CERES CCCM Data Quality Summary

RelD2
Updated 6/17/24

Investigation: **CERES**

Data Product: **CALIPSO, CloudSat, CERES, and MODIS (CCCM)**

Data Set: **CALIPSO-CALIOP,**
CloudSat-CPR,
CERES-FM-3,
Aqua-MODIS

Data Set Version: **RelD2 (908909)** **Release Date: June 21, 2024**

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

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 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 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 users
The difference of the D2 version from the D1 version is primarily in the cloud base height for convective clouds. The D2 cloud base heights are generally lower than the D1 cloud base heights and are a result of fixing a bug in the D1 version (please see Section 2.0 for details).

TABLE OF CONTENTS

Section Page

LIST OF FIGURES

1.0 Nature of the CCCM Product

The CALIPSO-CloudSat-CERES-MODIS (CCCM) data set integrates measurements from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), CloudSat Cloud Profiling Radar (CPR), Clouds and the Earth's Radiant Energy System (CERES), and the Moderate Resolution Imaging Spectroradiometer (MODIS) data. The cloud and aerosol properties from CALIOP and cloud properties from the CPR are matched to a MODIS pixel and then an Aqua CERES footprint. The product contains only the CERES footprint in each scan that has the highest CALIPSO and CloudSat ground track coverage. The product consists of all cloud and aerosol properties derived from MODIS radiances included in the Single Scanner Footprint (SSF) product and computed irradiances included in the Cloud Radiative Swath (CRS) product. Two sets of SSF variables are included with the CCCM data. One set covers the entire CERES footprint, and the other set is only over the CALIOP and CPR ground track. CERES derived top-of-atmosphere (TOA) shortwave, longwave and window irradiances by angular distribution models are also included. In addition, irradiance profiles computed by a radiative transfer model using MODIS-, CALIOP-, and CPR-derived aerosol, clouds, and surface properties are included in the product. Furthermore, MODIS-derived cloud properties from the algorithm that incorporates CALIOP and CPR cloud information are also included. MODIS-derived cloud properties and TOA irradiances derived from CERES radiances are produced by the same algorithm that produces the CERES SSF and CRS products. However, the CCCM product should not be considered as a climate data record since various input data product versions and algorithm modifications will occur along the course of the measurement period. The scan and packet numbers unique to the CERES footprint provide the means to match the data to other CERES products, although the CCCM product contains more near nadir CERES footprints compared with SSF and CRS products. The resulting HDF granule contains 24 hours of data.

2.0 Difference of the Current Version (RelD2 908909) from the Previous Version (RelD1 907908)

This version uses R05 CloudSat and version 4-51 CALIPSO data products, MODIS-derived cloud properties by an improved Ed4 CERES cloud algorithm, and top-of-atmosphere (TOA) irradiances derived from Edition 4 CERES Angular Distribution Model (ADM). In addition, a problem in the previous version (D1) has been corrected. Differences of D2 from the D1 version include:

1) A bug to merge CloudSat-derived cloud base for convective clouds was fixed. This fix results in lower cloud base heights for convective clouds for D2 than corresponding D1 cloud base heights (Figure 2-1). Clouds with cloud base detected by CloudSat only were affected by this bug. Differences of computed and observed top-of-atmosphere irradiances for D1 and D2 versions are nearly the same, but slight improvements are noted in D2 (Figure 2-2 versus Figure 2-4, and Figure 2-3 versus Figure 2-5).

2) CALIPSO version 4-51 data prodcuts were used in D2 compared to version 4 used in D1.

3) CALIPSO-only clouds detected from the 80-km horizontal averaging were restored in D2. In D1, we excluded those clouds since their cloud radiative impacts were negligible and were treated as clear in radiative transfer calculations. In D2, we restored those clouds to keep the CALIPSO information as it is to avoid possible confusion. Users can still filter out those optically thin clouds using cloud top/base source information as discussed in Section 4.0.

