NASA CR-122486

080410-1-F

THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
SPACE PHYSICS RESEARCH LABORATORY

FINAL REPORT: OGO-VI DATA ANALYSIS

PREPARED ON BEHALF OF THE PROJECT BY

D. R. TAEUSCH

RECEIVED
NASA STI FACILITY
INPUT BRANCH
OCT 1972

UNDER CONTRACT WITH:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
CONTRACT NO. NAS5-9328
GREENBELT, MARYLAND

(NASA-CR-130058) OGO-6 DATA ANALYSIS Final Report, 29 Apr. 1966 - 30 Jun. 1972 D.R. Taeusch (Michigan Univ.) Aug. 1972 15 p CSCL 22C
N72-32813
Unclas
G3/30 42081

ADMINIST

OFFICE OF RESEARCH ADMINISTRATION · ANN ARBOR

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Final Report: OGO-VI Data Analysis		5. Report Date August 1972 6. Performing Organization Code
7. Author(s) D. R. Taeusch		8. Performing Organization Report No. 080410-1-F
9. Performing Organization Name and Address Space Physics Research Laboratory, Department of Electrical and Computer Engineering, College of Engineering, The University of Michigan, Ann Arbor, Michigan 48105		10. Work Unit No. 11. Contract or Grant No. NAS5-9328
12. Sponsoring Agency Name and Address Goddard Space Flight Center Greenbelt, Maryland 20771		13. Type of Report and Period Covered Final, 29 April 1966-30 June 1972 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The present report gives a general summary of the results of the data reduction effort for the OGO-VI Neutral Atmosphere Composition experiment.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Quadrupole mass spectrometer Gas-surface interaction model Winter Helium bulge	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	15	$3.00

TABLE OF CONTENTS

1. INTRODUCTION

The Space Physics Research Laboratory of The University of Michigan, in collaboration with Goddard Space Flight Center, Laboratory for Planetary Atmospheres, provided the instrumentation for the OGO-VI Neutral Atmospheric Composition experiment. Following the successful launching of OGO-VI, the NAC operated successfully on an essentially full-time basis for the two years of operation of the satellite, providing atmospheric composition data during all seasons, local times, and latitudes.

The data obtained from the NAC experiment are of excellent quality, and have helped to uncover many previously unobserved phenomena. Also, the data have made possible further studies of gas-surface interactions within the mass spectrometer, thereby significantly augmenting confidence in the reduced data, and enhancing the integrity of the instrument for future experiments.

2. SATELLITE AND INSTRUMENTATION

The OGO-VI satellite was launched on June 5, 1969. Its orbit had perigee and apogee altitudes of approximatley 400 and 1100 km, respectively, and an inclination of 82°. The motion of the line of apsides (-3°/day) and the precession of the orbit plane (-1°/day inertial, -2°/day solar), along with virtually continuous operation of the NAC experiment have served to provide coverage of atmospheric composition over widely ranging altitudes, latitudes, and local times.

The mass spectrometer is a closed source quadrupole instrument with a small orifice oriented continually into the orbit plane of the satellite toward the direction of the velocity vector. Atmospheric gas particles enter through the orifice into an antechamber, where they interact thermally and chemically with the surfaces prior to ionization by a 90 V electron beam. The ions are directed into a quadrupole analyzer, where they are separated according to their e/m ratio. The selected ion strike the first dynode of a multiplier. The resulting multiplier output pulses are counted, and the measured count is proportional to the number density of the selected mass in the antechamber.

The instrument has three basic modes of operation. The bulk of the data has been obtained in the "stepping" mode, in which the analyzer is sequentially tuned to preselected masses, namely amu 2, 4, 16, 28, 32, and total. This sequence is repeated every 9 sec, providing a spatial resolution of about 70 km. Periodically (every 6 min) or continuously on command, the entire mass range from 1 to 46 amu is scanned in 55 sec. The third mode, on command, permits fixed tuning to any of the preselected masses above, and thus for a single mass the spatial resolution can be decreased to about 0.5 km.

