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

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Acknowledgements

- Thanks to Carol Davidson & her Land SIPS (formerly Land PEATE) Team for processing control point residuals and testing Geo LUTs updates

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

- Thanks to the NOAA STAR VIIRS SDR Team and many other branches of the JPSS Program

Outline

- SNPP VIIRS Geolocation Performance and Trends
- J1/N20 VIIRS Geolocation Performance and Trends
- Some expectations of J2 VIIRS
- Improvements and future work
- Conclusions

VIIRS Geolocation Performance

Residuals	**SNPP VIIRS C. 1.0**	**J1/N-20 VIIRS Prel.**	Aqua MODIS C6.1	Terra MODIS C6.1
Track mean	**13 m**	**7 m**	1 m	0 m
Scan mean	**4 m**	**-24 m**	0 m	0 m
Track RMSE	**58 m**	**62 m**	46 m	43 m
Scan RMSE	**52 m**	**59 m**	53 m	44 m
Data-days	**2447 (6.7 yrs)**	**282 (0.8 yrs)**	5910 (16.2 yrs)	6725 (18.4 yrs)
Missing days	**1**	**6**	10	59
Daily matched GCPs w/ I1/B1	**204**	**183**	223	258

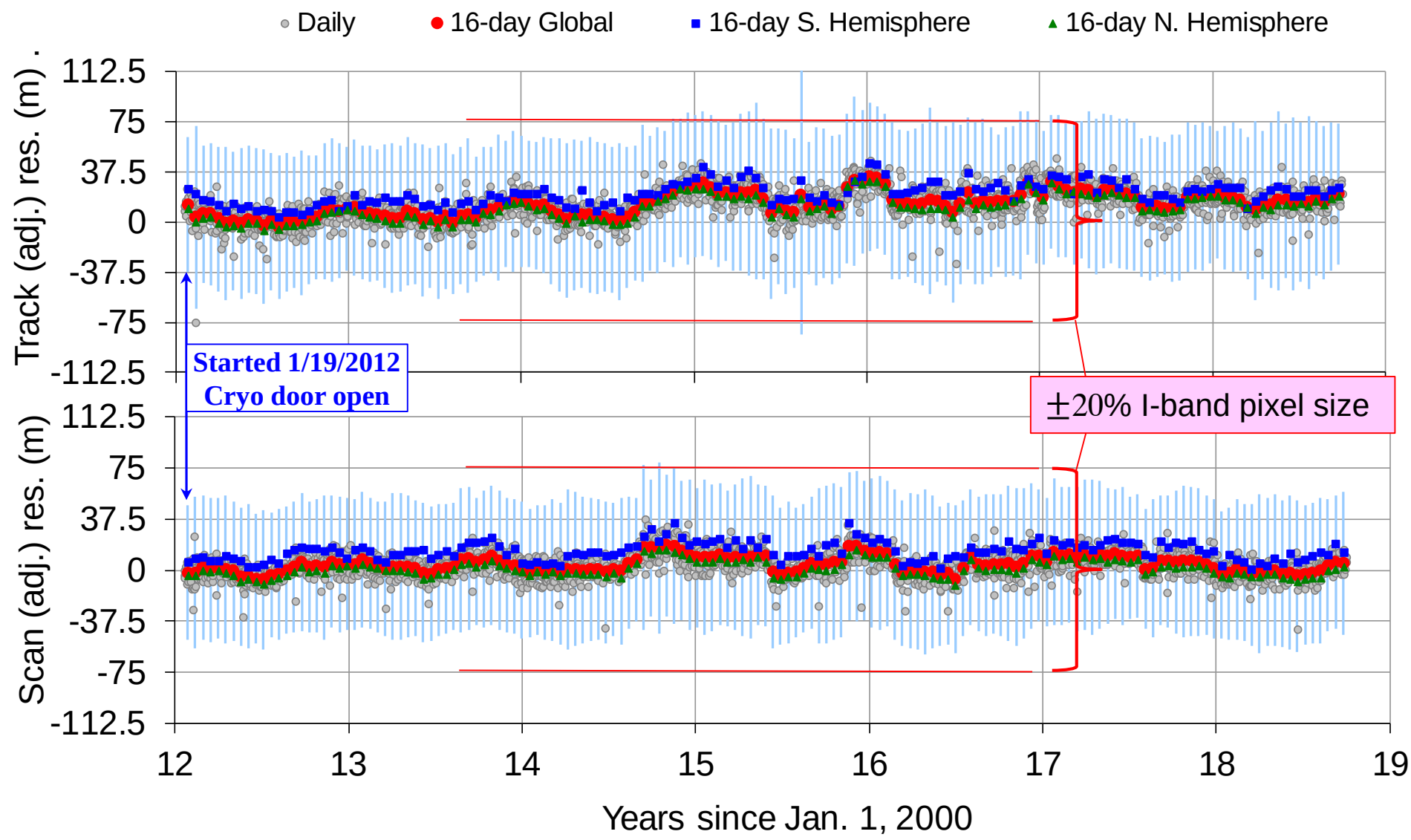
- **Nadir equivalent** accuracy (RMSE – Root Mean Square Error) . (MODIS for reference)
  - Meet Spec: 125 m (1σ); **within 20% I1 HSI (375 m) = 75 m @ nadir for VIIRS**
  - Band-to-band mis-registration to other bands adds bias to RMSE to **:** $RMSE = \sqrt{\sigma^2 + \mu^2}$
- MODIS – VIIRS differences

  Aqua use definitive ephemeris data → 27 hour latency

  SNPP attitude data is not as good, see Slide #13

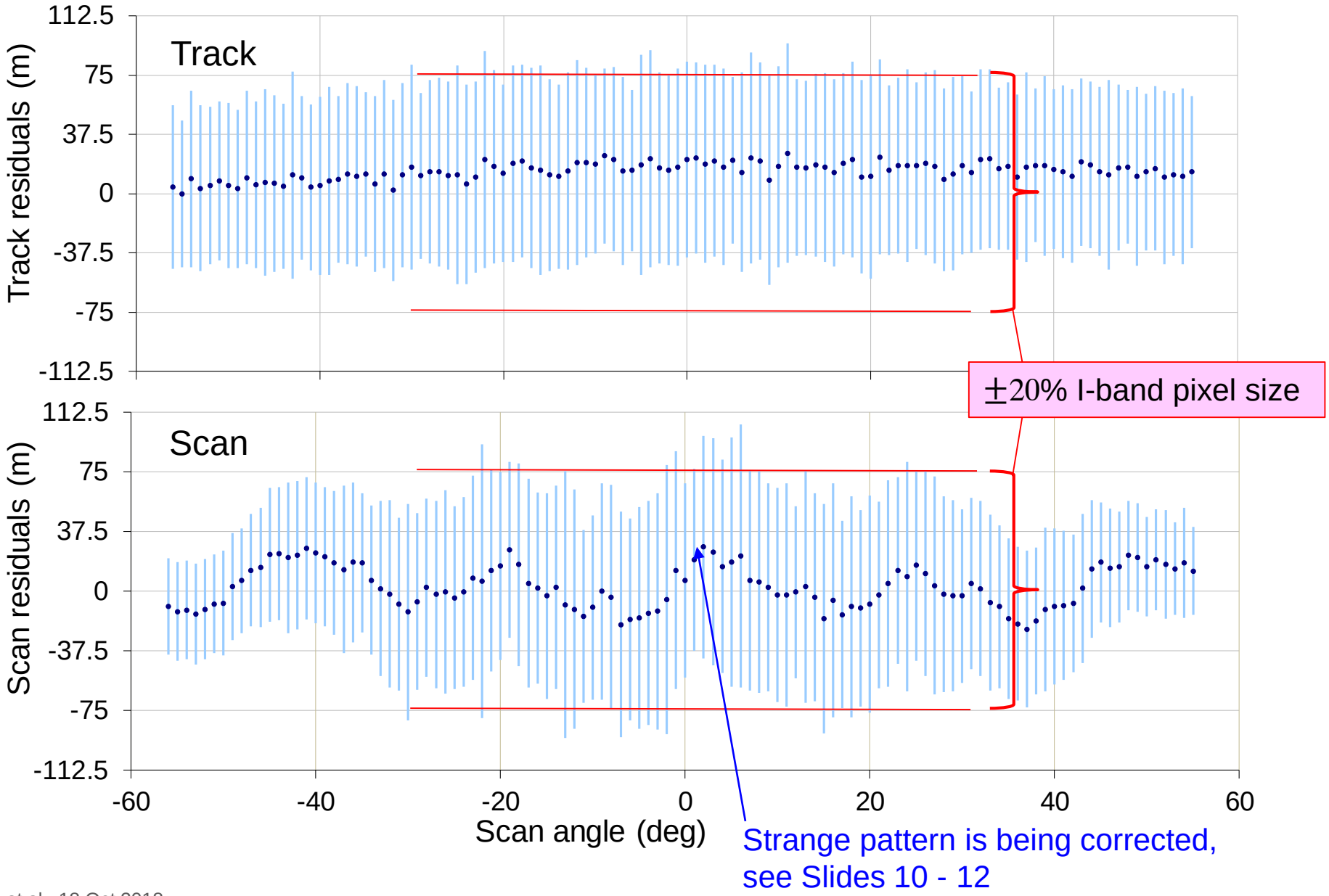
  DEM resolutions: older 1 km for VIIRS vs newer 0.5 km for MODIS C6/C6.1

