Modeling the Time-Dependent Optical Properties of the Multicomponent Aerosols in the Marine Boundary Layer

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LONG-TERM GOALS

The ultimate goal of this project is to improve the predictive understanding of the time-dependent, frequency-dependent, radiative properties of multicomponent aerosols containing mineral dust in the marine environment.

OBJECTIVES

Specific objectives of the current research are:

(1) elucidate the links between dust particles morphology (shape and size), composition, optical properties and related radiative effects;

(2) relate the properties of dust to its source and investigate the evolution of dust properties during transport in the marine boundary layer, focusing on the comparative analysis of the Asian, African, Southwestern U.S., and Saudi Arabian types of dust.

(3) improve algorithms for prediction of frequency-dependent optical properties of mineral dust accounting for its mineralogical composition, life cycle, and interaction with other atmospheric aerosols in the clean and polluted marine environment.

APPROACH

Our approach combines comprehensive analysis of the empirical data on dust microphysical, optical, and radiative properties and advanced numerical modeling techniques. During FY2001, we were focusing on the ACE-Asia field experiment conducted in the spring of 2001.

WORK COMPLETED

We analyzed a number of dust samples collected in China and Southwestern U.S. to establish representative morphology of dust particles. These samples represent different dust sources and were collected at the surface or in situ (aircraft sampling) at the various distances from the source. Each sample consist of several thousands of particles in the size range $D<4\mu m$ or $D<20\ \mu m$.

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A new technique was developed and tested to utilize the data on particle morphology obtained by means of individual particle analysis to provide input information required for computation of optical properties of nonspherical dust aggregates using a discrete-dipole-approximation (Kalashnikova et al., 2000, Kalashnikova and Sokolik 2001a,b).

Combining forward modeling, satellite observations, and surface measurements of atmospheric radiation, optics and aerosol chemical composition, we characterized the radiative signature of aged Asian dust reaching the North Pacific Ocean and Hawaii. In particular, we used routine ground-based measurements conducted at Mauna Loa Observatory (MLO), Hawaii, in conjunction with TOMS satellite data, focusing on dust outbreaks springs of 1997-2000 (Quijano et al., 2001).

Overall, we successfully completed all tasks planned for FY2001.

RESULTS

Mineral aerosol presents a particularly difficult case in climate and remote sensing studies, because its absorption and scattering of atmospheric radiation depend strongly on dust source region, morphology (i.e. shape and size), mineralogy, and state of mixture with other species. Based on analysis of dust samples, we demonstrated that a composition-shape-size distribution (CSS-distribution) must be known to adequately predict dust optical properties. Our calculations show that there are various differences between the single-scattering albedo and scattering phase function of the nonspherical dust aggregates and those of volume-equivalent spheres. The single scattering albedo is a key optical characteristic for predicting the heating or cooling effects of dust, while the phase function is important for the remote sensing applications. Detailed modeling of these characteristics is especially crucial because no reliable

