Improving the CERES Derivation of SW TOA Broadband Fluxes from GEO Narrowband Radiances with the Anticipation of the Next Generation GEO Sensors

F. J. Wrenn IV[1], D. R. Doelling[2], L. Liang[1], L. C. Nguyen[1], M. Sun[1], and R. I. Raju[1]

1. Science Systems and Applications, Inc. Hampton, VA 2. NASA Langley Research Center Hampton, VA

CERES monthly averaged datasets

CERES provides the climate community 3 types of monthly averaged datasets and are available at the following web site.
http://ceres.larc.nasa.gov/order_data.php

1) EBAF – Monthly and climatological averages of TOA and surface clear-sky (spatially complete) fluxes, all-sky fluxes, and cloud radiative effect (CRE), where the TOA net flux is constrained to the ocean heat storage term (0.58Wm^{-2}). These fluxes are appropriate for climate model comparisons, since the net balance is not tied to the CERES calibration and surface fluxes are consistent with the TOA fluxes. These fluxes are diurnally complete.
2) SSF1deg – CERES single satellite monthly and daily averaged TOA fluxes and MODIS cloud properties using constant meteorology at the time of the CERES measurement. These fluxes are not diurnally complete and should not be used when comparing to other Terra or Aqua datasets
3) SYN1deg – CERES monthly and daily averaged combined Terra and Aqua satellite fluxes and MODIS cloud properties with 3-hourly 5-satellite geostationary derived broadband fluxes and cloud properties. The geostationary derived broadband fluxes are used to infer the flux in between the CERES observations on either Terra (10:30) or Aqua (1:30pm) satellites. These fluxes are diurnally complete, but do contain some residual geostationary artifacts. The geostationary derived broadband fluxes are carefully normalized to the CERES fluxes to maintain the CERES instrument calibration and remove artifacts.

Level 3B: Spatially (regional, global, etc.) and temporally (daily, monthly, etc) averaged fluxes where the net flux has been energy balanced.

Data Product (Information & Documentation)	Description	Parameter	Resolution	Version/ Availability	Order Data
EBAF-TOA	Monthly and climatological averages of TOA clear-sky (spatially complete) fluxes, all-sky fluxes, and cloud radiative effect (CRE), where the TOA net flux is constrained to the ocean heat storage. Data Quality Summary	i	i	i	Browse & Subset
EBAF-Surface	Monthly and climatological averages of computed surface clear-sky fluxes, all-sky fluxes, and cloud radiative effect (CRE), consistent with the CERES EBAF-TOA fluxes. Data Quality Summary User-Applied Grid Correction	i	i	i	Browse & Subset

Level 3: Spatially (regional, global, etc.) and temporally (daily, monthly, etc) averaged fluxes and clouds.

Data Product (Information & Documentation)	Description	Parameter	Resolution	Version/ Availability	Order Data
SYN1deg	CERES geostationary (GEO) enhanced temporally interpolated TOA fluxes, MODIS and 3-hourly GEO cloud properties, MODIS aerosols, and computed TOA, surface and in-atmospheric (profile) fluxes consistent with the observed TOA fluxes, clouds and aerosols. Data Quality Summary	i	i	i	Browse & Subset
SSF1deg	CERES constant meteorology temporally interpolated TOA fluxes, MODIS clouds and aerosols. Data Quality Summary	i	i	i	Browse & Subset
ISCCP-D2like	CERES-MODIS and GEO daytime cloud properties stratified by ISCCP cloud types and in the similar D2 format. Data Quality Summary	i	i	i	Browse & Subset

Level 2: CERES instantaneous footprint level (20km nominal) fluxes and cloud properties.

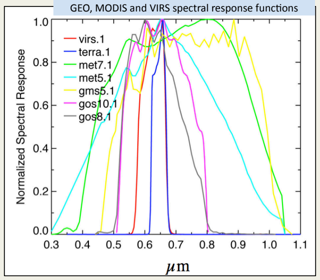
Data Product (Information & Documentation)	Description	Parameter	Resolution	Version/ Availability	Order Data
SSF	CERES observed TOA fluxes, MODIS clouds and aerosols, and parameterized surface fluxes. Terra Data Quality Summary Aqua Data Quality Summary	i	FOV*	i	Browse & Subset

*FOV: Field-of-View instantaneous footprint data.

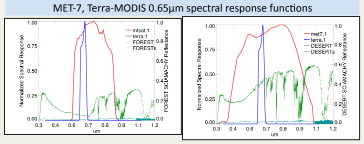
Background

1) CERES has used 15 GEO satellites over the last 12 years. Each one has a unique spectral response function. The older GEOs have mainly broadband functions, whereas the newer and future imagers will resemble the MODIS channels.
2) The GEO radiances need to be converted into broadband radiances in the CERES processing to estimate the diurnal flux in between CERES measurements.
3) These must be a function of surface, cloud and angle, since each of these has a very different spectral signature

