

**Improved Exploitation of Field Data Sets to Address Aerosol Radiative-Climatic Effects and  
Development of a Global Aerosol Climatology**  
RTOP 622-44-75-10

PI: Philip B. Russell, NASA Ames Research Center, Moffett Field, CA 94035-1000  
Co-Is: Beat Schmid<sup>1</sup>, Jens Redemann<sup>1</sup>, and John M. Livingston<sup>2</sup>  
<sup>1</sup>Bay Area Environmental Research Institute  
<sup>2</sup>SRI International

**Goals and Objectives** (from February 1998 proposal)

The goals of this research are to (A) improve understanding of aerosol radiative forcing of climate and (B) help guide the development of an aerosol climatology. Our proposed approach is to improve the exploitation of data already acquired in two multiplatform field experiments, the Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX) and the second Aerosol Characterization Experiment (ACE-2), plus other experiments when appropriate. The objectives are given by the following task specifications:

- (1) Improve the cloud-screening in the TARFOX and ACE-2 airborne and shipborne sunphotometer optical depth data sets, perform more general quality checks, and archive reprocessed data as necessary,
- (2) Investigate the question of the best aerosol optical models (e.g., complex refractive indices, internal vs. external mixtures, shapes) to account for observed aerosol compositions (e.g., water, carbonaceous material, sulfates, minerals) and for observed relationships between measured size distributions and measured optical coefficients (e.g., extinction, backscatter, total scatter, absorption),
- (3) Develop and test a new, more automated technique for retrieving particle size distributions from optical depth spectra, and apply it to field-measured data sets,
- (4) Compare results of the new size distribution retrievals to those of previous retrievals, to size distributions measured in situ, and to models used in retrievals from imaging spectrometers on satellites and aircraft, and
- (5) Investigate the relationship between water vapor and aerosol properties, with the goal of using water vapor information to improve satellite retrievals of aerosol optical depth and radiative forcing.

**2<sup>nd</sup> Year Progress Report** (Grouped by numbered objective above):

1. Airborne Sunphotometer Data Quality Checks: A new cloud screen was developed and applied to the Ames Airborne Tracking Sunphotometer (AATS-6) data set from TARFOX. The cloud-screened data set was archived at the Langley DAAC. Cloud-screened AATS data from ACE-2 were previously archived. This task is now complete.

2. Mixed Aerosol Optical Modeling: For two TARFOX case studies, the vertical structure of the effective aerosol complex index of refraction has been estimated from a combination of lidar, sunphotometer and in situ particle size distribution data [Redemann et al., 2000a]. The combined aerosol fundamental properties thus retrieved were used to estimate the vertical structure of the single scattering albedo. These single scattering albedos were compared to independent estimates using in situ measurements of aerosol scattering and absorption [Redemann et al., 2000b]. The vertical profiles of the aerosol single scattering albedo were shown to agree well within the error bars of the two methods. A core/shell model of internally mixed, single sulfate particles with soot cores was used to study the changes in particle size, light scattering and absorption that accompany changes in ambient relative humidity [Redemann et al., 1999]. The sulfate species considered were sulfuric acid, ammonium sulfate and ammonium bisulfate. The work has been extended to quantify the absorption humidification factors of realistic, dry particle size distributions. A manuscript describing these results is in preparation for submission to GRL.

3. Automated Size Distribution Retrievals: The multimodal technique, based on regularities found in AERONET skylight retrievals [Remer et al., 1998a], was refined and further tested with AATS-6 and -14 data from TARFOX and ACE-2. Multimodal parameter evolutions along horizontal transects and vertical profiles were retrieved.

4. Size Distribution Comparisons and Closure Studies: Results described in last year's progress report have now been published in the ACE-2 special issue of *Tellus* [Collins et al., 2000; Durkee et al., 2000; Flamant et al., 2000; Gasso et al., 2000; Livingston et al., 2000; Russell and Heintzenberg, 2000; Schmid et al., 2000a; Welton et al., 2000]. A new ACE-2 closure result with the University of Arizona Micro-Pulse Lidar was published in conference proceedings [Schmid et al., 2000b]. This task also supported the use of our airborne sunphotometer data in a variety of closure studies published in the second TARFOX special issue of *J. Geophys. Res.* [Ferrare et al., 2000a,b; Hartley et al., 2000; Ismail et al., 2000].

