

Characterization Of Aerosols And Atmospheric Parameters From Space-Borne And Surface-Based Remote Sensing

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LONG-TERM GOAL

The long-term goal for this project is threefold: (i) to develop remote sensing procedures for determining aerosol loading and optical properties over land and ocean, (ii) to use these properties for atmospheric corrections over coastal regions, and (iii) to assess what combination of hyperspectral information can lead to the best results.

OBJECTIVES

In preparation for the era of hyperspectral sensors in remote sensing, we need to establish a climatology of aerosol properties and of spectral reflectance for land, ocean and coastal regions. These specific features will be used to develop aerosol remote sensing capability and in the future corrections of remote sensing data.

APPROACH

During FY99, we have pursued two projects on studying aerosol properties: one is the remote sensing and retrieval of dust over land, and the other is the use of ground-based and airborne instruments to characterize aerosol properties over coastal regions. Although the Landsat TM has limited spectral capability between 0.47 and 2.1 μm , it is still the most qualified instrument in space in acquiring remote sensing data for dust study. we plan to apply similar techniques to the hyperspectral measurements when the data become available. From February 20 to March 12, 1999 an intensive operational period (IOP) of the Electro-Optical Propagation Assessment in Coastal Environments (EOPACE) study was conducted in the vicinity of the Army Corps of engineers research pier at Duck, North Carolina. The purpose of this IOP was to study the transport of coarse marine aerosols, their microphysical properties, and the radiative transfer environment in a coastal zone. The NASA Ames Solar Spectral Flux Radiometer (SSFR) was integrated on the CIRPAS Twin Otter to measure zenith irradiance and nadir radiance. A suite of passive radiometers, 2 sunphotometers, and a micropulse lidar from NASA GSFC were operated around the Army Corps of engineers research facility. By analyzing these integrated data sets, we will be able to gain insight into the radiative balance in the rarely studied coastal environment. In addition, we continue to compile and assimilate existing measurements of spectral reflectance in the coastal regions (e.g., collaboration with NASA SeaWiFS group and Drs. Curtiss O. Davis and Bo-Cai Gao at the Naval Research Laboratory in analyzing hyperspectral measurements of ocean reflectance from navy ships). To further extend the Saharan dust study, we plan to conduct airborne hyperspectral measurements (with NASA/Ames instrument) and ground-based remote sensing (as part of EOS validation activities) to study the physical and optical

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properties of airborne dust, in support of ONR PRIDE-2000 campaign (Puerto Rico Dust Experiment, June-July 2000).

WORK COMPLETED

The Navy/NASA collaboration on EOPACE/Duck'99 mission was to study the radiative environment in a coastal zone. Coastal zones present special problems in atmospheric optics. Ocean color and temperature exhibit strong gradients. White capping and sun glint (which are highly wind speed dependent) cause further ocean color changes. A large portion of the light extinction budget is accounted for by large and giant sized aerosol particles that are difficult to characterize. Special emphasis is being placed on deducing surface flux measurements and the hyperspectral radiometer data collected on the CIRPAS Twin Otter. Figure 1 shows the general environmental conditions and the areas of CIRPAS Twin Otter operation and flight tracks. Our mission was successfully accomplished and currently we are proceeding quality check, calibration, and preliminary analysis of all radiation data.

