CERES_EBAF_Ed4.2 Data Quality Summary

Version 3
Released 5/3/2024

Investigation: **CERES**
Data Product: **EBAF**

Data Set: **Terra (Instruments: CERES-FM1 or CERES-FM2)**
Aqua (Instruments: CERES-FM3 or CERES-FM4)
NOAA-20 (Instrument: CERES-FM6)

Data Set Version: **Edition4.2** **Release Date: January 2, 2024**

CERES Visualization, Ordering and Subsetting Tool: https://ceres.larc.nasa.gov/data/

This document provides a high-level quality assessment of the CERES Energy Balanced and Filled (EBAF) data product. As such, it represents the minimum information needed by scientists for appropriate and successful use of the data product. For a more thorough description of the methodology used to produce EBAF, please see Loeb et al. (2018) and Kato et al. (2018). 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.

Notes to Users:

- To ensure you are using the latest version of EBAF, please check the version and release date in the netCDF file you have against the version and release date in this Data Quality Summary.

1.0 Introduction

This document simply outlines the differences between EBAF Edition4.2 and Edition4.1. Please see the EBAF Edition4.1 data quality summary for more information.

2.0 Motivation for transitioning to a NOAA20-only EBAF record and introducing EBAF Ed4.2

The EBAF Ed4.2 product combines the a) Terra only record from March 2000 to June 2002, b) the Terra & Aqua record July 2022 to March 2022, and c) the NOAA20-only record from April 2022 onward (see presentation here). The transition from the Terra and Aqua record to a NOAA20-only record was prompted by the Terra and Aqua orbits drifting outside of their maintained 15-minute local equator crossing time. The Terra and Aqua spacecraft have begun orbital maneuvers in 2021 to exit their respective orbits and are slowly drifting towards terminator orbits reaching 9AM and 3PM local equator crossing times in 2026. An Aqua spacecraft anomaly in early April 2022, which caused MODIS WV channel anomalies, accelerated the transition to a NOAA20 record. The corrected WV calibration coefficients will be available in MODIS Collection 7.

The SSF1deg product monthly regional fluxes will be impacted by the changing Terra and Aqua orbital drifts. The SSF1deg product accounts for the diurnal variation by assuming constant meteorology to compute the 24-hour average fluxes. Many regions have systematic diurnal cycles, where the clouds decrease during the day (maritime stratus regions) or where the clouds increase during the afternoon (land afternoon convective regions). For these regions, changing the local crossing time would impact the monthly mean fluxes as the Terra and Aqua orbits start to drift and would therefore impact the long-term regional flux trends. Even a 15-minute drift can result in a SW monthly regional flux changes of 2 Wm^{-2} based on 15-minute Geostationary Earth Radiation Budget (GERB) studies (see presentation here). Since the EBAF product relies on the long-term flux regional flux stability of the SSF1deg product, the decision was made to transition to a NOAA20-only EBAF record beginning in April 2022.

Beginning in April 2022, the Edition4A SYN1deg product will transition from a Terra, Aqua and hourly geostationary (GEO) dataset to a Terra, NOAA20 and hourly GEO dataset. The SYN1deg dataset provides the diurnal asymmetry factors (DAR) needed to apply the diurnal SW models to the CERES SSF1deg SW all-sky observations. The SYN1deg all-sky LW fluxes are the basis for EBAF LW all-sky fluxes. The resulting SYN1deg product LW fluxes should not be impacted by the Terra drifting orbits, since the daily averaged fluxes are mostly based on the hourly GEO fluxes, which are carefully normalized regionally with the CERES fluxes. Once the Terra satellite is decommissioned, the SYN1deg product will transition to a NOAA20 and hourly GEO dataset.

