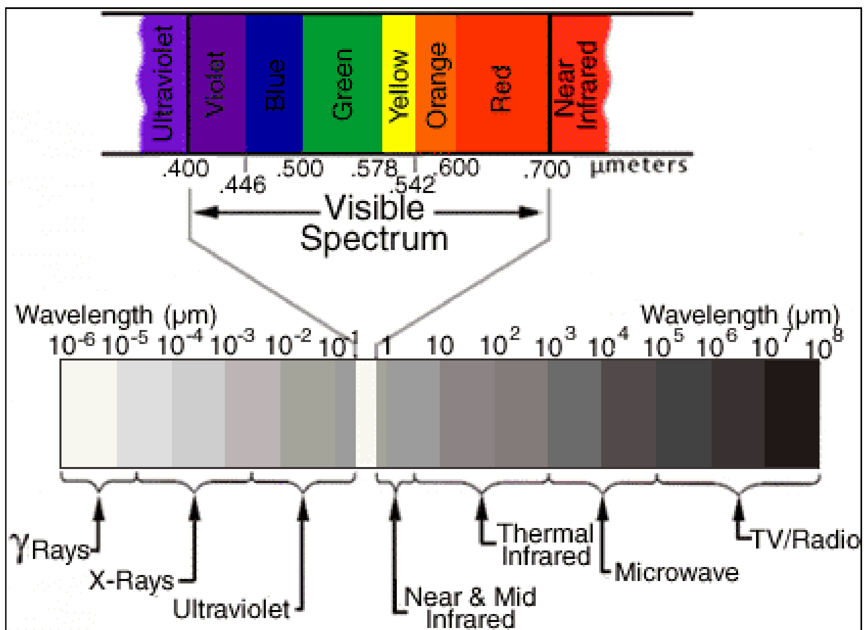
Microwave remote sensing

Rudi Gens
Alaska Satellite Facility –
Remote Sensing Support Center

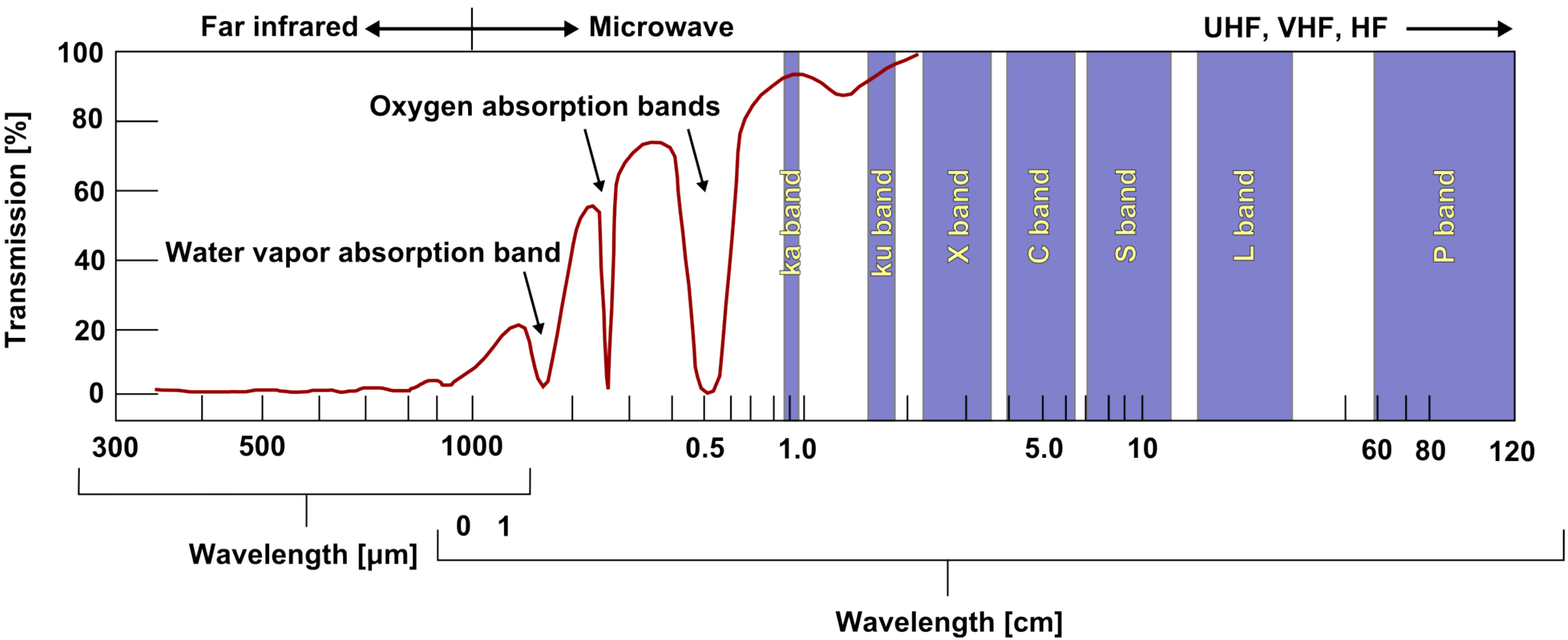
UNIVERSITY OF ALASKA FAIRBANKS

Remote Sensing Fundamental

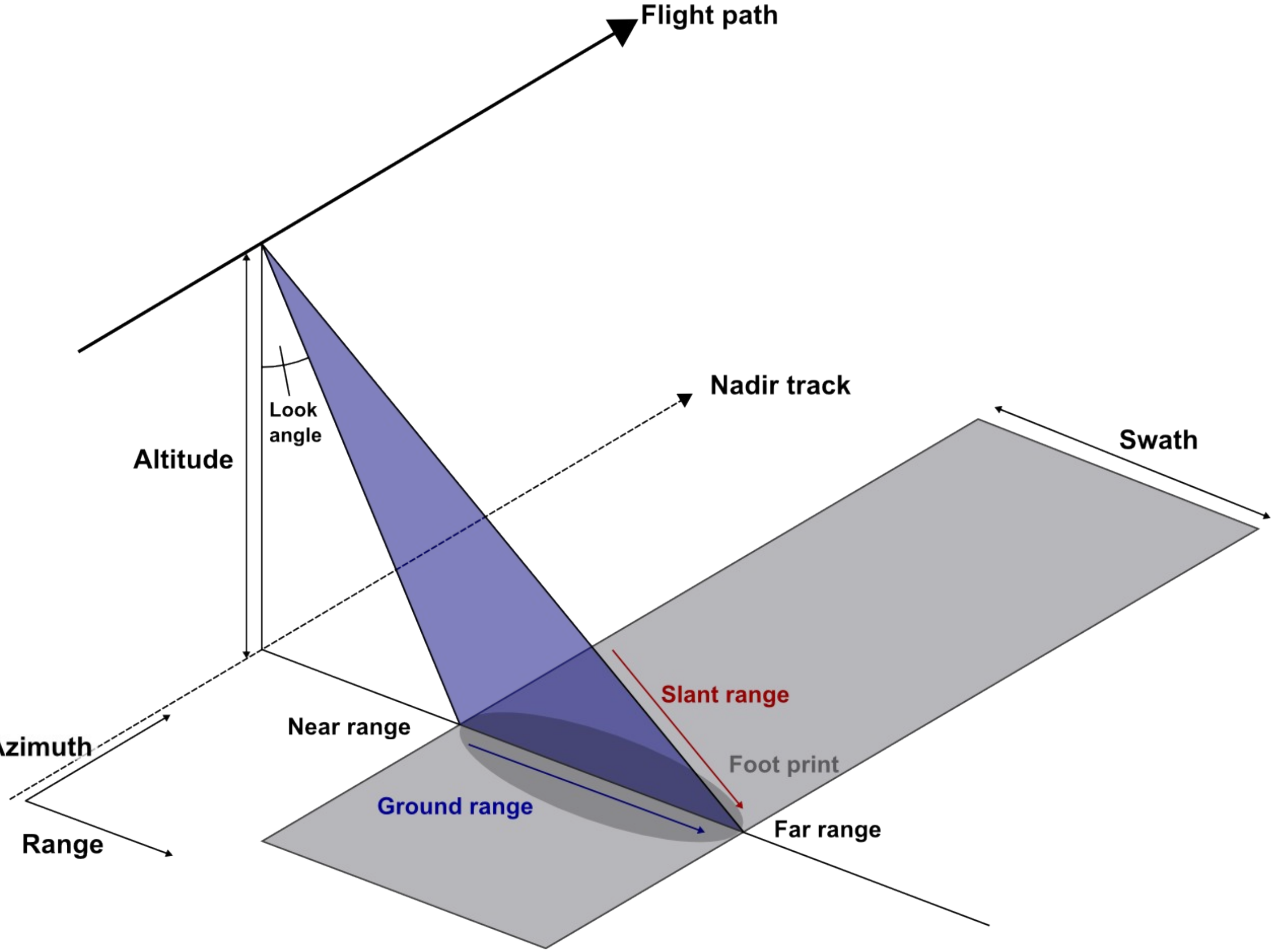
- The entire range of EM radiation constitute the EM Spectrum
- SAR sensors sense electromagnetic radiations in the microwave region of the EM Spectrum



