3-Dimensional Data Validation of Shuttle Radar Topographic Mission (SRTM) in Lokoja Area of Nigeria

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Abstract

This study attempts a 3-D data validation of the Shuttle Radar Topographic Mission (SRTM) with the conventional ground survey-based topographic data in order to establish a geospatial resemblance ratio between the two. The SRTM image of Lokoja area of Nigeria was processed using Erdas Imagine 9.1, ILWIS 3.2, Idrisi 32, ArcView GIS 3.2, and Surfer8 respectively. The results showed good contour and terrain model harmonization between the SRTM and topographic map-based derived elevation values for regions of ground elevations ranging between 34m and 154m above mean sea level (AMSL), while the results gradually worsen in areas of ground elevation range of 155m to 254m and 255 to 400m / above respectively.

Eighty (80) common grid nodes were queried in the topographic map-based and SRTM-based digital terrain models and the analysis of the differential shows that terrain heights in the range of 255m to 400m had a standard deviation of ±59.591m. Less accurate results were observed from the SRTM in Patti hill and other hilly regions; evidenced in their large deviations from the topographic map data. Terrain heights in the range of 34m-154m and 155m-254m showed standard deviations of ±18.567m and ±4.930m respectively.

The study reveals that the vertical exaggeration that results from radar data propagates more errors on heights in regions of higher elevation above the mean sea level. Four validation models were developed for the correction of approximate topographic heights from SRTM for use in the study area and elsewhere in Nigeria as an alternative to relevant small-scale topographic data for physical planning and development.

Keywords: *Radar, Topographic, 3D, Validation, Small-Scale Map, Analysis*

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1.0 Introduction

The production of small-scale topographic maps and elevation models using the classical field surveying and geodetic methods is rather expensive and limited in the capacity of the earth surface data gathered in the processes. Therefore, alternative data sources with advantages in terms of synoptic coverage, data capacity, flexibility and interoperability in the likes of SRTM, InSAR and Radar Altimetry need be exploited to generate near-accurate and accurate elevation data for engineering design, environmental hazard management, urban and rural development purposes, etc. The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of the Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle 'Endeavour' during an 11-day mission in February 2000. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA) [12].

Prior to SRTM, Synthetic Aperture Radar Interferometry (InSAR) as signal to a processing technique, had provided the launch pad for the convenient and cost-effective measurement of relatively accurate points' elevation data over a large area of coverage. InSAR applications have been demonstrated by various authors such as [4], [8], [1], etc. However, the emergence of Global Land Cover Facility (GLCF) SRTM data present another forward-looking attempt in resolving the problem of determination of shape and size of the earth.

The Global Land Cover Facility (GLCF) SRTM data can be opened by any software that supports the Geospatial Tagged Image File Format (GeoTIFF) 1.0 standard, such as ENVI, Imagine, ArcGIS, ArcView, PCI, etc. The SRTM-UTM files are in exactly the same coordinates as the GeoCover Landsat imagery. However, the file sizes are different. The SRTM-UTM dataset has a buffer of 7.5 km around the Worldwide Reference System-2 (WRS-2) tile. Also, all the GeoCover Landsat images are in UTM zone north, while the SRTM-UTM data are in UTM zone north only if the region lies in the Northern Hemisphere. For SRTM-UTM data in the Southern Hemisphere, UTM zone south was used. Most GeoTIFF-ready software can handle this seamlessly.

Some potions of SRTM data have negative values because the first edition of GLCF SRTM data is not what the USGS labels as "Finished"; rather, it is referred to as "Unfinished" SRTM datasets, which have missing values. The Jet Propulsion Laboratory (JPL) of National Aeronautics and Space Administration (NASA) used value -32768 for missing pixels, which the GLCF maintains. During the projection from geographic to UTM coordinates, the mid-high latitudes have much overlap between scenes, and, therefore, much need for interpolation. When a lot of missing values (-32768) are present during a cubic convolution resampling in these areas, the result would be less useful than a nearest neighbour resampling. Thus, a nearest-neighbour resampling was adopted.

