

**Final Report for Research Conducted at  
The Scripps Institution of Oceanography, University of California San Diego  
from  
2/2002 to 8/2003  
for  
Aerosol and Cloud-Field Radiative Effects in the Tropical Western Pacific:  
Analyses and General Circulation Model Parameterizations**

**PI: Andrew M. Vogelmann**

The PI, Dr. Andrew Vogelmann, moved from the Scripps institution of Oceanography (SIO) to the Brookhaven National Laboratory (BNL) effective September 2003. Remaining funds at SIO were deobligated and transferred to BNL, and the Year 3 funding was sent directly to BNL. This is the final report for the research conducted at SIO, which is being completed at BNL. The scope of the research will remain the same at BNL, and I anticipate that the research will benefit from additional expertise available through enhanced collaborations with BNL scientists.

While at SIO, I have made significant progress towards contributing to the scientific objectives of the Atmospheric Radiation Measurement (ARM) Program. The research was directed toward analyses of aerosol radiative properties in the Tropical Western Pacific (TWP), and reconstructing the 3D TWP cloud fields from observations. Details of the specific research components are given below.

## **A. Description of Research Results**

### *1) TWP Aerosol Radiative Properties*

#### *a. Manus Aerosol Radiative Forcing and Radiative Character*

ARM observations are used to quantify the aerosol radiative effects in the climatically important Tropical Western Pacific (TWP). The TWP sites are downwind from Southeast Asia where much biomass burning occurs and can advect over the tropical warm pool. Preliminary ARM results (Vogelmann, 2001) found that during August-October 1997 such aerosols had a large impact on the surface radiative energy budget at the Manus TWP site. These values are much larger than would be expected from a typical maritime aerosol, and were on par with values found at the continental Southern Great Plains (SGP) site.

This result was placed in a broader climatological context by evaluating the aerosol radiative effects at the TWP sites over the course of the year and for multiple years. These results were presented at the ARM Science Team Meeting (Vogelmann, 2002). The aerosol character is determined based on clear-sky aerosol optical depths and Angstrom coefficients obtained from the MFRSR measurements at the Manus site. The yearly cycle of these parameters were analyzed from the measurements made continuously from Aug 1999 to Oct 2001. Results find the presence of (small) continental-sized aerosol particles during much of the year, but with the greatest presence during the August-October biomass-burning season. The August-October periods were analyzed from 1997 to 2001. All periods show aerosol optical depths and Angstrom coefficients that are larger than those expected for a tropical marine environment. The observations from the El Niño year in 1997 exceed those from any other period. Conversely,

2001 had record amounts of rainfall within the region, leading to the smallest optical depths of the periods.

A manuscript describing these results is in preparation (Vogelmann and Conant, 2004). It derives the aerosol radiative forcing at the Manus site for the August-October period, and analyzes the single-scattering properties since 1997. These properties are being compared to those at the SGP for the August-October period; and factors affecting the geographic and the year-to-year variabilities are explored. These results are compared to those obtained from other prominent geographical regions and field programs.

#### *b. SOAR Single-Scattering Albedo Retrievals*

In collaboration with Dr. Reynolds and Dr. Miller (BNL), we worked to place the Manus site observations in the context of the broader TWP region using cruise data obtained by the ARM Shipboard Oceanographic and Atmospheric Radiation (SOAR) Program. Aerosol single-scattering albedo, in particular, is critical for determining how aerosols interact with radiation, but it is not routinely measured in such remote locations. We tested a method to obtain single-scattering albedo from radiometric data for application to the Manus and SOAR datasets (presented at the 2003 ARM STM, Vogelmann et al., 2003).

We adapted the direct-diffuse ratio method by Anikin et al. (2002), who developed a set of equations that parameterize the ratio in terms of aerosol optical depth, single-scattering albedo, asymmetry parameter, and surface albedo. The retrieval method was tested using SOAR MFRSR data obtained during the ACE-Asia Field Program, where ‘truth’ was obtained from the concurrently measured optical and chemical data. Specifically, in situ surface measurements of single-scattering albedo were made at ambient relative humidity (Carrico et al., 2003), and an aerosol optical model of single-scattering albedo and asymmetry parameter was constructed from in situ chemical and optical measurements (Markowicz et al., 2003). This provided a severe test for the retrieval method, because of the complex and highly variable nature of the ACE-Asia aerosol.

