Workshop on ASTER and MODIS Data for Land Surface Studies: An Overview of the ASTER Instrument & Data Products

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U.S. Geological Survey

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MTPE/ESE Mission

The Earth Science Enterprise (ESE) Mission is dedicated to understanding the total Earth system and the effects of humans on the global environment.

Terra Platform (AM-1)

ASTER	**JPL, LP DAAC, GDS (Japan)**
CERES	**Langley**
MISR	**Langley, JPL**
MODIS	**Goddard, EDC, NSIDC**
MOPITT	**Canadian Space Agency, U of Toronto**

Organizational Framework of ASTER

Japan Ministry of Economy Trade and Industry (METI)

Ground Data System, Operations, Science Processing

Jet Propulsion Laboratory

Science Coordination, Research, Algorithm Development

LP DAAC

Ingest, Archive, Distribution, On-demand processing

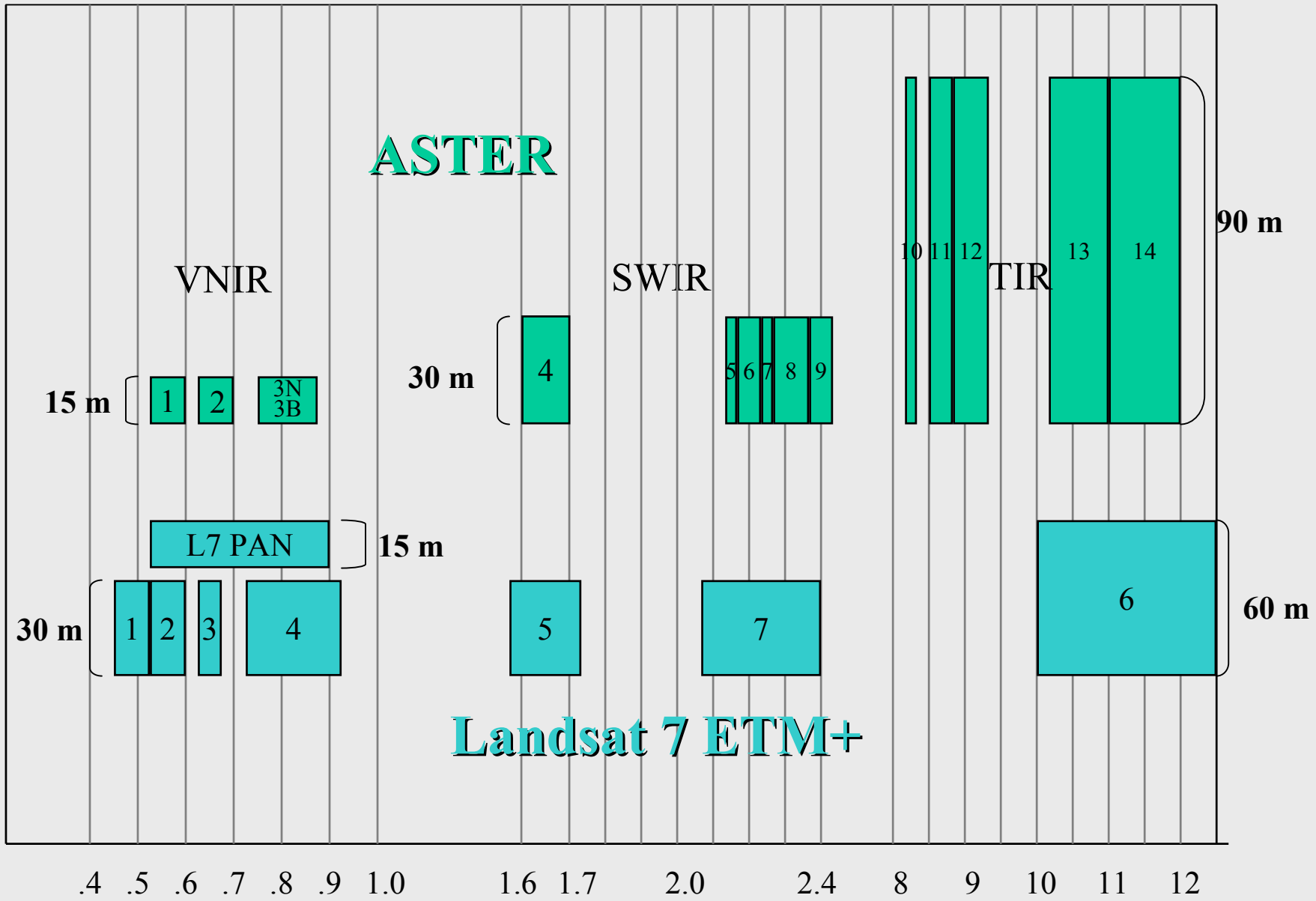
GSFC DAAC

Level-0 Data Reception & Distribution

ASTER Instrument Performance Requirements

Swath Width	**60 km**
Total cross-track coverage	**± 116 to ± 318 km**
Band-to-Band registration	**0.2 pixels (intra-telescope)** **0.3 pixels (inter-telescope)**
Peak Data Rate	**89.2 Mbps**
Duty Cycle	**8% (VNIR & SWIR)** **16% (TIR)**

ASTER Spectral Bands



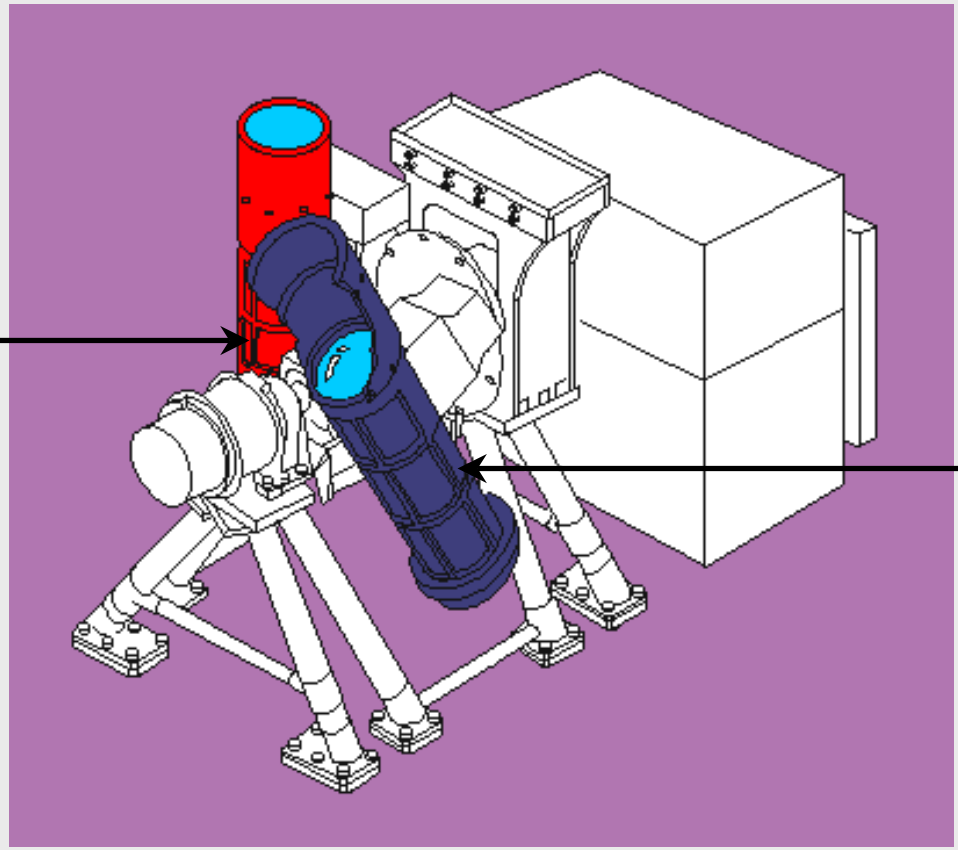
ASTER Instrument & Sensor Systems: Baseline Performance Requirements

Subsystem	Band No.	Spectral Range (μm)	Spatial Res.
VNIR	1 2 3N 3B	0.52 – 0.60 0.63 – 0.69 0.78 – 0.86 0.78 – 0.86	15 m
SWIR	4 5 6 7 8 9	1.600 – 1.700 2.145 – 2.185 2.185 – 2.225 2.235 – 2.285 2.295 – 2.365 2.360 – 2.430	30 m
TIR	10 11 12 13 14	8.124 – 8.475 8.475 – 8.825 8.925 – 9.275 10.25 – 10.95 10.95 – 11.65	90 m