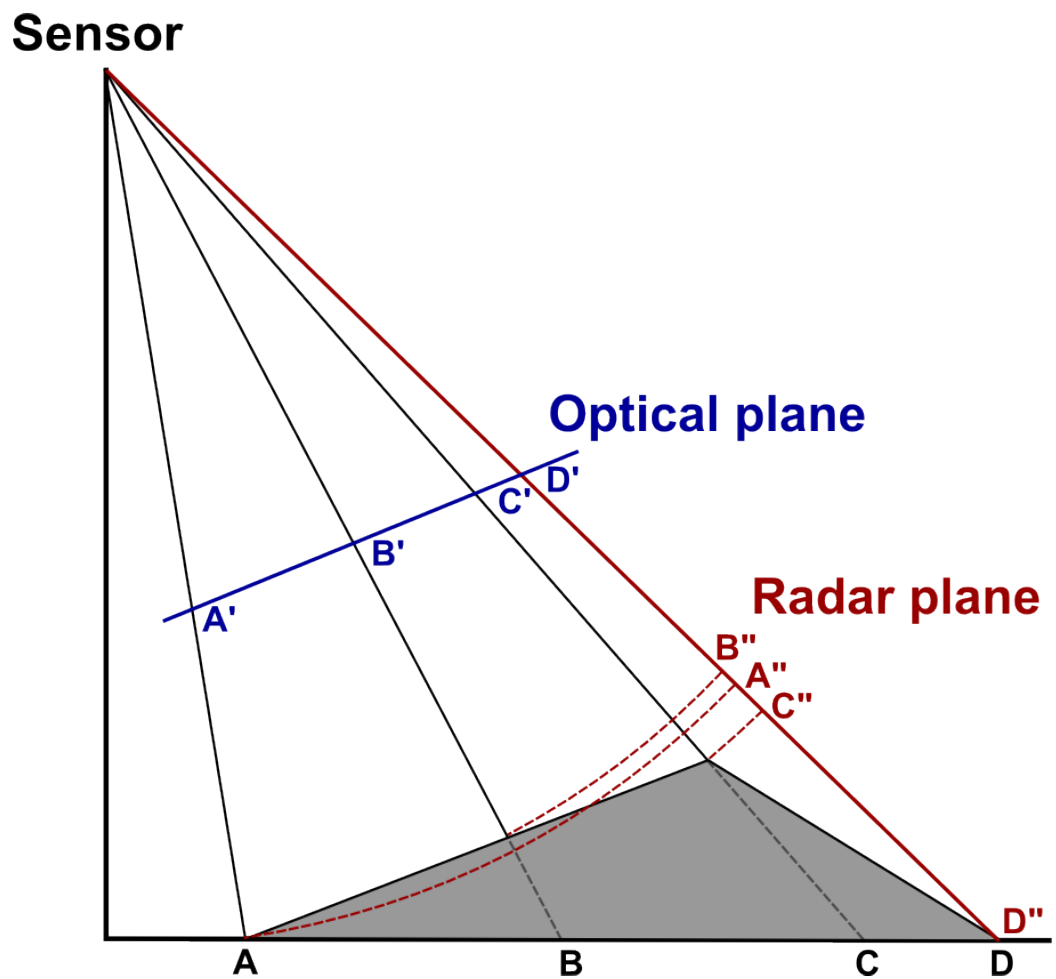
Radar wavelengths



Radar geometry



Optical versus radar

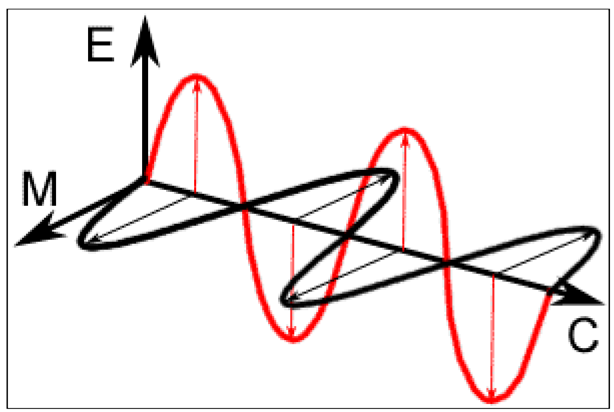


Resolution

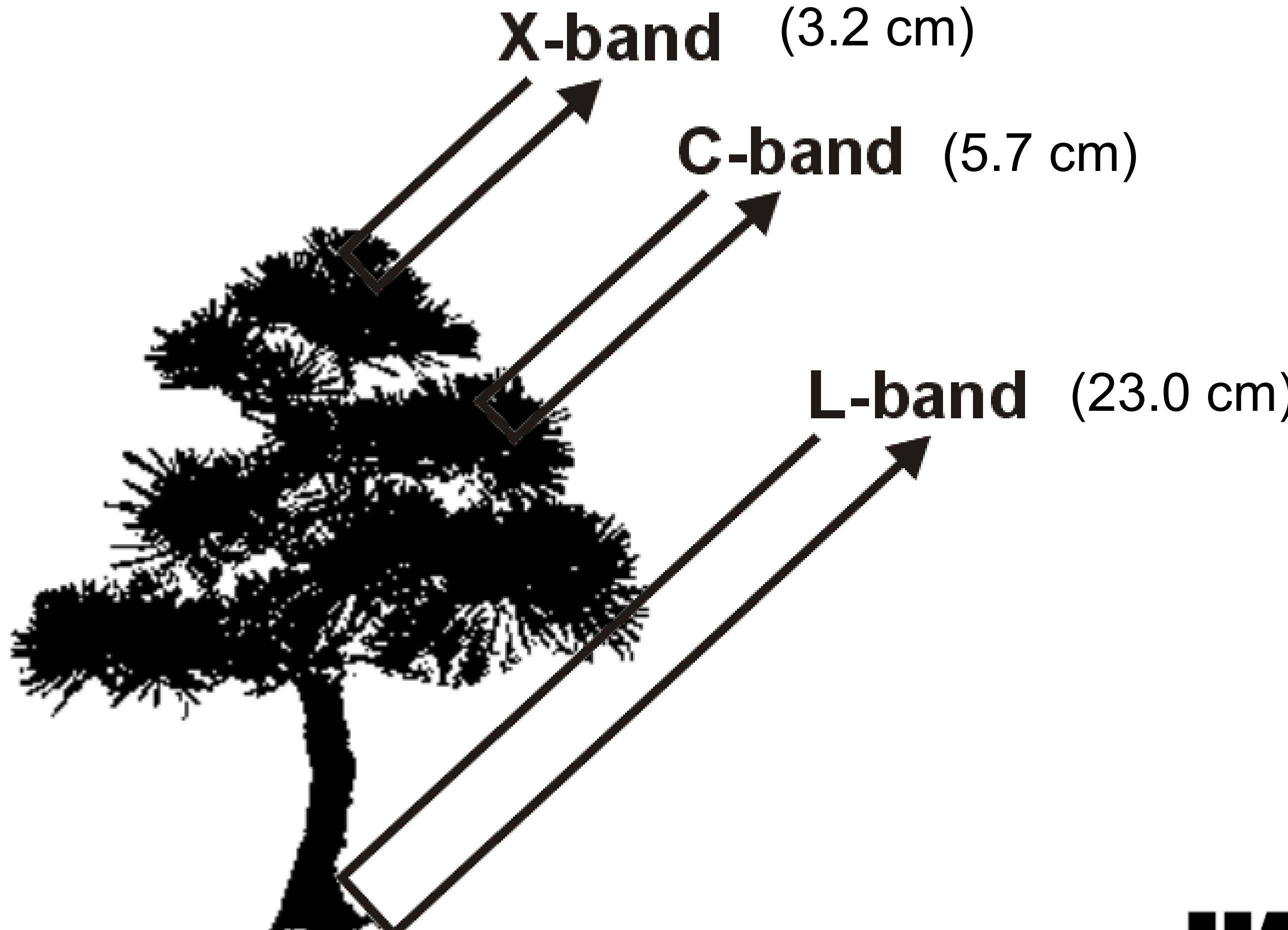
- *Answers to the following question*
  - Given two very bright infinitesimally small scattering centers, what is the smallest distance at which you can separate them and observe two objects?
- Objects can be much smaller than the resolution and still be observable
  - such as bright point objects like stars

Polarization

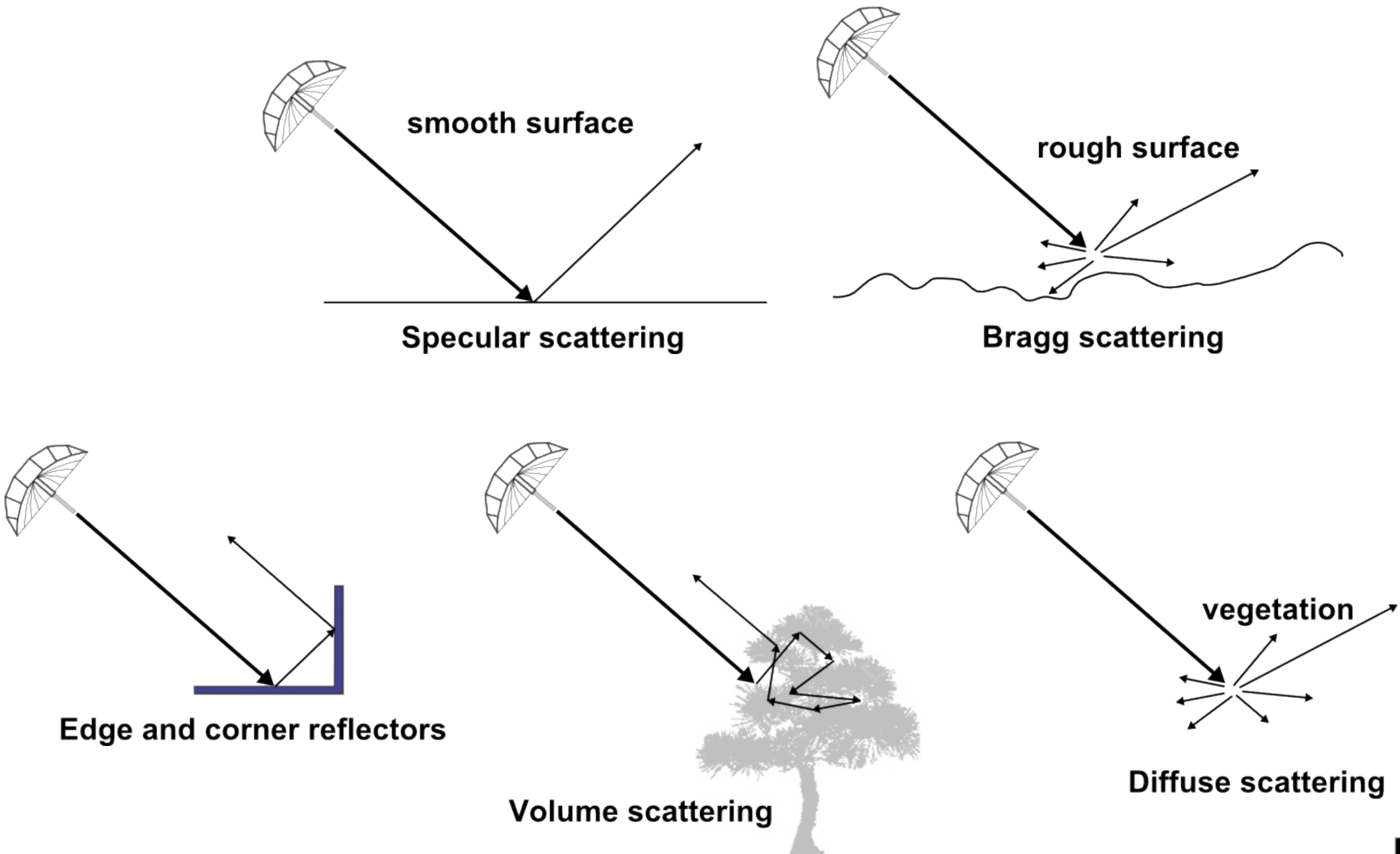
- EM radiation propagates as two orthogonal waves, with an electric and magnetic component, moving at right angles to the direction of wave propagation.



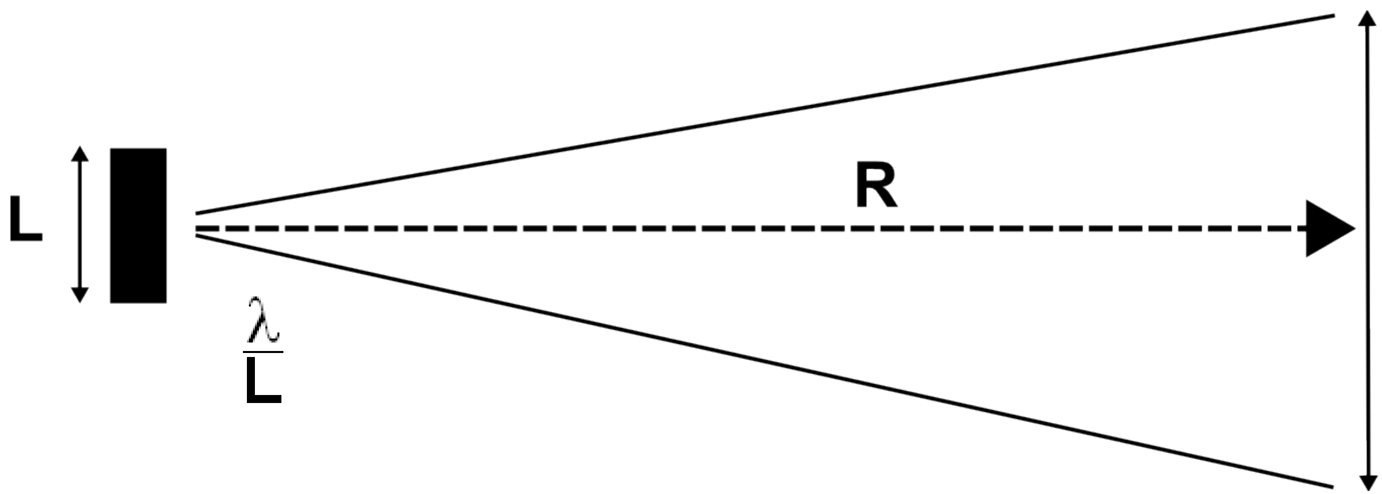
Radar wavelengths



Radar scattering



Real aperture radar

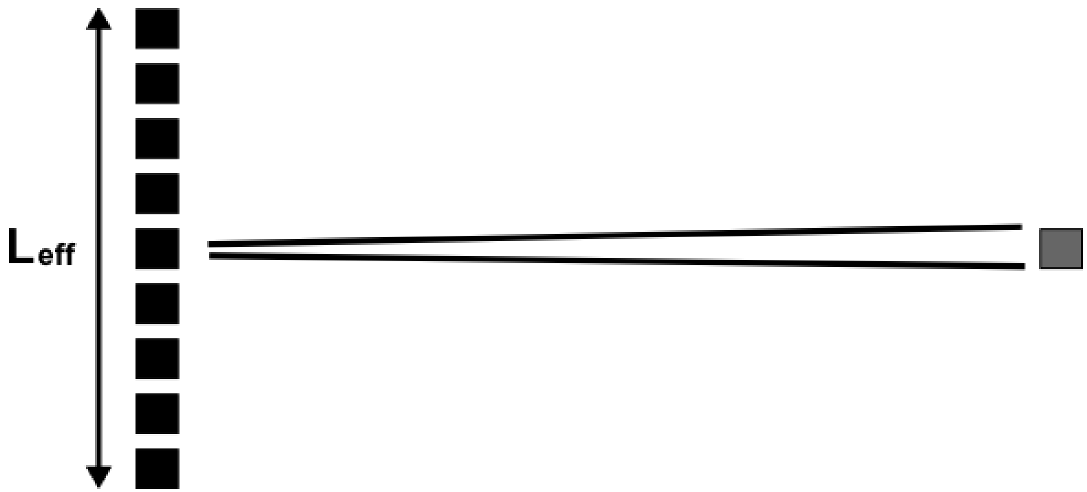


Resolution:

$$\frac{\lambda R}{L}$$

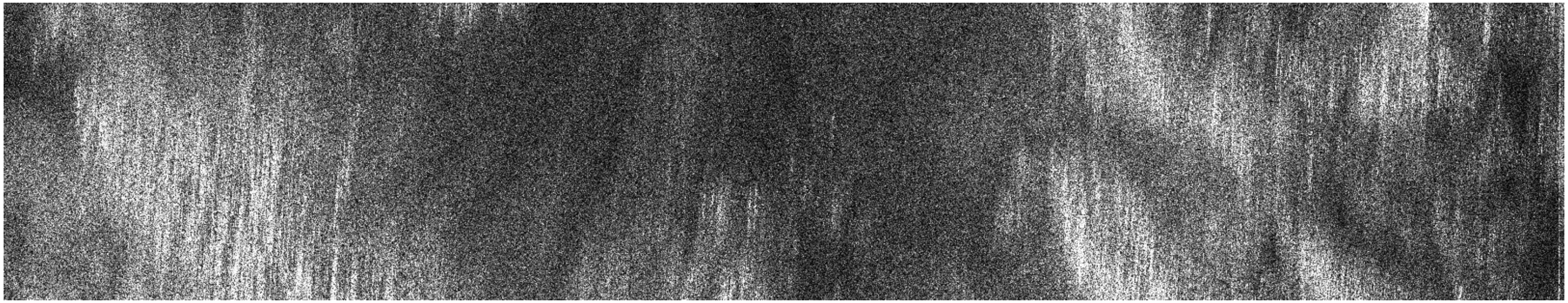
- cross-range resolution can be only improved
  - smaller wavelength
  - longer antenna
- all radiating parts in phase

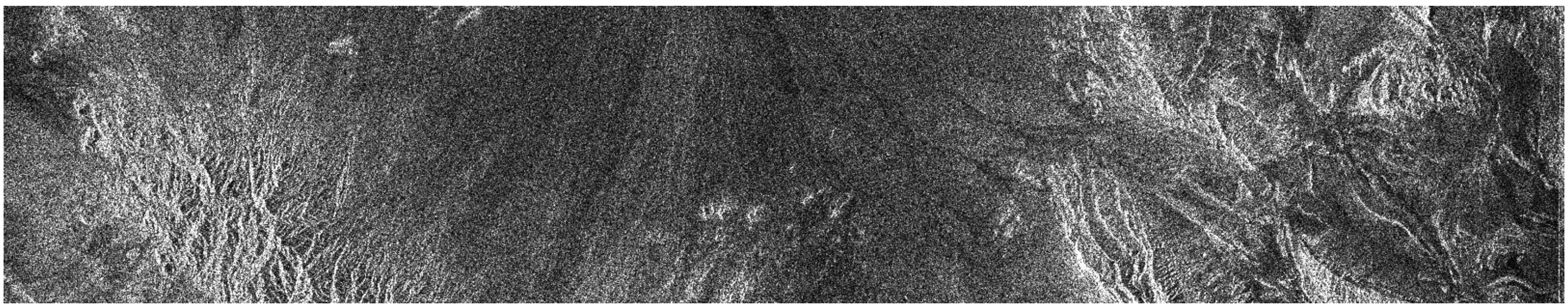
Synthetic aperture radar



- many little antennas form an effectively long antenna
- all radiating elements in phase

