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Multispectral Imagery And Higher Level Products Available From The Land Processes Distributed Active Archive Center, U.S. Geological Survey EROS Data Center

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Abstract

There are many types of multispectral imagery and higher level products available from the Land Processes Distributed Active Archive Center at the U.S. Geological Survey EROS Data Center, including data produced from the Moderate Resolution Imaging Spectroradiometer on the Terra and Aqua satellites, the Enhanced Thematic Mapper Plus on Landsat 7, and the Advanced Spaceborne Thermal Emission and Reflection Radiometer on Terra. Information on these various instruments and their respective data products is available on the World Wide Web. The data products can be obtained by using the NASA EOS Data Gateway.

Introduction

The Land Processes Distributed Active Archive Center (LP DAAC) was established at the U.S. Geological Survey (USGS) EROS Data Center as part of NASA's Earth Observing System Data and Information System (EOSDIS) initiative to process, archive, and distribute land-related data collected by EOS sensors, thereby promoting the interdisciplinary study and understanding of the integrated Earth system (http://edcdaac.usgs.gov/main.html). In 1999, the LP DAAC's role was expanded to include processing and distribution responsibilities related to Landsat 7 data.

This article is designed to be a guide to multispectral imagery and higher level products available from the LP DAAC. The first two sections explain how to order the products and describe data formats and tools. The last section describes multispectral imagery and higher level products from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua satellites, the Enhanced Thematic Mapper Plus (ETM+) on Landsat 7, and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on Terra. World Wide Web links are provided throughout the article to guide readers to germane online references.

Ordering Data Products

The data products discussed in this article are publicly available for searching, browsing, and ordering from the EOS Data Gateway (EDG) at http://edcimswww.cr.usgs.gov/pub/imswelcome. A tutorial is available to assist with EDG navigation at http://edcdaac.usgs.gov/tutorial. Once a user becomes familiar with the EDG, it is a powerful tool for accessing and obtaining a broad range of earth science data and information.

Terra and Aqua MODIS data products are currently available at no cost. Landsat 7 ETM+ data are available for US$475.00 (Level 0) and US$600.00 (Level 1) per scene. They can also be ordered as floating scene products. Terra ASTER L1A and L1B datasets are priced at US$55.00 per scene. ASTER higher level products are currently available at no cost. A full products price list is maintained at http://edcdaac.usgs.gov/pricing.html.

In addition to the EDG client, there are some products available at no charge through the LP DAAC Data Pool (http://edcdaac.usgs.gov/tutorial/datapool.html). The Data Pool is an online archive that provides FTP access to select ASTER and MODIS data products.

The USGS and the LP DAAC provide a Global Visualization Viewer (GloVis) that facilitates searching for cloud free data worldwide, located at http://edcdaac.usgs.gov/aster/glovis.html. Currently, GloVis hosts Landsat 4, 5 and 7 browse images, as well as Terra ASTER browse images. Efforts are

underway to provide MODIS browse via the EDG and GloVis by 2004. In the meantime, the MODIS Land Science Team provides a global browse viewer at http://landqa2.nascom.nasa.gov/browse/browse.cgi.

For more information on NASA EOS and the satellite instruments mentioned in this article, please refer to http://eos.gsfc.nasa.gov/projects.html. For more information on the NASA DAAC Alliance, including product information, see http://nasadaacs.eos.nasa.gov/index.html.

Data Product Formats and Tools

Landsat 7 ETM+ data can be ordered in several data formats, including Hierarchical Data Format (HDF), GeoTIFF, and Fast L7A Format. For an explanation of Landsat 7 file formats, and to order sample data, go to http://edcdaac.usgs.gov/samples.

MODIS and ASTER data are provided in an HDF format specific to NASA EOS (HDF-EOS). Information on the HDF-EOS format and related software tools is provided through the HDF-EOS Tools and Information Center at http://hdfeos.gsfc.nasa.gov/hdfeos/index.cfm. To view documentation on HDF-EOS and other EOSDIS-related topics, refer to the EOSDIS Core System (ECS) Data Handling System at http://edhs1.gsfc.nasa.gov. Use a “Quick Search” on a topic to retrieve a list of pertinent documents.

Other organizations, such as universities and state agencies, have developed their own sets of tools to work with NASA EOS datasets. An Internet search for "HDF-EOS" can provide these and many other links to HDF-EOS information. In addition, many commercial software packages are beginning to provide support for the HDF-EOS format.

To access information on software tools specifically developed for MODIS HDF-EOS gridded products, refer to the LP DAAC Data Products Page at http://edcdaac.usgs.gov/dataproducts.html, and look under "Terra MODIS" for the "MODIS Reprojection Tool" or the "MODIS LPDOPE Tools."

