Introduction to SAR interferometry

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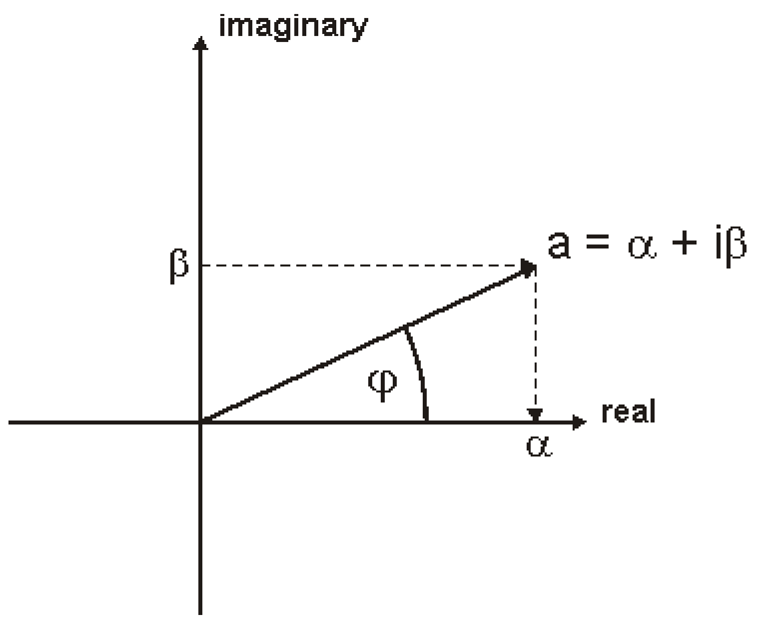
Amplitude and phase



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

Total phase

$$\varphi = 2\pi \frac{2r}{\lambda} + \varphi_0$$

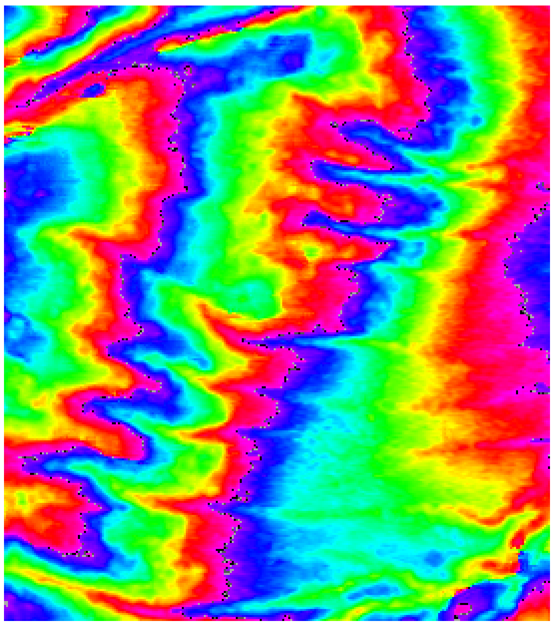
- round-trip distance $2r$
- scattering part φ_0 (interaction of the wave with the ground – unknown)
- radar wavelength λ

