FINAL TECHNICAL REPORT

NASA GRANT NAG 5-349

"Analysis of Atomic Thermospheric Nitrogen Density"

(NASA-CR-176354) ANALYSIS OF ATCMIC N86-13851
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Dr. Mark J. Engebretson
Principal Investigator
Augsburg College
Minneapolis, Minnesota 55454

I. OVERVIEW

NASA Grant NAG 5-349 provided Dr. Mark Engebretson ar ociates with support for the analysis of atomic nitrogen density data obtained by the Neutral Atmospheric Composition Spectrometer (NACS) on board the Dynamics Explorer-2 satellite. Initial funding was for an exploratory study of the feasibility of obtaining ambient densities of N from source densities of NO. Funding was continued under the Dynamics Explorer Guest Investigator Program when initial studies indicated probable success in obtaining such ambient densities. The major scientific focus of the later work was to be to characterize the behavior of N densities at high latitudes.

As a result of this grant two presentations each were made at AGU meetings and at NASA-sponsored workshops, one paper has been published in the Journal of Geophysical Research and one in a volume of conference proceedings, and two additional papers are being readied for submission to journals.

II. PERSONNEL

Dr. Engebretson, currently Associate Professor of Physics at Augsburg College, performed all of the preliminary analysis work associated with this grant from July through October, 1983, and developed key elements of all the data reduction, numerical modeling, and graphical display software used subsequently. He is solely responsible for the application of the observed surface chemistry to the problem of identifying the shuttle glow.

Joel Nelson and Scott Reeve were Undergraduate Assistants from November 1983 through May 1985 and from June 1985 through July 1985, respectively. Joel was responsible for most of the operations involved in the data reduction and display effort of this project, did much of the programming for graphics displays, and was co-author of Engebretson and Nelson (1985).

Joel is now a graduate student in physical chemistry at the University of Wisconsin, where he is supported by a teaching assistantship. Scott Reeve, currently a Junior at Augsburg College, was responsible for data reduction and graphical display of data during the summer of 1985.

Jeffrey Stein, a Ph. D. candidate in Atmospheric Physics at the University of Minnesota, worked as a Research Associate on this project from August 1984 through July 1985. Jeff's primary contributions were (a) development of a numerical model of the time-dependent concentration of gases adsorbed on the surfaces of the NACS ion source, for both spinning and despun orbits, and (b) the preparation of a paper on the response of N at southern auroral and polar latitudes during a geomagnetic storm. Jeff completed work on the model, presented his work on the geomagnetic storm variations of N at the spring 1985 meeting of the AGU in Baltimore (Stein and Engebretson, 1985), and is continuing to prepare his paper for publication.

III. ANTICIPATED OUTCOMES AND CURRENT RESULTS

A. Preliminary study of DE-2 NACS atomic nitrogen data taken during spinning orbits: Over 90% of the spinning NACS passes (essentially all those which had complete orbit and attitude data) were processed as we attempted to check for consistency in the NACS data and conformity to known geophysical variations in thermospheric N densities. Ambient densities for these orbits were determined at 1-minute intervals and written to files on private data tapes using the DE central computer. These densities can also be easily regenerated from MAF files of NACS ion source densities using standard software prepared by Dr. Engebretson and Joel Nelson. Data from all of these orbits have been used as input to Alan Hedin's modeling efforts (see item IV-B below).

B. Analysis of surface chemistry effects in the NACS ion source, with the aim of obtaining ambient N densities using NACS data: We have established that in the NACS instrument, as in earlier satellite-borne mass spectrometers, incoming N atoms react with O atoms adsorbed on ion source surfaces and desorb as NO, which becomes a quantitative measure of thermospheric N densities under certain conditions (Engebretson and Nelson, 1985).

By restricting early studies to spinning orbits, Dr. Engebretson was able to show that the net NO signal (forward-facing minus backward-facing) had a scale height appropriate to a neutral species of 14 amu and a seasonal/local time variation consistent with that observed for thermospheric N using earlier satellite-borne mass spectrometers (Engebretson et al., 1977).

We found, however, that extensive modeling of the surface chemistry was necessary in order to provide an absolute calibration of these N densities, because the dominant desorption time observed for the NO signal, 30 s, was very near the 60-s spin period of the DE-2 spacecraft. Jeff Stein ran extensive altitude-, temperature- and time-dependent simulations of source density variations using this model during Fall 1984. The results of these simulations were used in all subsequent absolute density determinations using NACS N density observations. Determinations of absolute densities on spinning orbits are now routine; despun orbits still require extensive fitting of individual orbits to model parameters.

