(SNPP + J1/N20 + J2+) VIIRS Geolocation Status

NASA VIIRS Characterization Support Team (VCST)
Geometric Calibration Group

Guoqing (Gary) Lin, SSAI/GSFC code 619
Robert E. Wolfe, NASA/GSFC Code 619
John Dellomo, GST/GSFC Code 619
James C. Tilton, NASA/GSFC Code 606
Ping Zhang, Bin Tan, SSAI/GSFC Code 619

NASA MODIS/VIIRS STM Calibration Workshop
College Park, Maryland
18 November 2019

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

VIIRS Geolocation Performance

Residuals	SNPP VIIRS C1.1	J1/N20 VIIRS C2	Aqua MODIS C6.1	Terra MODIS C6.1
Track mean	**15 m**	**-1 m**	1 m	0 m
Scan mean	**5 m**	**2 m**	0 m	0 m
Track RMSE	**59 m**	**55 m**	46 m	43 m
Scan RMSE	**52 m**	**49 m**	53 m	45 m
Data-days	**2847 (7.8 yrs)**	**669 (1.8 yrs)**	6310 (17.3 yrs)	6725 (19.5 yrs)
Missing days	**1**	**3**	10	59
Daily matched GCPs w/ I1/B1	**202**	**193**	222	258

- **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

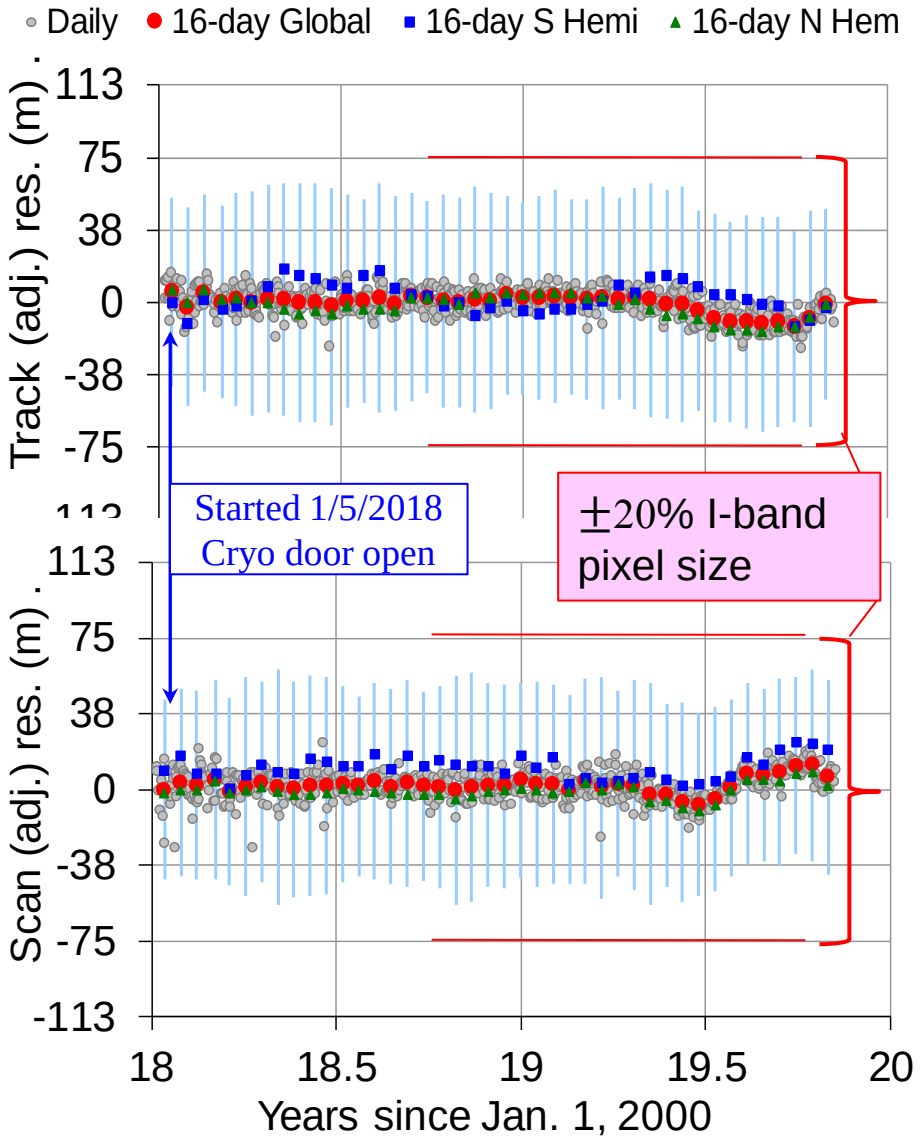
  Aqua use definitive ephemeris data → 27 hour latency

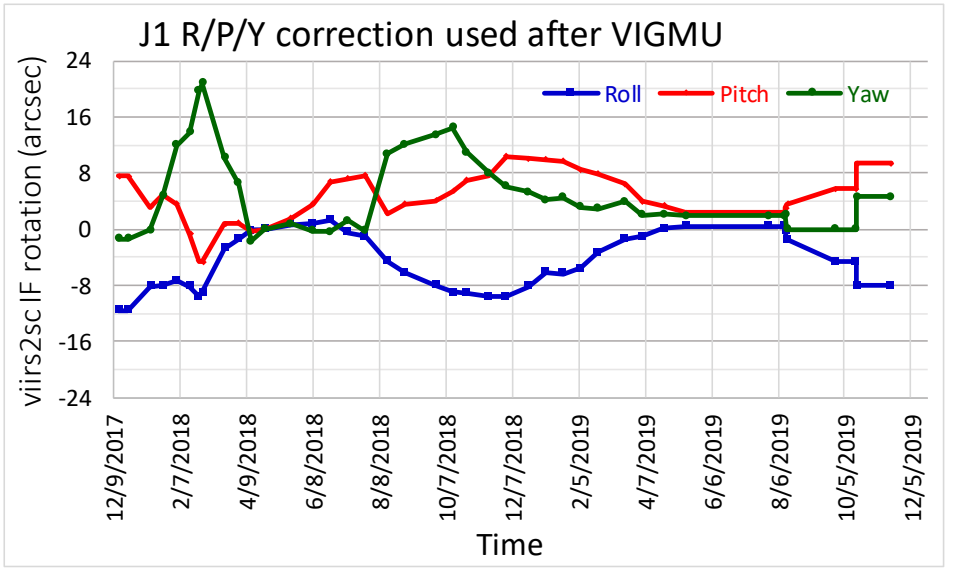
  SNPP attitude data is not as good but improvement is coming, see Slides #11 & 12

