GACP THIRD YEAR PROGRESS REPORT

Name: John A. Reagan* and Kurtis J. Thome†

Institution: University of Arizona
Electrical and Computer Engineering*
Optical Sciences†
P.O. Box 0104
Tucson, AZ 85721-0104

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.

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) 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 this project began initially in February, 1999, rather than September, 1998, when many of the GACP projects were initiated, we are currently (Sept. 30, 2001) only about half way through our third year of work. However, a number of tasks earmarked for the third year of this project are either nearing completion or are well along at this point. Activities and accomplishments of note to date are summarized as follows:

- Continued analysis of ACE-2 Micro-Pulse Lidar (MPL) and solar radiometer data to characterize the aerosol extinction-to-backscatter ratio, S_a, for the marine boundary layer and near the surface for both clean and somewhat polluted conditions. Some results of this work to be given in a paper by Powell and Reagan to be presented at the upcoming A&WMA Regional Haze and Global Radiation Balance meeting, 2-5 October, 2001, Bend, Oregon.

- Continued analysis of lidar, solar radiometer and scattering nephelometer data obtained during the LINC experiment at Bondville, IL to obtain lidar derived aerosol extinction-to-backscatter ratios, S_a, for different atmospheric conditions, for comparison with the nephelometer derived ratios. Obtained agreement in the S_a derived by these two different approaches. These results included in a paper by Reagan, Thome and Powell presented at IGARSS'01, 9-13 July, Sidney, Australia.

- Continued assessment of multiple instrument observations to investigate differences between measurements of solar transmittance, sky radiance and downwelling irradiance, and the impact of these differences on retrieved aerosol properties. Efforts focused on comparison of AERONET aerosol retrievals with those obtained from MPL and scattering nephelometer measurements made during LINC at Bondville, IL. Obtained reasonable agreement in the aerosol extinction-to-backscatter ratio, S_a, determined by these three approaches. These results included in a paper by Reagan, Thome and Powell presented at IGARSS'01, 9-13 July, Sidney, Australia.

- Continued measurement assessments and modeling studies towards the goal of establishing an aerosol extinction-to-backscatter ratio, S_a, climatology. Collective results from lidar, AERONET and scattering nephelometer S_a observations, coupled with modeling based on the aerosol data bases used in establishing the MISR aerosol climatology, yield a bounded and consistent range of S_a values for the mid-visible spectral range. The observed range of S_a values can be further sub-divided into smaller ranges by using relatively few aerosol models (marine, dust, smoke and continental clean and polluted). Some results of this work to be given in a paper by Reagan, Thome and Powell to be presented at the upcoming A&WMA Regional Haze and Global Radiation Balance meeting, 2-5 October, 2001, Bend, Oregon.

- Continued interactions with AERONET group at NASA Goddard (i.e., O. Dubovik, B. Holben & A. Smirnor) focusing on classification of common aerosol types identified by investigation of the AERONET data base and characterization of critical aerosol radiative parameters (e.g., extinction-to-backscatter ratio, single-scatter albedo and asymmetry factor) associated with these common aerosol types. Also in the process of comparing these parameters with those of similar model types identified from the MISR aerosol climatology.

- Continued cooperative interactions with NASA groups involved in developing spaceborne lidar programs (i.e., GLAS and the PICASSO-CENA ESSP-3 missions). Have posed an aerosol extinction-to-backscatter ratio selection scenario for application in the processing of PICASSO-CENA spaceborne lidar data (presentation made on this at PICASSO-CENA Science Team meeting, NASA Langley, April 4-6, 2001; P.I. John Reagan also a member of the PICASSO-CENA Science Team). This selection scenario also included in the paper by Reagan, Thome and Powell presented at IGARSS'01, 9-13 July, Sidney, Australia.

PROJECT RESULTS HIGHLIGHTS:

1) Demonstrated and applied Micro-Pulse Lidar (MPL) techniques for quantitative retrieval of aerosol backscatter, extinction and the aerosol extinction-to-backscatter ratio. Obtained characteristics of aerosols during the ACE-2 Tenerife and LINC Bondville, IL campaigns.

2) Found that extinction-to-backscatter ratios for typical lidar wavelengths, based on measurements and literature, can be used to derive at least five characteristic aerosol types.