C. Study of the behavior of N at high latitudes:

1. Because the simulations of source densities had been carried out first using data from spinning orbits, which occurred infrequently throughout the lifetime of DE-2, we chose first to look at the set of such passes through the low altitude cusp. These were used to test recently

published optical observations of a cusp-related source of N atoms. The results of this study were first presented at a DE team meeting in summer 1984, were later presented at the NASA/Goddard Workshop on Thermospheric Dynamics in October 1984, and were recently published in the Journal of Geophysical Research (Engebretson and Nelson, 1985).

2. After submission of this paper, and with the cooperation of George Carignan of the University of Michigan, it was decided to study a series of approximately 40 consecutive orbits over the Southern pole and auroral zone April 27-30, 1982. Although all of these passes were despun, the consecutive nature of the orbits suggested that modeling efforts could provide a repeatable absolute density correction. Jeff Stein presented the results of this study at several fixed geographic latitudes and two local times at the spring 1985 meeting of the AGU (Stein and Engebretson, 1985). Dr. Engebretson presented an updated version to the DE team meeting in July 1985, and further work is being done before this paper is submitted for publication. The results so far indicate no new phenomena. The response of N near and above 300 km altitude at 8.4 and 20.4 hours local time is often similar to that of O, with only occasional deviations attributable to local chemistry or nonlinear dynamics. These results are similar to those of Engebretson and Mauersberger (1983), who found at most times only a weak gas dynamic response of N to auroral activity. Our DE-2 study did not cover the local time period in which Engebretson and Mauersberger (1983) found sharp, temporary depletions in N densities after isolated substorm activity.

IV. UNANTICIPATED RESULTS

A. Surface chemistry studies relevant to the shuttle glow: The calculation of ambient N densities from signals of mass 30 observed in a mass spectrometer ion source is complicated by the fact that two molecular species, NO and NO_2, both have mass 30 as their major spectral peak. Modeling efforts in the NACS ion source were expected to be more difficult than in the case of the open source OSS mass spectrometers on the Atmosphere Explorer satellites because the closed source nature of the NACS ion source would cause increased source background effects in the NACS instrument. The use of a gold plated ion source appeared to alleviate this problem to some extent, but the degree of consistency in the NACS data from orbit to orbit was much better than had been anticipated. It was noted that there was considerably less NO_2 present in the NACS ion source than was found in the OSS ion source, and that ion source warmup effects were not as significant. As a result, although NO appeared to be still the most long-lasting surface contaminant produced in space on the walls of the NACS ion source, the ion source density of NO could be satisfactorily modeled in a manner similar to that used with the AE-OSS ion sources (Engebretson and Mauersberger, 1979).

Swenson et al. (1985) suggested on the basis of optical spectroscopic data that excited NO_2 might be the source of the red continuum glow observed on ramming surfaces of the space shuttle. A recent paper by Yee et al. (1985) gives additional support to this mechanism from AE-C optical measurements. The study of Swenson et al. (1985) and subsequent communications led Dr. Engebretson to look again at the surface reactions inferred from observations on both the AE and DE satellite mass spectrometers.

Preliminary observations, presented at NASA/Marshall Space Flight Center in May 1985 (Engebretson, 1985), supported the NO_2 hypothesis by showing that NO_2 is preferentially produced by ramming O atoms impinging on adsorbed NO or other odd nitrogen adsorbates. It was noted that the AE-D OSS mass spectrometer also used a gold plated surface, but exhibited larger amounts of NO_2 relative to NO than either the AE-C OSS or the DE-2 NACS instruments. The difference between the NACS data and the AE data was apparently caused by the absence of hot, ramming O atoms in the NACS ion source because of its closed ion source design.

