CERES Aqua Edition2C CRS Data Quality Summary

Investigation:	**CERES**
Data Product:	**Clouds and Radiative Swath (CRS)**
Data Set:	**Aqua (Instruments: CERES-FM3 or CERES-FM4, MODIS)**
Data Set Version:	**Edition2C**

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES (Wielicki et al., 1996) Science Team. This document briefly summarizes key validation results, provides cautions where users might easily misinterpret the data, provides links to further information about the data product, algorithms, and accuracy, and gives information about planned data improvements. This document also automates registration in order to keep users informed of new validation results, cautions, or improved data sets as they become available.

This document is a high-level summary and represents the minimum necessary information for scientific users of this data product.

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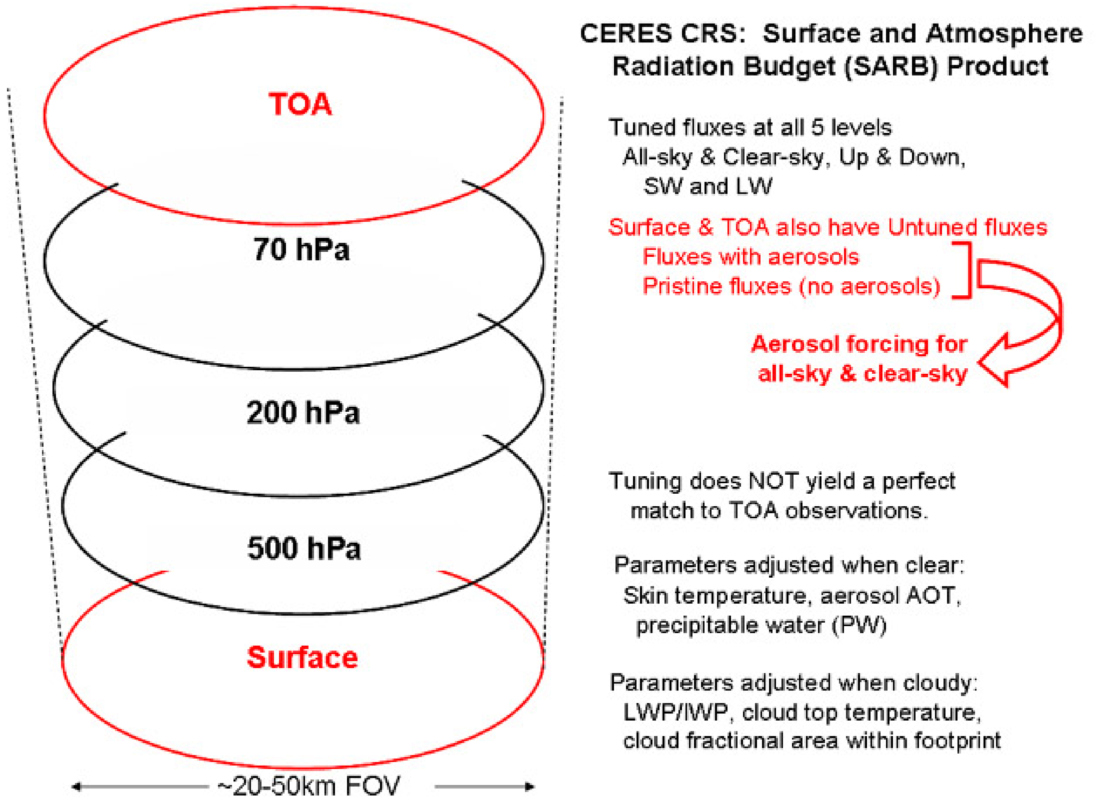

Figure 1 CRS: CERES Surface and Atmosphere Radiation Budget (SARB) product

Nature of the CRS Product

The CRS product evolves and has different versions. The present document has a core message: How Aqua Edition2C CRS (which employs MODIS Collection 5 and covers May 2006 onward) differs from Aqua Edition2B CRS (which employs MODIS Collection 4, initiates the CERES CRS Aqua coverage in July 2002, and extends through April 2006). The experienced user of Aqua Edition2B CRS should now skip to the section "How Aqua Edition2C CRS Differs from Aqua Edition2B CRS". The inexperienced user should scan the paragraphs of this Introduction; and if CRS then sounds interesting, the extensive descriptions in the Data Quality Summary of Aqua Edition2B CRS should be consulted FIRST. The cloud and aerosol properties for broadband radiative transfer calculations in Aqua Edition2C CRS are based on the more recent MODIS Collection 5 narrowband radiances. There were essentially no changes to the Minnis cloud retrieval algorithms but Remer and colleagues (web search for "MODIS Collection 5 aerosols") did improve on the aerosol retrieval algorithms used in Collection 4; those are the changes.

