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The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) after fifteen years: Review of global products

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ABSTRACT

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a 15-channel imaging instrument operating on NASA's Terra satellite. A joint project between the U.S. National Aeronautics and Space Administration and Japan's Ministry of Economy, Trade, and Industry, ASTER has been acquiring data for 15 years, since March 2000. The archive now contains over 2.8 million scenes; for the majority of them, a stereo pair was collected using nadir and backward telescopes imaging in the NIR wavelength. The majority of users require only a few to a few dozen scenes for their work. Studies have ranged over numerous scientific disciplines, and many practical applications have benefited from ASTER's unique data. A few researchers have been able to mine the entire ASTER archive, that is now global in extent due to the long duration of the mission. Six examples of global products are described in this contribution: the ASTER Global Digital Elevation Model (GDEM), the most complete, highest resolution DEM available to all users; the ASTER Emissivity Database (ASTER GED), a global 5-band emissivity map of the land surface; the ASTER Global Urban Area Map (AGURAM), a 15-m resolution database of over 3500 cities; the ASTER Volcano Archive (AVA), an archive of over 1500 active volcanoes; ASTER Geoscience products of the continent of Australia; and the Global Ice Monitoring from Space (GLIMS) project.

Introduction

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a 15-channel imaging instrument operating on NASA's Earth Observing Terra morning orbital platform since 1999 (Yamaguchi et al., 1998). ASTER was built and provided by Japan's Ministry of Economy, Trade, and Industry (METI). ASTER has three separate optical subsystems: the visible and near-infrared (VNIR) radiometer, acquiring images in 3 bands with a 15 m instantaneous field of view (IFOV), and an additional backward-looking band for stereo; the shortwave infrared (SWIR) radiometer, acquiring images in 6 bands with a 30 m IFOV; and the thermal infrared (TIR) radiometer, acquiring images in 5 bands with a 90 m IFOV (Fig. 1). ASTER acquires images in all bands with a swath width of 60 km. It orbits the earth in a sun-synchronous near-polar orbit, with an equator crossing time of 10:30am, and the daytime repeat visit interval is 16 days at the equator.

There are several constraints on ASTER operations and data acquisitions. The primary constraint on how much data ASTER can acquire is dictated by the amount of space ASTER is allocated on the Terra solid state recorders, since there is no direct broadcast capability for ASTER; all data are relayed through the Tracking and Data Relay Satellite System to ground stations, several times each day. The maximum average data rate allocated to ASTER, based on two-orbit average, is 8.3 Mbps, which corresponds to 8 min of full-mode daytime operation per orbit. Other constraints include dissipation of heat, available power, length of downlink windows, design limitations of instrument components, and ability to schedule observations with the ASTER instrument.

ASTER, because of its limited duty cycle, is scheduled every day for specific data collections. These collections are selected from all the pertinent requests that potentially could be observed on a given day. A data base has been assembled that contains different categories of requests to collect data. These fall into three categories:

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0303-2434/

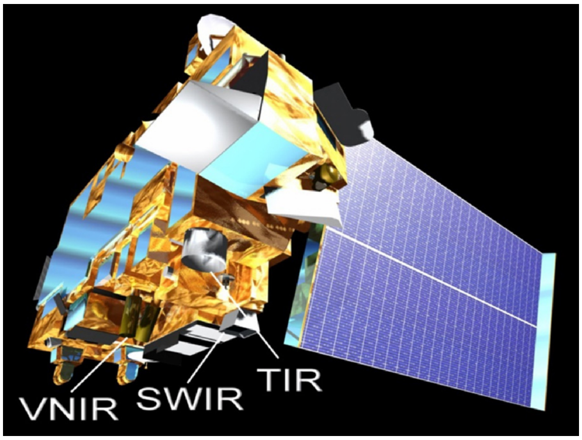

Fig. 1. Artist's rendition of the ASTER instrument on Terra.

(1) engineering data that are collected to monitor the instrument health and safety; (2) calibration data that are acquired as part of both vicarious and onboard calibration activities; (3) science data that are acquired to meet the science needs of the mission.

The science team developed the ASTER scheduler that automatically creates an observation schedule every day for upload and execution by ASTER. The data collection database is used to determine all possible submitted and requested observations that potentially could be observed on any given day. This always greatly exceeds the capabilities of ASTER to acquire data, so a triage is performed by the scheduler using prioritization parameters. We have additionally developed a system that allows manual modification of the one-day schedule to allow for emergency or urgent acquisitions (Duda and Abrams, 2012). These would include observations of natural disasters, such as volcanic eruptions, earthquakes, and hurricanes.

