JPSS VIIRS SDR SCIENCE OVERVIEW

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Outline

- VIIRS SDR Cal/Val Science Team
- Sensor/Algorithm/Product Overview
- Top Ten Accomplishments
- JPSS-1 Readiness
  - J1/SNPP orbits and inter-calibration
- Calibration reanalysis
- Summary and Path Forward

VIIRS SDR Cal/Val Team Members

PI	Organization	Team Members	Roles and Responsibilities
C. Cao	STAR	-	Team lead
W. Wang/S. Blonski	STAR/ERT	J. Choi, Y. Gu, S. Mills (consultant)	VIIRS SDR calibration/validation for S-NPP, J1. (Prelaunch studies; software code changes and ADL tests; Postlaunch monitoring and LUT update)
C. Wallisch/F. DeLuccia	Aerospace	G. Moy, E. Haas, C. Fink, D. Moyer, P. Isaacson, and several others	VIIRS operational calibration update; RSB autocal; J1 LUT delivery;
J. Xiong	VCST	J. McIntire, G. Li, N. Lei, T. Schwarting	VIIRS TV data analysis; prelaunch characterization; LUT development
CICS	UMD/CICS	Y.Bai, Z. Wang, X. Shao (PT), B. Zhang(PT)	Geolocation validation, ADCS analysis, intercomparisons, solar diffuser calibration
CIMSS	U. Wisconsin	C. Moeller	VIIRS RSR, and Water Vapor band study
CIRA	CIRA	Sirish Uprety	Vicarious calibration, DNB calibration

VIIRS Instrument Overview

•VIIRS is a scanning imaging radiometer onbaord the Suomi NPP, and JPSS satellites in the afternoon orbits with a nominal altitude of 829km at the equator, and a swath width of ~3000km;

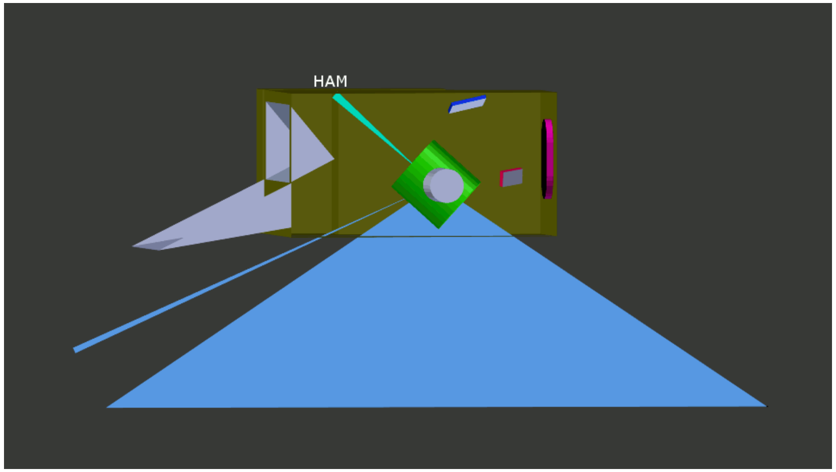
VIIRS has 22 types of SDRs:

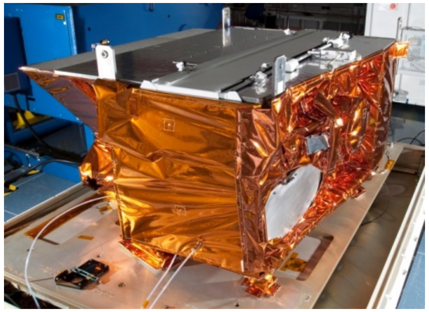
- *•16 moderate resolution (750m), narrow spectral bands (11 Reflective Solar Bands (RSB); 5 Thermal Emissive Bands (TEB))*
- *•5 imaging resolution(375m), narrow spectral bands (3 RSB; 2 TEB)*
- *•1 Day Night Band (DNB) imaging (750m), broadband*

•VIIRS Onboard calibration relies on the solar diffuser (SD), solar diffuser stability monitor (SDSM), space view (SV), and the blackbody (BB);

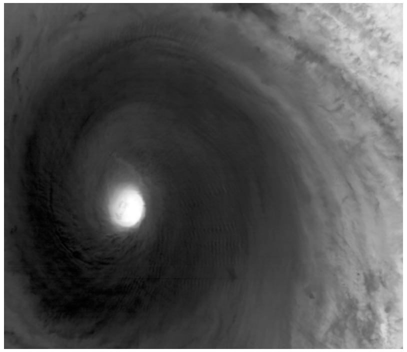
•Vicarious calibration also used (lunar, dark ocean for DNB, and cal/val sites);

•Calibration is performed per band, per scan, per half angle mirror side (HAM), and per detector.