Introduction

The CRS product (Figure 1) is designed for studies which require fields of clouds, humidity and aerosol that are consistent with radiative fluxes from the surface to the Top Of the Atmosphere (TOA); for example, studies of cloud and aerosol forcing at both TOA and surface, or investigations of possible errors in retrievals of TOA fluxes, cloud properties, surface skin temperature, etc. It is quite a task to manipulate the huge files of this ungridded data set, which spans the globe with about 100 megabytes per day. Potential users are strongly encouraged to visit the CAVE web site which is a gateway to a point and click version of the radiative transfer code used here; user-friendly time series of subset (small) files at a few locations; validation at ~50 independent ground-based sites (ARM, BSRN, and SURFRAD); and an ocean albedo look up table (LUT) for GCMs. Gridded forms of CRS have the name "FSW". Some users will prefer to wait for the arrival of the gridded and time-averaged (3-hourly) "SYN" product, in which geostationary imager data, in addition to MODIS, will be used as inputs for cloud optical properties in SARB calculations. Potential users may also benefit from the CERES Archival Data web site when attempting to determine the CERES data product of interest.

CRS software is developed and managed by the CERES Surface and Atmospheric Radiation Budget (SARB) Working Group (WG); the above "CAVE" URL is an operating environment for the WG and its users. Like its parent Single Scanner Footprint (SSF), CRS corresponds to an instantaneous CERES broadband footprint. The footprint has nominal nadir resolution of 20 km for half power points but is larger at other view angles (Figure 2). The major inputs (Figure 3) to the CRS software are the instantaneous scene identification, cloud and aerosol properties from the MODIS cloud imager pixels (resolution ~1 km), and TOA radiation (from the CERES instrument) contained on the respective SSF footprint; along with 6-hourly gridded fields of temperature, humidity, wind, and ozone, and climatological aerosol data contained on the Meteorological, Ozone, and Aerosol (MOA) product. MOA includes meteorological data provided by GEOS4 and the Stratospheric Monitoring Group Ozone Blended Analysis (SMOBA, Yang et al., 2000) ozone profiles from NCEP. Aerosol information is taken from MODIS and from MATCH. The CRS product contains the SSF input data; through-the-atmosphere radiative flux profiles calculated by SARB algorithms that partially constrain to CERES TOA observations; adjustments to key input parameters (i.e., optical depth for cloudy footprints and skin temperature for clear footprints); and diagnostic parameters. CRS fluxes are produced for shortwave (SW), longwave (LW), the 8.0-12.0 µm window (WN), both upwelling and downwelling at TOA, 70 hPa, 200 hPa, 500 hPa, and the surface (Figure 3). To permit the user to infer cloud forcing and direct aerosol forcing, we include surface and TOA fluxes that have been computed for cloud-free (clear) and aerosol-free (pristine) footprints; this accounts for aerosol effects (SW and LW) to both clear and cloudy skies.

THIS IS IMPORTANT: When Aqua Edition2B/2C CRS (and also Terra Edition2B/2F CRS) were processed, only an older form of CERES observations were available for broadband TOA fluxes, namely Aqua SSF Edition2B/2C. The CERES Science Team now recommends a set of "Rev1" corrections (see the SSF Quality Summaries) to SW observations at TOA. Rev1 corrections are time dependent and can exceed 1%. THE USER IS CHARGED TO CORRECT THE CERES TOA OBSERVATIONS AS PER REV1. Aqua Edition2B/2C CRS (and Terra Edition2B CRS) do not account for the Rev1 correction. The end product of Aqua Edition2B CRS (and Terra Edition2B CRS), is a "tuned" flux, which has been constrained to more closely approach CERES observations at TOA by modifying inputs like cloud optical depth, surface albedo, etc. Tuned CRS fluxes are hardly ever equal to observed SSF fluxes. Untuned CRS fluxes can be obtained by subtracting the "adjustment" from the "tuned" flux; the tuned fluxes and the adjustments are archived. Over land and over the cryosphere, even the untuned fluxes are affected by the CERES TOA observations of SW, as they are used to estimate surface albedo. Over the ice-free ocean, CERES TOA SW observations do not affect untuned CRS calculations. In the mean over ice-free ocean, CRS untuned SW calculations at TOA are closer to the Rev1 corrected observations, than they are to original SSF observations. See the table of Rev1 corrections. When a user orders a CRS file, an SSF file will come automatically attached; the file has SSF parameters first, then CRS parameters. The broadband SSF observations should be corrected as per the Aqua SSF Edition2C Quality Summary.