4) For daytime, a scaling factor of the merged cloud extinction coefficient was derived using the MODIS visible scaled cloud optical depth (VSCOD), i.e. VSCOD constraining method. The VSCOD constraining method was implemented in the RelB1 algorithm, and no changes have been made. In contrast, for nighttime, a new constraining method for the merged cloud extinction profile was implemented in the CCCM RelD1 algorithm. Specifically, a scaling factor was derived to ensure that the merged cloud extinction profile generates consistent thermal emission with the value inferred from MODIS cloud effective temperature and cloud optical depth, i.e., infrared thermal emission (IREMIS) method. This method improved the radiative calculation results especially when the retrieved MODIS cloud top height was biased. However, the cloud thermal emission easily saturates once the cloud optical depth > 5. As a result, the derived scaling factor was often underestimated especially for deep convective clouds. To overcome this issue, a hybrid method was considered for nighttime in the RelD2 algorithm. That is, if the CALIPSO-CloudSat-derived cloud top temperature is colder than the MODIS cloud top temperature by 20 K or more, and CALIPSO-CloudSat top temperature is colder than the skin temperature –by 20 K or more, the IREMIS method is used. Otherwise, the VSCOD method is used.

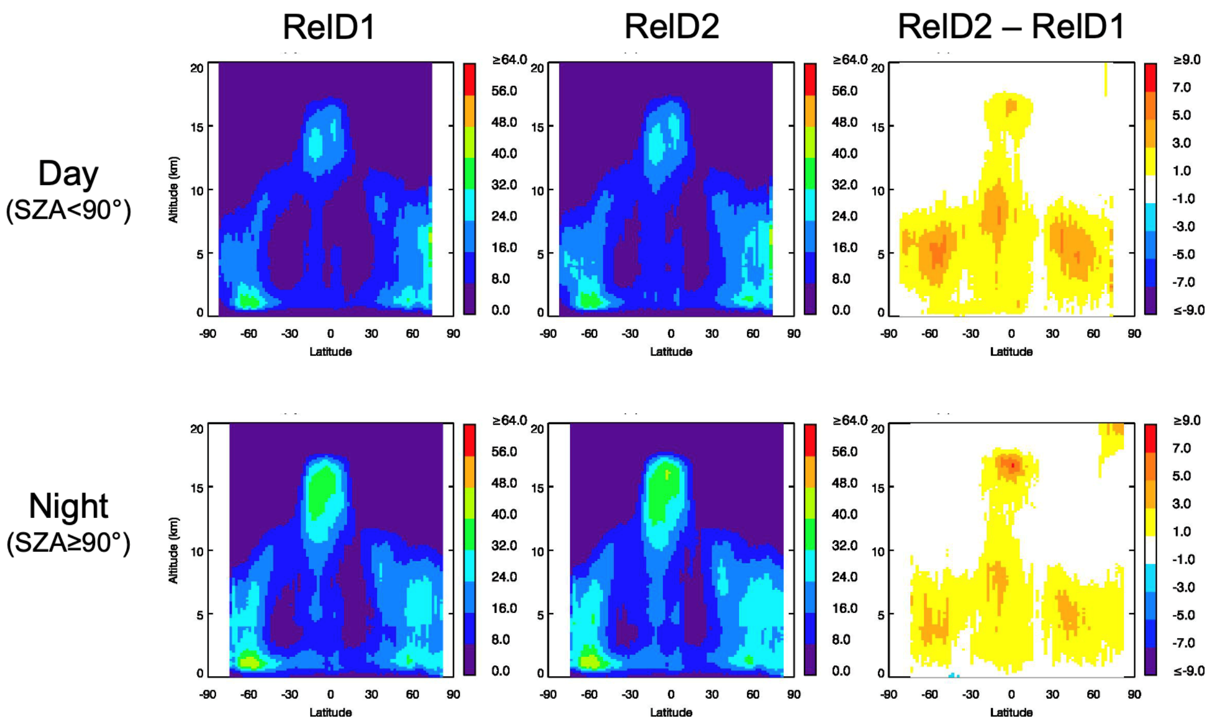

Figure 2-1. Volume cloud fraction in % obtained from RelD1 (left column) and RelD2 (middle column) versions of CCCM product for January 2008. The right column shows the difference of volume cloud fraction (D2 – D1). To compute cloud fraction profile, cloud top (CCCM-13) and base heights (CCCM-15) of up to 16 cloud groups are used for each CERES footprint. The cloud fraction profiles are computed from 0 km to 20 km with a 0.16-km interval. The cloud base/top heights (CCCM-13 and CCCM-15) are obtained by combining CALIPSO and CloudSat cloud detections.

