ATMOSPHERIC SCIENCE DATA CENTER

CERES Terra Edition2G CRS Data Quality Summary

Investigation:	**CERES**
Data Product:	**Clouds and Radiative Swath (CRS)**
Data Set:	**Terra (Instruments: CERES-FM1 or CERES-FM2)**
Data Set Version:	**Edition2G**

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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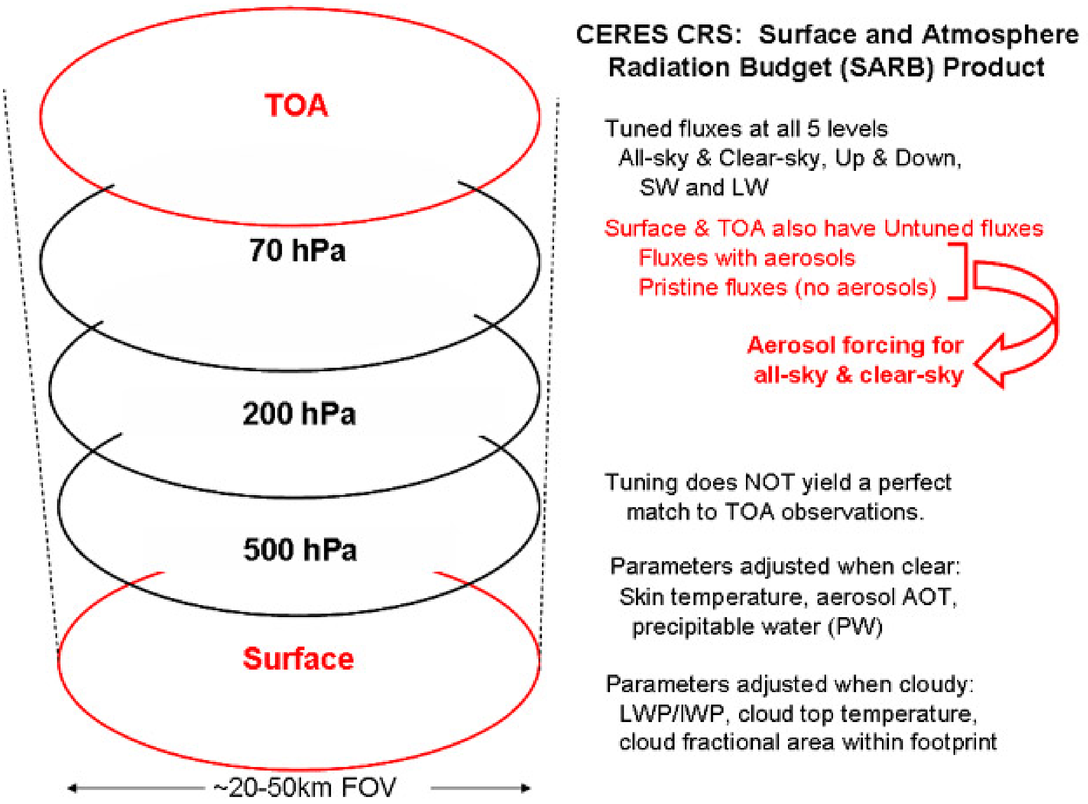

Figure 1 CRS: CERES Surface and Atmosphere Radiation Budget (SARB) product

Nature of the CRS Product

CRS, like other CERES products, evolves and has different versions. The present document has a core message: How Terra Edition2G CRS differs from Terra Edition2B CRS and Terra Edition2F CRS. Terra Edition2B CRS spans March 2000 to June 2006; employs GEOS-4 for temperature and humidity; uses SSF based on MODIS Collection 4 radiances; and has aerosols from 3 sources (MATCH which assimilates MODIS, instantaneous MODIS retrievals when available, and a Langley interpolation of MODIS). Terra Edition2F CRS spans May 2006 (2 months overlap with Edition2B) to December 2007; again employs GEOS-4 for temperature and humidity; but uses SSF based on MODIS Collection 5 radiances and has aerosols from only 2 sources (MATCH which assimilates MODIS and instantaneous MODIS retrievals when available). Terra Edition2G CRS now spans January 2008 to June 2009 (and is expanding); but switches to GEOS-5 for temperature and humidity; and like Edition2F, it uses SSF based on MODIS Collection 5 and has aerosols from only 2 sources (MATCH which assimilates MODIS and instantaneous MODIS retrievals when available). One of the aerosol sources (the Langley interpolation of MODIS aerosols) unique to Terra CRS Edition2B produced very sporadic errors. Terra CRS Edtion2B had another unique defect early in its record; some months used faulty values of land surface albedo for cloudy skies; this had a significant impact to SW calculations over deserts. The same Minnis et al. cloud retrieval algorithms were used in Edition2B/2F/2G; the change from MODIS Collection 4 (Ed2B) to Collection 5 (Ed2F/2G) radiances had some impact on cloud products. However, the Remer et al. aerosol retrieval algorithms in Collection 4 and 5 were somewhat different.