When referring to a CERES data set, please include the satellite name and/or the CERES instrument name, the data set version, and the data product. Multiple files which are identical in all aspects of the filename except for the 6 digit configuration code (see Collection Guide - when available) differ little, if any, scientifically. Users may, therefore, analyze data from the same satellite/instrument (here Aqua/CERES/MODIS), data set version (here Edition2C), and data product (here CRS) without regard to configuration code. This CRS data set may be referred to as "CERES Aqua Edition2C CRS".

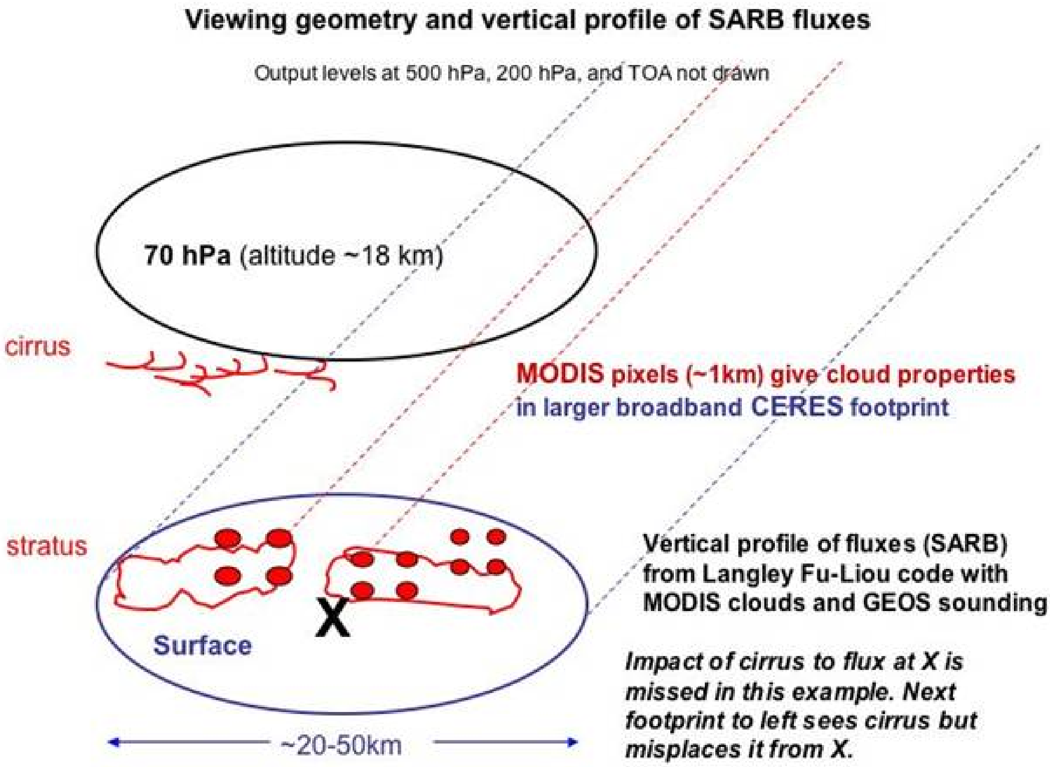

Figure 2: Typical viewing geometry showing small MODIS pixels within large CERES footprints