5. Water Vapor/Aerosol Interactions and Satellite Retrievals: Comparisons between ambient (humidified) aerosol optical depth spectra measured by AATS-6 and computed from shipboard dry-aerosol measurements, humidity profiles and models of aerosol hygroscopic growth were described by Livingston et al. [2000]. Our water vapor retrieval algorithms have been updated to include the latest spectroscopy [e.g., Ingold et al., 2000; Schmid et al., 2000d]. Results of water vapor intercomparisons have been presented and submitted for publication [Schmid et al., 2000c,d,e]. Optical depths we measured in the 1997 Atmospheric Radiation Measurement Water Vapor Intensive Observation Period (ARM WVIOP) were used to study the relationship between water vapor and model-measurement differences in solar irradiance at the ground [Pilewskie et al., 2000].

6. [Extra, not in proposal]: A \$60K augmentation helped support instrument preparation and measurements in the Puerto Rico Dust Experiment (PRIDE, June-July 2000) and the South African Regional Science Initiative (SAFARI, August-September 2000). These experiments study the radiative effects of desert dust, biomass smokes, and other aerosols. They include major validation studies of aerosol retrievals by sensors on EOS Terra and other satellites.

### **3rd Year Statement of Work**

1. Airborne Sunphotometer Data Quality Checks: This task is now complete.

2. Mixed Aerosol Optical Modeling: We plan to expand our study of the aerosol absorption humidification (using the shell/core particle model) to chemical species different from the sulfate species considered

previously. In an extension of the absorption humidification work, we will estimate the impact of assuming absorption humidification factors equal to unity in conjunction with measurements of dry aerosol optical properties for estimates of the wet single scattering albedo. In order to develop an integrated picture of aerosol hygroscopic growth in relation to chemical composition and optically measured or derived properties, we will attempt to use the newly developed model to correlate sunphotometer-derived extinction with sunphotometer-derived water densities during aircraft spirals flown in TARFOX and ACE-2.

3. Automated Size Distribution Retrievals: Using optical depth spectra measured during ACE-2, the recently completed Puerto Rico Dust Experiment (PRIDE), and the upcoming SAFARI-2000 campaign, we will apply the multimodal retrieval technique in conjunction with trajectory analyses to try to identify dependence of marine boundary layer volume aerosol distribution on air mass origin. We also plan to use AATS-6 measurements obtained at various altitudes up to 5 km during PRIDE to investigate the applicability of the multimodal retrieval algorithm to Saharan dust optical depth spectra. In-situ measurements taken during PRIDE will be used to adjust the dust modal radii, as necessary. A range of refractive indices representative of the most recently published results of dust composition will be used in the retrievals. Where possible, the volume aerosol size distribution retrievals will be compared with analogous results obtained from analyses of vertical profiles of Saharan dust optical depth spectra obtained in the Canary Islands nearer the dust source with the AATS-14 during ACE-2. Finally, we intend to apply the multimodal retrieval technique to airborne sunphotometer optical depth spectra obtained through biomass burning smoke during SAFARI-2000. The work will use the smoke size modes found by Remer et al. [1996; 1998b] for Brazil biomass smokes and will also look at results from SAFARI 92 for possible differences in African smokes and other South African aerosols. Extinction spectra for each mode will be precalculated for a variety of size-dependent chemical compositions based on the SCAR-B and SAFARI 92 results. We will also investigate whether the shell/core results of Task 2 can be applied in the multimodal retrieval technique.

4. Size Distribution Comparisons and Closure Studies: We will extend the comparisons between sunphotometer-retrieved and in-situ-measured size distributions. For this we will use data from the Pelican aircraft in ACE-2, Navajo in PRIDE (June/July 2000) and CV-580 in SAFARI-2000 (August/Sept 2000). Those will include flights in the polluted and unpolluted MBLs, in dust and smoke. In this comparison we will also use the inversion method developed in Task 3. This technique can provide a means of incorporating size-dependent refractive indices, and thereby accounting for observed size-dependent particle compositions. We will also compare results of our retrieved size distributions to models used in retrievals from imaging spectrometers on satellites and aircraft. One goal of these comparisons will be to identify potential improvements to the retrieval model size distributions and thereby the accuracy of the imaging spectrometer retrievals of optical depth.