Real versus Synthetic Aperture

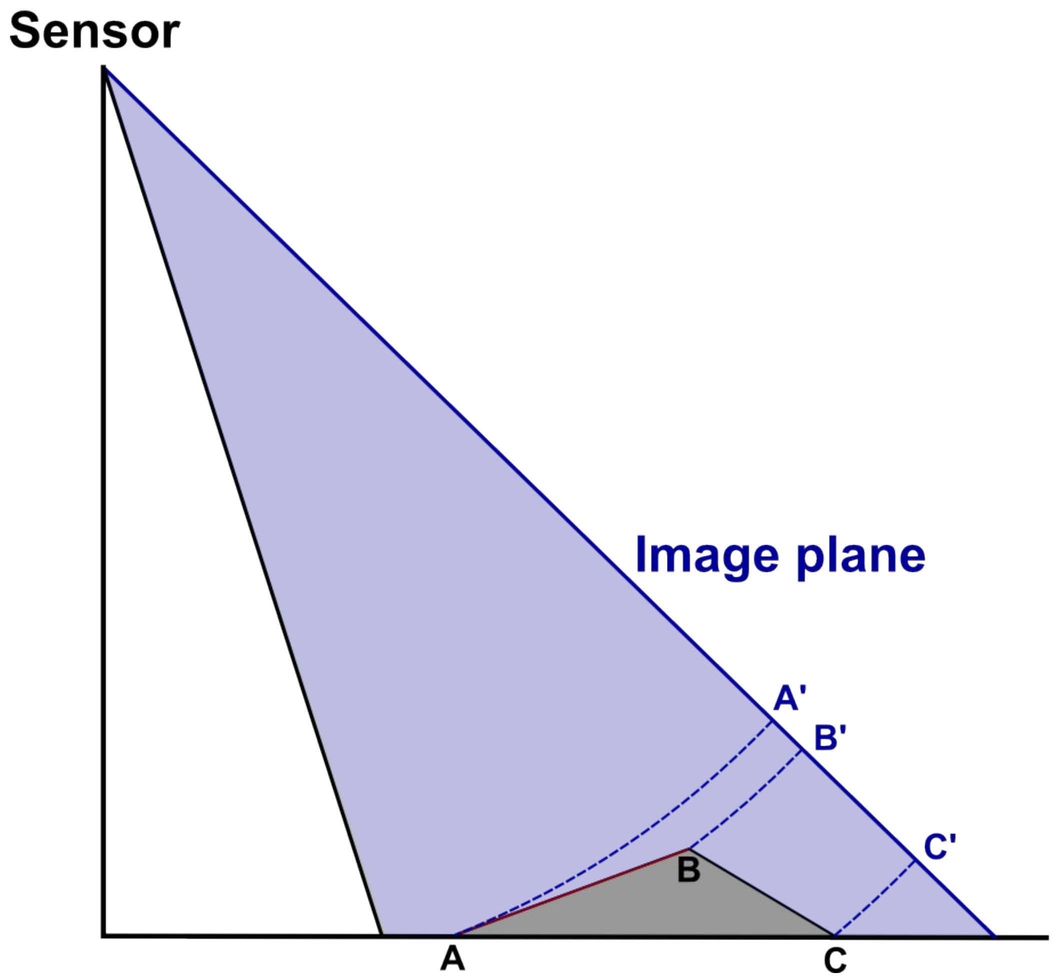




Geometric *distortions*

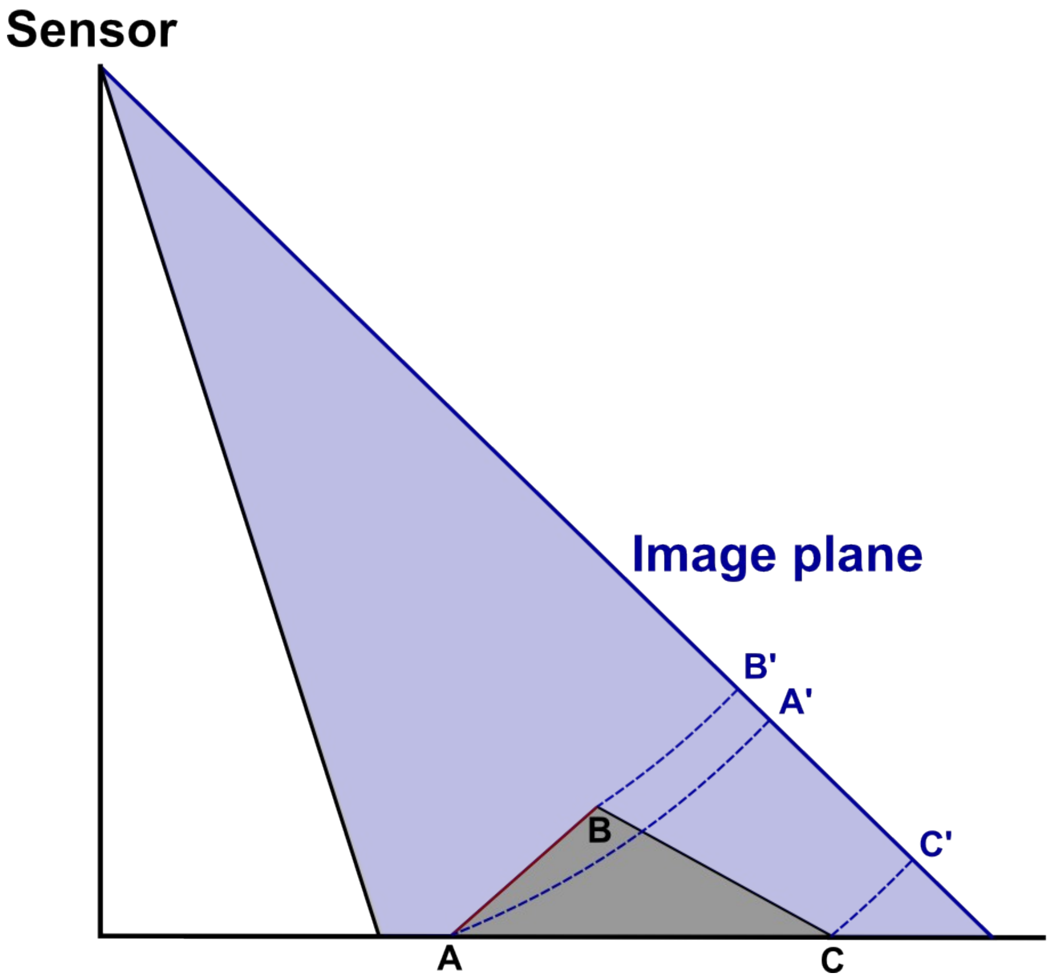
- caused by the side looking geometry of radar
  - foreshortening
  - layover
  - shadow

Foreshortening



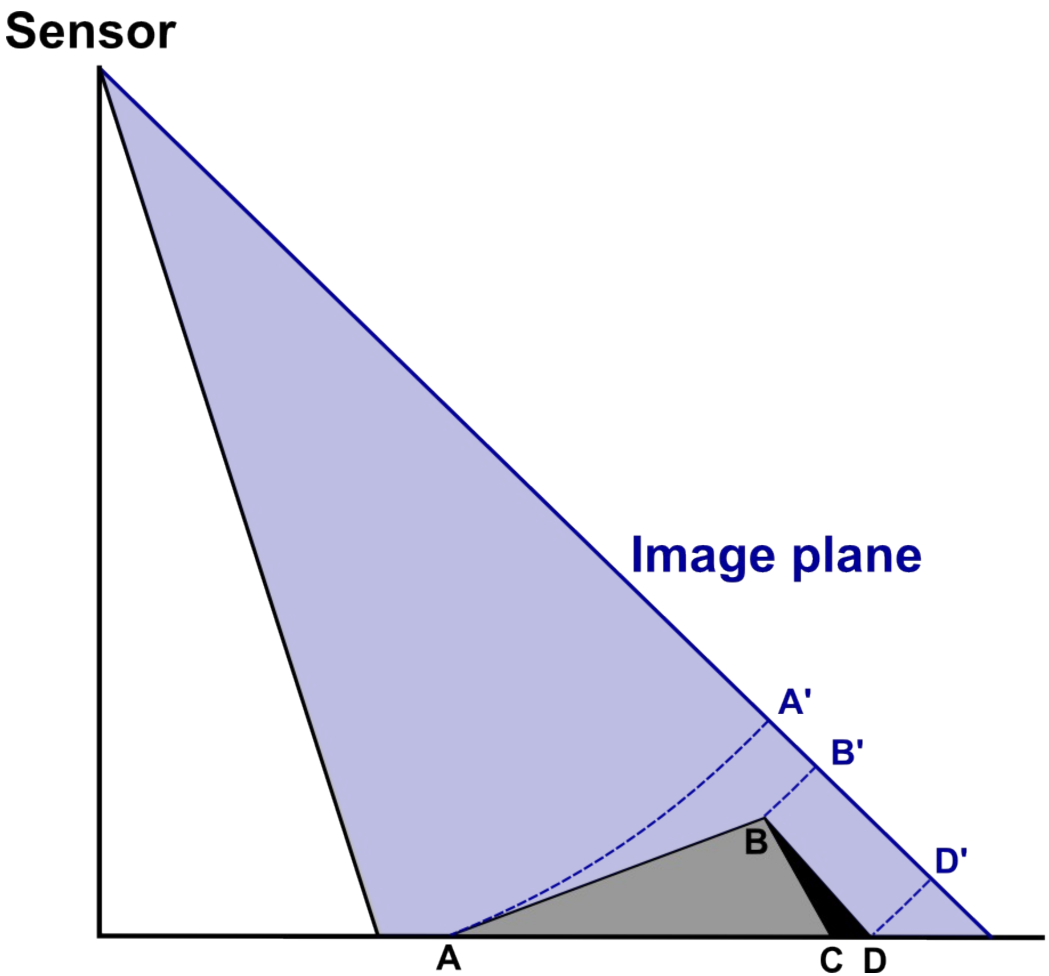
- distance A-B on the slope is shortened to A'-B' in the SAR image
- bright pixel values

Layover



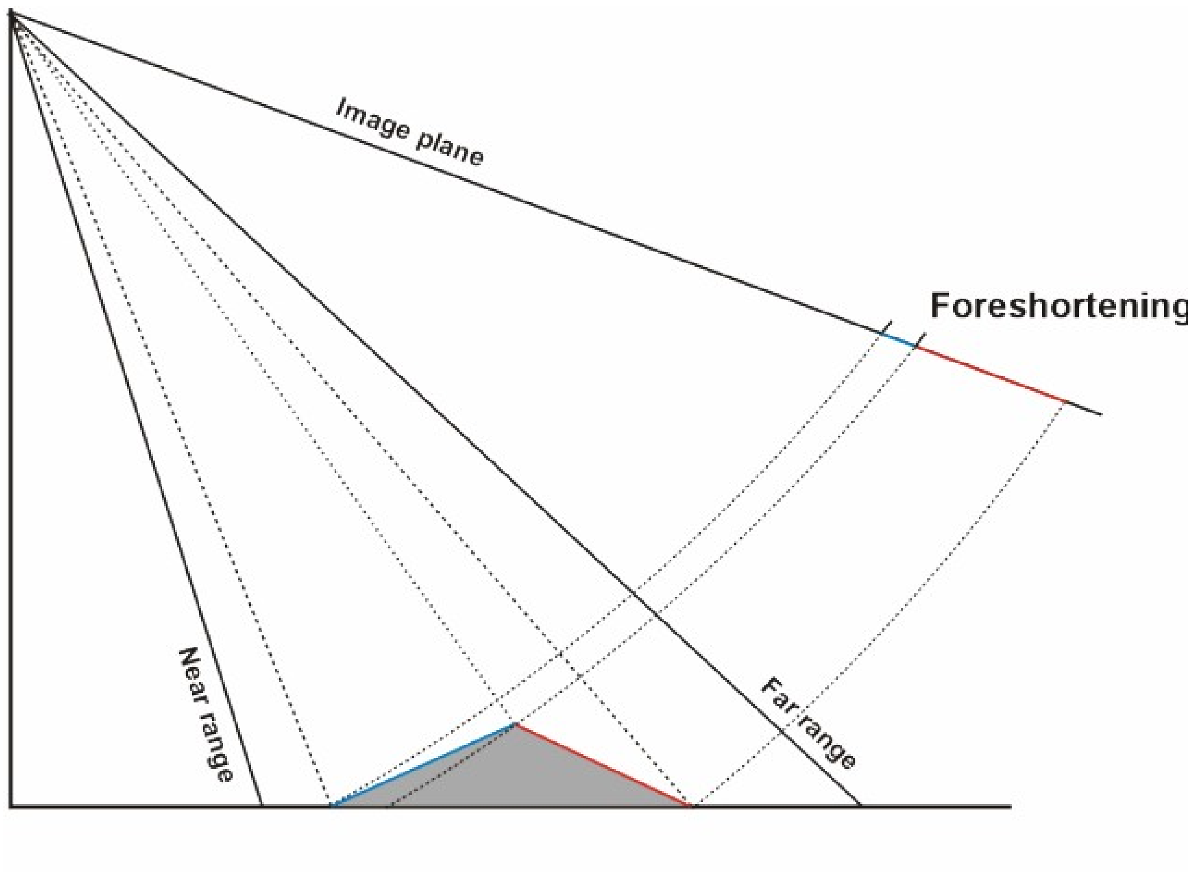
- distance A-B on the slope is shortened to A'-B' in the SAR image
- extreme case of foreshortening
- top of the mountain is closer to the sensor than the bottom
- bright pixel values

Shadow

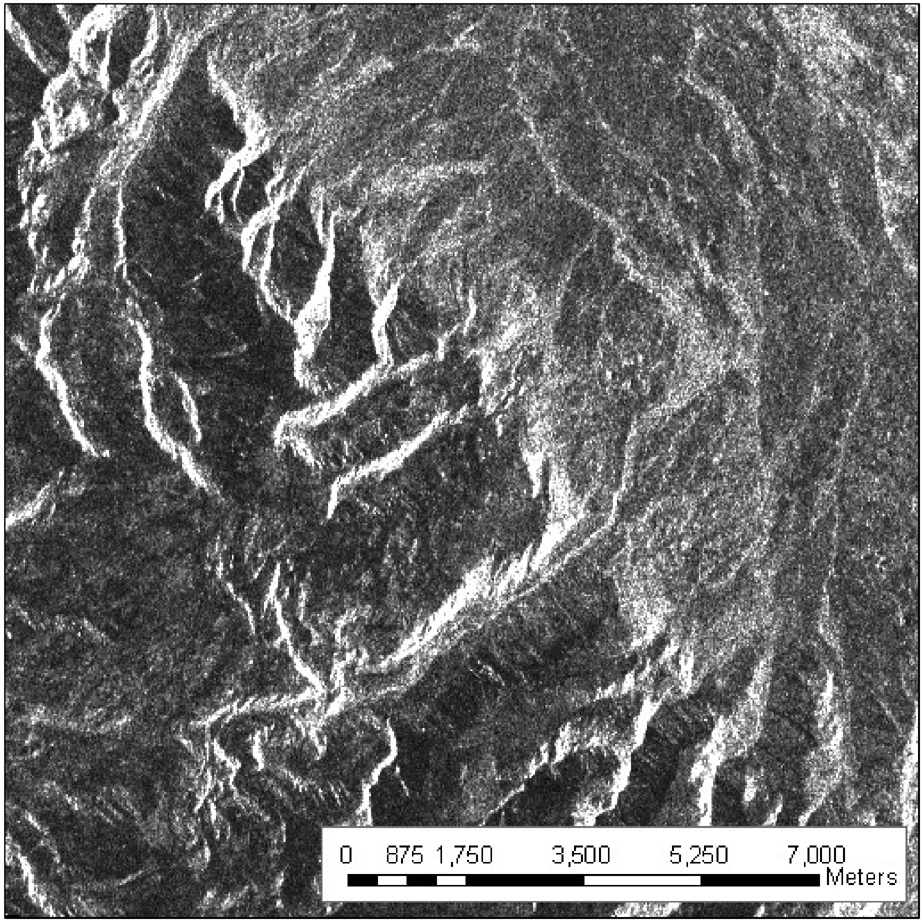


- distance B-C on the slope does not appear in the SAR image
- top of the mountain high enough so that backslope is completely in the shadow
- dark pixel values