ASTER Instrument & Sensor Systems: Baseline Performance Requirements

	Band Number	Spectral Range (μm)	Radiometric Resolution (σ)	Absolute Accuracy	Spatial Resolution	Signal Quantization Levels
VNIR	1 2 3N 3B	0.52 - 0.60 0.63 - 0.69 0.78 - 0.86 0.78 - 0.86	NEΔρ 0.5 %	≤ ± 4 %	15 m	8 bits
SWIR	4 5 6 7 8 9	1.600 - 1.700 2.145 - 2.185 2.185 - 2.225 2.235 - 2.285 2.295 - 2.365 2.360 - 2.430	NEΔρ 0.5 % NEΔρ 1.3 % NEΔρ 1.3 % NEΔρ 1.3 % NEΔρ 1.0 % NEΔρ 1.3 %	≤ ± 4 %	30 m	8 bits
TIR	10 11 12 13 14	8.125 - 8.475 8.475 - 8.825 8.925 - 9.275 10.25 - 10.95 10.95 - 11.65	NEΔT 0.3 %	≤ 3K (200 - 240K) ≤ 2K (200 - 270K) ≤ 1K (270 - 340K) ≤ 2K (340 - 370K)	90 m	12 bits

ASTER Instrument & Sensor Systems: VNIR Subsystem Design



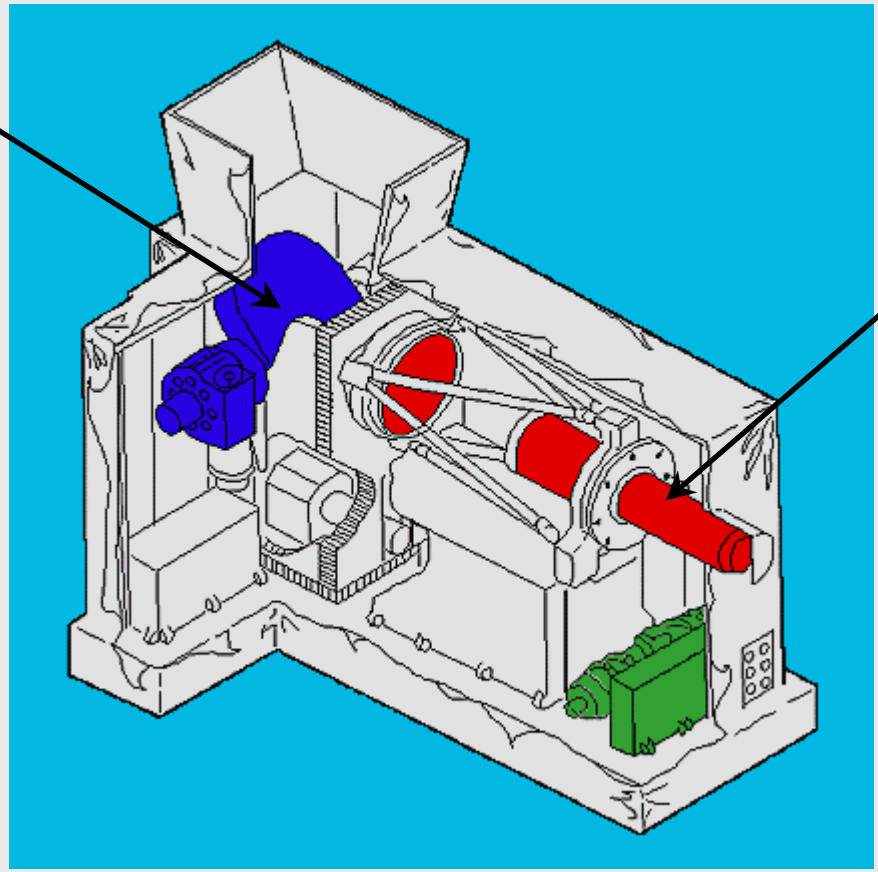
The nadir & backward-looking telescope pair is used for same orbit stereo imaging, & can be rotated as a unit +/- 24° to provide extensive cross-track pointing capability.

ASTER Instrument & Sensor Systems: SWIR Subsystem Design

Pointing Module:

The pointing mirror can point +/- 8.54° from the nadir direction to allow coverage of any point in the spacecraft's 16 day mapping cycle.

This mirror is also periodically used to direct light from either of 2 calibration lamps into the system's telescopes.

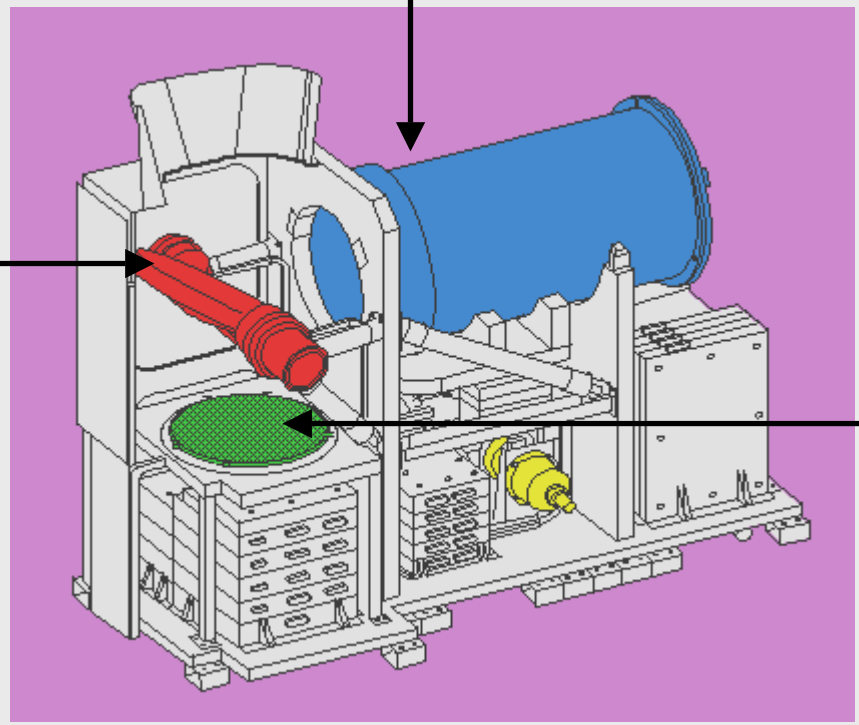


SWIR Subsystem's single fixed refracting telescope

ASTER Instrument & Sensor Systems: TIR Subsystem Design

Scan Mirror:

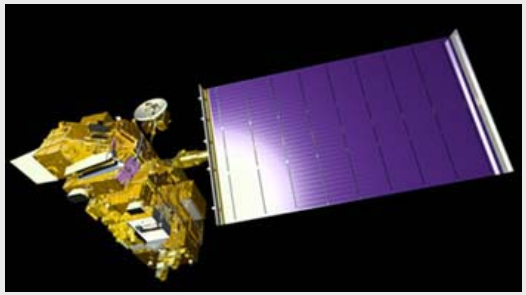
The scan mirror is used for both scanning & pointing. The mirror can point +/- 8.54° from the nadir direction to allow coverage of any point on the Earth in the spacecraft's 16 day mapping cycle.



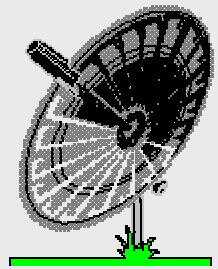
Reference Plate (Blackbody):

A high emissivity reference plate is used as the on-board calibration reference for the TIR Subsystem. This plate is viewed before & after each observation to provide an estimate of instrument drift, and instrument gain and offset.

ASTER Data Flow



TERRA Satellite



TDRSS White Sands

Goddard DAAC
EOS Data Ops

Production
Stream

Expedited Stream

ASTER GDS - Japan

EROS Data Center Land
Processes DAAC

ASTER Data Processing Flow

Terra

TDRSS

US

EDOS-GSFC

JAPAN (GDS)

RCC: Radiometric Calibration Coefficients

CCSDS: Consultative Committee for Space Data Systems

CCSDS L-0 Data

TIR: 10 - 14

SWIR: 4 - 9

VNIR: 1 - 3

CCSDS Packets

Depacketizing

Instrument Source Data

4 - TIR 10 - 14

3 - SWIR 4 - 9

2 - VNIR 3N & 3B

1 - VNIR 1 & 2

Demultiplexing

VNIR L-0A

Stagger Realignment

SWIR L-0A

Stagger Realignment

TIR L-0A

VNIR RCC

V-R DB

VNIR Geo Sys Correction

V-G DB

SWIR RCC

S-R DB

SWIR Geo Sys Correction

S-G DB

TIR RCC

T-R DB

TIR Geo Sys Correction

T-G DB

VNIR L-0B DATA

SWIR L-0B DATA

TIR L-0B DATA

Cloud Coverage Calculation

VNIR Scene Cutting

SWIR Scene Cutting

TIR Scene Cutting

VNIR L-1A DATA

SWIR L-1A DATA

TIR L-1A DATA

ASTER LEVEL - 1A DATA

ASTER LEVEL - 1B DATA

DERIVED HIGHER-LEVEL DATA PRODUCTS

US (LP-DAAC)

ASTER Data Processing: Front-End Processing Flow

- Level-0 data received by EDOS at GSFC DAAC through TDRSS/White Sands Complex, NM
- EDOS sends Level-0 data to Ground Data System (GDS) in Japan
- GDS processes Level-0 to Level-0A in the Front-End Processing Module
- Land Processes DAAC ingests,archives, distributes L1A and L1B data and produces on-demand products

ASTER Data Processing Levels

Level-0 to Level-0B
- radiometric and geometric system corrections are calculated

Level-0B to Level-1A
- scene delineation according to the World Reference System
- geolocation data are generated
- Level-1A data product contains image data and appended radiometric coefficients, geolocation, and auxiliary data

Level-1A to Level-1B
- radiometric calibration and geometric resampling applied

ASTER Data Processing: Routine vs. On-demand

* Not all products are routinely produced when the data are collected.