Because one of the weak points in the NO_2 model (brought out at the May 1985 Workshop on Spacecraft Glow) was the lack of laboratory support for the chemistry inferred from optical and mass spectrometric studies in space, Dr. Engebretson and Scott Reeve worked during the summer of 1985 to analyze the changes in surface chemistry observed during the first few orbits of operation of the DE NACS instrument. These changes are caused by the first exposure of ion source surfaces to large fluxes of reactive thermospheric gases (O and N). These results, presented at the July 1985 DE team meeting, are consistent with earlier results from AE-C and AE-D first exposures. They show a marked change in surface recombination properties as a result of a buildup of adsorbed atomic oxygen and atomic nitrogen and a rapid depletion of carbon, largely by reaction to form CO and CO_2. Both sets of results support the NO_2 glow hypothesis, and are included in a paper being readied for submission to Geophysical Research Letters and presentation at the fall 1985 meeting of the AGU.

B. MSIS modeling: As part of Alan Hedin's efforts to update his MSIS model of thermospheric composition, an attempt is being made to include atomic nitrogen densities and variations. Dr. Engebretson published the first global model of atomic nitrogen at 375 km altitude (Engebretson et al., 1977), and has during 1985 assisted Dr. Hedin in obtaining all the available N data from the AE and DE data bases. Joel Nelson provided Dr. Hedin with software to retrieve N densities from all spinning orbits of DE-2. Nearly all of the data has been accessed at this time, and will be included in the global model. It is anticipated that this work will provide an easily accessible source of information on the global variations of N, and thus will provide an extremely useful dissemination of the results determined with the help of this grant.

V. COMPUTER GRAPHICS EQUIPMENT

In the first supplement to this grant NASA provided funds for a color graphics terminal for the display of thermospheric densities. The device chosen, a SEIKO GR-1104, has extremely good resolution (1024 x 780 pixels) at a cost of under $5000, and is upward compatible with Tektronix 4014 terminals. Dr. Engebretson, with the help of George Fleming of the DE Sigma 9 programming team, developed color graphics extensions for the DI-3000 graphics package in early 1984. Since that time we have used the DI-3000 package on the DE computer to produce several different graphical displays used in presentations at DE team meetings, AGU meetings, and other conferences. The SEIKO terminal has also been used to prepare black and white images for use in publications.

Because Dr. Engebretson expects to continue his involvement in DE data analysis, both in cooperation with DE-NACS personnel and with Dr. Laurence J. Cahill, Co-Investigator on the DE-1 and DE-2 magnetometers and in other NASA-funded programs, it is requested that this terminal, purchased by Augsburg College with funds provided by this grant, be allowed to remain at Augsburg College.

VI. UNFINISHED BUSINESS

A. The paper on N observations relevant to the shuttle glow will be submitted for publication shortly. Comments on a draft version are being contributed by Alan Hedin and George Carignan as well as others.

B. The paper by Jeff Stein on the response of N densities during geomagnetic storm periods at high latitudes has not been submitted for publication.

C. There has been no time to analyze other DE-2 data in the polar regions. Such additional sets of data, covering different local times and seasons, are necessary in order to obtain a complete picture of the behavior of N at high latitudes. Because the necessary ion source model and graphical display software are now in place, new analyses could now be accomplished with considerably less effort. This work must await further project support, however, as Dr. Engebretson is currently on a year's sabbatical leave at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, working on geomagnetic micropulsations, his other principal area of scientific interest.

VII. REFERENCES

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VIII. PUBLICATIONS AND PRESENTATIONS SUPPORTED BY THIS GRANT

A. Publications

Engebretson, M. J., AE and DE mass spectrometer observations relevant to the shuttle glow, in Second Workshop on Spacecraft Glow, NASA Conference Publication 2391, edited by J. H. Waite, Jr. and T. W. Moorehead, pp. 46-54, 1985.

Engebretson, M. J., and J. T. Nelson, Atomic nitrogen densities near the polar cusp, J. Geophys. Res., 90, 8407, 1985. /

B. Presentations

Engebretson, M. J., Atomic nitrogen densities near the polar cusp, NASA Goddard Workshop on Thermospheric Dynamics, Calverton, MD, October 3-4, 1984.

Engebretson, M. J., AE and DE mass spectrometer observations relevant to the shuttle glow, Second Workshop on Spacecraft Glow, NASA Marshall Space Flight Center, Huntsville, AL, May 6-7, 1985.

Stein, J. W., and M. J. Engebretson, The response of thermospheric atomic nitrogen at south polar latitudes to a geomagnetic storm, Spring Meeting of the American Geophysical Union, May 27-31, 1985. (Abstract in Eos Trans. AGU, 66, 321, 1985.)

