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# Evidence for Liquid Droplets in a -65° Cold Cirrus Observed by LIDAR Above Sodankyla (Finland) During S.E.S.A.M.E .

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## INTRODUCTION

It is widely accepted that pure water cannot exist as a liquid below about -40°. Theoretical and laboratory studies confirm this behavior for pure water. Nevertheless, liquid droplets have been seldom observed in cirrus clouds down to -50°C. Multiwavelenght, depolarization LIDAR tecnique can help to hunt unusually cold supercooled clouds. The presence of non-depolarizing cloud layers is indicative of scattering with cylindrical symmetry, possible both with spherical droplets and with ice plates horizontally oriented. In this work, a -65°C cold, non-depolarizing cloud observed in Finland is analysed, concluding that supercooled droplets are responsible for the absence of depolarization in most of the layer.

## MEASUREMENTS

A multiwavelenght depolarization LIDAR operated in Sodankyla (Finland) during the SESAME campaign . Several high tropospheric cloud events have been observed. Almost all such clouds showed the typical depolarization ratio (10-40%) of cirrus clouds , as observed in Antarctica [Del Guasta et al., 1993] and in the arctic [ Del Guasta et al., 1994 ] with a similar LIDAR.

On a particular case (starting at 16 GMT on February 12, 1995 and observed for about 20 min), an unusual layer at 10 km showing no depolarization for most of the time was observed. In Fig. 1 the time evolution of the vertical profile of the backscattering polarized parallel to the laser linear polarization ($\beta p$) and that shifted 90° with it ($\beta s$) is shown (x axis are minutes). The ratio of the perpendicular and parallel backscattering gives the aerosol depolarization ratio, that is almost zero above 10.2 km.

The PTU soundings of the day (Fig.2, before and after the measurement) show the advection of warm air during the day, up to about 10 km . The temperature of the cirrus layer is between -65 and -70° in both soundings; the layer is close to the tropopause. The water concentration at the layer level is 10 ppm at 11 GMT of 12/02 and becomes 40 ppm at 23 GMT, following the warm front arrival. The backward trajectories at 250 mb (about 10 km) with end point above Sodankyla computed for 18 GMT show the airmass rising corresponding to the warm front arrival. Such trajectories show that air was coming from the arctic before the cloud event , and from the atlantic ocean in the late afternoon: Oceanic , wet air advected into the dry and cold arctic air at the study layer height.