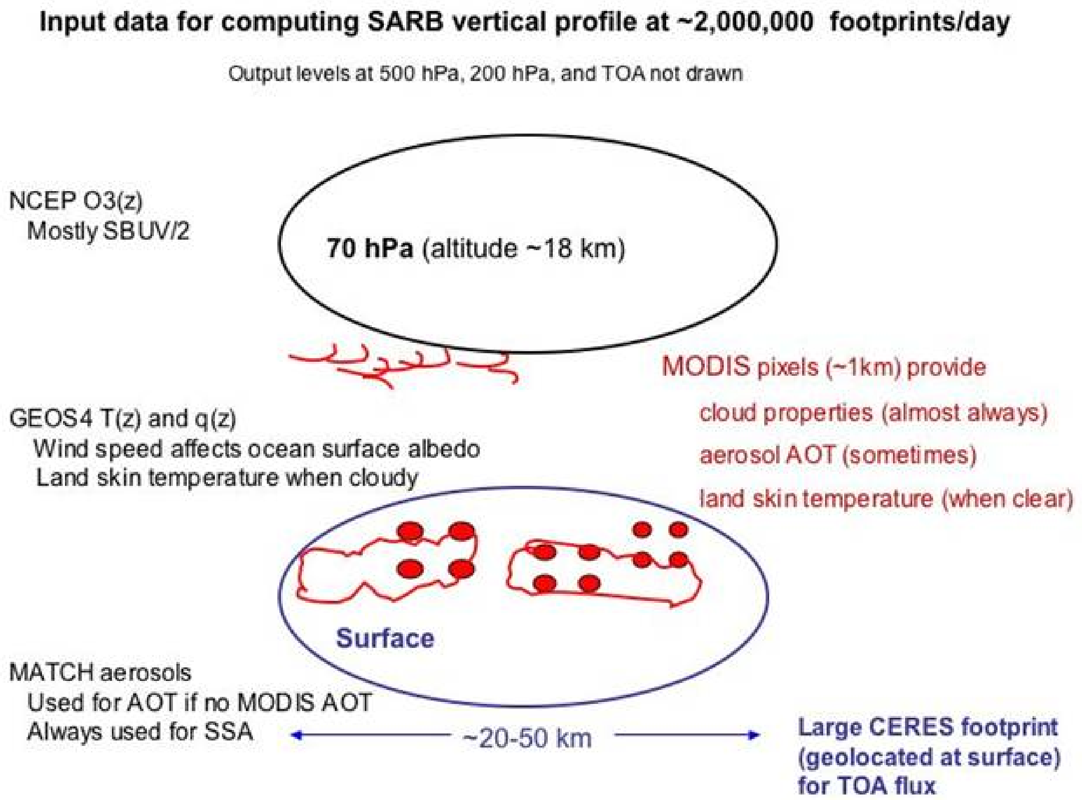

Figure 3. Inputs for determining the Surface and Atmosphere Radiation Budget (SARB)

How Aqua Edition2C CRS Differs from Aqua Edition2B CRS

Here we compare Aqua Edition2C CRS with Aqua Edition2B CRS indirectly, by showing how each differs respectively from other data taken at the same time. CRS represents the Surface and Atmosphere Radiation Budget (SARB) at the surface, 500 hPa, 200 hPa, 70 hPa, and TOA with tuned broadband SW and LW fluxes for all-sky (total-sky) and clear-sky conditions in CERES footprints (~20 km); untuned fluxes are available and surface and TOA only. Computed CRS fluxes are compared with broadband CERES observations at TOA. At the surface, we compare with ground-based measurements. The cloud properties for Edition2B calculations were provided by SSF, which generated them from MODIS Collection 4 radiances with a kluge of algorithms from Minnis and colleagues; aerosol optical thickness was obtained from Collection 4 (MATCH ran Collection 4). Aqua Edition2B CRS starts in July 2002 and ended in April 2006. Aqua Edition2C CRS starts in May 2006. The change in Edition2C is the use of MODIS Collection 5.