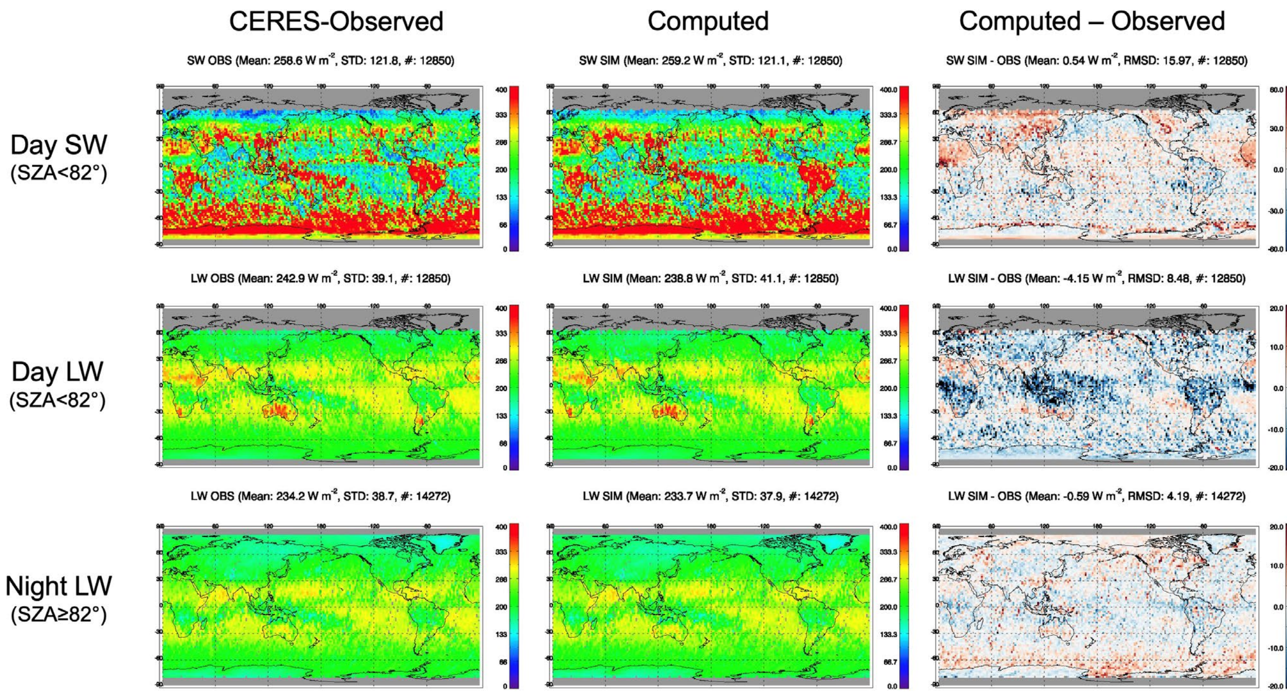

Figure 2-2. (left column) CERES-observed, (middle column) computed, and (right column) computed minus observed values for (top row) daytime shortwave, (middle row) daytime longwave, and (bottom row) nighttime longwave irradiances in W m^{-2} for January 2008 in the RelD2 CCCM product. In this comparison, only CERES footprints with valid CALIPSO or CloudSat observations are used.

