Radar Fundamentals

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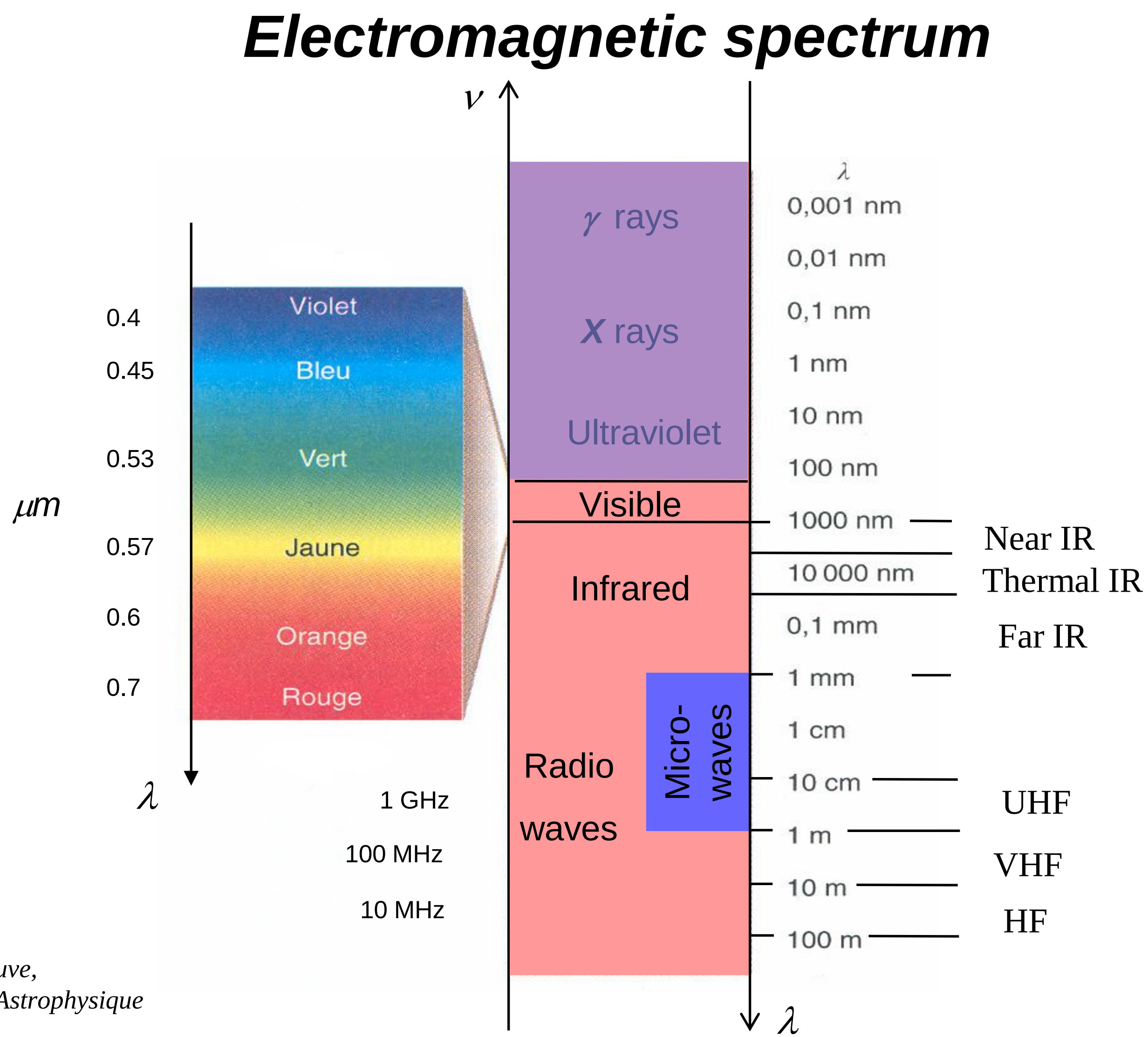
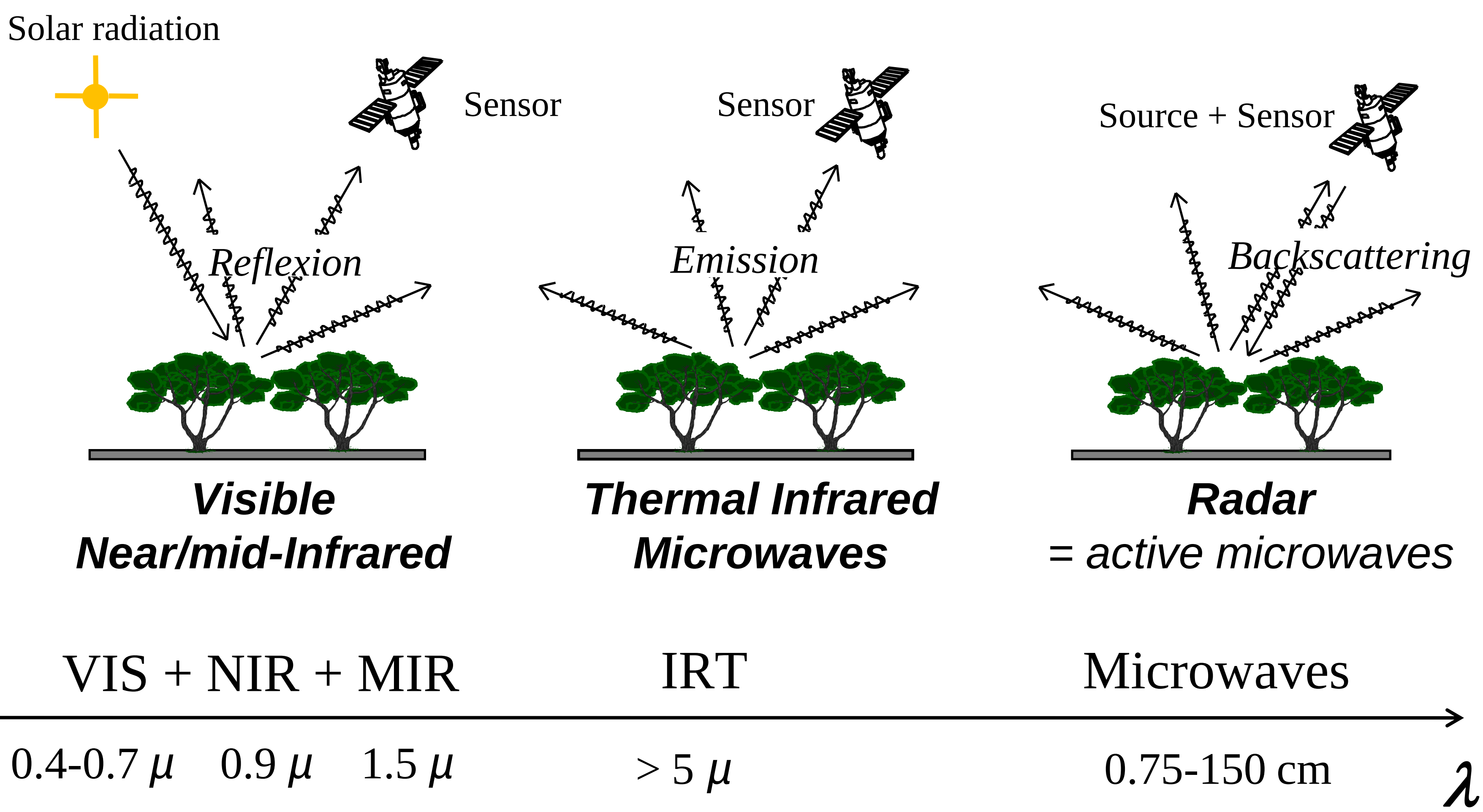
Electromagnetic coherent wave

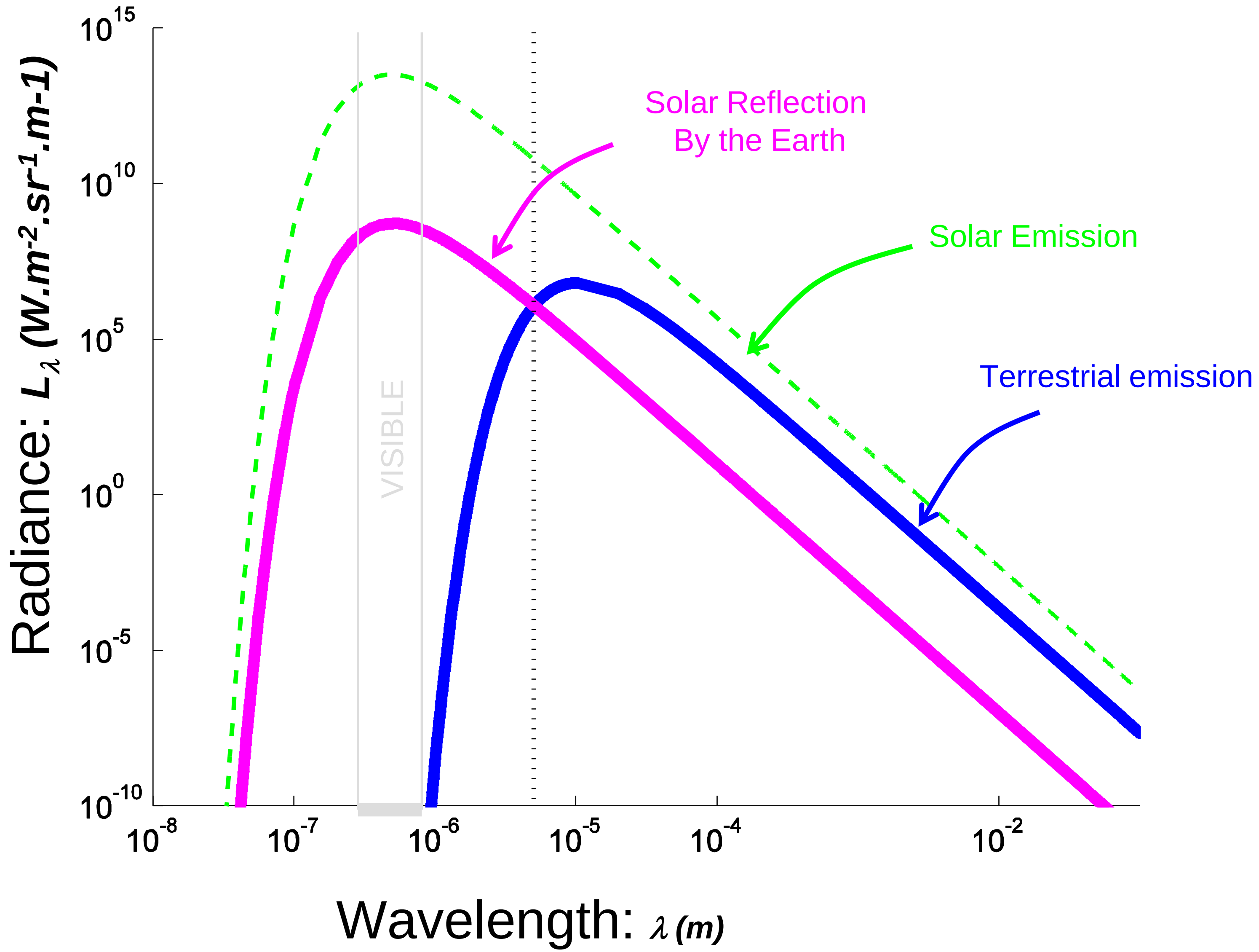


From *Seguin & Villeneuve, Astromnomie et Astrophysique*

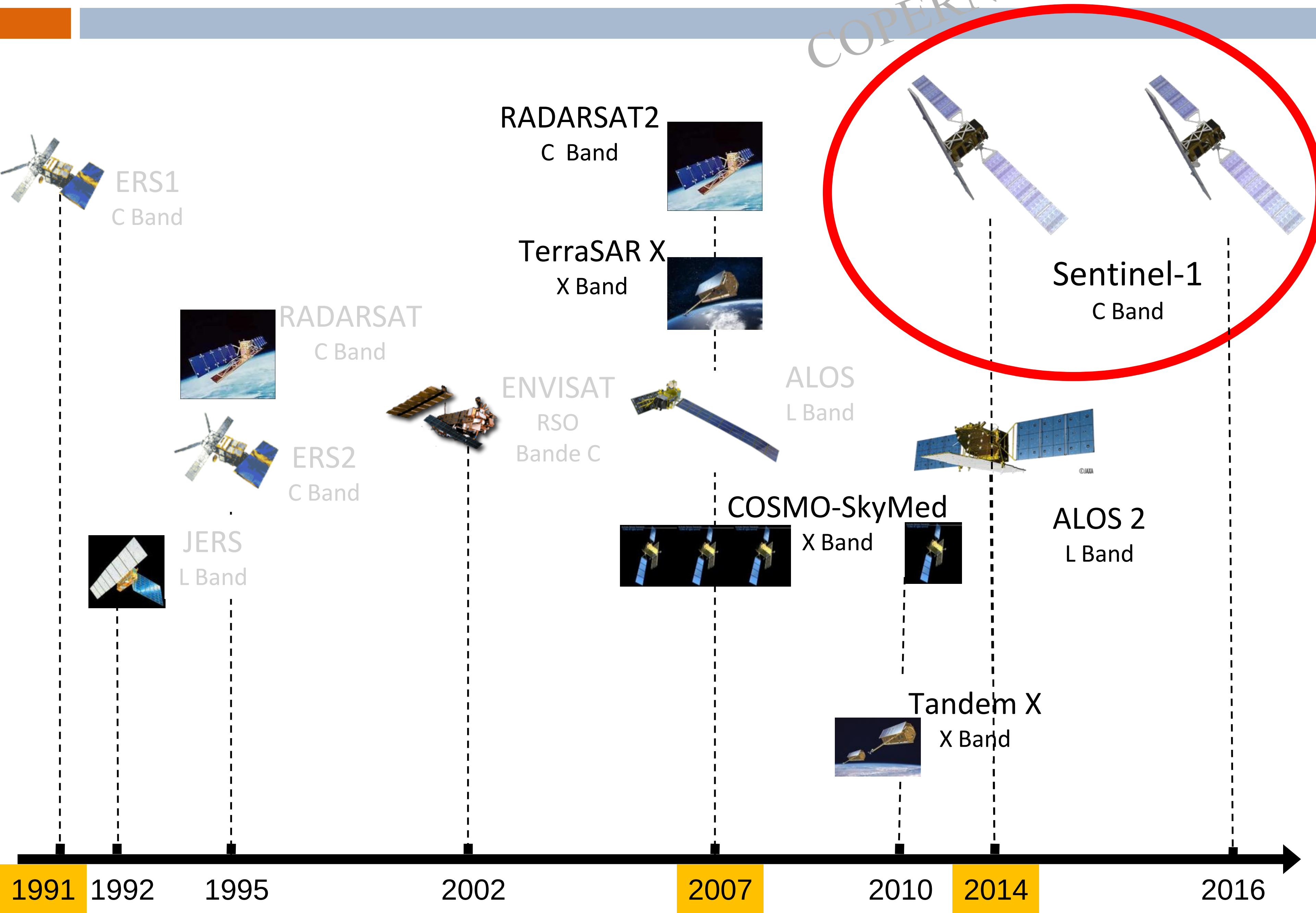
Remote Sensing observations mode



The electromagnetic radiation Coming from the Earth



SPACEBORNE SAR SENSORS



SAR data: summary

Name	*Acquisition period*	*Band Frequency*	*Polarization mode*	*Spatial resolution (m)*	*Revisit time (days)*	*Scene cover (km)*
ERS-1 / 2	91 - 11	C	VV	20	35	185x185
JERS	92 - 98	L	HH	20	44	75 x 75
Radarsat	95 – 13	C	HH	10-100	24	35 x 500
ASAR	01-13	C	1 or 2 pol. HH/HV/VV	30-1000	few -35	100x500
PALSAR	07-11	L	Polarimetric HH/HV/VV	10-100	few-24	100-500
Radarsat-2	2007 -	C	Polarimetric HH/HV/VV	1-15	5 to 10	NA
TerraSAR-X	2007 -	X	1 or 2 pol. HH/HV/VV	1-20	few-11	5-100
Cosmo-Skymed	2007 -	X	1 or 2 pol HH/HV/VV	1-100	12 h	10-200
SAOCOM	2015	L	Polarimetric HH/HV/VV	7-100	few-16	60-320
Sentinel 1	2015	C	1 or 2 pol HH/HV/VV	5 - 100m	few-12	80-400
ALOS-2	2015	L	Polarimetric HH/HV/VV	3-100	few-14	25-350

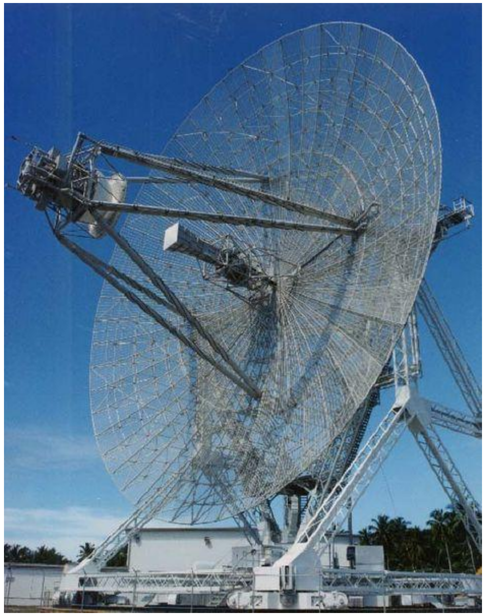
Radar Fundamentals

RADAR:

RAdio **D**etection **A**nd **R**anging

Emition of emw

Reception backscattered echoes



US Army

Road RADAR (© US police)

Imaging RADAR PALSAR (© NASDA)

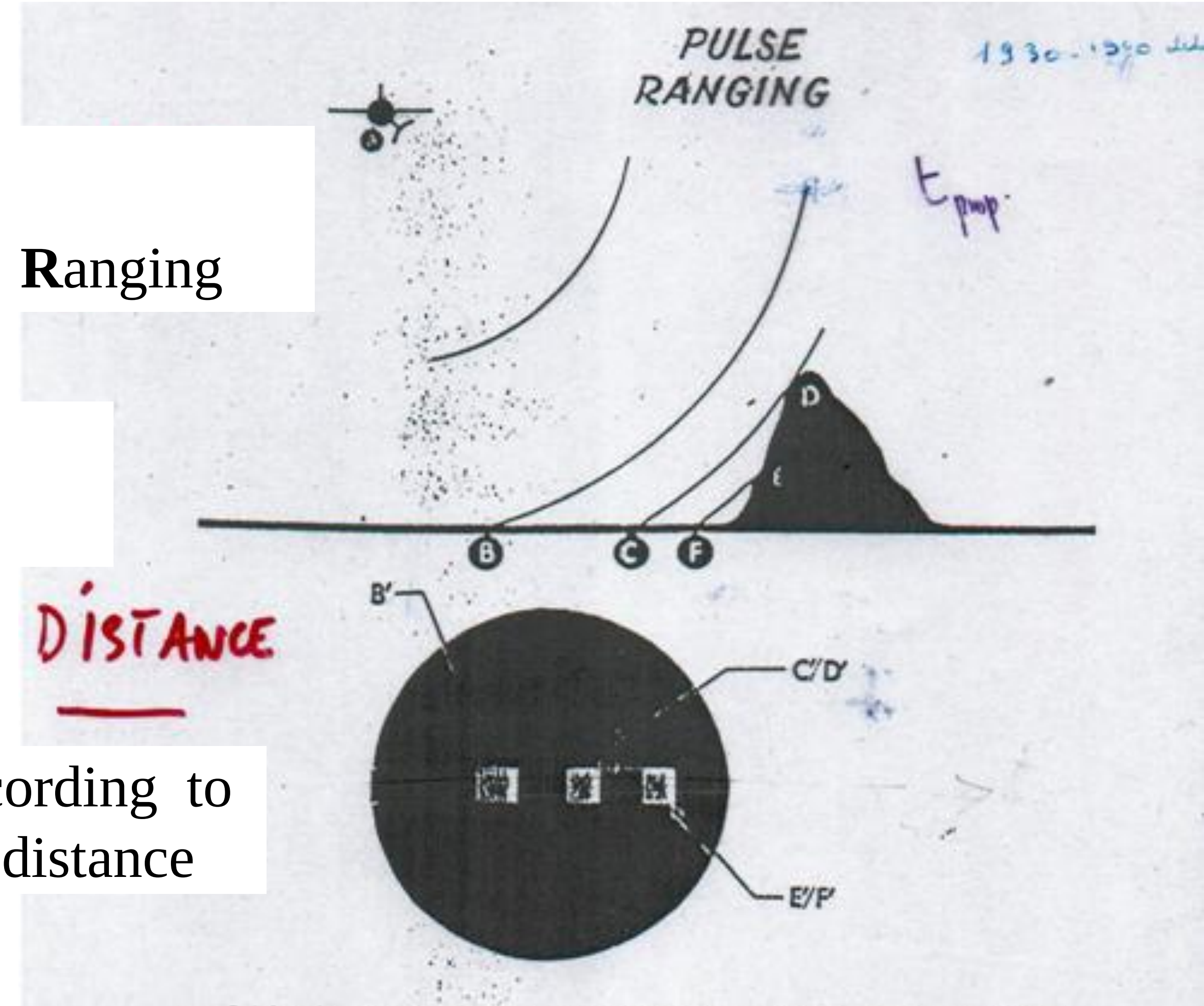
Radar Fundamentals

RADAR:

RAdio **D**etection **A**nd **R**anging

Active mode
with **coherent wave**

Echoes are **ranged** according to
Antenna – target distance

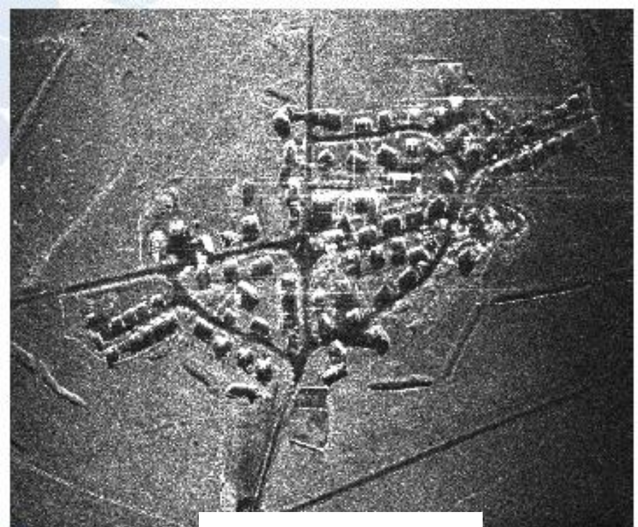


ure 3.4 Imaging process and geometry of an image line (courtesy of Loral Defense Systems).

Radar Fundamentals

Active mode ➔ night acquisition

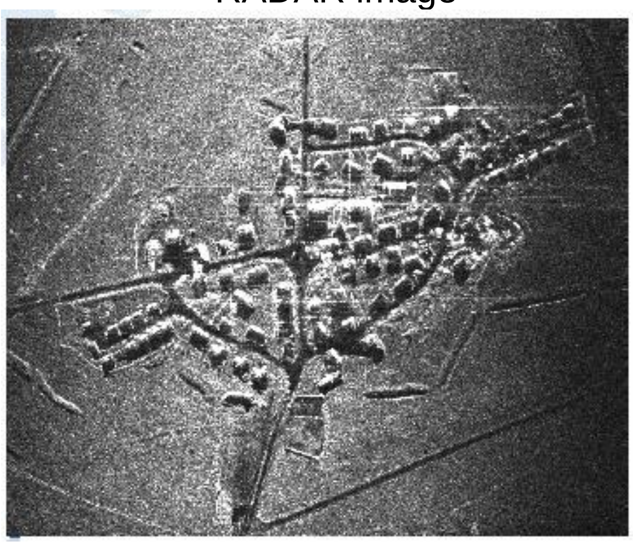
D
A
Y

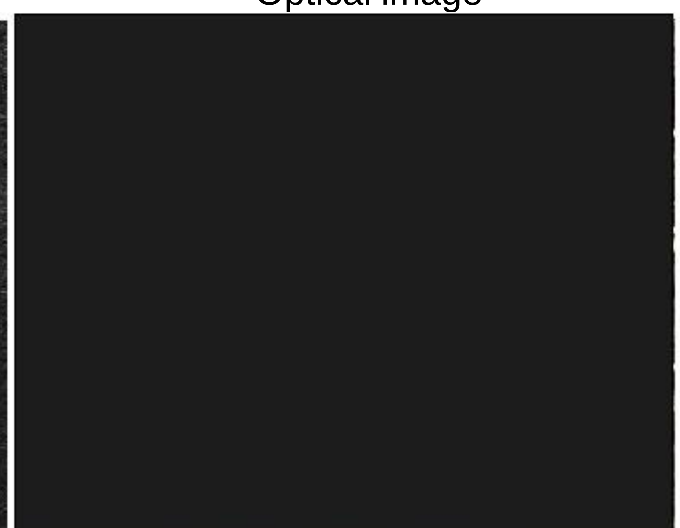


RADAR image

Optical image

N
I
G
H
T





Source:
INFOTERRA

OUTLINE

I. Electromagnetic coherent waves

II. Radar imaging - Spatial resolution

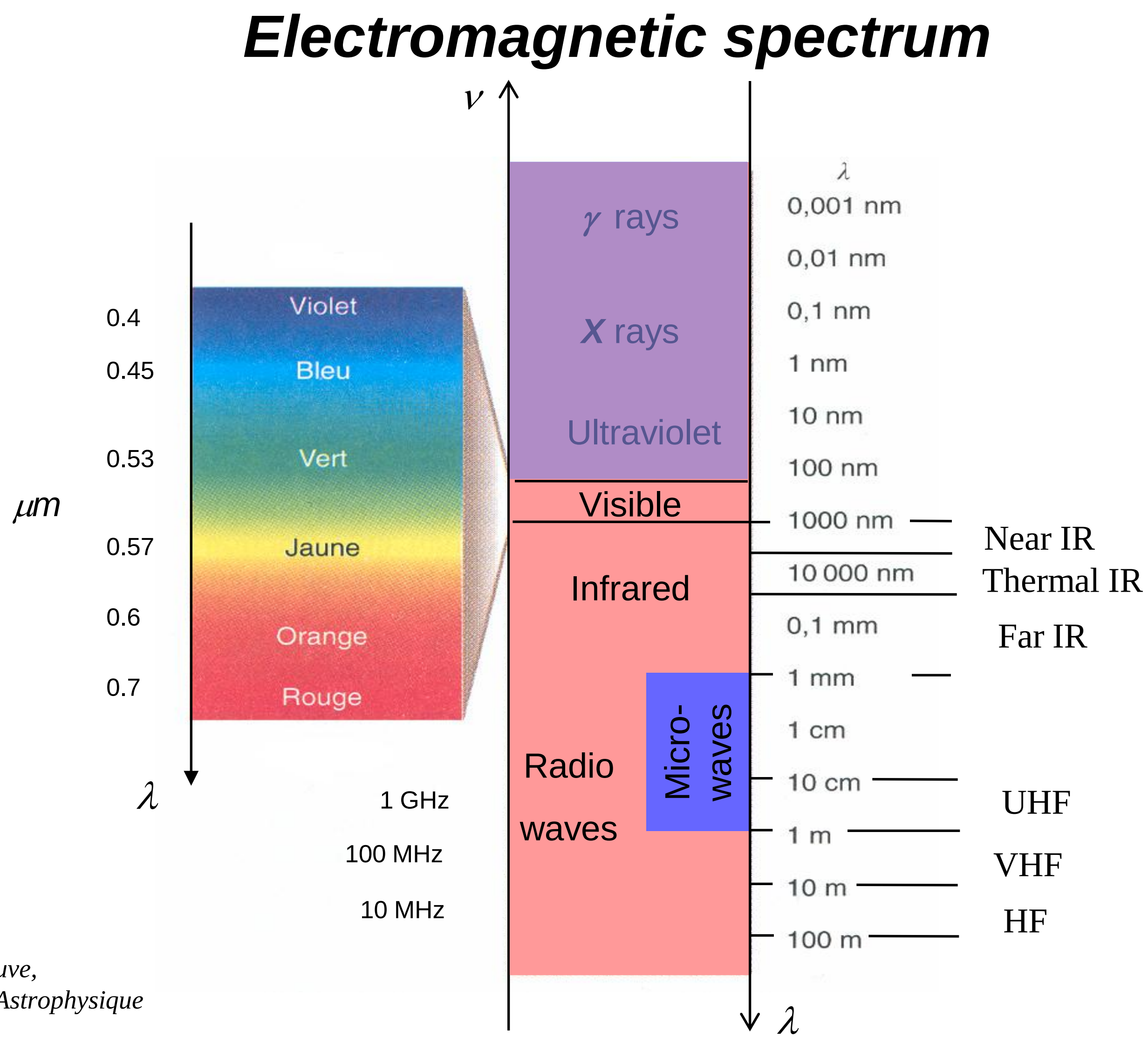
III. Frequency – wavelength

IV. Polarization

V. Radar response sensitivity

VI. Relief effects

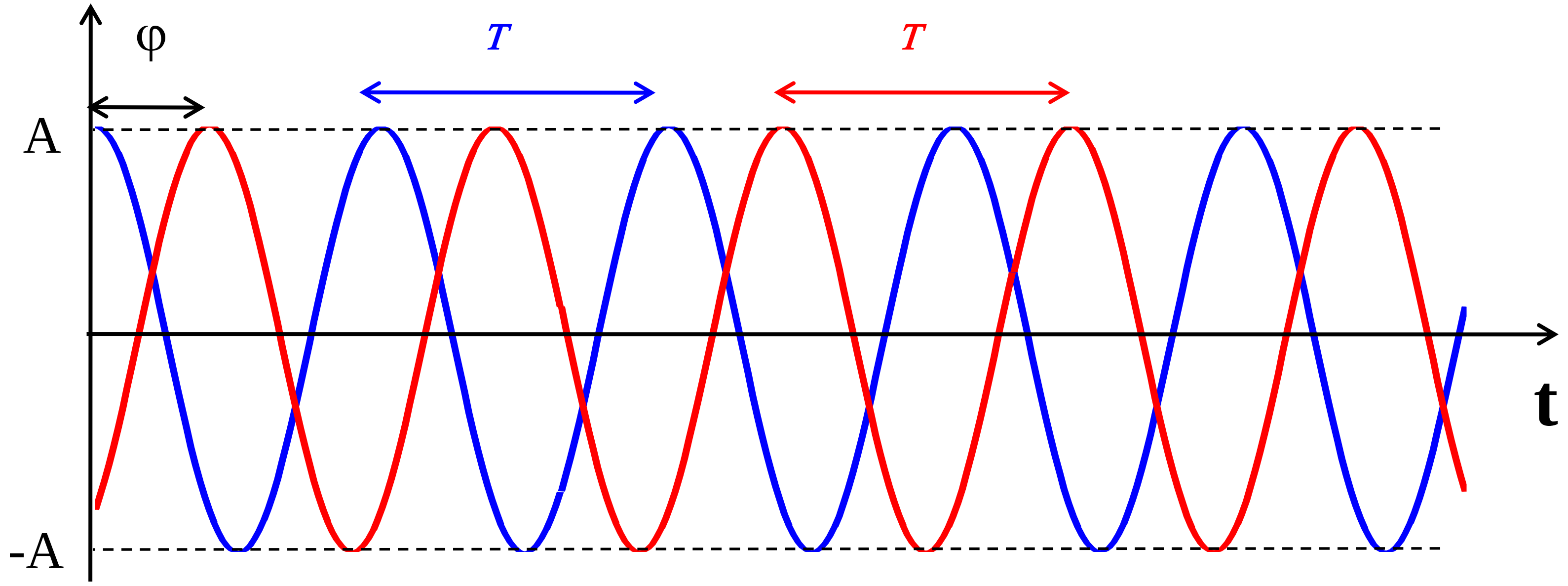
Electromagnetic coherent wave



From *Seguin & Villeneuve, Astromnomie et Astrophysique*

Electromagnetic coherent wave

Coherent wave: ***temporal*** behaviour



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

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

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

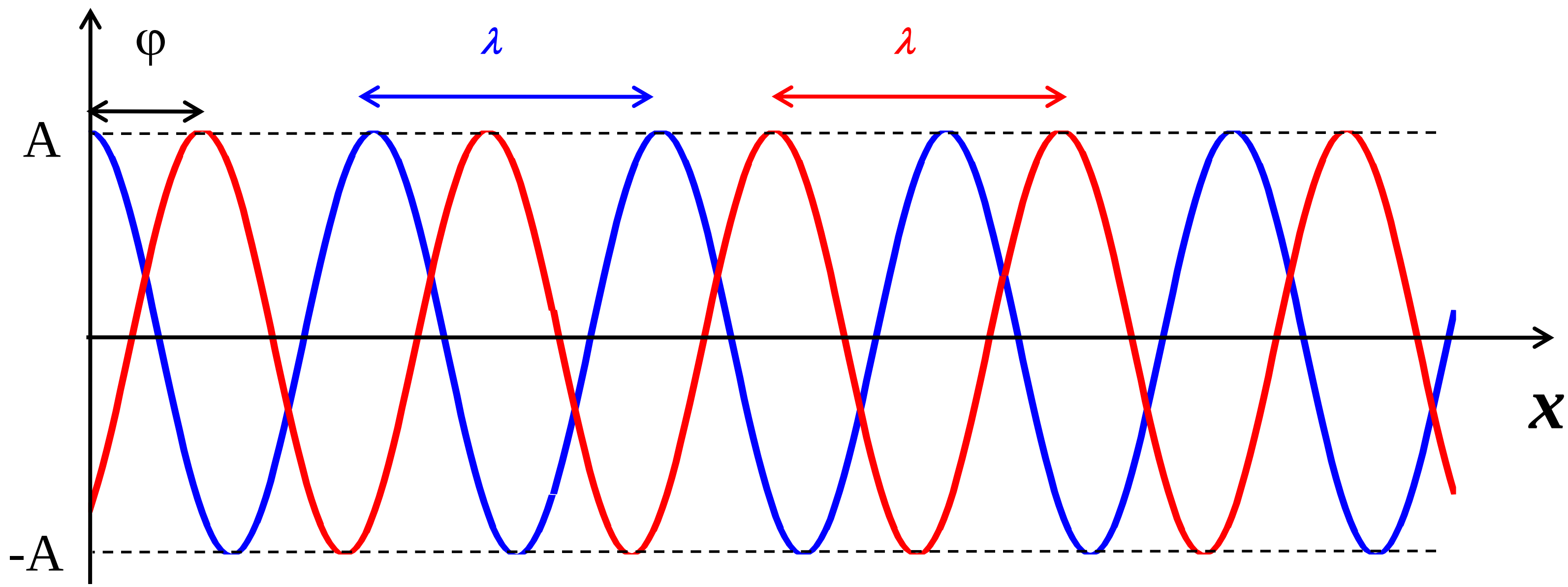
A: amplitude

T: time period

φ: phase shift

Electromagnetic coherent wave

Coherent wave: ***spatial*** behaviour



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

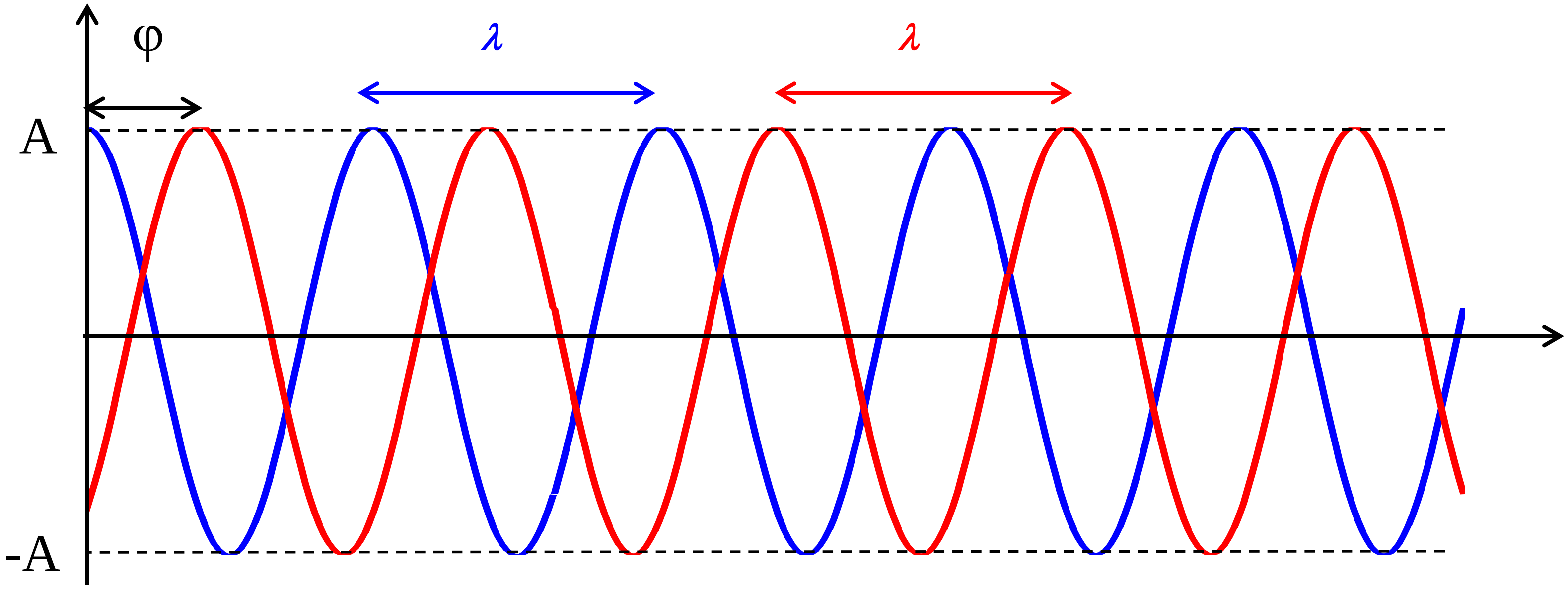
$y(x) = A\cos\left(\frac{2\pi}{\lambda}x - \varphi\right)$

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

A: amplitude
λ: spatial period = wavelength
φ: phase shift
c: light celerity = 3.10^8 m/s

Electromagnetic coherent wave

Coherent wave: ***spatial*** behaviour



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

OUTLINE

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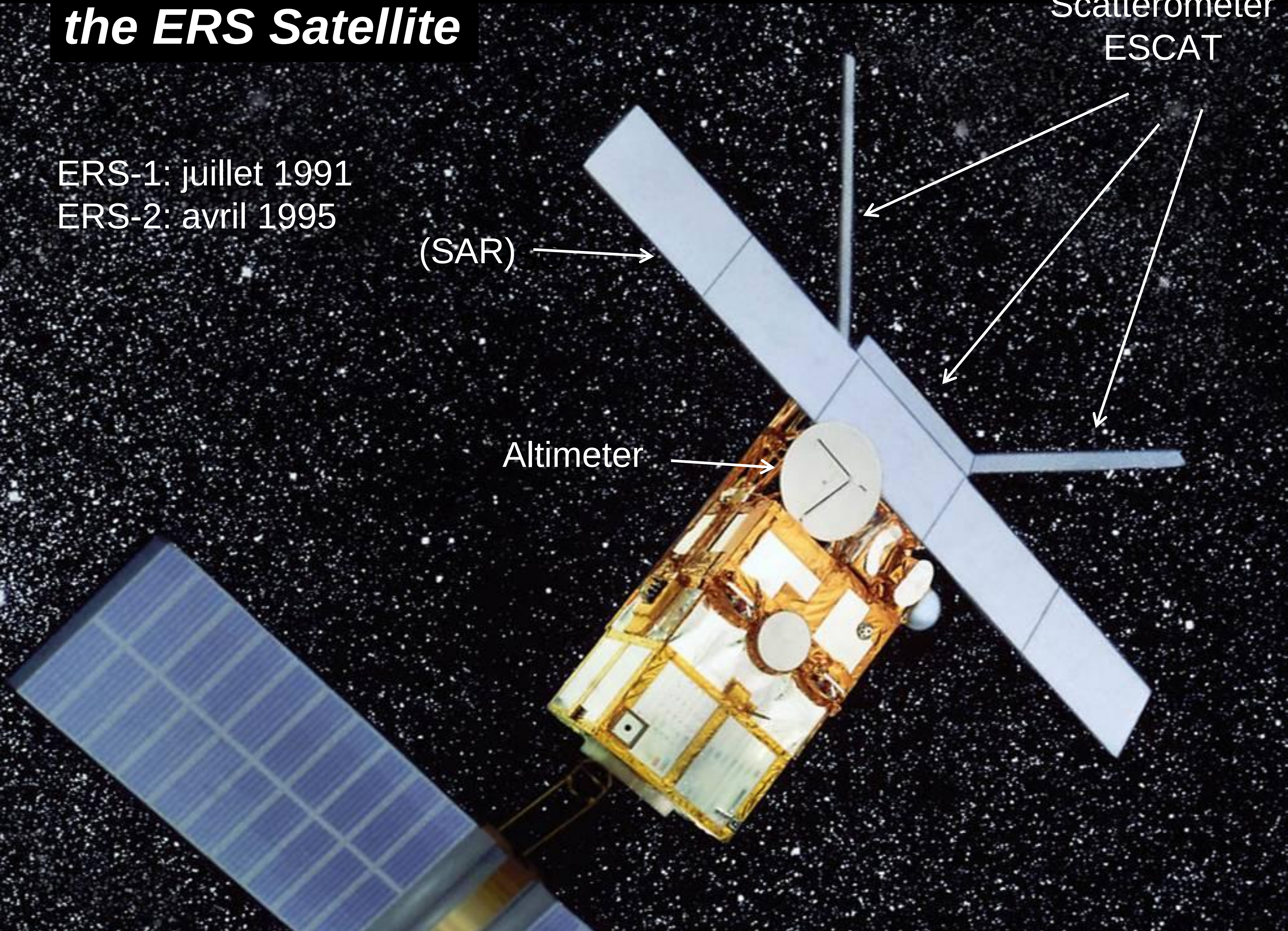
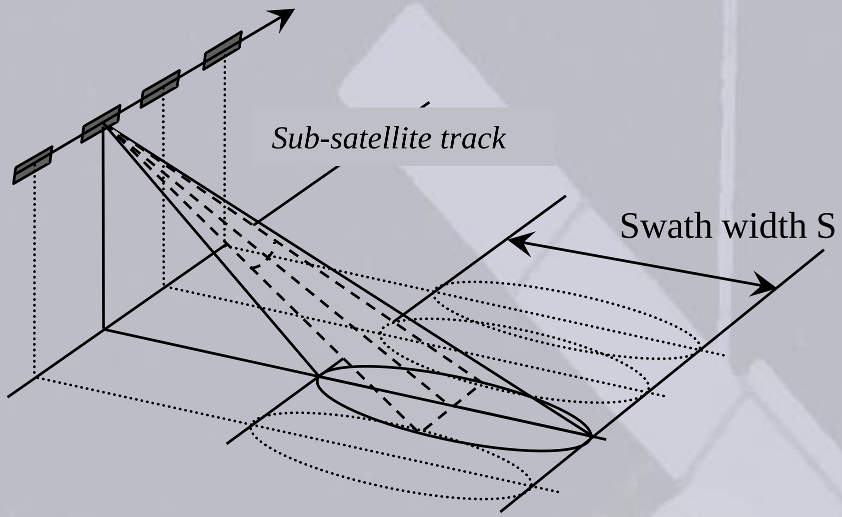
the ERS Satellite

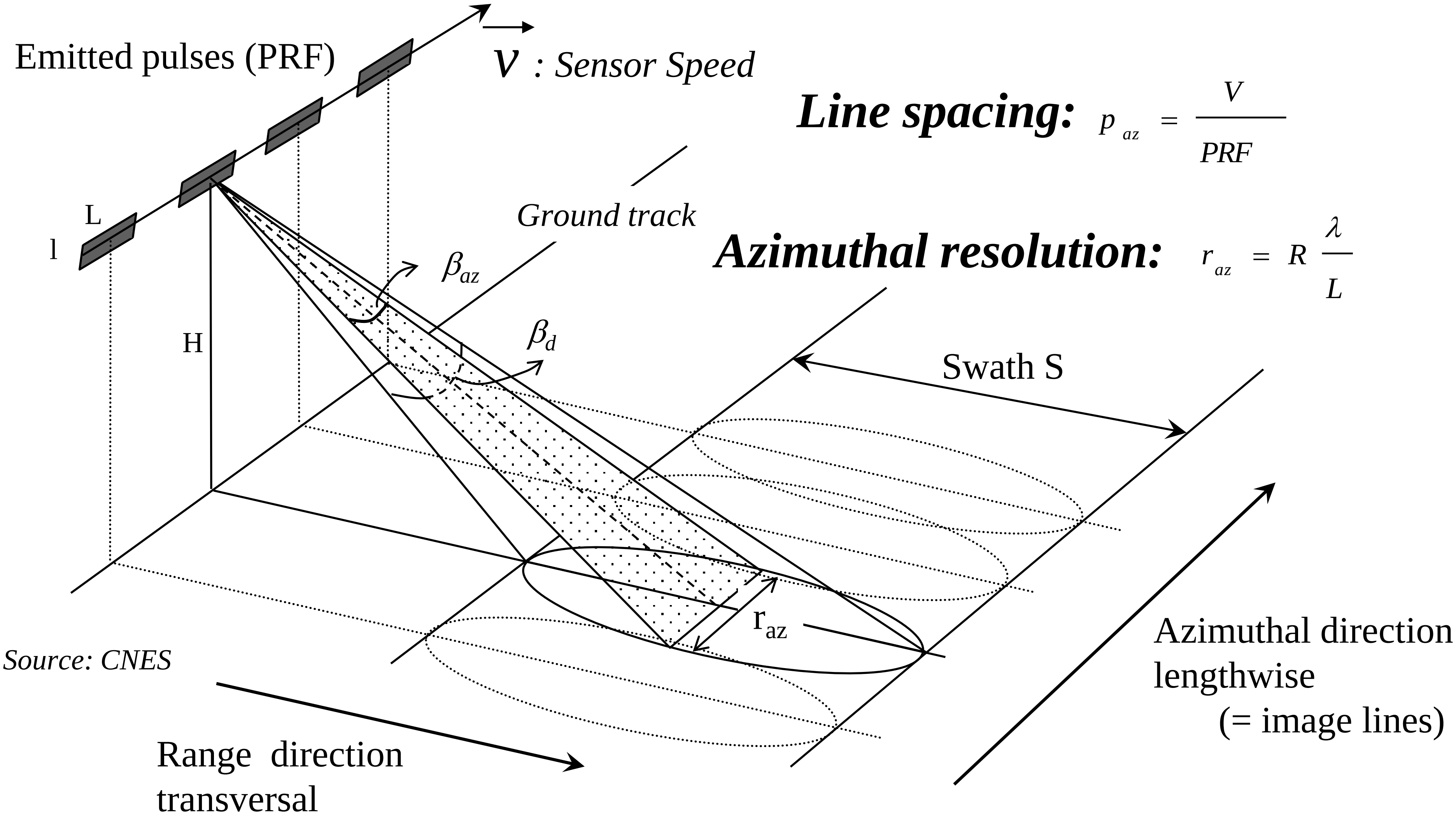


Side looking radar sensors (λ > cm)



