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Optical Properties of the Atmosphere

Contract F19628-68-C-0233

Six Month Technical Summary No. 1

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Prepared for

Air Force Cambridge Research Laboratories

Office of Aerospace Research

United States Air Force

Bedford, Massachusetts

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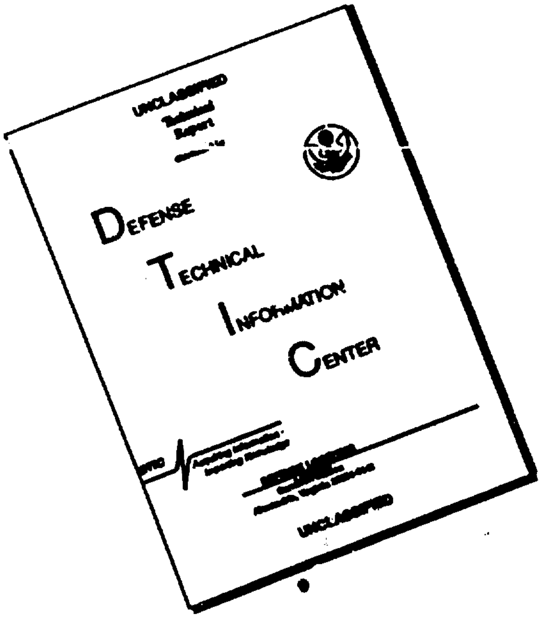

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I. INTRODUCTION

An understanding of the interaction between infrared radiation and the earth's atmosphere is necessary in a number of disciplines. The accuracy with which the interaction can be predicted has increased significantly in recent years due to the availability of large computers, better laboratory data, improved instrumentation, etc. The accuracy required has also increased so that the accuracy currently achievable is less than required, and both the theoretical and experimental programs have to be refined in order to achieve the accuracies desired. Our group has been engaged in a continuing program to develop theoretical calculations for predicting their interactions and to gather experimental data pertinent to the problem, particularly at high altitudes. Data pertinent to this problem have been and will be obtained by recording the solar spectrum in various wavelength intervals at various altitudes above the earth's surface during a series of balloon flights. Data of this sort are suitable for comparison with calculations in the wavelength regions where the residual absorptions at high altitudes exceed a few percent. In other wavelength regions (the so-called windows) the residual absorptions may be several orders of magnitude less than a few percent. The transmittance data cannot be obtained with sufficient accuracy for measurements of this sort. Data pertinent to these regions will be obtained by measuring the background radiance in their wavelength regions using ultrasensitive radiometers.

Although this is called a six-month summary, the period covered is only three months since the contract started April 1. During this period a balloon flight was made to obtain transmittance data in the 2.7μ region, and two flights have been made to obtain data concerning the background radiance in various wavelength regions at high altitudes. Reduction of the data obtained during the last flights made under the preceding contract has been completed and analyses of these data are in progress. A summary of the flights and discussions of the significant features of the analyses are given below.

2. FLIGHT DETAILS

2.1 Transmittance Flight

Whenever discussions arise concerning precision measurements from balloons where water vapor could affect the measurements, the question of possible contamination of the measurement by water vapor outgassed from the balloon comes up. Unfortunately, a lot of inaccurate data, misinterpreted data and pure fiction exist concerning the contamination that can arise from the balloon. In order to obtain quantitative data concerning this problem, a joint flight was arranged with the group from the Canadian Armament Research and Development Establishment, who have instrumentation to obtain solar spectra in the 2.7μ region from a B-57 aircraft. The flight plan called for the aircraft to follow the balloon up in altitude insofar as possible from 10 km to 18 km. The balloon was to be stopped at 18 km for an hour to make sure data were obtained by both the aircraft and the balloon instrumentation at a common altitude. The balloon was then to ascend to float altitude. The absorptions due to water vapor in the vicinity of 2.6μ, as observed in the spectra obtained from the balloon, were to be compared with those obtained from the aircraft. The balloon was launched at 0602 MST, April 24, and an average ascent rate of 250 m/min. was established. When the balloon had reached 17 km, helium was valved in order to stop the balloon at 18 km. Some difficulty was encountered in valving and the balloon overshot the desired altitude. More gas was valved and a descent was established and the balloon levelled off at 18 km. The balloon was allowed to remain at that altitude for an hour. At this time ballast was dropped and the balloon started ascending again. The balloon was allowed to ascend until it reached floating altitude (31 km). The flight was terminated at 1245 MST to facilitate recovery. The equipment was recovered without incident. The aircraft followed the balloon ascent as closely as possible after the balloon had reached an altitude of 14 km and made a number of data gathering runs at 18 km while the balloon was at that altitude.

