P1.31 EVALUATION OF SHORTWAVE RADIATION BUDGET ALGORITHM DEVELOPED FOR THE NEXT-GENERATION GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE (GOES-R)

Hongqing Liu[1*], Istvan Laszlo[2] and Hye-Yun Kim[3]
[1]Dell Services Federal Government
[2]Center for Satellite Applications and Research, NOAA/NESDIS
[3]I.M. Systems Group

1. GOES-R ABI SHORTWAVE RADIATION BUDGET ALGORITHM

The shortwave (SW) radiation budget algorithm (SRB) developed for the Advanced Baseline Imager (ABI) onboard the next generation Geostationary Operational Environmental Satellite (GOES-R) is a hybrid algorithm based on the NASA CERES/Surface and Atmospheric Radiation Budget (SARB) algorithm (Charlock and Alberta, 1996) and on the University of Maryland (UMD) SRB algorithm (Pinker and Laszlo, 1992). The primary algorithm uses ABI Level 2 products (e.g., surface abledo, cloud optical depth, particle size, and top height for cloudy scenes; and aerosol optical depth and single scattering albedo for clear scenes) to estimate the SW fluxes in a forward scheme, hence termed the "Direct Path". When the ABI retrieval products are not available the algorithm switches to an appropriately modified version of the UMD algorithm developed at NOAA/NESDIS/STAR. The latter inversion algorithm, named the "Indirect Path", requires ABI observed channel reflectances as major inputs with minimal reliance on derived ABI products. It uses the SW broadband TOA albedo estimated from narrowband reflectances in selected ABI bands using spectral Narrow-to-Broadband (NTB) conversion and angular correction to estimate atmospheric transmittance. Surface Downward SW Radiation (DSR) and TOA Reflected SW Radiation (RSR) are produced by the algorithm. Within each grid, there are up to four scene types including two clear (clear-sky snow/ice-free and clear-sky over snow/ice) and two cloudy scenes (water cloud and ice cloud), and retrieval is carried out on a scene basis. The retrieved fluxes corresponding to each scene are then weighted according to the scene fractions to yield the all-sky flux. Figure 1 shows the major components of the ABI SRB algorithm.

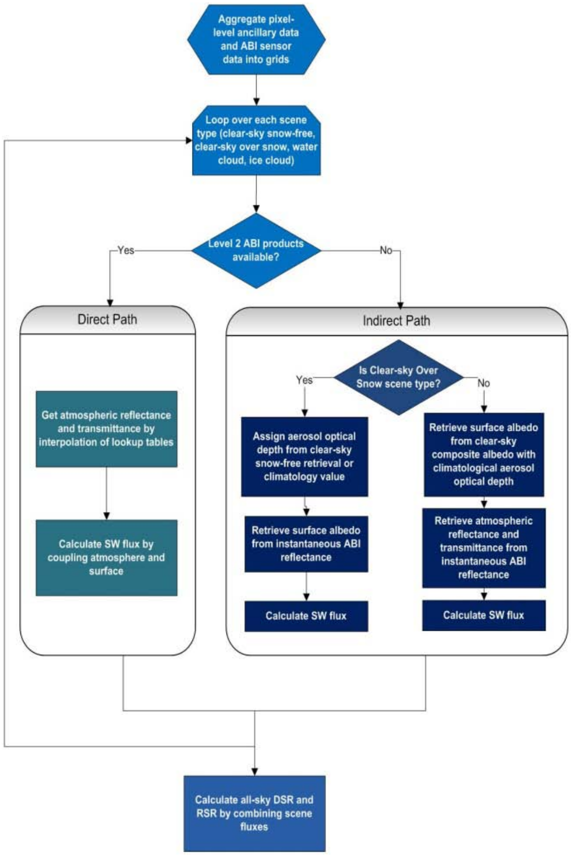

Figure 1. Flowchart of ABI SRB algorithm.

2. EVALUATION OF ABI SRB ALGORITHM

Evaluation of the ABI SRB algorithm is performed with CERES/ARM Validation Experiment (CAVE), SEVIRI, and MODIS data.

2.1 *Validation with CAVE Data*

CAVE dataset includes collocated CERES and ground flux measurements over 52 stations during a 7-year period (1-8/1998; 3/2000-6/2006). Indirect path retrievals are driven by CERES footprint TOA upward broadband SW radiation directly without narrow-to-broadband conversion and angular correction. Direct path uses atmosphere and surface data including

---

* Corresponding author address: Hongqing Liu, World Weather Building, 5200 Auth Road, Camp Springs, MD 20788; e-mail: Hongqing.Liu@noaa.gov.

cloud optical depth/phase/height/particle size retrieved from TRMM/MODIS imager; aerosol optical depth and single scattering albedo from imager retrievals or MATCH model; total precipitable water from GEOS assimilation products; TOMS Total Column Ozone retrievals; and surface albedo retrieved from CERES. Figure 2 shows the accuracy (bias) and precision (standard deviation) of DSR retrievals from direct and indirect path is comparable.

