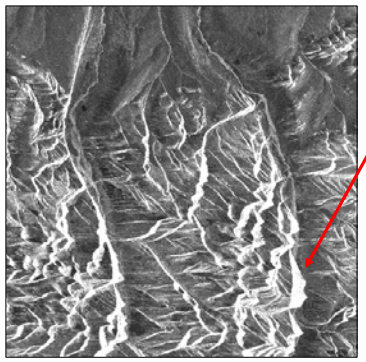
Terrain correction and ortho-rectification

Rüdiger Gens

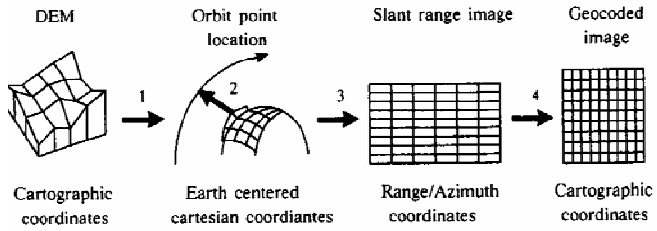
Terrain correction

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



Source: Bayer et al., 1991, Terrain influences in SAR backscatter and attempts to their correction. IEEE Transactions on Geoscience and Remote Sensing, 29(3):451-462.

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

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

- 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

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

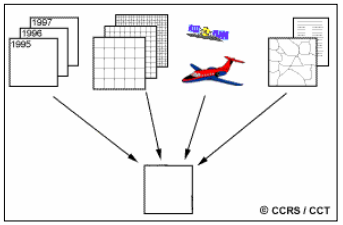
Layover / Shadow masks

- 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.

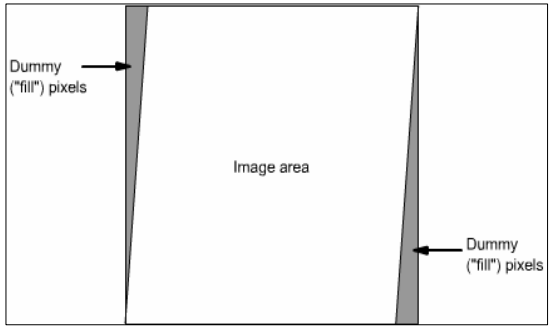


- Evaluation, exploitation and comparison of remotely sensed images requires geometrically corrected data.

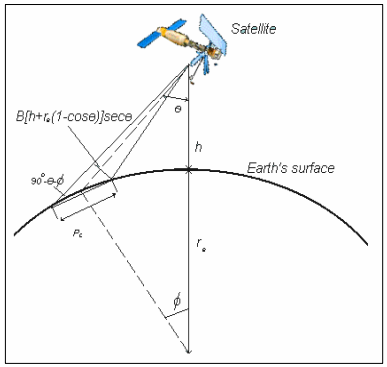
Sources of distortions

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

Earth Rotation

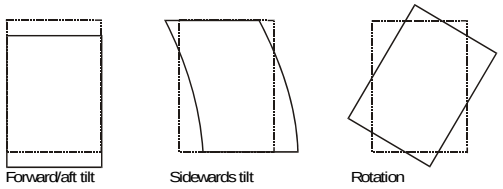


Earth Curvature



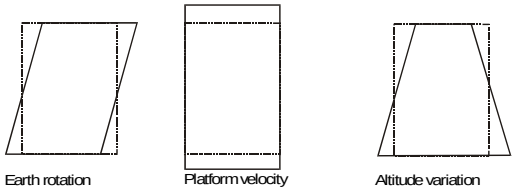
Platform Variations

- Displacements due to sensor orientation

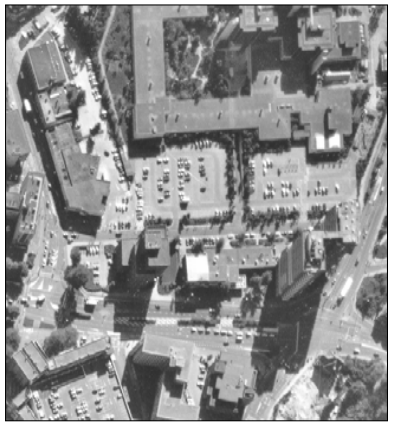


Platform Variations

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



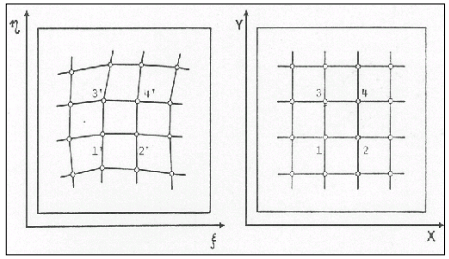
Effects of Terrain Relief



- Height or elevation differences result in "relief displacement"

