Characterization of Dust Aerosols and Atmospheric Parameters from Space-borne and Surface-based Remote Sensing: Application of Community Radiative Transfer Algorithms to Navy Electro-Optical Models

Dr. Si-Chee Tsay
NASA Goddard Space Flight Center, Greenbelt, MD 20771
301-614-6188 (voice), 614-6307 (fax), e-mail: tsay@climate.gsfc.nasa.gov

Dr. Q. Jack Ji
NASA Goddard Space Flight Center, Greenbelt, MD 20771
301-614-6231 (voice), 614-6307 (fax), e-mail: ji@climate.gsfc.nasa.gov

Dr. Jeffrey S. Reid
Atmospheric Propagation Branch, SPAWAR Systems Center, San Diego, CA 92152-5001
619-553-1419 (voice), 553-1417 (fax), e-mail: jreid@spawar.navy.mil

Dr. Douglas L. Westphal
Marine Meteorology Division, Naval Research Laboratory, Monterey, CA 93943-5502
831-656-4743 (voice), 656-4769 (fax), e-mail: westphal@nrlmry.navy.mil

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LONG-TERM GOAL

The long-term goal for this project is threefold: (i) to characterize dust aerosols (i.e., Saharan and Gobi dusts) and atmospheric parameters (e.g., column water vapor) from space-borne and surface-based remote sensing, (ii) to investigate quantitatively their radiative forcing and climatic effects by analyzing and modeling data obtained from various ONR/NASA field campaigns, and (iii) to construct and utilize computationally efficient radiation post-processors for running on US Navy Aerosol Analysis and Prediction System to estimate aerosol radiative flux perturbation and general visibility conditions from visible to thermal IR wavelengths.

OBJECTIVES

Target detection and visibility tactical decision aid products used by the United States Navy are based on the Target Acquisition Weather Software (TAWS). As part of the Naval Research Laboratory Aerosol Analysis and Prediction System (NAAPS) development, aerosol microphysics codes are for the first time being implemented. The objectives of this project are to validate the regional transport and visibility aspects of the US Navy NAAPS by using observational data combining with current state-of-the-art atmospheric radiative transfer simulations.

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14. ABSTRACT

The long-term goal for this project is threefold: (i) to characterize dust aerosols (i.e., Saharan and Gobi dusts) and atmospheric parameters (e.g., column water vapor) from space-borne and surface-based re-mote sensing, (ii) to investigate quantitatively their radiative forcing and climatic effects by analyzing and modeling data obtained from various ONR/NASA field campaigns, and (iii) to construct and util-ize computationally efficient radiation post-processors for running on US Navy Aerosol Analysis and Prediction System to estimate aerosol radiative flux perturbation and general visibility conditions from visible to thermal IR wavelengths.

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APPROACH

During FY01, we have pursued two tasks on studying aerosol properties: one is the use of ground-based remote sensing instruments to characterize dust aerosol properties over desert regions, and the other is the modeling efforts to implement current state-of-the-art atmospheric radiative transfer codes into Navy TAWS. Under the ACE-Asia plan (Aerosol Characterization Experiment-Asia for dust and anthropogenic aerosols), the majority of the mission assets and analysis are focused on Cheju Island, just south of the Korean peninsula. While the ACE-Asia science team has deemed that such a methodology can maximize their efforts and goals, such a mission plan does not necessarily reflect the interests of the Navy 6.2/6.4 and NASA/EOS communities. In essence, the ACE-Asia method is akin to receptor modeling. But we know that aerosol particle properties are dynamic and likely change greatly on the continental passage. Thus, an emphasis on a single receptor site may not truly characterize the variability of East Asian aerosols. We employ data collected by the SMART system (*cf*. Fig. 1) to develop and compare US Navy visibility and transport models, as well as to achieve NASA's EOS validation. In particular, by placing the SMART system in the vicinity of Asian deserts (Gobi and Taklamakan), we have a second receptor site near the source region of Asian dust. By comparing radiation data from the SMART site to those collected at a string of AERONET sun photometers along the Pacific Rim, we will get a first order estimate of aerosol particle variability in this region.