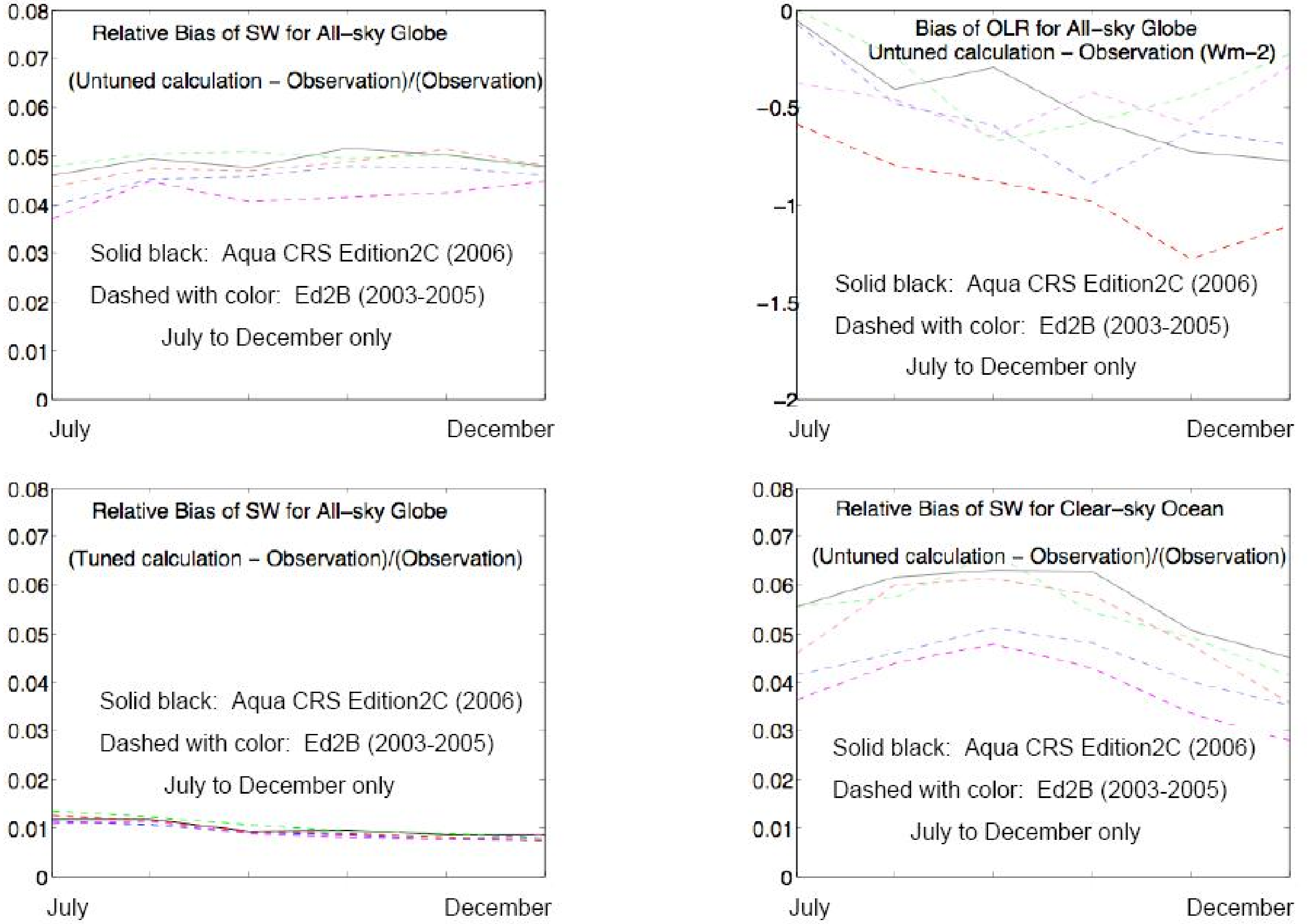

Figure 4: Biases of CRS calculations with SSF observations. CRS and SSF Ed2C (Ed2B) use MODIS Collection 5 (4).
CRS Ed2C vs. SSF Ed2C and CRS Ed2B vs SSF Ed2B for months of July though December in respective years.

The upper left panel in Figure 4 shows the relative bias of the untuned calculation for reflected SW at TOA with respect to CERES observations in all sky conditions. The relative bias was evaluated from a raw monthly mean of the footprint-by-footprint bias divided by the correpsonding raw monthly mean of the footprint-by-footprint observed flux. It is not a grid-box statistic. Because higher latitudes are observed more frequently than lower latitudes, a footprint-by-footprint statistic places less weight on the tropics than does a grid-box (area-weighted) statistic. The large scale comparison in Figure 4 spans six-month blocks (July to December), one (2006) for CRS Ed2C and four (2002-2005) for CRS Ed2B. For relative biases of untuned all-sky global SW (upper left) and the correponding tuned all-sky global SW (lower left), CRS Ed2C performance is quite comparable to that of CRS Ed2B. The upper right panel of Figure 4 indicates the untuned, all-sky global simulation of OLR in Ed2C is very much like that in Ed2B. For a description of the Aqua CRS software and the more extensive comparison of Ed2B with data see the Data Quality Summary of Aqua Edition2B CRS.

While tests of all-sky fields for SW and OLR rely heavily on the quality of the cloud properties used for radiative transfer calculations, differences in the aerosol inputs (i.e., Collection 4 and 5) have more impact on the reflected SW for the clear regions of the ocean. See the lower right of Figure 4 for generally favorable comparison of the calculations in Aqua Editon2C CRS with the calculations in Aqua Edition2B CRS. However, for all-sky global and clear-sky ocean, both CRS Edition2B and CRS Edition2C calculations have large relative biases (~0.05 or 5%) with respect to CERES observations. This shows both calculations as "too bright" (or the observations as "too dark"). In the same vein, the SW calculations in Terra Edition2B CRS are significantly brighter than CERES observations.

