VALIDATION OF TOA BROADBAND FLUXES DERIVED FROM GMS DURING TOGA/COARE

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Introduction

Tropical clouds play an important role in the hydrological cycle, radiation budget, and general circulation. In order to study the impact of tropical clouds on the radiation budget accurate broadband (BB) fluxes must be computed in climate simulations. Thus, top-of-the-atmosphere (TOA) BB fluxes must also be accurately measured. Except for the Earth Radiation Budget Experiment (ERBE) Wide Field Of View (WFOV) data, satellite-measured BB flux data are unavailable during COARE. When the typical BB satellite data are available, they are limited in temporal sampling, usually twice a day per satellite. Furthermore, the BB nominal footprints are relatively large, 32 km for ERBE on ERBS.

The Geostationary Meteorological Satellite (GMS) can provide much better temporal (hourly) and spatial (up to 1.25 km) sampling of the fluxes but is limited by its narrowband (NB) measurements. Thus, the NB data are used to estimate the BB fluxes. The method for converting NB radiances to BB fluxes is based on historical measurements from coincident GMS collocated with ERBE-scanner data. BB fluxes are computed from the GMS NB radiances along with Layered Bispectral Threshold Method (LBTM) cloud products (Minnis et. al. 1995) on three spatial grids. The binned fluxes, cloud products and grid specifications are available at the following web site.

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

The validation of these GMS NB-based BB fluxes during COARE is based on ERBE-WFOV data.

GMS Data

The visible (VIS, 0.65µm) GMS radiances are calibrated against the visible channel of the NOAA-Advanced Very High Resolution Radiometer (AVHRR) because it has been reliably calibrated against a stable desert target over many years. To estimate albedo, the NB VIS radiances L are converted to VIS albedo

$$\alpha_n = \pi L / [\delta(d)\, \mu_0\, E\, \chi(\mu_0,\mu,\psi)]$$

where δ is the Earth-Sun-distance correction factor for Julian day d, E, the VIS solar constant for GMS, is 526.9 $Wm^{-2}sr^{-1}\mu m^{-1}$, μ_0 and μ are the cosines of the viewing and solar zenith angles, ψ is the relative azimuth angle, and χ is the bidirectional reflectance model described by Minnis and Harrison (1984). The bidirectional model is available for three scene types: clear water, clear land and clouds.

The infrared (IR, 11.0µm) GMS temperatures are calibrated onboard. The nadir NB flux

$$M_{ir} = 1.97\, \pi\, B(T[\mu_0,]) / \gamma(\mu_0,)$$

is estimated using the plank function B and a limb darkening function γ defined by Minnis and Harrison (1984) and the 1.97 accounts for the bandwidth.

Baseline Narrow-to-BB Model

BB fluxes from the ERBS-scanner 2.5° latitude and longitude gridded S9 data product were matched within the local half hour of GMS NB fluxes for the month of December 1986 (DEC86). The ERBS satellite has a precessing orbit which allows it to sample 12 local hours in 36 days. The spatial domain of the data was bounded by 12.5°S, 10°N, 137.5°E and 180°E. The data were regressed following Minnis et. al. (1995) to yield the following albedo equation,

$$\alpha_b = 0.0571 + 0.720\alpha_n + 0.0287\alpha_n^2 + 0.0523 \ln(1/\mu_o)$$

where α_b is the BB albedo. ERBS viewing zenith angles were limited to 45° and solar zenith angles to 84°. The OLR equation is as follows,

$$M_{lw} = 76.69 + 4.473M_{ir} - 0.012M_{ir}^2 + 0.003\, M_{irl} \ln(RH[\%])$$

where M_{lw} is the OLR and RH is the column weighted relative humidity above the radiating surface based on the 2.5° global gridded NMC product. The coefficient of the RH term is near zero and indicates that the NMC RH cannot resolve changes in humidity in the warm pool. However, this term works well over midlatitudes. The statistics of the NB to BB fit can be found in Table 1.

DEC86	ALBEDO	OLR(Wm-2)
#	334	860
MEAN	0.33	210.3
RMS	0.027	7.2
RMS%	8.1	3.4

Table 1. The NB to BB fit statistics for GMS and ERBS-scanner during December 1986, 2.5° regions.

ERBE-WFOV Comparisons

The ERBS-WFOV has measured fluxes since November 1984 until the present. The WFOV is a cavity radiometer with on-board calibration and views the Earth from limb to limb. The WFOV data are gridded into 10° regions and for this comparison a minimum of 5 measurements per region were required. The GMS and scanner data were averaged into the 10° regions defined by 10°S to 10°N and 140°E to 180°E and matched to within ± 0.5 hours.

ALBEDO	DEC86 SCANNER	DEC86 GMS	COARE GMS
#	24	16	138
MEAN	0.33	0.39	0.28
SLOPE	0.86	0.82	0.78
BIAS	0.010	.016	0.008
RMS	0.031	.044	.045
RMS%	9.4	11.3	16.3

Table 2. Comparison of ERBS-WFOV with GMS BB and scanner albedos, 10° regions.

OLR (Wm-2)	DEC86 SCANNER	DEC86 GMS	COARE GMS
#	46	35	404
MEAN	210.1	201.9	223.4
SLOPE	0.87	0.84	0.87
BIAS	3.8	2.9	2.2
RMS	9.3	12.5	11.5
RMS%	4.4	6.2	5.1

Table 3. Same as Table 2 except for OLR.

During TOGA/COARE (Nov. 1992 to Feb. 1993) only ERBE-WFOV can be matched with GMS (10° regions), but the two datasets cover much different spatial scales. To understand the scale effects, it necessary to compare the ERBE scanner and WFOV data. The DEC86 GMS data were matched with scanner data and the scanner matched with WFOV data. The DEC86 GMS albedos have an rms difference of .044 with the WFOV data. This value is close to the square root of the sum (.041) of the squared rms errors of the scanner-GMS fit (.027) and the scanner-WFOV fit (.031). For OLR (Table 3), the DEC86 GMS-WFOV difference of 12.5 Wm^{-2} is approximately equal to $11.8^2 = 7.2^2 + 9.3^2$. While the DEC86 NB to BB fit is unbiased, the scanner-WFOV comparison reveals a bias error and a slope less than one. The WFOV underestimates the high end and overestimates the low end for both the albedo and OLR, because extremely clear and cloudy conditions cannot be resolved for the 10° regions. Thus, the DEC86 GMS should be the guideline when comparing COARE with WFOV. The COARE slope, bias, and rms are very similar to DEC86. This suggests that, if scanner data were available during COARE, the 2.5° GMS BB albedos would have the same difference statistics as those shown in Table 1.

Concluding Remarks

From comparisons with the ERBS-WFOV during DEC86 and COARE, the instantaneous GMS-derived BB albedos are within ±0.03 (10%) and the OLR is within ±7 Wm-2 (3%) and are not biased. Time averaged errors will be much smaller and also unbiased. The NB to BB relationship, therefore, can be used confidently for an extended time period over this limited spatial domain. The NB to BB equation assumes that the surface albedo, aerosols, etc. are the same, on average, year to year. Convection was more common during DEC86 than during COARE, but the WFOV comparisons indicate the weather differences had little effect on the flux accuracy. Thus, the GMS-based TOA fluxes comprise an accurate dataset for verification of model results.

References

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