# The Use of ArcGIS 9 to Generate Large Elevation Products

Xiaopeng Li, Trina Kuuskivi, Henry Gansen, Steve Dowding

## ABSTRACT

This paper describes how ArcGIS tools were used for generating countrywide and US statewide DEM datasets derived from the Shuttle Radar Topography Mission (SRTM) data. ArcGIS tools were selected because of their superior end-to-end functionalities and capabilities for producing large raster DEMs. For example, ArcView's World Political Boundary Shapefiles were used to determine the extent of each country and US state; Spatial Analyst's Mosaic function was used to merge the data. The final products are consistent and homogenous DEM datasets in ESRI's GRID format together with a shaded-relief rendition of each DEM.

In this paper, the SRTM data, methodology, tools, processes and procedures of the project are described in detail. In addition, the paper addresses how ArcGIS successfully dealt with the issues inherent when working with the SRTM datasets and the quality control processes needed. Conclusions and potential applications of the products are provided at the end of the paper.

## 1. INTRODUCTION

Digital elevation models (DEMs) are a numerical description of the earth's topography or surface. They constitute a fundamental layer of a geospatial infrastructure framework and they are necessary for many geospatial applications. There is a growing demand for DEMs to meet wide range applications. Currently, several different technologies are being used to generate DEMs at various resolutions and accuracies, each with their own strengths and limitations. Among the technologies, interferometric synthetic aperture radar (IFSAR) technology coherently combines microwave signals collected from two across-track displaced antennae, bringing many operational advantages for cost-effective, wide-area, three-dimensional mapping endeavours.

Some applications require high-resolution and high-accuracy DEMs for detailed surface description. There also exist occasions where large-area, consistent, and current medium-resolution DEMs are highly advantageous. For example, DEMs with resolution ranging from about 30 m to 100 m are indispensable for many country and regional geospatial applications, such as watershed analysis, natural resource inventory, environmental monitoring, etc.

In recognition of this need, Intermap has applied its long-time IFSAR knowledge (Li et. al., 2004) and SRTM mapping experience (Dowding et. al., 2004), to successfully complete a recent project to generate consistent global medium-resolution DEM product to supplement the company's nationwide 5-m high-resolution NEXTMap DEM product. This project used commercially available "finished" Shuttle Radar Topography Mission

(SRTM) DTED® data as input and was implemented mainly within an ArcGIS 9 environment. The objective of this paper is to present the steps taken in the implementation of the project. After a brief introduction to the input SRTM data, the processes, tools used and the output of the project are described in great detail.

## 2. INPUT DATA _ "FINISHED" SRTM DTED® DATASET

Intermap's worldwide project used the "finished" National Geospatial-Intelligence Agency (NGA) and National Aeronautics and Space Administration's (NASA) SRTM data distributed by the United States Geological Survey (USGS) through its EROS data center.

The SRTM, flown in February 2000, acquired radar data covering approximately 80 percent of the Earth's landmass. These data were used in the production of SRTM Digital Terrain Elevation Data (DTED®). During SRTM production, the data were edited _ also referred to as "finishing"_ delineating and flattening water bodies, better defining coastlines, removing "spikes" and "wells", and filling small voids. The "finished" SRTM DTED® products are distributed and are publicly available as part of the DTED® product set through the USGS EROS data center. Table 1 summarizes the major specifications of the product.

**Table 1. Specifications of the "Finished" SRTM DTED® Products***

| Items | Specifications | Note |
|---|---|---|
| Extent of product unit | $1^o$ x $1^o$ (latitude x longitude) | Edge matched |
| Horizontal resolution (latitude x longitude) | Level 1: 3" x 3" ($0^o$ to $50^o$ latitude), 3" x 6" ($50^o$ to $60^o$ latitude) | Derived from the Level 2 product |
| | Level 2: 1" x 1" ($0^o$ to $50^o$ latitude), 1" x 2" ($50^o$ to $60^o$ latitude) | |
| Vertical precision | 1 m | All elevations are in integer meters |
| Dimension (posts) | Level 1: 1201 x 1201 ($0^o$ to $50^o$ latitude)<br>1201 x 601 ($50^o$ to $60^o$ latitude) | See Figure 1 for coverage |
| | Level 2: 3601 x 3601 ($0^o$ to $50^o$ latitude)<br>3601 x 1801 ($50^o$ to $60^o$ latitude) | See Figure 2 for coverage |
| Horizontal datum | WGS84 | |
| Vertical datum | Mean sea level defined by EGM 96 geoid | |
| Vertical accuracy | 16 m LE90 (absolute) | |

* This table is compiled from JPL (2005) and USGS (2005a).

