OUTLINE

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

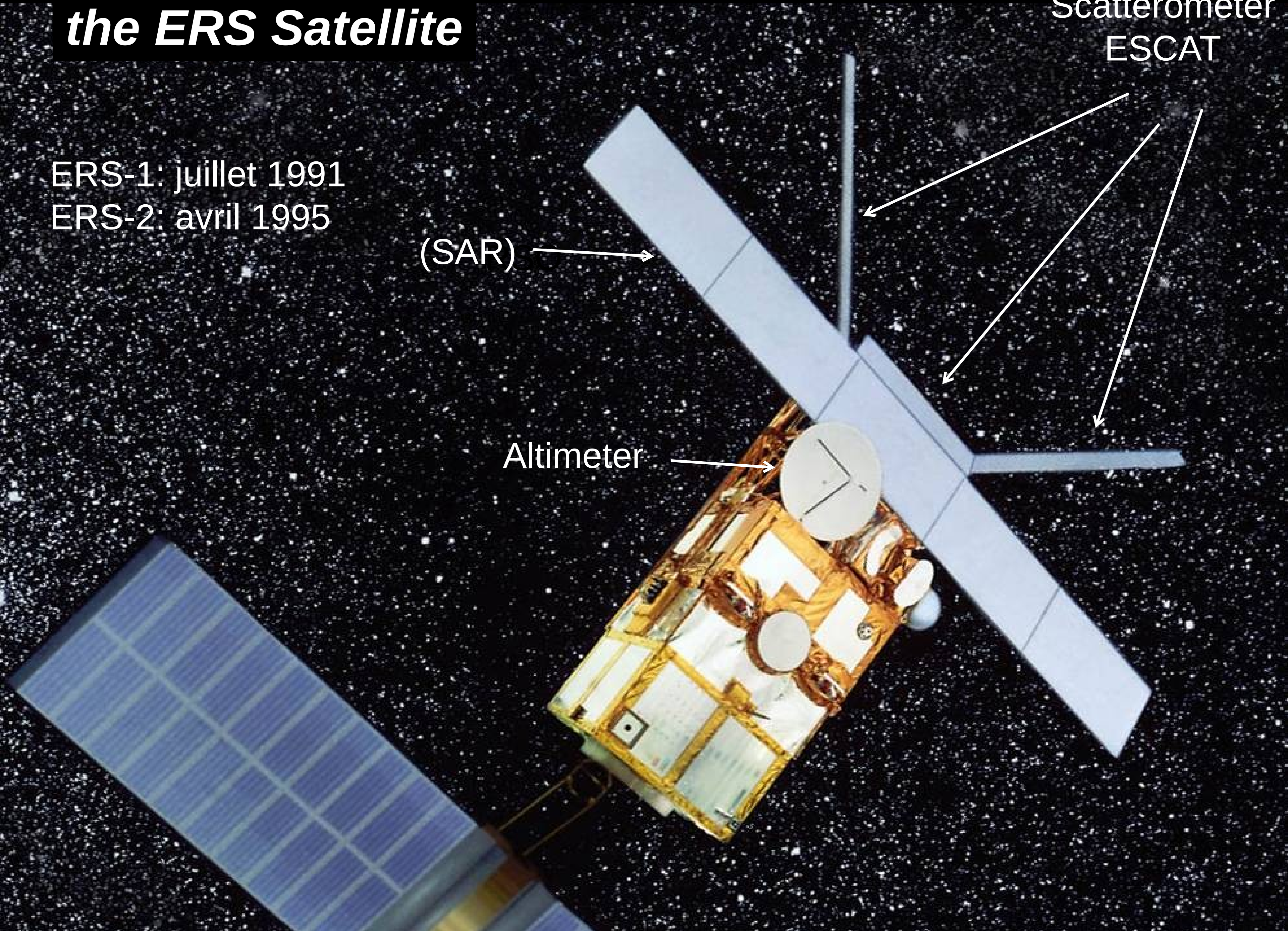
Université Gustave Eiffel

LaSTIG

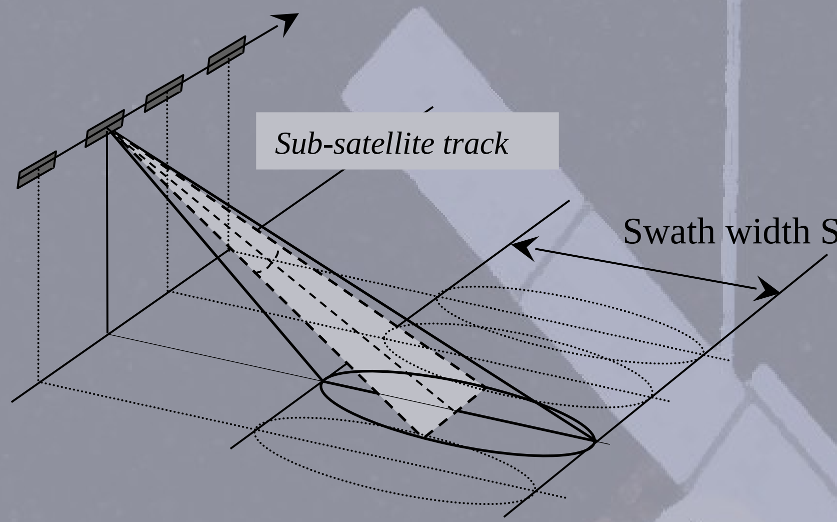
Laboratoire des Sciences et Technologies de l'Information Géographique

the ERS Satellite

ERS-1: juillet 1991
ERS-2: avril 1995

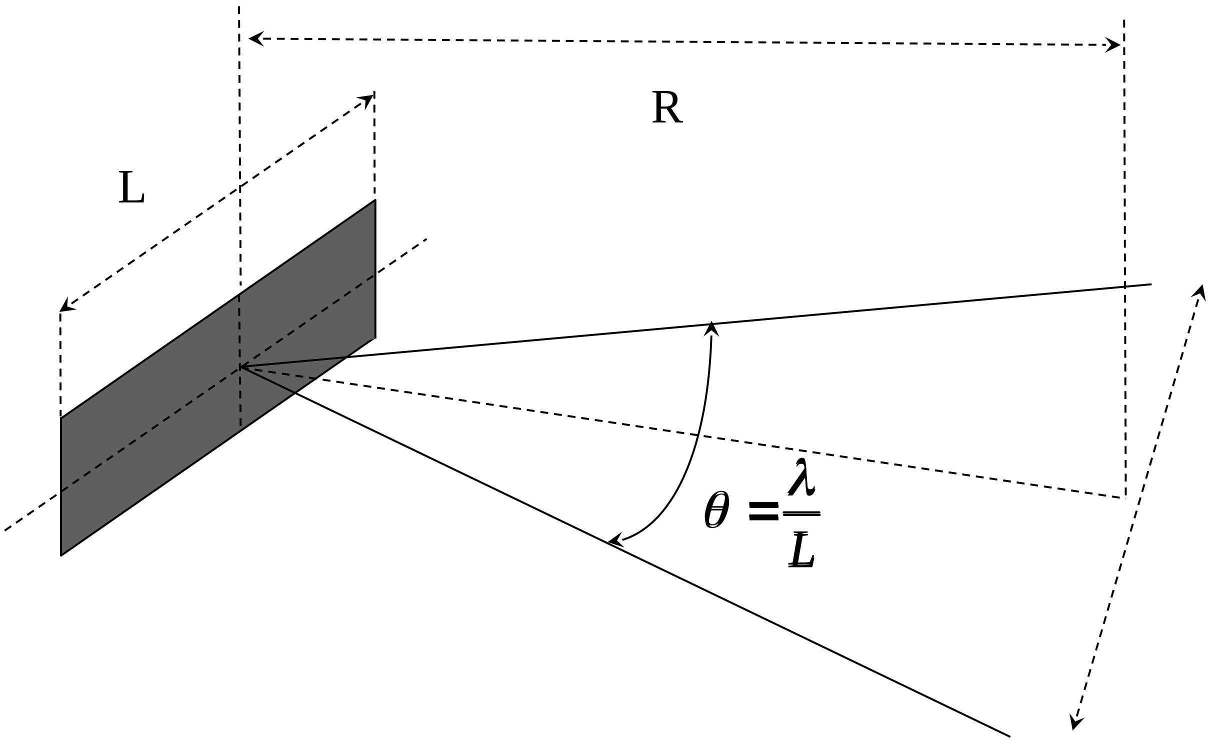


Side looking radar sensors (λ > cm)



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***

ANTENNA APERTURE



Resolution
$\delta r = \theta \cdot R$

Ex.: L = 4 m, R = 4 km (airborne), λ = 3 cm (X band) δr = ***30 m***

L = 10 m, R = 800 km (spaceborne), λ = 6 cm (C band) δr = ***4,5 km***

Spatial resolution:

smallest distance allowing the separation of two objects

Optical data:

sensor spatial resolution < image pixel size

==> pixel size same as spatial resolution

hence the use of one word for the other

Radar data:

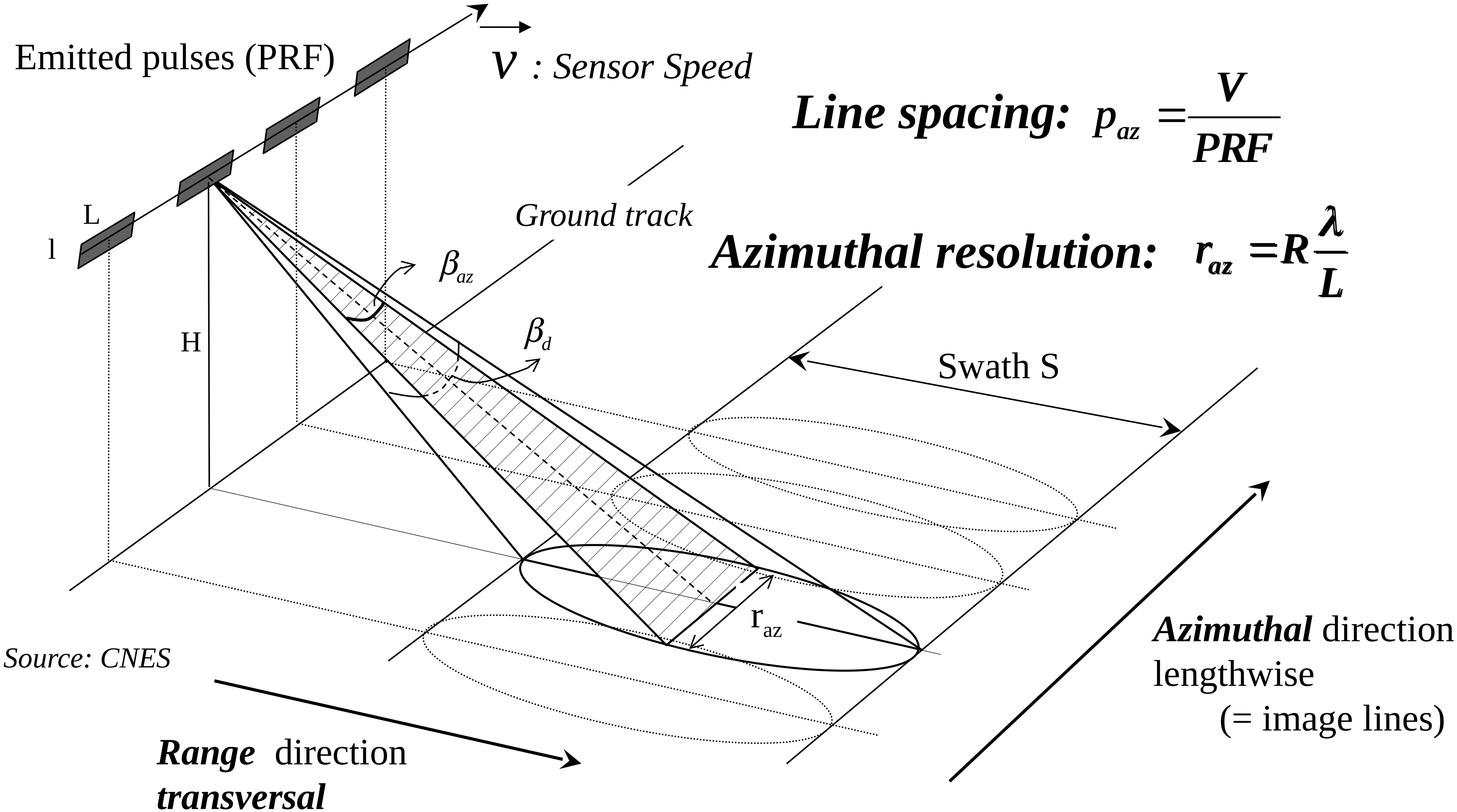
sensor spatial resolution > image pixel size