* User can request a product to be generated based on their own specifications. These products are made from previously collected Level-1B data granules, except for DEM which requires Level-1A data.

* On-demand products are not routinely archived (except for DEM).

ASTER Data Processing: Routine vs. On-Demand Production

Routine data products

Level-1A (VNIR, SWIR, & TIR)

Level-1B (VNIR, SWIR, & TIR)

On-demand products

Decorrelation Stretch

Brightness Temperature

Surface Reflectance

Surface Radiance

Surface Emissivity

Surface Kinetic Temperature

Polar Surface & Cloud Classification

Digital Elevation Model (DEM)

ASTER Data Processing: Routine vs. On-demand

Users must identify Level-1B granule(s) as input and ensure that the granule has required data for processing the request.

To produce:	You require bands:
Decorrelation Stretch (VNIR)	1, 2, 3N
Decorrelation Stretch (SWIR)	4, 5, 6, 7, 8, 9
Decorrelation Stretch (TIR)	10, 11, 12, 13, 14
Brightness Temperature	10, 11, 12, 13, 14
Surface Emissivity	10, 11, 12, 13, 14
Surface Reflectance	1, 2, 3N, 4, 5, 6, 7, 8, 9
Surface Kinetic Temperature	10, 11, 12, 13, 14
Surface Radiance (VNIR, SWIR)	1, 2, 3N, 4, 5, 6, 7, 8, 9
Surface Radiance (TIR)	10, 11, 12, 13, 14
Digital Elevation Model (DEM)	3N, 3B
Polar Surface & Cloud Classif.	All bands except 3B

ASTER Acquisition Strategy

ASTER is an "on-demand" instrument…data will only be acquired if a request has been submitted.

Acquisition requests are accepted only from authorized users and the ASTER Science Team.

DAR – request from Authorized ASTER user
STAR – Science Team Acquisition Request – request on behalf of the entire Science Team
xAR – either a DAR or a STAR
Global Mapping Mission – images in all ASTER bands of the Earth's land areas will be acquired at least once.

ASTER Acquisition Strategy

ASTER Scheduler – maximizes science return over a day's observations.

Reads all active DARs and STARs in the ASTER GDS and uses a prioritization function to read the alternative observing modes for each time step.

Also reads global cloud-cover forecast when generating the One-Day Schedule.

ASTER Data Processing: Public Data Acquisition

The general science community has access to all data acquired by Science Team requests via the EOS Data Gateway (EDG).

Users may view data acquisitions completed and scheduled using the ASTER Java DAR Tool (JDT).

Only the Science Team or authorized users may schedule data acquisition requests.

User authorization process is described on the On-Demand web page.

ASTER V002 and V003 Products from the LP DAAC

The Japanese Ground Data System (GDS) started processing ASTER Level-1 data (and re-processing of earlier data) using a newer, improved algorithm (Version 04.00R00) and also an improved set of radiometric calibration and geometric correction coefficients databases on May 1, 2001. To avoid user confusion in identifying different versions of the same granule in search results, it was decided at LP DAAC to migrate Level-1 data produced in Japan on and after May 1, 2001 (and the routinely-produced higher-level products derived from them) to a separate collection, which is version 003.

The key determinants of the collection split are:

- Production Date & Time: **May 1, 2001** at GDS, Japan
- PGE Version: Version **04.00R00** (and higher versions) at GDS, Japan
- Geometric Database Version: **02.00** (and higher versions)
- Radiometric Database Version: **02.05** (and higher versions)

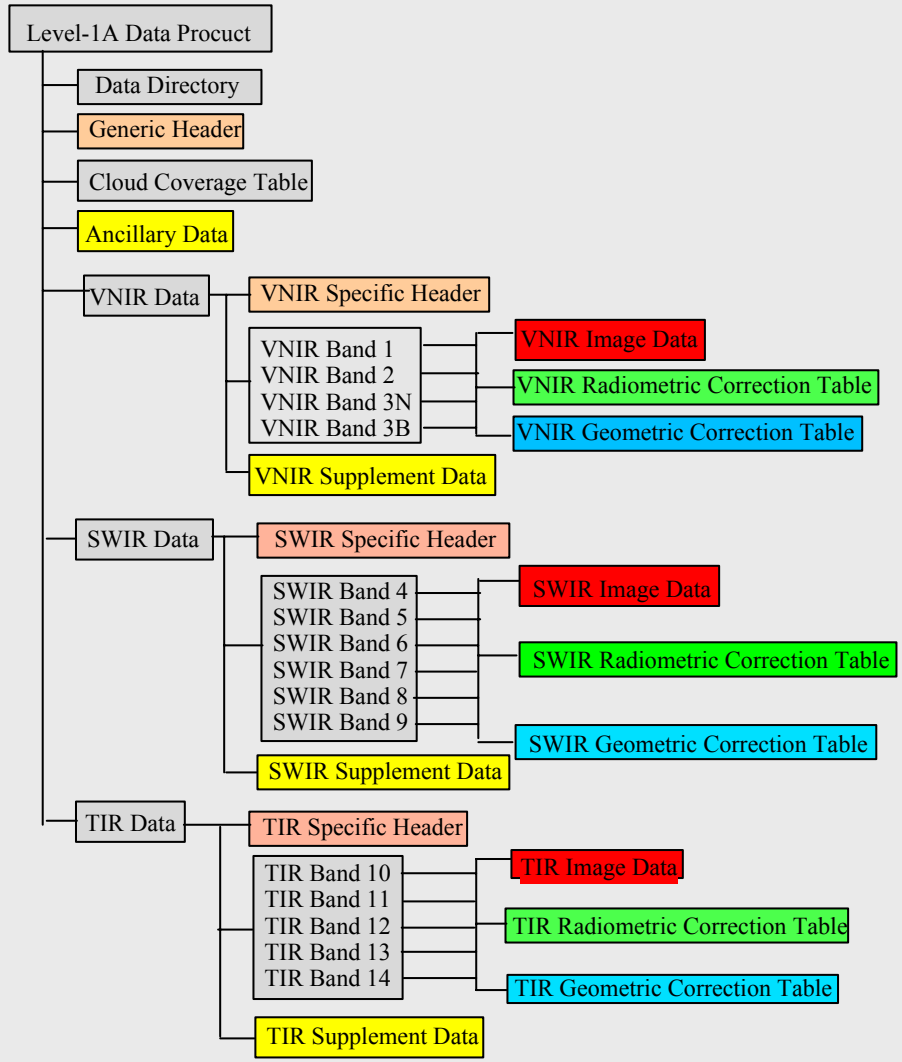
ASTER Level-1A:
Reconstructed Unprocessed Instrument Data

Level: 1A
Units: Counts
Resolution: 15, 30, 90 m
Size: 107 Mbytes
Mode: Routine

Description: Reconstructed, unprocessed, instrument digital counts with ground resolution of 15, 30, & 90 m. Data have radiometric calibration coefficients and geometric correction coefficients appended but not applied.

ASTER Level-1A Data Product

- Level-1A data are formally defined as reconstructed, unprocessed instrument data at full resolution.
- the ASTER Level-1A data consists of the image data, the radiometric coefficients, the geometric coefficients and other auxiliary data, without applying the coefficients to the image data to keep the original data values
- Data Format: HDF-EOS
- All image data, meta data, tables are accommodated in one file.
- Data file size is about 107 Mb.



ASTER Level-1B:
Registered Radiance at Sensor

Level: 1B
Units: w/m^2/sr/μm
Resolution: 15, 30, 90 m
Size: 118 Mbytes
Mode: Routine

Description: Contains radiometrically calibrated & geometrically co-registered data for all the ASTER channels. Both intra- and inter-telescope registration have been applied.

