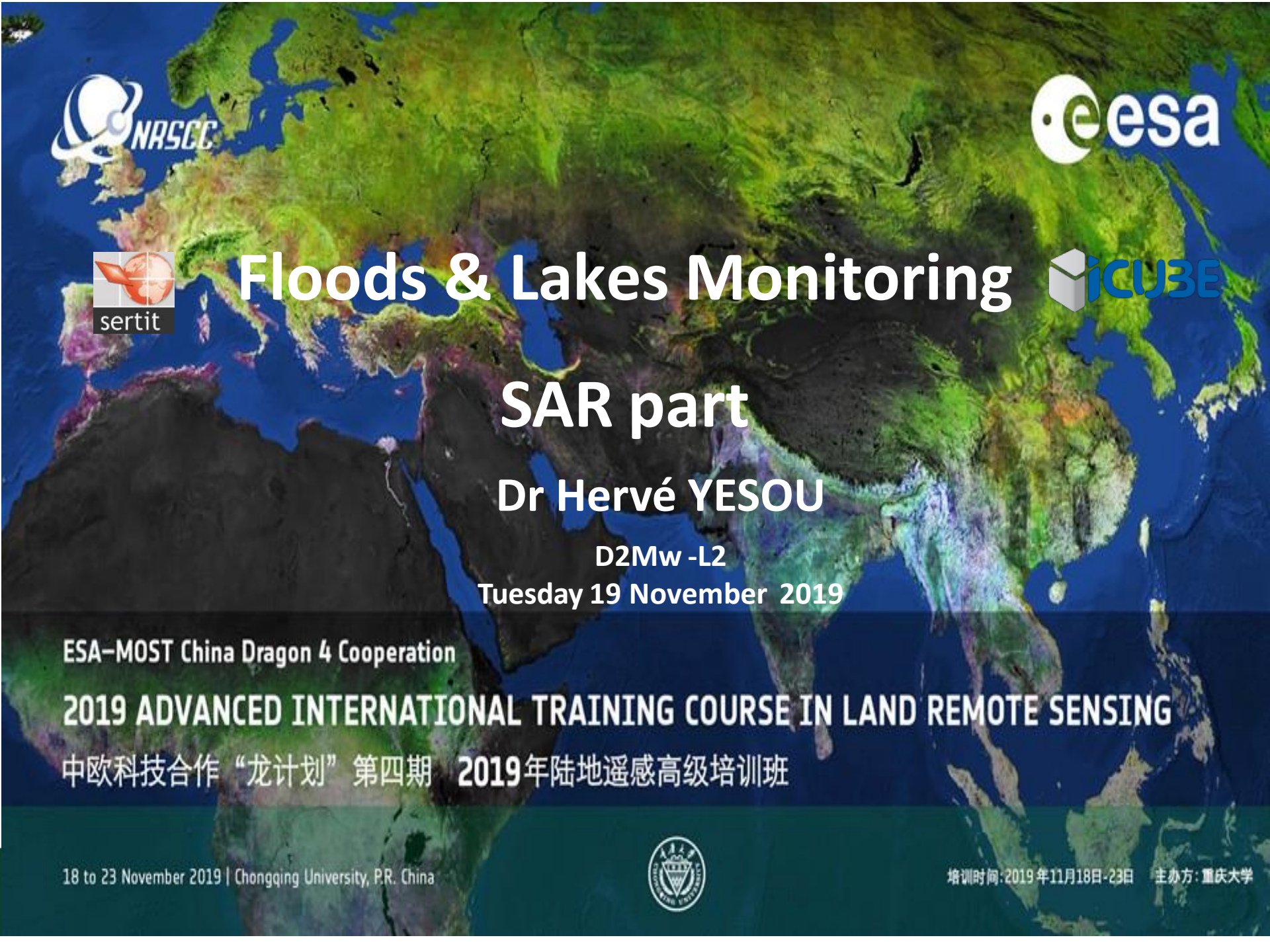


Floods & Lakes Monitoring

SAR part

Dr Hervé YESOU

D2Mw -L2

Tuesday 19 November 2019

ESA–MOST China Dragon 4 Cooperation

2019 ADVANCED INTERNATIONAL TRAINING COURSE IN LAND REMOTE SENSING

中欧科技合作“龙计划”第四期 2019年陆地遥感高级培训班

18 to 23 November 2019 | Chongqing University, P.R. China

培训时间:2019年11月18日-23日 主办方:重庆大学

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**

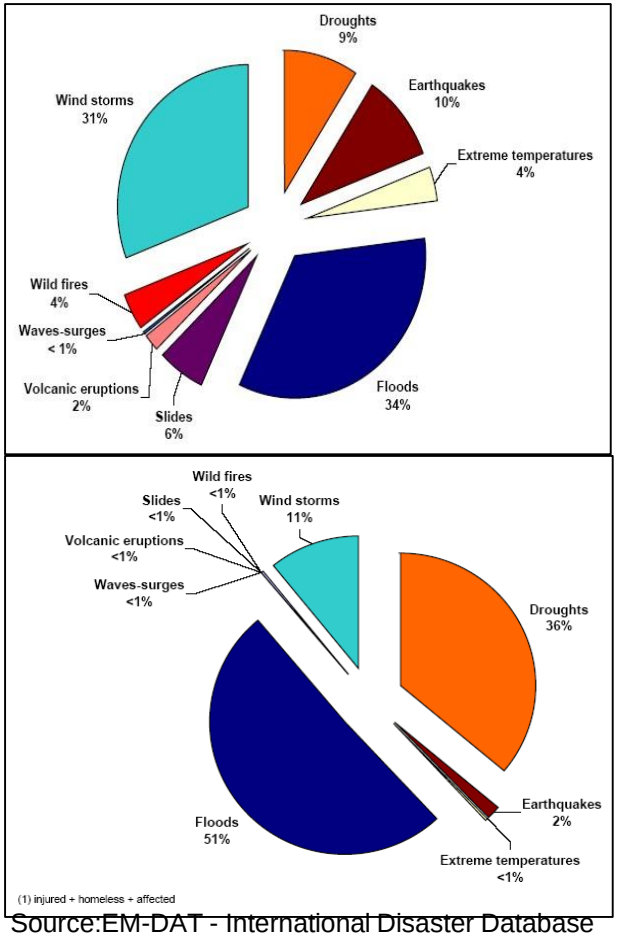
Flood plain and lakes monitoring

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

Concluding remarks

Why it is relevant to map and monitor flood events?

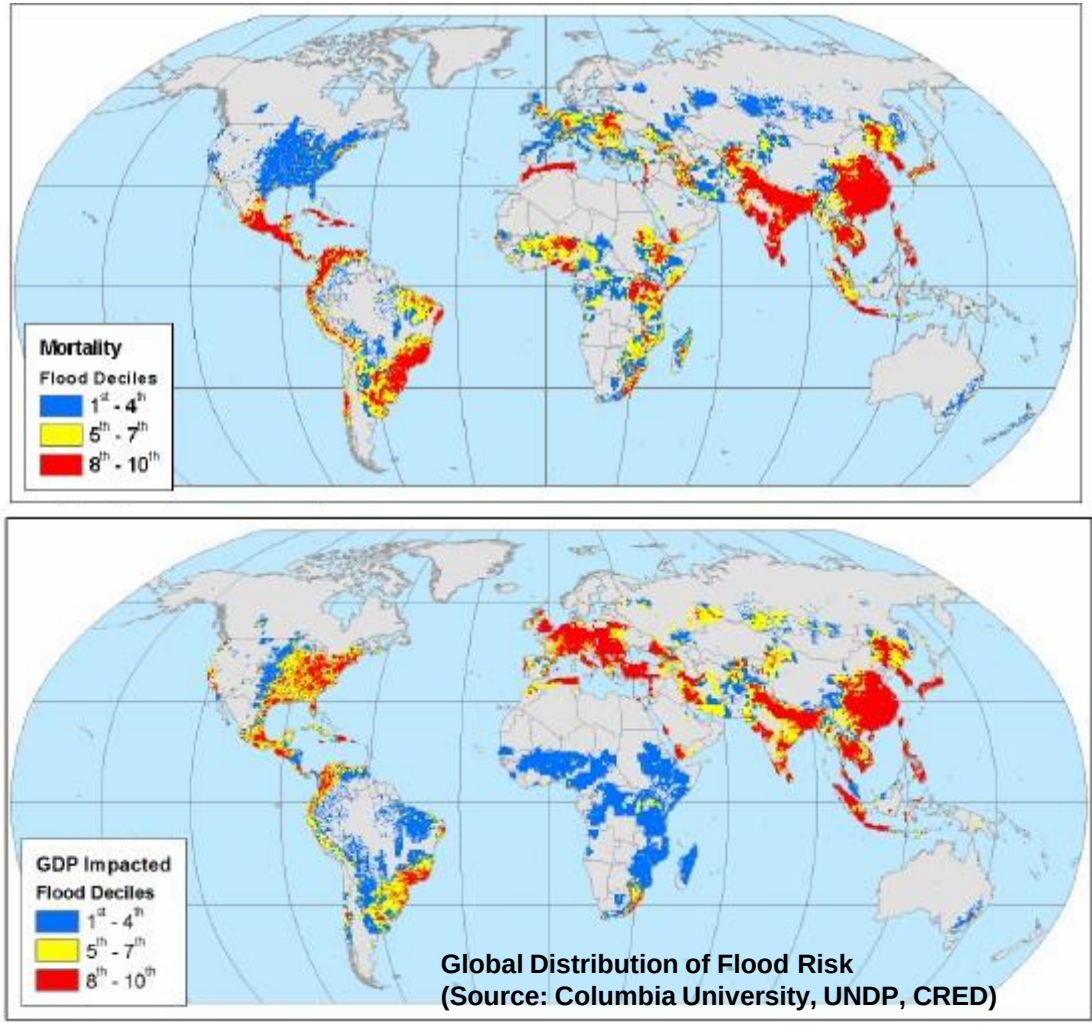
- **Floods: 34% world natural hazards between 1974-2003**
- **Near 200 millions of affected people each year (more than half of affected people by a natural hazards)**
- **More than 170 000 deceases from 1980 to 2000**
- **With climate change it would become worse**
- **Fitting floods is one of the most important environmental challenge**



Source:EM-DAT - International Disaster Database

Why it is relevant to map and monitor flood events?

- **Floods: worldwide**
- **Important mortality in Asia, Central- South America, Eastern Africa**
- **Important economic loss in Europe, Northern America as well as Asia**
- **Most dramatic are not the most costly ones (Nargis: 140 000 , none insurance prime, whereas 2008 spring floods in US and Germany 1,1billion $ each**

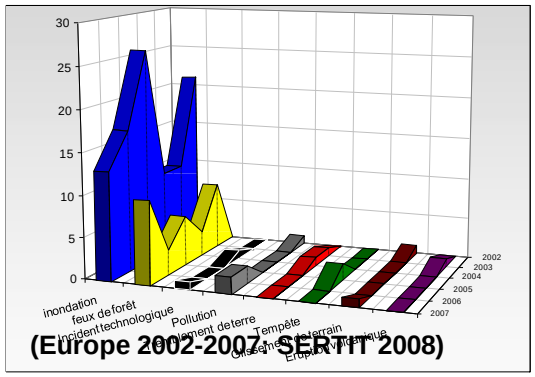


Global Distribution of Flood Risk
(Source: Columbia University, UNDP, CRED)

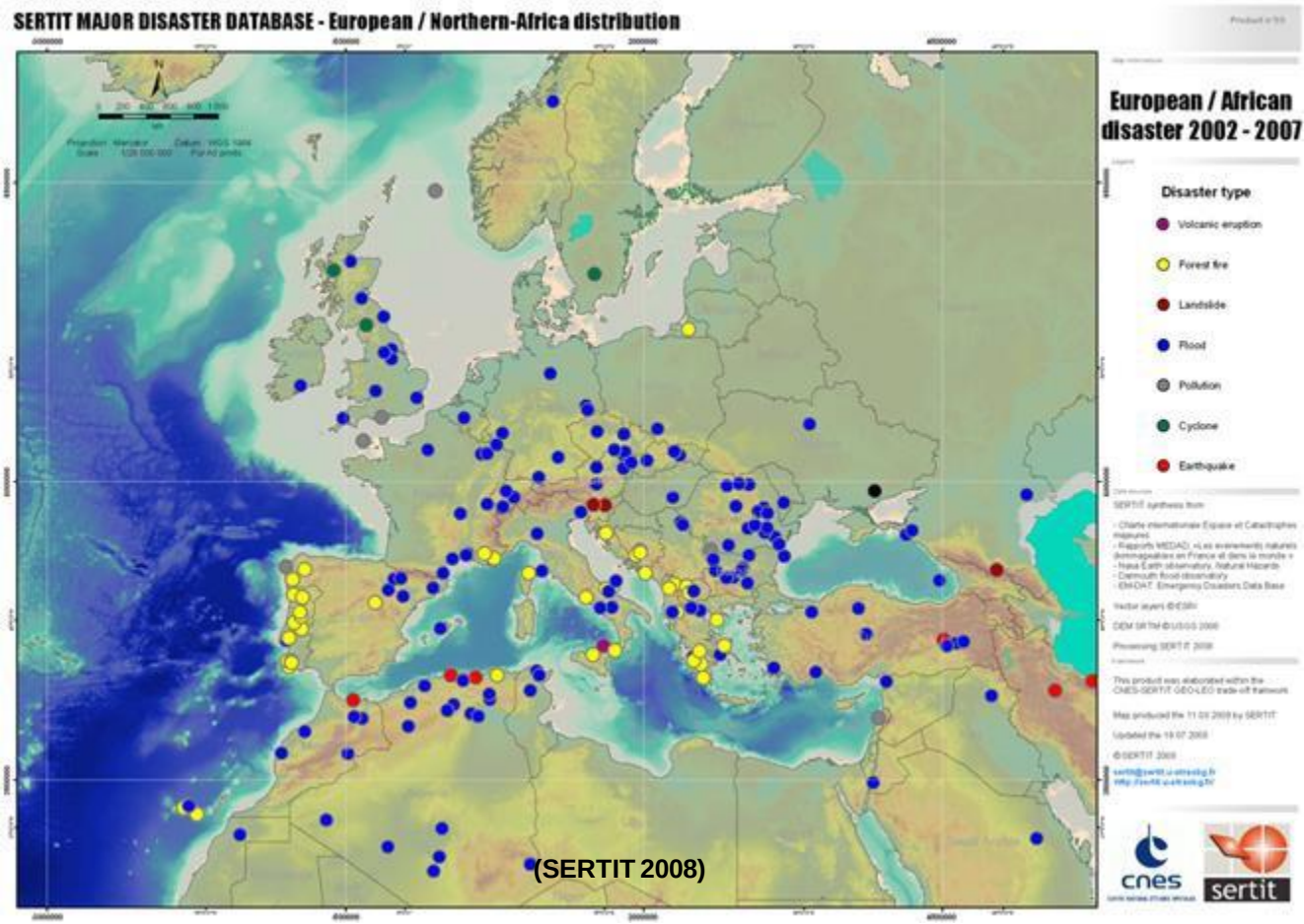
Why it is relevant to map and monitor flood events?

