

Outgoing Longwave Radiation Climate Data Record

1. Intent of This Document and POC

1a) This document is intended for users who wish to compare satellite derived observations with climate model output in the context of the CMIP5/IPCC historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model output. References are provided at the end of this document to additional information.

Dataset File Name (as it appears on the ESGF):

--to be added once file is accepted-----

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units:	<i>rlut, W m⁻²</i>
Spatial resolution:	<i>1.0-deg in latitude and longitude</i>
Temporal resolution and extent:	<i>Daily and monthly averaged, from 01/1979 – 12/2013</i>
Coverage:	<i>Global</i>

3. Data Origin

The Daily OLR CDR algorithm main components include the HIRS radiance calibration, OLR retrievals (HIRS and Imagers), the HIRS/Imager OLR blending procedure, and the temporal integration that determines the daily mean OLR at each 1°x1° grid box. **Figure 1** provides the overview for the Daily OLR CDR production system.

HIRS Daily OLR CDR Production System Overview

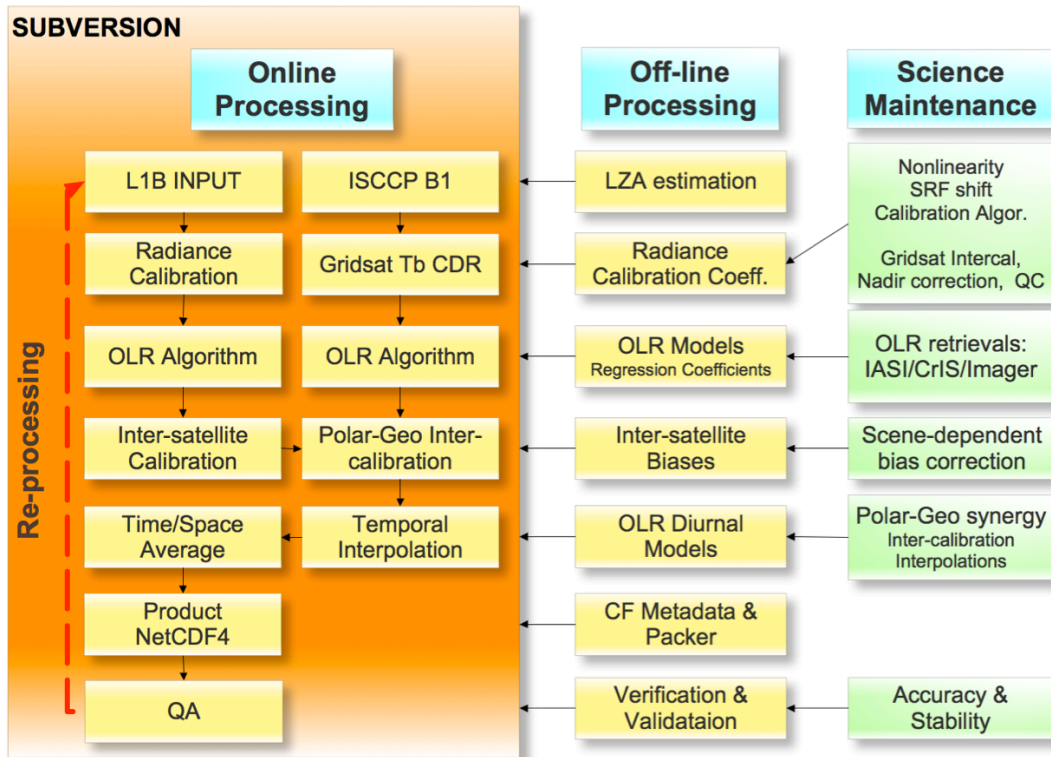


Figure 1 DAILY OLR CDR production system overview.

The HIRS/Imager OLR blending procedure performs the inter-calibration of the HIRS and Imager OLR, the temporal interpolation for missing (e.g., for orbital gaps over the tropics), and the daily integral. This is carried out over a “7-day boxcar” for each of the $1^\circ \times 1^\circ$ grid boxes, where the “7-day boxcar” is a moving boxcar unit spanning 7 days centered on the target day.

