Improved TOA Broadband Shortwave and Longwave Fluxes Derived for SGP using GOES-11

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Introduction

- Diurnal cycle of Earth radiation budget (ERB) a key factor in thermo-dynamic and hydrological processes, esp. convective heat exchange, at various large scales; models should be able to simulate it
- Current satellites measure non-polar ERB only at specific local times
  - CERES *Terra*: 1030/2230 LT *Aqua*: 0130/1330 LT
- Geostationary (GEO) satellites can estimate TOA fluxes 24/7
  - need conversion of narrowband (NB) radiances to broadband (BB) shortwave (SW) and longwave (LW) fluxes
- NASA/Langley Cloud group routinely derives cloud & radiative parameters from various satellites using VISST & SIST algorithms
  - empirical fits (1 LW, 1 SW) from 2004 GOES-10 & CERES Terra routinely used to convert GOES-11 NB to BB fluxes over ARM Southern Great Plains (SGP)
  - need GOES-11 specific fits that account for day/night and seasonal differences, to estimate GOES-11 BB fluxes for Jun 2006 - onward

OBJECTIVE

- Develop & assess fits for SGP based on CERES Terra,Aqua & GOES-11 data

Approach

- Match 1^o averages of GEO data with CERES SFC (32-42^{o}N, 91-105^{o}W)
  Fits: 2004 GOES-10/Terra (operational) and 2007 GOES-11/Terra & Aqua
- Compare results of both fits using 2008-09 CERES Terra and Aqua data
- Compare modeled & GOES-11 fluxes over diurnal cycle

Data & Methodology

- CERES 1°grid instantaneous Gridded Surface Fluxes and Clouds (SFC): Terra Ed2F, Aqua Ed2C Rev-1 CERES FM-1/2/3 scanner 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
- GOES11 1°-avg calibrated 0.65-µm albedos A_{nb} and 10.8-µm fluxes M_{nb}
- Match 2007 CERES & GOES-11 1° data within ±15 minutes of overpass time for CERES VZA < 65°
- Fit matched data to[1]:

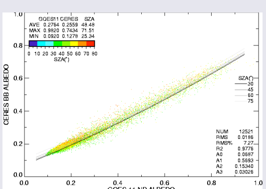
$$A_{SW} = a_0 + a_1 * A_{nb} + a_2 * A_{nb}^2 + a_3 * \ln(1/\mu_o) \quad (1)$$

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

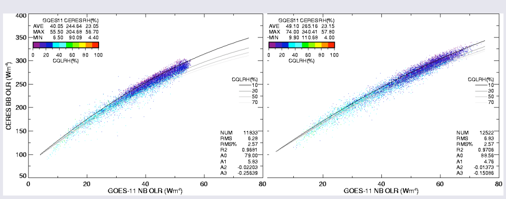
where colRH=column-weighted RH from RUC profiles

- Apply 3rd-order correction to OLR

GOES11-CERES *Terra/Aqua* NB-BB Fits



Autumn (Sep-Nov07) daytime GOES-11 NB regressed against Terra and Aqua CERES BB fluxes at 1^o res) albedo (top), and LW fluxes for nighttime (bottom left) and daytime (bottom right). Spring, summer and winter seasonal fits for the rest of 2007 were also derived (not shown).

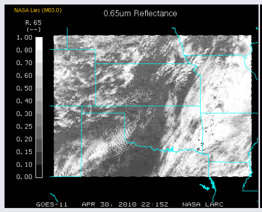


RMS errors for 2007 GOES-11 vs Terra-Aqua NB-BB fits

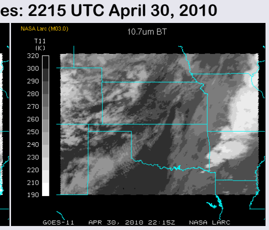
RMS Errors	OLR Day, Wm^{-2}	OLR Night, Wm^{-2}	Land SW, albedo
Spring (Mar-May)	8.0 (3.3%)	7.5 (3.4%)	0.019 (6.4%)
Summer(Jun-Aug)	7.4 (2.7%)	8.6 (3.5%)	0.017 (7.5%)
Autumn (Sep-Nov)	6.8 (2.6%)	6.3 (2.6%)	0.019 (7.3%)
Winter (Dec-Feb)	6.2 (2.8%)	5.1 (2.4%)	0.023 (5.9%)

Results

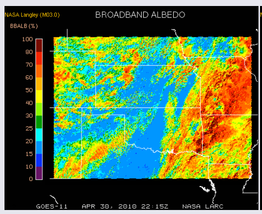
GOES11-derived BB Fluxes: 2215 UTC April 30, 2010



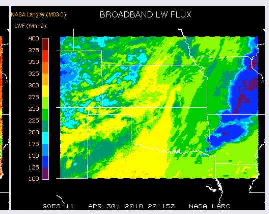
Visible Reflectance (0.65 µm)



IR Brightness Temp (K; 11 µm)



BB SW TOA Albedo (%)



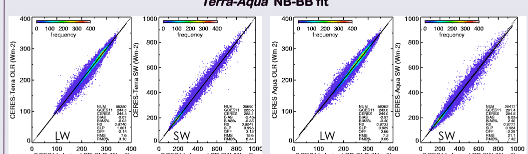
BB LW TOA Flux (Wm^{-2})

Validation with CERES

2007 GOES-11 vs Terra, Aqua

GOES-11 vs Terra | GOES-11 vs Aqua

Terra-Aqua NB-BB fit

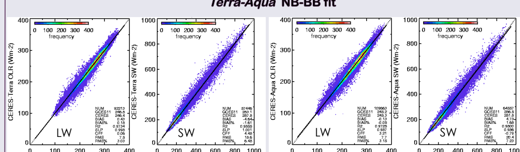


GOES-11 fluxes derived using 2007 GOES-11 vs Terra-Aqua NB-BB fits, compared to CERES Terra (left) and Aqua (right) BB fluxes, for same time period.

