Terrain correction of SAR imagery

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Outline

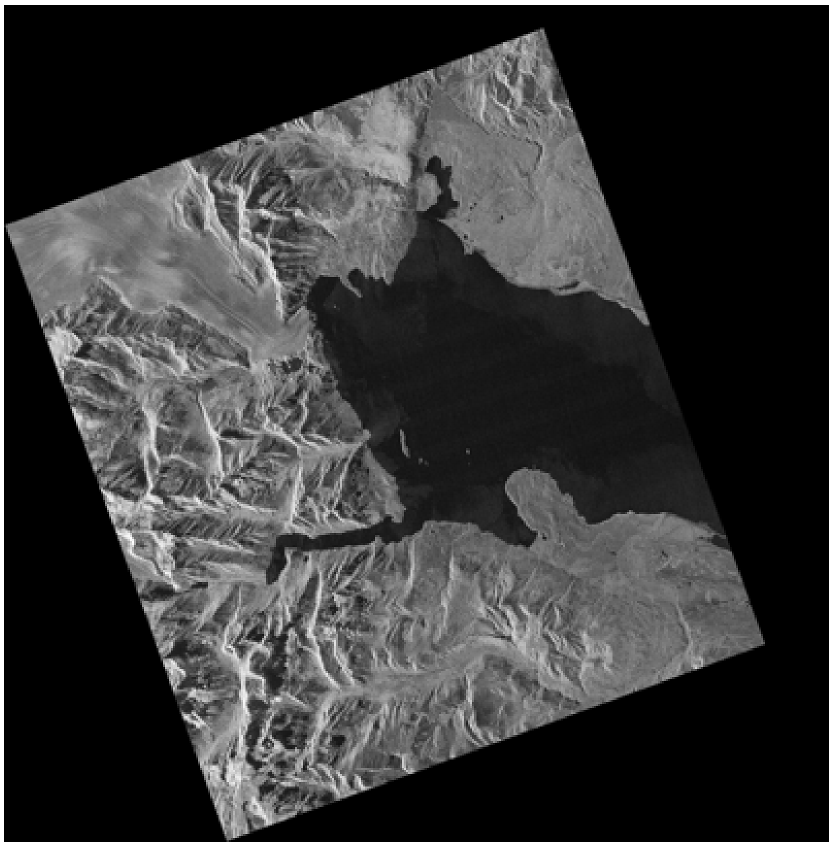
- various geocoding levels
  - geocoded ellipsoid corrected (GEC)
  - geocoded terrain corrected (GTC)
  - radiometric terrain corrected (RTC)
- geometric terrain correction
- radiometric terrain correction
- composites

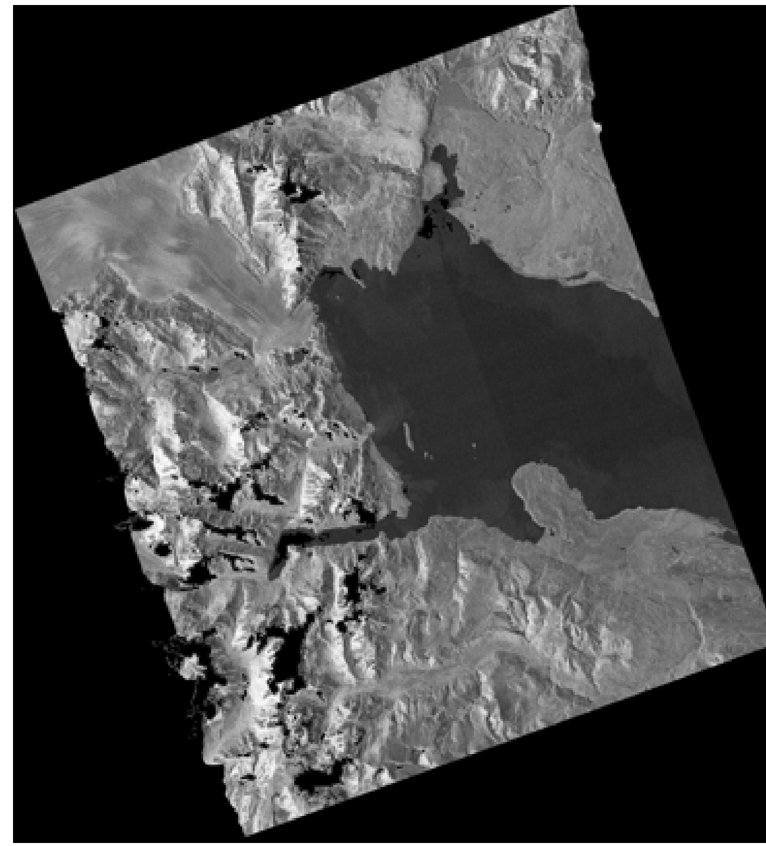
Why geometric terrain correction ?