The experienced user of Terra Edition2B and Edition2F CRS should now skip to the section "More on How Terra Edition2G CRS Differs from Edition2B and Edition2F". 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 Terra Edition2B CRS should be consulted FIRST.

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 the arrival of the gridded and time-averaged (3-hourly) "SYN" product, in which geostationary imager data, in addition to MODIS, are 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 Terra Edition2B/2F/2G CRS were processed, an older form of CERES observations were available for broadband TOA fluxes. 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. CRS does not account for the Rev1 correction. One end product of 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 slightly 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 by the user.

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 Terra/CERES/MODIS), data set version (here Edition2G), and data product (here CRS) without regard to configuration code. This CRS data set may be referred to as "CERES Terra Edition2G CRS".

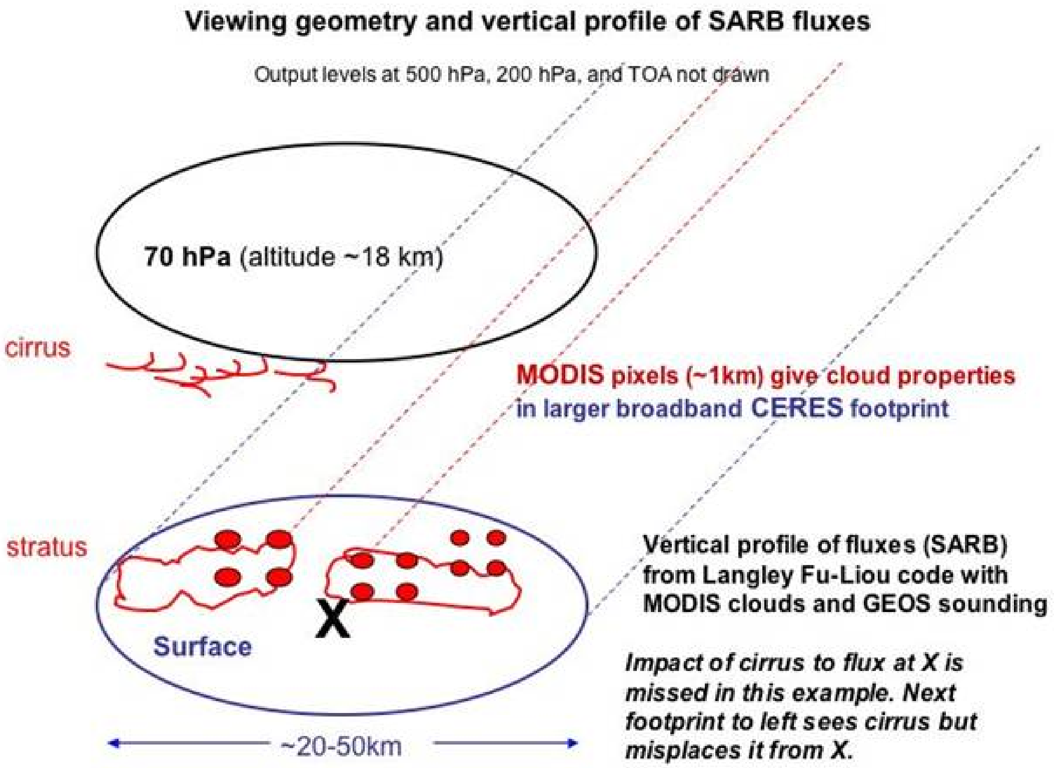

Figure 2: Typical viewing geometry showing small MODIS pixels within large CERES footprints

