# Improved TOA Broadband Shortwave and Longwave Fluxes Derived for ARM Domains

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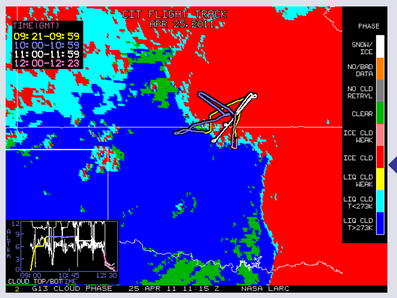
## Introduction

- Top-of-atmosphere (TOA) broadband (BB) longwave (LW) and shortwave (SW) fluxes essential for evaluating climate change and studying cloud radiative interactions
- Current satellites measure non-polar fluxes only at specific 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
- Need satellite-specific fits for day/night, land/ocean, & seasonal differences, to estimate BB fluxes for:
  - GOES-10, Pt Reyes, CA MASRAD (Mar - Sep 2005)
  - GOES-13, SGP MC3E (April - June 2011)
  - MTSAT2, TWP (July 2010-present)

## OBJECTIVE

- Develop & assess fits for SGP, Pt Reyes, & Darwin based on CERES Terra vs GOES-10, GOES-13, & MTSAT2 data

### Cloud Phase 1115 UTC




MOTIVATION: Apply GEO NB-BB fits to derive TOA BB Albedo and LW Fluxes for various domains/time periods, such as SGP during MC3E

Citation flight during MC3E, on April 25, 2011; track overlay on VISST-derived Cloud Phase (left)

## Approach

- Match 1° averages of GEO data with CERES SFC
  - MASRAD (30°-46°N, 112°-132°W); GOES-10; Mar - Aug05
  - SGP (32°-42°N, 91°-105°W); GOES-13; Dec08 - Apr09, May - Nov10
  - TWP (0°-17°S, 121°-140°E); MTSAT2; Jul - Sep10

  Fits: GEO vs CERES Terra
- Compare resulting fits using CERES Terra, Aqua SFC[1], FLASHflux[2] data

## Data & Methodology

- CERES 1° grid instantaneous Gridded Surface Fluxes and Clouds (SFC): Terra/Aqua Ed3A FM-1/2/3 and FLASHflux V2 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, $\mu_o$ = cos(SZA), SZA = solar zenith angle
- GEO 1° -avg calibrated 0.65-μm albedos $A_{nb}$ and 10.8-μm fluxes $M_{nb}$
- Match CERES & GEO 1° data: ±15 minutes of overpass, CERES VZA < 65°
- Fit matched data to[3]:

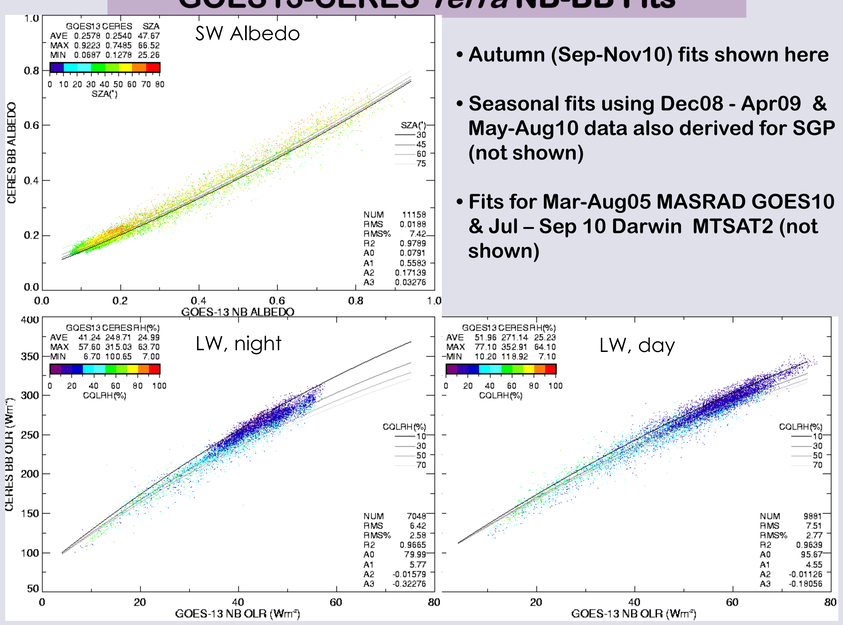
$$A_{SW} = a_0 + a_1 * A_{nb} + a_2 * A_{nb}^2 + a_3 * \ln(1/\mu_o) \quad (1)$$

