CHAPTER 3: RESOURCES USED

3.1 Introduction

Resources are required to carry out any research activity. Resources used for this research study consist of computer systems, software, SLC image data pairs for various terrain, ground control points from topo-maps, GPS reference points, reference Optical DEMs, reference SAR DEMs, published articles and text books. In addition to the above, a few software utilities are developed by me, tested and used. ERS-1&2 tandem data imaged over Indian region and downloaded at Shadnagar ground receiving station is ingested, processed and archived at NRSC. Basically, this data is in raw data CEOS format. For selected geographical areas, raw data products are identified and processed to get Single Look Complex image pairs. Required data pairs for this study are identified as per data selection guidelines prescribed for repeat pass interferometry technique and used. NRSC has a GCP library data base developed using precision observations from GPS satellites. These GCPs are of better than +1m accuracy and the GCP points required for this study are used from this data base. Pixel matching techniques used in this research study requires accurate reference DEMs. For this purpose, after a detailed survey, Carto DEM sets are found to be suitable. NRSC has developed a Carto DEM data base for all India sub continent. Required elevation model tiles are examined, extracted and taken from NRSC
DEM archives and used as reference DEMs. As secondary set of reference DEMs, SRTM DEMs are downloaded from internet website. SRTM DEMs corresponding to the areas of study are segmented and used. Extensive literature survey is carried out to collect secondary data from various related national journals, international journals, technical reports from various academia, reference text books from ISRO and JNTUH library. Besides this, computer systems, various software packages available in Microwave Remote Sensing laboratory, inhouse developed software modules are used to carry out this research work. Details of software utilities developed for this research purpose are given in 3.3.1.

3.2 Computer Systems

Configuration of the computer system used for carrying out the research is a two CPU, dual core, Xeon processor based work station with 3.60 GHz clock. This HP Workstation model xw8200 has 2.0 GB RAM, loaded with Microsoft Windows XP, and Red Hat Linux 4.6.3 dual operating systems with ‘gcc version 3.4.6 20060404’ compiler. ‘C’ Computer language is used for coding in-house developed software utilities listed in section 3.3.1. In addition to this, a computer system with Intel Xeon E5410 at 2.33 GHz processor with 4 GB RAM loaded with Windows Microsoft Windows XP Professional Version 2002 Service Pack 3 operating system is used for image display and analysis activities. Another computer system with Intel
Xeon E5410 at 2.33 GHz processor with 3.25 GB RAM with Windows Microsoft Windows 2007 Service Pack 2 operating system is used for carrying out the research work.

### 3.3 Software

In house developed software developed by me along with general software available at NRSC are used for this study.

##### 3.3.1 In-house developed software

Following software modules are implemented in ‘C’ to perform various activities required for this study. The Software Utilities developed by me for this research study are:

- ‘demerr_statistics.c’ software module is implemented and used to compute bipolar error difference at each grid cell, and also to compute error statistics like Mean, Standard Error, Accuracy Ratio, RMSE of error, Minimum, Maximum and standard deviation of elevation, absolute mean, and NIMA LE 90.
- ‘ourlier_rm.c’ software utility is implemented and used to identify and remove outliers from generated InSAR DEMs.
- ‘Spot height_check.c’ is developed to select check points spread across the DEM for quality control based on the user input. This software is also used to vary the number of check points systematically in InSAR DEM to study and analyze error behavior.
• ‘Affine_trans.c’ software utility is written to select required image segment
• ‘Surface_roughness.c’ software is implemented to estimate surface roughness indices for optical and SAR DEMs
• ‘Variogram.c’ is coded to compute semi variogram
• ‘Fractal_dbc.c’ is developed to compute fractal dimensions
• ‘Montecarlo_sim.c’ software program is written to simulate error fields, to filter the error fields, and to realize synthetic DEMs

3.4 Reference DEMs

Check points or reference DEMs must have a superior accuracy, which means their accuracy has to be better at least by a factor of 3 to 5 times (Hohle Joachim et al. 2006). Very accurate Optical Carto DEMs and LiDAR DEMs are used for InSAR DEM uncertainty studies.

3.4.1 CartoDEM

Elevation data sets derived from pan stereo cameras of Cartosat-1 satellite are basically Digital Surface Models. Throughout the thesis, these elevation models are referred as CartoDEM. CartoDEM archives at NRSC covers more than 80% of India land surface. These optical DEMs are generated using images obtained with fore and aft PAN cameras in along track with near instant stereo viewing mode. CartoDEM are archived in WGS-84 datum in Geo-tiff format. Horizontal data posting is 1/3 arc second or ~10m. Absolute planimetric accuracy (CEP 90) is stated to be ±15m. Absolute Vertical
accuracy of (LE 90) ±8m and relative vertical LE 90 accuracy of ~± 5m are the quoted values for carto DEMs.

### 3.4.2 ALTM DEM

Another source of accurate reference DEM used is Laster DEM obtained from Advanced Laser Terrain Mapping system. This elevation model is stated to be very precise providing elevation values of the order of better than 1m in WGS84 datum.

### 3.4.3 SRTM DEMs

SRTM-X band DEMs of 1 arc second (30m) spacing are available for 60 deg N and 56 deg South latitude and SRTM-C DEMs of 3 arc (90 m) horizontal resolution are available for entire world with vertical accuracy of ±16m. The elevation data used in this study are SRTM-C and are referenced to MSL as approximated by WGS-84 EGM96 geoids and horizontally geo-referenced to WGS-84 ellipsoid in UTM projection (Konstantinos Nikolakopoulos et al. 2005). SRTM DEMs of 5 deg x 5 deg tiles are downloaded in Geo Tiff format. SRTM DEMs are in fact DSM as the received echoes are from upper vegetation, buildings also are embedded into the data set (Andreas Koch et al. 2000). Accuracy of SRTM X and C-band DEMs were published to be ±5.6 m and ±9.6 m for X and C-band respectively under the estimation of 10% mean slope value (Yastikla N et al. 2009). The SRTM-C accuracy goals were an absolute accuracy of ±16m, relative vertical accuracy of
±10m, and absolute horizontal accuracy of 20m, all at the 90% confidence level (Salamonowicz P. 2003, Michael Seymour et al. 1998).

3.5 Ground Control Points

Ground control point is a point on the surface of the earth whose location is specified with latitude, longitude and height in an established co-ordinate system. Ground Control Points, commonly known as GCPs, allow images to be geo-referenced to a higher level of accuracy. GCP library is established at NRSC using GPS measurements are available in WGS-84 reference frame. These GCPs are used as another source for quantification of uncertainty in InSAR DEMs.

3.6 Conclusion

Hardware, software, literature on the subject, and the scientific data are some of the essential resources identified for carrying out the research activity. The computer systems used, the software developed exclusively for this study by the author (Kesavarao P.), standard software packages used, actual data used for generation of InSAR DEMs, external reference DEMs, Ground Control points are discussed in this chapter. Literature reveals that InSAR DEMs could be generated with ERS images to an accuracy of ±23m in urban areas, ±5m in bare areas without vegetation and buildings (Jaan Rong Tsy et al. 2001), and with best case height accuracies of under ±3m rms for local areas. In next chapter, details of experimental data design methodology of DEMs are discussed.