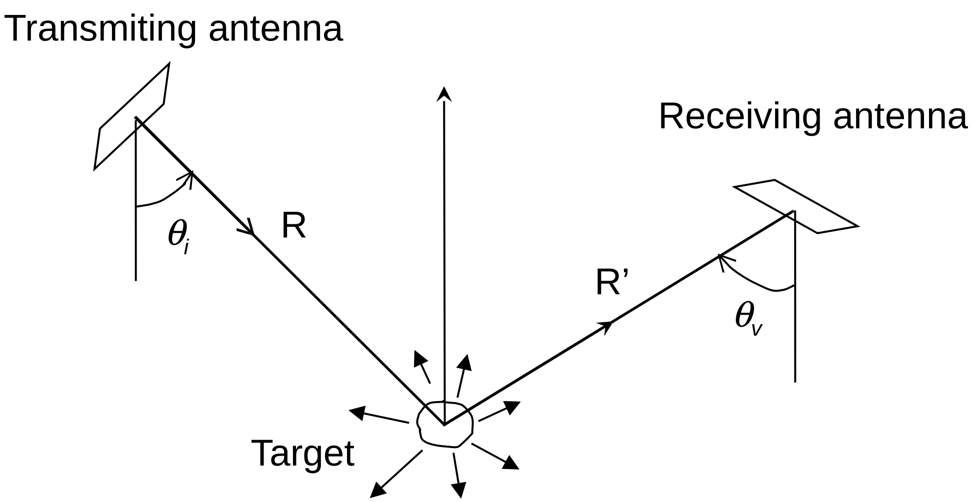
OUTLINE

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

Université Gustave Eiffel

LaSTI
Laboratoire des Sciences et Technologies de l'Information Géographique

The radar equation



Transmited power:

$$P_i = \frac{P_e G_e}{4\pi} d\Omega \qquad (W)$$

Receiving irradiance at distance R:

$$E_i = \frac{P_e G_e}{4\pi R^2} \qquad (W/m^2)$$

Intercepted power from the target (W):

$$P_s = \frac{P_e G_e}{4\pi R^2} RCS$$

Radar Cross Section (m²)

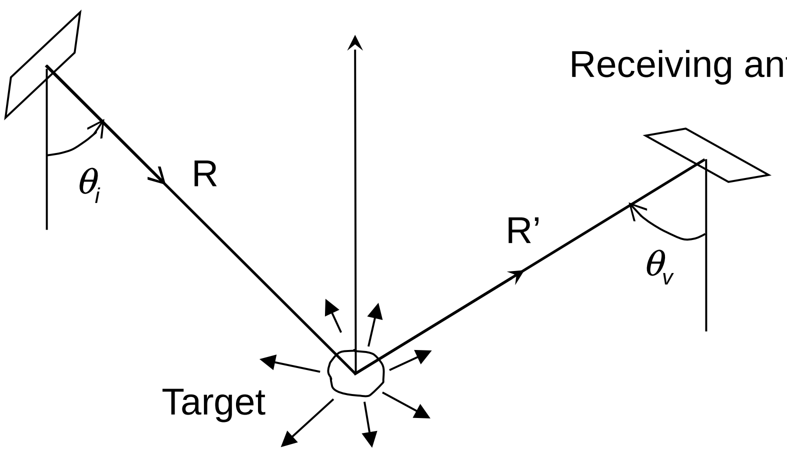
Intensity emited from the target (isotrope):

$$I = \frac{P_S}{4\pi} = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi} \qquad (W/sr)$$

Power received by surface dS at distance R':

$$P_r = I\, d\Omega = I \frac{dS}{R'^2} = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi R'^2} dS \qquad (W)$$

The radar equation



Power received by dS at distance R'

$$P_r = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi R'^2} dS \qquad (W)$$

Recived irradiance at distance R'

$$E_r = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi R'^2} \qquad (W/m^2)$$

Power received by the antenna:

(W)

The radar equation

Radar Cross Section (m^2)

Power received by the antenna: $$dP_r = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi} \frac{G_r \lambda^2}{4\pi R^2} \quad (W)$$

Case of expanse surfaces:

Radar Backscattering Coefficient: $$\sigma^0 = \frac{RCS}{d\Sigma} \quad (m^2/m^2)$$

 Analogous to the reflectance in Optical domain

$$dP_r = \frac{P_e G_e}{4\pi R^2} \frac{\sigma^0 d\Sigma}{4\pi} \frac{G_r \lambda^2}{4\pi R^2}$$

$$\sigma^0 = \frac{(4\pi)^3}{\lambda^2} \frac{\langle P_r \rangle}{P_e} \frac{R^4}{\iint_{Surf.obs.} G_e G_r \, d\Sigma}$$

σ^0 high dynamic

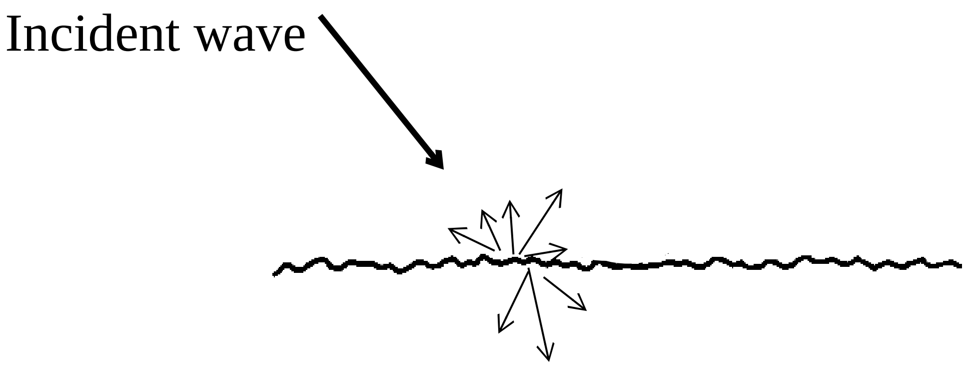
==> dB units (log. scale)

$$\sigma^0_{dB} = 10.\log_{10}\left(\sigma^0_{Nat}\right)$$

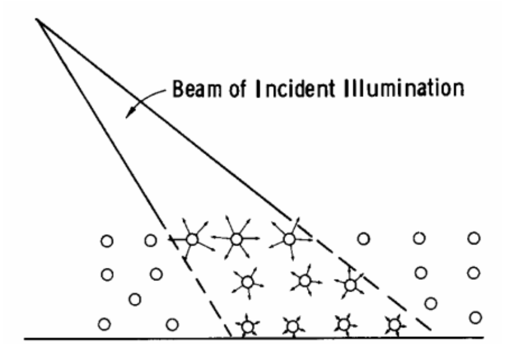
Radar images interpretation rules

2 cases of figure:

Surface scattering (interaction occurs at the interface between beth media)

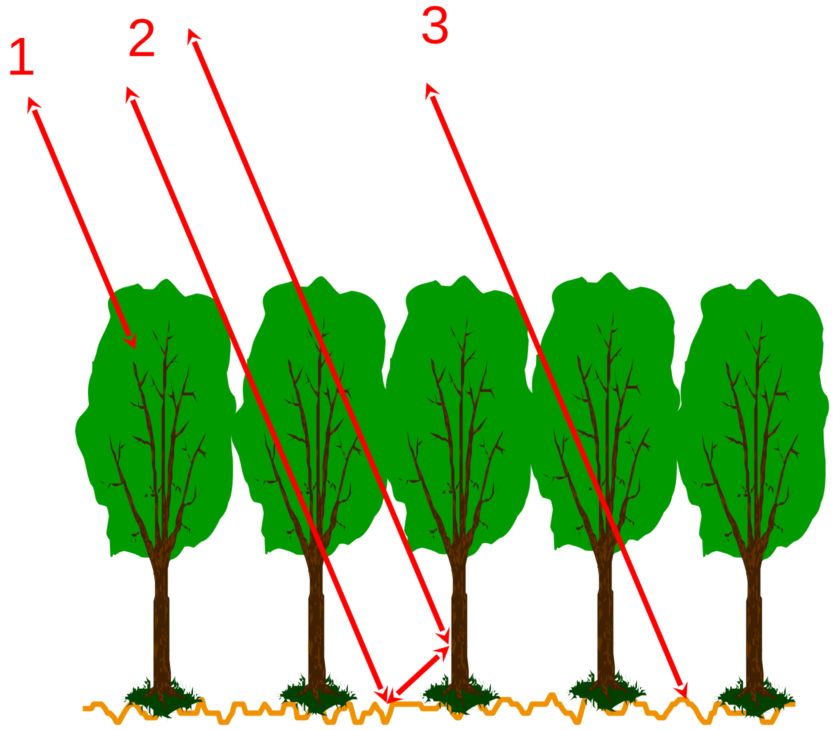


Volume scattering (interaction with multiple elements = scatterers)



Radar images interpretation rules

Scattering Mecanisms over vegetation



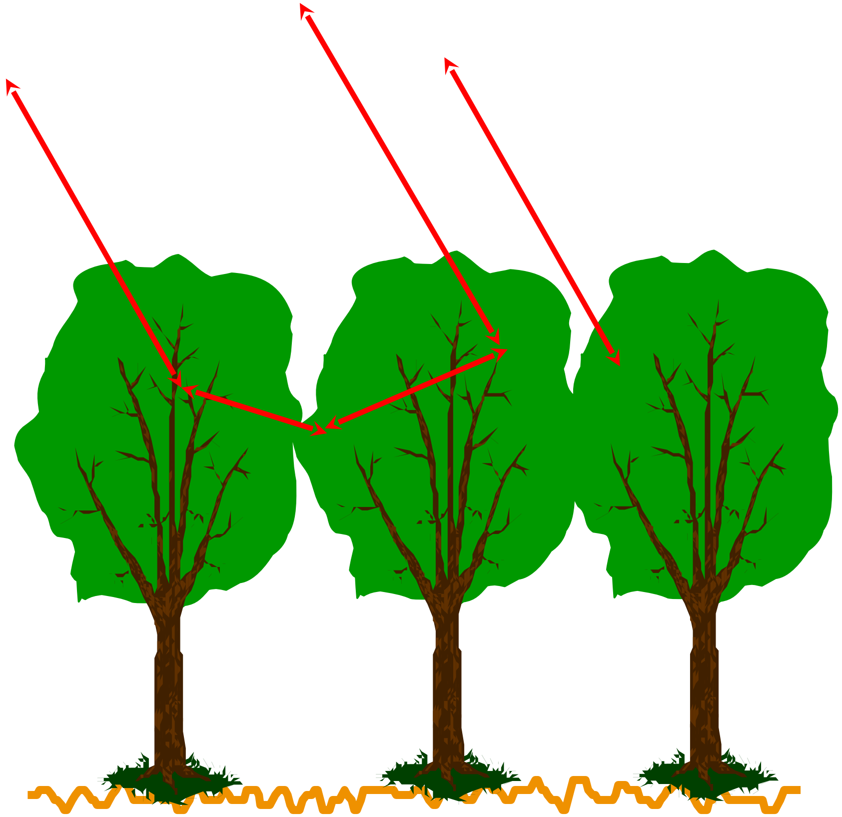
1: vegetation only

2: soil-vegetation interaction

3: soil attenuated by vegetation

Radar images interpretation rules

Dense vegetation

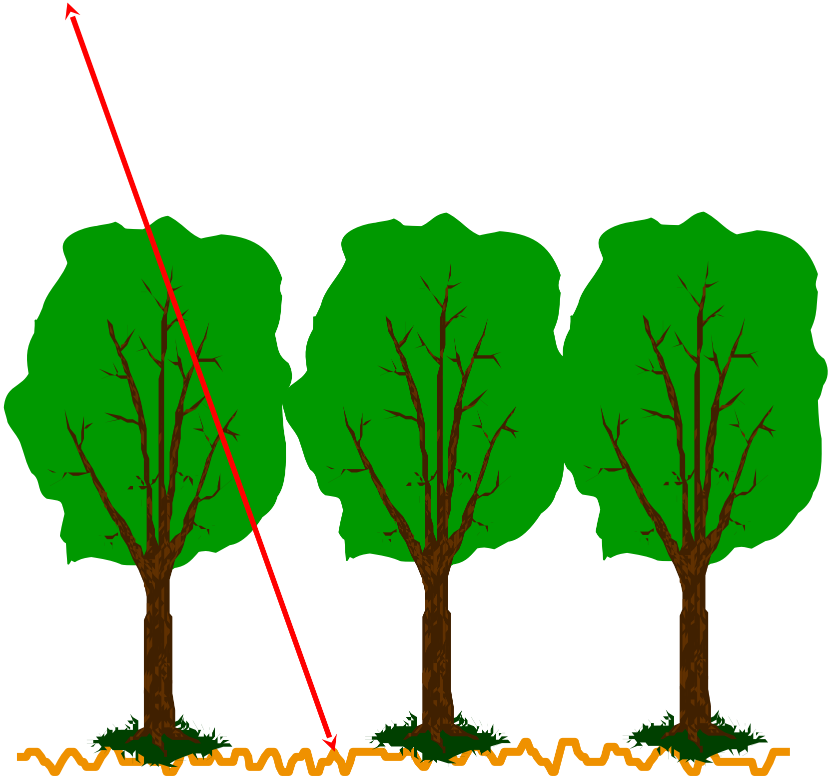


Vegetation contribution

==> ***Volume scattering***

Radar images interpretation rules

Sparse vegetation



Soil attenuated by vegetation

==> ***Surface scattering***

Radar response sensitivity

bare soils or water surfaces

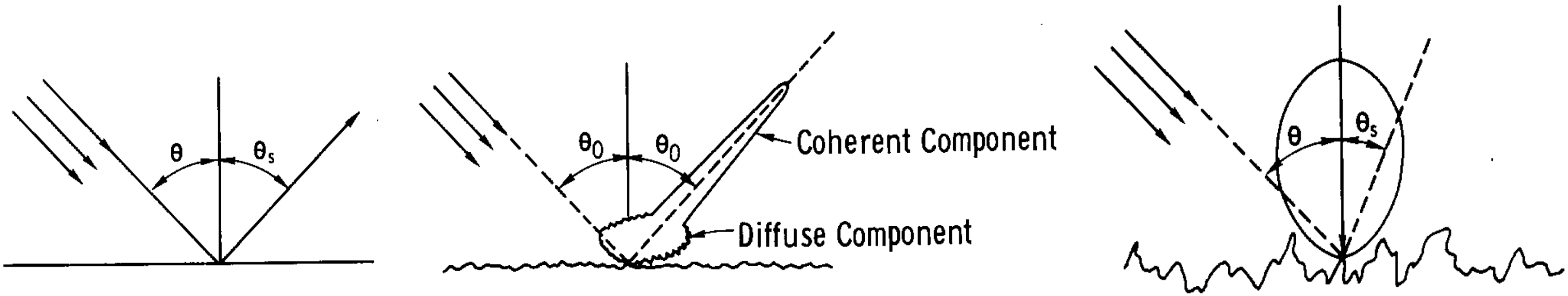
Surface Scattering

Radar images interpretation rules

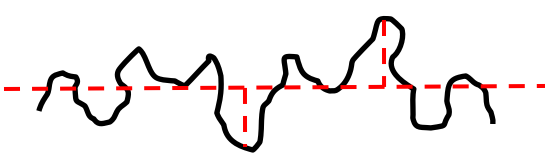
Surface scattering

Soil: homogeneous medium ==> scattering at the interface

Influence of roughness



Surface roughness is refered to the radar wavelength



σ: rms height

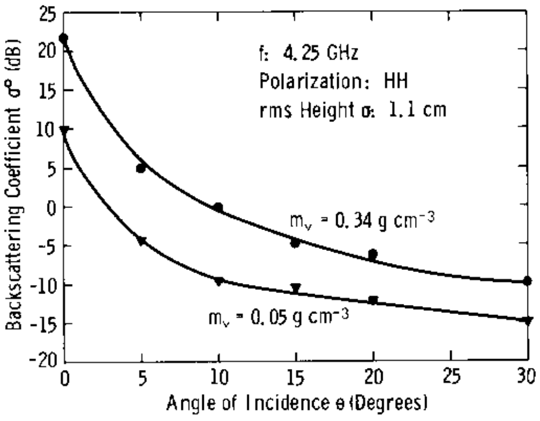
$$\sigma < \frac{\lambda}{8\cos\theta} \quad \text{==>} \quad \text{smooth surface}$$

ERS (λ = 5 cm, θ = 23°): s > 2.10^{-2}: every soil is rough!

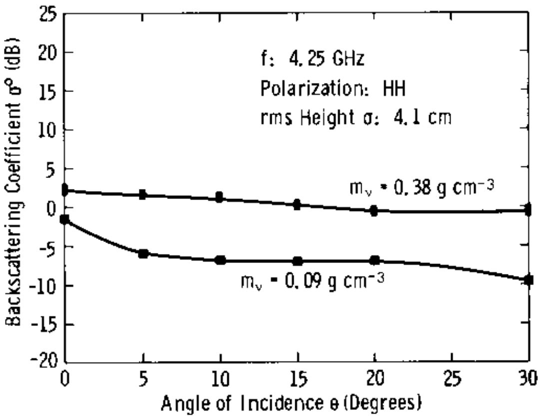
Radar images interpretation rules

Surface scattering

Smooth surface



(a)

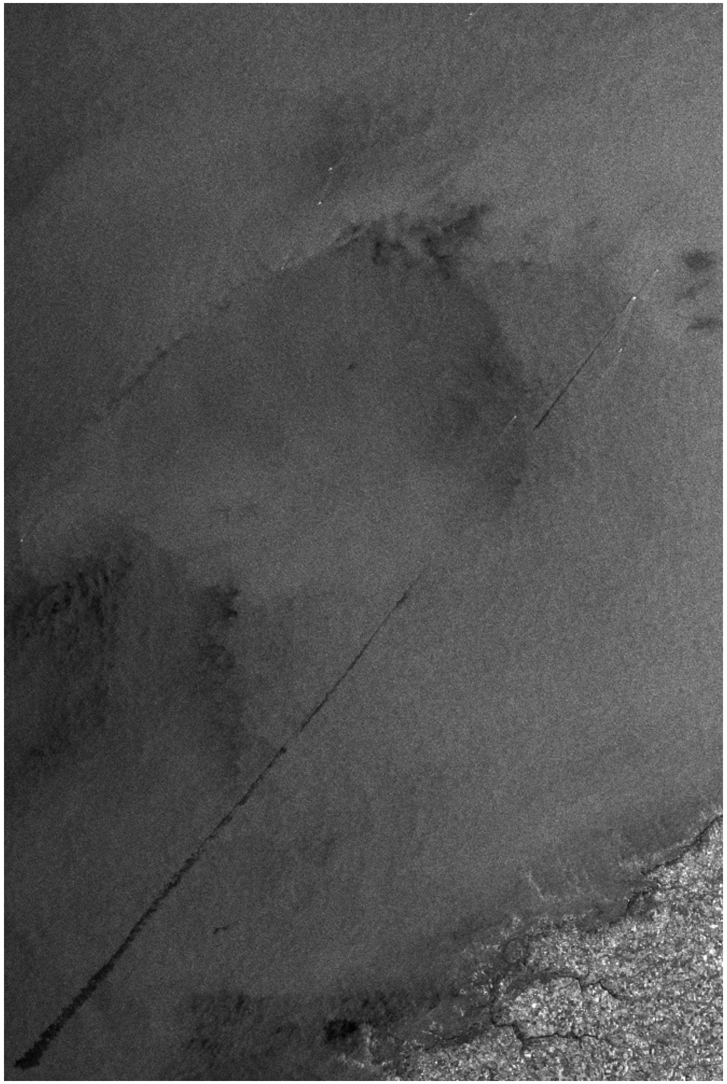


(b)

