

Department of the Interior
U.S. Geological Survey

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Level 1 Precision Terrain Corrected Registered At-Sensor Radiance Product (AST_L1T)

AST_L1T Product User's Guide

Version 1.0

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Abstract

This document provides a User's Guide for ASTER Level 1 Precision Terrain Correction Registered At-Sensor Radiance (AST_L1T) products. It supplements the JPL ASTER Users Handbook with new information on AST_L1T including an update to the Handbook's section on ASTER Data Search and Order.

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Section 1 Introduction

1.1 Background

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a multispectral imager that was provided by the Japanese Ministry of International Trade and Industry (MITI) for launch on board the National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) Terra spacecraft in December, 1999. Since the ASTER instrument's launch, the mission has generated nearly 3 million ASTER scenes offering a rich range of observations that span the visible infrared, shortwave infrared, and thermal infrared of the observable spectra.

The ASTER instrument is comprised of four telescopes covering 14 frequency bands, three nadir-pointing telescopes, plus an additional aft-pointing telescope duplicating the frequency of nadir band 3. One nadir-pointing telescope covers visible and near infrared (VNIR) frequencies with 3 bands at 15-meter resolution. Another covers short wave infrared (SWIR) frequencies with 6 bands at 30-meter resolution. The third covers thermal infrared (TIR) wavelength with 5 bands at 90-meter resolution. The aft-pointing telescope using the Band 3 frequency covers the same scene 55 seconds behind the VNIR nadir band 3, enabling stereo views. ASTER pointing capabilities are such that any point on the globe can be accessed at least once every 16 days in all 14 bands, and once every 5 days for the visible / near infrared bands.

The Department of the Interior (DOI) U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center and NASA partner to establish, develop, and operate the Land Processes (LP) Distributed Active Archive Center (DAAC). The LP DAAC's mission is to acquire, archive, and provide user access to NASA's land processes data, such as those derived from ASTER. Raw ASTER data are downlinked from Terra and forwarded by NASA to Japanese resources for initial processing. AST_L1A data are routed from Japan to the LP DAAC for archiving and further processing. Utilizing a Japanese provided algorithm, the LP DAAC is capable of processing AST_L1A data to AST_L1B at-sensor calibrated radiance. Using AST_L1B as an input, the LP DAAC produces higher level products on-demand using algorithms provided by the Jet Propulsion Laboratory (JPL).

Besides hosting the LP DAAC Program, the EROS Center also hosts the Landsat Program that processes raw ETM+ data to higher-level products. Landsat data collection characteristics are similar to those of ASTER. In response to the 2011 Terra Senior Review requesting Level 2 products be ortho-rectified, the LP DAAC proposed to the ASTER Science Team that an ortho-rectified, precision terrain corrected registered at-sensor radiance Level 1 product (AST_L1T) be produced for use as a standard input to Level 2 algorithms. The Earth Science Data and Information System (EOSDIS) Science Operations Office (SOO) serving as a primary sponsor in coordination with USGS, approved the proposal to use existing AST_L1B code enhanced with USGS Landsat geometric precision and terrain correction techniques to create a new Level 1 product, AST_L1T. In conjunction with the proposal, JPL has agreed to update its

AST_L1B based Level 2 algorithms to utilize the LP DAAC AST_L1T product as an input for producing Level 2 products.

Figure 1-1 illustrates Landsat and ASTER having similar operational aspects specifically with respect to spectral observations. Appendix A provides a more detailed comparison between Terra-ASTER, Landsat 7, and Landsat 8 at the instrument level.

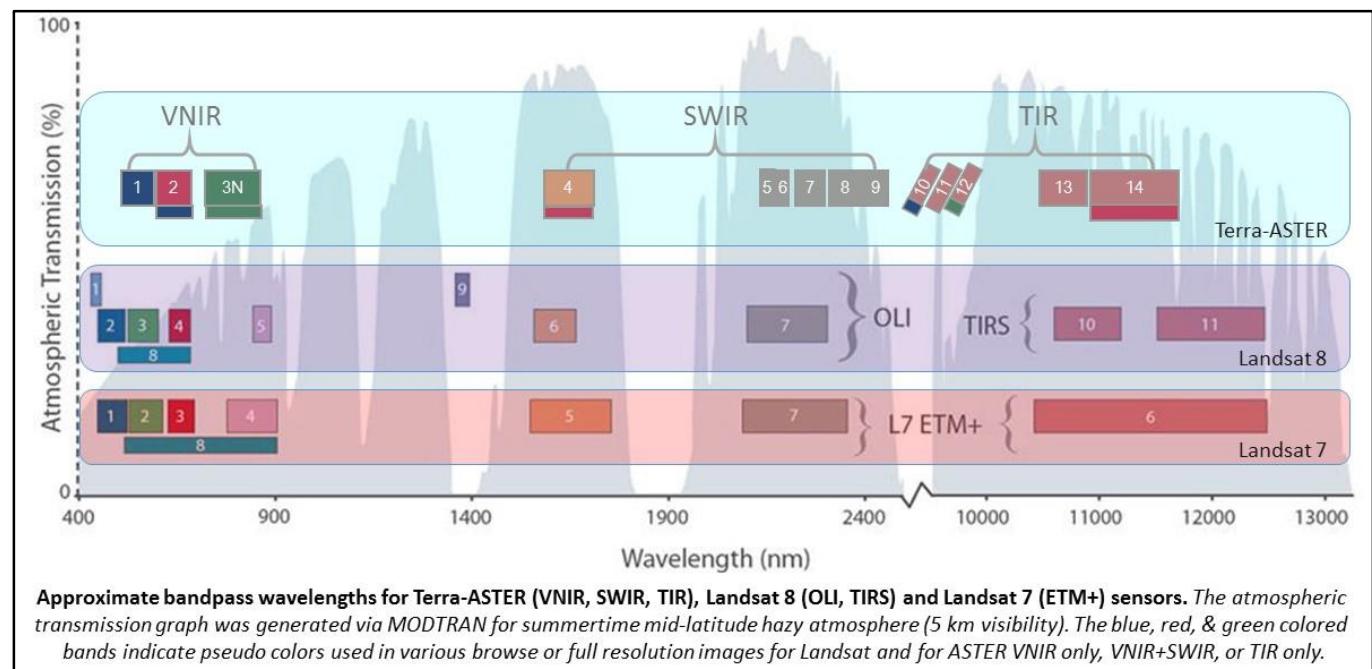


Figure 1-1. Terra-ASTER and Landsat 7/8 Spectral Bands Compared

The new AST_L1T algorithm uses both Earth and satellite models along with standardized globally distributed ground control points (GCPs) and digital elevation models (DEMs) to produce a multi-file product and two associated products. The AST_L1T product is comprised of an EOSDIS HDF-EOS2 science data file, an XML metadata file, and one or both a Visual full resolution location-tagged GeoTiff image file and / or a Thermal full resolution location-tagged GeoTiff image file. The generation of GeoTIFF full resolution images depends upon band acquisition settings or sensor environmental conditions for any given satellite observation. The products associated with the AST_L1T multi-file product include a quality assessment (QA) text report product and the BROWSE product consisting of JPEG low resolution browse (visual, thermal, and quality) files.

1.2 Data Access Policy

Access to and redistribution of ASTER product data available from the LP DAAC is subject to contractual agreements between NASA and the Japanese owners of the ASTER sensor. Refer to the web page https://lpdaac.usgs.gov/products/aster_policies for the most current policy regarding user access.

Since mid-2009, the LP DAAC has been permitted to make collections of AST_L1B scenes acquired over the United States and territories available to **all end users** at no charge. The AST_L1B policy over the United States and territories was extended to the AST_L1T products upon their public release in 2015. In addition, approved NASA supported researchers and their affiliates, educational users, and federal partners may order ASTER products from the LP DAAC global collection. Thus, there is a distinction between an "approved user" and a "registered user". That is, while users may be *registered* to order data, they may not be *approved* to order from all locations covered within the global collection.

To become approved for global access, users are first required to register by creating a NASA account to search and order. Following registration, users become "ASTER Approved Users" by filling out an application form online at <https://lpdaacaster.cr.usgs.gov/afd/index.php> indicating that they fall into one of the following categories:

- NASA Affiliated User
 - NASA-funded investigator
 - Researcher from interagency and international partners affiliated with NASA through joint projects
 - Researchers receiving NASA funds through a third party
- Educational User (including NASA-sponsored and non-NASA-sponsored) university or K-12 levels
 - Students in a formal degree program
 - Educational setting as part of the curriculum
- Federal Partner
 - Projects funded by the US federal government
- Contractor employed by a Federal Partner

As per the application process, approved users are limited to a justified number of scenes for the length of time that privileges are granted. ASTER privileges expire when either of these limits is reached. However, users may re-apply for privileges as needed.

1.3 User Benefits¹

Prior to AST_L1T, users had access to AST_L1B products, which required additional processing and resampling to achieve ortho-rectification, or to the AST14 product, which relies on processing-intensive, closed-source production code and is unavailable to Level 2 processing. Thus ortho-rectification required additional effort that increased complexity and risk to investigator processes including a potential for unnecessary data error due to multiple resamplings. The new AST_L1T product provides quick turn-around of consistent GIS-ready data. AST_L1T features a single resampling from the AST_L1A to be used either directly in investigations or as input into Level 2 Earth surface parameter generation, such as surface reflectance and temperature emissivity.

¹ LP DAAC proposal to stakeholders via Behnke, DATA Templates

Previously, for visualization, ASTER users also had to create their own images or use AST_L1A low resolution non-location-tagged browse images. The new AST_L1T product includes two full resolution ortho-rectified location-tagged GeoTIFF image files as well as low resolution AST_L1T browse. The GeoTIFF files allow users to overlay location-tagged features and also to compare with other ASTER scenes for visually examining the extent of natural disasters or change detection. The full resolution images can be used by non-technical end users without the need for special image analysis software allowing a reduction in investigator's cost. A full resolution visual image consists of 3 bands from the VNIR and SWIR telescopes producing a near psuedo color image that can be used when a daytime view is needed by the user. The thermal image is created from 3 bands of the TIR telescope, creating a view showing temperatures not only during the day but also at night. It is anticipated, as user client systems advance, that the full resolution images (FRIs) will form a base layer that allows users to zoom in and out of scenes. The new AST_L1T browse JPEG files are generated from the GeoTIFF files providing a thumbnail view of the AST_L1T product rather than the AST_L1A browse that was provided in the past.

1.4 Science Usage²

The intended and appropriate user scenarios for the AST_L1T product parallel current scenarios for AST_L1B or AST14OTH products. As a basis for ortho-rectification of Level 2 products, these uses include but are not limited to:

- Land surface climatology: monitoring land surface parameters such as surface temperature; to understand land surface interaction and energy and moisture fluxes; changes in glacial extent
- Vegetation and ecosystem dynamics: investigations of vegetation and soil distribution and their changes to estimate biological productivity, understand land-atmosphere interactions, and detect ecosystem change
- Volcano monitoring of eruptions and precursor events, such as gas emissions, eruption plumes, development of lava lakes, eruptive history, and eruptive potential
- Hazard monitoring: observation of the extent and effects of wildfires, flooding, coastal erosion, earthquake damage, and tsunami damage
- Hydrology: understanding global energy and hydrologic processes and their relationship to global change; evapotranspiration from plants
- Geology and soils: the detailed composition and geomorphologic mapping of surface soils and bedrocks to study land surface processes and Earth's history
- Land surface and land cover change: monitoring desertification, deforestation, and urbanization; providing data for conservation managers to monitor protected areas, national parks, and wilderness areas

² LP DAAC proposal to stakeholders via Behnke, DATA Templates

Section 2 ASTER Instrument Overview

2.1 Product Chain

Figure 2-1 illustrates a product-oriented view of the overall ASTER operations concept where forward processing of ASTER data has been augmented for the new AST_L1T Product Generation Executable (PGE). ASTER expedited processing is unchanged in the current implementation. Not shown is historical processing (the initial instance of reprocessing), which is a batch process that injects previously ingested AST_L1As into the nominal-processing flow to produce AST_L1T products ranging back to initial ASTER data collection.

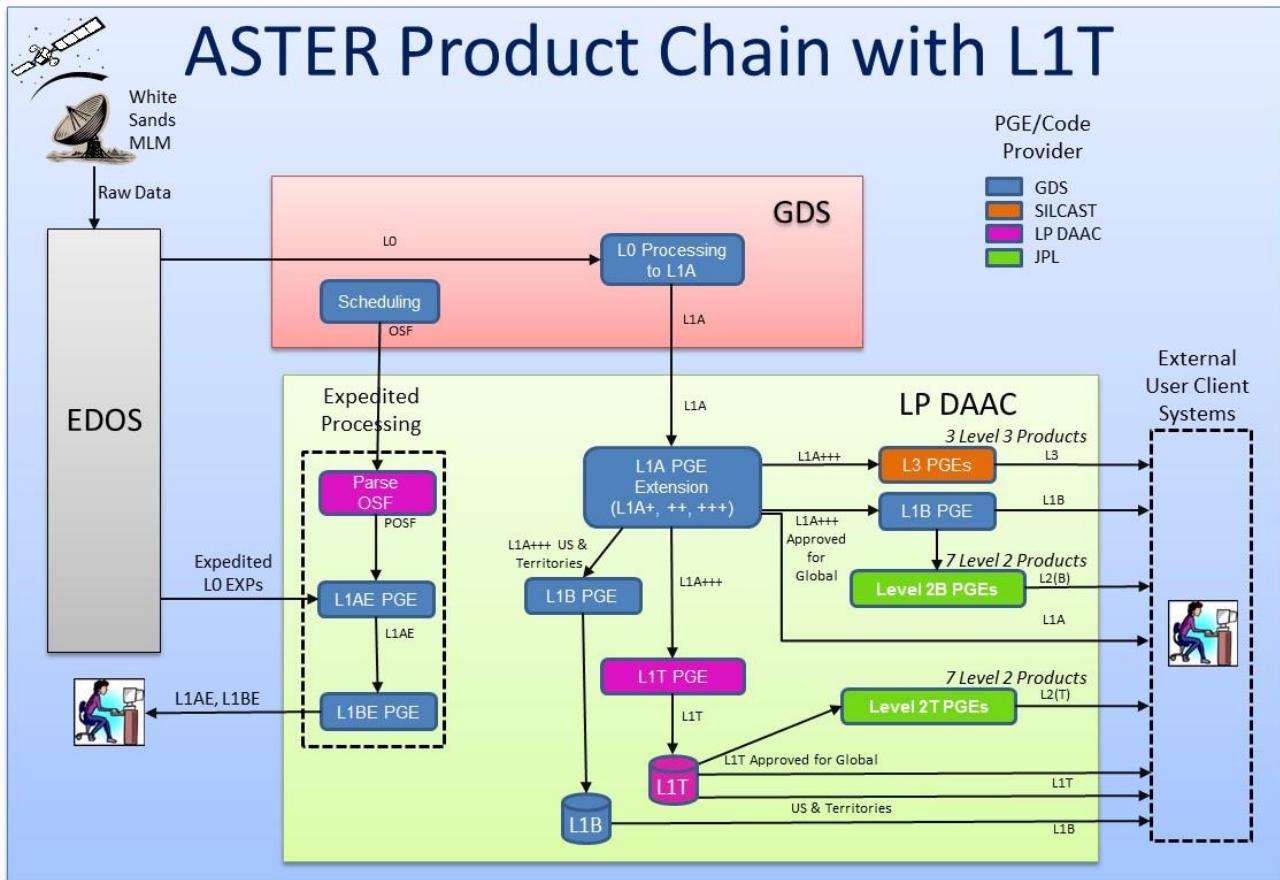


Figure 2-1. ASTER Operations Concept

The EOS Operations Center (not shown in the figure) commands the ASTER instrument to collect data per the long-term acquisition plan merged with near-term Data Acquisition Requests (DARs). ASTER raw data are downloaded from the Terra satellite by NASA's EOS Data and Operations System (EDOS) and transferred to Japan's Ground Data System (GDS). Refer to Appendix B for a discussion on the ASTER data acquisition strategy.

Upon ingest of an AST_L1A from GDS granules over the United States and its territories, they are processed to produce AST_L1B products. These AST_L1B products are saved in the open Data Pool for direct download or for order / download from user clients search and order systems. Simultaneously, the LP DAAC associates GDS-provided AST_L1A browse images to the AST_L1B products.

The new implementation modifies the legacy operations concept such that AST_L1T granules are routinely produced for all arriving AST_L1A granules. AST_L1T products over the United States and its territories are saved in the open Data Pool for direct download or for order / download from user client search and order systems.

All users may order and download AST_L1B and AST_L1T scenes/granules over the US and US Territories, ASTER L1A & L1B Expedited products, and the ASTER Global Digital Elevation model for no charge. Approved users may order ASTER products from anywhere on the globe. Approved users may also request on-demand processing of Level 2 products using AST_L1B or AST_L1T products as an input. Level 3 products are orderable and made from the AST_L1A. On-demand products (only produced upon ordering of the product and not saved), such as AST_L1A, higher-level products, and AST_L1B over international areas of interest are available only to approved users via an application process. All AST_L1T products available are created and archived but the granules over international areas of interest are available only to approved ASTER users. More information on the application process and qualifications is available on the [ASTER Policies Page](#) under the heading Data Access for NASA Approved Users. Otherwise, the on-demand data products are available through [Japan's ERSDAC WWW IMS](#) interface at a cost.

2.2 Instrument Sensors

Depending on sensor commanding for any given data acquisition, ASTER downlinks may be comprised of some, or all, of the following bands described in Table 2-1. The design of each sensor is discussed in Section 2.0 of the ASTER User Handbook Version 2.

<u>Label</u>	<u>Telescope Pointing</u>	<u>Wavelength (μm)</u>	<u>Description</u>	<u>Resolution (m)</u>
VNIR_Band1	Nadir	0.520–0.600	Visible green/yellow	15 (8 bit)
VNIR_Band2		0.630–0.690	Visible red	
VNIR_Band3N		0.760–0.860	Near infrared	
VNIR_Band3B	Backward	0.760–0.860		
SWIR_Band4	Nadir	1.600–1.700	Short-wave infrared	30 (8 bit)
SWIR_Band5		2.145–2.185		
SWIR_Band6		2.185–2.225		
SWIR_Band7		2.235–2.285		
SWIR_Band8		2.295–2.365		
SWIR_Band9		2.360–2.430		

<u>Label</u>	<u>Telescope Pointing</u>	<u>Wavelength (μm)</u>	<u>Description</u>	<u>Resolution (m)</u>
TIR_Band10	Nadir	8.125–8.475	Long-wave infrared or thermal infrared	90 (12 bit)
TIR_Band11		8.475–8.825		
TIR_Band12		8.925–9.275		
TIR_Band13		10.250–10.950		
TIR_Band14		10.950–11.650		

Table 2-1. ASTER Sensor Characteristics

VNIR_Band3B is not used in AST-L1T processing or included in the product.

The only major ASTER instrument-related problem to date deals with the SWIR sensor, which suffered a setback due to its anomalously high detector temperatures. The anomaly has rendered SWIR data unusable since April 1, 2008. To minimize system impact, SWIR bands are not used after April 2008 even though they may be marked in metadata as having been acquired. Eventually, in August 2012, SWIR was turned off altogether and dummy data is included in the AST_L1A products after that point. Since the SWIR bands are used in the cloud coverage calculations in the AST_L1A product headers, the loss of SWIR makes the cloud coverage percent calculation unreliable. The AST_L1T product does not include SWIR band data after April 1, 2008.

2.3 AST_L1A Data³

ASTER AST_L1A raw data are reconstructed from Level 0 analog values referred to as unprocessed instrument digital numbers (DN). This product contains depacketized, demultiplexed, and realigned instrument image data with geometric correction coefficients and radiometric calibration coefficients appended **but not applied**. These coefficients include:

- Corrections for SWIR parallax as well as inter- and intra-telescope registration.
 - The parallax error is caused by the offset in detector alignment in the along-track direction and depends on the distance between the spacecraft and the observed earth surface.
 - Parallax corrections are carried out with the image matching technique or the coarse DEM database, depending on cloud cover.
- Spacecraft ancillary and instrument engineering data (coefficients):
 - The radiometric calibration coefficients, consisting of offset and sensitivity information, are generated from a database for all detectors using real temperature values in the instrument supplementary data, and are updated periodically.
 - The geometric correction is the coordinate transformation for band-to-band co-registration. The coordinate transformation of the line of sight vector uses ancillary information from instrument supplementary data and spacecraft ancillary data to identify the observation points in

³ This subsection is paraphrased from Section 3.1 of the ASTER User Handbook Version 2

latitude/longitude coordinates on the Earth's surface defined by the WGS84 Earth model.