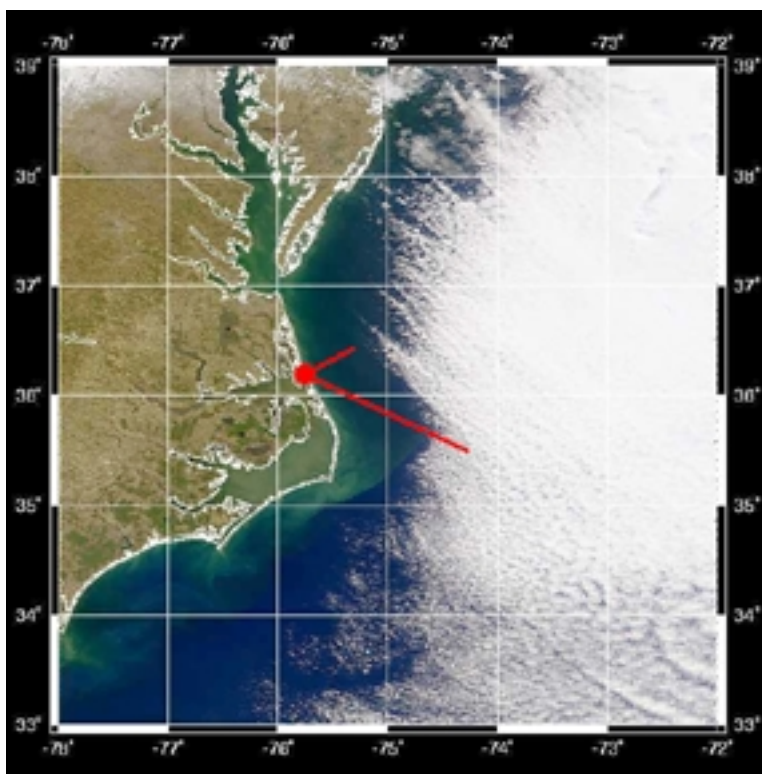


Figure 1: An example of SeaWiFS image (Red, Green, and Blue composite) over the coast of North Carolina with two typical flight tracks for measuring the microphysical, optical, and radiative properties of cloud, aerosol, and chlorophyll.

RESULTS

In EOPACE/Duck'99 our participation was directed towards establishing the variability of aerosol composition and concentration in marine airmasses by determining the radiative effects of boundary layer marine aerosol. The hyperspectral data were used to characterize the sea surface reflectance in a coastal region and to compare with open ocean reflectance for purposes of improving aerosol optical depth retrievals from the AVHRR satellite and validating SeaWiFS ocean color products. The Twin Otter was also equipped with instrumentation to measure aerosol size distributions and key atmospheric microphysics parameters. Together with the aircraft flux measurements these data allow us to derive estimates of the solar spectral radiative forcing in the boundary layer and to examine dependencies on sea-surface spectral albedo and surface roughness. Figure 2 shows spectra of downwelling irradiance (left) at the aircraft altitudes shown in the legend and time series, or flight tracks, of nadir reflectance (right). The most prominent features are oxygen A and B absorption bands (680 nm and 762 nm) and the near-infrared water vapor absorption bands. Other factors contributing to spectral magnitude include aerosol absorption and aerosol and molecular scattering. From previous field studies we have found that a bias exists between measured and modeled downwelling irradiance which is highly correlated with water vapor, and increases at a rate of 9 Wm^{-2} per cm of water vapor. However, the greatest contribution to the bias comes from the mid-visible part of the spectrum, rather than in the strong water vapor bands. This indicates that the cause of the discrepancy may not be directly due to water vapor absorption but instead to something that is correlated with water vapor, such as aerosol extinction. The EOPACE data set will provide important new evidence towards resolving the source of this bias.