One can follow this route yet further. Note that more recent (2006) CRS Ed2C fields for untuned SW (upper left for all-sky globe and lower right for clear-sky ocean) show a bit more bias than does an average of the earlier (2002-2005) CRS Ed2B. CRS Ed2C (Ed2B) biases are evaluated with respect to SSF Ed2C (Ed2B) observations, and those SSF observations do **not** include recent "Rev1" adjustments to observations. Rev1 adjustments were not available when Aqua Edition2B/2C CRS calculations were made. If applied, the Rev1 adjusments to observations would slightly reduce (by ~0.01 or 1%) the untuned SW bias of Aqua Edition2C CRS in the upper left and lower right of Figure 4. See the section User Applied Revisions for Current Edition for more on Rev1.

We now shift to a comparison of Aqua Edition2B CRS and Editon2C CRS with surface measurements. Eight months (May to December 2006) of Aqua Edition2C CRS were available for this task. To retain seasonal consistency, the same May to December domain is used for the years 2003, 2004, and 2005 with Aqua Edition2B CRS. The 17 CAVE sites selected for the test are listed in the bottom of Table 1; vital surface measurements of downwelling SW and downwelling LW were available at all sites for each month of the test domain. A CRS footprint was compared with a surface measurement when the center of the footprint was within 25 km of the site. There are typically 3 or 4 such footprints for each overpass of Aqua. High latitude sites are viewed more frequently than low latitude sites. Hence each site was given an equal weight when determining mean fluxes, biases, etc. While the satellite has some drift (so the solar zenith angle SZA varies), and interannual climate variablitiy is always present, the grand means for TOA solar insolation, sky cover (from MODIS), precipitable water (PW), reflected SW at TOA and measured surface insolation for CRS Ed2B and CRS Ed2C in Table 1 are very similar.

Tables 2 and 3 compare untuned and tuned CRS calculations with broadband observations at TOA (from CERES, as in Figure 4) and the surface (ground measurements), all for the domain of the 17 CAVE sites. Values for bias and RMS of the larger Aqua CRS Ed2B record are treated in its respective Data Quality Summary. Our main thrust here is a vetting of the shorter record of Aqua Edition2C CRS by way of comparison with Ed2B. A glance at the columns for "Ed2B-Ed2C" (bias in Table 2 and RMS in Table 3) shows that for the grand mean of 17 sites, the differences between Aqua Edition2C CRS and Edition2B CRS are not significant for most variables.

The largest magnitudes for Ed2B-Ed2C are found in the biases with respect to surface observations for upwelling SW at the surface (-5.40 and -5.43 Wm^{-2} for untuned and tuned in Table 2). This ~ -5 Wm^{-2} discrepancy in bias reflected SW at the surface should be compared to the flat Aqua Edition2B CRS bias of ~ -25 Wm^{-2}. As site measurements of surface albedo are notoriously dependent on local land use, which can vary from year to year, a -5 Wm^{-2} discrepancy in upwelling surface SW is not a cause for concern. We do not find an "echo" in the Ed2B-Ed2C columns for SW up at TOA, where the broadband measurements and calculations are in the same spatial domain.

One surprise in Tables 2 and 3 are the statistics for downwelling SW at the surface under clear skies: Despite the differences in aerosol inputs (MODIS Collection 4 for Ed2B versus Collection 5 and some changes to retrieval algorithms by Remer and colleagues for Ed2C), the bias for CRS Ed2C is little different from Ed2B. While aerosol forcing at a given site in CRS Ed2C often differs from that in CRS Ed2B, the effect has largely cancelled for the 17 sites used here. This is a topic for further research.

Table 1: Surface and Satellite Data at 17 CAVE sites for
Aqua Edition2B CRS (May to December, 2003-2005)
Aqua Edition2C CRS (May to December, 2006)

	Averages of All-sky Values				**# CERES looks at site**
	TOA down (Wm^{-2})	**Sky (% clear)**	**SZA (deg)**	**PW (mm)**	
Ed2B: Mean	972.14	44.69	40.91	25.93	Total = 48238
Ed2C: Mean	967.60	44.75	41.23	25.97	Total = 16087
	All sky		**Clear sky**		
	Ed2B	Ed2B-Ed2C	Ed2B	Ed2B-Ed2C	
Obs SW TOA (reflected)	259.28	1.50	146.08	-5.09	
Observed SW down	570.58	-1.31	712.68	12.34	

CAVE Sites:

