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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Research Laboratory of Electronics
Cambridge, Massachusetts

SENSING OF METEOROLOGICAL VARIABLES
BY LASER PROBE

During the period February 1 - July 31, 1966, NASA Grant NGR-22-009-131 has been the main source of support for the research activities of our group. Some of the research outlined below, however, has been partially supported by NASA Grant NGR-22-009-(114) which is particularly directed toward the investigation of upper atmospheric dust by optical radar.

The first phase of a study of stratospheric aerosols in the altitude range between approximately 10 km and 30 km has been completed. The study has utilized data that had been collected in 1964 and 1965 with our optical radar, for the most part, at a location in Lexington, Massachusetts. Source data were also collected at College, Alaska during the summer of 1964, at a time when noctilucent clouds could be studied. For the purposes of analysis, observations made on more than 100 nights are available. The average characteristics of the layer, as well as its fluctuations, have been studied by statistical methods. The existence of a broad maximum at a height of approximately 16 km has been confirmed. The results have indicated a much higher dust content than previous investigations had shown, because of volcanic eruption in the fall of 1963. The fluctuations of the aerosol content of the stratosphere have been correlated with various meteorological quantities. In particular, a negative correlation between the fluctuations of dust and ozone has been found. This correlation tends to support the view that ozone is rapidly destroyed in the presence of large amounts of dust.

During the analyses use has been made of a Benson-Lehner semi-automatic digitizer Type OSCAR-F. This machine, whose original value exceeded $10,000, was obtained from the Lincoln Laboratory, M.I.T., as a surplus item. The data originally stored on 35-mm film are digitized and then transferred to punched cards for further use with the computational facilities of M.I.T. The costs involved in the use of the digital computer, amounting to several machine-hours, in the past, have not been charged to our grants. It is our intention to submit these results for publication to a scientific journal.

Another investigation is under way to study analytically the optical-scattering properties of atmospheric aerosols. Extensive computations of the back-scattering cross section of absorbing spheres have been carried out, as well as integrations to take care of physically reasonable size distributions. We hope to complete this investigation before the end of the year.

The problem of determination of atmospheric kinetic parameters by the scattering of laser light is one of great interest to us. In a proposed technique for measuring atmospheric temperature the broadening of the laser spectral line, because of scattering by atmospheric gases, is to be detected. Some preliminary analyses show that a transmitted power of 6×10^5 watts in a single mode is necessary for an atmospheric probe. The instrumentation that we consider necessary for a device of this exploratory type should consist of these principal items: a single-mode ruby laser, appropriate optical apparatus for transmission and reception of echoes, a broadband light detector, a four-channel multiplexer for separating the various microwave channels that are necessary for measuring the linewidth of the scattered spectral line, four calibrated superheterodyne receivers, and two double-beam oscilloscopes. We have explored some of the design parameters in detail, and should soon be ready to place orders for the instrumentation which is not available in our laboratory.

We have constructed and tested several He-Ne and Argon lasers, and we have modified an existing ruby laser for single-mode operation. A CO_2 laser is being built. We have also constructed chambers for the laboratory observation of scattering from atmospheric constituents.

A limited amount of research time has been spent in preparing some future experiments to detect Raman scattering of laser light by atmospheric gases.

Other work has been directed toward observation of the scattering of light from inhomogeneities in a plasma.

Our optical radar has been improved during the past year by the addition of a new azimuth and elevation mount. A better cooling system for the laser has been fitted, and some work has been done to improve the working conditions in the instrumentation trailer, which we have had on extensive loan from NASA, Goddard Space Flight Center, Rocket Flight Branch.

At the present time, measurements of the upper atmosphere by optical radar are being conducted in Norway. The primary object is to obtain quantitative information on the occurrence, height, structure, and other physical characteristics of the noctilucent clouds. This study is a continuation of research initiated in 1964 when two optical radars were taken to Alaska and Sweden. The results of that research had excited interest in examining the structure of the clouds during twilight and at night when no other optical techniques are available. They also indicated how important the choice of location is to the success of the effort. This time, we have located our apparatus near Oslo, Norway. The apparatus is contained in the NASA instrumentation trailer.

The choice of Oslo as a desirable location for the experiments emerged from several considerations. Measurements of noctilucent clouds with optical radars of present design have had the best chance of success at 60° latitude, the peak probability of occurrence of these clouds in the Northern Hemisphere being in the period 15 July-15 August. In lower latitudes the probability of seeing the clouds is reduced; higher latitudes provide longer periods of twilight when the optical radar is handicapped by a high level of sky background. Oslo is at 60°N. and has one of the highest records of clear sky in Northern Europe. The city has adequate supplies of scientific hardware, as well as dry ice and nitrogen that we need for operating the apparatus. There is good connection with the United States by plane. It has good hospitals; this advantage has been of particular importance this year.

The hospitality extended to us by the Norwegian Defence Research Establishment has greatly facilitated the carrying out of our experiments. The modern facilities of the establishment, including workshop, laboratories, library, as well as logistic support have been put at our disposal.

Apparatus similar to ours is being developed and operated with the support of NASA by the University of Stockholm, Institute of Meteorology. They maintain a small network of observing stations for the detection of noctilucent clouds. We expect a fair amount of collaboration and data exchange.

Simultaneously with the noctilucent clouds study, measurements are being made of the stratospheric aerosol content. A comparison should then be possible with data obtained previously for the purpose of establishing a latitudinal, as well as a time, dependence.

A developmental airglow meter is also being operated. This instrument should be capable of measuring the intensity of the OH rotational lines. From knowledge of the relative intensity the temperature of the emitting layer, presumably mesospheric, should be obtained. These data are of great interest because the presence of noctilucent clouds has been associated with the temperature at the mesopause, and also because of a possible role of H_2O, which is a probable constituent of noctilucent clouds, in the formation of OH by dissociation.

A theoretical investigation to determine the amount of ionization produced by micrometeorites is well under way. The large influx of micrometeorites in the Earth's atmosphere may be responsible for the production of ionization in amounts comparable to those needed in the E-region at night and in some types of Sporadic E irregularities. The problem has been reconsidered and the ionization resulting from neutral-neutral collisions of the ambient gas induced by the meteoroid is being calculated. This investigation has been mainly supported by NASA Grant NGR-22-009-(114) and was partly carried out while the principal investigator was at the Smithsonian Astrophysical Observatory.