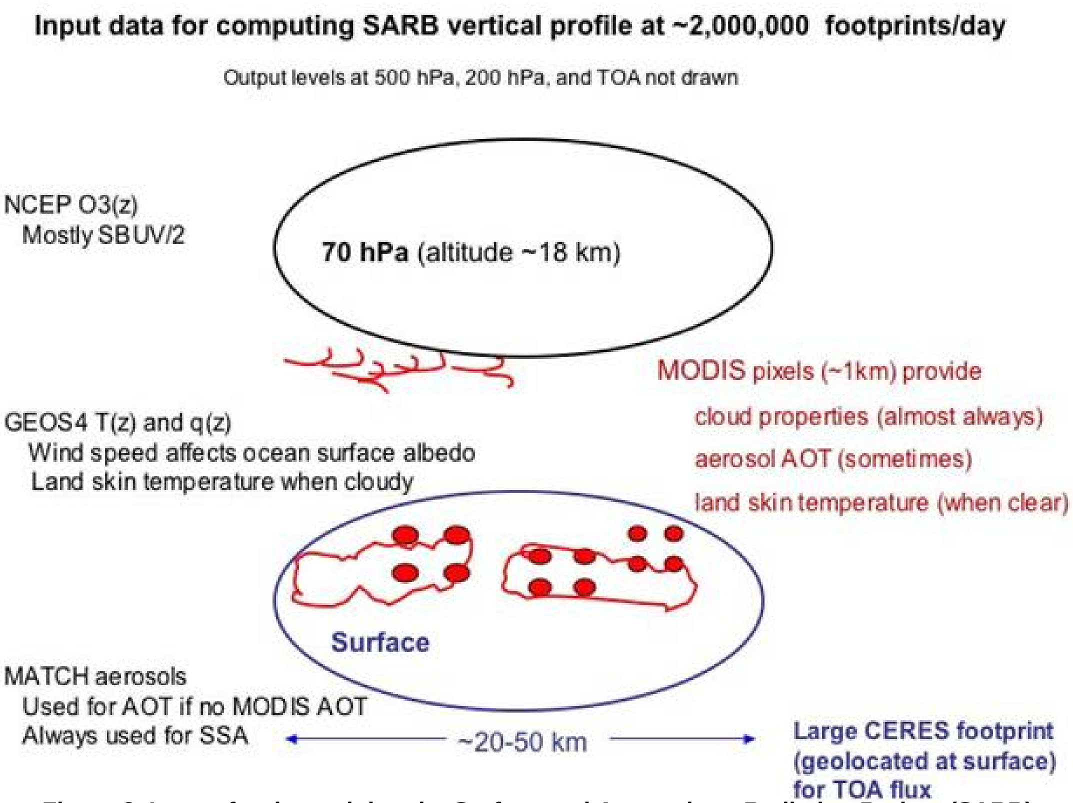

Figure 3. Inputs for determining the Surface and Atmosphere Radiation Budget (SARB)

More on How Terra Edition2G CRS Differs from Edition2B and Edition2F

The first paragraph of the section "Nature of the CRS Product" explained the basic differences among the Terra Edition2B, Edition2F, and Edition2G of CRS. The big change is the use of GEOS-5 temperature and humidity in Terra Edition2G CRS. GEOS-5 is often less humid than GEOS-4 from 200 hPa to 500 hPa but more humid above 200 hPa. While this is generally the case on 20071215 (December 15, 2007), the impact to the tuned in-atmosphere LW divergences in Figure 4a (top) is not pronounced in the zonal mean. The "clear day" LW diverences in Figure 4a (top) are obtained from daytime-only footprints (fields of view or FOV) with theoretical cloud-free calculations (made for every FOV regardless of sky condition). The Terra Edition2F CRS (solid lines in Figure 4a) uses GOES-4, and an unofficial run of Terra Edition2G CRS (dashed) with GEOS-5 covers the same day. A close look at the biases for untuned OLR calculations provides some basis for suggesting that the GEOS-5 soundings in Edition2G are an improvement on the GEOS-4 used in Edition2F. "Clear sky" in the lower panel of Figure 4b signifies actual cloud-free conditions using the MODIS scanner, with the further restriction to only ocean FOVs. The bottom left (right) shows the scatter of the untuned bias of clear-sky Edition2F (Edition2G) versus the precipitable water from SSMI, which itself was not used in the calculations. The precipitable water (PW) of GEOS-4/Edition2F and GEOS-5/Edition2G both compared well with SSMI. We suggest more fidelity in the GEOS-5 input used in Edition2G, however, because of the *reduced scatter* in the bottom right (Edition2G) when compared with the bottom left (Edition2F). The standard deviation (correlation) of CRS Edition2F clear-sky, ocean-only, untuned OLR with observations is 5.6 W/m**2 (0.95). The corresponding standard deviation (correlation) of CRS Edition2G is better at 3.6 W/m**2 (0.98). Note that Figure 4a-b covers only a single day.