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

Interferometric fringe

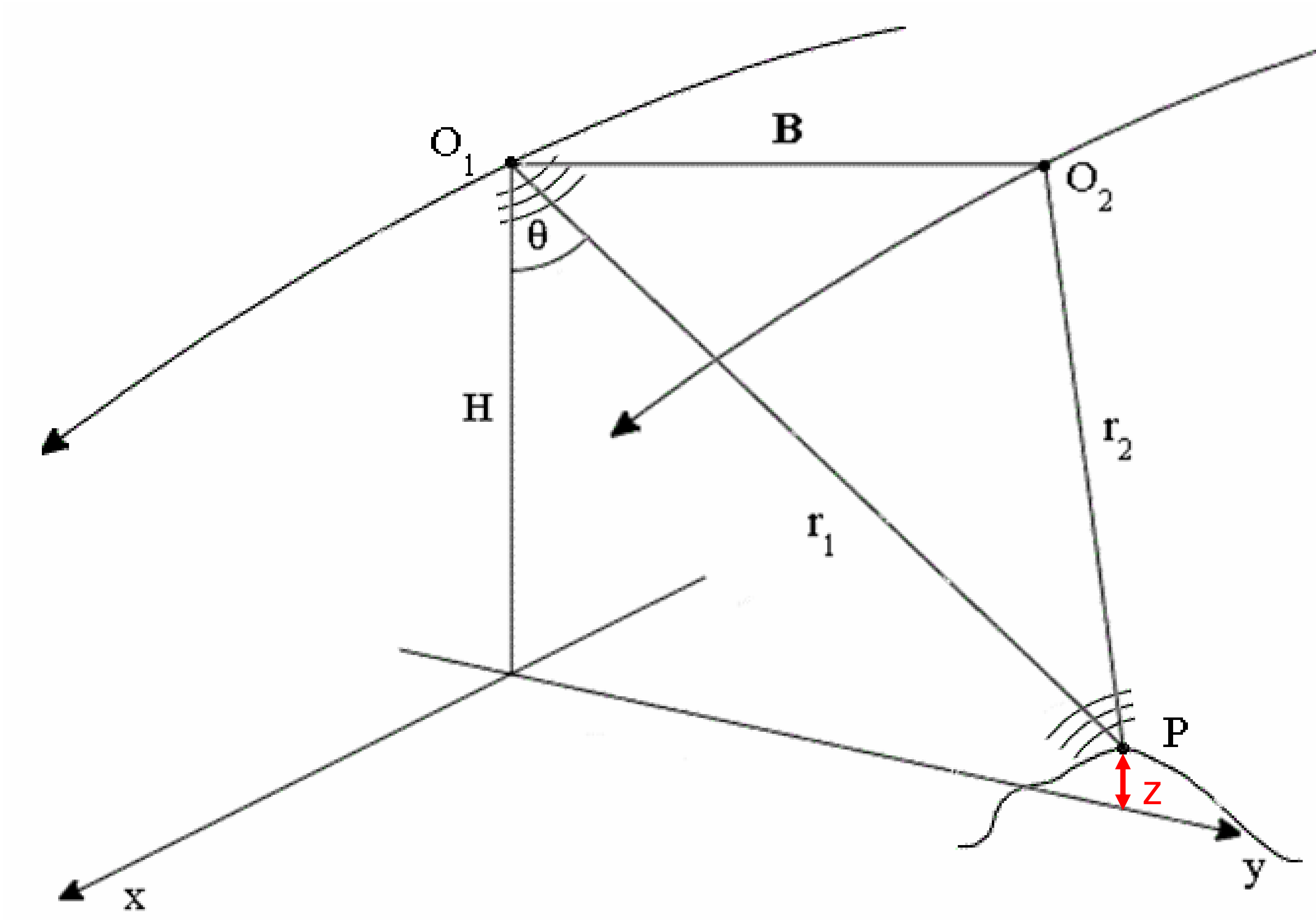


- represents the whole range of the phase in an interferogram from 0 to 2π in a full color cycle

Interferometric fringe

- fringes are not necessarily parallel
  - gradient can vary in near range versus far range
  - phenomenon is caused by the baseline vector varying as a function of time during acquisition when the two tracks are diverging or converging

