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LIDAR STUDY OF STORM TOPS

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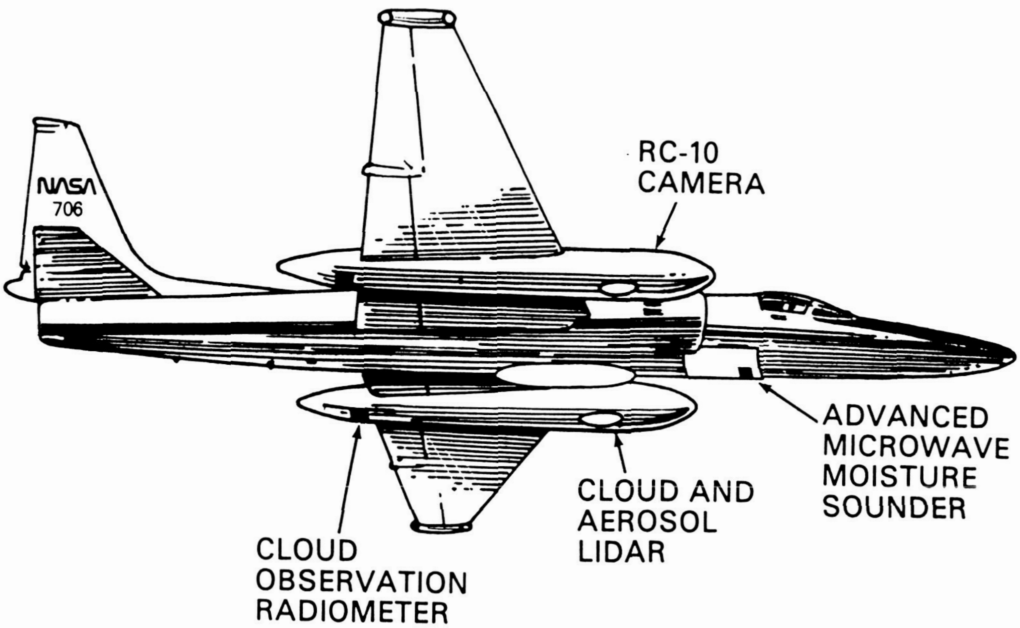
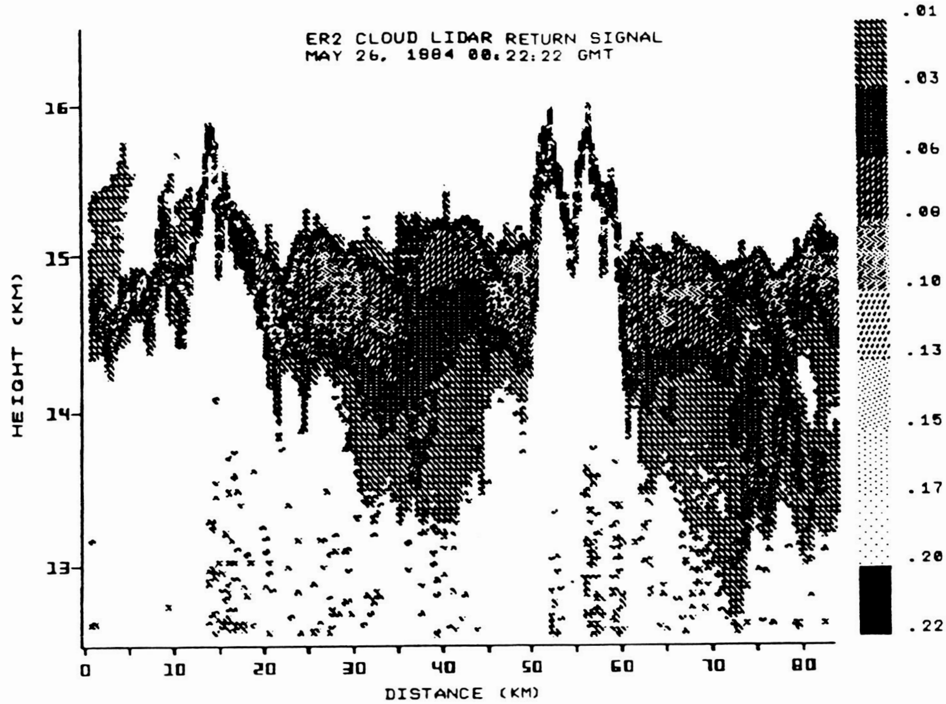
Satellite thermal and visible observations are routinely used for storm tracking and diagnostics. In recent years attempts have also been made to apply satellite measurements to the study of evolutional factors for storms such as divergence and subsidence mechanisms. These studies involve analysis of the thermal height structure of the storm tops as obtained from the satellite observations. An outstanding problem is the importance of emissivity effects for the interpretation of the storm top thermal radiance measurements. In part to understand the correct interpretation of satellite observations, a storm top observation experiment involving advanced instrumentation on board a high-altitude NASA aircraft has been in progress. A downlooking lidar system has been an important part of the instrument complement. A combined analysis of the lidar return data and thermal radiance measurements has been developed to study cloud top emissivity effects and their relation to satellite observations.

