Status Report #1:
Validation of MOPITT Column and Profile CO from Spaceborne, Airborne, and Ground-based Interferometers

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http://beet.umbc.edu/~mcmillan/PROJECTS/MOPITT_val/MOPITT_val.html

Submitted to

David Starr
EOS Validation Scientist

1 Summary

This report summarizes work preformed during the first six months of NASA funded effort in support of validation of MOPITT CO measurements. Progress has been made on many of the first-year objectives outlined in the original proposal including CO retrieval algorithm development and advising the MOPITT Science Team on validation strategies. During the WAVES EOS AM-1 Validation Workshop, Dr. McMillan strongly suggested a pre-launch MOPITT validation exercise to stimulate algorithm development and testing, evaluate data transfer protocols, assist with validation team integration, and improve planning for future validation experiments. Dr. McMillan has commenced preliminary analysis of data acquired during the Pre-launch MOPITT Validation Experiment (Pre-MOVE) in early March, 1998, at the Southern Great Plains DOE ARM CART site. This summer will see the addition of a post-doctoral associate to assist Dr. McMillan with this research. Although the untimely demise of the Japanese ADEOS spacecraft carrying IMG precludes its use for direct MOPITT validation, IMG data could assist with MOPITT algorithm validation. Projected activities for the next six months include continued involvement in planning future MOPITT validation experiments, final analysis of Pre-MOVE data, simulation and testing of a new fast model CO retrieval algorithm, and the first CO retrievals from the new NPOESS NAST-I instrument.

2 MOPITT Validation Planning

The WAVES EOS AM-1 Validation Workshop (10/21-22/97) provided an excellent forum for convening a meeting of the PI's of the EOS supported MOPITT validation proposals along with MOPITT PI Jim Drummond, MOPITT Science Team member Hank Reichle, and MOPITT Validation lead Jinxue Wang. This was the first, and thus far only, meeting of what I term the "MOPITT Validation Team." To date, the MOPITT Science Team has conferred no official status on this group nor this PI. However, I was invited to present a talk on my validation proposal at the Canadian MOPITT Workshop sponsored by the MOPITT PI in Toronto (10/4/97).

As a result of the WAVES meeting, we agreed there was a compelling desire to conduct a pre-launch MOPITT validation experiment. At my suggestion, the Oklahoma DOE ARM CART site was selected as a convenient location for the Pre-launch MOPITT Validation Experiment (Pre-MOVE). Dr. Wang coordinated the requisite logistics and observations performed during the first week of March, 1998. I have commenced preliminary analysis of Pre-MOVE AERI and SORTI spectra (see following section).

As lead author of the calibration and validation plan for the the upcoming (8/6-9/25/98) NASA Third Convection And Moisture EXperiment (CAMEX-III), I suggested MOPITT make use of the outstanding CAMEX-III instrument complement for an early post-launch MOPITT validation experiment. Unfortunately, the EOS AM-1 launch delay terminated our planning for on-orbit validation during CAMEX-III. Dr. Wang and I continue to discuss additional pre-launch validation activities during CAMEX-III, and I remain avaliable to assist in planning any future MOPITT validation exercises.

3 Pre-MOVE Data Analysis

Preliminary analysis of the AERI data acquired during Pre-MOVE is ongoing using our existing AIRS prototype CO retrieval algorithm previously validated with HIS spectra. Currently, I am exploring improvements to this CO retrieval algorithm to account for AERI's higher spectral resolution, approximately twice that of AIRS and HIS. In addition, because the original radiative transfer routine was developed to calculate up-welling thermal radiances, I am investigating refinements to more accurately calculate the downwelling radiances measured by AERI and SORTI. Once the radiative transfer routine is refined, my analysis of SORTI data will commence.

4 New Retrieval Algorithms and Fast Models

In addition to refining the calculation of downwelling radiances, regular processing of large numbers of AERI spectra will require a more rapid radiative transfer routine than our current rapid line-by-line model (k-CARTA). Moreover, the large data volume expected from upcoming HIS, Scanning-HIS, and NAST-I flights necessitates a rapid radiative transfer routine, a "Fast Model," for these instruments. To these ends, I am collaborating with Dr. Strow and colleagues in developing HIS, NAST-I, and AERI Fast Models as well as new physical retrieval algorithms, including CO, using these Fast Models. This work is supported by this grant, my NASA ACMAP grant, and an NPOESS grant to Dr. Strow.