3) Determined that derived estimates of extinction-to-backscatter ratios obtained from models used by current satellite sensors for aerosol retrievals match, at least for mid-visible wavelengths, those of the characteristic aerosol types found in 2) above.

4) Found that results from passive radiometers, nephelometers, and lidar agree to within the uncertainties of each method, when temporal and spatial sampling differences between the sensors are considered, and the sensors are well understood.

5) Developed a methodology to select the aerosol extinction-to-backscatter ratio for processing of global spaceborne lidar data such as that from LITE or for future satellite missions (e.g., GLAS and ESSP3, formally PICASSO-CENA). This methodology is being applied for continued analysis and re-examination of LITE data.

6) Determined that primary impact of aerosol types on satellite calibration/validation is driven by the absorption of the aerosols, indicating that sites dominated by smaller aerosols will typically give larger uncertainties than those with larger aerosols.

The above noted results are presented either in the publications listed in the project Bibliography or papers still in preparation. Additional results of note are also anticipated from ongoing work through the remainder of the project funding period.

GACP BIBLIOGRAPHY

Name: John A. Reagan and Kurtis Thome

Institution: University of Arizona

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

Publications:

V.M. Karyampudi, 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.

B. Schmid, D. Collins, S. Gassó, E. Öström, D. Powell, E. Welton, P. Durkee, J. Livingston, P. Russell, R. Flagan, J. Seinfeld, D. Hegg, K. Noone, K. Voss, H. Gordon, J. Reagan, J. Spinhirne, "Clear-sky closure studies of tropospheric aerosol and water vapor during ACE-2 using airborne sunphotometer, airborne in-situ, space-borne, and ground-based measurement," *EOS Trans. Amer. Geophys. Union*, 80, F193, 1999.

J.A. Reagan 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.

D.M. Powell, J.A. Reagan, M.A. Rubio, W.H. Erxleben and J.D. Spinhirne, "ACE-2 multiple-angle micro-pulse lidar observations from Las Galletas, Tenerife, Canary Islands," *Tellus,* Vol. 52b, pp. 652-661, 2000.

J. Reagan, D. Powell, W. Erxleben, M. Rubio and J. Spinhirne, "MPL First-Look Results from LINC," *Proc. IGARSS 2000 Symposium* (IEEE), pp. 1622-1624, Honolulu, HI, July 24-28, 2000.

B. Schmid, D. Collins, S. Gassó, E. Öström, D. Powell, E. Welton, P. Durkee, J. Livingston, P. Russell, R. Flagan, J. Steinfeld, D. Hegg, K. Noone, K. Voss, J. Reagan, J. Spinhirne and D.M. McIntosh, "Airborne Sunphotometer, airborne in-situ, space-borne, and ground-based measurements of troposphoric aerosol in ACE-2," *Proc. IGARSS 2000 Symposium* (IEEE), pp. 1613-1615, Honolulu, HI, July 24-28, 2000.

K. Thome and P. Nandy, "Accuracy of ground-reference calibration of imaging spectroradiometers at large sensor view angles," *Proc. SPIE,* Vol. 4132, 2000.

J.A. Reagan, K.J. Thome and D.M. Powell, “Lidar Aerosol Ratio: Measurements and Models,” *Proc. IGARSS 2001 Symposium* (IEEE), pp. 84-87, Sydney, Australia, July 9-13, 2001.

D.M. Powell and J.A. Reagan, “Retrieval of the Atmospheric Extinction-to-Backscatter Ratio Using Lidar Multi-Angle Sensing,” paper accepted for presentation at A&WMA Specialty Conference on Regional Haze and Global Radiation Balance - Aerosol Measurements and Models, 4 pp., Bend, Oregon, Oct. 2-5, 2001.

J.A. Reagan, K.J. Thome and D.M. Powell, “Towards Establishing an Aerosol Extinction-to-Backscatter Ratio Climatology,” paper accepted for presentation at A&WMA Specialty Conference on Regional Haze and Global Radiation Balance - Aerosol Measurements and Models, 11 pp., Bend, Oregon, Oct. 2-5, 2001.

J. M. Holmes and K. Thome, "Comparison of modeled and measured downwelling, diffuse irradiance at a ground-reference calibration test site," *Proc. IGARSS 2001 Symposium* (IEEE), pp. 78-80, Sydney, Australia, July 9-13, 2001.