  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/N20 C2 geolocation errors

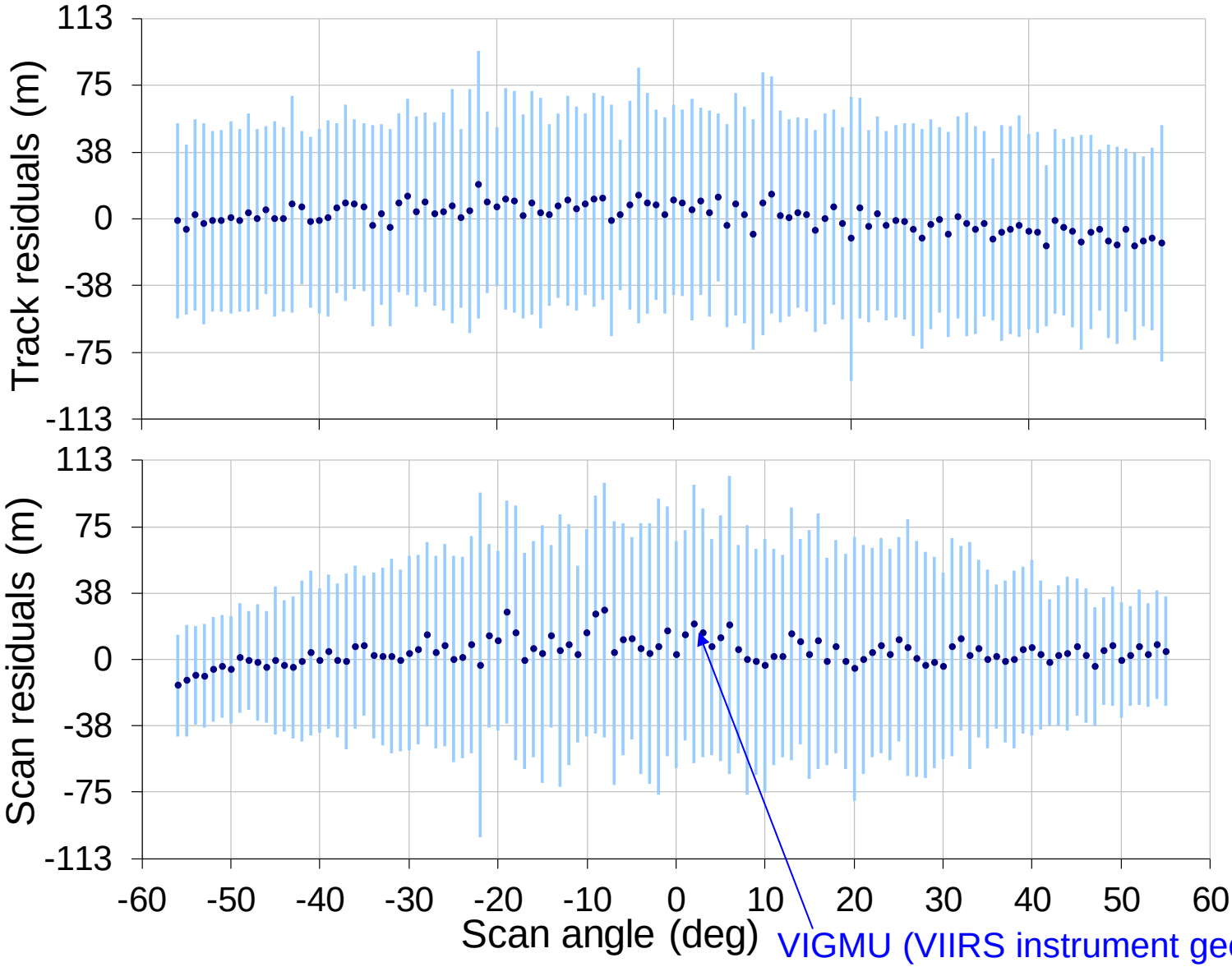




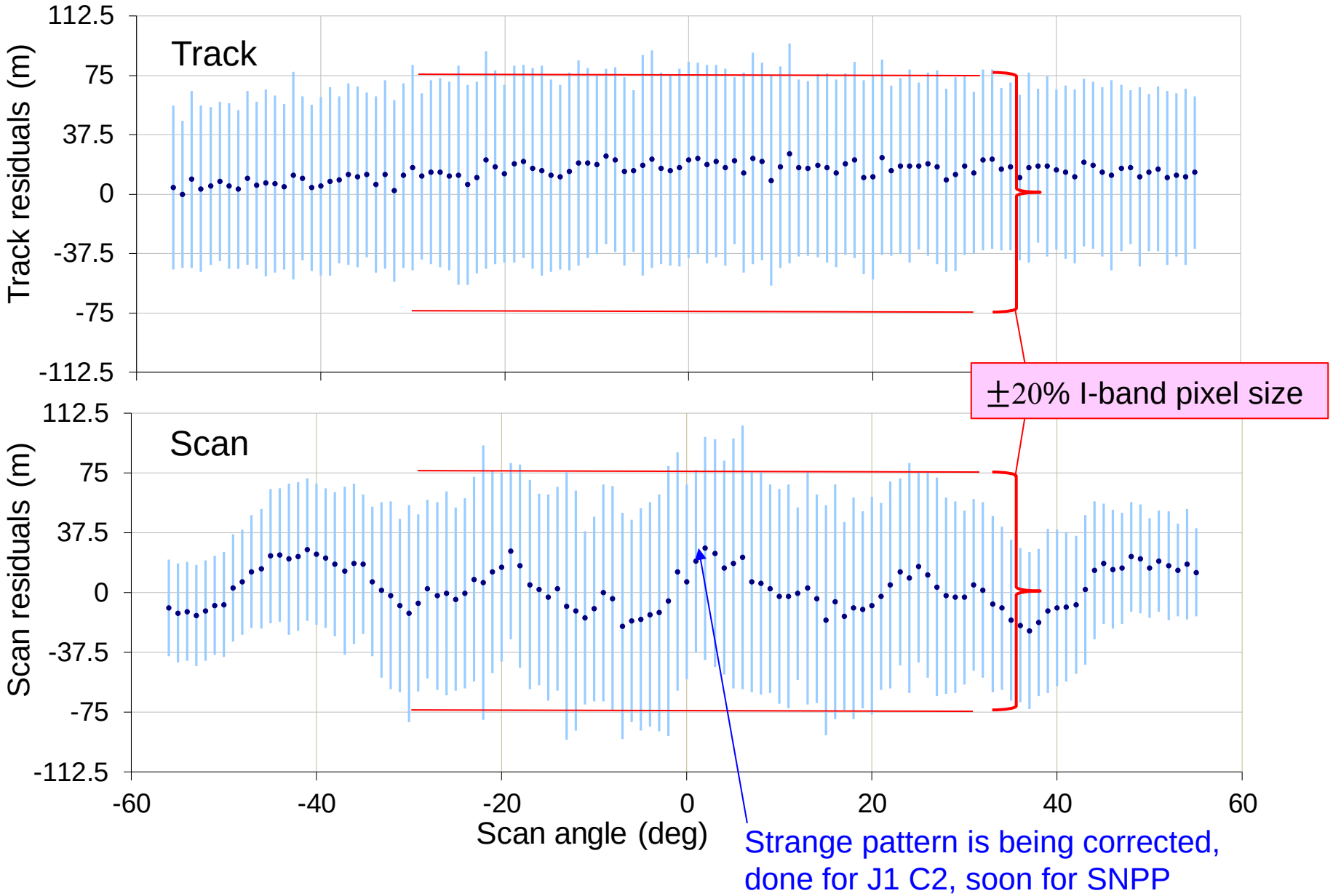
- J1 VIGMU (VIIRS instrument geometric model update) has been implemented.
- J1 temporal pointing variation is large and temporal correction has been implemented.

