MODIS Geolocation Status

MODIS Level 1 Workshop

January 30, 2008

Robert Wolfe, Mash Nishihama and James Kuyper

MODIS Geolocation Team

NASA GSFC Code 614.5

Geolocation C5 changes

- Incorporate new ancillary data
  - Shuttle Radar Terrain Mission (SRTM) Digital Elevation Model data
  - Land/water mask based on MODIS data from Boston University
- Updated ground control points based on GeoCover Landsat 7 products
- New flag (GeoloctionAccuracySuspect) identifying times near/after maneuvers
- Terra northern/southern hemisphere difference correction
  - using sun-angle dependent in-orbit correction
  - also, long-term trend updated (both Terra and Aqua)
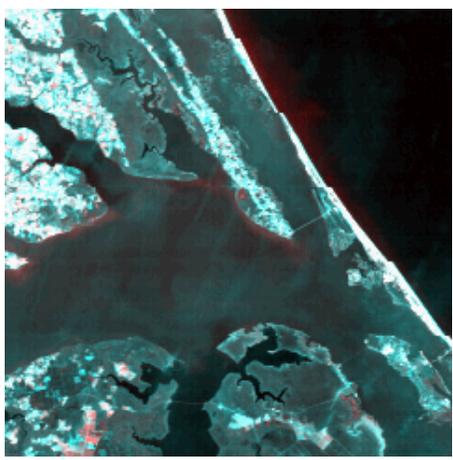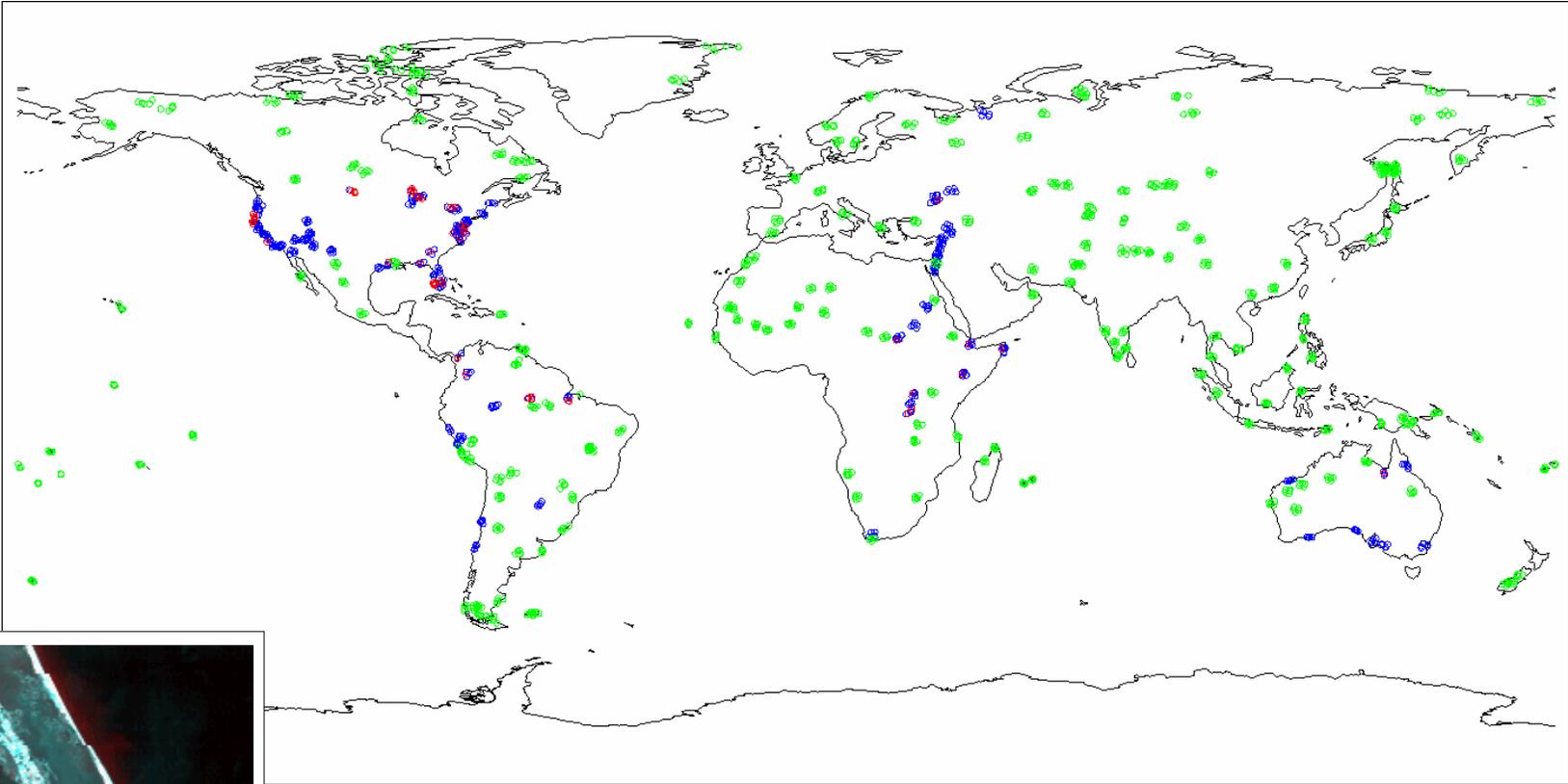
Ground Control Points (GCPs)

Image chips from Landsat TM/ETM scenes

51 chips removed (red) – C4 only
366 chips kept (blue) – C4 and C5
990 new chips (green) – C5 only

Geolocation C5 results

Terra

- Excellent results – C5 Root Mean Square (RMS) error in nadir equivalent units is better than accuracy goal
- Sun angle fit corrects for most of northern/southern hemisphere differences
- Large errors occur after orbit maneuvers (about 12 per year)
  - accuracy in following orbit suspect

Aqua

- Good results – C5 RMS error is better than goal in track direction but slightly over goal in scan direction (but much better than specification – 150 m)
- Small remaining northern/ southern hemisphere difference
- Definitive ephemeris is used for best results – causes up to 24 hr processing delay

