VIIRS SDR Cal/Val:
S-NPP Update and JPSS-1 Preparations

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VIIRS SDR Cal/Val Posters:

- Xi Shao — *Spectral Degradation of Solar Diffuser on Suomi NPP VIIRS due to Surface Roughness-induced Rayleigh Scattering*
- Zhuo Wang — *Suomi NPP VIIRS Detector Dependent Relative Spectral Response Variation Effects using Line-by-Line Radiative Transfer Model Calculations*

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Suomi NPP VIIRS

VIIRS (Visible Infrared Imaging Radiometer Suite):

- Multispectral scanning radiometer launched on the Suomi NPP (National Polar-orbiting Partnership) satellite on **October 28, 2011**
- First instrument in a 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)
- Began Earth observations in reflective solar bands (**RSB**s) on **November 21, 2011** and in thermal emissive bands (**TEB**s) on **January 20, 2012**
- Provides global measurements of land, ocean, and atmosphere with daily temporal resolution in 22 spectral bands between **400 nm and 12 µm**:
  - 5 Imaging, 375-m bands (3 RSB, 2 TEB, each with 32 detectors)
  - 16 Moderate-resolution, 750-m bands (11 RSB, 5 TEB, each with 16 detectors)
  - 1 broadband Day/Night , 750-m band (**DNB**) – also a reflective band, but beyond scope of this presentation because its calibration procedure differs from RSB
- 6 out of the 14 RSBs are dual-gain: <u>each gain state is calibrated separately</u>
- Optical system includes a rotating telescope and a two-sided half-angle mirror (HAM): <u>each HAM side is also separately calibrated</u>

VIIRS as An Instrument Suite

Although VIIRS is an integrated system with common telescope and electronics, it can also be seen as a suite of three scanning radiometers with distinct performance characteristics and calibration methods:

- **TEB** measurements (in 7 channels) cover the spectral range from 3.5 to 12.5 μm and are calibrated using onboard blackbody and space-view data collected during **every scan**
- **RSB** measurements consist of 14 channels covering the range from 400 to 2280 nm: RSB calibration uses onboard solar diffuser data collected **once per orbit** and space-view data from **every scan**
- **DNB** covers the broad spectral range of 500-900 nm with high dynamic range measurements that are only partially calibrated by the solar diffuser data: complete DNB calibration requires special Earth observations conducted **once per month**

This presentation focuses on RSB.
Two VIIRS Cal/Val posters provide more information on TEB and RSB.