5 Research Associate

This summer, a new post-doctoral associate will join me in performance of these research activities. Final interviews for this position will occur in the near future. Support for this position is shared with my closely related NASA ACMAP grant and an EOS Validation grant to Co-I Dr. Morris. Dr. Morris' grant and his work on this project are closely related and include the development of a turn-key tropospheric trajectory mapping model to assist with MOPITT CO validation.

6 Projected 6-month Plan

Projected activities for the next six months include:

- Hire a new post-doctoral research associate,
- Complete improved routines for calculating downwelling radiances,
- Complete analysis of Pre-MOVE AERI data with an enhanced AIRS prototype CO retrieval algorithm,
- Start development of a SORTI CO retrieval algorithm,
- Continue involvement with the planning of future MOPITT validation activities,
- Simulate and test new Fast Models for AERI, HIS, and NAST-I,
- Continue development of new physical CO retrieval algorithms using the new Fast Models, and
- Perform first CO retrievals from NPOESS NAST-I spectra.

SATELLITE VALIDATION DATA OBTAINED IN TROPICAL WESTERN PACIFIC REGION

PROJECT TITLE:

OPERATION OF MICROWAVE RADIOMETER IN THE TROPICAL PACIFIC FOR CALIBRATION AND VALIDATION OF SATELLITE DATA

ABSTRACT:

Continuous surface measurements of the total amounts of water vapor and cloud liquid passing over Kavieng, Papua New Guinea were made by microwave radiometer during January and February 1993. These data supplement a one-year period of observations obtained at Porto Santo Island in the Madeira Archipelago in the Atlantic Ocean from 1 June 1992 through 15 June 1993. These data sets are being employed to improve the quality and accuracy of water vapor and liquid water retrievals from satellite data. The long-term benefits of this work will be (1) to improve the quality of data products from meteorological satellites, thereby enhancing satellite monitoring of climate changes, and (2) to improve our understanding of the relationships between clouds and solar radiation and the implications for global warming.

PROJECT GOALS AND METHODOLOGY:

As the primary "greenhouse" gas, water vapor plays a significant role in global climate. The global distribution of water vapor can only be measured by satellites. However, satellite measurements of water vapor have been hindered by a lack of verification data on time and space scales compatible with the satellite overflights. For example, the twice daily vapor measurements provided by the global upper air network (radiosondes) seldom coincide with overflights by polar orbiting satellites and are nonexistent over the oceans. Another shortcoming of the radiosonde is that liquid water is not measured.

Global circulation models perform well except when clouds are included. The cause of the poor performance is a lack of understanding of the relationship between cloud liquid water content and solar radiation. Improved understanding of this relationship is fundamental to accurate prediction of global warming. Again, the meteorological satellite is the only tool that can address this problem on a global scale.

The goal of this research project is to create a data base of information which can be used to improve the accuracy of satellite measurements of water vapor and cloud liquid. Currently, microwave radiometers are the only source of continuous measurements of water vapor and liquid water in clouds. Accordingly, our methodology is to employ surface-based microwave radiometers at various locations around the world to obtain water vapor and liquid water data during satellite overflights. Through comparison of the simultaneous satellite and surface-based data, new retrieval algorithms can be derived which improve the quality and accuracy of the satellite vapor and liquid water measurements.

DATA COLLECTION AND ANALYSIS:

Continuous measurements of water vapor and cloud liquid by microwave radiometer were obtained during the Tropical Oceans Global Atmosphere (TOGA) Coupled Ocean-Atmosphere Response Experiment (COARE). Observations were made at Kavieng, Papua New Guinea (2.6S, 150.8E) and on board the Research Vessel (R/V) Moana Wave during cruises between Guam and Ponape. Microwave radiometers were also operated at Porto Santo Island (33N, 16.4W) for one year (June 1992 to June 1993), and on the NOAA ship R/V Malcolm Baldrige during June 1992. Supporting data consisted of downwelling solar flux, and surface meteorological data.