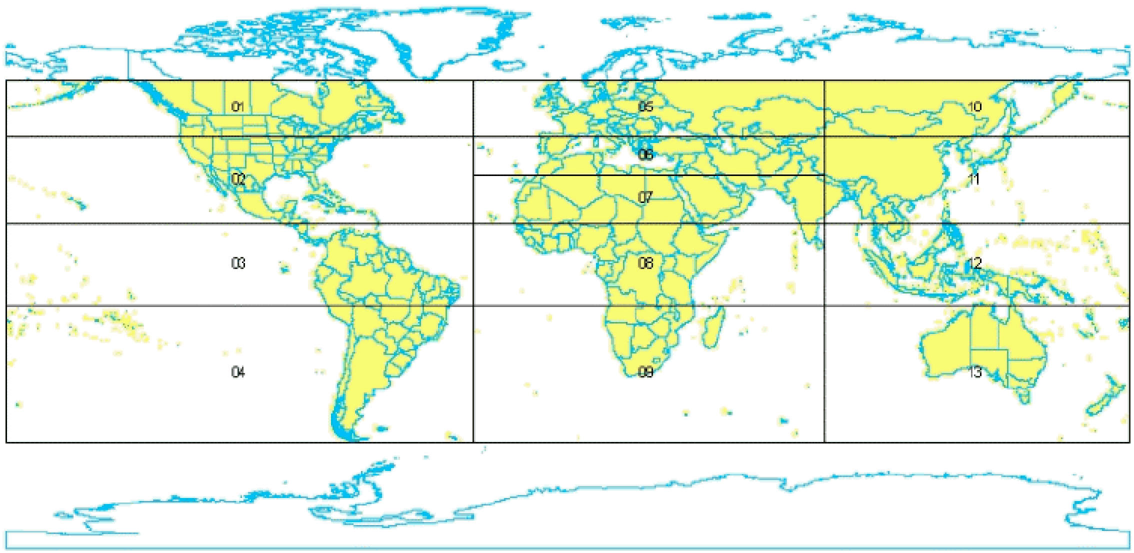


**Figure 1. SRTM "Finished" 3-arc second Dataset Coverage (USGS, 2005b)**

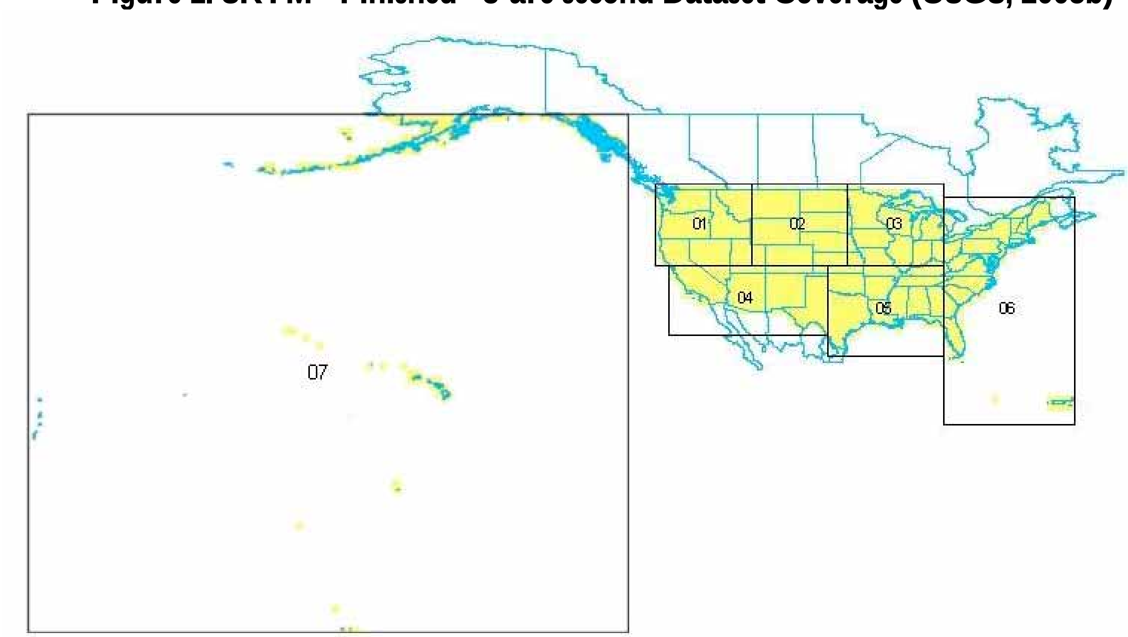


**Figure 2. SRTM "Finished" 1-arc second Dataset Coverage (for United States and Territorial Islands) (USGS, 2005c)**

Note: each numbered grid area above represents a single DVD containing SRTM data.