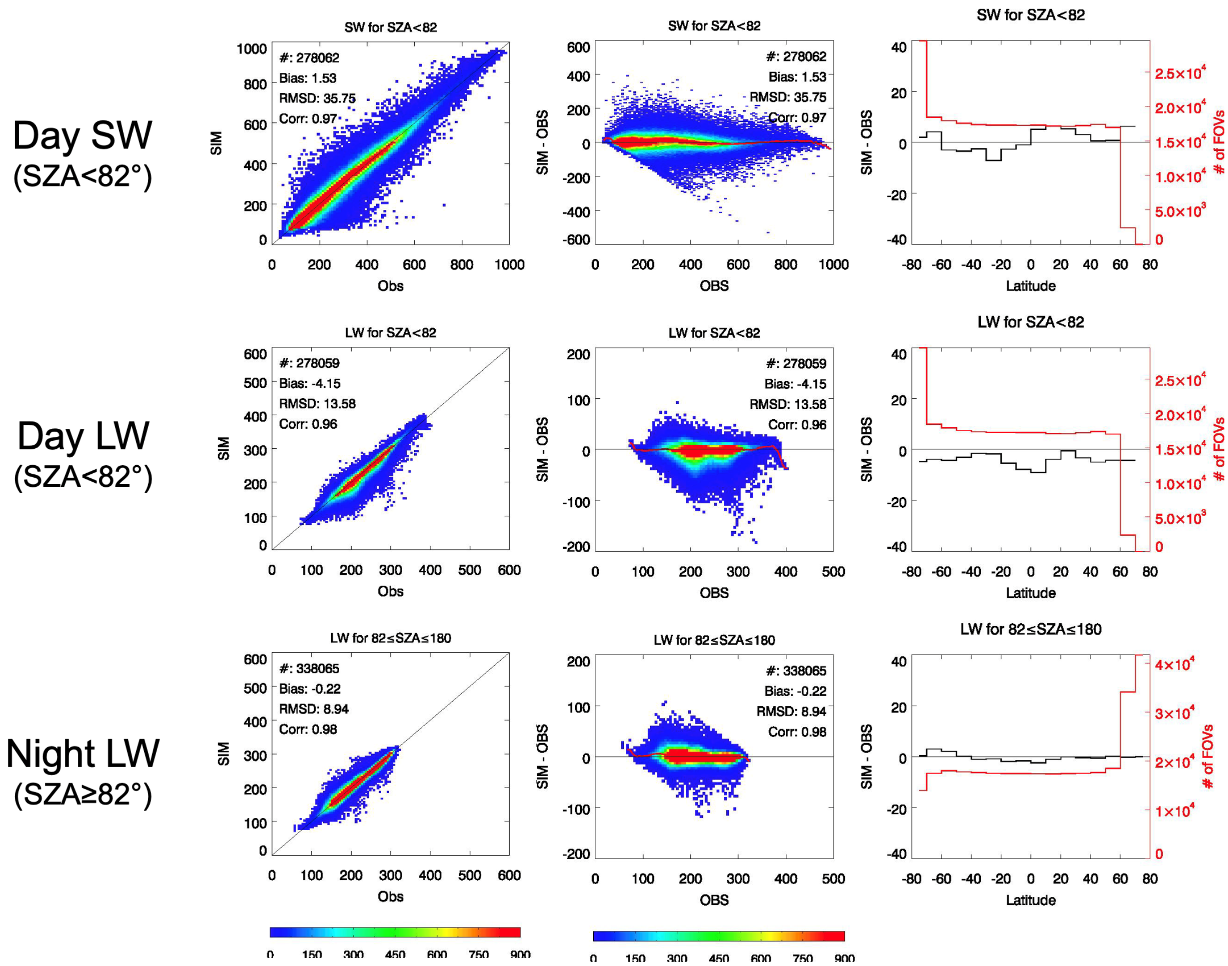

Figure 2-3. Scatter plots between CERES-derived and computed top-of-atmosphere (top) shortwave, (middle) daytime longwave, and (bottom) nighttime longwave irradiances (W m^{-2}) for January 2008 in the RelD2 CCCM product. In this comparison, only CERES footprints with valid CALIPSO or CloudSat observations are used.

