Expanding validation capabilities for J1 VIIRS

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Outline

- Introduction
- Sensor on-orbit calibration/validation
  - Characterize radiometric stability and accuracy
- S-NPP VIIRS validation techniques
  - Sensor intercomparison using SNO/SNO-x
    - Reference standards: Instruments such as MODIS, OLI, further expanded to GOSAT TANSO-FTS.
  - Pseudo-invariant calibration sites
  - Deep Convective Clouds (DCC)
  - Comparing SDR products
- Summary

Introduction

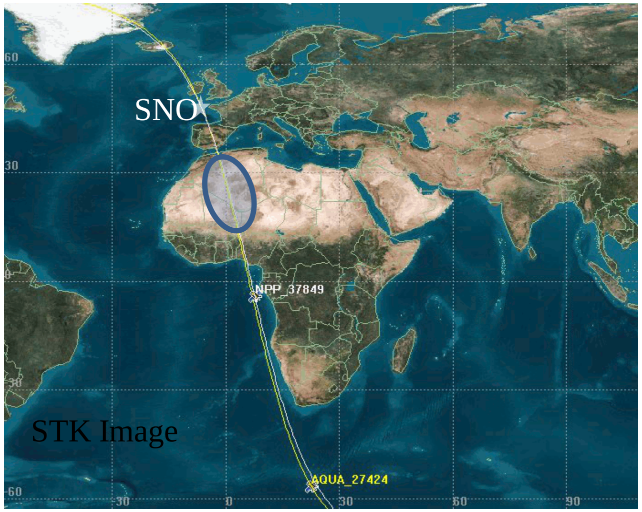
- Satellite instrument degradation is a common phenomena.
- If characterized well, data can easily meet high standard radiometric accuracy.
- Radiometric validation
  - assess the stability and accuracy: independently verifying the instrument performance
  - tracks how well the onboard calibration system is.
  - results can be used as feedbacks to further improve the calibration.
- VIIRS calibration stability and accuracy are continuously monitored using independent methods since early launch.
- Similar to S-NPP VIIRS, postlaunch radiometric validation is critical for J1 VIIRS
  - Primary motive is to ensure that the data quality is well within the specification.
  - Monitoring calibration stability through independent techniques.
    - trending the instrument over vicarious calibration sites, Lunar and DCC.
  - Characterizing radiometric accuracy
    - comparing with other well calibrated instruments.
    - vicarious calibration using underflights during satellite overpass.

S-NPP VIIRS Radiometric Validation

- Every radiometric validation technique has its own limitations so multiple techniques are used.
- Instrument comparison to evaluate radiometric accuracy and consistency
- Reference instruments used in comparison are AQUA MODIS, Landsat-8 OLI, and GOSAT TANSO-FTS (mainly for CO2 absorption M10 band).
- Hyperspectral measurements from EO-1 Hyperion, AVIRIS along with radiative transfer models such as MODTRAN, 6S are used:
  - characterize the spectral characteristics of calibration sites
  - quantify the spectral differences between the instruments during intercomparison.
- Radiometric validation techniques used are:
  - SNO
  - SNO-x
  - Vicarious Calibration Sites
  - Deep Convective Clouds
  - Lunar Trending
  - SDR product comparison from different agencies

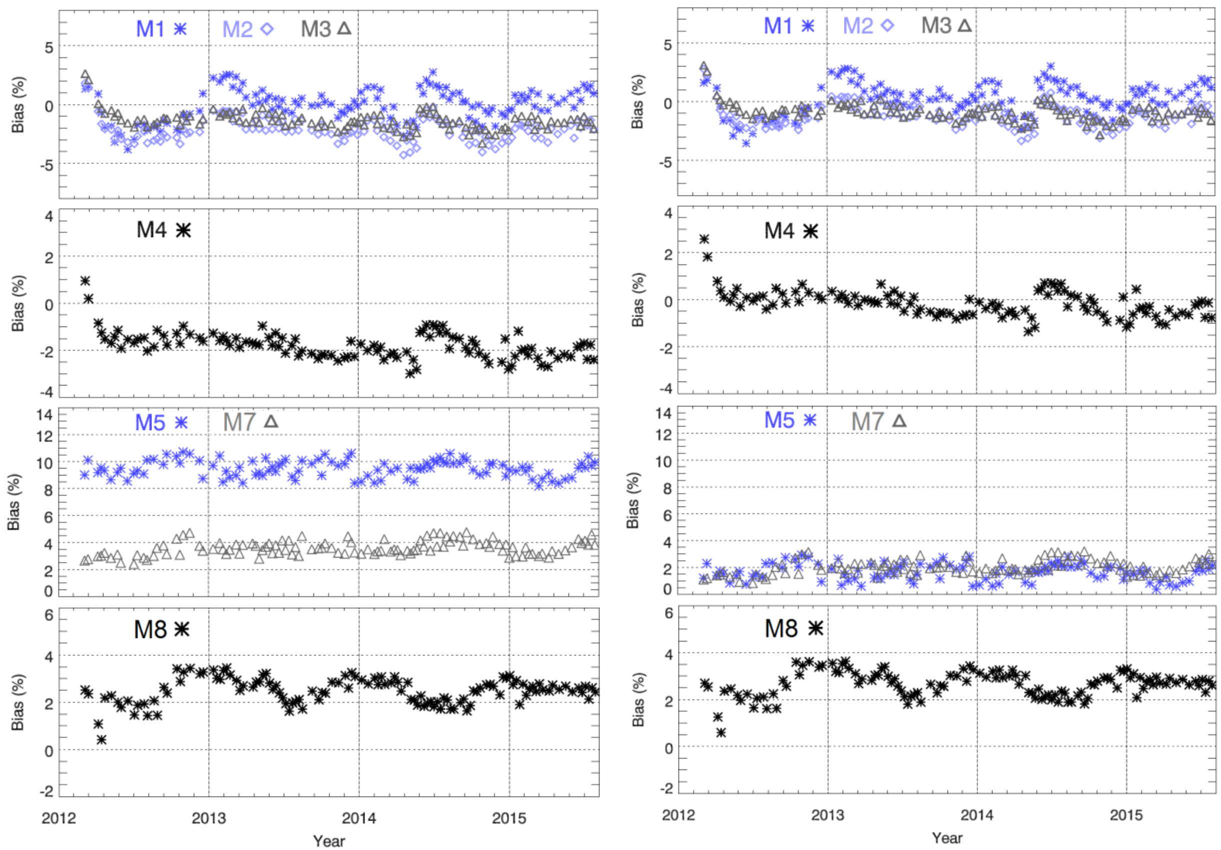
Simultaneous Nadir Overpass (SNO)