Effects of Terrain Relief

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



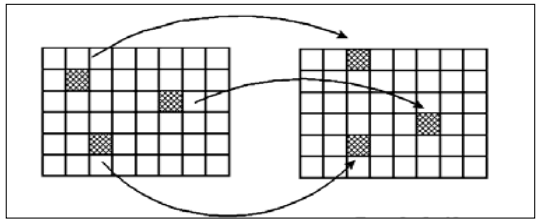
Steps in Geometric Correction

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

Co-registration

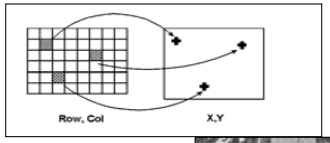
- Coregistration can therefore be
  - Image-to-image
  - Image-to-map
  - Image with measured GCPs.

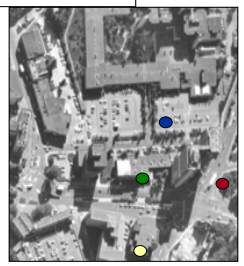
Image to image registration

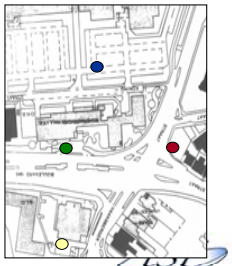


Master image Slave image

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’

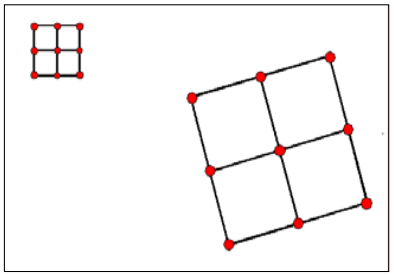
Polynomial Order

- 1st order: 6 parameters
  $x = a_0 + a_1x + a_2y$
  $y = b_0 + b_1x + b_2y$
- 2nd order: 12 parameters
  $x = a_0 + ... + a_3x^2 + a_4xy + a_5y^2$
  $y = b_0 + ... + b_3x^2 + b_4xy + b_5y^2$

Terrain correction and ortho-rectification

Conformal transformation

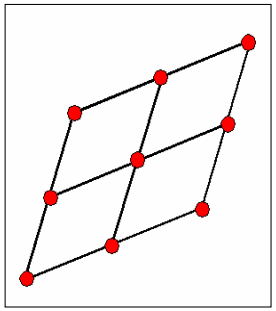
- preservation of angles (shape)
- translation
- rotation
- scaling



Terrain correction and ortho-rectification

Affine transformation

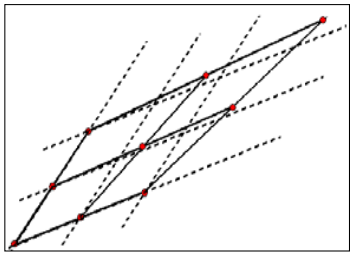
- preservation of parallels
- translation
- rotation
- scaling



Terrain correction and ortho-rectification

Bi-linear transformation

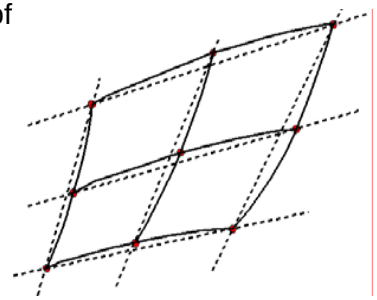
- no preservation of parallels translation
- rotation
- scaling



Terrain correction and ortho-rectification

2nd order transformation

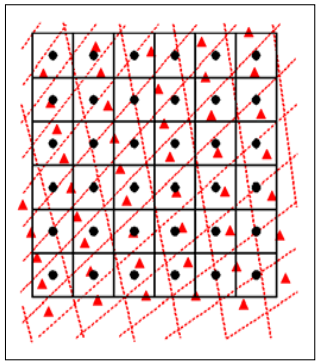
- no preservation of parallels
- straight lines become curved
- translation
- rotation
- scaling



Terrain correction and ortho-rectification

Resampling

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



Terrain correction and ortho-rectification

Interpolation methods

- Nearest Neighbor

- Bi-linear Interpolation

- Cubic Convolution

Terrain correction and ortho-rectification

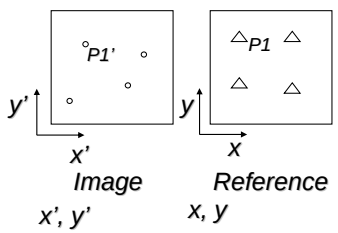
Geocoding

- Geocoding involves transforming image coordinates (local) to map projected coordinates (real world).