Soil *roughness*: ***angular*** effect

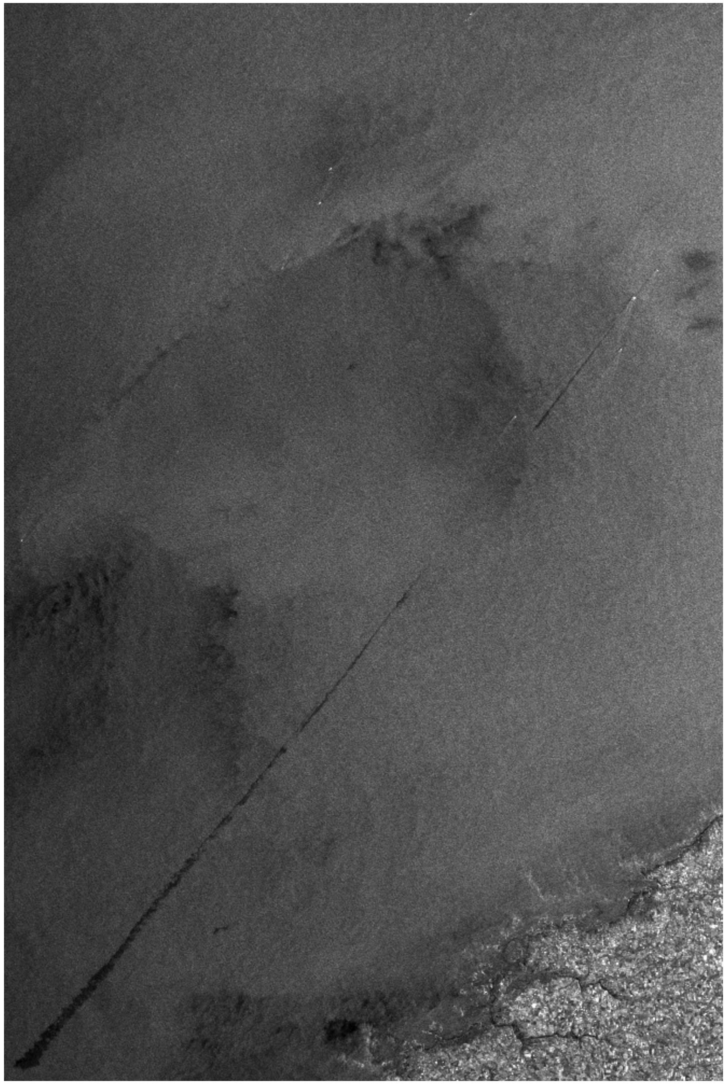
Soil *moisture*: ***shift level*** effect

Radar response sensitivity



ERS (bande C, 23°, VV): 9 mars 1999

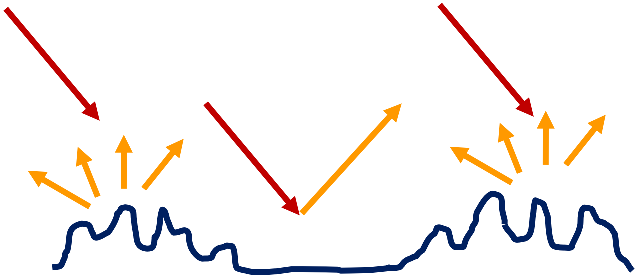
Radar response sensitivity



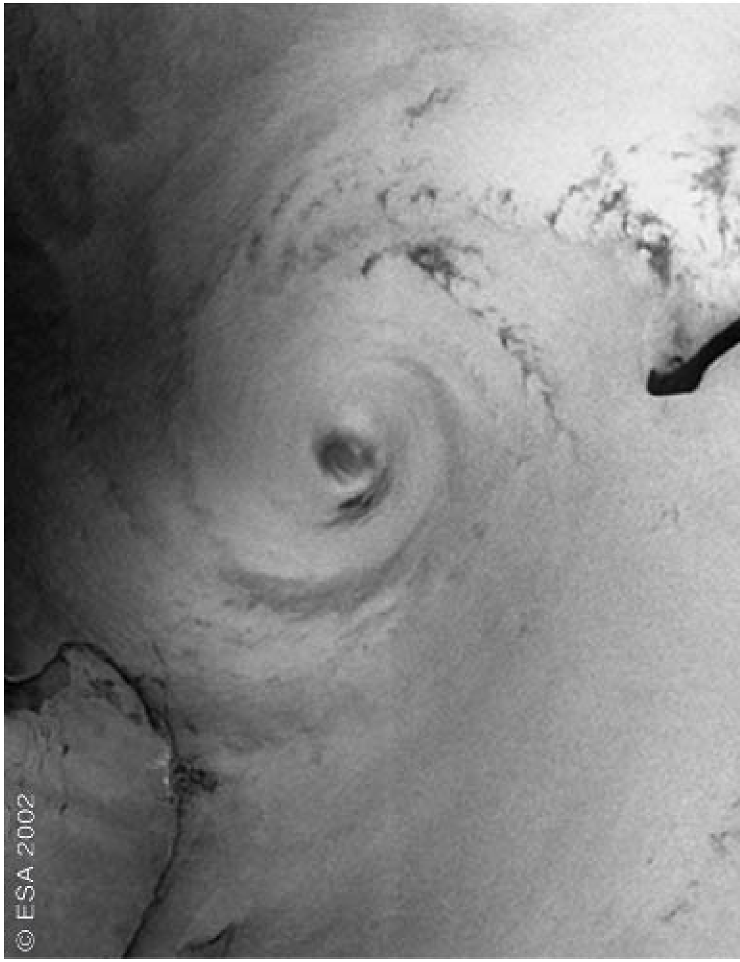
ERS (bande C, 23°, VV): 9 mars 1999

Over surface water:

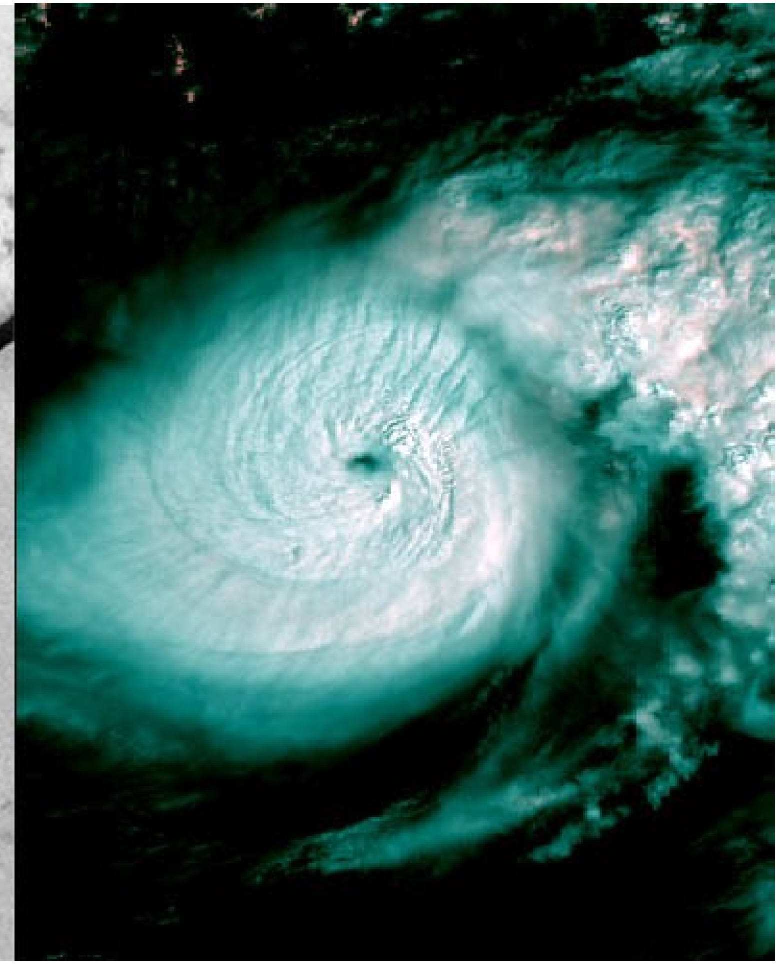
surface roughness too



Typhon Isidore
Mexico - 21.09.2002



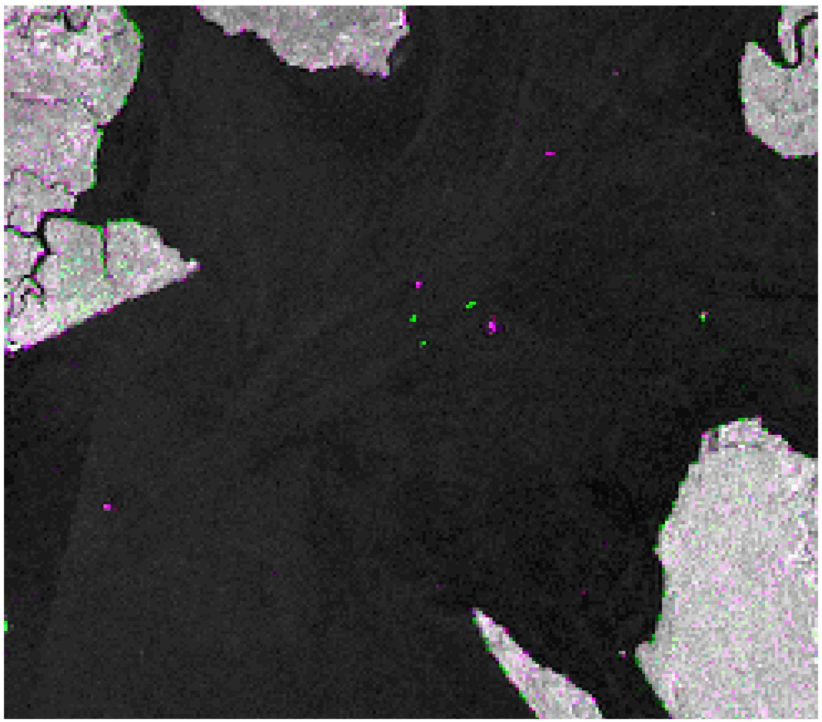
ASAR



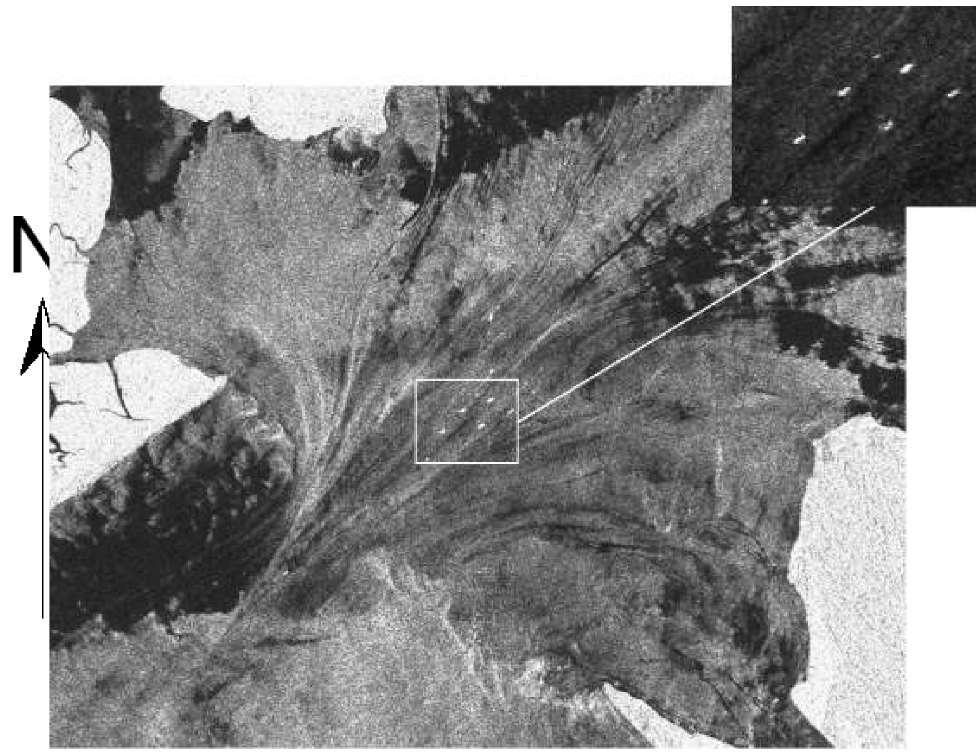
MERIS (600 m)

Frequency - wavelength

Exercice: why is it required to know the wavelength λ?



JERS sensor
(Bande L, λ = 25 cm)

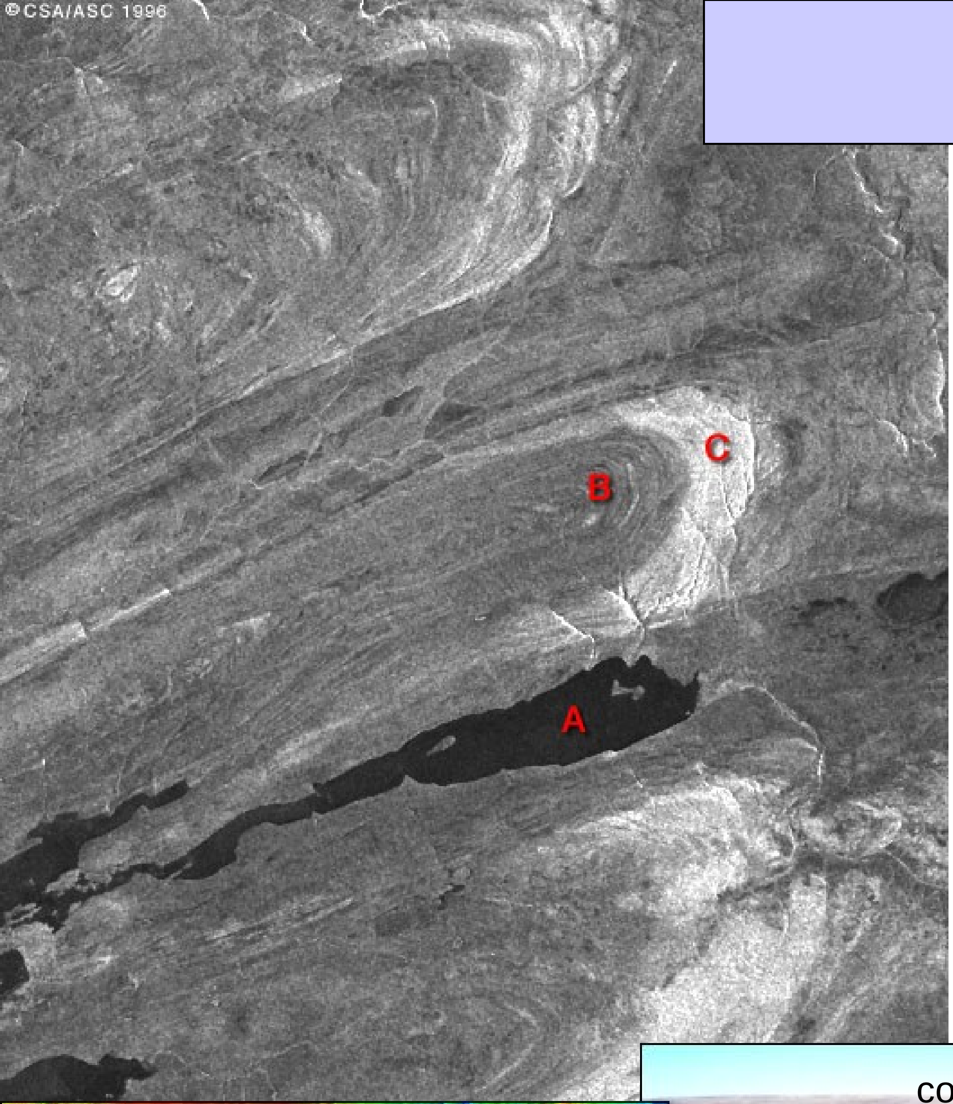


ERS sensor
(Bande C, λ = 6 cm)

ERS radar image in Sahel

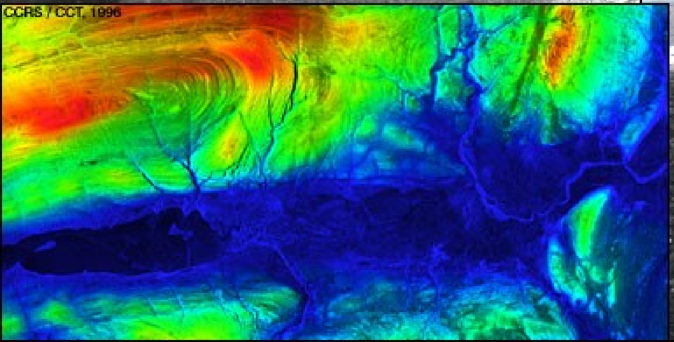
Over bare soil: depends on
Roughness
Soil moisture