Analysis of these data included derivation of statistical descriptions, comparisons of radiometric water vapor and cloud liquid with satellite measurements, and comparison of measurements with radiative transfer models.

RESULTS AND ACCOMPLISHMENTS:

A preliminary investigation of current methods (algorithms) for retrieval of water amounts from satellite measurements was completed. Six vapor and four liquid water algorithms from the literature were examined using a one-month period of data from Porto Santo Island. A new algorithm has been developed based upon the form of the most promising algorithm from the literature. The new algorithm has significantly improved the agreement between satellite retrievals of water vapor and liquid and the ground-truth data for the one-month test period.

FUTURE WORK:

The performance of the new algorithm is currently being evaluated for the data from the Tropical Western Pacific region and the one-year period of data collected at Porto Santo Island in the North Atlantic. The results will be employed to improve further retrieval algorithms for atmospheric water vapor and cloud liquid. Our ground-truth data have been supplied to colleagues in other government laboratories (NOAA, NASA) and to universities for their use in studies in climate and global change.

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National Polar-Orbiting Environmental Satellite System (NPOESS)

Sponsor: Department of Defense, Department of Commerce

The Departments of Defense and Commerce are combining their previous separate polar-orbiting meteorological satellites systems into a single integrated system known as the National Polar-Orbiting Environmental Satellite System. NPOESS will combine the missions of the Defense Meteorological Satellite Program (developed and operated by the US Air Force) with that of the TIROS/NOAA-Series of weather satellites (developed by NASA and operated by the National Oceanic and Atmospheric Administration). Through the incorporation of improved technologies and consolidation of management and operations, NPOESS will both achieve significant cost savings and provide major improvements in the types and accuracies of the derived environmental data products. Although, the NPOESS is planned to begin full operations late in the first decade of the 21st century, consolidation of DMSP and TIROS/NOAA operations is already underway.

AER has a long involvement with NPOESS's precursor programs, most recently with DMSP Block 6. AER took the lead responsibility for environmental algorithm design, development and testing as part of a team led by what is now Lockheed Martin. Many of the environmental requirements from DMSP Block 6 have continued into NPOESS, although in many cases they have been modified to accommodate DOC needs. As part of its DMSP Block 6 contract efforts, AER also led the analysis of environmental sensing capabilities for tasks which directly addressed early versions of the NPOESS requirements.

AER's brings experience in the development, validation and testing of algorithms, and in the systems engineering process to support the optimization of advanced sensors which can be directly applied to each of the major NPOESS sensor suites:

VIIRS

- Visible/Infrared Imaging Radiometer Suite
- An advanced multi-channel imaging radiometer

CrIS

- Cross-track Infrared Sounder
- A high spectral resolution infrared sounder for temperature and water vapor profiling

CMIS

- Conical Microwave Imaging Suite
- A conically-scanned microwave imaging sensor with integrated sounding capability

OMPS

- Ozone Mapping Profiling Suite
- An advanced sensor for total ozone and ozone profile measurements

CrIMS

- Cross-track Microwave Sounding Suite
- Cross-track scanning sensor for temperature and water vapor profiling which works in conjunction with the CrIS

Additional capabilities which AER brings to NPOESS are:

- Algorithm development and testing
- Support for optimization sensor design
- End-to-end sensor/system modeling
- Calibration/validation programs
- Software development

AER links related to NPOESS:

- Unified Retrieval
- End-to-End Sensor Modeling

For more information concerning NPOESS contact AER's NPOESS Program Manager, Ron Isaacs.

ATMOSPHERIC CHEMISTRY MODELING AND ANALYSIS PROGRAM

Goal:

To improve our understanding of the distribution of chemically and radiatively active trace constituents and aerosols in the troposphere and stratosphere at regional to global scales, through the development of computational models representing atmospheric chemistry and transport processes, and model-based analysis and interpretation of atmospheric constituent and dynamical data.