==> these 2 notions remain different

Radar Imaging – spatial resolution

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

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



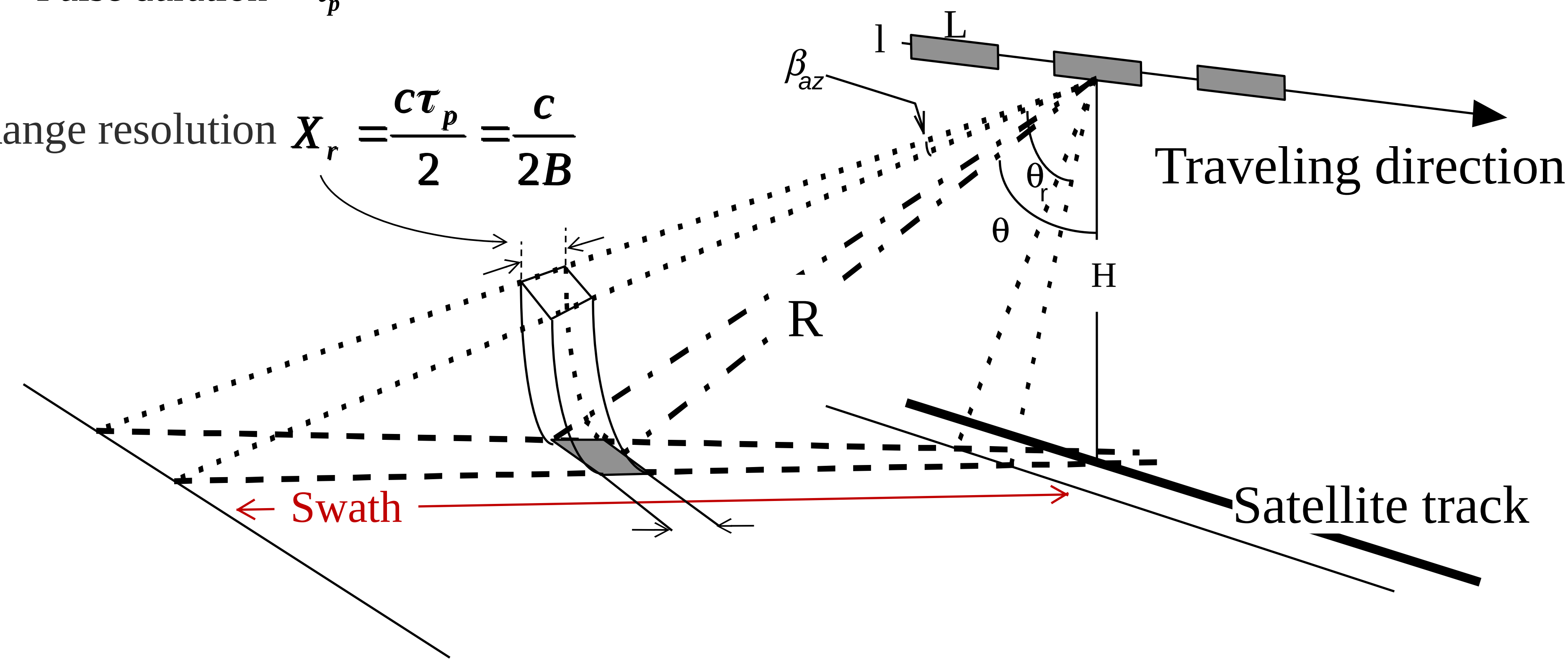
Numerical Application (ERS):

PRF=1680 Hz, V=7km/s	*L=10 m, λ =5.6 cm, H =700 km, θ =23°*
$\boldsymbol{p_{az}}$ ***5 m***	$\boldsymbol{r_{az}}$ ***4.2 km***

Radar Imaging – spatial resolution

Pulse duration = τ_p =

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



⚘ ***Increase the pulse B***

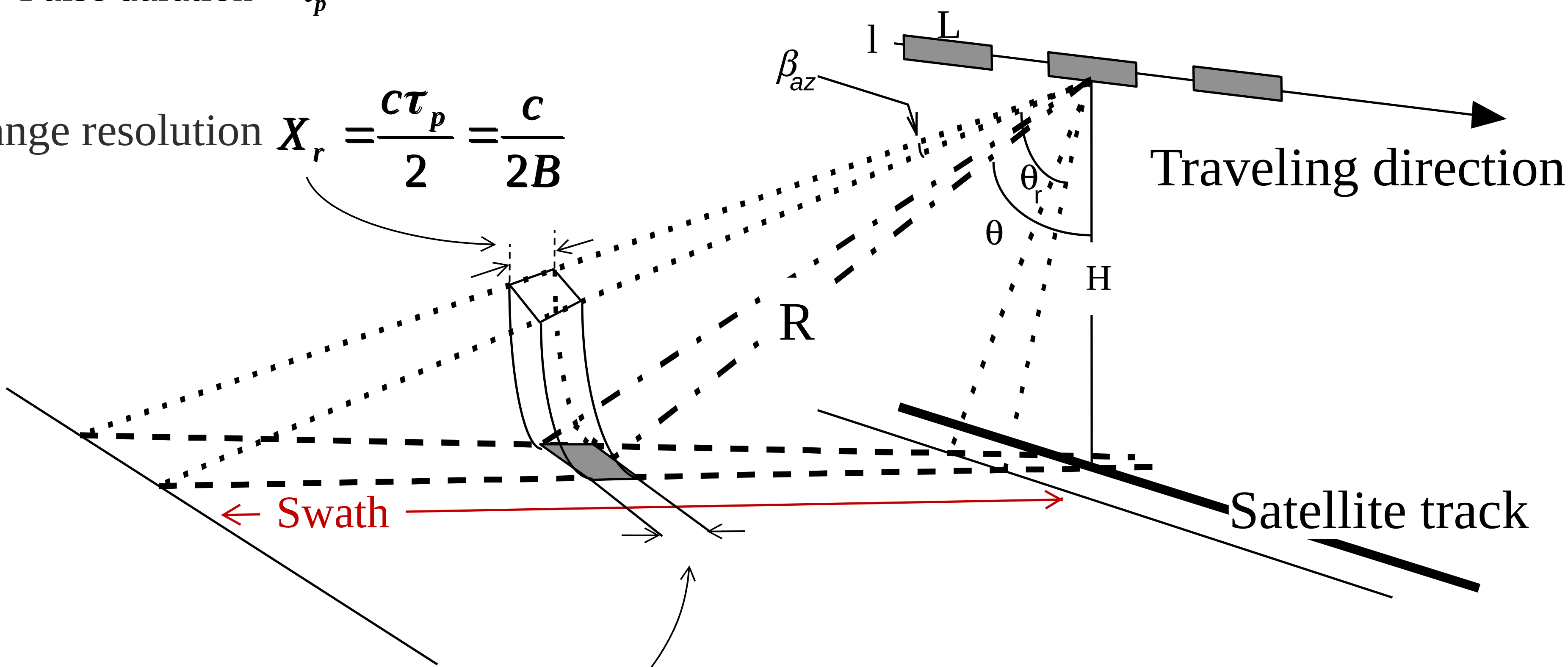
Num. Appl. (ERS): *τ_p = 37 μs B ~~30 kHz~~ 15.5 MHz*

X_r 10 m

Radar Imaging – spatial resolution

Pulse duration = τ_p =

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



Ground Range resolution:

$$X_{gr} = \frac{c\tau_p}{2\sin\theta} = \frac{c}{2B\sin\theta}$$

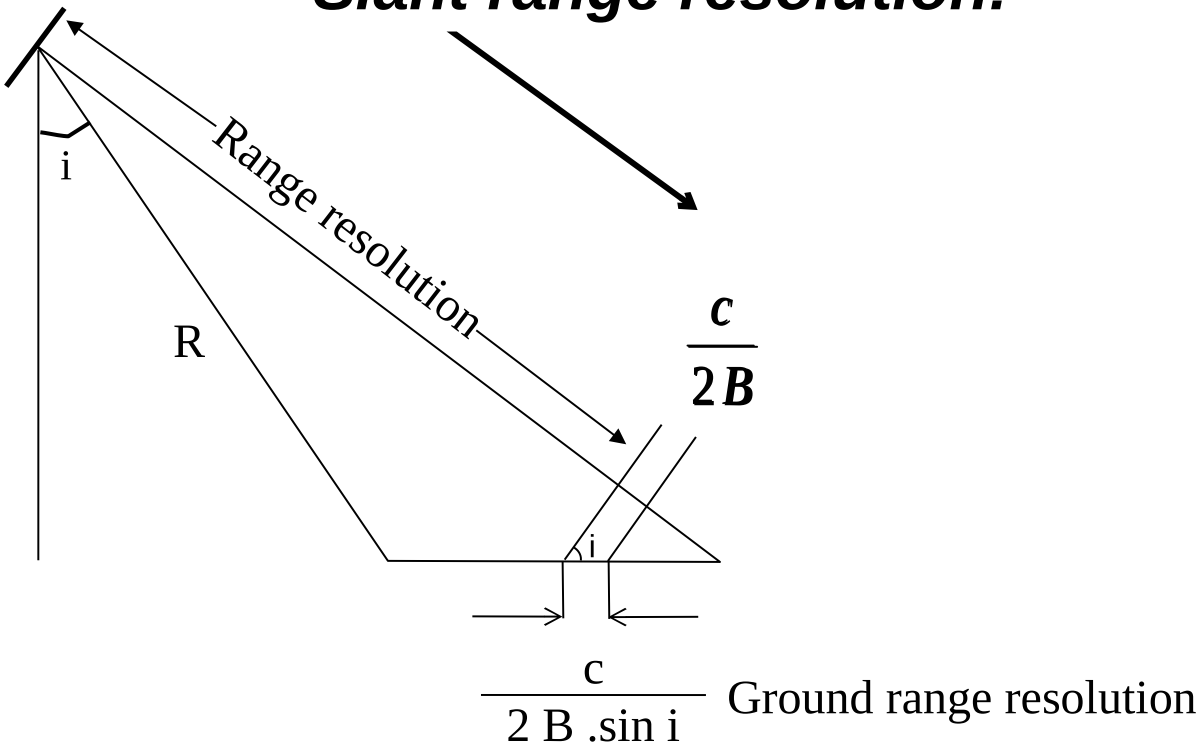
- ***Increase the pulse B***

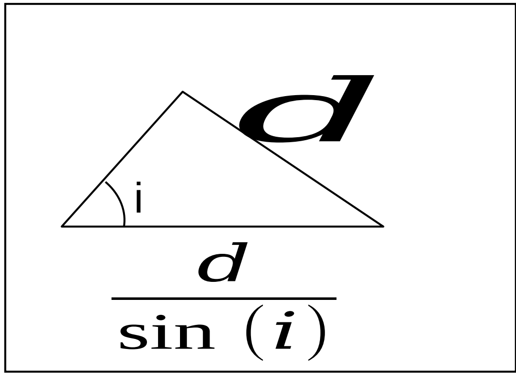
Num. Appl. (ERS): *τ_p = 37 μs B ~~30 kHz~~ 15.5 MHz*

X_r 10 m

Radar Imaging – spatial resolution

Slant range resolution:



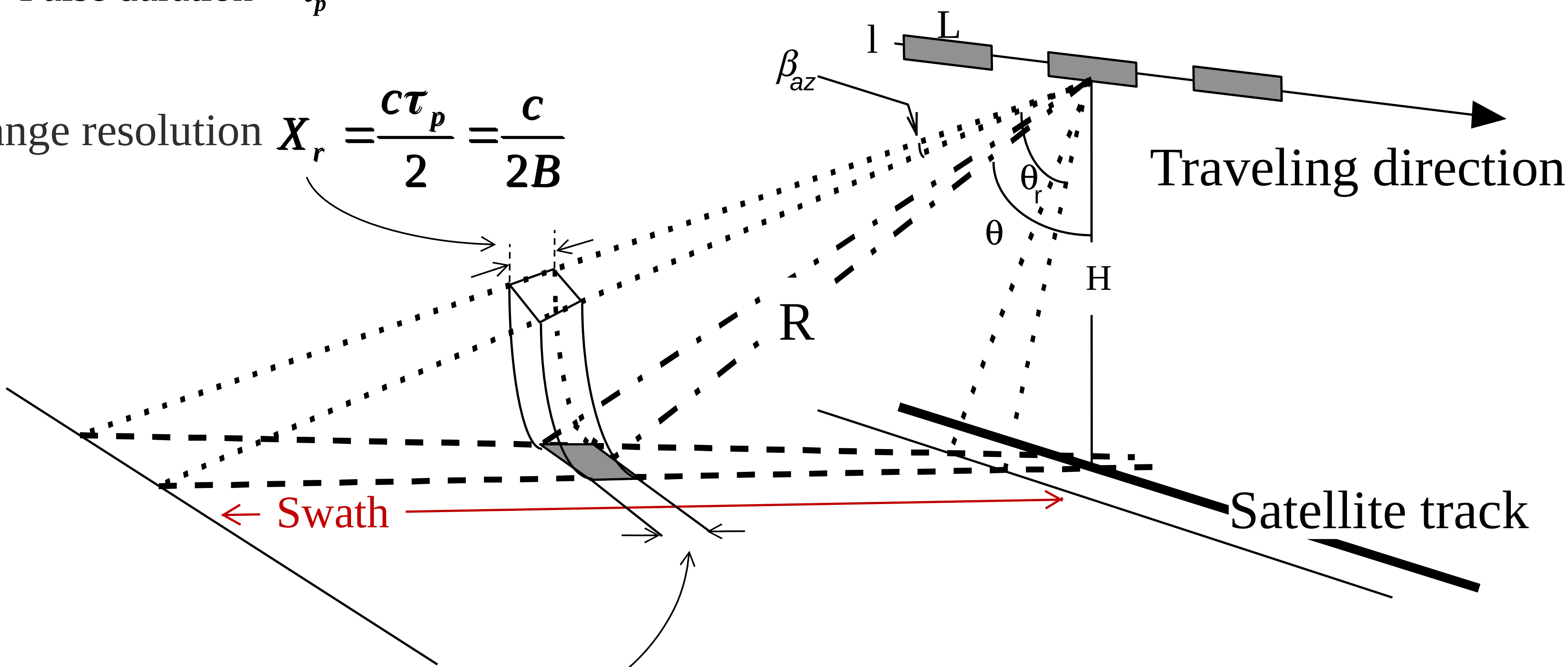


Ground range resolution: $X_{gr} = \frac{c}{2B\sin(i)}$

Radar Imaging – spatial resolution

Pulse duration = τ_p =

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



Ground Range resolution:

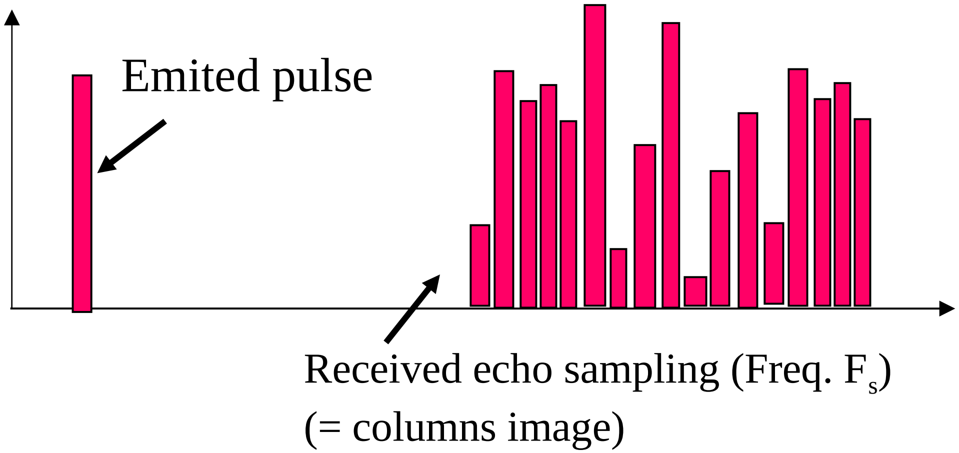
$$X_{gr} = \frac{c\tau_p}{2\sin\theta} = \frac{c}{2B\sin\theta}$$

- ***Increase the pulse B***

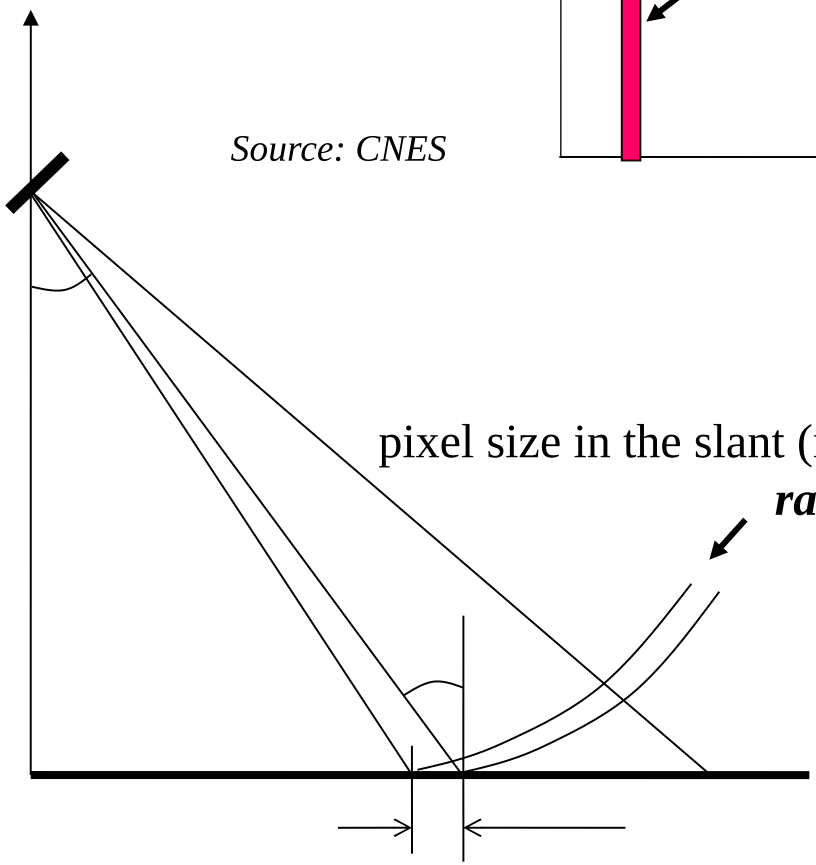
Num. Appl. (ERS): *τ_p = 37 μs B ~~30 kHz~~ 15.5 MHz*

X_r 10 m X_{gr} 25 m

Radar Imaging – spatial resolution



Source: CNES



pixel size in the slant (radar) geometry:

range pixel size: $p_s = \frac{c}{2.Fs}$

$p_g = \frac{c}{2.Fs.\sin}$

Ground pixel size

Numerical application: ERS

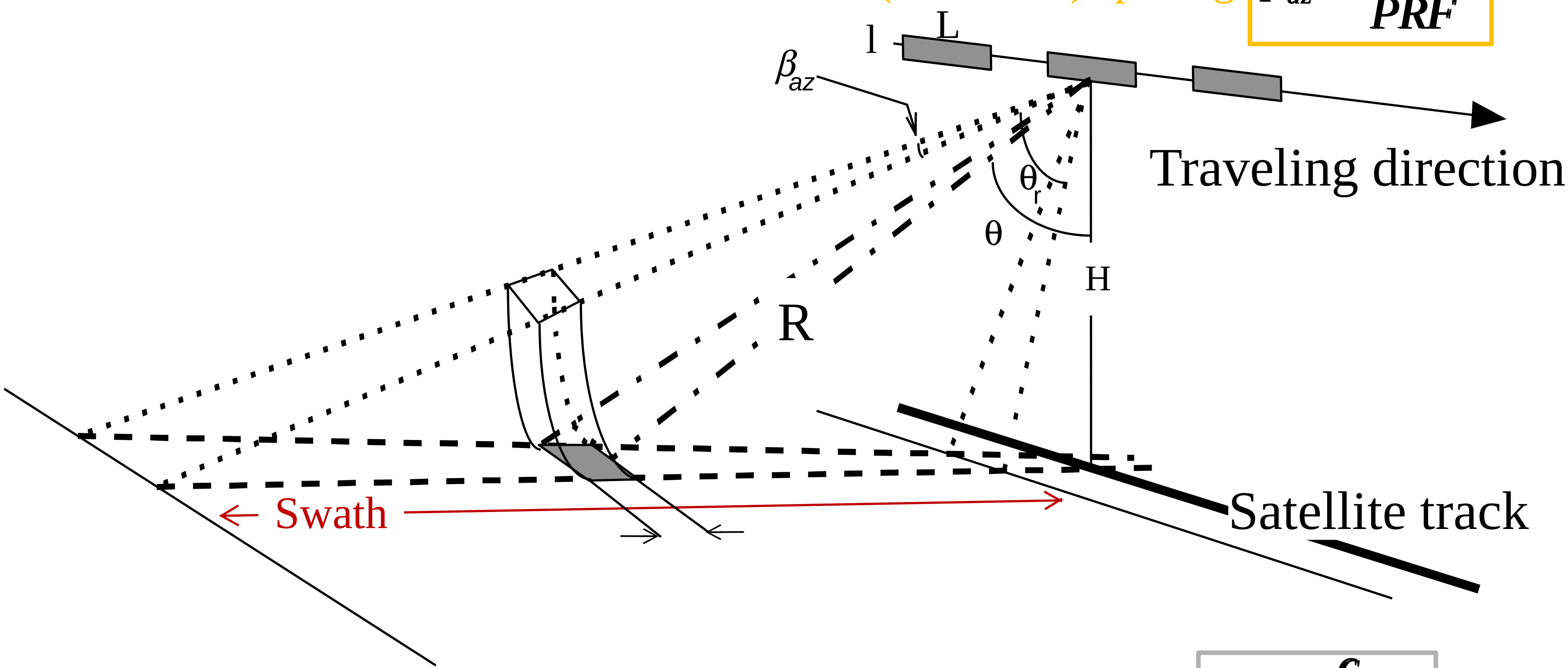
F_s = 19 MHz

$\boldsymbol{p_s}$ ***8 m***

$\boldsymbol{p_g}$ ***20 m***

Radar Imaging – spatial resolution

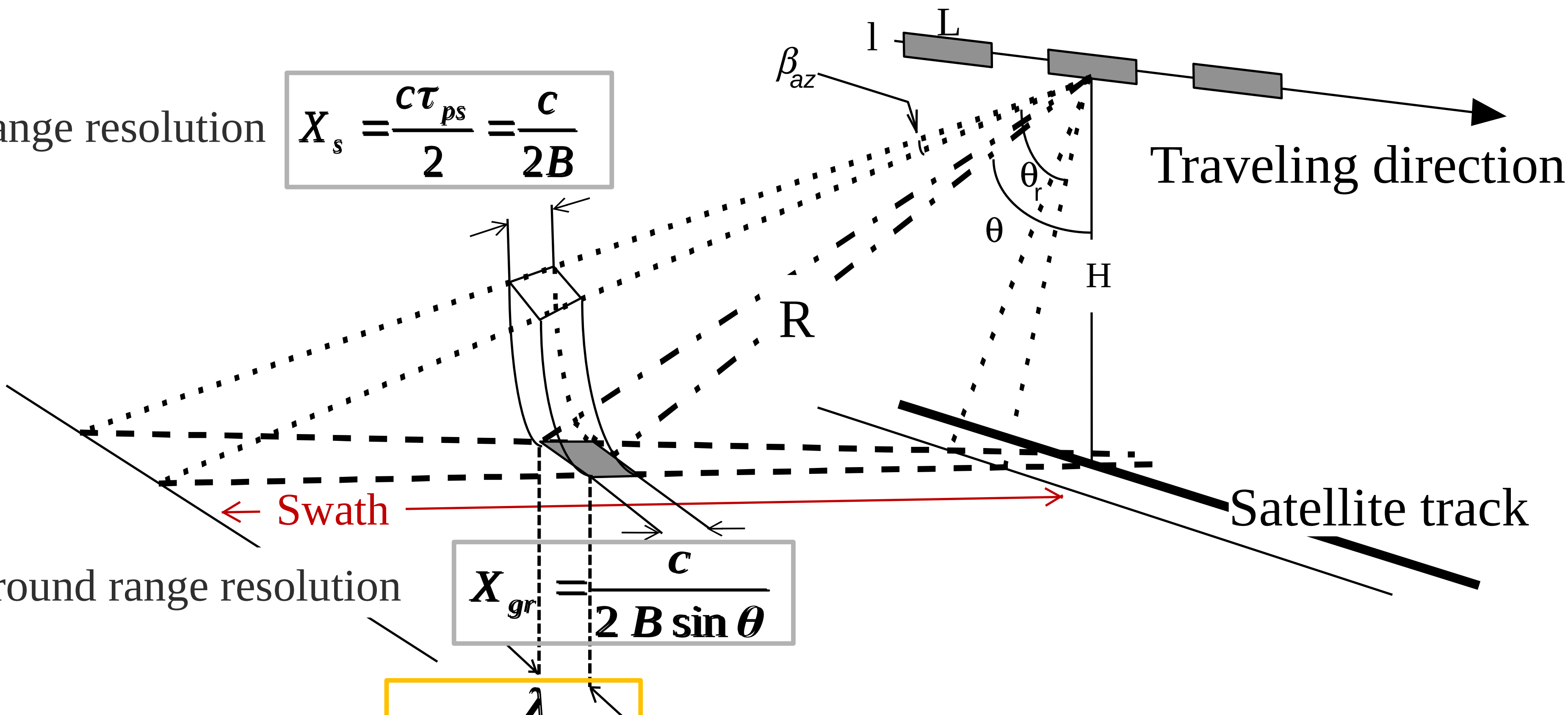
Line (azimuthal) spacing $p_{az} = \frac{V}{PRF}$



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

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

Radar Imaging – spatial resolution



Range resolution $$X_s = \frac{c\tau_{ps}}{2} = \frac{c}{2B}$$

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

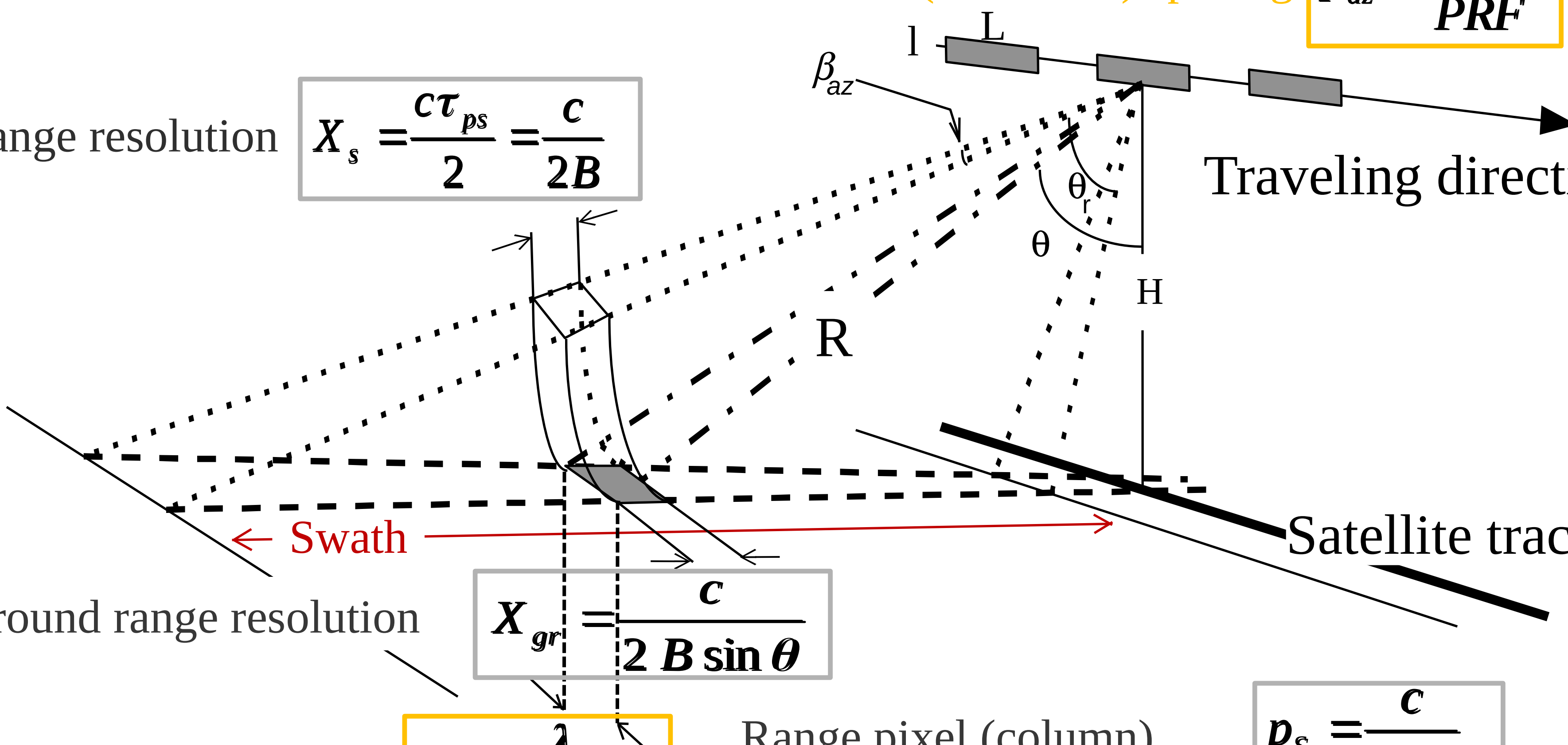
Azimuthal resolution $$X_{az} = \frac{\lambda}{L}R$$

