GACP Accomplishment Report

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TITLE: Determination of Regional Aerosol Radiative Forcing from Remote Sensing Data and Model Simulations

ABSTRACT: This investigation is to study the direct radiative forcing in regions that are influenced by sulfate, dust, and biomass burning aerosols. We focus on these three types of tropospheric aerosols, frequently observed over the Atlantic Basin and Asian Pacific, to develop an understanding of aerosol direct radiative forcing on a regional scale. Since tropospheric aerosols have a relatively short lifetime with large temporal and spatial variations, satellite observations constitute the most effective means to address and assess what radiative effects the deposition of aerosols may have upon these regions. In addition, radiative transfer modeling is required to bridge the angular and spectral gaps of satellite observations, and surface remote sensing provides additional information content for comparisons that confirm quantitatively the usefulness of the integrated data.

The intent of this proposal is to support data analysis, model simulation, and collaboration with a group of scientists led by B. N. Holben of AERONET at NASA Goddard Space Flight Center. Specifically, the proposed objectives are:

(1) to extend the insights, to be learned from the EOS/AM1 MODIS measurements, to the re-analysis of collocated AVHRR and GOES data. Experience gained from the analysis of MODIS Airborne Simulator data acquired during recent field campaigns proves the concept effective;

(2) to mobilize an existing suite of surface remote sensing instruments, including broadband radiometers, shadow-band radiometer, sunphotometer, micropulse lidar, and microwave radiometer, to collocate with satellite nadir overpass at targeted areas for enhancing the AERONET data base and providing data for intercomparisons; and

(3) to perform model simulations, based on our past work, of a very sophisticated column-radiation model which includes molecular scattering, gaseous absorption, particulate extinction, and surface bidirectional reflection that produces accurate radiance fields and fluxes at any level and viewing geometry. This column-radiation model also utilizes a comprehensive physical/optical aerosol model which includes the relative humidity effects and allows a variety of partitions of chemical component and mass. With the aid of these models, we plan to conduct sensitivity studies of aerosol radiative forcing and

to quantify the range of uncertainty.

GOALS: Study the direct radiative forcing in regions that are influenced by sulfate, dust, and biomass burning aerosols, using satellite, aircraft and surface remote sensing data.

OBJECTIVES: Determine the downwelling irradiance at the surface for comparison with coordinated satellite derived ones, and retrieve aerosol optical thickness and other microphysical parameters from surface remote sensing to compare with spaceborne/airborne retrievals for better understanding of clear-sky and aerosol characteristics, in turn, direct radiative forcing.

APPROACH: Mobilize an existing suite of surface remote sensing instruments (including broadband radiometers, shadow-band radiometer, sunphotometer, micro-pulse lidar, and microwave radiometer) to collocate with satellite nadir overpass at targeted areas. Perform column-radiation modeling to analyze field measurements and to fuse the space-borne and ground-based remote sensing data.

TASKS COMPLETED: We have (1) successfully participated in the NASA TRMM South China Sea Monsoon Experiment (SCSMEX'98) for surface flux radiation measurements, the Navy EOPACE/Duck'99 coastal zone aerosol experiment for collocating SeaWiFS and surface remote sensing, and the Aerosol Recirculation and Rainfall Experiment (ARREX/SAFARI'99) of airborne and ground-based remote sensing for biomass burning aerosols, (2) actively participated in the ACE (Aerosol Characterization Experiment)-Asia Science Steering Committee on coordinating EOS/Terra and surface remote sensing of Asian dust radiative forcing, and (3) analyzed SCSMEX data to deduce surface radiation budget from in situ measurements for the workshop, conference presentation and paper publications.

FUTURE PLANS: Continue to (1) analyze field campaign data in retrieving surface radiation budget for publications, (2) participate the SAFARI-2000 (South Africa Fire-Atmosphere Research Initiative) experiment for measuring biomass burning aerosols and industrial pollution, and (3) perform column-radiation simulations to conduct sensitivity studies of aerosol radiative forcing and to quantify the range of uncertainty.