- **Floods: Europe**

- **Central Europe**
- **British Islands**
- **South France**



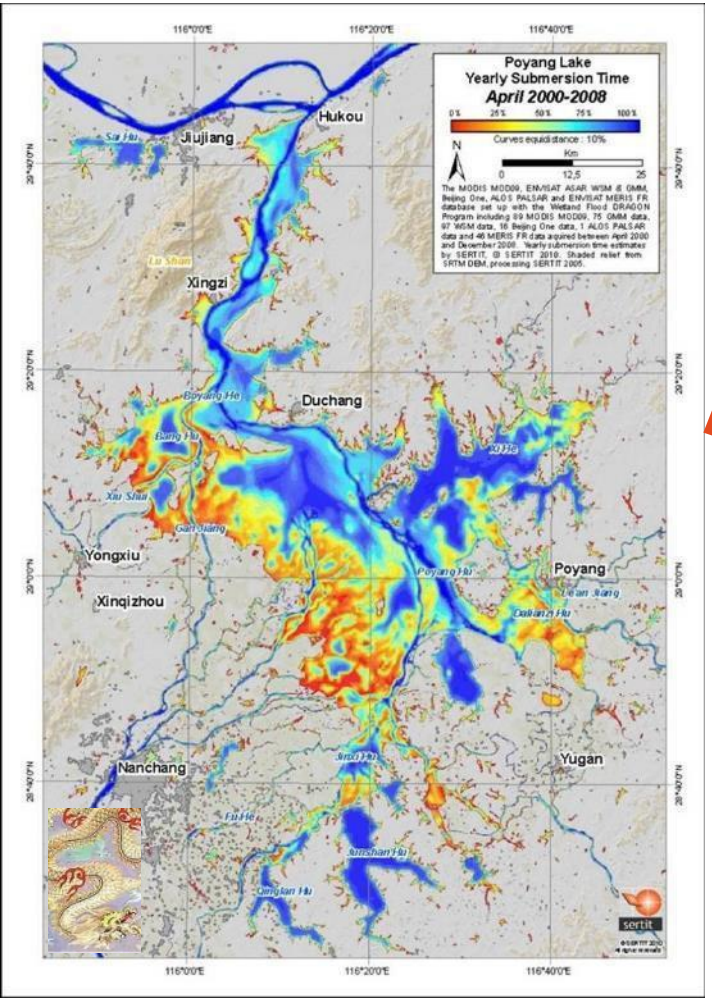
(Europe 2002-2007 SERTIT 2008)

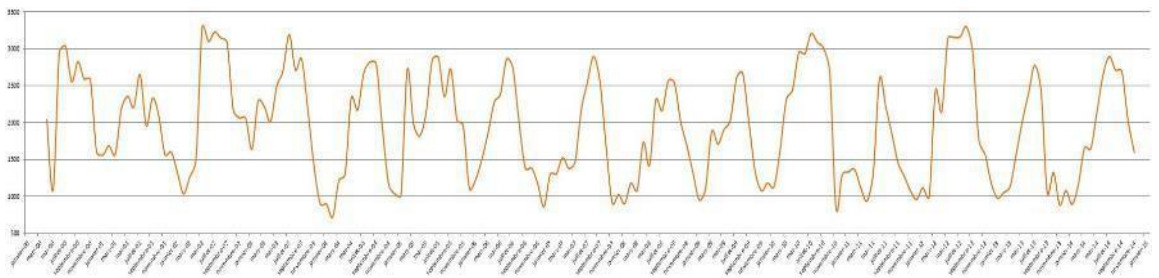


(SERTIT 2008)

Why it is important to monitor water bodies?

Request to a secured resource allowing to monitoring large areas with a reduced revisiting time (10 days)





Poyang lake, PR China

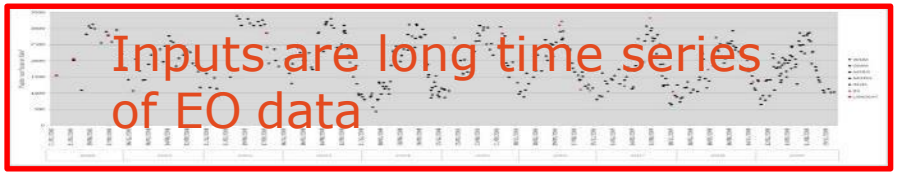
15 years of monitoring

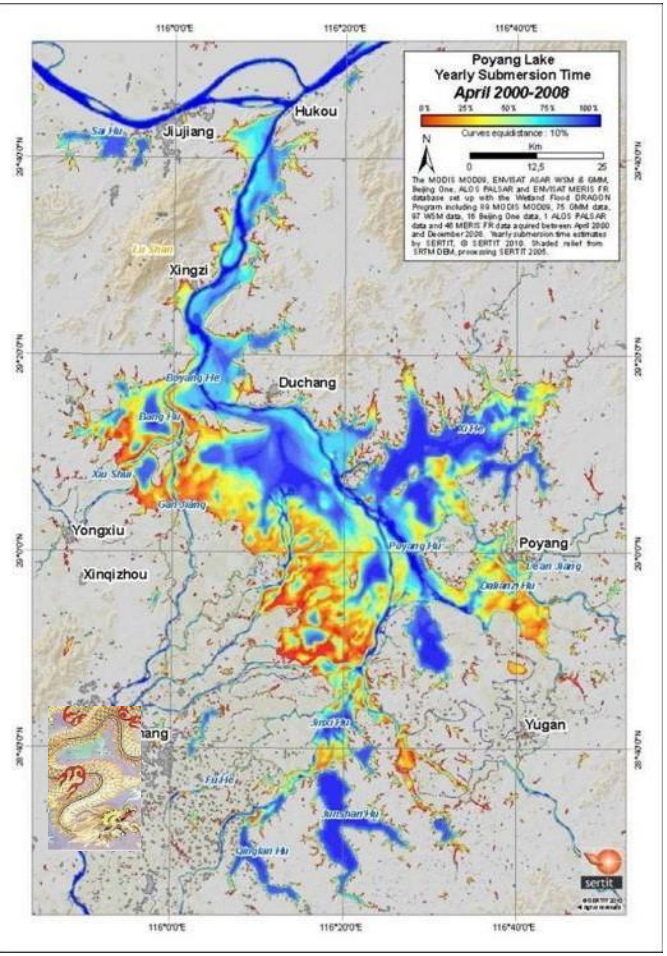
Important to monitor water resource as water is a key element for human being and life

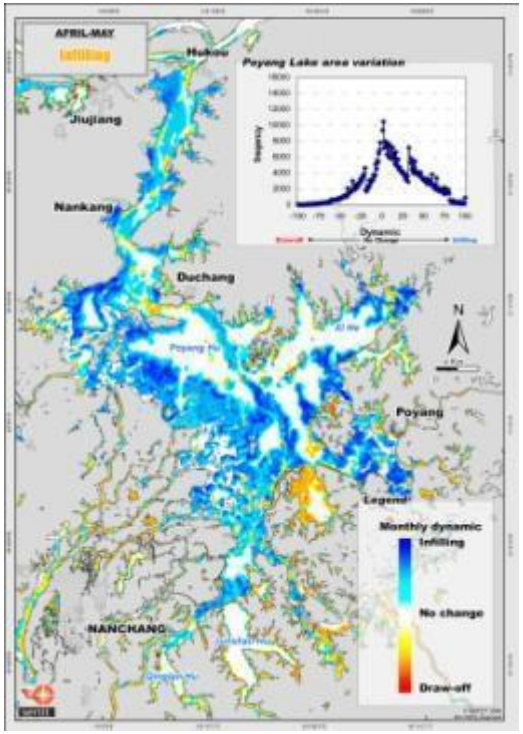
Better understanding of water cycle

Why it is important to monitor water bodies?

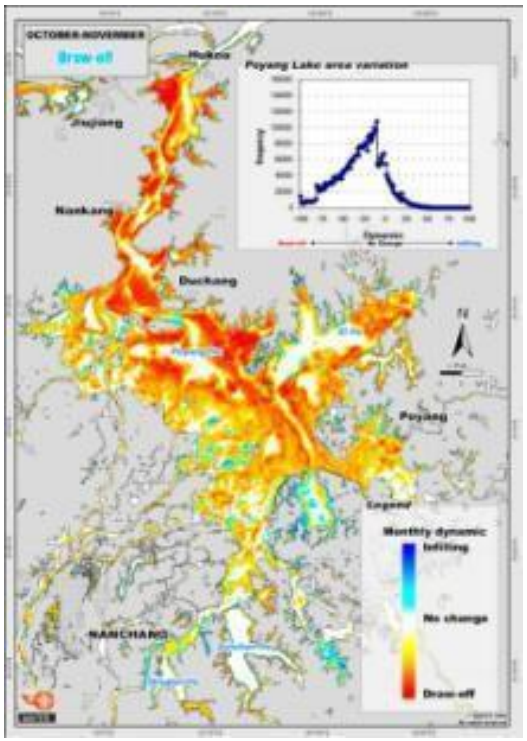
Monitoring：keys for **hydrological modeling**







Water mass movement: infilling



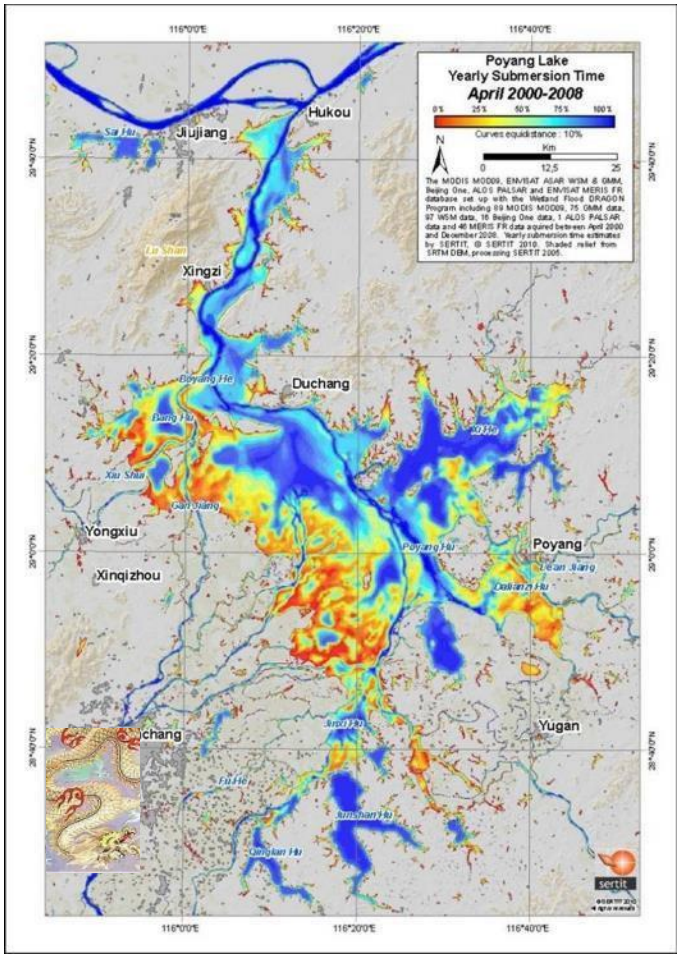
Water mass movement draw off

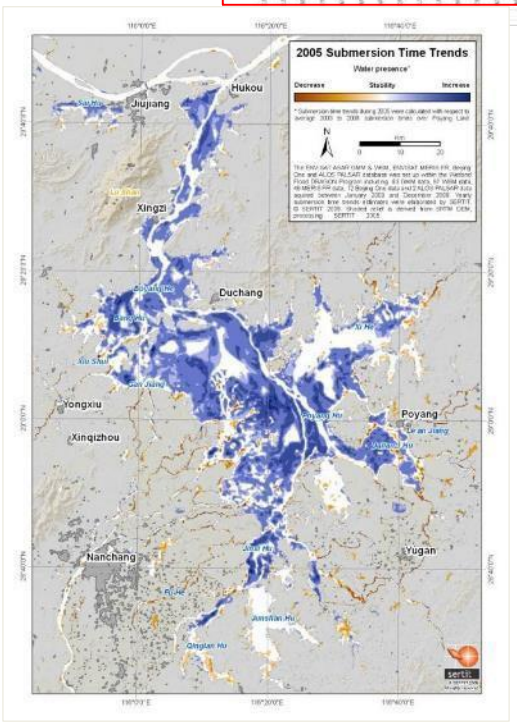
Why it is important to monitor water bodies?