Data Products

The data products presented in this article cover a wide range of spatial, temporal, and spectral resolutions. Terra and Aqua MODIS instruments provide near-daily global coverage, collecting data over a wide spectral range and producing a large number of higher level products. Landsat 7 ETM+ imagery are at a higher spatial resolution, and the satellite revisits an area every 16 days. Landsat data have been collected for more than 30 years, so the mission provides continuity, which is important for monitoring long-term changes to the land surface. The Terra ASTER instrument is unique, with three telescopes that have off-nadir pointing capabilities, along-track stereo image acquisition, high spatial and spectral resolution, and numerous higher level products that users can order on demand. Combined, the MODIS, ETM+, and ASTER datasets

provide a comprehensive, multifaceted view of the Earth's surface.

Terra and Aqua MODIS

NASA launched the first MODIS aboard the EOS Terra satellite on December 18, 1999, and launched the second MODIS aboard the EOS Aqua satellite on May 4, 2002. The Terra spacecraft crosses the Equator at 10:30 a.m., and Aqua crosses at 1:30 p.m. local time. The Terra and Aqua MODIS instruments provide global, near-daily repeat coverage at spatial resolutions ranging from 250 m up to 1 km. Refer to the MODIS Web site at http://modis.gsfc.nasa.gov for more information. The Terra mission is described at http://eos-am.gsfc.nasa.gov. The Aqua mission is described at http://eos-pm.gsfc.nasa.gov.

Terra MODIS data products were released as Version 1 (V001) "Beta" products in 2000, followed by a release of Version 3 (V003) "Provisional" products in 2001. Version 4 (V004) "Validated" products were released in January 2003. Aqua MODIS products are primarily the same as those of Terra, but they are acquired at different times of day, under different solar illumination, sensor view angles, and climatic conditions. Version 3 (V003) "Provisional" products were released in April 2003. Product maturity definitions are provided by the MODIS Land Quality Assessment Web site at http://landdb1.nascom.nasa.gov/QA_WWW under its "Help/FAQ" section. For a description of all MODIS data products available from the LP DAAC, see http://edcdaac.usgs.gov/modis/dataprod.html.

MODIS Level 2 products. Level 2 (L2) MODIS products are commonly known as “swath data,” representing 5-minute sensor acquisition intervals. Products are generated using full-resolution (1 km), time-referenced, geometrically corrected, and radiometrically corrected input from which geophysical variables, such as thermal anomalies or land surface temperature, are derived (Figure 1). MODIS Level 2 products are distributed in HDF-EOS swath format.

MODIS Level 2G products. Level 2G (L2G) MODIS products are Level 2 products referenced to a uniform space-time grid scale and are commonly referred to as “gridded data” organized as tiles (Figure 2). Initially, MODIS V001 and V003 products were projected to the Integerized Sinusoidal (ISIN) map projection (Figure 3). Aqua MODIS and V004 Terra MODIS data products are projected to the Sinusoidal (SIN) map projection. All Level 2G products are distributed in the HDF-EOS grid format.

MODIS Level 3 products. Level 3 (L3) MODIS products are gridded composites of geophysical and biophysical parameters. These data products are temporally aggregated over 8-day, 16-day, 32-day, 96-day, and 365-day acquisition periods. Products include surface reflectance and vegetation indices (Figure 4). All Level 3 products are distributed in the HDF-EOS grid format.

MODIS Level 4 products. Level 4 (L4) MODIS products are gridded model output from the integration of lower level data. Products include leaf area index

and net photosynthesis models (Figure 5). All Level 4 products are distributed in the HDF-EOS grid format.

