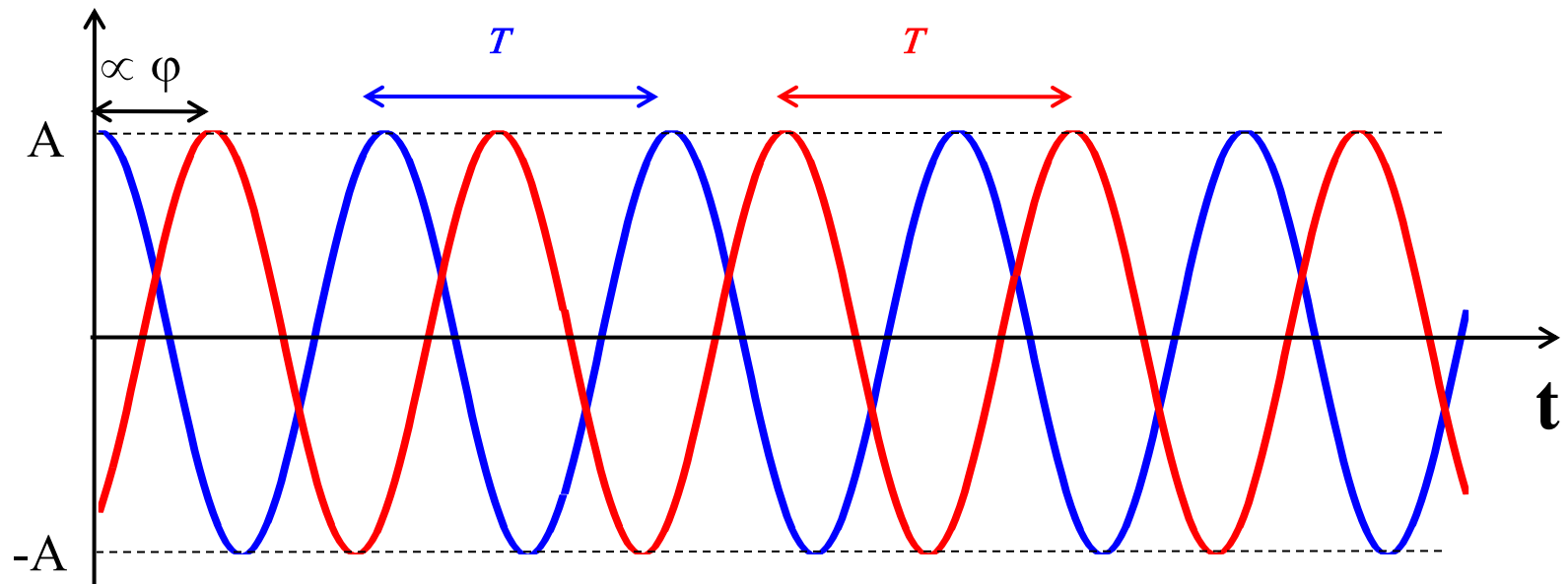


OUTLINE

- 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



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

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

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

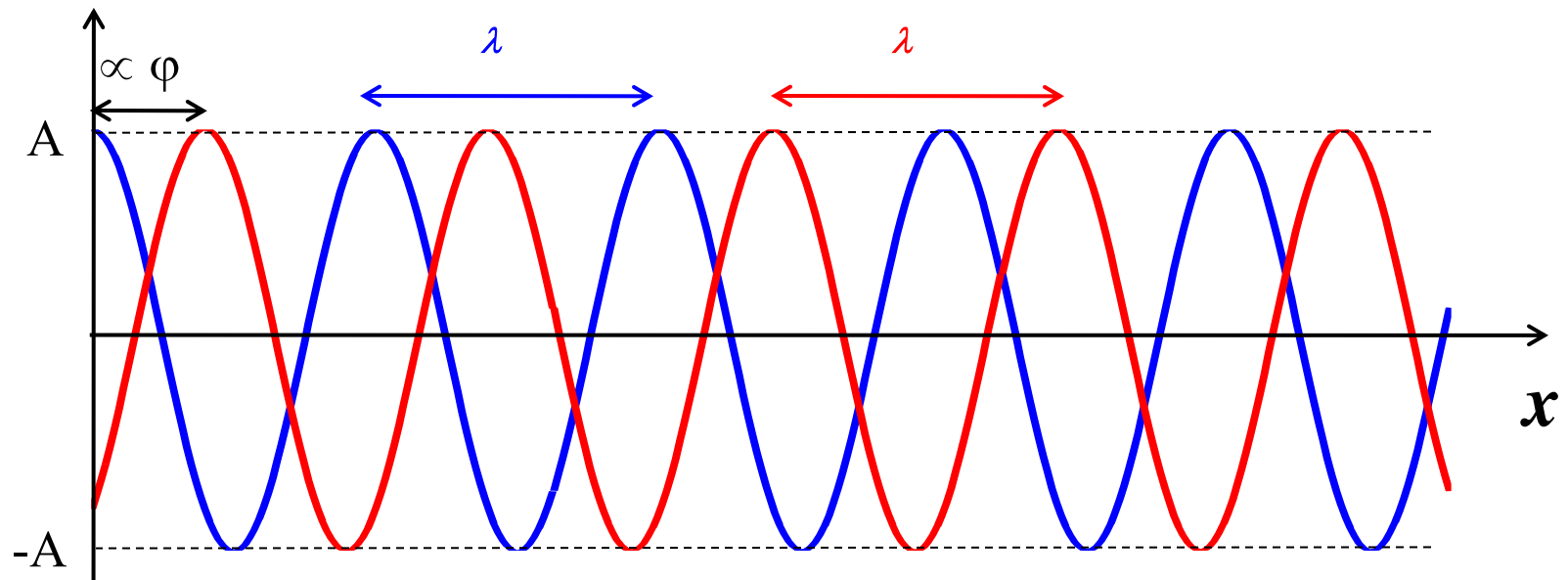
A : amplitude

T : time period

φ : phase shift

Electromagnetic coherent wave

Coherent wave: *spatial* behaviour



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

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

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

A : amplitude

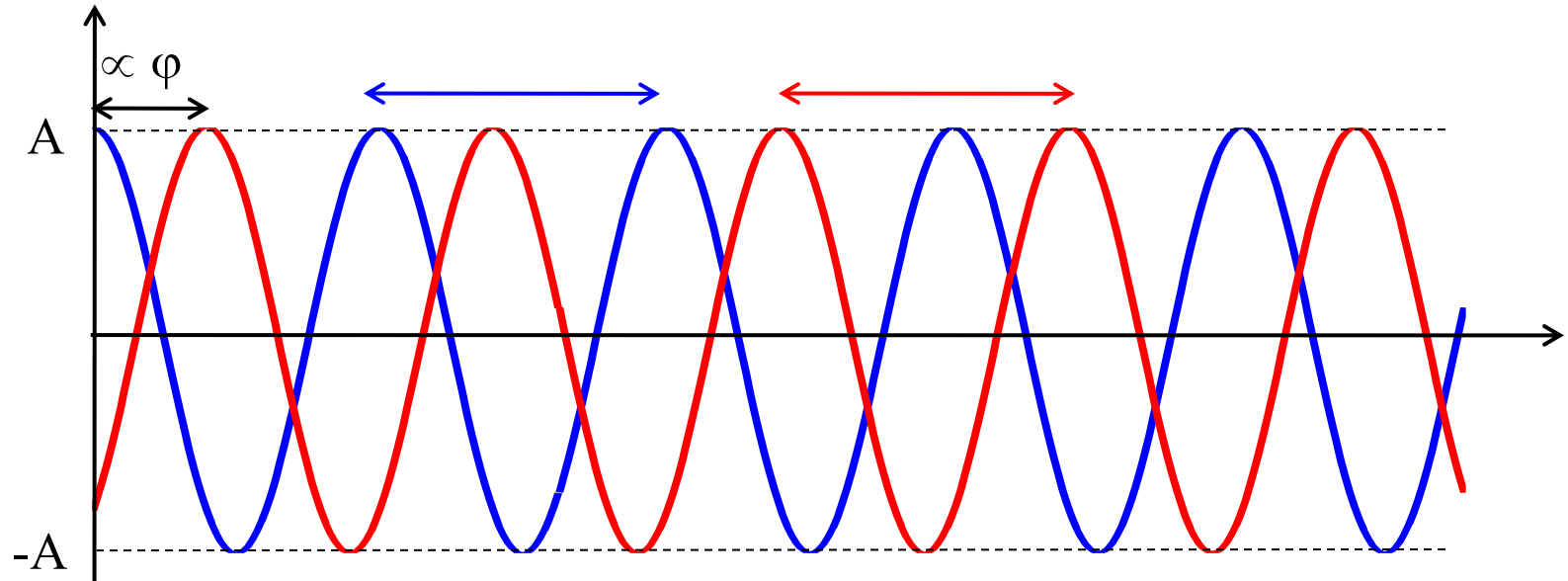
λ : spatial period = wavelength

φ : phase shift

