Improving Satellite Moderate Resolution Instrument Geolocation Accuracy in Rough Terrain

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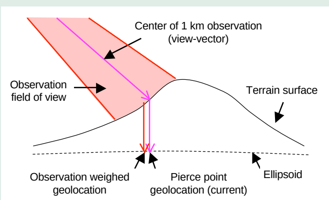
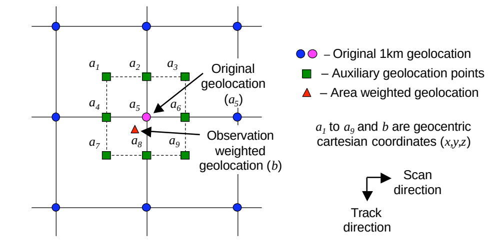
Introduction

For each 1 km observation, the current MODIS geolocation approach calculates where the view-vector, the center of the observation instantaneous field of view (IFOV), intersects the terrain surface interpolated from the 1 km digital elevation model. With the recent Shuttle Radar Terrain Mapping Mission (SRTM) terrain model data, which has a finer spatial resolution and better accuracy than previous global terrain models, there is an opportunity to improve moderate resolution sensor geolocation accuracy in rough terrain. We have developed an advanced first-order observation weighted geolocation approach and have evaluated under what conditions this new approach is significantly better than the current pierce point approach. This new approach has the potential to improve the accuracy of the MODIS land geophysical products in rough terrain.



Method



The first order approximation of the observation weighted point is:

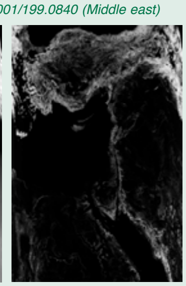
$$b = \frac{(a_1 + a_4 + a_7 + a_3 + a_6 + a_9)\,w_1 + (a_2 + a_5 + a_8)\,w_2}{6w_1 + 3w_2}$$

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.

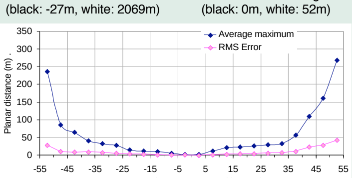
Initial results

Example 1: MODIS Terra 2001/199.0840 (Middle east)

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

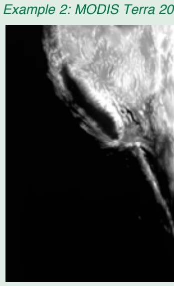


Geolocation difference – current minus obs. Weighted (black: 0m, white: 52m)

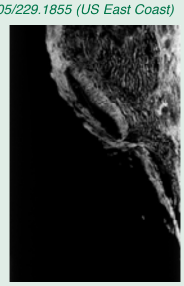


Geolocation difference – planar distance vs. scan angle

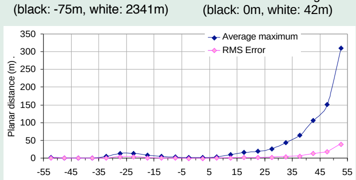
Example 2: MODIS Terra 2005/229.1855 (US East Coast)



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



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



Geolocation difference – planar distance vs. scan angle

Example 1 is a scene over the Middle East and shows the typical height variation of a typical MODIS scene, with both relatively flat and mountainous areas. In the scene center is the Mediterranean Sea and in the top part of the scene are the Taurus Mountains, which are medium height (~2km).

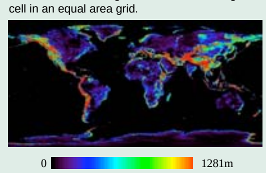
The difference in the plane between the two approaches was computed for the entire scene as a function of scan angle. For twenty-one 5° zones across the 110° MODIS swath width, the graph for this example shows the Root Mean Square (RMS) Error and the average zonal maximum. The planar distance RMS Error is small at nadir and grows to more than 40m near the edge of the swath. For the entire scene, the planar distance RMS Error is 15m.

The average zonal maximum planer distance was computed by first finding the maximum difference in each zone separately for each scan and then averaging the maximum difference across all of the scans. This difference becomes larger than 50m at about 40° scan angle. The average maximum planar difference over the whole scene is 59m.