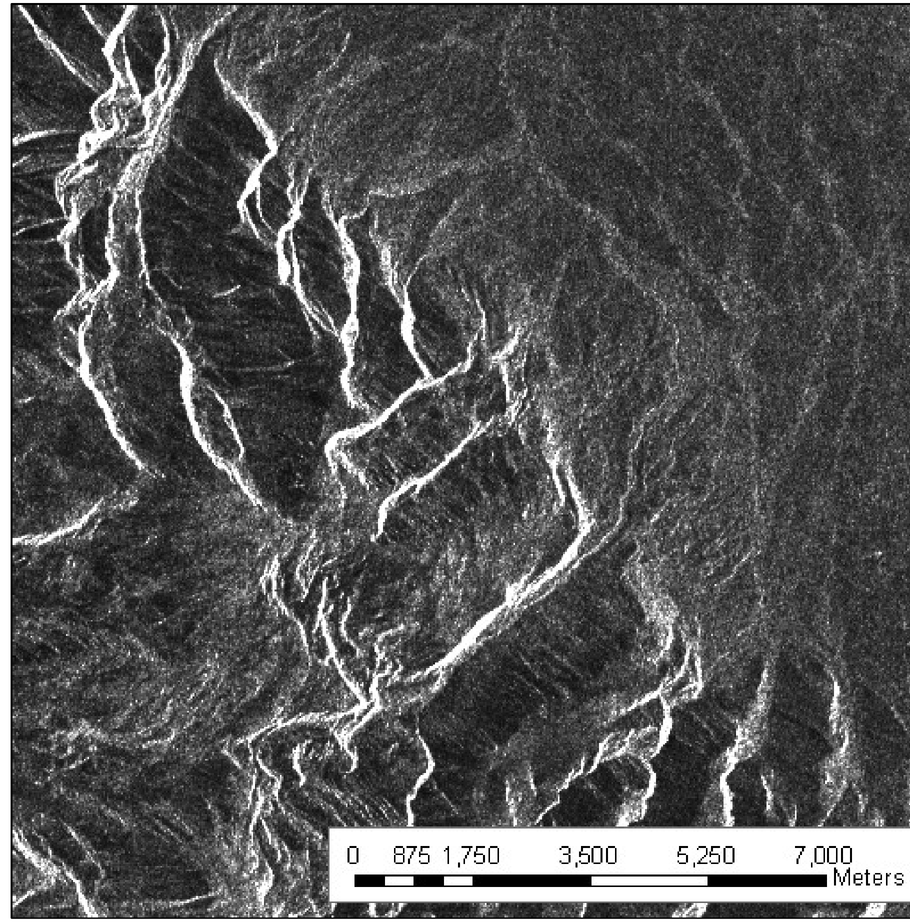
Geometric distortions



Distortions: Foreshortening

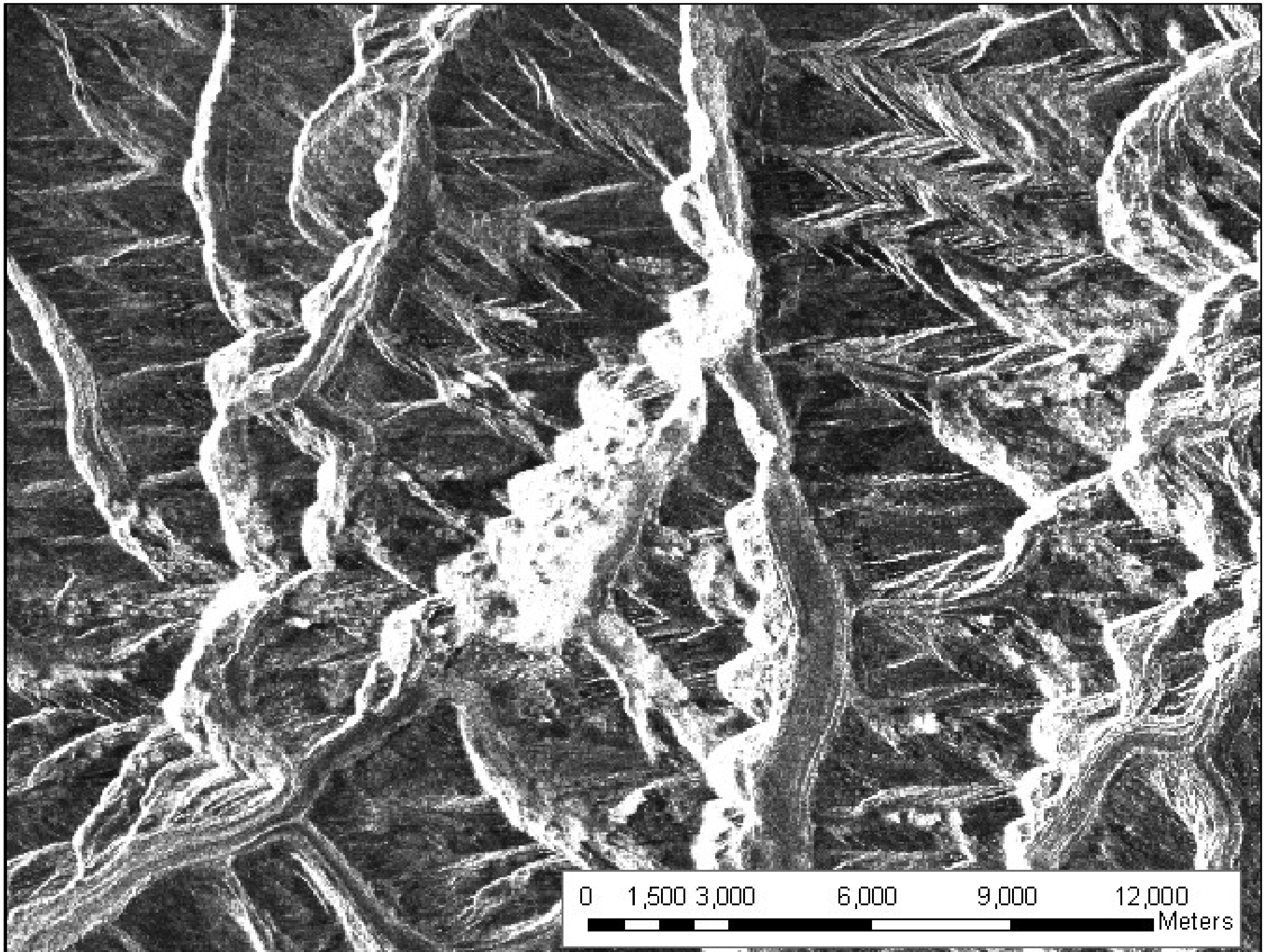


JERS-1 Credits: JAXA



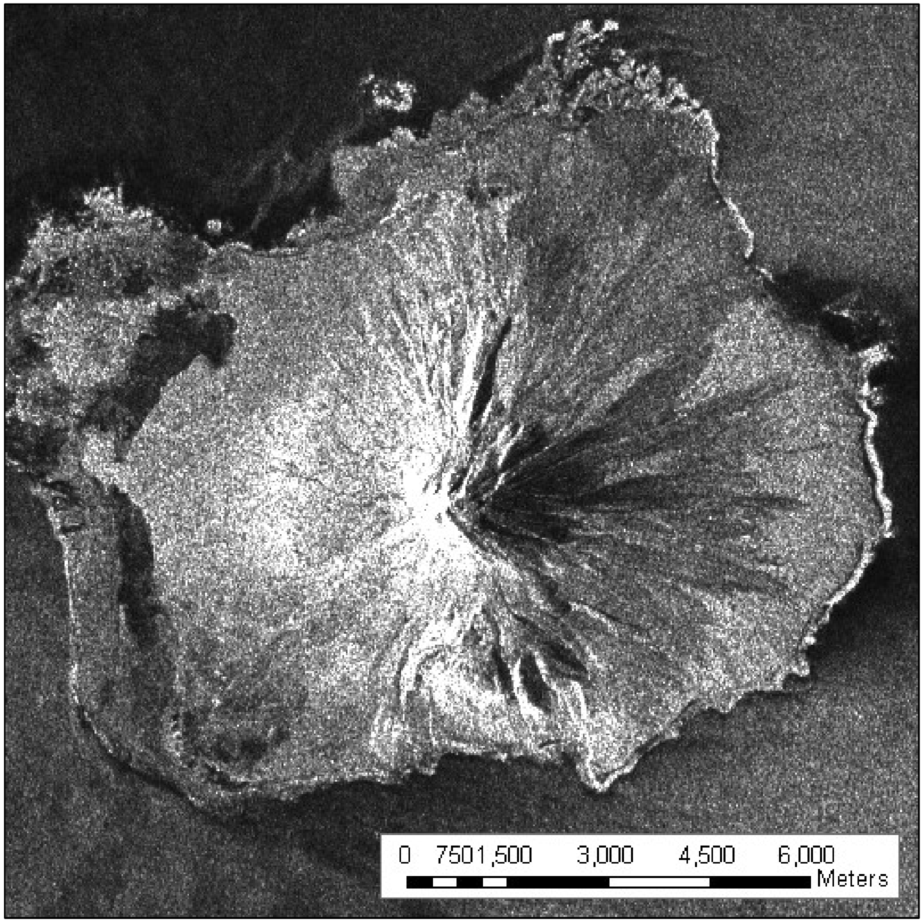
Radarsat-1 Credits: CSA

Distortions: Layover

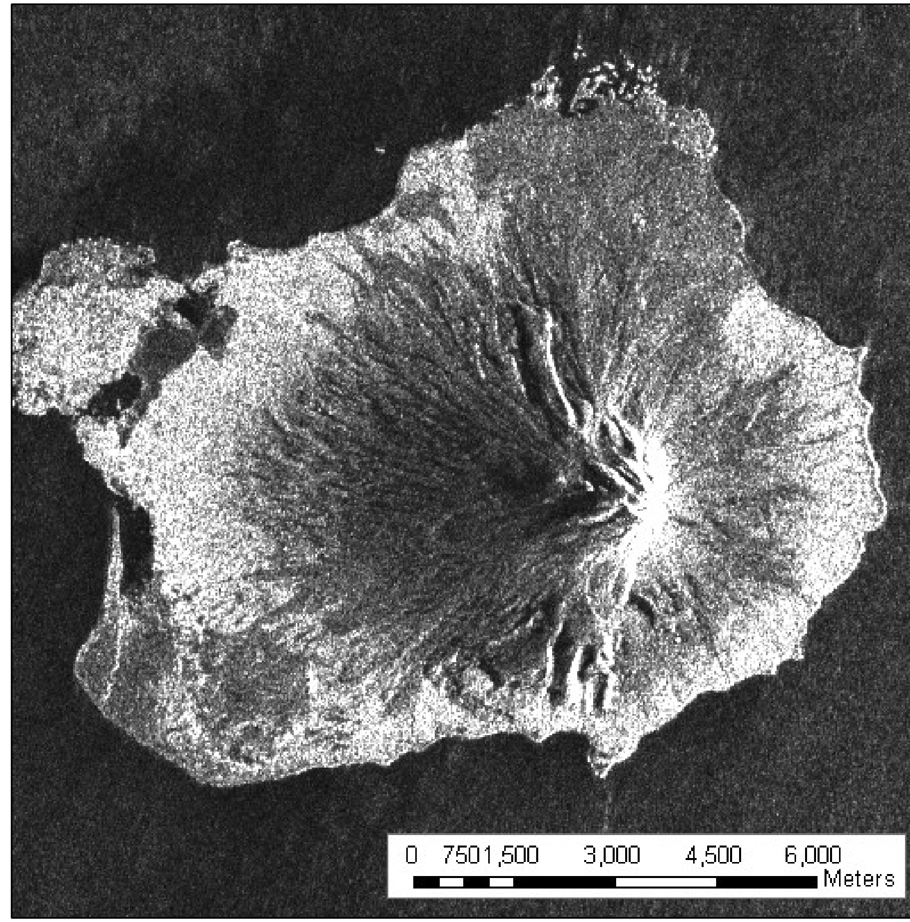


Credits: CSA

Distortions: Shadow



Ascending



Descending

Credits: CSA

Advantages of SAR

- Use day and night
  - Active sensor
- Sees through clouds (mostly)
  - wavelength of microwaves versus light
- Repeat coverage
- Good for physical feature detection
- Resolution

Disadvantages of SAR

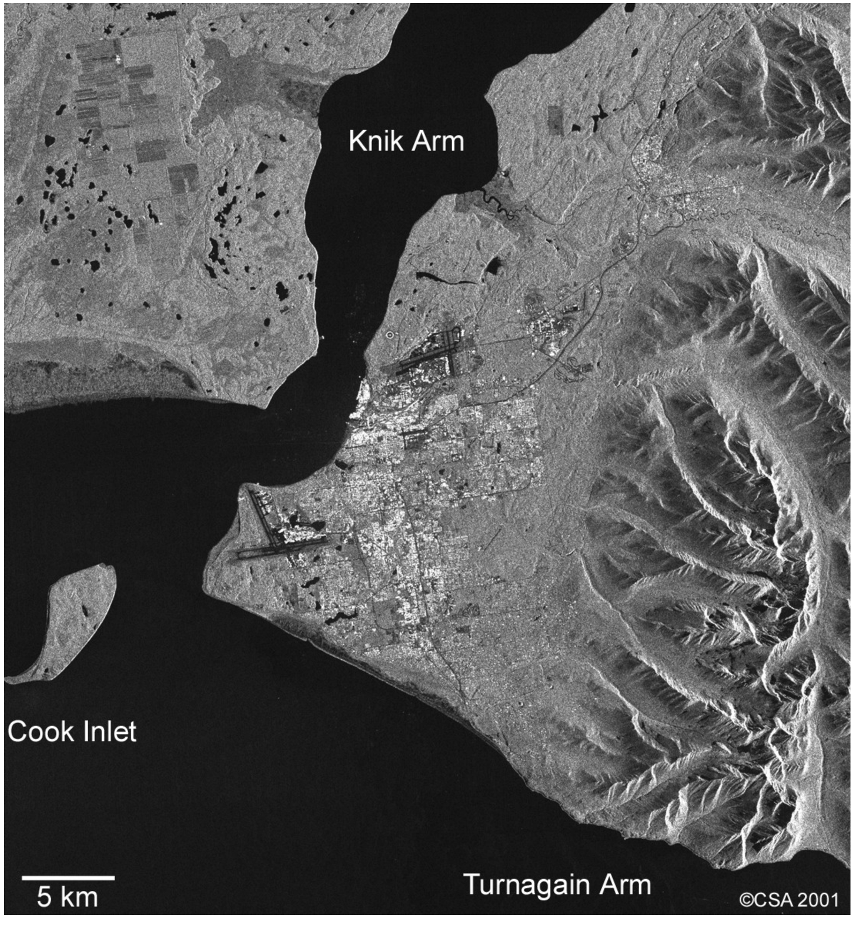
- It is not a picture
  - Calibration
  - Interpretation
- Extensive computer processing
  - Time delays
  - Data quality issues
- Few platforms
  - Continuity of data
  - Competition for data
- Resolution

Why is radar side looking?

