MODIS Geolocation Status

MODIS Science Team Meeting
Calibration Breakout Session

April 17, 2013

Robert Wolfe,
Mash Nishihama and
James Kuyper

MODIS Geolocation Team

NASA GSFC Code 619
Ground Control Points (GCPs)

1214 GCPs

Image chips from Landsat TM/ETM scenes
Geolocation C5/C6 results

Terra

- Excellent results – Root Mean Square Error (RMSE) in nadir equivalent units is better than accuracy goal
- Large errors occur ~1.5 hr after maneuvers (about 12 per year)
  - accuracy in following orbit suspect

Aqua

- Good results – RMSE is better than goal in track direction but slightly over goal in scan direction (but much better than specification – 150 m)
- Definitive ephemeris is used for best results – causes up to 24 hr processing delay

<table>
<thead>
<tr>
<th>Terra</th>
<th>Aqua</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>C6</td>
</tr>
<tr>
<td>Along-track RMSE (m)</td>
<td>43</td>
</tr>
<tr>
<td>Along-scan RMSE (m)</td>
<td>44</td>
</tr>
<tr>
<td>Years of Data</td>
<td>13.1</td>
</tr>
<tr>
<td>Ground Control Point Match-ups/day</td>
<td>263</td>
</tr>
</tbody>
</table>

Note: These results are for MODIS Band 1, which is used in the control point matchup. Other bands must be offset by the band-offsets published by the MODIS calibration team.
Terra trend and update details
Terra long-term trend (w/o correction)

RMSE with no correction:  Track: 49 m (+7 m vs C6)  Scan: 47 m (+5 m vs C6)
Actual Terra C5 residuals

C5 RMSE  Track: 43 m  Scan: 44 m
Terra C6 residuals (estimated)

C6 RMSE  Track: 42 m (-1 m vs C5)  Scan: 42 m (-2 m vs C5)
Terra Sun angle Correction

**Used in C5**

**Track (from C4 fit)**

- \[ y = -0.0074x^2 + 1.2704x - 44.415 \]
- \( R^2 = 0.8514 \)

**Scan (from C4 fit)**

- \[ y = -0.0068x^2 + 1.3044x - 49.118 \]
- \( R^2 = 0.8886 \)

**Used in C6**

**Track (from C5 fit)**

- \[ y = -0.0025x^2 + 0.5511x - 22.682 \]
- \( R^2 = 0.7863 \)

**Scan (from C5 fit)**

- \[ y = -0.0031x^2 + 0.7185x - 34.362 \]
- \( R^2 = 0.8647 \)

Small overcorrection in C5 – was corrected in C6
Terra C6 geometric parameter changes

- **Change in geometric biases and scan mirror rate**
  - Based on global hierarchical maximum decent search
  - Main changes in track direction are in split between spacecraft to instrument pitch and telescope tilt values
  - Small changes to mirror parameters (alpha, beta and gamma)
  - Sample time bias (delta added to nominal 333.333 µsec)

<table>
<thead>
<tr>
<th>Bias</th>
<th>Units</th>
<th>C5</th>
<th>C6</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>s/c to inst – roll</td>
<td>arcsec</td>
<td>251.8</td>
<td>251.8</td>
<td>0.0</td>
</tr>
<tr>
<td>s/c to inst – pitch</td>
<td>arcsec</td>
<td>83.4</td>
<td>129.4</td>
<td>46.0</td>
</tr>
<tr>
<td>s/c to inst – yaw</td>
<td>arcsec</td>
<td>97.9</td>
<td>97.9</td>
<td>0.0</td>
</tr>
<tr>
<td>mirror – alpha</td>
<td>arcsec</td>
<td>-4.1</td>
<td>-3.3</td>
<td>0.8</td>
</tr>
<tr>
<td>mirror – beta</td>
<td>arcsec</td>
<td>38.0</td>
<td>40.0</td>
<td>2.0</td>
</tr>
<tr>
<td>mirror – gamma</td>
<td>arcsec</td>
<td>-0.6</td>
<td>-0.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>telescope – tilt</td>
<td>arcsec</td>
<td>-180.6</td>
<td>-218.7</td>
<td>-38.1</td>
</tr>
<tr>
<td>sample time (delta)</td>
<td>µsec</td>
<td>0.0</td>
<td>3.1</td>
<td>3.1</td>
</tr>
</tbody>
</table>
Aqua trend and update details
Aqua Long-term Trend (w/o Correction)

RMSE with no correction: Track: 60 m (+15 m vs C6)  Scan: 56 m (+5 m vs C6)
Actual Aqua C5 residuals

Years since Jan. 1, 2000

Track (adj.) res. (m).
-75 -50 -25 0 25 50 75

Scan (adj.) res. (m).
-75 -50 -25 0 25 50 75

Daily 16-day Global 16-day Southern Hemisphere 16-day Northern Hemisphere

C5 RMSE  Track: 48 m  Scan: 53 m
Aqua C6 residuals (estimated)

C6 RMSE  Track: 46 m (-2 m vs C5)  Scan: 51 m (-2 m vs C5)
Aqua Sun angle Correction

Track and Scan sun-angle effects
- no correction in C5
- used in C6
Aqua C6 geometric parameter changes

