SAR Interferometry

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Outline

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- What does InSAR do?
- Why does InSAR work?
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  - Phase unwrapping
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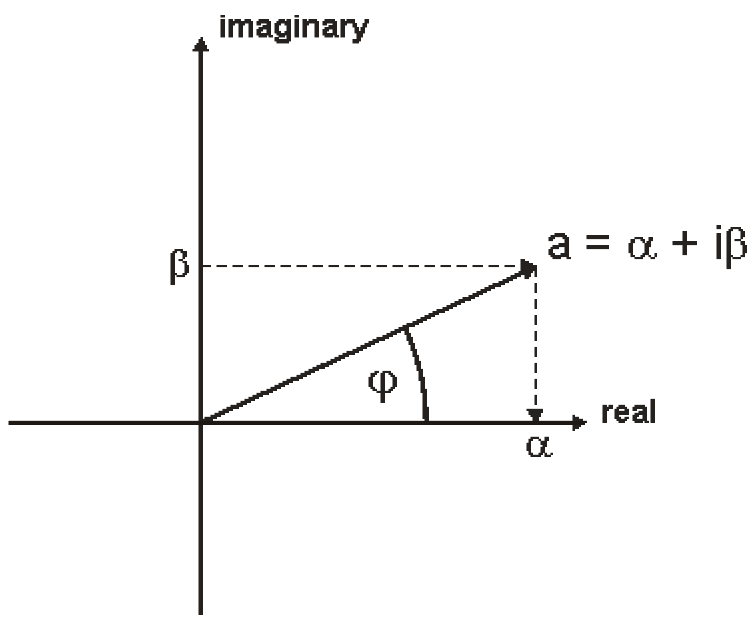
  - Geocoding
- Applications

Relevant terms



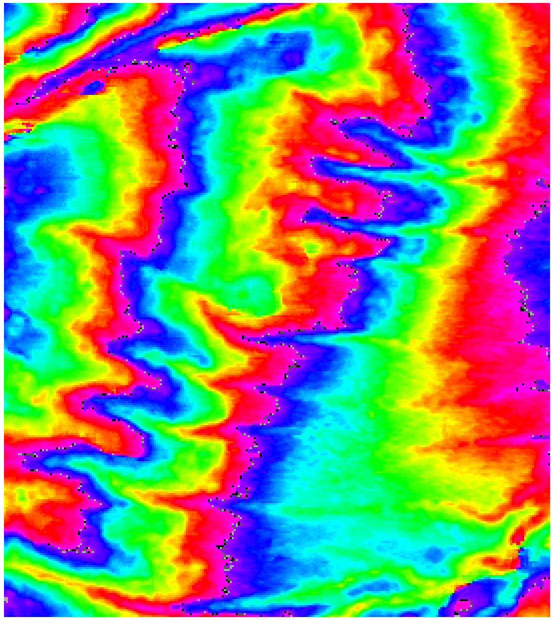
- amplitude
  - measure of the strength of the signal
- phase
  - angle of a complex number

Relevant terms

- baseline
  - separation between the two antenna positions either mounted on an aircraft or realized by two repeating satellite orbits

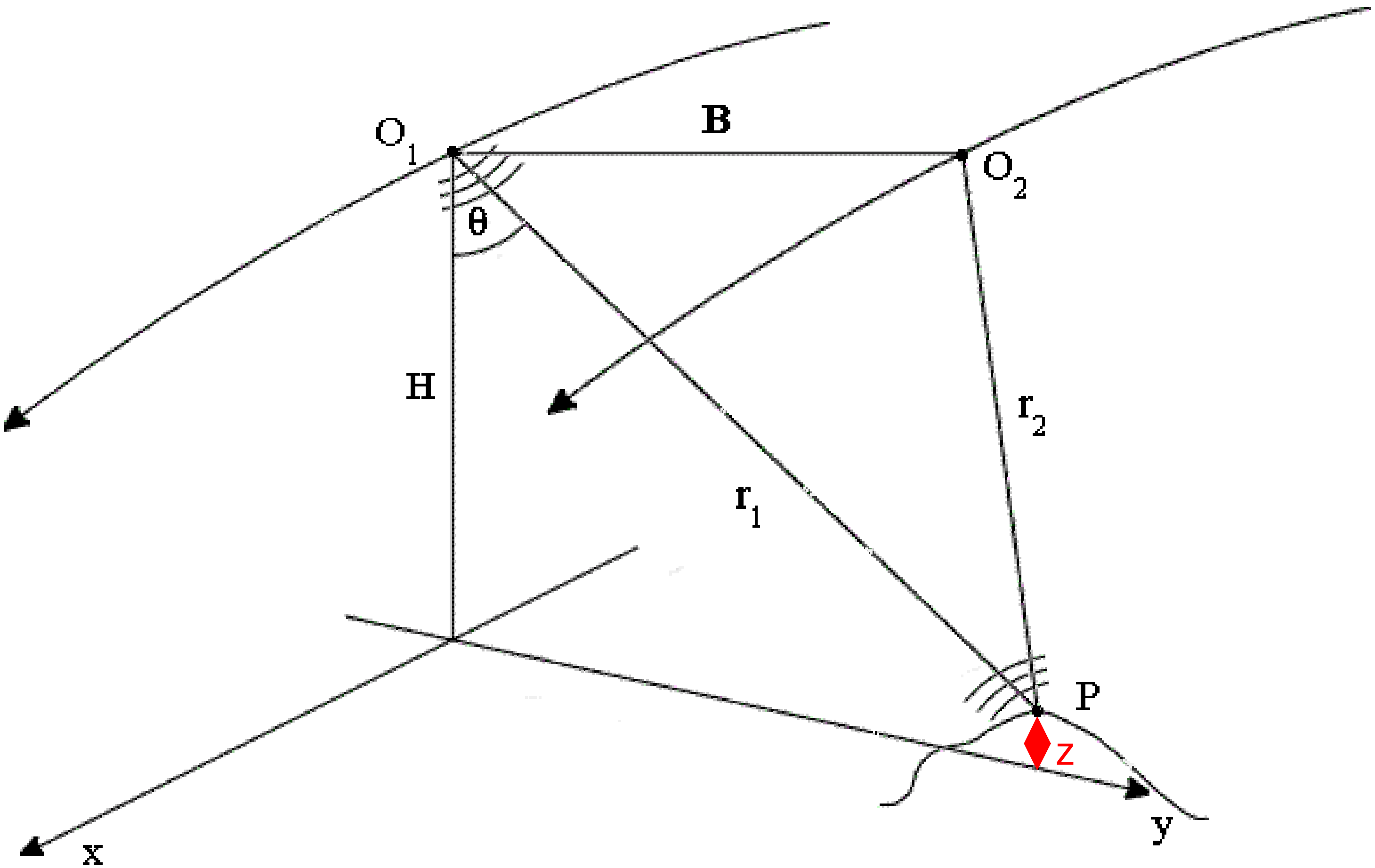
Source: Gens and van Genderen, IJRS, 1996