Strategy:

To develop models of atmospheric chemistry and physics for both the troposphere and the stratosphere, and to interpret atmospheric trace gas and aerosol data, emphasizing the characterization of spatial and temporal variability and distinguishing between natural and anthropogenic origins of this variability.

Elements:

Develop and evaluate computational models of tropospheric and stratospheric chemistry and transport for studies of the current atmosphere, as well as for retrospective and predictive studies, and to provide planning and data analysis for field campaigns.

Develop and evaluate models of stratospheric and tropospheric aerosol and stratospheric cloud formation and their chemical and physical effects.

Characterize the variability of atmospheric trace constituent and aerosol concentrations and quantify their dependence on natural factors such as the solar cycle, volcanic eruptions, the quasi-biennial oscillation, El Nino Southern Oscillation, and particle precipitation events, and human activities, such as chloroflourocarbon emissions and other industrial activities.

Develop coupled chemistry-climate models which will simulate the combined effects of greenhouse warming and ozone depletion.

Develop modeling tools for the inference of sources and sinks of trace gases at the Earth's surface and in the atmosphere.

Extend analysis of current or historic satellite data to obtain and validate research products and support analysis of non-NASA data sets.

Develop methods for inferring amounts of surface UV radiation and absorbing tropospheric aerosols from space based data.

Provide modeling and analysis support for externally sponsored assessments such as WMO/UNEP Ozone Assessment and the IPCC Climate Change Assessment, as well as for the assessment of the Atmospheric Effects of Aircraft Program.

TOTAL OZONE MAPPING SPECTROMETER SCIENCE TEAM

Goal:

To further the study of data from the Total Ozone Mapping Spectrometer (TOMS) series of instruments, including the applications of TOMS data to studies of atmospheric chemistry, transport, and radiation distributions as well as the validation of TOMS data through comparison with ground-, aircraft-, balloon-, and space-based measurements.

Strategy:

To analyze, interpret, and support the validation of TOMS measurements of atmospheric ozone, sulfur dioxide, tropospheric aerosols, and surface ultraviolet radiation, as well as to examine the tropospheric ozone products derived in part from TOMS data in the context of related measurements.

Elements:

Validation of TOMS measurements through comparison with relevant correlative data, including those obtained from currently existing ground-based networks, currently operating space instruments, and aircraft- and balloon-borne sensors.

Construction of long-term data sets for TOMS products, with special attention paid to ensuring long-term stability of calibration of individual instruments and consistency of different instruments

Use of measurements of TOMS-observed quantities in studies of their seasonal, interannual, and longer-term variations, and comparison with results of relevant model calculations

Analysis of algorithms currently used for TOMS and related data products and further improvement as appropriate

Dr. Julio T Bacmeister Naval Research Laboratory
Parametermization of Gravity Wave Variability for Chemical and Microphysical Models

Dr. Richard P Cebula Hughes STX Corporation
SBUV/2 and SSBUV Solar Spectral Irradiance Data Analysis

Dr. Sushil Chandra Goddard Space Flight Center
Tropospheric Ozone Derived from Combined High-Density TOMS and UARS MLS/HALOE Measurements

Dr. Sundar A Christopher University of Alabama Huntsville
Validation and Intercomparison of TOMS Aerosol Products Using Satellite and Ground Based Measurements

Dr. Jack Fishman Langley Research Center
Further Studies of Troposphere Chemistry Using Satellite Data

Dr. Marvin A Geller State Univ of New York Stony Brook
Proposal for SPARC Data Center

Dr. Dana Hartley Georgia Institute of Technology
Deducing Regional Surface Fluxes of Carbon Monoxide Using an Inverse Method

Dr. Benjamin M Herman University of Arizona
Algorithm for Future Ozone Profiling Using Limb Scatter Measurements

Dr. Jay R Herman Goddard Space Flight Center
The Global Effect of Absorbing and Non-Absorbing Aerosols on Surface Ultraviolet Light

Dr. R Stephen Hipskind Ames Research Center
Meteorological and Data Management Support for Ozone Research

