POLYTECHNIC INSTITUTE OF NEW YORK

Department of Meteorology and Oceanography

July 1975

BASIC RESEARCH IN METEOROLOGY AND ATMOSPHERIC PHYSICS

Final Report for the Period

1 January - 31 June 1975

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Principal Investigator

NASA Grant No. NSG 5041

Project HIAM II

(NASA-CR-143491) BASIC RESEARCH IN METEOROLOGY AND ATMOSPHERIC PHYSICS Final Report, 1 Jan. - 31 Jun. 1975 (Polytechnic Inst. of New York.) 11 p HC $3.25 CSCL 04A

N75-31617

Unclas

G3/46 35072

EFFECT OF THE VARIATIONS OF THE ELECTROMAGNETIC PROPERTIES OF THE THREE PHASES OF WATER ON MEASUREMENTS OF ATMOSPHERIC AND OCEANOGRAPHIC PARAMETERS BY MICROWAVE INSTRUMENTS ABOARD SATELLITES

By

Charles P. Keller

One of the major concerns of global atmospheric circulation models and ocean state prediction models is the magnitude of the effect of water due to its dielectric properties in contributing to satellite-observed radiation measurements. In this connection a knowledge of the emissivity of water and consequently of the sea surface is necessary for proper interpretation of satellite data.

The Fresnel equations relate the reflectivity, r, to the dielectric constant (relative permitivity) which is a function of frequency, ν, and temperature, T, to that emitted by a theoretical black body over the same frequencies, ν, and at the same temperature, T, the following expression results. (Chow, 1971).

$$e\,(T) = \frac{\int (1 - r\,(\nu, T)\;\; B\,(\nu, T)\, d\nu}{\int B(\nu, T)\, d\nu}$$

During this research period I have searched for information on the relative permittivity of water.

In general the relative permittivity is a complex quantity designated as $\epsilon^{*} = \epsilon - J\epsilon'$ or $\epsilon^{*} = (\eta - J\kappa)^{2}$ where J is the imaginary term equaling $\sqrt{1}$. From this $\epsilon = \eta^{2} - \kappa^{2}$ and $\epsilon' = 2\,\kappa\eta$ where,

η = refractive index. κ = absorption coefficient, i. e., the factor to which the amplitude of the electromagnetic wave is reduced when traversing a distance of one wavelength in vacuum.

The Debye equation relates the quantities ϵ and ϵ' by means of the electromagnetic angular frequency ω, and a relaxation time τ which is the time required for molecules to respond to the applied field. The Debye equations for polar molecule's (water is polar) can be used in the microwave region for water. The inaccuracy in these quations increases as $\omega\tau >> 1$.

The relaxation time for water ranges for $0^\circ C$ to $30^\circ C$ from 17.7 to 7.1 picoseconds, respectively. This is a variation of 60% (National Bureau of tandards). Thus with frequencies from 1 GH_z to 100 GH_z , $\omega\tau$ varies from 0.1 to 4.45, respectively, which is still less than a factor of ten times 1. At frequencies higher than 1 MH_z , and for molecules that have fixed relaxation times, τ, values for the complex permittivity or ϵ and ϵ' can be calculated using the following Debye Equation which consists of a constant part ϵ_∞ and a polar part which varies with frequency and temperature.

$$\epsilon = \epsilon_\infty + \frac{\epsilon_o - \epsilon_\infty}{1 + \omega^2 \tau^2}$$

$$\epsilon' = \frac{\omega \tau (\epsilon_o - \epsilon_\infty}{1 + \omega^2 \tau^2}$$

with $\epsilon_\infty = 5.0$

where $\epsilon_o = 88.15 - 41.4\theta + 13.1\theta^2 - 4.6\theta^3$

and $\theta =$ Celsius per 100 C

(E.H. Grant, 1967)

and τ is given by:

$\tau =$ constant $e^{v/KT}$

where v activation energy (see Table 1)

In the above I have discussed liquid water. Now a short comment on water vapor. Since water is strongly polar a good approximation for relative permittivity is:

$$(\epsilon - 1) \quad \alpha \quad \frac{\text{Partial pressure of water vapor}}{(\text{absolute temperature})^2}$$

or in general the relative permittivity of a mixed gas is

$$(\epsilon_i - 1) \quad \alpha \quad \frac{Pc}{(\text{absolute temperature})^2}$$

provided that the vapor isn't near its condensation point. From above the total relative permittivity of a mixture of gases is:

$$(\epsilon - 1)_{\text{Total}} = \sum_{i} (\epsilon_i - 1) \;\alpha\; \sum \left(\frac{Pc^{o}}{(\text{absolute temperature})^{2}} \right)$$

(GWC Kaye and T. H. Lany, 1973)

I would like to acknowledge Dr. Joseph Hogan, who advised me, for his thoroughness in guiding through the various aspects of this project.

TABLE 1

T($^{\circ}$C)	0	10	20	30
τ (Picoseconds)	17.7	12.6	9.2	7.1

REFERENCES

Chow, Ming-Dah, 1971: Calculation of Infrared Flux at the Sea Surface, Geophysical Science Laboratory of New York University, Department of Meteorology and Oceanography Report TR 71-1.

Grant, E. H. and R. Shack, 1967: *Br. T. of Appl. Phys.* pg. 1807.

Kaye, G.W.C. and T. H. Laby. 1973: *Tables of Physical and Chemical Constants,* 14th ed., Longman Group Ltd., London pg. 116.