RMSE Track: 55 m Scan: 49 m, nadir equivalent

J1/N20 Scan Angle Residuals

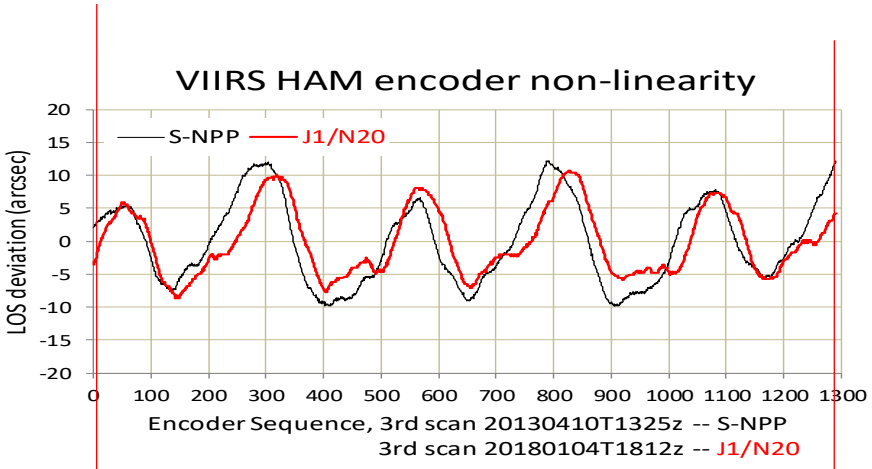


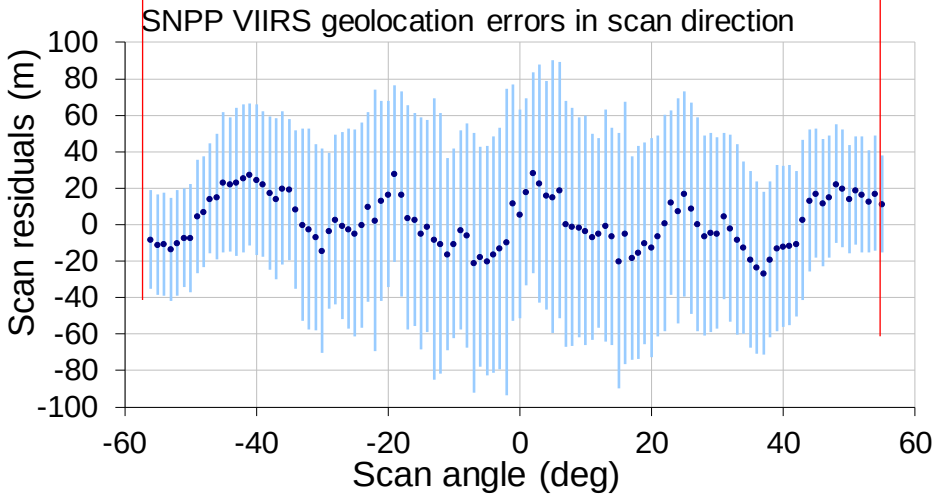
SNPP Scan Angle Residuals



Lin et al., 18 Nov 2019

VIGMU:
VIIRS instrument geometric model update





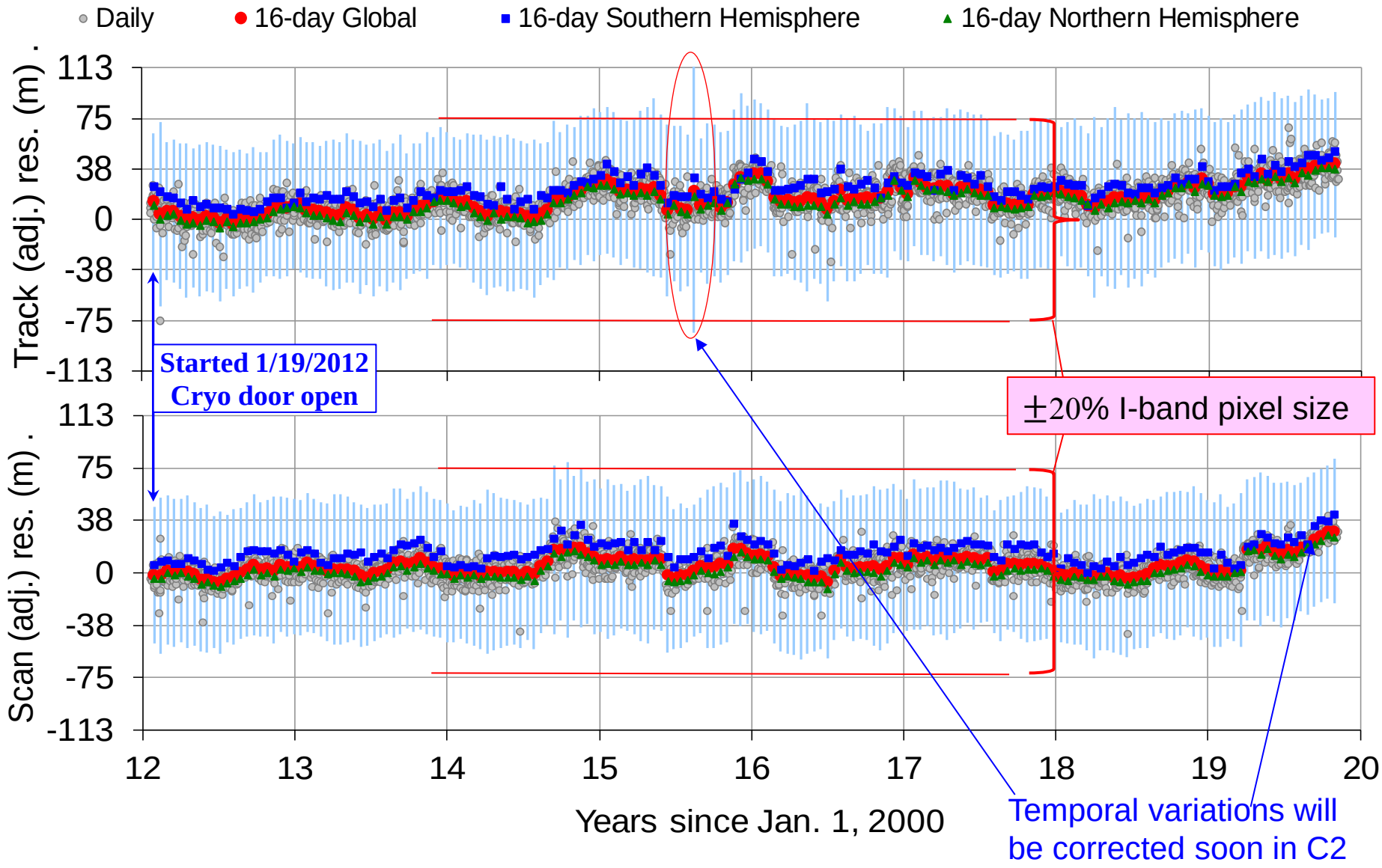
- Puzzle: ground geolocation SW is supposed to correct RTA/HAM motion non-linearity