The VNIR and SWIR data are 8-bit and have variable gain settings. The TIR data are 12-bit with a single gain.

Raw AST_L1A is further processed on-demand before it is made available directly to users or as an input to downstream processing. The additional processing steps occur in the following order:

- 1) AST_L1A+ application of geometric correction of errors accounting for earth rotation angle and earth nutation.
- 2) AST_L1A++ application of geometric database correction to address cross-track geolocation errors associated with night-time TIR scenes.
- 3) AST_L1A+++ application of radiometric corrections due to on-board calibration lamps degradation over time causing sensor gain correction variation.

2.4 Radiometry⁴

As has been the case for AST_L1B, AST_L1T data are offered in terms of scaled radiance. To convert from Digital Numbers (DN) to radiance at the sensor, the unit conversion coefficients (defined as radiance per 1 DN) are used. Spectral radiance is expressed in units of watts divided by meters squared times steradian times micrometer [W/(m²*sr*μm)] per DN. The relation between DN values and radiances is shown below:

- a DN value of zero is allocated to pixels not containing data and can be considered transparent
- a DN value of 1 is allocated to zero radiance
- a DN value of 254 is allocated to the maximum radiance for VNIR and SWIR bands
- a DN value of 4094 is allocated to the maximum radiance for TIR bands
- a DN value of 255 is allocated to saturated pixels for VNIR and SWIR bands
- a DN value of 4095 is allocated to saturated pixels for TIR bands

The maximum radiances depend on both the spectral bands and the gain settings as shown in Table 2-2.

Band No.	Maximum radiance (W/(m ² *sr*μm))			
	High gain	Normal Gain	Low Gain 1	Low gain 2
1	170.8	427	569	N/A
2	179.0	358	477	
3N	106.8	218	290	
3B	106.8	218	290	

⁴ This subsection is paraphrased from Section 5 of the ASTER User Handbook Version 2

4	27.5	55.0	73.3	73.3
5	8.8	17.6	23.4	103.5
6	7.9	15.8	21.0	98.7
7	7.55	15.1	20.1	83.8
8	5.27	10.55	14.06	62.0
9	4.02	8.04	10.72	67.0
10	N/A	28.17	N/A	N/A
11		27.75		
12		26.97		
13		23.30		
14		21.38		

Table 2-2. Maximum Radiance Values for all ASTER Bands and all Gains.

The radiance can be obtained from DN values as follows:

$$\text{Radiance at-sensor} = (\text{DN value} - 1) \times \text{Unit conversion coefficient}$$

Table 2-3 shows the unit conversion coefficients of each band

Band No.	Unit Conversion Coefficient (W/(m ² *sr*μm)/DN)			
	High gain	Normal Gain	Low Gain 1	Low gain 2
1	0.676	1.688	2.25	N/A
2	0.708	1.415	1.89	
3N	0.423	0.862	1.15	
3B	0.423	0.862	1.15	
4	0.1087	0.2174	0.290	0.290
5	0.0348	0.0696	0.0925	0.409
6	0.0313	0.0625	0.0830	0.390
7	0.0299	0.0597	0.0795	0.332
8	0.0209	0.0417	0.0556	0.245
9	0.0159	0.0318	0.0424	0.265
10	N/A	6.822 × 10 ⁻³	N/A	N/A
11		6.780 × 10 ⁻³		
12		6.590 × 10 ⁻³		
13		5.693 × 10 ⁻³		
14		5.225 × 10 ⁻³		

Table 2-3. Calculated Unit Conversion Coefficients.

2.5 Geometry⁵

ASTER's geometric system correction primarily involves the rotation and the coordinate transformation of the line of sight vectors (geocentric) of the detectors to the coordinate system of the Earth (geodetic). This is done as part of ASTER Level 1 processing at

⁵This subsection is paraphrased from Section 6 of the ASTER User Handbook Version 2

GDS using engineering data from the instrument (called supplementary data) and similar data from the spacecraft platform (called ancillary data). The geometric correction of ASTER data has evolved through elaborate processes of both pre-flight and post-launch calibration.

2.5.1 Pre-Flight Calibration

Pre-flight calibration is an off-line process to generate geometric parameters. Parameters such as detector Line of Sight (LOS) vectors and pointing axes information are evaluated toward the Navigation Base Reference (NBR) of the spacecraft to determine instrument accuracy and stability. These data are stored in the geometric system correction database.

2.5.2 Post-Launch Calibration

Following launch of ASTER, these parameters are being corrected through validation using ASTER Ground Control Points (GCPs)⁶ and inter-band image matching techniques. Geometric system correction in the post-launch phase entails the following processes:

- Pointing correction
- Coordinate transformation from spacecraft coordinates to the orbital
- Coordinate transformation from orbital coordinates to the earth's inertial
- Coordinate transformation from earth's inertial coordinates to Greenwich
- Improving band-to-band registration accuracy through image-matching involving SWIR parallax correction and Inter-telescope registration

Based on V2.1 of the Geometric Correction Database, the geometric performance parameters of ASTER are summarized in Table 2-4. Where a particular AST_L1A granule does not meet these performance maximums, the AST_L1T may not be able to meet these maximums either.

Parameter		Version 2.1 Geometric Db
Intra-Telescope Registration	VNIR	< 0.1 pixel
	SWIR	< 0.1 pixel
	TIR	< 0.1 pixel
Inter-Telescope Registration	SWIR/VNIR	< 0.2 pixel
	TIR/VNIR	< 0.2 pixel
Pixel Geolocation Knowledge	Relative	< 15 m
	Absolute	< 50 m

Table 2-4. Geometric Performance of ASTER Level 1.

2.5.3 Geometric System Correction Database

There is an evolving geometric system correction database that is maintained at GDS. This database provides the geometric correction coefficients that are applied in producing the AST_L1T product data. The AST_L1T data like the AST_L1B, has the

⁶ Not the same as GLS 2000 Ground Control Points (GCPs) used for AST_L1T processing.

radiometric and geometric coefficients applied to the AST_L1A data. The AST_L1T image is projected onto a rotated map (rotated to “north up”) at full instrument resolutions. The AST_L1T data generation also includes co-registration of the SWIR and TIR data to the VNIR data (resulting in the affine grid coefficients). And in addition, for SWIR in particular, the parallax errors due to the spatial locations of all of its bands are corrected. The data are stored together with metadata in the HDF file. The geometric correction reference in an AST_L1T product is provided in metadata embedded in the HDF as well as that provided in the XML metadata file. In the HDF file, this is present as the GeometricDBVersion field in the *productmetadata.0* attribute.

2.5.4 Geographic Conventions

Figure 2-2 illustrates the actual image after an AST_L1A scene has been rotated north-up. For an AST_L1A image, the location of the four corners correspond to the area of the actual image. In the case of AST_L1B and AST_L1T images, these locations correspond to the corners of the entire scene (the four corners include the fill or no-data area).

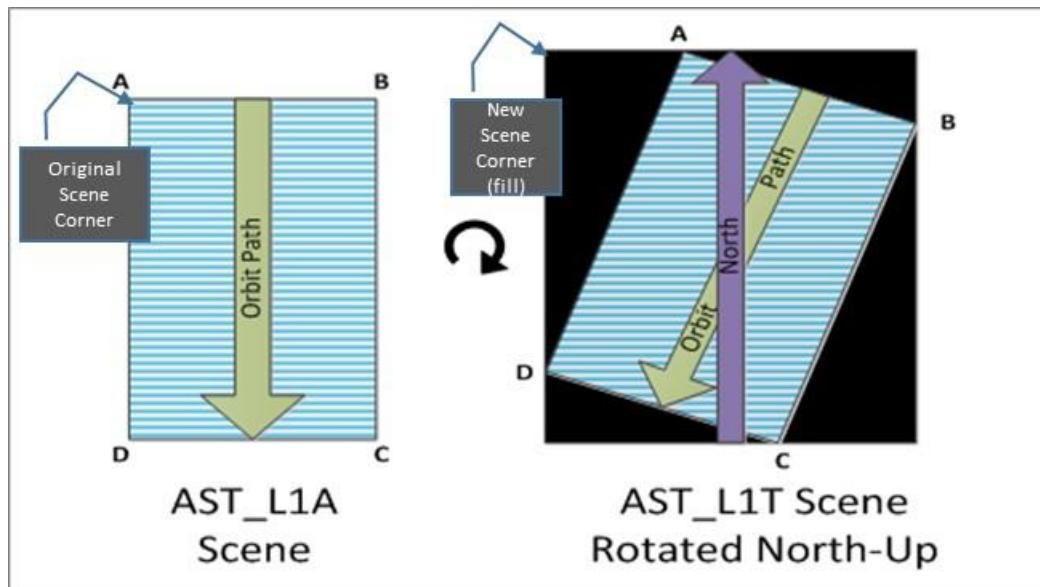


Figure 2-2. AST_L1A Image Rotated North-Up in AST_L1T Product

AST_L1B data define a scene center as the geodetic center of the scene obtained from the AST_L1A attribute named “SceneCenter” from the HDF-EOS2 *productmetadata.0* attribute. SceneCenter in AST_L1T is not exactly the same as in AST_L1A, rather it is the actual center on the rotated coordinates.⁷ Table 2-5 provides an example of the embedded metadata listing the four corners⁸ and scene center for AST_L1A, AST_L1B, and AST_L1T products in degrees.

⁷ Experience indicates that differences are observed at the sixth significant digit following the decimal in Latitude only.

⁸ Points are in (y,x) notation where “y” latitude and “x” is longitude.

Example: AST_L1T_00303022001180031		
AST_L1A (y,x)	AST_L1B (y,x)	AST_L1T (y,x)
OBJECT = UPPERLEFT	OBJECT = UPPERLEFT	OBJECT=UPPERLEFT
VALUE = (38.371925, -104.985303)	VALUE = (38.38275034471, -105.063365793084)	VALUE=(38.3824888283457, -105.18193394103)
OBJECT = UPPERRIGHT	OBJECT = UPPERRIGHT	OBJECT=UPPERRIGHT
VALUE = (38.276098, -104.268059)	VALUE = (38.2696062382925, -104.220911313396)	VALUE=(38.3800318673019, -104.219513324943)
OBJECT = LOWERLEFT	OBJECT = LOWERLEFT	OBJECT=LOWERLEFT
VALUE = (37.817597, -105.139441)	VALUE = (37.8225375573003, -105.180457655311)	VALUE=(37.7108562381888, -105.180279399827)
OBJECT = LOWERRIGHT	OBJECT = LOWERRIGHT	OBJECT=LOWERRIGHT
VALUE = (37.722386, -104.427565)	VALUE = (37.7102666494694, -104.344198661)	VALUE=(37.7084575408995, -104.226610397362)
OBJECT = SCENECENTER	OBJECT = SCENECENTER	OBJECT=SCENECENTER
VALUE = (38.047135, -104.702209)	VALUE = (38.047135, -104.702209)	VALUE=(38.0471370921037, -104.702209)

Table 2-5. Geographic Extent (Degrees) for ASTER Level 1 HDF Products.

Figure 2-3 illustrates that the AST_L1T HDF corner pixels from each instrument are co-centered unlike the case for AST_L1A and AST_L1B. This is done to facilitate the AST_L1T terrain-precision correction process. Because of the pixel dimensions, AST_L1T TIR pixels are co-centered with every third SWIR pixel and every sixth VNIR pixel. Likewise, every SWIR pixel is co-centered with every other VNIR pixel.

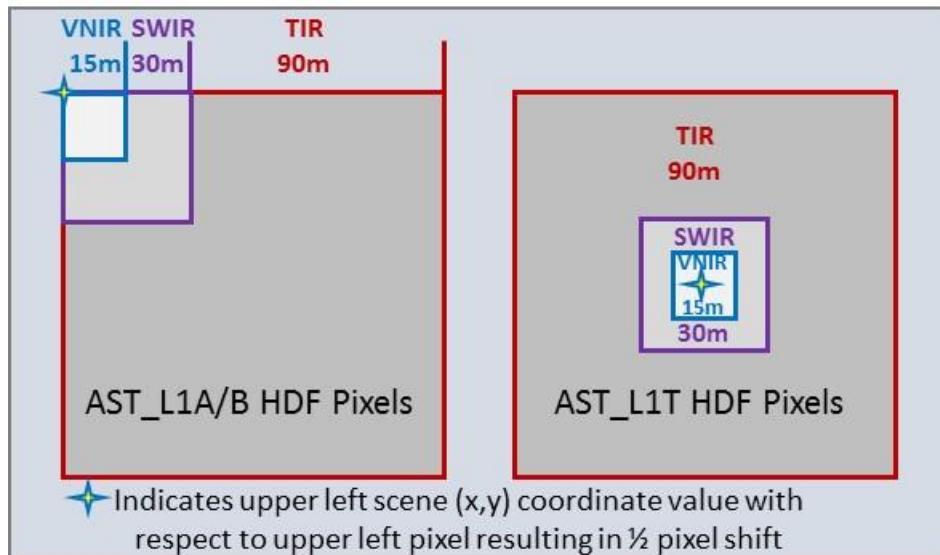


Figure 2-3. Pixel Centering for AST_L1A/B and AST_L1T Bands

The LP DAAC introduced new metadata fields in the AST_L1T embedded *productmetadata.1* group to include spheroid code, UTM zone number, scene four corners, and scene center. These fields complement the map projection method (a fixed value of "UTM") found in embedded metadata fields of the *productmetadata.{v, s, or t}* groups carried forward from AST_L1B to AST_L1T for each band. This allows LP DAAC

to employ the same Transverse Mercator (TM) map projection approach for AST_L1T as is used by the Landsat Program. This approach is accepted by all the major analysis tools as a slight variation of the Universal Transverse Mercator (UTM) system where the northing coordinates are negative values in the Southern Hemisphere. In this case, the analysis tools recognize a zero false northing with a 500,000 meter false easting as a valid representation of UTM for both hemispheres.

Pixel orientation is critical with respect to the scene's reported four corners. For example, in AST_L1A and AST_L1B HDF products, the upper left hand corner embedded metadata value of the scene is also the upper left corner of the upper left pixel. However for AST_L1T HDF, the upper left hand corner embedded metadata value for the scene is actually the pixel center coordinates of the co-centered upper left pixel(s) in the product. Thus for any given AST_L1T band, the true upper left hand coordinate is offset from the upper left hand corner coordinate by $\frac{1}{2}$ the band's pixel size. The same applies for the AST_L1T upper right, lower left, and lower right scene corner coordinates. Note that all AST_L1T scene corners are fill pixels.

The co-centered pixel approach does not work well with analysis tools on GeoTIFF products. Therefore the LP DAAC specifies the GeoTiffKey "RasterPixelsArea" rather than "RasterPixelsPoint" to characterize the pixel locations in building the GeoTIFF files. This causes the four corner pixel to move back to the edges. Table 2-6 (using _T.tif) and Table 2-7 (using _V.tif) both illustrate the four corners in meters for GeoTIF/HDF product pairs, one for the northern hemisphere and the other for southern hemisphere. Note that the coordinates differ by $\frac{1}{2}$ pixel⁹ in each example because the HDF pixel grid is defined in a "pixel is point" fashion.

Example: AST_L1T_00303122000173206 (Northern Hemisphere)			
Corner	GeoTIFF_T (x,y)	HDF (x,y)	Diff (x,y)
Upper Left	(229905, 4662765)	(229950, 4662720)	(-45, 45)
Lower Left	(229905, 4585365)	(229950, 4585410)	(-45, -45)
Upper Right	(316305, 4662765)	(316260, 4662720)	(45, 45)
Lower Right	(316305, 4585365)	(316260, 4585410)	(45, -45)

Table 2-6. AST_L1T Northern Hemisphere Corner Points (Meters) TIR.

Example: AST_L1T_00305122010131728 (Southern Hemisphere)			
Corner	GeoTIFF_V (x,y)	HDF (x,y)	Diff (x,y)
Upper Left	(649252.5, -788032.5)	(649260, -788040)	(-7.5, 7.5)
Lower Left	(649252.5, -861487.5)	(649260, -861480)	(-7.5, -7.5)
Upper Right	(732517.5, -788032.5)	(732510, -788040)	(7.5, 7.5)
Lower Right	(732517.5, -861487.5)	(732510, -861480)	(7.5, -7.5)

Table 2-7. AST_L1T Southern Hemisphere Corner Points (Meters) VNIR.

⁹ The LP DAAC GeoTIFF specification calls for the visual GeoTIFF (_V.tif) to have a $\frac{1}{2}$ pixel resolution of 7.5 meters and separately the thermal GeoTIFF (_T.tif) to have a $\frac{1}{2}$ pixel resolution of 45 meters.

Section 3 ASTER L1T Algorithm Overview

The AST_L1T product is created by performing the geometric and radiometric corrections on the original AST_L1A image data. The AST_L1T algorithm applies Earth and satellite models, control points, and elevation models, ultimately projecting the result onto rotated map (north-up) at full instrument resolutions. The algorithm ensures all calibrations and corrections historically applied to AST_L1B data are also applied to the AST_L1T data, including: radiometric calibration based on the most recently available radiometric databases, scene registrations for SWIR and TIR data, geometric processing (with improvements for nighttime TIR geo-location), and corrections for the SWIR cross-talk. For SWIR specifically, corrections are applied for parallax errors due to the spatial locations of its bands. All geometric corrections are applied using a single re-sample. In addition to the HDF-EOS2 product, full resolution location-tagged images are created using a standard three band combination (red, green, and blue), stretched and formatted as GeoTIFF files.

The AST_L1T algorithm was constructed by “wrapping” Landsat AST_L1T functionality within a version of the existing AST_L1B algorithm. This includes:

- Generation of the AST_L1A input product via supplemental algorithms
- Reuse of AST_L1B housekeeping and product formatting code
- Reuse of the AST_L1B algorithms including:
 - Application of radiometric and geometric corrections
 - Application of cross-talk correction coefficients
 - Generation and application of affine transformation coefficients
- Modification and reuse of Landsat’s AST_L1T geometric algorithms¹⁰ including:
 - Systematic – used twice: generates the systematic grid by rotating from image space to Universal Transverse Mercator (UTM) north up and to make the DEM grid
 - Geometric Pyramid – scale input image to reference image (if necessary)
 - GCP Correlate – computes x/y offsets for GCPs to be used for precision grid generation
 - Precision Refine – generates the precision grid
 - Geodetic Evaluation – checks the results of Precision Refine to see if it is necessary to fall back to systematic processing
 - DMS Retrieve Ancillary – used twice, once to retrieve the DEM data for the scene, and once to retrieve the GCPs for the scene
 - Resampling –only a single resample of input scene
 - Geometric Verification Algorithm – geometric verification determines the relative accuracy of the terrain and precision corrected scene when compared to a corresponding ortho-rectified GLS2000 standard scene

¹⁰ Selective re-use of Landsat Product Generation System (LPGS) and Image Assessment System (IAS).

Refer to Appendix C for a continued overview of the algorithm or consult the ASTER Level 1 Precision Terrain Corrected Registered At-Sensor Radiance Product (AST_L1T) Algorithm Theoretical Basis Document (ATBD) for all specific details.