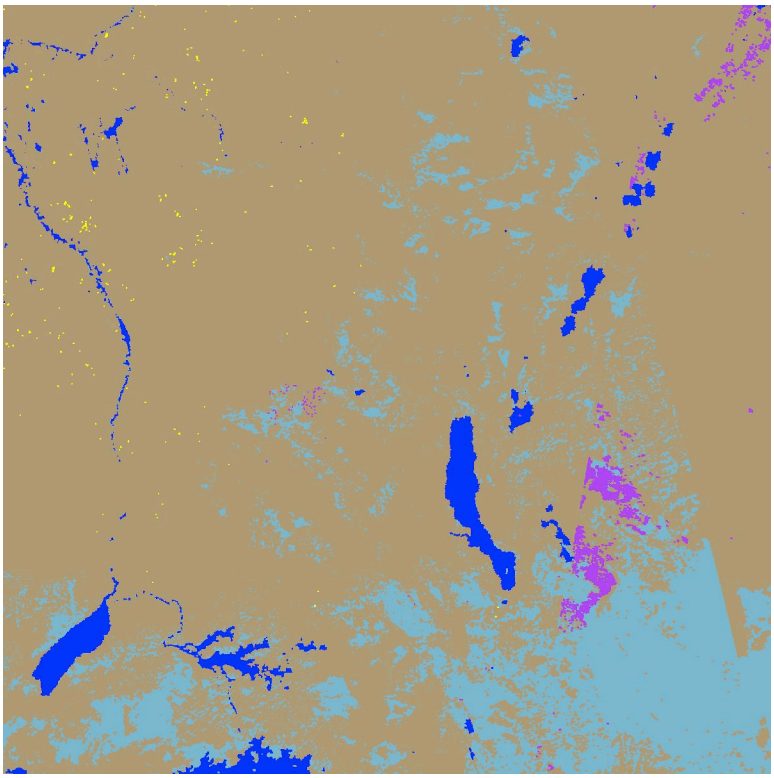

Figure 1. A MODIS/Terra thermal anomalies/fire 5-min L2 swath 1 km V003 product acquired over the Sudan-Ethiopia border in December 2000. Fires are visible as yellow pixels in the northwestern corner of the image. [Image provided by the LP DAAC: http://edcdaac.usgs.gov/modis/mod14therm.html.]

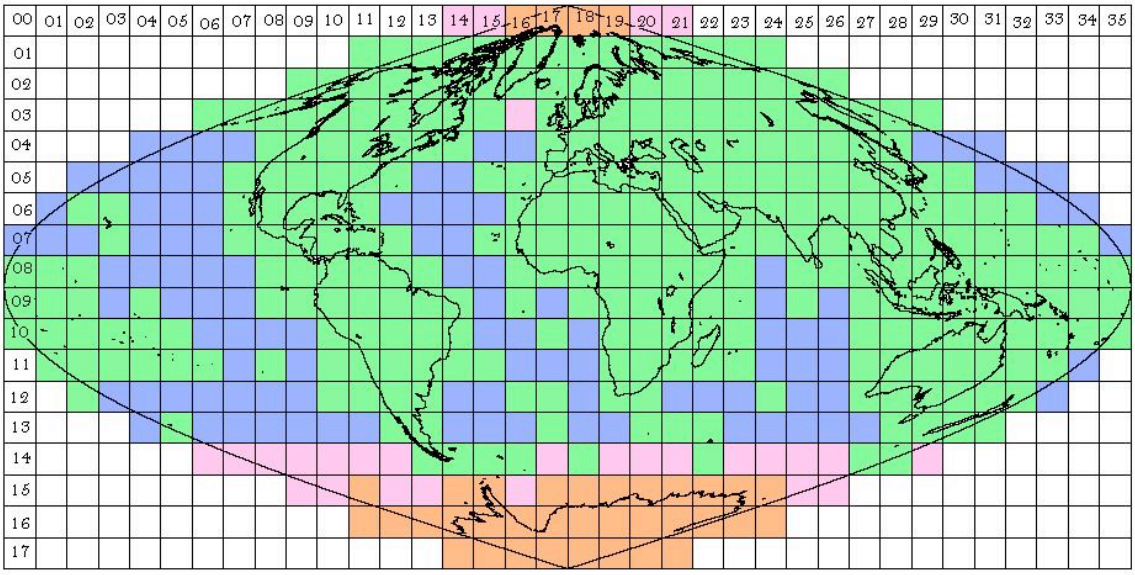

Figure 2. A map of the tile numbers (horizontal and vertical) used to reference MODIS higher level gridded products. [Image provided by the MODIS Land Science Team, Goddard Space Flight Center.]

Figure 3. A MODIS/Terra surface reflectance daily L2G global 250 m ISIN grid V003 product acquired over the Northeastern United States. Most of the Atlantic Ocean has been masked from the image. [Image provided by the LP DAAC: http://edcdaac.usgs.gov/modis/mod09gqk.html.]