- Long term trend from SNPP VIIRS still shows the pattern, but in the opposite direction

Answer:

Lsight = Ltel - 1/M (Ltel – Lhamvector)

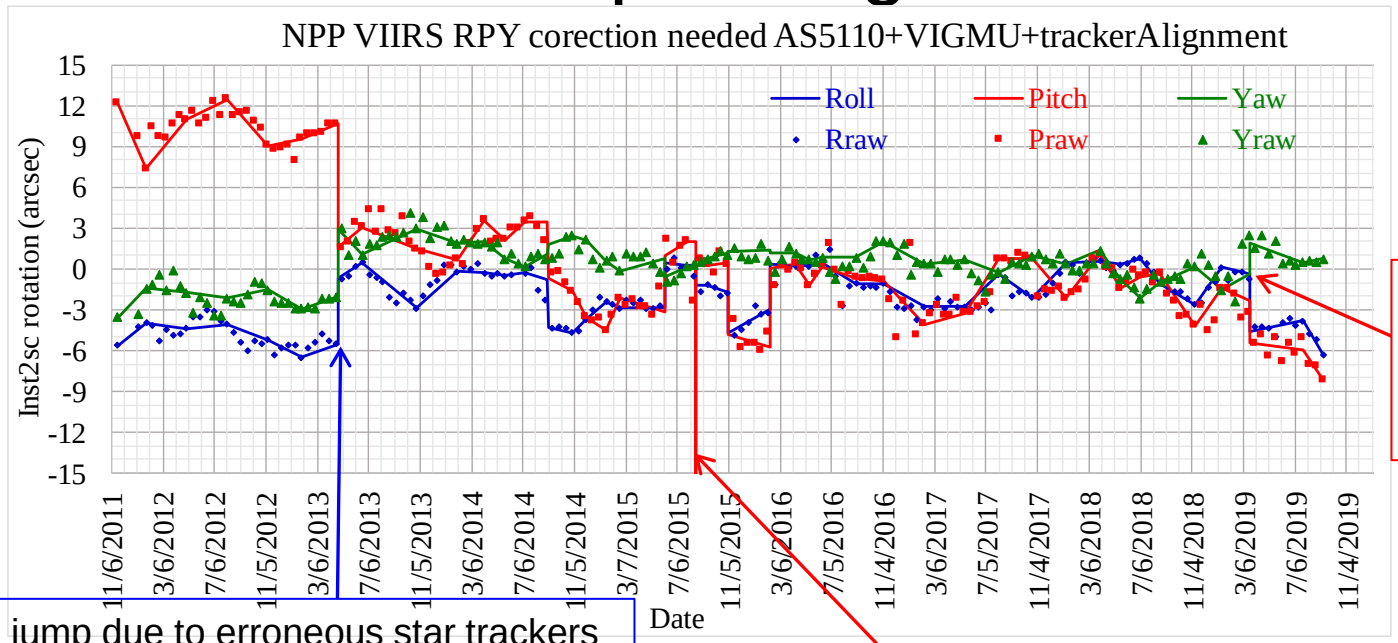
where M = -4 (not +4 as we are currently using), which affects line of sight due to the parts of RTA/HAM motion non-linearity (non-synchronization), which are relatively small

