Water bodies mapping
SAR principles

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French Lebanese summer school on Remote Sensing

Beirut May 30th to June 3rd , 2022

Cloudy , rainy weather

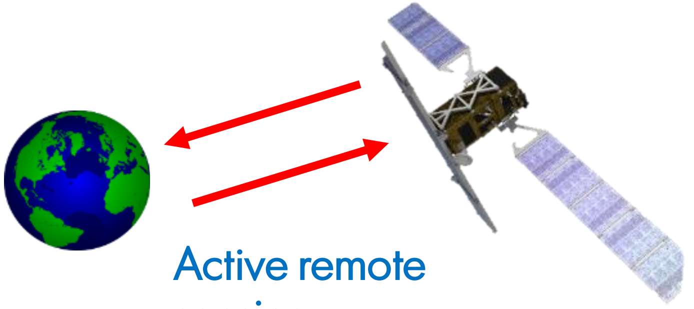
Sunny weather

⇒ Sentinel 1

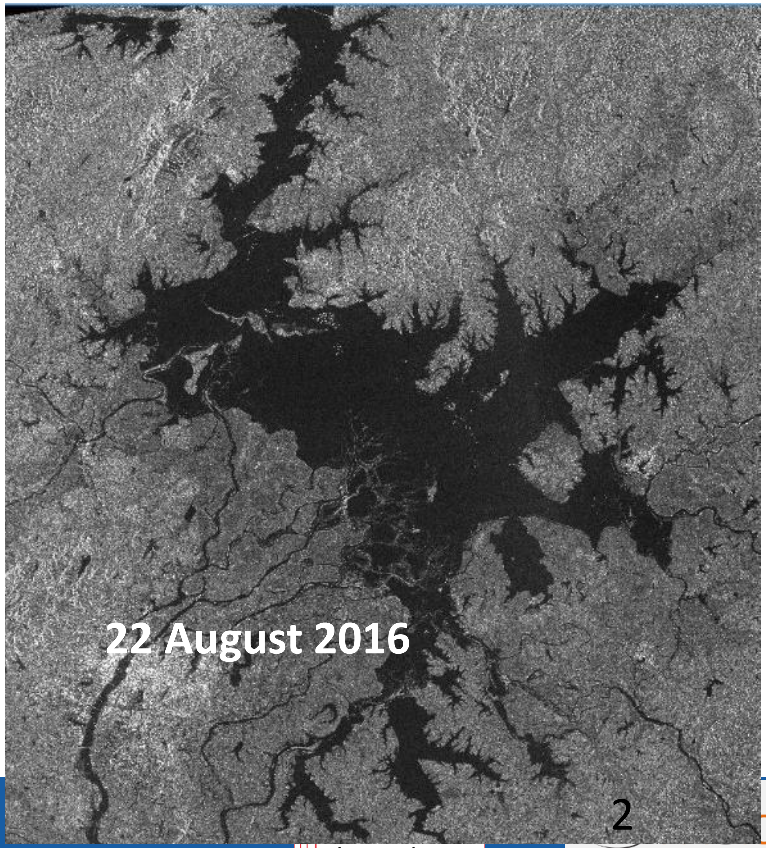
⇒ Radarsat

⇒ TSX & CSK

⇒ Gaofeng 3



Active remote sensing
SAR sensors



Wavelenghts pertinent for water surface mapping/monitoring

Mapping+ reconnaissance intelligence

Hydrology + land cover/use

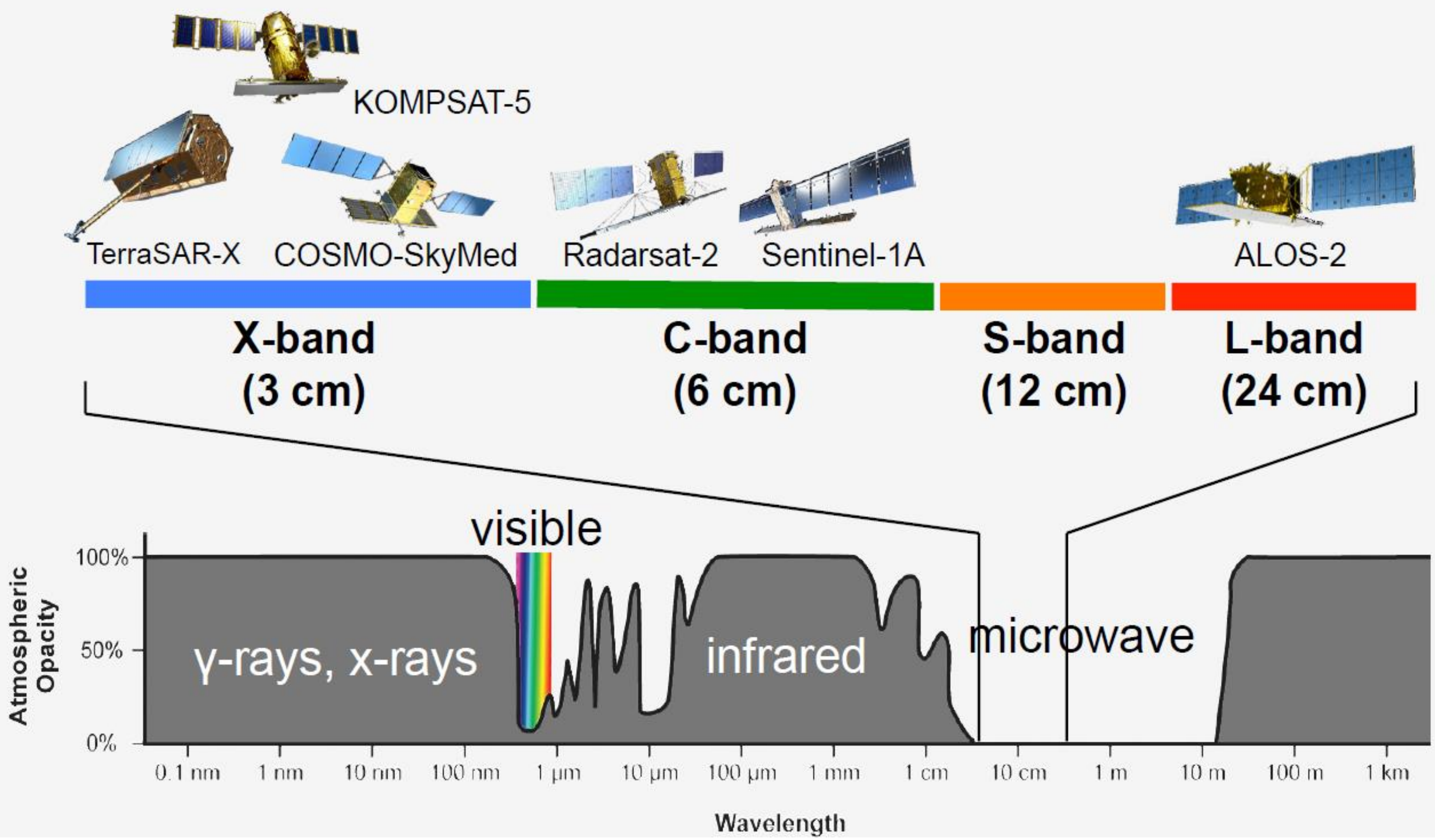
Flood under vegetation Biomas

Biomas DEM under forest

Bandes	Ka	K	Ku	X	C	S	L	P
Fréquence (GHz)	40-26.5	26.5-18	18-12.5	12.5-8	8-4	4-2	2-1	1-0.3
Longueur d'onde (cm)	0.75-1.1	1.1-1.67	1.67-2.4	2.4-3.75	3.75-7.5	7.5-15	15-30	30-100
Polarisation	HH, VV, HV, VH							

Images acquired in X, C, S, L Bands are potentially suitable for water bodies mapping

Wavelenghts pertinent for water surface mapping/monitoring



Why SAR is a performing tool for water bodies and flood mapping ?

Near all weather capability

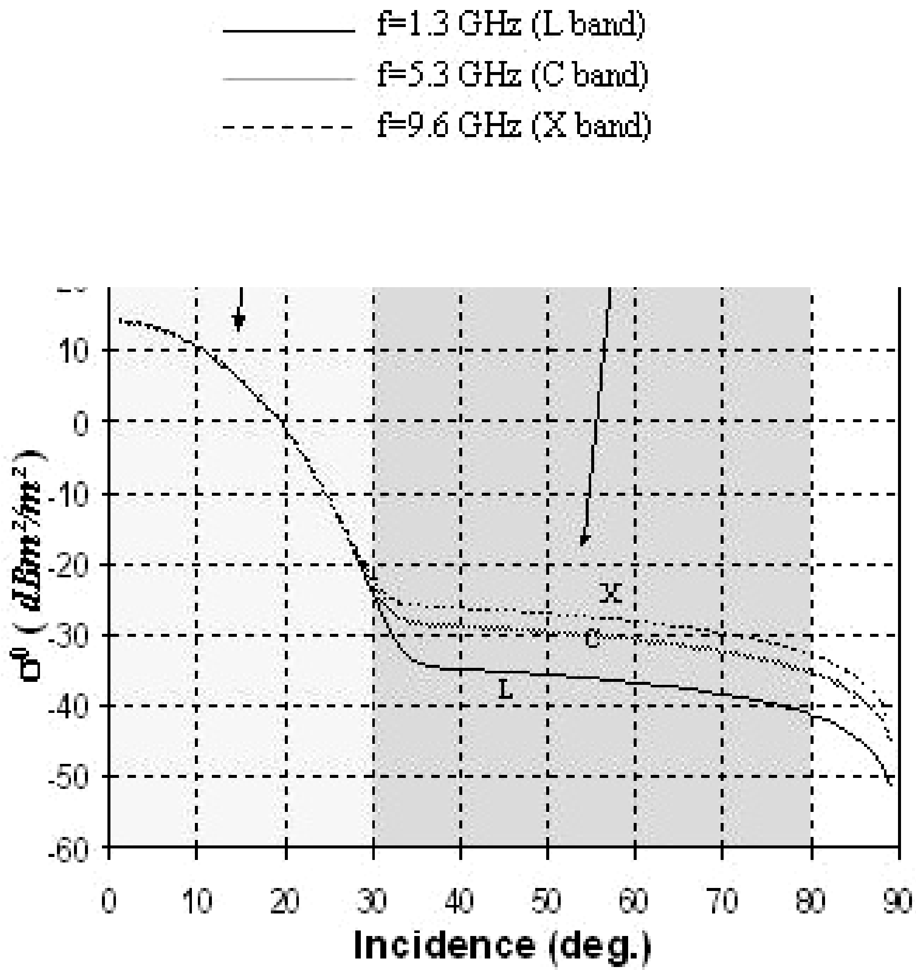
Day & night capabilities

Relative large swath

Relative good revisit

On SAR data water surfaces have low values of BS

But local weather (wind/rain) effect altering the signal



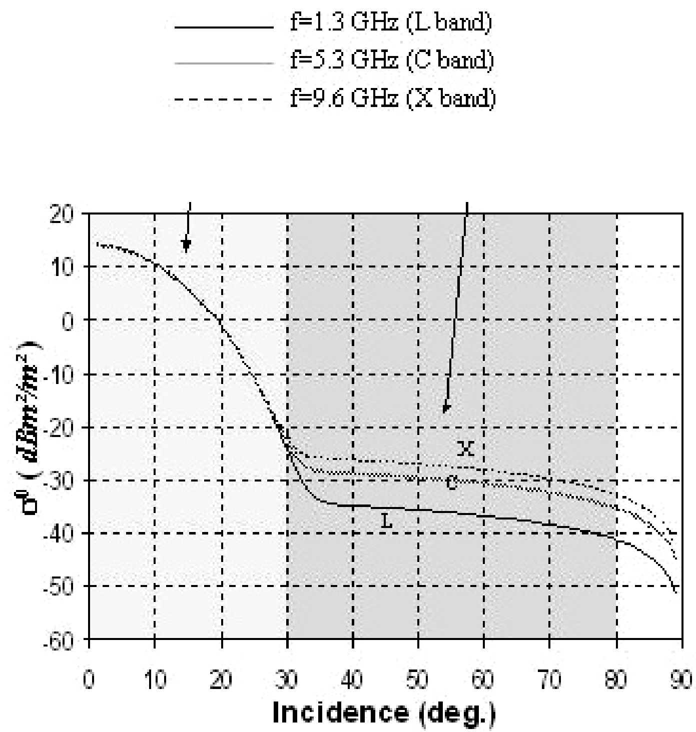
semi-empirical function of backscatter coefficient σ^0 as a function of incidence (for a mean sea), for 3 different radar bands

From Sarti, 2004

Why SAR is a performing tool for water bodies and flood mapping ?

Therefore sensibility more or less important depending of the wavelength to:

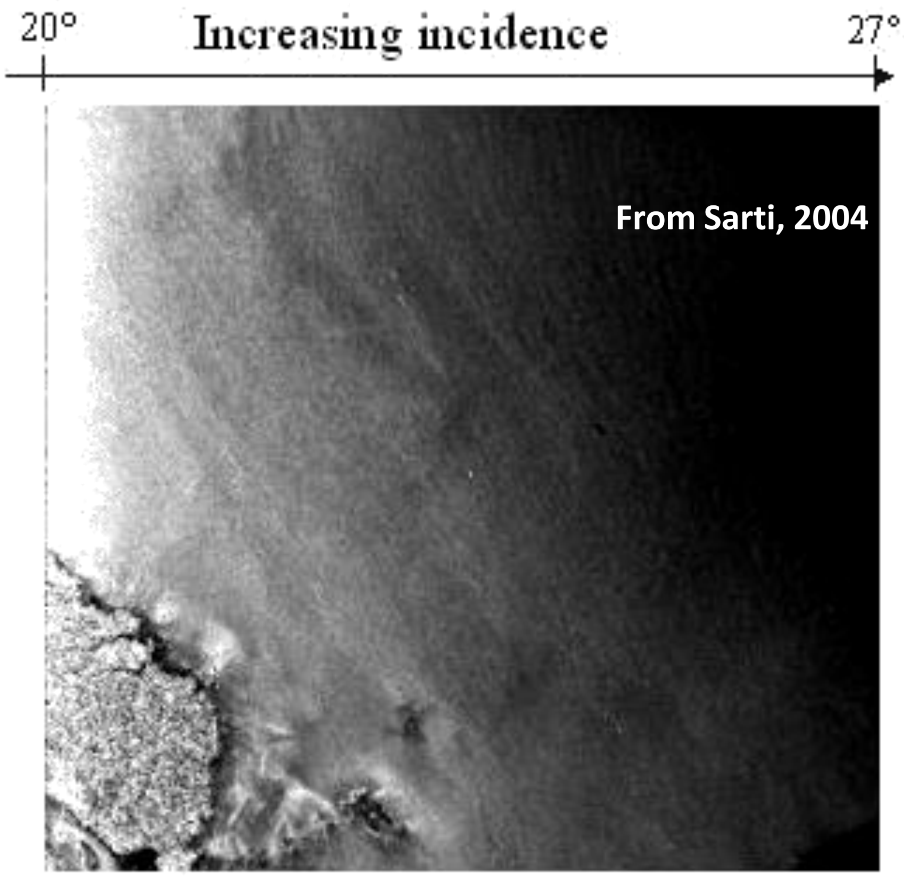
- **Acquisition parameters (incidence angle**
- **Wind locally can alter the surface roughness**
- **Rain locally can alter the signal path**



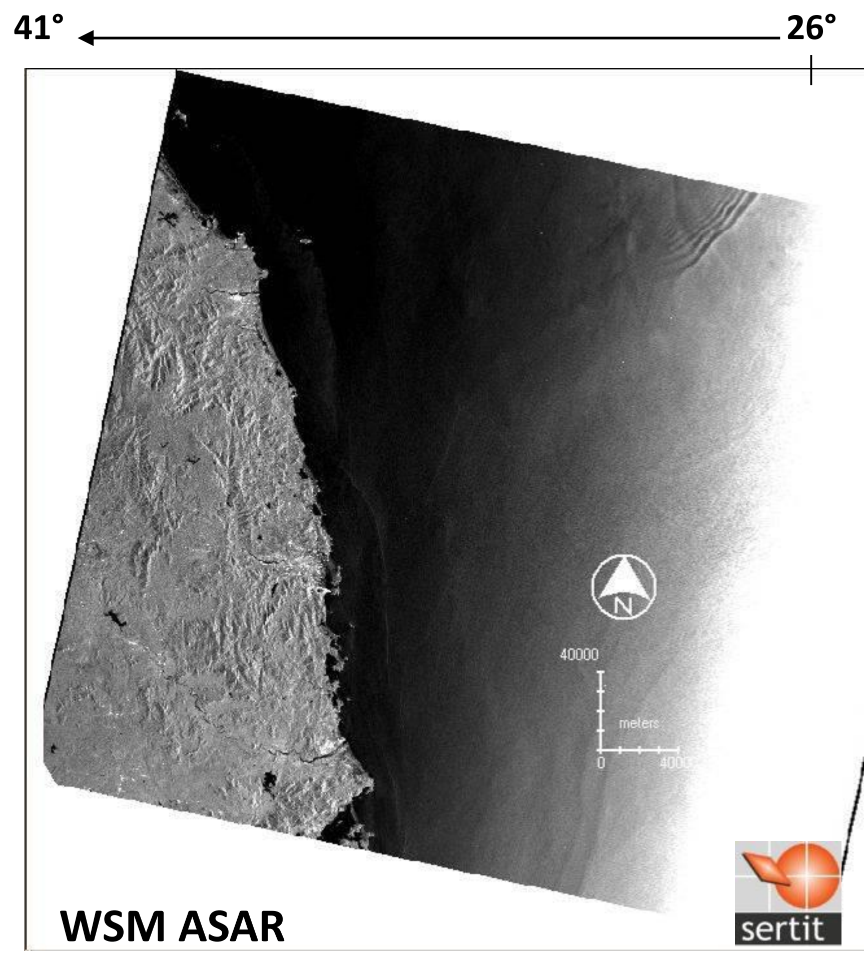
semi-empirical function of backscatter coefficient σ^0
as a function of incidence (for a mean sea), for 3 different radar bands

From Sarti, 2004

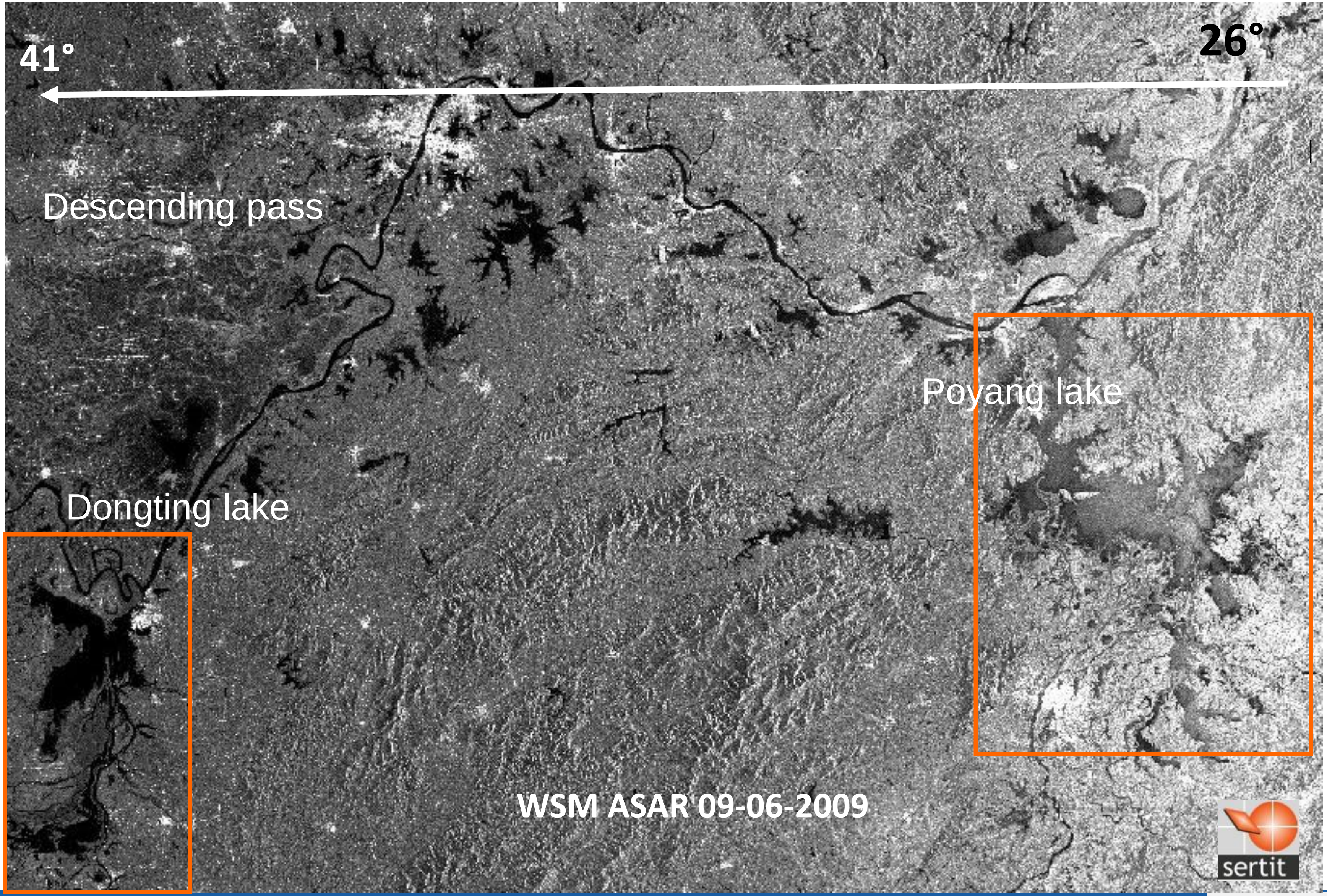
Water backscattering in function of incidence angle



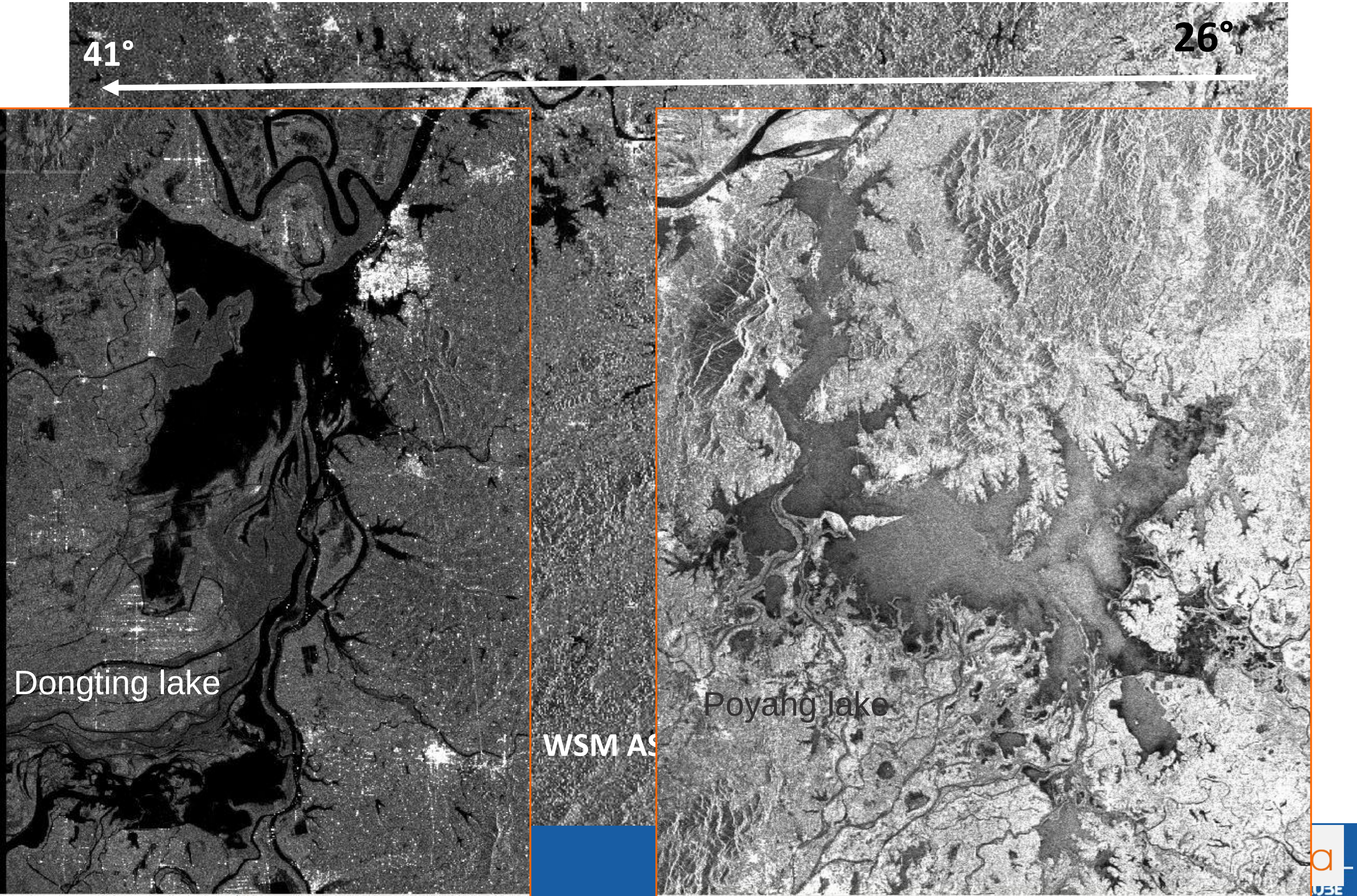
Incidence effect observed on a RADARSAT S1 (20°-27°)



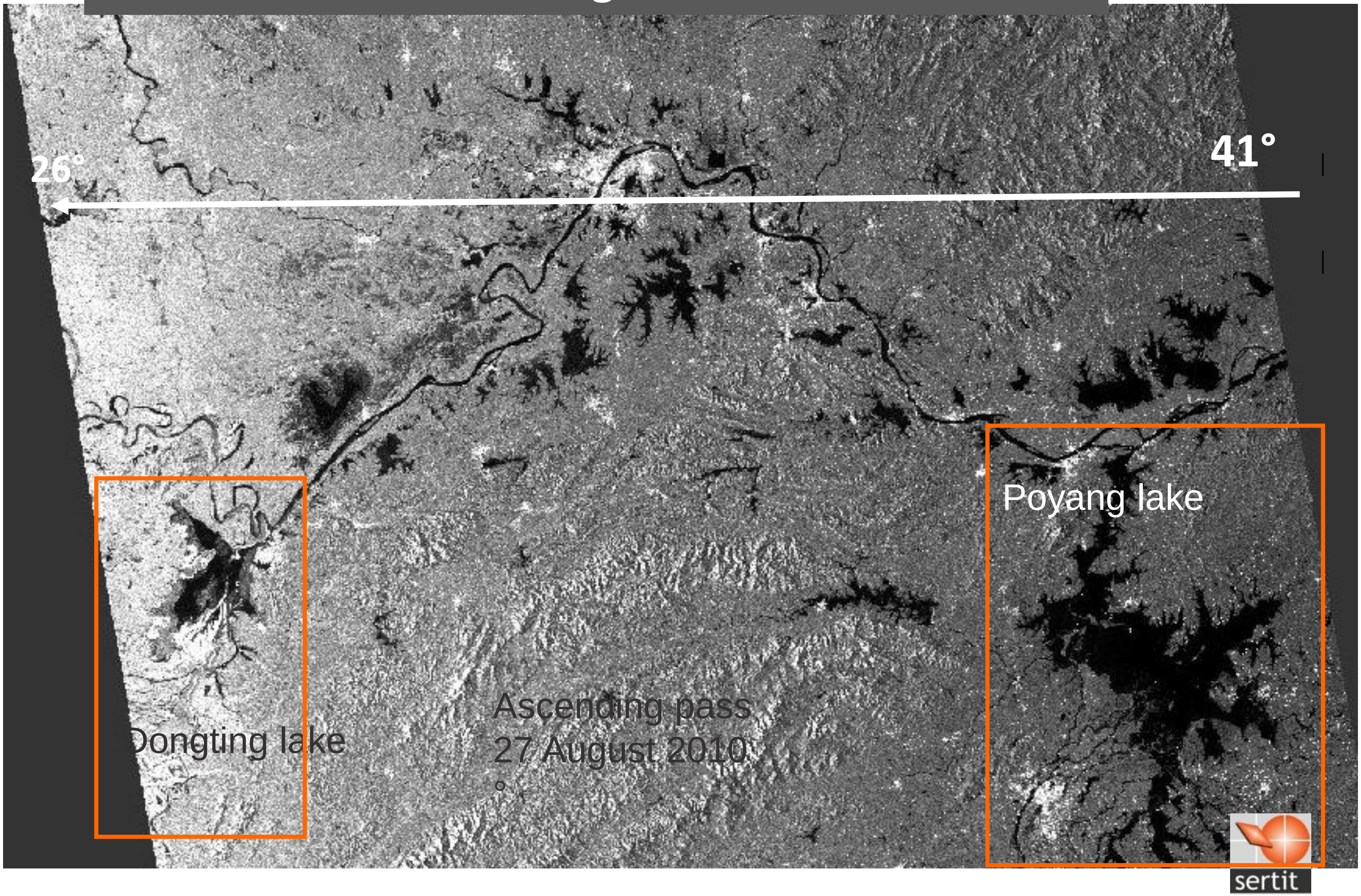
Water backscattering in function of incidence angle



Water backscattering in function of incidence angle

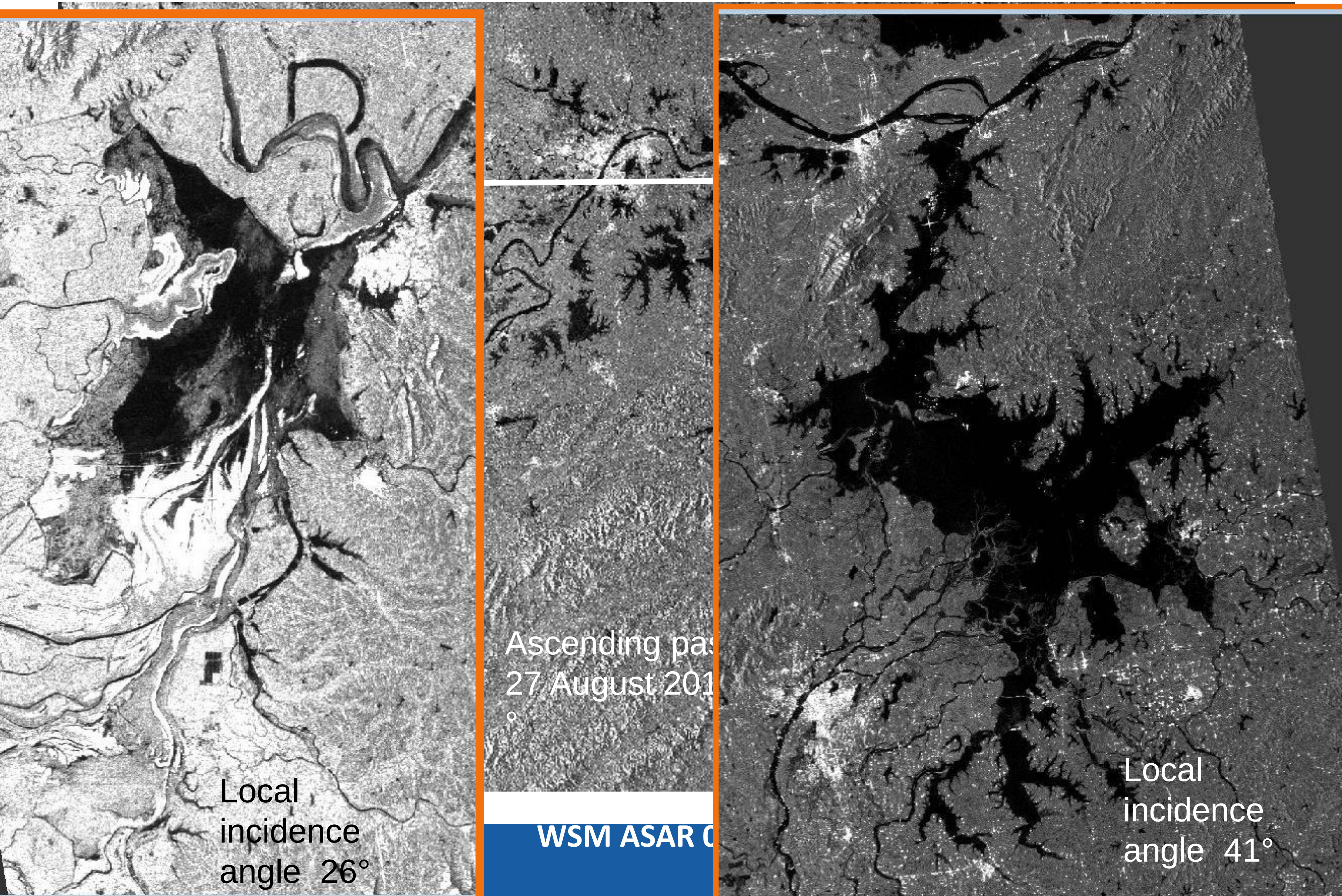


Water backscattering in function of incidence angle

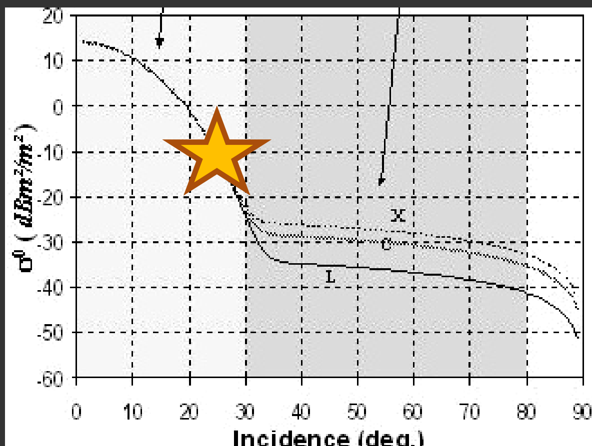


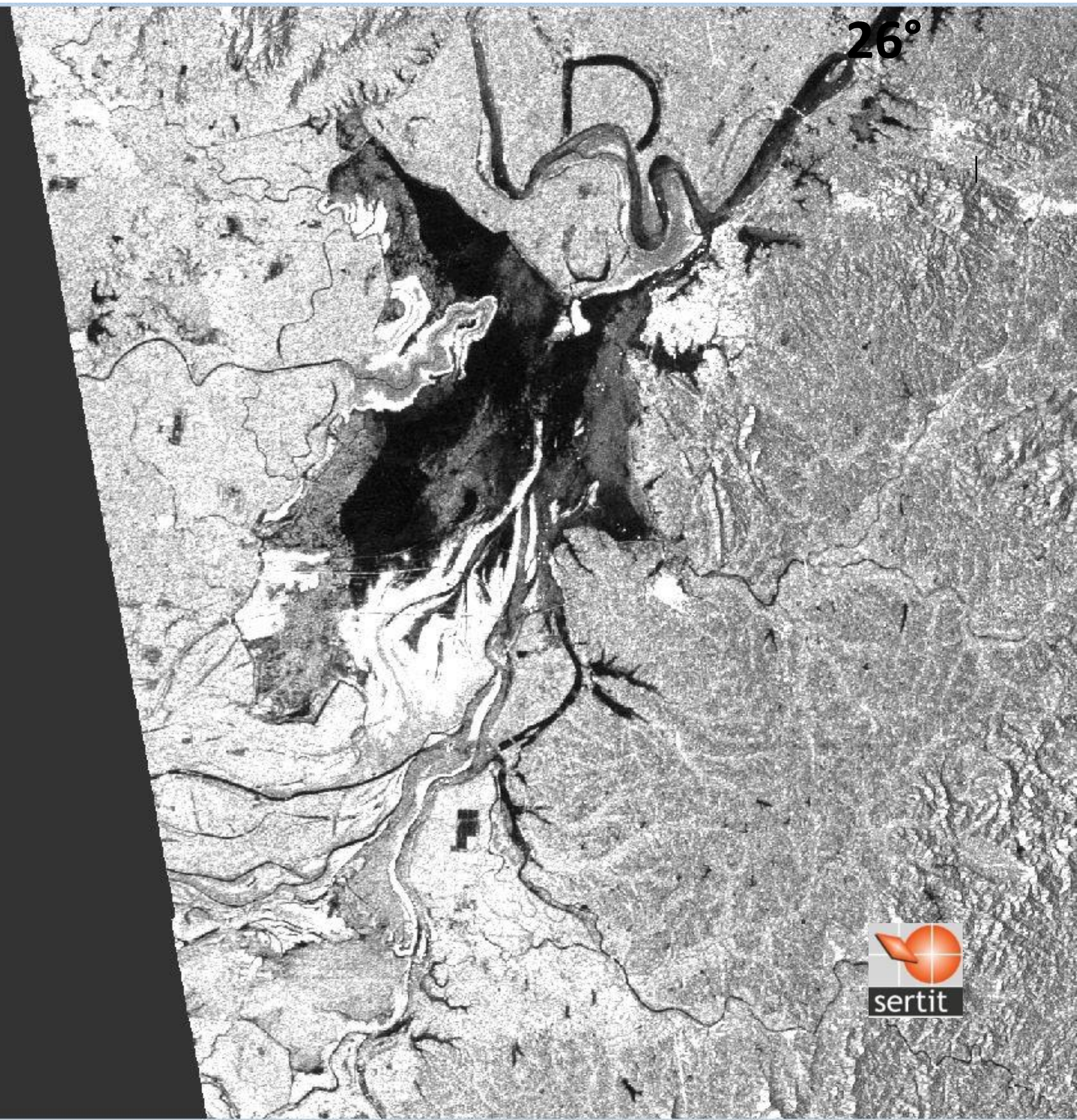
WSM ASAR 09-06-2009

Water backscattering in function of incidence angle



Water backscattering in function of incidence angle

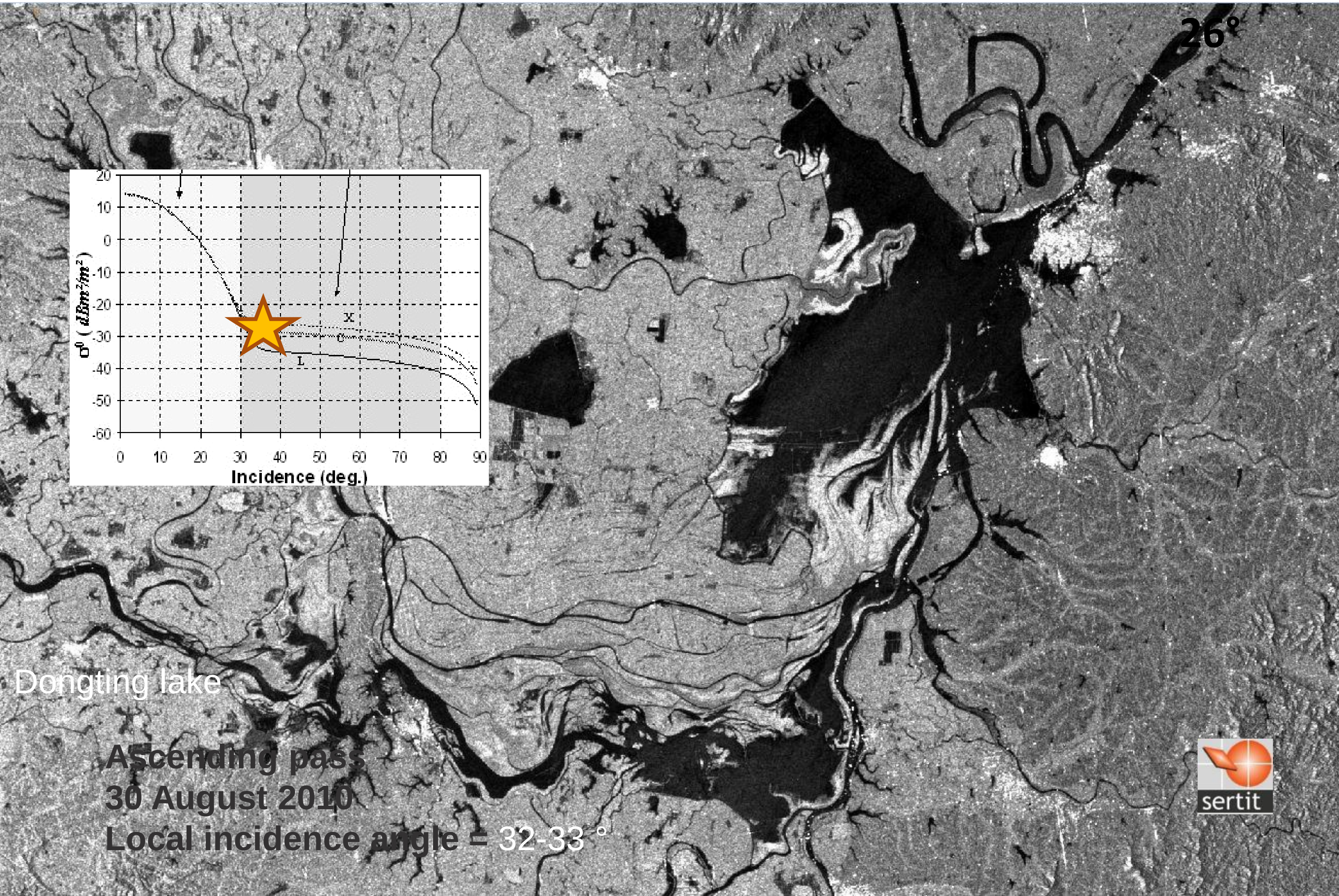




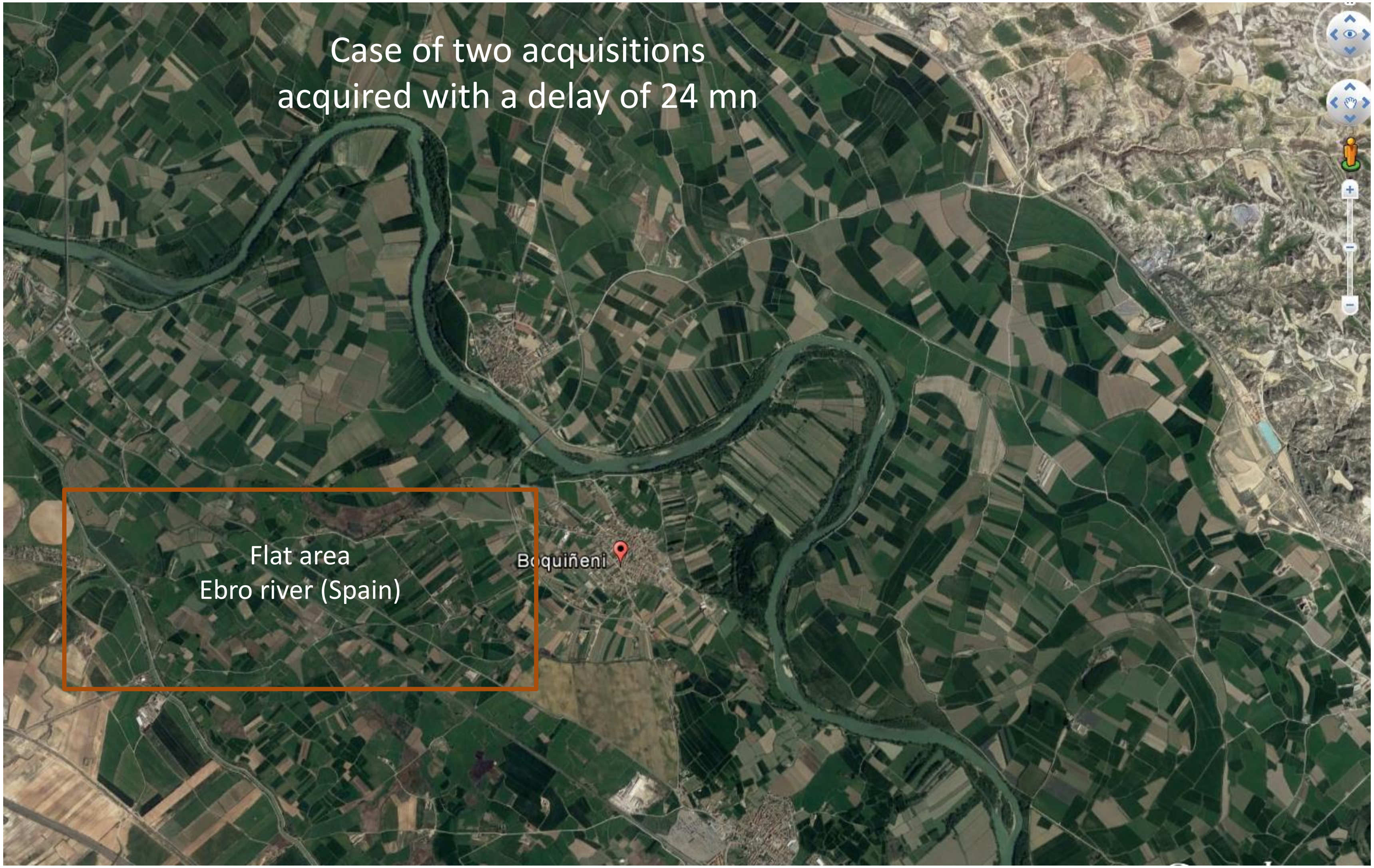
Dongting lake

Ascending pass
27 August 2010
Local incidence angle = 26
Plus wind and/or flooded vegetation effect? °

