P1.8 DEVELOPMENT OF THE GOES-R ABI OUTGOING LONGWAVE RADIATION PRODUCT

Hai-Tien Lee[(1)], Istvan Laszlo[(2,1)], and Arnold Gruber[(1)]

[(1)]University of Maryland, College Park, MD [(2)]NOAA/NESDIS, Camp Spring, MD

1. INTRODUCTION

The next generation of NOAA Geostationary Operational Environment Satellite, R series (GOES-R), is scheduled for launch in approximately 2014 and will provide critical support for NOAA's missions with its advanced instruments and a comprehensive suite of quantitative environmental data. Complete Earth Radiation Budget (ERB) parameters at both the top of the atmosphere and the Earth's surface are planned to be derived from the Advanced Baseline Imager (ABI) observations. This would be the first time that such parameters are derived operationally from the NOAA geostationary satellites, whereas the top of the atmosphere ERB parameters have been derived operationally and continuously from the NOAA TIROS-N series Polar Orbiting Environmental Satellites (POES) since 1979.

This paper describes the development of the preliminary version of the Outgoing Longwave Radiation (OLR) algorithm that will be implemented for the GOES-R ABI instrument. The Moderate-Resolution Imaging Spectroradiometer (MODIS) onboard NASA EOS satellites and the Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard the EUMETSAT METEOSAT satellites were employed as surrogate for ABI for the development of the OLR algorithm. The Single Scanner Footprint (SSF) OLR product derived from the broadband observations by the NASA Cloud and Earth's Radiant Energy System (CERES) was used as the validation reference. We have assessed the instantaneous OLR retrieval errors from MODIS- and SEVIRI-derived OLR surrogating ABI capability that are about 5 and 4 Wm^{-2}, over the globe and over the Eumetsat-8 full-disk domain, respectively. This is very encouraging as it is within the instantaneous error of the one-sigma uncertainty of the broadband OLR observations, about 5 Wm^{-2}. Nevertheless, relatively large biases were observed over some regions, e.g., deserts and subtropical oceans. Errors in the EUMETSAT released SEVIRI radiance data appeared to contribute to some view zenith angle dependent biases in the SEVIRI-based OLR. The validation results and its error analysis for the SEVIRI studies will be shown here. The methods for improving regional accuracies will also be discussed.

2. METHODOLOGY

Ellingson et al. (1989) developed the multi-spectral OLR estimation method using the narrowband radiance observations from the High-resolution Infrared Sounder (HIRS). Vigorous validation efforts have been performed for the HIRS OLR products with broadband observations derived from the Earth Radiation Budget Experiment (ERBE) and the Clouds and the Earth's Radiant Energy System (CERES) by Ellingson et al. (1994) and Lee et al. (2007). This method was also successfully adapted to the current GOES Sounder and Imager instruments (Ba et al., 2003; Lee et al., 2004). These studies showed that this algorithm could reliably achieve an accuracy of OLR estimation of about 5 to 8 Wm^{-2} with essentially no bias. It is therefore the method of choice for the GOES-R ABI instrument for delivering the OLR EDR (Environmental Data Record) that would satisfy the 20 Wm^{-2} threshold accuracy requirement defined in the GOES-R Mission Requirement Document (MDR-2B) as of March 2005.

The multi-spectral OLR algorithm can be described by

$$OLR = a_0(\theta) + \sum_{i=1}^{n} a_i(\theta) N_i(\theta) \tag{1}$$

Equation 1 assumes that the OLR can be estimated by the sum of the narrowband radiance N_i of the i^{th} predictor channel weighted by the corresponding regression coefficients a_i and an intercept term, a_0. The regression coefficients and radiances are functions of local zenith angle, θ, such that the OLR can be obtained directly from slant path observations. The basic procedures for development, including sounding database, radiation parameter simulation, and cloud treatment followed Lee et al. (2007).

Two OLR models were developed for SEVIRI using radiance observations that closely resemble the ABI instruments. The Model A uses SEVIRI channels 6, 9 and 11; while the Model B uses channels 5, 6, 7, 11. The corresponding ABI channels are listed in the Table 1.

Table 1. List of SEVIRI and ABI channels used in OLR estimation.

SEVIRI	Center	Type	ABI
5	6.2 μm	Water vapor (high tropo.)	8
6	7.3 μm	Water vapor (mid tropo.)	10
7	8.7 μm	Water vapor (low tropo.)	11
9	10.8 μm	Window	13
11	13.4 μm	Near surface temp.	16

3. VALIDATION DATA AND RESULTS

The SEVIRI radiance data from June 21-27 and December 11-17, 2004 over the Meteosat-8 (Schmetz et al., 2002) full disk domain were collocated with CERES SSF data from all four instruments, FM1 & 2 (Ed.2B) and FM3 & 4 (Ed.1B), onboard Terra and Aqua satellites, respectively.