5. Water Vapor/Aerosol Interactions and Satellite Retrievals: In an empirical approach we will correlate sunphotometer-derived aerosol extinction with sunphotometer-derived water densities during aircraft spirals flown in the experiments mentioned in Task 4. We will also consider trajectory studies and large-scale water vapor distributions (obtained from satellites) to investigate aerosol exposure to humidity prior to the sunphotometer measurement. Results of this task will be integrated with those of Task 2 above, in an effort to develop an integrated picture of aerosol hygroscopic growth in relation to chemical composition and optically measured or derived properties.

## References

- Collins, D. R., Jonsson, H. H., Seinfeld, J. H., Flagan, R. C., Gassó, S., Hegg, D., Russell, P. B., Livingston, J. M., Schmid, B., Öström, E., Noone, K. J., and Russell, L. M. In situ aerosol size distributions and clear column radiative closure during ACE 2. *Tellus B* 52, 498-525, 2000.
- Durkee, P. A., Nielsen, K. E., Russell, P. B., Schmid, B., Livingston, J. M., Collins, D., Flagan, R. C., Seinfeld, H. H., Noone, K. J., Öström, E., Gassó, S., Hegg, D., Bates, T. S., Quinn, P. K., and Russell, L. M. Regional aerosol properties from satellite observation: ACE-1, TARFOX and ACE 2 results. *Tellus B* 52, 484-497, 2000.
- Ferrare, R., S. Ismail, E. Browell, V. Brackett, M. Clayton, S. Kooi, S. H. Melfi, D. Whiteman, G. Schwemmer, K. Evans, P. Russell, J. Livingston, B. Schmid, B. Holben, L. Remer, A. Smirnov, P. Hobbs. Comparisons of aerosol optical properties and water vapor among ground and airborne lidars and sun photometers during TARFOX. *J. Geophys. Res.*, 105, 9917-9933, 2000a.
- Ferrare, R., Ismail, S.; Browell, E.; Brackett, V.; Kooi, S.; Clayton, M.; Hobbs, P. V.; Hartley, S.; Veefkind, J. P.; Russell, P.; Livingston, J.; Tanre, D., Hignett, P., Comparisons of LASE, aircraft, and satellite measurements of aerosol optical properties and water vapor during TARFOX, *J. Geophys. Res.*, 105, 9935-9947, 2000b.
- Flamant, C., J. Pelon, P. Chazette, V. Trouillet, P. K. Quinn, R. Frouin, D. Bruneau, J. F. Leon, T. Bates, J. Johnson, and J. Livingston, Airborne lidar measurements of aerosol spatial distribution and optical properties over the Atlantic Ocean during a European pollution outbreak of ACE-2. *Tellus B* 52, 662-677, 2000.
- Gassó, S., Hegg, D. A., Covert, D. S., Noone, K., Öström, K., Schmid, K., Russell, P. B., Livingston, J. M., Durkee, P. A., and Jonsson, H. Influence of humidity on the aerosol scattering coefficient and its effect on the upwelling radiance during ACE-2. *Tellus B* 52, 546-567, 2000.
- Hartley WS, Hobbs PV, Ross JL, Russell PB, Livingston JM, Properties of aerosols aloft relevant to direct radiative forcing off the mid-Atlantic coast of the United States, *J. Geophys. Res.*, 105, 9859-9885, 2000.
- Ingold, T., B. Schmid, C. Mätzler, P. Demoulin, and N. Kämpfer, Modeled and empirical approaches for retrieving columnar water vapor from solar transmittance measurements in the 0.72, 0.82 and 0.94-mm absorption bands. *J. Geophys. Res.*, 2000 (in press)
- Ismail S, Browell EV, Ferrare RA, Kooi SA, Clayton MB, Brackett VG, Russell PB, LASE measurements of aerosol and water vapor profiles during TARFOX, *J. Geophys. Res.*, 105, 9903-9916, 2000.
- Livingston, J. M., V. N. Kapustin, B. Schmid, P. B. Russell, P. K. Quinn, T. S. Bates, P. A. Durkee, and V. Freudenthaler, Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE 2. *Tellus B* 52, 594-619, 2000.
- Pilewskie P, Rabbette M, Bergstrom R, Marquez J, Schmid B, Russell PB, The discrepancy between measured and modeled downwelling solar irradiance at the ground: Dependence on water vapor, *Geophys. Res. Lett.*, 27, 137-140, 2000.
- Redemann, J., P.B. Russell, P. Hamill, Measurements and modeling of aerosol absorption and single scattering albedo at ambient relative humidity, AGU Fall Meeting, *EOS Transactions AGU*, 80, 206, 1999.
- Redemann, J., P.B. Russell. Lidar-aided estimates of the vertical structure of the direct shortwave aerosol radiative forcing of climate, Proc. Symp. Lidar Atmos. Monitoring, AMS Annual meeting, Long Beach, CA, pp. 24-25, 2000.
- Redemann, J., R.P. Turco, K.N. Liou, P.B. Russell, R.W. Bergstrom, B. Schmid, J.M. Livingston, P.V. Hobbs, W.S. Hartley, S. Ismail, R.A. Ferrare, E.V. Browell, Retrieving the vertical structure of the