Pulse duration = $\tau_p = 1/B$

Radar Imaging – spatial resolution

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

Range resolution $X_s = \frac{c\tau_{ps}}{2} = \frac{c}{2B}$



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

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

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

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

Pulse duration $= \tau_p = 1/B$

Radar Imaging – spatial resolution

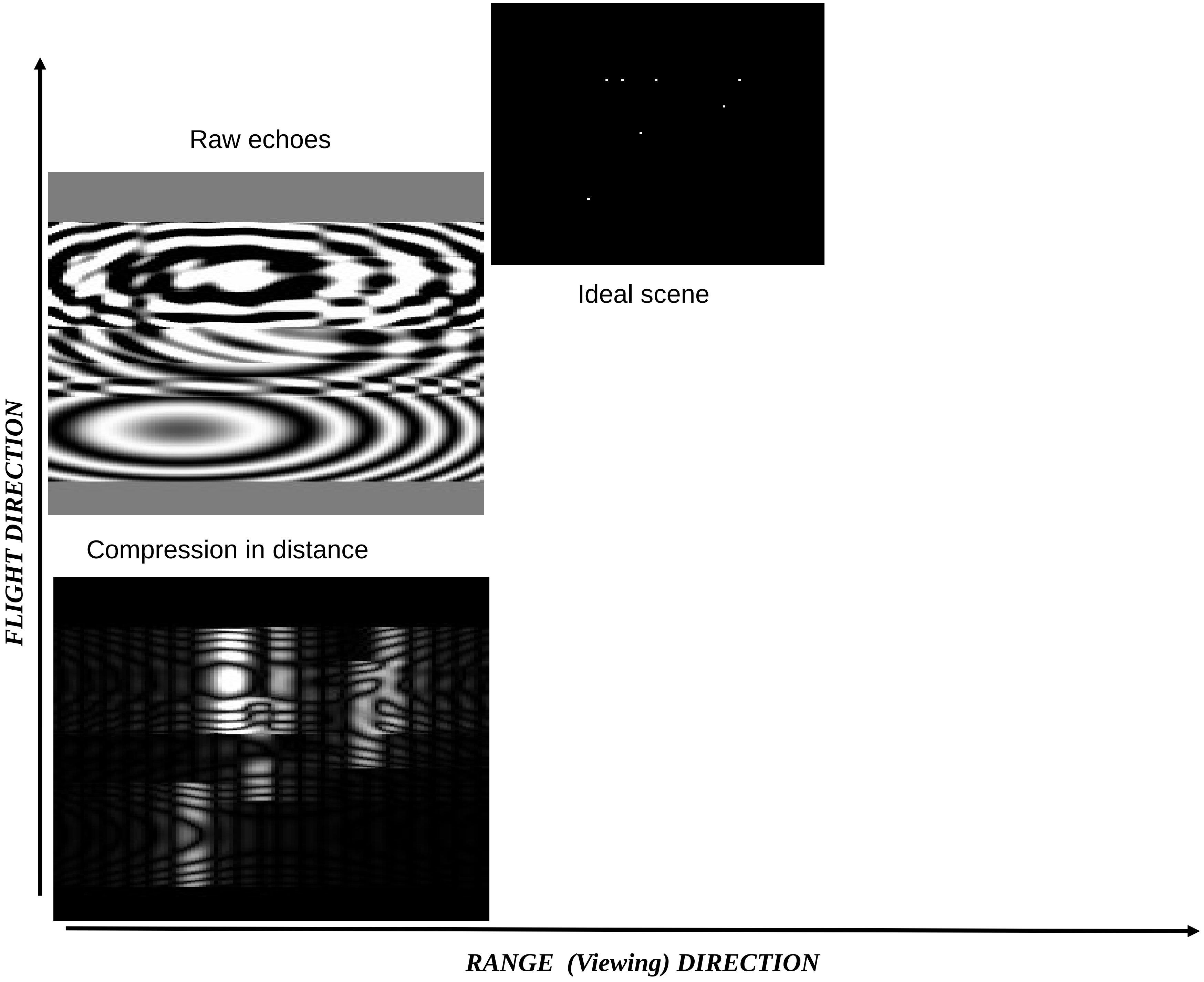
Case of ERS

	Range: Slant (radar)	Range: Ground	Azimuth
Resolution	$X_s = \frac{c}{2B}$ = 10 m	$X_{gr} = \frac{c}{2B\sin(\theta)}$ = 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
= 18-24°
B =15.5 MHz

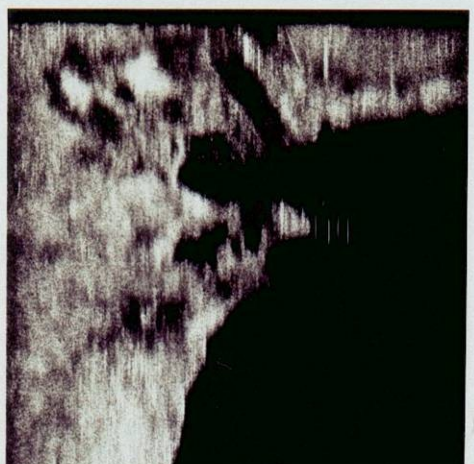
R = 15.5 MHz
L = 10 m


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

FLIGHT DIRECTION

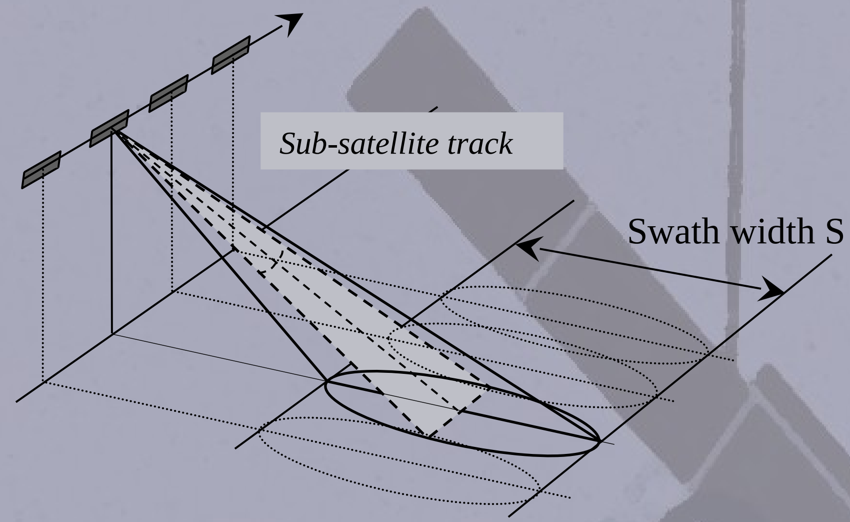
NON COMPRIME DISTANCE
NON COMPRIME AZIMUT

Document



COMPRIME DISTANCE
NON COMPRIME AZIMUT

Side looking radar sensors (λ > cm)



SAR: Synthetic Aperture Radar

Raw echoes recording

Coherent *sum* ***(A, ϕ)***

Spatial resolution

fine (1 - 30 m)

Radiometric resolution

Low (speckle)

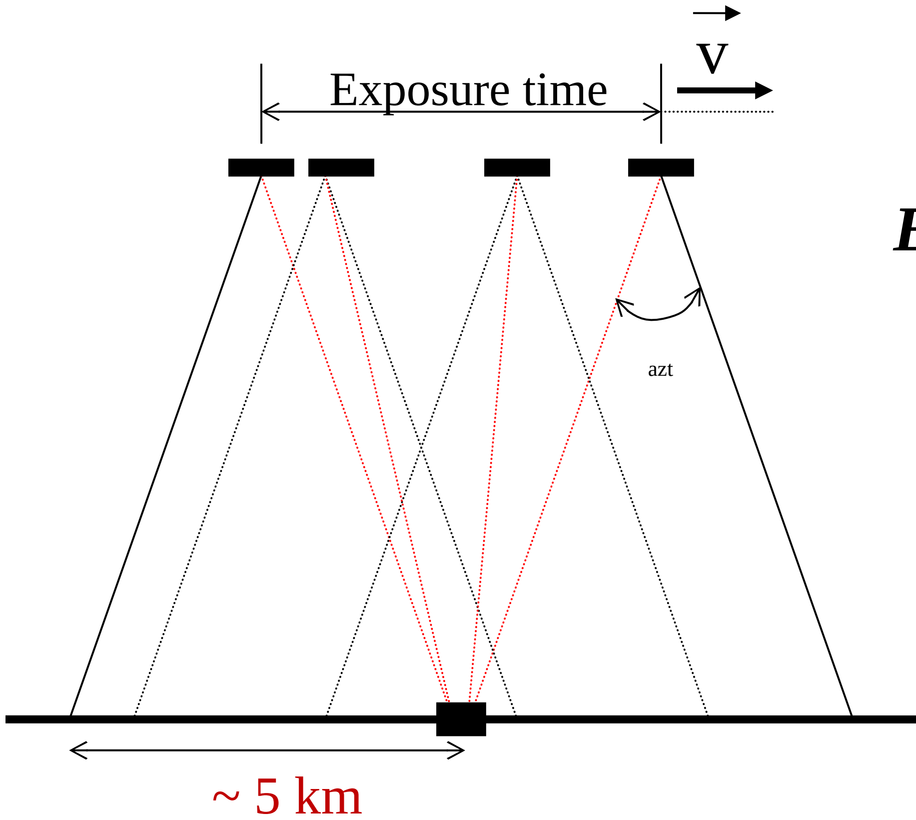
Original application

Land - sea

Radar Imaging – spatial resolution

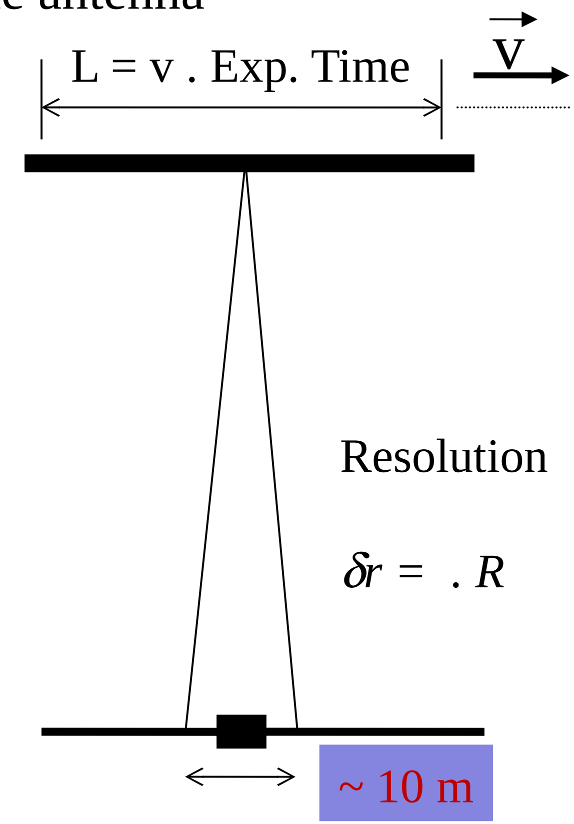
Synthetic Aperture Radar: ***(i.e. improvment of azimuthal resolution)***