Scatterometers		***SAR: Synthetic Aperture Radar***
	Raw echoes recording	
Incoherent sum ***(I)***		***Coherent*** sum ***(A, ϕ)***
	Spatial resolution	
Low (25 – 50 km)		***fine*** (1 - 30 m)
	Radiometric resolution	
High (400 Looks)		***Low*** (speckle)
	Original application	
sea (winds)		***Land - sea***

Radar Imaging – spatial resolution



Source: CNES

Line spacing: $p_{az} = \frac{V}{PRF}$

Azimuthal resolution: $r_{az} = R\frac{\lambda}{L}$

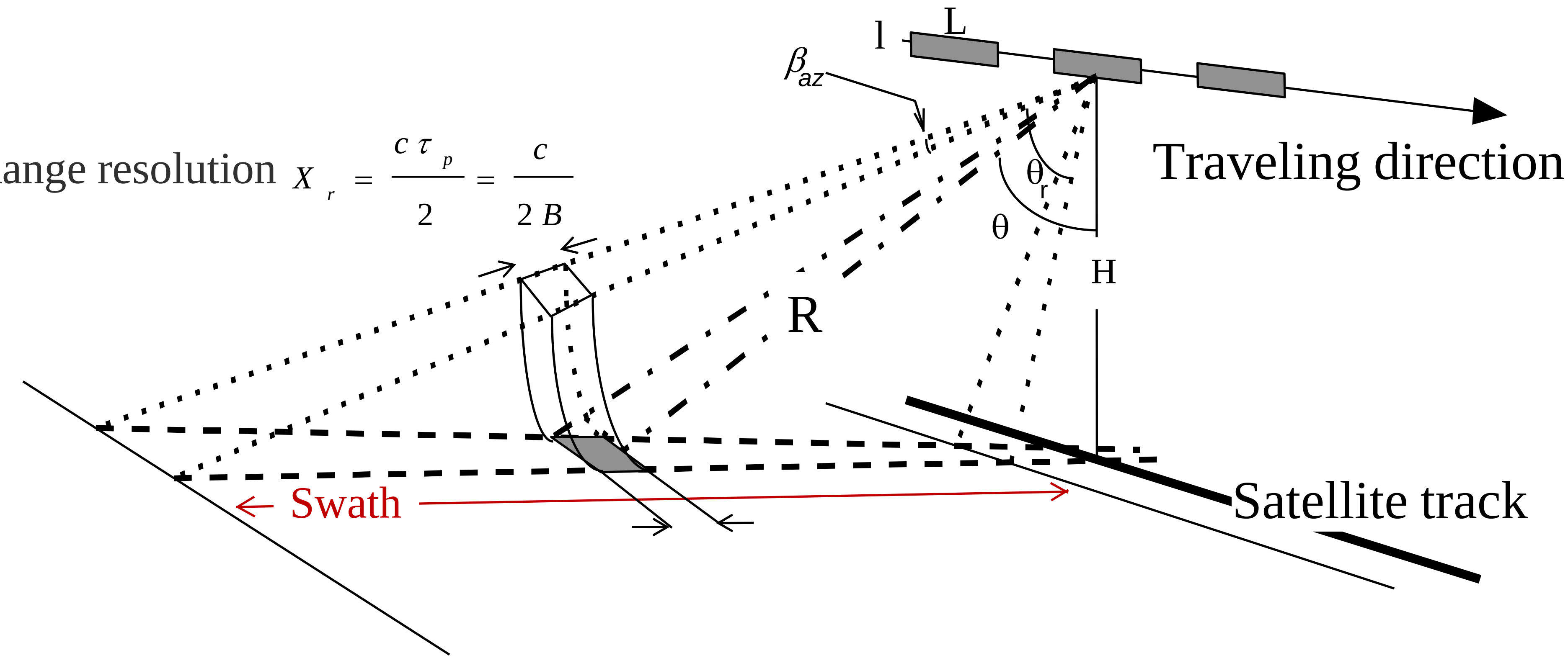
Numerical Application (ERS):

PRF=1680 Hz, V=7km/s — $\boldsymbol{p_{az} \approx 5\ m}$

L=10 m, λ =5.6 cm, H =700 km, θ =23° — $\boldsymbol{r_{az} \approx 4.2\ km}$

Radar Imaging – spatial resolution

Range resolution $X_r = \frac{c\,\tau_p}{2} = \frac{c}{2B}$



Pulse duration $= \boldsymbol{\tau_p} = \frac{1}{B}$

Num. Appl. (ERS): $\tau_p = 32\ \mu s$ ➔ $B \approx 30\ kHz$

$\boldsymbol{X_r \approx 5\ km}$

Range Resolution

Emission: x(t)

Eeception: y(t) = x(t-t_0)

Low signal/noise

⇒ Correlation $C_{xy}(\tau) = C_{xx}(\tau - t_0)$

Only depends on the autocorrelation of the emited pulse

⇒ Choice: pulse with autocorrelation very narrow: Chirp

$$\cancel{\cos(2\pi \nu_0 t) \quad -\tau \leq t \leq \tau}$$

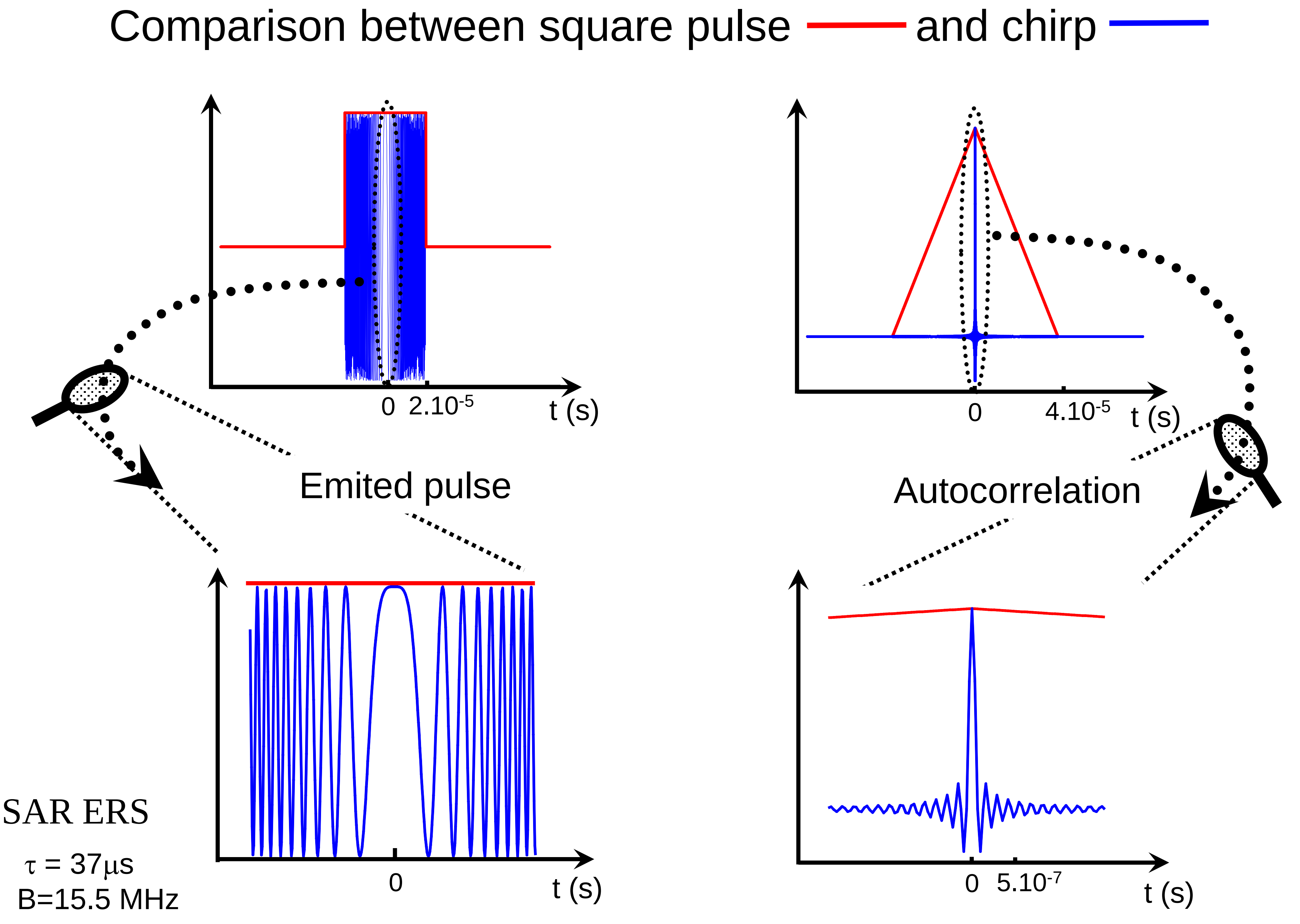
$$\cos\left[2\pi\left(\nu_0 t + \frac{B}{\tau_p} t^2\right)\right] \quad -\frac{\tau_p}{2} \leq t \leq \frac{\tau_p}{2}$$

$$\cancel{\frac{c\,\tau_p}{2}}$$

Range resolution $\frac{c}{2B}$

$$\cancel{\frac{c\,\tau_p}{2\sin\theta}}$$

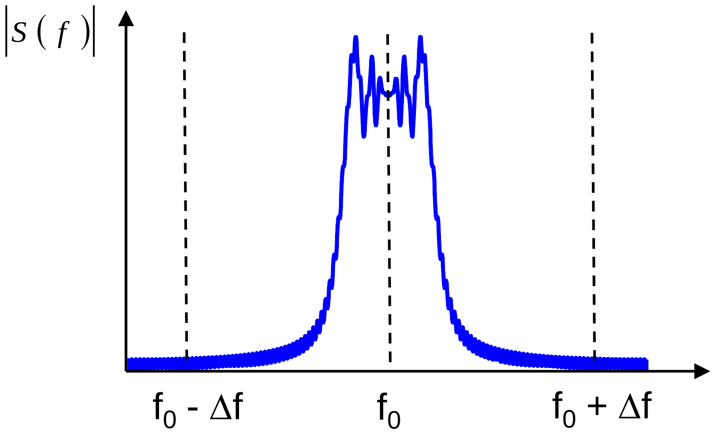
Ground range resolution $\frac{c}{2B\sin\theta}$



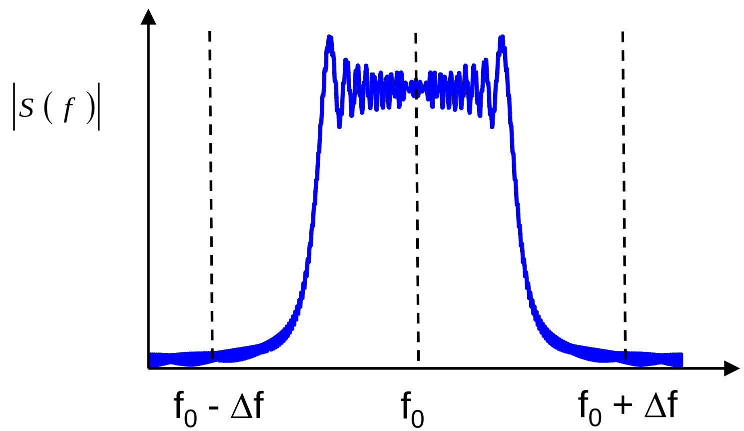
Comparison between square pulse and chirp
0
2.10-5
t (s)
0
4.10-5
t (s)
Emited pulse
Autocorrelation
SAR ERS
τ = 37µs
B=15.5 MHz
0
t (s)
0
5.10-7
t (s)

Amplitude spectrum of the chirp

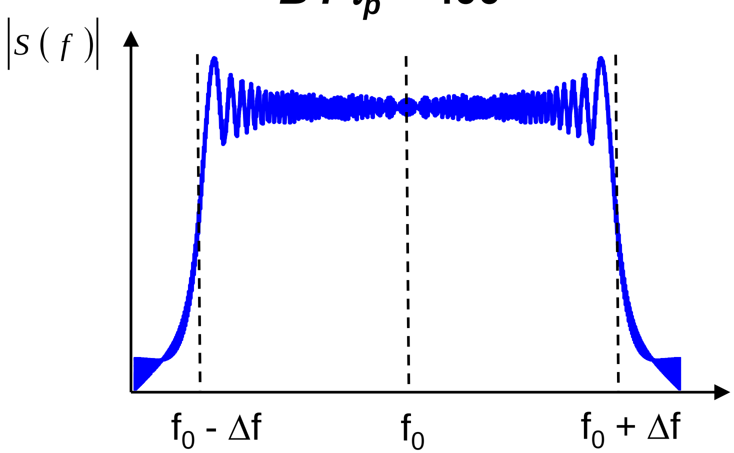
B . τ_p = 100



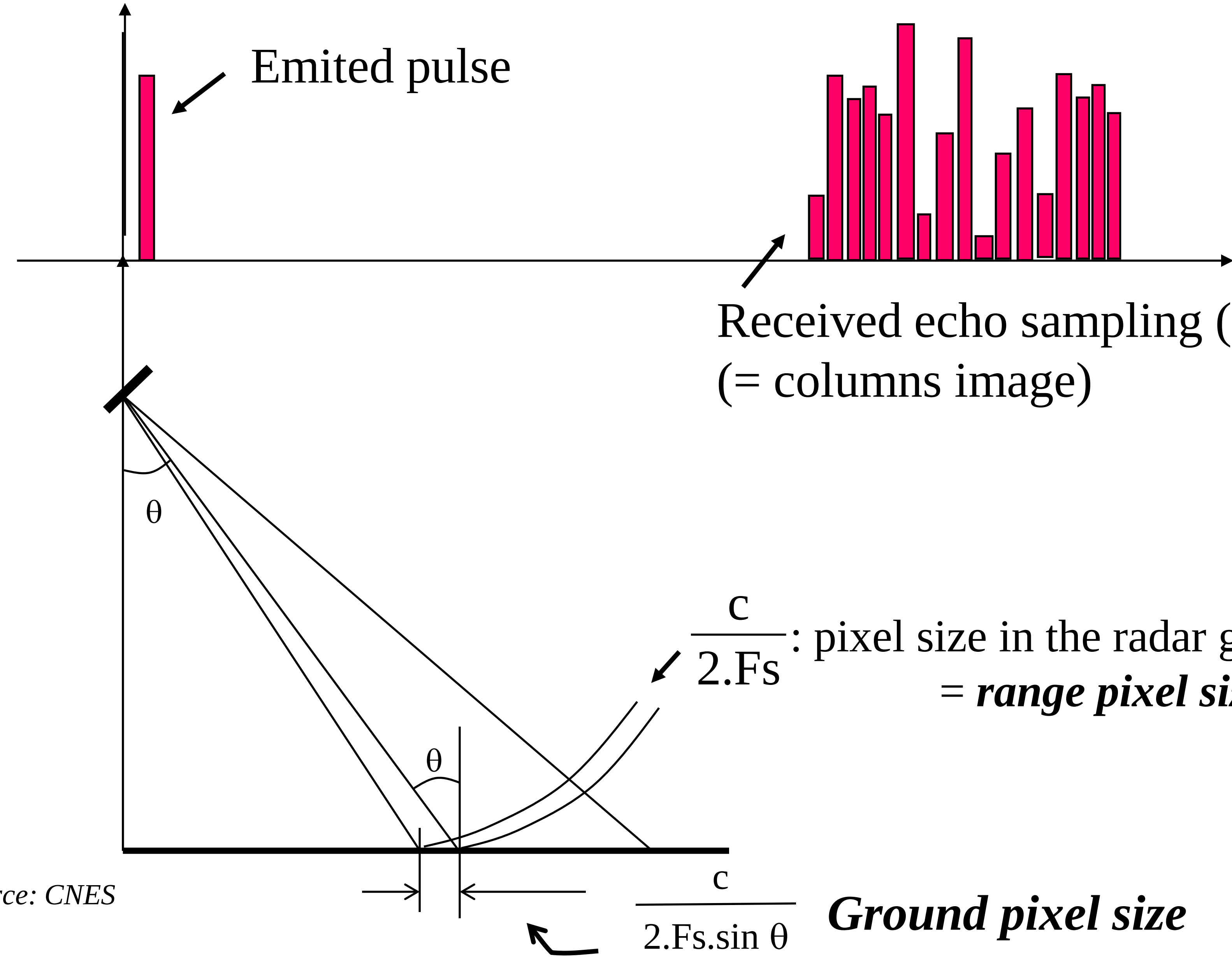
B . τ_p = 200



B . τ_p = 400



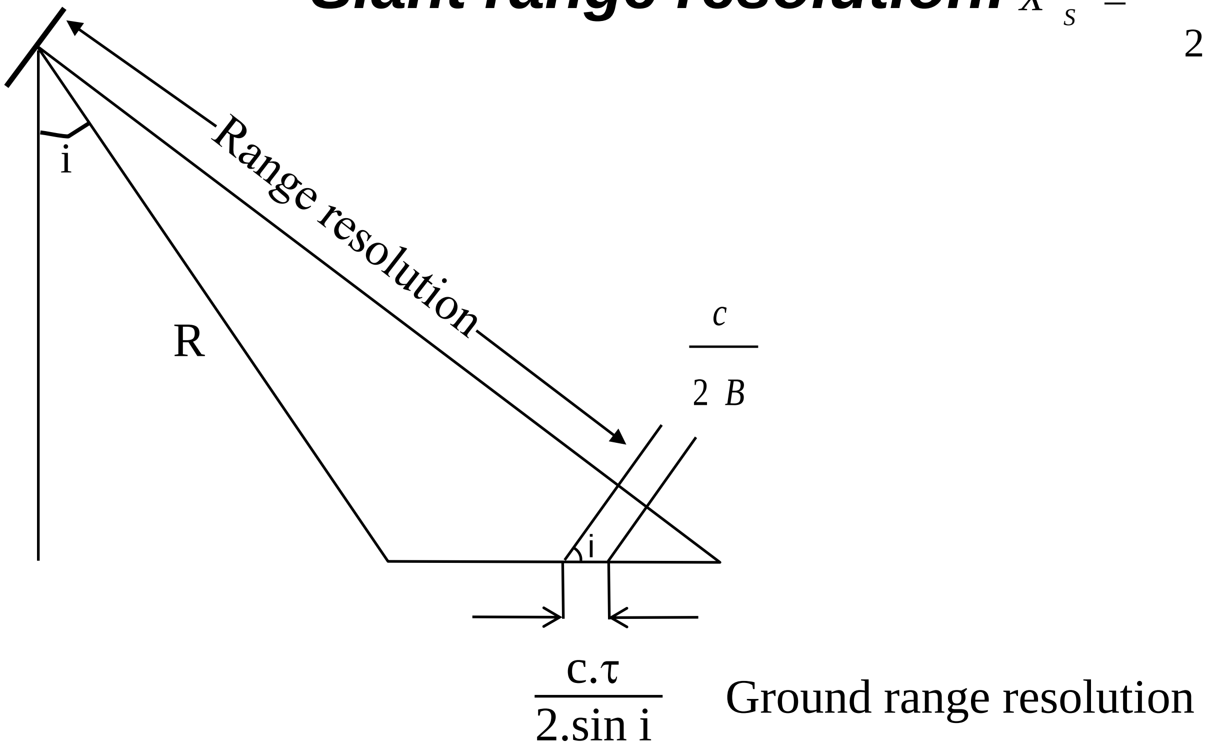
Radar Imaging – spatial resolution

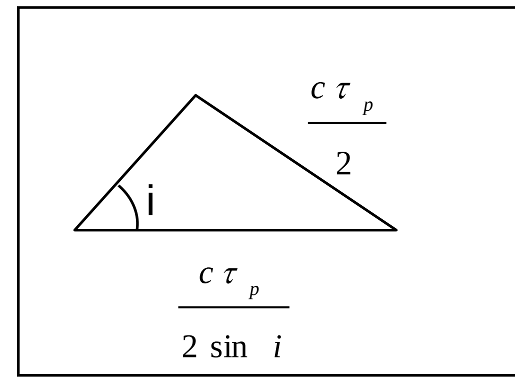


Source: CNES

Radar Imaging – spatial resolution

Slant range resolution: $$X_s = \frac{c\,\tau_p}{2} = \frac{c}{2B} \qquad \tau_p = \frac{1}{B}$$

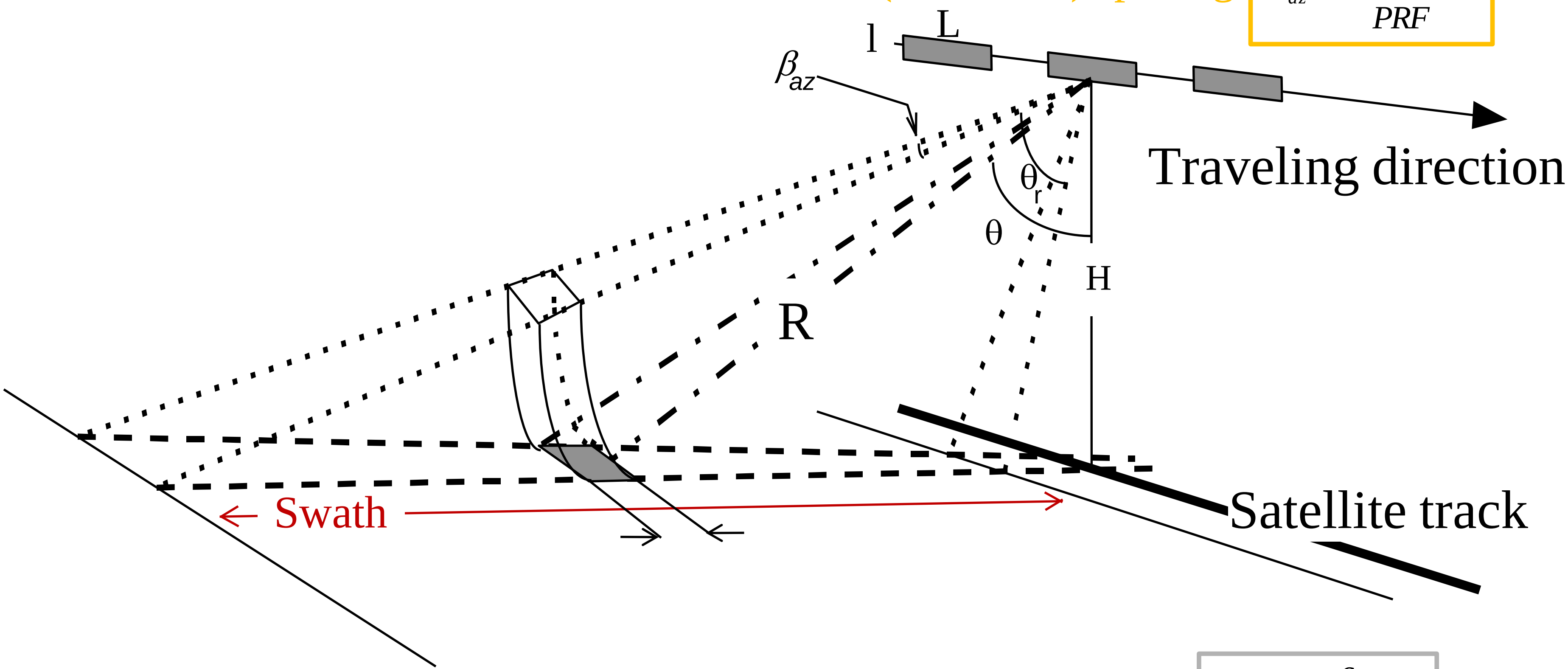




Ground range resolution: $$X_{gr} = \frac{c}{2B\sin(i)}$$

Radar Imaging – spatial resolution

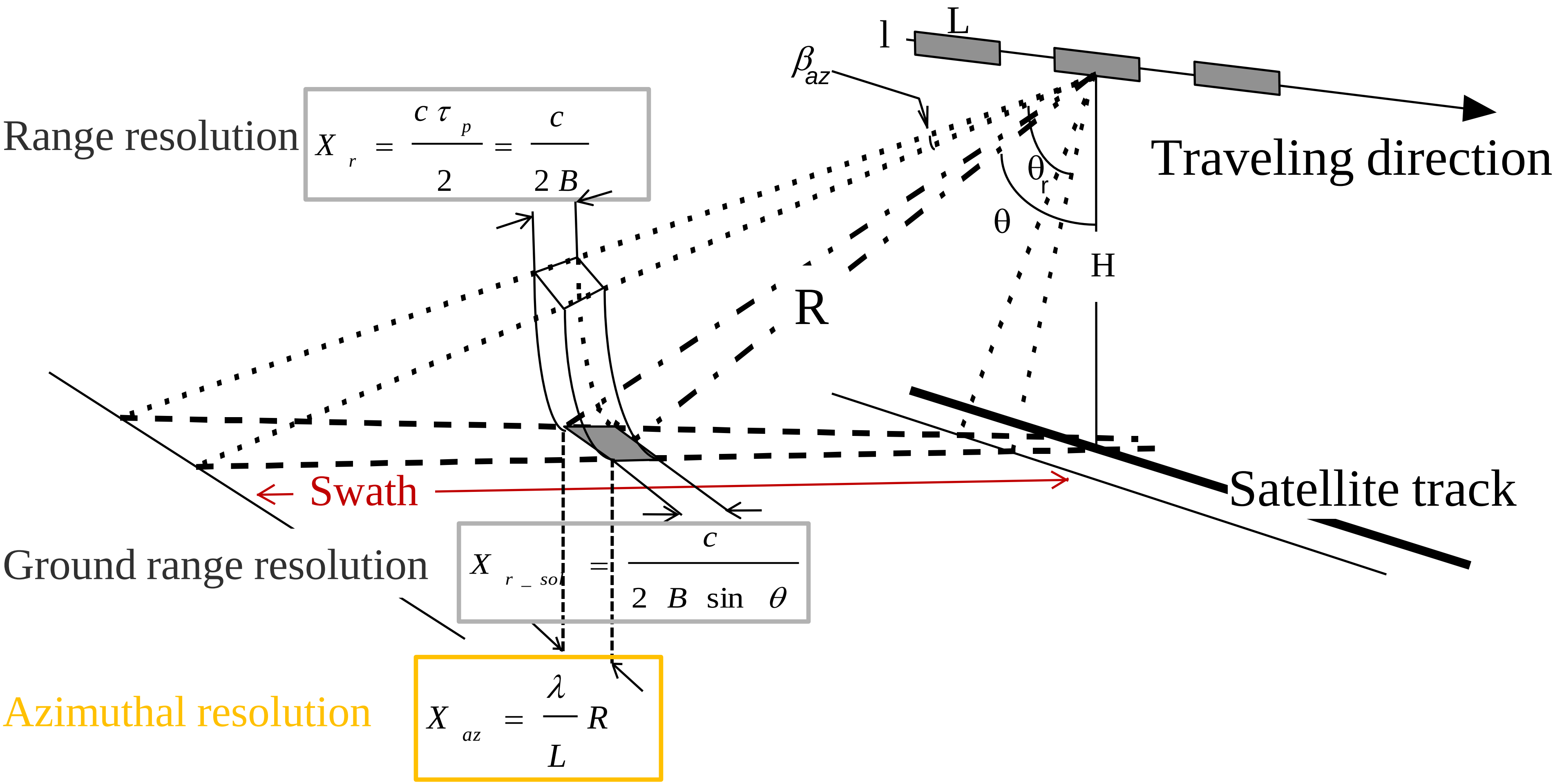
Line (azimuthal) spacing $p_{az} = \dfrac{V}{PRF}$



Range pixel (column) size $p_S = \dfrac{c}{2 F_S}$

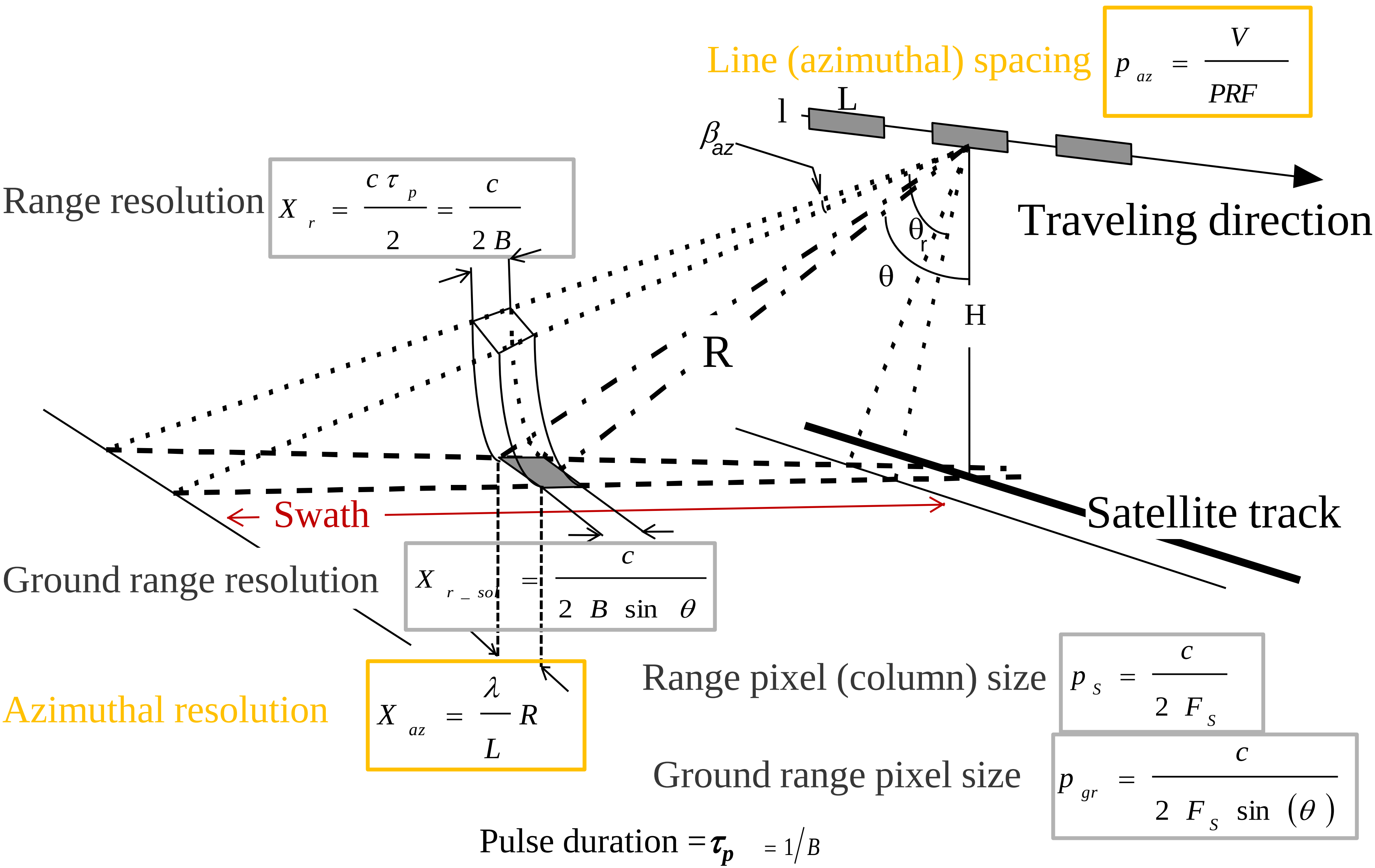
Ground range pixel size $p_{gr} = \dfrac{c}{2 F_S \sin(\theta)}$

Radar Imaging – spatial resolution



Pulse duration $= \tau_p = 1/B$

Radar Imaging – spatial resolution



Radar Imaging – spatial resolution

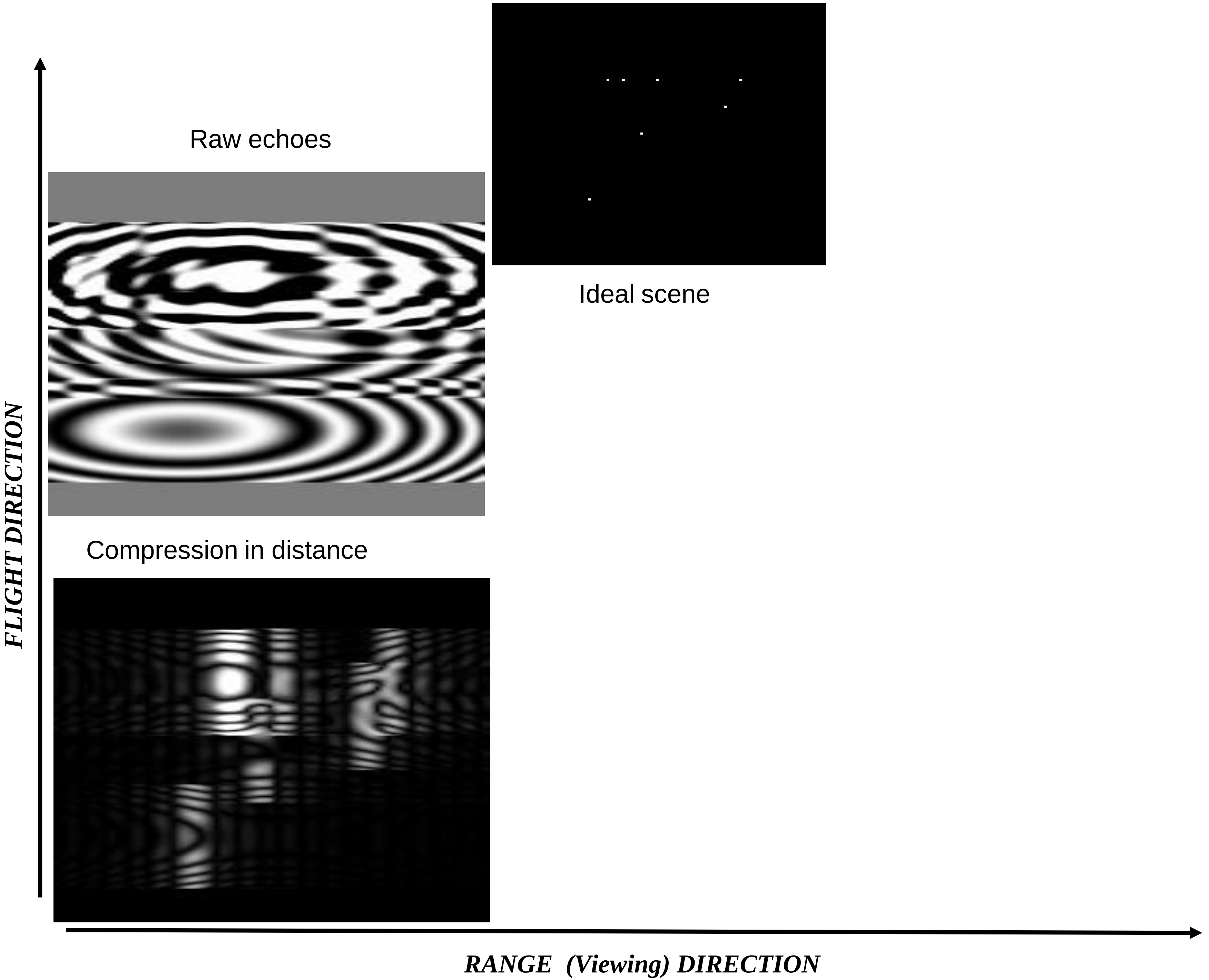
Case of ERS

	Range		Azimuth
	Slant (radar)	Ground	
Resolution	$X_r = \frac{c}{2B}$ ***= 10 m***	$X_r = \frac{c}{2B\sin(\theta)}$ ***= 25 m - 32 m***	$X_{az} = \frac{\lambda}{L}R$ ***~5 km***
Pixel size	$p_s = \frac{c}{2F_s}$ ***= 8 m***	$p_{gr} = \frac{c}{2F_s\sin(\theta)}$ ***= 20 m - 26 m***	$p_{az} = \frac{V}{PRF}$ ***= 4 m***

λ = 5.6 cm
V= 7 km/s
PRF=1680 Hz

F_S= 19 MHz
Θ = 18-24°
B=15.5 MHz

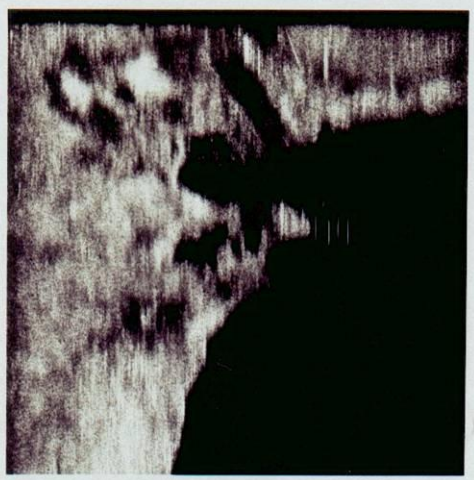
R = 15.5 MHz
L = 10 m


Raw echoes
Ideal scene
Compression in distance
FLIGHT DIRECTION
RANGE (Viewing) DIRECTION

FLIGHT DIRECTION

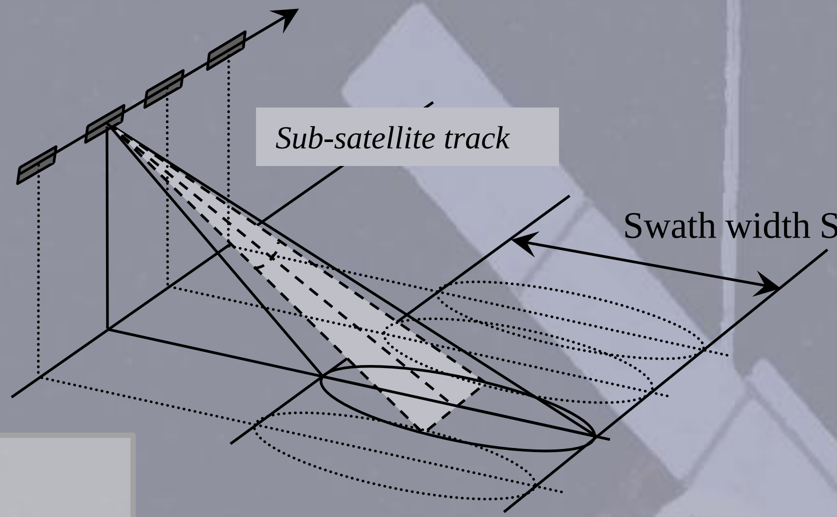
NON COMPRIME DISTANCE
NON COMPRIME AZIMUT

Document



COMPRIME DISTANCE
NON COMPRIME AZIMUT

Side looking radar sensors (λ > cm)

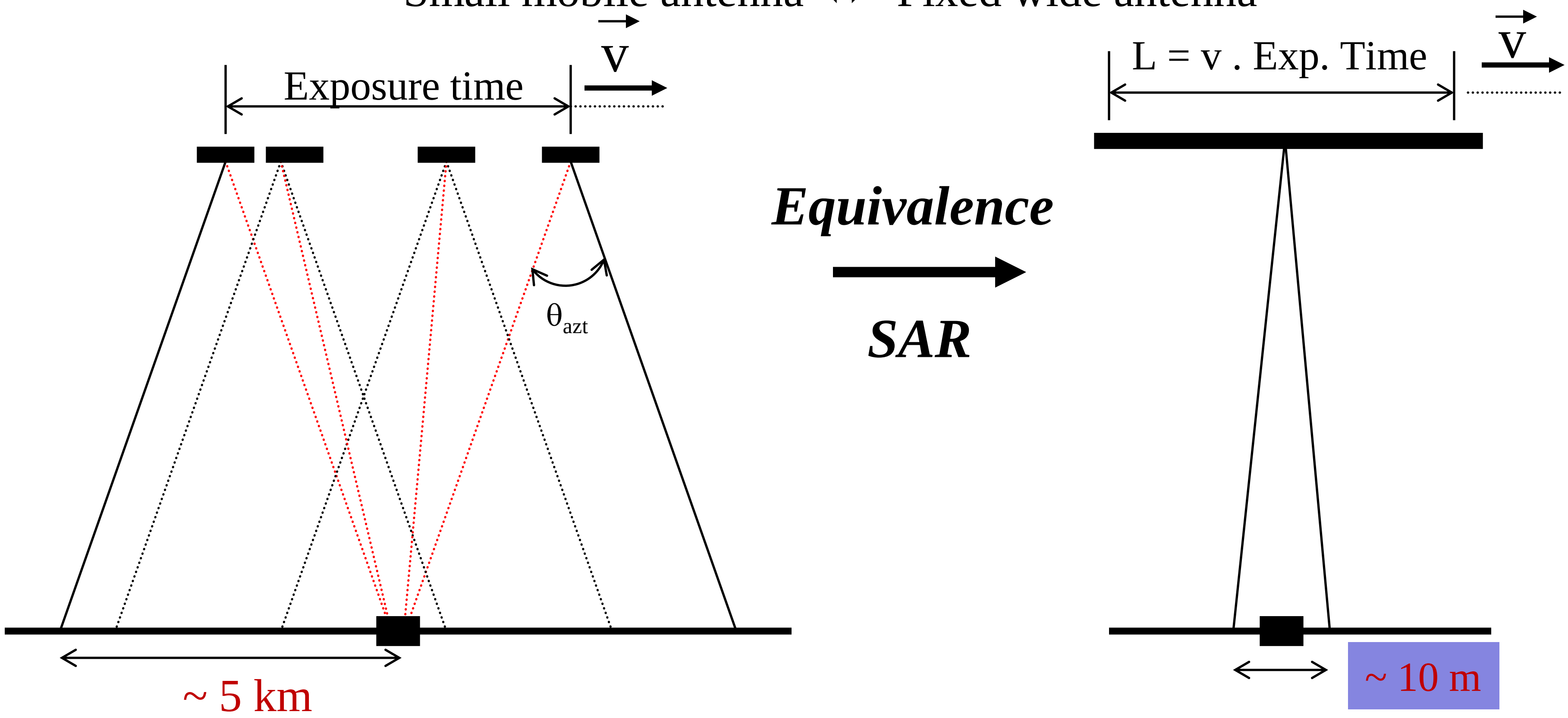


Scatterometers		SAR: Synthetic Aperture Radar
	Raw echoes recording	
Incoherent sum ***(I)***		***Coherent*** *sum* ***(A, ϕ)***
	Spatial resolution	
Low (25 – 50 km)		***fine*** (1 - 30 m)
	Radiometric resolution	
High (400 Looks)		***Low*** (speckle)
	Original application	
sea (winds)		***Land - sea***

