FORM A: GACP ACCOMPLISHMENT REPORT

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Institution: University of Arizona

TITLE: Combined Lidar and Passive Sensing Techniques for Characterization of Aerosol Radiative Effects

ABSTRACT:

This proposal describes work combining active and passive ground-based methods to better understand the physical properties of aerosols to improve the retrieval of these properties from passive satellite data. The proposal joins the resources of the Atmospheric Remote Sensing Laboratory (ARSL) and the Remote Sensing Group (RSG) of the University of Arizona to capitalize on the expertise of both groups and their complement of field instrumentation. The groups will study data from past field campaigns for innovative combinations of these ground- and aircraft-based measurements to help develop techniques for the retrieval of aerosol properties from satellite data. The research also relies on field campaigns funded through other projects to improve ground-based validation techniques and to constrain the uncertainties from satellite-retrieved aerosol properties. A key element of this project is the combination of active and passive approaches through the use of Micro-Pulse Lidar (MPL) linked with solar irradiance and sky radiance measurements. Also, critical to this work will be the retrieval of the single scatter albedo at several sites in the desert southwest to investigate the feasibility of regular around-based monitoring of this parameter.

GOALS:

The principal goal of this project is to develop/demonstrate ways of combining active and passive ground-based remote sensing methods to improve the retrieval of aerosol physical/optical properties from satellite data. Allied to this is the added goal of achieving better understanding of the physical/optical properties of aerosols through application of these combined sensing methods, thereby, improving our knowledge of global aerosol properties.

OBJECTIVES AND APPROACHES:

The objectives of the work on this project are focused on providing an understanding of the measurements that are critical to the development of a global climatology of aerosols. Such measurements include simple solar radiometer data, lidar-based retrievals, and downwelling sky radiance. To achieve the goals of this project, as listed earlier, our objectives and approaches are:

1) Investigate improvements in the retrieval of aerosol characteristics when passive and active approaches are combined. The key strategy to combining active and passive observations is that they are each more strongly sensitive to different radiative effects. Hence, aerosol retrievals based on a combination of active and passive measurements

should more accurately represent the true radiative efforts of aerosols, having been based on and constrained to yield collective agreement with a greater variety of radiative measurements.

2) Further development/application of horizontal and slant-path Micro-Pulse Lidar (MPL) sensing techniques. The slant-path approach permits retrieval of aerosol extinction profiles and the aerosol extinction-to-backscatter ratio, a parameter particularly useful in constraining/validating aerosol phase functions retrieved by other methods.

3) To understand better the accuracy of ground-based, passive retrievals by

- Evaluating the usefulness of hyperspectral measurements over the entire solar-reflective range.

- Comparing multiple instrument observations providing measurements of direct solar irradiance, downwelling sky irradiance, and downwelling sky radiance. This will provide further experimental verification of the accuracy of these measurements and the accuracy of aerosol retrievals from such information.

- Comparing the calibration of AERONET radiometers obtained at the main calibration facility at the Goddard Space Flight Center to one obtained at the University of Arizona. This should allow a better understanding of the limits of the sky radiance measurements of this global suite of instruments.

4) Use lidar and auxiliary radiometric data gathered during past and on-going experiments to extract and infer aerosol radiometric parameters, such as extinction, optical depth, extinction-to-backscatter ratio and, subsequently, single-scattering albedo and a phase-function asymmetry parameter.

TASKS COMPLETED:

As funding for our project only became available in February of this year, there are no significant completed tasks to report. However, work is in progress continuing the analysis of lidar data sets obtained from LITE and ACE-2 (Micro-Pulse Lidar data) to extract additional aerosol information. Funding from the LITE and ACE-2 projects has been expended/projects completed. Continued analysis of these valuable data sets to add to our current understanding of global aerosol properties is one of the tasks included in our GACP proposal. Additional tasks completed, while not regarded as being of major significance but still necessary to achieving the goals of the project, are as follows:

- Refurbishing of a spectropolarimeter for measurements of solar irradiance and sky radiance was completed and preliminary testing of the instrument has begun.

- Comparisons between several ground-based solar radiometers. These included several systems built in the Atmospheric Remote Sensing Laboratory (ARSL) at the University of Arizona, an AERONET radiometer, and the lightweight, portable Micro Tops instrument.

FUTURE PLANS:

A number of activities are in progress pursuant to achieving the goals of this project. They are summarized as follows:

- Continued analysis of LITE data to extract further information about global aerosol extinction and backscatter characteristics.