Monitoring：keys for

long term change : lakes are climate sentinels

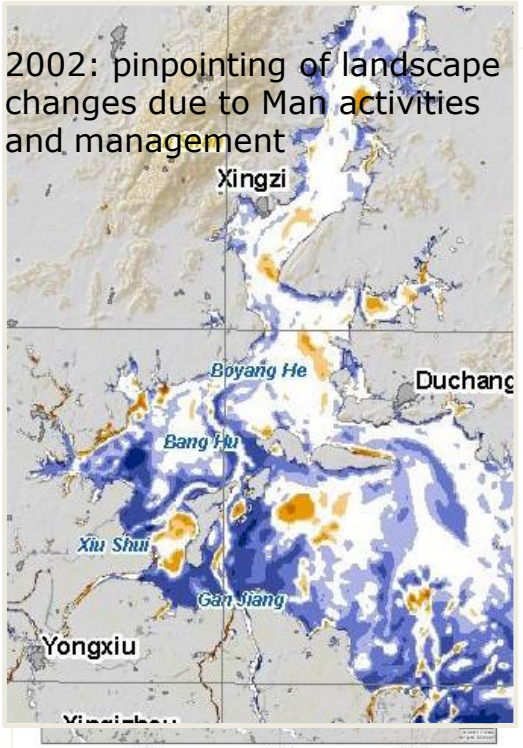
Inputs are long time series of EO data





2005：water stay longer period due to the February flood

2002: pinpointing of landscape changes due to Man activities and management

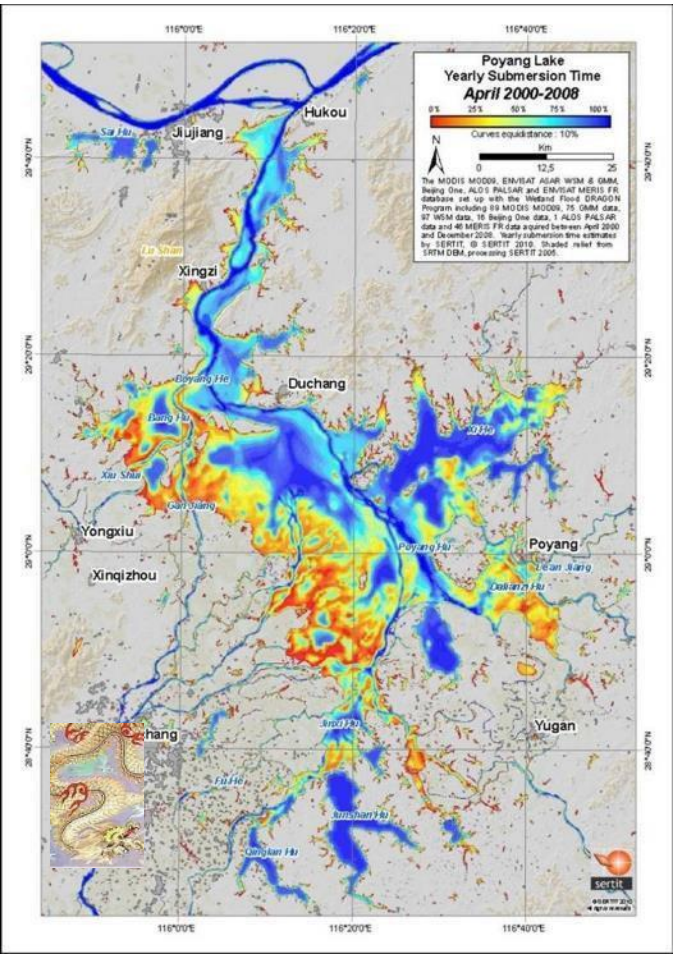


2008：Deficit of water stay in the delta part

Why it is important to monitor water bodies?

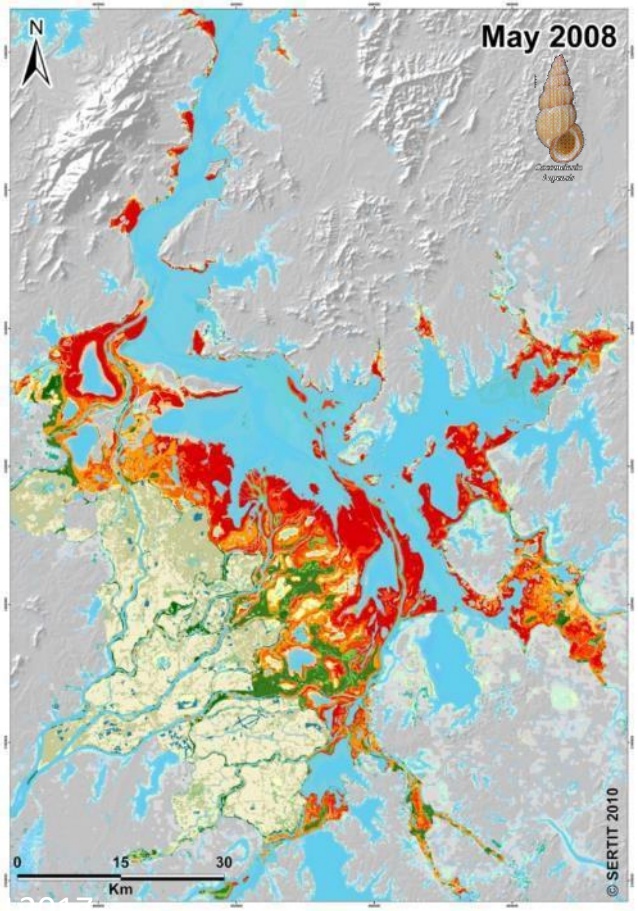
Monitoring : keys for epidemiology

Inputs are long time series of EO data



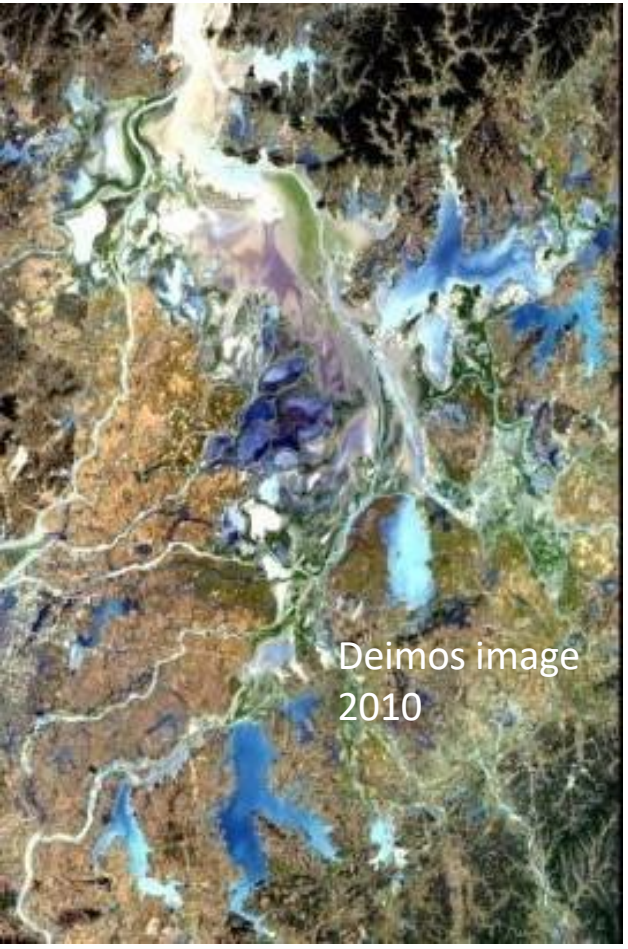
Water = key element in epidemiologyift Malaria, Rift valley fever, Schistosiomasis Etc …

Dynamic element=> need to be monitor



Why it is important to monitor water bodies?

Monitoring : keys for **Biodiversity**



Inputs are long time series of EO data

Water = key element
driving force of
sensible ecosystem
Etc …

Input for oriented
field survey

Near 30 years of exploitation of EO data for water bodies mapping and monitoring

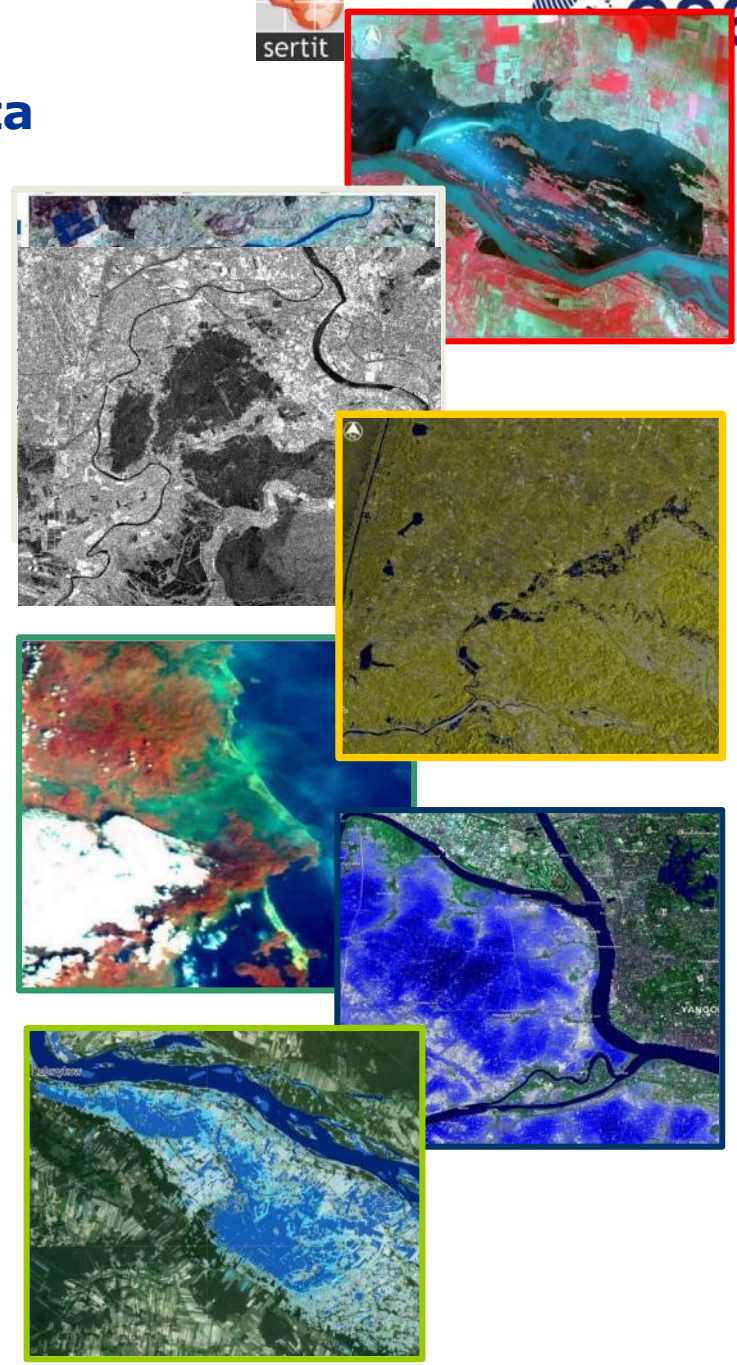
Improvement from one generation to another one

- SPOT1-3 to SPOT4-5=> SPOT 6-7
- SPOT => Pleaides VHR
- MODIS => MERIS=> S3 OCLI
- Sentinel2

- ERS =>ENVISAT=> Sentinel 1A/B
- HJ 1C => Chang Zheng 4C
- Radarsat 1 => Radarsat 2
- VHR SAR TerraSar X and CSK

Improvement in term of

- Swath
- Resolution
- Radiometric quality
- Revisiting time
- Access to images
- Derived products



