Interferometric SAR

Mark van der Meijde and Harald van der Werff

With thanks to Ian Brown

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

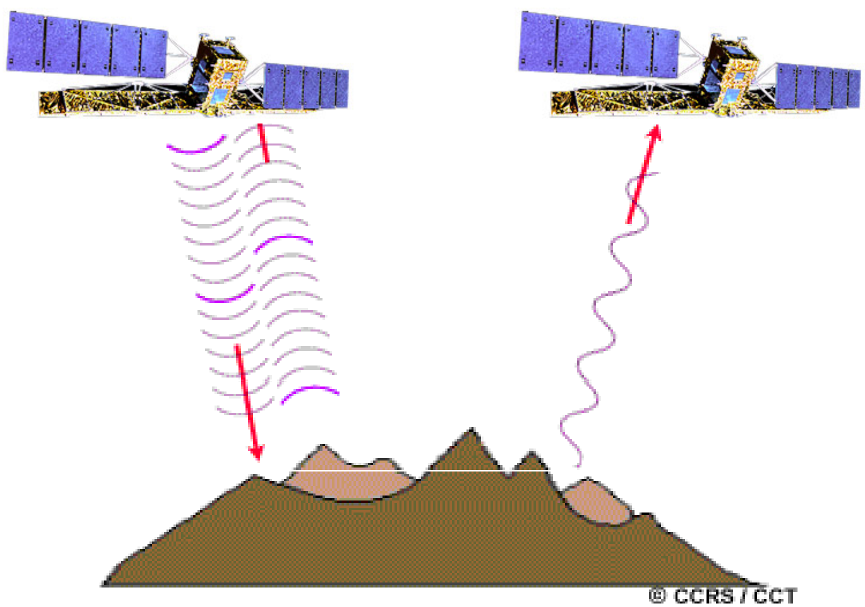
Key Online References:

- Scientific SAR Users Guide
  www.asf.alaska.edu/contents.html
- What is imaging radar? (NASA JPL)
  http://southport.jpl.nasa.gov/desc/imagingradarv3.html
- Atlantis Scientific / Frank Paul
  http://www.geo.unizh.ch/~fpaul/sar_theory.html

Introduction

- Microwave RS is *Active* or *Passive*
- These operate at centimetre wavelengths
- The radar waves can penetrate cloud and operate in darkness
- Civilian use began with Seasat in 1979 (miltary uses began in the 1960s)

Active **vs.** *Passive*



Wavelengths and Frequencies

P-Band	30-100 cm	0,3-1 GHz
L-Band	15-30 cm	1-2 GHz
S-Band	7,5-15 cm	2-4 GHz
C-Band	3,75-7,5 cm	4-8 GHz
X-Band	2,4-3,75 cm	8-12,5 GHz
Ku-Band	1,67-2,4 cm	12,5-18 GHz
K-Band	1,1-1,67 cm	18-26,5 GHz
Ka-Band	0,75-1,1 cm	26,5-40 GHz

Active Radar- SAR

Synthetic Aperture Radar (SAR) relies on the:

- Ability of an antenna to transmit a brief EM pulse in a precise direction
- Ability to detect, with similar precision, the scattered echo (at much lower power)
- Ability to measure the time delay accurately (thereby deriving the range)
- Ability to scan with the directional beam to examine a wider area
- Ability to undertake spectral analysis of the returned signal to increase resolution (Doppler)

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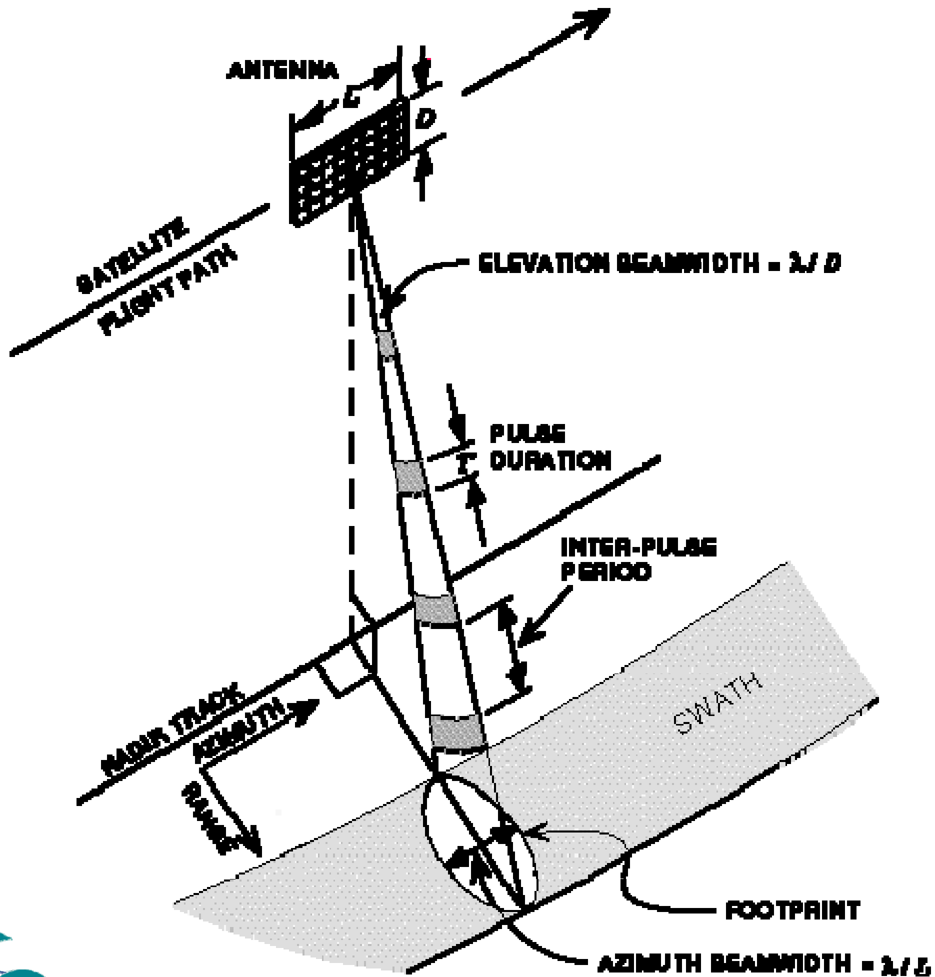
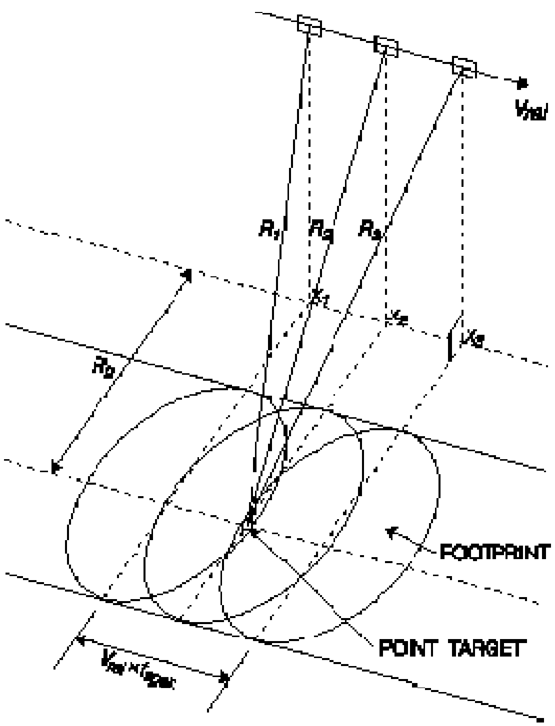
Scanning Configuration of a right-looking SAR

