Aerosol Radiative Effects and Single-Scattering Properties in the Tropical Western Pacific

A. M. Vogelmann and P. J. Flatau
Center for Atmospheric Sciences
Scripps Institution of Oceanography
University of California
San Diego, California

M. A. Miller, M. J. Bartholomew, and R. M. Reynolds
Brookhaven National Laboratory
Upton, New York

P. J. Flatau
University Corporation for Atmospheric Research
Naval Research Laboratory
Monterey, California

K. M. Markowicz
Institute of Geophysics
University of Warsaw
Warsaw, Poland

Introduction

The Atmospheric Radiation Measurement (ARM) Tropical Western Pacific (TWP) sites are downwind from Southeast Asia where biomass burning occurs and can advect over the tropical warm pool. Previous research (Vogelmann 2001, 2002, 2003) indicates that aerosol forcing was particularly large during the 1997 El Niño, as observed at Manus Island. (Although, the TWP forcing efficiency was large, it was smaller than that observed at the Southern Great Plains [SGP]). The TWP forcing efficiency suggests an aerosol single-scattering albedo that is significantly lower than typical conservative maritime values. Further, large Angstrom exponents are observed at all times of year at Manus, suggesting a frequent presence of small, continental-sized/type particles at this remote island. Aerosol single-scattering albedo is critical for determining how aerosols interact with radiation, but it is not routinely measured in such remote locations and cannot be retrieved from satellite observations.

Towards the goal of determining the aerosol properties and their radiative effects in the TWP, our objective is to test a method that retrieves the aerosol single-scattering albedo from radiometric data. The method will be explored that can use measurements available from Manus, and across the broader TWP region using cruise data obtained by the ARM Shipboard Oceanographic and Atmospheric Radiation (SOAR) Program (Reynolds et al. 2001; Miller et al. 2002; Miller et al. 2003).

Approach

We adapt the direct-diffuse ratio method by Anikin et al. (2002) for retrieving single-scattering albedo. They developed a set of equations that parameterize the ratio in terms of aerosol optical depth, single-scattering albedo, asymmetry parameter, and surface albedo. The asymmetry parameter is parameterized based on the Angstrom exponent and the aerosol type (which specifies the real part of the refractive index).

We test the retrieval using SOAR multi-filter rotating shadowband radiometer (MFRSR) data, and the optical and chemical data obtained concurrently during the Aerosol Characterization Experiment (ACE)-Asia Field Program. During ACE-Asia, in situ surface measurements of single-scattering albedo were made at ambient relative humidity (Carrico et al. 2003). Further, an aerosol optical model of single-scattering albedo and asymmetry parameter was developed based on in situ chemical and optical measurements (Markowicz et al. 2003). The aerosol scattering model produces very good agreement with instantaneous pyranometer measurements (bias of 4.4 Wm^{-2}, root mean square of 12.9 Wm^{-2}). Using the ACE-Asia data set provides a severe test for the retrieval method because of the complex and highly variable nature of the ACE-Asia aerosol.

Results

We find that adapting the Anikin et al. (2002) method for SOAR data holds promise. The best agreement with ACE-Asia single-scattering albedo data are achieved by fitting the asymmetry parameter-Angstrom relationship using output from Markowicz et al. (2003) optical model rather than from moderate-resolution atmospheric radiance and transmittance aerosol models. Similar to previous studies, the direct-diffuse ratio must be scaled by 0.9 as well.

Preliminary comparisons of the retrieved single-scattering albedos to those from the aerosol model and surface observations indicate that some days/cases compare very well. However, accuracies vary more from day to day than within days, suggesting there are unresolved dependencies on aerosol type. Also, within each day, there is a tendency for the variability in the retrieval to be much greater than for the observations.

Future research will analyze the retrieval deficiencies and the means for their correction. The resulting method will be applied to TWP site and SOAR datasets. These analyses will explore the variability of single-scattering albedo within the TWP region, and assess its potential impact on the regional radiative energy balance as well as satellite retrievals, which are used to monitor aerosols across the vast region.

Acknowledgments

We thank Kip Carrico for the use of his single-scattering albedo data. TWP, SGP, and SOAR data were obtained from the ARM Program sponsored by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Environmental Sciences Division. This work is supported by the ARM Program through BER, U.S. Department of Energy, Grant No. DE-FG03-02ER63341, the ARM Ocean Program, National Aeronautics and Space Administration Sensor

Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies, and the National Science Foundation.

Corresponding Author

Andrew Vogelmann, avogelman@ucsd.edu, (858) 534-6472

References

Anikin, P., M. A. Sviridenkov, and E. V. Romashova, 2002: Estimation of aerosol single-scattering albedo over ZSS from MFRSR data. In *Proceedings of the Twelfth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, ARM-CONF-2002. U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_0204/anikin-p.pdf

Carrico, C. M., P. Kus, M. J. Rood, P. K. Quinn, and T. S. Bates, 2003: Mixtures of pollution, dust, sea salt, and volcanic aerosol during ACE-Asia: Aerosol Radiative Properties as a Function of Relative Humidity. *J. Geophys. Res*., submitted.

Markowicz, K. M., P. J. Flatau, P. K. Quinn, C. M. Carrico, M. K. Flatau, A. M. Vogelmann, D. Bates, M. Liu, and M. J. Rood, 2003: Influence of relative humidity on aerosol radiative forcing: An ACE-Asia Experiment Perspective. *J. Geophys. Res.,* in press.

Miller, M. A., M. J. Bartholomew, and R. M. Reynolds, 2002: The accuracy of marine shadow-band measurements of aerosol optical thickness and Angstrom exponent. *J. Atmos. Ocean. Tech*., in revision.

Miller, M. A., R. Frouin, M. J. Bartholomew, K. Knobelspiesse, R. M. Reynolds, M. Wang, G. Fargion, and P. K. Quinn, 2003: Aerosol optical properties during ACE-Asia, to be submitted.

Reynolds, M. R., M. A. Miller, and M. J. Bartholomew, 2001: A fast-rotating, spectral shadowband radiometer for marine applications. *J. Atmos. Ocean. Tech.*, **18**, 200-214.

Vogelmann, A. M., 2001: Observed aerosol radiative forcings: Comparison for Natural and Anthropogenic Sources. . In *Proceedings of the Eleventh Atmospheric Radiation Measurement (ARM) Science Team Meeting*, ARM-CONF-2001. U.S. Department of Energy, Washington, D.C

Vogelmann, A. M., 2002: Aerosol radiative effects in the Tropical Western Pacific. In *Proceedings of the Twelfth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, ARM-CONF-2002. U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_0204/vogelmann-am.pdf

Vogelmann, A. M., and W. C. Conant, 2003: Observed aerosol radiative forcings: Comparison for Natural and Anthropogenic Sources. *J. Geophys. Res.,* to be submitted.