On-Orbit Measurement of the Effective Focal Length and BBR of the VIIRS Sensors

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Introduction

We report here on the measurement of the effective focal length (EFL) and Band-to-Band Registration (BBR) of selected bands of the SNPP and J1 VIIRS sensors from on-orbit data. This is achieved by simulating VIIRS data with Landsat 8 OLI data utilizing the VIIRS geolocation data generated with varying values of focal length. For each scan of a selected VIIRS data set, various subsets of the data are examined to find the subset with the highest spatial correlation between the original and simulated VIIRS data using the nominal geolocation information. Then, for this best subset, the focal length value and the spatial shift are varied to find the values that produce the highest spatial correlation between the original and simulated VIIRS data. This best focal length value is taken to be the measured instrument EFL and the best spatial shift is taken to be the registration of the VIIRS data relative to the Landsat data (from which the VIIRS BBR can be inferred).

Overview of the Approach

1. Select pairs of cloud free VIIRS and Landsat data sets from the same date over high contrast features visible in the VIIRS data.
2. Generate several instances of VIIRS geolocation data based on varying values of focal length.
3. For each scan of the VIIRS data, over the portion covered by the available Landsat data, simulate several subsets of the VIIRS data using the nominal geolocation data and appropriate system point spread function, and select the subset that produces the highest spatial correlation.
4. Visually inspect the Landsat and VIIRS subsets to ensure that each subset does not cover a large area of water. Revise the subset selection, if necessary. (Measurements over large areas of water usually give very high spatial correlations but also often give essentially random results for best focal length and spatial shift values.)
5. For the selected subset, measure the spatial correlation between the original and simulated VIIRS data for varying values of focal length and spatial shift, and note the spatial shift that produces the highest spatial correlation. Take this best spatial shift as the registration of the VIIRS data relative to the Landsat data.
6. For the best spatial shift, fit the plot of spatial correlation values versus focal length values to a 2nd degree polynomial curve and take the focal length that produces the maximum of the curve to be the measured focal length. Note the peak and R^2 fit of this curve as measurement quality factors.
7. Repeat steps 2-6 for the remaining relatively cloud free scans from the VIIRS data with coverage by available relatively cloud Landsat data.
8. Tabulate the results from each VIIRS data set and report the mean and standard deviation values for the measured focal length and spatial shift values for scan subsets with high spatial correlation and R^2 values (ideally spatial correlation >= 0.99 and R^2 >= 0.995).

Measurement of Spatial Shift and Simulation Quality with Cross Correlation

To maximize the performance of the cross correlation, we scaled the original and simulated VIIRS image data to the same range and maintained the data in floating point.

We represent the spatial shift between the original and simulated VIIRS image as *r* (row shift) and *c* (column shift) and the shifted simulated image as s_{rc}. Positive column and row shifts move the simulated VIIRS image up (south) and to the left (east).

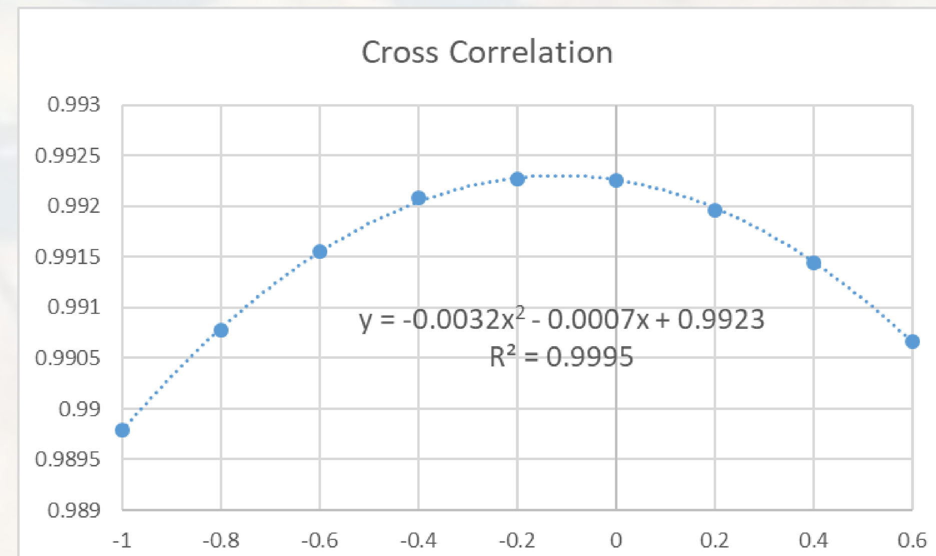
We define the cross correlation (*CC*) between the original VIIRS image, *o*, and the shifted simulated image, s_{rc}, as:

