CERES_SYN1deg_Ed3A

Data Quality Summary (8/8/2013)

Investigation: **CERES**
Data Product: **SYN1deg-Month, SYN1deg-M3Hour, SYN1deg-3Hour**

Data Set: **Terra+Aqua 7/2002 – Current**
Terra only 3/2000 – 6/2002

Data Set Version: **Edition3A**

Subsetting Tool Availability: http://ceres.larc.nasa.gov/order_data.php

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Science Team. The document 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 is a high-level summary and represents the minimum information needed by scientific users of this data product. It is strongly suggested that authors, researchers, and reviewers of research papers re-check this document for the latest status before publication of any scientific papers using this data product.

NOTE: To navigate the document, use the Adobe Reader bookmarks view option. Select "View" "Navigation Panels" "Bookmarks".

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TABLE OF CONTENTS

Section Page

1.0 Nature of the CERES_SYN1deg_Ed3A Products 1

2.0 Cautions and Helpful Hints 2

3.0 Version History 6

3.1 Changes between Edition2 and Edition3A 6

4.0 Accuracy and Validation 7

4.1 Edition3A 7

4.2 Edition2 7

5.0 References 8

6.0 Expected Reprocessing 9

7.0 Attribution 10

8.0 Feedback and Questions 11

LIST OF FIGURES

Figure Page

Figure 2-1. CERES input datasets used to produce CERES_SYN1deg_Ed3A. 5

1.0 Nature of the CERES_SYN1deg_Ed3A Products

The CERES SYN1deg products provide CERES-observed temporally interpolated top-of-atmosphere (TOA) radiative fluxes and coincident MODIS-derived cloud and aerosol properties and include geostationary-derived cloud properties and broadband fluxes that have been carefully normalized with CERES fluxes in order to maintain the CERES calibration. They also contain computed untuned TOA, in-atmosphere, and surface fluxes and computed fluxes tuned or constrained to the CERES-observed TOA fluxes. The computed fluxes are produced using the Langley Fu-Liou radiative transfer model. Computations use MODIS and geostationary satellite cloud properties along with atmospheric profiles provided by GMAO. The tuned adjustments to clouds and atmospheric properties are also provided. The computations are made for all-sky, clear-sky, pristine (clear-sky without aerosols), and all-sky without aerosol conditions. Each parameter is available at the 3-hourly, monthly 3-hourly, and monthly temporal resolutions on 1°–regional, zonal, and global spatial scales. Fluxes are provided for clear-sky and all-sky conditions in the longwave (LW), shortwave (SW), and window (WN) regions.

The CERES SYN1deg products use 3-hourly radiances and cloud property data from geostationary (GEO) imagers to more accurately model variability between CERES observations. To use GEO data to enhance diurnal sampling, several steps are involved. First, GEO radiances are cross-calibrated with the MODIS imager using only data that is coincident in time and ray-matched in angle. Next, the GEO cloud retrievals are inferred from the calibrated GEO radiances. The GEO radiances are converted from narrowband to broadband using empirical regressions and then to broadband GEO TOA fluxes using ADMs and directional models. To ensure GEO and CERES TOA fluxes are consistent, a normalization technique is used. Instantaneous matched gridded fluxes from CERES and GEO are regressed against one another over a month from the 5°×5° latitude-longitude regions. The regression relation is then applied to all GEO fluxes to remove biases that depend upon cloud amount, solar and view zenith angles, and regional dependencies. The all-sky GEO LW TOA fluxes use the same approach as in Edition2 and employ regional instantaneous normalization.

The regional means are determined for 1° equal-angle grid boxes calculated by first interpolating each parameter between the times of the CERES/GEO observations to produce a complete 1-hourly time series for the month. After interpolation, the time series is used to produce mean parameters. Monthly means are calculated using the combination of observed and interpolated parameters from all days containing at least one CERES observation.

Inputs to the CERES SYN1deg product include CERES Edition3 instrument gains and time-varying spectral response functions and gridded daily files derived from the Edition3A Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF) archival data product.

We urge users to visit the new CERES data subsetting/visualization/ordering tool at http://ceres.larc.nasa.gov/order_data.php, which provides an alternate user interface and a wider range of data formats (e.g., ASCII, netCDF) than is available with the Atmospheric Science Data Center (ASDC) ordering tool, which provides HDF only.