SNPP C1 geolocation errors

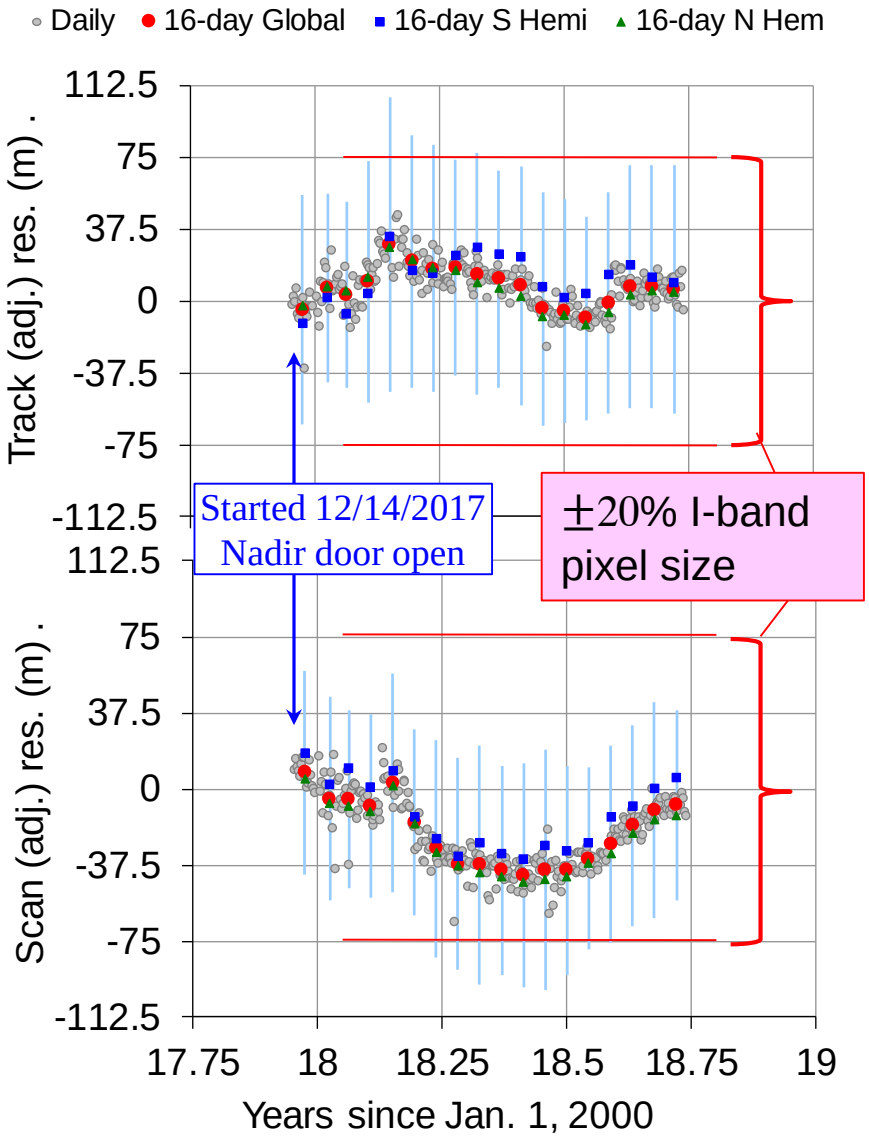


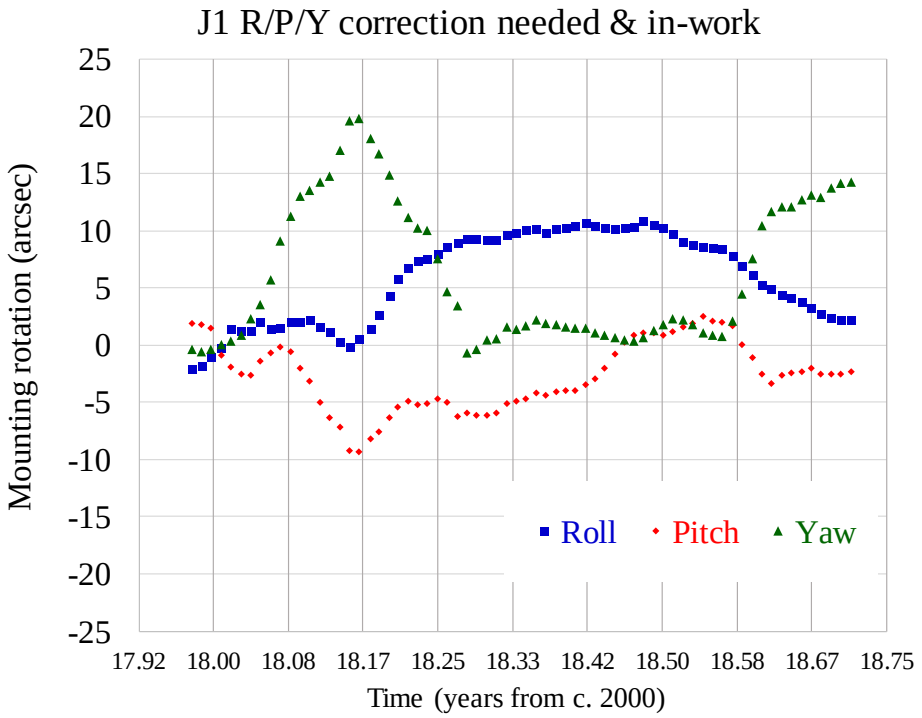
C1.1 RMSE Track: 58 m Scan: 52 m, nadir equivalent

SNPP Scan Angle Residuals



J1/N20 preliminary geolocation errors

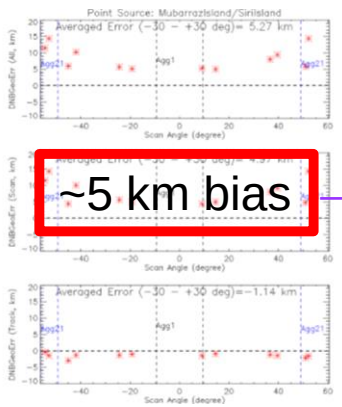




- J1 temporal pointing variation is large (> SNPP). Yaw and pitch pointing variations cause geolocation error ~ 250 m @ edge of scan.
- MODIS-like correction is being worked for both SNPP and J1 pointing variations.

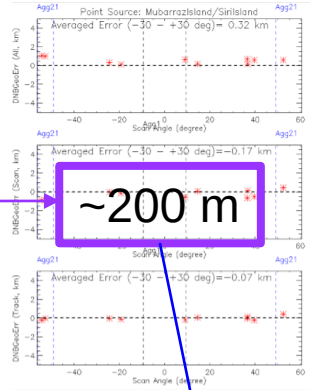
Preliminary RMSE Track: 62 m Scan: 59 m, nadir equivalent

J1 DNB geolocation



~5 km bias

NOAA Operational
- Nadir
  - Overall: ~5.3 km
  - Scan: ~ +5 km
  - Track: ~ -1 km
- BOS/EOS
  - Scan: > 10 km
  - Track: ~ -1 km



