Microwave remote sensing

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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
Optical versus radar

Sensor

Optical plane

Radar plane

A' B' C' D'
A'' B'' C'' D''
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

- **X-band** (3.2 cm)
- **C-band** (5.7 cm)
- **L-band** (23.0 cm)
Radar scattering

Specular scattering

smooth surface

Bragg scattering

rough surface

Edge and corner reflectors

Volume scattering

Diffuse scattering

vegetation
Real aperture radar

- 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

Sensor

Image plane

A' B' C D'
Geometric distortions

Image plane

Foreshortening

Near range

Far range
Distortions: Foreshortening

JERS-1  Credits: JAXA

Radarsat-1  Credits: CSA
Distortions: Layover
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.
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.
Flooding of Red River in North Dakota. Trees and water serve as corner reflectors.
Open water maps derived from unsupervised clustering classification.
Texture analysis used to distinguish forest from open water in flooded Amazon.
Hydrology

Radarsat image of Yukon River during Spring thaw.
Flood Mapping

Multi-temporal SAR flood data fused with Optical data

Credits: Pohl, ITC
Hydrology

Discerning bathymetry from SAR backscatter

17 Jan. 1992
25 Feb. 1992
29 Mar. 1992
6 May 1992

Credit: Martin Jeffries

Frozen to lake bottom
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.
Subsidence measured from 1996-2000 on the Oued Rhir area (Algeria)

- well locations shown in blue
Primary source of Ocean surface roughness:
Gravity-capillary Waves

Wind generated waves
Wavelength - order of 1 cm

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

Close-up photo of Capillary Waves