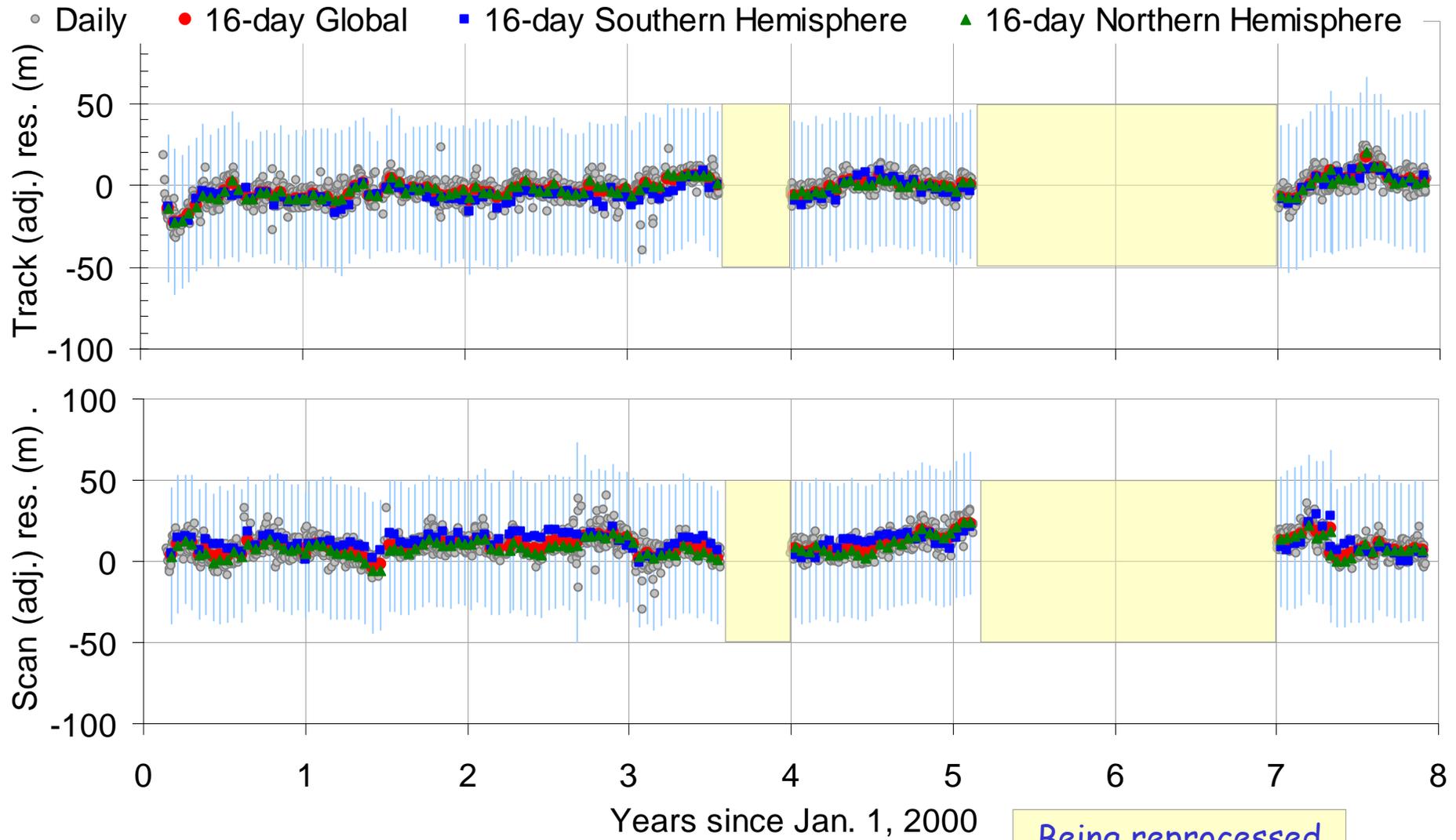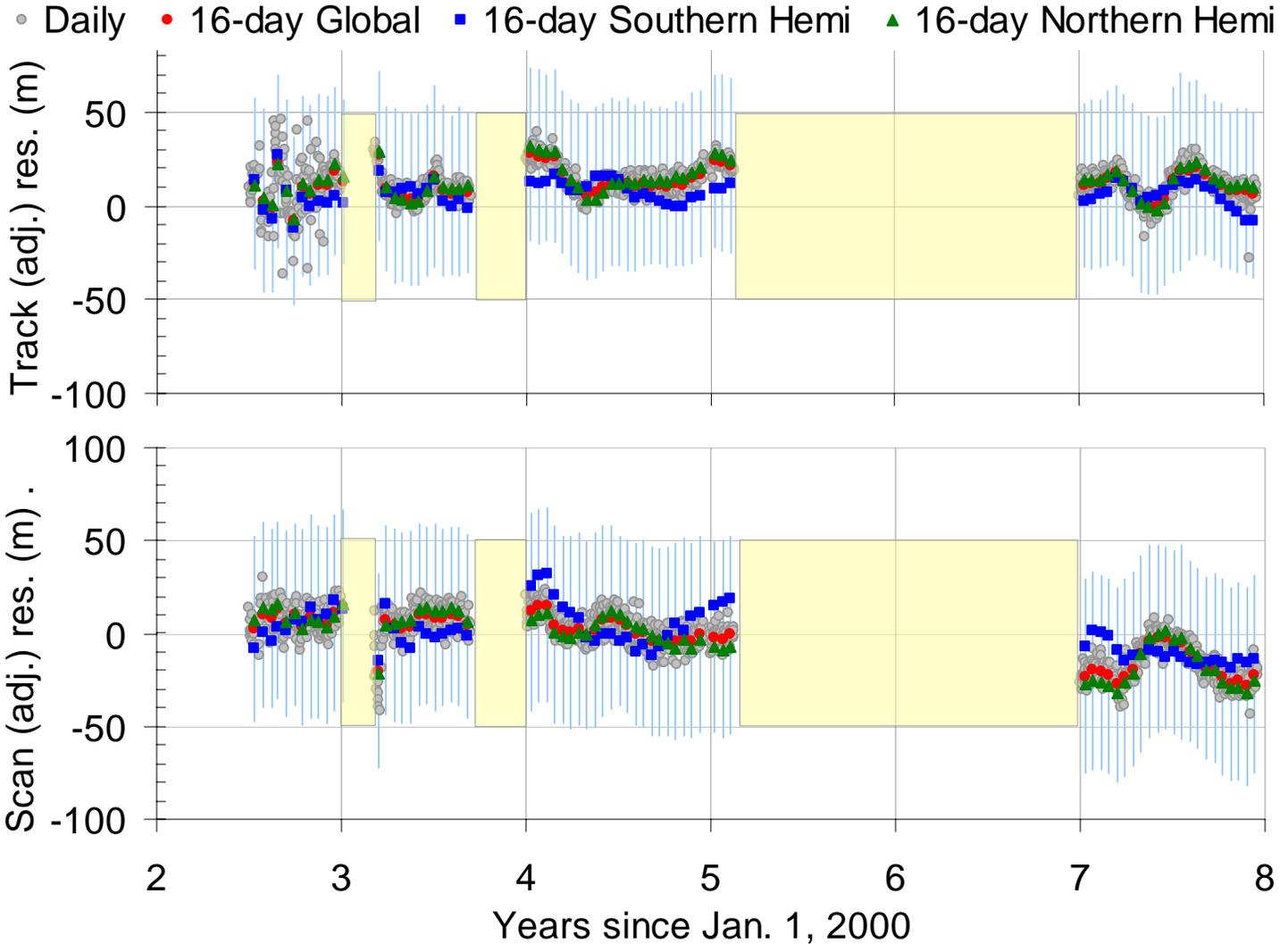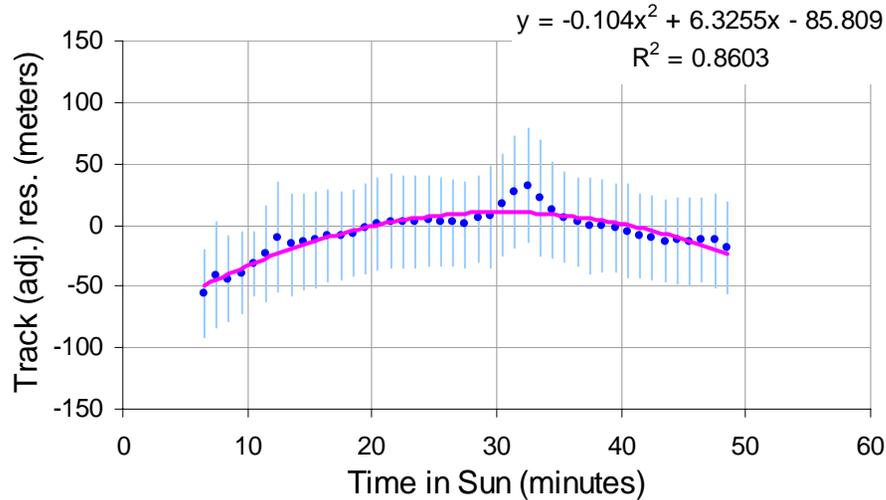|	Terra	Aqua
Along-track RMS error (m)	42	47
Along-scan RMS error (m)	43	52
Years (processed of total)	5.4 of 7.9	3.0 of 5.6
Ground Control Point Match-ups/day	272	233