ASTER Level-1B Data Product

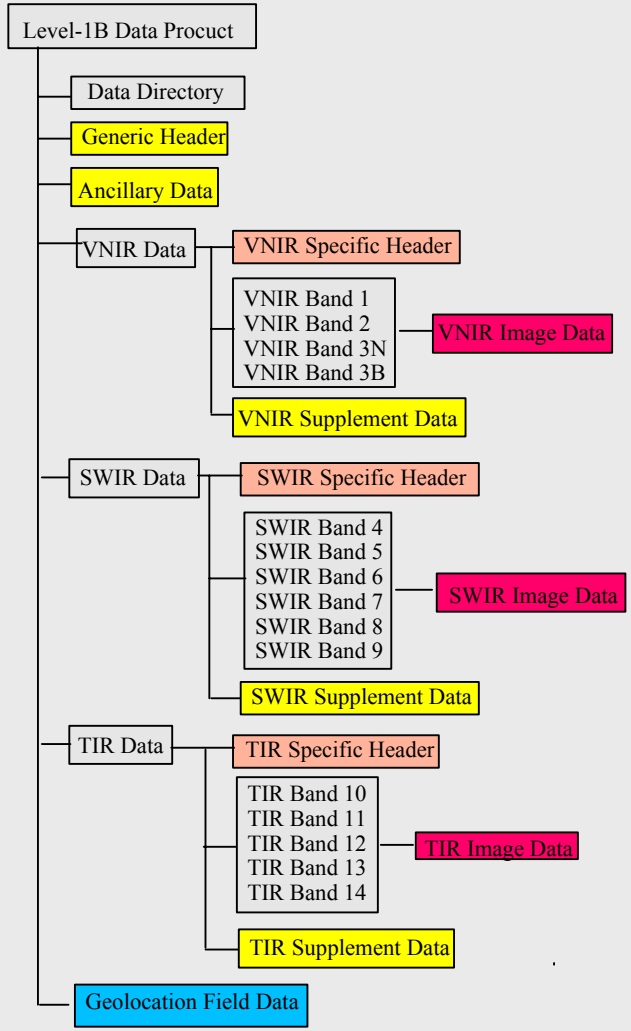
- The Level-1B data product can be generated by applying the Level-1A coefficients for radiometric calibration and geometric resampling.

  Map projection : UTM, LCC, SOM, PS, Lat/Long

  Resampling : NN, BL, CC

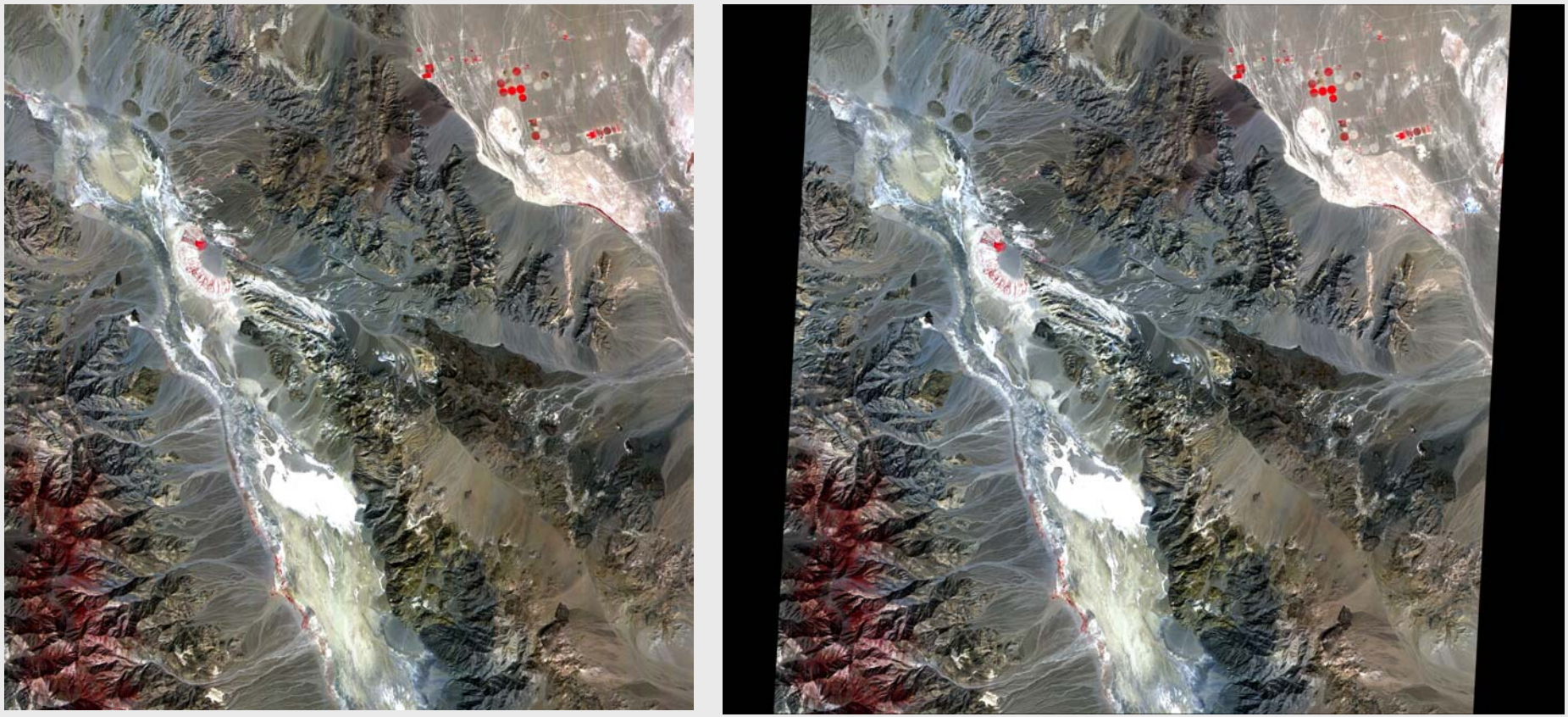
- The geolocation field data are included in the Level-1B data to know the pixel position (latitude/longitude) on the ground.

- Data file size is about 118 Mb.



