(SNPP + J1/N20 + J2 + J3)

VIIRS Geometric Calibration Status

NASA VIIRS Characterization Support Team (VCST)
Geometric Calibration Group

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

NASA MODIS/VIIRS Calibration Workshop
Virtual
25 February 2021

Outline

- Changes since STM in November 2019
- SNPP VIIRS Geolocation Performance and Trends in C1.1, C2
- J1/N20 VIIRS Geolocation Performance and Trends in C2, C2.1
- Expectations for J2, J3 VIIRS
- Plan in future work
- Conclusions

Changes since last STM

1) SNPP C2 and J1/N20 C2.1 use refreshed ground control point (GCP) chip library from Landsat-8 images, ~ 4X daily matches, to measure geolocation errors
2) 16-day geolocation errors are stratified in the morning quarter orbits (mostly south hemisphere) and the afternoon quarter orbit (mostly north hemisphere) by sun angle with respect to satellite trajectories
3) J3 VIIRS thermal vacuum tests are mostly done
    1) EFL is shortened and scan rate increases to avoid scan-to-scan underlaps
    2) track BBR displays offsets similar to J1 VIIRS at ~20% I-band pixels or ~10% M-band pixels between VisNIR bands and SWMWIR/LWIR bands
4) Chip library for band I3 is collected and tested for measuring on-orbit SNPP and J1/N20 I3 geolocation errors

VIIRS Geolocation Performance

Residuals	SNPP VIIRS C1.1	SNPP VIIRS C2	J1/N20 VIIRS C2	J1/N20 VIIRS C2.1
Track mean	**14 m**	**1m**	**-1 m**	**-5 m**
Scan mean	**5 m**	**7 m**	**1 m**	**7 m**
Track RMSE	**59 m**	**58 m**	**55 m**	**57 m**
Scan RMSE	**52 m**	**48 m**	**49 m**	**46 m**
Data-days	**3288 (9.0 yrs)**	**1247 (3.4 yrs)**	**1101 (3.0 yrs)**	**573 (1.6 yrs)**
Missing days	**1**	**1**	**3**	
Daily matched GCPs w/ I1	**201**	**838**	**193**	**847**

New Chip Library

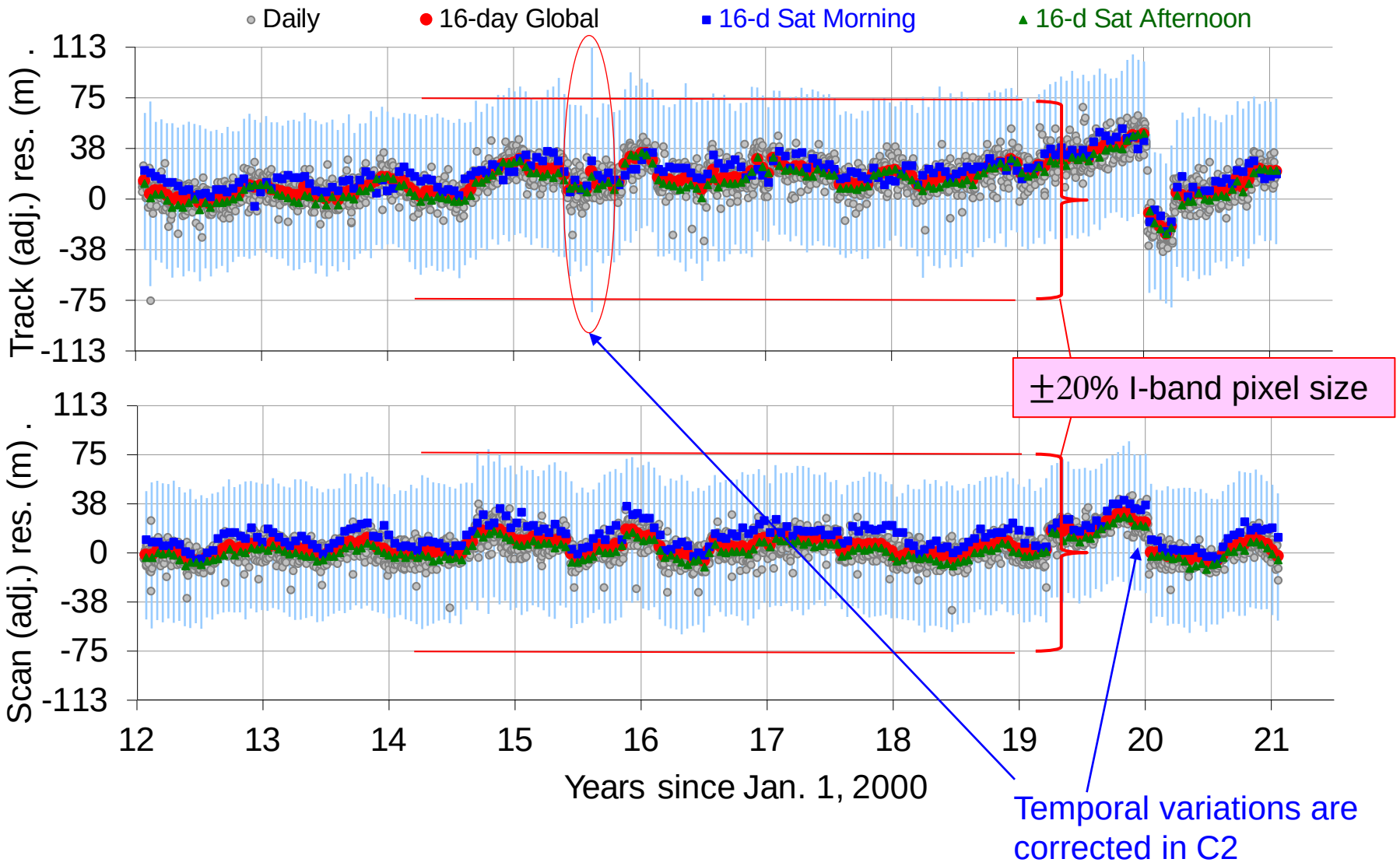
- **Nadir equivalent** accuracy (RMSE – Root Mean Square Error)
  - Meet Spec: 125 m (1σ); **within 20% I1 HSI (375 m) = 75 m @ nadir for VIIRS**
  - Band-to-band mis-registration to other bands adds bias to RMSE to : $RMSE = \sqrt{\sigma^2 + \mu^2}$
- Notes

  SNPP C2 uses Kalman filter for attitude improvement, VIGMU to remove oscillations in scan direction, and time-dependent instrument-to-spacecraft interface angles to remove temperal pointing variations

