On June 29, 2009 the Ministry of Economy, Trade, and Industry (METI) of Japan and the U.S. National Aeronautics and Space Administration (NASA), jointly released the global digital elevation model (GDEM) of the Earth's land surface (Figure 1), derived from the images acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The ASTER GDEM is the most up-to-date, complete digital topographic data set of the Earth available to the public, covering the global land surface from 83 degrees north to 83 degrees south latitude. In 2007 the GDEM was offered by METI and NASA to the Group on Earth Observations (GEO) at the Summit of Ministers in Capetown, and accepted as a contribution to the Global Earth Observing System of Systems (GEOSS) to serve societal needs.

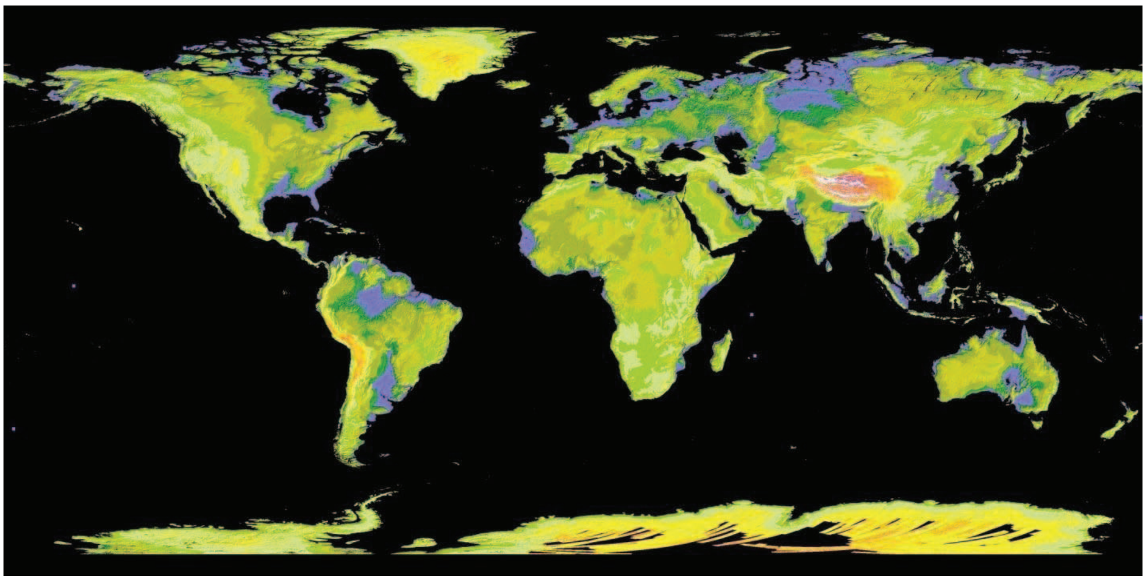

Figure 1. ASTER GDEM, shaded relief version, with color-coded elevations; white is highest, red and orange next, yellows and greens next, purple lowest.

Prior to the release of the ASTER GDEM, the most complete DEM available to the public was the Shuttle Radar Topography Mission (SRTM) data set (Farr and Kobrick, 2000; Farr et al., 2007). SRTM was a joint mission of NASA, German Aerospace Center, and the National Geospatial-Intelligence Agency. The SRTM data were created using interferometric processing of L-band synthetic aperture radar (SAR) data. Because of its cloud-penetrating capability, acquisition of the SAR data set was accomplished in 11 days. The SRTM DEM is a surface model, with canopy, as is the ASTER GDEM. The SRTM data were released to the public at 90 m postings for areas outside the U.S., and 30 m postings for the US and its Territories. The SRTM DEM covers the Earth from 60 degrees north to 57 degrees south latitude, thus missing the land masses north of 60 degrees (Greenland; northern Canada, Europe, Asia, and Alaska) and Antarctica. The only other global data set available is the GTOPO30 DEM, with 1 km postings (GTOPO30 Documentation, 2009).

ASTER is a 14-band imaging instrument, built for METI, and operating on NASA's Terra platform. Launched in December 1999, ASTER has collected over 1,700,000 images of the land surface; each image is 60 x 60 km, and includes a backward-looking band that allows creation of digital elevation models. The 28 degree look angle gives a base-to-height ratio of 0.6. The pixel size of the visible and near infrared bands (and the stereo band) is 15 m.

The methodology used to produce the ASTER GDEM involved automatic processing of the entire archive:

a) Each of the 1,264,118 daytime VNIR scenes that had a stereo pair, was stereo-correlated to produce individual scene-based DEMs with 30 m postings. This was done using standard photogrammetric methods and a complete camera model of the ASTER VNIR instrument.
b) The individual scenes were passed through a cloud-screening algorithm to identify cloud-contaminated pixels; data from all ASTER bands were used to identify clouds.
c) For each output pixel, all of the acceptable DEM values were stacked and averaged, removing residual bad values and outliers. Where only 1 or 2 pixel values were available, the ASTER DEM value was replaced by an available existing reference DEM, or was forced to be void if no fill-in DEM was available.
d) The mosaicked and averaged DEM values were partitioned into about 22,600 1 x 1 degree tiles, posted at 30 meters (approximately 1 arc-second), projected in rectangular (cylindrical equidistant projection) format, and referenced to the WGS84 ellipsoid. The tile size is 3601 x 3601.
e) The GDEM tiles are signed 16-bit integers in GeoTIFF format.