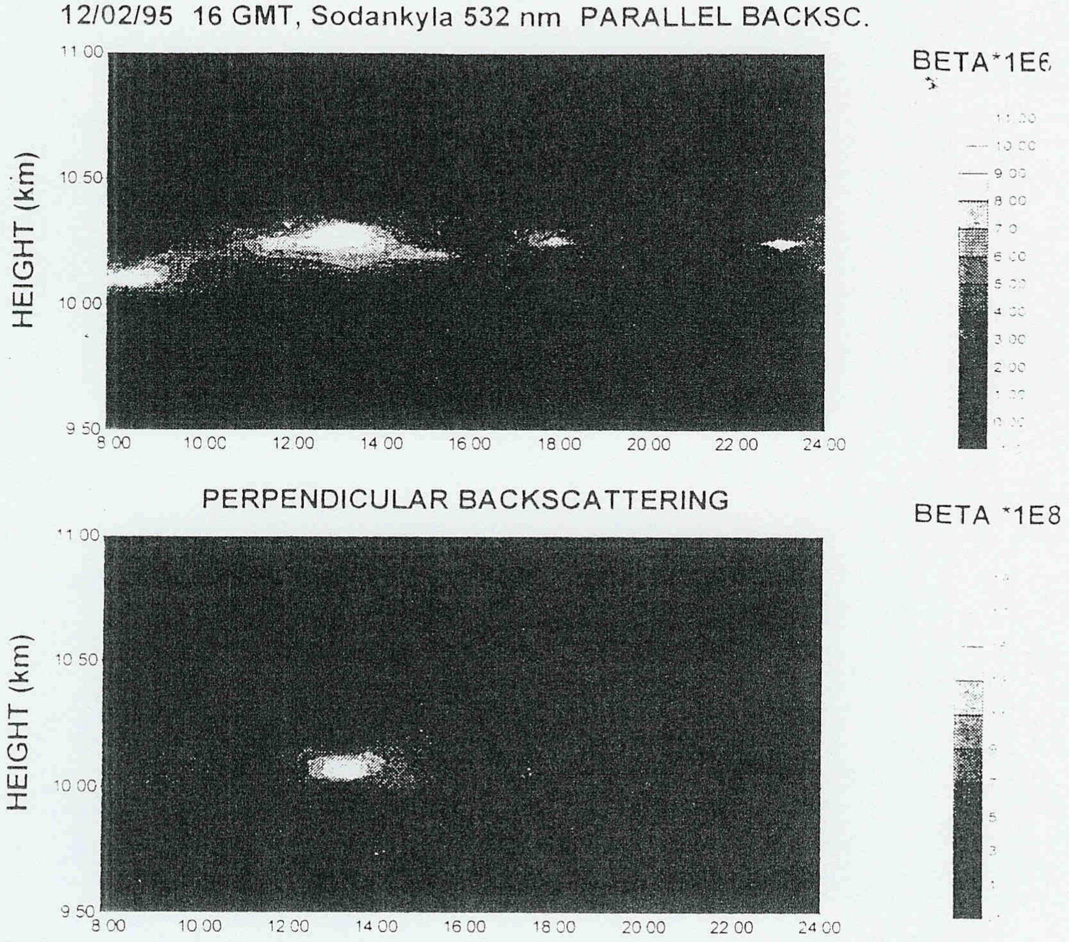


Fig.1: time evolution of the backscattering in the cirrus layer. x are minutes from 16:00 GMT.

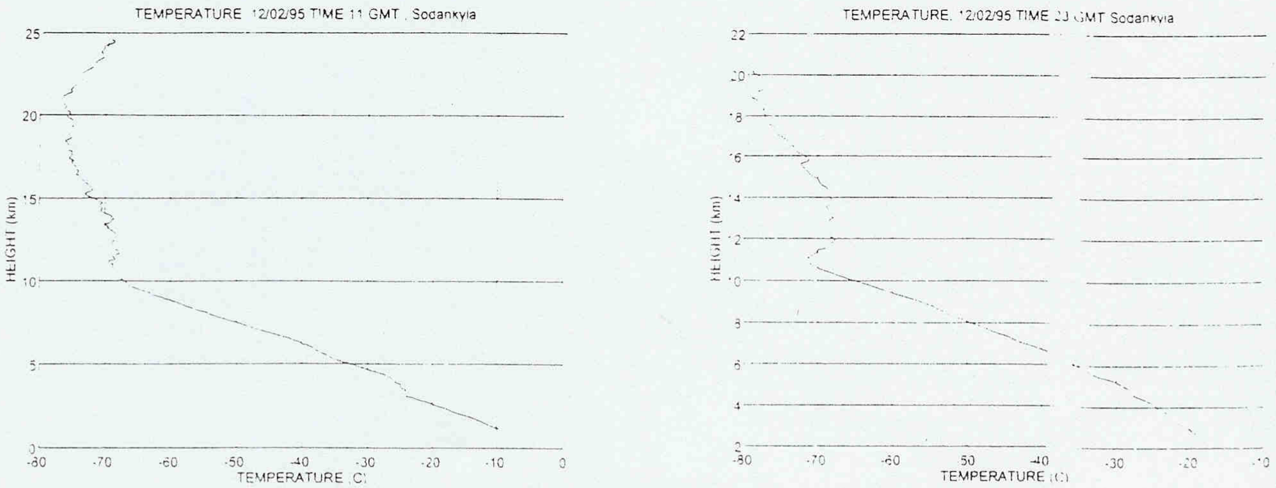


Fig.2: PTU soundings at 11 GMT and 23 GMT (before and during the front arrival)

