

3D Mapping of Selected Regions Using NavIC Receivers

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Abstract:- 3D mapping is profiling of objects in three dimensions to map real objects. It is an important tool in creating 3D scenes of a location that are useful for many studies like high rise development, building interior and exterior and effects of a disaster. Among the several other ways to obtain a 3D map, remote sensing satellite data or a UAV can also be used to obtain the mapping data. Remote sensing is a technology that allows measuring object's properties from a distance, which is currently undergoing tremendous advances in both precision and areas of applicability. Large area 3D city models can be created using stereo pairs of aerial photographs or high-resolution satellite images and is less cost-effective technique for many applications. UAV'S take aerial images over an area incorporated with spatial data based on GNSS to produce a high-resolution 3D image. The main objective of our project is to prove a method of elevation mapping alternate to DEM for a low- budget experiment or survey of a smaller region. It also shows that mapping is, yet another application of Navigation with Indian Constellation (NavIC) developed by ISRO. We achieved this by using the NavIC receivers available to us from the college NavIC Lab. The antenna is firmly placed on a mobile platform, along with the setup which includes a laptop to record the data and to display the signal strength from the satellites; a fair strength of signal from four satellites was the minimum requirement for a reading of reasonable accuracy. The setup is required to be moved along the area to be studied, in a gridded manner. The area is gridded and marked prior to the conduction of survey. This helps to cover most of the irregularities and variations in the topography. With this project we hope to demonstrate the use of satellites to prepare highly accurate 3D Digital Elevation Models which has numerous applications in geological studies.

I. INTRODUCTION

3D mapping is a complex application. By keeping the flight height, number of pixels per image width, sensor width and increased focal length results in a better resolution image. Its generation and visualization using high resolution data is very critical for urban planning, disaster management and other utility services 3D mapping has numerous applications in topographic surveys, disaster analysis, archaeological mapping, agriculture, and disaster management process.

The IRNSS user receiver is taken for a field survey with the help of mobile vehicle. It is mainly focused on the study of college golf course in the IRNSS, GPS and hybrid modes of operation. The variation of altitude across the region of survey, the data variations and sudden drop across the dense canopy are considered for the analysis. The data gathered from the sophisticated systems is converted into imagery or directly processed using electronic computers. The obtained data is converted to 3D maps using Surfer 3D/2D mapping software.

The IRNSS and GPS hybrid receiver can be taken for a field survey with antenna mounted on a mobile vehicle in an open space. The signal strength will be independent of the speed of the moving vehicle with the apparatus and thus varying speed will not affect the survey results. IRNSS receiver can be used to process signals which can help to analyze the data which is recorded on processing unit. It has two (L5 & S) bands. IRNSS can give accurate position values that is latitude, longitude and altitude of an object attached with receiver within its coverage area and thus helps in determining data sets required for a 3D mapping. A minimum of 3 satellites are required to determine the position of the location. The signal experiences attenuation in areas of vegetation and there is an improvement in hybrid mode. Out of the 12 available channels, 4 strong channels are enough for tracking the position.

A Digital Elevation Model (DEM) represents the latitude, longitude, and altitude of Earth i.e., X, Y and Z. DEMs that are available in public domain are ASTER, SRTM and CartoDEM. CartoDEM is a software by Space Application Centre, ISRO. To generate a CartoDEM the users can browse pictures of DEM and corresponding ortho-images on the NRSC website. CARTOSAT-I provides stereo data which can be used to generate DEM with high resolution. Higher spatial resolution does not ensure higher accuracy in elevation data. Compared to SRTM and ASTERDEM for accuracy, Indian DEM shows large elevation errors which is why it is not widely used.

The images for DEM generation were available on Bhuvan portal of ISRO. Bhuvan is a web-based utility which allows users to explore a set of map-based content prepared by ISRO. It offers spatial resolutions up to 1 meter. Since its launch, users have experienced various difficulties. The site has been either inaccessible or very slow at times, due to low

band width and servers. It renders layers unevenly and at times images are completely blocked. It claims to produce images from a perceived altitude of 10 meters, but results show otherwise. If many locations of same name exist, Bhuvan sometimes fails to return multiple results. We also found that high resolution maps and images were not open to public use. If in future better resolution maps and images are made accessible to the public, we can generate more accurate models from which various terrain features and aspects could be determined.

II. METHODOLOGY

In order to proceed with the study, the graphs are generated for the data of Doppler shift and Signal to Noise Ratio. Initially to start with the study we require the data from IRNSS satellites. This data was available to us from the receiver that is installed in NavIC lab of FET, Jain University, Bangalore. The data will be recorded for every second for twenty-four hours. Similarly, the data will be recorded for every month (until some error occurs in receiver's software) in csv format. The receiver data is stored in a folder of IRNSS parameters. Inside the folder the data for whole week will be available according to days of the week and for 24hours, wherein we can observe several excel files such as SATB (for both L5 and S frequency bands), POSB, CLKB and DOPB files. Each file provides unique information of the GNSS system.

SATB files contains all the data that provides the information regarding the satellite signal transmission. It contains the data channel number, Doppler shift, Signal to Noise Ratio, Azimuth, Elevation, Reject Code and Lock time. The data will be recorded for all the seven satellites of IRNSS. This file available for two frequency bandwidth L5 and S band separately.

POSB file stores all the parameters that represents the position of the satellite in space (X, Y and Z co-ordinates) and its velocity in the same directions. It also contains the data regarding the deviations of the satellite. It also stores the data regarding the status of the system, position fix time, position error and the time required to first fix the error.

CLKB file contains all the data regarding the atomic clocks of the satellite and receiver also. It provides the information regarding the clock bias, clock drift, inter bias and the UTC time offset. This information is useful for the correction for the error in the atomic clocks. The same is followed for GPS atomic clocks also.

DOPB file consists of the data of the satellite positions dilutions data as GDOP (geometrical dilution of position), VDOP (vertical dilution of position), HDOP (horizontal dilution of position) and TDOP (time of dilution of position).

Surfer 2D & 3D mapping software was used to generate 3D maps. It is a grid-based mapping program that interpolates irregularly spaced XYZ data into a regularly spaced grid. There are several gridding options available like kriging, nearest neighbor, natural neighbor etc. We used the kriging

method of gridding for our purpose. Grids may also be imported from external sources.

Bhuvan was used for DEM generation. Bhuvan 2D offers powerful, user-friendly mapping technology to organize the satellite and map data easily.

II. PROCEDURE AND ANALYSIS

A. Procedure

First, we switch on the receiver and give it some time to calibrate itself, till it shows the coordinate values then we launch the software on the laptop. Make sure all connections are tight and secure. Start a new session and save it under a new file for a given patch. Start moving around the site along the previously plotted path with the trolley: first go along the circumference then move zigzag through the site. If the receiver does not receive data, stop, and wait until it receives data (data from at least 4 satellites should be collected at all times). Once a certain patch is complete, save the session and repeat the process 3 times for the patch to minimize the errors. The required values are then averaged in order to get more accurate results and compensate for missing data due to loss of signal or loose connections.

Several problems encountered during the survey which accounted for errors in the obtained data. These included loose connection of the equipment mainly the LAN cable, heavy vibration of the trolley due to which the antenna kept shaking, battery connection problems. Deeper depressions in the site could not be completely covered due to the low mobility of the trolley in rough terrain. Loss of signals from the satellites occasionally

For all the patches, 3 sets of latitude, longitude and altitude values are obtained which is first averaged out to get a more accurate set of final data. After obtaining the final averaged set of latitude, longitude and altitude values for each patch, Surfer 2D & 3D Mapping Software is used to generate the 3D surface maps.

