ESA-MOST Dragon 4 Cooperation

ADVANCED TRAINING COURSES ON LAND REMOTE SENSING

中国科学技术部-欧空局 “龙计划”四期 2019陆地遥感高级培训班

Agriculture SAR

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L1: SAR remote sensing

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SAR: Active microwave imaging systerm

PASSIVE SENSORS

Detect the reflected or emitted electromagnetic radiation from natural sources

Non imaging (ex. Microwave radiometer, magnetic sensor)

Imaging (ex. cameras, optical mechanical scanner, spectrometer, microwave radiometer)

ACTIVE SENSORS

Detect reflected responses from objects irradiated by artificially-generated energy sources

Non-Imaging (ex. microwave radiometer, microwave altimeter, laser)

Imaging (Real Aperture Radar, **Synthetic Aperture Radar**)

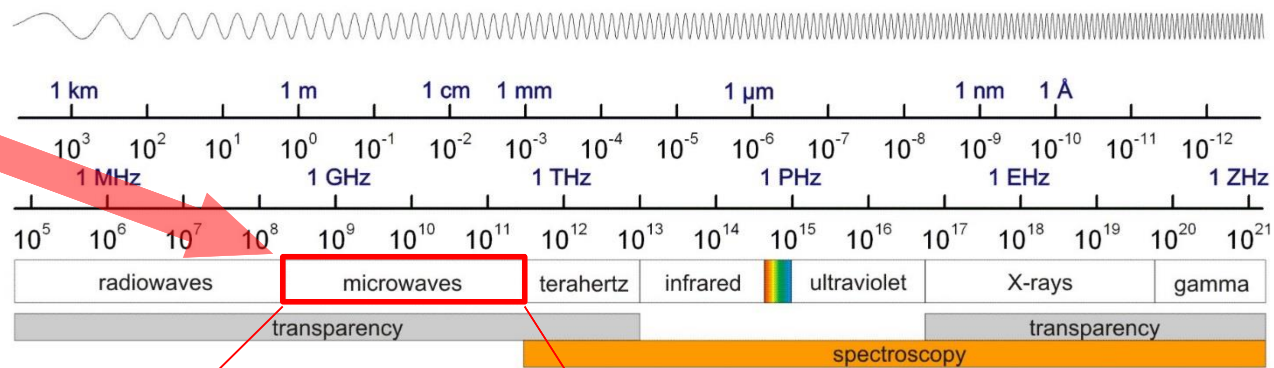
RADAR: Radio Detection and Ranging

SLAR: Side Looking Airborne Radar

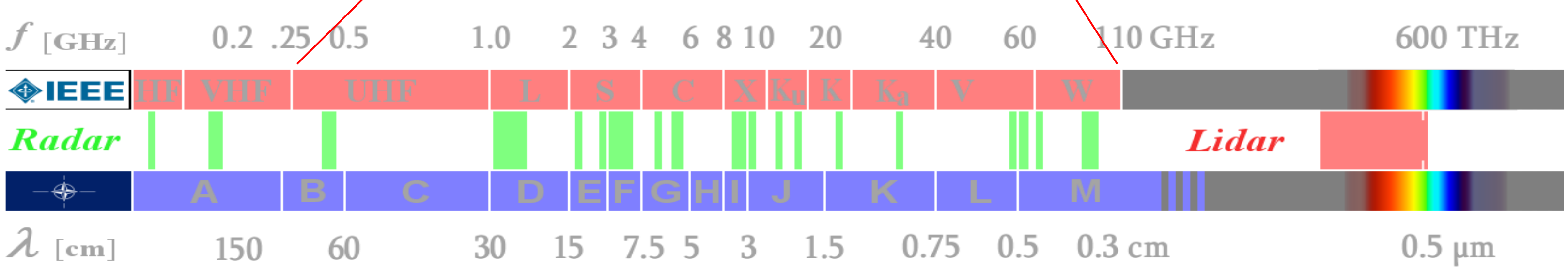
SAR: Synthetic Aperture Radar, airborne systems developed in 1950's