Image interpretation

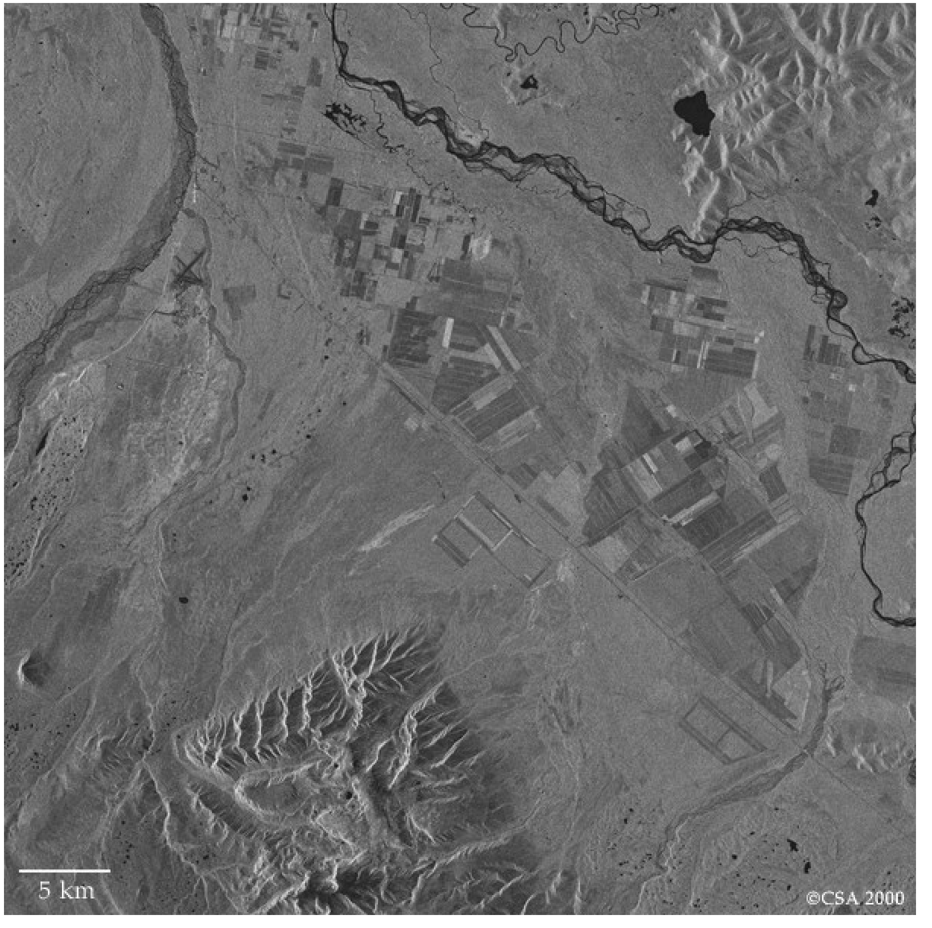
SAR applications

Geomorphology



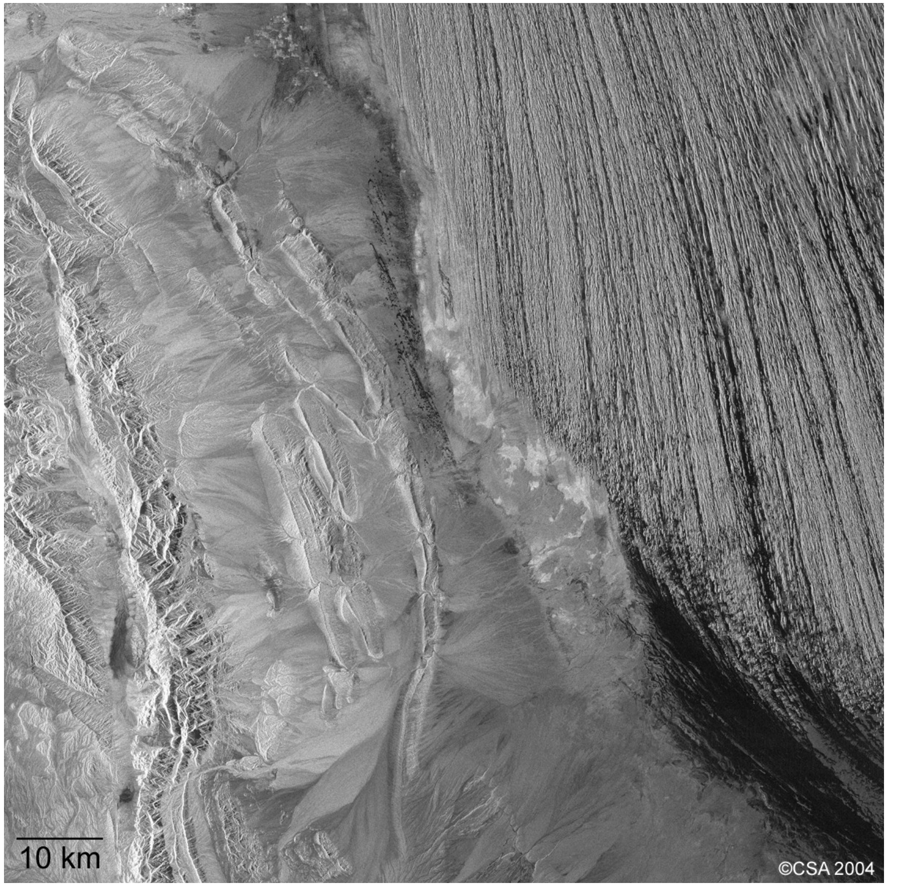
Radarsat image of Anchorage depicting varied returns of urban area.

Geomorphology



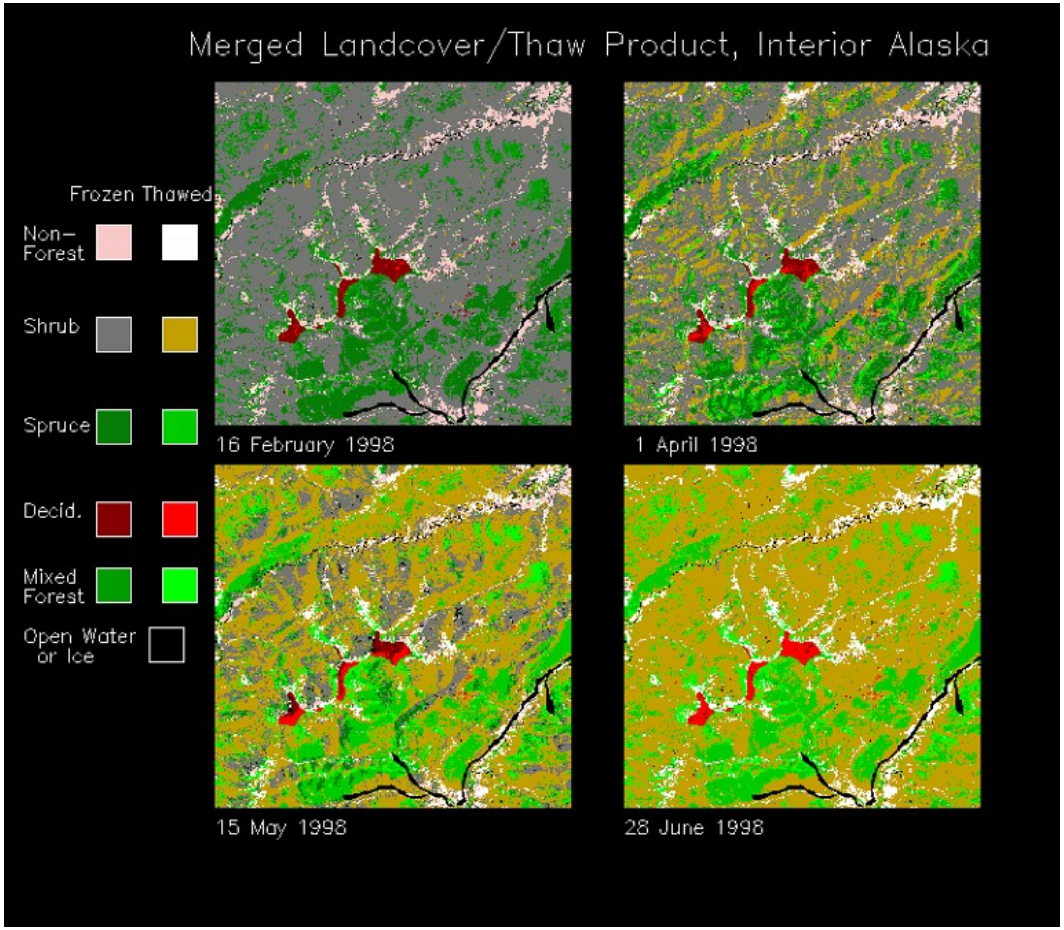
Radarsat Fine-1 image of Delta Junction.
Agricultural fields are highlighted by SAR.

Geomorphology



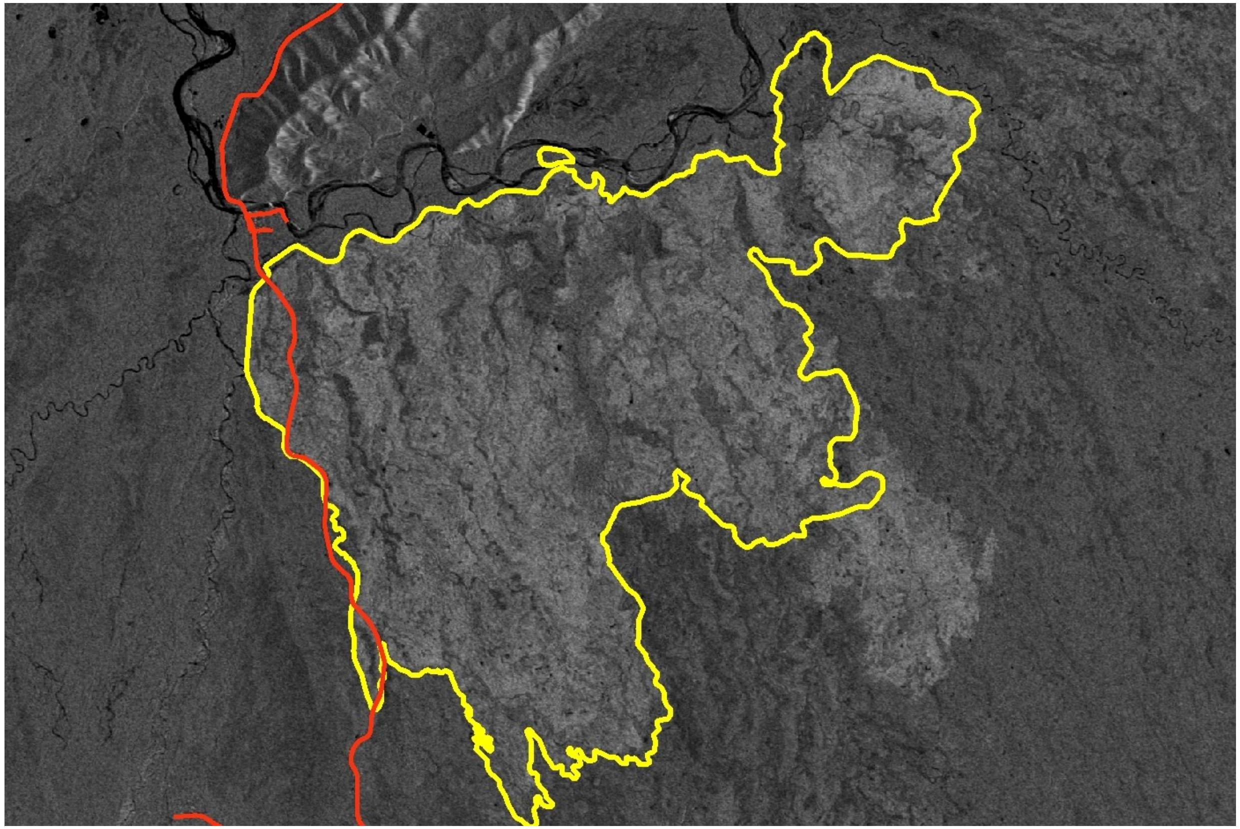
Radarsat Standard image of Dasht-E-Lut Desert, Iran.
Linear yardangs formed by unidirectional winds over clay sediment.