In the second example, the left half of the scene is primarily ocean and the right half is over the South Western USA and Mexico's Baja Peninsula. In this example, as expected, both the RMS Error and average zonal maximum difference are very small for the portion of the scene primarily over the Pacific Ocean. The right portion of the scene, where there is significant terrain variation in the Rocky Mountains, the differences are similar to the first example, with a 45m RMS Error near the right edge of the scene and the average zonal maximum difference exceeding 50m at a scan angle of 35°. For the entire scene, the RMS Error is 10m and the average maximum difference is 38m.

Global terrain elevation height variation

To better understand the locations where there is potential for improvement, the local variation in global terrain height was calculated by taking the difference between the minimum and maximum terrain height within each 5.6km grid cell in an equal area grid.



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.

Discussion & Future Work

The first order area weighted approach was examined for two MODIS scenes, but the study is not conclusive. Near the edge of the scan the average maximum planar distance difference is large (~300m) – clearly larger than the MODIS geolocation accuracy goal. However, the planar distance RMS Error is very small at nadir and is less than 50 m near the edges of the scan. The overall effect on geolocation accuracy is limited because the error only occurs under certain conditions, where there is significant terrain variation and at larger scan angles. The effects are further mitigated by the coarseness of the 1km terrain model, because the geolocation is only calculated at 1km (not 500m or 250m), and because of the increase in size of the observation IFOV at larger scan angles.

Further analysis is needed to understand the impact of this new approach on high-level geophysical terrestrial products, e.g., Snow Cover, Vegetation Cover Change, Burn Scar Detection and Albedo, in areas with significant terrain relief and variation. Second and higher order observation weighting approximations could be tried to see if any further benefit is gained by more accurate area weighting approaches. A trade study is also needed to see whether computing 500m geolocation along with a 500m model would have more positive impact on the higher level products than computing the 1km observation weighted geolocation.

MODIS Geolocation Results

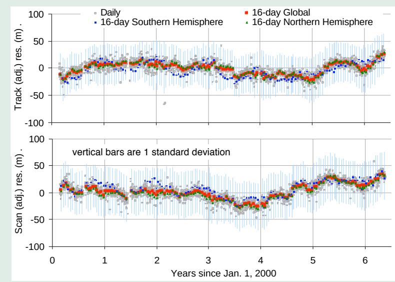
Summary of Collection 4 (C4) control point residuals

	Terra	Aqua
Track RMS Error* (m)	**38**	**44**
Scan RMS Error* (m)	**44**	**54**
Control Point Matchups per Data-day	82	73

Overall geolocation accuracy is close to or better than science goal of 50m for MODIS on both Terra and Aqua.

* Root Mean Square (RMS) Error in nadir equivalent units.

Terra C4 Residual Details and Collection 5 (C5) Plans

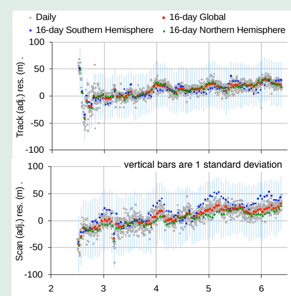


80% of the Control Point Match-ups are in Northern Hemisphere so the Global trend tracks the Northern Hemisphere trend. The C5 algorithm was changed to include sun angle dependence to remove North/South hemispherical differences.

Other C5 changes include use of new SRTM Digital Elevation Model and Boston Univ. MODIS-derived Land/Water Mask, an improved scan mirror motion interpolation, and a refreshed control point library (990 additional points from Landsat 7 with a better global distribution).

Aqua C4 Residual Details and C5 Plans

The Aqua scan direction residuals are larger than Terra partially because of AMSR-E jitter.



The Aqua C5 changes are same as Terra, except the Sun angle dependence was not used. For C5, the Aqua global long-term trend has also been calculated and removed.

More work is needed for both Aqua and Terra to understand any systematic effects on the control point match-ups caused by terrain shadowing.

Acknowledgment

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