Polar orbiters have low temporal sampling rate – twice a day for a given location from each satellite. The daily OLR can be erred by as much as 100 Wm^{-2} locally if diurnal variation is not accounted for accurately yet the daily diurnal variation is too transient to be described by static diurnal models. The geostationary observations, with a 30-minute to 3-hourly refresh rate over full disk domains, can be used to provide the OLR diurnal variation information needed for accurate daily OLR determination.

A blending procedure is devised to merge HIRS/Imager OLR data for the daily OLR determination. Since the HIRS OLR retrieval has higher precision and is considered as the absolute radiometric reference, the Imager OLR is adjusted towards the HIRS OLR within a processing unit termed “7-day boxcar” on the grid-by-grid basis (see **Figure 2**).

The blending procedure involves the following steps:

1. HIRS OLR is gridded as hourly data time stamped at the middle of the hour; Imager OLR is gridded as 3-hourly data, stamped at the nominal hours, 00Z, 03Z, ...
2. Construct 7-day boxcar data with HIRS and Imager OLR data

3. Apply Inter-calibration for HIRS OLR. Average HIRS OLR if observations occupy on the same hour box.
4. Interpolate (spline) the Imager OLR to hourly bins and construct coincident HIRS/Imager pairs for use in Imager to HIRS calibration.
5. The Imager to HIRS calibration produces two results: (a) linear adjustment function; (b) an offset (ie., forced with slope one)
6. The linear regression may not always yield reliable results, e.g., when the OLR variation is low (leads to poor signal to noise ratio), or when the fitting has relative low confidence. The method (b) will be applied for either one of the following scenarios:
 - a. HIRS OLR variance is too small ($STD < 20 Wm^{-2}$)
 - b. The explained variance by the linear regression is less than 50%
 - c. When the number of calibration pairs is less than 7
7. Imager OLR data is adjusted and now reaching the same absolute radiometric level as in HIRS
8. Combine Imager OLR with HIRS OLR to form a single hourly time series
9. Apply trapezoidal rules over all available data (at a 3-hourly or better sampling rate) to derive the integral for the target day.
 - a. For full CDR production, the target day is the center (4th day) of the 7-day boxcar
 - b. For interim production, the target day will be on the 6th day for a 36-hr lag production

This process effectively removes scene-dependent biases in the Imager OLR retrievals. The 7-day temporal window provides sufficient number of coincident samples for Imager-to-HIRS calibration purpose while keeping the origins of the biases locally both in space and time (e.g., water vapor variation). It also enables the daily mean derivation even when HIRS is not available due to orbital gap or missing orbits on the target day, once the imager OLR data and its calibration information is available. This procedure essentially eliminates the need of spatial orbital gap filling which can cause relatively large errors even with the optimum interpolation method.

The daily temporal integral can then be accurately determined with all the available OLR data, the HIRS and the calibrated Imager OLR, at a 3-hourly or better temporal sampling interval.