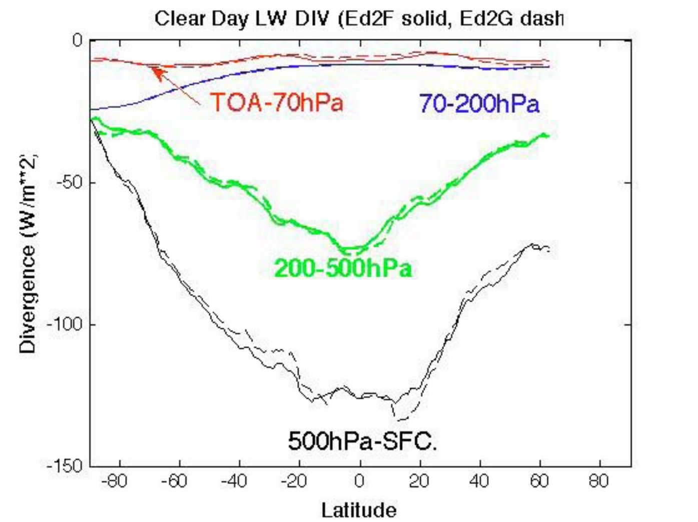

Figure 4a: LW Divergences for Theoretically Clear Daytime FOVs (15 December 2007)

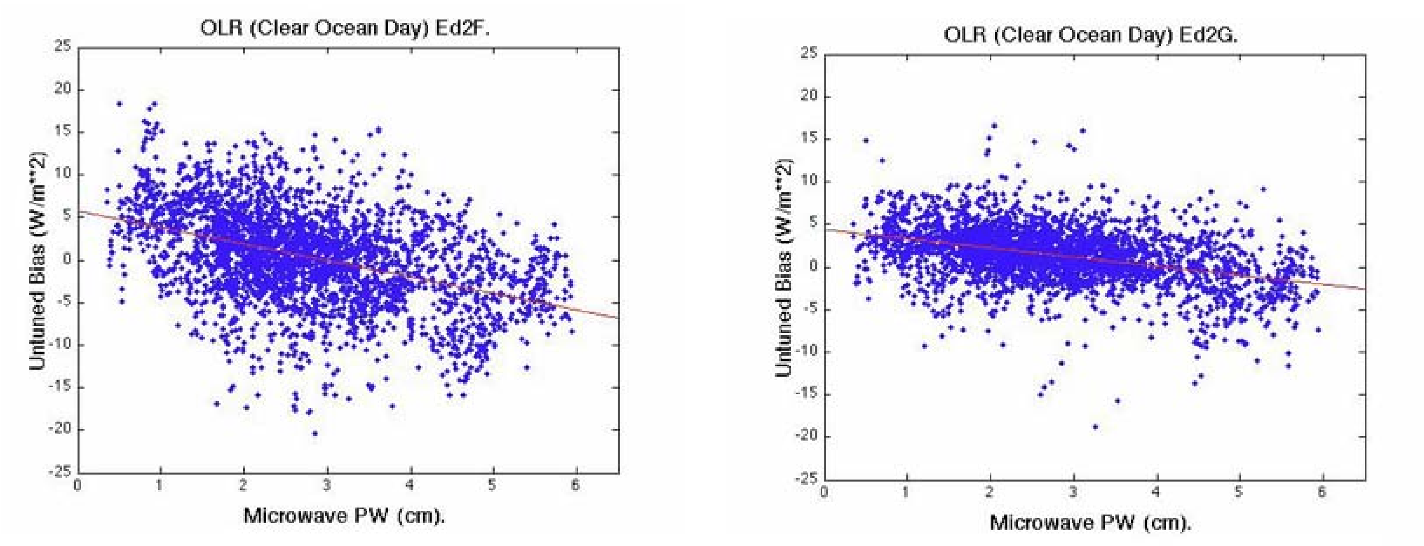

Figure 4b: Untuned OLR Biases for Clear-sky (MODIS screen), Ocean only Daytime FOVs (15 Dec 2007)

GEOS-5 is also the new arrival in Terra Edition2G SSF, which provides the cloud retrievals for CRS. The Terra Edition2G SSF Data Quality Summary informs of an increase of nighttime cloud fraction in polar regions and a smaller decrease of nite cloud fraction at lower latitudes; and a slight reduction in lower cloud tops during day and slight increase at night.