- effective aerosol complex index of refraction from a combination of aerosol in situ and remote sensing measurements during TARFOX, *J. Geophys. Res.* *105*, 9949-9970, 2000a.
- Redemann, J., R.P. Turco, K.N. Liou, P.V. Hobbs, W.S. Hartley, R.W. Bergstrom, E.V. Browell, and P.B. Russell, Case studies of the vertical structure of the direct shortwave aerosol radiative forcing during TARFOX, *J. Geophys. Res.*, *105*, 9971-9979, 2000b.
- Remer, L. A., and Y. Kaufman, Dynamic aerosol model: Urban/industrial aerosol, *J. Geophys. Res.*, *103*, 13,859-13,871, 1998a.
- Remer, L. A., Y. Kaufman, and B. Holben, The size distribution of ambient aerosol particles: Smoke vs. urban/industrial aerosol. *Global Biomass Burning*, J. S. Levine, Ed., MIT Press, Cambridge, MA 519-530, 1996.
- Remer, L. A., Y. Kaufman, B. Holben, A. M. Thompson, and D. McNamara, A model of tropical biomass burning smoke aerosol size distribution, *J. Geophys. Res.*, *103*, 31,879-31,892, 1998b.
- Russell, P. B., and J. Heintzenberg, An overview of the ACE 2 clear sky column closure experiment (CLEARCOLUMN), *Tellus B* *52*, 463-483, 2000.
- Schmid, B., Livingston, J. M., Russell, P. B., Durkee, P. A., Collins, D. R., Flagan, R. C., Seinfeld, J. H., Gassó, S., Hegg, D. A., Öström, E., Noone, K. J., Welton, E. J., Voss, K., Gordon, H. R., Formenti, P., and Andreae, M. O. Clear sky closure studies of lower tropospheric aerosol and water vapor during ACE 2 using airborne sunphotometer, airborne in-situ, space-borne, and ground-based measurements. *Tellus B* *52*, 568-593, 2000a.
- Schmid B., 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, J. Reagan, J. Spinhirne. Airborne sunphotometer, airborne in-situ, space-borne, and ground-based measurements of tropospheric aerosol in ACE-2. 20th International Geoscience and Remote Sensing Symposium, Honolulu, Hawaii 24-28 July 2000b (invited).
- Schmid B., J. Michalsky, D. Slater, J. Barnard, R. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, and P. Russell. Comparison of columnar water vapor measurements during the fall 1997 ARM Intensive Observation Period: optical methods. Proceedings of the 10th ARM Program Science Team Meeting, San Antonio, Texas. March 13-17, 2000c. Available online [http://www.arm.gov/docs/documents/technical/conf\\_0003/schmid-b.pdf](http://www.arm.gov/docs/documents/technical/conf_0003/schmid-b.pdf)
- Schmid B., J. Michalsky, D. Slater, J. Barnard, R. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, P. Russell, T. Ingold, and I. Slutsker. Comparison of columnar water vapor measurements during the fall 1997 ARM Intensive Observation Period: solar transmittance methods. *Applied Optics* (submitted) 2000d.
- Schmid B., J. Michalsky, D. Slater, J. Barnard, R. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, and P. Russell. Comparison of columnar water vapor measurements during the fall 1997 ARM Intensive Observation Period: optical methods. 20th International Geoscience and Remote Sensing Symposium, Honolulu, Hawaii 24-28 July 2000e.
- Welton, E. J., Voss, K. J., Gordon, H. R., H. Maring, Smirnov, A., Holben, B., Schmid, B., Livingston, J. M., Russell, P. B., Durkee, P. A., Formenti, P., and Andreae, M. O.,. Ground-based lidar measurements of aerosols during ACE 2: Instrument description, results, and comparisons with other ground-based and airborne measurements. *Tellus B* *52*, 636-651, 2000.

