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CONTRAIL OBSERVATION BY GROUND BASED SCANNING LIDAR

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Introduction

Contrails form from water vapour exhausts of aircrafts flying in the higher troposphere and lower stratosphere. Being composed of ice crystals, they bear a greenhouse potential like thin cirrus clouds (Liou, 1985). An additional increase of 0.4% cloud coverage due to contrails over mid Europe was retrieved from satellite data (Schumann and Wendling 1990). To investigate the formation and life cycle, height, thickness and optical parameters of contrails, the IFU has built a mobile scanning lidar employing a Nd:YAG laser and a 52cm cassegrain telescope for depolarization and multiwavelength backscatter measurements.

The Experimental Setup

Investigating contrails moving with wind speeds up to 40 m/s by ground based remote sensing requires an accurate and fast pointing and scanning measurement system. To achieve a stable assembly we mounted laser, receiving optics and detection unit together on a high resolution two axes scanning mount.

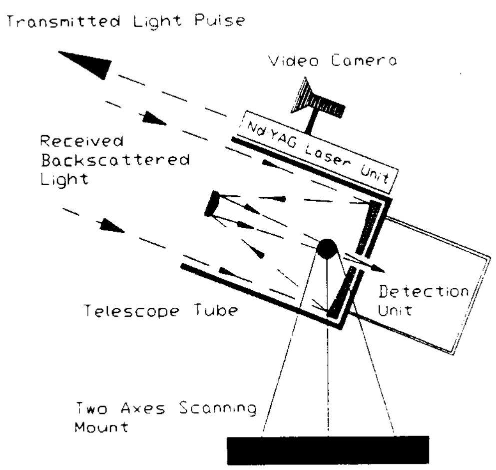

Fig.1. Modular setup of the scanning lidar system

Summary of the system specifications:

The **transmitter** is a Q-switched Nd:YAG laser with pulse energies of 1J @ 1064nm, 0.55J @ 532nm, and 0.28J @ 355nm, a pulse width < 7ns, a pulse repetition rate of 10Hz and a beam divergence of 0.5mrad. The **receiver** is a ∅ 52cm cassegrain telescope with 0.5 to 6 mrad FOV. The **detectors** are THORN EMI photomultipliers 9128A with modified voltage dividers and range gate circuits for 532nm and 355nm detection and an InGaAs Photodiode with hybrid preamplifier for 1064nm (under test). Depolarization profiles are taken at 532nm alternatively to 3-wavelength measurements. **Data acquisition** is done by a 50MS/s 3-channel transient recorder from Kontron/ Germany with max. 1MB record length/ch., yielding a height resolution of 3m. Data is transferred by IEEE-bus to the system PC. The system PC controls on line scanning by the two axes scanning mount under multiple tasking WINDOWS. With each scanning step a video picture of the contrail is saved to the PC hard disk by a frame-grabber to support the analysis of the measurements. The **scanning mount** pointing and repeatability accuracy exceeds the laser beam divergence of 0.5mrad. Its max. turning velocity is 20°/s. The whole system including supporting equipment is accommodated in a 20 feet standard container for the sake of mobility. One half of the containers slides back over the other one to give way for the semi-hemispherical measurement range. Details of the system are described in Freudenthaler et.al. (1993).

Measurements:

Fig.2 and Fig.3. show two examples of contrail measurements, one about 10s old, composed of 35 consecutive profiles, the other one about 1 hour old, retrieved from 26 profiles. The two vortices of the airplane are clearly distinguishable in the attenuated backscatter signal plot in Fig.2A. They are about 60m apart and each about 20m in diameter with a third scattering trail between

the vortices but 20m below. The linear depolarization ratio (Fig.2B) is about 25% in the vortex cores and decreases with distance to them. The plot of the one hour old contrail (Fig. 3A) still shows two centers of maximum backscatter about 900m apart and a depolarization ratio of 40% to 50% with a peak of over 50% below the left center. Spots above the contrail are due to signal noise.
Calculation of the aerosol backscatter coefficient was done applying Klett's inversion analysis (Klett, 1985) with an extinction to backscatter ratio of 0.04 for the contrail region. Multiple scattering was neglected. The analysis yielded an optical thickness from about 0.1 over the right branch to 0.4 over the left. Based on first experiences presented here, the variation of optical parameters during complete life cycles of contrails will be studied in future.

