Radiometric Consistency Between S-NPP and NOAA-20 VIIRS Reflective Solar Bands

Sirish Uperty¹, Xi Shao¹, Changyong Cao², Bin Zhang¹, Wenhui Wang¹
¹University of Maryland/CISESS, ²NOAA/NESDIS/STAR
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• Background
• Sensor Intercomparison Techniques
  – SNO
  – SNOx
  – PICS
  – DCC
  – Ray matching based Geo-Leo
• Summary
To ensure the calibration quality is well within specification, VIIRS radiometric performance needs to be continuously monitored and independently validated.

The radiometric consistency of NOAA-20 and S-NPP VIIRS is evaluated using:

- **SNO over polar region**
  - S-NPP bias relative to MODIS
  - NOAA-20 bias relative to MODIS
  - Bias between S-NPP and NOAA-20: Double differencing

- **Extended SNO (SNOx) over desert and ocean**
  - SNOx extended over African desert and tropical ocean
  - Bias between S-NPP and NOAA-20: Double differencing (similar to SNO)

- **Pseudo-Invariant Calibration Sites (PICS)**
  - VIIRS reflectance trending over Libya 4
  - NOAA-20 and S-NPP VIIRS are compared with Landsat OLI

- **Deep Convective Cloud (DCC)**
  - Trending both the VIIRS instrument over DCC

- **Ray matching technique**
  - Comparing each VIIRS sensor with GOES-16 ABI and double differencing
NOAA-20 Spectral Bias Relative to S-NPP

- S-NPP and NOAA-20 RSRs are not identical and can have minor differences.
  - Results in spectral bias
  - Spectral Band Adjustment factors (SBAF) used based on Sciamachy
    Ref: NASA Langley tool (https://www.ptr.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SBAF)
  - Spectral bias for all bands are on the order of 1% or less except M4 (desert: ~3.2%).

\[
\text{Spectral Bias} = \frac{(\text{NOAA-20} - \text{S-NPP}) \times 100\%}{\text{S-NPP}}
\]

<table>
<thead>
<tr>
<th>Target</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>M7</th>
<th>M8</th>
<th>M10</th>
<th>I1</th>
<th>I2</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Pole</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>-0.8%</td>
<td>0.2%</td>
<td>-0.4%</td>
<td>0.0%</td>
<td>0.5%</td>
<td>0.3%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>DCC</td>
<td>0.0%</td>
<td>0.7%</td>
<td>0.2%</td>
<td>-0.4%</td>
<td>0.0%</td>
<td>-0.4%</td>
<td>-0.1%</td>
<td>0.7%</td>
<td>0.2%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Libyan Desert</td>
<td>-1.1%</td>
<td>0.0%</td>
<td>0.1%</td>
<td>3.2%</td>
<td>0.3%</td>
<td>1.0%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>1.5%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>
Evaluating NOAA-20 and S-NPP Consistency using Polar SNOs

- Both NOAA-20 and S-NPP have SNOs with AQUA.
- Study uses SNOs from both SH and NH.
- SNO: Near identical solar and sensor geometry for both sensors.
- Use AQUA MODIS as a transfer radiometer.
- Double differencing indicates the radiometric consistency between S-NPP and NOAA-20 VIIRS.
• Bias trends are changing over time.
• After H-factor update (March 23, 2018), NOAA-20 is lower than S-NPP by ~-2.5-3%
• Further after F-factor update in end of April, NOAA-20 VIIRS drops by nearly 1%
• NOAA-20 reflectance lower than S-NPP by 3.6%
NOAA-20 VIIRS M5 and M7 Bias

- Large bias exists for M5 (~-5.5%) and M7 (~-3.5%) because S-NPP VIIRS M5 and M7 calibration are biased high by ~2%.
Evaluating NOAA-20 and S-NPP Consistency using Extended SNO (SNOx) over Saharan Desert

- SNOs extended to low latitude Saharan desert and tropical ocean.
- Allows instrument comparison within few minutes of time difference (usually <16 mins).
- Regularly used to monitor S-NPP Bias relative to MODIS since launch
  - [https://ncc.nesdis.noaa.gov/VIIRS/VIIRS_MODIS_Intercomparison.php](https://ncc.nesdis.noaa.gov/VIIRS/VIIRS_MODIS_Intercomparison.php)
- Both NOAA-20 and S-NPP VIIRS can be compared to and AQUA MODIS using SNO-x.
- Double differencing to evaluate the NOAA-20 and the S-NPP consistency.

*SNO-x Ref: Uprety et al. 2013, Jtech*
M1-4 Bias Trends (Desert SNOx)

- M1-4 bias for NOAA-20 ranges from -3.5% to -2%.
- SNOx bias over Saharan desert consistent with SNO bias over polar region.
Both M5 and M7 NOAA-20 VIIRS biases are lower than S-NPP.

Bias agrees with polar SNO to within 0.5%

M5 and M7 suggest large bias because S-NPP VIIRS M5 and M7 are biased high by about 2%. 

M5 (0.672 µm)

NOAA-20 Bias: ~-5.5%

M7 (0.865 µm)

NOAA-20 Bias: ~-4%
M8 and M10 Bias Trends (Desert SNOx)

- NOAA-20 VIIRS is lower than S-NPP for both M8 (~-3%) and M10 (~-2%).
• Comparison performed over clear sky tropical ocean using SNOx.

• Uses VIIRS high gain only

• M1-3 suggest bias on the order of -2% more recently.

• HG (over ocean) and LG (Polar SNO and Desert SNOx) Bias are consistent.
Pseudo-invariant Calibration Site (Libya 4) to Validate VIIRS Radiometric Consistency
• ROI: 30 km at lat/lon: 28.55° /23.4°
• Clear sky nadir observations
• Spectral differences accounted
• NOAA-20 VIIRS reflectance is lower than S-NPP
• NOAA-20 VIIRS M1 indicates larger bias (-5%) whereas the bias for the rest of the bands agree well (mostly within 1%) with previous methods.
Note: Both NOAA-20 and S-NPP VIIRS are scaled using SBAF to account spectral difference relative to OLI.
All NOAA-20 bands are biased low, consistent to previous results.

 Courtesy from Wenhui Wang, GST@NOAA/STAR
GOES-16 ABI and VIIRS Intercomparison

- Intercomparison is performed near SNO using all sky tropical ocean observations
- Ray matching technique is used to match the sensor and solar geometry
- ROI size: ±20° lat/lon from sub-satellite location.
  - For each SNO, average all bias values computed over 0.5°*0.5° lat/lon bins.
Radiometric Consistency Between VIIRS

- Weekly averaged bias time series: more uniform sampling of dynamic range over bins
- NOAA-20 VIIRS TOA reflectance lower by ~2-3%, with noisier trends
- ABI band 2 has drop from April 2019:
  - operational calibration update lowering reflectance by nearly 6%
  - Improves the ABI agreement with VIIRS to ±2%

\[\text{Drop due to cal. update, Apr. 2019}\]
Summary

• Study suggests that NOAA-20 VIIRS observed TOA reflectance is consistently lower (2-3%) than S-NPP VIIRS for all RSB.
• Larger bias exists for M5 (-4.5%) and M7 (-4%) because S-NPP VIIRS M5 and M7 absolute calibration are biased high by ~2%.
• Results from five major independent validation methods agree to within 1% for most bands.
• VIIRS radiometric performance is regularly monitored using all the techniques presented.
• Bias for NOAA-20 VIIRS investigation will be continued for root cause.
Questions?