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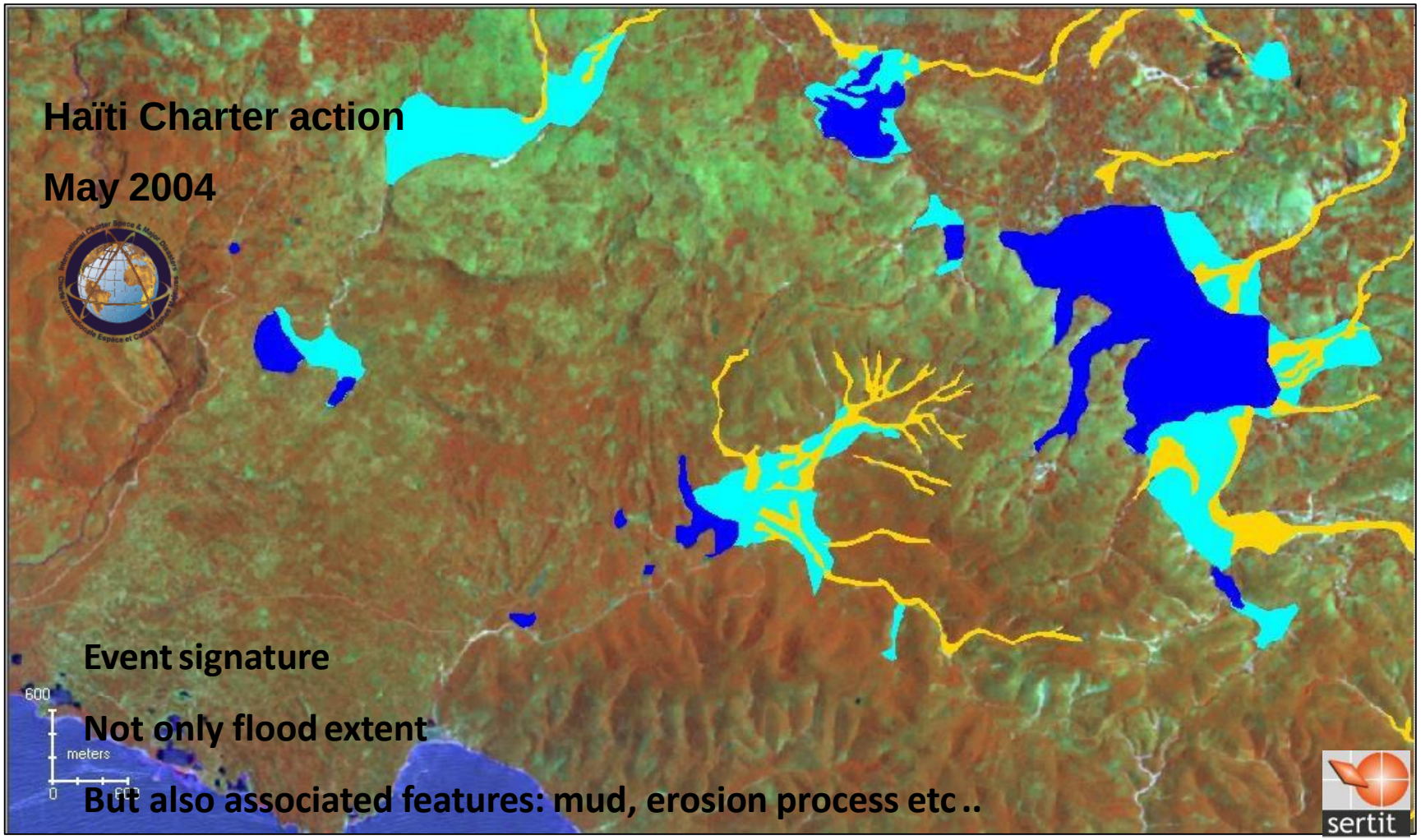
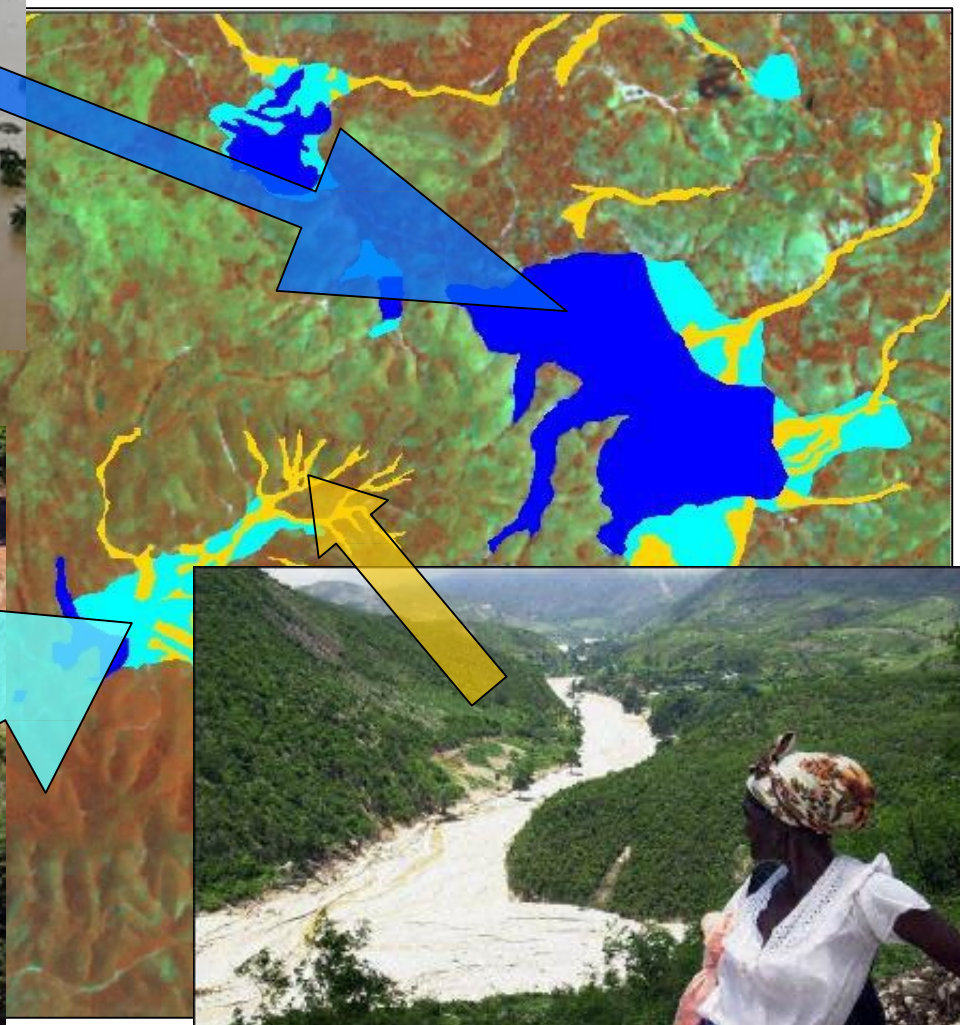
Concluding remarks