Geometry of SAR interferometry



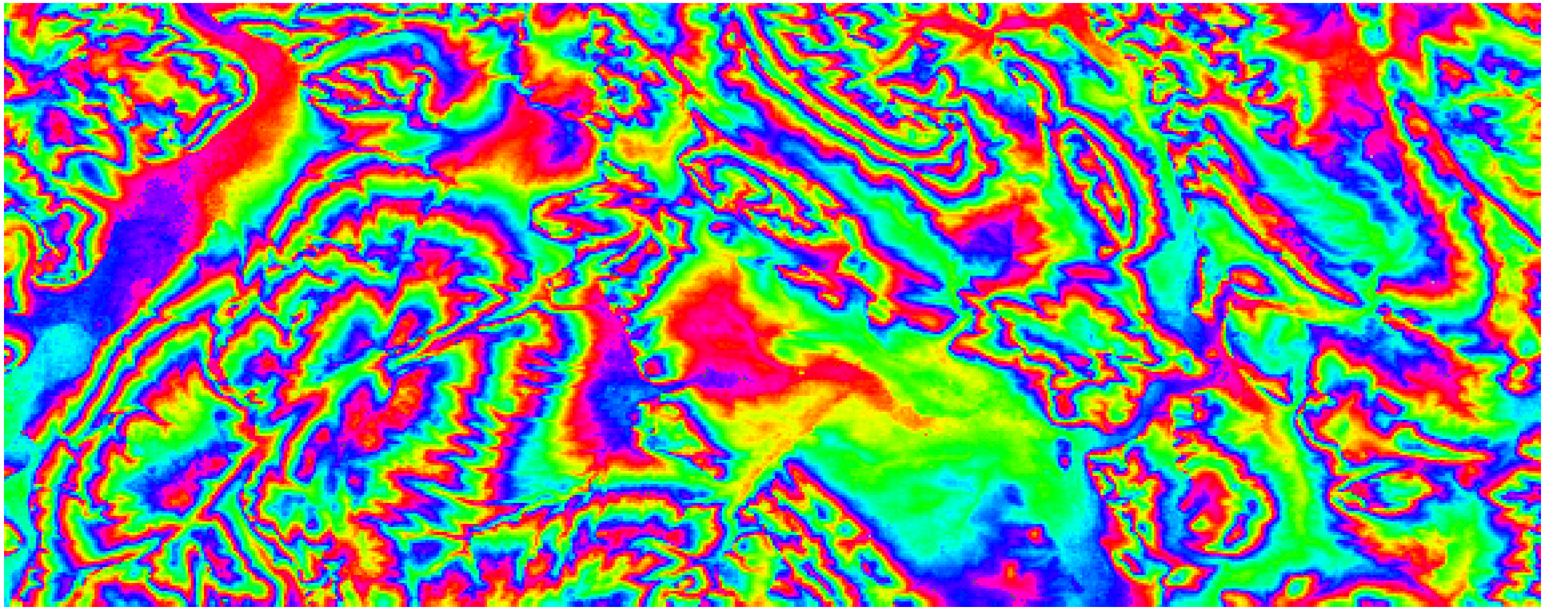
Why does InSAR work?

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

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

Interferogram



complex multiplication of the two images; i.e. the corresponding amplitudes have to be averaged and the corresponding phases have to be differenced at each point in the image

