Improvements to Broadband Shortwave and Longwave Top of Atmosphere Fluxes from Geostationary Satellites

Science and Systems Applications Inc, Hampton, VA

**Introduction**

- Satellite monitoring of top-of-atmosphere (TOA) broadband (BB) shortwave (SW) and longwave (LW) fluxes is important for understanding cloud-radiative interactions, evaluating climate change, and for other applications.
- Geostationary satellites (GEO) are advantageous since their positioning allows them to observe the full diurnal cycle across most of the globe with high temporal resolution. Most GEO’s, however, are only equipped with broadband (NB) instruments.
- Narrowband-to-broadband (NB-BB) flux conversions are employed operationally within the NASA Langley SaCORPS (Satellite Cloud Observations and Radiative Property retrieval System) in order to estimate BB radiation parameters at GEO resolutions, but have limitations.

**Objectives**

- Improve SaCORPS NB-BB formulas by incorporating additional NB spectral information, and by better accounting for dependencies on view angle, water vapor loading, scene type and seasonality
- Apply initially to GOES-13 covering ARM (Atmospheric Radiation Measurement) Mobile Facility GO-AMAZON (Green Ocean-AMAZON) domain
- Assess accuracy of improvements and potential for application to other geostationary satellites

**Validation with CERES: GOES-13 Derived LW fluxes vs Aqua and Terra**

- Table 1: Comparison of LW fluxes from GOES-13 and CERES Aqua for different days and scenes.

**Results**

- Figure 3: GOES-13 LW fluxes are then normalized to CERES. This step accounts for variation in surface albedo and other systematic changes from the globally derived MODIS-CERES LW NB-BB fits, improving the linear correlation. A linear correction is determined for each 1 bin in the GO-SHORST domain, from monthly matched data within the surrounding 5 x 5 region.

**New SW NB-BB Procedure (in progress)**

- Operational method (data and domain same as LW Method)

**Summary**

- A new LW NB-BB procedure has been developed using MODIS 6.7/11um and CERES BB fluxes which better accounts for dependencies on water vapor, scene type, view angle, time of day, and seasonality
- RMS errors for LW MODIS-CERES NB-BB fits: daytime LW 0.53-5.2%; Ocean 0.5%-4.4%; Snow 0.8%-6.0% Nighttime LW 0.5%-4.0%; Ocean 0.4%-3.7%; Snow 0.7%-2.4%
- Validation with CERES Terra and Aqua shows decreased LW Bias and RMS over the GO-DIAMOND domain/O/P’s, when applying updated fits and normalization

**Future Work**

- Apply to other geostationary satellites and domains
- More validation with CERES and comparisons with Fu-Liou modeled fluxes
- New Procedure for SW NB-BB in development that adapts CERES Edition 5 NB-BB methodology:
  - Incorporates theoretical RT modeled BB SW radiation, since angle bins (SZA, RAZ) from Aqua/Terra are incomplete for SW GEO applications
  - Initial evaluation will utilize GOES-13 GO-AMAZON dataset validated with CERES and Fu-Liou RT modeled fluxes

**NW/NB-NB procedure**

- Proposed GMT/RT model applied to BB SW and LW
- In progress: accuracy and potential for application to other GEOs

** LW Data & Methodology**

**“Operational” NB-BB Flux Fits:**

- Input data for Fit:
  - CERES footprints Terra, Aqua/L&P MODIS EE5 BB fluxes \( M_{\text{eff}} \)
  - GOES-NB matched resolution 15 min fluxes \( R_{\text{GOES}} \)
  - LW fluxes derived separately for land and ocean, but include both day/night
  - Derived over Florida Domain, Summer 2002

- Fit matched data to:

\[
M_{\text{eff}} = A + A_{\text{LW}}M_{\text{eff}} + A_{\text{BB}}M_{\text{eff}} + A_{\text{MB}}(\text{VH}) \quad \text{(1)}
\]

Where \( M_{\text{eff}} = \text{LW flux} \times \text{VH} \) or \( \text{daytime column-weighted RH from model, e.g. RUC}\)

**“Updated” NB-BB Flux Fits:**

- Input data for Fit:
  - Global, month-specific CERES Aqua PM Edition 4 Single Scanner Footprint (SSF)
  - Collocated CERES BB LW fluxes \( M_{\text{NB}} \)
  - MODIS NB 11um \( R_{\text{NB}} \) , 8um \( R_{\text{NB}} \) radiances
  - LW fluxes derived in similar fashion to CERES SYN1deg product LW NB-BB
  - Day vs night
  - 7 scene types (Ocean, Snow, Forest, Grass, Bright Desert, Dark Desert)
  - Derived using Visible Zonal Averages (VZA, Total Precipitable Water (TPW), and \( R_{\text{NB}} \))
  - \( R_{\text{NB}} \) bin splits (0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10) (from CERES MOD Products)
  - \( R_{\text{NB}} \) bin separation 0.06 for MODIS.
  - \( R_{\text{NB}} \) using MODIS VZA (0.00, 0.01, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12)
  - \( R_{\text{NB}} \) (VZA) = 0.00, 0.01, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12

- Fit matched data to:

\[
M_{\text{NB}} = a + bR_{\text{NB}} + cR_{\text{NB}} + dR_{\text{NB}}^{2} \quad \text{(2)}
\]

- GOES-13 11um, 8um brightness temperatures calibrated to MODIS
- MODIS-CERES fits applied to GOES-13 \( R_{\text{NB}} \) \( R_{\text{NB}} \) yield intermediate fluxes \( M_{\text{eff}} \)
  - Applied over GO-AMAZON domain (39N-10S, 50W-70W)
  - GO-AMAZON IOP 1 & 2 (Feb-Mar 84 Wet Season, Sep-Oct 14 Dry Season)
- GOES-13 updated intermediate fluxes \( M_{\text{NB}} \) normalized to CERES Aqua
  - match 1+ GOES-13 vs CERES Aqua Edition 3 Surface Fluxes and Clouds (SFC) gridded 1st LW fluxes within local region during month
  - determine linear correction, apply to each \( R_{\text{NB}} \) gridbox to yield final “Updated” LW fluxes

- Validate by comparing results with CERES SFC Terra, and CERES Edition 4 SYN1deg gridded hourly product

**Validation with CERES: GOES-13 Derived LW fluxes vs Aqua and Terra**

- Figure 2: Validation with CERES Terra and Aqua shows decreased LW Bias and RMS over the GO-DIAMOND domain/O/P’s, when applying updated fits and normalization

**More Information and Data Available:**

- Mandana Thieman (m.m.thieman@nasa.gov)
- William Smith, Jr (william.l.smith@nasa.gov)
- Patrick Minnis (p.minnis@nasa.gov)

**Figure 1.** Global monthly March 2014 Ocean Day MODIS R\(_{10}\), plotted against collocated Aqua CERES BB fluxes. Plot represents flux at Planet-view (VZA < 20°) and Aqua-view (VZA > 20°). Vertical lines depict boundaries of \( R_{10} \) bins.

**Figure 2.** Relative difference between GOES-13 and CERES Aqua BB for different days and scenes.

**Figure 3.** GOES-13 LW fluxes are then normalized to CERES. This step accounts for variation in surface albedo and other systematic changes from the globally derived MODIS-CERES LW NB-BB fits, improving the linear correlation. A linear correction is determined for each \( 1 \) \( \times 1 \) gridbox in the GO-SHORST domain, from monthly matched data within the surrounding \( 5 \times 5 \) region.