# Development of the GOES-R ABI Outgoing Longwave Radiation Product

**P1.8**

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## 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.

## 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

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

This 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, , 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 below.

| 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 |

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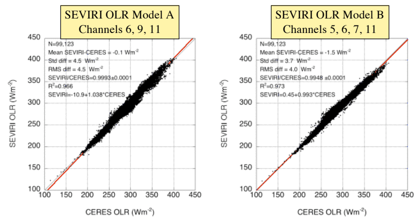
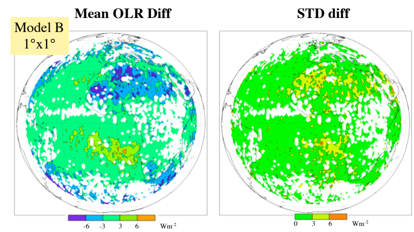
## VALIDATION RESULTS

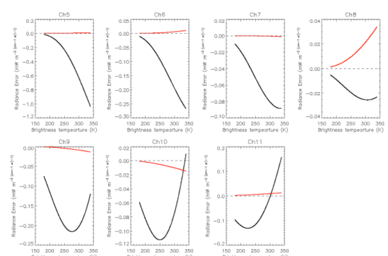



The SEVIRI radiance data from June 21-27 and December 11-17, 2004 over the Meteosat-8 full disk domain were collocated with CERES SSF data from all four instruments, FM1 & 2 (Ed.2B) and FM3 & 4 (Ed.1B), onboard Terra and Aqua satellites, respectively. Instantaneous OLR estimates were compared for homogeneous scenes with local zenith angles matched to within ±1° and a temporal window within ±7.5 minutes.



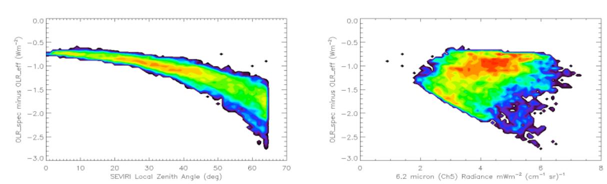

These maps show the mean and standard deviation of the differences between SEVIRI (Model B) and the CERES OLR for 1° equal-angle areas. The overall accuracy of the SEVIRI OLR is quite satisfactory as most areas have mean and standard deviation of the OLR differences within 3 $Wm^{-2}$. However, as also 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.

## SEVIRI RADIANCE ERROR



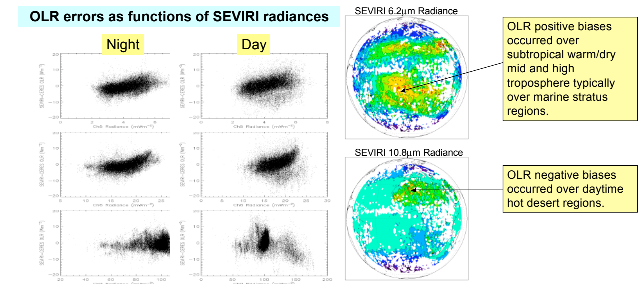

EUMETSAT provides, by mistake, the "spectral radiance" instead of the "effective radiance" for the infrared channels. This figure shows the radiance errors as functions of brightness temperature (black curves). The red curves are the differences in the radiance corrections using EUMETSAT versus CICS derived coefficients. These differences are the largest for channel 8 (9.7 μm); an investigation of this large difference is ongoing.

The impact of this error in estimating OLR from SEVIRI is model dependent as different channels have different error characteristics. The impact on the SEVIRI OLR estimation using Model B is plotted as a function of the SEVIRI local zenith angle and 6.2-μm radiances. This indicated that the SEVIRI radiance error can cause limb and/or scene dependent OLR biases. 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.

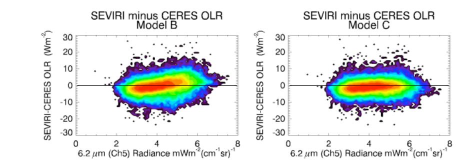


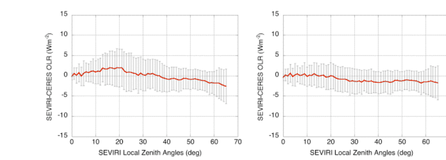

## REGIONAL ACCURACY IMPROVEMENT

**OLR errors as functions of SEVIRI radiances**

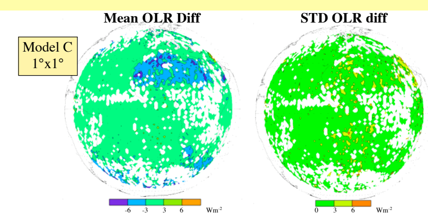



An experimental OLR model (referenced as **Model C**) that uses non-linear predictors and derived with stage-wise regression analysis produces better results in terms of modeling water vapor effects. The Model C predictors are composed of the radiances of SEVIRI channel 5, 6, 7, 9, 11, and the square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




The OLR bias 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.




## FUTURE WORKS

More modeling experiments will be conducted to better understand the error characteristics. The expansion of sounding database seems necessary to provide sufficient amount of desert and subtropical representations.

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