Converting Geostationary Narrowband Radiances to Fluxes for the CERES SYN1deg Product

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1 INTRODUCTION

The Clouds and the Earth's Radiant Energy System (CERES) project provides the climate community with three types of monthly averaged Level3 data sets. These data are as follows. The Energy Balanced and Filled (EBAF) provides consistent TOA and surface fluxes for clear and all-sky fluxes as well as cloud radiative effect (CRE) (Loeb et al 2009). EBAF clear-sky fluxes are spatially complete and the all-sky TOA net flux is constrained to the ocean heat storage term (0.58Wm^{-2}). These fluxes are appropriate for climate model comparisons, since the net balance is not tied to the CERES calibration and surface fluxes are consistent with the TOA fluxes. Fluxes provided by EBAF combine the stability of the SSF1deg product and the diurnal sampling of the SYN1deg products without the geostationary artifacts. Secondly, SSF1deg are CERES single satellite monthly and daily averaged TOA fluxes and MODIS cloud properties. The SSF1deg temporally interpolates between observations by assuming constant meteorology at the time of the CERES measurement. These fluxes are not diurnally complete but based on the regional scene conditions of either the Terra (10:30 AM) or the Aqua (1:30 PM) overpass times. Lastly, SYN1deg are CERES monthly and daily averaged combined Terra and Aqua satellite fluxes and geostationary (GEO) derived broadband fluxes and associated MODIS and GEO cloud properties. The SYN1deg employs three-hourly (Edition3) or one-hourly (Edition4), geostationary satellite observations from five-satellite contiguous geostationary domains. The geostationary derived broadband fluxes are used to infer the flux in between the CERES observations on Terra and Aqua satellites (Doelling et al. 2013).

The goal of this paper is to discuss the methodology and validation of converting GEO narrowband radiances to broadband fluxes. The current method (up to Edition4) is to convert GEO narrowband radiances to MODIS-like visible radiances based on radiative transfer models to take into account the GEO-specific spectral response functions. The MODIS-like visible radiance is then converted to a broadband radiance through empirical models based on coincident MODIS and CERES flux measurements. These broadband radiances are then converted to fluxes based on the same CERES angular directional models (ADMs) used in converting CERES radiances into fluxes based on CERES observations from the TRMM precessing satellite. These fluxes are diurnally complete, but contain some residual geostationary artifacts. The GEO derived broadband fluxes are regionally normalized to the CERES fluxes to maintain the CERES instrument calibration and to mitigate GEO artifacts.

Currently, there are several methods being studied to improve the conversion of GEO narrowband radiances into CERES-like broadband radiances. One method would convert GEO radiances directly to broadband fluxes using radiative transfer models. The GEO spectral responses are much broader than the visible MODIS band. This method would preserve more spectral information than the current method. The main focus of this study is to quantify the impact of the ADMs used to infer the GEO fluxes.

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2 BACKGROUND

Each geostationary has a unique spectral response function (Fig. 1). The older GEO satellites (Met-7) are more broadband than the newer GEOs (Met-9) which more closely resemble the MODIS band 1 0.65μm channel.

Once the GEO radiances are converted into broadband radiances, they are validated against CERES measurements. The radiances are then converted into fluxes by using an ADM that was developed during the CERES TRMM mission. Since the TRMM satellite precessed it observed all solar zenith angles during the day over the tropics. The Terra and Aqua sampling does not allow for near sunrise and sunset solar zenith angle conditions. The TRMM ADM is a function of surface type, cloud fraction, cloud phase, angle, and satellite. Thus this paper will also seek to evaluate the TRMM ADM against the CERES Terra and Aqua Ed3 ADM as well as how the GEO cloud retrievals impact the TRMM ADM to quantify the largest source of error.

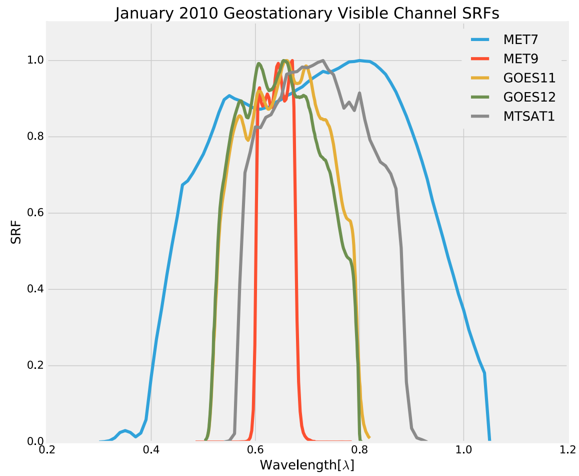

Figure 1. Spectral response functions of five geostationary satellites for the visible channel.

