X. GEOPHYSICAL RESEARCH

A. High Magnetic Fields*

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RESEARCH OBJECTIVES

The approach to the problem of producing megagauss fields by capacitor discharge has been changed from the conventional one of using a single-turn coil in which the magnetic pressure is directed outward, to the use of a Z-pinch in which the magnetic field surrounds a short straight conductor, and the magnetic pressure is directed inward. The reasons for this change follow.

1. The stored capacitor energy is first converted almost entirely into magnetic energy, and not simultaneously into kinetic energy, because of explosion. A very modest installation, 20 kJ, can produce fields of several megagauss.

2. If the current carrying rod is sufficiently large (a few millimeters in our installation), it is only partly evaporated by a discharge, and the factors influencing performance can be quantitatively studied. In particular, the amount of material melted and evaporated, and the temperatures reached by the current-carrying sheath, called the M-M (metal-megagauss) interface, can be investigated.

3. In certain ranges, the pressure produced by the Z-pinch may be useful for solid-state studies.

The apparatus is to consist of eight 15-μf capacitors operated at 20 kV, connected through spark gaps to the periphery of 2 reinforced metal plates, 3 ft in diameter. They are shorted at the center by replaceable rods of variable length and diameter.

Preliminary experiments with only 4 or 5 of the capacitors used have produced moderately damped discharges with 1/4 period of approximately 1 μsec. A field of 1.5 Mgauss is estimated to have been produced around a Mo rod, 1 cm long and 0.4 cm in diameter.

It is interesting to note that approximately 15 kJ/cc are required to evaporate copper or steel, whereas discharges of this magnitude have passed through rods having a total volume of ~0.25 cc apparent melting and evaporating over only a thin surface layer, ~0.05 cm. Further study is needed to determine how the capacitor energy is dissipated. It is possible that it goes to heating the M-M interface. Further experiments along this line are contemplated during the next few months with the completed apparatus.

An interesting research program in which the methods described above for producing megagauss fields could be used would be to test the theoretical predictions in the paper "High Energy Electromagnetic Conversion Processes in Intense Magnetic Fields" by Thomas Erber, Rev. Mod. Phys. 38, 626 (1966).

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X. GEOPHYSICAL RESEARCH

B. Upper Atmospheric Physics*

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

Much of the research in our group is concerned with the properties and use of coherent light in connection with problems of atmospheric physics. The NASA trailer has been instrumented as a mobile laboratory for research in atmospheric optics and contains the optical radar, as well as other instrumentation.

For about a year, we have been analyzing the results of measurements carried out with the optical radar during 1964 and 1965. These measurements provide profiles of the optical backscattering cross section of the atmosphere as a function of altitude and are interpreted to supply information on the dust content of the atmosphere from 10 km to 150 km. The analysis of a large sample of the stratospheric data has been completed and will be published soon. These observations of the stratospheric aerosols were made at Lexington, Massachusetts, during the two-year study and also at College, Alaska, in the summer of 1964.

The data have been compared with various meteorological parameters associated with conditions in the lower stratosphere. A significant negative correlation between fluctuations of dust and ozone has been found in the measurements.

At present, we are concerned with the reduction of data in the 35-150 km range. Although difficulties in the reliable operation of a semiautomatic digitizer have slowed down the data reduction, we hope to complete the reduction early in 1967.

We expect to be able to study the mesospheric dust content, its possible relation to the electron recombination in the D-region, as well as the possible influx of micrometeoric materials and its relation to E-region ionization.

With regard to the first problem, we are interested in the possibility of simultaneously performing dust density measurements by optical radar and electron density measurements by rocket, and are considering collaborative efforts with other groups.

The production of ionization by micrometeorites have been investigated for a simple model based on the acceleration of upper atmospheric molecules by incoming micrometeorites and the successive neutral-neutral ionizing collisions. It is found that a conservative value of 4×10^3 tons/day for the influx rate of cosmic dust on Earth is sufficient to produce ionization in amounts found in the E-region at night; since there is still no satisfactory explanation for the formation of the E-region at night, this is probably a significant result. The results of this will be submitted for publication.

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Another aspect of the role of dust in the upper atmosphere with which we are concerned, at present, is its relation with rainfall; we have correlated fluctuations of stratospheric dust amounts with the occurrence and amounts of precipitation, but, thus far, we have been unable to find a relationship. We expect to extend the investigation to include mesospheric dust and thus check the validity of Bowen's hypothesis.

Essential to the interpretation of the optical radar data is the availability of theoretical backscattering cross sections for spheres and ensembles of spheres with specified size distributions. We have extended existing computations to cover a wide range of complex values for the refractive index and have considered a variety of size distributions. The computations are almost complete, although we are facing the task of a meaningful yet compact presentation of the data.