## 3. REASONS FOR SELECTING ArcGIS 9

The worldwide project involves ingestion, mosaicking, clipping, and quality control and assurance of large raster DEM data. For production purposes, an efficient easy-to-use software package with required functions was expected to carry out the main steps of the project. It was determined after a careful comparison that ESRI's ArcGIS 9 fit well to the purpose of our project, since it offers superior end-to-end functionality and capabilities of processing large raster DEMs. For example, the ArcView's Political Boundary Shapefiles were used to determine the extent of each country and US states; Spatial Analyst's mosaic function was employed to merge the data.

## 4. PROJECT PROCESS AND IMPLEMENTATION

The process of the worldwide project consists of DEM and shaded relief generation, error detection/fixing, as well as quality control and quality assurance. Generally, it was implemented as a chain, with the following separate steps/phases with quality control points (QCPs) being conducted at specific steps. Figure 3 illustrates the high-level process flow.

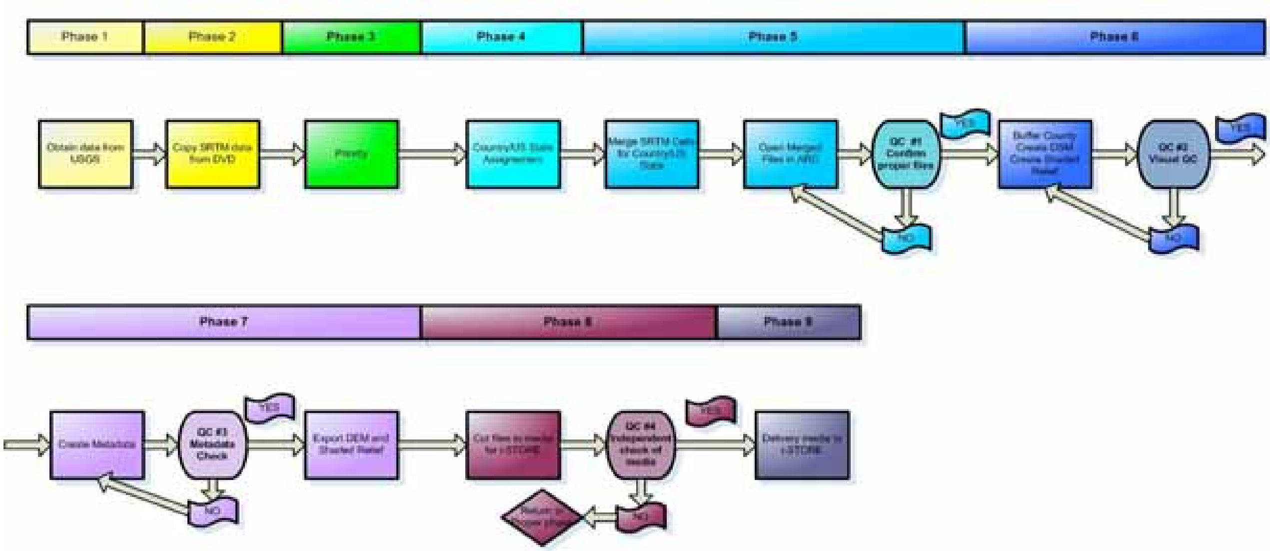


**Figure 3. Process Flow Chart with Quality Control Points (QCPs)**

### 4.1 Data Preparation

"Finished" SRTM DTED® Level 1 and Level 2 data were purchased from EROS of the USGS. The data are in DTED format delivered on DVDs with each one costing $60 US. There are 13 DVDs for Level 1 product and 7 for Level 2 product. The SRTM DTED® data were then ingested into the proper directory of the workstations where the data would be further processed.

### 4.2 Determine Priority and Assign Mapping Units

Management determined the appropriate SRTM DTED® data required for each specific mapping units (countries, US states or territories) for processing based on the priority and SRTM data availability at a particular time. The operators assigned themselves a mapping unit by updating the index map using ArcGIS 9. The index map was updated when data was placed online. Country or state boundaries were generated based on ESRI's ArcView Political Boundary Shapefiles, which were then used for the subsequent clipping operation.