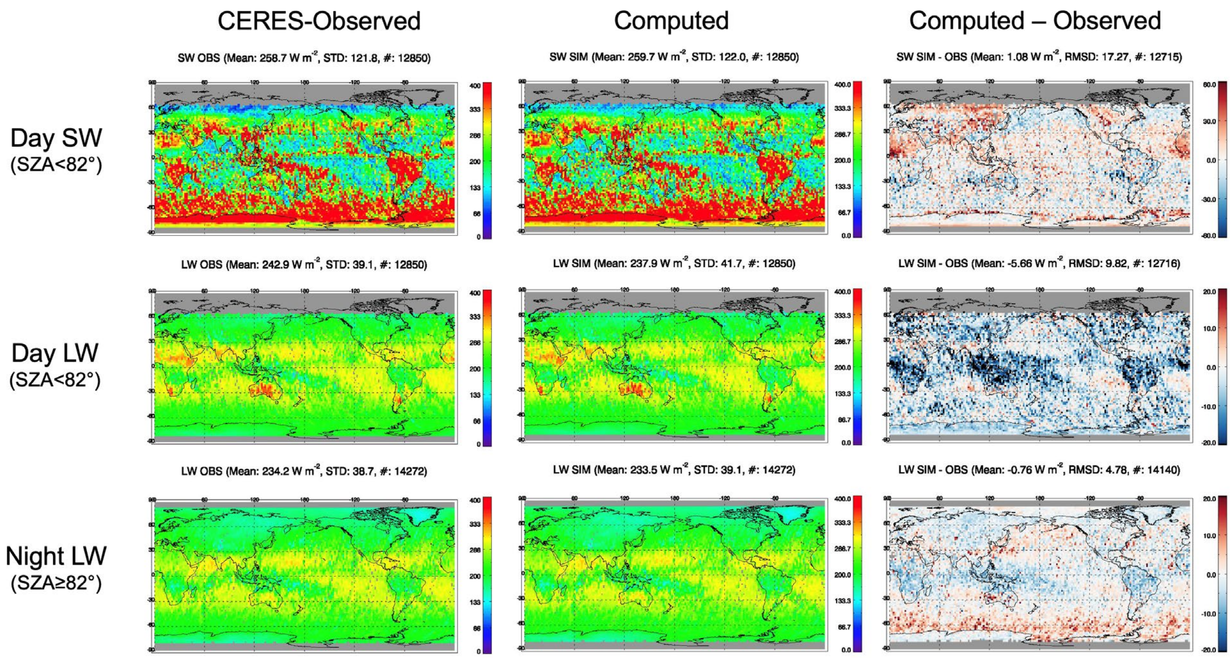

Figure 2-4. Same as Figure 2-2 but from the RelD1 CCCM product.