We shall also extend the computations to cover scattering angles different from 180°; these tables will be of use in interpreting photometric and visual observations of scattering from the zodiacal light and from atmospheric stratifications, as well as an aid in estimating the feasibility of forward-scattering optical communication links.

Some estimate will also be carried out of the effects of various aerosol distributions over the response of the Dobson photometric technique for the measurement of atmospheric ozone.

During the summer 1966, the optical radar was taken to Norway to continue the investigation of noctilucent clouds which was initiated in 1964. Several noctilucent displays have been observed and we have collected a very large amount of data that is now being analyzed.

An important advantage of the optical radar technique when applied to noctilucent clouds is that, since our observations are performed at night as well as at twilight, we should be able to describe the development of the cloud when no other techniques of observation are available. From the 1964 data we inferred the possibility of substantial vertical motion for the cloud, and hope with present data to be able to substantiate the earlier findings.

The stratospheric aerosol layer was also observed continuously in Norway during the summer 1966; we intend to draw a comparison with activity in the previous years and establish the presence of a latitudinal gradient in the concentration which was suggested in the earlier work.

An OH airglow meter that utilizes photon counting techniques is being developed and was also operated in Norway during observation of noctilucent clouds. The importance of studying OH is based on (a) its role in the dissociation of H_2O (H_2O is possibly a major constituent of noctilucent clouds), (b) the fact that the excitation of the rotational-vibrational bands of OH probably reflects the ambient temperature of the mesophere, and (c) the relation between OH and Na airglow activity. We are designing a multichannel photometer to scan simultaneously several airglow lines.

Another area of interest in our group is the measurement of atmospheric temperatures by the broadening of laser radiation backscattered by air molecules. We have theoretically analyzed and partially implemented schemes for heterodyne and homodyne detection, as well as more conventional schemes utilizing optical filtering, and we are now assembling a system consisting of a high-power Ar^+ laser of high spectral purity, and a pressure-scanned Fabry-Perot interferometer.

We are now becoming interested in the generation of high power at the wavelength of optical transitions of atmospheric gases; the possibility exists that, because of resonant scattering, cross sections would be greatly enhanced, thereby enabling observation of the presence of even minor constituents in the upper atmosphere and in the laboratory. We are carrying out experiments to explore the practicality of carrying out observations at the following wavelengths: 6560.1 Å (He^+), 3582 Å (N_2^+), 6707.9 (Li), 5973 (O_2), 5889 (Na), 7698.9 and 7665.9 (K), as well as other transitions.

It would appear that it is possible to generate high outputs at these wavelengths by the combination of Raman effects, second-harmonic effects, and thermal tuning of laser light. The possibility of measuring the linewidth of resonant transitions in laboratory plasmas, by tuning the laser to a specific transition, suggests a method for the measurement of the concentration, as well as the temperature, of ionic species.

Further work on the laser scattering-diagnostic technique for plasmas, first developed in this laboratory, is now being carried out. We are making observations of incoherent scattering of pulsed ruby laser light in a reflex discharge and modifying the system to study the possibility of observing scattering from a CW Ar^+ laser light; the use of a relatively low-power, continuous source would be a great advance in the practicality of this diagnostic tool.

G. Fiocco

1. POSSIBLE RELATION BETWEEN DUST AND RAINFALL

Since the nucleating properties of dust provide a mechanism for starting the condensation of water vapor, the vagaries of weather might be somewhat related to fluctuations of the dust content of the atmosphere. Bowen[1,2] has furnished evidence that peaks in average amounts of daily rainfall followed, with approximately one month time lag, the dates of known meteor showers; this suggests that meteor showers influence world rainfall.

These results have been the object of controversy (see, among others, Martyn,[3] Kleine and Brier,[4] and Rosinski and Pierrard[5]). One criticism is that, because of the large variety of sizes expected in the dust influx and of the resultant difference in settling velocities, it would appear difficult to preserve the necessary coherence in the vertical transport process to determine detectable effects.

We have made observations of the dust content of the atmosphere at Lexington, Massachusetts, for almost 2 years, in 1964 and 1965, and data related to the stratospheric dust content are now available. The data were obtained by observing with an optical radar the echoes backscattered by atmospheric constituents and comparing their intensities with the returns that one would obtain from a dust-free atmosphere (see Fiocco and Grams,[6] and Grams and Fiocco[7]).

The optical radar technique is particularly sensitive to particles in the size range ~0.1-1 μ radius, since a transmitted wavelength, λ = 0.094 μ, is utilized. This is the typical spectrum of particle sizes obtained in the stratosphere by balloon and aircraft collections.

