

GIS spatial analysis for Otteri Nullah sub basin of Chennai city by using Digital Elevation Model (DEM).

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Abstract: Digital elevation models (DEMs) represent the topography that drives surface flow and are arguably one of the more important data sources for deriving variables used by numerous hydrologic models. The majority of digital elevation models (DEMs) are generated using photogrammetric methods. Recent remote sensing techniques, such as radar interferometry (InSAR), have also been used to generate high quality DEMs over a great area. Space borne high resolution DEMs with almost global coverage, such as ASTER and SRTM were made available to the public in the last few years. This paper aims to assess the quality of global DEMs compared with SOI topographical data and real-time kinematic GPS (RTK-GPS) data in urban watershed of Otteri nullah sub-basin of Chennai City.

Key words: Topography, Elevation, Kinematics, Model and Resolution

1. Introduction:

Geographic Information System (GIS) is a computer-based system that provides the following four sets of capabilities to handle geo-referenced data: input, data management (data storage, maintenance and retrieval), manipulation and analysis, and output. GIS allow interpreting and visualizing data in many ways that reveal relationships, patterns and trends in form of maps, globes, reports and charts. Digital Elevation Models (DEM) provides a model of the continuous representation of the earth's elevation surface. This form of spatial data provides a model of reality that contains deviations from the truth, or errors. The nature and extent of these errors are often unknown and not readily available to users of spatial data. Our lack of knowledge about these errors constitutes uncertainty. Nevertheless, DEMs are one of the most important spatial data sources for digital hydrologic analyses as they describe the topography that drives surface flow. Use of DEMs in hydrologic studies is ubiquitous and potentially influences results of distributed parameter hydrologic models that rely on DEMs for the derivation of input parameters. In the past decade DEM data has become increasingly available to spatial data users due to the decrease in data and computer costs and the increase in computing power. DEMs produced from technologies such as Light Detection and Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (IFSAR) sensors are more readily available. These remotely-sensed DEM production methods provide users with high

resolution DEM data that have stated vertical and horizontal accuracies in centimeters, making them more desirable, yet costly in both dollars and processing requirements. DEM users with limited budgets can obtain DEMs from government sources or can conduct field surveys using global positioning systems (GPS) and interpolate DEMs for smaller study areas. No matter the source, DEM products provide clear and detailed renditions of topography and terrain surfaces. These depictions can lure users into a false sense of security regarding the accuracy and precision of the data. Potential errors, and their effect on derived data and applications based on that data are often far from users' consideration (Wechsler, 2003).

Our responsibilities as DEM data users and researchers are to accept, minimize errors to the best of our technical capabilities, and obtain a reliable estimate of their nature and extent. Based on these understandings, the tasks are to develop and implement methods to quantify and communicate the uncertainty associated with the propagation of errors in spatial data analyses. The research reported in this paper brings together knowledge about the components and characteristics of DEM specifically related to hydrologic applications. This paper aims to assess the quality data of contour and spot height of DEM by using SOI toposheets, using real-time kinematic GPS (RTK-GPS), ASTER and SRTM has been analysed.

2. Method and Material

2.1. Height Reference Data: RTK-GPS:

Real-time kinematic (RTK) GPS deliver instantaneous point coordinates with centimetre-level accuracy. There are many applications that take advantage of RTK technology, including topographic surveying, engineering construction, geodetic control, vehicle guidance and automation, etc. [6]. RTK positioning uses a static GPS receiver as a reference station located at a known point. Another receiver is used as the rover, which can move and survey any point of interest within a limited range from the reference station. Both receivers make observations of the GPS signals at the same time and a radio data link between the two receivers permits data to be sent from the reference to rover, where the calculation of coordinates is carried out. For the field survey at the test site, the reference receiver station was set up on top of a hill on a trig station. The rover receiver was mounted on a car roof so that the survey could be easily conducted by driving around the region within the radio link coverage, which is approximately 8km from the reference station in our set-up.