- **SNO**: Comparison of simultaneous measurements from two or more instruments at their orbital intersection with almost identical viewing conditions
- Orbital intersection usually occurs at high-latitude polar region for polar orbiting satellites
- Extended SNO (**SNO-x**) in low latitudes is an approach inherited from SNO approach that extends orbits to low latitudes for inter-comparing sensors over a wide dynamic range such as over ocean surface, desert targets, green vegetation etc.
- VIIRS and MODIS sensors are compared at overlapping regions of extended SNO orbits at North African deserts and over ocean to assess radiometric bias.
- This approach will be adopted for J1 to evaluate its radiometric performance.



VIIRS Comparison with MODIS (SNO-x)

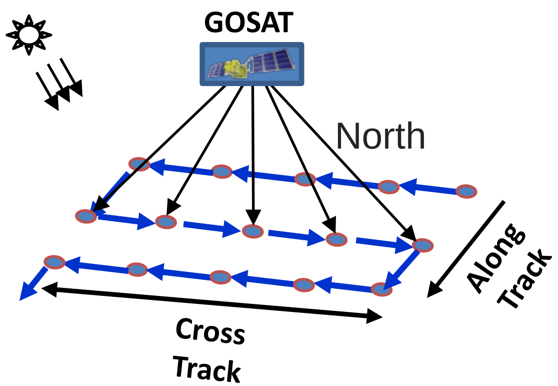
Before Spectral correction | **After** Spectral correction

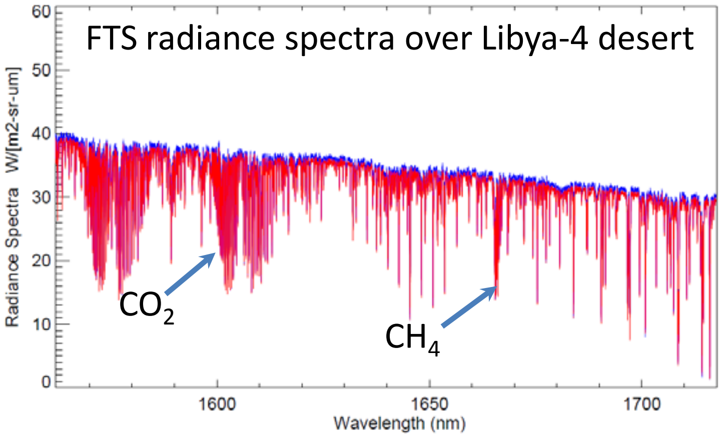


- VIIRS bias estimated through SNO-x by comparing with AQUA MODIS *(Uprety et al. 2013, JTech)*
- The bias suggested that VIIRS radiometric performance mostly meet requirements (± 2%)
- Bias trends are very important to characterize the instrument stability and radiometric accuracy
- Similar intercomparison will be done for J1 VIIRS to evaluate its bias (short/long term)

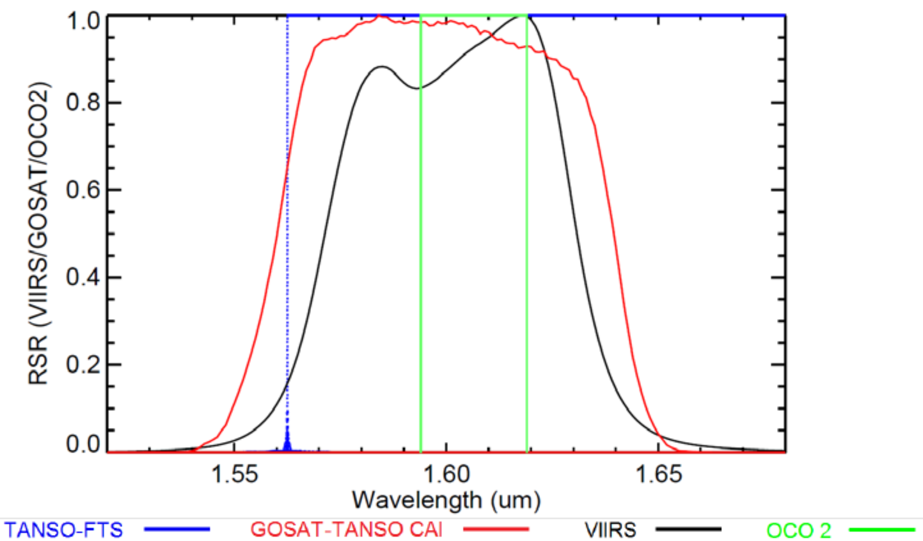
GOSAT TANSO-FTS for VIIRS M10 Validation