The following time series (Figures 5-9) compare untuned calculations of Terra Edition2, Edition2F and Edition2G CRS with their respective SSF observations at TOA on the FOV scale. The Figures are not grid-box statistics; each FOV within a given domain (i.e., ocean only) for a month has equal weight. Because higher latitudes are observed by Terra more frequently than lower latitudes, a FOV-by-FOV statistic places less weight on the tropics than does a grid-box (area weighted) statistic. Figure 5 has the bias (calculations minus observations) for untuned all-sky OLR over the entire globe from March 2000 to June 2009. January of each year is marked with a thin dotted vertical line. Untuned CRS calculations in Figure 5 use absolutely no input from broadband SSF observations; day is solid; nite is dashed. Edition2B is blue; Edition2F is red; Edition2G is green, starts in January 2008. Note the increasing bias *trend* for daytime OLR in the first 60 months; this is due to faulty observations of daytime OLR in the early Terra Edition2B SSF which will be corrected in Edition3. The dashed lines of Figure 5 show a weaker, decreasing bias *trend* in nighttime all-sky OLR spanning Editions 2B, 2F and 2G.

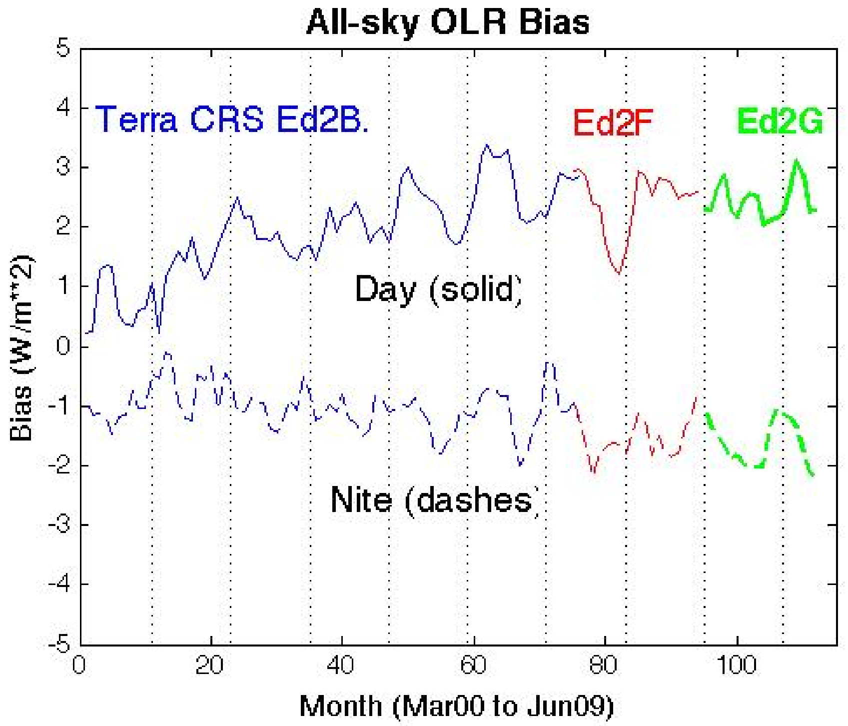

Figure 5: Untuned OLR bias for all-sky over entrie globe (March 2000 - June 2009)

Figure 6 shows the untuned OLR bias over ocean, here defined as any FOV for which the predominant IGBP type is classified as "water". CERES has 20 IGBP types, and a specific FOV may consist of up to 8 distinct IGBP types. Figure 7 is the land analog of Figure 6; here land is any FOV that does not have "water" as the predominant IGBP type. Untuned CRS calculations in Figure 6-7 again use no input from broadband SSF observations. Land biases for untuned all-sky OLR, which typically have their largest values during March or April, are more seasonal than ocean biases. The solid lines in Figures 6 and 7 cover all-sky conditions; dashed lines represent clear-sky FOVs for which MODIS detects no clouds. For both ocean and land, the difference between untuned all-sky bias and untuned clear-sky bias is typically just 1-2 W/m**2. This suggests that on the very large scale (i.e., all ocean FOVs for a whole month), the cloud forcings to OLR from calculations and observations are consistent to within 1-2 W/m**2 for Editions 2B, 2F and 2G. Recall that averaging over a great scale can easily mask large, compensating errors. The untuned biases for clear-sky OLR over ocean are typically -1 W/m**2 on the monthly scale of Figure 6. A single day of clear-sky ocean data in the bottom panels of Figure 4b reveals larger biases with systematic dependence on PW.