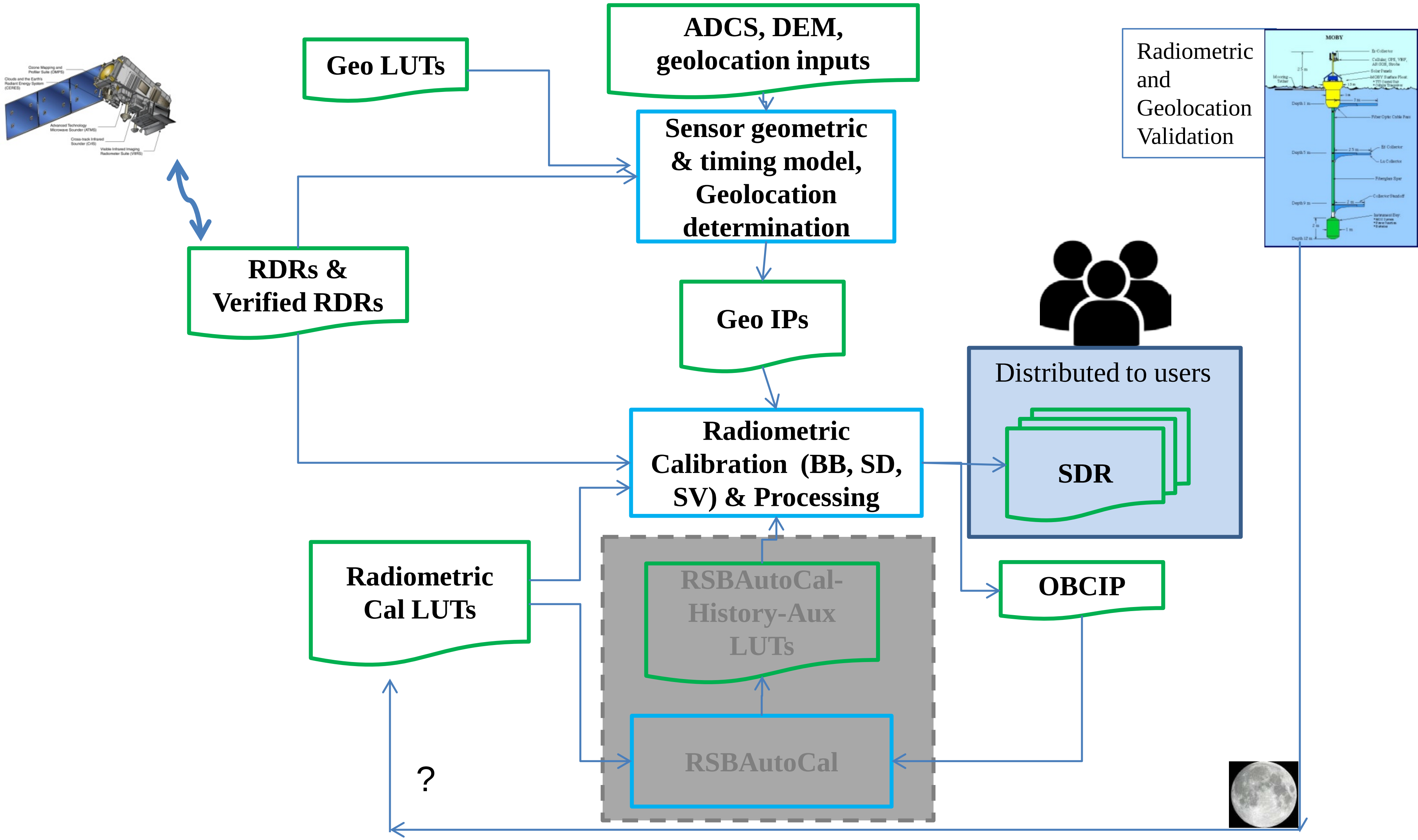


VIIRS instrument



Super Typhoon Nepartak

VIIRS RDR to SDR Processing



VIIRS Calibration Algorithm Overview (TEB/RSB)

Thermal Emissive Bands (TEB):

$$F = \frac{\mathrm{RVS}\ (\theta_{obc},\ B) \cdot \left[\overline{\epsilon_{obc}(\lambda)}\ \cdot \overline{L\ (T_{obc}\ (t)\ ,\ \lambda)} + \overline{L_{obc\_rfl}\ (T_{sh}\ (t)\ ,\ T_{cav}\ (t)\ , T_{tele}\ (t)\ , \lambda)}\right]}{\sum_{j=0}^{2} C_j dn_{obc}{}^{j}} + \frac{(\mathrm{RVS}\ (\theta_{obc}, B) -\ 1) \cdot \left(\frac{\left\{\left(1 - \overline{\rho_{rta}(\lambda)}\ \right) \cdot \overline{L(T_{rta}\ (t),\ \lambda)} - \overline{L(T_{ham}\ (t),\ \lambda)}\right\}}{\overline{\rho_{rta}}(\lambda)} \right)}{\sum_{j=0}^{2} C_j dn_{obc}{}^{j}}$$

$$\overline{L_{ap}}\,(\theta_{ev}, B) = \frac{F \cdot \sum_{j=0}^{2} C_i\,(T_{det}, T_{ele})\ \ dn_{ev}{}^{j} + (1 -\ \mathrm{RVS}\ (\theta_{ev}, B)) \left(\frac{\left\{\left(1 - \overline{\rho_{rta}(\lambda)}\ \right) \overline{L(T_{rta},\ \lambda)} - \overline{L(T_{ham},\ \lambda)}\right\}}{\overline{\rho_{rta}}(\lambda)} \right)}{\mathrm{RVS}\ (\theta_{ev},\ B)}$$

Reflective Solar Bands (RSB):

$$F = \frac{RVS\,(\theta_{sd}, B)\,.\cos(\theta_{inc})\,.\left[\overline{\tau_{sds}\ (\phi_h, \phi_v,\ \lambda,\ d)\,.\,E_{sun}\,(\lambda, d_{se})\,\mathrm{BRDF}\,(\phi_h, \phi_v,\ \lambda}\right])}{\sum_{i=0}^{2} c_i\ .\ dn_{sd}^{i}}$$

$$\overline{L_{ap}}\,(\theta, B) = \overline{L_{ap}\,(\theta, \lambda)} = \frac{\overline{\Delta L_{det}}\,(\theta, B)}{RVS\,(\theta, B)} = \frac{F\ .\ \sum_{i=0}^{2} C_i\ .\ dn^{i}}{RVS\ \ (\theta, B)}$$

VIIRS Calibration Algorithm Overview (DNB)

Day/Night Band (DNB):

$$L = RVS(n)A\left(m, N_{agg}, g\right)dn_{EV}(m,n)$$

$$dn_{EV}(m,n) = DN_{EV}(m,n) - DN_0(m,n,g)$$

$$A_{LGS} = \frac{\overline{L}_{SD}}{dn_{DNB}}$$

$$dn_{DNB} = DN_{SD\_DNB} - DN_{SV\_DNB}$$

$$\overline{L}_{SD} = RVS(\theta_{SD})\cos\theta_{inc}\int_{DNB} RSR_{DNB}(\lambda)E_{SUN}(\lambda)BRDF(\lambda)\tau_{SDS}(\lambda)H(\lambda)d\lambda$$