3. DATA REDUCTION

The data reduction effort was undertaken jointly by the Laboratory for Planetary Atmospheres, Goddard Space Flight Center, and the Space Physics Research Laboratory, The University of Michigan, with all of the production being performed by the Goddard Space Flight Center computers. The telemetered experiment output is reduced in a two-step process that yields first source density and finally ambient density. The process which yields ambient densities from the reduced source densities involves applying the usual kinetic theory of gases as well as the gas-surface interaction model developed from these data.

The output of the first step in the process was the constituent density in the instrument ion source. This approach permitted proceeding with the data reduction prior to the availability of the ancillary data (position, velocity, altitude, etc.) and also postponed the need for the gas-surface model.

At the same time a major effort was undertaken, again jointly by GSFC and The University of Michigan, to characterize the gas-surface interactions so that the source densities could be related to the ambient densities. Examination of the source density plots immediately indicated that the OGO-VI NAC experiment was measuring variations in the neutral atmospheric composition that had not previously been observed. Some interpretive work was done with these early data, but the major effort was addressed to solving the several problems standing in the way of large scale production of ambient density. In early 1971 a gas-surface model was completed and, following the programming of the model into the ambient density reduction process, the final phase of data reduction was begun. By the end of 1971, the reduction of virtually all of the measured data to ambient densities had been completed.

4. RESULTS

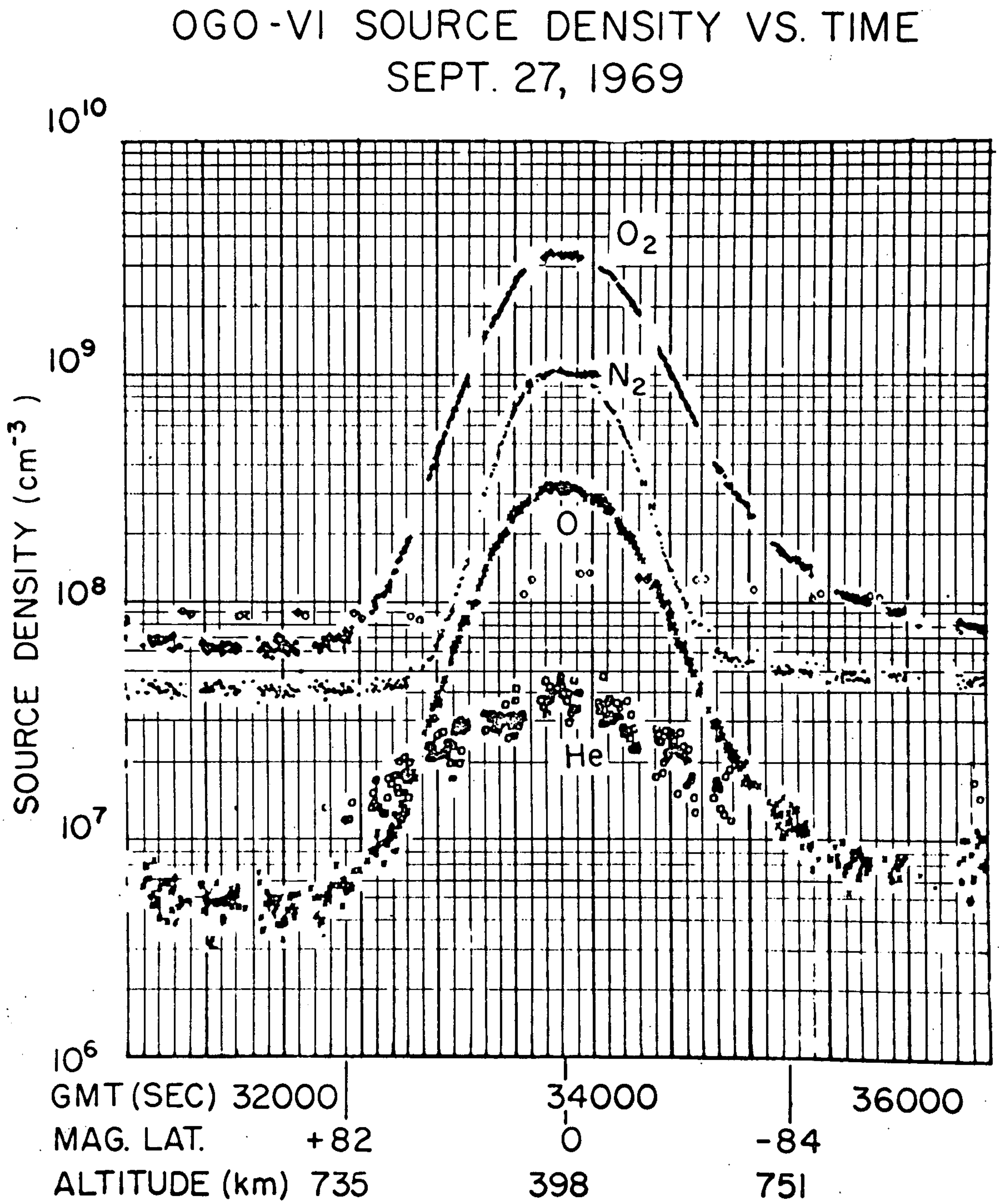
The OGO-VI NAC data have been used in several studies which have contributed to an increased understanding of the neutral atmosphere. The highlights of these studies are reviewed briefly below. Included is a discussion of the gas-surface interaction study made possible by the measurements and necessary for their interpretation.