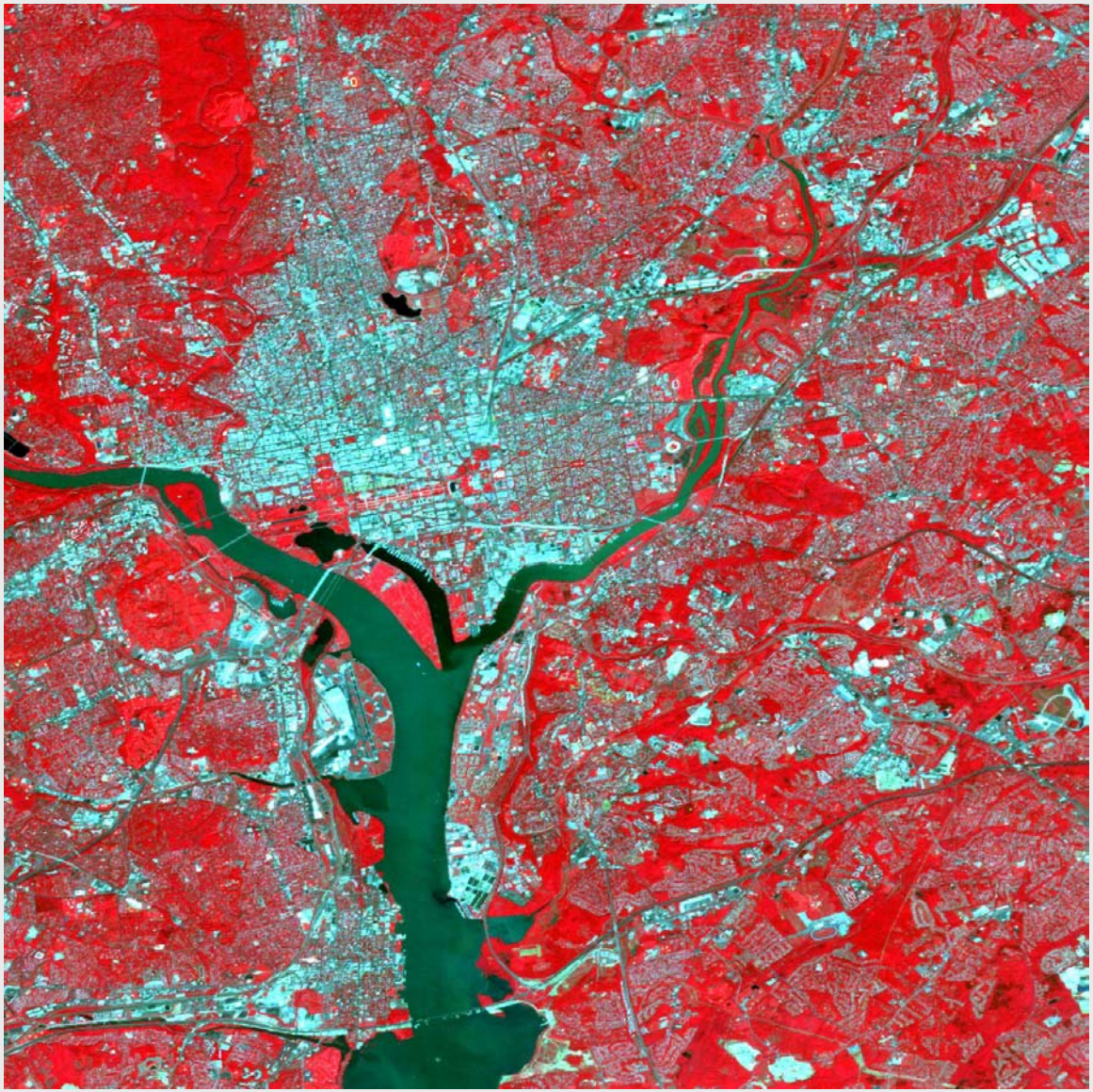
Level-1A

Level-1B

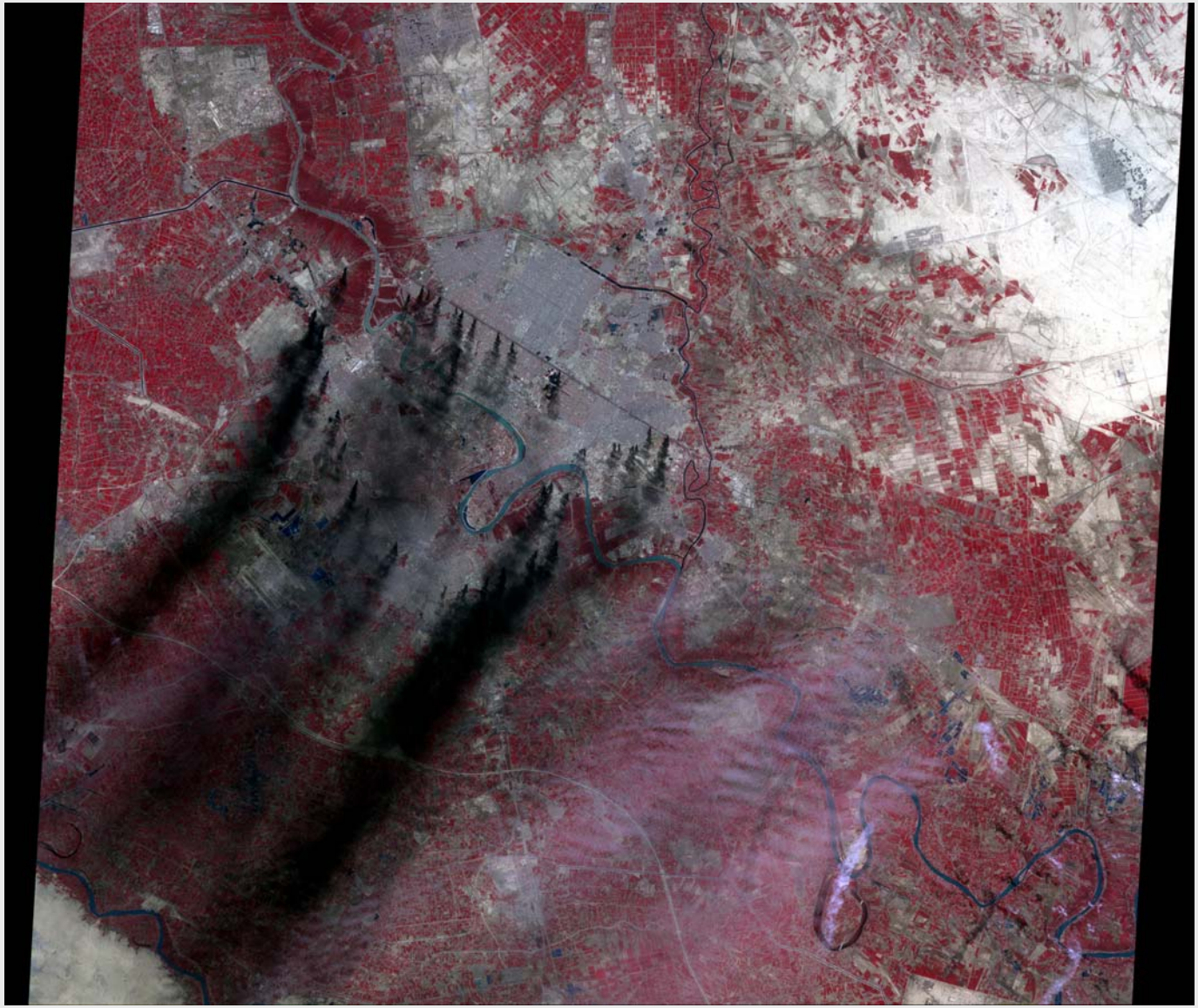


ASTER scene comparison, Utah, USA

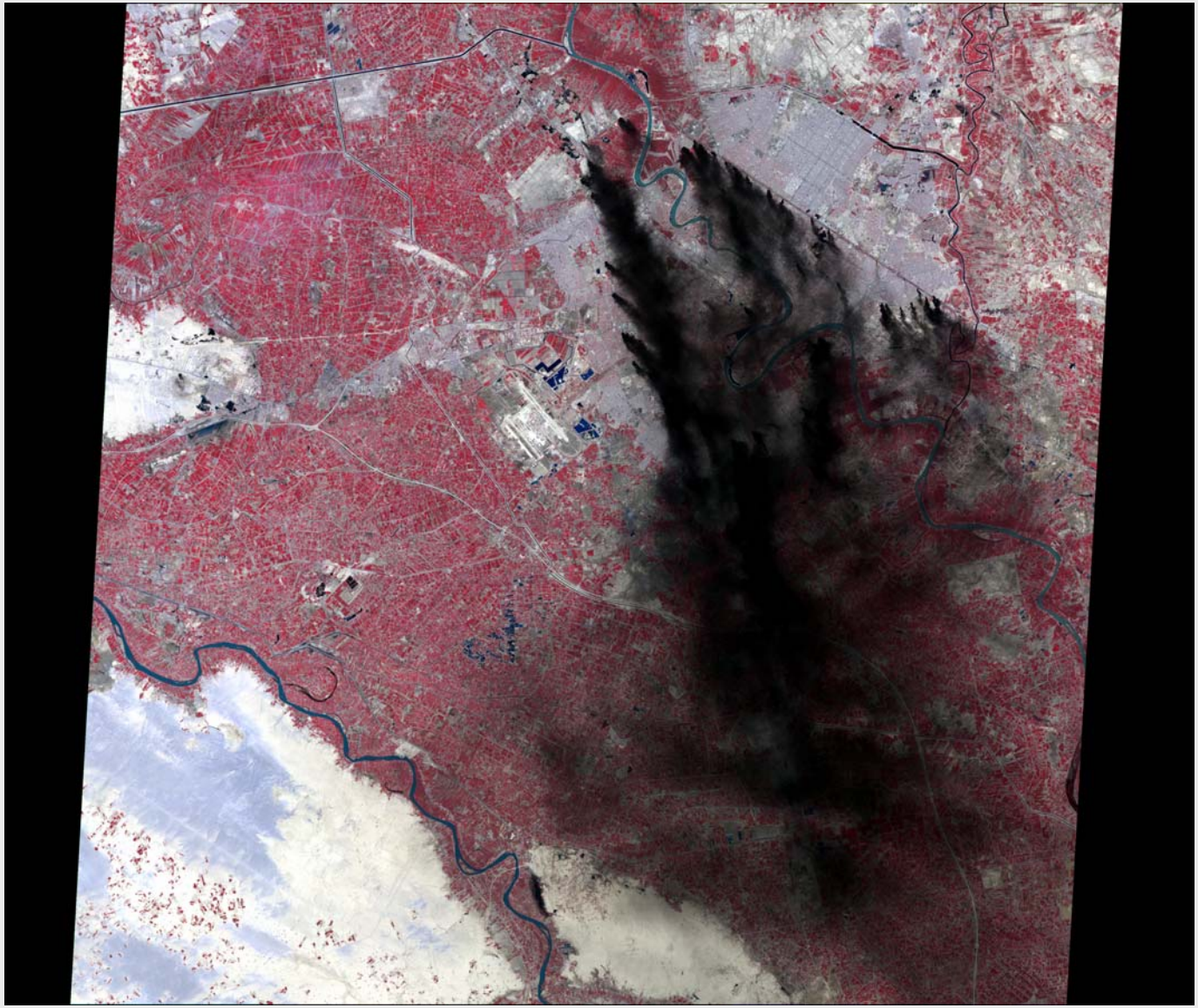
ASTER Level-1B Area around DC



ASTER Level-1B: Baghdad, March 31, 2003

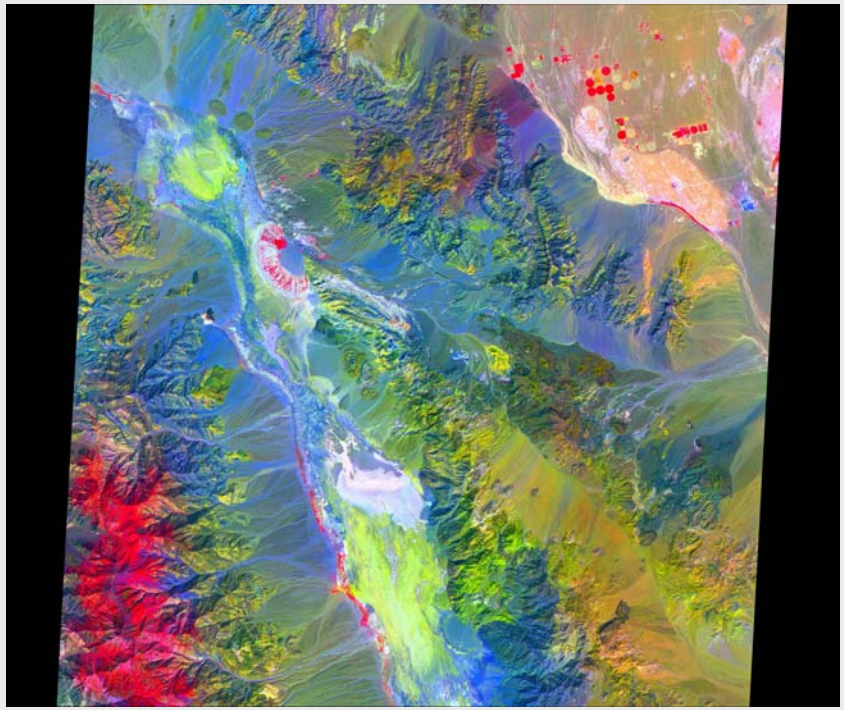


ASTER Level-1B: Baghdad, April 2, 2003



ASTER Decorrelation Stretch: VNIR, SWIR, & TIR

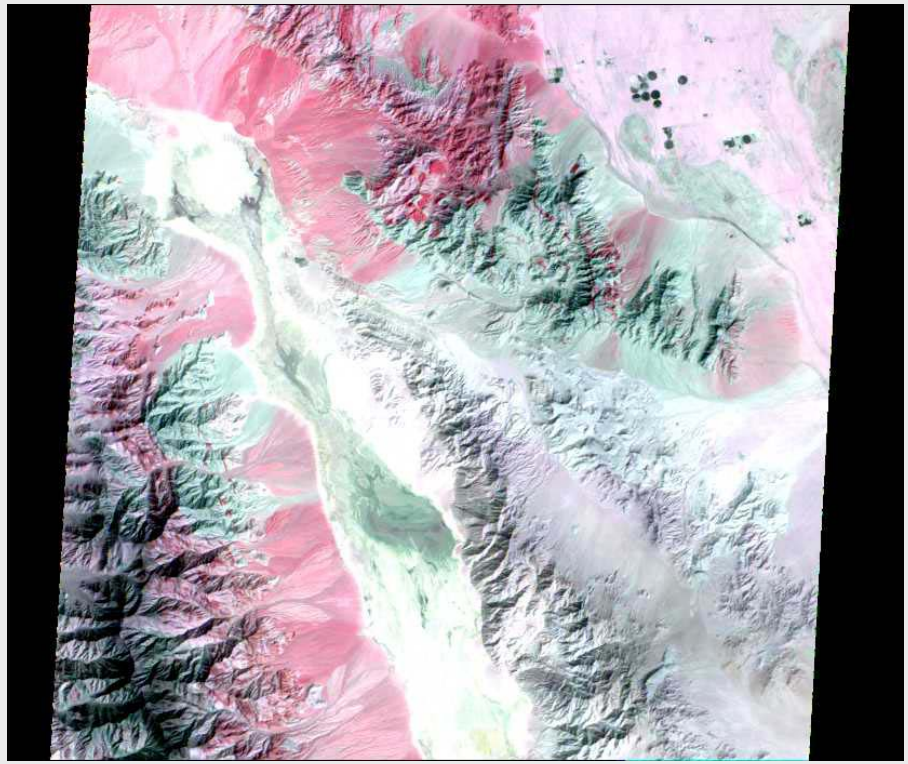
Level: 2
Units: none
Resolution: 15, 30, 90 m
Size: 53, 13, 1 Mb
Mode: On-demand



Description: A decorrelation stretch algorithm is applied to all 3 sets of radiance data. In VNIR & SWIR, it enhances band-to-band reflectance variations. In TIR, it enhances band-to-band