Land Use / Land Change



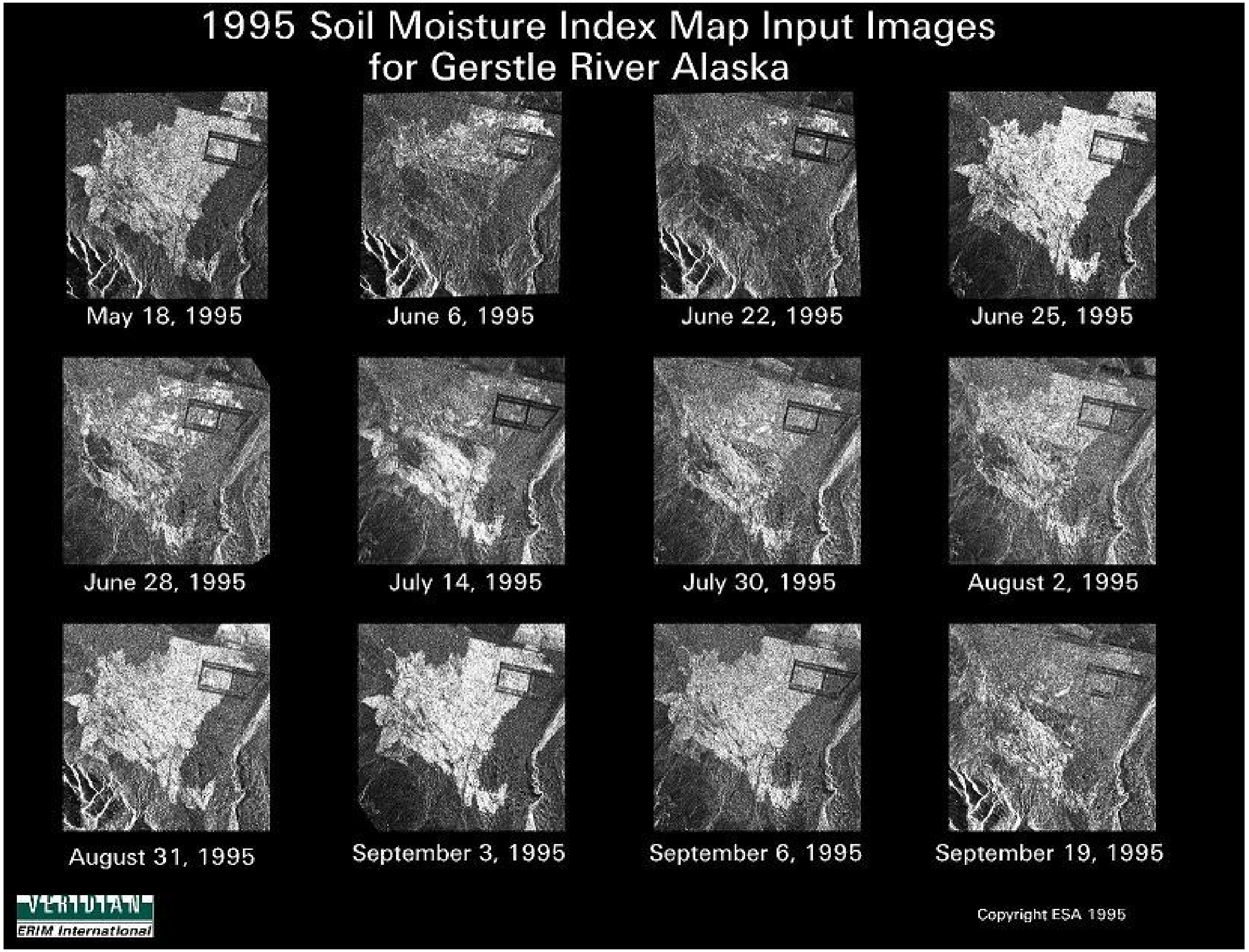
Freeze/thaw processes mapped in Interior Alaska from fused Landsat classification and JERS imagery.

Burn Scar Detection

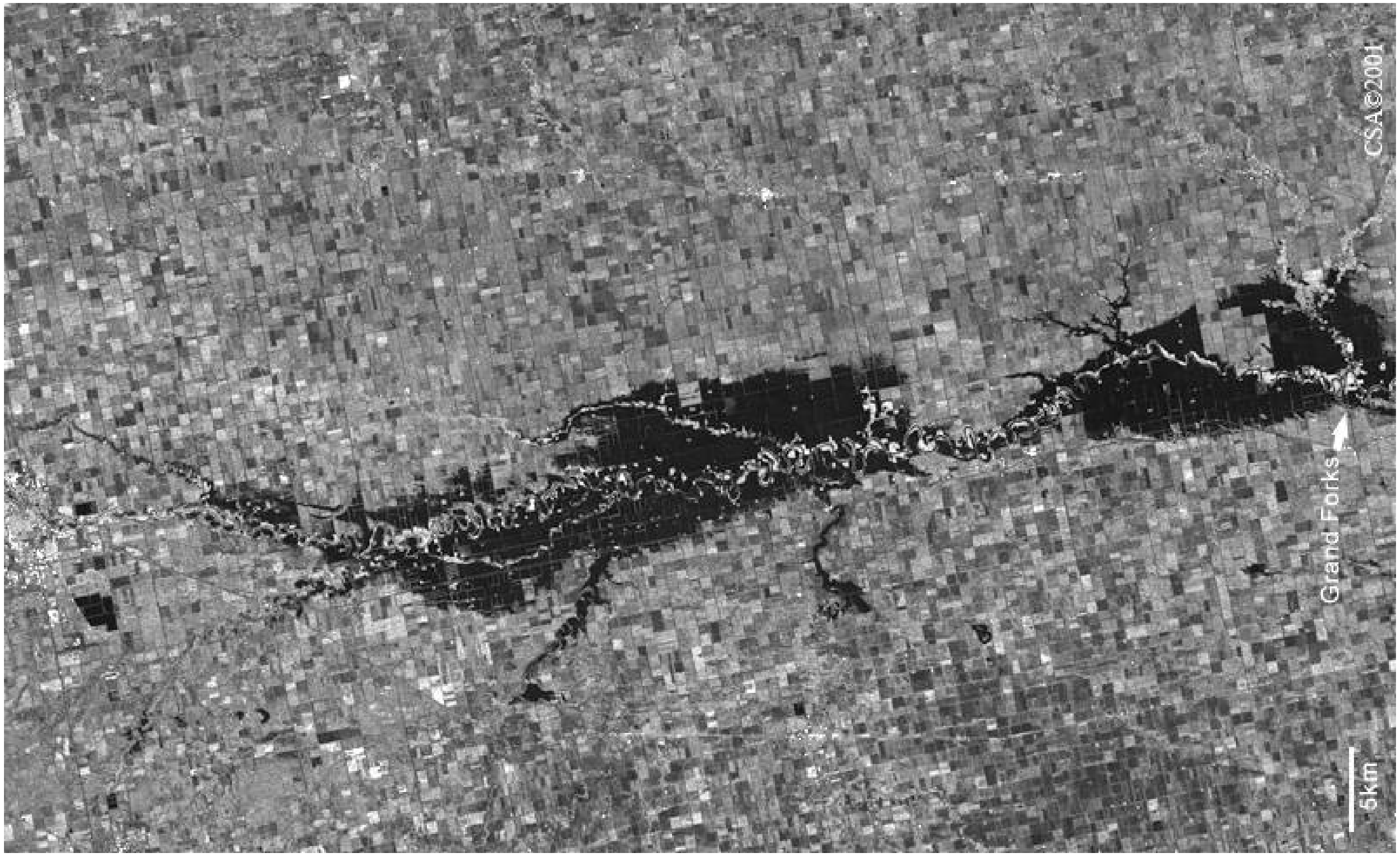


C-band image (ERS-2) highlights burn scar through sensitivity to soil moisture. Yellow line represents official Alaska Fire Service (AFS) burn scar perimeter for Parks Hwy fire. Anomaly in SE may indicate error in AFS perimeter.

Soil Moisture Measurement

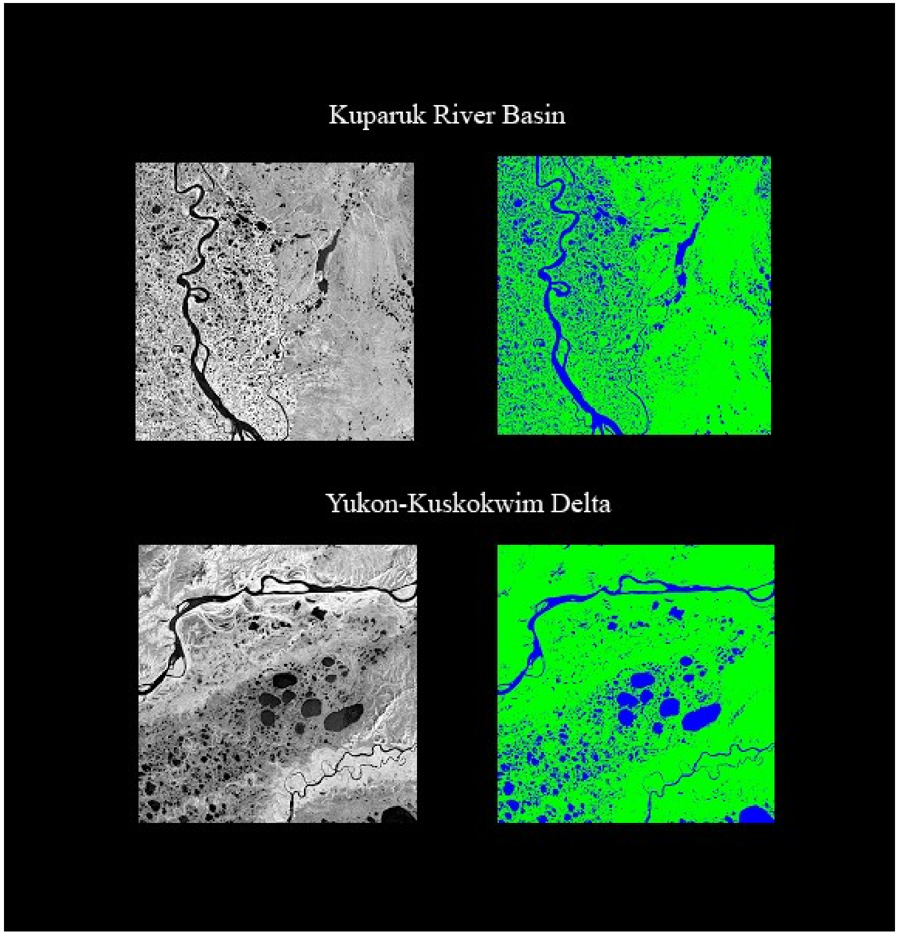


Hydrology



Flooding of Red River in North Dakota. Trees and water serve as corner reflectors.

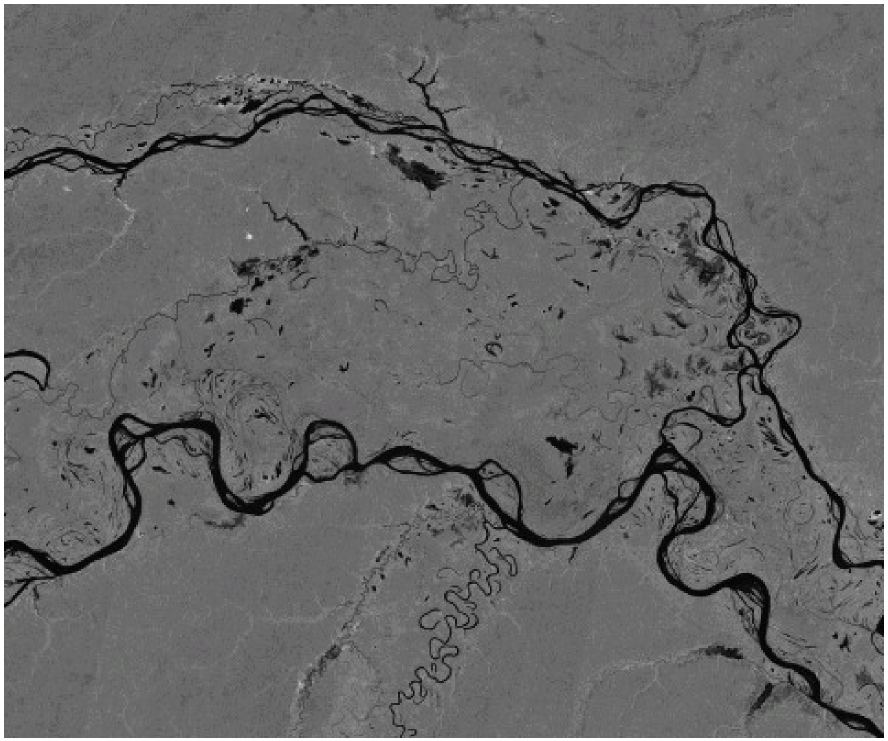
Hydrology



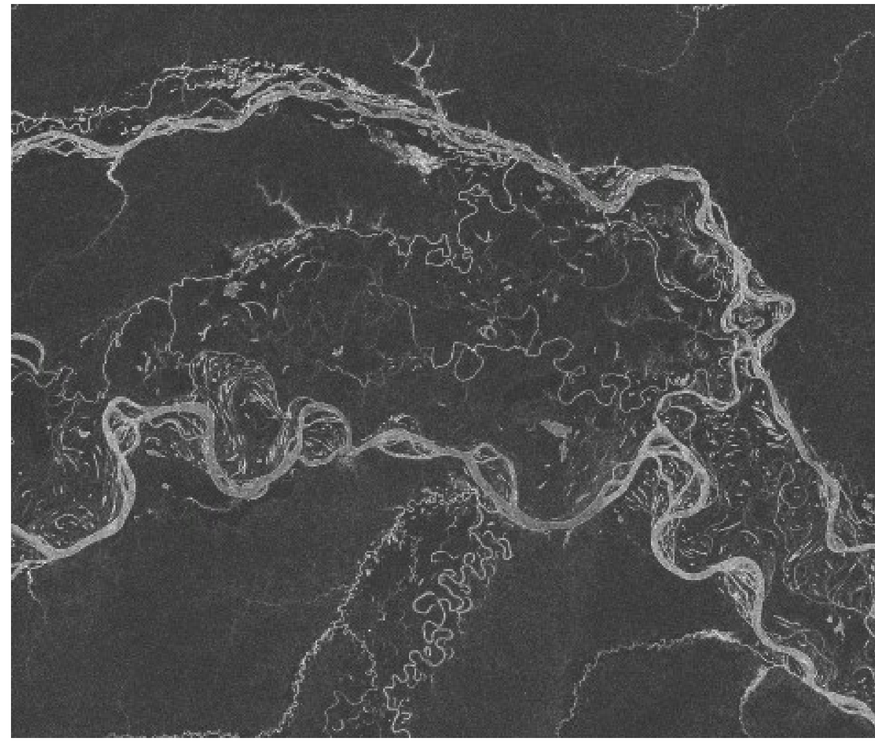
Open water maps derived from unsupervised clustering classification.