$$A_{MGS} = G_{LGS/MGS}A_{LGS}$$

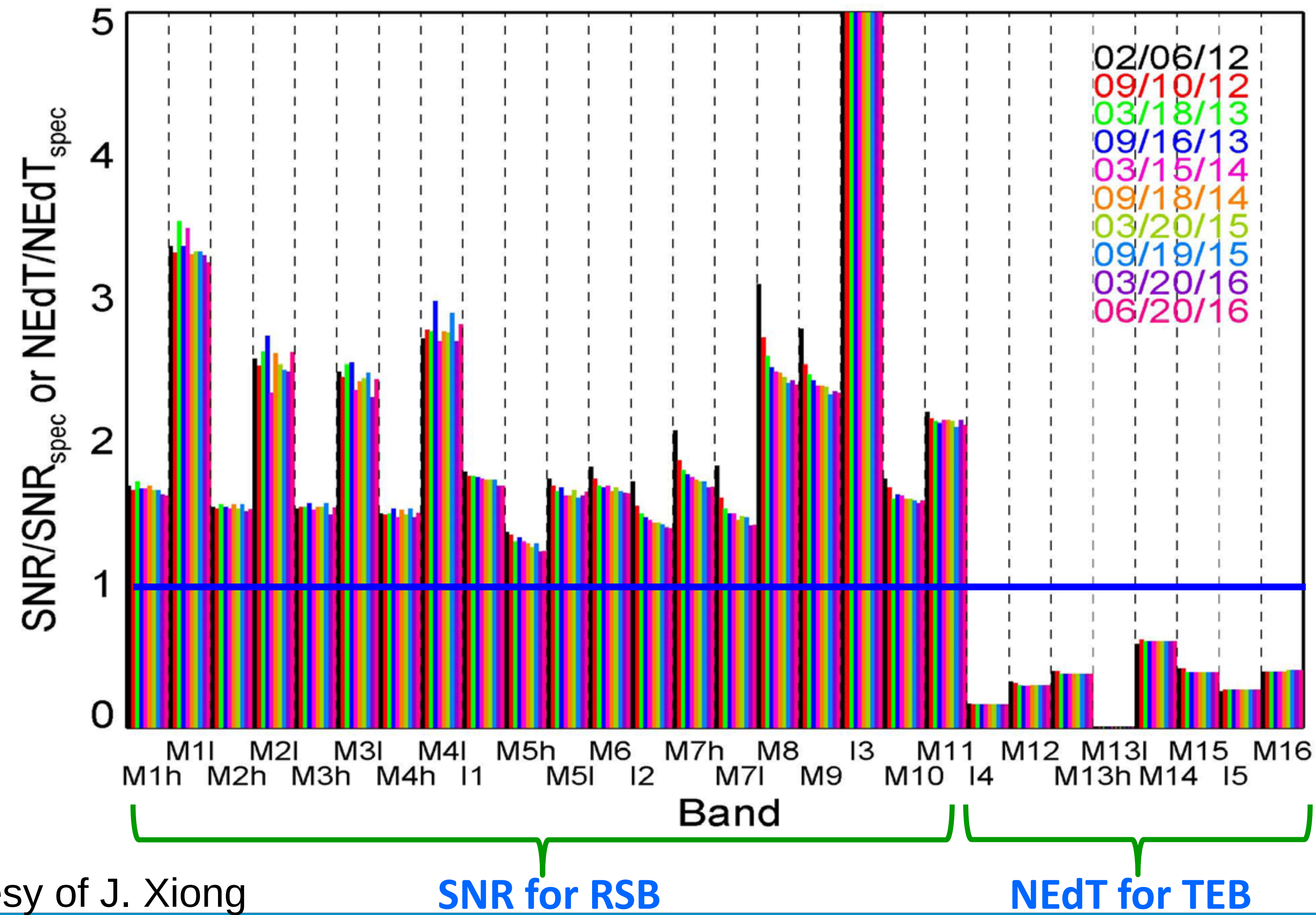
$$A_{HGS} = G_{MGS/HGS}G_{LGS/MGS}A_{LGS}$$

VIIRS SDR Product Requirements from JPSS L1RD

Attribute	Threshold	Objective
Center Wavelength	412 to 12,013 nm	412 to 12,013 nm
Bandpass	15 to 1,900 nm	15 to 1,900 nm
Max. Polarization Sensitivity	2.5 to 3.0 %	2.5 to 3.0 %
Accuracy @ Ltyp	0.4 to 30 %	0.4 to 30 %
SNR @ Ltyp or NEdT @ 270 K	6 to 416 or 0.07 to 2.5 K	6 to 416 or 0.07 to 2.5 K
FOV @ Nadir	0.4 to 0.8 km	0.4 to 0.8 km
FOV @ Edge-of-Scan	0.8 to 1.6 km	0.8 to 1.6 km
Ltyp or Ttyp	0.12 to 155 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 210 to 380 K	0.12 to 155 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 210 to 380 K
Dynamic Range	0.12 to 702 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 190 to 634 K	0.12 to 702 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 190 to 634 K

