GACP Progress Report

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

2nd Year Progress Report:

The objectives of this project are: (a) to determine the downwelling irradiance at the surface for comparison with those derived from coordinated satellites, and (b) to 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. To achieve these goals, our approach is to mobilize an evolving suite of surface remote sensing instruments, SMART (Surface Measurements for Atmospheric Radiative Transfer), to collocate with satellite nadir overpass at targeted areas. The SMART includes broadband radiometers, shadow-band radiometer, sunphotometer, solar spectrometers, whole-sky camera, micro-pulse lidar, and microwave radiometer, as well as meteorological probes for atmospheric pressure, temperature, humidity, and wind speed/direction. For assuring the success of this research, understanding the accuracy of downwelling irradiance measured at the surface is essential. A great deal of our past year is devoted to characterize our flux radiometers.

Pyrgeometers and Pyranometers are fundamental instruments widely used for quantifying atmosphere-surface energetics in climate studies. The dome effect of these instruments can cause a measurement uncertainty larger than 10 W m^{-2}. Based on careful analysis, the dome factors (ratio of emissivity to transmissivity) of our two new pyrgeometers are found to lie in the range between 1.1 and 2.0. These values are far smaller than the value of 4.0 suggested by the World Meteorological Organization. The laboratory-determined dome factors fall within this range, if pyrgeometers approach equilibrium with the blackbody target during calibration cycles. In addition, theoretical calculations reveal that thermal reflection of the dome is not negligible; in turns, the dome factor is expected to be smaller. From our recent field campaigns, consistent results for the dome factors are also obtained by analyzing nighttime pyrgeometer measurements, which were regarded as approaching an equilibrium state. Thus, uncertainty caused by selection of dome factor alone can reach 10-15 W m^{-2}.

Similar thermal characteristics of the dome can be observed in pyranometer measurements. We utilized an energy balance equation to describe the thermal dome effect of pyranometers that is commonly referred to as the nighttime negative outputs or the dark-offset. Lacking direct measurements of the dome and case temperatures of pyranometer (e.g., model PSP), we used measurements from a pyrgeometer (e.g., model PIR) to derive and to account for the thermal dome effect of collocated pyranometers. We approximate $\varepsilon_d = 0.71$, $(T_c)_{PSP} = (T_c)_{PIR}$, and $(T_d)_{PSP} = 0.996(T_d)_{PIR}$, and demonstrate that the thermal dome effect causes the nighttime PSP negative outputs (larger than 5 W m^{-2}). During daytime, solar heating and other effects on PSP are involved. Therefore, to better calibrate PSPs and to calculate the dome effect, the case and the dome temperatures of the PSP should be measured. Nonetheless, as a speculation, if we simply extend the nighttime approximation into the daytime, then there would be over 3% underestimation in PSP measurements, or up to about 25 W m^{-2} at noon. The aforementioned results are reported in the work of Ji and Tsay (2000) and Tsay et al. (to be in 2001). This approach suggests a sound method to evaluate the uncertainty range involving long-term surface radiation measurements for radiative forcing in climate study.

For the past year, we have (1) successfully participated in and analyzed data from the Aerosol Recirculation and Rainfall Experiment (ARREX/SAFARI'99) of airborne and ground-based remote sensing for biomass burning aerosols, and (2) conducted the Puerto Rico Dust Experiment (PRIDE, June-July 2000) to study the long-range transport of Saharan dust. The SMART is situated against the prevailing wind from the East, and encountered a dust event in roughly 4-5 days during the IOP. For this deployment, we have introduced a new pyrgeometer and additional broadband solar direct and diffuse radiation measurements. Spectral direct and diffuse (0.4-2.5 µm) measurements were also attempted by utilizing a solar tracker. These data, as well as data sets acquired from the past campaigns, will be available to the research community soon after calibration. Currently, we are setting up a SMART web page to show quick preview and summary of all data sets. Eventually, these data will be downloadable from the web.

We also 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.

3rd Year Statement of Work:

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; the Aerosol Recirculation and Rainfall Experiment (ARREX/SAFARI'99) for airborne hyperspectral and surface remote sensing of biomass burning aerosols; and the Puerto Rico Dust Experiment (PRIDE'00) for Saharan dust transported from Africa across the Atlantic into the Caribbean. 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

(a) Refereed Publications:

1. Wen, G., S.-C. Tsay, R. Cahalan and L. Oreopoulos, 1999: Path Radiance Technique for Retrieving Aerosol Optical Thickness over Land. *J. Geophys. Res. Atmos.*, **104**, 31,321-31,332.

2. Chou, M.-D., K. T. Lee, S. C. Tsay and Q. Fu, 1999: Parameterization for Cloud Longwave Scattering for Use in Atmospheric Models. *J. Climate*, **12**, 159-169.

3. Ji, Q., and S.-C. Tsay, 2000: On the Dome Effect of Eppley Pyrgeometers and Eppley Pyranometers. *Geophys. Res. Lett.*, **27**, 971-974.

4. Lau, K. M., Y. Ding, J.-T. Wang, R. Johnson, T. Keenan, R. Cifelli, J. Gerlach, O. Thiele, T. Rickenbach, S.-C. Tsay, and P.-H. Lin, 2000: A Report of the Field Operations and Early Results of the South China Sea Monsoon Experiment (SCSMEX). *Bull. Amer. Meteor. Soc.*, **81**, 1261-1270.

5. Lin, P. H., M.-D. Chou, Q. Ji and S.-C. Tsay, 2000: Clear-Sky Surface Shortwave Radiation during South China Sea Monsoon Experiment. *Geophys. Res. Lett.*, submitted.

6. Tsay, S.-C., M. D. Jhabvala, Q. Ji, D. Rapchun, and P. K. Shu, 2000: Thermal Characteristics of Pyrgeometer and Pyranometer in Atmosphere-Surface Energetic Measurements. *J. Atmos. Oceanic Tech.*, to be submitted.

(b) Presentations at professional society meetings and workshops:

1. Tsay, S.-C., 1998: ACE-Asia and AM1 & PM1/EOS: A 2000^+ Field Campaign on Asian Dust and Pollution Aerosol. Cheju Island, Korea.

2. Tsay, S.-C., 1999: Surface Radiation Measurements in SCSMEX'98. Macau.

3. Tsay, S.-C., 1999: Radiation Measurements during Aerosol Recirculation and Rainfall Experiment (ARREX/SAFARI-2000). Boulder, Colorado.

4. Tsay, S.-C. and Q. Ji, 2000: Thermal Characteristics of Pyrgeometer and pyranometer in Surface-Atmosphere Energetic Measurements. St. Petersburg, Russia.