3 CERES TEMPORAL INTERPOLATION

The SSF1deg observed fluxes only contain one or two measurements per day depending on whether you consider shortwave or longwave, respectively. To derive a more diurnally complete daily flux we employ geostationary observations. Adding geostationary observations can account for the flux difference not observed by CERES over regions of Earth that have an asymmetric diurnal cycle about noon (Fig. 2).

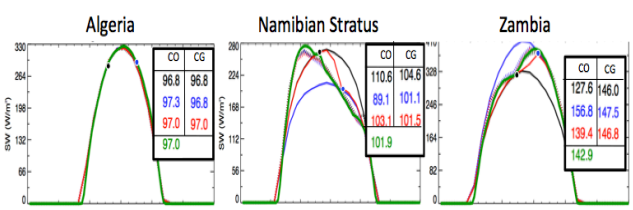

Figure 2. Three regions of Earth that exhibit strong diurnal flux cycles. Each figure contains solid lines indicating the constant meteorology Terra (black), Aqua(blue), Terra+Aqua (red) monthly hourly SW fluxes for January 2010. Dotted lines indicate the same but with geostationary data added. The green line indicates Geostationary Earth Radiation Budget (GERB) (Harries et al 2005) measurements (onboard the Met-8 GEO satellite centered at 0° East) that are taken as truth for this comparison. The monthly mean fluxes (Wm-2) are located in the upper left.

Figure 2 shows that for a region like Algeria with a symmetric diurnal cycle about noon, the addition of geostationary data does not add value to the diurnal cycle. However, over the Namibian maritime stratus region we can see that Terra (10:30 AM) sampling overestimates the monthly mean SW flux, while Aqua underestimates the reflected solar radiation due to the morning maximum in cloud cover. Over land afternoon convection regions, such as Zambia, we find the opposite effect. The maximum in cloud cover occurs in the afternoon so that Terra underestimates and Aqua overestimates the SW monthly mean flux. Combining Terra and Aqua observations more accurately captures the diurnal cycle than from either Terra or Aqua. The dotted lines that indicate observations containing geostationary data show an improved ability to capture the diurnal cycle not observed by either Terra or Aqua.

4 METHODOLOGY

The conversion of narrowband geostationary radiances to broadband fluxes is a four step process: 1) the geostationary narrowband radiances are calibrated against MODIS, since GEO satellites lack onboard calibration. 2) Narrowband radiances are converted to broadband radiances employing empirical and theoretical models. 3) Fluxes are then inferred from the broadband radiances using an ADM developed during the CERES TRMM mission. 4) Finally, the GEO derived fluxes are normalized regionally to maintain the CERES instrument calibration.

The main focus of this study is to quantify the impact of the ADMs used to infer the GEO fluxes. The Terra and Aqua Edition4 ADM (Su et al 2015) is an improvement on the original TRMM ADM (Ed2) (Loeb et al 2003). First we need to evaluate the difference between Ed4 and the TRMM ADM using the same MODIS clouds for scene identification and CERES observed radiance. Second, we need to evaluate the SW flux difference when using GEO rather than MODIS cloud properties. This analysis allows us to evaluate the error introduced when using geostationary cloud properties in the ADM.

4 RESULTS

Figure 3 shows the first analysis that compares the Edition4 ADM to the TRMM ADM using the same MODIS clouds and CERES observed radiances. This comparison is useful because it allows us to evaluate any systematic biases there are from using the TRMM ADM. As mentioned before, it is necessary to use the TRMM ADM to infer fluxes from geostationary observations because its tropical precession orbit allowed it to sample a greater range of view and azimuth angles than the ADMs that were developed during Terra and Aqua. The top panel of Figure 3 reveals a thick zone of positive biases in the northern Pacific Ocean. These are the zones with large solar zenith angles typical during the Northern Hemisphere winter. Even with this positive bias, the global bias is less than one percent. This could suggest that the MODIS and the TRMM-VIRS cloud properties behaved differently for large solar zenith angles. This may indicate that the MODIS cloud properties are not suited for use with the TRMM ADM. The second panel displays the root mean square error and shows a similar pattern as the bias panel. There is a continuous strip of anomalously high errors just south of the Equator. This is most likely due to sun-glint. Over sun-glint conditions cloud properties are extremely difficult to retrieve. Even still, the global error is below two percent.