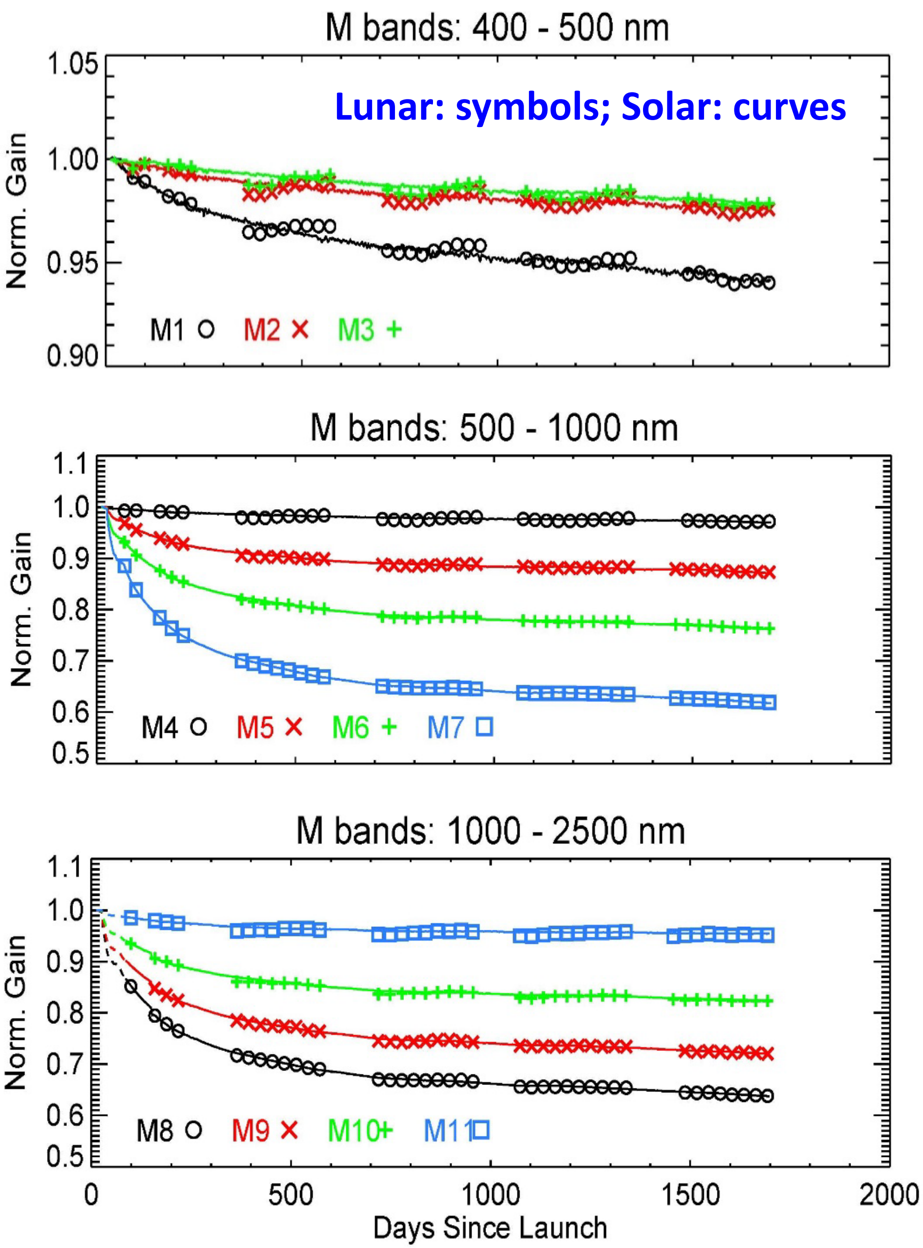
VIIRS Noise Performance

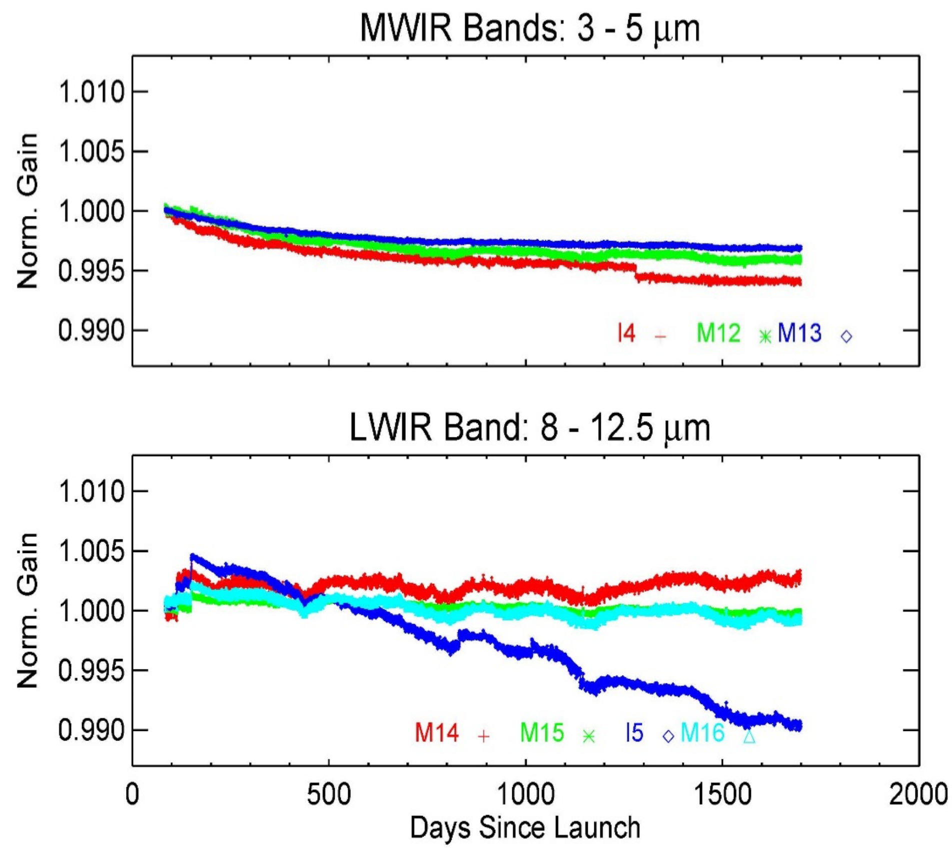
(SNR/SNR$_{SPEC}$ > 1) or (NEdT/NEdT$_{SPEC}$ < 1): better performance



Courtesy of J. Xiong

VIIRS Responsivity Change since Launch





- Large changes in NIR and SWIR (due to mirror contamination)
- Small changes in VIS, MWIR, and LWIR

Courtesy of J. Xiong

VIIRS SDR Team Accomplishments (FY16)

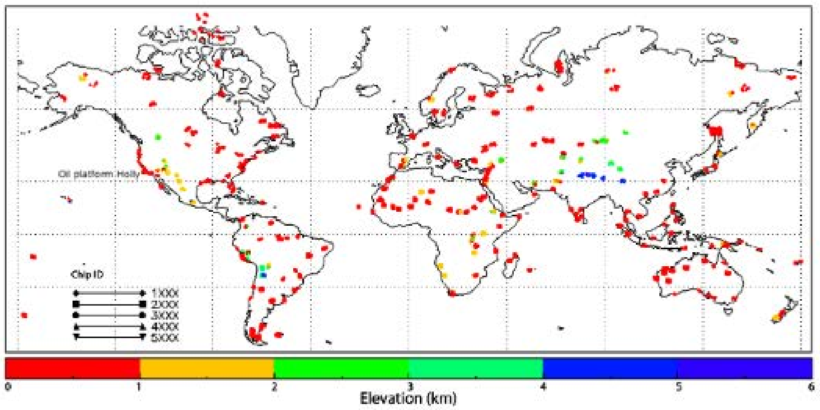
1. J1 DNB Aggregation Mode code change
2. VIIRS Remote Sensing Journal Special issue (28 papers)
3. J1 LUT delivery
4. J1 waiver trade study
5. Water vapor band trade study
6. Geolocation CPM transition web and DBMS interface
7. DNB VROP (702 + 705) calibration reanalysis
8. Solar diffuser surface roughness induced degradation model
9. Testing F-LUT from OC group for operational and re-processing
10. Active nightlight for DNB SBIR project entering Phase II
11. Collaboration with GOES-R on UAS field campaign

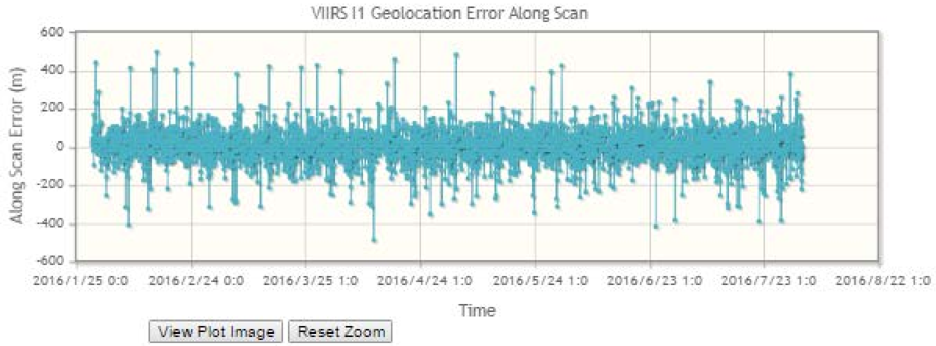
- Monitoring Tools/Website
  - VIIRS SDR home page: http://ncc.nesdis.noaa.gov
  - ICVS: http://www.star.nesdis.noaa.gov/icvs/status_NPP_VIIRS.php