On the Surfer home page, select 'New Plot' and then select 'Grid Data' and select the final averaged excel sheet with latitude, longitude, and altitude values. Define the X, Y & Z axis with latitude, longitude, and altitude columns, respectively, and choose '3D Surface' as the plot type and click 'Finish'. After finishing, Surfer will process the data and generate the 3D surface map for the patch.

Repeat this procedure for each patch. The variation of different parameters for each satellite like Doppler, pseudo range, delta range, signal-to-noise ratio, ionospheric delay and the total number of satellites, GDOP, VDOP, TDOP, PDOP, HDOP with time (in seconds) is also plotted using Microsoft excel.

B. Apparatus and setup

Equipment used includes a battery, to power the receiver; antenna and IRNSS receiver, to receive signals from satellites; laptop, to launch the software to collect the data; LAN cable, to transfer data; connector cables, to connect various devices;

trolley. used to move the setup through the site; ropes used to keep the setup in place.

To setup the equipment, the battery is connected to the IRNSS receiver (white cable in the figure). Antenna is connected to the receiver (black cable) and the receiver to the laptop using LAN cable (blue cable). The whole setup is done on a trolley for easy movement. The setup is held in place with ropes to keep it from falling during the survey.



Fig. 1. Setup of the apparatus

C. Using CARTOSAT -1 for DEM generation

Indian Remote Sensing Satellite Cartosat-1 is an along-track stereo mission. The DEM generated using the stereo images of Cartosat-1 with 1 arc sec (~30m) posting are available on Bhuvan portal of NRSC/ISRO for free download along with the technical documents. It is released as version 1.0 initially for the entire country and subsequently improved version 1.1 R1.

- 1) Go to website <https://bhuvan-app3.nrsc.gov.in/> and select Open Data Archive
- 2) Select subcategory as Cartosat-1 & Product as latest CartoDEM which is CartoDEM Version-3 R1 and zoom in to the desired location for obtaining the DEM for the required region

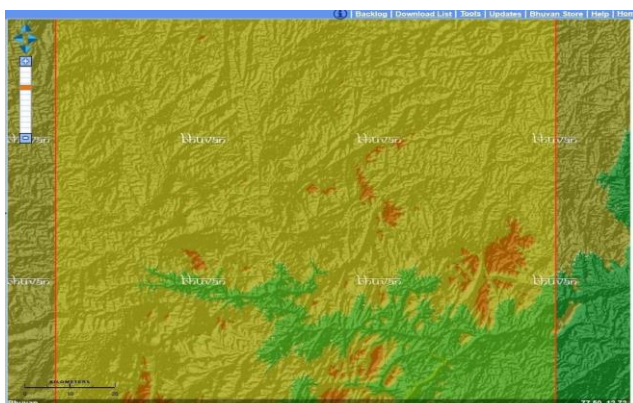


Fig. 2. DEM generated for the area under study

D. Map Analysis



Fig. 3. 3D Map for Patch 1

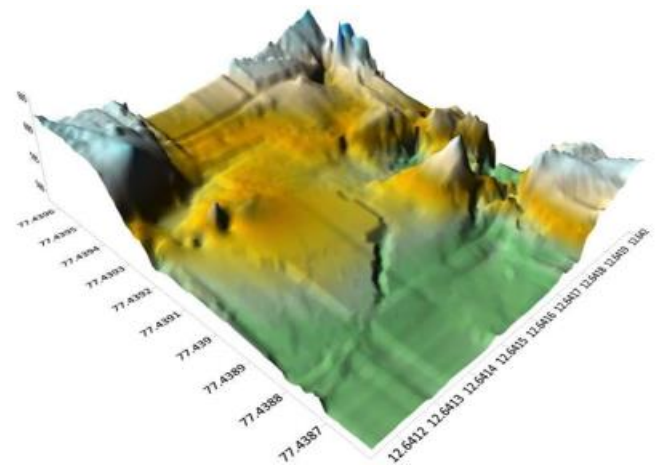


Fig. 4. 3D Map for Patch 2

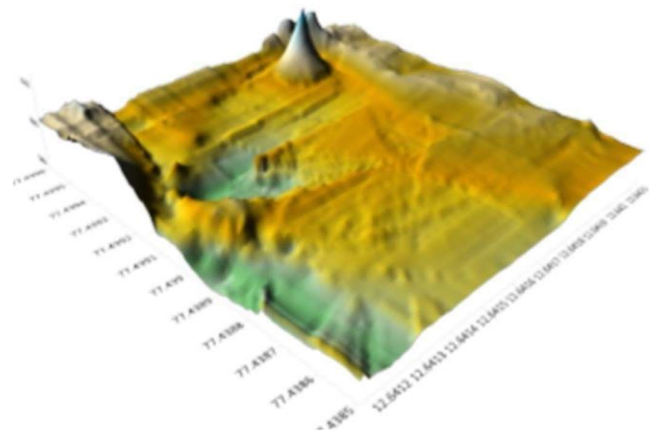
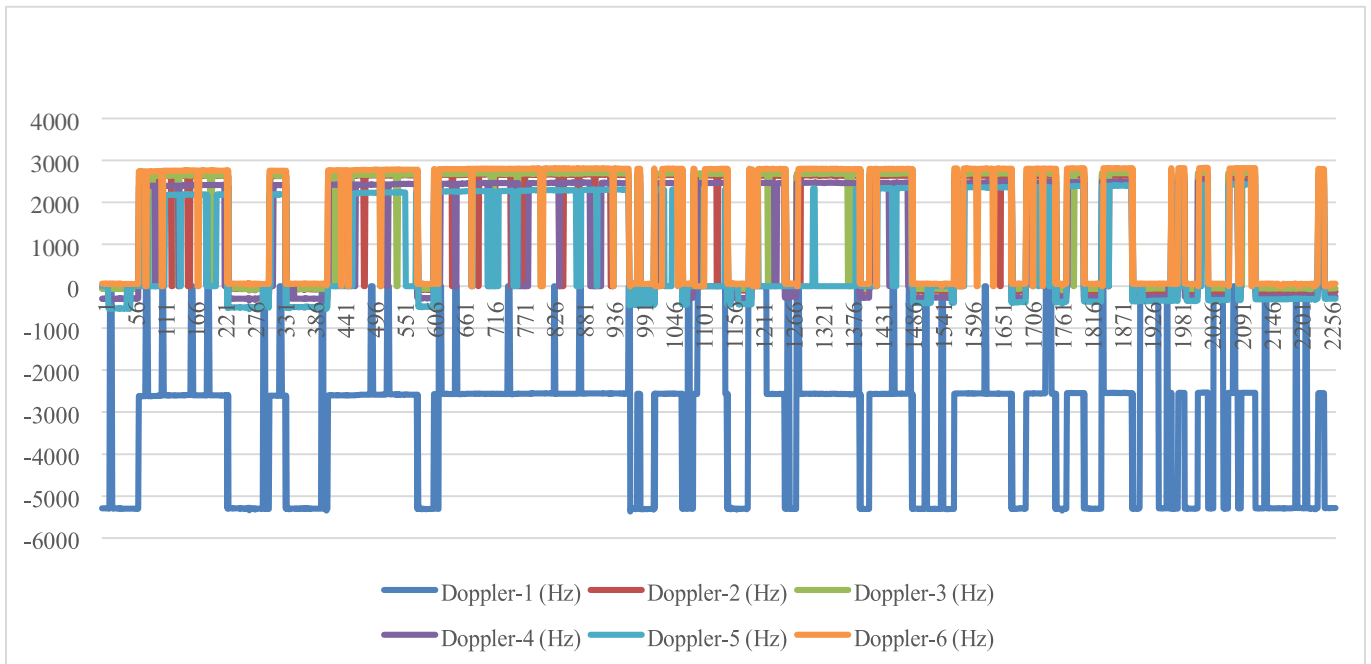


