

Foreword

The Shuttle Radar Topography Mission— Data Validation and Applications

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Introduction

February 2006 marked six years since the flight of the Shuttle Radar Topography Mission (SRTM), a joint project of the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA), with participation from the German Space Agency (DLR) and the Italian Space Agency (ASI). The result of the mission has been an unprecedented near-global high-resolution elevation dataset. Since the Shuttle flight, the mapping community has eagerly anticipated the availability of this new source of basic topographic information. All SRTM data production has been completed, and the data are now being used in numerous applications. To help document SRTM data quality and characteristics, and to describe applications that have benefited from the data, a collection of papers has been compiled for this special issue.

SRTM holds a unique position among Earth remote sensing missions. The 11-day February 2000 mission was the only Space Shuttle flight dedicated to topographic mapping, and it represents the only space-based platform to use single-pass synthetic aperture radar interferometry. The mission used radar equipment that was flown and operated successfully aboard the Shuttle previously in 1994. The original radar equipment was supplemented by outboard radar antennas deployed on a 60-meter mast extending from the Shuttle's cargo bay. The mast has the distinction of being the longest rigid structure ever flown in space. See the Highlight Article in this issue by Michael Kobrick, the SRTM project scientist at the Jet Propulsion Laboratory (JPL), for further information on the background, history, context, and configuration of the mission.

The engineering accomplishments realized in the successful construction, flight, and operation of the radar interferometer are reason enough to recognize the significance of SRTM. However, the resulting near-global elevation dataset is the achievement of note for the earth science and geospatial data user communities, and thus, it is the focus of this special issue. Never before had the vast majority of the Earth's surface been mapped with a single, consistent method in such a short period of time, resulting in an unprecedented topographic "snapshot."

Despite being one of the Earth's most fundamental geophysi-

cal properties, the detail and accuracy at which land surface elevation had been mapped varied greatly across the globe prior to SRTM. This fact, in combination with the pervasive requirement for detailed topographic information for many earth science studies, led to considerable anticipation of SRTM-derived elevation data. Although a preliminary research-grade elevation dataset became available within a couple of years of the mission, it was not until late 2004 that all final, edited data were available. Since that time, the user community has embraced the availability of SRTM data, and the data are being used in many operational and research settings. These varied uses are evidence that the primary mission objective—to provide high-quality global elevation data for civil, military, and scientific users—is being met. The widespread use of SRTM data also demonstrates the tremendous market interest in such global geospatial data resources, which heretofore had not been addressed for civilian applications.

The user community has several options for SRTM data type, format, and access. One-arc-second resolution data (approximately 30 meters) are available over the United States and its territories, while three-arc-second resolution data (approximately 90 meters) are available over non-U.S. areas. Additionally, users have the choice of three-arc-second data produced at NGA by systematic subsampling of the full-resolution one-arc-second data or three-arc-second data produced at JPL by averaging the one-arc-second data. Most users acquire SRTM data from one of the following sources:

- U.S. Geological Survey (USGS)—viewing, download, and media copies (<http://seamless.usgs.gov/> or <http://eros.usgs.gov/products/elevation.html> or <ftp://e0srp01u.ecs.nasa.gov/srtm/>)
- University of Maryland Global Land Cover Facility—download (<http://glcf.umiacs.umd.edu/data/srtm/>)
- Consultative Group for International Agriculture Research—download (<http://srtm.csi.cgiar.org/>)
- German Aerospace Center—X-band products (http://www.dlr.de/srtm/index_en.html)
- Integrated Committee on Earth Observation Satellites (CEOS) European Data Server—viewing and download (<http://icedes.ge.ucl.ac.uk/>)

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Research Topics Addressed

A few studies characterizing and/or applying SRTM data have appeared in the scientific literature. However, because all data products are now easily accessible by the user community, interest in SRTM data is widespread and many more results of SRTM studies are ready for dissemination. To foster communication and sharing of results among the SRTM data users community, a workshop on SRTM data validation and applications was co-sponsored by NASA, NGA, USGS, the CEOS/Working Group on Calibration and Validation/Terrain Mapping Subgroup, and the International Society for Photogrammetry and Remote Sensing. The workshop was held in Reston, Virginia, on June 14–16, 2005, and was attended by more than 175 participants from 14 countries. Results of validation studies and applications of SRTM data were reported in more than 40 oral presentations and more than 20 poster presentations. Further information on the workshop and most of the presentations are available at <http://edc.usgs.gov/conferences/SRTM/>. Several of the results documented in the papers contained in this special issue were initially reported at the workshop.