## GACP Bibliography

Publications and presentations since 1<sup>st</sup> Year GACP Report (August 1999). Bold font indicates member of Ames Airborne Sunphotometer-Satellite Group.

**Totals:** 7 1<sup>st</sup>-author peer-reviewed; 10 co-author peer-reviewed; 11 1<sup>st</sup>-author conf proc; 6 1<sup>st</sup> author other presentation)

a) *Peer-reviewed Journal Papers*

Collins, D. R., Jonsson, H. H., Seinfeld, J. H., Flagan, R. C., Gassó, S., Hegg, D., **Russell, P. B., Livingston, J. M., Schmid, B., Öström, E., Noone, K. J., and Russell, L. M.** In situ aerosol size distributions and clear column radiative closure during ACE 2. *Tellus B* 52, 498-525, 2000.

Durkee, P. A., Nielsen, K. E., **Russell, P. B., Schmid, B., Livingston, J. M., Collins, D., Flagan, R. C., Seinfeld, H. H., Noone, K. J., Öström, E., Gassó, S., Hegg, D., Bates, T. S., Quinn, P. K., and Russell, L. M.** Regional aerosol properties from satellite observation: ACE-1, TARFOX and ACE 2 results. *Tellus B* 52, 484-497, 2000.

Ferrare, R., S. Ismail, E. Browell, V. Brackett, M. Clayton, S. Kooi, S. H. Melfi, D. Whiteman, G. Schwemmer, K. Evans, P. **Russell, J. Livingston, B. Schmid, B. Holben, L. Remer, A. Smirnov, P. Hobbs.** Comparisons of aerosol optical properties and water vapor among ground and airborne lidars and sun photometers during TARFOX. *J. Geophys. Res.*, 105, 9917-9933, 2000a.

Ferrare, R., Ismail, S.; Browell, E.; Brackett, V.; Kooi, S.; Clayton, M.; Hobbs, P. V.; Hartley, S.; Veefkind, J. P.; **Russell, P.; Livingston, J.; Tanre, D., Hignett, P.,** Comparisons of LASE, aircraft, and satellite measurements of aerosol optical properties and water vapor during TARFOX, *J. Geophys. Res.*, 105, 9935-9947, 2000b.

Flamant, C., J. Pelon, P. Chazette, V. Trouillet, P. K. Quinn, R. Frouin, D. Bruneau, J. F. Leon, T. Bates, J. Johnson, and J. **Livingston,** Airborne lidar measurements of aerosol spatial distribution and optical properties over the Atlantic Ocean during a European pollution outbreak of ACE-2. *Tellus B* 52, 662-677, 2000.

Gassó, S., Hegg, D. A., Covert, D. S., Noone, K., Öström, K., **Schmid, K., Russell, P. B., Livingston, J. M., Durkee, P. A., and Jonsson, H.** Influence of humidity on the aerosol scattering coefficient and its effect on the upwelling radiance during ACE-2. *Tellus B* 52, 546-567, 2000.

Hartley WS, Hobbs PV, Ross JL, **Russell PB, Livingston JM,** Properties of aerosols aloft relevant to direct radiative forcing off the mid-Atlantic coast of the United States, *J. Geophys. Res.*, 105, 9859-9885, 2000.

Ismail S, Browell EV, Ferrare RA, Kooi SA, Clayton MB, Brackett VG, **Russell PB,** LASE measurements of aerosol and water vapor profiles during TARFOX, *J. Geophys. Res.*, 105, 9903-9916, 2000.

**Livingston, J. M., V. N. Kapustin, B. Schmid, P. B. Russell, P. K. Quinn, T. S. Bates, P. A. Durkee,** and V. Freudenthaler, Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE 2. *Tellus B* 52, 594-619, 2000.

Pilewskie P, Rabbette M, **Bergstrom R, Marquez J, Schmid B, Russell PB,** The discrepancy between measured and modeled downwelling solar irradiance at the ground: Dependence on water vapor, *Geophys. Res. Lett.*, 27, 137-140, 2000.