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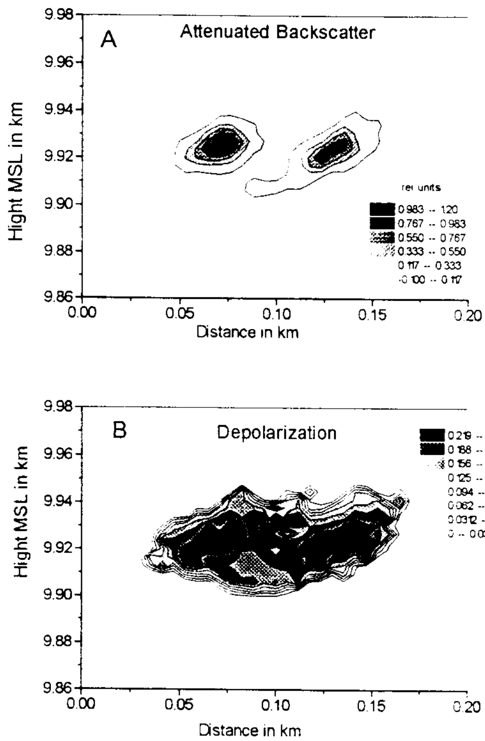

Fig. 2 Cross section of a 10s old contrail. Temperature at contrail level -51°C.
A: Attenuated backscatter signal in relative units. B: Linear depolarization ratio.

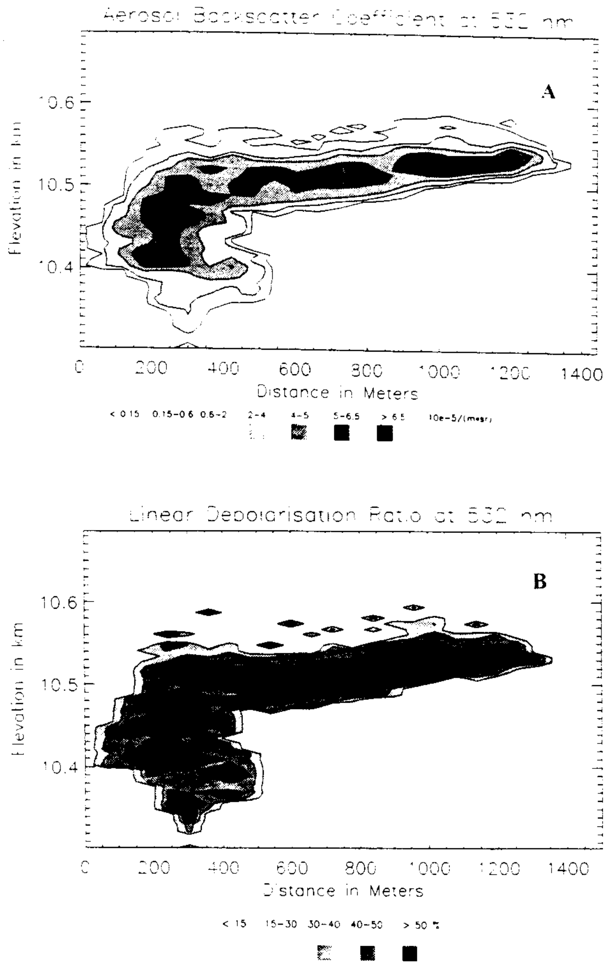

Fig.3 Cross sectio of a contrail about 1 hour old. Temperature at contrail level -61°C.
A: Aerosol backscatter coefficient (see text). B: Linear depolarization ratio.

References:

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