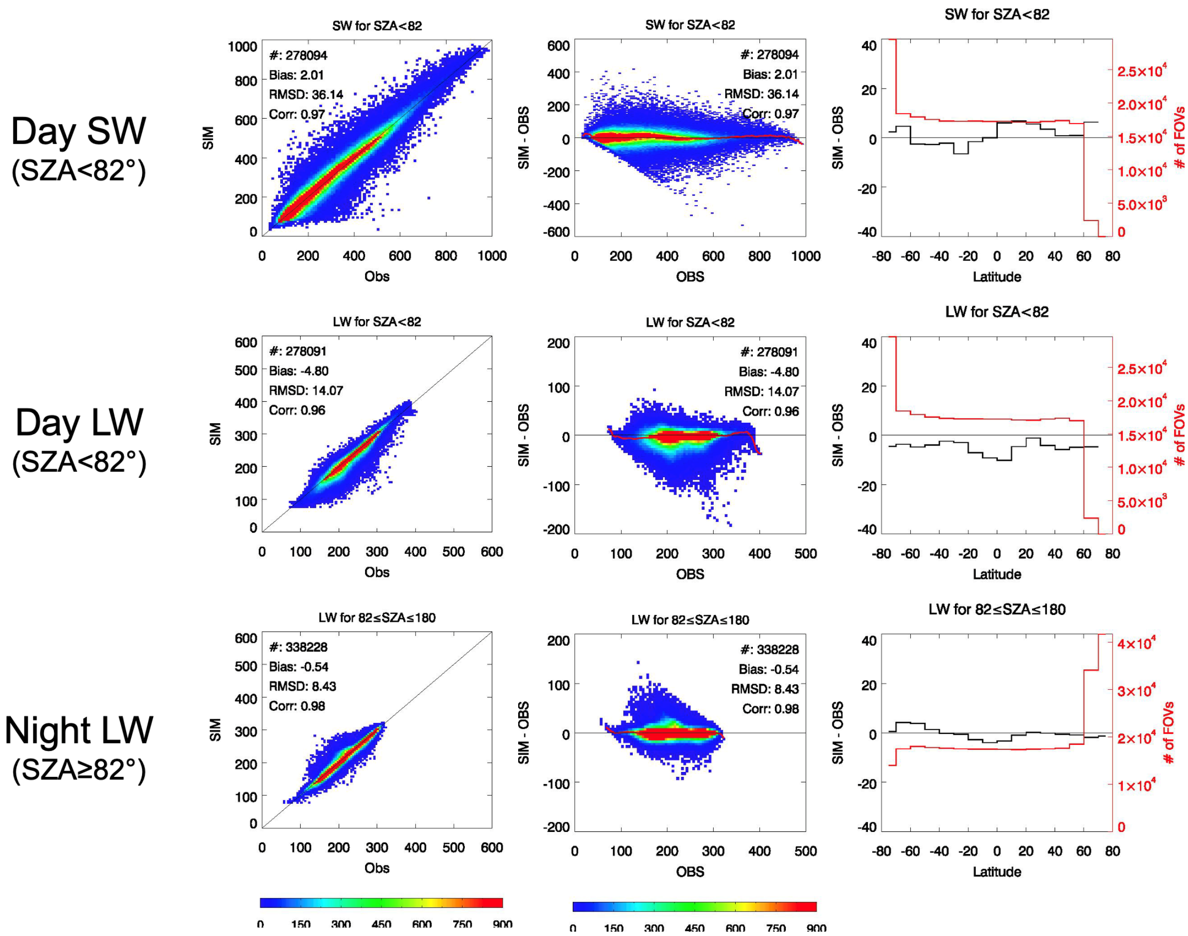

Figure 2-5. Same as Figure 2-3 but from RelD1 CCCM product.

3.0 Data Used for Producing CCCM Data (Version D2)

Data used for producing currently available CCCM version D2 data are:

- CALIPSO
  1. CALIPSO_VFM: CAL_LID_L2_VFM-Standard-V4-51.YYYY-MM-DDTHH-*hdf
  2. CALIPSO_05kmALay: CAL_LID_L2_05kmALay-Standard-V4-51.YYYY-MM-DDTHH-*hdf
  3. CALIPSO_05kmCLay: CAL_LID_L2_05kmCLay-Standard-V4-51.YYYY-MM-DDTHH-*hdf
  4. CALIPSO_05kmCPro: CAL_LID_L2_05kmCPro-Standard-V4-51.YYYY-MM-DDTHH-*hdf
- CloudSat
  1. CLOUDSAT_CLDCLASS:YYYYJDY*_CS_2B-CLDCLASS_GRANULE_P1_R05_E06_F00.hdf
  2. CLOUDSAT_CWC-RO:YYYJDY*_CS_2B-CWC-RO_GRANULE_P1_R05_E06_F00.hdf
  3. CLOUDSAT_2C-ICE: YYYJDY*_CS_2C-ICE_GRANULE_P1_R05_E06_F00.hdf
- MODIS (retrievals are done by the CERES cloud algorithm)
  1. MAC: MAC021S1.AYYYYJDY.HHMM.002.*hdf
  2. MAC_GEO: MAC03S1.AYYYYJDY.HHMM.002.*.hdf
  3. MAC_AEROSOL: MAC04S1.AYYYYJDY.HHMM.002.*.hdf
- CERES
  1. Aqua FM3 Edition4 IES

4.0 Cautions, Helpful Hints, and Known Problems:

- Users also need to read the CALIPSO, CloudSat, CERES, and MODIS quality summaries or similar documents before they analyze variables from those instruments.
  - **CALIPSO:** Data Quality Statements and user's guide
  - **CloudSat:** CloudSat Standard Data Products
  - **CERES and MODIS:** CERES SSF Terra/Aqua Edition4A Data Quality Summary
- CALIPSO, CloudSat and MODIS data are separated and stored by CERES footprints. For each CERES scan line, a CERES footprint that contains the largest CALIPSO and CloudSat ground track was kept in CCCM.
- To use more reliable computed irradiances with valid CloudSat and CALIPSO measurements, CCCM-8 and CCCM-11 need to be checked whether these are at least greater than 90 and 28, respectively.
- Besides cautions related to the variables mentioned in CALIPSO and CloudSat documents, other cautions in using variables in this product.