2.2. Digital Elevation Models: SRTM:

Synthetic aperture radar (SAR) measures both amplitude and phase information of the back-scattered radar signals from imaging pixels on the Earth's surface. Radar interferometry (InSAR) exploits the phase information recorded in two SAR images to derive geodetic information of terrain. The phase difference between two SAR images acquired at slightly different satellite positions contains the information of topography with respect to the SAR imaging geometry and wavelengths. InSAR has demonstrated its capability of generating DEMs [11] and [7]. An 11day space Shuttle Radar Topography Mission (SRTM) was successfully flown in February 2000. This mission used InSAR with C- (5.6cm) and X- (3cm) bands of the microwave to create the first DEM of entire earth between the latitude ranging from 60°N to 57°S. SRTM used two antennas, separated 60 m apart, to image the earth's surface instantaneously [5]. The Cband antenna has an imaging swath width of 225 km while the X-band antenna was only limited to a swath of 45 km. Therefore the coverage of X-band is limited and does not provide in global coverage. As the fact that X-band wavelength cannot penetrate the vegetation and C-band wavelength

will be reflected at the top of the canopies, the elevation measured by SRTM is also referred to as a digital surface model (DSM), which represents the height of the ground surface objects including vegetations. The C-band SRTM DEM data can be downloaded from the USGS EROS Data center. By combining the data from both ascending and descending orbits, the topography data with a post spacing of 1 arc-second (approximately 30m) is released for the coverage within United States and 3 arc-second (approximately 90m) resolution data are available elsewhere. The C-band SRTM data for Australia, New Zealand and South Pacific Islands were released in October 2004.

2.3. ASTER:

Since 1986, the SPOT satellites (SPOT-1 to 4) have provided cross-track satellite optical stereo images for generating DEMs. However, due to the difficulty of obtaining cloud free cross-track stereo pairs, the work of DEM generation for a global coverage is very challenging. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), was designed to take along-track stereo image pairs. The sensors pointing nadir and backward to acquire the along-track stereo pair increased the chances of getting cloud free image pairs. ASTER, built by the Ministry of Economy, Trade and Industry (METI) of Japan, onboard the NASA Terra satellite was launched on 18 December 1999 [3]; ASTER GDEM Team 2009). Then SPOT-5, which was launched on 4 May 2002, also equipped the forward and backward looking sensors to acquire the along-track stereo pairs. The ASTER global digital elevation model (GDEM) was released by METI and NASA on 29 June 2009. ASTER GDEM covers the land surfaces between 830N and 830S with estimated accuracies of 20m and 30m at 95% confidence for vertical and horizontal data, respectively (ASTER GDEM Team 2009). The DEM is delivered in 1 x 1 degree tiles as GeoTIFF files with a resolution of 30m.

Therefore, the capabilities of ASTER stereo image that provides DEM with high spatial resolution (15 m) is very important for remote sensing and GIS (Geographic Information System) users to enhance the accuracy of desired height information. The method of DEM generation from satellite stereo image (Such as ASTER, SPOT, etc) and the accuracy of generated DEM have been published

in many research reports, for examples: [2], [8], [4] and [9]. Several study results show that the vertical accuracy of ASTER DEM approaches to 25 m, but in area with less vegetation coverage, the accuracy can rise approximately to 9-11 m [2] and Richard Selby, PCI Geo. Furthermore, ASTER DEM has better accuracy for medium scale mapping (1:100.000 and 1:50.000) [9].

3. Study Area:

Chennai Metropolitan Area extending North South over 30kms along the coast of Bay of Bengal. The corporation of Chennai spreads over 174sq.km and the Chennai basin geographically

lies in between latitudes 12°30'N and longitude 17°18'E and 80°21'. The Chennai Corporation divides entire Chennai into 12 watersheds .In these watersheds we are studied about one watershed that is Otteri Nullah. Otteri Nullah is geographically located at co-ordinates 13.09398° N 80.21060°E .t is an east-west waterway, which run-through north Chennai, starting at the village of Mullam proceeding through Purasawalkam and then passing through Buckingham and carnatic Mills before meeting the Buckingham canal at Bainbridge and it is the largest among the other watersheds.