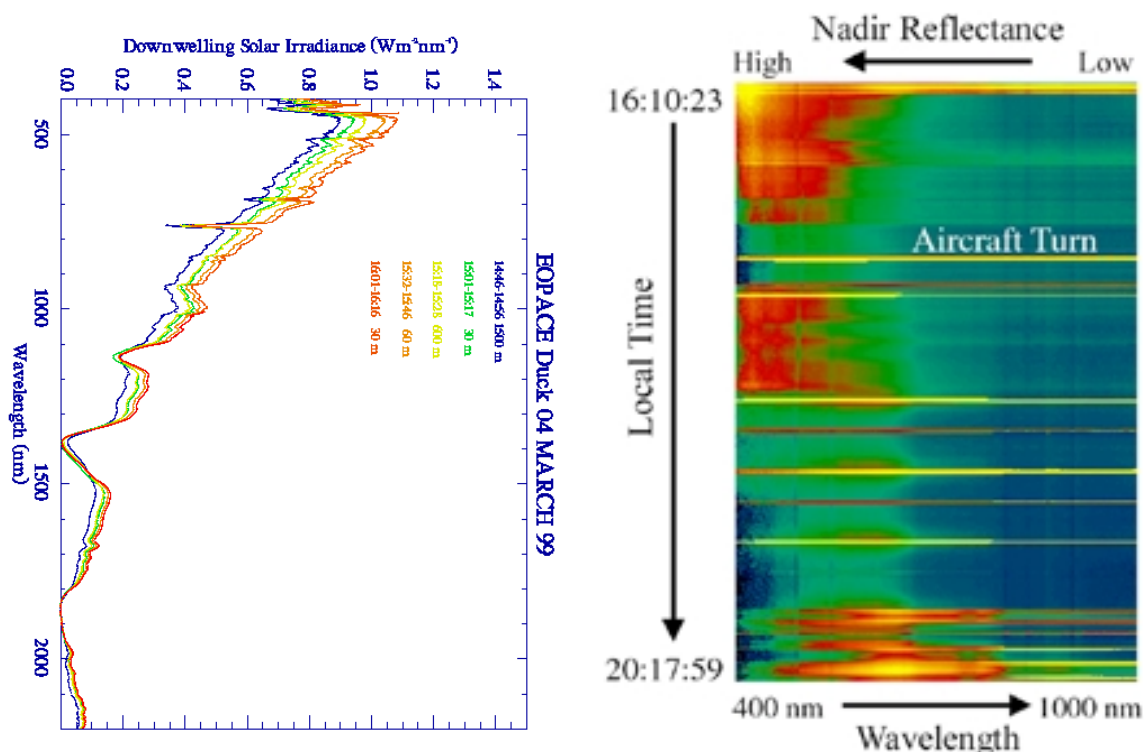


Figure 2: An example of downwelling spectral solar irradiance acquired at different aircraft altitude (left) and nadir reflectance (right) along flight tracks, starting out over greenish-coastal waters, more open water, turn, back track, turn, then changing aircraft altitude causing spectral brightness shift due to changes in aerosol and molecular scattering, and repeat the sequence.

The method for remote sensing of smoke or sulfates over vegetated (dark) regions by Kaufman *et al.* (1997) is extended to include dust over the desert (bright surface). Now, this method can derive aerosol properties in the blue (0.4-0.5 μm) and the red (0.6-0.7 μm) spectral regions. Figures 3a & 3b show the two Landsat images used as an example in the analysis. The much brighter image in the dusty day indicates that dust backscattering of sunlight is stronger than the two way absorption of sun light (to the surface and back to space).