Radar Imaging – spatial resolution

Synthetic Aperture Radar: *(i.e. improvment of azimuthal resolution)*

Small mobile antenna ⇔ Fixed wide antenna



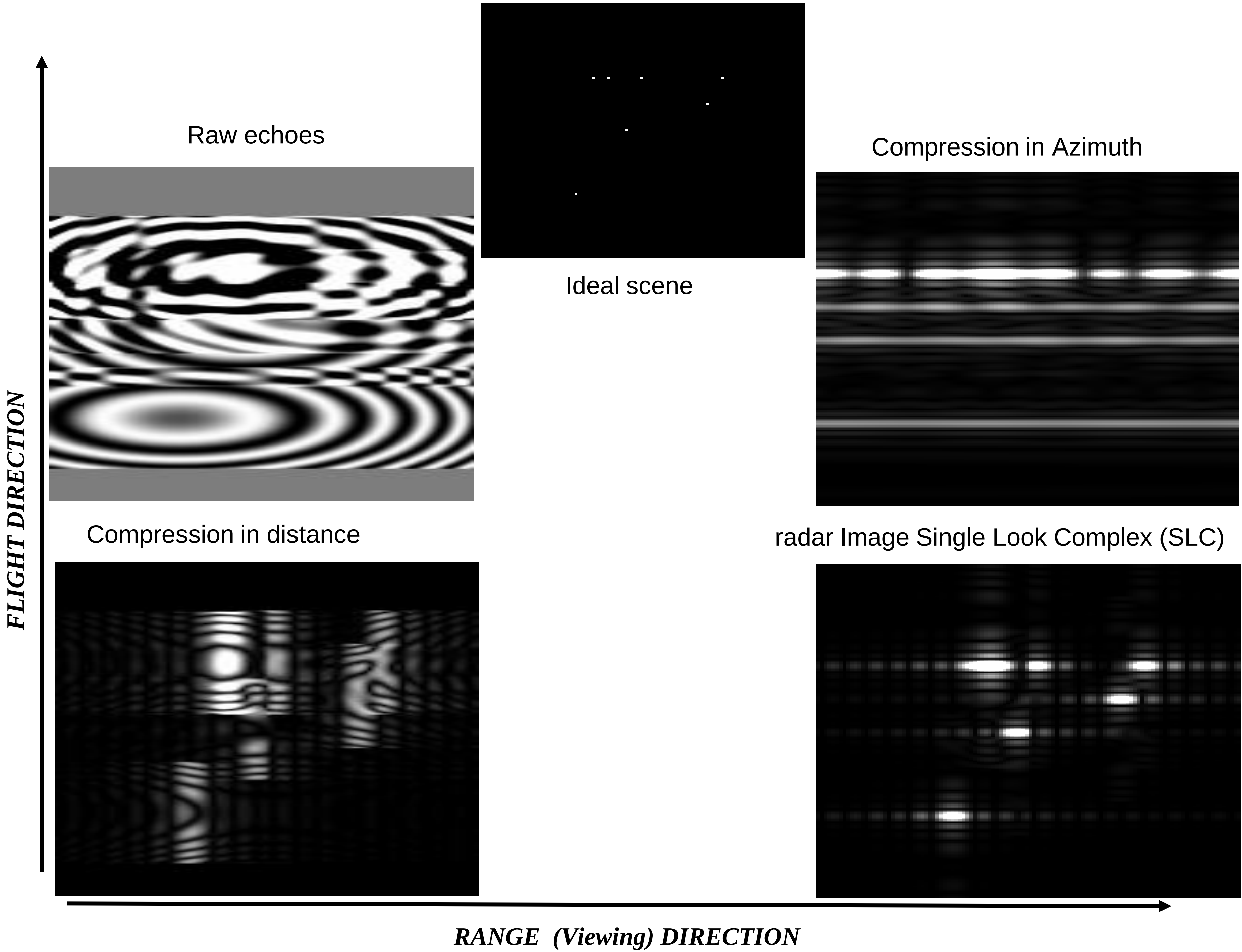
Coherent sum of the successive echoes

Adaptative filtering (Doppler Bandwidth)

$$B_D = \frac{2V}{L}$$

⟶ Gain in azimuthal resolution

$$X_{az} = \frac{V}{B_D} \Rightarrow X_{az} = \frac{L}{2}$$



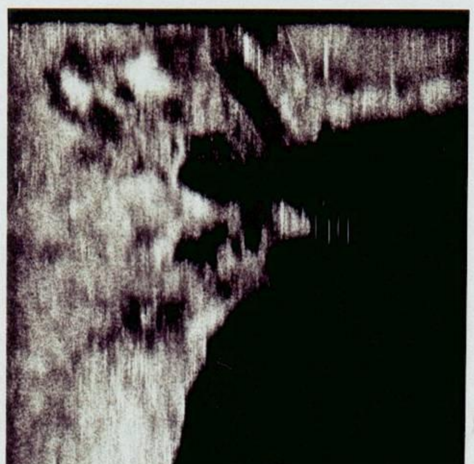
Raw echoes
Ideal scene
Compression in Azimuth
Compression in distance
radar Image Single Look Complex (SLC)
FLIGHT DIRECTION
RANGE (Viewing) DIRECTION

FLIGHT DIRECTION

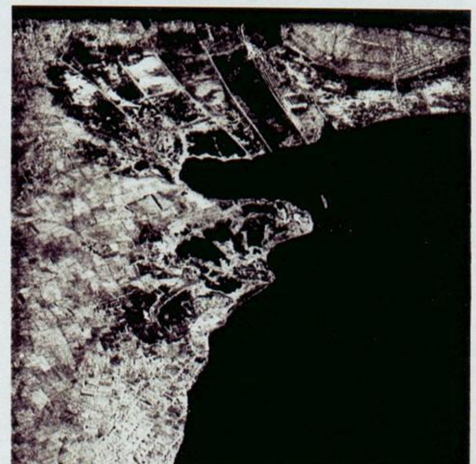
NON COMPRIME DISTANCE
NON COMPRIME AZIMUT

NON COMPRIME DISTANCE
COMPRIME AZIMUT

Document CNES



COMPRIME DISTANCE
NON COMPRIME AZIMUT



COMPRIME DISTANCE
COMPRIME AZIMUT

Radar Imaging – spatial resolution

Case of ERS SAR *(after aperture synthesis)*

	Range		Azimuth
	Slant (radar)	Ground	
Resolution	$X_r = \frac{c}{2B}$ **= 10 m**	$X_r = \frac{c}{2B\sin(\theta)}$ **= 25 m - 32 m**	$X_{az} = \frac{\lambda}{L} R$ **= 10 m**
Pixel size	$p_s = \frac{c}{2F_s}$ **= 8 m**	$p_{gr} = \frac{c}{2F_s \sin(\theta)}$ **= 19 m - 26 m**	$p_{az} = \frac{V}{PRF}$ **= 4 m**

Case of TERRASAR-X

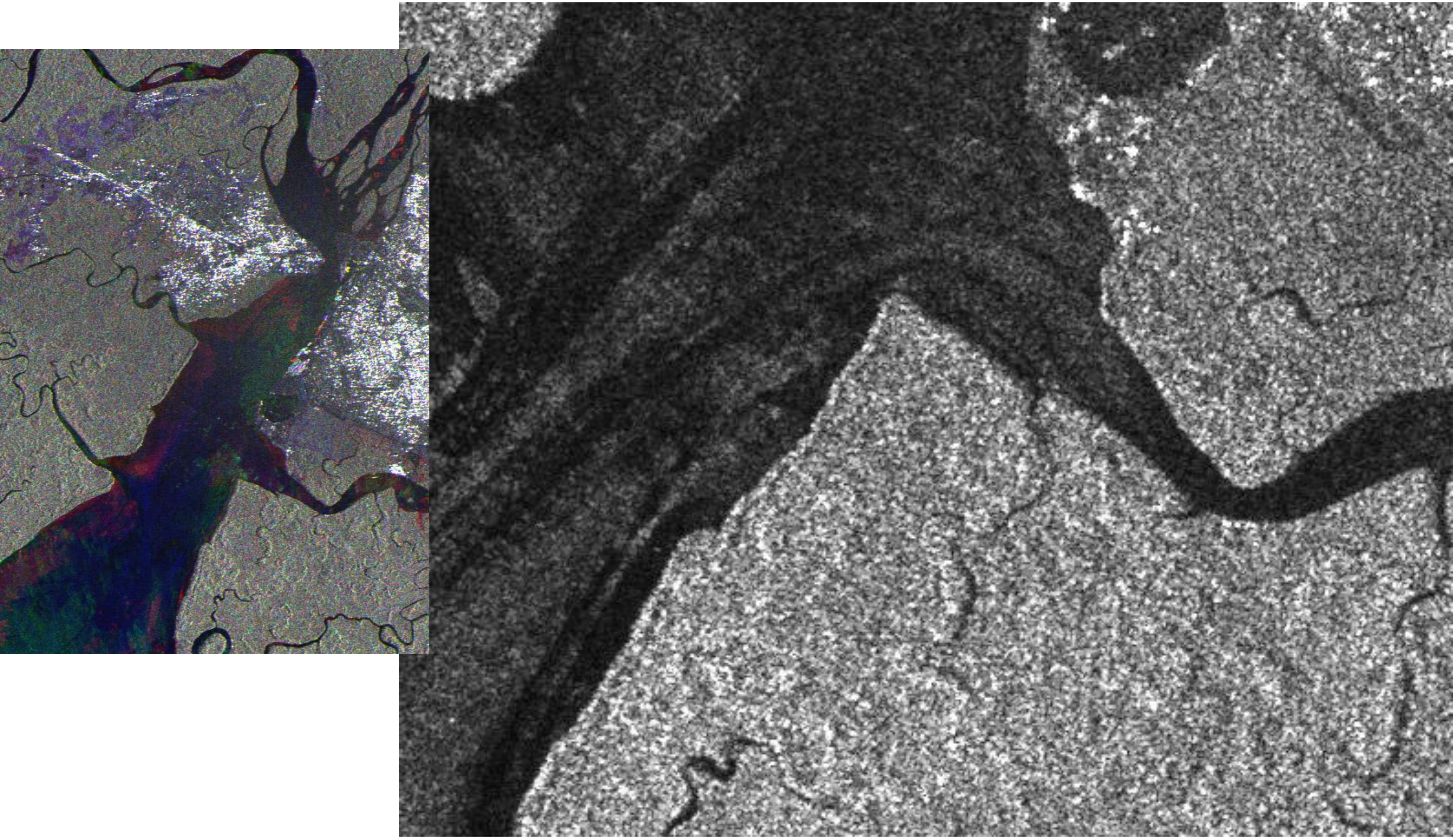
	Range		Azimuth
	Slant (radar)	Ground	
Resolution	***1.2 m***	***1.5 m – 3.5 m***	***1.1 m***
Pixel size	***0.6 m***	***0.75 m – 1.75 m***	***0.6 m***

RADARSAT - Scansar Wide : 27 mars 1999

Rail d’Ouessant: RADARSAT - Standard 6 : 3 août 1999

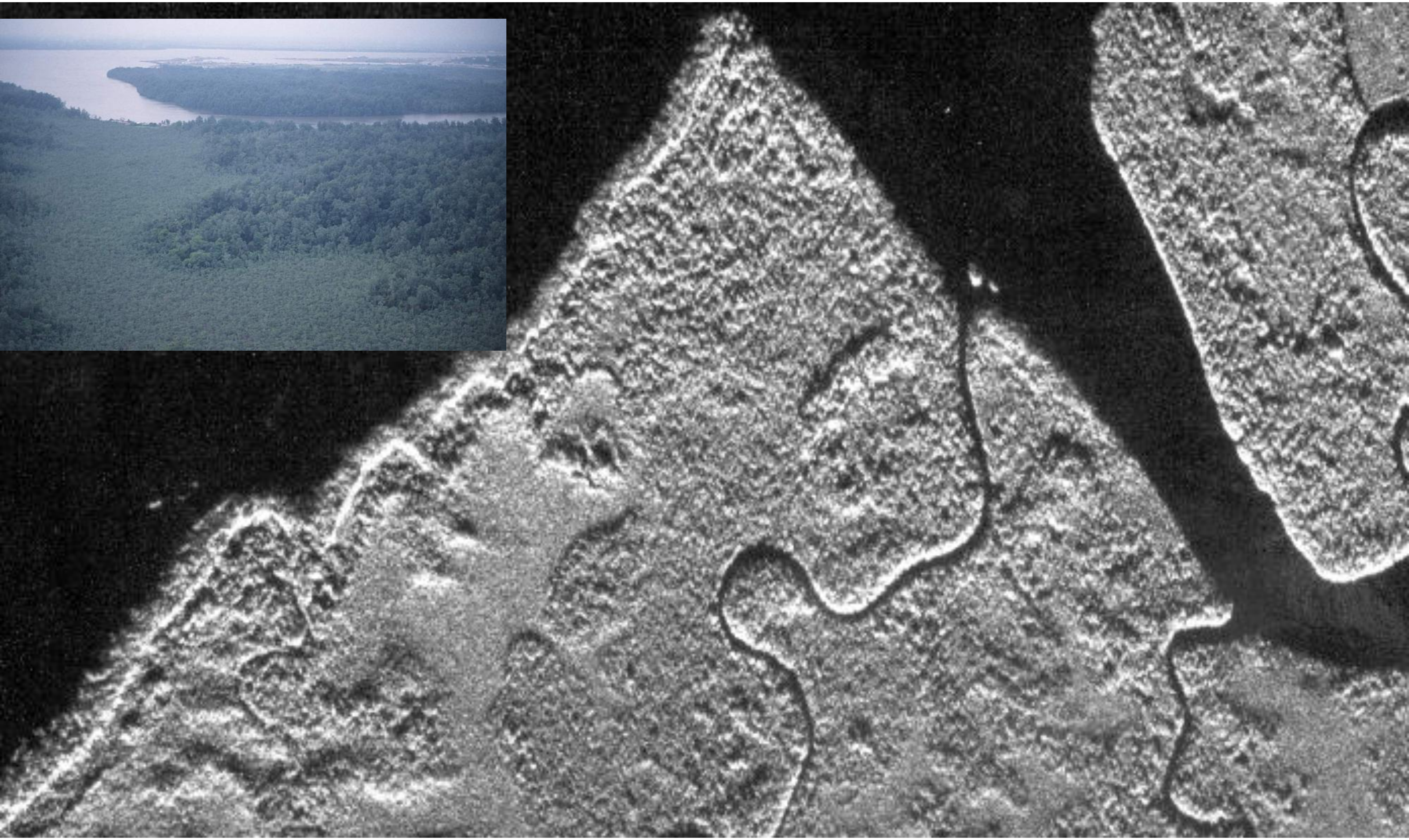
La Manche
ASAR
22 novembre 2003
(rés. 150 m)

Radar Imaging – spatial resolution



ERS Resolution ~ 25 m, pixel 12,5m

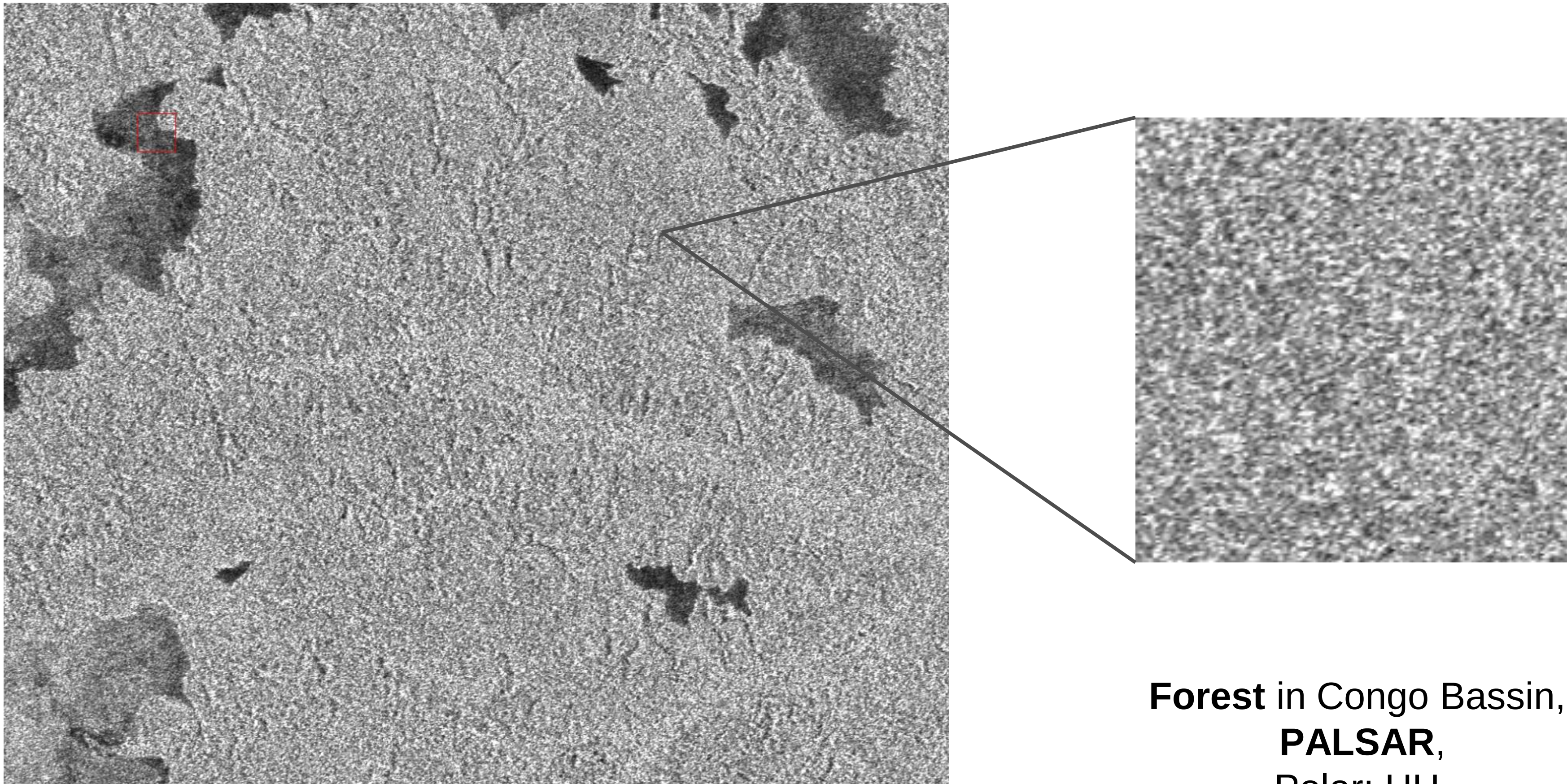
Radar Imaging – spatial resolution



DLR airplane radar resolution ~ 3 m

Radar Imaging – spatial resolution

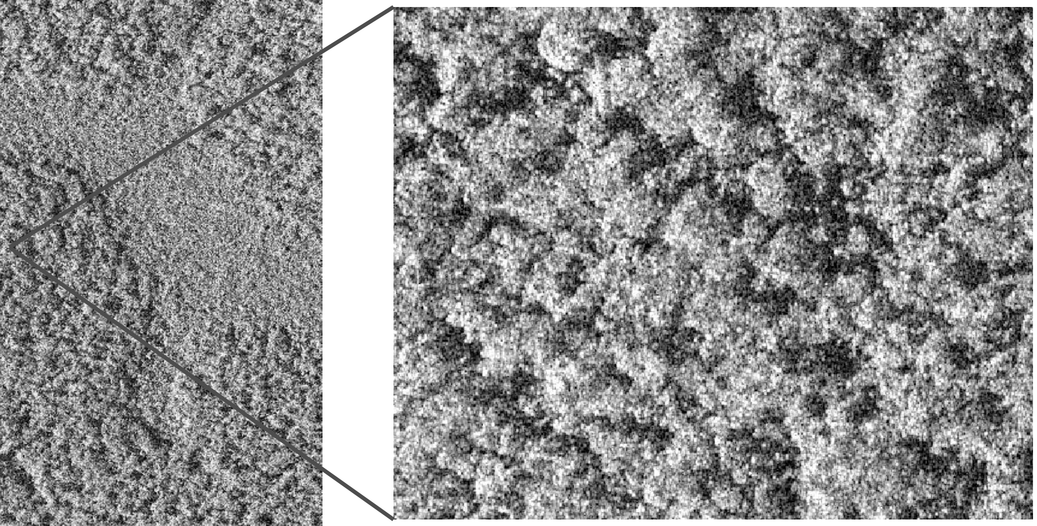
Radar data



Forest in Congo Bassin,
PALSAR,
Polar: HH,
Spat.Resolution: 20 m

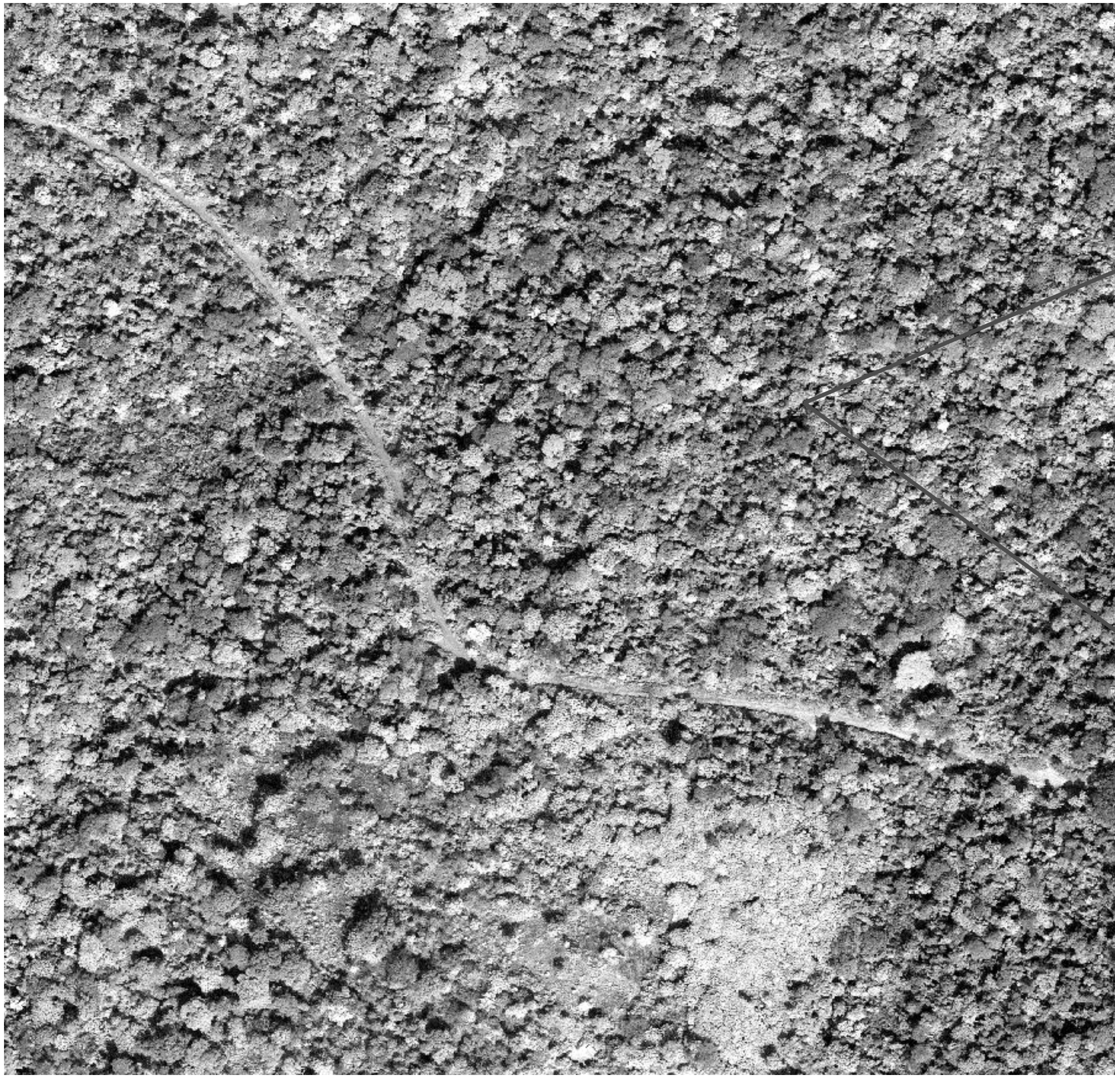
Radar Imaging – spatial resolution

Radar data

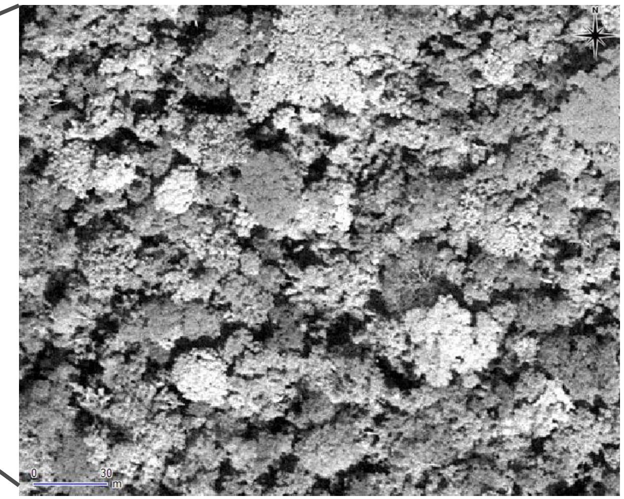


Forest in Cameroon,
TerraSAR-X, Spot Light,
Polar: HH,
Spat.Resolution: 1 m

Radar Imaging – spatial resolution



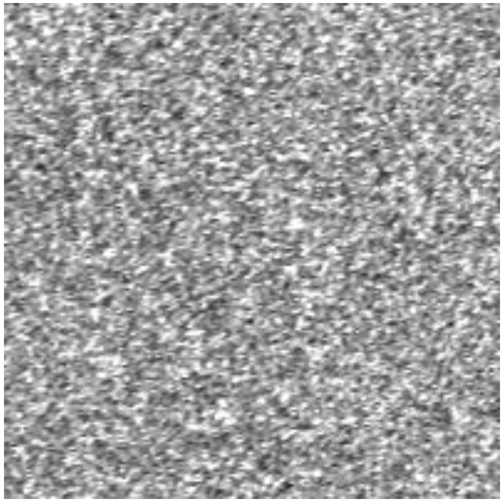
Optical data



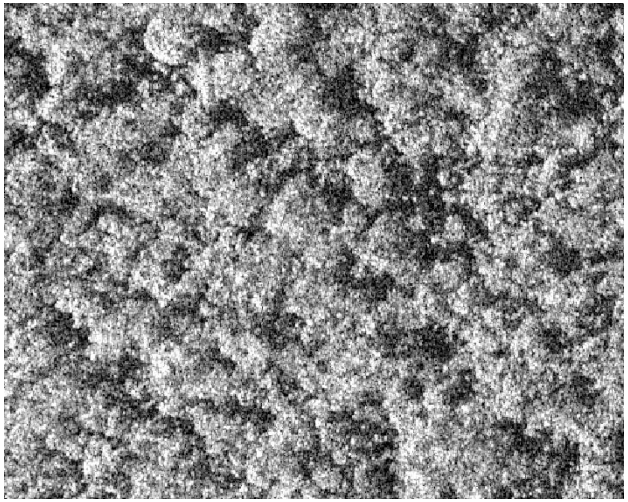
Forest in Cameroon,
Geoeye, Panchromatic,
Spat.Resolution: 0.5 m

Radar Imaging – spatial resolution

RADAR Data

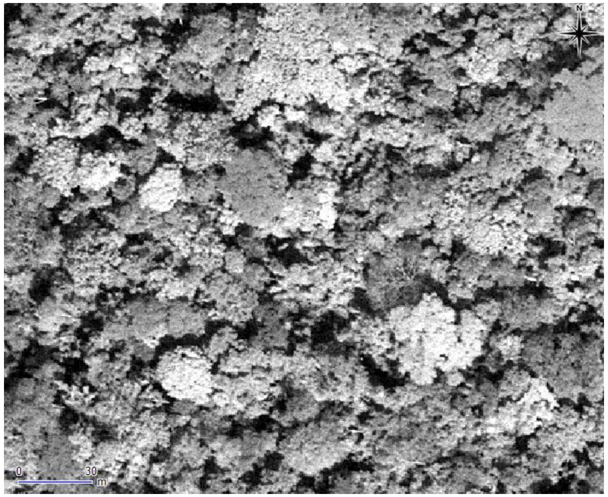


Forest in Congo Bassin,
PALSAR,
Polar: HH,
Spat.Resolution: 15 m



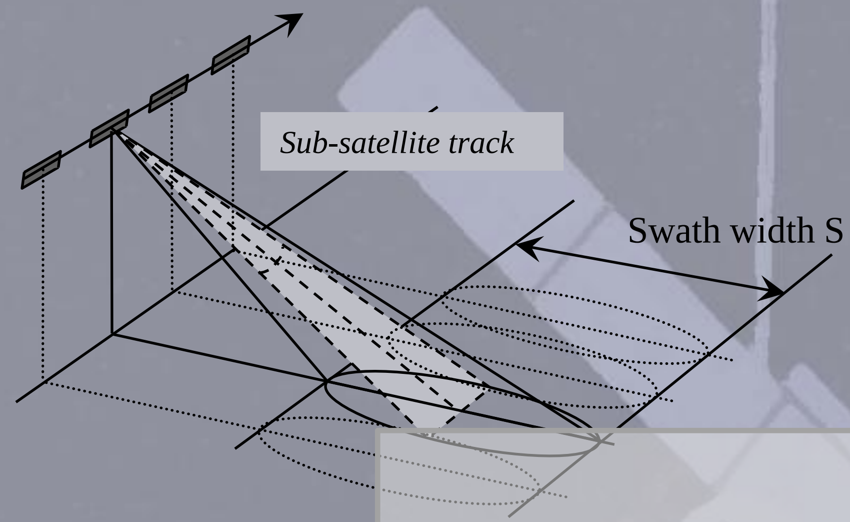
Forest in Cameroon,
TerraSAR-X, Spot Light,
Polar: HH,
Spat.Resolution: 1 m

Optical Data



Forest in Cameroon,
Geoeye, Panchromatic,
Spat.Resolution: 0.5 m

Side looking radar sensors (λ > cm)



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	Raw echoes recording	
Inco ***(I)***		***Coherent*** *sum* ***(A, ϕ)***
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(25 – 50 km)		***fine*** (1 - 30 m)
	Radiometric resolution	
High (400 Looks)		***Low*** (speckle)
	Original application	
sea (winds)		***Land - sea***

See Speckle Part

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III. Frequency – wavelength

IV. Polarization

V. Radar response sensitivity

VI. Relief effects

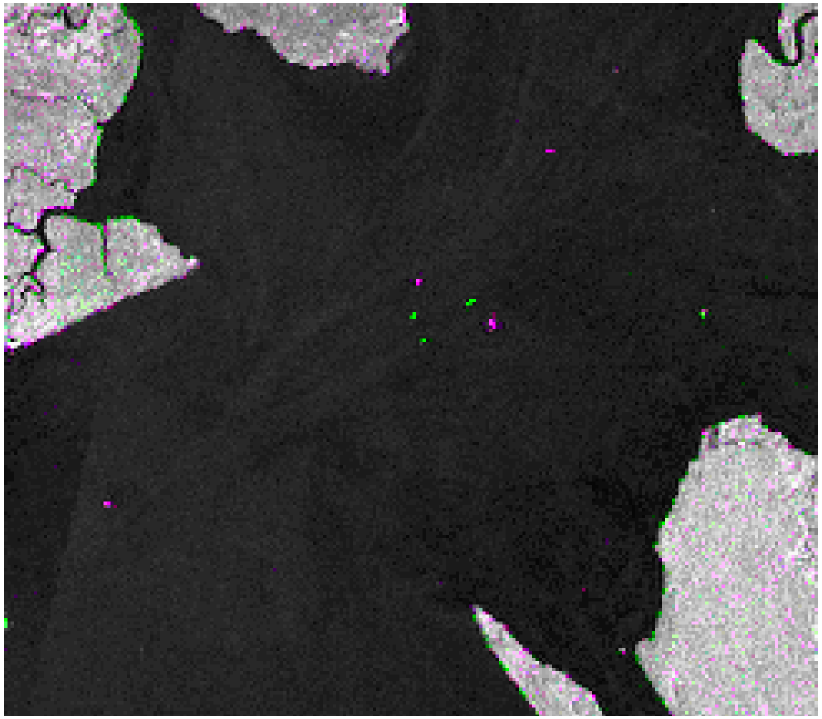
Fréquency – Wavelength

$$f = \frac{c}{\lambda}$$

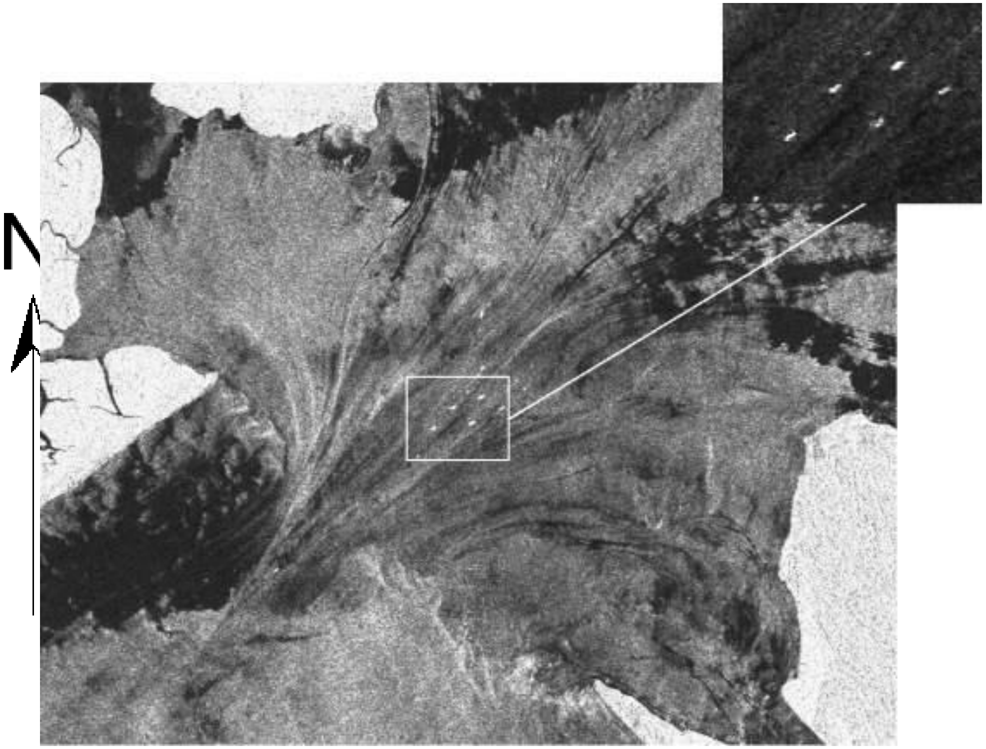
Bande X	**λ ~ 3 cm**	**f ~ 10 GHz**
Bande C	**λ ~ 6 cm**	**f ~ 5 GHz**
Bande L	**λ ~ 25 cm**	**f ~ 1,2 GHz**
Bande P	**λ ~ 70 cm**	**f ~ 400 MHz**

Frequency - wavelength

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

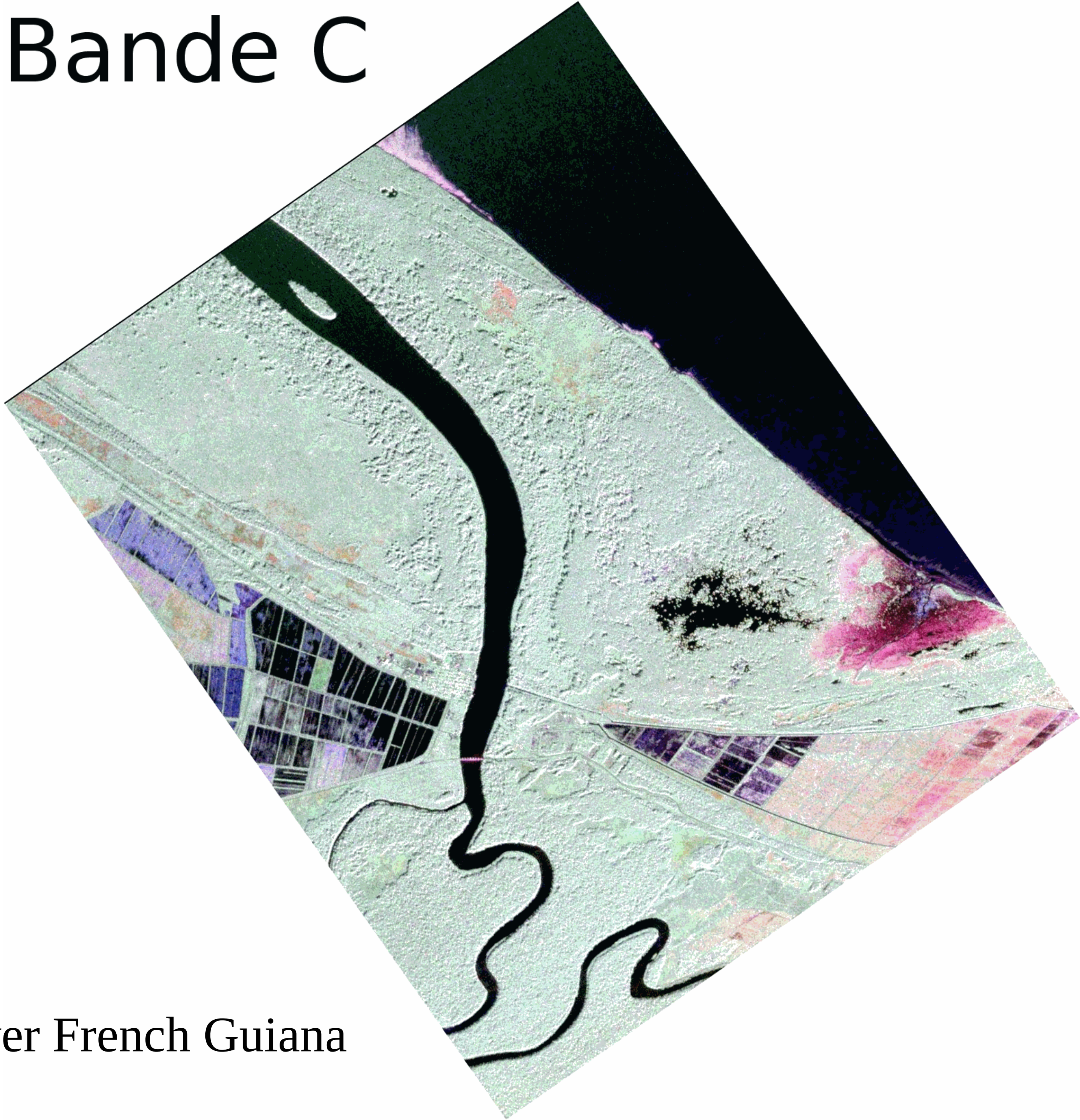


JERS sensor
(Bande L, λ = 25 cm)



ERS sensor
(Bande C, λ = 6 cm)

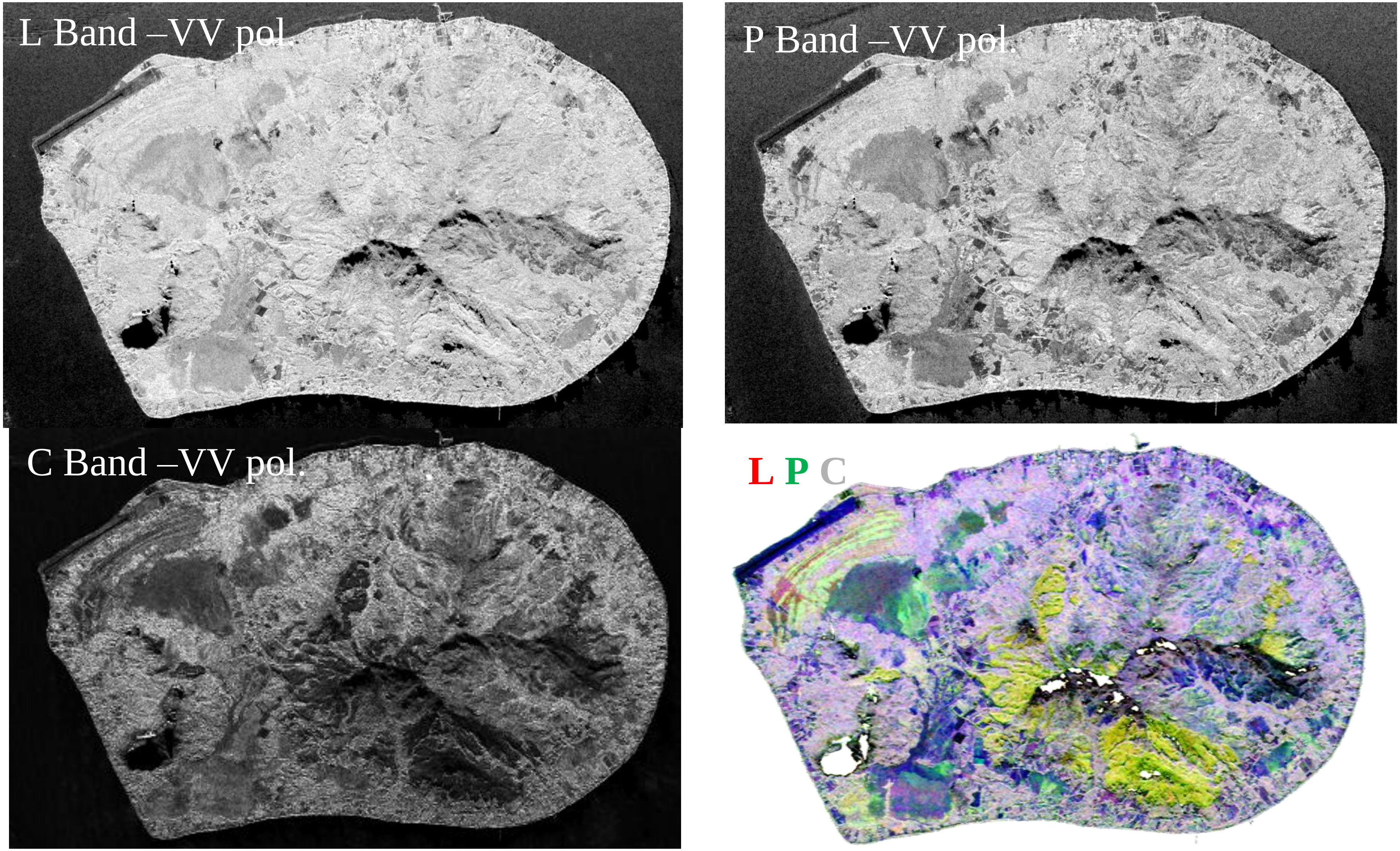
Bande C



Radar response over French Guiana

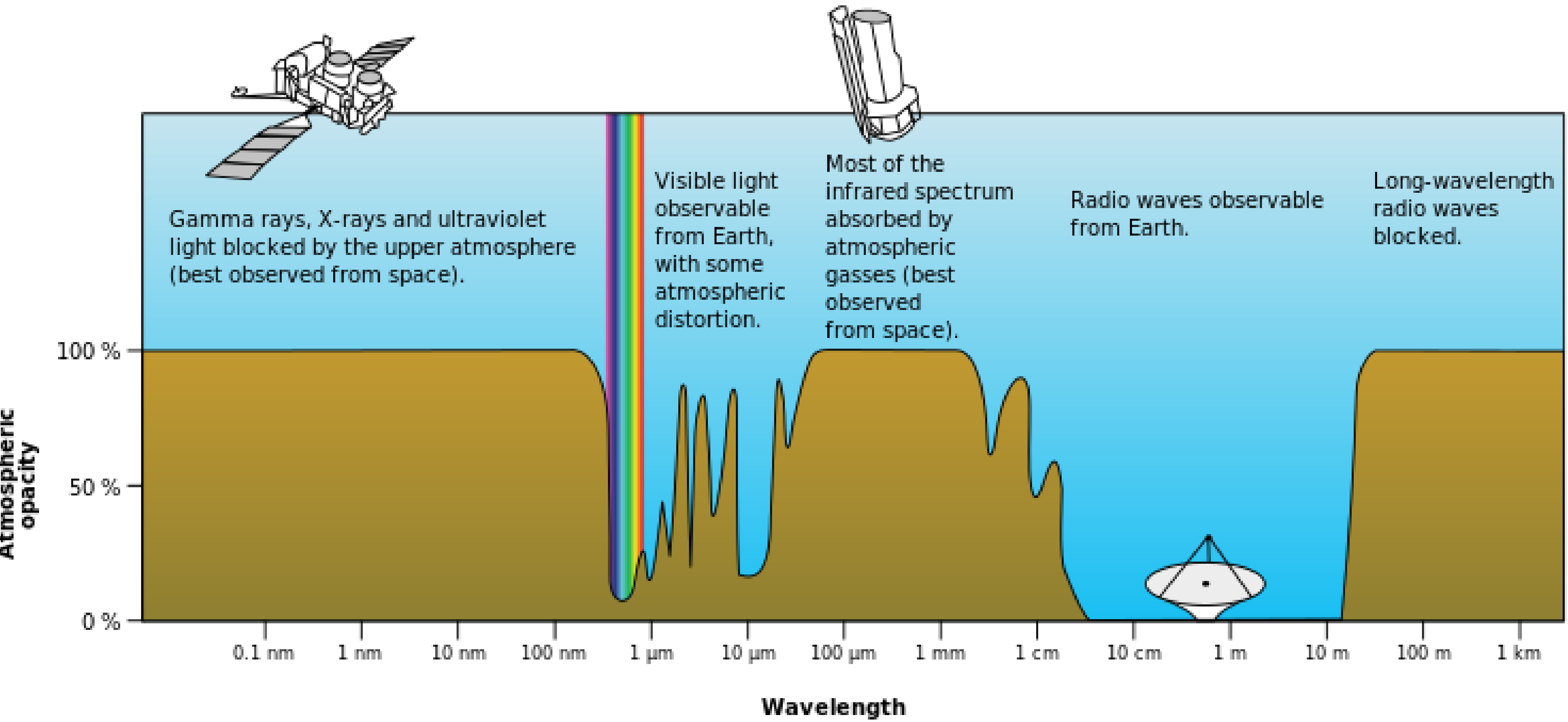
Frequency - wavelength

Tubuai Island, Vegetation discrimination



Frequency - wavelength

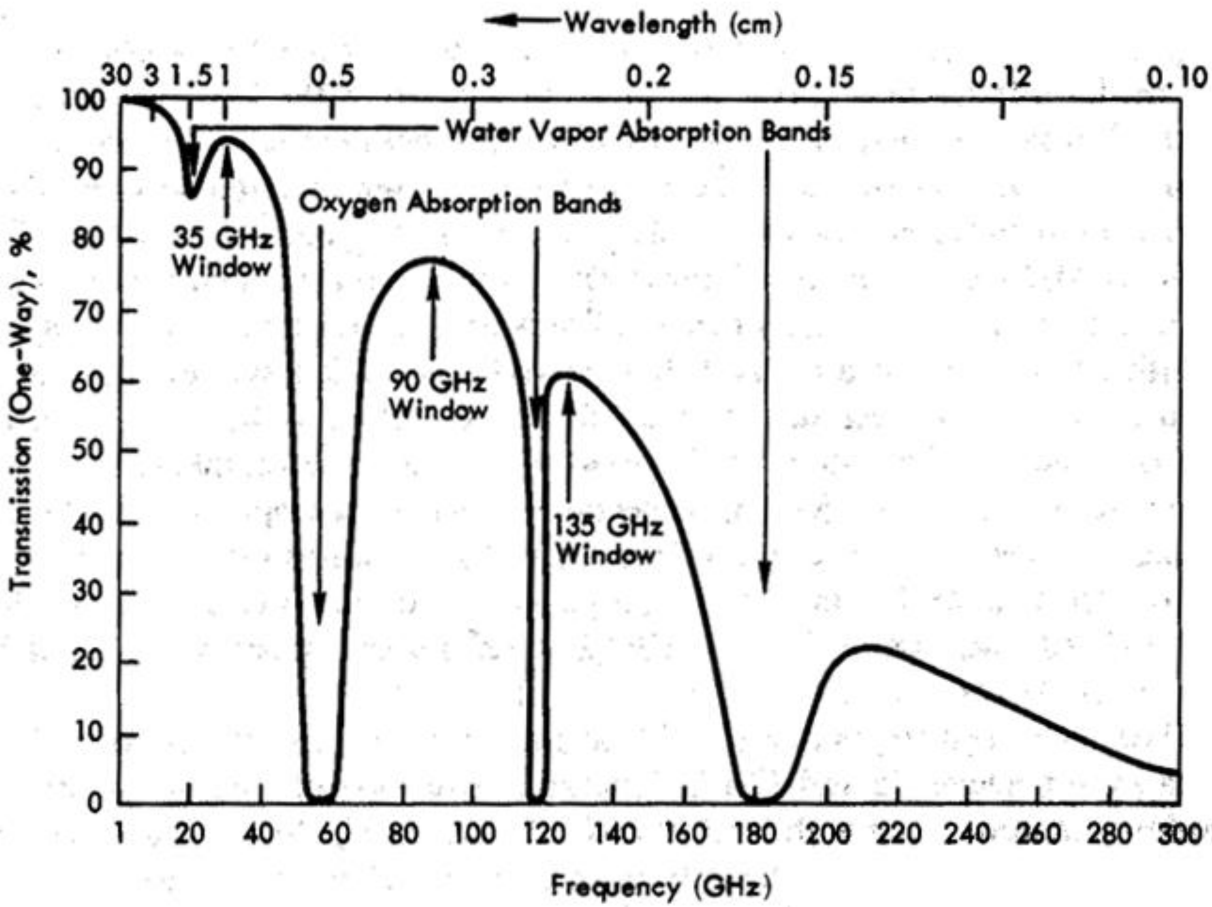
Radar: all weather acquisition



Source: Wikipedia

Frequency - wavelength

Radar: all weather acquisition

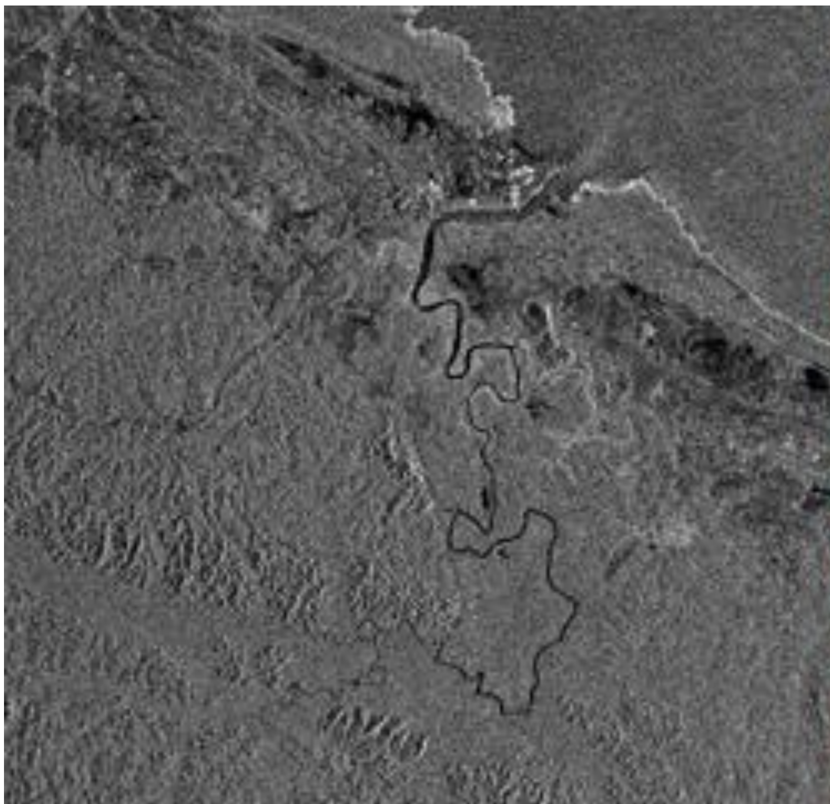


Source: Ullaby *et al*.