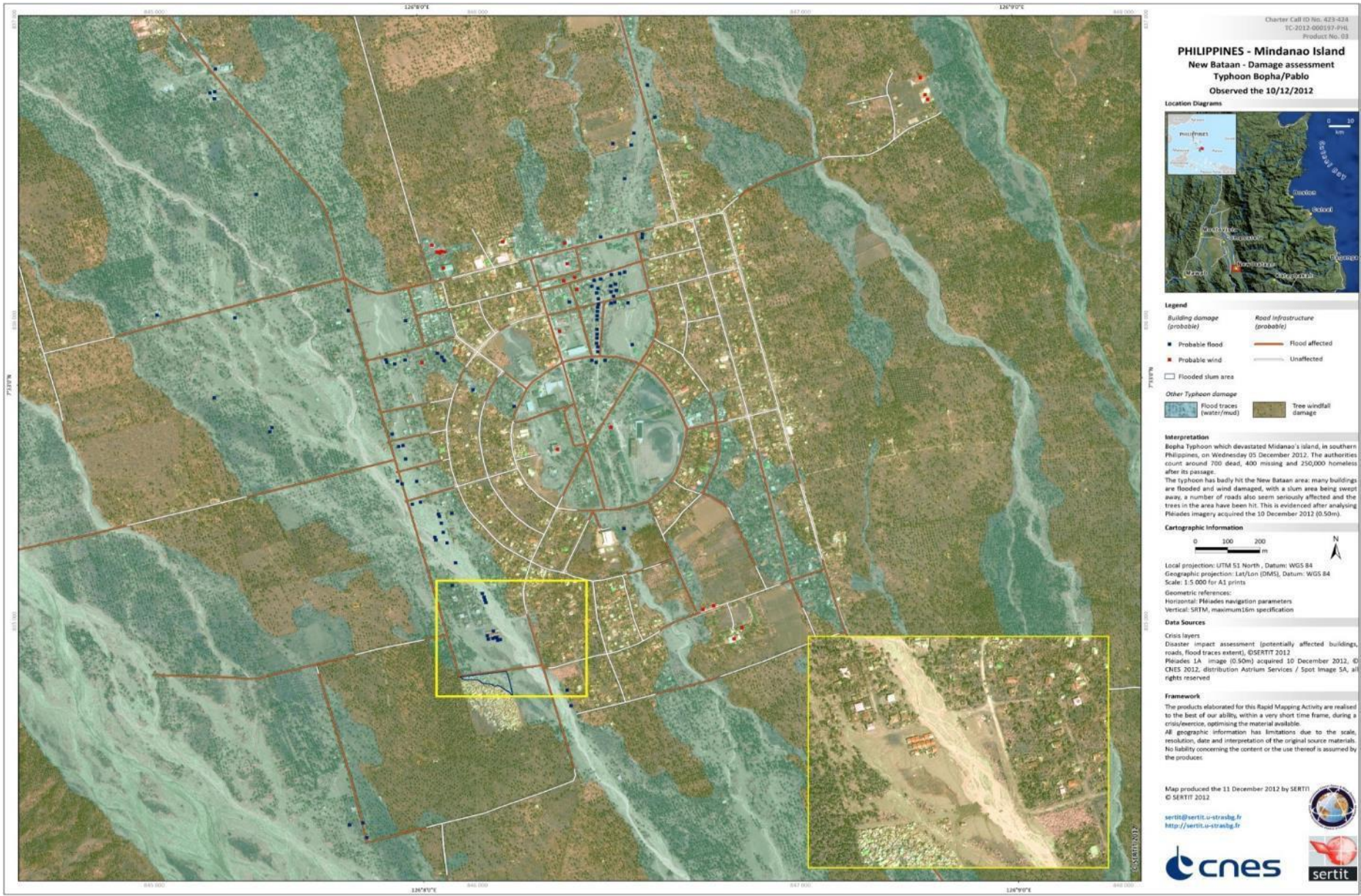
Flood patterns recognition



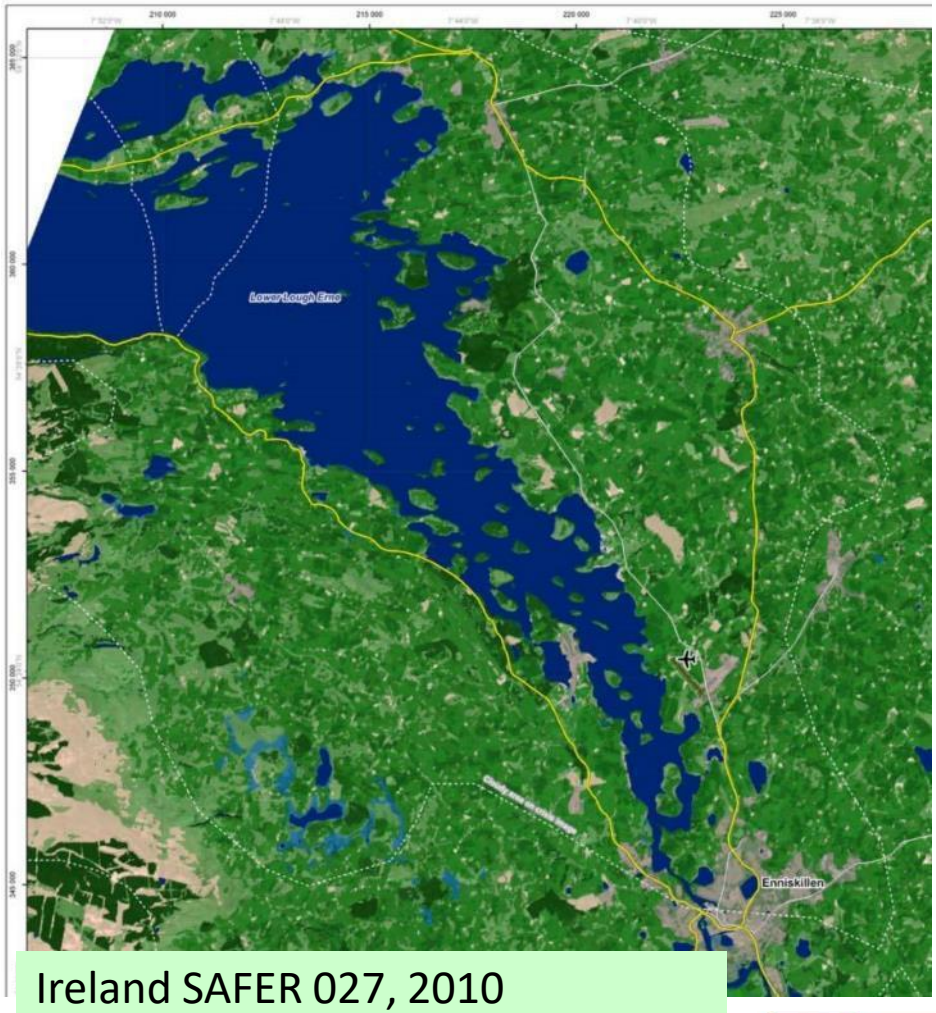
Event signatures

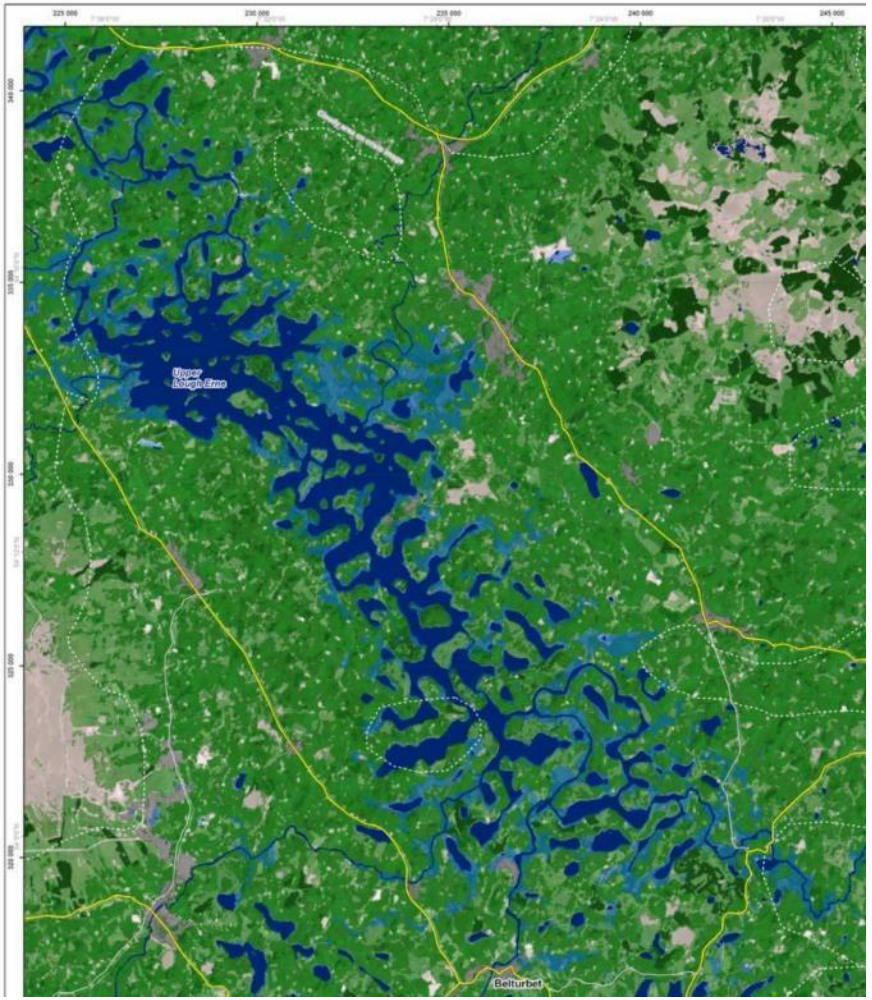


Flood patterns recognition



Flood patterns recognition

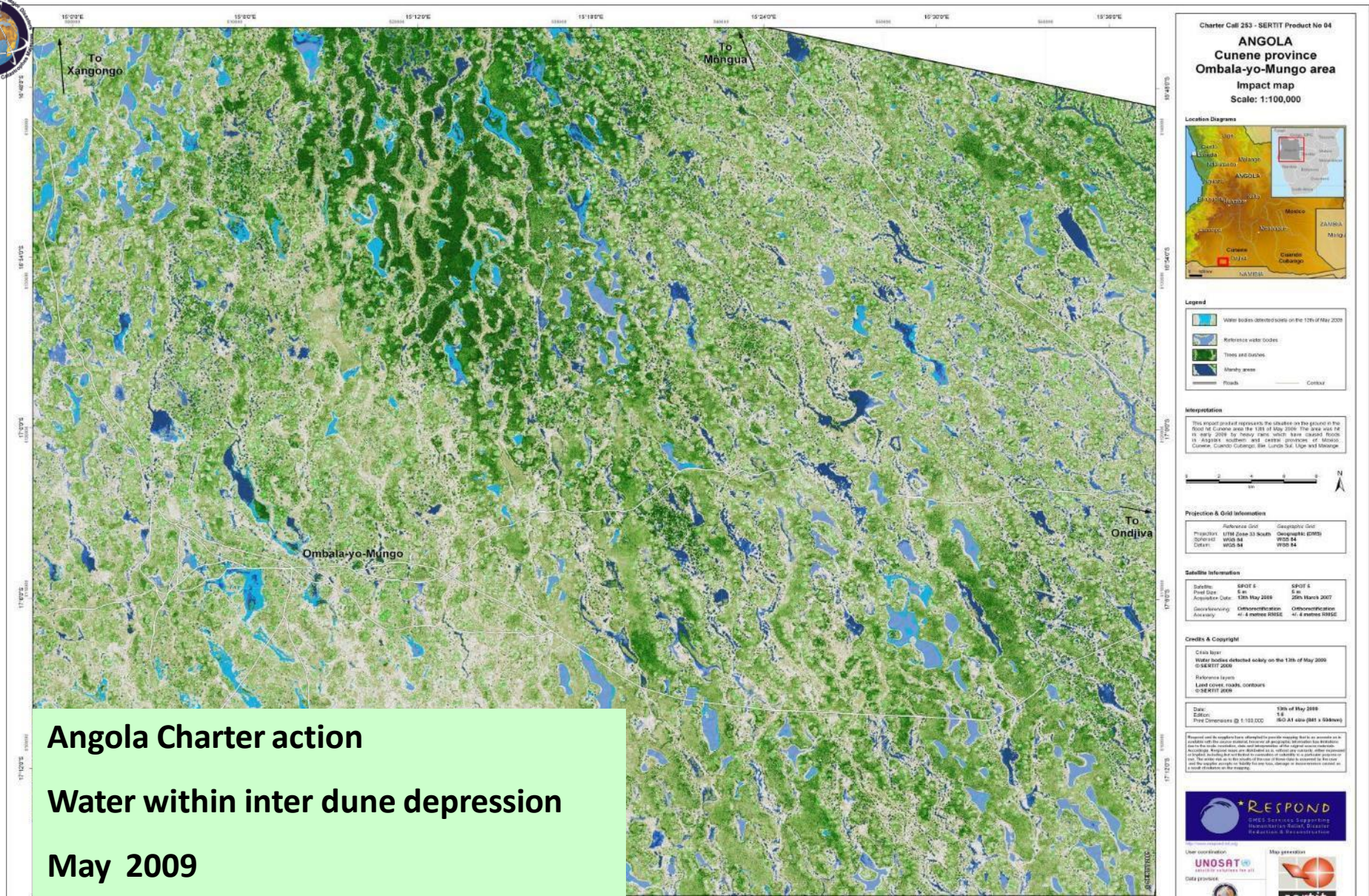




Ireland SAFER 027, 2010

Water within bogs

Flood patterns recognition



Angola Charter action

Water within inter dune depression

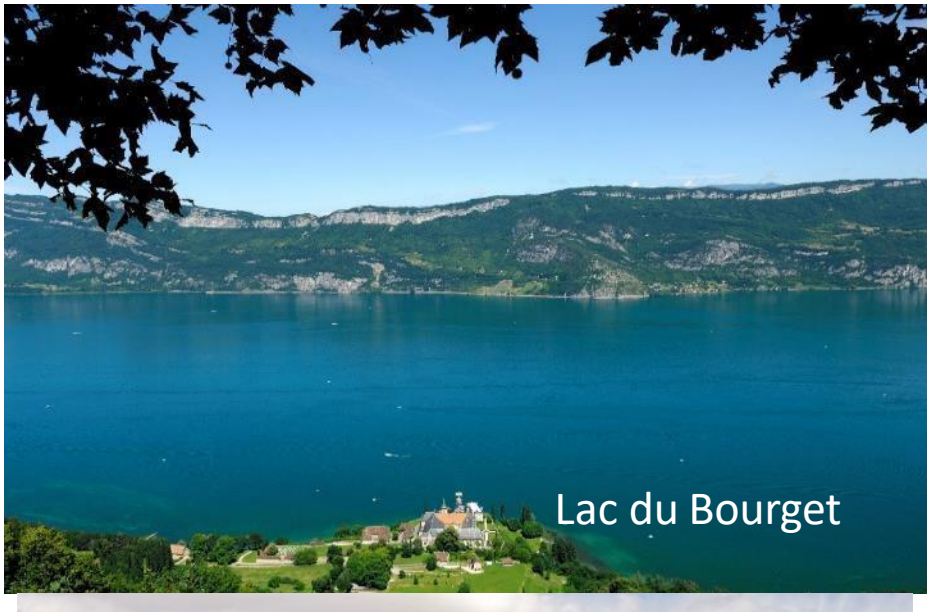
May 2009

Lakes and water bodies:
Landscape variability that will be captured by EO Sensors


Okavongo delta and river


Niger Inner delta and river

Lakes and water bodies: Landscape variability



Lakes and water bodies: Landscape variability

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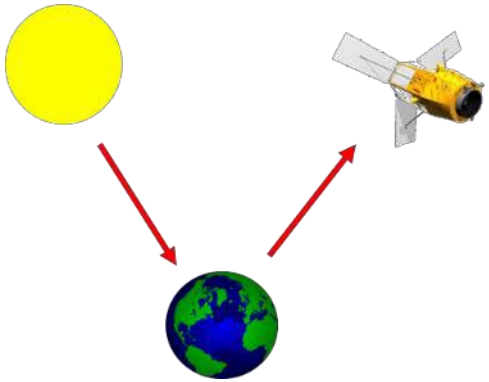
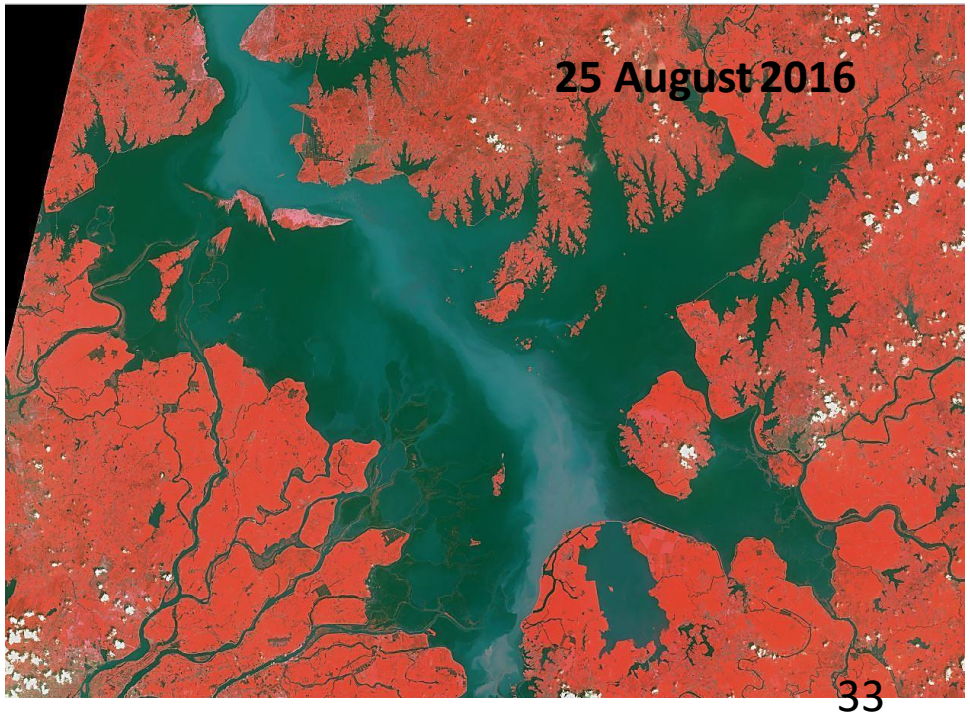
Concluding remarks

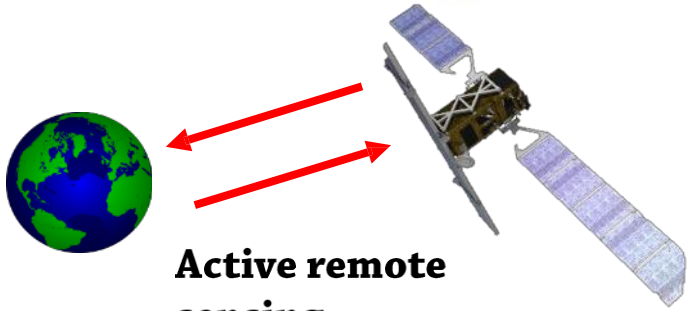
Clear sky
Sunny weather
⇒ Sentinel 2
⇒ Pléiades HR