Water backscattering in function of incidence angle



Water backscattering in function of incidence angle



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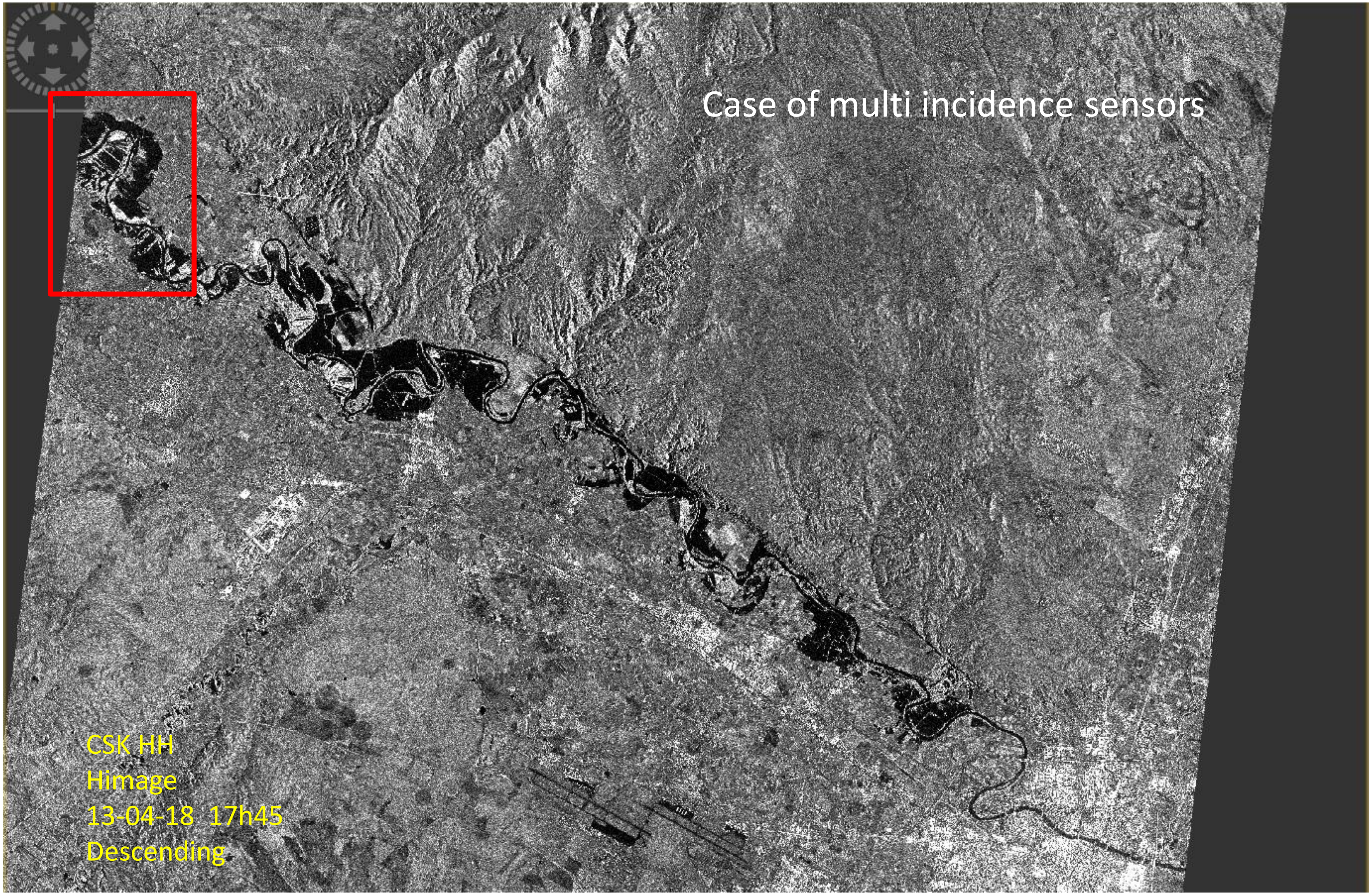

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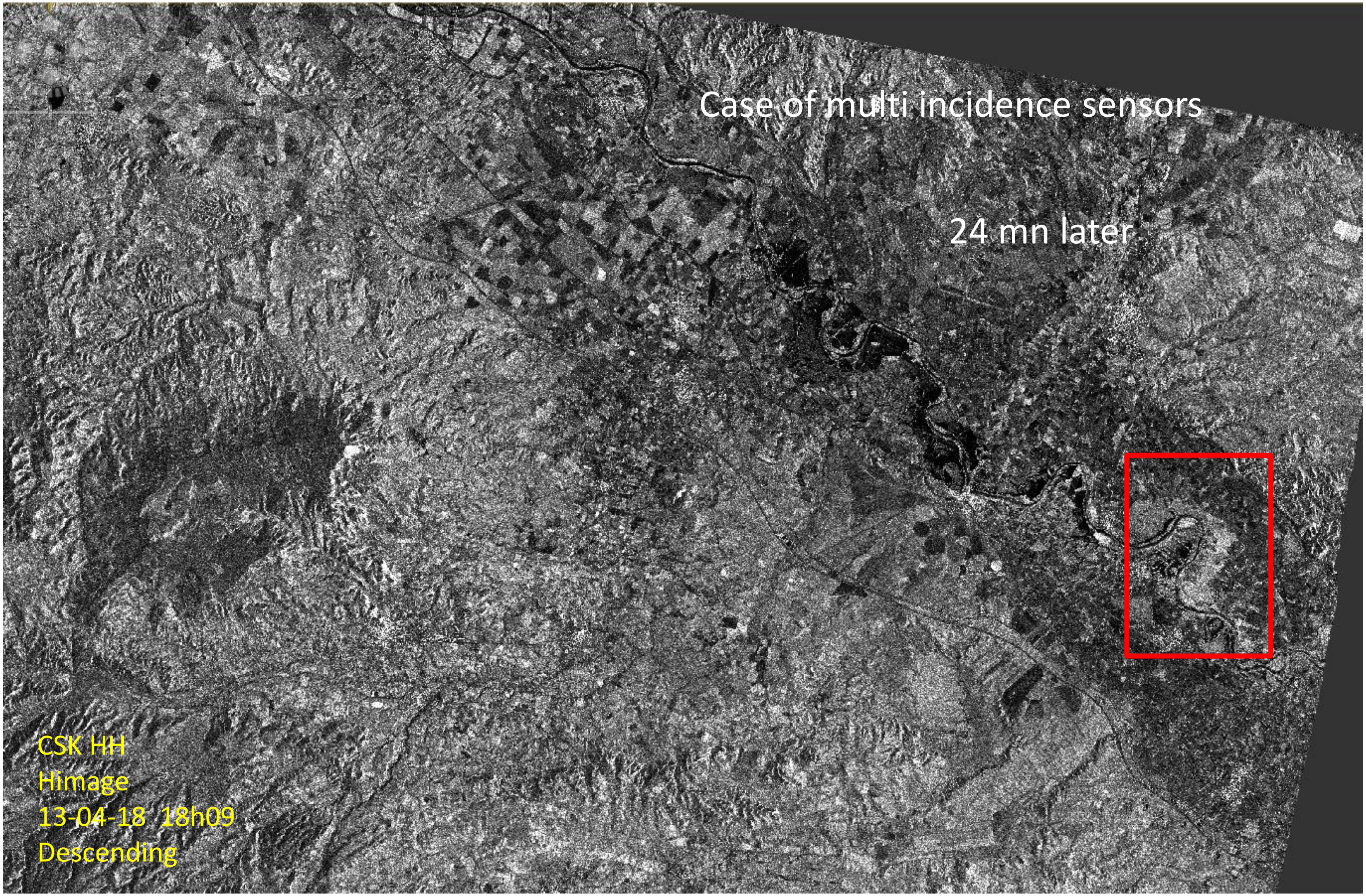

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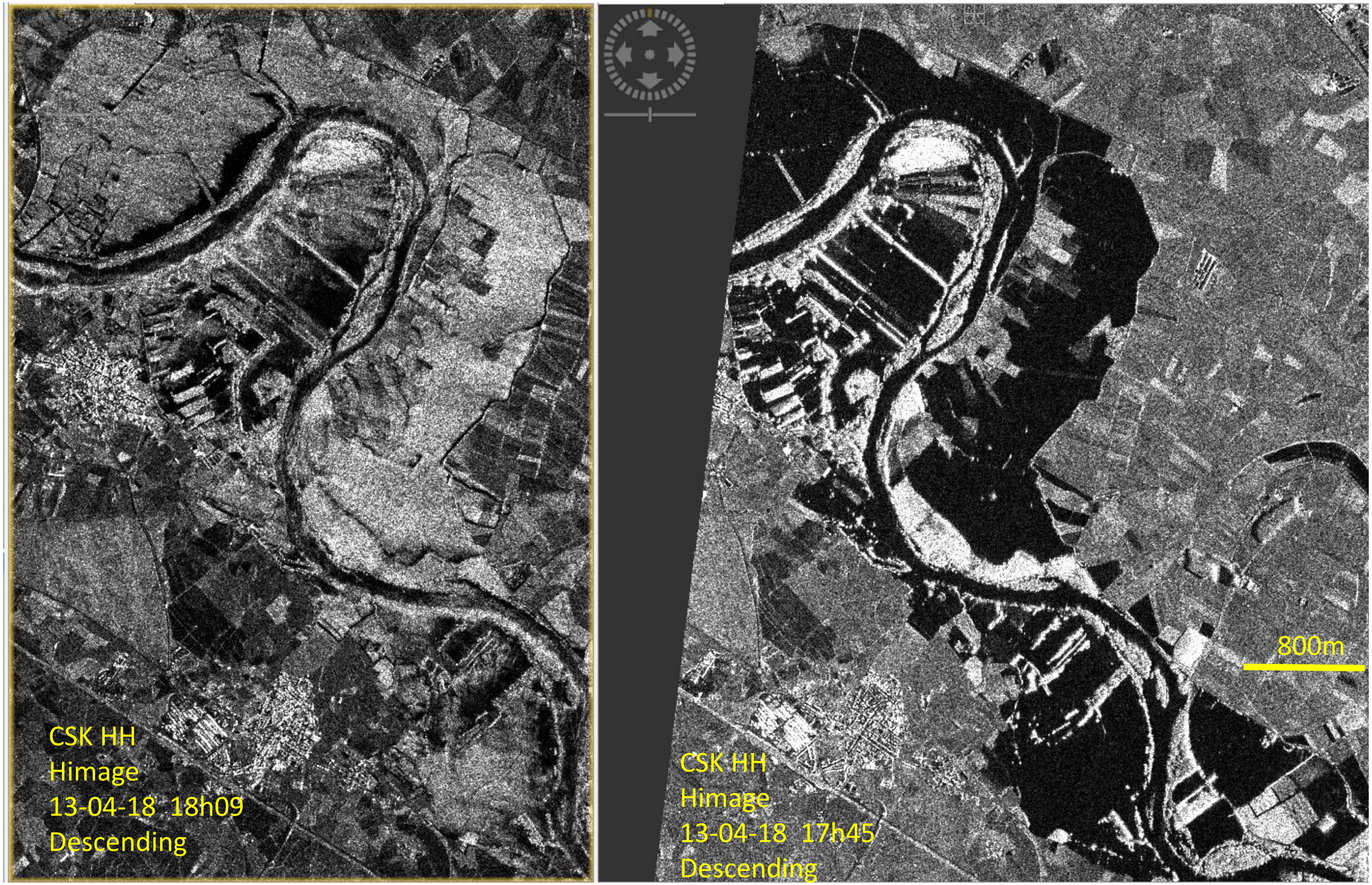
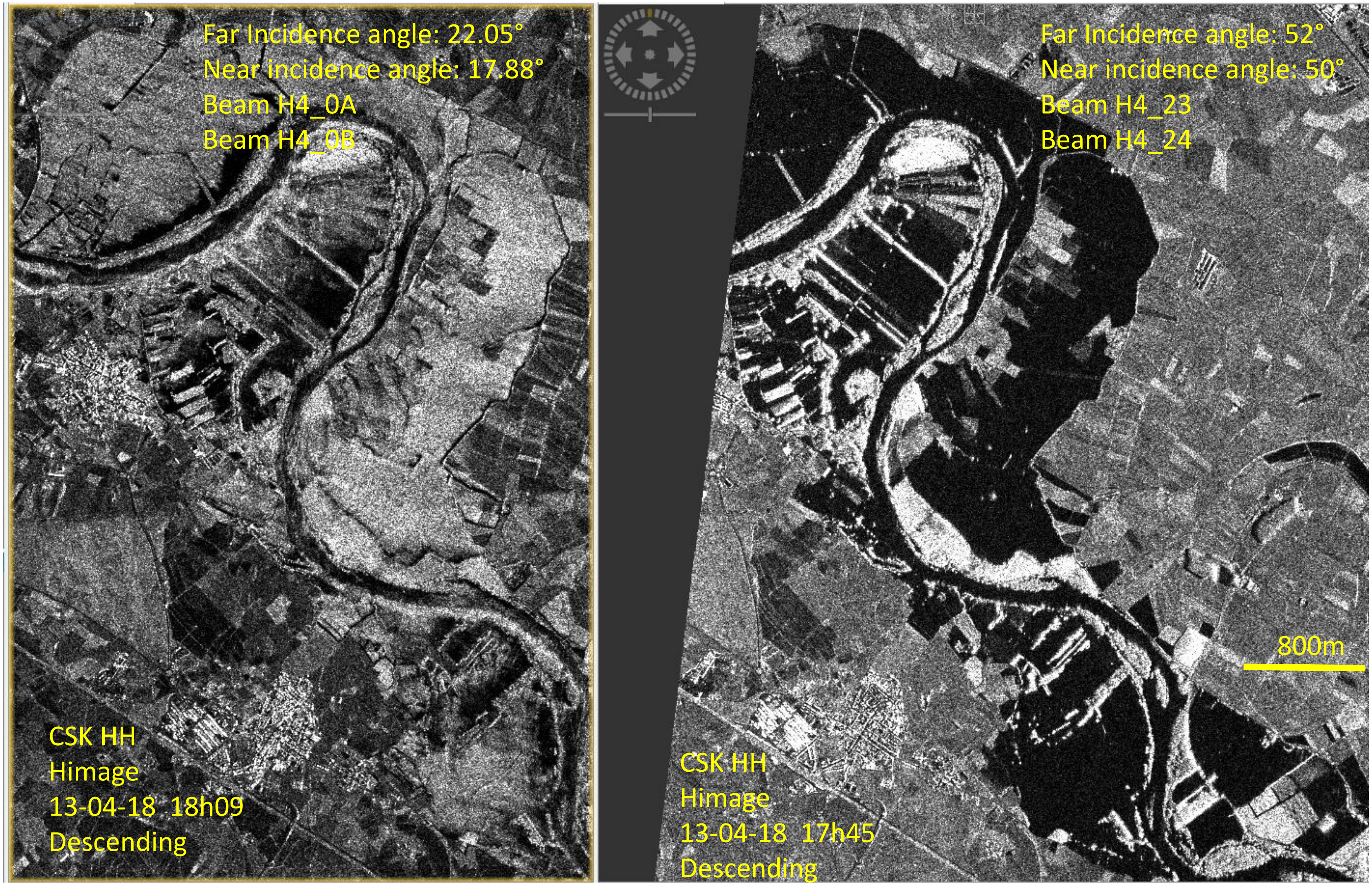


Water backscattering in function of incidence angle



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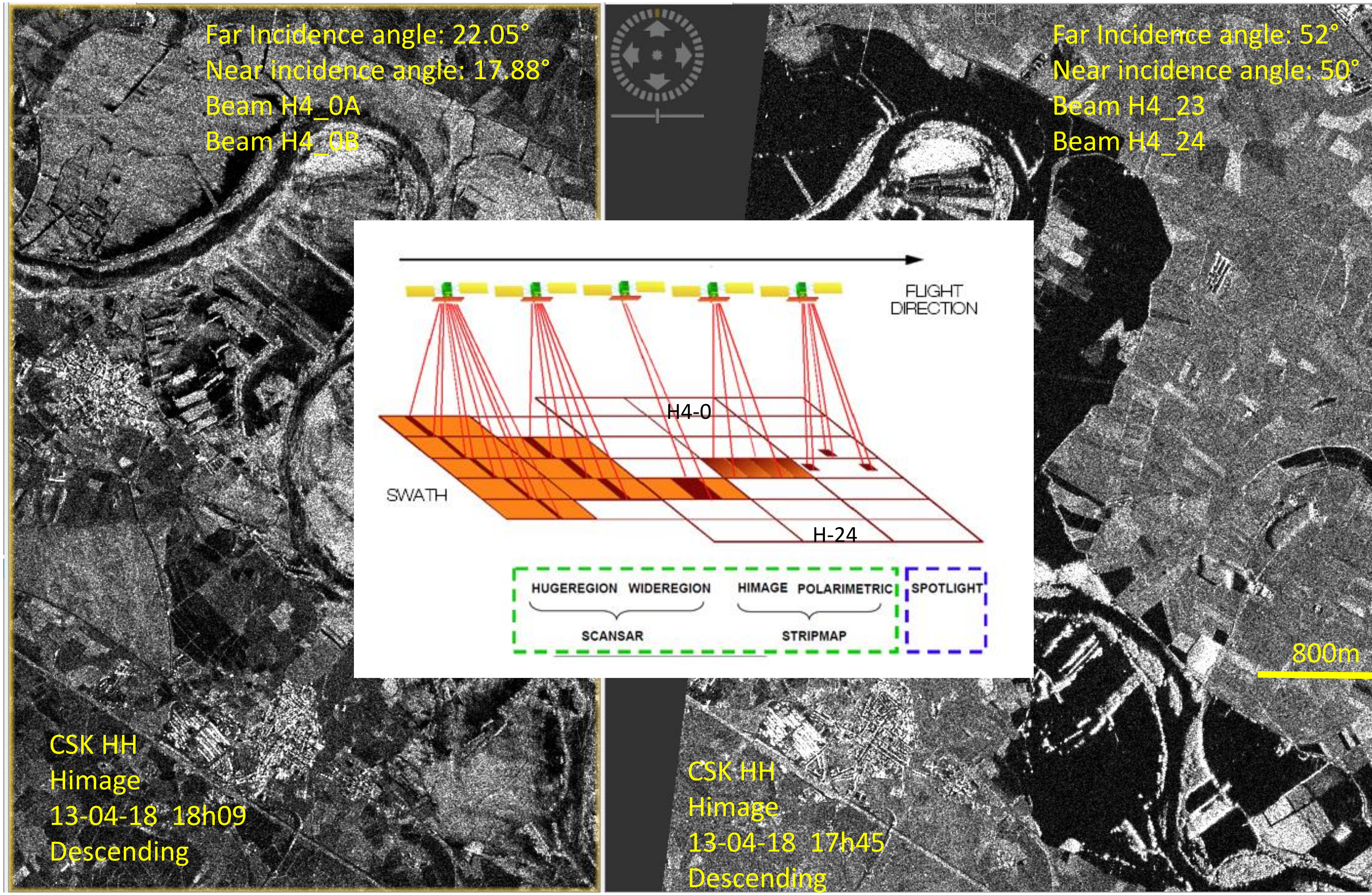
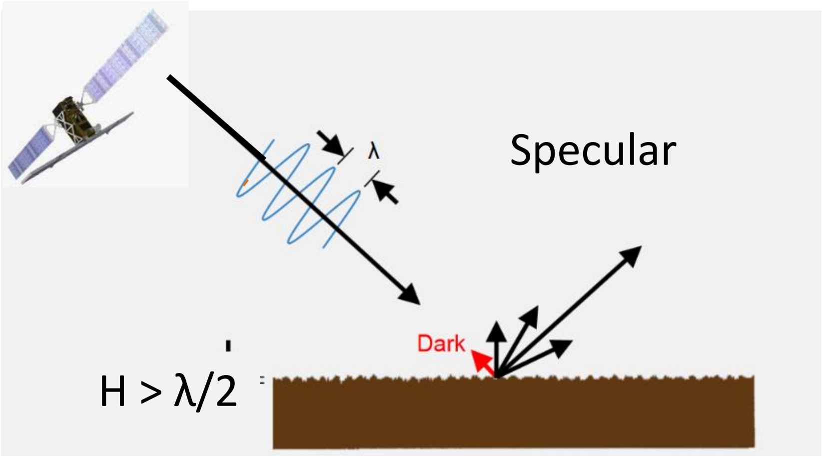


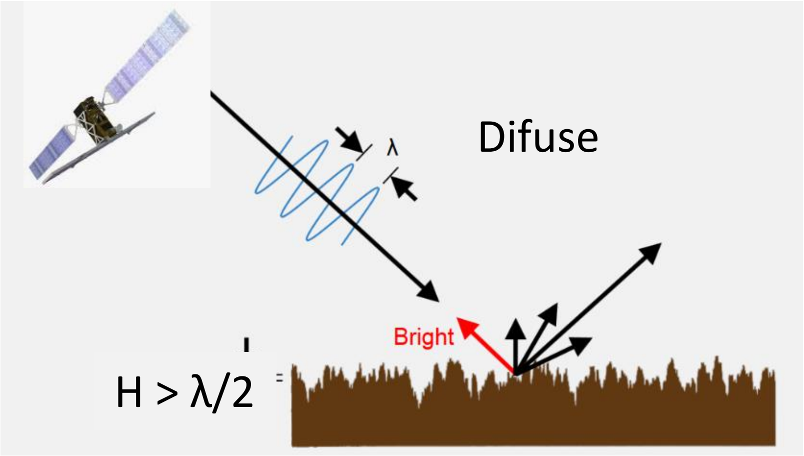
Water backscattering in function of surface roughness



λ varies
from
K 1cm
X 3cm
C 5.6cm
S 10cm
L 23cm
P 70cm

HJ-C
ALOS PALSAR

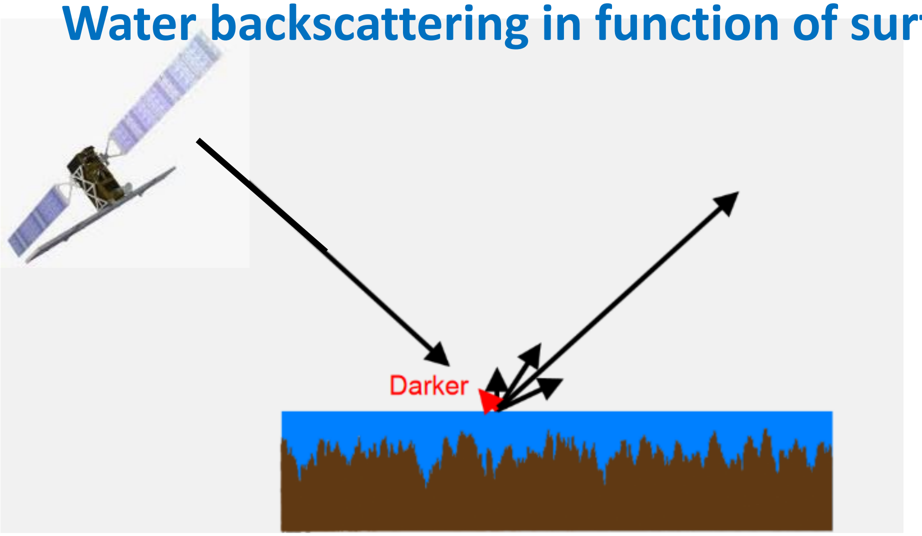
Case for bare soils
Rayleigh criterions



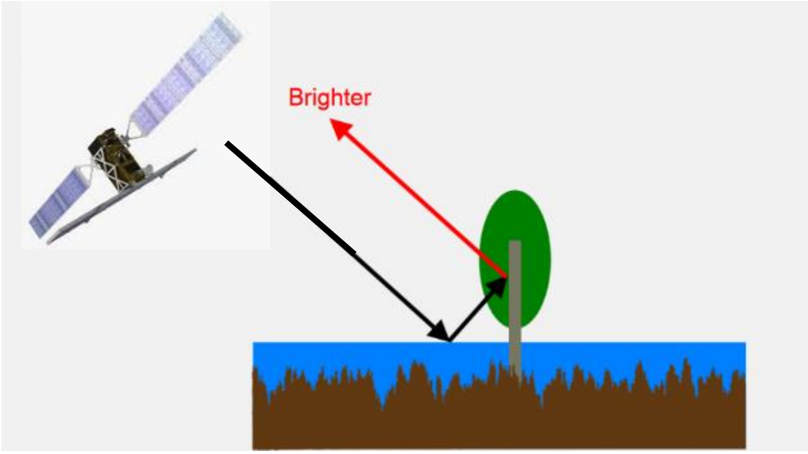
VH being less sensitive than VV

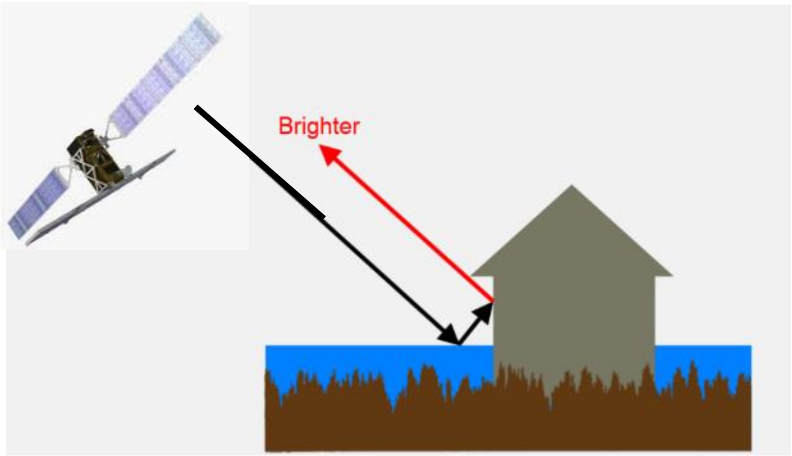
Adapted from Sang-Ho Yun, NASA JPL

Water backscattering in function of surface roughness



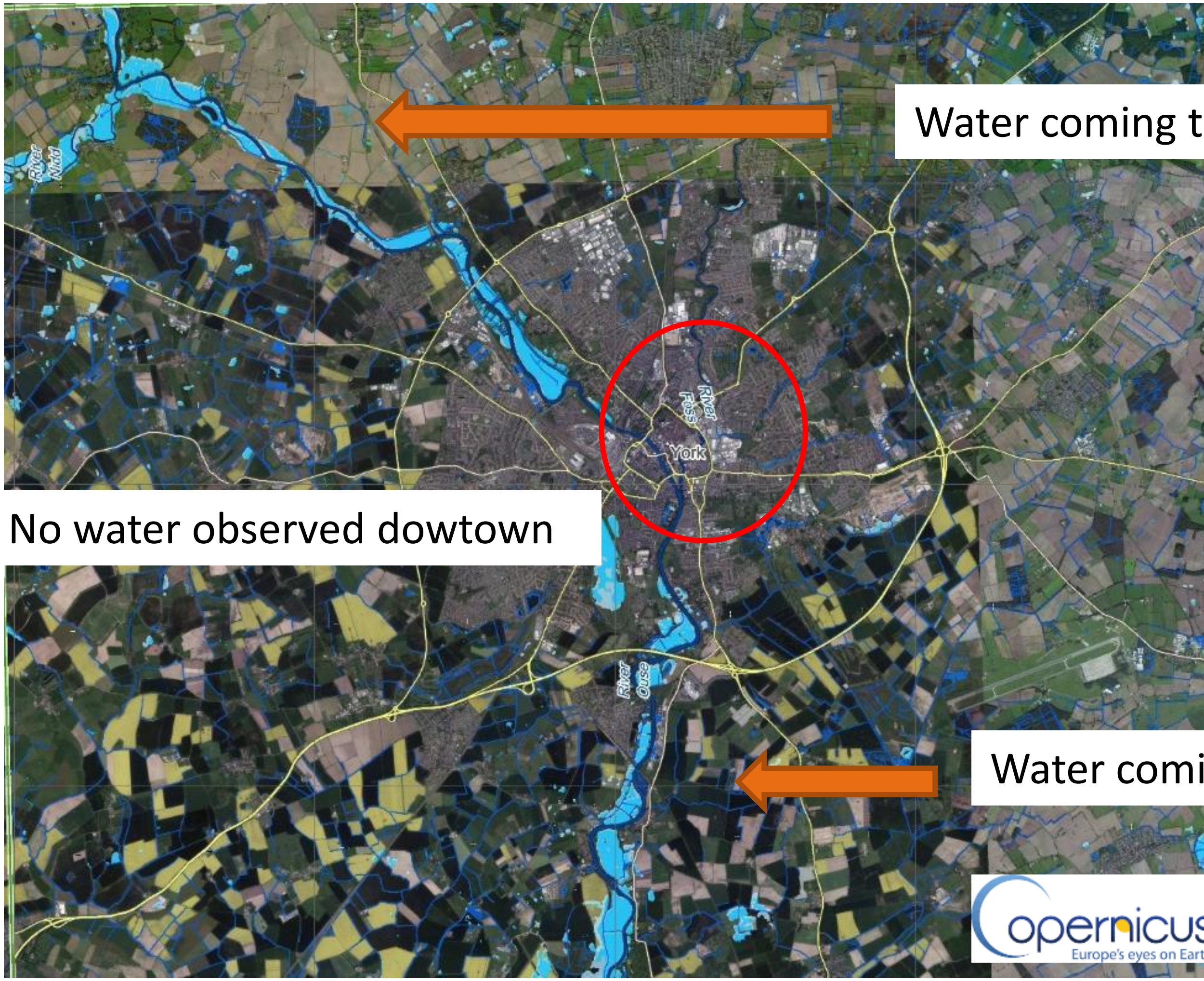
Case of water surface in various environments





Adapted from Sang-Ho Yun, NASA JPL

SAR and Urban area: December 2016 Flood in York, England, based on Radarsat 2 imagery:



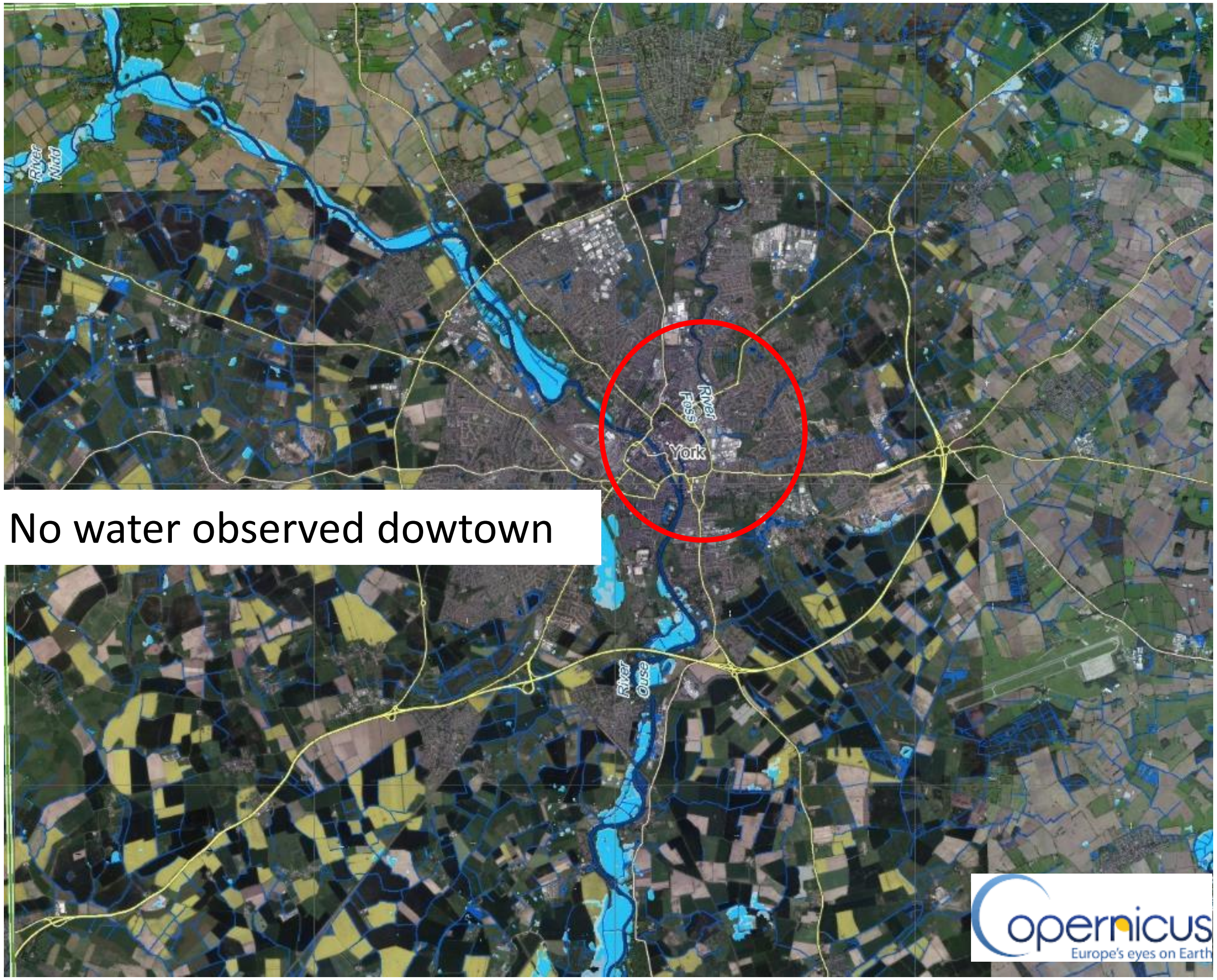
Water coming towards the city

No water observed dowtown

Water coming out the city

Illustration of SAR limitation in Urban area

SAR and Urban area: December 2016 Flood in York, England, based on Radarsat 2 imagery:

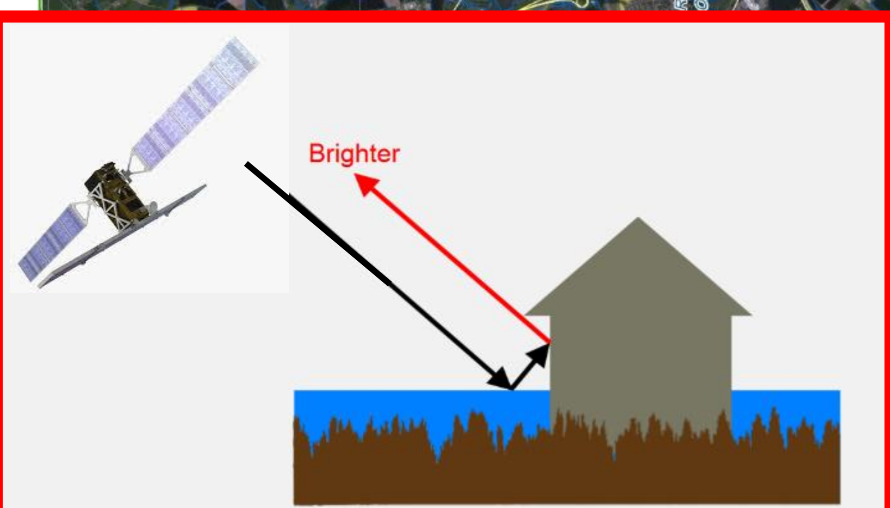


No water observed dowtown

English Prime Minister visiting the affected York downtown

SAR and Urban area: December 2016 Flood in York, England, based on Radarsat 2 imagery:

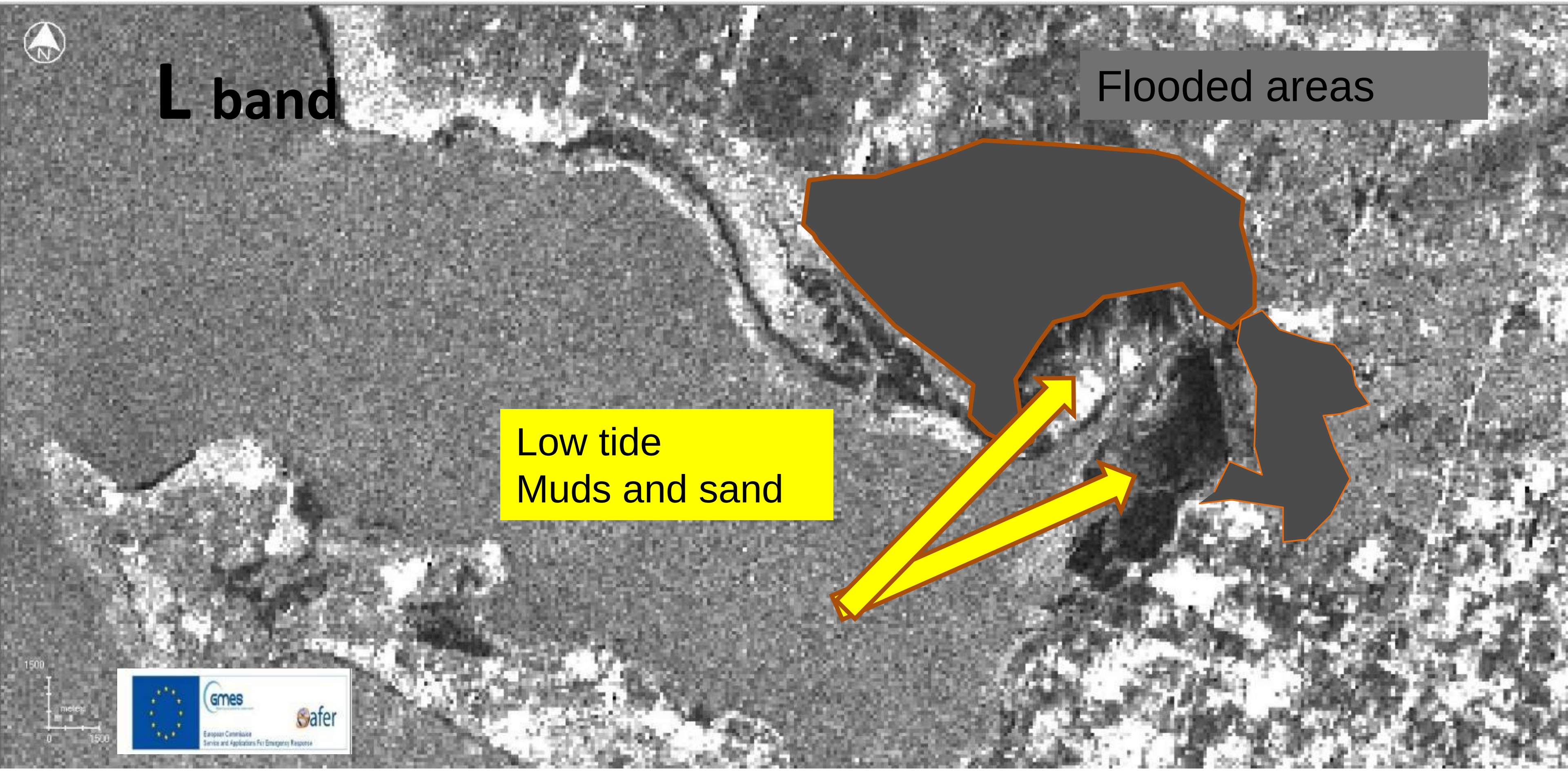
No water observed dowtown



Strong SAR signal in urban environment no capability for water recognition

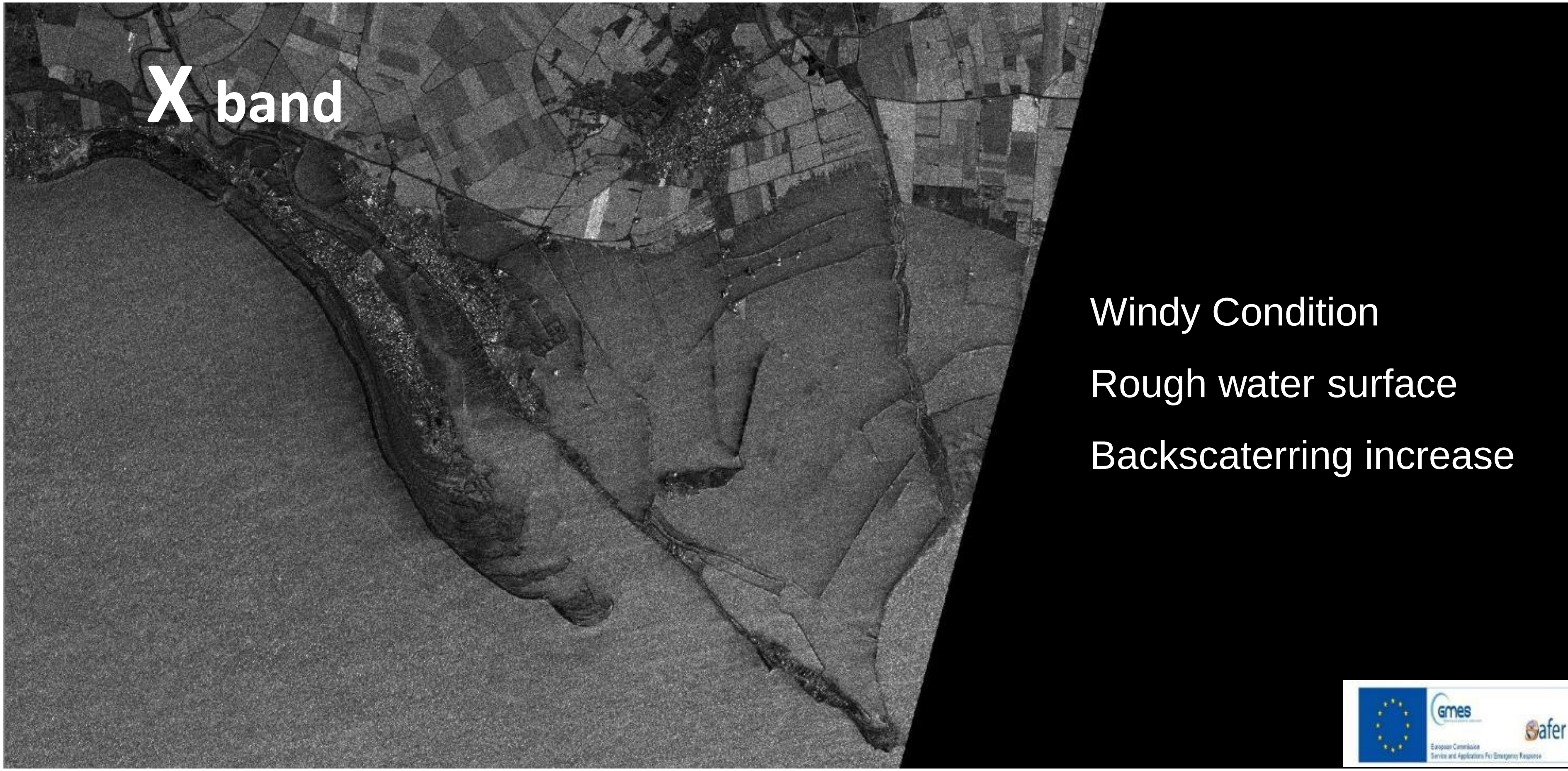
PALSAR bande L HH,
ScanSAr mode,
10h56 the 2010 03 01

Water backscattering in function of surface roughness



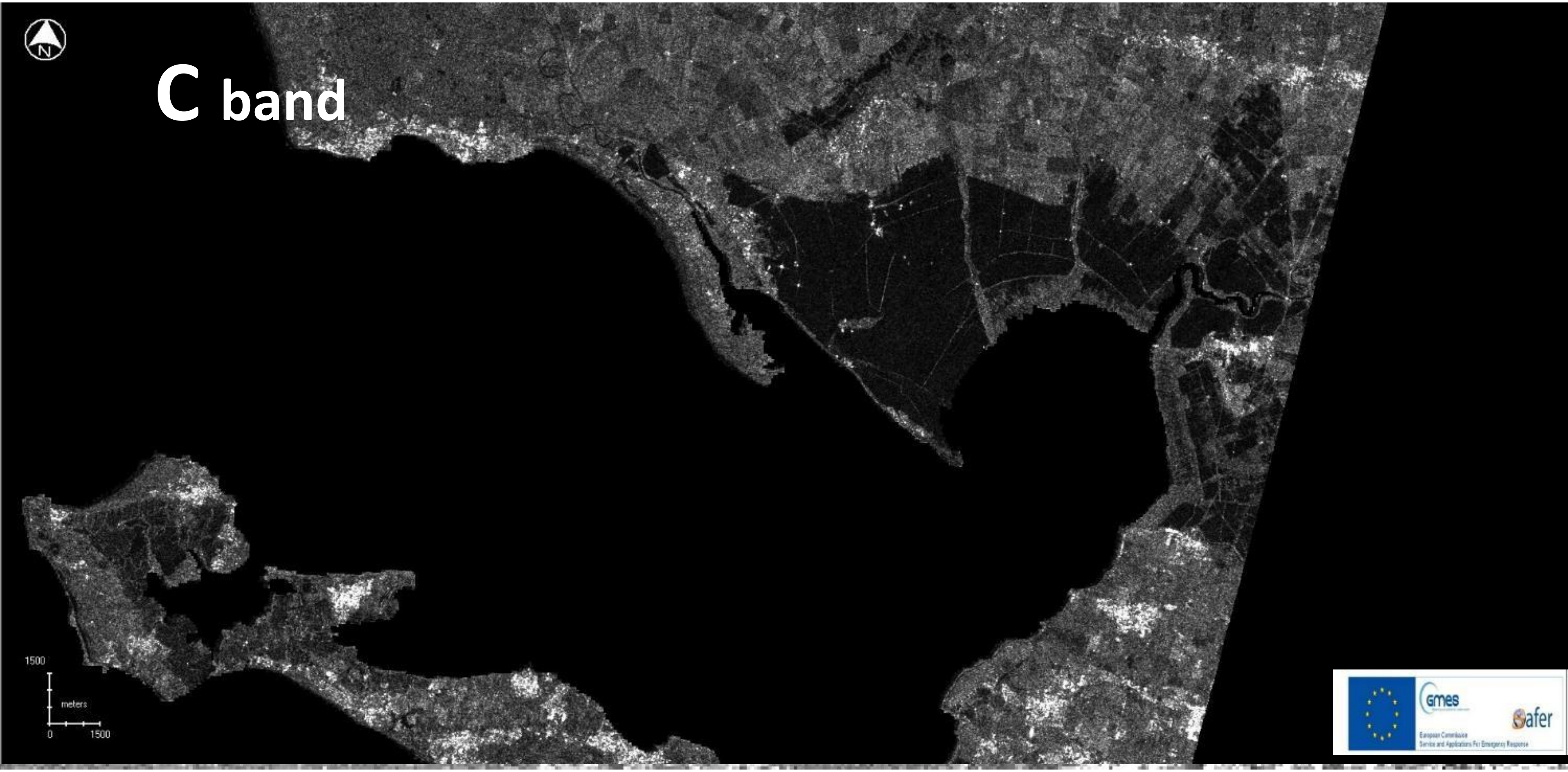
Water backscattering in function of surface roughness