Dr. Lon L Hood University of Arizona
Satellite Data Studies of Stratospheric Ozone

Dr. Robert D Hudson University of Maryland College Park

Direct Measurements of Tropospheric Ozone from TOMS Data

Dr. Jae Hwan Kim Korea National University
Derivation of Tropospheric Ozone Column from TOMS Data

Dr. Arlin J Krueger Goddard Space Flight Center
Volcanic Plume Analysis Using TOMS and AVHRR Data

Dr. Steven A Lloyd Johns Hopkins University
TOMS Validation and UTLS Photochemistry Using ER-2 and Ground-Based Datasets

Dr. W Wallace McMillan University of Maryland Baltimore Cnty
A Climatology of Tropospheric CO over the Central and Southeastern United States and the Southwestern Pacific Ocean Derived from Space, Air, and Ground-based Infrared Interferometer Spectra

Dr. Hope A Michelsen Harvard University
Investigation of the Photochemical Processes that Control Stratospheric Ozone: An Analysis of Remote and In-Situ Data Sets

Dr. Kenneth R Minschwaner New Mexico Inst of Mining & Techlgy
Ground Based Measurements of Total Ozone, Cloud Properties, and UV Doses

Dr. Michael J Newchurch University of Alabama Huntsville
Aerosol Retrievals from High Resolution Broadband ATMOS Solar Occultation Spectra

Dr. Michael J Newchurch University of Alabama Huntsville
Derivation of Tropospheric Ozone Climatology and Trends from TOMS Data

Dr. Paul A Newman Goddard Space Flight Center
A Proposal for the Analysis of Aircraft and Satellite Data and Support for NASA Missions

Dr. Samuel J Oltmans NOAA
TOMS Validation Using the Ground Based Dobson Network

Dr. Joyce E Penner University of Michigan Ann Arbor
Tropospheric Trace Gas Budgets: Interactions with Aerosols

Dr. Pinhas Alpert Tel Aviv University
Membership in TOMS Science Team

Dr. Raymond Alan Plumb Massachusetts Institute of Technology
Large-Scale Stratospheric Transport Processes

Dr. Joseph M Prospero University of Miami
TOMS Validation Based on Profiles of Aerosol Properties in the Lower Troposphere as Obtained with Light Aircraft Systems

Dr. Ellis E Remsberg Langley Research Center
A Mapping and Analysis of the Reprocessed NIMBUS 7 LIMS Profile Data Set

Dr. Lars Peter Riishojgaard University of Maryland Baltimore Cnty
Assimilation of Ozone Data for Global Change Studies

Dr. Drew Shindell Columbia University
Chemistry-Climate Coupling in a GCM with Simplified Tropospheric Chemistry

Dr. John L Stanford Iowa State University
Small-Scale Tropopause Dynamics and TOMS Total Ozone

Dr. Richard S Stolarski Goddard Space Flight Center
Constructing a Unified Ozone Record for Detection of the Anticipated Ozone Recovery

Dr. Michael E Summers Naval Research Laboratory
Middle Atmospheric Hydrogen Photochemistry

Dr. Azadeh Tabazadeh Ames Research Center
Developing and Validating an Aerosol Model for the Upper Troposphere

Dr. Larry W Thomason Langley Research Center
Improvements to the SAGE I Data Processing Algorithm

Dr. Anne M Thompson Goddard Space Flight Center
SHADOZ (Southern Hemisphere ADditional OZoneondes): A Data Set for TOMS Validation, Process Studies and Modeling

Dr. Owen B Toon University of Colorado Boulder
Theoretical Investigations of Clouds and Aerosols in the Stratosphere and Upper Troposphere

Dr. Darryn W Waugh Johns Hopkins University
Inferring Aspects of Transport and Mixing in the Stratosphere and Troposphere from Chemical Tracer Measurements

Dr. Steven C Wofsy Harvard University
Analysis of Interannual and Long Term Variations of Stratospheric Transport of Ozone and Development of an Ozone Climatology from the Ground to 1 MB

Dr. Yuk L Yung California Institute of Technology
Study of Tropospheric Ozone and UV Reflectivity Using TOMS Data