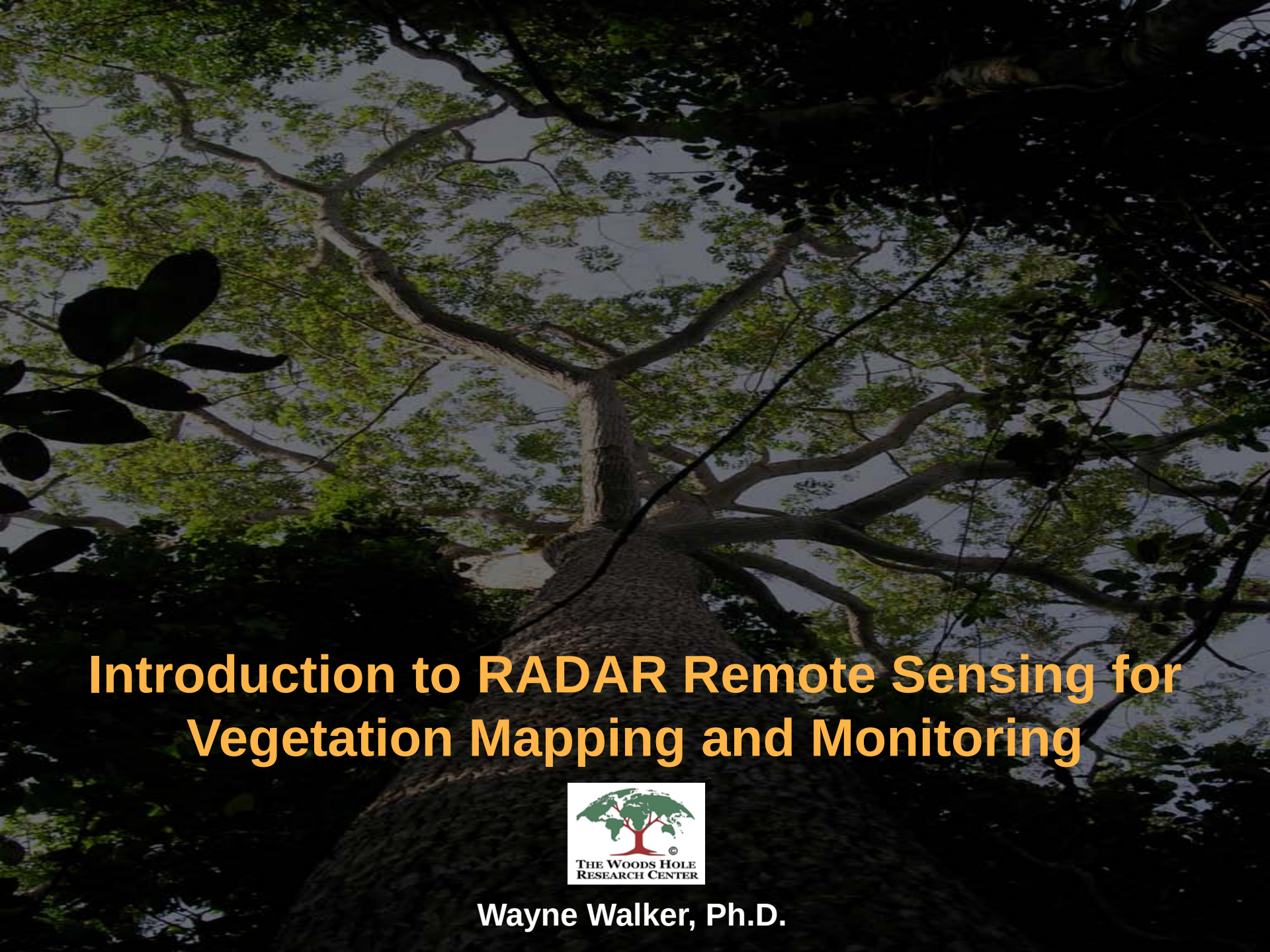


Introduction to RADAR Remote Sensing for Vegetation Mapping and Monitoring

THE WOODS HOLE RESEARCH CENTER

Wayne Walker, Ph.D.

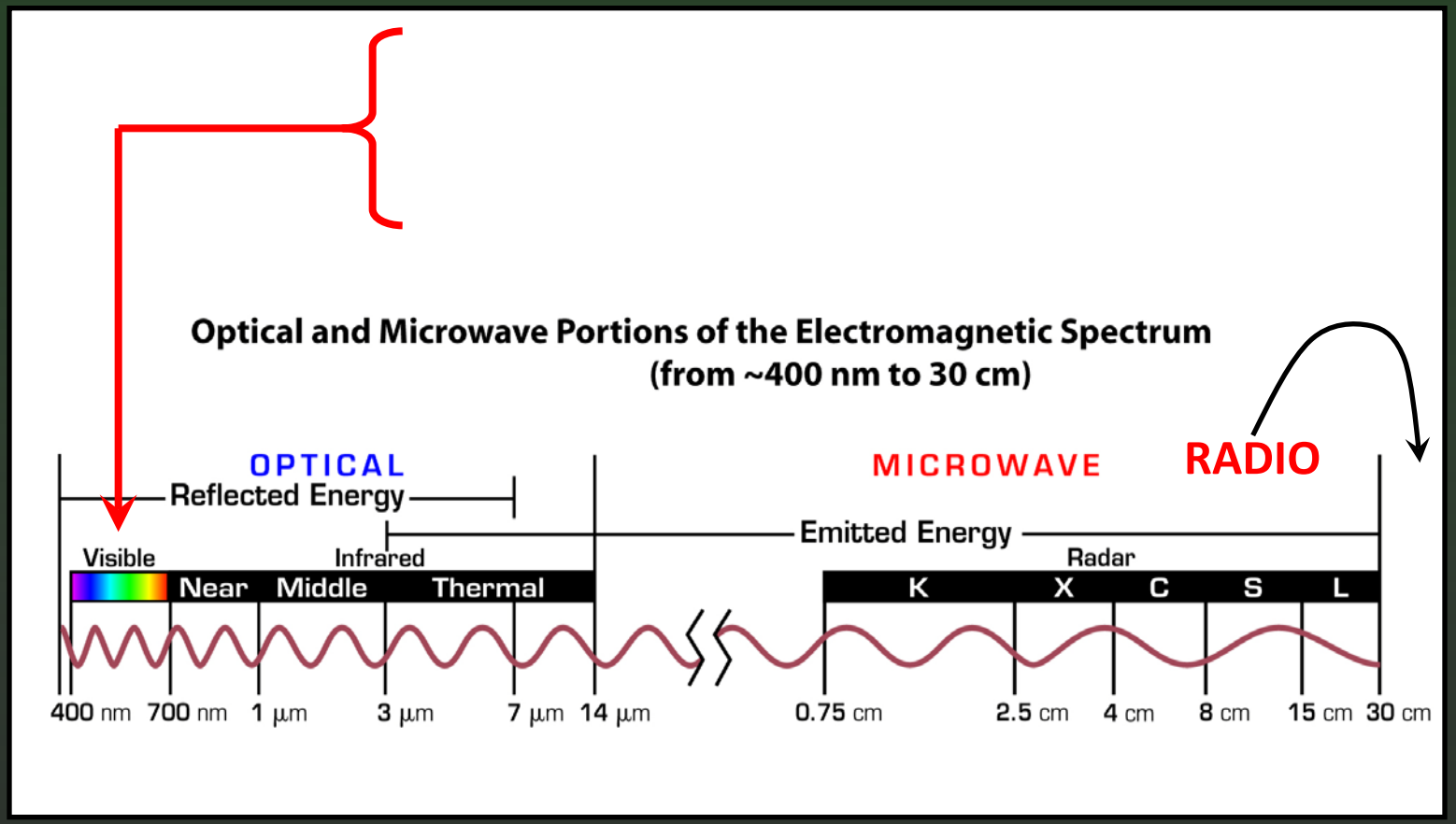
Outline

- What is RADAR (and what does it measure)?
- RADAR as an active sensor
- Applications of RADAR to vegetation mapping/monitoring
- What determines RADAR backscatter from vegetation?
  - ✓ System parameters (Sensor)
  - ✓ Target parameters (Ground)
- What is Speckle?
- Photographic review of forest structure

What is RADAR?

RADAR is an acronym that stands for:

Radio Detection and Ranging

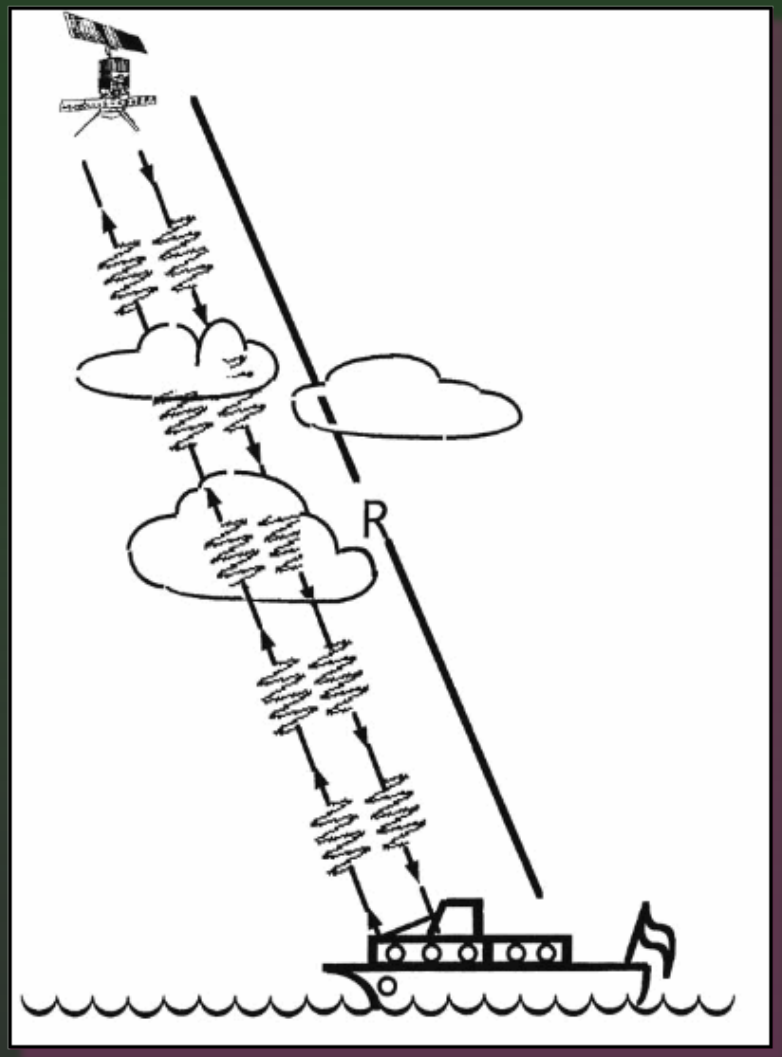


What is RADAR?

RADAR is an acronym that stands for:

Radio Detection and Ranging

- Running time: $t = 2R/c$
- Distance: $R = ct/2$

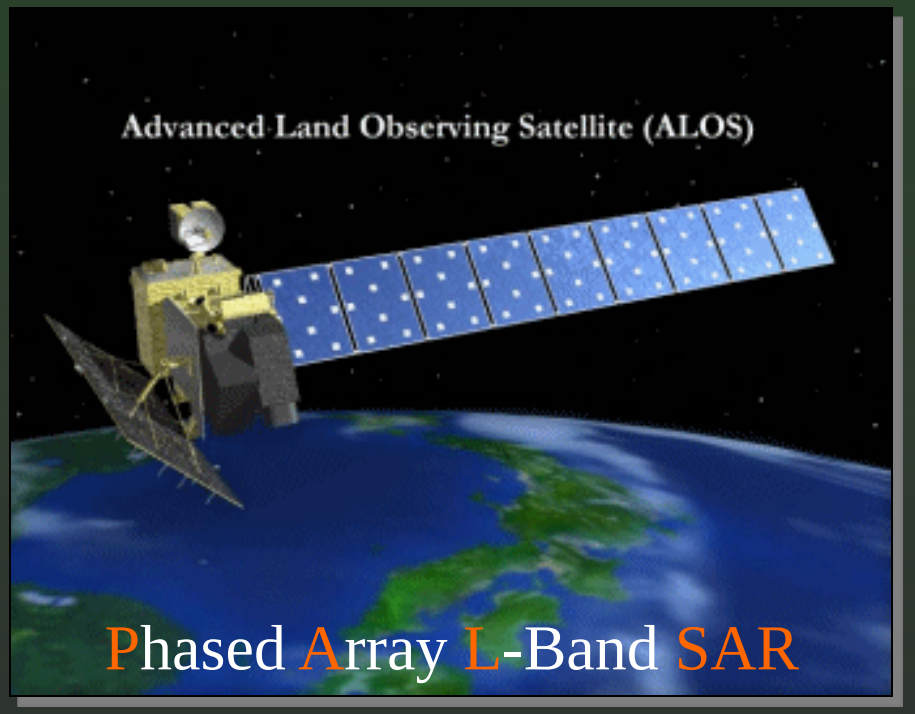


What is RADAR?