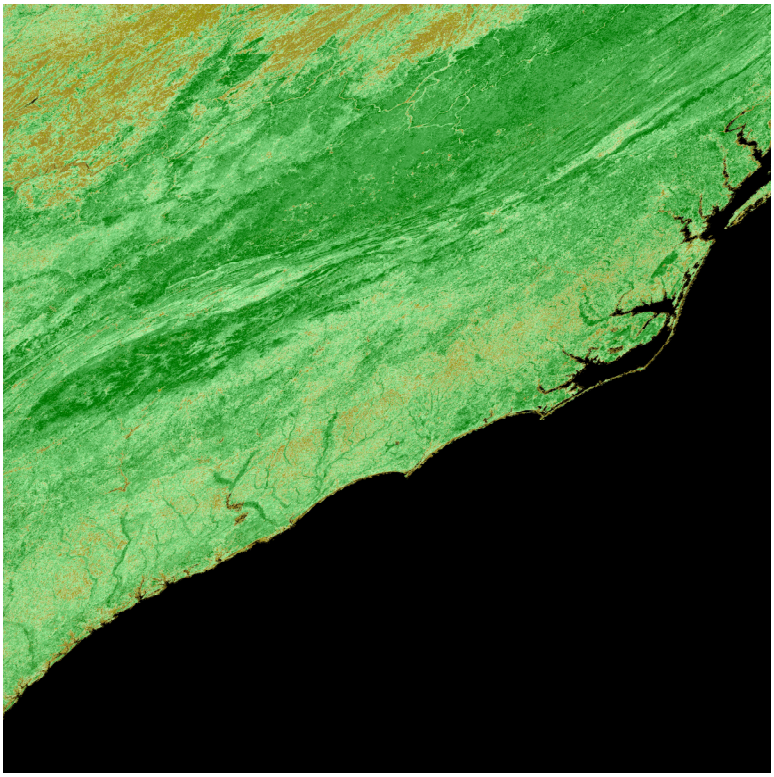

Figure 4. Normalized Difference Vegetation Index from a MODIS/Terra vegetation indices 16-day L3 global 250 m ISIN grid V003 product acquired over the Northeastern United States. Water has been completely masked from the image. [Image provided by the LP DAAC: http://edcdaac.usgs.gov/modis/mod13q1.html.]

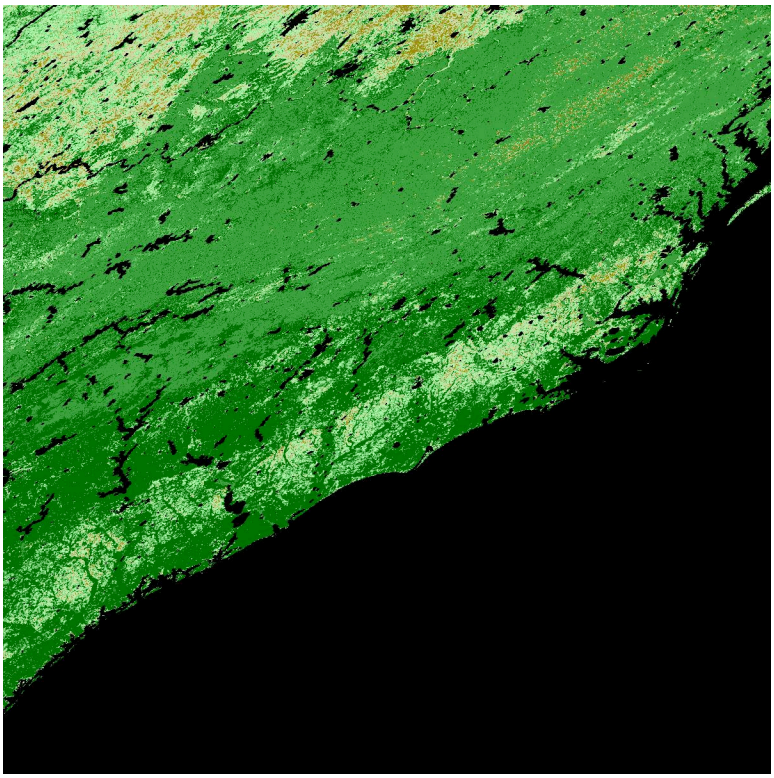

Figure 5. Fraction of photosynthetically active radiation from a MODIS/Terra leaf area index/FPAR 8-day L4 global 1 km ISIN grid V003 product acquired over the Northeastern United States. Water has been completely masked from the image. [Image provided by the LP DAAC: http://edcdaac.usgs.gov/modis/mod15a2.html.]

Landsat 7 ETM+

NASA launched the ETM+ aboard the Landsat 7 satellite on April 15, 1999. The Landsat 7 ETM+ provides global coverage every 16 days at spatial resolutions ranging from 15 to 60 m. For more information on Landsat 7, refer to the USGS Landsat 7 Web site at http://landsat7.usgs.gov. For information on the Landsat Data Continuity Mission, refer to http://ldcm.usgs.gov/index.html. For a description of Landsat 7 ETM+ data products available from the LP DAAC, see http://edcdaac.usgs.gov/landdaac/landsat7/l7_dataprod.html.

ETM+ Level 0R products. The Level 0R (L0R) product is reformatted, raw data (Figure 6a). Reformatting includes shifting pixels by integer amounts to account for (1) the alternating forward-reverse scanning pattern of the ETM+ sensor, (2) the odd-even detector arrangement within each band, and (3) the detector offsets inherent to the focal-plane array engineering design. Pixels are neither resampled nor are they geometrically corrected or registered (i.e., the pixels are not aligned per scan line). For more information, see http://edcdaac.usgs.gov/landsat7/l70rwrs.html.

ETM+ Level 1R products. The Level 1R (L1R) product is a radiometrically corrected L0R product (Figure 6b). This product (1) corrects detector artifacts, such as coherent noise, banding, striping, and dropped lines or pixels and (2) is calibrated to radiance units and scaled to unsigned 16-bit integer values. Radiometric corrections are not reversible. Pixels are neither resampled nor are they geometrically corrected or registered (i.e., the pixels are not aligned per scan line). For more information, see http://edcdaac.usgs.gov/landsat7/l7wrs_l1.html.