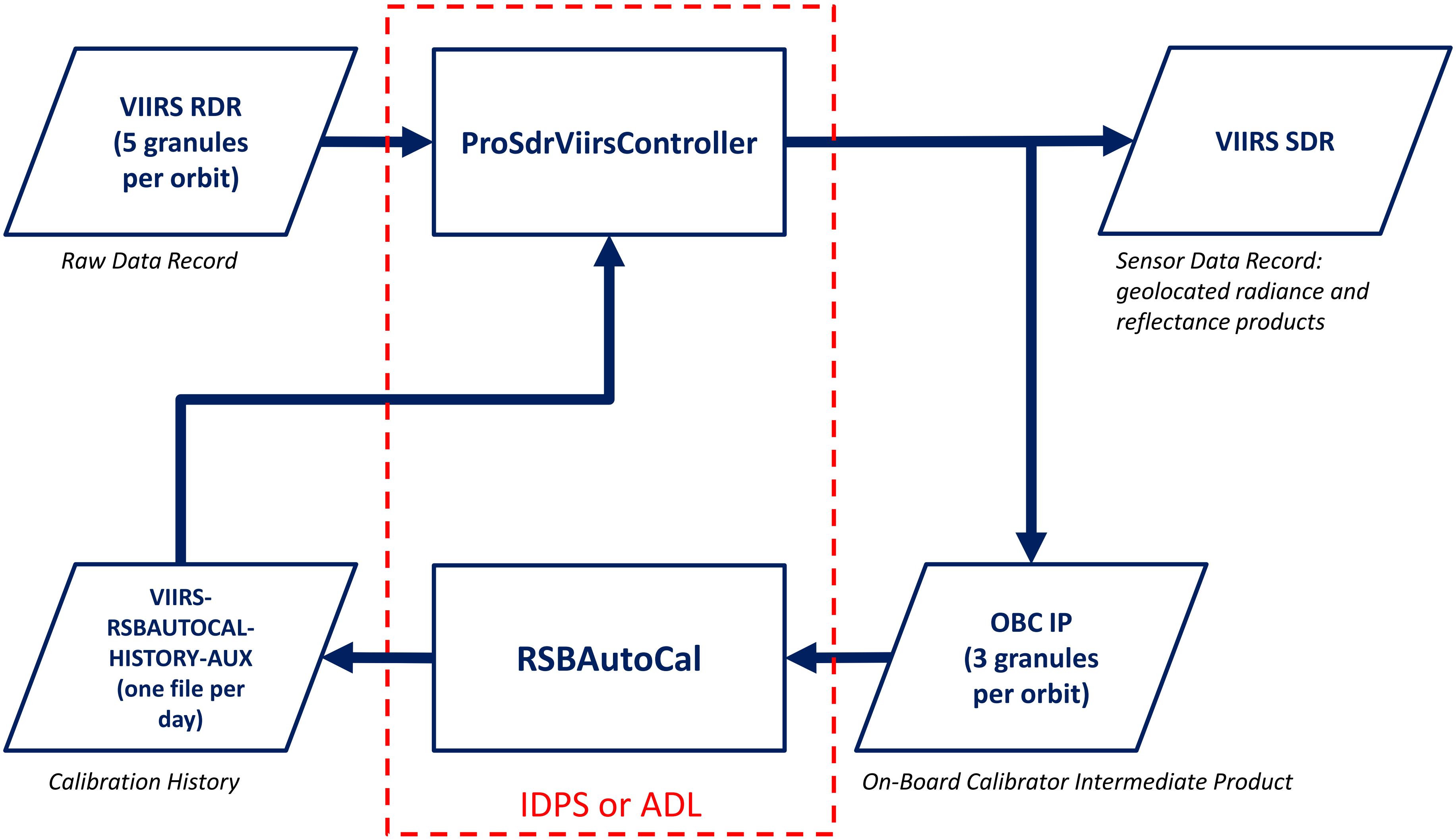
Project Goals: Validation and Reprocessing

- NOAA operational VIIRS sensor data records are produced by the Interface Data Processing Segment (IDPS) of the JPSS Common Ground System
- Users have access to the IDPS code through the Algorithm Development Library (ADL) that can also be applied to process VIIRS data
- Because of an unexpected VIIRS telescope throughput degradation, RSB calibration needs frequent updates (weekly at present)
- An automated procedure has been implemented in IDPS that calculates the RSB calibration coefficients from solar diffuser measurements after every orbit
- The presented work has two goals:

  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

  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

Flowchart of the VIIRS Solar Calibration Processing



VIIRS RSB Radiometric Calibration

- Calibration equation for each pixel of Earth View data:

$$L = \langle F \rangle \frac{c_0 + c_1 \Delta n + c_2 \Delta n^2}{RVS} \qquad \Delta n = \Delta n_{EV} - \langle \Delta n_{SV} \rangle$$

- The c_i coefficients and the Response-Versus-Scan angle (RVS) functions are derived from prelaunch tests
- The F factors provide scaling between the prelaunch and on-orbit calibration coefficients and are calculated from detector response when solar diffuser is illuminated by the sun:

$$F = \frac{\cos AOI_{SD}}{c_0 + c_1 \Delta n_0 + c_2 \Delta n_0^2} \frac{\int \tau_{SDS}(\lambda) \cdot BRDF_{SD}(\lambda) \cdot \frac{\Phi_{sun}(\lambda)}{4\pi d^2} \cdot RSR(\lambda) d\lambda}{\int RSR(\lambda) d\lambda} \qquad \Delta n_0 = \Delta n_{SD} - \langle \Delta n_{SV} \rangle$$