3.0 Using regional climatology adjustments to transition between satellite records

The Terra&Aqua period is considered the most diurnally accurate part of the EBAF record, since the Terra (10:30 MLT) and Aqua (1:30 MLT) observations provide most of the regional diurnal information supplemented by a small geostationary-derived flux contribution (Loeb et al 2018 and Loeb and Doelling 2020). The Terra-only and NOAA20 (1:30MLT) records rely more on the geostationary-derived fluxes to estimate the daily flux means. To mitigate the flux discontinuity between Terra-only and Terra&Aqua records, the CERES EBAF Ed4.2 product applies regional climatology adjustments to the Terra-only record (March 2000 to June 2002) based on 5-years of overlap (July 2002 to June 2007). Calendar month dependent monthly mean flux climatology is computed over the overlap period. The adjustment applied to a calendar month for the Terra-only record is the mean difference of corresponding calendar months over the overlap period. The Terra-only EBAF dataset is processed during the overlap period to compute the regional climatology adjustment,

$$\hat{F} = F(Terra) + [\bar{F}(Terra\&Aqua) - \bar{F}(Terra)] \qquad (1)$$

where $\hat{F}$ is the flux with the climatological adjustment, F(Terra) and F(Terra&Aqua) are fluxes for, respectively, the Terra-only and Terra&Aqua periods, and the overbar indicates the climatological monthly mean fluxes computed for the 5-year overlap period. The bracketed term on the right side of Eq. (1) is the climatological adjustment. The regional climatology adjustment is used for both TOA and surface fluxes and is explained here. Similarly, for the NOAA20-only record (beginning in April 2022) the climatology is based on the May 2018 to March 2022 overlap period. SW and LW flux regional climatology adjustments were computed for both all-sky and clear-sky conditions. For TOA fluxes, the regional flux climatology adjustments were not applied if the year-to-year monthly Terra&Aqua minus Terra-only flux standard deviation or dispersion was greater than 20%. The regional clear-sky flux climatology adjustments were only utilized if all years during the overlap period had valid clear-sky fluxes (from either observed CERES footprints or MODIS narrowband to broadband fluxes) before spatial filling. The SW climatology adjustment was not applied if the resulting SW flux was less than 0.0 Wm^{-2}. To ensure that the climatology adjustments did not impact the regional and global trends, the trend of the climatologically adjusted NOAA20-only minus the Terra&Aqua fluxes during the overlap period was found to be much smaller than the overall Terra&Aqua trend (here). Similarly, the climatologically adjusted NOAA20-only minus the Terra&Aqua fluxes during the overlap period monthly regional or global anomalies were also found to be smaller than the overall Terra&Aqua anomalies. This validates that the flux regional climatology adjustments are not introducing any artificial trends or anomalies in the EBAF Ed4.2 record; the analysis can be found here. The EBAF Ed4.1 dataset did incorporate clear-sky flux climatology adjustments during the Terra-only record but did not incorporate all-sky flux or cloud climatology adjustments. Table 3-1 describes the climatology adjustment strategy as a function of satellite record.

The cloud properties were also climatologically adjusted. The cloud properties were cloud-fraction weighted to obtain the cloud climatology adjustments. No regional cloud property climatology adjustments were made over regions that did not have valid cloud property observations for each year during the overlap period. The cloud climatology adjustments were not applied if the resulting cloud fraction, cloud effective temperature, cloud effective pressure, and cloud optical depth was less than 0%, 200K, 200hPa, 0.05 or greater than 100%, 310K, 980hPa, 40, respectively.

Table 3-1. Satellite data record range and associated climatology adjustment strategy.

Data Range	Clear-sky fluxes	All-sky fluxes	Cloud properties
03/2000 – 06/2002	Terra[a]	Terra[c]	Terra[c]
07/2002 – 03/2022	Aqua	Terra+Aqua	Terra+Aqua
04/2022 – onwards	NOAA20[b]	NOAA20[d]	NOAA20[d]

[a] *Adjusted so that 07/2002-06/2007 climatology matches Aqua's*
[b] *Adjusted so that 05/2018-03/2022 climatology matches Aqua's*
[c] *Adjusted so that 07/2002-06/2007 climatology matches Terra+Aqua's*
[d] *Adjusted so that 05/2018-03/2022 climatology matches Terra+Aqua's*

