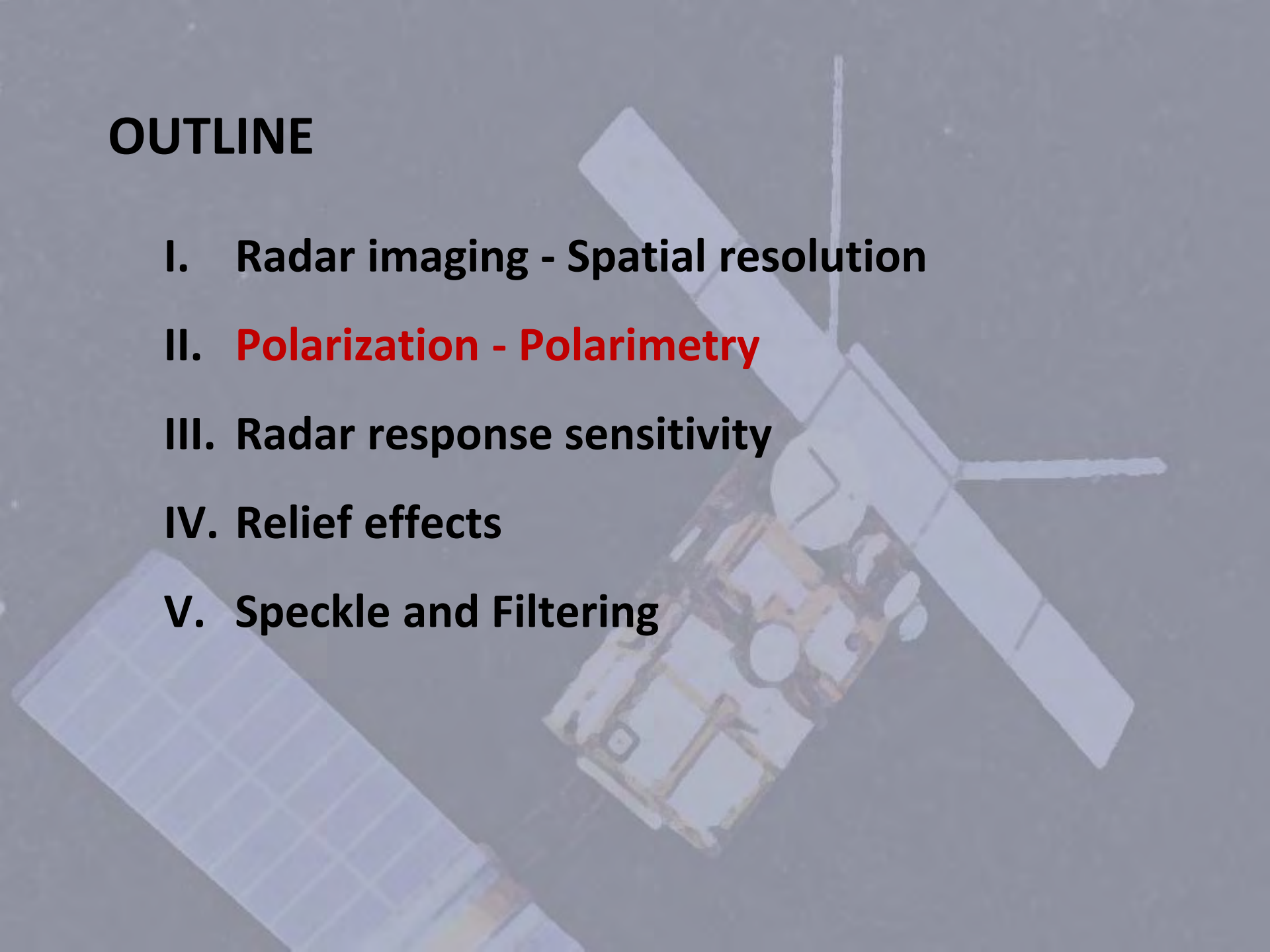


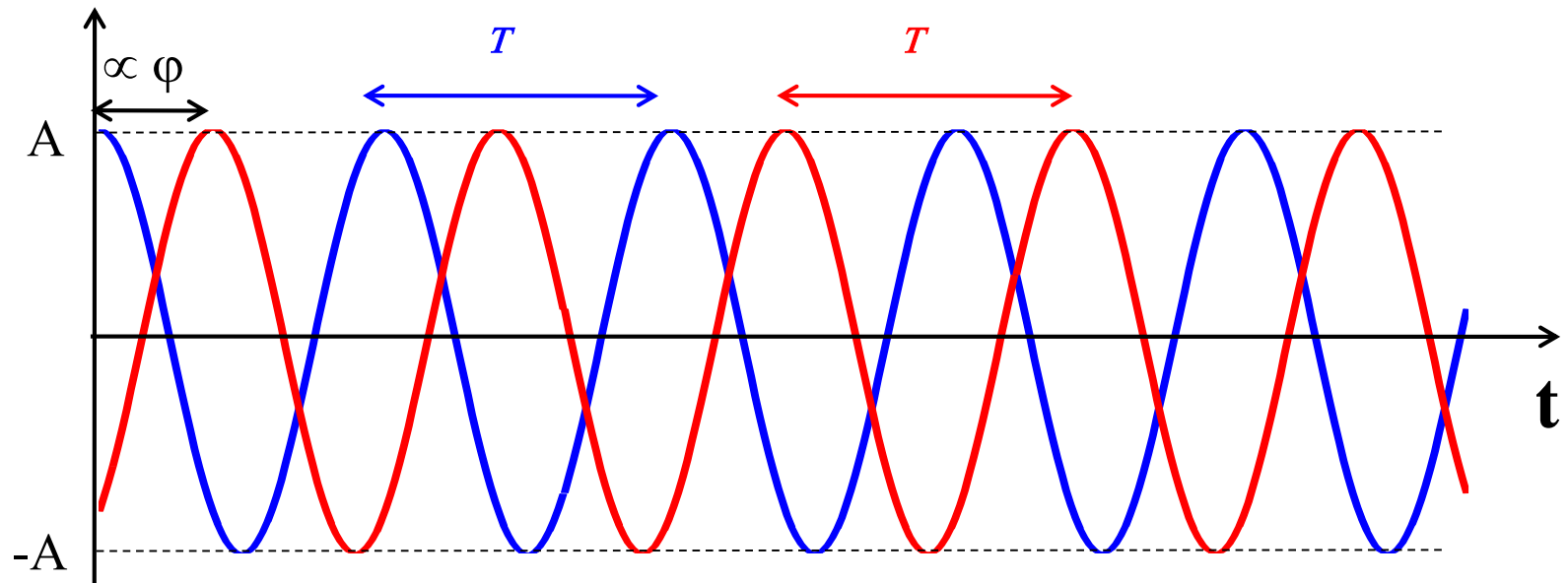
# OUTLINE

- I. Radar imaging - Spatial resolution
- II. **Polarization - Polarimetry**
- III. Radar response sensitivity
- IV. Relief effects
- V. Speckle and Filtering