- GOSAT is a cooperative project among JAXA, NIES and the MOE.
- Launched on January 23, 2009 with payloads: Thermal and Near Infrared Sensor for Carbon Observation - Fourier Transform Spectrometer (TANSO-FTS) and a Cloud and Aerosol Imager (TANSO-CAI)
- TANSO-FTS:
  - RSB bands: 0.76, 1.64, and 2.00 um
  - Spectral resolution: 0.2 wavenumbers (about 0.05 nm at 1.6 µm)
  - Spatial Resolution: ~10.5 km
- There are not very good references to validate M10. MODIS has a number of inoperable detectors for matching band.





GOSAT FTS and VIIRS



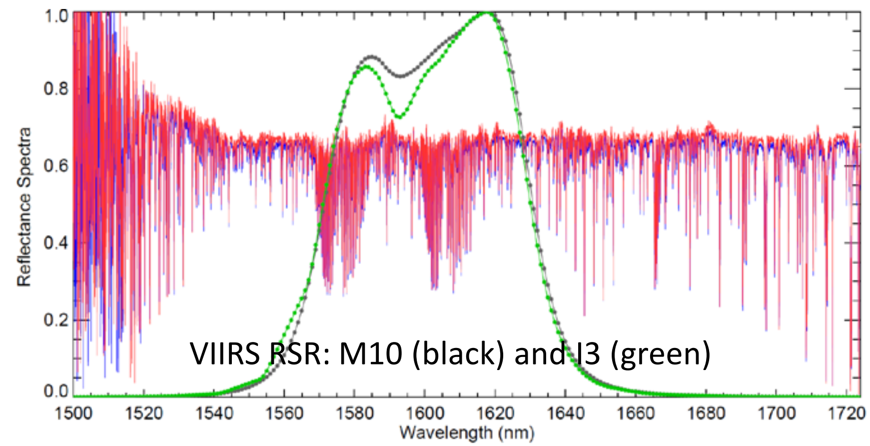
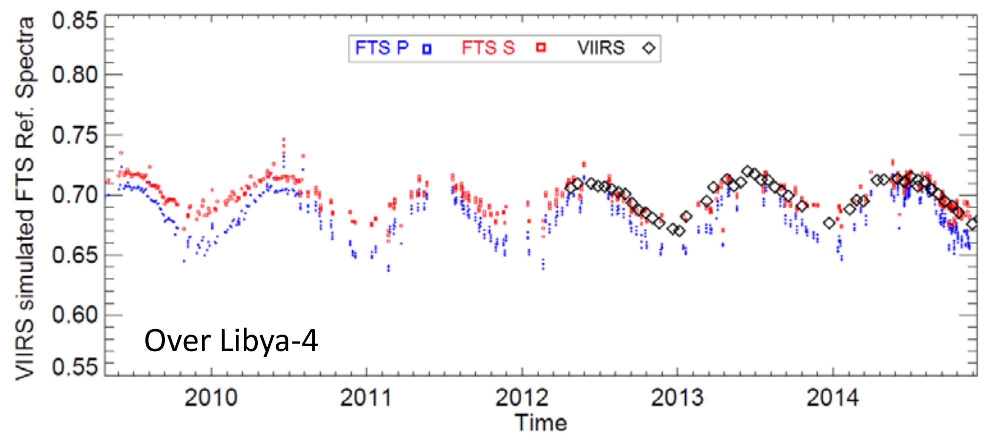


Figure. GOSAT FTS reflectance spectra for P and S polarized reflectance over Libyan Desert.

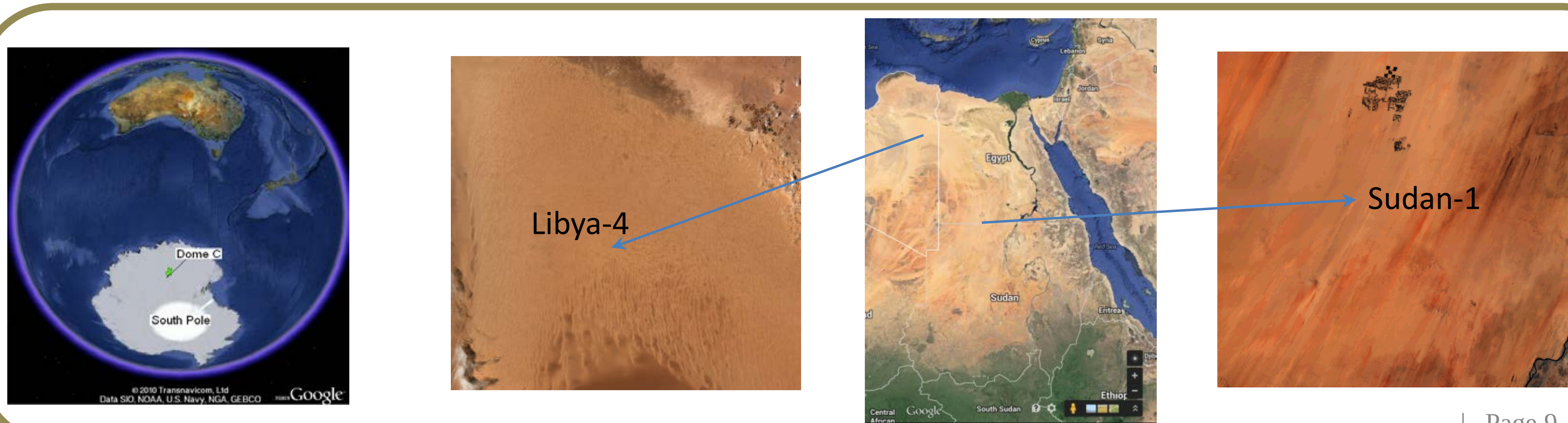
- FTS hyperspectral measurements over Libya-4 convolved with VIIRS RSR and compared.
- VIIRS M10 and FTS S polarized light agree very well to within 0.5% ± 0.9%.
- In future, planning to use OCO-2 as well.