4.1. Gas-Surface Interaction

In the closed-source instrument, the ambient gas undergoes many surface collisions before ionization and subsequent analysis. As a result of this interaction between the gas and the surfaces, the composition of the source density differs significantly from the ambient. The most striking manifestation of this is seen in Figure 1 in the abundance of O_2 in the source. The atomic oxygen is largely recombined and is measured in the molecular form. The measured mass 16 is very near the fractionation value for a pure O_2 measurement, which indicates that the atomic oxygen is almost totally recombined. Less obvious, but of great importance to the interpretation of the measurement, are the effects of adsorption and desorption. The measured values of 28 amu and 32 amu at apogee, for example, are the result of desorption of gases from the surface.

A surface model has been developed that takes into account the adsorption-desorption process in a physically reasonable manner, including the chemical and physical interactions on the surface that lead to the production of CO, CO_2, and NO. A paper concerning this gas-surface model was presented at the Fall AGU Meeting (1971) and has been submitted for publication.

Figure 1


OGO-VI SOURCE DENSITY VS. TIME
SEPT. 27, 1969
10^{10}
10^9
10^8
10^7
10^6
SOURCE DENSITY (cm^{-3})
O_2
N_2
O
He
GMT (SEC) 32000
34000
36000
MAG. LAT. +82
0
-84
ALTITUDE (km) 735
398
751

4.2. Atmospheric Variations during Geomagnetic Storms

One set of data made available early in the reduction effort was for the period between September 27 and October 3, 1969, during which a geomagnetic storm occurred. It was apparent from a study of the data that the current theories and data interpretations did not describe the neutral composition atmospheric variations during magnetic storms realistically. A paper discussing this topic was presented at the 1970 COSPAR meeting in Leningrad, and was subsequently published in Space Research XI. Another paper on the subject was presented at the 1970 Fall Meeting of the AGU in San Francisco. And, finally, a study of the data was published in Journal of Geophysical Research in December 1971.

Further studies of neutral composition variations during periods of geomagnetic activity were then initiated, and papers discussing the atmospheric behavior during storms occurring in late July 1969 and early March 1970 were presented in 1971 at the Fall AGU Meeting in San Francisco.