- Solar calibration (F) is conducted once per orbit
- Solar diffuser reflectance ($BRDF$) initially has been measured once per orbit, then once per day, and now – three times per week, by the Solar Diffuser Stability Monitor (SDSM)

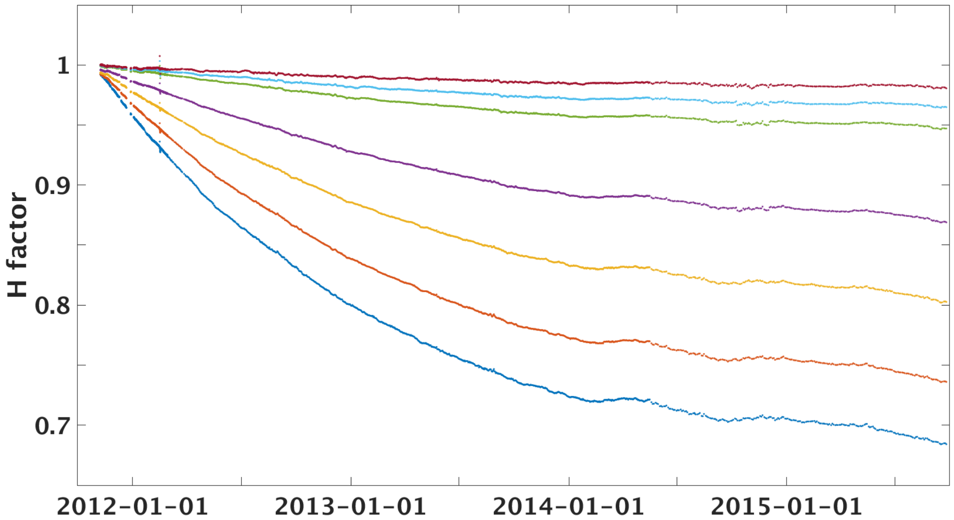
Calibration Improvements

The reprocessed calibration coefficients are based on the following major changes in the VIIRS RSB data processing:

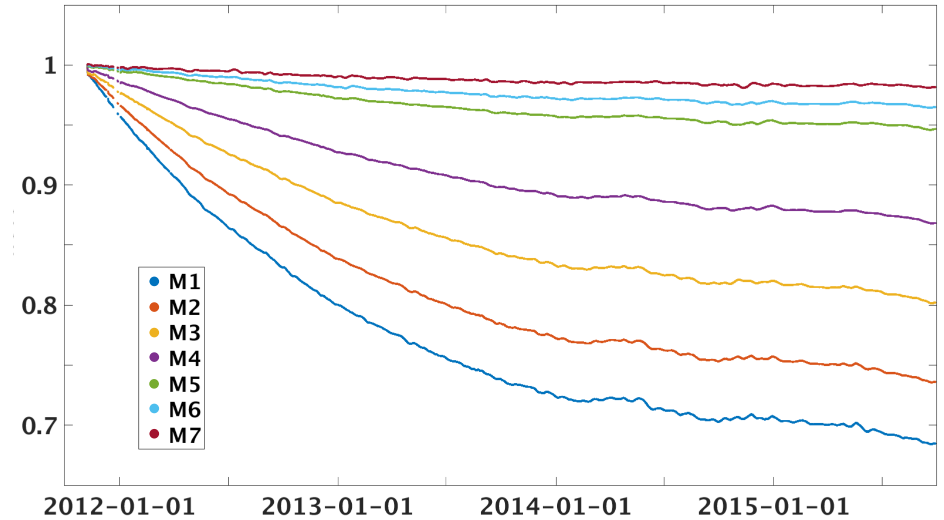
- Corrected solar vectors: after a processing code update, orientation of the Sun-satellite vectors has changed by as much as 0.2°
- Improved solar attenuation screens transmittance and solar diffuser bidirectional reflectance tables: angular dependence was optimized based on reanalysis of the on-orbit yaw maneuver and the routine onboard calibrator measurements acquired during the first three years of the Suomi NPP mission
- 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 (RHW) filter parameters: smoothing of the aggregated calibration coefficients was improved by damping oscillations while maintaining sensitivity to trend changes

