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Foreword

This informal progress report of Project HIAM, Grant No. NSG-499, is presented in four parts. The first three parts are summaries prepared by the three graduate students who are presently supported under the grant. [redacted]

James E. Miller

1. Summary of work of Richard S. Greenfield

The major effort on atmospheric breakers has been to extend the work previously reported by Greenfield (1963). A model has been developed which is more general than those previously considered. This model consists of a two-layer fluid resting on a solid, nonrotating parabolic surface. Thereby, the model can approximate a wave propagating over a mountain. The computations to determine the initial breaking point of an internal gravity wave initiated in such a model are being carried out by a graduate student on an IBM 7094 to be used in his Master's thesis. The student's work is being supervised by project personnel. In conjunction with this computational work, an attempt is being made to develop a perturbation solution for the breaking point in this model, analogous to the solution derived by Greenfield for the simpler model.

Also an effort is being made to locate data which might be useful in establishing the validity of the models as approximations to observable atmospheric phenomena. A literature survey of the work done on the mesometeorological observational networks is being done in connection with this aspect of the research. These networks are primarily research tools for gathering data on a scale which is between one and two orders of magnitude smaller than the scale at which routine meteorological data is gathered.

It is anticipated that both the computations and the perturbation solution for the latest model will be obtained in the near future. With these results and those reported earlier, it is hoped that other aspects of the atmospheric breaker may be examined and compared with atmospheric data obtained from one of the mesometeorological networks.

<u>Reference</u>

Greenfield, R. S., 1963: An analysis of breaking atmospheric waves. Final Report under Grant No. NSG-168-61, BREAKERS PROJECT, 56 pp.

2. Summary of work of Eugene Chermack

Introduction

In the study of the redistribution and transmission of electromagnetic energy through the atmosphere, gaseous absorption and molecular scatter has been given prime attention. The effect of particulate matter in the form of haze, dust, and complex droplets has thus far received scant attention. Lack of information as to the physical composition of the atmospheric aerosol has been the main drawback to the study of aerosol optics. In principle, if one determines the composition and distribution of aerosol particles, the scattering and absorption properties of the atmospheric aerosol can be calculated.

The work on this project so far has been in the nature of a literature search, some of the results of which follow.

The Atmospheric Aerosol

The size distribution, height distribution, and composition of the atmospheric aerosol particles must be known before any answers to optical properties can be obtained. Although the term "optical" applies strictly to the visible region of electromagnetic radiation, for the sake of brevity in this report, optical properties will mean all electromagnetic transfer properties including U-v, visible, and I-R.

Junge's works (1961a,1961b) did much to further the knowledge of the aerosol. He found that, in the range of the optically significant particles, the size distribution of particles followed a simple inverse power law. In addition, his chemical analysis of the aerosol should prove an invaluable guide as to the composition of atmospheric particulate matter. The most common radicals found in Junge's collections seemed to be NH_4 and SO_4. Currently this project is concerned with the refractive index frequency dependence of ammonium sulfate.

More recent work by Fenn (1962) has revealed an interesting feature of aerosol size distributions. It appears that the aerosol does not follow a continuous distribution as Junge has found but occurs rather in discrete size ranges. The magnitude and size of these discrete distributions depends on time and locality. However

the peaks of the discrete concentrations were found to lie along the line of the profile as found by Junge. This discrepancy between Junge's and Fenn's results probably arises from the better size resolution obtainable through the latter's longer sampling times. It seems likely that meaningful size and height distributions of the aerosol can be constructed based on the observations of Fenn and Junge, and thus the model problem should reduce to one of aerosol composition (and therefore optical properties as determined by the refractive index of the substance involved).

Aerosol refractive index

In general the refractive index of a substance assumes a complex form, the imaginary part of which is related to the degree of absorption a substance exhibits. Non-absorbing particles will have a real refractive index. The index for a given substance is a function of wavelength and it is usual for a selective absorber to have a real refractive index over part of the E-M spectrum and a complex refractive index in other regions of the spectrum (this is true, for example, in the case of water.)

Much of the literature search so far has been concerned with the wavelength dependence of the refractive index. Thus far, it appears that little has been determined about the indices of the inorganic substances found in aerosols. Van de Hulst (1957) tabulated some refractive indices for substances such as water and a few metals as a function of wavelength, but neglected to indicate the source of this information. It may become necessary to determine experimentally the refractive indices pertinent to the aerosol if, as seems to be the case, these are not in the literature.

In principle, given a model profile and suitable refractive indices, one can calculate such parameters as aerosol absorption cross section, scattering cross section and therefore extinction cross sections as well as angular intensity functions. Thus one obtains all information necessary to determine the absorption and redistribution of E-M radiation by the aerosol. Several workers have done this on a limited basis. Fenn (1962) has had calculations made for carbon particles coated

with various thicknesses of water as a function of size parameter. He used a refractive index of carbon of 1.59 - 0.66 i and did not consider its wavelength dependence (if any existed.) Calculations were carried out by Deirmendjian (1960) for several complex refractive indices (mainly those suggested by van de Hulst) which further indicate the feasibility of calculations.

The literature search will continue with hopes of finding pertinent refractive index data. Meanwhile the feasibility of an experimental program to determine the required indices will be considered.

Bibliography

Deirmendjian, D., R. Clasen, and W. Viezee, 1961: Mie scattering with complex index of retraction. JOSA, vol. 51, pp. 620-633.

Fen, R., 1962: Personal communication.