Hydrology

JERS-1 Radar Backscatter Image

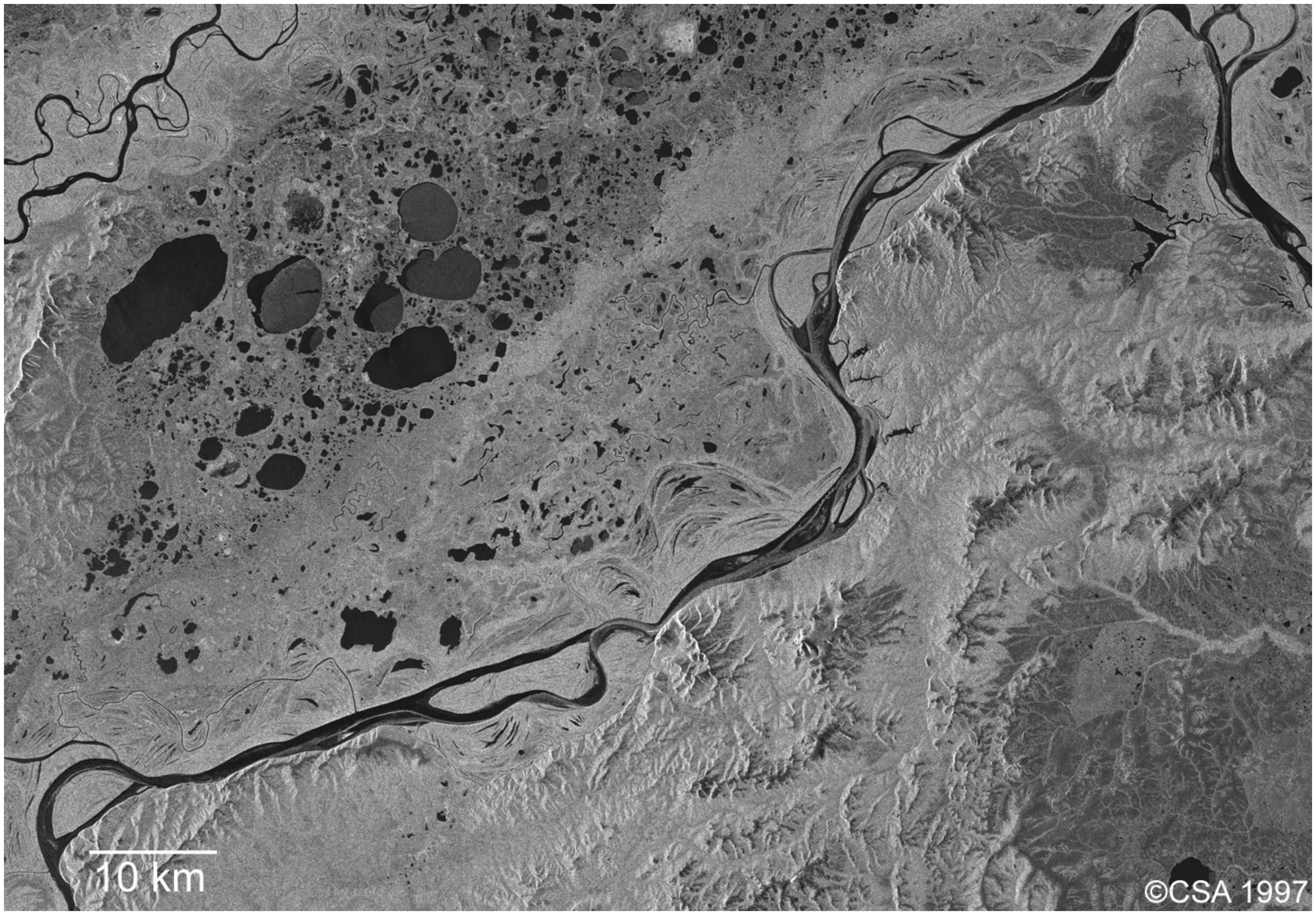


JERS-1 Texture Analysis Image



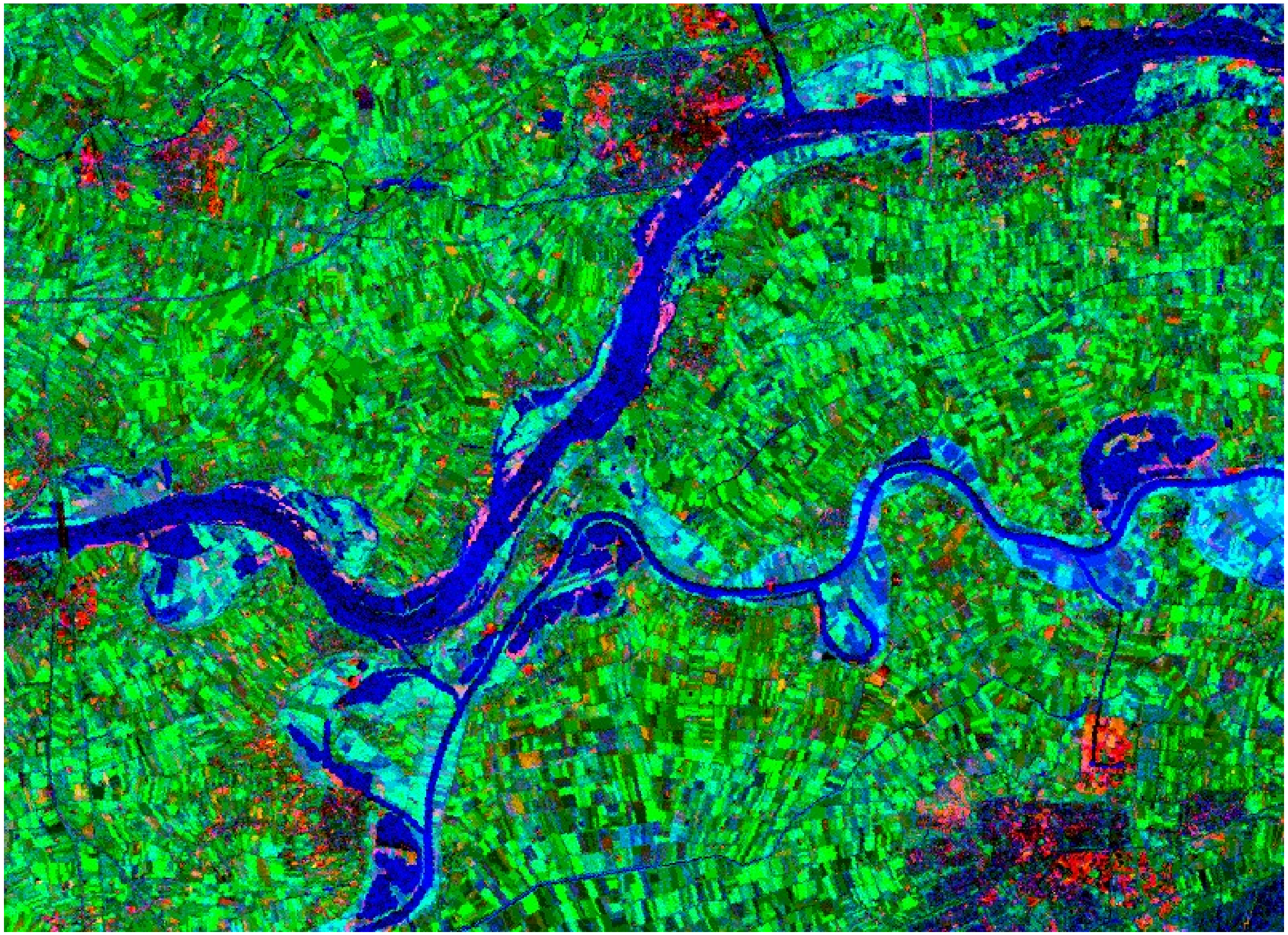
Texture analysis used to distinguish forest from open water in flooded Amazon.

Hydrology



Radarsat image of Yukon River during Spring thaw.

Flood Mapping



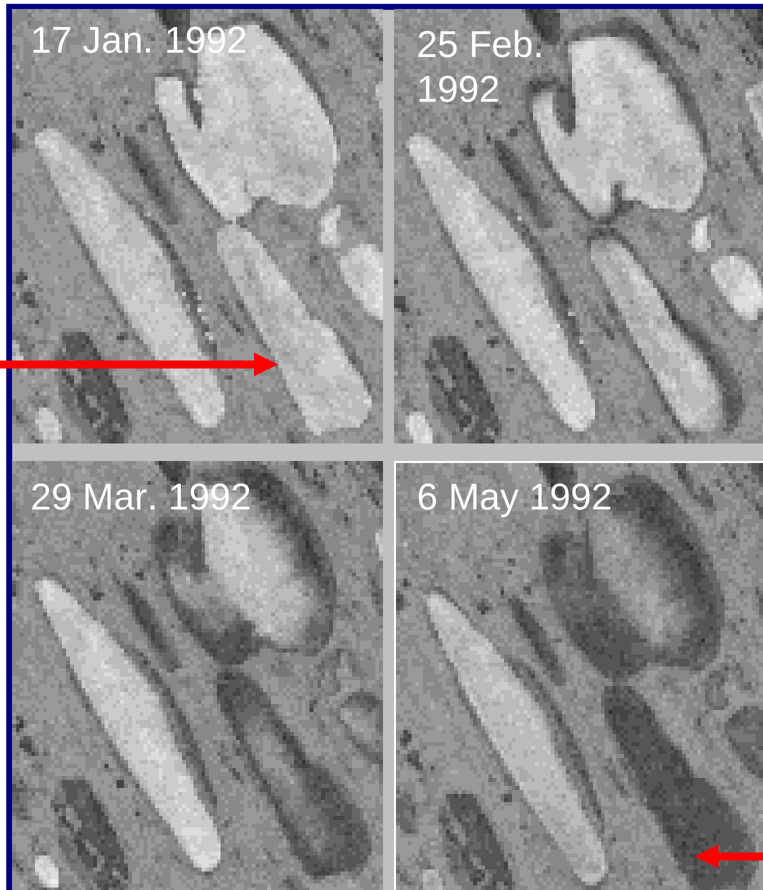
Credits:
Pohl, ITC

Multi-temporal SAR flood data fused with Optical data

Hydrology

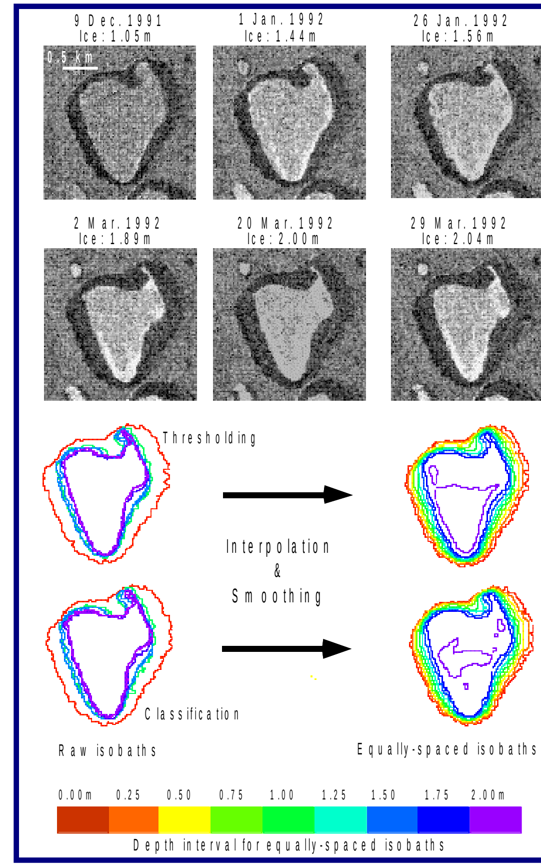
Discerning bathymetry from SAR backscatter