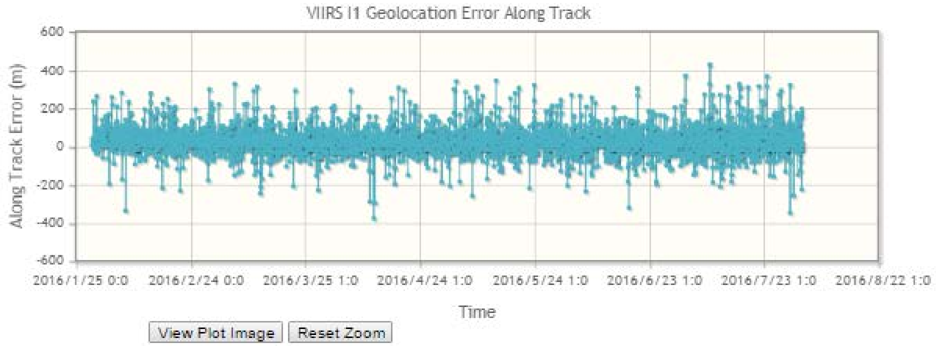
Geolocation monitoring on the web

- Transitioned NASA CPM capability
  - Landmark based geolocation monitoring
  - Landsat chips
  - Running on STAR servers
  - Results dynamically published on the web

- Enhanced the functionality:
  - Added web interface and dynamic plotting
  - Back-end DBMS support under testing