Relevant terms



- fringe
  - represents the whole range of the phase in an interferogram from 0 to 2π in a full color cycle

Geometry of SAR interferometry



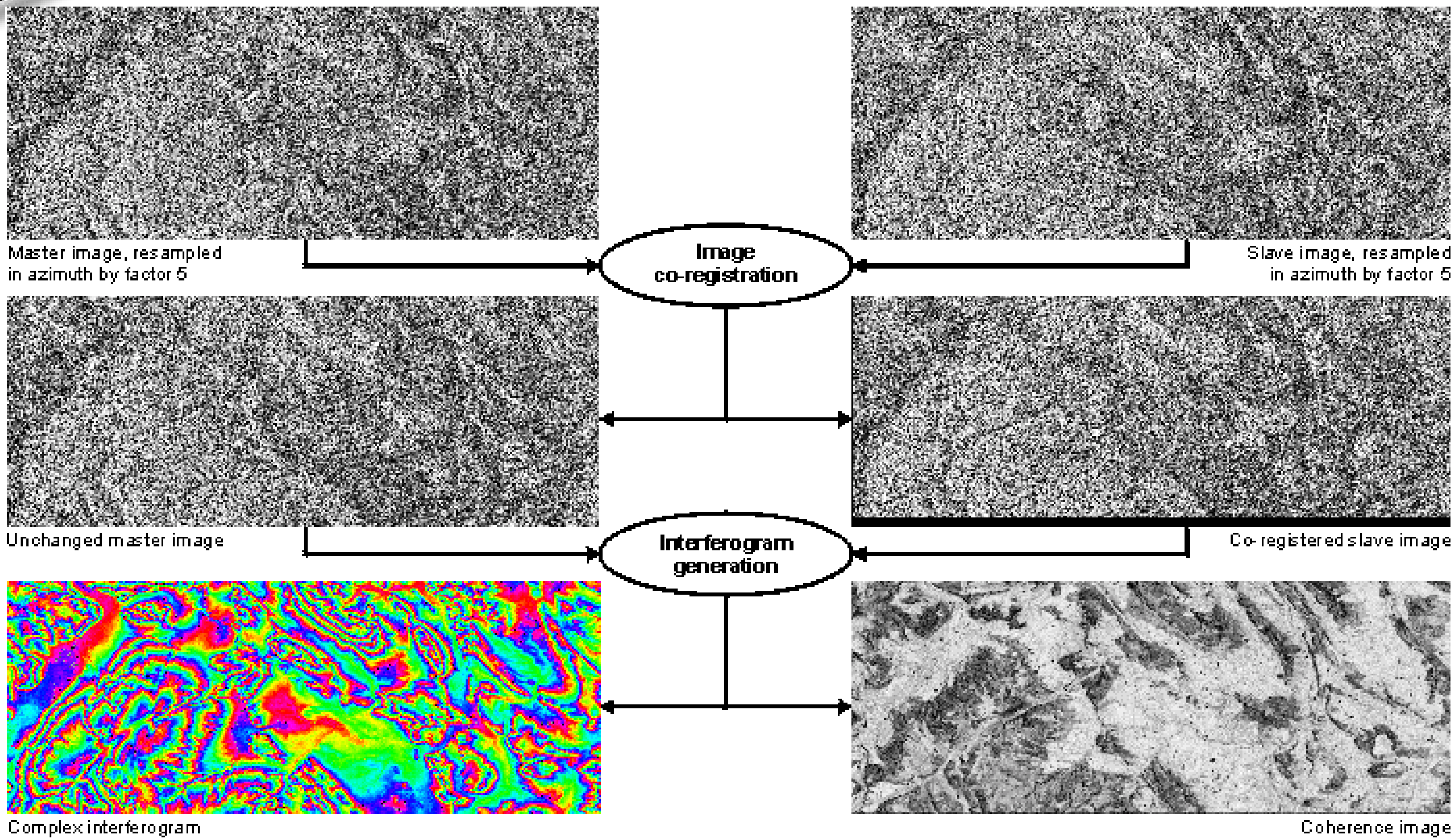
What does InSAR do?

- extracting three-dimensional information out of a radar image pair covering the same area
  - digital elevation model
  - change detection

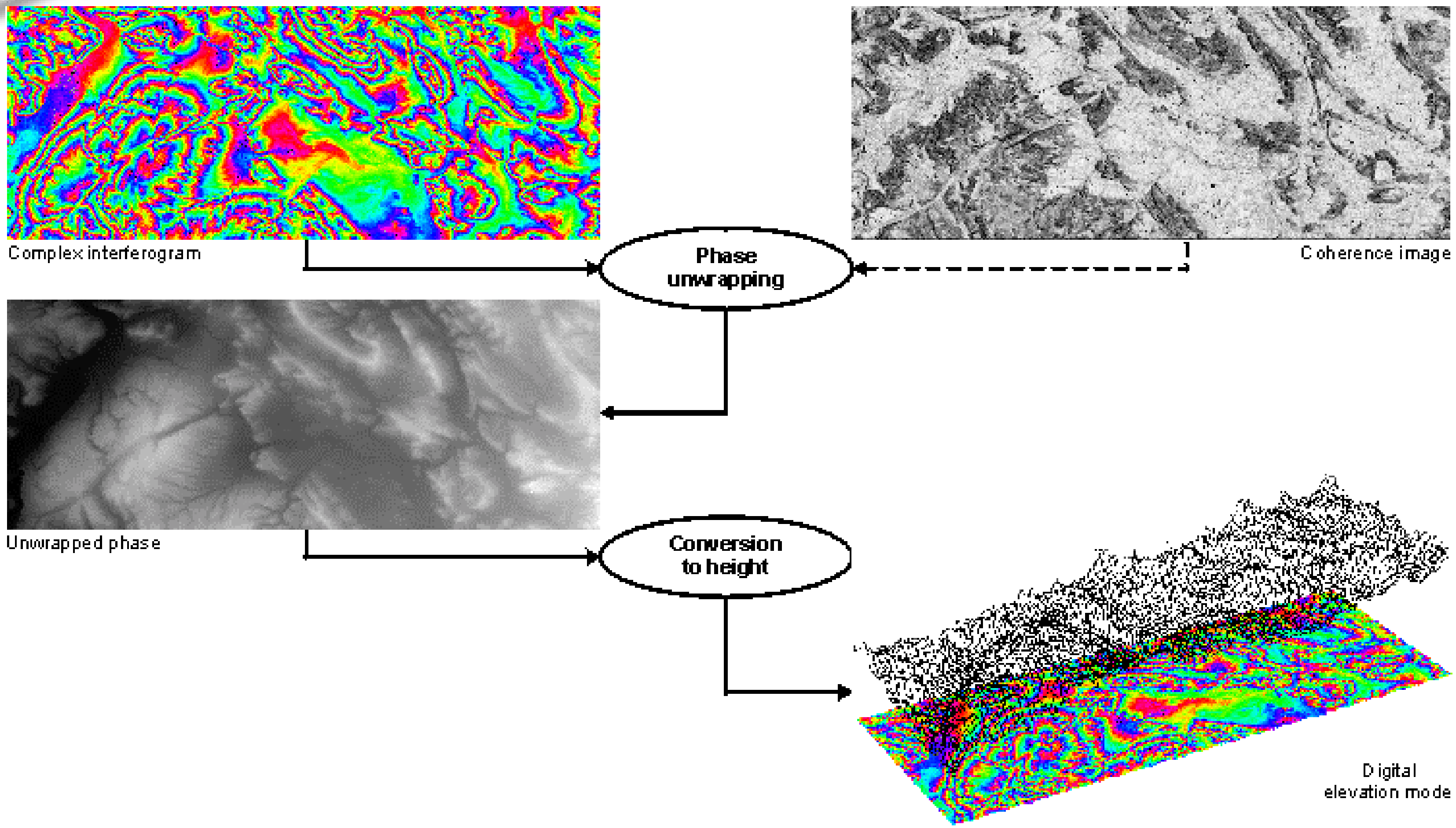
Why does InSAR work?

