

4. SAR remote sensing for forestry

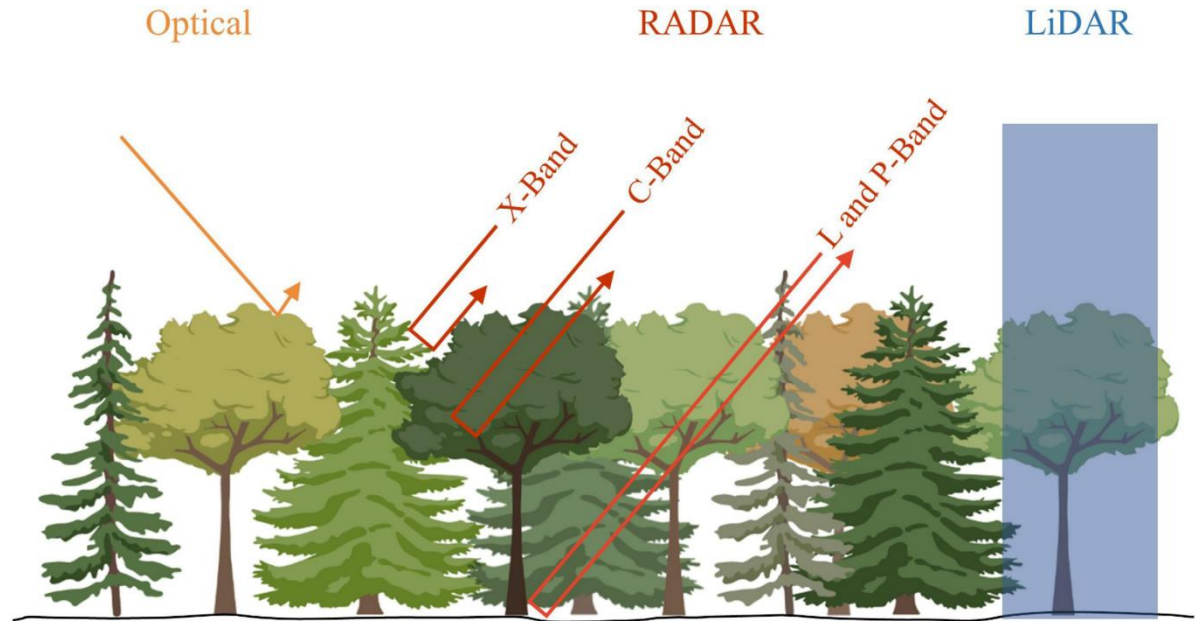
Parameters to Consider for a Forestry Mapping

Radar Parameters

- Wavelength
- Polarizations
- Incidence Angle

Surface Parameters

- Structure
- Dielectric



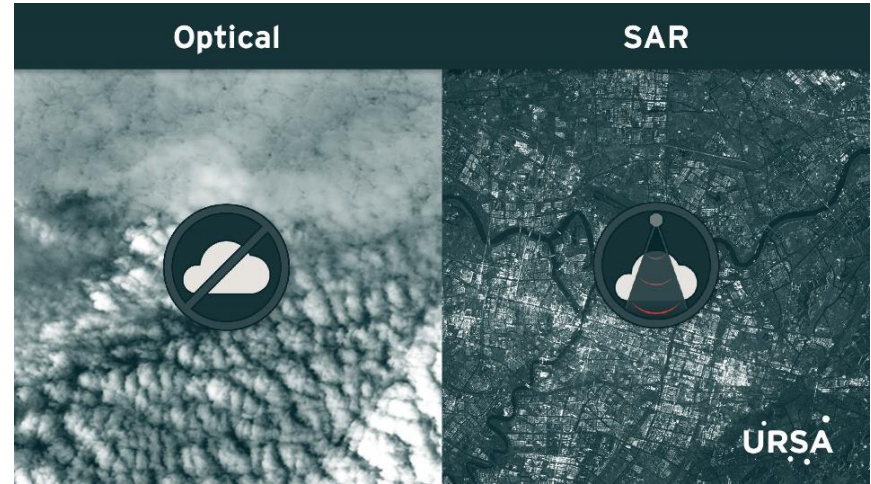
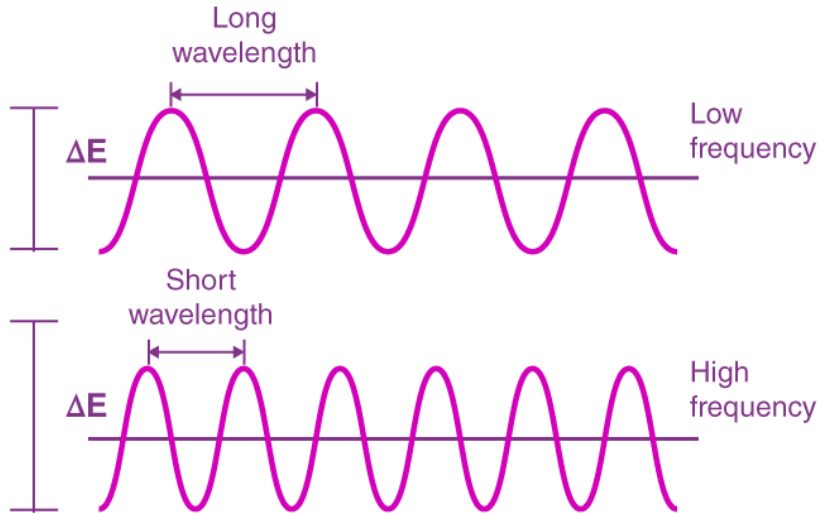
Radar Parameters to Consider for a Forestry Mapping

Frequency and Wavelength

$$\text{Wavelength} = \frac{\text{speed of light}}{\text{frequency}}$$

Active remote sensing sensors generate EM-waves

- no sunlight required night time acquisitions possible
- no problems due to bad illumination