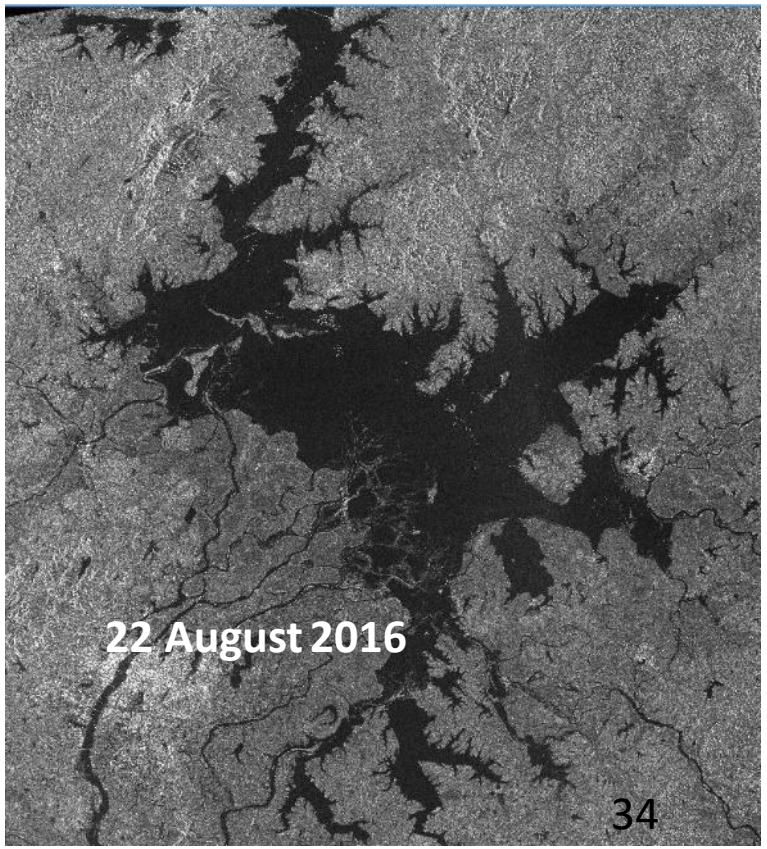
Pasive Remote Sensing
Optical sensors



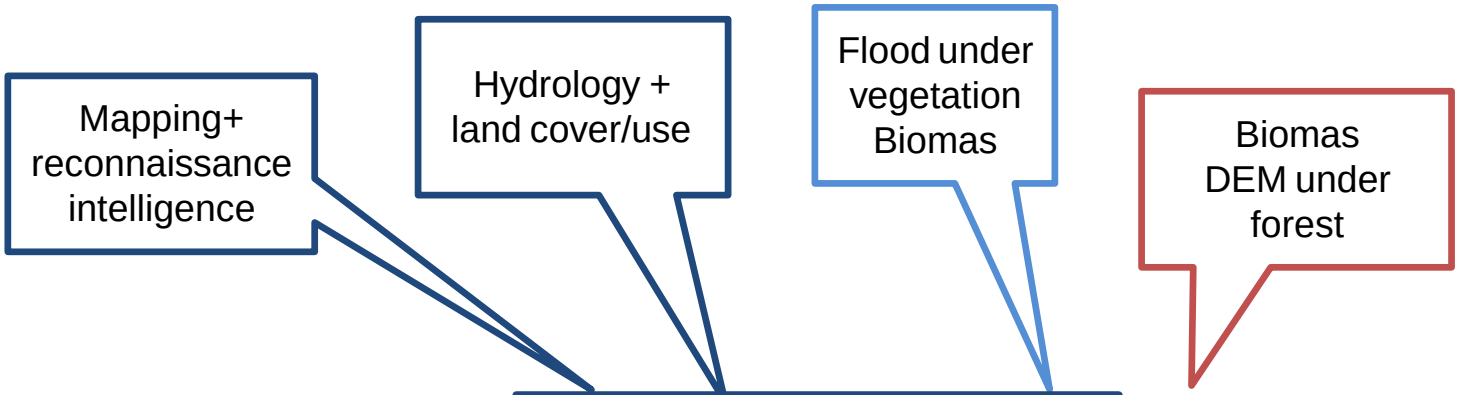
Cloudy , rainy weather
Sunny weather
⇒Sentinel 1
⇒Radarsat
⇒TSX & CSK
⇒ Gaofeng 3



Active remote sensing
SAR sensors



Wavelenghts pertinent for water surface mapping/monitoring



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

2010 Poland Floods : Rapid Mapping Areas and EO data

Poland Floods May - June 2010				
Category	Satellite	Sensor/Beam	Acquisition (UTC)	Res. (m)
VHR2	COSMO-SkyMed	Himage	26/05/2010 00:00:00	1 - 4
HR1	RADARSAT-2	Ultra-Fine	22/05/2010 05:02:47	4 - 10
HR1	RADARSAT-2	Fine	12/06/2010 04:49	
HR1	RADARSAT-2	Fine	12/06/2010 04:50	
HR1	RADARSAT-2	Fine	15/06/2010 16:25	
HR1	RADARSAT-2	Fine	16/06/2010 04:33	
HR1	RADARSAT-2	Fine	18/06/2010 16:38	
HR1	RADARSAT-2	Fine	25/06/2010 16:34	
HR1	RADARSAT-2	Fine	25/06/2010 16:34	
HR1	RADARSAT-2	ML Fine	25/05/2010 16:38:27	
HR1	RADARSAT-2	Fine	26/06/2010 04:41	
HR1	TerraSAR-X	ScanSAR	26/05/2010 16:43:18	
HR1	TerraSAR-X	ScanSAR	27/05/2010 16:26:01	
HR1	TerraSAR-X	Stripmap	13/06/2010 16:17	
HR1	COSMO-SkyMed	Himage	09/06/2010 00:00	
HR1	COSMO-SkyMed	Himage	10/06/2010 00:00	
HR1	COSMO-SkyMed	Himage	11/06/2010 00:00	
HR1	ENVISAT ASAR	IM	20/06/2010 00:00	
HR2	RADARSAT-2	Fine	22/05/2010 16:25:34	10 - 30
HR2	RADARSAT-2	Fine	23/05/2010 04:33:25	
HR2	RADARSAT-2	Multi-Look	25/05/2010 05:15:23	
HR2	RADARSAT-2	ML Fine	25/05/2010 16:38:04	
HR2	RADARSAT-2	ML Fine	26/05/2010 04:46:04	
HR2	ERS-2	SAR Standard	19/05/2010 20:39:00	
HR2	ENVISAT ASAR	IM	16/06/2010 00:00	
HR2	ENVISAT ASAR	IM	20/06/2010 00:00	
HR2	ALOS PALSAR		21/05/2010 21:27:20	
MR	ENVISAT	WSM	25/05/2010 20:22:18	> 30
Total Radar crisis data : 28				
HR1	SPOT5	Multispectral 10m	21/05/2010 09:40:00	
HR1	Formosat-2	Panchromatic	23/05/2010 08:34:00	
HR2	SPOT5	Multispectral 10m	21/05/2010 09:40:00	
HR2	SPOT5	Multispectral 10m	21/05/2010 09:40:00	
HR2	ALOS AVNIR-2		21/05/2010 10:18:06	
Total Optical crisis data : 5				

2010 Poland Floods : Rapid Mapping Areas and EO data

- Location: South of Poland - Vistula, Odra and Warta rivers regions
- Due to heavy rains, the level of main rivers increased quickly: daily rainfall was equal to the average cumulative rainfall for two months
- Two flood waves hit the interested regions (higher than the century-oldwater level)
- All National Reserve of the rescue forces of the State Fire Service were mobilized
- Damages in infrastructure, properties, casualties, and long term process for revitalisation

2010 Poland Floods : Rapid Mapping Areas and EO data

2010 Poland Floods : Rapid Mapping Activity Summary

FLOODS in POLAND
Vistula, Odra and Warta Rivers

- **SAFER GERS38, GERS41**
  Date of Activation: 19/05/2010
  (Poland National HQ of the State Fire Service)
  Date of Closure: 02/07/2010

- ***Multi Satellite Data used by SERTIT:***
  ERS-2
  ENVISAT ASAR
  RADARSAT-2
  Terra SAR-x
  COSMO-SkyMed
  ALOS PALSAR

  SPOT 5
  Formosat-2
  ALOS AVNIR-2
  LANDSAT 5

- ***30 products provided by SERTIT :***
  Reference up-to-date maps
  Flood extent maps
  Flood dynamics maps
  Flood impact maps

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Concluding remarks

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

Near all weather capability

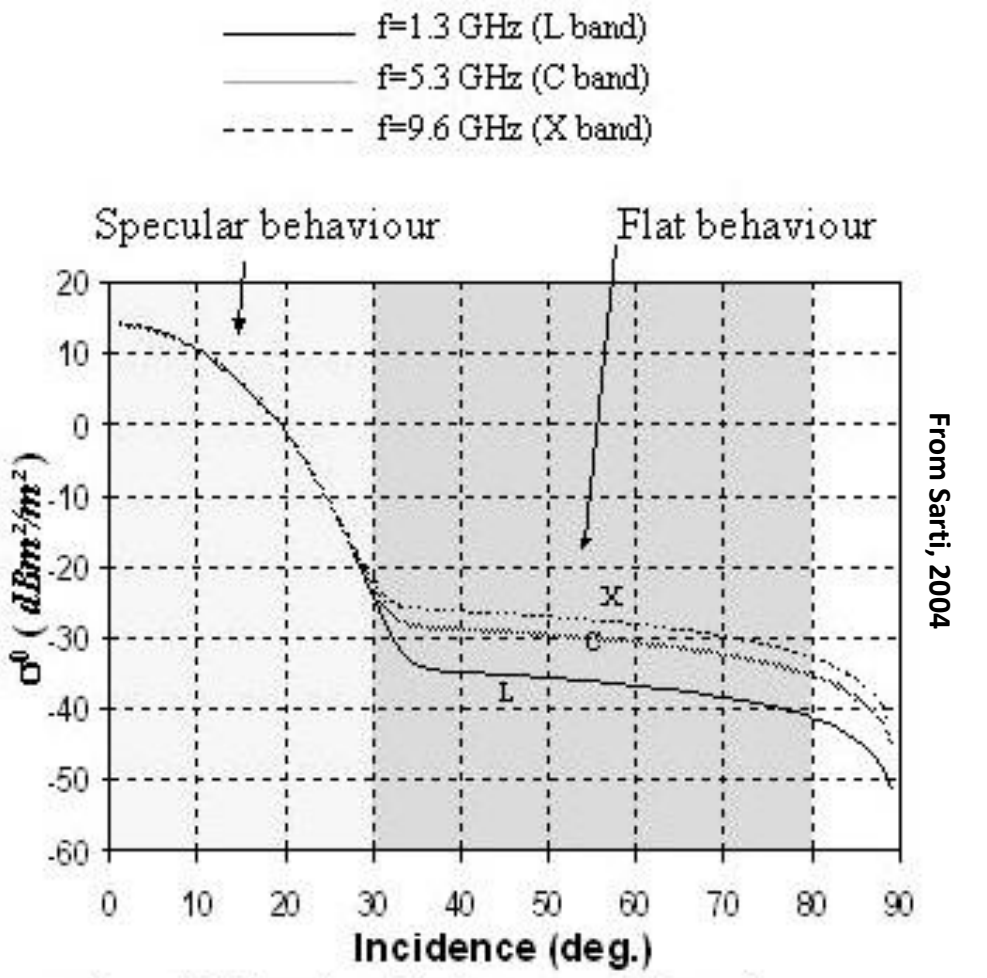
Day & night capabilities

Relative large swath

Relative good revisit

On SAR data water surfaces have low values of BS

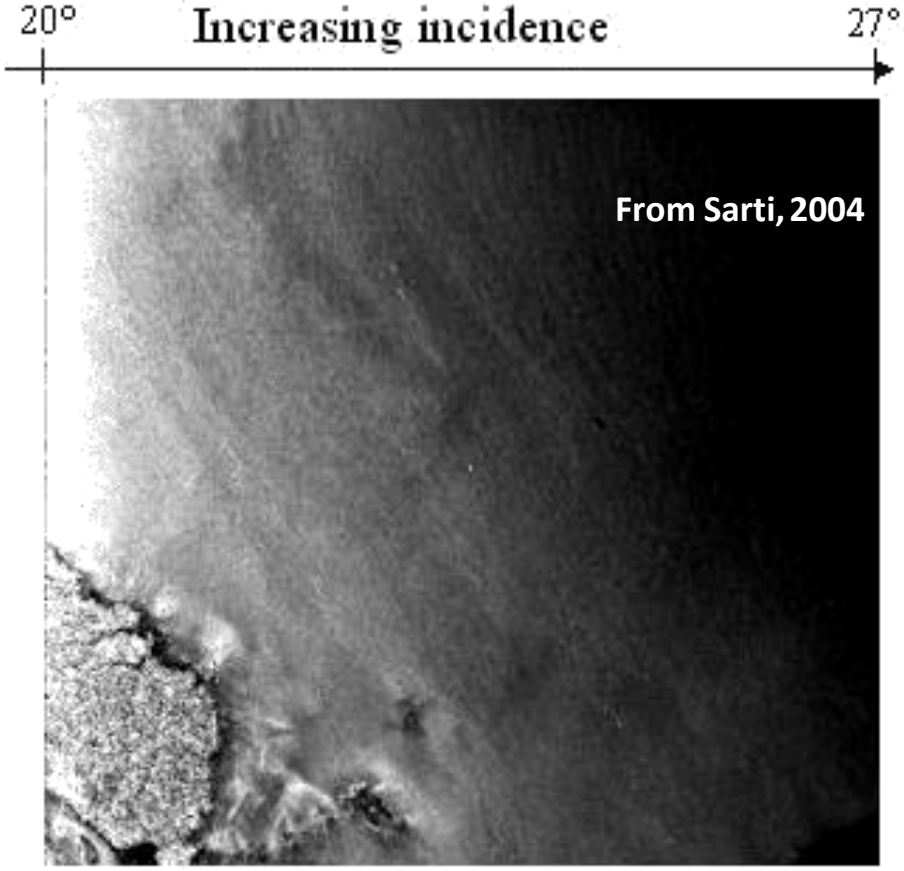
But local weather (wind/rain) effect altering the signal



