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DEVELOPMENT OF DATA PROCESSING, INTERPRETATION AND ANALYSIS SYSTEM FOR REMOTE SENSING OF TRACE ATMOSPHERIC GAS SPECIES

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FOREWORD

This report describes the work completed on the supplement to the research project "Development of Data Processing, Interpretation and Analysis System For Remote Sensing of Trace Atmospheric Gas Species." The work was supported by the Chemistry and Dynamics Branch of the Atmospheric Sciences Division of NASA Langley Research Center through a supplement to research grant NCC1-34. The grant was monitored by Mr. W. D. Hypes of the Atmospheric Sciences Division, Mail Stop 483, Telephone: (804) 865-4396.

A Supplement to the Research Project

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By

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SUMMARY

Highly efficient methods are developed for the analysis and reduction of MAPS data. Specific attentions are directed to analyze the data from tne OSTA-3 correlative measurements of aircraft research flights and from the OSTA-3 shuttle flight. Methods are developed for error analyses of the aircraft and spacecraft instruments. The LSI 11/23 software system is modified and expanded for future data analyses.

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1. INTRODUCTION

The MAPS Research Project is concerned with the measurement of the global distribution of mid-tropospheric carbon monoxide. The measurement technique for the MAPS instrument is based on non-dispersive gas filter radiometer operating in the nadir viewing mode. The MAPS experiment has two passive remote sensing instruments. The prototype instrument which is used to measure tropospheric air pollution from aircraft plaftforms and a third generation instrument which is used to measure carbon monoxide in the mid and upper troposphere from space platforms.

The major objectives of this study were as follows:

1. To complete work on OSTA-1 data.
2. To develop techniques for the reduction and analysis of the OSTA-3 spacecraft and aircraft research data.
3. To provide analysis and develop new data retrieval algorithms based on the OSTA-3 N_2O channel.
4. To provide instrument error analysis for the MAPS spacecraft and aircraft data.
5. To expand and develop new data reduction software systems for the MAPS LSI 11/23 computer.

2. OSTA-1 EXPERIMENT

A paper which presents the results of the MAPS OSTA-1 space shuttle experiment was written by the MAPS research group. The title of the paper is "Middle and Upper Tropospheric Carbon Monoxide Ratios as Measured by a Satellite Borne Remote Sensor During November 1981." This paper discusses the usable data obtained during the first flight, presents information on

the accuracy of the data, and discusses the CO results. The paper has been submitted for publication in the Journal of Geophysical Research-Atmospheres.

The documentation and the reduced data from the MAPS OSTA-1 experiment were prepared for archival with the National Space Science Data Center.

3. OSTA-3 EXPERIMENT

The MAPS experiment flew as part of the OSTA-3 payload on the October 1984 flight of the Space Shuttle (STS-41G). This was the second research flight for the MAPS instrument. During the 8 day mission, the MAPS experiment recorded approximately 105 hours of data. This nadir viewing data provides measurements of tropospheric CO between 58°N and 58°S latitude.

In support of the spacecraft experiment, a correlative measurements program was conducted with a prototype instrument on an aircraft platform. Data was collected on seven research flights.

The reduction and analysis of the OSTA-3 spacecraft and aircraft data is an involved and complicated procedure involving many research personnel. To insure the analysis of the data progressed in a timely manner, a detailed data processing flowchart was developed and used to coordinate the efforts of the MAPS research group.

To define the meteorological conditions for the OSTA-3 spacecraft data, eleven atmospheric models were developed. These models were processed by the MAPS radiative transfer program to compute the predicted atmospheric radiation for the three channels as a function of solar zenith angles for night and day and with surface emissivities for land and water.

The predicted atmospheric radiation from the atmospheric models was

then used in a regression analysis technique to generate the coefficient sets for the data inversion program. The data inversion program selects the coefficient set to be used in the calculation of CO on the basis of signal function weighted temperature, terrain base and a day or night condition. After extensive analysis, sixty-six coefficient sets were selected for use in the data inversion.