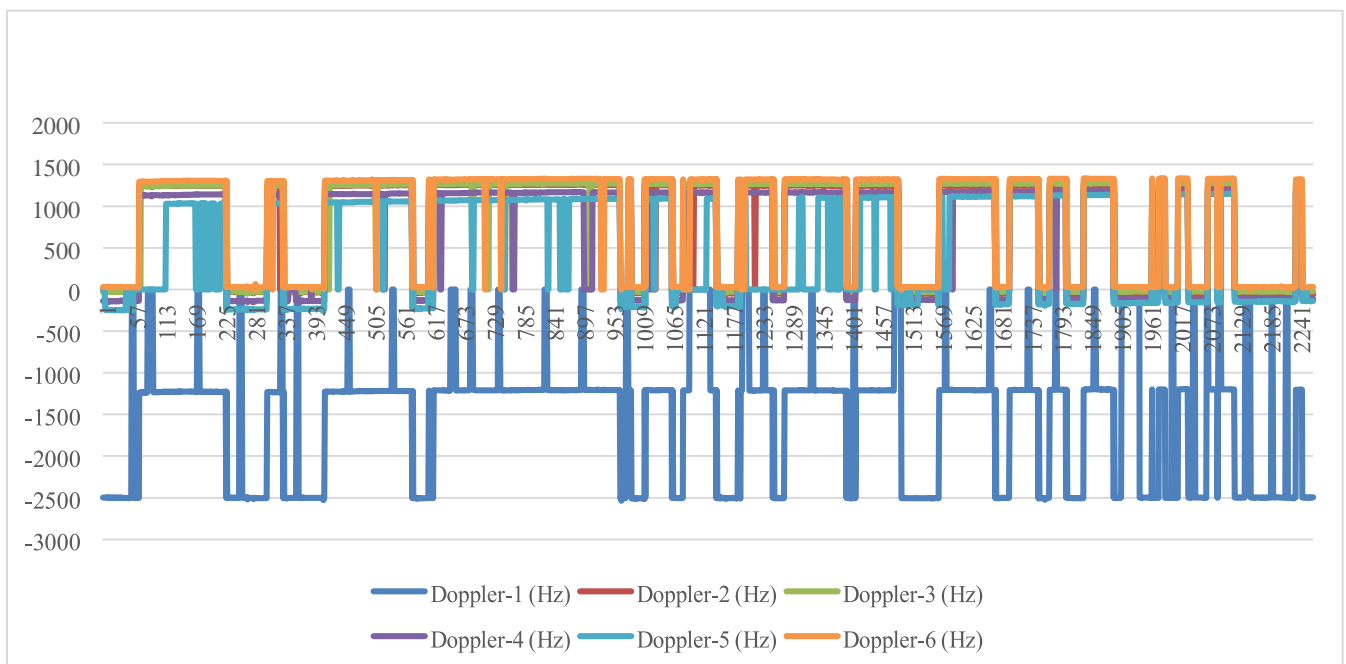
Fig. 5. 3D Map for Patch 3

➤ *Plotting variation of satellite parameters with time*

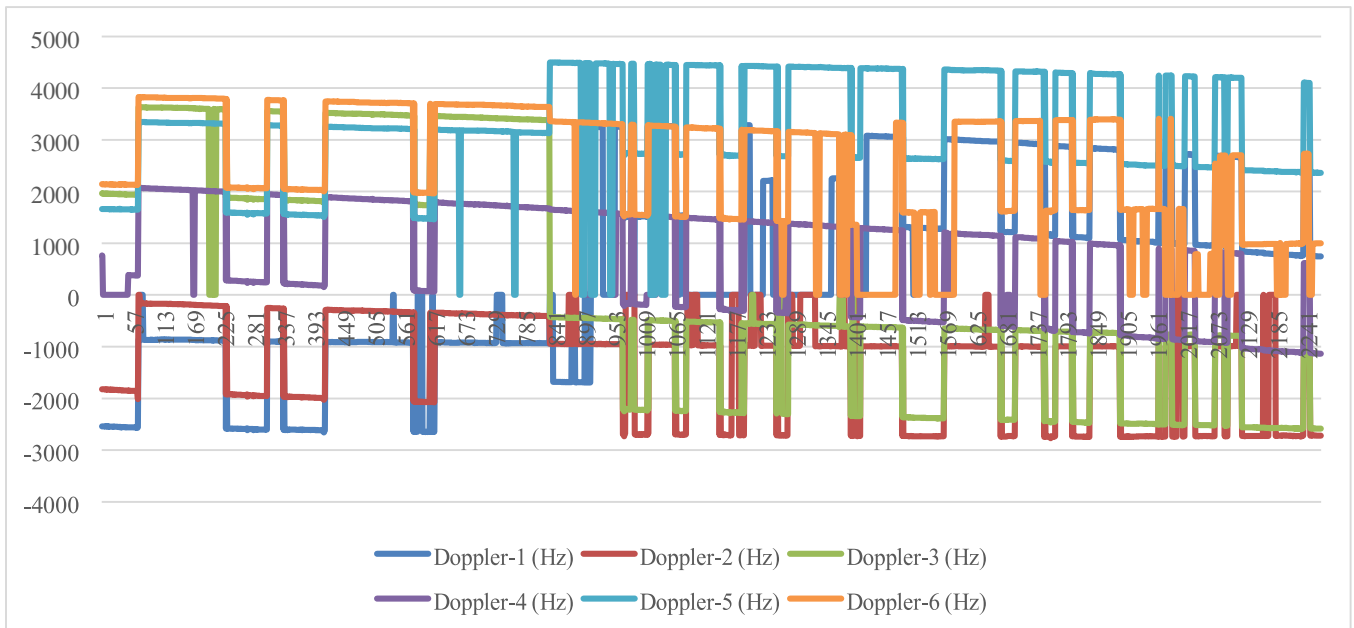
The graphs below show the variation of Doppler for each of the 6 satellites for all received S1, L1 & S5 frequency band, respectively.



Graph 1. Variation of Doppler with Time (S1 Band)