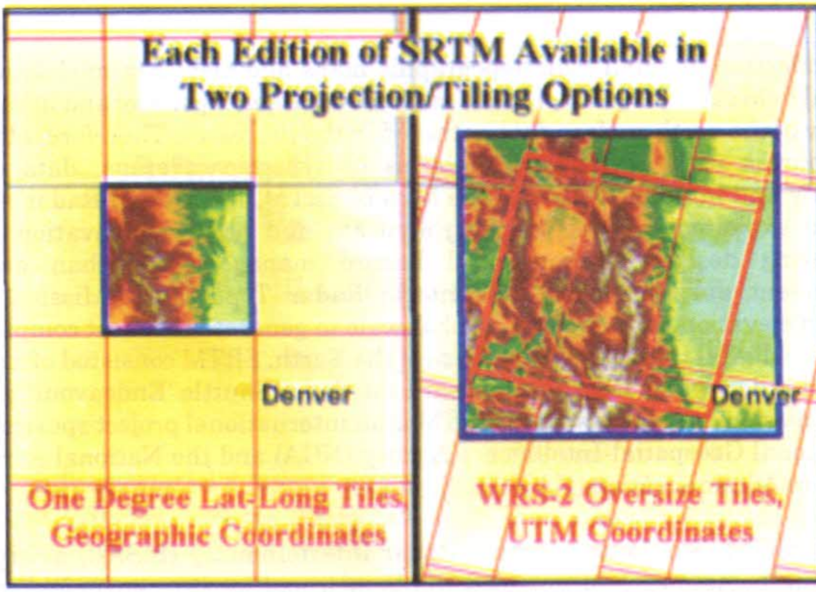

Fig. 1.1: Lat/Long and UTM Data Tiles of SRTM [12]

JPL anticipated the release of their "Finished" edition of SRTM ostensibly in September 2004, which could not be realized. Their target was to process that data and put the revised GLCF SRTM online within two weeks. All GLCF SRTM is distributed using 16-bit GeoTIFF files. It has several advantages when compared to the DEM format or the GRID format, with which some modellers may be more familiar. It should be noted that:

1. GeoTIFF is the actual standard of raster geospatial data that can be used across many software platforms. The GLCF aims to provide interoperable datasets.
2. Each elevation point takes 2 bytes to store in a 16-bit GeoTIFF file, while taking about 20 bytes to store in a USGS DEM format file.
3. The GeoTIFF file contains all the information within the single file, but the ArcGRID format needs several files to contain data and geographic information. Therefore, providing SRTM data in the form of GeoTIFF lets the user to download, manipulate and store data faster and more efficiently.

For the three types of most widespread applications using elevation data, GeoTIFF-formatted SRTM data can be used for 3-D modelling as in the following paths: (i) For 3-D '*fly-throughs*' using elevation data and surface imagery, many software can take GeoTIFF directly, such as ERDAS Imagine; (ii) for Hydrological/Civil Engineering modelling, many applications, such as Mike11, take solely USGS DEM format. In these instances, it is recommended that GeoTIFF files be converted to DEM format; which many geospatial software can accomplish; (iii) some 3-D GIS applications accept GeoTIFF directly while others may require conversion to DEM or ArcGRID formats.

Using elevation data in GeoTIFF format provides the user with an array of elevation data; However, it may be useful to refer to the USGS DEM format specifications and the GeoTIFF specifications. Since most software do not explain the process for conversion from DEM to GeoTIFF or vice versa, it is important to synchronize the datums and projections of all data.

1.1 Microwave Remote Sensing

A spectral signature is recognized on a radar image data by its properties of reflectivity, spectral properties and polarization properties. This is possible in the microwave domain where the wavelength is reasonably large compared to variations of many properties of interest to measure. The interaction between the electromagnetic wave and the medium varies with the wavelength. Normally the penetration into the earth is larger at longer wavelength and there may occur resonances between natural objects and an electromagnetic wave with a wavelength of the same order as the dimensions of the medium. The development of radar technology goes back to World War 2 and, by tradition from this time, the different wavelength regions have been denoted as given in Table 1 [3], [9].