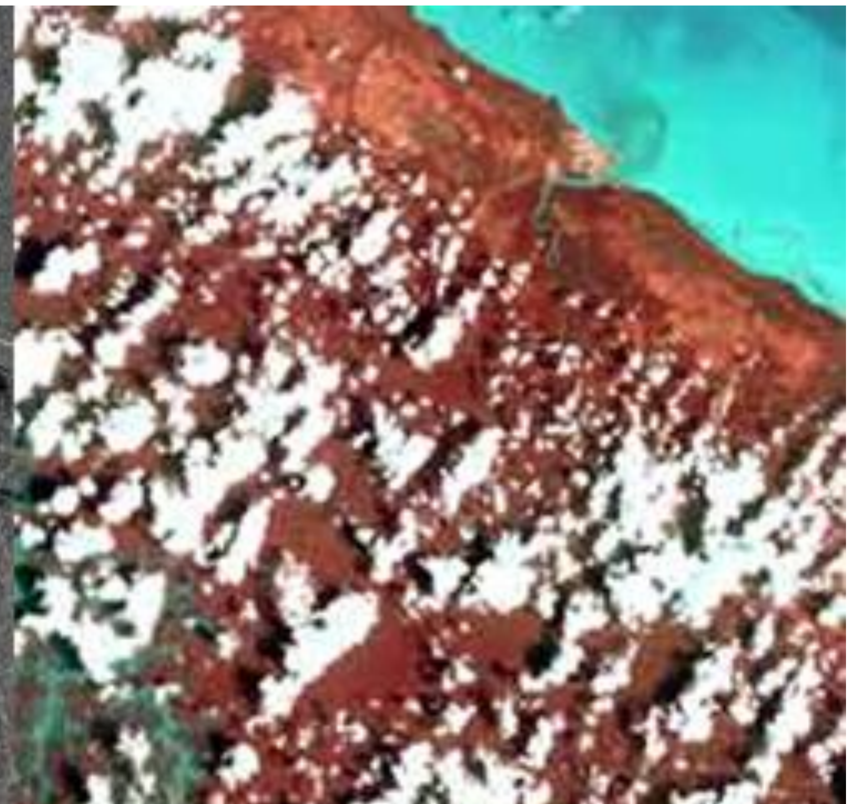
Frequency - wavelength

no problem with rain and cloudy conditions

Radar, ERS

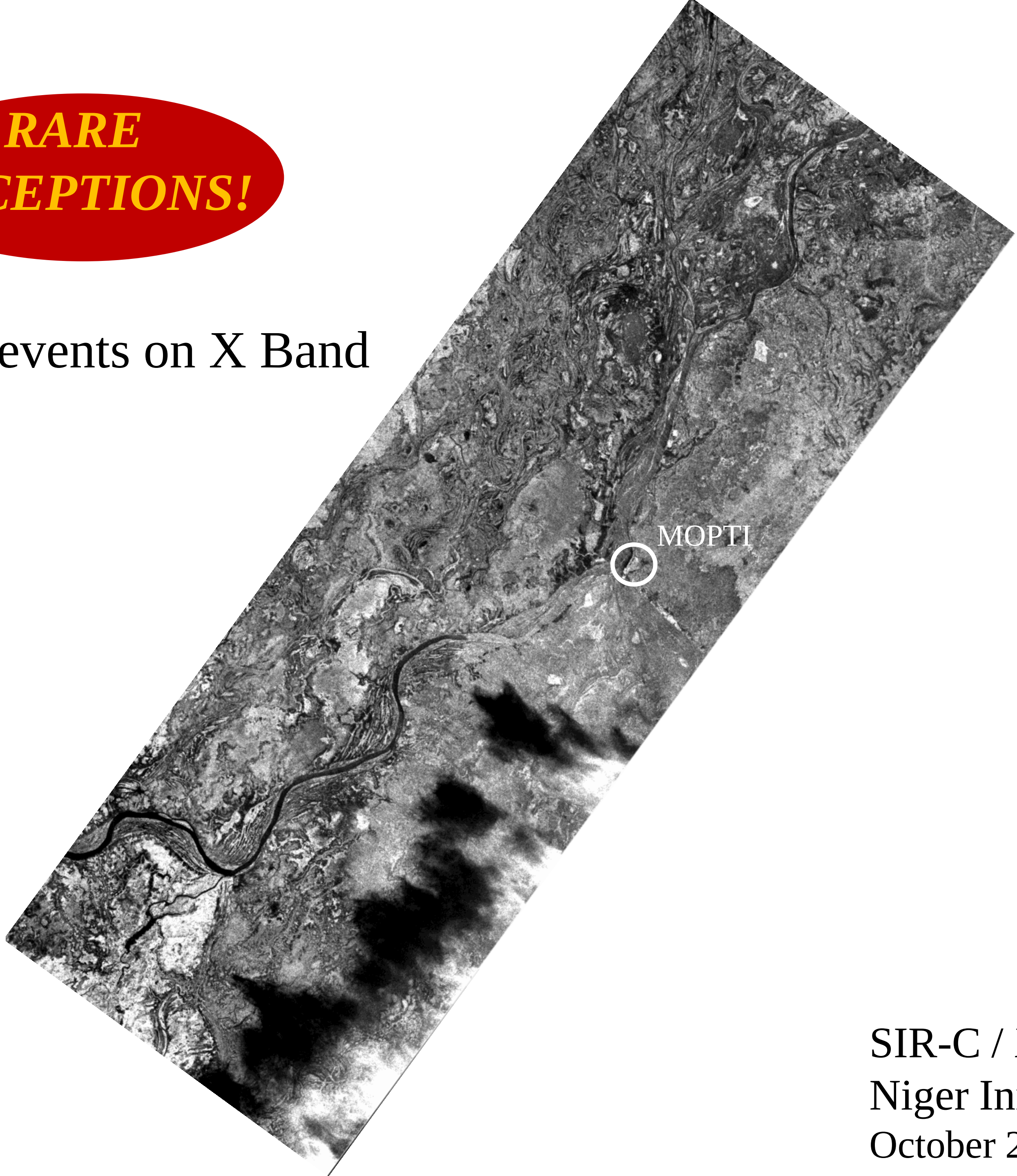


Optical, SPOT



RARE EXCEPTIONS!

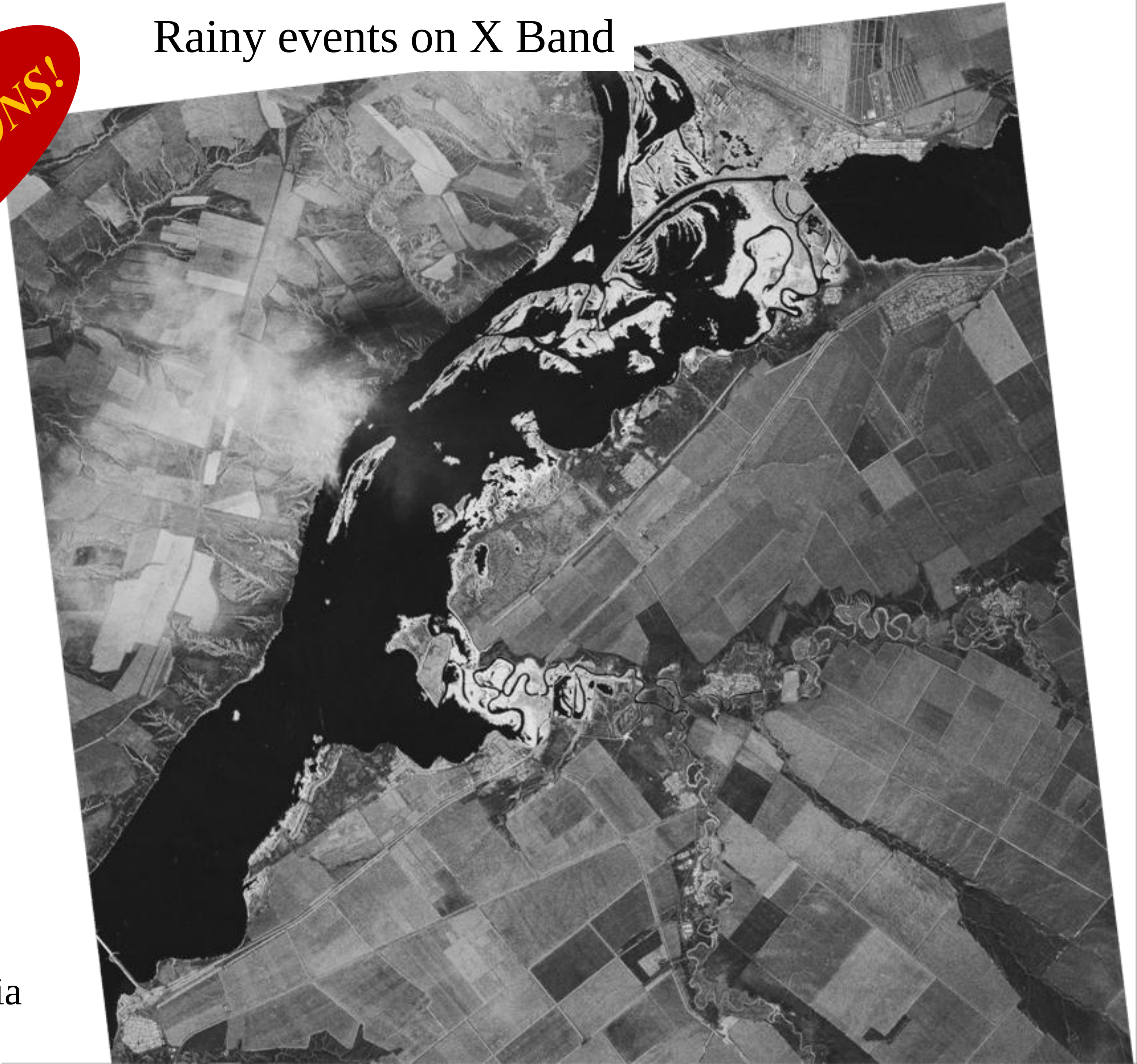
Rainy events on X Band



SIR-C / X-SAR
Niger Inner Delta, Mali
October 2, 1994

Rainy events on X Band

RARE EXCEPTIONS!

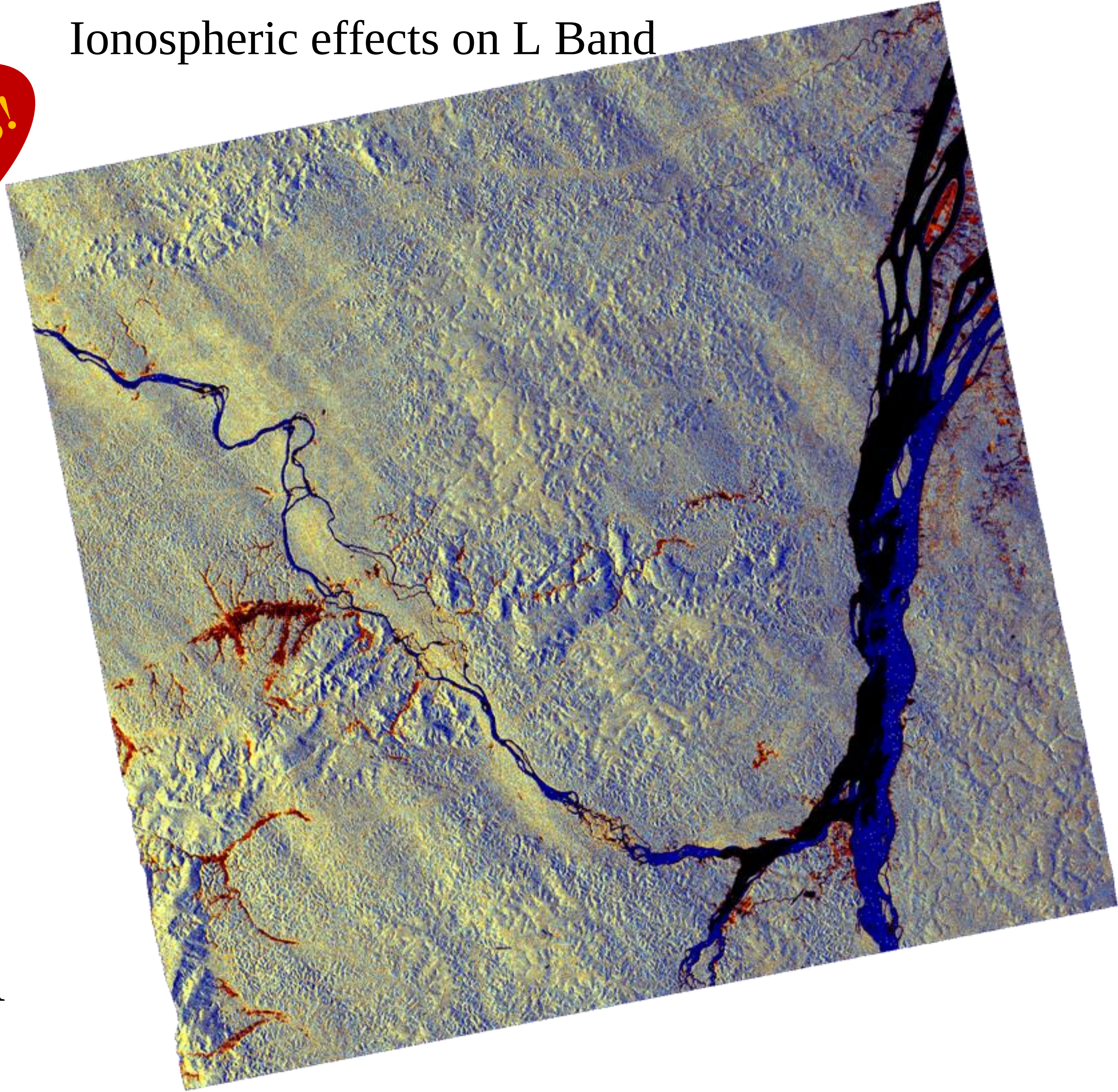


TerraSAR-X

Don River, Russia
June 19, 2007

Ionospheric effects on L Band

RARE EXCEPTIONS!



ALOS-PALSAR

AMAPA, Brazil

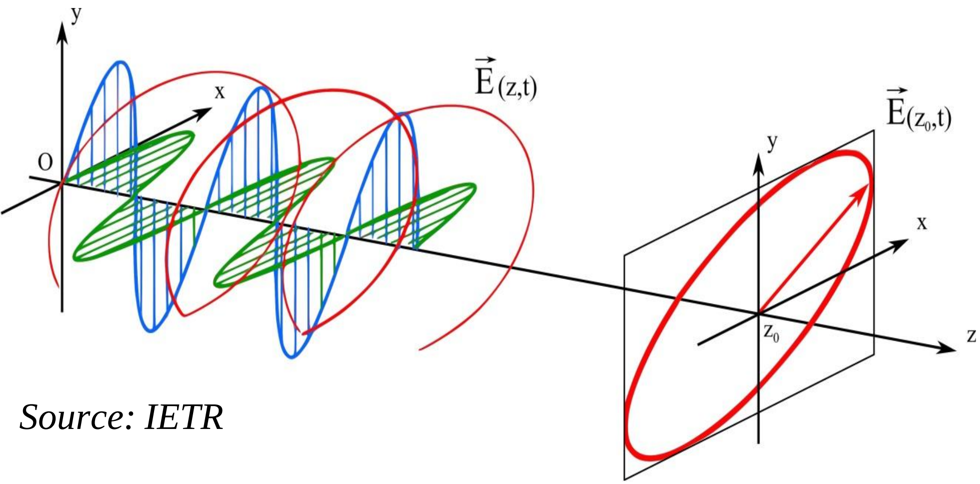
OUTLINE

I. Electromagnetic coherent waves
II. Radar imaging - Spatial resolution
III. Frequency – wavelength
IV. Polarization - Polarimetry
V. Radar response sensitivity
VI. Relief effects

Polarization

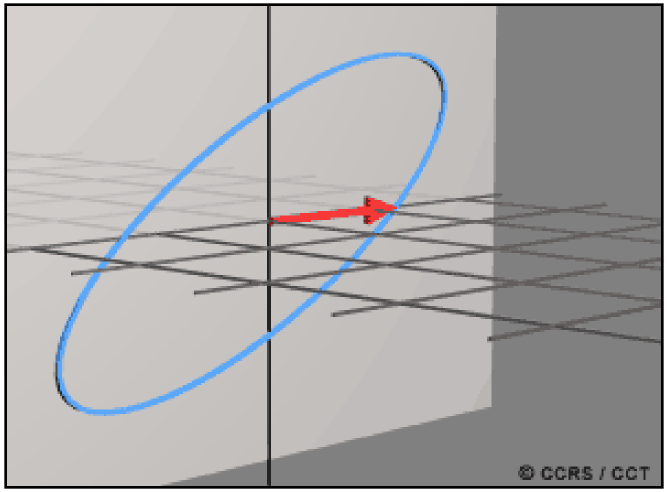
Important characteristics of cohetent EMW:

Electromagnetic field evolution is predictable



Source: IETR

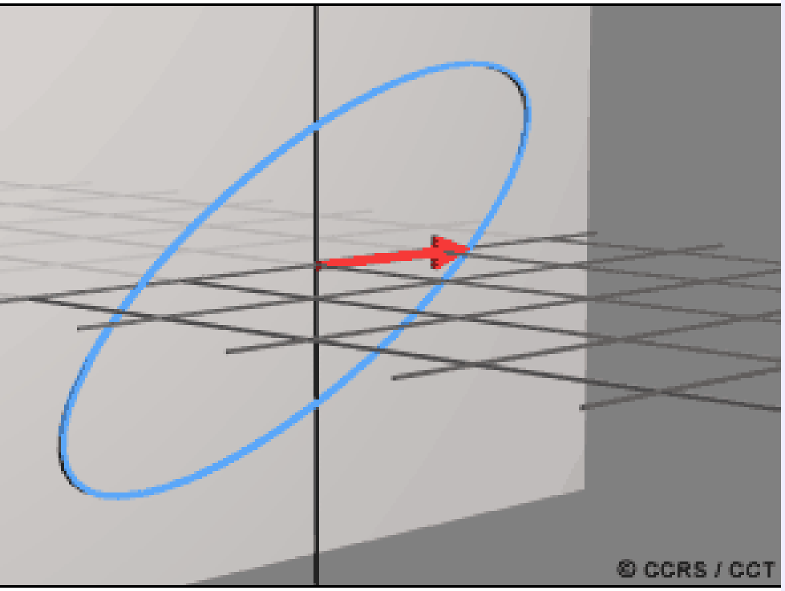
Most general: ***Elliptical*** *polarization*



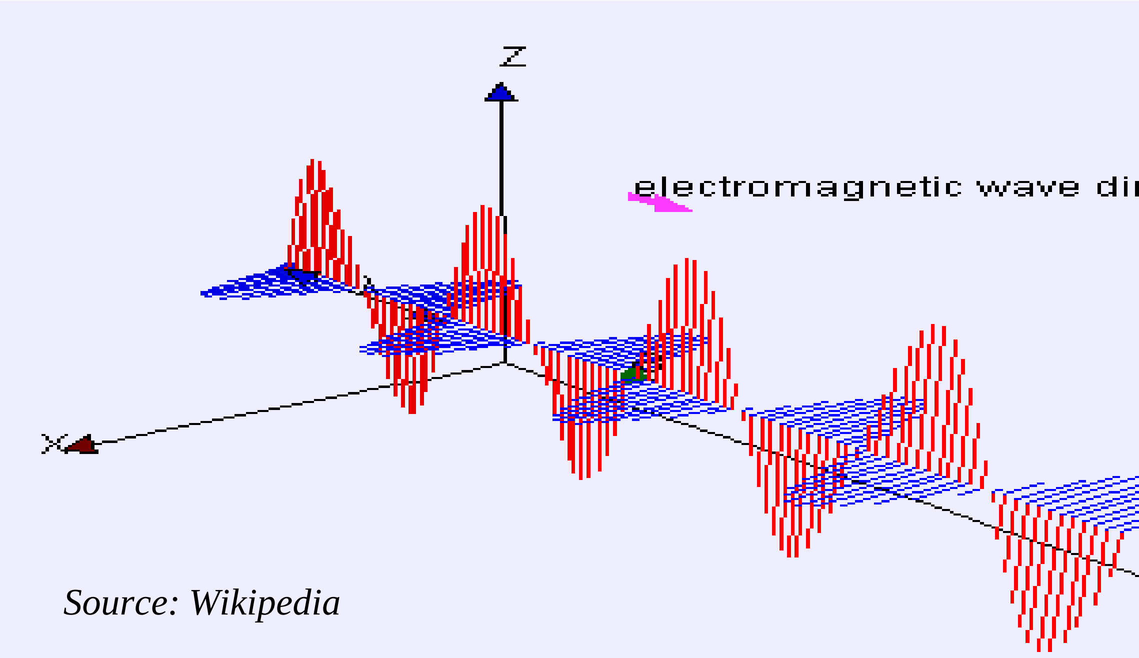
C Cedric Lardeux

Polarization

Most general:
***Elliptical** polarization*



Common radar sensor:
***Linear** polarization*



Source: Wikipedia

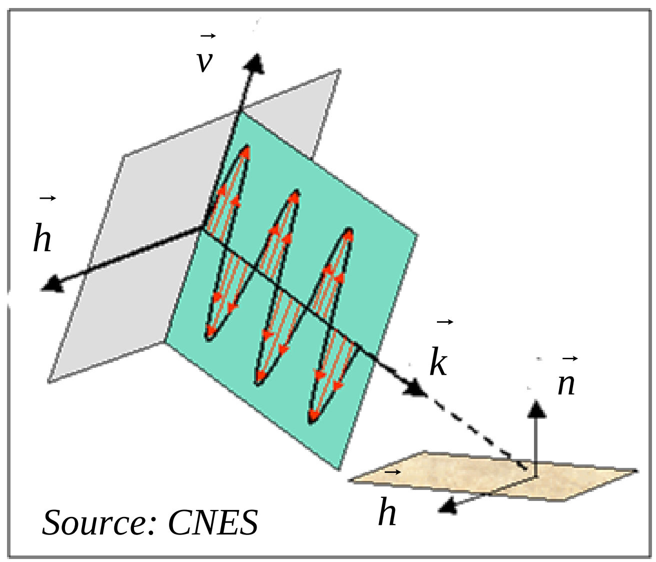
Polarization

Radar :

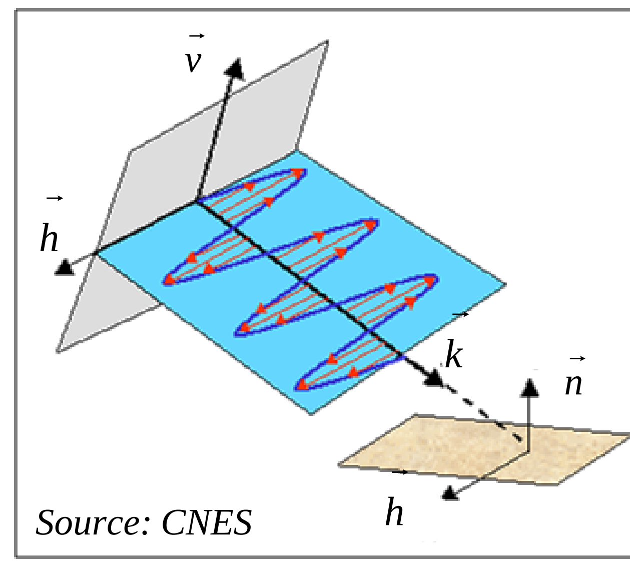
transmits a EMW in a give polarization

measures the backscattered wave contribution in a given polarization

Vertical *polarization*



horizontal *polarization*



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

$\vec{k}$: Direction of illumination

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

Polarization

Polarization characterisation of a radar acquisition:

VV — ERS, ASAR

reception emission

HH — JERS, RADARSAT, PALSAR

reception emission

HV — ASAR, PALSAR

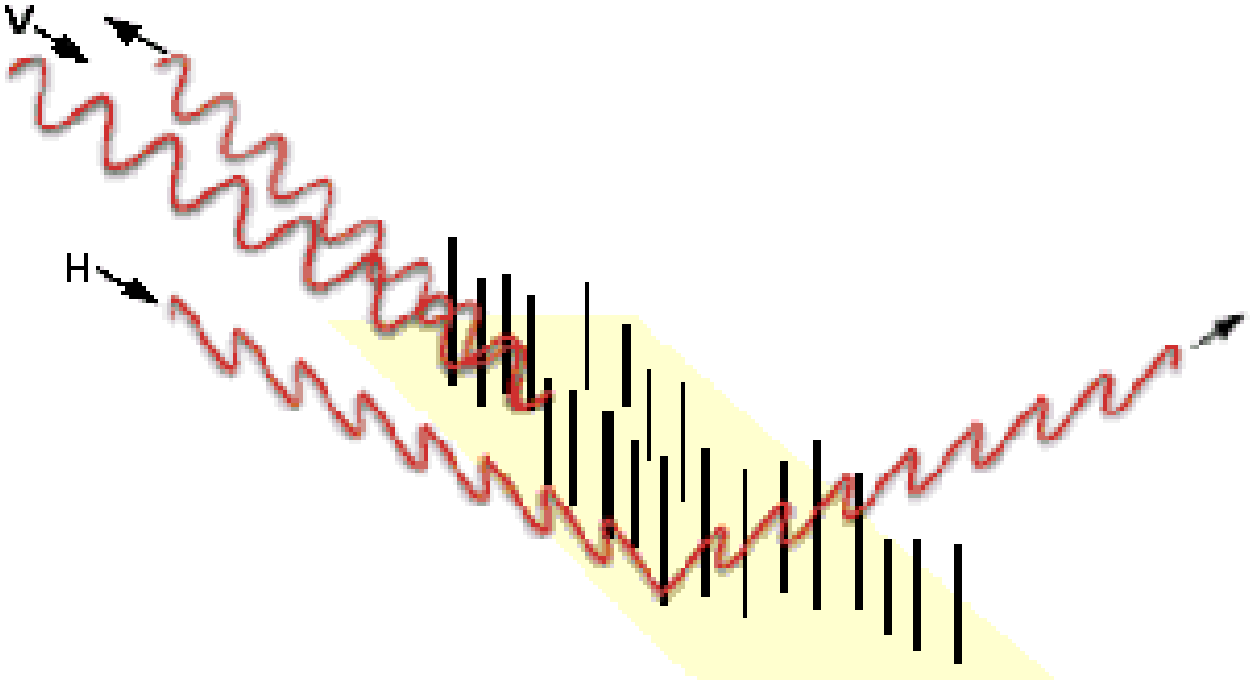
reception emission

VH — ASAR, PALSAR

reception emission

Polarization

Surface with vertical structures



☞ ***What is the point?***

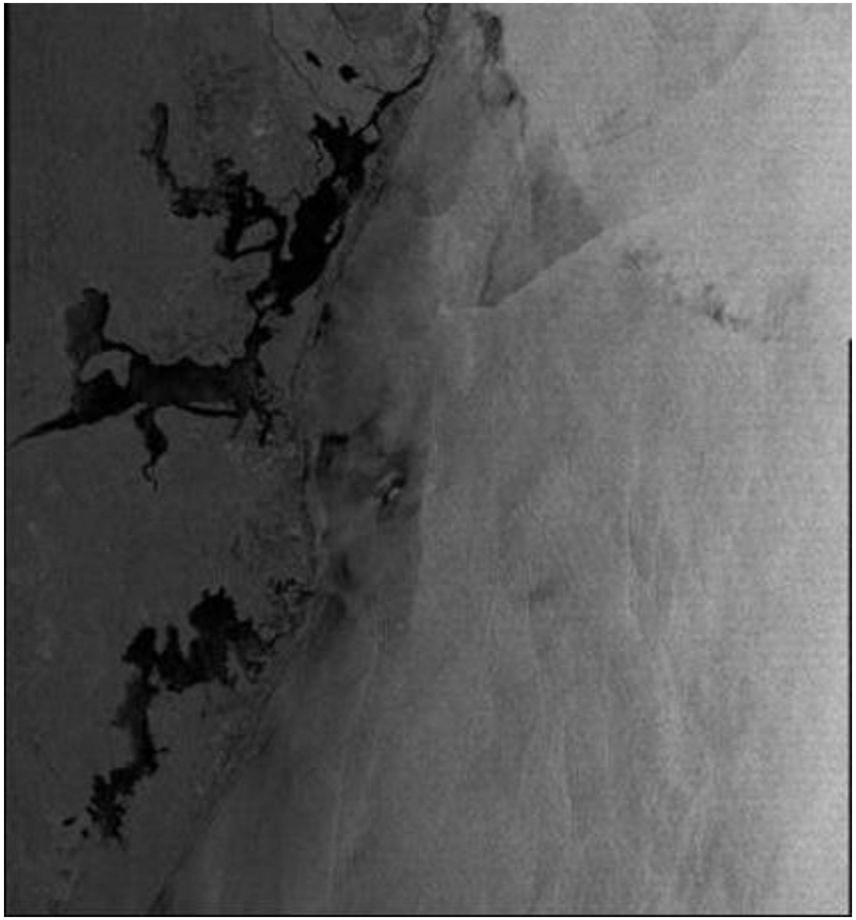
Polarization

Microwave oven

☞ ***What is the point?***

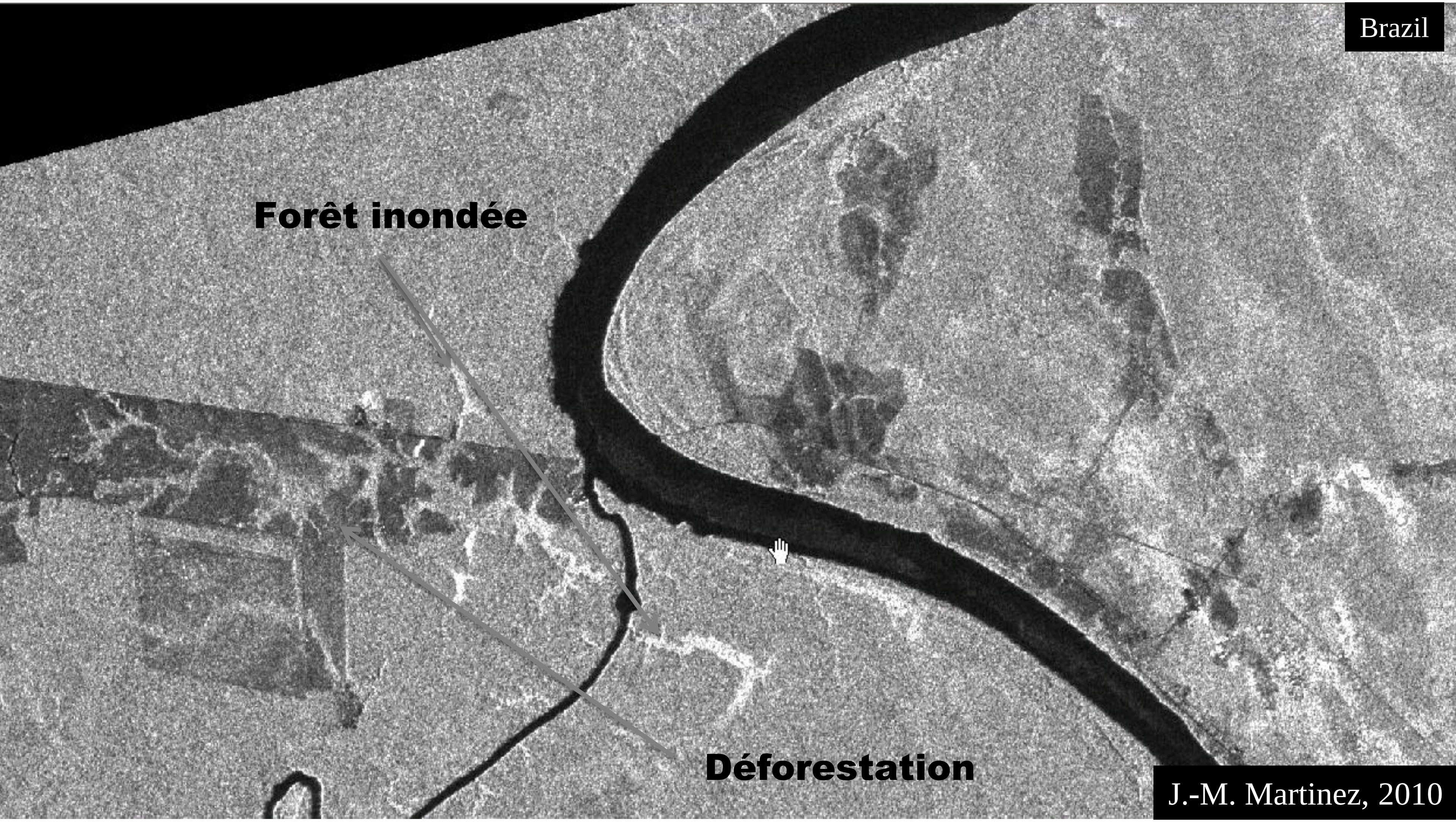
Polarization

polar VV



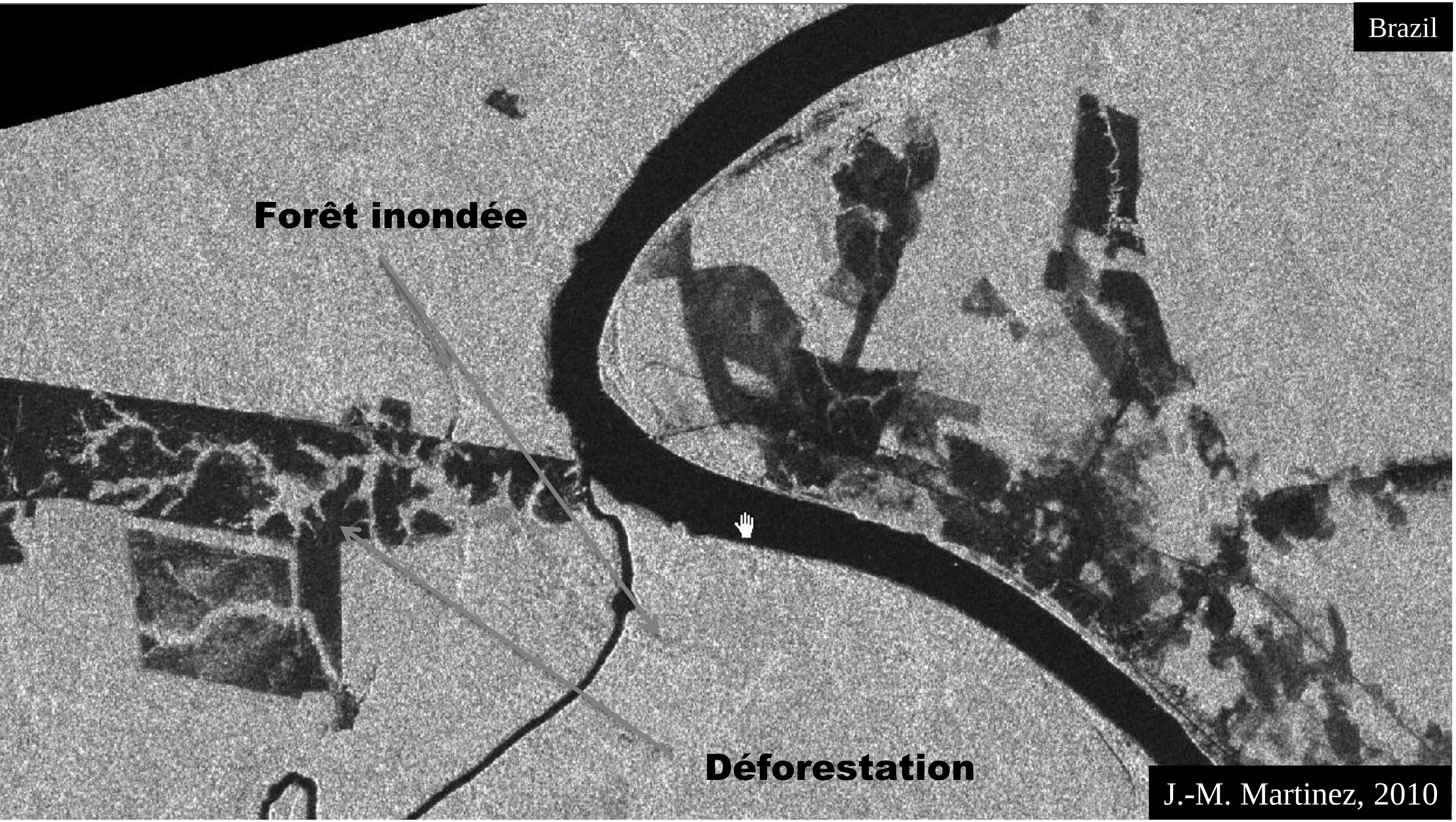
polar HV

Polarization



ALOS acquisition (λ = 24 cm)- Polarization ***HH***

Polarization



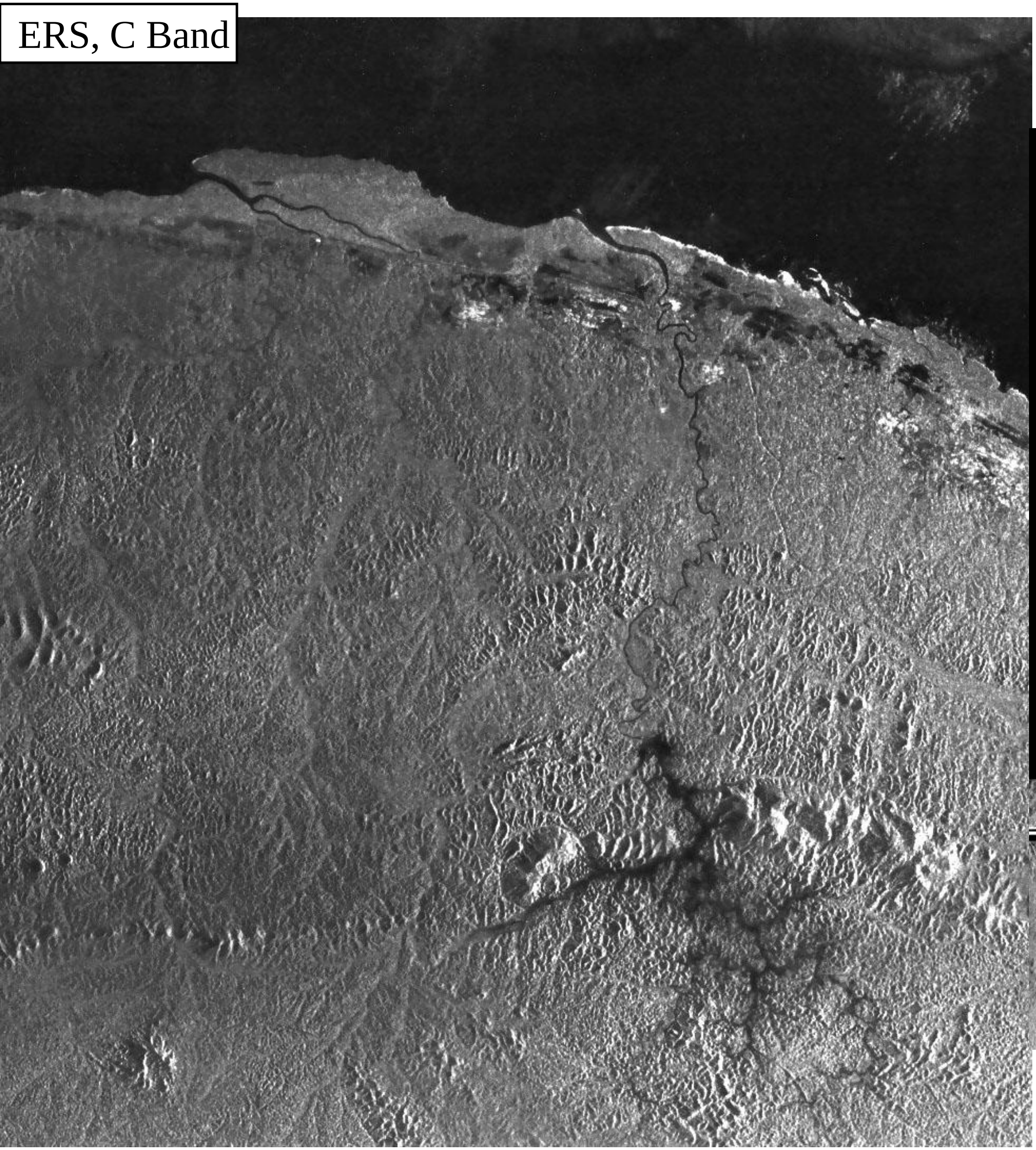
ALOS acquisition (λ = 24 cm)- Polarization ***HV***

