The International Society for Optical Engineering

SPIE Newsroom

10.1117/2.1200607.0306

Digital elevation models generated from multispectral stereo satellite imagery

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Local-level, high-accuracy topographic maps are produced from satellite-borne radiometer images.

High-accuracy topography of the Earth's surface is very important for local-level geoscientific applications, such as watershed management, communication systems siting, and terrain modeling. While existing digital elevation models (DEMs) and other land cover maps provide topographic data at global, regional and national scales, they are non-existent or of insufficient accuracy for many local areas.

In the past decade, a number of data sources, including spatial resolution satellite sensors, have been used in conjunction with digital photogrammetry, in which the location of a point is determined by triangulation from two or more observation locations, to derive land cover maps at the local level.[1,2] However, the confusion of spectral responses from different features has posed a significant image classification problem for map generation. Researchers are trying to improve the accuracy of classification for this application using digital image processing techniques.[3]

For DEM production, the advanced spaceborne thermal emission and reflection radiometer (ASTER) aboard NASA's Terra satellite presents two important advantages. ASTER provides multispectral measurements in visible (two channels) and near infrared (one channel) with 15m spatial resolution, as well as in short-wave infrared (six channels) with 30m resolution. The combined use of visible, near infrared, and short-wave infrared channels in the classification scheme improves classification accuracy. Additionally, ASTER's along-track stereo-data acquisition method—in which fore and aft images from a single orbit are used—is superior to the more-commonly-used across-track method, in which images are obtained6 from different orbits.[4–6]

Figure 1. A digital elevation model of Crete was produced using data from the ASTER instrument on NASA's Terra satellite.

The remote sensing application for land-cover and digital-elevation-models service (REALDEMS), a joint Greek and American project, was set up to provide accurate DEMs and land cover maps capable of being used in local studies. The service used data from ASTER in combination with the global positioning system (GPS) and field observations to produce the required models.

The accuracy at which absolute elevations can be derived by photogrammetric techniques is governed by the base-to-height ratio (or geometric stereo disposition), the reliability of the correlation procedure, and the accuracy and density of control points on the ground (GCPs).[5] The base-to-height ratio for ASTER is 0.6, which is not exceptionally high, but the accuracy of the image-matching procedure is high (±1 pixel), since both of the images of the stereo-pair have been acquired along-track, virtually simultaneously, and under the same atmospheric conditions. Moreover, the 3D positional accuracy of the GCPs in the REALDEMS project was high since differential GPS was used. Finally, the GCPs were numerous (more than 10 per scene) and uniformly distributed within each image of the stereo pair.

REALDEMS used a digital stereo correlation approach to calculate parallax differences from ASTER stereo pairs. Because only the component of parallax parallel to the base

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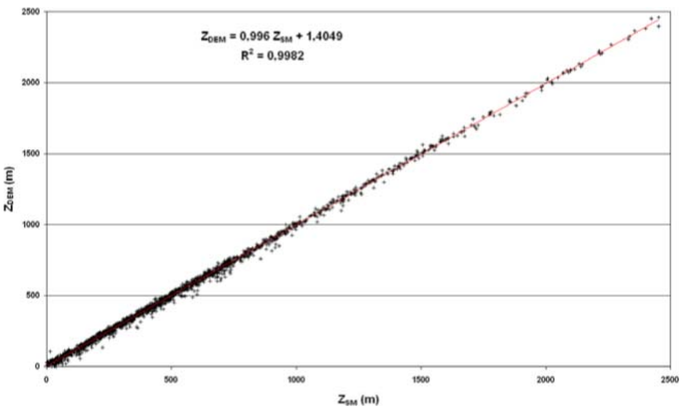

Figure 2. *ASTER-derived elevations (Z_{DEM}) compare favorably to elevations from survey monuments (Z_{SM}) derived from 1:5000 survey maps for Crete.*

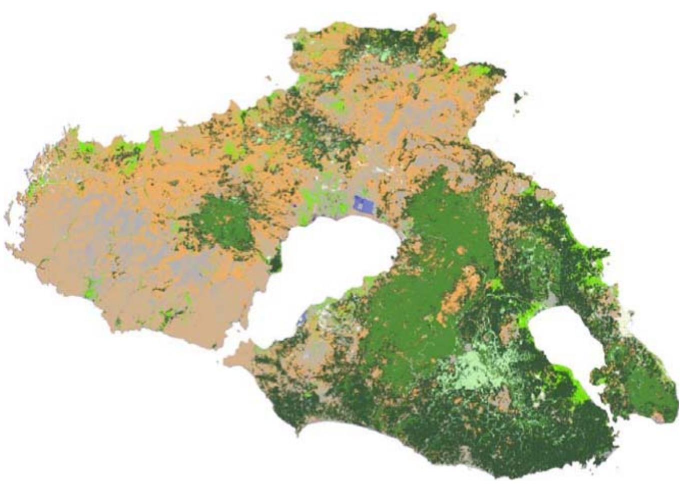

Figure 3. *A land cover map of Lesvos was produced from ASTER data.*

line (along-track) differs between the two ASTER images, one-dimensional cross-correlation was an adequate means of parallax computation. The parallax differences were then converted to absolute elevations with the use of GCPs.[7]

The root mean square error method was used to assess the resultant DEM planimetry and elevations, and ASTER-derived elevations were compared with those of the National Trigonometric Network of Greece survey monuments with excellent results (see Figure 2). For land cover mapping, a supervised classification scheme was developed and the maximum likelihood algorithm was used (see Figure 3).

Results were validated in case studies at selected application areas. DEMs created by the project have better than 20m accuracy for the Greek islands of Crete and Lesvos.

Additional results of the REALDEMS project are mosaics of orthorectified ASTER multispectral images, land cover maps, and watershed characterizations at selected sites, where slopes and aspects were measured, hydrographic networks were mapped, and subbasins were identified and documented in vector format.

The accuracy of REALDEMS products are quite satisfactory for large-catchment hydrological parameterization, evidencing the high potential of ASTER imagery to support watershed management.[8] Moreover, the produced DEM can be used as a data product in its own right or for satellite image orthorectification.

REALDEMS (http://www.realdems.gr) is a joint effort of the Foundation for Research and Technology – Hellas, NASA's Jet Propulsion Laboratory, the University of the Aegean, and PLANO SA, with funding from the Greek General Secretariat for Research and Technology.

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Michael Abrams, ASTER science team leader, has more than 10 years' experience with ASTER data. He was involved with the initial instrument design, the placement of short-wave infrared bands, and demonstrating the value of including an along-track stereo band to allow production of DEMs.

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