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

Electromagnetic coherent wave

Coherent wave: *spatial* and *temporal* behaviour



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

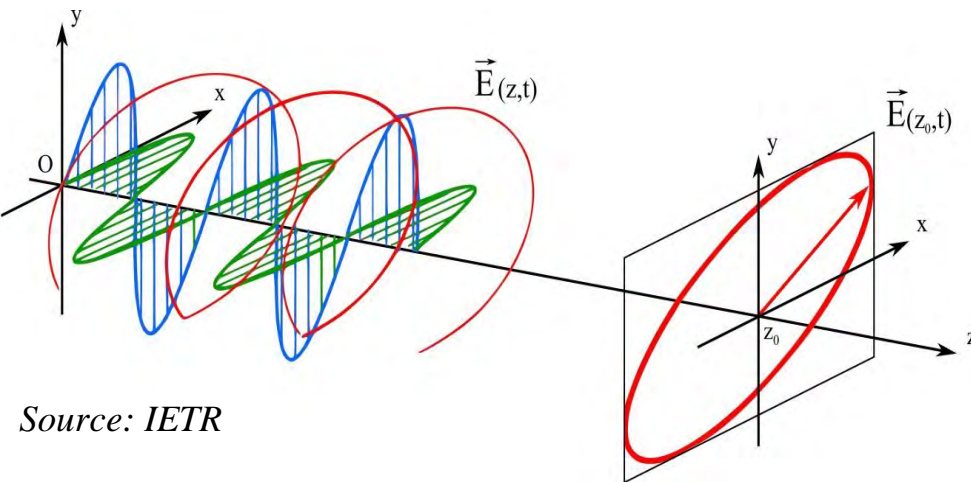
Amplitude: A

Intensity: $I = A^2$

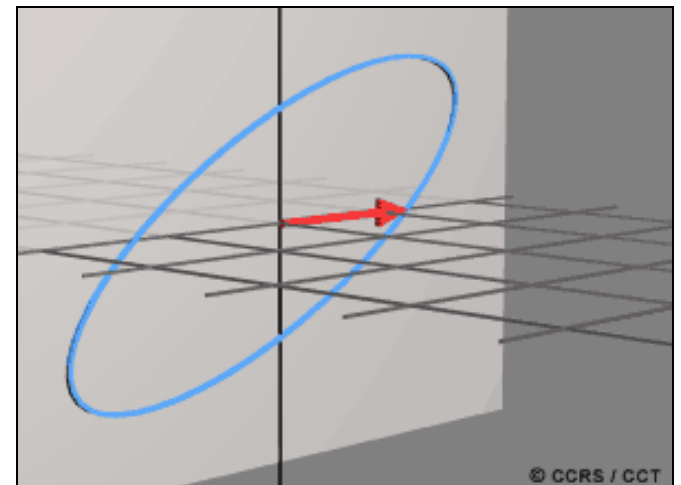
Polarization

Important characteristics of coherent EMW:

Electromagnetic field evolution is predictable



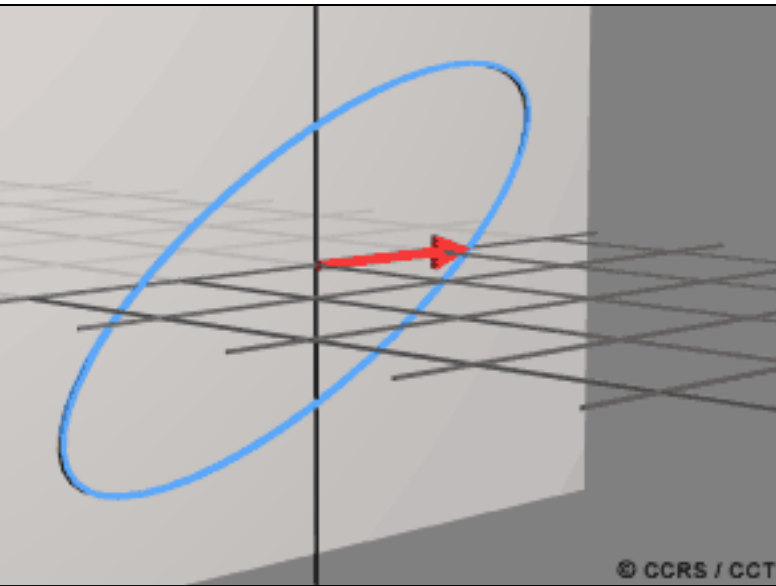
Most general: ***Elliptical*** polarization



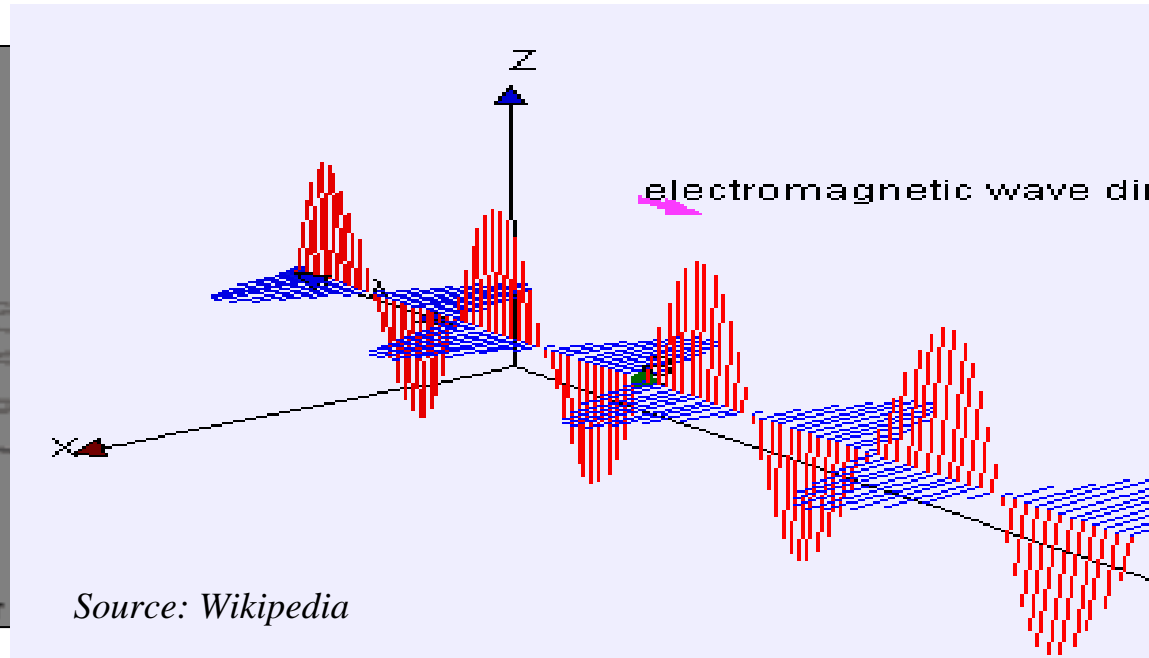
Source: IETR

Polarization

Most general:
Elliptical polarization



Common radar sensor:
Linear polarization



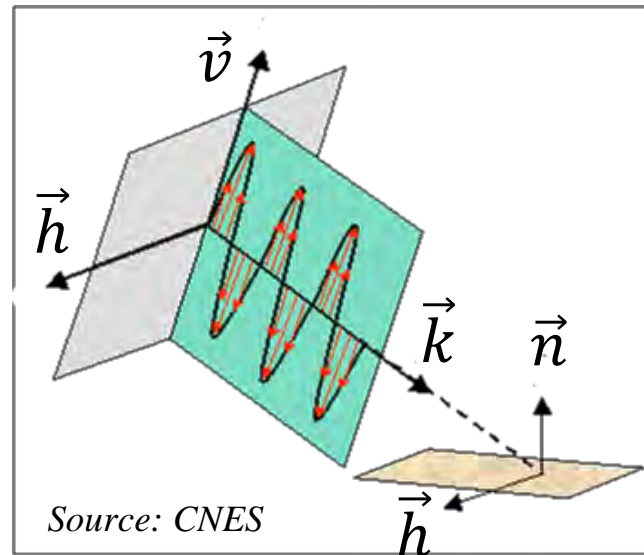
Polarization

Radar :