- coherent signal
  - single frequency and phase
- same geometry covering the same area from slightly different position in space

Processing chain



Processing chain



Data sets

- satellite data
  - ERS-1, ERS-2, RADARSAT-1, ENVISAT (C-band)
  - JERS-1 (L-band)
- airborne data
  - AirSAR, TOPSAR (research)
  - E-SAR, DOSAR, Star3i (commercial)
- shuttle
  - SIR-C / X-SAR mission (NASA + DLR)
  - Shuttle Radar Topography Mission (SRTM)

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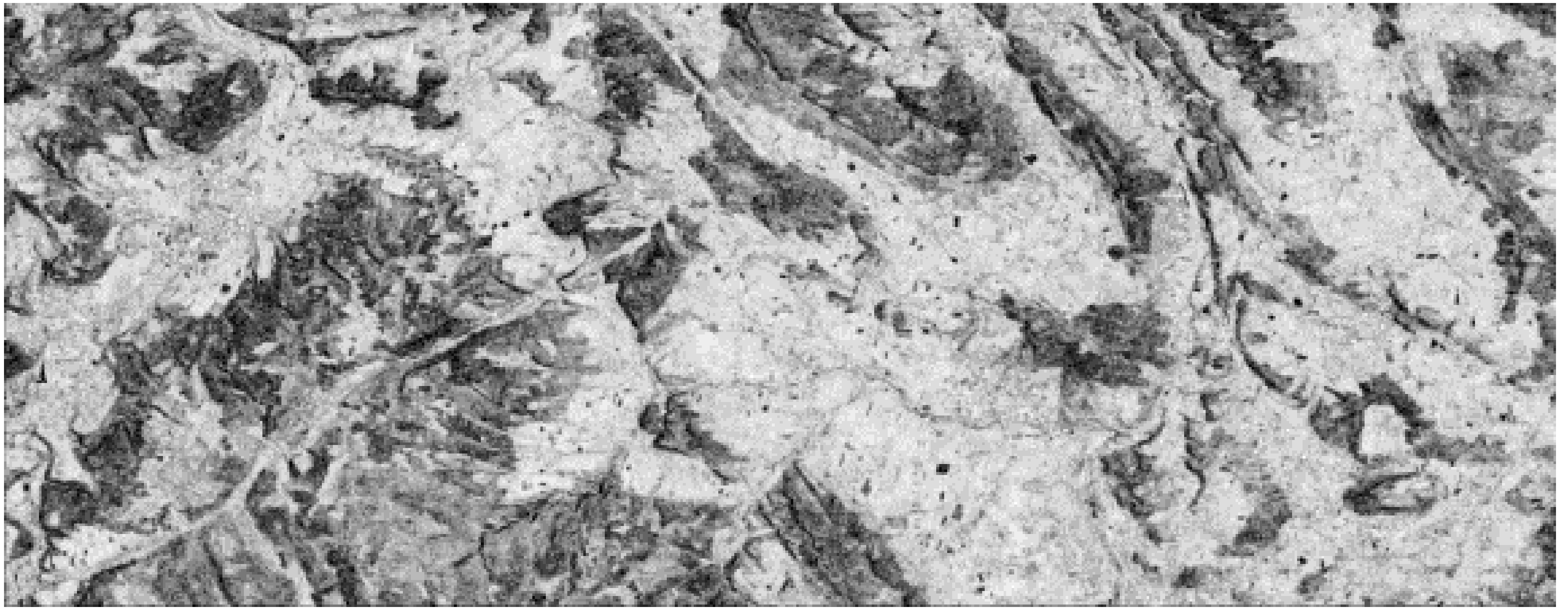
Coregistration

- alignment of master and slave image
- trade off between processing time and accuracy of technique applied
- coarse coregistration
  - matching images on a pixel level (shift in x and y)
- fine coregistration
  - sub-pixel alignment of images
  - large variety of techniques

Coregistration

- quality requirement to avoid phase errors
  $\rightarrow$ ⅛ of a pixel
- interpolation method
  - nearest neighbor, bilinear, cubic splines, sinc
- quality measure: coherence

Coherence image



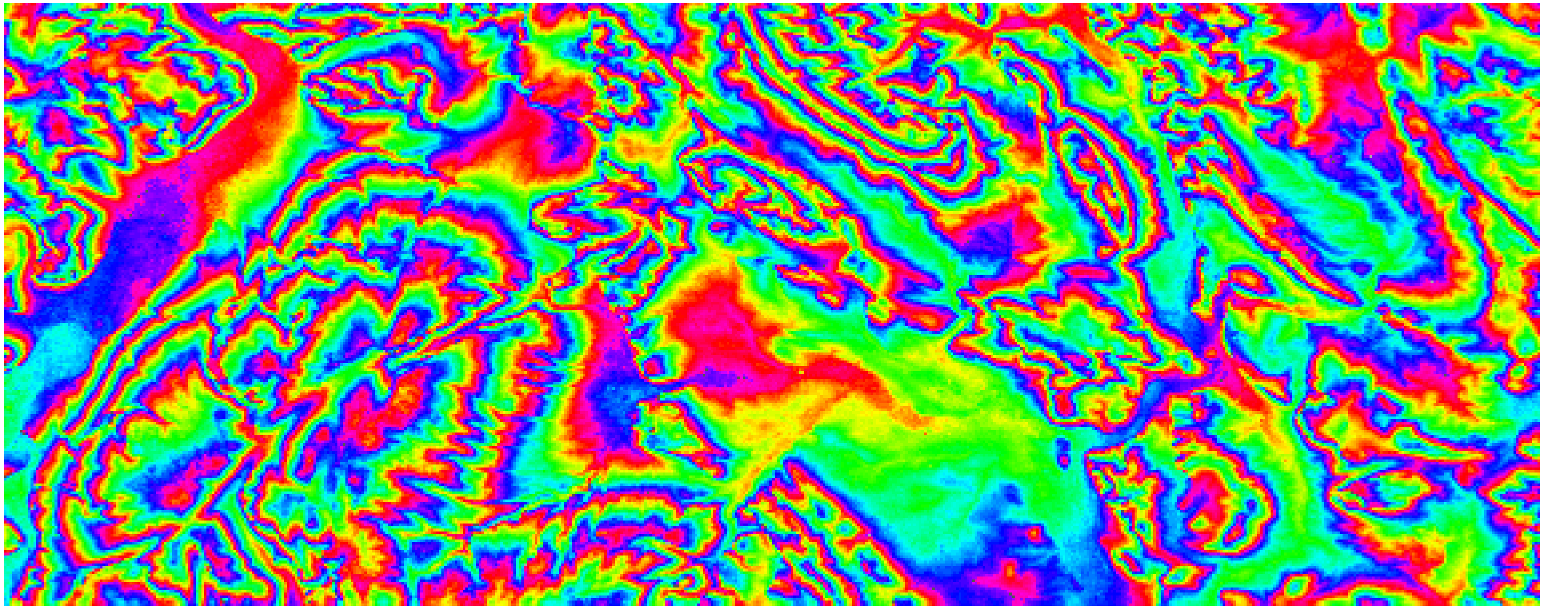
- measure for the correlation of corresponding signals
- ranges from 0 to 1