Terrain correction and ortho-rectification

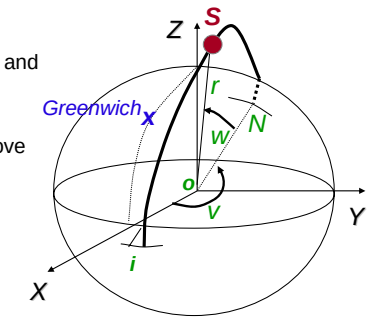
Polynomial Geometric Model

- 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

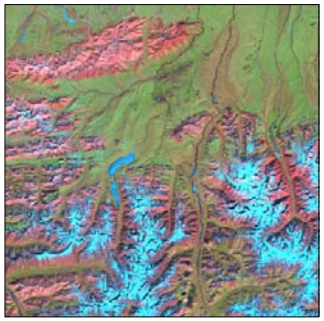


Comparison – Geometric Models

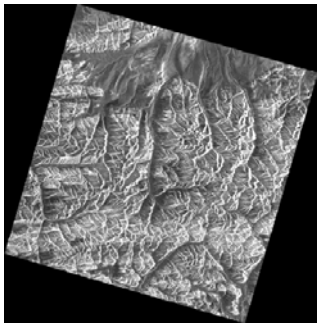
- Polynomial
  - flat terrain
  - lower accuracy
  - many GCP's
  - computationally less intensive
  - applicable to any type of sensor data
- Sensor
  - any type of terrain
  - high accuracy
  - few GCP's
  - computationally intensive
  - specific model needed for each sensor data

Combining radar and optical data – Example Brooks Range

That is what you have

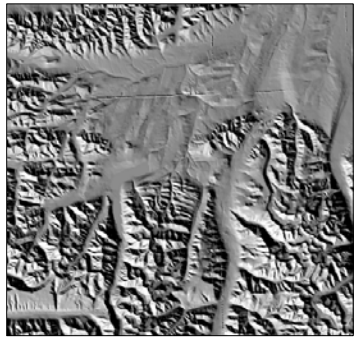


Landsat ETM-7



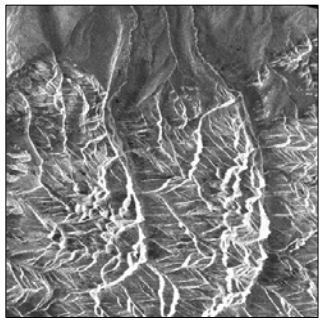
ERS-1

Reference DEM

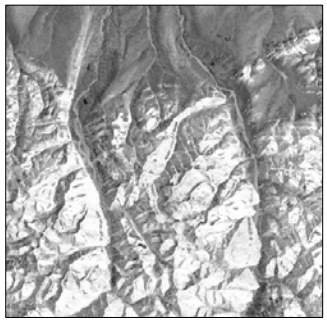


- shaded relief of the reference DEM
- average height used for geocoding
- used for terrain correction

Terrain correction

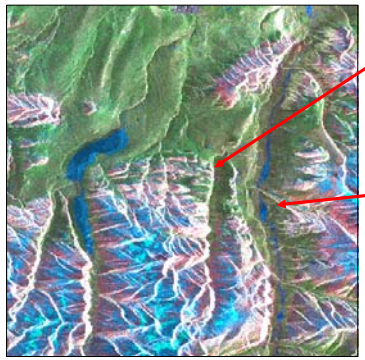


Geocoded image



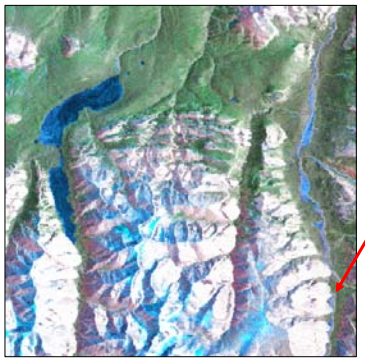
Terrain corrected image

IHS transformation without TC



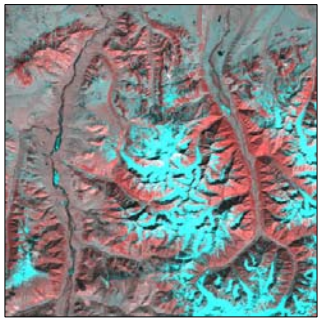
- Areas with correct reference height line up
- Areas with significant height differences show large offsets

IHS transformation with TC

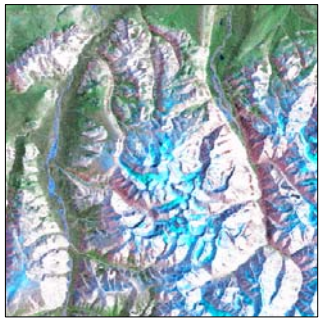


- Things line up !
- Areas where mountains tops created severe layover can be corrected but not fully recovered

Combination – more information



Optical image



Optical + radar combined

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