Solar Diffuser Degradation

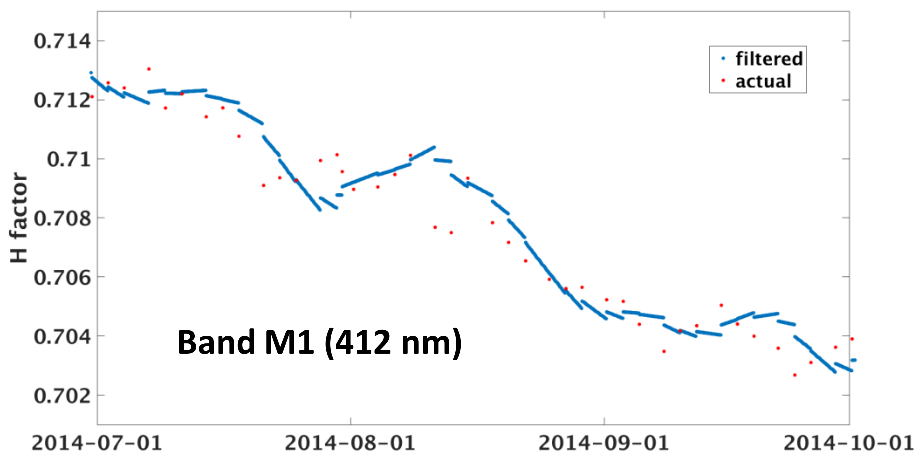
Derived by RSBAutoCal from actual SDSM data without filtering



After calculation by RSBAutoCal and application of the RHW filter

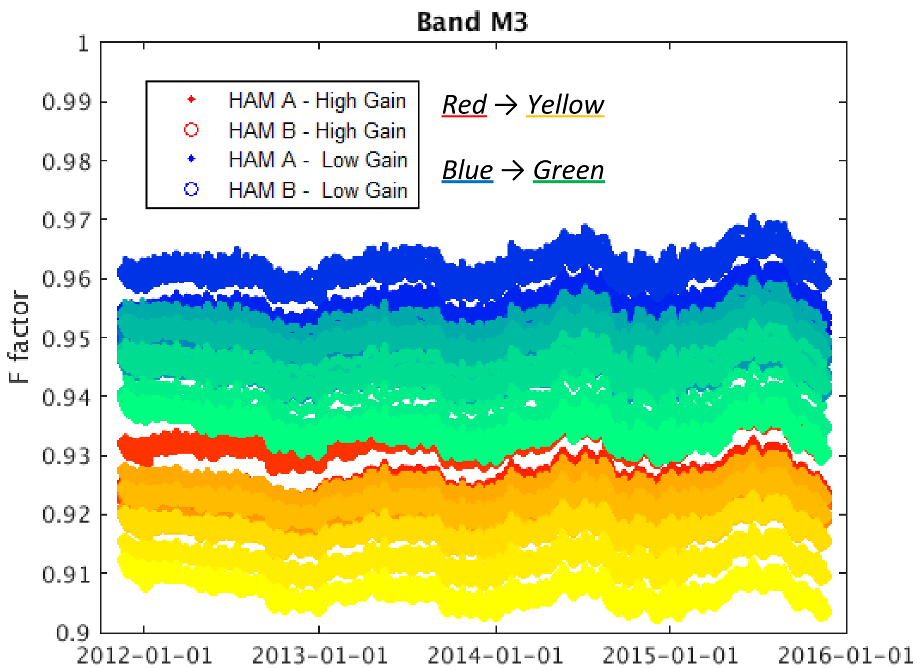


- H factors define degradation of the solar diffuser BRDF from an initial value
- They are calculated from SDSM measurements as ratios of SD reflected signal to direct solar signal
- SD degrades faster for bands with shorter band-pass wavelengths (similarly to MODIS)
- The RHW filter removes spurious data (such as the yaw maneuver points from Feb. 2012), reduces short-term variability, and interpolates between the less-frequent SDSM measurements