4.3. Winter Helium Bulge

Reber and Nicolet (1965) have observed that the latitudinal distribution of helium in the upper thermosphere is such that the maximum densities are seen in the winter hemisphere during solstices. Such a helium latitude gradient was assigned to explain certain satellite drag data by Keating and Prior (1968). The OGO-VI NAC experiment data have provided a more detailed picture of this gradient. The results have been presented at the 1970 COSPAR neeting in Leningrad, and have been published in Journal of Geophysical Research (Reber, Harpold, Horowitz, and Hedin, 1971).

The theories that support these data assume a general form of wind or circulation system that redistributes the gases latitudinally, with the lower mass constituents being driven away from the summer hemisphere. These circulation theories may also be used to describe atmospheric behavior during magnetic storms.

4.4. Polar Dynamics

At the Spring 1971 AGU Meeting, Hedin and Reber described a study of the magnetically-quiet northern fall polar atmosphere. The OGO-VI NAC data during this period indicated constituent dynamics caused by energy depositions that are not associated with current geophysical indices. This is being studied for publication in the near future.

4.5. Model Atmospheres

The OGO-VI NAC experiment data have shown that there are many inadequacies in current model atmospheres. The basic problem arises from the fact that dynamics were not included in these models. The OGO data are showing that atmospheric dynamics are a very important part of any treatment that describes real atmospheric behavior.

During quiet times (constant $F_{10.7}$, $K_p \leq 2$), the winter helium bulge indicates that circulation is present and affecting the atmosphere. The effect on the magnitude of the latitude gradients of the major constituents is not yet determined, but it is known to exist. The effect referred to here is one which differs from the basic density gradients due to temperature gradients, and therefore one which emphasizes a nonunique relationship between density and temperature. This of course affects both the seasonal and the diurnal variations in the quiet atmosphere, and studies are now under way which will better define these variations.

For geophysically disturbed periods, such as geomagnetic storm times, current models are totally inadequate. It has been determined from the OGO-VI NAC data that during these times energy is deposited in the polar regions (above 40° and below 40° latitude), causing Joule heating of the neutral atmosphere at these latitudes and initiating circulation systems which are upward at high latitudes, toward the equator at mid-latitudes and high altitudes, and downward at the equator, thus transporting mass and some energy to the equatorial regions. The return flow is most likely at low altitudes back to the polar regions. The process is similar to quiet time circulation, differing only in the magnitude and the source of the heating function.

5. CURRENT AND FUTURE ACTIVITIES

Data from the OGO-VI NAC have provided information for several continuing studies presently supported under NASA Grant NGR23-005-561. Ongoing studies include the analysis of atmospheric behavior during periods of geomagnetic activity and the development of models describing that behavior, studies directed towards a better understanding of seasonal variations in the latitudinal and longitudinal distributions of the major atmospheric constituents, and studies of the long term behavior of absolute constituent densities and their variance from current models.

A. E. Hedin and associates at Goddard Space Flight Center are constructing a model of the neutral atmosphere based on the OGO-VI NAC observations which will provide the scientific community with a large fraction of the data in the form of an equation which describes the atmosphere between the latitudes of ±50° for quiet geomagnetic conditions.

Other anticipated work includes proposed studies of variations in constituent density apparently ordered by geomagnetic longitude or magnetic local time, studies of the behavior of NO and other trace constituents to determine the processes responsible for their presence, correlations of OGO-VI data with information from coincident passes of the Sam Marco III satellite, and studies of horizontal pressure gradients along the orbital path of the satellite leading to information about neutral winds in the earth's thermosphere.

6. PRESENTATIONS AND PUBLICATIONS

1. "Neutral Atmospheric Composition Data from the Quadrupole Mass Spectrometer," C. A. Reber, A. E. Hedin, N. W. Spencer, D. N. Harpold, G. R. Carignan, and D. R. Taeusch, presented at AGU, Washington, D. C., April 1970.

2. "Density Fluctuations in the Neutral Atmosphere," A. E. Hedin, D. N. Harpold, J. E. Cooley, and R. Horowitz, presented at AGU, Washington, D. C., April 1970.

