Validation of GOES-10 Satellite-derived Cloud and Radiative Properties for the MASRAD ARM Mobile Facility Deployment

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1.Introduction

The ARM Mobile Facility (AMF) deployment at Pt Reyes, CA as part of the Marine Stratus Radiation Aerosol and Drizzle experiment (MASRAD), 14 March -14 September 2005 provided an excellent chance to validate satellite cloud-property retrievals with the AMF's flexible suite of ground-based remote sensing instruments. For this comparison, NASA LaRC GOES10 satellite retrievals covering this region and period were re-processed using an updated version of the Visible Infrared Solar-Infrared Split-Window Technique (VISST), which uses data taken at 4 wavelengths (0.65, 3.9,11 and 12 μm resolution), and computes broadband fluxes using improved CERES (Clouds and Earth's Radiant Energy System)-GOES-10 narrowband-to-broadband flux conversion coefficients. To validate MASRAD GOES-10 satellite-derived cloud property data, VISST-derived cloud amounts, heights, liquid water paths are compared with similar quantities derived from available ARM ground-based instrumentation & with CERES fluxes from *Terra*.

2. Methodology

GOES10 cloud properties derived using VISST:
- *MASRAD domain 30°N – 46°N; 112°W – 132°W*
- *March 14 – September 14, 2005*
- *gridded into 1° (1deg) resolution boxes*
- *average of 9 pixels (9pix) surrounding the AMF*
- *20 km radius average surrounding the AMF*

VISST 9pix cloud properties validated for:
Liquid Water Path (LWP)
- *Microwave Radiometer (MWR)*
- *No Wet Window, Obs > -40 gm⁻², QC Check*
- *minimum of 40 MWR obs within 15 min avg*
- *VISST Warm Cloud Amount 100%, SZA < 70°*

Cloud Amount
- *Total Sky Imager (TSI) Opaque + Thin*
- *min 25 TSI observations within 15 min avg*
- *SZA < 80°*

VISST 20 km radius cloud properties validated for:
Cloud Base Height
- *Ceilometer (CEIL)*
- *single layer cloud only*
- *minimum 110 obs within 30 min avg*
- *VISST Warm Cloud Amount 100%*

VISST 1deg radiative properties validated for:
Broadband Shortwave & Longwave Fluxes
- *CERES Terra 20-km Single Scanner Footprint TOA/Surface Fluxes & Clouds (SSF; Caldwell et al, 2006) averaged in 1° SSF footprint product: Monthly Gridded Surface Fluxes & Clouds*
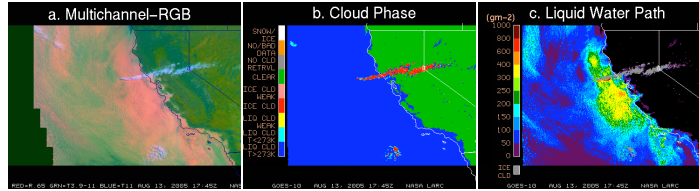- *MASRAD domain, matched within 15 min*

3. Results

Figure 1. August 13, 2005, 1745 UTC image showing widespread marine stratus clouds over the MASRAD domain, in a) GOES10 RGB image, b) VISST-derived cloud phase, and c) VISST-derived LWP.
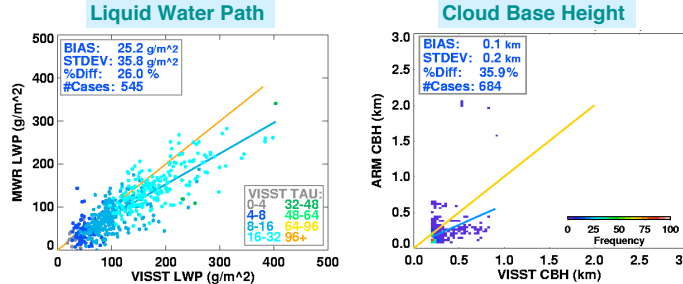

Figure 2. Comparison of VISST- and MWR-derived LWP over MASRAD period. VISST overestimates MWR slightly, but general agreement is good.

LWP(MWR) = 0.72 LWP(VISST) + 9.4 gm⁻².

