SHORTWAVE RADIATION BUDGET PRODUCTS FROM GOES-R SERIES ABI

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ABSTRACT

Two shortwave (SW) radiation budget products, downward SW radiation at surface (DSR) and the reflected SW radiation at top of atmosphere (RSR), are routinely generated from the Advanced Baseline Imager (ABI) onboard the GOES-R series of US satellites. Both products require a SW broadband top-of-atmosphere (TOA) albedo converted from ABI narrowband reflectances. The narrow-to-broadband (NTB) conversion is currently derived from simulated broadband and narrowband reflectances, which have limitations in capturing the full range of variabilities present in satellite observations. We are experimenting with deriving empirical NTB from pairs of ABI and Clouds and Earth's Radiant Energy System (CERES) observations. ABI SW radiation products estimated with the empirical spectral conversion are generated and their evaluation with reference data is presented in this paper. The use of ABI SW products in the verification of model prediction is also presented using forecast DSR values in the Global Forecast System from NOAA/NCEP.

Index Terms – Shortwave radiation budget, ABI, GOES-R, spectral conversion

1. INTRODUCTION

Downward shortwave (SW) radiation at the surface (DSR) and the reflected SW radiation at the top of atmosphere (RSR), collectively referred to as shortwave radiation budget (SRB) products, have been routinely generated every 60 minutes at NOAA/NESDIS from measurements taken by the Advanced Baseline Imager (ABI) onboard the GOES-R series of geostationary satellites. DSR and RSR, at horizontal spatial resolution of 50 and 25 km, respectively, are the cloud-fraction weighted averages of fluxes retrieved separately for clear and cloudy scenes during daytime.

In the operational SRB algorithm, the spectral conversion used to estimate the TOA broadband albedo is based on simulated broadband and narrowband ABI reflectances. The simulations are not expected to capture the full range of atmospheric and surface conditions occurring in nature, therefore we have attempted to establish an empirical spectral conversion from pairs of ABI and the Clouds and Earth's Radiant Energy System (CERES) observations.

Two experimental ABI DSR products are generated at 2 km, one with simulation-based and the other is with empirical spectral conversion. The products are evaluated using ground-based reference data. The dataset and methods used are briefly described in the following sections.

2. DATASETS

Advanced Baseline Imager (ABI) Level 2 products and the Clouds and Earth's Radiant Energy System (CERES) Fast Longwave And Shortwave Fluxes (FLASHFlux) data [3] for 13 months (May 2016 to May 2017) are used to construct pairs of ABI and CERES (matchup) data. The ABI Level 2 products used in this step are top- of-atmosphere (TOA) reflectances in ABI bands 1 – 6, clear sky mask, cloud phase, and cloud optical depth [4] – [5].

Experimental ABI shortwave (SW) products are generated for five months (Jul to Nov 2019) with the two spectral conversions. One-minute averages of ground-based DSR measurements are obtained from the NOAA solar radiation network [6].

To demonstrate the merit of satellite retrievals for verification of forecast downward SW radiation at the surface, instantaneous DSR available in the ~12 km Global Forecast System (GFS) files are collected [7].

3. METHODS

The empirical narrow-to-broadband conversion derived from narrowband ABI and broadband CERES reflectance pairs is obtained in four steps: 1) 2-km ABI top-of-atmosphere (TOA) reflectances within the 25- km CERES (at nadir) footprints are averaged, 2) a CERES TOA broadband reflectance is estimated by applying the inverse of the CERES angular distribution model to the CERES TOA broadband albedo, 3) ABI- CERES matchups are classified according to scene type, angular bins, etc., 4) coefficients of relationships between CERES broadband and ABI narrowband reflectances are determined for each class.

ABI clear mask and cloud products are also averaged within the CERES footprint; these are used to determine the scene type along with the CERES cloudy footprint area information.

The criteria used in the matchup classification are scene types, surface types, solar zenith angle, and cloud optical depth.

4. PRELIMINARY RESULTS

To mitigate the impact of spatial mismatch between ABI and ground-based Downward Shortwave Radiation at surface, the 2-km ABI DSR retrievals are spatially averaged within 50-km grids centered on the ground stations, while the ground DSRs are temporally averaged within a ±30-minute time window centered on the ABI observation time. Two DSR products, with simulation based and empirical narrow-to-broadband (NTB) conversion respectively, are evaluated using two metrics: mean bias (retrieval minus reference) and standard deviation of biases. These are referred to as accuracy and precision. Overall accuracy and precision of instantaneous DSR retrievals are 4 and 84 Wm^{-2} with simulation based and 5 and 67 Wm^{-2} with empirical NTB conversion. Binned DSR retrieval errors vs. reference DSRs are shown in Figure 1, where each bin has 5,336 matchups. The accuracies of DSRs from the two NTB conversions are similar, but the precision is greatly improved with the empirical NTB conversion, especially at the low range of DSR (DSR < 200 Wm^{-2}). The low range of DSR usually corresponds to high solar zenith angles near sunrise and sunset or cloudy sky. The experimental ABI DSR product with the empirical NTB

Surface downward shortwave radiation from Global Forecast System is compared with reference data and with ABI DSR with empirical NTB from Nov 2019 to Mar 2020. For this comparison, daily-average DSR is calculated from the instantaneous values. The overall accuracy and precision of daily DSR from forecast are 8 and 27 Wm^{-2} and those from ABI DSR with empirical NTB conversion are -2 and 20 Wm^{-2}.