emissivity variations. The decorrelation stretch algorithm calculates the principal components of a 3-band image, normalizes the variances of the vectors, then rotates back into RGB color space.

ASTER Brightness Temperature

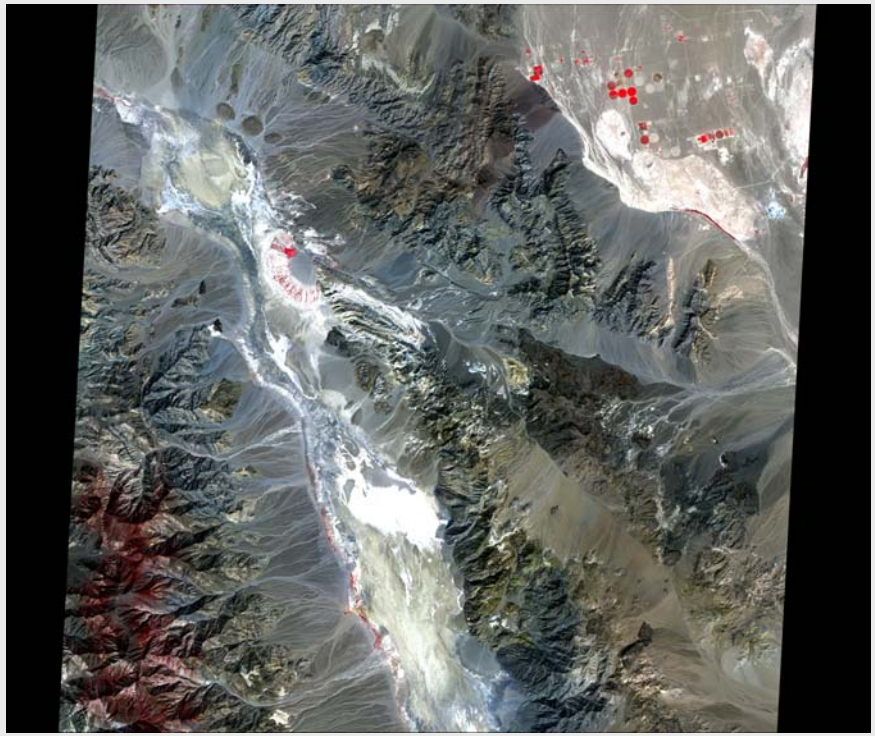
Level: 2
Units: C
Resolution: 90 m
Size: 6 Mb
Mode: On-demand



Description: Brightness temperature is the apparent temperature of a surface assuming a surface emissivity of 1.0, ignoring atmospheric effects. It is the temperature that a blackbody would be in order to produce the radiance measured by the sensor. Useful for observing volcanic ash clouds, detecting ice leads in the Arctic, and natural & anthropogenic fires.