3. "Response of the Neutral Atmosphere to Geomagnetic Disturbances," D. R. Taeusch, G. R. Carignan, and C. A. Reber, presented at the XIIIth Plenary Meeting of COSPAR, Leningrad, May 1970; published in Space Research XI, 1971.

4. "The Horizontal Distribution of Helium in the Earth's Upper Atmosphere," C. A. Reber, G. R. Carignan, N. W. Spencer, D. N. Harpold, A. E. Hedin, and R. Horowitz, presented at the XIIIth Plenary Meeting of COSPAR, Leningrad, May 1970; published in Space Research XI, 1971.

5. "The Horizontal Distribution of Helium in the Earth's Upper Atmosphere," C. A. Reber, D. N. Harpold, R. Horowitz, and A. E. Hedin, J. Geophys. Res., 76, No.7, March 1971.

6. "Neutral Composition Variations in the Auroral Zone During a Magnetic Storm," D. R. Taeusch and G. R. Carignan, presented at AGU, San Francisco, December 1970.

7. "Apparent Daily Variation of Atmospheric Densities near the South Pole," A. E. Hedin, C. A. Reber, and R. Horowitz, presented at AGU, San Francisco, December 1970.

8. "OGO-VI Observations of Composition Variability in the Neutral Atmosphere," G. R. Carignan, C. A. Reber, and D. R. Taeusch, presented at AGU, San Francisco, December 1970.

9. "Minor Gases Measured with the OGO-VI Neutral Mass Spectrometer," D. N. Harpold, presented at AGU, Washington, D.C., April 1971; to be submitted for publication.

10. "The Distribution of Neutral Gases in the Northern Fall Polar Atmosphere," C. A. Reber and A. E. Hedin, presented at AGU, Washington, D.C., April 1971.

C

11. "Neutral Composition Variation Above 400 Km During a Magnetic Storm," D. R. Taeusch, G. R. Carignan, and C. A. Reber, _J. Geophys. Res._, _76_, No. 34, December 1971.

12. "Response of the Neutral Atmosphere Associated with an Impulse in Geomagnetic Activity," D. R. Taeusch, G. A. Schmitt, and B. B. Hinton, presented at AGU, San Francisco, December 1971.

13. "The Neutral Atmosphere Response to the Large Magnetic Storm of 8 March 1970," G. R. Carignan and C. A. Reber, presented at AGU, San Francisco, December 1971.

14. "Gas-Surface Interactions in the OGO-VI Neutral Composition Experiment," B. B. Hinton, G. A. Schmitt, and A. E. Hedin, presented at AGU, San Francisco, December 1971.

15. "A Global Empirical Model of Thermospheric Composition Based on OGO-VI Mass Spectrometer Measurements," A. E. Hedin and H. G. Mayr, NASA Document X-621-72-103, Goddard Space Flight Center, Greenbelt, Maryland, March 1972.

16. "Thermospheric Winds from Experimental Density Data," B. B. Hinton and G. A. Schmitt, presented at AGU, Washington, D.C., April 1972.

17. "The 'Auroral Bulge' in the Neutral N_2 Atmosphere," C. A. Reber and A. E. Hedin, presented at AGU, Washington, D.C., April 1972.

18. "Neutral Composition in the Thermosphere," D. R. Taeusch and G. R. Carignan, to be published in _J. Geophys. Res._, September 1972.

19. "Role of Gas Surface Interactions in the Reduction of OGO-6 Neutral Gas Particle Mass Spectrometer Data," A. E. Hedin, B. B. Hinton, and G. A. Schmitt, NASA Document X-621-72-90, Goddard Space Flight Center, Greenbelt, Maryland, March 1972.

7. REFERENCES

Keating, G. M., and E. J. Prior, "The Winter Helium Bulge," Space Research VIII, 982-992, North-Holland Publishing Company, Amsterdam, 1968.

Reber, C. A., and M. Nicolet, "Investigation of the Major Constituents of April-May 1963 Heterosphere by the Explorer XVII Satellite," Planet. Space Sci., 13, 617-646, 1965.