Terrain correction and ortho-rectification

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Why geometric terrain correction?

- remove effects of side looking geometry of SAR images
- necessary step to allow geometric overlays of remotely sensed data from different sensors and/or geometries

Backward geocoding

**Backward geocoding**

- DEM coordinates are transformed into the earth-centered rotating (ECR) Cartesian coordinate system
  - orbit modeled by second degree polynomial
  - orbit grid point for each DEM grid point needs to satisfy SAR range equation and SAR Doppler equation
  - Radarsat orbits might need substantial refinement using tie points

**Forward geocoding**

- DEM coordinates (latitude, longitude, height) conversion into SAR image coordinates (line, sample)
  - solving the Doppler shift equation – relates relative velocity between point on the Earth and satellite to measured frequency shift of returned radar pulses
  - shift equation only dependent on time
  - equation solved using Newton-Raphson iteration

**Backward geocoding**

- solution non-linear system
  - iteration along orbit for each DEM pixel
  - iteration results (image time and range coordinates) are linearly transformed into coordinate system of slant range image
  - resampling assigns image grey value of slant range image to output pixel of geocoded image
  - depending on the relation between DEM and radar resolutions interpolation methods important
  - bilinear interpolation appropriate (Small et al., 1997)

**Forward geocoding**

- generation of simulated SAR image
  - using ephemeris data as input to satellite model
  - using DEM information for a given location as input to Earth model
  - backscatter values from simple backscatter model
  - results in simulated SAR image in real SAR image geometry
**Forward geocoding**

- correlation of real and simulated SAR image
  - matching of points on a regular grid
  - calculation of mapping function that relates points in simulated and real image
- geocoding using mapping function
  - geolocating SAR image while correcting for terrain related distortions

**Layover / Shadow masks**

- can be derived from DEM
- useful to provide information about problem areas
  - shadow regions – no information available
  - layover and foreshortening – reduced spatial resolution

**Ortho-rectification**

**Need**

- During data acquisition the image is geometrically distorted due to sensor, platform and object characteristics.
- Evaluation, exploitation and comparison of remotely sensed images requires geometrically corrected data.
Sources of distortions

- Earth rotation
- Earth curvature
- Platform variations
- Terrain relief

Earth Rotation

Earh Curvature

Platform Variations

- Displacements due to sensor orientation
Platform Variations

- Displacements due to the relationship between the sensor and the earth’s surface

Effects of Terrain Relief

- Displacements caused by relief differences are not systematic. They cannot be predicted.

Effects of Terrain Relief

- Height or elevation differences result in “relief displacement”

Steps in Geometric Correction

1. Original image
2. Co-registration
3. Transformation
4. Resampling / Interpolation
5. Geocoding
**Co-registration**

- Coregistration can therefore be
  - Image-to-image
  - Image-to-map
  - Image with measured GCPs.

**Image to image registration**

Master image  Slave image

**Image to map registration**

**Transformation**

- Transformation involves calculation of a mathematical function which fits the tie points optimally. This could be
  - First order polynomial (conformal, affine, bilinear)
  - Second order polynomial
  - Higher order polynomials

- Note: The term ‘georeferenced image’ is sometimes used for an image that has been transformed. At other times, the term is used synonymously with the term ‘geocoded image’
**Polynomial Order**

- 1st order: 6 parameters
  \[ x = a_0 + a_1x + a_2y \]
  \[ y = b_0 + b_1x + b_2y \]

- 2nd order: 12 parameters
  \[ x = a_0 + \cdots + a_3x^2 + a_4xy + a_5y^2 \]
  \[ y = b_0 + \cdots + b_3x^2 + b_4xy + b_5y^2 \]

**Conformal transformation**

- preservation of angles (shape)
- translation
- rotation
- scaling

**Affine transformation**

- preservation of parallels
- translation
- rotation
- scaling

**Bi-linear transformation**

- no preservation of parallels
- translation
- rotation
- scaling
2nd order transformation

- no preservation of parallels
- straight lines become curved
- translation
- rotation
- scaling

Resampling

- Resampling is required because pixels of a transformed or georeferenced image and a raster database do not coincide

Interpolation methods

- Nearest Neighbor
- Bi-linear Interpolation
- Cubic Convolution

Geocoding

- Geocoding involves transforming image coordinates (local) to map projected coordinates (real world).
**Polynomial Geometric Model**

- **Polynomial**
  - sensor independent
  - statistical principles
  - corrects image locally
  - no information on imaging geometry needed

**Sensor Geometric Model**

- **Sensor Model**
  - sensor specific
  - analytical reconstruction of image formation using orbit and sensor parameters
  - corrects image globally
  - small No. of GCP’s to improve parameters
  - DEM

**Comparison – Geometric Models**

- **Polynomial**
  - flat terrain
  - lower accuracy
  - many GCP’s
  - computationally less intensive
  - applicable to any type of sensor data

- **Sensor**
  - any type of terrain
  - high accuracy
  - few GCP’s
  - computationally intensive
  - specific model needed for each sensor data

**Combining radar and optical data – Example Brooks Range**
Terrain correction and ortho-rectification

That is what you have

Landsat ETM-7
ERS-1

Reference DEM

- shaded relief of the reference DEM
- average height used for geocoding
- used for terrain correction

Terrain correction

Geocoded image
Terrain corrected image

IHS transformation without TC

- Areas with correct reference height line up
- Areas with significant height differences show large offsets
IHS transformation with TC

- Things line up!
- Areas where mountains tops created severe layover can be corrected but not fully recovered

Bottom line

- need to terrain correct radar imagery in order to properly combine them with optical images
  - for moderately steep to steep terrain
  - on a case by case basis for low slopes