4.0 The total solar irradiance dataset for the EBAF Ed4.2 product

The EBAF Edition 4.1 total solar irradiance (TSI) reference was based on Solar Radiation and Climate Experiment (SORCE) version 15, which was used between 25Feb2003 to 30Jun2013. The WRC composite (Mar2000 to 24Feb2003), RMIB composite (01Jul2013 to 31Oct2014), SORCE/TSIS-1 composite (01Jan2018 to 25Feb2020) and TSIS-1/TIM V3 beginning in 25Feb 2020 TSI datasets were radiometrically scaled to the SORCE V15 calibration. More information regarding the EBAF Ed4.1 TSI is found here. The solar community has a new TSI composite that combines TSI sensor records and is known as the community consensus TSI dataset; it was created by G. Kopp using the methodology of Dudok de Wit et al. (2017). The daily community consensus TSI composite can be accessed here. Since the community consensus TSI dataset has a longer lag time than the near-real time EBAF product, the TSIS-1/TIM V3 is appended to the community consensus TSI data beginning with May 7, 2022. The TSIS-1/TIM V3 is first radiometrically scaled to the community consensus record, utilizing the previous 100 days of overlap to determine the scaling factor. The EBAF Ed4.2 global TSI record mean is ~0.16 Wm^{-2} greater than the corresponding Ed4.1 value (see Figure 4-1). The EBAF product was energy balanced using the same Ed4.1 ocean heat storage value and based on the same 10-year period between July 2005 and June 2015, avoiding the single satellite periods. The resulting EBAF Ed4.2 minus Ed4.1 global net flux record mean difference (March 2000 to March 2022) is less than 0.02 Wm^{-2}.

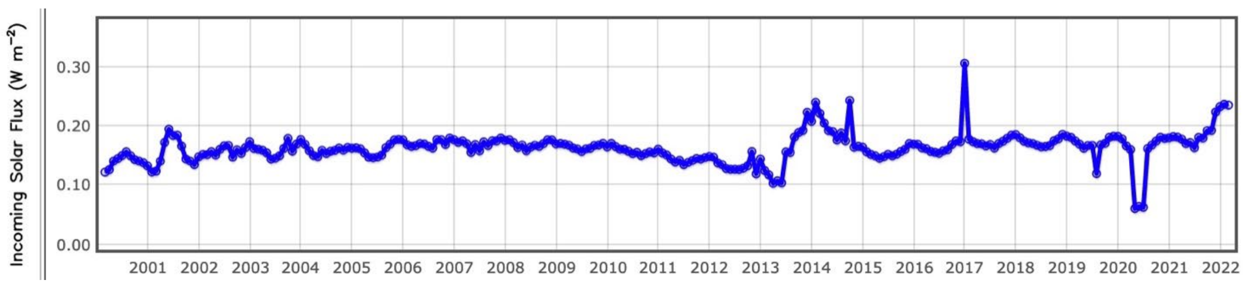

Figure 4-1. The EBAF Ed4.2 minus Ed4.1 total solar incoming difference.

5.0 EBAF Ed4.2 major algorithm improvements

- Fixed the diurnal asymmetry ratio (DAR) coding bug. DAR is computed by taking the morning minus afternoon SW flux ratio from the SYN1deg product. DAR should be computed in local time but was mistakenly computed in GMT, which resulted in pairing the afternoon flux and the morning flux of the following local day. This caused large spurious values of DAR near the dateline (Loeb and Doelling 2020 and here). DAR is used to compute the SW diurnal corrections applied to the SSF1deg product to compute the EBAF SW monthly mean regional fluxes.
- The EBAF product estimates clear-sky SW and LW fluxes in mostly overcast regions, which contain no clear-sky CERES observed footprints, by applying narrowband to broadband coefficients to the MODIS channel radiances within the clear portion of CERES partly cloudy footprints (Loeb et al. 2018). The MODIS narrowband to broadband coefficients are based on regressions of matched clear-sky footprint MODIS channel and CERES radiances. The MODIS-derived broadband radiances are then converted to fluxes using the CERES angular directional models (ADMs) and corrected to match the observed footprint clear-sky fluxes. The EBAF Ed4.1 narrowband to broadband coefficients were based on MODIS collection 5 across the entire record regardless of the MODIS collection used. For EBAF Ed4.2, the MODIS or VIIRS narrowband to broadband coefficients are based on the collection (C) number that is consistent with imager version used in the CERES record. MODIS C5 coefficients were applied between 2000 and February 2016, MODIS C6.1 coefficients were applied between March 2016 and March 2022, and NOAA20 VIIRS C2.1 coefficients are applied beginning in April 2022. See Table 5-1 to note the MODIS and VIIRS collection timelines used in the CERES record.