Interferogram generation

- complex multiplication of the two images
- corresponding amplitudes have to be averaged
- corresponding phases have to be differenced at each point in the image

  $\rightarrow$ phase difference related to height
- multilooking of interferogram

Interferogram



Phase unwrapping

- looking for the correct integer number of phase cycles that needs to be added to each phase measurement to obtain the correct slant range distance
- absolute phase is wrapped into the interval $(-\pi,+\pi] \rightarrow$ ambiguity problem
- solving ambiguity referred to as phase unwrapping

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Phase unwrapping

- no standard procedure to solve the phase unwrapping problem
- large variety of algorithms developed
- generally trade off between accuracy of solution and computational requirements
- two types of strategy to solve the phase unwrapping problem
  - path-following methods (local approach)
  - minimum-norm methods (global approach)

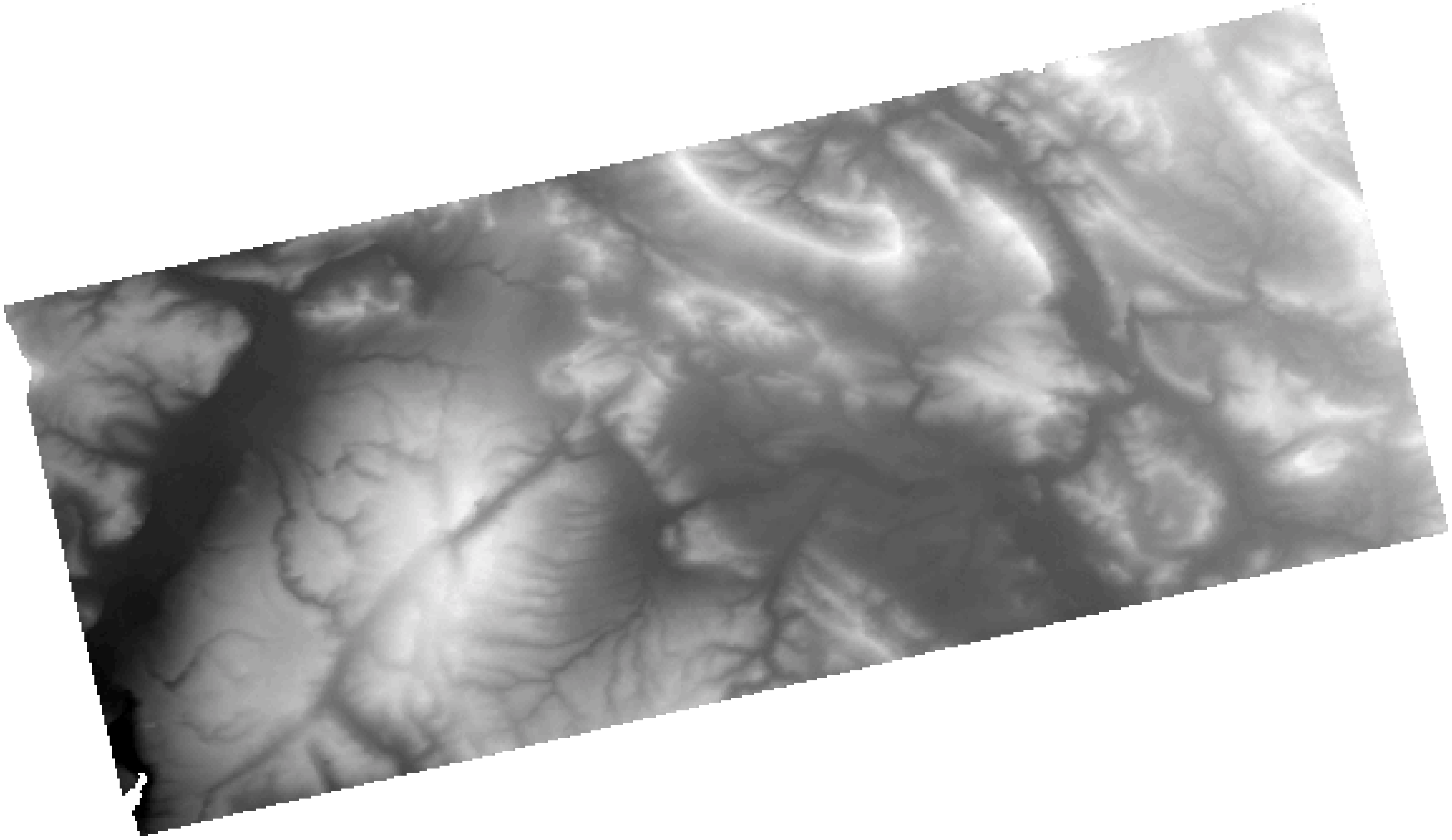
Phase unwrapping

- ways of simplifying the problem
  - filtering the phase before unwrapping
  - removing topographic phase before unwrapping
    $\rightarrow$ requires reference DEM
  - choice of geometry: short baseline

Conversion phase to height

- adding of topographic phase (in case removed before phase unwrapping)
- creation of the elevation map
- estimating an error map based on coherence image, baseline and unwrapped phase
- mapping from slant range to ground range geometry

Digital elevation model



Geocoding

- defines the transformation between local coordinate system and global Cartesian coordinates
- two different ways of implementation
  - Doppler frequency calculated on DEM positions and satellite orbit (requires reference DEM)
  - refinement of baseline and imaging geometry (no reference DEM required)