Junge, C. E., and J. E. Manson, 1961a: Stratospheric aerosol studies. Journ. Geophys. Res., vol. 66, pp. 2163-2182.

Junge, C. E., C. W. Chagnon, and J. E. Manson, 1961b: Stratospheric aerosols. J. Meteor., vol. 18, pp. 81-108.

van de Hulst, H. C., 1957: Light Scattering by Small Particles. Wiley and Sons, New York, 470 pp.

3. Summary of work of Joseph S. Hogan

The research work I have been engaged in since June may be divided into three parts:

I. For a few months preceding June 1963, and during the period from June through Mid-August, I had been directing my efforts toward an evaluation of the magnitude of the amount of ozone produced in the lower atmosphere by electric discharge phenomena associated with thunderstorms, and a comparison of this quantity with the amount of ozone produced at higher levels by the photochemical processes accompanying the atmospheric absorption of solar ultra-violet radiation.

To these ends I first examined the opinions expressed in the literature and found that two schools of thought existed on this subject, one holding that thunderstorm production of ozone was quite large while the other considered it negligible. Both of these opinions were based on large scale energy-dissipation estimates involving rather questionable assumptions. What I attempted to do was examine the actual physics of the problem in enough detail to uncover any fallacies in previously reasoned arguments and thus obtain a more realistic estimate of the actual amount of ozone produced by thunderstorms.

I found that the lightning process is an extremely complicated one and that all of the parameters involved vary widely over the globe and with time in any one place. Statistically, however, one type of lightning discharge is most common, a "stepped-leader", three-stroke, cloud to ground flash; rather realistic averages of the cloud heights, current magnitudes and time scales are available for the description of this "typical" phenomenon. It was hoped to eventually treat the physics of this phenomenon in fine detail and thus obtain an estimate of the products of such a process to determine the amount of ozone which would result.

I attempted to explain the stepped-leader process by first examining a highly simplified model: a cylindrical volume throughout which electrons are uniformly distributed is considered to exist in otherwise empty space in which an external electric field is directed along the axis of the cylinder. This volume is allowed

to expand under the action of the internally produced field, and the field vector at points both inside and outside the charge distribution is computed for different times after release. Thus the motion of the charge under these conditions can be deduced. The symmetry of the model allows the resultant electric field vector to be described by two components, axial and radial. These two components are exactly expressible only in terms of two impossible volume integrals which must be approximated numerically-graphically.

Not being able to program these integrations due to my unfamiliarity with computing machines, I began to approximate the integrals by manual methods. This work became overly time-consuming and burdensome so that toward the latter part of the summer I decided to abandon it for the time being with the thought of returning to it after vacation in September and of better acquainting myself with computer methods in the interim.

I decided on the advice of my advisor to discontinue my work in this field and to engage in some other research in which I had interest and which might lead directly to a doctoral dissertation.

II. From the time of our meeting with Dr. Jastrow in early October, until mid-November, I was engaged in seeking out a suitable area of research which might lead to a doctoral dissertation and at the same time be of interest to NASA and myself. This investigation involved general reading in the field of planetary atmospheres as well as meetings with C. Prabhakara and S. I. Rasool of the Institute for Space Studies. These gentlemen offered several interesting problems for my consideration and suggested many related readings. Out of the many problem areas which were considered, I feel that my energies might best be spent in an investigation of the physical properties and circulation of the planet Jupiter. Knowledge of this planet is scanty. Its composition is guessed at, its temperature range is unknown, and even its physical appearance which is clearly observable with a large telescope is anything but clearly understood. In addition, little formal research has been done on this planet, as compared with the many investigations of Mars and Venus.

During the time mentioned, therefore, I familiarized myself with general background material on planetary atmospheres, decided on a field of research in which to proceed, and built up a sizeable bibliography on the planet Jupiter itself.

III. In mid-November, I set aside my work on Jupiter temporarily to give time to a problem in which NASA and Dr. Rasool himself are apparently greatly interested - the ozone distribution and consequent heating on Mars. Using the same relationships derived for photo-chemical equilibrium in the earth's atmosphere, I substituted Martian values for the various parameters to obtain a solution for the Martian atmosphere. This had already been done by others who assumed a surface pressure of $\sim$80 mb. It has recently been shown, however, that the Martian surface pressure is $\sim$20 mb and, since the solution of the equilibrium equations is quite sensitive to pressure, the calculations must be redone. To obtain a solution for the ozone distribution an iterative procedure was used. First, it was assumed that no ozone was present and that all attenuation of solar ultra-violet light was made by molecular oxygen, and a preliminary ozone distribution was obtained in this way. These values of ozone number density were substituted back into the equations and new values (smaller) obtained. This same procedure was repeated again.

The results of my calculations indicate the presence of an ozone layer on Mars with a maximum of $\sim 10^{12}$ ozone molecules per cm^3 at a height of $\sim$25 km and a total ozone content of 0.17 cm ATM. These values are not very different from their counterparts on earth. The value of 0.17 cm ATM is above an upper limit set on the ozone content on Mars of 0.05 cm ATM by spectroscopic observations. This can only mean that the amount of oxygen actually present on Mars must be smaller than the value we have assumed - how much smaller I intend to determine. Recently, from the ozone profile I have determined heating rates which are rather high. But since a more modest estimate of oxygen content will lower the ozone content, the heating rates will also be reduced. I am working on this aspect of the problem at present. When more moderate heating rates are obtained, I intend to determine a temperature profile for Mars also.