- Barrow, AK (GMD)
- Boulder Tower, CO (GMD)
- Chesapeake Light (LaRC)
- Desert Rock, NV (SURFRAD)
- E01-Larned (ARM)
- E03-LeRoy (ARM)
- E13-Central Facility (ARM)
- E20-Meeker (ARM)
- E22-Cordell (ARM)
- Fort Peck, MT (SURFRAD)
- Kwajalein (GMD)
- Manus Island/TWP (ARM)
- Nauru Island/TWP (ARM)
- Penn State, PA (SURFRAD)
- Samoa (GMD)
- South Pole (GMD)
- Table Mountain, Boulder, CO (SURFRAD)

Table 2: CRS Biases at 17 CAVE sites (calculation-observation in Wm^{-2})

	All sky		**Clear sky**	
	Ed2B	**Ed2B-Ed2C**	**Ed2B**	**Ed2B-Ed2C**
Untuned SW up TOA	7.86	-0.92	-0.28	0.60
Tuned SW up TOA	1.55	-0.18	0.25	0.06
Untuned SW down SFC	9.73	-0.99	6.83	-0.79
Tuned SW down SFC	18.24	-1.80	7.93	0.93
Untuned SW up SFC **	-26.18	-5.40	-33.76	1.83

Tuned SW up SFC **	-24.44	-5.43	-33.38	1.85
Untuned OLR	-1.53	-0.24	-1.95	-0.26
Tuned OLR	-0.42	-0.16	-1.47	0.12
Untuned LW down SFC	-8.09	-0.07	-7.37	0.91
Tuned LW down SFC	-8.36	-0.07	-8.55	0.80
Untuned LW up SFC **	-5.84	-0.80	1.21	1.30
Tuned LW up SFC **	-4.75	-0.27	0.69	2.52
** 2 of 17 sites lack surface measurements of upwelling radiation				

Table 3: CRS RMS at 17 CAVE sites (calculation vs observation in Wm^{-2})

	All sky		**Clear sky**	
	Ed2B	**Ed2B-Ed2C**	**Ed2B**	**Ed2B-Ed2C**
Untuned SW up TOA	26.06	-1.79	4.69	0.18
Tuned SW up TOA	8.20	-1.08	1.45	-0.15
Untuned SW down SFC	126.15	-0.38	28.52	0.33
Tuned SW down SFC	126.45	-0.40	28.80	-0.30
Untuned SW up SFC **	56.73	4.08	46.87	3.48
Tuned SW up SFC **	56.24	3.68	46.50	-3.80
Untuned OLR	8.41	-0.46	5.61	-0.11
Tuned OLR	4.65	-0.22	3.06	-0.12
Untuned LW down SFC	19.01	0.09	15.64	0.89
Tuned LW down SFC	19.23	-0.03	16.32	0.19
Untuned LW up SFC **	26.56	-0.26	20.24	-1.26
Tuned LW up SFC **	25.00	-0.36	20.05	-0.71
** 2 of 17 sites lack surface measurements of upwelling radiation				

User Applied Revisions for Current Edition

The purpose of User Applied Revisions is to provide the scientific community early access to algorithm improvements which will be included in the future Editions of the CERES data products. The intent is to provide users simple algorithms along with a description of how and why they should be applied in order to capture the most significant improvements prior to their introduction in the production processing environment. ***It is left to the user to apply a revision to data ordered from the Atmospheric Science Data Center.*** Note: Users should never apply more than one revision. Revisions are independent.

CRS Edition2C-Rev1

The CERES Science Team has approved a table of scaling factors known as "Rev1" for CERES SW observations. Each CRS file is a compendium of first the SSF record for a given CERES footprint, followed by the SARB radiation transfer results for that footprint. (See http://www-cave.larc.nasa.gov/cave/pages/crs.html) Within a CRS file, the REV1 correction should only be applied to the observed CERES flux value that is contained in the SSF portion of the CRS record. (CRS parameter #38 SW flux.) This should be done as per the Aqua SSF Edition2C Quality Summary.

This revision is necessary to account for spectral darkening of the transmissive optics on the CERES SW channels. By March 2005, this darkening has reduced the average global all-sky SW flux measurements by 0.9 and 0.7 percent for Aqua FM3 and FM4 data respectively. A complete description of the physics of this darkening appears in the CERES BDS Quality Summaries under the Expected Reprocessing section. After application of this revision to the Edition2B CRS data set, users should refer to the data as Aqua Edition2C-Rev1 CRS.