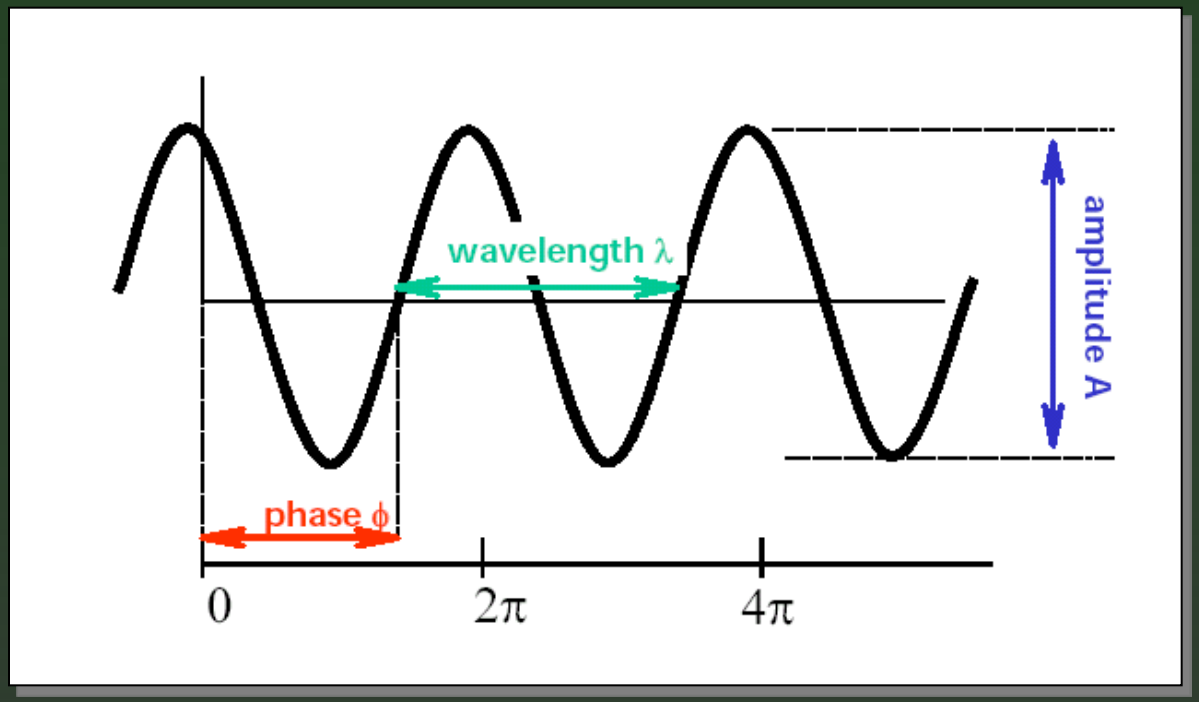
SAR is an acronym that stands for:

Synthetic Aperture RADAR

All imaging RADAR sensors used for remote sensing are Synthetic Aperture Radars.



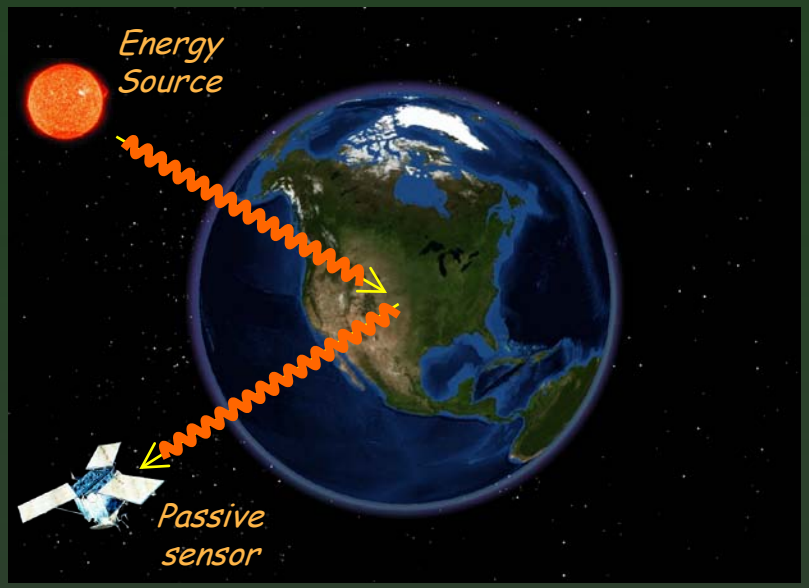
What does RADAR measure?



- Amplitude depends on target properties (structure and dielectric properties).
- Phase is a function of the distance between sensor and the target as well as target properties.

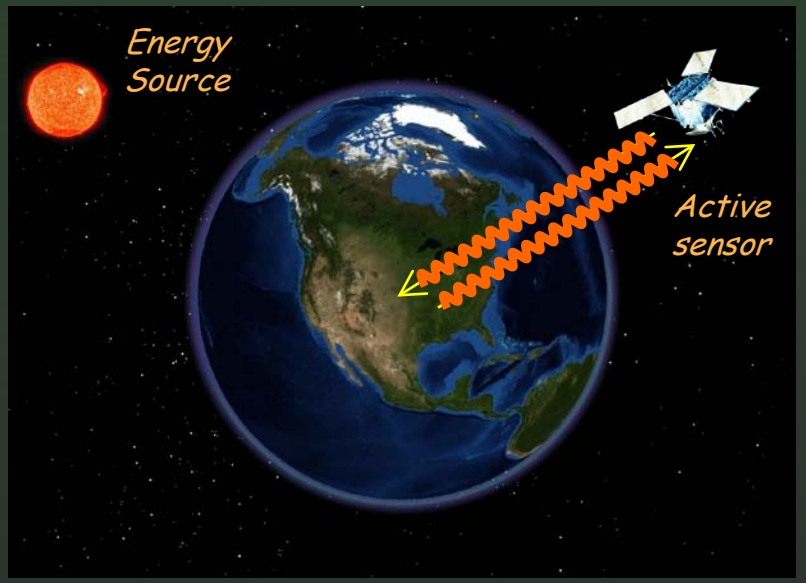
A. Roth, MFFU Sommerschule, 2000

RADAR as an active sensor



Passive sensors:

- Rely on the sun as an energy source
- Detect only naturally occurring energy



Active sensors:

- Act as their own energy source
- Detect backscattered energy

Applications of RADAR to vegetation mapping/monitoring

- Applications

- ✓ Mapping forest/land cover
- ✓ Mapping wetlands (inundated/flooded versus non-flooded)
- ✓ Mapping structural attributes (height, basal area, biomass, volume)
- ✓ Monitoring disturbance (logging, fire, windthrow, insect damage)
- ✓ Monitoring change (deforestation, degradation, reforestation)
- ✓ Monitoring photosynthetic processes (growing-season length)

What determines radar backscatter from vegetation?

➢ System Parameters (Sensor)

- ✓ Wavelength/Frequency (X, C, L, and P bands)
- ✓ Polarization (HH, VV, and HV)
- ✓ Incidence angle
- ✓ Resolution

➢ Target Parameters (Ground)

- ✓ Structure (size, orientation, and distribution of scattering surfaces)
- ✓ Surface roughness (relative to wavelength)
- ✓ Dielectric constant (moisture content)
- ✓ Slope angle/orientation

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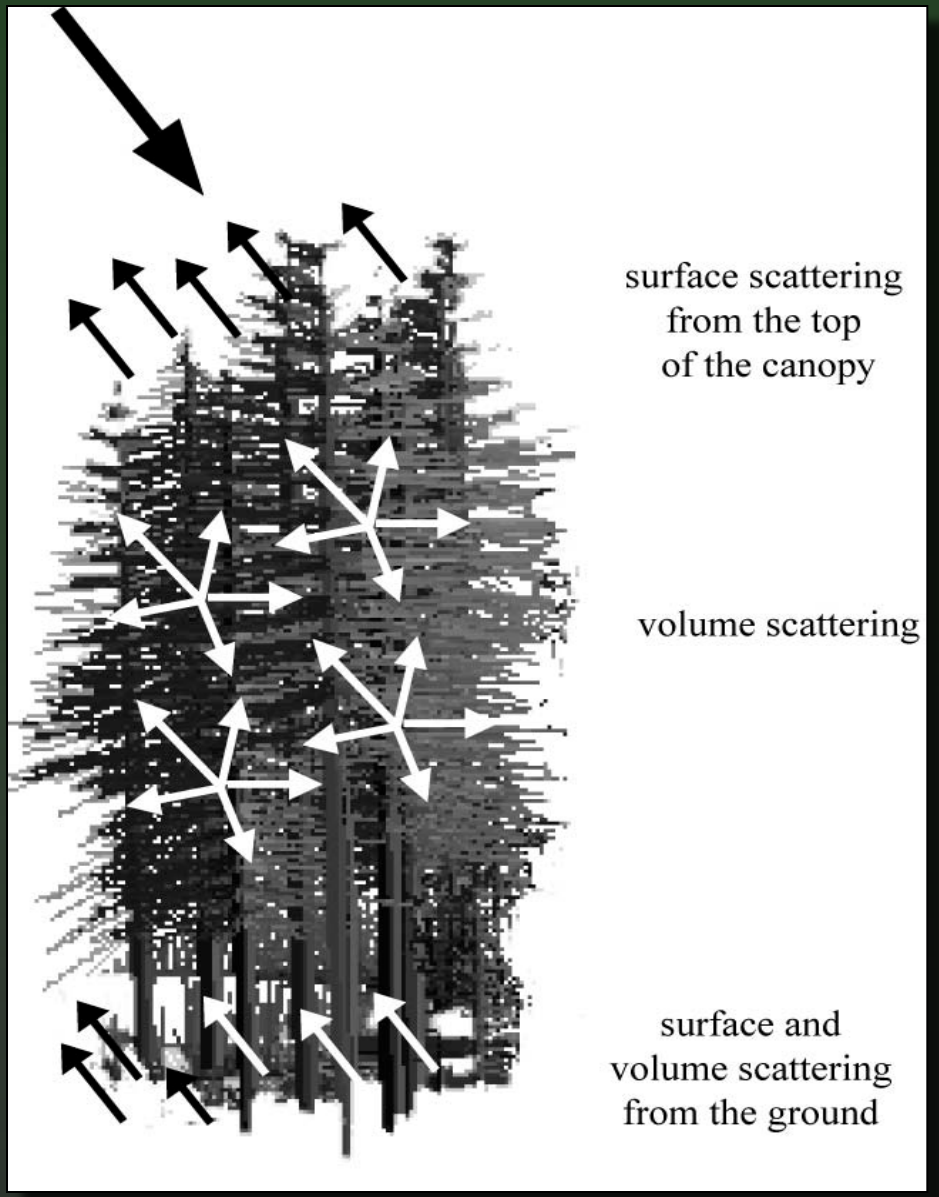
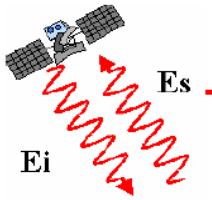
- System Parameters (Sensor)
  - ✓ Wavelength/Frequency (X, C, L, and P bands)
  - ✓ Polarization (HH, VV, and HV)
  - ✓ Incidence angle
  - ✓ Resolution

