Atmospheric Net Fluxes Inferred from CERES/SARB Fluxes

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Introduction

The Clouds and the Earth's Radiant Energy System (CERES) instrument (Wielicki et al. 1996) on board the Tropical Rainfall Measurement Mission (TRMM) satellite has archived eight months of Top Of Atmosphere (TOA) fluxes in two forms. The first archived under the name "ES8" are TOA fluxes calculated in a manner identical to the Earth Radiation Budget Experiment (ERBE) methodology and a second newer data product under the name Single Satellite Flux (SSF). The SSF data utilize new anisotropic directional models derived from the CERES TRMM data for inversion of TOA fluxes, and VIRS pixels collocated within the larger CERES footprint to determine cloud fraction and properties. A soon to be archived data product, the Clouds and Radiative Swath (CRS), includes fluxes calculated through the atmosphere beneath each CERES footprint using the Fu and Liou radiation transfer model (Fu and Liou, 1993). In this paper CERES TOA data are matched to surface observations of broadband radiation at a number of sites in the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) testbed over parts of Kansas and Oklahoma. Once matched in space and time, atmospheric absorption is calculated for both clear and all sky conditions to obtain estimates of cloud forcing of the atmosphere.

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Data

CERES data provides broadband observations of total (0.3-∞ µm), shortwave (0.3-5.0 µm) and window (8-12.0 µm) fluxes during the CERES/ TRMM time period of January through August 1998. CERES processing derives two fluxes from the same radiance observation. The ES8 data are based on the ERBE methodology where scene type is based on a Maximum Likelihood Estimation technique, which determines cloud fraction, and the Anisotropic Directional Models (ADMs) of Suttles et al. (1988), which were derived from Nimbus 7 data, for inverting the TOA radiances to fluxes. New CERES SSF fluxes are inverted from ADMs created from CERES/TRMM observations. Included in the SSF data product are cloud properties and fractions based on analysis of VIRS imager pixels collocated within the larger CERES footprint. This supplies a truer estimate of cloud amount within each footprint. These data can be retrieved from the NASA Langley Atmospheric Data Center at http://eosweb.larc.nasa.gov/.

Observations of surface shortwave flux data come from the CERES /ARM Validation Experiment (CAVE) database. The CAVE data is a compendium of data collected by a number of other surface radiometric observation programs. These include Department of Energy's ARM, Baseline Surface Radiation Network (BSRN), NOAA's Climate Monitoring Diagnostics Laboratory (CMDL), and NOAA ARL Surface Radiation (SURFRAD) programs. The CAVE project collects surface data supplied by these projects and averages it to 30-minute temporal resolution. CAVE includes when available, broadband observations of reflected shortwave (SW) radiation, direct normal and diffuse shortwave insolation, upwelling and downwelling longwave (LW) radiation along with other surface meteorological and aerosol observations. Because of the time frame and requirement of cloud fraction based on SW radiometry (Long and Ackerman 2000), only data from 20 ARM/SGP surface sites are included in the following analysis. More information and the CAVE data are available at: http://www-cave.larc.nasa.gov/cave/.

Model Calculations

The CERES Surface and Atmospheric Radiation Budget (SARB) data product, the CRS product, will provide model calculations of broadband fluxes at several levels in the atmosphere including TOA and surface. The radiation transfer model is a modified version of the model developed by Fu & Liou (1993). It is a delta-two stream (2 for SW, 2/4 for LW) with fifteen spectral bands from 0.2 to 5.0 µm in SW and twelve spectral bands between 2850 and 0 cm^{-1} in LW. Cloud properties are provided on the CERES SSF product and come from VIRS imager pixels, collocated and energy weighted, within the CERES footprint. The Model of Atmospheric Transport and CHemistry (MATCH) developed by Collins et al. (2001) provides aerosol optical depths over land. Over ocean the Stowe et al. (1996) algorithm, based on VIRS imager data, calculates aerosol optical depth. Atmospheric pressure, temperature, and water vapor profiles are purchased from the ECMWF. Ozone profiles are supplied by the NCEP in their Stratospheric Monitoring Group Ozone Blended Analysis (SMOBA) product from SBUV and TOVS data.

