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

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

- **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

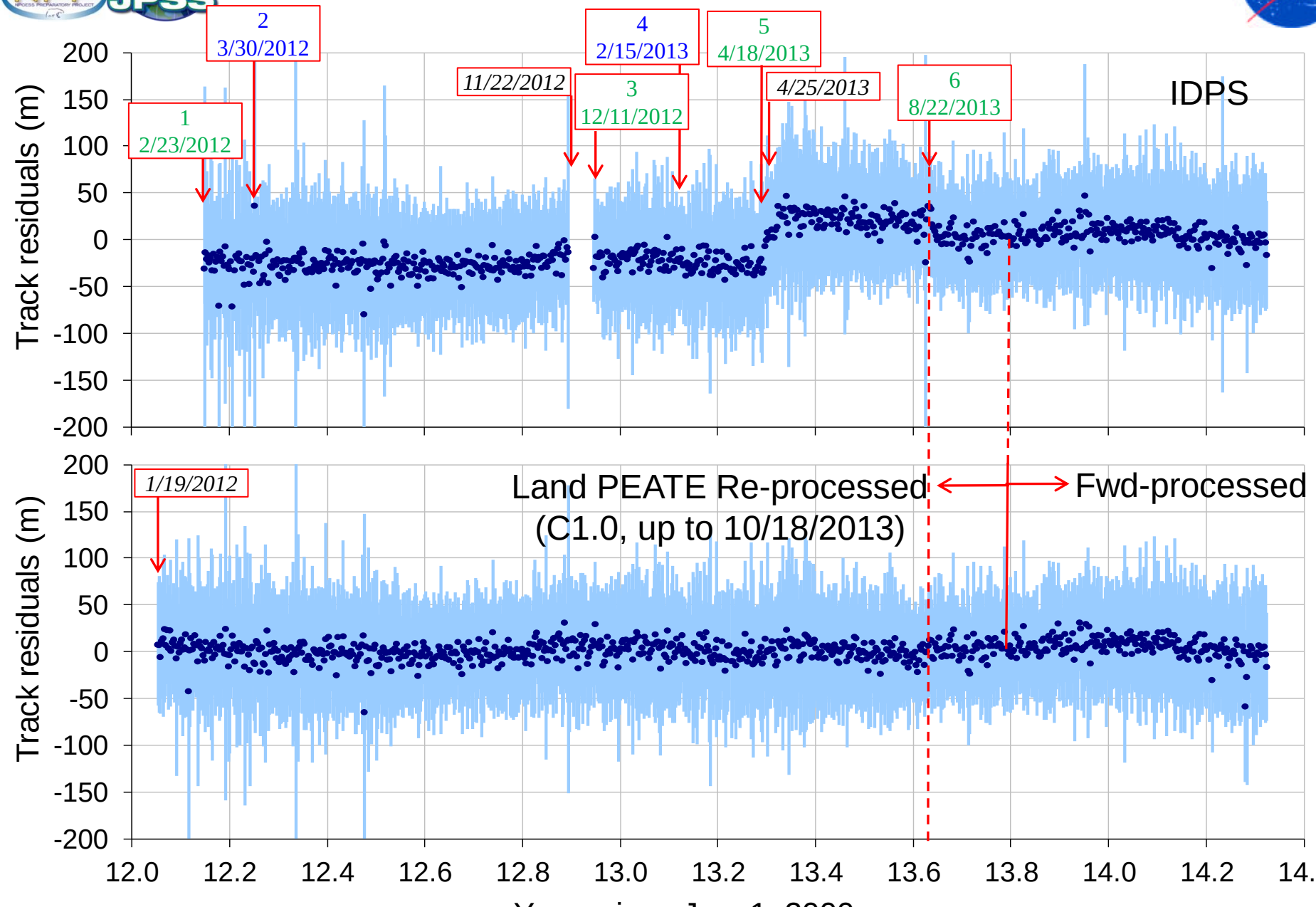
  Land PEATE: 19 Jan 2012 to 28 April 2014

On-orbit Geolocation LUT Updates

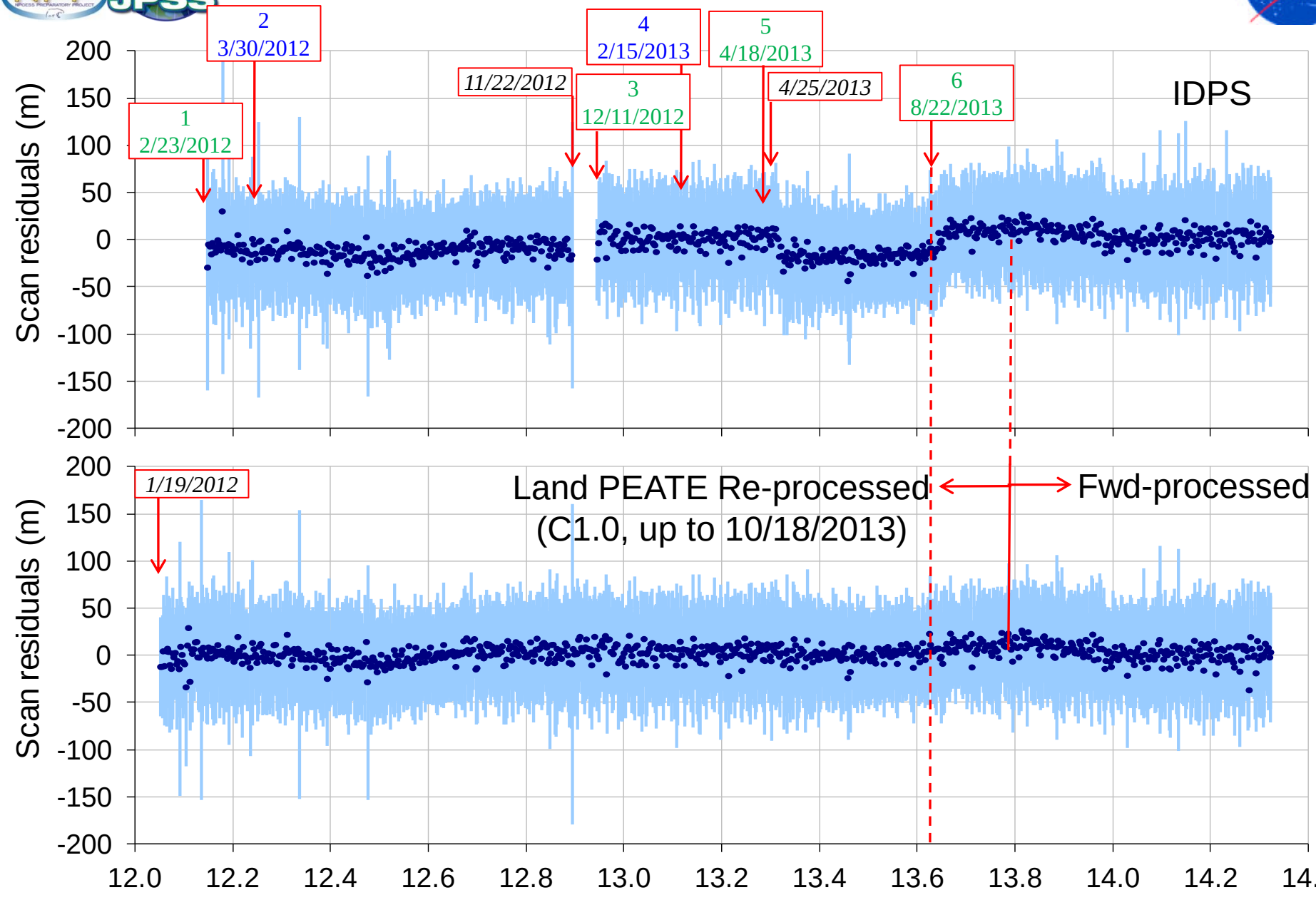
Update	Date	Description	Comments
a	*1/19/2012*	*Cryo-radiator door open*	*All VIIRS band available, LPEATE re-process start date*
1	2/23/2012	Initial mounting coef. update	Removed bias ~ 1.3 km
2	3/30/2012	Initial DNB FPA center update	Removed bias ~ 1 km
b	*11/22/2012*	*Scan control electronics (SCE)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

