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Lidar and Radiometer Results from the ER-2 for the FIRE Field Experiments

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I. Introduction

The airborne lidar and radiometers which were flown during the FIRE cirrus and marine stratus field experiments had multiple objectives. Cloud parameters of direct interest, such as cirrus infrared emittance or convective scales for marine stratus, may be derived from the observations and analyzed along with the available cloud physics and meteorological observations. Additionally however a stated goal of the FIRE studies was to validate satellite cloud retrievals. To this end a number of derived products are to be available from the basic lidar and radiometer observations. The characteristics of the derived products will be described, and in addition analysis results for cloud radiometric and structure parameters will be presented. This extended abstract will be used to describe the available data products, and the associated presentation will emphasize case study analysis results.

II. Lidar Observations

A basic parameter from the ER-2 lidar observations is cloud top height and structure, and calculated cloud height and the attenuated backscatter profiles are to be made available as derived products. Calculated cloud height with aircraft navigation is to be available for all days through NCDS. Backscatter files will be made available on request. However,

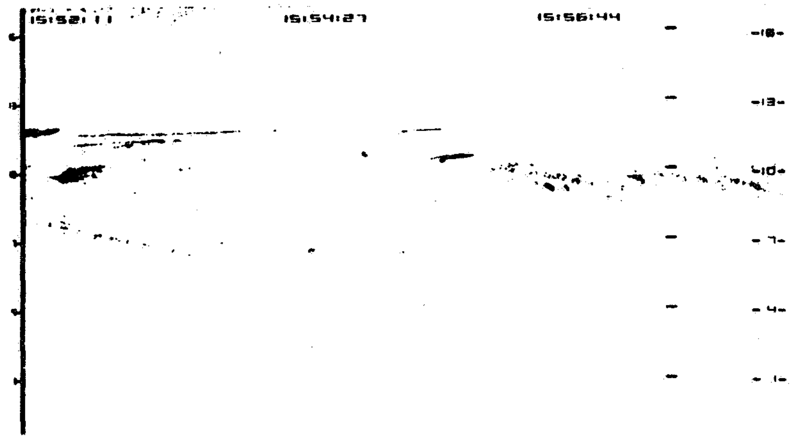

Fig. 1 Lidar data from cirrus from October 22,1988 as a function of height in km and time.

application of the data products requires understanding of the data characteristics and the calculation procedure. In the case of cloud height , for cirrus the height derivation from lidar data is not necessarily unambiguous. Lidar return data is illustrated in Fig. 1 for a partial flight line from October 22, 1988. The gray scale intensity in Fig. 1 represents the log of the return signal. In principle the cloud height may be determined from the discontinuity of the scattered signal. On a shot by shot basis for thin clouds, however, the calculation is not direct. A single laser return at full bandwidth is shown in Fig. 2. The signal is from the beginning

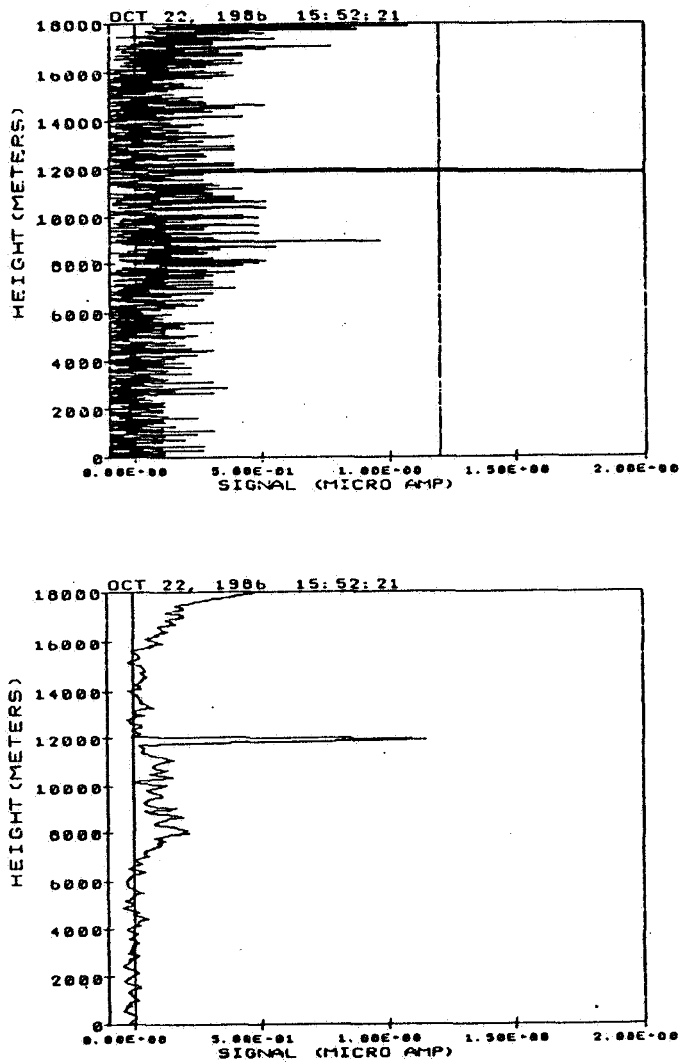

Fig. 2-3 Single laser return signal at full bandwidth and with filtering.

of the flight line in Fig. 1, and contains a dense shallow cloud and diffuse extended cloud. The fluctuations of the signal are due to background signal noise which is proportional to the square root of the bandwidth. A high bandwidth for the received signal is required in order to correctly measure scattering from dense clouds. However thin clouds will be obscured by the noise associated with high bandwidth and filtering is required. In Fig. 3 the signal has been filtered to a 375 m. vertical resolution. The thin lower cloud layer becomes apparent, but the peak signal of the upper dense layer has been distorted.