Small mobile antenna □ Fixed wide antenna



Equivalence

SAR



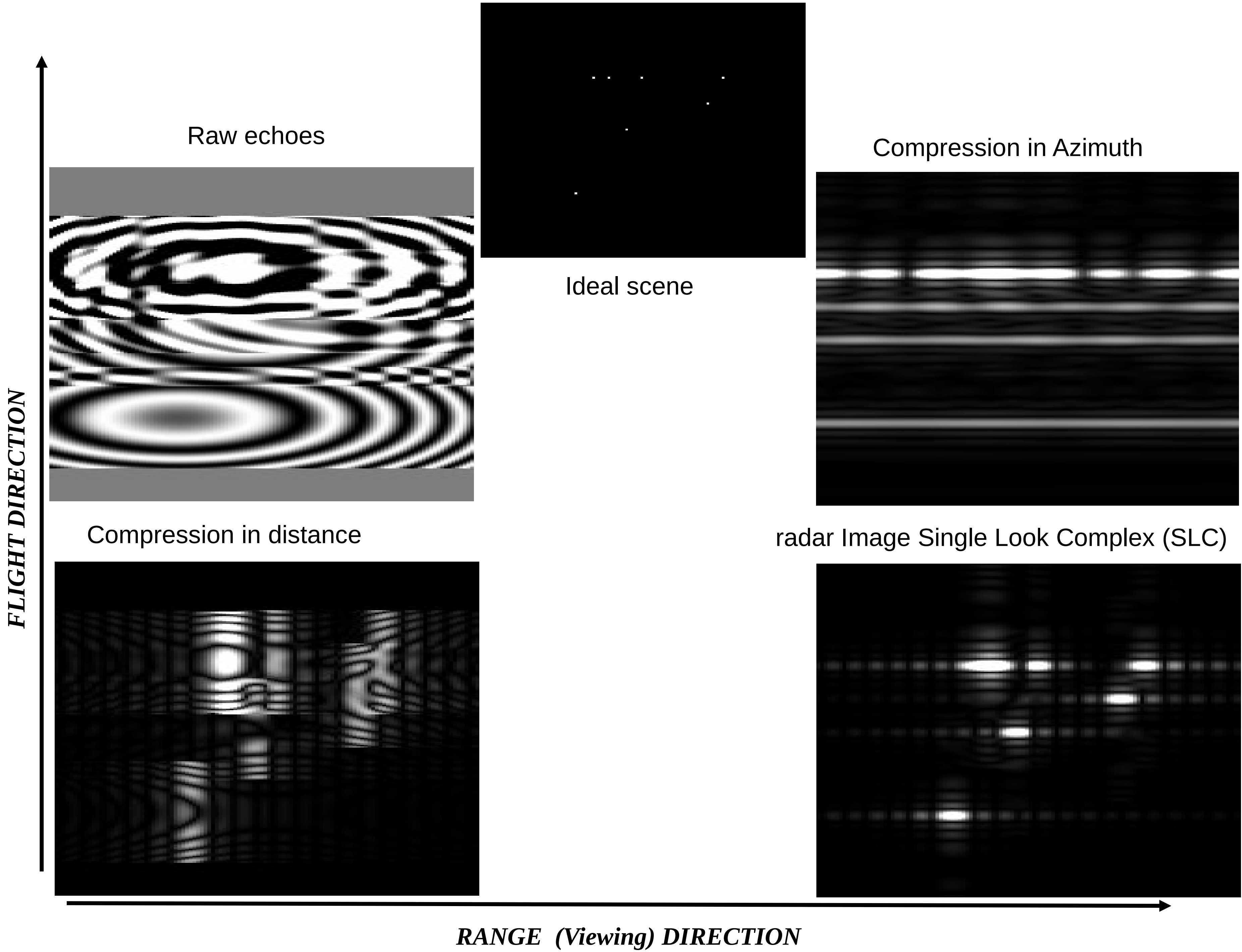
Coherent sum of the successive echoes

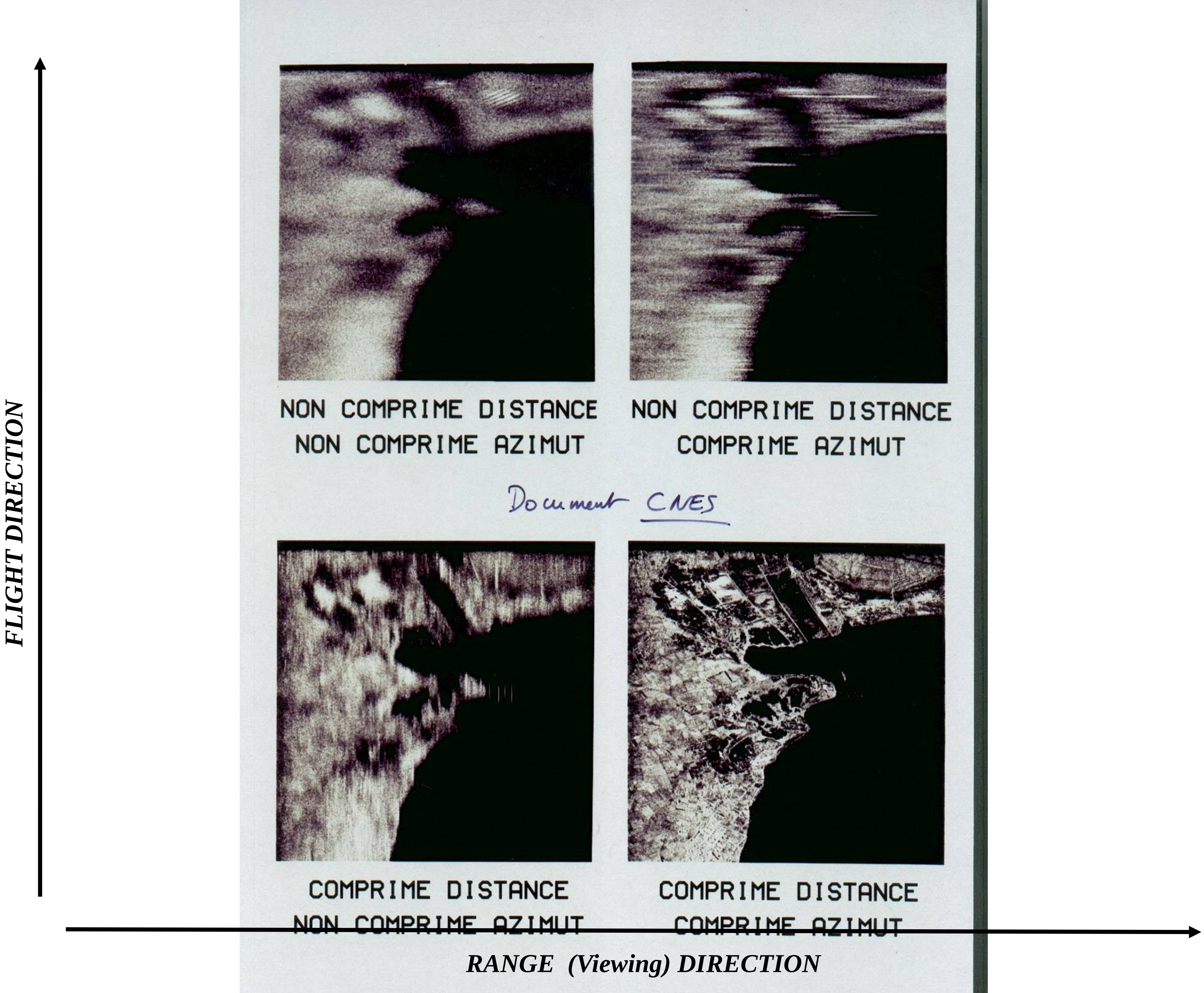
Adaptative filtering (Doppler Bandwidth)

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

Gain in azimuthal resolution

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


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
RANGE (Viewing) DIRECTION

Radar Imaging – spatial resolution

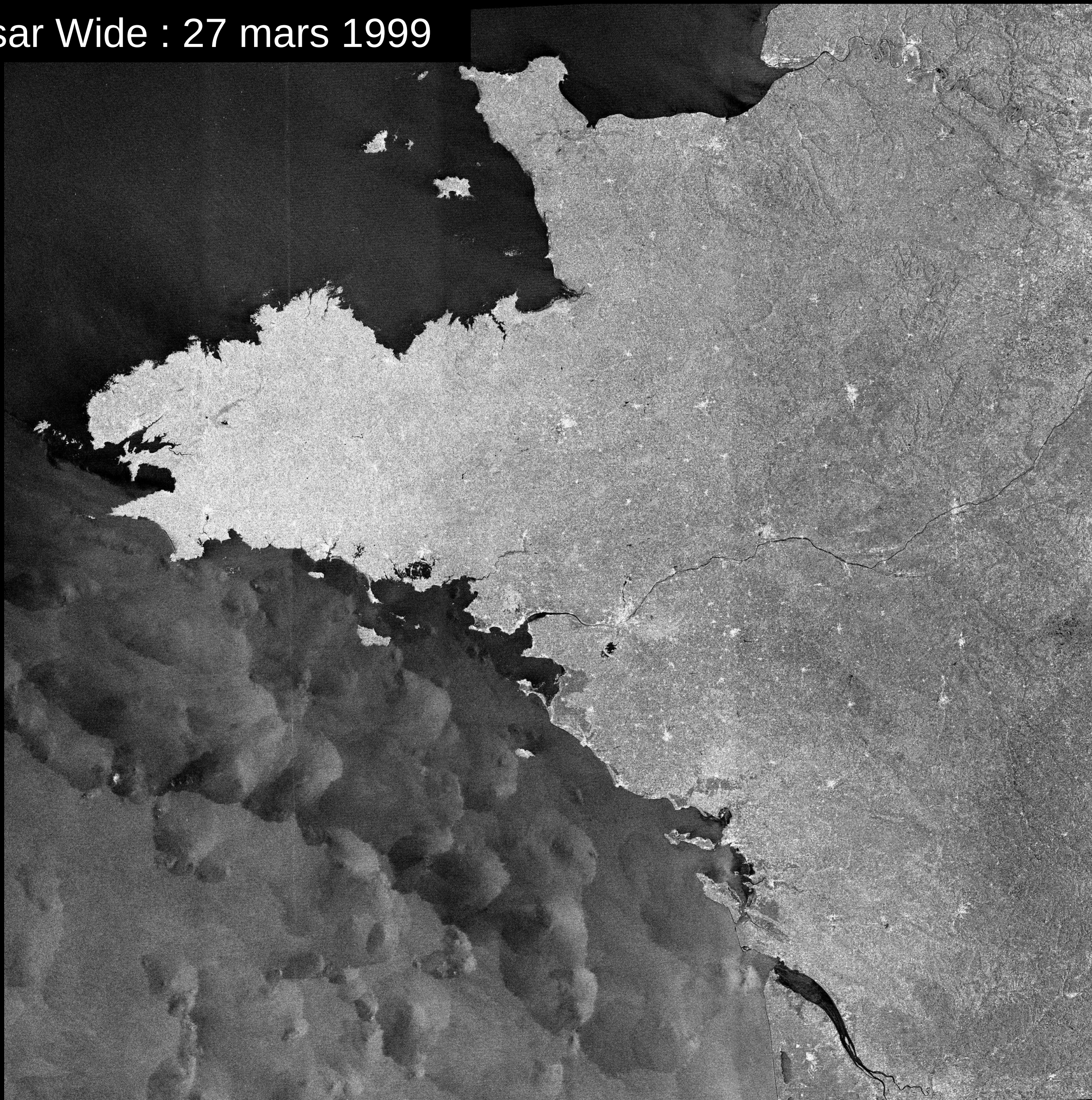
Case of ERS SAR *(after aperture synthesis)*

	Range: Slant (radar)	Range: Ground	Azimuth
Resolution	$X_r = \frac{c}{2B}$ = 10 m	$X_r = \frac{c}{2B\sin(\theta)}$ = 25 m - 32 m	$X_{az} = \frac{\lambda}{L_{synth}} R$ = 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: Slant (radar)	Range: Ground	Azimuth
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