Figure 1. The SMART system: (a) many shortwave and longwave broadband radiometers, (b) shadow-band radiometer, (c) sun photometers, (d) solar spectrometers, (e) micro-pulse lidar, (f) whole-sky camera, and (g) microwave radiometer, as well as (h) meteorological probes for atmospheric pressure, temperature, humidity, wind speed/direction and (k) surface moisture content.

Current Navy visibility products do not adequately account for the radiative and meteorological impacts of aerosol particles. In particular, these products reveal great difficulty in predicting EO system performance in coastal environments, such as the Middle East, Balkans, and Korea, due to uncertainties in aerosol types, environmental parameters and limitations in current radiative transfer algorithms. EO system performance models could be improved by (1) making use of data from weather and aerosol prediction models, such as the NAAPS, and (2) upgrading the radiative transfer models. It is essential to develop radiative transfer post-processors that will take diagnostic and prognostic output fields from the NAAPS and generate EO products suitable for visibility prediction. For computational efficiency, two algorithms will be created. The low-resolution algorithm will run on each of the NAAPS grid points for each forecast period. Based on the NAAPS output variables (e.g., aerosol mass, type and vertical distribution), it give rough estimates of boundary layer visibility for the visible, near-IR, shortwave IR, and longwave IR window regions. Next, the high-resolution radiative post processor can be run on specific NAAPS grid-points when additional detail is needed. Based on a full 3-dimensional radiative transfer scheme, this processor has the ability to give atmospheric visibility estimates as a function of user specified variables such as altitude, look angle, target effective temperature contrast, and specific spectral ranges.

WORK COMPLETED

The Navy/NASA collaboration on ACE-Asia mission was to study the radiative environment in the desert region and coastal zone. Special emphasis is being placed on deducing surface flux measurements and spectral observations collected from many ground-based and space-borne sensors. Figure 2 illustrates the general environmental conditions and the specific effects of dust outbreak near the source regions for two dust missions, namely the PRIDE and ACE-Asia campaigns. Our ACE-Asia mission was successfully accomplished (March-May 2001) and currently we are proceeding quality check, calibration, and preliminary analysis of all radiation and microphysical data.

