Geo-Referencing ASTER Level-1B Data

Introduction

All image processing software packages employ distinctive procedures for projecting and geo-referencing image data. Some software packages have incorporated specific import routines that geo-reference ASTER data on ingest, however, most have not. The purpose of this document is not to provide step-by-step instructions for loading ASTER Level-1B data into any particular software package, but rather to outline the various components necessary to geo-reference the data in most application software. All this information is also applicable to the Level-2 On-Demand Products derived from ASTER Level-1B data except for the ASTER Digital Elevation Model (DEM) product which is generated from an ASTER Level-1A data set.

Accessing ASTER Level-1B Metadata

The information needed to geo-register ASTER Level-1B data is located within the "embedded" metadata (i.e., the metadata contained within the header of the ASTER image data). To access that metadata you will need software capable of reading HDF-EOS-formatted data. A list of public domain software that handle HDF-EOS is available from http://edcdaac.usgs.gov/dataformat.html. Note that the ".met" file accompanying the ASTER data file does NOT contain all the required information to geo-reference ASTER data, and therefore, we suggest utilizing the embedded hdf metadata.

Specific Metadata Attributes Required for Geo-Referencing ASTER Level-1B Data

Depending on your software, any or all of the following information may be necessary to geo-reference your ASTER Level-1B image:

Category	Name as Referenced in the Embedded HDF Metadata File	HDF-EOS Subcategory	Description

Scene Corner Coordinates	SCENEFOURCORNERS	productmetadata.0	This denotes the coordinates of the upper-left, upper-right, lower-left and lower-right corners of the scene (latitude and longitude) where: lat: geodetic latitude long: geodetic longitude Unit: Degrees
Map Projection	MAPPROJECTIONNAME Or MPMETHOD (band#)	coremetadata.0 productmetadata.v productmetadata.s productmetadata.t	The name of the mapping method for the data. The available map projections are: Equi-Rectangular Lambert Conformal Conic Polar Stereographic Space Oblique Mercator, and Universal Transverse Mercator --- Map Projection Method: 'EQRECT', 'LAMCC', 'PS', 'SOM', or 'UTM',
Datum	Not specified in the metadata	Not specified in the metadata	WGS84 (for all ASTER data processed at GDS)
Zone (UTM)	UTMZONECODE (band#)	productmetadata.v productmetadata.s productmetadata.t	For VNIR, SWIR and TIR: Zone code for UTM projection (when mapping without UTM: 0 fixed). If southern zone is intended, use negative values
Number of Pixels and Lines	IMAGEDATAINFORMATION	productmetadata.v productmetadata.s productmetadata.t	VNIR: 4980 pixels x 4200 lines (1 BPP)* VNIR (3B): 4980 pixels x 4600 lines (1 BPP) SWIR: 2490 pixels x 2100 lines (1 BPP) TIR: 830 pixels x 700 lines (2 BPP) *BPP: Bytes Per Pixels
Rotation Angle	MAPORIENTATIONANGLE	productmetadata.0	This denotes the angle between the path-oriented image and the map-oriented image within the range -180.0 to 180.0 Unit: Degrees
Cell Size	SPATIALRESOLUTION	productmetadata.0	The nominal spatial resolution: VNIR: 15 SWIR: 30 TIR: 90 Unit: Meters
Resampling Method	RESMETHOD (band#)	productmetadata.v productmetadata.s	Resampling Method: CC: Cubic Convolution

		productmetadata.t	BL: Bilinear NN: Nearest Neighbor

ASTER Level-1B Geo-Referencing Methodology

How one geo-registers an ASTER Level-1B image will vary depending on what image processing software package one uses. The following is a generic description of the process independent of any particular image processing system. All the required attributes for geo-registering an ASTER Level-1B image are available from the embedded metadata in the hdf file and include:

- SCENEFOURCORNERS
- MAPORIENTATIONANGLE
- PROCESSINGPARAMETERS (Projection information)
    - MPMETHOD
    - UTMZONECODE
    - RESMETHOD

SCENEFOURCORNERS represent the geodetic latitude and longitude coordinates (UPPERLEFT, UPPERRIGHT, LOWERLEFT, LOWERRIGHT) of the ASTER Level-1B scene.

The MAPORIENTATIONANGLE denotes the angle of rotation between the path-oriented image and the transformed map-projected coordinates. Ranging from -180° to +180°, it provides the amount by which the ASTER Level-1B image is rotated from True North.

The PROCESSINGPARAMETERS object group lists a number of attributes among which MPMETHOD lists the projection used and UTMZONECODE provides the zone information. The PROCESSINGPARAMETERS object group is numbered 1 through 14 for each of the ASTER bands (VNIR, SWIR and TIR). The component objects within this group are also numbered likewise.

You will have to edit the header information for the chosen set of ASTER Level-1B bands that you need to geo-register. The header information for hdf files are encapsulated within the main hdf file itself (this is different from the external .met file).

Your image processing system (assuming it handles the hierarchical data format) will likely have a mechanism to display the embedded header information and save it to an ASCII file, and also edit their attributes.