ETM+ Level 1G products. The Level 1G (L1G) product is radiometrically and geometrically corrected (systematic) to user-specified parameters, including output map projection, image orientation, pixel size, and resampling kernel (Figure 6c). The correction algorithms model the spacecraft and sensor attitude using data generated by onboard computers during imaging. Sensor, focal plane,

and detector alignment information provided by the Image Assessment System in the Calibration Parameter File is also used to improve the overall geometric and radiometric fidelity. The resulting product is free from distortions related to the sensor (e.g., jitter, view-angle effect), satellite (e.g., attitude deviations from nominal), and Earth (e.g., rotation, curvature). Residual error in the systematic L1G product is less than 250 m (1 sigma) in flat areas at sea level. The systematic L1G correction process does not use ground control or relief models to attain absolute geodetic accuracy. For a report on L1G geometric accuracy, see http://landsat7.usgs.gov/news/lpso_rpt.html. For more information on L1G products, go to http://edcdaac.usgs.gov/landsat7/l7wrs_l1.html.

(a) (b) (c)

Figure 6. Landsat 7 ETM+ images processed to different levels: (a) Level 0, (b) Level 1R, and (c) Level 1G. Note that the pixels are not aligned per scan line in (a) or (b), as seen by the left-to-right variation in the airport runway located at the center of each image. This is corrected in (c) through L1G processing. [Images provided by the USGS: http://landsat7.usgs.gov/l7_processlevels.html.]

Terra ASTER

NASA launched ASTER aboard the EOS Terra satellite on December 18, 1999. The ASTER instrument was built by a consortium of Japanese government,

industry, and research groups. It has a complement of three different telescopes with varying pointing capabilities. The spatial resolution of ASTER imagery ranges from 15 to 90 m. The acquisition schedule for ASTER is limited to 8% of the Terra duty cycle, and thus data are not acquired continuously. The management of the ASTER instrument is guided by science teams from Japan and the United States of America. One of the goals of the science teams is to accomplish a “one-time” mapping of the global landmasses. For a description of ASTER data products available from the LP DAAC, see http://edcdaac.usgs.gov/aster/asterdataprod.html.

The LP DAAC offers numerous ASTER On-Demand products, where a user can select a Level 1A or Level 1B image and have the data processed to higher level products based on algorithms developed by the science teams. On-demand orders will be supported by the EDG in the Spring of 2003. In the meantime, orders can be placed by going to the ASTER On-Demand Gateway at http://edcdaac.usgs.gov/asterondemand/index.html.

The NASA Jet Propulsion Laboratory (JPL) leads the U.S. Science Team, and it publishes a wide variety of information on ASTER including product release notes, instrument designs, example applications, and an image gallery (http://asterweb.jpl.nasa.gov). The ASTER User Handbook, coauthored by NASA JPL and the LP DAAC, is provided under the “Documents” link, or http://asterweb.jpl.nasa.gov/documents/documents.htm.

A data acquisition request (DAR) process is available for those interested in submitting a request for data that have not yet been acquired or requested. For more on the DAR process, refer to http://asterweb.jpl.nasa.gov/gettingdata.

ASTER Level 1A products. The ASTER Level 1A (L1A) contains reconstructed, unprocessed instrument data derived from the telemetry streams of the three separate telescopes: the 15 m visible near-infrared (VNIR) telescope, the 30 m shortwave-infrared (SWIR) telescope, and the 90 m thermal-infrared (TIR) telescope. The data are produced at the Ground Data System (GDS) facility of the Earth Remote Sensing Data Analysis Center in Tokyo, Japan, and shipped to the LP DAAC on tapes. The L1A data have geometric and radiometric calibration coefficients calculated and appended to the metadata, but these corrections are not applied to the imagery (Figure 7). The metadata also include corrections for SWIR parallax, and any intratelescope and intertelescope registration information. ASTER L1A data are used to generate relative or absolute digital elevation models (DEM) on demand (Figure 8). For more information on ASTER L1A data, see http://edcdaac.usgs.gov/aster/ast_l1a.html. For more on ASTER DEMs, see http://edcdaac.usgs.gov/aster/ast14dem.html.

