

MODULE – 7 LECTURE NOTES – 3**SHUTTLE RADAR TOPOGRAPHIC MISSION DATA****1. Introduction**

Availability of a reasonably accurate elevation information for many parts of the world was once very much limited. Dense forest, high mountain ranges etc. were remained unmapped, mainly because of the difficulty in getting to these places. Objective of the Shuttle Radar Topographic Mission (SRTM) was to create near global data set on land elevations, using radar images. The mission was headed by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA).

The space shuttle Endeavour was employed in the mission to carry the payloads to the space. The space shuttle Endeavour with the SRTM payloads was launched on 11th February 2000. The Endeavour orbited the Earth at an altitude of 233 km, with 59 deg. inclination, and the radar onboard the space shuttle was used to collect the images of the land surface. The mission was completed in 11 days. These radar images were interpreted to generate a high resolution elevation data, at a near global scale.

Radar system is advantageous over the optical systems as it can operate day and night, and in bad weather. Also, by using space-borne radar system for the mapping, the accessibility issues are eliminated. Thus in the SRTM, around 80% of the land areas were swiped using the radar and the digital elevation data was generated.

The near-global elevation data generated by the SRTM finds extensive applications in the areas of earth system sciences, hydrologic analyses, land use planning, communication system designing, and military purposes.

This lecture covers the details of the SRTM, and the near global SRTM elevation data.

2. Instruments onboard the payload of the SRTM

The SRTM instruments consisted of two antennas. One antenna was located at the bay of the space shuttle. A mast of 60 m length was connected to the main antenna truss and the second antenna was connected at the end of the mast as shown in Fig.1. The mast provided the baseline distance between the two antennas.

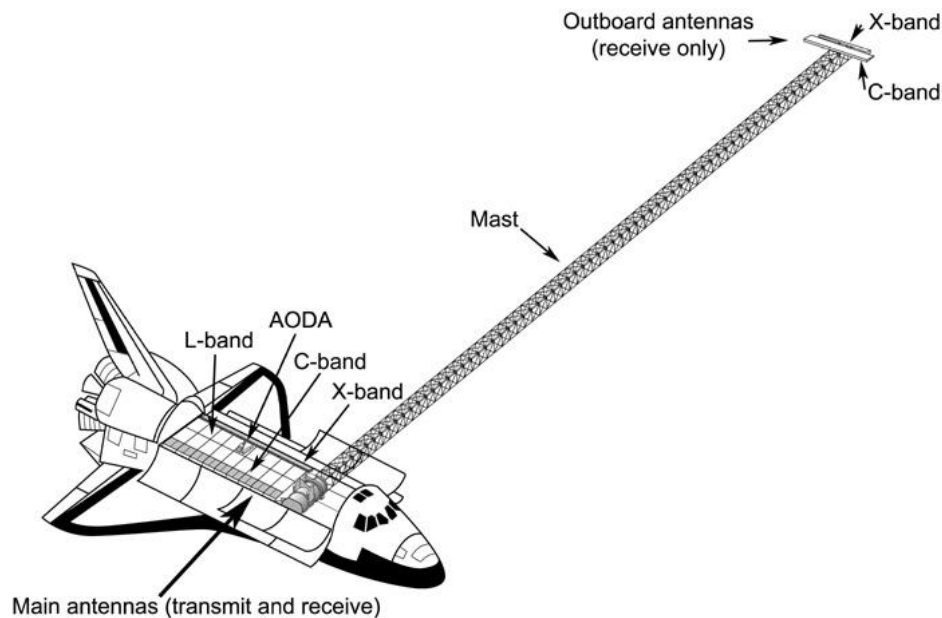


Figure 1. Schematic representation of the SRTM instruments

(Source: <http://www2.jpl.nasa.gov/srtm>)

2.1 Main antenna

The main antenna consisted of two antennas to work in two different wavelengths. The two microwave bands used in the SRTM were the C band and X band.

C-band Radar Antenna

The C-band antenna could transmit and receive radar signals of wavelength 5.6 centimeters. The swath width of the (width of the radar beam on Earth's surface) C-band antenna was 225 kilometers. C-band data was used to scan about 80% of the land surface of the Earth (between 60°N and 56°S) to produce near-global topographic map of the Earth.