Scattering from vegetation

Types of scattering from a pine stand

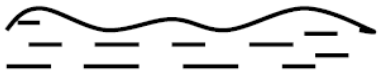


Scattering mechanisms



Surface scattering

water



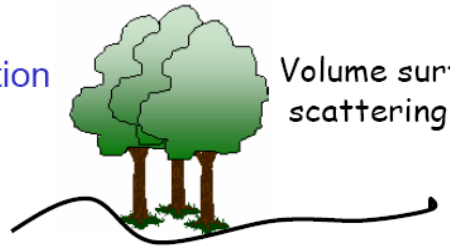
Surface scattering

soil, rock

Volume scattering if penetration

Volume scattering

vegetation



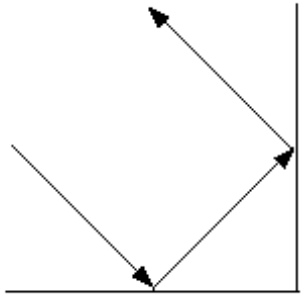
Volume surface scattering

Volume scattering

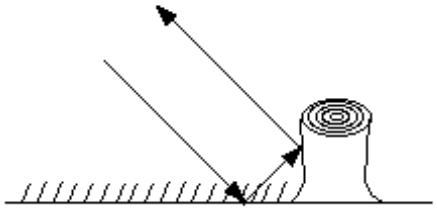
snow

Surface scattering

Surface scattering



Double Bounce
(Corner Reflector)



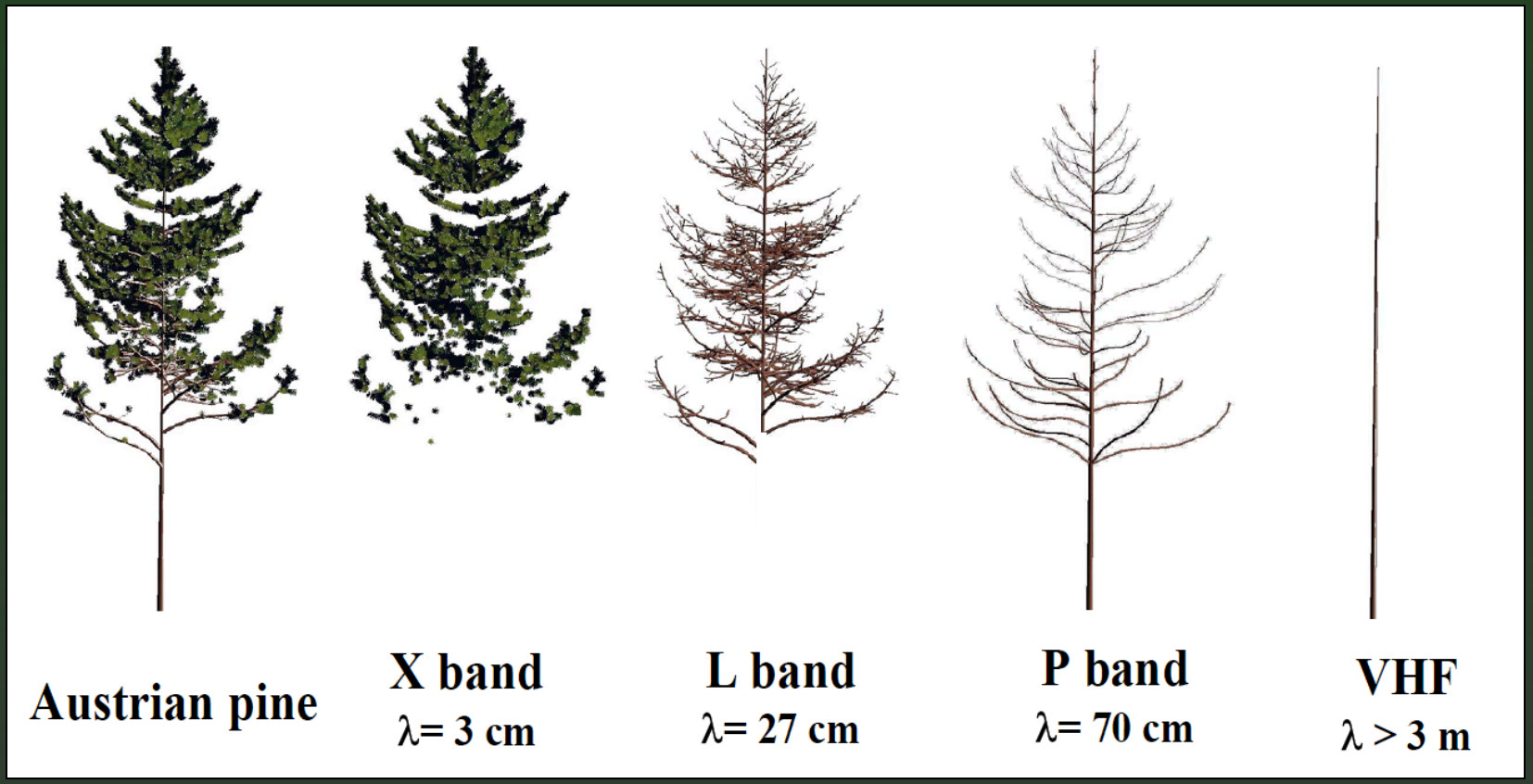
Double Bounce
One possible natural occurence - reflecting off two smooth surfaces, grass and a freshly-cut tree's stump

Wavelength/Frequency

Table 1: Microwave frequency bands

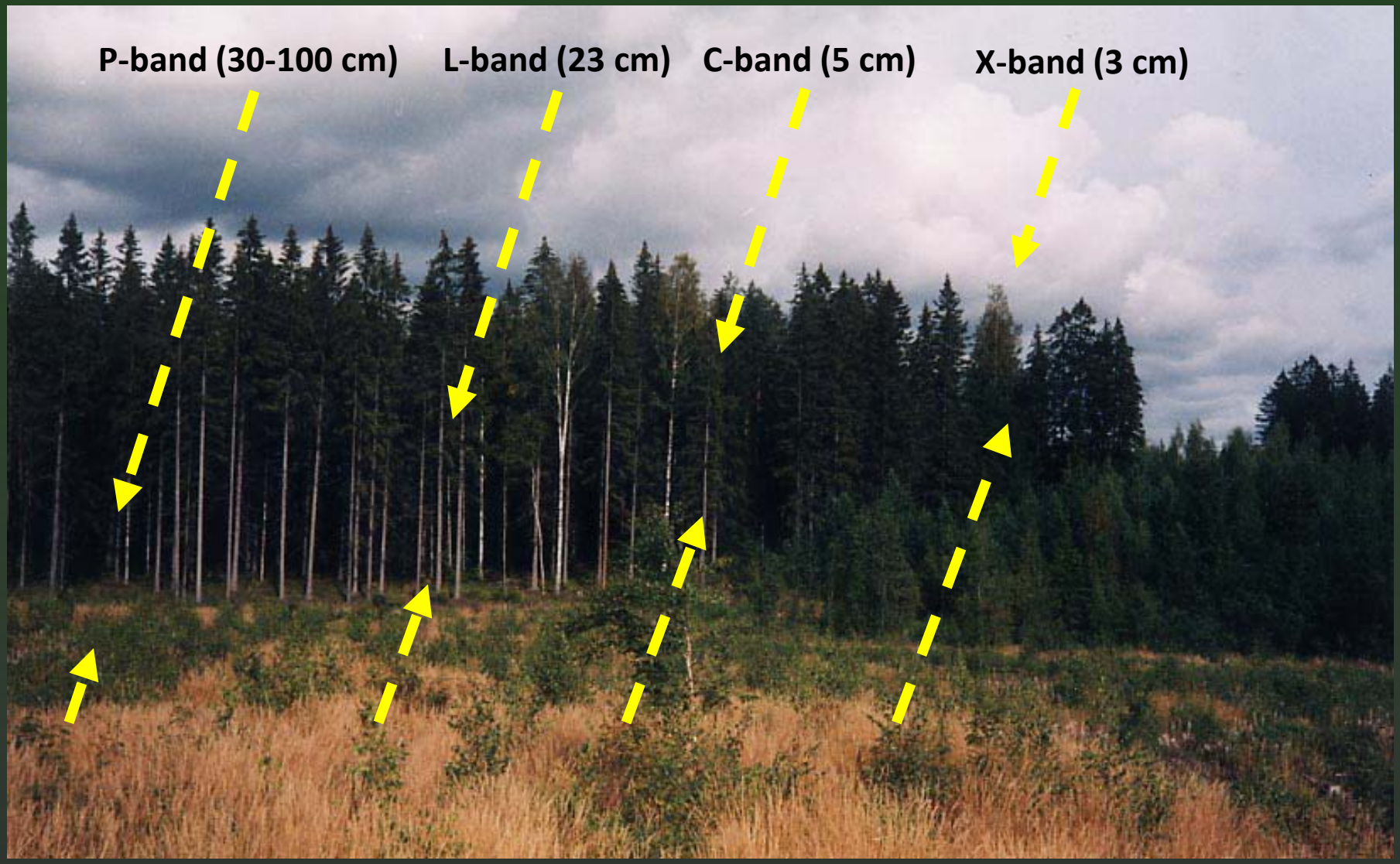
Band	Frequency, GHz	Wavelength, cm
P-band	0.225- 0.39	133 - 77
L-band	0.39 - 1.55	77 - 19
S-band	1.55 - 3.90	19 - 7.7
C-band	3.90 - 6.20	7.7 - 4.8
X-band	5.75 - 10.9	5.2 - 2.8
K_u-band	10.9 - 18.0	2.8 - 1.7
K_a-band	18.0 - 36.0	1.7 - 0.8

Wavelength/Frequency



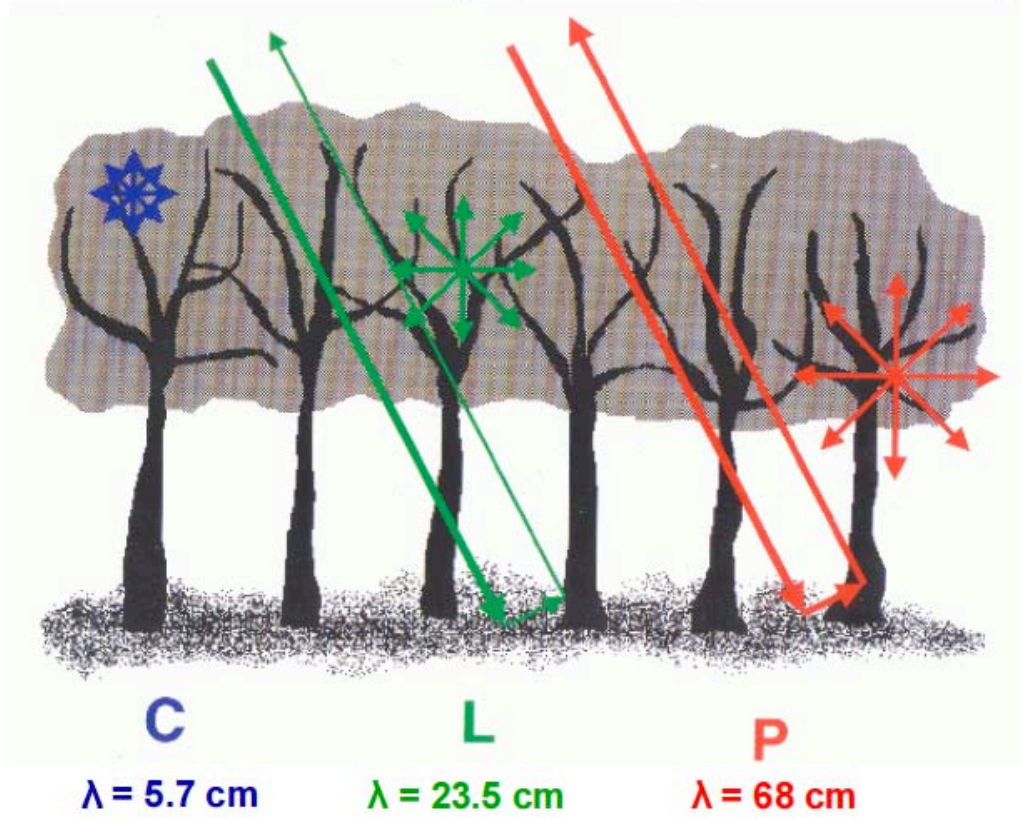
- The primary scatterers in a tree canopy are elements (leaves, branches, and stems) with a size on the order of the wavelength or larger and an orientation similar to that of the incoming signal polarization.
- Elements smaller than the wavelength produce little backscatter but can attenuate the signal

