Enabling Vegetation Structure Estimation from SRTM Correlation Data

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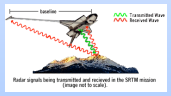
The Shuttle Radar Topography Mission (SRTM)

- SRTM was a NASA SAR mission that flew in 2000 on the Space Shuttle. The main objective of the mission was to measure the Earth's topography.
- For every location on earth between ± 60 degrees, SRTM acquired crossing paths of InSAR HH/VV data, with incidence angles between 20 and 60 degrees.
- One C-band SAR was in the cargo bay of the Shuttle
- 60 meters away, attached to a retractable mast, was another C-band antenna that could receive the reflected signal as well.

The complex imagery from each antenna was used to form an interferogram with a 60 m baseline.
From this interferogram, the SRTM DEM was created.



www.jpl.nasa.gov/srtm

SRTM data processing

- During ground processing, several products were generated, including:
  - The image (or radar brightness) data
  - The interferogram
  - The DEM
  - The correlation (at various polarizations and incidence angles) between the images
- The standard SRTM DEM products were formed by combining the terrain height from two acquired terrain height swaths (with resulting root 2 improvement in height accuracy) and projecting the result to geographic coordinates.
- About half the imaged ground pixels were imaged at both HH and VV polarizations, and most locations on earth were imaged at 2 look angles.

SRTM Products

- DTED-1 format terrain height data
- DTED-2 format terrain height data
- Terrain height error (THED)
- Ascending and descending ortho-rectified image mosaics (OIM)
- Seam/Hole Composite maps
- A vector shoreline database (the SRTM Water Body Dataset, SWBD)
  - Produced by NGA, which depicts all of the ocean coastlines, lake shorelines, and rivers.

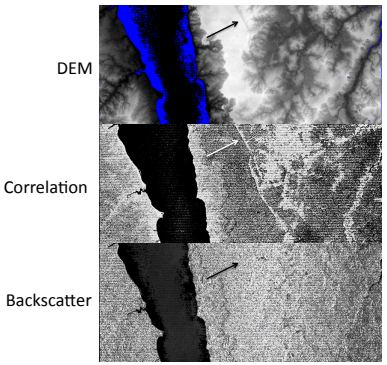
There were several other products produced during ground processing:

- Unprojected strip map format in the along-track projection (but projected to the SRTM derived topography) of the Space Shuttle ground tracks
- 30m x 30m terrain height product
- 30m x 30m terrain height error product
- 30m x 30m backscatter imagery
- 30m x 30m correlation product

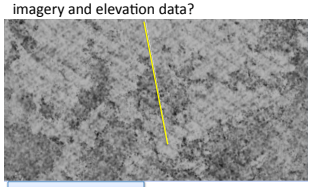
Why hasn't the SRTM correlation data been used to estimate vegetation structure?

- The data is corrupted by a systematic error
  - Magnitude of correlation varies (usually) roughly horizontally across image swath, of varying intensity
  - There was an extensive effort to examine the correlation data for this purpose, but the systematic errors prevented the product from achieving the desired accuracy
  - The backscatter data shows similar behavior
- The correlation data is bundled with 'unclassified but sensitive' 30m height data
  - By itself, the correlation data is not 'sensitive'
- Its existence has not been widely publicized
- It has not been archived in a user friendly way
  - Mike Kobrick's NASA MEASURES task will begin distributing some of these data files in the future.

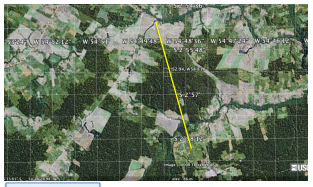
Tapajos Forest, Brazil



How does the correlation compare with imagery and elevation data?

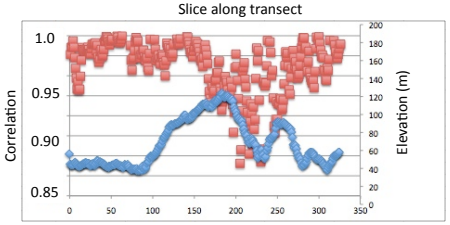


Average correlation



Google Earth

Slice along transect



Correlation
Elevation

Corrections to correlation data?

- The best way to eliminate these errors is during the initial ground processing of the SAR data
  - There was an unsuccessful attempt to correct this problem
  - Did not impact topography measurement
  - it is not currently feasible to reprocess the SRTM data
- Therefore, if we want to examine this data, these systematic errors will have to be corrected according to our knowledge of how this error manifests itself.
- image-processing techniques combined with appropriate interpolation between minimally affected pixels could be used to filter out some of the variations of the banding in the imagery (at the expense of resolution)

SRTM beams

- Beam 1: HH polarization, center look angle ~36 deg
- Beam 2: VV polarization, center look angle ~45 deg
- Beam 3: VV polarization, center look angle ~50 deg
- Beam 4: HH polarization, center look angle ~54 deg

Table 1-1. SRTM κ_z values and Standard Deviation of correlation values within each beam

SRTM Beam number	κ_z at middle of beam	Standard Deviation of correlation values over uniform target
1	.078	2.2%
2	.058	1.6%
3	.048	1.6%
4	.042	1.4%

Estimating vegetation structure from correlation data

$$\gamma_{obs} = \gamma_{vol} \cdot \gamma_{geom} \cdot \gamma_{th} \cdot \gamma_t$$

The observed correlation γ_{obs}

$$\gamma_{vol} = \frac{\int \sigma(z) e^{-jk_z z} dz}{\int \sigma(z) dz}$$

where $\sigma(z)$ is the radar backscatter as a function of the height, z. It can be seen that γ_{vol} is a function of k_z

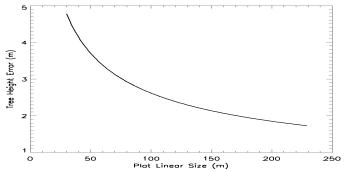
$$\kappa_z = \frac{4\pi B_\perp}{\lambda R \sin\theta}$$

Where λ is the wavelength
θ is the radar look angle
R is the range
$B_\perp$ is the perpendicular baseline
κ_z may be calculated for each image pixel for each SRTM beam.

$$\gamma_{vol} \sim \frac{\sin(\kappa_z h_v/2)}{\kappa_z h_v/2}$$

if $\sigma(z)$ is modeled as the radar back - scatter returned from a target with uniform scattering from the ground to height h_v

Vegetation height error versus linear resolution scale for SRTM values of κ_z



Assuming standard deviation of correlation over areas of presumed uniform vegetation structure is a measure of the error in correlation measurement

Further validation

- Assume the SRTM DEM is the elevation of a point somewhere within the forest canopy
- Subtraction of forest height (as estimated from the correlation data) from the SRTM DEM would therefore result in a bare earth DEM
- The statistics of the difference of this bare earth DEM from the National Elevation Dataset (NED) (a bare-earth DEM of the USA) will allow an analysis of systematic errors in the algorithm for vegetation height (within those areas covered by the NED) as well as allowing for an accuracy assessment of the vegetation height product.

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