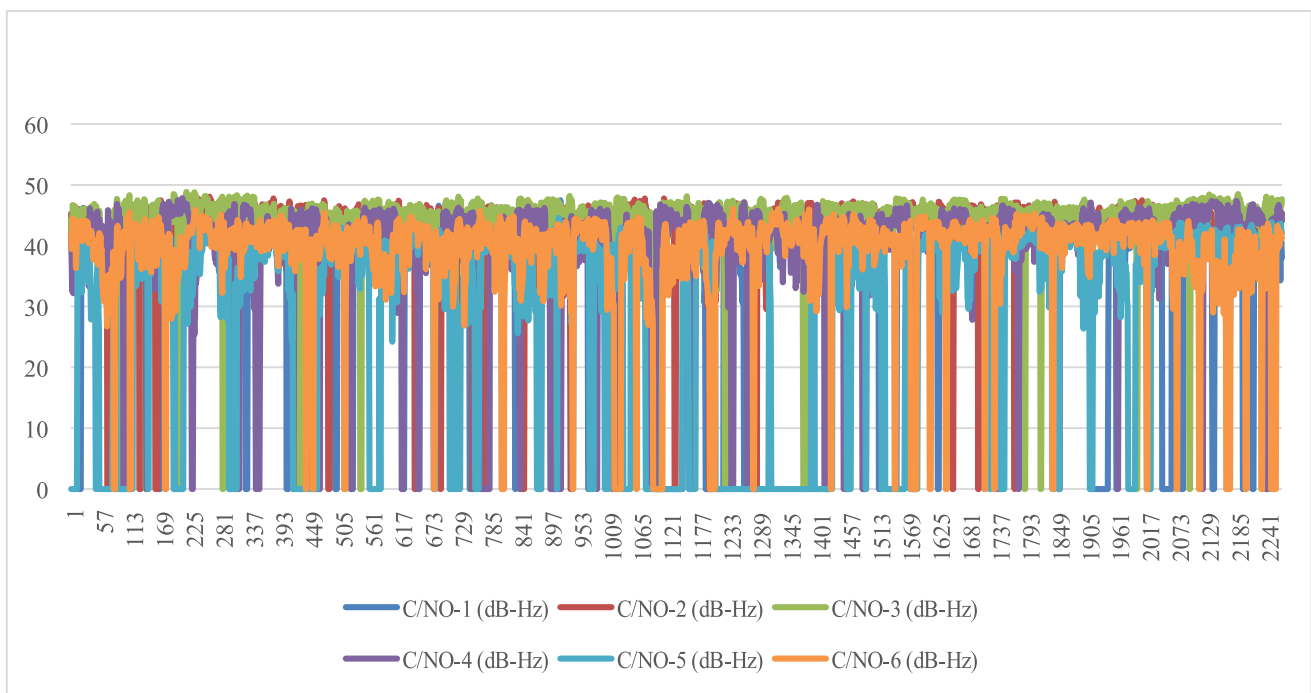


Graph 2. Variation of Doppler with Time (L1 Band)

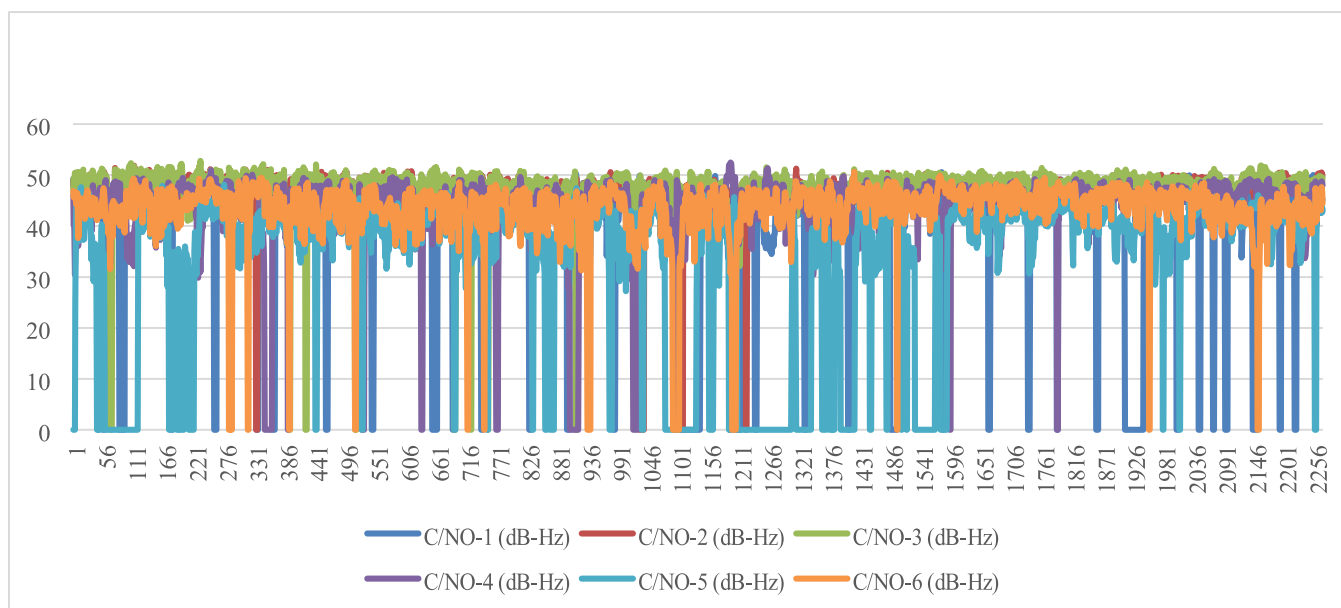


Graph 3. Variation of Doppler with Time (L5 Band)

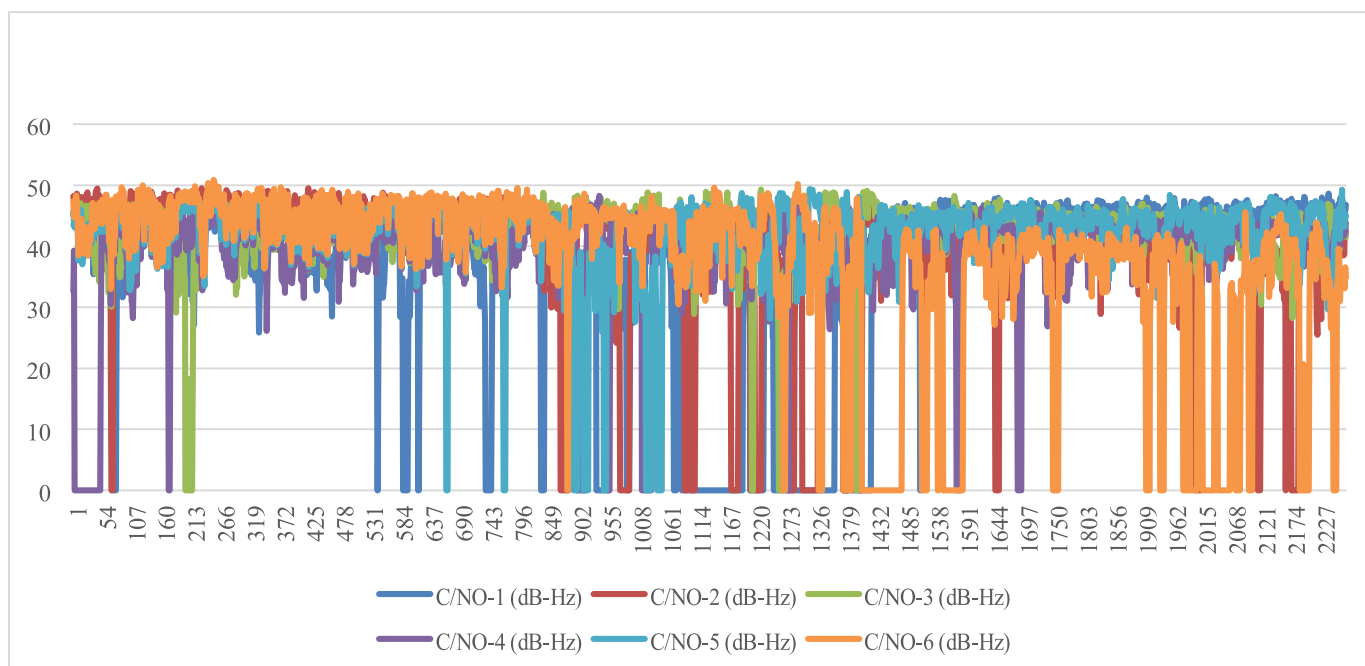
The graphs show the variation of Signal-to-Noise ratio for each of the 6 satellites for all received S1, L1 & S5 frequency band. We can observe that for every satellite its almost similar but S1 band has the least. We can, also, observe the variation in signals over time.