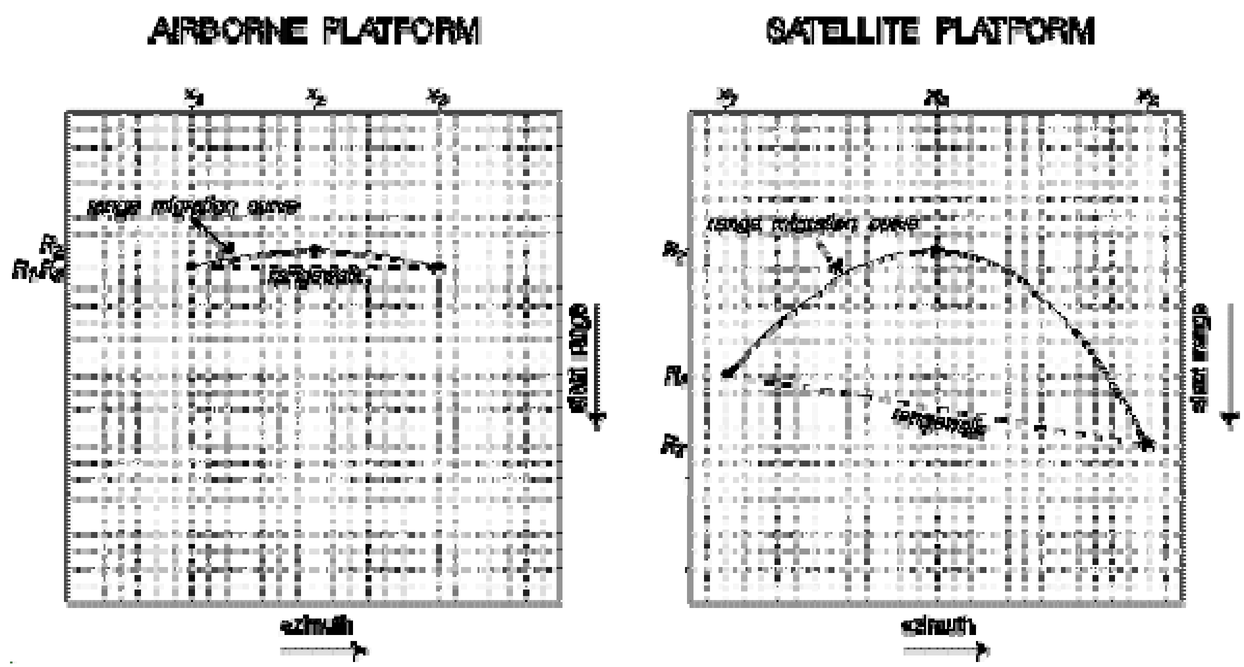


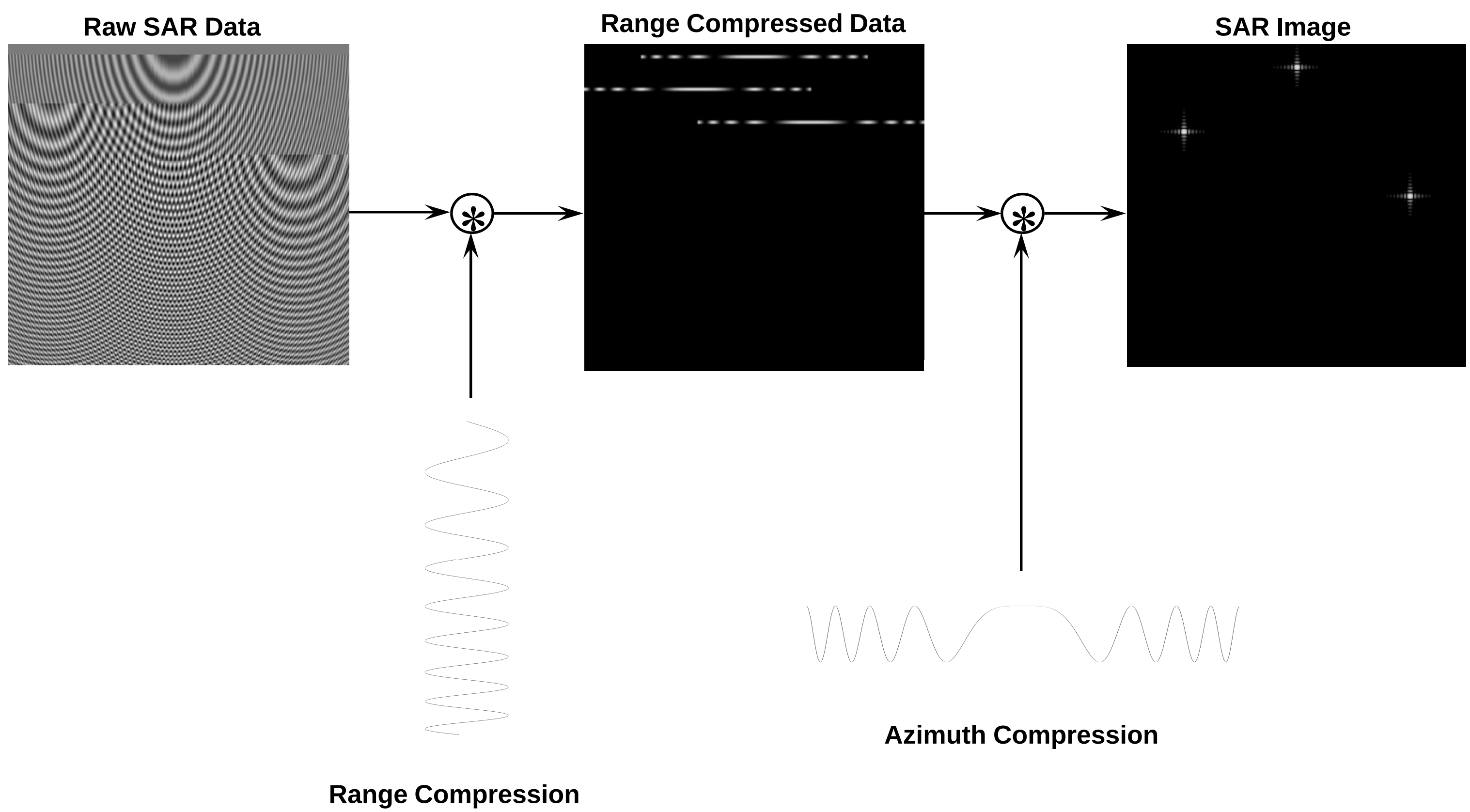
$$D_g = \frac{\lambda R_m}{D_a \cos \eta}$$

The swath width is a function of the wavelength, antenna height and incidence angle

Chirp Compression





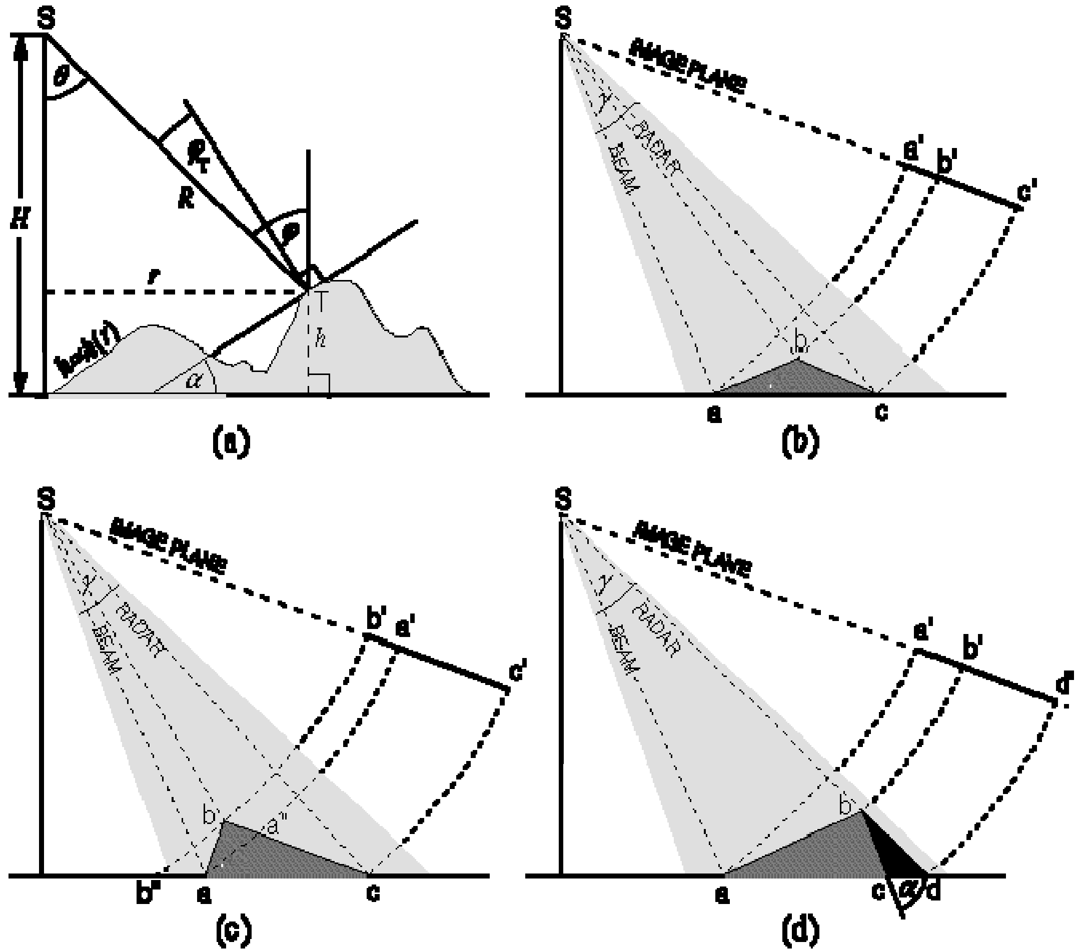


From Dr J. Van Zyl

Terrain Correction

- Aims at improving image geometry and radiometric properties
- Derives local relief using a Digital Elevation Model (DEM)
- Then synthesises a SAR image from the DEM which is georeferenced to the original
- Output is a corrected image formed from the synthesised SAR and original