SNPP C1.1 geolocation errors



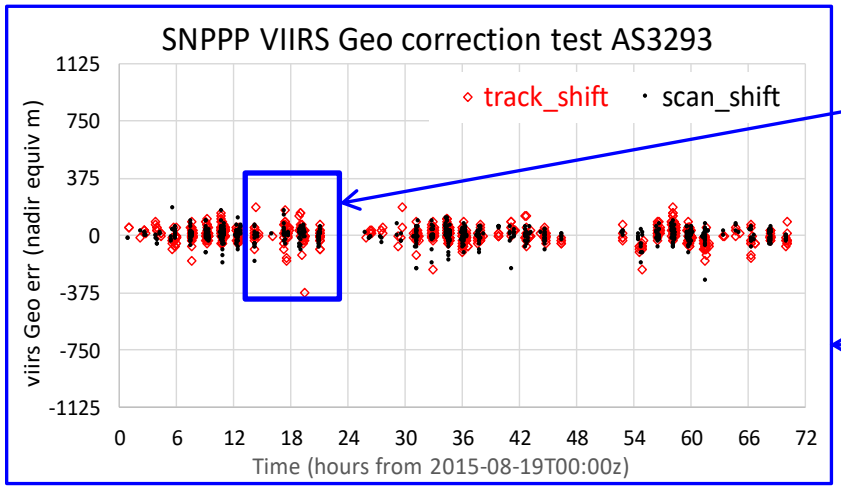
C1.1 RMSE Track: 59 m Scan: 52 m, nadir equivalent