Terra C5 residuals
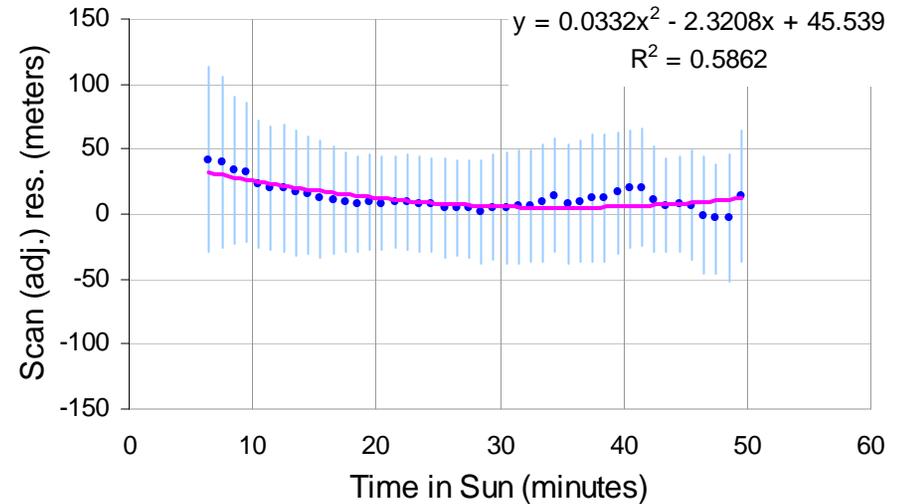
Aqua C5 residuals

Note northern & southern hemispherical differences

Terra C4 vs. C5 sun angle effect

C4

C5

$y = -0.104x^2 + 6.3255x - 85.809$
$R^2 = 0.8603$

$y = 0.0229x^2 - 1.5448x + 20.861$
$R^2 = 0.5131$

$y = -0.0947x^2 + 6.3162x - 91.205$
$R^2 = 0.8939$

$y = 0.0332x^2 - 2.3208x + 45.539$
$R^2 = 0.5862$

Small scan overcorrection in C5 – will be corrected in C6
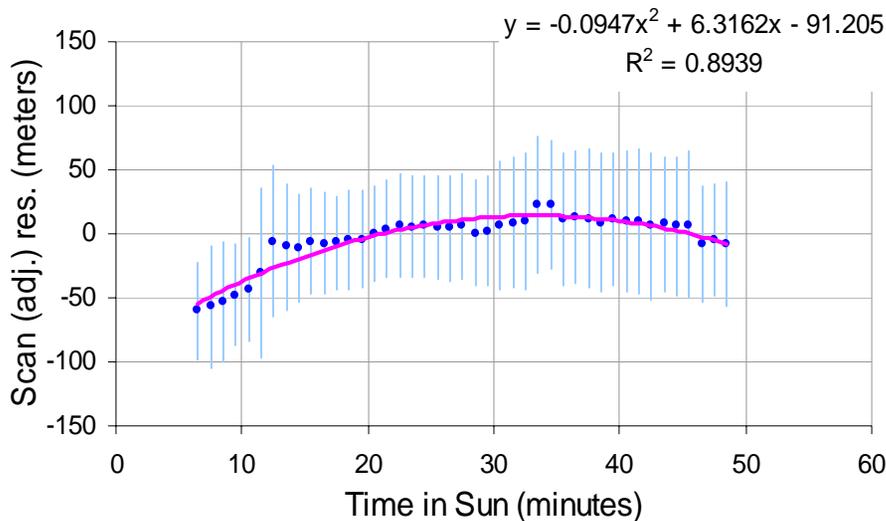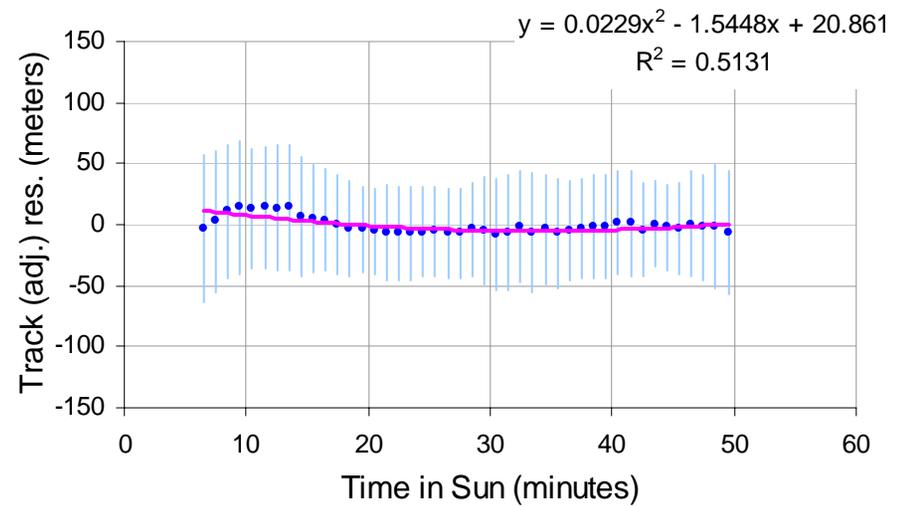
Aqua C5 sun angle effect

C5

Clear Track sun-angle effect in C5 – will be corrected in C6

$$y = 0.0465x^2 - 3.2727x + 61.313$$
$$R^2 = 0.9077$$

Scan sun-angle effect in C5, but starts at 10°, not 0° – could be corrected in C6

$$y = -0.0511x^2 + 3.3779x - 51.8$$
$$R^2 = 0.7412$$
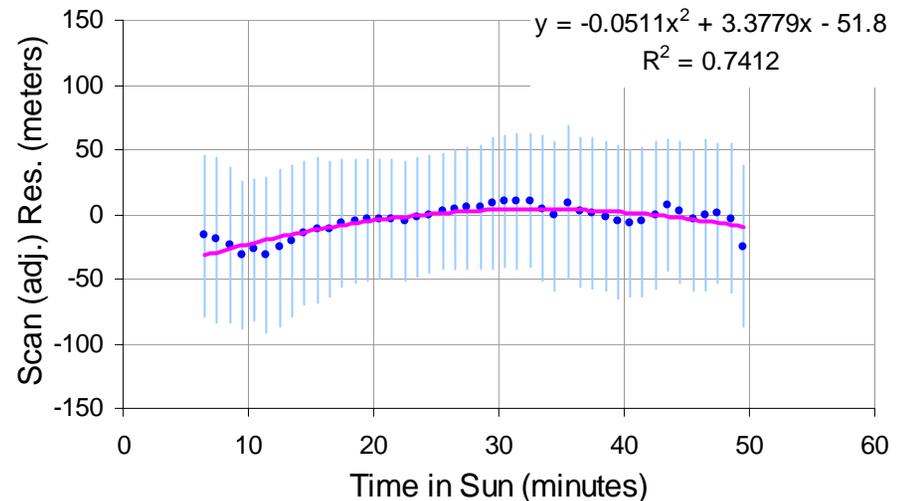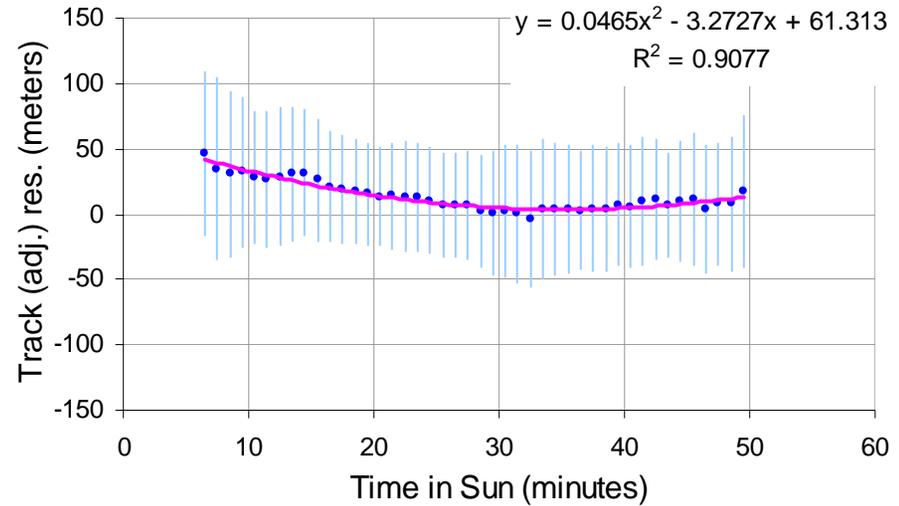
Terra Maneuvers