Radar Parameters to Consider for a Forestry Mapping

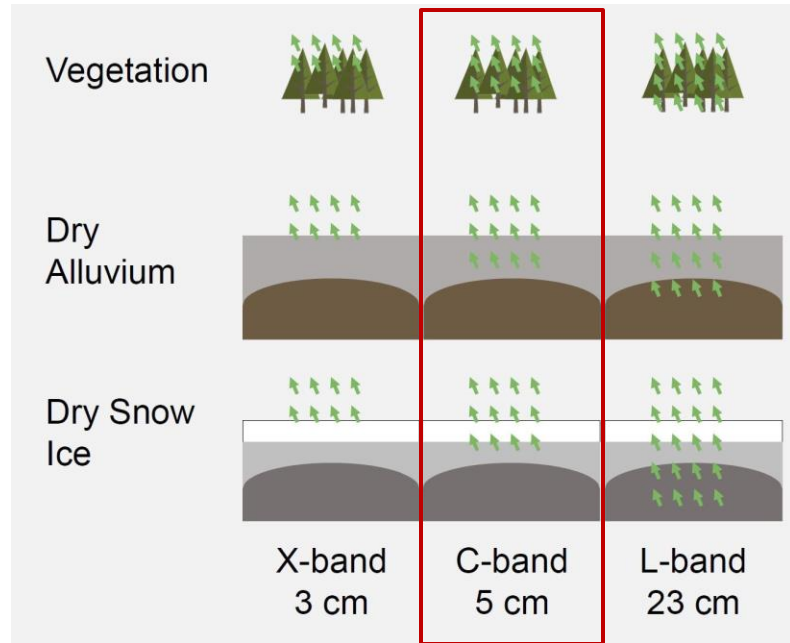
Frequency and Wavelength

Band	Frequency	Wavelength	Typical Application
Ka	27–40 GHz	1.1–0.8 cm	Rarely used for SAR (airport surveillance)
K	18–27 GHz	1.7–1.1 cm	rarely used (H ₂ O absorption)
Ku	12–18 GHz	2.4–1.7 cm	rarely used for SAR (satellite altimetry)
X	8–12 GHz	3.8–2.4 cm	High resolution SAR (urban monitoring,; ice and snow, little penetration into vegetation cover; fast coherence decay in vegetated areas)
C	4–8 GHz	7.5–3.8 cm	SAR Workhorse (global mapping; change detection; monitoring of areas with low to moderate penetration; higher coherence); ice, ocean maritime navigation
S	2–4 GHz	15–7.5 cm	Little but increasing use for SAR-based Earth observation; agriculture monitoring (NISAR will carry an S-band channel; expands C-band applications to higher vegetation density)
L	1–2 GHz	30–15 cm	Medium resolution SAR (geophysical monitoring; biomass and vegetation mapping; high penetration, InSAR)
P	0.3–1 GHz	100–30 cm	Biomass. First p-band spaceborne SAR will be launched ~2020; vegetation mapping and assessment. Experimental SAR.

Radar Parameters to Consider for a Forestry Mapping

Penetration through vegetation as a Function of Wavelength and dielectric characteristics

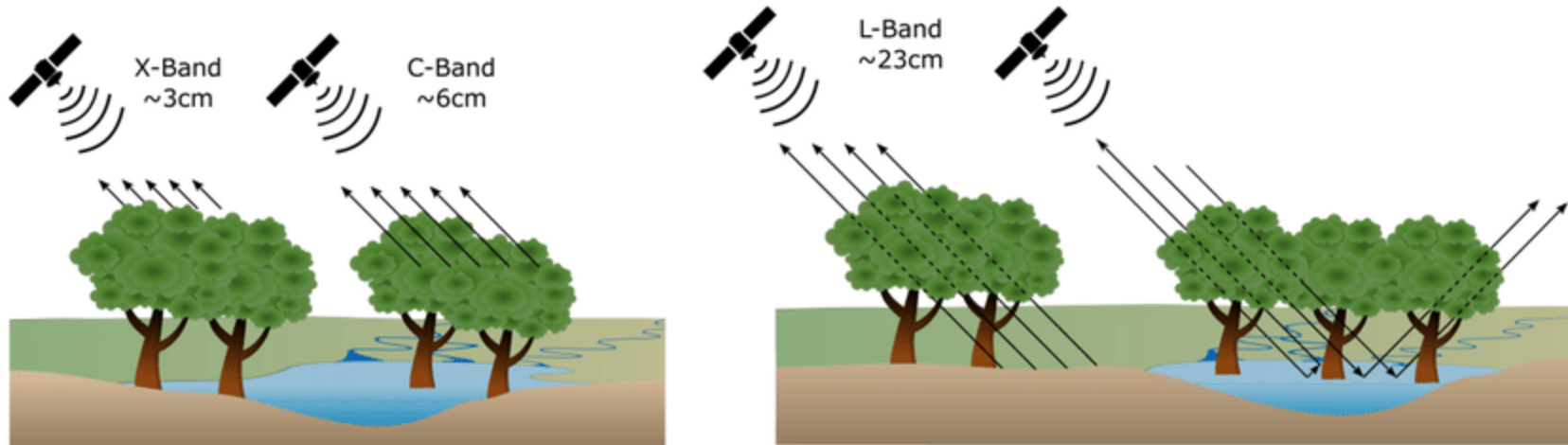
- The penetration depth is depending on **wavelength** and **dielectric characteristics** of objects
- Penetration is the predominant consideration when selecting a wavelength
- Typically, longer wavelengths result in greater penetration into the target



Source: <https://medium.com/@preet.balaji20/decoding-synthetic-aperture-radar-sar-remote-sensing-sar-series-part-1-getting-started-d3409eb3b2e3>

Radar Parameters to Consider for a Forestry Mapping

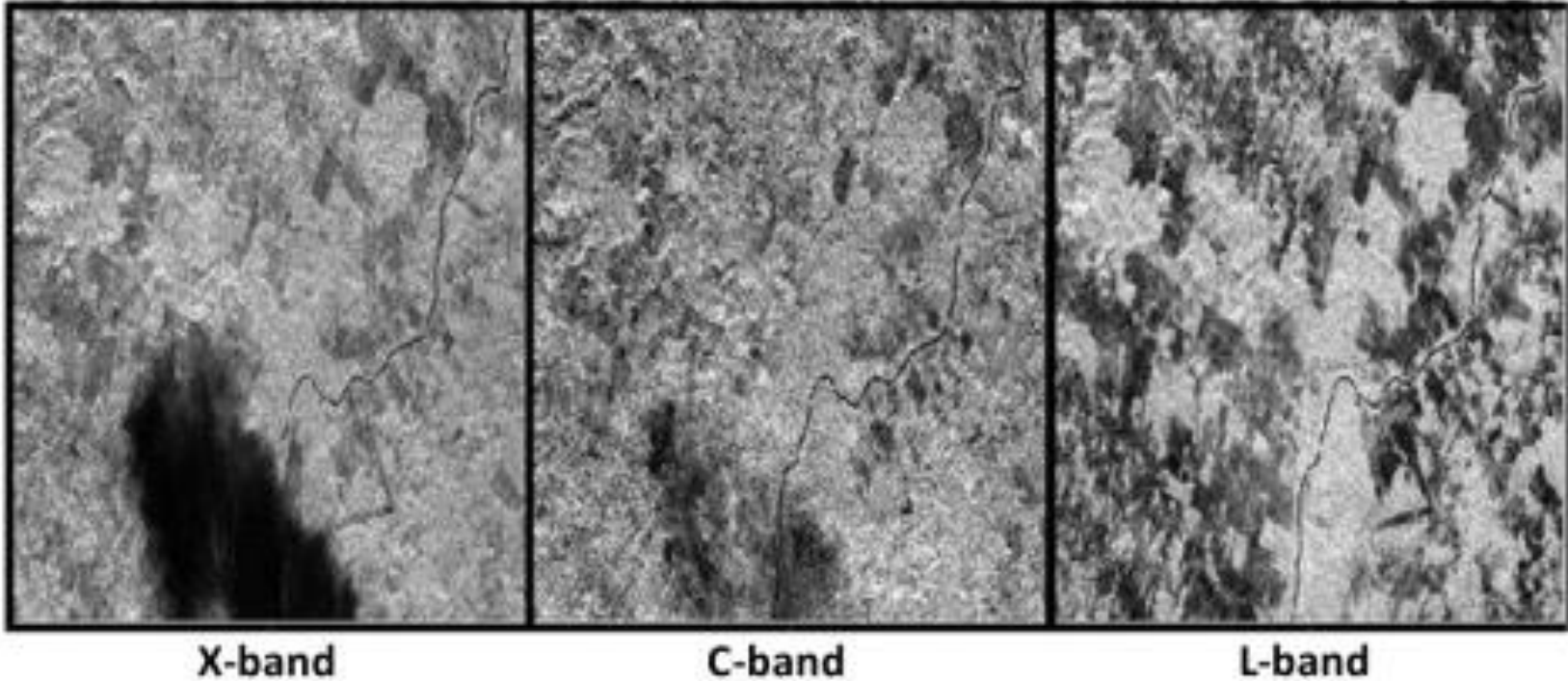
Penetration through vegetation as a Function of Wavelength and dielectric characteristics