For the cloud top detection, a simple threshold detection would miss thin layers or produce spurious results. The detection algorithm applies a sequence of smoothing filters each with an associated threshold starting at the greatest smoothing. Both detection of thin clouds and a more accurate top height for dense clouds is obtained. Since both corrections for the aircraft pressure altitude and pitch and roll are applied, absolute height accuracy is less than 15 m for dense clouds such as marine stratus. The minimum scattering discontinuity at which a thin cloud may be detected is approximately at a backscatter cross section five times above molecular scattering. However the height detection does not acquire all cloud tops. The height determination for the

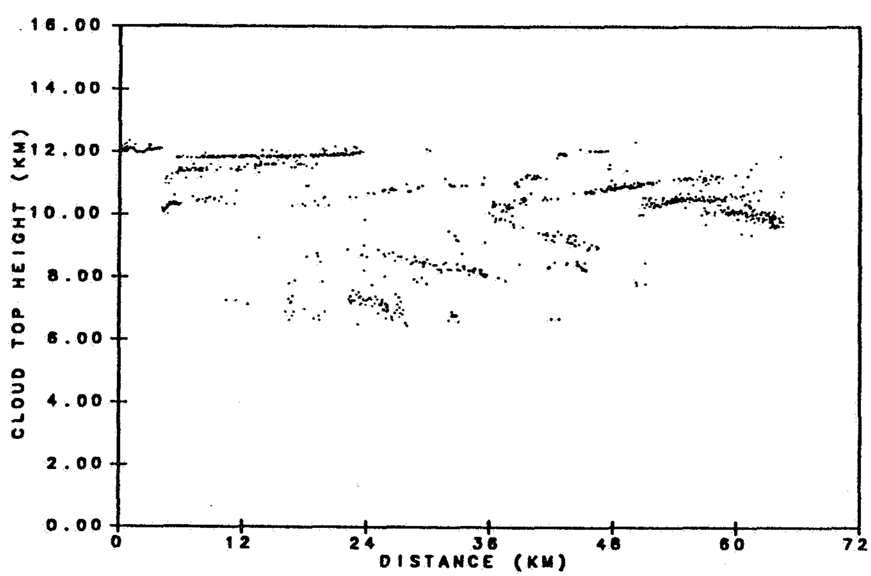

Fig. 4 Derived cirrus cloud top height.

data of Fig. 1 is given in Fig. 4. For the thin extended cloud layer, the height is found as a distribution of values through the layer.

The lidar attenuated backscatter result for a single laser return is in similar form to the signal as shown in the second figure. The total signal is a sum of the scattered signal plus an offset from the ambient background. The signal in Fig. 2 has had the offset subtracted. In order to obtain the attenuated backscatter values with units of (1/km-sr) the scattered signal is scaled by an appropriate constant. The constant is derived from the high altitude molecular scattering. In order to apply the lidar attenuated backscatter for any given application, filtering appropriate to the application must be applied.

III. Radiometer Observations

There were two separate cross track scanning, multi-wavelength radiometers on the ER-2 for the FIRE observation flights. A description of the wavelengths and operating parameters for the Multi-spectral Cloud Radiometer and the Daedalus Cloud Radiometer have been given in the FIRE working documents. The raw data is in the form of intensity proportional digital counts as a function of time and scan angle. The basic derived parameter is the radiometric intensity and the related cloud reflectance which requires a calibration constant for each radiometric channel. For the thermal channels the calibration is directly obtained from on board black bodies. In the case of visible and near infrared channels, the calibration is derived from standard integrating spheres. Initial results from calibration with a single integrating sphere indicated errors as large as 30%. However three separate integrating spheres were involved in the calibrations and an inter analysis could be applied to obtain more correct results. Data from the MCR is processed and available as radiance values with integrated aircraft navigation. Currently DCR observations can be requested as files containing any subset of wavelength channels but must be merged separately with calibration and navigation data.

VI. Analysis

Analysis of results for the cirrus case study of October 28 have been emphasized. The cloud emittance, transmittance, reflectivity and cross sections are derived from combined analysis of the lidar and radiometer data. Parameters are related to height structure and temperature. Some surprising structure for cirrus as been observed, for example the shallow but very dense layers embedded in generally diffuse layers as seen in Fig. 1. Marine stratocumulus cloud top height and liquid water distribution has been analyzed (see abstract by Boers and Spinhirne).