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

where colRH = column-weighted RH from RUC[4]/GFS profiles

- Apply 3rd-order correction to $M_{LW}$

## GOES13-CERES *Terra* NB-BB Fits



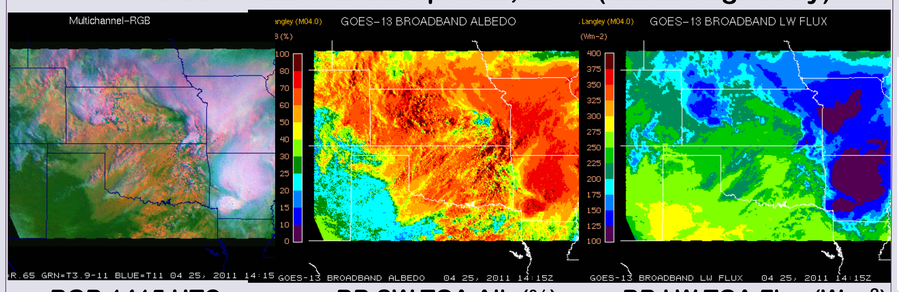

- Autumn (Sep-Nov10) fits shown here
- Seasonal fits using Dec08 - Apr09 & May-Aug10 data also derived for SGP (not shown)
- Fits for Mar-Aug05 MASRAD GOES10 & Jul – Sep 10 Darwin MTSAT2 (not shown)

## RMS errors for GEO vs. CERES Terra NB-BB fits

| RMS Errors | OLR Day, $Wm^{-2}$ | OLR Night, $Wm^{-2}$ | SW, albedo |
|---|---|---|---|
| SGP GOES13 Spring (Mar-Apr09, May10) | 8.5 (3.4%) | 7.8 (3.5%) | 0.020 (6.6%) |
| SGP GOES13 Summer(Jun-Aug10) | 8.2 (2.9%) | 10.9 (4.3%) | 0.018 (8.1%) |
| SGP GOES13 Autumn (Sep-Nov10) | 7.5 (2.8%) | 6.4 (2.6%) | 0.019 (7.4%) |
| SGP GOES13 Winter (Dec08-Feb09) | 7.2 (3.0%) | 5.5 (2.5%) | 0.024 (7.9%) |
| MASRAD GOES10 Spring (Mar-May05) Land | 7.1 (2.9%) | 5.7 (2.5%) | 0.019 (6.9%) |
| MASRAD GOES10 Spring (Mar-May05) Ocean | 5.3 (2.3%) | 5.4 (2.2%) | 0.017 (7.4%) |
| MASRAD GOES10 Summer (Jun-Aug05) Land | 8.0 (2.7%) | 6.9 (2.6%) | 0.014 (7.2%) |
| MASRAD GOES10 Summer (Jun-Aug05) Ocean | 6.2 (2.4%) | 6.8 (2.5%) | 0.016 (6.0%) |
| Darwin MTSAT2 Jul-Sep10 Land | 7.3 (2.6%) | 8.3 (3.2%) | 0.018 (8.3%) |
| Darwin MTSAT2 Jul-Sep10 Ocean | 7.5 (2.9%) | 8.0 (3.1%) | 0.020 (11.5%) |

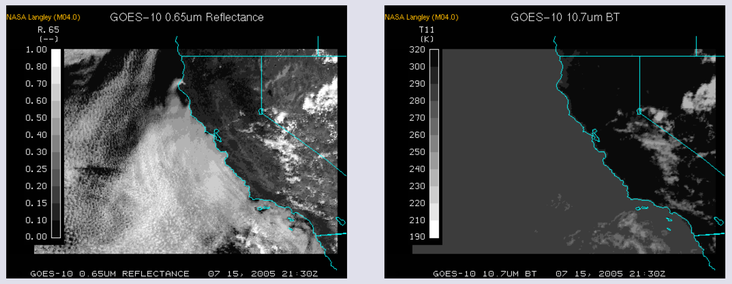
## Examples of Instantaneous Results

### SGP: GOES-13 BB Fluxes: April 25, 2011 (MC3E Flight Day)

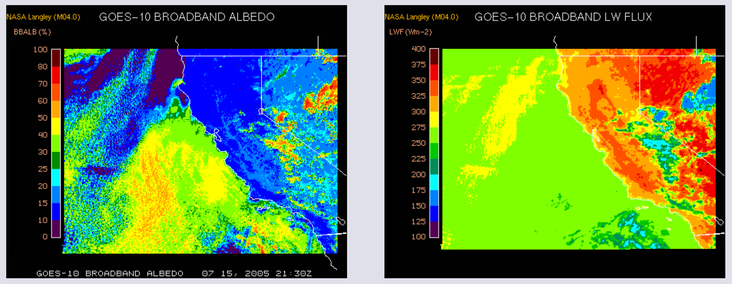



RGB 1415 UTC | BB SW TOA Alb (%) | BB LW TOA Flux ($Wm^{-2}$)