The end product of Aqua Edition2C CRS, is a "tuned" flux, which has been constrained to more closely approach CERES observations at TOA by modifying inputs like cloud optical depth, surface albedo, etc. Tuned CRS fluxes are hardly ever equal to observed SSF fluxes. Untuned CRS fluxes can be obtained by subtracting the "adjustment" from the "tuned" flux; the tuned fluxes and the adjustments are archived. Over land and over the cryosphere, even the untuned fluxes are affected by the CERES TOA observations of SW, as they are used to estimate surface albedo. Over the ice-free ocean, CERES TOA SW observations do not affect untuned CRS calculations. In the mean over ice-free ocean, CRS untuned SW calculations at TOA are closer to the Rev1 corrected observations, than they are to original SSF observations.

Cautions and Useful Hints

Informal additions to this document will be posted at http://www-cave.larc.nasa.gov/cave under "CRS Advice". This is the first release of a Aqua CRS, and documentation is sparse. The Quality Summary of Terra Edition2B CRS is more extensive and may be a helpful guide at this stage.

- To reduce the effect of electronic crosstalk signals in Window channel measurements induced by high Shortwave (bright) scenes, a bridge balance memory patch was developed and uploaded on September 30, 2004 and unloaded on October 12, 2004. This patch was intended to modify the Window bridge balance set to point to midrange (2048). This patch, however, inadvertently set the bridge balance set points to midrange (2048) for all 3 channels. This reduced the dynamic range for the Total and Shortwave channels leading to saturated radiometric measurements. Saturations typically occurred for the brightest earth-viewing scenes, resulting in data dropout at high radiance values. This will affect users who produce their own monthly means from the instantaneous values contained on this product and users studying SW and LW fluxes for deep convective clouds. While the Edition2C dataset does not include the affected data, users looking at both the Edition2B and Edition2C datasets need to be aware of this error.

- One useful hint concerning Aqua Edition2B CRS (and Terra Edition2B CRS): The computed SARB reflects too much SW flux at TOA, when compared with CERES broadband observations for overcast conditions. Tuning reduces the SW bias at TOA but apparently transfers it to the surface. This SW TOA problem was not so evident in the TRMM Edition2C CRS, which used the VIRS imager (rather than MODIS on Aqua and Terra) for the cloud property retrieval. CAVE shows that the biases in surface SW insolation in Terra Edition2B CRS and Aqua Edition2B/2C CRS are less than those in TRMM Edition2C CRS. Compared with TRMM CRS, Aqua and Terra CRS benefit from both (a) a more up to date parameterization of gaseous absorption of SW and (b) explicit satellite-based retrievals of AOT over land. The common use of the term "2C" in the names of both the Aqua Edition2C CRS and TRMM Edition2C CRS data products is unfortunately confusing. These two products indeed cover, respectively, the Aqua and TRMM spacecraft. But the Aqua Edition2C algorithms for SSF and CRS are advances on (not the same as) the corresponding TRMM Edition2C algorithms for SSF and CRS.

Accuracy and Validation

Accuracy and validation discussions are found at the link:

- How Aqua Edition2C CRS Differs from Aqua Edition2B CRS
- Data Quality Summary of Aqua Edition2B CRS

References

- List of CERES CRS References

Expected Reprocessing

In the longer term, yet more advanced versions of CRS are expected. A future run will use a "frozen" NWP analysis. There will be advances in the TOA fluxes. SSF will use new techniques to identify multilayer clouds. For an indefinite time, however, we anticipate continuing, significant uncertainties in CRS products for

- surface SW and atmospheric absorption of SW because of mixed phase clouds (land and sea), aerosol single scattering albedo (land and sea) and AOT (land);
- LW fluxes at the surface and at 500 hPa because of multiple layer clouds (land and sea).

Referencing Data in Journal Articles

The CERES Team has gone to considerable trouble to remove major errors and to verify the quality and accuracy of this data. Please provide a reference to the following paper when you publish scientific results with the CERES Aqua Edition2B CRS data:

Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee III, 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.

When Langley ASDC data are used in a publication, we request the following acknowledgment be included: "These data were obtained from the NASA Langley Research Center EOSDIS Distributed Active Archive Center."

The Langley ASDC requests two reprints of any published papers or reports which cite the use of data that we have distributed. This will help us determine the use of data that we distribute, which is helpful in optimizing product development. It also helps us to keep our product related references current.

Feedback

For questions or comments on the CERES Quality Summary, contact the User and Data Services staff at the Atmospheric Science Data Center.

Informal contact to the SARB WG is accessible by selecting "The Group" at the CAVE web site.

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