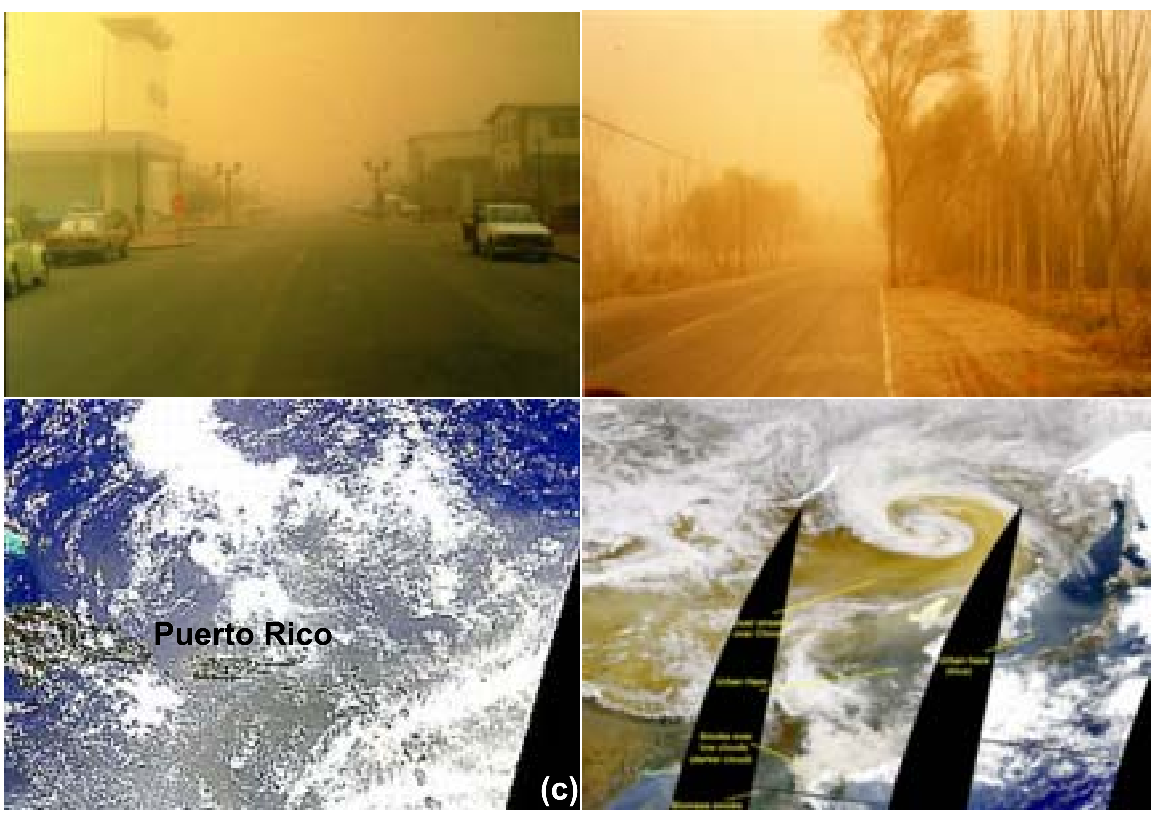

Figure 2. (a) Saharan dust outbreak over Walvis Bay, Namibia (more in the brown), (b)Taklamarkan dust outbreak over Dunhuang oasis, China (more in the yellow), and examples of SeaWiFS image (Red, Green, and Blue composite) in the vicinity of (c) Puerto Rico after long range transport over Atlanta Ocean, and (d)eastern Asia of China, Korea, and Japan.

During the past quarter, we have built interfaces between NOGAPS (Navy meteorological model) and MODTRAN (MODerate-resolution radiative TRANsfer model) to compute visibility, and between NAAPS and Fu-Liou 4-stream radiative transfer model (Fu and Liou 1993) to derive shortwave and longwave fluxes. The interfaces are subroutines that produce the input parameter control files used by MODTRAN and Fu-Liou radiative transfer codes. Precision tests of the radiative transfer models (MODTRAN and Fu-Liou codes) are performed in SGI computing system. Test runs by using NOGAPS outputs are performed to derive the atmospheric visibility, assuming a pre-existing aerosol model in MODTRAN. Since the output of NAAPS provides only aerosol mass concentrations, a sub-routine needs to be built for incorporating aerosol physical properties (e.g., refractive index, size distribution, and vertical profile) and Mie theory for calculating aerosol extinction for use in deriving aerosol optical depth. The aerosol models are pending upon the field measurements. Currently, we are building the aerosol interface subroutine for an arbitrary aerosol model. Specifically, we have focused on two aspects, namely the computation of aerosol optical properties and the modification of Fu-Liou code. After completing the combination of visibility and energetics calculations (or the low-resolution task), and thorough testings, then, we will move into the full-resolution radiance field calculation (i.e., using DisORT of Tsay *et al*. 1990).

RESULTS

Since the project has only started in less than six months, results presented here are preliminary. While PRIDE is designed to measure the properties of Saharan dust transported across the Atlantic Ocean to the Caribbean, the ACE-Asia is focused on the regional to global impact of Asian dust. The optical depths (at 0.5 μm wavelength) of dusts in Puerto Rico averaged 0.3, with a maximum of 0.6, and the dust layers were almost always present at the surface. These values are two to three times higher near the source region of Dunhuang oasis, China for ACE-Asia. For both dust studies (PRIDE and ACE-Asia) all cloud-free data, based on sun photometer and whole-sky camera observations, are used to quantify the radiative forcing of dust aerosols. Since it was difficult to obtain cloud-free conditions for even a single day in Puerto Rico, the air mass (solar zenith angle) is introduced as a parameter. The slopes ($\Delta F/\Delta\tau$, as shown in Fig. 3) of each slice of air mass depict the solar radiative forcing, and their values clustered around –95 Wm^{-2} for PRIDE and around –160 Wm^{-2} (cooling) at local solar noon. We intend to examine more in-depth by using data from shadow-band (continuous data for direct and diffuse radiation) and spectral-flux (dust influenced only) radiometers.