  New chip library is used in SNPP C2 and J1/N20 C2.1 re-processing

Re-processing of SNPP C2 and J1 C2.1 L1 data is mostly done

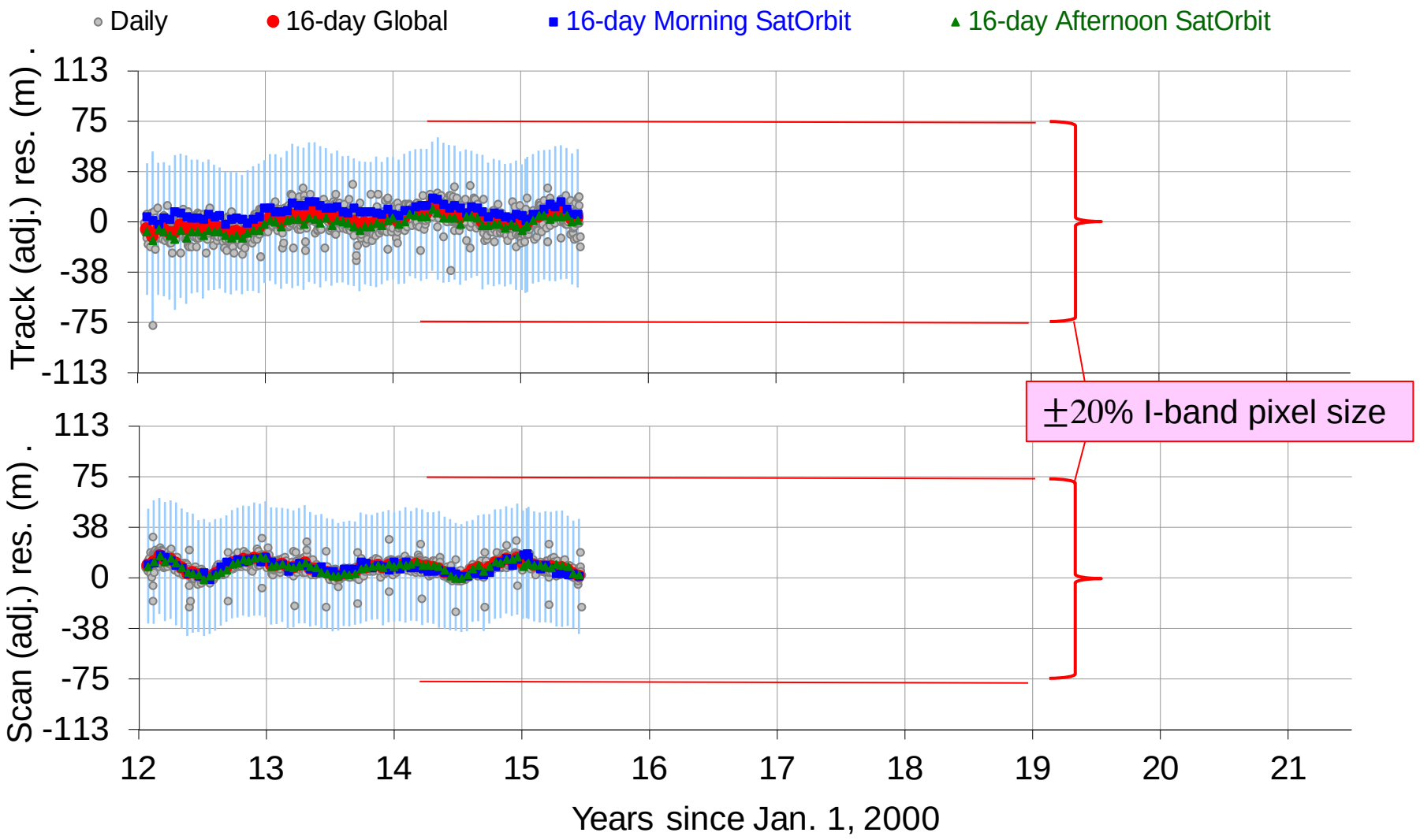
SNPP C1.1 geolocation errors



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

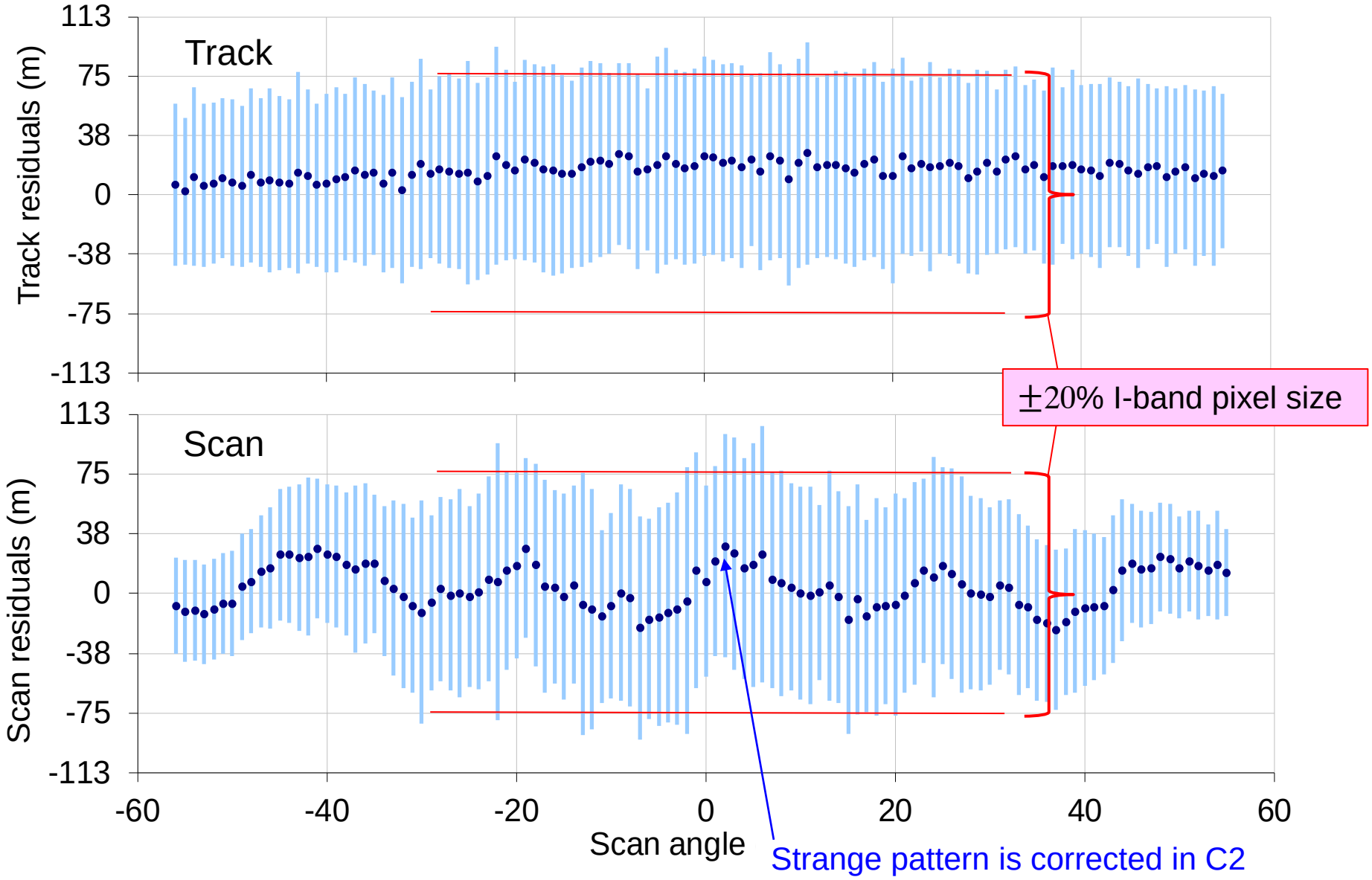
SNPP C2 geolocation errors

New Chip Library



C2 RMSE Track: 58 m Scan: 48 m, nadir equivalent

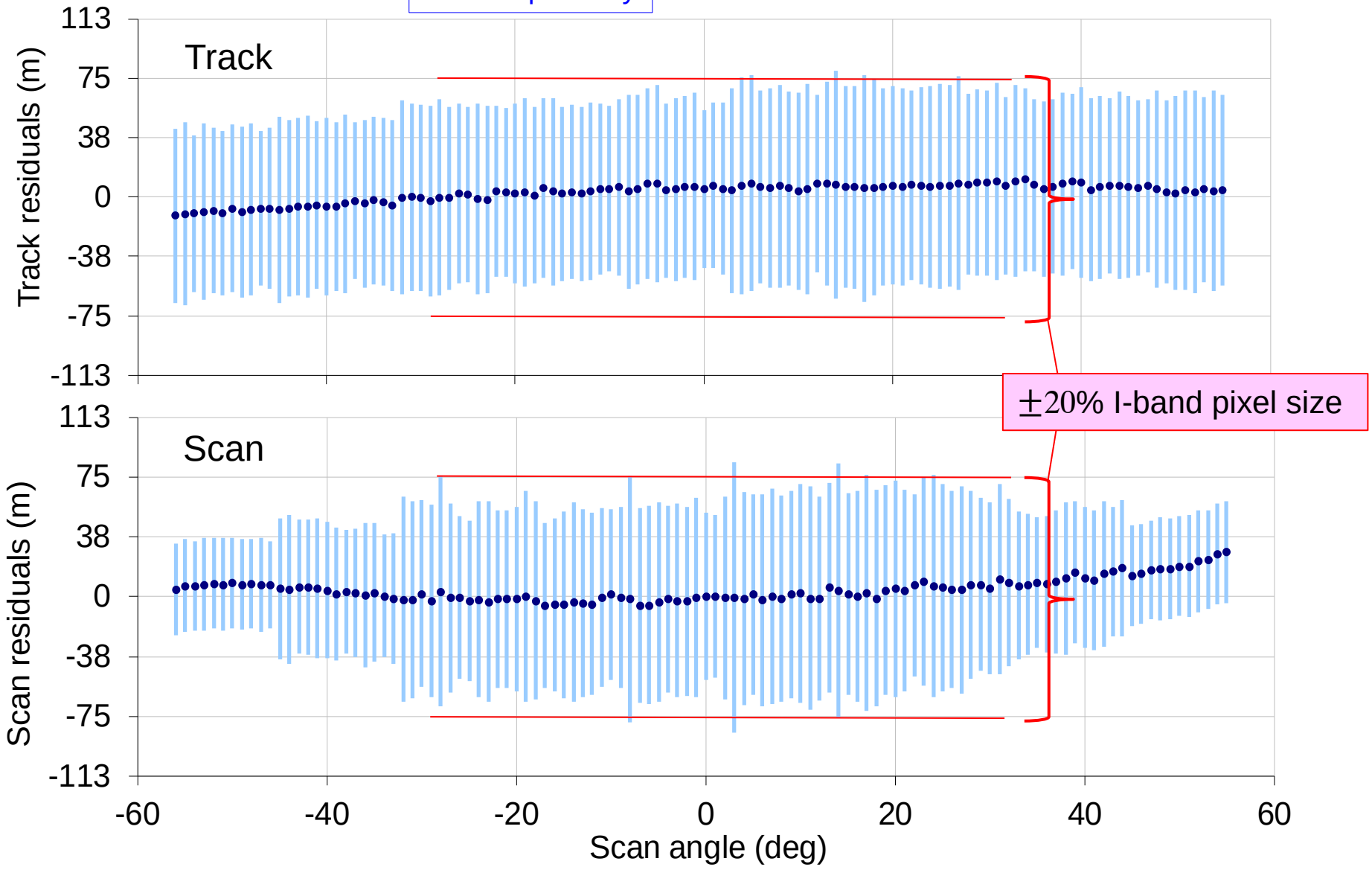
SNPP C1.1 Scan Angle Residuals



Lin et al., 25 Feb 2021

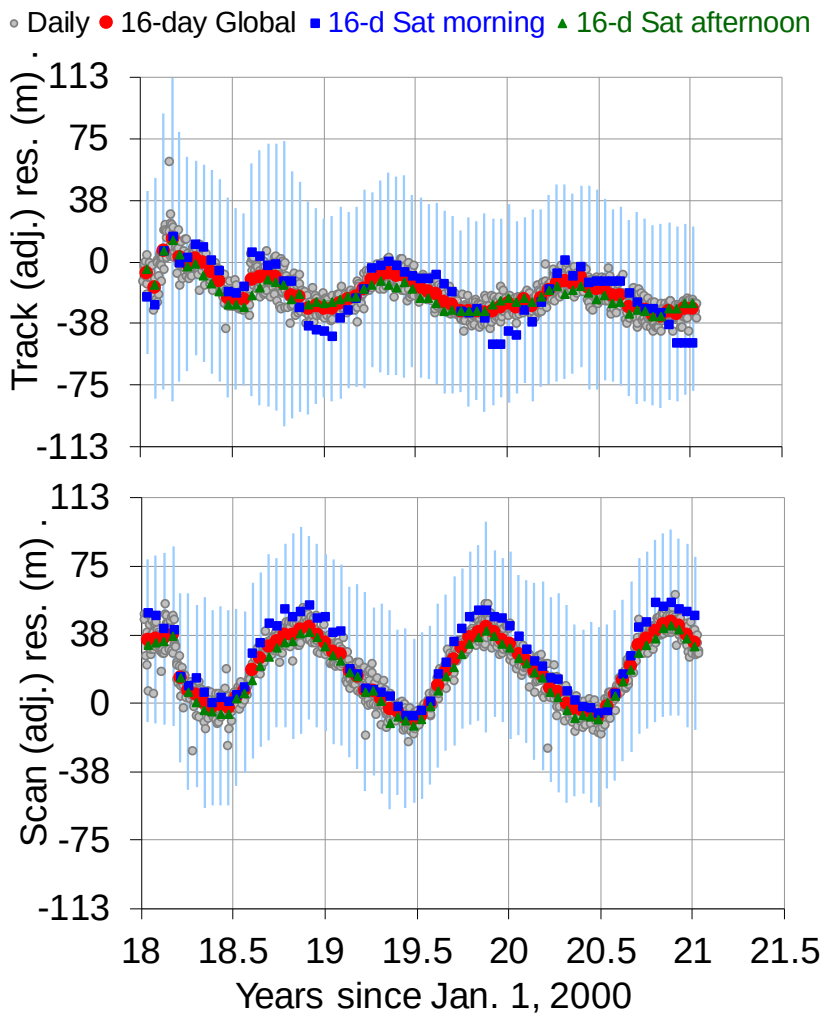