Key: All bands impacted DNB only *External event*

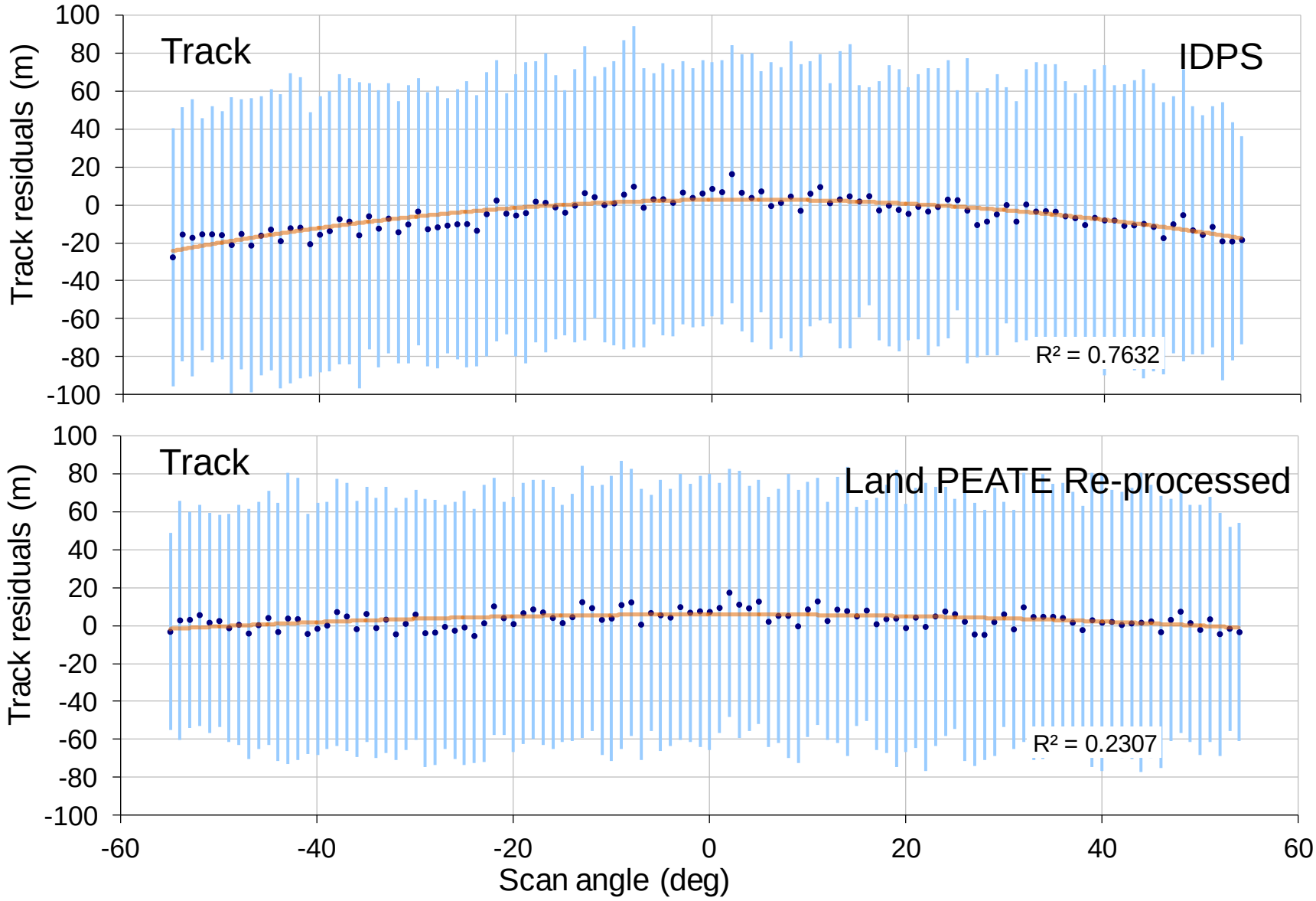
VIIRS Track Residual Trends



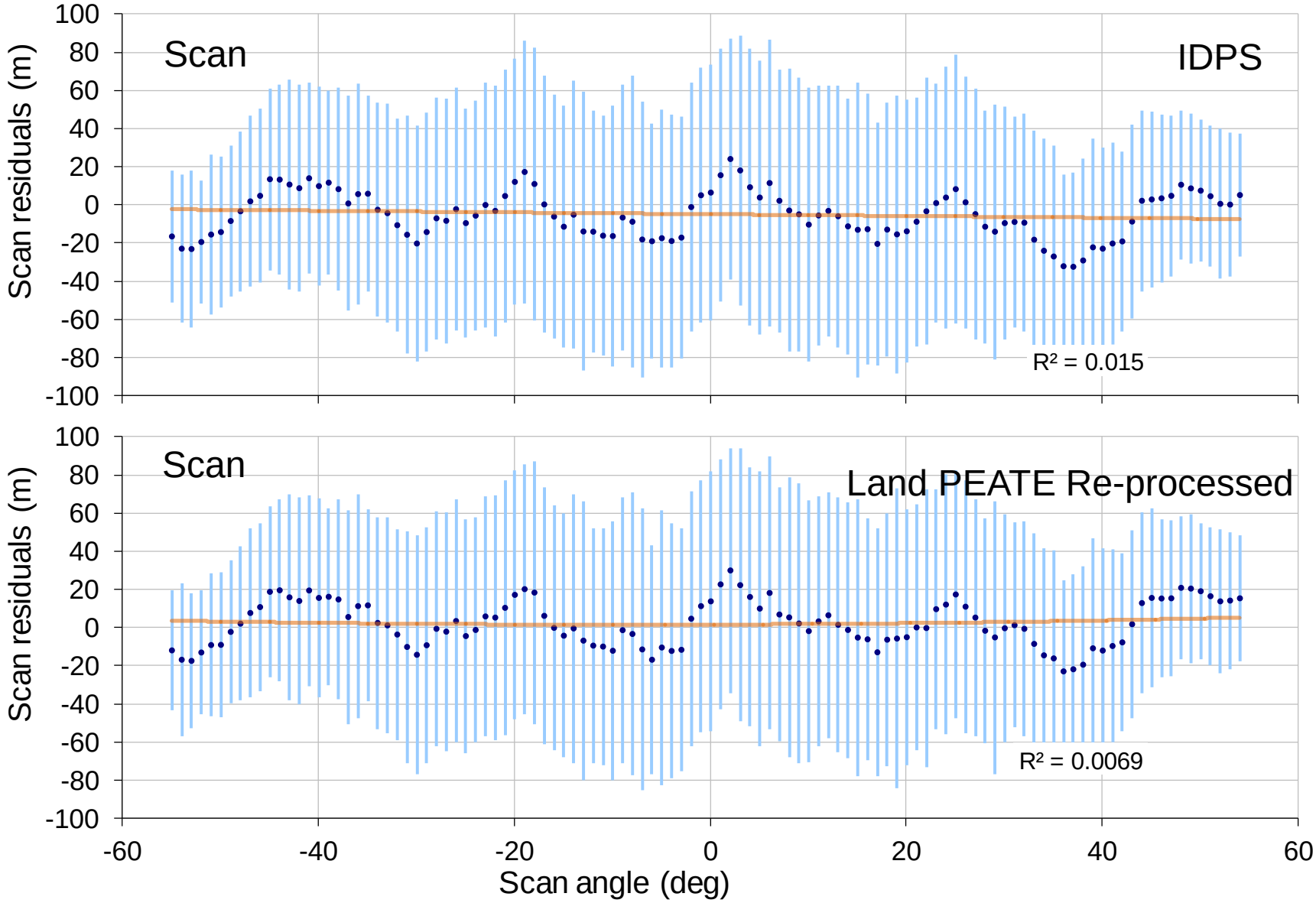
VIIRS Scan Residual Trends



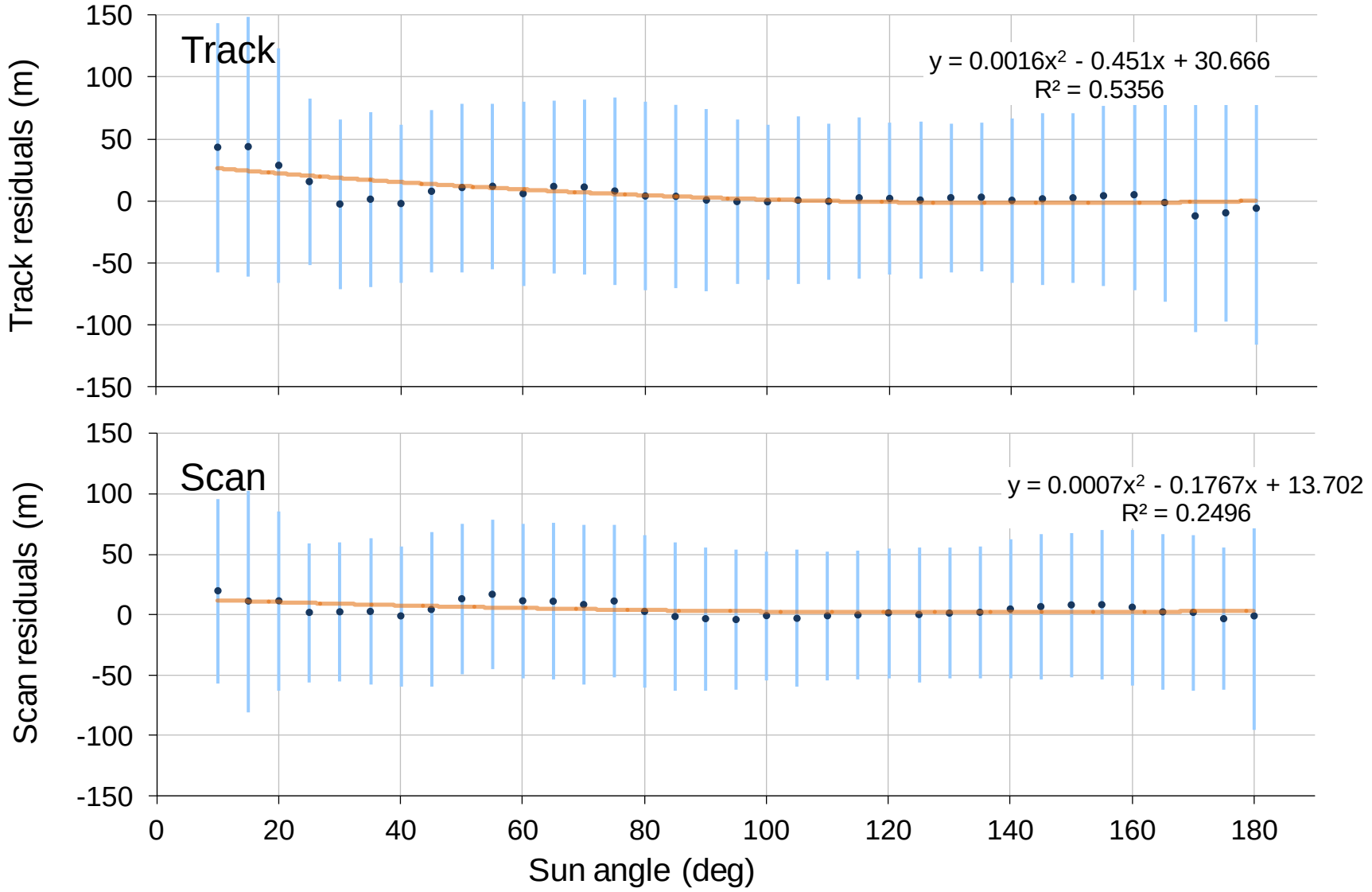
VIIRS Scan Angle Residuals



VIIRS Scan Angle Residuals

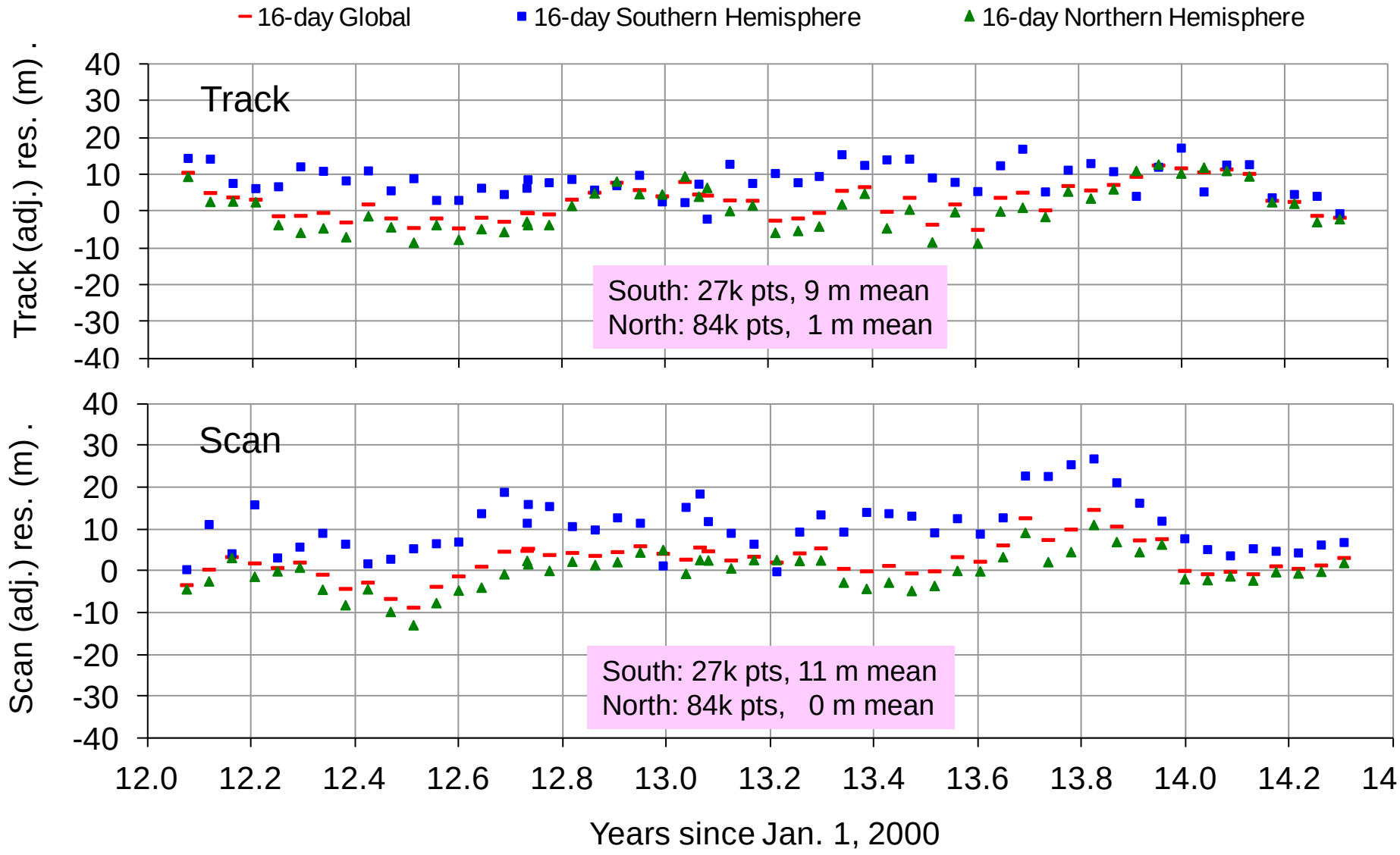