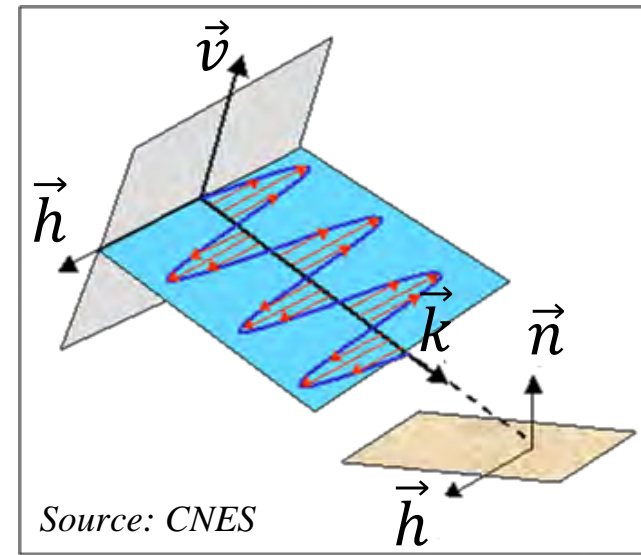
transmits a EMW in a give polarization

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

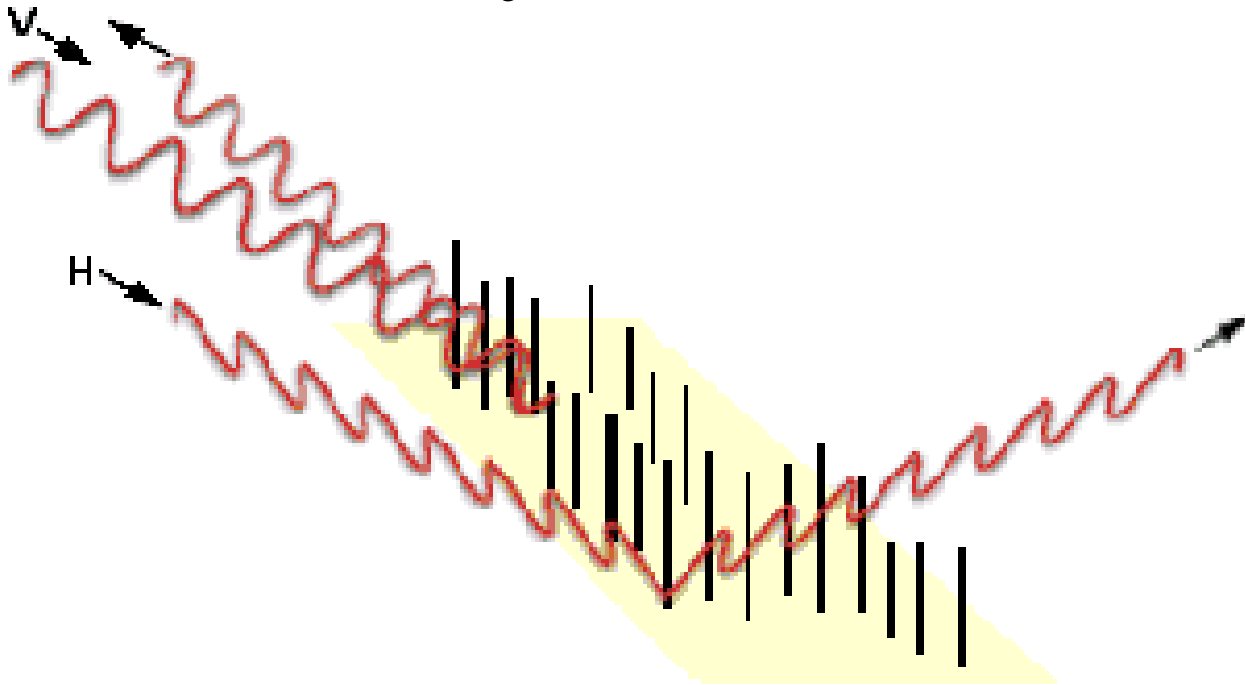
ASAR, PALSAR, Sentinel-1

VH
reception emission

ASAR, PALSAR, Sentinel-1

Polarization

Surface with vertical structures



Polarization

Microwave oven



Polarization

Brazil

Flooded forests

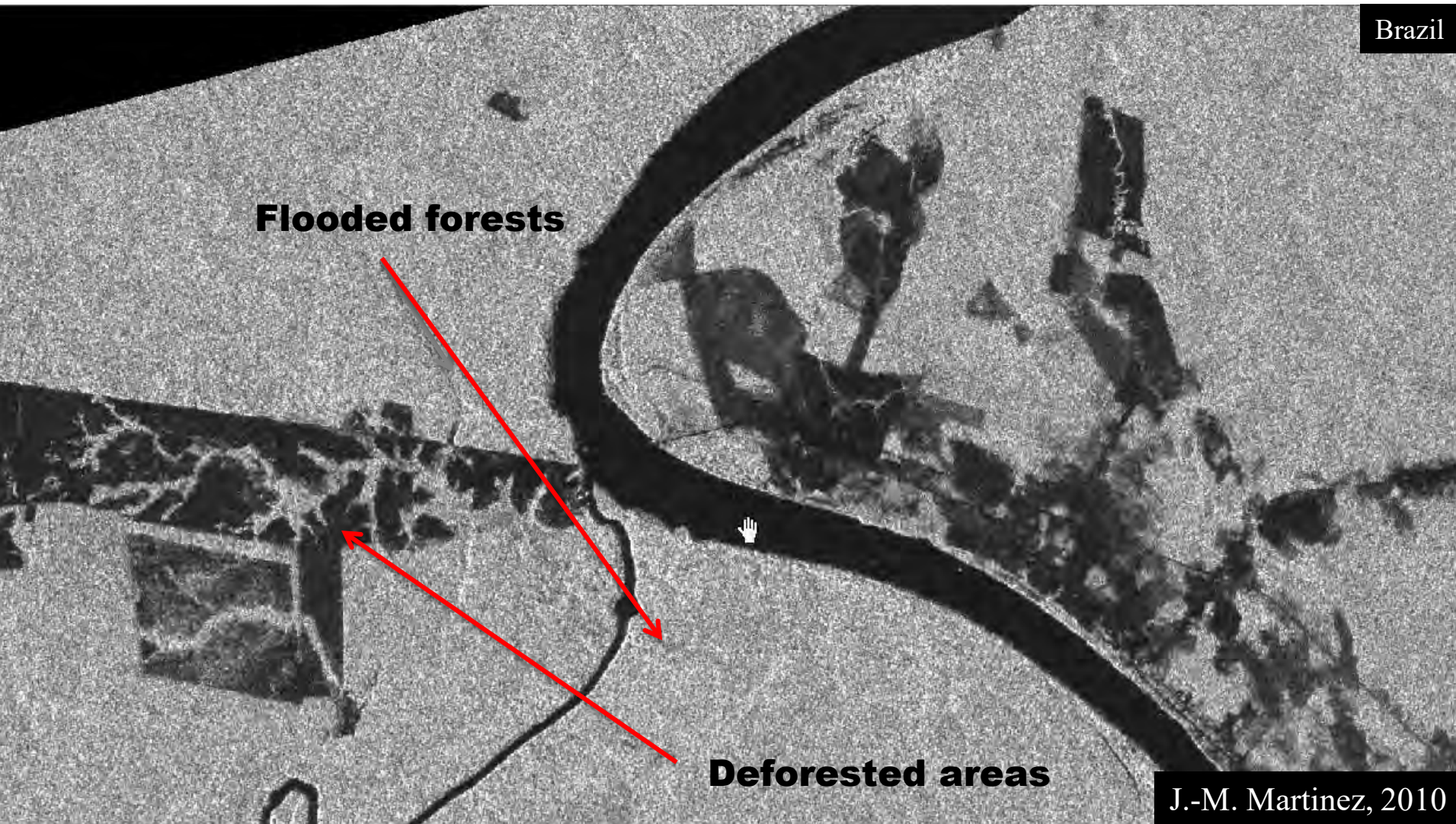
Deforested areas

J.-M. Martinez, 2010

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

Polarization