Source: <https://medium.com/@preet.balaji20/decoding-synthetic-aperture-radar-sar-remote-sensing-sar-series-part-1-getting-started-d3409eb3b2e3>

Radar Parameters to Consider for a Forestry Mapping

Penetration through vegetation as a Function of Wavelength and dielectric characteristics

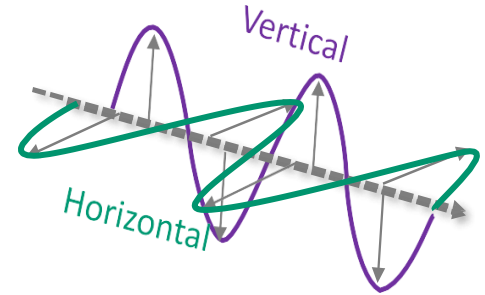


Radar Parameters to Consider for a Forestry Mapping

Polarisation

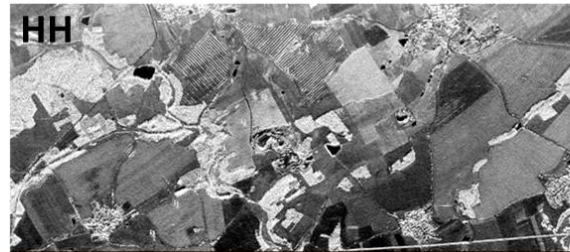
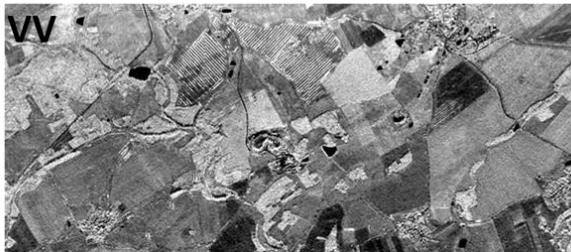
The radar signal is polarised:

Radar: **transmits** a EMW in a given polarization
measures the backscattered wave contribution in a given polarization



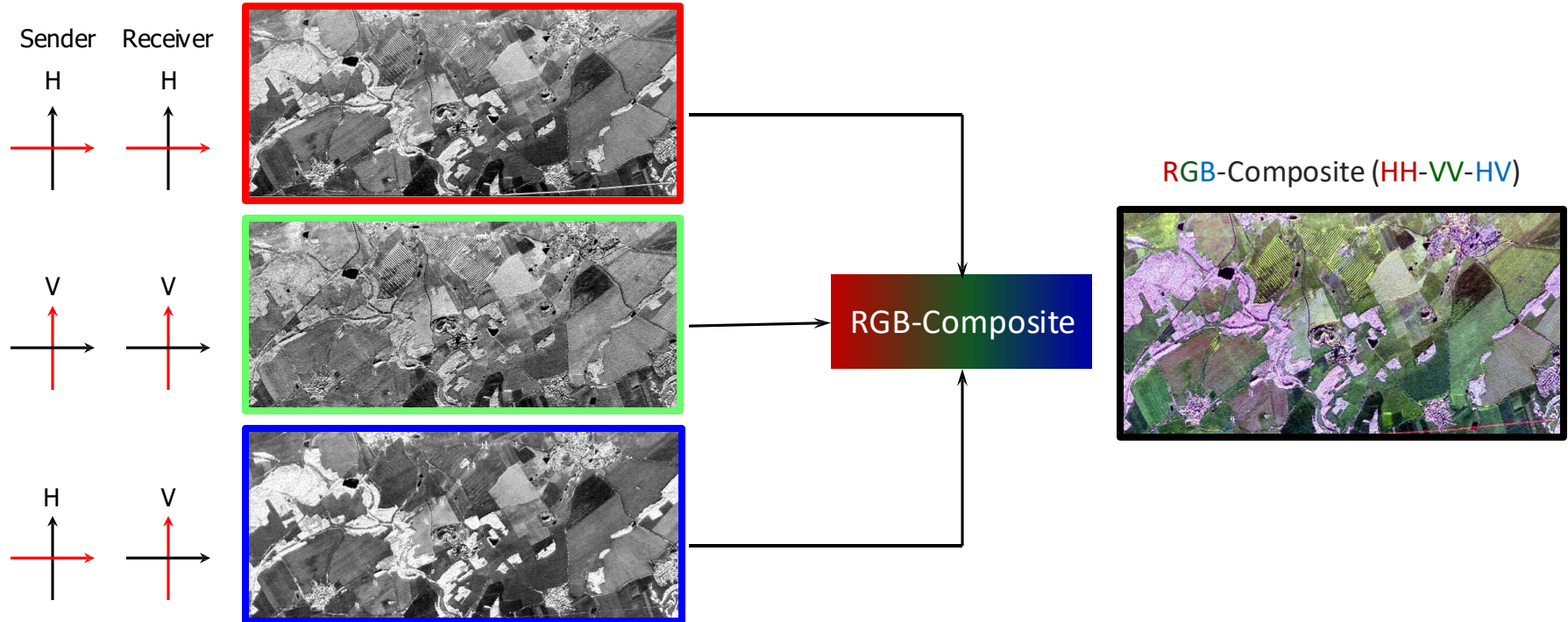
The four combinations of SAR data polarizations:

- **HH**: Horizontal Transmit, Horizontal Receive
- **HV**: Horizontal Transmit, Vertical Receive
- **VH**: Vertical Transmit, Horizontal Receive
- **VV**: Vertical Transmit, Vertical Receive
- **Quad-Pol Mode**: When all four polarizations are measured
- Different polarizations can determine physical properties of the observed object.



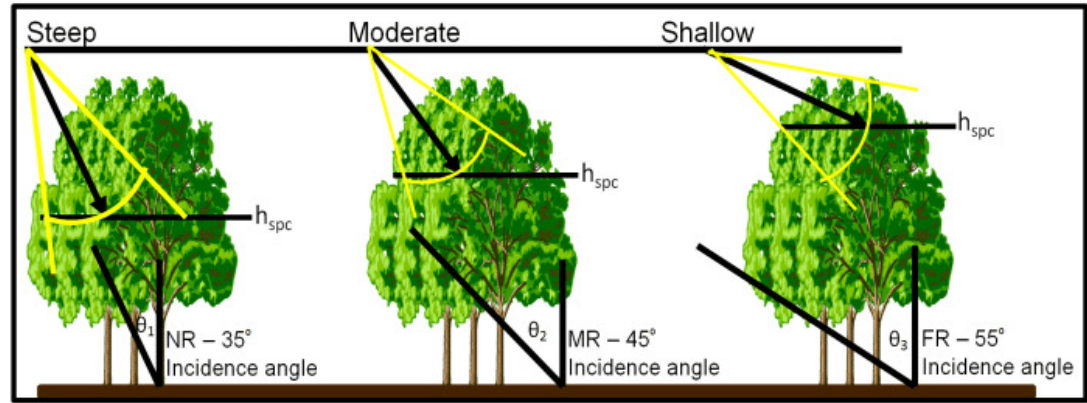
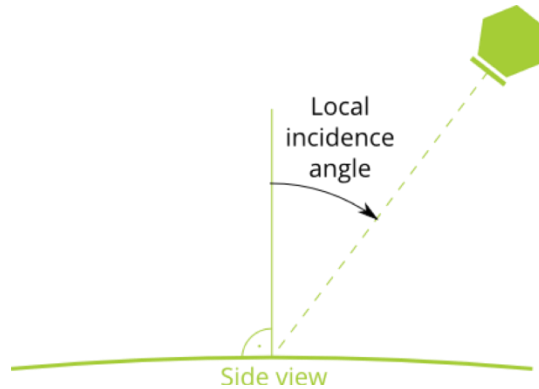
Radar Parameters to Consider for a Forestry Mapping