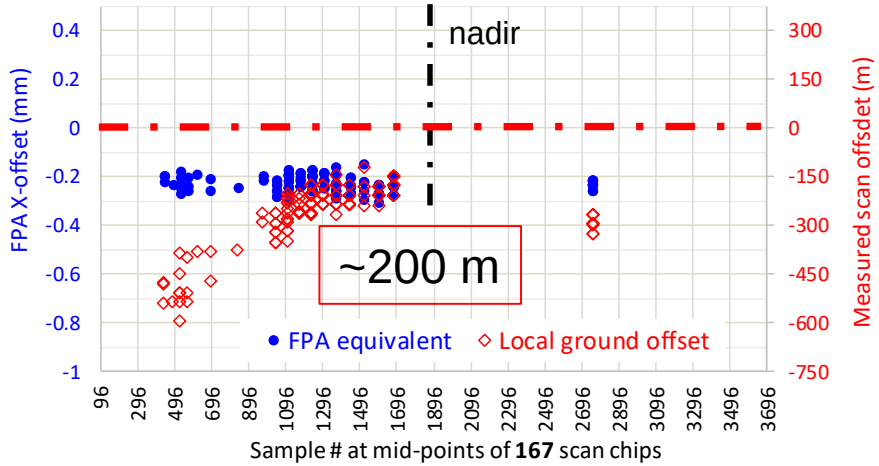
~200 m

Reprocessed using updated DNB GEO PARAM LUT
- Nadir
  - Overall: ~ 300 m
  - Scan: < 200 m
  - Track: <100 m
- BOS/EOS
  - Scan: < 1 km
  - Track: ~ < 100 m

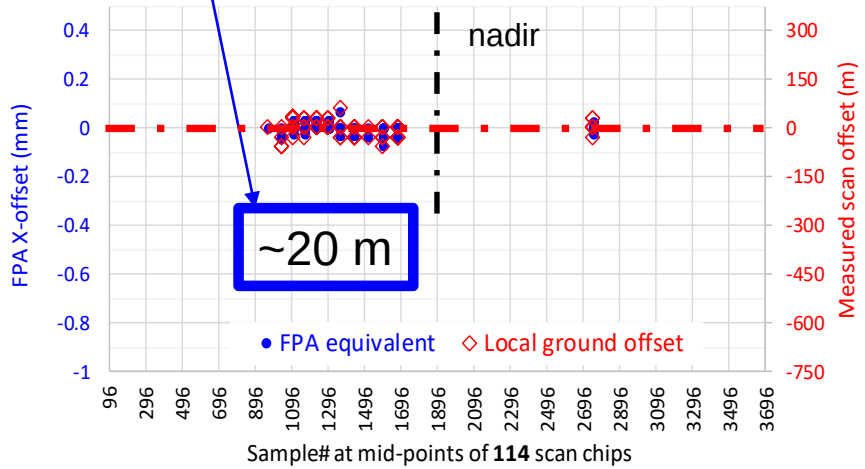
Courtesy of Wenhui Wang and Slawomir Blonski of NOAA STAR

On-orbit Cal, further

J1/N20 DNB scan geo offset (LSIPS LUT r1)

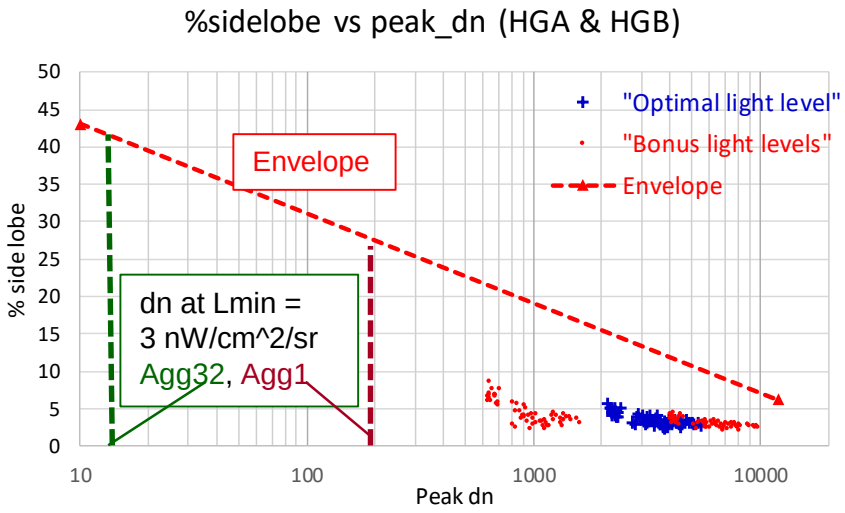


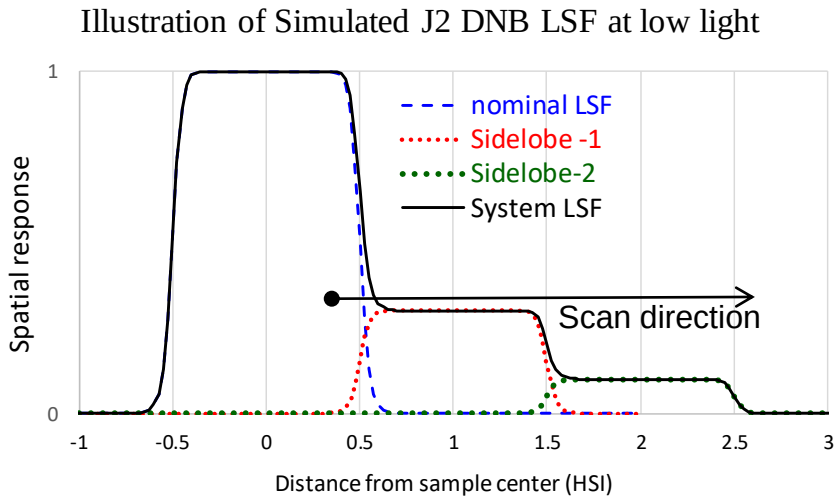
J1/N20 DNB scan geo offset (LSIPS LUT r2)



Expectations for J2 VIIRS

- Band-to-band co-registration -- good
- Pointing – good
- Geolocation – should be good with on-orbit calibration
- Line spread functions (LSFs) / modulation transfer functions (MTFs) – mostly good, except DNB at low light

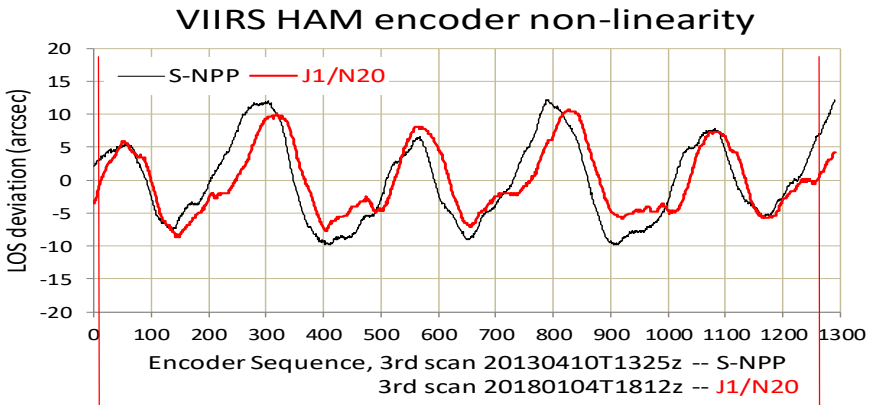


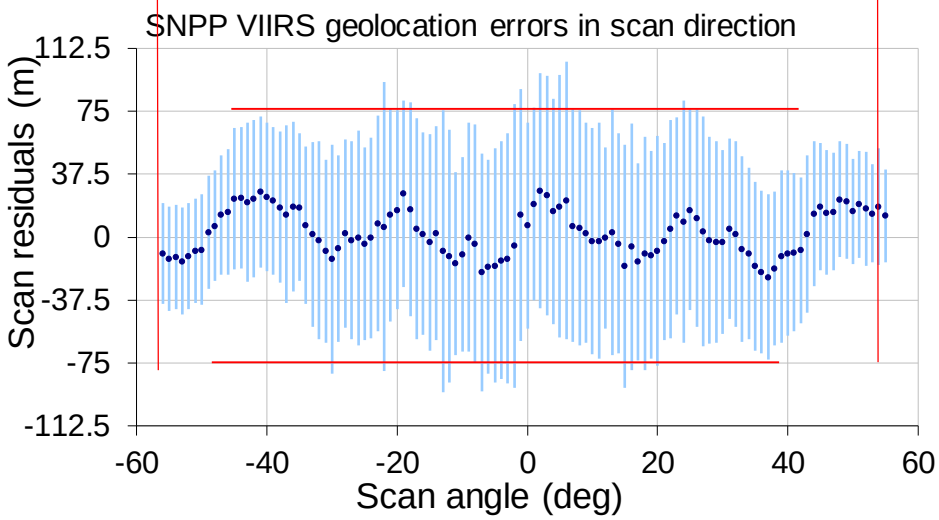


Incorrect J2 voltage setting causes the charge in the current sample to remain behind in the transfer gate and be deferred into the next sample in the scan direction

Lin et al., 18 Oct 2018

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 large enough to skew the errors outside of ± 20% I-band pixel size