# Electromagnetic coherent wave

Coherent wave: *temporal* behaviour



$$y(t) = A \cos\left(\frac{2\pi}{T} t\right)$$

$$y(t) = A \cos\left(\frac{2\pi}{T} t - \phi\right)$$

$$T = \frac{1}{f_0}$$

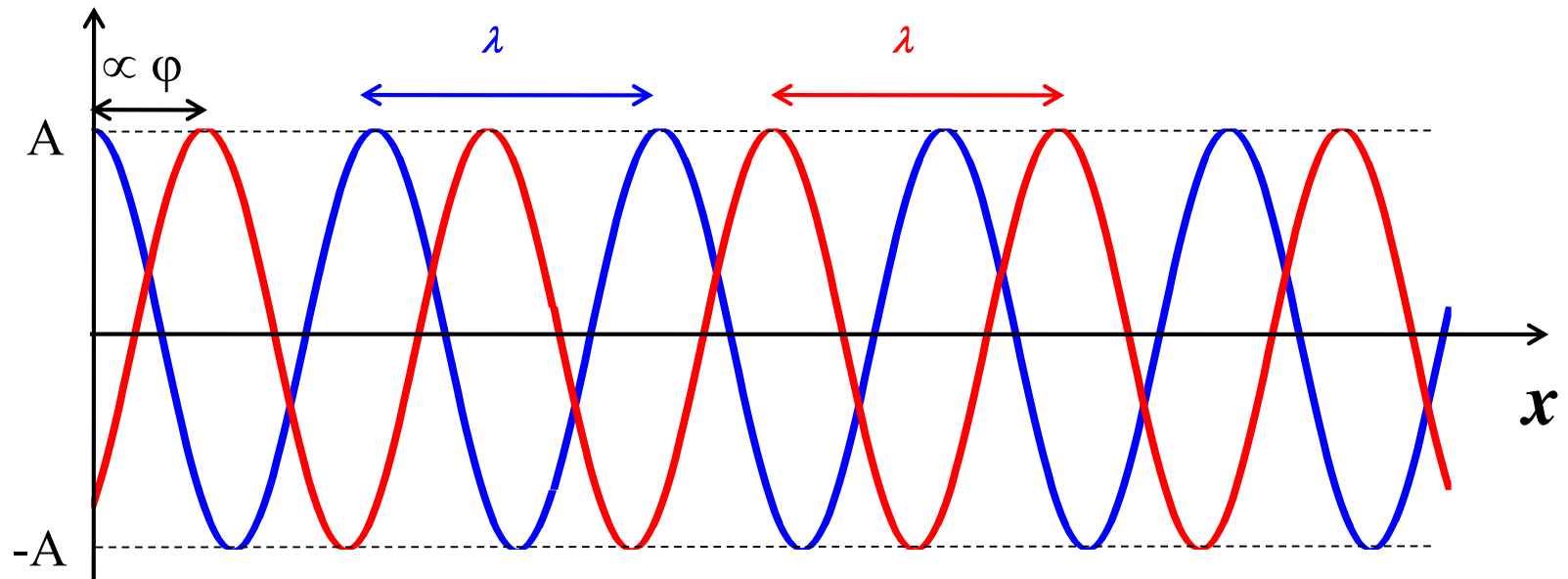
A: amplitude

$T$ : time period

$\phi$ : phase shift

# Electromagnetic coherent wave

Coherent wave: *spatial* behaviour



$$y(x) = A \cos\left(\frac{2\pi}{T}x\right)$$

$$y(x) = A \cos\left(\frac{2\pi}{T}x - \varphi\right)$$

$$\lambda = c T = \frac{c}{f_0}$$

$A$ : amplitude

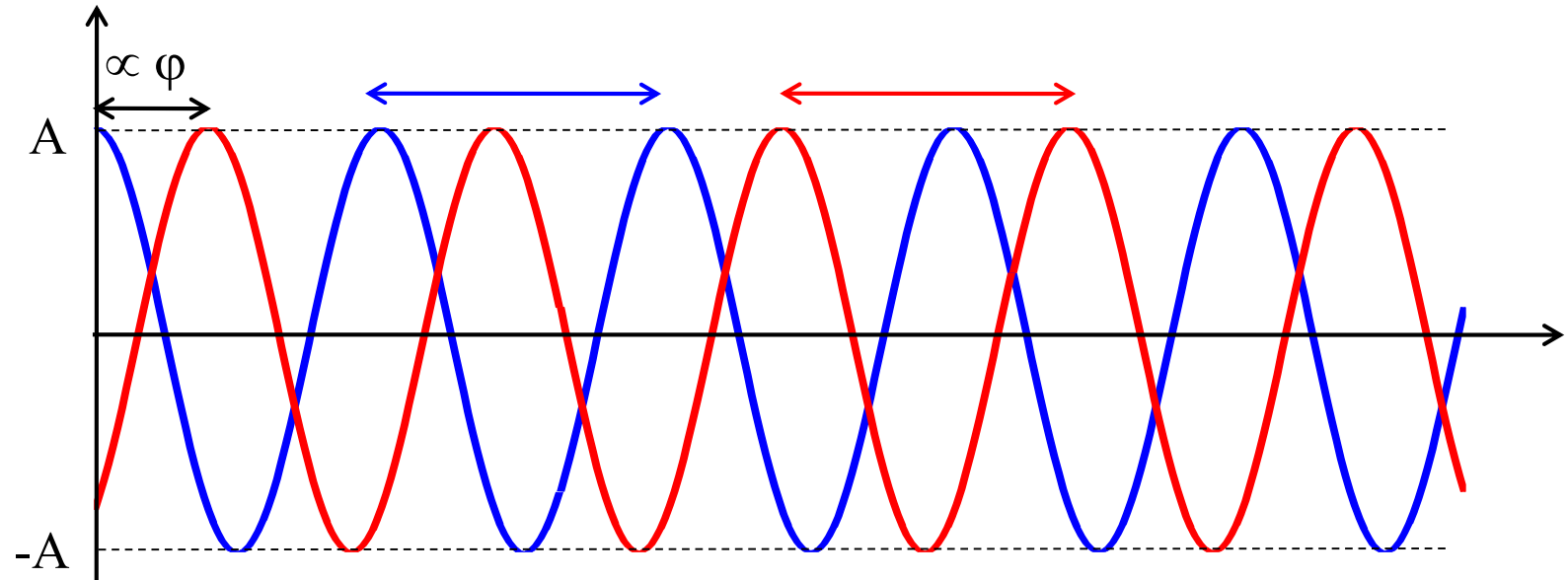
$\lambda$ : spatial period = wavelength

$\varphi$ : phase shift

$c$ : light celerity =  $3 \cdot 10^8$  m/s

# Electromagnetic coherent wave

Coherent wave: *spatial* and *temporal* behaviour



$$\psi(x, t) = A \cos\left(2\pi f_0 t - \frac{4\pi}{\lambda} x + \phi\right)$$

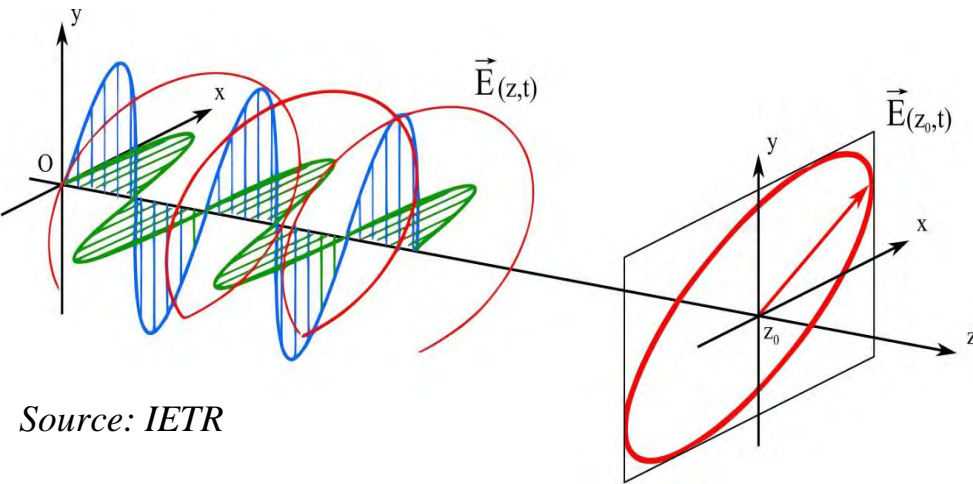
Amplitude:  $A$

Intensity:  $I = A^2$

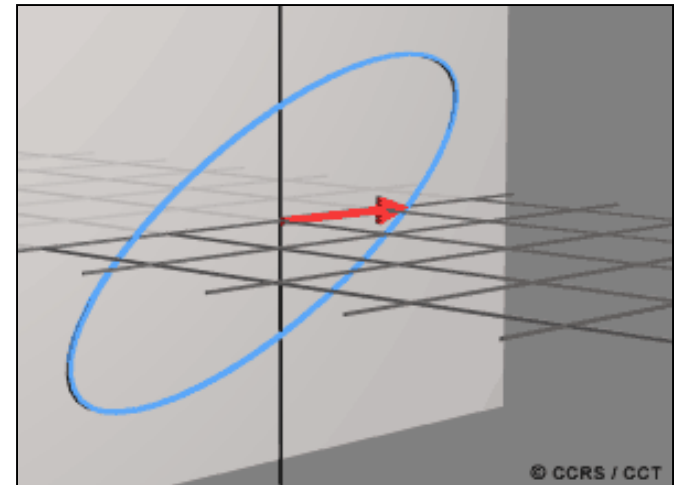
# Polarization

Important characteristics of coherent EMW:

Electromagnetic field evolution is predictable

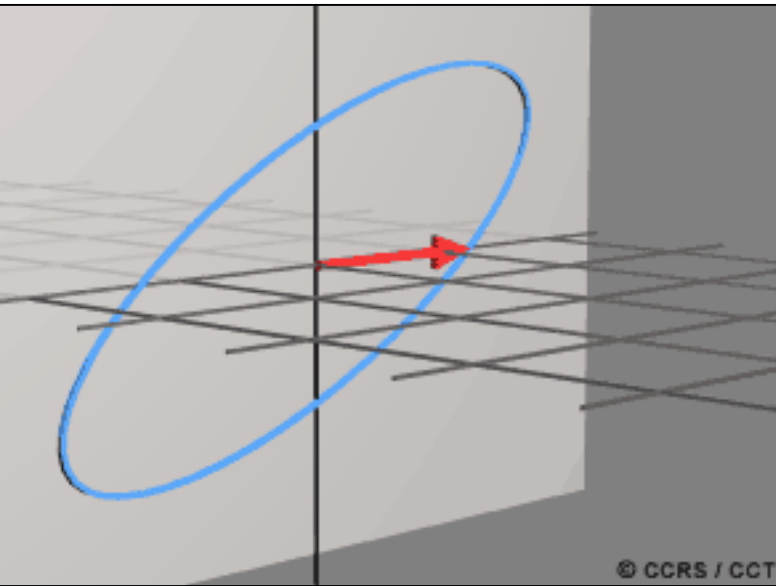


Most general: ***Elliptical*** polarization

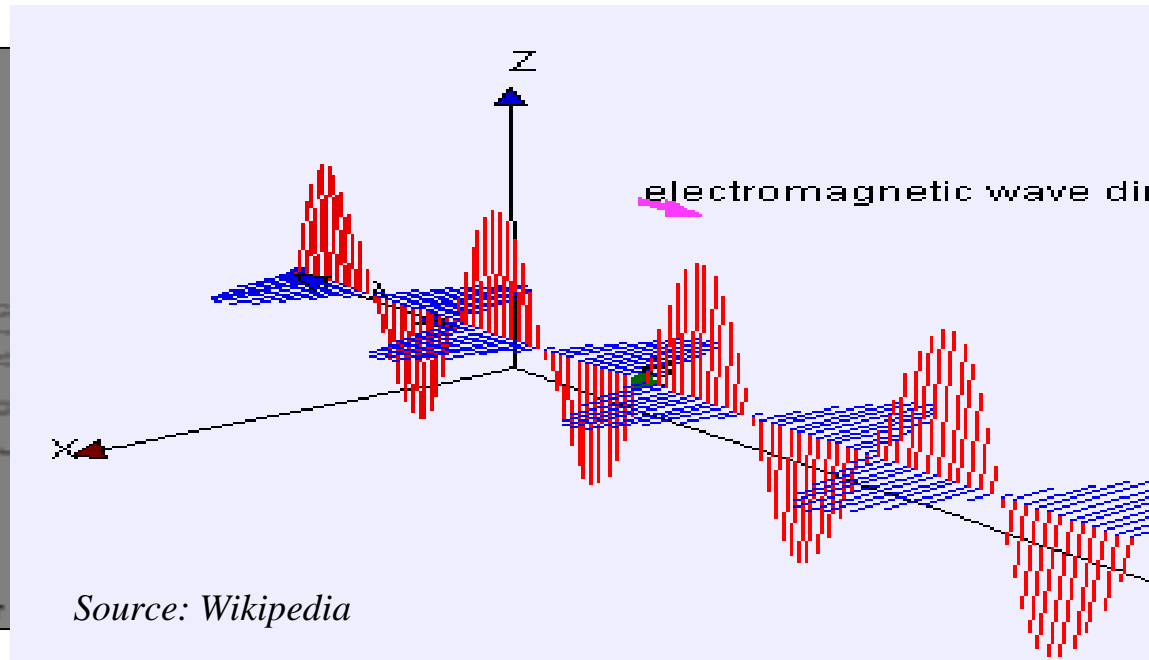


# Polarization

Most general:  
*Elliptical polarization*



Common radar sensor:  
*Linear polarization*



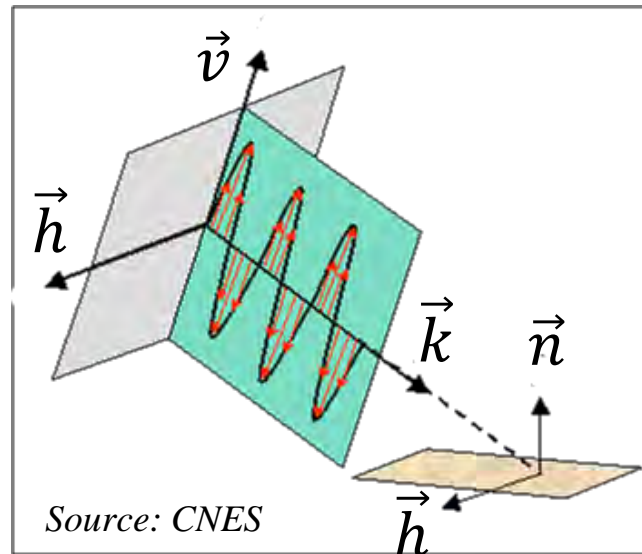
# Polarization

## Radar :

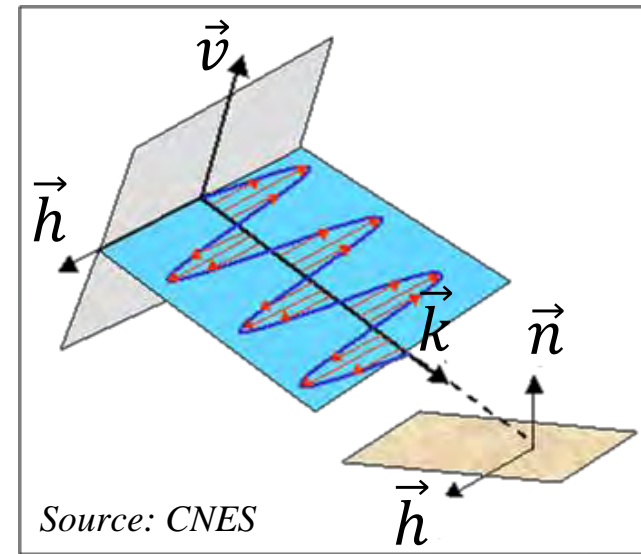
*transmits* a EMW in a give polarization

*measures* the backscattered wave contribution in a given polarization

*Vertical polarization*



*Horizontal polarization*



$(\vec{k}, \vec{n})$  incident plane

$\vec{k}$  : Direction illumination

$\vec{n}$  : Normal to the observed surface

# Polarization

Polarization characterisation of a radar acquisition:

**VV**  
reception emission

ERS, ASAR, Sentinel-1

**HH**  
reception emission

JERS, RADARSAT, PALSAR

**HV**  
reception emission

ASAR, PALSAR, Sentinel-1

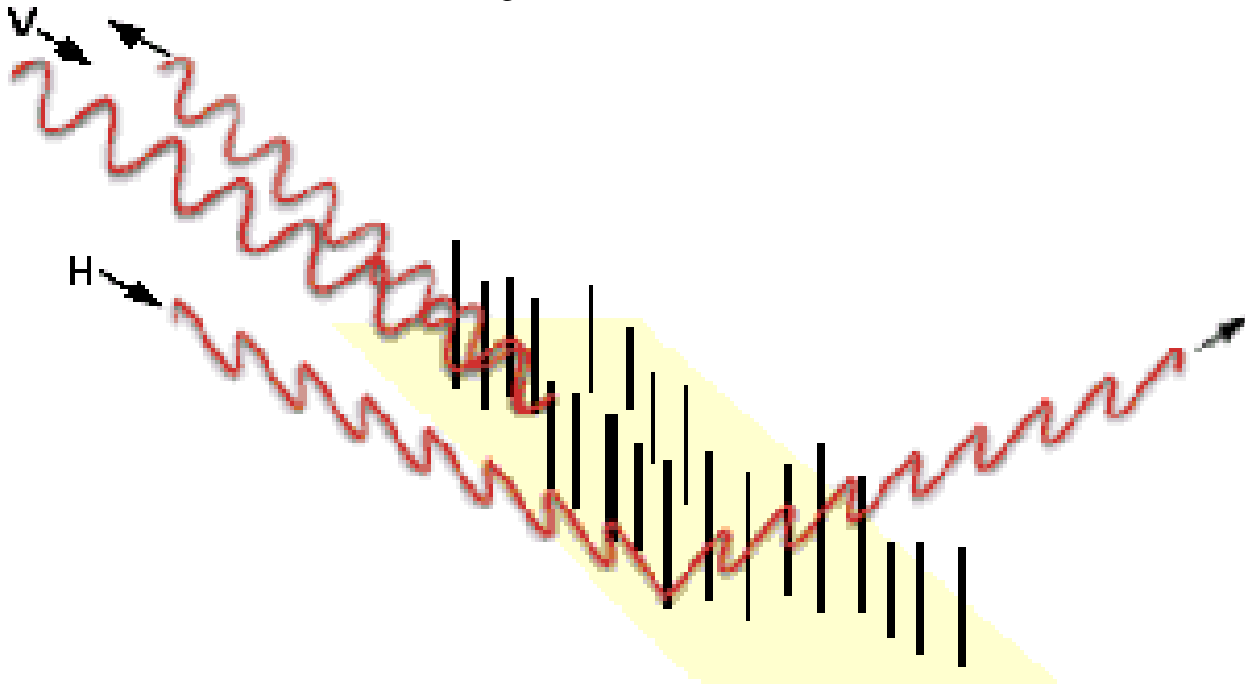
**VH**  
reception emission

ASAR, PALSAR, Sentinel-1



# Polarization

*Surface with vertical structures*



# Polarization

*Microwave oven*



# Polarization

Brazil

**Flooded forests**

**Deforested areas**

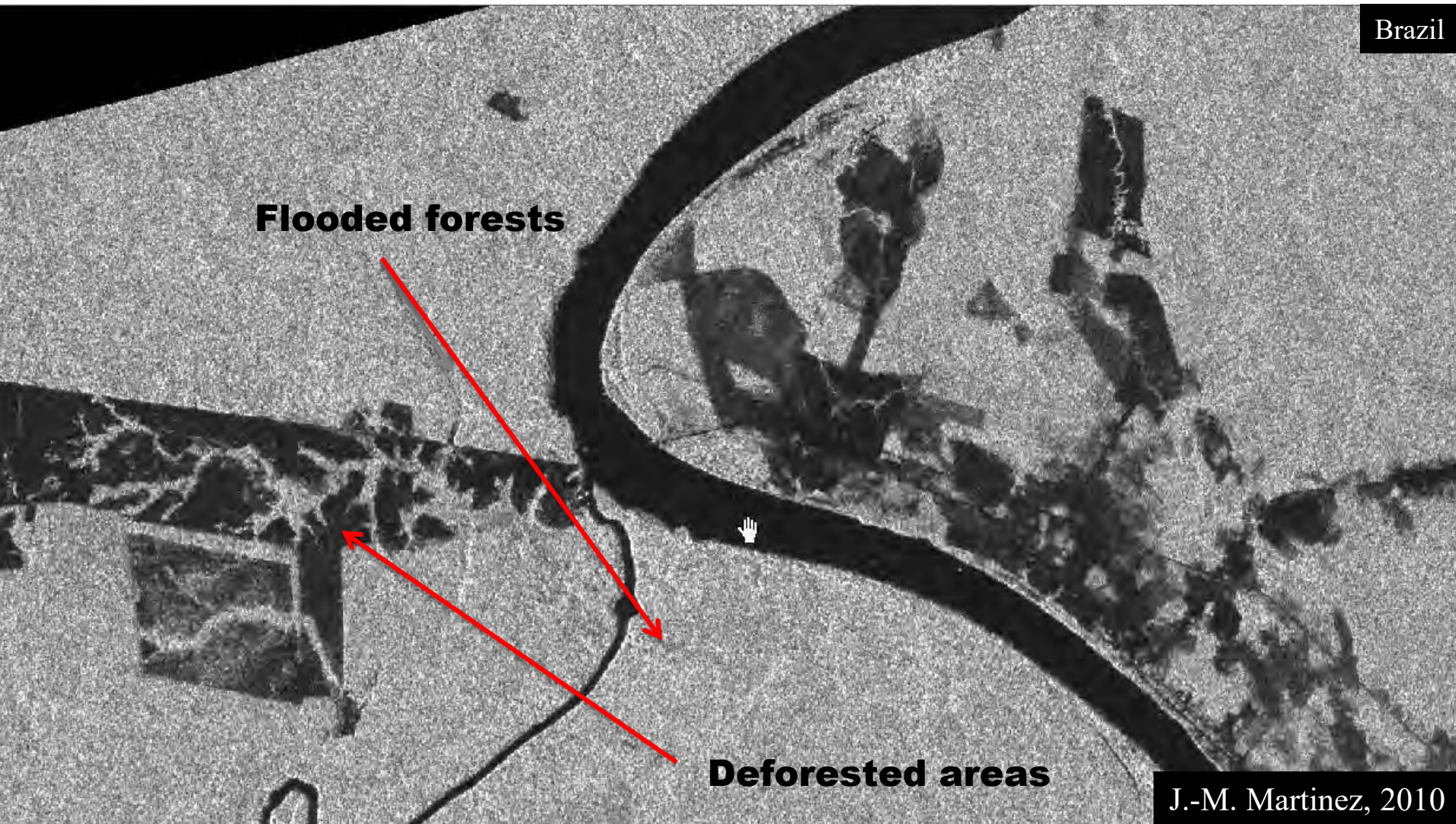
J.-M. Martinez, 2010

ALOS acquisition ( $\lambda = 24$  cm)- Polarization ***HH***



# Polarization

Brazil



ALOS acquisition ( $\lambda = 24$  cm)- Polarization *HV*



# Polarization

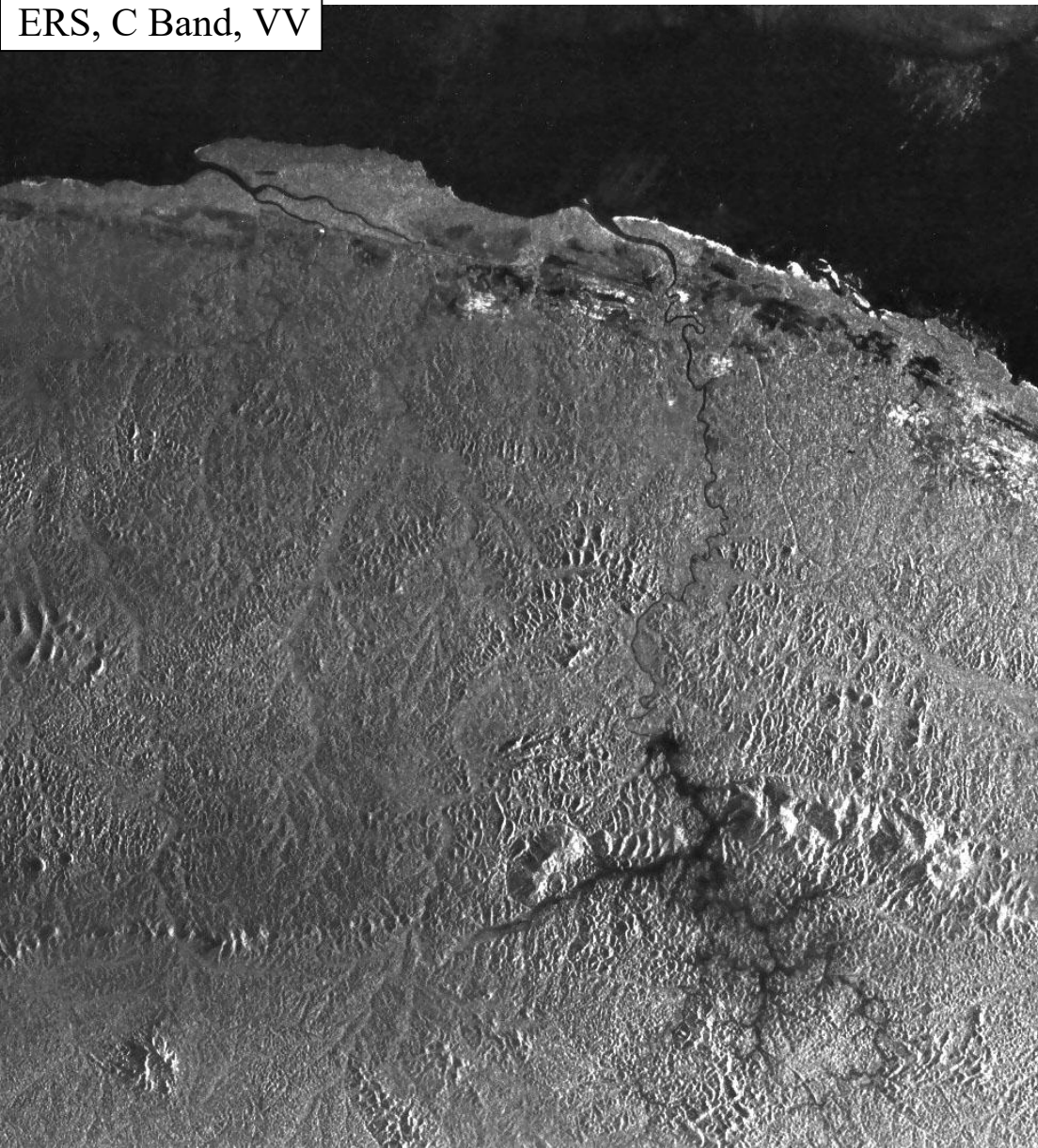
Monitoring of the Petit Saut Dam, French Guiana, Flooding beginning: 1994



