How is a digital elevation model made?

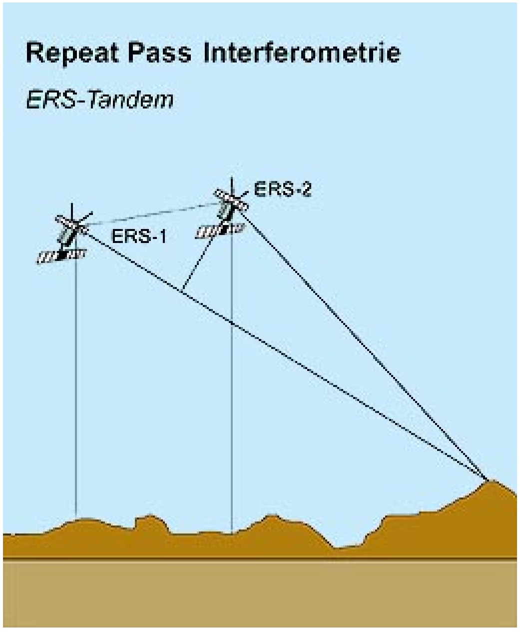
The Earth Observation Center (EOC) provides value-added products derived from remote sensing data for use in science as well as trade and industry. These value added products also include digital elevation models (DEM) derived from radar data using SAR interferometry methodology.

A **digital terrain model** (DTM) depicts the topographical surface of the ground. This can be contrasted to a **digital elevation model** (DEM), which also includes all the objects on that surface, such as vegetation and buildings.

In contrast to the two-dimensional representations typical of aerial or satellite images and topographical maps, DEMs have the advantage that land surface altitude information is depicted in terms of elevation values for each pixel. With this z-value a three-dimensional representation and analysis of the surface in question becomes possible.

Radar recording systems offer completely new possibilities to generate digital elevation models. Since they actively send out microwave signals they do not require an external light source, as do conventional optical recording systems which depend on sunlight. This means that data can be received independently of the time of day (or night). And because of the centimeter-range wavelengths utilized, the radiation can penetrate the atmosphere virtually uncorrupted, so radar systems can operate independently of the weather as well. This radar advantage is particularly useful for areas with high annual cloud coverage, such as near the equator.

The three-dimensional orientation of a ground pixel cannot be unambiguously determined with only one radar image. Similar to stereo images, two images must be recorded from different positions and then combined.

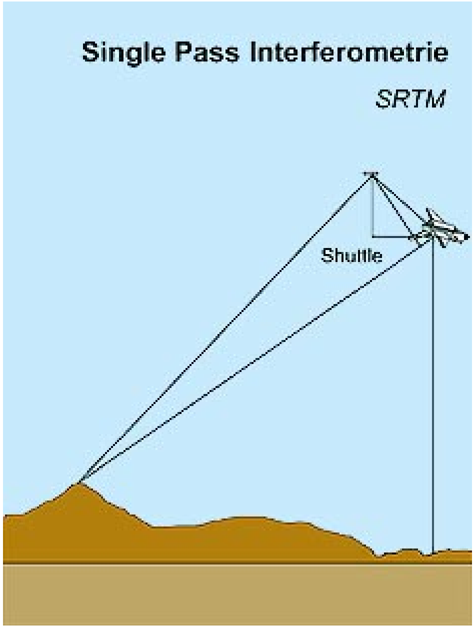


The two images can be recorded either at the same time using one transmit-receive antenna and a second receiver antenna placed some distance away (lower figure), or with a time lag by recording a second image during a second flight over the relevant area from a slightly different orbit (figure at left). The first case is called **single-pass interferometry**, the second **repeat-pass interferometry**.

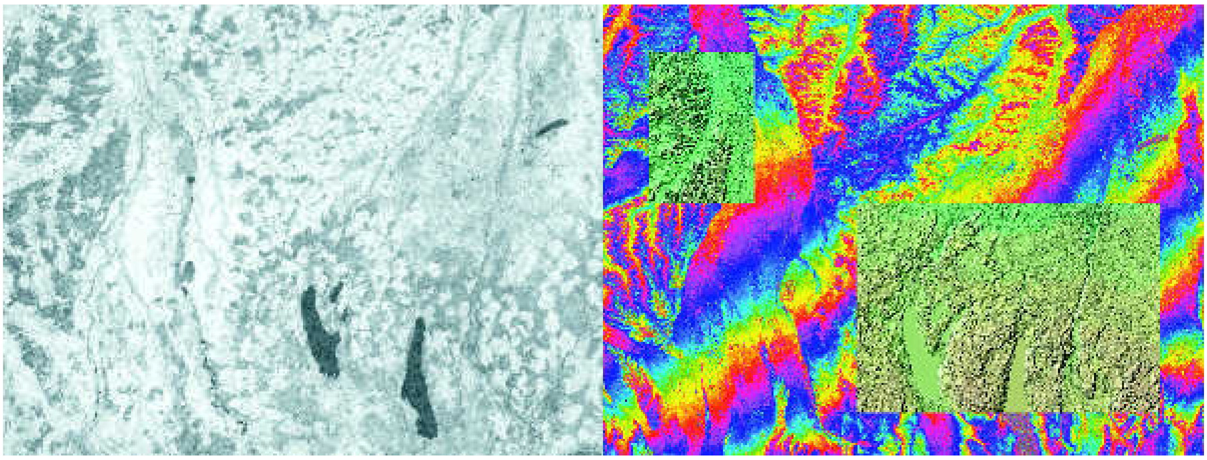
During so-called **tandem missions** (for example, ERS-1 and 2) the same ground location is recorded after a 24 hour interval with a typical spatial offset (baseline) of 80 to 300 meters.

Changes in wind or other atmospheric conditions as well as precipitation that take place during the interval can affect the correlation of the two recordings.

In the case of the Shuttle Radar Topography Mission (**SRTM**) the two recordings were simultaneously recorded by two antennas spatially separated by the 60 m mast. Correlation of the two recordings is established from the so-called coherence of the radar data, which is also an indication of the expected quality of the digital elevation model..



Interferometry



Coherence map at left and interferogram at right, the latter superimposed with two segments of a digital elevation model.

In the **coherence map** (left), for every pixel the similarities in both recordings are assigned grey values. Coherent areas are bright, areas with lower coherence, for example water bodies, are dark. It is not possible to derive altitude information for incoherent surfaces. Coherence maps are being successfully used to classify vegetation.

The steps involved in generating the **interferogram** (right) include precisely matching the two images and using filters for enhancement. Every color value represents a phase value between 0 and 2pi, whereby the colors continuously repeat and form stripes known as fringes. As can be seen, the ground topography can already be recognized in the interferogram. In the right image the equivalent digital elevation model has been superimposed on the interferogram in two places as an illustration, using an illuminated relief visualization color-coded for altitude. The phase differences are converted to altitude values, taking into account the flight orbit. Finally, these values are transformed into a map projection (UTM) or geographical coordinate system.