  - **Cloud property retrieval from MODIS radiances by the CERES cloud code (Edition 5 beta)**
    - When optically thick clouds (cloud top temperature less than 233 K) occur in a footprint, the daytime cloud phase of all clouds within the footprint is sometimes all ice even when low-level clouds are present within the footprint.
    - Thick dust aerosols are often identified as clouds.
    - The algorithm uses a two-habit model (Liu et al. 2014) to retrieve ice cloud properties, which is an improvement from the CERES Edition 4 cloud code that uses a single rough model.
    - Daytime cloud optical thickness over snow/ice regions is derived from a combination of 1.6-µm and 1.24-µm channels, while the CERES Edition 4 cloud code uses only the 1.24-µm channel.
  - **CALIPSO CloudSat derived cloud fraction**
    - The sum of cloud group cloud fractions (cloud group area percentage coverage CCCM-12) or 100 minus cloud-free area percent coverage (CCCM-21) is the cloud fraction over a CERES footprint. When computing a cloud fraction averaged over an area and a time period, it is recommended to check the total number of good CloudSat profiles (CCCM-8) and total number of good CALIPSO profiles (CCCM-11). Because of a large sensitivity difference between CALIOP and CPR, when one of the instruments is down, the cloud fraction is different from the value derived from both instruments.

- A smaller ice particle size (50% value of the correct value) was used in the irradiance computation. The impact is less than 1 Wm^{-2} in a monthly mean for most of regions (See Figure 4-1).

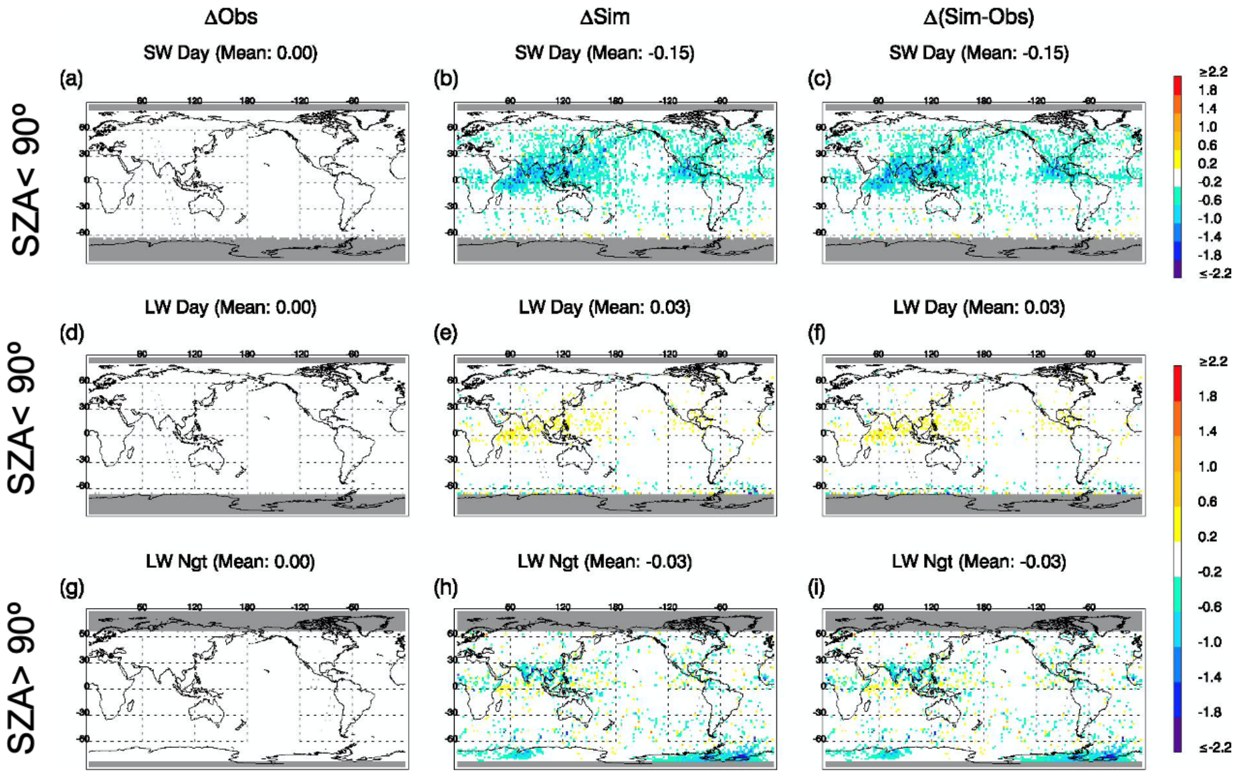

Figure 4-1. Estimated error in top-of-atmosphere (top) shortwave, (middle) daytime longwave, and (bottom) nighttime longwave irradiances (W m^{-2}) due to the use of smaller ice particle size (50% value of the correct value). Because the asymmetry parameter is not very sensitive to particle size for a two-habit ice crystal model (Fig. 4 of Loeb et al., 2018), the impact is smaller than a hexagonal ice crystal model would have given.