X-band Radar Antenna

The X-band antenna was used to transmit and receive radar signals of wavelength 3 centimeters. Using the shorter wavelengths, X-band radar could achieve higher resolution compared to C-band radar. However, the swath width of the X-band radar was only 50 km. Therefore, the X-band radar could not achieve near global coverage during the mission.

2.2 The mast

The mast was used to maintain the baseline distance between the main antenna and the outboard antenna. The length of the mast was 60 m and was inclined at 45 deg. from the vertical.

2.3 Outboard antenna

The outboard antenna was connected to the end of the mast. It was used only to receive the radar signals scattered back from the land surface. No signal was transmitted from the outboard antenna.

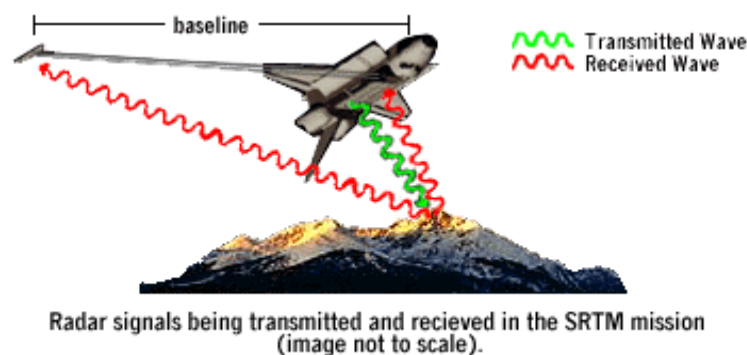


Figure 2. Radar signals transmitted and received in the SRTM mission

(Source: www.esru.strath.ac.uk)

The outboard antenna also contained two antennas: one was used to receive radar signals in the C-band, and the other in the X-band. Wavelengths of the C and X band signals were 5.6 cm and 3 cm, respectively.

3. How SRTM generates the elevation data

In SRTM, principle of radar interferometry was used to extract the elevation data.

In SRTM, space-borne, fixed baseline, single-pass interferometry was adopted, in which the signal was sent from a single source and the energy scattered back (radar return) was recorded simultaneously using two antennas placed at a fixed known distance apart.

The main antenna located at the bay of the space shuttle was used to send the radar signals. The radar return was recorded at both the main antenna and the outboard antenna (located at 60m away from the main antenna using the mast).

Fig.3 shows the schematic representation of the SRTM radar system employed for capturing the topographic information.

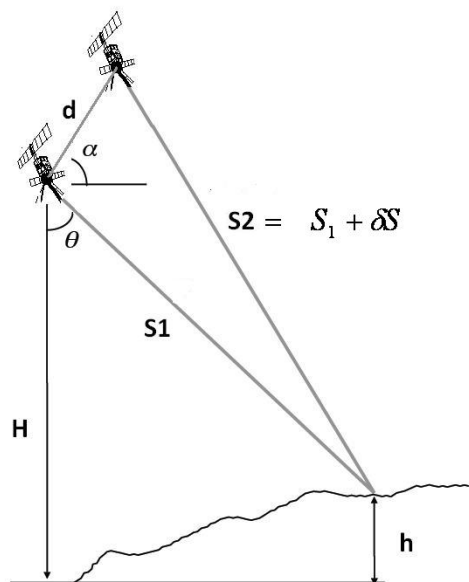


Figure 3. Schematic representation of the STRM imaging

The images recorded at the two antennas were combined to generate the interferogram (or the interference fringes). Since the two antennas were separated by a fixed distance, the radar returns from an object recorded at these two antennas differed in phase, depending upon the distance of the target from the radar antenna. The inteferogram was used to accurately calculate the phase difference between two signals for each point in the image.

Knowing the wavelength of the signal (which were 5.6 cm and 3cm for the C and X bands, respectively), fixed base length (which was 60m) and the phase difference, the slant range S of the object was calculated, by using the principles of trigonometry. Further, the elevation (h) of the target was calculated as shown below.

$$h = H - S_1 \cos(\theta)$$

Where, H is the height of the antenna from the ground level, which in this case is the altitude of the orbit (233 km). The parameter θ is the look angle of the radar signal.