SNPP C2 Scan Angle Residuals

New Chip Library

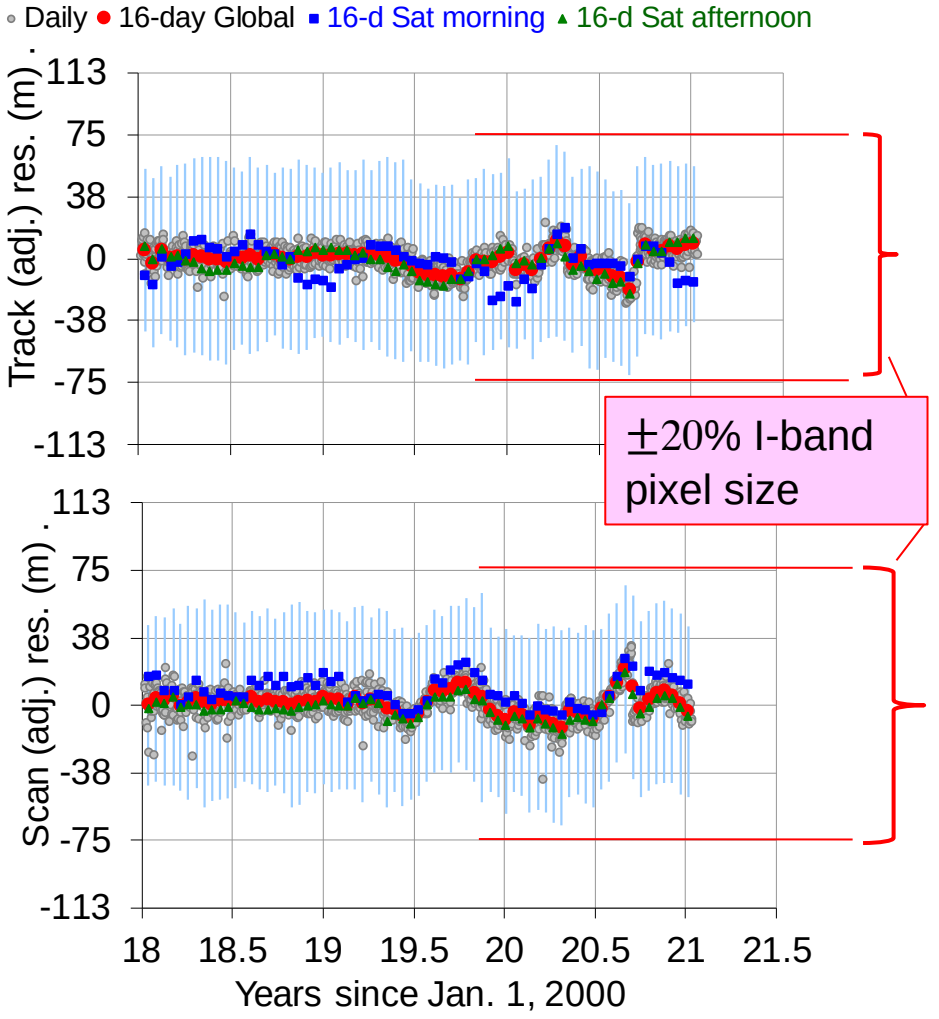


J1/N20 C2 geolocation errors

Uncorrected



Corrected for temporal variation

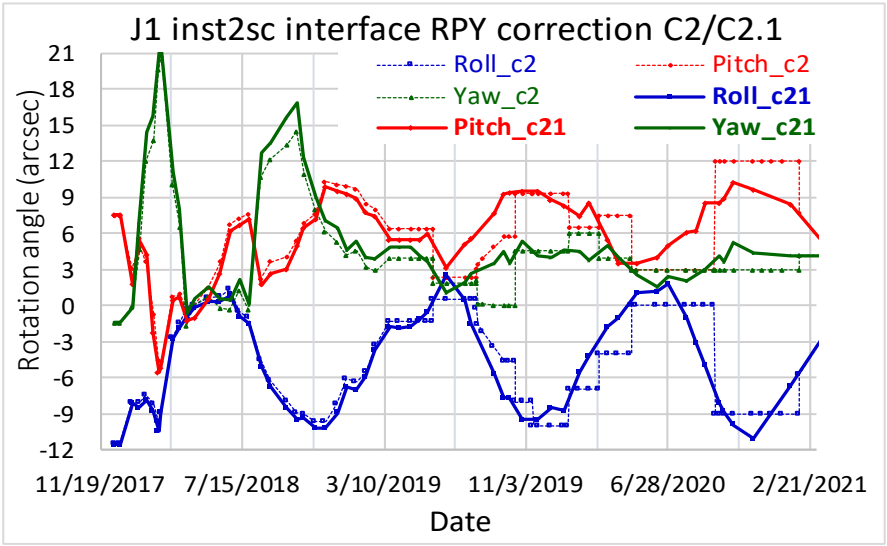


C2 RMSE Track: 55 m Scan: 49 m, nadir equivalent

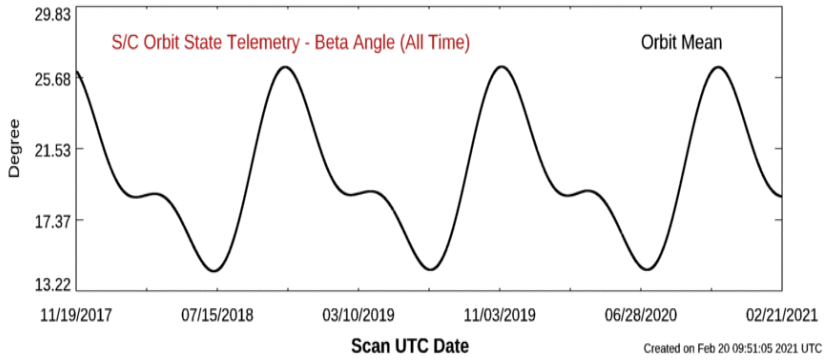
J1/N20 C2.1 geolocation errors

New Chip Library

Pointing correction

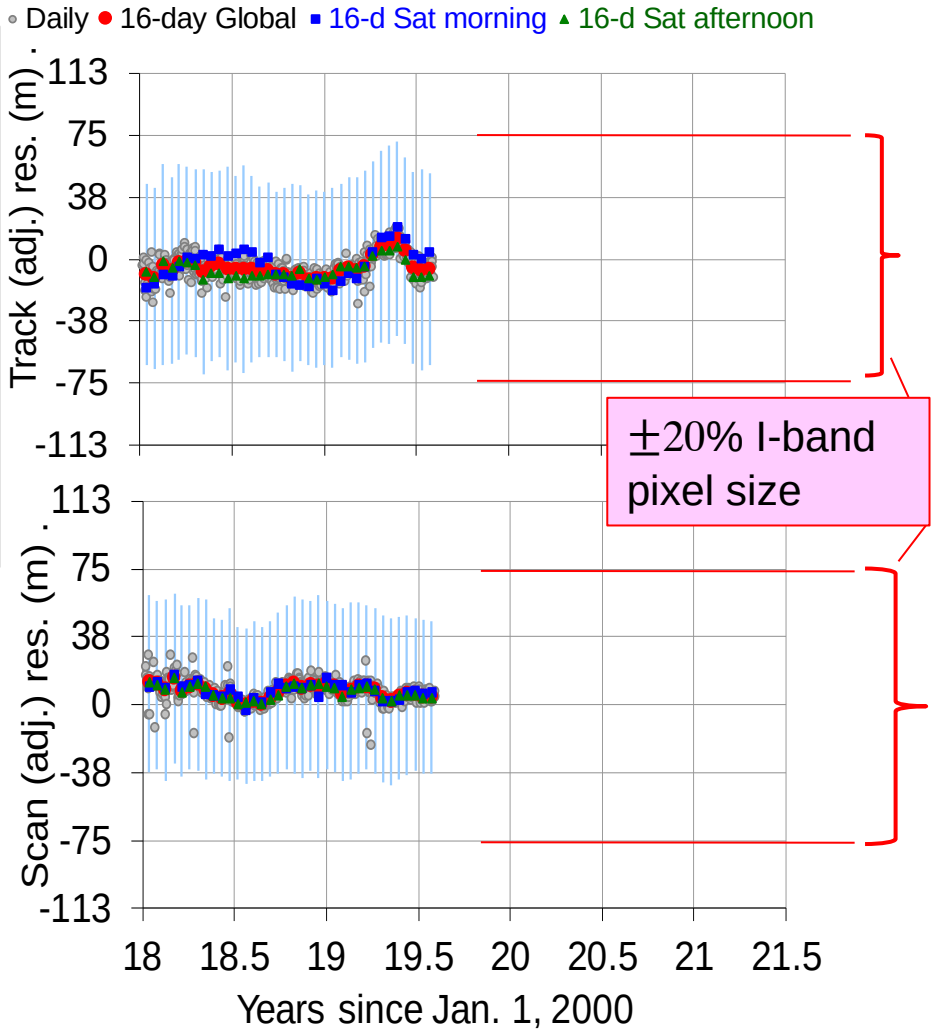


Pointing variation is likely related to beta angle



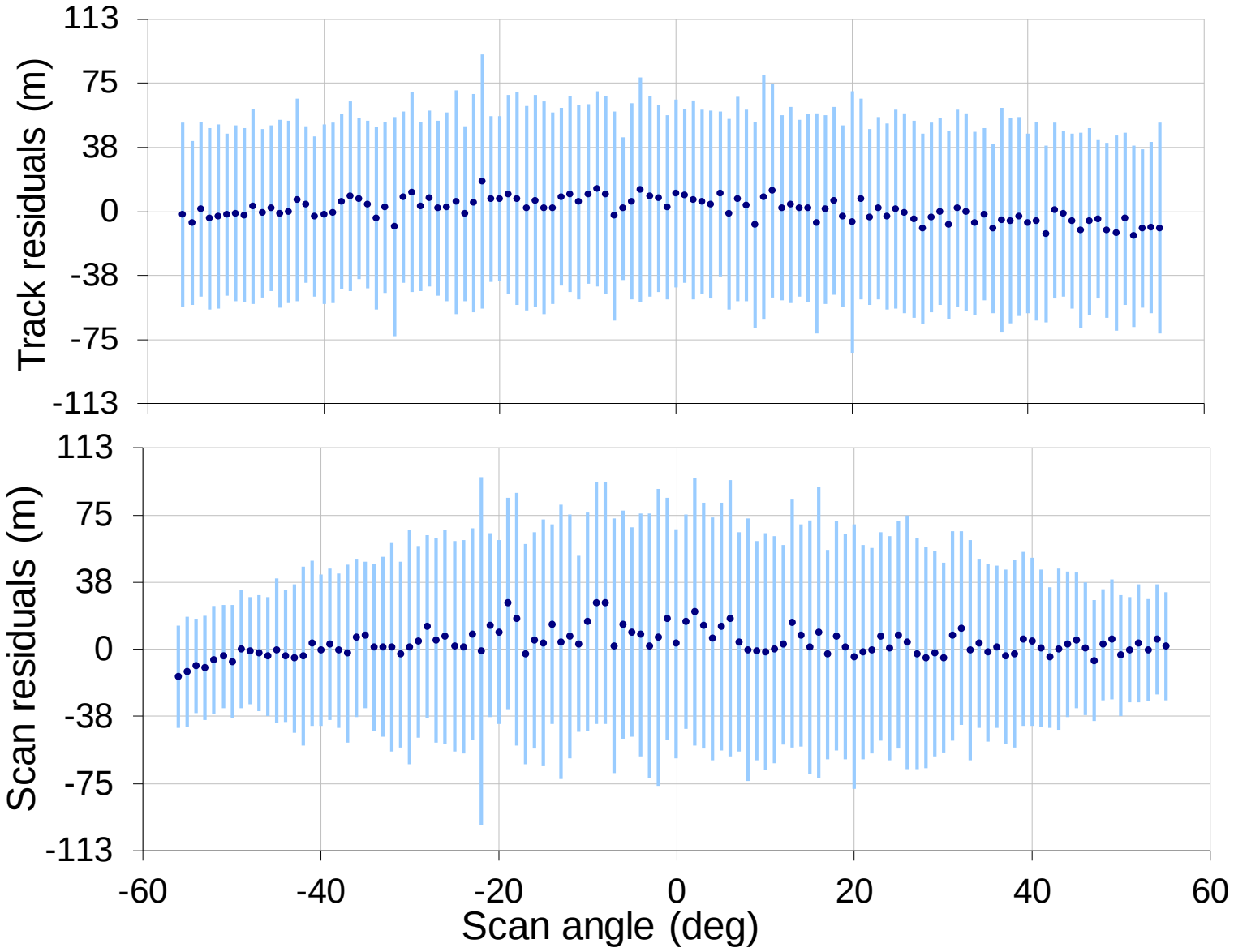