Net Fluxes

Atmospheric absorption for both clear and all sky conditions is calculated using CERES TOA and CAVE surface observations, and with SARB model results. Net absorption is defined as the TOA net (Down-Up) flux differenced from the net surface flux. A schematic is shown in Fig. 1.

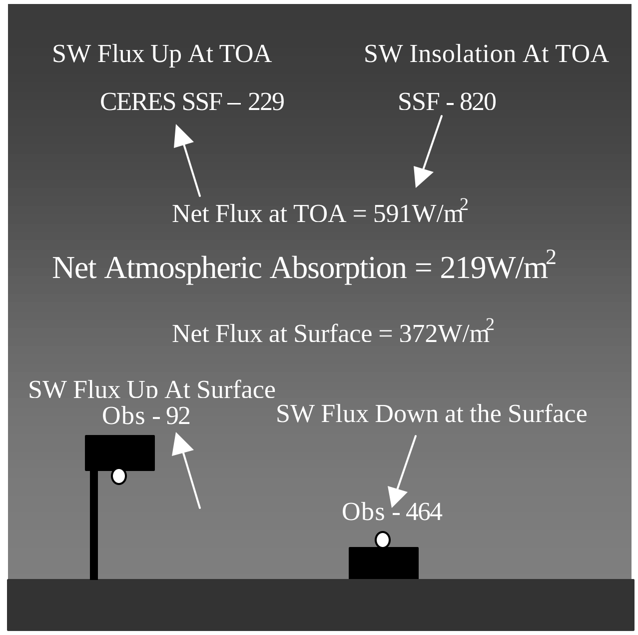

Figure 1. Example upward and downward net fluxes and net atmospheric absorption.

Surface SW fluxes have been corrected using the nighttime offset method of Dutton et al. (2001) for errors due to thermal effects on the SW pyranometers. Net absorption amounts were calculated using both ES8 and SSF TOA data. As there was not an appreciable difference between them for our purposes, only results from the SSF data are shown below. Results for net atmospheric absorption in clear and all sky conditions and cloud forcing are given in Tables 1 and 2 for the SSF and CAVE surface observations, and the CRS model results respectively.

Absorption From *CERES SSF* Data and VIRS Imager Est of Cloud Fraction					
Atmospheric Absorption W/m^2				Mean Cos(SZA)	
All Sky (n)	Clear Sky (n)	Cld-Fraction Filter	Cloud Forcing	All Sky	Clear Sky
217.0 (3190)	205.0 (1096)	VIRS = 0.00	12.0	0.61	0.58
217.0 (3190)	153.0 (120)	SWFA = 0.00	68.0	0.61	0.46
217.0 (3190)	205.0 (544)	SWFA <= 0.05	16.0	0.61	0.62
217.0 (3190)	206.0 (658)	SWFA <= 0.15	15.0	0.61	0.62

Table 1. Atmospheric absorption calculated from CERES/SSF observations at TOA and CAVE observations at the surface: for all sky and clear skies (columns 1 and 2), method of determining cloud amount (column 3), cloud forcing and mean solar zenith angles (proxy for sampling.)

Absorption From *SARB Model Results* and VIRS Imager Est of Cloud Fraction					
Atmospheric Absorption W/m^2				Mean Cos(SZA)	
All Sky (n)	Clear Sky (n)	Cld-Fraction Filter	Cloud Forcing	All Sky	Clear Sky
177.0 (3190)	161.0 (1096)	VIRS = 0.00	16.0	0.61	0.58
177.0 (3190)	122.0 (120)	SWFA = 0.00	54.0	0.61	0.46
177.0 (3190)	164.0 (544)	SWFA <= 0.05	13.0	0.61	0.62
177.0 (3190)	165.0 (658)	SWFA <= 0.15	12.0	0.61	0.62

Table 2. Same as Table 1 except atmospheric absorptions are calculated from constrained Fu & Liou model results for same CERES footprints.