- In 2007 Land science team noticed that in Terra C5 large geolocation errors were occurring near maneuvers were causing problems in the L3+ Land products
    - C4 also had this problem
- Plans had been made for C5 to exclude data near maneuvers from the Land daily and multi-day products
    - However, this was not fully implemented (or tested)
    - Also, the maneuver table contained errors
- LDOPE began routinely screening data near maneuvers to attempt to exclude this data from daily and higher level products
- In parallel, the geolocation team began to re-examination the issue of which ephemeris and attitude sources should be used near maneuvers

Ephemeris/Attitude File Types

- Available from the GDAAC (aka. GES DISC)
  - Must be in SDP Toolkit ephemeris/attitude format
- L0 files (APID4) containing TONS data from EDOS
  - A0 Attitude (AM1ATTN0) – angles limited to ± 2048 arcsec
  - E0 Ephemeris (AM1EPHN0)
- "Definitive" attitude files from Flight Dynamics (FDD)
  - AF Attitude (AM1ATTNF) – angles not limited
- Definitive ground based ephemeris files from FDD
  - EF Ephemeris (AM1EPHNF)
    [The original name AM1EPHNF was changed to AM1EPHN0 to support needs of the GDAAC. Now that PGE01 is run by MODAPS, we are returning to back to AM1EPHNF.]
  - Generated only upon request;
    routinely requested when E0 has >= 1% missing data

Terra Maneuvers – History

- Originally, PGE01/Geolocation production rules favored AF and EF over A0 and E0, on the assumption that "definitive" data was better than raw data
- In late 2000, it was discovered that the predicted ephemeris inputs used to perform coordinate conversions during the creation of AF files rendered them less accurate than A0 files, and PGE01 production rules were changed to prefer A0 files
- Exception: the GDAAC was asked to use AF during maneuvers, when A0 data is less accurate due to angle limits [For unknown reasons, this was never actually done]
- In late 2007, geolocation inconsistencies related to maneuvers led to a re-examination of the issue of which ephemeris and attitude sources should be used, and whether the answer to that question was different for different types of maneuvers, or during particular time periods associated with the maneuvers

Terra Maneuvers – Analysis

- For every maneuver, FOT announces an associated time period during which there is expected to be a loss of pointing accuracy (LPA)
- For three types of maneuvers, ephemeris and attitude files of all four types were collected covering the entire LPA period, and in some cases a two-hour time period before or after the LPA period [Logistics prevented a larger sample size]
- MODIS control points were used to assess the accuracy of each of four combinations of attitude and ephemeris files
- The number of successful control point matches proved to be the best indicator of the accuracy of each source; the actual control point residuals when a match was found showed no clear pattern

Terra Maneuvers – Conclusions

- AF files contain implausibly large pre-maneuver values, and implausible discontinuities at granule boundaries [FDD is investigating]

- EF does not produce significantly better results than E0

- A0 files usually produce more accurate results than AF files

- For thrust maneuvers, during the post-maneuver LPA period:
  - EF produce significantly worse results than E0
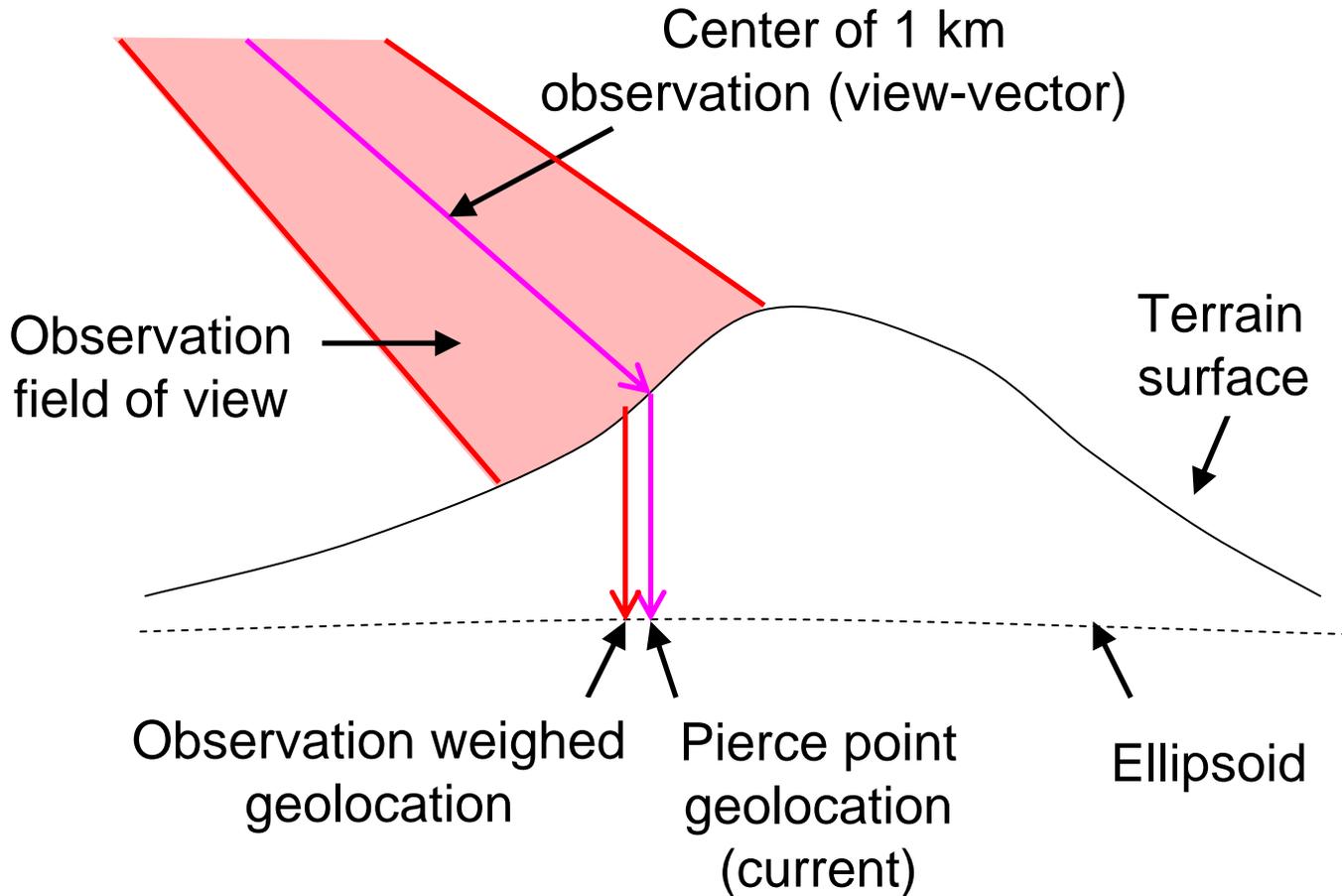 - AF produce slightly more accurate results than A0