The electromagnetic spectrum

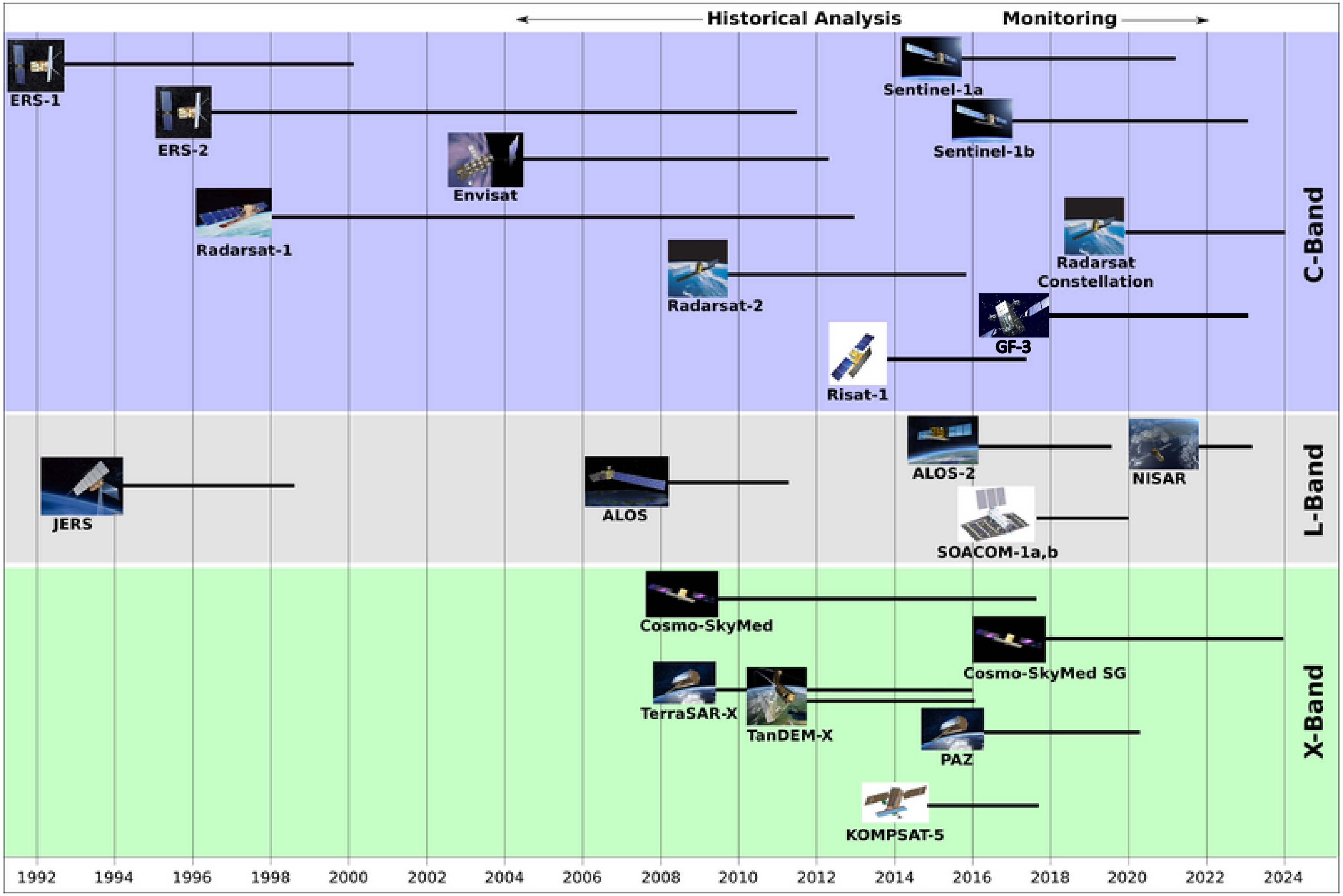
SAR remote sensing



Radar frequency



Spaceborne SARS



Characteristics of SAR remote sensing

Advantages compared to optical remote sensing

- Day and night operation (independence of sun illumination)
- All weather capability (small sensitivity of clouds, light rain)
- No effects of atmospheric constituents (multitemporal analysis)
- Sensitivity to dielectric properties (water content , biomass, ice)
- Sensitivity to surface roughness (ocean wind speed)
- Accurate measurements of distance (interferometry)
- Sensitivity to man made objects
- Sensitivity to target structure (use of polarimetry)
- Sub-canopy/sub-surface penetration

Characteristics of SAR remote sensing

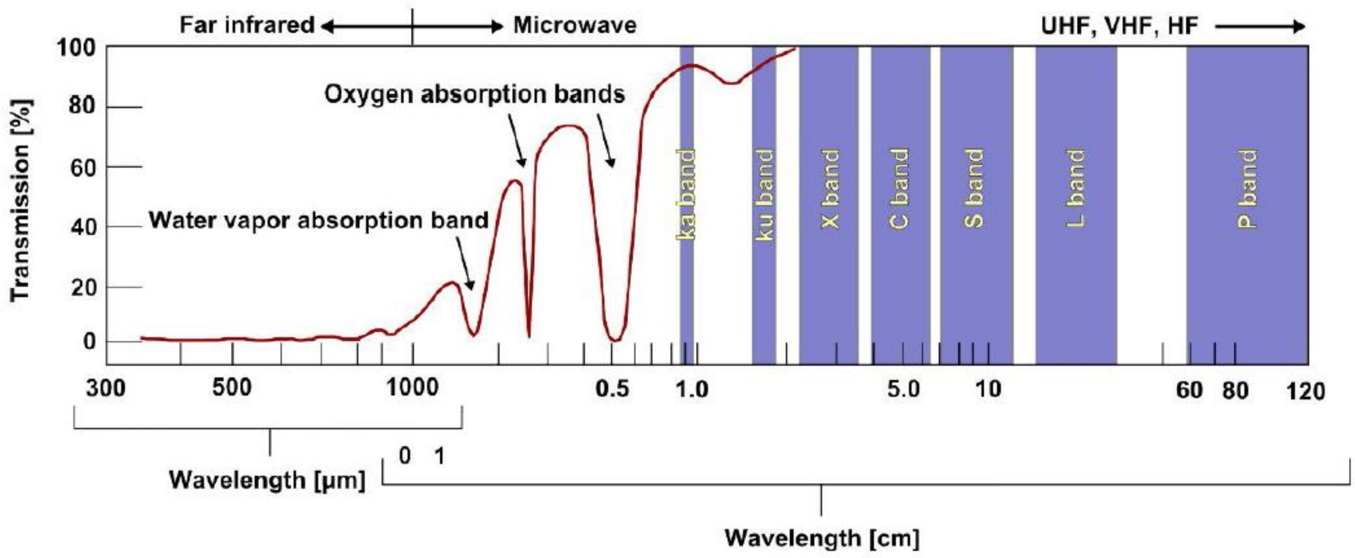
☐ Inconvenients

- Complex interactions (difficulty in understanding, complex processing)
- Speckle effects (difficulty in visual interpretation)
- Topograhic effects
- Effect of surface roughness