Lin et al., 18 Oct 2018

Image flipping

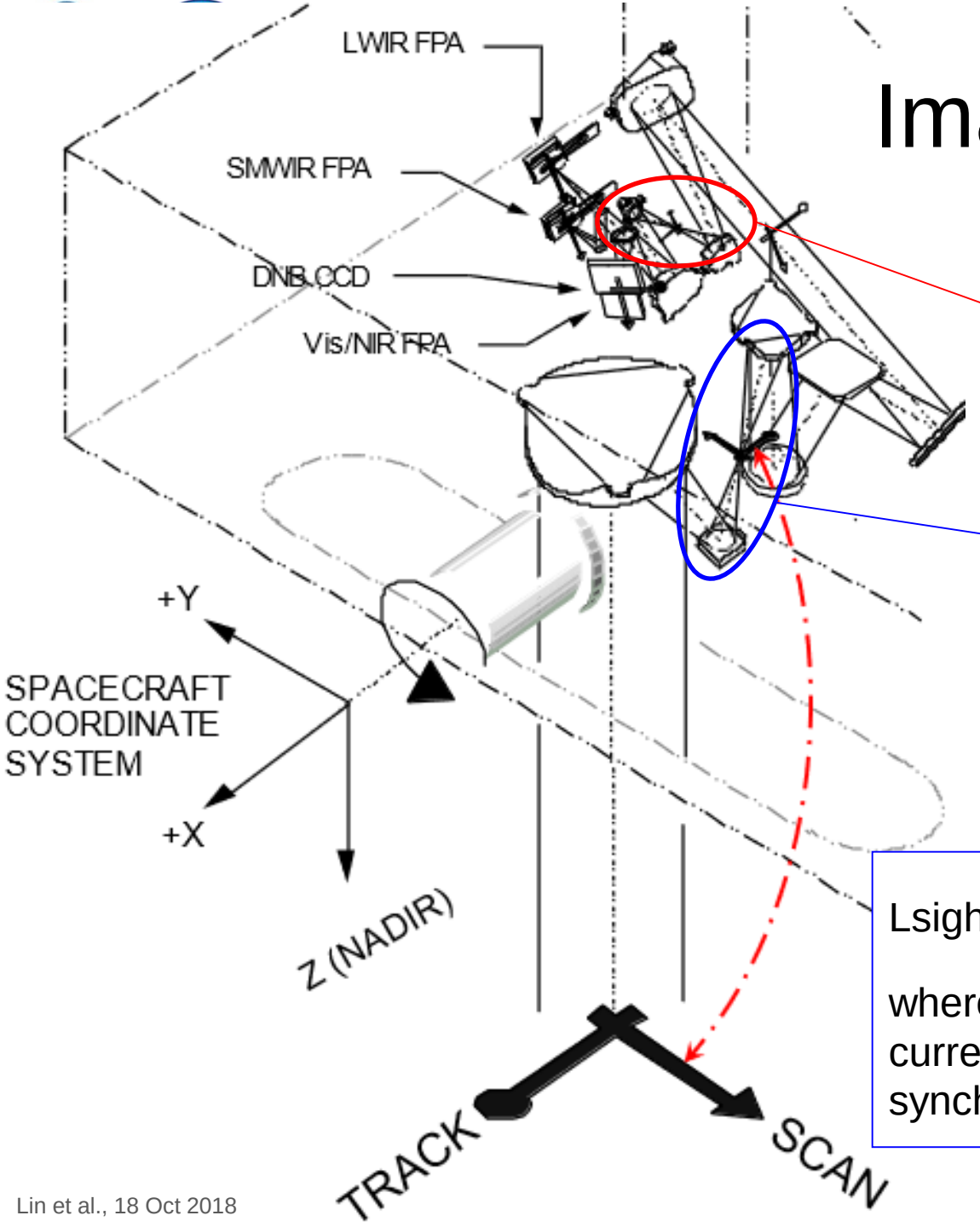


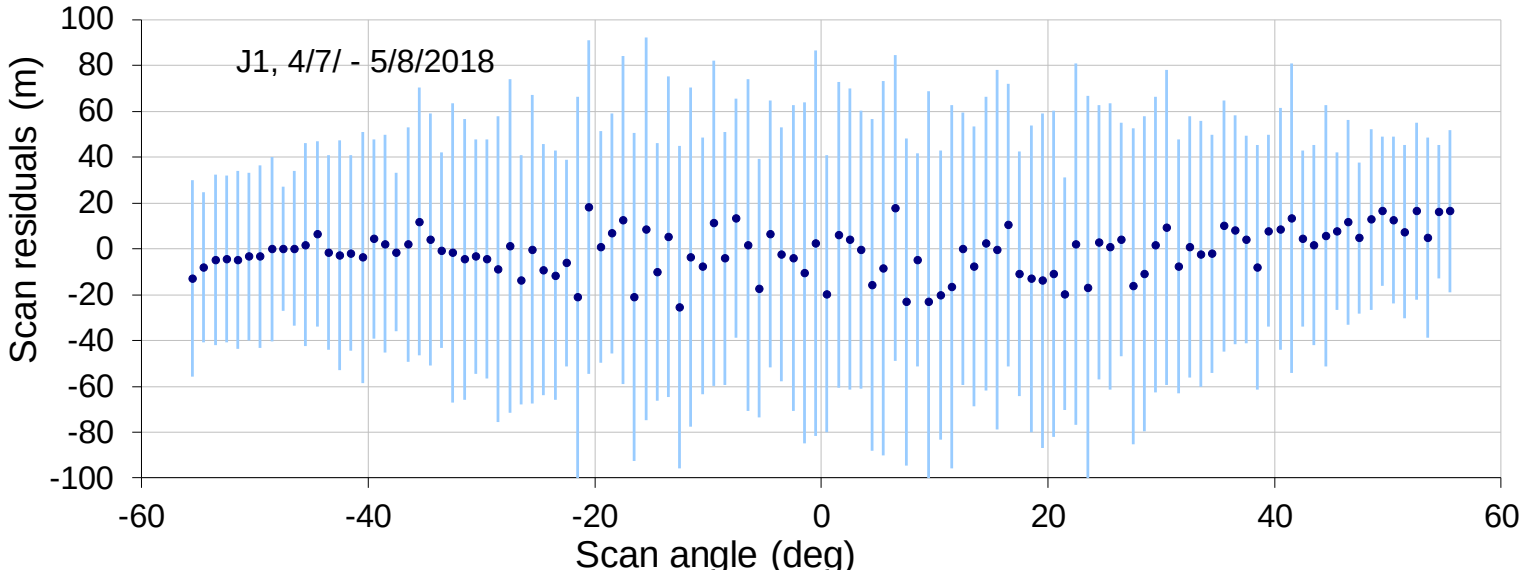
Image flipping after HAM

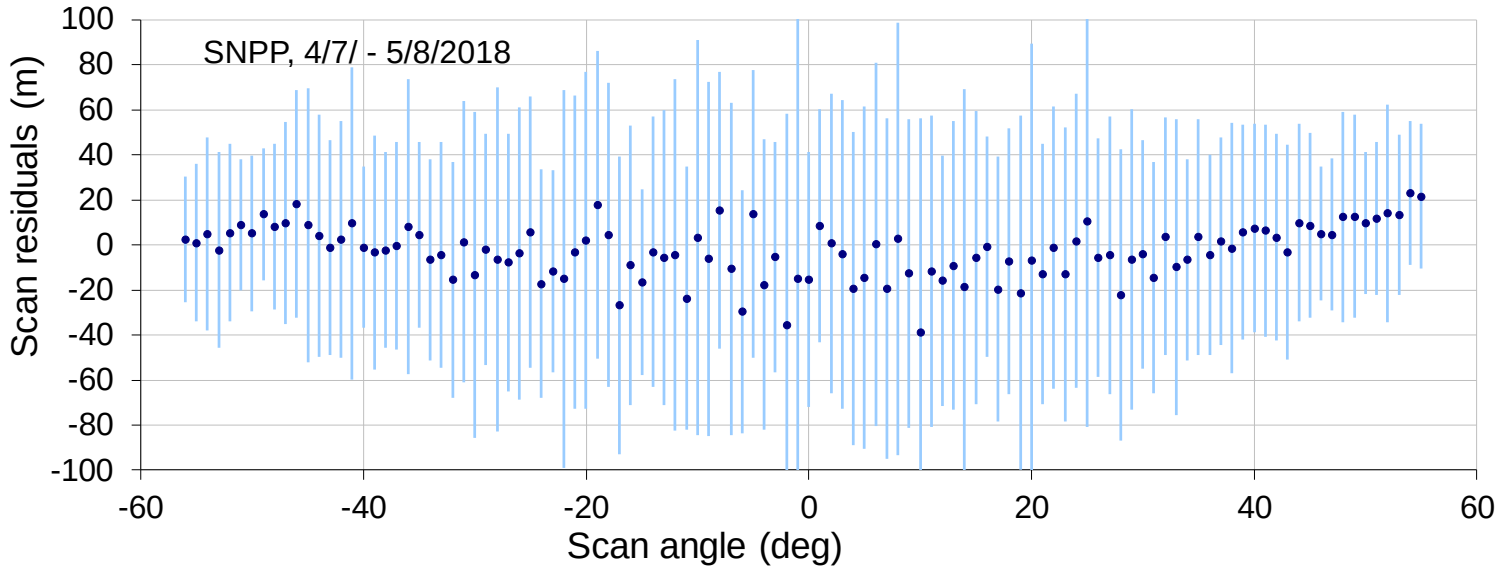
Image flipping before HAM

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

where M = -4 (not +4 as we are currently using), which affect non-synchronization of RTA/HAM only