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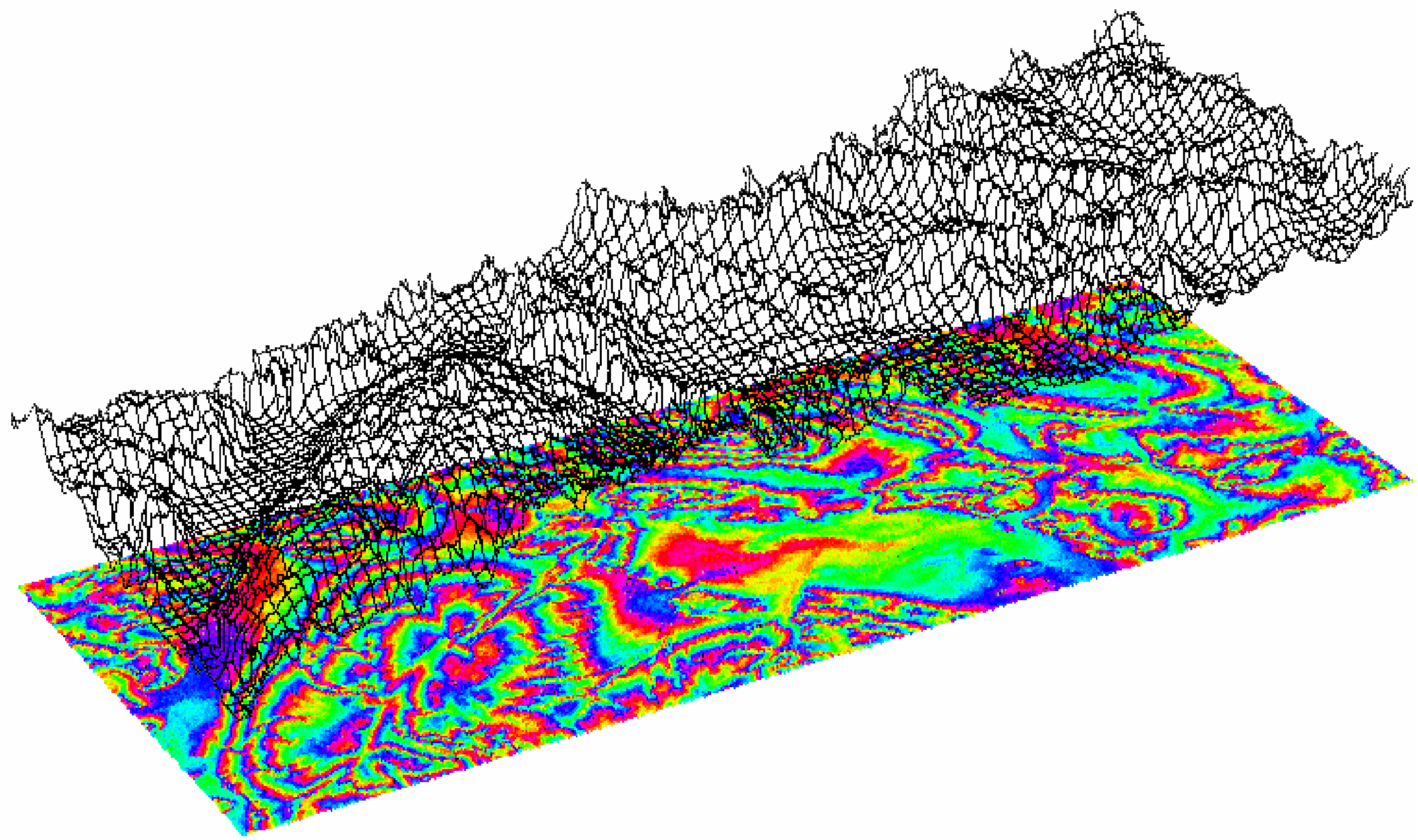
Digital elevation model



Interferometric techniques

- across-track interferometry
  - regular airborne geometry
- along-track interferometry
  - airborne geometry
  - monitoring ocean currents or other moving objects
- repeat-pass interferometry
  - usually spaceborne
- differential interferometry
  - change detection

Differential interferogram

- change detection: measurement of small-scale movements in the vertical direction
- displacement measured is not vertical, but along the viewing direction
- *relative* accuracy of the order of a few centimetres or even less vs. *absolute* accuracy of digital elevation models of about 10-15 meters (for ERS data)