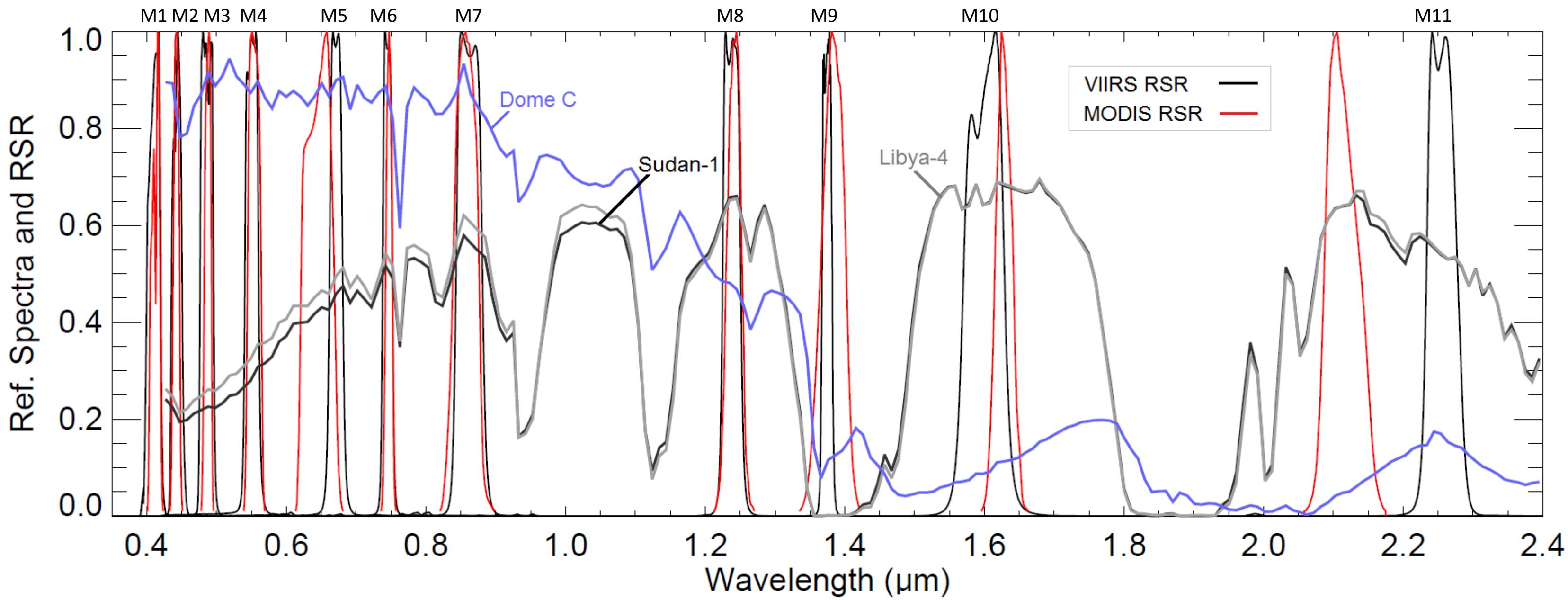
Ref: Uprety et al. 2015 (submitted to Jtech)

Vicarious Calibration Sites

- Vicarious Calibration Sites such as deserts, snow sites, etc are used as independent sources of radiometric cal/val for satellite instruments either with or without onboard calibration devices
- These sites can be used to characterize the sensor degradation, validate the radiometric performance, perform the inter-comparison between sensors etc.
- VIIRS calibration performance has been continuously monitored and characterized using a number of Saharan desert calibration sites such as Libya-4 and Sudan-1 deserts, ocean sites such as near Moby in Hawaii, Antarctica Dome C snow flat.