All weather capability

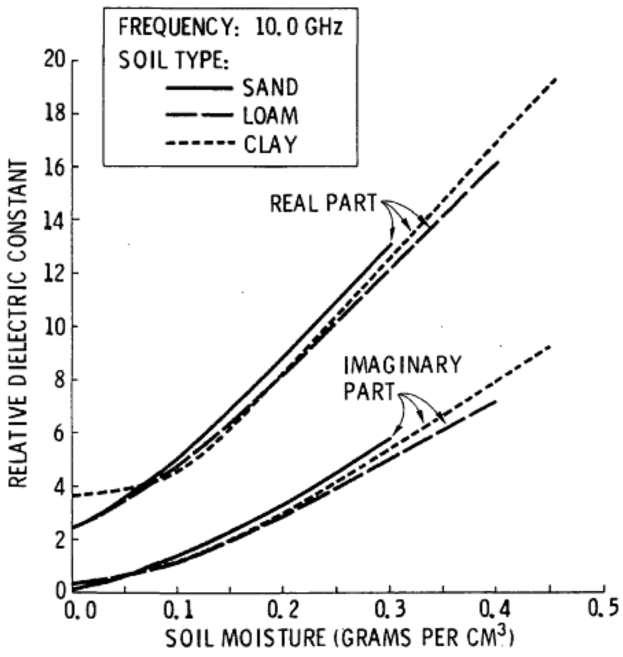
An ‘ *all-weather* ’ imaging system: small sensitivity of clouds, light rain

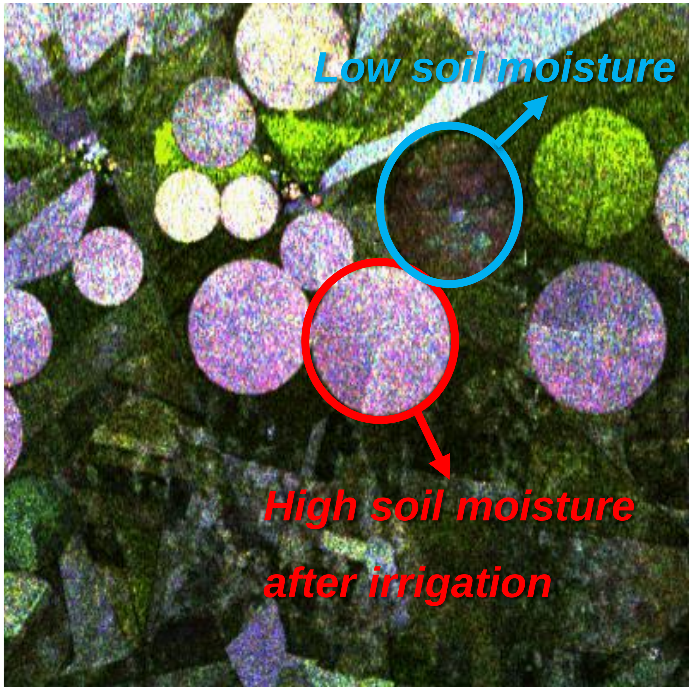
A microwaves system: cloud penetrating capabilities as Marginal atmospheric effects



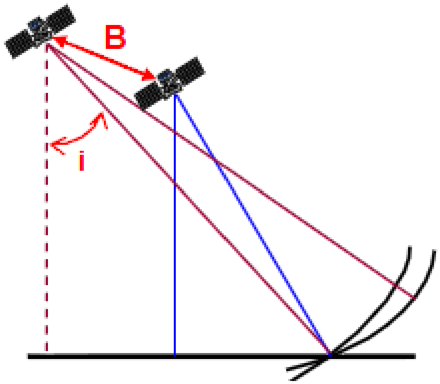
Sensitivity to dielectric properties

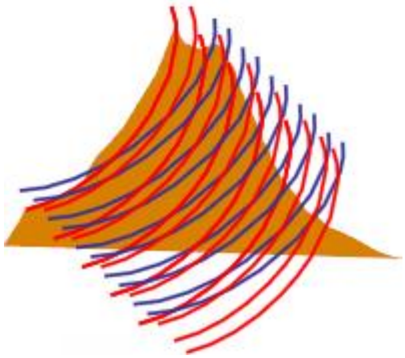
Sensitivity to ***dielectric constants*** and consequent to water content