VIIRS Sun Angle Residuals



Land PEATE Re-processed, no correction yet

VIIRS Hemispheric Residuals

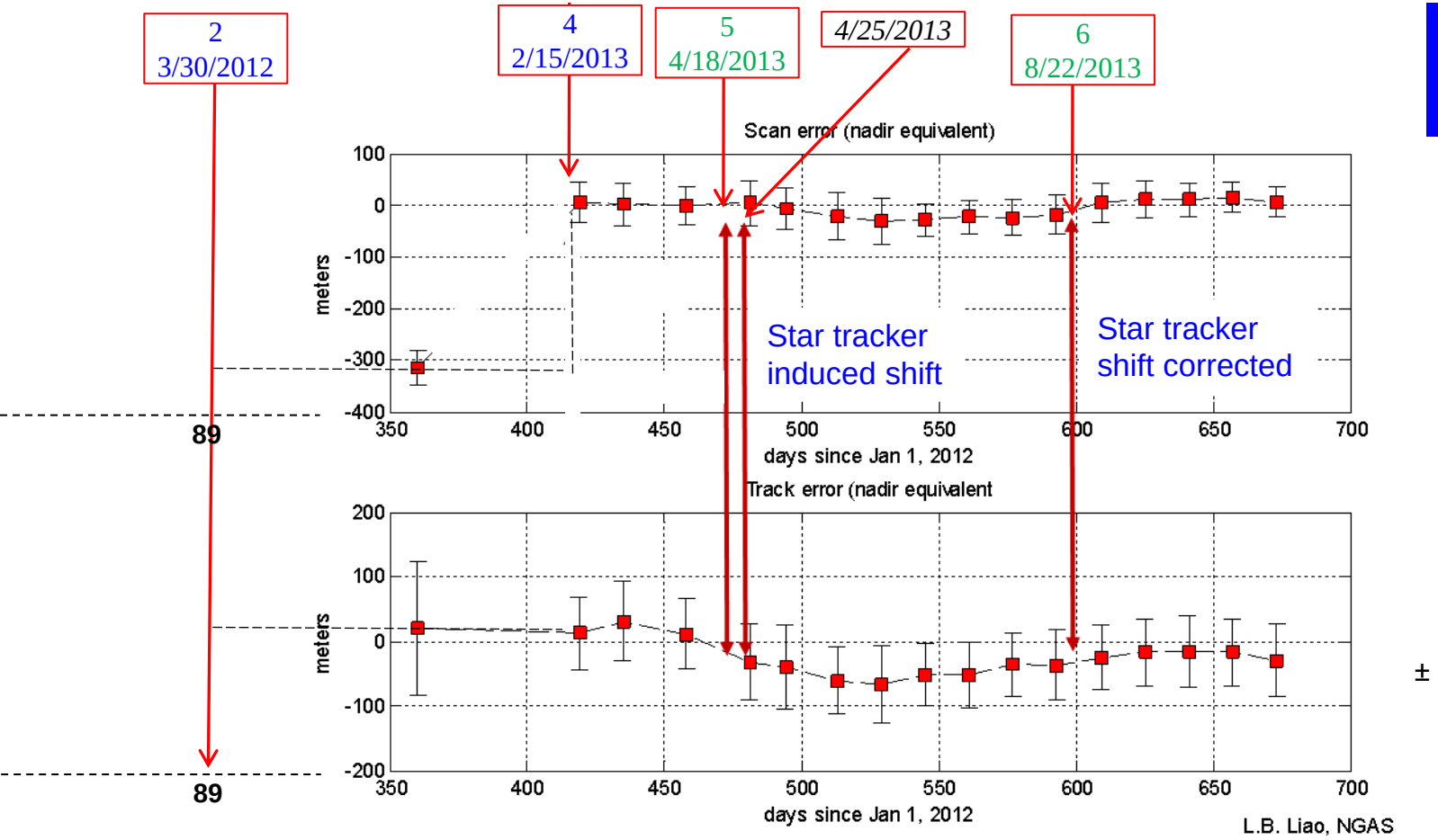


Land PEATE Re-processed, no correction yet

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 μ = 838.8 km (Chart 17)

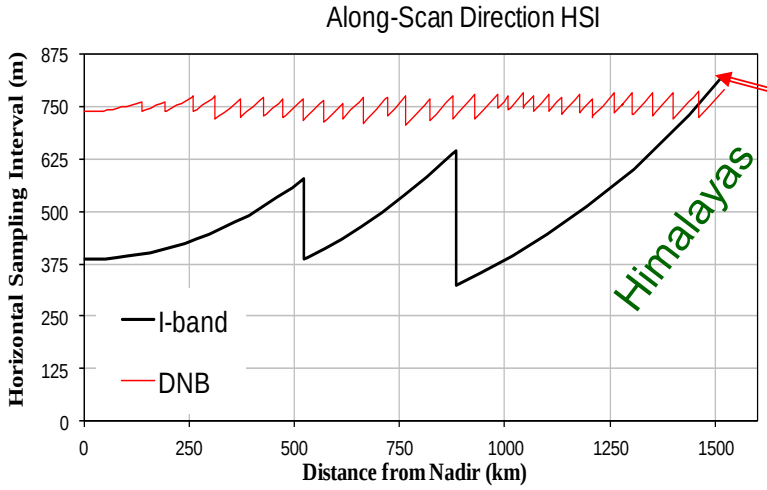