$$CC = \max_{rc}\left\{\frac{\sum_x \sum_y [o(x,y)-\bar{o}][s_{rc}(x,y)-\overline{s_{rc}}]}{\sqrt{\sum_x \sum_y [o(x,y)-\bar{o}]^2 \sum_x \sum_y [s_{rc}(x,y)-\overline{s_{rc}}]^2}}\right\}$$

The *r* and *c* values correspond to the measured VIIRS geolocation offset relative to Landsat.

Measuring the Effective Focal Length

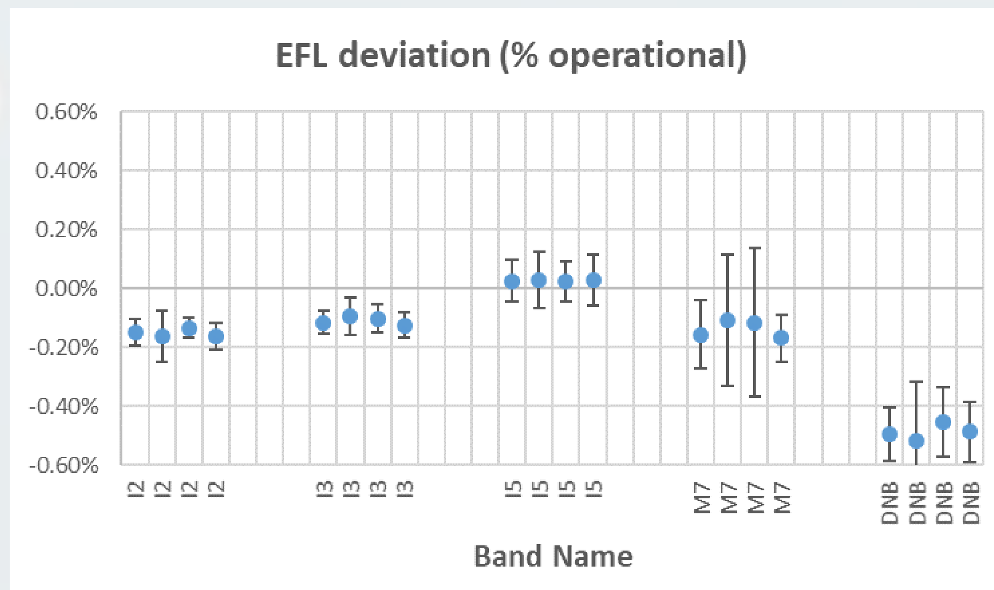
We varied the assumed focal length value for the SNPP VIIRS geolocation data over the values -1.0%, -0.8%, -0.6%, -0.4%, -0.2%, 0.0%, 0.2%, 0.4%, and 0.6% change from the current operational focal length value, and varied the assumed focal length for J1 VIIRS over the values -1.0%, -0.5%, -0.25%, 0.0%, 0.25%, 0.5%, and 1.0% change. For the selected subset from scan 66 of the SNPP VIIRS data set at 1824 UTC on April 29, 2018, we have the plot:

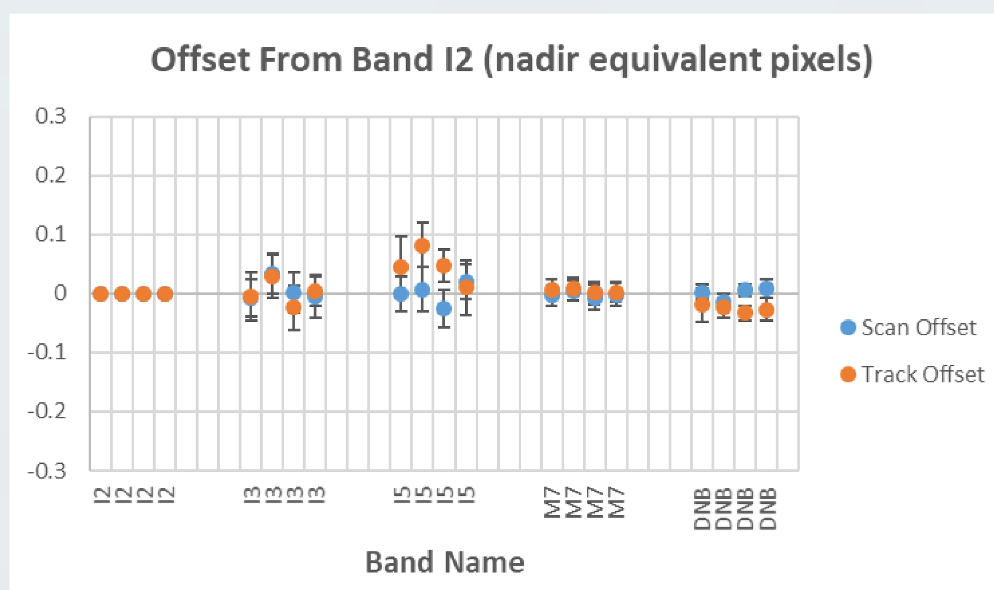


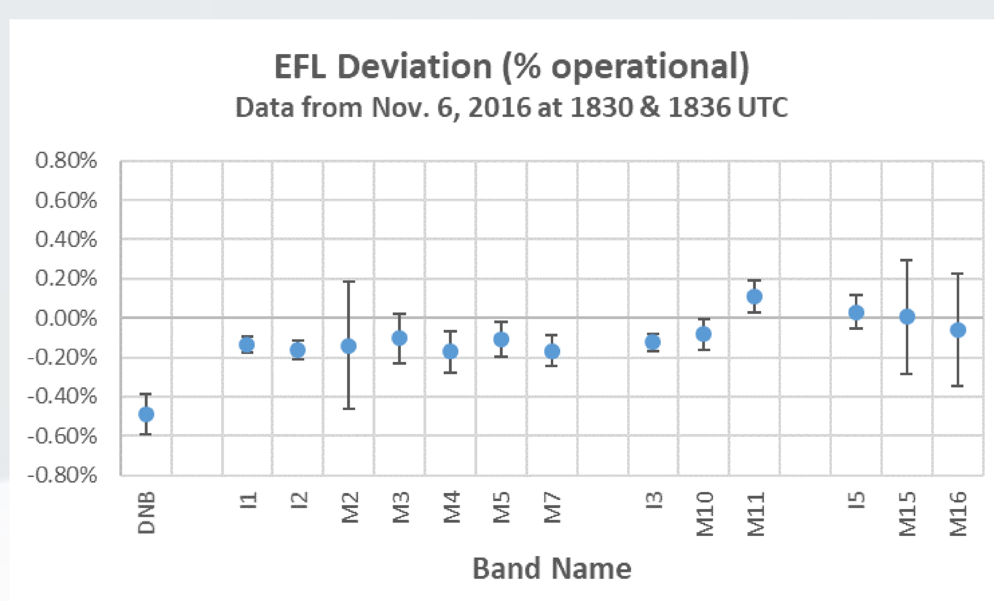
The plot of the measured values forms a very smooth curve that can be fit closely by a 2nd degree polynomial. The first derivative of this curve can be solved to find the location of the peak of the curve: the peak is at -0.150% change.

