

Aerosol Radiative Closure in the Marine Atmosphere Based on Transmissometer Measurements

Joseph M. Prospero
Division of Marine and Atmospheric Chemistry
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149 U.S.A.
phone (305) 361-4789 fax (305) 361-4891 email: jprospero@rsmas.miami.edu

Hal Maring
Division of Marine and Atmospheric Chemistry
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149 U.S.A.
phone (305) 361-4679 fax (305) 361-4891 email: hmaring@rsmas.miami.edu

Dennis L. Savoie
Division of Marine and Atmospheric Chemistry
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149 U.S.A.
phone (305) 361-4712 fax (305) 361-4891 email: dsavoie@rsmas.miami.edu
Award Number: N00014-98-1-0902

LONG-TERM GOALS

The long term goal of this program is to characterize the radiative properties of aerosols over the oceans so as to understand the factors that affect radiation transmission in the marine boundary layer (MBL) close to the ocean surface.

OBJECTIVES

We will perform field studies in which we measure the spectrally-resolved transmission properties of the marine atmosphere while making concurrent measurements of aerosol physical, chemical and radiative properties. The aerosol properties are then used in a radiative model to ascertain if the model can duplicate the atmospheric transmission measurements. The degree of agreement between the transmission measurements and the model results is a measure of the adequacy of the characterization of the aerosol properties and the radiative model. The comparison (commonly referred to as "closure") is the ultimate test of the completeness of our knowledge of atmospheric radiative properties. These studies will be carried out in coastal and near-continental ocean regions that are impacted by continental aerosols. Specific objectives are:

Report Documentation Page

*Form Approved
OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 30 SEP 1999	2. REPORT TYPE	3. DATES COVERED 00-00-1999 to 00-00-1999			
4. TITLE AND SUBTITLE Aerosol Radiative Closure in the Marine Atmosphere Based on Transmissometer Measurements		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

- to resolve and distinguish between the relative contribution of marine and continental aerosols to the radiative properties of the near-shore marine atmosphere;
- to investigate the sensitivity of the radiative properties of ambient aerosols in the coastal region to changes in relative humidity and to partition the relative humidity effects to specific aerosol components; and
- to develop and validate closure models for atmospheric transmission in the marine atmosphere.

The ultimate objective is to link our measurements of aerosol radiative properties to regional/global aerosol transport models so that we can predict the aerosol radiative environment over the oceans, especially in coastal regions.

APPROACH

The general strategy for accurately assessing the radiative properties of ambient aerosols has been to carry out "closure" experiments. Many *in situ* measurements of the atmospheric particle light scattering have been made with nephelometers at 550 nm [Hoppel *et al.*, 1990; Quinn *et al.*, 1995]. More recently, a limited number of measurements have been made of aerosol light scatter and backscatter using the TSI 3563 multi-wavelength nephelometer (450, 550 and 700 nm) for comparison with the calculated radiative behavior of the aerosols (e.g., integrated light scatter and the backscatter fraction). Although these measurements have provided important information, the use of nephelometers for *in situ* radiative closure studies suffer from numerous shortcomings. The effective viewing angle is truncated so that the full range of angular scattering is not measured; this is a severe problem for large particles such as soil particles and sea-salt droplets [Fitzgerald, 1977]. Moreover, substantial losses of particles larger than about 10 μm diameter can occur within nephelometer intakes. Additional problems are associated with relative humidity changes (and hence changes in particle characteristics) within the system due to poorly characterized internal heating and hysteresis effects. Because nephelometers yield point measurements, any spatial inhomogeneity in aerosol concentrations will increase the uncertainty of extrapolations from these measurements. Nephelometers only measure scattered light; consequently, total extinction which includes absorption can only be estimated.

Because it makes use of measurements throughout a vertical cross-section of the real ambient atmosphere, column closure has been an important component in many field programs (e.g., ACE-1, TARFOX, ACE-2, etc.). These measurements can, however, suffer from the very dynamic nature of the atmosphere. The temporal and spatial distribution of aerosol (and other atmospheric) properties can change substantially during the course of an aircraft mission.

Because of these shortcomings, several recent closure studies have been based on measurements of light transmission through the atmosphere over long path lengths using transmissometers. Transmissometers are routinely used to monitor visibility; for example, an extensive network exists in the national park system, IMPROVE (Interagency Monitoring to Protect Visual Environments) [Malm *et al.*, 1994]. Although the IMPROVE nephelometer, transmissometer and aerosol data have been used with some success to obtain closure at 550 nm [White *et al.*, 1994], the transmissometer and nephelometer data could not be readily reconciled because of the severe underestimate of light scatter by large soil particles. Similar problems are expected in marine environments where sea-salt aerosol is usually the dominant component. Transmissometers, in contrast, permit us to measure light extinction in the marine boundary layer at ambient relative humidities without the problems associated with intake efficiencies for large particles and with spatial concentration variations on the scale of kilometers.

We propose to extend our transmissometer measurements to other wavelengths so that we can characterize aerosol light extinction as a function of wavelength. Many aerosol properties (for example, size) are strongly wavelength dependent. These measurements of light extinction combined with complementary aerosol measurements that we normally perform routinely in field programs, will enable us to perform path length closure calculations. Using verified data, we will be able to refine models of aerosol scattering and absorption as functions of aerosol composition (type) and size (for example, in the NEPH3 model). Further, these data and models can then be used to generate and refine algorithms used to relate satellite remote sensing data to aerosol properties in the atmosphere.