4. Processes involved in the SRTM

Various steps involved in the generation of SRTM elevation data are shown in Fig.4.

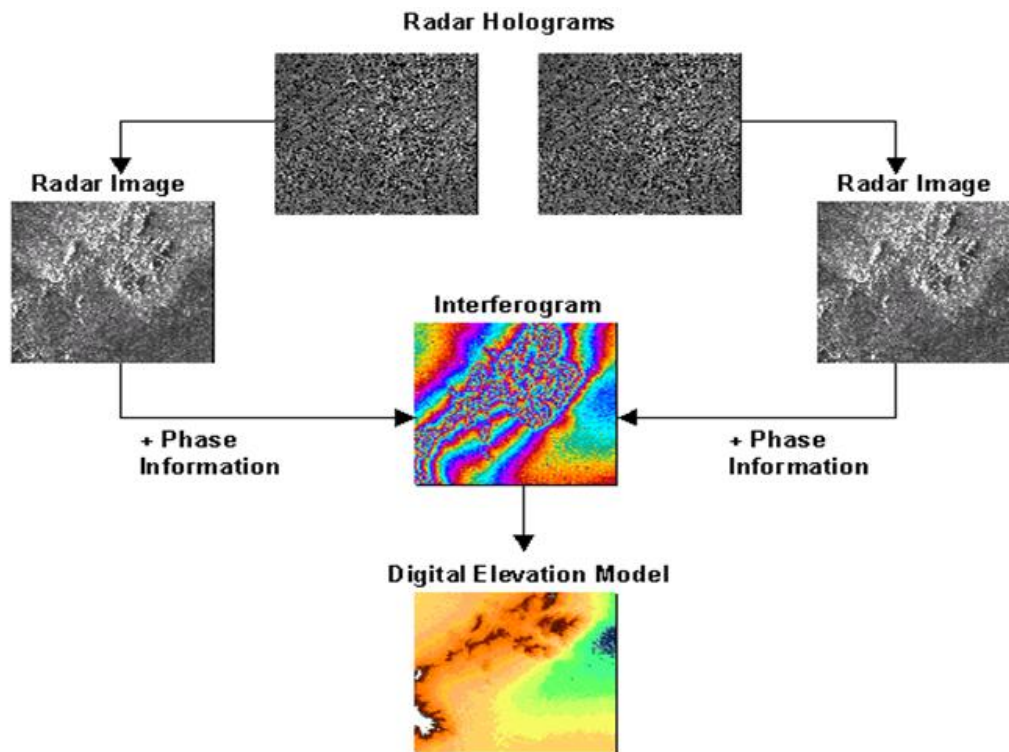


Figure 4. Steps involved in the SRTM elevation data generation

(Source: ces.iisc.ernet.in)

Two radar antennas were used to simultaneously capture the radar returns and the radar images or the radar holograms were created. The radar holograms recorded at the main antenna and the outboard antenna were combined to generate the interferogram (or the fringe

map), which displays bands of colors depending up on the phase difference (interferometric phase) between the signals received at the two antennas. The phase difference was then used to calculate the difference in the distance of the target from the two antennas, which was further used to estimate the height of the target.

5. SRTM elevation data details

SRTM digital elevation data was generated from radar signals using the principles of radar interferometry. This elevation data was then edited to fill small voids, remove spikes, delineate and flatten water bodies, and to improve the coastlines.

The C-band antennas were used to scan almost 80% of the land surface of the Earth (between 60°N and 56°S) to produce the near-global topographic map of the Earth at a spatial resolution of 1 arc-seconds. Due to the smaller swath with of the X-band antennas, near global coverage could not be achieved using the X-band.