Wavelength/Frequency

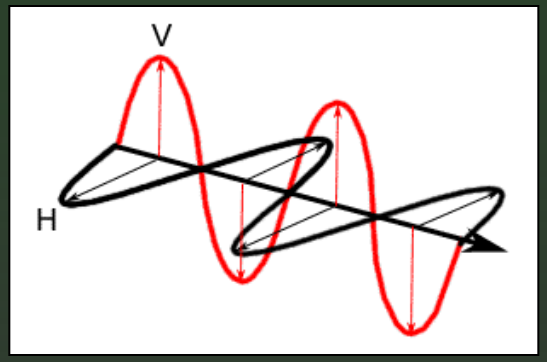


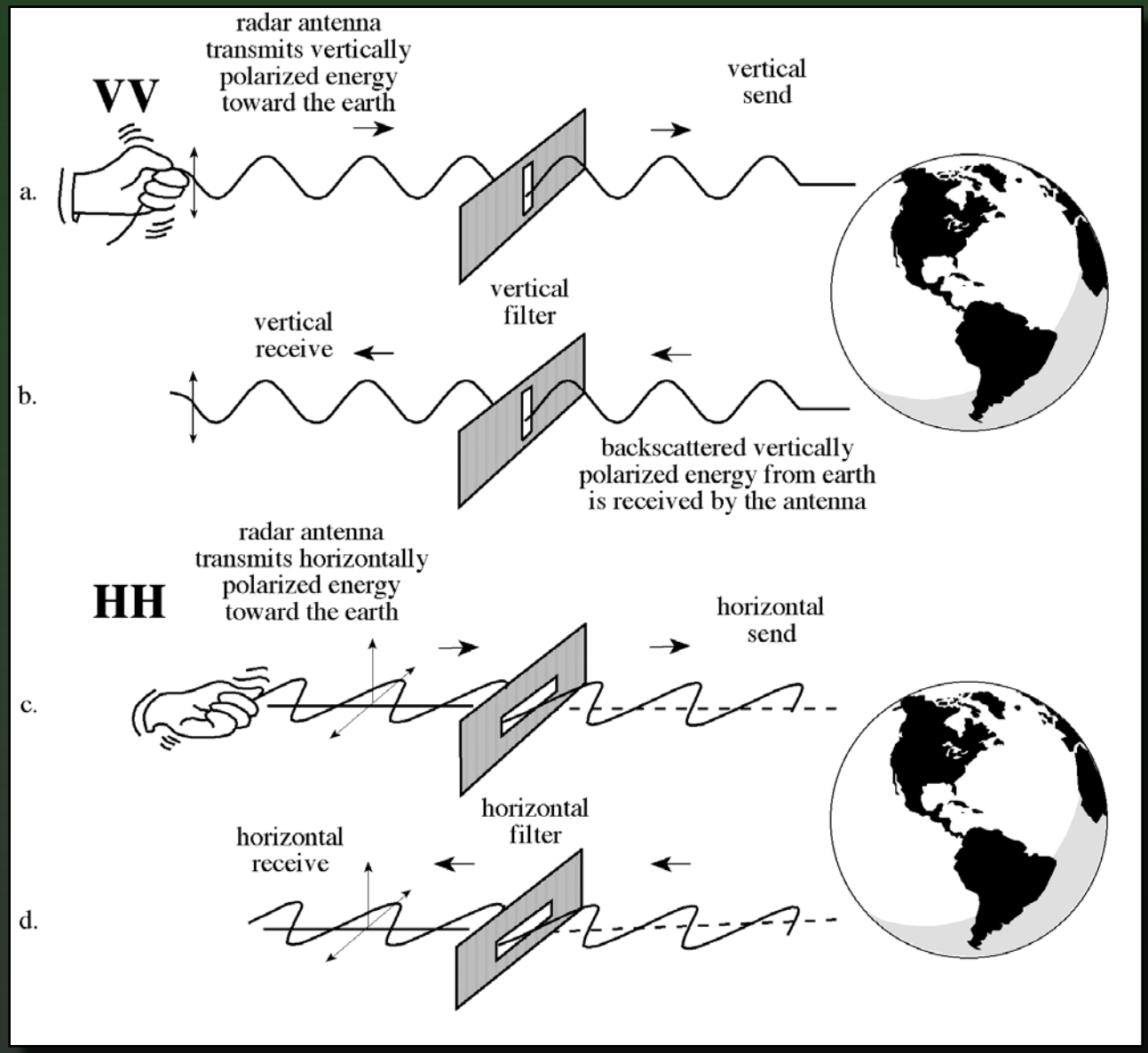
The longer the wavelength, the greater the sensitivity to the vertical structure of vegetation

Wavelength/Frequency



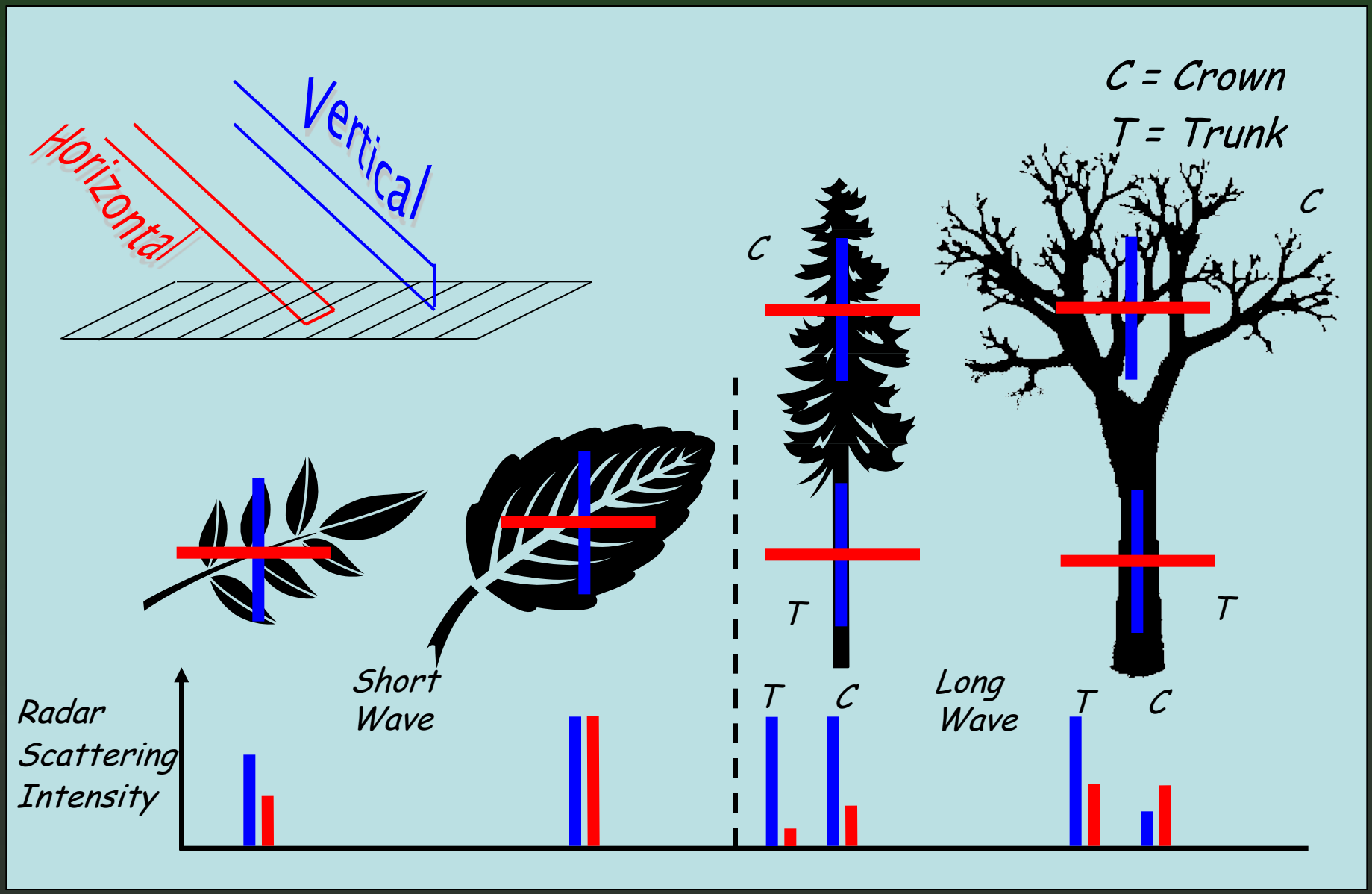
Polarization



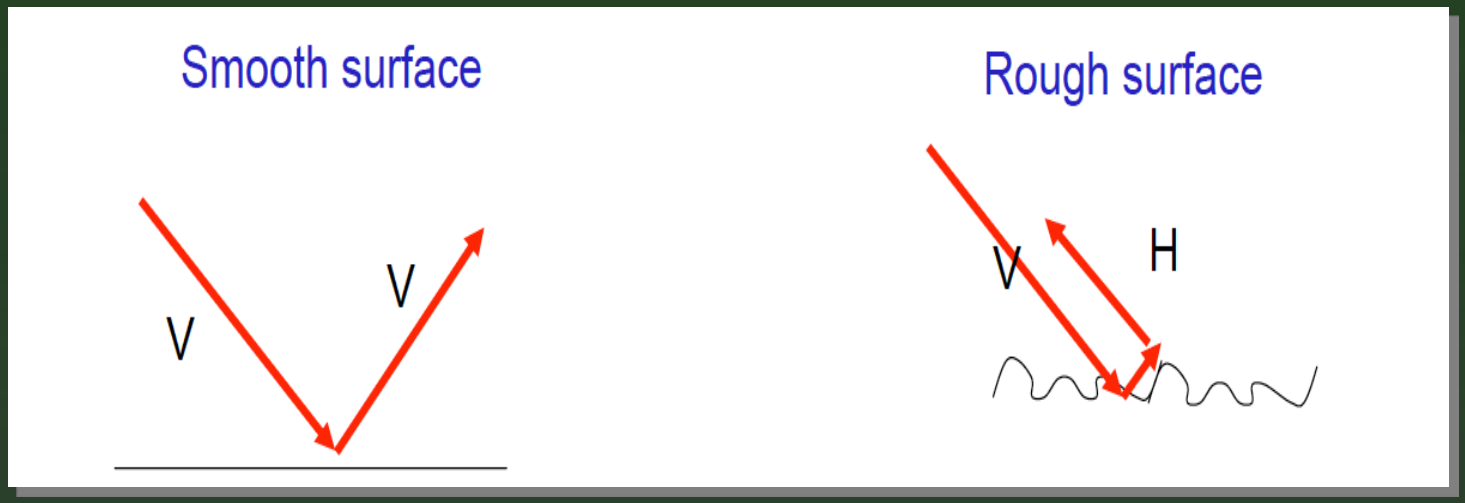


Source: J. R. Jensen. 2000. Remote Sensing of the Environment.