The steps comprising the process of geo-registering your ASTER image will vary with each application software system, and hence cannot be generalized. But some of the broadly common requirements might include:

- specifying the values for the corner column-row (pixel-line) image coordinates
- specifying the correct pixel resolution for x and y
- specifying the MAPORIENTATIONANGLE value
- specifying the output projection parameters including the projection and its related information, datum etc. Presently, the datum information is not included in the metadata.

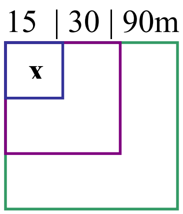
Committing the above changes and re-displaying your Level-1B should ensure that the image is displayed in geographic latitude-longitude coordinates. You can further verify the quality of geo-registration by overlaying a reliable vector coverage layer of the same area that has the same projection coordinates as your ASTER Level-1B image.

Unique Features of ASTER Level-1B Data

Pixel Reference Location

There is a fundamental difference between the alignment of the image bands and how their pixels are referenced. Assuming that we have the full complement of data from all the three sensors (VNIR, SWIR, and TIR), the VNIR Band-2 is used as the reference band, and data for all the three sensors are aligned by the upper-left **corners** of their upper-left pixels. When there are only SWIR and TIR bands present, the SWIR Band-6 is used as the reference band. When a Level-1B data set contains only TIR data, the TIR Band-11 is used as the reference band.

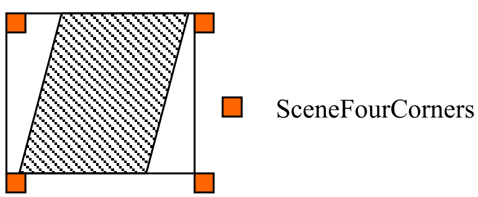
The SceneFourCorners upper-left is calculated using Band-2 of the VNIR (or Band-6 of SWIR or Band-11 of TIR as warranted by the data acquisition), and represents the **center** of the upper left image pixel. You may need to make necessary adjustments to the x and y values representing the centers of any particular sensor's upper-left image pixel depending on how your specific image processing software references the pixel location (see diagram below where “x” is the SceneFourCorners upper-left).



This diagram represents the upper-left pixel of each of the bands of VNIR, SWIR and TIR in an ASTER Level-1B data set

Footprint of an ASTER Level-1B Image

The footprint of an ASTER Level-1B image is somewhat unique when viewed in the context of the alignment of its SceneFourCorners. Only the upper-left pixel of the SceneFourCorners lies within an ASTER Level-1B (or Level-2) image extent. The other three corner coordinates represent locations that are one pixel beyond the extent of the image.



Path- or Satellite-Orientation of an ASTER Level-1B Image

The ASTER instrument aboard the Terra satellite platform orbits the Earth at 10:30 AM local equator-crossing time. This renders day-time orbits to be descending passes while night-time orbits are ascending passes. The MapOrientationAngle denotes the angle of rotation between the path-oriented image and the transformed map-projected coordinates. Ranging from -180° to +180°, it provides the amount by which an ASTER Level-1B image is rotated to or from True North. It is therefore, positive and clock-wise for descending orbits, and negative and counter clock-wise for ascending orbits. This field is present in:

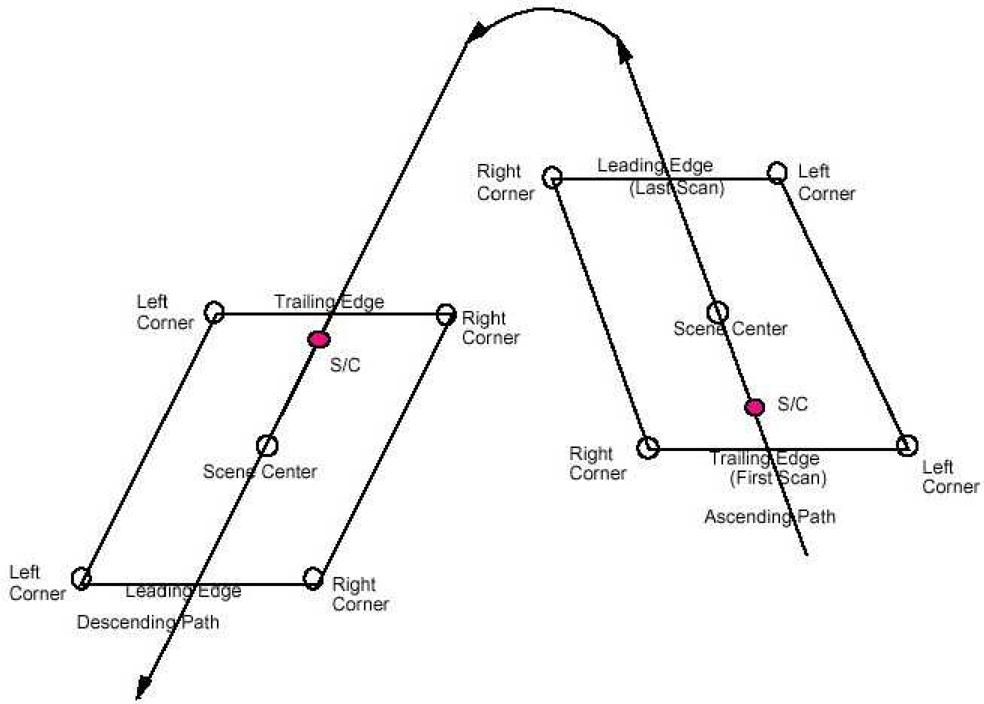
- ASTER Level-1B data sets processed at the Ground Data System (GDS), Japan using version 4.0 (and higher versions) of the Level-1 algorithm, and available from the LP-DAAC in Sioux Falls, SD.
- ASTER Level-2 products produced at the LP-DAAC, in Sioux Falls, SD.