Courtesy: https://www.star.nesdis.noaa.gov/icvs/status_N20_sc.php

Corrected for temporal variation



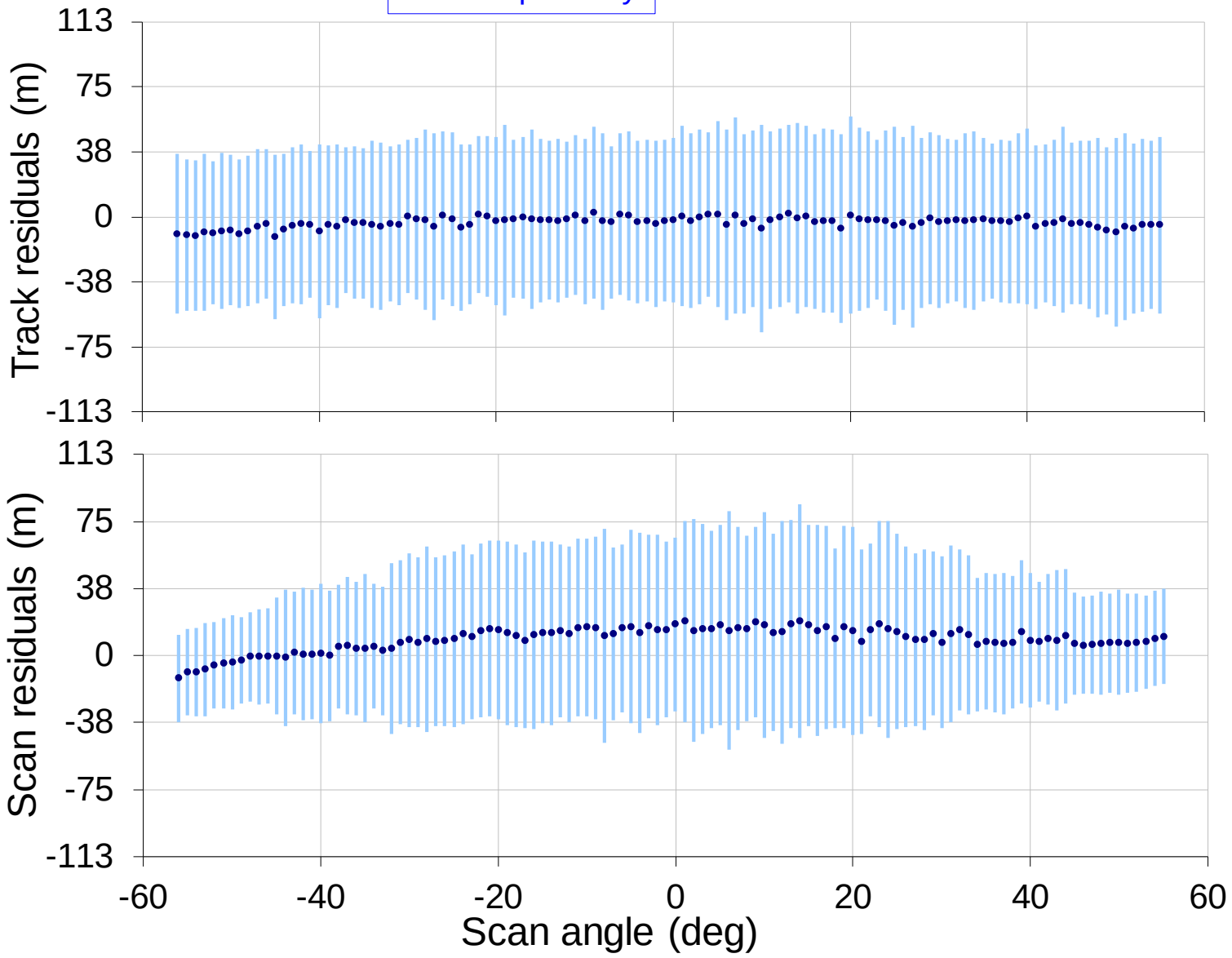
C2.1 RMSE Track: 58 m Scan: 46 m, nadir equivalent

J1/N20 C2 Scan Angle Residuals



J1/N20 C2.1 Scan Angle Residuals

New Chip Library



Expectations for J2 VIIRS

- J2 launch planned date – September 2022 (?)
- J2 Geolocation – should be good with on-orbit calibration
- J2 Band-to-band co-registration – good
- J2 LSF/MTF – mostly good except DNB at low light