Polarization

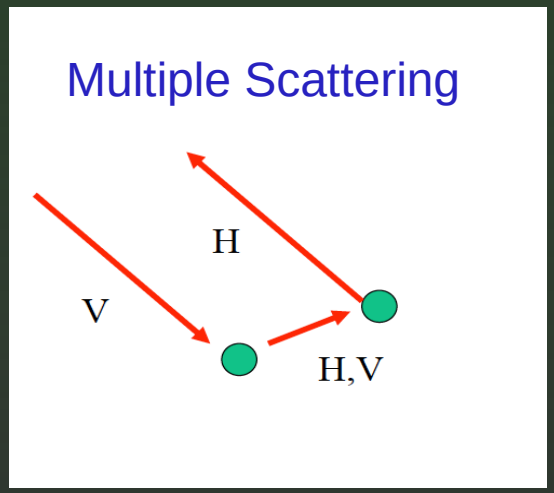


Polarization



No Depolarization

Little Depolarization

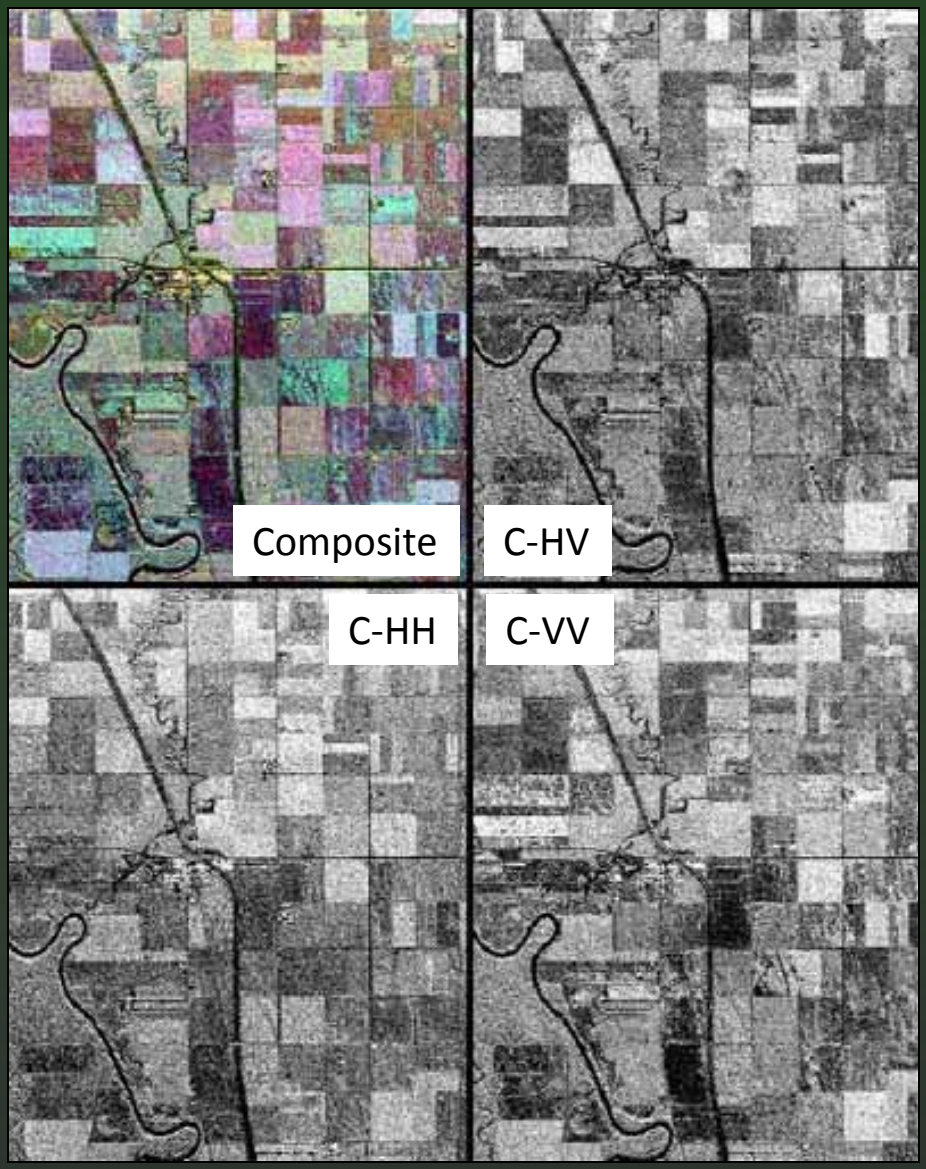


Depolarization

Depolarization occurs mainly over vegetation, hardly over open ground. Cross polarization (HV or VH) is very sensitive to vegetation parameters

Courtesy of T. LeToan

Polarization



HH, VV, HV and color composite of linear polarization images of agricultural fields in southern Manitoba (© CCRS 1993). Acquired by the CV-580 C-band SAR. Processed and provided by CCRS.

Incidence angle

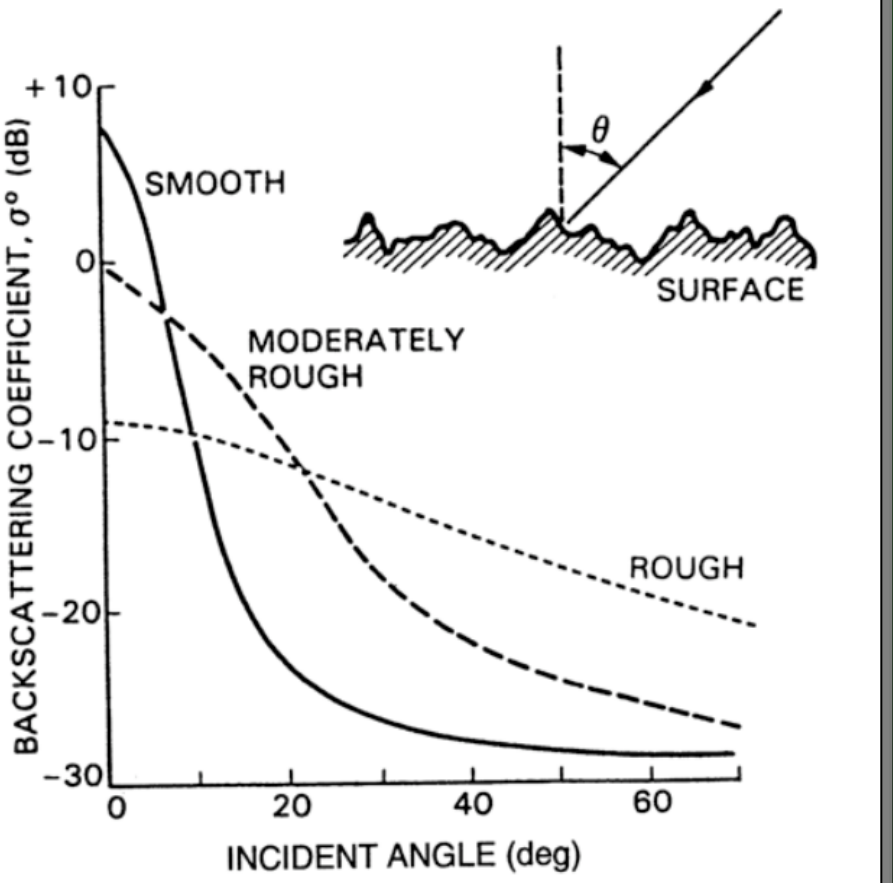
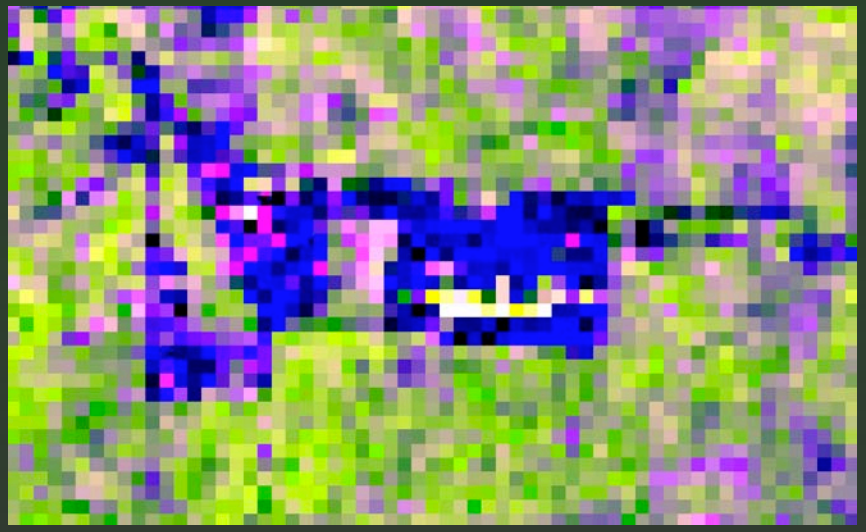


Figure 3-37. Typical radar backscatter curves for smooth, moderately rough and very rough surfaces. As the incident angle (θ) decreases, the probability of greater backscatter increases, especially as the target becomes smoother. (NASA, 1989).