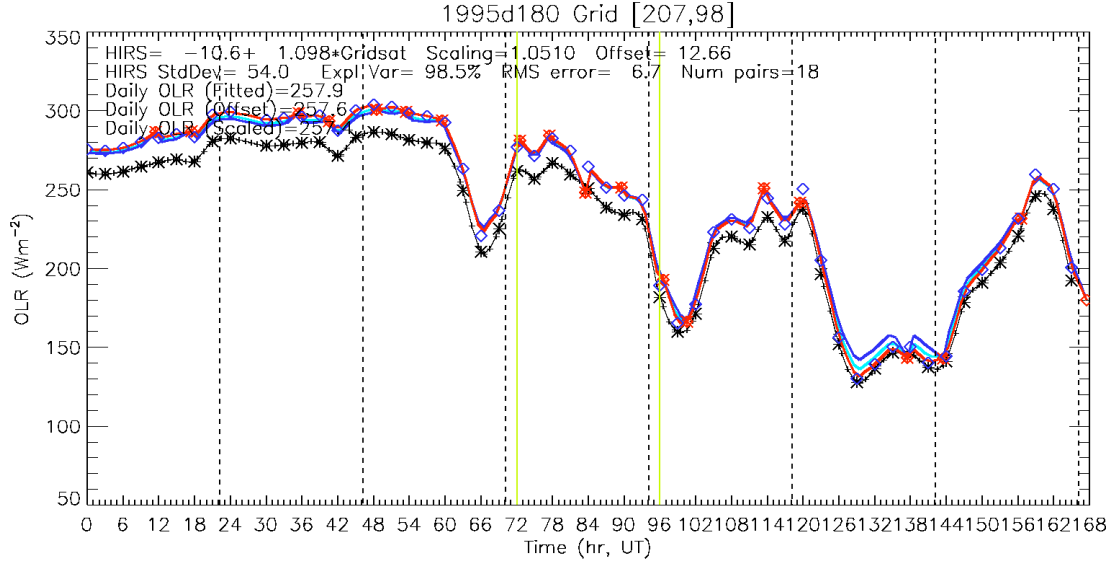


Figure 2 Example 7-day boxcar for day 180 of year 1995 on the grid cell [207,98]. The Imager OLR (black stars) is calibrated against the HIRS OLR (red points). The calibrated Imager OLR (blue diamonds) is obtained through the linear function determined by the regression on the coincident HIRS/Imager OLR pairs. The daily OLR for the target day (between the two green lines) is derived with trapezoidal rule applying to all OLR data, including the HIRS OLR and the calibrated Imager OLR data. To visualize the temporal integration, the red curve indicates the OLR variation described with combined HIRS and Imager OLR, after the Imager OLR is linear adjusted. The blue curve represents that when the imager OLR is adjusted only by the Offset, while the cyan curve represents that when the Imager OLR is adjusted by the scaling method (which is not used in this algorithm). The impact of the Imager OLR calibration can be seen as the gap between the black curve (connecting the original Imager OLR data points) and the red curve, with the latter represents the “best estimate” of the OLR diurnal variations with the blended information.

4. Validation and Uncertainty Estimate

The monthly dataset presented here is an average of the daily dataset. In the monthly dataset, *rlutNobs* refers to a per-grid-cell count of the number of non-fill values over each month. Similarly, *rlutStddev* is the standard deviation of non-fill values at each grid cell and month. No *Stderr* is available.

The multi-spectral OLR estimation method was developed by Ellingson et al. (1989) that use narrowband radiance observations from the High-resolution Infrared Sounder (HIRS) to estimate TOA total longwave flux. Vigorous validation efforts were performed for the HIRS OLR estimation technique against broadband observations derived from the Earth Radiation Budget Experiment (ERBE) and the Clouds and the Earth’s Radiant Energy System (CERES) (see Ellingson et al., 1994; Lee et al., 2007). The multi-spectral OLR estimation technique has been adapted successfully to the GOES- Sounder (Ba et al., 2003) and GOES-Imager instruments (Lee et al., 2004). These studies have shown that this OLR estimation algorithm can reliably achieve with an accuracy of about 4 to 8 Wm⁻² for various instrument type, with biases (precision) that

are within the respective radiometric accuracy of the reference instruments. The HIRS OLR algorithm has been implemented to generate the NESDIS operational HIRS OLR product since September 1998, and the GOES Imager OLR is implemented as part of the operational GOES Surface and Insolation Product (GSIP). A variant of this method has been developed and implemented for the upcoming GOES-R Advanced Baseline Imager instrument (Lee et al., 2010).

The precision and accuracy of the Daily OLR CDR product are determined by the comparisons to the reference broadband OLR products. Preliminary evaluations showed very good results. The assessments indicate that the Daily OLR CDR has an accuracy of about 2 Wm^{-2} with a precision of about 2 Wm^{-2} and with a significant improved stability referenced to the CERES EBAF Ed.2.6r, SYN1deg Ed.3A, and ERBS WFOV Non-scanner Ed.3rev1 OLR products (see Lee, 2014a, 2014b).

Figure 3 summarizes the OLR differences between Daily OLR CDR and the CERES EBAF Ed2.6r for about 12 years data record from March 2000 to June 2012, on the monthly basis. The mean and standard deviation of the OLR differences indicate that for the majority of the globe, the Daily OLR CDR is within $\pm 3 \text{ Wm}^{-2}$ relative to the EBAF with standard deviations within 3 Wm^{-2} . Note that the CERES OLR product has an uncertainty of about 1.5%.