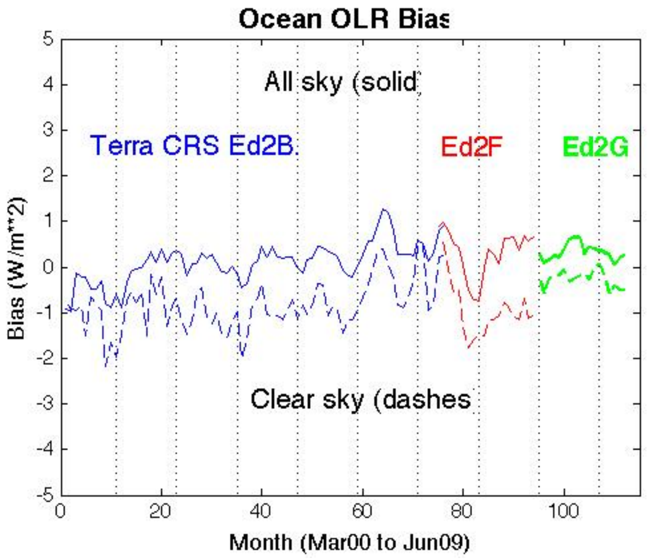

Figure 6: Untuned OLR bias over ocean

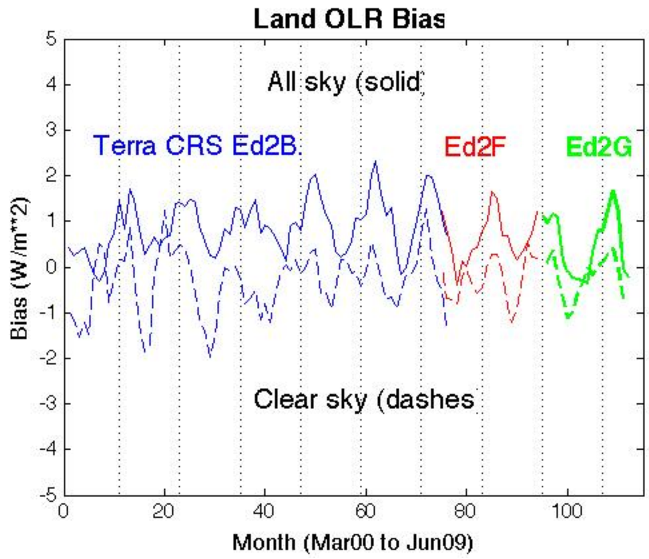

Figure 7: Untuned OLR bias over land

Figure 8 compares untuned calculations for reflected SW to TOA with the observations reported on SSF (not corrected for Rev1) over ocean; all-sky biases are solid lines; clear-sky biases are dashed. The untuned CRS calculations in Figure 8 do not employ inputs from broadband observations on SSF. Ocean surface albedos are based on the theoretical formulation of Jin et al., which has been carefully validated. The SW biases reported in Figures 8 and 9 combine both daytime and nighttime FOVs. For example, the reflected SW to TOA over a clear ocean typically has a value of about 80 W/m**2 for much of the day. Here, by combining day and night, the mean reflected SW to TOA over clear ocean then falls to about 40 W/m**2. An absolute bias of 2 W/m**2, which is common for clear sky (dashed lines in Figure 8), then marks a relative bias of 5%. Because the mean all-sky SW observed value in the domain of Figure 8 is about 115 W/m**2, the untuned *relative* biases for all-sky SW over ocean are also about 5%. Because CERES *observations* for broadband SW and OLR indicate a value for planetary net radiation that is unacceptably high, the large relative bias for untuned SW calculations over ocean is not a major source for concern about the calculations. But sharp temporal changes to untuned bias can flag problems in the calculations. Note, for example, the rapid increases of clear-sky SW bias over ocean near months 67 (Edition2B, May 2005). The Data Quality Summary for Edition2B explains the consequences of a sporadic bug for aerosol inputs. The bug was removed from Edition2F and Edition2G.

