Terra Orbit Drift and its Impacts on MODIS Geometric Performance

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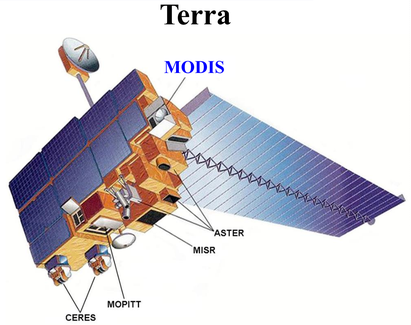
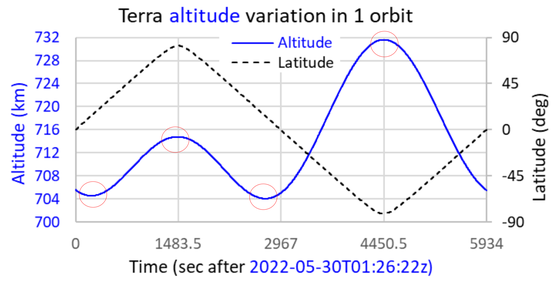
1. Introduction

Terra platform (incl. MODIS) was launched 25 years ago this month on Dec. 18, 1999.

- Near polar orbit
- Sun-synchronous
- Inclination angle = 98.2°
- Nominal altitude = 705 km
- Period = 98.9 min = 5933 sec
- Local time descending node = 10:30 am
- Ground track repeat = 16 days
- Repeated ground tracks = 233

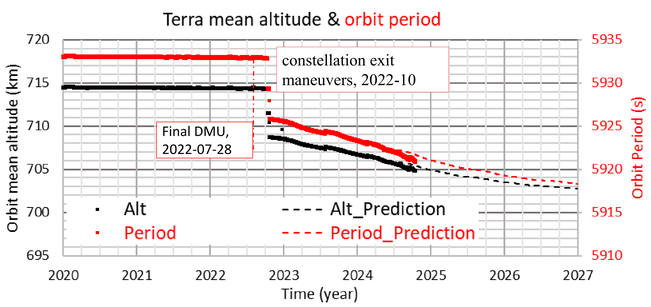


- The nominal altitude of 705 km is referred to the satellite height above the theoretical spherical earth with the Equatorial radius of 6,378.137 km.
- The actual altitude over the ellipsoidal earth varies, from ~ 704 km near the Equator, ~714 km near the N. Pole, and ~732 km near the S. Pole

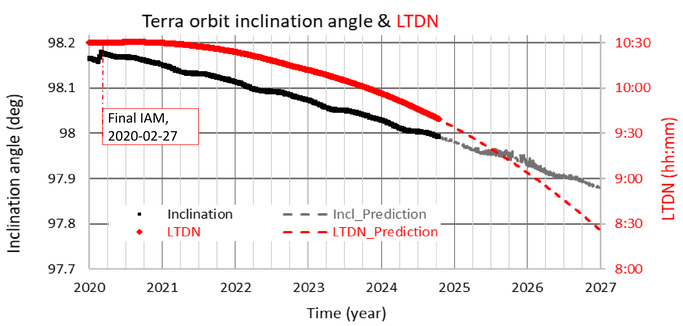


2. Orbit drift in the extended mission

Altitude & period



Inclination & LTDN (local time at descending node)

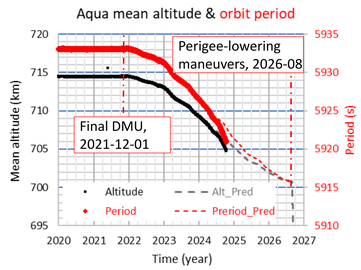


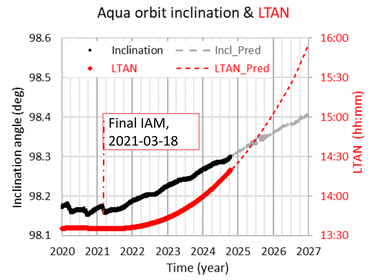
0. Abstract

NASA Terra satellite has provided earth observations from its 5 onboard instruments for 25 years since its launch in December 1999. All these instruments are still mostly healthy, and observations are expected to extend 2 more years of life into late 2026. The onboard fuel is preserved by ceasing inclination adjust maneuvers (IAMs, stopped 2020) and drag make-up maneuvers (DMUs, stopped 2022). Without IAMs, the orbital plane is drifting, changing the sunlight conditions by late 2026 from nominal 10:30 AM to 8:30 AM local time at descending node (LTDN). The ceasing of DMUs combined with a constellation exit maneuver in October 2022 result in orbit altitude drifting down. Altitude will drift from a nominal mean of 715 km to 702 km by late 2026. A companion earth observing satellite, Aqua, is going through a similar orbit drift process. This presentation shows the details of the drifts, that have potentials to impact data products, especially those products from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on Terra and Aqua satellites.

Orbit drift in a sister satellite, Aqua

Aqua platform (incl. MODIS) was launched 22 years ago on 2002-05-04.