Spat. res. 150 m

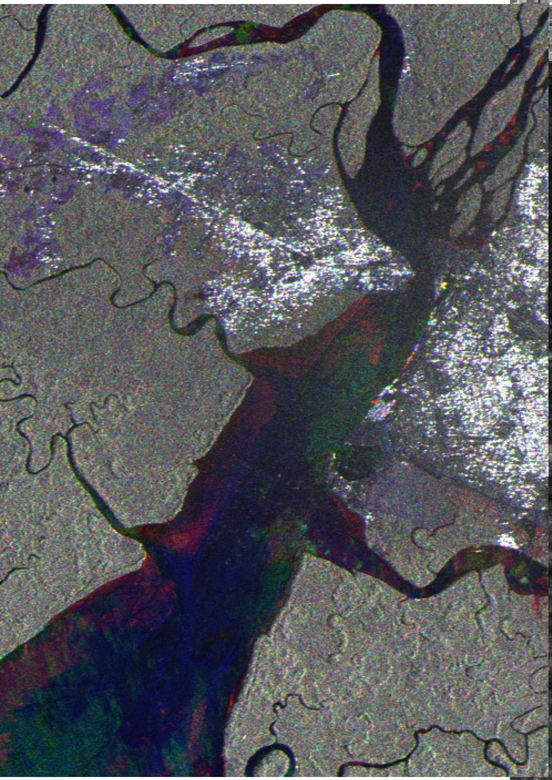
The Ouessant Rail
RADARSAT - Standard 6 : 3 Aug.1999