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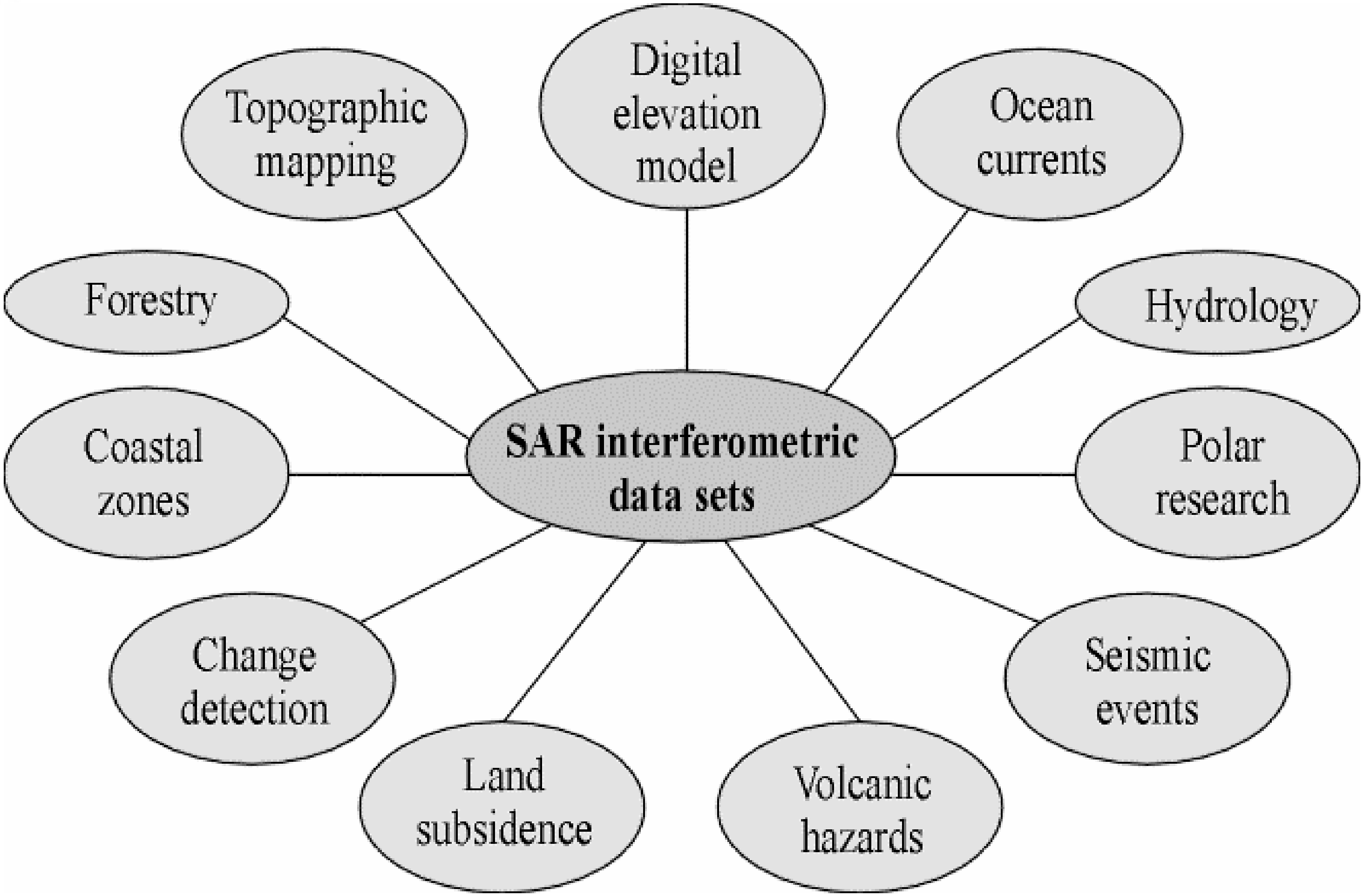
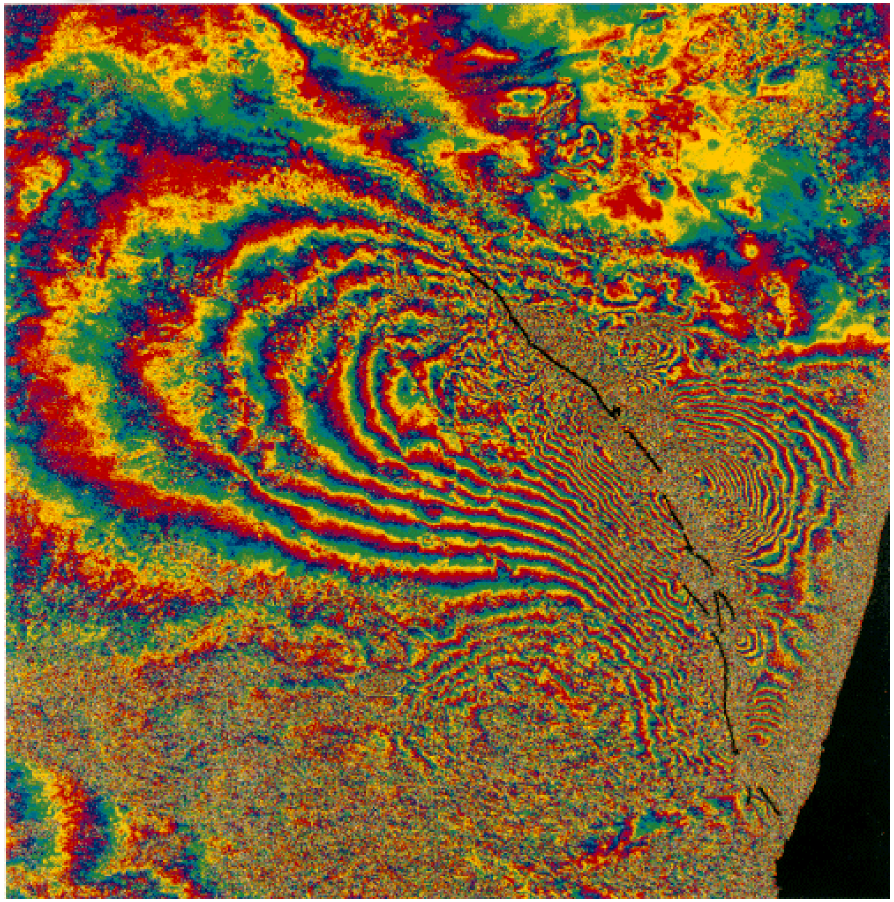
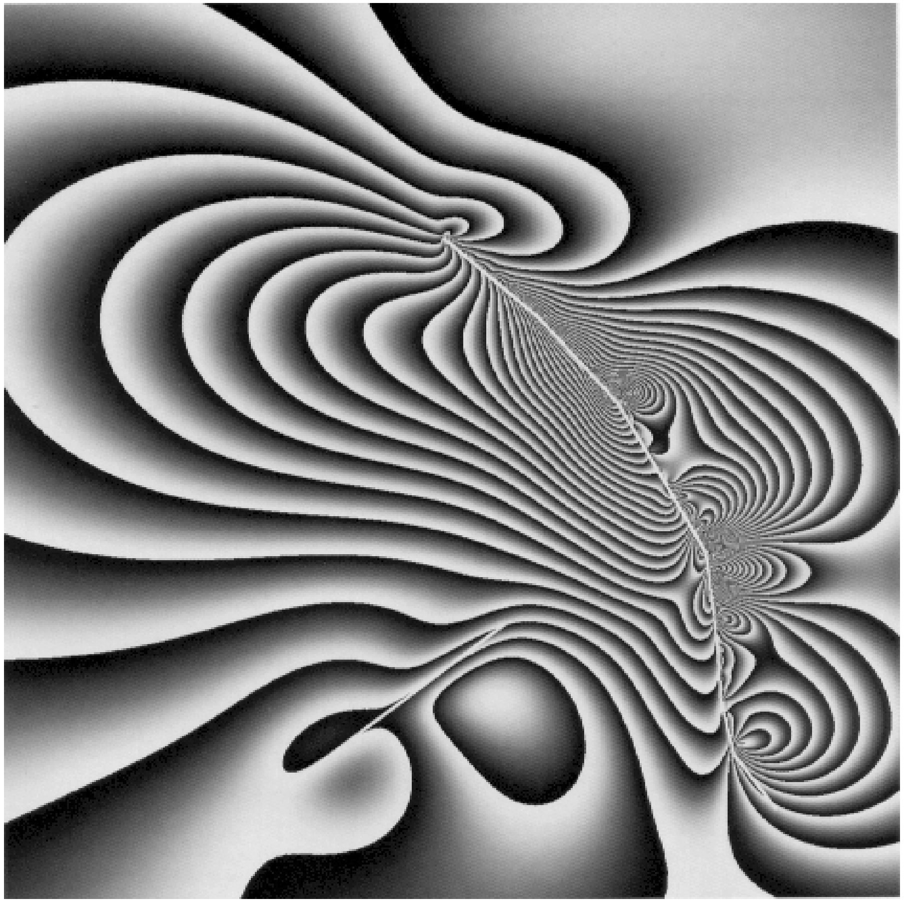
Interferometric applications