In the case of ASTER Level-1 data produced prior to the implementation of algorithm version 4.0 (before May 2001), MapOrientationAngle is named SceneOrientationAngle (in the hdf metadata), and is measured as the angle from the path-oriented image to north-up. ***If you are using an ASTER Level-1B processed prior to May 2001, using an algorithm version that is less than 4.0 (referred to as PGEVERSION in the hdf metadata), it is important to bear in mind that the SceneOrientationAngle values have reverse signs.***

There are two collection versions of the routinely produced ASTER Level-1 data sets available from the LP-DAAC (Versions 002 and 003). Typically, all data sets produced with algorithm version 4.0 (and higher versions) are available in the version 003 collection while data sets produced with algorithm versions lower than 4.0 are available in the version 002 collection.

The upper-left for an ASTER scene is relative to the orbital path of the Terra satellite (the diagram below relates to Landsat-7 satellite but is also useful in visualizing the orbital paths of the Terra satellite platform).

Ascending and Descending Orbital Paths
(Source: Landsat 7 Processing System (LPS) Output Files Data Format Control Book, 510-3FCD/0195, July 1998)



Geometric Correction Table

ASTER HDF metadata contains Geometric Correction Tables (GCTs) for each telescope, including the VNIR 3B band. These GCTs are arrays of pixel/line locations and their corresponding geographic coordinates. It is important to remember that for ASTER Level-1A and Level-1B data, the GCTs are in geocentric coordinates. For all ASTER Level-2 products, the GCTs are in geodetic coordinates.

GCTs contain information that are internal to the swath data structures. As part of the geometric correction, each scene is divided into block units, and the processing of the scene is done block by block in both the along-track and cross-track directions. The values for the lattice points constitute coordinates for each lattice block located by their center pixel and their corresponding latitudes and longitudes in geocentric coordinates.

The stepping in each dimension is specified in the structural metadata of the swath. The interval spacing for the GCT begins with
(0, 0), and increments by values contained in the HDF metadata fields named ImageLine and ImagePixel.

Example of a VNIR Swath stepping:
VNIR Structural metadata is in a global attribute called StructMetadata.0

```
OBJECT = DimensionMap_1
GeoDimension = GeoTrack
DataDimension = ImageLine
Offset = 0
Increment = 420
END_OBJECT = DimensionMap_1
OBJECT = DimensionMap_2
GeoDimension = GeoXtrack
DataDimension = ImagePixel
Offset = 0
Increment = 498
END_OBJECT = DimensionMap_2
```

The stepping cross-track is 498 pixels and the along-track stepping is 420 pixels. Both Offsets are zero. The 11 x 11 arrays give the locations for the following pixels (using 0 for smallest index):

```
(line, sample) = (0,0), (0, 498),  ...          (0, 4980)
                 (420,0), (420, 498) ...        (420, 4980)
                 (840,0)  (840, 498) ...        (840, 4980)
                   .                              .
```

.   .
(3780,0), (3780,498) ...   (3780,4980)
(4200,0) ...   (4200, 4980)

ASTER Level-1B and ASTER Level-2 GCT values, and the SceneFourCorners values are both generated from the Level-1B. The SceneFourCorners upper-left matches the GCT (0, 0) out to 6 decimal places. The GCT coordinates are more precise, extending out to 12 or more decimal places. There should be no significant difference between the positional accuracy of the data using either the GCT values as ground control, or the SceneFourCorners upper-left and MapOrientationAngle to orient either the ASTER Level-1B data or Level-2 products.

The equation to convert the swath-based geocentric coordinates to geodetic coordinates is:

Geodetic = Arctan [(tan (Latitude)) / 0.99330562]

This equation is for the WGS 84 datum only. Geocentric longitudes do not need to be converted to geodetic since they both are the same and they also share the same reference meridian and axis.

Geodetic versus Geocentric Coordinates

Geodetic coordinates specify a location on the Earth's oblate (non-spherical) surface. Geodetic latitude is defined as the angle between the equatorial plane and a line normal to the surface at that location. Geodetic longitude is the angular distance between the location's meridian and the Greenwich meridian.

Geocentric coordinates relate to a reference system where the origin is the center of the Earth. Geocentric latitude is defined by the angle between the equatorial plane and a line from the local position to the intersection of the axis of rotation with the equatorial plane. Geodetic longitude and geocentric longitude are the same because they share the same reference meridian and axis.