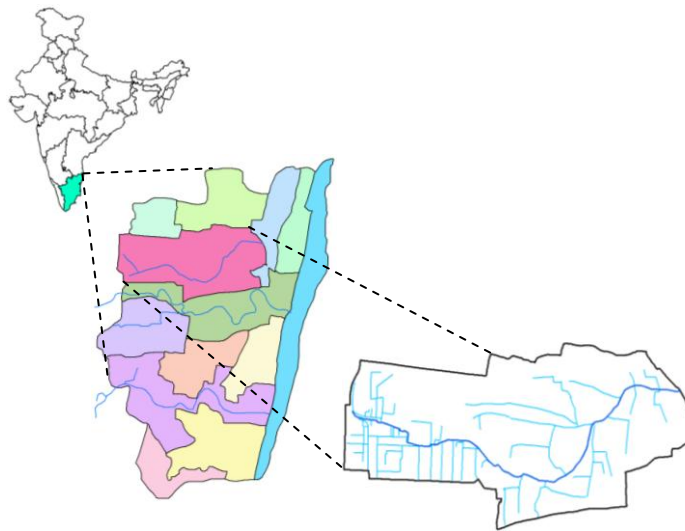


Figure 1. Study area of Ottari Nullah sub-basin of Chennai City

4. Results

The posting resolutions of ASTER, SRTM DEM and survey of India (SOI) are about 30m, 90m, and 30m respectively. There were 49 RTK-GPS points selected in the study area to assess these DEMs. The locations of the GPS points are overlaid on an aerial photograph and shown in Figure 2. The heights of SOI, ASTER and SRTM DEMs are shown in Figure 3 (a) – (d). The heights of the DEMs were extracted based on the locations of GPS points with the aid of GIS. The height differences between the DEMs are shown in Figure 4. It can be noticed that elevations in both ASTER and SRTM DEMs are underestimated while the elevations in DEM tends to be higher than the SOI and GPS data. The root-mean-square error (RMSE) for SOI,

RTK-GPS, ASTER and SRTM DEMs are 5.649m, 6.641m, 15.388m, and 11.053m respectively.

Statistical properties DEM are also given in the table 1 with respective to RTK-GPS location for illustration purpose only as the height accuracy of SOI and RTK-GPS may not be adequate to assess the quality of ASTE AND SRTM DEMs. SOI and RTK-GPS statistical properties are almost identical. ASTER statistical properties are not identical, this may be due to the height correction using the altimetry data as discussed earlier in this paper. Finally, the SOI and RTK-GPS DEMs of the Ottari nullah basin of Chennai city best use in urban water shed delineation as compared with ASTRA and SRTM DEMs data.

Table1. Statistical properties of different Digital Elevation Model points with respective to RTK-GPS location.

Parameter	SOI	RTK-GPS	ASTER	SRTM
Min	2.79	2.91	4.00	3.00
Max	10.19	11.14	27.00	16.00
Mean	5.38	6.38	14.61	10.61
Std	1.73	1.86	4.87	3.12
Skew	1.29	0.18	0.31	-0.48
RMSE	5.649	6.641	15.388	11.053

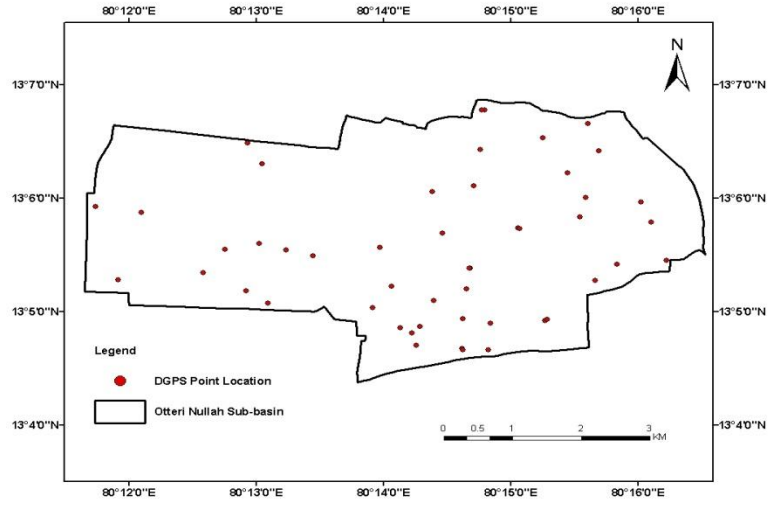


Figure 2. Survey points of the Real-time kinematic (RTK) GPS in the study area.