GEO, MODIS and VIRS spectral response functions

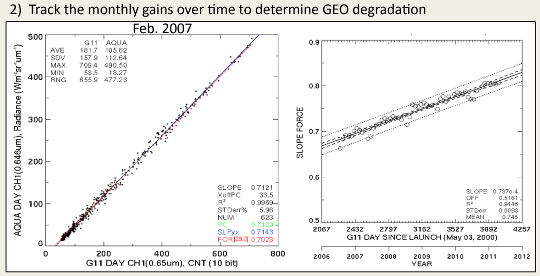


Forest and desert spectral reflectances from SCIAMACHY and MTSAT-1, MET-7, Terra-MODIS 0.65μm spectral response functions



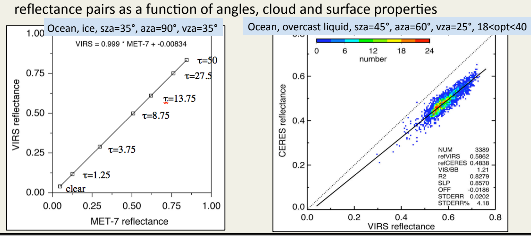
GEO visible inter-calibration with MODIS

1) Linearly regress coincident ray-matched or bore-sighted GEO visible counts and MODIS 0.65μm radiance to obtain monthly gains.
2) Track the monthly gains over time to determine GEO degradation



GEO narrowband to broadband models

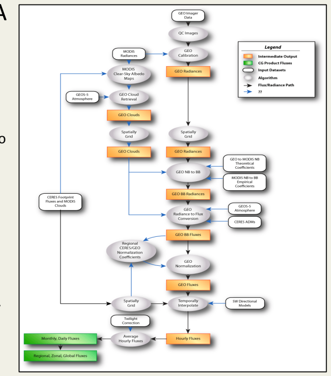
1) Compute, using DISORT, the GEO and MODIS/VIRS reflectances as a function of angles, cloud and surface properties. Use a linear regression of reflectance pairs based on optical depth to convert GEO reflectance to MODIS/VIRS reflectance
2) Compute the linear regression of MODIS/VIRS and CERES observed coincident reflectance pairs as a function of angles, cloud and surface properties



GEO visible narrowband radiance to SW TOA flux conversion Edition2 methodology

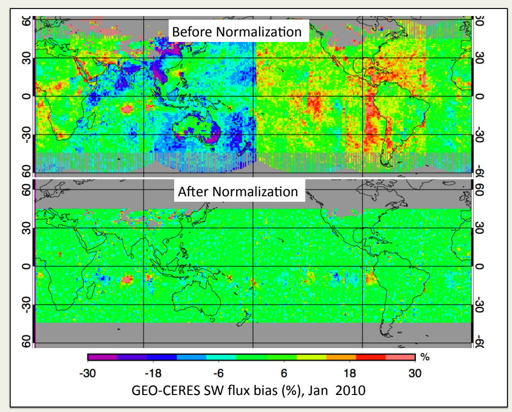
The GEO radiances are converted broadband fluxes using a 6-step process.

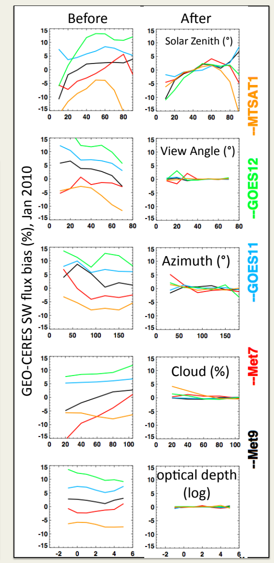
1) The GEO visible radiances are inter-calibrated against Terra-MODIS 0.65μm calibration, since they have no onboard calibration.
2) The GEO visible and IR radiances are used to compute GEO cloud properties. These cloud properties will select the correct narrowband to broadband and angular directional model (ADM) factors
3) The GEO visible radiances are converted to equivalent MODIS 0.65μm radiances using DISORT as a function of angle and cloud properties.
4) The GEO equivalent MODIS 0.65μm radiances are converted to CERES-like broadband radiances using empirical model based on coincident MODIS 0.65 μm and CERES radiances using CERES SSF or footprint dataset.
5) The GEO broadband radiances are converted to fluxes using the same CERES angular directional models that CERES instrument radiances use.
6) The GEO derived broadband fluxes are then normalized regionally by regressing the GEO and CERES coincident fluxes order to maintain the CERES instrument calibration. This removes most regional, angular, cloud property dependent GEO SWTOA flux artifacts.



GEO derived broadband regional flux normalization

Using a moving 5°x5° latitude by longitude domain linearly regress all of the coincident GEO and CERES SW TOA 1°x1° regional fluxes within an 1.5 hour. This ensures that most dependencies are not biased as a function of angles, region or cloud properties.





Future Work (Edition 4)

1) Instead of using a 2-step GEO visible narrowband to CERES broadband SW TOA flux conversion, eliminate the GEO equivalent MODIS 0.65μm conversion step and directly convert using DISORT theoretical radiances. Also use all available visible channels on the new GEO sensors
2) Retrieve 5 channel GEO cloud properties rather than 2-channel, taking advantage of the new multi-channel GEO imagers
3) Use hourly GEO data, eliminating the need for temporal interpolation in between CERES and 3-hourly GEO fluxes
4) Use both GEO IR and WV channels to convert to broadband LW fluxes