ASTER Surface Reflectance: VNIR & SWIR

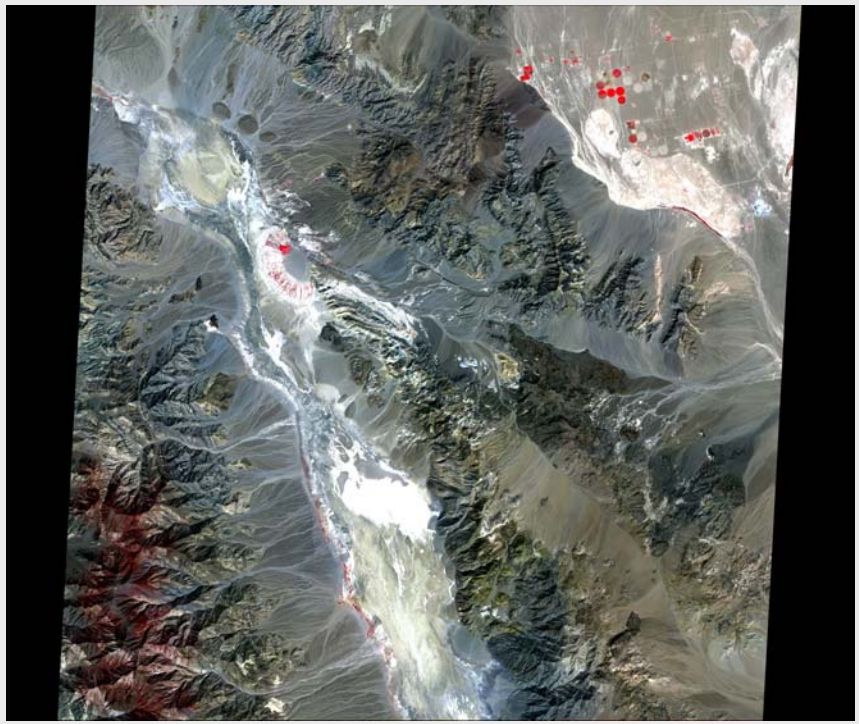
Level: 2
Units: %
Resolution: 15, 30 m
Size: 238 Mb
Mode: On-demand



Description: Surface reflectance data, recorded as percent reflectance, derived by applying atmospheric corrections to observed radiance. Uses a Gauss-Seidel iteration of the Radiative Transfer Code.

ASTER Surface Radiance: VNIR, SWIR, & TIR

Level: 2
Units: w/m^2/sr/μm
Resolution: 15, 30, 90 m
Size: 238 (VNIR, SWIR), 6 (TIR) Mb
Mode: On-demand



Description: Atmospherically corrected surface radiance calculated for clear sky scenes. Includes surface-reflected and surface-emitted components for TIR.

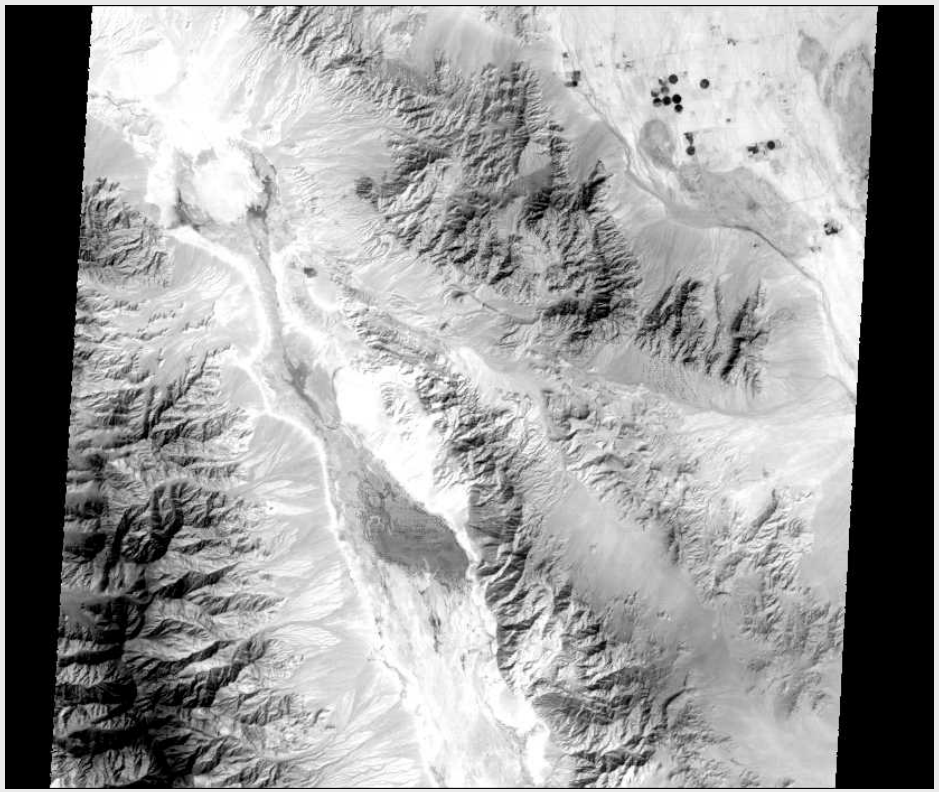
ASTER Surface Emissivity

Level: 2
Units: None
Resolution: 90 m
Size: 6 Mb
Mode: On-demand

Description: The surface emissivity product is generated over land from the 5 TIR channels. It uses a Temperature/Emissivity Separation algorithm. It is designed to recover precise and accurate emissivities for mineral substrates.

ASTER Surface Kinetic Temperature

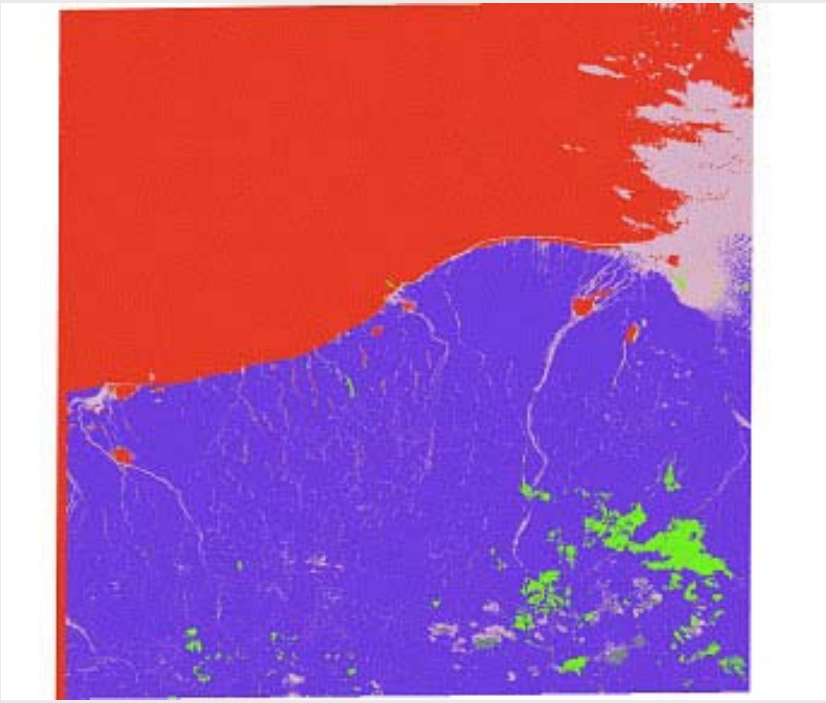
Level: 2
Units: K
Resolution: 90 m
Size: 125 Mb
Mode: On-demand



Description: Land surface temperature in degrees Kelvin derived from land surface emissivity. Uses the same TES algorithm as the Emissivity product.

ASTER Polar Surface & Cloud Classification

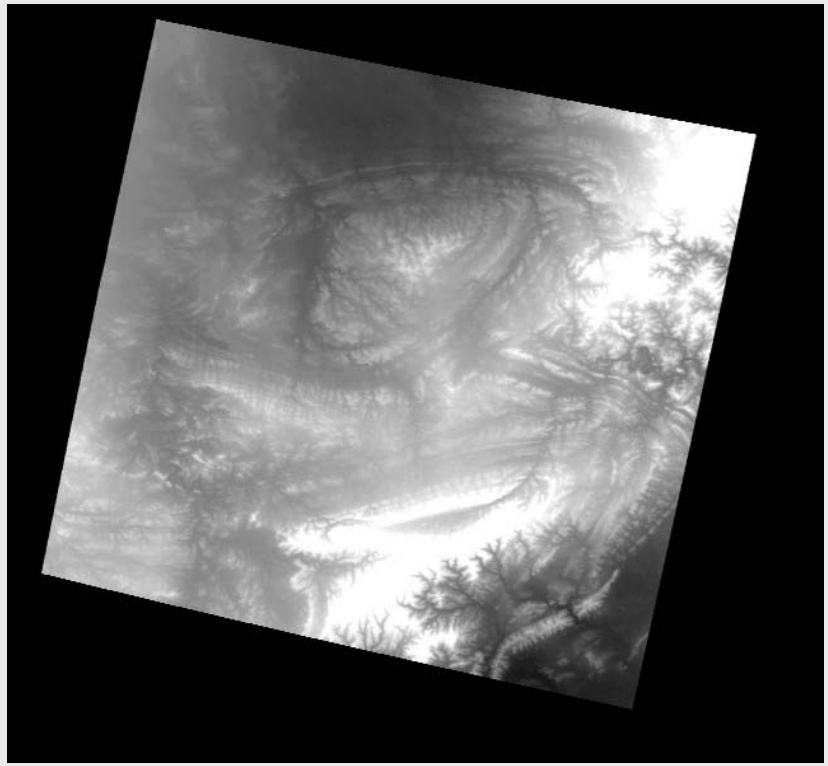
Level: 2
Units: Thematic
Size: 42 Mb
Mode: On-demand



Description: The ASTER On-Demand Polar Surface and Cloud Classification is an on-demand product that provides a classification map discriminating between different surface and cloud features over polar areas. The primary aim of this product is to classify the cloud and snow-ice spectral signatures in both the visible and infra-red wavelengths. Presently this algorithm is designed to work with data acquired during the daytime, and there subsequently will be a version that works with the night-time data.