Section 4 ASTER L1T Product Architecture

The AST_L1T product is technically comprised of an Earth Science Data and Information System (EOSDIS) granule and associated support files. The AST_L1T granule is a multi-file product, which includes an HDF-EOS2 data product file, full-resolution images, and associated metadata files. Some sensor-specific data may not be present depending upon band acquisition settings or sensor environmental conditions at the time of acquisition:

- HDF: AST_L1T Data Product comprised of a maximum of fourteen bands of calibrated radiance data and embedded Object Description Language (ODL) metadata
- GeoTIFF: VNIR/SWIR Visual Full Resolution Image and/or TIR Thermal Full Resolution Image with embedded GeoKey type metadata
- XML: Individual metadata files corresponding to HDF, bundled browse, and QA text files

In addition, each AST_L1T granule has associated products, which includes low-resolution browse with a QA browse, and a QA text report:

- JPEG: Standalone reduced resolution browse
- JPEG: Single-band black and white reduced resolution browse overlaid with red, green, and blue (RGB) markers for GCPs used during the geometric verification quality check
- HDF: All associated reduced resolution JPEG browse bundled into a single file
- Text: Geometric quality assessment report

4.1 ASTER L1T Granule Components

4.1.1 HDF AST_L1T Data Product

The overall structure of the AST_L1T HDF-EOS2 product maps closely to the legacy AST_L1B product (see the ASTER User Handbook Version 2). The AST_L1T Data Product contains generic and specific embedded metadata, image data, geolocation fields (latitude and longitude), and supplementary data for up to three sensors in a hierarchical format. The nominal size (areal dimension) of an ASTER scene is about 60 km by 60 km. Table 4-1 outlines the AST_L1T dataset characteristics.

Characteristic	VNIR	SWIR	TIR
Image dimensions (rows x columns)	varies by scene (e.g., 5800 x 6600)	$\frac{1}{2}$ VNIR (e.g. 2900 x 3300)	$\frac{1}{3}$ SWIR (e.g., 960 x 1100)
Bit-type	8-bit unsigned integer	8-bit unsigned integer	16-bit unsigned integer
Pixel Size	15 m	30 m	90 m
Area	Varies by scene		
Projection	Universal Transverse Mercator		
Data format	Hierarchical Data Format – EOS2		

Table 4-1. AST_L1T Dataset Characteristics

Figure 4-1 illustrates the hierarchical AST_L1T product structure which differs considerably from the AST_L1A product structure. The AST_L1T is the same as the AST_L1B structure except VNIR band (3B) is not included in the product.

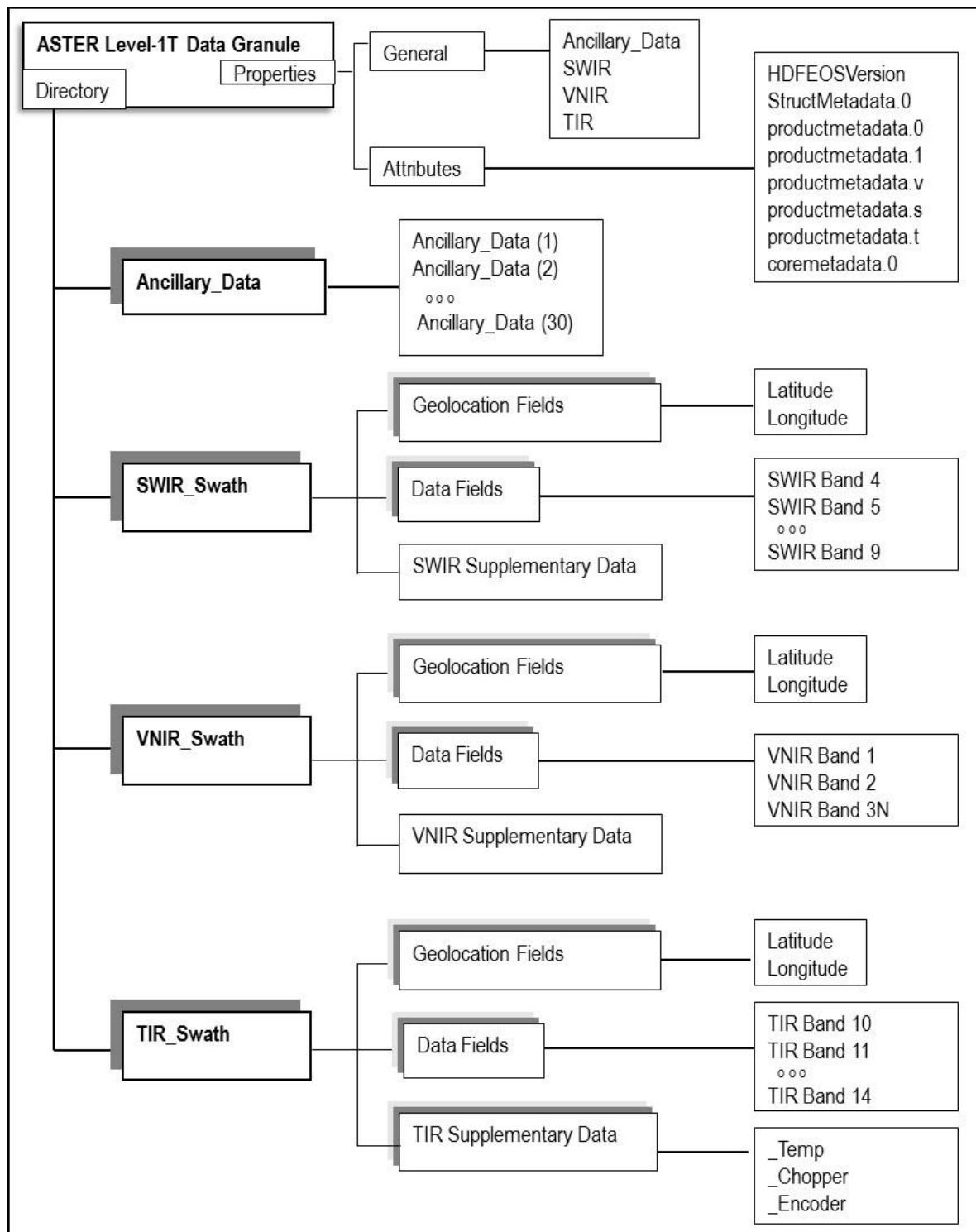


Figure 4-1. AST_L1T HDF Product Structure

The HDF file header has 8 Attribute sections. The last 7 attributes are in ODL metadata format. Refer to AST_L1T Product Specification for a detailed review of embedded metadata for the following attribute sections.

- Attribute #1: "*HDFEOSVersion*" [HDFEOS Version]
- Attribute #2: "*StructMetadata.0*" [Swath¹¹ structure metadata]
- Attribute #3: "*productmetadata.0*" [ASTER-generic metadata]
- Attribute #4: "*productmetadata.1*" [Product-generic metadata]
- Attribute #5: "*productmetadata.v*" [Product-specific VNIR metadata]
- Attribute #6: "*productmetadata.s*" [Product-specific SWIR metadata]
- Attribute #7: "*productmetadata.t*" [Product-specific TIR metadata]
- Attribute #8:¹² "*coremetadata.0*" [Inventory-core metadata]

Spacecraft ancillary and instrument engineering supplementary data used by the algorithms are included.

For each scene, the latitude and longitude geolocation arrays are two 11×11^{13} matrices of **geodetic** latitude and longitude in units of degrees used by the algorithms. The block size of the geolocation array is (number of lines)/10 by (number of samples¹⁴)/10 which, unlike the case for L1B, varies by scene due to the fact L1T is rotated north-up.

For each band present, the scene data fields contain reconstructed digital numbers at full resolution which have been radiometrically calibrated, geometrically co-registered, and terrain and precision corrected. The VNIR and SWIR data are 8-bit and have variable gain settings. The TIR data are significant to 12-bits in a 16-bit field with a single gain.

VNIR and SWIR supplementary data containers are empty; TIR supplementary data contains temperature, chopper, and encoder data carried over from AST_L1T for information purposes.

¹¹ Swath usage here is archaic; StructMetadata defines “scene” structures for each band although the term “swath” is used in the metadata object names for scene. In more current usage, scenes are actually cut outs of image strips for each band from a continuous acquisition (a.k.a., swaths) when the acquisition has more than one scene.

¹² ASTER L1A contains a [Bad Pixel Information] Attribute which is not carried over to AST_L1B or AST_L1T.

¹³ There are 10×10 blocks requiring 11×11 lat/long pairs to allow for all the corners of each block. Thus for 9 interior block edges, the right hand corner longitude of a given block is the same as the left hand corner’s longitude of the next right-adjacent block. To complete the grid, two additional longitudes covering the left most and right most block edges are therefore required. A similar approach applies for the upper and lower latitudes of each block.

¹⁴ The terms samples and pixels are interchangeable in this document.

4.1.2 Full Resolution Image

Using the GDAL geographic imaging package, the AST_L1T algorithm produces full resolution GeoTIFF image files from AST_L1T HDF (simultaneously with the reduced resolution browse JPEG). Full Resolution Images (FRI) are provided for users who prefer GeoTIFF over HDF. FRI files may ultimately be part of a multi-level browse capability. FRI generation is sensitive to scenarios where one or more sensors have been turned off or have health issues (e.g., only TIR is on at night, SWIR was deemed unhealthy past April 2008, and SWIR was turned off August 2012). Pixels are sized at 8-bits and remain DNs in each of the bands; the TIR bands were scaled down from 16-bits to 8-bits per the GeoTIFF specification.

Table 4-2 defines FRI pseudo color composite images generated from a subset of bands as determined by availability within each specific AST_L1T product.

Bands Available	Red	Green	Blue	Pixel Size	GeoTIFF DN Units
VNIR/SWIR	B4 ¹⁵	B3N	B2	15 meter	Changed from Reflectance to Radiance
VNIR only	B2	B3N	B1	15 meter	Changed from Reflectance to Radiance
TIR	B14	B12	B10	90 meter	Changed from Radiance to Degrees Kelvin scaled from 16-bit to 8-bit

Table 4-2. GeoTIFF (and Browse) Band Characteristics.

4.1.3 XML Metadata

The ODL metadata embedded in the HDF file header provides field values available at algorithm execution time. **Once the HDF data product is produced it is never re-opened for update.** Because some metadata does not become available until after the algorithm was run, the granule also includes a separate XML metadata file. The XML file contains key metadata replicated from the HDF file as well as other metadata not found in ODL such as FRI file names, browse file names and other fields related to core system processing. Also the XML file allows for data management updates that may impact metadata field values post production.

Several distribution scenarios provide either the granule XML file or a similar XML formatted file to the user as an option to accompany the HDF data product. Because some embedded metadata fields are also found in the XML files, they may have been updated in the external XML files. The general rule of thumb is to start with the embedded metadata and then override it with like fields from the XML metadata.

Examples of repeated metadata include source data (L1A) and production date-time groups, reference databases, Digital Object Identifier (DOI), spatial extent, map projection, QA flags, on/off status of sensors, sensor pointing angles, gain settings, descending/ascending, and type of correction achieved. The repeated metadata generally identifies the data product. An example of updated metadata is cloud cover since cloud cover is provided a number of days post-production. Cloud cover is set to

¹⁵ SWIR is resampled from 30 meter to 15 meter to align with VNIR bands.

the most current value available at XML creation; cloud cover is always the most current value available for user client search and order systems. Metadata found in XML files and not the HDF header includes the names of associated FRI files, database pointers to reduced resolution browse, and essential system data useful for problem triage (such as checksum and core system database IDs). Appendix D provides an XML dump (with some redundant text removed) for a typical AST_L1T HDF file.

ODL and XML metadata often have different parameter names. Table 4-3 illustrates both the ODL SCENEFOURCORNERS and XML GPolygon metadata values for an example AST_L1T file. (Redundant ODL/XML syntax removed to aid readability.) Note that the values agree in both metadata types.

L1T_00303262005171548_20141222114612_66074	
ODL	XML
GROUP = SCENEFOURCORNERS	<GPolygon>
OBJECT = UPPERLEFT VALUE = (45.5419899574936, -93.4018255912307)	<PointLongitude>-93.4018255912307 <PointLatitude>45.5419899574936
OBJECT = UPPERRIGHT VALUE = (45.5405432330736, -92.2985842710224)	<PointLongitude>-92.2985842710224 <PointLatitude>45.5405432330736
OBJECT = LOWERRIGHT VALUE = (44.8471098271548, -92.3070515243552)*	<PointLongitude>-92.3070515243552 <PointLatitude>44.8471098271548
OBJECT = LOWERLEFT VALUE = (44.8485221806005, -93.3969745689327)*	<PointLongitude>-93.3969745689327 <PointLatitude>44.8485221806005
OBJECT = SCENECENTER VALUE = (45.1968464839957, -92.852588)	No equivalent XML

* Two scene corner objects swapped from original ODL flow to simplify comparison of values

Table 4-3. Comparing ODL to XML Scene Boundary Coordinates (Degrees).

Table 4-4 illustrates ODL and XML cloud cover parameter values. Note that in this case that the XML values have been updated since AST_L1A acquisition.

L1T_00303262005171548_20141222114612_66074	
ODL (copied from AST_L1A ODL)	XML (revised with more current values)
OBJECT = SCENECLoudCOVERAGE VALUE = 5	QAPercentCloudCover 12 SceneCloudCoverage 12
OBJECT = QUADRANTCLoudCOVERAGE VALUE = (12, 2, 4, 2)	UpperLeftQuadCloudCoverage 10 UpperRightQuadCloudCoverage 21 LowerLeftQuadCloudCoverage 9 LowerRightQuadCloudCoverage 7
Computed CC Average: $(12+2+4+2)/4 = 5$	Computed CC Average: $(10+21+9+7)/4 = 11.5$ (Rounded up to integer for value of 12)

Table 4-4. Comparing ODL to XML Cloud Cover.

XML files related to product HDF files have two sources depending on the users' distribution approach. One source is from the core system made available from the *order* process which contains a full set of fields, while the other is from the Reverb *download* process, which contains a subset of fields that were sent to the ECHO server by the core system. XML from either source should be adequate for science data processing support but the full core system XML is needed for problem triage.

Users who order data from client systems may also receive small XML metadata files for bundled browse and QA text reports. These XML files provide production date-time groups and essential system data useful for problem triage.

4.2 ASTER L1T Associated Products

4.2.1 Reduced Resolution and QA Browse

Reduced resolution browse (a.k.a., thumbnail) images assume the same band combination as their associated full resolution images because both are generated simultaneously from the same virtual raster files. Both are created from the AST_L1T HDF using GDAL tools. Reduced resolution browse have the same size in pixel dimensions relative to nominal AST_L1A reduced resolution browse. It is only necessary to reduce TIR by 4% because its 90 meter pixel dimensions are already very near to nominal browse size. Given that TIR has 1/36th the pixels of the either the VNIR-only or the VNIR/SWIR¹⁶-combination FRI, it is necessary to reduce these 15 meter pixels by 84% in order to correspond to nominal browse pixel dimensions.

The geometric verification process is used to generate a grayscale Quality Assessment browse JPEG file having color-coded displacement rankings of standard scene ground control points overlaid on a reference band (B4 if SWIR available or B2 if only VNIR). The JPEG files are overlaid with a color-coded displacement rankings. Rankings indicate number of pixels off nominal (Red greater than 3 pixels, Yellow between 3 and 2 pixels, Blue between 2 and 1 pixel, Cyan between 1 and 0.5, or Green for less than $\frac{1}{2}$ pixel). The scene must be comparable to a GLS 2000 standard scene, be a daytime scene, and have VNIR or SWIR telescopes on in order to generate a QA browse file. The QA browse file is not generated for TIR only HDF files.

The algorithm bundles the browse files in a single HDF file which is eventually split into the various JPEG browse images for downstream access by user client search and order systems. The bundled browse HDF files are distributed in user orders while standalone JPEG browse are made available for download scenarios. Note that the Visual browse is only produced if VNIR is on, the Thermal browse is only produced if TIR is on, and the QA browse is only produced when a QA report is generated.

¹⁶ SWIR 30 meter pixels are sub-sampled to align with the VNIR in the combination FRI so that combination pixel size is 15 meter.

4.2.2 QA Report

The geometric verification algorithm produces logs that are used to populate a text report providing quality assessment of geometric corrections for the AST_L1T Product. This file contains a listing of the GCPs that were used to assess the geometric location of the pixels. The report provides an independent geometric verification of the corrected pixels by using the GLS 2000 Standard Scene to create a grid of GCPs (not the same as the correction GCPs) and those are compared to the corrected AST_L1T reference band. The report summarizes the total correlated GCPs; mean, median and standard deviation in pixel offset; and mean, median, and standard deviation in RMSE by quadrant and full scene. This is only produced if the precision correction is attempted, VNIR or SWIR ON, and for Day only scenes.

4.3 File Naming Conventions

The AST_L1T product consists of an HDF data file, and Full-Resolution Image (FRI) GeoTIFF files. The associated products produced consist of browse image JPEG files (a Visual browse, a Thermal browse and/or a QA browse) and a QA text file. The AST_L1T may contain either all or some TIR, VNIR, and SWIR bands depending on instrument scheduling and health. At least one FRI and one browse file will be present.

File names are constructed as "L1T Short Name"_"Collection Version""Start Date-Time-Group"_"Production Date-Time-Group"_"Processing Random Number". Table 4-5 provides example values for fields.

File Name Field	Format	Example Value
L1T Short Name	AST_L1T	AST_L1T
Collection Version	Integer 3	003
Start Date-Time-Group	DDMMYYYYhhmmss	01112010002054
Production Date-Time-Group	YYYYDDMMhhmmss	20140423133114
Processing Random Number	Integer 5	12345

Table 4-5. Example File Name Fields

The short name, AST_L1T, is used in file naming conventions for the terrain and precision corrected products. The inaugural collection version is 003. If a change in the AST_L1T or AST_L1A algorithms necessitates the reprocessing of AST_L1Ts or AST_L1As, then processing will increase the version of the collection for both AST_L1A and AST_L1T. If only the AST_L1T algorithm changes, then only the AST_L1T and its associated products will change. In either case, reprocessing would be required for all AST_L1T in the archive. For each granule, a unique processing number is assigned to the files associated with the granule. File name type extensions are identified in Table 4-6.

File Name Type	Extension Code	ESDT
Science data file	.hdf	L1T
Visual FRI for VNIR/SWIR bands (GeoTIFF)	_V.tif	L1T
Thermal FRI for TIR bands (GeoTIFF)	_T.tif	L1T
Browse bundled in a single HDF file	_BR.hdf	BROWSE

File Name Type	Extension Code	ESDT
Line, sample locations of the control points that correlated and comprehensive set of information regarding the verification	_QA.txt	QA
XML metadata file (three file types: hdf.xml, _BR.hdf.xml, and _QA.txt.xml)	.xml	N/A
Individual browse files extracted from a _BR.hdf file	_BR.{2,3,4}.{VNIR, TIR, QA}.jpg	N/A

Table 4-6. Example Output File Name Type Extensions

HDF bundled browse files may include up to three JPEG images: (1) Visual browse, (2) Thermal browse, and (3) single-band black and white browse overlaid with red, green, and blue (RGB) markers indicating GCPs used during the geometric verification quality check. Table 4-7 illustrates the file names that would be constructed for AST_L1T files based on an AST_L1A file named:

AST_L1A_00301112010002054_20140423133114_12345.hdf.

Example file names	Dissemination Method
HDF: AST_L1T Data Product AST_L1T_00301112010002054_20140423133114_12345.hdf	Client download, Client order, HTTP download
GeoTIFF: Visual FRI AST_L1T_00301112010002054_20140423133114_12345_V.tif	Client download, Client order, HTTP download
GeoTIFF: Thermal FRI AST_L1T_00301112010002054_20140423133114_12345_T.tif	Client download, Client order, HTTP download
XML: Metadata AST_L1T Data Product G1000067890-LPDAAC	(Reverb only) Client download
XML: Metadata AST_L1T Data Product AST_L1T_00301112010002054_20140423133114_12345.hdf.xml	Client order, HTTP download
XML: Metadata Browse AST_L1T_00301112010002054_20140423133114_12345_BR.hdf.xml	Client order
XML: QA Report AST_L1T_00301112010002054_20140423133114_12345_QA.txt.xml	Client order
JPEG: Stand Alone Reduced Resolution Browse and single-band black and white image overlaid with red, green, and blue (RGB) markers for GCPs used during the geometric verification quality check AST_L1T_00301112010002054_20140423133114_12345_BR.2.VNIR.jpg AST_L1T_00301112010002054_20140423133114_12345_BR.{2,3}.TIR.jpg AST_L1T_00301112010002054_20140423133114_12345_BR.{3,4}.QA.jpg <i>{ } Number in extension depends upon VNIR and/or TIR ON</i>	Client download, HTTP download
HDF: Bundled Browse AST_L1T_00301112010002054_20140423133114_12345_BR.hdf	Client order
Text: Geometric Quality Verification Report AST_L1T_00301112010002054_20140423133114_12345_QA.txt	Client order, HTTP download

Table 4-7. Example ASTER Output File Names

The user should note that different granule file combinations are offered depending on the dissemination method (client order, client download, HTTP download) selected. Refer to Appendix J to compare file naming conventions between AST_L1A, AST_L1B, and AST_L1T for client download and client order scenarios.

