2nd Year Progress Report submitted to GACP

The Direct Radiative Forcing of Biomass Burning Aerosols: Investigations during SCAR-B and ZIBBEE

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Task 1

Using high temporal resolution (half-hourly) GOES-8 imager data and radiative transfer calculations, smoke aerosol optical thickness (τ) is retrieved over selected sites in South America and Central America. The degradation of the signal response in GOES-8 visible channel is estimated and the satellite-retrieved τ values are then compared against ground-based sunphotometer measurements. The satellite-retrieved values are in good agreement with ground-based measurement sites over South America with mean linear correlation coefficients of 0.97. Over Central America the mean correlation coefficient is 0.80. A single scattering albedo of 0.90 (at 0.67 μm) yields the best agreement between measured and calculated values that is consistent with previous studies. However, our results show that the retrieved optical thickness results are sensitive to single scattering albedo and surface reflectance. For example, a 7% change in single scattering albedo (0.87-0.93) yields an uncertainty in aerosol optical thickness of 10% for small optical thickness (τ=0.5) and an uncertainty of about 25% for larger optical thickness values (τ=1.5). Although the GOES-8 visible channel has undergone significant degradation since launch, smoke aerosol optical thickness can be estimated if proper procedures are used to account for this degradation effect.

Zhang, J., S. A. Christopher, and B. Holben, Intercomparison of aerosol optical thickness derived from GOES-8 Imager and Ground-Based Sun Photometers, J. Geophysical Res., revised version submitted, July 2000. http://www.atmos.uah.edu/~sundar/papers/jgr_2000.pdf

Task 2

Using collocated data from the Visible Infrared Scanner (VIRS) and the Clouds and the Earth's Radiant Energy Budget Scanner (CERES) from the Tropical Rainfall Measuring (TRMM) satellite, observational estimates of the instantaneous Shortwave Aerosol Radiative Forcing (SWARF) of smoke aerosols at the top-of-atmosphere (TOA) are obtained for four days in May 1998 during a biomass burning episode in Central America. The detection of smoke aerosols is demonstrated using VIRS imagery. Assuming a single scattering albedo (ω_o) of 0.86 (at 0.63 μm) that is representative of absorbing aerosols, smoke optical thickness ($\tau_{0.63}$) is retrieved over ocean areas. The average $\tau_{0.63}$ for these four days was 1.2 corresponding to a SWARF value of -68 Wm^{-2}. The SWARF changes from -24 to -99 Wm^{-2} as $\tau_{0.63}$ changes from 0.2 to 2.2. Global observational estimates of biomass burning aerosol radiative forcing can be obtained by combining data sets from TRMM and Terra satellites.

Christopher, S.A., J. Chou, J. Zhang, X. Li and R.M. Welch, Shortwave Direct Radiative Forcing of Biomass Burning Aerosols Estimated From VIRS and CERES. Geophys. Res. Letters, 27, 2197-2200 (http://www.atmos.uah.edu/~sundar/papers/grl_2000.pdf).

Task 3

Using *in situ* measurements of aerosol optical properties and ground-based measurements of aerosol optical thickness (τ_s) during the **S**moke, **C**louds **a**nd **R**adiation-**B**razil (SCAR-B) experiment, a four-stream broadband radiative transfer model is used to estimate the downward shortwave irradiance (DSWI) and top-of-atmosphere (TOA) shortwave aerosol radiative forcing (SWARF) in cloud-free regions dominated by smoke from biomass burning in Brazil. The calculated DSWI values are compared with broadband pyranometer measurements made at the surface. The results show that for two days when near-coincident measurements of single-scattering albedo (ω_0), and aerosol optical thickness (τ_s) are available, the root mean square errors between the measured and calculated DSWI, for daytime data are within 30 W m^{-2}. However, for five days during SCAR-B, when assumptions about ω_0 have to be made and also when τ_s was significantly higher, the differences can be as large as 100 W m^{-2}. At the TOA, the SWARF per unit optical thickness ranges from -20 to -60 W m^{-2} over four major ecosystems in South America. Our results show that τ_s and ω_0 are the two most important parameters that affect DSWI calculations. For SWARF values, surface albedos also play an important role. It is shown that ω_0 must be known within 0.05, and τ_s at 0.55 μm must be known to within 0.1, to estimate DSWI to within 20 W m^{-2}. The methodology described in this paper could serve as a potential strategy for determining DSWI values in the presence of aerosols. However, the wavelength dependence of τ_s and ω_0 over the entire shortwave spectrum is needed to improve radiative transfer calculations. If global retrievals of DSWI and SWARF from satellite measurements are to be performed in the presence of biomass-burning aerosols on a routine basis, a concerted effort should be made to develop methodologies for estimating ω_0 and τ_s from satellite and ground-based measurements.