Discussions with the personnel from C.A.R.D.E. after the flight revealed that they had an instrument malfunction and obtained data only during a short period when the aircraft and balloon were at an altitude of 16 km. Examination of the data obtained with the balloon instrumentation indicated that the temperature control unit on the spectrometer malfunctioned early in the flight. The unit recovered, however, and operated properly during the latter part of the flight. The lack of thermal control caused the optical alignment to shift slightly with a resulting loss of signal. Solar spectra were recorded but with low amplitude. Once the unit started operating again, proper alignment was achieved and excellent spectra were obtained throughout the remainder of the flight. At the time the CARDE data were obtained, the balloon spectra obtained were of low amplitude. It has been possible to obtain data concerning the water vapor absorption at this time; however, the scatter is greater than it would have been if the unit was operating properly. The absorption data obtained at this time agree quite well with the data obtained by CARDE. At these altitudes the contribution of any contamination to the measurement appears to be negligible.

2.2 Background Radiance Flights

Two flights have been made during this period with the AVCO cold aperture radiometer. The first flight was launched at 2340 MST April 19 from Holloman AFB. The balloon was allowed to ascend with average ascent rate of 250 m/min. until it reached floating altitude (31 km). Helium was valved after the balloon had been floating for about 30 minutes and a descent rate of 75 m/min. established. The balloon was allowed to descend until it reached an altitude of 18 km when the flight was terminated. The equipment was recovered in excellent condition.

Previous flights with this unit indicated that the background radiance above 18 km was below the sensitivity of the radiometer. The radiometer had been modified for this flight in order to increase the sensitivity. This modification consisted of mounting a single filter directly in front of the detector where it could be cooled to approximately liquid helium temperatures. The telemetered data indicated that the background radiances were too low. Examination of the instrumentation after it had been recovered indicated that a deposit had been formed on the window due to a preflight malfunction in the antifrost system. This reduced the transmittance to the point that no meaningful data were obtained during the flight.

The radiometer was flown again on June 29. The instrumentation was launched at 0615 MDT. The balloon ascended with an average ascent rate of 250 m/min. and reached a floating altitude of 31 km. The balloon was allowed to float for a short period, then helium was valved and a descent of 100 m/min. established. The flight was terminated at 1151 MDT to facilitate recovery. The equipment impacted north of Truth or Consequences, New Mexico, and was recovered in excellent condition.

For this flight the radiometer was equipped with filters that passed radiation in the region from 18μ to 22μ. Examination of the data obtained during the flight indicates that everything operated properly and data were obtained throughout the flight. The data are currently being analyzed.