Polarisation – Example of multiple polarisations for vegetation studies



Radar Parameters to Consider for a Forestry Mapping

Incidence angle



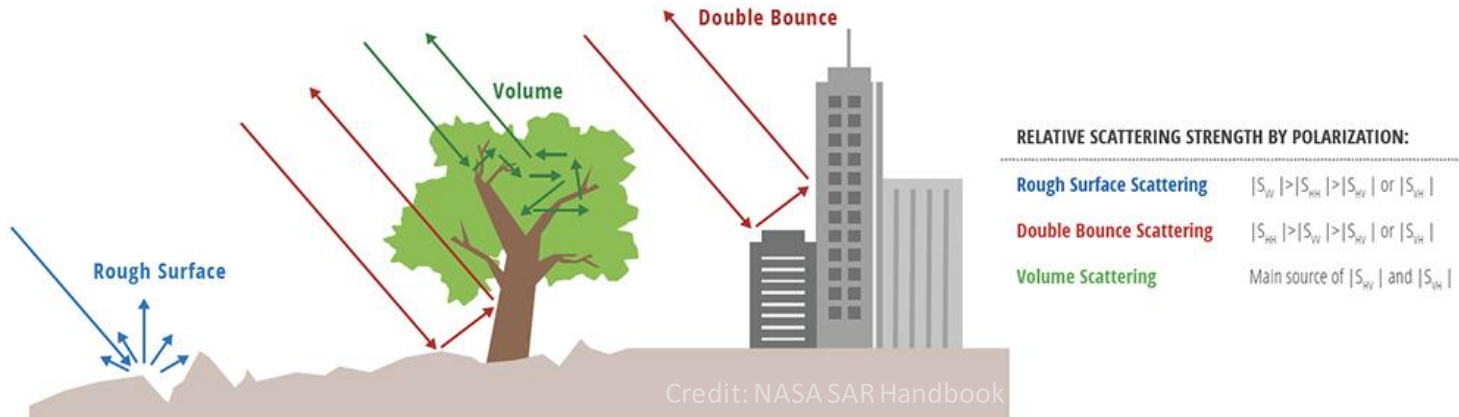
Local Incidence Angle:

- Refers to the angle formed between the radar illumination direction and the Earth's surface
- Takes into consideration the local slope of the terrain
- Affects the brightness of the image
- Determined by the sensor's altitude
- Results in varying geometric configurations across different points in the image's range direction

Radar Parameters to Consider for a Forestry Mapping

Signal interaction

Analyzing the signal intensity from these various polarizations provides insights into the composition of the observed surface, as it relates to the following types of scattering:



Rough surface scattering

- most sensitive to VV scattering
- caused f.e. by bare soil or water

Volume scattering

- most sensitive to cross-polarized data like VH or HV
- scattering by the leaves and branches

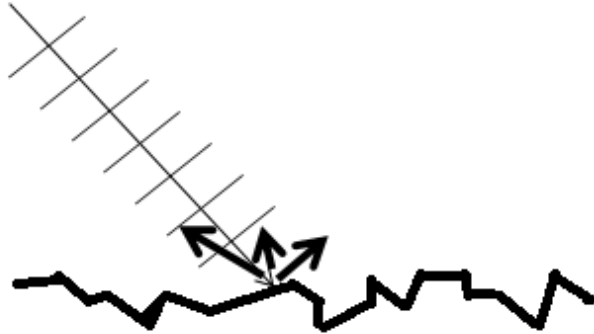
Double bounce

- most sensitive to an HH polarized signal
- caused by buildings, tree trunks, or inundated vegetation

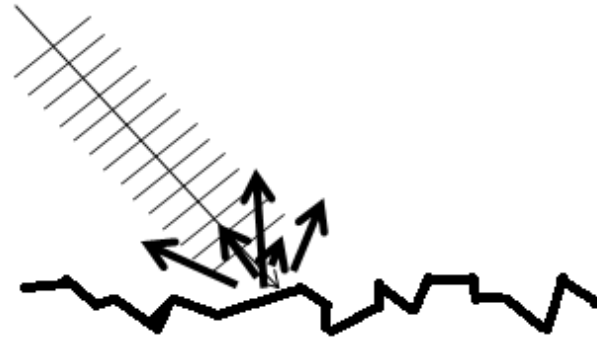
Radar Parameters to Consider for a Forestry Mapping

Radar backscattering

- The intensity of backscattered energy typically increases with surface roughness



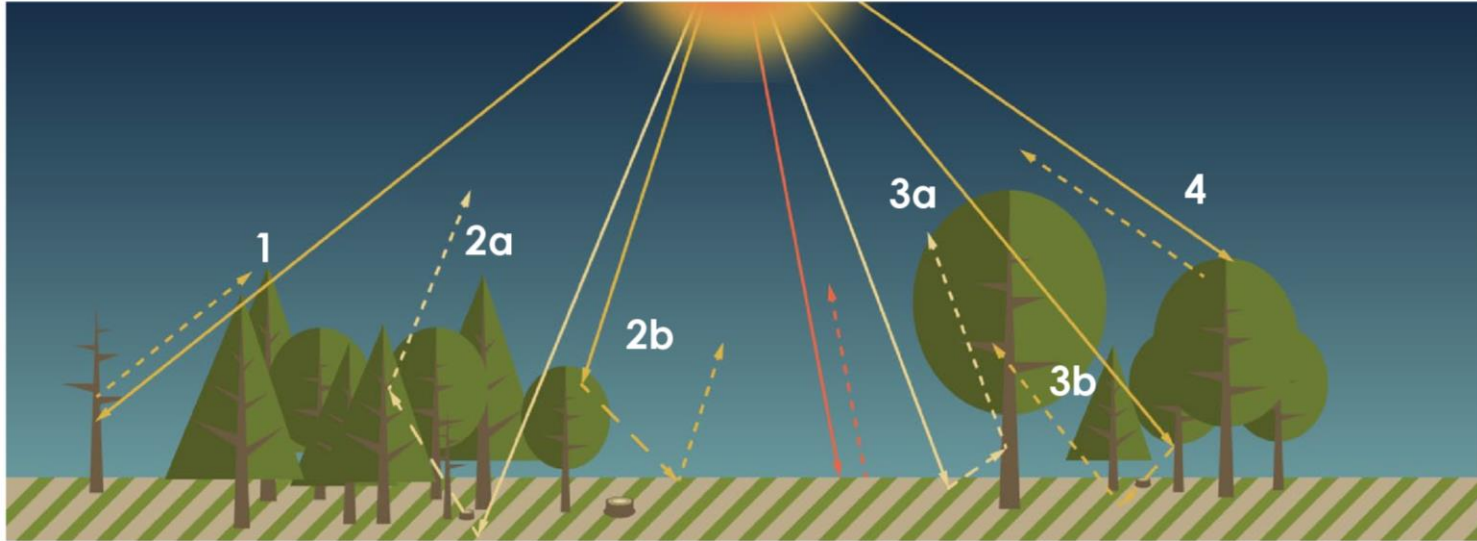
The surface appears smooth to long wavelength
=> Backscattering is low



The surface appears rough to shorter wavelength
=> Backscattering increases

Radar Parameters to Consider for a Forestry Mapping

Radar backscattering in Forests

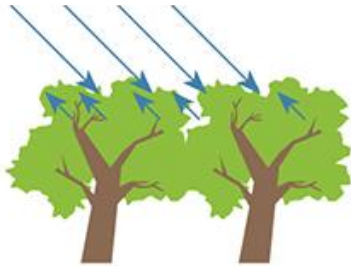
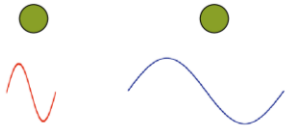


Dominant backscattering sources in forests: (1) direct scattering from tree trunks, (2a) ground-crown scattering, (2b) crown-ground scattering, (3a) ground-trunk scattering, (3b) trunk-ground scattering, (4) crown volume scattering.