In addition to the high level of participation in the SRTM data workshop, further evidence of the breadth of SRTM data usage is seen in the number of responses to the call for papers for this special issue. More than 50 manuscripts were submitted, with the topics covering a broad range of uses of SRTM data and comparison with other topographic data sources. Further indication of the widespread interest in SRTM data is seen in the increasing number of SRTM-related presentations at conferences. For instance, over the last several years at the annual fall meeting of the American Geophysical Union there has been an average of more than 20 SRTM-related presentations given per year.

Collectively, the papers in this special issue address several topics of importance to users of SRTM data, including:

- horizontal and vertical accuracy of SRTM elevation data products
- spatial resolution characterization of SRTM elevation data products
- comparison of SRTM elevation data products with other types of elevation data, especially data derived from other remote sensing systems
- comparison of SRTM C-band products with X-band products in terms of accuracy and spatial resolution
- generation of datasets derived from SRTM elevation data and comparison of derivative products with similar products derived from other sources of elevation data
- applications of SRTM elevation data and derived products

Our goal in presenting the research results in this special issue is to increase the available knowledge about SRTM data quality and characteristics, thereby leading to more informed users and uses of the data. When geospatial datasets are thoroughly validated and assessed, especially one as fundamental as elevation, then the information contained therein can be more appropriately applied with increased confidence in resultant conclusions. It is intended that participating space agencies within CEOS will, in the future, set up moderated Web pages for users to report results of their own analysis and/or data quality issues.

The final SRTM C-band data products were produced in a two-stage process in which the Jet Propulsion Laboratory generated the initial elevation data products from the interferometric radar data, and then NGA performed editing and formatting to produce Digital Terrain Elevation Data (DTED®). A significant part of the editing process involved setting elevations for lakes, rivers, and ocean coastlines. The paper by Slater et al. provides details on the criteria and procedures used to produce the final DTED® products. A by-product of the water editing process, the SRTM water body data file, which is essentially a 30-meter resolution water mask, is available for distribution to the user community.

The specification for SRTM C-band elevation data included requirements for an absolute vertical accuracy of 16 meters (linear error at 90% confidence, with respect to the reflective surface), a relative error of 10 meters (linear error at 90% confidence), and an absolute horizontal accuracy of 20 meters (circular error at 90% confidence). Rodriguez et al. present results of an extensive error assessment of SRTM data, showing that all accuracy requirements have been met. They also present detailed descriptions of the vertical and planimetric components of the error, the geographical distribution, and spatial structure. The analysis by Hoffman and Walter shows that elevation data derived from the X-band data also meet the accuracy specifications. Hoffmann and Walter also present an approach for combining the C- and X-band elevation data, resulting in a product with reduced data voids and decreased noise (reduced random errors).

An important question for many users of SRTM data is how do they compare with other elevation datasets? In particular, over the United States, how do SRTM data compare with the USGS National Elevation Dataset (NED)? The work reported by Guth examines 12 geomorphometric parameters calculated from SRTM and NED data as a mechanism to assess SRTM data quality. Guth's analysis also includes an assessment of the spatial resolution of one-arc-second SRTM data, showing that the true information content is somewhat less than one-arc-second, a conclusion that agrees with previous studies.

A unique characteristic of SRTM data, in contrast to other

large-area topographic datasets, is that the elevation measurement represents the height of the "reflective surface," or the surface from which the radar beam is reflected back to the sensor. The paper by Hofton et al. and the paper by Carabajal and Harding present the results of SRTM validation using airborne and spaceborne lidar, respectively. In each case, the effects of the presence of vegetation are analyzed. These analyses show that generally the elevation measured by SRTM in vegetated areas occurs well above ground level but also below the canopy top, indicating that SRTM penetrated the canopy in forested areas but usually not all the way to the ground. The study documented by Simard et al. makes use of the first return nature of SRTM elevation data to map tree height and calculate standing biomass of mangrove forests in Everglades National Park.

The availability of SRTM elevation data is facilitating new applications, as well as aiding the conduct of studies using elevation data where the resolution and accuracy of previously existing data limited the detail of the analysis. Kiel et al. demonstrate the use of SRTM data to measure the elevation of large water bodies, and they comment on the applicability of such an approach for proposed space-based monitoring of water surface elevations. The paper by Menze et al. presents a method for processing SRTM data to conduct an initial regional archaeological survey in an area where suitable elevation data were not previously available.

The SRTM results documented in this special issue are just the beginning of what we believe will be many significant SRTM-related findings reported in the scientific literature in the near future. Based on the SRTM experience, the advantages of a dedicated topographic mapping mission are clear, including a day/night, all-weather data collection system, broad-area coverage, a consistent processing approach, and freely available data access for final products. Given that elevation information is a fundamental requirement for so many operational applications and research studies, our hope is that the results obtained from using SRTM data will provide the impetus for the community to work towards future Earth remote sensing missions dedicated to ongoing, routine monitoring of land surface topography.

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