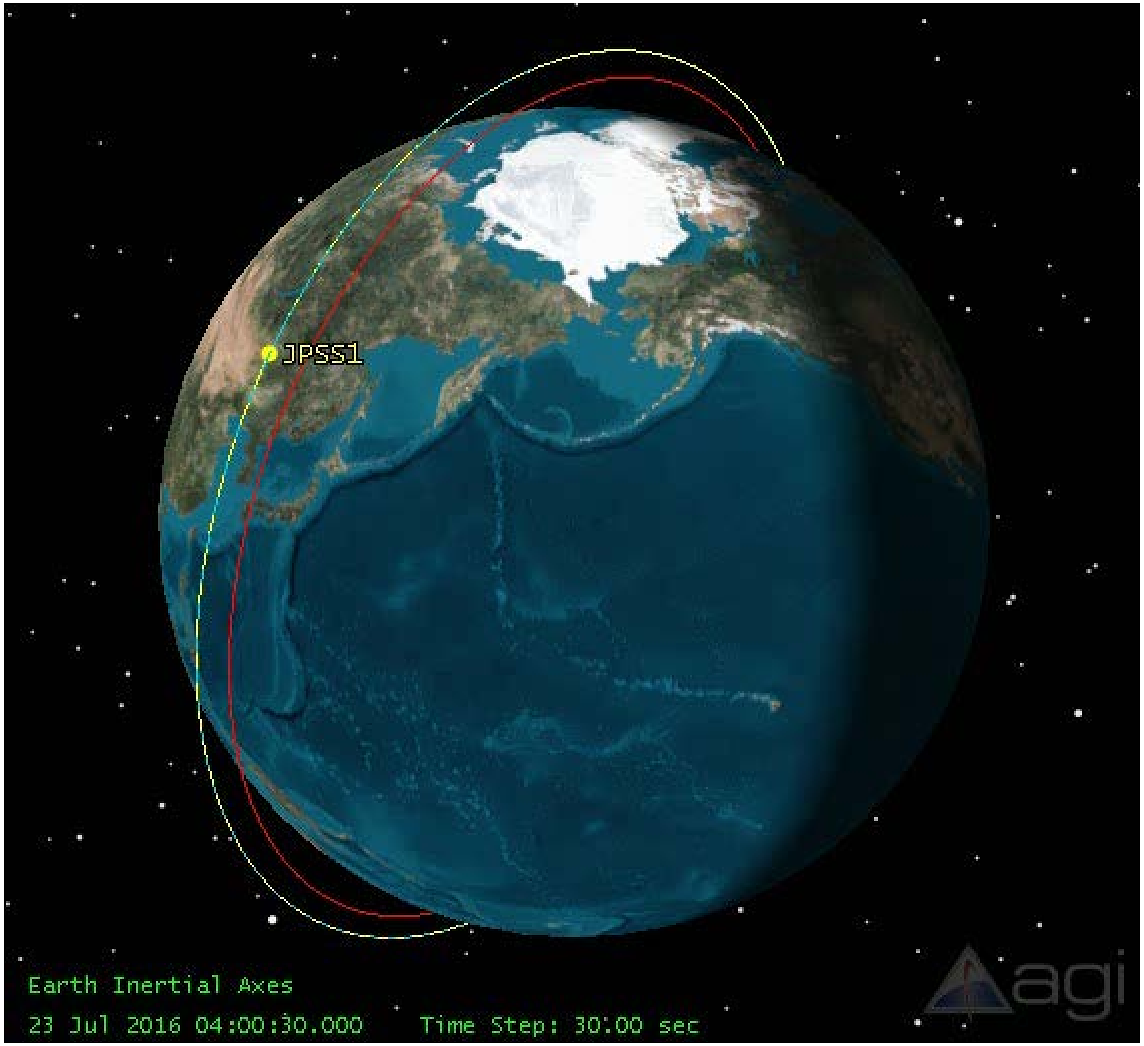






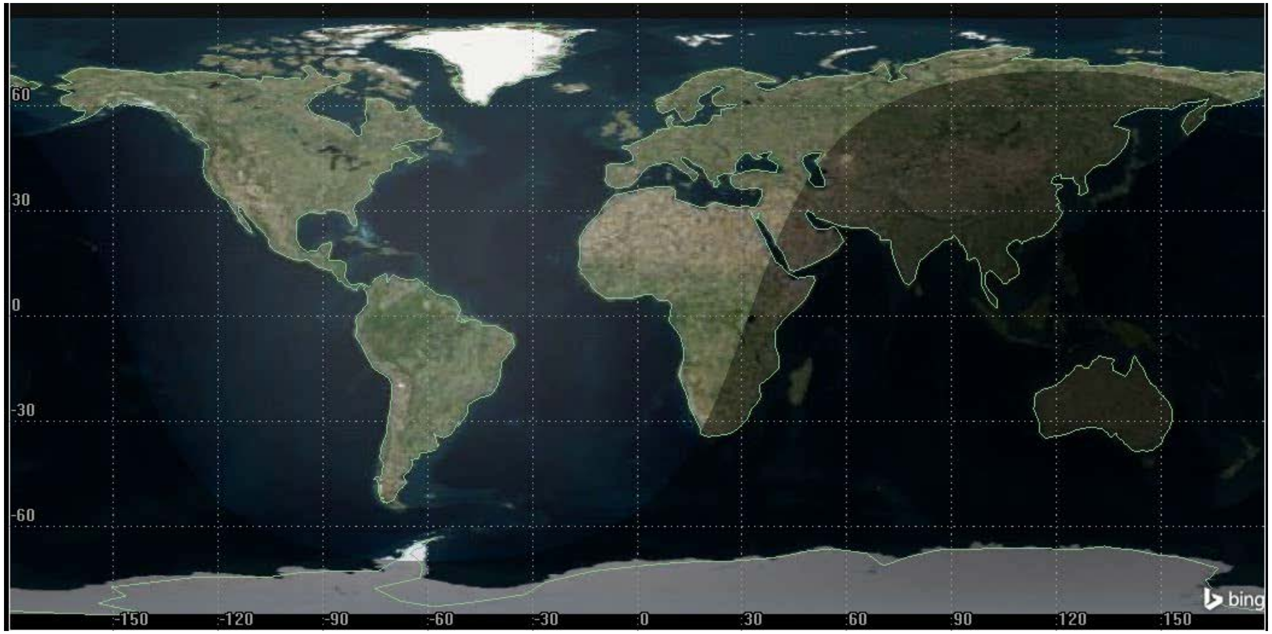
VIIRS intercalibration between J1 and SNPP

- Transfer orbit altitude is about 10km lower than final orbit
- SNO opportunities exist if instruments are turned on and **collecting earth view data before orbit raising**
- There will **be NO SNOs between SNPP and J1 after reaches final orbit**
- However, the current schedule shows VIIRS nadir door **will not be open till day 45,** which will miss the inter calibration opportunity



Intercalibration Opportunities between J1 and SNPP at Simultaneous Nadir Overpass (SNO)

- SNPP will be flying directly above J1 before the orbit raising
- Allows direct comparisons between SNPP and J1 earth view data (if nadir door opened)
- Support most waiver studies by comparing SNPP and J1 data (polarization, nonlinearity, data quality, consistency, etc…)



- Day 10: J1 reaches transfer orbit at ~814 km altitude with similar equator crossing as final orbit; VIIRS turn on
- Day 33: Orbit raising
- Day 45: J1 reaches final orbit: 50.75min separation from SNPP; same equator crossing as that of SNPP
- Day 45: VIIRS Nadir Door open; Cryocooler door open
  - Several maneuvers and tests are not yet scheduled:
    - Pitch/Yaw maneuvers, DNB VROP 702/705, WUCD, Lunar Maneuver

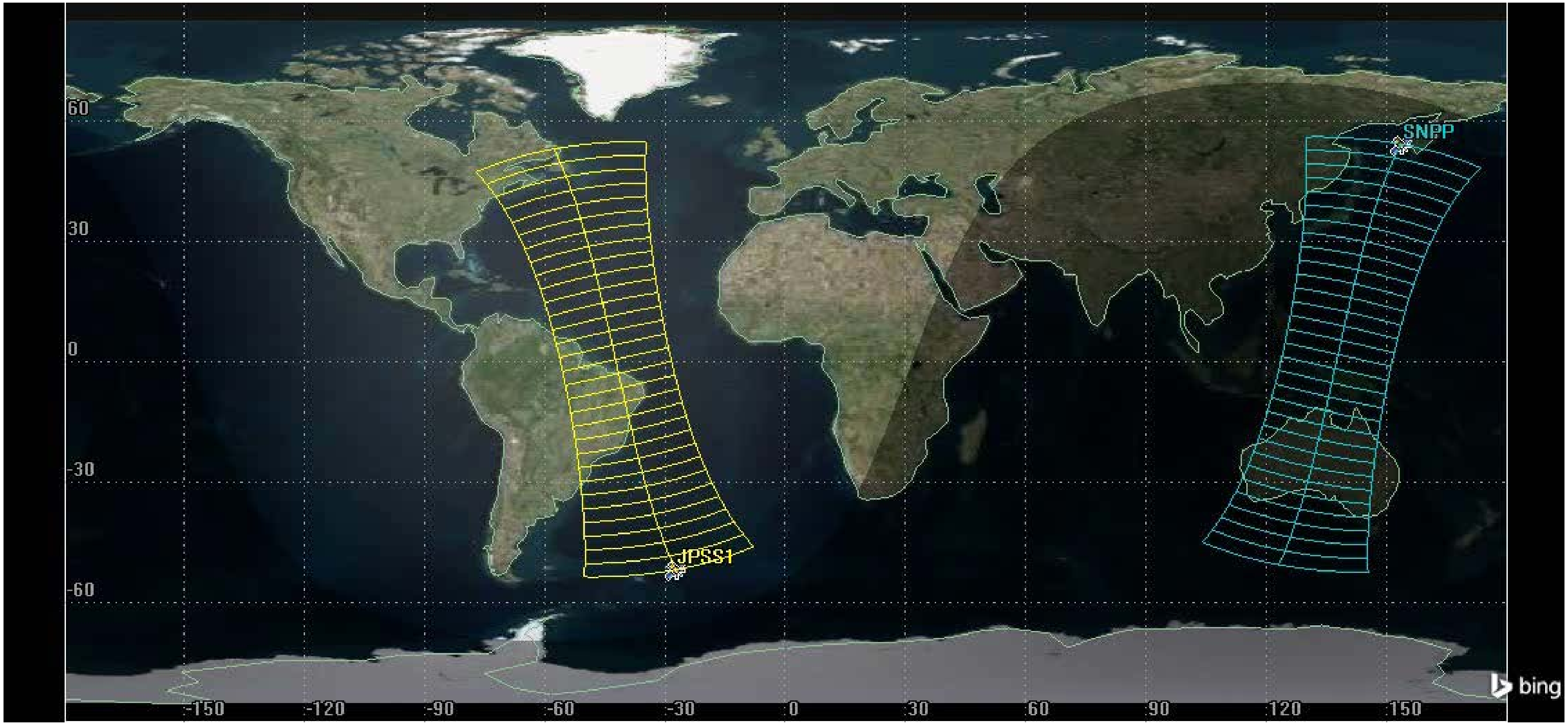
- Current schedule for provisional maturity (90 days) may be affected