Biases of daily averages of experimental ABI and GFS DSRs are shown in Figure 2. Biases of daily average DSR of forecast DSR are between -15 and 58 Wm^{-2}, while those of ABI DSR are between -27 and 22 Wm^{-2}. Large biases in both daily DSRs are observed under cloudy skies. The largest bias (58 Wm^{-2}) is observed in daily DSR from GFS on 03/21/20. Diurnal variation of DSR and biases of forecast, ABI experimental products with empirical NTB, and ground at Bondville on the same day are shown in Figure 3.

5. SUMMARY

To better account for atmospheric and surface conditions present in Advanced Baseline Imager observations and therefore to improve estimates of Downward Shortwave Radiation at surface, empirical spectral conversion coefficients are established from pairs of ABI and the Clouds and Earth's Radiant Energy System observations. The ABI DSR product with empirical narrow-to-broadband (NTB) conversion improves the precision of instantaneous DSR when compared with the ABI DSR product with simulation based NTB conversion (currently being used in the operational algorithm). It also agrees better with the daily average DSR from ground data than the daily average DSR from forecast.

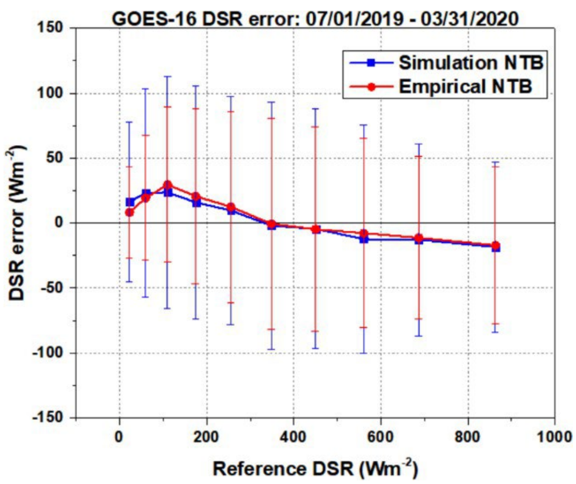

Figure 1. GOES-16 DSR retrieval error (retrieval minus reference DSR) as a function of reference DSR. Symbols are accuracy and whiskers are precision.

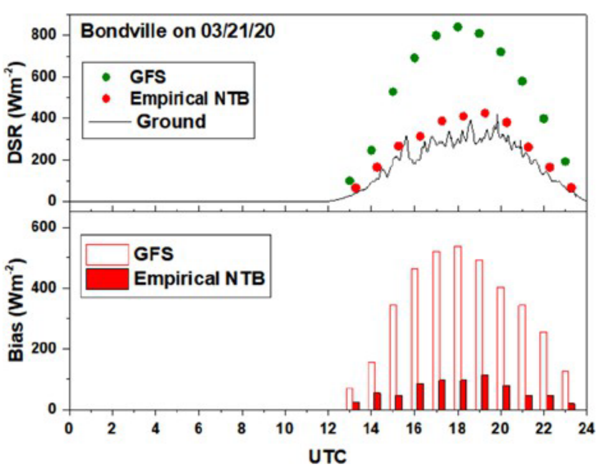

Figure 2. Daily average DSR error from GFS forecast and from ABI empirical NTB conversion for Nov 2019 to Mar 2020.

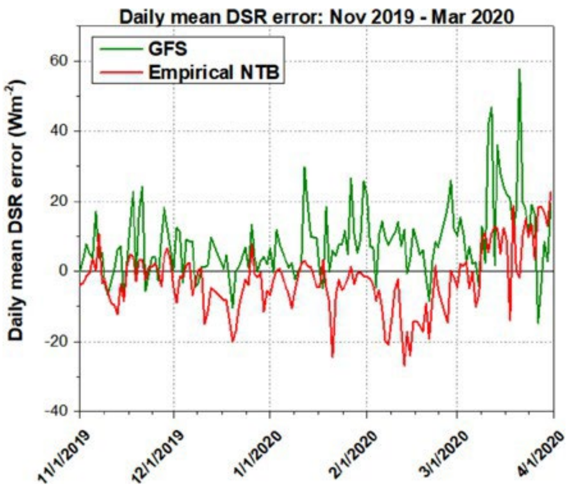

Figure 3. Example of diurnal variation of DSR at Bondville on 03/21/19. Spatially averaged forecast DSR and experimental ABI DSR with empirical NTB conversion are compared with temporally averaged ground measurement in the top panel and DSR biases are in the bottom panel.

6. REFERENCES

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