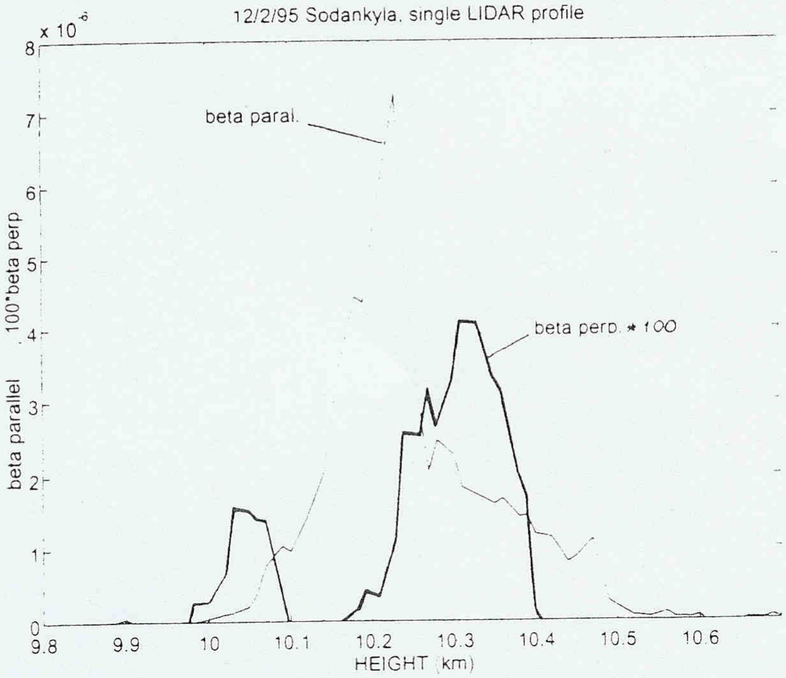


Fig.3 : A LIDAR profile of the layer: regions with no perpendicular signal are evident, showing the presence of supercooled droplets.

The analysis of the multiwavelenght LIDAR data at 532 and 355 nm gives for the study layer the same integrated backscattering at both wavelenghts, indicating the presence of particles larger than 1-2 microns. The vertical profiles of βs and βp show layers with no perpendicular backscattering, and parallel backscattering up to 3E-5 [1/(m sr)], alternate with slighly depolarizing layers (depolarization<10%) (g.e., Fig.3).

## DISCUSSION

The lack of depolarization in most of the cloud layer has two possible microphysical interpretations:

1) **Horizontally oriented ice plates ?**

Plates smaller than 1mm can in principle show horizontal orientation, leading to anomalous backscattering. This consists in a strongly enhanced backscattering with no depolarization, as observed for exemple by [Platt et al.,1978]. Plates are not expected below -30°C with low water vapor concentrations [Pruppacher and Klett, 1978; Chen and Lamb, 1994]. Anyway, trigonal plates have been observed in cirrus at -83°C by [Heymsfield , 1986], showing the real possibility to find plates at very low temperatures .

The βp values observed in the study layer are comparable with those observed in common cirrus below -40°C [Del Guasta et al.,1993], and do not reach the high values (>1E-3 1/(m sr)) expected by [Popov and Shefer,1994] and observed by [Platt et al., 1978] in the case of oriented plates (an unrealistic particle density of less than 0.008/liter is required to have so low anomalous backscattering values). Another observation suggesting to reject the hypotesis of oriented plates comes from Fig.3, that is only a sample of the cloud vertical profiles: the peak in the parallel backscattering correspondes to a layer with no perpendicular backscattering. In the case of anomalous backscattering, oriented plates enhance the parallel beta, but they do not deplete the depolarized signal coming from the other cloud particles in which the oriented plates are embedded. To explain Fig.3 in terms of oriented plates, we must suppose the presence of pure oriented plates in the central layer (10.1-10.2 km), and the presence of different particles elsewhere. It is hard to sustain the presence of pure oriented plates in a narrow layer 100 m thick.

2)**Supercooled droplets**

It is widely accepted that pure water cannot exist as a liquid below about -40°. Theoretical [Heymsfield and Sabin, 1989] and laboratory studies [DeMott and Rogers, 1990] showed that homogeneus freezing immediately occur at colder temperatures. But pure water exists only in textbooks, and air coming from the ocean (like that in the study cloud) contains large amounts of hygroscopic condensation nuclei (CCN like ammonium solfate, sea salt, etc.), depleting the freezing point of water. If the nuclei are large enough (g.e. >10E-12 g for ammonium solfate, corresponding to a radius of the order of 1 micron), the homogeneus freezing can occur at below -60°, leading to the survival of liquid droplets in a very cold environment [Sassen 1992]. A few supercooled layers between -40° and -50° have been observed by [Sassen 1992]. With this hypotesis, Fig.3 can be easily explained with the presence of freezing particles embedded in a supercooled, liquid aerosol background.
At present, this cloud layer is the coldest supercooled cloud observed in the troposphere.

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