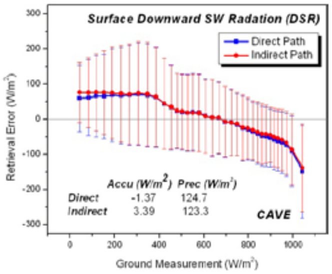

Figure 2. DSR Retrieval error as a function of ground truth. Symbols represent the retrieval bias of each bin, whiskers denote the standard deviation of retrieval errors.

Performance of ABI direct and indirect path retrievals are compared with SARB and GSIP satellite algorithms. Table 1 shows the overall statistics are comparable to other satellite retrievals.

Table 1. Overall retrieval accuracy and precision (W/m^2) are comparable from several satellite algorithms.

Algorithm	***Accuracy***	***Precision***
NASA CERES/Surface and Atmospheric Radiation Budget (SARB)	5.6	123.5
NOAA GOES Surface and Insolation Product (GSIP)	3.4	127.7
ABI Direct Path Retrieval	-1.4	124.8
ABI Indirect Path Retrieval	3.4	123.4

2.2 *Validation with SEVIRI Data*

Indirect path retrieval is evaluated with SEVIRI data by using L1B SW reflectances; image-based cloud mask; NCEP reanalysis water vapor; OMI column ozone. Sensor data are averaged into ½ degree grids for full disk during four months (Jan., Apr., Jul., Oct.) of year 2006. Validation of the SEVIRI DSR uses measurements from 9 BSRN stations. A 30-minute temporal average was applied to the ground observations. Validation of the retrieved RSR uses GERB measurements made every 17 minutes with nadir footprint size of 45 x 40 km. Validation was performed with the temporally closest GERB measurements without interpolation in time. Table 2 shows the overall accuracy and precision of the retrieved for four months of year 2006. Retrieved RSR do not exhibit obvious seasonal dependence.

Table 2. Statistics of indirect path retrievals with SIVIRI data for four months of 2006.

	DSR		***RSR***	
	Accuracy	***Precision***	***Accuracy***	***Precision***
Jan.	15.9	83.3	-9.5	51.3
Apr.	16.0	93.2	-9.5	53.0
Jul.	-5.6	91.3	-5.5	42.8
Oct.	3.1	90.5	-10.6	55.0

Diurnal dependence of RSR retrieval error is investigated by comparing to GERB measurements. Relatively large error appears at morning, noon and evening time. There is no obvious scene type dependence regarding to the clear-sky and cloudy retrievals. Figure 3 shows the diurnal variation of RSR retrieval errors for July, 2006.

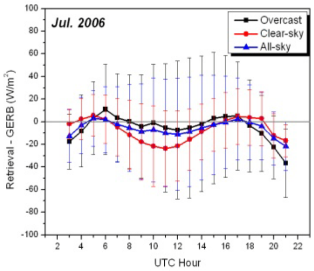

Figure 3. RSR Retrieval error as a function of UTC time for July 2006.

2.2 *Validation with MODIS Data*

L1B MODIS reflectance from both Terra and Aqua are collected over 12 ground stations (SURFRAD, ARM, COVE, CMDL) within GOES domain for the period of 03/2000-12/2009. Also collected are MODIS retrieved cloud optical depth, cloud particle size, cloud phase, cloud top height, aerosol optical depth, total precipitable water and ozone (TOMS/OMI daily data is used for filling in missing values), cloud and snow mask, and surface albedo. Pixel-level MODIS data are averaged within 5/25/50 km square grids. Hybrid algorithm is used for this validation, where indirect path is invoked for ~65% of clear-sky and ~50% of cloudy-sky cases.

Table 3. Statistics of hybrid retrieval with MODIS data.

	DSR		***RSR***	
	Accuracy	***Precision***	***Accuracy***	***Precision***
50km	-10.0 (-1.7%)	118.9 (20.7%)	18.1 (6.7%)	45.0 (16.6%)
25km	-11.2 (-1.9%)	112.6 (19.6%)	18.9 (7.0%)	52.8 (19.5%)
5km	-13.3 (-2.3%)	112.2 (19.5%)	20.5 (7.5%)	71.9 (26.5%)

As shown in Table 3, DSR retrieved from the hybrid SRB algorithm does not exhibit obvious spatial scale dependence, while the precision of RSR decreases as spatial resolution increases. Certain stations exhibit seasonal dependence in the time series of monthly mean hybrid retrievals (Figure 4), for example, underestimation of DSR in winter from stations TBL and SXF; over-/under-estimation of RSR in winter/summer from DRA.