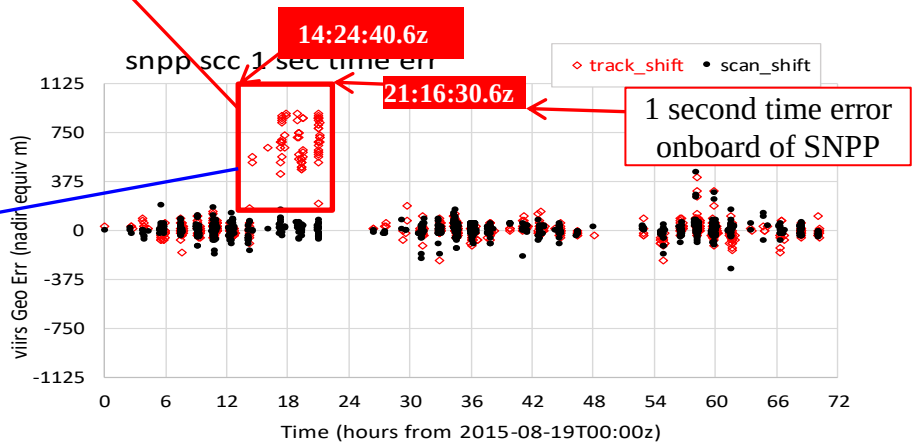
SNPP VIIRS pointing error/correction



Strange jump after Star Tracker-2 reset

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



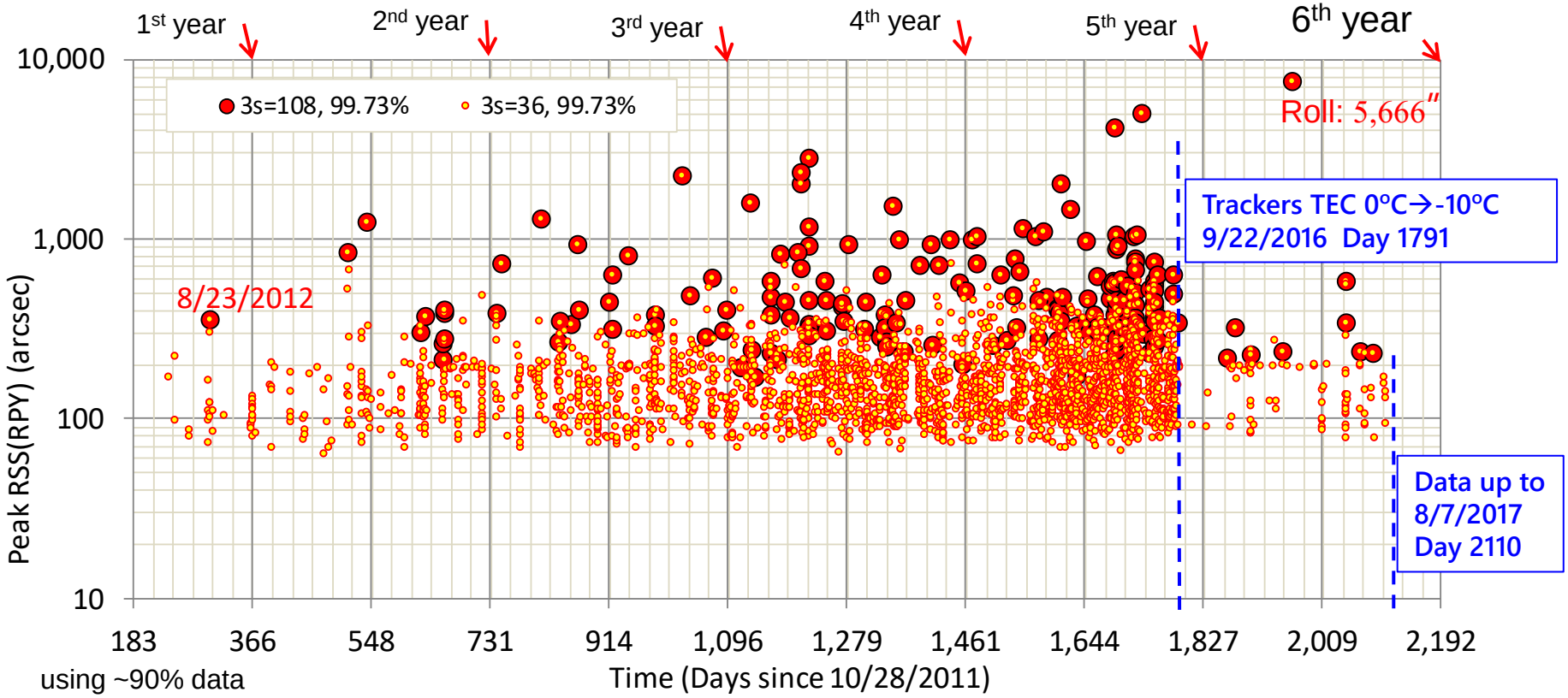


1 second time error onboard of SNPP

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

SNPP SC attitude performance

- - Spec outage and trend

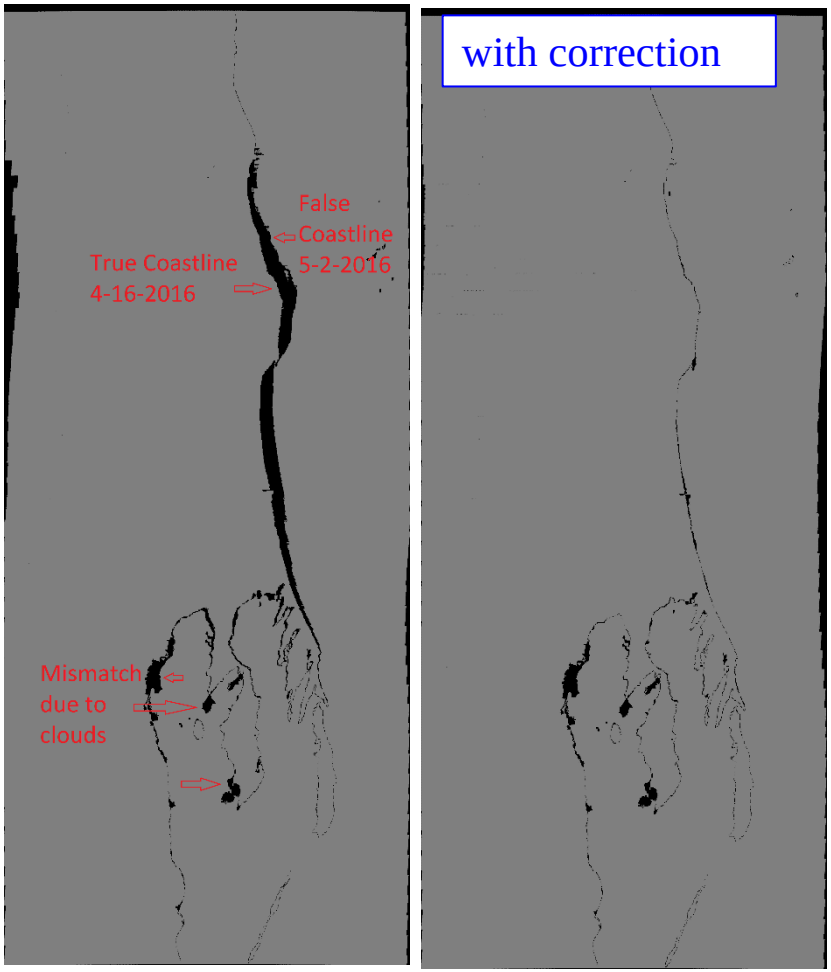


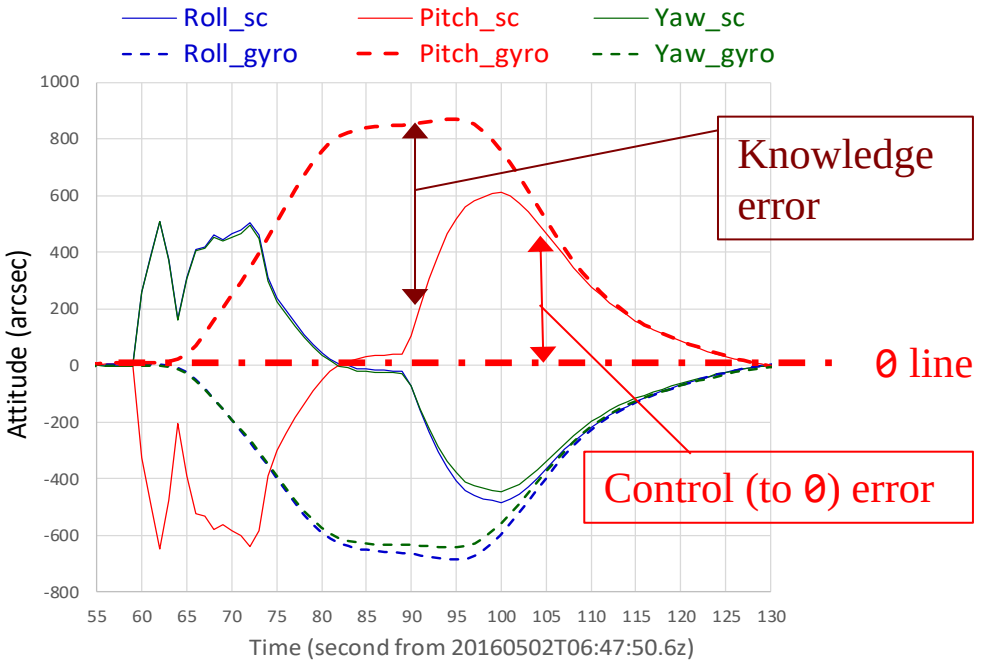
- Large circles for control spec outage; Small dots hint knowledge spec outage
- Star tracker cooling improved SNPP attitude performance
- We are seeking for further improvements[1]
- SW with Kalman filter to refine the attitude for NASA SIPSs will be implemented soon
- J1 is performing better but we are monitoring