Surface Water Frozen

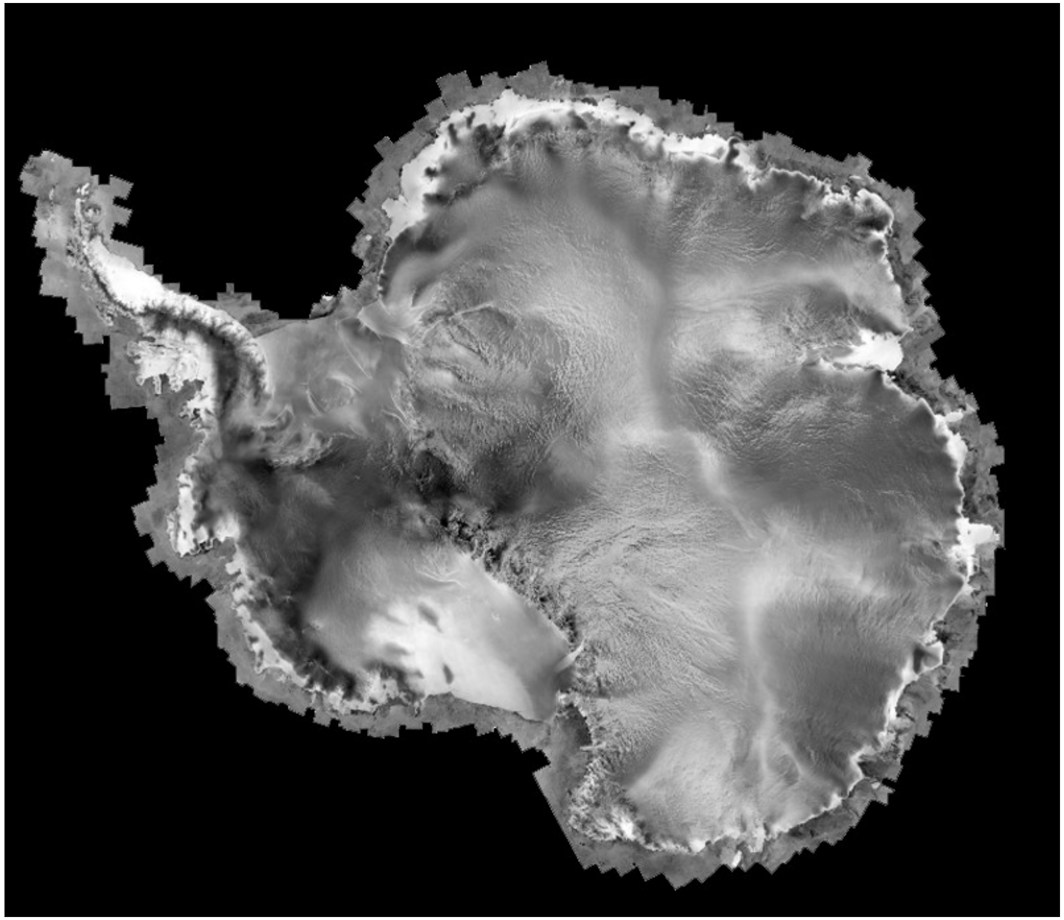


Frozen to lake bottom

Credit: Martin Jeffries

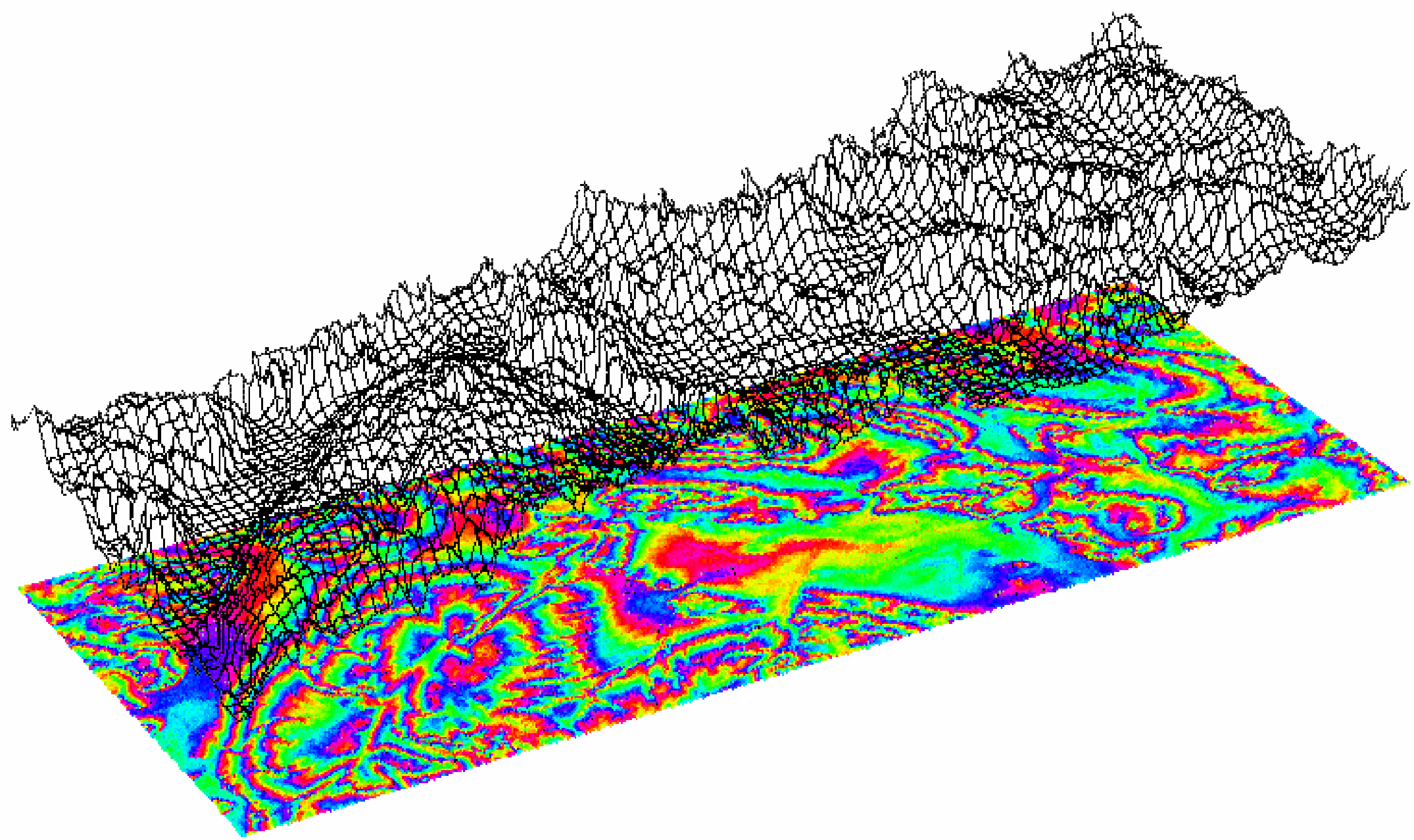


Mapping

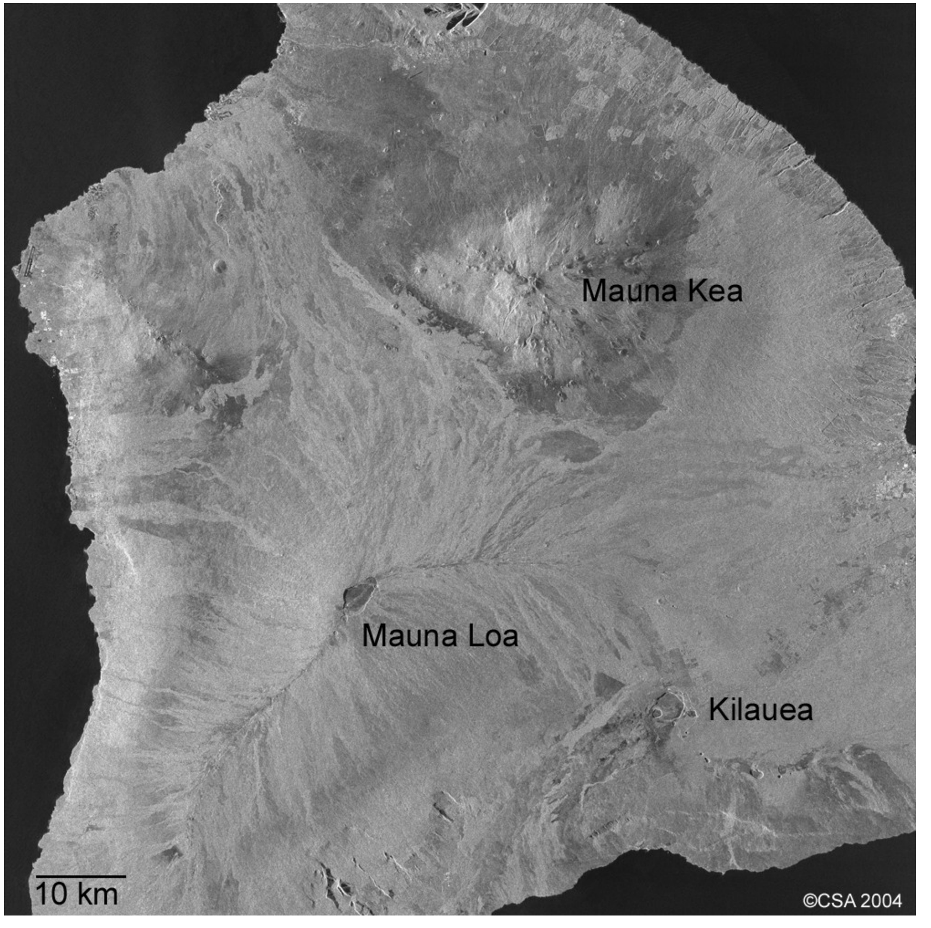


Radar map of Antarctic formed from mosaic of Oct 1997 Radarsat images.

DEM Generation



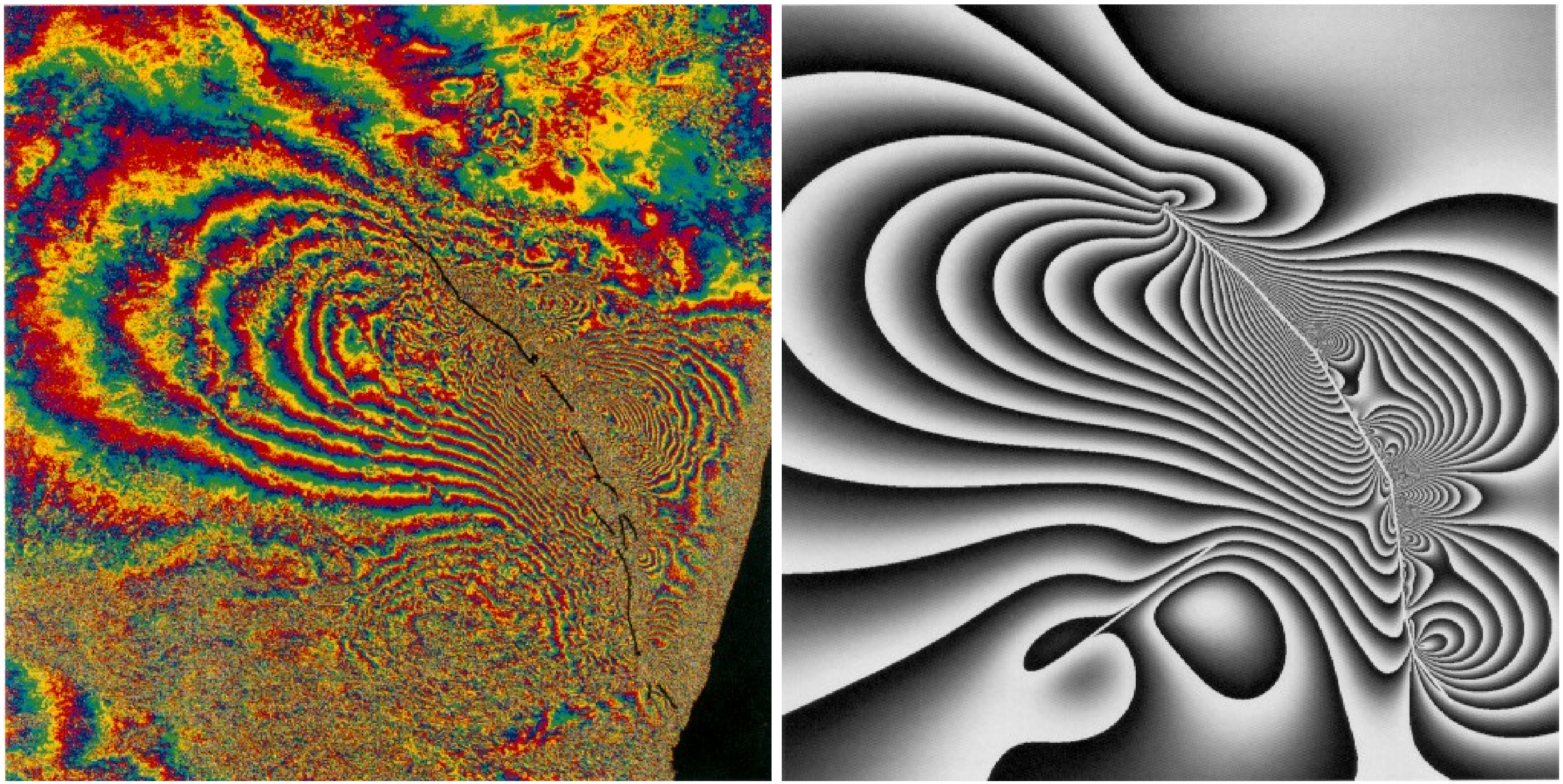
Volcanology



Radarsat image of Hawaii showing three stages of shield volcano evolution.

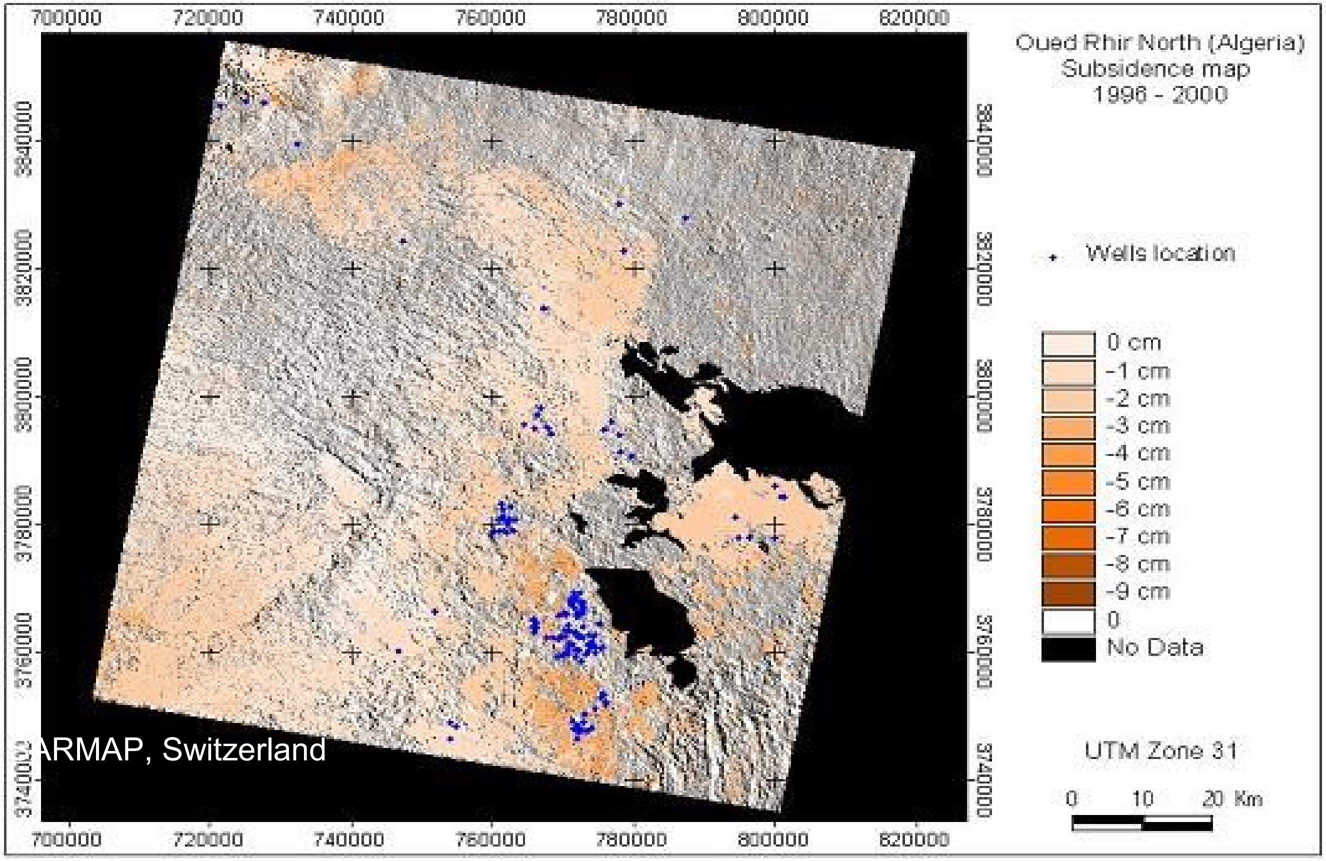
Tectonics

Interferogram and model of Landers earthquake, California



Massonnet, D. et al 1993. The Displacement Field Of The Landers Earthquake Mapped By Radar Interferometry. *Nature*, **364**(6433): 138-142.

Subsidence Monitoring



Subsidence measured from 1996-2000 on the Oued Rhir area (Algeria)

- well locations shown in blue

Ocean Monitoring

Primary source of Ocean surface roughness:
Gravity-capillary Waves

Close-up photo of Capillary Waves

Wind generated waves
Wavelength - order of 1 cm

Waves get modulated by:
- Changing wind speed
- Oil spill
- Other surfactants
- Upwelling
- Currents
- Bathymetry