Table 5-1. The imager and collection used to compute the imager-derived clear-sky fluxes.

Data range	03/2000- 06/2000	07/2002-02/2016	03/2016-03/2022	04/2022-onwards
Imager & collection	Terra-MODIS C5	Aqua-MODIS C5	Aqua-MODIS C6.1	NOAA20-VIIRS C2.1

6.0 EBAF Ed4.2 minor changes

- For October 2004, the EBAF Ed4.2 monthly mean fluxes are based on October 13 to 31 observations, whereas the EBAF Ed4.1 incorrectly based the monthly mean fluxes on all days in October. The Aqua-CERES instrument radiance observations saturated over bright Earth targets resulting in spurious fluxes over the first 12 days of the month. The instrument issue was resolved on October 13, 2004.
- From August 16 to September 3, 2020, the Aqua spacecraft experienced an anomaly. For EBAF Ed4.1, NOAA20 observations were simply substituted for the missing days during the anomaly. For EBAF Ed4.2, the August 2020 monthly mean fluxes and clouds are based entirely on the NOAA-20-only climatology adjusted fluxes and clouds (like the NOAA20-only record beginning in April 2022).
- The EBAF Ed4.1 product did not properly apply the SW flux twilight correction (Kato and Loeb 2003) to all December months. This correction accounts for the refracted SW flux over regions with solar zenith angles greater than 90°. EBAF Ed4.2 applied the SW flux twilight correction for all months.
- The EBAF Ed4.1 product incorporated spurious MODIS granules during August 18, 2000 (Terra-MODIS) and August 6, 2002 (Aqua-MODIS), resulting in noisy cloud property retrievals that impacted the ADM scene selection used to convert the CERES radiance to fluxes. EBAF Ed4.2 product did not utilize those days in its processing.
- During the early Terra-CERES record, data gaps greater than one week occurred during August 6-18, 2000, June 15-July 2, 2001, and March 20-28, 2002. The EBAF Ed4.2 utilized the SW and LW fluxes from the SYN1deg product for the days with no CERES observations over non-polar regions. The SYN1deg GEO-derived fluxes were carefully normalized with CERES observations that were available during other days of the month. Over polar regions (>60° in latitude), the monthly mean fluxes are based on days with data only. This enables a more accurate observed monthly mean flux to facilitate comparisons with climate models.
- The EBAF Ed4.1 product utilized MODIS C5 until March 2018 and transitioned to MODIS C6.1 beginning in April 2018 when MODIS C6.1 became available. MODIS C6.1 mainly addressed spurious WV channel issues that occurred after the Terra spacecraft anomaly (February 18-29, 2016) (Wilson et al. 2017). The entire MODIS C6.1 L1B record was reprocessed; however, the CERES project only reprocessed the SSF1deg and SYN1deg records using MODIS C6.1 between February 2016 and March 2018). EBAF Ed4.2 incorporated the updated February 2016 and March 2018 SSF1deg and SYN1deg records.
- A SYN1deg SW temporal interpolation error was fixed in EBAF Ed4.2 when GEO regions experience glint conditions that occur over tropical oceans. During glint conditions, no GEO SW fluxes are derived but are temporally interpolated between neighboring non-glint hourly GEO fluxes. A more accurate DAR is obtained by this proper SW interpolation.
- Both Edition 4.1 and Edition 4.2 surface fluxes are based on the SYN1deg-Month product, which contains hourly surface fluxes. In the Edition 4.1 product, all MODIS-, VIIRS-, and geostationary satellite-derived cloud properties are used for surface flux computations. Geostationary satellites provide hourly cloud properties outside the MODIS and VIIRS overpass times. In Editon 4.2, only MODIS- and VIIRS-derived cloud properties are used; no geostationary satellite-derived cloud properties are used. Cloud properties derived from

MODIS and VIIRS are temporally interpolated in computing hourly fluxes. For the interpolation, clouds are separated into four types depending on cloud top pressure (Kato et al. 2018). Cloud properties that are interpolated include fraction, cloud top and base pressures, optical depth, particle (ice and liquid) size, and water phase (1 for liquid and 2 for ice).