The SEVIRI radiance observations were averaged for 3x3 pixels (native resolution is 3 km at the

* *Corresponding author address:* Hai-Tien Lee, CICS/ESSIC-NOAA, University of Maryland, College Park, MD 20742. E-mail: lee@umd.edu.

sub-satellite point) centered on the CERES footprint (about 20 km nadir). Homogeneity indicators are defined for the 0.6-µm and 10.8-µm channels as the ratio of the difference of the maximum and minimum values to the mean for each of the 3x3-pixel SEVIRI area. Homogeneous scenes are filtered through this indicator at a threshold of 0.01 for the 10.8-µm channel. The temporal matching window is ±7.5 minutes.

Instantaneous OLR estimates were compared for homogeneous scenes with local zenith angles matched to within ±1°. (Note that the azimuthal angles were not matched.) The RMS differences between the SEVIRI estimated OLR and the CERES OLR are about 4.5 and 4.0 Wm^{-2} for Model A and B, respectively. The mean differences are -0.1 and -1.5 Wm^{-2}, which are within the CERES 1% accuracy of about 2 to 3 Wm^{-2}. The comparison of the instantaneous OLR is shown in **Fig. 1.** Both models showed very good linear relationship with the CERES, with a SEVIRI to CERES ratio very close to one (0.9993±0.0001 and 0.9948±0.0001). The numbers of samples are close to one hundred thousand.

Fig. 2 shows the mean and standard deviation of the differences between SEVIRI (Model B) and the CERES OLR for 1° equal-angle areas. The overall accuracy of the SEVIRI OLR is quite satisfactory as most areas have mean and standard deviation of the OLR differences within 3 Wm^{-2}. However, as also seen in these maps, there are noticeable regional problems: a) negative biases over deserts, b) positive biases over subtropical oceans, and c) seemingly limb dependent biases.

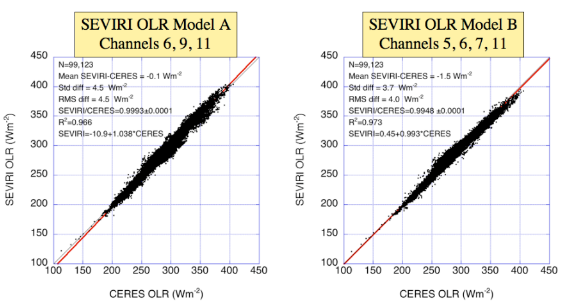

Fig. 1. OLR validation results for SEVIRI OLR models A and B.

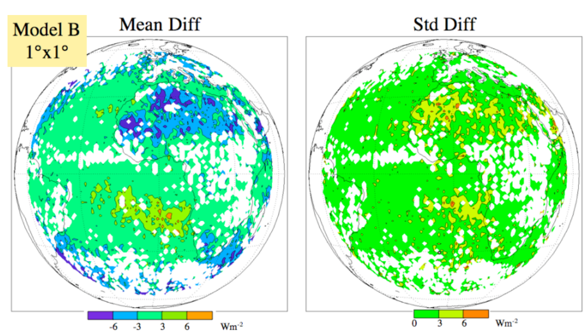

Fig. 2. Mean and standard deviation of the Model B SEVIRI OLR minus CERES OLR for 1° equal-angle areas.

4. SEVIRI RADIANCE ERROR

EUMETSAT provides, by mistake, the "spectral radiance" instead of the "effective radiance" for the infrared channels. **Fig. 3** shows the radiance errors as functions of brightness temperature. The impact of this error in estimating OLR from SEVIRI is model dependent as different channels have different error characteristics. **Fig. 4** shows the changes in the SEVIRI OLR estimation using Model B as a function of the SEVIRI local zenith angle. The SEVIRI radiance error can cause limb dependent OLR biases.

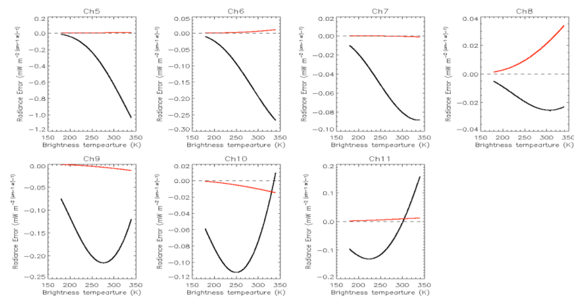

Fig. 3. Spectral minus effective radiances as a function of brightness temperature for the SEVIRI infrared channels (black). The red curves are the differences in the radiance corrections using EUMETSAT versus CICS derived coefficients. These differences are the largest for channel 8 (9.7 µm); an investigation of this large difference is ongoing.