Terra Maneuvers – C5 Handling

- Terra PGE01 production rules are being modified so that:
  - AF will be used from the maneuver start to end
  - For thrust maneuvers, AF will be used until the end of the period of loss of pointing accuracy
  - In all other cases, A0 will be used
  - E0 files will always be used, the EF files will never be used (except when it is the only ephemeris available)
- Definitive maneuver lists (for both Aqua and Terra) have now been obtained from FOT
- Atmosphere will hide L2+ products when geolocation errors exceed 1km
- Land will set QA low flags on L2+ products during times when the geolocation errors exceed(ed) specification (150m)
  - Land will continue to work to exclude this data from L3 products
- Geolocation team will determine if additional special handling for Aqua maneuvers is needed
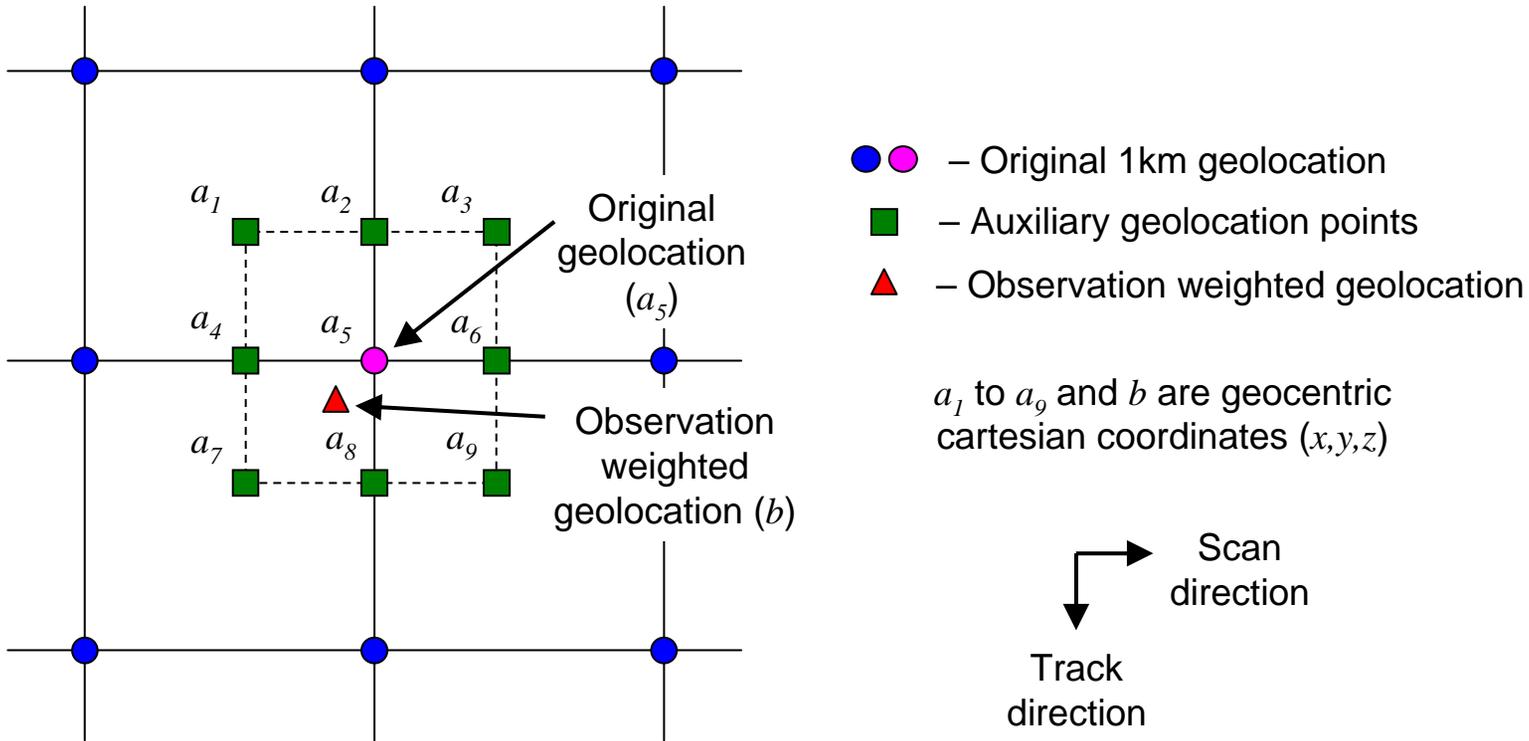
Enhanced terrain correction (area based)

Center of 1 km
observation (view-vector)

Observation
field of view

Terrain
surface

Observation weighed
geolocation

Pierce point
geolocation
(current)

Ellipsoid

First order method

a_1 a_2 a_3

a_4 a_5 a_6

a_7 a_8 a_9

Original geolocation (a_5)

Observation weighted geolocation (b)

⬤🟣 – Original 1km geolocation

🟩 – Auxiliary geolocation points

🔺 – Observation weighted geolocation

a_1 to a_9 and b are geocentric cartesian coordinates (x,y,z)

Scan direction

Track direction

The first order approximation of the observation weighted point is:

$$b = \frac{(a_1 + a_4 + a_7 + a_3 + a_6 + a_9)\, w_1 + (a_2 + a_5 + a_8)\, w_2}{6\, w_1 + 3\, w_2}$$

where $w_1 = 1/4$ and $w_2 = 1/2$. These weights simulate the triangular time-integrated Point Spread Function (PSF) in the scan direction and the rectangular PSF in the track direction.