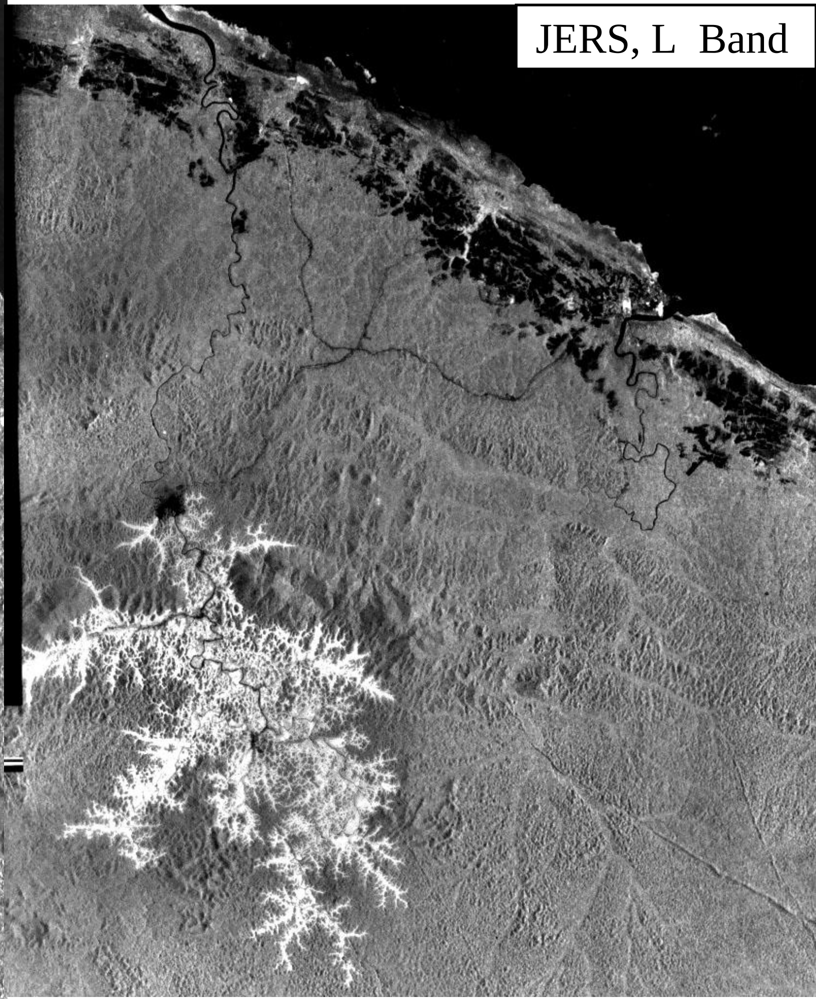
Polarization

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

Polarization

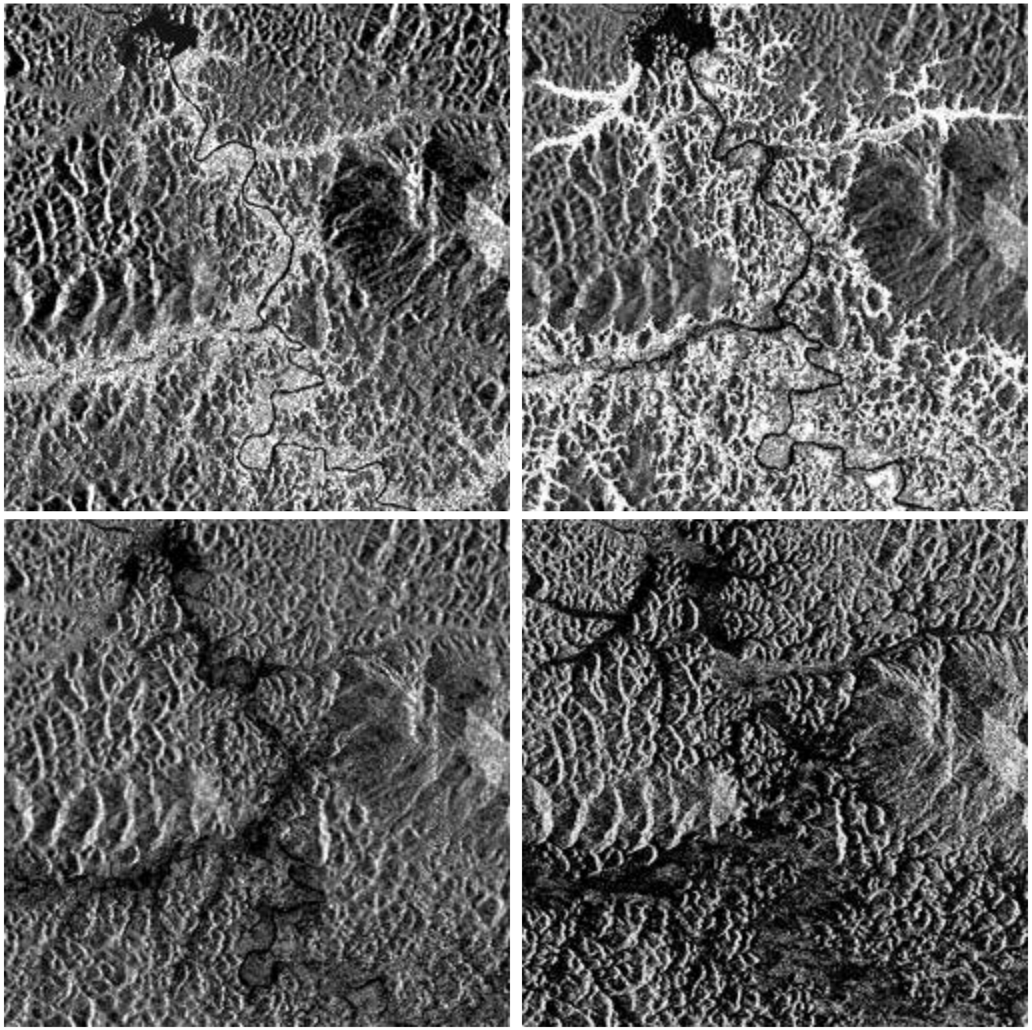
Polarization





Polarization

1995 1997

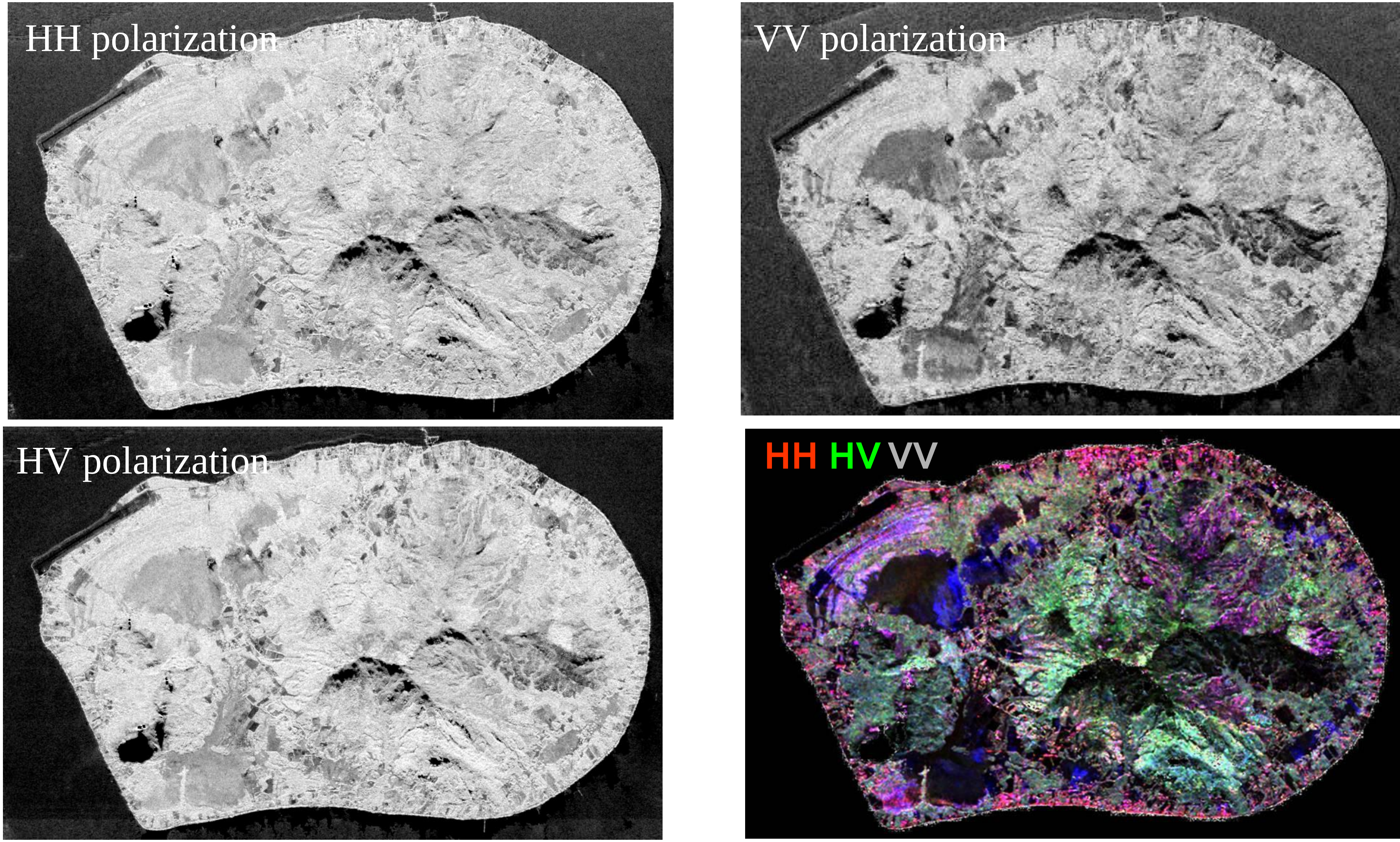


JERS

ERS

Polarization

Tubuai Island, vegetation discrimination, L Band



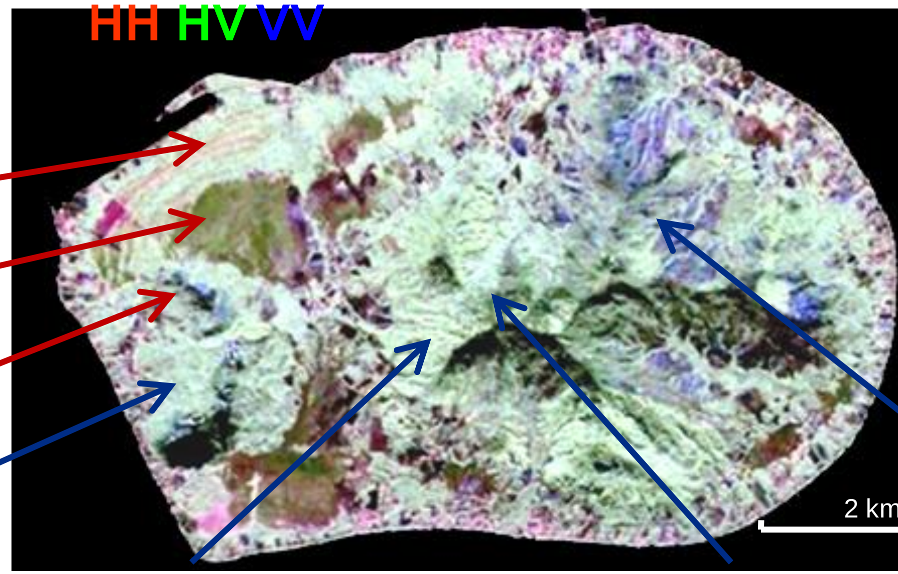
Polarimétrie radar pour la cartographie des forets

Île de Tubuai, Polynésie française

7 différentes classes:

- sols nus
- marécages
- landes à fougères

<u>*4 espèces forestières*</u>



Données AIRSAR
bande L (λ = 24 cm)
août 2000

- Purau
- Falcata

Polarization

in visible domain also!

Polarization

in visible domain also!

Vertical

Horizontal

Rees, 2012

Radar images interpretation rules

Intensity (or Amplitude) Images

Surface scattering (bare soils)	smooth	rough
VV > HH	low	high
HV ~ 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 ~ HH ~ HV

Radar images interpretation rules

Amplitude (or Intensity) Images

Surface scattering (bare soils)

Amplitude

VV > ***HH***

HV ~ 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 ~ HH ~ 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 discrimnation

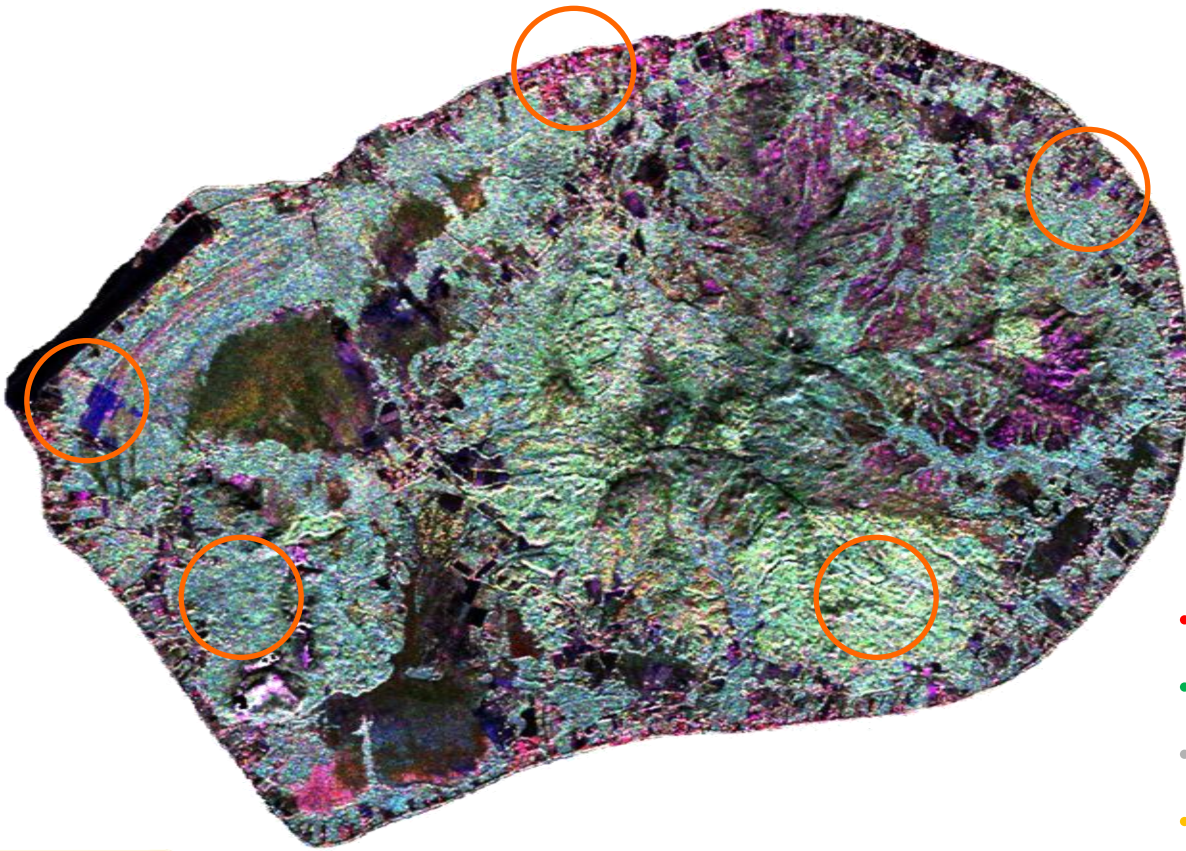
HH polarization

For flooded/Non flooded vegetation

Urban areas

Radar images interpretation rules

Intensity Image



HH HV VV

Tubuai Island

AISAR data, L Band

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

~ **Purau**

Radar images interpretation rules

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

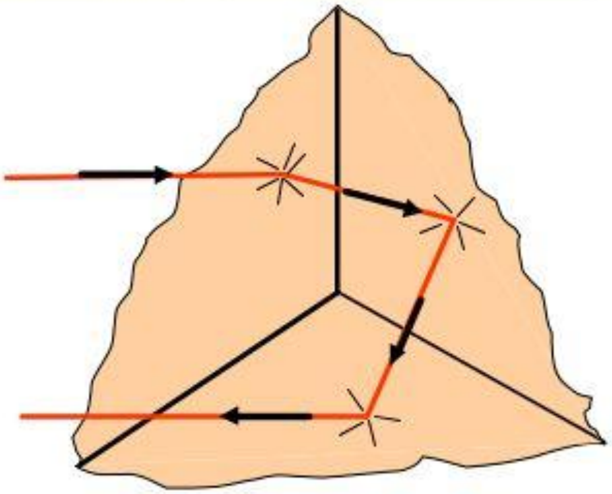
VV,HV

HH, VV

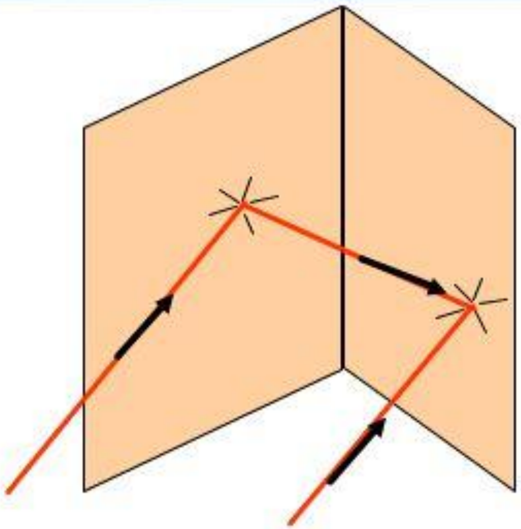
Radar images interpretation rules

Polarimetric Data: Amplitude + Phase Images

Behavior of the differential phases



Odd number of reflexions:
Ex: Trihedral target type
$\phi_{HH}-\phi_{VV} \approx 0°$



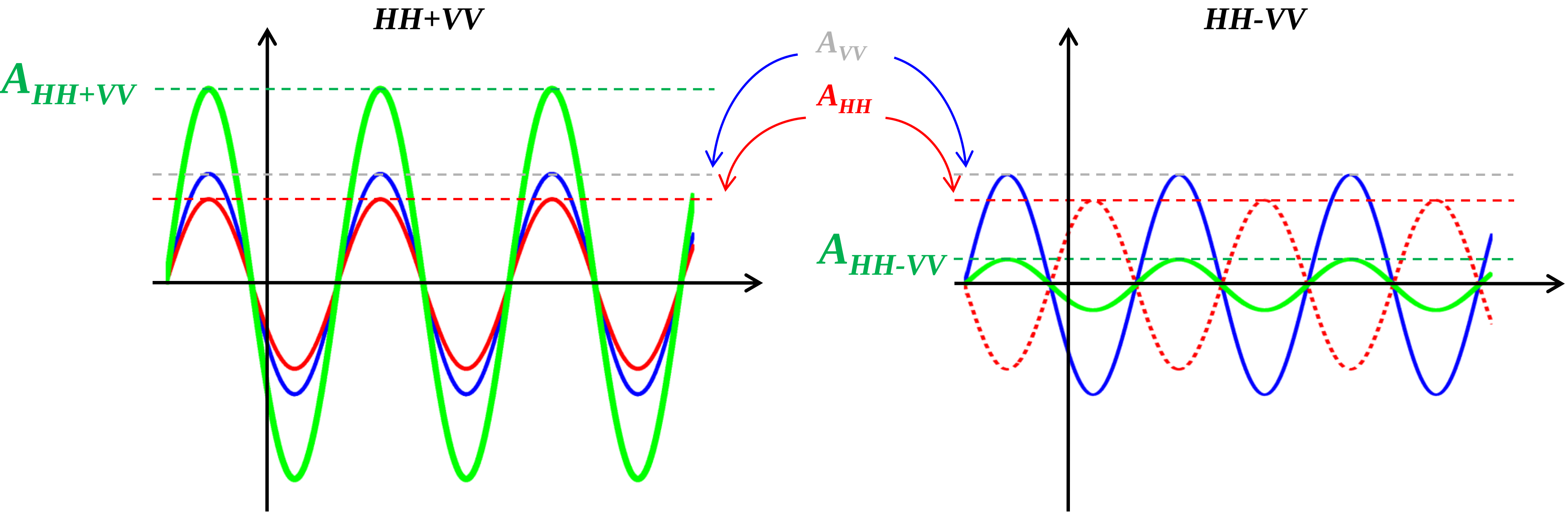
Even number of reflexions:
Ex: dihedral target type
$\phi_{HH}-\phi_{VV} \approx 180°$

Radar images interpretation rules

Polarimetric Data: Amplitude + Phase

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

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

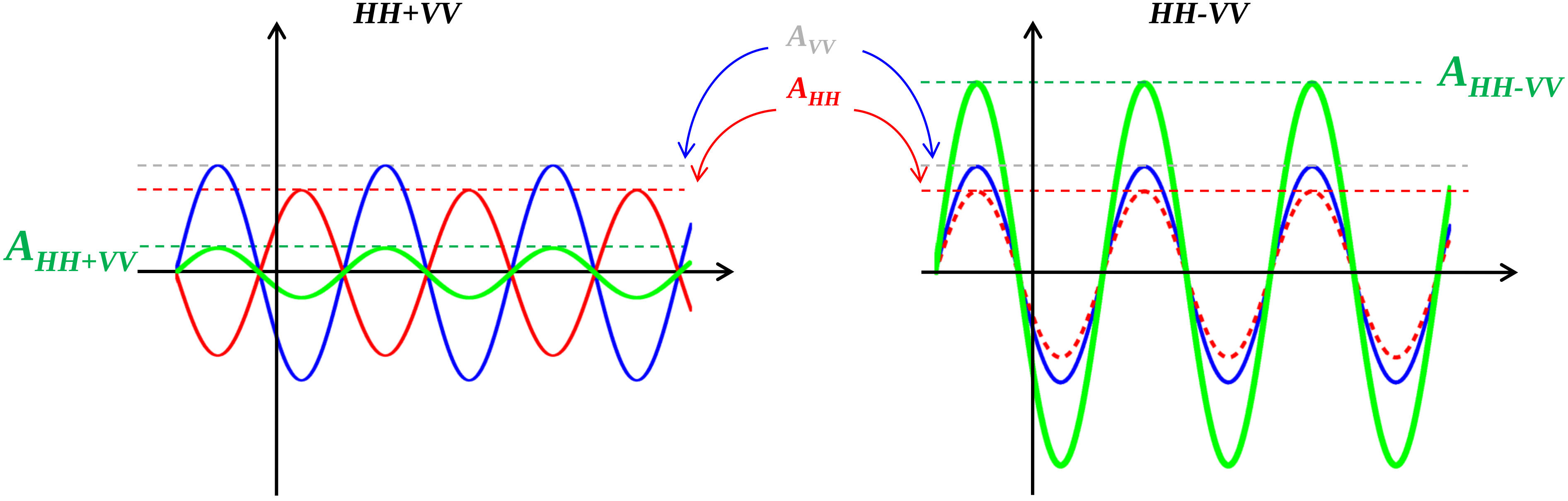


Radar images interpretation rules

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 ~ 0

Phase difference

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

|HH+VV| 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| high

Wild areas (dense habitat, screes,…)

VV ~ HH ~ HV

Radar images interpretation rules

Polarimetric Data: Amplitude + Phase Images

|*HH+VV*|

Bare surfaces

HV polarization

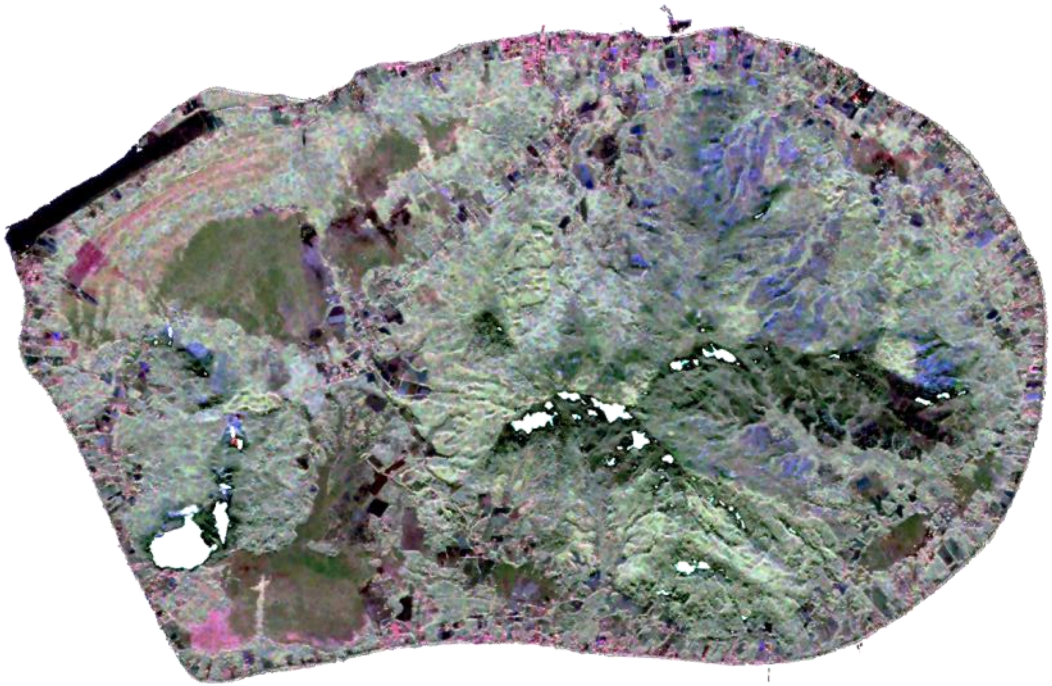
For Forest/Non forest discrimnation

|*HH-VV*|

For urban areas and flooded vegetation

Radar images interpretation rules

Polarimetric Image: Pauli Representation



Tubuai Island

AISAR data, L Band

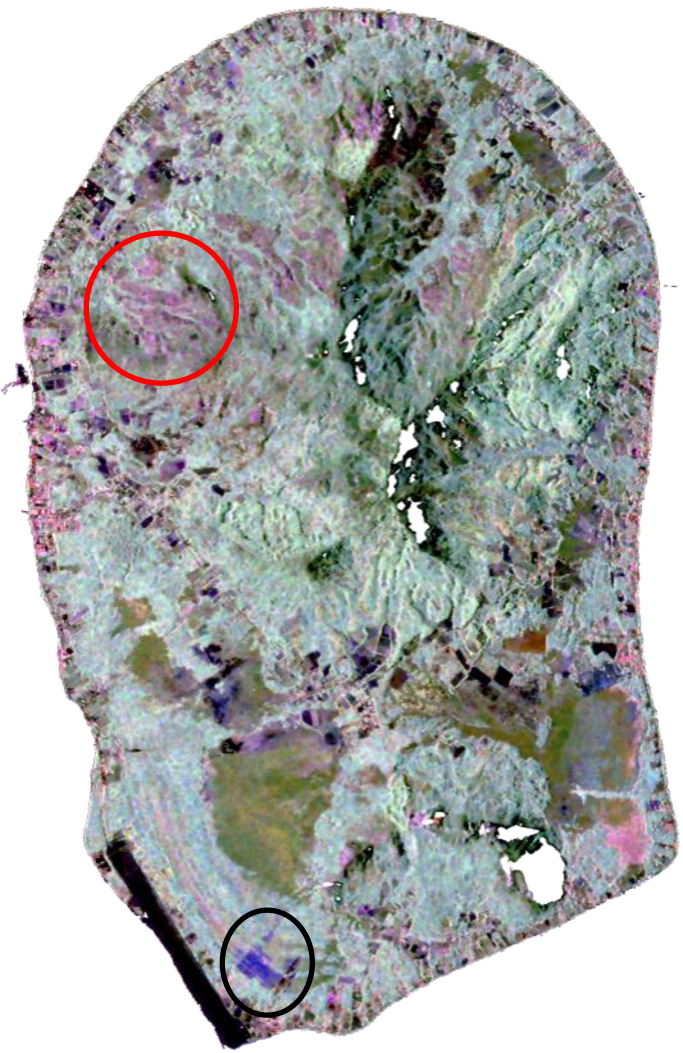
- ***Double bounds***
- ***Dense vegetation***
- **Bare soil**
- **Pinus** et **Falcata**

~ **Purau**

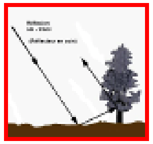
|HH-VV| HV |HH+VV|

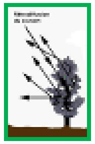
Radar images interpretation rules

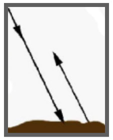
Pauli Representation



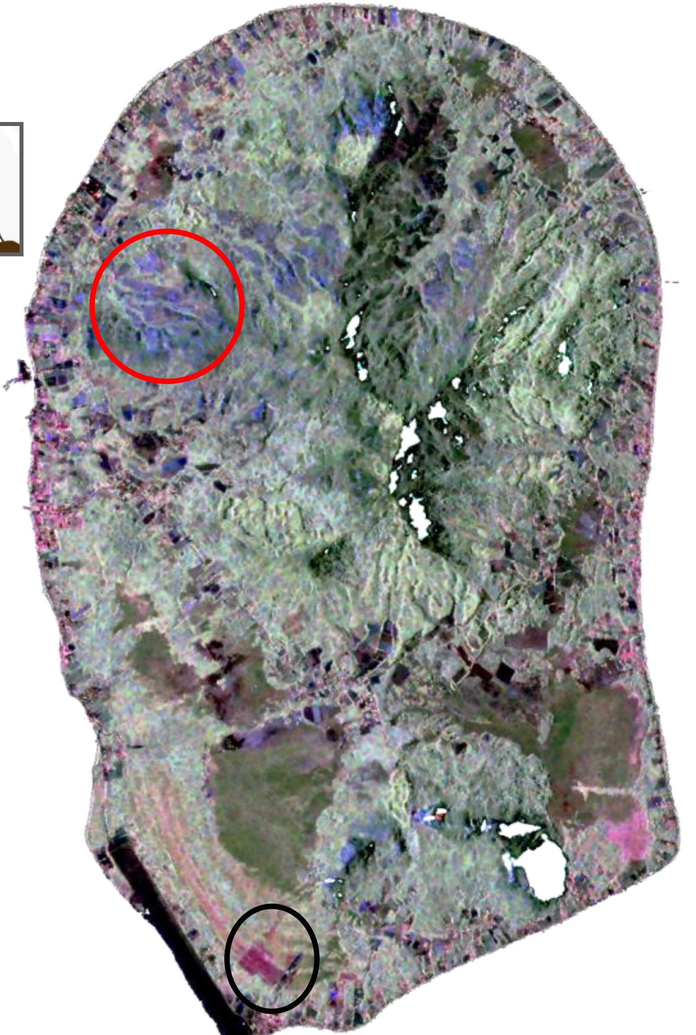
HH HV VV





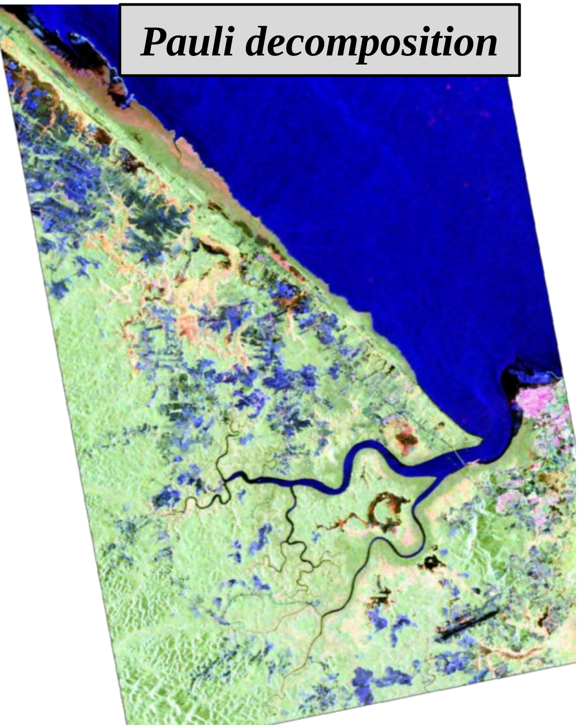


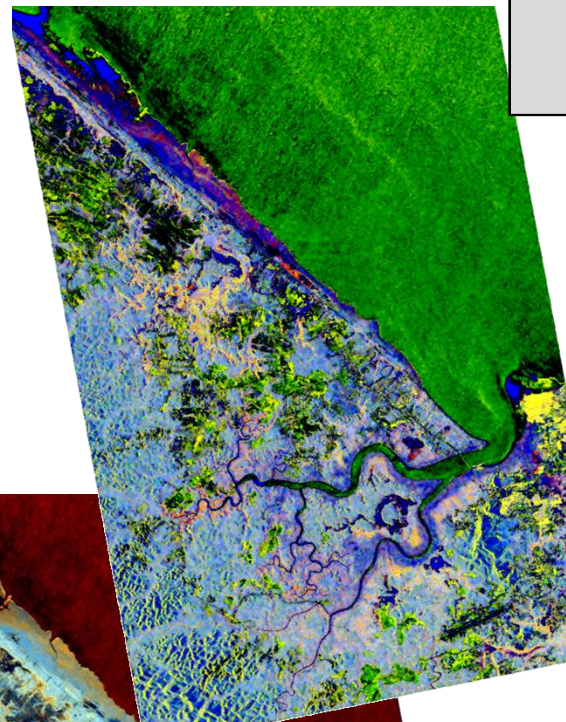
Quickbird



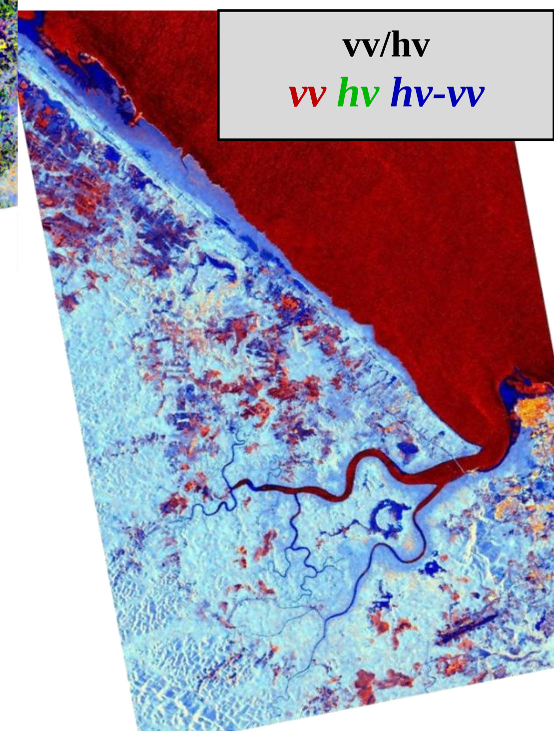
|HH-VV| |HV| |HH+VV|

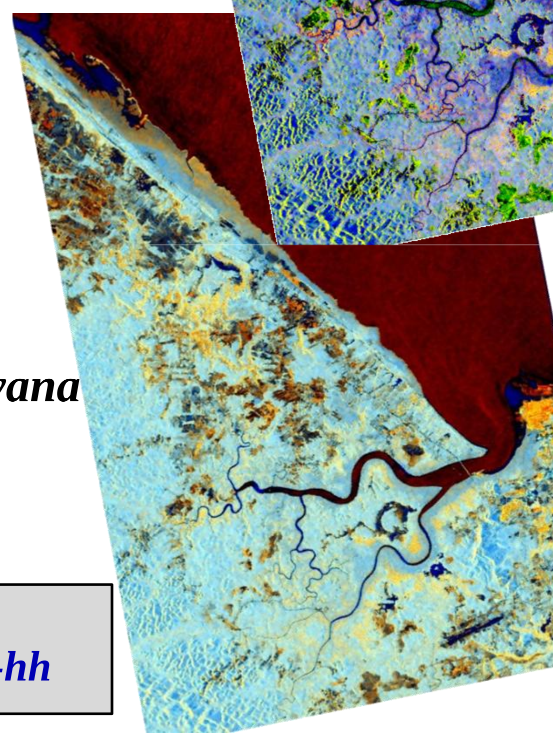
Radar images interpretation rules





Natural Vegetation - French Guyana
PALSAR (L Band)





OUTLINE

I. Electromagnetic coherent waves

II. Radar imaging - Spatial resolution

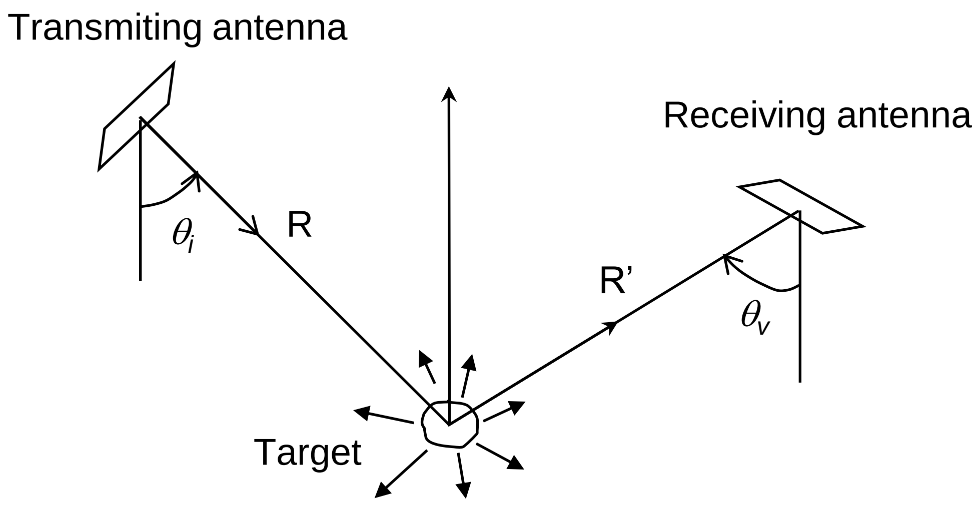
III. Frequency – wavelength

IV. Polarization

V. Radar response sensitivity

VI. Relief effects

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)

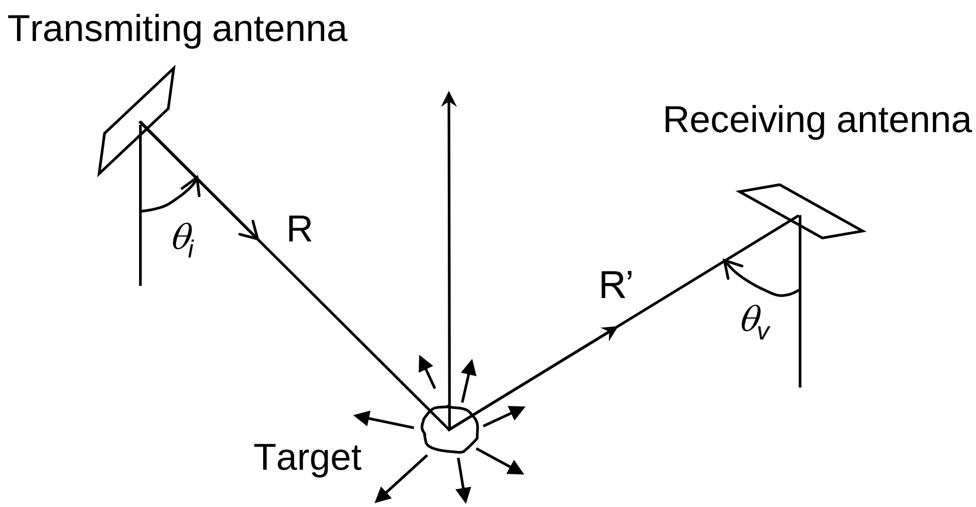
Intensity emited from the target (isotrope):

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

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: $P_r = E_r\, dA = E_r \frac{G_r \lambda^2}{4\pi} = \frac{P_e G_e}{4\pi R^2} \frac{SER}{4\pi R'^2} \frac{G_r \lambda^2}{4\pi} \quad (W)$

The radar equation

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

Case of expanse surfaces:

Radar Backscattering Coefficient: $\sigma^0 = \frac{RCS}{d\Sigma}$ *(m²/m²)*

➔ *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)

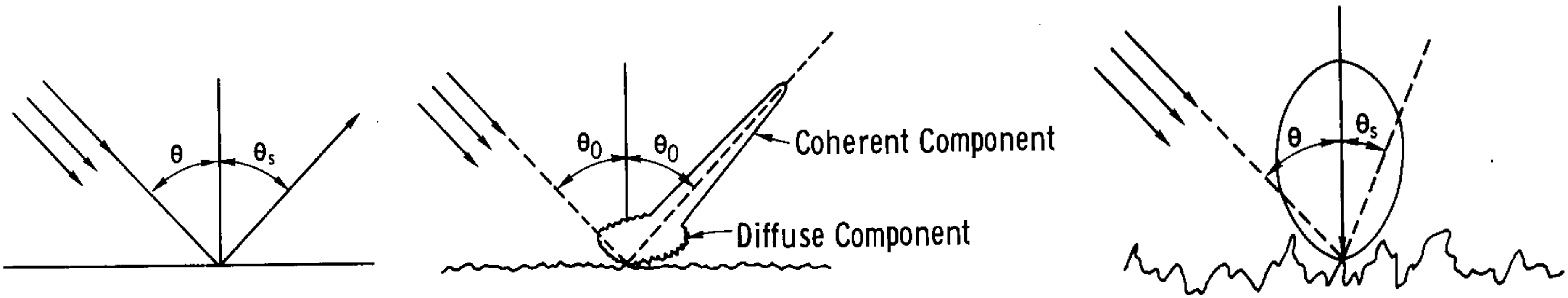
$$\sigma^0_{dB} = 10 . \log_{10} \left(\sigma^0_{Nat} \right)$$

Radar images interpretation rules

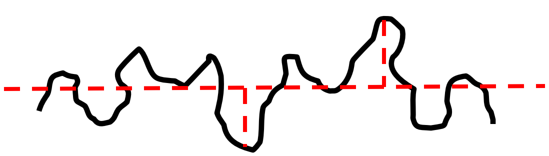
Surface scattering

Soil: homogeneous medium ==> scattering at the interface

Influence of roughness



Surface roughness is refered to the radar wavelength



σ: rms height

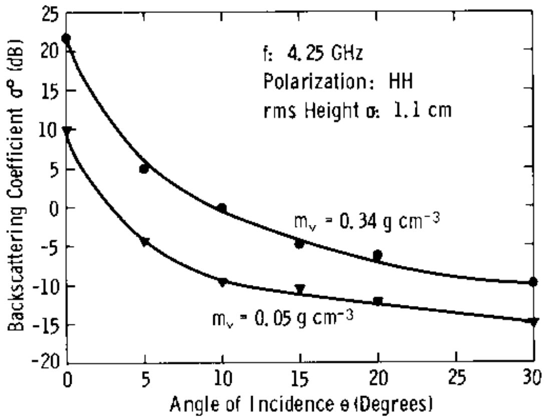
$$\sigma < \frac{\lambda}{8 \cos \theta}$$ ==> smooth surface