SNPP VIIRS Results

The measured data is from archive set 5000 from the dates 11/6/20165/6/2017, 1/7/2018 and 4/29/2018. The operational EFL is -0.353% of the nominal EFL for SNPP VIIRS I- & M-bands.

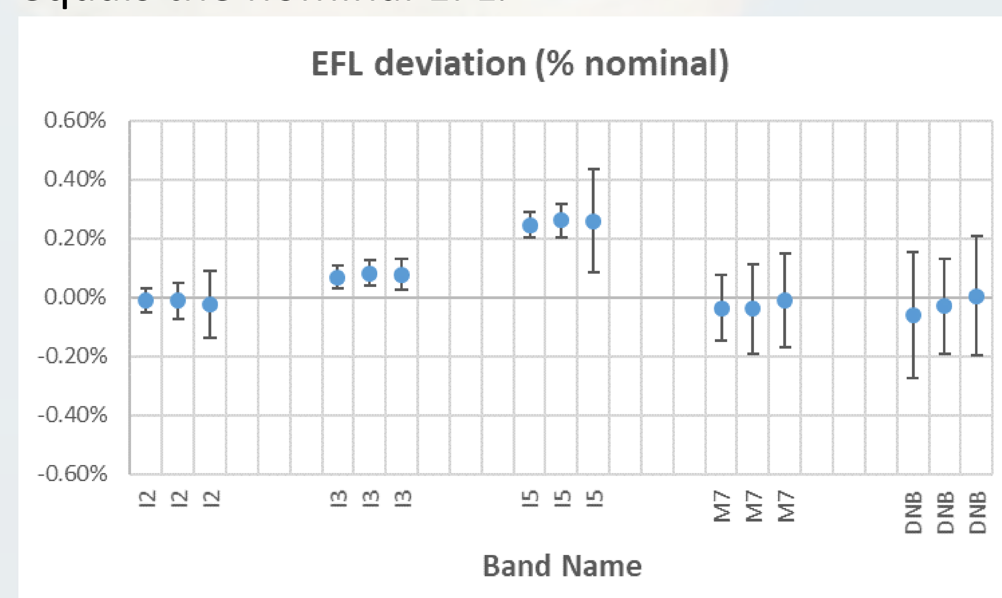


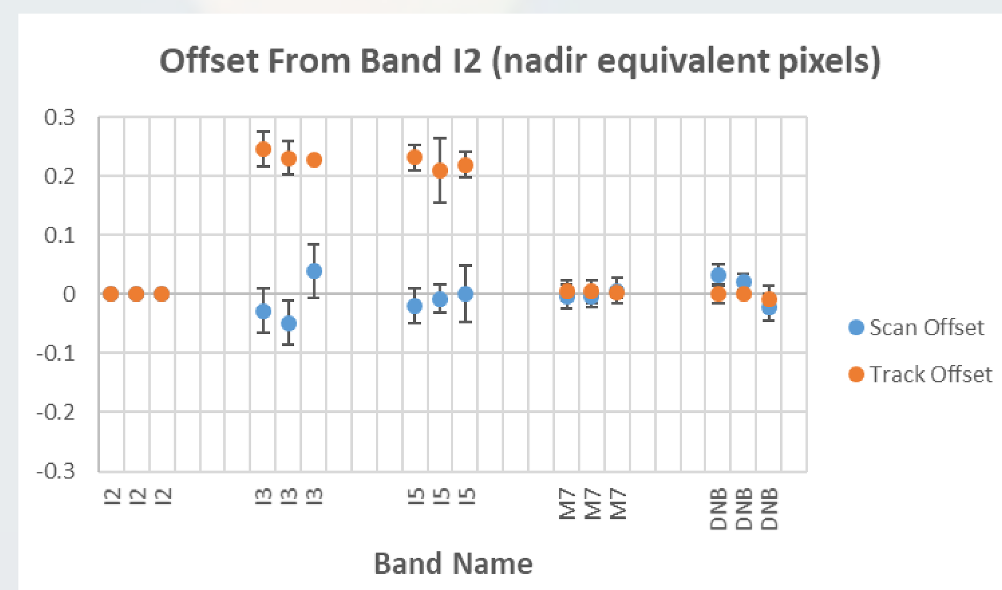


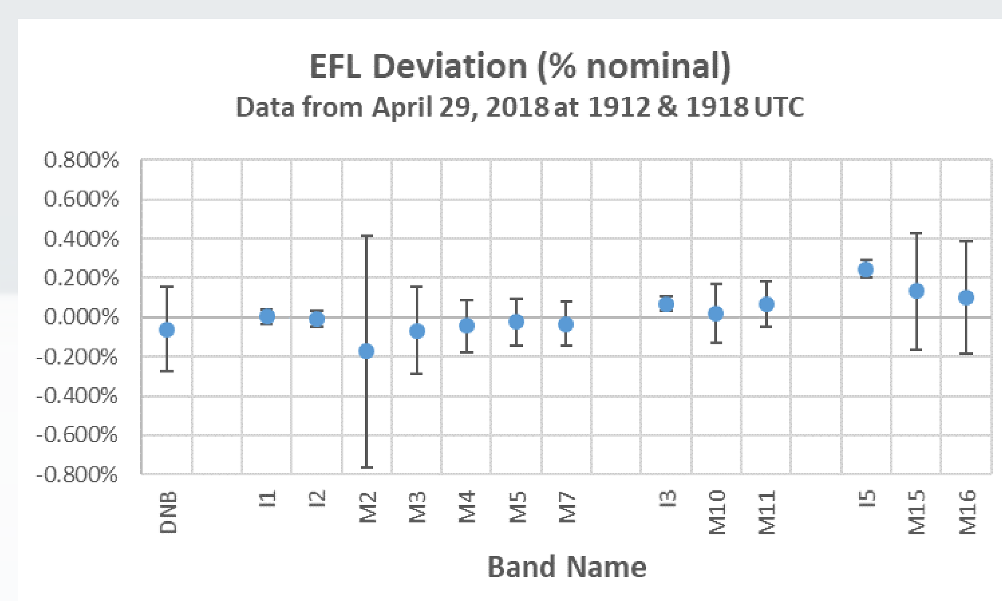


J1 VIIRS Results

The measured data is from archive set 3194 from the dates 4/29/2018, 4/30/2018 and 5/28/2018. For J1 VIIRS the operational EFL equals the nominal EFL.







Conclusions

We have measured the EFL of SNPP and J1 VIIRS, along with the spatial offset of the geolocation, versus the Landsat OLI instrument.

The original (nominal) assumed focal length for SNPP VIIRS was too long, so the current operational focal length was adjusted to be 0.353% shorter than nominal. Measured in reference to the current operational focal length, we have found that the measured EFL deviation is very close to 0.0% for the I-bands and M-bands. However, the EFL deviation is still relatively high for the DNB at about -0.5%. The measured BBR is very good with less than 0.08 nadir equivalent pixel shift for SNPP VIIRS.

The measured EFL is very close to the assumed (nominal) focal length for J1 VIIRS, with less than 0.1% deviation (except for I-band 5 at about 0.25% deviation). The measured BBR for J1 VIIRS is offset by over 0.2 pixel along track for bands I3 and I5, but excellent otherwise with less than 0.04 nadir equivalent pixel shift.

Reference and Acknowledgment

James C. Tilton, Robert E. Wolfe, Guoqing (Gary) Lin and Zhangshi (Albert) Yin, "On-Orbit Measurement of the Focal Length of the SNPP VIIRS Instrument," in *Proceedings of the IEEE Int'l Geosci. and Remote Sens. Symp.*, Fort Worth, TX, USA, pp. 4056-4059, July 23-28, 2017.

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