Brazil



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

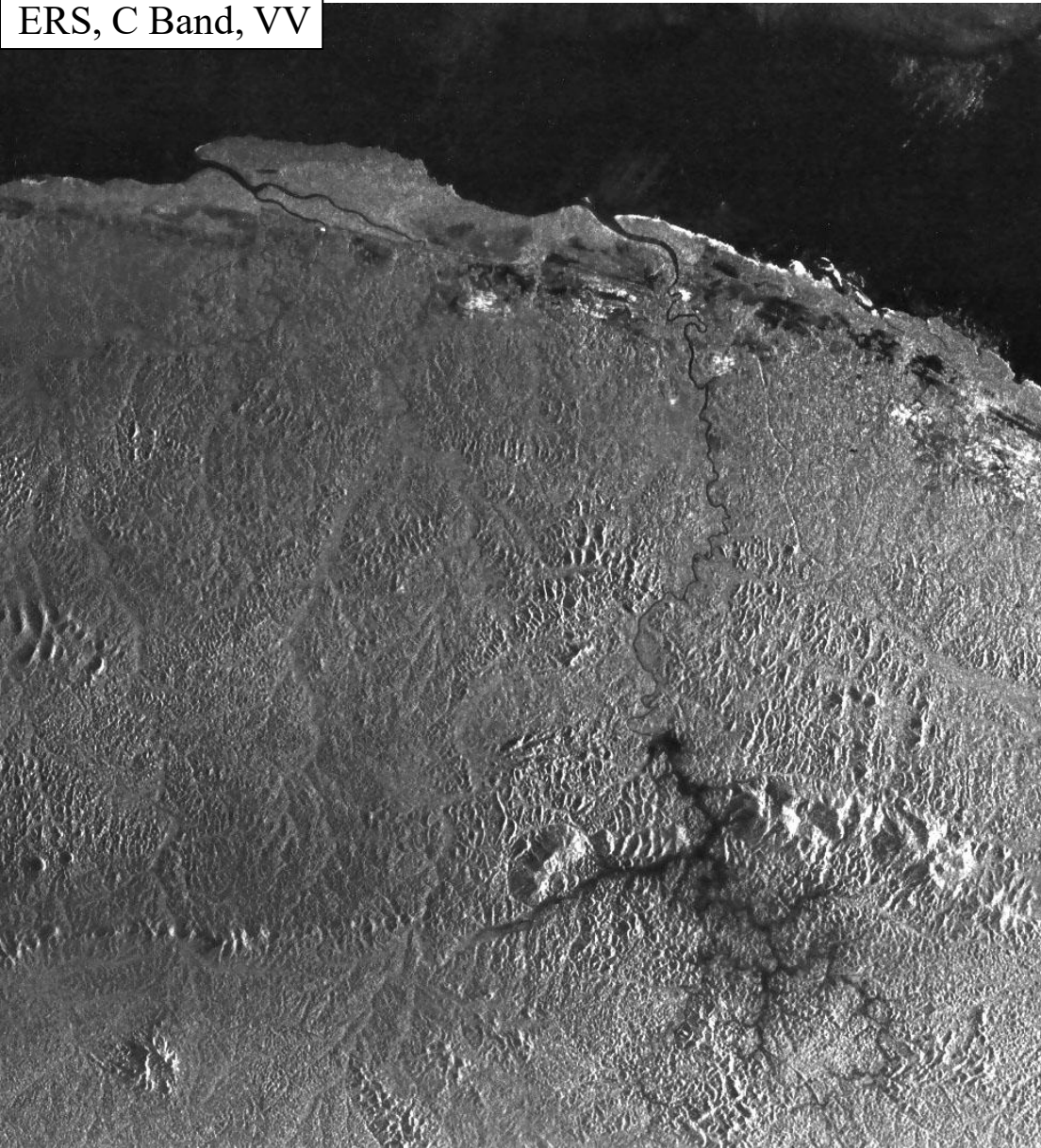
Polarization

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

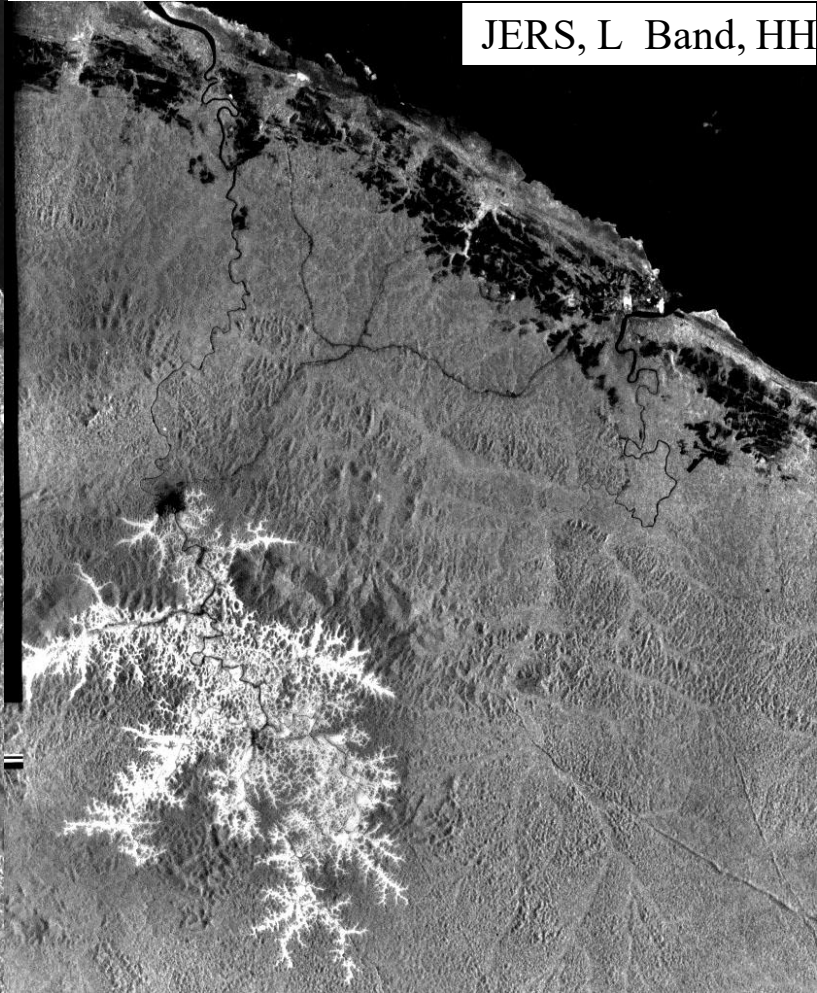


Polarization

ERS, C Band, VV



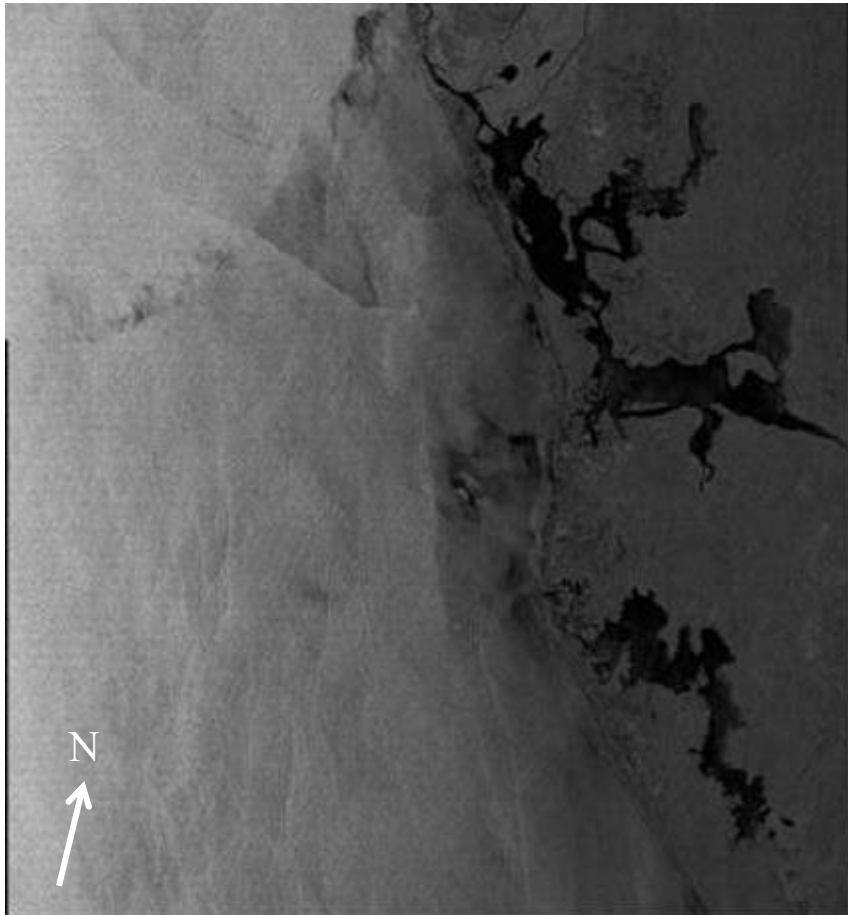
JERS, L Band, HH



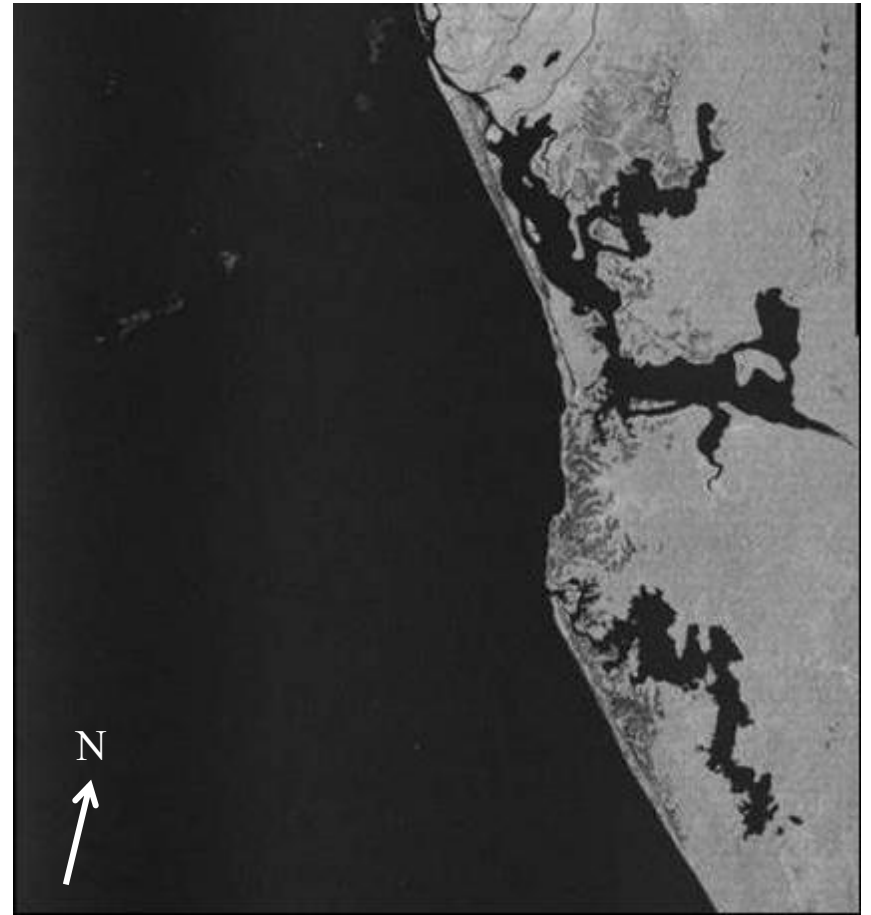
Polarization

ASAR acquisition Gaboon

VV



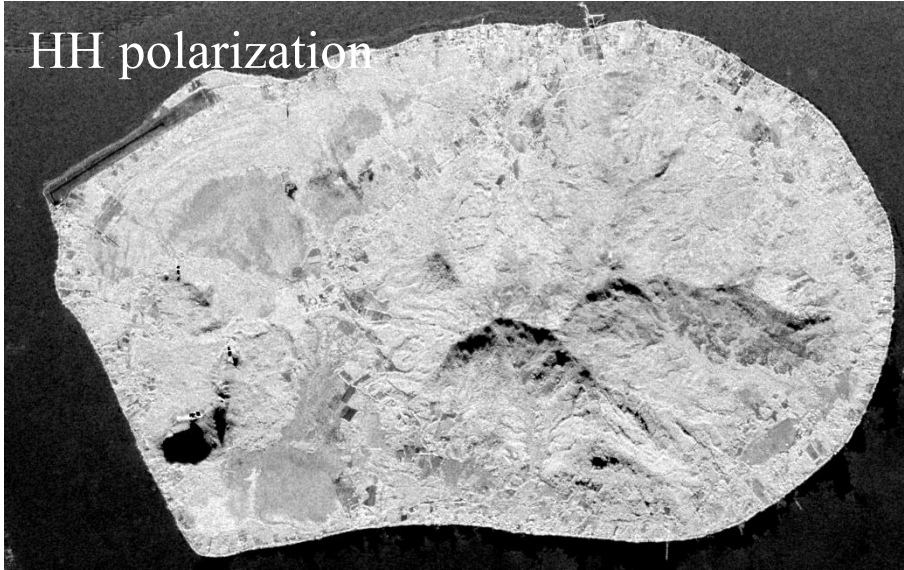
HV



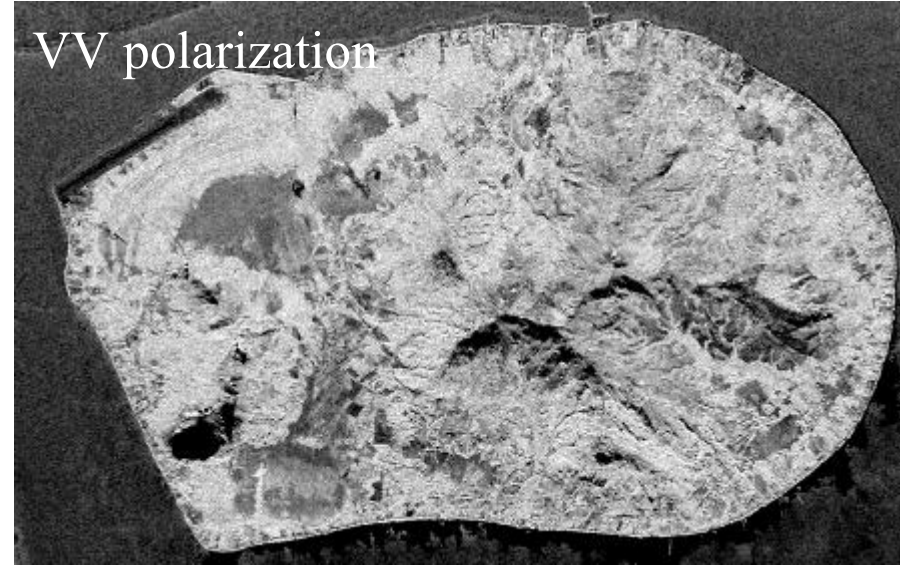
Polarization