Canada



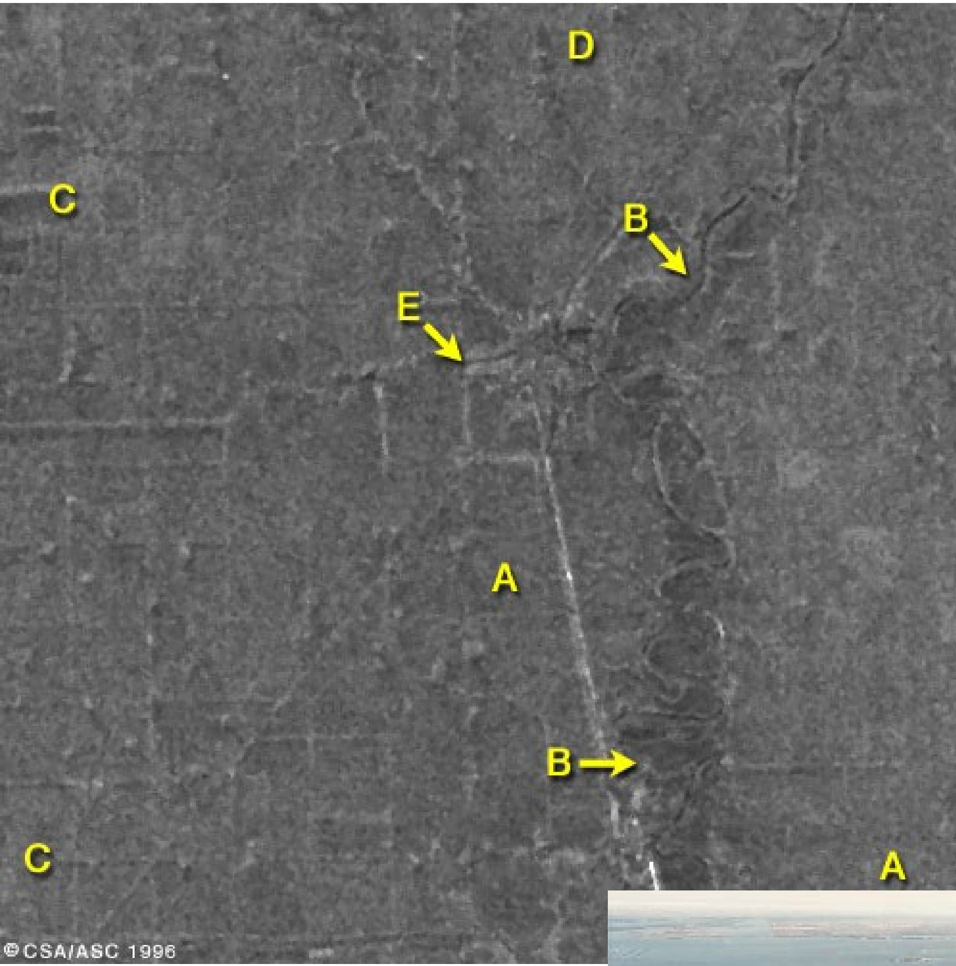
Siltstone 1.5 cm

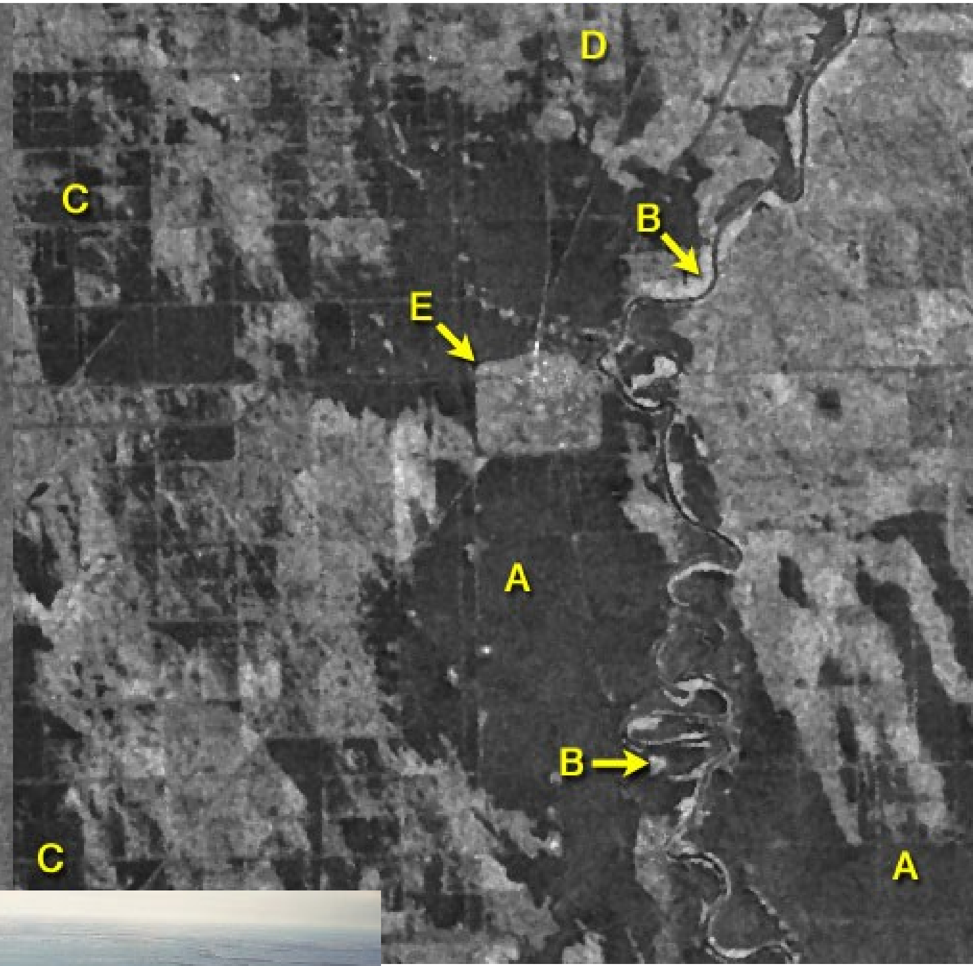
limestone 4.5cm



contact

Flooded areas monitoring





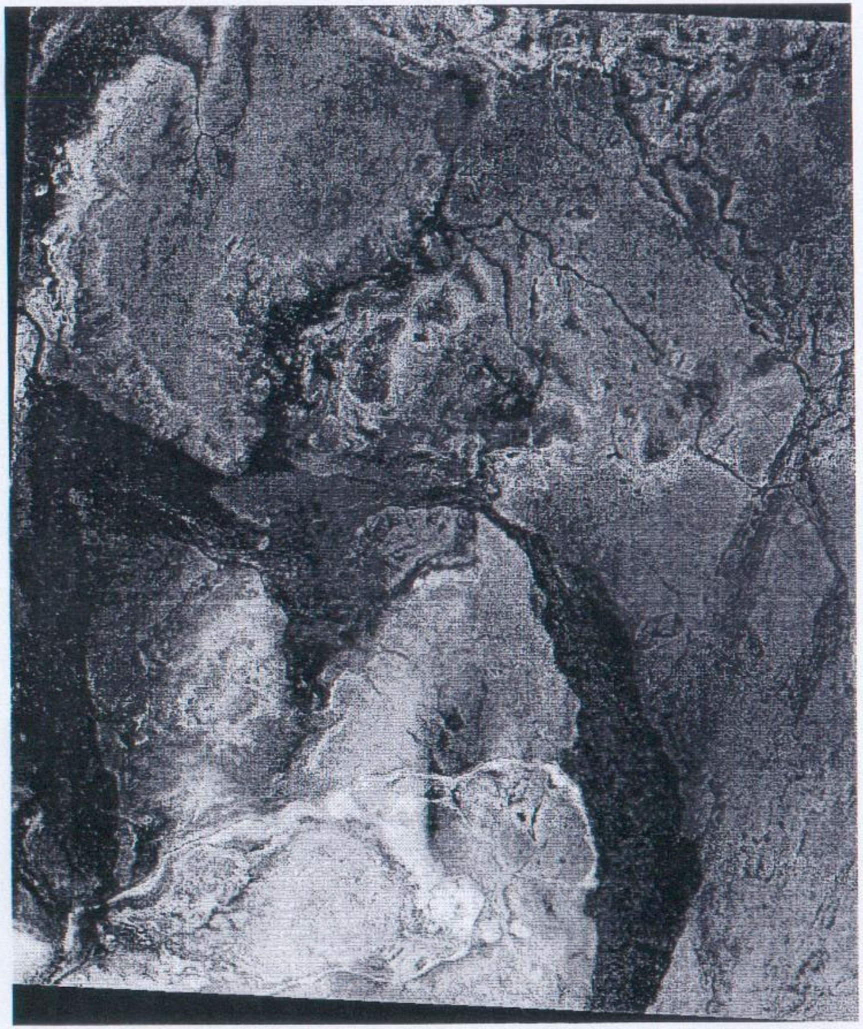
March 23 1996

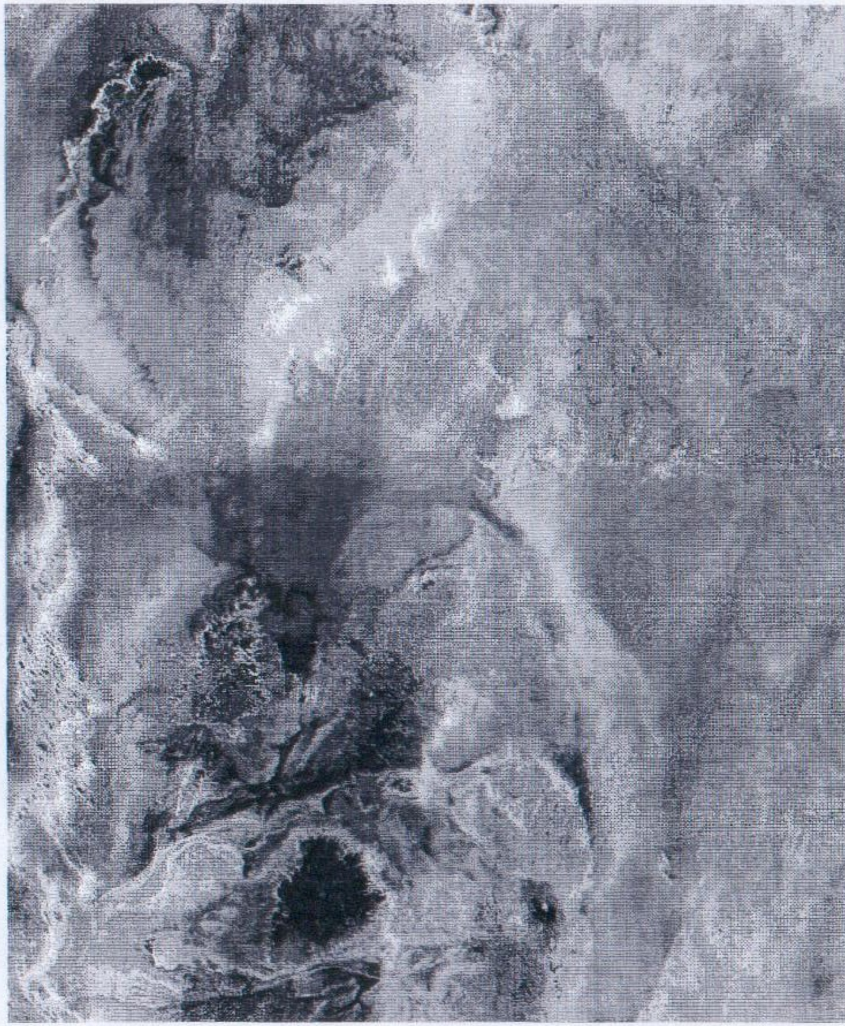
April 25 1996

The Red River, China

Penetration effect

Radar ERS   optical





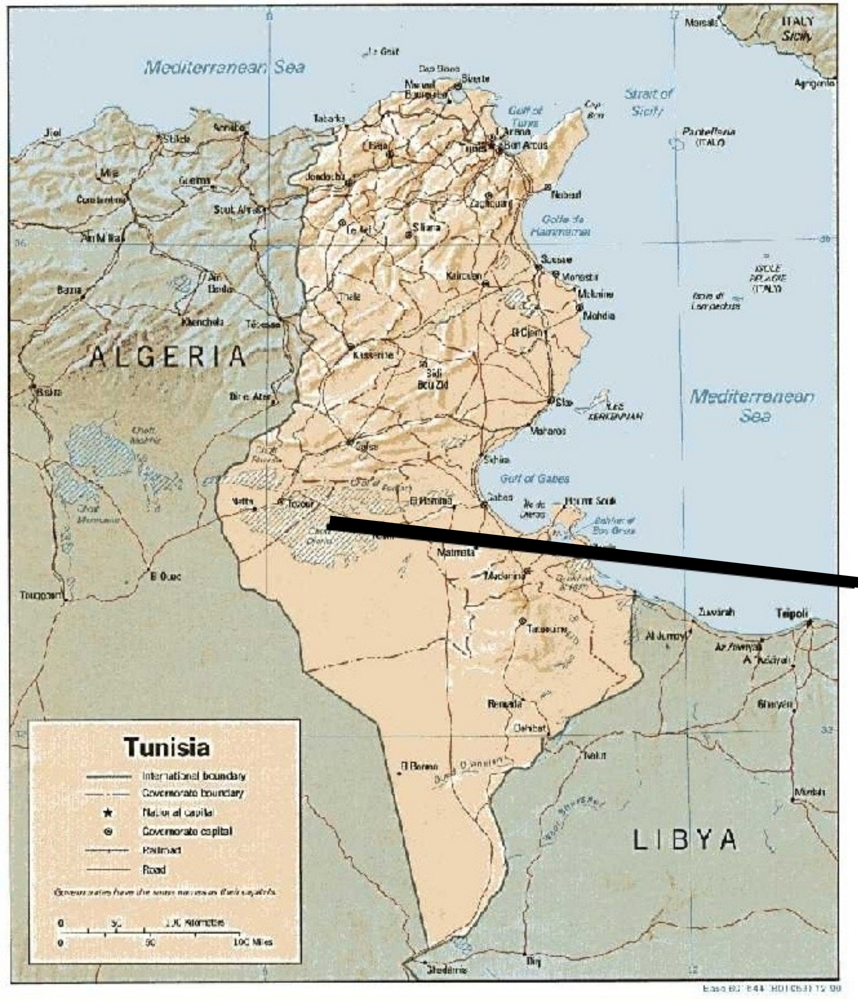
"Tin Etki" Aïn Cheikh Oued Temenrasset

Desert Algeria

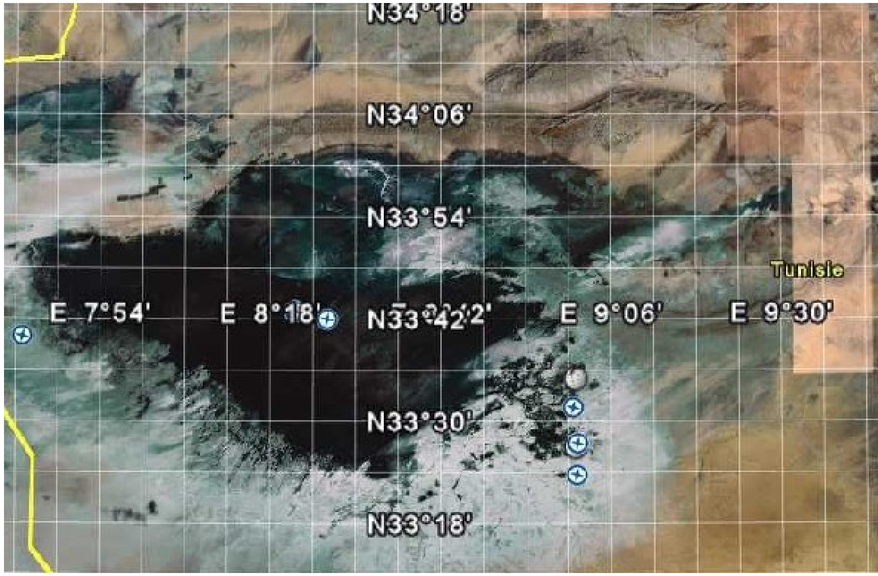
Effect of penetration

SIR A
band L

The Chott El Jerid, Tunisia



A vast evaporitic (80 x 120 km) area

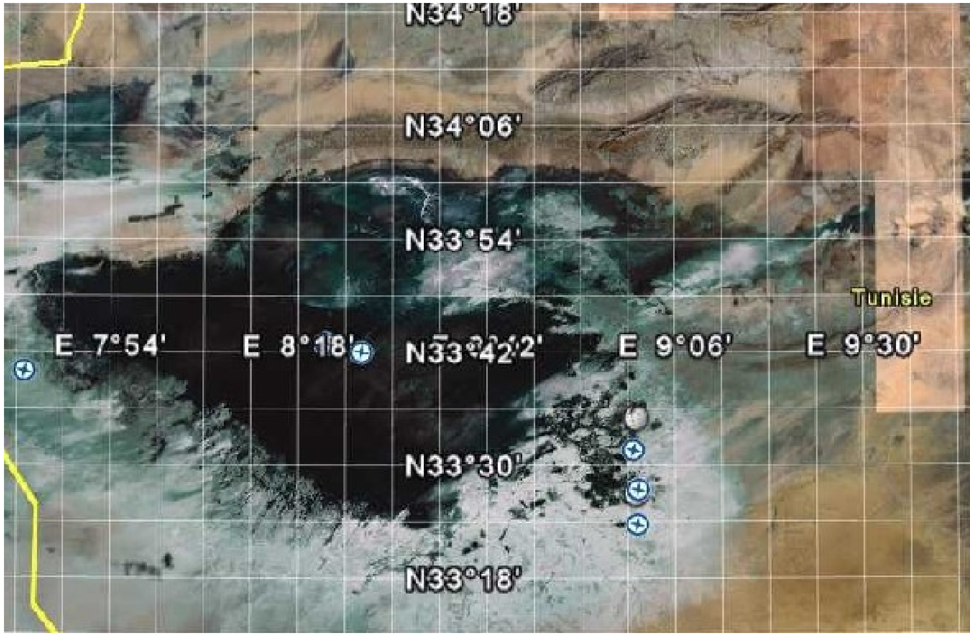


60 km

Discharge playa from a major aquifere (upward percolation)

+

occasional runoff from neighbouring playa (Fedjadj).



Temporary flooding

Playas: Evaporites (saline deposits)

Flooded / dry surface

Wettest months

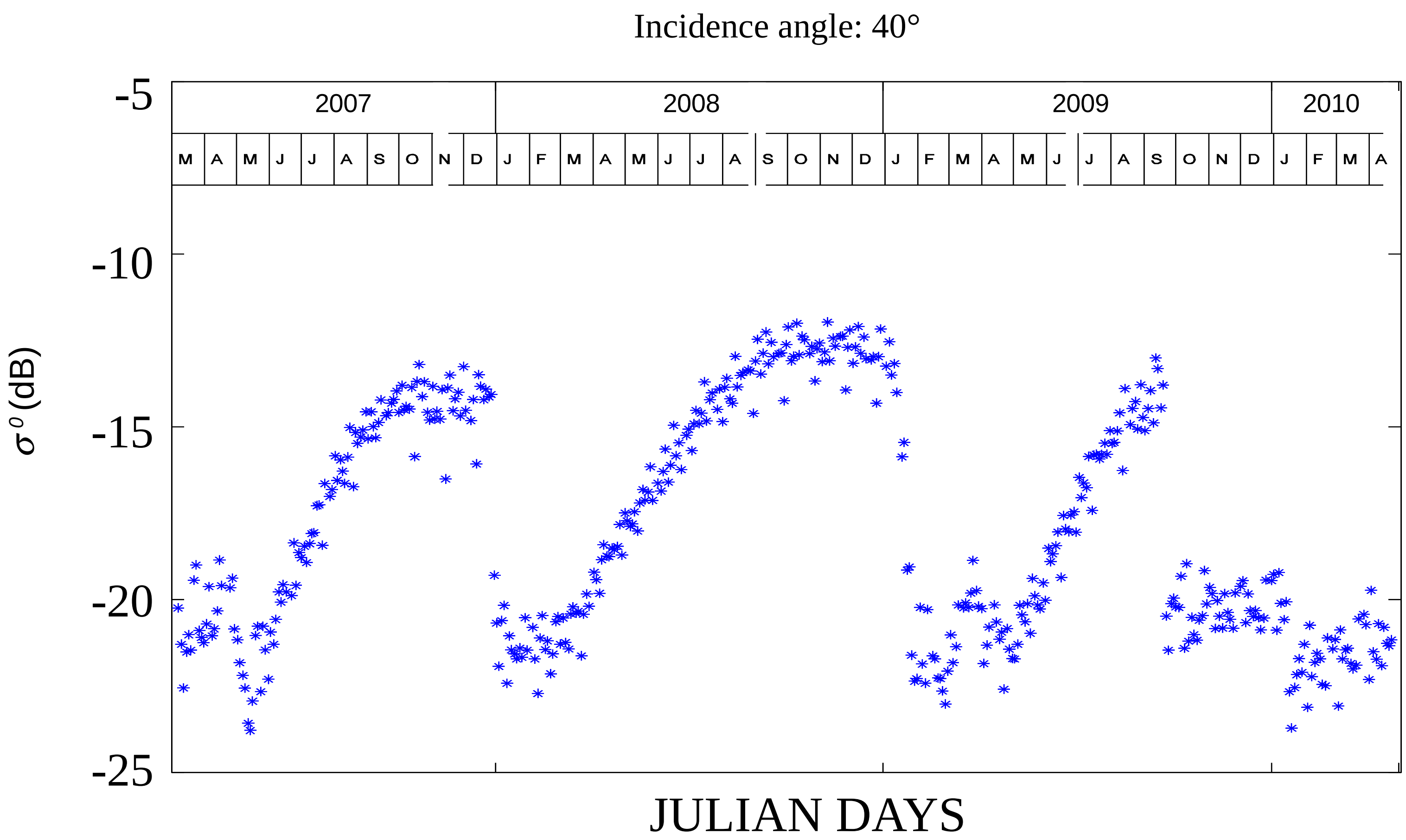
sudden smoothing due to dissolution of saline crust
+ dramatic change of diel. const. (saline solution)

Summer months:

evaporation → halite crystal growth → increase of roughness

Lab and ground measurements, Death Valley
(roughness, dielectric constant)