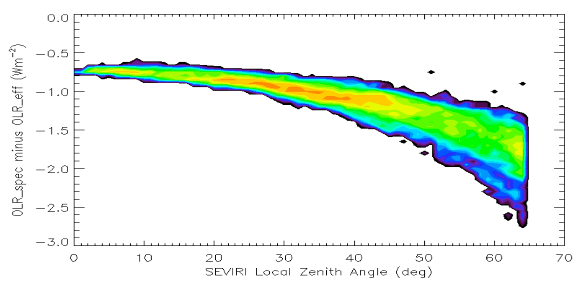

Fig. 4. Differences in OLR when derived with SEVIRI spectral radiances minus that with the effective radiances as a function of local zenith angle. Number density contour interval is at the power of ten. The SEVIRI radiance errors resulted in limb dependent OLR errors.

Using the SEVIRI effective radiance, the Model B SEVIRI OLR estimates have improved the mean and RMS differences to about -0.3 and 3.6 Wm^{-2}, respectively, for to the same data set as used in Fig. 1.

A planned change in the SEVIRI radiance processing will be implemented on the operational chain on April 1st 2008 followed with the reprocessing of the full archive from Feb. 1st 2004. (EUM, 2007)

5. REGIONAL ACCURACY IMPROVEMENT

The primary source of regional errors is related to the modeling of water vapor and surface temperature effects. Linear regression models might not be able to adequately account for these effects, and non-linear predictors might be required as suggested by the geographical distribution of OLR errors (Fig. 2) compared to the distribution of SEVIRI radiances (**Fig. 5**). Scatter plots of OLR errors versus the radiances (see poster) also clearly show that the Model B errors are dependent on the predicting variables.

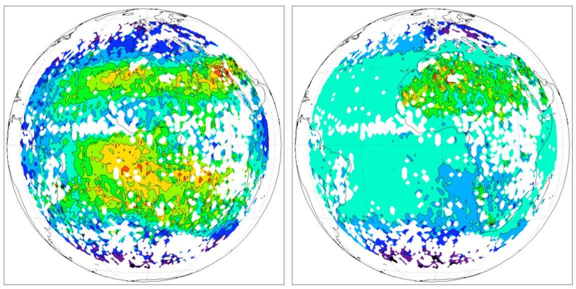

Fig. 5. Mean SEVIRI radiances of channel 5 (6.2 μm) (left) and 9 (10.8 μm) (right) for the validation samples.

An experimental OLR model (referenced as Model C) that uses non-linear predictors and derived with stage-wise regression analysis produces better results in terms of modeling water vapor effects. As seen in **Fig. 6,** the apparent dependence of SEVIRI OLR error in 6.2μm radiances in Model B is effectively removed in Model C. The Model C predictors are composed of the radiances of SEVIRI channel 5, 6, 7, 9, 11, and the square and cube of channel11 radiances.

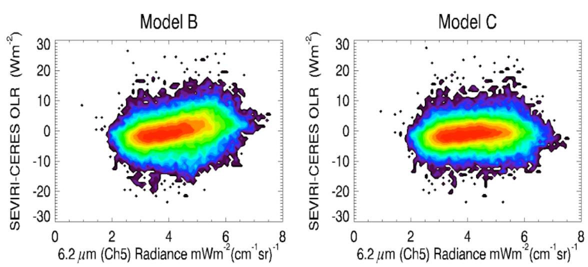

Fig. 6. SEVIRI OLR errors as function of channel 5 (6.2 μm) radiances for Model B (left) and Model C (right).

The corresponding 1° equal-angle area average of SEVIRI minus CERES OLR differences for SEVIRI Model C is shown in **Fig. 7**, where the bias errors in the subtropical oceanic regions were largely eliminated. However, the negative biases over desert regions are still present at similar magnitudes about -3 to -6 Wm^{-2}. The standard deviations in both subtropical oceanic and desert areas are significantly reduced such that the SEVIRI OLR achieved a precision to within about 3 Wm^{-2} in almost the entire hemisphere.

7. FUTURE WORKS

We plan to conduct more modeling experiments for better understanding the error characteristics. The expansion of sounding database seems necessary to provide sufficient amount of desert and subtropical representations.

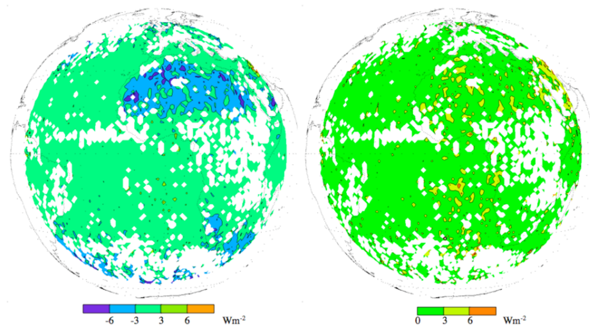

Fig. 7. Similar to Fig. 2 but is for SEVIRI OLR Model C.

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