The dust content of the stratosphere during the period of study was an order of magnitude larger than usual, because of the injection of volcanic material following the eruption of Mt. Agung, in 1963. It is therefore doubtful whether any of the features of the stratospheric aerosol layer at the time of observation could be attributed to the influx of extraterrestrial dust.

Since our study has provided us with a record of the stratospheric dust content and its fluctuations, we have correlated the relative dust amounts at heights of 12 km and 16 km with the daily amount of precipitation averaged among 103 stations in New England,[8] in order to establish whether some relationship with rainfall might exist. Although the stratospheric dust smounts are probably not related to meteoric activity, one might expect the incursion of stratospheric dust into the upper troposphere to affect the amount of rainfall, regardless of the source. The time scale for stratospheric-tropospheric exchange is difficult to specify, however, since such processes are, at best, only poorly understood. The times involved in the vertical diffusion from the lower stratosphere to the upper tropopause may be several weeks (Junge et al.[9]). The length of time necessary to introduce stratospheric dust into the troposphere makes it almost naive to assume that a correlation between the two local parameters might be found. Our study of the stratospheric dust layer (Grams and Fiocco,[7]) indicated a degree of persistence of stratospheric dust amounts involving time periods of almost a week. Assuming a wind velocity of 20 m/sec, one may estimate the length scale of a stratospheric dust "cloud" to be of continental dimensions. This lends considerably more justification for comparing the rainfall figure for the New England states with the stratospheric dust

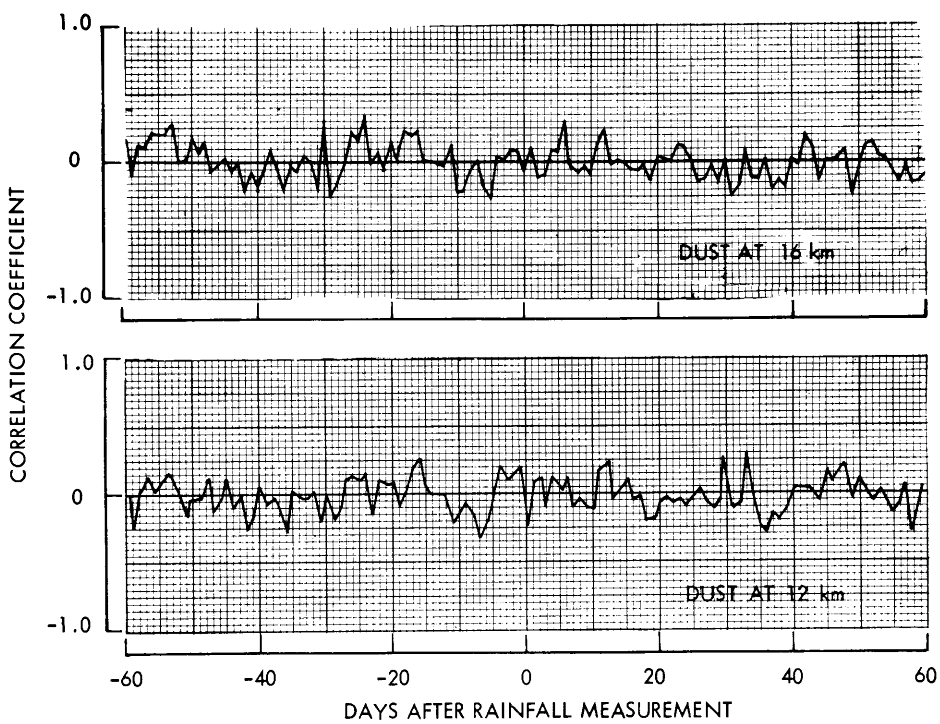

Fig. X-1. Correlation coefficient for rainfall and stratospheric dust measurements as a function of time lag.

measurements carried out at Lexington, Massachusetts.

The curves in Fig. X-1 show the correlation coefficient as a function of the time lag between the measurements of the dust content at different heights and the averaged measurements of rainfall. The correlation coefficients have been computed by using approximately 60 pairs of data. Although small positive peaks are apparent for time lags of 15-25 days, these might be ascribed to the limited size of our statistical sample. No evident trend exists to indicate a correlation between the two physical quantities.

Such correlations are only indirectly a test of Bowen's hypothesis. In order to establish a meteoric effect on rainfall, we should perhaps try to correlate mesospheric amounts of dust with rainfall. In fact, the mesospheric amounts of dust should be related to meteoric influx, and a local measurement of it should exhibit more global features than a local measurement of stratospheric dust. Data related to the mesosphere have also been collected and will be available for such analyses at a future data.

G. Fiocco, G. W. Grams

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