Foreshortening, Layover and Shadow



Radar scattering

- When a radar wave encounters a surface *scattering* or *absorption* occurs
- Scattering is the redirection of the energy (i.e. Backscattering, reflection or refraction)
- Absorption is the conversion of the enrgy to another state (i.e. To heat)
- *Extinction* of the wave occurs when the radiation is negated through absorption and scattering

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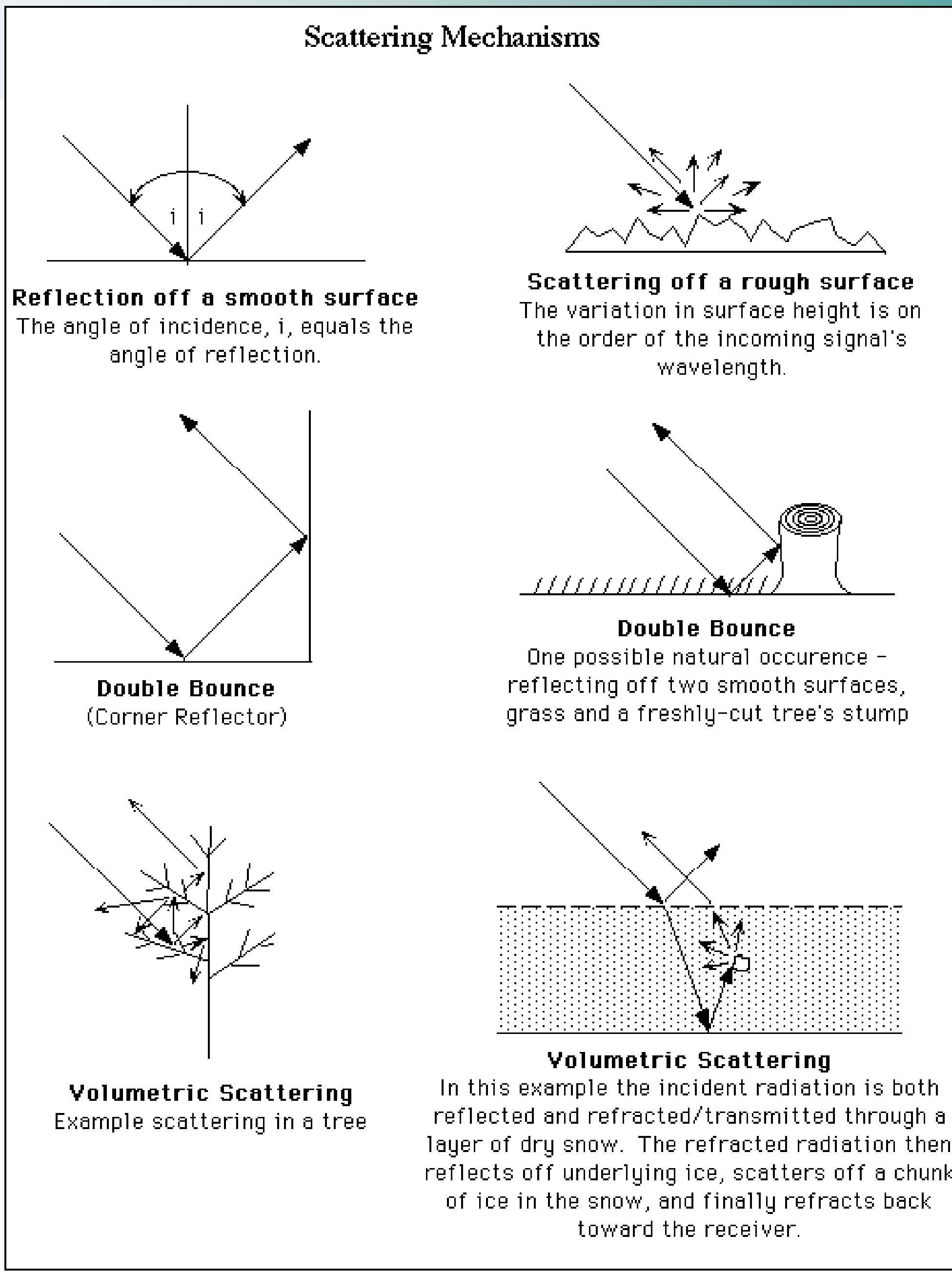
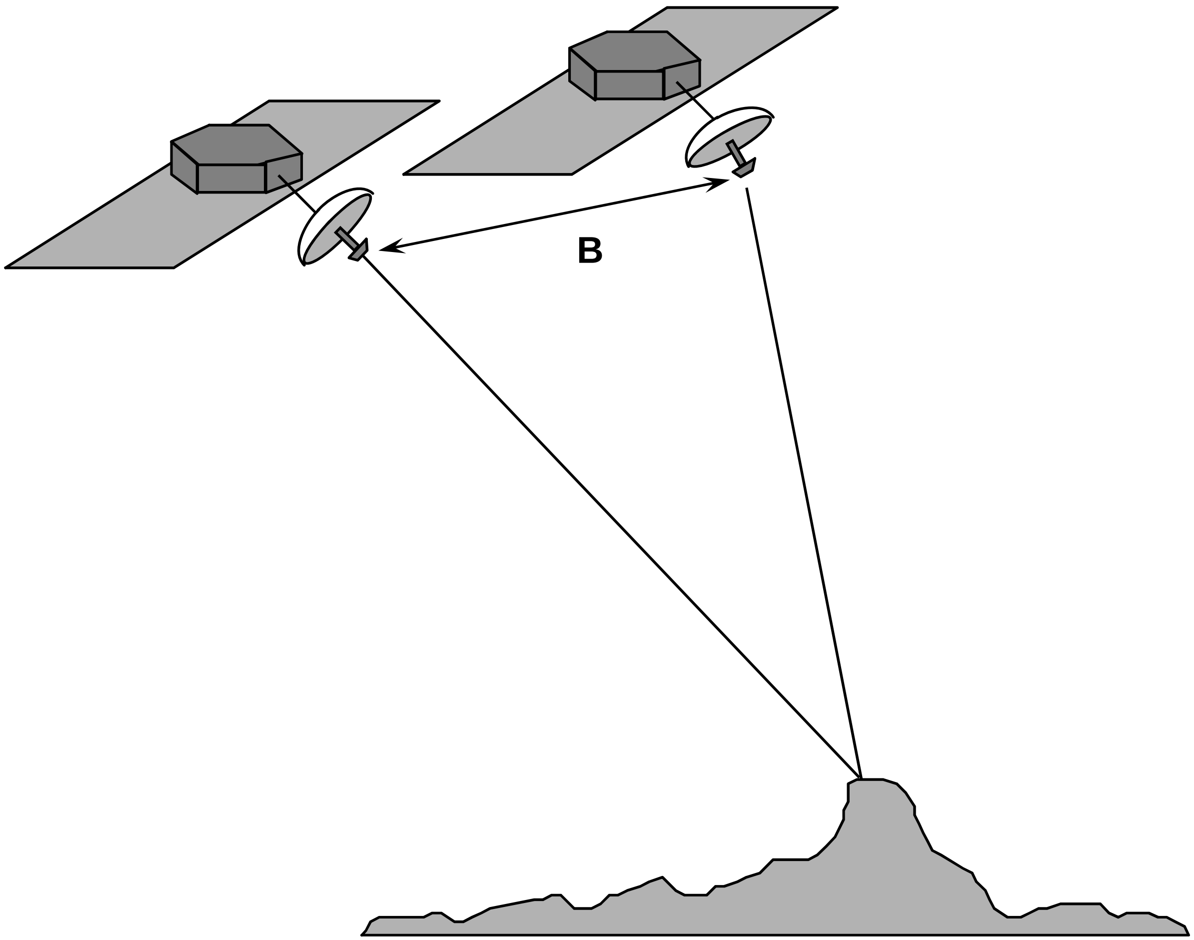