2.0 Cautions and Helpful Hints

The CERES Science Team notes several CAUTIONS regarding the use of CERES SYN1deg Ed3A data:

- The CERES SYN1deg Edition3A product can be visualized, subsetted and ordered from: htttp://ceres.larc.nasa.gov.
- A marked trend of -0.6 W m^{-2} per decade is observed in LW Cloud Radiative Effect (CRE) from the CERES EBAF-TOA Edition2.7 product between March 2000 and February 2013. The CERES team suspects at least part of this trend is spurious. LW CRE is determined from the difference between clear-sky and all-sky TOA fluxes. To determine clear-sky TOA fluxes, a cloud mask is applied to MODIS pixel data in order to distinguish between clear and cloud-contaminated areas. The cloud mask algorithm relies on many ancillary inputs, including output from a meteorological assimilation system. In January 2008, the source of assimilated meteorological data was changed from GEOS-4.1 to GEOS-5.2.0. The CERES team noticed a discontinuity in MODIS-based nighttime cloud fraction after the change, whereas daytime cloud fraction appeared to be unaffected. Since the nighttime cloud mask relies more heavily on assimilated meteorological data than daytime (since no visible MODIS radiances are available at night), the CERES team suspects the nighttime cloud fraction discontinuity is related to the GEOS-4.1 to GEOS-5.2.0 change. While the all-sky LW TOA flux is fairly immune to the GEOS-4 to GEOS-5 change, clear-sky LW fluxes are not, as they depend strongly upon the cloud mask. The CERES team continues to evaluate the impact of the GEOS-4.1 to GEOS-5.2.0 change on clear-sky and all-sky TOA fluxes and plans to update this Data Quality Summary as new information becomes available. This problem will ultimately be resolved in Edition4 (expected to be available in early 2015), which will use a consistent version of meteorological assimilation data throughout the record.
  - The SYN1deg product was produced for December 2007 with both versions of GEOS to help users evaluate the impact of the change. SYN1deg is a primary input to the EBAF product. For further information, please visit: http://ceres.larc.nasa.gov/science_information.php?page=Dec2007_GEOS-5.
- A full list of parameters on the CERES SYN1deg is contained in the CERES Data Product Catalog (DPC) that is available in PDF.
- Note that with CERES SYN1deg it is no longer necessary to use the user-applied revisions that were recommended when analyzing Edition2 SW TOA fluxes.
- Processing is performed on a nested grid. This grid uses 1° equal-angle regions between 45°N and 45°S and maintains area consistency at higher latitudes. The product contains a complete 360x180 1° grid created by replication.
- Daily means can be computed by averaging the corresponding day of 3-hourly values from the SYN1deg-3Hour product.
- Zonal means are the average of all non-default regional values along a latitude band. Caution must be taken when using zonal means where there are many regional default

values. No spatial interpolation is performed.

- The global mean is the area-weighted average of all 180 zonal means. The zonal mean is interpolated between neighboring zones when all of the regional values are default within a latitudinal zone. This interpolation occurs most frequently with SW flux near the polar night terminator. For SW flux the interpolation assumes constant albedo from the last available latitude. SW flux is calculated as the product of this albedo with analytically computed monthly mean solar insolation.

- When the solar zenith angle is greater than 90°, twilight flux (Kato and Loeb 2003) is added to the SW TOA flux to take into account the atmospheric refraction of light. The magnitude of this correction varies with latitude and season. In general, the regional correction is less than 0.5 W m^{-2} and the global mean correction is 0.2 W m^{-2}. The albedo is defined as a daytime quantity and is computed from the SW flux without the contribution of the twilight flux, divided by the incoming solar flux. There will be cases near the terminator that will have a greater SW flux than the incoming solar, and this is due to the contribution of twilight. The all-sky and clear-sky twilight flux are estimated independently and are not equivalent.

- Albedo is defined as a daytime parameter. The albedo multiplied by the solar incoming flux can be used to estimate the daytime SW flux, which does not include the twilight flux discussed in the previous paragraph.

