Top-of-Atmosphere Shortwave and Longwave Broadband Fluxes Derived over ARM SGP using Improved Techniques

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Introduction

- Top-of-atmosphere (TOA) broadband (BB) longwave (LW) and shortwave (SW) fluxes needed to evaluate Earth's Radiation Budget (ERB)/climate change & to study cloud and radiative interactions
- Current satellites with long temporal record measure SGP fluxes at roughly the same local times daily
  - -CERES *Terra*: 1030/2230 LT *Aqua*: 0130/1330 LT
- TRMM observes at a range of times, but on-board CERES was only available Jan-Aug 1998
- Geostationary (GEO) satellites can estimate TOA fluxes 24/7
  - -narrowband (NB) radiances converted to BB SW and LW fluxes, using current empirical fits to CERES Terra data
  - -Difficult to adequately capture diurnal cycle with limited CERES overpasses
- NASA/Langley Cloud group routinely derives cloud & radiative parameters from various satellites using VISST & SIST algorithms
  - -GOES-x vs CERES Terra NB-BB fits, accounting for seasonal and diurnal changes routinely used to convert GOES NB to BB fluxes over ARM SGP
  - -Examine ways to better estimate diurnal cycle/improve overall accuracy, in GOES-8 derived SW and LW fluxes
    - -*Implement TRMM to increase SZA range of observations*
    - -*Investigate use of GOES-8 6.7 & 11-μm fluxes in LW NB-BB fit, after Sun et al*

OBJECTIVE

- Develop & assess fits for SGP based on CERES Terra, TRMM & GOES-8 data

Approach

- Match 1° averages of GEO data with CERES SFC (32-42°N, 91-105°W)
  Fits: Jun-Aug00: GOES8/Terra (operational fit) & GOES8/TRMM-Terra
- Compare results of both fits using Jul-Aug 02 CERES Terra & Aqua data
- Compare Fu-Liou modeled & GOES8-derived fluxes over diurnal cycle

Data & Methodology

- CERES 1°grid instantaneous Gridded Surface Fluxes and Clouds (SFC):
  Terra Ed3, Aqua Ed3 CERES FM-1/2/3 scanner,TRMM Ed2B PFM BB fluxes:

A_{SW} = SW albedo; M_{LW} = LW flux or OLR; $M_{SW} = A_{sw} * E_o * \mu_o$
E_o = incoming SW flux, μ_o = cos(SZA), SZA = solar zenith angle

- GOES-8 1°-avg calibrated 0.65-μm albedos A_{nb} and 10.8-μm fluxes M_{nb}
- Match Jun-Aug00 CERES & GOES-8 1° data within ±15 minutes of overpass time for CERES Terra (TRMM) VZA < 65° (45°)
- Fit matched data to[1]:

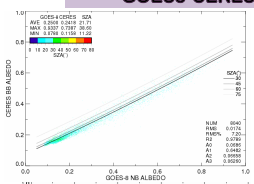
$$A_{SW} = a_0 + a_1 * A_{nb} + a_2 * A_{nb}^2 + a_3 * \ln(1/\mu_o) \quad (1)$$

$$M_{LW} = A_0 + A_1 * M_{nb} + A_2 * M_{nb}^2 + A_3 * M_{nb} * \ln(\text{colRH}) \quad (2)$$

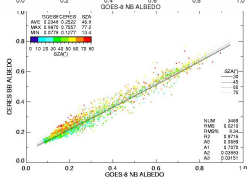
where colRH=column-weighted RH from RUC profiles

- Apply 3rd-order correction to OLR

GOES8-CERES SW NB-BB Fits

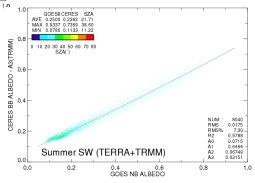


Summer (Jun-Aug00) daytime GOES-8 NB regressed against Terra BB albedos. Terra's 1/daytime overpass at ~10:30 AM limit SZA to a narrow range. This fit can yield good accuracy near Terra overpass times, but reduced accuracy during rest of the day.