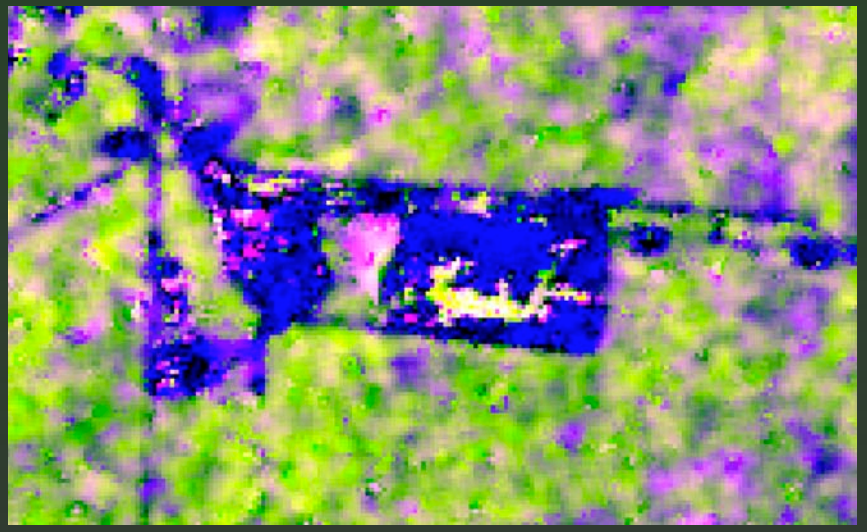
Resolution

Sensitivity to Type Boundaries

50 m



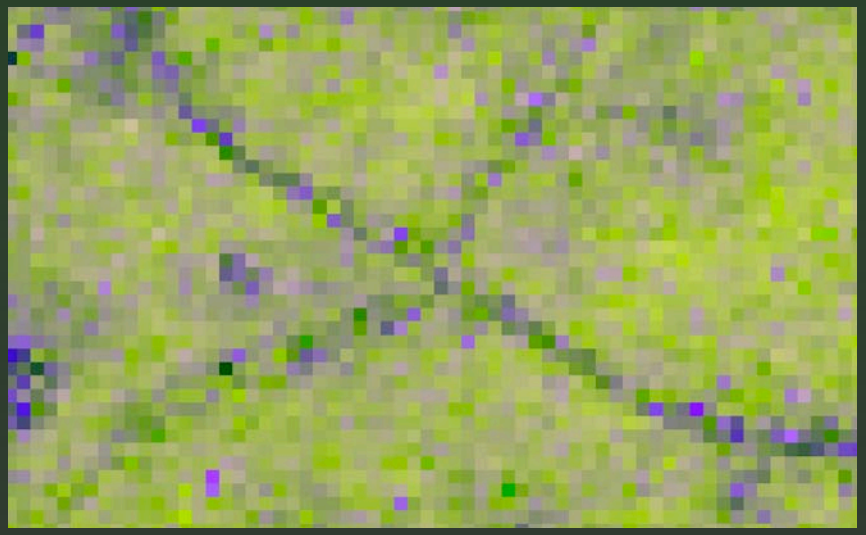
15 m



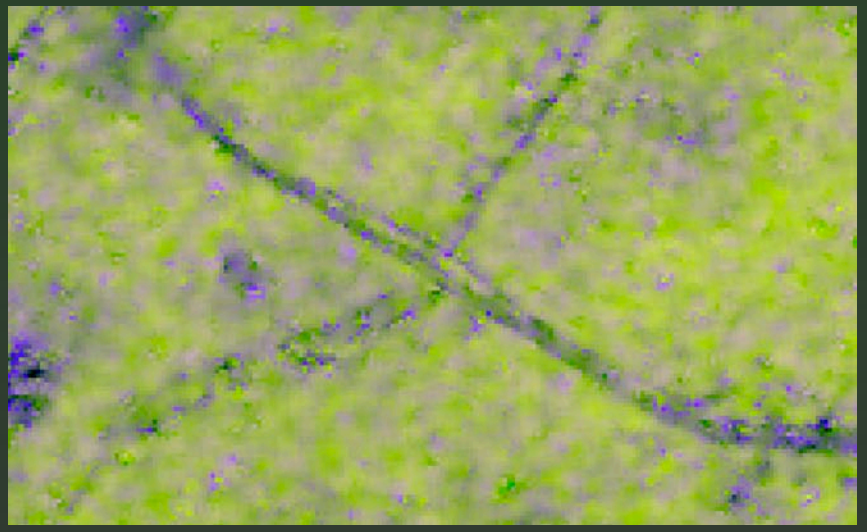
Resolution

Sensitivity to Type Boundaries

50 m



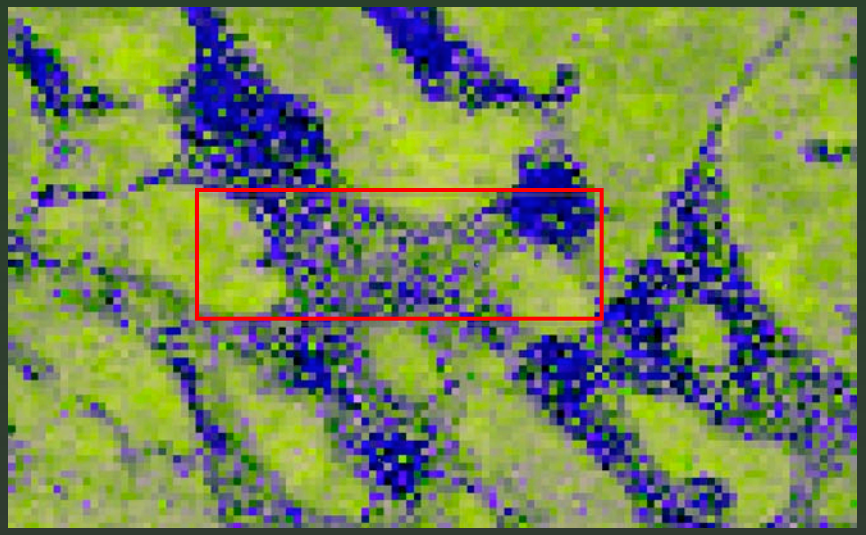
15 m

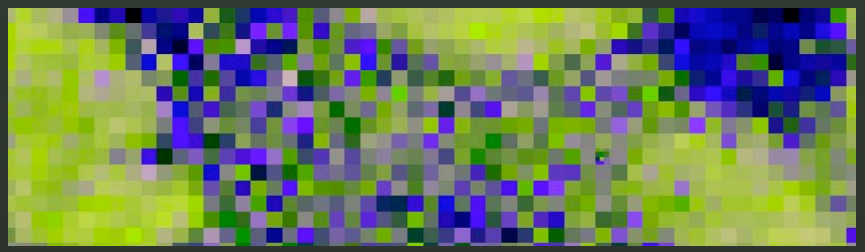


Resolution

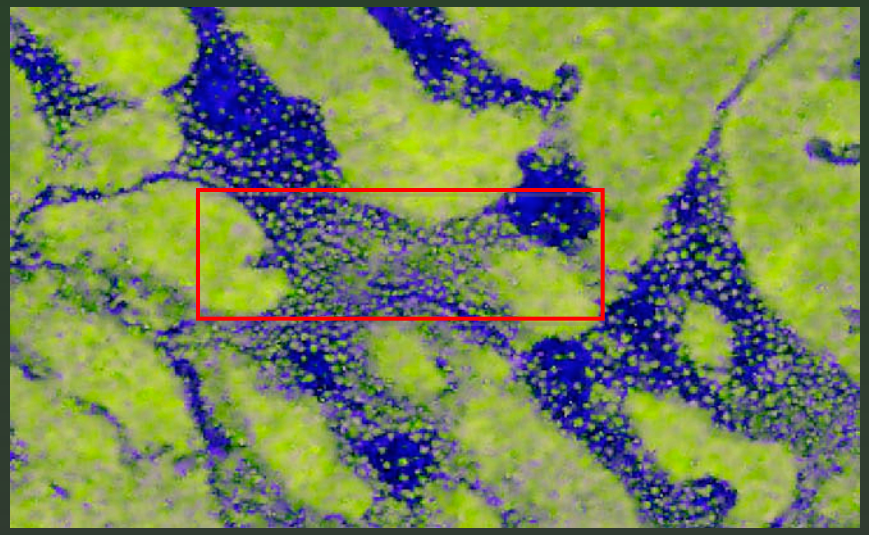
Sensitivity to Individual Trees

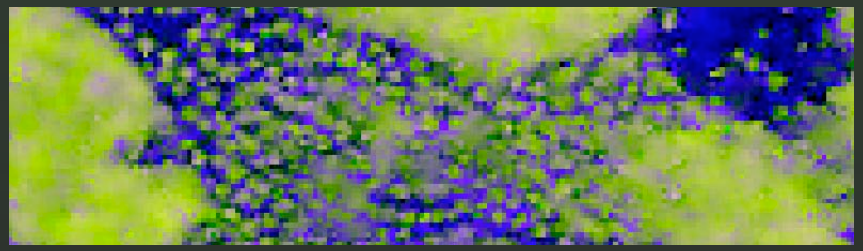
50 m





15 m





What determines radar backscatter from vegetation?

➢ System Parameters (Sensor)

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- Target Parameters (Ground)
  - ✓ Structure (size, orientation, and distribution of scattering surfaces)
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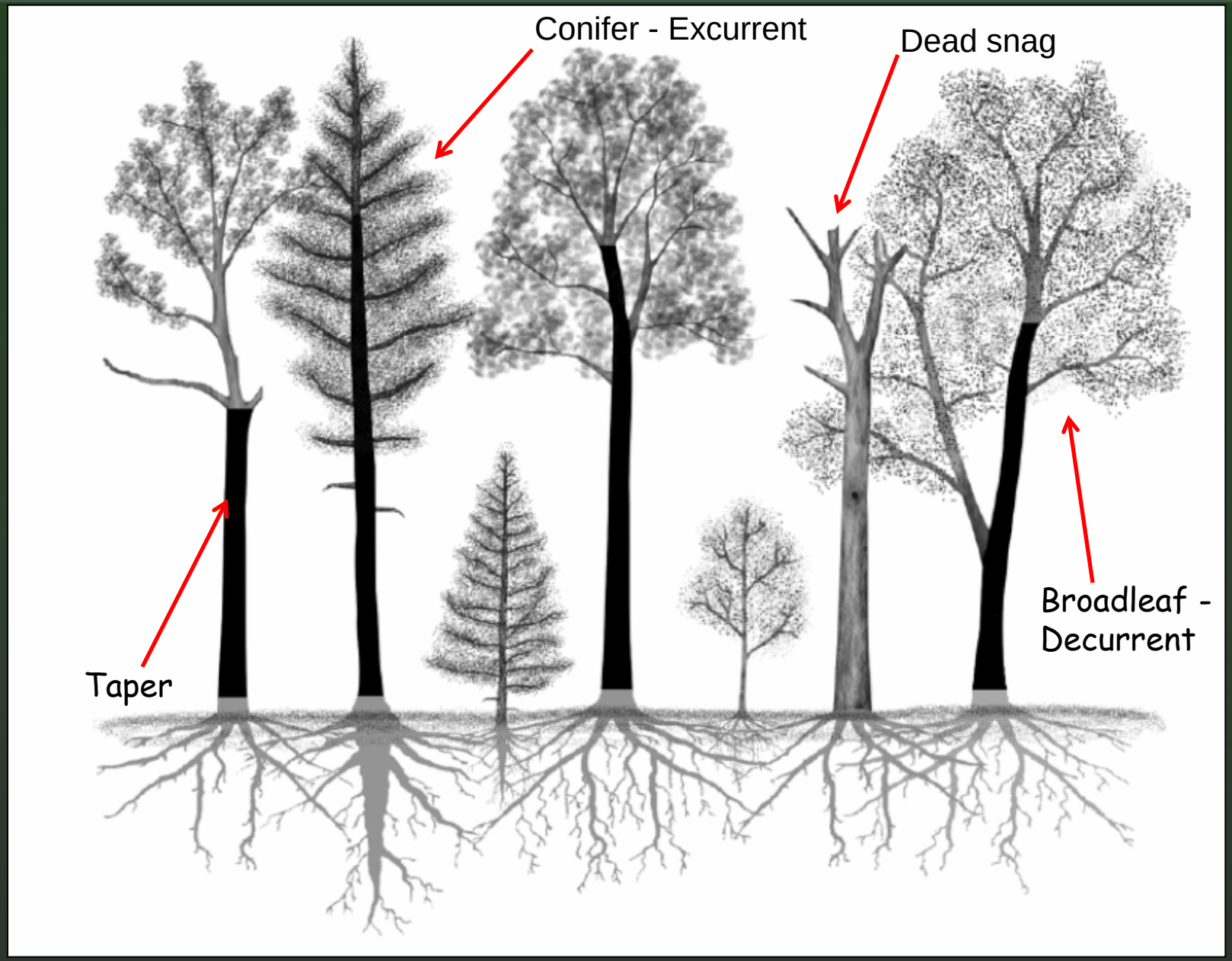
  - ✓ Slope angle/orientation

Structure



Structure

SAR Fundamentals

Growth Form	Herbaceous		Woody			
	Gramineous	Stalk Dominated	Shrubs	Trees		
				Excurrent	Decurrent	Columnar
	 (i.e., grass)	 (i.e., corn)	 (i.e., alder)	 Gymnosperms (i.e., pine)	 Angiosperms Dicotyledons (i.e., maple, oak)	 Angiosperms Monocotyledons (i.e., palm)
Structural Characteristics ***Trunks***	None	None	Many small trunks with characteristic orientations	Conical trunk with layered dielectric	Cylindrical, forked trunk with layered dielectric	Cylindrical trunk of homogeneous dielectric
Branches	Non-woody stems	Non-woody stems	Many small branches and stems	Branch size and orientation varies with height. Branches tend to be long and thin	Branches forked, few horizontal elements. Branches often short and thick	None
Foliage	Blade-like	Blade-like erectophile	Blade-like or broad leaves	Needles	Broad leaves	Blade-like clump at top of trunk.

98-20011

Surface roughness

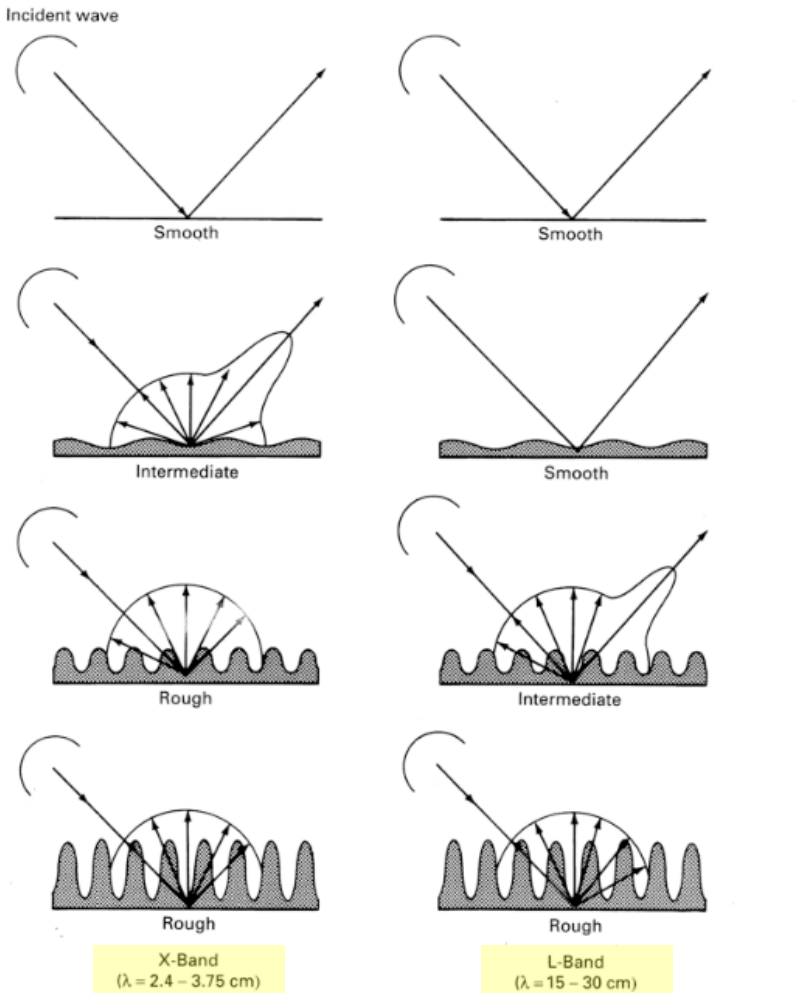


Figure 8.23 X-band and L-band radar reflection from surfaces of varying roughness. (Modified from diagram by Environmental Research Institute of Michigan.)

