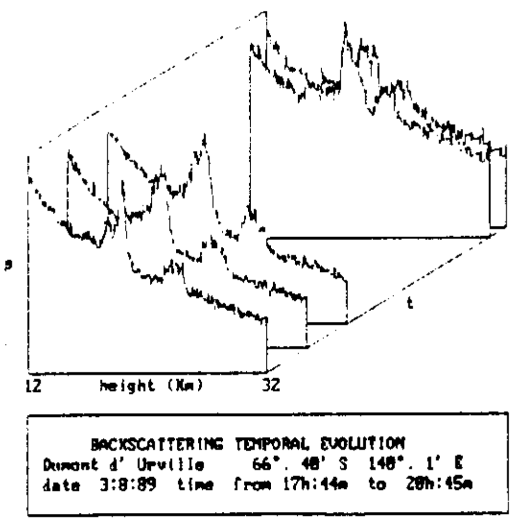


Fig 6

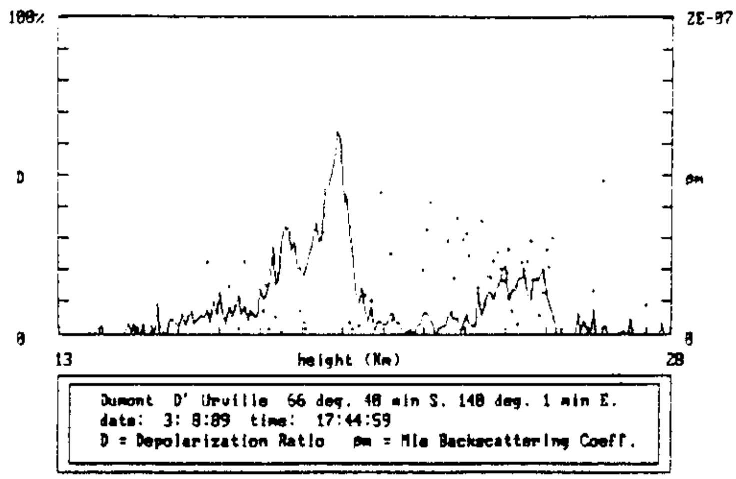


Fig 8

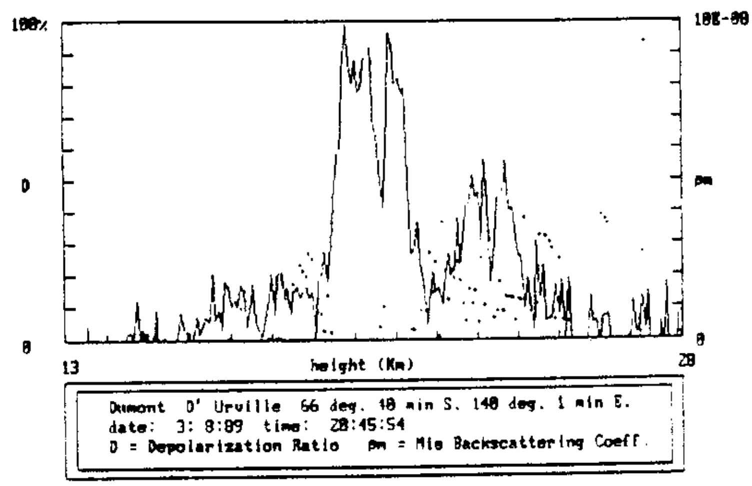
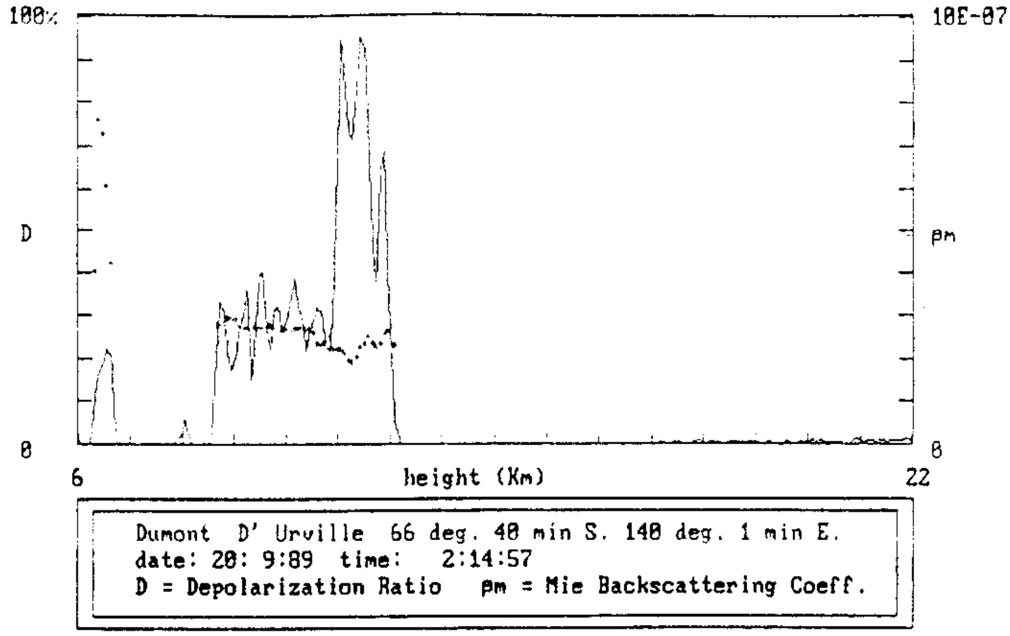


Fig 9



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