Graph 4. Variation of Signal-to-Noise Ratio with Time (S1 Band)

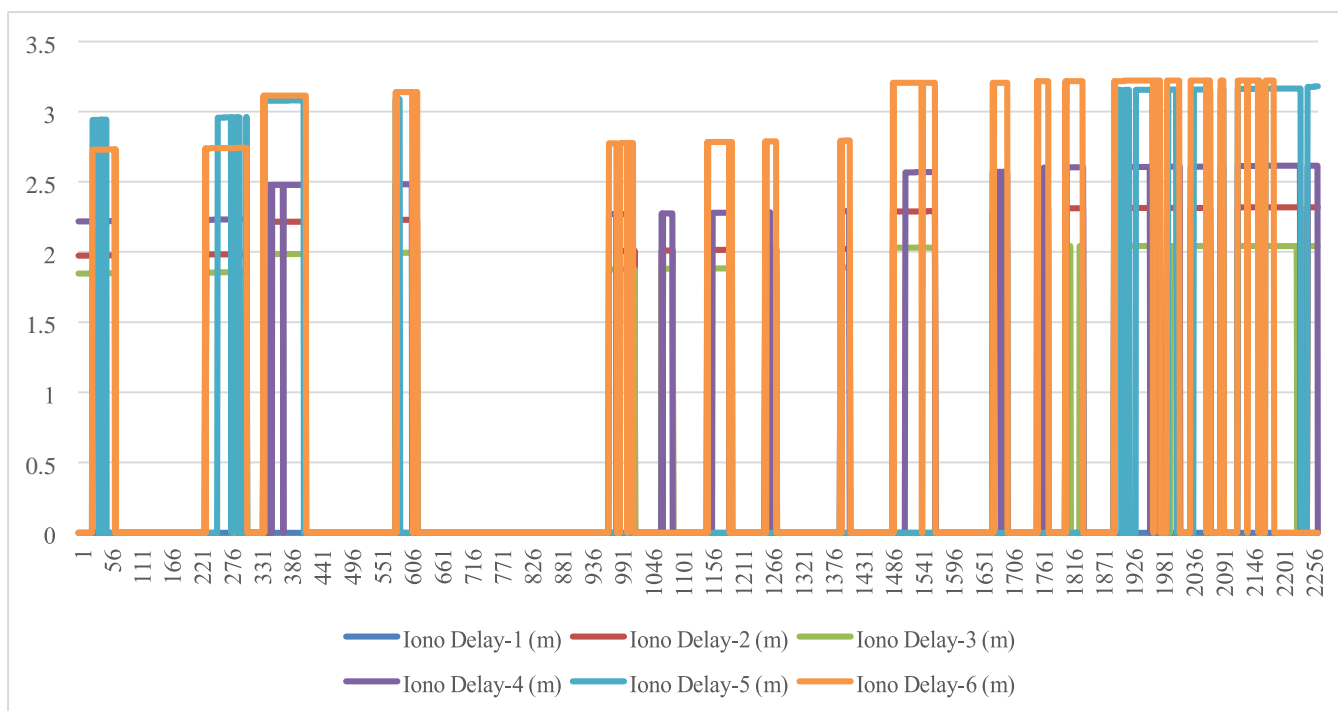


Graph 5. Variation of Signal-to-Noise Ratio with Time (L1 Band)

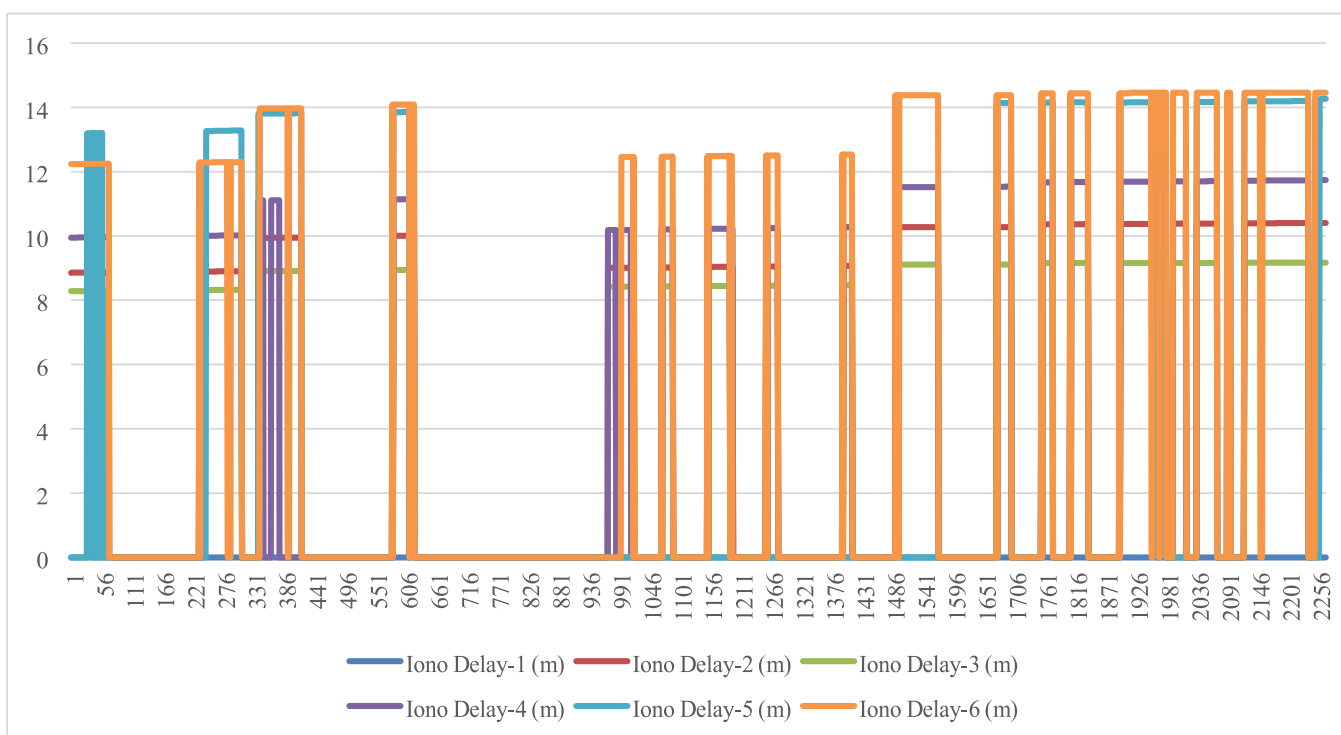


Graph 6. Variation of Signal-to- Noise Ratio with Time (L5 Band)

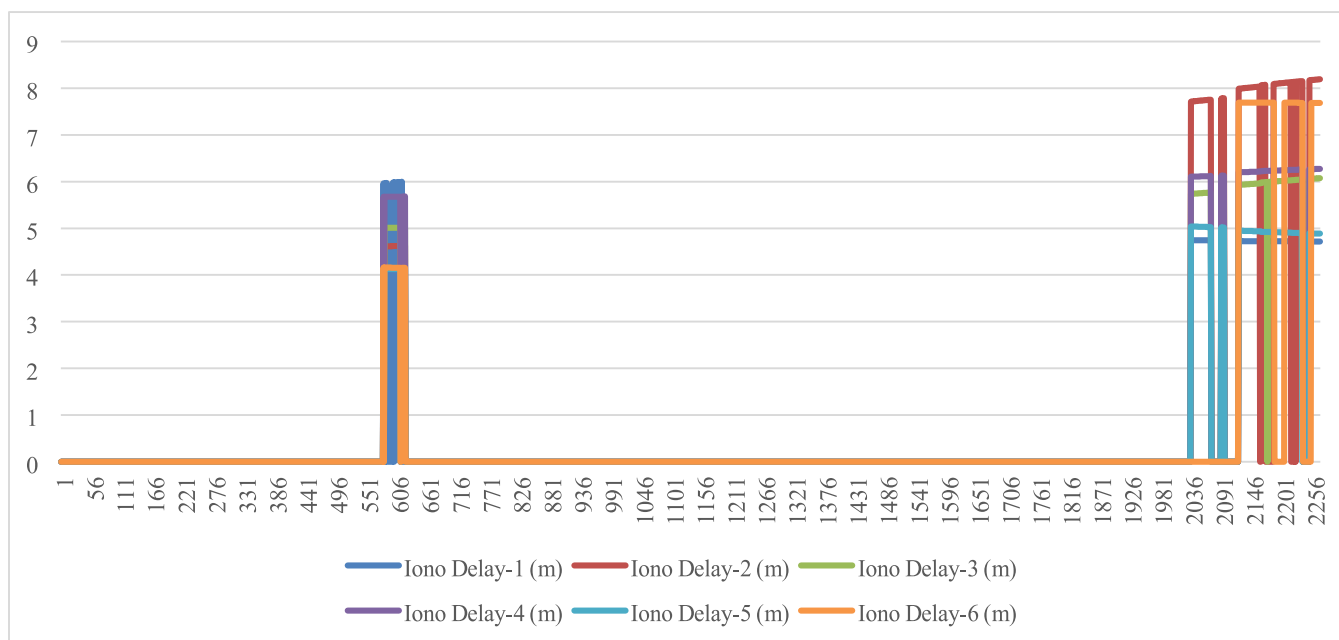
The graphs below, show the variation of ionospheric delay for each of the 6 satellites for all received S1, L1 & S5 frequency band. It is observed that L1 Band has the most ionospheric delay