J-1 VIIRS Instrument Waivers – Algorithm Updates

Waiver	VIIRS SDR Team Actions	Impact on Ground Processing System	Actions
Polarization sensitivity	Characterize the polalrization phenomena both pre and post launch	Post-launch code and LUT changes are likely	SDR team to develop methods to baseline and monitor on-orbit polarization changes; EDR teams to implement polarization corrections; Intercalibratin at SNOs with SNPP would help greatly. Unfortunately, currently no plan for SNO observations despite opportunity exist before orbit raising
DNB nonlinearity	Develop agg mode dependent calibration algorithm and test them in ADL	Aggregation Code and associated LUTs to work on aggregation modes 21 and 21/26 developed, tested, and delivered	Require extensive postlaunch validation of the new aggregation mode, and update of LUTs postlaunch; Intercalibratin at SNOs with SNPP would help greatly. Unfortunately, currently no plan for SNO observations despite opportunity exist before orbit raising.
Emissive band radiometric calibration	Investigate potential impacts on striping; may require algorithm enhancements	TBD postlaunch	Additional evaluation required postlaunch. Intercalibratin at SNOs with SNPP would help greatly. Unfortunately, currently no plan for SNO observations despite opportunity exist before orbit raising.
SWIR nonlinearty and uncertainty	Develop dual calibration to accommodate low radiance nonlinearity	Post-launch code and LUT changes are likely	Requires additional research to implement SWIR nonlinearity correction (low priority); Intercalibratin at SNOs with SNPP would help greatly.
Spatial Resolution DFOV & MTF	Monitor performance postlaunch	TBD	Impact on ground processing system is not expected unless postlauch test shows the need otherwise
Relative spectral response	Provide RSR on website	LUT updates in work	Final RSR is ready but waiting for official release ; Intercalibratin at SNOs with SNPP would help greatly.
Crosstalk	Monitor performance postlaunch	TBD	Impact on ground processing system is not expected unless postlauch test shows the need otherwise
Band to band registration	Monitor performance postlaunch	TBD	Impact on ground processing system is not expected unless postlauch test shows the need otherwise
M8/M9/I4 saturation (M6 rollover)/DNB	Post-launch code and LUT changes are likely	Post-launch code and LUT changes are likely	Currently under study; requires postlaunch validation; Intercalibratin at SNOs with SNPP would help greatly.
Near field scattering	Monitor performance postlaunch	TBD	Impact on ground processing system is not expected unless postlauch test shows the need otherwise
DNB straylight	Develop straylight correction for J1 VIIRS/DNB	Post-launch code and LUT changes are likely	Methodology used for S-NPP can be adapted for J1 to make corrections; requires the development of J1 LUT postlaunch; Intercalibratin at SNOs with SNPP would help greatly.
M1/M2 Absolute uncertainty	Monitor performance postlaunch	TBD	Requires improved calibration postlaunch such as lunar; Intercalibratin at SNOs with SNPP would help greatly.
M11 Uncertainty	Monitor performance postlaunch	TBD	Requires improved calibration postlaunch such as lunar; Intercalibratin at SNOs with SNPP would help greatly.

Red Font: Prelaunch code/LUT updates required Green Font: Mitigation prelaunch unnecessary

J1 vs. SNPP coverage



- Both on the same orbital plane
- Both have the same orbital equator crossing (LTAN)
- ~50.75 mins separation: one is observing in day while the other is at night
- Ground track repeating cycle is 16 days for each, and 8 days when combined
- Improved temporal coverage (~50 mins interval around 1:30pm)

Special issue of *Remote Sensing* (Guest Editor: Dr. Changyong Cao
"VIIRS Cal/Val and Applications" 28 papers published
(http://www.mdpi.com/journal/remotesensing/special_issues/VIIRS?view=default)

Chapter 1 Overview of Calibration/Validation		
Xiong, Xiaoxiong; Bu	Overview	Assessment of S-NPP VIIRS On-Orbit Radiometric Calibration and Performance
Sun, Junqiang; Wang	Overview	VIIRS Reflective Solar Bands Calibration Progress and Its Impact on Ocean Color Products
Datla, Raju; Shao, Xi	Overview	Comparison of the Calibration Algorithms and SI Traceability of MODIS, VIIRS, GOES, and GOES-R ABI Sensors
Zhou, Lihang; Divak	Overview	An Overview of the Joint Polar Satellite System (JPSS) Science Data Product Calibration and Validation
Hillger, Don; Kopp, T	Overview	User Validation of VIIRS Satellite Imagery
Chapter 2 Instrument Onboard Calibration and Prelaunch Characterization		
Blonski, Slawomir; C	OBC	Suomi NPP VIIRS Reflective Solar Bands Operational Calibration Reprocessing
Shao, Xi; Cao, Chang	OBC	Spectral Dependent Degradation of the Solar Diffuser on Suomi-NPP VIIRS Due to Surface Roughness-Induced Rayleigh Scattering
Lee, Shihyan; Cao, C	OBC	Soumi NPP VIIRS Day/Night Band Stray Light Characterization and Correction Using Calibration View Data
Wang, Zhuo; Cao, C	OBC	Assessing the Effects of Suomi NPP VIIRS M15/M16 Detector Radiometric Stability and Relative Spectral Response Variation on Striping
Oudrari, Hassan; Mc	Prelaunch	JPSS-1 VIIRS Radiometric Characterization and Calibration Based on Pre-Launch Testing
McIntire, Jeff; Moye	Prelaunch	Pre-Launch Radiometric Characterization of JPSS-1 VIIRS Thermal Emissive Bands
Moyer, David; McInt	Prelaunch	JPSS-1 VIIRS Pre-Launch Response Versus Scan Angle Testing and Performance