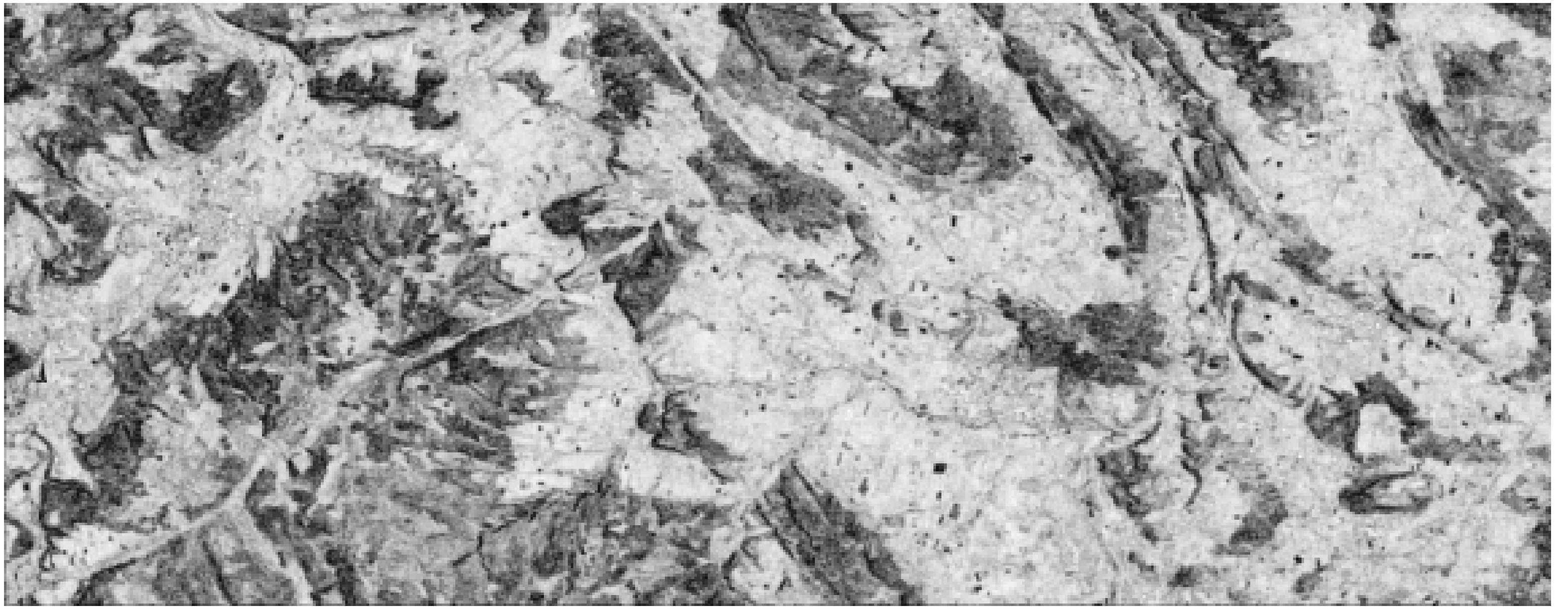
Interferometric phase

$$\Delta\varphi = 2\pi \frac{2\Delta r_{12}}{\lambda} = \Delta\varphi_{frac} + 2\pi \cdot N$$