Fig.5 and 6 show the coverage of C-band and X-band elevation data, respectively

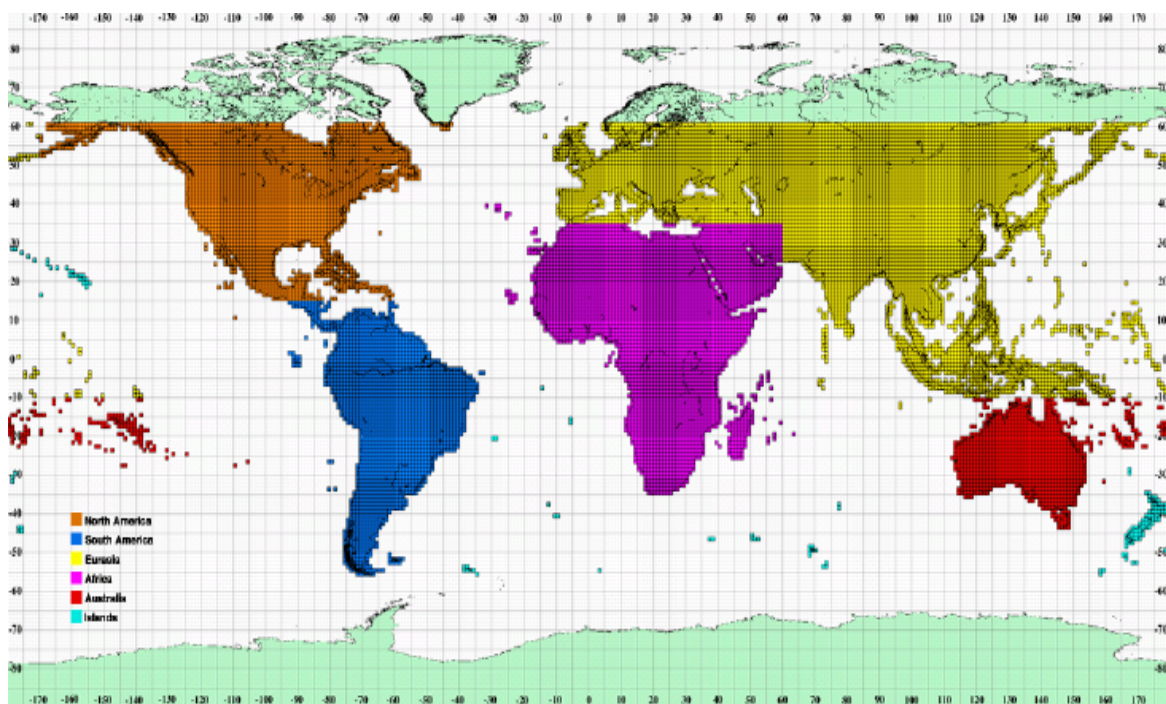


Figure 5. Coverage of the SRTM C-band elevation data (Source: <http://www2.jpl.nasa.gov>)

