

## **Software Provenance Scope and Purpose**

This software provenance summary documents the operational lineage of ASTER data processing with emphasis on traceability, calibration context, and long-term interpretability of the archive. Rather than duplicating Algorithm Theoretical Basis Documents (ATBDs) or published calibration studies, this section captures how processing software, calibration inputs, ancillary data sources, and computing environments evolved over time and how those changes were operationally applied to ASTER products.

The provenance described here focuses on Product Generation Executables (PGEs), radiometric and geometric calibration databases, external atmospheric and auxiliary inputs, and major processing environment transitions that affect product consistency and scientific interpretation. Detailed algorithm formulations, mathematical models, and instrument physics remain documented in existing ATBDs and peer-reviewed literature and are referenced where appropriate.

Together with the version and processing history narrative, this provenance summary provides the contextual information needed for future users to understand how ASTER products were generated, how calibration and inputs evolved over the mission lifetime, and how scientific continuity was maintained across reprocessing campaigns.

## **Software Provenance and Processing Lineage**

ASTER data products are generated through a series of Product Generation Executables (PGEs) that transform raw instrument observations into calibrated, geolocated, and scientifically usable products. Software provenance for ASTER is documented through the evolution of these PGEs, their supporting calibration inputs, ancillary datasets, and processing environments as implemented operationally at the LP DAAC throughout the mission lifetime.

ASTER PGEs have evolved incrementally since launch to address instrument aging, orbital changes, improved scientific understanding, and advances in ancillary data availability. Updates were introduced through explicitly versioned PGEs and calibration databases, validated prior to operational deployment, and applied consistently within the DAAC processing environment. This approach preserved continuity of the science archive while improving product accuracy, robustness, and traceability.

Radiometric calibration is applied through externally generated Radiometric Calibration Coefficients (RCCs), which are developed and validated by the ASTER science and calibration teams using on-orbit measurements and peer-reviewed methodologies. PGEs apply these versioned calibration lookup tables (LUTs) to convert instrument engineering units into geophysical radiances; the underlying calibration physics is defined externally and applied operationally rather than recomputed within DAAC software. Major RCC updates (e.g., RCC v5) reflect improved characterization of long-term instrument sensitivity drift and are explicitly associated with corresponding PGE releases.

## **Ancillary Inputs Used in ASTER Level 2 Processing**

ASTER Level 2 products are generated from calibrated Level 1 inputs using a set of external ancillary datasets that support atmospheric correction, geolocation context, and physical parameter retrievals. Over the mission lifetime, the specific ancillary sources evolved, but the functional categories of inputs remained consistent.

Atmospheric state inputs are primary drivers of Level 2 processing. Early processing relied on climatology datasets and NCEP/TOVS (NOAA TIROS Operational Vertical Sounder) products to supply ozone and atmospheric profile information. With advances in ancillary availability, later PGE versions incorporated MOD07\_L2 atmospheric profile products derived from MODIS observations, significantly improving atmospheric correction accuracy. Additional dynamic sources, including GDAS (Global Data Assimilation System), were later supported, and ultimately MERRA-2 (Modern-Era Retrospective analysis for Research and Applications, Version 2) was adopted as the preferred atmospheric reanalysis input due to its global coverage and long-term consistency.

Ozone-specific ancillary inputs evolved in parallel and included climatological ozone fields, NCEP/TOVS ozone products, and Aura OMI (Ozone Monitoring Instrument) data. These inputs improved correction of atmospheric absorption effects and expanded processing options across different time periods.

Level 2 processing also incorporates surface and geophysical context inputs, including digital elevation models (DEMs) used to support elevation-dependent atmospheric correction and terrain-related adjustments. These DEMs are distinct from DEM generation workflows and serve only as ancillary context within Level 2 algorithms. Geoid and Earth reference models are applied to ensure consistency in elevation and geolocation interpretation.

Orbital and geometric ancillary data, including ephemeris and attitude information inherited from Level 1 processing, provide geometric context for Level 2 generation. Land/water masks and ancillary quality flags are used to support conditional processing logic and quality screening.

Beginning with later PGE versions, Level 2 processing implemented hierarchical fallback logic to ensure uninterrupted product generation. When preferred atmospheric inputs were unavailable, PGEs automatically reverted to secondary sources (e.g., MOD07 → GDAS → Climatology). This design preserved operational continuity while maintaining consistent, documented processing behavior across the archive.

## **Geometric Processing and L1T Collections**

Geometric processing for ASTER Level 1 Terrain-corrected (L1T) products has evolved over time. Earlier processing was delivered as Collection 1, while subsequent reprocessing introduced Collection 2, which incorporated updated geometric models, improved ephemeris and attitude

handling, refined DEM inputs for terrain correction, and ensured alignment with modern EOSDIS processing standards.

The transition from L1T Collection 1 to Collection 2 represents a processing environment and geolocation refinement rather than a change in instrument radiometry. Provenance of this transition is maintained through collection identifiers, versioned processing records, and product-level metadata, enabling users to distinguish between geometric processing baselines across the L1T archive.

