Suomi NPP VIIRS
Geolocation Performance & Improvements

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Acknowledgements

• Thanks Carol Davidson & her Land PEATE Team for processing control point residuals and possible two line element (TLE) use from both IDPS and LPEATE forward-&re-processed VIIRS geolocation products, and testing Geo LUTs updates

• Thanks Geo JAMs -- Alice Isaacman (retired) and Robert Williamson & John Dellomo -- for helping us resolving DRs in the DPE/DPA at the GRAVITE

• Thanks NGAS Team for updating DNB Geo LUTs
Outline

• Geolocation Performance and Trends
• Geolocation Improvements
  • accomplished
  • to be accomplished (potentially)
• Conclusions
Overall Geolocation Performance

<table>
<thead>
<tr>
<th>Residuals</th>
<th>Error IDPS</th>
<th>Error Land PEATE Re-processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track mean</td>
<td>-7 m</td>
<td>3 m</td>
</tr>
<tr>
<td>Scan mean</td>
<td>-5 m</td>
<td>3 m</td>
</tr>
<tr>
<td>Track RMSE</td>
<td>74 m</td>
<td>69 m</td>
</tr>
<tr>
<td>Scan RMSE</td>
<td>60 m</td>
<td>59 m</td>
</tr>
<tr>
<td>Data-days</td>
<td>796 (2.2 yrs)</td>
<td>831 (2.3 yrs)</td>
</tr>
<tr>
<td>Missing days</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>GCP matched w/ band I1</td>
<td>132</td>
<td>135</td>
</tr>
</tbody>
</table>

- **Nadir equivalent** accuracy (RMSE – Root Mean Square Error)
  - Meet Spec: 133 m (1σ); within 20% I-HSI (375 m) = 75 m @ nadir

- Time period:
  - IDPS: 23 Feb 2012 (VIIRS I/M-band LUT update) to 28 April 2014;
  - excluding 18 days right after A/B side switch
  - Land PEATE: 19 Jan 2012 to 28 April 2014
## On-orbit Geolocation LUT Updates

<table>
<thead>
<tr>
<th>Update</th>
<th>Date</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1/19/2012</td>
<td>Cryo-radiator door open</td>
<td>All VIIRS band available, LPEATE re-process start date</td>
</tr>
<tr>
<td>1</td>
<td>2/23/2012</td>
<td>Initial mounting coef. update</td>
<td>Removed bias ~ 1.3 km</td>
</tr>
<tr>
<td>2</td>
<td>3/30/2012</td>
<td>Initial DNB FPA center update</td>
<td>Removed bias ~ 1 km</td>
</tr>
<tr>
<td>b</td>
<td>11/22/2012</td>
<td><em>Scan control electronics (SCE) was switched from B-side to A-Side</em></td>
<td>Caused bias ~ 300 m</td>
</tr>
<tr>
<td>3</td>
<td>12/11/2012</td>
<td>Correction after SCE was switched from B-Side to A-side</td>
<td>Removed bias ~ 300 m</td>
</tr>
<tr>
<td>4</td>
<td>2/15/2013</td>
<td>Second, fine DNB FPA center update</td>
<td>Removed DNB bias ~ 300 m</td>
</tr>
<tr>
<td>5</td>
<td>4/18/2013</td>
<td>Second, scan angle dependent, fine Geo LUT update</td>
<td>Fine tuned and removed scan dependent biases</td>
</tr>
<tr>
<td>c</td>
<td>4/25/2013</td>
<td><em>Star tracker maintenance/re-alignment</em></td>
<td>Caused bias ~ 25 m</td>
</tr>
<tr>
<td>6</td>
<td>8/22/2013</td>
<td>Correction to the star tracker re-alignment</td>
<td>Removed bias ~ 25 m</td>
</tr>
</tbody>
</table>

**Key:**
- **All bands impacted**
- **DNB only**
- **External event**
VIIRS Track Residual Trends

Track residuals (m)

Years since Jan. 1, 2000

Wolfe et al., May 13, 2014

VCST/GEO 6
VIIRS Scan Angle Residuals

R² = 0.7632

R² = 0.2307
VIIRS Scan Angle Residuals

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

IDPS

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

Land PEATE Re-processed

R² = 0.015

R² = 0.0069
VIIRS Sun Angle Residuals

Track

Scan

y = 0.0016x^2 - 0.451x + 30.666
R^2 = 0.5356

y = 0.0007x^2 - 0.1767x + 13.702
R^2 = 0.2496

Land PEATE Re-processed, no correction yet
VIIRS Hemispheric Residuals

- 16-day Global
- 16-day Southern Hemisphere
- 16-day Northern Hemisphere

Track (adj.) res. (m).