Tubuai Island, vegetation discrimination, L Band

HH polarization



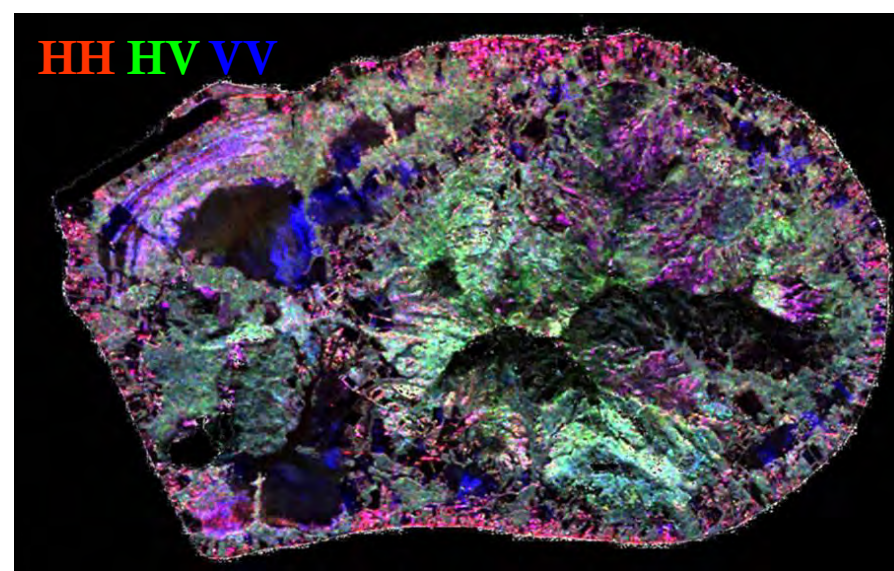
VV polarization



HV polarization



HH HV VV



Radar polarimetry for Forest types cartography

Tubuai Island, French Polynesia

7 different classes:

- bare soils
- swamps
- Fernlands

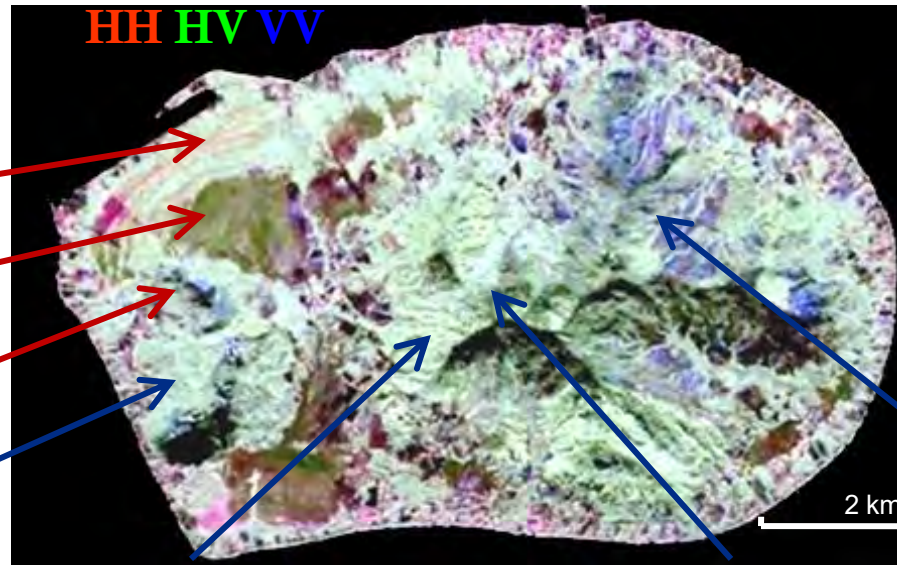
4 forests species

• Purau

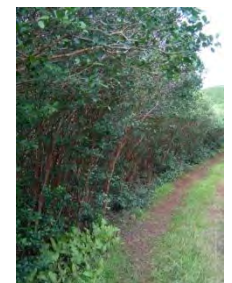
• Pines

• Falcata

• Guava



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



Polarization

in visible domain also!