TerraSAR X: 2010 03 03



ASAR ENVISAT
APP HH HV,
10h18 the 2010 03 04

Water backscattering in function of surface roughness

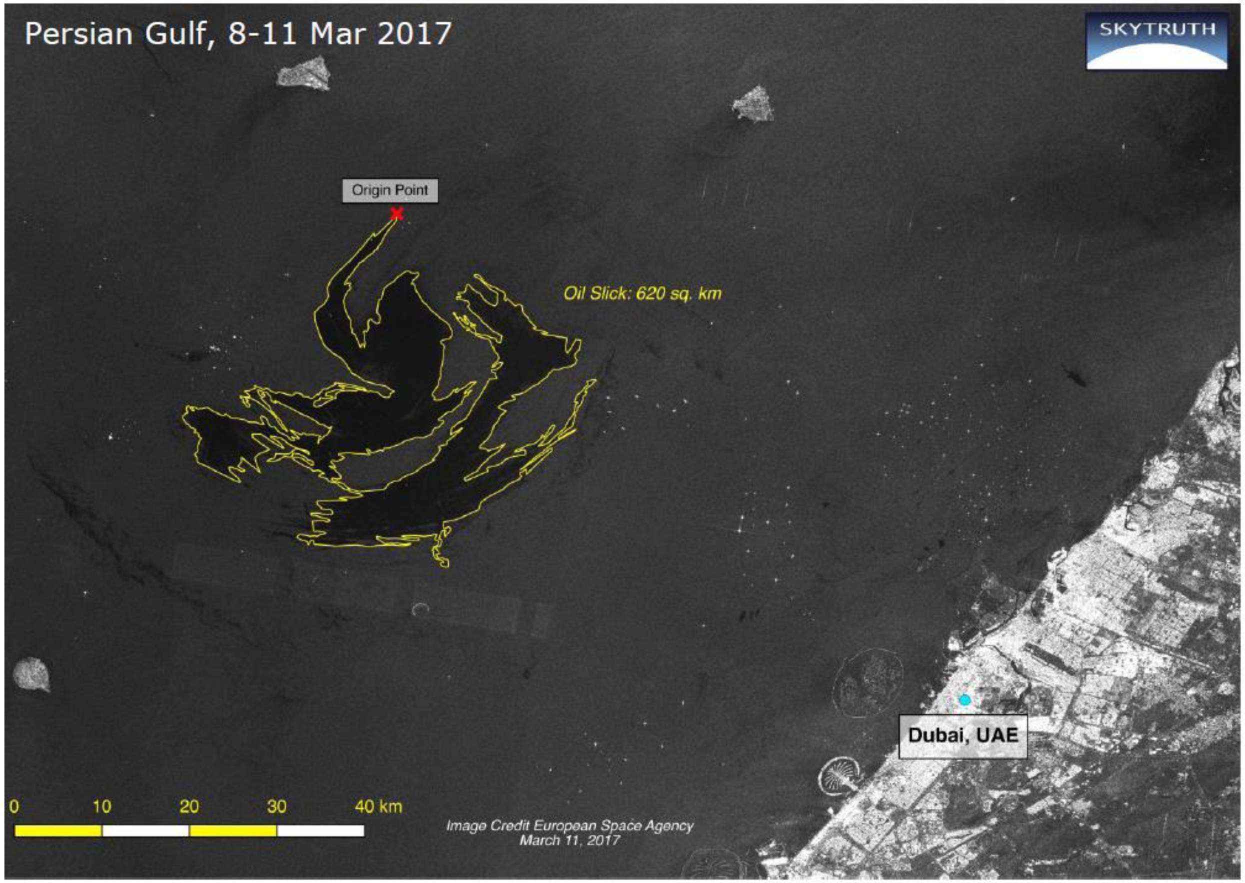


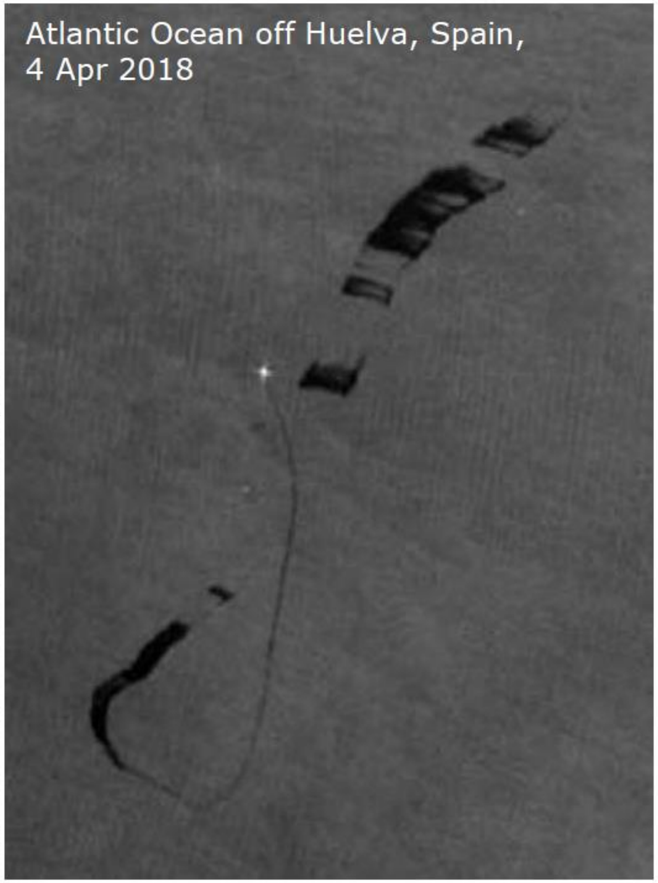
TerraSAR X: 2010 03 06

Water backscattering in function of surface roughness

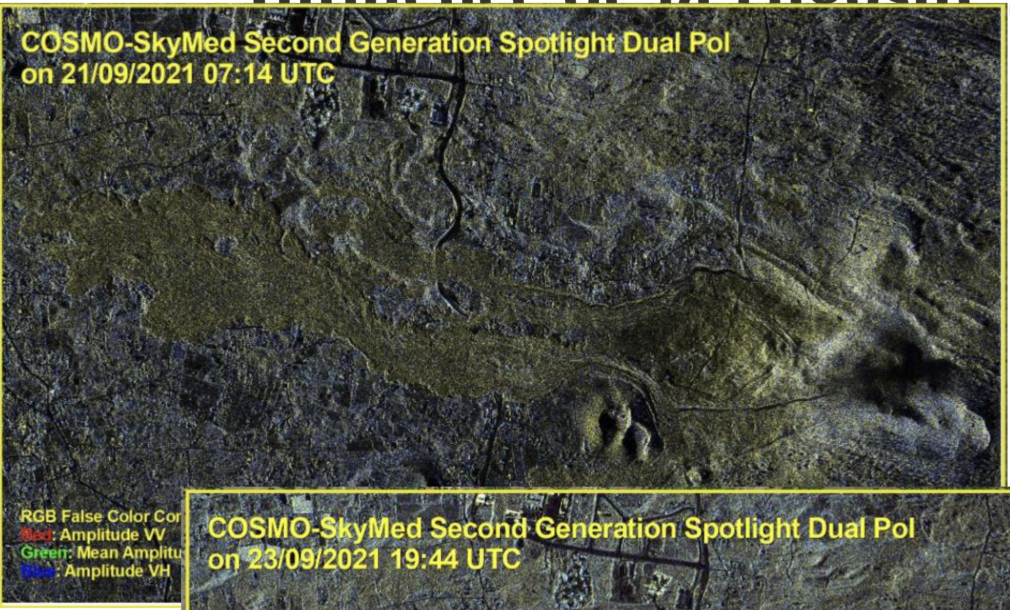
Influence de la rugosité sur le signal retrodiffusé

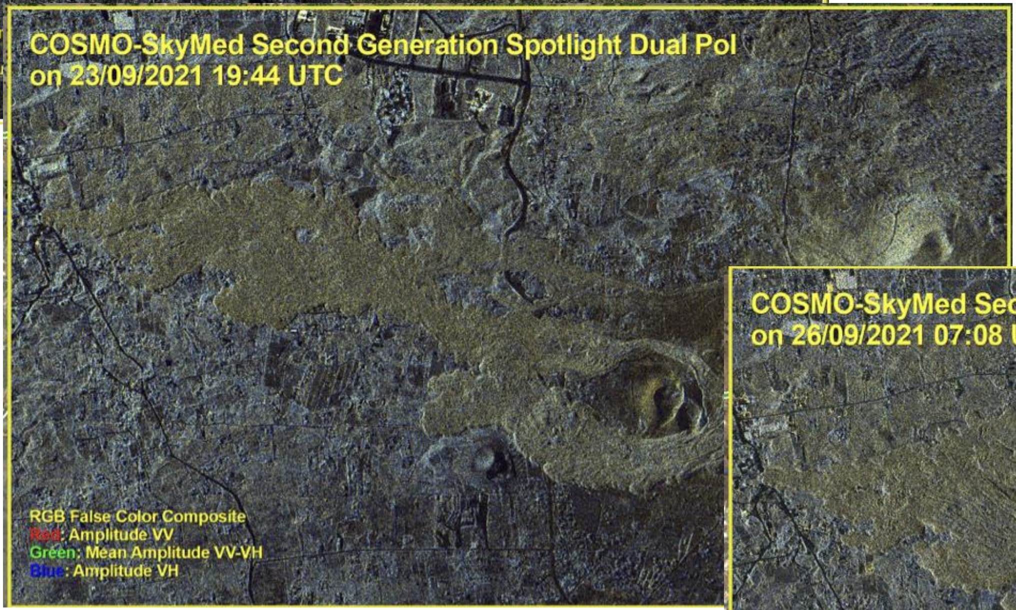
Oil Spill Detection and Monitoring

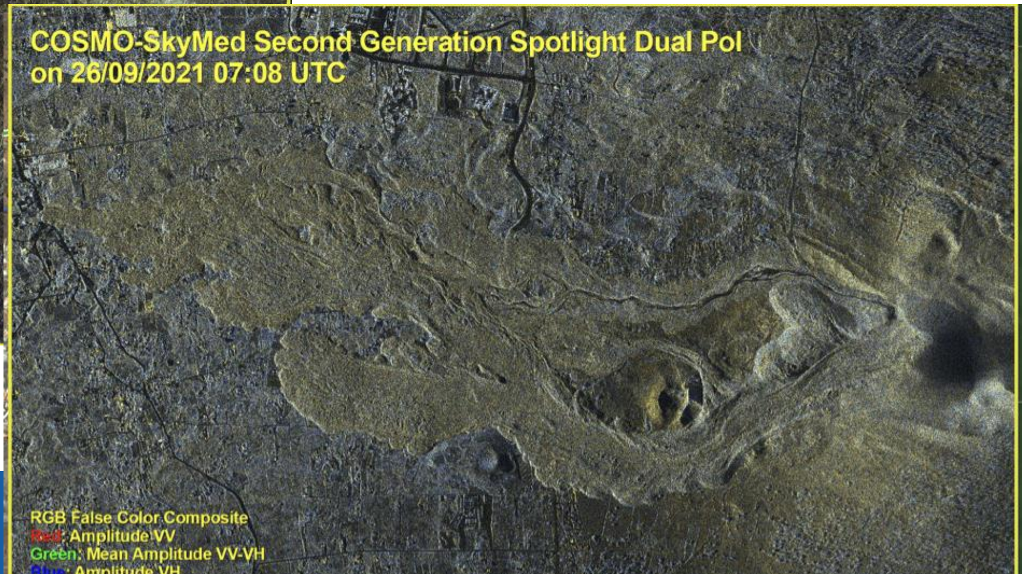




Influence de la rugosité sur le signal retrodiffusé







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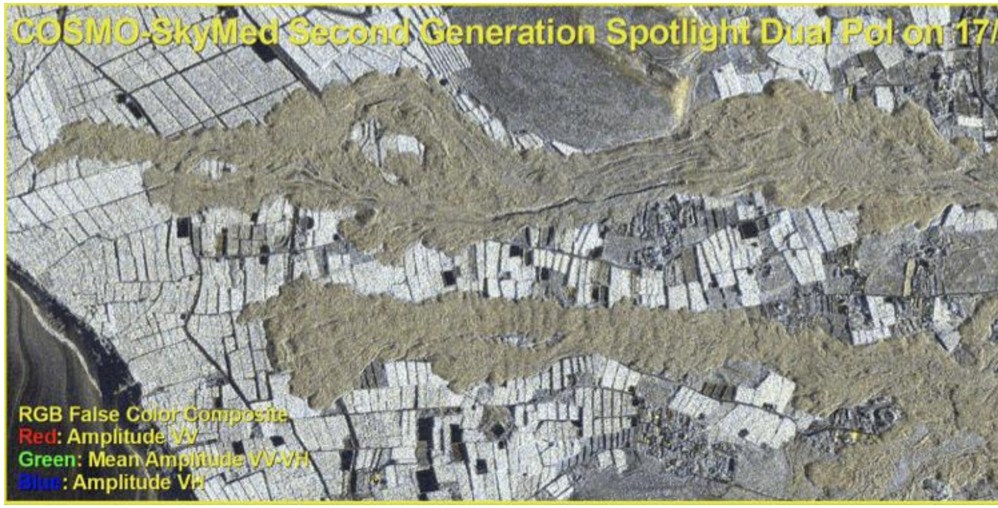
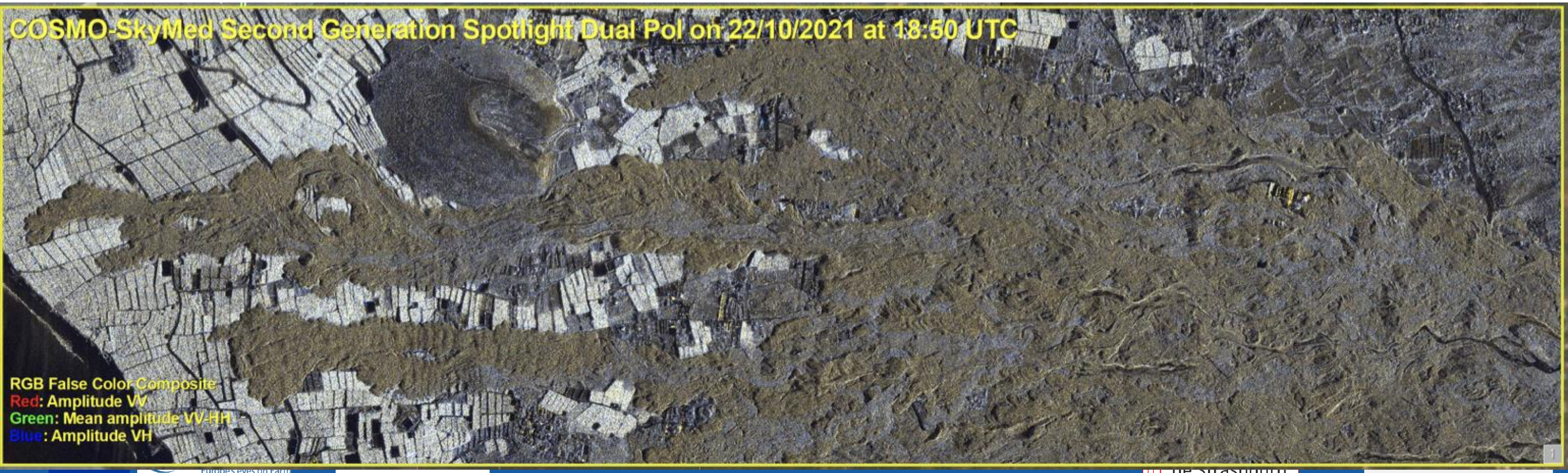




SAR: All weather system
Yes but !!!!

Distortions in the SAR observational data come from various factors.

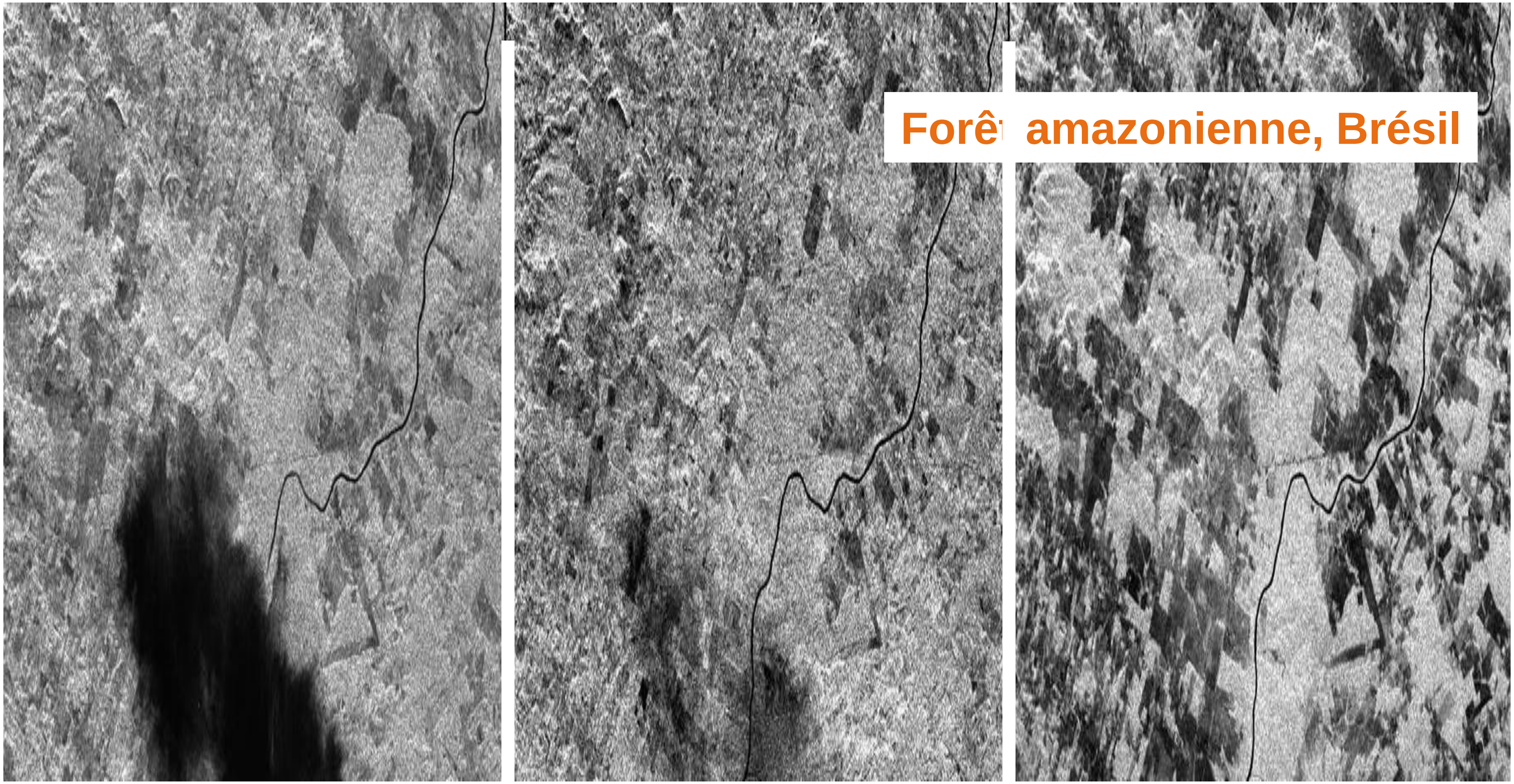
Absorption by the atmosphere
(oxygen, water vapor, and so on.)

Scattering by the weather particle
(Rain, snow, fog, and hail, etc.)

Faraday Rotation (FR)
Phenomenon of polarization rotation

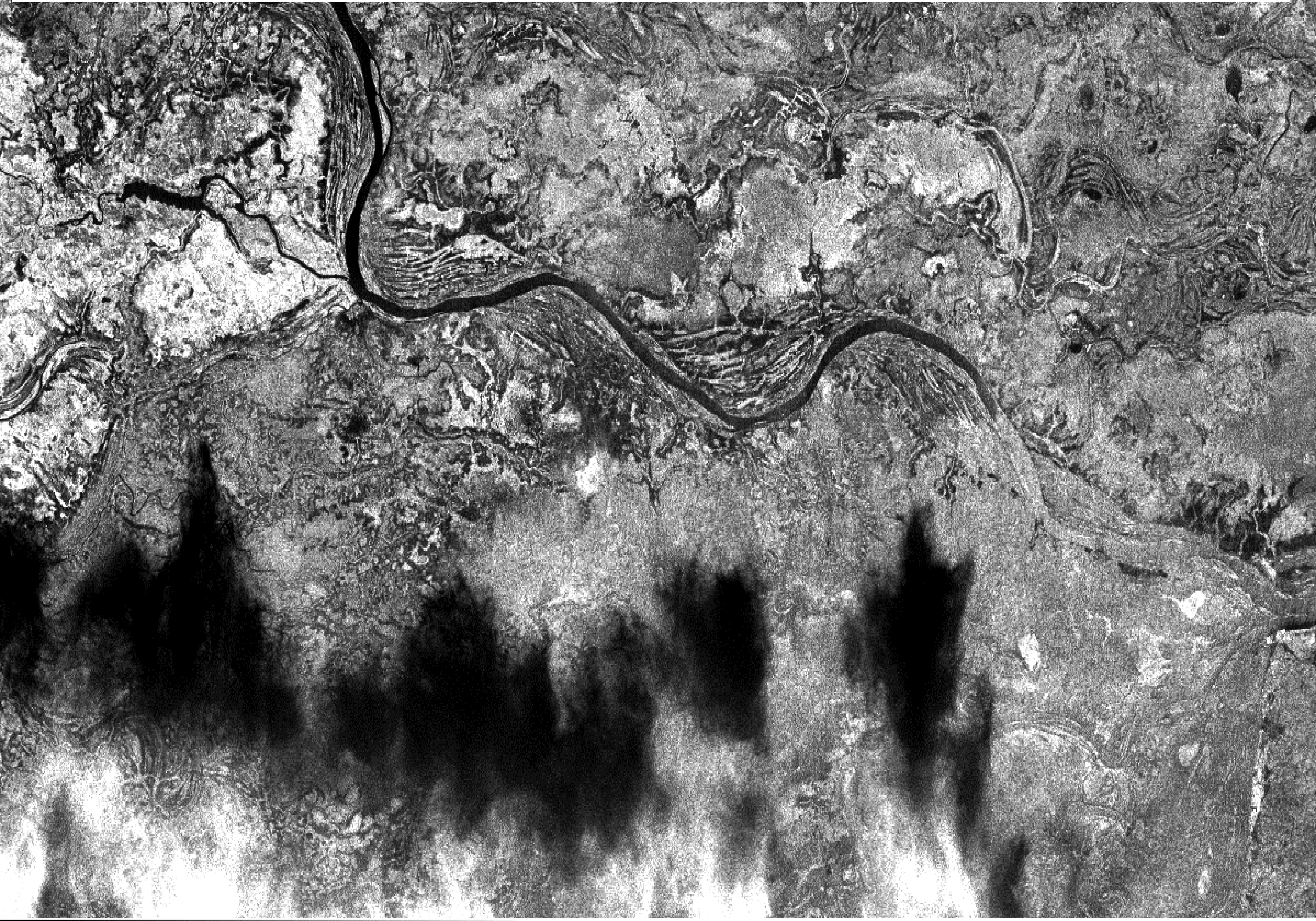
Observation Frequency	Example of SAR	Meteorological Particle	FR
X-Band	TerraSAR-X (9.65 GHz)	**Important**	**Negligible**
C-Band	RADARSAT-2 (5.405GHz)	↕	↕
L-Band	PALSAR (1.27GHz)	**Negligible**	**Important**

Signal attenuation by clouds and rain for smaller wavelengths

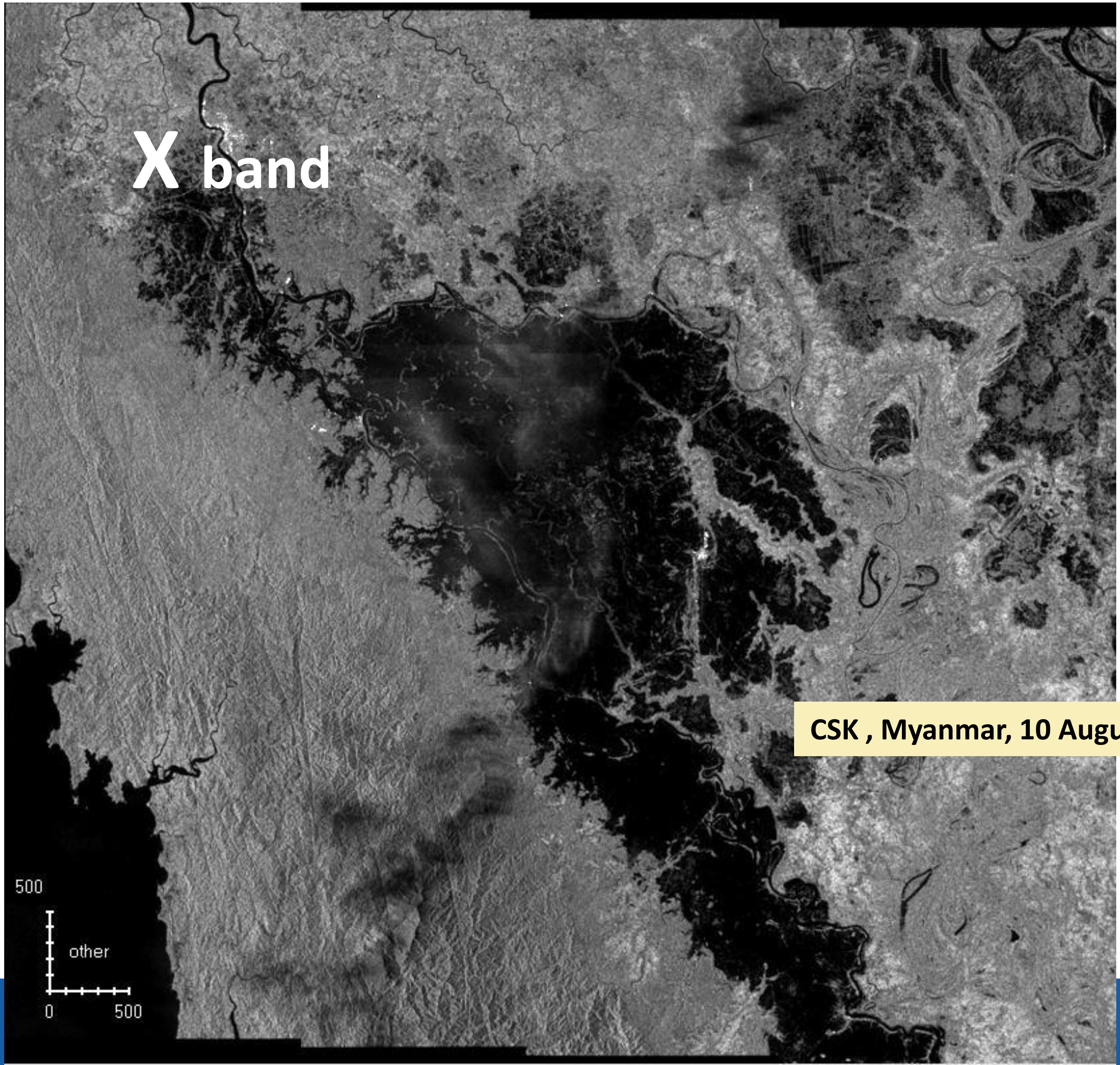


Bande X (3 cm) **Bande C (5.6 cm)** **Bande L (25 cm)**

Signal attenuation by rain (XSAR, MALI, 1994) – clouds and its shadow



Water backscattering in function meteorological condition : rain



CSK , Myanmar, 10 August 2015

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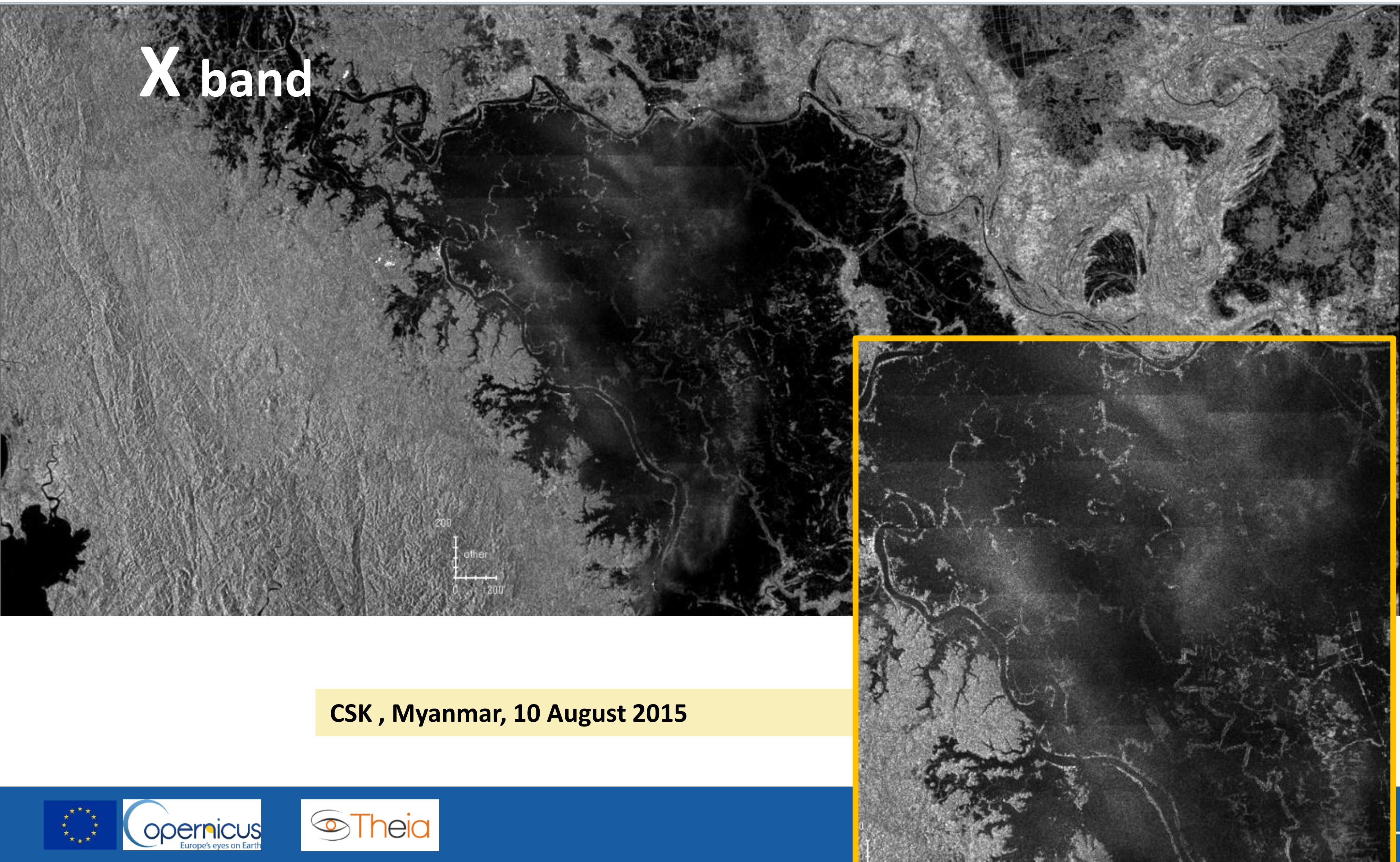

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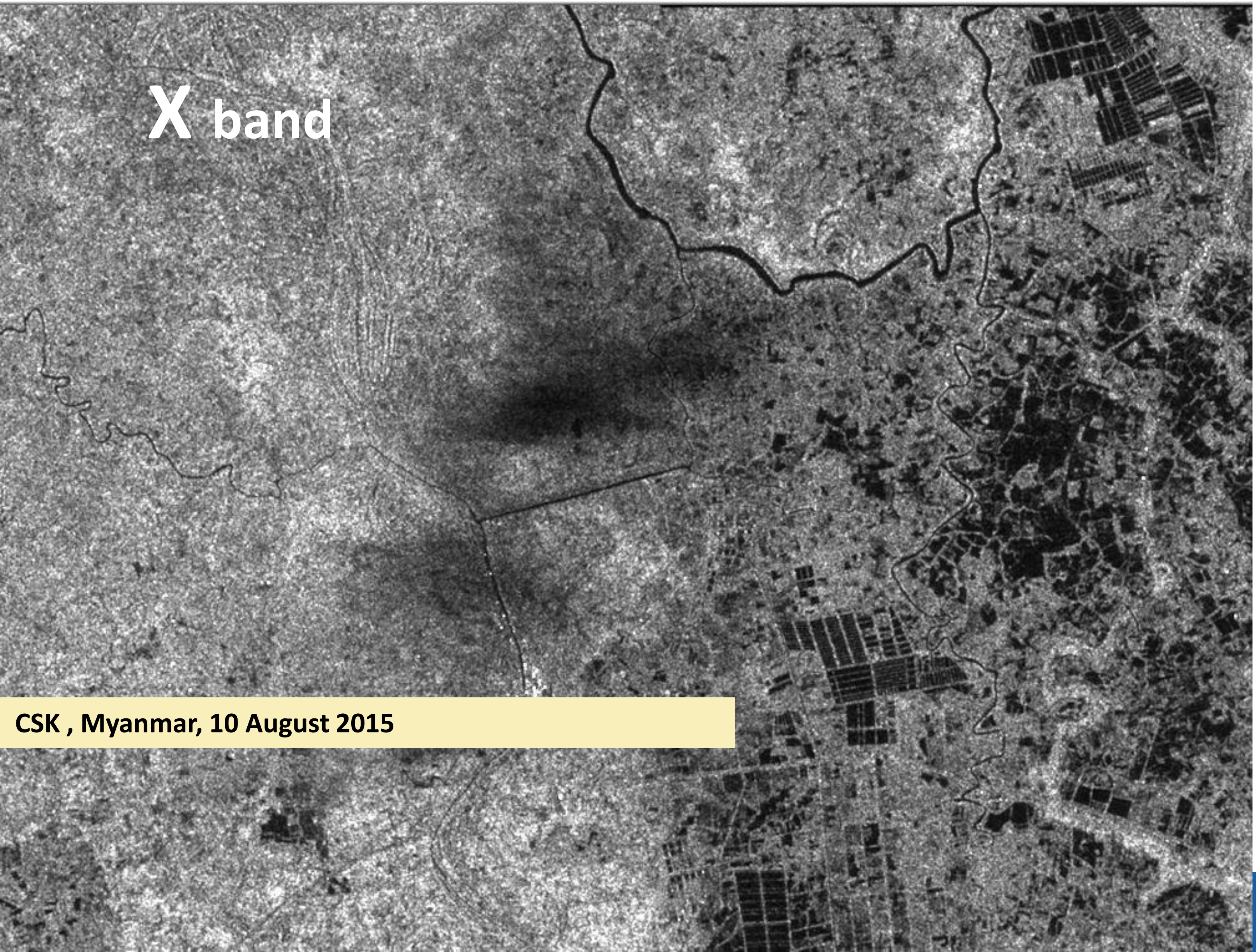
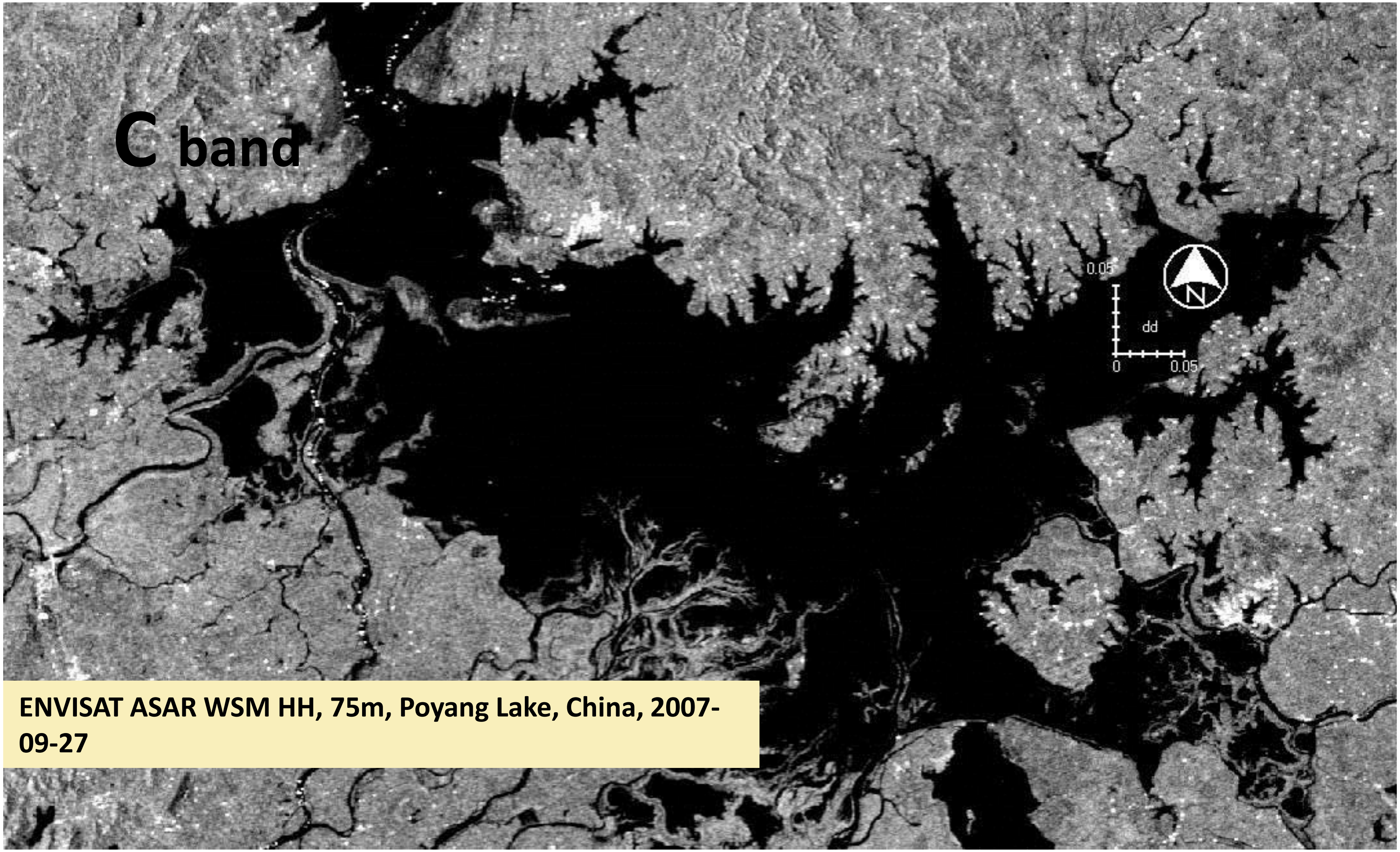
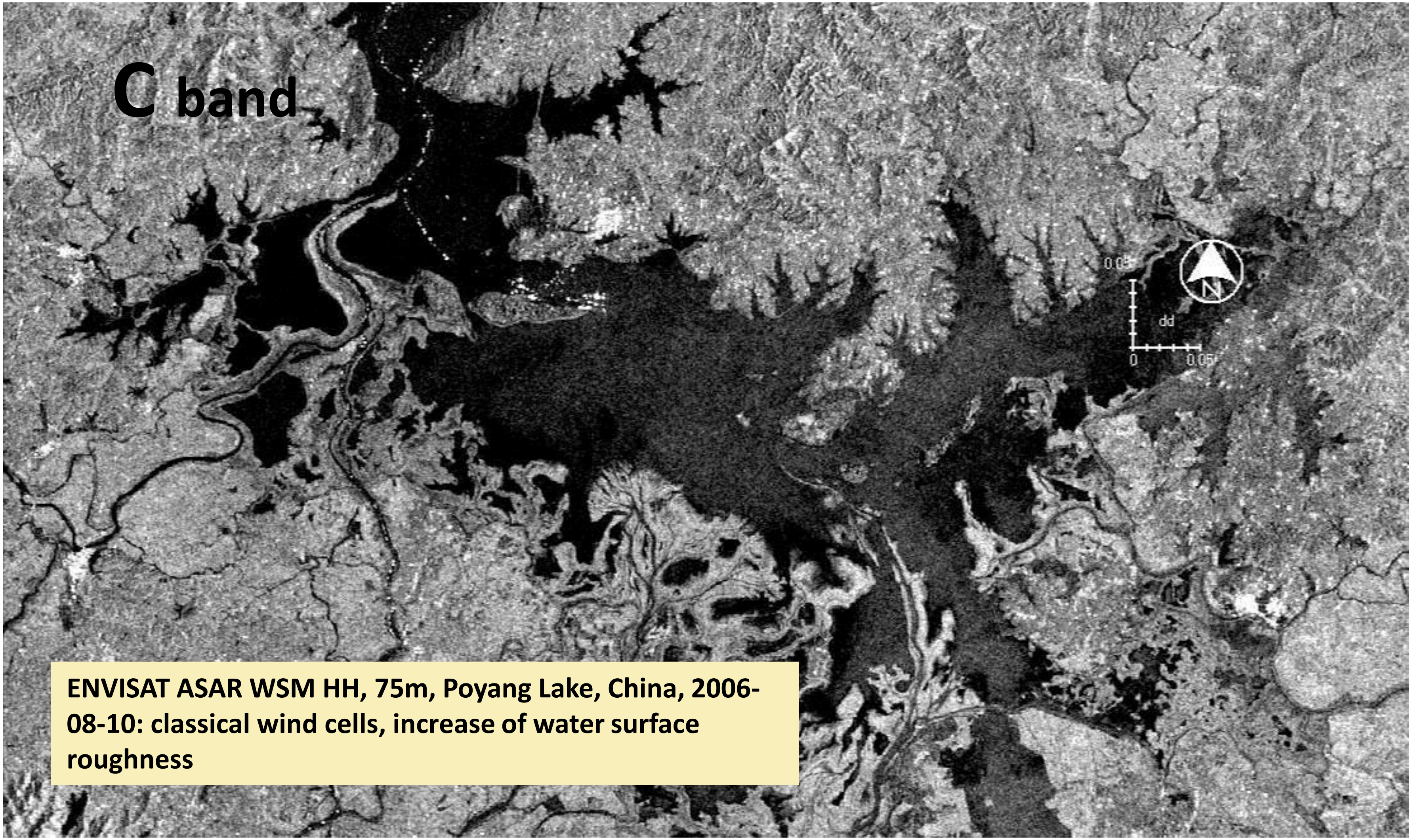


Water backscattering in function meteorological condition : Rain and wind



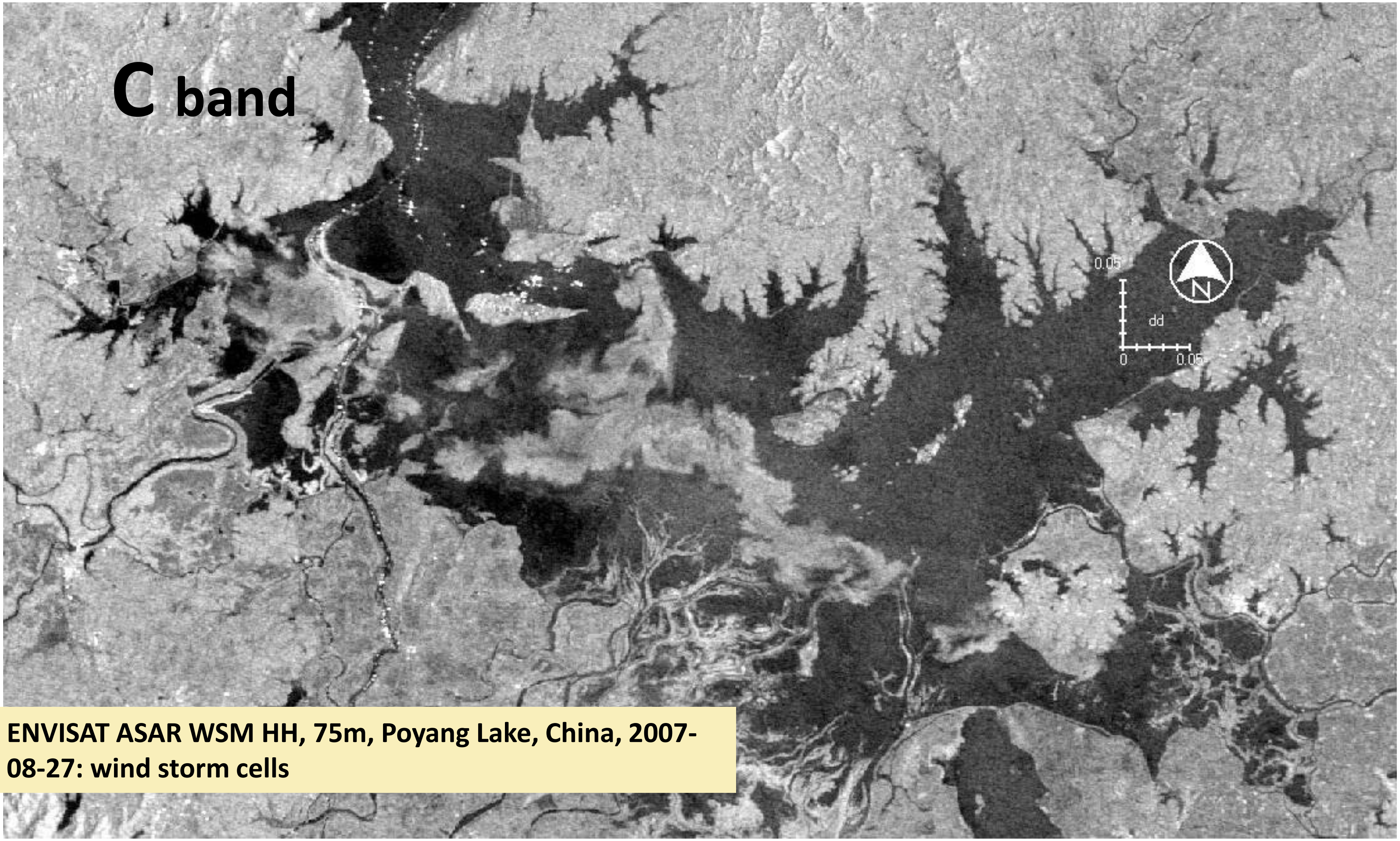
ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-09-27