DNB Geolocation based on coastal areas GCP matching

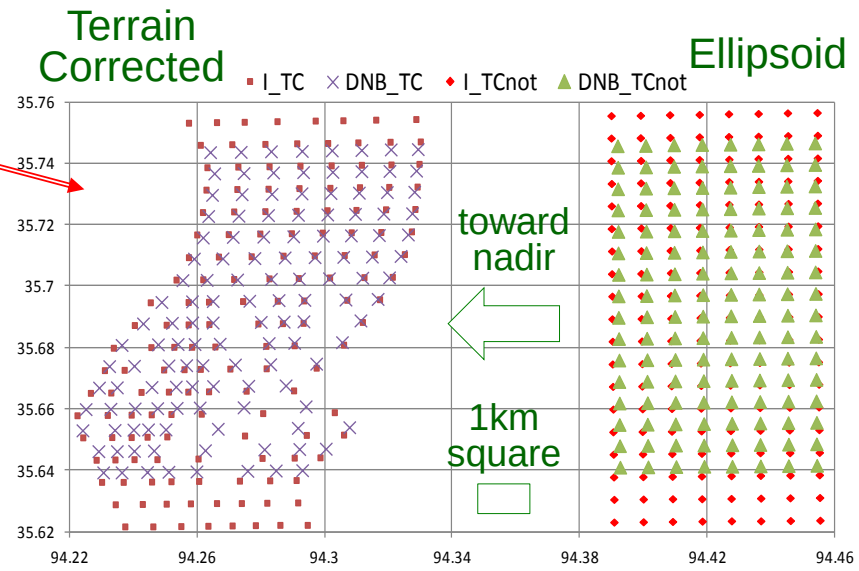


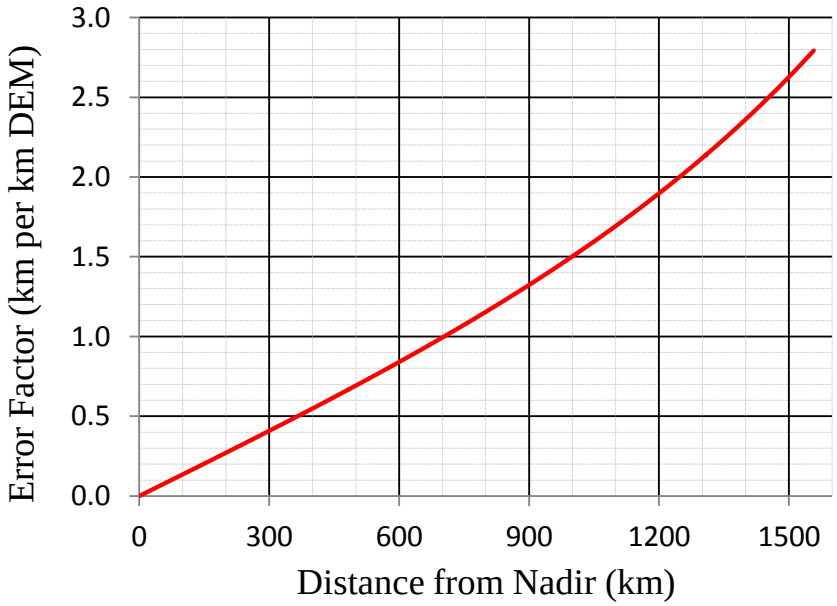
Courtesy of NGAS

As of Nov 4, 2013, the DNB geolocation accuracy is
Scan: 8 ± 33 μrad Track: -35 ± 68 μrad
Scan: 7 ± 28 m Track: -29 ± 57 m over coastal areas
(nadir equivalent with mean altitude of 838.8 km)