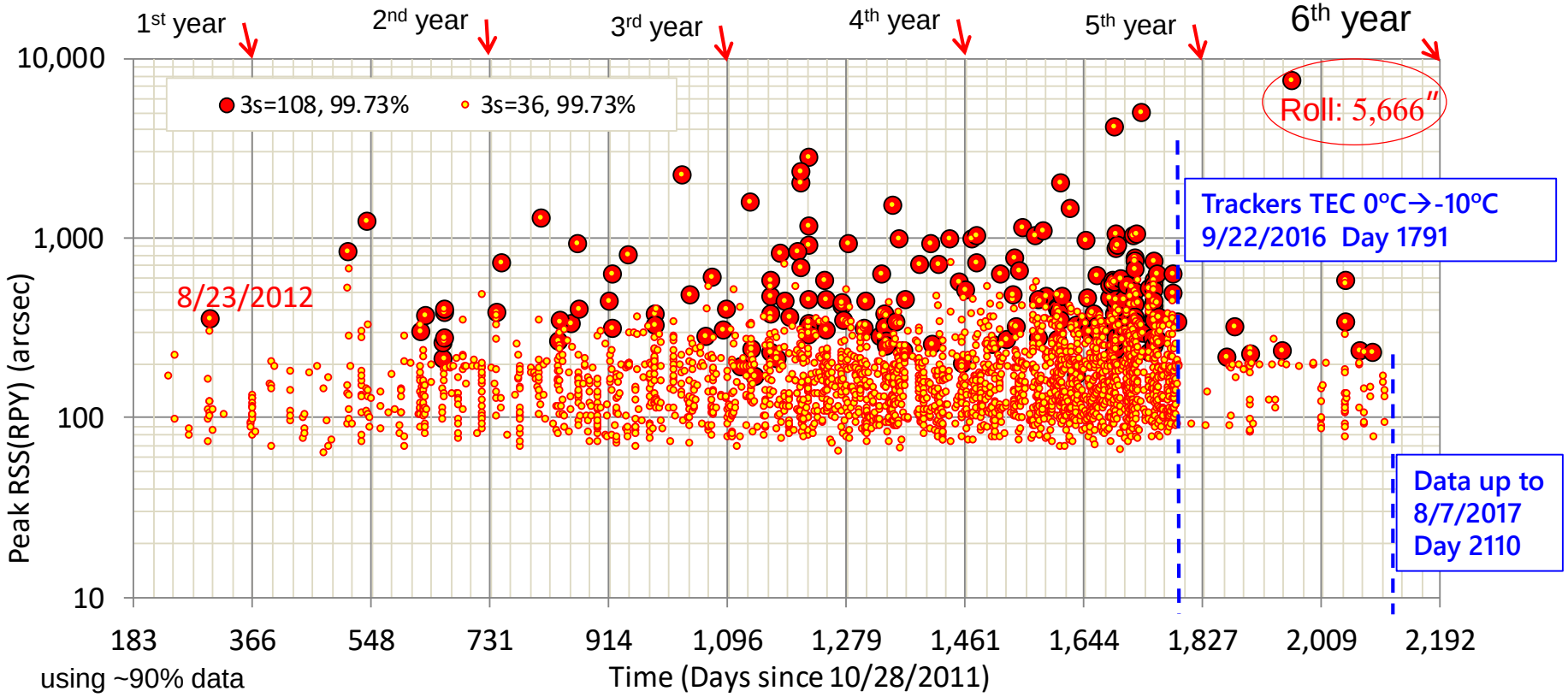
VIGMU tests – J1 & NPP





SNPP SC attitude performance

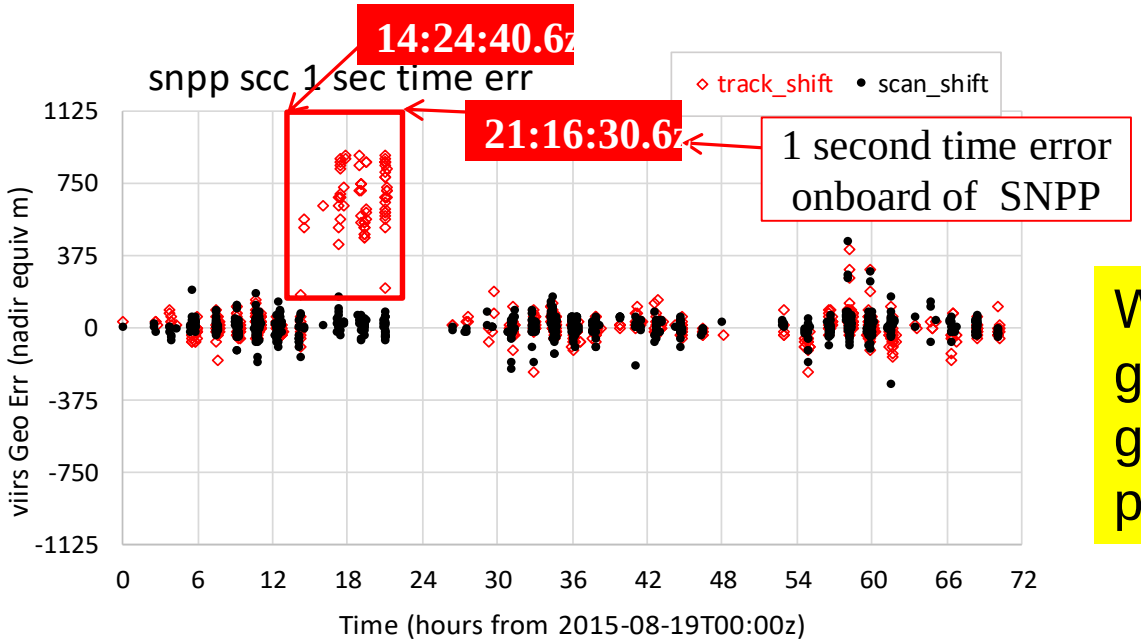
- - Spec outage and trend



- 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[3]
- We are developing SW with Kalman filter to refine the attitude for NASA SIPSs
- J1 is performing better but we are monitoring

3. 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

SNPP Events
→data exclusion for now



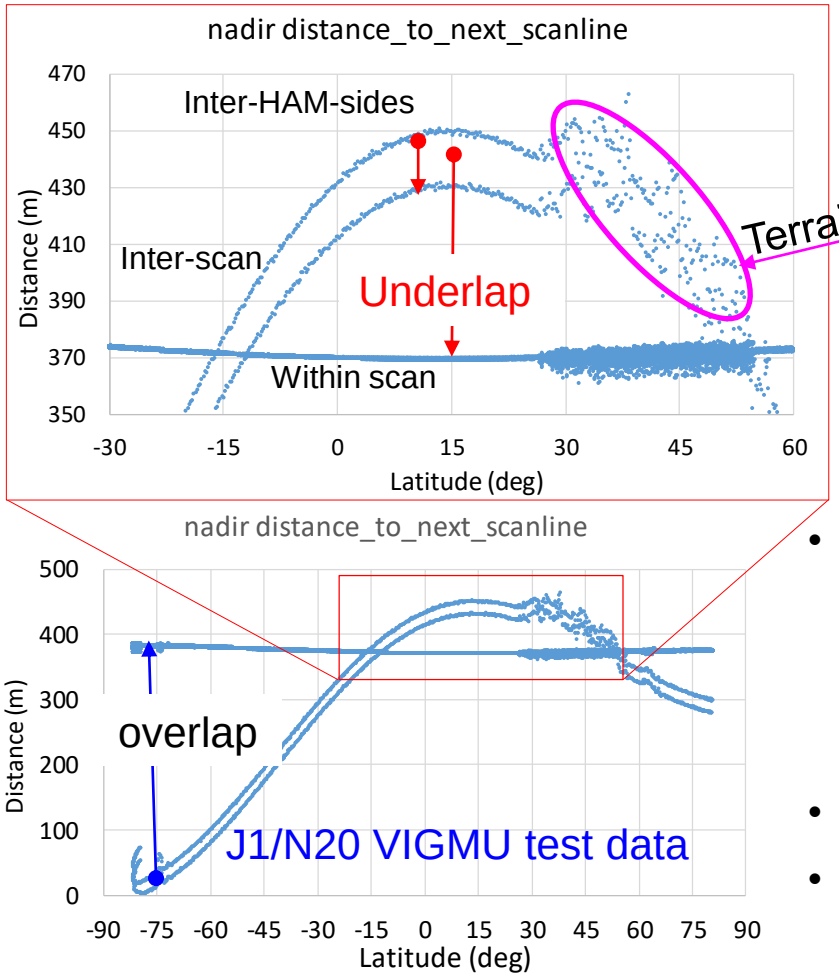
We will “hide” the granules where geolocation accuracy is poor.