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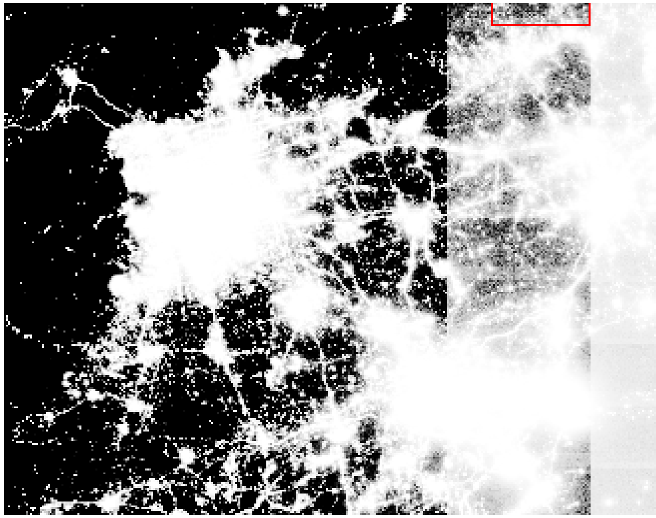
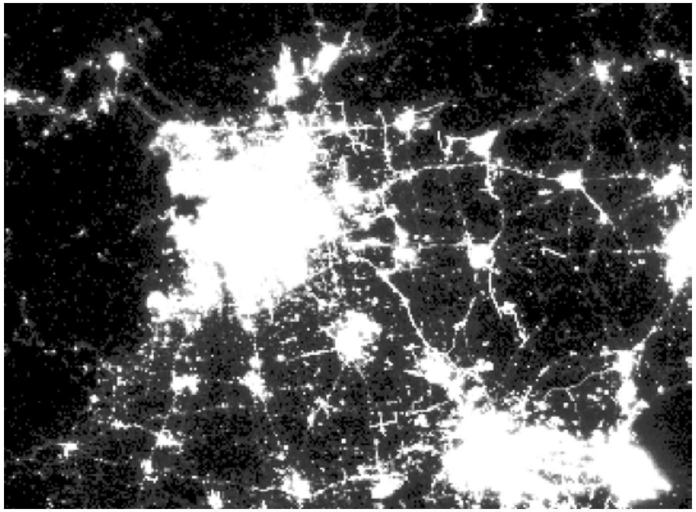
(http://www.mdpi.com/journal/remotesensing/special_issues/VIIRS?view=default)

Chapter 3 Sensor Data Record Intercomparisons and Monitoring		
Li, Yonghong; Wu, Ai:	SDR	Inter-Comparison of S-NPP VIIRS and Aqua MODIS Thermal Emissive Bands Using Hyperspectral Infrared Sounder Measurements as a Transfer Reference
Liang, Xingming; Igna	SDR	Preliminary Inter-Comparison between AHI, VIIRS and MODIS Clear-Sky Ocean Radiances for Accurate SST Retrievals
Yu, Fangfang; Wu, Xia	SDR	Radiometric Inter-Calibration between Himawari-8 AHI and S-NPP VIIRS for the Solar Reflective Bands
Wang, Likun; Trembl	SDR	Fast and Accurate Collocation of the Visible Infrared Imaging Radiometer Suite Measurements with Cross-Track Infrared Sounder
Wang, Zhipeng; Xion	SDR	Improved Band-to-Band Registration Characterization for VIIRS Reflective Solar Bands Based on Lunar Observations
Choi, Taeyoung; Shac	SDR	Radiometric Stability Monitoring of the Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) Reflective Solar Bands Using the Moon
Wang, Wenhui; Cao,	SDR	Monitoring the NOAA Operational VIIRS RSB and DNB Calibration Stability Using Monthly and Semi-Monthly Deep Convective Clouds Time Series
Madhavan, Sriharsha	SDR	Evaluation of VIIRS and MODIS Thermal Emissive Band Calibration Stability Using Ground Target
Chapter 4 Environmental Data Record Product Calibration/Validation		
Obata, Kenta; Miura,	EDR	Spectral Cross-Calibration of VIIRS Enhanced Vegetation Index with MODIS: A Case Study Using Year-Long Global Data
Liu, Yuling; Yu, Yunyu	EDR	Quality Assessment of S-NPP VIIRS Land Surface Temperature Product
Tu, Qianguang; Pan, I	EDR	Validation of S-NPP VIIRS Sea Surface Temperature Retrieved from NAVO
Brando, Vittorio; Lov	EDR	The Potential of Autonomous Ship-Borne Hyperspectral Radiometers for the Validation of Ocean Color Radiometry Data
Liu, Yinghui; Key, Jeff	EDR	Validation of the Suomi NPP VIIRS Ice Surface Temperature Environmental Data Record
Gao, Caixia; Zhao, Yo	EDR	An Investigation of a Novel Cross-Calibration Method of FY-3C/VIRR against NPP/VIIRS in the Dunhuang Test Site
Gladkova, Irina; Ignat	EDR	Improved VIIRS and MODIS SST Imagery
Jing, Xin; Shao, Xi; Ca	EDR	Comparison between the Suomi-NPP Day-Night Band and DMSP-OLS for Correlating Socio-Economic Variables at the Provincial Level in China

Calibration Reanalysis
Why? (Example of urban growth)



2012 original



2016

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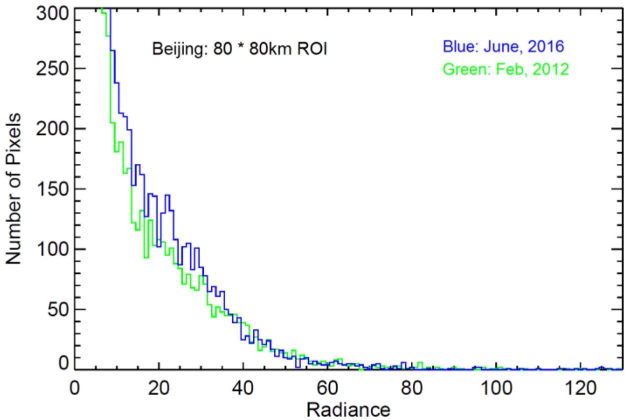

Quantitative comparisons of night light

Collaboration with GOES-R field campaign

- First test flight at UMD UAS test site in Bushwood, MD on Aug. 3, 2016 to demonstrate readiness for postlanch cal/val for GOES-R ABI and potentially VIIRS
- Provide 2D&3D imagery to NOAA National Estuary Research Reserve (NERR)
- Other sensors including both atmospheric and imaging will be tested later
- UAS is recognized by NOAA as one of the emerging technologies that can instill agility and infuse new technology in the NOAA observing system portofolio

UAS Test flight near Chesapeake Bay, MD

Collaboration with GOES-R field campaign – more to come…

Summary & Path Forward

The VIIRS SDR team has made great progress:

- Supported J1 VIIRS waiver studies
- Developed geolocation software code modifications for J1
- Developed and delivered at launch quality J1 VIIRS LUTs
- Transitioned and enhanced geolocation validation capabilities
- Water vapor band trade studies
- Documented research in peer reviewed publications (special issue)

Concerns:

- Time too short to reach provisional at L+90 (practically ~33 working days)
- Nadir door opens at L+day 45 significantly reduces the time required to update the on-orbit LUT, especially for VIIRS DNB, since both DNB offset and straylight LUT require VROPs that have yet to be scheduled (between L+50 and L+90?) which depends on the lunar cycle
- Missed SNO opportunity = extended effort in postlaunch cal/val