The first thing to note about the tables is how "clear sky" is determined. "VIRS" in the row indicates that cloud imager pixels within the CERES footprint were all determined by the pixel level cloud mask to be "clear". Because footprints are collocated with ARM surface sites there is also available the ShortWave Flux Analysis (SWFA) estimate of cloud fraction. This number is based on surface shortwave radiometry, whose methodology is outlined in Long and Ackerman (2000). Since the surface estimate is a stricter definition of clear one must relax the estimate upwards of 15% to begin to retrieve a sample with a similar mean cosine solar zenith angle. At this point the amount of cloud forcing is also reduced back down to that observed using only the VIRS cloud screening method.

Secondly note the difference in all sky absorption between observations (217W/m^2) and model results (177W/m^2). This discrepancy is partly explained in that surface observations of upward shortwave flux from ARM 10 meter towers tends to overestimate satellite observed surface fluxes by approximately 10W/m^2 due to uniform grassy scenes beneath the down looking pyranometers. There is also an error of 10-20W/m^2 that results from mismatched clear sky footprints (determined from imager pixels within the approximately 20km footprint which can all be clear) with the surface radiometer, which can have clouds in its hemispherical view. However different the absolute fluxes it is interesting to note that calculated cloud forcings remain nearly the same between observations and model results. This is encouraging in that it implies though the model insolation is 20-30W/m^2 higher than the observations, the inputs are still capturing the difference between clear and cloudy skies.

Tables 1 and 2 give a large overview of calculated absorptions for 20 ARM/SGP sites. Additional information, based on site-by-site calculations can be found at http://www-cave.larc.nasa.gov/cave. There, clicking on the "Site Statistics" link is a series of tables showing means and differences between observed and modeled fluxes when collocated with the surface observations for all available sites in the CAVE data base during 1998. Also included in these tables are cloud and aerosol forcing estimates based on the CRS model runs.

References

Collins, W.D., P.J. Rasch, B.E. Eaton, B.V. Khattatov, J.-F. Lamarque, and C.S. Zender, 2001: Simulating aerosols using a chemical transport model with assimilation of satellite aerosol retrievals. Methodology for INDOEX. *J. Geophs. Rev*. **106**, 7313-7336.

Dutton, E.G., J.J. Michalsky, T. Stofel, B.W. Forgan, J. Hickey, D.W. Nelson, T.L. Alberta, and I. Reda, 2001: Measurement of broadband diffuse solar irradiance using current commercial instrumentation with a correction for thermal offset errors, *J. of Atmos. & Ocean . Tech*., **18**, No. 3, 297-314.

Long, C. N. and T. P. Ackerman, 2000: Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects, *J. of Geophys. Research*, **105**, No. D12, 15609-15626.

Rutan, D. A., F.G. Rose, N. Smith, and T. P. Charlock, 2001: Validation data set for CERES Surface and Atmospheric Radiation Budget (SARB), WCRP GEWEX Newsletter, **11**, No. 1, 11-12.

Fu, Q., and K.N. Liou, 1993: Parameterization of the radiative properties of cirrus clouds. *J. Atmos. Sci*., **50**, 2008-2025

Stowe , L., A. Ignatov, R. Singh, 1996: Development, validation, and potential enhancements to the second generation operational aerosol product at NOAA/NESDIS, *J. Geophys. Res*., **102**, D14, 16923-16934.

Suttles J.T., R.N. Green, P. Minnis, G.L. Smith, W.F. Staylor, B.A. Wielicki, I.J. Walker, D.F. Young, V.R. Taylor, and L.L. Stowe, 1988: Angular radiation models for Earth-atmosphere system. NASA RP 1184.

Wielicki, B.A., B.R. Barkstrom, E.F. Harrison, R.B. Lee, G.L. Smith, and J.E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment. Bull. Amer. Meteor. Soc., 77, 853-868.