Scattering Mechanisms
i i
Reflection off a smooth surface
The angle of incidence, i, equals the angle of reflection.
Scattering off a rough surface
The variation in surface height is on the order of the incoming signal's wavelength.
Double Bounce
(Corner Reflector)
Double Bounce
One possible natural occurence - reflecting off two smooth surfaces, grass and a freshly-cut tree's stump
Volumetric Scattering
Example scattering in a tree
Volumetric Scattering
In this example the incident radiation is both reflected and refracted/transmitted through a layer of dry snow. The refracted radiation then reflects off underlying ice, scatters off a chunk of ice in the snow, and finally refracts back toward the receiver.

Interferometric SAR

- Complex SAR imagery has both *amplitude* and *phase* data
- *Phase* data is used to calculate the phase difference between two echos to calculate the precise path length
- Hence topography and surface displacement can be calculated from by acquiring data from two points in space….

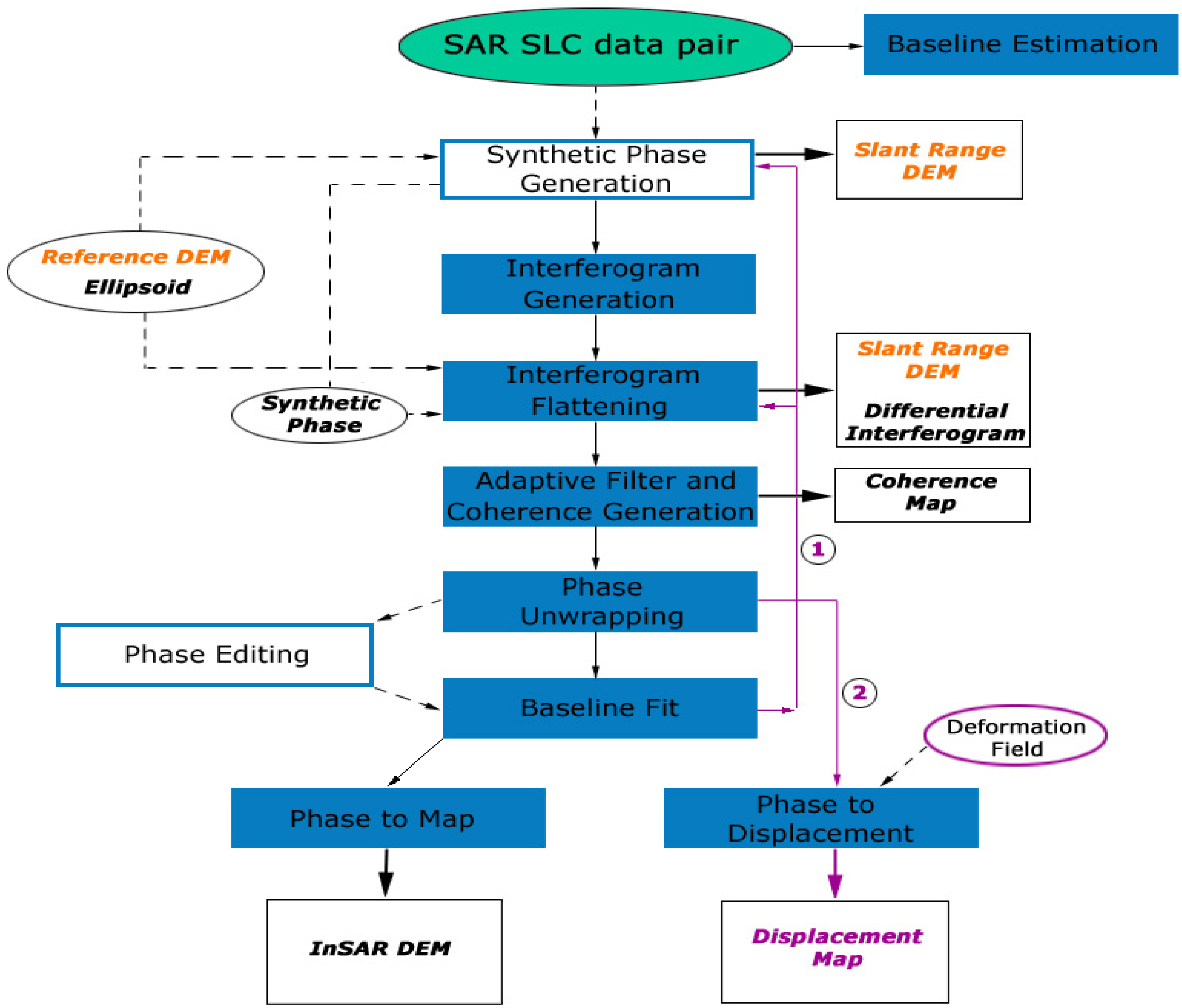
InSAR geometry

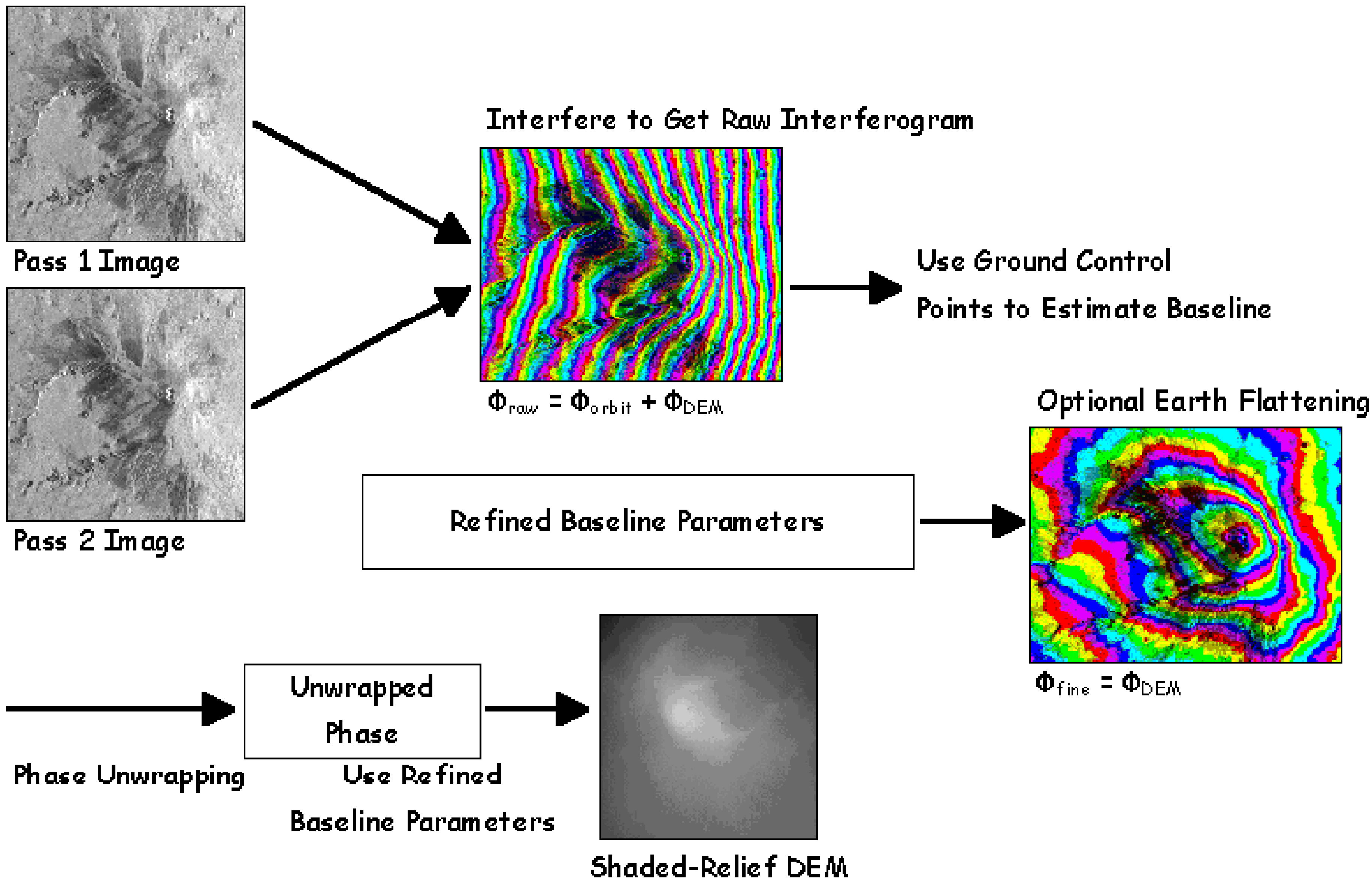


InSAR

- Precise knowledge of the orbit emphemeris allows the calculation of the baseline seperating two acquisitions
- The phase difference can then be calcuated to show path length difference and trignometry used to derive surface height
- Accuracies can be on the order of cm’s

(SARscape) InSAR processing chain




Pass 1 Image
Pass 2 Image
Interfere to Get Raw Interferogram
$\Phi_{raw} = \Phi_{orbit} + \Phi_{DEM}$
Use Ground Control
Points to Estimate Baseline
Optional Earth Flattening
$\Phi_{fine} = \Phi_{DEM}$
Refined Baseline Parameters
Phase Unwrapping
Unwrapped
Phase
Use Refined
Baseline Parameters
Shaded-Relief DEM