Modifications were made to the data inversion program because of changes in the radiance equations and the method of coefficient selection. Three orbits of OSTA-3 spacecraft data were selected and processed for analyses and comparison to aircraft in situ data. Additional analyses is required before the complete OSTA-3 data set will be processed.

The processing of atmospheric models for the seven aircraft research flights is in progress.

4. N_2O CHANNEL

In the MAPS data inversion process the atmospheric temperature along the orbital track must be known in order to infer the concentration of CO from the radiometric signals. For the OSTA-1 and OSTA-3 experiments these temperatures were obtained from the U.S. Fleet Numerical Oceanographic Center. Most of these temperatures were interpolations between points at which temperature measurements were actually taken. To obtain the atmospheric temperature at the point of measurement, the OSTA-3 version of the MAPS instrument was modified by replacing the low pressure CO gas cell with a cell containing nitrous oxide at 115 torr. Since N_2O is known to be uniformly distributed both horizontally and vertically in the troposphere, the measurement made through this filter should allow the atmospheric temperature to be estimated.

The OSTA-3 data will be processed using techniques similar to those applied in the OSTA-1 data analyses. Preliminary analysis of the N_2O data indicate that algorithms based on the N_2O channel may function as a cloud filter for the CO data channel. Analysis continues on the development of algorithms to determine atmospheric temperatures from the N_2O channel.

5. ERROR ANALYSIS

An error study was conducted on the OSTA-1 data to determine the error in inferred CO due to atmospheric modeling errors and to uncertainties in the instrument output, specifically, instrument noise, digitization errors and calibration errors. The precision and accuracy of the experiment were studied by examining potential error sources through the use of numerical models. An in-depth study was made of the method by which the radiance values were calculated from the calibration and the digital in-flight data to determine the expected accuracy of these calculations. These studies dealt primarily with the ΔV channel of the instrument. More limited studies of the $\Delta V'$ channel produced results that were similar except that instrument-induced errors were somewhat larger in that channel because of lower signal levels. The noise level is essentially the same in both channels.

The error in the mixing ratio of CO at 55 ppbv due to instrument error was found to be about 12 percent. This error includes the effect of detector noise, uncertainty in the measurement of internal blackbody and instrument mainframe temperatures, digitization errors and atmospheric modeling errors. Errors induced in the CO mixing ratio by ΔV channel and by V channel errors were calculated separately and combined. A substantial part of this 12 percent error results from detector noise. The results of the

study are included in the OSTA-1 paper previously mentioned.

The methodology used in the error analysis of the OSTA-1 instrument data may be used, with some modifications, to perform error studies of the OSTA-3 data.

6. LSI 11/23 COMPUTER

The MAPS project used a LSI 11/23 computer system for inflight data collection during the OSTA-3 correlative measurements program. The computer system and the operating system have been expanded to assist in the analysis of the OSTA-3 spacecraft and aircraft data.

A library of scientific subroutines was installed in the operating system and thoroughly tested. An instrument error analyses software system was developed for the prototype remote sensor.

7. FEASIBILITY STUDY

A preliminary feasibility study on the possibility of obtaining a spaceborne multi-level measurement of the atmospheric CO mixing ratio from a satellite remote sensor has been completed. The study was based on experience obtained from the MAPS passive nadir gas filter radiometer flown on the space shuttle. The results of these studies have shown that it is possible to design an experiment having CO signal functions peaking in the upper troposphere ($\simeq$ 300 mb), lower mixing level ($\simeq$ 1000 mb). A discussion of the results of this study, specifically the method, signal functions, and signal strengths was presented at the 1985 American Geophysical Union Fall Meeting.

8. CONCLUSIONS

The following specific tasks were completed during the present study:

1. completion of OSTA-1 data analysis,
2. development of OSTA-3 data reduction procedure,
3. preliminary analysis of OSTA-3 data,
4. preliminary analyses of the N_2O data,
5. development of spacecraft and aircraft instrument error analysis software,
6. expansion of LSI 1/23 computer system for future data analysis, and,
7. feasibility studies for a multi-level spaceborne remote sensor.

The results of the work conducted under this study were delivered when completed to the technical monitor and/or designated personnel.