Figure 9 shows the untuned SW biases over land. Recall that "land" here includes the cryosphere. Unlike both untuned SW calculations over the ocean and untuned OLR calculations (anywhere), untuned SW calculations over land indeed employ SSF observations at TOA as inputs. Clear-sky SW calculations over land use a look-up-table (LUT) to radiative transfer calculations to estimate the broadband surface albedo. The small biases for clear sky SW over land (dashed lines in Figure 9) then signify a LUT that is not perfect. A monthly surface albedo history (SAH) of LUT results from the clear-sky FOVs spanning an entire month is used to estimate the surface albedo for cloudy FOVs. Untuned biases for all-sky SW over land are larger than for clear-sky SW. The performance of the new CRS Edition2G for SW over land is similar to that of Edition2B and Edition2F.

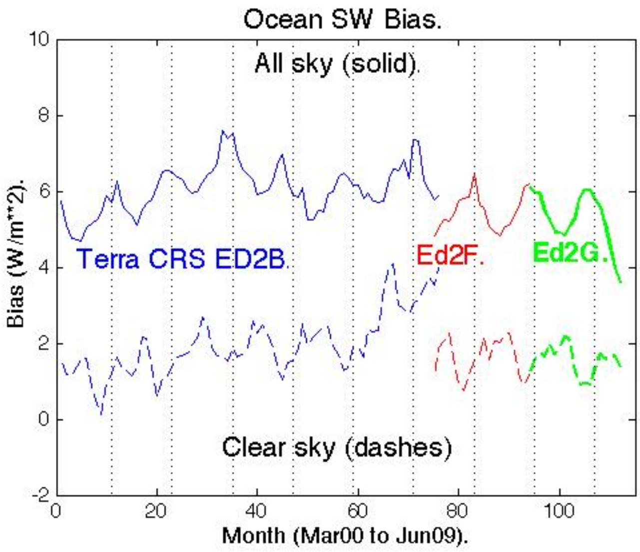

Figure 8: Ocean SW bias

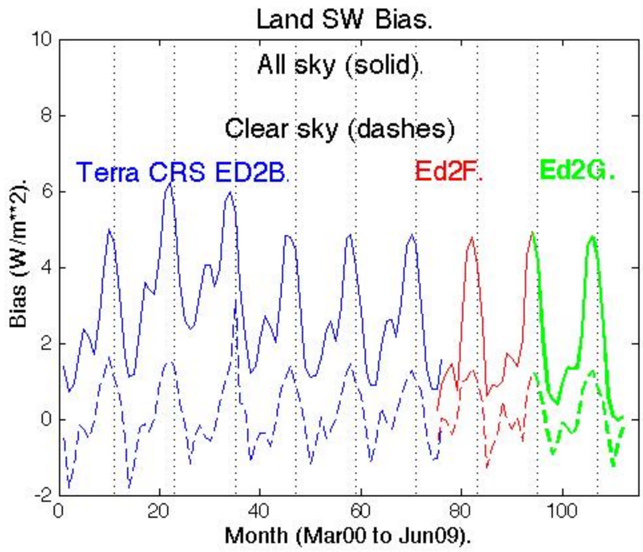

Figure 9: Land SW bias

Initial comparisons of Terra CRS Edition2G with surface observations on the CAVE URL indicate that the new fields of temperature and humidity in GEOS-5 have reduced some of the large bias in downwelling LW flux for clear skies. There is also a general reduction of SW aerosol forcing with the introduction of MODIS Collection 5 data in Edition2F (early 2006) that continues in Edition2G. The Data Quality Summaries of Terra Edition2B and Edition2F show that CRS calculations are quite noisy when compared with observations at the surface and TOA on short time scales.

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 Edition2G-Rev1

Please attend to the paragraph in the Introduction above that starts with the words "THIS IS IMPORTANT".

Cautions and Useful Hints

This is the first release of a Terra Edition2G CRS. Edition2G users will benefit by spending some play time on the CAVE web site. The Quality Summary of Terra Edition2B CRS is more extensive and may be a helpful guide at this stage.

One useful hint concerning Aqua Edition2B/2C CRS (and Terra Edition2B/2F/2G 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 Edition2B/2C and Terra Edition2B/2F/2G 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:

- Data Quality Summary of Terra Edition2F CRS
- Data Quality Summary of Terra 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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