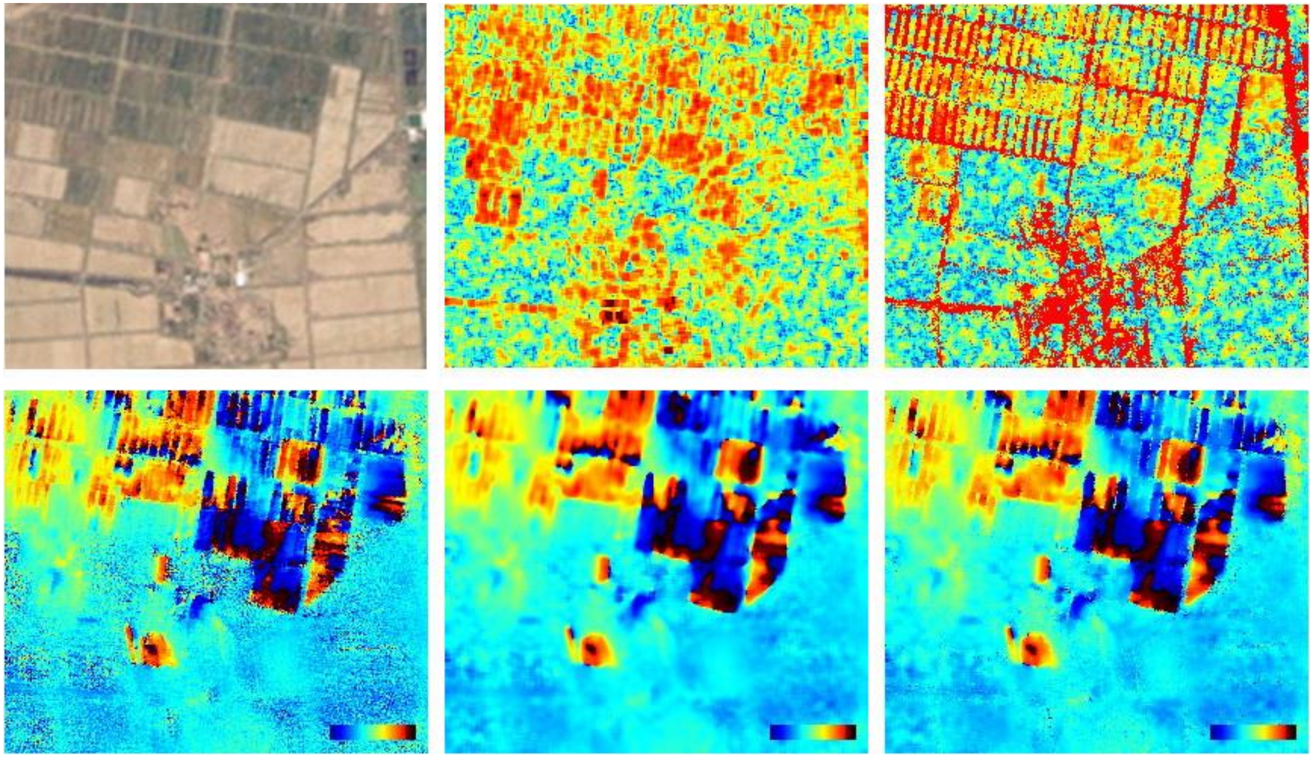




Accurate range measurement

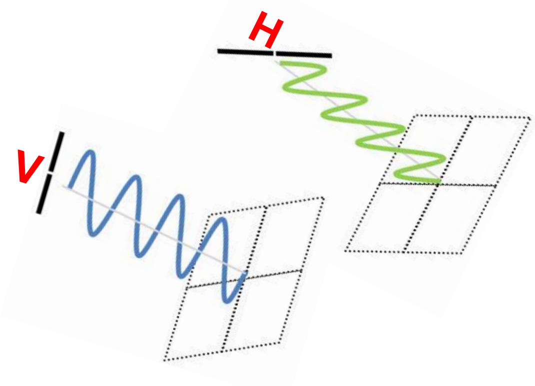






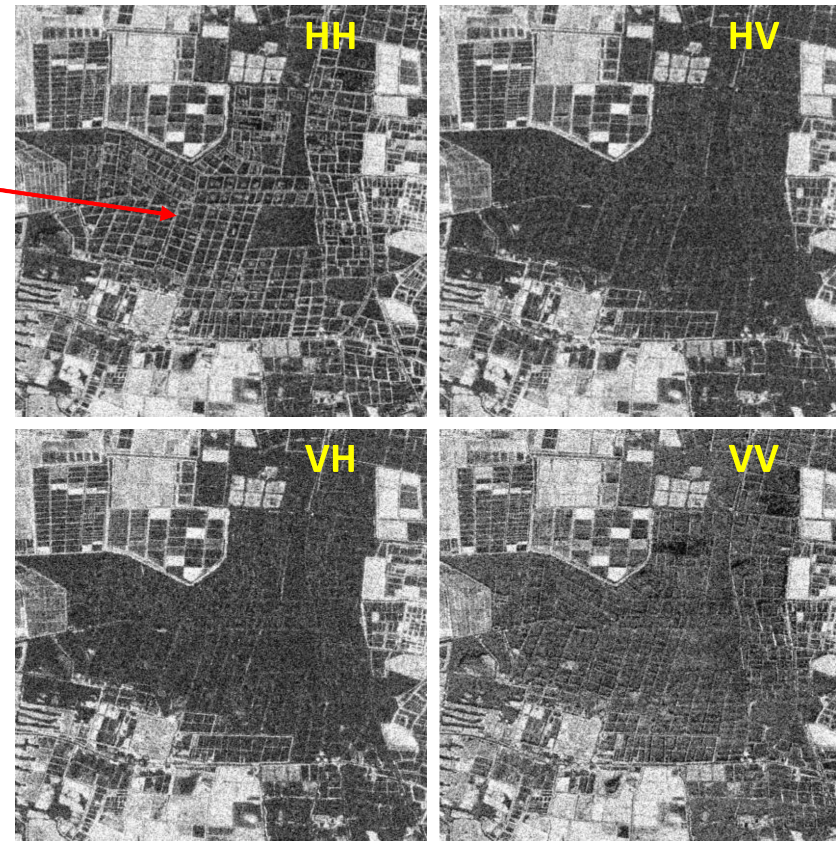
Interferometric coherence and Interferometric phase