4.4 Telescope Combinations

Day-to-day implementation of the ASTER data acquisition strategy results in various combinations of telescope activation. Variations in telescope commanding determines the types of image data available in the AST_L1A dataset collection. By default, these variations in the AST_L1A are replicated in associated AST_L1T. Further variations are possible due to the fact that SWIR was deemed unhealthy past April 2008. Specifically, the AST_L1T algorithm does not produce SWIR AST_L1T images from AST_L1A (where SWIR is present) for the time period ranging from April 1, 2008 SWIR through August 2012. SWIR was turned off August 2012 eliminating the inconsistency between AST_L1A and AST_L1T SWIR. Table 2-1 illustrates the various combinations of image data observed in AST_L1A hdf files and potentially associated AST_L1T granules.

L1A Telescopes Available	L1T Telescopes Available	L1T_T.tif	L1T_V.tif
VNIR + SWIR+ TIR	VNIR + SWIR+ TIR	Yes	Yes
VNIR + SWIR+ TIR	VNIR + TIR	Yes	Yes*
VNIR + SWIR	VNIR + SWIR	No	Yes
VNIR + SWIR	VNIR	No	Yes*
SWIR + TIR	SWIR + TIR	Yes	No
SWIR + TIR	TIR	Yes	No
VNIR + TIR	VNIR + TIR	Yes	Yes*
VNIR only	VNIR	No	Yes*
TIR only	TIR	Yes	No

*Note: GeoTIFF band selection differs because SWIR B4 is not available; no size impact.

Table 4-8. Potential Mapping of AST_L1A Bands to AST_L1T.

4.5 Download Expectations

Based on current experience with existing ASTER browse, it is reasonable to expect that the Visual, Thermal or QA browse files to upload and display in under one second. However, users may experience AST_L1T granule downloads to average considerably longer than that experienced for AST_L1A downloads especially when the additional GeoTIFF FRI files are taken into account.

Table 4-9 provides estimated AST_L1T file and granule sizes for various AST_L1A telescope combinations based on current LP DAAC holdings.¹⁷ LP DAAC historical holdings prior to April 2008 are weighted heavily on the top four rows of the table.

L1A Telescopes Available	Typical L1A HDF File Size	L1T Telescopes Used	Estimated L1T HDF File Size	L1T Granule Size
VNIR + SWIR+ TIR	117 MB	VNIR + SWIR+ TIR	140 MB	227 MB
VNIR + SWIR+ TIR	117 MB	VNIR + TIR	98 MB	185 MB
VNIR + SWIR	107 MB	VNIR + SWIR	129 MB	214 MB
VNIR + SWIR	107 MB	VNIR	86 MB	171 MB
SWIR + TIR	35 MB	SWIR + TIR	47 MB	49 MB

¹⁷ File sizes given in the table were estimated using “pigeonhole” ranging, actual file sizes may differ considerably about the average depending on how much rotation of the scene was required.

L1A Telescopes Available	Typical L1A HDF File Size	L1T Telescopes Used	Estimated L1T HDF File Size	L1T Granule Size
SWIR + TIR	35 MB	TIR	9 MB	11 MB
VNIR + TIR	85 MB	VNIR + TIR	94 MB	181 MB
VNIR only	80 MB	VNIR	86 MB	171 MB
TIR only	6 MB	TIR	9 MB	11 MB
	Visual FRI		85 MB	
	Thermal FRI		2 MB	

Table 4-9. Estimated Output File Sizes

Ultimately, file moves from the HTTP server to user resources depends upon how fast the user's remote system can take data. FRI-only downloads will be somewhat faster than what it takes to download their associated HDF files.

Section 5 Search, Order and User Tools

5.1 Terminology

Within the EDOS user community, the terms scene, product, or granule can often be correctly used interchangeably. “Scene” is most often used in a visual context. “Product” is more often used to describe the output of a process that converts an input to a new science level. “Granule” is more often used to represent an aggregation of files to make up a whole instance of a product (e.g., science data, browse, metadata, and QA information). Thus the term granule is often used in the context of user client systems to cover all usable elements of a product. The term “dataset” is typically used to represent an aggregation of granules having a fundamental attribute in common, such as having been produced using a specific version of an algorithm (e.g., AST_L1T version 003). Finally, the term “collection” is typically used to aggregate datasets having a common attribute, such as an instrument (ASTER) or processing level (AST_L1T).

5.2 Search and Order Approaches

ASTER AST_L1T products are made available to the user community through online interfaces provided by both NASA and USGS. The LP DAAC pushes AST_L1T metadata to external systems that support search engines accessed through user client tools. In addition, users who are very familiar with the ASTER dataset collection may choose to directly download AST_L1T from the public LP DAAC Data Pool by using HTTP access. For this document, the user can acquire AST_L1T granules from NASA Reverb, USGS/EROS EarthExplorer, USGS/EROS GloVis, and the LP DAAC Data Pool.

5.2.1 NASA ECHO/Reverb

NASA provides the EOS Clearing HOuse (ECHO) system to serve its Reverb user client. Reverb supports many EOS data products so the user generally down selects to specific collections and datasets in order to quickly locate science granules of interest. Science granules from the dataset are placed in a shopping cart which is used to provide options for allowing access to the entire granule or its elements.

To fast track to AST_L1T granules, it is recommended that user enters the characters “AST_L1T” in the “Search Terms” field. Also it is recommended that users plot an area of interest on the map and consider entering “Temporal Search” for start and end of data acquisition. These steps lead to an offering of datasets for selection and finally to a granule list. Granules can be inspected using browse and information buttons before being selected for inclusion in the shopping cart.

Reverb provides both user client *download* and *order* capabilities for registered users. The download capability allows users to select individually data, metadata, or browse from granule(s) listed in the shopping cart. Upon selection, the user downloads small files containing URLs that allow final retrieval of each of the granule elements. Generally, the URLs are accessed during the Reverb session but this is not necessary

for data and browse; it is necessary to keep the original open to download metadata from Reverb.

The order capability also works from the shopping cart. Orders ultimately result in messages being emailed to the user from the LP DAAC indicating that the order is ready. The message has a URL that allows the user to download a .zip file containing the granule as well as a URL to the order directory to allow the user to selectively download granule elements. The order process may be preferred over direct download for acquiring data after the Reverb session has ended, especially for orders containing several granules.

The URL used to start a Reverb session is:

Reverb

Refer to Appendix F for screen-shots illustrating a typical Reverb search and order/download session.

5.2.2 NASA LP DAAC Data Pool

NASA provides computer resources deployed at and managed by the LP DAAC to allow direct download of granule elements from an on-line service referred to as the “public Data Pool”. AST_L1T data found on the public Data Pool have been made available subject to contractual agreements between NASA and Japan. The LP DAAC has been permitted to make collections of AST_L1T scenes acquired over the United States and territories available to users at no cost.

Unlike user clients, the public Data Pool does not help to guide users to specific collections via search parameters. Rather users navigate using HTTP access by selecting from directories within a hierarchy. Thus users who choose to download from public Data Pool collections are expected to be very familiar with the ASTER acquisition and processing history in order to navigate to the desired granules. This is because directories are named for collections, datasets, and granule acquisition date. Users of the public Data Pool must interrogate the metadata elements of each granule in order to determine location and inspect bundled browse elements to determine scene quality or cloud coverage.

The URL used to start a public Data Pool session is:

Data Pool

Refer to Appendix G for screen shots illustrating a typical public Data Pool *download* session.

5.2.3 USGS EarthExplorer

USGS/EROS provides the EarthExplorer (EE) user client to access certain land process granules exported by the LP DAAC such as AST_L1T. For AST_L1T, EE provides LP

DAAC URLs for *download* only. EE is very similar to Reverb in its functionality but provides a slightly different look and feel for selection of search criteria. EE is strictly land processes orientated, so it offers less in the way of interdisciplinary datasets than Reverb but offers much more land science datasets. EE has the capability of displaying lines of communication on browse images which is a feature not offered by Reverb.

To search, discover, and download AST_L1T granules, EE users select search criteria such as an area of interest polygon on a map along with other fundamental criteria used to down select granules from NASA LP DAAC collections. Selected granules are added to a shopping cart which offers several download options.

The URL used to start an EarthExplorer session is:

[EarthExplorer:](#)

Refer to Appendix H for screen shots illustrating a typical EarthExplorer search and order/download session.

5.2.4 USGS GloVis

USGS/EROS provides the Global Visualization Viewer (GloVis) user to access certain Land Process granules exported by the LP DAAC such as AST_L1T. GloVis provides both client *download* and *order* capabilities. GloVis is strictly land processes orientated so it offers less in the way of interdisciplinary datasets than Reverb but offers more land science datasets. GloVis immediately displays browse images for an area of interest selected on the map and provides many map layer choices.

To search, discover, and download AST_L1T granules, GloVis users select a point on a map along with other fundamental criteria, such as the ASTER collection, which is then used to select browse images about the map point. Thus GloVis is especially useful for users interested in specific sites on the globe. An “Add” button is used to select specific scenes of interest to be saved in a list window. The file download option allows the user to download metadata and scene for all browse shown on the map or only those in the list window. A “Send to Cart” button sends the items in the list window to a shopping cart. Once in the shopping cart, the user can submit an order and view an order confirmation page. From that point on, the user opens an order notice e-mail sent from the LP DAAC with URLs that allow the user to download a .zip of the granules or selectively download individual elements of the granule.

The URL used to start a GloVis session is:

[GloVis:](#)

Refer to Appendix I for screen shots illustrating a typical GloVis search and order/download session.

5.3 Data Manipulation Tools

The majority of the proprietary as well as public domain image processing and GIS software packages that currently support HDF-EOS format are expected to handle the ASTER L1T product given that an AST_L1T scene is reprojected north-up in UTM space. Several tools are available to allow users to manipulate the data through a number of capabilities including the following:

- Reformatting, reprojecting, and mosaicking
- Data quality assessment
- GIS and image processing
- Multispectral data analysis

Table 5-1 is a list of some of the publicly available tools that support ASTER data manipulation. An updated list, with current URLs, can found on the current LP DAAC WEB page:

<https://lpdaac.usgs.gov/tools>

Tool	Description
LP DAAC Tools	Maintained by LP DAAC
ASTER DAR Tool	Schedule ASTER data tasking requests
ASTER Overpass Predictor	Estimate future ASTER imaging locations
Public Domain Tools	Maintained by external provider
HEG	HDF-EOS to GeoTIFF Conversion
MultiSpec	Multispectral Image Data Analysis
HDFView	Data Visualization
Cube Visualization (CV)	Data Visualization
HDFLook	Data Visualization/Processing
WebWinds	Data Visualization/Processing
WinVicar	Windows-Based Image Processing
HDF Explorer Lite	Data Visualization
hdf2bin	HDF-to-Binary Conversion
hdf2asc	HDF-to-ASCII Conversion
NCSA HDF Tools	HDF Utilities
GDALInfo	Visualize HDF embedded ODL metadata and select GeoTIFF GeoKeys
GeoTIFF_GUI	Visualize select GeoTIFF GeoKeys

Table 5-1. ASTER Data Manipulation Tools

HDFView was used extensively to interrogate sample AST_L1T HDF files to support the writing of this document. Figure 5-1 illustrates two scenarios for discovering embedded ODL metadata in a sample AST_L1T HDF file. The ODL can be selected and copied to office automation tools (e.g., MS Word, Excel, PowerPoint, etc.) to simplify metadata investigation. Figure 5-2 shows a scenario used to display VNIR Band 1 as a greyscale image. The HDFView file open function also allows the user to open HDF files in edit mode for basic processing and modification.

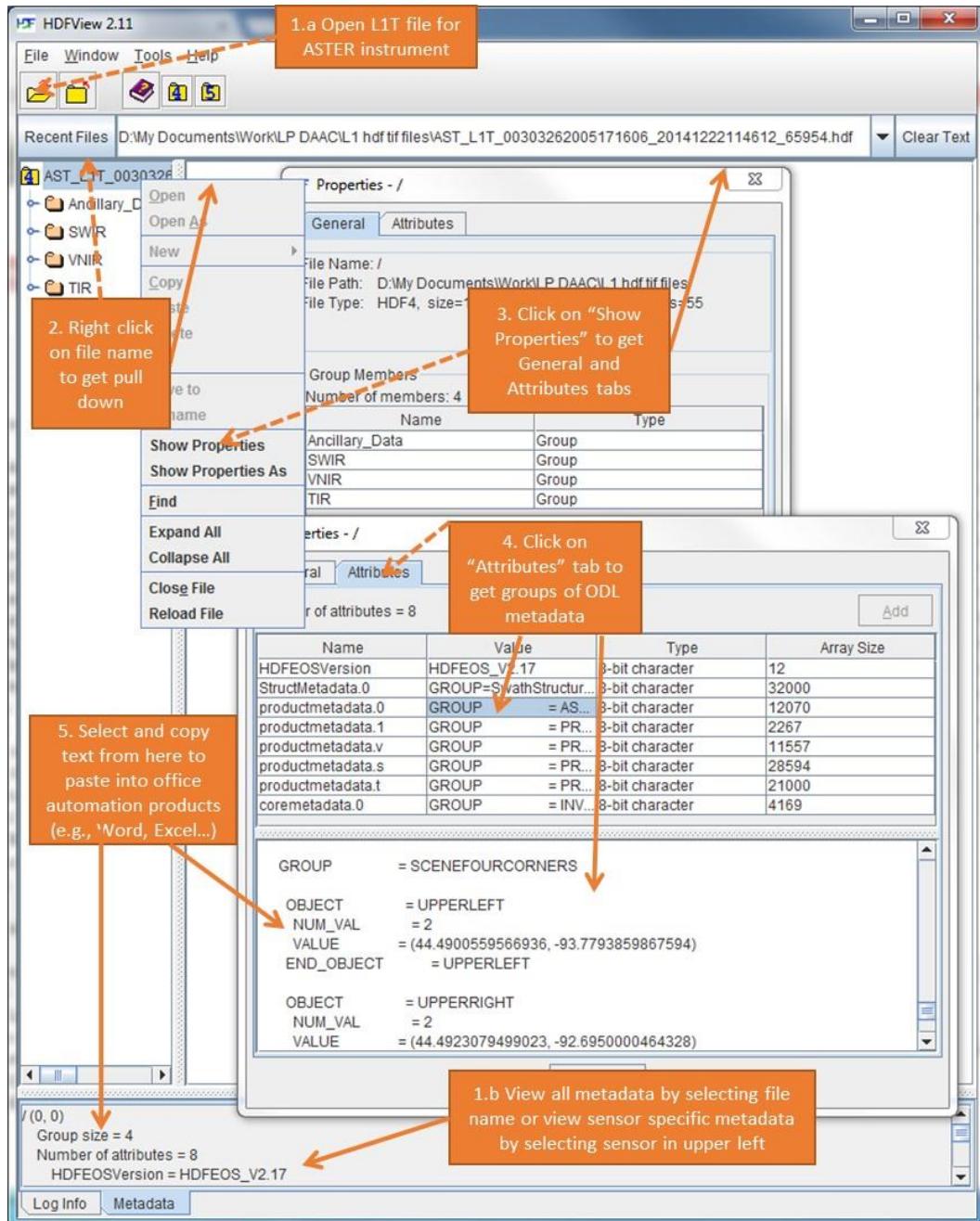


Figure 5-1. HDFView Metadata Discovery

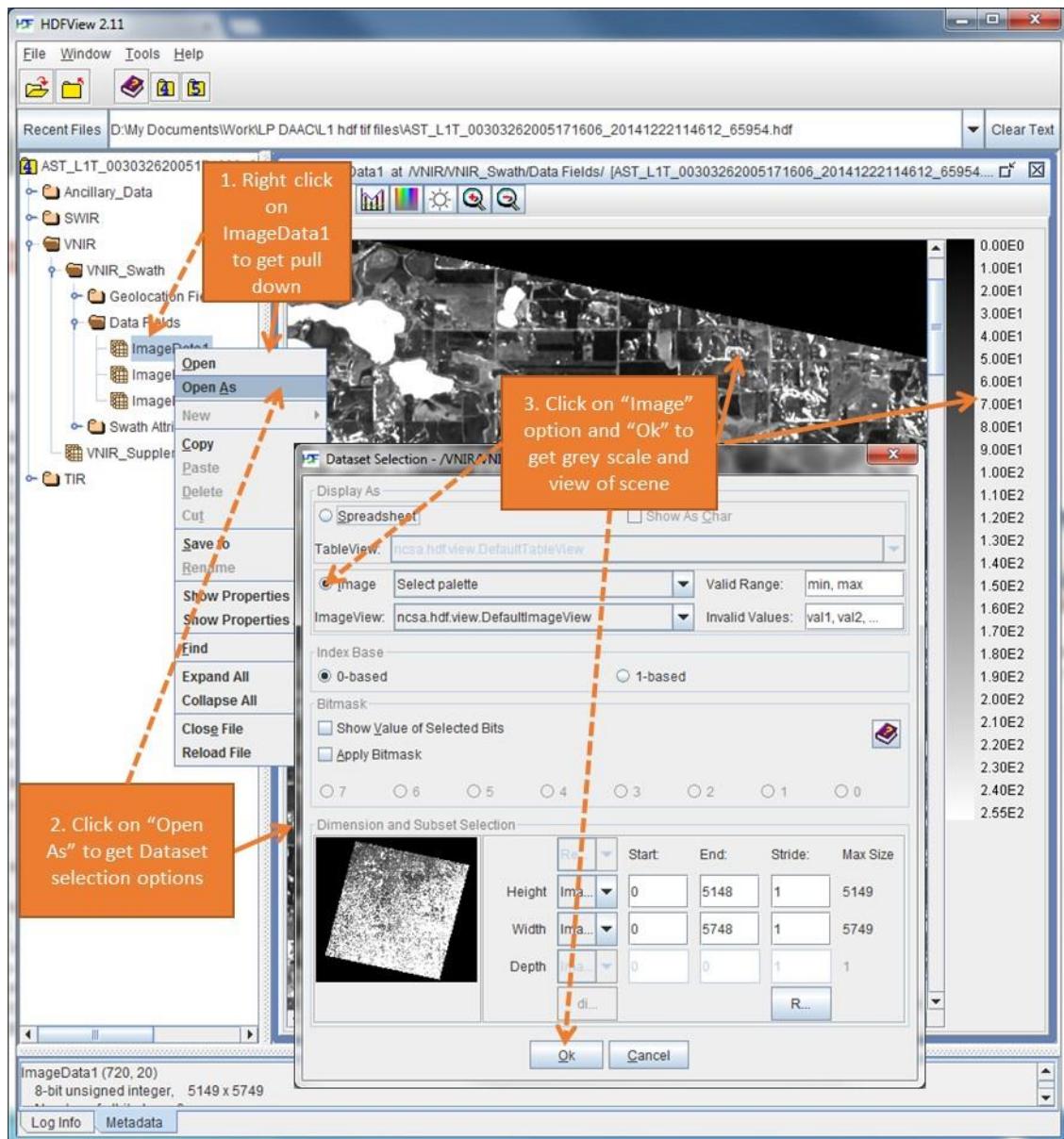


Figure 5-2. HDFView Image Display

There is also a sizable selection of tools available to the science user community for performing operations on ASTER HDF files. ENVI by RSI and ERDAS Imagine by Leica Geosystems are examples of two popular commercial off the shelf (COTS) tools in wide use. Like HDFView, another popular public domain tool is the HDF-EOS to GeoTIFF (HEG) conversion tool. The URL below provides a 2006 document discussing the use of ENVI, ERDAS, and HEG to geo-reference AST_L1B. Although AST_L1T is already geo-referenced, the document is useful to observe some of the capabilities these tools provide to manipulate AST_L1T HDF files.

https://lpdaac.usgs.gov/sites/default/files/public/aster/docs/ASTER_GeoRef_FINAL.pdf

Section 6 Processing Irregularities

Several irregularities were observed while processing 6 million AST_L1A historical source files to create associated AST_L1T products. In one case, visual full resolution images, having a SWIR band, were found to have color stripes on the east and west edges. In these cases, striping is a normal condition resulting from an attempt to preserve all available data available in the bands. Two other cases observed are due to rare anomalies in support information embedded the original AST_L1A HDF. One anomaly, associated with bad mapping data, causes clipped corners in the rotated AST_L1T image. The other anomaly, due to bad affine coefficients, causes warping in the image. If errors other than the ones pointed out in this section are observed, users are encouraged to notify the LP DAAC using the contact information found on the web page: https://lpdaac.usgs.gov/user_services.