- necessary step to allow geometric overlays of remotely sensed data from different sensors and/or geometries

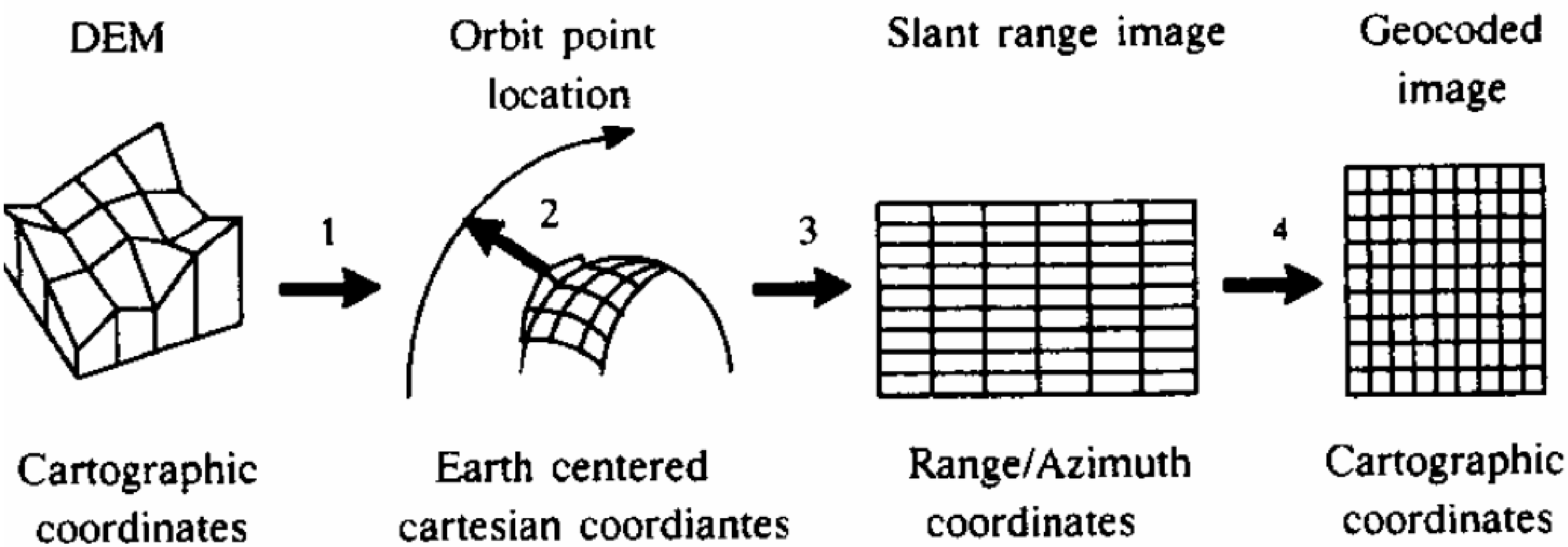
Why geometric terrain correction ?

Terrain correction of SAR imagery





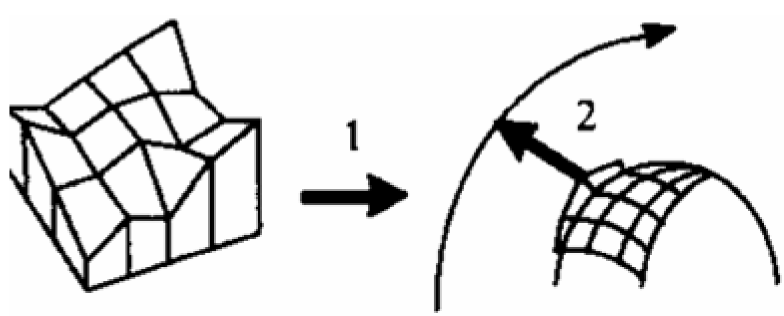
Backward geocoding



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.