Engebretson, M. J., DE mass spectrometer observations relevant to the shuttle glow, Fall Meeting of the American Geophysical Union, December 9-13, 1985. San Francisco, CA.

A copy of the paper submitted for publication in the Proceedings of the Second Conference on Spacecraft Glow was included in the June 30, 1985 status report. Copies of the abstracts for the Spring and Fall 1985 AGU meetings are appended to this report, as is a reprint of the paper published in the Journal of Geophysical Research. A85-49220

IX. ACKNOWLEDGEMENTS

Thanks are due to George Carignan for his readiness to offer support, advice, and needed criticism, to Alan Hedin for his helpful introduction to the NACS data and for his continued assistance, and to Robert Hoffman, Dynamics Explorer Project Scientist, for his continual encouragement of these efforts.

The Response of Thermospheric Atomic Nitrogen at South Polar Latitudes to a Geomagnetic Storm

JEFFREY W. STEIN and MARK J. ENGEBRETSON (Department of Physics, Augsburg College, Minneapolis, MN 55454)

The Neutral Atmospheric Composition Spectrometer (NACS) on the Dynamics Explorer-2 satellite measured O, N_2, He, and N densities during 45 consecutive orbits April 27-30, 1982. A geomagnetic storm with sharp onset and rapid recovery occurred early in this period, followed by a series of isolated substorms. The perigee of DE-2 at this time was near the south pole, and the satellite's orbital plane traversed meridians at 8.4 and 20.4 hours local time. N densities increased at each high latitude sampled during the initial large magnetic storm, and gradually returned to lower levels in its aftermath. Atomic nitrogen densities responded in an inconsistent manner to isolated substorm activity 1-3 days after the main storm period. Although variations in N densities were often intermediate between those of O and N_2, on certain occasions N density increases could not be easily explained by gas dynamical processes, suggesting the important role of odd nitrogen chemistry in determining N densities at high latitudes.

1. 1985 Spring Meeting

2. 003558838

3. (a) Corresponding Address

Jeffrey W. Stein
Department of Physics
Augsburg College
Minneapolis, MN 55454

(b) Telephone number:

612-330-1040 or 1000

4. SA (Aeronomy)

5. None

6. O (Oral)

7. None

8. (a)

(b) Mark J. Engebretson
Department of Physics
Augsburg College
Minneapolis, MN 55454

(c)

(d) Student rate applicabl

9. C (Contributed)

DE-2 Mass Spectrometer Observations Relevant To The Shuttle Glow

MARK J. ENGEBRETSON (The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland 20707)

Recent work by Swenson et al. [Geophys. Res. Lett., 12, 97, 1985] has suggested that NO_2 may be responsible or the observed continuum glow near surfaces of the space shuttle. This report will review earlier observations of thermospheric atomic nitrogen (N) at shuttle altitudes using mass spectrometers and of related odd nitrogen (N, NO, and NO_2) reactions on spacecraft surfaces, and will present new data from the Neutral Atmospheric Composition Spectrometer (NACS) on the Dynamics Explorer-2 satellite, all of which are supportive of this hypothesis. Comparison of data from the closed-source DE-2 NACS instrument and the Open-Source Neutral Mass Spectrometers (OSS) on the Atmosphere Explorer-C and -D satellites indicates similar behavior of NO in each case but significant differences in the behavior of NO_2. (1) Initial surface conditioning effects in the DE-2 NACS ion source are found to be similar to those observed by the AE-D OSS instrument. In each case there is a buildup of O_2 and NO, products of surface recombination, during the initial exposure of ion source surfaces to thermospheric gases. (2) Although signals of NO and NO_2 are highly dependent on surface temperature and surface composition, it appears that direct exposure of ion source surfaces to rammed gas is a necessary condition for the production of large amounts of NO_2. Our data also indicate that elevated surface temperatures can significantly reduce the production of NO_2, likely by causing more rapid desorption of NO from these surfaces.

1. 1985 Fall Meeting

2. 000745585

3. M. J. Engebretson
JHU/APL
Laurel, MD 20707
953-5000 ext. 8275

4. SA (Aeronomy)

5. None

6. P (poster)
0355

7. 40% at NASA Worshop
on Spacecraft Glow
Huntsville, AL
May, 1985

8. Murrie W. Burgan
JHU/APL
Laurel, MD 20707

9. (C (Contributed)