VIIRS Geolocation Status

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Acknowledgements

- Thanks to Land SIPS Team for processing control point residuals and testing Geo LUTs updates

- Thanks to Fred Patt of NASA Ocean Group for helping us understand and resolve issues related to ephemeris and attitude data

- Thanks to NOAA colleagues and many friends of the JPSS Program for assistance
Outline

- J1/N20 VIIRS Geolocation Performance and Trends in C2
- SNPP VIIRS Geolocation Performance and Trends in C1.1, and preparation for C2 re-processing
- Some expectations of J2, J3+ VIIRS
- Plan in future work
- Conclusions
<table>
<thead>
<tr>
<th>Residuals</th>
<th>SNPP VIIRS C1.1</th>
<th>J1/N20 VIIRS C2</th>
<th>Aqua MODIS C6.1</th>
<th>Terra MODIS C6.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track mean</td>
<td>15 m</td>
<td>-1 m</td>
<td>1 m</td>
<td>0 m</td>
</tr>
<tr>
<td>Scan mean</td>
<td>5 m</td>
<td>2 m</td>
<td>0 m</td>
<td>0 m</td>
</tr>
<tr>
<td>Track RMSE</td>
<td>59 m</td>
<td>55 m</td>
<td>46 m</td>
<td>43 m</td>
</tr>
<tr>
<td>Scan RMSE</td>
<td>52 m</td>
<td>49 m</td>
<td>53 m</td>
<td>45 m</td>
</tr>
<tr>
<td>Data-days</td>
<td>2847 (7.8 yrs)</td>
<td>669 (1.8 yrs)</td>
<td>6310 (17.3 yrs)</td>
<td>6725 (19.5 yrs)</td>
</tr>
<tr>
<td>Missing days</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>59</td>
</tr>
<tr>
<td>Daily matched GCPs w/ I1/B1</td>
<td>202</td>
<td>193</td>
<td>222</td>
<td>258</td>
</tr>
</tbody>
</table>

- **Nadir equivalent** accuracy (RMSE – Root Mean Square Error) . (MODIS for reference)
  - Meet Spec: 125 m (1σ); within 20% I1 HSI (375 m) = 75 m @ nadir for VIIRS
  - Band-to-band mis-registration to other bands adds bias to RMSE to: \( RMSE = \sqrt{\sigma^2 + \mu^2} \)

- MODIS – VIIRS differences
  - Aqua use definitive ephemeris data \(\rightarrow\) 27 hour latency
  - SNPP attitude data is not as good but improvement is coming, see Slides #11 & 12
  - DEM resolutions: older 1 km for VIIRS vs newer 0.5 km for MODIS C6/C6.1

**SNPP VIIRS C2 re-processing will start soon**
J1/VIGMU (VIIRS instrument geometric model update) has been implemented.

J1 temporal pointing variation is large and temporal correction has been implemented.

RMSE Track: 55 m  Scan: 49 m, nadir equivalent
J1/N20 Scan Angle Residuals

VIGMU (VIIRS instrument geometric model update) implemented in J1 C2
SNPP Scan Angle Residuals

Track residuals (m) vs. Scan angle (deg)

Scan residuals (m) vs. Scan angle (deg)

±20% I-band pixel size

Strange pattern is being corrected, done for J1 C2, soon for SNPP

Lin et al., 18 Nov 2019
VIGMU: VIIRS instrument geometric model update

- Puzzle: ground geolocation SW is supposed to correct RTA/HAM motion non-linearity
- Long term trend from SNPP VIIRS still shows the pattern, but in the opposite direction

Answer:

\[ L_{\text{sight}} = L_{\text{tel}} - 1/M \ (L_{\text{tel}} - L_{\text{hamvector}}) \]

where \( M = -4 \) (not +4 as we are currently using), which affects line of sight due to the parts of RTA/HAM motion non-linearity (non-synchronization), which are relatively small
SNPP C1.1 geolocation errors

- **Track (adj.) res. (m):** 59 m
- **Scan (adj.) res. (m):** 52 m, nadir equivalent

Temporal variations will be corrected soon in C2

Lin et al., 18 Nov 2019

VCST/GEO 9
SNPP VIIRS pointing error/correction

SNPP VIIRS Geo correction test AS3293

The 1 second time error is theorized as attitude pitch error of -213 arcsec. Test results of ground control truth prove it!