### MASRAD: GOES10-derived BB Fluxes: July 15, 2005 2130 UTC

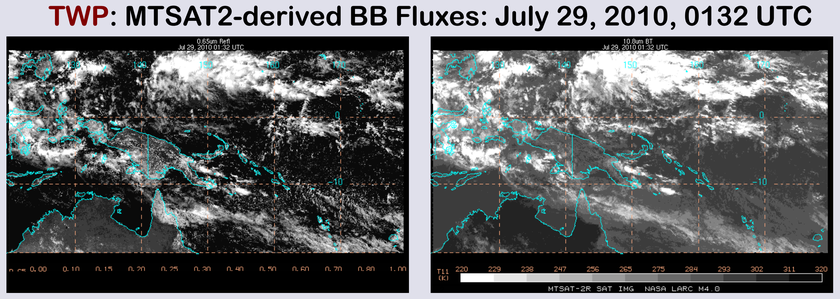



Visible Reflectance (0.65 μm) | IR Brightness Temperature (11 μm)

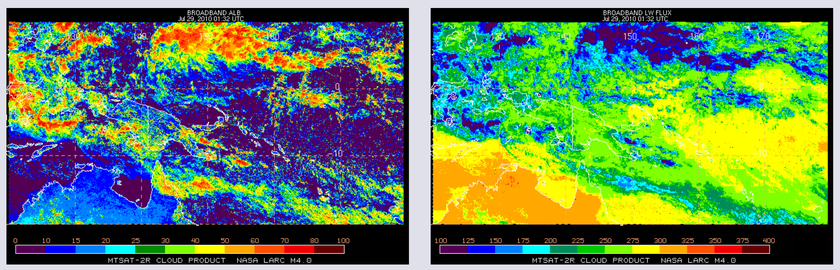



BB SW TOA Alb (%) | BB LW TOA Flux ($Wm^{-2}$)

### TWP: MTSAT2-derived BB Fluxes: July 29, 2010, 0132 UTC



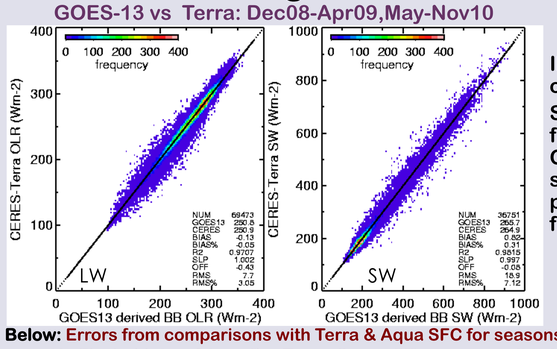
Visible Reflectance (0.65 μm) | IR Brightness Temperature (11 μm)



BB SW TOA Alb (%) | BB LW TOA Flux ($Wm^{-2}$)

## Validating with CERES Data

GOES-13 vs Terra: Dec08-Apr09,May-Nov10



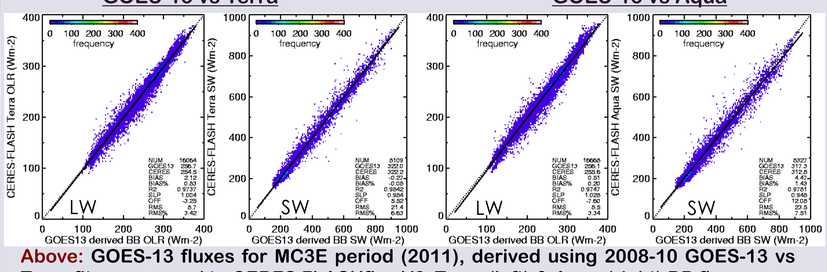

Illustrating the quality of the fits:
SGP GOES-13 BB fluxes compared to CERES Terra SFC for same time period/domain used in fit derivation (left).