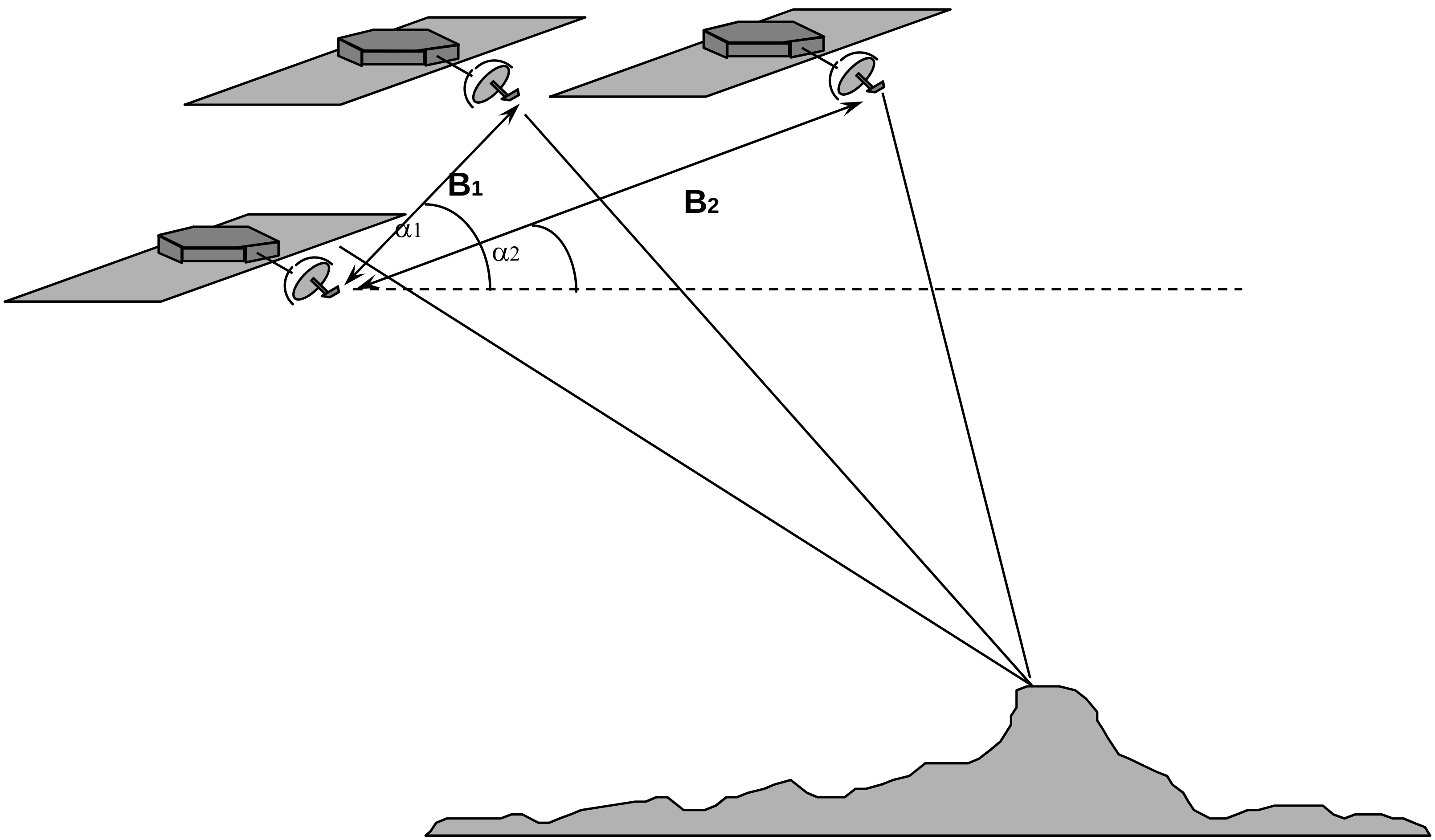
Differential Interferometry (DInSAR)

- Normally interferometry utilises two images from different orbits (*repeat-path interferometry*) to create an elevation model
- However, the use of three or four images allows elevation data to be extracted from the interferogram to produce surface displacement or motion
- DInSAR describes the use of multiple-interferogram or *differential interferometry*

DInSAR (example)

1. An image pair (a & b) are combined to create an interferogram (ab) showing topography
2. A third image (c) is combined with either a or b to create a second interferogram (ac)
3. Interferogram ac is subtracted from ab showing change in x, y and z directions dependent on the baseline of the dataset