Water backscattering in function meteorological condition : Rain and wind



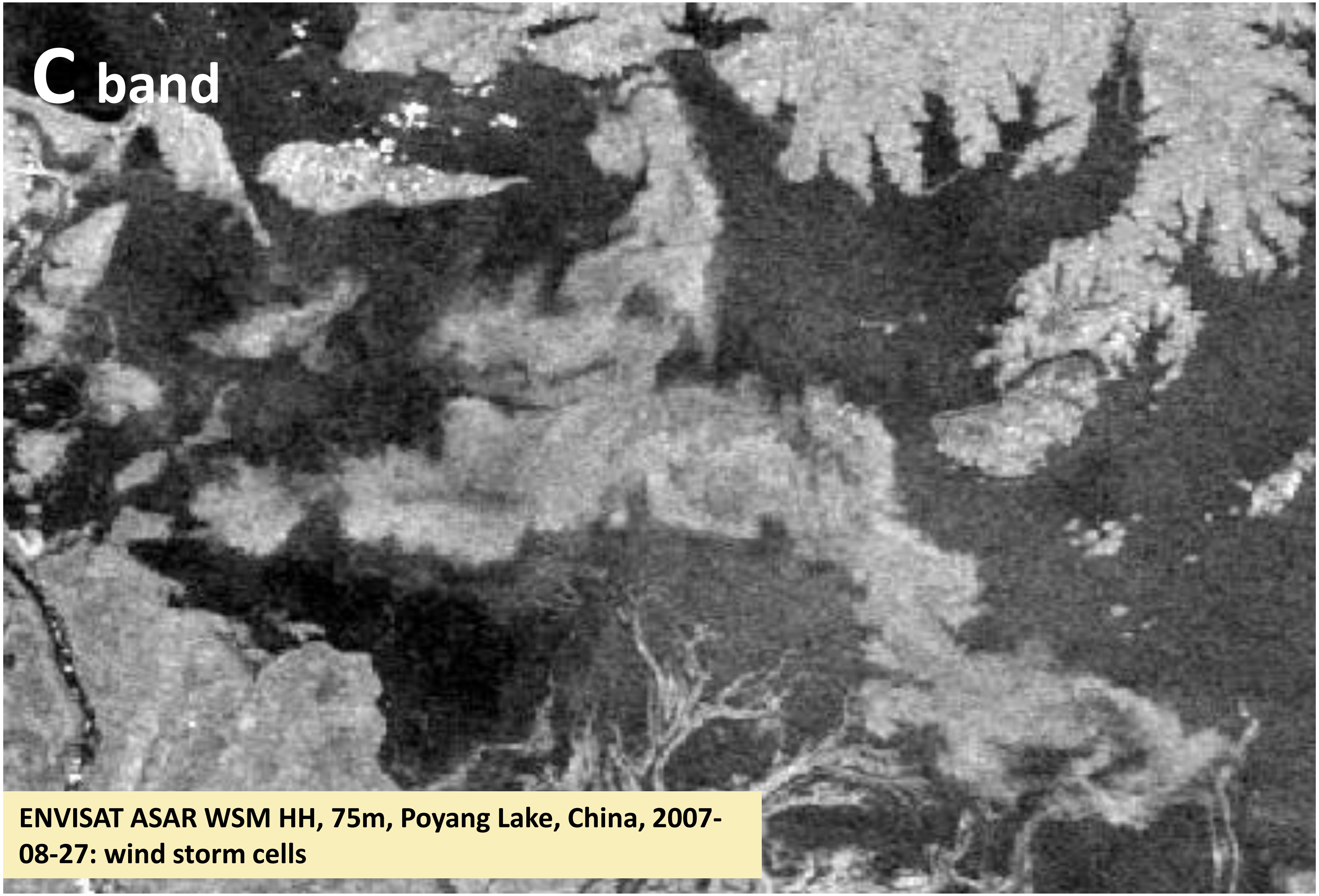
ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2006-08-10: classical wind cells, increase of water surface roughness

Water backscattering in function meteorological condition : Rain and wind



ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-08-27: wind storm cells

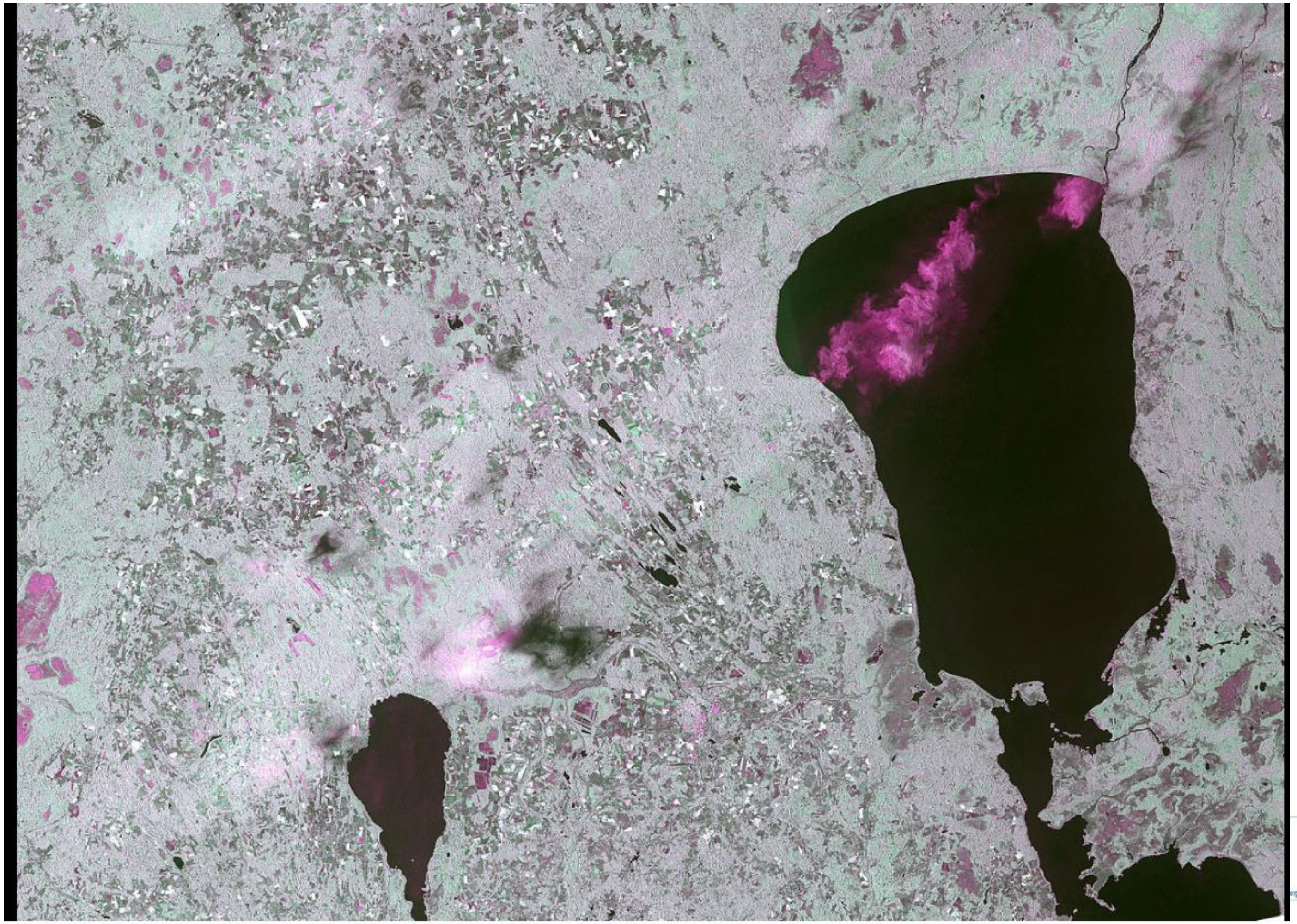
Water backscattering in function meteorological condition : Rain and wind



ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-08-27: wind storm cells

Water backscattering in function meteorological condition : Rain and wind

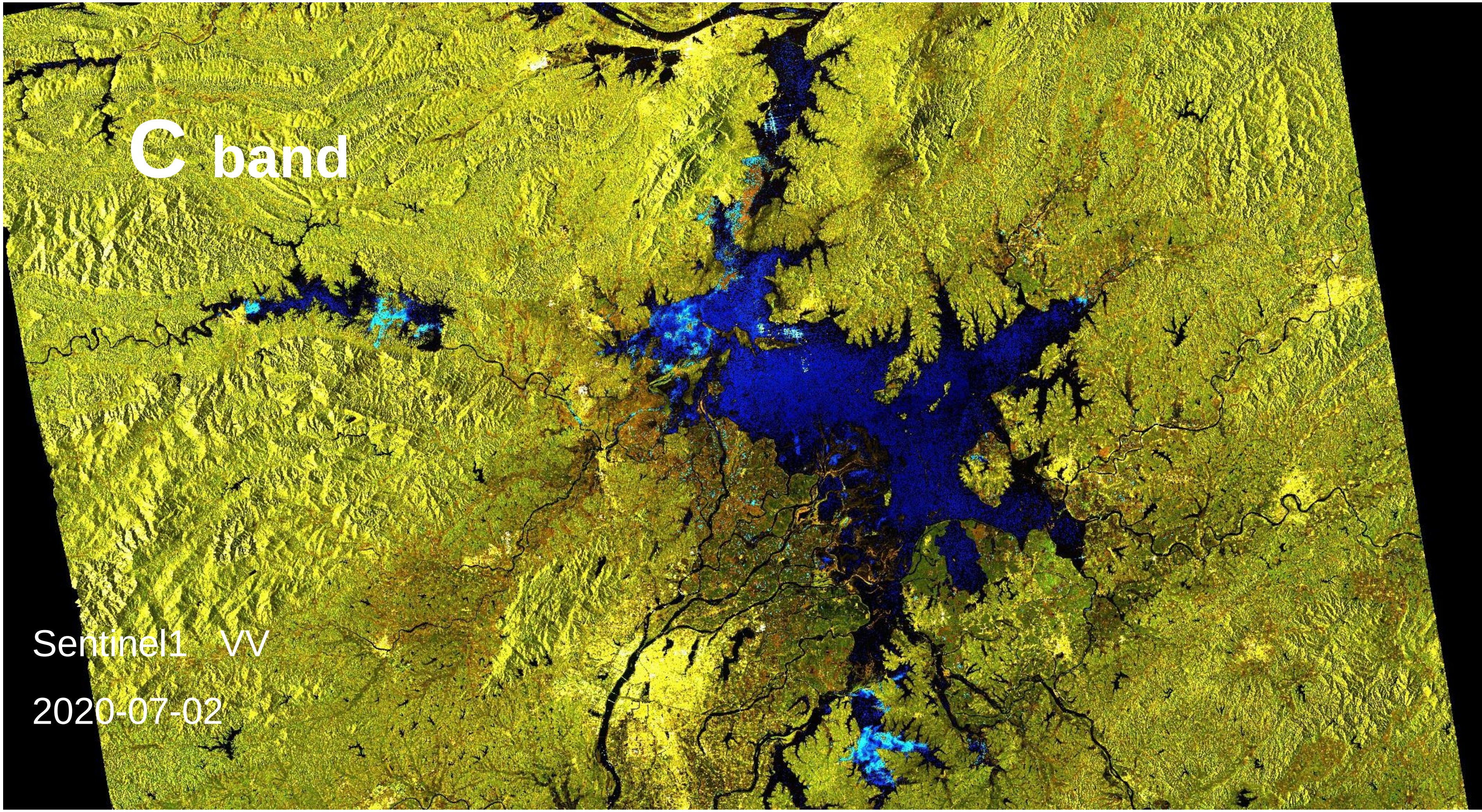
Sentinel1
C Band



our RGB image of VV-, VH- and VV+VH-polarisation backscatter.

Sentinel1)

Influence de la meteorologie sur le signal retrodiffusé



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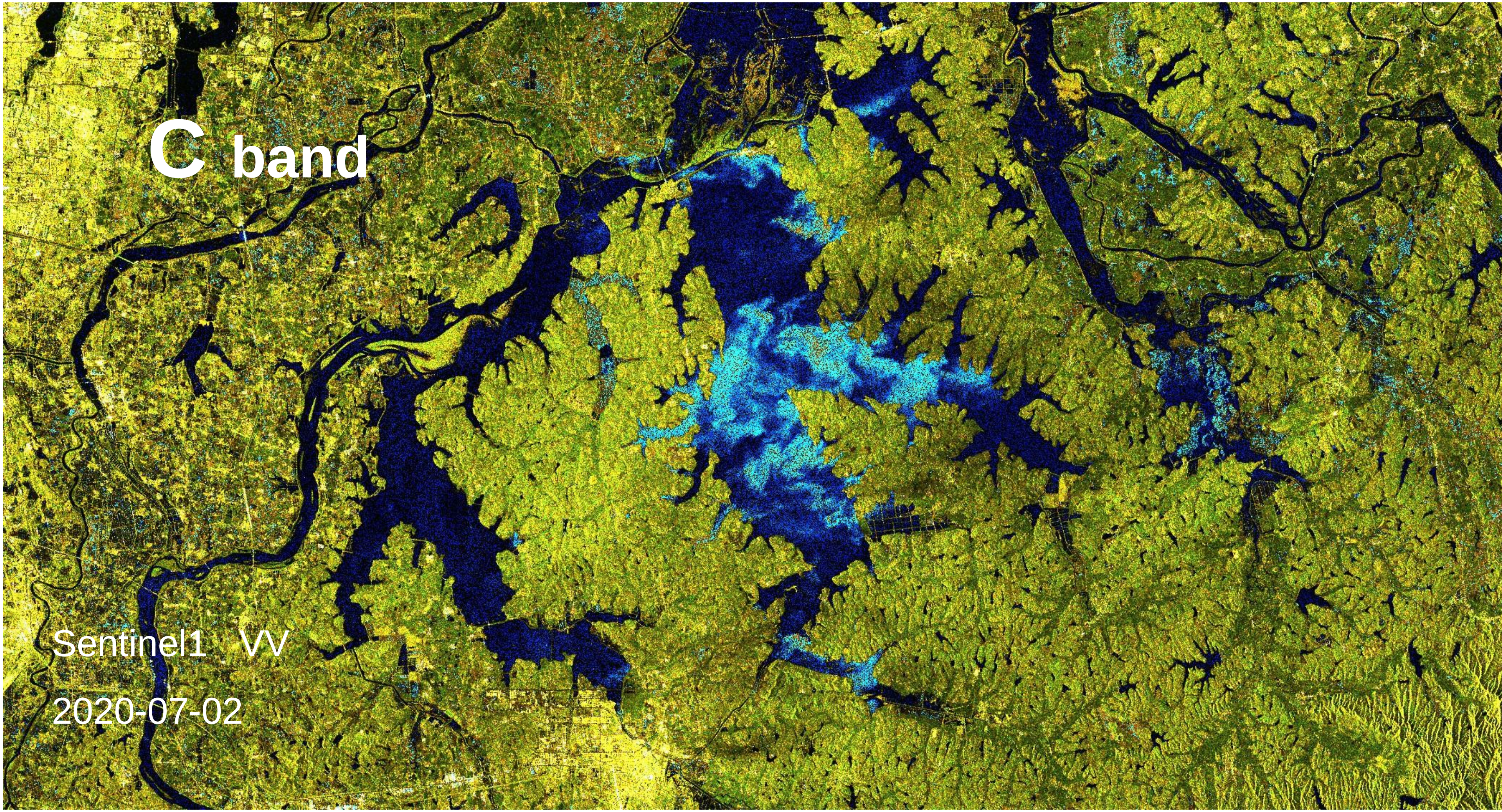

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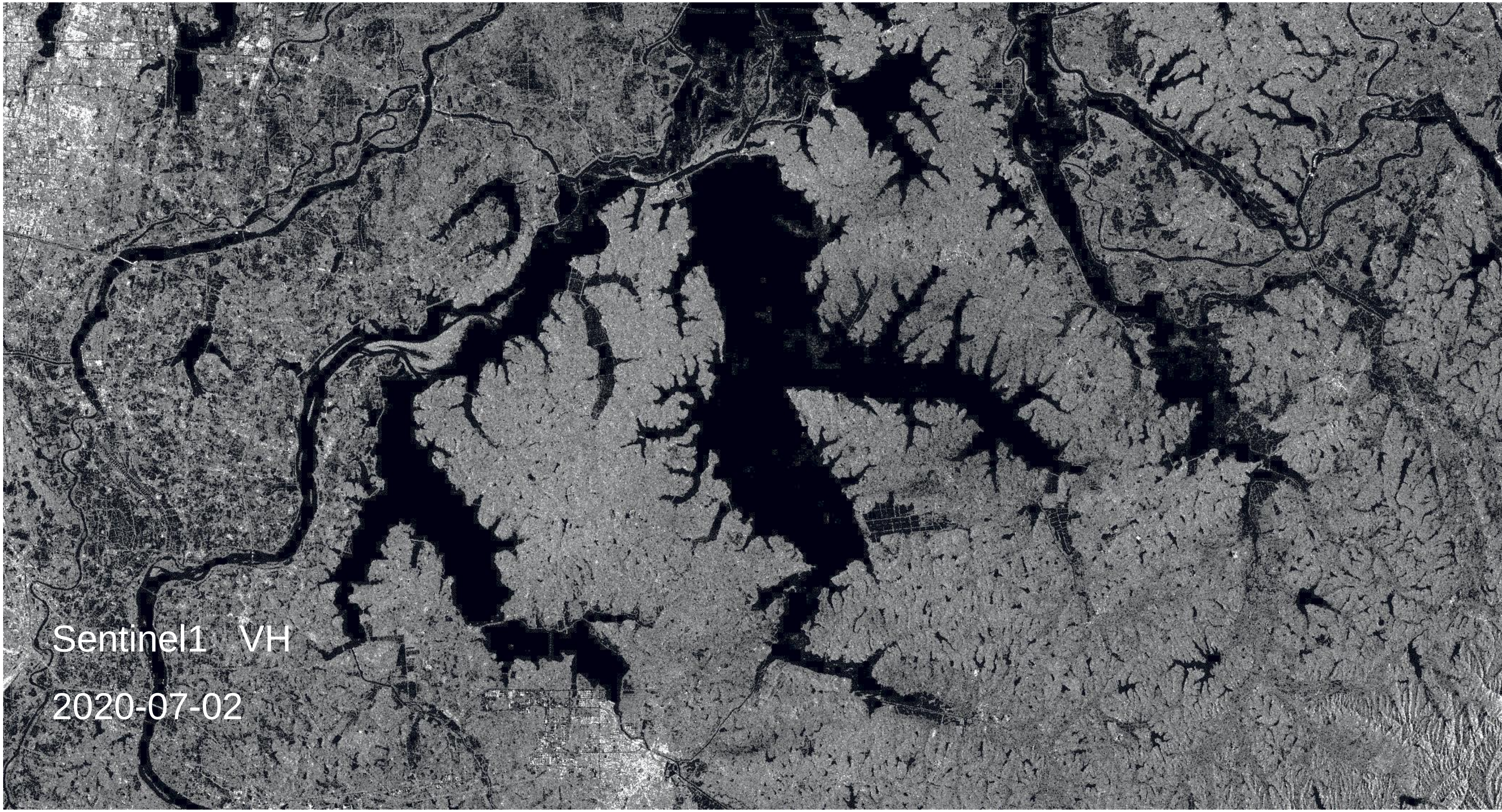

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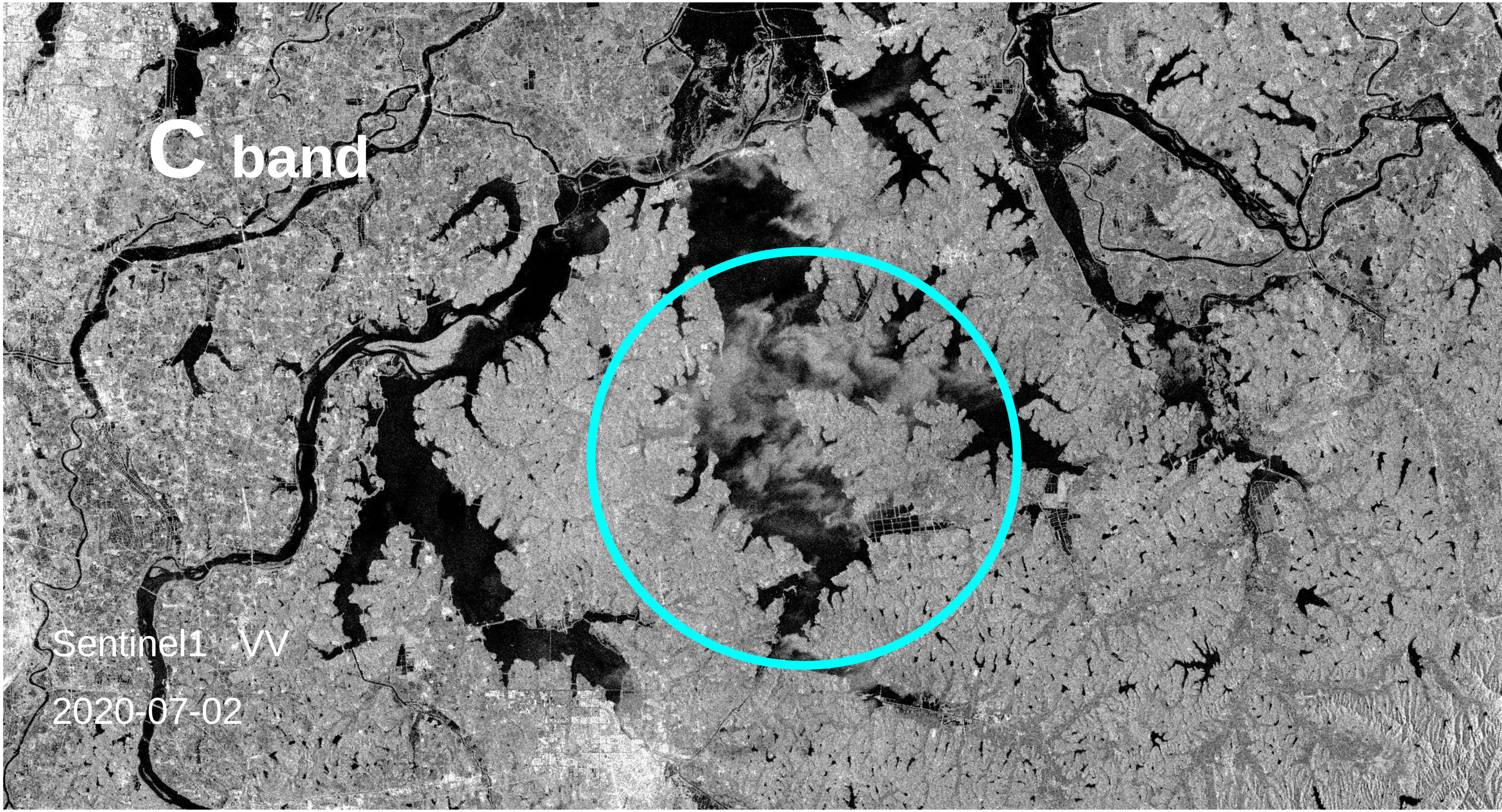
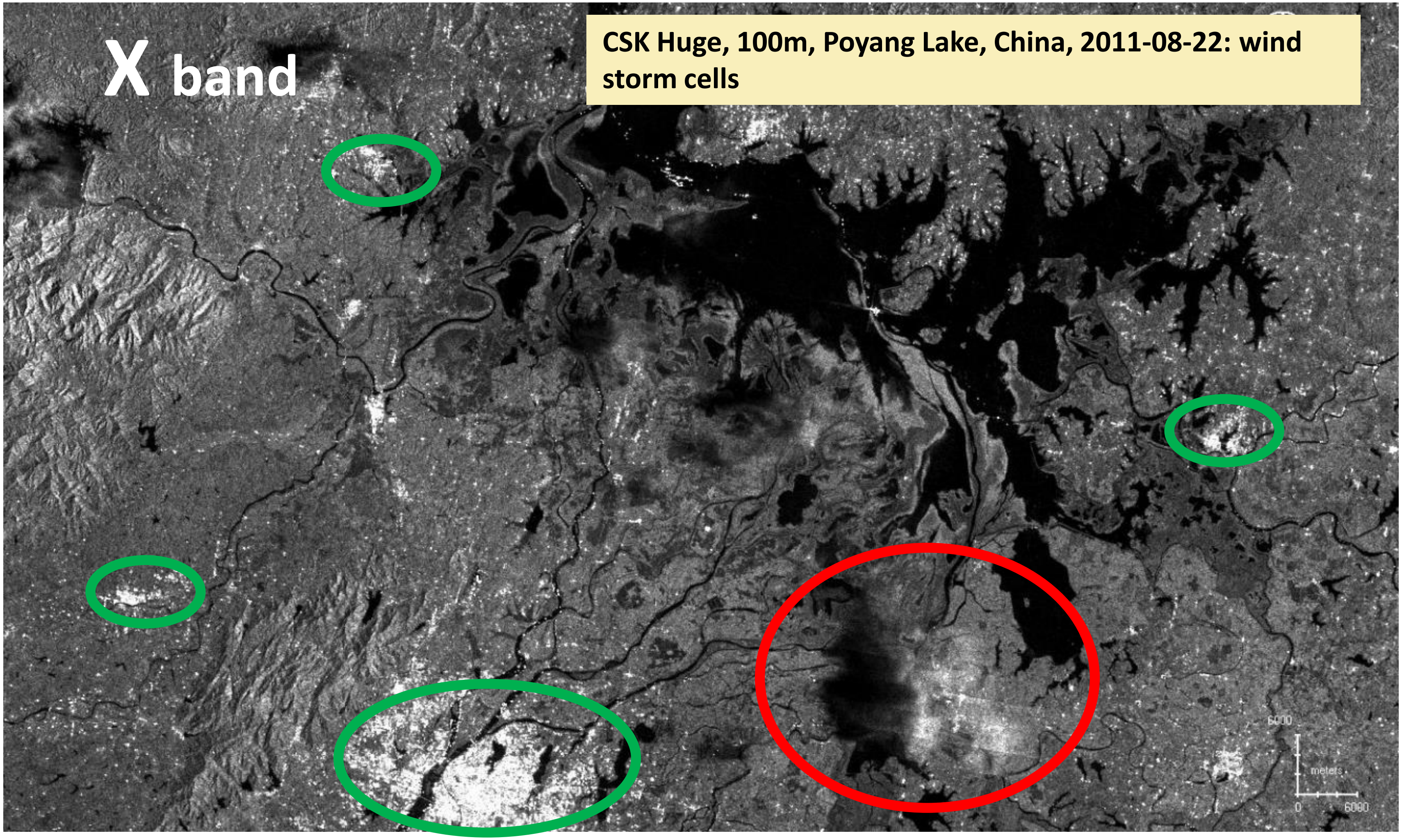
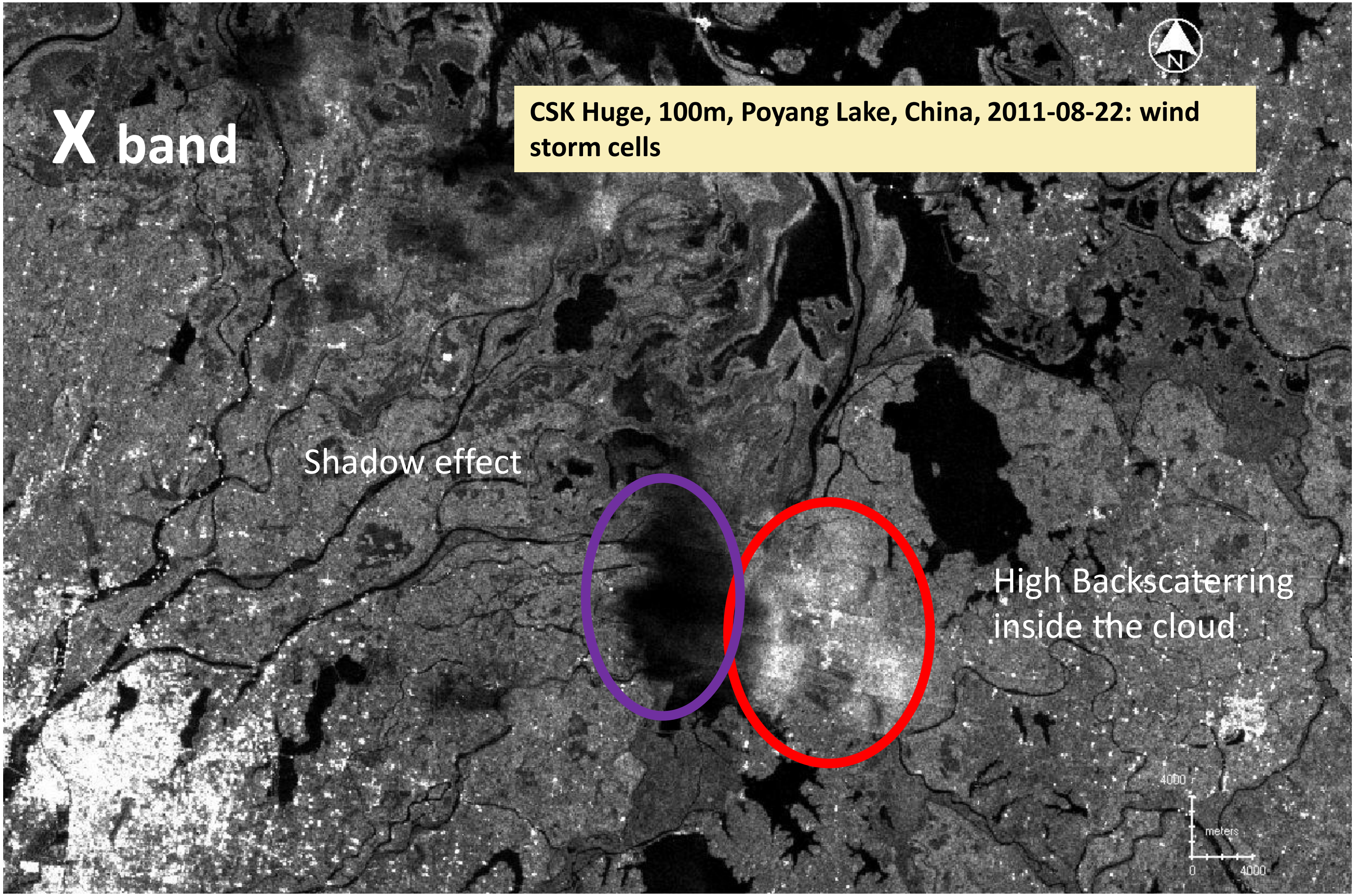


Water backscattering in function meteorological condition : Wind

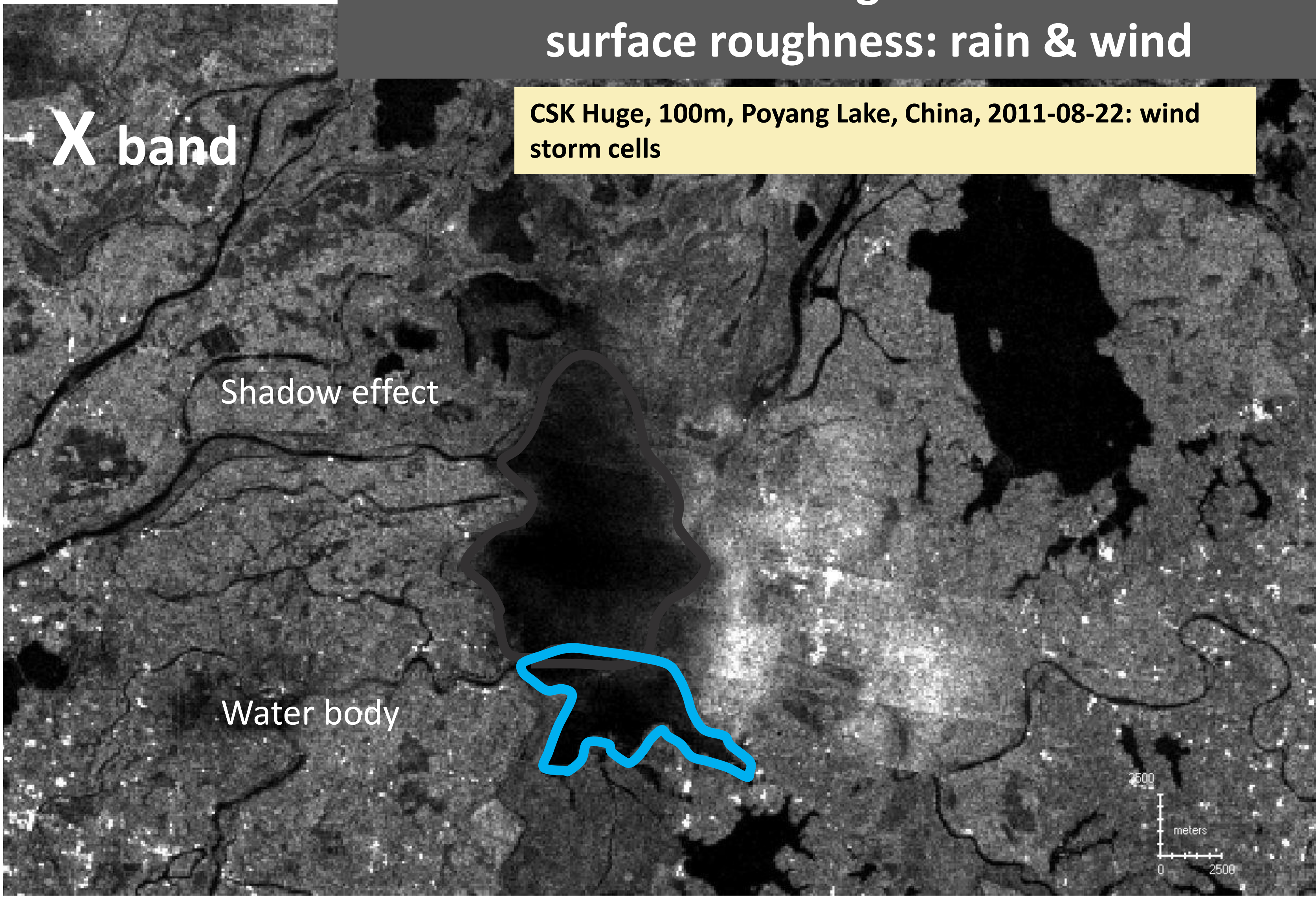


Water backscattering in function meteorological condition : Wind

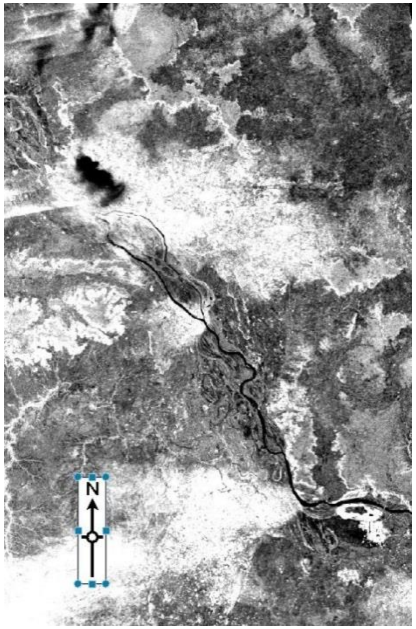


Water backscattering in function of water surface roughness: rain & wind

CSK Huge, 100m, Poyang Lake, China, 2011-08-22: wind storm cells



Water recognition in function of meteo conditions
Wavelength dependencies

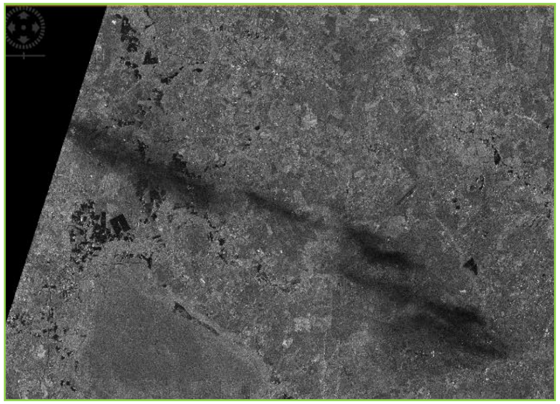


C band:

1 image ASAR ENVISAT en bande C, over +200 analyzed
Few Sentinel1 case one reported on the Web, one on Poyang

X Band

•1 image CSK Huge, over 15 analyzed (China)…
•1 TerraSAR X Stripmap, over 5 analysed (Ivory coast
•1 TerraSAR X ScanSAR, over 3 analysed (Niger : attenuation and huge backscaterring
•1 CSK, over 2 CSK (Myanmar)
• 1 over 15 Kompsat 5, Florence Cyclone September 2018

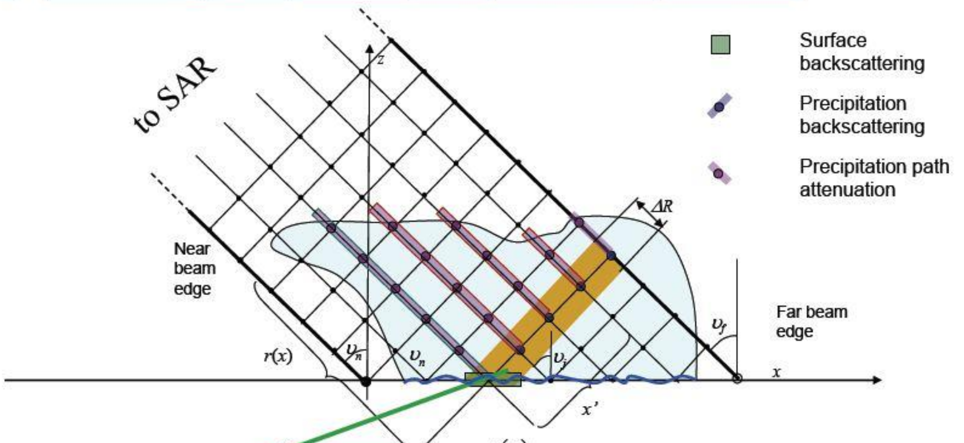


Water backscattering in function of cloud /precipitation : country with contrasted rainy/dry season

Very high sensibility to rainfall and clous in X ba

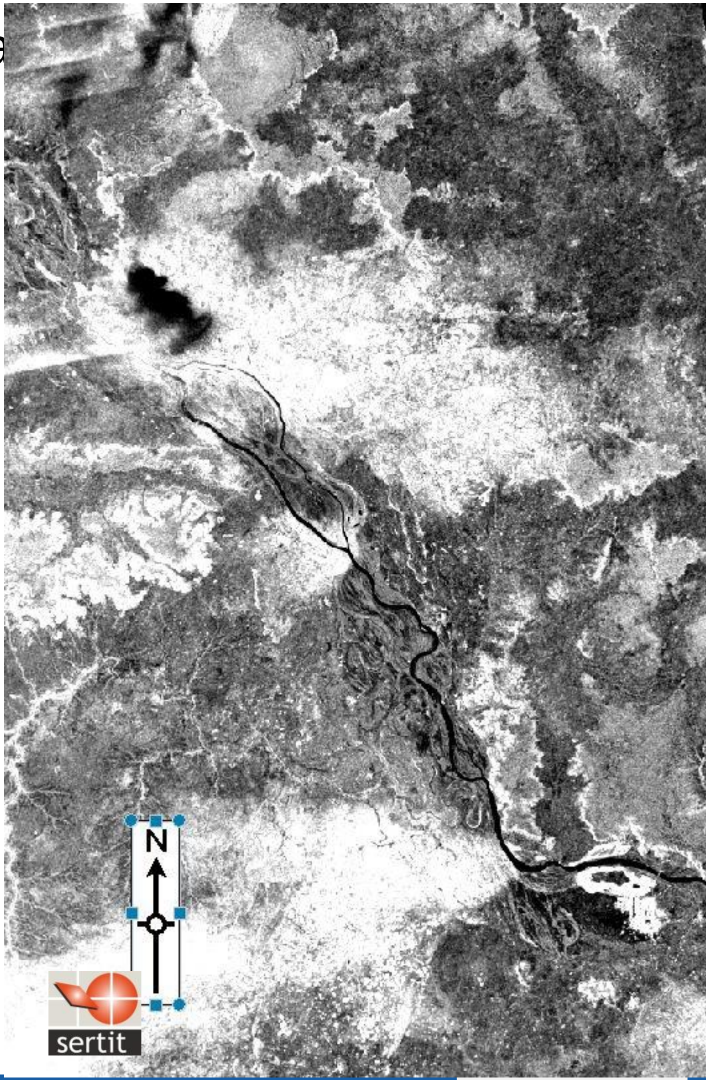
Be careffull!!

- backscattering and attenuation of radiation by hydrometeors in the rain cells;
- Backscattering of sea induced by the impact of raindrops and wind.



$$\sigma^0(Q) = \sigma_s^0 \cdot l[r(x)] + \sin\upsilon \int_0^{p(x)} \eta_p(x') \cdot l[r(x')]\, dx'$$

Baldini et al., 2012, from Meteo Italy



Presentation outline

Introduction: Why water bodies and flood mapping and monitoring

Flood and lakes in the landscape

Short cut of Physical basis for Water bodies mapping

Elements for water bodies extraction based on SAR imagery

SAR sensors for water bodies and/or flood mapping

- Past mission
- On going missions
- Future missions

Flood plain and lakes monitoring

- Short term Monitoring
- Long term monitoring
- Meteo climato parameters

Concluding remarks

Former, actual and future SAR missions valuable for water surface mapping/monitoring

Mapping+ reconnaissance intelligence

Hydrology + land cover/use

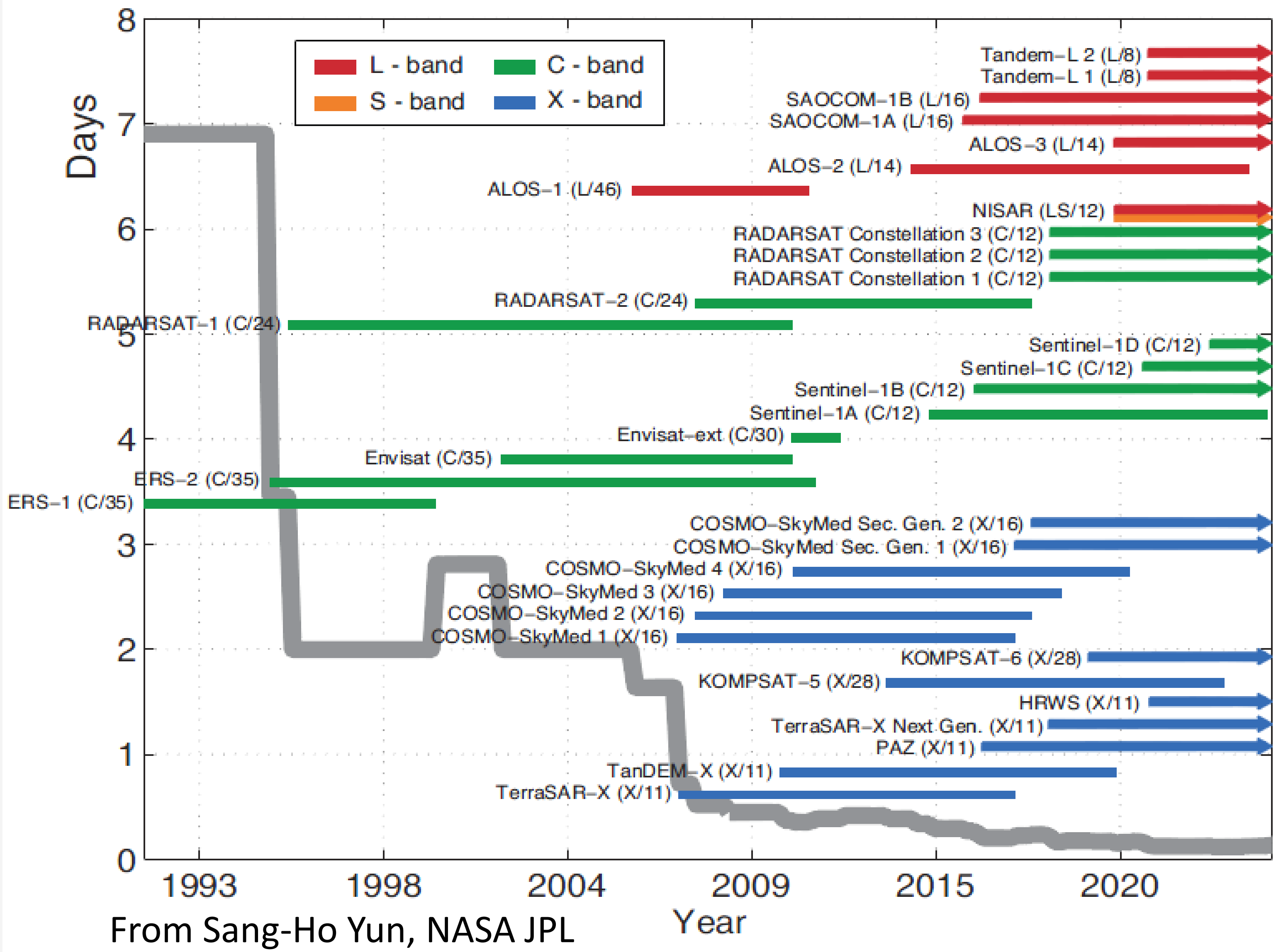
Flood under vegetation Biomas

Biomas DEM under forest

Bandes	Ka	K	Ku	X	C	S	L	P
Fréquence (GHz)	40-26.5	26.5-18	18-12.5	12.5-8	8-4	4-2	2-1	1-0.3
Longueur d'onde (cm)	0.75-1.1	1.1-1.67	1.67-2.4	2.4-3.75	3.75-7.5	7.5-15	15-30	30-100
Polarisation	HH, VV, HV, VH							

Images acquired in X, C, S, L Bands are potentially suitable for water bodies mapping

Former, actual and future SAR missions



From Sang-Ho Yun, NASA JPL

Former & old missions: precursors and rich archive

1978 : First civilian SAR, SEASAT (USA).; 108 days

1981 : SIR A Mission, on board on US Shuttle , band L

1984 : SIR-B, Mission, on board on the US Shuttle, Band L, 5 - 13 October 1984

1991 : ERS-1 , ESA , launch 17 of July 1991 and ended in march 2000

1992 : J-ERS , Japan

1994 : SIRC X SAR, two shuttle's missions (10 days: 9-04 - 20-04- 1994 and 30-09 - 11-10-1994**.** Bande L, C et X

1995 : ERS-2 , in tamdem with ERS1 , ended in September 2011 (16 years of operation)