ASTER Digital Elevation Model (DEM)

Level: 3
Units: meters
Input Resolution: 15 m
Output Resolution: 30 m
Size: ~35 Mb
Mode: On-demand
Stereo Base-to-Height Ratio: 0.6 (Along-Track)



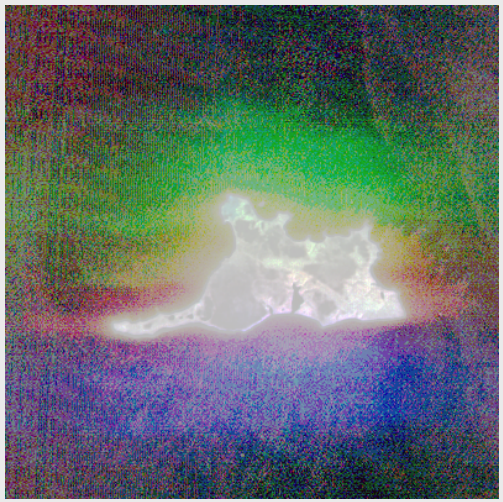
Description: Topographic data set generated by photogrammetric methods using nadir & aft stereo images. Both absolute (with user-supplied GCPs) and relative DEMs are produced. Absolute horizontal & vertical accuracy with ground control: <= 7 m and relative accuracy without ground control: 10 m.

Known ASTER Problems

SWIR Crosstalk

Crosstalk refers to an unwanted signal from either an optical or electrical source that affects acquired bands of an image. ASTER SWIR bands have optical crosstalk wherein signal from one spectral band bleeds into a different spatial position in the same band, and signal from one spectral band bleeds into one or more spectral bands. The result is that ASTER spectra of known material may not match ground or other remotely sensed spectra.

Artifacts appear in SWIR images, especially those with large contrast such as coastlines and islands. Bands 5 and 9 most prominently depict the problem.



Stretched SWIR bands (4,5,9) of a Japanese Island (400 x 400 pixels). Although visible in images with strong contrast, SWIR crosstalk is not visible but present in other images.

Known ASTER Problems

SWIR Crosstalk

The Japanese ASTER team developed a Level-1 SWIR crosstalk correction software that they implemented for Windows. Subsequently, further enhancements, analyses and improvements have led to a new algorithm for crosstalk correction. JPL is implementing this algorithm in the forthcoming delivery of higher-level product software code to LP DAAC.

The current version of the crosstalk correction algorithm will not correct the edges of the image. Data from outside the image would be required for a complete correction that presently is not available. It also does not correct all the artifacts as their causes are still being evaluated and understood. These include interactions between calibration, absorption due to water vapor, and the crosstalk component.

Known ASTER Problems

Level-1 Geometry Issues:

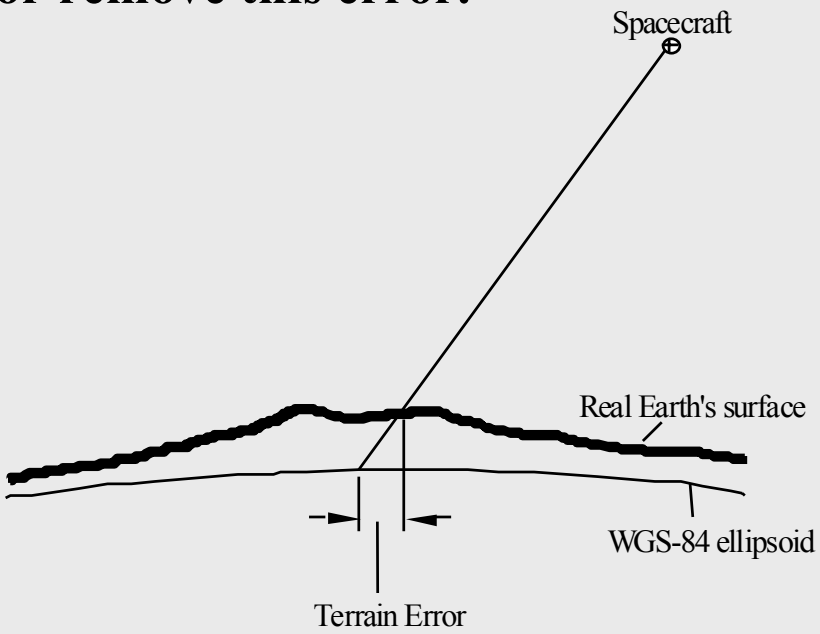
Earth Rotation Angle Error (Fujisada Correction)

Since all the HDF metadata values (SCENEFOURCORNERS, 11-by-11 latitude/longitude geolocation arrays etc.) are calculated using knowledge of the spacecraft pointing and ASTER instrument pointing, an error in the Earth's rotation angle was discovered. This produces a lat/lon-dependent error of up to 700 meters for night-time acquisitions. This error correction has been modelled with a polynomial, & applied to all Level-1 data sets produced (at GDS) after June 3, 2004. All data sets produced before this date are candidates for correction via the JPL website.

Known ASTER Problems

Level-1 Geometry Issues: Altitude Correction

Since all the ASTER HDF lat/lon coordinates use the WGS-84 ellipsoid as their reference datum, they do not account for the actual elevation. Hence the published lat/lon coordinates are the intersection of the WGS-84 ellipsoid and an extension of the line-of-sight vector. The lat/lon coordinates have an inherent terrain error caused by the difference between the WGS-84 ellipsoid and the actual Earth's surface. This correction attempts to reduce or remove this error.



The earth rotation angle error correction and the altitude correction will soon be available upon request from JPL's ASTER web site.

ASTER Data Applications

The primary science objective of the ASTER mission is to improve [our] understanding of the local and regional-scale processes occurring on or near the Earth's surface and lower atmosphere, including surface-atmosphere interactions (Yamaguchi *et al*., 1998).

Areas of ASTER science investigation include:

- ★ **Land surface climatology**
- ★ **Monitoring volcanoes**
- ★ **Hazards monitoring**
- ★ **Carbon cycle in the marine ecosystem**
- ★ **Geology and soils**
- ★ **Aerosols and clouds**
- ★ **Hydrology**

ASTER Data Applications

Examples of research topics being pursued by the EOS Interdisciplinary Science PIs and the ASTER Science Team members:

- **Global assessment of active volcanism/volcanic hazards – P. Mouginis-Mark, A. Kahle**
- **Hydrology, hydrochemical modelling in Alpine drainage basins – J. Dozier**
- **Climate, erosion & tectonics in mountain systems – B. Isacks**
- **Lithologic mapping in arid regions - Yamaguchi & Tsuchida**
- **Paleoclimatology based on glacial monitoring in Central Asia – A. Gillespie**
- **Monitoring glaciers of the Antarctic coastal regions – H. Kieffer**
- **Mapping carbonatite and alkaline rocks in the African Rift valley – L. Rowan**
- **Estimation of SiO_2 content of igneous rocks using ASTER TIR data - Ninomiya**
- **Mapping & monitoring of coral reefs - Matsunaga & Kayane**
- **Spatial variation of surface energy & mass fluxes over land surfaces - J. Schieldge**

Public Domain Software for Handling HDF-EOS Format

http://hdfeos.gsfc.nasa.gov/hdfeos/viewingHDFEOS.html

http://hdfeos.gsfc.nasa.gov/hdfeos/softwarelist.cfm

WINVICAR:

http://winvicar.jpl.nasa.gov

HDFEOS-to-GeoTiff (HEG):

http://hdfeos.gsfc.nasa.gov/hdfeos/details.cfm?swID=4

http://hdfeos.gsfc.nasa.gov/hdfeos/software/HEG/HEG_UsersGuide.pdf

Java HDF Viewer (JHV):

ftp://ftp.ncsa.uiuc.edu/HDF/HDF/java/source/unpacked/docs/UsersGuide/JHV2.7/index.html

Webwinds:

http://www.sci-conservices.com/rel14/webpage/wwhome.html

http://www.sci-conservices.com/rel14/webpage/webhelp.html