Global terrain elevation height variation

Local variation in global terrain height calculated by taking the difference between the minimum and maximum terrain height within each 5.6 km grid cell in an equal area grid
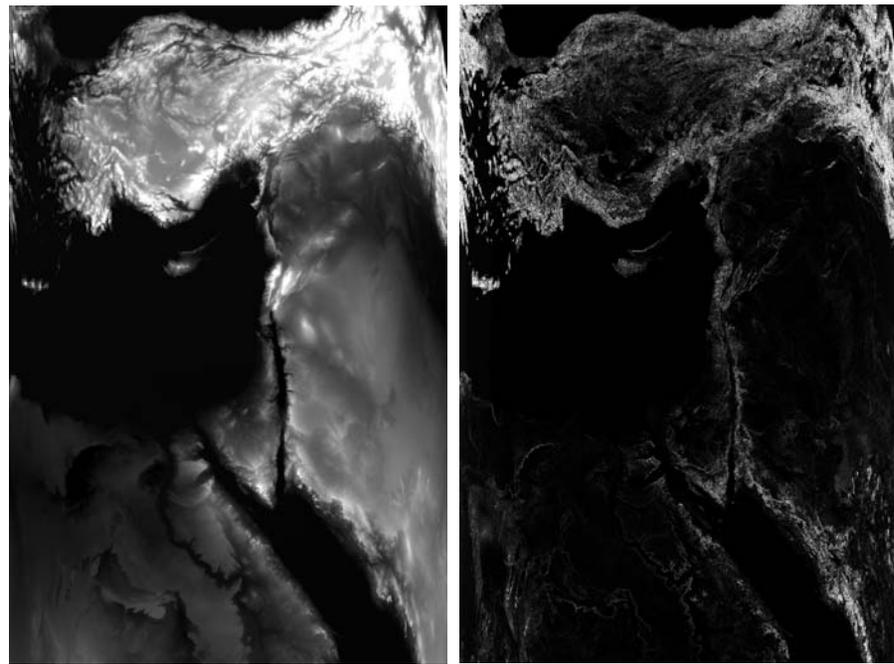

0 ▬▬▬▬▬▬▬▬▬▬▬ 1281m
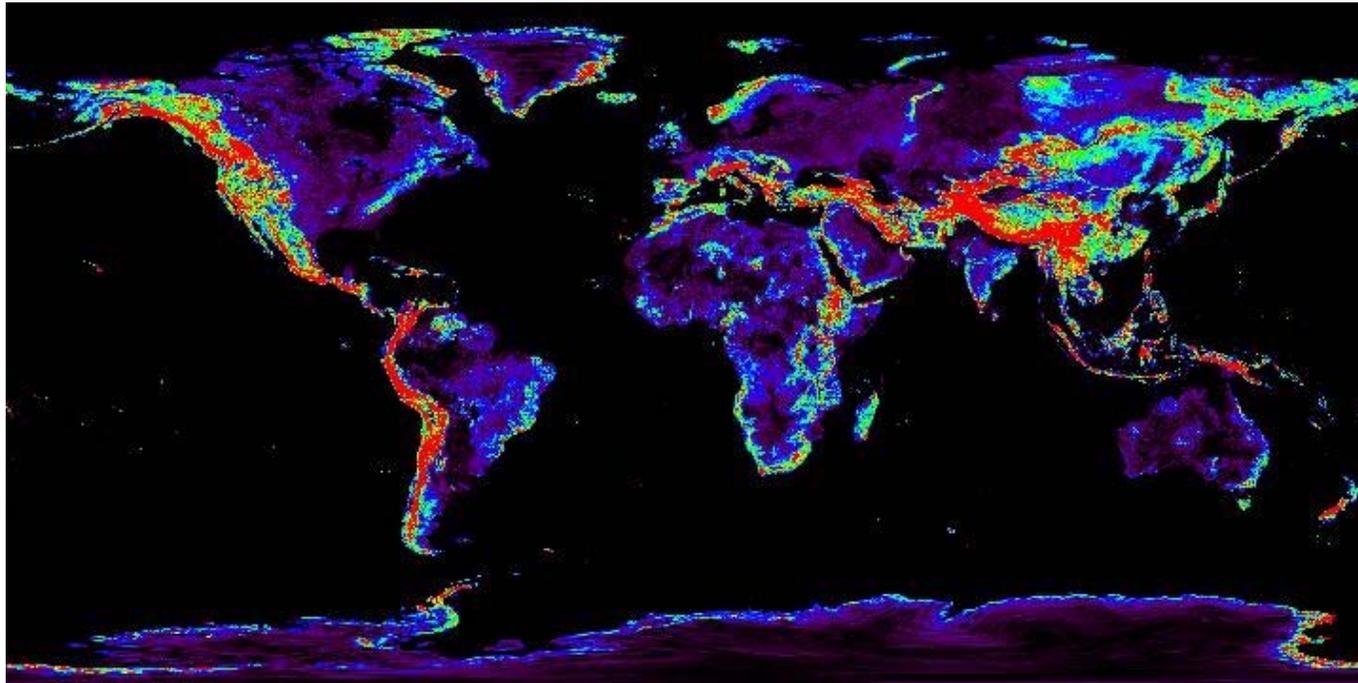
Over the land area, the local variation is
250m or more over 19% of the area, and
500m or more over 9% of the area
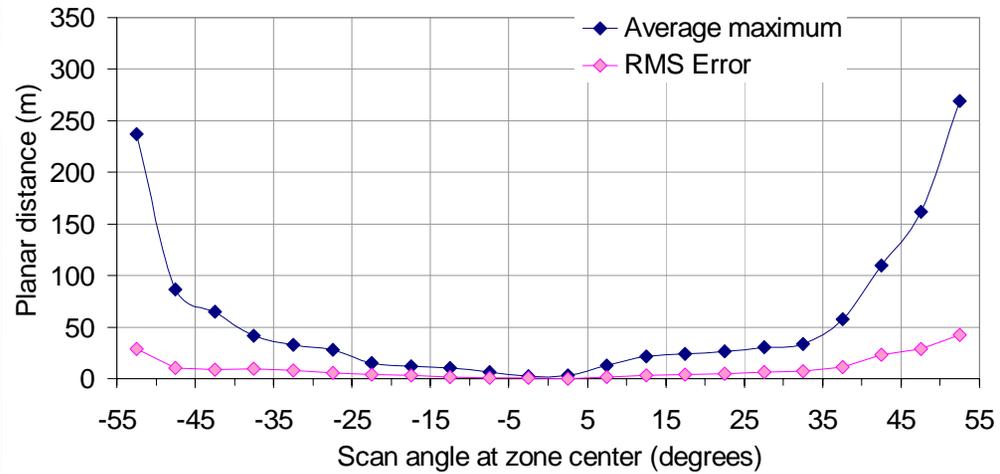
2001/199.0840
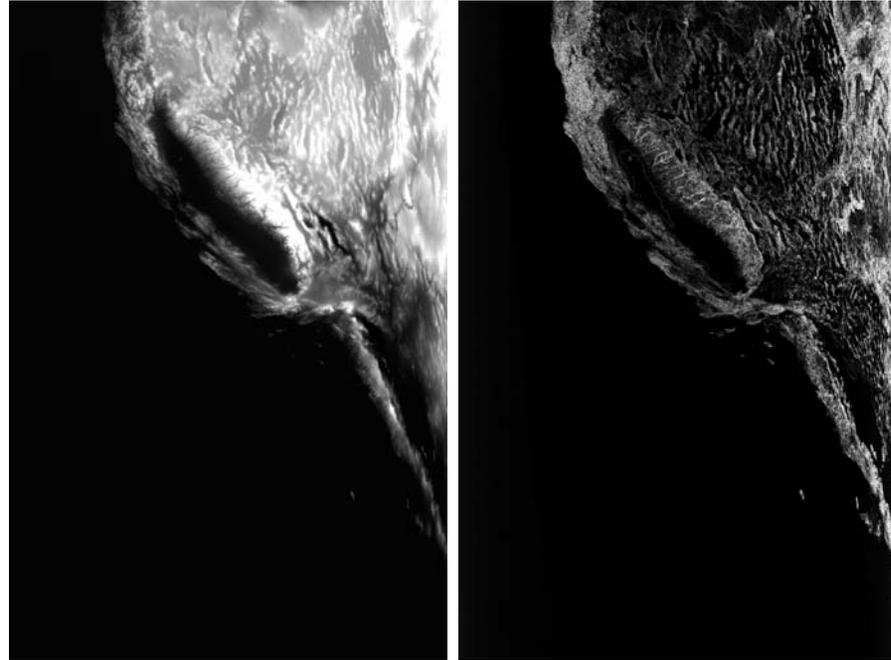