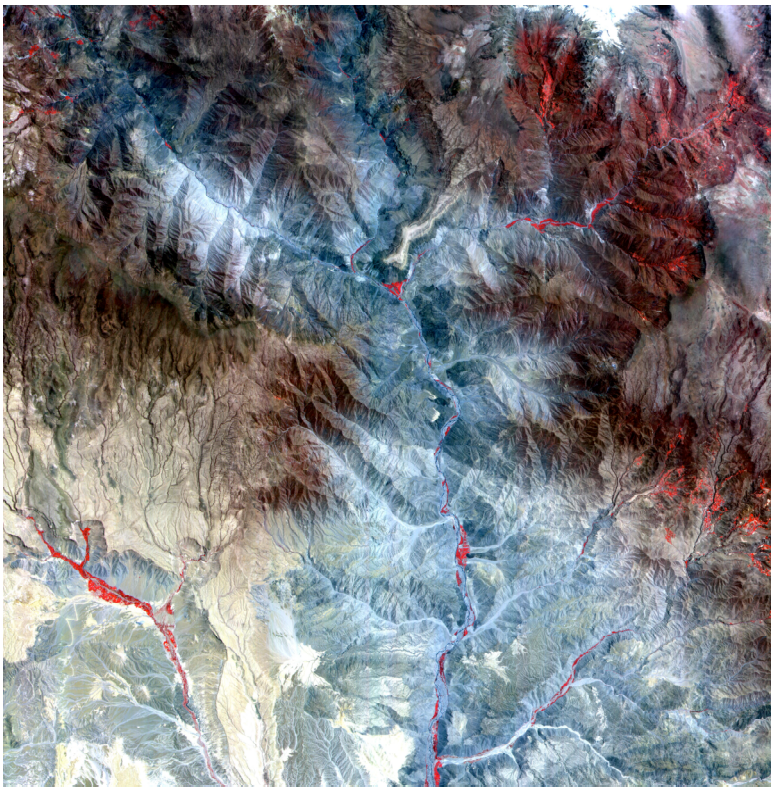

Figure 7. An ASTER L1A image acquired over Southern Peru, displayed using a false color-infrared composite (VNIR 3, 2, 1 (red, green, blue (RGB))). [Image provided by the LP DAAC.]

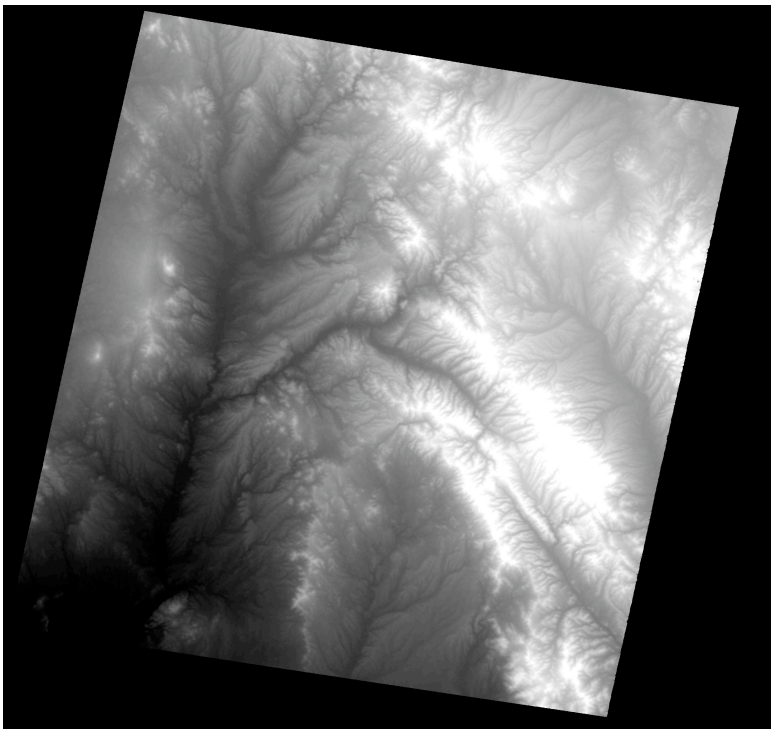

Figure 8. An on-demand ASTER DEM generated from an L1A image acquired over Sonora State, Northwestern Mexico. [Image provided by the LP DAAC.]

ASTER Level 1B products. The ASTER Level 1B (L1B) data produced by applying the radiometric calibration and geometric correction coefficients from the L1A metadata. Both intratelescope and intertelescope registration corrections are also performed. The L1B has the same number of bands, at the same resolution, as the L1A product (Figure 9). L1B data are geographically referenced to the universal transverse Mercator (UTM) projection using the World Geodetic System of 1984 (WGS-84) datum. They are path oriented to preserve spectral values.

L1B data are used as inputs for generating numerous on-demand higher level geophysical products, such as brightness temperature, surface reflectance, and

surface radiance (Figures 10-12). For more information on ASTER L1B data, refer to http://edcdaac.usgs.gov/aster/ast_l1b.html. The ASTER On-Demand Gateway (http://edcdaac.usgs.gov/asterondemand/index.html) provides the required information and links necessary for placing on-demand orders for ASTER Level 2 and Level 3 products. Please note that on-demand orders will be enabled through the EDG at some point during the Spring of 2003.