DNB Terrain Correction Geolocation

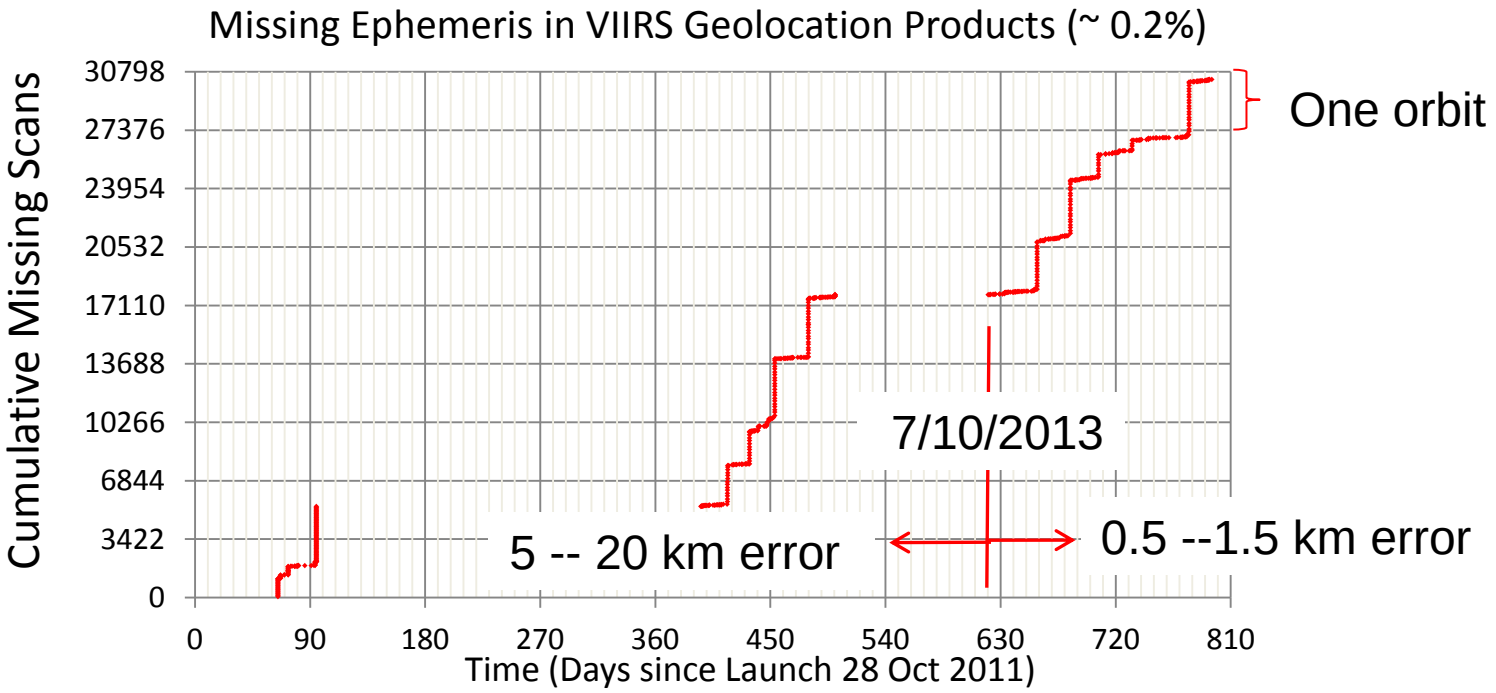






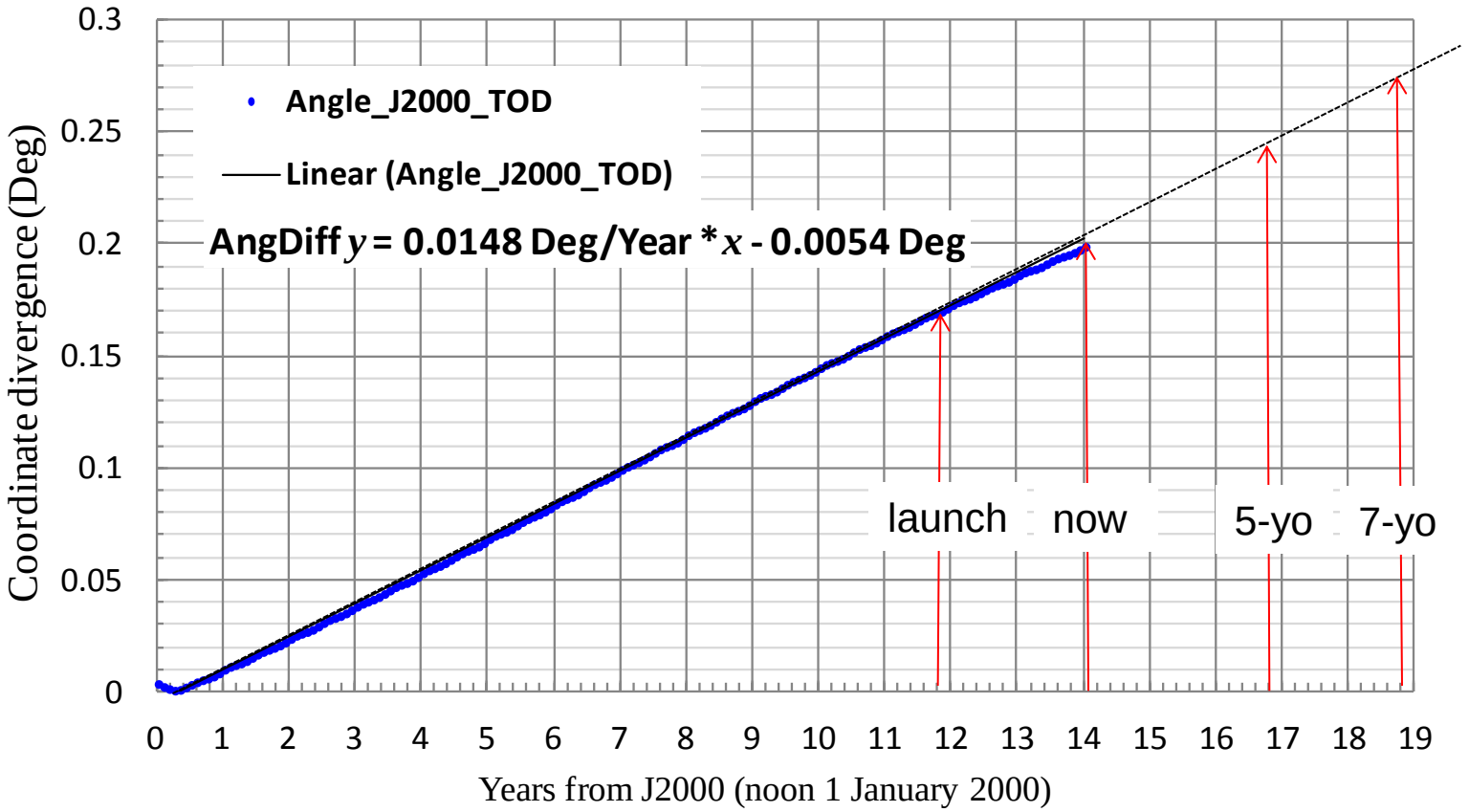
- The un-corrected DNB geolocation error depends on position off-nadir and terrain height
- DNB Geo LUTs updates based on coast areas (Thanks to NGAS)
- DNB TC geolocation products available from LPEATE since May 2013
- DNB TC geolocation products generated in IDPS **Mx8.4 22 May 2014**

TLE use and geolocation errors



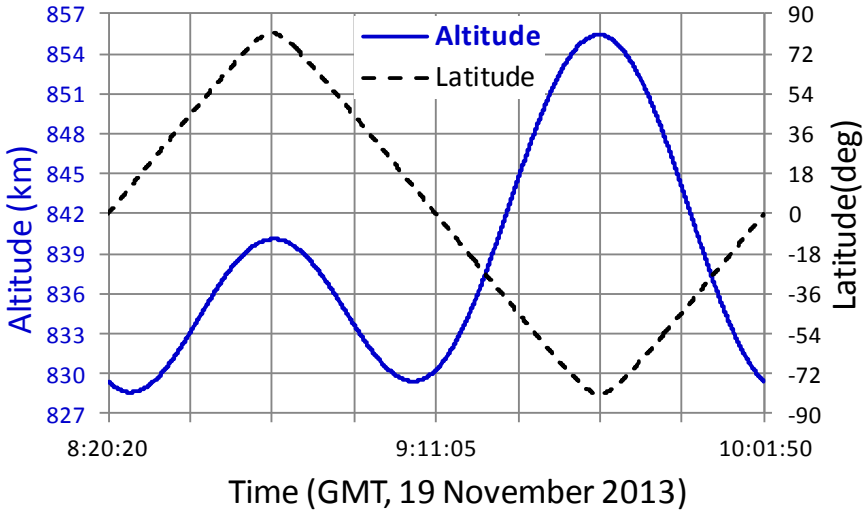
- TLE used in IDPS when SC diaries were delayed to and
- 314 days (periods 65-95, 395-501 & 620-795) of data checked
- 0.2% of scans used TLE backupdata =? Data availability loss
- Most of them occurred in whole-orbit chunks
- A CCR reduced geolocation bias from (up to) 20 km to (up to) 1.5 km on 10 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