Geolocation Elevation
(black: -27m, white: 2069m)

Geolocation difference
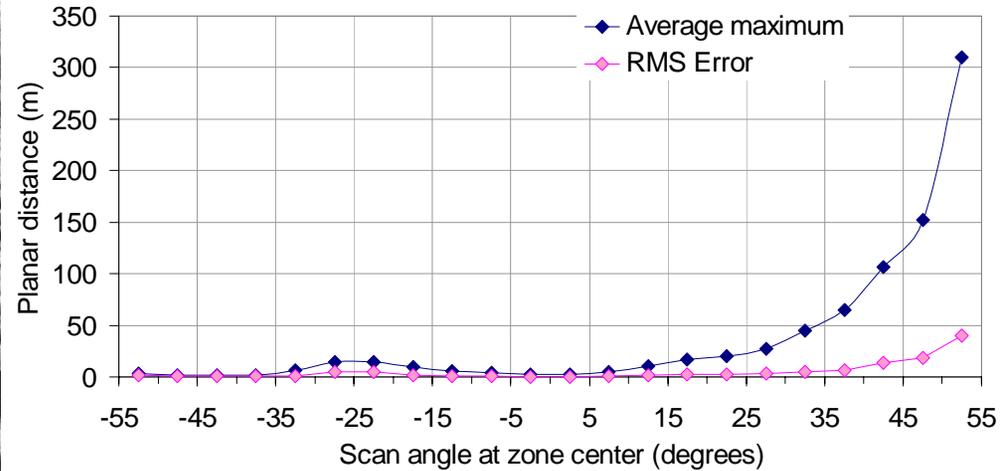current minus obs. weighted
(black: 0m, white: 52m)

2005/229.1855

Geolocation Elevation
(black: -75m, white: 2341m)

Geolocation difference
current minus obs. weighted
(black: 0m, white: 42m)

1. Update error analysis
   - based on C5 residuals, update long-term trend, biases and sun-angle corrections
2. Incorporate new ancillary data
   a. Shuttle Radar Terrain Mission (SRTM) Digital Elevation Model data (500m below 60 latitude?)
   b. Land/water mask based on SRTM (or other) data (500m?)
3. Updated ground control points based on improved GeoCover Landsat 7 products
4. Further improve maneuver handling
5. Compute 500 m geolocation (using 500m SRTM) and provide in the form of 8-bit offsets from a bilinear-interpolation of the 1 km data
6. Enhanced 1 km terrain correction (area based)
   - less additional computation needed if combined with # 5
7. Develop and implement an algorithm to remove the AMSR-E jitter from the along-scan mirror motion for MODIS/Aqua

8. Write spacecraft temperature to geolocation product, for transfer to the Control Point Residuals file, to better characterize thermal effects on geolocation accuracy

9. Write the solar elevation correction (roll, pitch and yaw) to geolocation product, for transfer to the Control Point Residuals files

10. Add a scan SDS reporting the quality and type of the ephemeris/attitude data used in our calculations

11. Correct the setting of *attitQuat* when EA Source is "MODIS Packet" (of interest only for Direct Broadcast users). When that source is used, the *attitQuat* is currently set to a constant value indicating nominal orientation (roll, pitch, and yaw are all zero). *attitQuat* is used only in the calculation of the solar "elevation" angle correction.

Questions?