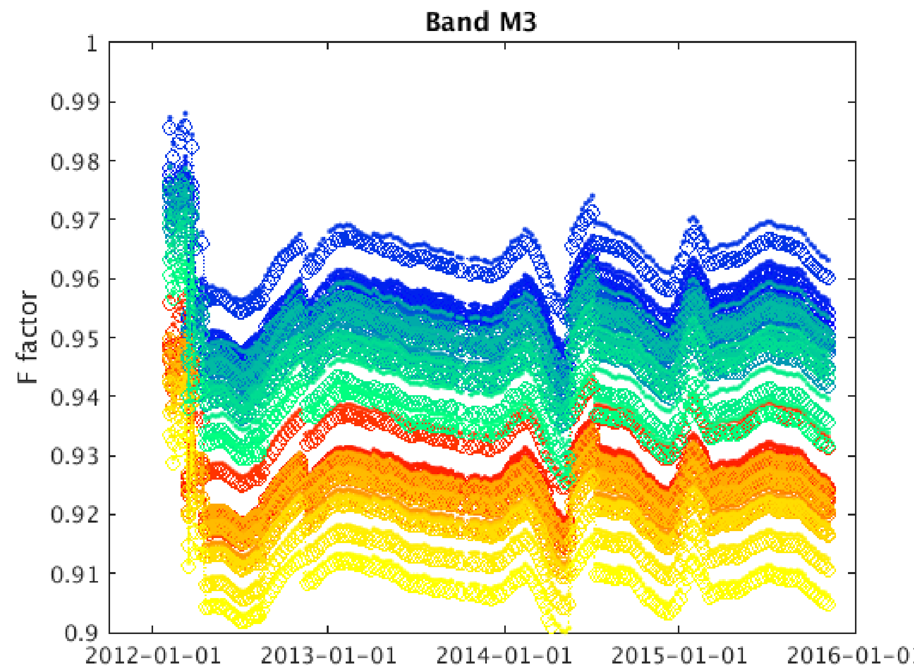


F Factor Time Series for Band M3 (488 nm)