Baselines

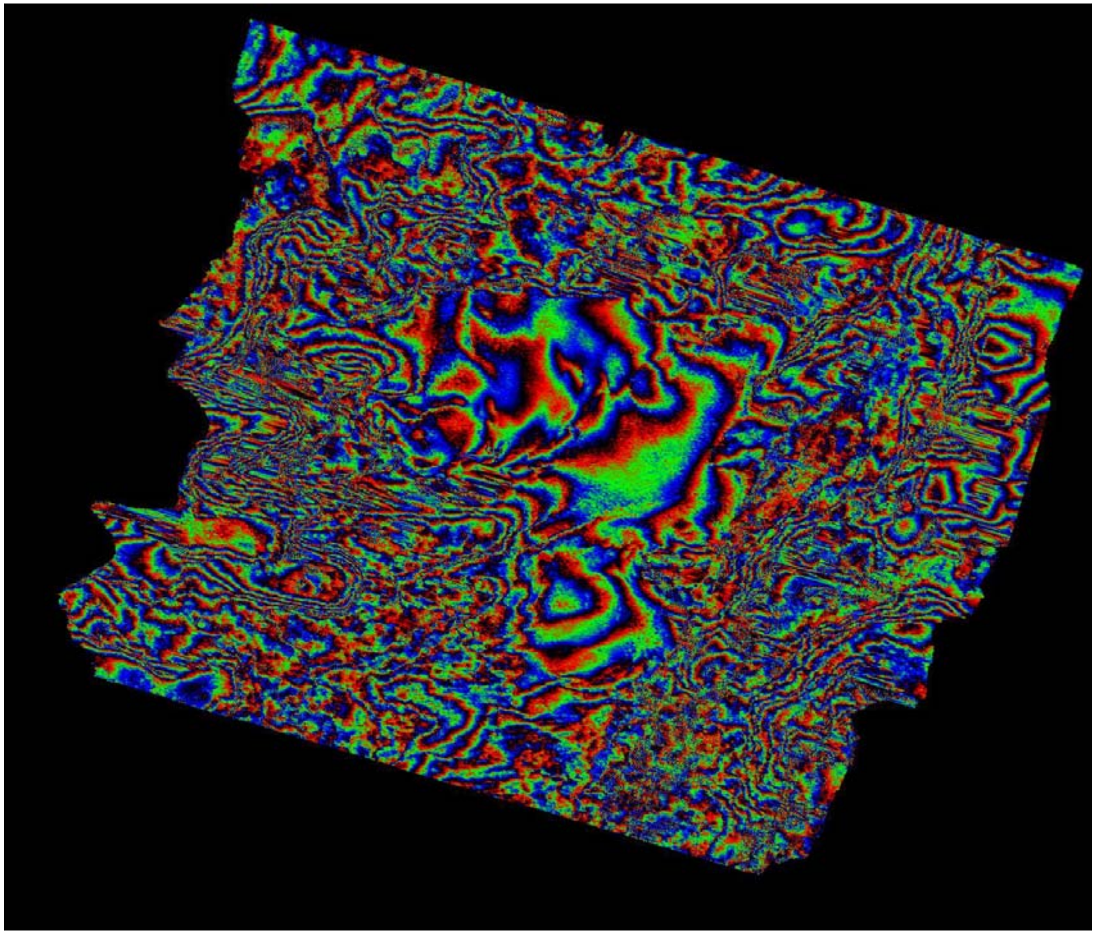


Baselines

- The *perpendicular baseline* describes the seperation of the two image paths for an interferometric pair
- Long baselines ~300-800 m provide good separation for the derivation of topography
- Short baselines (<100 m) are better for motion detection

- Thus a long baseline of 400 m may be used to create a DEM
- Then a short baseline pair may be acquired to create a horizontal motion map from which topography is removed using the first DEM
- Or, the second pair may also have a long baseline to map topography so that subsidence or motion in the z direction can be mapped.

Blåmannsisen, north Norway



A note about coherence

- InSAR requires that a degree of stability is maintained between the image acquisitions
- Low *coherence* (i.e. A unstable surface such as blowing sand or water) will result in noise
- Coherence can therefore have applications too.

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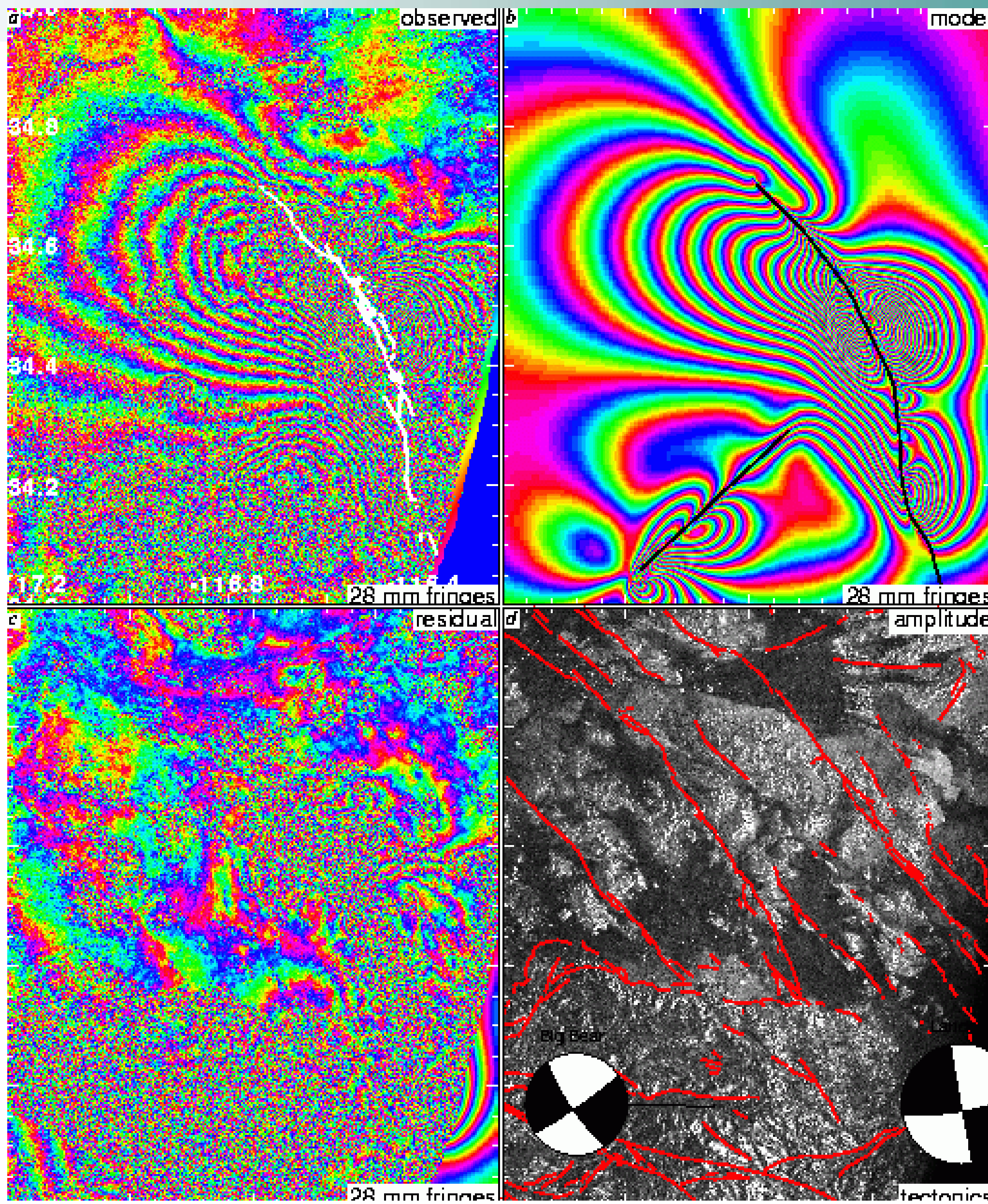
Tectonic modelling



BAM earthquake displacement