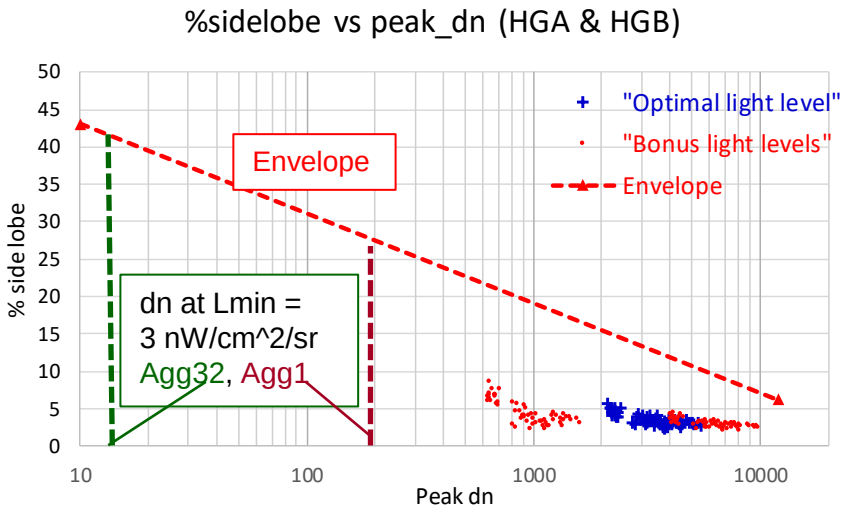
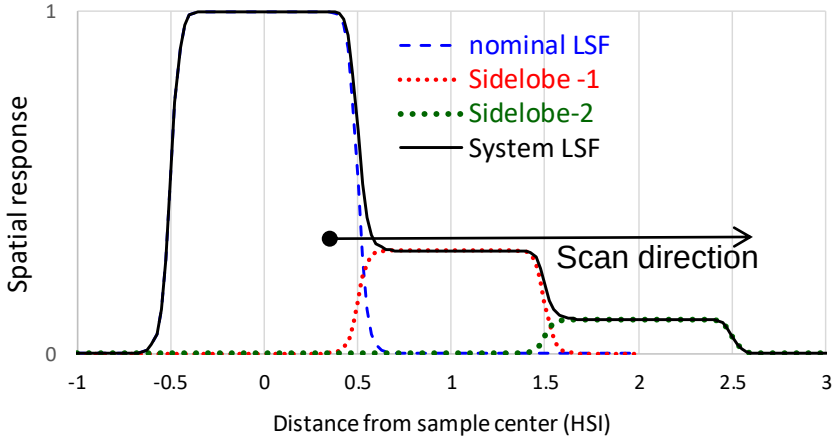


Illustration of Simulated J2 DNB LSF at low light



Incorrect J2 voltage setting causes the charge in the current sample to remain behind in the transfer gate and be deferred into the next sample in the scan direction

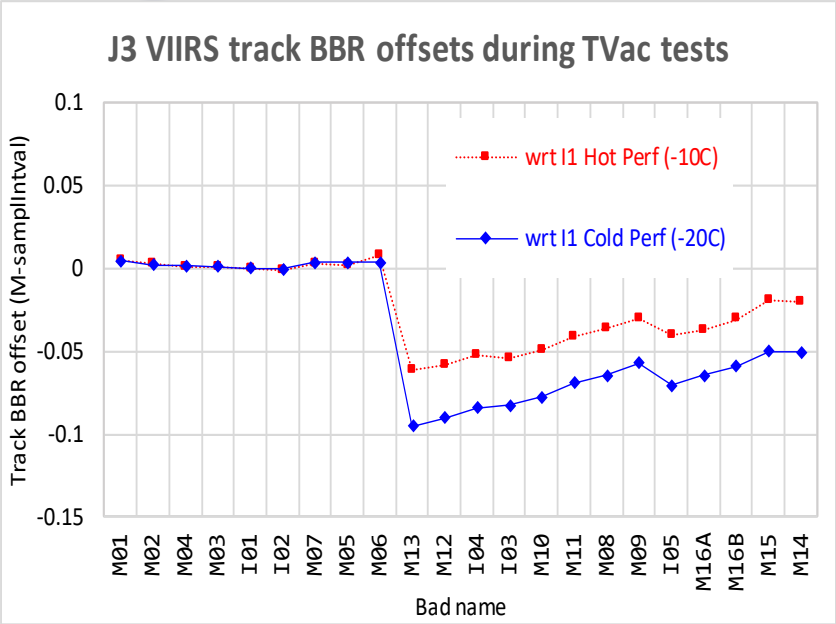
Expectations for J3 VIIRS

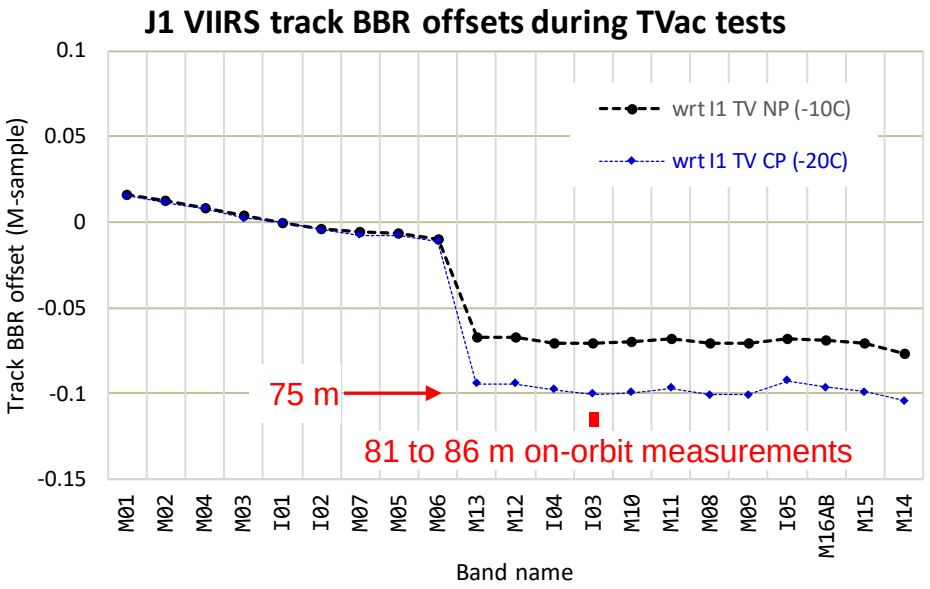
- J3 Geolocation – should be good with on-orbit calibration
- J3 Band-to-band co-registration – offset in track direction (next chart)
- J3 LSF/MTF -- good
- J3 EFL is shortened and scan rate is increased to mitigate scan-to-scan underlaps
  - Swath width increases

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

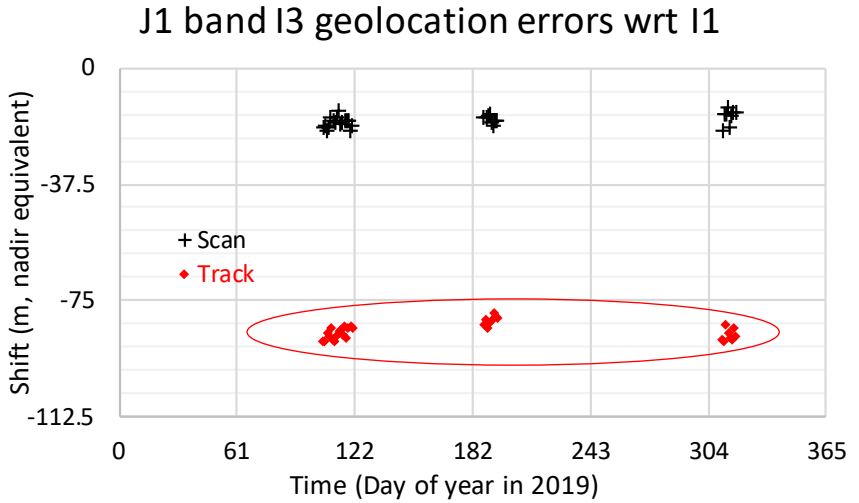
Platform	EFL (mm)	Scan rate (rad/s)	Scan period (s)	EV scan angle (deg)	EV ground distance (km)
SNPP, JPSS-1, JPSS-2	1141	3.517	1.7867	+/- 56.04	+/- 1510
JPSS-3, JPSS-4	1131.8	3.545	1.7724	+/- 56.50	+/- 1550

J3, J1/N20 track BBR offsets





- Will measure bands I1, I3 geolocation errors on-orbit
- Will try to measure geolocation errors in other bands



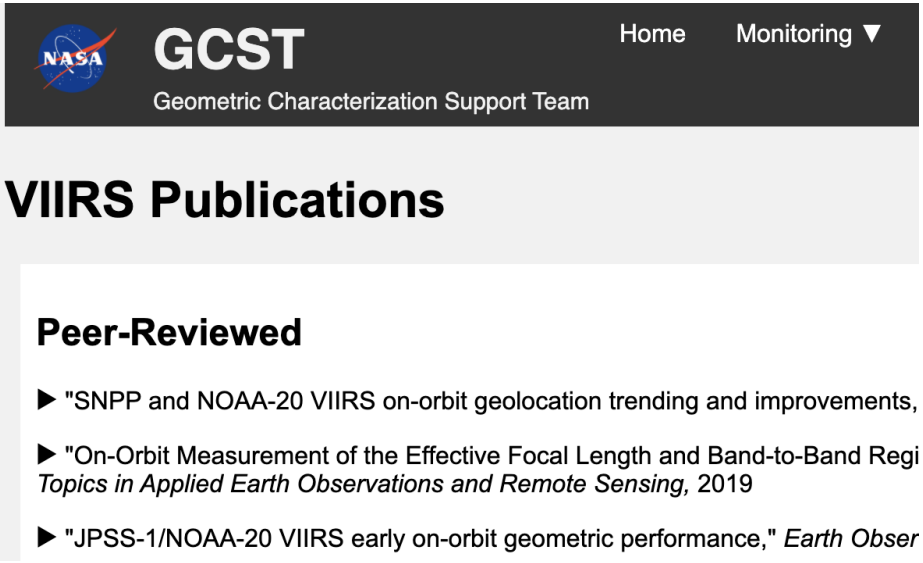
For more band pairs, see: J.C. Tilton, R. E. Wolfe, G. Lin, and J. J. Dellomo, "On-Orbit Measurement of the Effective Focal Length and Band-to-Band Registration of Satellite-Borne Whiskbroom Imaging Sensors." *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, VOL. 12, NO. 11, November 2019, pp4622-4633, DOI: 10.1109/JSTARS.2019.2949677.

Future work

1) Routine monitor and LUTs update as needed
2) Replace ephemeris in SC diary with GPS data
3) Update DEM from 1 km to 500m resolution
4) Create ground control point chip library in multi-spectral bands and implement in geolocation monitoring system (Landsat-8 band B6 chips available now for VIIRS band I3 geolocation error detection)
5) Create GCST (Geometric Characterization Support Team) website
6) Update LWM (year by year)
7) Automate GEO LUT updates

Anything else?