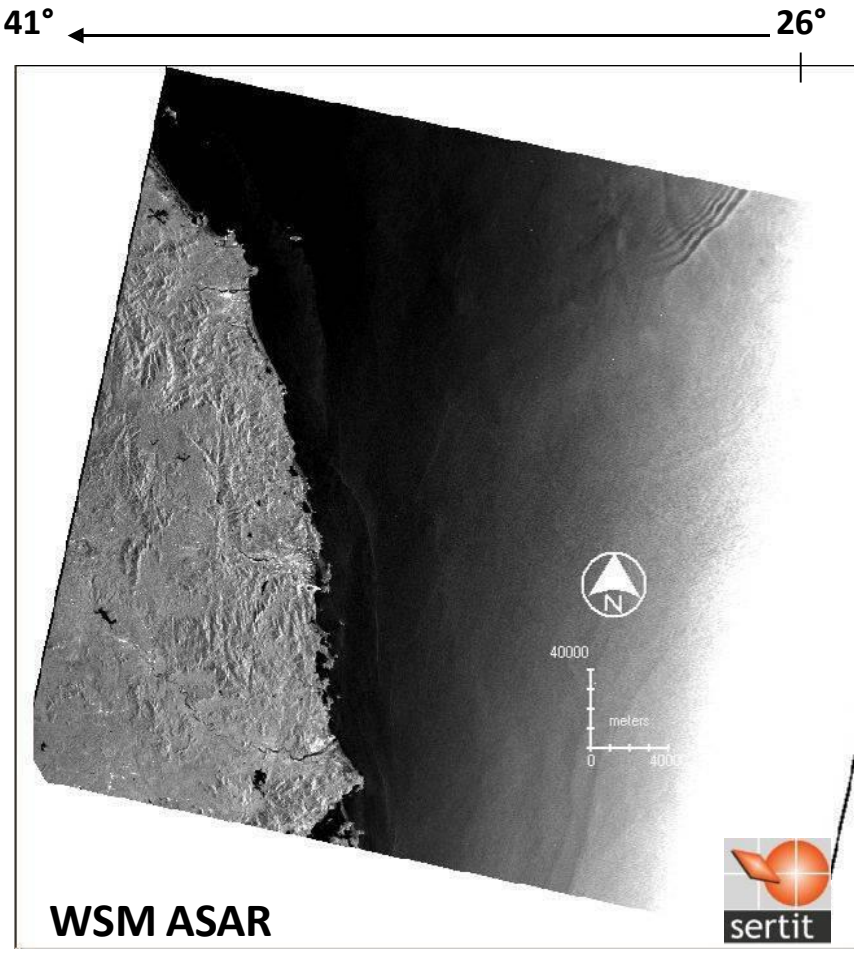
semi-empirical function of backscatter coefficient σ^0
as a function of incidence (for a mean sea), for 3 different radar bands

From Sarti, 2004

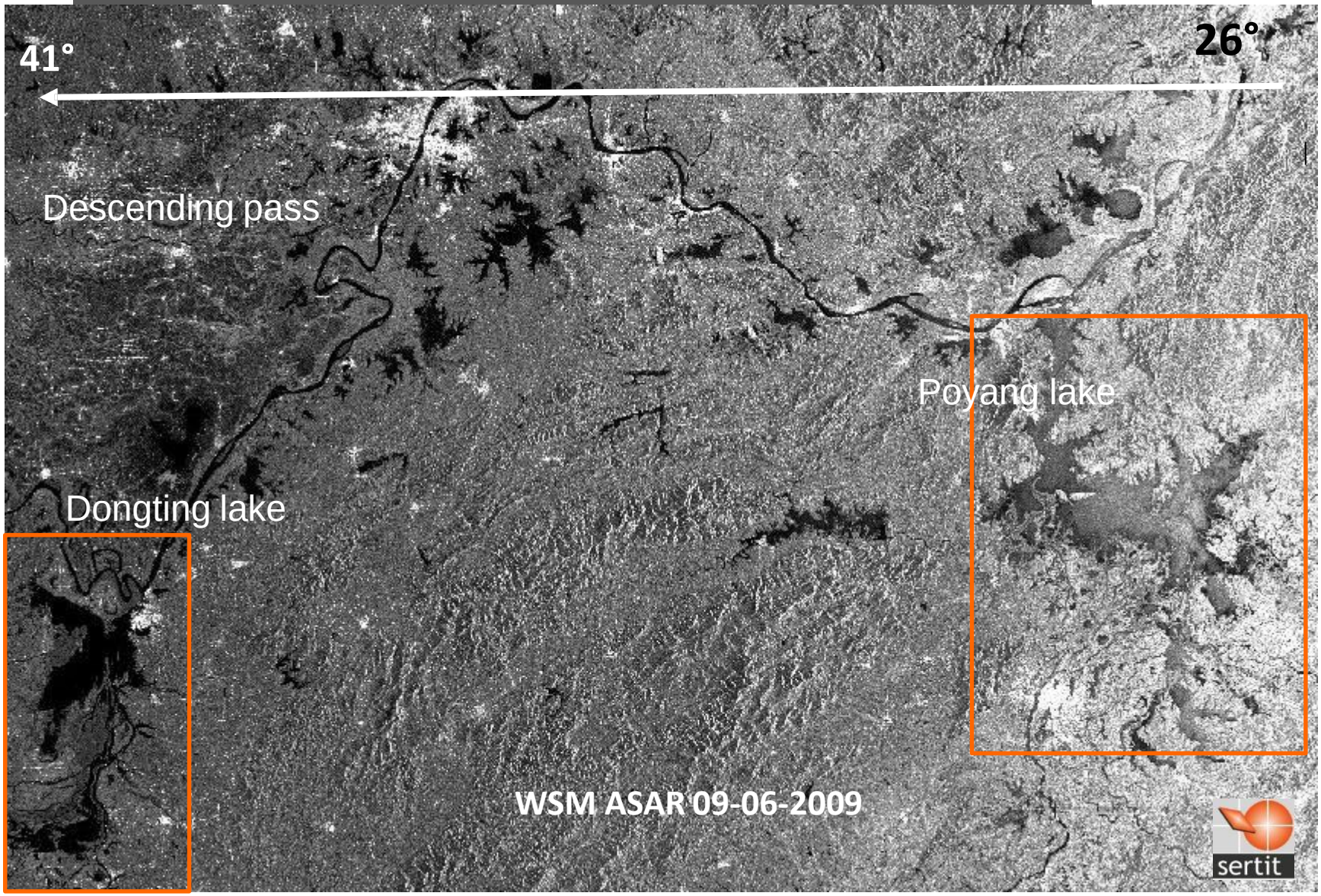
Water backscattering in function of incidence angle



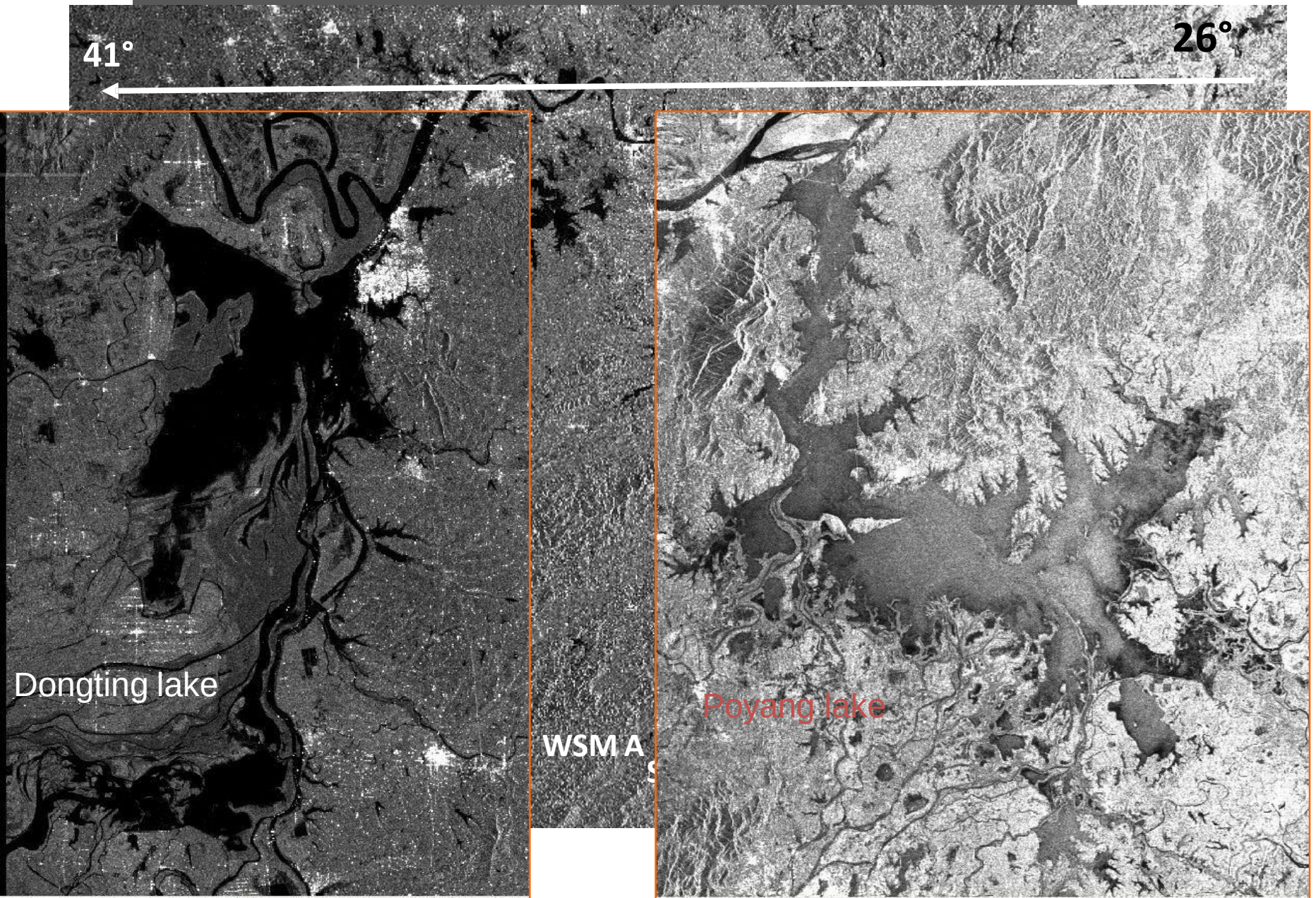
Incidence effect observed on a RADARSAT S1 (20°-27°)



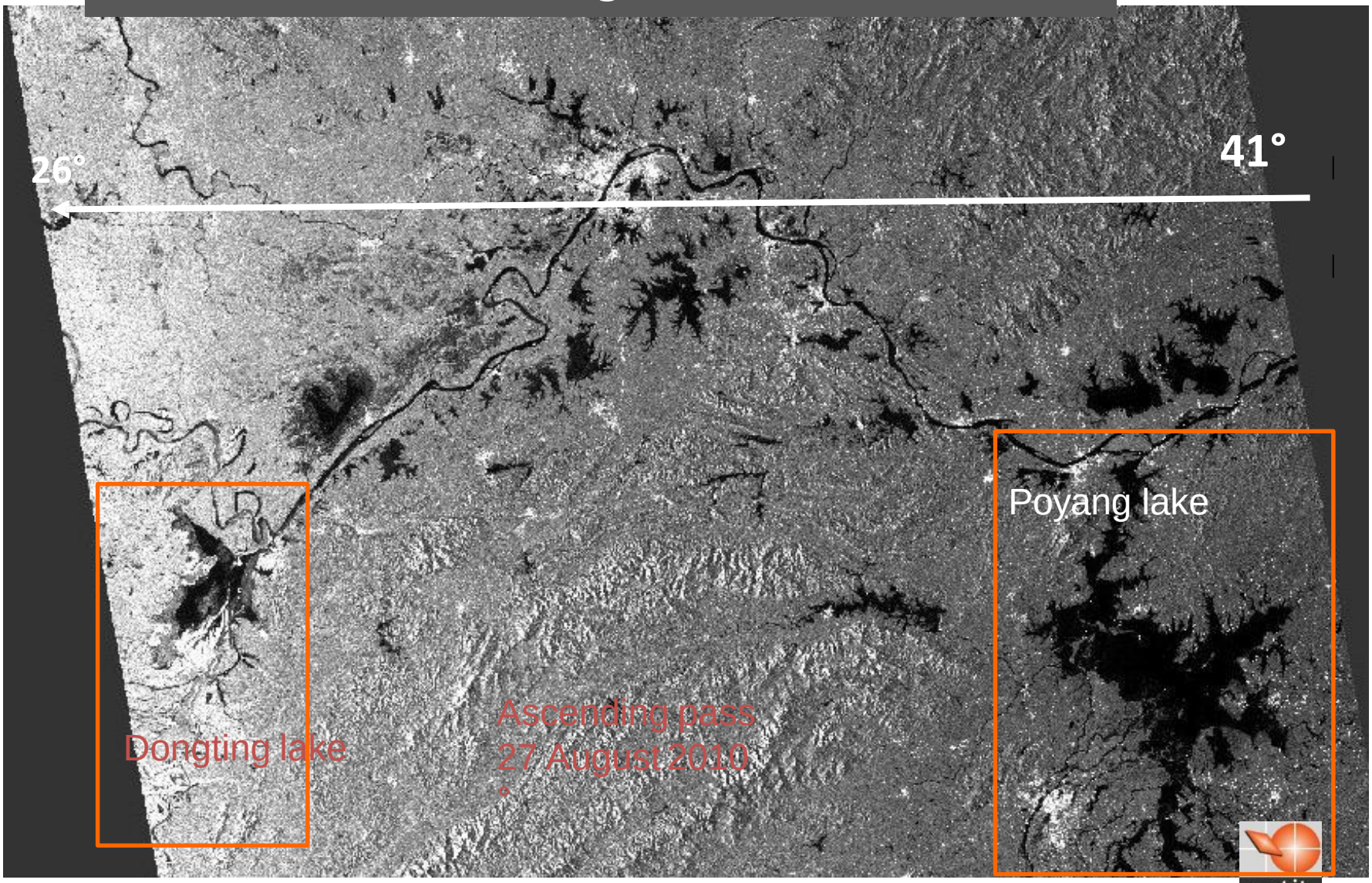
Water backscattering in function of incidence angle