ASCAT temporal signature over the **Chott el Jerid**

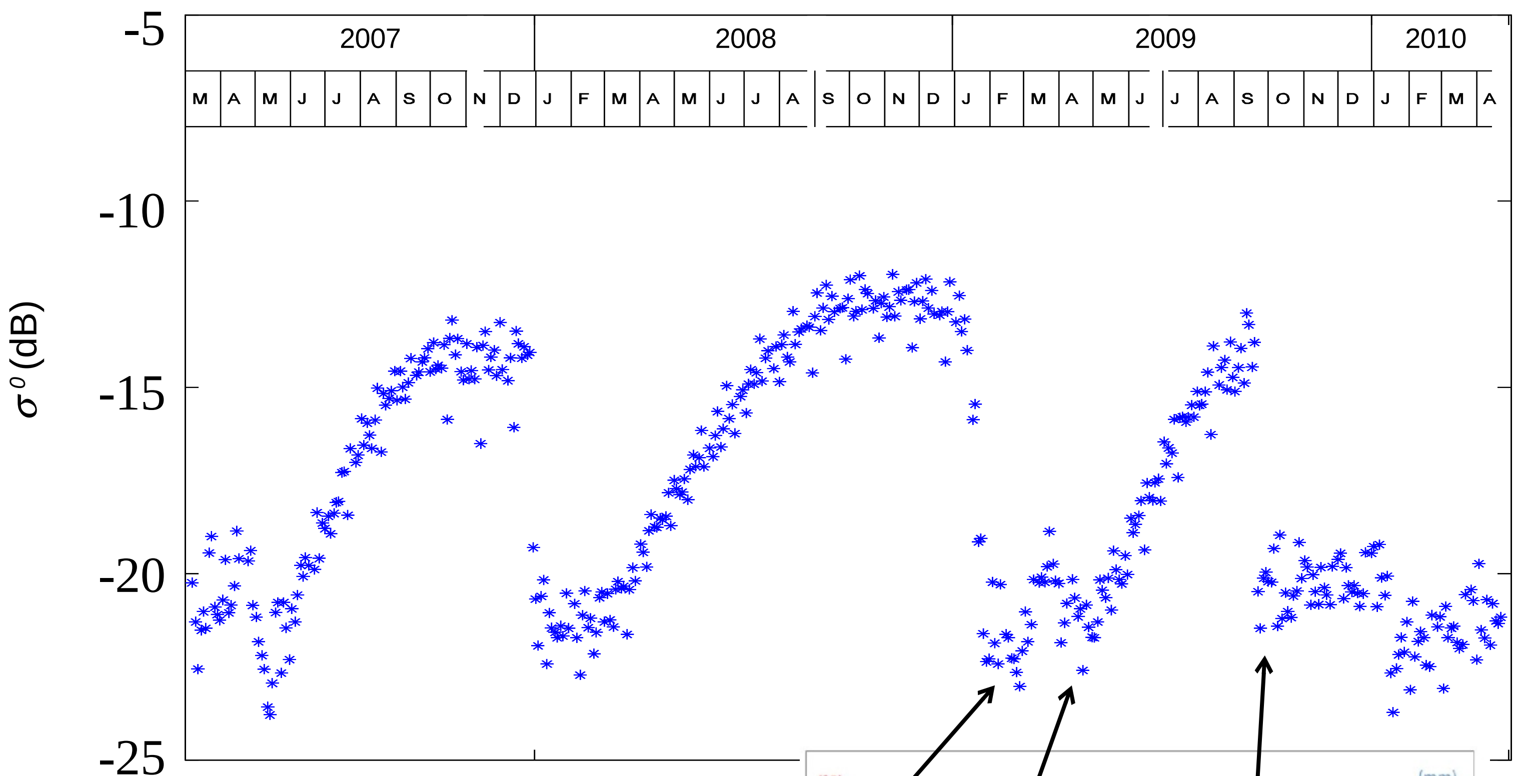


High temporal dynamic (> 10 dB)

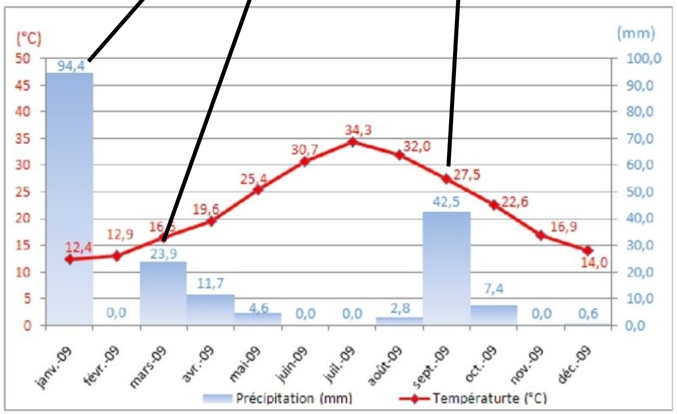
Linked to environment seasonal variations

ASCAT temporal signature over the **Chott el Jerid**

Incidence angle: 40°

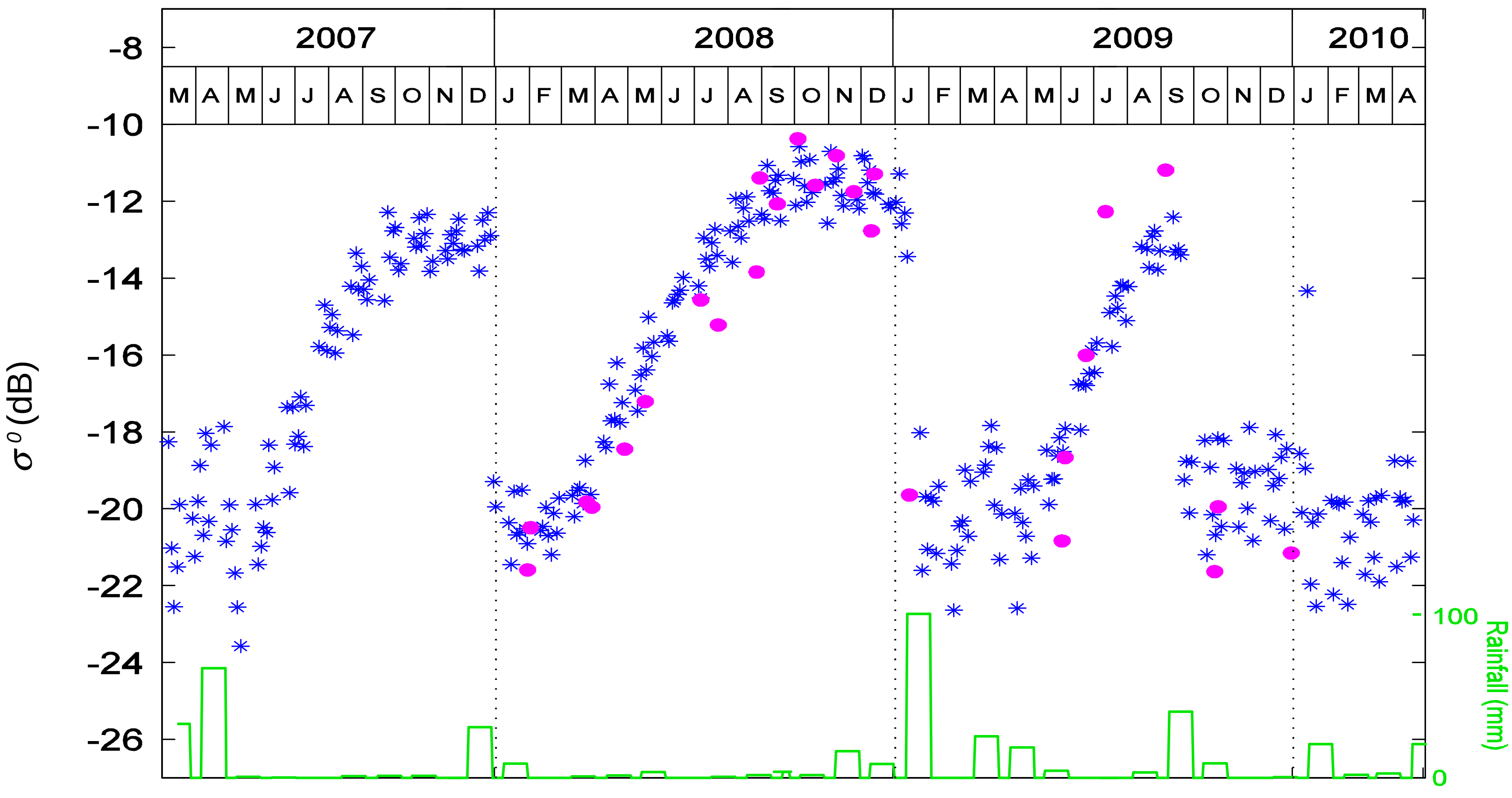


Precipitation, Tozeur, 2009



ASCAT/ASAR temporal signature over the **Chott el Jerid**

Incidence angle: 40°

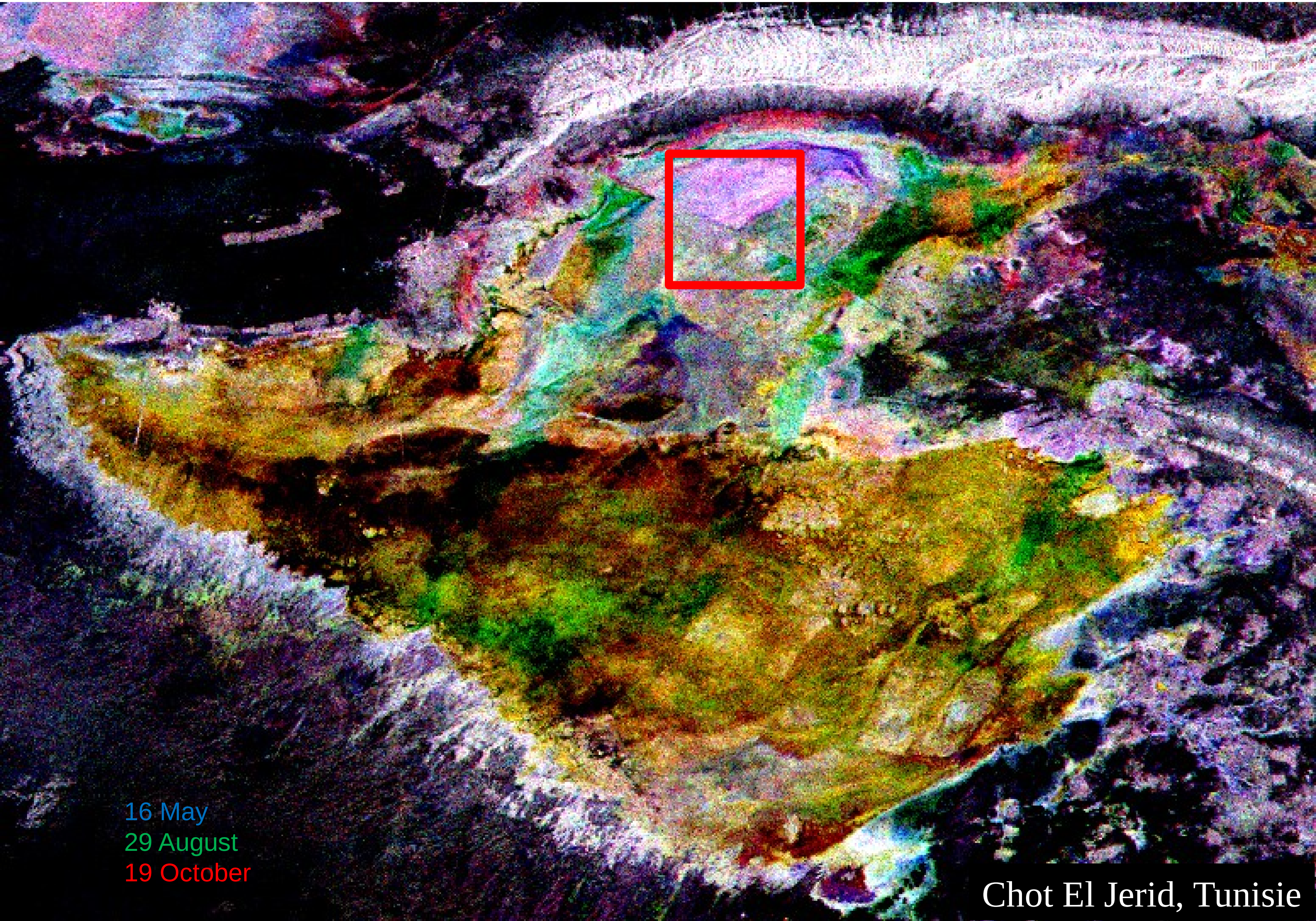


JULIAN DAYS

: METOP – ASCAT

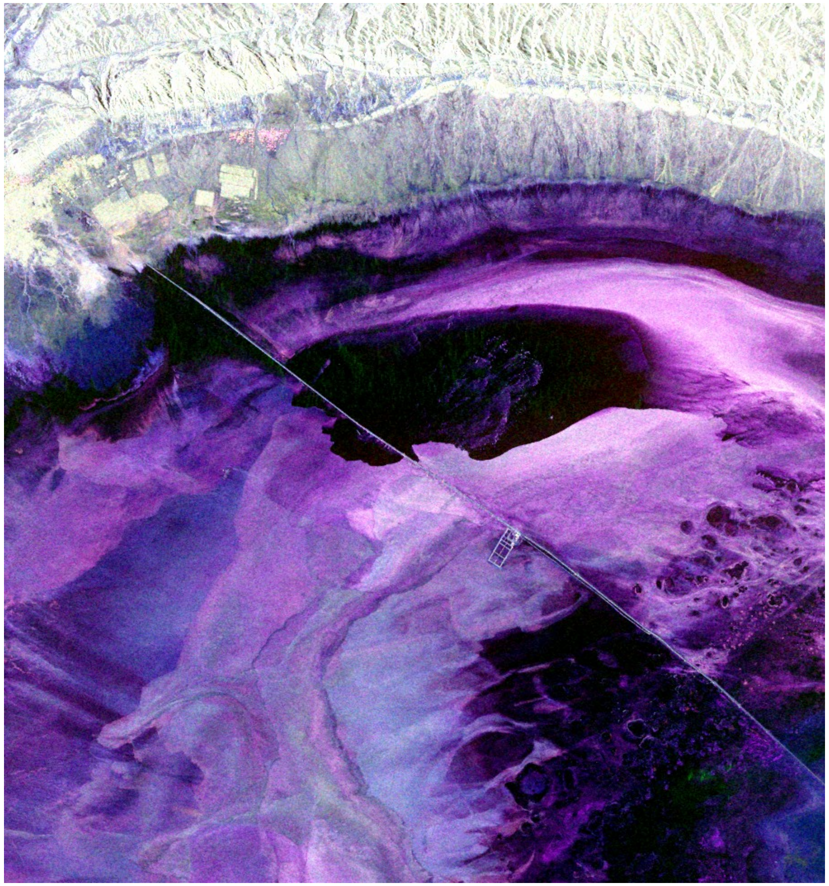
: ENVISAT - ASAR

ASCAT well suited for monitoring seasonnal dynamic


16 May
29 August
19 October
Chot El Jerid, Tunisie

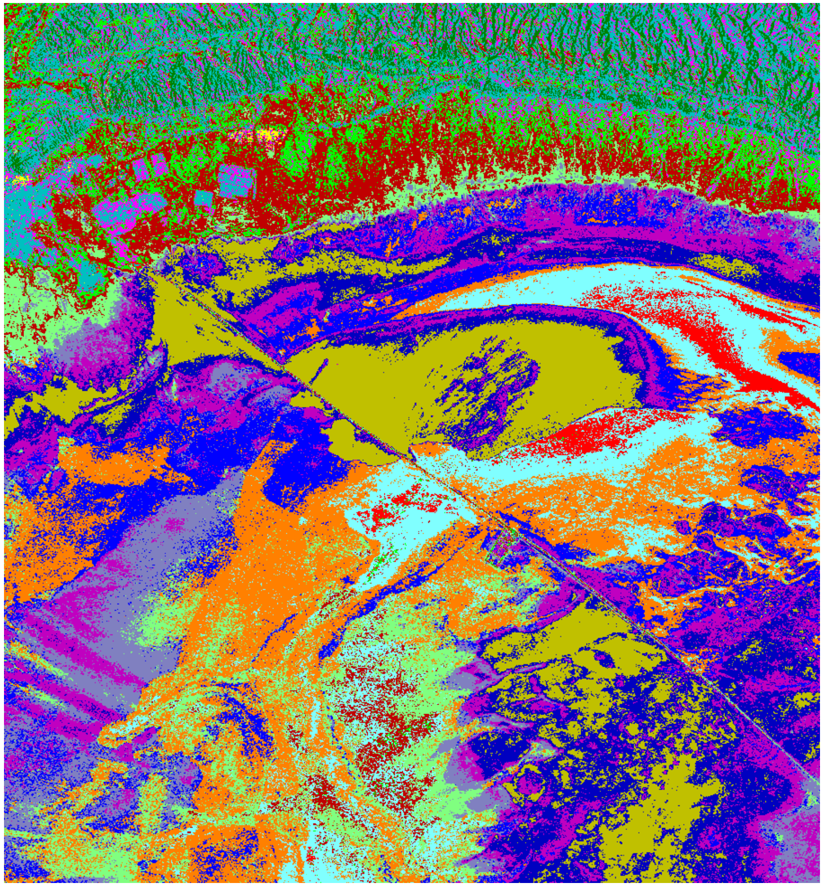
Polarimetric data classification

Chott El Djerid



Decomposition de Pauli

Radarsat-2 - 17 avril 2009



Classification H/A/alpha

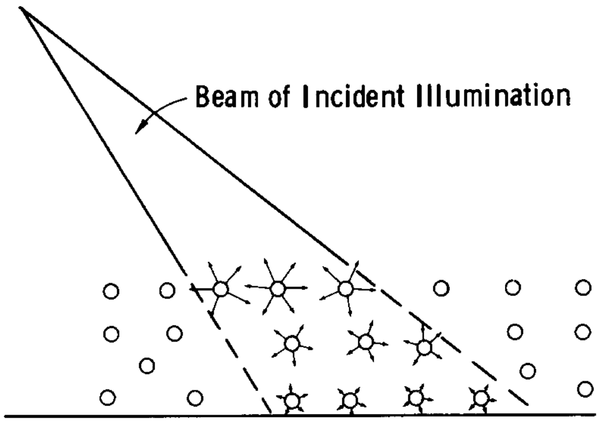
Radar response sensitivity

Over vegetation

Volume scattering

Radar images interpretation rules

Volume scattering



Inhomogeneous medium (vegetation cover)

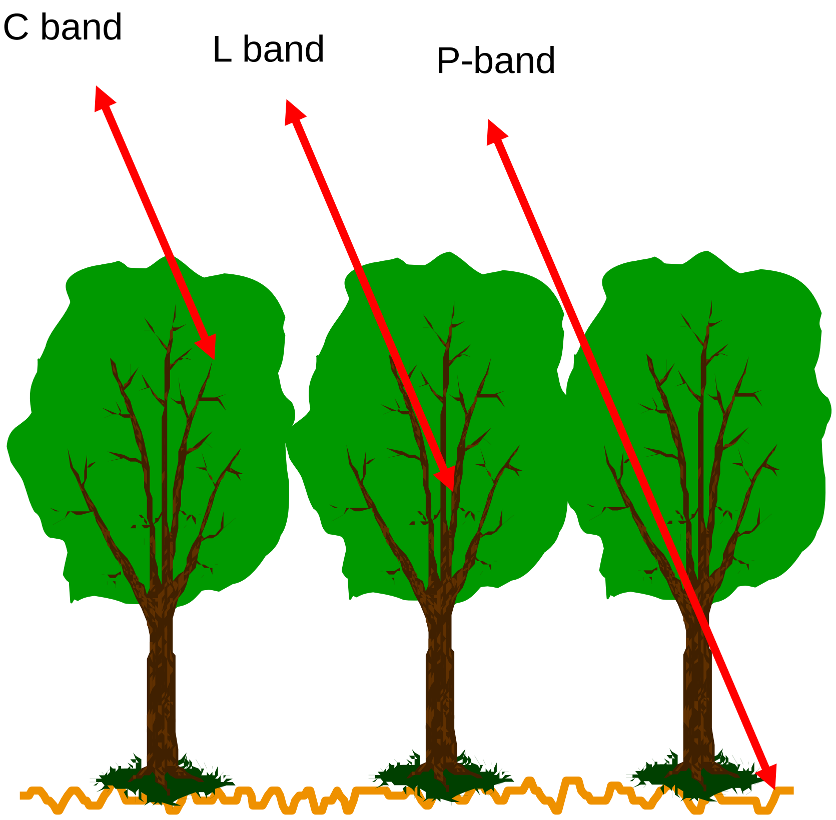
each inhomogeneity (leaves, branches….) scatters incident wave in all direction

