CERES/ARM Validation Experiment

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Introduction

The Clouds and the Earth's Radiant Energy System (CERES) project (Weilicki et al. 1996) is a series of broadband scanning radiometers measuring total (0.3-oo µm), reflected (0.3 - 5.0 µm), and window (8 - 12 µm) energy. The instruments, on board the Tropical Rainfall Measurement Mission (TRMM) and Earth Observing System (EOS) Terra and Aqua satellites, measure radiation at the top of the atmosphere (TOA). However, CERES also computes the Surface and Atmospheric Radiation Budget (SARB) of the vertical column for each broadband footprint (~10 - 40 km). Inputs for these calculations include cloud optical properties (determined by higher resolution imagers), atmospheric profiles of pressure, temperature, relative humidity (European Centre for Medium-Range Weather Forecasting [ECMWF]), ozone (National Centers for Environmental Prediction [NCEP]), and a characterization of the column loading of aerosols (currently monthly climatologies over land and imager-derived optical depths over the oceans). With these inputs and global maps estimating spectral variation of surface albedo and emissivity (see: http://tanalo.larc.nasa.gov:8080/surf_htmls/ SARB_surf.html), a modified one-dimensional (1D) radiative transfer code (Fu and Liou 1993), (run online see: http://srbsun.larc.nasa.gov/flp0300/) computes broadband shortwave (SW), longwave (LW), and window infrared (IR) fluxes within the atmosphere. Given the large number of input variables, the global scope of the problem, and the natural variability of the atmosphere, there is an obvious need for validation of the fluxes as calculated.

CERES/ARM Validation Experiment (CAVE)

The formal product for the SARB consists of radiative fluxes at the surface, 500hPa, 200hPa, 70hPa, and TOA. Computations for TOA are compared directly with observations at the medium resolution CERES footprints. Given the limited availability of global in situ flux observations within the atmosphere, we turn to validation at the surface. The sites selected for the CERES "Atmospheric Radiation Measurement (ARM) Program Validation Experiment (CAVE)" are indicated in Figure 1. All CAVE sites subscribe to traceable calibration protocols. Consistent with the CERES goal of relating radiation to climate change, the CAVE sites observe and record several radiation fields nearly continuously for the long term. Many CAVE sites have auxiliary measurements useful for validating the inputs of radiative transfer computations and for validating diagnostic quantities like aerosol radiative forcing. The goal of CAVE is to make available, via the World Wide Web, a continuous informal record of radiation and meteorological data having:

- TOA broadband observations from the CERES instruments collocated in space and time with

- surface broadband flux measurements.

Where available, CAVE includes other variables such as meteorological records of surface temperatures, humidity and winds; as well as aerosols and, if available, temperature T(z) and humidity q(z) profiles. A pilot form of this project is developed more thoroughly in the CERES/ARM/GEWEX or CAGEX experiment (Charlock and Alberta 1996). CAGEX provides user-friendly sets of radiation, T(z) and q(z) observations; and includes fluxes computed by a radiative transfer model. Given the larger and continuous nature of CAVE, we attempt to supply the observations in an easy to use format, leaving analyses primarily to the researcher. The CAVE record begins on January 1, 1998, shortly after the CERES instrument on the TRMM satellite first began taking data. Depending upon the surface site, the data sets will be continuous and kept nearly up to date.

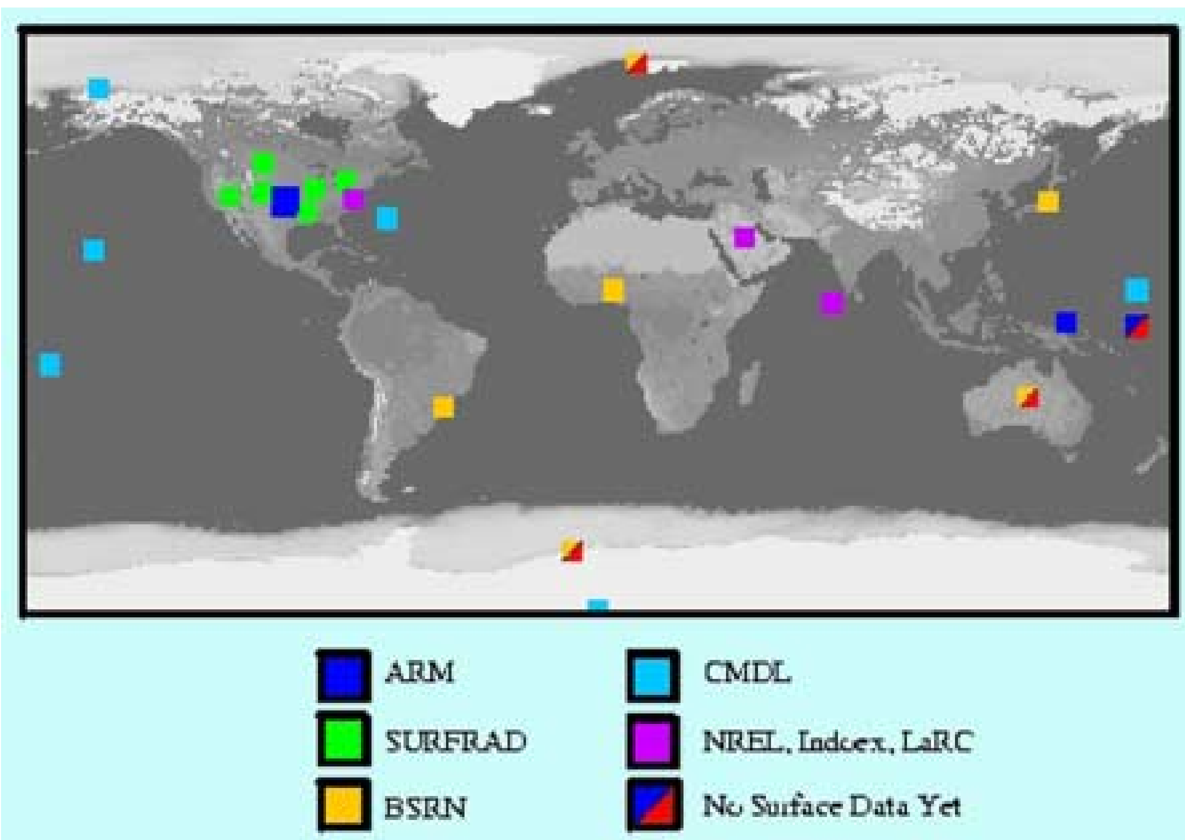

Figure 1. Locations of CAVE sites.