Calculated by RSBAutoCal

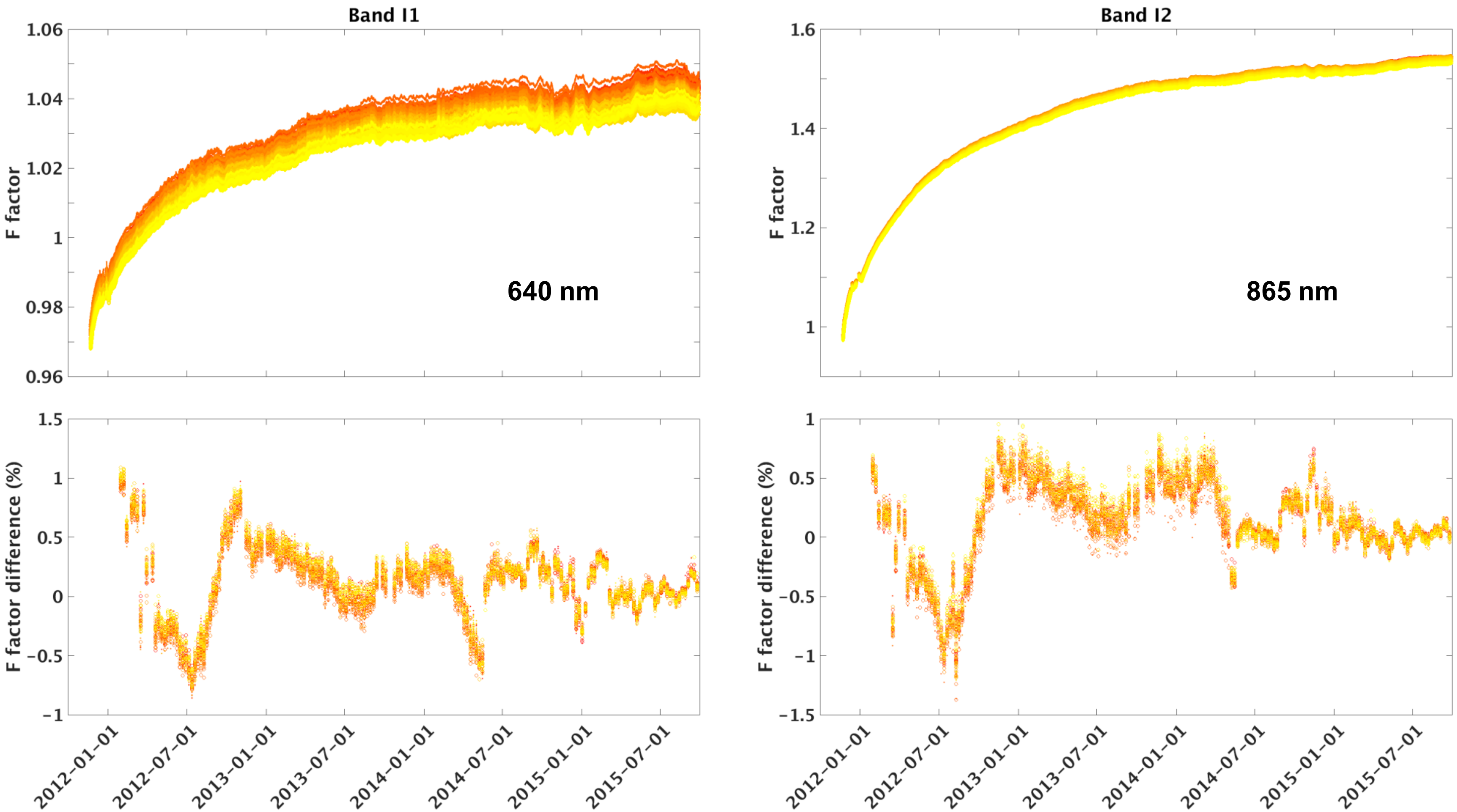


Used in operational IDPS processing



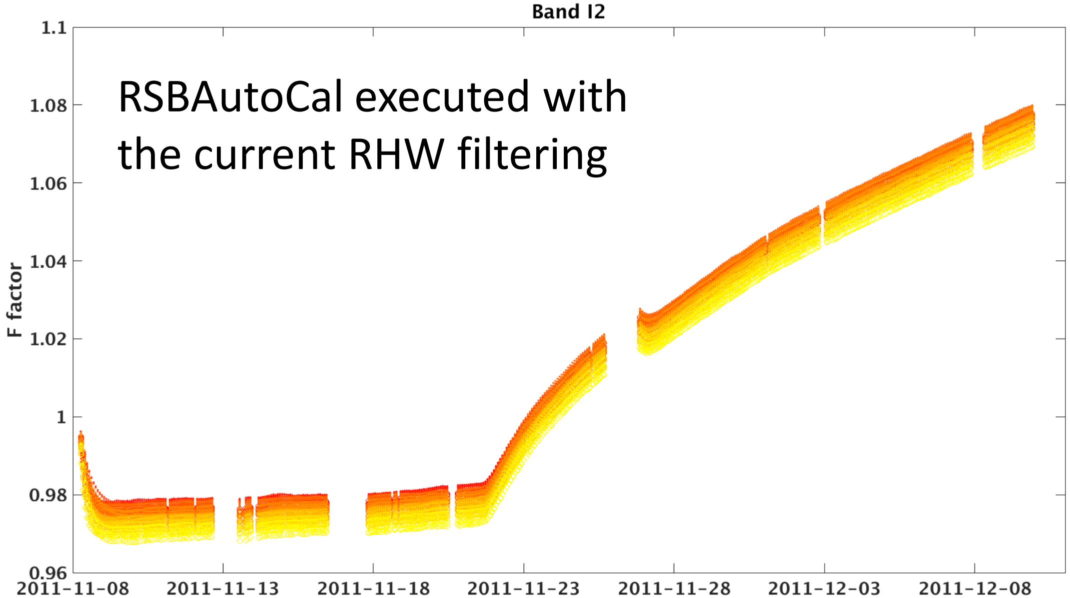
- RSBAutoCal calculates the F factors from the beginning of VIIRS operations on orbit
- F factors derived by RSBAutoCal for band M3 are more consistent over long term while short-term variability remains
- Larger variability of the operational F factors, which was due to initial uncertainties in processing parameters, is no longer present after reprocessing