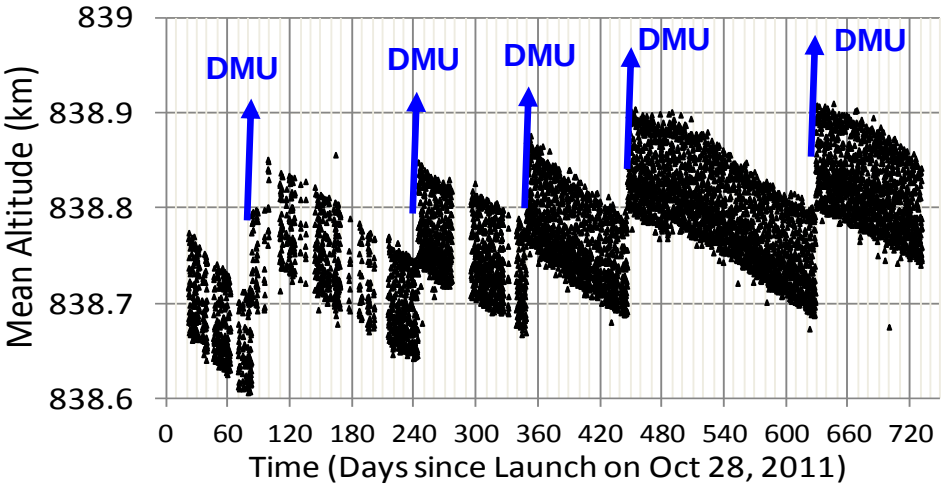
Solar & Lunar Vector Correction



- 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? μ =838.8 km





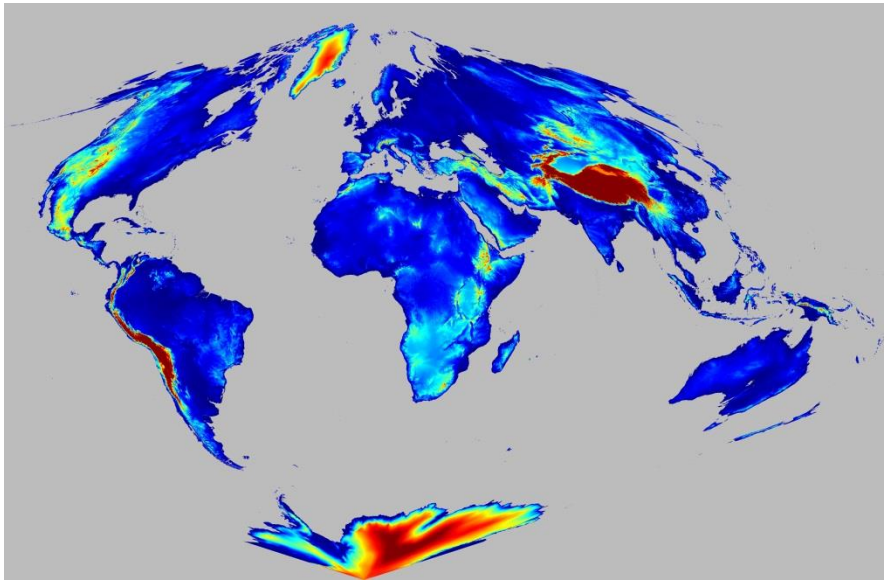
- Altitude (km)
  - Mean: 838.8 ±0.2 Peak-to-Valley
  - Min: 828.5 ±0.6 P-V; Max: 856 ±0.6 P-V; Equator: 829.8 ±1.0 P-V
- Drag make-up (DMU) maneuvers keeps altitude from falling and 16-day ground track repeatable (±20 km P-V)
- Local time of ascending node (LTAN) drifts from 13:25:24 in Nov 2011 westward 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 ±0.3 sec P-V
- Inclination angle drifts 98.65 → 98.72 deg (0.07 degrees more away from the poles) in 2 years, and continues to move away from the poles

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

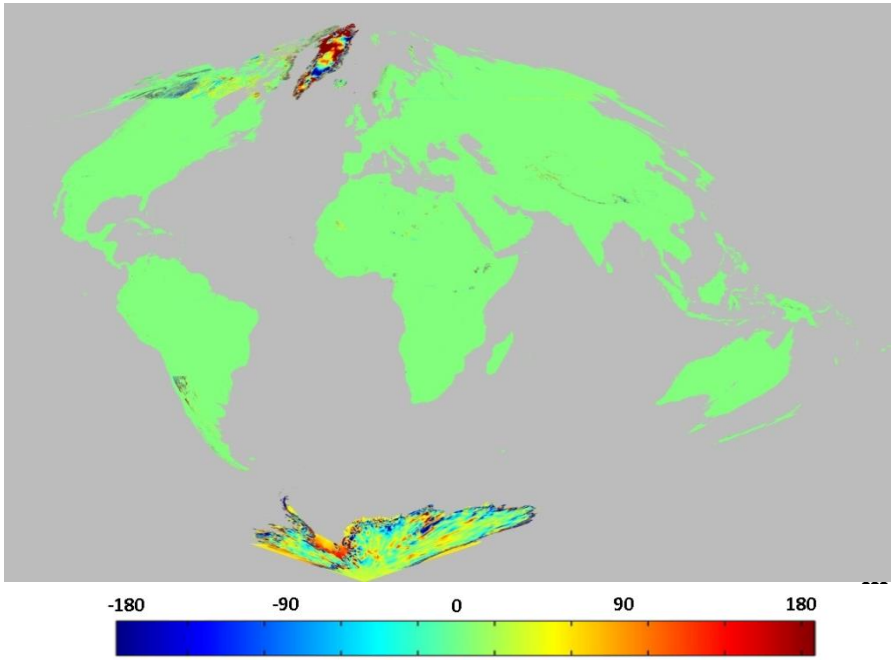
Old and new DEMs Analysis

500 m DEM used in MODIS C6



- MODIS C6 DEM, 1 km and 500 m resolution, from GMTED2010 http://pubs.usgs.gov/of/2011/1073/pdf/of2011-1073.pdf), **since November 2011, with equal area sinusoidal projection**
- MODIS C5 1 km DEM is used in **VIIRS, with polar stereographic projection**

DEM improvement, MODIS (C6-C5) height, 1 km cells



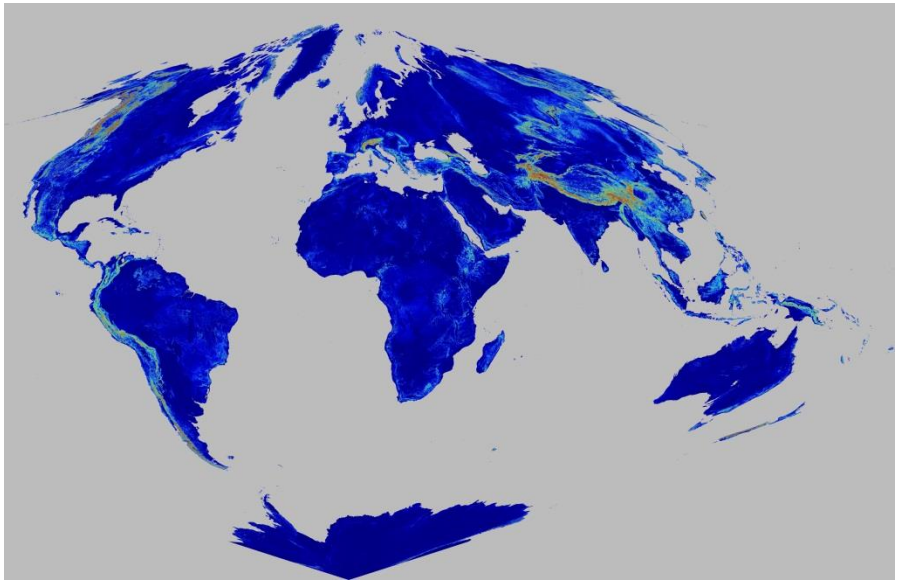
- 33.5% of land area has no change
- **13.7% of land area has a change ranges > 10 m**
- C6 DEM fixes some of the issues with C5 DEM in the non-polar regions
- **C6 DEM fixes extensive issues at the poles**