Sensitivity to target structure



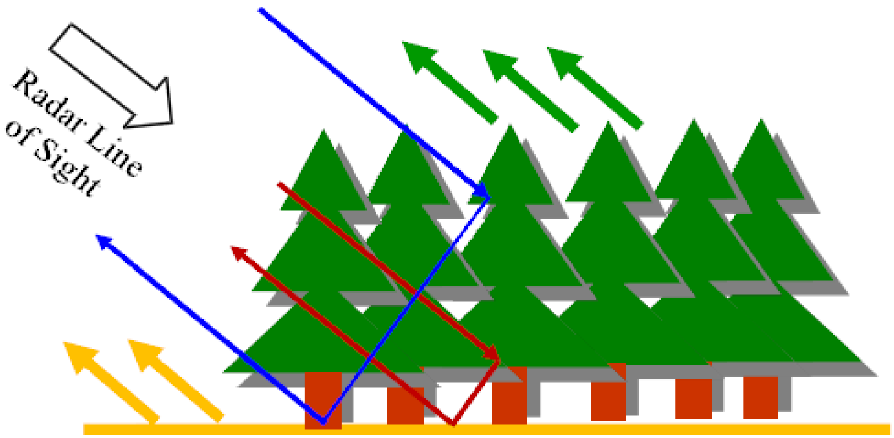
Pen

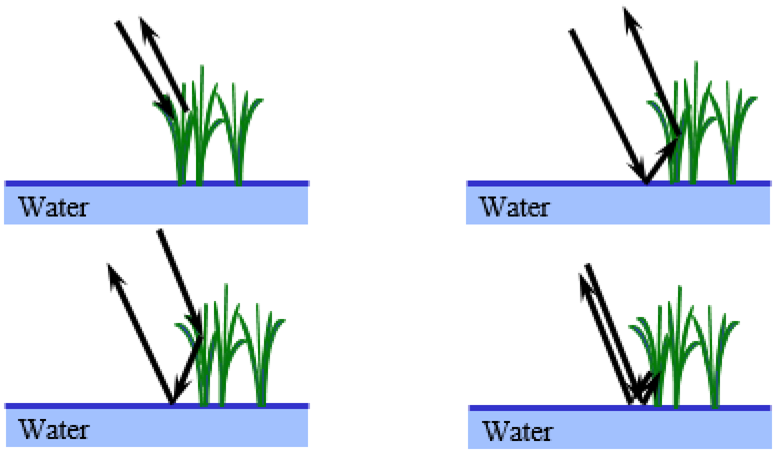
Pen-crab Culturing



Sub-canopy penetration

Penetrate the canopy and interacted with sub-canopy layers, more sensitive to height and biomass.





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Basic measurement

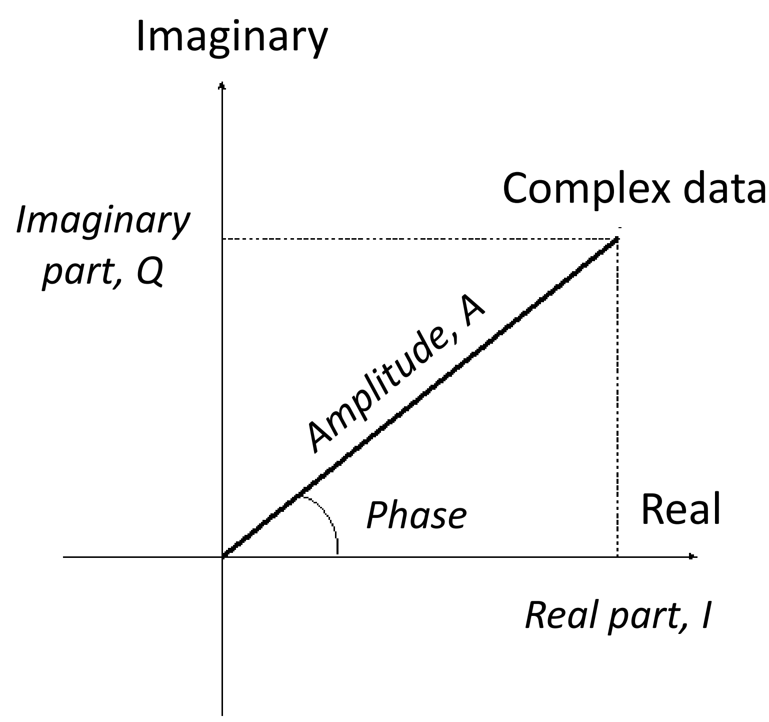
The basic measurement of a SAR is **complex data (*amplitude and phase*)**

Main types of SAR images:

A is the amplitude image.

$I = A^2$ is the intensity image.