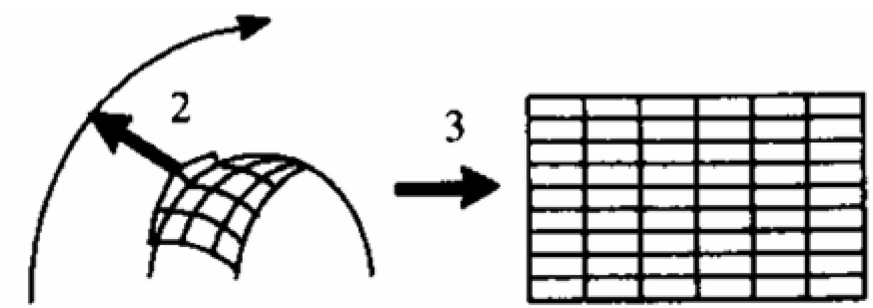
Backward geocoding

- 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



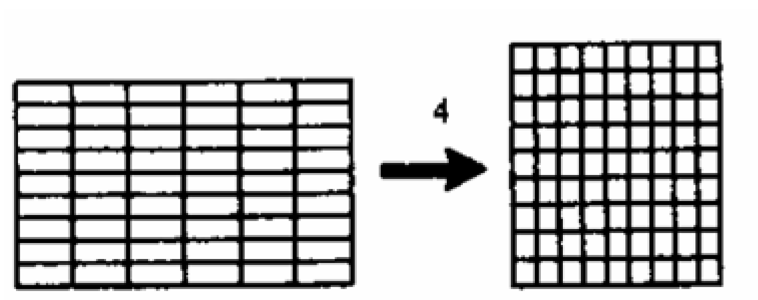
Backward geocoding

- 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



Backward geocoding

- 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

Why radiometric terrain correction ?

- some SAR applications require absolute radiometric calibration accurate to within 1 dB
  - e.g. biomass estimation

→requires generalization of many assumptions widely made in the SAR literature
  - radar equation
  - area effect

Processor corrections

- cross-track radiometric correction generally applied to ground range products
  - elevation antenna pattern
  - range spreading loss

Radar equation

$$\overline{P}_r = \frac{\lambda^2}{(4\pi)^3} \cdot \int_{Area} \frac{P_t \, G^2 \, \sigma^0}{R^4} \, dA$$

- received power P_r
- transmitted power P_t
- radar wavelength λ
- two-way antenna gain G^2
- slant range R
- backscatter coefficient (ground range) σ^0

Radar equation

$$\overline{P}_r = \frac{\lambda^2}{(4\pi)^3} \cdot \int_{\text{Area}} \frac{P_t\, G^2\, \sigma^0}{R^4}\, dA$$

- integrates over area illuminated within a radar resolution cell
- without DEM available antenna gain usually treated by SAR processors as locally constant
- simplification by assuming the illuminated area is determined by local DEM slope alone
→ does not account for geometric distortions

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Area effect

- local incidence angle models fail
  - do not into account the non-homomorphic (many-to-one) nature of relationship between the range-Doppler geometry of SAR images and that of a map projection
  - terrain variations cause multiple DEM grid points to coincide at a singular radar geometry grid location, and vice-versa

Area effect

- rough topography
  - fore-slopes are subject to foreshortening and layover → lower local image resolution
  - back-slopes have better local image resolution than on a plain

→need for local area estimates based on DEM simulations rather than ellipsoid models

Antenna Gain Pattern (AGP)

- antenna gain pattern
  - modeled using Earth ellipsoid
  - compensation applied before image generation
- ellipsoid-based compensation needs to be reversed before terrain-dependent AGP compensation can be applied

Terrain corrected composites

- combining ascending and descending data
- multiple contributions have weights according to their local resolution

Current ‘terrcorr' implementation

- forward geocoding approach
- no mosaicking capabilities for larger areas
- no radiometric terrain correction
- requires level one imagery
  - area of interest issue
  - no level zero input capability

Conclusions

- two different approaches to geometric terrain correction
  - backward geocoding
  - forward geocoding
- radiometric terrain correction possible on various levels of effort
- compositing the way to improve radiometric quality
  - comparable to DEM generation approach