Graph 7. Variation of Ionospheric Delay with Time (S1 Band)

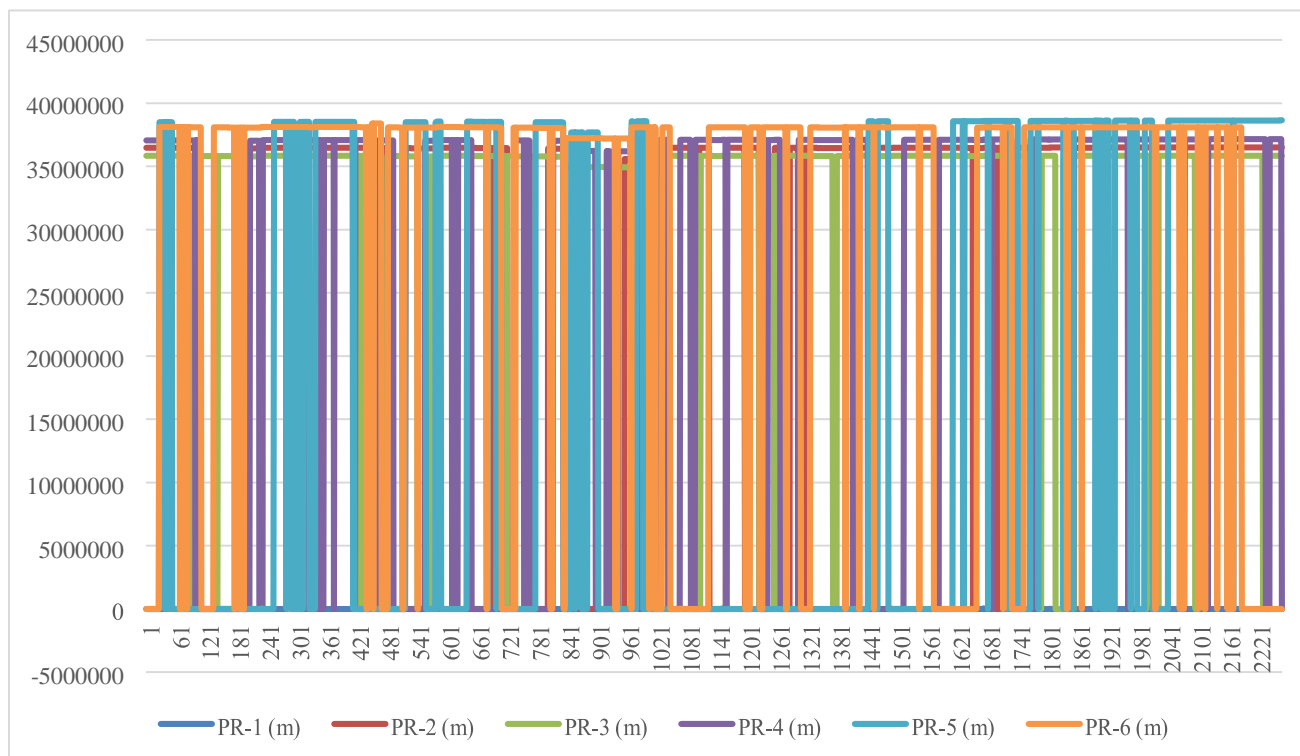


Graph 8. Variation of Ionospheric Delay with Time (L1 Band)

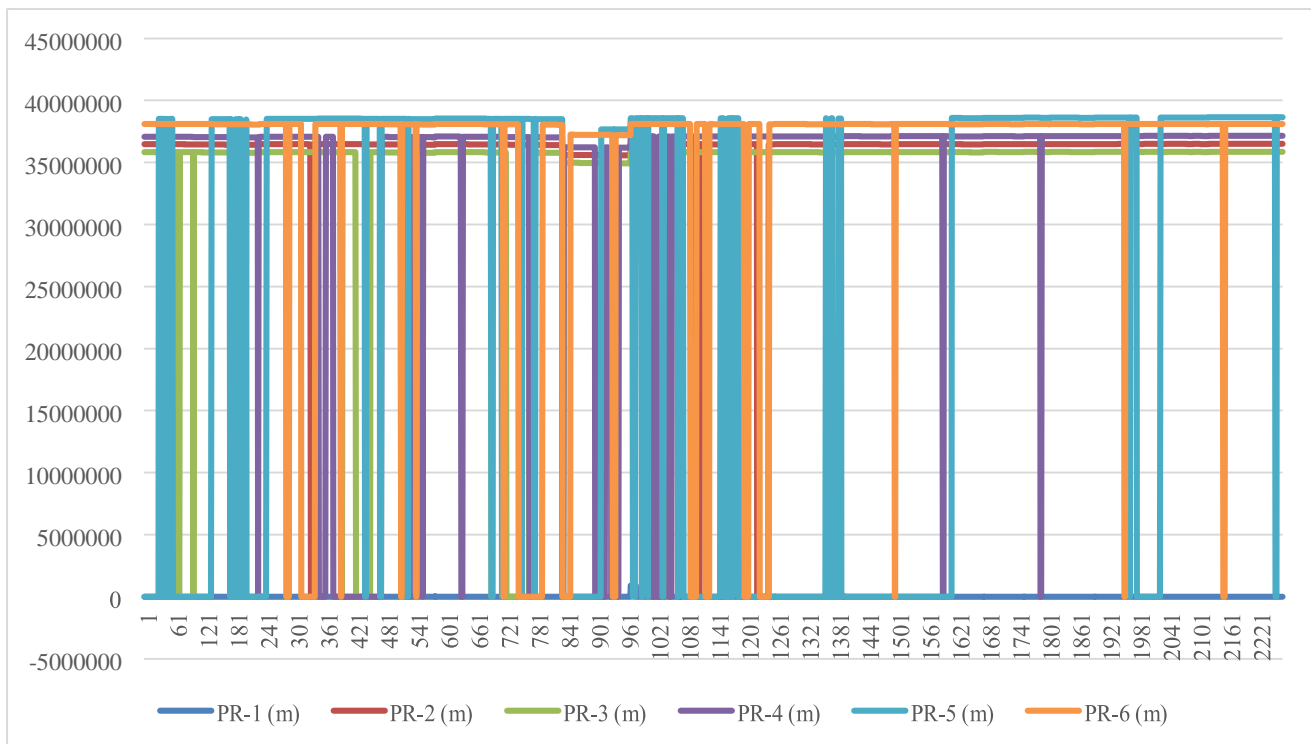


Graph 9. Variation of Ionospheric Delay with Time (L5 Band)