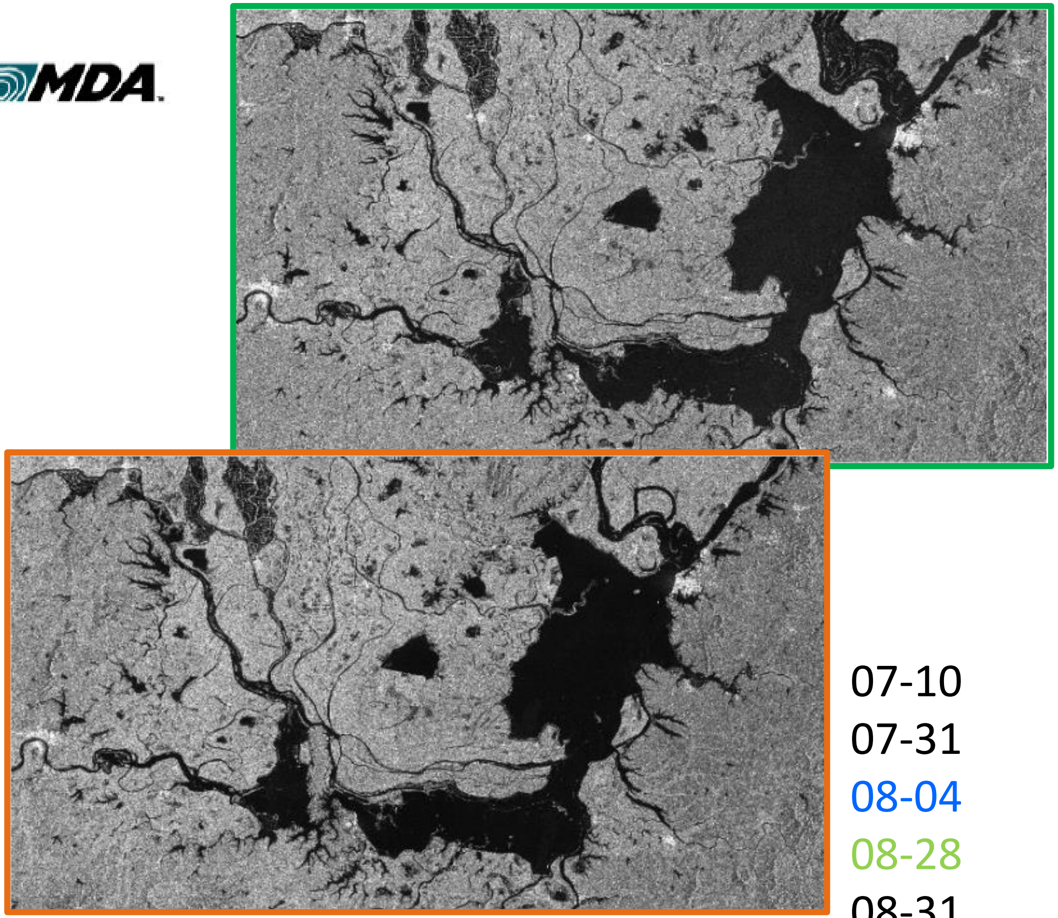
1995 : RADARSAT 1, Canadian Space Agency

2000 : Mission SRTM, topographic mission on the shuttle , 11-22 February 2000

2002 : Envisat, Europeen Space Agency endend 12 of May 2012

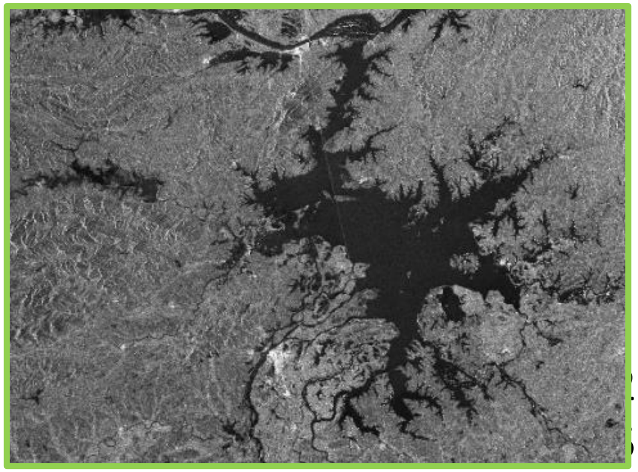
2006 : PALSAR's L-band SAR, on ALOS mission (ended in 2011)

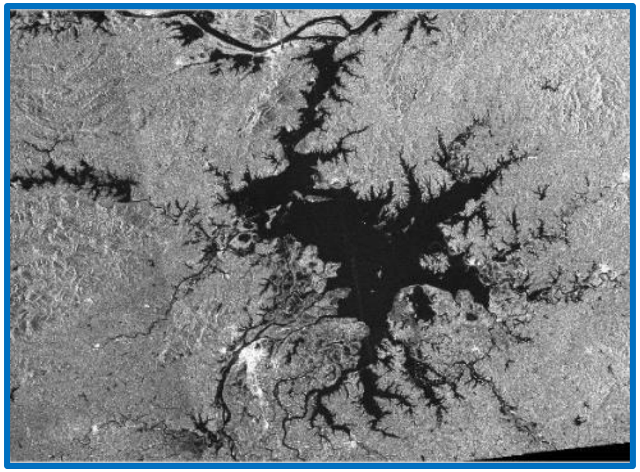
Importance of the Archive: Flood memory
Radarsat over 1998 Yangtze historical flood



07-10
07-31
08-04
08-28
08-31

Dongting 1998: SCN, SCW, SGF

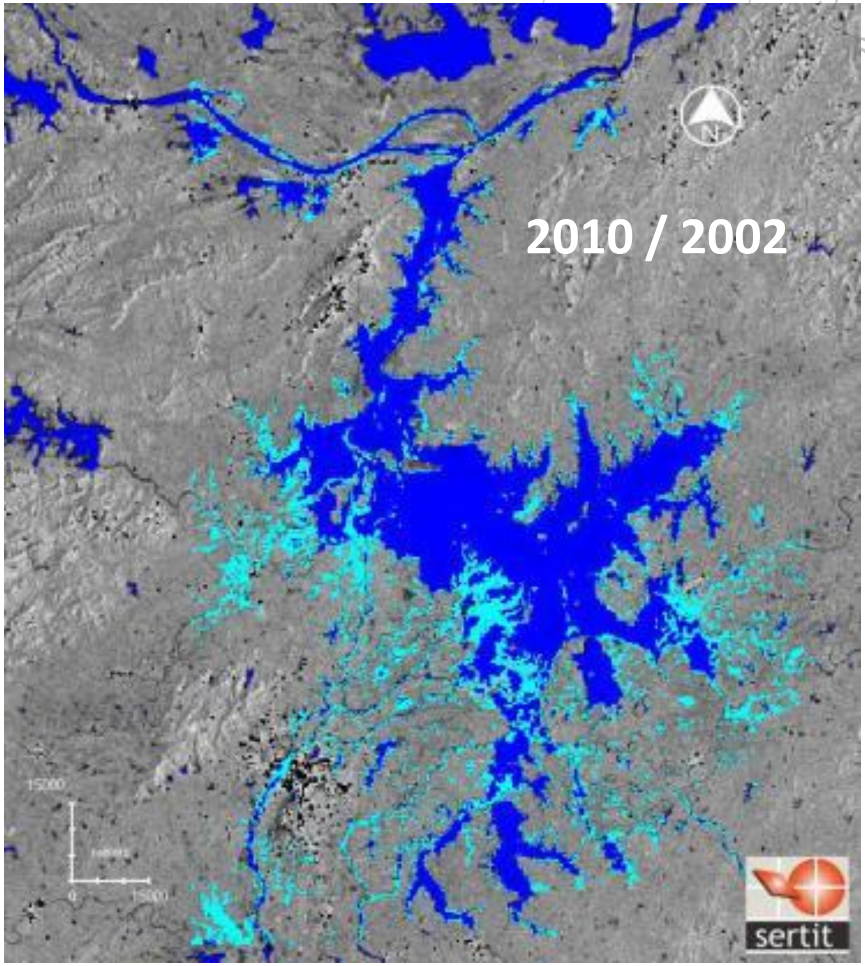


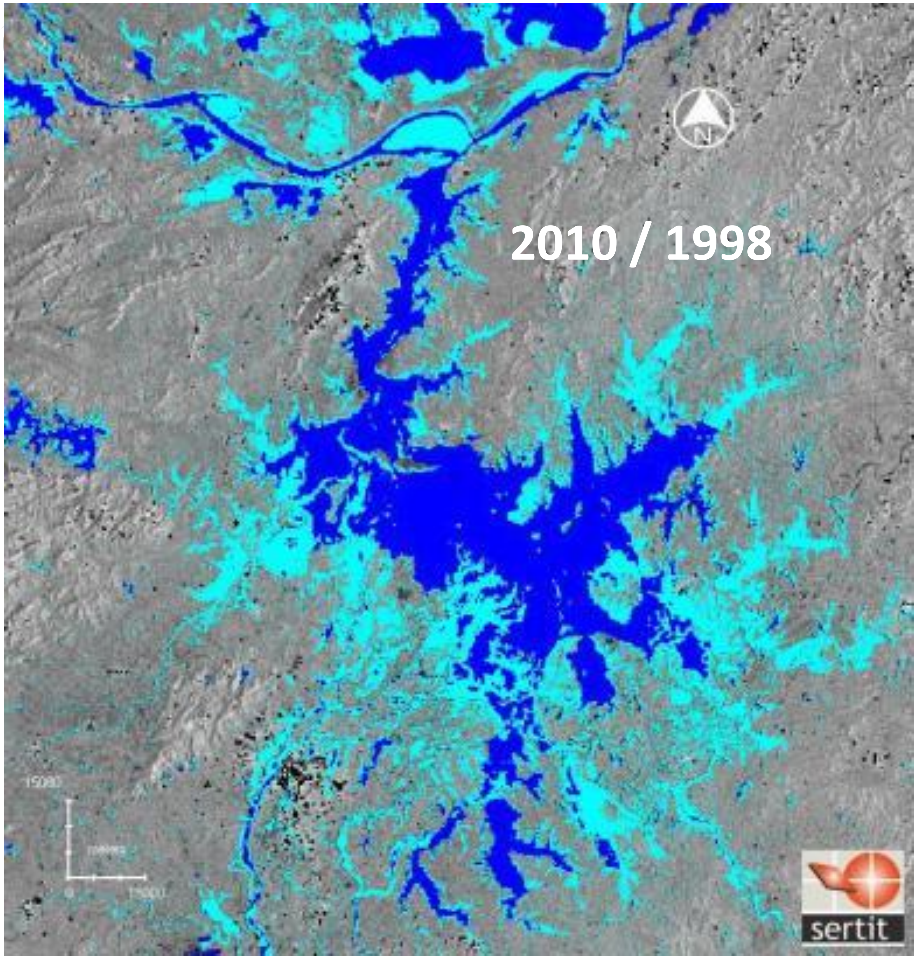


07-31
08-04
08-07
08-14
08-17
08-31

Poyang 1998: SGF, SCW,

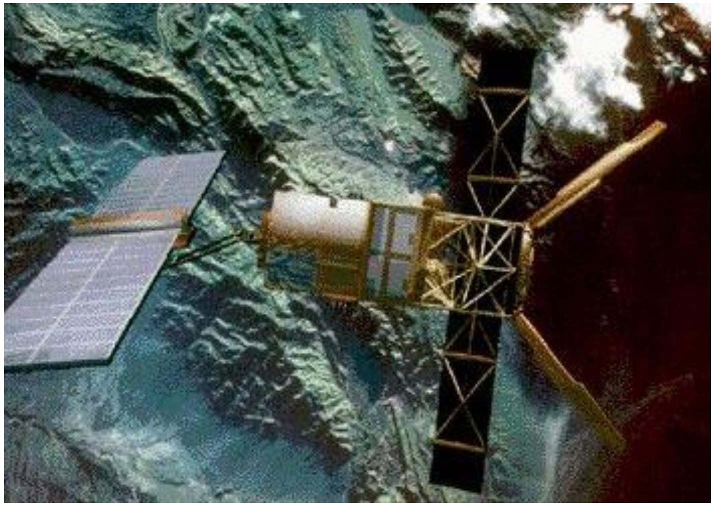
Analysis of Poyang lake Summer 2010 flood





2010 flood event is an important one in Poyang last decade history
2010 extent (3354 km²) no far to the 2002 extent (3392 km²)
2010 much smaller in term of extent than 1998 (4116 km2)

ERS 1 - 2



ERS 1 launch, 1991,17 of July
ERS 2 in 1995, 21 of April

C Band, VV

Cycle: 35 days
Cycle: 3 days

Cycle: 265 days, Geoid & bathymetry

Operational mode	Band	Center frequency	Polarization	Incidence angle	Spatial resolution	Swath width
SAR Imaging mode	C-band	5.3 GHz	LV (linear vertical)	23º at mid-swath	10-30 m	100 km
SAR Wave	C-band	5.3 GHz	LV	23º +0.5º	30 m	5 km x 5 km
AMI-SCAT (wind)	C-band	5.3 GHz	LV	Fore/aft: 25º-29º Mid: 18º-47º	50 km	500 km

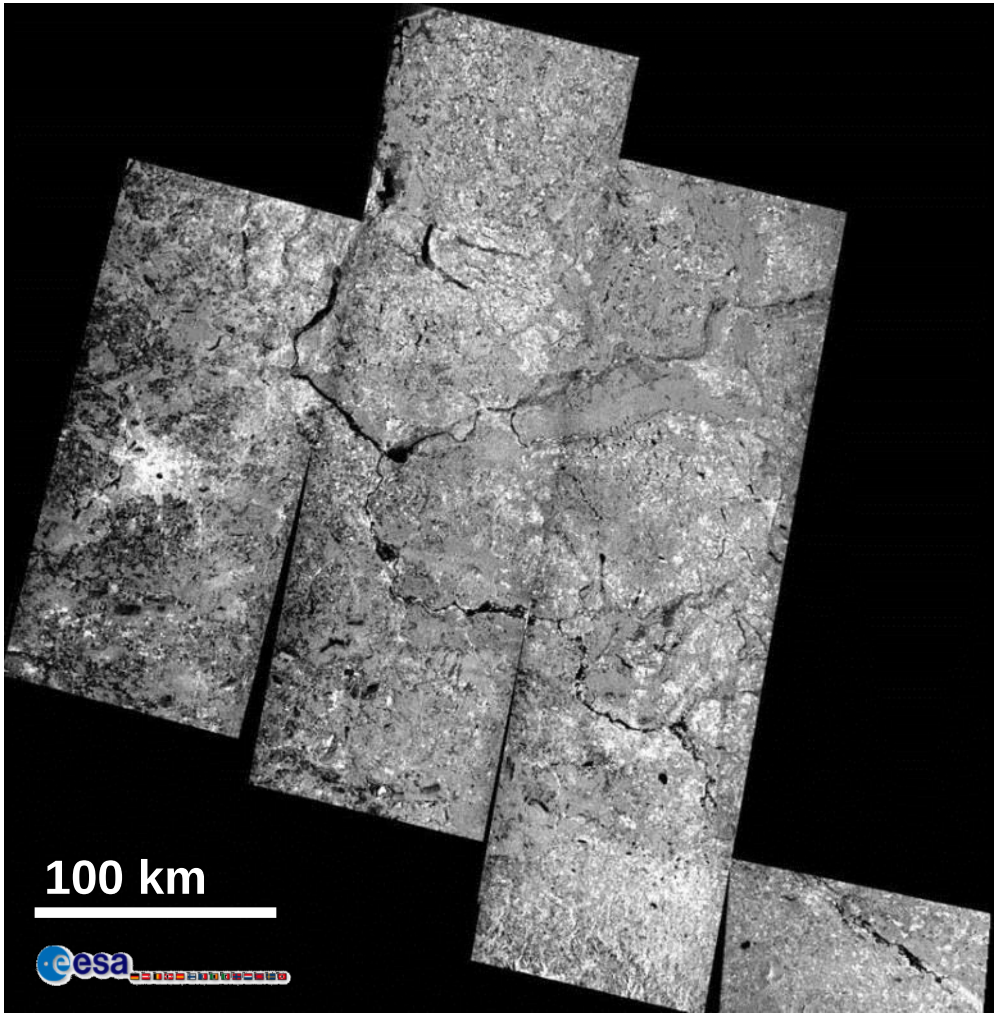
ERS 1 - 2

ERS SAR data have been wordily exploited for flood mapping

(cf numerous papers on ESA conferences)

- Thames flood 1992
- Camargue flood in 1993
- Meuse flood 1993-1994
- Aude flood 1996
- Oder flood in 1997
- Chinese flood in 1998
- and many more…

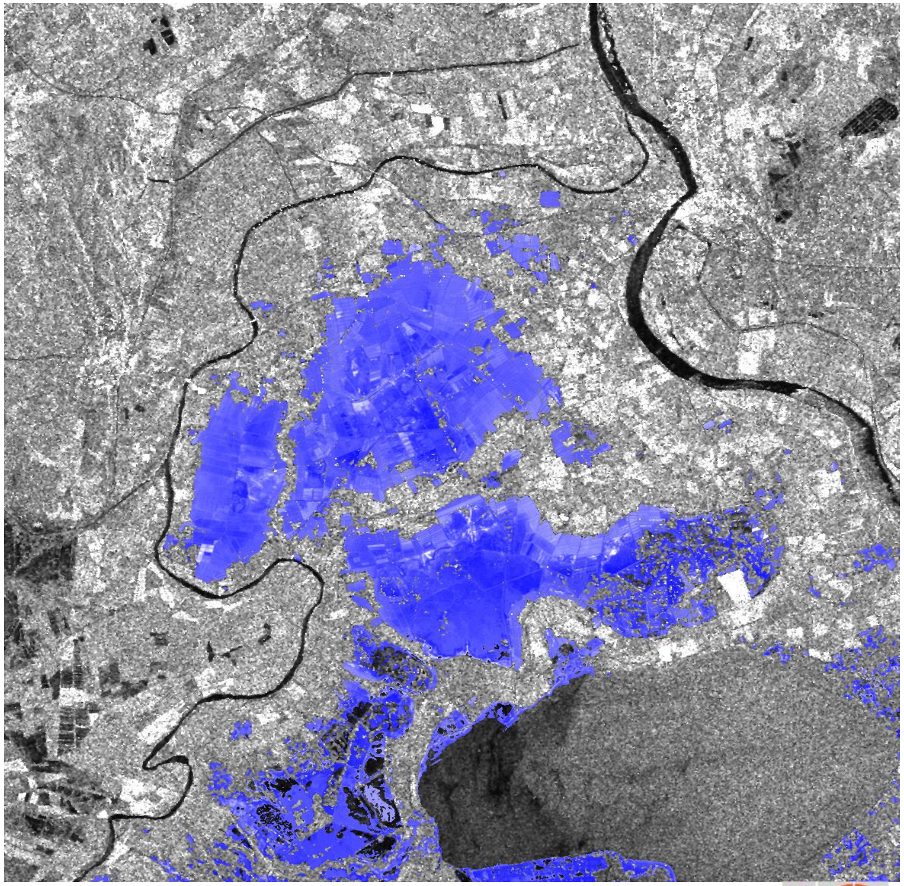
Exploiting mostly the Amplitude



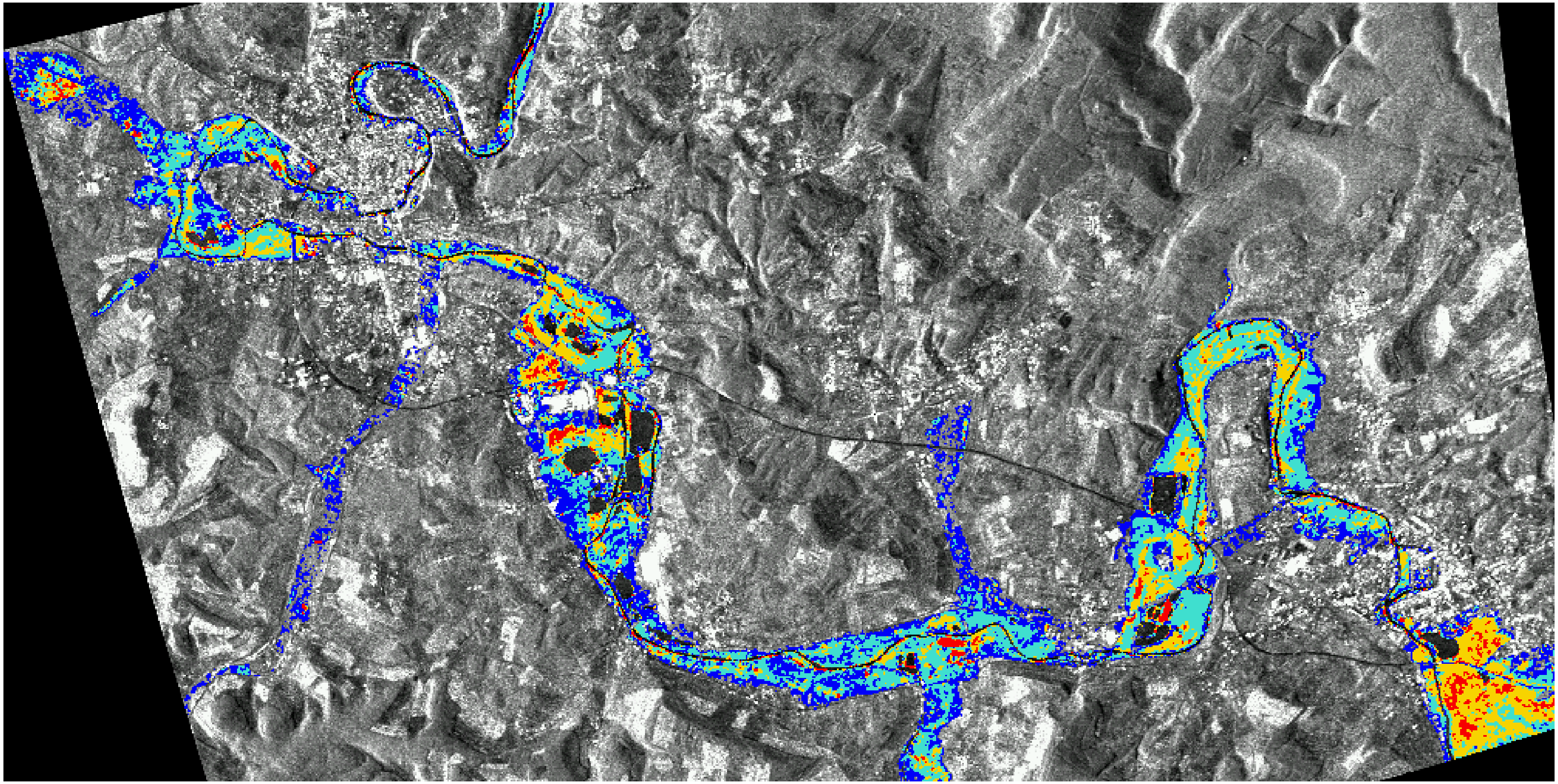
ERS Mosaïque over the Oder river : Acquired 30-07 to 9-08-97

Flood mapping based on ERS 1 - 2

Camargue flood event: November 1993



Flood mapping based on ERS 1 - 2



ERS: experimental 3 days mode from winter 93 to spring 94
Map of water permanency during the Meuse flood draw off in spring 1994
(Yésou et Chastanet, 2000)

Few examples of Coherence exploitation

Flood mapping based on ERS 1 - 2 INSAR

Aude 96 flood event

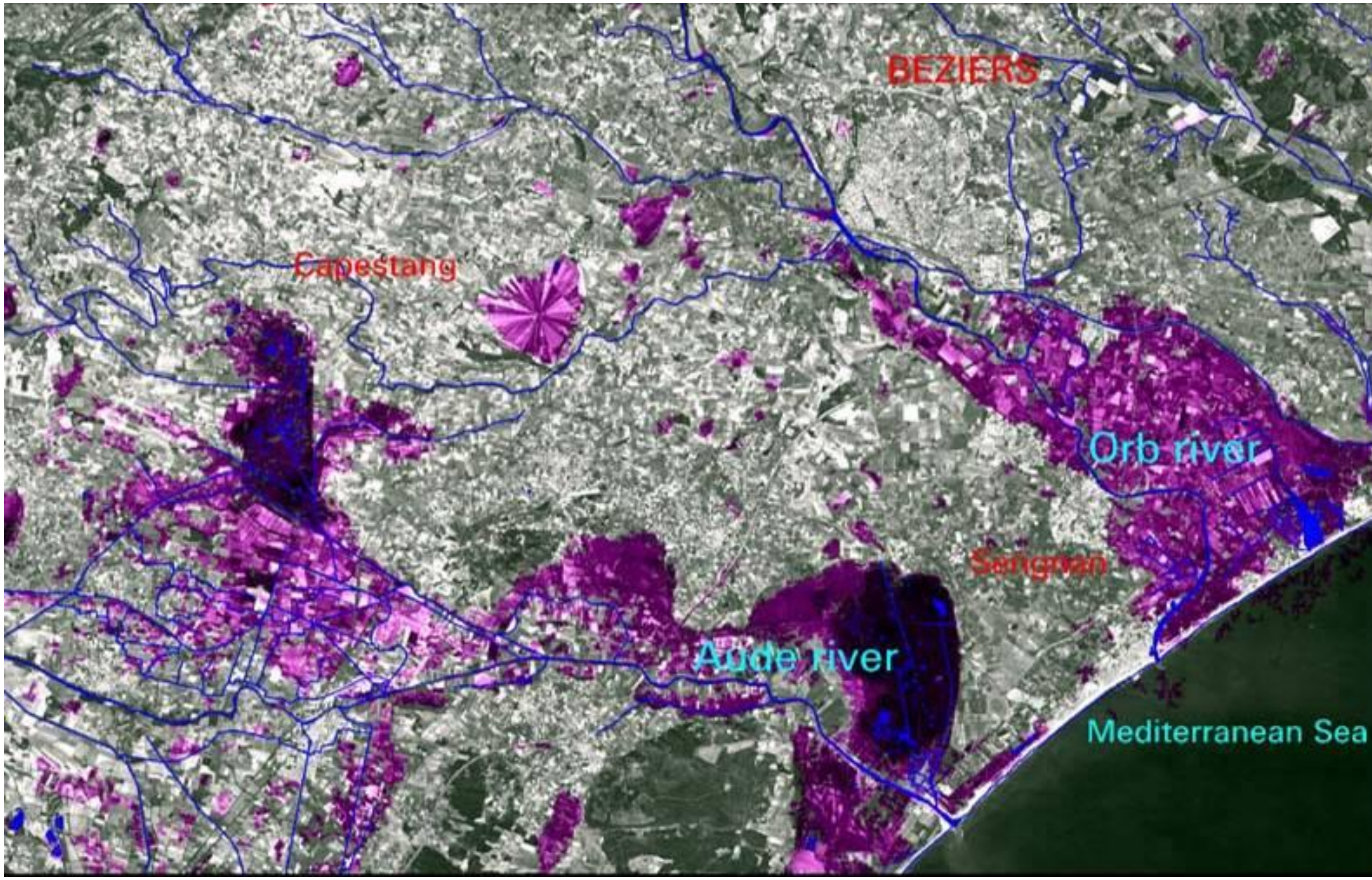
ERS-2: 7 8 1995
ERS-2: 29 01 1996
ERS-1: 28 01 1996

Acquisition near the maximum of the flood

2 consecutives images

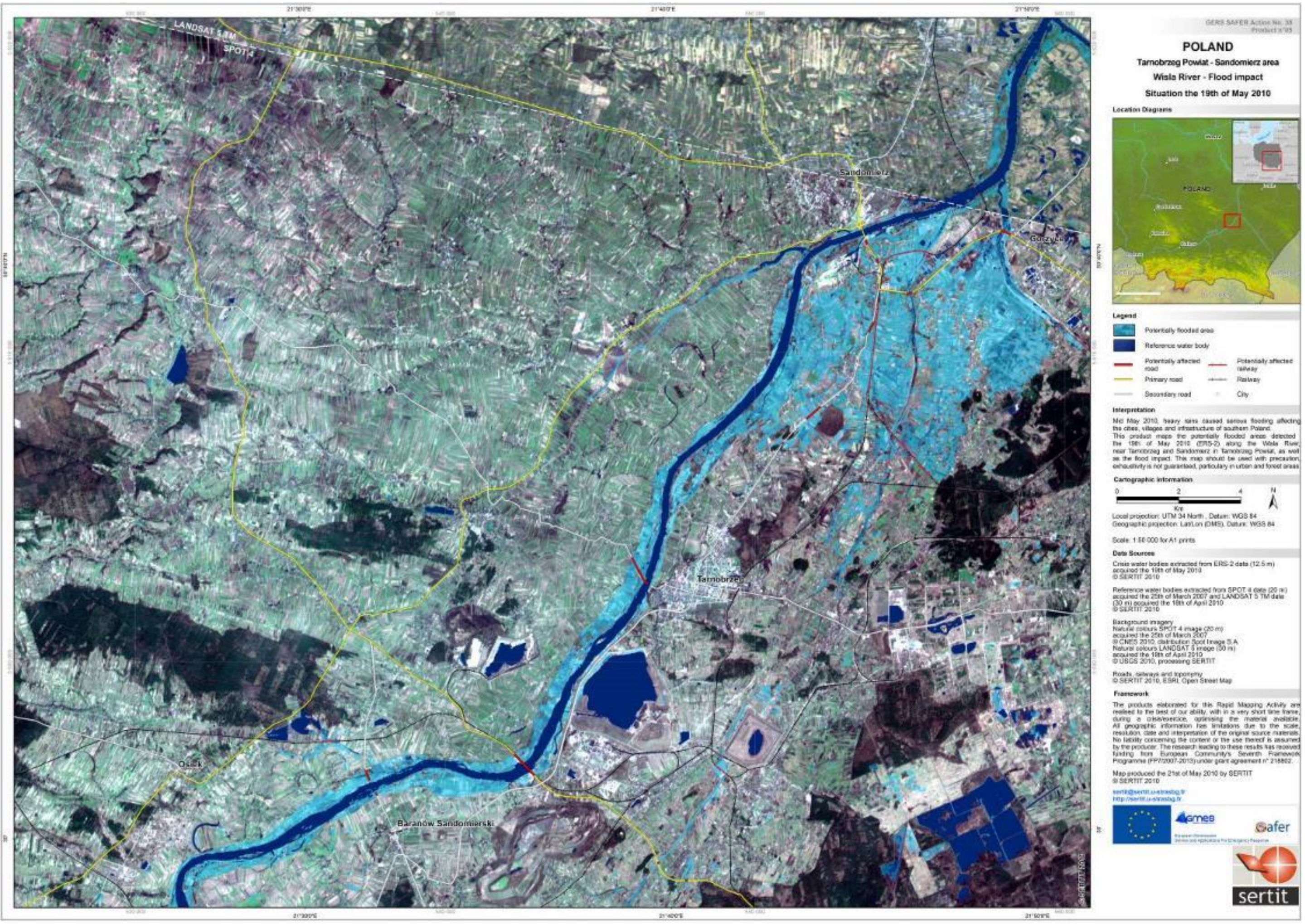
Exploitation of the phase information: lost of coherence on water surface

(Marinelli et al., 97 ; Nico et al., 2000 ; Sarti, 2004)



(© CEMAGREF 1996 , © ESA, 1996)

Last flood mapping based on ERS 2



Thanks to ERS2 availability

1srt image acquired

1srt product generated over Poland Spring 2010 Flood

19 May 2010

ASAR ENVISAT: flood mapping

ENVISAT water recognition potential

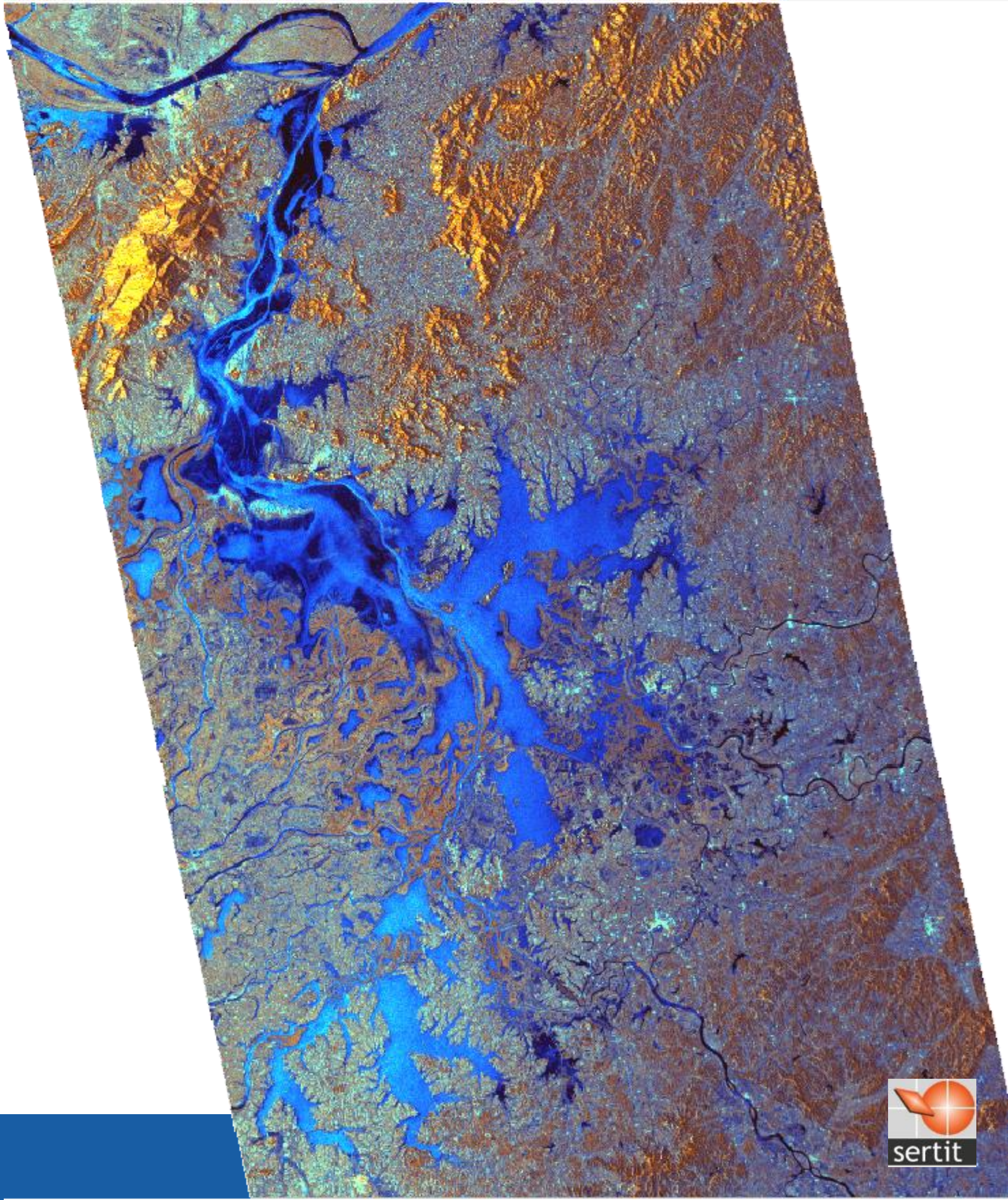
DRAGON ESA MOST

APP image

Stripe of two images

HH-HV (diff HH-HV)

20-02-05

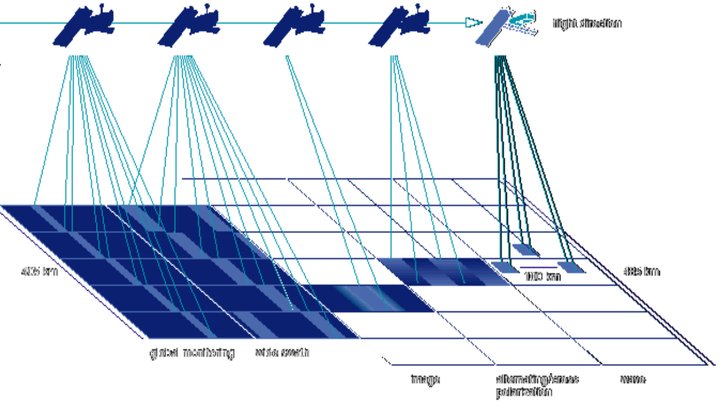


ASAR ENVISAT: flood mapping

ASAR ENVISAT good successor of ERS with improvements:

1 – Better water recognition potential

- **most of case HH mode >> HH-HV >>>>> VV**
- **particular case of S1 : HV >> HH >>>>VV**



2- Better revisit thanks to:

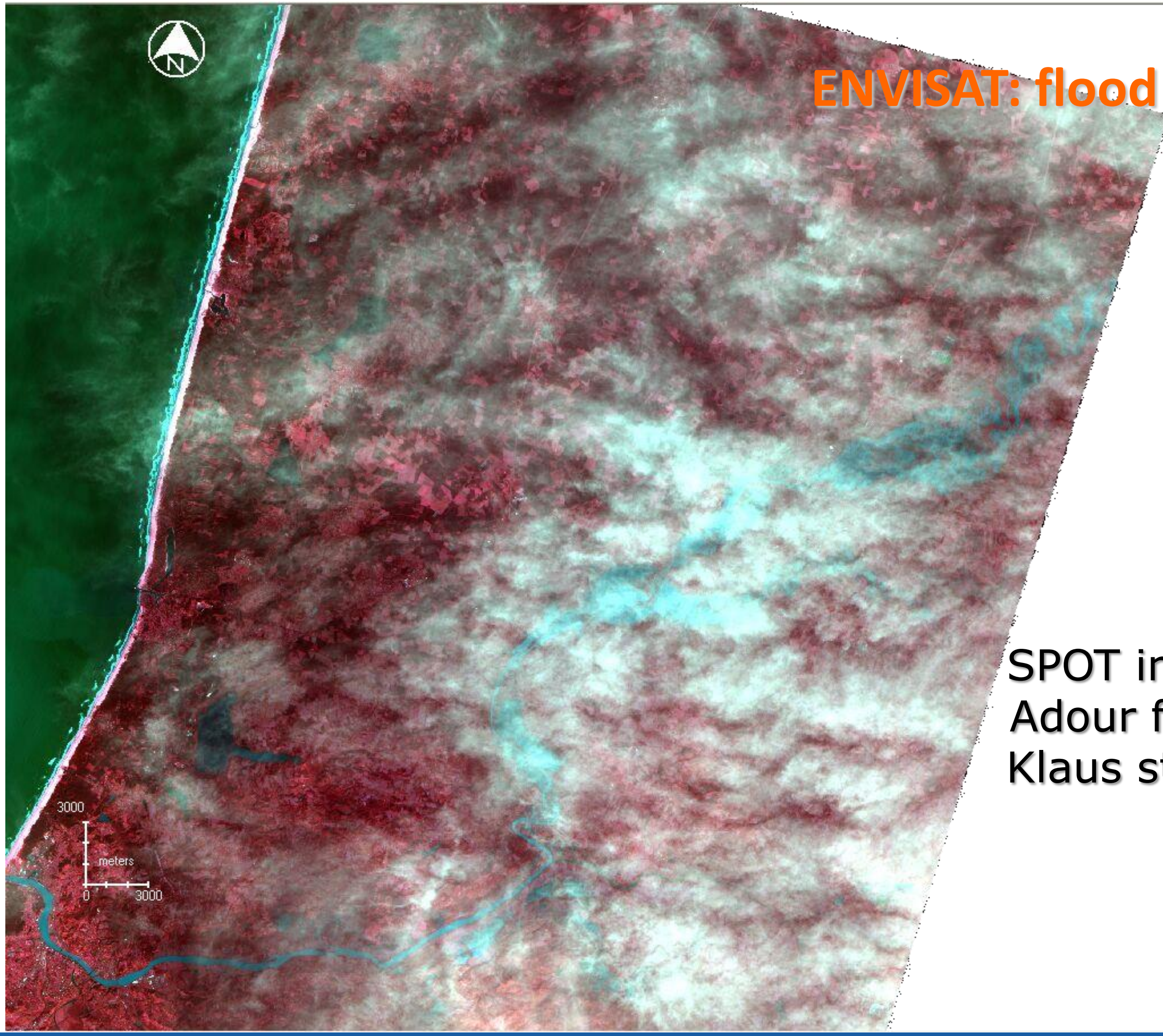
- **Multi beams**
- **Wide Swath mode**

3 – Flooded low vegetation recognition

See for example Ferrazzoli P., Karszenbaum H., Grings F.

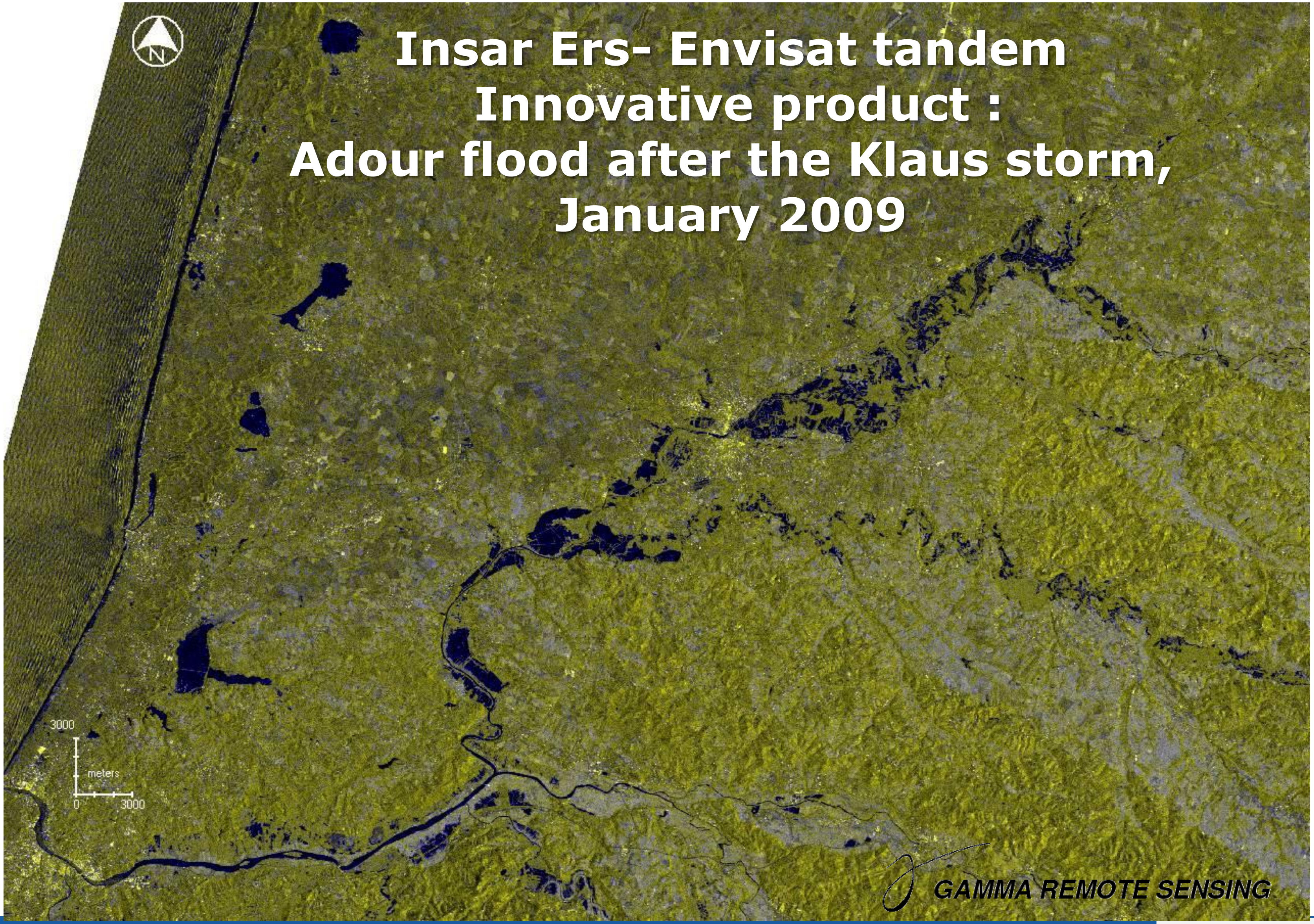
Also in some favourable cases, possibility of identification of flooded forest thanks to double-bounce phenomenon

ENVISAT: flood rapid mapping



SPOT image over the Adour flood after the Klaus storm, January 2009

Insar Ers- Envisat tandem Innovative product : Adour flood after the Klaus storm, January 2009



Université de Strasbourg

On going SAR Missions

2007 : June launches constellation Cosmo Skymed constellation , and Terra SAR X
December: Radarsat 2

2012 : launch of RISAT (ISRO) , operational mode in 2015

2014 : Launch ALOS 2, bande L

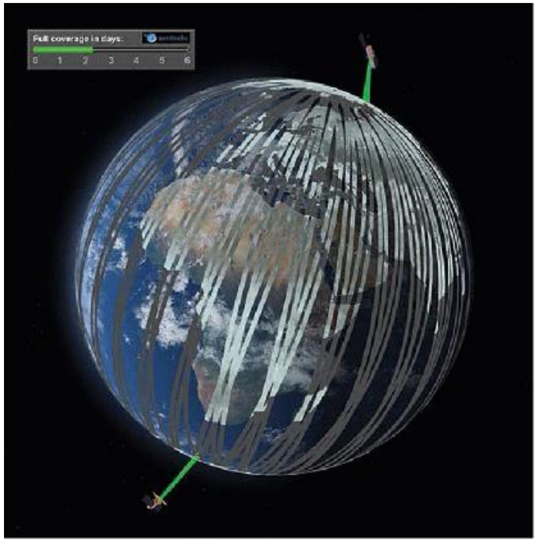
2014-2016: Launches of Sentinel 1A and 1B (Constellation Copernicus)

2016 : Gaofeng 3, C band (Quad Pol)

SENTINEL 1

The Sentinel-1 series : part of the GMES programme
Sentinel1A, 2014   Sentinel1B, 2016

Priority : ensure continuity for C-band data
Improvement of SAR signal (30% better than ENVISAT)



Multi mode

- Strip map: 80 km swath , 5m
- Interferometric Wide swath mode IW, 250km, 20 m
- Extra wide EW Swath , 400 km , 25x100 m
- Wave mode, WV, low data rate, 5x20m
- Swath 250 km

Polarisation modes:

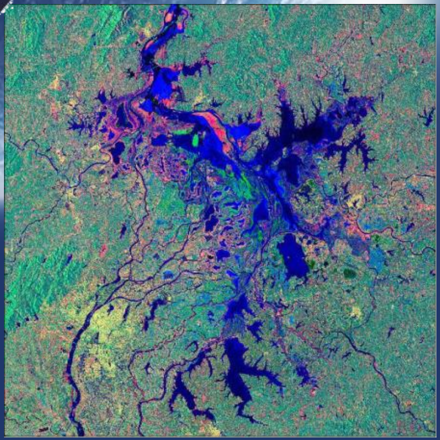
- VV or HH in wave mode
- Selectable dual pol for all other mode HH+HV; VV+VH

Exploited satellite data

• Sentinel1 mission

Launch date: Sentinel1A: April, 3, 2014, Sentinel 1B: April, 25, 2016

Nominal end of the mission: 2028 + S11D and S1 1C satellites (2035?)