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

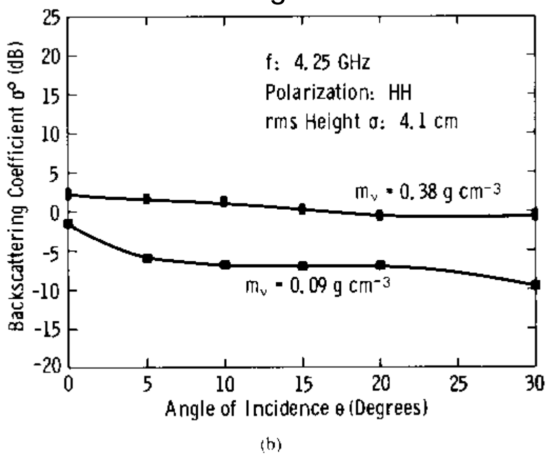
Radar images interpretation rules

Surface scattering

Smooth surface



Rough surface



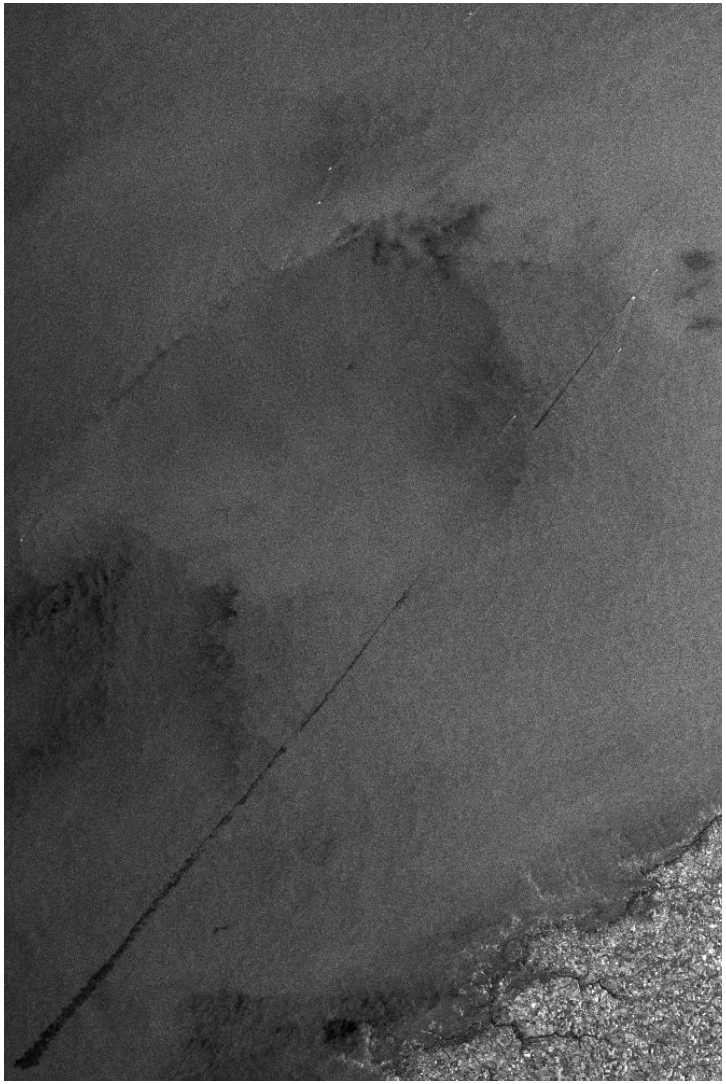
Soil *roughness*: ***angular*** effect

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

ERS radar image in Sahel

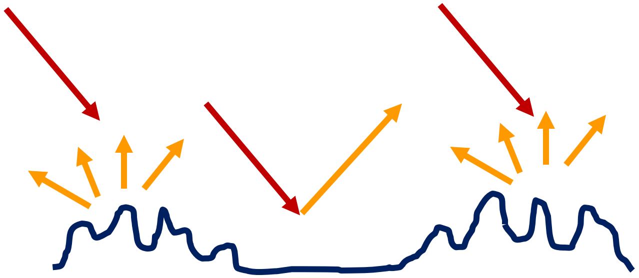
Over bare soil: depends on
Roughness
Soil moisture

Radar response sensitivity



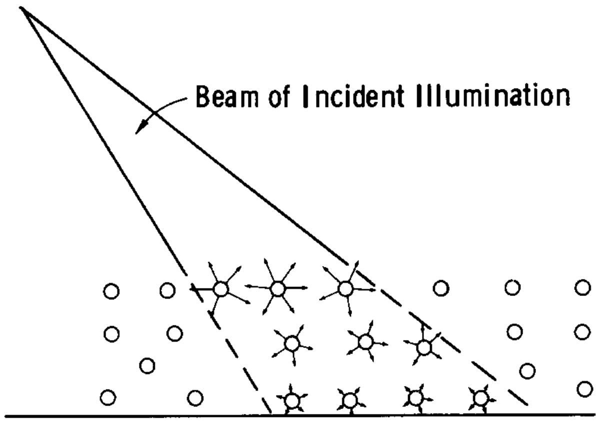
ERS (bande C, 23°, VV): 9 mars 1999

Over surface water:
surface roughness too



Radar images interpretation rules

Volume scattering



Inhomogeneous medium (vegetation cover):

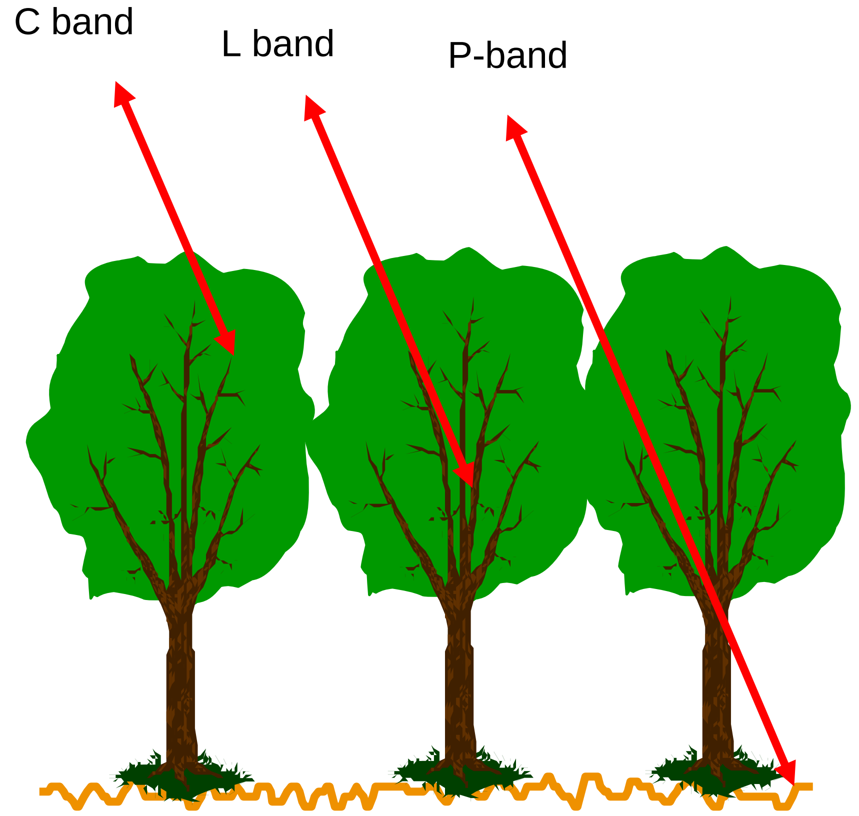
each inhomogeneity (leaves, branches….)
scatters incident wave in all directions

Multiple scattering
+
Absorption

==> wave attenuation within the layer

Radar images interpretation rules

Volume scattering

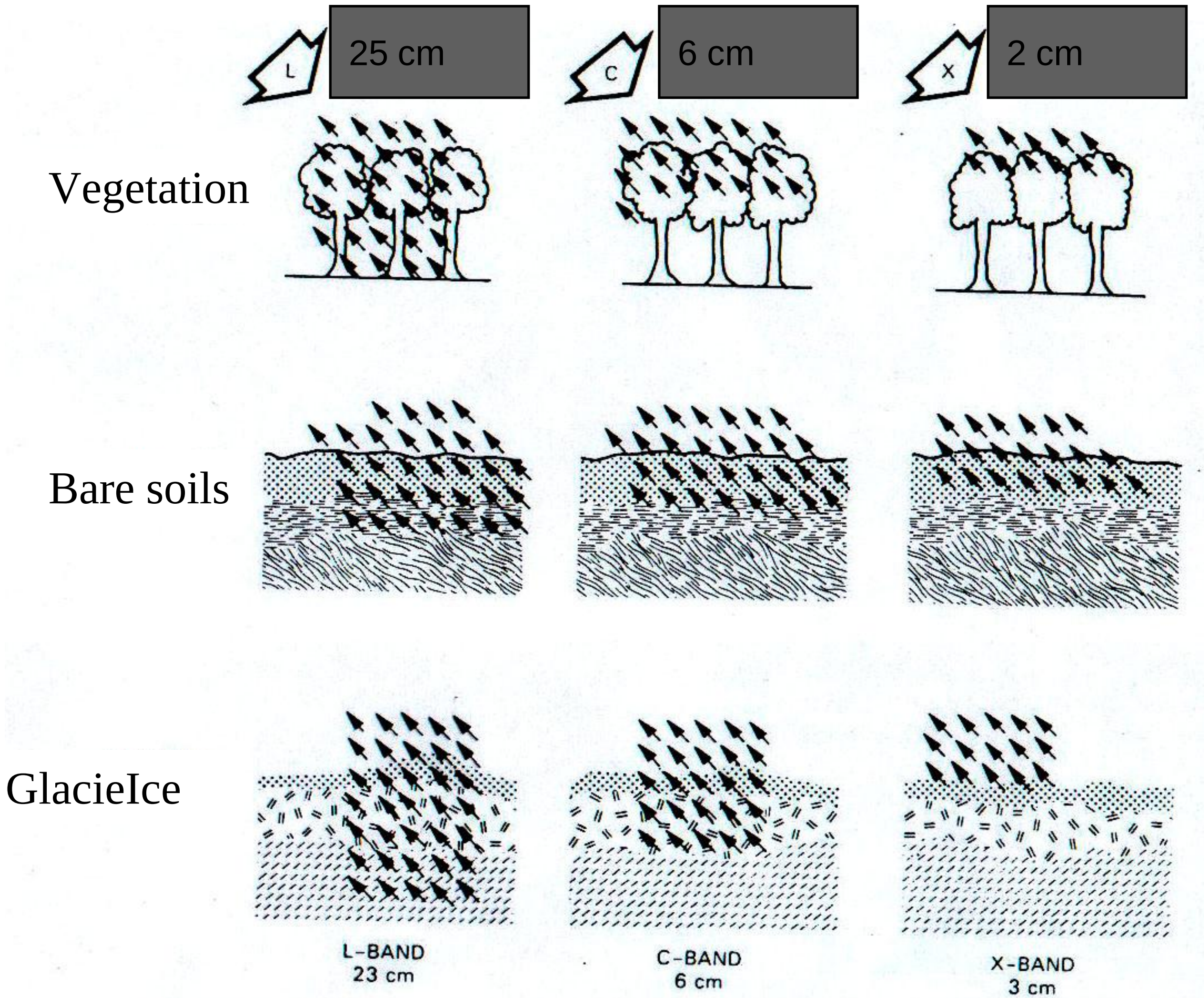


Penetration Depth:

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

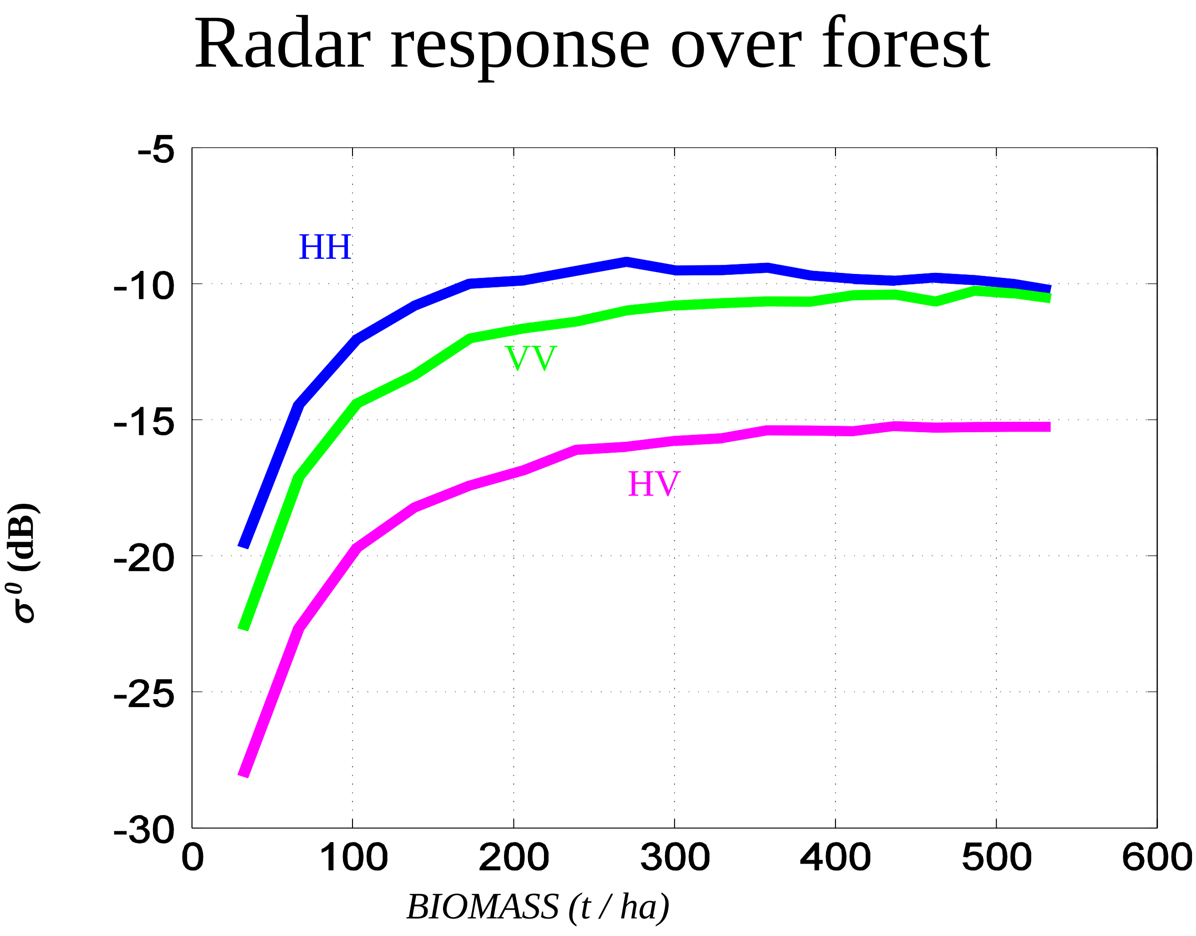
Penetration ↗ { Biomass ↘ ; wavelength ↗ }

Radar response sensitivity



Penetration depth is proportional to λ

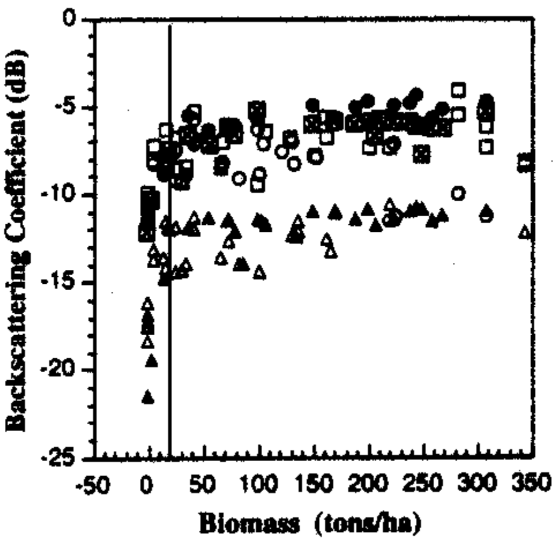
Radar images interpretation rules



Volume Scattering

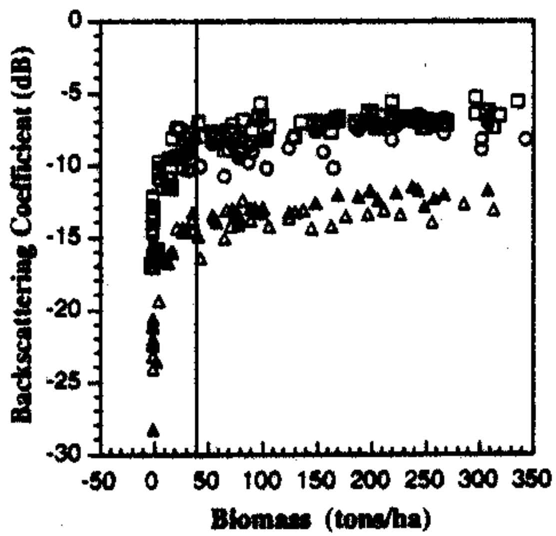
Radar saturation level with vegetation density

C band



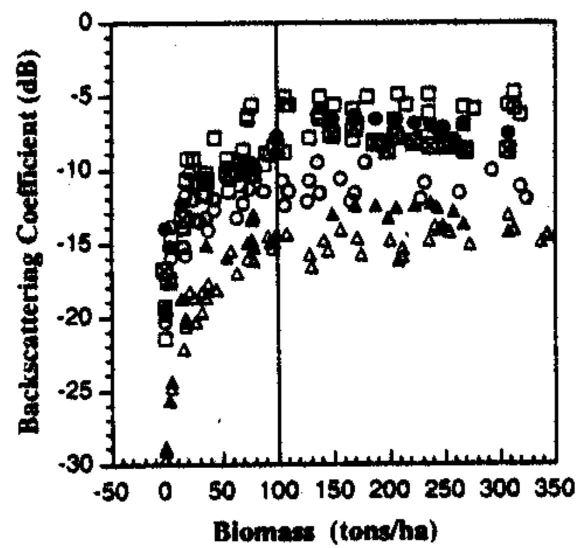
20 tons/ha

L band



40 tons/ha

P band

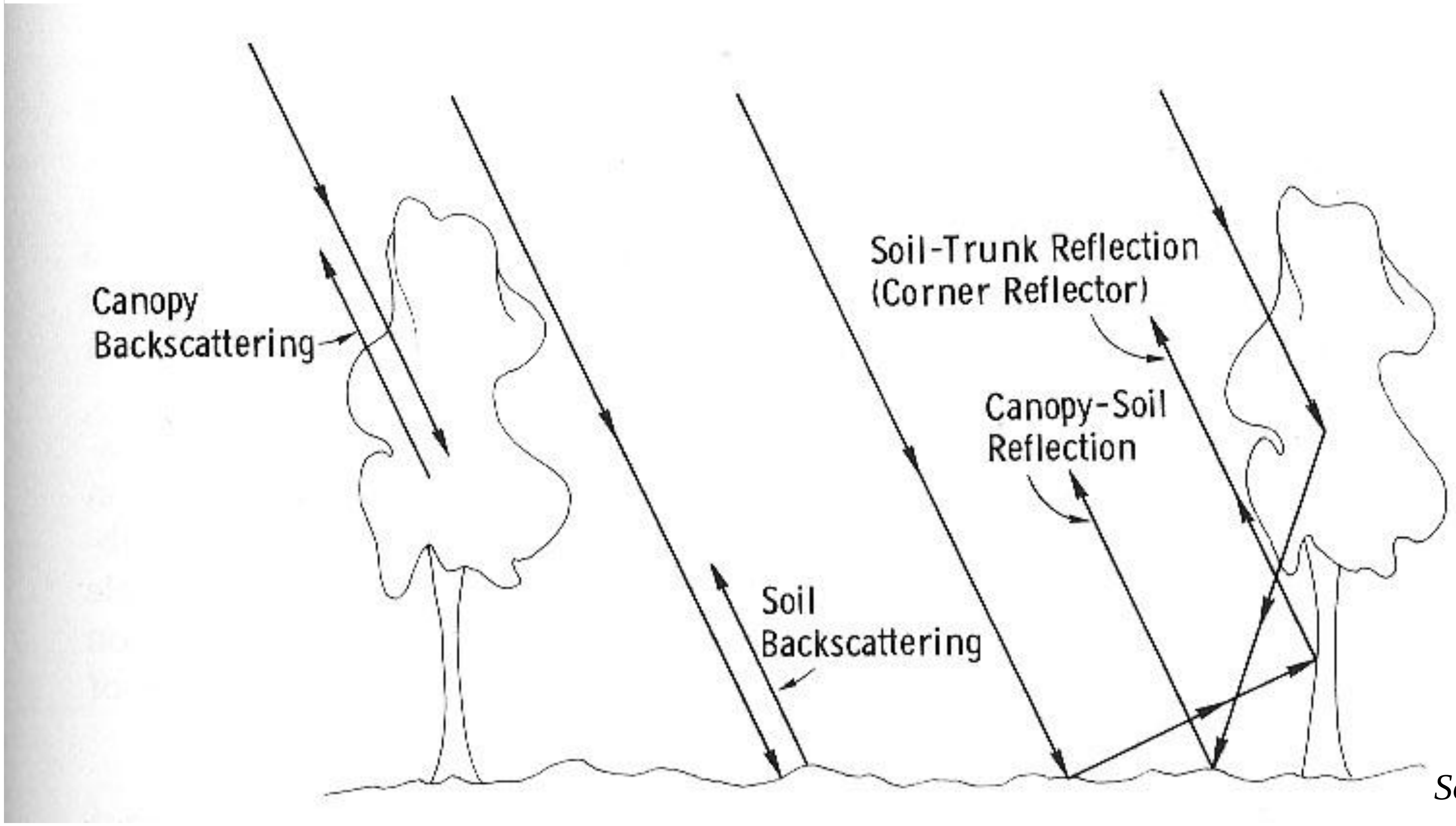


100 tons/ha

from Imhoff et al. 19?

Radar response sensitivity

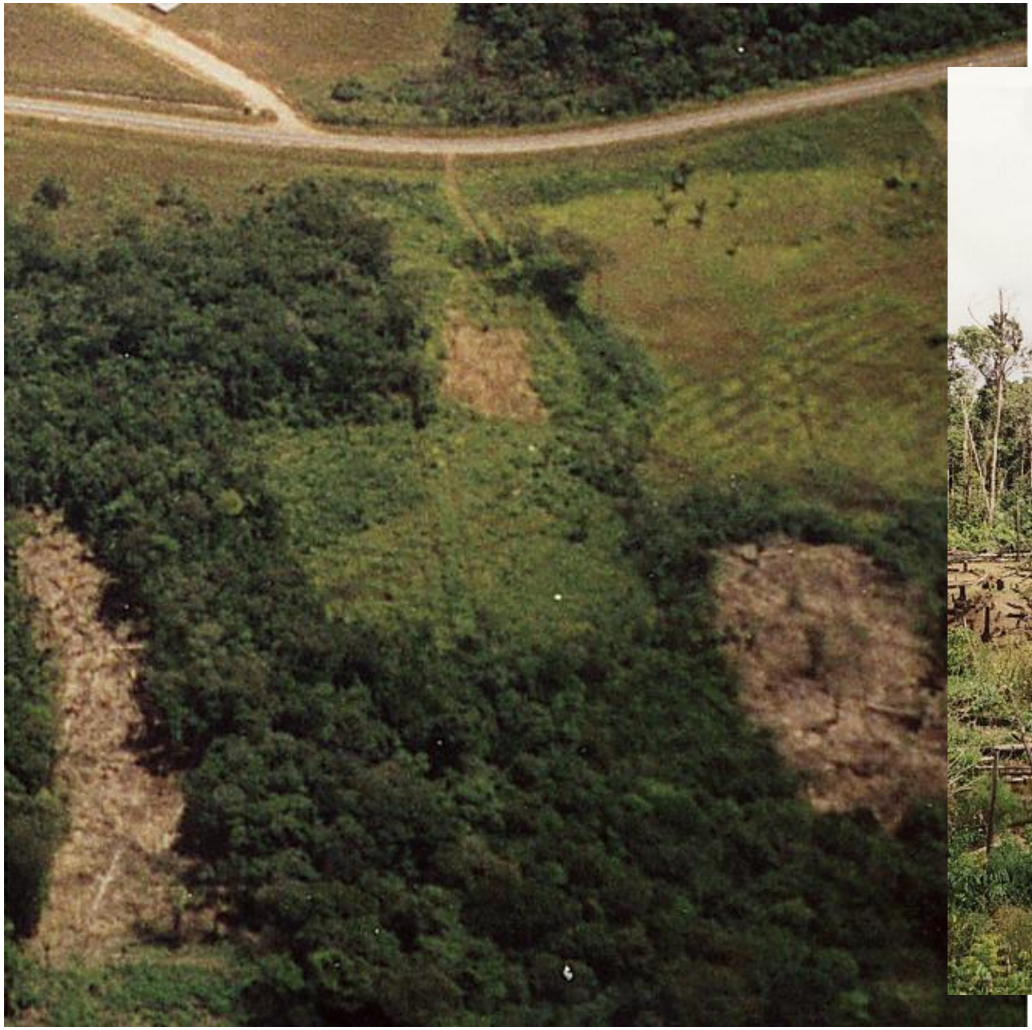
Backscattering mechanism on vegetation



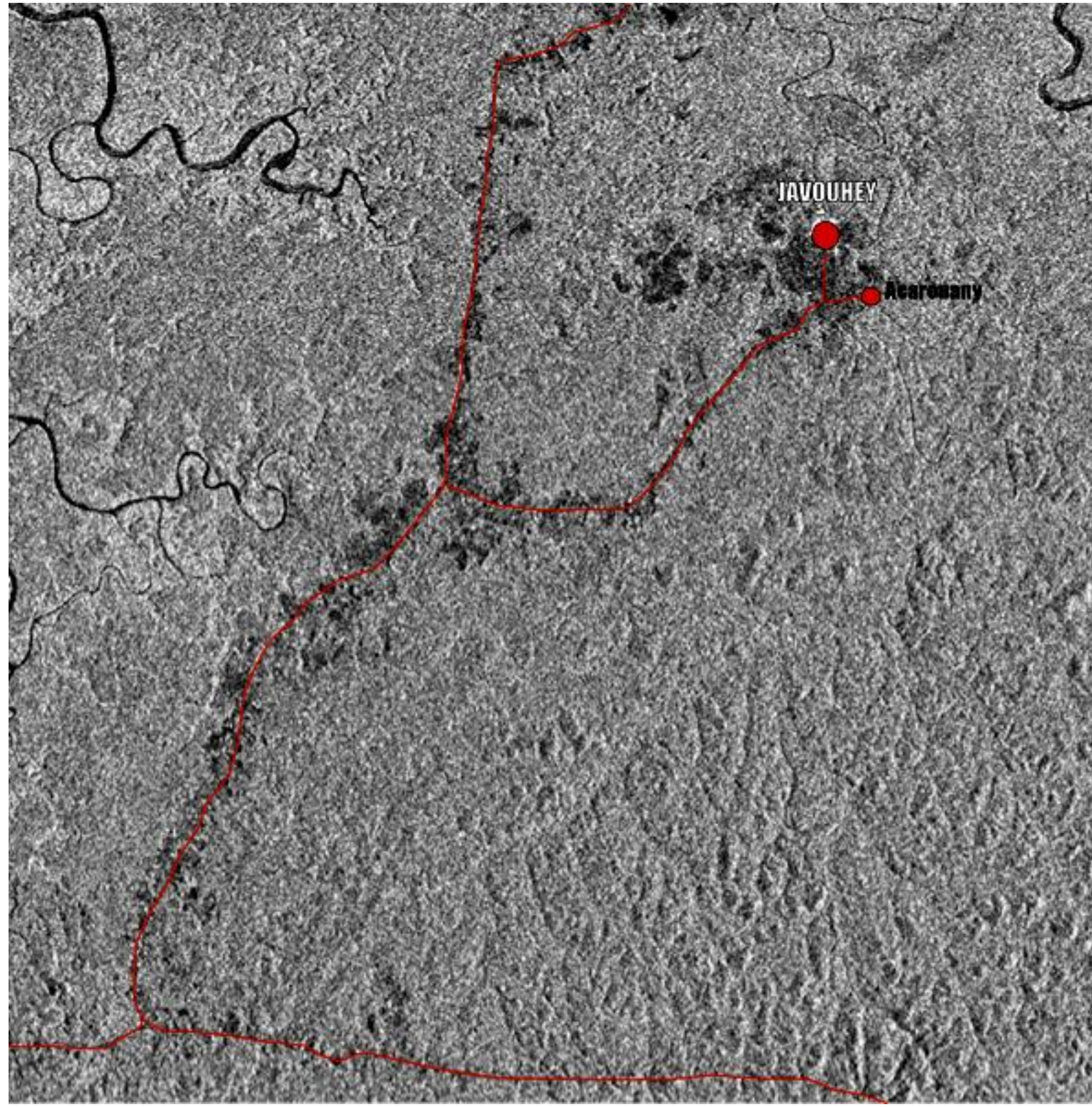
Source: Ulaby et al.

Radar response sensitivity

Local Agricultural Deforestation along road



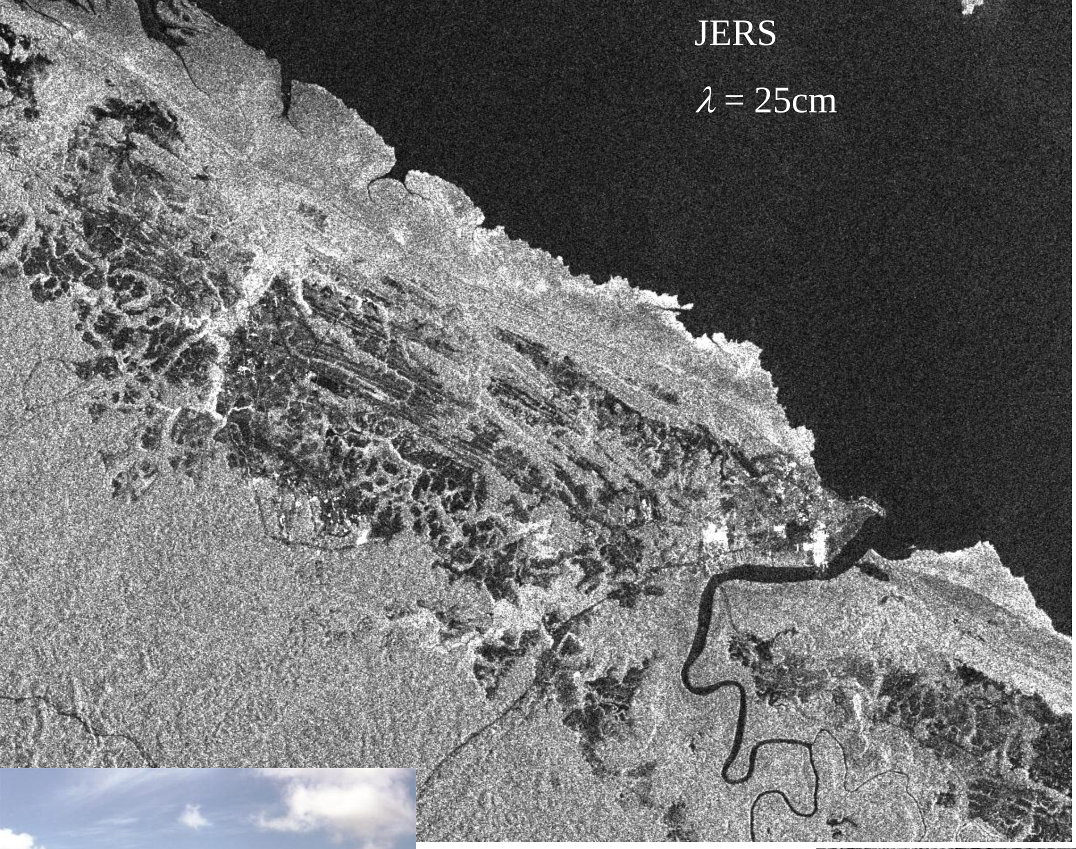
Radar response sensitivity

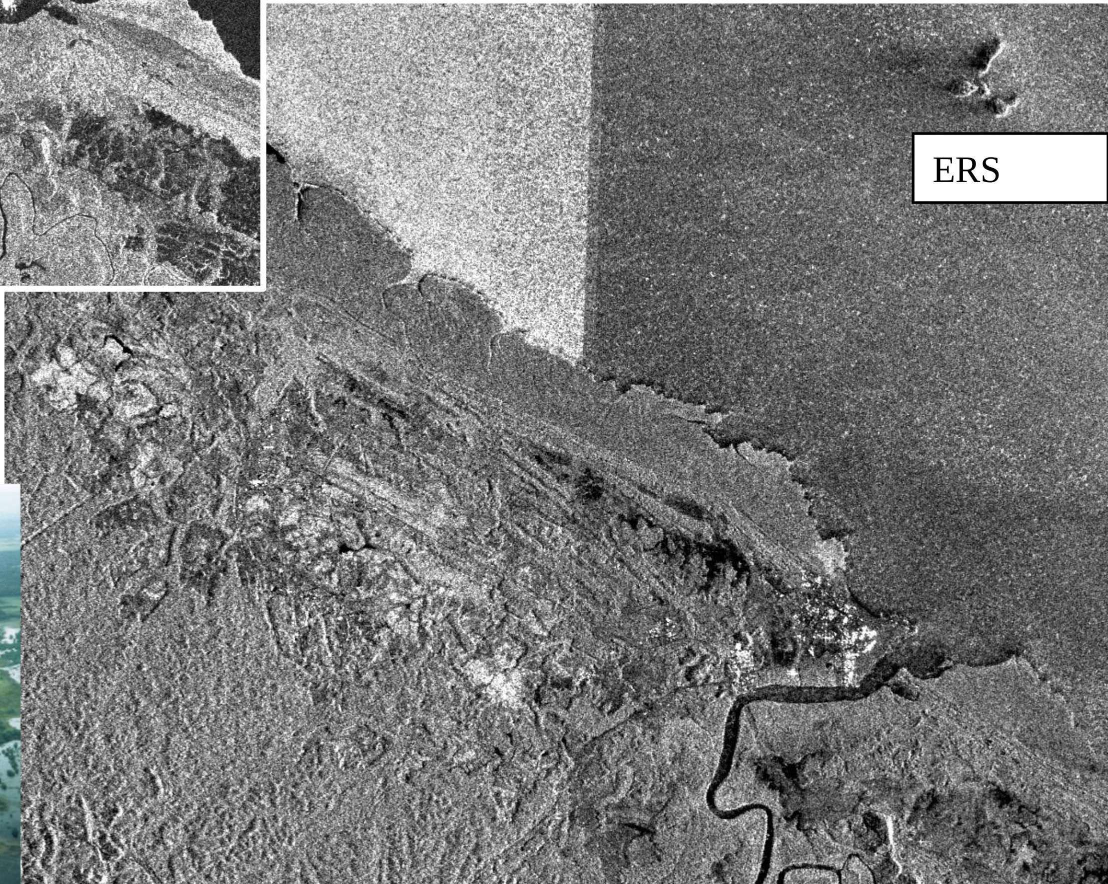


Radar response sensitivity

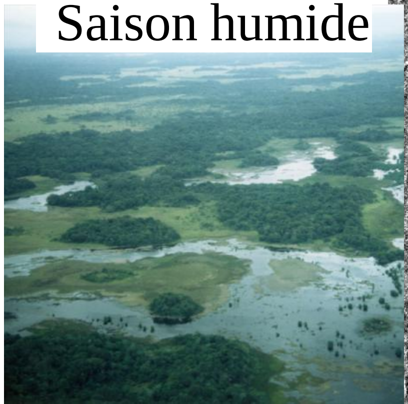
Cameroun (région Ngaoundéré: Cultural practice, burned area