Jan-Aug98 daytime GOES-8 NB regressed against TRMM BB fluxes. TRMM's precessing orbit yields observations at all times of day, increasing SZA range, providing a more robust fit. However, TRMM data only available for 8 months.

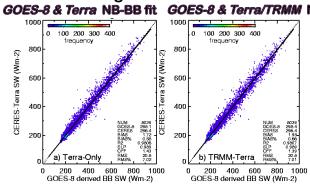
To use the strengths of long-term Terra coverage and enhanced SZA range of TRMM, the SZA term from the TRMM NB-BB fit is combined with data used to create the Terra fit.



SW Validation with CERES

Jun-Aug00 GOES-8 vs Terra

GOES-8 & Terra NB-BB fit *GOES-8 & Terra/TRMM* NB-BB fit

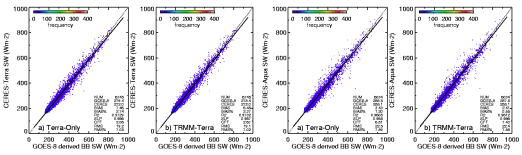


SW fluxes from using Jun-Aug00 from two fits compared to CERES Ed3 Terra fluxes

Independent Assessment: Jul-Aug02 GOES-8 vs Terra/Aqua

GOES8vs Terra-TRMM NB-BB fit

GOES-8 vs Terra GOES-8 vs Aqua



Jul-Aug02 GOES-8 SW fluxes compared to CERES Ed3 Terra data.

Same as at left, but with respect to CERES Ed3 Aqua. Bias and RMS errors summarized in table below.

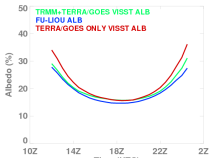
Bias (RMS) Errors	SW, Wm^{-2} w/r/t Terra	SW, Wm^{-2} w/r/t/ Aqua
G8-Terra	7.5 (19.2)	3.4 (22.5)
G8-TRMM/Tr	6.5 (19.1)	2.4 (22.4)

• Biases and RMS errors slightly improved using Terra-TRMM NB-BB fit

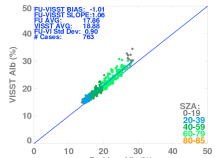
Comparison of GOES8 SW with Theory

Fu-Liou Radiative Transfer Model (RTM) Fluxes

- Correlated-k distribution code; 2 stream SW, 2/4 stream LW
- Spectral surface emissivity (BB ~0.981)[2]
- Surface albedo derived from CERES obs clr-sky TOA[3]
- ARM MFRSR aerosol optical depths
- Cloud properties from VISST/SIST applied to GOES-8 as input
- Used ECMWF/DAO sounding data[4] & O_3
- Used VISST-derived & ECMWF/DAO Skin Temperature



Jun-Aug00 clr-sky SW fluxes, RTM vs GOES-8: half-hourly binned averages of SW albedo. Updated GOES8-Terra/TRMM fit tracks RTM better than operational GOES8-Terra fit.

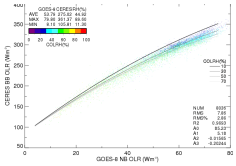


Scatterplot of Jun-Aug00 RTM vs GOES-8-Terra/TRMM derived clear-sky SW albedos; bias smaller compared to GOES8-Terra fit (see table below).

Summary of differences between RTM-derived & GOES-8 SW BB fluxes for 1° box (36.5°N 97.5°W), for G8-Terra & G8-Terra/TRMM fits.

$SW_{RTM} - SW_{G8}$	Clr Bias (W/m^2)
G8-Terra	-2.1
G8-Terra/TRMM	-1.0

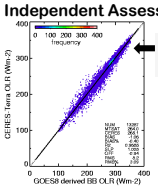
GOES8-CERES LW NB-BB Fits



Summer (Jun-Aug00) daytime GOES-8 NB LW fluxes regressed against Terra BB fluxes; summer nighttime GOES8-Terra fit also derived (not shown).