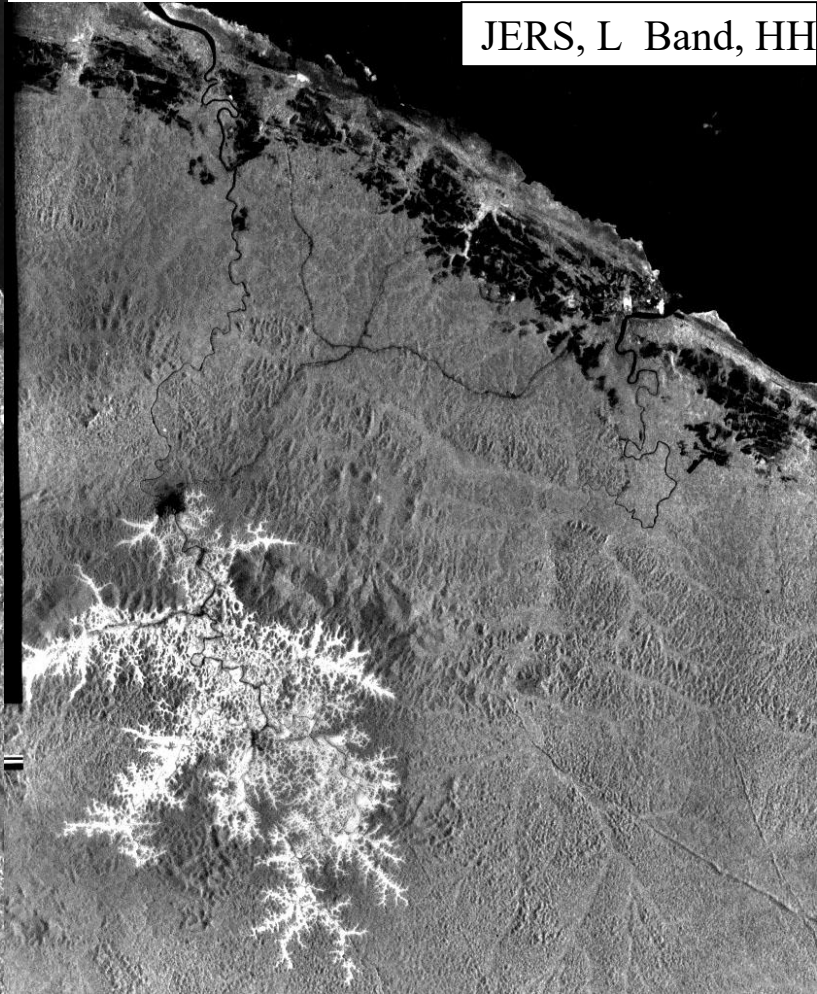


# Polarization

ERS, C Band, VV



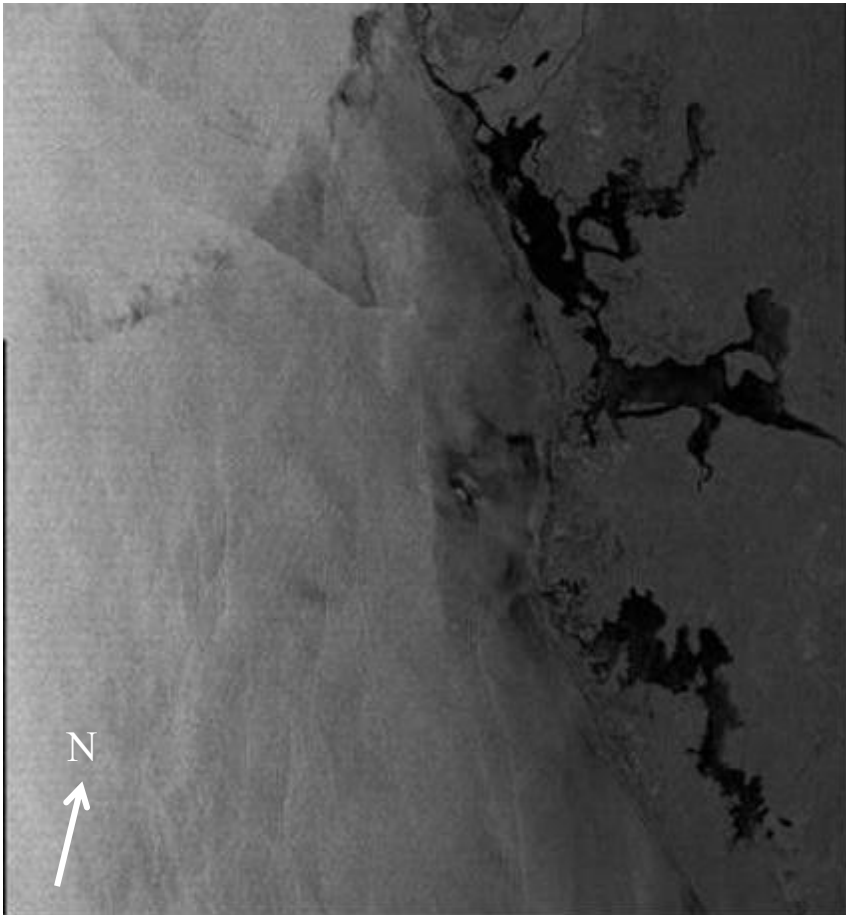
JERS, L Band, HH



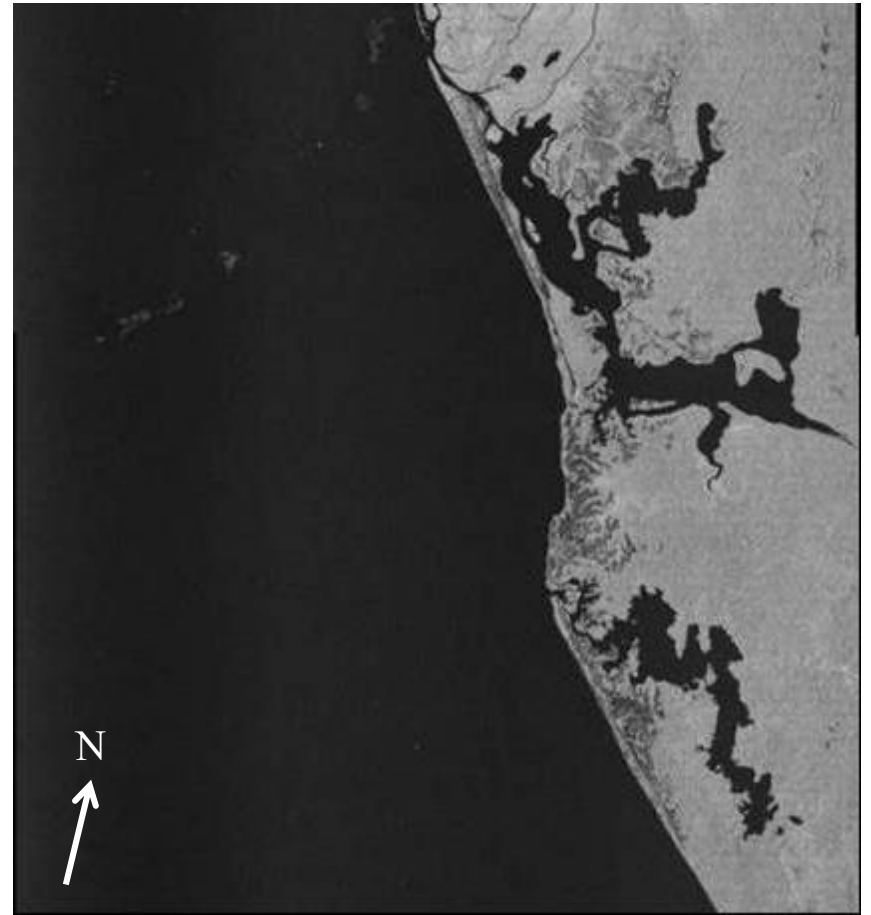
# Polarization

## ASAR acquisition Gaboon

VV



HV





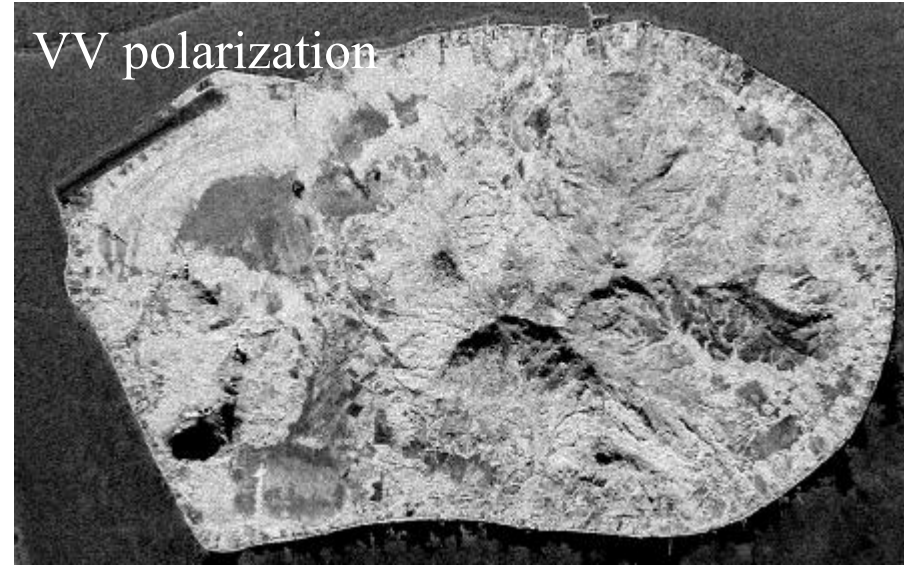
# Polarization

Tubuai Island, vegetation discrimination, L Band

HH polarization



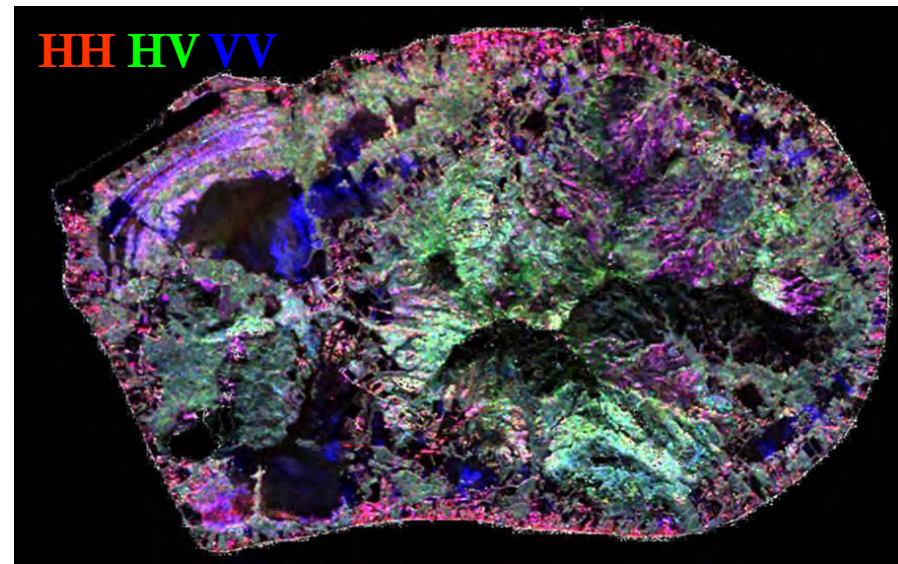
VV polarization



HV polarization



HH HV VV





# Radar polarimetry for Forest types cartography

Tubuai Island, French Polynesia

## 7 different classes:

- bare soils
- swamps
- Fernlands

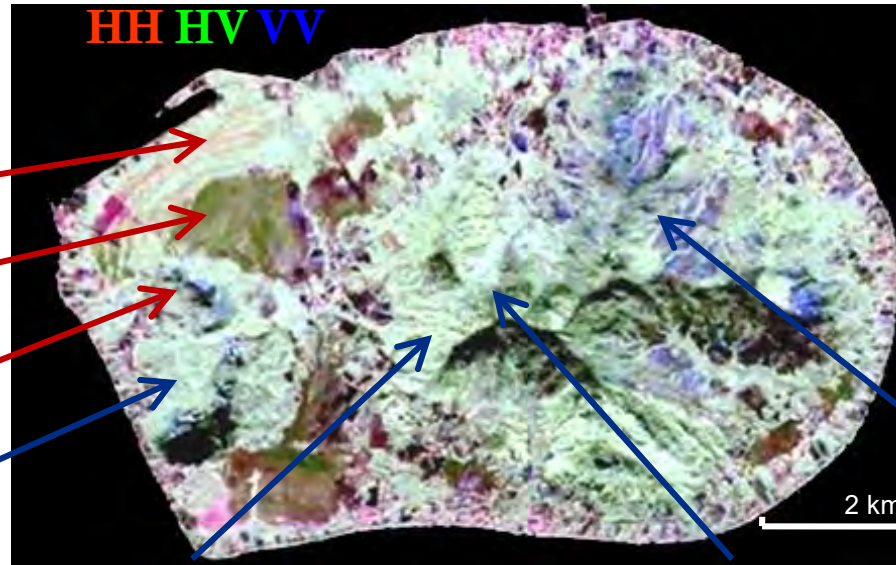
4 forests species

• Purau

• Pines

• Falcata

• Guava



AIRSAR data  
L band ( $\lambda = 24$  cm)  
Aug. 2000





# Polarization

in visible domain also!