- In the Edition 4.1 product, GEOS-5.4.1 provides temperatue and humidity profiles for the surface flux computations. In Edition 4.2, MERRA-2 temperature and humidity profiles are used for surface flux computations.

7.0 Cautions and Helpful Hints

The CERES Science Team notes several CAUTIONS and HELPFUL HINTS regarding the use of CERES_EBAF_Ed4.2:

- TOA and surface Cloud Radiative Effects (CREs) in EBAF Ed4.2 are determined using the new clear-sky fluxes determined for the total region. This differs from EBAF Ed4.0, which determined CRE using clear-sky fluxes determined from cloud-free portions of a region only.
- The CERES_EBAF_Ed4.2 product can be visualized, subsetted, and ordered from: https://ceres.larc.nasa.gov/data/.
- The Aqua satellite experienced an anomaly preventing any data transmittal from August 16 to September 3, 2020. CERES processing filled this Aqua gap with the SSF NOAA-20 Ed1B fluxes and clouds from August 16-31. September 1-3 was not filled.
- Global means are determined using zonal geodetic weights. The zonal geodetic weights can be obtained from (https://ceres.larc.nasa.gov/data/general-product-info/#geodetic-zone-weights-information).
- Climatological mean values are determined for a base period of July 2005 – June 2015.

(a) <u>TOA Fluxes:</u>

- Users are cautioned that all-sky SW and LW TOA fluxes are determined from Terra only from March 2000-June 2002, combined Terra and Aqua for July 2002-March 2022, and NOAA20 for April 2022 onwards. Clear-sky TOA fluxes are derived from Terra prior to July 2002, and Aqua thereafter until April 2022 onwards, which are based on NOAA20.
- The monthly means of regional clear-sky LW are based on both daytime and nighttime observations. Regions with large diurnal clear-sky LW fluctuations, such as interior Australia, the Atacama Desert, Namibia, and the Sahel, was impacted by using incorrect clear-sky LW narrowband-to-broadband coefficients that severely limited the nighttime sampling of partial footprint clear-sky LW fluxes from the associated imager. These regions have anomalously larger clear-sky LW fluxes than the surrounding regions, since they were only based on daytime observations. This error only impacts the April 2022 to January 2024 data months. For December 2023 and January 2024, large outliers of clear-sky LW fluxes were identified and removed at the regional level. These regions were then spatially filled from surrounding regions. Beginning with the data month February 2024, the correct coefficients were used, and consequently the climatological adjustment factors were updated (Section 3.0). These corrections eliminated most of the anomalous regional clear-sky LW fluxes.
- In determining monthly mean cloud free area clear-sky SW TOA fluxes from daily mean values, the daily mean SW fluxes are weighted by the gridbox clear area fraction in order to minimize the influence of cloud contamination on the monthly mean clear-sky SW TOA flux. In contrast, daily mean clear-sky LW TOA fluxes are weighted equally when computing gridbox monthly mean values.
- Since TOA flux represents a flow of radiant energy per unit area and varies with distance from the earth according to the inverse-square law, a reference level is also needed to define satellite-based TOA fluxes. From theoretical radiative transfer calculations using a model that accounts for spherical geometry, the optimal reference level for defining TOA fluxes in radiation budget studies for the earth is estimated to be approximately 20 km. At this reference level, there is no need to explicitly account for horizontal transmission of solar

radiation through the atmosphere in the earth radiation budget calculation. In this context, therefore, the 20-km reference level corresponds to the effective radiative "top of atmosphere" for the planet. Since climate models generally use a plane-parallel model approximation to estimate TOA fluxes and the earth radiation budget, they implicitly assume zero horizontal transmission of solar radiation in the radiation budget equation and do not need to specify a flux reference level. By defining satellite-based TOA flux estimates at a 20-km flux reference level, comparisons with plane-parallel climate model calculations are simplified since there is no need to explicitly correct plane-parallel climate model fluxes for horizontal transmission of solar radiation through a finite atmosphere. For a more detailed discussion of reference level, please see Loeb et al. (2002).