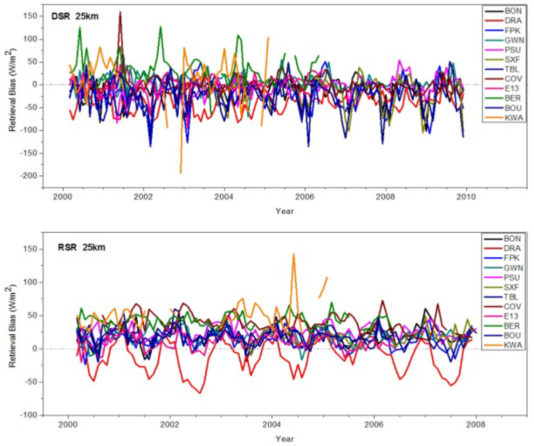

Figure 4. Time series of monthly mean 25km retrieval bias of DSR (top) and RSR (bottom) for each station.

Retrievals from direct and indirect paths exhibit similar dependence patterns on the satellite cloud fraction, solar zenith angle and measurement values (Figure 5). It is noted that about 50% (20%) of clear-sky (cloudy-sky) indirect path retrievals failed to converge to the converted TOA albedo, which indicates the need for further improvement of the narrow-to-broadband conversion and clear-sky composite albedo determination.

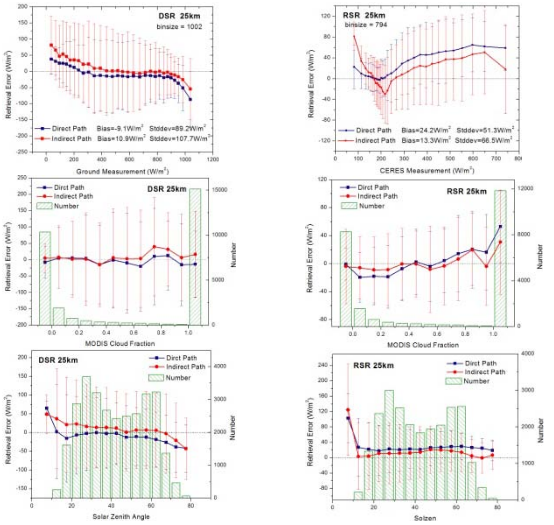

Figure 5. Retrieval errors as a function of measurements (top), cloud fraction (middle) and solar zenith angle (bottom) for DSR (left) and RSR (right).

Due to the field-of-view difference, satellite and ground measurements may register inconsistent scene fraction that contributes to the discrepancy in the validation. Figure 6 shows that DSR retrieval precision is improved by 25% when validation is performed on the cases where cloud fraction from satellite and ground is consistent (difference < 10%).

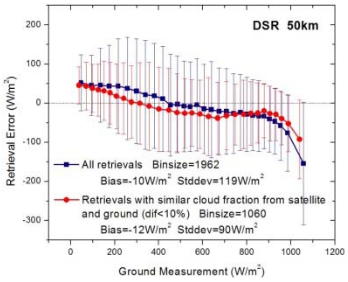

Figure 6. DSR Retrieval error as a function of ground measurements when only match-ups with consistent satellite and ground observed cloud fraction are used (Red). Also shown is the validation result using all match-ups (Blue).

3. CONCLUDSION

1. ABI SRB algorithm has been developed for GOES-R ABI instrument. Extensive validation with MODIS proxy data shows the overall accuracy and precision is -10 (-2%) and 120 (20%) W/m^2 for DSR and 18 (7%) and 45 (17%) W/m^2 for RSR at 50km resolution.
2. For the indirect path retrieval with SEVIRI data, there is no obvious seasonal dependence of retrieved RSR. For the hybrid retrievals with MODIS data, certain stations exhibit seasonal variation. Over the full SEVIRI disk, overall uncertainty of RSR tends to be large in the early and late UTC hours and negative bias is found at noon time. Among MODIS retrievals, larger errors are found in the extreme solar zenith angles.
3. Performance of direct and indirect path is relatively comparable; both overestimate RSR at overcast conditions.
4. Insistent cloud fraction registered in satellite and ground measurements contributes to the low precision of DSR retrievals.

4. REFERENCES

Charlock, T. P., and T. L. Alberta, 1996: The CERES/ARM/GEWEX Experiment (CAGEX) for the retrieval of radiative fluxes with satellite data. *Bull. Amer. Meteor. Soc*., 77, 2673-2683.

Pinker, R.T., and I. Laszlo, 1992: Modeling surface solar irradiance for satellite applications on a global scale. *J. Appl. Meteorol.*, 31, 194-211.