VIIRS REFLECTIVE SOLAR BANDS CALIBRATION REPROCESSING

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ABSTRACT

Radiometric calibration coefficients for the VIIRS reflective solar bands have been reprocessed from the beginning of the Suomi NPP mission until present. An automated calibration procedure, implemented in the JPSS operational data production system, was applied to reprocess onboard solar calibration data and solar diffuser degradation measurements. The latest processing parameters from the operational system were used to include corrected solar vectors, optimized directional dependence of attenuation screens transmittance and solar diffuser reflectance, updated pre-launch calibration coefficients without an offset term, and optimized Robust Holt-Winters filter parameters. The parameters were consistently used to generate a complete set of the radiometric calibration coefficients for the entire duration of the Suomi NPP mission. The reprocessing has also demonstrated that the automated calibration procedure can be successfully applied to all solar measurements acquired from the beginning of the mission until the full deployment of the automated procedure in the operational processing system.

***Index Terms*—** Remote sensing, spectroradiometers, radiometry, calibration, validation

1. INTRODUCTION

The VIIRS (Visible Infrared Imaging Radiometer Suite) sensor onboard the Suomi NPP (National Polar-orbiting Partnership) satellite is the first instrument in the series that is being deployed on the JPSS (Joint Polar Satellite System) spacecraft by NOAA (National Oceanic and Atmospheric Administration) and NASA (National Aeronautics and Space Administration) [1]. The Suomi NPP VIIRS has been acquiring Earth observations since November 2011. The observations consist of 22 spectral channels with 14 of the channels located in the RSB (reflective solar band) range of 400 to 2280 nm. After applying radiometric calibration, VIIRS RSB TOA (top-of-atmosphere) measurements of radiance and reflectance are processed to create environmental data products that include ocean color and chlorophyll concentration, green vegetation fraction, and polar wind vectors that are derived from the cloud motion. To assure quality of the data products, uncertainty of the VIIRS radiometric calibration for the RSB channels M1 to M11 and I1 to I3 is expected not to exceed 2% at typical radiance levels [2].

RSB radiometric calibration coefficients are derived from onboard solar diffuser measurements that are conducted once per orbit [3]. Solar calibration data from multiple orbits are aggregated before a new set of the coefficients is created and subsequently implemented in the operational processing. Since it was found early in the Suomi NPP mission that responsivity of the VIIRS instrument in several spectral bands decreases with time much faster than expected, accuracy of the radiometric calibration has been maintained by updating the coefficients with the weekly frequency (approximately every 100 orbits). The radiometric calibration procedure and the processing parameters have been improved several times throughout the lifetime of the mission. Initially, only values of the coefficients were updated every week. Later, changes of the coefficients during each week were predicted as well. Currently, an automated procedure has been implemented that updates the RSB calibration coefficients after every orbit [4].

The presented work had two goals:

1. Validation: to demonstrate that the automated calibration procedure can be successfully applied to all solar diffuser measurements acquired from the beginning of the Suomi NPP mission until the full operational deployment of the automated procedure
2. Reprocessing: to generate a complete set of the calibration coefficients while consistently using the latest processing parameters that are optimized based on knowledge gained during the entire Suomi NPP mission so far

The reprocessed radiometric calibration coefficients derived by the automated procedure have been compared with those previously applied in the SDR (Sensor Data Record) production at the NOAA operational IDPS (Interface Data Processing Segment) system.

IDPS generates VIIRS data products in near real time with latency currently limited to no more than few hours. The processing coefficients in IDPS are not based on interpolation between past calibration measurements, but rather an extrapolation of the calibration coefficients into

the future is always required. Reprocessing that uses the same approach may be less accurate than those based solely on the interpolation [5-6], but it affords the most consistent SDR production for the entire duration of the Suomi NPP mission.