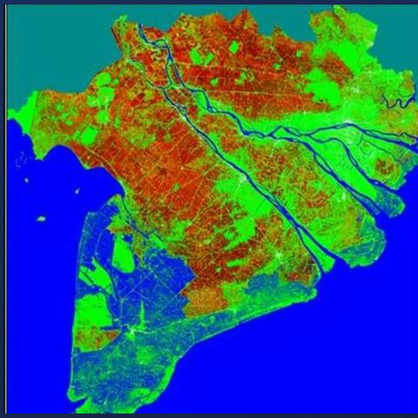


Mission objectives: part of Copernicus constellation:

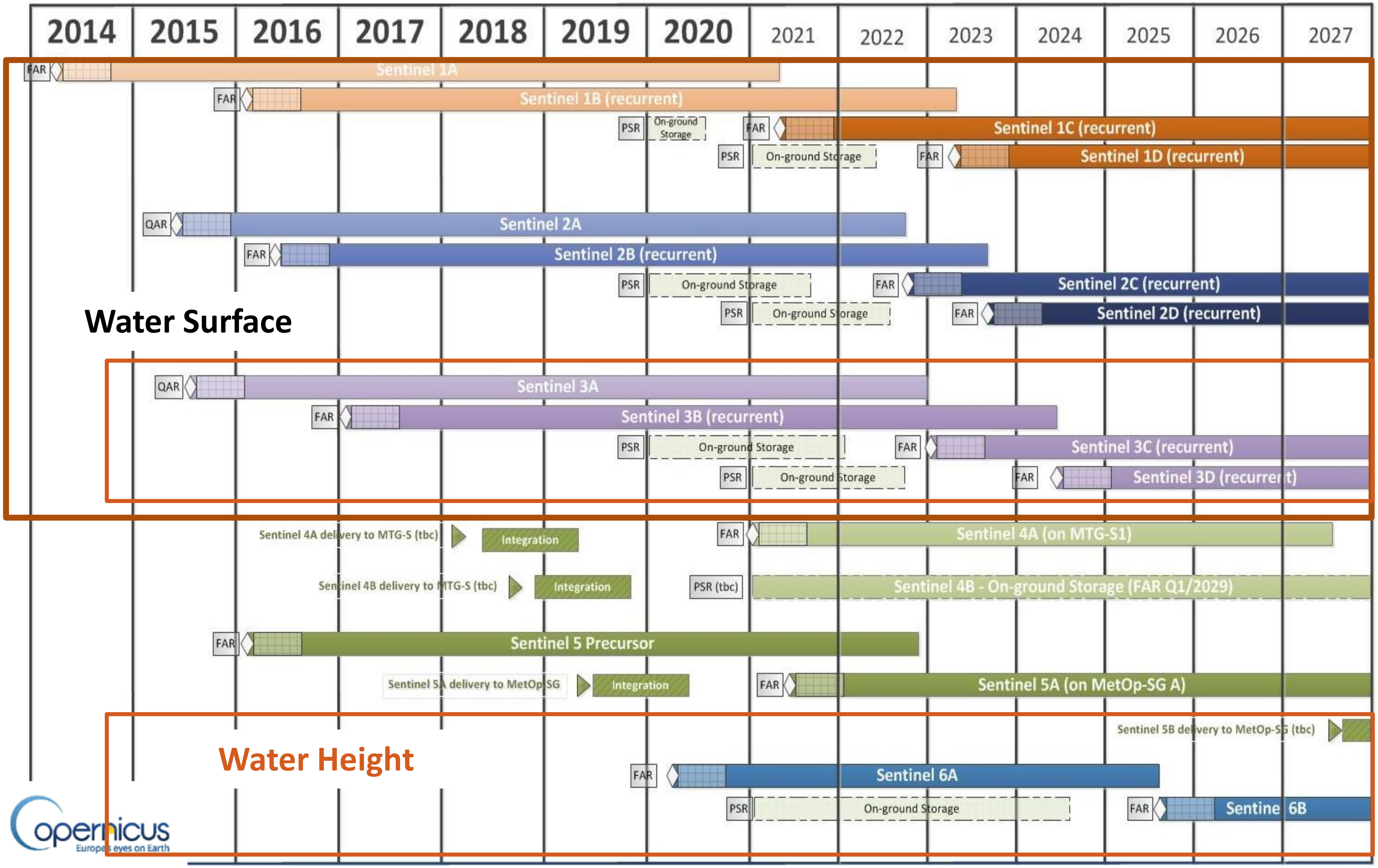
- **provide enhanced revisit frequency, coverage, timeliness and reliability for operational services and applications requiring long time series.**
- **Ocean: monitoring Marine Environment, surveillance maritime transport zones**
- **Monitoring polar environment: ice shelves, glaciers**
- **Changing lands: agriculture/forestry**
- **Emergency response: floods, earthquake, landslides**

Sentinel 1 main innovations:

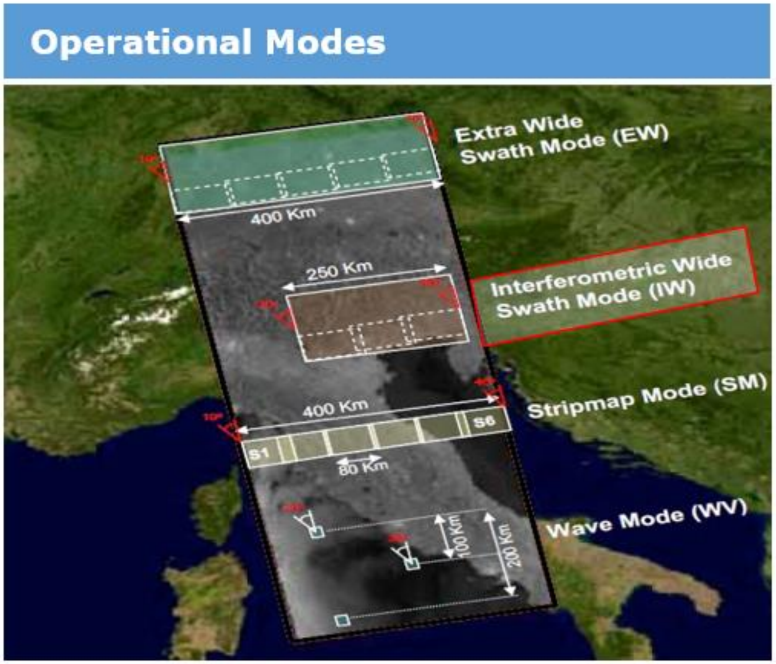
- **Nominal 12 days revisit , 6 days for constellation**
- **Multimode: resolution 5m in SM mode and 20m in IWS mode**
- **Selectable dual polarization**
- **Systematic acquisition and open & free access**



Copernicus missions (ESA) exploitable for hydrology



SENTINEL 1



GRD Level 1 product resolution	Swath Width	Polarisation
50m (3 ENL)	> 400 km	HH+HV or VV+VH
20m (5 ENL)	> 250 km	HH+HV or VV+VH
9m (4 ENL)	> 80 km	HH+HV or VV+VH
50m (140 ENL)	20x20 km² at 100 km spacing	HH or VV

Interferometric Wide (IW)
default mode over land

SENTINEL 1

Acquisition mode	Product type	Resolution class	Resolution (range x azi) (m)	Pixel spacing (range x azi) (m)	No of looks (range x azi)	ENL
SM (Stripmap Mode)	SLC	-	1.7 x 4.3 to 3.6 x 4.9	1.5 x 3.6 to 3.1 x 4.1	1 x 1	1
	GRD	FR	9 x 9	4 x 4	2 x 2	3.9
		HR	23 x 23	10 x 10	6 x 6	34.4
		MR	84 x 84	40 x 40	22 x 22	464.7
IW (Interferometric Wide Swath)	SLC	-	2.7 x 22 to 3.5 x 22	2.3 x 17.4 to 3 x 17.4	1	1
	GRD	HR	20 x 22	10 x 10	5 x 1	4.9
		MR	88 x 89	40 x 40	22 x 5	105.7
EW (Extra Wide Swath)	SLC	-	7.9 x 42 to 14.4 x 43	5.9 x 34.7 to 12.5 x 34.7	1 x 1	1
	GRD	HR	50 x 50	25 x 25	3 x 1	3
		MR	93 x 87	40 x 40	6 x 2	12
WV (Water Vapor)	SLC	-	2.0 x 4.8 and 3.1 x 4.8	1.7 x 4.1 and 2.7 x 4.1	1 x 1	1
	GRD	MR	52 x 51	25 x 25	13 x 13	139.7

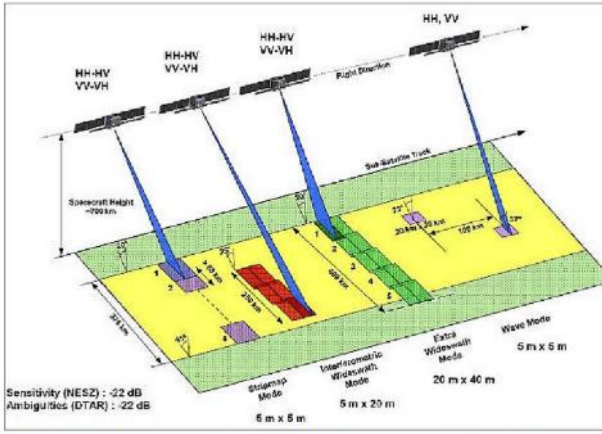
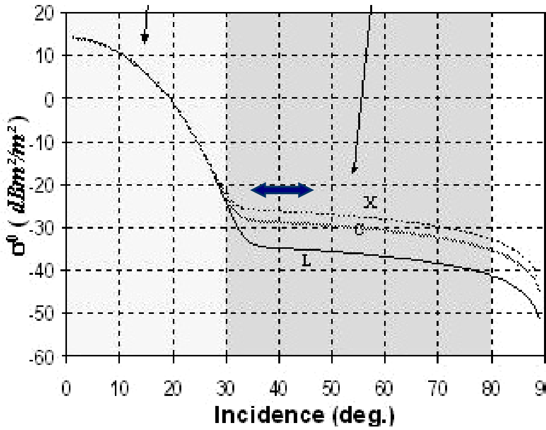
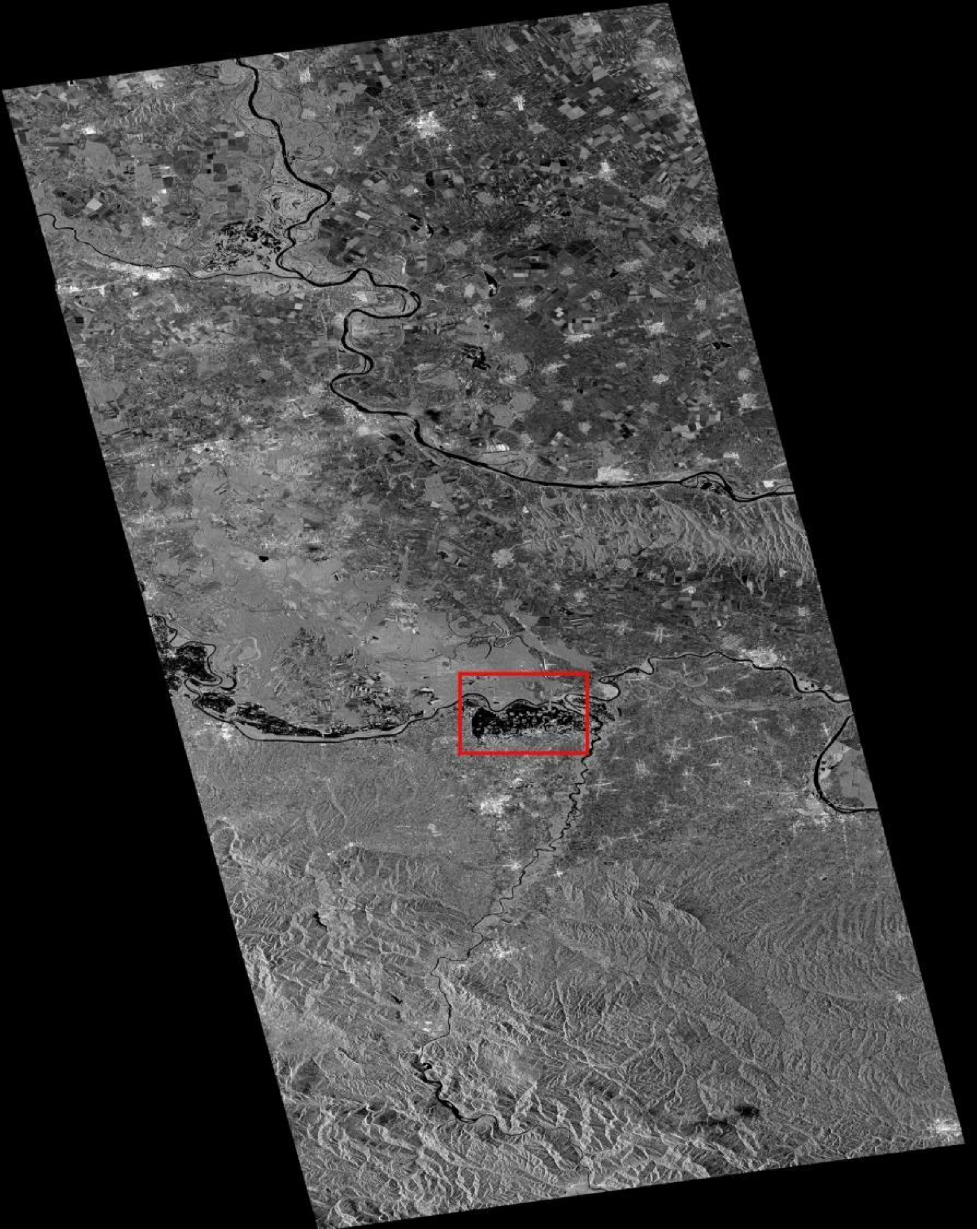


Figure 129: Overview of the Sentinel-1 C-SAR instrument observation scheme and operational support (image credit: ESA)



Copernicus
Europe's eyes on Earth

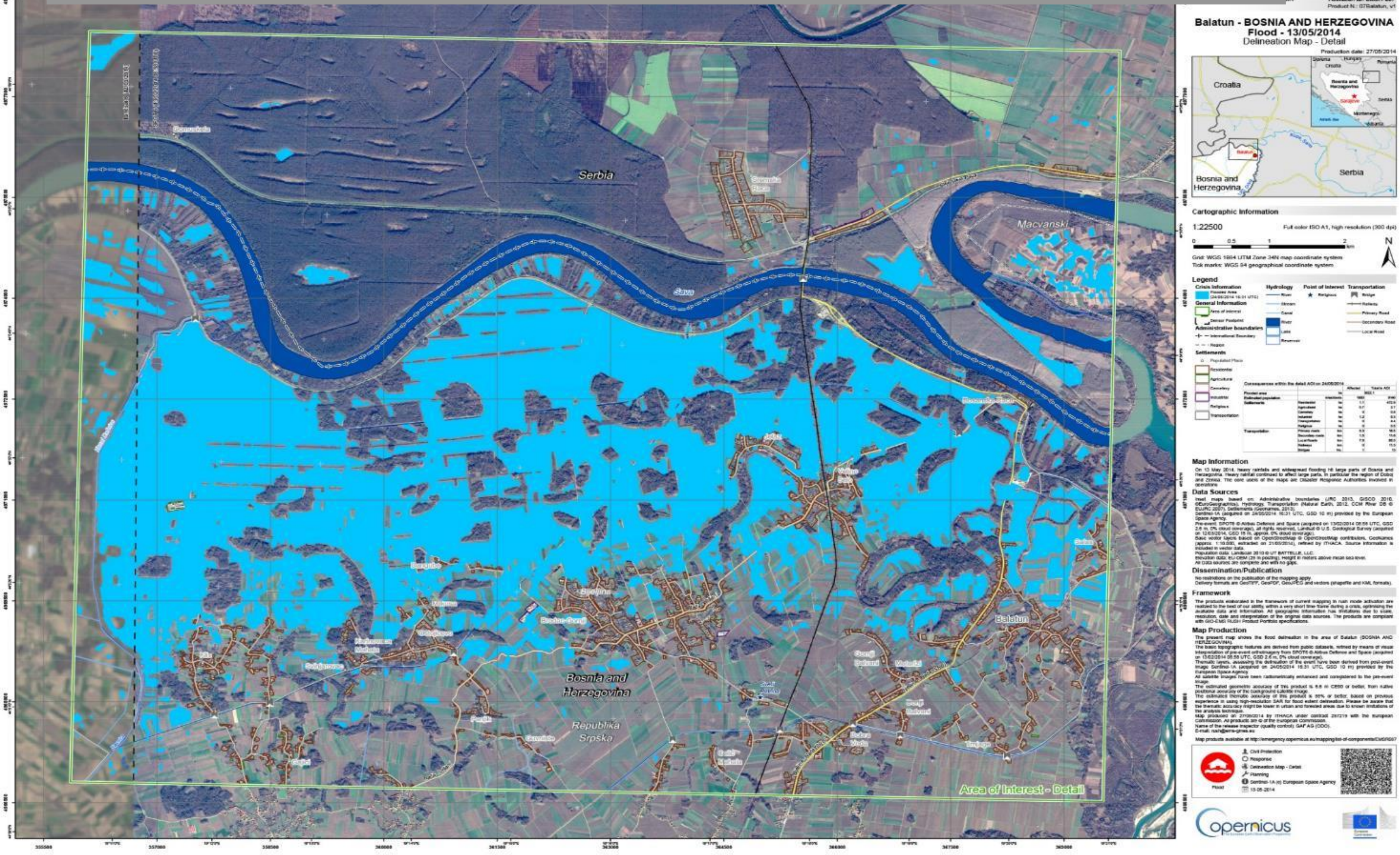


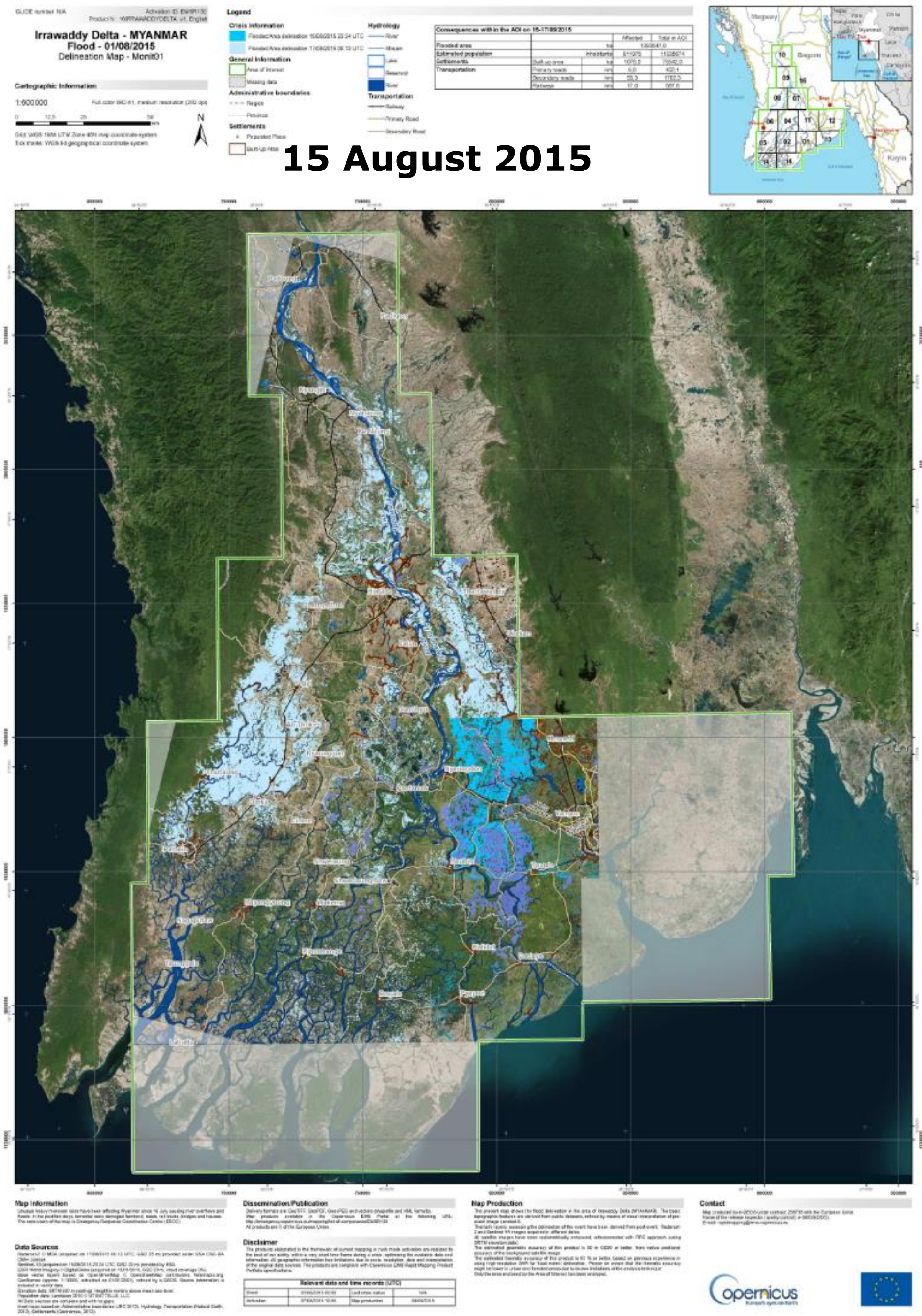
Sentinel Flood mapping: a rare example of strip map exploitation

Bosnia and Herzegovina

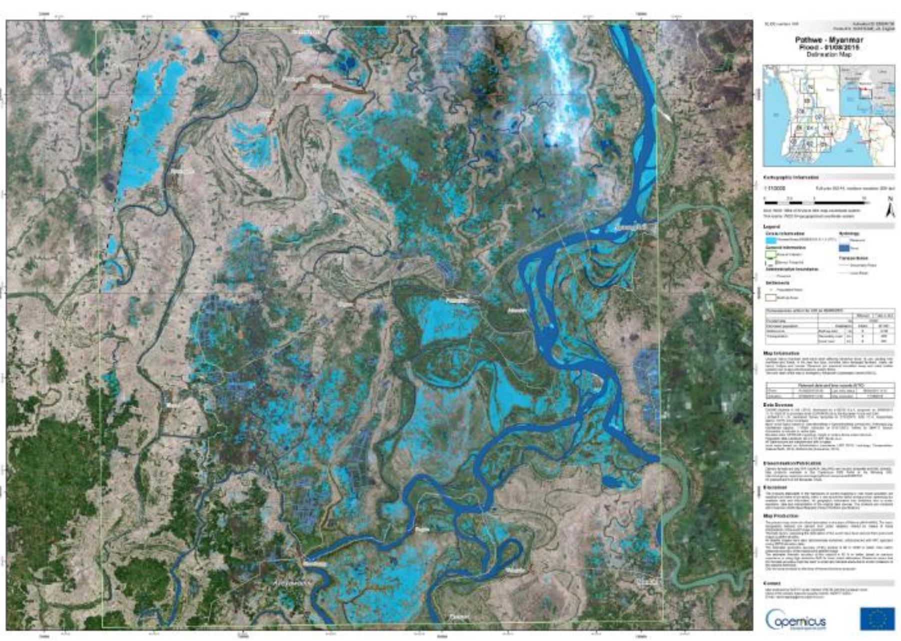
May 2014

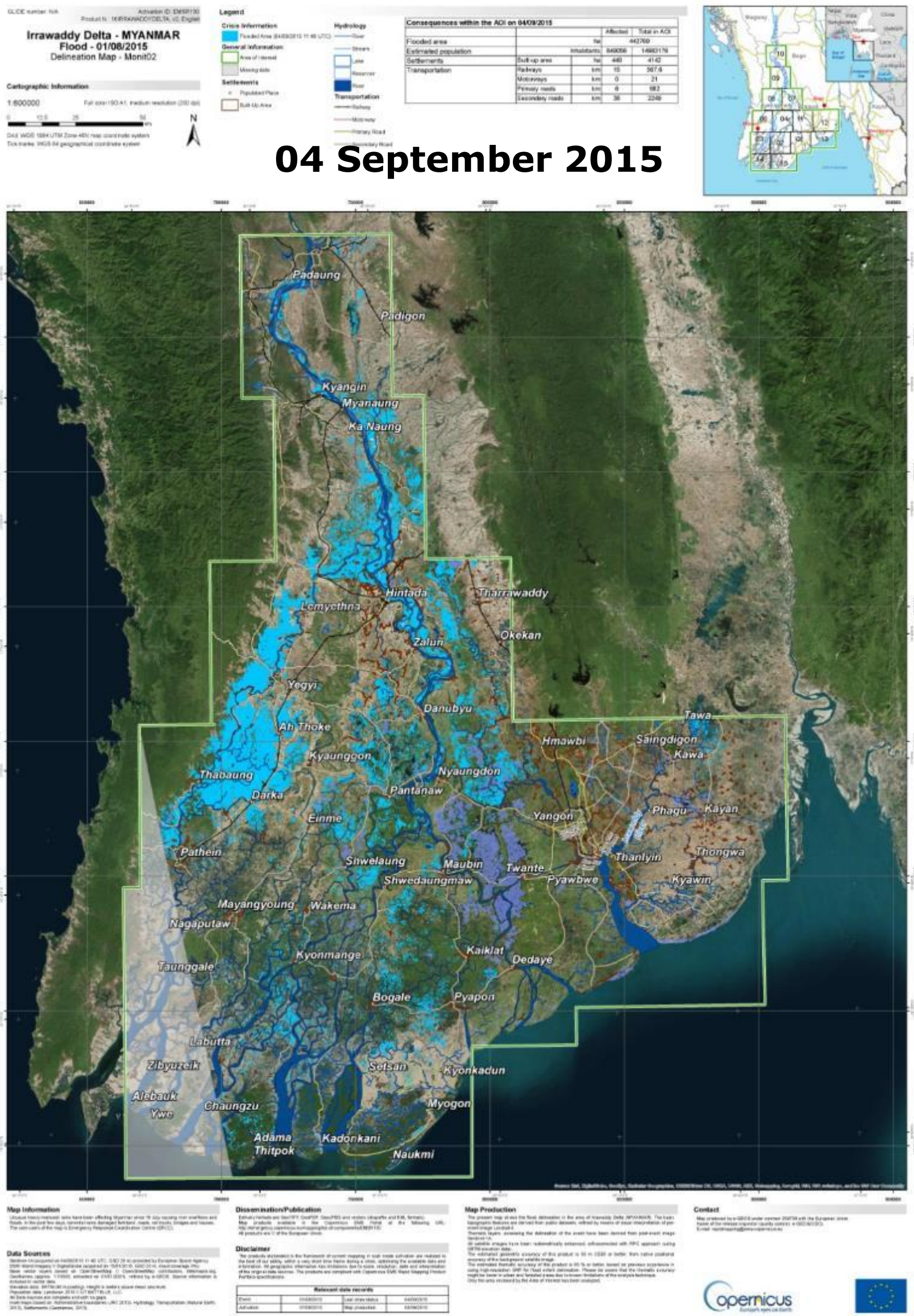
Sentinel Flood mapping: a rare example of strip map exploitation





Myanmar
Heavy monsoon rain caused river overflow and flooding in August 2015





Myanmar
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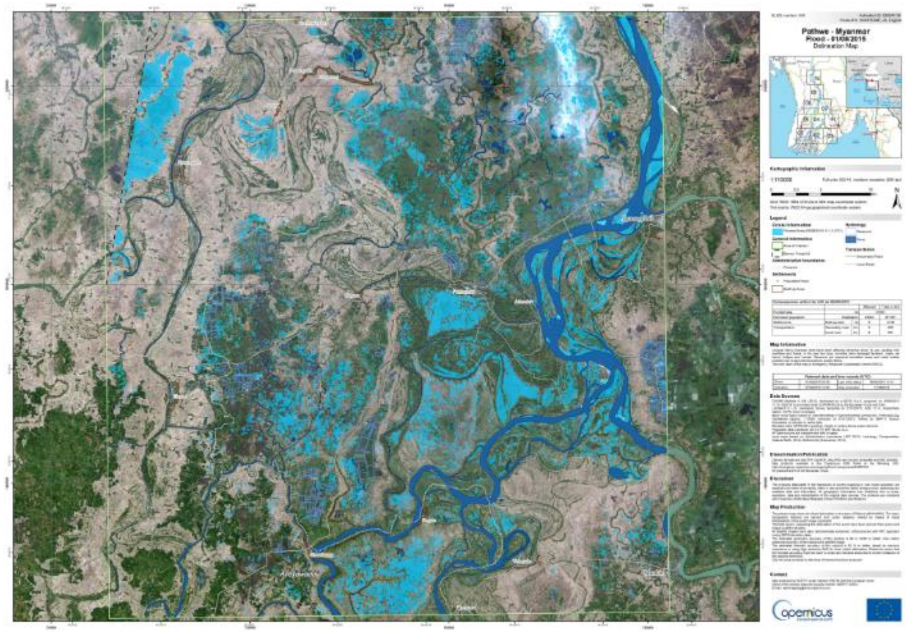
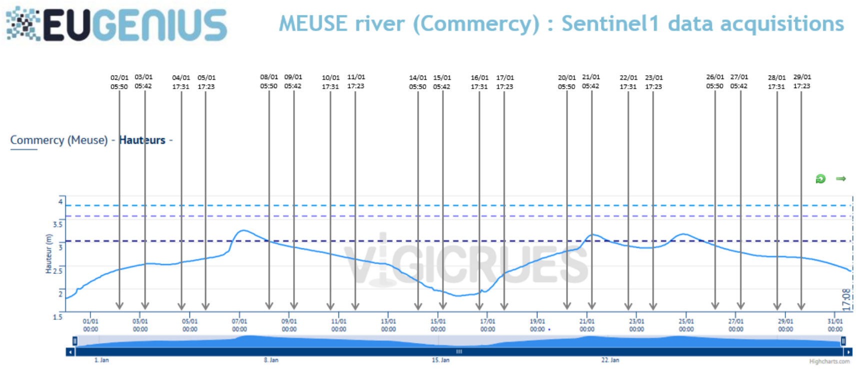
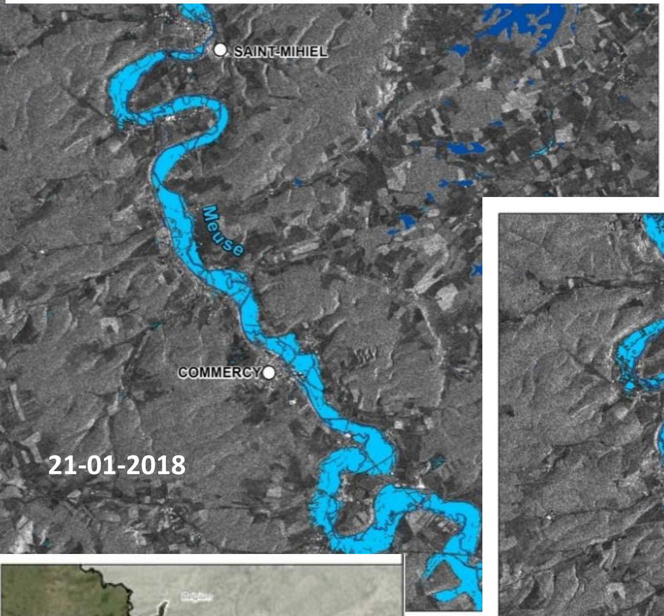
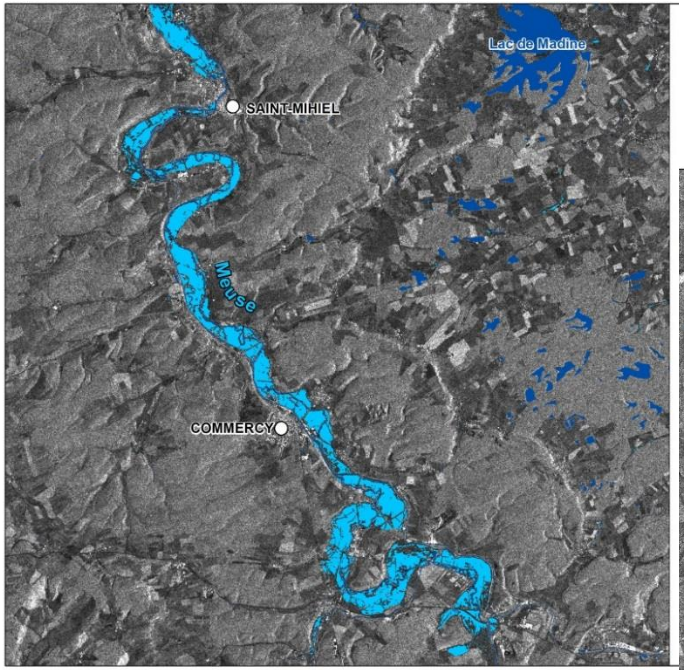


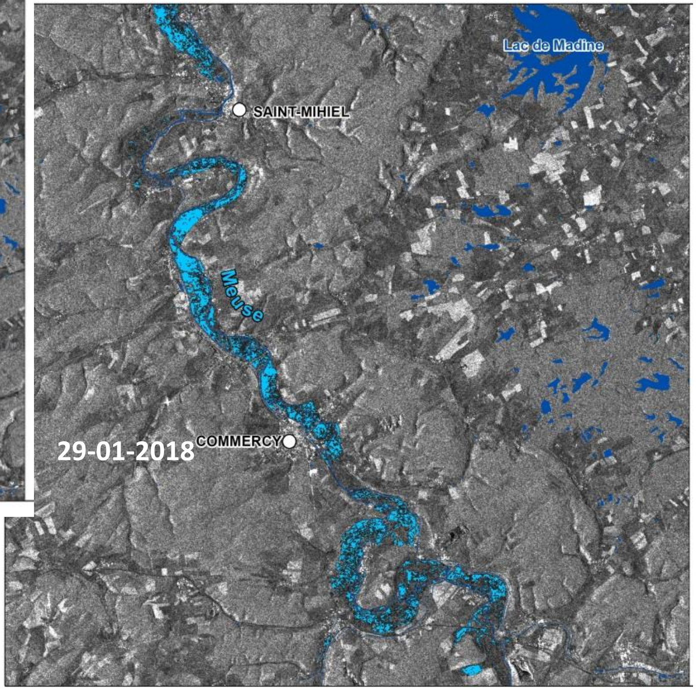
Copernicus
Europe's eyes on Earth

Sentinel1 data acquisitions during the Flood Events of January 2018 in the Grand Est region









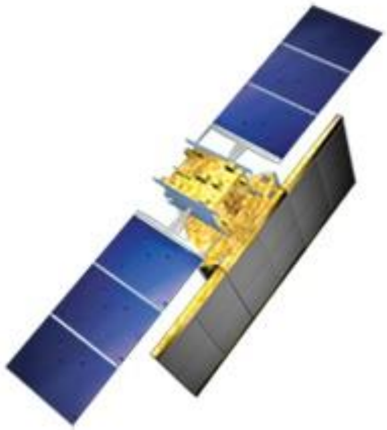
RISAT

Indian satellite

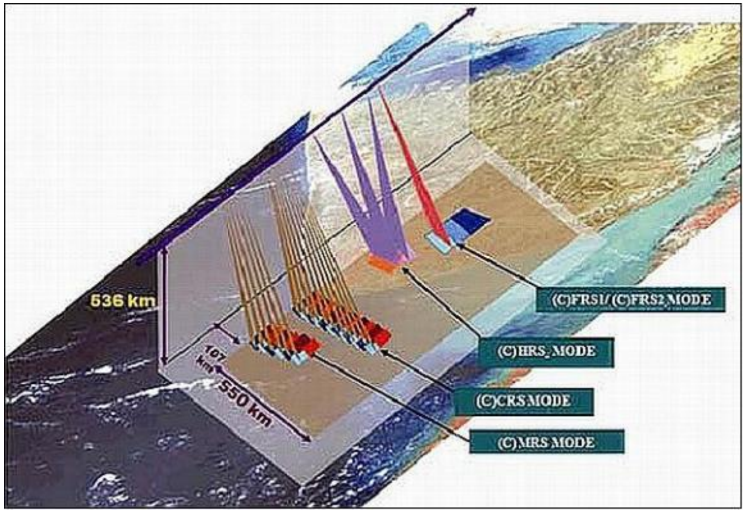
C Band

Launch: 01 May 2012

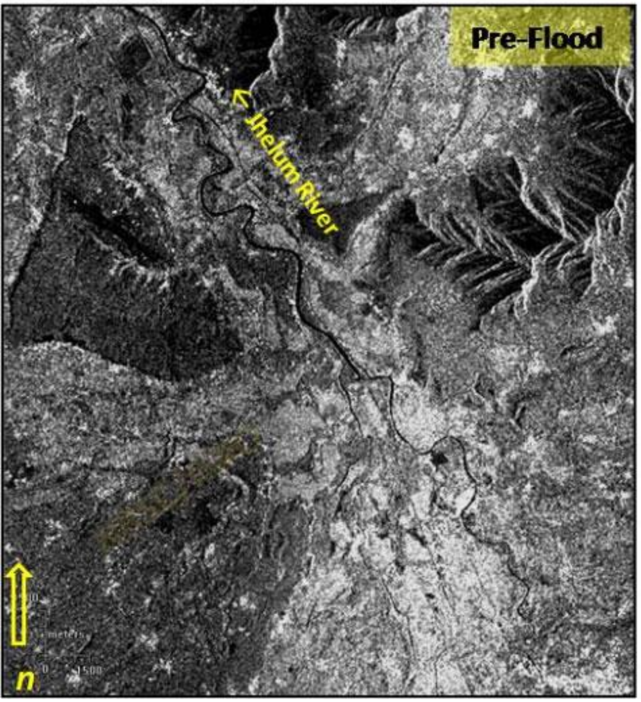
- Swath: 10 to 223 km
- Single : Dual Pol (HH+ HV) + Hyd Polarimetry



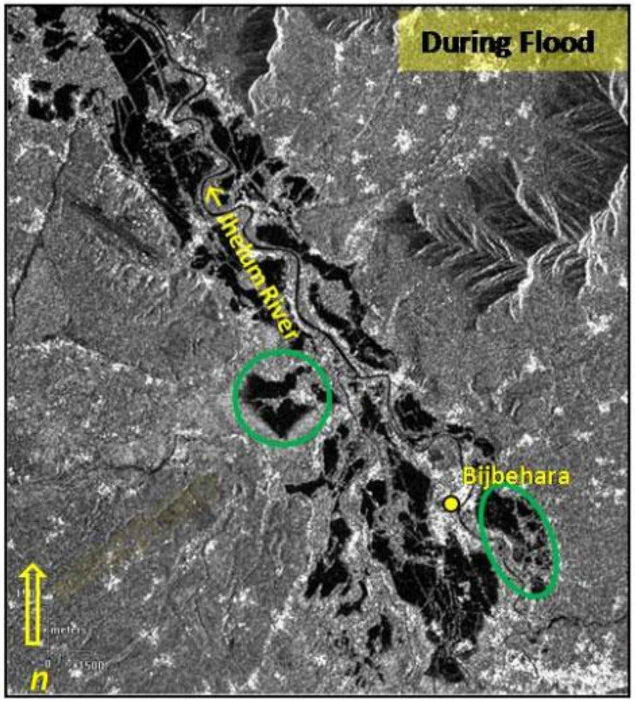
Mode		Resol (Az rang	Swath	Pol	Beam
SpotLight	HRS	>2m	10	Dual-hybrid	
Strip map 1	FRS-1	3*2m	25	Dual-hybrid	
Strip map 1	FRS-2	6*4m	25	Quad pol	
MediumScanSAR	MRS	25*8m	115	Dual-hybrid	6
Coarse ScanSAR	CRS	50*8	223	Dual-hybrid	12



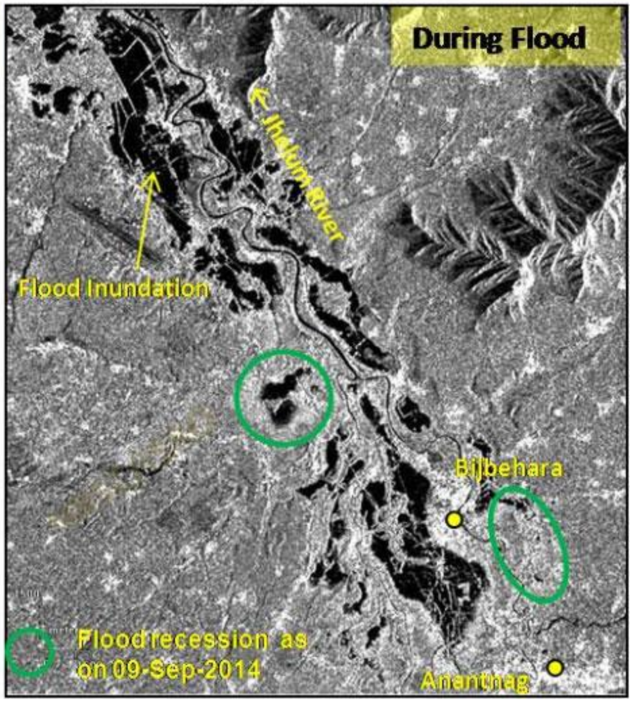
RISAT-1 image of 14-Aug-2014



RISAT-1 image of 08-Sep-2014



RISAT-1 image of 09-Sep-2014



The VHR and polarimetric SAR:

X band VHR SAR: TerraSAR, CosmoSkymed

C BAND: RadarSAT II: VHR and Full Pol

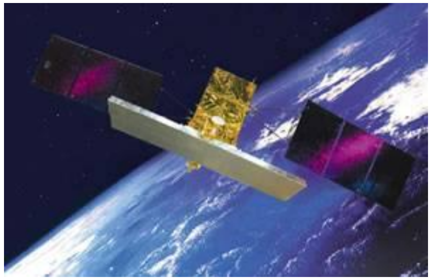
GAOFENG 3: VHR and Full Pol

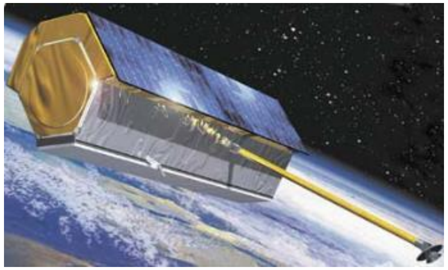
L Band : PALSAR II bi & Full Pol, large swath ScanSAR mode

The VHR and polarimetric SAR: TerraSAR, CSK

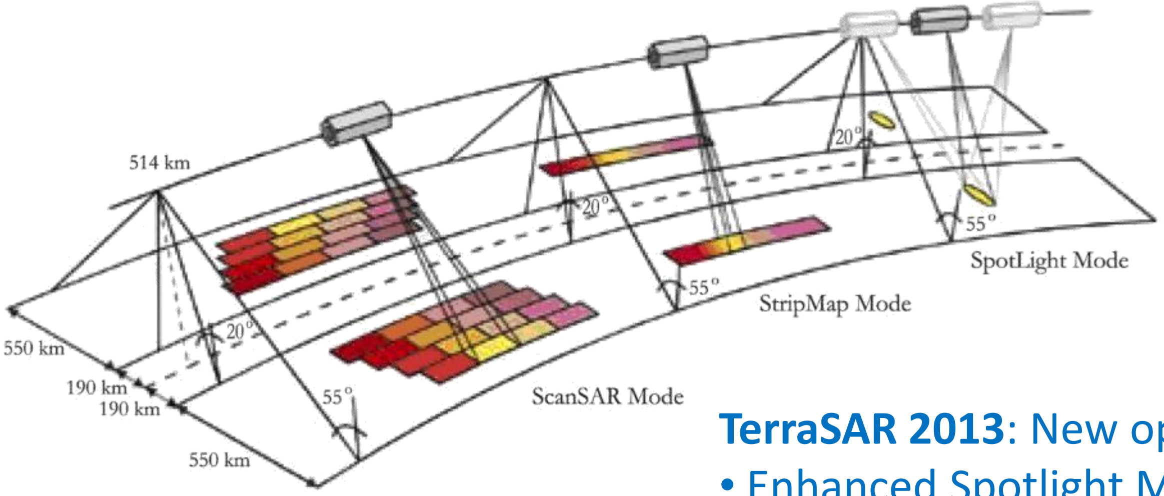
X band VHR satellites

- **Cosmo-Skymed:** Italian, Launch: 08-06-07 , Constellation of 4 Dual civilian-military
- **Terra SAR:** German, Launch: 15-06-07