As shown in the first figure, the cloud and aerosol lidar experiment has been flown on board the ER-2 aircraft along with a



Cloud and storm observation experiment

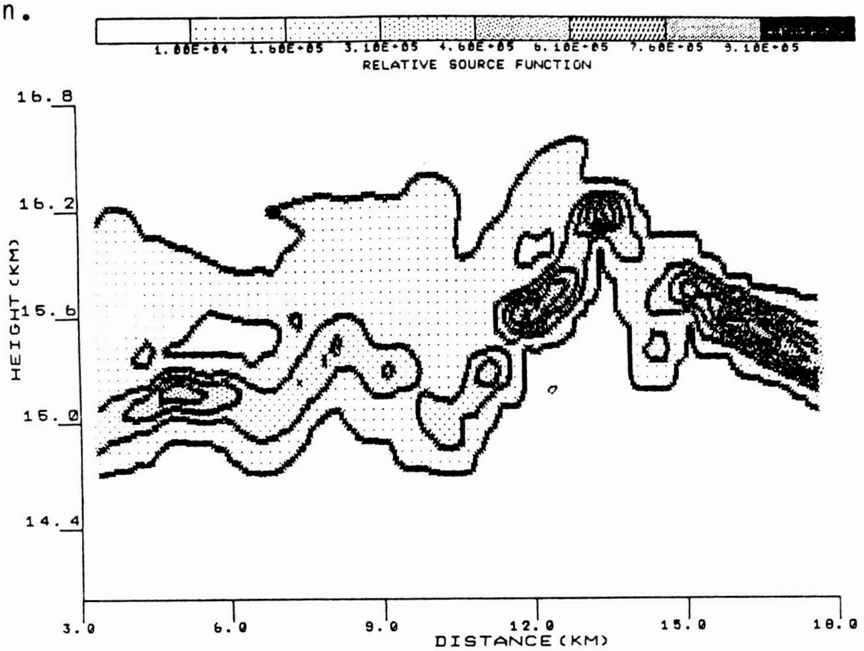
multi-spectral scanning radiometer and a microwave sounding instrument. A description of the lidar system and initial results for lidar observations of the structure of severe storm tops have been given in Spinhirne et al. (1983). The most recent experiment was a study of midwest severe storms in May 1984. An example of the lidar return data for an 80 km flight line over an intense storm is shown in the second figure. The flight data



Lidar return from storm top

indicate several overshooting convective towers surrounded by areas of diffuse cloud structure. The nadir radiance measurement at 11 um corresponding to each lidar return is obtained from the cloud radiometer.

The thermal radiation emission from a cloud top is related to the vertical cloud temperature and the vertical particle density structure. An analysis of the thermal radiance based on the lidar return data is possible since the lidar return is also dependent on the vertical cloud density. The initial procedure of the combined analysis is a correction of the backscatter lidar return signal for the apparent attenuation. The assumption is made that the optical characteristics of the cloud particles are constant with altitude, and a constant factor which relates the lidar backscatter cross section to the thermal absorption cross section may then be derived. The actual solution involves an iterative procedure. The emitted radiance is calculated from the absorption cross section profile and an assumed vertical temperature structure. An example of the result for a segment of the flight line shown in the second figure is given in the third figure. The contribution to the radiance from a given cloud top area would be proportional to the indicated relative source function.



Relative contribution function for the emitted thermal radiance of a cloud top segment

The following preliminary conclusions may be presented. The density for the top of convective cells overshooting the tropopause is such that the observed brightness temperature gives an accurate measurement of the cloud top temperature. The penetrating cells are surrounded by a diffuse anvil structure from which the upward radiation at the cloud top may arise from several kilometers into the cloud. Isolated cirrus layers, which are at times found in the stratosphere overlying the storm tops, are typically too thin and of too limited an areal extent to have an important effect on the observed thermal brightness. Such results may be applied to give a clearer dynamical interpretation from satellite observations of storm systems.

REFERENCE

Spinhirne, J. D., M. Z. Hansen, and J. Simpson, 1983: The structure and phase of cloud tops as observed by polarization lidar. J. Clim. Appl. Meteo., 22, 1319.