- When the cloud layer is detected from the CALIPSO 80-km horizontal averaging but not by CloudSat, the layer is likely to be optically thin and its cloud radiative impact is negligible. Therefore, this layer is treated as clear in radiative transfer calculations. In the RelD1 product, this layer is removed in the 16 cloud group information (CCCM-12, CCCM-13, and CCCM-15). However, the clear-sky fraction area (CCCM-21) was not accordingly updated in the RelD1 product. To minimize the confusion, we do not modify 16 cloud group information in the RelD2 product. In other words, the CALIPSO 80-km clouds are restored in the CCCM RelD2 product. Users can identify these optically negligible cloud layers using a cloud top/base source flag (CCCM-14, CCCM-16) and a horizontal averaging scale used for CALIPSO cloud detections (CCCM-16d).

5.0 Version History

March 2013: B1 version was released.

October 2021: D1 version was released.

June 2024: D2 version was released.

6.0 References

Ham, S.-H., S. Kato, F. G. Rose, S. Sun-Mack, Y. Chen, W. F. Miller, and R. C. Scott, 2022: Combining cloud properties from CALIPSO, CloudSat, and MODIS for top-of-atmosphere (TOA) shortwave broadband irradiance computations: Impact of cloud vertical profile, J. Appl. Meteorol. Clim., 61, 1449-1471, DOI: 10.1175/JAMC-D-21-0260.1.

Ham, S.-H., S. Kato, F. G. Rose, D. Winker, T. L'Ecuyer, G. G. Mace, D. Painemal, S. Sun-Mack, Y. Chen, and W. F. Miller (2017), Cloud occurrences and cloud radiative effects (CREs) from CERES-CALIPSO-CloudSat-MODIS (CCCM) and CloudSat radar-lidar (RL) products, J. Geophys. Res. Atmos., 122, doi:10.1002/2017JD026725.

Kato, S., S. Sun-Mack, W. F. Miller, F. G. Rose, Y. Chen, P. Minnis, and B. A. Wielicki, 2010: Relationships among cloud occurrence frequency, overlap, and effective thickness derived from CALIPSO and CloudSat merged cloud vertical profiles. J. Geophys. Res., 115, D00H28, https://doi.org/10.1029/2009JD012277.

Liu, C., P. Yang, P. Minnis, N. Loeb, S. Kato, A. Heymsfield, and C. Schmitt, 2014b: A two-habit model for the microphysical and optical properties of ice clouds. Atmos. Chem. Phys., 14, 13 719–13 737, https://doi.org/10.5194/acp-14-13719-2014.

Loeb, N. G., P. Yang, F. G. Rose, G. Hong, S. Sun-Mack, P. Minnis, S. Kato, S. Ham, W. L. Smith, S. Hioki, G. Tang, 2018: Impact of Ice Cloud Microphysics on Satellite Cloud Retrievals and Broadband Flux Radiative Transfer Model Calculations. J. Climate, 31(5), 1851–1864. doi: 10.1175/JCLI-D-17-0426.1.

7.0 Feedback and Questions

For questions concerning the data and parameters ordered through the CERES subsetting/visualization/ordering tool https://ceres.larc.nasa.gov/data/, please email LaRC-CERES-Help@mail.nasa.gov.

For comments involving the CERES CCCM Data Quality Summary, please email LaRC-CERES-Help@mail.nasa.gov.

For questions concerning data ordered at the Atmospheric Science Data Center (ASDC) https://asdc.larc.nasa.gov/project/CERES, please contact the staff there.

8.0 Document Revision Record

The Document Revision Record contains information pertaining to approved document changes. The table lists the Version Number of the document, 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
V1	06/17/2024	• Initial version of document.	All