- Change in geometric biases and scan mirror rate
  - Based on global hierarchical maximum decent search
  - Small changes to telescope tilt and mirror parameters (alpha, beta and gamma)
  - Sample time bias (delta added to nominal 333.333 µsec)

<table>
<thead>
<tr>
<th>Bias</th>
<th>Units</th>
<th>C5</th>
<th>C6</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>s/c to inst – roll</td>
<td>arcsec</td>
<td>409.6</td>
<td>409.6</td>
<td>0.0</td>
</tr>
<tr>
<td>s/c to inst – pitch</td>
<td>arcsec</td>
<td>582.1</td>
<td>582.1</td>
<td>0.0</td>
</tr>
<tr>
<td>s/c to inst – yaw</td>
<td>arcsec</td>
<td>-76.3</td>
<td>-76.3</td>
<td>0.0</td>
</tr>
<tr>
<td>mirror – alpha</td>
<td>arcsec</td>
<td>-5.6</td>
<td>-6.2</td>
<td>-0.6</td>
</tr>
<tr>
<td>mirror – beta</td>
<td>arcsec</td>
<td>37.1</td>
<td>37.0</td>
<td>-0.1</td>
</tr>
<tr>
<td>mirror – gamma</td>
<td>arcsec</td>
<td>-6.4</td>
<td>-5.9</td>
<td>0.5</td>
</tr>
<tr>
<td>telescope – tilt</td>
<td>arcsec</td>
<td>-422.2</td>
<td>-420.6</td>
<td>1.6</td>
</tr>
<tr>
<td>sample time (delta)</td>
<td>µsec</td>
<td>0.0</td>
<td>6.6</td>
<td>6.6</td>
</tr>
</tbody>
</table>
C6 Changes - Algorithm (Science)

1. Update error analysis: use C5 residuals to update long-term trend, sun-angle corrections and geometric parameter biases

2. Incorporate new ancillary data
   a. Improved 500m Shuttle Radar Terrain Mission (SRTM) Digital Elevation Model data
   b. Improved Land/water mask (500m) developed by UMD

3. Compute 500m geolocation and provide in the form of 8-bit offsets from a bilinear-interpolation of the 1 km data

4. Enhanced 1 km terrain correction (area based)
   - synergistic with 500m geolocation, since weighted average of 500m pixel centers is used to approximate 1km time-integrated weighting function
C6 observation weighted terrain correction

Center of 1 km observation (view-vector)

Observation field of view

Terrain surface

Observation weighed geolocation (C6)

Pierce point geolocation (C5)

Ellipsoid
Observation weighted terrain correction

The first order approximation of the observation weighted point is:

\[
b = \frac{\left( a_1 + a_3 + a_4 + a_6 \right) w_1 + \left( a_2 + a_5 \right) w_2}{4 w_1 + 2 w_2}
\]

where \( w_1 = 1 \) and \( w_2 = 2 \). These weights approximate the **triangular** time-integrated weighting function in the **scan** direction and the **rectangular** weighting function in the **track** direction.
Example: Terra - Middle east

2001/199.0840

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

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

New for C6: 500m geolocation (pierce point)
is also available, stored as offsets from
1km geolocation (observation weighed)
New C6 DEM

• Current C5 DEM
  – SRTM based gap filled
  – Uncertain about the heritage of the approach to reducing resolution and gap filling
  – Only available at 30 arc-sec (~1km) DEM

• New C6 DEM (Source: USGS and NGA, Danielson et al.)
  – Being used at 15 arc-sec (~500m)
  – Better data is now available for gap filling
  – Using best available approach to reducing resolution and gap filling
Old vs. New DEM

MODIS Geolocation Height (data-day 2010/221)

Current DEM (C5)

New DEM (C6)
New Land Water Mask in C6 MOD03

Terra Granule 19:25, Day 2003-193

C5

C6

- Shallow Ocean
- Land
- Coastline/shoreline
- Shallow Inland Water
- Ephemeral Water
- Deep Inland Water
- Moderate Ocean
- Deep Ocean
Water present method at 1km

The water present value \( b \) (range 0 to 8) is

\[
b = (a_1 + a_3 + a_4 + a_6) + 2(a_2 + a_5)
\]

These weights approximate the triangular time-integrated weighting function in the scan direction and the rectangular weighting function in the track direction.
New Water Present in C6 MOD03

Land Water Mask

Water Present

- Shallow Ocean
- Land
- Coastline/shoreline
- Shallow Inland Water
- Ephemeral Water
- Deep Inland Water
- Moderate Ocean
- Deep Ocean

Terra granule subset 2003/193 16:20
Maneuver Handling

- Definitive maneuver lists (for both Aqua and Terra) are being obtained regularly from FOT
- LDOPE routinely screens data near maneuvers to exclude this data from daily and higher level products
- Atmosphere hides L2+ products when geolocation errors exceed 1km
- For C6 the geolocation team will continue to work with the Terra and Aqua FOTs to find a better solution (no real progress yet)
Questions?
1. Solar elevation correction (roll, pitch and yaw) written to geolocation product – for transfer to the Control Point Residual files

2. Added scan metadata reporting the quality and type of the ephemeris/attitude data used in the calculations

3. For some users (DB and Oceans): Added file level metadata indicating whether or not terrain correction was performed. *(Terrain correction is always used in MODAPS.)*

4. For DB users: Correct the setting of attitQuat when ephemeris source is "MODIS Packet“. 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.