6.1 Edge Striping on Visual FRI Having SWIR Band

AST_L1T visual full resolution images having SWIR band 4¹⁸ exhibit a red stripe on the west (right) side and a green stripe on the east (left) side of the image. The image RGB bands consist of SWIR band 4 (red), VNIR band 3N (green), and VNIR band 2 (blue). As illustrated in Figure 6-1, the L1A data for these bands have different ground “foot prints”, most likely due to slightly differing telescope ground views. The bands used in the color images are not trimmed to the common ground coverage because data in the trimmed regions may be of interest to some users.

AST_L1T_00306032001190608_20150429152117_4161_V.tif

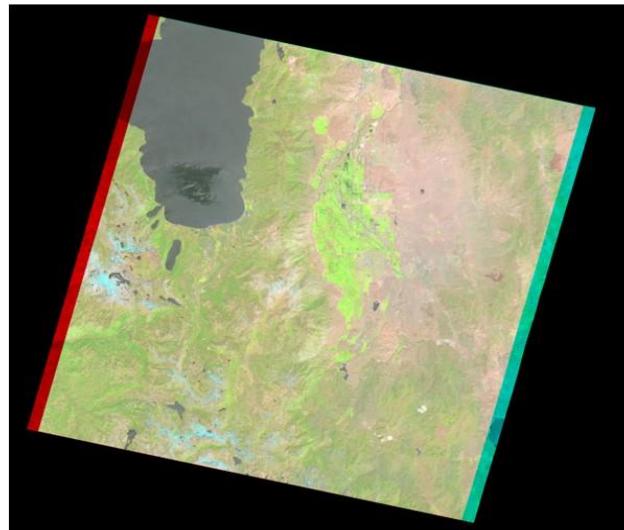


Figure 6-1. Edge Striping in Visual FRI having SWIR Band

6.2 Clipped Corners on VNIR-Only HDF

For some AST_L1T VNIR only scenes, the information used for mapping from L1A to L1B space contains errors. The AST_L1T PGE uses L1A to L1B mapping parameters

¹⁸ In the Visual FRI having a SWIR band, SWIR band 4 is resampled from 30 meter resolution to be compatible with 15 meter VNIR bands.

for systematic corrections such as band offsets, so these errors are inherited by the AST_L1T. Figure 6-2 illustrates what happens when the PGE projects the left and right boundary data outside the scene frame which in this case is the lower left corner.

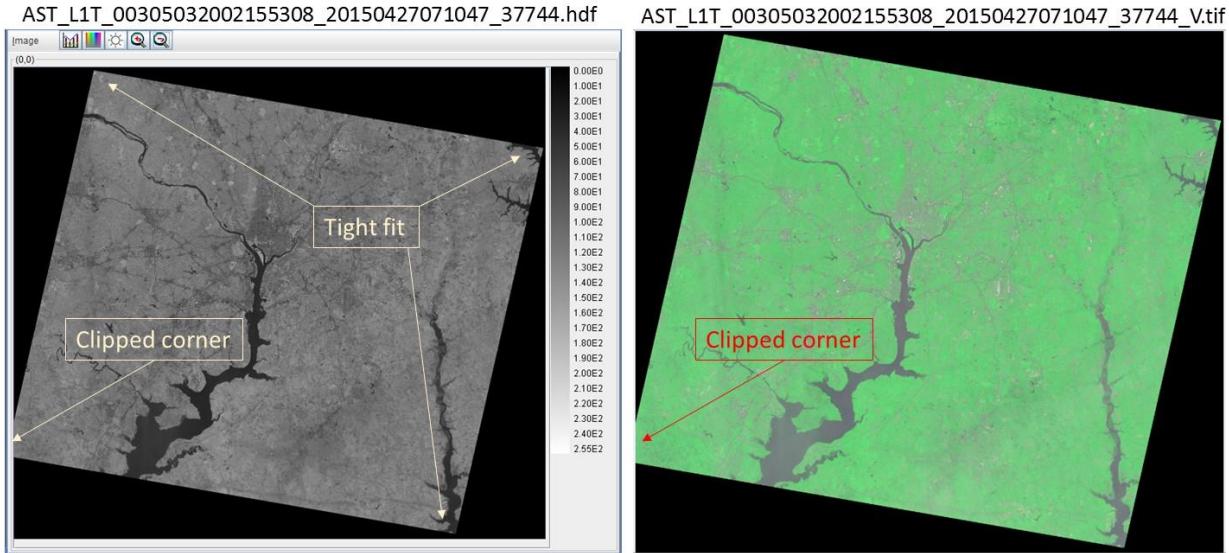


Figure 6-2. Clipped Corner for VNIR-only AST_L1T HDF and _V.TIF

6.3 Warping Due to Bad Affine Coefficients

Under certain conditions, a few AST_L1A products will not process up to the AST_L1T level or they may process but result in a warped image. To date the main failure has been due to bad affine coefficients that cause AST_L1T resampling to fail. Under AST_L1T production rules the entire product fails if any band in the file fails to process. This is unlike AST_L1B production which only fails if all bands to fail to process. Both Figure 6-3 and Figure 6-4 provide examples of failures seen in AST_L1A files that have succeeded to process to AST_L1B but **failed** in AST_L1T production.

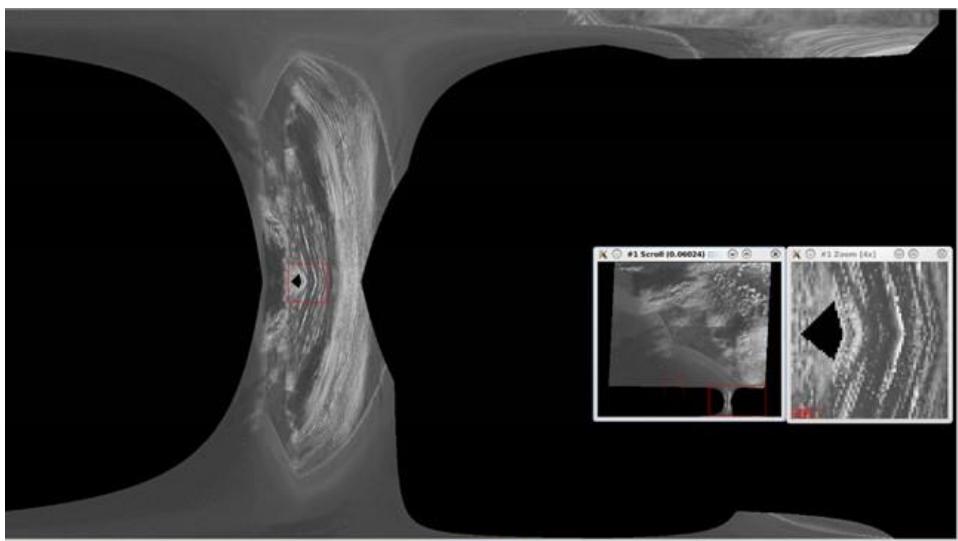


Figure 6-3. Bottom Warping AST_L1B Which Fails AST_L1T PGE

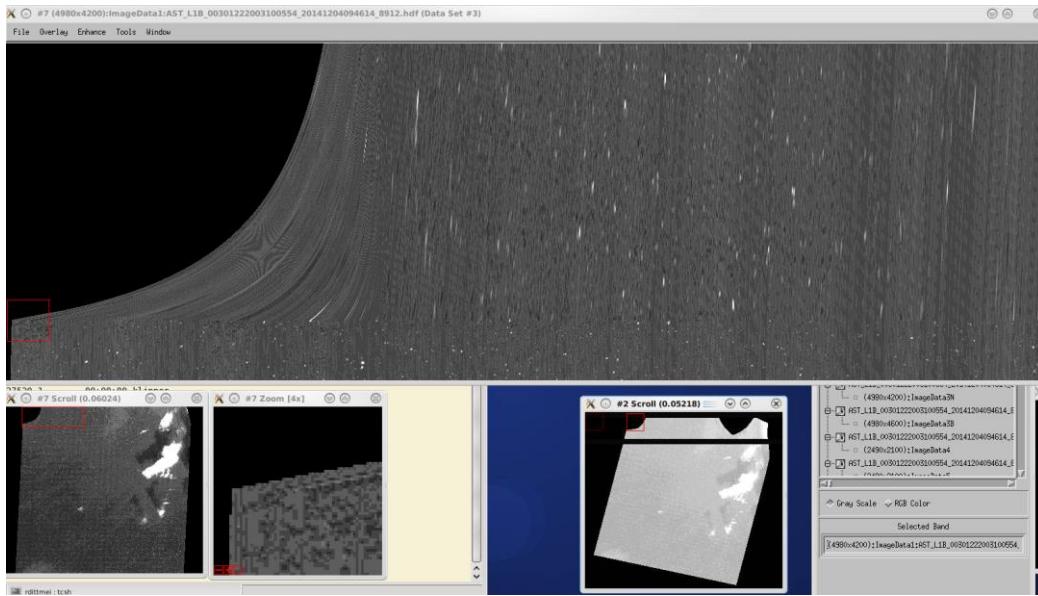
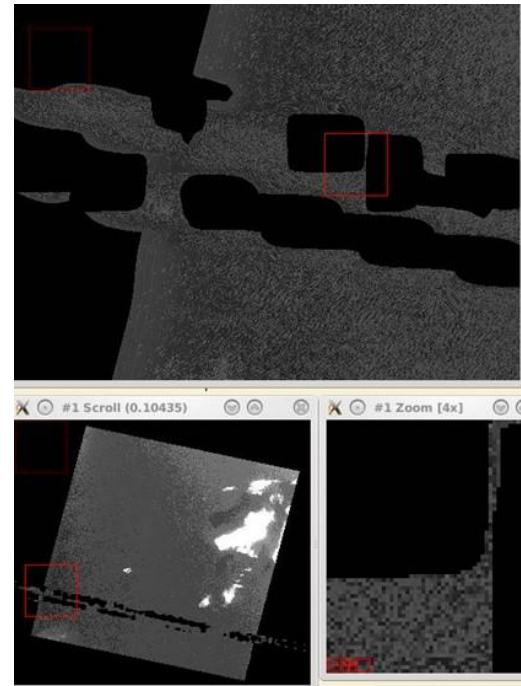


Figure 6-4. Top Warping AST_L1B Which Fails AST_L1T PGE

A subset of production runs involving bad affine coefficients **may succeed** in producing an AST_L1T product. In these rare cases, production results in an image with some warped areas. Figure 6-5 illustrates a production run involving bad affine coefficients which resulted in an AST_L1T having anomalous artifacts near the bottom of the scene.

Figure 6-5. Bottom Warping Which Succeeds in AST_L1T Production



References and Information

ERSDAC	Level-1 Data Working Group, ASTER Science Team, 1996, Level-1 Algorithm Theoretical Basis Document for ASTER Level-1 Data Processing Version 3
JPL	Abrams, Hook, Ramachandran, 2002, ASTER User Handbook Version 2
NASA/ESDIS	Behnke, DATA Templates [<i>for Product Developers, DAAC and ESDIS-SOO, and Science Community Participants</i>] – Modified with 2012 LP DAAC proposal for AST_L1T
USGS/LP DAAC	Daucsavage, March 2015, AST_L1T Product Specification
USGS/LP DAAC	Meyer, Siemonsma, February 2015, Algorithm Theoretical Basis Document (ATBD) for Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Level 1 Precision Terrain Corrected Registered At-sensor Radiance Product (AST_L1T)
USGS/LP DAAC	LP DAAC User Services, March 2006, Geo-Referencing ASTER Level-1B Data: General Overview and Examples of Particular COTS Packages and Public Domain Software, https://lpdaac.usgs.gov/sites/default/files/public/aster/docs/ASTER_GeoRef_FINAL.pdf

Glossary

ASTER – The Advanced Spaceborne Thermal Emission and Reflection Radiometer instrument provides 14 multispectral bands from visible through thermal infrared.

ASTER L1T PGE – Used generically throughout this document to represent product generation software that includes the AST_L1T executable utilizing the systematic L1B correction, L1Core which is part of Landsat's precision and terrain correction production executable modified to handle ASTER data, GDAL to generate GeoTIFF full-resolution browse as well as JPEG reduced-resolution browse, and ASTER Gverify (geometric verification) to generate geometric Quality Assessment data.

EarthExplorer – A USGS EROS Earth Science metadata and service discovery tool linked to the USGS inventory. The EE user client allows users to query collections for granules, view reduced resolution (thumbnail) browse, view collection or granule metadata, view QA information, view granule extents on a map, and select individual granules for direct download from the LP DAAC.

Earth Science Data Type –Used to convey relationships between product attributes and their characteristics and to enable EOSDIS Core System interfaces for a product.

ECHO – The EOS Clearing HOuse (ECHO) is an Earth Science metadata and service registry populated with metadata and browse imagery from data partners, such as the LP DAAC. ECHO is an open system providing Application Program Interfaces (APIs) to the Earth science community, which are used to build client systems. The LP DAAC exports metadata information to ECHO, which provides product inventory to the Reverb user client. ECHO serves as an order broker for user client systems.

Global Visualization Viewer (GloVis) – A USGS EROS Earth Science data discovery tool linked to the USGS inventory. GloVis provides a graphic map display from which a user can select any area of interest and immediately view all available browse images within the USGS inventory for the specified location.

Granule – Used to represent a collection of files that aggregate together to make up a whole instance of a given level of a product.

Historical Processing – The operation executed to process lower-level products to replace higher-level products is generally referred to as reprocessing in the earth science community. Reprocessing implies that an older version of the higher-level product will be supplanted with a newer version. A special case of reprocessing occurs when there is no older version to replace. This special case is referred to as historical processing because it is needed to initialize the collection usually going back through an archive from the point where forward processing of the new product eventually started.

Product – Often used in the context as the output of a process that converts an input to a new science level. Product is the preferred term but usage often becomes unwieldy in sentences containing several derivations of the word.

Reverb – A NASA-provided Earth Science metadata and service discovery tool linked to the ECHO inventory. The Reverb user client allows users to create accounts, view collection summary information, filter product collections using keywords, save queries as bookmarks, query collections for granules, view reduced resolution (thumbnail) browse, view collection or granule metadata, view QA information, view granule extents on a map, select individual granules for direct download, or place orders to data providers, such as the LP DAAC.

Scene – Most often used in a visual context or as an index in a database.

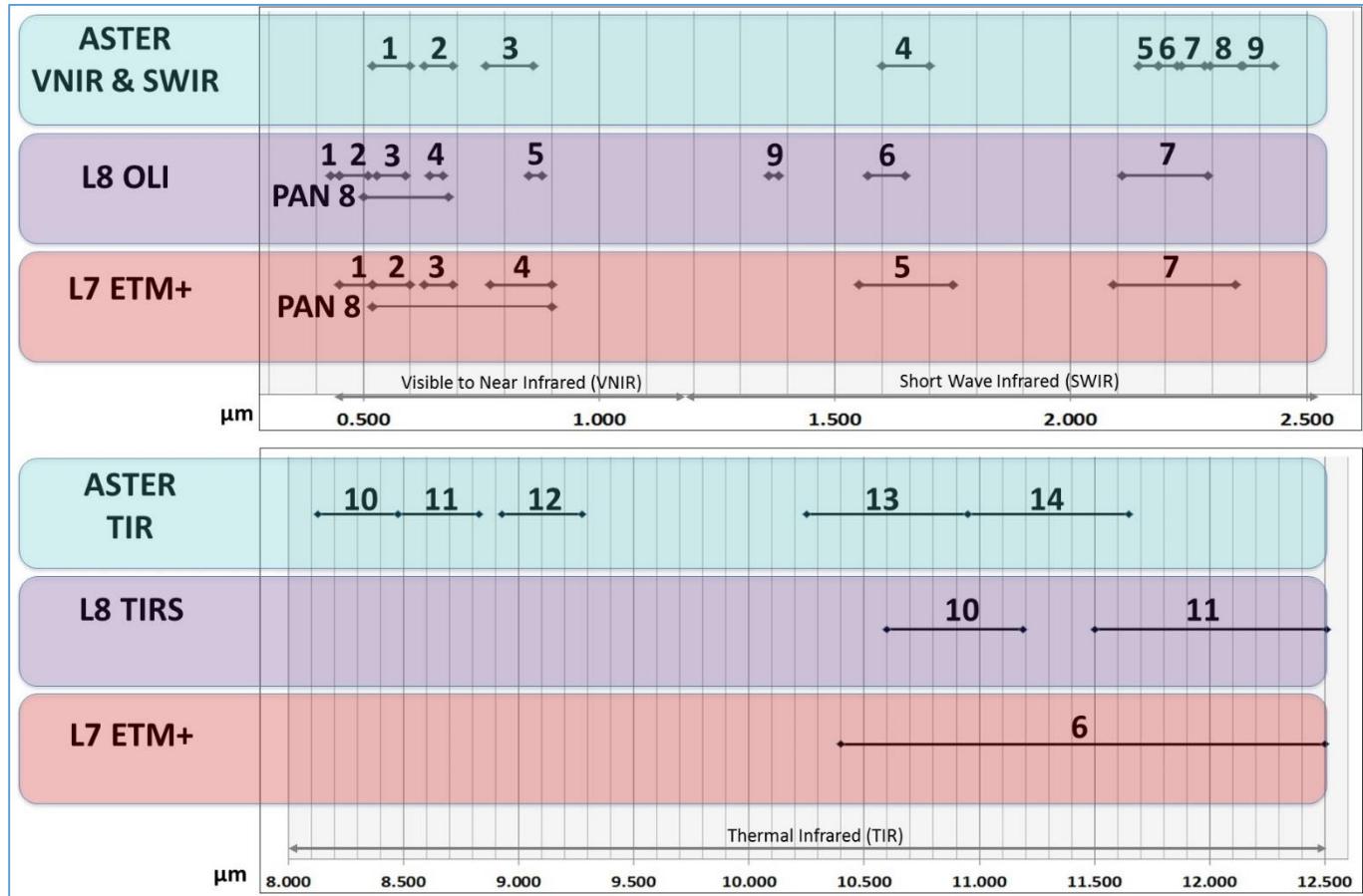
Acronyms

Acronym	Description
ASTER	Advanced Spaceborne Thermal Emission and Reflectance Radiometer – an instrument on the Terra satellite
ATBD	Algorithm Theoretical Basis Document
CAL/VAL	Calibration / Validation
DEM	Digital Elevation Model
DN	Digital Numbers
ECHO	EOS Clearing HOUse
ECS	EOSDIS Core System
EDOS	EOS Data and Operations System
EDS	Expedited Dataset
EE	EarthExplorer – <i>Search system for direct download of ASTER products</i>
EOS	Earth Observing System
EROS	Earth Resource Observation Sciences
ESDIS	Earth Science Data and Information System
ESDT	Earth Science Data Type
EXP	Expedited
FRI	AST_L1T Full Resolution Image (GeoTIFF)
GDS	Ground Data System (Japan)
GloVis	USGS Global Visualization Viewer – Search system for direct download and/or order of ASTER products
GUI	Graphical User Interface
HDF	Hierarchical Data Format
HTTP	HyperText Transfer Protocol
JPL	Jet Propulsion Laboratory
L(n)	Science Product Level (n = 1, 2, or 3)
L1A	ASTER Level 1 Reconstructed, Unprocessed Instrument Digital Numbers
L1AE	ASTER Level 1A Expedited via DAR process
L1B	ASTER Level 1 Radiometrically Calibrated, Geometrically Co-registered
L1BE	ASTER Level 1B Expedited via DAR process
L1T	ASTER Level 1 Precision Terrain Corrected Registered At-sensor Radiance
LP DAAC	Land Processing Distributed Active Archive Center
NASA	National Aeronautics and Space Administration
OSF	Orbit Schedule File
PGE	Product Generation Executable
POSF	Parsed OSF
Reverb	NASA system for direct download and/or order of ASTER products via ECHO inventory
SILC	Sensor Information Laboratory Corporation (for ASTER)

SIPS	Science Investigator-led Processing Systems
SWIR	Short Wave Infrared
TIR	Thermal Infrared (Long Wave)
USGS	United States Geological Survey
VNIR	Visible Near Infrared

Appendix A ASTER and Landsat Spectral Comparisons

The following figure compares the Terra-ASTER and Landsat spacecraft, instruments, and bands within the observable spectrum.