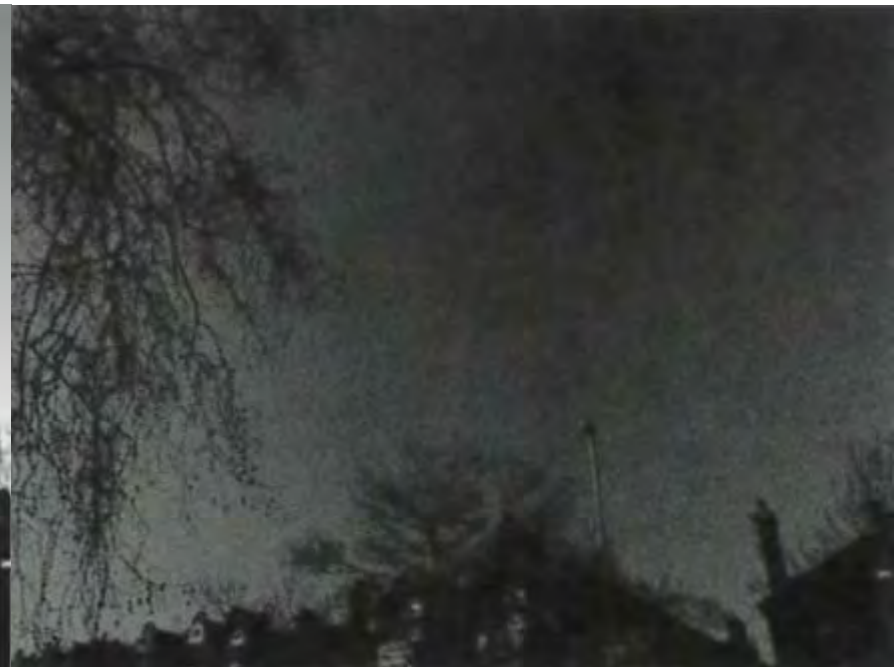
Polarization

in visible domain also!

Vertical



Horizontal



Radar images interpretation rules

Intensity (or Amplitude) Images

Surface scattering (bare soils) smooth rough

$VV > HH$

low

high

$HV \sim 0$

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

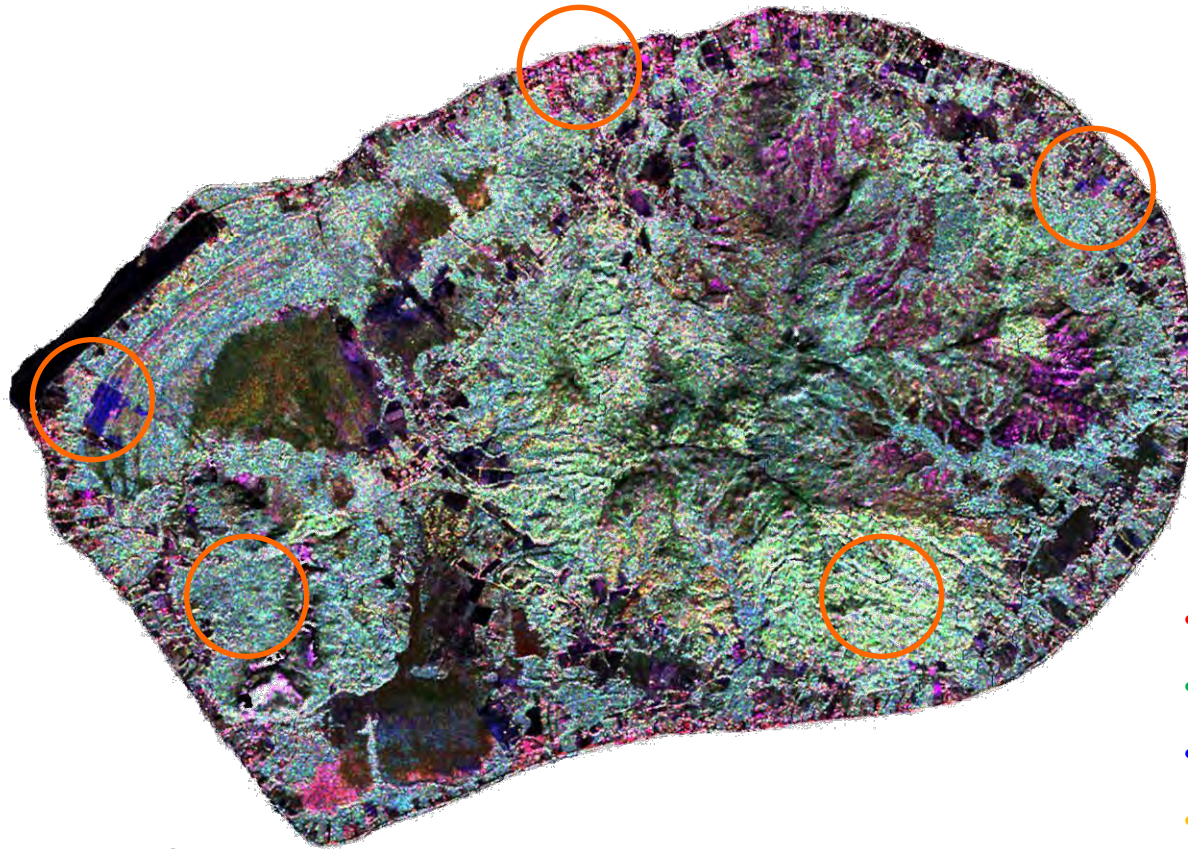
For Forest/Non forest discrimination

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

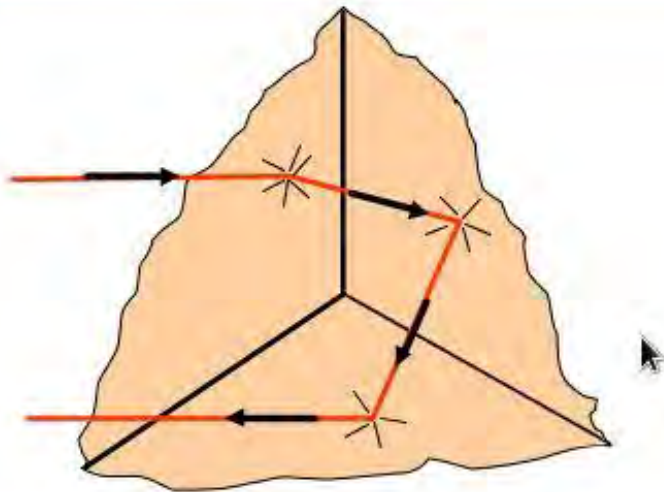
VV, HV

HH, VV (PALSAR, RADARSAT-2)

Radar images interpretation rules

Polarimetric Data: Amplitude + Phase Images

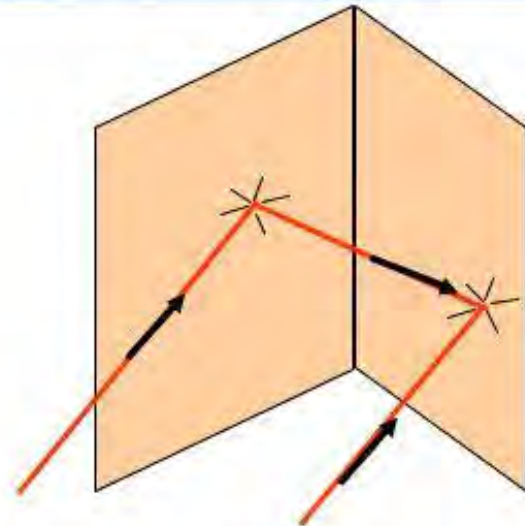
Behavior of the differential phases



Odd number of reflexions:

Ex: Trihedral target type

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



Even number of reflexions:

Ex: dihedral target type

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

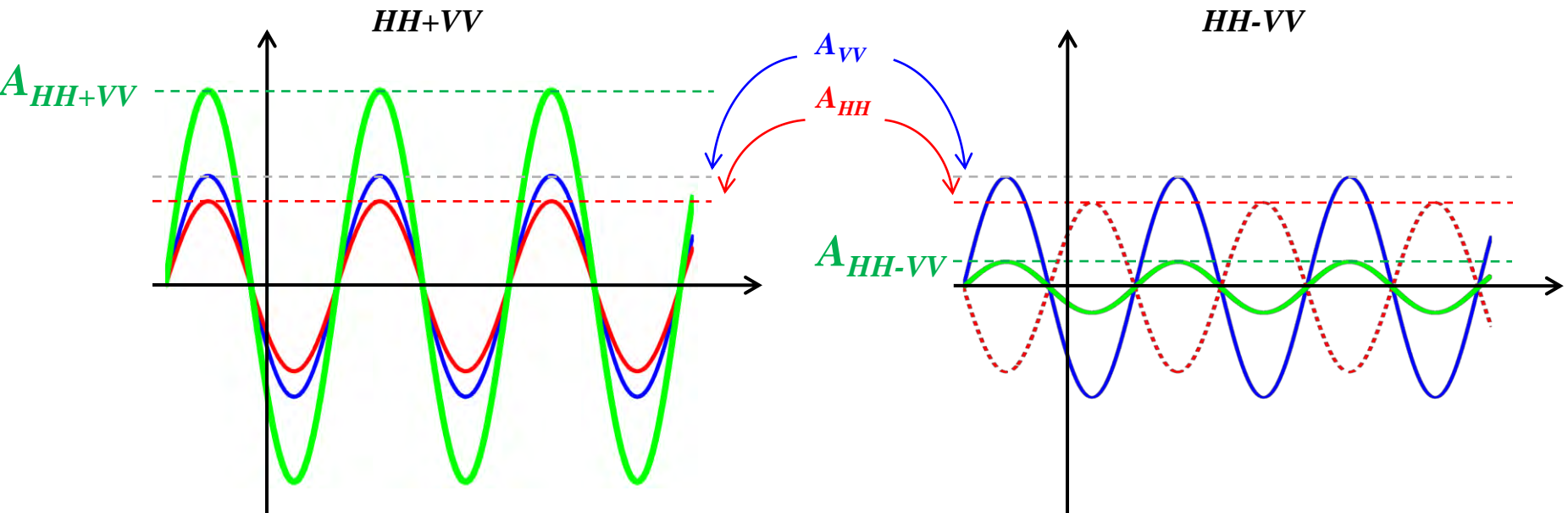
Radar images interpretation rules

Polarimetric Data: Amplitude + Phase

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

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

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



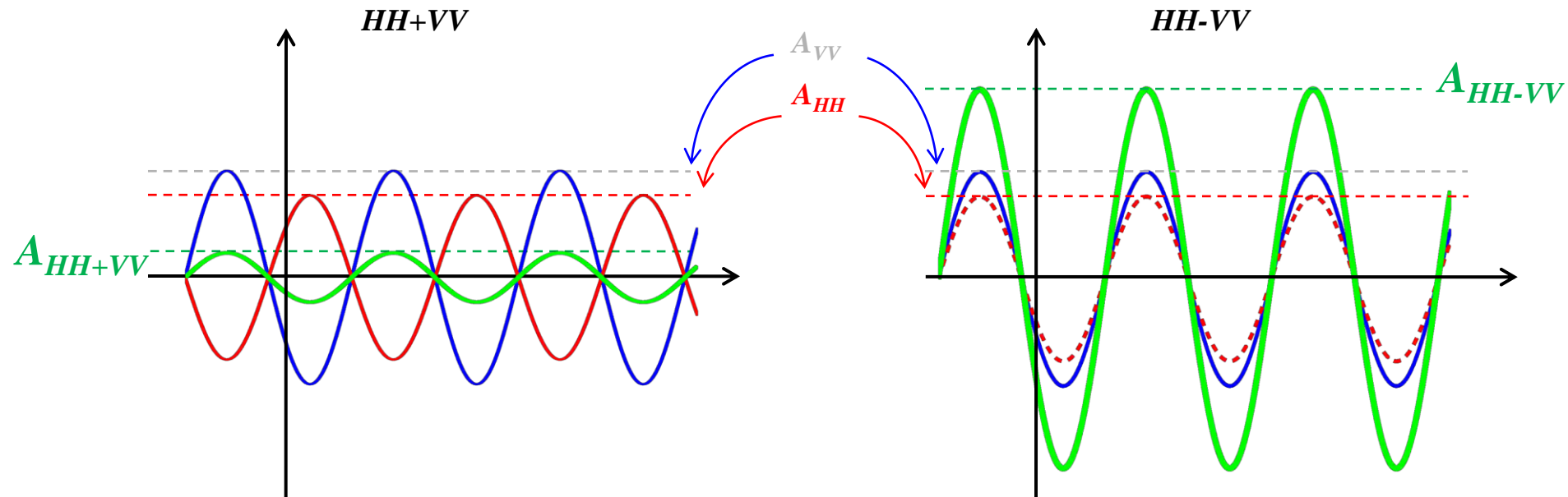
Radar images interpretation rules

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

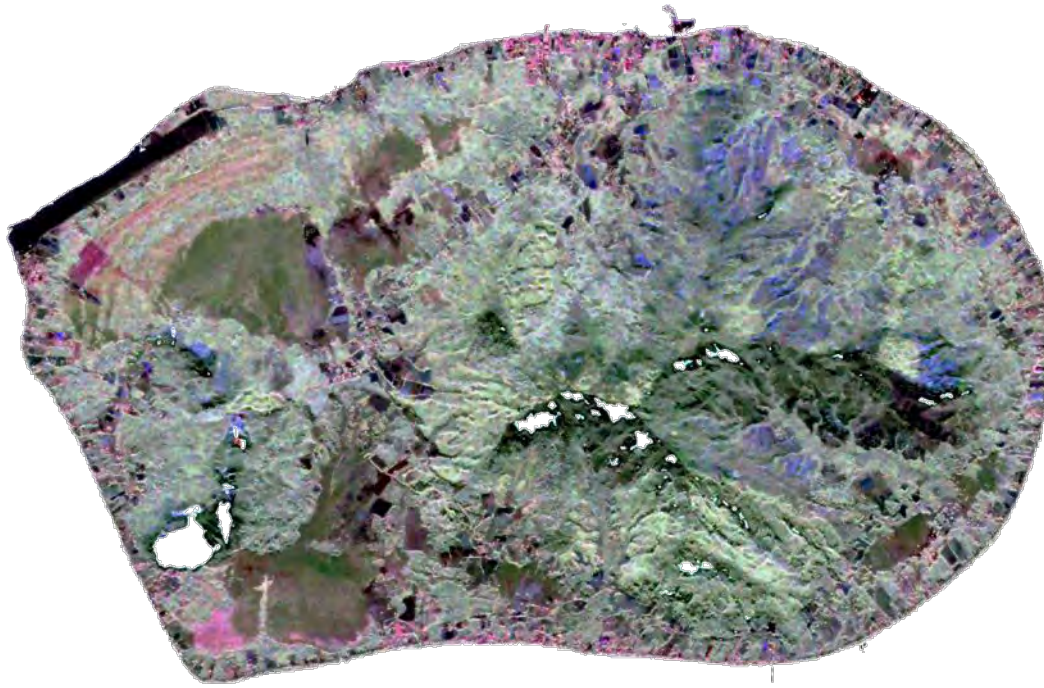
For Forest/Non forest discrimination

/HH-VV/

For urban areas and flooded vegetation

Radar images interpretation rules

Polarimetric Image: Pauli Representation



Tubuai Island

AISAR data, L Band

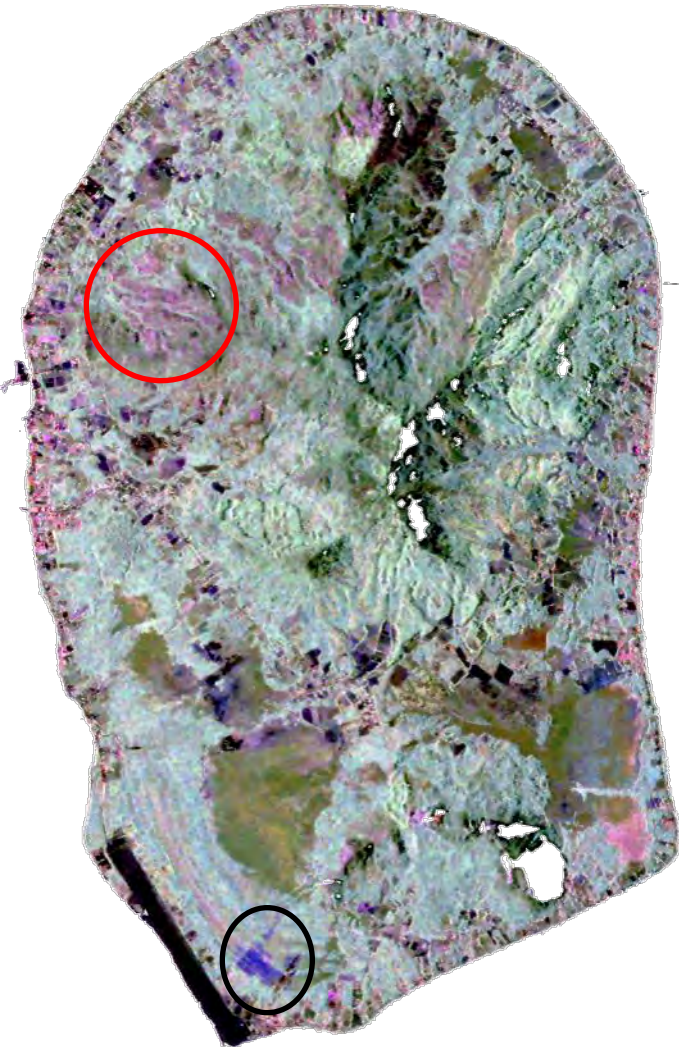
- **Double bounds**
- **Dense vegetation**
- **Bare soil**
- **Pinus et Falcata**