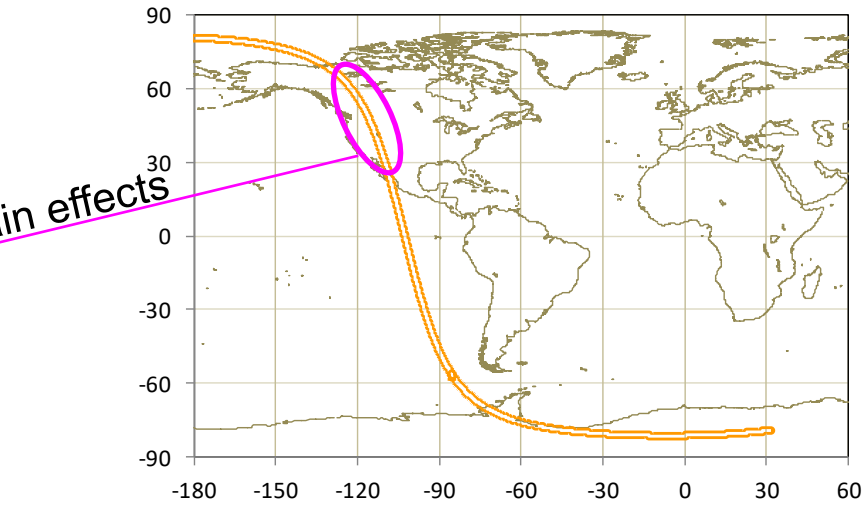
- Leap second insertions: 2012-07-01, 2015-07-01, 2017-01-01
- Inclination adjustment maneuvers: poor pointing ~ 2 hours after
  - #1-4: 2014/ 7/30+9/10+10/15+11/12;
  - #5: 2015 9/23; #6: 2016 9/29;
  - #7: 2017 9/28; #8: 2018 9/27.
- Drag make-up maneuvers: 28 DMUs up to 2018-07-17.

J1 VIIRS Scan-to-scan underlaps

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

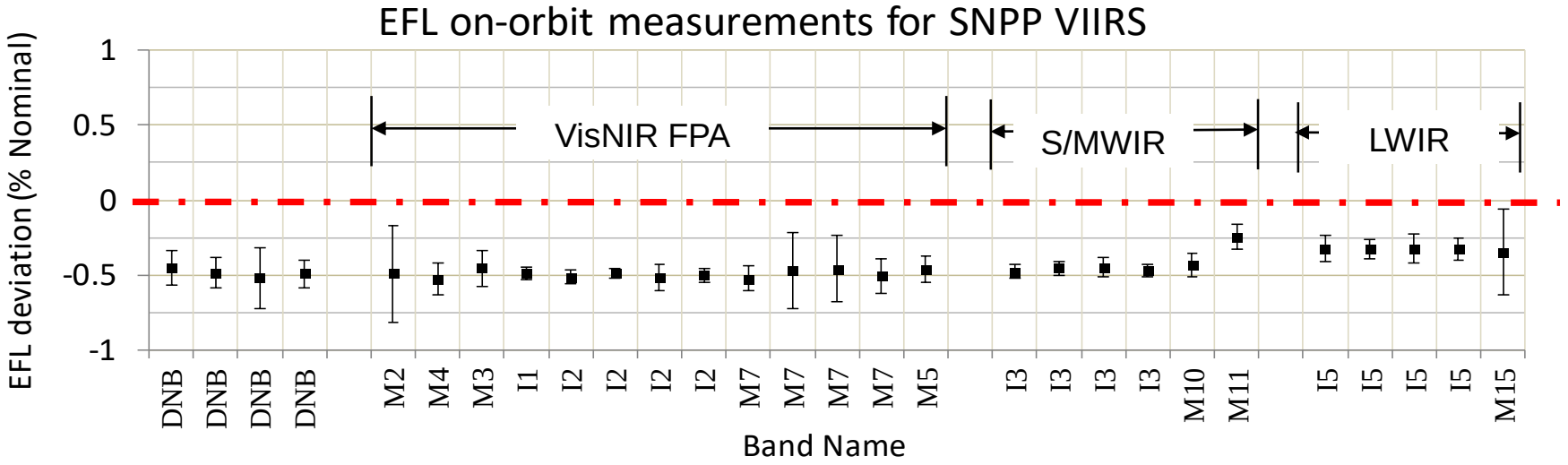
where F = effective focal length = Mag x aft optic focal length, p = detector "pitch" interval in the track direction, n = # detectors, h = range from satellite to earth terrain surface altitude, T = scan period, *i*=inclination angle (in ECI) < 90 deg for J1, V_{ECI} = spacecraft ground speed in the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

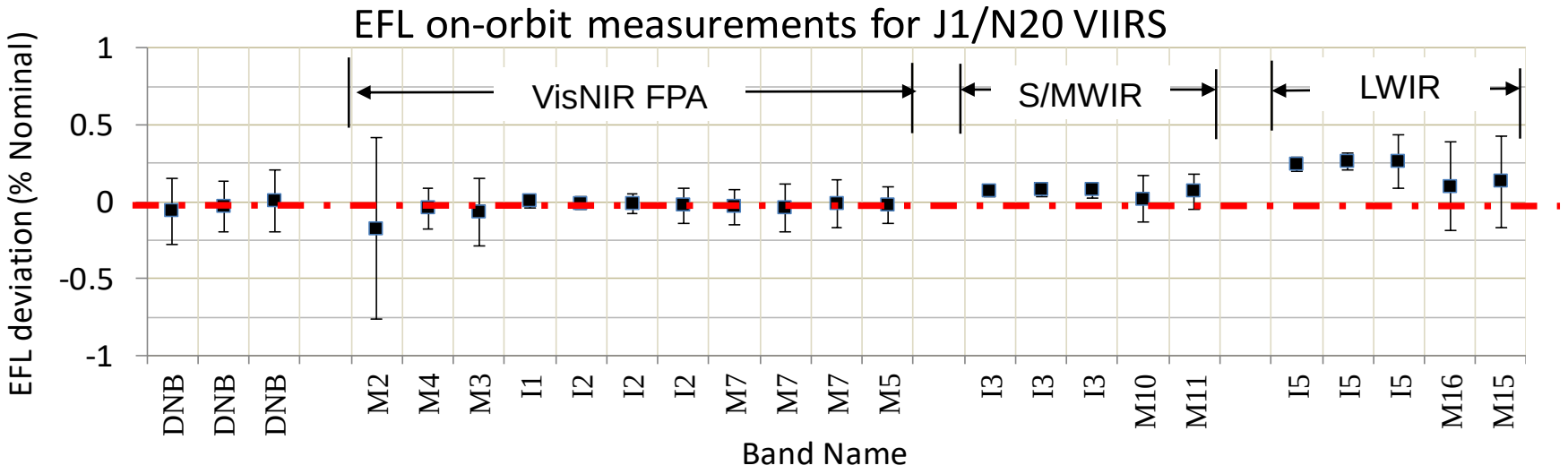




- Widest underlaps occur at nadir near 15N at ~ 70 m in this case. They narrow down as J1 goes north or south due to increasing altitude. They also close in off nadir angles (@ ~10 deg) due to bowtie effects
- High terrain widens the underlaps.
- SNPP VIIRS has less of this issue because of its shorter focal length and scan speed (~0.4%)

On-orbit focal length measurements





- A +0.1% EFL change means +12 m change in scan-to-scan underlap where it exits.