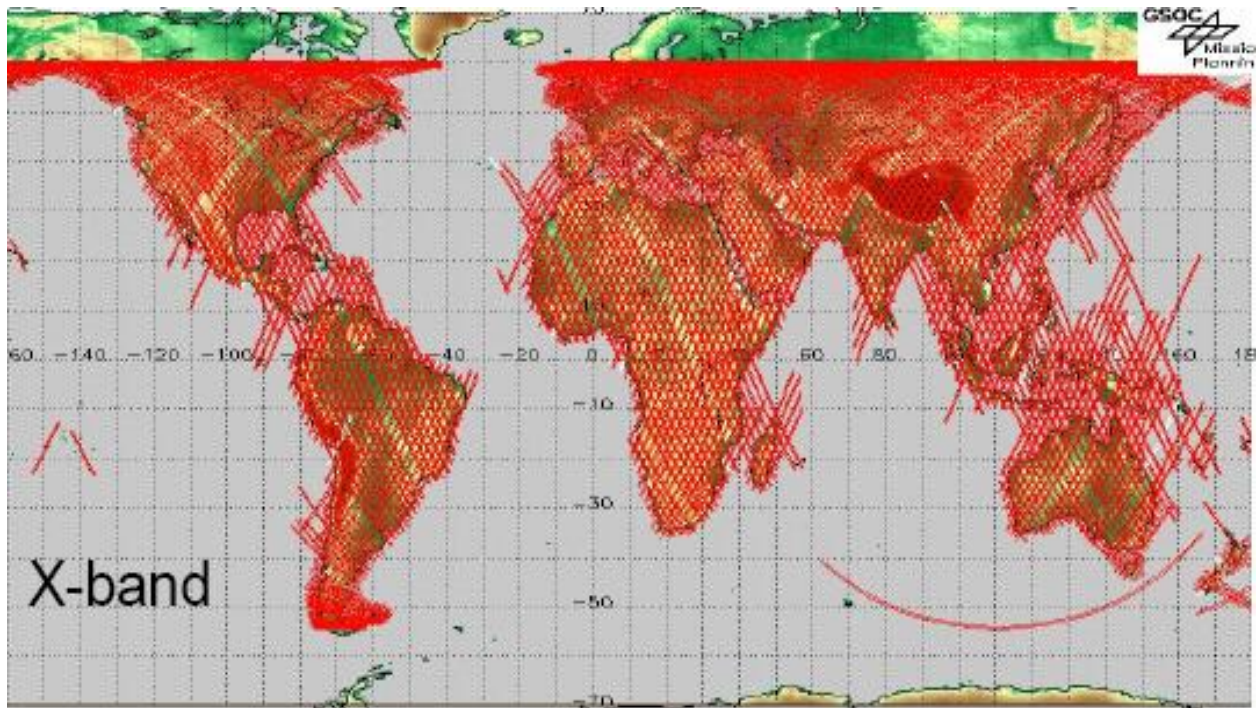


Figure 6. Coverage of the SRTM X-band elevation data (Source: <http://www2.jpl.nasa.gov>)

SRTM provides processed DEM at two different spatial resolutions, 1 arc-second (approximately 30 m) only for the United States and Australia, and reduced 3 arc-second (approximately 90 m) for 80% of the globe. The data can be obtained from the USGS Earth Explorer website (<http://earthexplorer.usgs.gov/>).

The SRTM elevation data is available in two formats.

- Digital Terrain Elevation Data (DTED): Each file contains regularly spaced grids containing the elevation information. This format can be directly used in the GIS platform.
- Band interleaved by line (BIL): In this format, the elevation data is available for regular grids, in binary format. A header file is used to describe the layout of the grids and the data format.

The publicly available SRTM DEM is geo-referenced using WGS84 datum. In the data set, unit of elevation is meters. The elevation data gives less than 16m accuracy in the absolute elevation and less than 10m accuracy in the relative vertical height, at 90% confidence level.

6. Practical Use of SRTM Data in the Tropics

In the study by Jarvis [<http://srtm.csi.cgiar.org/PDF/Jarvis4.pdf>] , a total of 5 case studies are being provided that analyse the quality, accuracy and usability of SRTM data. It was shown that SRTM DEM is by far a great improvement on the previously existing global DEM products like GTOPO30. Studies were also conducted to analyse the precision of SRTM data in the tropics using GPS data. SRTM DEM was found to be more accurate with errors systematically related to aspect. Data from GPS were compared with SRTM elevation information for a single catchment. The study concludes that at the catchment scale, high quality 1:10,000 cartographic maps produce a more detailed DEM than the 92-m SRTM DEM even though the vertical errors were similar. Case study results are provided which look at the problem of missing data holes in SRTM DEM. The errors introduced due to an interpolation technique for filling SRTM holes were shown. A detailed hydrological analysis of the case study region showed that overall, the interpolation technique for filling missing data holes perform quite well in representing the hydrological characteristics of the catchment.

Case study results present by Jarvis conclude that SRTM derived DEMs provide greater accuracy than TOPO DEMs. At the same time, this does not necessarily mean that it contains more details. It was suggested that 3-arc second SRTM DEMs failed to capture topographic features at the scales of 1:25,000 and below. Hence, presence of cartography with scales above 1:25,000 (eg., 1:50,000 and 1:100,000) implied usage of SRTM DEMs. For hydrological modeling application, if good quality cartography data of the scale 1:25,000 and below are available, digitizing and interpolating this cartographic data was deemed suitable for better results. This is because even though SRTM 3-arc second DEMs perform well for hydrological applications, these are on the margin of usability.