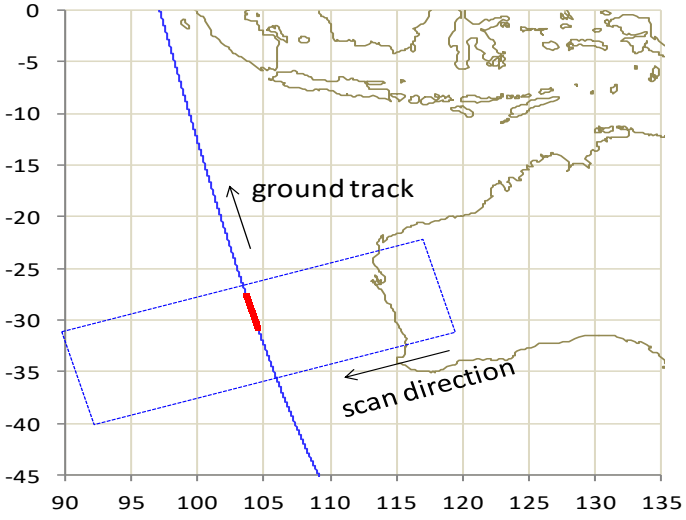
1. My eRooms > S-NPP Flight Operations and Support > FARB > All Discussion Topics--Artifacts and Minutes > DR 6348--SNPP STAR TRACKER DEGRADATIONS OVER MISSION LIFE: ATTITUDE EXCURSIONS AND LUNAR INTRUSIONS > SNPP ADCS and Geolocation Report

Attitude control & knowledge errors

2016-05-02 06:48:50 – 06:50:40z



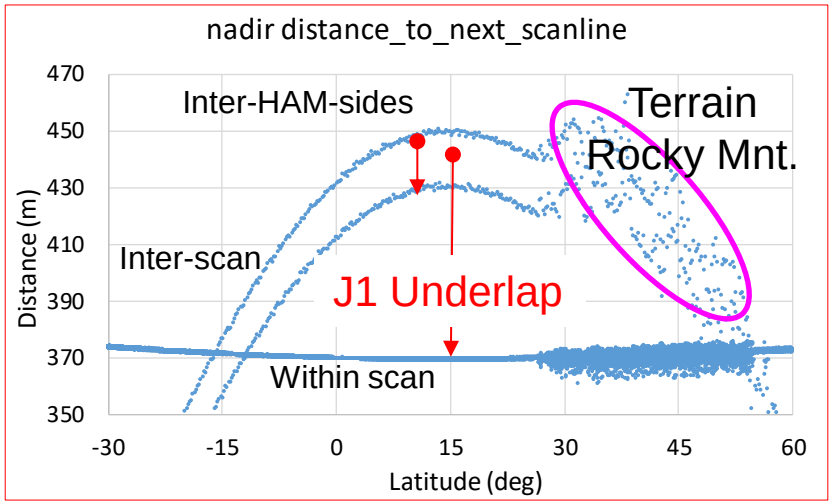


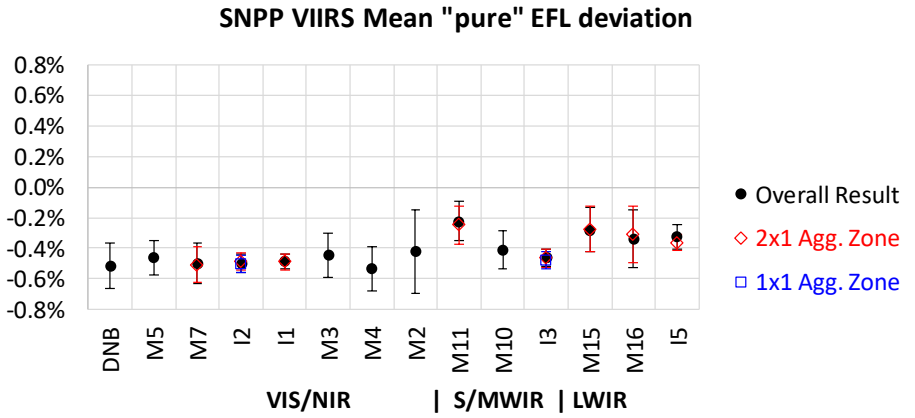


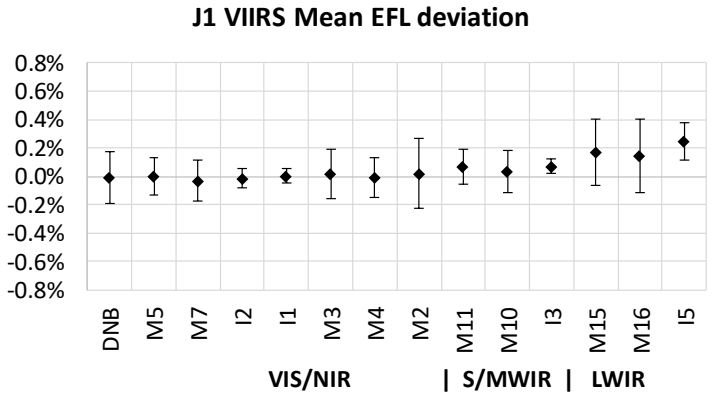
- Western Australian coast (south up)
- Difference in “land”/”Water” masks from data 16 days earlier