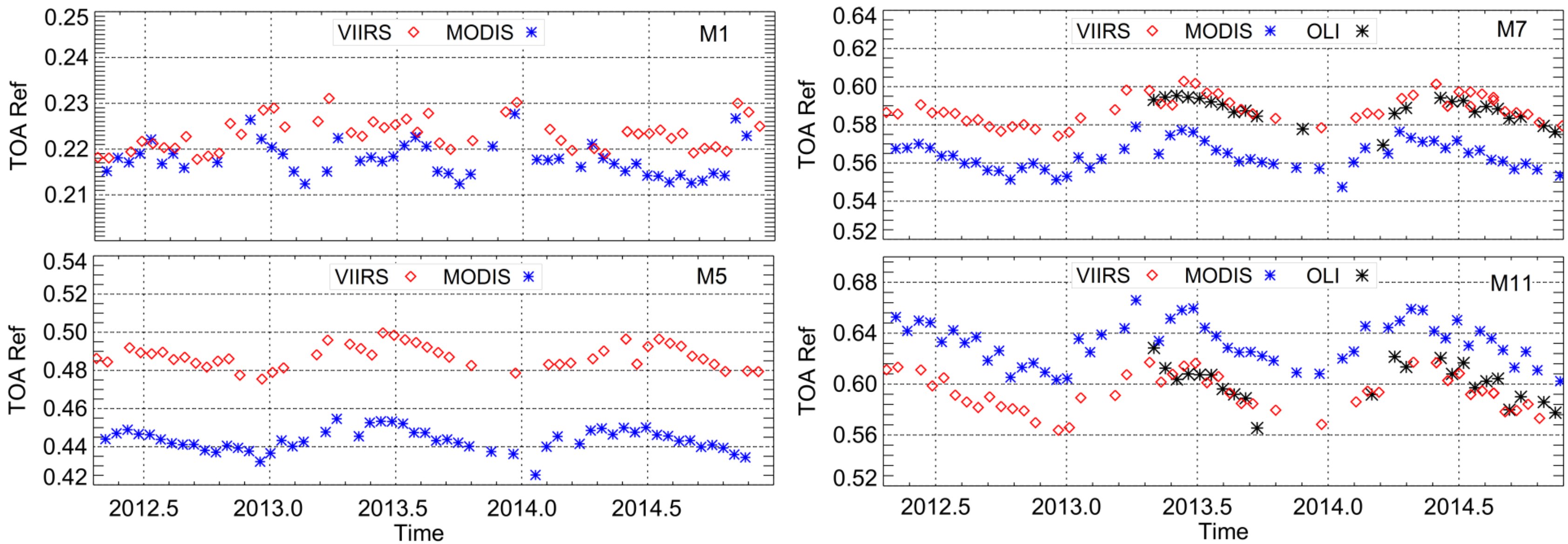


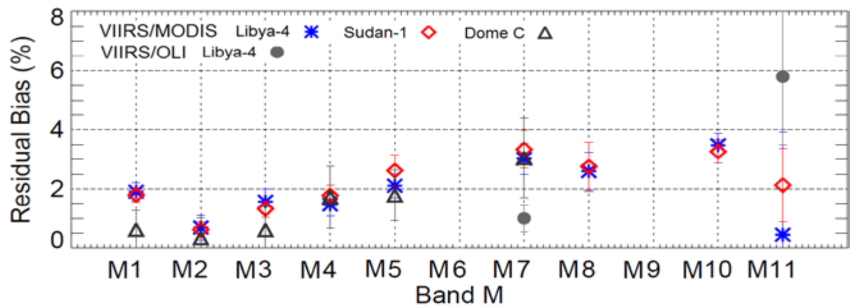
Why choose Multiple Targets?

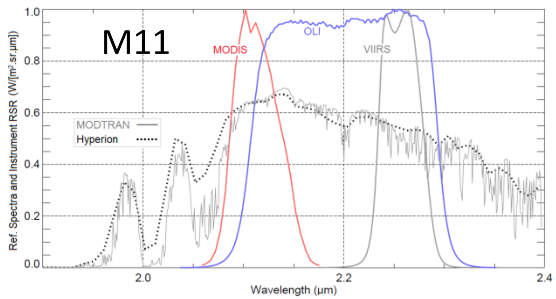


- Desert: Better for longer wavelength RSB.
- Ocean: Uses high gain for most of the dual gain RSB bands.
- Dome C: Spectrally nearly flat over VNIR
- DCC: High reflected radiance for VNIR with low atmospheric absorption variability.
- Moon: Reflectance is nearly constant at a given phase angle.