## 4.3 Merge SRTM DTED® Cells

During this step, the operators mosaicked together the selected SRTM DTED® cells ($1^o$ by $1^o$) using ArcGIS 9 (ArcView) based on the SRTM cell coverage of the particular mapping unit. Inputs to this step were the ingested SRTM DTED® cells and the output was a single GRID file containing all the necessary data that had been merged together. For example, Rhode Island of US covered two cells and Argentina covered 391 cells. However, due to the software file size limitation, some big countries had to be divided into several mapping units. For instance, Russia (covering 1345 cells) was split up into seven units.

The merging was conducted using the mosaicking function in the *RasterCalculator* provided with the Spatial Analyst extension. The process could take up to 5-10 minutes to run for each mapping unit. Once finished the operator would have a DEM mosaic of all input raster with positive and negative elevation across the whole range.

A series of quality control and assurance tasks were designed and conducted at certain points of the processing chain _ Quality Control Points (QCPs) _ to ensure that intermediate products met the specification before moving on. In such, potential errors could be detected and get fixed at the earliest possible processing stage.

### 4.3.1 QCP #1

After the merging, the operators needed to confirm that the operation was conducted properly. At this QCP, an inspection of the merged image was carried out to:

- Visually ensure the merged GRID file matched and contained the entire country/area of interest.
- Visually ensure the file was created using the proper projection.
- Check minimum and maximum elevation values to make sure they corresponded to the original SRTM data.

## 4.4 Generate DEM and Shaded Relief for Each Mapping Unit

This step took the quality-controlled merged data as input and output a DEM and a shaded relief for each mapping unit _ a particular country, US state etc. During the execution, the operators applied 12-nautical-mile buffers to delineate the shorelines, boundaries, and islands for the mapping unit in ArcView. The operator then created a DEM and the associated shaded relief representation of the mapping unit by clipping from the merged GRID file using Spatial Analyst.

### 4.4.2 QCP 2

At this point, a visual inspection was conducted to ensure that the shorelines, boundaries and islands were properly clipped. The operator would also use other software packages to open the DEM and shaded relief product for an independent check. Furthermore, elevations of the input (original "finished" SRTM data) and the output (merged and clipped DEM) were compared to ascertain that the processing did not change the values.

### 4.5 Create Metadata and Export Data

An associated metadata file specific for each mapping unit was generated using Arc Catalog, which provided explanations about the sources of the data, possible discrepancies and important information regarding the country/area contained in the DEM and shaded relief. The metadata meet Federal Geographic Data Committee (FGDC) standards.

#### 4.5.1 QCP 3

After the metadata generation, the operator checked the content and spelling of the metadata to ensure that the product met predetermined format requirements.

### 4.6 Data Finishing and Delivery

The operators placed the files on the appropriate media (CD/DVD/hard drive etc.) for the client. An independent inspection was carried out to check file structure and format before the data delivery.

## 5. PRODUCTS OF THE PROJECT

Products from the above-described worldwide project contain DEM, shaded relief and associated metadata file for each mapping unit. There are 224 total mapping units _ US state, territorial islands, individual countries or combined small countries. Figures 4 and 5 show the color-coded shaded relief of California, US and the country of Romania, respectively. However, if required, several mapping units can be combined together to form DEM and shaded relief for larger regional applications, such as areas covering several US states or several small countries. For example, Haiti and Dominican Republic were combined as one mapping unit.

While keeping most of the inherent characteristics (Table 1) of the input "finished" SRTM DTED®, e.g. projection, datum, resolution and accuracy, the DEM products from the project can be provided in most other standard projection and coordinate systems, including Universal Transverse Mercator (UTM), State Plane, etc. The DEM and shaded relief products are provided in ESRI GRID format or other custom formats.

Many regional applications are made possible with the availability of such consistent medium-resolution, large-area DEMs where no other appropriate datasets exist. These application include:

- Portrayal of natural resource inventories for developing countries or regions.
- Derivation of topographic maps, thematic maps, and other geospatial products.