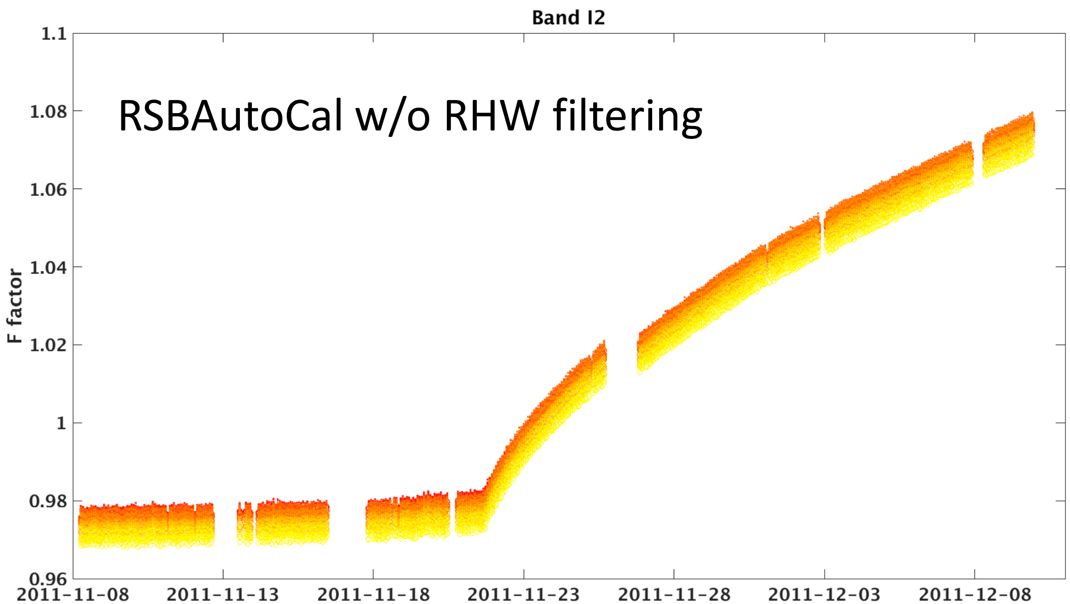
F Factor Changes Due to Telescope Degradation



- Telescope degradation is corrected by the automated procedure in agreement with the operational F factors while some improvement can be seen
- Differences between the reprocessed and operational F factors remain within 1-2% and are correlated between some band pairs (such as the NDVI bands I1 and I2)

Automated RSB Calibration During LEOA





- LEOA: Launch, Early Orbit, and Activation
- Transient filter effects occurred for about two days after VIIRS was turned on and began measuring calibration data (confirmed by calculations w/o filtering)
- Calculations stabilized before Earth observations started on November 21, 2011 (and RTA degradation began or intensified)
- This example shows how the automated calibration procedure can be used during JPSS-1 LEOA

Summary

- 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 differences between the reprocessed and operational F factors in general have not exceeded the VIIRS SDR radiometric calibration uncertainty and remain in the 1-2% range, except for the bands M1-M3 before May 2012
- The improved calibration coefficients can be further used to reprocess VIIRS SDR and other data products
- Since the SDR radiance and reflectance products are directly proportional to the F factors, the relative improvements between the original, operational products and the reprocessed ones will be the same as the differences between the F factors
- The reprocessed calibration history files are available though the VIIRS SDR home page at the NOAA National Calibration Center website: http://ncc.nesdis.noaa.gov/VIIRS/