Any change in priority order?



Conclusions

- SNPP VIIRS geolocation performance is good
  - Mean errors for I- & M-bands are ~ 10 m and uncertainties are ~ 60 m at nadir, statistically.
  - C2 perform better after implementing: 1) Kalman Filter for attitude; 2) VIGMU (VIIRS instrument geometric model update); 3) temporal pointing correction.
- J1/N20 VIIRS geolocation performance is good
  - Bands in the cold focal plane assemblies (FPAs) have relatively large track BBR offsets (~ 85 m)
- J2 (→N21) VIIRS geolocation is expected to perform fine
- J3 VIIRS thermal vacuum tests are mostly done
  - Shorter EFL and faster scan rate (and wider swath width) are expected to avoid scan-to-scan underlaps
  - Track BBR offsets are large for I-bands in cold FPAs

Questions?

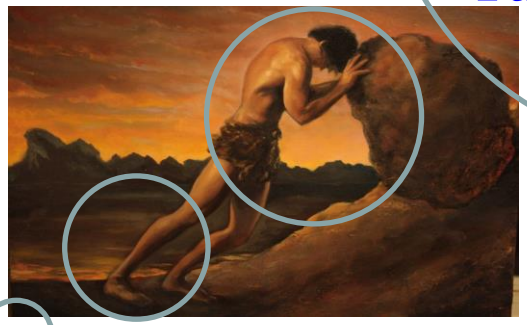
Local arithmetic mean $A_k = \frac{1}{N_k}\sum_{i=1}^{N_k} x_{ki}$

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

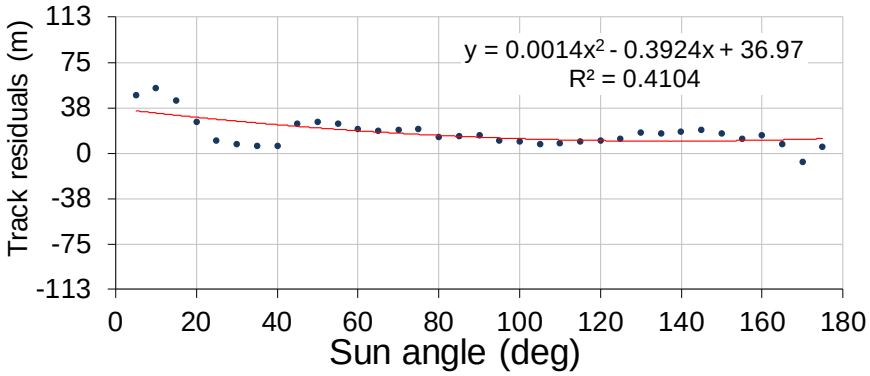


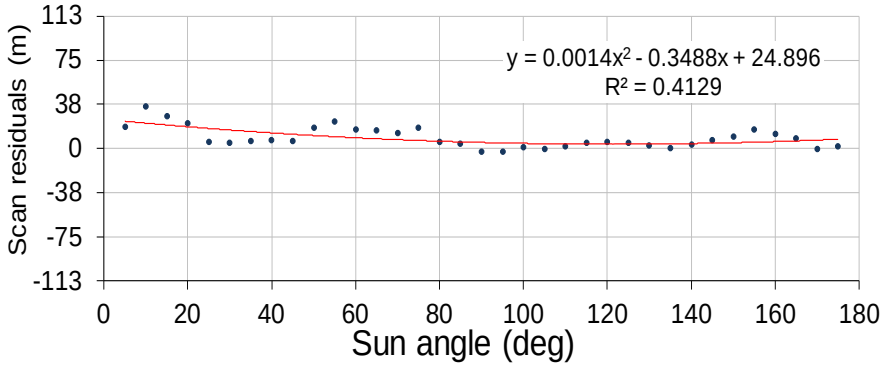
Thank you !