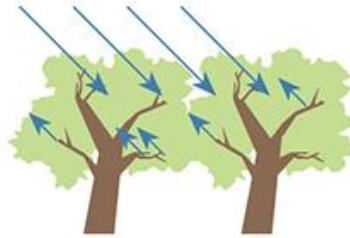
Surface Parameters to Consider for a Forestry Mapping

Structure

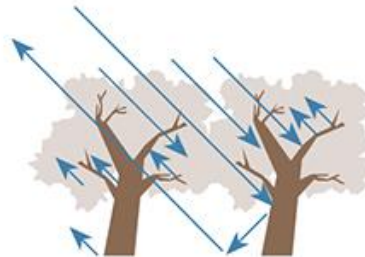
Size Relative to Wavelength



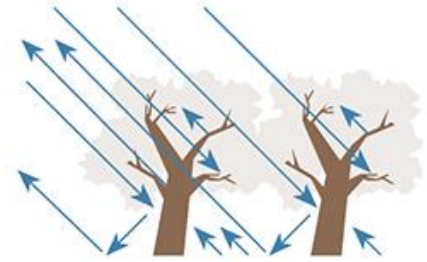
X-BAND 3 cm



C-BAND 6 cm



L-BAND 24 cm



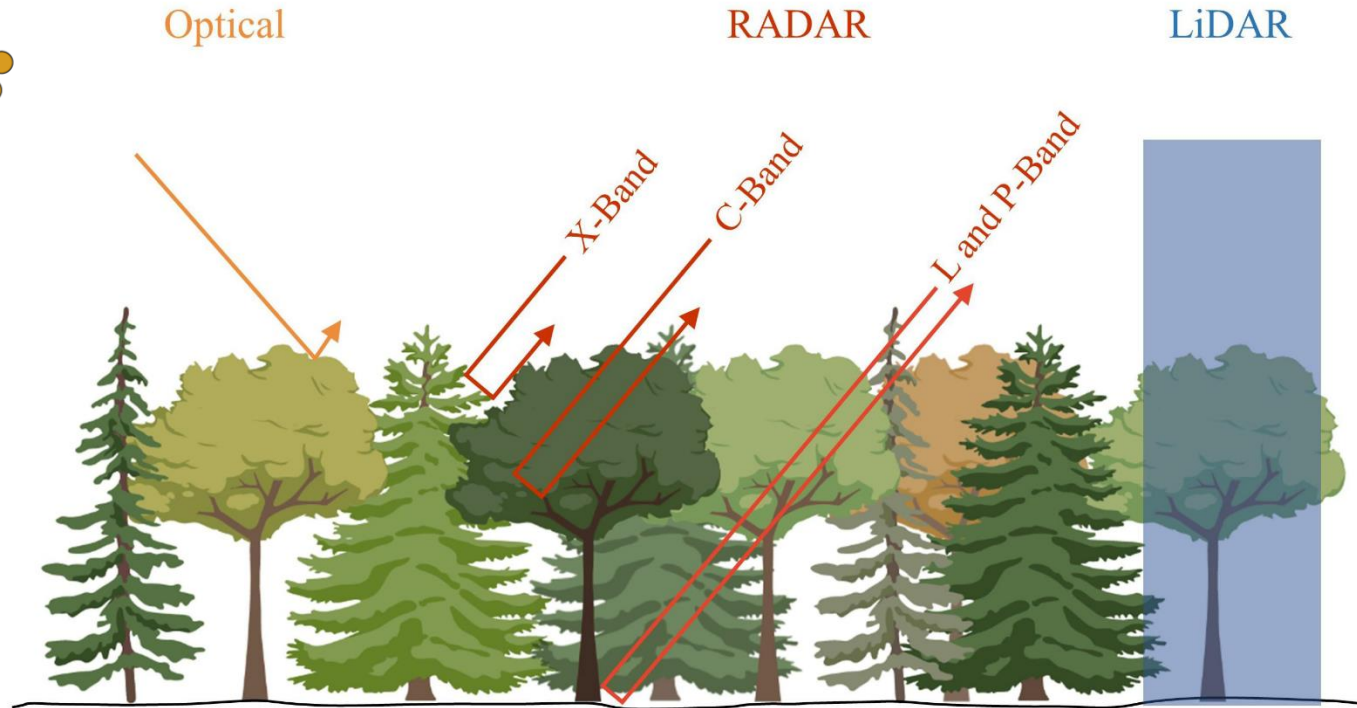
P-BAND 65 cm

- **P-band SAR:** provide information for forest biomass and height estimations
- **L-band SAR:** forest cover and change monitoring using dual polarization (cross-pol most sensitive to forest structure (e.g. JERS-1, ALOS PALSAR))
- **C-band:** dense time-series for accurate detection of forest cover change
- **X-band:** application in forest degradation assessment and forest height estimation (e.g. using TanDEM-X)

Surface Parameters to Consider for a Forestry Mapping

Structure

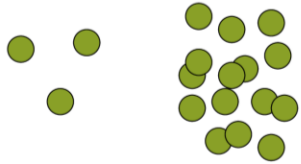
Size & Orientation



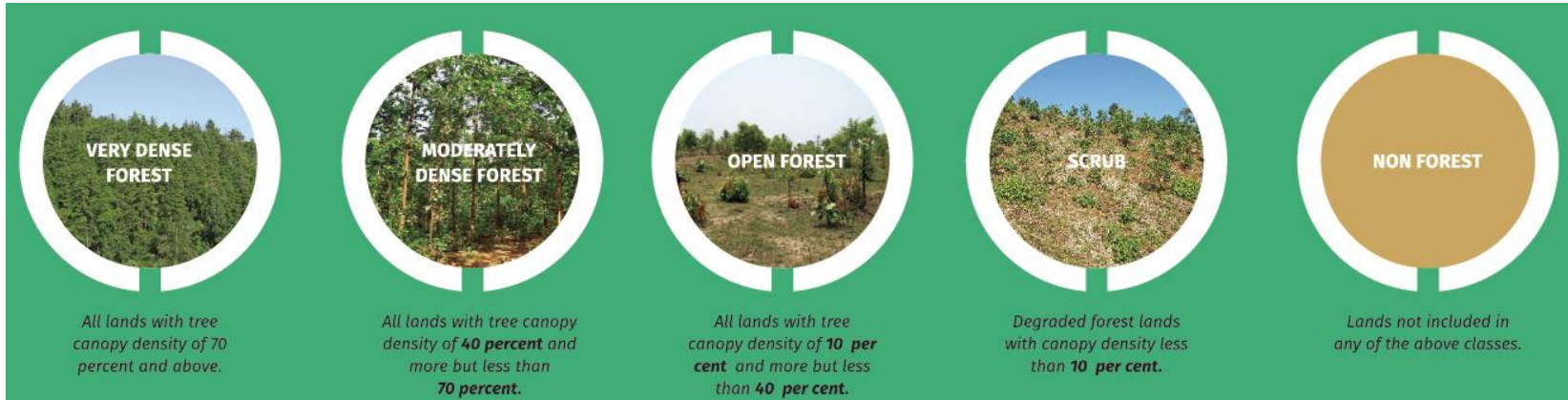
Surface Parameters to Consider for a Forestry Mapping

