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CERES/ARM VALIDATION EXPERIMENT (CAVE)

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1. Introduction

The Clouds and the Earth's Radiant Energy System (CERES) project (Wielicki et al. 1996) is a series of broadband scanning radiometers measuring total (0.3-∞ 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). Another goal of CERES is to compute the Surface and Atmospheric Radiation Budget (SARB) of the vertical column for each footprint. Inputs for these calculations include cloud optical properties (determined by higher resolution imagers), atmospheric profiles of pressure, temperature, relative humidity (ECMWF), ozone (NCEP), and a characterization of the column loading of aerosols by a chemical transport model that assimilates aerosol sources and sinks (Collins et al., 2001). 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 1-D radiative transfer code (Fu & Liou, 1993), (on line at: http://srbsun.larc.nasa.gov/flp0300/) computes broadband shortwave (SW), longwave (LW), and window 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.

2. CERES/ARM Validation Experiment (CAVE)

The formal product for the SARB consists of radiative fluxes at the surface, 500hPa, 200hPa, 70hPa and TOA. TOA computations are compared directly with CERES observations. Given the un-availability of in-situ flux observations within the atmosphere we turn to validation at the surface. The sites selected for the CERES "ARM" Validation Experiment (CAVE) are indicated in Figure 1.

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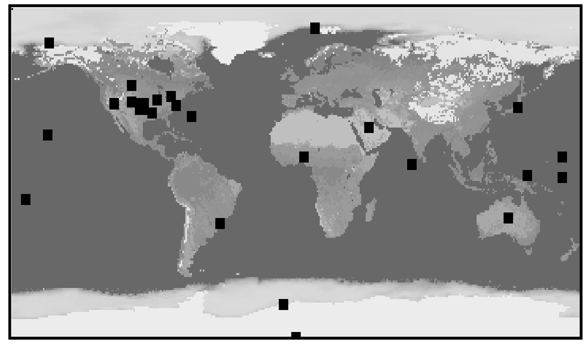

Figure 1. Locations of CAVE sites.

All CAVE sites subscribe to traceable calibration protocols. Consistent with the CERES goal of relating radiation to climate change, CAVE sites observe and record several radiation fields almost continuously for the long-term. Many CAVE sites have auxiliary measurements useful for validating 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 an informal, continuous record of radiation and meteorological data having:

(1) TOA broadband observations from the CERES instruments collocated in space and time with,

(2) 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). (See http://www-cagex.larc.nasa.gov/cagex/) 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.

3. 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 then collocate in time, CERES observations with the surface sites. To keep the data sets small a standard time step of 1/2 hour and time span of 1 month per file is chosen. Surface data is averaged into continuous 1/2 hour intervals and placed into the Surface, Aerosol, & Meteorology (SAM) files. 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 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 Atmospheric Radiation Measurement Program (ARM), Climate Monitoring & Diagnostics Laboratory (CMDL), NOAA Surface Radiation Research Branch, SURFRAD data, and the Baseline Surface Radiation Network (BSRN). Other groups supplying data include NASA Langley Research Center's Chesapeake Lighthouse CERES Ocean Validation Experiment (COVE), the National Renewable Energy Resources Laboratory (NREL) Saudi Solar Village, NASA Goddard Spaceflight Center's Aerosol Network (AERONET) and the Indian Ocean Experiment (INDOEX). 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 observations, several calculated fields are added to the CAVE files. We have adjusted surface SW radiometer data, where possible, to provide a more accurate flux record. For example, measurements of diffuse shortwave with the shaded Eppley pyranometers are susceptible to offsets of several Wm^{-2} due to thermal IR exchange between the detector and dome (Dutton et al., 2000). This first order correction for the "night offset" at ARM SGP and other CAVE sites is noted when provided. Many CAVE files include supplementary estimates of cloud cover based on temporally intensive surface SW radiometric data (Long and Ackerman, 2000). These data can be used to validate classifications of sky conditions from satellites and models.

4. Visualization

Several plotting routines are made available at the CAVE web site for easy visualization of the data sets. These routines are web based and require no downloading of programs or data to execute. The "SAMPLOT" routine will read any site/month of available surface data (a SAM file), plot a summary table showing the contents and basic statistics, and can produce a postscript image of any of the available data within the file. A similar plotting capability exists for the TOA CERES files called "CERESPLOT". Finally, a page is provided to summarize the Long/Ackerman cloud fraction data made available in the SAM files. This plotting routine reads the SAM files for any available time period and plots a summary graph of the cloud amount.

5. Profile Data

The sparsest data set within the CAVE data base is the atmospheric profile data. Recently a set of radiosonde data from the ARM/SGP central facility (CF) was added to the CAVE data base for 1998 and 1999. This data takes thrice daily balloon sondes from ARM and places them into files based on the 1/2 hour CAVE format. Between sonde launches, 1/2 hour intervals are filled via interpolation. Humidity profiles are scaled to the Microwave Radiometer precipitable water observed for that time. CAVE files contain a number of single variables and profiles of geopotential height, pressure, temperature, water vapor mixing ratio and ozone (updated daily) from NCEP.