**Redemann, J., R.P. Turco, K.N. Liou, P.B. Russell, R.W. Bergstrom, B. Schmid, J.M. Livingston,** P.V. Hobbs, W.S. Hartley, S. Ismail, R.A Ferrare, E.V. Browell, Retrieving the vertical structure of

the effective aerosol complex index of refraction from a combination of aerosol in situ and remote sensing measurements during TARFOX, *J. Geophys. Res.* 105, 9949-9970, 2000

**Redemann, J., R.P. Turco, K.N. Liou, P.V. Hobbs, W.S. Hartley, R.W. Bergstrom, E.V. Browell, and P.B. Russell**, Case studies of the vertical structure of the direct shortwave aerosol radiative forcing during TARFOX, *J. Geophys. Res.*, 105, 9971-9979, 2000.

**Russell, P. B., and J. Heintzenberg**, An overview of the ACE 2 clear sky column closure experiment (CLEARCOLUMN), *Tellus B* 52, 463-483, 2000.

**Schmid, B., J. J. Michalsky, R. N. Halthore, M. C. Beauharnois, L. C. Harrison, J. M. Livingston, P. B. Russell, B. Holben, T. Eck, and A. Smirnov**, Comparison of aerosol optical depth from four solar radiometers during the Fall 1997 ARM Intensive Observation Period, *Geophys. Res. Lett.*, 17, 2725-2728, 1999.

**Schmid, B., Livingston, J. M., Russell, P. B., Durkee, P. A., Collins, D. R., Flagan, R. C., Seinfeld, J. H., Gassó, S., Hegg, D. A., Öström, E., Noone, K. J., Welton, E. J., Voss, K., Gordon, H. R., Formenti, P., and Andreae, M. O.** Clear sky closure studies of lower tropospheric aerosol and water vapor during ACE 2 using airborne sunphotometer, airborne in-situ, space-borne, and ground-based measurements. *Tellus B* 52, 568-593, 2000.

**Schmid B., J. Michalsky, D. Slater, J. Barnard, R. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, P. Russell, T. Ingold, and I. Slutsker.** Comparison of columnar water vapor measurements during the fall 1997 ARM Intensive Observation Period: solar transmittance methods. *Applied Optics* (submitted) 2000d.

Welton, E. J., Voss, K. J., Gordon, H. R., H. Maring, Smirnov, A., Holben, B., **Schmid, B., Livingston, J. M., Russell, P. B., Durkee, P. A., Formenti, P., and Andreae, M. O.,** Ground-based lidar measurements of aerosols during ACE 2: Instrument description, results, and comparisons with other ground-based and airborne measurements. *Tellus B* 52, 636-651, 2000.

***b) First-authored Conference Proceedings or Abstract Publications***

- Livingston, J.M., Kapustin, V.N., Schmid, B., Russell, P.B., Quinn, P.K., Bates, T.S., Durkee, P.A., Nielsen, K., Freudenthaler, V., Wiegner, M., Covert, D.S.,** Shipboard sunphotometer measurements of aerosol optical depth spectra during ACE 2 and comparison with selected ship, aircraft, and satellite measurements. Sixth Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC) September 13-17, 1999, Bologna, Italy.
- Redemann, J., P.B. Russell, P. Hamill,** Measurements and modeling of aerosol absorption and single scattering albedo at ambient relative humidity, AGU Fall Meeting, *EOS Transactions AGU*, 80, 206, 1999.
- Redemann, J., P.B. Russell.** Lidar-aided estimates of the vertical structure of the direct shortwave aerosol radiative forcing of climate, Proc. Symp. Lidar Atmos. Monitoring, AMS Annual meeting, Long Beach, CA, pp. 24-25, 2000.
- Russell, P. B., J. M. Livingston, B. Schmid, R. W. Bergstrom, P. Hignett, P. V. Hobbs, and P. A. Durkee,** North Atlantic aerosol properties and direct radiative effects: key results from TARFOX and ACE 2. Proceedings of the 10th Conference on Atmospheric Radiation of the American Meteorological Society, pp. 490-493, Madison, Wisconsin, 26 June-2 July 1999.
- Russell, P. B., R. W. Bergstrom, J. M. Livingston, and B. Schmid,** North Atlantic aerosol properties for radiative impact assessments, derived from column closure analyses in TARFOX and ACE 2, IUGG99, XXII General Assembly of the International Union of Geodesy and Geophysics, Birmingham, England, 18-30 July 1999.
- Russell, P. B., R. W. Bergstrom, B. Schmid, J. M. Livingston,** North Atlantic aerosol properties for radiative impact assessments, derived from column closure analyses in TARFOX and ACE 2. Sixth Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC) September 13-17, 1999, Bologna, Italy.
- Russell P B, R W Bergstrom, B Schmid, J M Livingston, J Redemann, P K Quinn, C M Carrico, M J Rood** North Atlantic aerosol single scattering albedos: TARFOX and ACE 2 results and their relation to radiative effects derived from satellite optical depths. *EOS Trans. Amer. Geophys. Union*, 80, F212, 1999.
- Schmid, B., Russell, P. B., J. M. Livingston, S. Gassó, D. Hegg, D. Collins, J. Seinfeld, E. Öström, K. Noone, P. Durkee, E. J. Welton, K. Voss, V. N. Kapustin, T. S. Bates, and P. K. Quinn,** Clear column closure studies of urban-marine and mineral-dust aerosols using aircraft, ship, satellite and ground-based measurements in ACE-2. Proceedings of the 10th Conference on Atmospheric Radiation of the American Meteorological Society, pp. 323-326, Madison, Wisconsin, 26 June-2 July 1999.
- Schmid, B., J. M. Livingston, P. B. Russell, P. A. Durkee, H. Jonsson, D. Collins, R. C. Flagan, J. Seinfeld, S. Gassó, D. A. Hegg, E. Öström, K. J. Noone, E. J. Welton, K. Voss, H. R. Gordon, P. Formenti, and M. O. Andreae,** Clear sky closure studies of lower tropospheric aerosol and water vapor during ACE 2 using airborne sunphotometer, airborne in-situ, space-borne, and ground-based measurements. *Sixth Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC)* September 13-17, 1999, Bologna, Italy.
- Schmid B, 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 measurements. *EOS Trans. Amer. Geophys. Union*, 80, F193, 1999.