We currently have the capability to measure total aerosol light scattering and backscattering at multiple wavelengths (TSI Model 3563 high sensitivity Integrating Nephelometer) as well as total scattering at a single wavelength (Radiance Research M903 Nephelometers - 7x). We measure aerosol light absorption at 565 nm (Radiance Research~Particle/Soot Absorption Photometers - 4x, modified to be deployed in the marine boundary layer) and of white light (modified McGee Scientific Aethalometers - 3x). We measure light absorption as a function of wavelength using aerosol samples collected with a Multiple-Orifice Uniform Deposit Impactor (MOUDI) in an Optronics OL 740A spectroradiometer with an Optronics 740-70 Diffuse Reflectance Attachment (essentially an integrating sphere). With verified light extinction data, we can develop and enhance models of aerosol light extinction by utilizing measurements of aerosol size distributions and chemical composition. We measure aerosol size distributions using a combination of instruments (TSI Model 3025 Ultrafine Condensation Particle Counter (UFCPC) measures total particle concentration from 3-1000 nm, TSI Scanning Mobility Particle Sizer (SMPS) Model 3934 measures aerosol particle number size distributions from 13-850 nm, and TSI Aerodynamic Particle Sizer (APS) Model 3310 measures from 0.8-15 μm). We measure total aerosol mass concentration using a R & P Tapered-Element Oscillating Microbalance (TEOM 1400a). We measure chemical composition of size segregated aerosols collected using a MOUDI with 11 stages. Chemical analyses are performed using ion chromatography, atomic absorption, gravimetry, and colorimetry.

We have acquired a multi-wavelength transmissometer under a recent DURIP award. This instrument is first and only multi-wavelength transmissometer built by Optec Inc., the company that manufactures transmissometers for the NPS program.

We plan to deploy this instrument at our laboratory in Miami, Florida, in order to make preliminary measurements of mineral dust, sea salt, and accumulation mode aerosols. During the second year of the project we will take the transmissometer along with our other aerosol samplers and instrumentation to a remote location, possibly Izaña, Tenerife, Canary Islands to make extensive and detailed measurements of mineral dust.

WORK COMPLETED

Since taking delivery of this instrument well into the first year of this project, we have developed remote deployment and mounting systems, transport systems, as well as instrument control and data logging systems. The instrument is currently deployed in our laboratory in test mode. We are working with the manufacturer to rectify a small number of minor design flaws and troubleshoot the new electronics. We have requested and obtained permission to deploy the source half of the transmissometer on the roof of *Island Breakers*. This ten story apartment building on Key Biscayne is approximately 4.5 km with a clear line of sight from Science, Library and Administration Building on

the campus of the University of Miami's Rosenstiel School of Marine and Atmospheric Science where the receiver half of the transmissometer will be mounted.

RESULTS

Since we are developing a new prototype instrument, the first year of this project has been dedicated to verifying the correct operation of the instrument and to making the new multi-wavelength transmissometer system capable of being deployed in the marine environment. Instrument shelters and weather-resistant electrical and electronic connectors have been incorporated so the transmissometer can be safely deployed in harsh environments. In addition, we have added solar electric power generation to enable the deployment of this instrument in locations without electrical power. We expect to deploy the instrument outdoors and to start collecting data in Miami within the next month.

IMPACT/APPLICATIONS

The direct effect of aerosols on radiative transfer can be very significant and can affect visibility and climate. The current state-of-the-art methods of measuring light scattering (nephelometer) and absorption (Aethelometer, PSAP, diffuse reflectance) are compromised because of large and often uncharacterized errors. We expect the new multi-wavelength transmissometer will enable us to make accurate spectral measurements of aerosol light extinction of important aerosol types.

Combined with other measures of aerosol physical, optical, chemical properties, the transmissometer data will be incorporated in closure calculations. In addition, the data generated as part of this project will be used to improve models of aerosol properties.

TRANSITIONS

Since the new multi-wavelength transmissometer has not yet been deployed outside the laboratory, we have not been able to generate spectral light extinction data. Nevertheless, we have received inquiries from scientists interested in acquiring a multi-wavelength transmissometer.

RELATED PROJECTS

We plan to coordinate both our transmissometer measurements in Miami and at a remote site with measurements of aerosol properties versus altitude made using our Light Aircraft Aerosol Package (LAAP) as part of a NASA funded project. These coincident measurement programs should allow us to extend the spectral measurements of light extinction made with the transmissometer to different altitudes.

REFERENCES

- Fitzgerald, J. W., Angular truncation error of the integrating nephelometer in the fog droplet range, *J Appl. Met.*, 16, 198-204, 1977.
- Hoppel, W. A., J. W. Fitzgerald, G. M. Frick and R. E. Larson, Aerosol size distributions and optical properties found in the marine boundary layer of the Atlantic Ocean, *J Geophys. Res.*, 95, 3659-3686, 1990.

- Malm, W. C., J. F. Sisler, D. Huffman, R. A. Eldred, and T. A. Cahill, Spatial and seasonal trends in particle concentration and optical extinction in the United States. *J Geophys. Res.*, 99, 1347-1370, 1994.
- Quinn, P. K., S. F. Marshall, T. S. Bates, D. S. Covert and V. N. Kapustin, Comparison of measured and calculated aerosol properties relevant to the direct radiative forcing of tropospheric sulfate aerosol on climate, *J Geophys. Res.*, 100, 8977-8991, 1995
- White, W. H., E. S. Macias, R. C. Ninenger, and D. Schorran, Size-resolved measurement of light scattering by ambient particles in the Southwestern U.S., *Atmos. Environ.*, 28, 909-921, 1994.