Prior to their decision to release, NASA and METI, in cooperation with the U.S. Geological Survey (USGS), Earth Remote Sensing Data Analysis Center (Tokyo, Japan), and other collaborators, conducted extensive preliminary validation and characterization studies of the ASTER GDEM. The results of those studies are briefly summarized below. For a discussion of these and additional GDEM accuracy assessment and characterization results, please download the "ASTER Global DEM Validation Summary Report" from https://lpdaac.usgs.gov/lpdaac/content/download/4009/20069/version/1/file/ASTER+GDEM+Validation+Summary+Report+-+FINAL+for+Posting+06-28-09.pdf.

Validation of the GDEM over the conterminous United States (CONUS) was done by the U.S. Geological Survey and NASA. The 934 CONUS ASTER GDEM tiles were compared with USGS NED data and with more than 13,000 ground control points (GCPs). For vertical accuracy, in comparison with NED data, the mean differences, standard deviations, and root mean square errors (RMSEs) were calculated for each tile and for all CONUS, as well as by National Land Cover Dataset (NLCD) class, terrain type, and stack number. Table 1 presents the results of ASTER GDEM minus NED for the NLCD water class, three aggregated NLCD land cover type classes (urban, forest, and open), and one additional category that seeks to reduce the effects of water and snow/ice.

Table 1. Raster-based ASTER GDEM vertical accuracy results for CONUS, including the NLCD water class and three aggregated land cover type classes. All values are in meters.

ASTER GDEM minus NED			
Land Cover Type Name	**Mean**	**Std. Dev.**	**RMSE**
All CONUS	**-3.64**	**8.75**	**10.87**
Water	-1.32	15.71	16.53
Urban	-4.06	6.94	9.06
Forest	1.72	9.93	10.93
Open	-6.40	7.31	10.33
Excluding Water	**-3.77**	**8.19**	**10.46**

and Ice & Snow			

Results where GDEM values were compared to GCPs at more than 13,000 benchmarks scattered across the CONUS were consistent with the NED studies: RMSE value of 9.37 m (GDEM) vs 10.46 m (NED). These RMSE values convert to vertical errors of just under and just over 20 m at the 95% confidence level, respectively.

An important objective of the preliminary validation study was to identify and characterize any artifacts or residual anomalies that may affect the overall accuracy of the data set, reduce its usefulness for certain applications, or make it cosmetically unattractive. It is clear that the ASTER GDEM does contain anomalies and artifacts that degrade its overall accuracy, represent barriers to effective utilization of the GDEM for certain applications, and give the product a distinctly blemished appearance in certain, exaggerated renditions.

For this version of the ASTER GDEM, no inland water mask has been applied, and all values for lakes and rivers are those that were automatically calculated in the generation of the ASTER GDEM. Consequently, most lakes and rivers have ranges of elevations in the ASTER GDEM, rather than a "flattened" single elevation for lakes and continuously changing elevations for rivers. In contrast, the SRTM DEMs have been edited using a surface water mask that results in substantially more accurate water surface elevation in those data sets than for the ASTER GDEM.

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REFERENCES

Abrams, M., Bailey, B., Tsu, H., Hato, M., 2009, "The ASTER Global DEM", *Photogrammetric Engineering and Remote Sensing*, in press.

ASTER Global Validation Summary Report, 2009, Viewed July 23, 2009, https://lpdaac.usgs.gov/lpdaac/content/download/4009/20069/version/1/file/ASTER+GDEM+Validation+Summary+Report+-+FINAL+for+Posting+06-28-09.pdf.

Chrysoulakis, N., Abrams, M., Kamarianakis, Y., Stanislawski, M., 2010, "Validation of the ASTER derived Global DEM product (GDEM) for the area of Greece", *Int. Journal Remote Sensing*, in press.

Farr, T.G., M. Kobrick, 2000, Shuttle Radar Topography Mission produces a wealth of data, Amer. Geophys. Union Eos, v. 81, p. 583-585.

Farr, T. G., et al. 2007, The Shuttle Radar Topography Mission, Rev. Geophys., 45, RG2004, doi:10.1029/2005RG000183.

GTOPO30 Documentation, 2009, Viewed July 26, 2009, http://edc.usgs.gov/products/elevation/gtopo30/README.html.

Yamaguchi, Y., Kahle, A., Tsu, H., Kawakami, T., Pniel, M., 1998, Overview of Advanced Thermal Emission and Reflection Radiometer (ASTER), IEEE Trans. Geosci, Remote Sens., 36, 1062-1071.