Estimating VIIRS Radiometric Bias

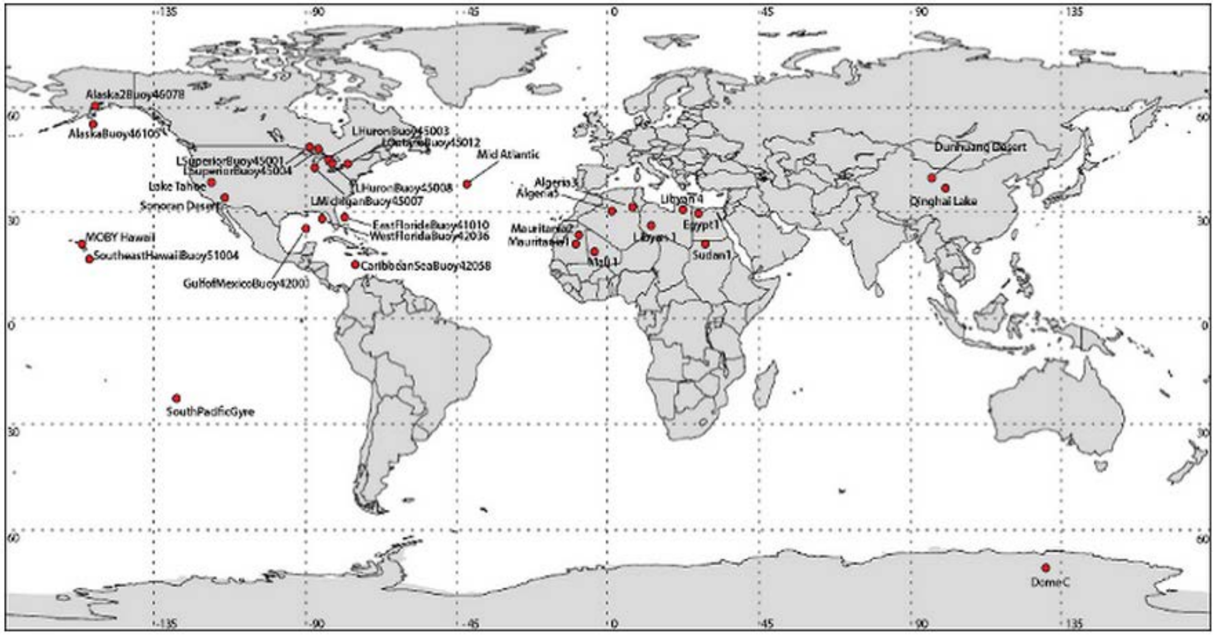






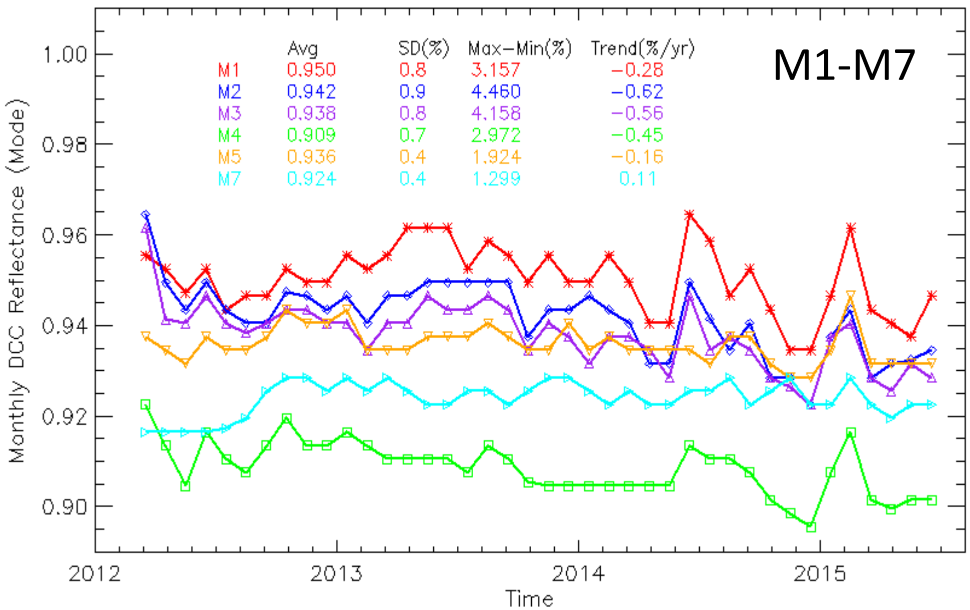
- Track radiometric stability (trending over the desert sites) and accuracy (compare with MODIS and OLI) of VIIRS *(Uprety and Cao, 2015, RSE).*
- Bias trends provide critical feedbacks about VIIRS radiometric performance in absolute scale.
- System analysis will be expanded to J1 VIIRS to monitor its radiometric performance.

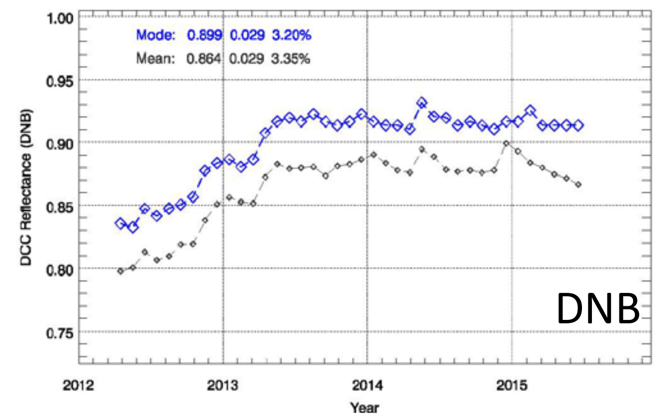
Validation Time Series

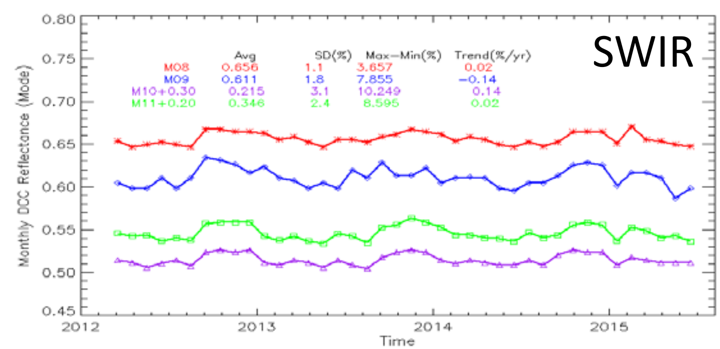


- Monitor calibration stability of VIIRS using a large number of world-wide calibration sites.
- Construct the radiometric time series over about 30 vicarious sites to monitor the stability of the VIIRS calibration.
- Tracking the calibration stability by trending the nadir observations as the satellite overpass through these sites
- Service is available from NCC website for VIIRS (*http://ncc.nesdis.noaa.gov/VIIRS/VSTS.php*)
- System can be modified to suit for the study of J1 VIIRS calibration stability over time

Deep Convective Clouds (DCC)







- DCC time series for VIIRS RSB and DNB operational calibration stability monitoring.
- The time series are updated monthly and available online at:
  https://cs.star.nesdis.noaa.gov/NCC/VSTS.
- J1 VIIRS will also be adopted with this technique to assess the calibration stability.