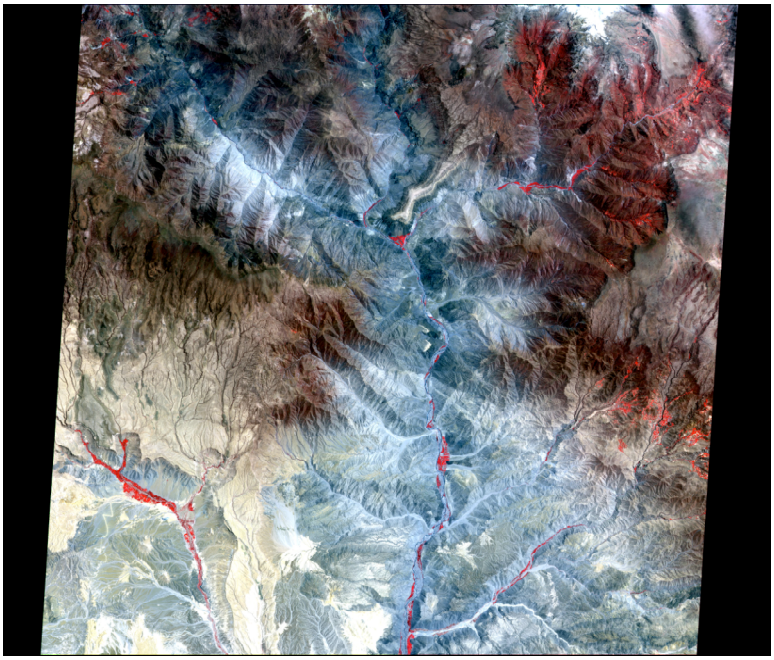

Figure 9. An ASTER L1B image acquired over Southern Peru, displayed using a false color-infrared composite (VNIR 3, 2, 1 RGB). Note that the L1B is path oriented. [Image provided by the LP DAAC.]

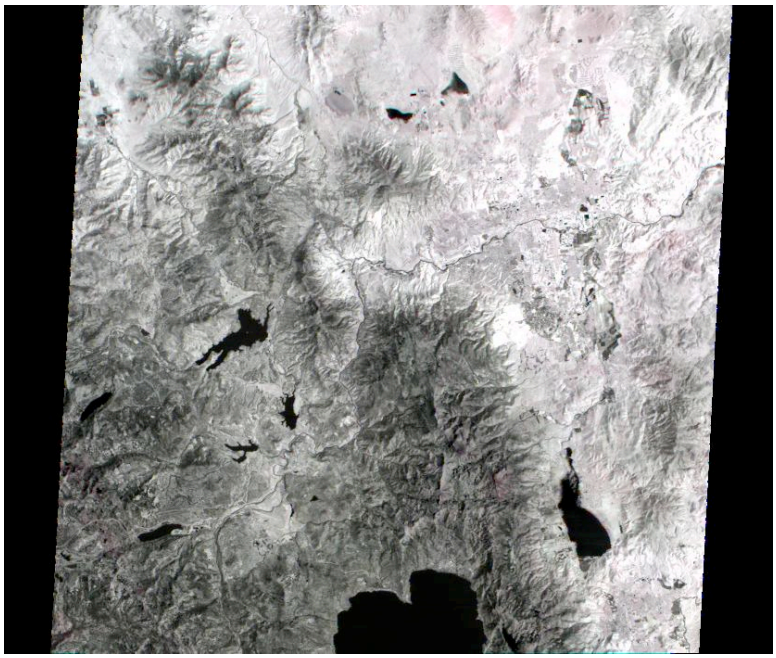

Figure 10. An on-demand ASTER surface radiance product generated from the thermal-infrared bands of an ASTER L1B image acquired just north of Lake Tahoe. The image is displayed using a 14, 12, 10 band combination (RGB). [Image provided by the LP DAAC.]

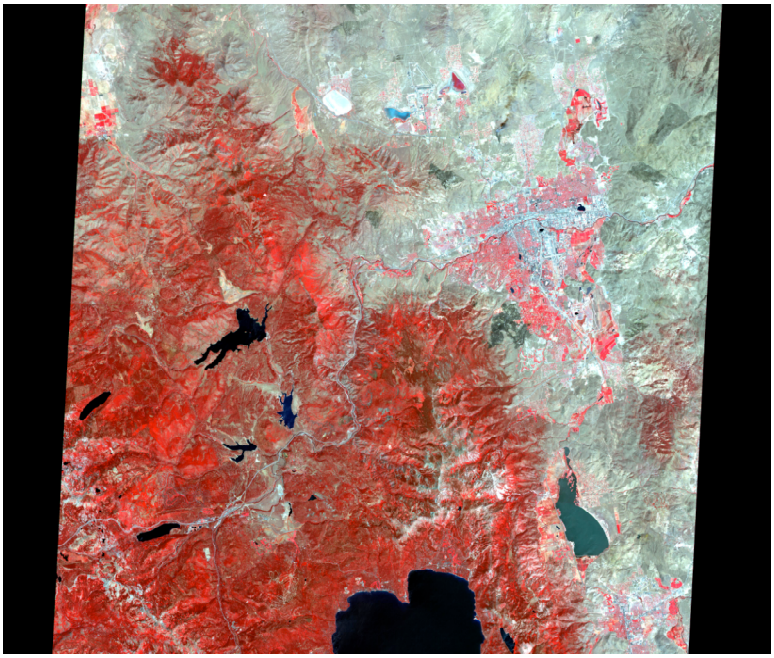

Figure 11 An on-demand ASTER surface reflectance product generated from the visible near-infrared bands of an ASTER L1B image acquired just north of Lake Tahoe. The image is displayed using a 3, 2, 1 band combination (RGB). [Image provided by the LP DAAC.]