(the phase of a single image is not exploitable)



The radar cross-section

The radar cross-section (RCS) is defined as

$$\sigma_{pq} = 4\pi \left| S_{pq} \right|^2 = 4\pi R^2 \frac{P_s}{P_i} \quad (\mathrm{m}^2)$$

R is the radar-target distance

P_i is the incident power

P_s is the power scattered by the target

The backscattering coefficient

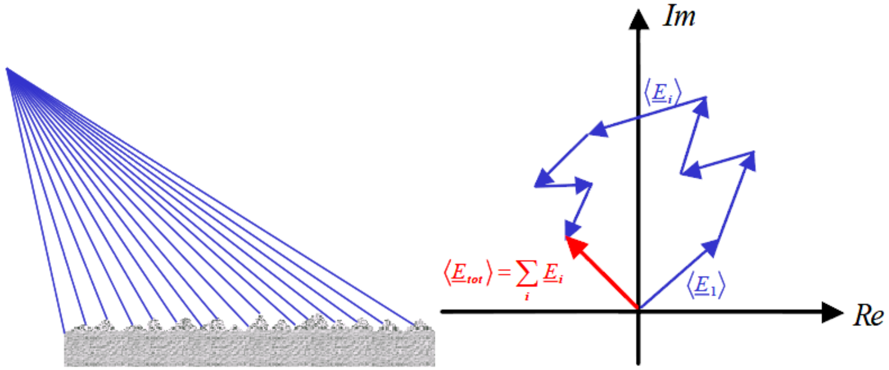
For **distributed targets** each resolution cell contains many scatterers and the phase varies rapidly with position

The **differential backscattering coefficient**, σ^o, is

$$\sigma^o = \frac{4\pi R^2}{\Delta A}\frac{P_s}{P_i}$$

where ΔA is the area of the illuminated surface over which the phase can be considered constant

The physical origin of speckle

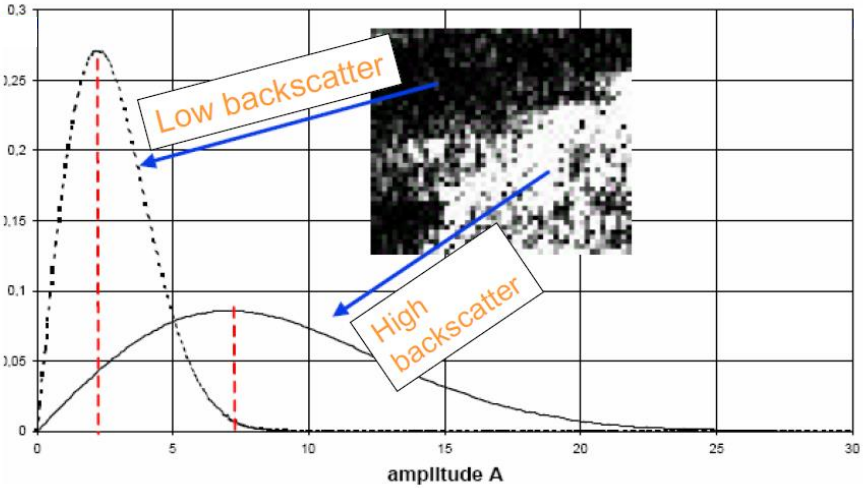


Resolution cells are made up of many scatterers with different phases, leading to interference and the noise-like effect known as ***speckle***

Statistics of speckle

Intensity image: exponential distribution

Amplitude image: Rayleigh distribution



Estimating the backscattering coefficient

Given L independent measurements from a uniform distributed target, the MLE of σ^o is given by

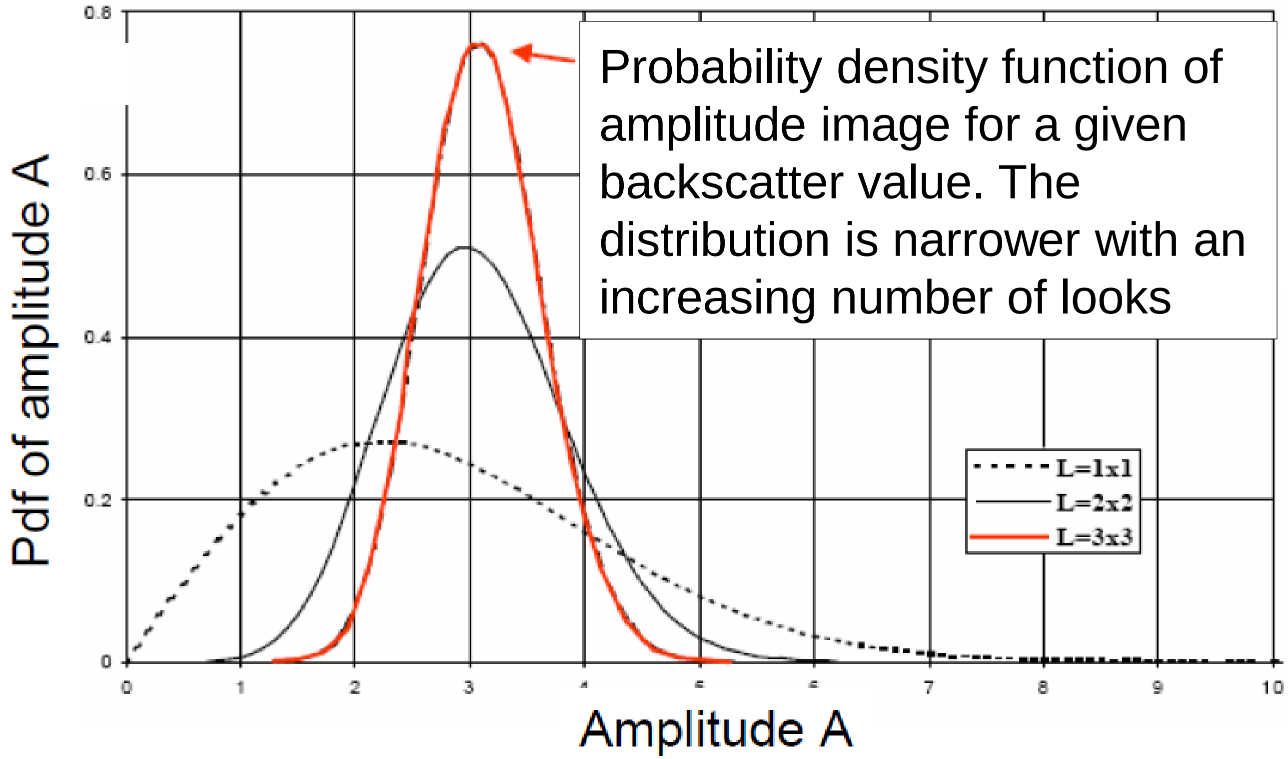
$$I = \frac{1}{L}\sum_{k=1}^{L} I^{(k)}$$