See poster for details, including BBR

Future work

1) Routine monitor and LUTs update as needed
2) VIGMU (VIIRS instrument geometric model update): test → production
3) Corrections for temporal pointing variations: test → production
4) Refresh ground control points with Landsat-8 images
5) Replace attitude in SC diary with Kalman filtered data
6) Replace ephemeris in SC diary with GPS data
7) Update DEM from 1 km to 500m resolution
8) Automate GEO LUT updates
9) Create Level-1 geolocation web (needed?)

Anything else?

Any change in priority order above?

Conclusions

- SNPP VIIRS geolocation performance is good
  - mean errors for I- & M-bands are ~ 10 m and uncertainties are ~ 60 m at nadir, statistically
  - DNB geolocation accuracy is only spot-checked and it is ok
  - The attitude system underperforms → geolocation error up to 7 km occurred occasionally. Attitude HW needs maintenance, and their output will be tweaked on the ground (re-working ephemeris and attitude data)
- J1/N20 VIIRS geolocation performance is ok
  - Early on-orbit calibration reduced biases from O(1km) to O(10m), including DNB
  - Correction for large pointing variation was worked, and will be operationalized soon
- J2 (→N21) VIIRS geolocation is expected to perform fine

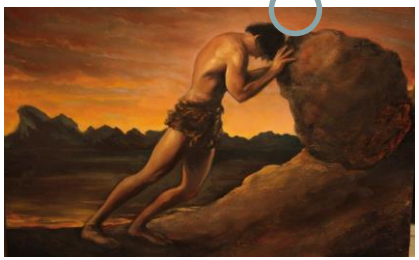
Questions?

Q: Do random variables exist?

A: Not really.

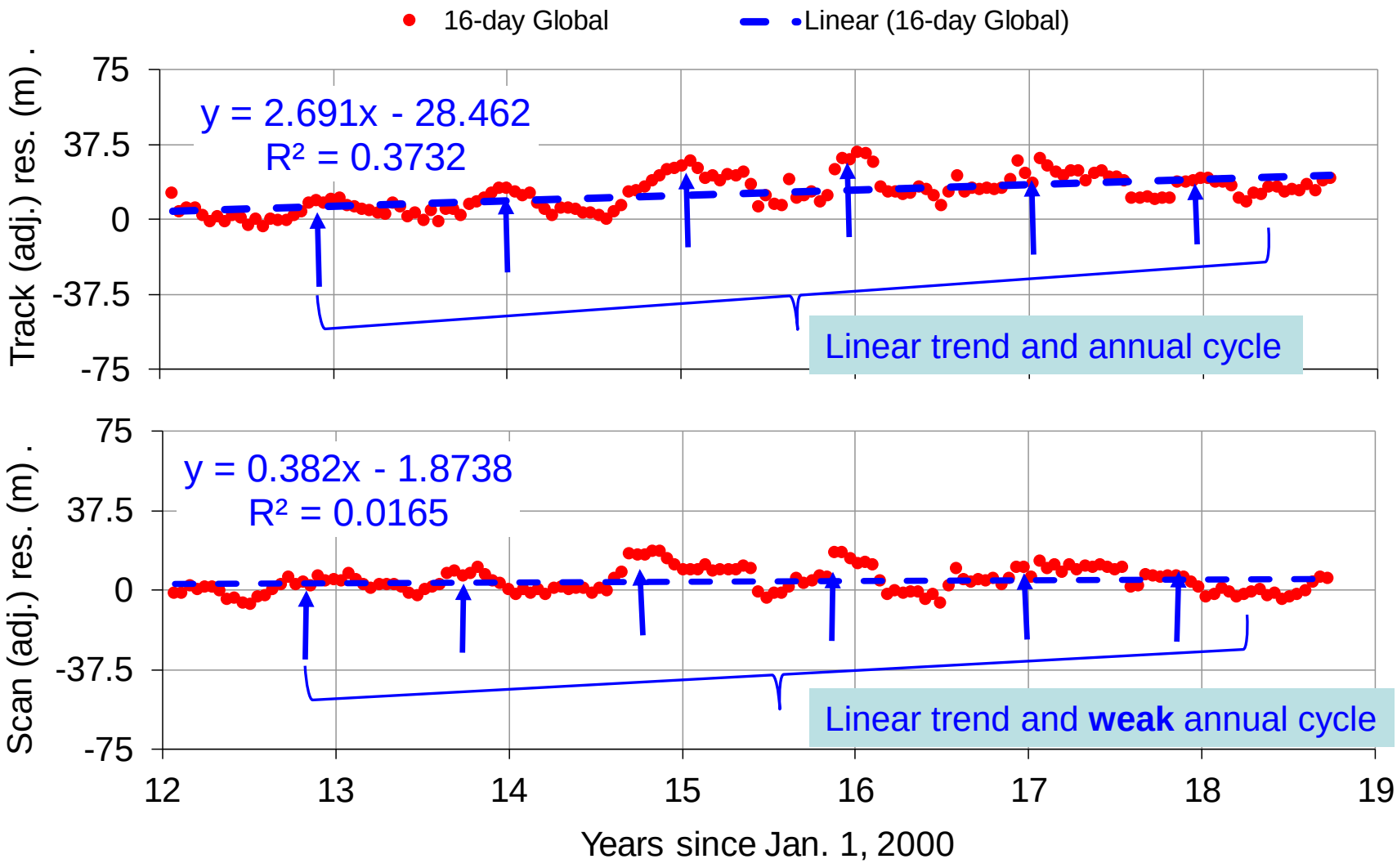
Q: What do we do?

A: Careful trending and de-trending.