Introduction to InSAR

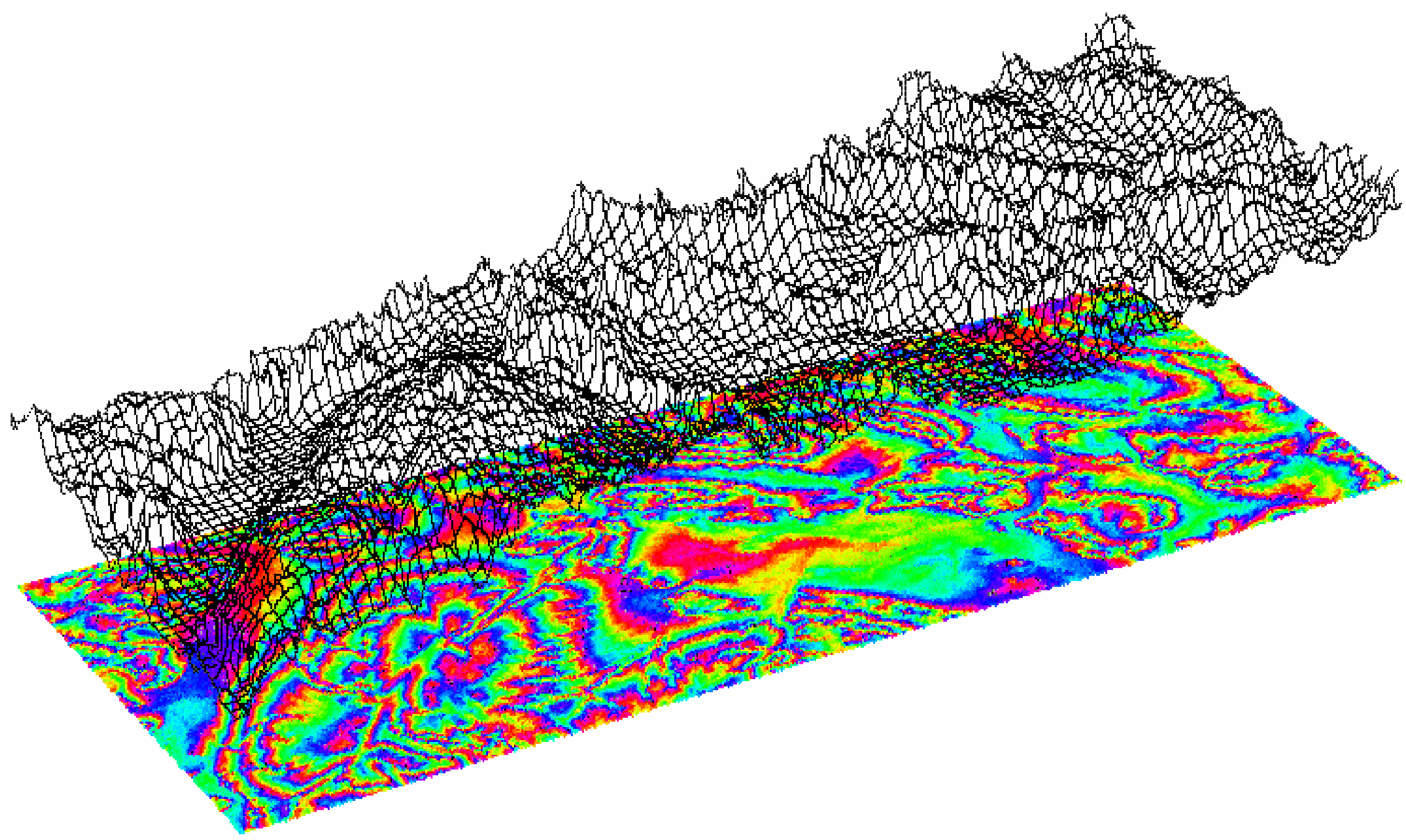
- assumption the elementary scatterers within each pixel are undisturbed in the time between the two image acquisitions *from exactly same location in space*
  - scattering part φ_0 does not change
  - phase difference is independent of the scattering mechanism
  - phase difference is a measure of the line-of-sight component Δr of the target displacement vector over the time interval between acquisitions
  - $\Delta\varphi_{frac}$ is interferometric phase