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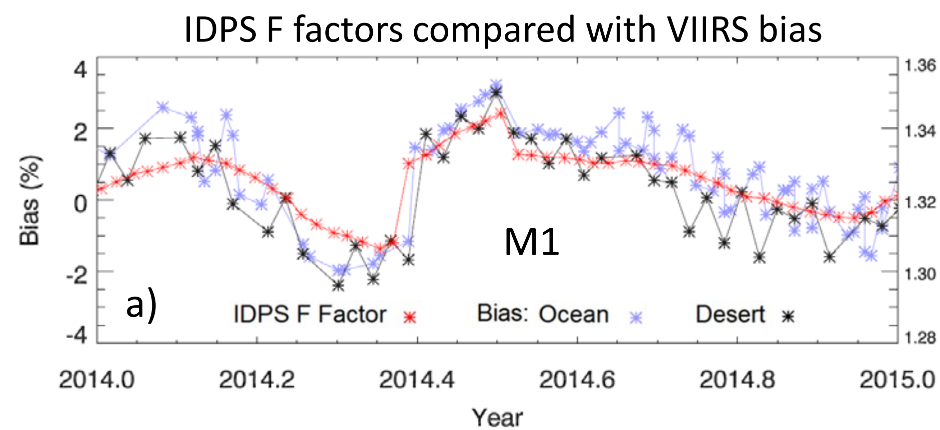
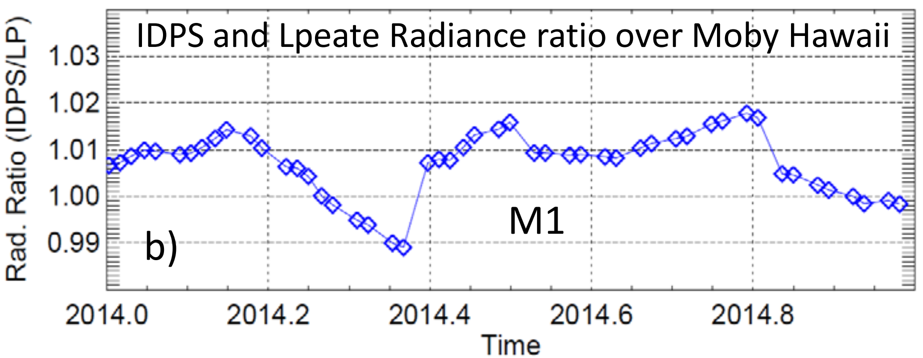
SDR Product Comparison

- IDPS F factors compared with VIIRS bias (using SNO-x) over ocean and desert (Figure a.)
- Bias trends track the operational F factors very well.
  - SNO-x validation provides significant feedbacks on onboard calibration performance
- Radiance ratio of VIIRS SDR from IDPS and Lpeate/SIPS.
  - Ratio trend (Figure b.) matches well with trends in top figure.
  - Suggests mainly the calibration differences.
  - Indicates that reprocessing IDPS products can improve the radiometric quality and consistency.