Scan-to-scan underlaps & EFL

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







- 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

Measured[1] EFL for SNPP will be implemented in C2 soon

1. J.C. Tilton, R. E. Wolfe, G. Lin, and J. J. Dellomo, "On-Orbit Measurement of the Effective Focal Length and Band-to-Band Registration of Satellite-Borne Whiskbroom Imaging Sensors." *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, (accepted 10/19/2019), doi:10.1109/JSTARS.2019.2949677.

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

Platform	EFL (mm)	Scan rate (rad/s)	Scan period (s)	EV scan angle (deg)	EV ground distance (km)
SNPP, JPSS-1, JPSS-2	1141	3.517	1.7867	+/- 56.04	+/- 1510
JPSS-3, JPSS-4	1131.8	3.545	1.7724	+/- 56.50	+/- 1550

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.

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 $A = \frac{1}{N}\sum_{k=1}^{M}(N_k A_k)$, $N = \sum_{k=1}^{M} N_k$

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

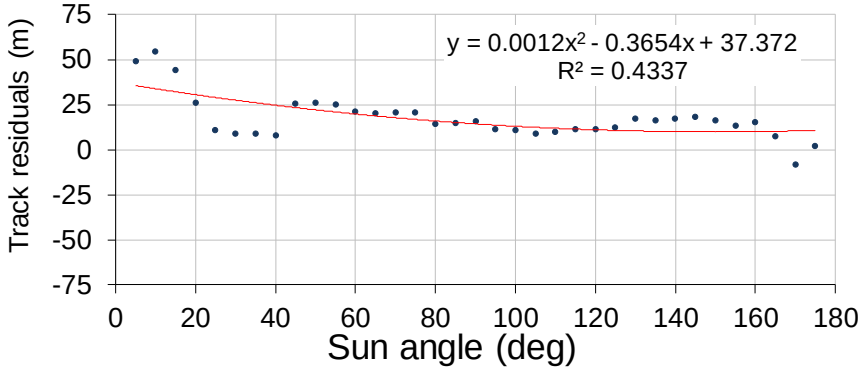
➔STAND: **S**hort **T**erm **A**nomalous **N**avigation **D**etection – credit to Bin Tan on GOES-R INR assessment

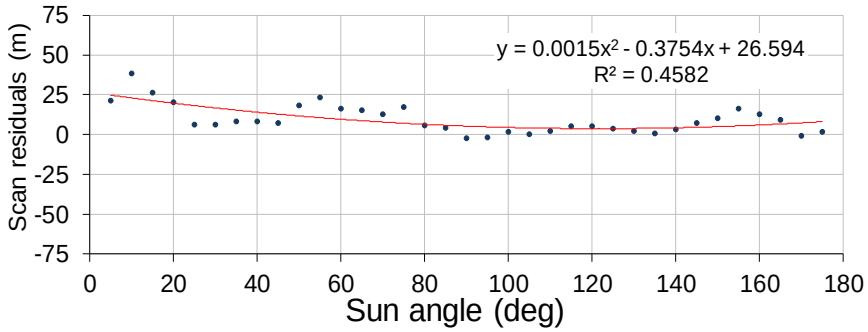
Thank you !

Backup Slides

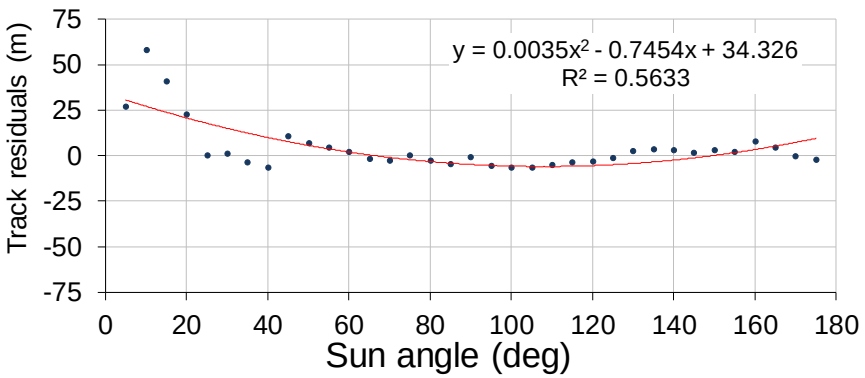
Sun angle dependence

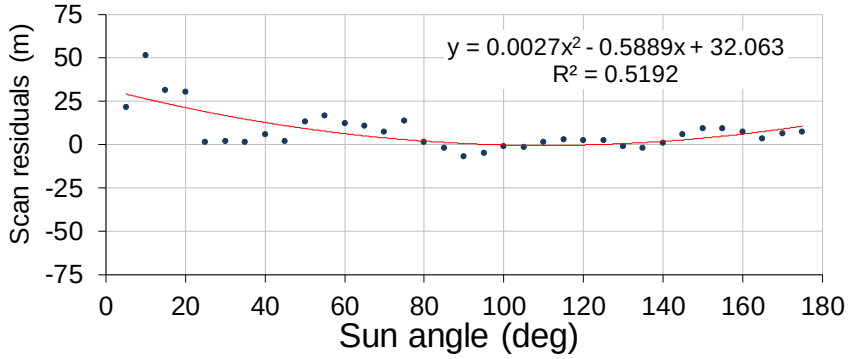
SNPP





J1/N20





Correction is in-work