- Unlike the CERES EBAF products, geodetic or oblate spheroid weighting is **not** used to derive the global flux mean from the zonal values. CERES_SYN1deg_Ed3A assumes a spherical Earth when averaging TOA insolation over the Earth's surface. This gives the well-known $S_o/4$ expression for mean solar irradiance, where S_o is the instantaneous solar irradiance at the TOA. When a more careful calculation is made by assuming the Earth is an oblate spheroid instead of a sphere, and the annual cycle in the Earth's declination angle and the Earth-sun distance are taken into account, the division factor becomes 4.0034 instead of 4. Consequently, the mean solar irradiance for CERES EBAF is ~1361/4.0034 = 340 W m^{-2}, compared to 1365/4 = 341.3 W m^{-2} for CERES SYN1deg Ed3A.

- The **clear-sky** LW fluxes incorporate GEO measurements. Despite the use of GEO narrow-to-broadband regressions and the above normalization technique, large biases in clear-sky LW TOA fluxes with GEO were observed. The large biases observed over desert regions are mainly due to the 3-hourly GEO input; for some longitudes this GEO input captures the diurnal maxima, whereas at longitudes shifted by 15° (one hour) the maxima is not captured.

- Only the CERES instrument that is in cross-track mode is used, since it provides uniform spatial distribution of footprints. No data from the Rotating Azimuth Plane Scan (RAPS) mode are used. There are two CERES instruments on the Terra and Aqua satellites. All CERES Terra/Aqua instruments were calibrated to be on the same radiometric scale. For Terra, the FM1 instrument spent the most time in crosstrack mode. For Aqua, FM4 was the prime crosstrack instrument prior to March 2005, when the SW channel failed. After March 2005, FM3 was permanently placed in crosstrack mode. Please see this month-to-month summary of the CERES operational scan modes on Terra and Aqua.

- Terra and Aqua CERES and MODIS measurements were combined after July 2002. Before July 2002 only Terra was used as input.

- For clear-sky fluxes, if the region did not observe a single clear-sky (cloud fraction <0.1%) footprint for the month, the monthly mean is default.
- Both untuned and tuned computed fluxes are available for TOA and surface fluxes. In-atmosphere fluxes are available only as tuned computed fluxes. Tuning takes place primarily at times of CERES TOA observations. The GEO-derived fluxes are not significantly tuned due to their large uncertainty in both clouds and flux properties. Therefore, the tuned product is very similar to the untuned, since GEO measurements are 80% of the inputs. For consistency do not combine tuned and untuned or observed fluxes. For example, in-atmosphere fluxes are only available as tuned and should only be combined with tuned TOA and surface fluxes.
- The observed TOA fluxes incorporate the solar irradiance from SORCE that are updated daily (SORCE Level 3 Total Solar Irradiance Version 10 available from: http://lasp.colorado.edu/sorce/data/tsi_data.htm) (Kopp et al. 2005). The SORCE total solar irradiance is ~1361 W m^{-2}.
- The untuned and tuned radiative transfer computed fluxes use a value of 1365 W m^{-2} for the total solar irradiance and are found in the parameter Tuned Clear-Sky SW Down or Tuned Total-Sky SW Down at TOA (level 1).
- Users should be aware that some of the key inputs used to produce SYN1deg Ed3A change at various times during the data record. Such changes, if large enough, may introduce spurious, unphysical jumps in the record. In the past, these changes were reflected in each CERES data product's version through a letter change (e.g., SRBAVG Edition2A, Edition2B, etc.). However, this proved cumbersome and confusing to many users. Now, changes to inputs will be documented in this DQS. Therefore, the SYN1deg letter changes will only reflect a reprocessing of the data record (e.g., due to a code bug). Figure 2-1 provides a current timeline of all input data sources used to produce the SYN1deg data products. Users are advised to use this table as reference in their analysis of SYN1deg data.