- Continued analysis of ACE-2 Micro-Pulse Lidar (MPL) and solar radiometer data to extract further information about aerosol extinction and backscatter properties and use of same in better defining aerosol properties needed to improve modeling of climate forcing by aerosols.

- Participation in a lidar, solar radiometer and scattering nephelometer experiment at Bondville, IL during late August and September of 1999 to validate lidar extinction retrievals and better characterize aerosol extinction to backscatter ratios for a variety of atmospheric conditions. This is a cooperative effort with another GACP funded project ("Validation of the Lidar Retrieval of Aerosol Extinction" - D.S. Covert & T.L. Anderson, PI's); MPL's to be used in the experiment are being loaned by NASA Langley Research Center. A slant-path sensing mirror system to be fitted to one of the MPL's is being loaned by Dr. Jim Spinhirne, NASA Goddard Space Flight Center.

- Continued evaluation of multiple instrument observations to understand the differences between measurements of solar transmittance, sky radiance, and downwelling irradiance and the impact of these differences on retrieved aerosol properties.

- Evaluate the ability of aerosol radiative models to predict the results of ground-based passive and active measurements. This work will begin by using the aerosol climatology developed for the MISR atmospheric correction plus further investigations of Micro-Pulse Lidar and solar radiometer data sets obtained from ACE-2.

- Continued cooperative interactions with ongoing MPL ground-based sensing programs and future spaceborne lidar programs. The MPL interactions include the DOE ARM and NASA MPL field programs coordinated by Dr. Jim Spinhirne, NASA Goddard Space Flight Center (GSFC). The spaceborne lidar interactions include the Geoscience Laser Altimeter System (GLAS) satellite atmospheric lidar program component, working with Dr. Jim Spinhirne, NASA/GSFC, and the new PICASSO-CENA ESSP satellite lidar program lead by NASA Langley Research

Center (P.I. John Reagan is a member of the PICASSO-CENA Science Team).

RESULTS:

As funding for our project only became available in February of this year, we have but limited results to report at this time. One area of note is the ongoing lidar aerosol retrieval work with data from the LITE and ACE-2 projects. Two recent publications about work with the LITE data, the results of which are directly useful for and the basis for continuing work on this project, are listed below:

Karyampudi, V.M., Palm, S.P., Reagan, J.A., Fang, H., Grant, W.B., Hoff, R.M., Moulin, C., Pierce, H.F., Torres, O., Browell, E.V., Melfi, S.H., "Validation of the Saharan Dust Plume Conceptual Model Using Lidar, Meteosat and ECMWF Data, " *Bull. Amer. Meteor. Soc.*, Vol. 80, pp. 1045-1075, 1999.

Reagan, J.A. and H. Fang, "Aerosol Retrieval from 1064 and 532/1064 nm LITE Data," *Proc. IGARSS'99 Symposium (IEEE)*, pp. 372-374, Hamburg, Germany, June 28-July 2, 1999.

Regarding ongoing work with the ACE-2 MPL data, a paper has been submitted for a Tellus ACE-2 special issue. The title, authors and abstract for this paper are as follows:

ACE-2 Multiple Angle Micro-Pulse Lidar Observations from Las Galletas, Tenerife, Canary Islands

Donna M. Powell, John A. Reagan, Manuel A. Rubio, Wayne H. Erxleben, and James D. Spinhirne

(submitted for publication in Tellus ACE-2 Special Issue)

Abstract:

Multiple-angle Micro-Pulse Lidar (MPL) observations were made at Las Galletas on Tenerife, Canary Islands during the Aerosol Characterization Experiment-2 (ACE-2) conducted June-July, 1997. A principal objective of the MPL observations was to characterize the temporal/spatial distributions of aerosols in the region, particularly to identify and profile elevated Saharan dust layers which occur intermittently during the June-July time period. Vertical and slant angle measurements taken July 16 and 17 characterize such an occurrence, providing aerosol backscatter, extinction, and optical depth profiles of the dust layer between one and five kilometers above mean sea level (MSL). Additionally, horizontal measurements taken in Las Galletas throughout the six-week period provide a time profile of the varying aerosol extinction at the surface. This profile exhibits the alternating periods of clean maritime air and pollution outbreaks that typified the region. Horizontal measurements also provide some evidence suggesting the possible influx of Saharan dust from the free troposphere to the surface. This paper

presents estimates of aerosol optical properties retrieved from the multi-angle MPL measurements in addition to an outline of the methodologies employed to obtain these results.