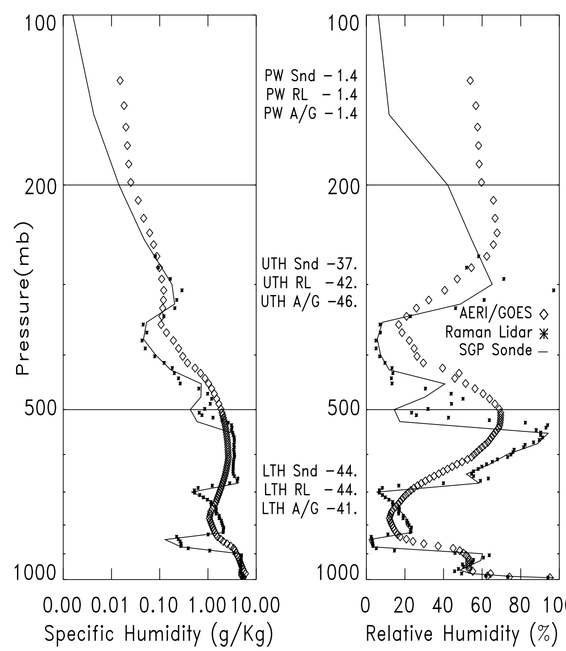

Figure 2. Humidity profile comparisons at ARM/SGP Central Facility.

To test these files, atmospheric profile data from two independent sources, the Raman Lidar (RL) and AERI/GOES (AG) at the ARM central facility are retrieved and compared to the CAVE sonde files. The ARM value added product from which the RL and AG data are taken is: "sgp10rlprofmr1turnC1.c1". It contains all the RL mixing ratio retrievals and the AG

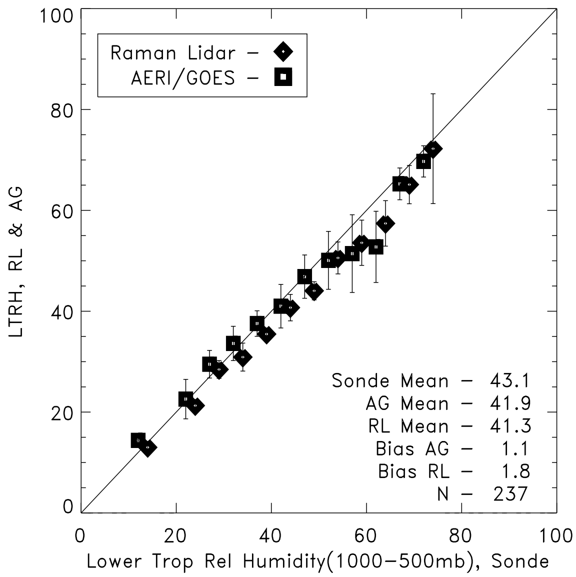

Figure 3. Comparison of mean (1σ) Raman Lidar & AERI/GOES Lower Tropospheric Relative Humidity (1000-500mb) for Jul through Oct 1998 at the ARM/SGP central facility.

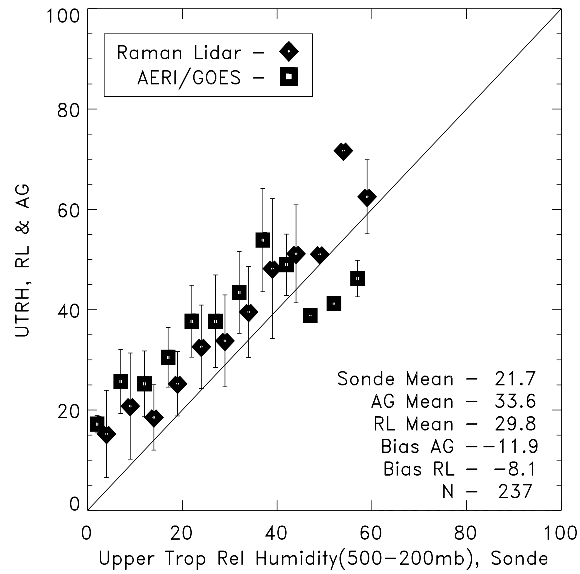

Figure 4. Comparison of mean (1σ) Raman Lidar & AERI/GOES Upper Tropospheric Relative Humidity (500-200mb) for Jul through Oct 1998 at the ARM/SGP central facility.

temperature and water vapor profiles (Turner et al. 2000). The RL and AG data are archived every 10 minutes. The temperature profiles from the AG product compare well with the sondes. The following plots focus on water vapor. Figure 2 shows the specific humidity and relative humidity profiles for the three products at ~6:30AM Local Time, Oct. 22, 1998. The micropulse lidar and ceilometer at the CF both show a cloud base of just under 5 km at this time. Water vapor shows considerable structure in the lower troposphere (1000-500mb) and the sonde and RL track each other closely while the AG product provides data that is smoother. All three provide total precipitable waters of 1.3cm and lower tropospheric relative humidity near 44%. In the upper tro-