The Data

The basic CAVE philosophy is to supply currently available, high-quality surface observations of broad band fluxes over a wide variety of scene types around the globe that are collocated in time and space with the CERES TOA observations. To keep the data sets relatively small and easy to handle, a standard time unit of 1/2 hour has been chosen. Surface data is averaged into continuous 1/2-hour intervals, while the intermittent “snap-shot” CERES observations are placed into the nearest 1/2-hour intervals in a similar format. Though this causes a large number of the time steps for a CERES data file to be empty, it facilitates comparison of TOA values with surface observations. Ancillary data sets (aerosols, etc.) are placed within the same 1/2-hour format as the surface and TOA files.

The participating groups from which we receive the bulk of radiometric fluxes and surface observations are: The ARM Program, The Baseline Surface Radiation Network (BSRN), Climate Monitoring & Diagnostics Laboratory (CMDL), and National Oceanic and Atmospheric Administration (NOAA) Surface Radiation Research Branch, Surface Radiation Budget Network (SURFRAD) data. Other groups supplying data include National Aeronautics and Space Administration (NASA) Langley Research Center’s Chesapeake Lighthouse CERES Ocean Validation Experiment (COVE), the Indian Ocean Experiment (INDOEX), the National Renewable Energy Resources Laboratory (NREL) Saudi Solar Village, and NASA Goddard Spaceflight Center’s Aerosol Network (AERONET). A number of other researchers have contributed their time and talent in supplying ancillary data such as aerosol information, profile data, and cloud amounts. Their contributions are noted on the web site.

Along with the observations, several calculated fields are added to the CAVE files. We have adjusted surface radiometric data, where possible, to provide a more accurate flux record. For example, measurements of diffuse SW with the shaded Eppley precision spectral pyranometer are susceptible to offsets of several Wm^{-2} due to thermal IR exchange between the detector and dome (i.e., Dutton et al. 2001). Timothy L. Alberta has supplied an algorithm enabling us to make a first-order correction for such “night offset” at ARM Southern Great Plains (SGP) and other CAVE sites. Many CAVE files include supplementary estimates of cloud cover based on temporally intensive surface radiometric data (Long and Ackerman 2000, hereafter LA). LA can be used to validate classifications of sky conditions from satellites and models.

Surface and TOA CAVE files may be readily combined to diagnose radiative forcings. For example, Table 1 shows the cloud forcing to the absorption of SW by the atmospheric column. This is determined by differencing the net SW at TOA (CERES) and at the surface (ground-based radiometers) when using either the cloud classification scheme based on the satellite Maximum Likelihood Estimator (MLE) or the surface LA analysis. Table 1 shows that to obtain a comparable sample size for MLE and LA, “clear sky” must be permitted to include cloud cover (as per LA) of up to 15 percent. As the LA estimate is relaxed, the LA “clear” sample size approaches that of the MLE. The mean solar zenith angles (SZAs) for LA and MLE are then nearly equal, and the cloud forcing to atmospheric absorption based on surface (LA) and satellite (MLE) sky classifications may be safely compared. For a cos(SZA) exceeding 0.6, the cloud forcing to atmospheric absorption is a relatively modest $11.7W/m^2$.

Table 1. Atmospheric absorption of SW CERES and CAVE (January to August 1998).

Cloud ID (Cloud Fraction)	Atmospheric Absorption W/m^2			Cos(SZA)	
	All-Sky (N)	Clear-Sky (N)	Cloud Forcing	All-Sky	Clear-Sky
MLE (0.00)	225.8 (5601)	223.0 (1477)	2.8	0.64	0.63
LA (0.00)	225.8 (5601)	156.4 (155)	69.4	0.64	0.45
LA (0.05)	225.8 (5601)	209.6 (810)	16.2	0.64	0.62
LA (0.15)	225.8 (5601)	214.1 (1013)	11.7	0.64	0.63

MLE - Satellite estimate of cloud fraction, CERES scene ID = Clear
LA - Surface pyranometer estimate of cloud fraction, Long and Ackerman 2000.

Web Availability

The CAVE data is made available via ftp over the World-Wide-Web. The homepage describing the various data sources and supplying the programs to read the data is found at:
http://www-cave.larc.nasa.gov/cave/

Surface and TOA data for the first eight months of 1998, the CERES/TRMM time period, are available. Surface observations from a number of sites up through 2001 are also available and CERES TOA footprint data from the Terra satellite, Version 1, are available from March through December 2000.

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References

Charlock, T. P., and T. L. Alberta, 1996: The CERES/ARM/GEWEX Experiment (CAGEX) for the retrieval of radiative fluxes with satellite data. *Bull. Amer. Meteor. Soc.*, **77**, 2673-2683.

Dutton, E. G., J. J. Michalsky, T. Stoffel, 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. Atmos. Oceananic Tech.*, **18**, 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. Geophys. Res.*, **105**, 15,609-15,626.

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

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.