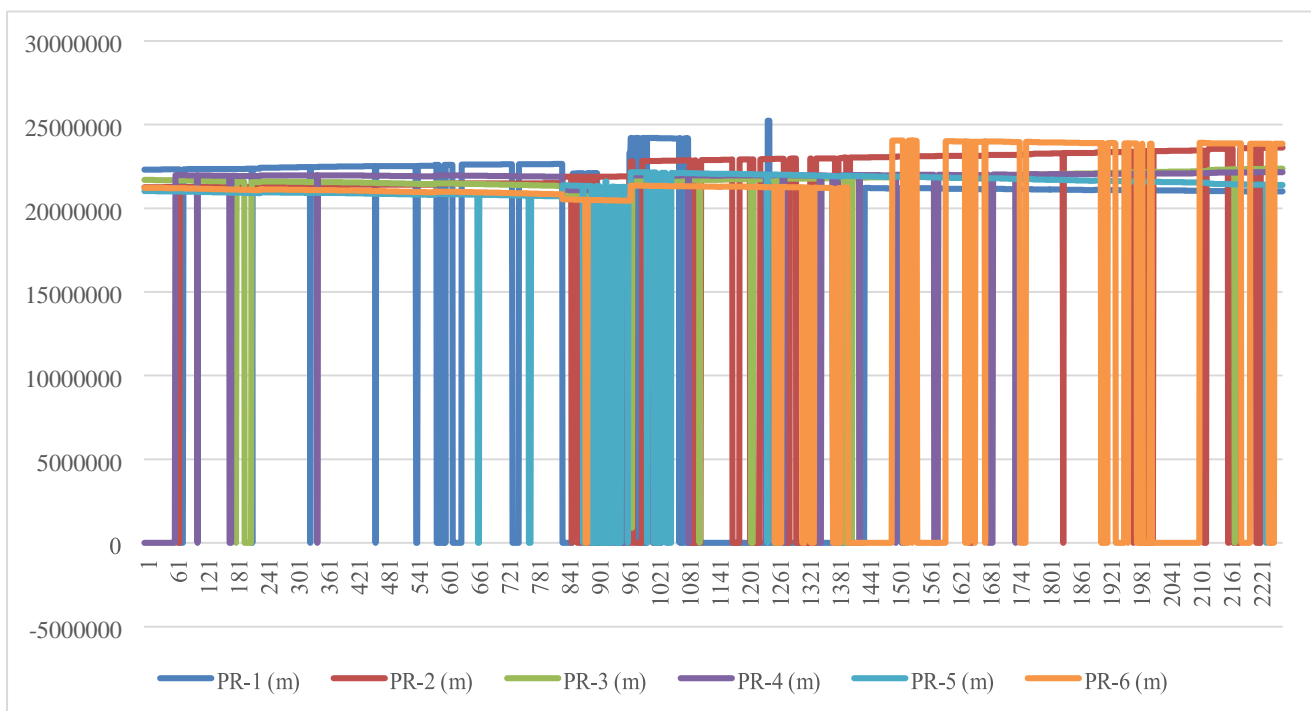
The graphs show the variation of Pseudo Range with time for each of the 6 satellites for all received S1, L1 & S5 frequency band and we can observe that the L5 Band has the least pseudo range.



Graph 10. Variation of Pseudo Range with Time (S1 Band)



Graph 11. Variation of Pseudo Range with Time (L1 Band)

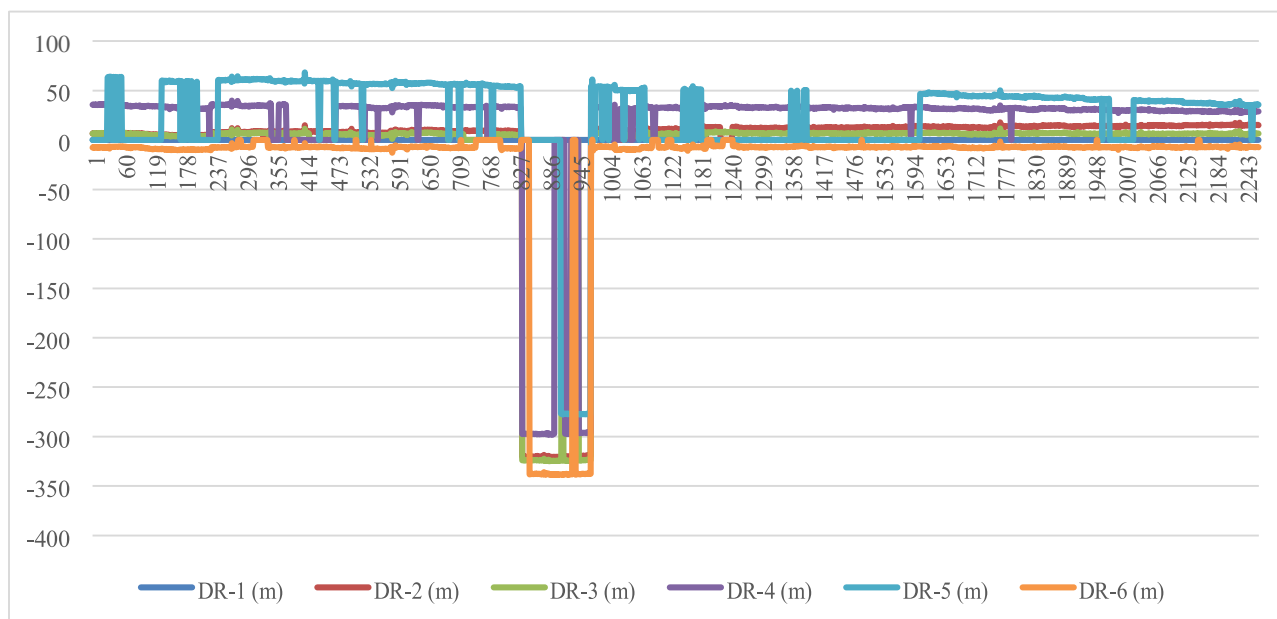


Graph 12. Variation of Pseudo Range with Time (L5 Band)

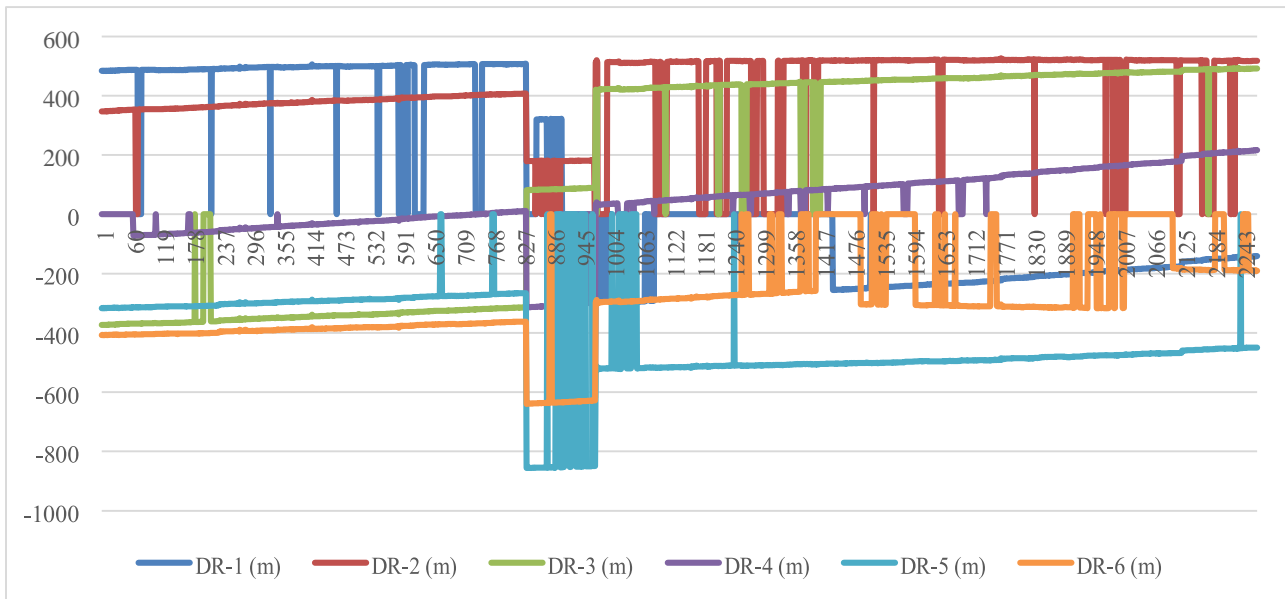
The graphs show the variation of Delta Range with time for each of the 6 satellites for all received S1, L1 & S5 frequency band and we can observe that the L5 Band has the most Delta range.