Within 60 deg latitudes

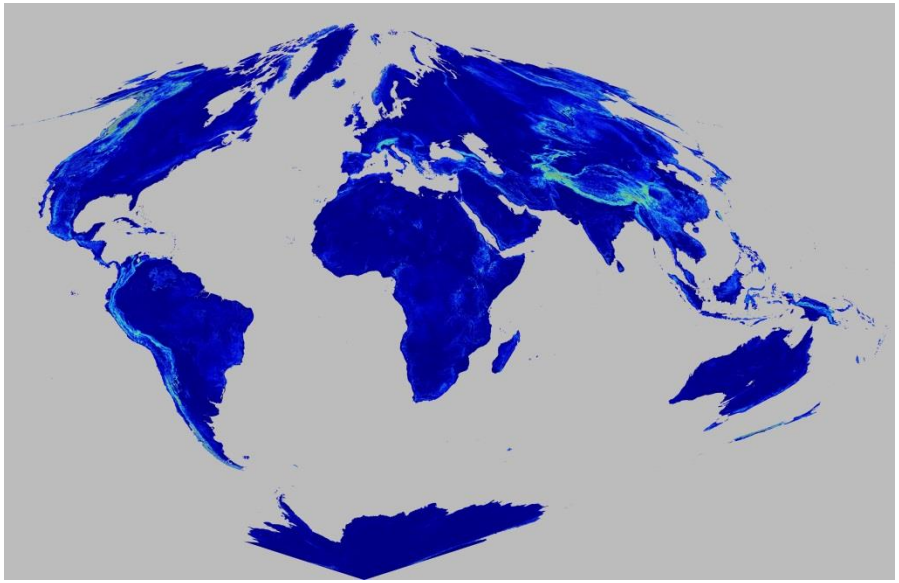
1. 40% of land area has no change
2. **2 % of land area has change > 10 m**

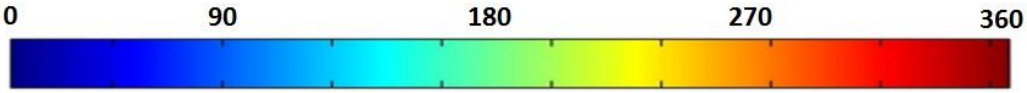
1 km vs. 500 m DEM

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

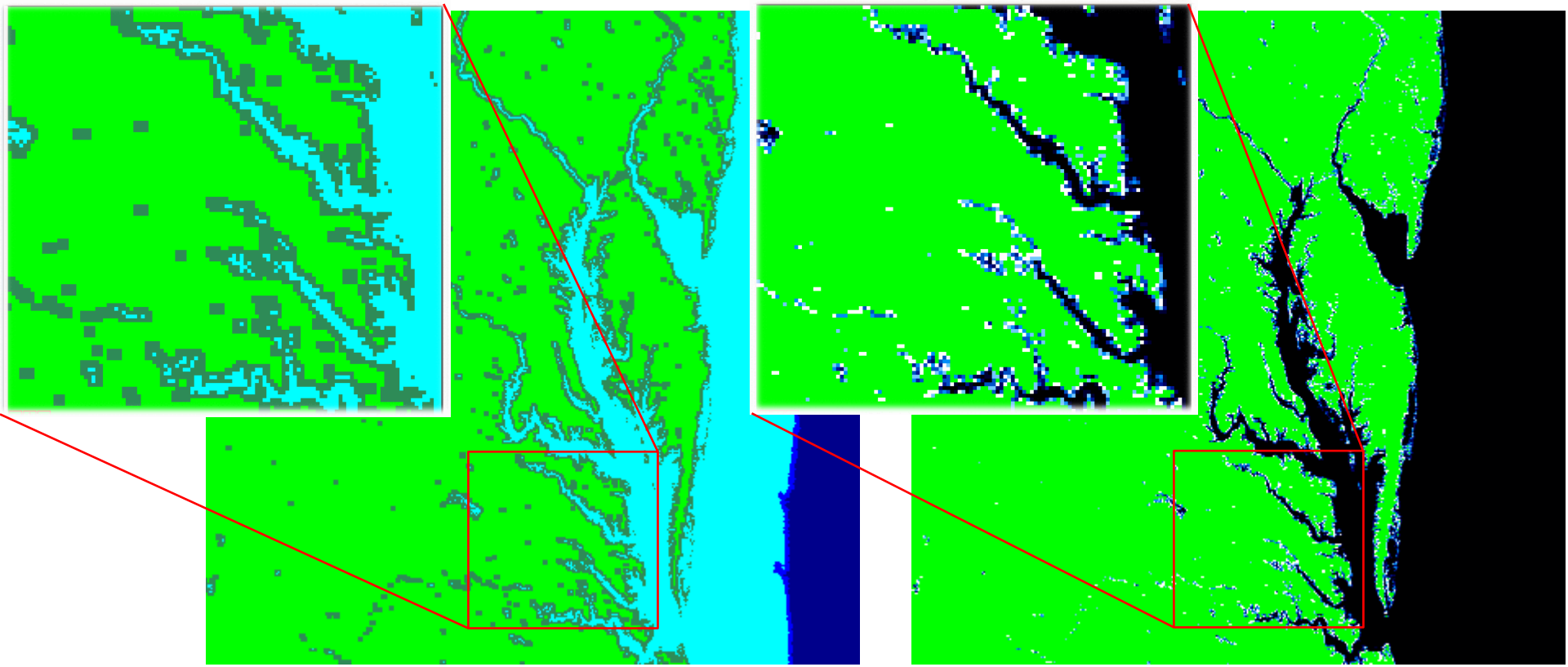
- **12% land area has a a diff of 50 m or more**
- 1.7% land area has a diff of 150 m or more

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

1 **8**

Experiment on DNB output format

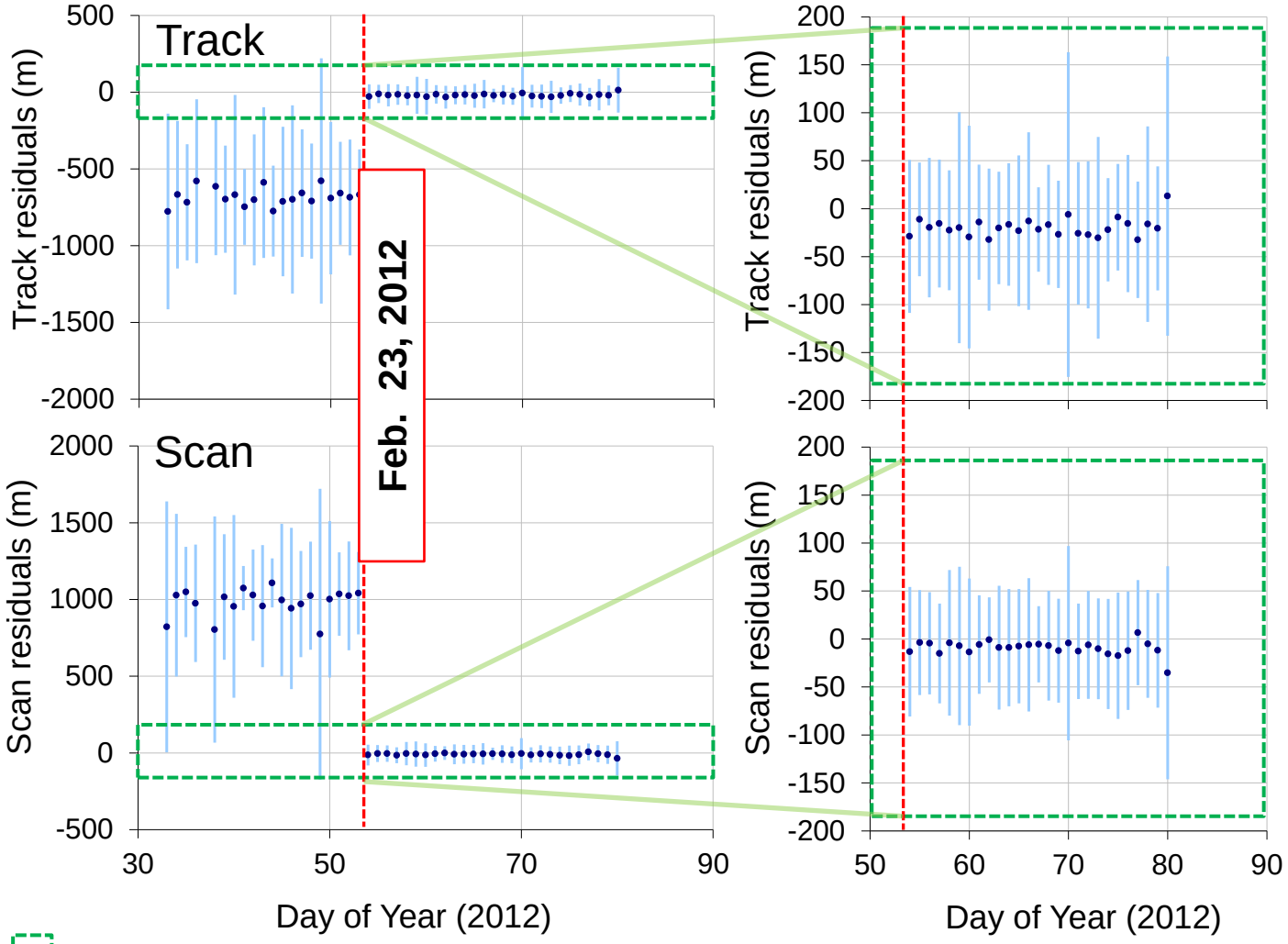
- Combined DNB TC Geo and Cal data
- Reformat: ~~FLOAT32~~INT16(solar/lunar/satellite zen/azi angles, height, sat-ground range) at pixel-level
- A whole day, 287 5-min granule files
- FLOAT32→ 100.97 GB
- INT16→ 36.77 GB
- 63.6% (35% from SciData, 29% from better HDF internal compression) savings in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