Multi mode, Spotlight, Stripmap, ScanSar
Pol capabilities

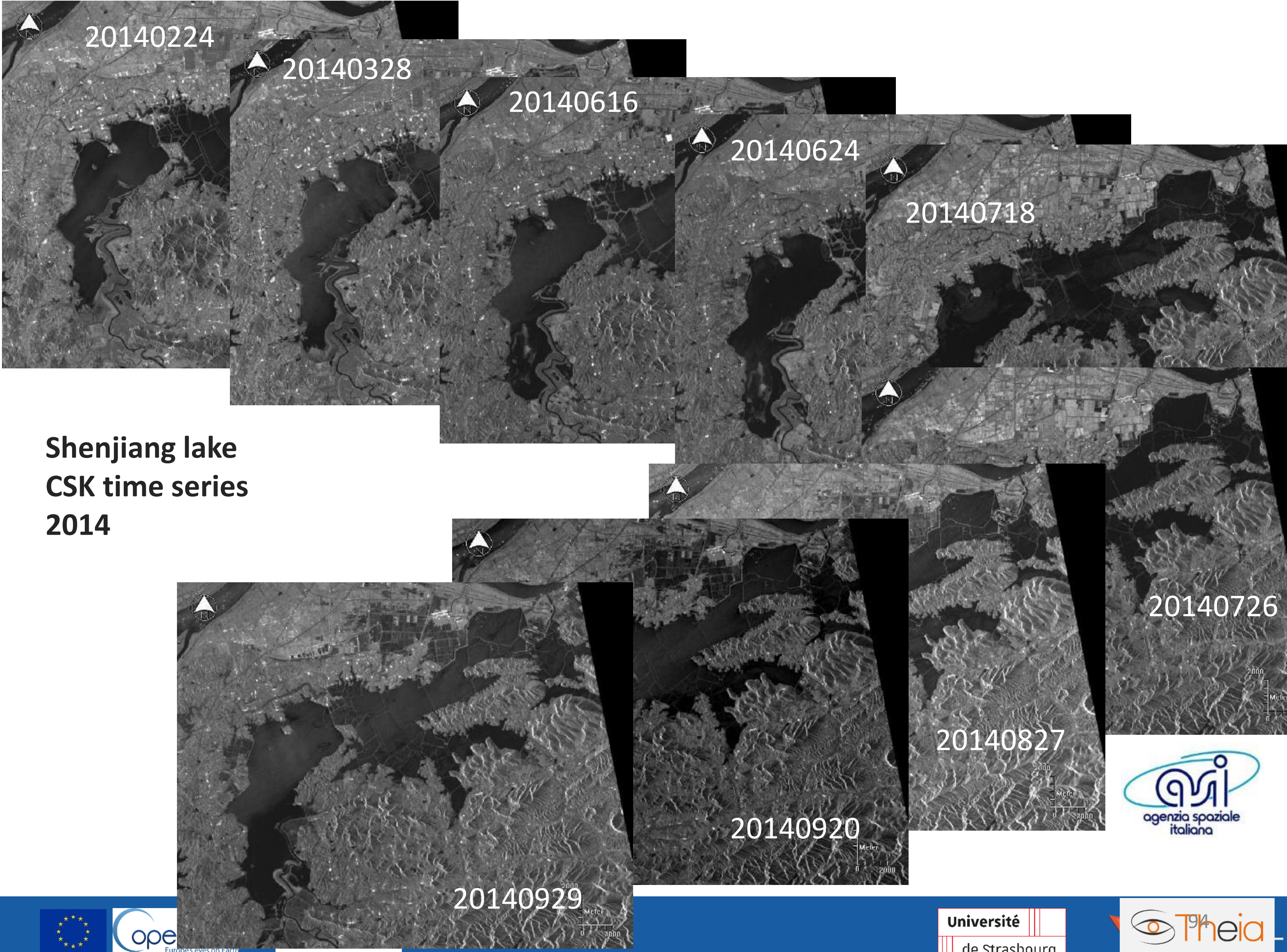


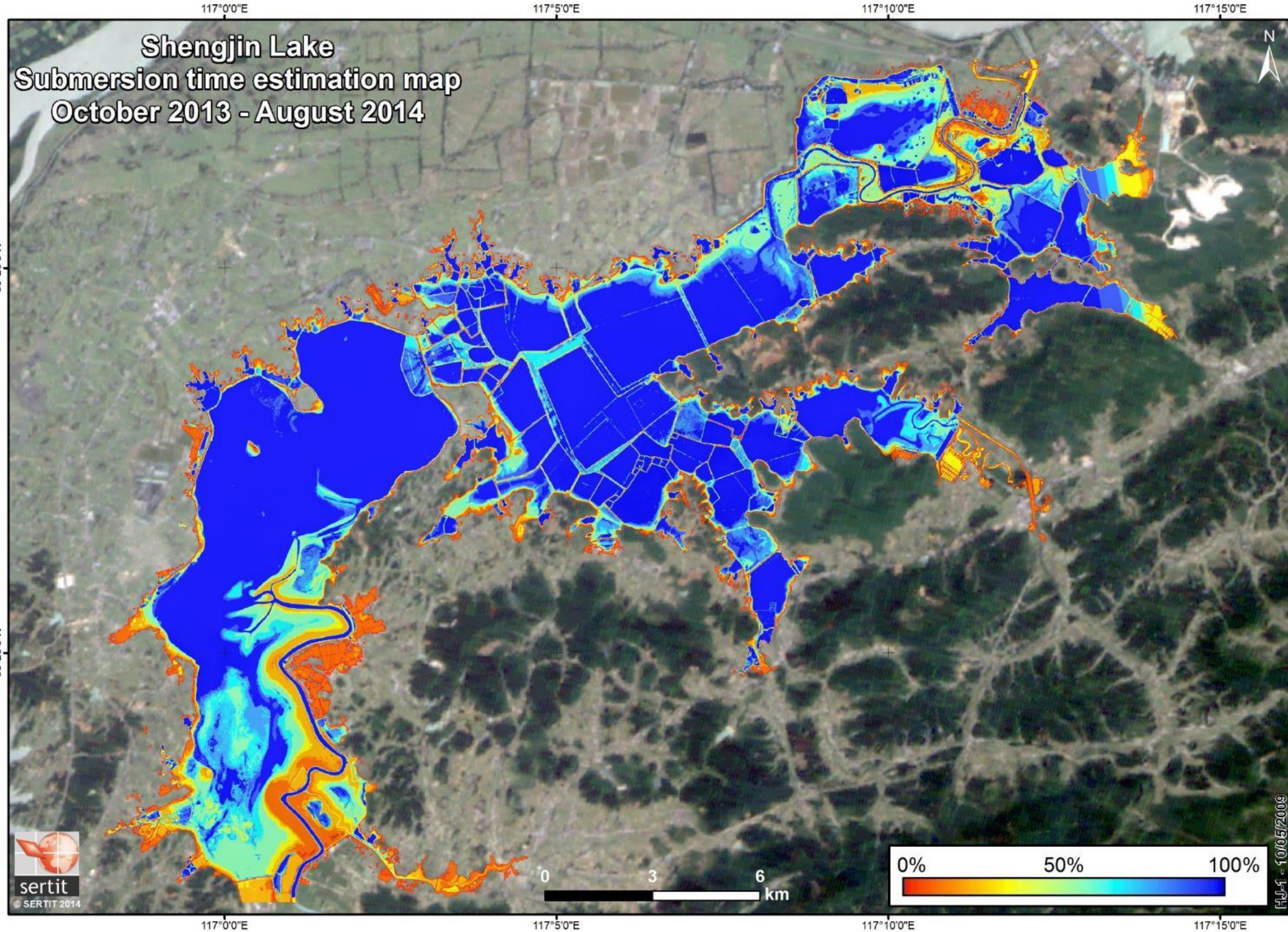
TerraSAR 2013: New operational Imaging Modes

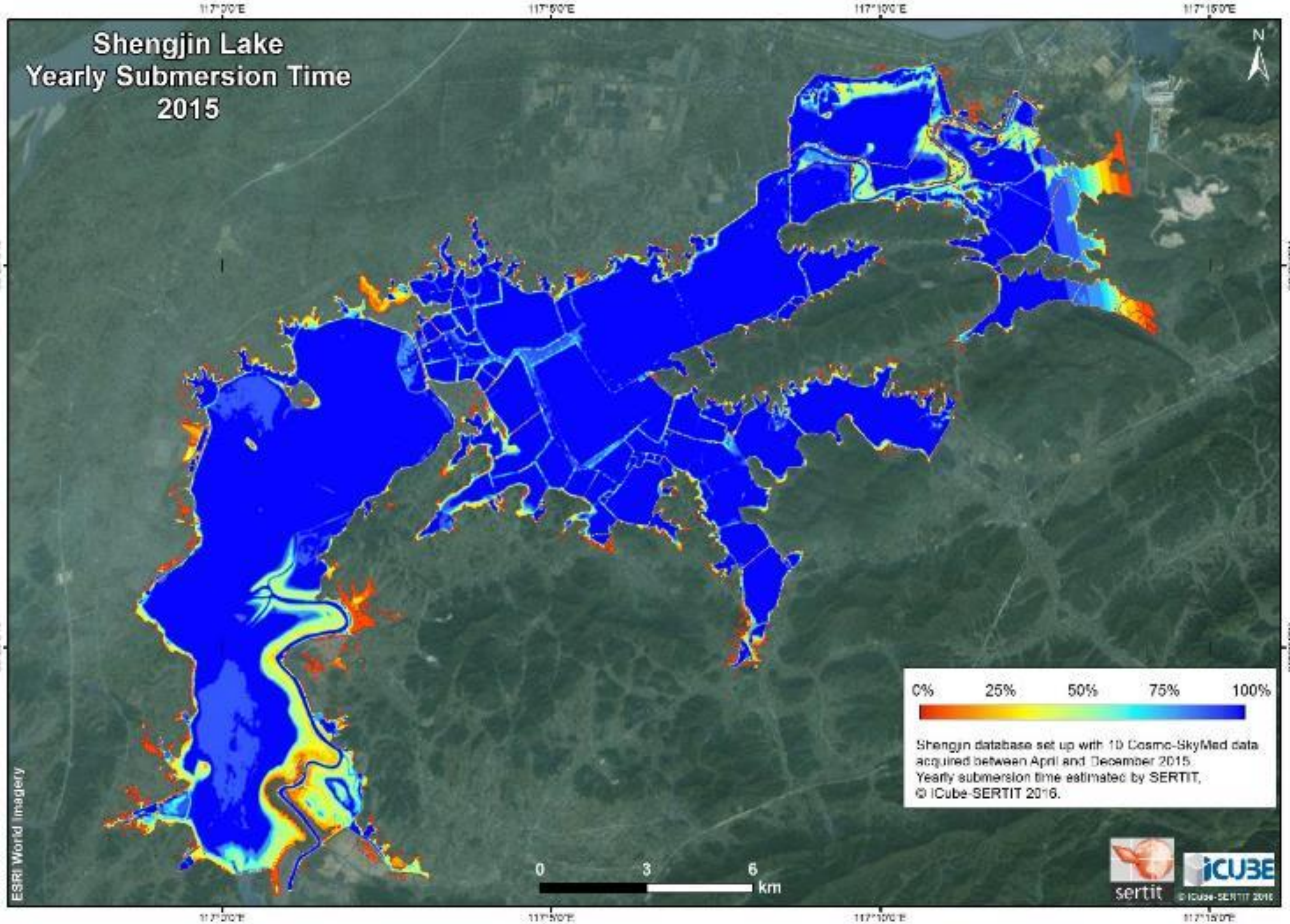
- Enhanced Spotlight Mode (Starring Spotlight).
- ScanSAR :expanded swath width (200 instead of 100km).

The VHR and polarimetric SAR: TerraSAR, CSK

Shenjiang lake
CSK time series
2014



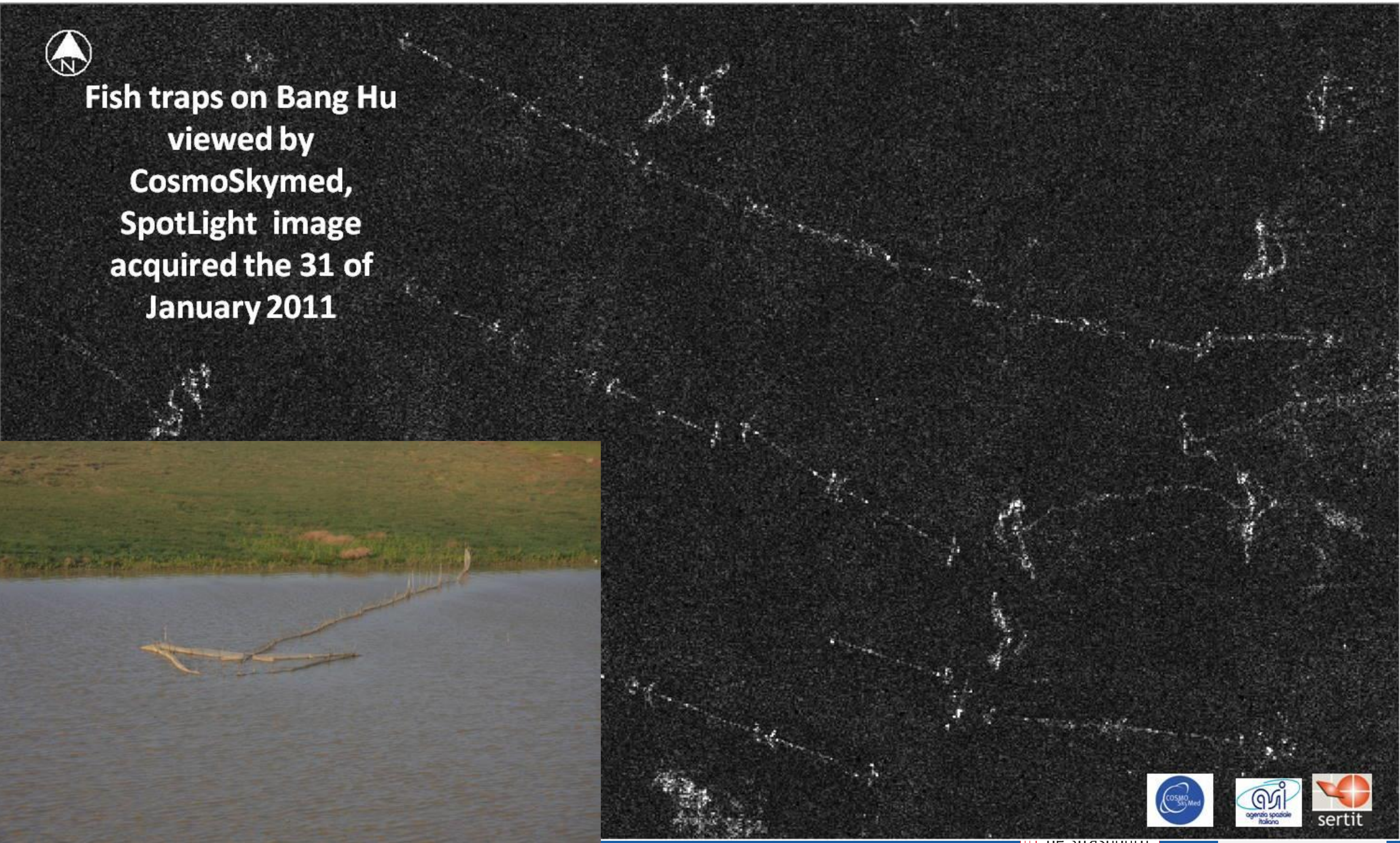

Shengjin Lake
Submersion time estimation map
October 2013 - August 2014
117°0'0"E
117°5'0"E
117°10'0"E
117°15'0"E
N
0
3
6
km
0%
50%
100%
sertit
© SERTIT 2014
HJ-1 - 10/05/2009



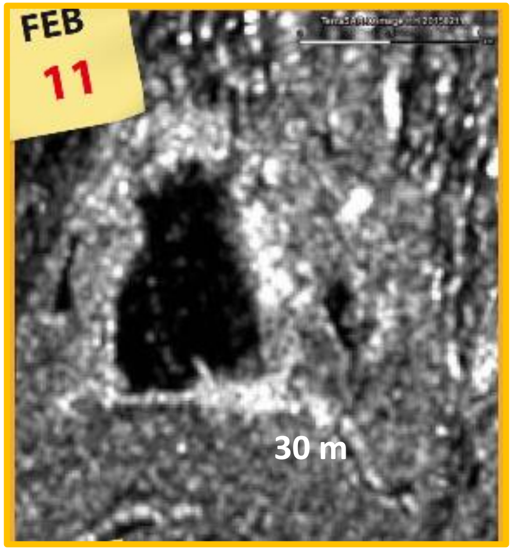
Shengjin Lake
Yearly Submersion Time
2015
0%
25%
50%
75%
100%
Shengjin database set up with 10 Cosmo-SkyMed data acquired between April and December 2015.
Yearly submersion time estimated by SERTIT.
© ICube-SERTIT 2016.
0
3
6
km
N
ESRI World Imagery
sertit
ICUBE

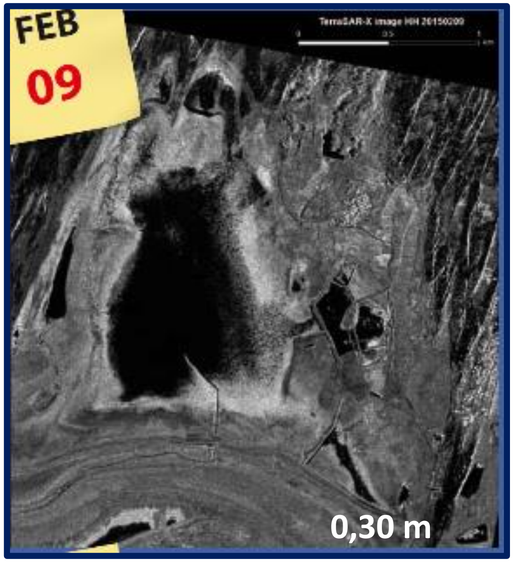
Water bodies mapping based on Cosmo Skymed Data:

Water bodies mapping based on Cosmo Skymed Data: Poyang lake China

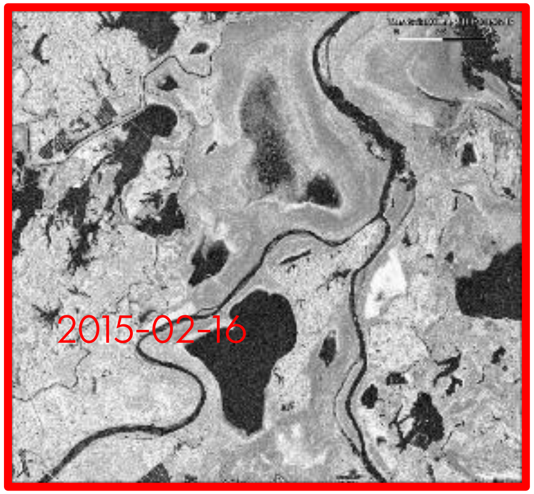


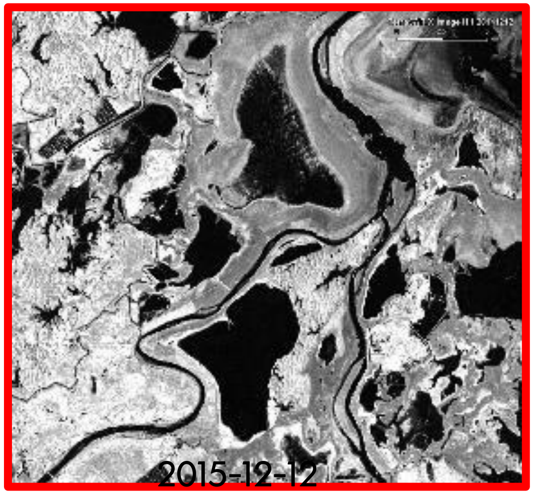
Multi resolution SAR





Multi resolution
Multi- temporelle

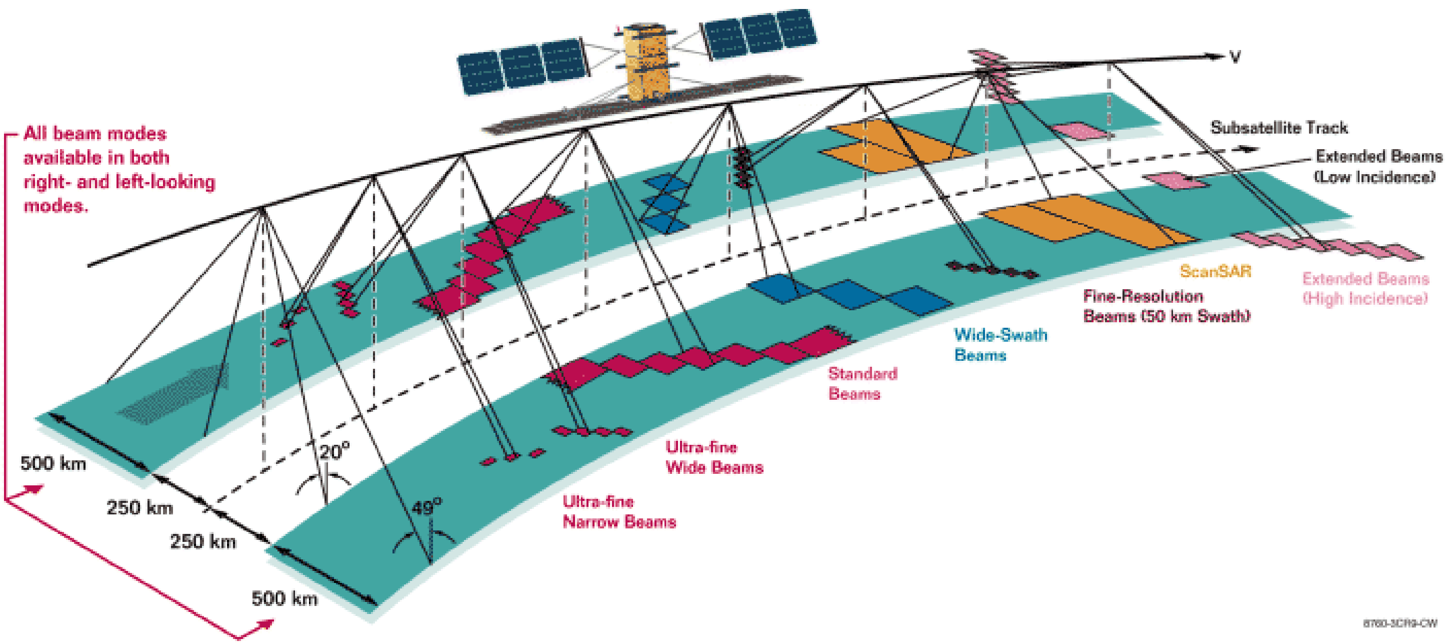


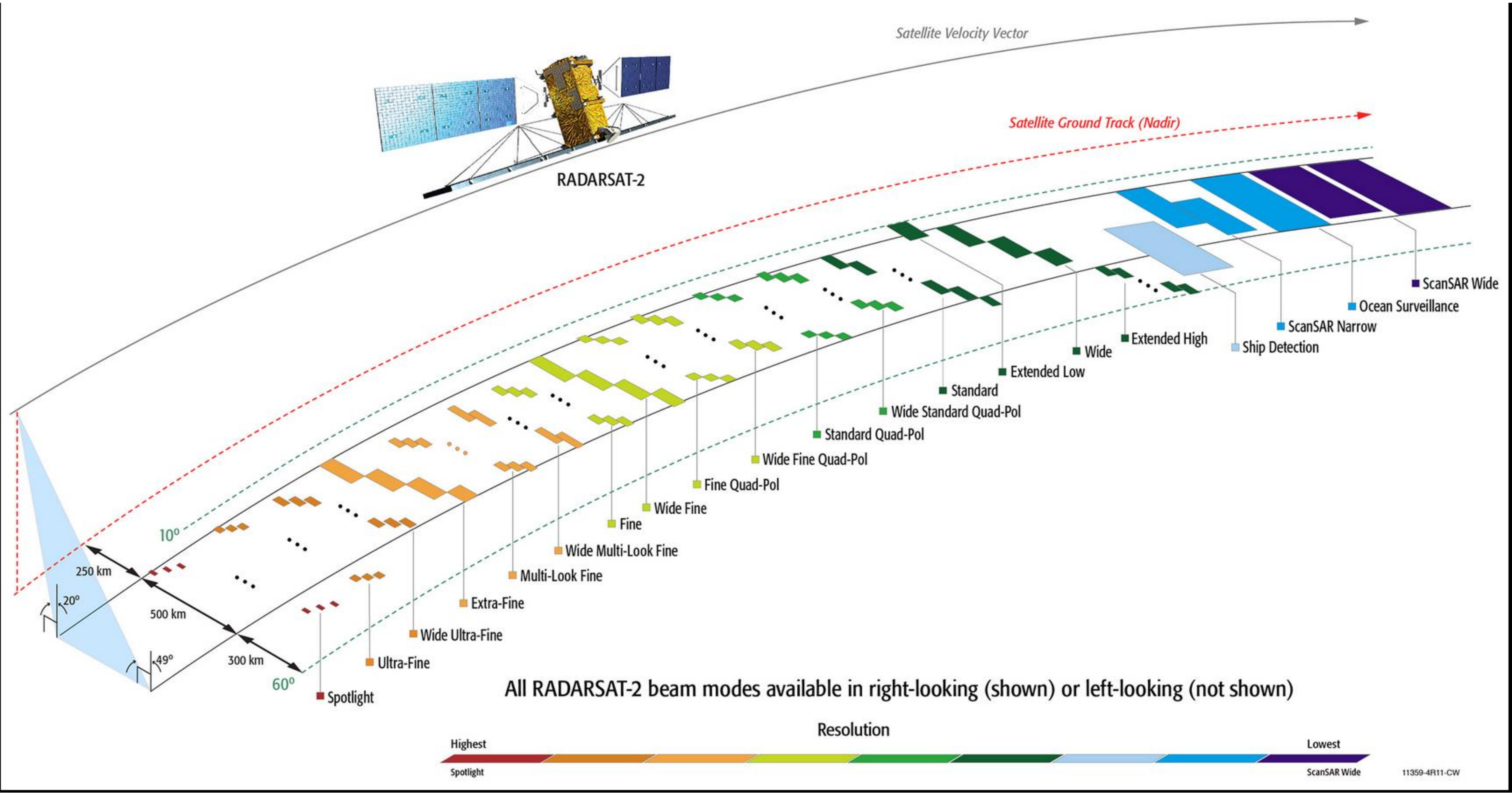


The VHR and polarimetric SAR: Radarsat

C band : Radarsat II: Canadian, left right looking
Launch: 14-12-07 C

- High resol mode, 3m band
- Full polarimetric mode (scientific)




Satellite Velocity Vector
RADARSAT-2
Satellite Ground Track (Nadir)
10°
60°
20°
49°
250 km
500 km
300 km
Spotlight
Ultra-Fine
Wide Ultra-Fine
Extra-Fine
Multi-Look Fine
Wide Multi-Look Fine
Fine
Wide Fine
Fine Quad-Pol
Wide Fine Quad-Pol
Standard Quad-Pol
Wide Standard Quad-Pol
Standard
Extended Low
Wide
Extended High
Ship Detection
ScanSAR Narrow
Ocean Surveillance
ScanSAR Wide
All RADARSAT-2 beam modes available in right-looking (shown) or left-looking (not shown)
Resolution
Highest
Lowest
Spotlight
ScanSAR Wide
11359-4R11-CW

RMC Characteristic

Beam modes	Nominal swath width (km)	Approximate resolution (m)
Low Resolution 100 m	500	100 x 100
Medium Resolution 50 m	350	50 x 50
Medium Resolution 30 m	125	30 x 30
Medium Resolution 16 m	30	16 x 16
High Resolution 5 m	30	5 x 5
Very High Resolution 3 m	20	3 x 3
Low Noise	350	100 x 100
Ship Detection	350	Variable
Spotlight	14 [5 km in azimuth]	1 x 3
Quad-Polarization	20	9 x 9

http://www.asc-csa.gc.ca/eng/satellites/radarsat/radarsat-tableau.asp

Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar

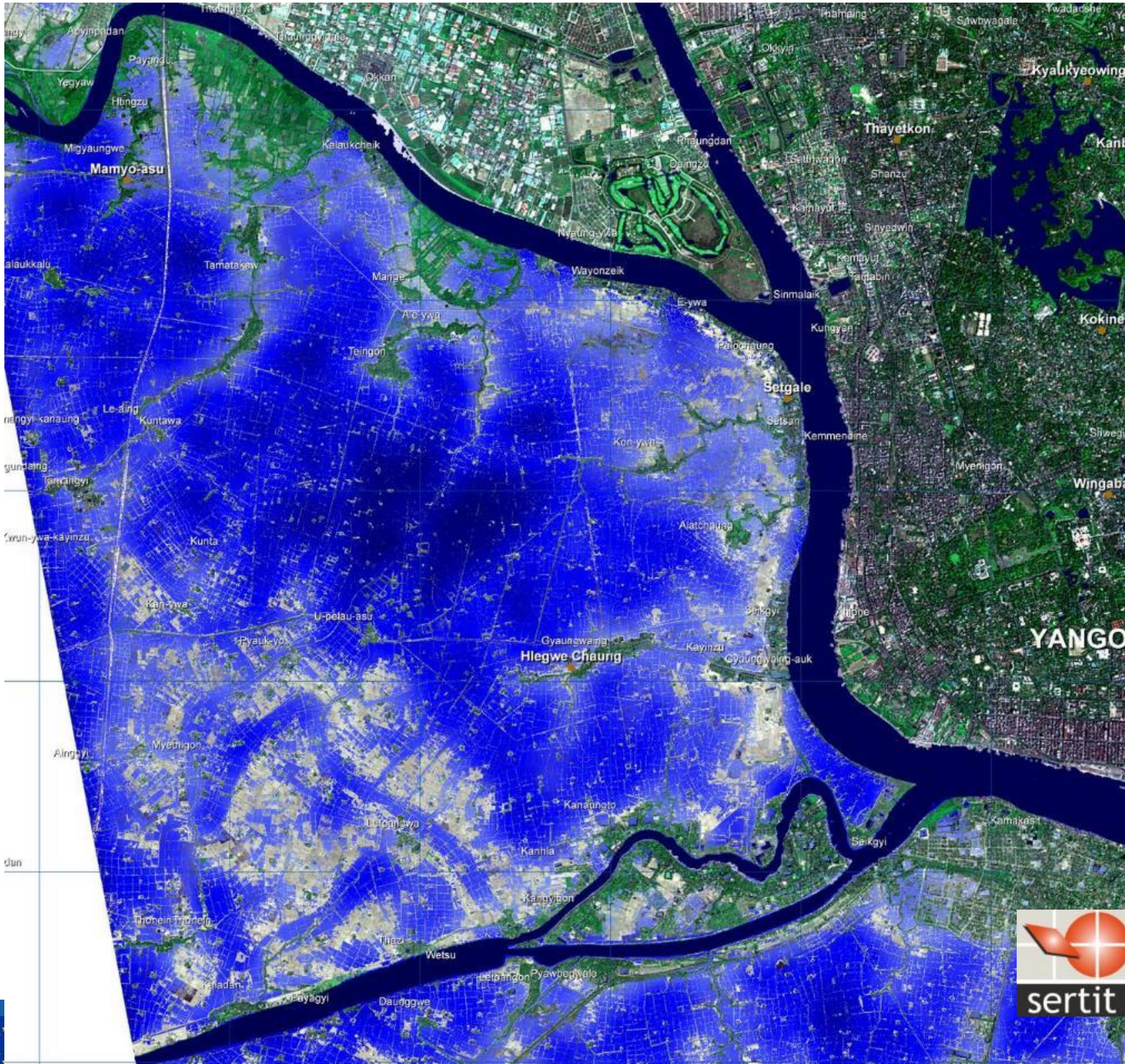
Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar

Radarsat Ultrafine mode : 3 m

Lot of details within rural areas

Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar

Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar



Fine resolution allowed to derived a very innovative information from a single crisis image

Relative water depth

Deep Shallow

Exploitation of VHR SAR: Radarsat II
Polarimetric approach

Exploitation of the polarimetric information based on the entropy (valuable technics in natural/Agricultural landscape)

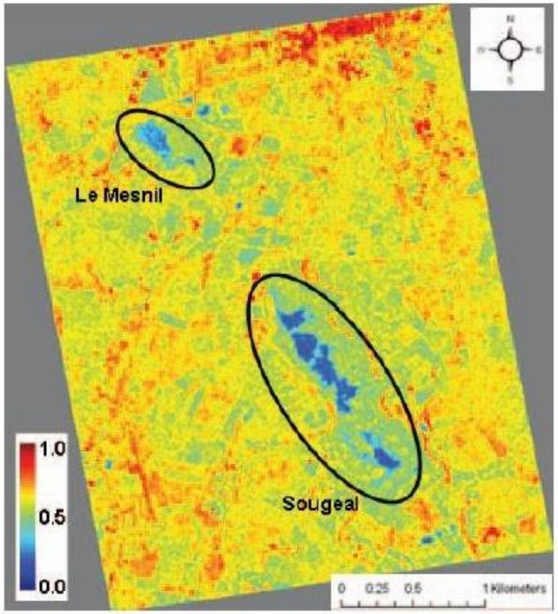


Figure 3- *The normalized Shannon Entropy (SE) image.*

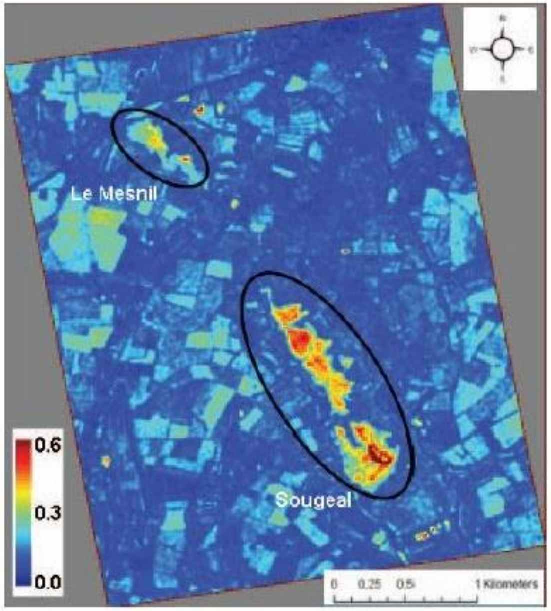


Figure 4- *Temporal coefficient of variation of the SE parameter*

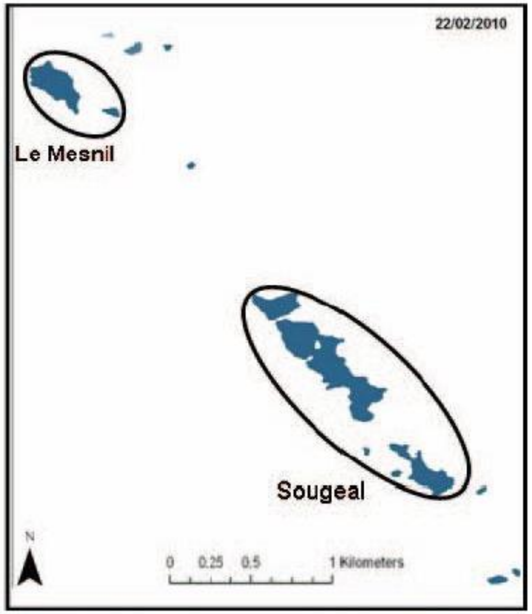


Figure 5-*The segmented SE image with the open water in blue*

From Maréchal, Pottier et al., Igarss 2011; Pottier et al., Igarss Munich 2012

Université de Strasbourg

Advanced Land Observing Satellite (ALOS II)
PALSAR

L Band

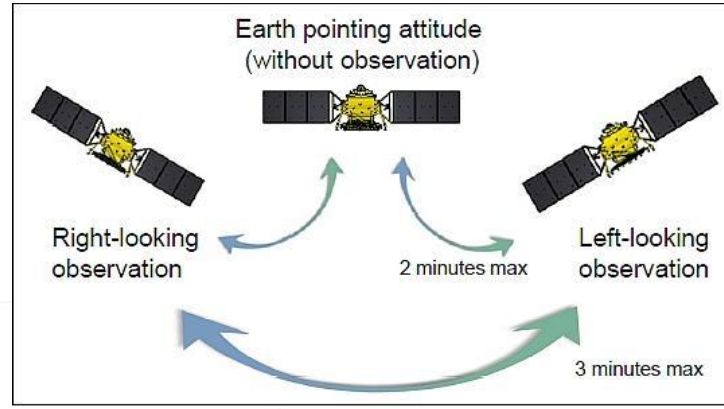
Phased Array type L-band
Synthetic Aperture Radar (PALSAR)

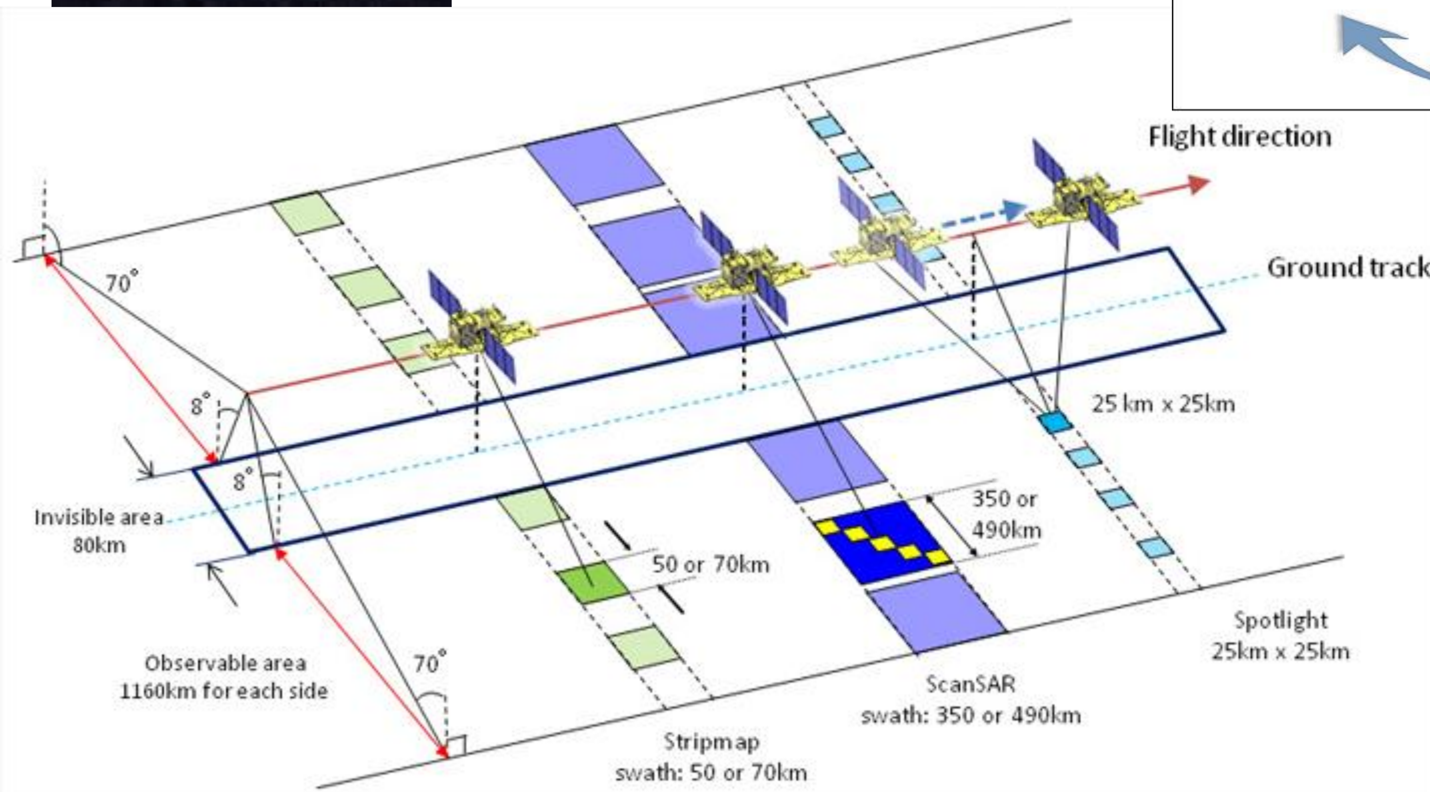
Left/right looking

WS to ultra fine (490 to 25km => 60 m to 1m)

24 May 2014

Advanced Land Observing Satellite (ALOS II) PALSAR





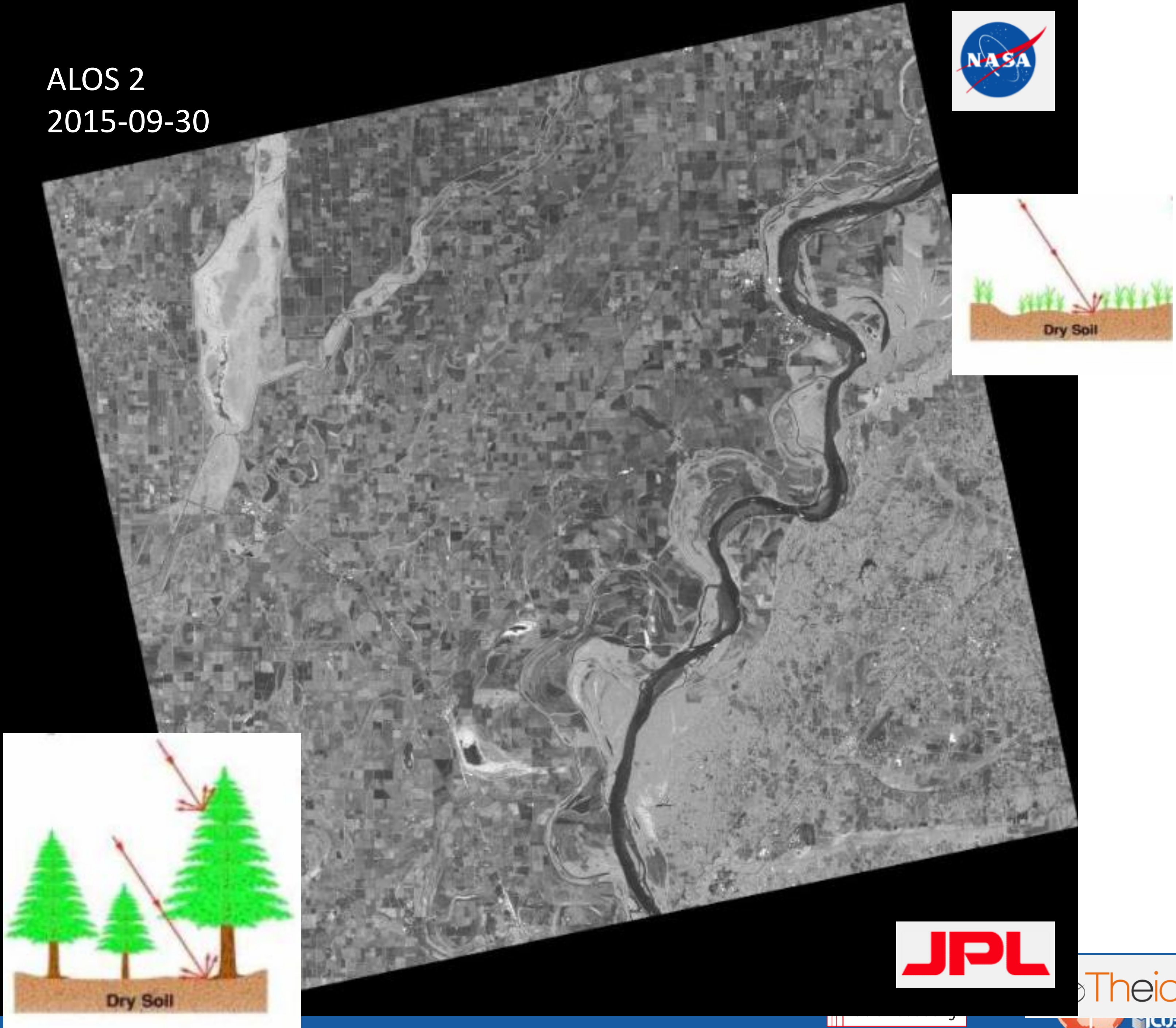
Advanced Land Observing Satellite (ALOS II) PALSAR

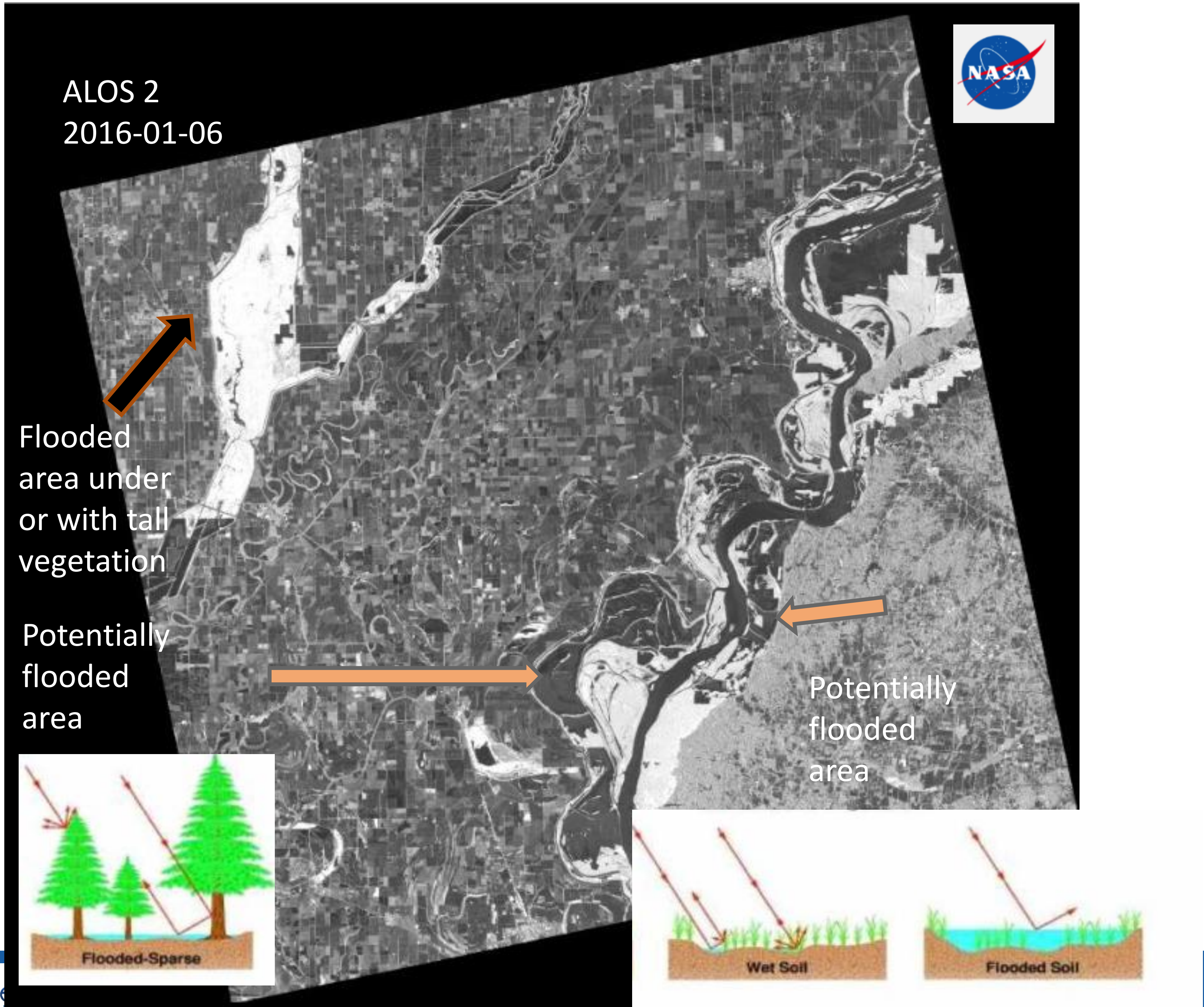
Observation mode	Spotlight	Stripmap					ScanSAR		
		Ultrafine [3m]	High sensitive [6m]		Fine [10m]		Normal		Wide
Bandwidth (MHz)	84	84	42		28		14	28	14
Resolution (m)	3×1 (Rg×Az)	3	6		10		100 (3 looks)		60
Incidence angle (deg.)	8 - 70	8 - 70	8 - 70	20 - 40	8 - 70	23.7	8 - 70		8 - 70
Swath (km)	25×25 (Rg×Az)	50	50	40	70	30	350 (5 scans)		490 (7 scans)
Polarization*	SP	SP/DP	SP/DP/CP	FP	SP/DP/CP	FP	SP/DP		SP/DP
NESZ (dB)	-24	-24	-28	-25	-26	-23	-26		
S/A (dB) Rg	25	25	23	23	25	20	25		
S/A (dB) Az	20	25	20	20	23				

* SP: HH or HV or VV, DP: HH+HV or VV+VH, FP: HH+HV+VH+VV, CP: compact pol. (experimental)

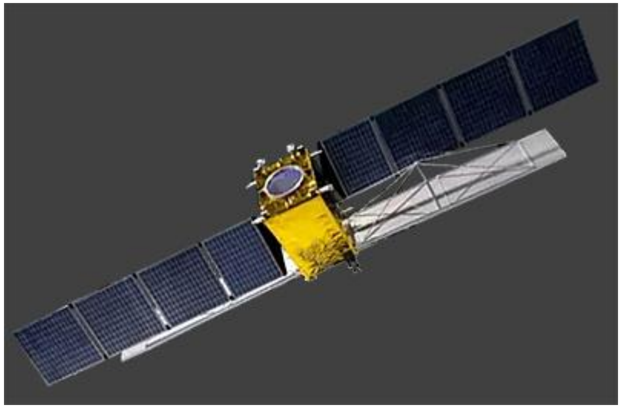
ALOS 2

2015-09-30




ALOS 2
2016-01-06
NASA
Flooded area under or with tall vegetation
Potentially flooded area
Potentially flooded area
Flooded-Sparse
Wet Soil
Flooded Soil

GAOFENG 3



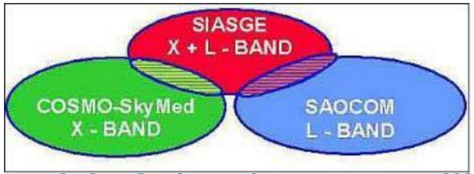
C band
Full Pol SAR

12 imaging modes WS to ultra fine mode with corresponding swath ranging from 650 km to 10 km

09 August 2016

Coming SAR missions

2017- 2018 : Radarsat Constellation Mission (RCM) , C Band, Singl, Dual, Hybrid Pol, Revisit 4 days (launch 12 -06-2019)

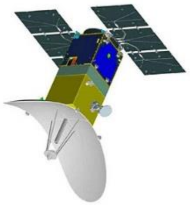


Italian-Argentine System of Satellites
for Emergency Management (SIASGE) constellation.