Backup Slides

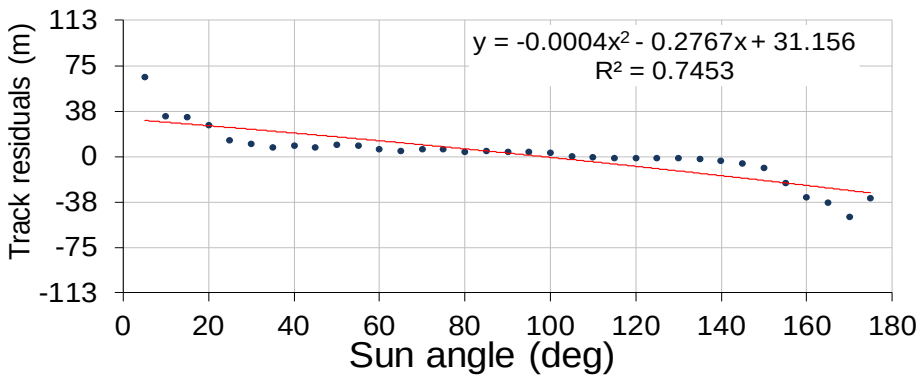
Sun angle dependence

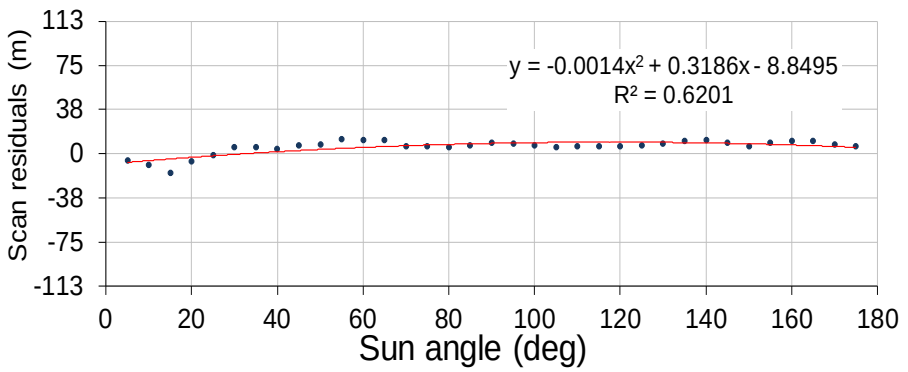
SNPP C1.1



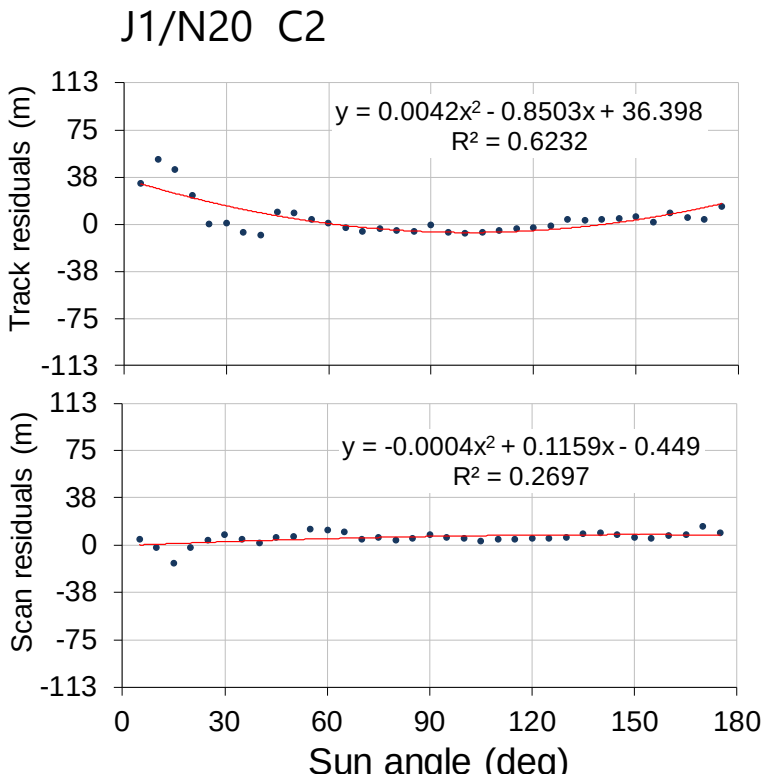


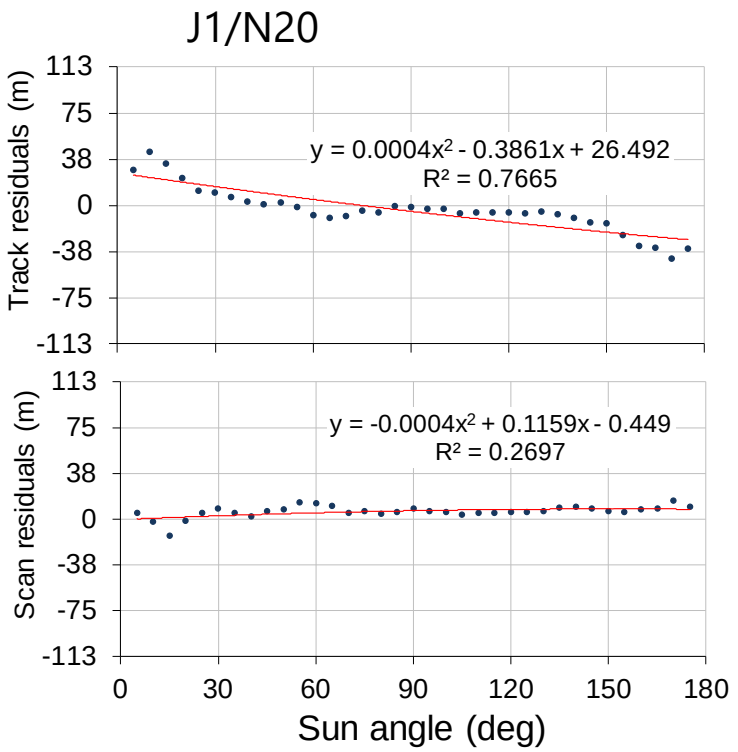
SNPP C2

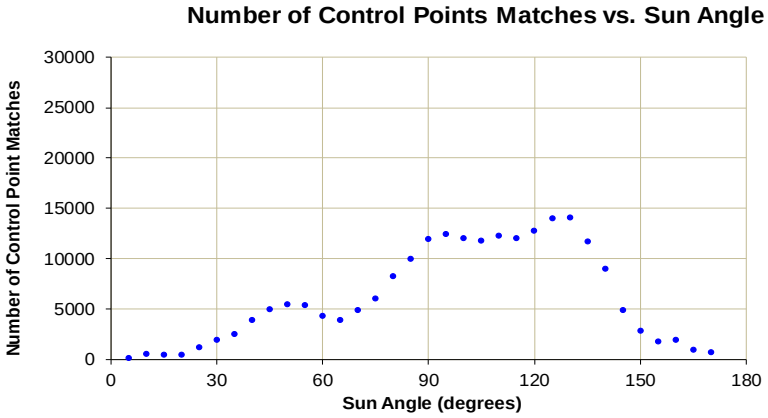


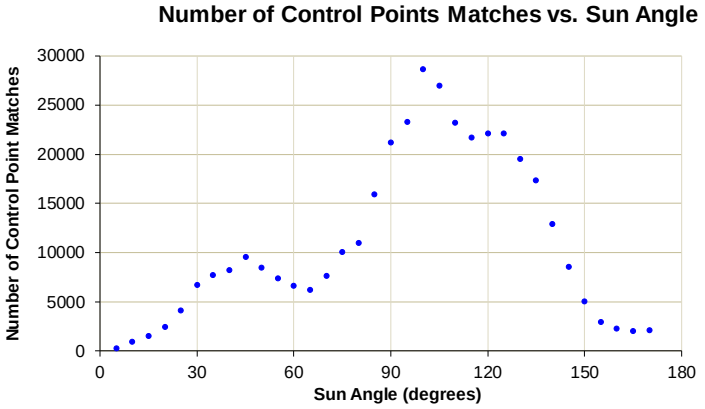


Sun angle dependence







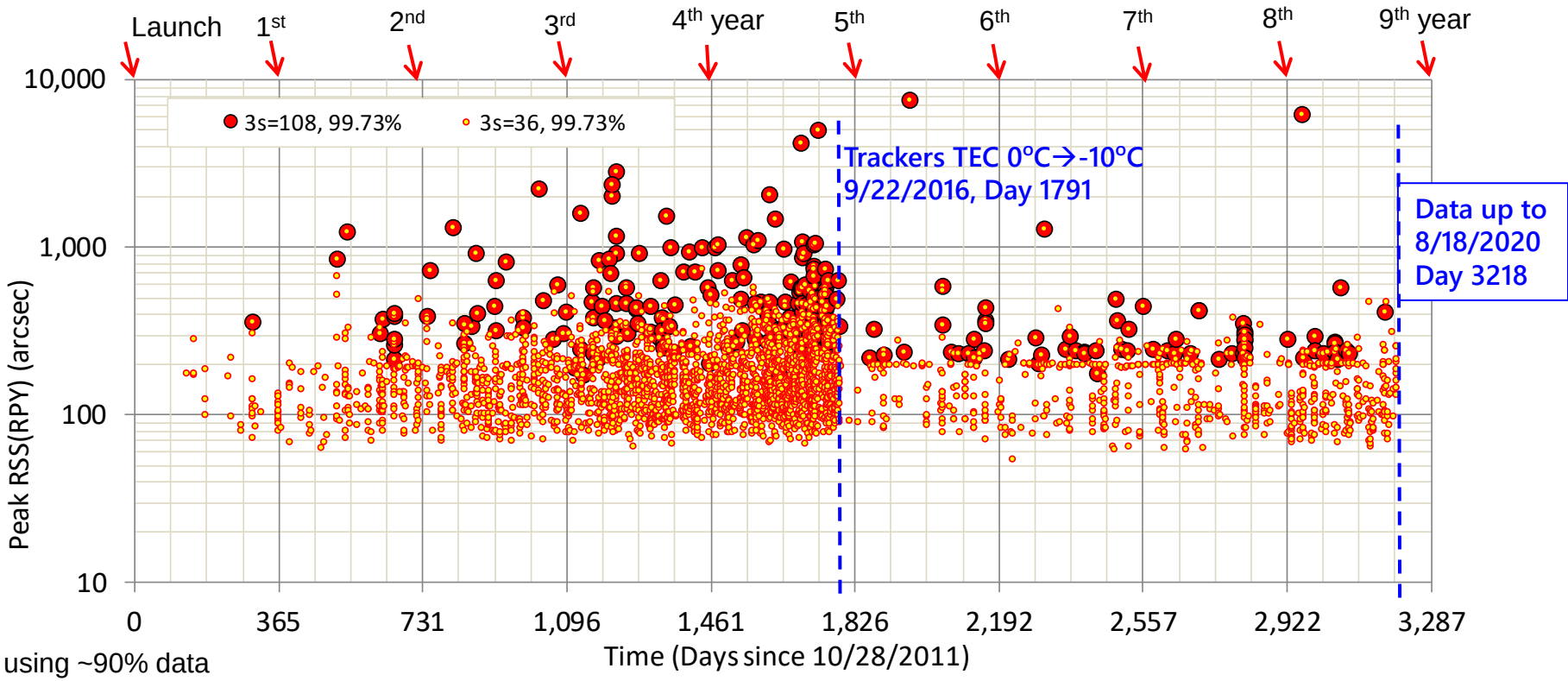


List of updates in C2

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

SNPP SC attitude performance

- - Spec outage and trend

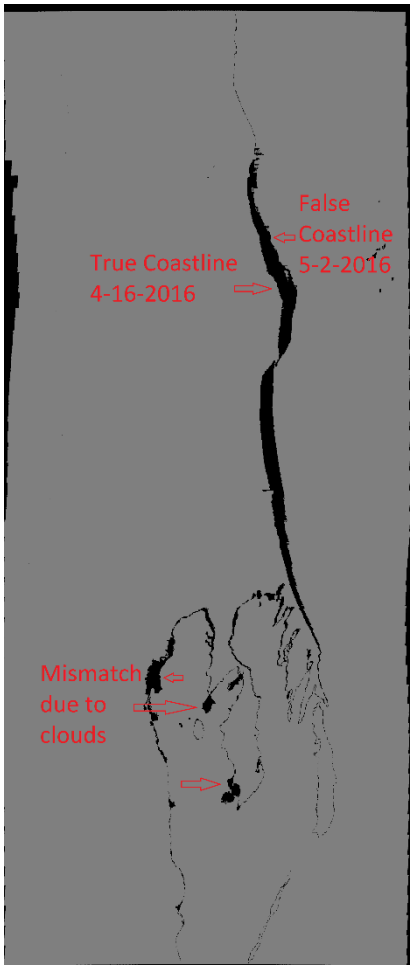


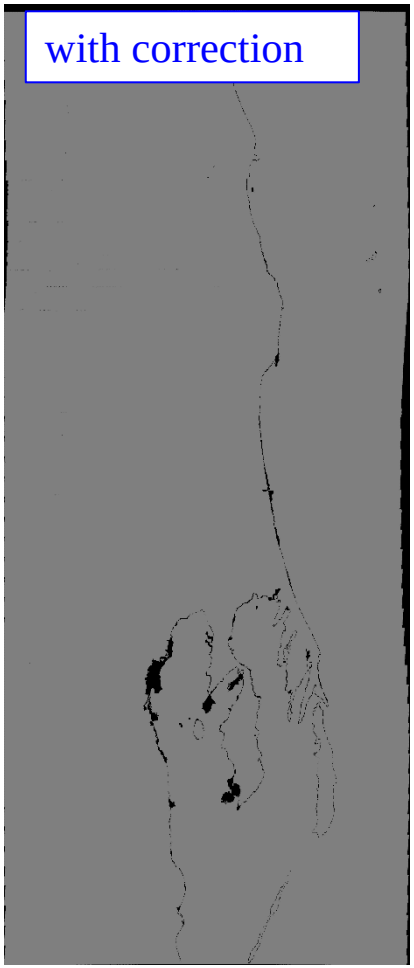
- Large circles for control spec outage; Small dots hint knowledge spec outage
- Star tracker cooling improved SNPP attitude performance
- We are seeking for further improvements[1]
- SW with Kalman filter to refine the attitude for NASA SIPSs will be implemented soon
- J1 is performing better but we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