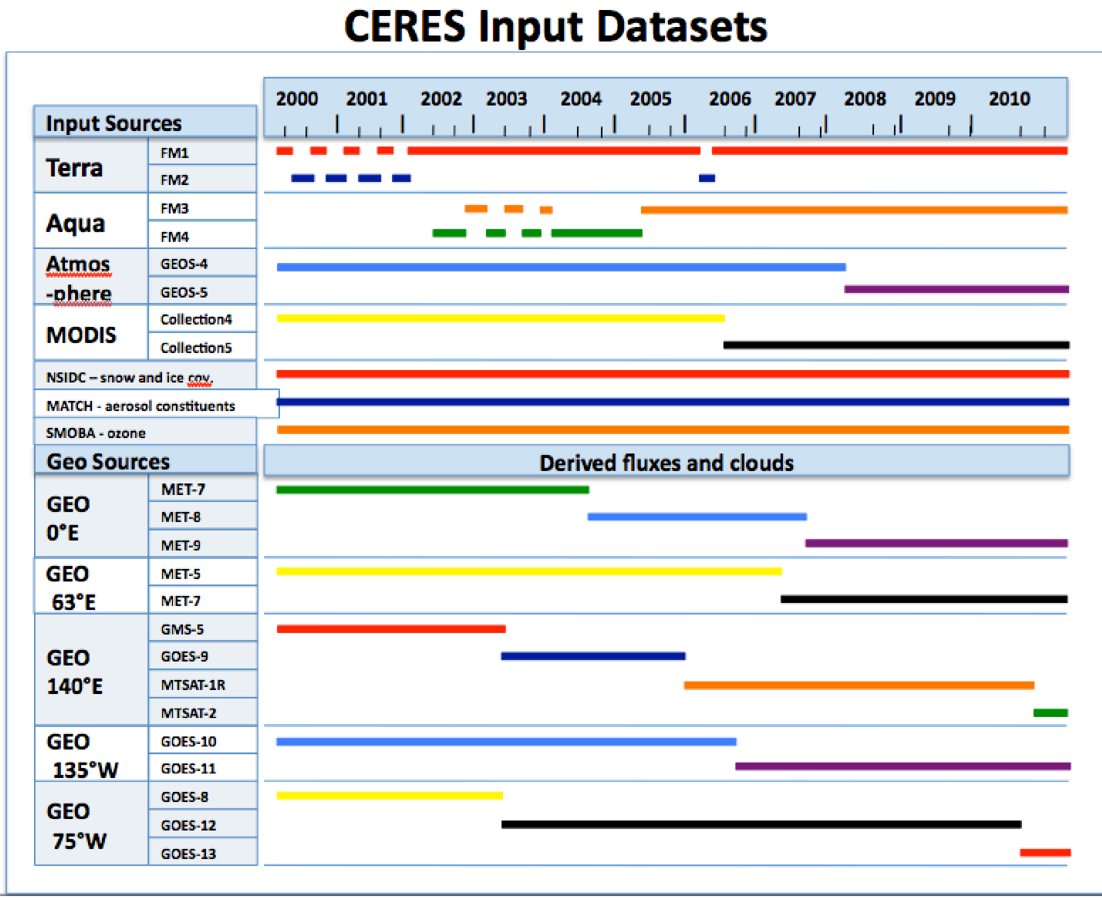

Figure 2-1. CERES input datasets used to produce CERES_SYN1deg_Ed3A.

- Coverage by geostationary satellites is between 60°S and 60°N. Also GEO calibration coefficients were updated incrementally in 3-year segments to facilitate production and may cause an unphysical jump.
- The GEO-enhanced SYN1deg TOA observed fluxes clearly add value in regions with strong diurnal cycles, such as over marine stratus and land convection. Monthly mean TOA fluxes can differ by 20 W m^{-2} or more depending on whether or not the diurnal cycle is explicitly taken into account (Doelling et al. 2013; Young et al. 1998). The GEO-derived TOA broadband fluxes, which have been carefully normalized with CERES fluxes to maintain the CERES calibration, do contain occasional artifacts. This does not pertain to the computed tuned or untuned fluxes. These artifacts may introduce noise into the regional temporal record, which may hamper deriving regional interannual variability (Doelling et al. 2013). As noted earlier, GEO artifacts are a function of the quality of the GEO instruments in the region, as well as the 3-hourly GEO time-sampling relative to the actual strength of the diurnal cycle in the region.

3.0 Version History

3.1 Changes between Edition2 and Edition3A

In Edition2, the CERES SYN1deg products were named SYN/AVG/ZAVG. The Edition3A products are now organized by time resolution into 3 products: SYN1deg-3Hour, SYN1deg-M3Hour, and SYN1deg-Month. The SYN1deg-M3Hour contains averages of all days during the month for each of the eight 3-hourly GMT time increments.