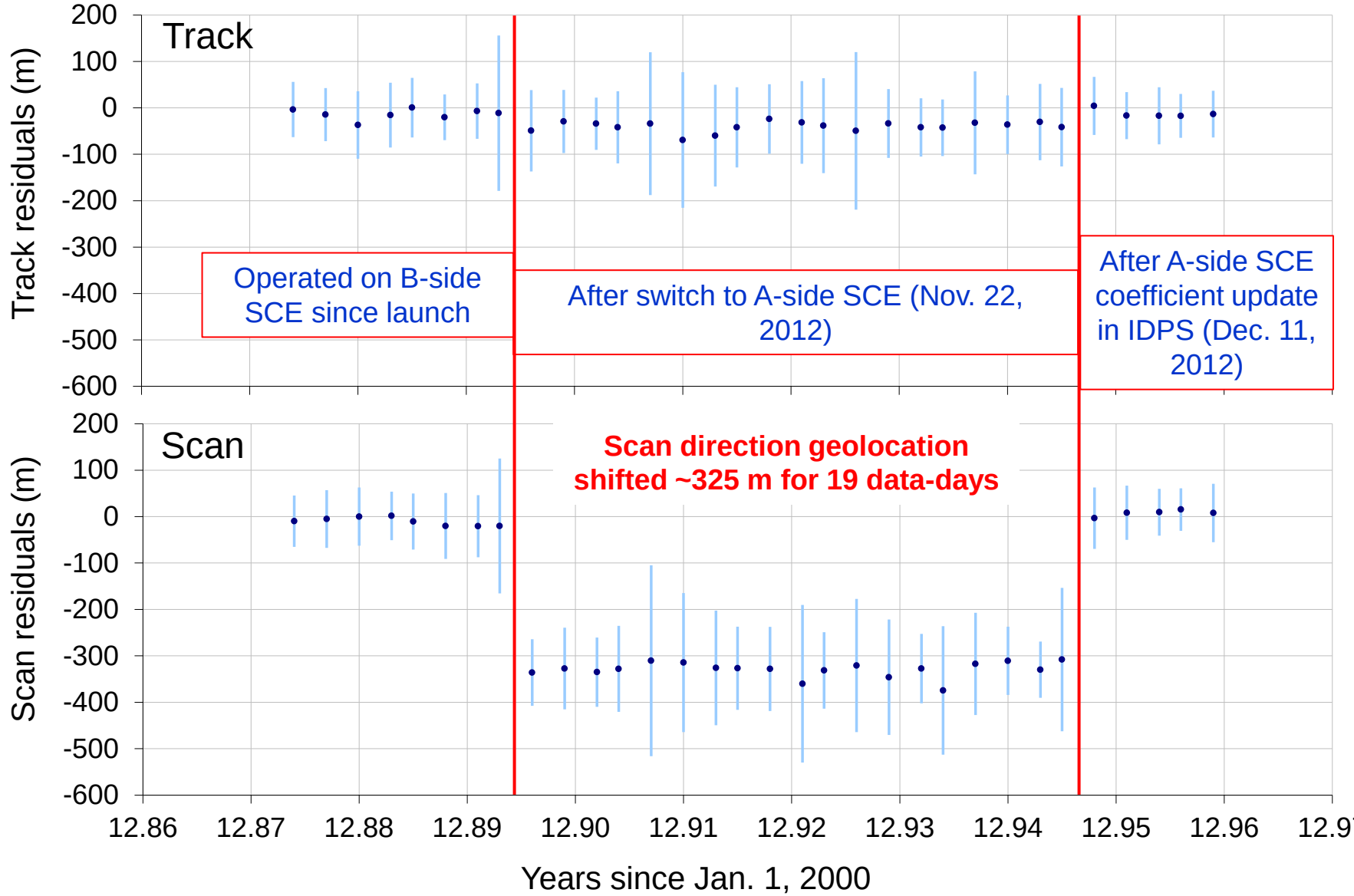
	Bias (m)	RMSE (m)
Track	-21	80
Scan	-8	64

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

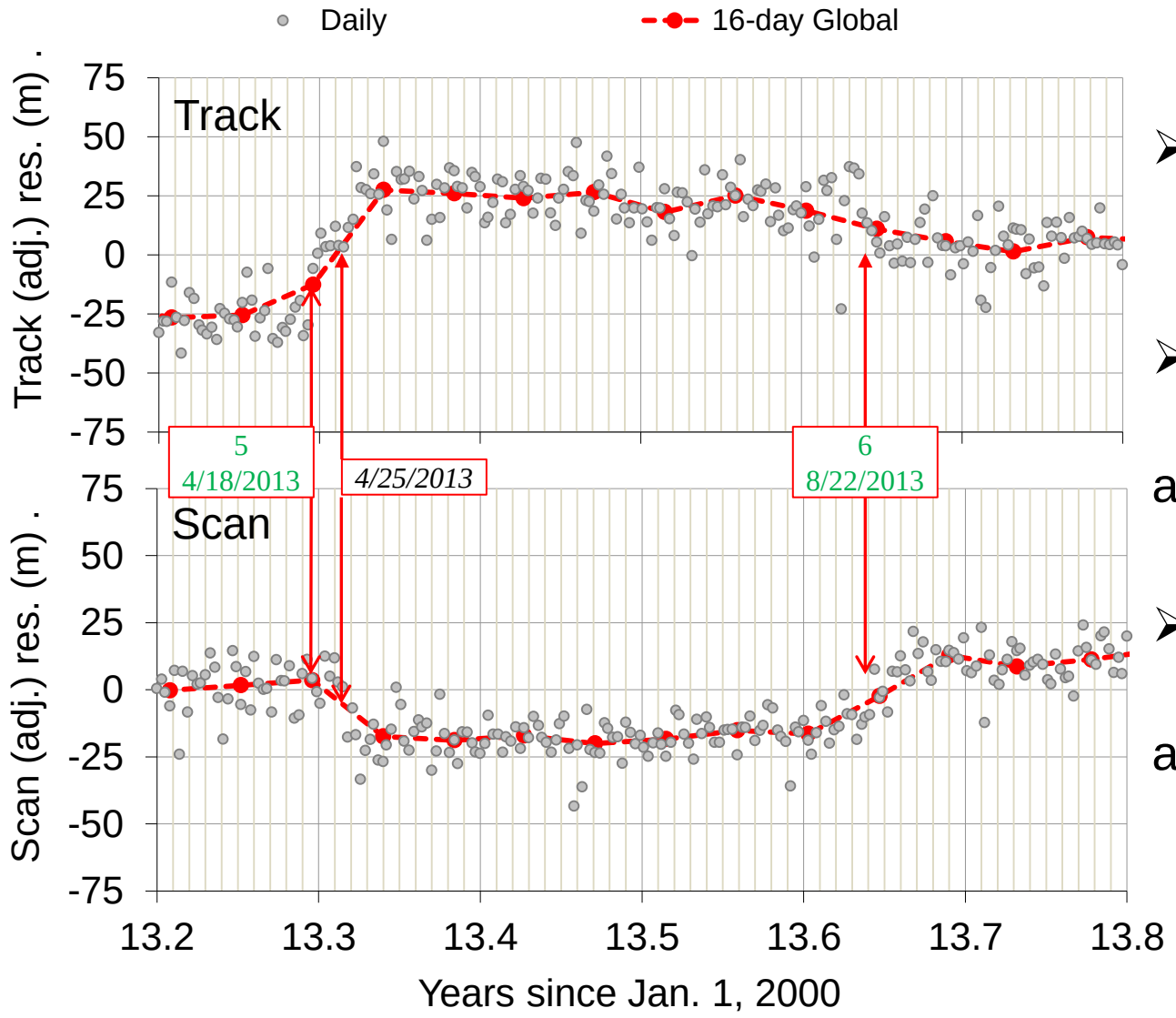
Nadir equivalent units;

Biases removed: Track -755 m, Scan 1118 m

Scan Control Electronics (SCE) Side Switch, Geolocation Error and Correction



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