2018-2019 : SAOCOM de la Conae, L band (Singl, Dual Twin Pol, revisit 4 days) two satellites A & B (first launched 7 October 2018)

2018- 2019 : COSMO SkyMed Second Generation , CSG (X band Sing/Dual/Quad Pol)

2018-2020: ICEYE X1 mission small satellites constellation (<100kg) 12-01-2018



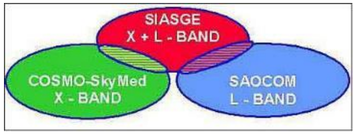
2019 -2022 LOTUSat-1 , X Band,

2021 : BIOMASS P band, not suitable for flood/lake mapping too coarse resolution (interest for DEM under forest)

2021 : NISAR , indo american mission, bande L et S

Missions récentes

Juin 2019: Radarsat Constellation Mission (RCM) , C Band, Singl, Dual, Hybrid , Pol, Revisit 4 days



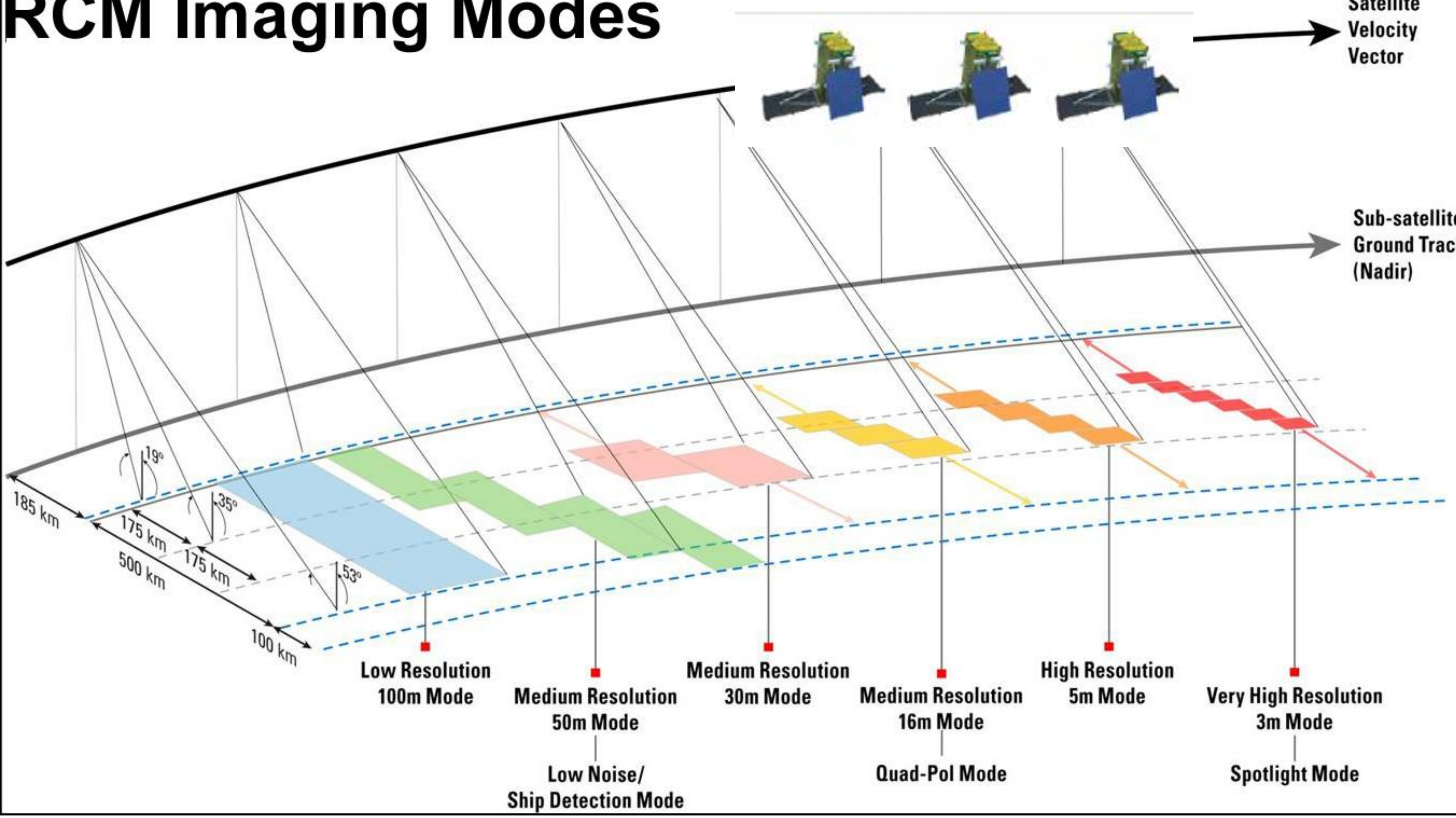
2018-2019 SIASGE Italian-Argentine System of Satellites for Emergency management

October 2018-2019 : SAOCOM de la Conae, L band

(Singl, Dual Twin Pol, revisit 4 days) two satellites A & B

2018- 2019 : COSMO SkyMed Second Generation , (X band Sing/Dual/Quad Pol)

RCM Imaging Modes



RMC Characteristic

Beam modes	Nominal swath width (km)	Approximate resolution (m)
Low Resolution 100 m	500	100 x 100
Medium Resolution 50 m	350	50 x 50
Medium Resolution 30 m	125	30 x 30
Medium Resolution 16 m	30	16 x 16
High Resolution 5 m	30	5 x 5
Very High Resolution 3 m	20	3 x 3
Low Noise	350	100 x 100
Ship Detection	350	Variable
Spotlight	14 [5 km in azimuth]	1 x 3
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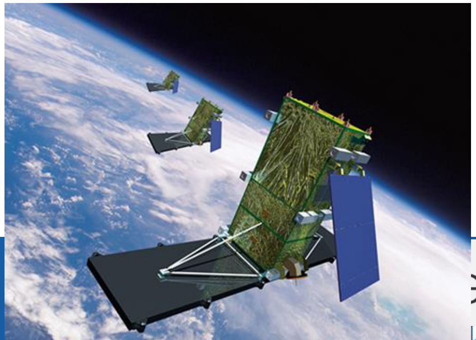
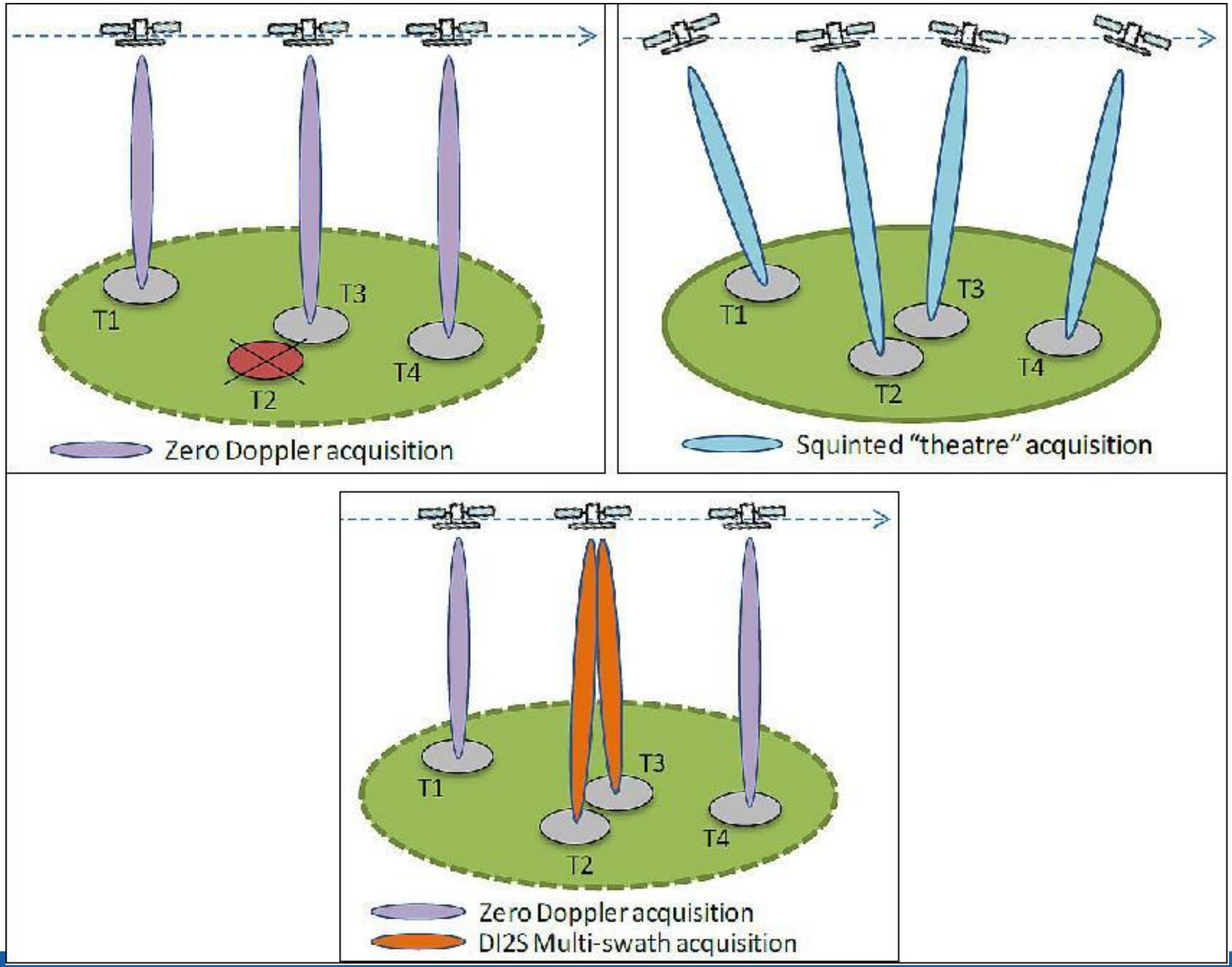
http://www.asc-csa.gc.ca/eng/satellites/radarsat/radarsat-tableau.asp



COSMO-SkyMed Second Generation (CSG) Constellation

Comparé à CSK: nouveaux modes d'acquisition, plus d'agilité, quad pol

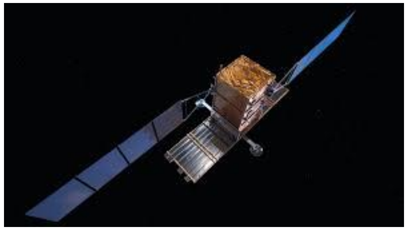


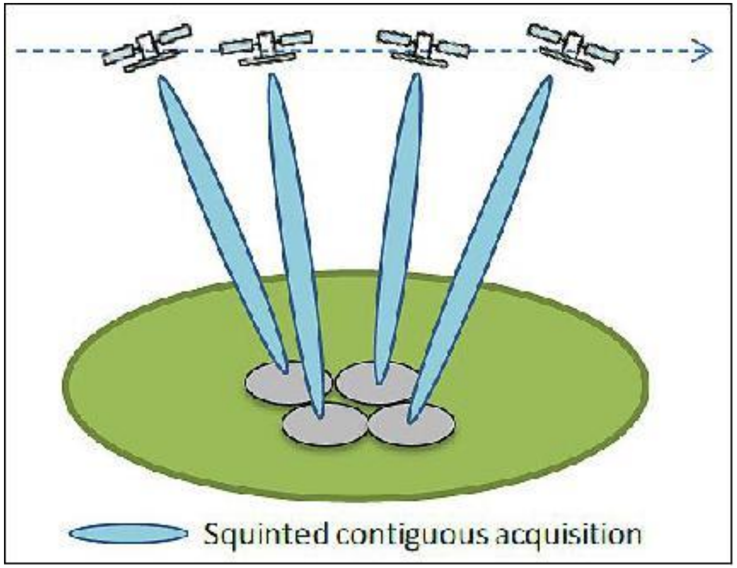
18 Decembre 2019

COSMO-SkyMed Second Generation (CSG) Constellation

Comparé à CSK: nouveaux modes d'acquisition, plus d'agilité

Mode category	Acquisition technique	Resolution (rg x az)	Swath (rg x az)	Polarization	User type
Narrow field image	Spotlight				Defense
		0.8 m x 0.8 m	10 km x 10 km	Single polarization	Civilian and Defense
		1.0 m x 1.0 m	10 km x 10 km	Double polarization	
Wide field image	Stripmap	3.0 m x 3.0 m	40 km x 2500 km	Double polarization	
		5.0 m x 20 m	30 km x 2500 km	Burst double polarization	
		3.0 m x 3.0 m	15 km x 2500 km	Quadruple polarization	
	ScanSAR	4.0 m x 20 m	100 km x 2500 km	Double polarization	
		6.0 m x 20 m	200 km x 2500 km	Double polarization	





COSMO-SkyMed Second Generation (CSG) Constellation

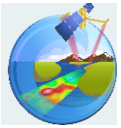
Support modes	Polarization	Access region (º)	Swath (azimuth x range) km	Resolution (azimuth x range) m	NESZ (dB)	Scientific geolocation (m)
Spotlight 2A	Single/Dual	20-25 25-50 50-60	3.1 x 7.3 3.2 x 7.3 4.4 x 7.3	0.35 x 0.55 0.35 x 0.51 0.35 x 0.48	-23.5 -22.5 -20	1.25 (90% CE)
Spotlight 2B	Single/Dual	20-60	10 x 10	0.63 x 0.63	-20	1.25 (90% CE)
Spotlight 2C	Single/Dual	20-25 25-50 50-60	5 x 10	0.8 x 0.8	-22 -20 -19	1.25 (90% CE)
Stripmap	Single/Dual	20-50 50-60	40 x 40 40 x 30	3 x 3	-22	2 (90% CE)
Ping-Pong	Dual/Quad	20-50 50-60	40 x 40 40 x 30	12 x 5	-24	10 (3σ)
Stripmap Quadpol	Quad	20-45	40 x 15	3 x 3	-25	2 (90% CE)
ScanSAR 1	Single/Dual	20-60	100 x 100	20 x 4	-22	10 (3σ)
ScanSAR 2	Single/Dual	20-50 50-60	200 x 200 200 x 190	40 x 6	-22	10 (3σ)

Missions à venir

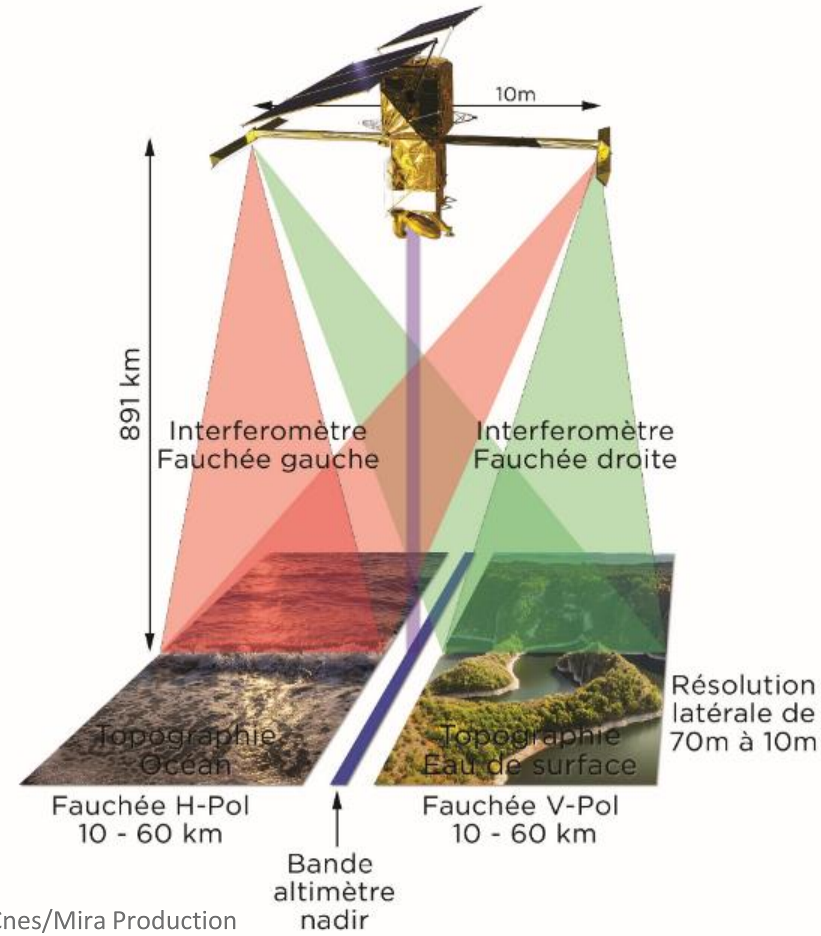
11-2022 SWOT: Altimetrie, INSAR

2023 : Lancement prévu de la mission BIOMASS P band

2023 : lancement de NISAR, mission indo américaine, bande L et S

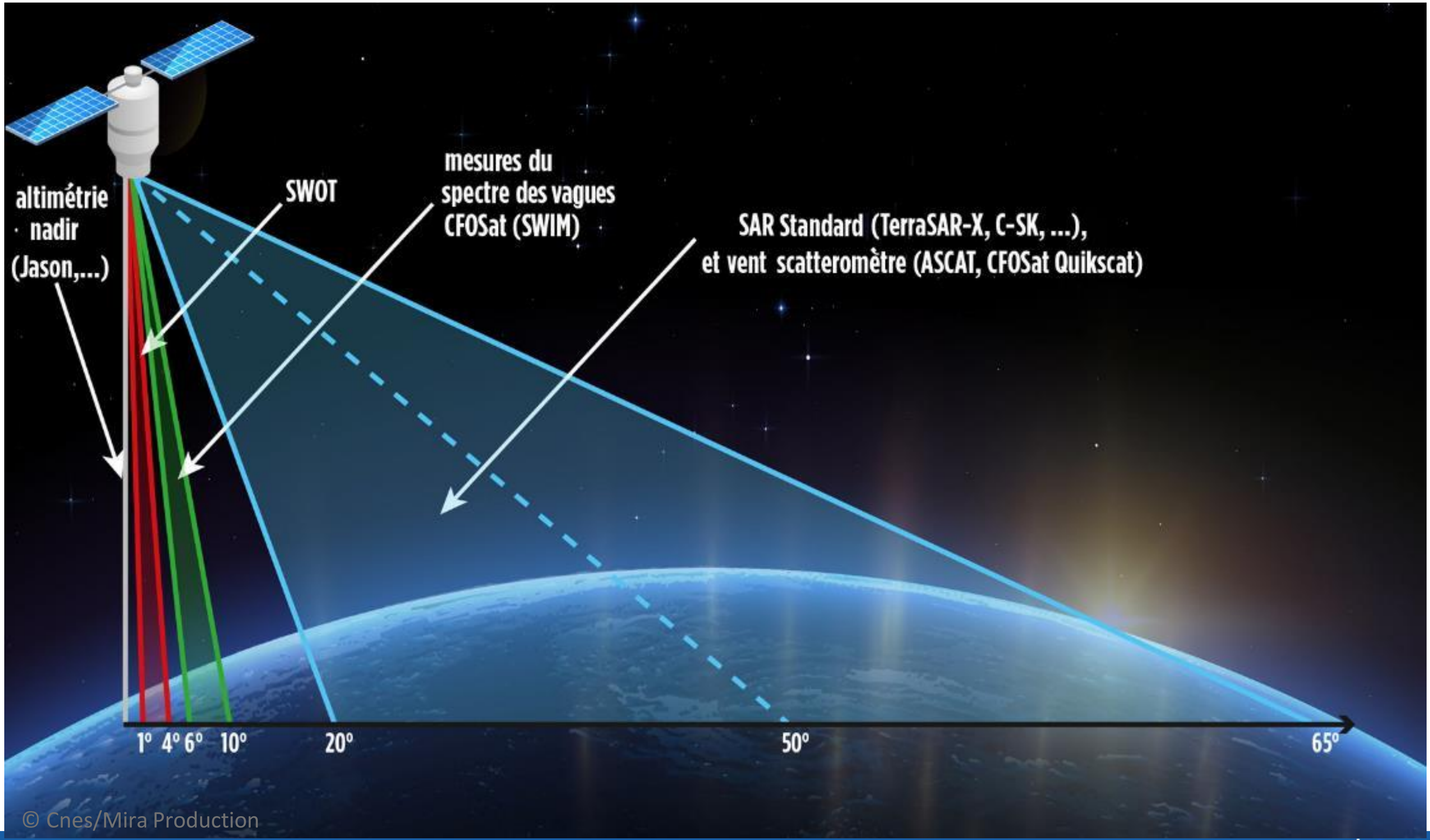


La mission Swot



- **Une coopération Nasa (USA) / Cnes (France) / CSA (Canada) / UKSA (UK)**
- **Un nouveau concept technique, l'altimétrie interférométrique à large fauchée (KaRIn)**
  - une image bidimensionnelle
  - Fauchée 2 x 50 km
  - Mesure radar (tous temps + jour/nuit)
- **Données**
  - Mesures « directes » : Hauteur d’eau, Pente, Largeur
  - *Mesures indirectes : Débit, Vitesse et amplitude des marées, Amplitude des vagues, Vitesse des courants…*

Angle d'incidence Swot par rapport à d'autres techniques spatiales



La mission Swot

	Mesures déductibles[1]	Exemples d'applications actuelles	L'apport de Swot
Lac / réservoirs	• **Hauteur** • Volume d'eau	• Suivis des variations de quantité d'eau des grands lacs (quelques centaines de km²) – ex : l'assèchement du Lac d'Aral par Topex/Poséidon	• Couverture des lacs et réservoirs plus petits dès 250 m x 250 m
Fleuve	• **Hauteur** • **Pente de surface** • Débit	• Suivis de la hauteur d'eau et de leurs variations dans les grands fleuves – ex : les crues de l'Amazone par Topex/Poséidon	• Couverture de tous les fleuves de largeur supérieur à 100 m (objectif de 50 m)
Région côtière	• **Hauteur** • Vitesse et amplitude des marées	• Aucune possibilité actuellement	• Possibilité de visualiser les côtes pour la première fois grâce à une meilleure résolution
Océan	• Vitesse des courants[2] • Vitesse du vent[3] • Amplitude des vagues • **Objets flottants (?)**	• Mesure des champs de vitesse du Gulf Stream par Envisat • Suivi de l'ouragan Isabel par Jason-1 et Envisat • Mesures des houles australes (dizaine de mètres) par Jason • Repérage de bateaux par les satellites SAR (résolution en fonction de la vitesse / état de l'eau)	• Applications à la subméso-échelle (< 300 km) • Meilleure précision et atténuation des perturbations • Meilleure résolution (à confirmer)

1. En gras : les grandeurs mesurables directement par SWOT. les autres s'obtiennent avec des modélisations / interpolations complétées éventuellement par d'autres mesures
2. Déduite des mesures de la pente de la topographie dynamique de l'océan et des modélisations océanographiques
3. Nécessitant un diffusiomètre

La mission Swot

Survol des domaines applicatifs potentiels de Swot

Donnés collectées

hydrologie

- Quantité d'eau retenue dans les lacs, rivières, réservoirs et autres zones humides
- Changement des quantités d'eau stockées
- Estimation de débit des grands fleuves / rivières

océanographie

- Courants côtiers
- Représentation des tourbillons marins à méso-échelle
- Altimétrie océanique globale haute résolution
- Bathymétrie océanique

Permettraient…

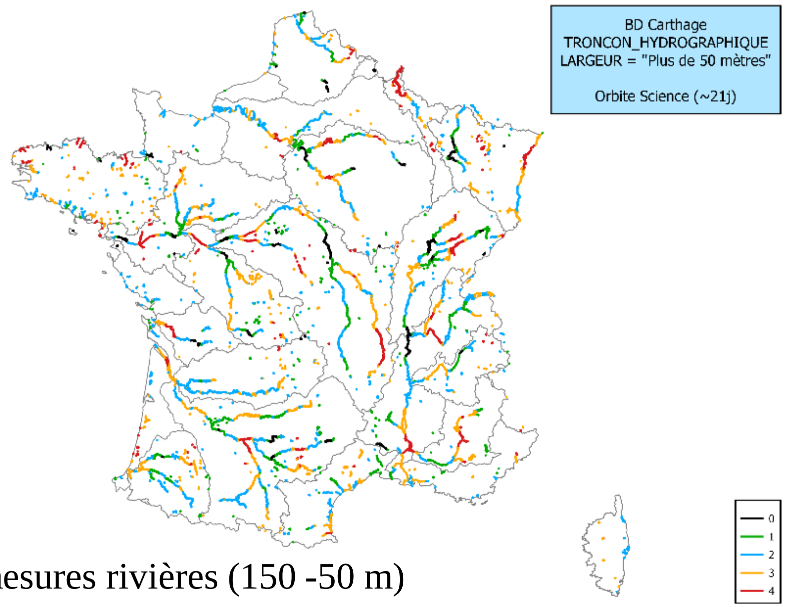
Applications possibles

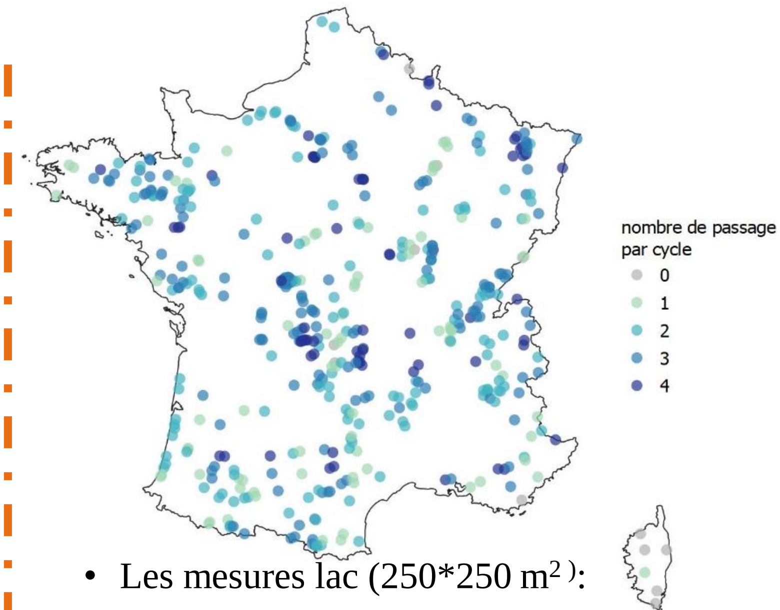
1. Gestion du partage des eaux (internationales & interrégionales)
2. Meilleure modélisation des inondations
3. Gestion des eaux claires pour la consommation urbaine, industrielle et agricole
4. Gestion de la production hydroélectrique
5. Prévention de la propagation des épidémies,
6. Gestion des estuaires
7. Aide a la navigation fluviale

Permettraient…

8. Prévisions météo et climatiques plus précises
9. Aide a la navigation et aux opérations de secours en mer
10. Aide aux pêcheurs
11. Aide aux plateformes pétrolières

Nombre d'observations SWOT par cycle (21 jours) sur les rivières et lacs français





- Les mesures rivières (150 -50 m)
  - Hauteur d'eau (en 2D),
  - Largeur,
  - Pente
- Grandeur déduite : le débit

- Les mesures lac (250*250 m^2):
  - Hauteur d'eau (en 2D),
  - Surface
- Grandeur déduite :
  - Variations de volumes

Schéma d'émission

Une des antennes (A2) émet, visant alternativement vers la fauchée gauche et droite, chacune avec une polarisation différente de l'onde radar émise.
Les deux antennes sont en réception. Utiliser deux polarisations permet de déterminer le côté vers lequel l'antenne a pointé; aux incidences utilisées, la réflexion sur l'eau n'a pas d'impact sur la polarisation (contrairement aux SAR).

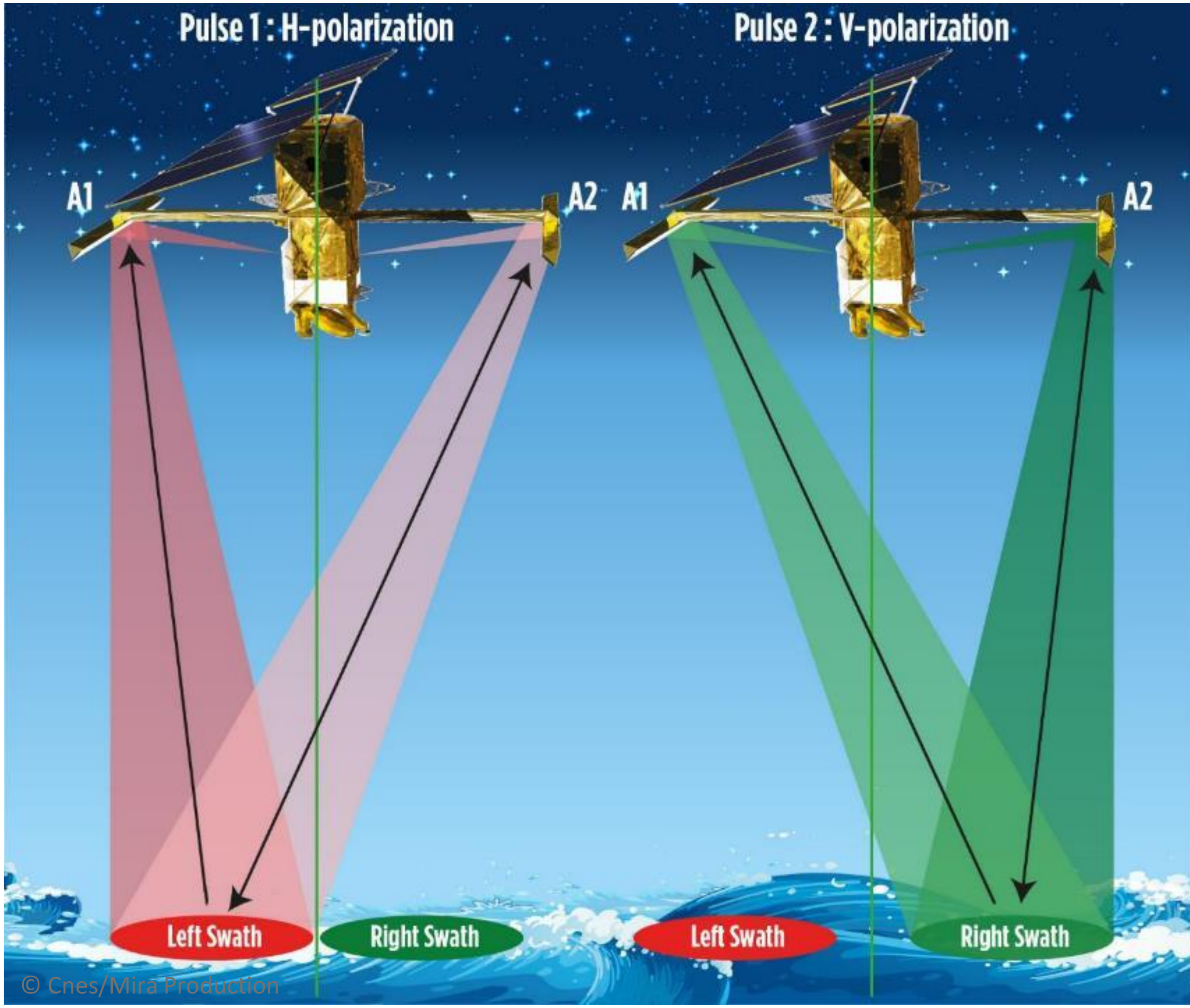


Schéma d'émission

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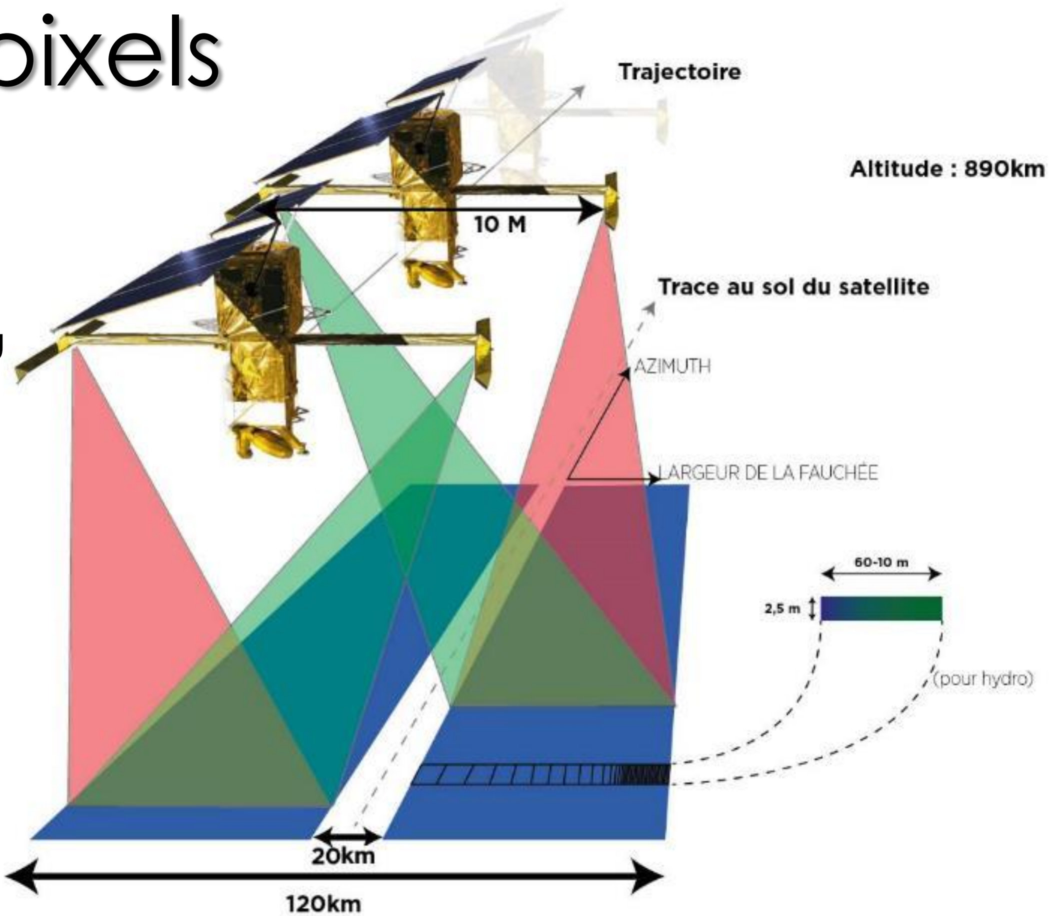
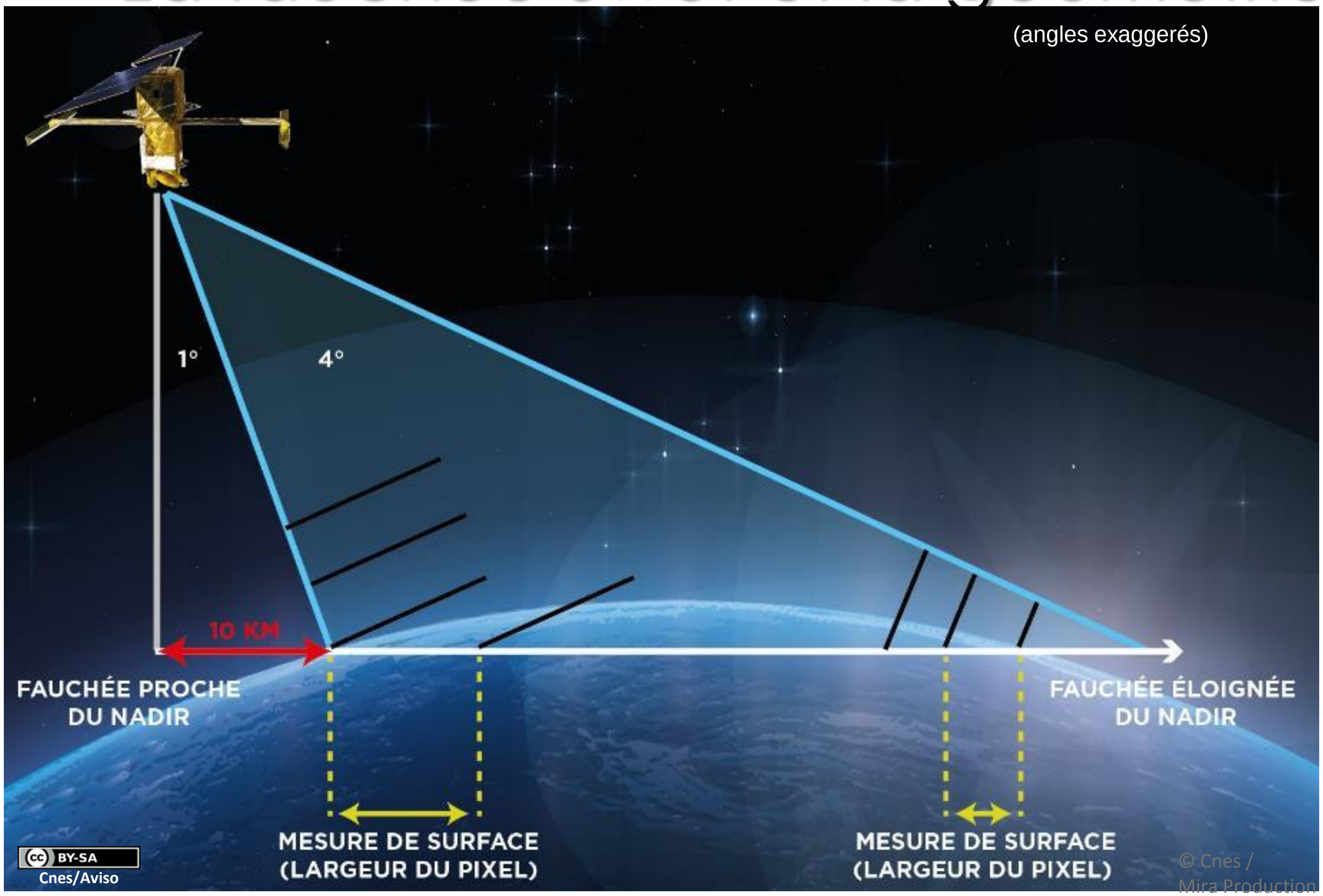
La fauchée Swot et la géométrie des pixels

- Les deux antennes (à l'extrémité de chaque mat) reçoit l'onde radar réfléchie venant des deux fauchées
- La succession des pixels en travers de la fauchée dérive du temps mis par l'onde à revenir au satellite
- Plus un pixel est loin du trou central, plus il est petit (en largeur, la hauteur restant la même).
- L'altimétrie Doppler est utilisée pour diviser l'empreinte au sol en unités plus petites (le long de la trace)



© Cnes/Mira Production

La fauchée Swot et la géométrie des pixels



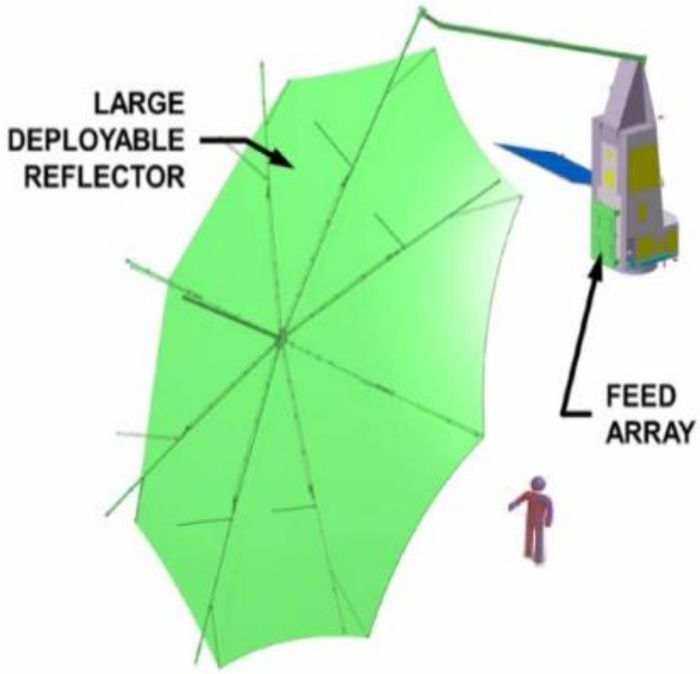
Perte de résolution près du nadir

+/- 10 km de zone aveugle de part et d'autre du nadir

Contraste terres / eaux réduit loin du nadir, car l'eau réfléchit mieux aux faibles incidences, alors que les terres réfléchissent à peu près de la même façon à toutes les incidences (la surface des terre est plus accidentée que celle de l'eau)

BIOMASS: Bande P

Key Parameters	
Sensitivity (NESZ)	≤ -27 dB
Total Ambiguity Ratio	≤ -18 dB
SLC resolution	≤ 60m x 8m
Dynamic Range	35 dB
Radiometric Stability	≤ 0.5 dB
Radiometric Bias	≤ 0.3 dB
Crosstalk	≤ -30 dB
Channel Imbalance	≤ -34 dB

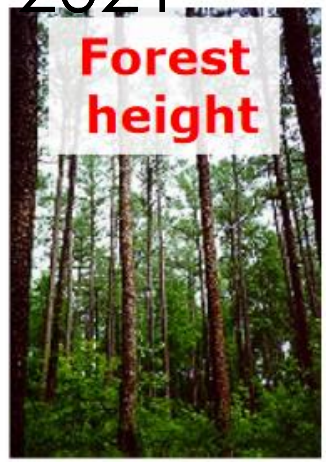


BIOMASS: Bande P

Lancement prévu en 2021

Above-ground biomass (tons/hectare)

- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20%, or 10 t ha^{-1} for biomass < 50 t ha^{-1}



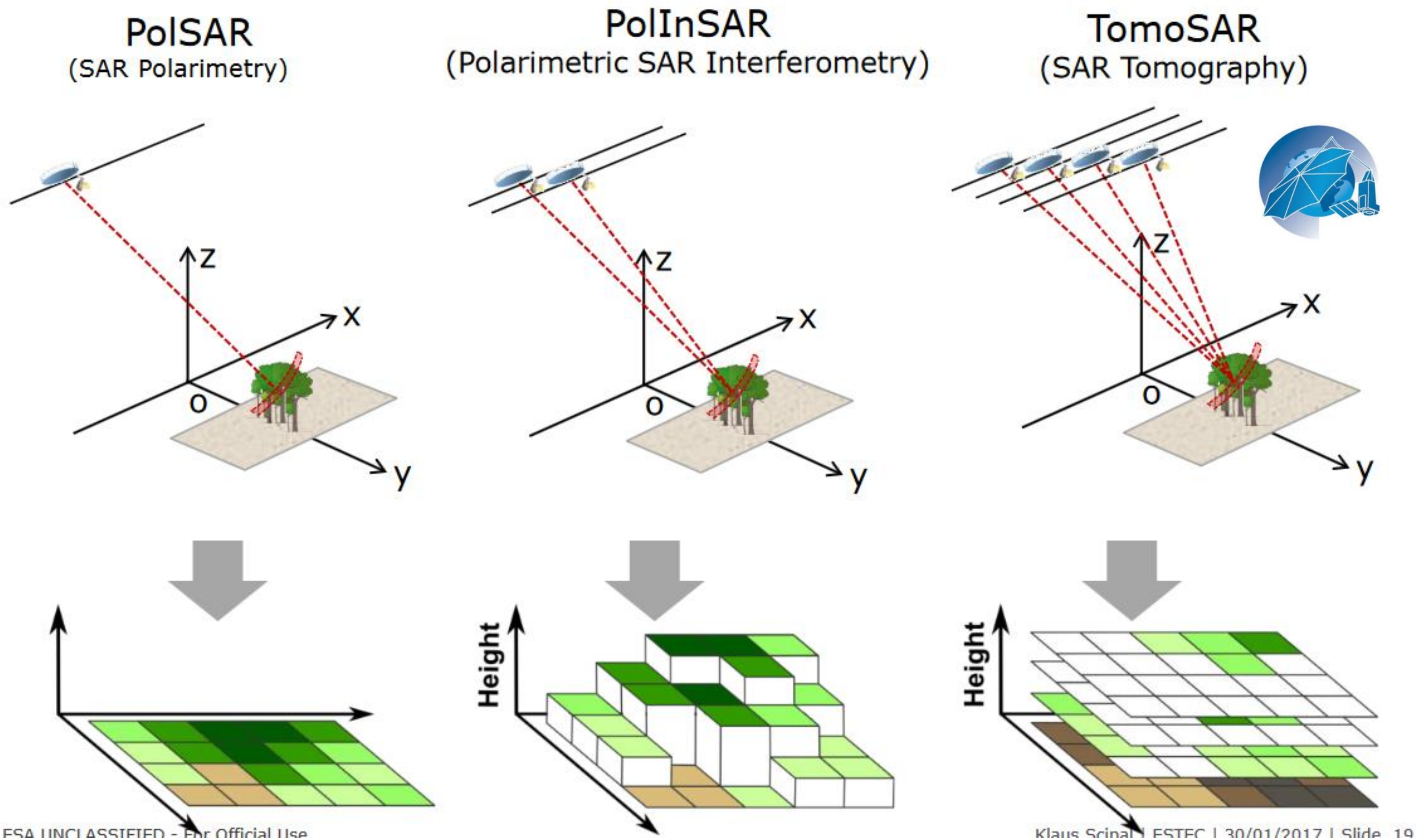
Upper canopy height (meter)

- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20-30%

Areas of forest clearing (hectare)

- 50 m resolution
- 1 map every 6 months
- global coverage of forested areas
- 90% classification accuracy

BIOMASS: Bande P



Thank you for your attention

Merci pour votre attention

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