2. PROCESSING DETAILS

VIIRS RSB radiometric calibration coefficients were reprocessed using the ADL (Algorithm Development Library) software that includes the IDPS code for the SDR production (version Mx8.8 with additional minor changes). The reprocessed coefficients are based on the latest processing parameters from the operational system that incorporate the following major changes:

- Corrected solar vectors: after a processing code update, orientation of the solar vectors changed by as much as 0.2 degree
- Improved solar attenuation screens transmittance and solar diffuser bidirectional reflectance tables: angular dependence was optimized based on reanalysis of the on-orbit yaw-maneuver and routine SDSM (solar diffuser stability monitor) measurements
- Updated pre-launch calibration coefficients: to improve consistency between bands with similar spectral response, offset terms were set to zero while only linear and quadratic terms remained
- Optimized Robust Holt-Winters filter parameters: smoothing of the aggregated calibration coefficient time series was improved by damping oscillations while maintaining sensitivity to trend changes

The same set of the processing parameters is consistently used in the entire reprocessing of the VIIRS RSB calibration coefficients.

The reprocessing was started with the VIIRS RDRs (Raw Data Records) to mitigate earlier processing errors such as the incorrect solar vector rotation or omission of some SDSM data. The datasets were obtained from the NOAA CLASS (Comprehensive Large Array-data Stewardship System) archive (http://www.class.noaa.gov/) or from the JPSS GRAVITE (Government Resources for Algorithm Verification, Independent Testing and Evaluation) system (https://gravite.jpss.noaa.gov/). When multiple sets existed for the same data granule, only the most complete one or the most recent one (when equal in size) was selected for the processing.

3. RESULTS

VIIRS solar calibration is based on measurements of light reflected from the onboard solar diffuser, and knowledge of the diffuser reflectance is fundamental to accuracy of the calibration. Separate solar diffuser measurements with SDSM are analyzed to derive the diffuser reflectance changes with time. Ratio of the reflectance value to a pre-launch measurement (the H factor) is directly used to scale the calibration coefficients for the visible and near-infrared bands (M1 to M7 and I1-I2).