Similar to the Terra satellite, the Landsat spacecraft are flying in a circular, near-polar orbit at an altitude of 705 km. The orbit is sun-synchronous with the Terra equatorial crossing at local time of 10:30 a.m. This renders daytime orbits to be descending passes while nighttime orbits are ascending passes. Terra returns to the same orbit every 16 days completing over 14 orbits per day. The orbit parameters are the same as those of Landsat, with an equatorial crossing time between 10:00 am and 10:15 am (local time). Terra and Landsat 7 are in the same orbit with Terra crossing the equator 15 minutes later than Landsat 7. Landsat 8 is offset from the other two satellites by 8 days.

The following table compares the Terra-ASTER and Landsat spacecraft, instruments, and bands for pixel size, band numbering scheme, and spectral wavelength collected.

Spacecraft	Instrument	Pixel size (m)	Band	Wavelength (μm)	
				From	To
Terra	ASTER VNIR	15	1	0.52	0.60
	ASTER VNIR	15	2	0.63	0.69
	ASTER VNIR	15	3	0.76	0.86
	ASTER SWIR	30	4	1.600	1.700
	ASTER SWIR	30	5	2.145	2.185
	ASTER SWIR	30	6	2.185	2.225
	ASTER SWIR	30	7	2.235	2.285
	ASTER SWIR	30	8	2.295	2.365
	ASTER SWIR	30	9	2.360	2.430
	ASTER TIR	90	10	8.125	8.475
	ASTER TIR	90	11	8.475	8.825
	ASTER TIR	90	12	8.925	9.275
	ASTER TIR	90	13	10.25	10.95
	ASTER TIR	90	14	10.95	11.65
Landsat 8	OLI	30	1	0.43	0.45
	OLI	30	2	0.45	0.51
	OLI	30	3	0.53	0.59
	OLI	30	4	0.64	0.67
	OLI	30	5	0.85	0.88
	OLI	30	6	1.57	1.65
	OLI	30	7	2.11	2.29
	OLI PAN	15	8	0.50	0.68
	OLI	30	9	1.36	1.38
	TIRS	100* (30)	10	10.60	11.19
	TIRS	100* (30)	11	11.50	12.51
Landsat 7	ETM+	30	1	0.45	0.52
	ETM+	30	2	0.52	0.60
	ETM+	30	3	0.63	0.69
	ETM+	30	4	0.77	0.90
	ETM+	30	5	1.55	1.75
	ETM+	60** (30)	6	10.40	12.50
	ETM+	30	7	2.09	2.35
	ETM+ PAN	15	8	0.52	0.90

* Landsat 8 TIRS Bands 10 and 11 acquired at 100 m, resampled to 30 m.

** Landsat 7 ETM+ Band 6 acquired at 60 m, resampled to 30 m.

References

ASTER <http://asterweb.jpl.nasa.gov/characteristics.asp>

Landsat http://landsat.usgs.gov/band_designations_landsat_satellites.php

Appendix B ASTER Data Acquisition Strategy

ASTER was not designed to continuously acquire data; daily acquisitions are scheduled and prioritized. The ASTER Science Team has developed a data acquisition strategy divided into three categories: local observations, regional monitoring, and global map.¹⁹

Local Observations

Local observations are made in response to DARs submitted by authorized ASTER users include, for example, scenes for analyzing land use, surface energy balance, or local geologic features. Local observations are often referred to as targets of opportunity such as volcanoes, floods, or fires. Requests for urgent observations of such phenomena must be fulfilled in short time periods (a few days) so they receive special handling.

Regional Monitoring Data

Regional datasets contain the data necessary for analysis of a large region or a region requiring multi-temporal analysis. Local Observation and Regional Monitoring requests are distinguished by the amount of viewing resources required. A number of Regional Monitoring tasks have been pre-designated by the ASTER Science Team, which include repetitive imaging of:

- The world's mountain glaciers
- The world's active and dormant volcanoes
- The Long-Term Ecological Research (LTER) field sites

Global Map

The Global Map dataset is available to investigators of every discipline to complement lower resolution data acquired more frequently by other EOS instruments. Each region of the Earth has been prioritized by the ASTER Science Team for observation using the following strategy:

- Minimum of one-time coverage
- High sun angle
- Optimum gain for the local land surface
- Minimum snow and ice cover
- Minimum vegetation cover, and
- No more than 20% cloud cover (perhaps more for special sub-regions).

Allocation of Science Data

The general strategy to allocate observations to the three categories is that approximately 25% of ASTER resources will be allocated to Local Observations, 50% to Regional Monitoring, and 25% to the Global Map. Global Map data is further subdivided to for 25% high priority areas, 50% for medium priority areas, and 25% for low priority areas.

¹⁹ This subsection is paraphrased from Section 7 of the ASTER User Handbook Version 2

Regional Monitoring and the Global Map will be acquired by ASTER in response to acquisition requests submitted by the ASTER Science Team acting on behalf of the science community via Science Team Acquisition Requests (STARs) directly to the ASTER Ground Data System in Japan. Under limited circumstances, STARs for Local Observations may also be submitted by the Science Team.

STARs for Regional Monitoring data are subject to a proposal that is evaluated by ASTER's science working groups before being formally submitted to the Science Team.

Appendix C ASTER Processing Flow

Processing is initiated immediately upon the arrival of new AST_L1A from Japan, but can also be scheduled should reprocessing be necessary. The LP DAAC used a version of the reprocessing capability in early 2015 to initialize the AST_L1T collection from the historical AST_L1A archive which goes back to the year 2000.²⁰

This discussion assumes the AST_L1A has sufficient content to allow processing otherwise the algorithm would exit without producing a product. Also to enhance readability, the discussion ignores checks for rare technical conditions that prohibit the use of digital elevation data for terrain correction. Therefore it is possible that some AST_L1T may be actually processed to a systematic or precision level without the benefit of terrain correction.

The input AST_L1A is comprised of reconstructed unprocessed instrument data that contains depacketized, demultiplexed, and realigned instrument image data with geometric correction coefficients and radiometric calibration coefficients calculated and appended **but not applied**. AST_L1A also includes the SWIR parallax corrections, and intra- and inter-telescope registration information. These calculated and appended correction coefficients are applied to all AST_L1T science data. Also the science data are rotated from the satellite path orientation to a north up orientation in UTM coordinate space.

The ASTER Level 1 precision terrain corrected registered at-sensor radiance product can result from one of two different levels of potential correction because of variations among the AST_L1A input scenes. The two main logic paths for correction levels are:

- a) Terrain+Precision correction:
Applicable to all daytime AST_L1A scenes where correlation statistics reach a minimum threshold
- b) Terrain+Systematic correction:
Applied to all AST_L1A input data for which the precision correction is not possible

Two less frequent corrections may occur for scenes with no corresponding terrain data such as ocean scenes: precision correction and systematic correction. Each band is only resampled once in the flow. A Quality Assessment process occurs after the AST_L1T product has been generated. Also a process is executed to generate full resolution images for users preferring GeoTIFF over HDF-EOS2 file formats.

Earth Rotation and Nutation

The AST_L1A+ supplemental algorithm was implemented on May 25, 2005 to address geolocation discrepancies caused by an incorrect calculation of the Earth's rotation

²⁰ This subsection is paraphrased from Section 2 of the ASTER L1T ATBD and Section 3 of the ASTER L1A/B ATBD.

angle and a longitudinal error resulting from an omission of compensation for nutation in the Earth's rotation.

An incorrect calculation of the Earth's rotation angle produced a geolocation error of up to 300 meters near the poles for daytime scenes and less than 100 meters below 70 degrees latitude. The longitude error for nighttime scenes is largest at the equator, and decreases to ~100 meters at the poles. A 6th degree polynomial model is used with static coefficients to correct latitude and longitude errors for data produced prior to June 3, 2004 with Geometric database versions older than 3.00.

Between September 2003 and April 2005 an Earth nutation-related longitudinal error can be corrected by post-processing AST_L1A data using an equation defined in the AST_L1T ATBD. The longitudinal error is dependent on the date of ASTER data acquisition. In general, the magnitude of error is less than 50 meters before July 2003, and increased to approximately 200 meters through the end of 2004. All ASTER Level 1 data distributed after April 2005 was produced with the AST_L1A+ supplemental algorithm incorporating geometric database version 3.0 or later, which corrects for nutation error.

TIR Bore Sight

The AST_L1A++ supplemental algorithm implemented on May 9, 2012 uses geometric database version 3.02 or greater to address geolocation discrepancies in the TIR bands for nighttime acquisitions of approximately 100–400 meters toward the cross-track direction. This cross-track error contributes to both latitudinal and longitudinal errors because ASTER's orbit, in relation to geographic north, varies with latitude. The AST_L1T ATBD provides several equations that are a function of the pointing angle and scene orientation angle to correct latitudinal and longitudinal errors.

VNIR Lamp Calibration

The AST_L1A+++ supplemental algorithm implemented in late 2014 addresses degradation of the VNIR on-board calibrator (OBC) affected by the dimming of the OBC halogen lamps over time. The VNIR lamp-based calibration method, selected over alternate methods based on real-estate limitations aboard the Terra platform, consists of two redundant onboard calibration halogen lamps. Data collected from these lamps every 33 days are used to generate radiometric calibration coefficients (RCC) that are normalized using pre-flight data providing for a precise and repeatable means to monitor temporal trends in the radiometric response of the sensor. When the new RCC values deviate from the existing trend by 2% or more, ASTER implements a new version of the RCC values. Since launch, the average change in response is 23% for band 1, 16% for band 2, and 10% for band 3. Currently, the AST_L1A+++ supplemental algorithm utilizes radiometric database version 4.13.

Appended Corrections Applied

The AST_L1T uses the AST_L1B algorithm to apply the aforementioned radiometric calibration coefficients that were calculated and appended, but not applied to the original AST_L1A data product. Refer to the Level-1 Algorithm Theoretical Basis

Document for ASTER Level-1 Data Processing (ERSDAC 1996) for a more detailed description of AST_L1B processing.

The appended coefficients also include original corrections for the TIR DC Clamp phenomenon, and inter- and intra-telescope bore alignment. Bad pixel values are evaluated and corrected. Radiance is converted to DN values taking into account both the acquisition gain settings and the gain calibration included within the radiometric database. DN values of the bad pixels are evaluated by the linear interpolation from the adjacent pixels, followed by the de-striping correction for the DN values of the image data.

SWIR Cross-talk Correction

The cross-talk correction algorithm is a supplementary algorithm developed to address a SWIR optical leak from band 4 resulting in a superimposed ghost image on bands 5–9. The leak occurs when Band 4 incident light is reflected by the detector's aluminum-coated parts and is projected onto the other detectors. The cross-talk effect also depends upon band-to-band parallax error and the distance between array pairs. Bands 9 and 5 display the most dominant effects because of their locational proximity to the Band 4 detectors. The original algorithm for cross-talk correction generates a cross-talk image by convolution between a band-4 image and the 2-D Gaussian function. However, the kernel function for convolution is not always symmetrical in the cross-track direction. The new kernel function considers all cross-talk components with sensitivity correction coefficients that are statistically determined from a sample scene.

Pseudo-affine Transformation Coefficients

According to the well-established usual procedure, logic from the AST_L1B algorithm transforms the path oriented coordinates to UTM coordinates, which are then linked back to the original AST_L1A input image coordinates using a set of eight pseudo-affine transformation coefficients per block, expressed by the pixel size units of each band.

Terrain Correction

Where sufficient elevation data exists, the AST_L1T product may exhibit one of two different levels of terrain correction due to variations in the AST_L1A input scenes. These two levels of correction are:

- 1) Terrain+Systematic correction: applied to AST_L1A input data for which the precision correction is not possible, usually because of poor ground imaging (e.g. heavily clouded scenes, night scenes, TIR only scenes) or where ground control is not available
- 2) Terrain+Precision correction: applicable to all daytime AST_L1A scenes where correlation statistics reach a minimum threshold

In addition to the two primary levels of terrain correction listed above, two less frequent scenarios may occur for scenes with no corresponding terrain elevation data. The two correction types are referred to as precision and systematic having no reference to the

term “terrain”. These production scenarios follow the respective processes of the primary levels, except the elevation-related components are skipped.

The table below summarizes four possible results that are allowed by the flexible AST_L1T algorithm. To determine the correction levels applied to a specific product, the user must examine metadata associated to the product.

Correction Level	Condition	Likelihood
Terrain+Systematic	Poor ground imaging, or where ground control is not available	Frequent
Terrain+Precision	Correlation statistics that achieve a minimum threshold	Frequent
Systematic	Uncorrelated scenes with no corresponding terrain data	Rare
Precision	Correlated scenes with no corresponding terrain data	Rare

Possible Correction Levels Summarized

Because ASTER SWIR band 4 has a similar spatial and spectral resolution to Landsat’s band 5, it is the preferred band for use in the modified Landsat geometric algorithm. However if band 5 is not available, (or for SWIR acquired after April 2008 when the data became saturated) then VNIR band 2 is used. Use of the modified Landsat geometric algorithm begins with the creation of the systematic grid where the AST_L1A input scene is rotated from the satellite path orientation to UTM north-up orientation. The points in the rotated image are then mapped back to those of the initial AST_L1A input image space.

Global Land Survey (GLS) 2000 (GLS2000) DEM tiles are mosaicked to create an intermediary terrain dataset spanning the geometric extents of the systematic grid. At this point, the algorithm must determine the level of correction that may be achieved.

- If the scene contains only TIR bands, the intermediary terrain dataset is resampled and clipped to the systematic reference image to create a matching pixel-for-pixel terrain dataset. The AST_L1A input scene will ultimately be resampled using both the terrain dataset and the systematic grid.
- If the scene contains bands other than TIR bands, the algorithm passes the systematic grid and the intermediary terrain dataset to the terrain-precision correction process, which begins with generating a precision grid. The precision grid is created by updating the systematic grid GCP offsets computed by correlating the GCP image chips to points in the systematic band. If the number of correlation chips and precision fit statistics are within the specified tolerances, the precision grid is then used to resample the terrain dataset. Then the resampling of the AST_L1A input scene will use both the terrain dataset and the precision grid.

Systematic Correction

ASTER Terrain Systematic correction compensates for distortion in AST_L1A data resulting from topographical variations and image data with off-nadir cross-track pointing angles. It includes determining the output map-projected image space, creating the systematic grid, mosaicking the GLS2000 DEM data, clipping the GLS2000 mosaic to match the scene boundaries, and resampling the DEM to match the final AST_L1T image space. The AST_L1A input image is then resampled using both the systematic grid and the matching DEM to create the terrain-systematic image. This comprises the default level of correction for TIR-only scenes, night scenes, scenes that contain high cloud-cover, and scenes that fail to create the precision grid necessary for the terrain precision correction process.

Precision Correction

Precision correction is performed for datasets where the number of correlation chips and precision fit statistics are within the specified tolerances. In this process, the previously generated systematic image is correlated with Landsat Modified Moravec Interest Operator (MMIO) ground control points. When the 30-meter SWIR reference band 4 is not available, the 15-meter VNIR band 2 is used for correlation. The 15-meter band is down-sampled to match the GLS2000 30-meter resolution GCP chips using the GPYRAMID algorithm. GPYRAMID creates a 30-meter resolution equivalent to that of the 15-meter VNIR band 2 to the 30-meter GCP chips. In general, the GPYRAMID algorithm creates under-sampled images using the Gaussian resampling technique at multiple resolutions.

The GCPCorrelate algorithm then correlates the ground control points, and generates line and sample offsets used to update the systematic grid and ultimately creates the precision grid. The GCPs used are small image chips (64x64 pixels) with geographic information that have been extracted from the reference image using the Modified Moravec Interest Operator (MMIO) algorithm developed to identify well-defined interest points from the reference scene (USGS/EROS 2008). Using these interest points increases the success of correlation with the search image and provides accurate offsets. By choosing chips that are well-distributed throughout the imagery, nonlinear differences between the image sources can be found. For AST_L1T processing, the GLS2000 dataset is used as reference image for the precision correction process. The USGS-validated GLS2000 reference dataset has an expected Root Mean Squared Error (RMSE) of 25 meters or less.

The REFINE algorithm generates the precision grid from the systematic grid using the registration information, such as GCP residuals. The REFINE algorithm starts by using the GCPs x and y offset generated with the GCPCorrelate algorithm. Each of the GCPs is adjusted for relief displacement in the input image (ASTER AST_L1A) using the systematic grid. The adjusted GCPs in the input image are projected back to the output grid space using the same systematic grid. The systematic image location of each GCP and its relief-adjusted correlated locations are used to fit the polynomial of either first or second order using the least squares fit method. Outliers are removed by comparing the residuals in the fit to the weighted standard deviation. The systematic grid is adjusted with the polynomial coefficients to generate a precision grid, which relates the output

projection location to the input line and sample location from the AST_L1A image. The geometric resampling algorithm uses the precision grid to create a precision terrain corrected product. By default, the second order polynomial fit is used for precision correction. If significant warping occurs from the second order polynomial fit, then a first order polynomial fit is used for precision correction. To determine warping on the precision corrected image, REFINE checks if the set of points along each edge of the precision corrected image lies in a straight line to within certain specified tolerance.

Resampling For Geometric Correction

ASTER images that have only systematic correction are resampled using both the terrain dataset (if available) and the systematic grid to create a terrain-systematic corrected image. ASTER images that have precision correction, are resampled using SWIR band 4 when it is available, with the terrain dataset (if available) and the precision grid to create a terrain-precision corrected image. If band 4 is unavailable, band 2 is used in its place. In any case, no matter which correction level is achieved, only one resampling is done to produce the final product.

Geometric Verification

The geometric verification algorithm (Gverify) determines the relative accuracy of the terrain and precision corrected scene when compared to the corresponding ortho-rectified GLS2000 scene. The algorithm uses a cross-correlation procedure along with a simple outlier detection algorithm to determine the relative offsets of the terrain corrected scene to the reference GLS2000, which are accurate to 25 meters. The result is a relative error estimate for four quadrants of the scene, overall relative error estimate of the full scene, and a color-coded greyscale browse image showing the relative offsets at different geographic locations within the scene.

Quality Assurance

Simple statistics, such as mean, median, standard deviation, and RMSE for the good GCPs²¹, are calculated for the entire scene by dividing the scene into four regions. The set of good GCP points are color-coded based on their ranks and overlaid on the terrain corrected product, then a browse image is generated. The quadrant RMSE and full scene RMSE are provided in the AST_L1T metadata files for the end user.

²¹ The Gverify ground control points (GCPs) are not the same as those used for precision registration (in GCPCorrelate). The points used in Gverify are defined by a relatively high-density uniform grid across the GLS 2000 Standard scene space, for the standard scene over the ASTER L1T scene center.