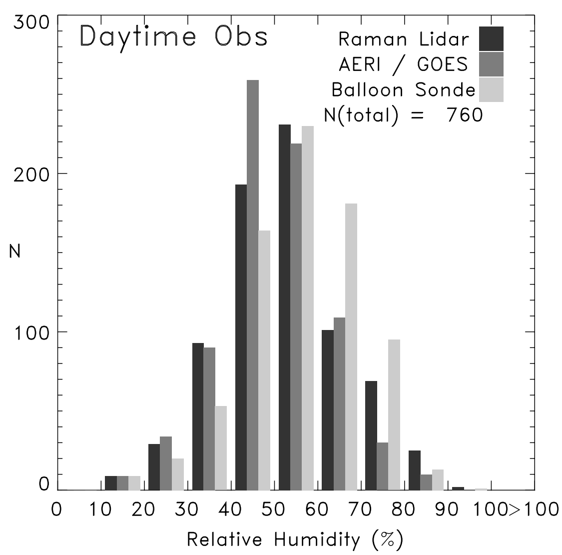

Figure 5. Comparison of daytime 1000mb-850mb integrated relative humidity for ARM/SGP Central Facility Balloon Sonde, Raman Lidar and AERI/GOES for Jul-Oct 1998.

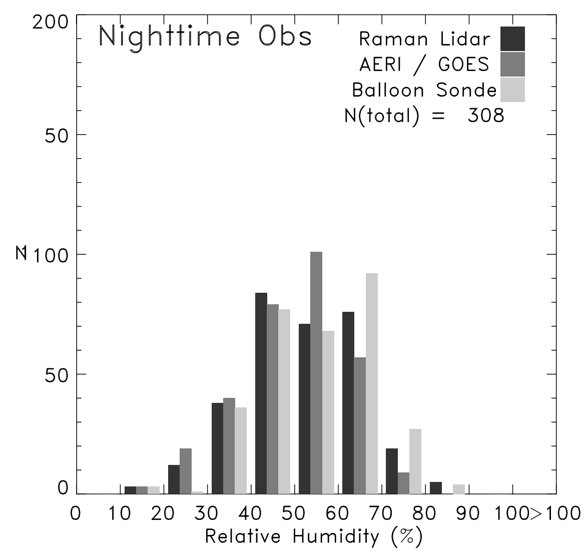

Figure 6. Comparison of nighttime, 1000mb-850mb integrated relative humidity for ARM/SGP Central Facility Balloon Sonde, Raman Lidar and AERI/GOES for Jul-Oct 1998.

posphere (500-200mb), retrievals appear less certain for all three. The upper tropospheric humidity shows close agreement in the mean between the RL and the sonde, around 22% where the AG shows a value of 36%. This is only a single case.

To summarize the comparisons statistically, profiles were processed for Jul., Aug., Sep. and Oct. 1998. In Figure 3, 1/2 hour averages of Lower Tropospheric Relative Humidity (LTRH) are binned by 5% ranges and compared to sonde LTRH if the observations are within +/- 4 hours of a balloon launch. Data points are retained only if all three methods retrieve a result for both LTRH and UTRH (CAVE data includes interpolated profiles). Since the RL does not provide much data above 500mb during the day this plot shows primarily night time data. Figure 3 shows that the RL and AG and Sonde data match well in the lower troposphere. Figure 4 shows the same summary but for Upper Tropospheric Humidity (500-200mb). Both the RL and the AG show significantly more water vapor in the upper troposphere though the RL has a slightly smaller bias with respect to the sonde humidities.

Figures 5 and 6 show histograms of the all sky relative humidity integrated between 1000mb and 700mb for the four month period (+/- 2 hours of balloon launch) during day and night respectively. One finds daytime distribution peaks vary. Sonde and RL data are more moist, peaking between 50% and 60% RH while AG is driest peaking between 40% and 50% RH. The distributions show that as the humidity increases, the sonde shows more moisture than the ground based retrieval methods. During the night, Figure 6, the RL and sonde data show twin peaks while AG retains a more normal distribution. The current schedule for launching balloons at the ARM CF is ~5:30AM, 2:30PM and 6:00PM local time. It is possible that the sonde data is biased high due to this type of sampling. The effect of the sampling requires further study.

The addition of these profile data to the CAVE data base enhances the data set for the running of radiation transfer models. It is planned to add these profiles continuously for the ARM Central Facility and for the ARM TWP sites.

6. Web Availability

The CAVE data is made available via ftp over the world-wide-web. The home-page 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 Mar 2000 through May 2001.

7. Acknowledgments

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8. References

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