3. DATA ANALYSIS

In addition to the balloon flights mentioned above, data have recently been obtained during three transmittance flights during which the wavelength regions from 6.2μ to 10μ, 10μ to 20μ, and from 4.7μ to 6.2μ were scanned. All three of these flights were launched in the afternoon, and solar spectra were obtained from float altitude (31 km) as the sun set. Reduction of the data obtained during these flights has been completed and preliminary data from two of the flights have been sent to groups known to have an interest in such data. The regions scanned contain many absorption features due to H_2O, CO_2, NO_3, and $C H_4$. Preliminary analysis of the absorptions observed during these flights has been concentrated on the following features: The setting sun spectra obtained during the flight made December 7, covering the region from 6.2μ to 10μ, revealed an enhanced absorption at 1326 cm^{-1} (~7.5μ). Detailed examination of the spectra obtained indicated that this was the Q branch of a large moment of inertia molecule and that the P and R branches were also present but that because of the narrow spacing of the rotational lines the individual rotational lines were not observable. A search of the literature concerning the absorptions due to various oxides of nitrogen indicated that HNO_3 was a possible source of the observed absorption. On the basis of some laboratory spectra obtained with the balloon-borne spectrometer using an absorption cell containing HNO_3 vapor, it was concluded that the absorption observed was due to HNO_3. The way the absorption grows as the sun sets indicates that the gas is layered and probably associated with O_3. A short note discussing these results has been published in the April 6 issue of Nature.

3.1 The 6.3μ H_2O Absorption Band

The absorptions due to a number of groups of lines in this region have been analyzed in order to determine the water vapor mixing ratio as a function of altitude in the stratosphere. Particular emphasis has been placed on the absorptions observed as the sun sets since the long atmospheric path traversed by the radiation in reaching the spectrometer in these cases increases the absorption to the extent that any effect due to contamination is negligible. The mixing ratio versus altitude profile has been determined from these data for the altitudes in excess of 20 km and a report is in preparation discussing these results.

3.2 The 15μ CO_2 band

The absorptions observed during the December 2 flight due to the 15μ CO_2 band are being compared with those predicted theoretically using a line by line integration technique. Two programs are being used in this comparison. The one is one developed by Dr. Kyle of our group and the other is one developed by Dr. Drayson of the University of Michigan. Unfortunately, there are no laboratory data available giving high resolution spectra for this region obtained with known amounts and pressure environment for the CO_2. It was hoped that it would be possible to confirm the decrease in CO_2 mixing ratio above the tropopause determined on the basis of absorptions in the 2.7μ and 4.3μ regions. The uncertainty in the band parameters may preclude this possibility since any differences between observed and predicted absorptions may be accounted for by inaccuracy in the band parameters. The results obtained with the two theoretical calculations are in good agreement; however, there are a few regions where significant differences occur. Comparisons with the observed spectra should determine which program is more accurate.

3.3 9.6μ Absorption

The absorptions observed in the region from 9.0μ to 10μ due to O_3 have been compared with the theoretical absorptions calculated on a line by line basis using the molecular parameters given by Clough and Kneizy.[1] The calculated absorptions are in good agreement with observed absorptions as long as the solar zenith angle was less than 90^o. Where the zenith angle reached 90^o and more and the absorptions became intense, significant differences appeared. The observed absorptions are greater than predicted. It was thought initially that there was another absorber present which was layered and only contributed significantly when the zenith angle was more than 90^o. Subsequent analysis has indicated that the differences are due to isotopic effects. The strength of this contribution is rather unexpected since the isotopic abundance is so small. The results emphasize the fact that many factors which would appear to be insignificant can make a significant contribution to the absorption under the proper conditions.

3.4 The Absorption at 5.8μ

During the flight made March 22 solar spectra covering the region from 4.5μ to 6.2μ were obtained from 31 km as the sun set. The long atmospheric path traversed by the radiation in this case enhanced the absorptions due to a number of the weaker bands. Most of the absorptions observed have been identified with the exception of one strong absorption feature at 5.8μ. Part of the observed absorption is due to a weak O_3 band; however, the overall shape of the observed absorption is such that it does not appear that the O_3 absorption can account for all of the observed absorption.

REFERENCE

[1] S. A. Clough and F. X. Kneizys, "Ozone Absorption in the 9.0 Micron Region," Scientific Report AFCRL-65-862, (1965).