Coherence image

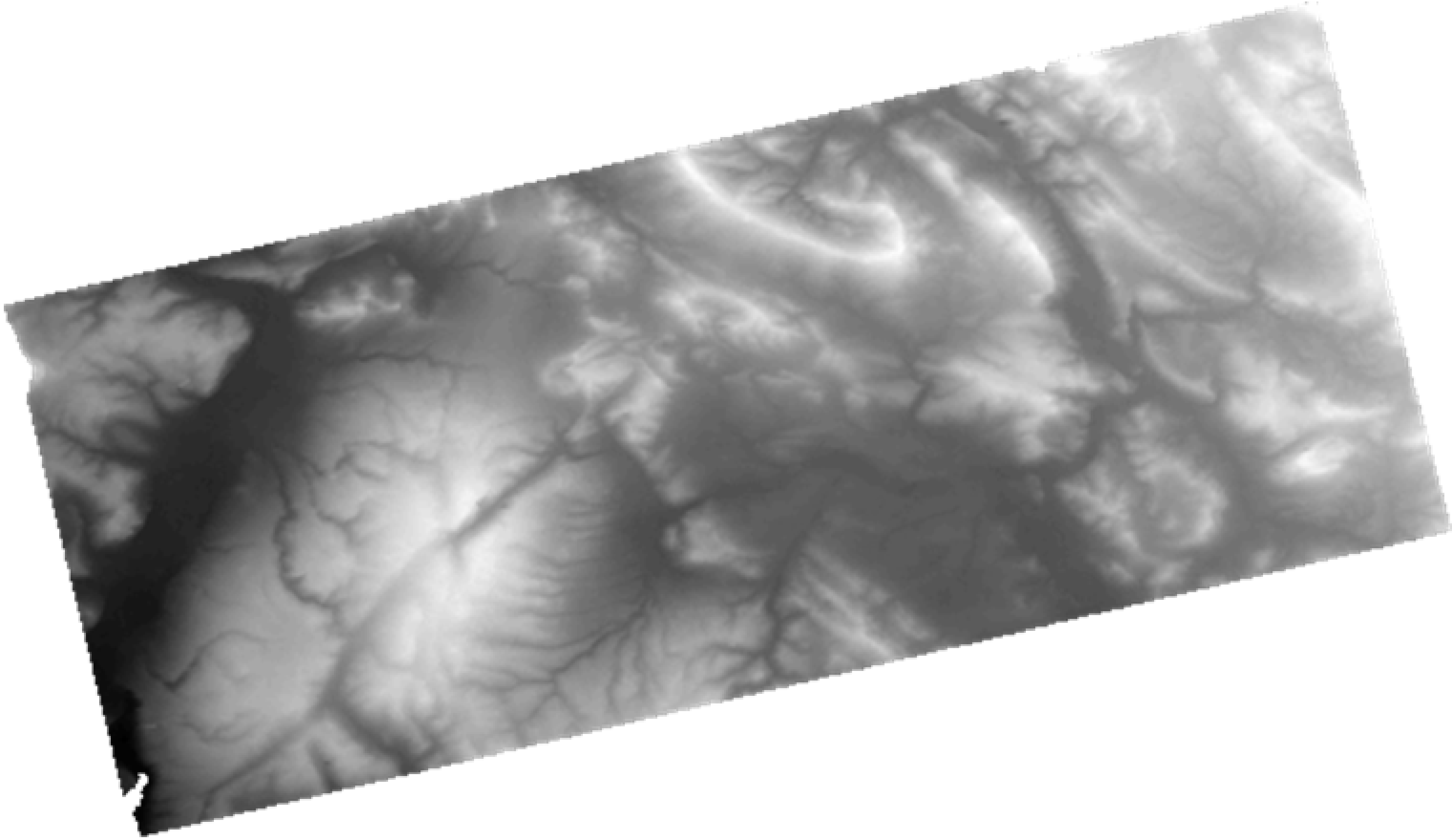


- measure for the correlation of corresponding signals
- ranges from 0 to 1

Digital elevation model



Digital elevation model



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)

Differential InSAR phase

$$\Delta r_{12} \approx \frac{\lambda}{4\pi}\left(\Delta\varphi_{12} - \Delta\varphi_{01}\frac{\overline{B}_{12}}{\overline{B}_{01}}\right)$$

- fundamental equation for detecting and measuring changes with InSAR
- provides line-of-sight component of the three-dimensional surface displacement vector
  - combination of ascending and descending orbit data can recover two independent components
- assumption that surface within a pixel deforms homogeneously