Structure

Density

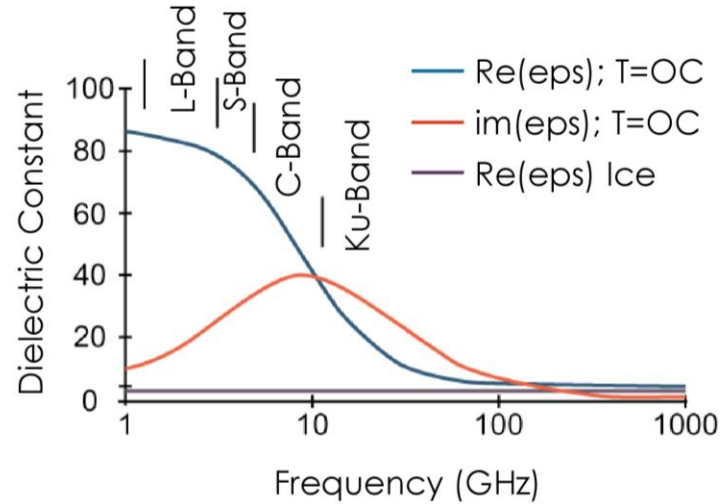
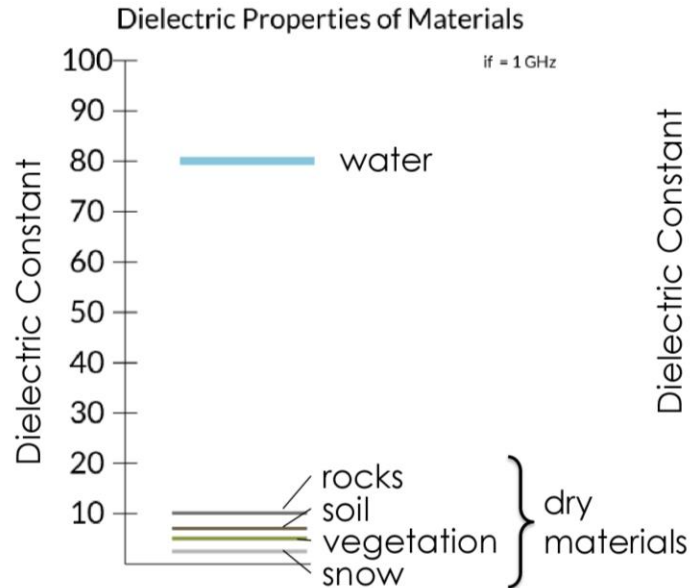


- The more dense the vegetation, the lower the probability of signal penetration through the canopy (influenced by wavelength)
 - Saturation issue - the signal reaches a maximum level at a specific biomass threshold, which varies according to wavelength:
 - C-band \approx 20 tons/ha (2 kg/m²)
 - L-band \approx 40 tons/ha (4 kg/m²)
 - P-band \approx 100 tons/ha (10 kg/m²)
- Combination of different polarizations can improve biomass estimates



Surface Parameters to Consider for a Forestry Mapping

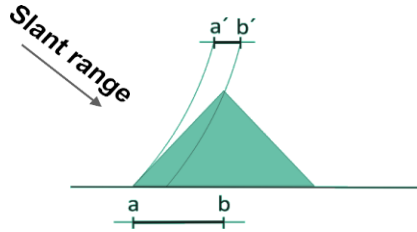
Dielectric constant



Surface Parameters to Consider for a Forestry Mapping

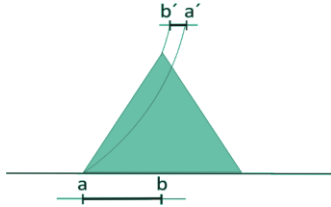
Geometric Effects

Foreshortening



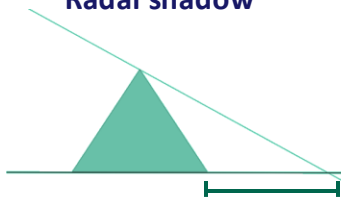
- Slopes oriented to the SAR appear compressed (Distance between a and b is shortened)
- Appears as very bright area
- More pronounced in near range (small incidence angle) than in far range (high incidence angles)

Layover



- Steep slopes oriented to the SAR lead to ghost images
- When radar beam reaches the top of a high feature (b) before it reaches the base (a)