The three ASTER subsystems worked perfectly until April 2008, when the SWIR subsystem suffered a failure, probably due to decoupling of the detector from the cold finger. Since then, we have acquired VNIR and TIR data, both together during the daytime, and with only the TIR at nighttime.

ASTER delivers 12 data products to users, created on-demand. Besides the lower level radiance-at-the-sensor products for each subsystem, we make available calibrated geophysical variables, such as atmospherically corrected reflectance, kinetic temperature, emissivity, and digital elevation model. Any or all products can be ordered from any scene that has been acquired by ASTER and is stored in the archive. Since March 2000, ASTER has acquired over 2.8 million scenes. We have achieved nearly complete global coverage with all of the instruments and stereo acquisitions; for most areas we have up to hundreds of scenes at different times of year. A few perennially cloudy areas are missing from the archive.

In the last 15 years, the ASTER project has distributed over 800 Tb of data to the science community, representing over 30 million data products. The user community is global, with data going to users in over 120 countries. Our community includes government agencies, educational institutions and commercial vendors. A survey of the refereed published literature from the prior 3 year provides insight into some of the applications of ASTER data by a large and varied user community. ASTER data have been used for archaeological applications (Agapiou et al., 2014), urban heat island effects (Hu et al., 2012; Liu and Zhang, 2011), wetlands monitoring (Bortels et al., 2011), landslide susceptibility mapping (Choi et al., 2012), monitoring vineyards and tea quality (Ducati et al., 2014; Dutta et al., 2011), flood hazard mapping (Forkuo, 2011; Gichamo et al., 2012; Hanada and Yamazaki, 2012), riparian vegetation change and mangrove mapping (Kellogg and Zhou, 2014; Tamura, 2012), geologic mapping and resource exploration (Mars, 2014; Pour and Hashim, 2012; van der Meer et al., 2014, 2012), and mapping tree species diversity (Mutowo and Murwira, 2012).

These studies used a few to several dozen ASTER scenes. However, after 15 years of successful data acquisition, the ASTER data archive contained sufficient scenes to allow global data sets to be extracted. Several research teams have produced continental and global products using the massive archive of ASTER data. The rest of this article describes six of these that have been released in the last few years: the ASTER Global Digital Elevation Model (GDEM), the ASTER Emissivity Database (ASTER GED), the ASTER Global Urban Area Map (AGURAM), the ASTER Volcano Archive (AVA), ASTER Geoscience products, and the Global Ice Monitoring from Space (GLIMS) project.

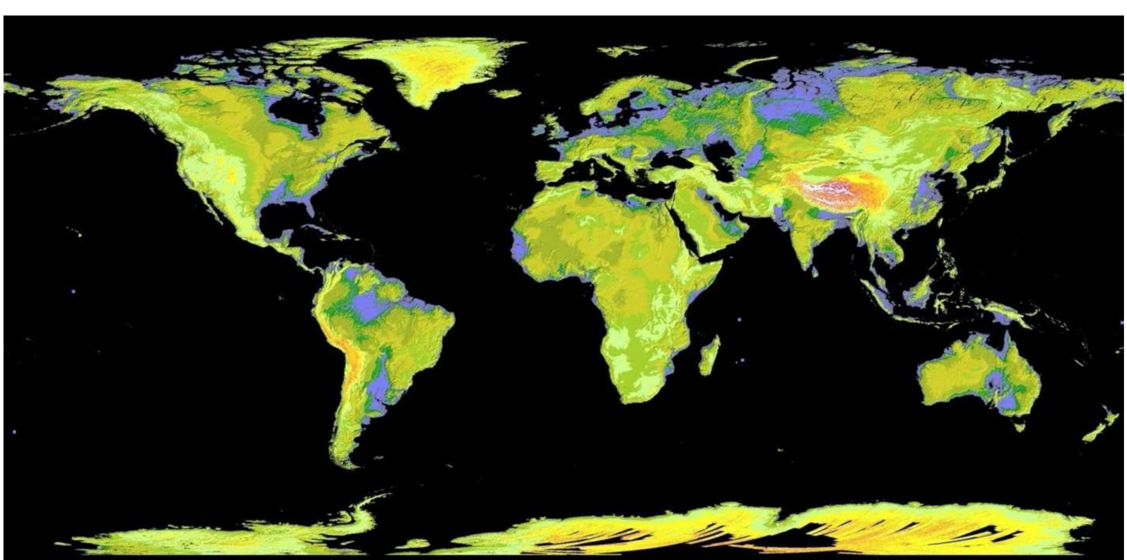

Fig. 2. ASTER GDEM, shaded relief version, with color-coded elevations; white is highest, red and orange next, yellows and greens next, purple and black lowest. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)