

Final Technical Report for Grant # DE-FG02-06ER64169

Bay Area Environmental Research Institute (BAER)

Period of Performance: January 2006 – June 30, 2007.

Funding for this effort became available in early January 2006 therefore we are considering January 1, 2006, as the official starting date. This is a 3 year award/effort. On October 2, 2006, Dr. Schmid (the PI of this award), joined PNNL as an Associate Director in the Atmospheric Science & Global Change Division. His ARM Science Team grant has been moved from the Bay Area Environmental Research Institute (BAER) to Pacific Northwest National Laboratory (PNNL). Dr. Hong Guan will continue to work for this project (20% of her time) through a subcontract from PNNL to BAER. June 30, 2007 was determined to be the close out date for the BAER Grant.

Purpose

The Atmospheric Radiation Measurement (ARM) program is funding this project to improve the methodology of ground-based remote sensing of the vertical distribution of aerosol and cloud optical properties, and their effect on atmospheric radiative transfer. Remotely-sensed and in situ observed aerosol, cloud physical, and optical properties collected during the May 2003 Aerosol Intensive Operational Period (AIOP) and the Aerosol Lidar Validation Experiment (ALIVE), conducted from September 11-22, 2005, are the basis for the investigation.

Approach

We have used ground-based lidar, airborne sunphotometer and in situ measurements and other data to evaluate the vertical profile of aerosol properties. We have been pursuing research in the following three areas:

1. **Aerosol Best Estimate Product – Sensitivity Study:** ARM is developing an Aerosol Best Estimate (ABE) Value Added Product (VAP) to provide aerosol optical properties at all times and heights above its sites. The ABE is used as input for the Broadband Heating Rate Profile (BBHRP) VAP, whose output will be used to evaluate the radiative treatment of aerosols and clouds in climate models. ARM has a need to assess how much detail is required for the ABE and if a useful ABE can be derived for the tropical and arctic climate research facilities (CRFs) where only limited aerosol information in the vertical is available. We have been determining the sensitivity of BBHRP to the vertical profile of aerosol optical properties used in ABE.
2. **Vertically Resolved Aerosol and Cloud Radiative Properties over the Southern Great Plains (SGP):** The AIOP delivered an unprecedented airborne radiometric and in-situ data set related to aerosols and clouds. The Center for Interdisciplinary Remotely-Piloted Aircraft Studies' (CIRPAS's) Twin Otter aircraft carried solar pointing, up- and down-looking radiometers (spectral and broadband, visible, and infrared) with the up-looking radiometers mounted on a stabilized platform. We are performing an integrated

analysis of the largely unexploited radiometric data set to provide observation-based quantification of the effect of aerosols and clouds on the radiation field. We will link aerosol and cloud properties measured in situ with the observed radiative fluxes using radiative transfer models. This over-determined dataset will provide validation of the BBHRP VAP.

3. Integrated Analysis of Data from the Aerosol Lidar Validation Experiment: The ABE VAP relies on continuous lidar observations to provide the vertical distribution of the aerosols above the ARM sites. The goal of ALIVE, conducted in September 2005, was the validation of the aerosol extinction profiles obtained from the SGP Raman lidar, which has been recently refurbished/updated, and the Micro Pulse Lidar, for which a new algorithm to retrieve aerosol profiles has recently been developed, using the National Aeronautics and Space Administration (NASA) Ames Airborne Tracking 14 channel Sun photometer. We are performing and publishing the integrated analysis of the ALIVE data set.

Key personnel:

PI: Dr. Beat Schmid

Co-I: Dr. Hong Guan

Technical Progress

This ARM Science Team effort is to study vertically resolved radiative properties of aerosols and clouds aimed at assessing the direct impact of aerosols and clouds on atmospheric radiative transfer.

This award is a renewal of a previous 3-year grant and offers a seamless transition of our efforts.

As spelled out in the proposal, we focused on three tasks:

Task 1: We are determining the sensitivity of the broad-band heating rate profiles (or more specifically aerosol radiative forcing profiles) to the vertical profiles of aerosol extinction, single-scattering albedo, and asymmetry parameter (i.e., the ABE) for clear-sky and cloudy conditions. As a starting point, we have been focusing on the radiative forcing at the top of the atmosphere (TOA) and at the surface. We are using Atmospheric Environmental Research's (AER's) Rapid Radiative Transfer Model-Shortwave (RRTM_SW) code to do these simulations. To ensure appropriate use of the code we have embarked on a detailed comparison with another widely used radiation code (Santa Barbara DISORT [Discrete Ordinate Radiative Transfer Model] Atmospheric Radiative Transfer [SBDART]). To this end, we joined forces with an ongoing effort led by Allison McComiskey (National Oceanic and Aerospace Administration, Boulder, Colorado). We find good agreement between the two codes for a wide range of inputs and scenarios. This joint sensitivity study gave us considerable insight and has been used in numerous presentations (see Presentations). A formal publication has been submitted very recently (*McComiskey et al. 2007* with B. Schmid and H. Guan). We have also completed runs assessing the results not only at TOA and the surface but throughout the

vertical profile. These results have also been shown in numerous presentations (see Presentations) and we have contributed to a recently submitted journal publication (*Magi et al.*, 2007 with B. Schmid).

Task 2: We have started an integrated analysis of the May 2003 Twin Otter AIOP radiometric data set to provide an observationally-based quantification of the effect of aerosols and clouds on the radiation field. This task will be continued and completed by PNNL.