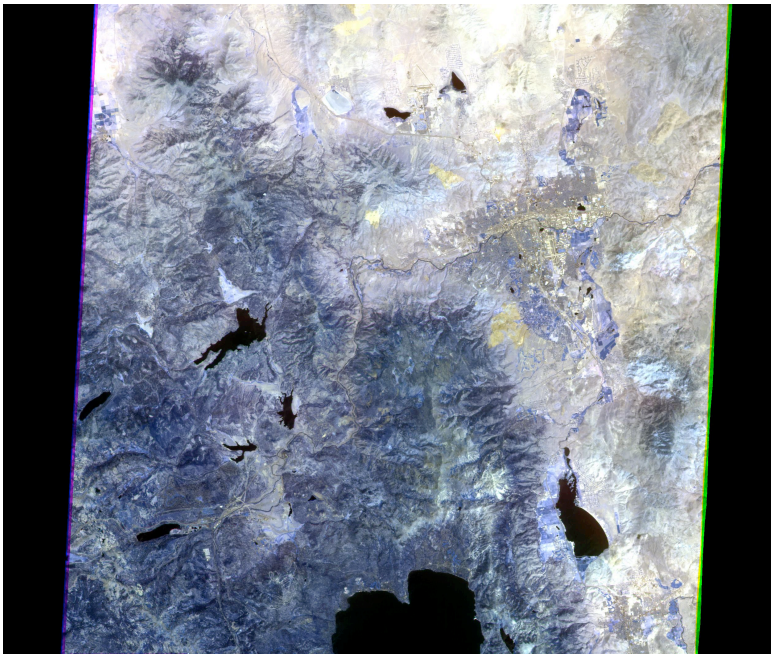

Figure 12. An on-demand ASTER surface reflectance product generated from the shortwave-infrared bands of an ASTER L1B image acquired just north of Lake Tahoe. The image is displayed using a 9, 7, 4 band combination (RGB). [Image provided by the LP DAAC.]

Summary

The number of satellite instruments and data products is increasing at a rapid rate, compared with just a decade ago. The information available on these datasets can be overwhelming. The authors hope that this article has served as a road map, facilitating the use of data products available from the LP DAAC.

Web References

EOS Data Gateway: http://edcimswww.cr.usgs.gov/pub/imswelcome

EOS Data Gateway Tutorial: http://edcdaac.usgs.gov/tutorial

LP DAAC Data Pool: http://edcdaac.usgs.gov/tutorial/datapool.html

Global Visualization Viewer: http://edcdaac.usgs.gov/aster/glovis.html

NASA: http://www.nasa.gov

USGS: http://www.usgs.gov

LP DAAC: http://edcdaac.usgs.gov/main.html

LP DAAC Data Products: http://edcdaac.usgs.gov/dataproducts.html

NASA DAAC Alliance: http://nasadaacs.eos.nasa.gov

NASA EOS: http://eospso.gsfc.nasa.gov

HDF-EOS Tools and Information: http://hdfeos.gsfc.nasa.gov/hdfeos/index.cfm

ECS Data Handling System: http://edhs1.gsfc.nasa.gov

NASA Terra: http://terra.nasa.gov

NASA Aqua: http://eos-pm.gsfc.nasa.gov

USGS Landsat 7: http://landsat7.usgs.gov/index.php

NASA Landsat 7 Gateway: http://landsat.gsfc.nasa.gov

MODIS Documentation: http://modis-land.gsfc.nasa.gov

MODIS Browse Images: http://landqa2.nascom.nasa.gov/browse/browse.cgi

Landsat 7 Documentation: http://landsat7.usgs.gov/resource.html

Landsat Data Continuity Mission: http://ldcm.usgs.gov/index.html

ASTER Documentation: http://asterweb.jpl.nasa.gov/documents/documents.htm

NASA JPL (ASTER): http://asterweb.jpl.nasa.gov

ASTER GDS: http://www.gds.aster.ersdac.or.jp/gds_www2002/index_e.html

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SMIT, P.F. 2002. Multispectral imagery available from the United States Geological Survey EROS Data Center's NASA Distributed Active Archive Center.

Proceedings XXII FIG International Congress: ACSM/ASPRS Annual Conference, Washington, DC, April 19-26.

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