National Bureau of Standards, 1958: *Dielectric Dispersion Data for Pure Liquids,* Cicrular No. 589, Table 3.

ORBITAL DETECTION OF EXTRASOLAR PLANETS

By

Gregory Matloff

In the June 1975 issue of JBIS, the final consideration of extrasolar planet detection using the Large Space Telescope in earth orbit or lunar orbit and the moon as an occulter was published, in a paper coauthored by me and Dr. A. J. Fennelly of Western Kentucky University. This paper considers photometric aspects of detecting planets of other stars, such as Signal to Noise Ratio (S/N), photon count, and Image Retrieval. The use of several LST's to construct an optical interferometer is considered. It is reasonable to expect that planet searches using photometric techniques can be instituted after the LST is launched in 1980, at least for the stars Alpha Centauri, Epsilon Eridani, and Tau Ceti.

I am currently preparing a critical review paper of optical schemes for extrasolar-planet detection, at the invitation of Dr. Anthony Martin, Editor of the Interstellar Studies section of the British Interplanetary Society. This paper, which is now being typed, discusses and compares optical systems that have been proposed for operation on the earth's surface, from earth orbit, and from the surface of the moon. It is hoped that the manuscript will be submitted this summer and that it will be published in 1976.

DETECTION OF STRATOSPHERIC AEROSOLS FROM EARCH ORBIT

By

Gregory Matloff

About 70% of the first draft of my Ph. D. thesis on this subject has been completed and is now being reviewed by Dr. R. Stewart of GISS. The thesis discusses a proposed system of aerosol monitoring above 15 km using orbital extinction measurements of stars setting through the stratospheric aerosol layer. Off-the-shelf celestial navigation systems (star trackers) using S4 and S20 spectral response photomultipliers are the basic optical elements of the detection system.

Calculation of extinction caused by molecules, ozone absorption, refraction, and aerosols are complete, for both sensors and stars of color temperature in the range 3,000 -- 20,000 K. I still must describe how the height distribution of the stratospheric aerosols can be obtained.

An unexpected bonus of the 2-sensor approach is that while both S4 and S20 response detectors can be utilized as aerosol detectors, the S-20 is much more sensitive to variations in the ozone layer. Thus, simultaneous monitoring of stratospheric ozone and aerosol seems feasible.

CHEMISTRY OF JUPITER'S ATMOSPHERE

By

Joseph Pinto

One of the classical problems of the study of planetary atmospheres is explaining the continued presence of molecules which are subject to photochemical dissociation. Methane and ammonia are trace constituents of the Jovian atmosphere, present with mixing ratios of 10^{-3} and 2×10^{-4} by volume, respectively, and are both subject to photodissociation. Photochemical destruction of methane and ammonia occurs, however, in spatially separated regions of the atmosphere. Methane destruction takes place primarily in the stratosphere and mesosphere, while ammonia destruction occurs mainly in the troposphere.

Methane dissociates into free radicals (CH_1 CH_2) and hydrogen. These free radicals will react among themselves and with the abundant hydrogen in the Jovian atmosphere to yield more complex hydrocarbon radicals and molecules. A large fraction of the methane dissociated in the Jovian upper atmosphere is recycled, the part which is irreversibly destroyed ($\sim 20\%$) goes into the production of more complex hydrocarbons. The primary products of ammonia photolysis are amino radicals (NH_2 groups) and hydrogen atoms. The hydrogen atoms liberated may either react with amino radicals to effectively recycle ammonia or react with hydrocarbon free radicals, which are transported downward, to yield more stable hydrocarbon molecules. The latter option seems the more likely.

The net columnar destruction rate of methane without the inclusion of a source of hydrogen atoms due to ammonia photolysis is in the order of 2×10^9 mol cm^{-2} sec.$^{-1}$ The net destruction rate after inclusion is closer to 1×10^9 mol cm^{-2} sec^{-1}. The net production of other molecules, such as methane, ethylene and acetylene, are also increased due to the destruction of free radicals.

At the temperatures of theJovian troposphere, which may reach 270 K at the 4 atmosphere level, Hogan (1974), the activation energy barriers which exist for certain reactions may be effectively surmounted. With a large source of hydrogen atoms, as from ammonia photolysis, it is then conceivable that more rapid and complex chemical processes leading to the formation of more higher order hydrocarbons are present in the Jovian troposophere.

Reference

Hogan, J., 1974: Private communication.

STRATOSPHERIC OZONE

By

Joseph Pinto

The distribution of stratospheric ozone is governed by a number of diverse physical processes, among which are those concerning transport, chemical kinetics and radiative transfer in the ultra-violet, visible and infra-red regions of the spectrum.

A numerical model designed to study the meridional, zonally and reasonally averaged distributions of equilibrium temperature, ozone and other trace species concentrations is currently under development. A comprehensive chemical scheme, which includes 100 chemical kinetic and photodissociation reactions involving 42 trace constituents, is being incorporated into the model. The model's domain of integration currently extends from 90° S to 90° N latitude and from 9 to 50 km in the vertical.

Preliminary results using only the Chapman photochemical scheme show, qualitatively, the correct latitudinal variation of columnar ozone abundances, although those computed are higher at all latitudes than observations. This indicates the importance of trace constituents such as the oxides of nitrogen, hydrogen and chlorine and carbon bearing compounds in regulating ozone abundances in the stratosphere.