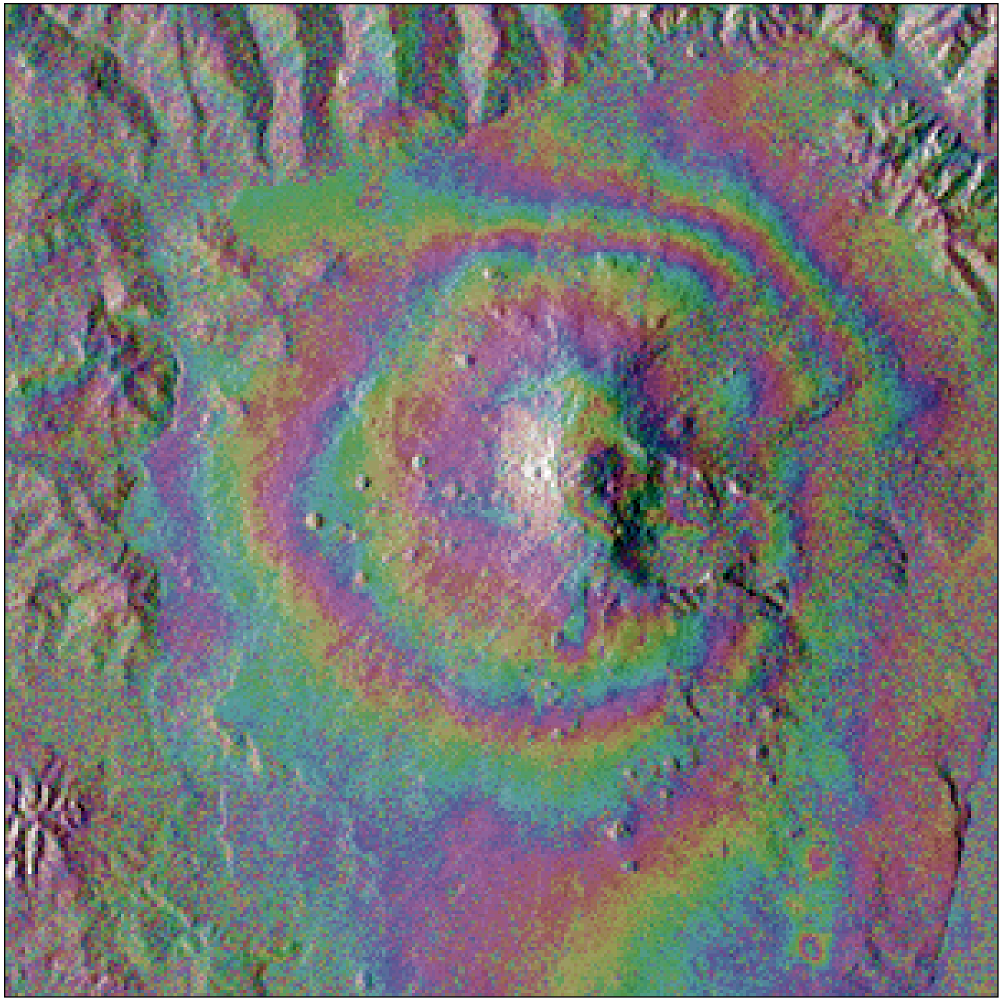
Seismic events





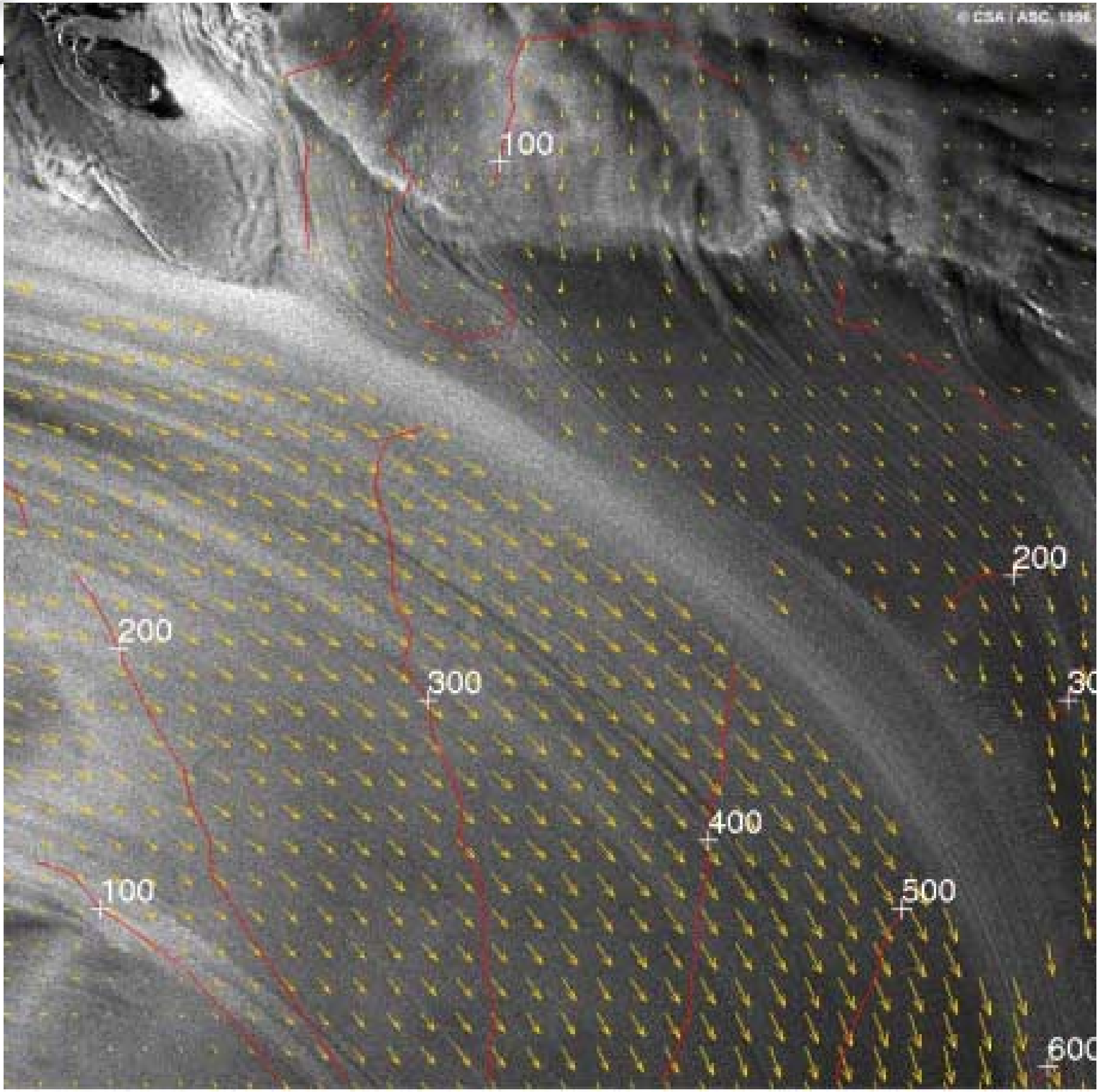
Source: Massonnet et al. (1993)

Volcanic hazards



Source: Massonnet (1997)