Appendix D Example XML Metadata

```

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"http://ecsinfo.gsfc.nasa.gov/ECSInfo/ecsmetadata.dtd">    <-SpatialDomainContainer>      <-PSA>


```

```

-<PSA> </PSA> -<PSA> <PSAName>FullResolutionVisibleBrowseAvailable</P
<PSAName>Band6_Available</PSAName> <PSAName>RadiometricDBVersion</PSAName> SAName>
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-<PSA> <PSAValue>2.878</PSAValue> <InputGranule>
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<PSAValue>158.043462</PSAValue> </PSA> iServerUR:13:[EDC:DSSDSRV]:20:BR:Browse.001:4808
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-<PSAName>GenerationDateandTime</PSAName> <PSAValue>http://dx.doi.org</PSAValue> </QAProduct>
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-<PSA> <PSAName>GeometricDBVersion</PSAName> <PSAValue>10.5067/ASTER/AST_L1T.003</PSAValue>
-<PSAValue>03.01, 2005-05-23</PSAValue> </PSA> </GranuleMetaDataTable>

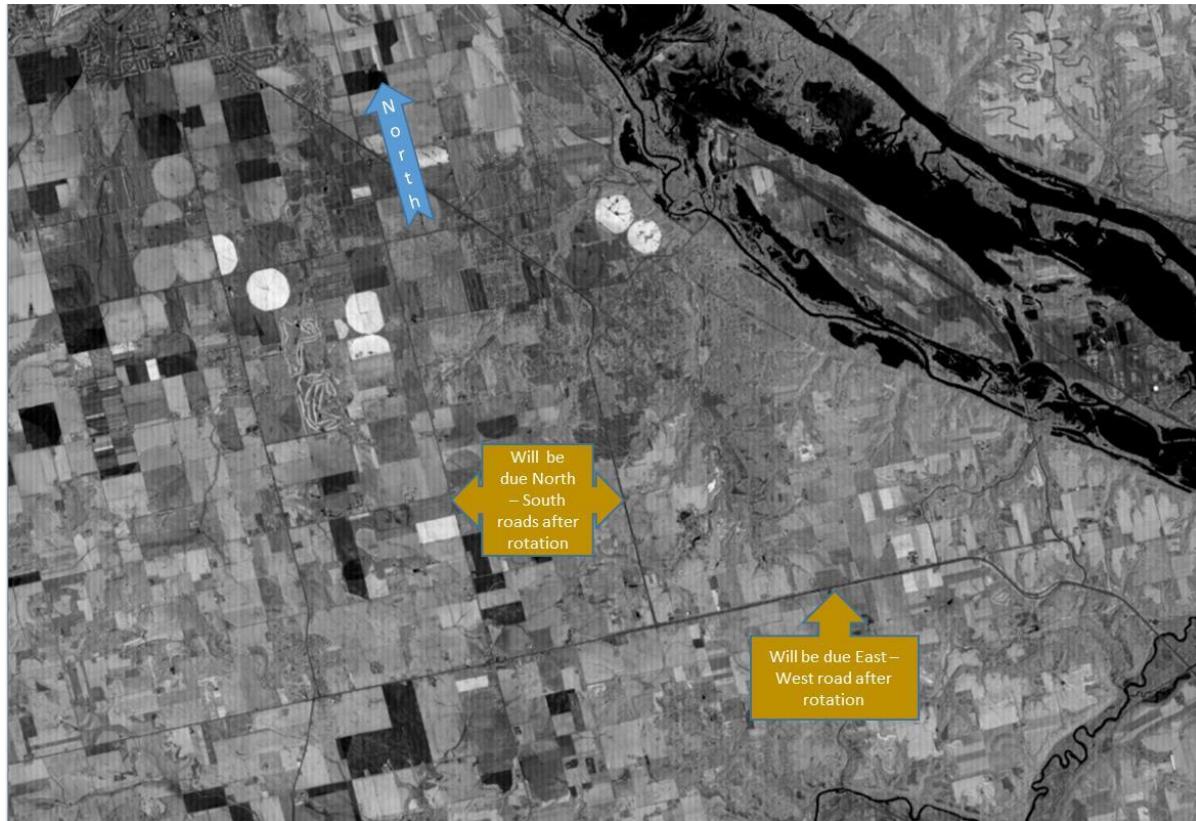
```

Appendix E Image Rotation Example

In this example, an AST_L1A scene for Minneapolis Band 3N is rotated in the AST_L1T scene. HDFView was used to capture screen shots from each of the two hdf files.

Note that there is no fill in the AST_L1A hdf file because the scene is represented in path orientation. The AST_L1A has a hdf.met ASTERSceneOrientationAngle value of 11.545023.

AST_L1A_00307032012171617_20140912110515_27039.hdf Band 3N



After the scene has been processed to AST_L1T, the hdf.xml
ASTERMapOrientationAngle value is 0.0 indicating the scene is orientated north up.

AST_L1T_00307032012171617_20141202145033_33210.hdf Band 3N



Appendix F Reverb Download/Order Session

The screenshot shows the EOSDIS Reverb search interface. At the top right, a red box highlights "1. Logged on to allow orders". On the left, a red box highlights "2a. Fast track to L1T by entering Collection ID" with an arrow pointing to the "Search Terms" field containing "AST_L1T". Another red box highlights "2b. Drag to indicate bounding box" with an arrow pointing to a map where a bounding box is being drawn over the Americas. On the right, a red box highlights "3. Hover over information to check Provider" with an arrow pointing to a provider icon next to a dataset entry.

National Aeronautics and Space Administration

EOSDIS NASA's Earth Observing System Data and Information System

Reverb | ECHO The Next Generation Earth Science Discovery Tool

Step 1: Select Search Criteria

Spatial Bounding Box: 23.886,-46.406,54.816,-125.859

Search Terms: AST_L1T

Temporal

Platforms & Instruments

Campaigns

Processing Levels

Science Keywords

Feedback? Tell us what you think.

Release Information

Upcoming Features

Wed Sep 19 2012 10:00:00
CMT 0500 (General Download Times)

4. Select Dataset from ASTER Collection

Step 2: Select Datasets

ASTER Level 1 precision terrain corrected registered at-sensor radiance V003
Archive Center: LPDAAC Short Name: AST_L1T Version: 3

ASTER Level 1 precision terrain corrected registered at-sensor radiance V003
Archive Center: PVC Short Name: AST_L1T Version: 3

ASTER Level 1 precision terrain corrected registered at-sensor radiance V003
Archive Center: LPDAAC Short Name: AST_L1T Version: 3

api-test.echo.nasa.gov/reverb/datasets/C1000000226-LPDAAC_T

Step 3: Discover Granules

Clear Selections

ASTER Level 1 precision terrain corrected registered at-sensor radiance V003
Archive Center: LPDAAC Short Name: AST_L1T Version: 3

5. Search for Granules within Dataset

Search for Granules

Search for Granules By ID

Step 1: Select Granules

List View **Map View** **Image View** **Timeline View**

[–] ASTER Level 1 precision terrain corrected registered at-sensor radiance V003
Archive Center: LPDAAC Short Name: AST_L1T Version: 3 Collection ID: C1000000226-LPDAAC_TS2

Save Granule Results as csv **Save Granule Results as kml** **Add Selected to Cart (1)**

Granule ID	Start Time	End Time	Online
AST_L1T_00303122000173157_20141223150...	2000-03-12 17:31:57 UTC	2000-03-12 17:31:57 UTC	
AST_L1T_00303122000173157_20141229145...	2000-03-12 17:31:57 UTC	2000-03-12 17:31:57 UTC	✓
AST_L1T_00303122000173157_20141231151...	2000-03-12 17:31:57 UTC	2000-03-12 17:31:57 UTC	✓
AST_L1T_00303122000173206_20141229145...	2000-03-12 17:31:57 UTC	2000-03-12 17:31:57 UTC	✓
AST_L1T_00303122000173206_20141229145...	2000-03-12 17:32:06 UTC	2000-03-12 17:32:06 UTC	✓
AST_L1T_00303122000173206_20141231151...	2000-03-12 17:32:06 UTC	2000-03-12 17:32:06 UTC	✓
AST_L1T_00303122000173206_20141231151...	2000-03-12 17:32:06 UTC	2000-03-12 17:32:06 UTC	✓
AST_L1T_00303122000173206_20141231151...	2000-03-12 17:32:06 UTC	2000-03-12 17:32:06 UTC	✓

Total Query Time: 3.45s

6. View browse and other information

7. Add granules to shopping cart

8. View shopping cart for ordering

Step 2: Go to Cart

View Items in Cart

Granule Details for AST_L1T_00303122000173206_20141223152956_88458

Granule UR: SC:AST_L1T.003:481761

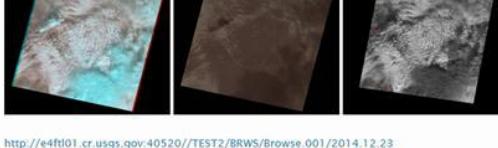
Spatial Extent: `[{"Polygon": {"Outer Boundary": ((42.0701305210452, -96.2641831786219), (41.3749112118328, -96.2291492829997), (41.3992464094348, -95.197985898448), ..., (42.0701305210452, -96.2641831786219)) "Holes": ()}]`

Temporal Extent: 2000-03-12T17:32:06.321000Z

Online Access: http://e4ft01.cr.usgs.gov/TEST2/BRWS/Browse.001/20141223152956_88458.hdf
http://e4ft01.cr.usgs.gov/TEST2/BRWS/Browse.001/20141223152956_88458_V.tif

Online Resources: http://e4ft01.cr.usgs.gov/AST_L1T_00303122000173206_20141223152956_88458_QA.txt

6. View browse and other information

Browse Products: 

Browse Access: http://e4ft01.cr.usgs.gov/40520//TEST2/BRWS/Browse.001/2014.12.23/AST_L1T_00303122000173206_20141223152956_88458_BR.2.jpg
http://e4ft01.cr.usgs.gov/40520//TEST2/BRWS/Browse.001/2014.12.23/AST_L1T_00303122000173206_20141223152956_88458_BR.3.jpg
http://e4ft01.cr.usgs.gov/40520//TEST2/BRWS/Browse.001/2014.12.23/AST_L1T_00303122000173206_20141223152956_88458_BR.4.jpg

Download Metadata: Native | Atom | ECHO 10 | ISO 19115

Show Additional Information

Shopping Cart

Remove	Item	Orderable	Downloadable	Services Available	Search Query
×	AST_L1T_003052000133932_20141223143303_72986	Yes	Yes	N/A	[?]
×	AST_L1T_003052000133932_20141223143303_72986	Yes	Yes	N/A	[?]

The following operations apply to all items currently in your cart.

Buttons: Empty Cart, Order, Download, Perform Service

Download Instructions:

Select URLs to Download:

- Data
- Metadata
- Browse

Format: Native

Select Download Option:

- Text File: [More Info](#)

File Download Window:

data_url_script_2015-01-02_164419.txt
727 bytes — nasa.gov — 3:44 PM

Show All Downloads

Buttons: Cancel, Save

Red Boxes:

- 9a. Select download options
- 10a. Order Granules
- 9d. Paste URL from file in browser
- 9c. Download Granules

Ordering 2 items from "ASTER Level 1 precision terrain corrected registered at-sensor radiance V003"

Order Options

Distribution Options

Media Type: Http Pull

Http Pull Media Format: File

In addition to science data and full resolution images, do you want to

Include associated Quality Assurance file in order?
 Include associated Browse file in order?

Order Receipt

Your submitted order information is:

Order ID: B0B8C393-4E96-CDA4-C9DB-D14FCA78FD0C ([Click to track](#))
Order status: SUBMITTING
Submitted on: Tue Dec 23 2014 17:53:25 GMT-0600 (Central Standard Time) (GMT-6:00)
Receive notifications: When orders reach a final state
Notifications will be sent to jdaucsavage@sgt-inc.com with further information.

Buttons: Back, Cancel Order, Submit Order, Return to Cart, Rerun Dataset Search, Start New Search

Red Box:

- 10.b Submit Order

Search Inbox (Ctrl+E)

Arrange By: Date Newest on top

Tuesday

- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Tue 12:14 PM
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048156 Tue 12:12 PM
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID DD6E3C74-A89B-004E-7D1F-7AA3E3BB910A Tue 12:09 PM

Last Week

- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS1 Fri 12/26
- LPDAAC@usgs.gov** LP DAAC ECS Order Notification Order ID: 0300143819 Fri 12/26
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID DF8F69D2-6A01-A7F6-8C87-0336EFA1D2AD Fri 12/26
- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Tue 12/23
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048145 Tue 12/23
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID B088C393-4E96-CDAA-C9DB-D14FCA78FD0C Tue 12/23
- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Mon 12/22
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID 06971C54-4890-5E49-D3D9-A3FF344181CD Mon 12/22
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048145 Mon 12/22
- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Mon 12/22
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID C4ADB9244E2F Mon 12/22
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048142 Mon 12/22

10.c Order notification from Reverb

Reverb Order Confirmation - ID B088C393-4E96-CDAA-C9DB-D14FCA78FD0C

reverb-support@echo.nasa.gov
Sent: Tue 12/23/2014 5:53 PM
To: John Daucavage

Dear John,

Thank you for your recent order. This email is to notify you that the following order has been received:

**** Order Overview ****
User Name: jdaucsts2
Order ID: B088C393-4E96-CDAA-C9DB-D14FCA78FD0C
Order Received: 2014-12-23T3:53:25Z
Tracking Link: <https://api-test.echo.nasa.gov/reverb/orders/B088C393-4E96-CDAA-C9DB-D14FCA78FD0C>

**** Order Item Manifest ****
Search URL: http://api-test.echo.nasa.gov/reverb/granules?utf8=%E2%9C%93&new_view=true&spatial_map=satellite&spatial_type=rectangle&keywords=AST_L1T&datasets=C1000000226-LPDAAC_TS2

Query Parameters:
*keywords: AST_L1T
*datasets: C1000000226-LPDAAC_TS2

Order Items:
*AST_L1T_0030305200133932_20141223143303_72986
*AST_L1T_0030305200133923_20141223124238_70179

Your order is being transmitted to the appropriate data provider(s) for processing. You will receive notifications from each data provider regarding your order's fulfillment. You may also receive notifications from the ECHO system according to your requested notification level.

For questions regarding order submission and/or tracking, please contact the ECHO Operations team at support@echo.nasa.gov. Please include your order's ID as a

Arrange By: Date Newest on top

Tuesday

- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Tue 12:14 PM
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048156 Tue 12:12 PM
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID DD6E3C74-A89B-004E-7D1F-7AA3E3BB910A Tue 12:09 PM

Last Week

- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS1 Fri 12/26
- LPDAAC@usgs.gov** LP DAAC ECS Order Notification Order ID: 0300143819 Fri 12/26
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID DF8F69D2-6A01-A7F6-8C87-0336EFA1D2AD Fri 12/26
- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Tue 12/23
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048145 Tue 12/23
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID B088C393-4E96-CDAA-C9DB-D14FCA78FD0C Tue 12/23
- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Mon 12/22
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID 06971C54-4890-5E49-D3D9-A3FF344181CD Mon 12/22
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048145 Mon 12/22
- support@echo.nasa.gov** Notification on status update for ECHO order from provider LPDAAC_TS2 Mon 12/22
- reverb-support@echo.nasa.gov** Reverb Order Confirmation - ID C4ADB9244E2F Mon 12/22
- LPDAAC@usgs.gov** LPDAAC ECS Order Notification Order ID: 0300048142 Mon 12/22

10.d Order availability from LP DAAC

LPDAAC_TS2

support@echo.nasa.gov
Sent: Tue 12/23/2014 5:55 PM
To: John Daucavage

Thank you for your order. Your submit request placed through the Earth Observing System Clearinghouse has been updated by data provider LPDAAC_TS2. Your request has moved from state PROCESSING to CLOSED.

Provider Comment:
Shipped

Order Details:
User placing order: jdaucsts2
Order GUID: B088C393-4E96-CDAA-C9DB-D14FCA78FD0C
Provider Order Tracking ID: 0300048145
ECHO Provider Order ID: 91805259-33E7-D6A6-C1E2-66D9492CC98A
Provider Id: LPDAAC_TS2

This is a system-generated email. Please do not reply to it. If you have any questions, please contact the ECHO Operations Team at [support@echo.nasa.gov] for further assistance.

HOST: e4ftl01.cr.usgs.gov:40520
DIR: /PullDir/030003546171166
Pull Download Links:
<http://e4ftl01.cr.usgs.gov:40520/PullDir/030003546171166/>
Download ZIP file of packaged order:
<http://e4ftl01.cr.usgs.gov:40520/PullDir/030003546171166.zip>
EXPR: 01/02/2015 17:53:36
MEDIA 1 of 1
MEDIAID:
GRANULE:
UR:10:DsShESDTUR:UR:15:DsShSciServerUR:13:[EDC:DSSDSRV]:20
:BR:Browse.001:481665
ESDT: Browse.001

TOTAL FILES: 2
FILENAME:
AST_L1T_00303052000133932_20141223143303_72986_BR.hdf
FILESIZE: 23692

10.e Link to LP DAAC directory allowing download of select granule files

10.f LP DAAC URL to download all granule files

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Name	Last modified	Size
Parent Directory		-
AST_L1T_00303052000133923_20141223124238_70179.hdf	23-Dec-2014 14:51	50M
AST_L1T_00303052000133923_20141223124238_70179.hdf.xml	23-Dec-2014 14:51	11K
AST_L1T_00303052000133923_20141223124238_70179_BR.hdf	23-Dec-2014 17:53	25K
AST_L1T_00303052000133923_20141223124238_70179_BR.hdf.xml	23-Dec-2014 17:53	1.0K
AST_L1T_00303052000133923_20141223124238_70179_T.tif	23-Dec-2014 14:51	2.3M

Opening AST_L1T_00303052000133923_20141223124238_70179_BR.hdf

You have chosen to open:
[AST_L1T_00303052000133923_20141223124238_70179_BR.hdf](#)
which is: hdf File (25.0 KB)
from: <http://e4ftl01.cr.usgs.gov:40520>

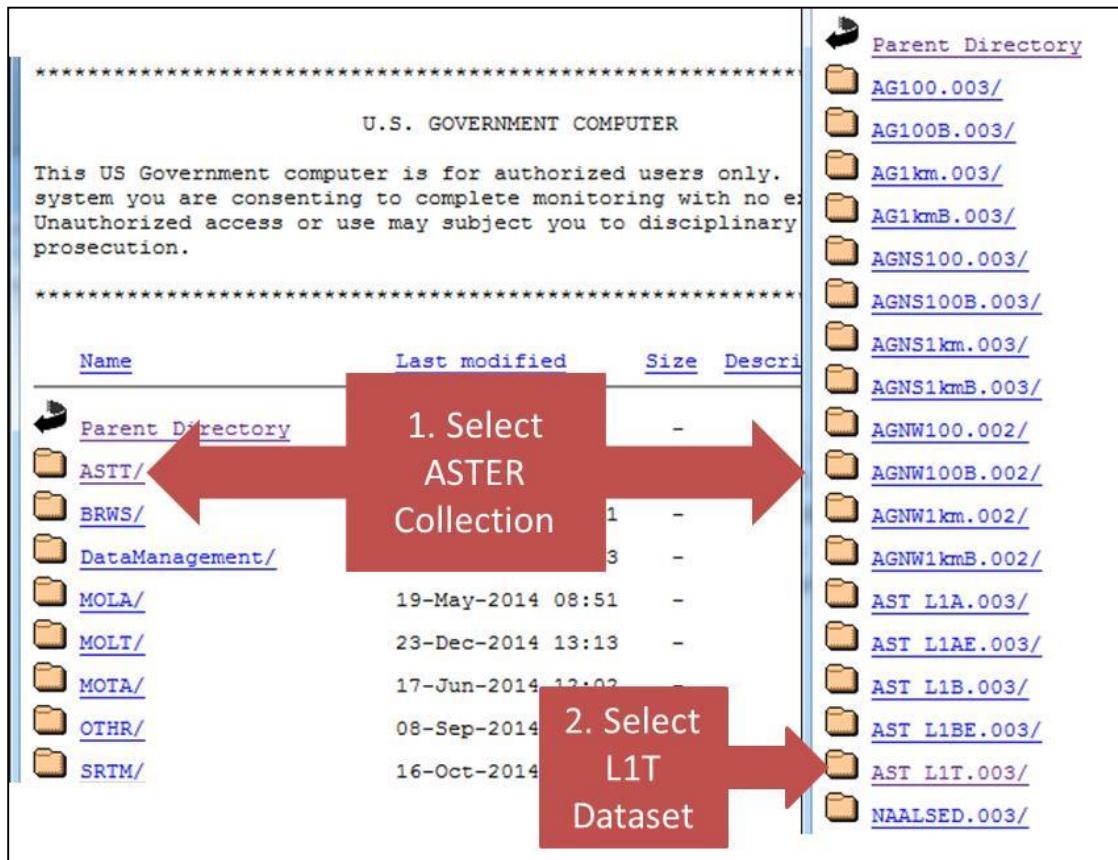
What should Firefox do with this file?