- Line-of-sight and viewshed analysis
- Tourism and virtual sky cruising
- 3-D fly-through and perspective view (Figures 6 and 7 show two examples)
- Transportation and telecommunication planning
- Flood modeling, flood risk analysis, watershed modeling

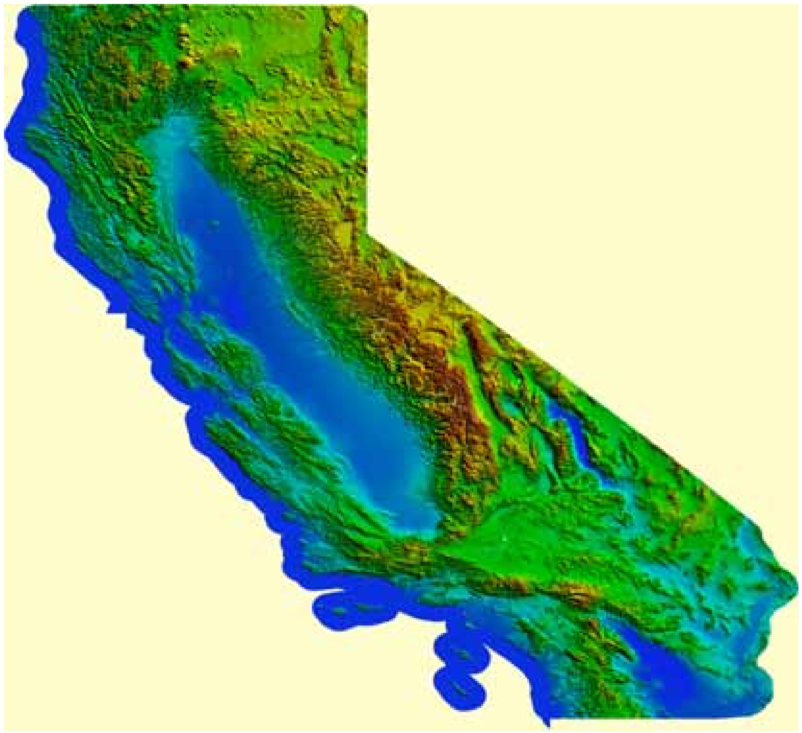

**Figure 4. Color-coded Shaded Relief of California**

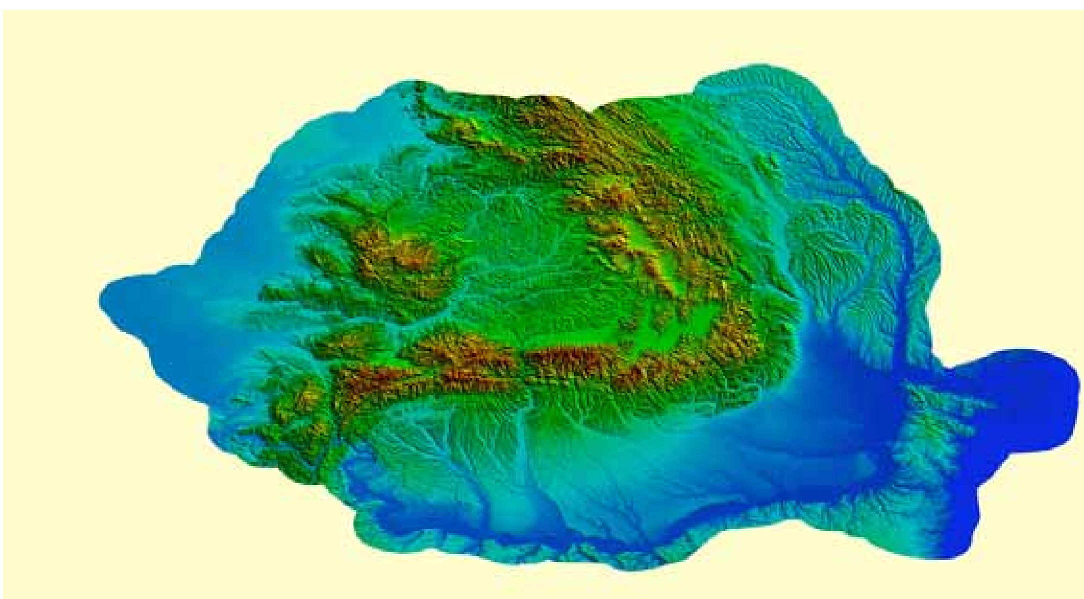

**Figure 5. Color-coded Shaded Relief of Romania**

**Figure 6. A Perspective View Generated from an Orthophoto and an SRTM DTED®**

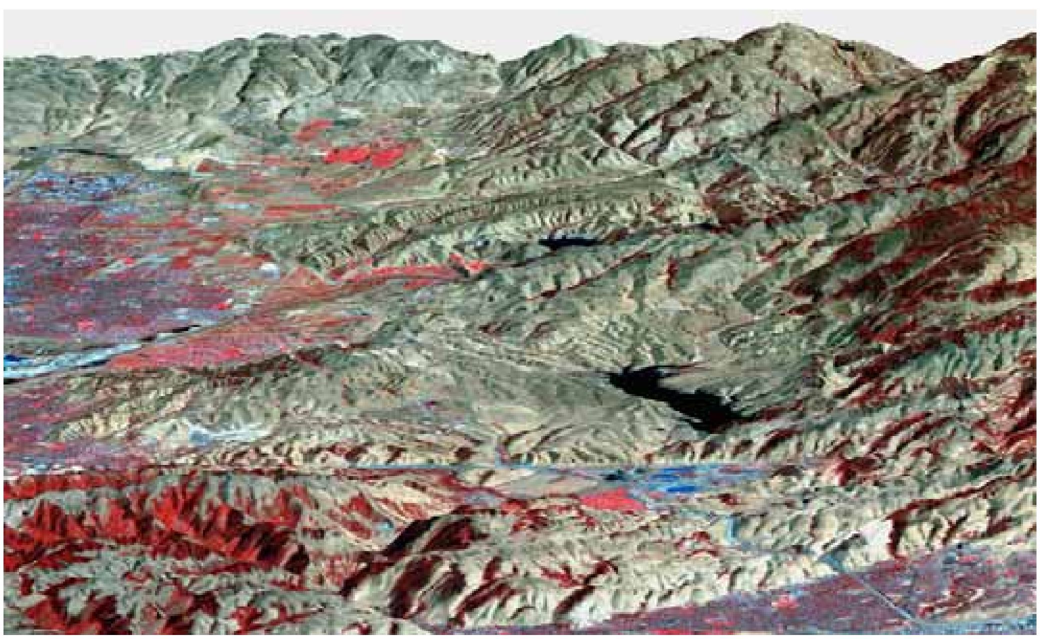

**Figure 7. A Perspective View Generated from an Orthorectified ASTER Image and an SRTM DTED®**

## 6. SUMMARY AND PROSPECT

Continuous and consistent geospatial datasets are a necessity for all national and regional economic development activities. Prior to this project, such datasets did not exist for every country, especially some developing countries.

This paper described a successful worldwide project conducted by Intermap Technologies to generate large-area digital elevation datasets using ArcGIS 9. The contributing factors to the success of the project are:

- The superior end-to-end functionalities of ArcGIS 9
- Appropriate cost-effective input SRTM data
- Intermap's long-time experience of IFSAR mapping and SRTM production