**Below:** Errors from comparisons with Terra & Aqua SFC for seasons used in fits. Aqua data not used in fits, but taken 3 hrs after Terra. Some difference possible in CERES Aqua/Terra data.

| Bias (RMS) Errors | LW, $Wm^{-2}$ | SW, $Wm^{-2}$ | LW, $Wm^{-2}$ | SW, $Wm^{-2}$ |
|---|---|---|---|---|
| | w/r/t SFC Terra | | w/r/t SFC Aqua | |
| SGP GOES13 Dec08-Apr09 May-Oct10 | -0.2 (7.8) | 0.6 (19.2) | -2.2 (7.9) | -2.2 (20.7) |
| MASRAD G10 Mar 14-Sep 14, 2005 | -0.1 (6.4) | 1.4 (19.2) | -0.4 (6.6) | 4.7 (19.8) |
| DARWIN MTSAT2 Jul-Oct10 | -1.2 (8.4) | 3.1 (22.1) | -2.1 (8.1) | 21.8 (25.6) |

### Independent Assessment: GOES13 vs Terra/Aqua FLASHFlux

GOES-13 vs Terra | GOES-13 vs Aqua




**Above:** GOES-13 fluxes for MC3E period (2011), derived using 2008-10 GOES-13 vs Terra fits, compared to CERES FLASHflux V2 Terra (left) & Aqua (right) BB fluxes.

**Below**: Errors from comparison with 2011 Terra/Aqua FLASHflux data GOES-13 April 22-Jun 30 2011 (SGP), and MTSAT2 Sep 2011 (Darwin)

| Bias (RMS) Errors | LW, $Wm^{-2}$ | SW, $Wm^{-2}$ | LW, $Wm^{-2}$ | SW, $Wm^{-2}$ |
|---|---|---|---|---|
| | w/r/t FLASHFlux Terra | | w/r/t FLASHFlux Aqua | |
| SGP MC3E GOES13 | 2.1 (8.7) | -0.3 (21.4) | 0.5 (8.5) | 4.5 (23.5) |
| MTSAT2 Sep2011 | 0.2 (7.4) | -2.9 (18.6) | -0.3 (7.3) | 18.4 (19.5) |

- All biases small except SW MTSAT2 w/r/t CERES Aqua SFC/FLASHflux

## Summary

- Evaluated GOES-10, GOES-13, MTSAT2-derived BB LW & SW TOA fluxes over MASRAD, SGP, & Darwin domains
  - Separate seasonal, land-water LW&SW, day-night LW fits
  - Derived using Terra
  - Validated w/ Terra/Aqua SFC(same period),FLASHFlux V2 (2011)
    - NOTE: FlashFlux likely differs from Ed3A SFC (pers comm, Sawaengphokhai 2012)
      - Aqua V2 SW FlashFlux ~4 $W/m^2$ < Ed3A; LW Day ~3 $W/m^2$ < Ed3A
      - Terra V2 LW FlashFlux Day ~5 $W/m^2$ < Ed3A
- BB LW fluxes from GEO-Terra fits agree well (< 1% bias) with Terra SFC, and also with Aqua SFC for same period (different time of day)
- GEO-derived BB LW fluxes agree well with Terra & Aqua FLASHflux during MC3E (GOES-13) and for Sep11 (MTSAT2); biases ~ 0% for Darwin, < 1% for SGP
- BB SW albedos from GEO-Terra compare well with Terra SFC for derivation period (all have < 1.5% bias)
- BB SW albedos for MASRAD & SGP compare well to Aqua SFC (< 2% bias), SW albedos from GOES13 during MC3E compared to Aqua and Terra FLASHflux have < 1.5% bias
- TWP MTSAT2 albedos ~9% > Aqua SFC, 2010 & FLASHFlux, 2011

### Future work

- Determine source of MTSAT2 error (likely calibration issue)
- Examine how to employ Aqua as well to improve BB flux
- employ RTM to examine diurnal dependencies of NB-BB fits
- re-derive NB-BB fits for all available years, seasons of SGP GOES-8-15, TWP MTSAT-1/2
- reprocess VISST datasets using updated NB-BB fits

*(http://www-angler.larc.nasa.gov or ARM Data Center)*

**References**

1 - Geier, E.B., R. N. Green, D. P. Kratz, P. Minnis, W.F. Miller, S. K. Nolan, and C. B. Franklin, 2001: Single satellite footprint TOA/surface fluxes and clouds (SSF) collection document.
2 - Stackhouse, P. W., Jr., D. P. Kratz, G. McGarragh, S. K. Gupta, and A. Wilber, 2006: Deriving Fast Global Radiative Fluxes from CERES Measurements: The FLASHFlux Project. CERES Science Team Meeting, 1-3 November, Hampton, VA
3 - Minnis, P. and W. L. Smith, Jr., 1998: *Geophys. Res. Lett.*, **25**, 1113-1116
4 - Benjamin, SG, D Devenyi, SS Weygandt, KJ Brundage, JM Brown, GA Grell, D Kim, BE Schwartz, TG Smirnova, and TL Smith. 2004. "An hourly assimilation/forecast cycle: The RUC." *Monthly Weather Review 132, 495-518*