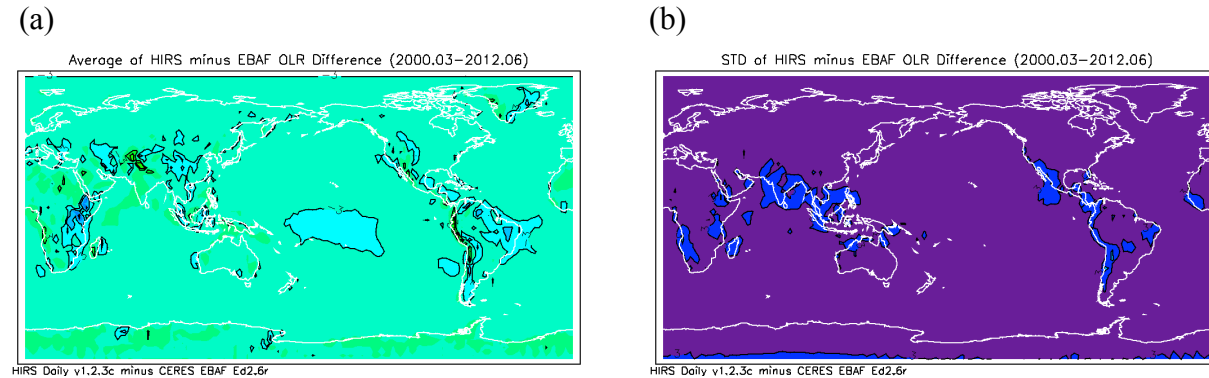


Figure 3 The OLR differences between Daily OLR CDR v01R02beta3c and the CERES EBAF Ed2.6r on the monthly basis: (a) mean OLR differences, and (b) standard deviation of the OLR differences, over the period of March 2000 to June 2012. Most areas in (a) are shown to have relative biases to within $\pm 3 \text{ Wm}^{-2}$. The purple and blue areas in (b) indicating standard deviations within 0-3 and 3-6 Wm^{-2} , respectively.

5. Considerations for Model-Observation Comparisons

Due to issues with the HIRS data, several periods have missing data for the entire grid. These include 25 days from 1980–1982, 179 days in 1985, and 4 days in 1994. All other grids should have valid data.

The availability of geostationary observations is not uniform over time as shown in **Figure 4**. The complete coverage was not achieved until late 1998, due to the unavailability of the Indian geostationary data. It is in general very heterogeneous in terms of observing instruments and spatial coverage. This imposes risks of introducing artifacts to the daily OLR derivation. The

blending procedure using “7-day boxcar” has put this into consideration, expecting that the grid-based calibration procedure can reliably remove the instrument and scene-dependent biases.

The monthly OLR product presented here is an average of the daily data. The resulting average will differ from the OLR-Monthly CDR (Lee et al. 2007), which does not include any geostationary data.