Multiple scattering
+
Absorption

==> wave attenuation within the layer

Radar images interpretation rules

Volume scattering

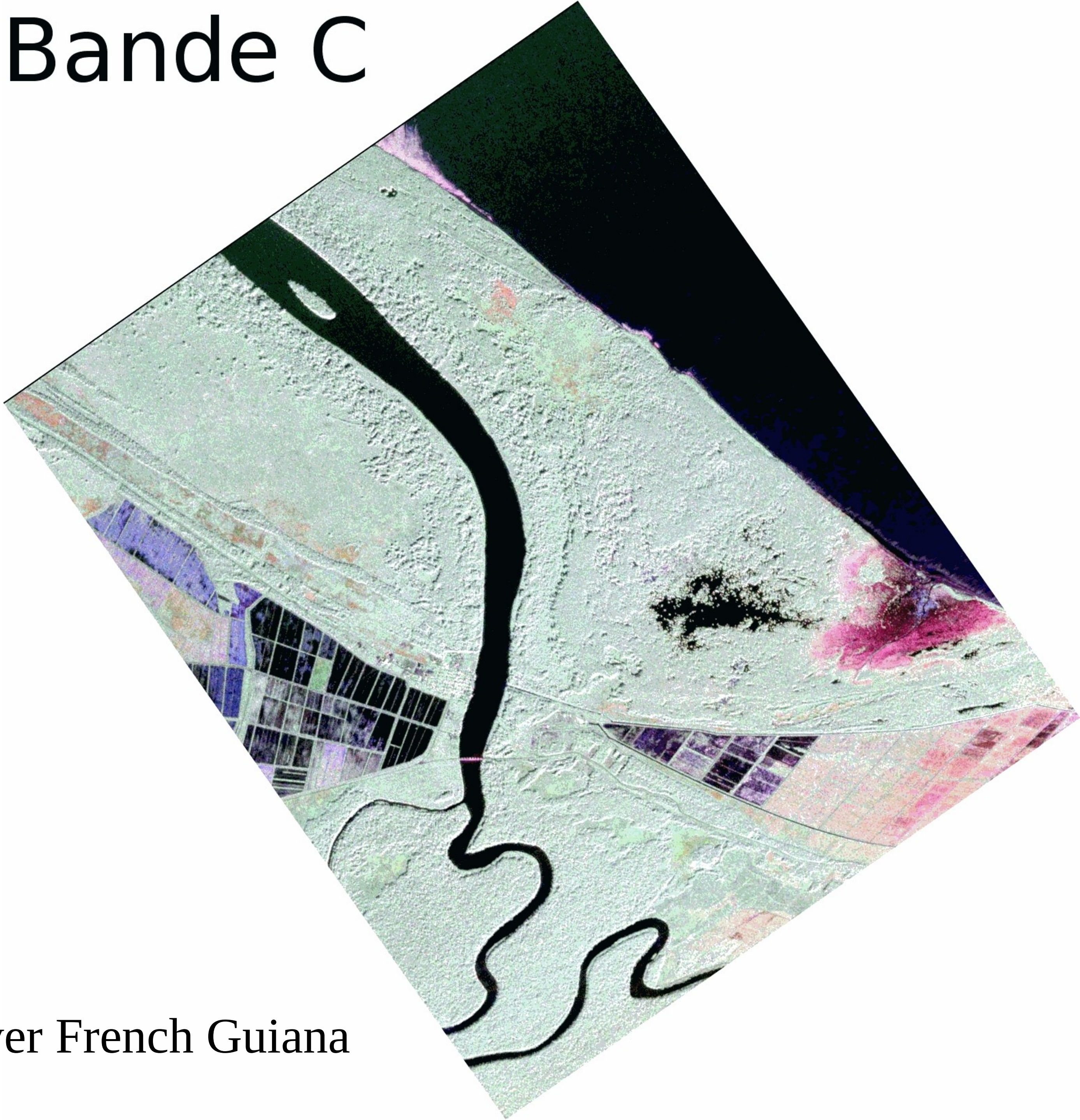


Penetration Depth:

$$\delta = \frac{\lambda}{4\pi \, \mathrm{Im}(\sqrt{\varepsilon})}$$

Penetration ↗ { Biomass ↘ ; wavelength ↗ }

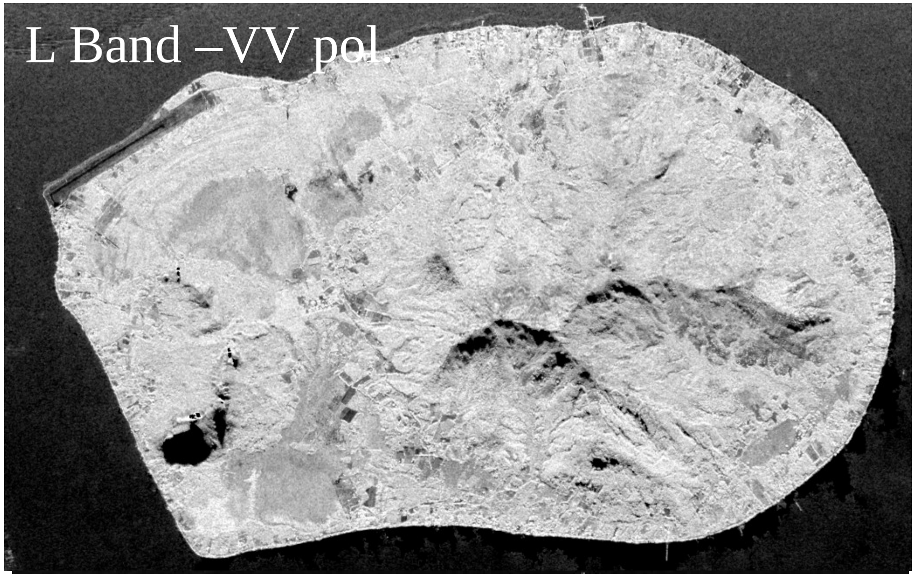
Bande C

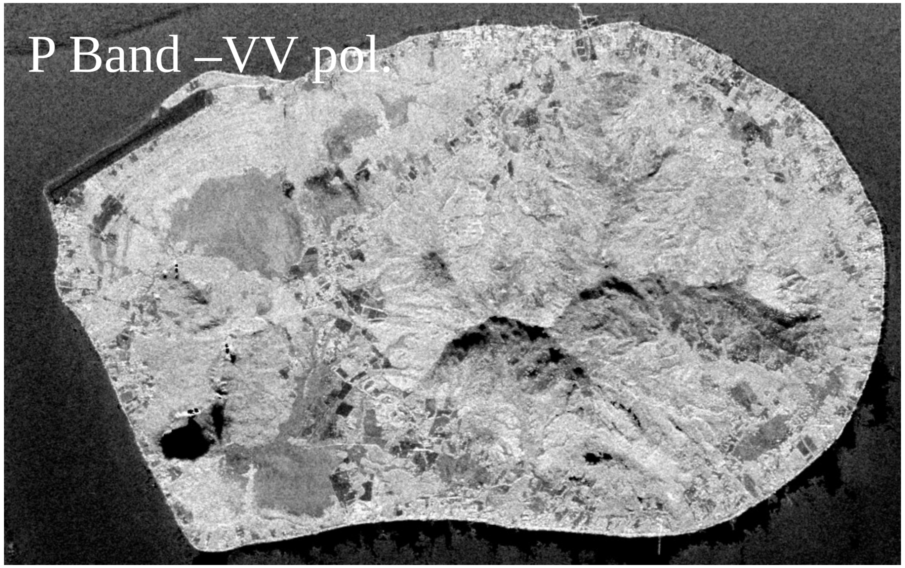


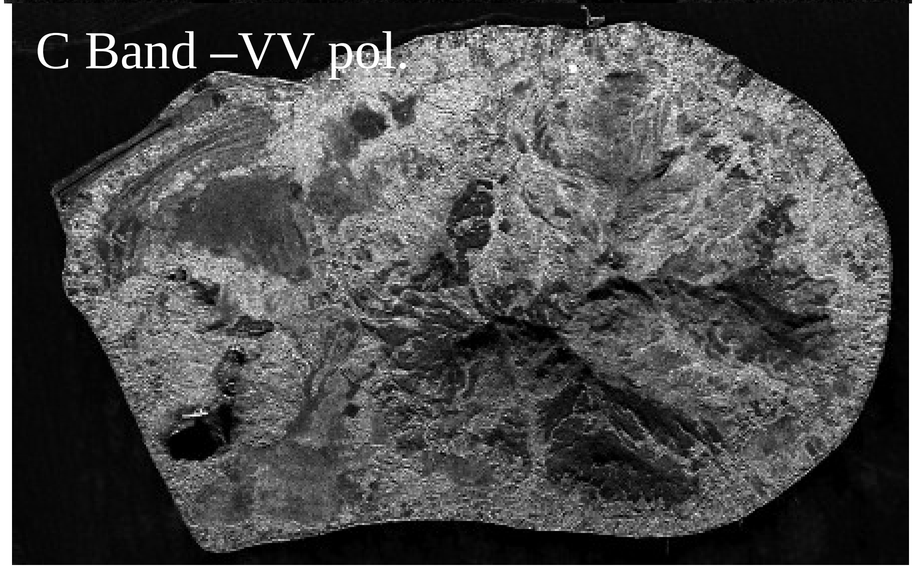
Radar response over French Guiana

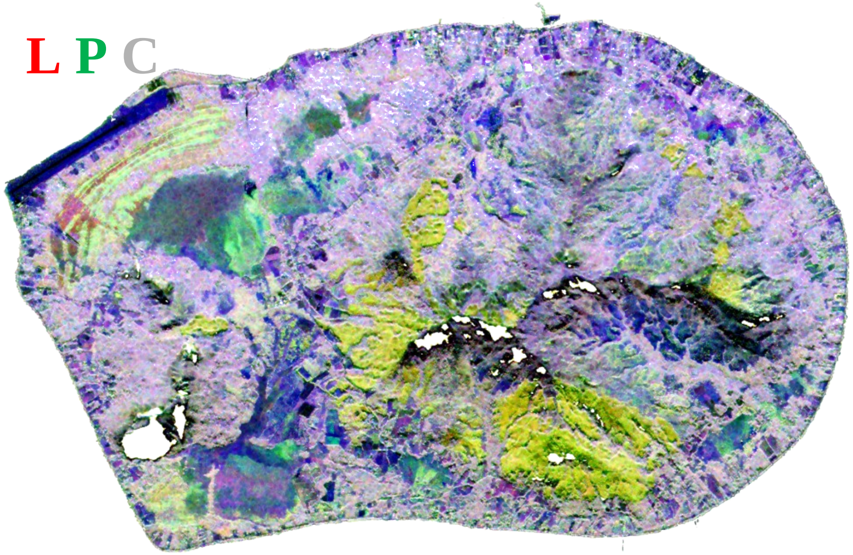
Frequency - wavelength

Tubuai Island, Vegetation discrimination

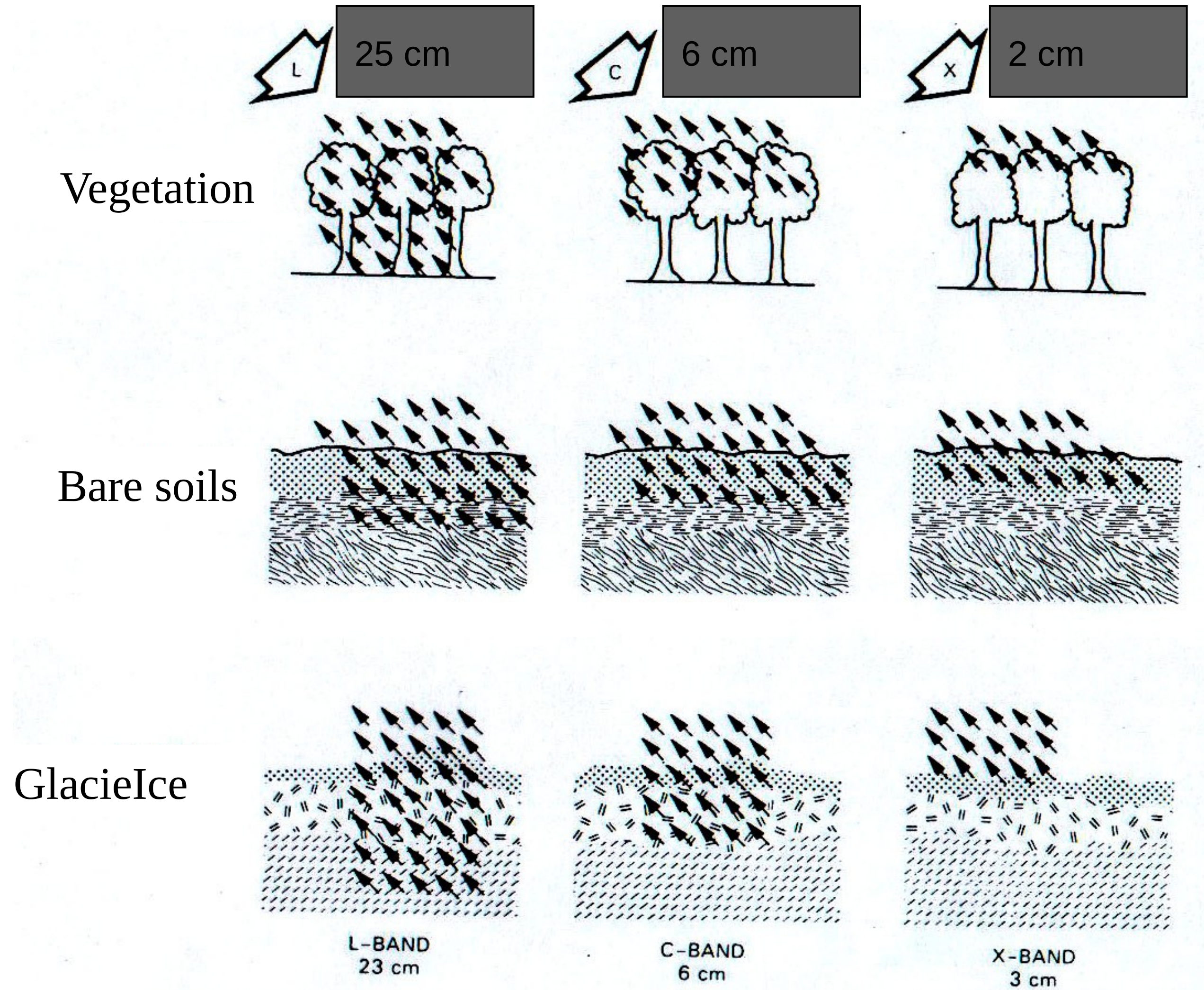








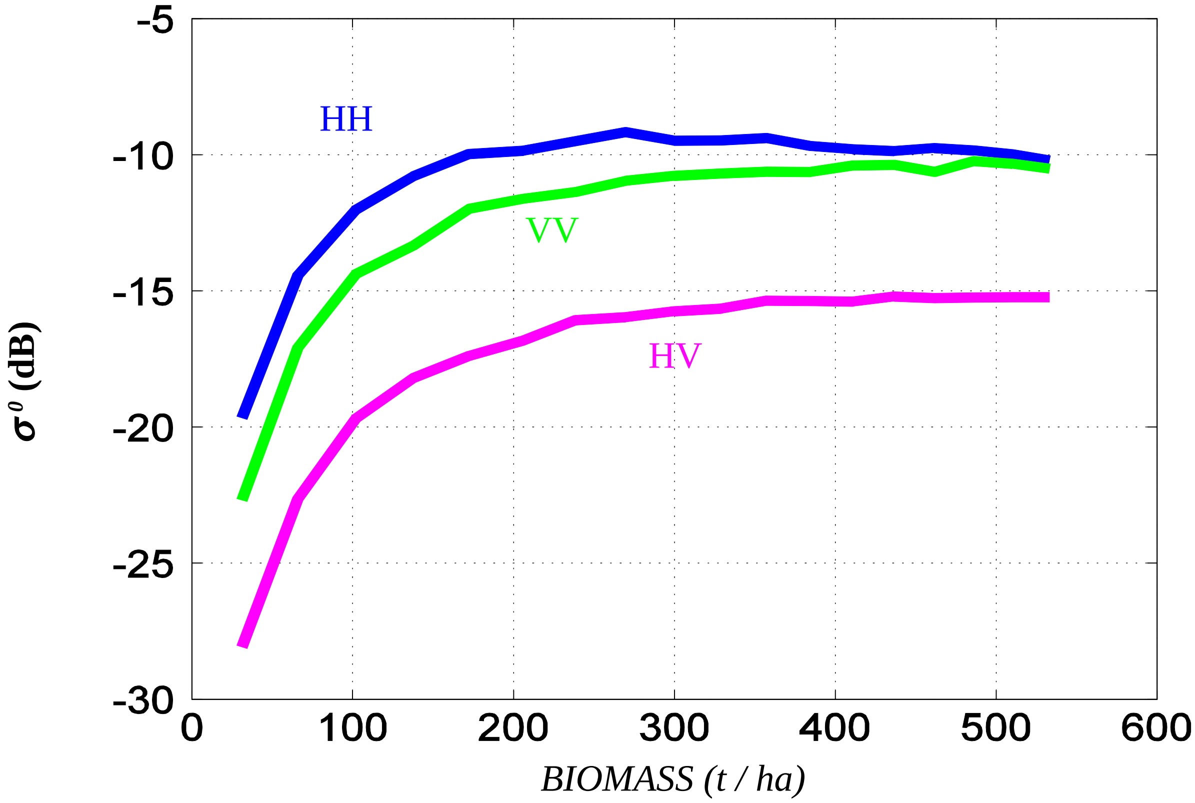
Radar response sensitivity



Penetration depth is proportional to λ

Radar images interpretation rules

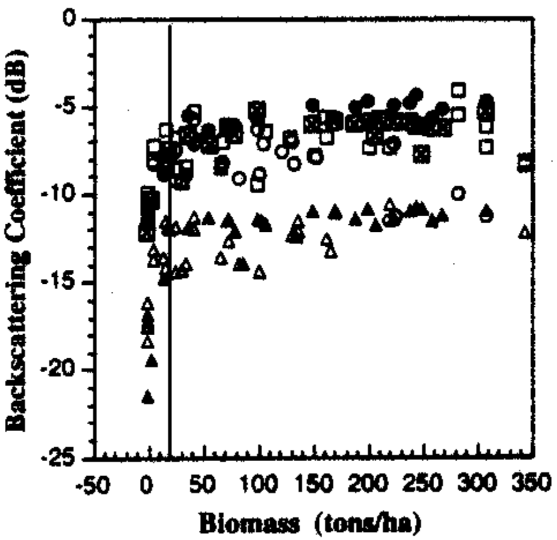
Radar response over forest



Volume Scattering

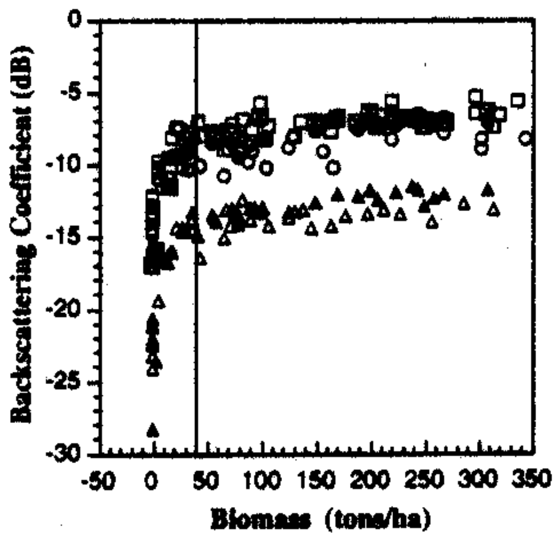
Radar saturation level with vegetation density