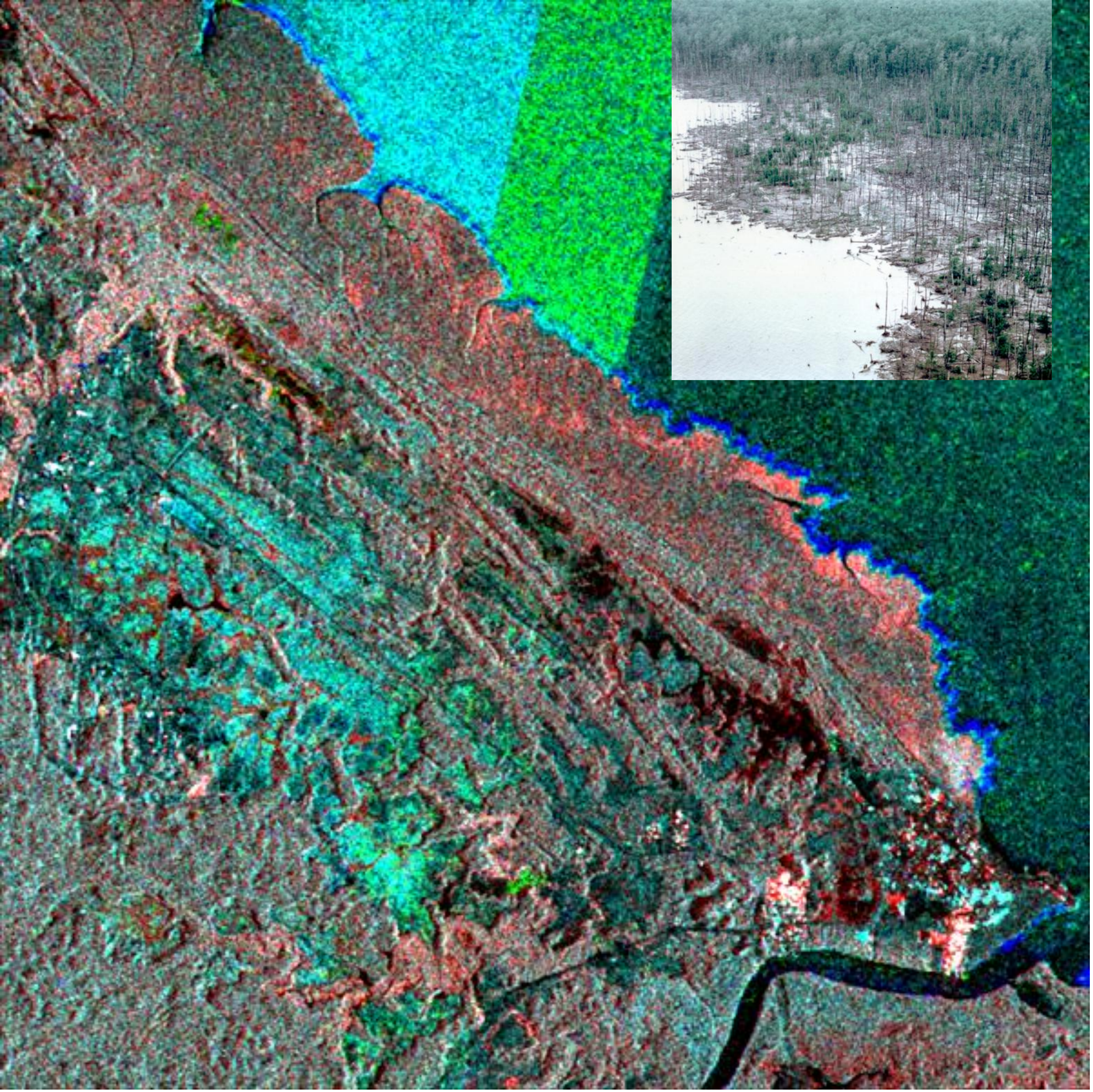
ERS C band l=6cm





Saison sèche

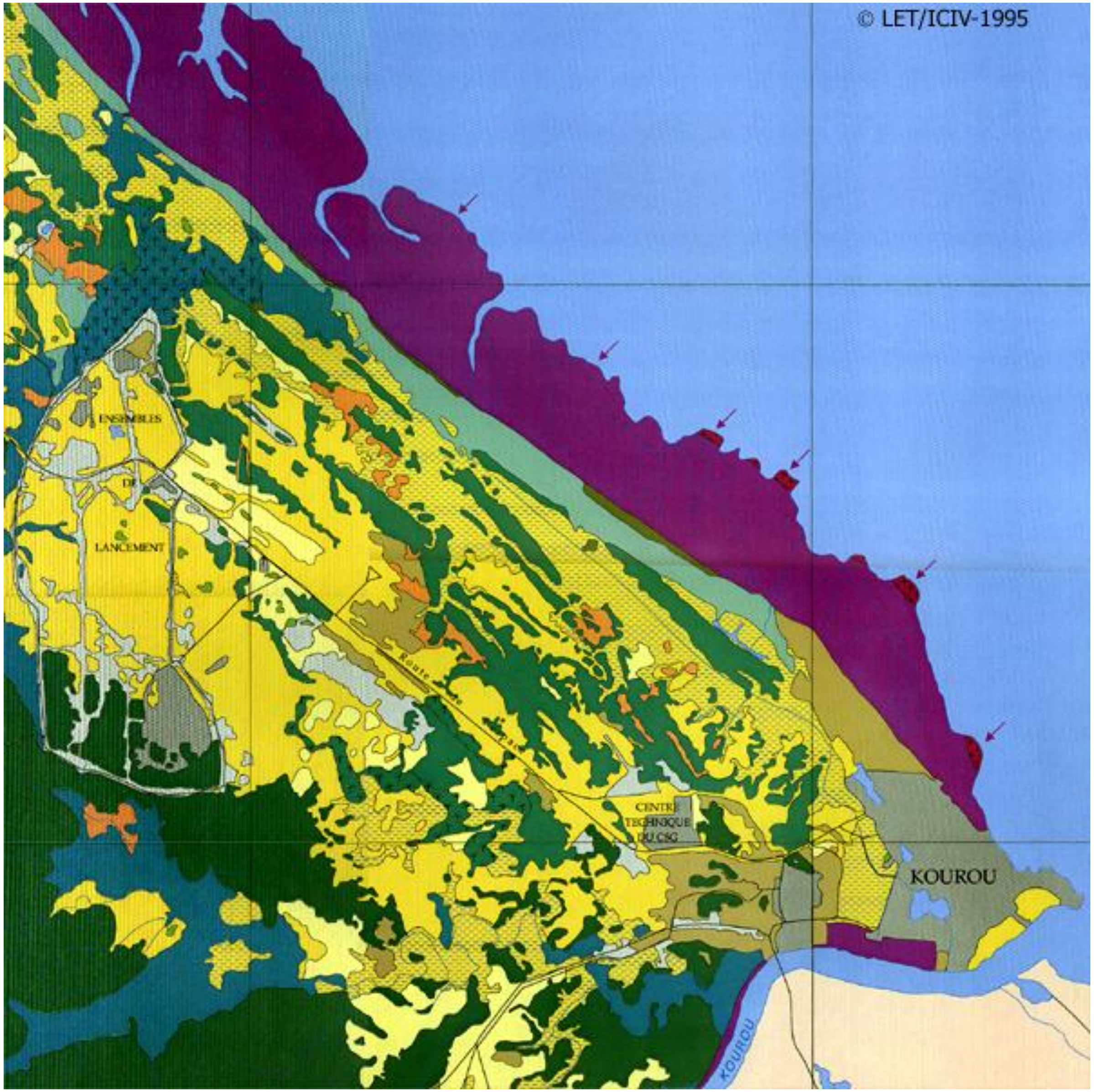




Color Composite

ERS and **JERS**

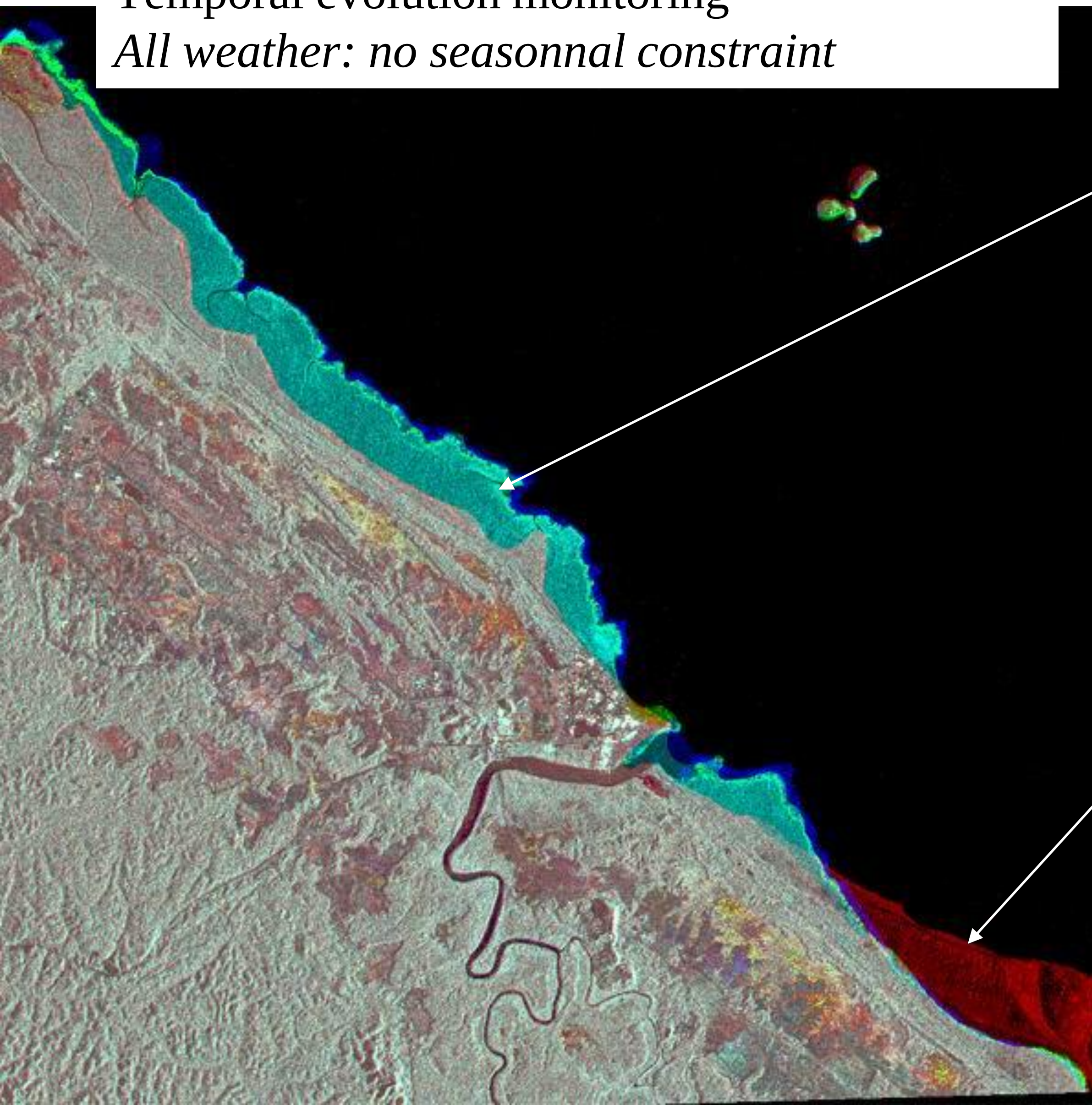
Radar response sensitivity

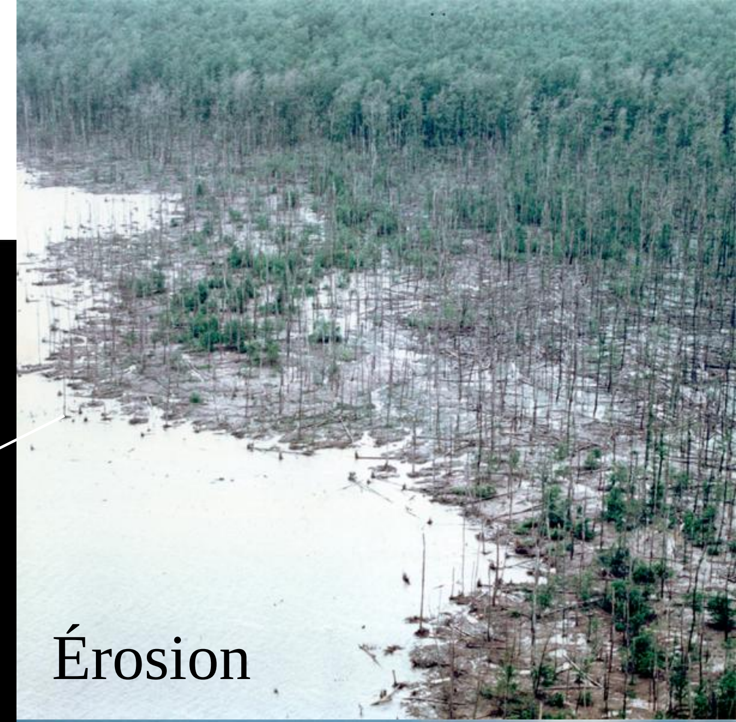


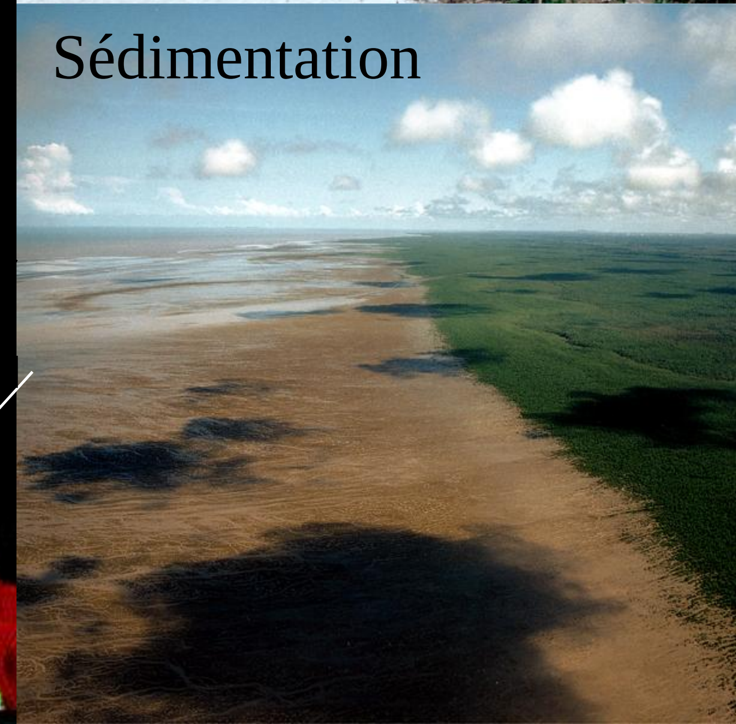
Radar response sensitivity

Temporal evolution monitoring

All weather: no seasonnal constraint

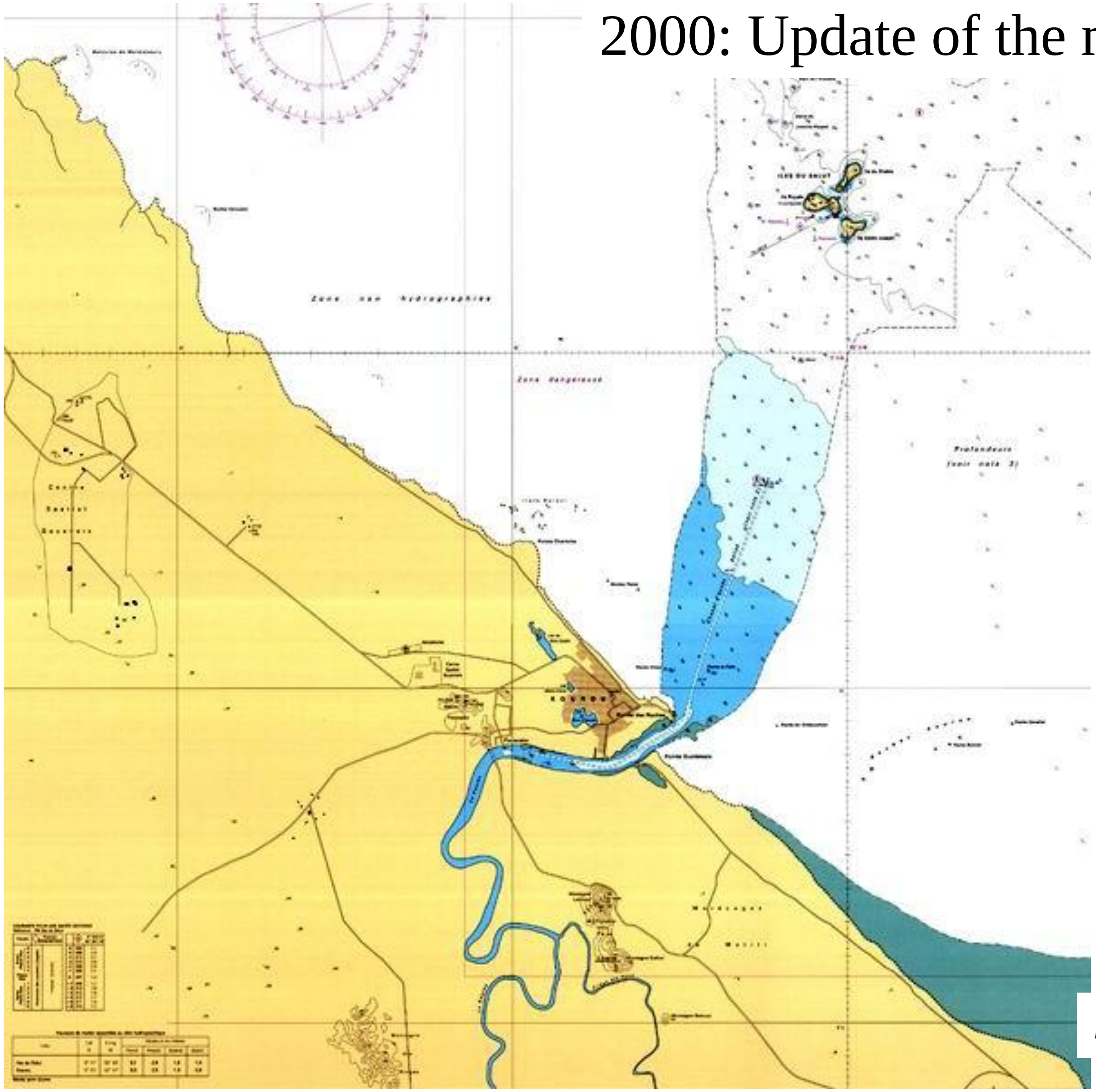






Radar response sensitivity

2000: Update of the marine map



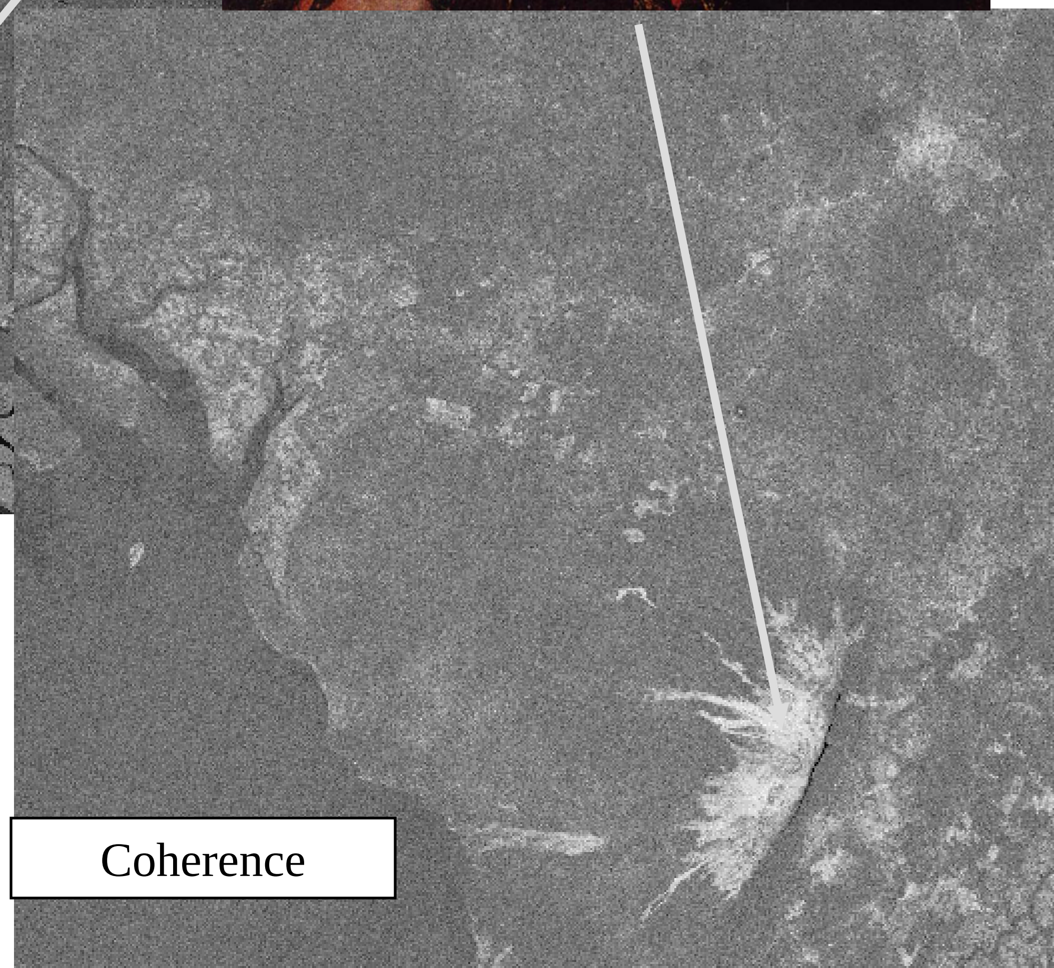
Source: SHOM/ Univ-MLV

Radar response sensitivity

RADAR COHERENCE:

2 radar acquisitions

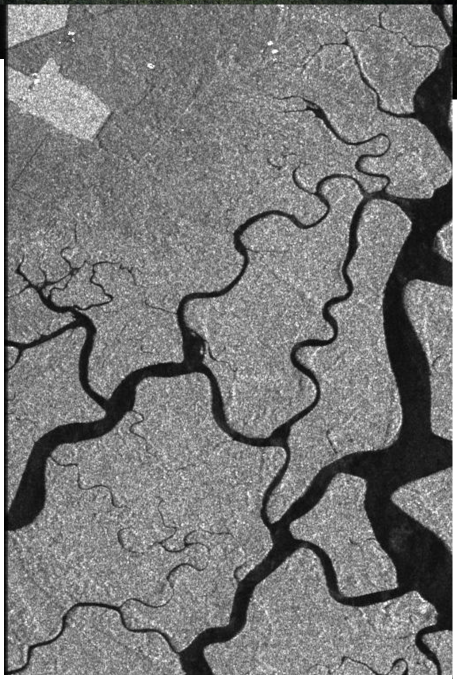
Temporal stability of the scatterers
within each resolution cell



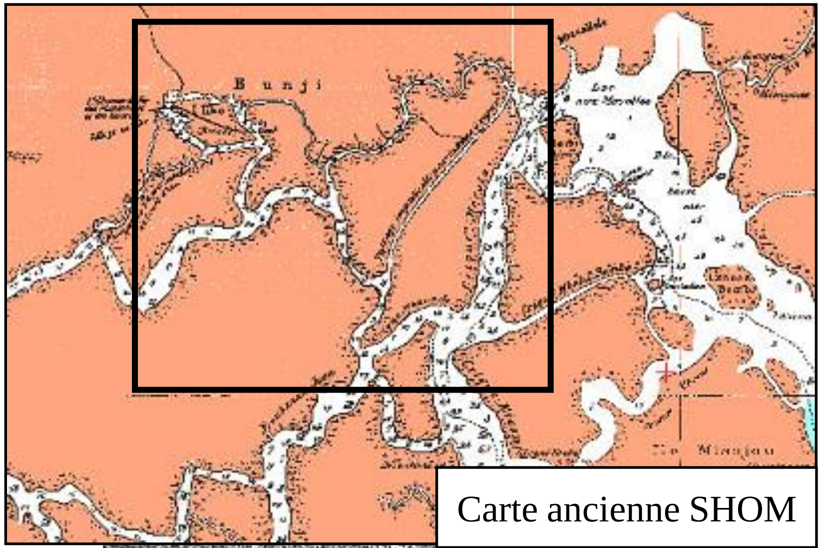
Mount Cameroun, ERS

Radar response sensitivity

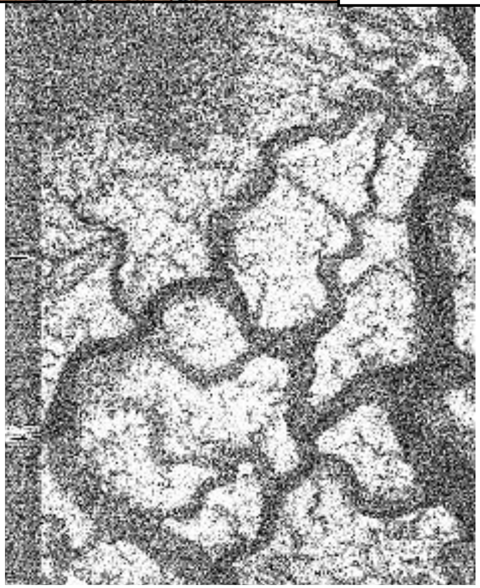
Mangroves



Amplitude ERS

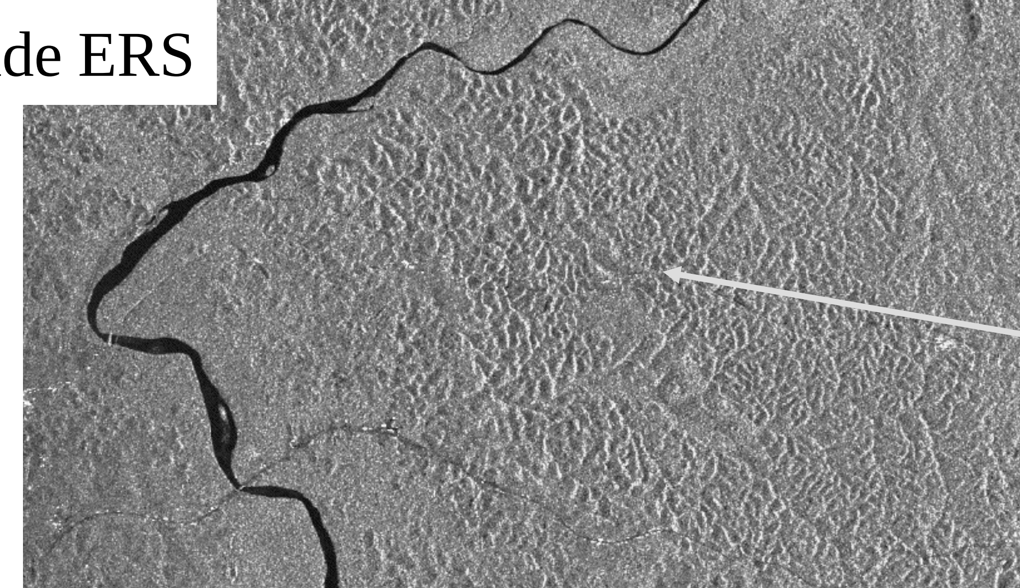


Carte ancienne SHOM

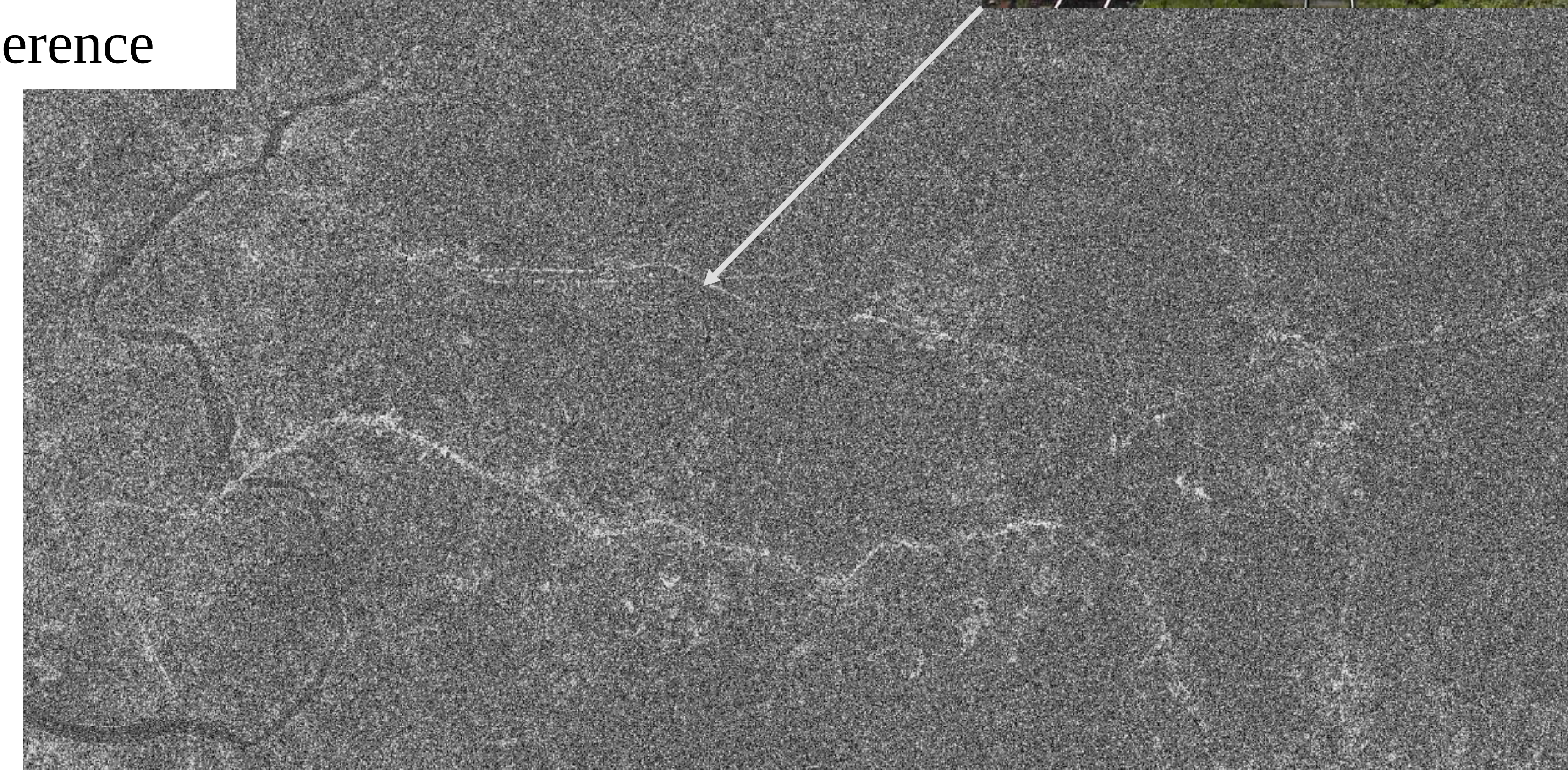


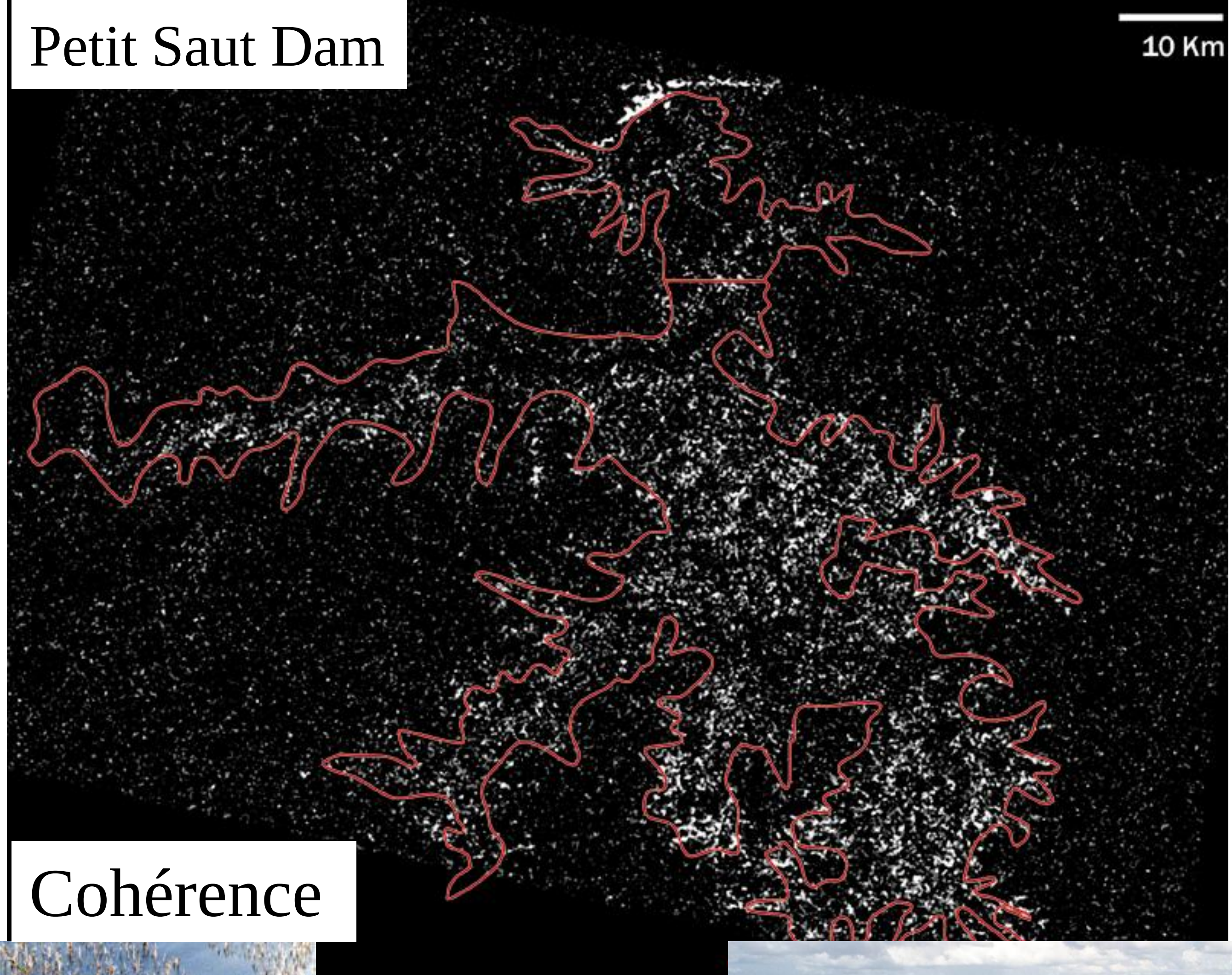
Coherence ERS

Amplitude ERS



Coherence




Petit Saut Dam
10 Km
Cohérence

OUTLINE

I. Electromagnetic coherent waves

II. Radar imaging - Spatial resolution

III. Frequency – wavelength

IV. Polarization

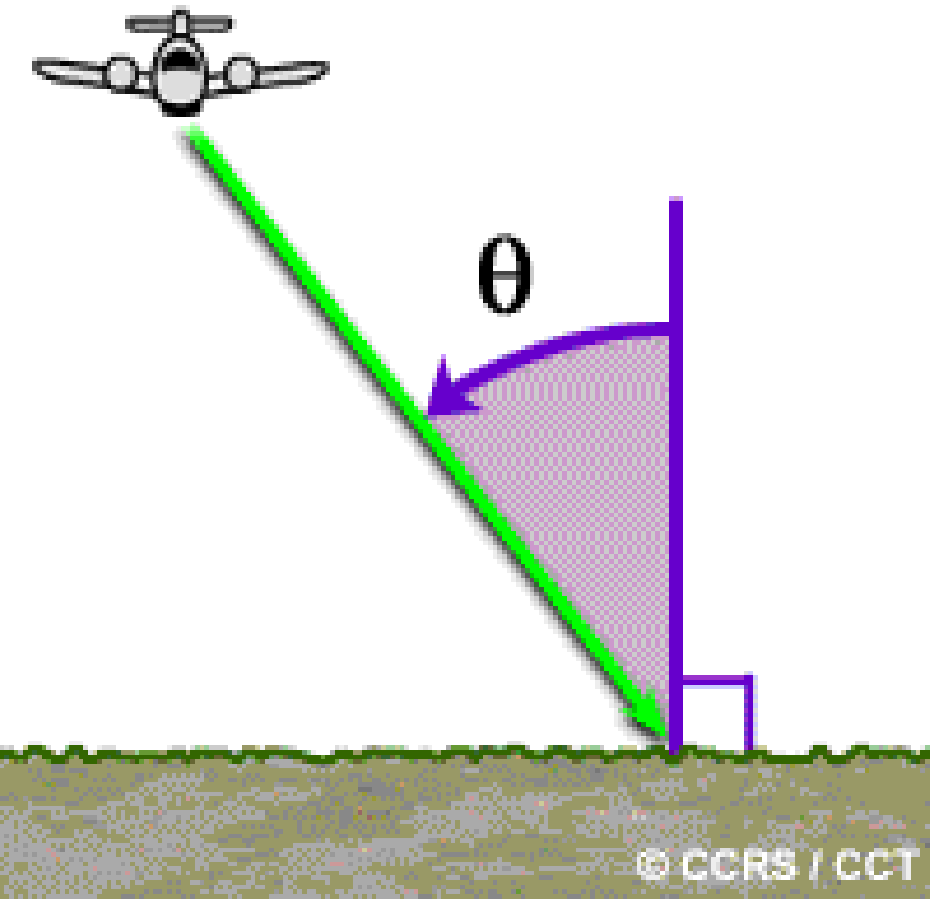
V. Radar response sensitivity

VI. Relief effects

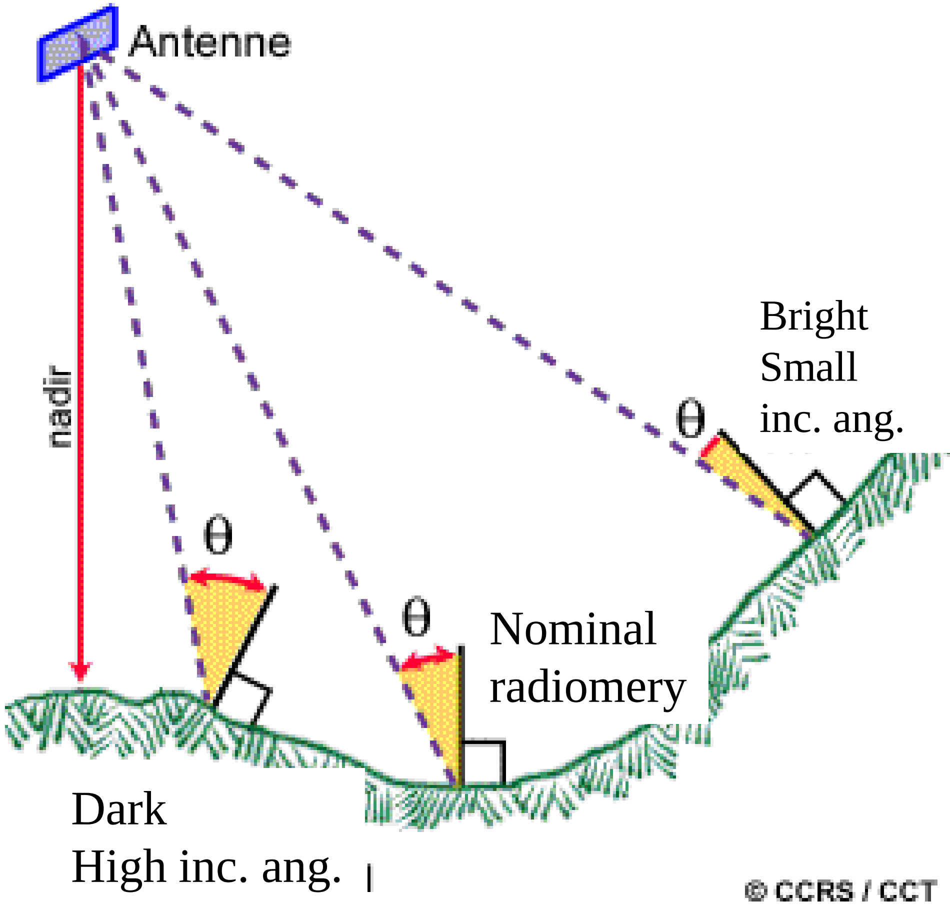
Relief effects

Acquisition incidence angle

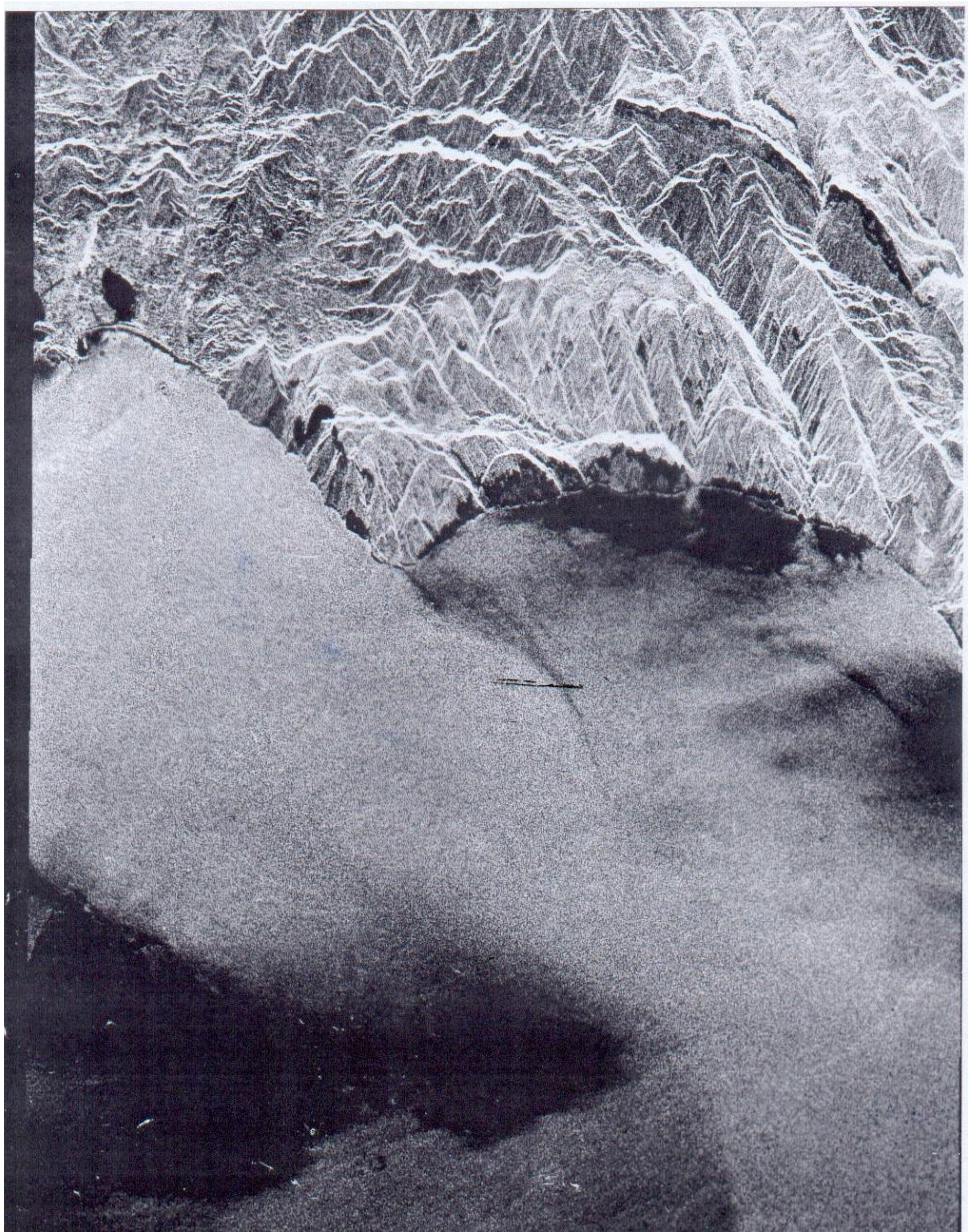
Incidence on flat terrain



Local ncidence on relief

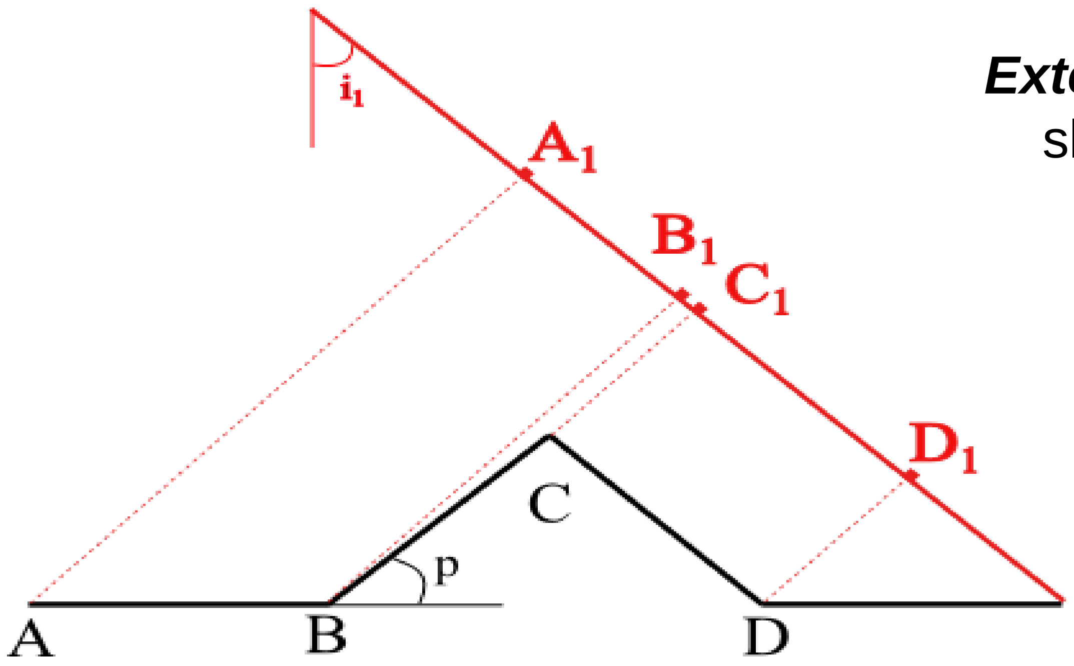


Relief effects



Relief effects

Echoes are **ranged** according to
Antenna – target distance



Foreshorting
slopes facing the radar

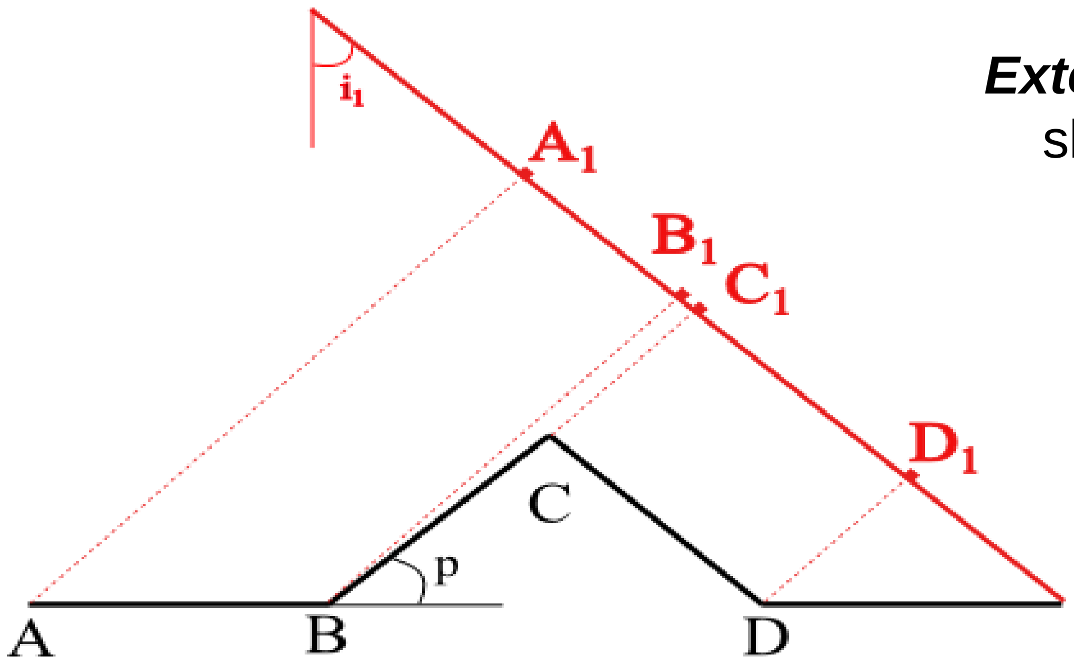
Extension
slopes backward to the radar

Relief effects

Echoes are **ranged** according to
Antenna – target distance

Foreshorting
slopes facing the radar

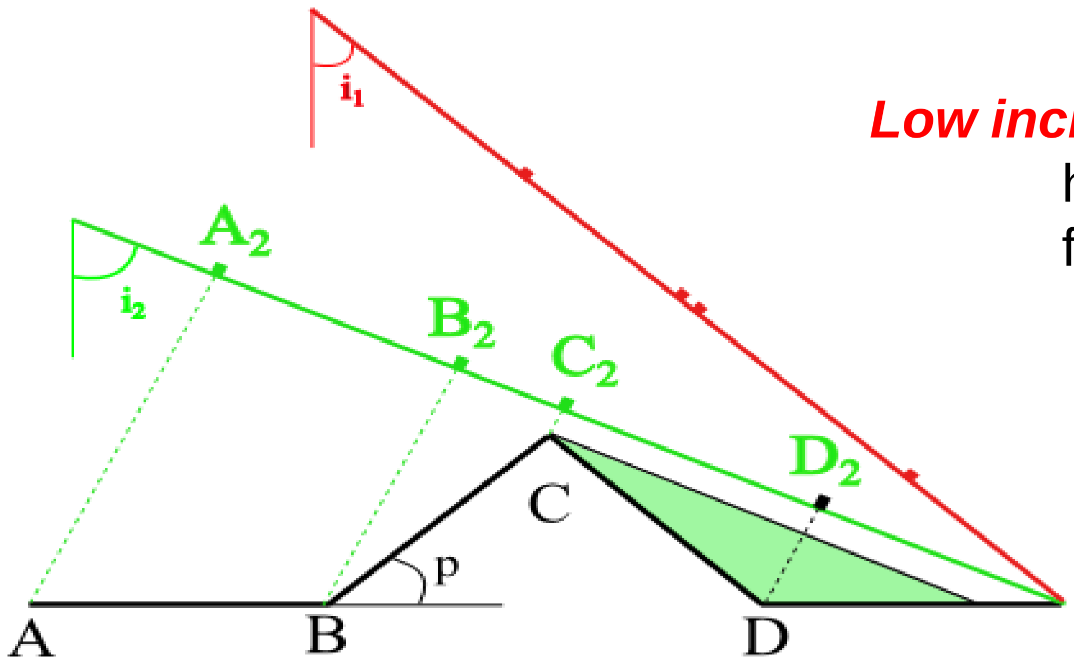
Extension
slopes backward to the radar



$A_1B_1 = AB\ \sin(i_1)$ $B_1C_1 = BC\ \sin(i_1 - p)$; $C_1D_1 = CD\ \sin(i_1 + p)$