Besides the publication efforts noted above, work has proceeded with the installation/refurbishment/implementation of instrumentation which is key to verifying and extending passive aerosol retrieval approaches. A Cimel solar radiometer was installed in February on the University of Arizona campus for inclusion in the AERONET. To date, measurements have included several cross-comparisons between the Cimel radiometer and the 10-channel solar radiometers developed at the ARSL. The data from the 10-channel instrument, while not collected throughout the entire day, are collected at much higher temporal resolution than the Cimel system and will be used to study short term variability of aerosols in the Tucson Valley.

Results of the data collections show good agreement between the two systems in retrieving optical depth, but the agreement varies from day to day with differences as large as 0.02 at an optical thickness of 0.10. Considering that the results are using two independently calibrated systems, no common calibration data sets, and different processing schemes, the agreement is quite good. Because of the proximity of the data collections to the radiosonde site at the Tucson International Airport (approximately 10 km from the radiometers), there was also an opportunity to evaluate column water vapor retrievals. Again, the agreement between the radiometers was found to be quite good, with differences for the most part less than 10%. Agreement with the radiosonde results also show relatively good agreement.

Work is in progress to upgrade/refurbish a spectropolarimeter for solar irradiance and sky radiance measurements. The tracking hardware was redone, tracking software for solar tracking was completed, and software for general sky pointing is currently being developed. A platform to allow a variety of radiometers to be mounted to the tracking mount was also developed. Several successful tests of solar tracking data collections were completed using a 3-channel solar radiometer. The spectropolarimeter was upgraded with new filter wheel drives, position encoders, and detector electronics.

FORM C: FUTURE PLANS

Name: John A. Reagan and Kurtis Thome

Institution: University of Arizona

Briefly describe your research plans for the second year of GACP.

As funding for this project only became available in February 1999, halfway through the first GACP annual cycle, our work plans for year two of GACP include some of the activities outlined for the first year in our original project proposal as well as commencing with our proposed second year activities. Our planned activities for year two of GACP are summarized as follows:

- Continued analysis of LITE spaceborne lidar data and ACE-2 Micro-Pulse Lidar (MPL) data, and associated solar radiometer data, to extract further information about global aerosol optical/physical properties and to test/validate how best to link these active and passive measurements in combined aerosol retrievals.

- Participation in a lidar, solar radiometer and scattering nephelometer experiment at Bondville, IL during late August and September of 1999 to validate lidar extinction retrievals and better characterize aerosol extinction to backscatter ratios for a variety of atmospheric conditions. This is a cooperative effort with another GACP funded project ("Validation of the Lidar Retrieval of Aerosol Extinction" - D.S. Covert & T.L. Anderson, PI's); MPL's to be used in the experiment are being loaned by NASA Langley Research Center. A slant-path sensing mirror system to be fitted to one of the MPL's is being loaned by Dr. Jim Spinhirne, NASA Goddard Space Flight Center.

- Continued evaluation of multiple instrument observations to understand the differences between measurements of solar transmittance, sky radiance, and downwelling irradiance and the impact of these differences on retrieved aerosol properties. Emphasis will be on further evaluations of diffuse-to-global observations and comparisons with results from the AERONET radiometer observations.

- Evaluate the ability of aerosol radiative models to predict the results of ground-based passive and active measurements. This work will begin by using the aerosol climatology developed for the MISR atmospheric correction plus further investigations of Micro-Pulse Lidar and solar radiometer data sets obtained from ACE-2.

- Continued cooperative interactions with ongoing MPL ground-based sensing programs and future spaceborne lidar programs. The MPL interactions include the DOE ARM and NASA MPL field programs coordinated by Dr. Jim Spinhirne, NASA Goddard Space Flight Center (GSFC). The spaceborne lidar interactions include the Geoscience Laser Altimeter System (GLAS) satellite atmospheric lidar program component, working with Dr. Jim Spinhirne, NASA/GSFC, and the new PICASSO-CENA ESSP satellite lidar program led by NASA Langley Research Center (P.I. John Reagan is a member of the PICASSO-CENA Science Team).

- Participation in calibration/validation activities related to the upcoming launch of the EOS Terra platform. This work will include activities related to the ASTER and MODIS sensors and collaborative work with MISR.