The CERES SYN/AVG/ZAVG observed/tuned/untuned fluxes assumed a solar constant of 1365 W m^{-2}. CERES SYN1deg Edition3A observed TOA uses time-varying solar irradiance from SORCE that are updated daily (SORCE Level 3 Total Solar Irradiance Version 10 available from: http://lasp.colorado.edu/sorce/data/tsi_data.htm) (Kopp et al. 2005). The SORCE total solar irradiance is ~1361 W m^{-2}. The Edition3A tuned and untuned fluxes still assume a solar constant of 1365 W m^{-2}.

Another departure from Edition2 is that CERES_SYN1deg_Ed3A uses the latest Edition3 instrument gains (see Edition3 BDS Data Quality Summary) and time-varying instrument spectral response functions. Furthermore, all 4 CERES instruments were placed on a common radiometric scale at the start of each mission (March 2000 for Terra; July 2002 for Aqua). For a detailed description of the Edition3 Instrument improvements, please see the following link (slides 20-70):

http://ceres.larc.nasa.gov/documents/STM/2010-04/2_Priestley_0410_STM_Newport News.pdf

4.0 Accuracy and Validation

4.1 Edition3A

Currently the Edition3A parameters are being validated. These results will shortly be summarized here. Until such a time, Edition3A accuracy most resembles that of the SYN1deg-lite Ed2.6 products which is described here:
http://ceres.larc.nasa.gov/documents/DQ_summaries/CERES_SYN1deg-lite_Ed2.6_DQS.pdf
Particular attention should be given to the summary of the geostationary artifact section on page 11. Additional information may be found in Kato et al. (2012) and Doelling et al. (2013).

4.2 Edition2

The Edition2 SYN/AVG/ZAVG Data Quality Summary can be accessed here:
https://eosweb.larc.nasa.gov/sites/default/files/project/ceres/quality_summaries/CER_SYN-AVG-ZAVG_Edition2.pdf

5.0 References

Doelling, D. R., N. G. Loeb, D. F. Keyes, M. L. Nordeen, D. Morstad, C. Nguyen, B. A. Wielicki, D. F. Young, and M. Sun, 2013: Geostationary enhanced temporal interpolation for CERES flux products, *J. Atmos. Oceanic Technol*., **30**, 1072-1090.

Kato, S. and N. G. Loeb, 2003: Twilight irradiance reflected by the Earth estimated from Clouds and the Earth's Radiant Energy System (CERES) measurements. *J. Climate*, **16**, 2646-2650.

Kato, S., N. G. Loeb, D. A. Rutan, F. G. Rose, S. Sun-Mack, W. F. Miller, and Y. Chen, 2012: Uncertainty estimate of surface irradiances computed with MODIS-, CALIPSO-, and CloudSat-derived cloud and aerosol properties. *Surv. Geophys*., doi:10.1007/s10712-012-9179-x.

Kopp, G., G. Lawrence, and G. Rottman, 2005: The Total Irradiance Monitor (TIM): Science Results, *Sol. Phys.*, **230**, 129-140.

Young, D. F., P. Minnis, D. R. Doelling, G. G. Gibson, and T. Wong, 1998: Temporal interpolation methods for the Clouds and Earth's Radiant Energy System (CERES) experiment. *J. Appl. Meteorol*., **37**, 572-590.

6.0 Expected Reprocessing

There is no scheduled reprocessing at this time. However it is expected that the temporal coverage of the CERES SYN1deg products will be updated in 6-month intervals to remain current.

7.0 Attribution

The CERES Team has made a considerable effort 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 Terra+Aqua SYN1deg Ed3A products:

> 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 referring to the CERES SYN1deg products, please include the data set version and the data product as:

> CERES SYN1deg-Month Ed3A
> CERES SYN1deg-M3Hour Ed3A
> CERES SYN1deg-3Hour Ed3A

When Langley ASDC data are used in a publication, we request the following acknowledgment be included:

> "These data were obtained from the Atmospheric Science Data Center at the NASA Langley Research 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.

8.0 Feedback and Questions

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

For questions about the CERES subsetting/visualization/ordering tool at http://ceres.larc.nasa.gov/order_data.php, please click on the feedback link on the left-hand banner.