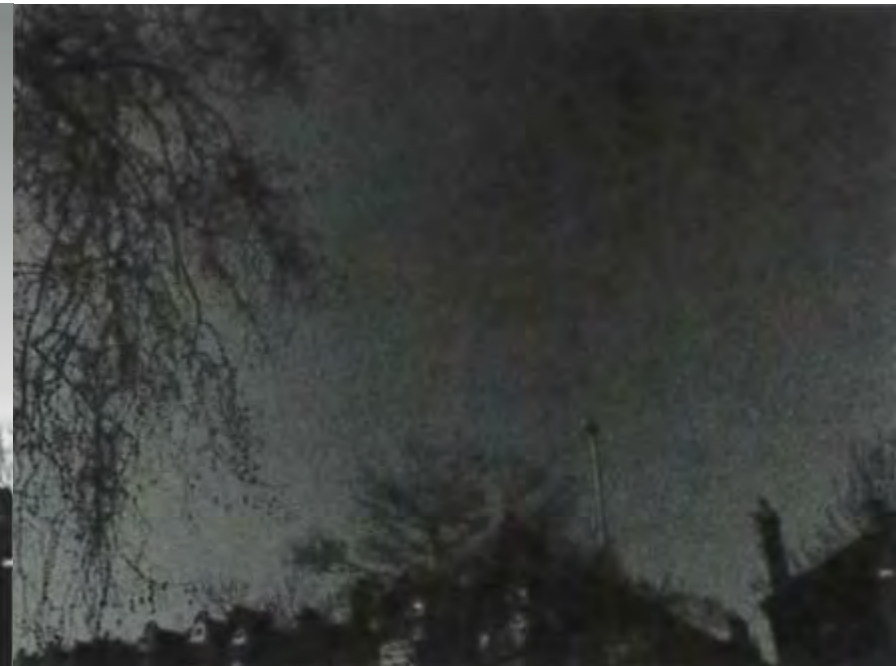


# Polarization

in visible domain also!

Vertical

Horizontal



# Radar images interpretation rules

## *Intensity (or Amplitude) Images*

Surface scattering (bare soils)

$$VV > HH$$

$$HV \sim 0$$

smooth

low

rough

high

Volume scattering (Dense forest)

HH, VV high

**HV high**

Double reflexion (urban areas, flooded vegetation)

$$HH > VV$$

Wild areas (urban areas, disorderly rocks)

$$VV \sim HH \sim HV$$

# Radar images interpretation rules

## *Intensity (or Amplitude) Images*

### VV polarization

For bare surfaces (roughness / moisture)  
vegetation with vertical structures (*i.e.* rice crops)

### HV polarization

For Forest/Non forest discrimination

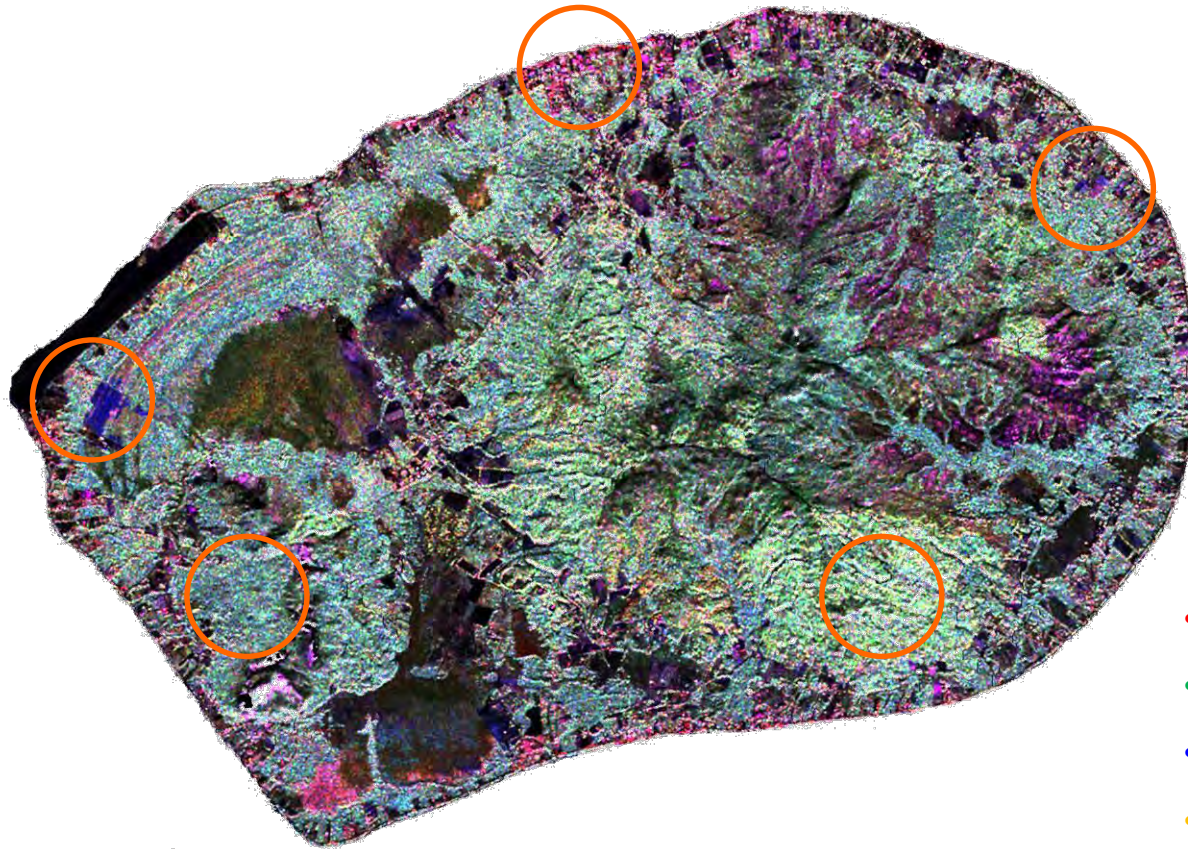
### HH polarization

For flooded/Non flooded vegetation  
Urban areas



# Radar images interpretation rules

## *Intensity Image*



### *Tubuai Island*

*AISAR data, L Band*

- **Double bounds**
- **Dense vegetation**
- **Bare soil**
- **Pinus et Falcata**

~ Purau

**HH HV VV**



# POLARISATIONS DIVERSITY $\neq$ POLARIMETRY

***INTENSITY Images (different polarization):***

***HH, HV, VV*** (ASAR)

***Fully Polarimetric Data: INTENSITY + PHASE***

***HH, HV, VV*** (PALSAR, RADARSAT-2)

***Partial Polarimetric Data: INTENSITY + PHASE***

***HH, HV***

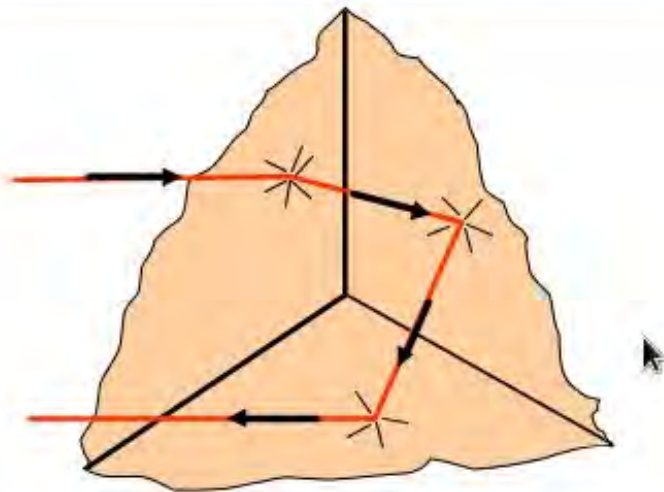
***VV, HV***

***HH, VV*** (PALSAR, RADARSAT-2)

# Radar images interpretation rules

## *Polarimetric Data: Amplitude + Phase Images*

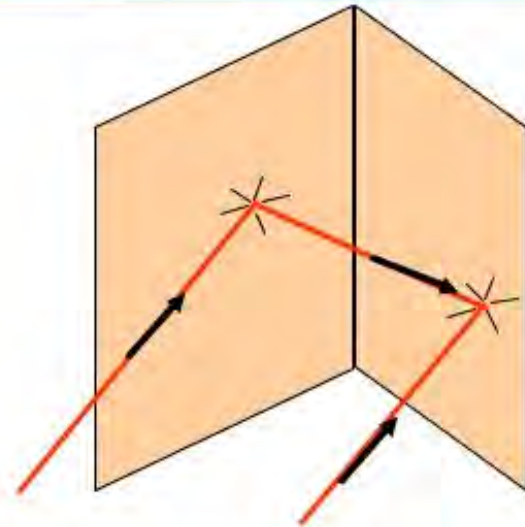
### Behavior of the differential phases



Odd number of reflexions:

*Ex: Trihedral target type*

$$\phi_{HH} - \phi_{VV} \approx 0^\circ$$



Even number of reflexions:

*Ex: dihedral target type*

$$\phi_{HH} - \phi_{VV} \approx 180^\circ$$



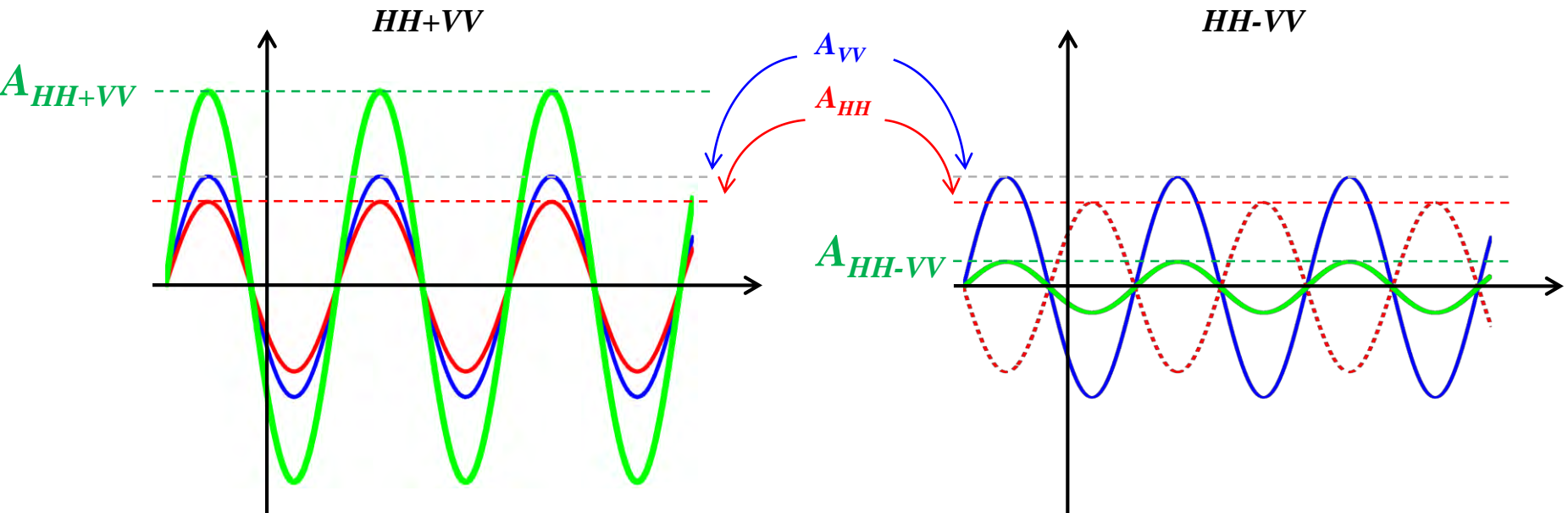
# Radar images interpretation rules

## *Polarimetric Data: Amplitude + Phase*

$$VV = A_{VV} \cos(\phi_{VV})$$

$$HH = A_{HH} \cos(\phi_{HH})$$

*Surface Scattering:  $\phi_{VV} = \phi_{HH}$*



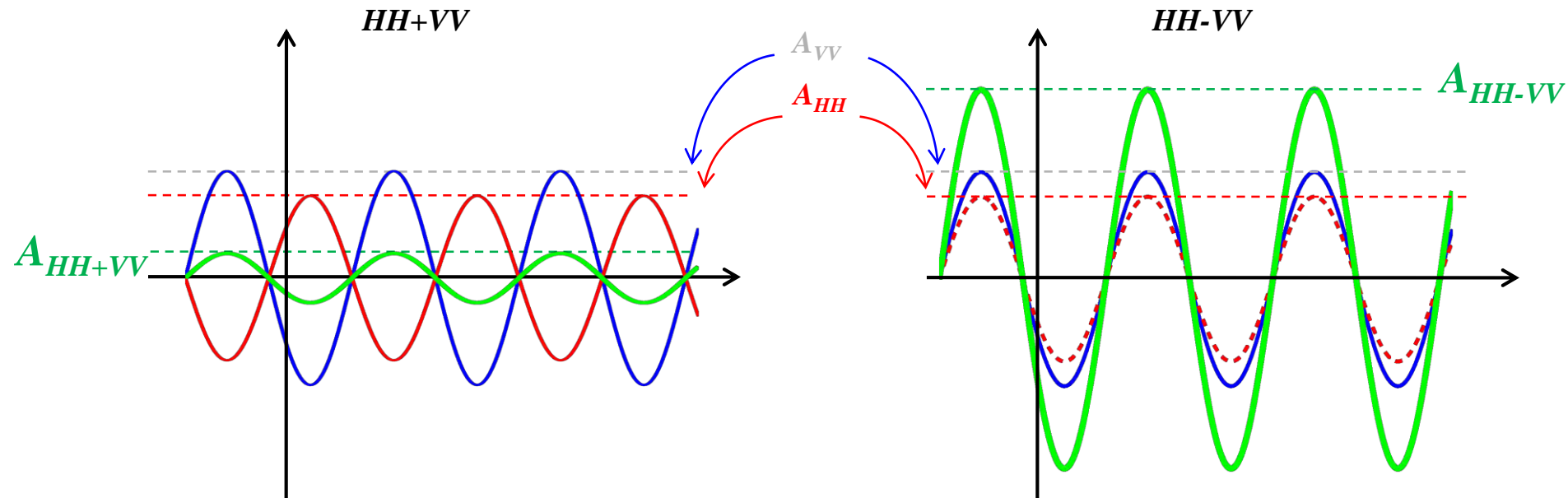
# Radar images interpretation rules

## *Polarimetric Data: Amplitude + Phase Images*

$$VV = A_{VV} \cos(\phi_{VV})$$

$$HH = A_{HH} \cos(\phi_{HH})$$

*Double bounds:*  $\phi_{VV} - \phi_{HH} = \pi$



# Radar images interpretation rules

## *Polarimetric Data: Amplitude + Phase Images*

### Surface scattering (bare soils)

Amplitude

$$VV > HH$$

$$HV \sim 0$$

Phase difference

$$\phi_{VV} - \phi_{HH} = 0$$

$$|HH + VV| \text{ high}$$

### Volume scattering (Dense forest)

HH, VV high

**HV high**

### Double reflexion (urban areas, flooded vegetation)

$$HH > VV$$

$$\phi_{VV} - \phi_{HH} = \pi$$

$$|HH - VV| \text{ high}$$

### Wild areas (dense habitat, screens,...)

$$VV \sim HH \sim HV$$

# Radar images interpretation rules

## *Polarimetric Data: Amplitude + Phase Images*

***/HH+VV/***

Bare surfaces

**HV polarization**

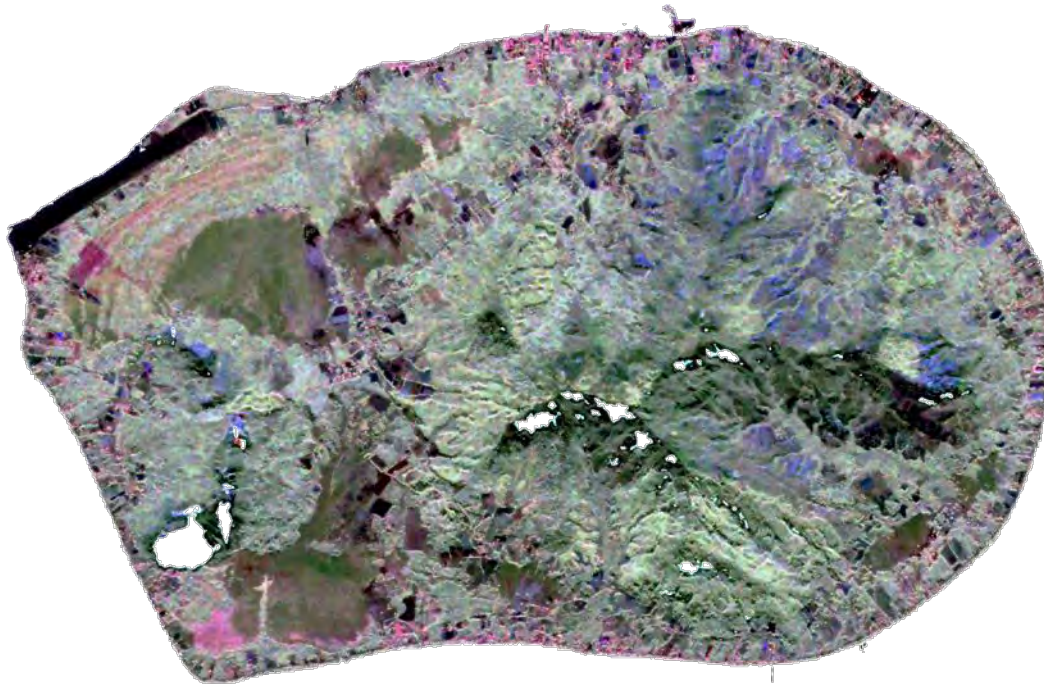
For Forest/Non forest discrimination

***/HH-VV/***

For urban areas and flooded vegetation

# Radar images interpretation rules

## *Polarimetric Image: Pauli Representation*



### *Tubuai Island*

*AISAR data, L Band*

- **Double bounds**
- **Dense vegetation**
- **Bare soil**
- **Pinus et Falcata**