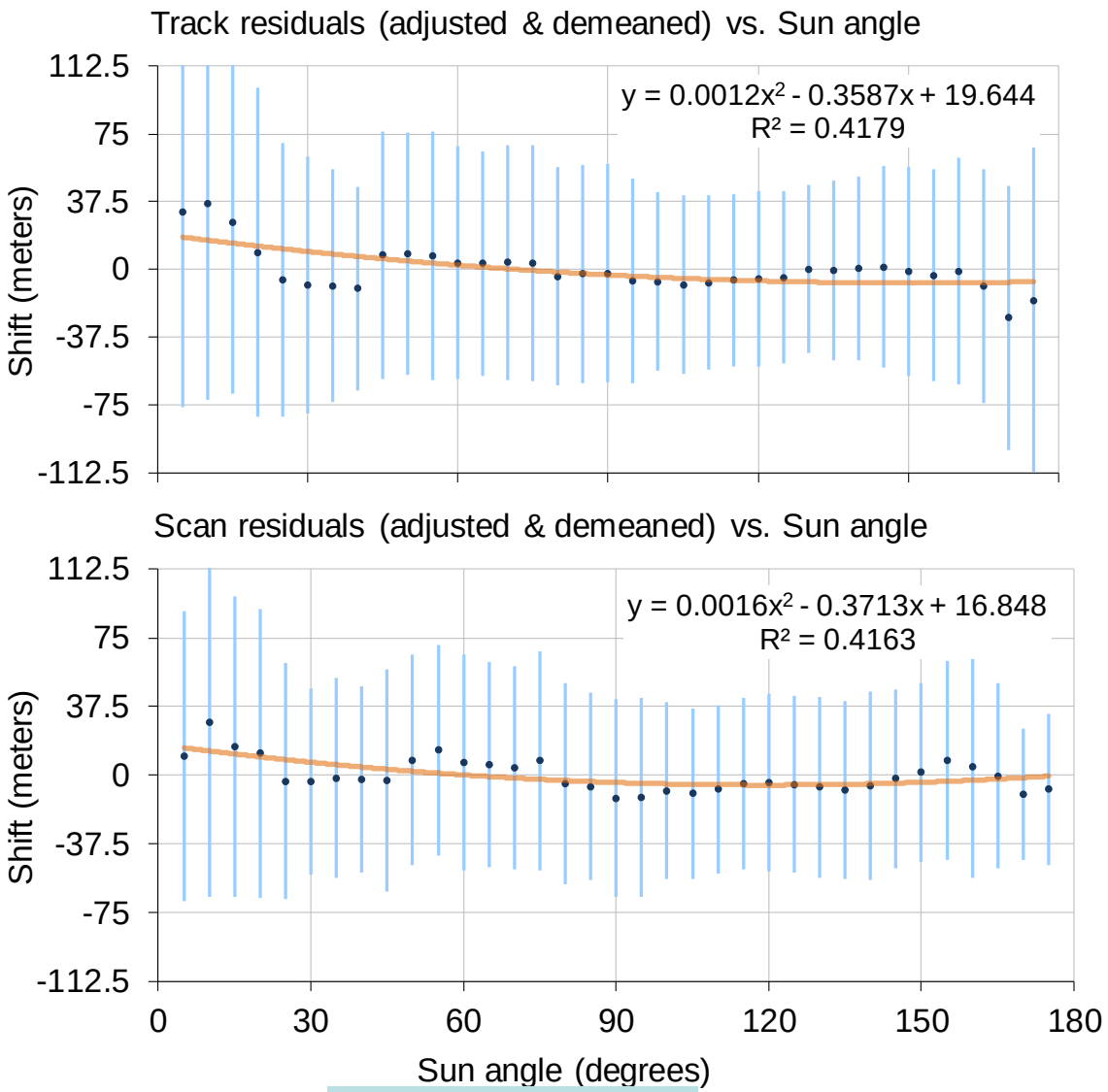
Backup Slides

SNPP Long-Term Trending and Correction



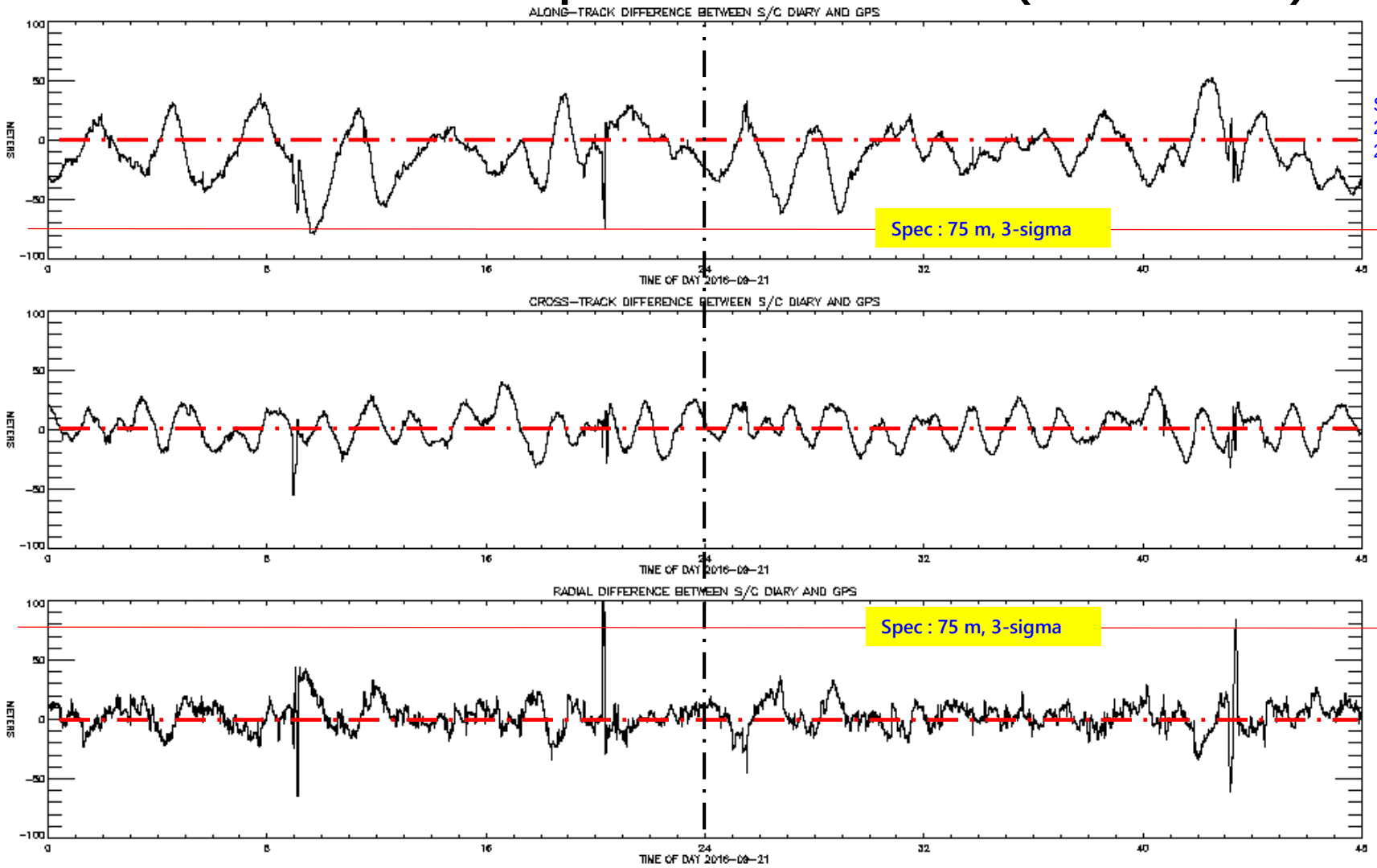
De-trending was worked and will be operationalized soon

SNPP sun angle dependence



Correction is in-work

SNPP orbit position errors (wrt GPS)

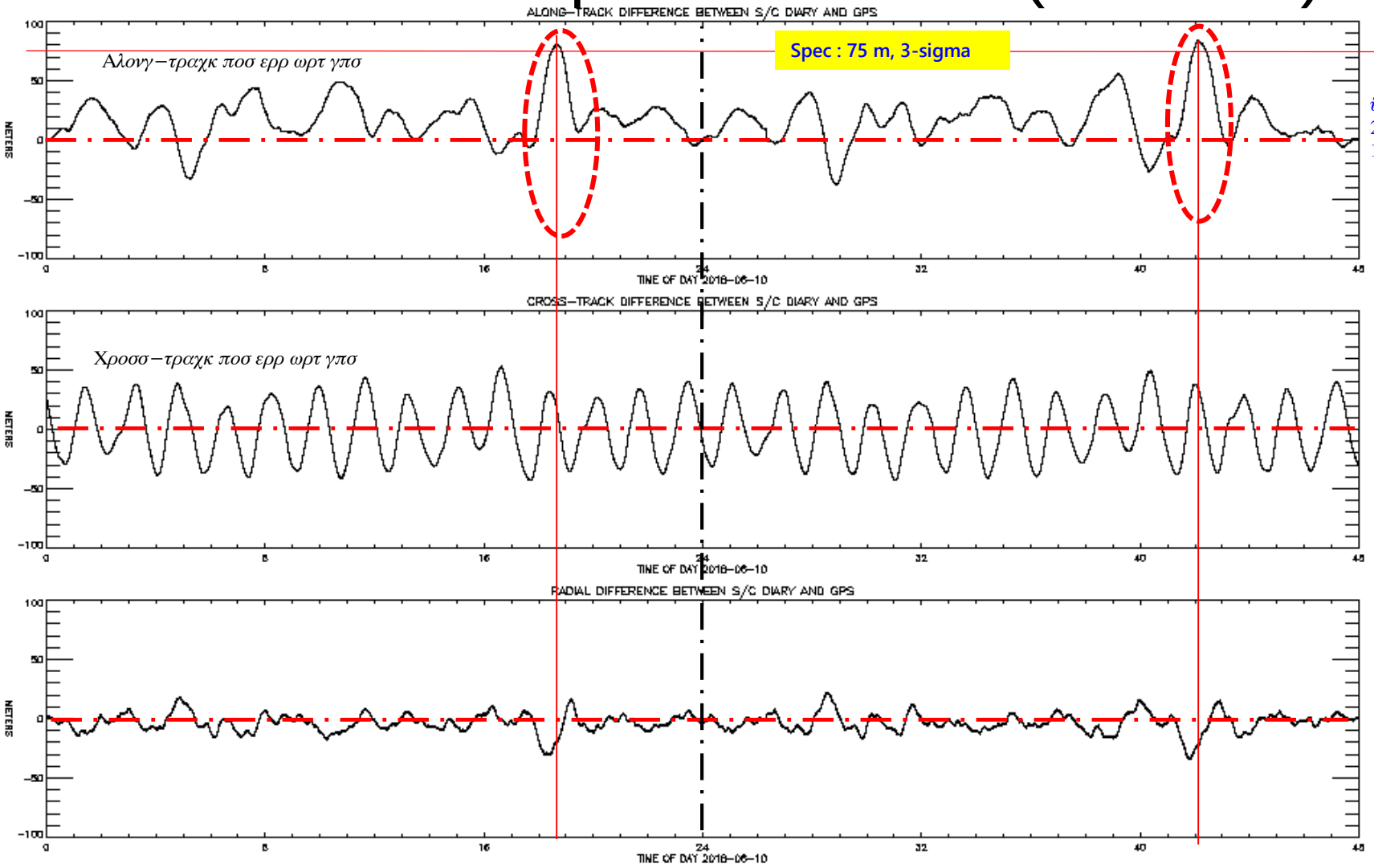


SNPP 2016-09-21+22

Correction is in-work

Plot courtesy: Fred Patt

J1/N20 orbit position errors (wrt GPS)



Correction is in-work

Plot courtesy: Fred Patt