C band



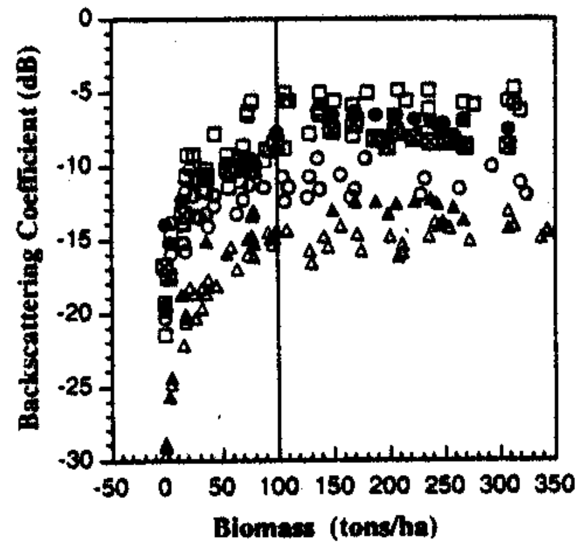
20 tons/ha

L band



40 tons/ha

P band

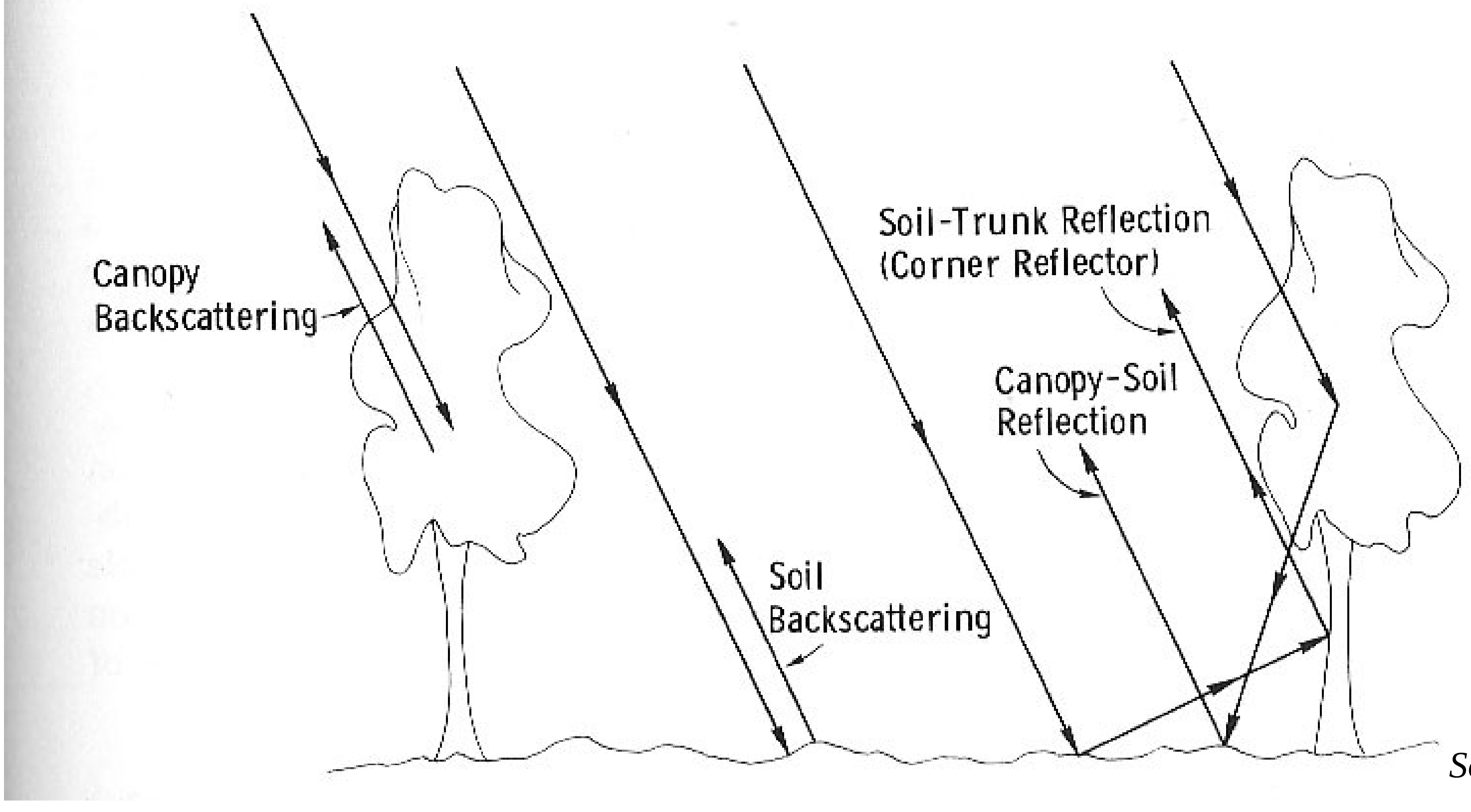


100 tons/ha

from Imhoff et al. 19?

Radar response sensitivity

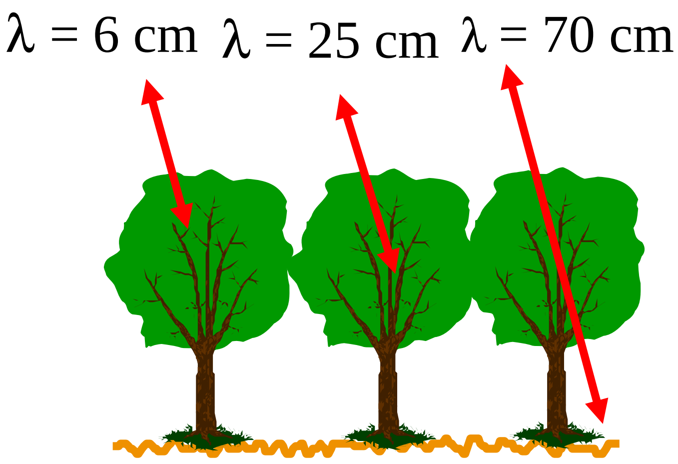
Backscattering mechanism on vegetation



Source: Ulaby et al.

Land surfaces monitoring with radar data

Radar observations sensibility



- Biomass
- Structure and moisture of vegetation
- Roughness and moisture of soils

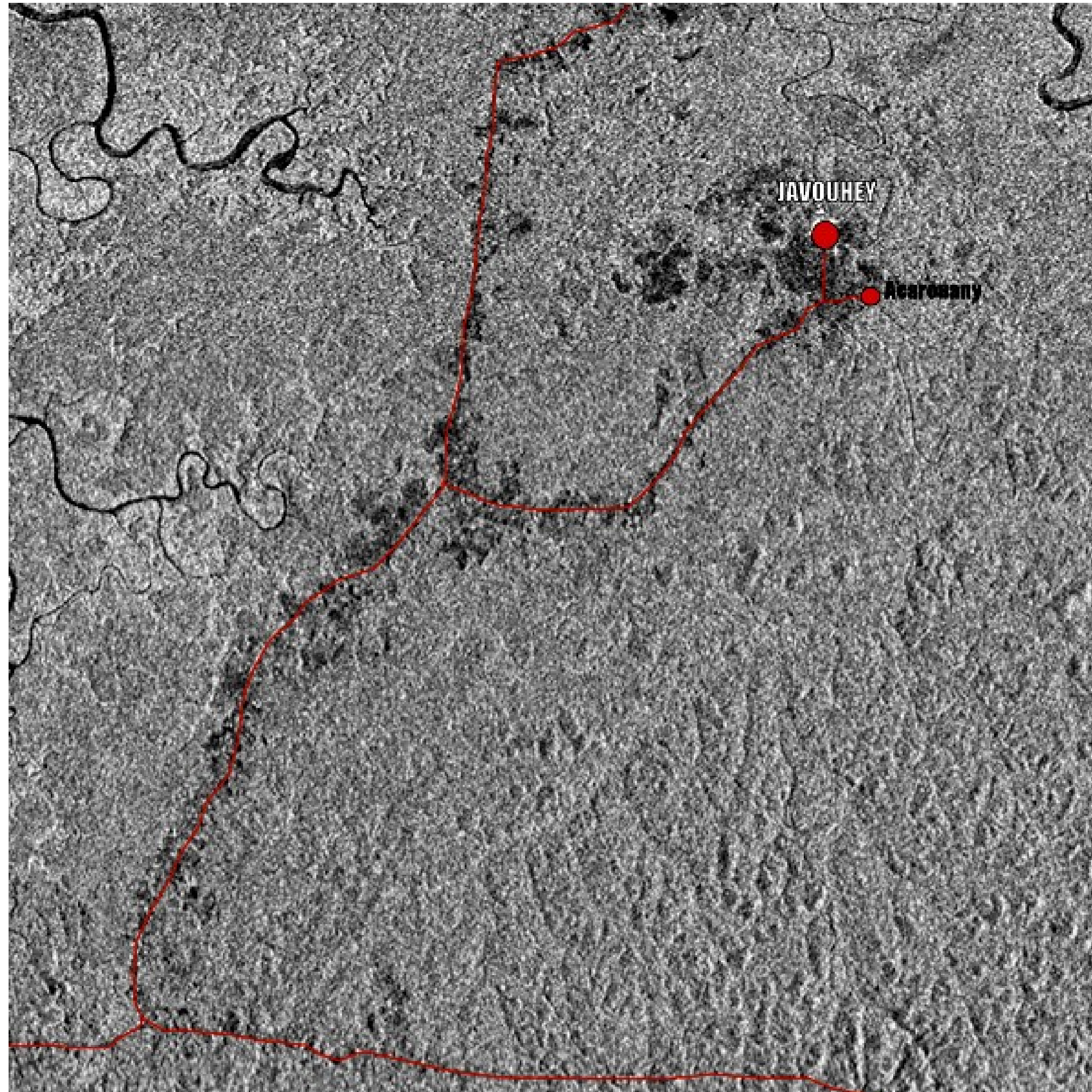
Access to key variables of ecosystem functionning

- Vegetation discrimination (type, espèces, état,….)
- Biomass (Net Primary Productivity)
- Vegetation phenology (periods of activity)
- Hydrological states of plant covers (stress, ….)
- Soil moisture