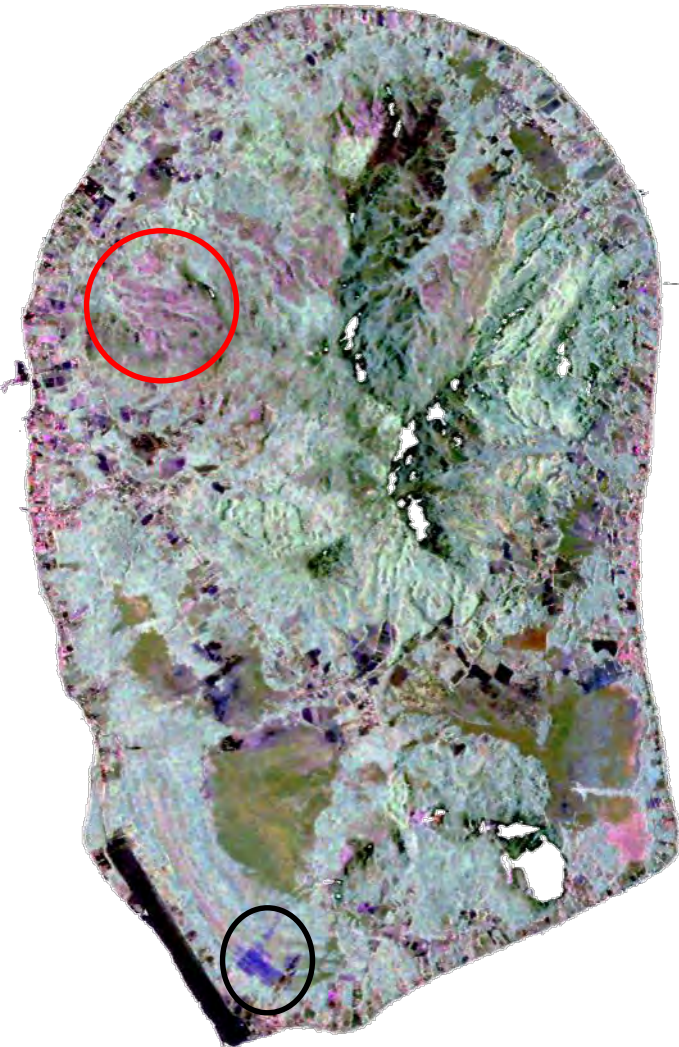
~ Purau

**|HH-VV| |HV| |HH+VV|**



# Radar images interpretation rules

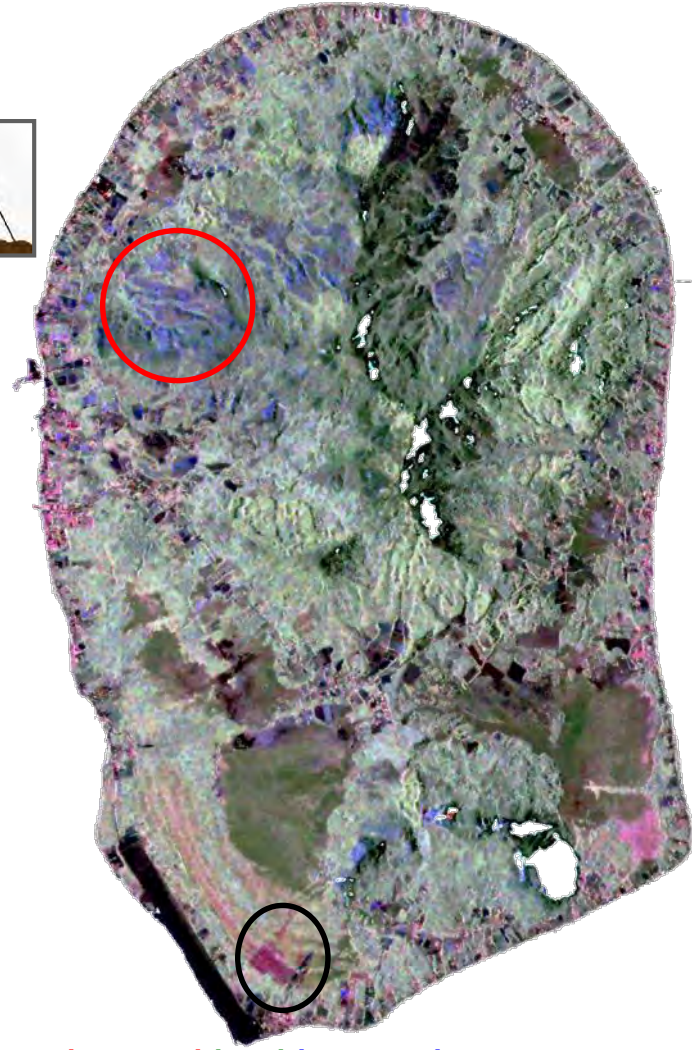
## *Pauli Representation*



HH HV VV



*Quickbird*

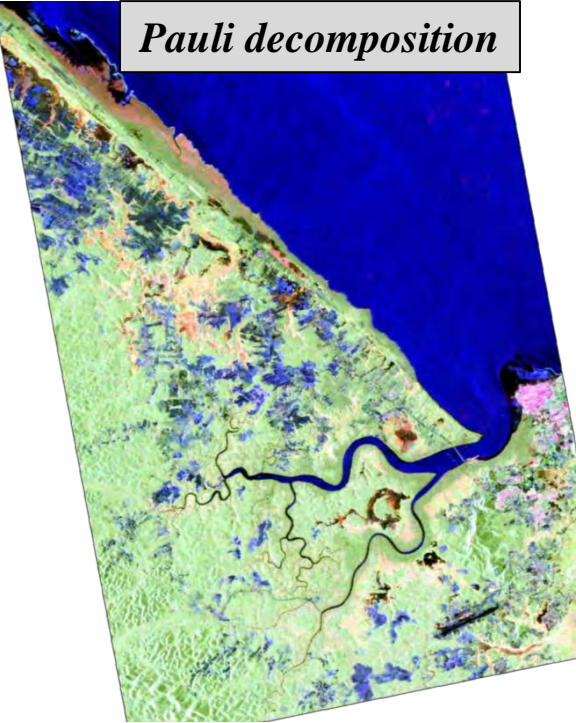


|HH-VV| |HV| |HH+VV|

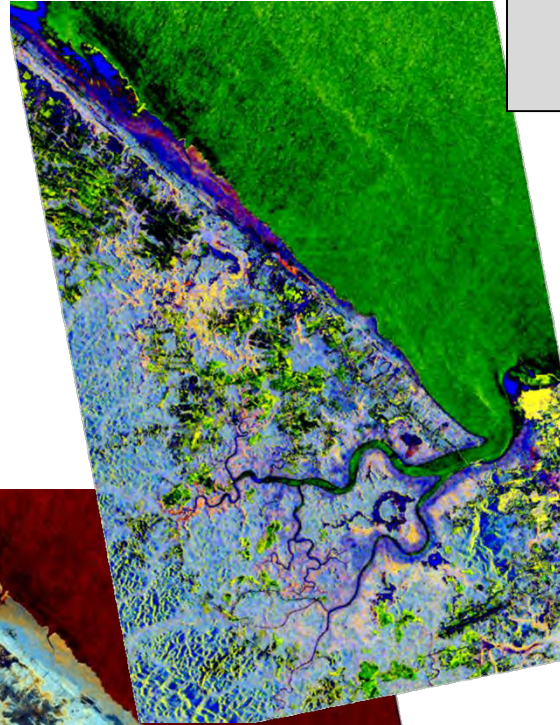


# Radar images interpretation rules

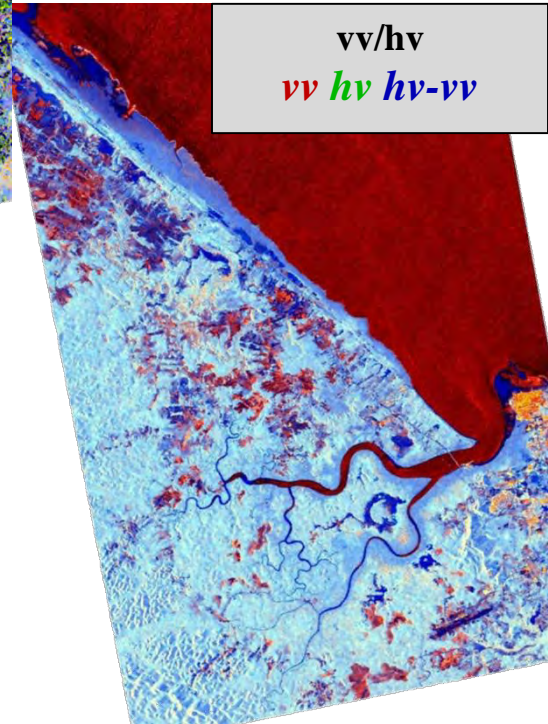
*Pauli decomposition*



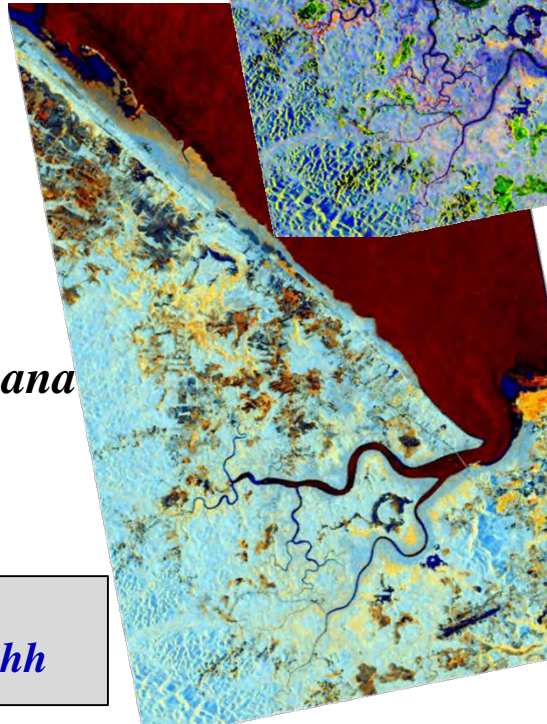
hh/vv  
*hh vv hh-vv*



vv/hv  
*vv hv hv-vv*



hh/hv  
*hh hv hv-hh*



*Natural Vegetation - French Guyana  
PALSAR (L Band)*