- As wavelength increases, greater height variation is required for roughness
- As incidence angle increases, greater height variation is required for roughness

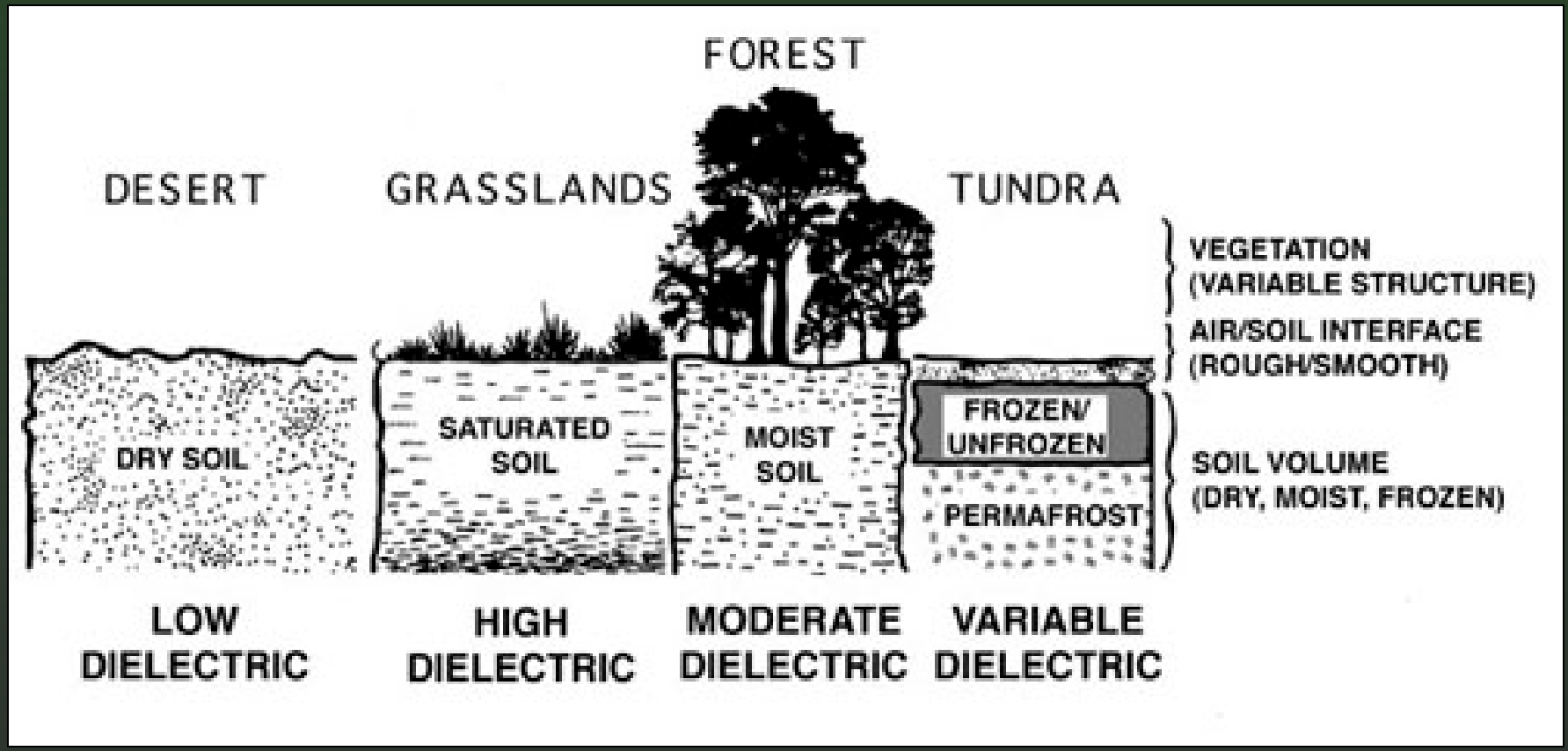
Dielectric constant (moisture content)

- Dielectric constant is controlled by the amount of moisture content
- Most common materials have dielectric constants from 1-100
- Radar backscatter is influenced by the amount of moisture in vegetation and soil by affecting the absorption and propagation of electromagnetic energy
- Increasing the moisture content reduces the penetration of the radar signal through a vegetation canopy or into soil.

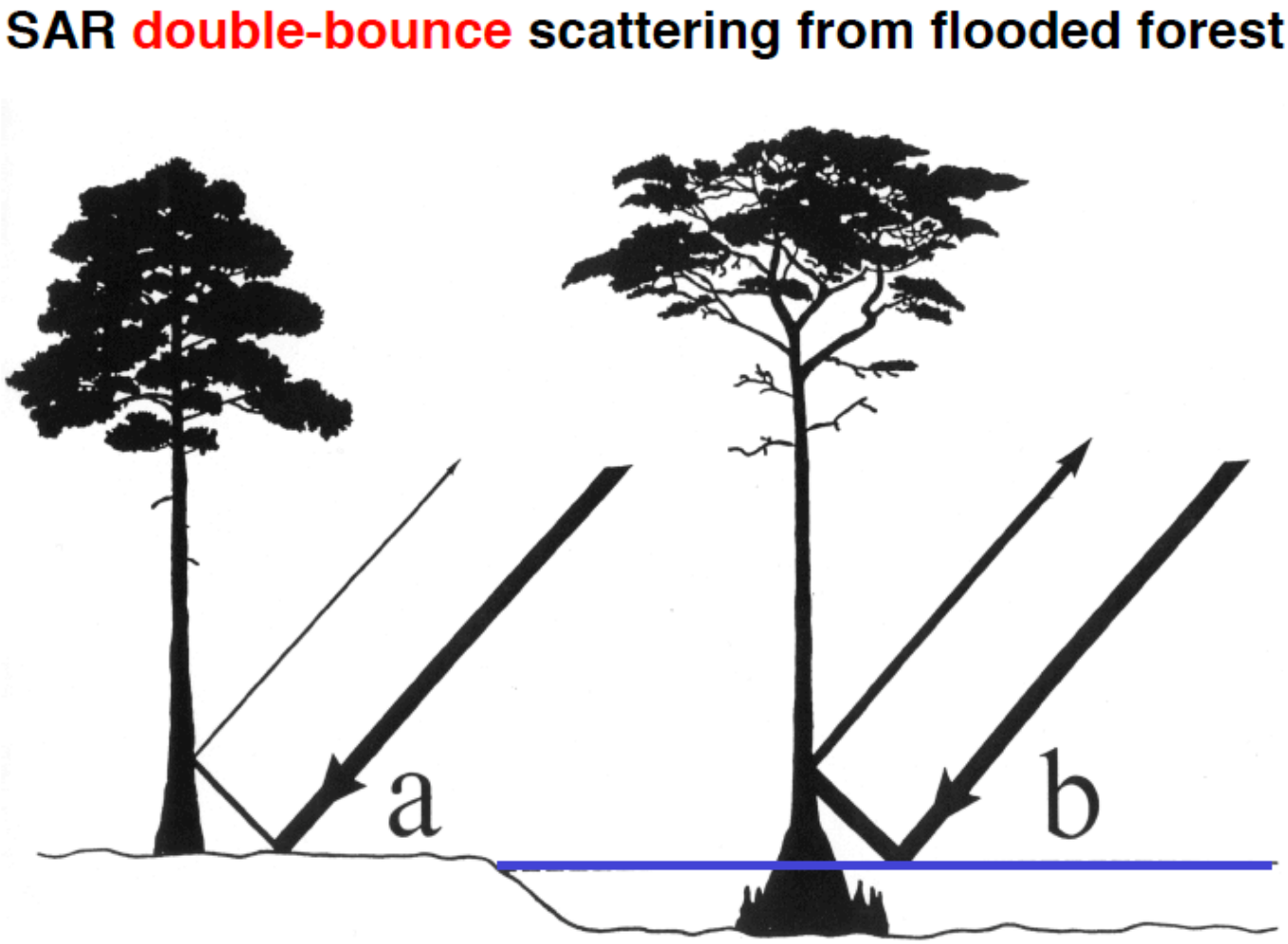
Material	Dielectric constant
Vacuum	1
Air	1.0005
Paper	3.5
Pyrex	4.7
Water (20°C)	80.4

Dielectric constant (moisture content)

Different vegetation types will all have different backscatter properties. In addition, the basic reflectivity of the soil, called the "dielectric constant" will change depending on the amount of water that the soil contains. Dry soil has a low dielectric constant and low radar reflectivity. Saturated soil is a strong reflector. Moist and partially frozen soils will have intermediate values.



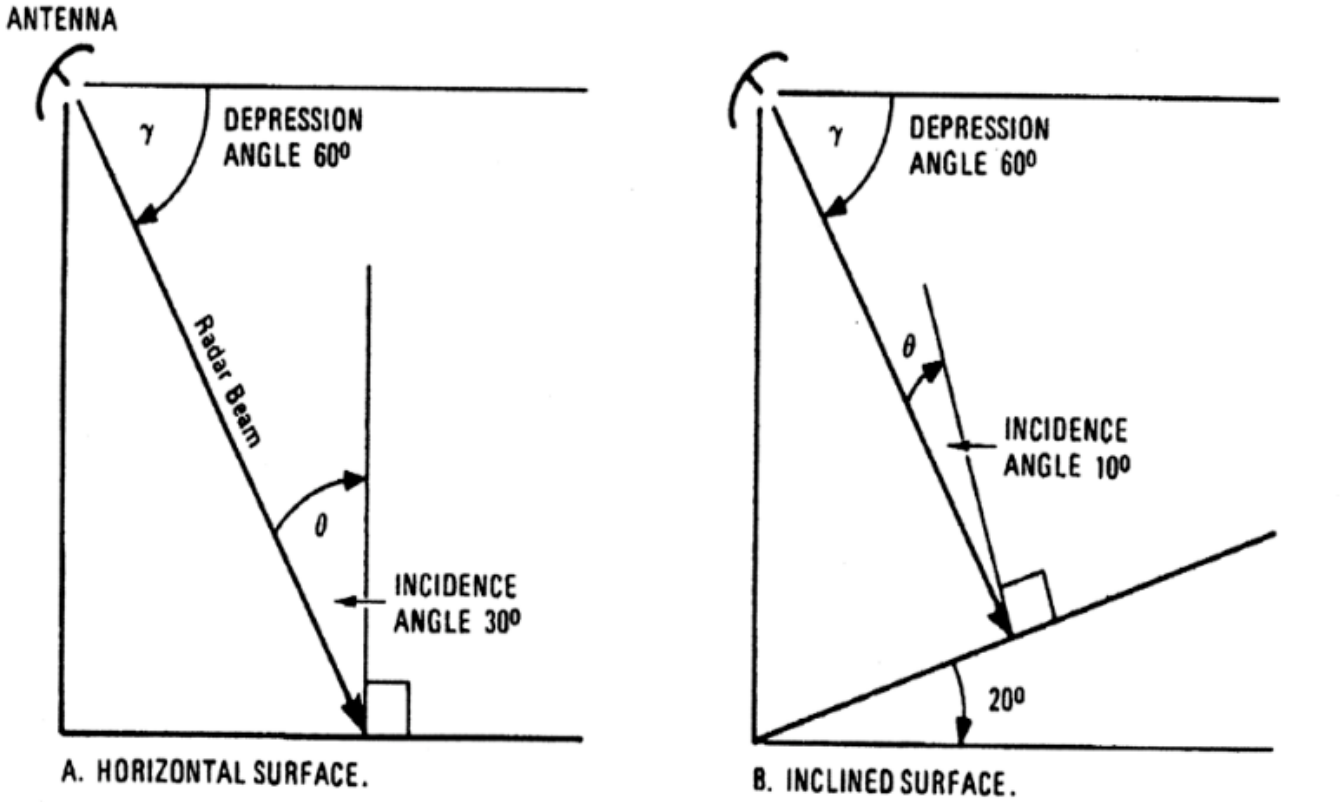
Dielectric constant (moisture content)