This jump due to erroneous star trackers realignment has been successfully tested

Strange jump after Star Tracker-2 reset
Large circles for control spec outage; Small dots hint knowledge spec outage

Star tracker cooling improved SNPP attitude performance

We are seeking for further improvements

SW with Kalman filter to refine the attitude for NASA SIPSs will be implemented soon

J1 is performing better but we are monitoring
• Western Australian coast (south up)
• Difference in “land”/“Water” masks from data 16 days earlier

Lin et al., 18 Nov 2019
**Scan-to-scan underlaps & EFL**

\[ \text{Overlap} = n \frac{p}{F} h - \left[ V_{ECI} - V_{earth0} \cos i \right] T, \quad \text{if } < 0 \rightarrow \text{underlap} \]

- Underlaps occur near 15°N, close off going north and south and off-nadir scan angles.
- High terrain widens the underlaps.
- SNPP has less of this issue because of its shorter focal length (~0.4%).
- J2 will have more of this issue, while J3+ mitigates the issue by shortening EFL.

*Lin et al., 18 Nov 2019*

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**SNPP VIIRS Mean "pure" EFL deviation**

**J1 VIIRS Mean EFL deviation**

Measured\(^1\) EFL for SNPP will be implemented in C2 soon

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List of updates in C2

• Both SNPP and J1/N20 VIIRS
  – Update VIIRS instrument geometric model (code + LUTs)
  – Correct for time-dependent pointing variations (code + LUTs)
  – Improve control point matching program (code)

• SNPP only
  – Replace attitude with Kalman filtered data in L1A (code)
  – Update EFL (LUTs)
  – Add MODIS-like water_present in M-band (code + products)
  – Correct errors due to a 1 second time jump 2015-08-19T14:24:40 – 21:16:31z.
Expectations for J2+ VIIRS

• J2 Band-to-band co-registration -- good
• J2 Pointing – good
• J2 Geolocation – should be good with on-orbit calibration
• J3 VIIRS ambient test has started.
  – Scan rate is increased and EFL is shortened to mitigated scan-to-scan underlaps
  – Swath width increases

Two sets of nominal EFLs and scan rates and EV coverages with altitude @ 828 km over Equator

<table>
<thead>
<tr>
<th>Platform</th>
<th>EFL (mm)</th>
<th>Scan rate (rad/s)</th>
<th>Scan period (s)</th>
<th>EV scan angle (deg)</th>
<th>EV ground distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNPP, JPSS-1,</td>
<td>1141</td>
<td>3.517</td>
<td>1.7867</td>
<td>+/- 56.04</td>
<td>+/- 1510</td>
</tr>
<tr>
<td>JPSS-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPSS-3, JPSS-4</td>
<td>1131.8</td>
<td>3.545</td>
<td>1.7724</td>
<td>+/- 56.50</td>
<td>+/- 1550</td>
</tr>
</tbody>
</table>
Future work

1) Routine monitor and LUTs update as needed
2) Refresh ground control points with Landsat-8 images
3) Replace ephemeris in SC diary with GPS data
4) Update DEM from 1 km to 500m resolution
5) Automate GEO LUT updates
6) Create Level-1 geolocation website

Anything else?

Any change in priority order above?
Conclusions

• J1/N20 VIIRS geolocation performance is excellent
  – VIGMU (VIIRS instrument geometric model update) and corrections for temporal pointing variations have been implemented in C2

• SNPP VIIRS geolocation performance is good
  – Mean errors for I- & M-bands are ~ 10 m and uncertainties are ~ 60 m at nadir, statistically. Improvement is expected in C2
  – DNB geolocation accuracy is good by spot-checking
  – The attitude system underperforms ➔ Kalman Filter is expected to improved geolocation accuracy soon in C2.

• J2 (N21) VIIRS geolocation is expected to perform fine

• J3 VIIRS started ambient testing, shorter EFL and faster scan rate (and wider swath width) @~0.8% are expected.

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Questions?

Local arithmetic mean
\[ A_k = \frac{1}{N_k} \sum_{i=1}^{N_k} x_{ki} \]

Local Stdev
\[ S_k = \sqrt{\frac{1}{N_k - 1} \sum_{i=1}^{N_k} (x_{ki} - A_k)^2} \]

Global arithmetic mean
\[ A = \frac{1}{N} \sum_{k=1}^{M} (N_k A_k) \quad N = \sum_{k=1}^{M} N_k \]

Global Stdev
\[ S = \sqrt{\frac{1}{N - 1} \sum_{k=1}^{M} \left[ N_k (A - A_k)^2 + (N_k - 1)S_k^2 \right]} \]

⇒ STAND: Short Term Anomalous Navigation Detection – credit to Bin Tan on GOES-R INR assessment

Thank you!
Sun angle dependence

**SNPP**

\[ y = 0.0012x^2 - 0.3654x + 37.372 \]

\[ R^2 = 0.4337 \]

**J1/N20**

\[ y = 0.0015x^2 - 0.3754x + 26.594 \]

\[ R^2 = 0.4582 \]

**VCST/GEO**

\[ y = 0.0027x^2 - 0.5889x + 32.063 \]

\[ R^2 = 0.5192 \]

\[ y = 0.0035x^2 - 0.7454x + 34.326 \]

\[ R^2 = 0.5633 \]

**Correction is in-work**