Glacier research



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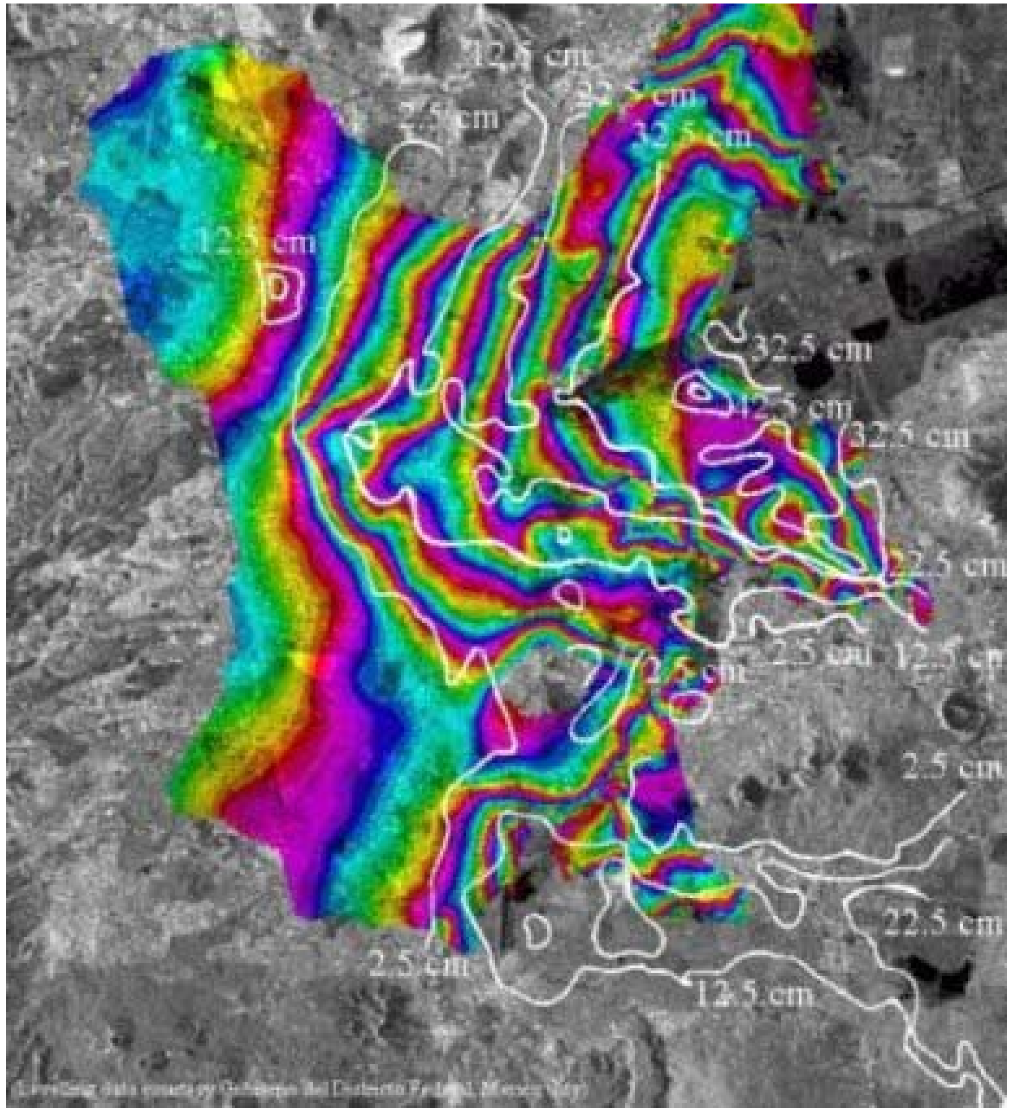
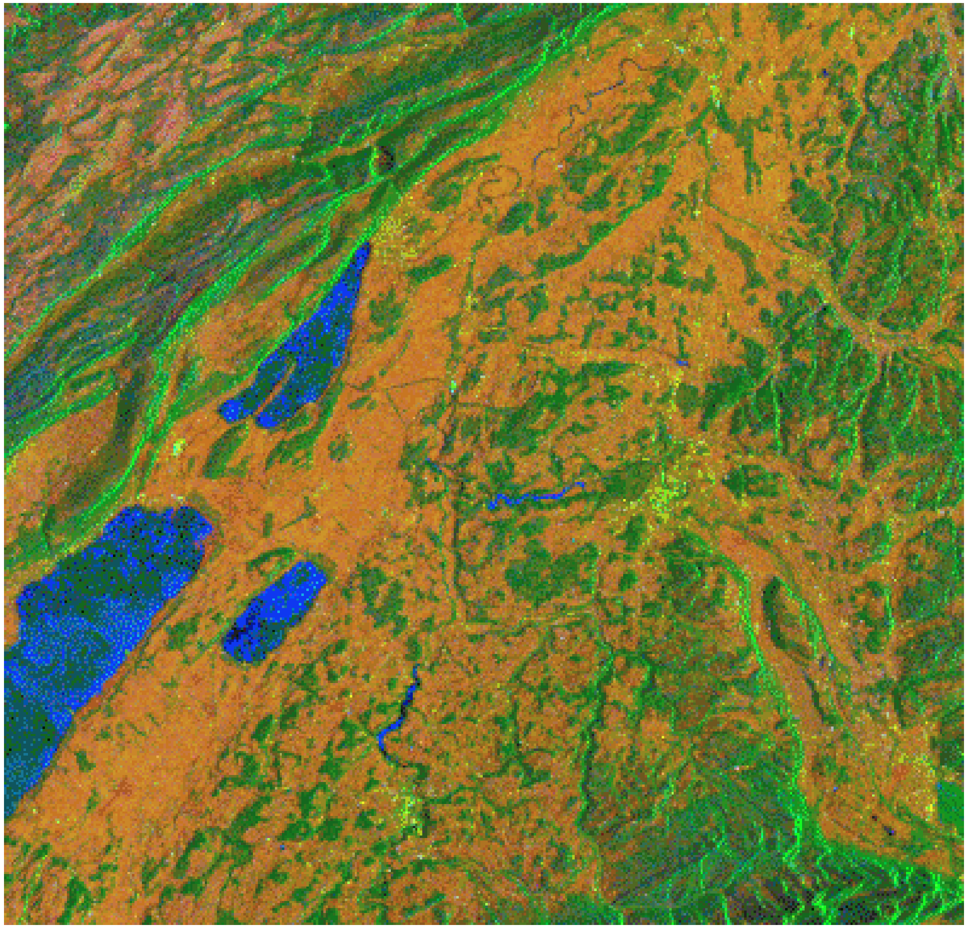
Land subsidence



Source: http://www.gamma-rs.ch/research/mexico.html

Forestry



- interferometric correlation (red)
- backscatter intensity (green)
- backscatter change (blue)

Source: Strozzi and Wegmüller (1997)

Questions