- When the solar zenith angle is greater than 90°, twilight flux (Kato and Loeb 2003) is added to the outgoing SW flux to take into account the atmospheric refraction of light. The magnitude of this correction varies with latitude and season and is determined independently for all-sky and clear-sky conditions. In general, the regional correction is less than 0.5 W m^{-2}, and the global mean correction is 0.2 W m^{-2}. Due to the contribution of twilight, there are regions near the terminator in which outgoing SW TOA flux can exceed the incoming solar radiation. Users should be aware that in these cases, albedos (derived from the ratio of outgoing SW to incoming solar radiation) exceed unity.
- EBAF uses geodetic weighting to compute global means. The spherical Earth assumption 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 is taken into account, the division factor becomes 4.0034 instead of 4. The following file provides the zonal geodetic weights used to determine global mean quantities. (https://ceres.larc.nasa.gov/data/general-product-info/#geodetic-zone-weights-information).
- Starting with the data date of August 2021, a supplemental dataset used to fill gaps in the microwave snow and ice data within 50 km of coasts (including large lakes and seas) changed to a higher resolution product, resulting in differences in those snow/ice maps. Figure 7-1 shows differences due to this change in the all-sky and clear-sky TOA SW and LW fluxes from SSF1deg-Ed4A-Aqua run for January 2021. The differences are restricted to coastlines and are generally less than 5 W m^{-2}.

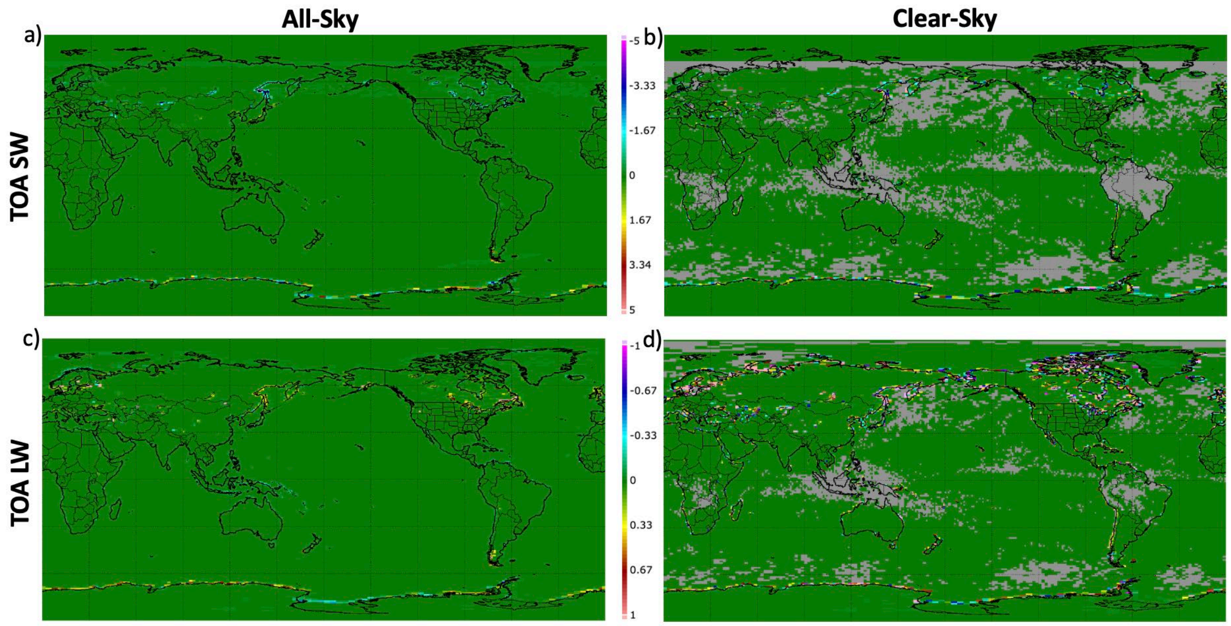

Figure 7-1. Differences in SSF1deg Ed4A monthly mean TOA fluxes (W m^{-2}) in January 2021 due to the change in the supplemental snow/ice dataset.