Christopher, S.A., X. Li, R.M. Welch, P.V. Hobbs, J.S. Reid, and T. F. Eck. Estimation of Downward andtop-of-atmosphere Shortwave Irradiances in Biomass Burning Regions during SCAR-B. J. Appl. Meteorology,2000 (in press).
(http://www.atmos.uah.edu/~sundar/papers/jam_2000.pdf

Task 4
Using a new angular distribution model (ADM) for smoke aerosols, the instantaneous Top-of-Atmosphere (TOA) Shortwave Aerosol Radiative Forcing (SWARF) is calculated for selected days over biomass burning regions in South America. The Visible and Infrared Scanner (VIRS) data is used to detect smoke aerosols and the Cloud and Earth Radiant Energy System (CERES) scanner data from the Tropical Rainfall Measuring Mission (TRMM) is used to obtain the broadband radiances. First, the ADM for smoke aerosols is calculated over land surfaces using a discrete-ordinate radiative transfer model. The instantaneous TOA shortwave (SW) fluxes are estimated using the new smoke ADM and compared with the SW fluxes from the CERES product. The RMS error between the CERES SW fluxes and fluxes using the smoke ADM is 13 Wm^{-2}. The TOA SWARFs per unit optical thickness for the 6 surface types range from –29 Wm^{-2} to –57 Wm^{-2}, showing that smoke aerosols have a distinct cooling effect. The new smoke ADM developed as part of this study could be used to estimate radiative impact of biomass burning aerosols.

Li, X., S.A. Christopher, J. Chou, and R.M. Welch, Estimation of shortwave direct radiative forcing of biomass burning aerosols using angular dependence models. J. Appl. Meteor., TRMM issue, 2000, in press.
(http://www.atmos.uah.edu/~sundar/papers/adm.pdf)

3rd Year Statement of Work

Task 1: To estimate the diurnal forcing of biomass burning aerosols using GOES imager data

Task 2: To use VIRS/CERES and MODIS/CERES data to estimate direct radiative forcing of aerosols.

GACP Bibliography

Christopher, S.A., J. Chou, J. Zhang, X. Li and R.M. Welch, Shortwave Direct Radiative Forcing of Biomass Burning Aerosols Estimated From VIRS and CERES. Geophys. Res. Letters, 27, 2197-2200.

L. Y. Chan, C. Y. Chan, S.A. Christopher, H. Y. Liu, S. J. Oltmans, and J. M. Harris, A Case Study on the Biomass Burning in Southeast Asia and Enhancement of Tropospheric Ozone over Hong Kong, Geophys. Res. Letters, 27, 1497-1482.

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Li, X., S.A. Christopher, J. Chou, and R.M. Welch, Estimation of shortwave direct radiative forcing of biomass burning aerosols using angular dependence models. J. Appl. Meteor., TRMM issue, in press, 2000.

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Reid, J.S., T. Eck, S.A. Christopher, B. Holben, and P. Hobbs, Use of the Angstrom Exponent to Estimate the Variability of Optical and Physical Properties of Aging Smoke Particles in Brazil, J. Geophys. Res. 104 27,473-27490,1999.