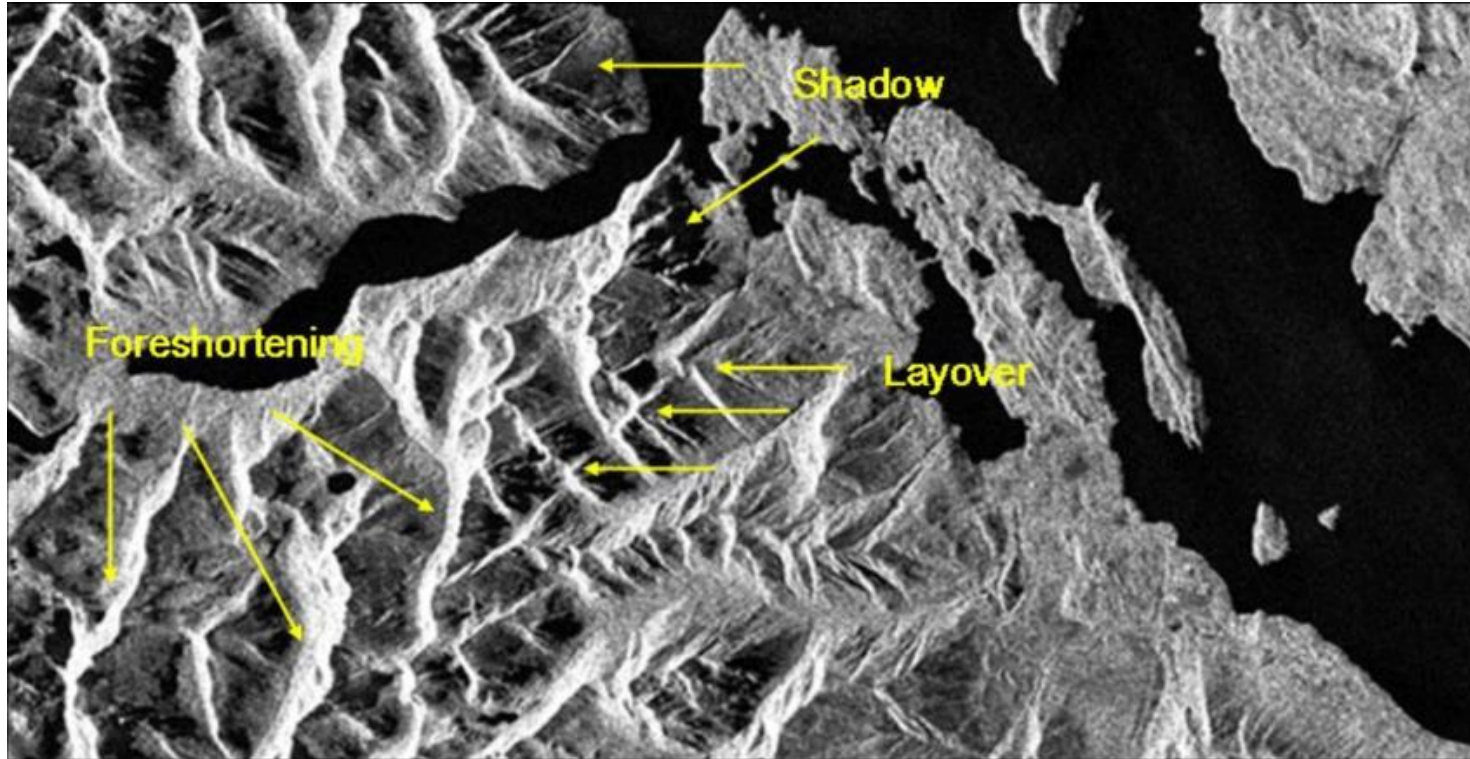
Radar shadow



- Steep slopes oriented away from the SAR return no signal
- No signals can be transmitted to this area (as it is blocked by the slope), thus no signals can be scattered back from these areas
- Appears as black area in the image

Surface Parameters to Consider for a Forestry Mapping

Geometric Effects



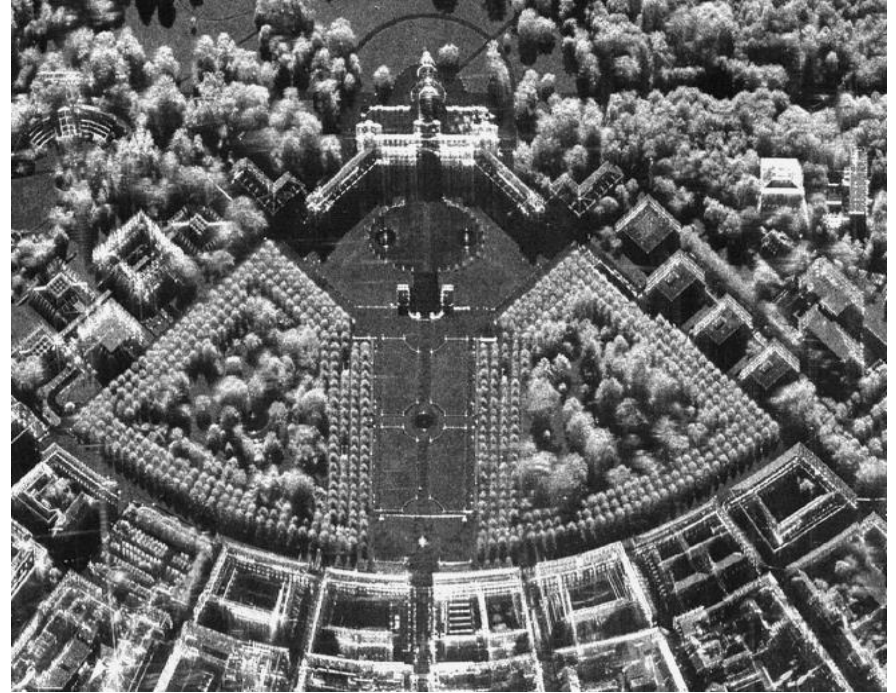
Source: <https://www.researchgate.net/profile/M-Lenzano/publication/263124688/figure/fig23/AS:614356547039256@1523485423960/Figura-9-Efectos-de-shadowing-foreshortening-y-layover-en-una-imagen-SAR-de-RADARSAT-1.png>

Surface Parameters to Consider for a Forestry Mapping

Geometric effects – side looking



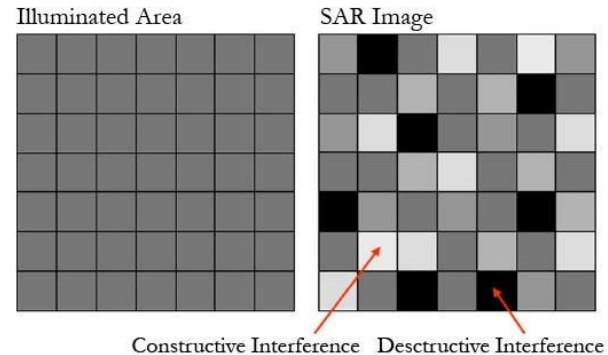
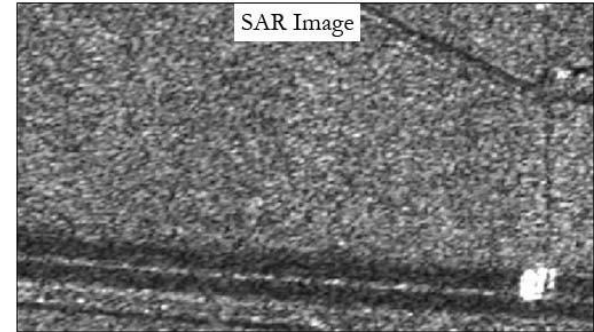
Google maps



Andreas R. Brenner and Ludwig Roessing, Radar Imaging of Urban Areas by Means of Very High-Resolution SAR and Interferometric SAR, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 46, NO. 10, OCTOBER 2008 (X-band)

Speckle

- Granular noise that affects radar images, reducing class spectral separability
- Degrades the quality of SAR image
- Results from random fluctuations in the return signal from an object
- Preprocessing is necessary to filter the images, aiming to minimize information loss
 - using of moving windows filters



Speckle

BEFORE FILTER APPLICATION:



AFTER FILTER APPLICATION:



L-HV RGB: 2007-07-03 2009-07-08 2010-07-11

Multitemporal speckle filter application on a perfectly co-registered time series data stack of ALOS L-band data over Louisiana, U.S