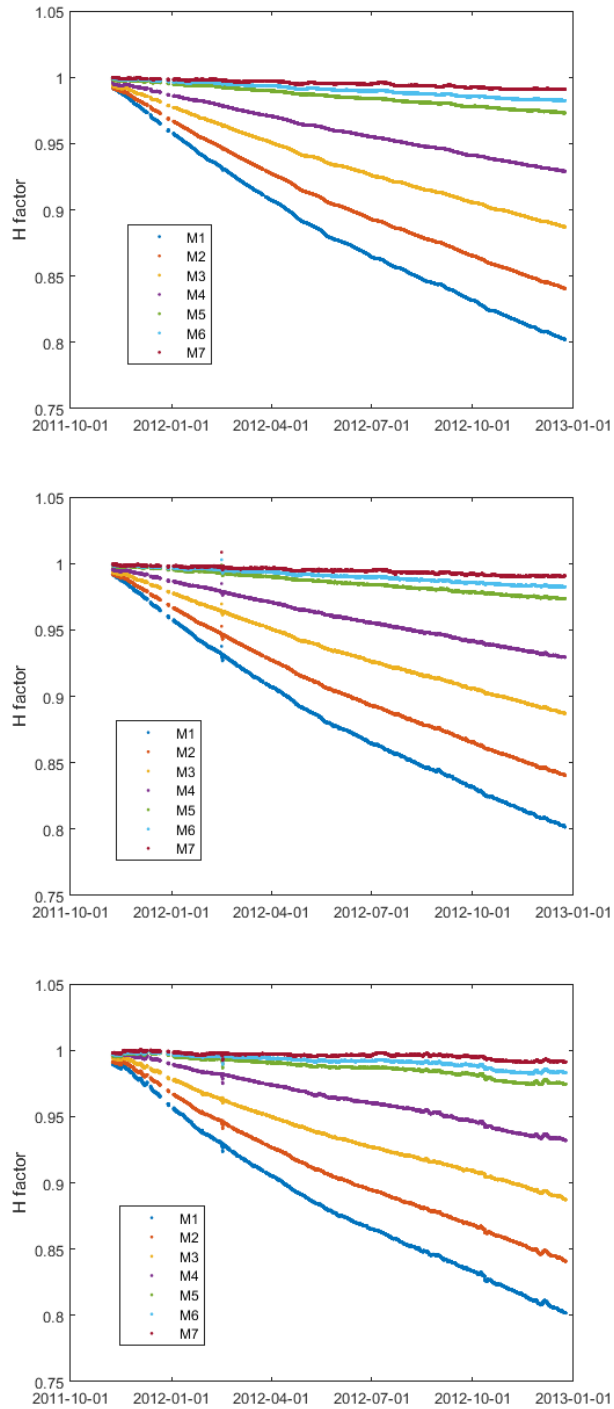

Fig. 1. Degradation of the Suomi NPP VIIRS solar diffuser reflectance (the H factor) as measured by the SDSM and analyzed by the ADL/IDPS automated calibration procedure using the current processing parameters with (top graph) and without (middle graph) time series filtering as well as using the previous values of the parameters (bottom graph).

Figure 1 shows that the time series of the H factors calculated during this reprocessing are much smoother than the ones generated without the processing changes discussed in the previous section. It is especially visible early in the mission and during the October-December period when the direction of the solar illumination of the spacecraft makes the SDSM measurements more difficult. The time series filtering has also improved the H factor calculations for the yaw maneuver measurements in February 2012. The reprocessed H factors were used in the calculations of the F factors that scale the VIIRS radiometric calibration coefficients from the pre-launch values.

Figure 2 shows a comparison of the reprocessed F factors with those previously used in the operational SDR production for one of the visible bands not significantly affected by the VIIRS telescope throughput degradation (M3). The F factors calculated by the automated procedure not only extend to the beginning of the Earth observations from VIIRS, but also appear more stable throughout the first year of the mission. Variability visible in the time series of the reprocessed F factors is on the order of only 1% and reflects uncertainty of the calibration. The changes of the operational F factors shown on the graph originate from the improvements in characterization of the VIIRS radiometric response that occurred during the first year of the mission [7]. The differences between the reprocessed coefficients and the original ones do not generally exceed ±2%, in agreement with the calibration uncertainty requirements.

Figure 3 shows the F factor comparison for the band M7 that is strongly affected by the telescope degradation (approx. 40% change during the first year) [8]. Even with the F factor changes dominated by the throughput decrease, one can notice that the reprocessed calibration coefficients are free of the spurious variability that affected the earlier operational F factors (changes in December 2012 are only due to an investigation of the degradation anomaly). The reprocessed F factors indicate more consistent changes in the UV-controlled degradation rate as should be expected when the Sun-Earth distance correction is included in the calculations.

Although some improvements of the calibration coefficients can be expected just from the consistent use of the same processing parameters for the whole mission period, Figures 2 and 3 show that after the reprocessing the solar diffuser degradation is better corrected for band M3, and the telescope degradation that is diminishing with time is better corrected after every orbit for band M7. Similar improvements in the reprocessed F factors can be seen for the other visible and near-infrared bands as well as for the short-wave infrared bands.