Open with HDF4 File (default) Save File
 Do this automatically for files like this from now on.

OK Cancel

10.e LP DAAC directory allowing download of select granule files

Appendix G Public Data Pool Download Session



Name
Parent Directory
2000.03.05/
2000.03.06/
2000.03.07/
2000.03.08/
2000.03.12/
2000.03.17/
2000.03.19/
2000.04.04/
2000.04.22/
2000.05.24/

Name
Parent Directory
AST L1T 00303172000001728 20141223152917 81931.hdf
AST L1T 00303172000001728 20141223152917 81931.hdf.xml
AST L1T 00303172000001728 20141223152917 81931_BR.2.jpg
AST L1T 00303172000001728 20141223152917 81931_T.tif
AST L1T 00303172000001728 20141229145158 27384.hdf
AST L1T 00303172000001728 20141229145158 27384.hdf.xml
AST L1T 00303172000001728 20141229145158 27384_BR.2.jpg
AST L1T 00303172000001728 20141229145158 27384_T.tif
AST L1T 00303172000001728 20141230095927 67411.hdf
AST L1T 00303172000001728 20141230095927 67411.hdf.xml
AST L1T 00303172000001728 20141230095927 67411_BR.2.jpg
AST L1T 00303172000001728 20141230095927 67411_T.tif
AST L1T 00303172000112120 20141223152946 86020.hdf
AST L1T 00303172000112120 20141223152946 86020.hdf.xml

3. Select Granules

Appendix H EarthExplorer Download Session

1. Enter Search Criteria

To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the [help documentation](#)), and/or choose a date range.

Address/Place Path/Row Feature Circle

Coordinates Predefined Area Shapefile KML

Degree/Minute/Second Decimal

- Lat: 51° 30' 31" N, Lon: 126° 33' 45" W
- Lat: 49° 02' 16" N, Lon: 063° 37' 58" W
- Lat: 23° 04' 46" N, Lon: 072° 46' 24" W
- Lat: 21° 56' 34" N, Lon: 122° 41' 43" W

Use Map Add Coordinate Clear Coordinates

Date Range Result Options

Search from: 01/01/1920 to: 12/31/2014
Search months: (all)

Data Sets Additional Criteria Results

Page Expires In 1:53:03

2. Select Your Data Set(s)

Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the Additional Criteria or Results buttons below. Click the plus sign next to the category name to show a list of data sets.

Use Data Set Prefilter ([What's This?](#))

Data Set Search:

- Landsat Archive
- Landsat CDR
- Landsat Legacy
- Landsat MRLC
- NASA LPDAAC Collections
 - AirMOSS Collections
 - ASTER Collections
 - ASTER Global DEM
 - ASTER Level 1B
- ASTER Global Emissivity Database
- MODIS BRDF and Albedo
- MODIS Gross Primary Productivity
- MODIS LAI/PAR
- MODIS Land Cover
- MODIS Land Surface
- MODIS Thermal Anisotropy
- MODIS Vegetation Index
- MODIS Water Mask
- NASA SRTM (SRTM 3) Collections
- WELD Collections

Orbview-3

Radar

SPOT - Historical

Clear All Selected Additional Criteria » Results »

2. Select ASTER Collection

3. Search for granules

4. Select download options

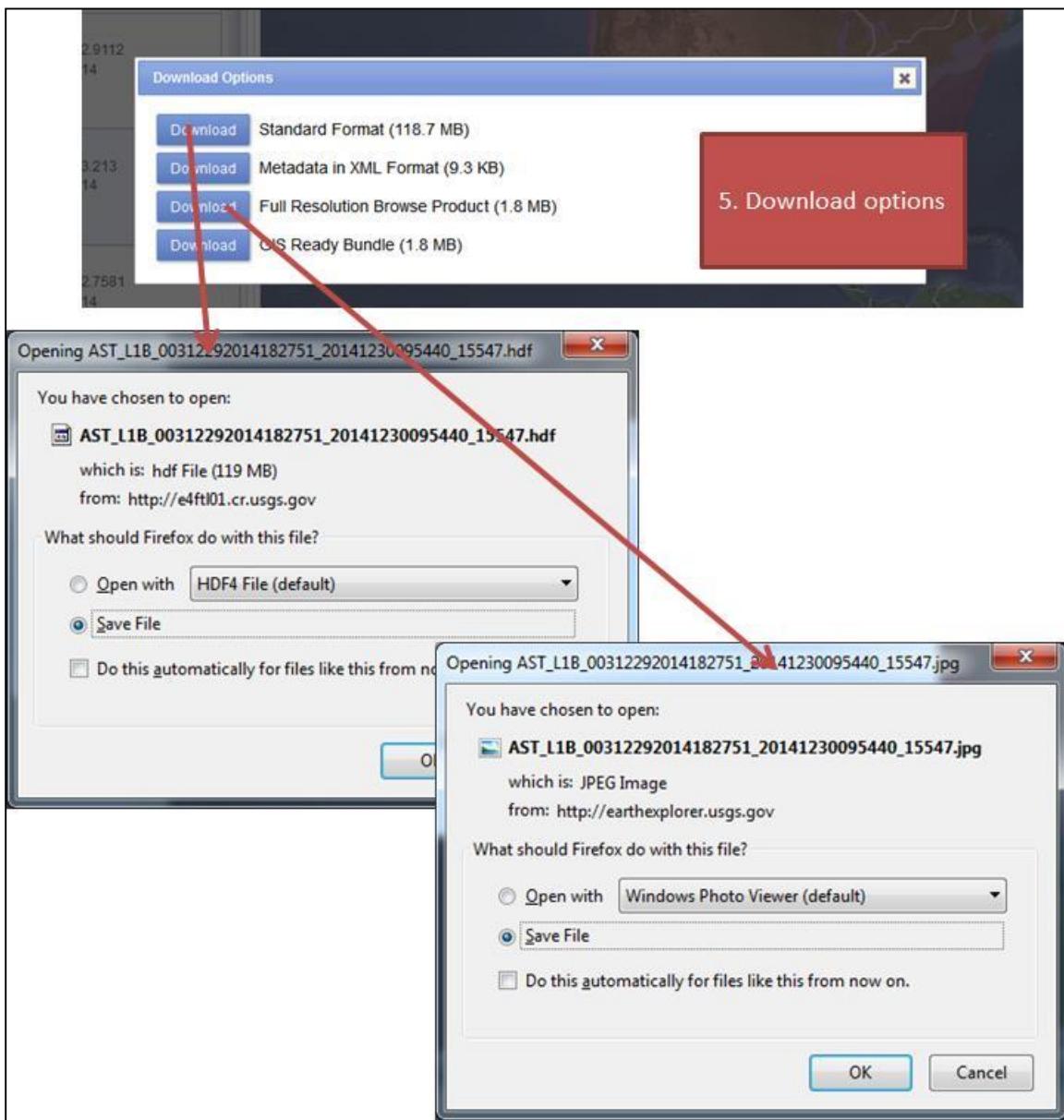
ASTER Level 1B

Downloads will not be available on Wednesdays between 8:00 AM and 12:00 PM CST due to scheduled weekly maintenance on the Land Processes Distributed Active Archive Center (LP DAAC).

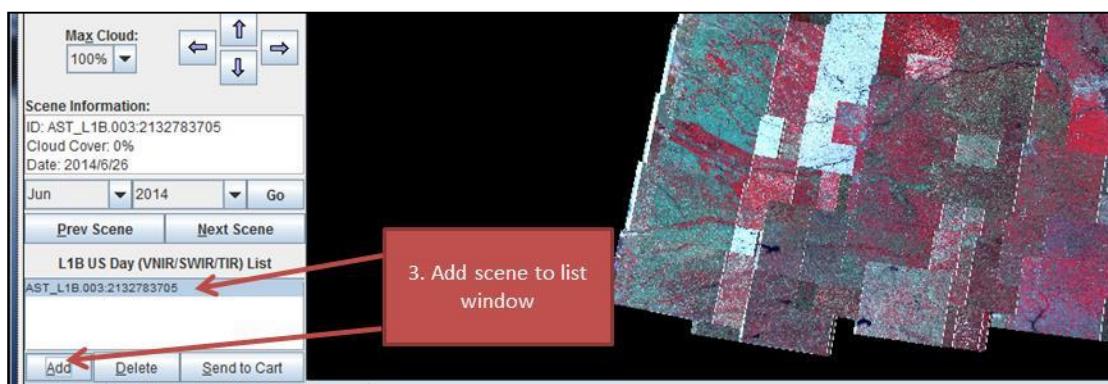
Please see the news article "[Change in Status Alert for the ASTER SWIR detector](#)" for information about SWIR bands 4 - 9.

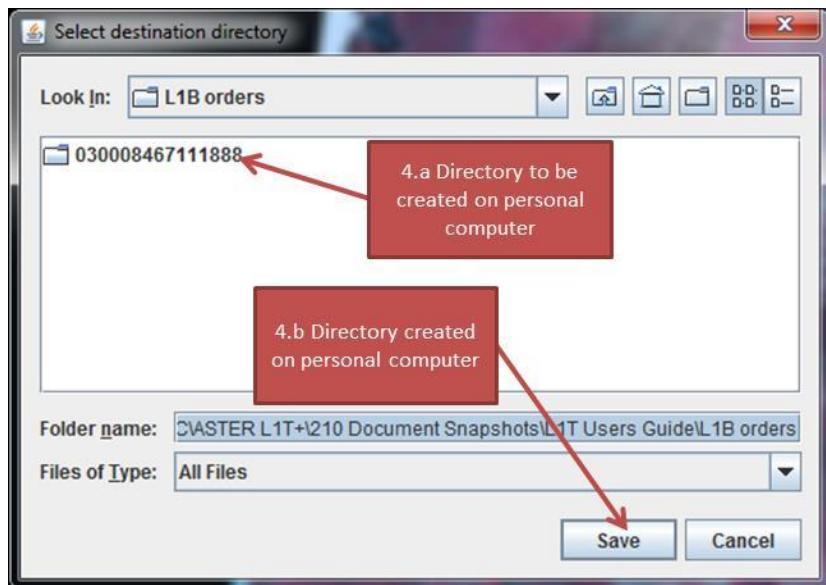
Displaying 1 - 10 of 100

Entity ID	Coordinates	Acquisition Date	Actions
2137368369	32.9227, -112.9112	29-DEC-14	
2137368367	31.627, -113.213	29-DEC-14	
2137368365	32.3928, -113.0628	29-DEC-14	
2137351753			

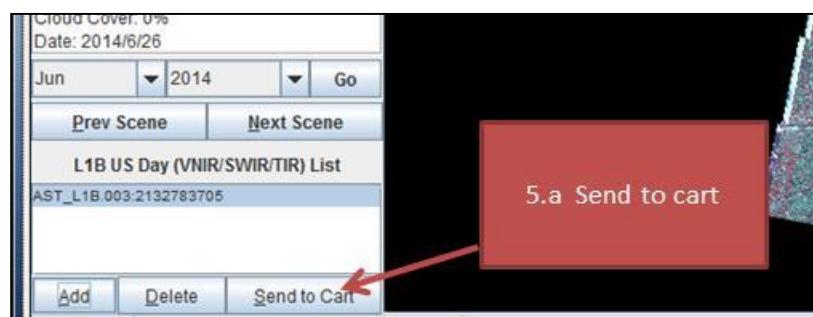


Appendix I GloVis Download/Order Session





L1B orders > glovis download 030008467111888 > 030008467111888				
Search 030008467111888				
Name	Date modified	Type	Size	
AST_L1B_00303022001180031_20140825150210_15218.hdf	12/27/2014 3:46 PM	HDF4 File	121,599 KB	
AST_L1B_00303022001180031_20140825150210_15218.hdf.xml	12/27/2014 3:46 PM	XML Document	10 KB	



Order

Note: Data sets may contain items with multiple product options. Expand a data set to view your list of ordered scenes including metadata and product options.

▲ ASTER (1)

Remove All Scenes Modify Options For All Scenes

Entity ID: 2132783705	5.b Commit order
Product: ASTER Level 1B US	
File Format: HDF	
Options: None	
Output Media: HTTP	

[Save Changes](#) [Proceed To Checkout »](#)

Order

Data Set ASTER	5.c Submit order	Return To Item Basket	Submit Order
-------------------	-------------------------	---------------------------------------	------------------------------

<input type="checkbox"/> <input type="checkbox"/> LPDAAC	LPDAAC ECS Order Notification Order ID: 0306919833 - Thank you for ordering from the N.	11:56 am
<input type="checkbox"/> USGS/EROS	USGS Online Order Confirmation (0101412317361) - USGS Online Order Confirmation — 0	11:50 am

++++++

LPDAAC ECS Order Notification

ORDERID: 0306919833
 REQUESTID: 0303218581
 USERSTRING:
 FINISHED: 12/31/2014 11:55:28

MEDIATYPE: HTTP
 MEDIAFORMAT: FILEFORMAT
 HOST: e4ftl01.cr.usgs.gov
 DIR: /PullDir/030321858117111
 Pull Download Links:
<http://e4ftl01.cr.usgs.gov/PullDir/030321858117111/>
 Download ZIP file of packaged order:
<http://e4ftl01.cr.usgs.gov/PullDir/030321858117111.zip>

EXPR: 01/10/2015 11:55:28
 MEDIA 1 of 1
 MEDIAID:
 GRANULE: UR:10:DsShESDTUR:UR:15:DsShSciServerUR:13:[EDC:
 DSSDSRV]:25:SC:AST_L1B.003:2132783705
 ESDT: AST_L1B.003

TOTAL FILES: 2
 FILENAME: AST_L1B_00306262014174809_20140627120846_17006.hdf
 FILESIZE: 86382005

FILENAME: AST_L1B_00306262014174809_20140627120846_17006.hdf.xml
 FILESIZE: 9330

5.d Link to directory to download individual files

5.e URL pulls files to personal computer download area

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5.d Directory allowing download of individual files

Name	Last modified	Size
Parent Directory		-
AST_L1B_00306262014174809_20140627120846_17006.hdf	27-Jun-2014 12:11	82M
AST_L1B_00306262014174809_20140627120846_17006.hdf.xml	27-Jun-2014 12:11	9.1K

Appendix J User Experience: Order/Download Results

Experience Factor	L1A	L1B	L1T
Browse button from granule list	Multiple orbit path-up images	Multiple orbit path-up images (L1A browse reused)	Multiple rotated north-up images
Browse in information button	Multiple orbit path-up images	Multiple orbit path-up images (L1A browse reused)	Multiple rotated north-up images
Downloadable	Yes	Yes	Yes
Download: Data	<p>Prior to ACL push -Data selection indicates AST_L1A#00303122000173259_03232002073131.hdf is not orderable as a raw product (as per contractual agreements with the Japanese owners of the ASTER sensor) resulting in the message:</p> <p>"No items you selected are downloadable"</p> <p><i>NOTE: A feature is that associated AST_L1B is suggested in shopping cart even though AST_L1B dataset not selected.</i></p>	<p>http://e4ftl01.cr.usgs.gov:40520//TEST_B/AST/AST_L1B.003/2000.03.12/... [same as download file]</p> <p>URLs in file (worked)</p> <p>Download:</p> <p>AST_L1B_00303122000173259_20120118115020_17379.hdf</p>	<p>http://e4ftl01.cr.usgs.gov:40520//TEST_B/AST/AST_L1T.003/2000.03.12/... [same as download files]</p> <p>URLs in file (worked)</p> <p>Download:</p> <p>AST_L1T_00303122000173224_20141223153036_100391.hdf</p> <p>AST_L1T_00303122000173224_20141223153036_100391_T.tif</p> <p>AST_L1T_00303122000173224_20141223153036_100391_V.tif</p>
Download: Metadata	<p>https://api-test.echo.nasa.gov/catalog-rest/echo_catalog/granules/G56350-LPDAAC_TS2?token=d39ee76a3e7004aaff90c09b7b660e5576240bc2d8c291ea9289405dc3b6e4a0%3AH8Ugy26v9KQ-3jAKXD7rNQ</p> <p>URL in file (worked – as long as Reverb session still open)</p> <p>Download via Save As: G56350-LPDAAC_TS2</p>	<p>https://api-test.echo.nasa.gov/catalog-rest/echo_catalog/granules/G1000003276-LPDAAC_TS2?token=17ee871fe294afea4aebeda66b96ec4caa82350b043912ca00495ff5623325dbd%3AH8Ugy26v9KQ-3jAKXD7rNQ</p> <p>URL in file (worked - as long as Reverb session still open)</p> <p>Download via Save As: G1000003276-LPDAAC_TS2</p>	<p>https://api-test.echo.nasa.gov/catalog-rest/echo_catalog/granules/G1000074628-LPDAAC_TS2?token=d39ee76a3e7004aaff90c09b7b660e5576240bc2d8c291ea9289405dc3b6e4a0%3AH8Ugy26v9KQ-3jAKXD7rNQ</p> <p>URL in file (worked - as long as Reverb session still open)</p> <p>Download via Save As: G1000074628-LPDAAC_TS2</p>

Experience Factor	L1A	L1B	L1T
Download: Browse	<p>http://e4ftl01.cr.usgs.gov:40510//TEST1_Da/BRWS/Browse.001/2011.10.27/:... [same as download files]</p> <p>URLs in file (worked)</p> <p>Download via Save As:</p> <p>BR Browse.001 2046033302 1.1.VNIR.jpg BR Browse.001 2046033302 1.2.SWIR.jpg BR Browse.001 2046033302 1.3.TIR.jpg</p>	<p>http://e4ftl01.cr.usgs.gov:40520//TEST2/BRWS/Browse.001/2012.01.18/:... [same as download files]</p> <p>URLs in file (worked)</p> <p>Download via Save As:</p> <p>BR Browse.001 2046033302 1.1.VNIR.jpg BR Browse.001 2046033302 1.2.SWIR.jpg BR Browse.001 2046033302 1.3.TIR.jpg</p>	<p>http://e4ftl01.cr.usgs.gov:40520//TEST2/BRWS/Browse.001/2014.12.23/:... [same as download files]</p> <p>URLs in file (worked)</p> <p>Download via Save As:</p> <p>AST_L1T_00303122000173224_20141223153036_100391_BR.2.VNIR.jpg AST_L1T_00303122000173224_20141223153036_100391_BR.3.TIR.jpg AST_L1T_00303122000173224_20141223153036_100391_BR.4.QA.jpg</p>
Orderable	No (yes if in ASTER free list and in ACL group)	Yes	Yes
Order: Data	If on free list AST_L1A_00303122000173259_20141230121056_2352.hdf	AST_L1B_00303022001180031_20140825150210_15218.hdf	AST_L1T_00303262005171548_20141222114612_66074.hdf
Order: Metadata	If on free list AST_L1A_00303122000173259_20141230121056_2352.hdf.met ²²	AST_L1B_00303022001180031_20140825150210_15218.hdf.xml	<p>AST_L1T_00303262005171548_20141222114612_66074.hdf.xml AST_L1T_00303262005171548_20141222114612_66074_BR.hdf.xml AST_L1T_00303262005171548_20141222114612_66074_QA.txt.xml</p>
Order: Browse	N/A	No	AST_L1T_00303262005171548_20141222114612_66074_BR.hdf
Order: QA Report	N/A	N/A	AST_L1T_00303262005171548_20141222114612_66074_QA.txt
Order: Checksum Report	If on free list checksum_report	checksum_report	checksum_report

²² AST_L1A metadata files have extensions “.hdf.met” while AST_L1T metadata extensions are “.hdf.xml”; special arrangements can be made to receive “hdf.met” metadata files for AST_L1T for rare special use cases.

Experience Factor	L1A	L1B	L1T
Order: GeoTIFF	N/A	N/A	AST_L1T_00303262005171548_20141222114 612_66074_T.tif AST_L1T_00303262005171548_20141222114 612_66074_V.tif