**Schmid B., J. Michalsky, D. Slater, J. Barnard, R. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, and P. Russell.** Comparison of columnar water vapor measurements during the fall 1997 ARM Intensive Observation Period: optical methods. *Proceedings of the 10<sup>th</sup> ARM Program Science Team Meeting*, San Antonio, Texas. March 13-17, 2000. Available online [http://www.arm.gov/docs/documents/technical/conf\\_0003/schmid-b.pdf](http://www.arm.gov/docs/documents/technical/conf_0003/schmid-b.pdf)

**c) First-authored Other Presentations**

**Redemann, J., P.B. Russell, R.P. Turco, B. Schmid, J.M. Livingston, R.W. Bergstrom, K.-N. Liou, R.F. Pueschel, E.V. Browell, P.A. Durkee, H.H. Jonsson, D.R. Collins, R.C. Flagan, J.H. Seinfeld, S. Gassó, E. Öström, K.J. Noone, E.J. Welton, K.J. Voss, H. R. Gordon, D.M. Powell, J.A. Reagan,** Synthesis of Remote Sensing and In Situ Measurements of Dust Aerosol Events. Workshop on Mineral Dust, June 9-11, 1999, Boulder, CO.

**Russell, P. B., B. Schmid, J. Redemann, J. M. Livingston, P. Pilewskie.** Airborne Sunphotometry and Integrated Analyses of Smoke and Haze Aerosols, Thin Clouds, Water Vapor and Ozone in SAFARI 2000: A proposed investigation, NASA EOS SAFARI 2000 Workshop. May 12-14, 1999, Boulder, CO.

**Russell, P B , B Schmid, J M Livingston, J Redemann, and R W Bergstrom,** Desert dust layers over polluted marine boundary layers: ACE-2 measurements and ACE-Asia plans, invited paper, Western Pacific Geophysics Meeting, Amer. Geophys. Union, Tokyo, June 27-30, 2000

**Schmid B.,** “Results from TARFOX and ACE-2 field campaigns”, Sunphotometer workshop, American Meteorological Society, Conference on Atmospheric Radiation, Madison, Wisconsin, 26 June-2 July 1999.

**Schmid B.,** “Ground based and airborne sunphotometry”, Seminar, NASA Goddard Institute for Space Studies, New York, 28 April 2000.

**Schmid B., J. Michalsky, D. Slater, J. Barnard, R. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, and P. Russell.** Comparison of columnar water vapor measurements during the fall 1997 ARM Intensive Observation Period: optical methods. 20th International Geoscience and Remote Sensing Symposium, Honolulu, Hawaii 24-28 July 2000e.