Table 1.1: Microwave Frequency Bands

Band	Frequency, GHz	Wavelength,cm
P-band	0.225- 0.39	133 -77
L-band	0.39 - 1.55	77 -19
S-band	1.55 - 3.90	19 - 7.7
C-band	3.90 - 6.20	7.7 -4.8
X-band	5.75 - 10.9	5.2 -2.8
Ku-band	10.9 - 18.0	2.8 -1.7
Ka-band	18.0 - 36.0	1.7 - 0.8

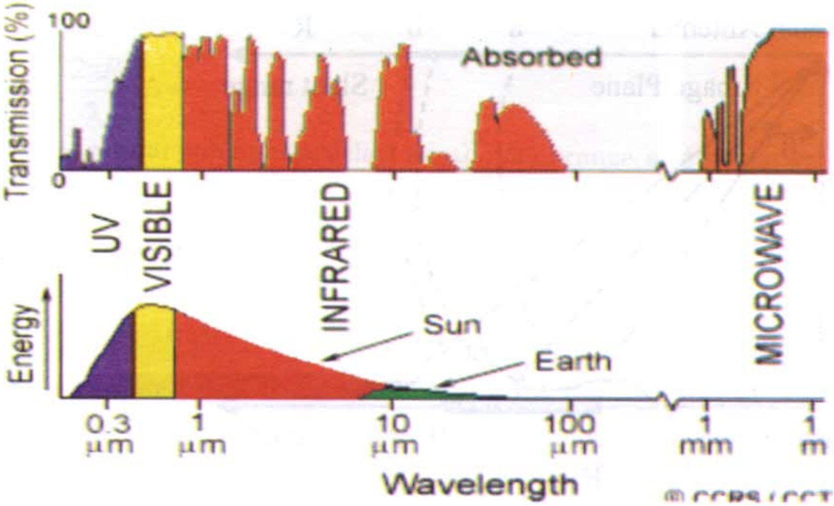

Fig. 1.2: Atmospheric Transmission over Wavelengths [2]

The interest in microwave sensors is partly due to their ability to propagate through the atmosphere without being influenced very much. This is illustrated by the atmospheric transmission over wavelengths of interest for remote sensing.

1.2 SRTM Imaging Geometry

SRTM is an imaging radar system, which is an active sensor--providing its own illumination in the form of microwaves. It receives and records echo reflected by the target, and then maps the intensity of echo into grey scale to form an image. Unlike optical and infrared imaging sensors, such imaging radar is able to take clear pictures day and night under all weather conditions. It sends microwave to ground continuously with a side-look angle in the direction perpendicular to the flying track (azimuth direction-Fig. 1.3).

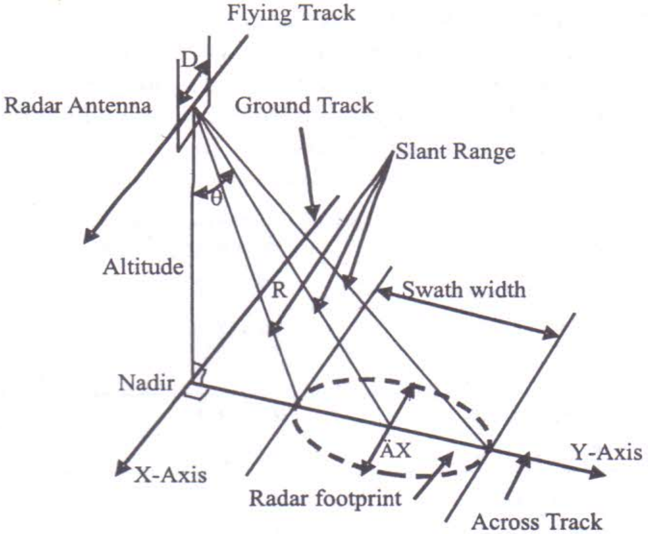

Fig. 1.3: Radar Imaging Geometry

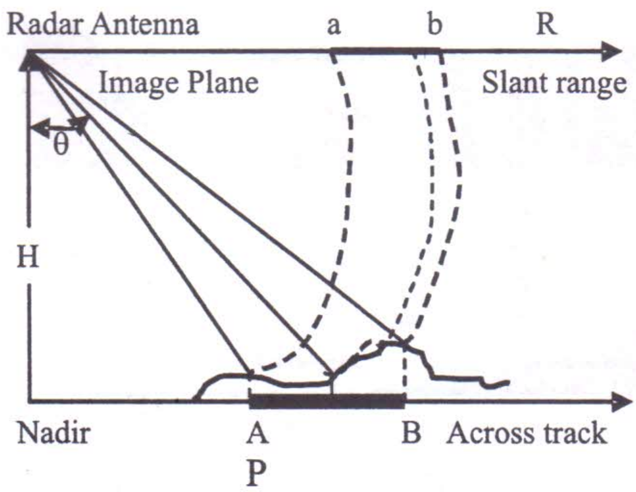

Fig. 1.4: Radar Sensor-Ground-Sensor Image Data Projection