Task 3: We are performing the integrated analysis of the data sets from ALIVE (Principal Investigator: B. Schmid) conducted over SGP from September 11-22, 2005. The comparisons among lidars, airborne- and ground-based sunphotometers are encouraging. The SGP Raman lidar upgrades resulted in considerably better performance when compared to the results of the 2003 Aerosol IOP. Results have been presented on several occasions (see Presentations). Several journal publications are in preparation. This task will be continued and completed by PNNL.

Additional Activities:

As the chairman of the ARM Aerosol Working Group (AWG), Dr. Schmid has been leading the AWG meetings, and he has also been attending all Science Team Executive Committee (STEC) and ARM Climate Research Facility (ACRF) board meetings.

Dr. Schmid, has been deeply involved in the planning of the SGP Cloud and Land Surface Interaction Campaign (CLASIC) Intensive Operational Period executed in June 2007.

Journal Publications

1. Magi B. I., Q. Fu, J. Redemann, and **B. Schmid**. A methodology to estimate the magnitude and uncertainty of biomass burning aerosol direct radiative forcing using aircraft measurements. *J. Geophys. Res.*, submitted, 1/24/2007.
2. McComiskey A., S. E. Schwartz, **B. Schmid**, **H. Guan**, E. R. Lewis, P. Ricchiazzi, J. A. Ogren. Direct Aerosol Forcing: Calculation from Observables and Sensitivities to Inputs. *J. Geophys. Res.*, submitted, 7/13/2007.

Presentations

1. **Schmid, B.**, Ferrare, R., Turner, D., Flynn, C., Cairns, B., Dominguez, R., Gore, W., Groff, D., Herman, B., Hovelman, B., Jefferson, A., Johnson, R., Knobelspiesse, K., Mendoza, A., Ogren, J., Petty, D., Russell, E., Russell, P., Roeder, L., Truong, N. The Aerosol Lidar Validation Experiment – ALIVE. 14th ARM Science Team Meeting, Albuquerque, New Mexico, March 27 - 31, 2006.
2. **Schmid B.**, Report on ARM Aerosol Working Group Activities. 14th ARM Science Team Meeting, Albuquerque, New Mexico, March 27 - 31, 2006.
3. **Schmid B.**, Aerosols in (almost) cloud-free skies, Pacific Northwest National Laboratory, Richland, WA, June, 2, 2006.

4. **Schmid B.**, J. Redemann, Q. Zhang, R. Ferrare, D. Turner, C. Flynn, P. Russell, J. Livingston, H. Jonsson. Remote sensing of aerosol from aircraft, surface and space. IGARSS 2006, Denver, CO, July 31 – August 2006.
5. **Schmid B.** and **H. Guan**. Vertically Resolved Radiative Properties of Aerosol and Clouds. ARM AWG Meeting, San Francisco, CA, November 1-2, 2006.
6. **Schmid B.**, AWG Report to ARM STEC, Washington D.C., December 5, 2006.
7. **Schmid B.**, **H. Guan**, A. McComiskey, S. McFarlane, M. Kuzmanoski, B. Magi, C. Flynn. The Sensitivity of Radiative Forcing and Heating Rates to the Aerosol Vertical Profile. 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
8. **Schmid B.**, Introduction to Aerosol Working Group Report Breakout Session, 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
9. **Schmid B.**, Aerosol Working Group Report to ARM STEC, 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
10. **Schmid B.**, Update on Aerosol Lidar Validation Experiment (ALIVE), 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
11. **Schmid B.**, CLASIC/CHAPS Air. 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
12. Ferrare, R., Turner, D., Flynn, C., Petty, D., Mendoza, A., Clayton, M., **Schmid, B.**, Raman lidar and MPL Measurements during ALIVE, 14th ARM Science Team Meeting, Albuquerque, New Mexico, March 27 - 31, 2006.
13. Ferrare R., Turner D., Flynn C., Petty D., Mendoza A., Clayton M., **Schmid B.**, Raman lidar and MPL Measurements during ALIVE. 7th International Symposium on Tropospheric Profiling: Needs and Technologies (ISTP), Boulder, CO, June 11th-17th, 2006.
14. McComiskey, A., Schwartz, S E, **Schmid, B**, Ricchiazzi, P, Lewis, E R, **Guan, H**, Ogren, J. Direct Aerosol Forcing: Calculation from Observables and Sensitivities to Inputs. (2006), Eos Trans. AGU, 87(52), Fall Meet. Suppl., Abstract A13B-0916.
15. Kiedron P., C. Flynn, R. Ferrare, B. Holben, J. Michalsky, **B. Schmid**, J. Slusser. Comparison of aerosol optical depth from passive and active measurements during the 2005 Aerosol Lidar Validation Experiment (ALIVE) at SGP. 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
16. Ferrare R., Turner D., M. Clayton, D. Petty, C. Flynn, **B. Schmid**. Aerosol and water vapor measurements acquired by the upgraded SGP Raman Lidar during ALIVE. 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.
17. Flynn C., A. Mendoza, R. Ferrare, D. Turner, D. Petty, M. Clayton, **B. Schmid**, R. Johnson, N. Truong. Comparison of aerosol extinction profiles from Micropulse Lidar, Raman Lidar, and NASA Ames Airborne Tracking Sun-Photometer during the 2005 Aerosol Lidar Validation Experiment (ALIVE) at SGP. 17th Atmospheric

Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.

18. Cairns B., A. Lacis, M. Alexandrov, B. Carlson and **B. Schmid**. Observed Surface Reflectance Distributions in the Southern Great Plains during ALIVE. 17th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, March 26-30, 2007, Monterey, California.