Source:<https://gis1.servirglobal.net/TrainingMaterials/SAR/Ch3-Content.pdf>

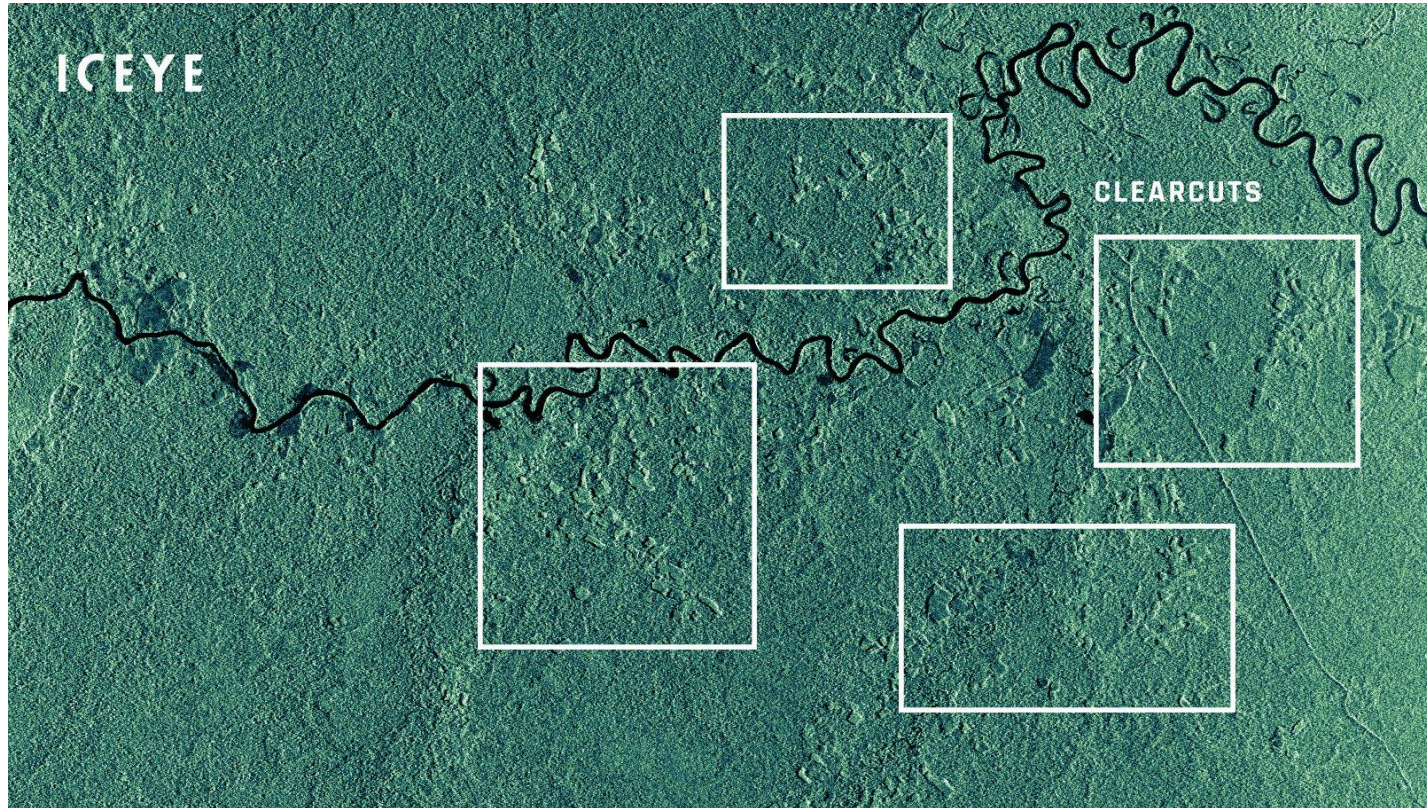
SAR for forestry - Applications

Expected backscatter characteristics for different vegetation transition scenarios

WAVELENGTH	POLARIZATION	RESPONSE BY FOREST TYPE					
		Sparse Forest (dry)	Sparse Forest (flooded)	Degraded Forest (dry)	Degraded Forest (flooded)	Dense Forest (dry)	Dense Forest (flooded)
C-band backscatter (g0)	WV	Medium to high; Depending on the roughness of the forest floor and moisture, there is lots of variation in this category	Low to medium; Depending on forest density, lots of forward scattering	Medium to high; most scattering from crown	Medium to high; most scattering from crown	Medium to high; most scattering from crown (Can be low in scenarios where absorption dominates and diminishes backscatter)	Medium to high; most scattering from crown (Can be low in scenarios where absorption dominates and diminishes backscatter)
	VH	Medium to high; Depending on the roughness of the forest floor and moisture, there is lots of variation in this category	Low to medium; Depending on forest density, lots of forward scattering	Medium to high; most scattering from crown	Medium to high; most scattering from crown	Medium to high; most scattering from crown (Can be low in scenarios where absorption dominates and diminishes backscatter)	Medium to high; most scattering from crown (Can be low in scenarios where absorption dominates and diminishes backscatter)
	WV/VH Ratio	Medium to high	Medium to high	Medium	Medium	Medium	Medium
L-band backscatter (g0)	HH	Low to medium; lower than dense forest and flooded sparse forest. At steep incidence angles, backscatter can be medium to high	Medium to high, depending on how much double bounce is contributing to the signal	Medium to high	High to very high, double bounce contributes to high backscatter	High to very high; higher than degraded forest, however at very high biomass levels we see saturation and no distinction with degraded forests	High to very high, double bounce contributes to high backscatter
	HV	Low to very low, depending on how dry the soils are	Low to very low. Most scattering is in the forward direction due to specular reflection	Medium to high	Medium to high, no seasonal variation with flooded forest floor	High to very high; volume scattering is dominant – best sensitivity to biomass	Medium to high, no seasonal variation with flooded forest floor
	HH/HV Ratio	Medium	High	Medium	High	Medium	High

SAR for forestry - Applications

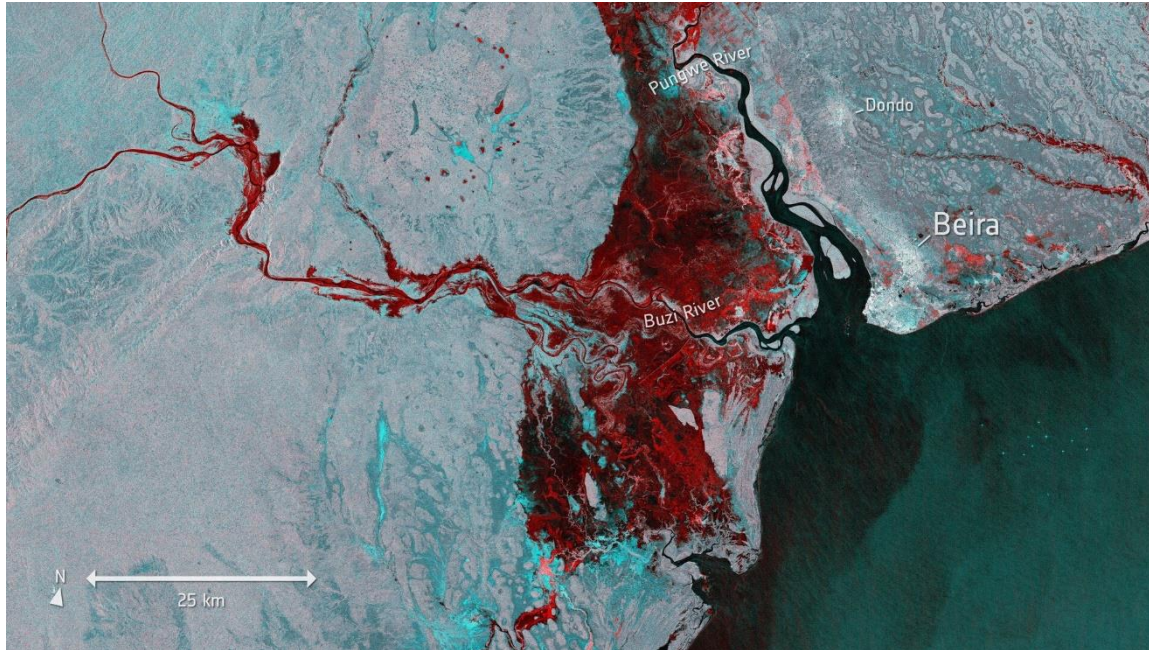
Detecting clearcuts



ICEYE SAR satellite Strip image of Masisea District, Peru, west of Area de Conservación Regional Imiría. The image was taken on 9th of April 2020.

SAR for forestry - Applications

Detecting inundated forests and floods



Floods imaged by Copernicus Sentinel-1
Millions of people in Mozambique, Malawi and Zimbabwe are struggling to cope with the aftermath of what could be the southern hemisphere's worst storm: Cyclone Idai. This image is from Copernicus Sentinel-1 and shows the extent of flooding, depicted in red, around the port town of Beira in Mozambique on 19 March. This mission is also supplying imagery through the Copernicus Emergency Mapping Service to aid relief efforts.

CREDIT: contains modified Copernicus Sentinel data (2019), processed by ESA



Thank you for the attention