RESULTS: Pyrgeometers and Pyranometers are widely used for measuring infrared (e.g., 4 to 50 µm) and solar (e.g., 0.28 to 2.8 µm) irradiance, respectively. These radiometers use identical case and sensor (thermopile) with different types of domes. The dome, acting as a spectral filter, alters the radiation balance between the sensor and the target. Lacking precise theoretical analysis, the dome effect has been ignored or crudely corrected for decades. It can easily lead to systematic errors exceeding 10 Wm^{-2}, which is unacceptable for current radiative forcing studies. A suite of ground-based radiometers was deployed at Dong-Sha Island (20° N, 120° E) during SCSMEX from May to June 1998. Analyzing these data, Ji and Tsay (1999) provide a highly simplified theory that explains the pyrgeometer dome effect and the pyranometer thermal effect very well. We show that the dome factors of our pyrgeometers are less than 1.0, which are significantly smaller than the previously assumed value of 4.0. This can affect the measured infrared irradiance by up to about 5%. Since every pyrgeometer has its own dome factor, one should not ignore the dome factor or choose a constant without measuring it. For pyranometer, we give a new equation that explains the origin of the thermal dome effect. It is essential to measure the case and the dome temperatures to properly account for the thermal effect.

During February-March 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. 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 characterizes. After successful deployment, special emphasis is being placed on reducing surface flux measurements and the hyperspectral radiometer data collected on the Navy CIRPAS twin otter. All participants have agreed to complete data sharing.

Sensitivity studies in aerosol optical thickness retrievals reveal that the apparent reflectance at the top of the atmosphere is very susceptible to the surface reflectance, especially when aerosol optical thickness is small. Uncertainties associated with surface reflectance estimation can greatly amplify the error of the aerosol optical thickness retrieval. To reduce these uncertainties, Wen et al. (1999) have developed a “path radiance” method to retrieve aerosol optical thickness over land by extending the traditional technique that uses the “dark object” approach to extract the aerosol signal. This method uses the signature of the correlation of visible and mid-IR reflectance at the surface, and couples the correlation with the atmospheric effect. We have applied this method to a Landsat TM (Thematic Mapper) image acquired over the Oklahoma Southern Great Plains (SGP) site of DoE's ARM (Department of Energy's Atmospheric Radiation Measurement) program. The retrieved mean aerosol optical thickness for TM band 1 at 0.49 µm and band 3 at 0.66 µm agree very well with the ground-based sunphotometer measurements at the ARM site. The ability to retrieve small aerosol optical thickness makes this path radiance technique promising. More importantly, the path radiance is relatively insensitive to surface inhomogeneity. The retrieved mean path radiances in reflectance units have very small standard deviations for both TM blue and red bands. This small variability of path radiance further supports the current aerosol retrieval method.

GACP SIGNIFICANT HIGHLIGHTS

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SIGNIFICANT HIGHLIGHTS: Since the introduction of thermopile, pyranometers (solar, e.g., 0.3-3.0 µm) and pyrgeometers (terrestrial, e.g., 4-50 µm) have become instruments commonly used for measuring the broadband hemispherical irradiances at the surface in a long-term, monitoring mode for decades. These worldwide distributions of surface measurements become even more important in the era of Earth remote sensing and radiative forcing in climate study. However, recent investigations from field campaigns have pointed out that erroneous factors (e.g., temperature gradients between the filter dome and detector, emissivity of the thermopile) are responsible for the unacceptable level of uncertainty (e.g., 10-20 W m^{-2}). For example, Figure 1 shows that the dome factors (i.e., defined as a ratio of dome emissivity to transmissivity) of our pyrgeometers, derived from SCSMEX surface radiation measurements, are less than 1.0, which are significantly smaller than the previously assumed value of 4.0. This can affect the measured infrared irradiance by up to about 5%. Using a newly developed instrument of Quantum Well Infrared Photodetector (QWIP), we have characterized the brightness temperature fields of pyranometers and pyrgeometers under various conditions. The QWIP is based on the superlattice (GaAs/AlGaAs) technology and has a noise equivalent temperature less than 0.1 K. For pyrgeometer dome factors, we found that the thermal reflection of the dome can be 10 times larger than that previously thought. For pyranometer, it is essential to measure the case and the dome temperatures to properly account for the thermal effect. Thus, the quality of pyranometer and pyrgeometer measurements can be improved largely by applying proper knowledge of the thermal parameters affecting the operation of the thermopile systems.