We found that adapting the Anikin et al. (2002) method for SOAR data holds promise. The best agreement with ACE-Asia single-scattering albedo data was achieved by: 1) fitting the asymmetry parameter-Angstrom relationship using output from Markowicz et al. optical model rather than from standard Modtran aerosol models; and 2) similar to previous studies, the direct-diffuse ratio needed to be scaled by 0.9. 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 that there are unresolved dependencies on aerosol type. In addition, within each day, there is a tendency for the variability in the retrieval to be much greater than for the observations. Future research will be needed to analyze the retrieval deficiencies and the means for their correction before the method may be applied to the TWP and SOAR datasets.

#### *2) 3D Cloud Fields*

The 3D structures of cloud fields in the TWP are being determined from ARM observations, which will ultimately be used to investigate cloud-radiative interactions and GCM parameterizations thereof. To reconstruct the 3D cloud fields, we have assembled algorithms and TWP data sets needed to ‘blend’ the orthogonal attributes of the 2D vertical view (X-Z) provided by profilers at the ARM site with the 2D horizontal (X-Y) view available from satellite data.

We have begun adapting a 3D cloud visualization tool for use in these reconstructions. The initial algorithm considered only satellite data, and we have begun restructuring the

algorithm to include data from the ARM vertically pointing sensors (i.e., the Active Remotely-Sensed Clouds Locations [ARSCL] value-added product). Further, the original algorithm was written in a graphics language that is dated (unfamiliar to most), and extremely machine specific. An undergraduate student was hired to upgrade the language so that the code could be worked on by programmers possessing a common language knowledge base, and to enable displaying the interactive algorithm on machines available at ARM meetings. Because of complexities of the coding, this has proven to be an unexpectedly difficult task and was not yet been completed. This work will be completed at BNL by their on-site visualization laboratory.

Placing ARSCL in the context of the surrounding 3D cloud field requires satellite data that provides a simultaneous 2D view of the radiative and optical properties within the TWP region. A Lagrangian cloud classification algorithm has been constructed that locates the convective cores within the region, and associates the attached, non-convective clouds with each core. The code processes the Minnis cloud products, but could use any satellite product (e.g., MODIS). A feature of this algorithm that it enables treating the variety of cloud types that exist in the TWP because it does not ‘threshold’ cloud properties to locate convective cores (as is commonly done). Instead, it uses a ‘relative’ search function that seems quite successful in locating the convective cores for a wide variety of test cases. The output from this algorithm provides a classification of the cloud type associated with each pixel and will be used to classify the cloud character during the ARSCL observations.

## **B. Programmatic Contributions**

I have served on the ARM Instantaneous Radiative Flux (IRF) Steering Committee during this period. Among other responsibilities, I have contributed to the planning and execution of yearly IRF workshops, and those held at the yearly at the ARM Science Team Meeting.

## **Publications**

Vogelmann, A. M., and W. C. Conant, 2004: Aerosol radiative effects in the tropical warm pool – A regional comparison. *Geophys. Res. Lett.*, (In preparation).

Vogelmann, A. M., 2002: Aerosol Radiative Effects in the Tropical Western Pacific. In *Proceedings of the Twelfth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, April 8-12, St. Petersburg, Florida.

([http://www.arm.gov/docs/documents/technical/conf\\_0204/vogelmann-am.pdf](http://www.arm.gov/docs/documents/technical/conf_0204/vogelmann-am.pdf))

Vogelmann, A.M., M.A. Miller, M.J. Bartholomew, R.M. Reynolds, P.J. Flatau, and K.M. Markowicz, Aerosol Radiative Effects and Single-Scattering Properties in the Tropical Western Pacific, 2003. In *Proceedings of the Thirteenth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, March 31 - April 4, 2003, Broomfield, Colorado, [http://www.arm.gov/docs/documents/technical/conf\\_0304/vogelmann-am.pdf](http://www.arm.gov/docs/documents/technical/conf_0304/vogelmann-am.pdf).

## **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*, April 8-12, St. Petersburg, Florida. ([http://www.arm.gov/docs/documents/technical/conf\\_0204/anikin-p.pdf](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.* (in press).
- 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).
- 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*, Atlanta, Georgia.  
([http://www.arm.gov/docs/documents/technical/conf\\_0103/vogelmann-am.pdf](http://www.arm.gov/docs/documents/technical/conf_0103/vogelmann-am.pdf)).