(b) <u>Cloud Properties:</u>

- Users are cautioned that imager-based cloud properties are determined from Terra only from March 2000-June 2002, combined Terra and Aqua for July 2002-March 2022, and NOAA20 for April 2022 onwards. ***Therefore, cloud properties may exhibit a discontinuity in July 2002 and in April 2022 owing to imager calibration differences and diurnal cloud property differences between the periods that may be unresolved with the cloud property climatological adjustment. See Section 3.0.***
- Because the Aqua MODIS 1.6 µm channel failed shortly after launch, the 1.24 µm channel is used as an alternative in both Aqua and Terra Ed4.2 daytime cloud optical depth retrievals over snow. However, the 1.24 µm channel is not optimal for cloud optical depth since surface reflectance can affect retrievals more than the 1.6 µm channel. Surface shortwave downward flux validation of radiative transfer results over Dome C using 1.6 µm and 1.24 µm cloud retrievals anecdotally suggest that the 1.24 µm cloud optical depths over snow are too large by several percent.
- The Terra-MODIS water vapor (6.76-µm) and the 8.55-µm channels have degraded since 2008, leading to some artificial trends in cloud properties that are most significant over polar regions (day and night) and non-polar oceans (nighttime). Corrections were made after the Terra spacecraft anomaly event (February 18-28, 2016) in an attempt to restore these channels to pre-degradation levels. As a result, some cloud properties also exhibit a sharp discontinuity and inconsistency before and after the Terra spacecraft anomaly over Antarctica and the Arctic Ocean during daytime and nighttime, and over the non-polar oceans during nighttime. The TOA SW and LW fluxes are not significantly affected.

(c) Surface Fluxes:

- Cloud radiative effects are computed as all-sky flux minus clear-sky flux.
- The net flux is positive when the energy is deposited to the surface, i.e. the net is defined as downward minus upward flux.
- There are regions where the surface flux adjustments are large, such as over the Andes, Tibet, and central eastern Africa. As a result, the deseasonalized anomalies over these regions can be noisy.
- Because the GEOS-5.4.1 skin temperatures was inadvertently used in Edition 4.2 instead of the MERRA-2 skin temperatures, when the regional trend of surface net longwave flux is computed over the Amazon, the magnitude of the trend is unphysically large.
- Because the degradation of Terra water vapor channels affected cloud retrievals starting around 2008, downward longwave flux anomalies over polar regions show a downward trend. Therefore, trend analyses with surface fluxes over polar regions from Ed4 EBAF-Surface should be avoided.
- Although the frequency of occurrence of a positive net shortwave cloud effect or a negative net longwave cloud effect is rare, they are not entirely absent when cloud free area clear-sky fluxes are used for the cloud effect calculation. A possible reason that these apparently unphysical cloud radiative effects occur is because of a mismatch of sampling between all-sky and clear-sky. For example, if clear-sky is sampled during daytime more often than during nighttime, the net clear-sky longwave flux is less negative than the net clear-sky longwave flux with a uniform sample throughout a month. Therefore, when the less negative clear-sky net longwave flux is subtracted from all-sky net longwave flux, which is also generally negative, the resulting net longwave cloud effect can be negative. For shortwave over polar region where the solar zenith angle changes rapidly over the course of a month, if clear-sky samplings occur when solar zenith angle is large and a smaller net clear-sky shortwave flux is subtracted from all-sky net shortwave flux, the cloud effect can be positive.
- To ensure surface and TOA fluxes are consistent, Lagrange multiplier processes are used to adjust the MODIS or VIIRS cloud properties within uncertainty to ensure flux computations at TOA are consistent with those observed at TOA. The surface flux is then recomputed using the adjusted cloud properties (see Kato et al., 2018 for more details).

8.0 Version History

December 2022: Released Edition 4.2 EBAF TOA fluxes.