Figure 3. Comparison of sample-weighted VISST- and ceilometer-derived Cloud Base Height over MASRAD period for warm clouds only. VISST slightly overestimates cloud base height, on average.
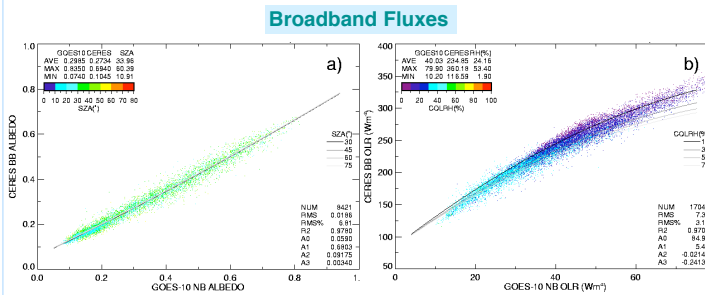
Broadband Fluxes

Figure 4. Determination of updated MASRAD narrow-to-broadband coefficients for *land-based* GOES10 vs CERES *Terra* fluxes, 1 March - 31 May 2005 a) SW, and b) LW. Coefficients A0,A1,A2,A3 (lower right hand corner) are used in a regression fit to derive VISST BB fluxes. Ocean-based fits & Jun-Aug 05 fits were also derived. A third order fit was finally applied to the LW data as noted below to eliminate low end bias.
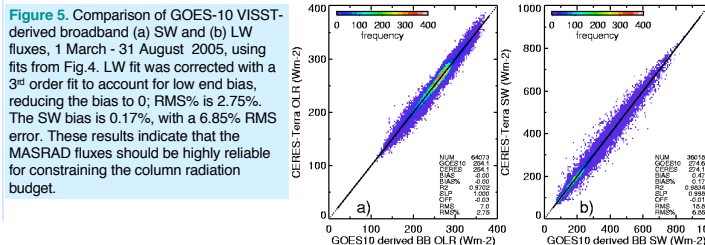
Figure 5. Comparison of GOES-10 VISST-derived broadband (a) SW and (b) LW fluxes, 1 March - 31 August 2005, using fits from Fig.4. LW fit was corrected with a 3rd order fit to account for low end bias, reducing the bias to 0; RMS% is 2.75%. The SW bias is 0.17%, with a 6.85% RMS error. These results indicate that the MASRAD fluxes should be highly reliable for constraining the column radiation budget.

Cloud Amount

		CLOUD AMT CASES (%) BY BIN			
T	**80-100%**	1	1	5	48
S	**50-80%**	1	2	2	1
I	**20-50%**	7	1	1	0
	0-20%	27	1	0	0
		0-20%	**20-50%**	**50-80%**	**80-100%**

VISST Cloud Amount (%)

Table 1. Comparison of VISST- and TSI-derived binned cloud amounts. Diagonal elements indicate percent of cases where TSI and VISST agreed on binned cloud percentage; off-diagonal elements represent disagreement. The two methods were in agreement 78% of the time. For all 4114 cases, VISST cloud amount was 7.6% less than TS average with RMS difference of 20.5%.

4. Summary and Future Work

Updated MASRAD GOES-10 VISST dataset overall agrees well with AMF ground-based instrument datasets. For SZA < 70°, VISST LWP generally agrees with MWR, with a bias of 25.2 gm⁻² and a standard deviation of 35.8 gm⁻². Bias can be eliminated with a linear correction. For SZA < 80°, 78% of TSI- and VISST-derived cloud amounts are in same bin. VISST bias is –7.6% & RMS = 20.5%.

Bias in the cloud base height comparison is minimal with small RMS error. No corresponding ARM ground-based measurements of this parameter were available for comparison. For stratus clouds, the VISST-derived base tracks cloud-top height, so the top should also be nearly as accurate as the base height. Future work will compare VISST cloud top heights with AMF radiosonde profiles of humidity.

New CERES-GOES NB-BB coefficients yield more accurate TOA LW and SW fluxes. Separate sets of coefficients were derived for land and ocean & for March-May 2005 and Jun-August 2005. Real-time (*previous*) version of MASRAD VISST fluxes (Mar 11-Aug 31 2005) had LW bias of 3.1% & RMS error of 3.2%, and SW bias of 4.3% & RMS error of 8.2%. *New* LW fit yields bias of 0% (RMS 2.7%). *New* SW bias is 0.2% (RMS 6.9%).

These initial comparisons show that updated MASRAD GOES cloud & radiation products should be valuable for model studies.

References
Caldwell, T. E. and Co-authors, 2006: Clouds and the Earth's Radiant Energy System (CERES) Data Management System, Data Products Catalog, Release 4, Version 14. 214 pp. (Avaialble at http://earth-www.larc.nasa.gov/ceresdoc/DPC/DPC_current/pdf/dpc.book.pdf)