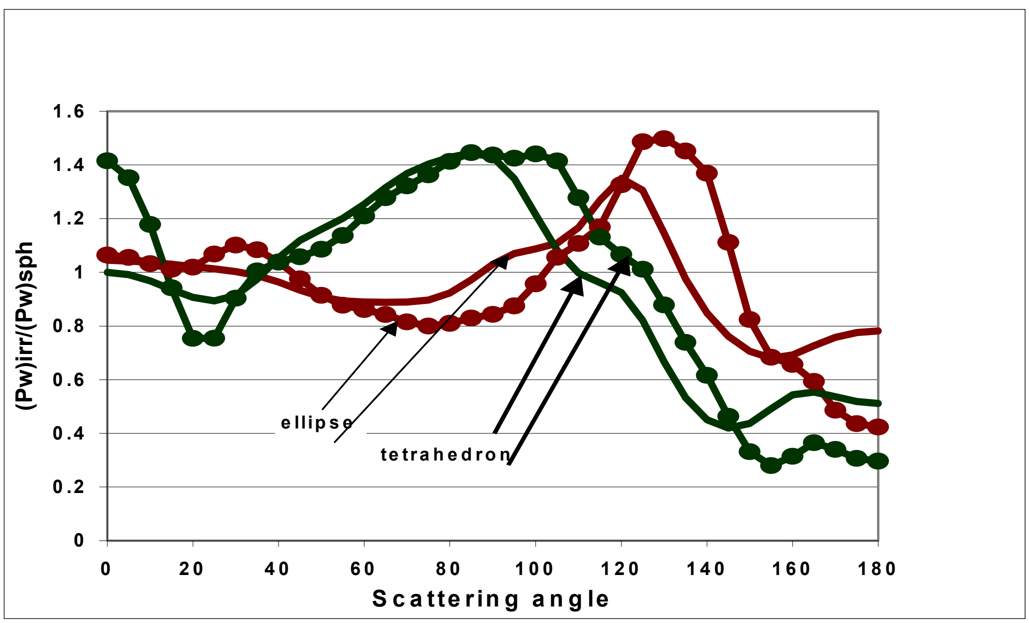

Figure 1. Ratio of scattered intensities of nonspherical to spherical dust particles at two wavelengths: dotted lines for 0.55 μm and solid lines for 0.86 μm (Kalashnikova and Sokolik, 2001a)

measurements are currently available. Figure 1 illustrates how nonspherical dust particles affect the angular scattered intensities.

Our analysis of collated TOMS observations and ground-based measurements conducted at the MLO, Hawaii, revealed that aged Asian dust might have the single-scattering albedo as low as 0.5-0.7 at the ultra-violet (UV) wavelengths. The presence of strong UV-absorbing carbonaceous aerosols internally and/or externally mixed with dust particles could be partly responsible for such a low single scattering albedo.

We started to work on characterization of dust sources in Northern China to quantify their strength in terms of dust emission rates of PM_{10} dust (i.e., particulates smaller than 0.01 mm in diameter). Asian dust PM_{10} are of special interest because they absorb and scatter light and might be transported over thousands of kilometers across the North Pacific and beyond to the west coast of the United States. We demonstrated that the main dust sources in Northern China are the Taklimakan Desert (the annual mean PM_{10} emission rate is about Q_{10}= 0.38 ton ha^{-1} yr^{-1}), the Central Gobi-Desert in the west Mongolian Plateau (0.24 ton ha^{-1} yr^{-1}), and the deserts located on the Alxa Plateau (Q_{10}= 0.05 ton ha^{-1} yr^{-1}) (Xuan and Sokolik, 2001a, b). Although maximum of dust emission occurs in spring, each type of sources has a distinct seasonal cycle.

IMPACT/APPLICATIONS

Our developed techniques to model the spectral optical properties of multicomponent aerosol containing dust can be employed in various remote sensing applications and in aerosol chemical transport models. Dust models are available at the dedicated web site: http://irina.colorado.edu/data-ref-dust.htm

TRANSITIONS

Our main results were published in peer-reviewed journals and presented at numerous scientific meetings.

Dr. Sokolik organized a special issue on Mineral Dust in the Journal of Geophysical Research. This issue consists of 35 papers dealing with modeling and measurements of dust production, transport and deposition, and related dust impacts upon atmospheric radiation and chemistry (J. Geophysical Research 106, Aug 27, 2001).

RELATED PROJECTS

We are currently independently funded under the NSF Atmospheric Chemistry program to work on analysis of the ACE-Asia data collected in spring of 2001. Both projects will provide a deeper insight into links between the Asian dust properties and related radiative effects.

SUMMARY

Large quantities of Asian dust, originating in Northern China, are carried out over the North Pacific to the west coast of the United States. We characterized source strengths and dust properties that are required to predict how Asian dust might affect the visibility and remote sensing in the marine

environment. Similar analysis will be performed for African, Southwestern U.S., and Saudi Arabian types of dust to elucidate links between a given dust source and the optical properties of airborne mineral aerosols originating from this source.

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