Schematics of changes in solar illumination

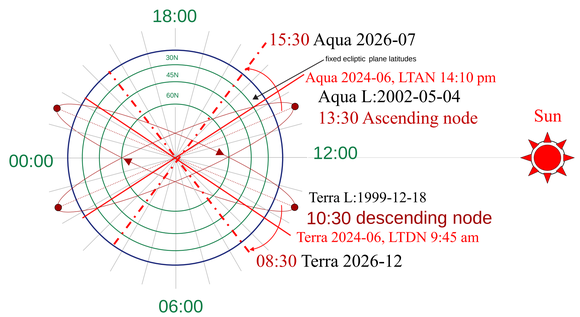
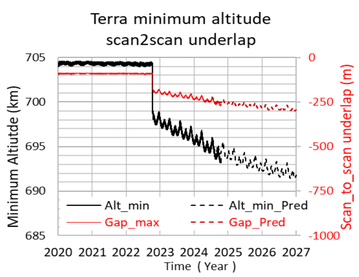
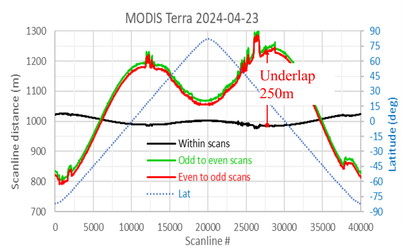


Diagram showing Sun-synchronous orbits from a top view of the local time zones for reference and descending /ascending nodes of 10:30 am and 13:30 pm, and their evolution.

3. MODIS scan to scan underlaps

MODIS on Terra has underlaps between one scan to the next scan. The largest occur at nadir over the Equator region. It increases from ~ 90m to ~ 250m over a scan width of 10,000 m.

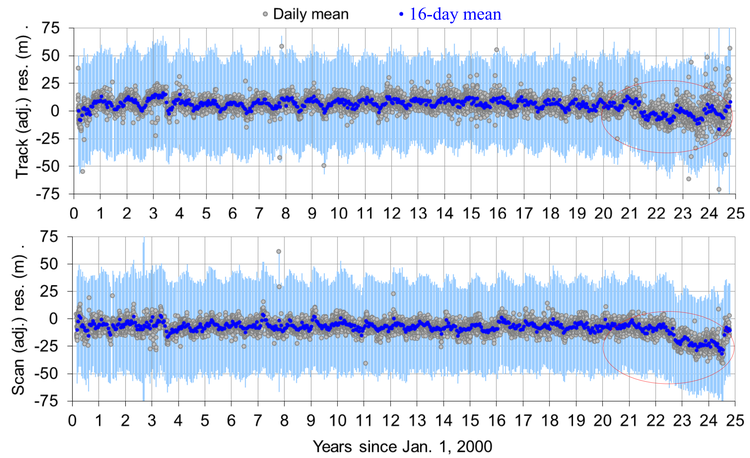




4. MODIS geolocation accuracy

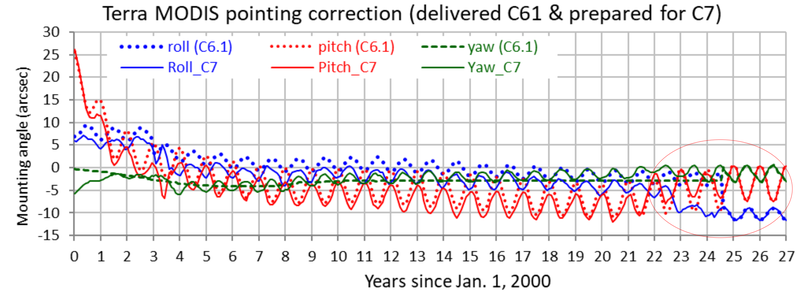
Geolocation accuracy for the MODIS observations via Terra satellite

Current data Collection is C6.1, which started in 2017. Geolocation biases were detected and corrected by Landsat-4, -5, -7 reference images. Landsat-8 images are now used as references (and to detect errors).



Geolocation error correction via instrument-to-sc interface alignment angles

C6.1 started in 2017. Forward-processing uses predicted pointing LUT once every two years after mid-2018, which becomes inaccurate after year 2021 due to unpredictable effects of changing solar illumination.



5. Concluding Remarks

- Terra started orbit drift in 2022.
  - Altitude drops ~ 2% from mean of ~715 km to 702 km by late 2026.
  - Local time at descending node (LTDN) changes from 10:30am to 8:30 am by late 2026.
- The impacts on geometric performance on MODIS are relatively small.
  - Scan-to-scan underlaps increase to ~ 250 m, 2.5% of swath width of 10 km.
  - Geolocation uncertainties increase to ~ 70 m (1-σ) , ~ 30% of a QKM band sampling interval. That increased part will be corrected in future re-processing.
- The impacts of orbit drifts in altitude and solar illumination on other environmental parameter retrievals may be more significant.

6. Key References

1. Wolfe, R.E.; Nishihama, M. Accurate MODIS global geolocation through automated ground control image matching. In *Image Registration for Remote Sensing*, Le Moigne, J., Netanyahu, N.S., Eastman, R.D., Eds. Cambridge Univ. Press: Cambridge, 2011, 437-455; doi: 10.1017/CBO9780511777684.022.
2. G. Lin, R.E. Wolfe, P. Zhang, J. C. Tilton, J. J. Dellomo, B. Tan, "Thirty-six combined years of MODIS geolocation trending," *Proc. SPIE* 11127, Earth Observing Systems XXIV, 1112715 (9 September 2019); doi: 10.1117/12.2529447.

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