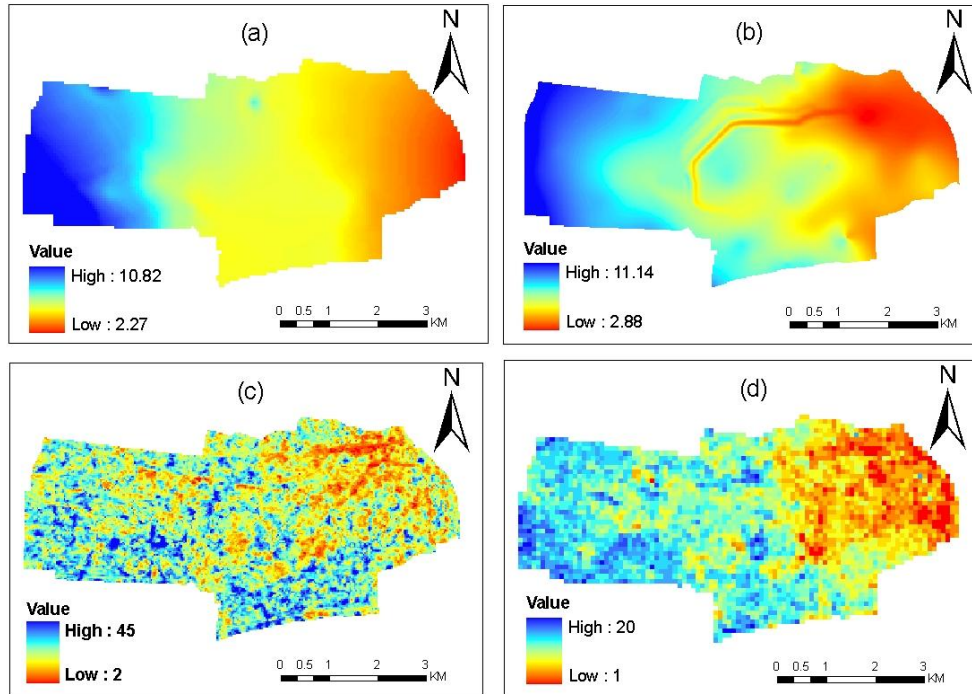


Figure 3. Digital Elevation Model of SOI (a), RTK-GPS (b), ASTER (c) and SRTM (d)

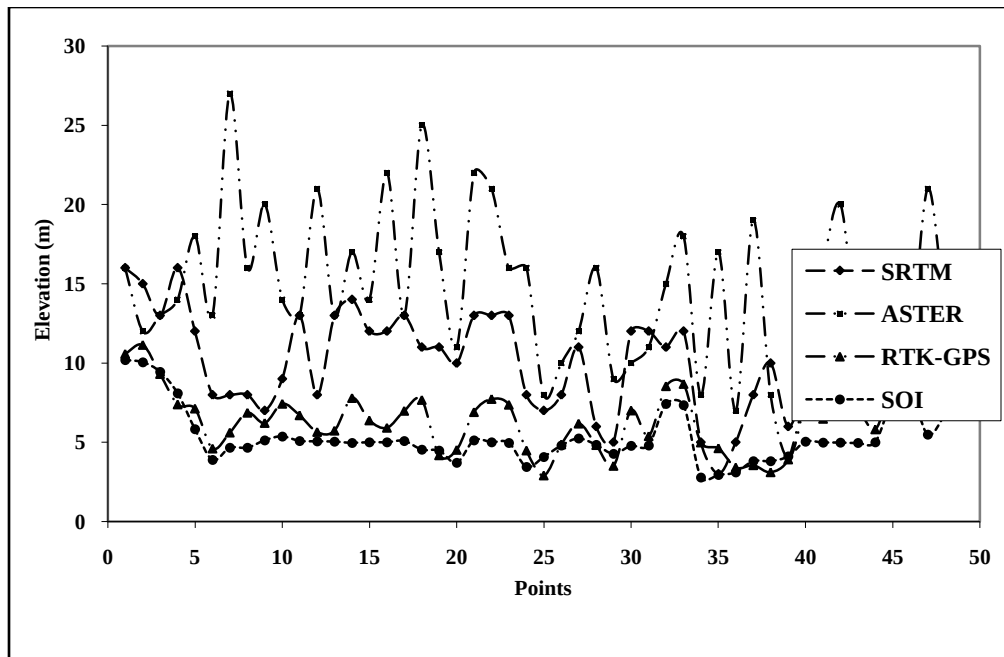


Figure4. Elevation differences between the Digital Elevation Models

5. Conclusion:

The quality of global digital elevation models of SOI, ASTER, and SRTM were assessed using real-time kinematic GPS data. Among the four DEMs, SOI has the smaller RMSE of 5.649m. The results showed that SOI has the lowest RMSE than the RLT-GPS, SRTM and ASTER DEMs. So for the applications of InSAR over urban region, the selection between using ASTER and SRTM DEMs as the reference of topography is important in order to minimize the topographic residual errors. SOI and RLT-GPS were gave the best representation in urban watershed delineation of Ottari nullah sub-basin of Chennai City. Therefore, ASTER and SRTM DEM may be not suitable for the urban hydrological applications.

6. References

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