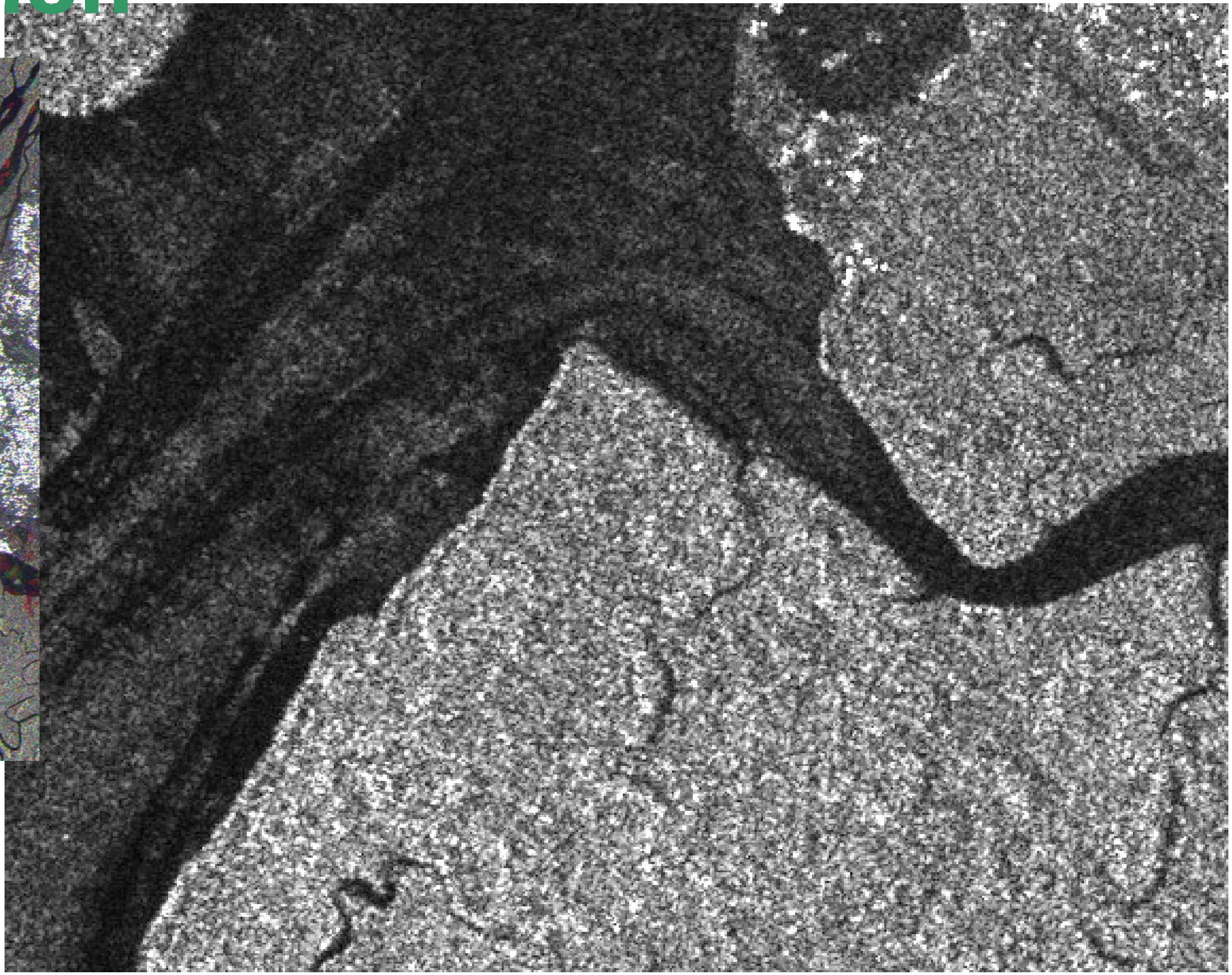
Spat. res. 30 m

The Channel
ASAR
22 novembre 2003

spat. res. 150 m

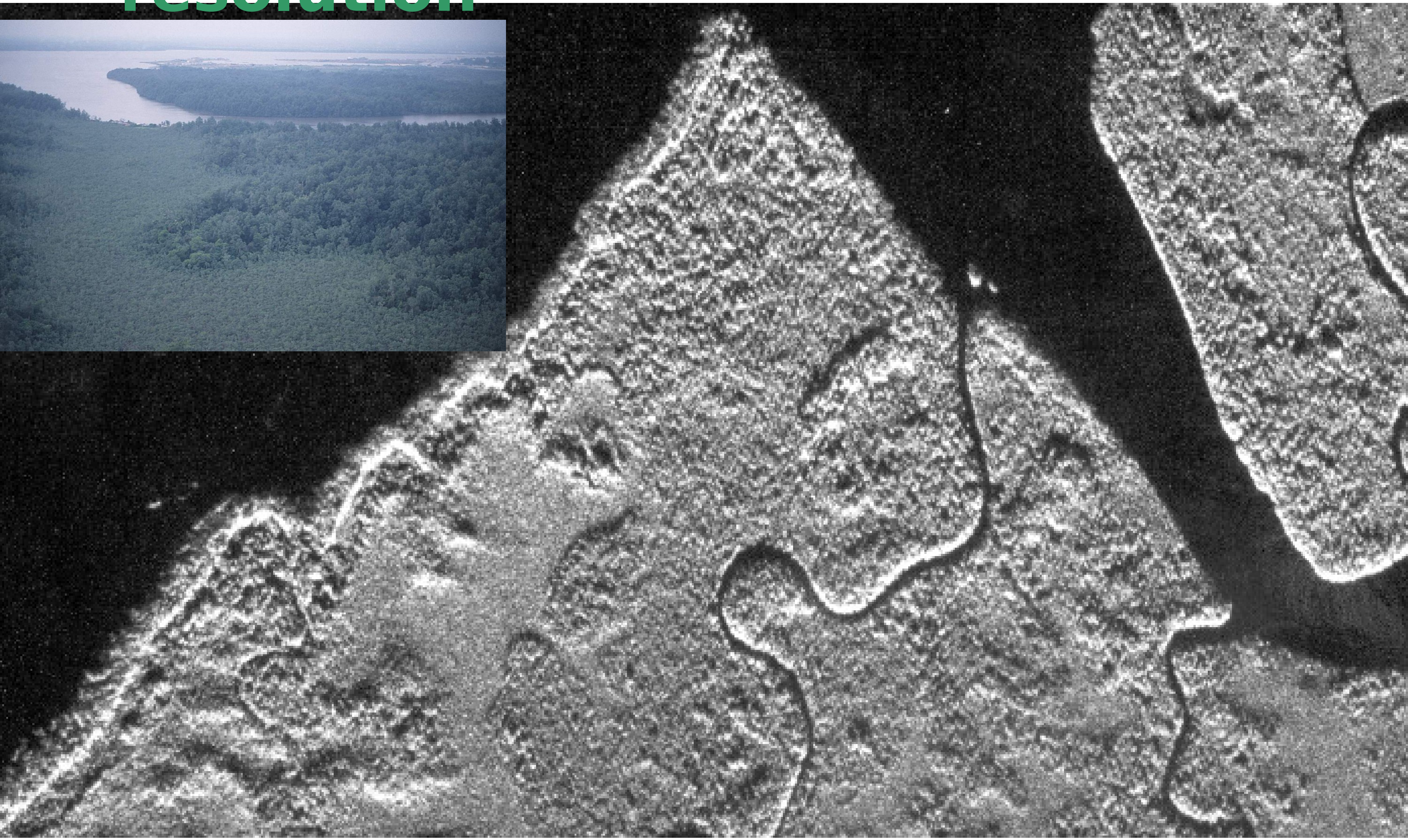
Radar Imaging – spatial resolution





ERS Resolution ~ 25 m, pixel 12,5m

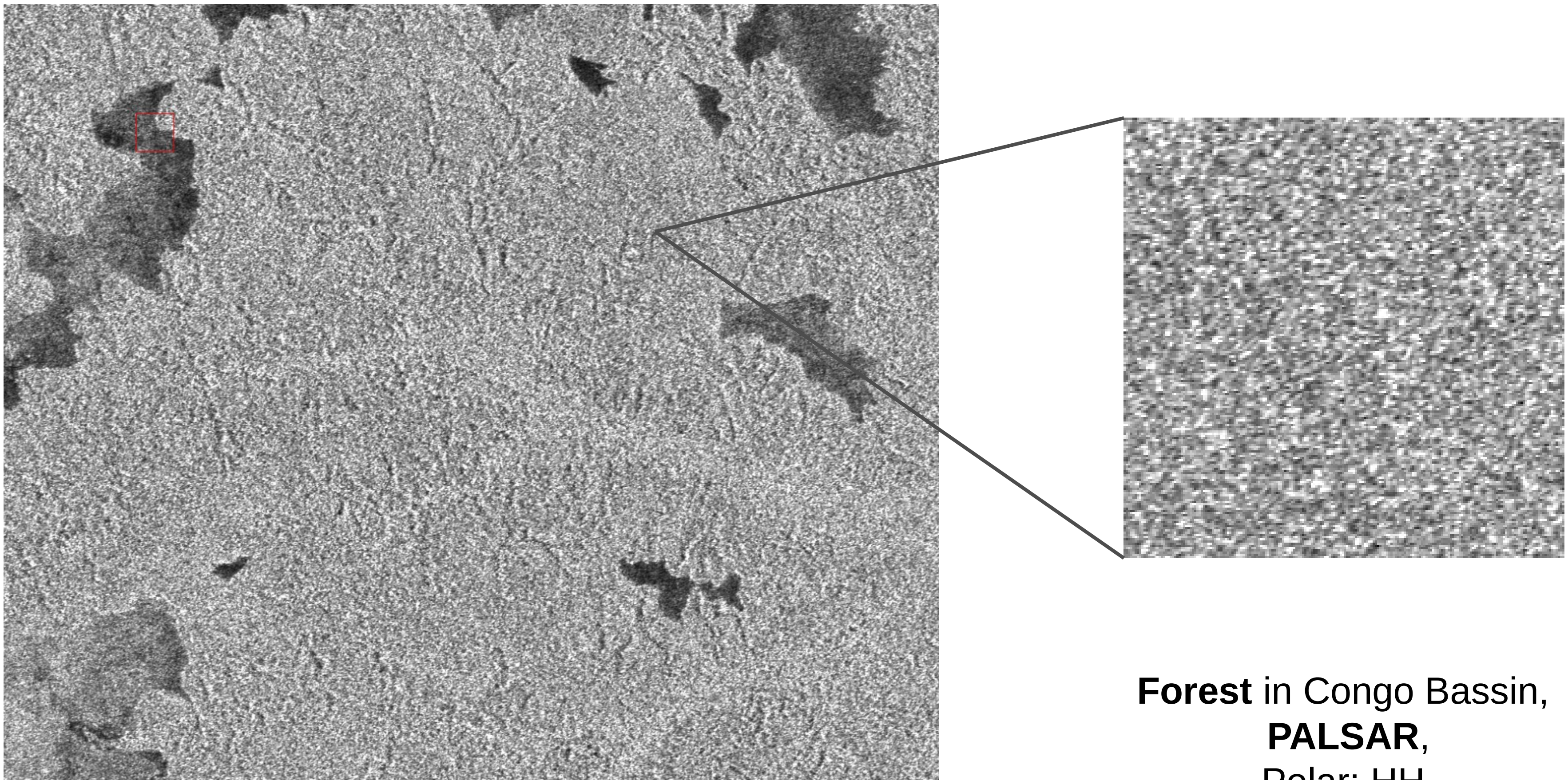
Radar Imaging – spatial resolution



DLR airplane radar resolution ~ 3 m

Radar Imaging – spatial resolution

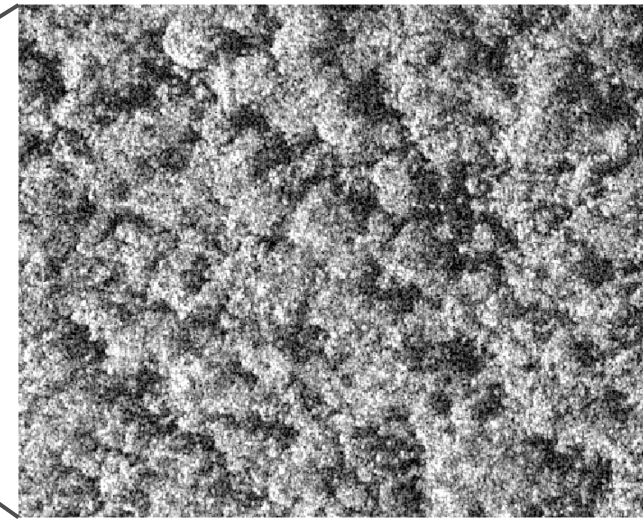
Radar data



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

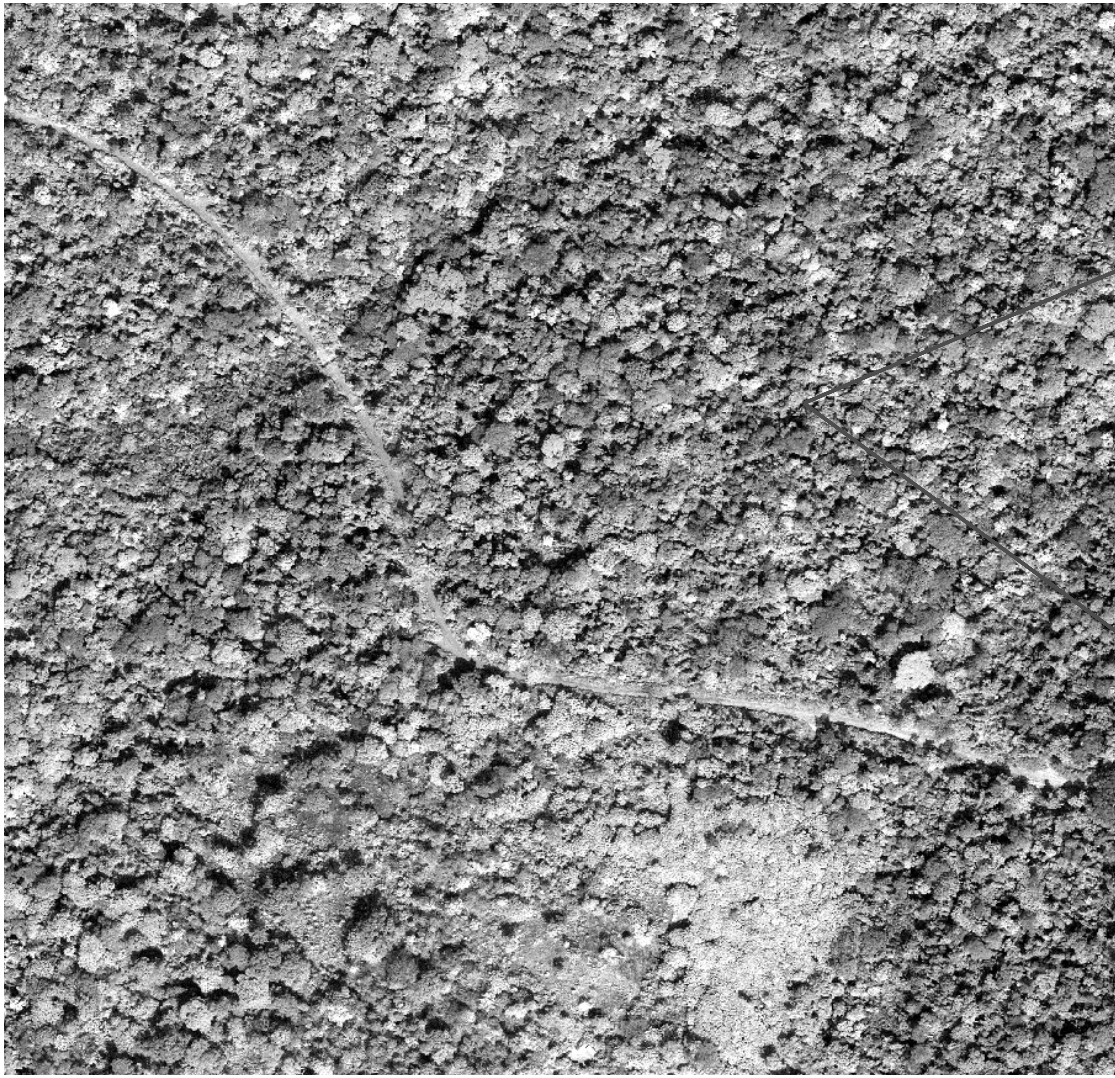
Radar Imaging – spatial resolution

Radar data

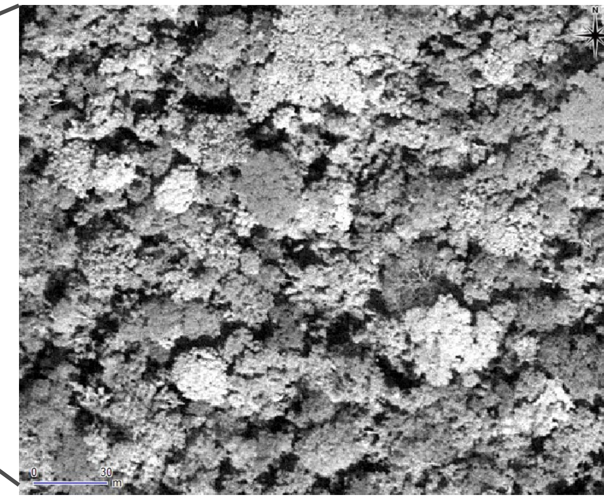


Forest in Cameroon,
TerraSAR-X, Spot Light,
Polar: HH,
Spat.Resolution: 1 m

Radar Imaging – spatial resolution



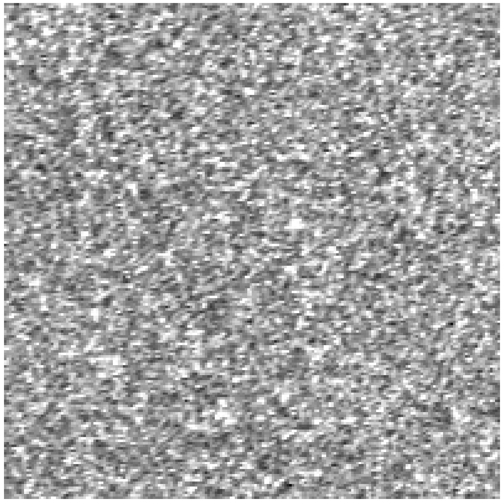
Optical data



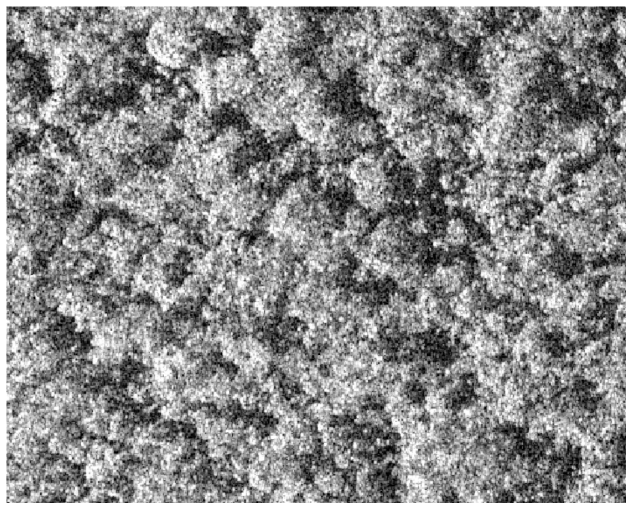
Forest in Cameroon,
Geoeye, Panchromatic,
Spat.Resolution: 0.5 m

Radar Imaging – spatial resolution

RADAR Data

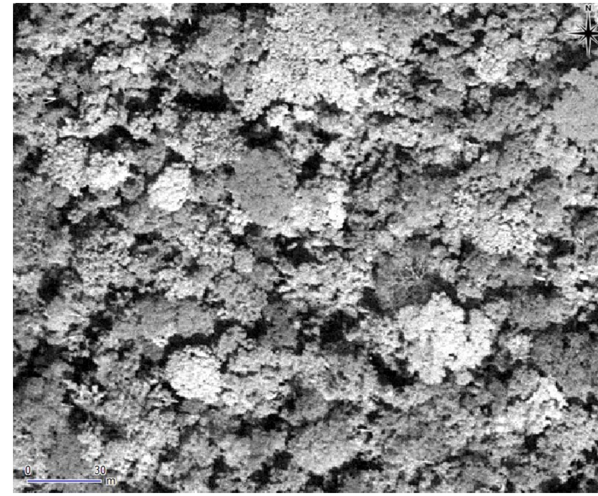


Forest in Congo Bassin,
PALSAR,
Polar: HH,
Spat.Resolution: 15 m



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