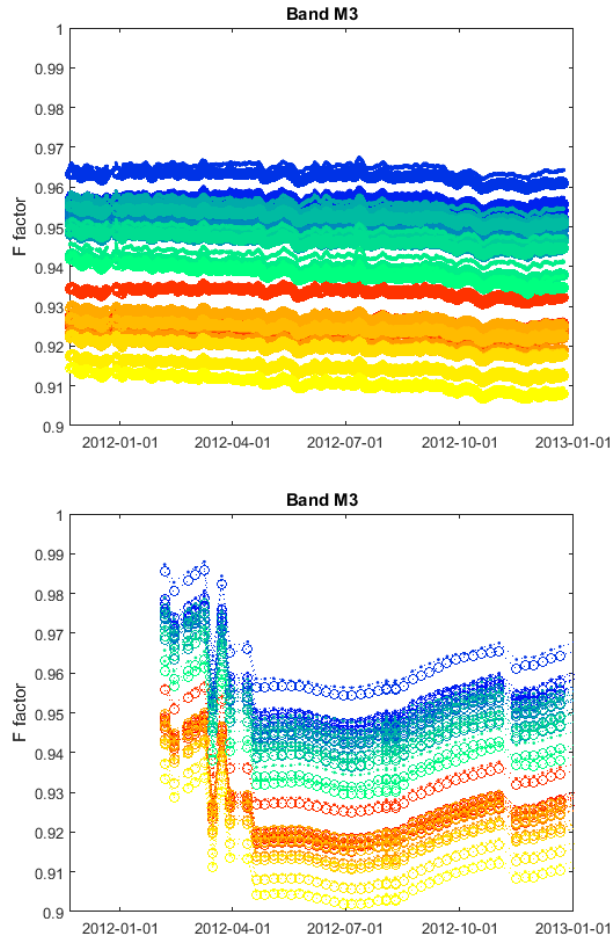

Fig. 2. Comparison of the VIIRS radiometric calibration scaling coefficients (the F factors) derived by the automated calibration procedure (top graph) versus those used in the operational production of the VIIRS SDR (bottom graph) for band M3. The half-angle mirror sides and the gain states are indicated by different symbols (dots and circles), while the F factors for each detector are shown with a different color from the red-yellow (for high/single gain) and blue-green (for low gain) palettes.

4. CONCLUSIONS

Reprocessing of the VIIRS RSB calibration coefficients using a new automated procedure has increased confidence in this approach by demonstrating that it can be applied to all solar calibration data previously acquired during the Suomi NPP mission. The improved calibration coefficients can be further used to reprocess VIIRS SDR and other data products. This may especially benefit direct broadcast ground stations when reprocessing of previously acquired VIIRS datasets is needed.

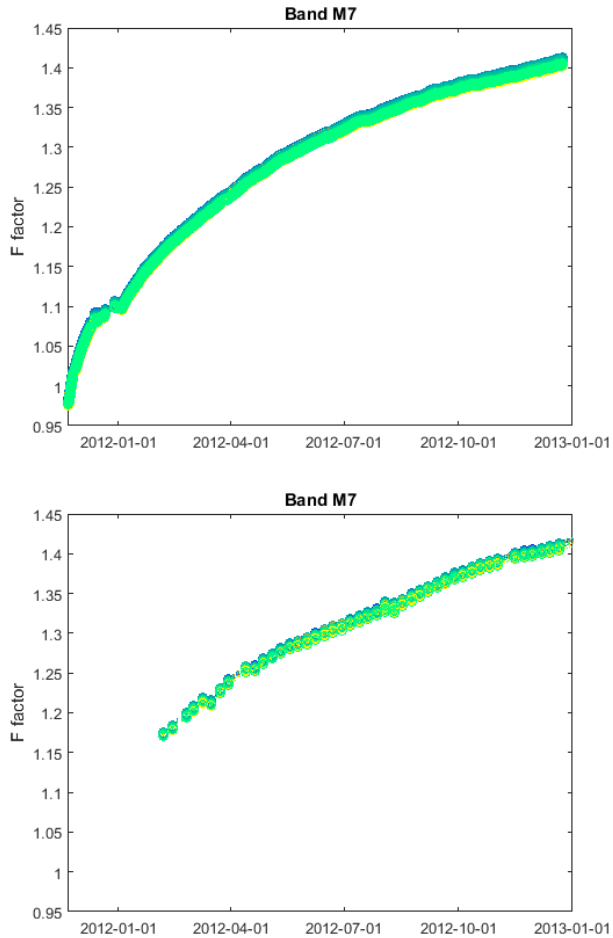

Fig. 3. Comparison of the VIIRS radiometric calibration scaling coefficients (the F factors) derived by the automated calibration procedure (top graph) versus those used in the operational production of the VIIRS SDR (bottom graph) for band M7. Symbol legend is the same as in Figure 2.

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