Differential InSAR phase

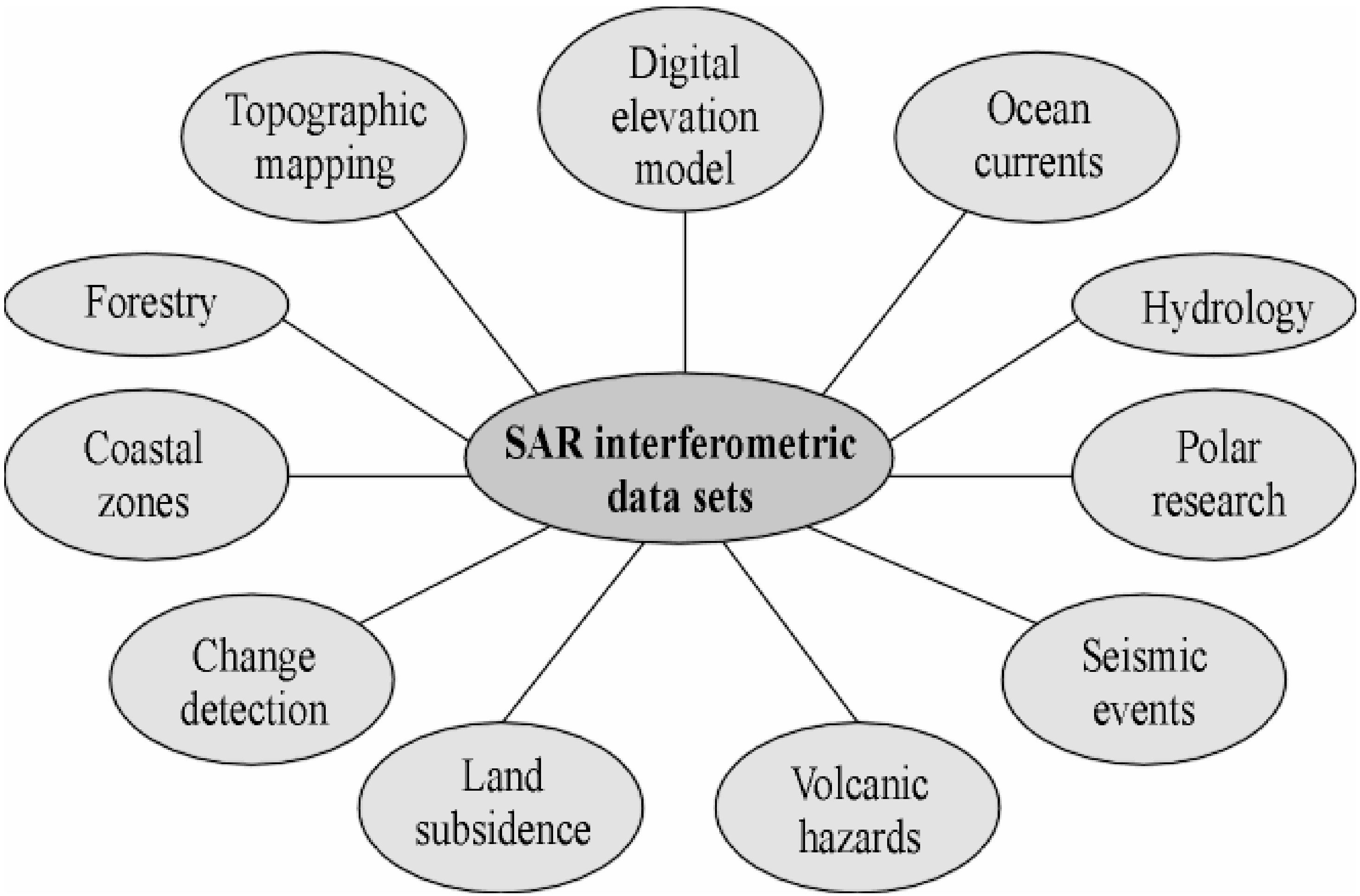
- backscatter behavior does not change significantly over time, i.e. unknown scatterer part can be neglected
  - significant change leads to temporal decorrelation
- phase unwrapping problem can be solved for large parts of the image
  - phase is modulo 2π
  - integer number of phase cycles is known
- large displacement cannot be detected
  - phase gradient limited to half the wavelength

Differential InSAR phase

- precision surface displacements requires accurate a priori estimate of topography

$$\sigma_{\Delta\varphi} = \frac{4\pi}{\lambda}\left(\sigma_{\Delta r} + \frac{B_{\perp}}{R\sin\gamma}\sigma_{h}\right)$$

Interferometric applications



InSAR applications: Deformation processes

- land subsidence
  - mining activities
  - withdrawal of water, gas and oil
- co-seismic and post-seismic displacement field related to earthquakes
- deflation and inflation of volcanoes
- dynamics of glaciers and ice sheets

InSAR applications: Deformation processes

- tectonic processes
- orogenesis and erosion
- coastal-zone changes

Trends and challenges

- Shuttle Radar Topography Mission (SRTM)
  - flown in February 2000
- swath processing
  - data volume
  - Doppler frequency issues
- DEM production for larger areas
  - SRTM
- long term monitoring
  - permanent scatterers