where the $I^{(k)}$ are individual intensity measurements

This does not depend on the original form of the data (amplitude, intensity or complex)

L is called the number of looks

Speckle: Multilooking effect



Probability density function of amplitude image for a given backscatter value. The distribution is narrower with an increasing number of looks

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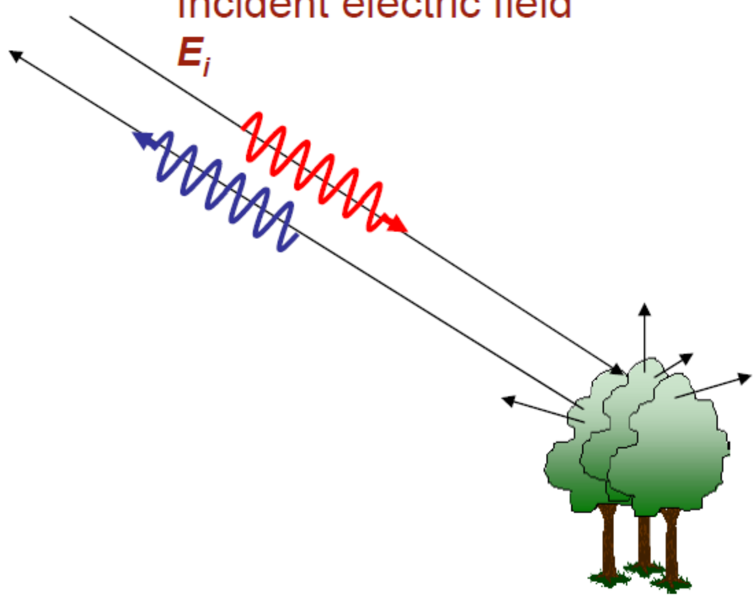
The radar scattering



the amplitude, phase and polarisation of E_s are modified with respect to E_i

$$E_s = \frac{e^{ikr}}{r} S E_i$$

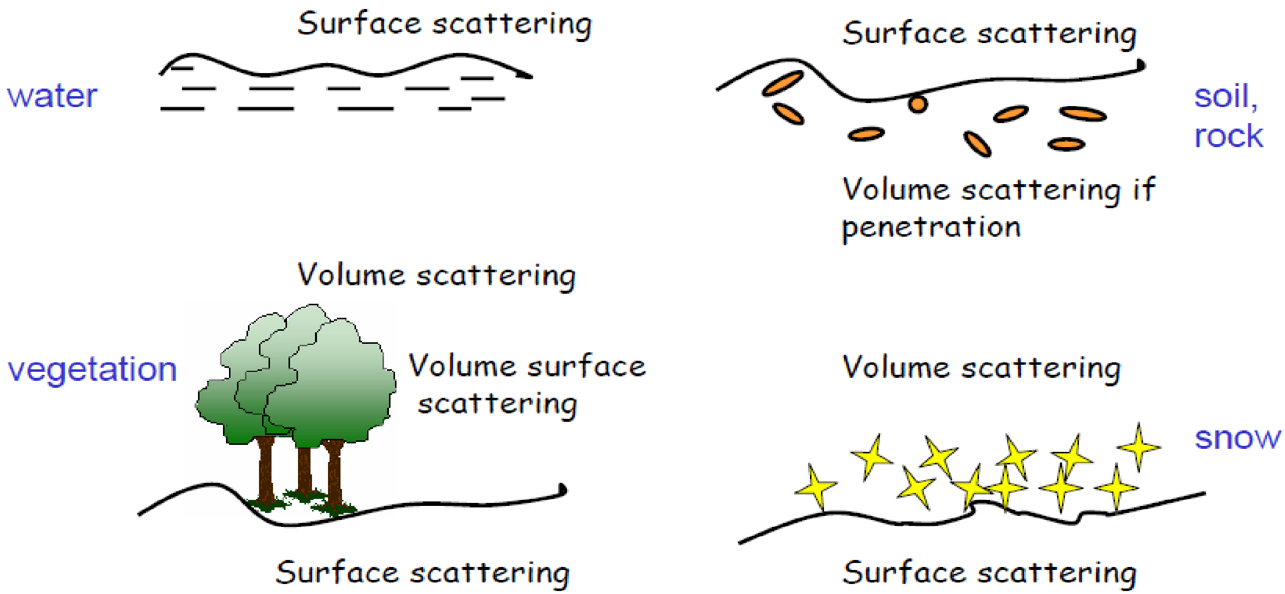
$$\begin{bmatrix} E_{sv} \\ E_{sh} \end{bmatrix} = \frac{e^{ikr}}{r} \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \begin{bmatrix} E_{iv} \\ E_{ih} \end{bmatrix}$$

$$S_{ij} = |S_{ij}| e^{i\phi_{ij}}$$

The scattering matrix contains information on the nature and characteristics of the observed media