Relief effects

Echoes are **ranged** according to
Antenna – target distance

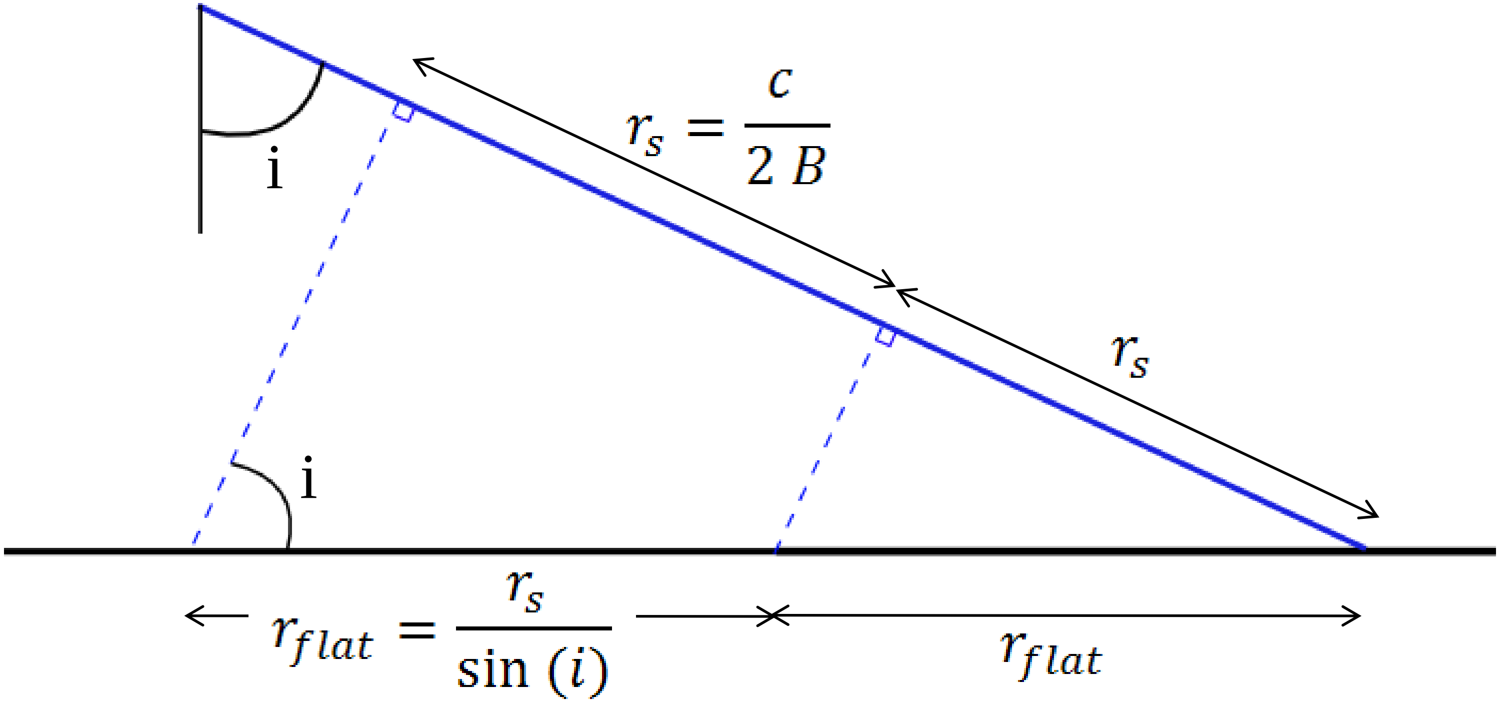


Low incidences angle
high geometrical distorsions
few shaddows

High incidence angle
low geometrical distorsions
lot of shadows

Relief effects

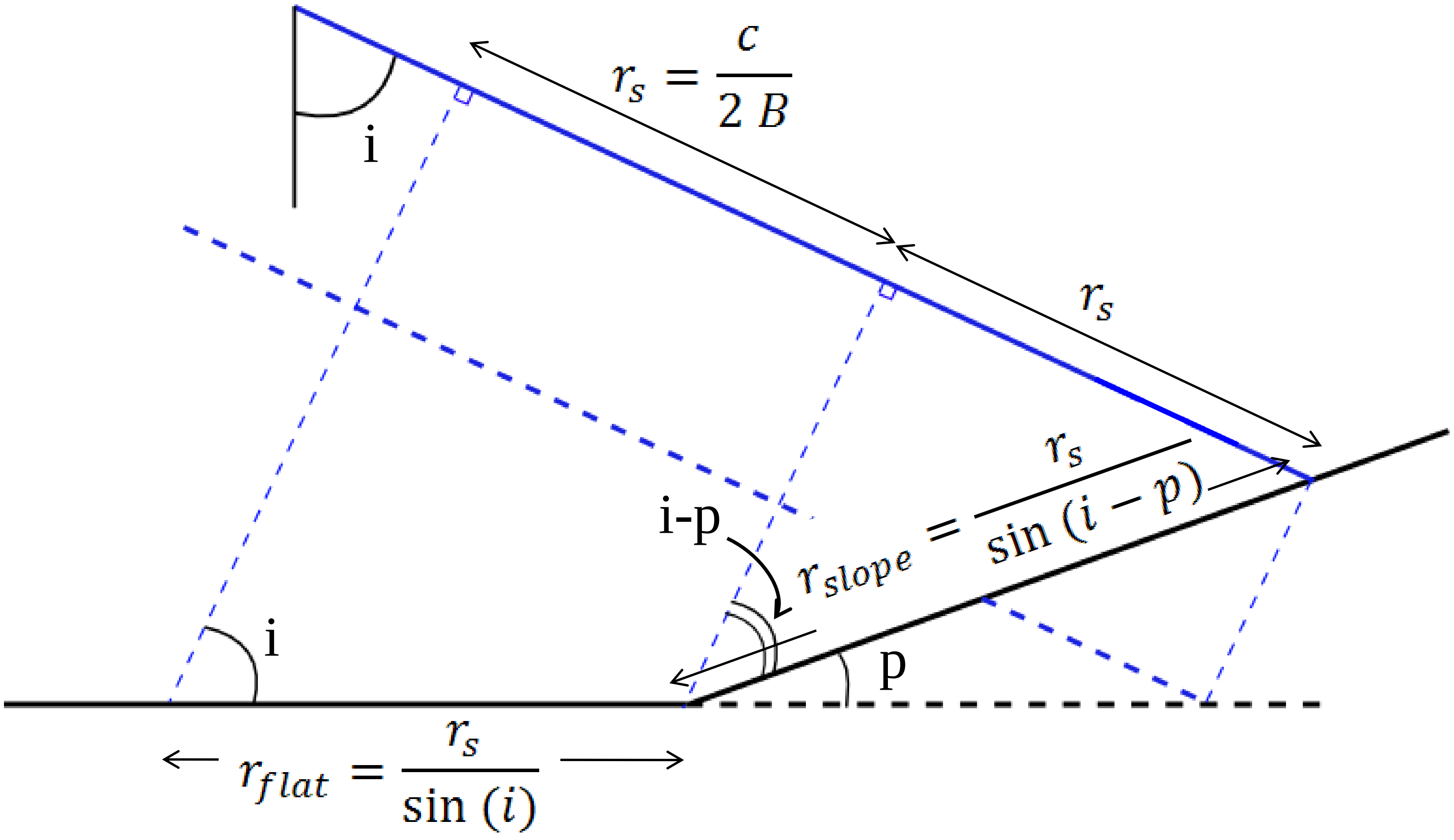
Range resolution

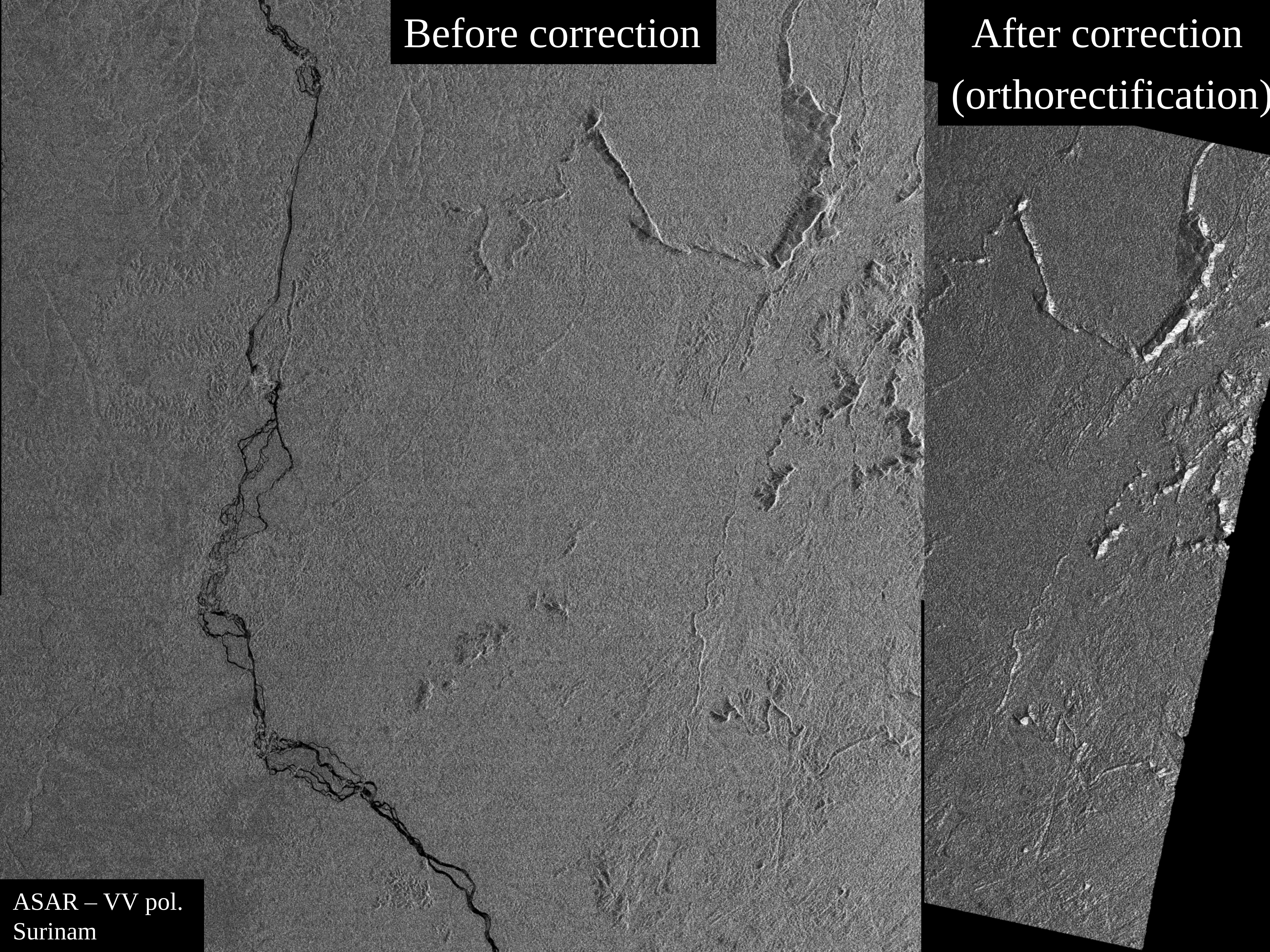


Relief effects

Range resolution

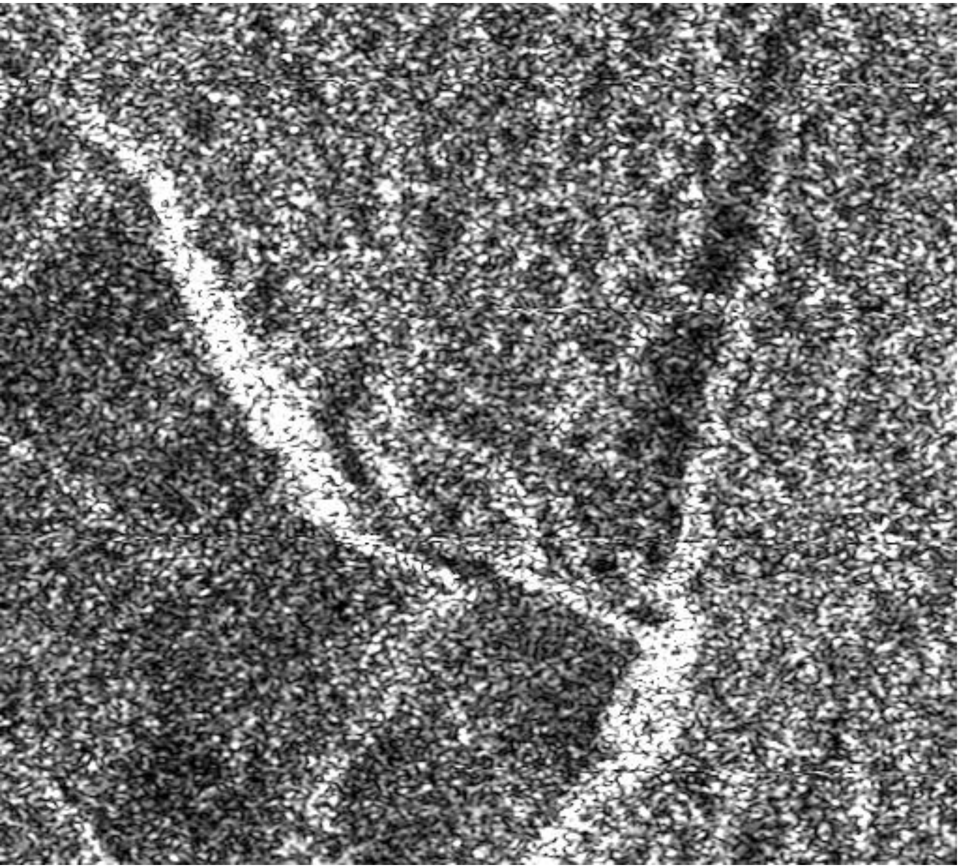
$$r_{slope} = r_{flat} \frac{\sin(i)}{\sin(i-p)}$$



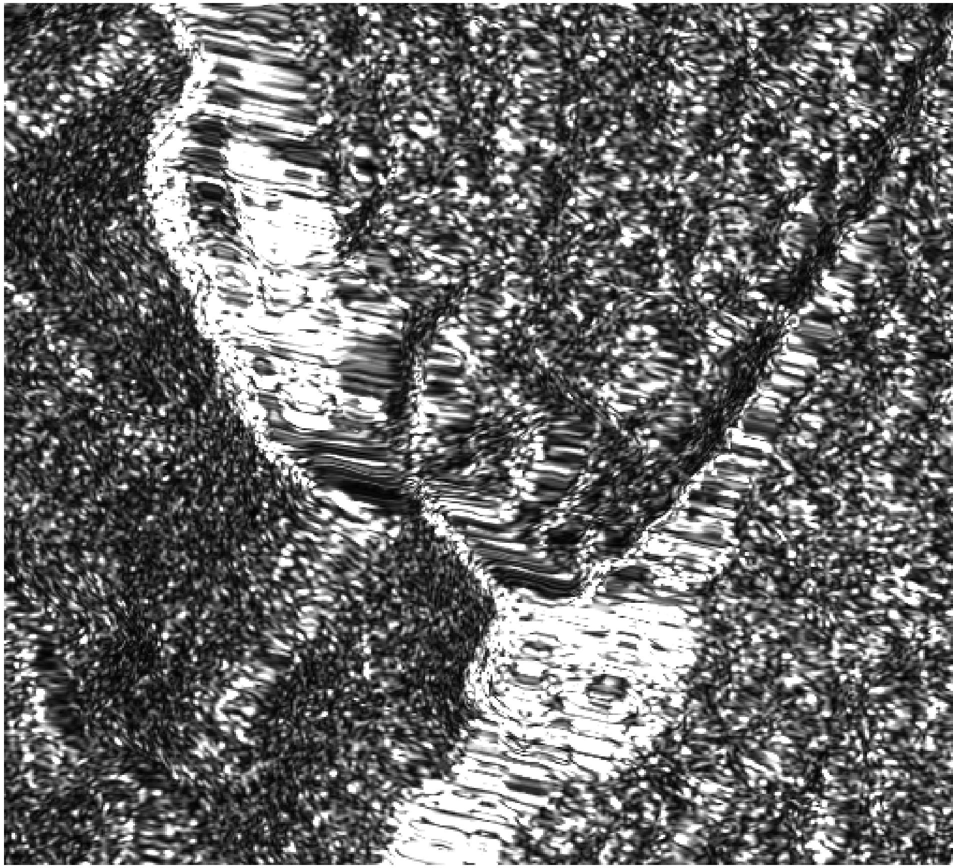

Before correction
After correction
(orthorectification)
ASAR – VV pol.
Surinam

Relief effects

Before correction

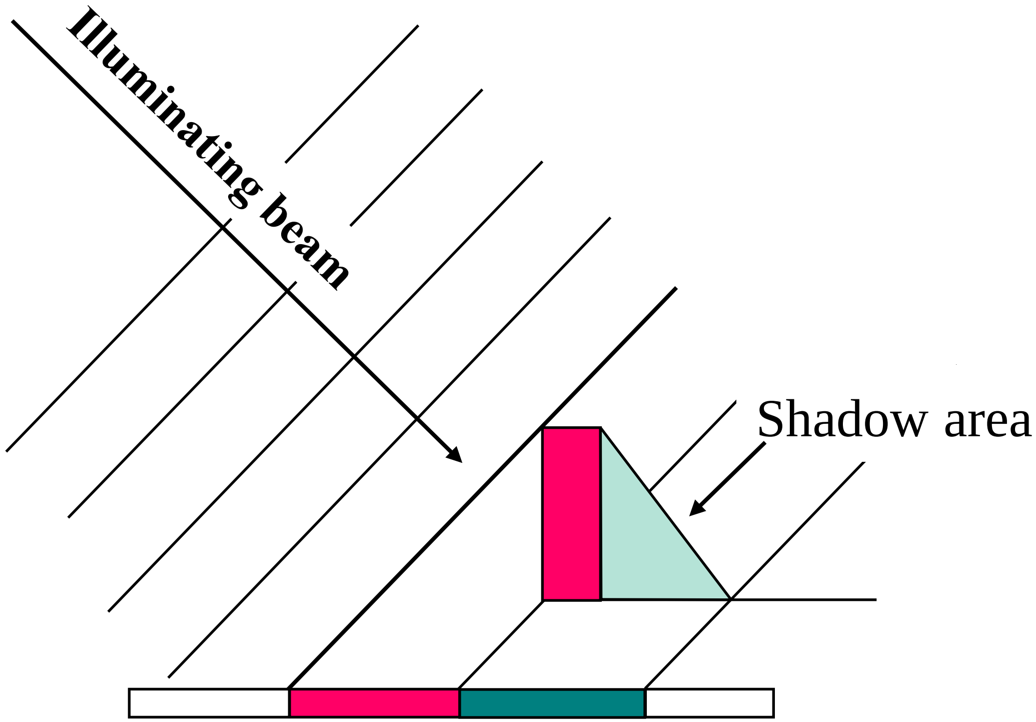


After correction
(Orthorectification)



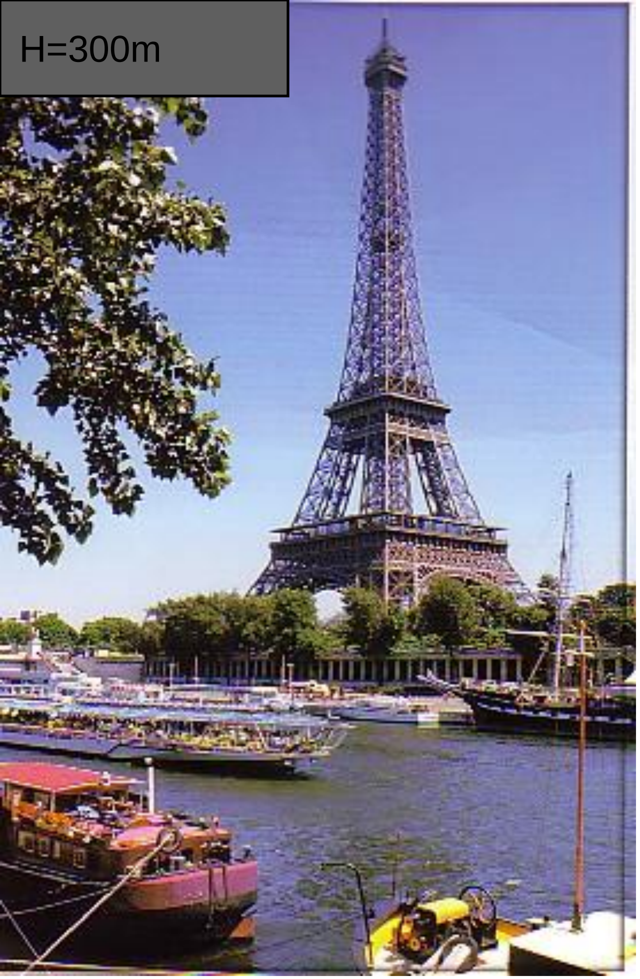
Relief effects

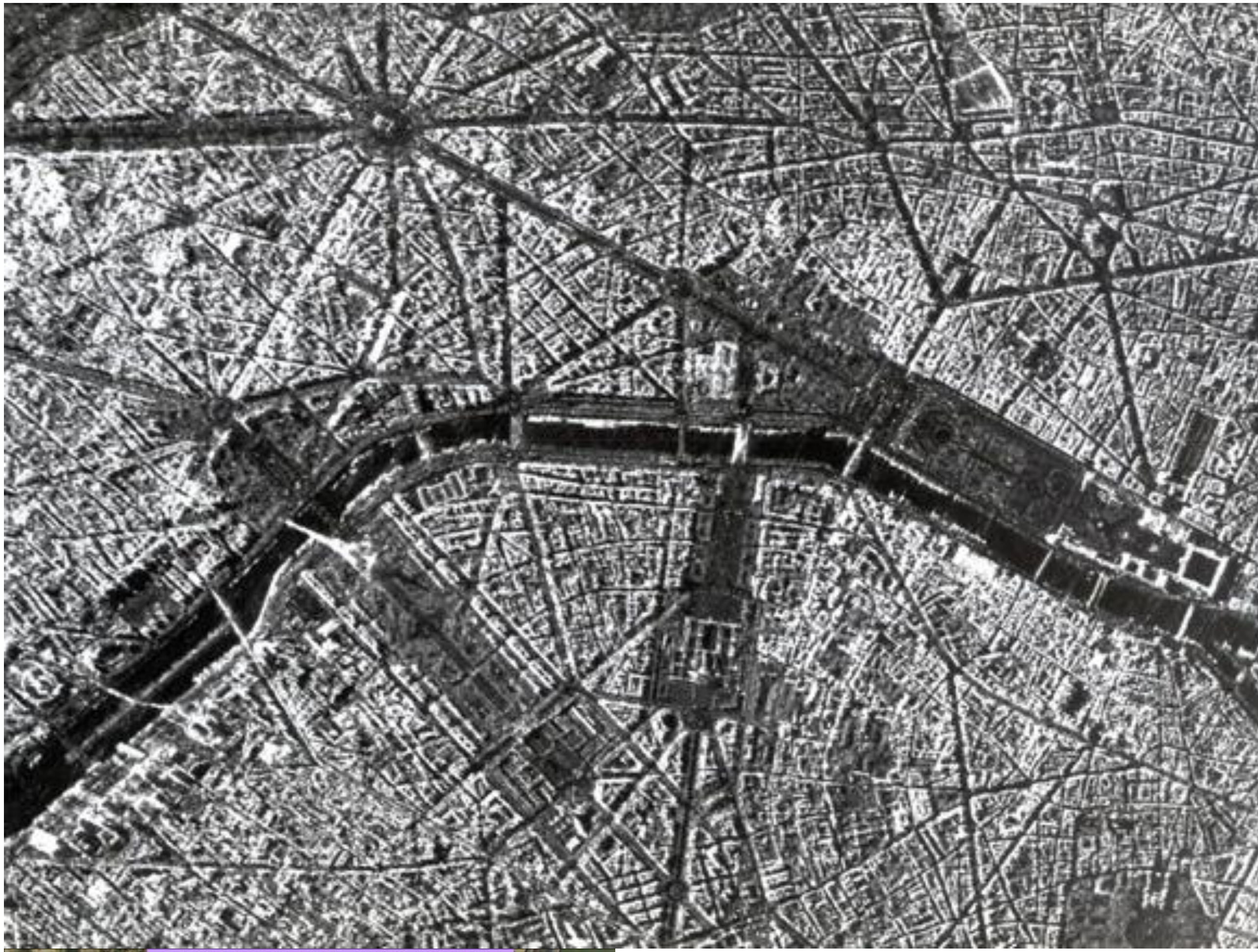
Layover effect



from CNES

Image Line generated





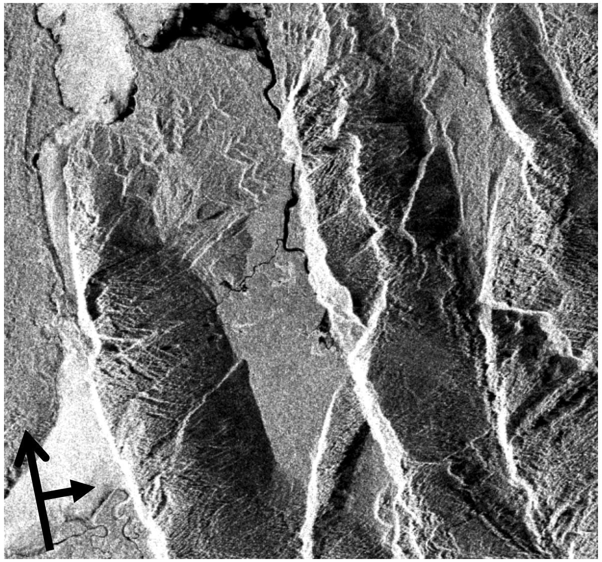
500 m

Relief effects

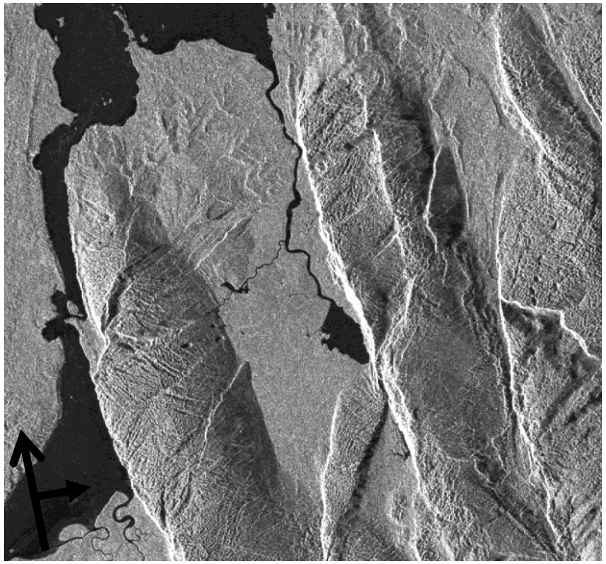
Exercice

The distortions of radar satellite scenes are the consequence of geometric relationships between the radar pulse and the topography

Landsat 7 ETM+
ortho



ENVISAT-ASAR IS3
Low view angle: 28°

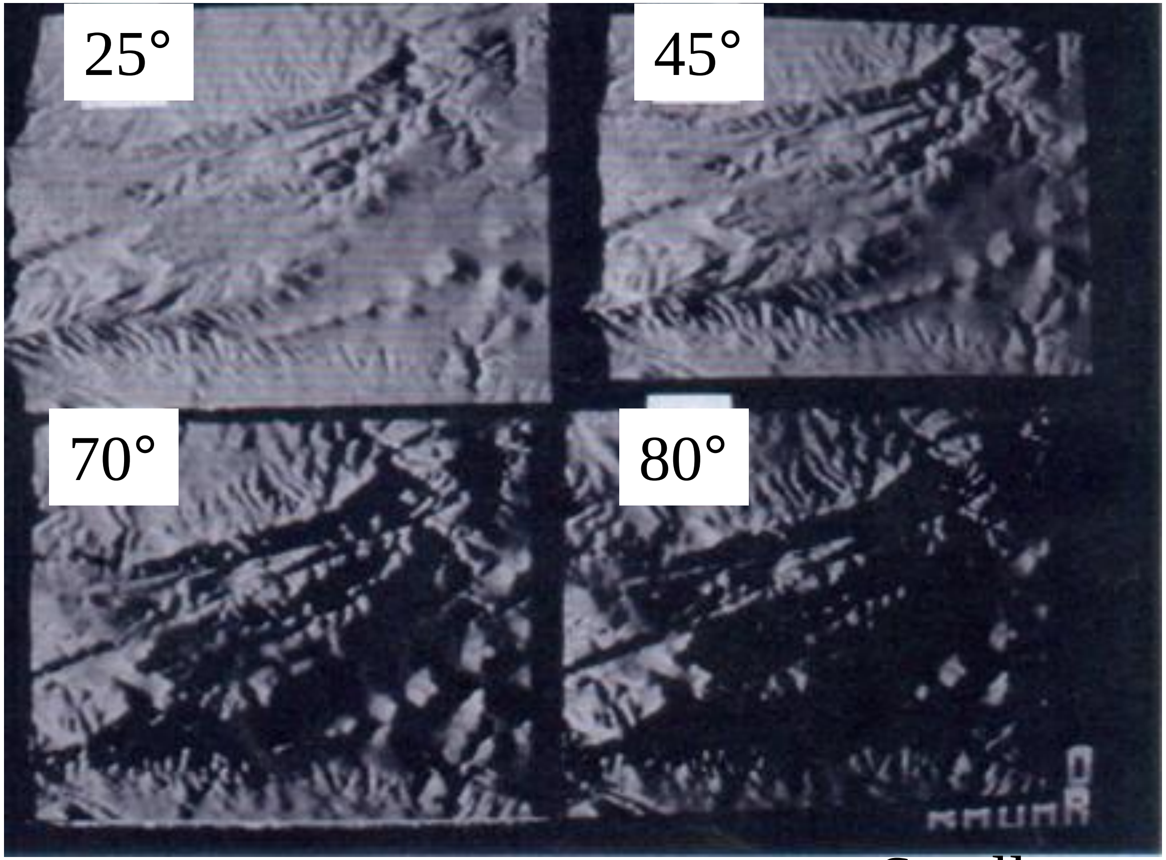


ENVISAT-ASAR IS7
High view angle 43°

Use geometric distortions of radar scenes to calculate the slope

Relief effects

Few shadows
High geom. distorsions



Small geom. Distorsions
Lot of shadows

Relief Effects

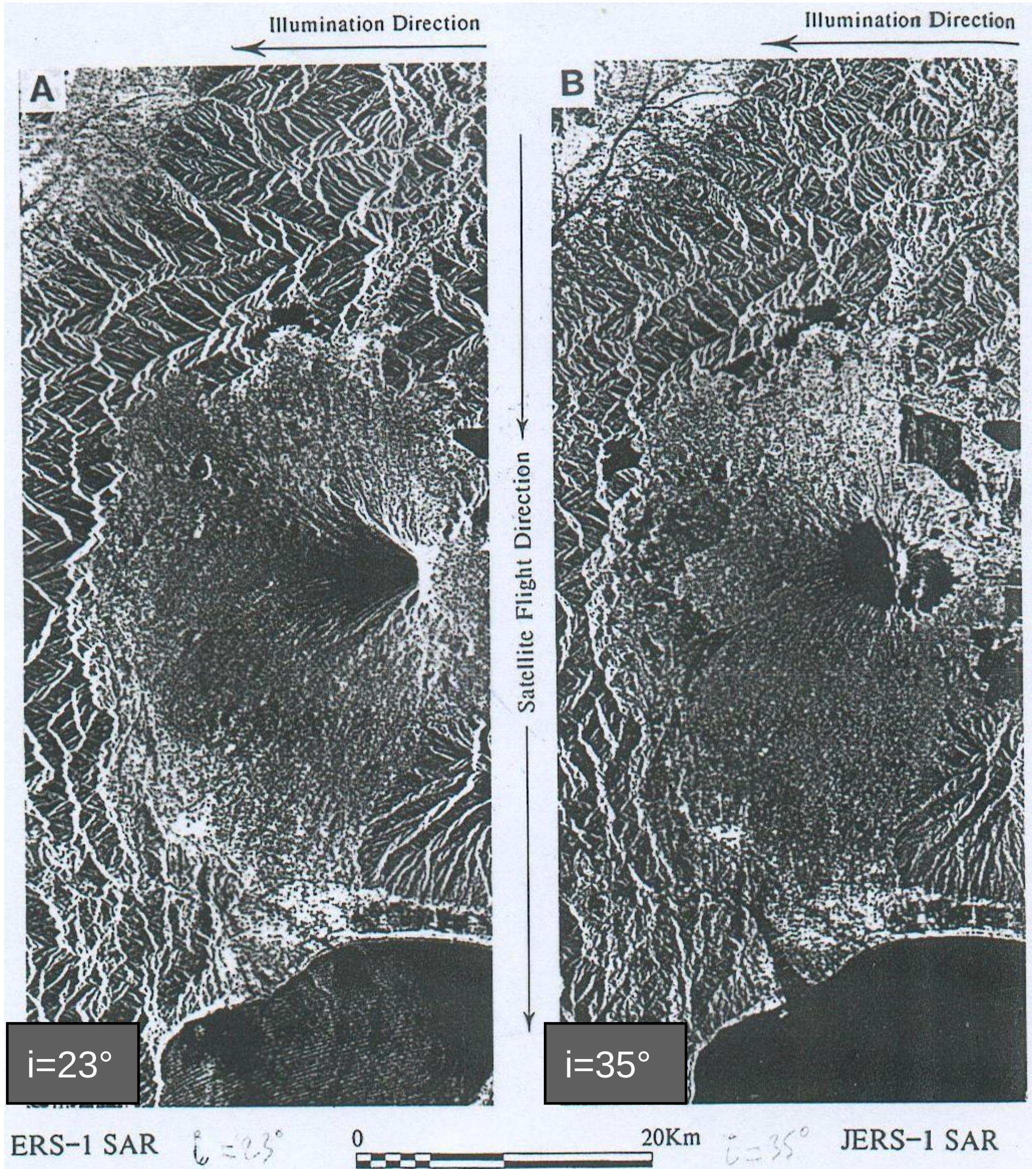
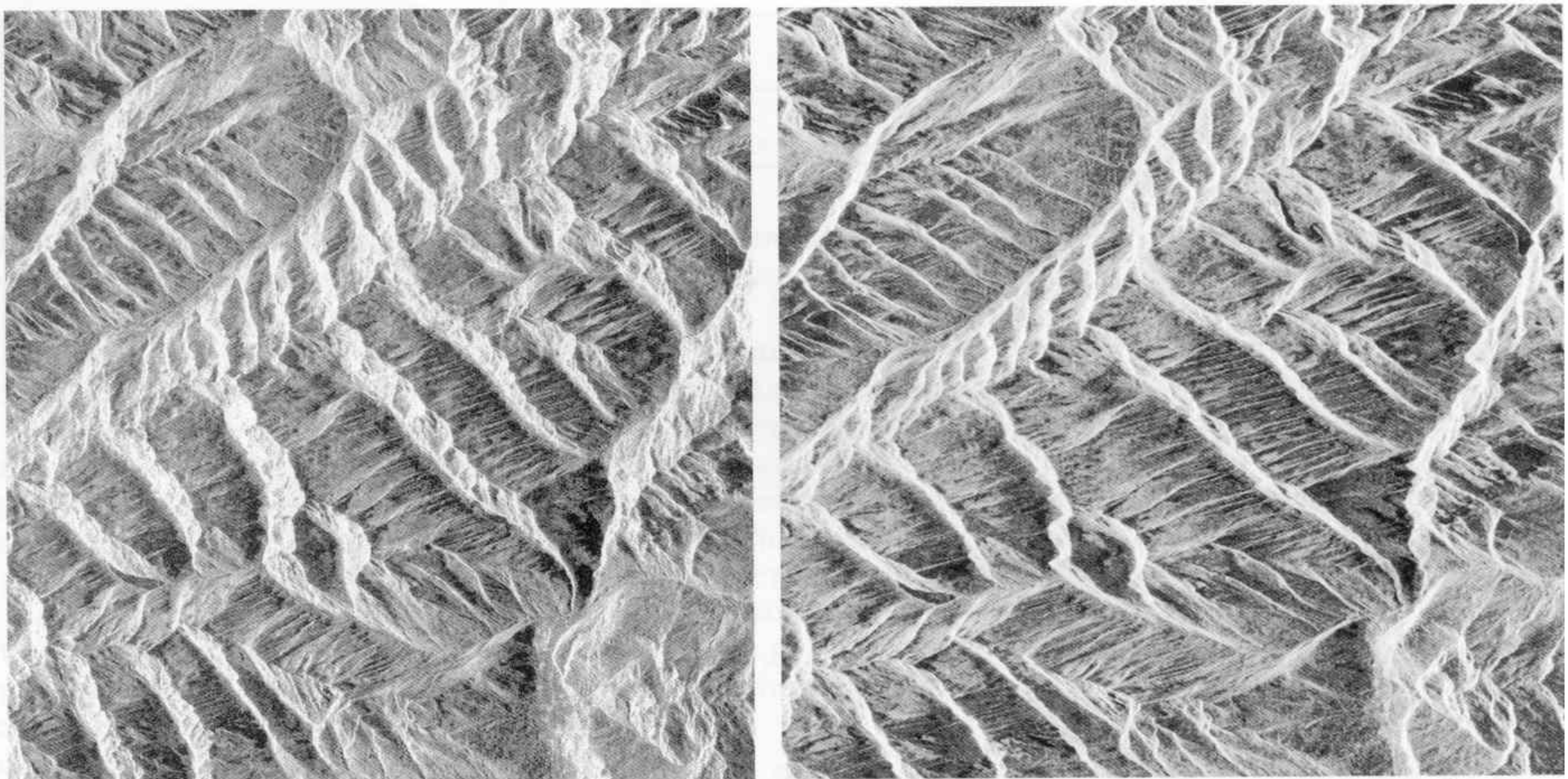


Figure 3.38 ERS-1 (a) and JERS-1 (b) SAR images of part of Japan, showing the volcano Mount Fuji. The fact that Mount Fuji is a nearly perfect cone with a circular summit crater serves to demonstrate the inappropriate depression angle of ERS-1 SAR by its apparently lying on its side. Many other rugged topographic features are also completely distorted by extreme layover. The JERS-1 image preserves the shape of the volcano, but still contains layover.

Relief Effects

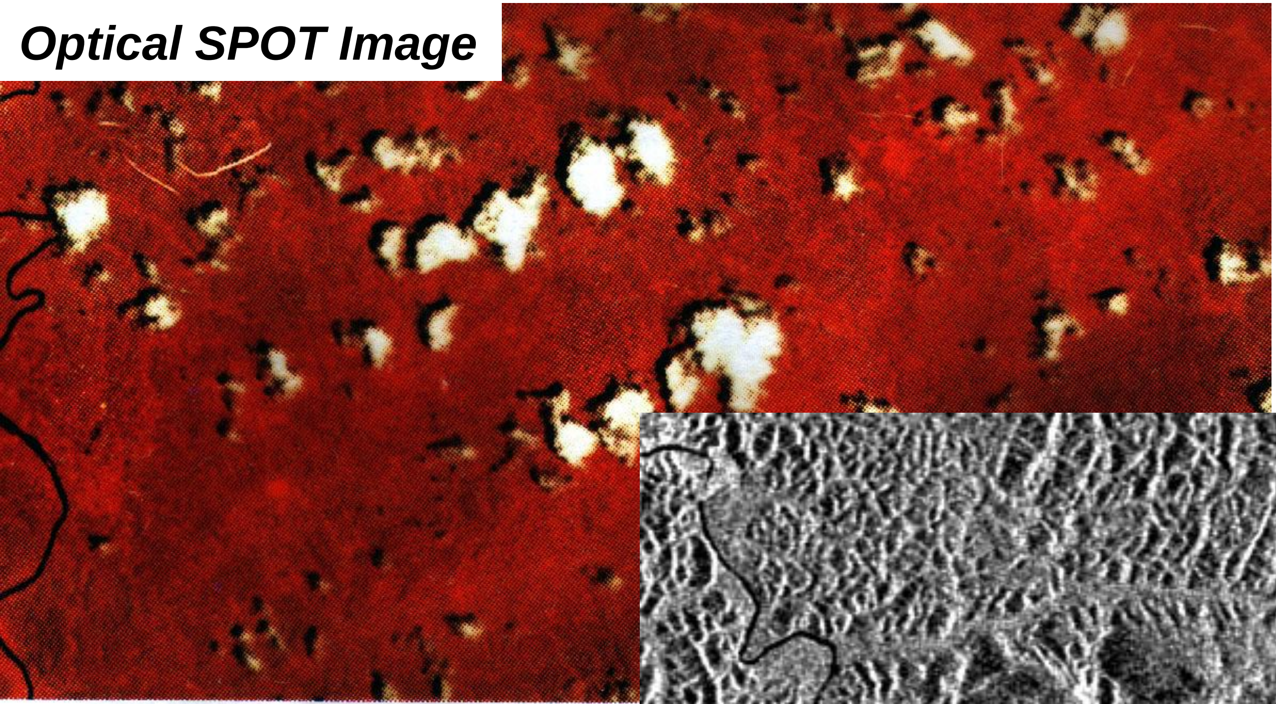


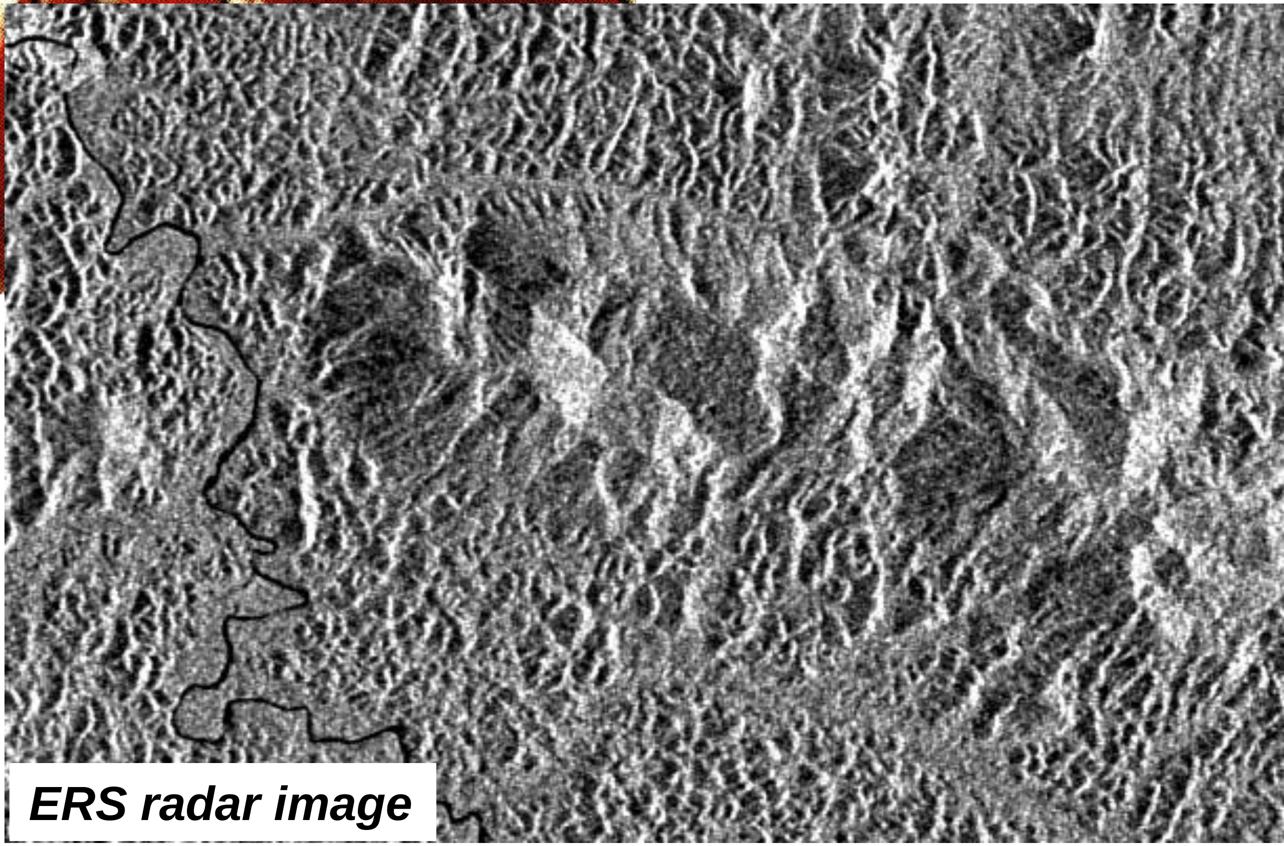
Flight Direction

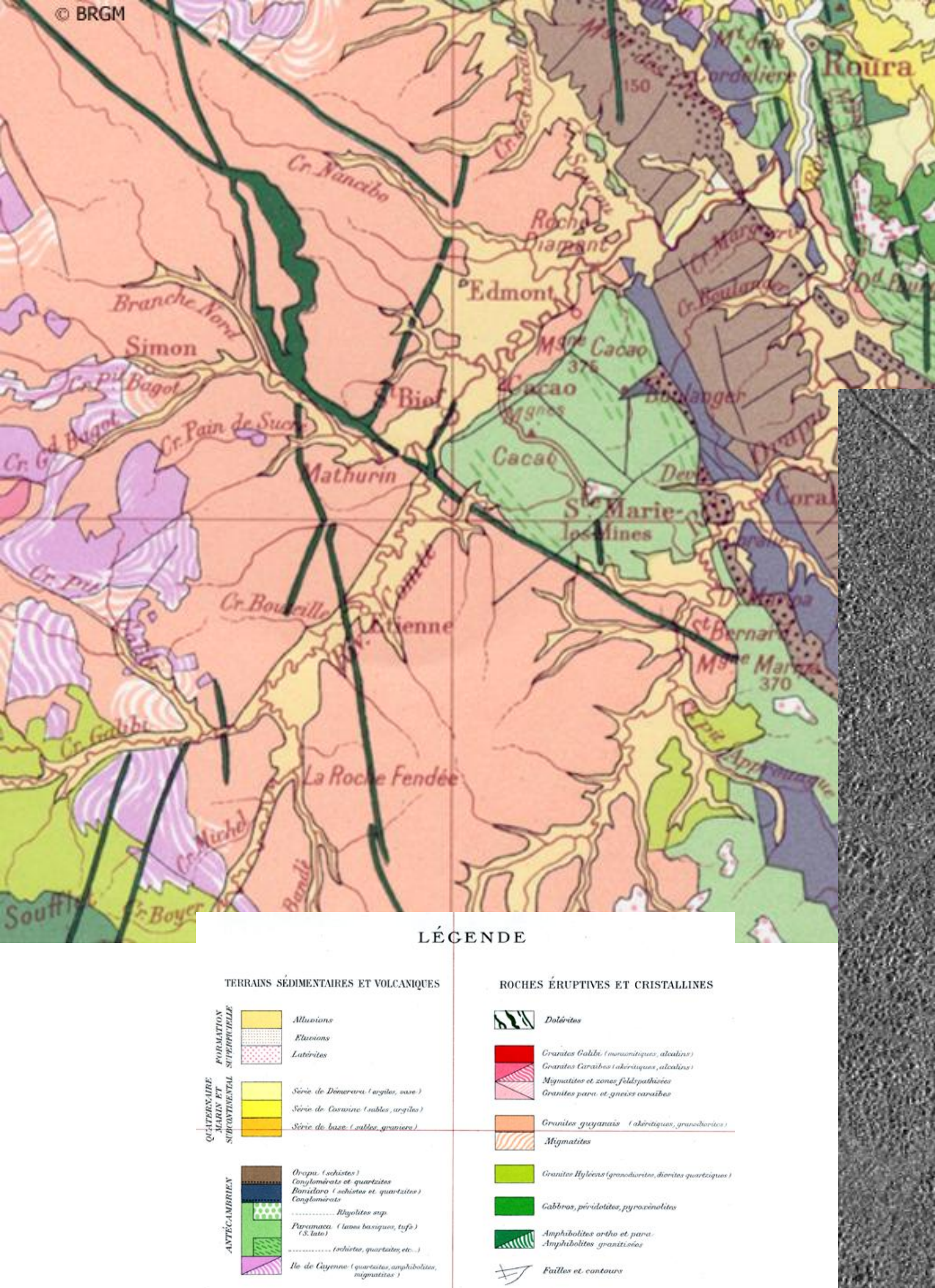
a. ERS-2 image acquired on 27/1/97, with incidence angles 24° - 26°

b. Radarsat fine beam image acquired on 2/2/97, with incidence angles 41° - 44°

Relief effects






© BRGM
Roura
Cr. Nancibo
Roche Diamant
Edmont
Branche Nord
Simon
Cr. Pit Bagot
St Biel
Mgne Cacao
375
Cacao
Mgnes Cacao
Cr. Pain de Sucre
Cr. Gd Bagot
Mathurin
Boulanger
Cr. Boulanger
St Marie les Mines
Cr. Bouille
St Etienne
St Bernard
Mgne Maripa
370
Cr. Galibi
La Roche Fendée
Cr. Michel
Cr. Boyer
LÉGENDE
TERRAINS SÉDIMENTAIRES ET VOLCANIQUES
FORMATION SUPERFICIELLE
Alluvions
Eluvions
Latérites
QUATERNAIRE MARIN ET SUBCONTINENTAL
Série de Démerara (argiles, vase)
Série de Coswine (sables, argiles)
Série de base (sables, graviers)
ANTÉCAMBRIEN
Orapu (schistes)
Conglomérats et quartzites
Bonidoro (schistes et quartzites)
Conglomérats
Rhyolites sup.
Paramaca (laves basiques, tufs) (S. lato)
(schistes, quartzites, etc...)
Ile de Cayenne (quartzites, amphibolites, migmatites)
ROCHES ÉRUPTIVES ET CRISTALLINES
Dolérites
Granites Galibi (monzonitiques, alcalins)
Granites Caraïbes (akéritiques, alcalins)
Migmatites et zones feldspathisées
Granites para et gneiss caraïbes
Granites guyanais (akéritiques, granodiorites)
Migmatites
Granites Hyléens (granodiorites, diorites quartziques)
Gabbros, péridotites, pyroxénolites
Amphibolites ortho et para
Amphibolites granitisées
Failles et contours