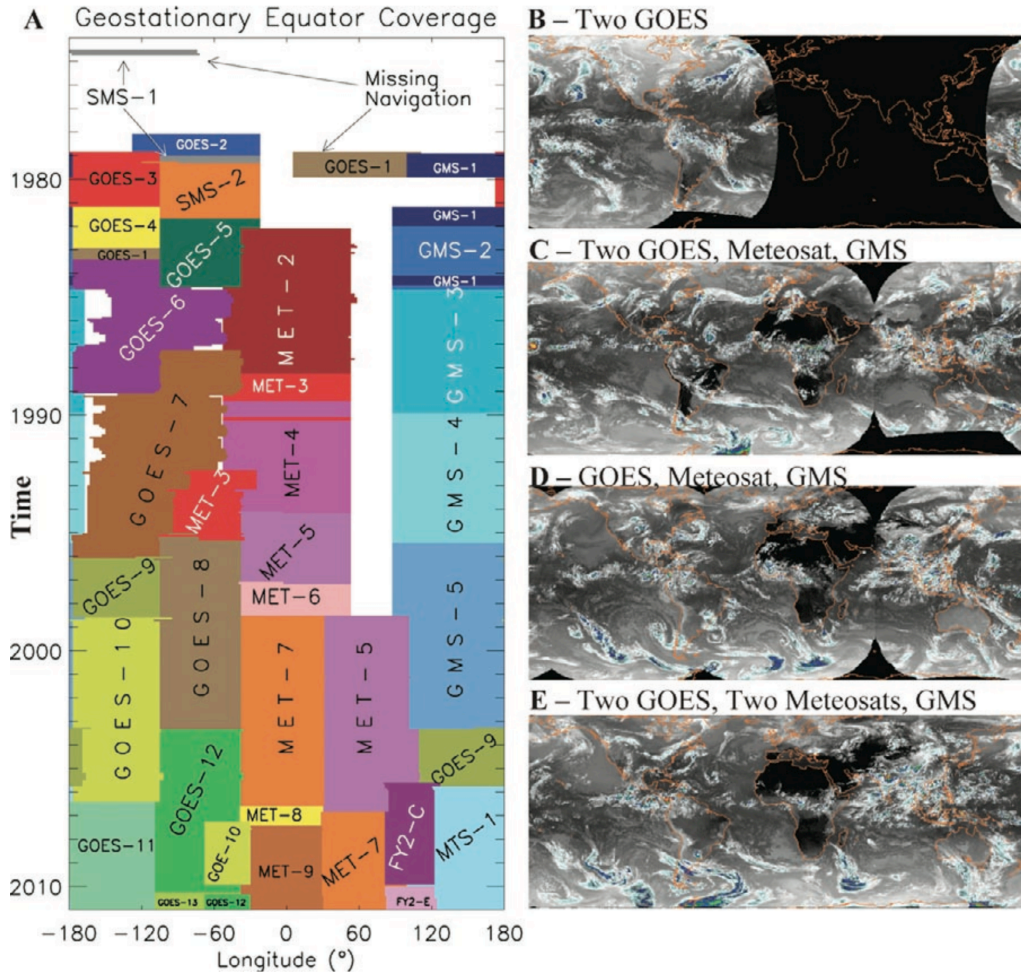


Figure 4 (a) Time series of ISCCP B1 geostationary satellite coverage at the equator (limited to a view zenith angle of 60° for illustrative purposes). (b)–(e) Sample GridSat coverage for typical satellite coverages: (b) two-satellite coverage with only *GOES-East* and *-West* in 1980, (c) four-satellite coverage that is typical of most of the period 1982–98, (d) typical three-satellite coverage when the United States was operating only one satellite (e.g., 1985–87 or 1989–92), and (e) five-satellite coverage that is typical of the current era (1998–present). Adapted from Knapp et al. (2011).

6. Instrument Overview

HIRS is one of the three sounding instruments that constitute the TIROS Operational Vertical Sounder (TOVS, and later becomes Advanced TOVS, ATOVS) system on board the NOAA TIROS-N series and Eumetsat MetOp-A/B satellites. The detailed description of HIRS instrument characteristics, Level-1b data format, the TOVS system, and the system configurations for the NOAA TIROS-N series polar orbiters can be found in the NOAA Polar Orbiter Data (POD) User's Guide (1998 version) and NOAA KLM User's Guide (2009 version).

The geostationary data comes from the GridSat CDR dataset (Knapp et al. 2011), which is derived from ISCCP B1 data (Knapp et al. 2008). Gridsat provides the inter-calibrated and limb-corrected brightness temperatures for window and water vapor channels. The Gridsat OLR is estimated with an algorithm adapted from the AVHRR OLR algorithm (Ohring et al., 1984). The uncertainties are about 3 to 4 times larger than those of HIRS OLR retrievals because the Imager observations lack of atmospheric vertical structure information, so the GridSat OLR is calibrated against the HIRS OLR retrievals to maintain absolute radiometric accuracy.

7. References

Dataset Citations

Lee, H.-T., 2014: *Climate Algorithm Theoretical Basis Document (C-ATBD): Outgoing Longwave Radiation (OLR) - Daily*. NOAA's Climate Data Record (CDR) Program, CDRP-ATBD-0526, 46 pp.

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Additional Reading

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8. Dataset and Document Revision History

Rev 0 – 27 January 2015