February 2023: Released Edition4.2 EBAF Surface fluxes.

January 2024: Revised surface fluxes and TOA total area clear-sky fluxes from March 2000 through June 2023.

9.0 References

Dudok de Wit, T. G. Kopp, C. Fröhlich, and M. Schöll (2017), Methodology to create a new total solar irradiance record: Making a composite out of multiple data records, *Geophys. Res. Lett.*, **44**, 1196-1203, doi:10.1002/2016GL071866.

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., F. G. Rose, D. A. Rutan, T. E. Thorsen, N. G. Loeb, D. R. Doelling, X. Huang, W. L. Smith, W. Su, and S.-H. Ham, 2018: Surface irradiances of Edition 4.0 Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) data product, *J. Climate*, **31**, 4501-4527, doi:10.1175/JCLI-D-17-0523.1.

Loeb, N. G., S. Kato, and B. A. Wielicki, 2002: Defining top-of-atmosphere flux reference level for Earth Radiation Budget studies. *J. Climate*, **15**, 3301-3309.

Loeb, N. G., D. R. Doelling, H. Wang, W. Su, C. Nguyen, J. G. Corbett, L. Liang, C. Mitrescu, F. G. Rose, and S. Kato, 2018: Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Top-of-Atmosphere (TOA) Edition-4.0 data product. *J. Climate*, **31**, 895-918, doi: 10.1175/JCLI-D-17-0208.1.

Loeb, N. G. and Doelling, D. R., 2020: CERES Energy Balanced and Filled (EBAF) from Afternoon-Only Satellite Orbits. *Remote Sens.* , **12**, 1280. https://doi.org/10.3390/rs12081280.

Wilson, T.; Wu, A.; Shrestha, A.; Geng, X.; Wang, Z.; Moeller, C.; Frey, R.; Xiong, X., 2017: Development and Implementation of an Electronic Crosstalk Correction for Bands 27–30 in Terra MODIS Collection 6. *Remote Sens.*, **9**, 569. https://doi.org/10.3390/rs9060569.

10.0 Attribution

When referring to the CERES EBAF product, please include the data product and the data set version as "CERES_EBAF_Ed4.2."

The CERES Team has put forth considerable effort to remove major errors and to verify the quality and accuracy of this data. Please provide a reference to the following papers when you publish scientific results with the CERES EBAF_Ed4.2.

Loeb, N. G., D. R. Doelling, H. Wang, W. Su, C. Nguyen, J. G. Corbett, L. Liang, C. Mitrescu, F. G. Rose, and S. Kato, 2018: Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Top-of-Atmosphere (TOA) Edition-4.0 Data Product. *J. Climate*, **31**, 895-918, doi: 10.1175/JCLI-D-17-0208.1.
PDF available at https://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-17-0208.1

Kato, S., F. G. Rose, D. A. Rutan, T. E. Thorsen, N. G. Loeb, D. R. Doelling, X. Huang, W. L. Smith, W. Su, and S.-H. Ham, 2018: Surface irradiances of Edition 4.0 Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) data product, *J. Climate*, **31**, 4501-4527, doi:10.1175/JCLI-D-17-0523.1.
PDF available at https://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-17-0523.1

When CERES data obtained via the CERES web site are used in a publication, we request the following acknowledgment be included: "These data were obtained from the NASA Langley Research Center CERES ordering tool at https://ceres.larc.nasa.gov/data/."

11.0 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 https://ceres.larc.nasa.gov/data/ please email LaRC-CERES-Help@mail.nasa.gov.

12.0 Document Revision Record

The Document Revision Record contains information pertaining to approved document changes. The table lists the Version Number, the date of the last revision, a short description of the revision, and the revised sections.

Document Revision Record

Version Number	Date	Description of Revision	Section(s) Affected
V0	12/09/2022	• Original document.	All
V1	01/27/2023	• Added text regarding the new Ed4.2 surface fluxes.	Sec. 3.0 and 6.0
V2	01/02/2024	• Added text about the revised Ed4.2 fluxes.	Sec. 7.0
V3	05/03/2024	• Added Cautions and Helpful Hints section.	Sec. 7.0