Graph 13. Variation of Delta Range with Time (S1 Band)



Graph 14. Variation of Delta Range with Time (L1 Band)



Graph 15. Variation of Delta Range with Time (L5 Band)

From the three 3D maps produced using surfer software we can see that it resembles the terrain. The map shows the variation on latitude, longitude and altitude values obtained from the IRNSS satellite data and is represented in the X, Y, Z axis, respectively. The maps are relatively easy to obtain using these parameters and using a 3D mapping software like Surfer. Accuracy of the map depends on the accuracy of the latitude, longitude and altitude values obtained from the receiver. Certain unwanted peaks and irregular depths are observed at certain places. These depths and peaks are the errors to the final map obtained. These errors maybe caused because of apparatus vibration while surveying, less accuracy of the values obtained from receiver or poor signal at certain places. These errors can be minimized by using a better trolley and a more compact and accurate antenna. The maps can be used as reference to study the topology of the region and properties of the area like volume of water it can hold, water flow direction and thus will help in analyzing and resolving flooding of the area

IV. CONCLUSION

3D mapping can be done using IRNSS. The IRNSS receiver can be used to receive various parameters and using these we can plot 3D maps of the sites and we can also find out various other parameters through plots of Signal-to-Noise ratio, pseudo range, delta range, GDOP, HDOP, VDOP, TDOP.

The 3D mapping is done by using the latitude, longitude, altitude values obtained from the receiver and plotting it in 3 axes coordinate system using a mapping software. The survey depends on the satellite coverage and thus will be affected by thick vegetation coverage. This method is more accurate and reliable in open areas with greater reception rate. The accuracy of the map also depends on the type of vehicle used for surveying which can cause errors. These errors can be minimized by taking steps like using a more stable and mobile trolley to carry the components, which will reduce vibration of

the trolley while surveying and hence give more accurate survey results. This method can be used only for surface evaluation as objects cannot be traced onto the map.

Hence, we can see the importance of 3d mapping as it will enable many other features and experiences that conventional mapping technologies lack, and it is also good that ISRO has come up with their own positioning system as it will reduce our reliance on GPS.

V. FUTURE SCOPE

This method proves more accurate with a better transport equipment like a pre-programmed or RC car fitted with a NavIC microchip. This will ease the process and can cover more area with less effort and time. Even large areas can be surveyed by using a vehicle fitted with apparatus provided the area is suitable for the vehicle to move in the required pattern. However, if in future better resolution maps and images are made accessible to the public more accurate models can be generated from which various terrain features and aspects could be determined.

The development of a NavIC Microchip is currently going on and will be available soon. ISRO has already signed contract with Qualcomm, a major chipset manufacturing company for smartphones and Xiaomi a major smart phone company for incorporating the new NavIC chip in their future products.

REFERENCES

[1]. Indian Regional Navigation Satellite System Signal in Space ICD for Standard Positioning Service (Version 1.0, ISRO-IRNSS-ICD-SPS-1.0), Indian Space Research Organization, 2014. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

- [2]. Harshada Harde, Prof. M. R. Shahade and Diksha Badnore, "Indian Regional Navigation Satellite System", International Journal of Research in Science & Engineering.
- [3]. N Raghu, K.N. Manjunatha and B Kiran, "Tracking of Satellites by Using Phased Array Antenna", International Conference on Electronics and Communication Systems (ICECS), 2014.
- [4]. N Raghu, K.N. Manjunatha and B Kiran, " A Comparative Study and Performance Analysis Using IRNSS and Hybrid Satellites", International Conference on Electronics and Communication Systems (ICECS)
- [5]. Indian Regional Navigation System, Parimal Majhiya, J.K.Hota
- [6]. Raghu N, Manjunath K.N, Kiran B, Rylan Chetia, "Mapping of Arkavathi Reservoir using IRNSS Receiver", Journal of Instrumentation and Innovations, ISSN:2249- 4731
- [7]. N Raghu, K.N. Manjunatha and B Kiran, "A Study on Mapping of Harohalli Lake Using IRNSS Receiver", International Journal of Telecommunications & Emerging Technologies. 2019; 5(2): 13–20p
- [8]. 2016, Mapping aerial images from UAV, Dunja Gotovac, Sven Gotovac, Vladan Papic, Department for Electronics and Computing, University of Split, Croatia <https://ieeexplore.ieee.org/document/7555938>
- [9]. Aman Jain, Akshay Vyas, Harsh Yadav, "Reviewing Indian Navigation Satellite – IRNSS", Reviewing Indian Navigation Satellite, 2014.
- [10]. Performance Analysis of IRNSS Receiver Signal Strength and Accuracy on a Moving Vehicle” by Gayathri K M, Thangadurai N, Vasudha M P Department of Electronics and Communication Engineering School of Engineering and Technology, Jain University, Bangalore, India
- [11]. Raghu N, Manjunatha K N & Kiran B “Determination and preliminary analysis of position accuracy on IRNSS satellites” presented at international conference on signal processing, April 6 – 8, 2016, India
- [12]. S. Muralikrishnan & Abhijit Pillai & B. Narender & Shashivardhan Reddy & V. Raghu Venkataraman & V. K. Dadhwal “Validation of Indian National DEM from Cartosat-1 Data” 8 March 2012, Indian Society of Remote Sensing 2012, National Remote Sensing Centre, Indian Space Research Organization, Hyderabad, India XIII.
- [13]. Temenoujka Bandrova, Milan Konečný, Sisi Zlatanova, “Three- dimensional maps for disaster management”, ISPRS congress, AtMelbourne, Volume: Volume I-4, XXII ISPRS Congress, August- September 2012 XIV.
- [14]. Gayathri K M, Thangadurai N, Vasudha M. P, “Positioning and Signal Strength Analysis of IRNSS and GPS Receiver in Plain and Vegetation area”, 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT) XV.
- [15]. Binoy B V, Shashank B, Hebbar R, Uday Raj, Karuppasamy S “Virtual 3D Mapping and Analysis using remote sensing data and photographs” XVI.
- [16]. Stella Pytharouli, Jock souter, Olympia Tziavou, “Unmanned Aerial Vehicle (UAV) based mapping in engineering surveys” Department of civil and environmental engineering, University of Strathclyde, UK XVII.
- [17]. International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015), DEM Generation Using Cartosat-I Stereo Data and its Comparison with Publically Available DEM, Sooraj
- [18]. Krishnana, N Sajikumarb*, Sumam K Sb