Scattering mechanisms

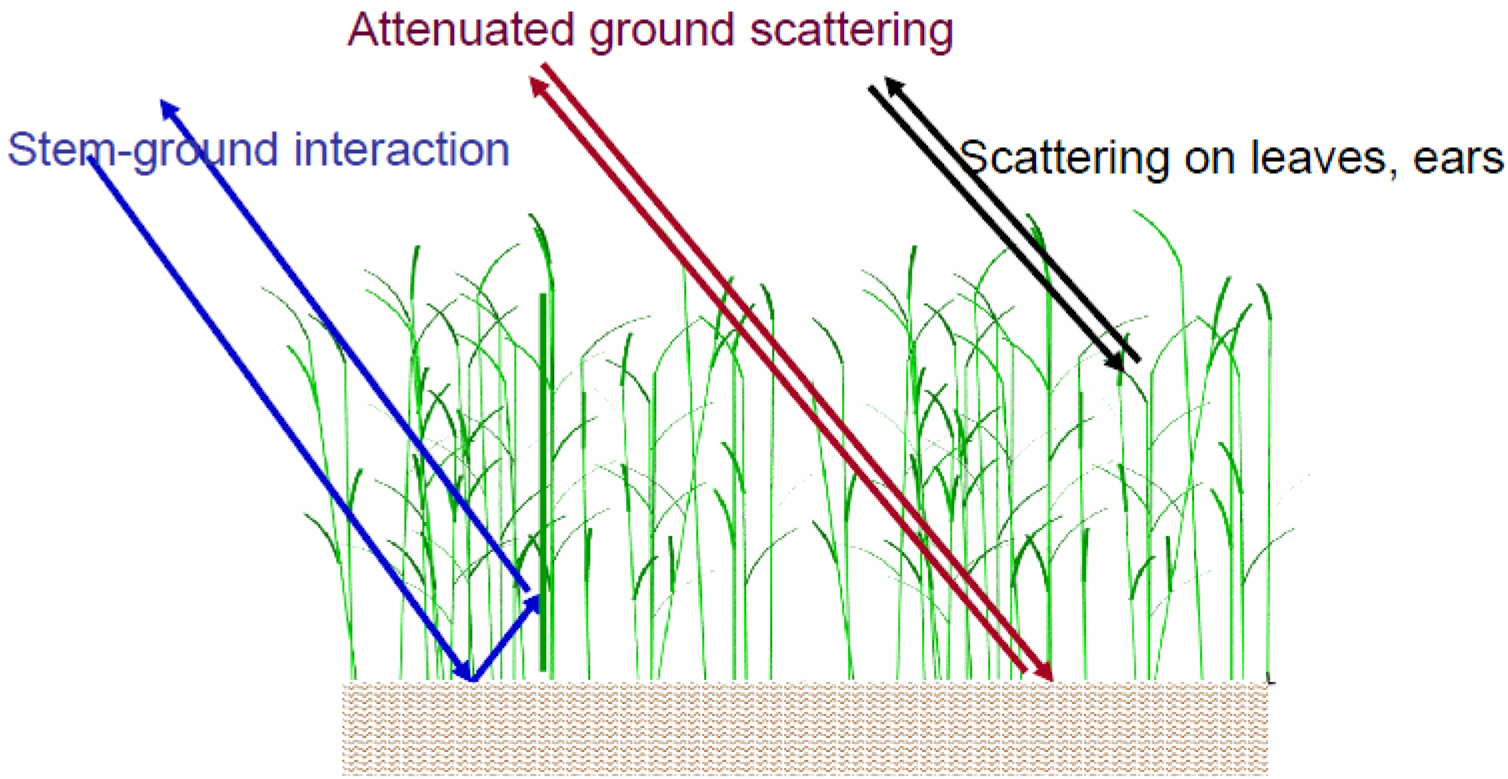
- The backscattered signal results from
  - *surface scattering*
  - *volume scattering*
  - *multiple volume-surface scattering*



Scattering mechanisms

- **The relative importance of these contributions depend on**
  - surface roughness
  - dielectric properties of the medium
- **All of these factors depend on**
  - the radar frequency
  - the polarization
  - the incidence angle

Scattering from a cereal canopy



Phase in SAR images

The SAR measurement contains an amplitude and a phase $S_{ij} = |S_{ij}| e^{i\phi_{ij}}$

The phase difference between scatterers of the incident waves travelling from the radar to a scatterer and back to the radar changes as:

$$\Delta\phi = \frac{2\pi\Delta r}{\lambda}$$

where Δr is the difference in the travel distance

Since the SAR resolution cell contains a large number of scatterers, the phase of pixels seems randomly distributed

If the scene is observed in 2 images, in which the scatterers remain unchanged in the resolution cell, the phase difference between pixels of the 2 images can be exploited

Polarimetry: the radar measures at the same time HH, VV, HV, VH and their phase difference

Interferometry: 2 radars observe the scene with a small shift in the look angle; or the same radar at different dates from lightly shifted orbit