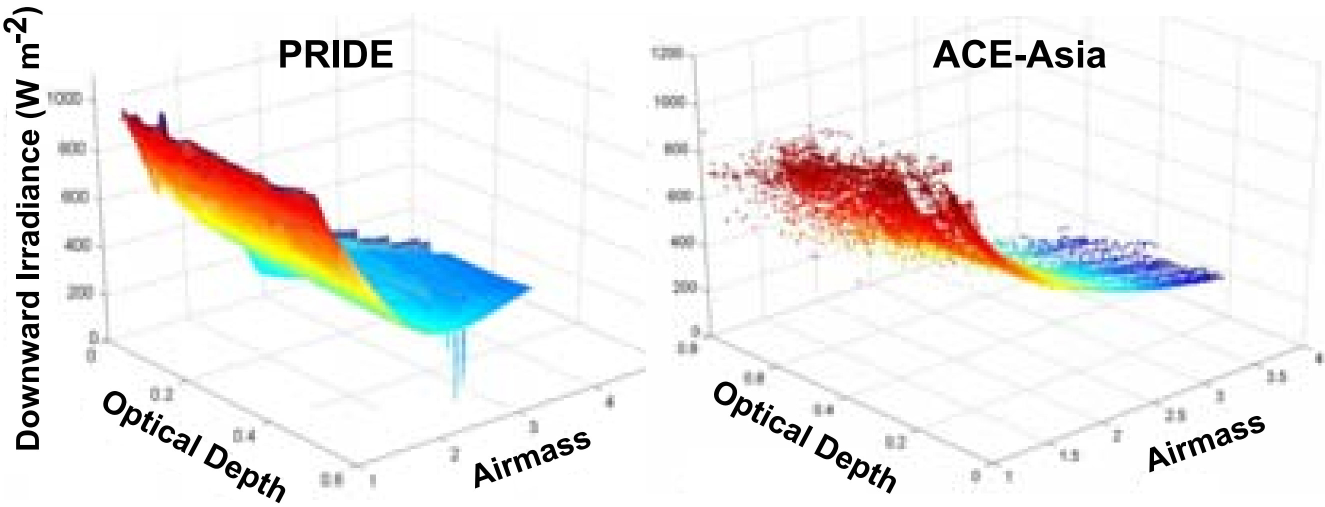

Figure 3. Three-dimensional representation of radiative forcing of dust aerosols for PRIDE (left0 and ACE-Asia (right).

IMPACT/APPLICATIONS

Spectral observations of dust properties from the space and from the ground create a powerful tool for determining the extinction of solar radiation by dust. Revisiting the dust properties and generating remote sensing procedures of dust are the first step for an attempt for visibility monitoring in coastal regions, as well as the dust effect on regional climate.

TRANSITIONS

We have developed a technique, using both satellite spectral data and ground-based observations, to derive the microphysical and radiative properties of dust aerosols. During FY99 collaboration, atmospheric visibility/radiation models and aerosol model will be transferred to scientists at SPAWAR and other Navy research institutes.

RELATED PROJECTS

This work is related to the NASA/EOS effort of remote sensing and validation of aerosols and their effect on climate.

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PUBLICATIONS

Tsay, S. C., J. Reid, Q. Ji, M. D. King, N. C. Hsu and E. J. Welton, 2001: Dust aerosols in PRIDE and ACE-Asia: A satellite/surface perspective, *Bull. Amer. Met. Soc*., in preparation.