Products from the project are finding applications in many traditional mapping fields and non-traditional markets where geospatial information plays an indispensable role. Furthermore, the application list will become longer with the increased awareness of the availability of such data products. Research is underway to study the combined use of medium- and high-resolution DEM for different applications and to investigate the performance difference between the different resolution DEM products.

## 7. REFERENCES


Dowding, S., T. Kuuskivi, X. Li (2004). Void fill of SRTM elevation data – principles, processes and performance. In: *Images to Decisions: Remote Sensing Foundations for GIS Applications*, ASPRS Fall Conference, September 12-16, Kansas City, MO, USA.

Li, X., K. Tennant, and G. Lawrence (2004). "Three-dimensional mapping with airborne IFSAR based STAR technology _ Intermap's experiences". In: *Proceedings of* XXth ISPRS Congress, July 12-23, Istanbul, Turkey, 2004.

JPL (2005). http://www2.jpl.nasa.gov/srtm/ (accessed on May 20, 2005).

USGS (2005a). http://srtm.usgs.gov/ (accessed on May 20, 2005).

USGS (2005b). http://edcsns17.cr.usgs.gov/srtmbil/ (accessed on May 28, 2005).

USGS (2005c). http://edcsns17.cr.usgs.gov/srtmbil2/ (accessed on May 28, 2005).


## AUTHOR INFORMATION


**Xiaopeng Li**
Ph.D., Mapping Scientist
Intermap Technologies Corp.
2 Gurdwara. Suite 200, Ottawa, ON, Canada, K2E 1A2
xli@intermap.com

**Trina Kuuskivi**
NEXTMap Production Manager, Intermap Technologies Corp.
tkuuskivi@intermap.com

**Henry Gansen**
Senior Project Manager, Intermap Technologies Corp.
hgansen@intermap.com

**Steve Dowding**
Director, NEXTMap Products Division, Intermap Technologies Corp.
sdowding@intermap.com