Years since Jan. 1, 2000

-40 -30 -20 -10 0 10 20 30 40

12.0 12.2 12.4 12.6 12.8 13.0 13.2 13.4 13.6 13.8 14.0 14.2 14.4

Track (adj.) res. (m).

Years since Jan. 1, 2000

-40 -30 -20 -10 0 10 20 30 40

12.0 12.2 12.4 12.6 12.8 13.0 13.2 13.4 13.6 13.8 14.0 14.2 14.4

Scan (adj.) res. (m).

Years since Jan. 1, 2000

-40 -30 -20 -10 0 10 20 30 40

12.0 12.2 12.4 12.6 12.8 13.0 13.2 13.4 13.6 13.8 14.0 14.2 14.4

South: 27k pts, 9 m mean
North: 84k pts, 1 m mean

South: 27k pts, 11 m mean
North: 84k pts, 0 m mean

Land PEATE Re-processed, no correction yet

Wolfe et al., May 13, 2014
Improvements accomplished

- Initial on-orbit and fine tuned I-/M-bands SDR/GEO LUTs (backup)
- Updated LUTs in responses to on-orbit changes (backup)
  1) Scan control electronics (SCE) side A (switched from side B in Nov 2012))
  2) Star tracker re-alignment in April 2013
- Worked DNB TC geolocation to be implemented in IDPS TTO 22 May 2014 (already in NASA Land PEATE since May 2013) (Chart 13&14)
- Reduced geolocation bias from (up to) 20 km to (up to) 1.5 km through a fix in calculation using backup TLE data (Chart 15)
- Corrected solar/lunar vector errors (~ 0.2 deg) in CmnGeo (Chart 16)
  - The correction will reduce RSB Cal bias ~0.5%+/-0.25%, expected TTO Mx8.5?/6 August?/October 2014
- Trended (2.5 years) SC ephemeris -- understand altitude $\mu = 838.8$ km (Chart 17)
As of Nov 4, 2013, the DNB geolocation accuracy is
Scan: $8 \pm 33\ \mu\text{rad}$  Track: $-35 \pm 68\ \mu\text{rad}$

Scan: $7 \pm 28\ \text{m}$  Track: $-29 \pm 57\ \text{m}$ over coastal areas
(nadir equivalent with mean altitude of 838.8 km)
• The un-corrected DNB geolocation error depends on position off-nadir and terrain height
• DNB Geo LUTs updates based on coast areas (Thanks to NGAS)
• DNB TC geolocation products available from LPEATE since May 2013
• DNB TC geolocation products generated in IDPS Mx8.4 22 May 2014
TLE use and geolocation errors

- TLE used in IDPS when SC diaries were delayed to and
- 314 days (periods 65-95, 395-501 & 620-795) of data checked
- 0.2% of scans used TLE backup data =? Data availability loss
- Most of them occurred in whole-orbit chunks
- A CCR reduced geolocation bias from (up to) 20 km to (up to) 1.5 km on 10 July 2013
- SRS baselined: “SRS.01.08_280 The Common Ground System shall provide the spacecraft diary, when available from the Spacecraft, within 30 seconds of the instrument data for a given data product.” → geo error reduce to ~ 100m for SC diary gap < 30 seconds
• Erroneous use of calls in the IDPS CmnGeo routines (J2000 and TOD)
• Combination of precession-nutation-polarWander pulls true vectors apart from the IDPS computed vectors at a rate of 0.015 deg/year from year 2000
• Correction in August/October 2014 timeframe will help VIIRS RSB calibration and ocean color products (& VIIRS TEB calibration by narrowing lunar intrusion into spaceView)
SNPP Altitude? $\mu = 838.8$ km