~ Purau

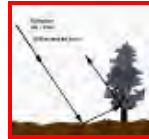
|HH-VV| |HV| |HH+VV|

Radar images interpretation rules

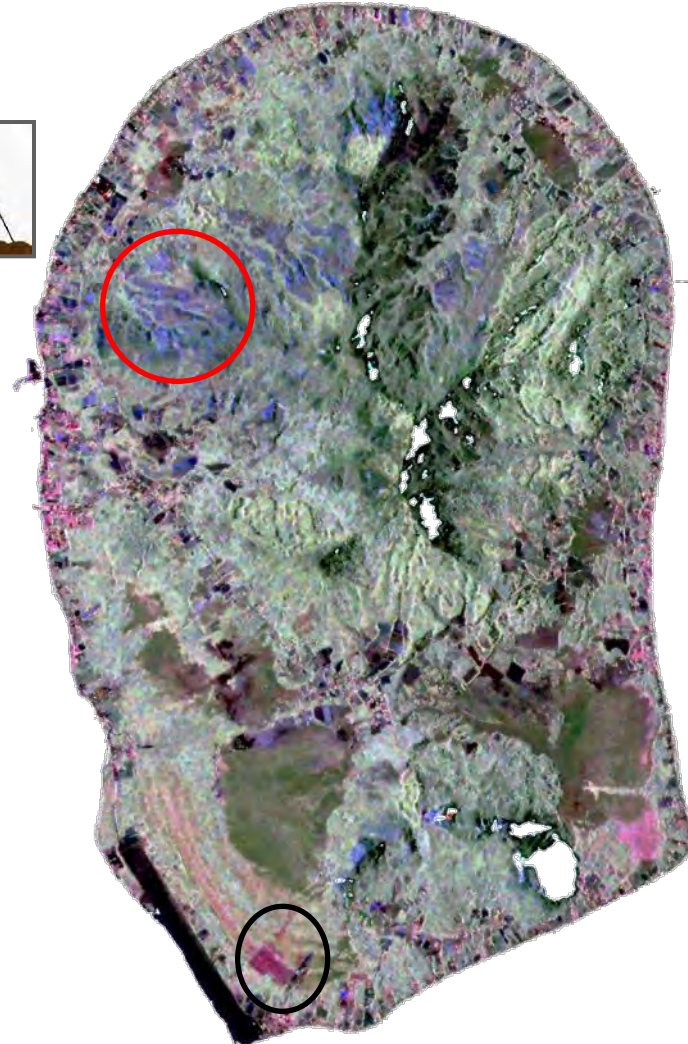
Pauli Representation



HH HV VV



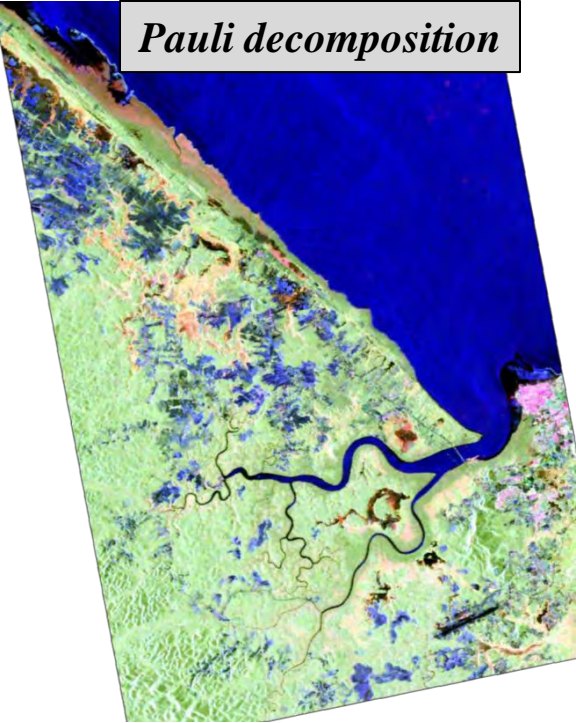
Quickbird



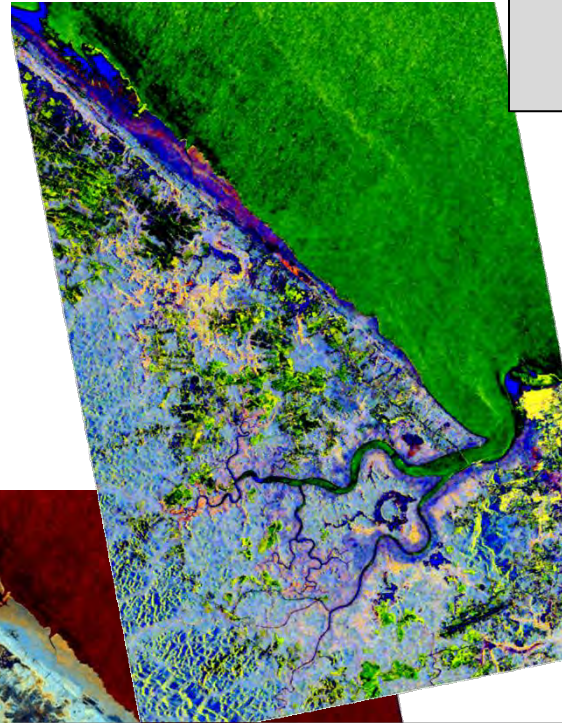
|HH-VV| |HV| |HH+VV|

Radar images interpretation rules

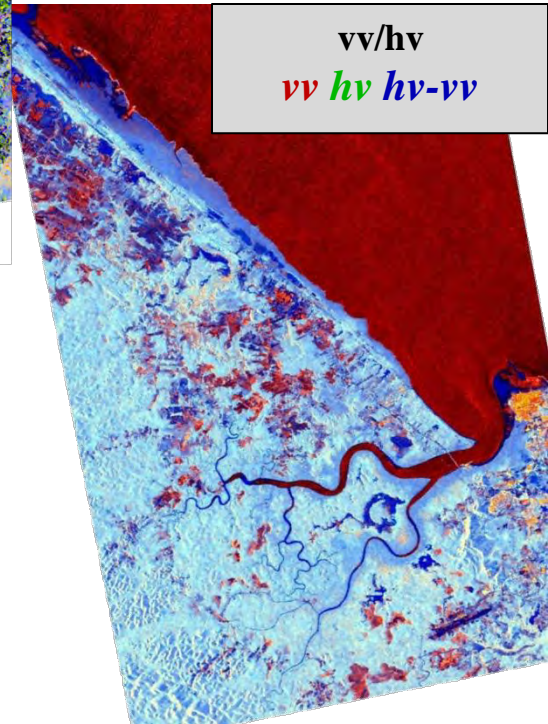
Pauli decomposition



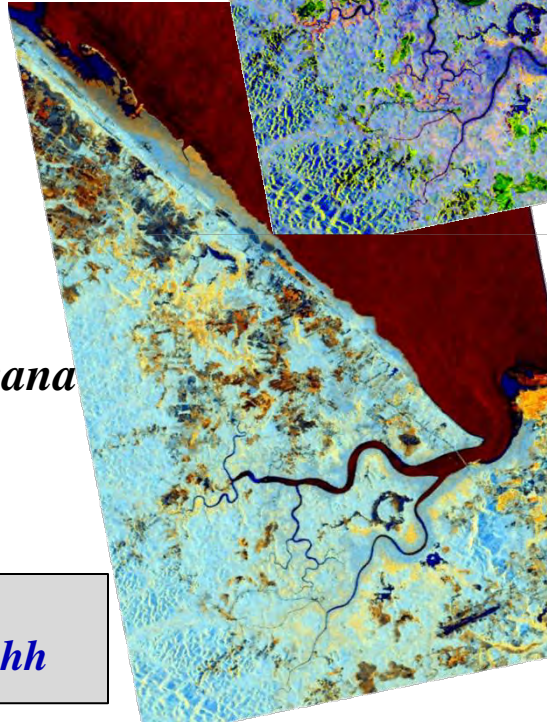
hh/vv
hh vv hh-vv



vv/hv
vv hv hv-vv



hh/hv
hh hv hv-hh



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