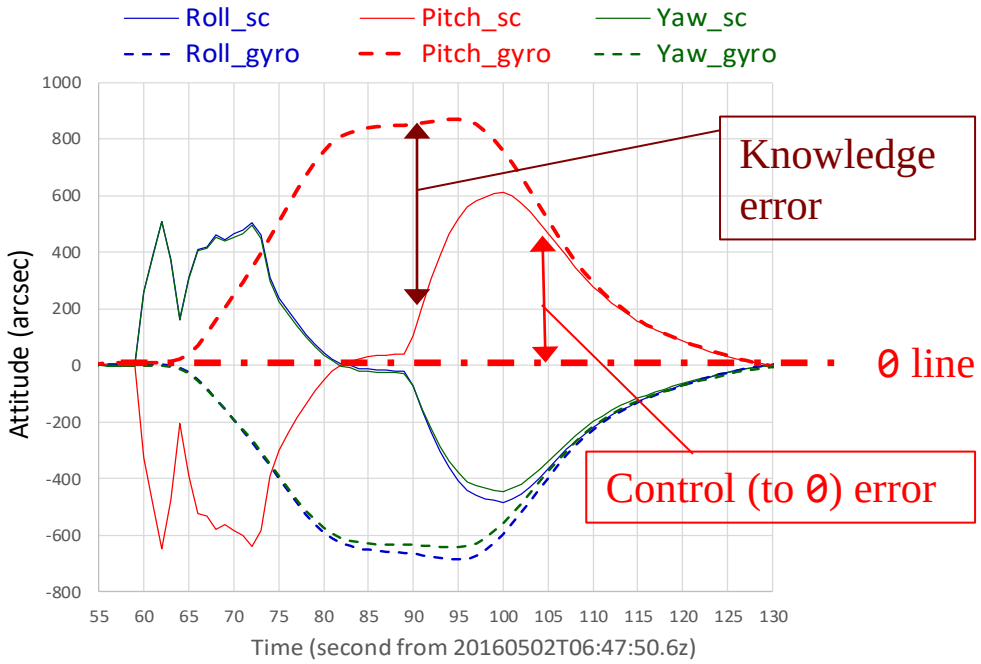
1. My eRooms > S-NPP Flight Operations and Support > FARB > All Discussion Topics--Artifacts and Minutes > DR 6348--SNPP STAR TRACKER DEGRADATIONS OVER MISSION LIFE: ATTITUDE EXCURSIONS AND LUNAR INTRUSIONS > SNPP ADCS and Geolocation Report

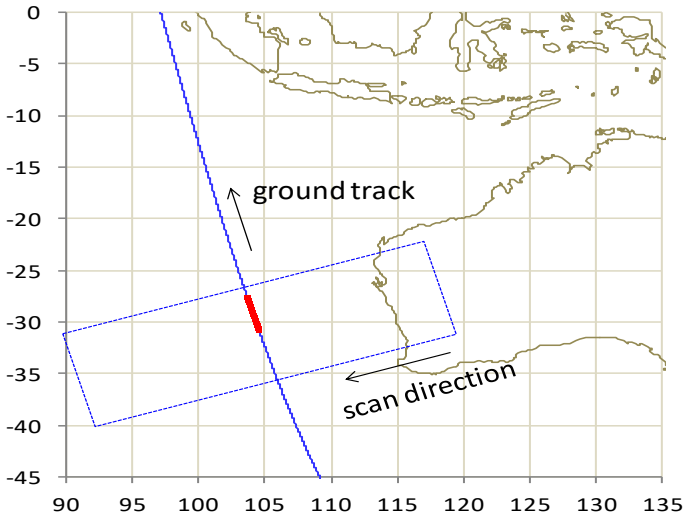
Attitude control & knowledge errors

2016-05-02 06:48:50 – 06:50:40z





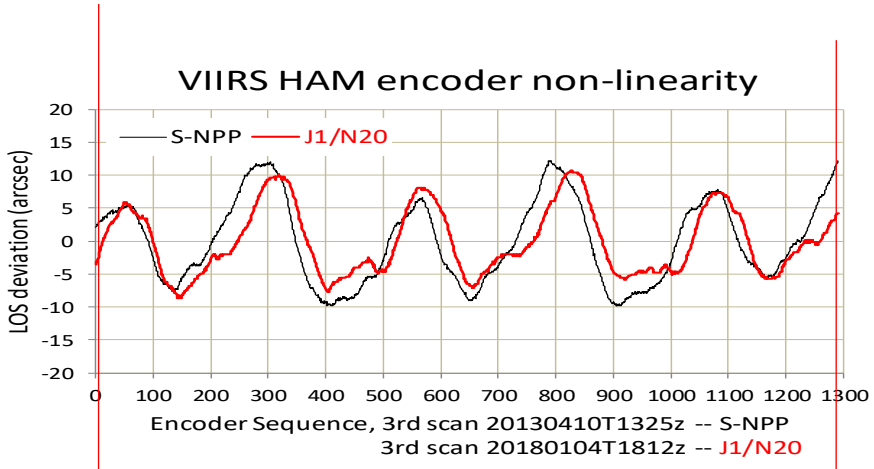


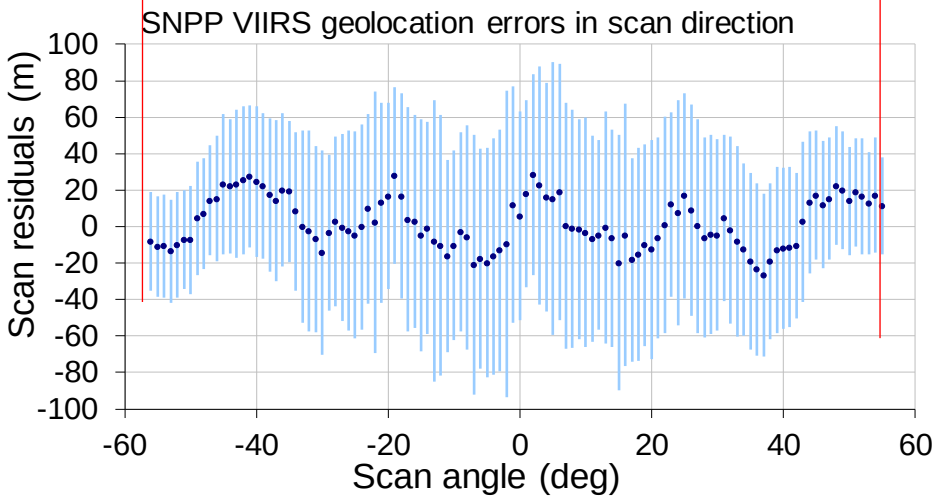


- Western Australian coast (south up)
- Difference in “land”/”Water” masks from data 16 days earlier

Lin et al., 25 Feb 2021

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)

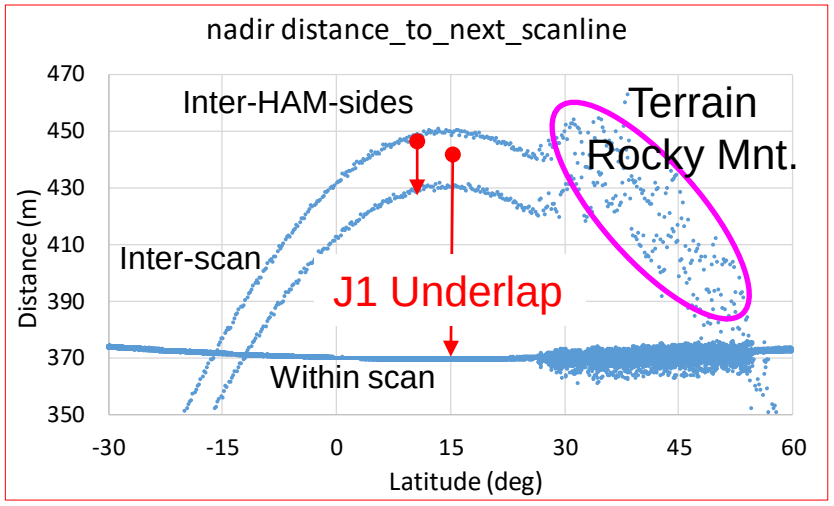
where M = -4 (not +4 as we are currently using), which affects line of sight due to the parts of RTA/HAM motion non-linearity (non-synchronization), which are relatively small

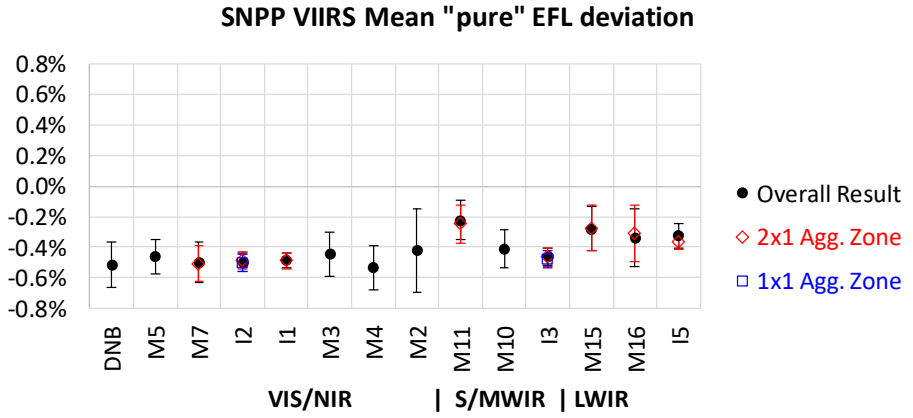
Lin et al., 25 Feb 2021

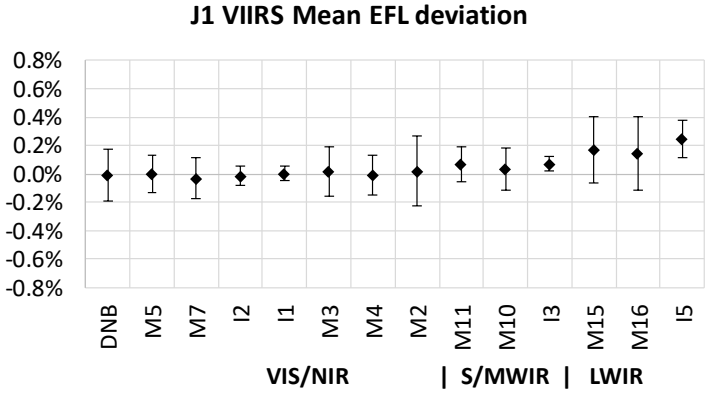
Scan-to-scan underlaps & EFL

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

where F = effective focal length = Mag x aft optic focal length, p = detector "pitch" interval in the track direction, n = # detectors, h = range from satellite to earth terrain surface altitude, T = scan period, *i*=inclination angle (in ECI) < 90 deg for J1, V_{ECI} = spacecraft ground speed in the inertial frame, Vearth0 = speed of earth rotation at equator, Overlap < 0 indicates 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 is implemented in C2

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*, VOL. 12, NO. 11, November 2019, pp4622-4633, DOI: 10.1109/JSTARS.2019.2949677.