Radar response sensitivity

Local Agricultural Deforestation along road

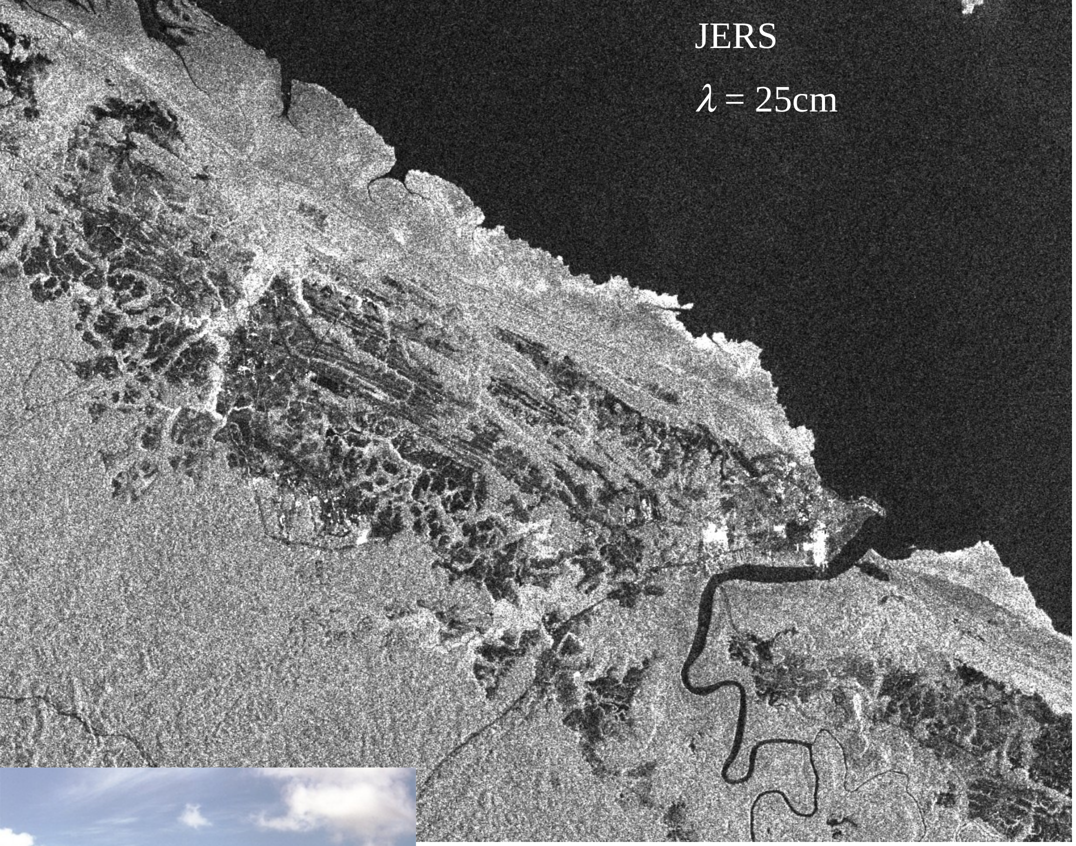
Radar response sensitivity

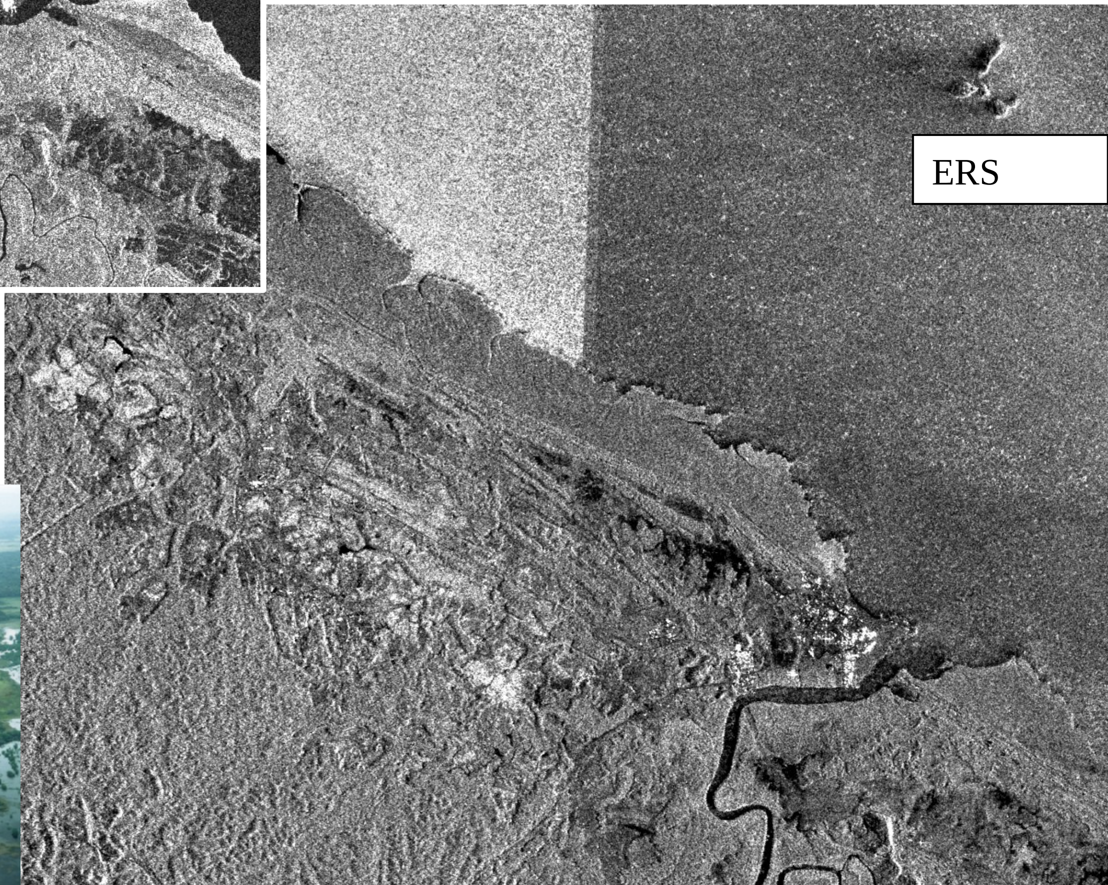


Radar response sensitivity

Cameroun (Ngaoundéré région : Cultural practice, burned area

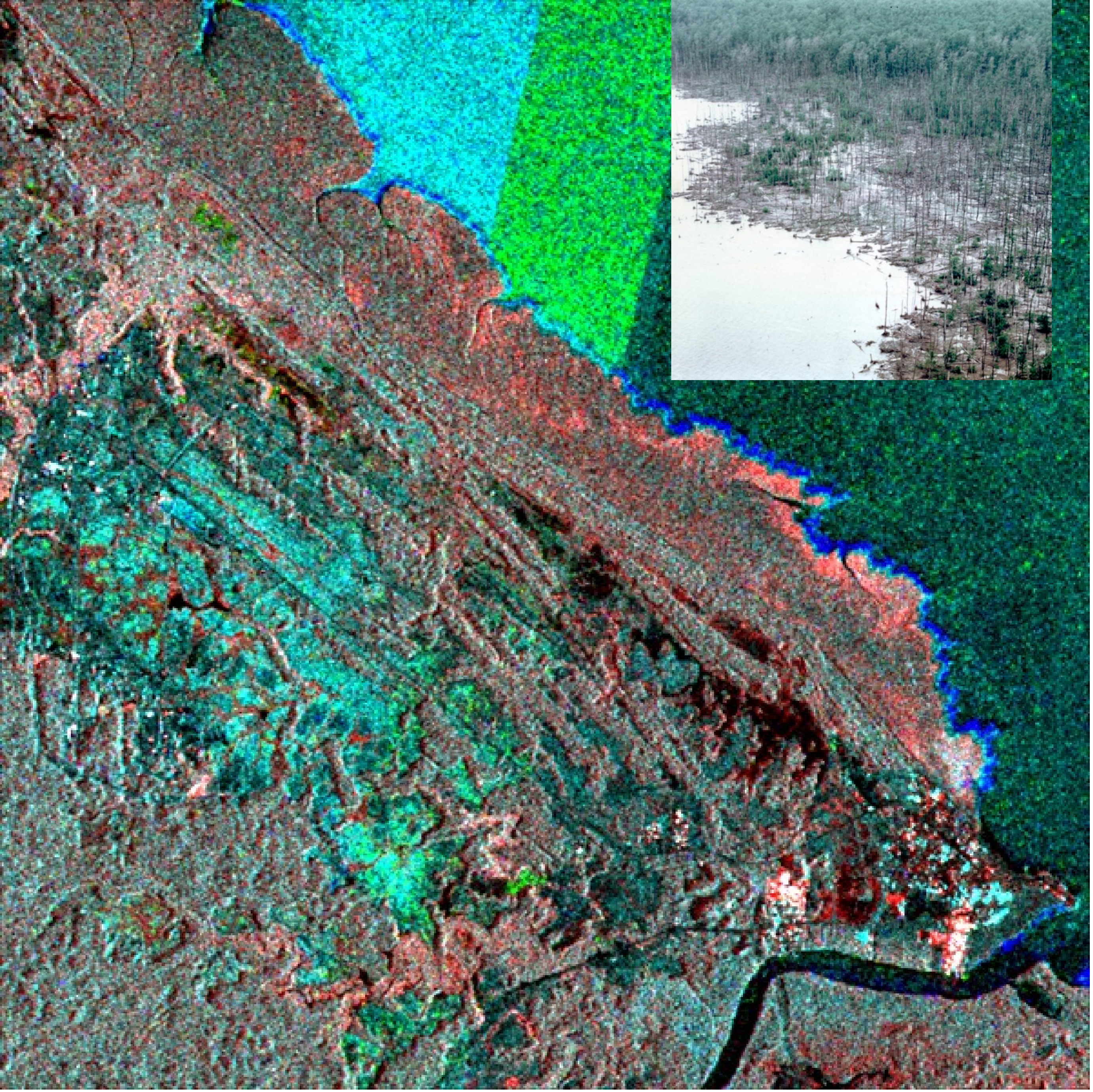
ERS C band l=6cm





Dry season

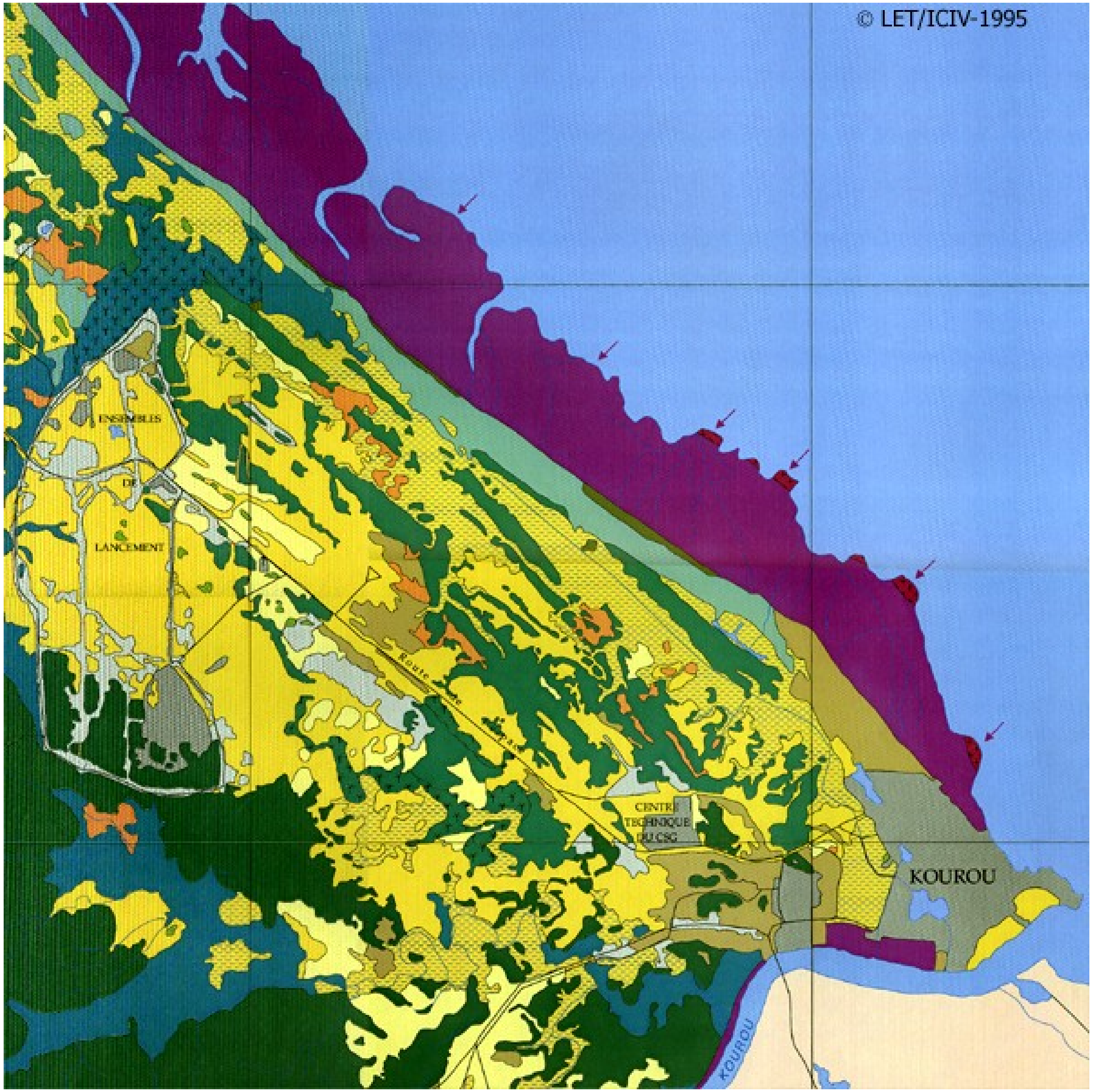
Wet season



Color Composite

ERS and **JERS**

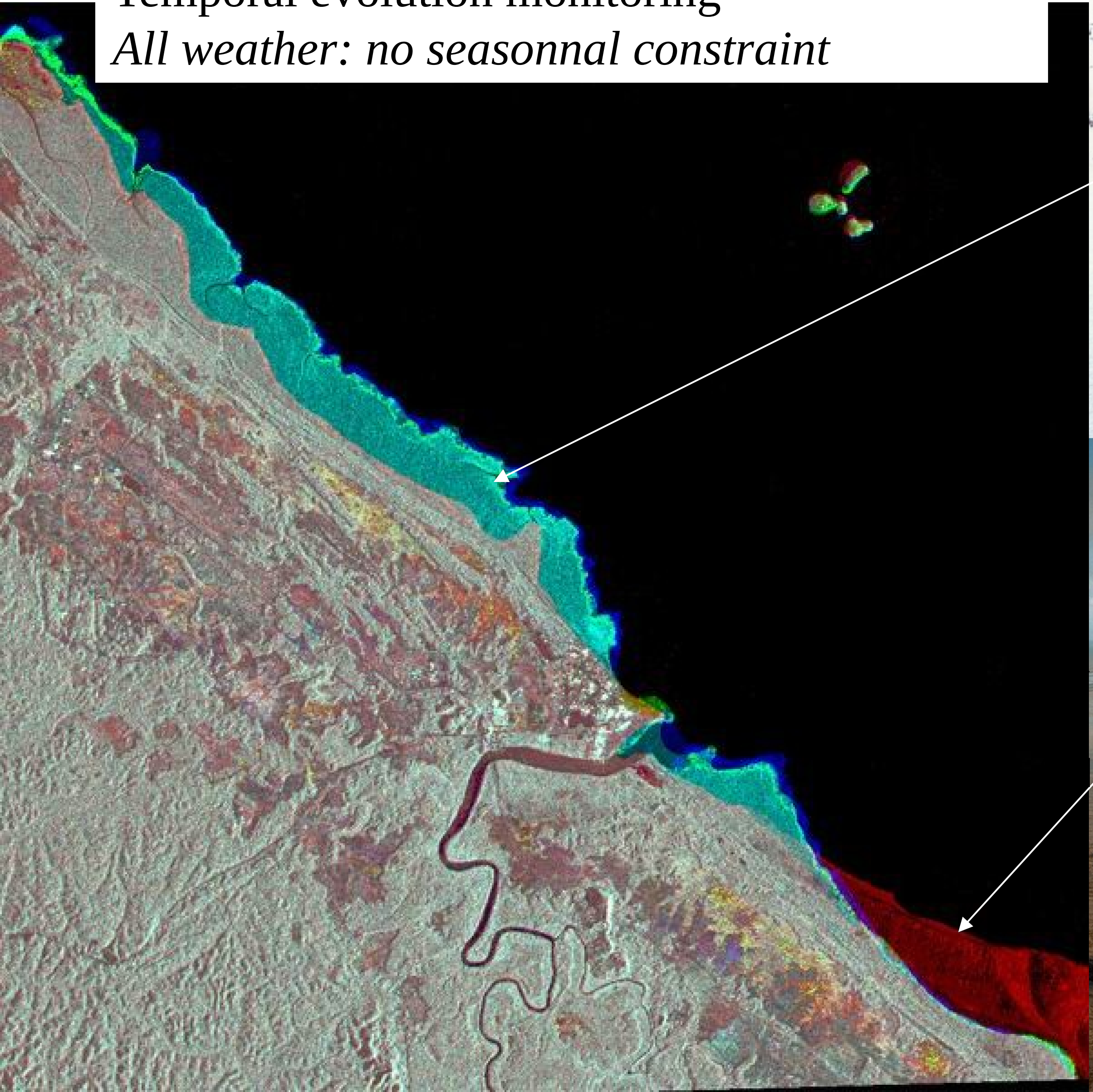
Radar response sensitivity

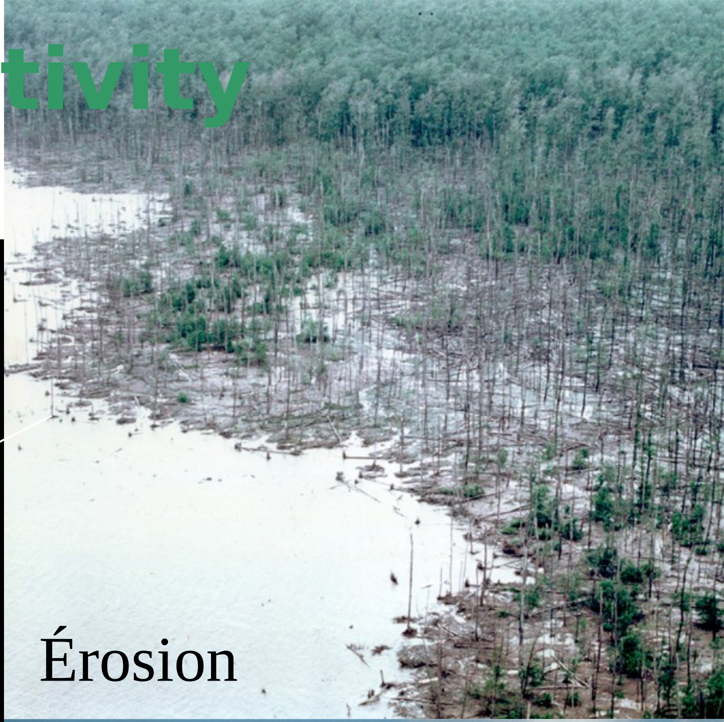


Radar response sensitivity

Temporal evolution monitoring

All weather: no seasonnal constraint



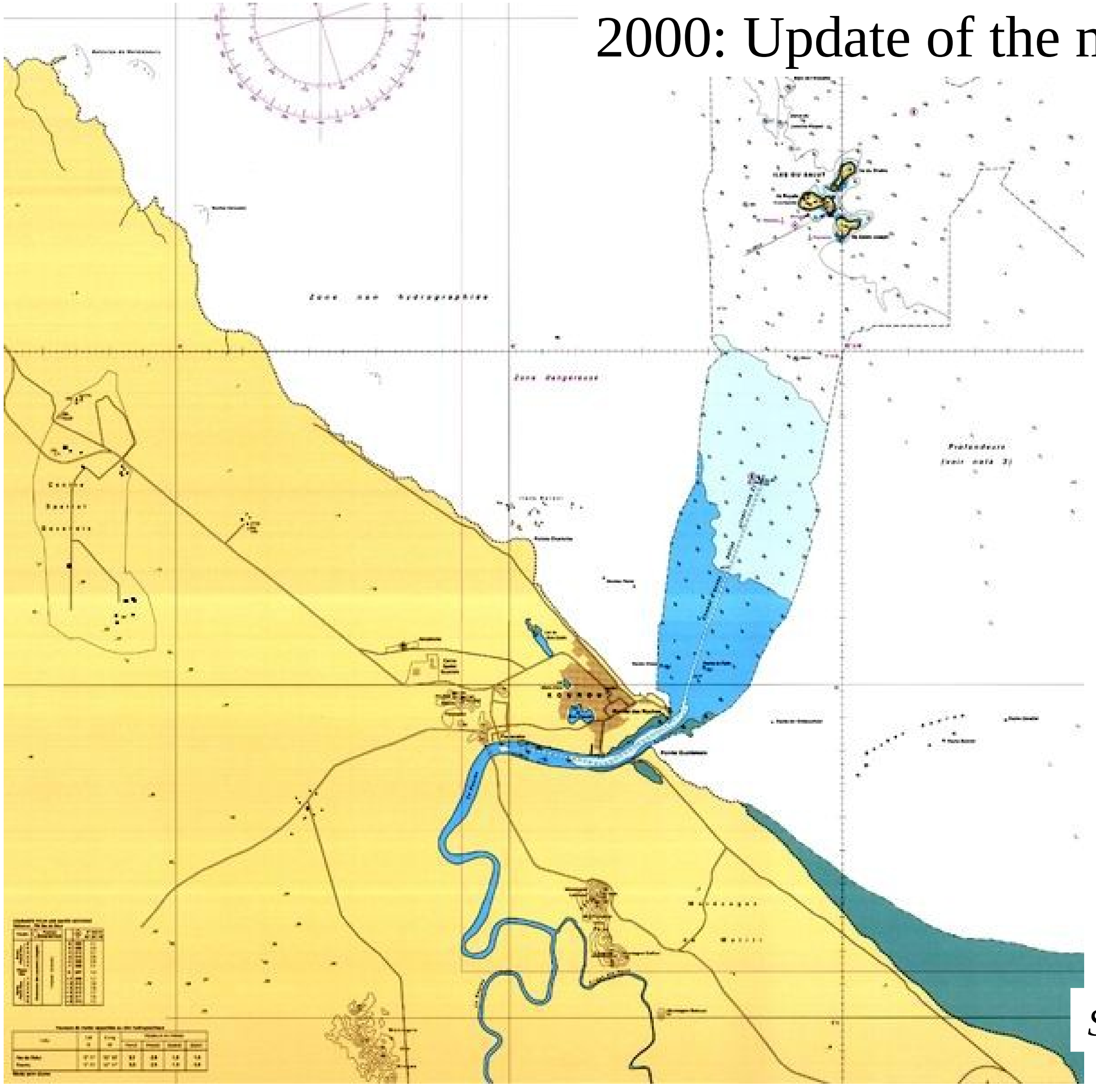


Érosion

Sédimentation

Radar response sensitivity

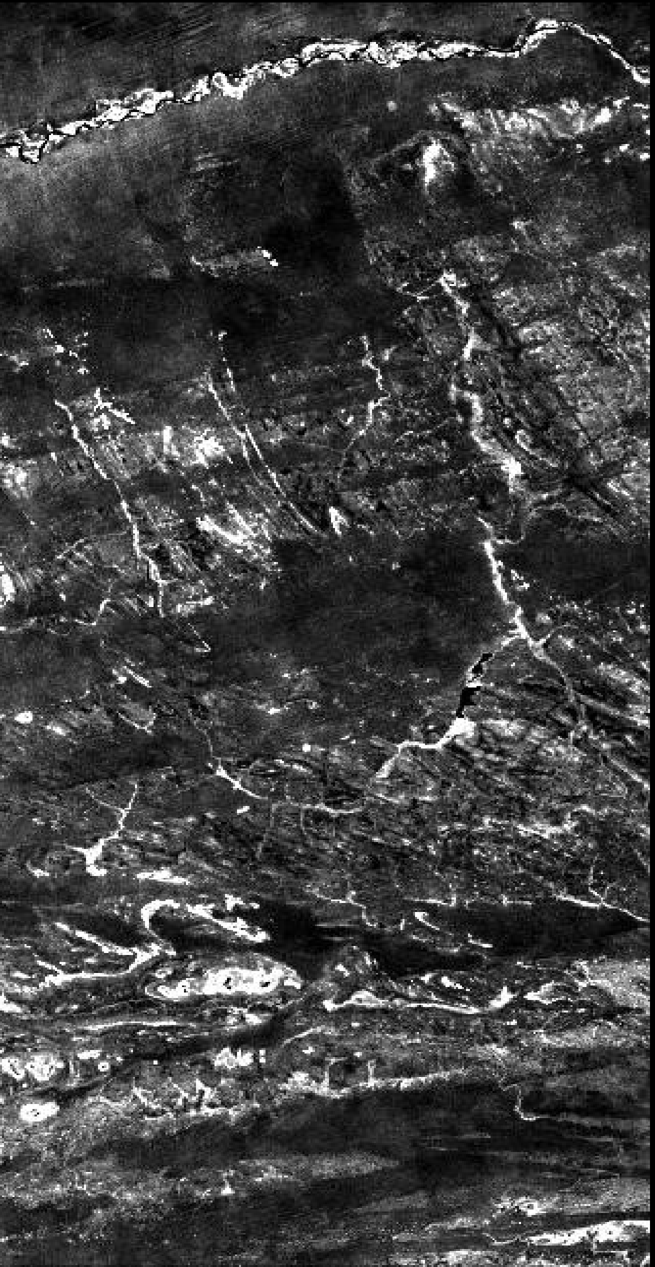
2000: Update of the marine map



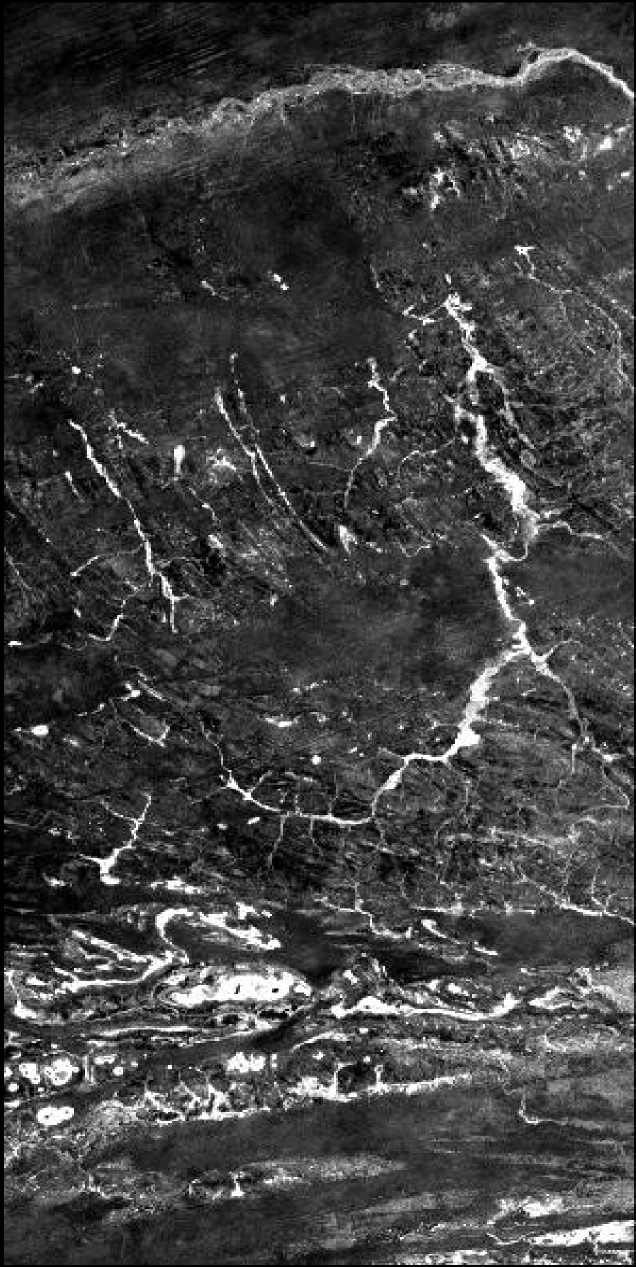
Source: SHOM/ Univ-MLV

Seasonal variations monitoring (Sahel)

ASAR (λ = 6 cm)



PALSAR (λ = 24 cm)