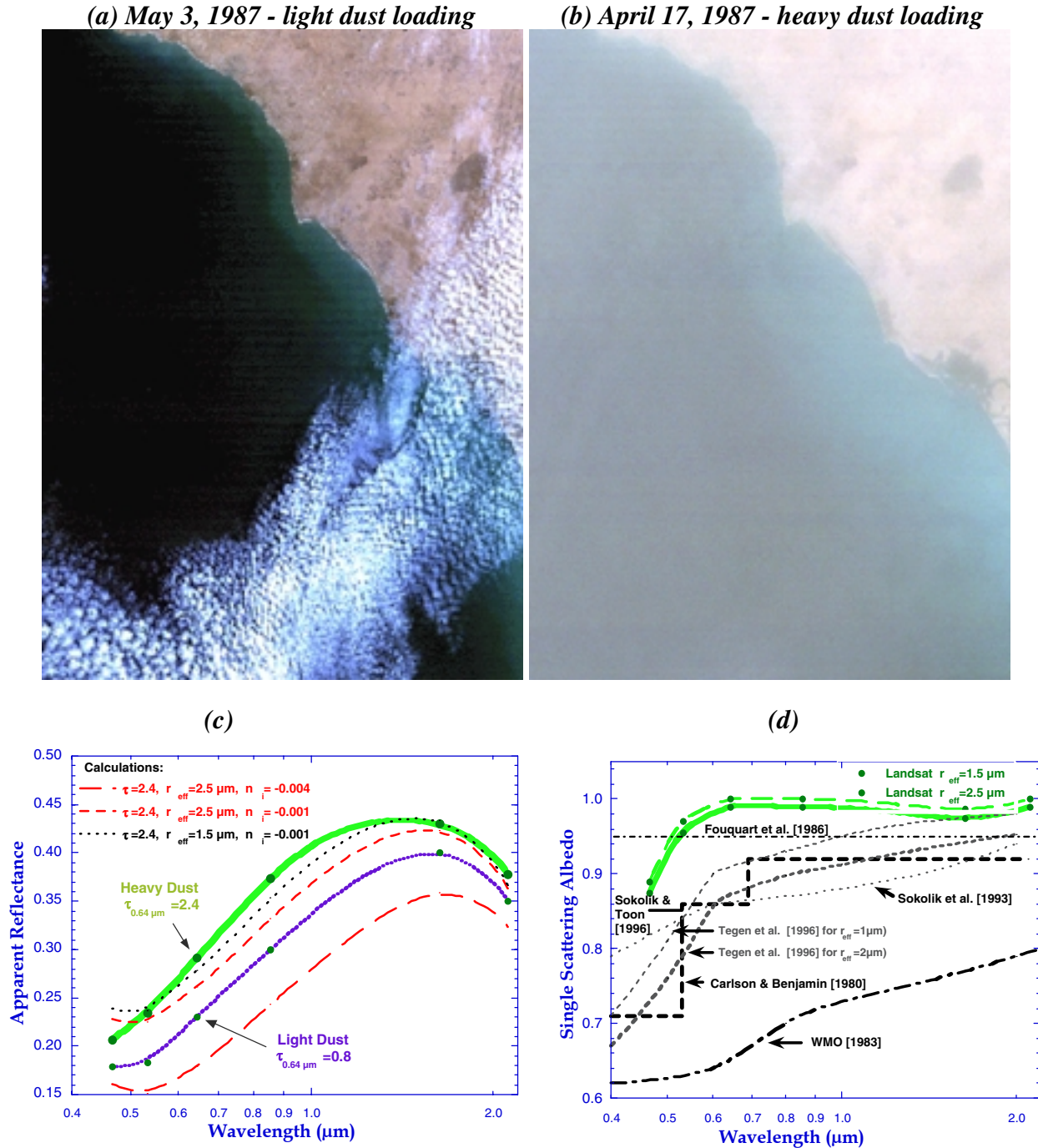


Figure 3: Landsat TM images over the coast of Senegal (a,b), and the modeling of apparent reflectance (c) with analyzed dust single scattering albedo (d). The derived dust absorption is much smaller than those in the present literature - black lines.

Using collocated sunphotometer data, we retrieved spectral optical depths for the light-dust and heavy-dust day were 0.8 and 2.4, respectively for wavelength at 0.64 μm . In addition, dust size distribution is dominated by a coarse mode with effective radius between 1.5 and 2.5 μm . Based on these parameters, we analyze all Landsat spectral channels to derive the spectral single scattering albedo. To explain the increase in the earth-surface reflectance due to the presence of dust, a close to zero absorption ($k_0 \sim 1$) has to be used. Even imaginary index of $n_i = -0.004$ ($k_0 = 0.83$ at $\lambda = 0.65 \mu\text{m}$), half of the WMO value, would cause a decrease rather than an increase in the apparent reflectance (Fig 3c). Thus, the absorption of solar radiation by Saharan dust is two to four times smaller than those documented in the open literature. Although dust absorbs in the blue, almost no absorption was found for wavelengths longer than 0.6 μm (Fig. 3d). Large scale application of this method to satellite data from the Earth Observing System can reduce significantly the uncertainty in the dust radiative properties, remote sensing from space and correction to derive the ocean properties.

IMPACT/APPLICATIONS

Spectral observations of dust properties from the space and from the ground create a powerful tool for determining the absorption of solar radiation by dust with an unprecedented accuracy. Revisiting the dust models and generating remote sensing procedures of dust over land are the first step for an attempt for hyperspectral remote sensing of coastal regions, as well as correction for the dust effect in these regions to derive the properties of the water and underwater surfaces.

TRANSITIONS

We have developed a technique, using both satellite spectral data and ground-based observations, to derive the dust particle size, single scattering albedo, and range of the refractive index. During FY99 collaboration, atmospheric transmission models (TransL/TransM) and aerosol model (AeroMie), developed at GSFC, were transferred to, used and have enjoyed by scientists at SPAWAR. The next stage is to compare the radiative transfer modeling results of spectral signal from dust and other aerosol types and the signal from chlorophyll between the SPAWAR and GSFC/Ames teams.

RELATED PROJECTS

This work is related to the NASA/MODIS effort of remote sensing of aerosol and their effect on climate.

REFERENCES

Kaufman, Y. J. , D. Tanré, L. Remer, E. Vermote, A. Chu, and B. N. Holben, Remote sensing of tropospheric aerosol from EOS-MODIS over the land using dark targets and dynamic aerosol models, *JGR-Atmosphere*, special issue on *Remote Sensing of Aerosol and Atmospheric Corrections*, **102**, 17051-17067, 1997.

PUBLICATIONS

Kaufman, Y. J., D. Tanré, A. Karnieli, L. A. Remer, and O. Dubovik, 1999: Re-evaluation of dust absorption and radiative forcing of climate using satellite and ground-based remote sensing. submitted to *J. Geophys. Res.*