Independent Assessment: 2008-09 GOES-11 vs Terra/Aqua

GOES-11 vs Terra | GOES-11 vs Aqua

Terra-Aqua NB-BB fit



GOES-11 fluxes, derived using 2007 GOES-11 vs Terra-Aqua fit, compared to CERES Ed2G Terra (left) and Ed2D Aqua (right) BB fluxes, 2008-09. Results compared with fluxes derived using GOES-10 vs Terra NB-BB fit in table below.

Bias (RMS) Errors	LW, Wm^{-2}	SW, Wm^{-2}	LW, Wm^{-2}	SW, Wm^{-2}
	w/r/t Terra		w/r/t/ Aqua	
G10-Terra	-3.3 (7.5)	16.7 (19.2)	-4.0 (7.9)	27.0 (21.0)
G11-Terra/ Aqua	0.4 (7.5)	-4.6 (18.6)	-0.1 (7.7)	4.7 (20.4)

- All biases improved by using Terra-Aqua NB-BB fit

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.

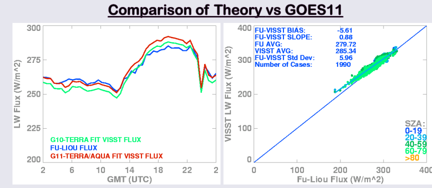
3- Rutan, D., F. Rose, M. Roman, N. Manalo-Smith, C. Schaaf, and T. Charlock (2009), Development and assessment of broadband surface albedo from Clouds and the Earth's Radiant Energy System Clouds and Radiation Swath data product, *J. Geophys. Res.*, ***114*, *D08125, doi:10.1029/2008JD010669.***

4- Caldwell et al., 2006, NASA.

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-11 as input
  (http://www-angler.larc.nasa.gov)
- Used ECMWF/DAO sounding data[4] & O_3
- Used VISST-derived & ECMWF/DAO Skin Temperature

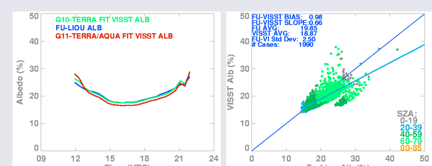
Comparison of Theory vs GOES11



Comparison of 2008 clr-sky LW fluxes from RTM and *GOES-11*: half-hourly binned averages of LW flux (left); scatterplot of LW fluxes derived using G11-Terra/Aqua fit vs RTM (right). Updated G11-T/A fit tracks RTM best at evening/ night, but overpredicts RTM more than G10-T fit in morning/afternoon.

Summary of differences between RTM-derived and GOES-11 SW and LW BB fluxes for 1^o box (36.5^{o}N 97.5^{o}W), for the G10-Terra and G11-Terra/Aqua fits.

$LW_{RTM} - LW_{G11}$	Clr Bias (All; W/ m^2)	Clr Bias (Day; W/ m^2)	Tot Bias (All; W/ m^2)	Tot Bias (Day; W/ m^2)	Tot Std Dev (All; W/ m^2)	Tot Std Dev (Day; W/ m^2)
G10-Terra	2.2	-1.4	0.65	-2.0	9.3	8.5
G11-Terra/Aqua	-1.9	-5.6	-7.3	-8.2	12.1	10.7



Comparison of 2008 clr-sky SW albedoes from RTM and *GOES-11*: half-hourly binned averages of SW albedo (left); scatterplot of fluxes using G11-Terra/Aqua fit vs RTM (rt).Operational G10-T fit tracks RTM better than updated G11-T/A fit

Summary of differences between RTM and GOES-11 SW clr-sky albedoes for 1^o box (36.5^{o}N 97.5^{o}W), for G10-Terra, G11-Terra/Aqua fits.

$SW_{RTM} - SW_{G11}$	2008(%) Bias (SD)	Spring (%) Bias (SD)	Summer (%) Bias (SD)	Fall (%) Bias (SD)	Winter (%) Bias (SD)
G10-Terra	0.1 (2.1)	0.7 (1.0)	-1.1 (0.9)	-0.4 (1.5)	3.2 (3.3)
G11-Terra/ Aqua	1.0 (2.5)	1.9 (1.2)	-0.8 (1.5)	0.3 (1.8)	4.7 (3.3)

Summary

- Evaluated GOES-11 BB LW & SW TOA fluxes over SGP 2007-09
  - Separate seasonal LW&SW, day-night LW fits
  - Derived using Terra and Aqua
  - Applying Terra-Aqua SW fit for GOES-11 improved biases at overpass times (compared to G10-Terra fit) in 2008-09
- BB LW clr-sky fluxes derived from G11-T/A fit agree well with RTM at night & differ during day. BB LW fluxes derived using G10-Terra fit closer to RTM for daytime, night/day clr+cloudy cases
- BB SW clr-sky albedos from G11-T/A compare well with RTM for Fall & Summer cases; G10-T closer to RTM for Spring & Winter. Overall there is more scatter in albedos from updated G11-T/A fit
- Future work:
  - Examine how to better employ Terra & Aqua to improve BB flux
    - Re-derive NB-BB fits for all available years, seasons of SGP GOES-8-14, TWP MTSAT-1/2
    - study daytime RTM-obs discrepancies for daytime clear LW
  - Process VISST datasets using updated NB-BB fits

(http://www-pm.larc.nasa.gov)