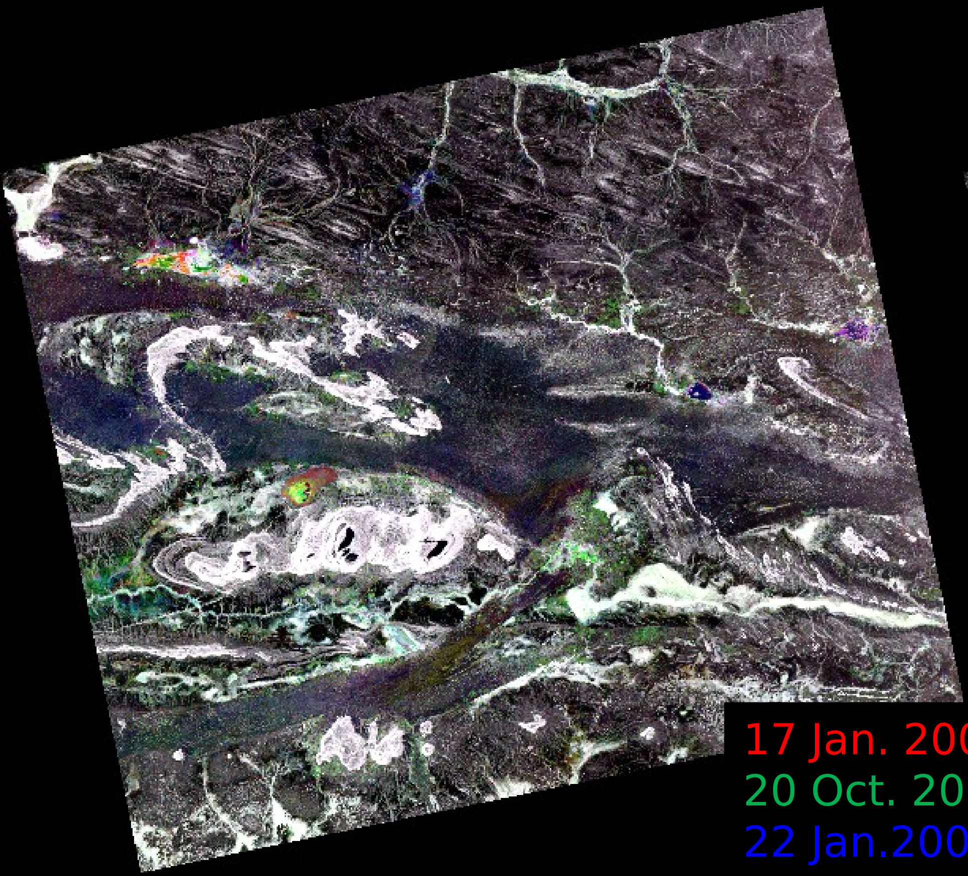
C Band (ASAR):
Sensitive to sandy and silty soils

Bande L (PALSAR)*:*
Better discrimination of geological structures

Remnant of alluvial system and lacustrine depressions

hange detection in a radar time series of 12 PALSAR images
Jan. 2007 – apr. 2009

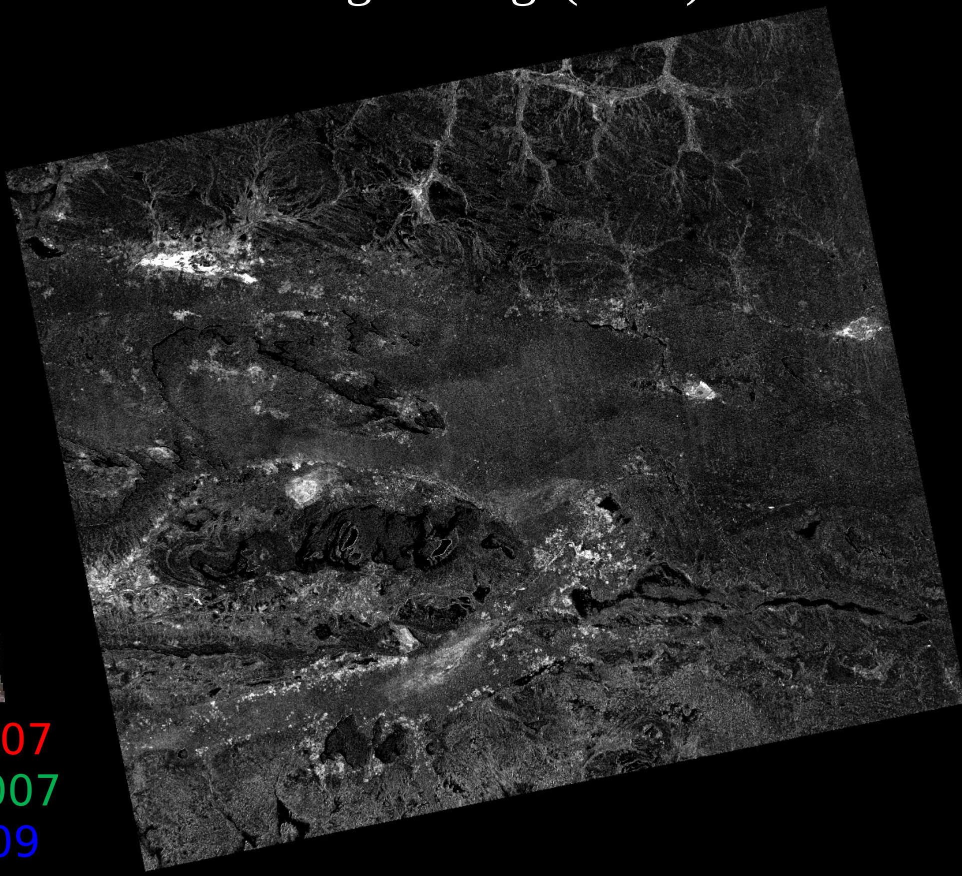
Color composite image



17 Jan. 2007
20 Oct. 2007
22 Jan.2009

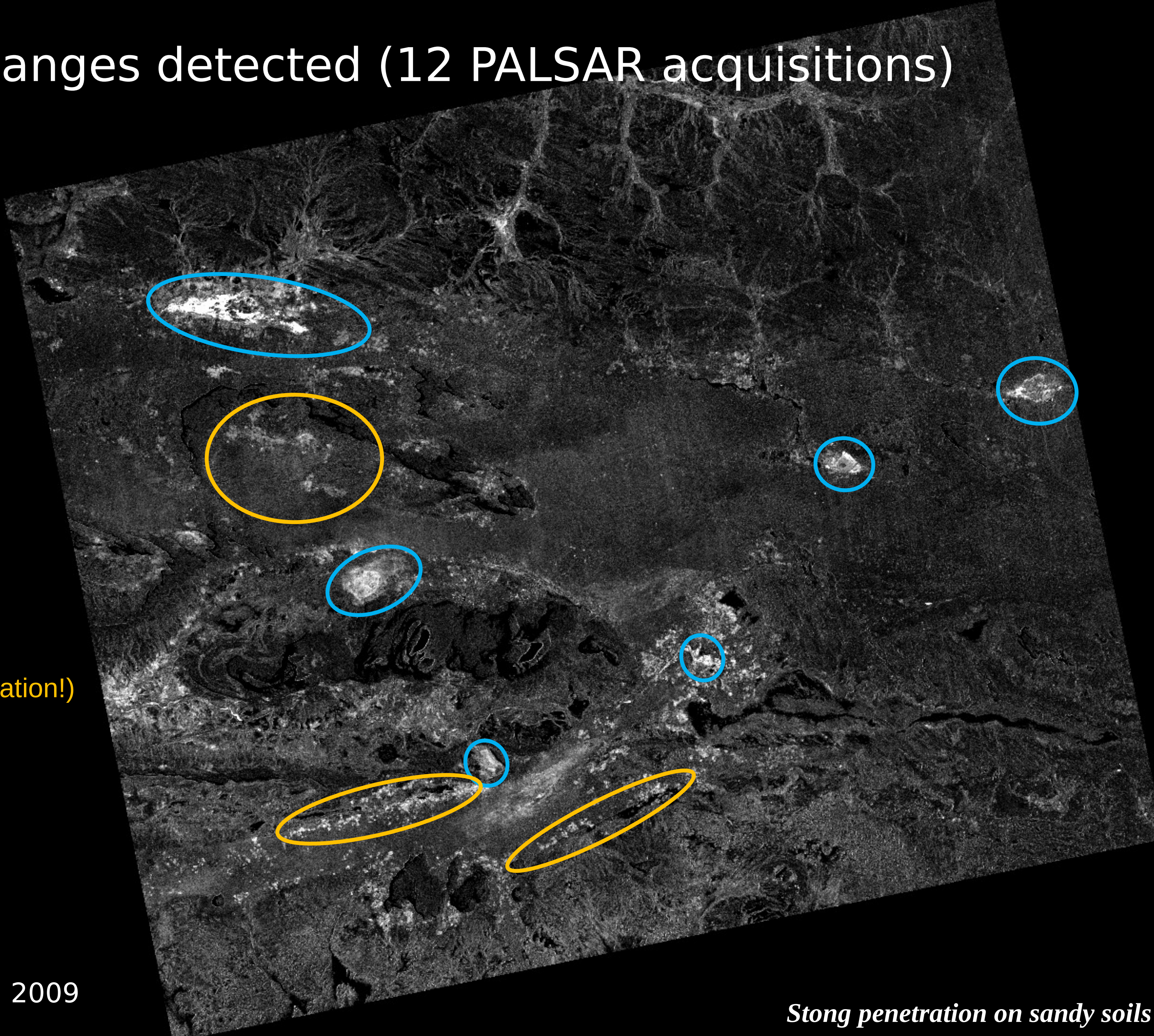
PALSAR Fine Beam
HH polarization

Changes image(HSV)



Jan. 2007 – Apr. 2009

mporal changes detected (12 PALSAR acquisitions)



ponds

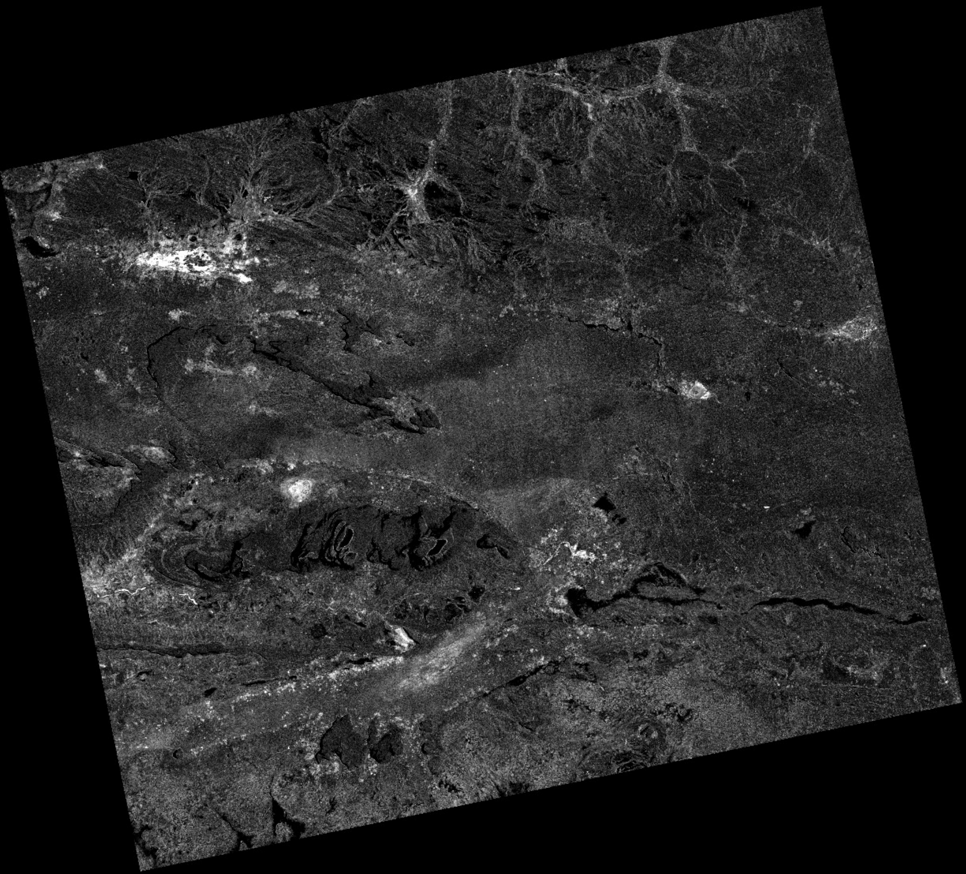
Millet fields
(depend on orientation!)

PALSAR
HH polarisation
Jan. 2007 – Mar. 2009

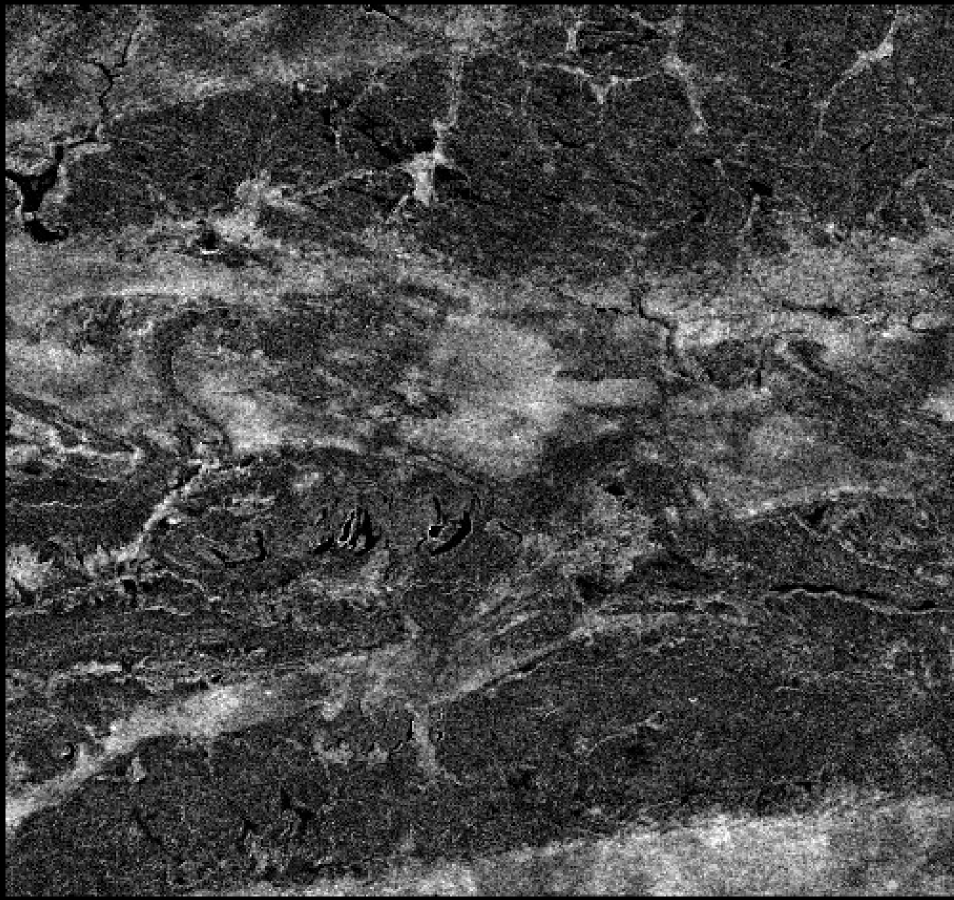
Stong penetration on sandy soils

Changes detection: C band / L band comparaison

PALSAR (λ = 24 cm)

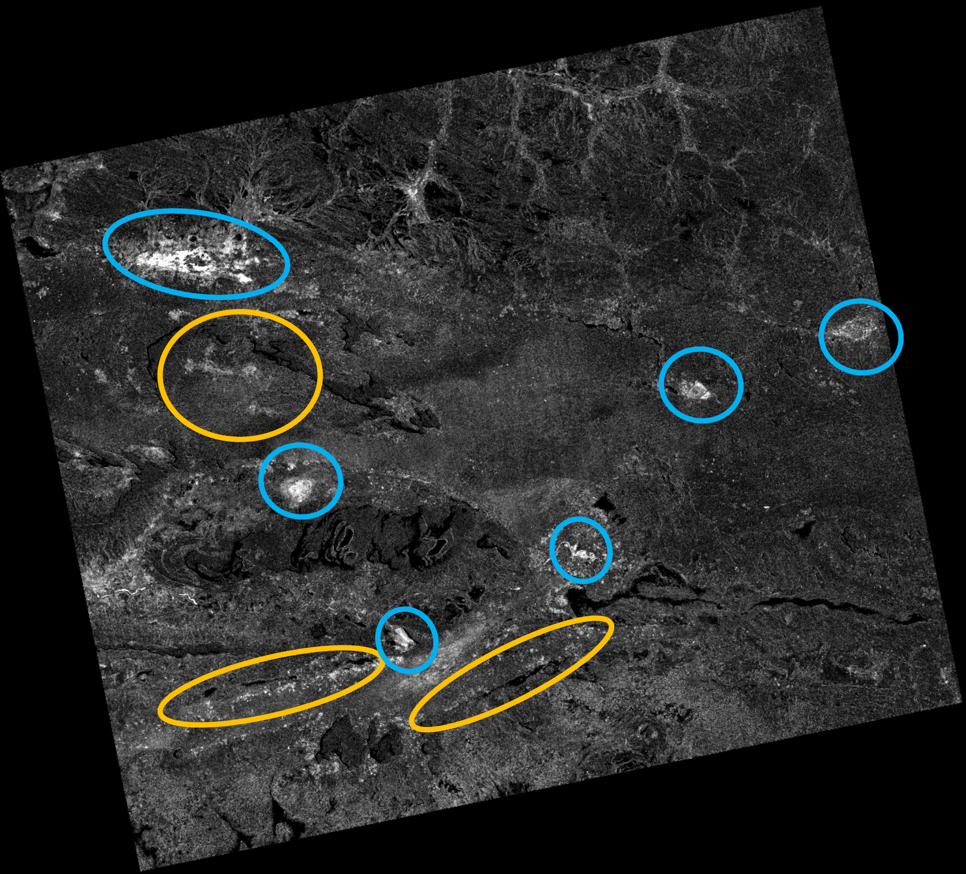


ASAR (λ = 6 cm)

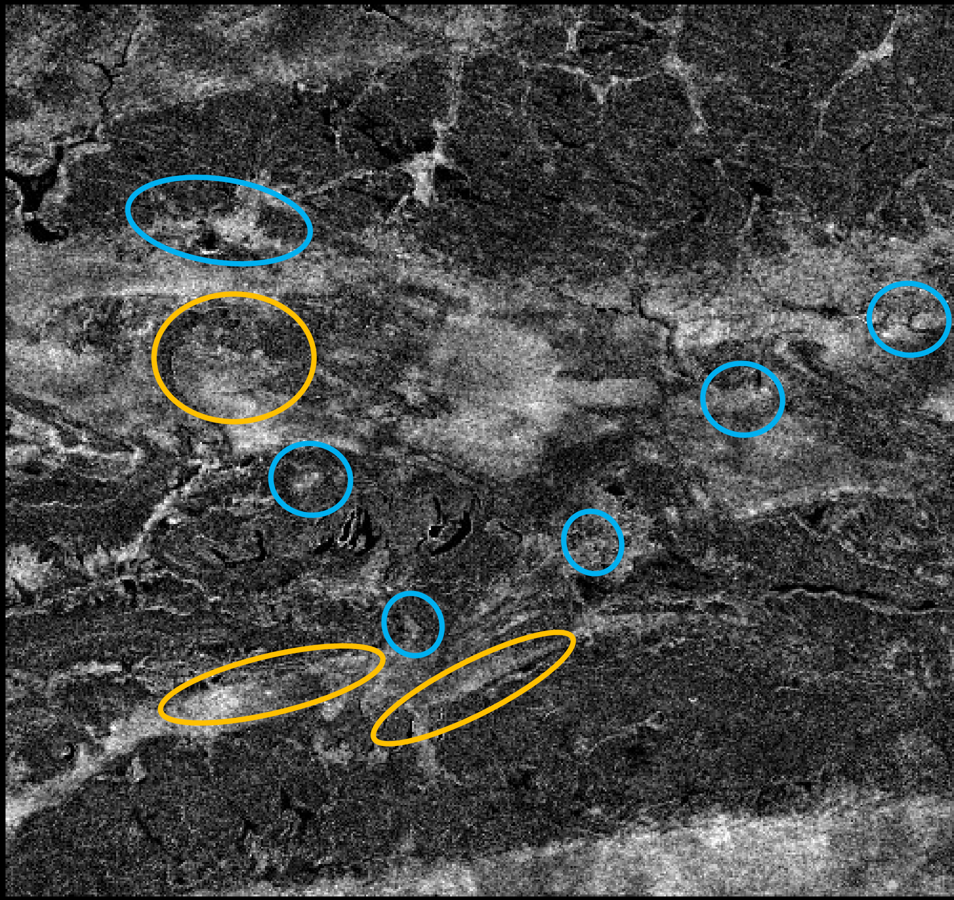


Changes detection: C band / L band comparaison

PALSAR (λ = 24 cm)



ASAR (λ = 6 cm)



Strong penetration on sandy soils
ponds
Millet fields

Weak penetration on sandy soils
surface states changes
sandy soils, ponds