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THE NEW LIDAR SYSTEM AT MUNICH (GERMANY)

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INTRODUCTION

It is generally accepted that clouds significantly modify the radiation budget of our planet and the hydrological cycle, and thus climate. Moreover, aerosol particles directly influence the radiation budget by scattering and absorbing radiation, and also indirectly by modifying cloud microphysics and, as a consequence, the radiative properties of clouds. Thus, the role of aerosol particles on climate must not be neglected. However, it is still a long way to incorporate aerosols in climate models as prognostic variable. Today, if ever, aerosol distributions and their properties are prescribed and parameterization schemes are very simple and crude.

Furthermore, there are severe shortcomings in global observations of the cloud and aerosol distribution and their properties. Spaceborne passive remote sensing must be improved in several aspects, e.g. with respect to the height-assignment of clouds, aerosol layers or the planetary boundary layer. Furthermore, thin clouds are often not detected by radiometry or misinterpreted. Global aerosol monitoring with high spatial and temporal resolution is also missing, attempts are limited to special conditions, such as over dark surfaces.

Active remote sensing by a lidar is a very promising tool to close some of the gaps in our present knowledge. As a pre-requisite advanced lidar systems and the corresponding data evaluation schemes must be developed. The Meteorological Institute of the University of Munich is currently building a new mobile lidar system to contribute to this goal. The lidar has the unique ability to make measurements under different wavelengths, polarization, observation angles and fields of view. This offers the opportunity to combine some of the known inversion techniques for gaining synergistic effects, and to develop new methods taking advantage of the simultaneousness of different measurements. It is hoped, that the scientific output constitutes a substantial progress in aerosol and cloud observations on a regional scale, and in the derivation of optical and microphysical properties. In a later stage there might be some spin-offs that can be beneficial for the development of spaceborne applications.

The lidar will be in operation from June 1994 on.

LIDAR SYSTEM

The transmitter of the lidar is a Nd:YAG laser emitting radiation at 1064 nm, 532 nm, and 355 nm simultaneously. The pulse energy at the fundamental wavelength is 650 mJ, the pulse repetition frequency is 10 Hz. The divergence of the laser pulse is 0.5 mrad. The optical receiver, a 30 cm diameter telescope, is mounted co-axial to the laser. Both are mounted on an assembly which can be moved independently in azimuth and zenith direction. The scan pattern, characterized by the angular steps and the angular velocity, is controlled by a free programable computer. The standard scan pattern is a two-dimensional vertical cross section (fixed azimuth) or a three-dimensional scan of atmospheric volumes. In the latter mode, volumes with an area of several tens of square kilometers and the height of the troposphere can be observed in less than about five minutes. The field of view of the receiver can be varied approximately between 0.5 and 4 mrad, yielding different spatial resolutions. The whole lidar system is housed in a van, thus being easily movable.

Polarization is measured at 532 nm wavelength in two planes, parallel and perpendicular in respect to the state of polarization of the emitted radiation. Two additional channels for polarization are designed, but not in operation in the first phase of the measurements. They can be used for the other two wavelengths or for measurements of the complete Stokes vector at one wavelength.

These technical specifications allow a wide range of different applications: the variable scan pattern allows to select that spatial sampling that is adequate to a given purpose, and the variable choice of up to six channels offers manifold combinations of simultaneous sets of data to obtain the meteorological parameters of interest.

SCIENTIFIC OBJECTIVES

The scientific objectives include observations of the spatial and temporal distribution of aerosol particles and clouds, and their optical properties. It is not clear to which extent microphysical properties can be inferred, too.

The spatial distribution and temporal evolution of cloud fields and aerosol layers are investigated for several purposes. First, they can be used to study dynamics and exchange processes using aerosol particles as tracers. Thus, special emphasis is put on mapping aerosol concentration of the planetary boundary layer over different orographic terrains. The usefulness of such a kind of measurements, e.g. for environmental studies, is demonstrated by Cooper et al. (1994) or Crum et al. (1987). Second, they can contribute to establish a 'complete' experiment for process studies of cloud formation, aerosol generation or aerosol transport. Three dimensional lidar data can significantly reduce sampling problems inherent in groundbased and airborne in-situ measurements and passive remote sensing. This is required to understand the processes, and to improve the development of parameterization schemes for numerical models. Third, they are useful to investigate different averaging procedures and the associated errors. This can support studies related to the interpretation of satellite measurements with medium spatial resolution as well as the derivation of regional averages gained from point measurements. As a conclusion, the capability to scan is one of the most interesting options of the lidar.

To derive optical properties of aerosol particles or clouds, the 'classical' inversion schemes for the extinction coefficient are applied. Depending on the turbidity of the atmosphere, the extinction coefficient or the backscatter coefficient is the primary parameter. Both, extinction and backscatter coefficients, can be determined independently if lidar measurements under different zenith angles are evaluated simultaneously, and the atmosphere under observation is horizontally homogeneous. This is a quite powerful method to directly measure the lidar ratio. Again, three-dimensional information are envisaged.

To derive microphysical parameters, more sophisticated remote sensing techniques are required. The most desired information certainly is the size of the particles. It is expected that measurements from the three wavelengths can give some information on a characteristic radius of the scatterers. Whether this information can also be derived from ratioing measurements from different fields of view – taking advantage of the different contribution of multiple scattering to the received signal – has not yet been demonstrated.

Information on the sphericity of the particles can be gained from polarization measurements. E.g., the discrimination of ice crystals and supercooled droplets is possible, as has been demonstrated earlier by several investigators (e.g., Sassen et al., 1992). Furthermore, oriented ice crystals can be identified by specular reflectance.

The corresponding algorithms are still under development. Real measurements will show whether the technical performance of the lidar is sufficient to obtain an acceptable accuracy.

MEASUREMENT PROGRAM

The first measurements are planned within the frame of ELITE'94, the European contribution to the correlative measurement campaigns for the first spaceborne lidar (LITE, Lidar In-Space Technology Experiment). This experiment is scheduled for September 1994 in Northern Germany.

During this campaign, one item are studies of the spatial distribution of cirrus fields. Comparisons between measurements with our groundbased scanning lidar and measurements from airborne lidars, taken simultaneously from the same cloud, will demonstrate the potentials of deriving cloud parameters by lidars. The comparison between spatial averages gained from a network of groundbased and airborne lidars on the one hand, and the LITE data on the other hand, will provide good estimates of the benefit of spaceborne lidars for climatological purposes.

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