Slope angle/orientation

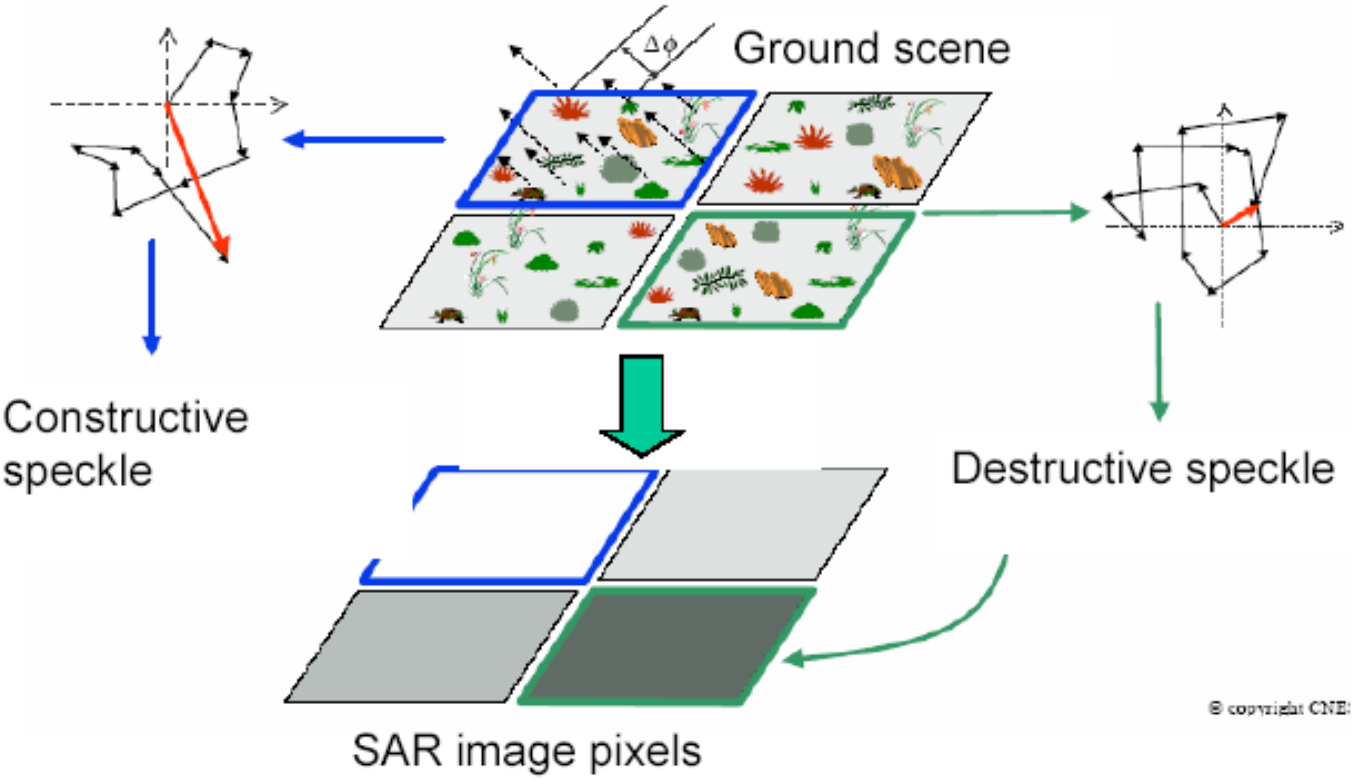
Relief changes the local angle of incidence. This leads to:

- **increase of σ¡ in fore slopes**
- **decrease of σ¡ in backslopes**



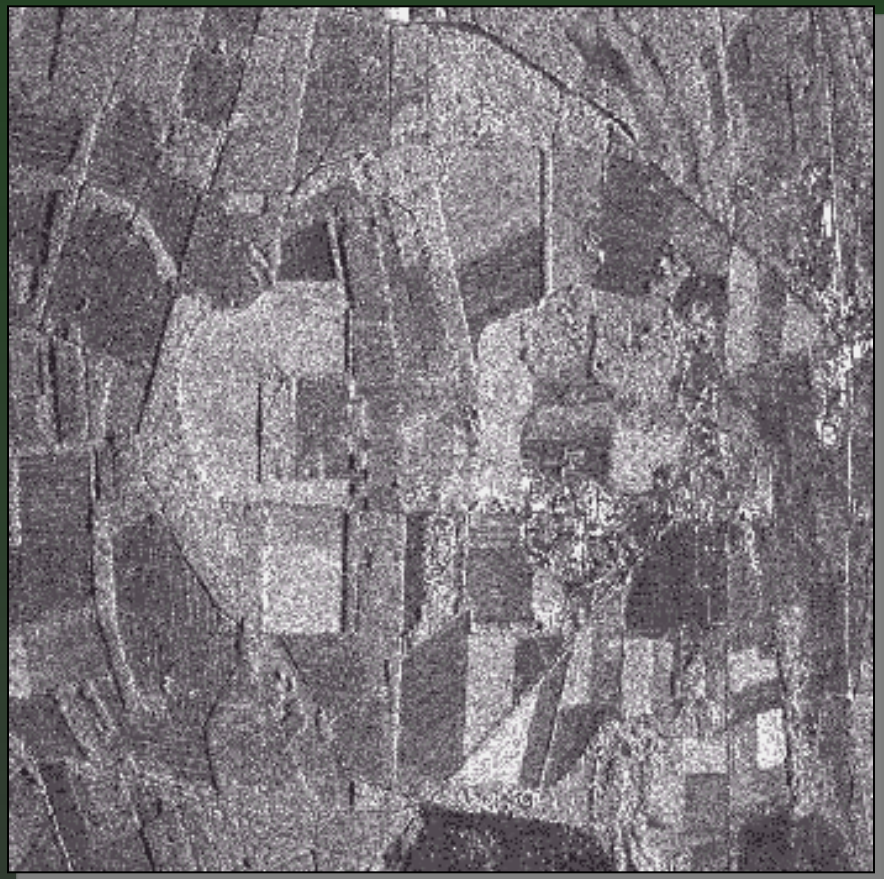
What is speckle?

The physical origin of speckle



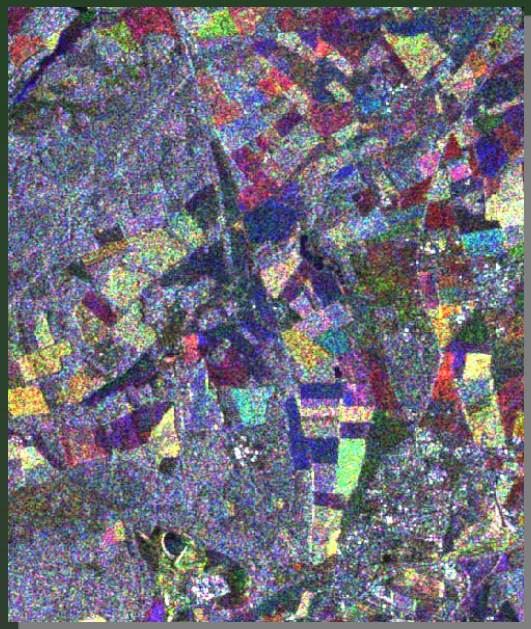
Resolution cells are made up of many scatterers with different phases, leading to interference and the noise-like effect known as **speckle**.

What is speckle?

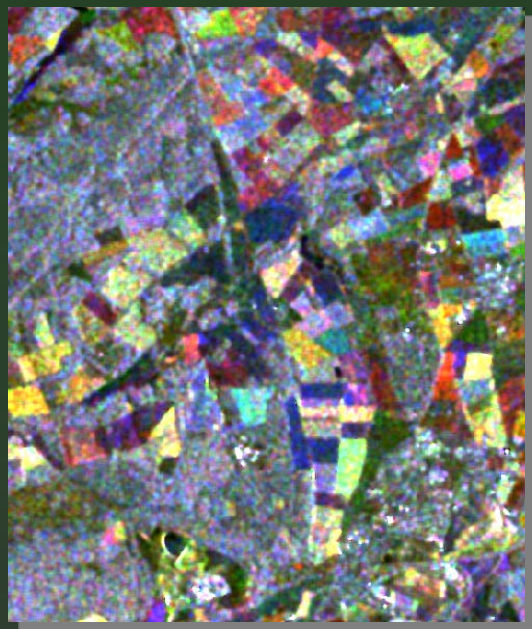


Speckle filtering always results in a loss of spatial resolution since it is carried out within moving windows.

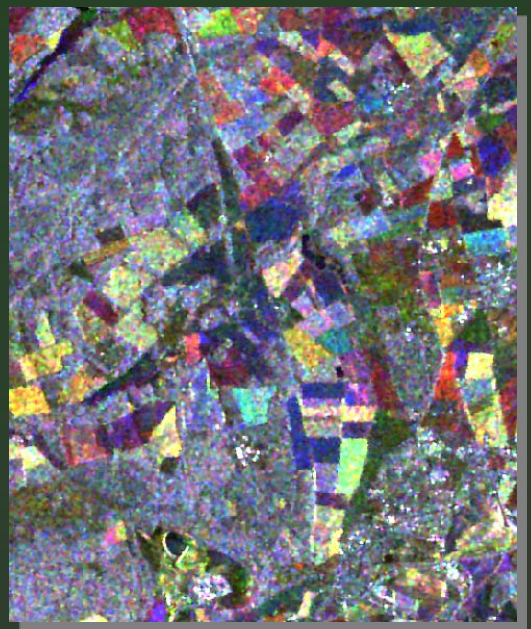
What is speckle?



Original data



Gamma MAP filter



Frost filter

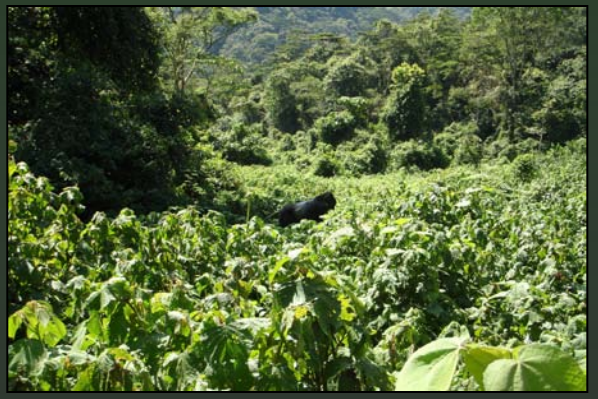
Speckle filtering always results in a loss of spatial resolution since it is carried out within moving windows.

Retford, UK ERS-2 SAR data April-September 1998

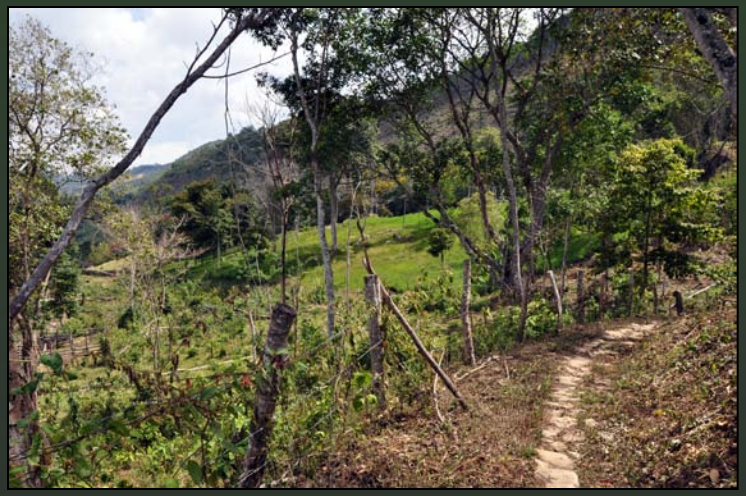
Structure at the individual tree level

Structure at the individual tree level

Structure at the landscape level (natural landscapes)



Structure at the landscape level (disturbed landscapes)



Structure at the landscape level (managed landscapes)

Structure at the landscape level (ice/snow)

Structure at the landscape level (fire)

Structure at the landscape level (moisture influences)

Thank you!

The Woods Hole Research Center