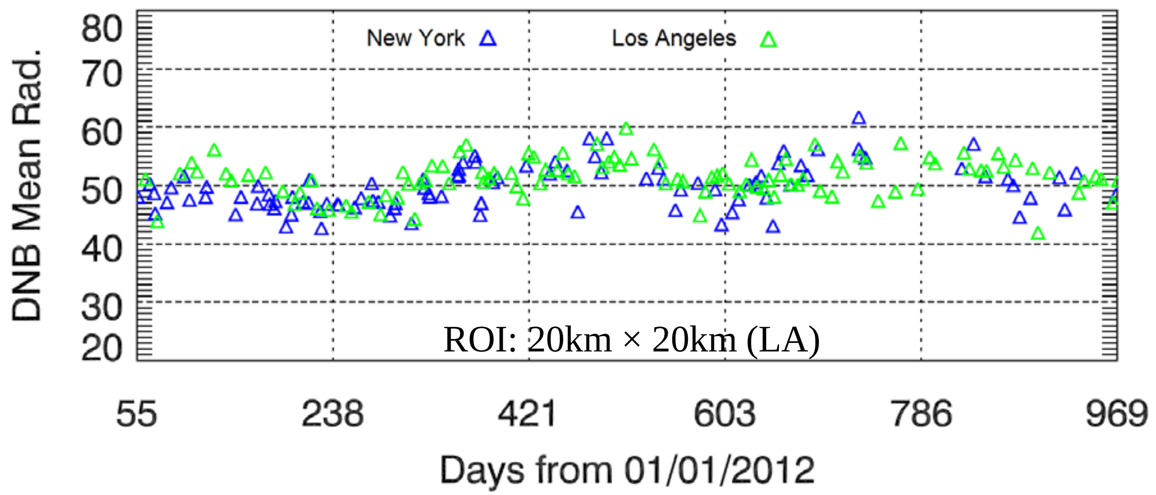


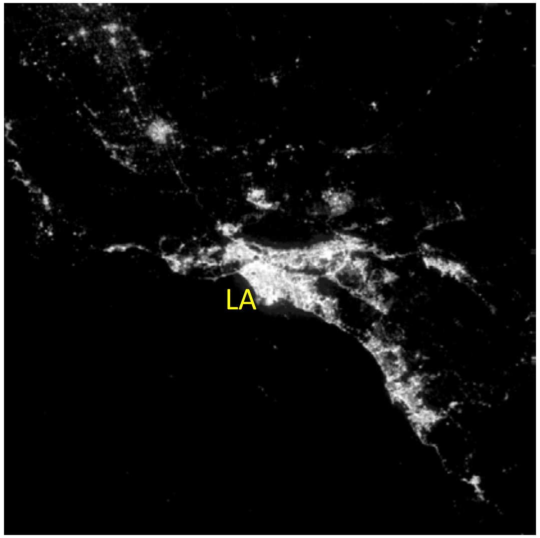


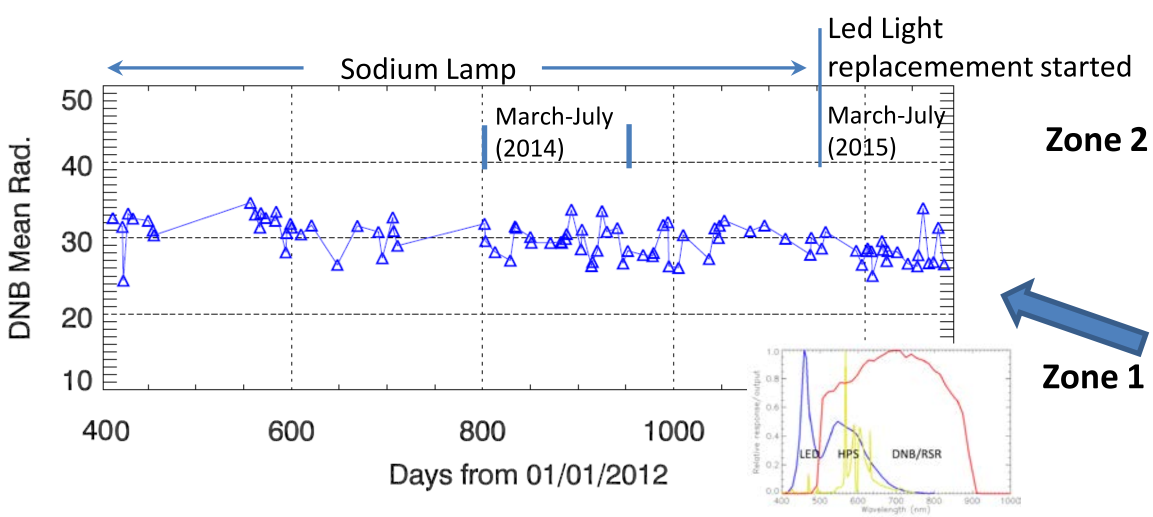
VIIRS DNB Validation

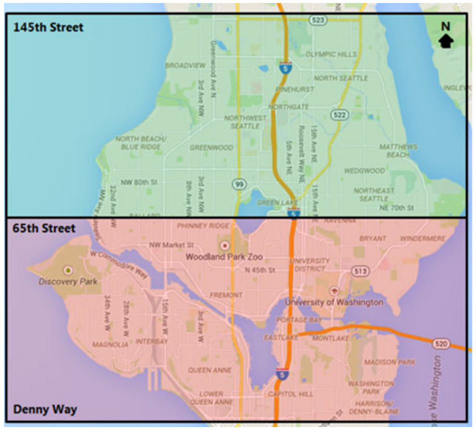
- New SBIR initiative to develop active nightlight for VIIRS DNB calibration/validation, working closely with NIST and NASA scientists (explained in earlier presentation)
  - Develop and deploy accurate active light sources (AALS) to selected calibration sites for the cal/val of the VIIRS DNB low light performance.
- DNB radiometric stability and accuracy:
  - Deep Convective clouds
  - City light time series
  - Bridge light time series (demonstrated in earlier presentation)
  - Comparison with other instruments using lunar illuminated targets such as Dome C site.

DNB Stability using City Lights









The conversion work will cover Seattle's arterial roadways between **Denny Way and 65th Street** (highlighted in **red**).

Depending on progress, this phase of work may extend north to **145th Street** (highlighted in **green**).

It is expected that all City of Seattle arterial roadways will be completed within two to three years.

- DNB unit: W/cm^2sr

Summary

- Radiometric validation techniques that has been developed and under continuous use for S-NPP VIIRS will be modified for analyzing the post-launch radiometric performance of J1 VIIRS.
- RSB validation techniques will be further expanded to include new instruments such as OCO-2 to evaluate the radiometric consistency with VIIRS M10.
- Apart from MODIS, OLI, FTS and OCO-2, we will have the opportunity to validate J1 VIIRS data with current S-NPP VIIRS.
- In addition, DNB validation will incorporate accurate active light source that will be developed through SBIR project.
- J1 validation will also leverage from GOES-R underflight project:
  - Ground truth measurement and absolute radiometric validation of J1 performance.