LW Validation with CERES

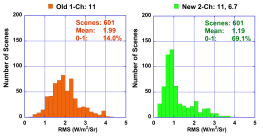
Independent Assessment: Jul-Aug02 GOES-8 vs Terra/Aqua



Jul-Aug02 LW fluxes from GOES-8 using Summer 2000 GOES-8/TRMM-Terra fit, compared to CERES Ed3 Terra. Other comparisons summarized below:

Bias (RMS) Errors	LW, Wm^{-2} w/r/t Terra	LW, Wm^{-2} w/r/t/ Aqua
Jul-Aug 2002	-1.1 (8.2)	-0.8 (7.8)
Jun-Aug 2000	-0.8 (8.3)	N/A

Future Work: Implementation of 6.7 & 11 μm in LW NB-BB fit

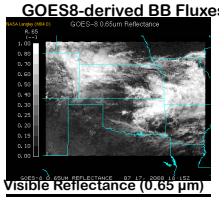


Preliminary work by M. Sun et al shows improved BB LW fluxes, when 6.7 & 11μm NB radiances used in NB-BB fit. For 601 scenes in April 2000, mean RMS dropped from 2.0 W/m² (w/11 μm) to 1.2 W/m² using 6.7+11μm fit, given by:

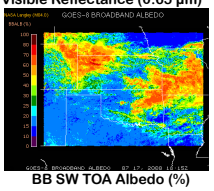
$$LW_{est} = a_0 + a_1 Rad_{11\mu m} + a_2 Rad_{6.7\mu m}$$

Results

GOES8-derived BB Fluxes: 1815 UTC July 17, 2000



Visible Reflectance (0.65 μm) IR Brightness Temp (K; 11 μm)



BB SW TOA Albedo (%) BB LW TOA Flux (Wm-2)

Summary

SW

- Improved GOES-8 derived BB SW TOA fluxes
  - Derivation of seasonal SW fits
  - New fit derived using Terra (advantage: availability of long-range record) and TRMM (observations at wider SZA range)
  - Combined Terra-TRMM SW fit for GOES-8 improved biases (compared to G8-Terra fit) when compared to Summer 2000, 2002 Terra and Aqua observations, as well as RTM
- BB SW clr-sky albedos from G8-Terra/TRMM compare well with RTM, improving bias from -2.1 W/m² (G8-Terra) to -1.0 W/m²

LW

- Derived GOES-8-Terra BB LW fit using 11um only
  - Seasonal, day-night differences accounted for
  - Validated summer 2000 (Terra) & 2002 (Terra and Aqua)

Future work

- Evaluate Jan-Aug98 GOES8-TRMM SW on a seasonal basis
- Apply seasonal TRMM SZA observation capability to SW G8-Terra fits from other seasons/time periods, to evaluate improvement
- Further examine usage of both 6.7 and 11um channels in derivation of seasonal/day/night LW GOES8-Terra fits.
  - Re-derive NB-BB fits for all available years, seasons of SGP GOES-8-15, TWP MTSAT-1/2
- Process VISST datasets using updated NB-BB fits
  (http://www-pm.larc.nasa.gov)

References

1 - Minnis, P. and W. L. Smith, Jr., 1998: *Geophys. Res. Lett.*, **25**, 1113-1116.
2- Wilbur, A. C., D. P. Kratz, S. K. Gupta, 1999: Surface Emissivity Maps for Use in Satellite Retrievals of Longwave Radiation. NASA/TP-1999-209362, 35 pp.
3- Rutan, D., F. Rose, M. Roman, N. Manalo-Smith, C. Schaaf, and T. Charlock (2009), Development and assessment of broadband surface albedo from Clouds and the Earth's Radiant Energy System Clouds and Radiation Swath data product, *J. Geophys. Res.*, **114, D08125, doi:10.1029/2008JD010669.**
4- Caldwell et al., 2006, NASA.