- Altitude (km)
  - Mean: $838.8 \pm 0.2$ Peak-to-Valley
  - Min: $828.5 \pm 0.6$ P-V; Max: $856 \pm 0.6$ P-V; Equator: $829.8 \pm 1.0$ P-V
- Drag make-up (DMU) maneuvers keeps altitude from falling and 16-day ground track repeatable ($\pm 20$ km P-V)
- Local time of ascending node (LTAN) drifts from 13:25:24 in Nov 2011 westward 66 km to 3:23:02 in Nov 2012 then back eastward 104 km to 13:26:46 in 4 Dec 2013, continues eastward
- Orbital period: 101.5 min $\pm 0.3$ sec P-V
- Inclination angle drifts $98.65 \rightarrow 98.72$ deg (0.07 degrees more away from the poles) in 2 years, and continues to move away from the poles

Wolfe et al., May 13, 2014
Potential Improvements

- Remove sun angle and hemispheric dependent geolocation biases (Charts 10&11)
- Update 1 km with 500m Digital Elevation Model (DEM) (such as those in MODIS Collection 6) (Charts 19&20)
- Insert 500m resolution Land/Water (L/W) mask (such as those in MODIS Collection 6) (Chart 21)
- Re-format geolocation output (Chart 22)
- Monitor on-orbit operations and response to possible events – another star tracker re-alignment is expected to happen
Old and new DEMs Analysis

MODIS C6 DEM, 1 km and 500 m resolution, from GMTED2010

MODIS C5 1 km DEM is used in VIIRS, with polar stereographic projection

- 33.5% of land area has no change
- 13.7% of land area has a change ranges > 10 m
- C6 DEM fixes some of the issues with C5 DEM in the non-polar regions
- C6 DEM fixes extensive issues at the poles

Within 60 deg latitudes
1. 40% of land area has no change
2. 2% of land area has change > 10 m
1 km vs. 500 m DEM

Variant of 500m DEMs within 1km grid

Maximum difference between 1km DEM and 500m DEMs within the 1km grid

Variations of 500 m DEM within 1km grids

- 18% land area has a variant more than 50 m
- 5.3% land area has a variant more than 150 m

Differences between 1 km and corresponding 500 m DEM

- 12% land area has a diff of 50 m or more
- 1.7% land area has a diff of 150 m or more
New Land Water Mask in C6 MOD03
Spatial Subset from Terra Granule 16:20, Day 2003-193

Land Water Mask

Water Present

Shallow Ocean
Land
Coastline/shoreline
Shallow Inland Water
Ephemeral Water
Deep Inland Water
Moderate Ocean
Deep Ocean

Wolfe et al., May 13, 2014
Experiment on DNB output format

• Combined DNB TC Geo and Cal data
• Reformat: FLOAT32 → INT16 (solar/lunar/satellite zen/azi angles, height, sat-ground range) at pixel-level
• A whole day, 287 5-min granule files
• FLOAT32 → 100.97 GB
• INT16 → 36.77 GB
• 63.6% (35% from SciData, 29% from better HDF internal compression) savings in storage
• 63.6% savings in delivery time → 2.7 times faster in delivering the same data content
Conclusions

- VIIRS geolocation performance is excellent
- Geolocation mean errors for I-/M-bands are near 0 and uncertainties are ~ 70 m at nadir, much better than the specification (133 m 1σ)
  - Caveat: DNB terrain corrected geolocation product is expected in Mx8.4 on 22 May 2014
- LUTs updating, prompt responding to events and “discoveries”, incorporating experiences from other remote sensing instruments help improve VIIRS geolocation accuracies
Backup Slides
Initial on-orbit geolocation LUTs Update

Error after LUT update (2/23/2012, doy 54)

<table>
<thead>
<tr>
<th></th>
<th>Bias (m)</th>
<th>RMSE (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track</td>
<td>-21</td>
<td>80</td>
</tr>
<tr>
<td>Scan</td>
<td>-8</td>
<td>64</td>
</tr>
</tbody>
</table>

27 days with average of 142 matchups/day (minus 12 outliers/day)

Biases removed: Track -755 m, Scan 1118 m

Nadir equivalent units;
Scan Control Electronics (SCE) Side Switch, Geolocation Error and Correction

Operated on B-side SCE since launch

After switch to A-side SCE (Nov. 22, 2012)

After A-side SCE coefficient update in IDPS (Dec. 11, 2012)

Scan direction geolocation shifted ~325 m for 19 data-days

(Nadir equivalent units)
Star Tracker Re-alignment and Correction

- 4/18/2013: Geo LUTs fine tuned
- 4/25/2013: Star tracker re-alignment
- 8/22/2013: Error ~ 25 m found and corrected