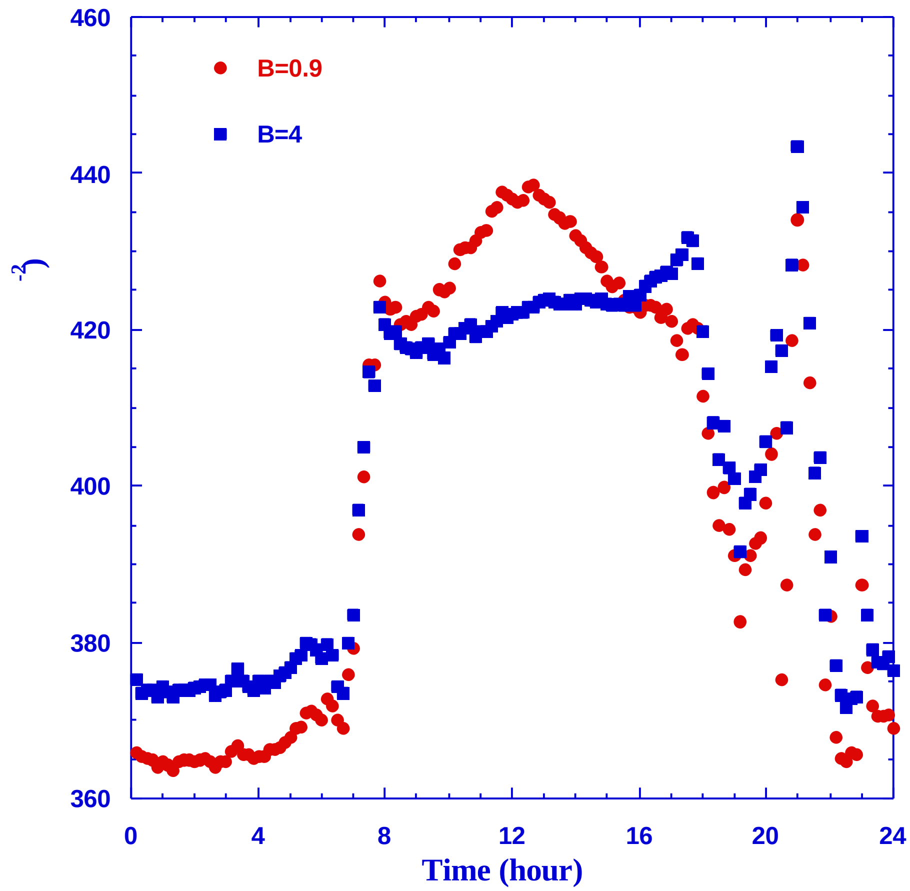

Figure 1. Differences of downwelling irradiance deduced at surface by applying derived (B=0.9) and assumed (B=4.0) dome factor (Ji and Tsay, 1999). The data were acquired during SCSMEX, May-June 1998.

GACP FUTURE PLANS

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We will continue to process and analyze data sets acquired from recent field campaigns for retrieving surface radiation budget for publications. These data sets include: the South China Sea Monsoon Experiment (SCSMEX'98) for TRMM satellite, GMS and surface remote sensing data, the Navy Electro-Optical Propagation Assessment in Coastal Environments (EOPACE'99) for SeaWiFS, airborne and surface remote sensing of coastal aerosols, and the Aerosol Recirculation and Rainfall Experiment (ARREX/SAFARI'99) for airborne hyperspectral and surface remote sensing of biomass burning aerosols We will also continue to participate the SAFARI-2000 (South Africa Fire-Atmosphere Research Initiative) experiment for measuring biomass burning aerosols and industrial pollution, as well as to participate actively in the ACE (Aerosol Characterization Experiment)-Asia Science Steering Committee on coordinating NASA/Terra and surface remote sensing of Asian dust radiative forcing. In addition, we will continue to perform column-radiation simulations for sensitivity study of aerosol radiative forcing and further improvement of retrieving aerosol optical thickness over land.

GACP BIBLIOGRAPHY

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