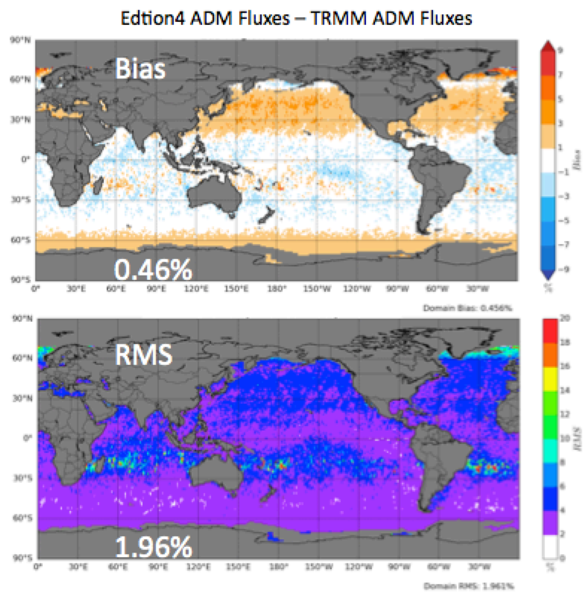

Figure 3: Comparison between the Edition4 ADM developed with Terra and Aqua and the TRMM ADM, both using MODIS clouds. The top panel is bias, and the bottom panel is the root mean square error. Data are from January 2010.

Figure 4 depicts the discrepancy in the SW flux due to the MODIS and GEO cloud property differences when applying the TRMM ADM on the same CERES observed radiances. The top panel of figure 4 shows the bias. The distinct zone in the Northern Hemisphere no longer appears, suggesting that the MODIS and GEO cloud properties are similar across solar zenith angle, when applying the TRMM ADM. However, a discontinuity can be seen at ~37° West, which is the boundary between two GEO satellites, indicating that the GEO cloud properties are satellite dependent. The SW flux bias and RMS error seem to be related to cloud regimes. Although the bias appears to be more widespread than in the figure 3, the total bias is only about one percent. The root mean square error however, shows a significant increase at about seven and a half percent. From this analysis it appears that the biggest source of error is the use of geostationary cloud properties.

5 FUTURE WORK

The results presented here appear to suggest that the GEO cloud properties used to determine the SW flux are the largest source of error. The MODIS cloud retrievals utilize many more channels than the single visible channel GEO cloud retrievals. However, the launch of the new 3rd generation GEO satellite, such as Himawari-8 and GOES-R, the GEO properties would be more similar to MODIS and thereby reduce the SW flux errors due to cloud property differences.

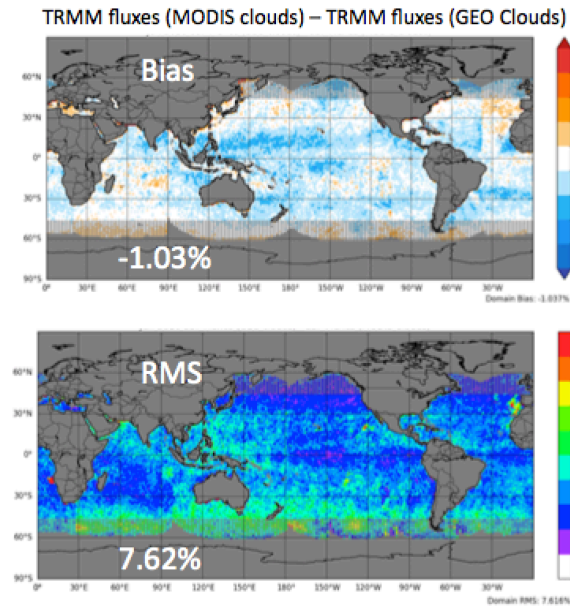

Figure 4: Comparison between GEO derived SW fluxes using MODIS cloud properties and GEO cloud properties. The top panel is bias and the bottom panel is root mean square error. Data are from January 2010.

6 REFERENCES

Doelling, D.R, and Coauthors, 2013: Geostationary enhanced temporal interpolation for CERES flux products. J. Atmos. Oceanic Technol., 30, 1072–1090, doi:10.1175/JTECH-D-12-00136.1

Harries, J. E., and Coauthors, 2005: The Geostationary Earth Radiation Budget Project. Bull. Amer.Meteor. Soc., 86, 945–960.

Loeb, N.G., N. Manalo-Smith, S. Kato, W. F. Miller, S. K. Gupta, P. Minnis, and B. A. Wielicki, 2003: Angular distribution models for top-of-atmosphere radiative flux estimation from the Clouds and the Earth's Radiant Energy System instrument on the Tropical Rainfall Measuring Mission Satellite. Part I: Methodology. J. Appl. Meteor., 42, 240–265.

Loeb, N.G., B. A. Wielicki, D. R. Doelling, G. L. Smith, D. F. Keyes, S. Kato, N. Manalo-Smith, and T. Wong, 2009: Toward optimal closure of the earth's top-of-atmosphere radiation budget. J. Climate, 22, 748–766.

Su, W., J. Corbett, Z. Eitzen, L. Liang, 2015a: Next-generation angular distribution models for top-of-atmosphere radiative flux calculation from CERES instruments: methodology. Atmos. Meas. Tech., 8(2), 611-632. http://dx.doi.org/10.5194/amt-8-611-2015.