### **Level 3 DEM Processing Context**

ASTER Level 3 Digital Elevation Model (DEM) products follow a distinct processing pathway from radiometric Level 2 products. DEMs are generated using large volumes of ASTER Level 1A scenes and the Sensor Information Laboratory Corp ASTER (SILCAST) stereo correlation software, which derives elevation through image matching rather than radiometric transformation. Radiometric calibration applied at the Level 1 stage influences DEM quality indirectly through image consistency and geometry but is not applied within the DEM algorithm itself.

DEM-specific algorithm formulations and stereo processing methods are documented in dedicated ASTER DEM ATBDs. Operational provenance is maintained through versioned SILCAST software configurations, documented processing campaigns, and DAAC processing records.

### **Traceability and Long-Term Preservation**

Traceability of ASTER software and processing methods is maintained through versioned PGEs, calibration databases, ancillary input records, and product-level metadata. Each ASTER product records the PGE version used during generation, enabling reconstruction of processing lineage at the file level. Historical PGE versions are retained within DAAC operations even as newer versions are promoted for production use. Publicly available processing logs, release notes, and DAAC announcements corroborate major software and calibration changes and provide additional provenance context.

For the ASTER Version 4 final processing campaign, software provenance culminates in a static, reprocessed collection spanning the full mission period. Version 4 processing incorporates updated atmospheric corrections, refined geolocation, and formalized fallback mechanisms. On-demand processing was discontinued for this collection, while forward processing continues through the end of the mission to ensure continuity until decommissioning. The resulting Version 4 archive preserves a consistent, well-documented record of ASTER data products for long-term scientific use.

Detailed algorithm formulations, calibration methodologies, and theoretical foundations remain documented in ASTER ATBDs and peer-reviewed literature. This provenance summary

complements those sources by documenting the operational evolution of software, calibration inputs, ancillary data, and processing environments, ensuring ASTER products remain interpretable, reproducible, and scientifically credible for future users.

**ASTER Processing & Calibration Lineage\***  
*Operational Evolution of Software, Calibration, and Access*

<b>Launch</b>	<b>December 1999</b>
	Terra launch with ASTER onboard
<b>Early Ops</b>	<b>2000 - 2005</b>
	Initial Mission Phase
	<ul style="list-style-type: none"> <li>• Baseline Calibration</li> </ul>
	<ul style="list-style-type: none"> <li>• Early PGEs</li> </ul>
	<ul style="list-style-type: none"> <li>• Tape-based Data Transfer</li> </ul>
	<ul style="list-style-type: none"> <li>• Foundational Level-2 Algorithms</li> </ul>
<b>On-Demand Era Begins</b>	<b>2006</b>
	Major Ground System Shift
	<ul style="list-style-type: none"> <li>• LP DAAC begins on-demand L1B processing</li> </ul>
	<ul style="list-style-type: none"> <li>• Current correct coefficients applied at order time</li> </ul>
	<ul style="list-style-type: none"> <li>• Entire L1A archive becomes reprocessible</li> </ul>
<b>Mature Operations</b>	<b>~2007 - 2015</b>
	Stable long-term operations phase
	<ul style="list-style-type: none"> <li>• Incremental PGE updates</li> </ul>
	<ul style="list-style-type: none"> <li>• Calibration refinement cycles</li> </ul>
	<ul style="list-style-type: none"> <li>• Expanded science use &amp; validation studies</li> </ul>
<b>Ancillary Modernization Phase</b>	<b>~2016 - 2025</b>
	Modern Processing era
	<ul style="list-style-type: none"> <li>• Structured PGE version tracking</li> </ul>
	<ul style="list-style-type: none"> <li>• Improved ancillary data sources</li> </ul>
	<ul style="list-style-type: none"> <li>• More formal configuration control &amp; provenance tracking</li> </ul>
<b>L1T Collection 2 Implementation</b>	<b>~2019-2020</b>
	Geolocation / terrain correction processing update
	<ul style="list-style-type: none"> <li>• New geometric processing baseline for L1T archive</li> </ul>

<b>Version 4 Reprocessing</b>	
	<b>2021-2023</b>
	<ul style="list-style-type: none"> <li>• Broad archive reprocessing using updated PGEs</li> </ul>
	<ul style="list-style-type: none"> <li>• Consistent calibration &amp; algorithm baselines applied mission-wide</li> </ul>
<b>Final Operations Phase</b>	<b>2024 – 2025</b>
	<ul style="list-style-type: none"> <li>• Terra orbit drift impacts acquisition strategy</li> </ul>
	<ul style="list-style-type: none"> <li>• Limitation ASTER tasking</li> </ul>
	<ul style="list-style-type: none"> <li>• Focus shifts toward archive stewardship, reprocessing and long term usability</li> </ul>

\*The timeline presented here reflects a best-effort reconstruction of the operational evolution of ASTER processing, calibration, and data access systems, based on available documentation and internal records. Specific implementation dates and transitions may be approximate where formal records are incomplete or not explicitly documented.