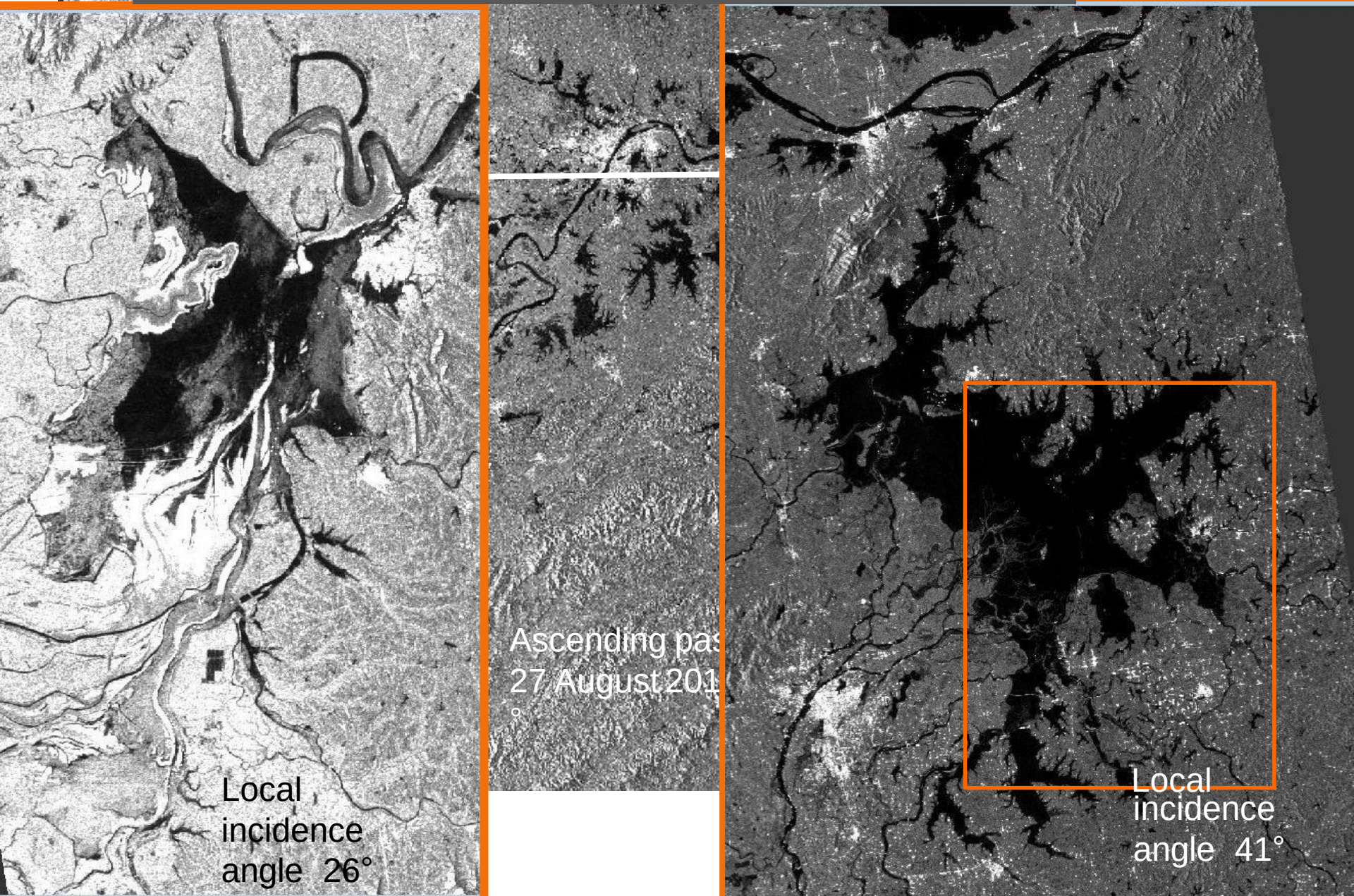
Water backscattering in function of incidence angle



Water backscattering in function of incidence angle



Water backscattering in function of incidence angle



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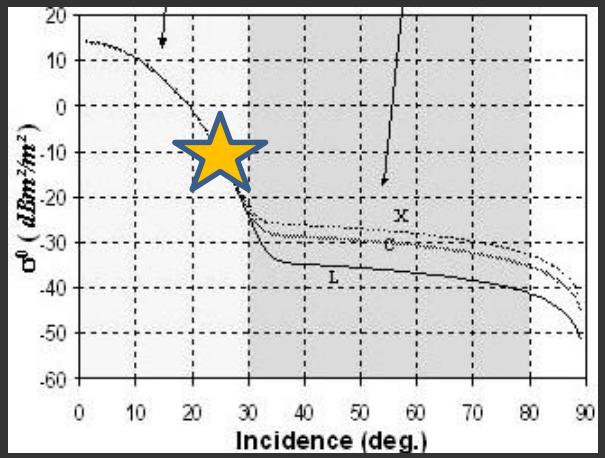
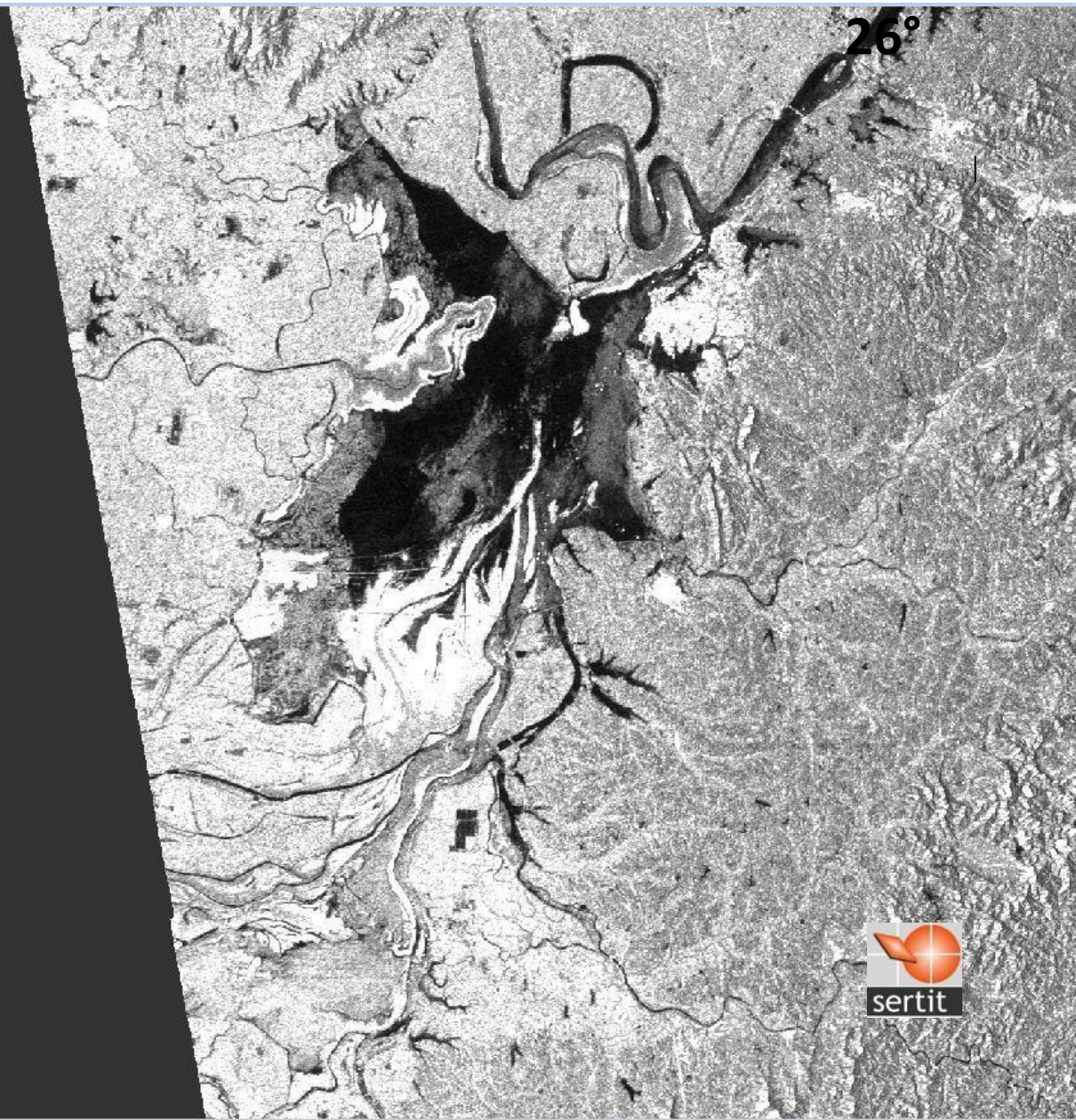
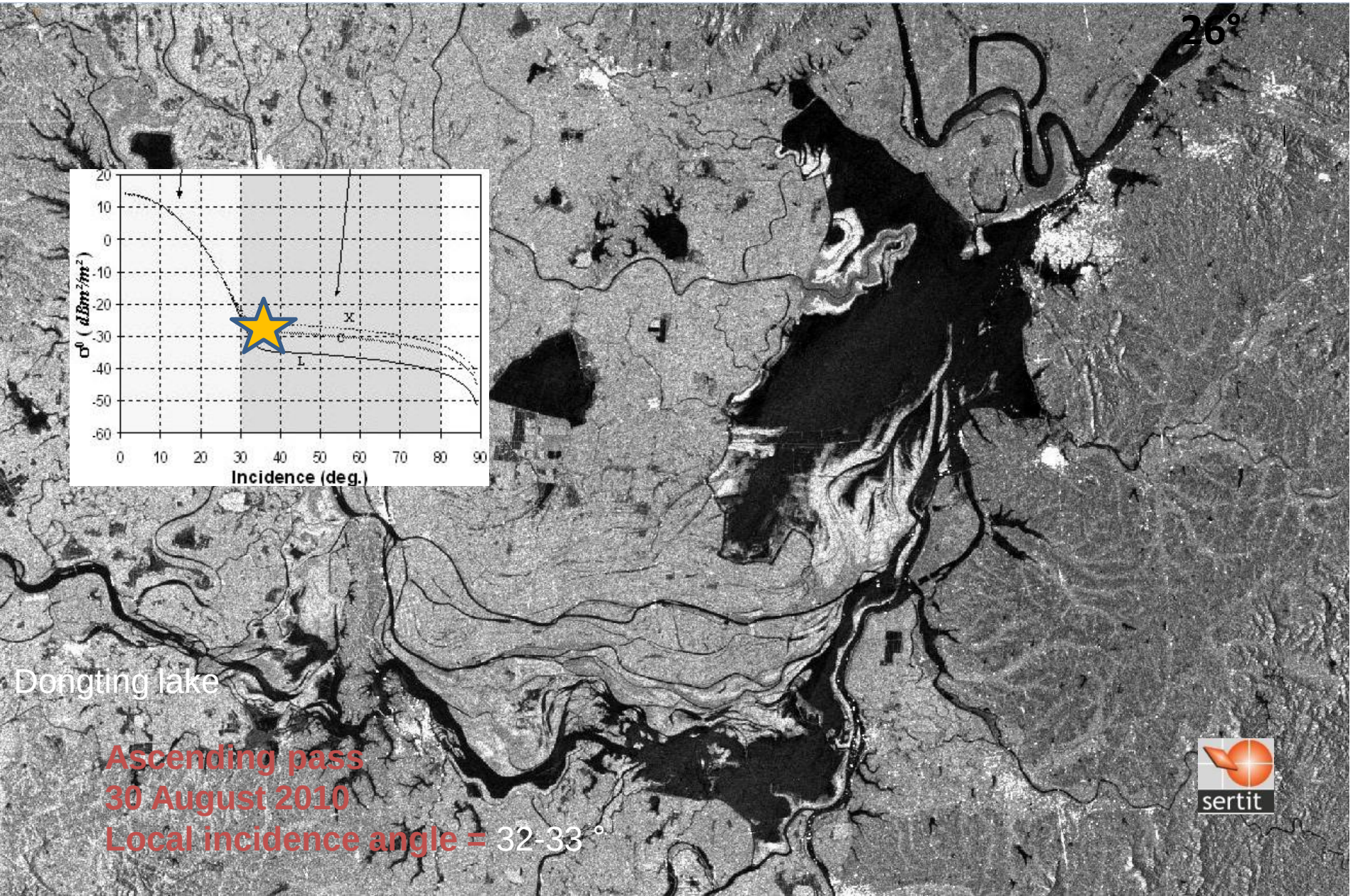


Dongting lake

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 surface roughness

Signal - Surface interactions Rayleigh criterion

Specular reflection (smooth surface)

$h < \lambda / 8\cos\theta$

Diffuse reflection (rough surface)

$h > \lambda / 8\cos\theta$

λ varies from

K 1cm X

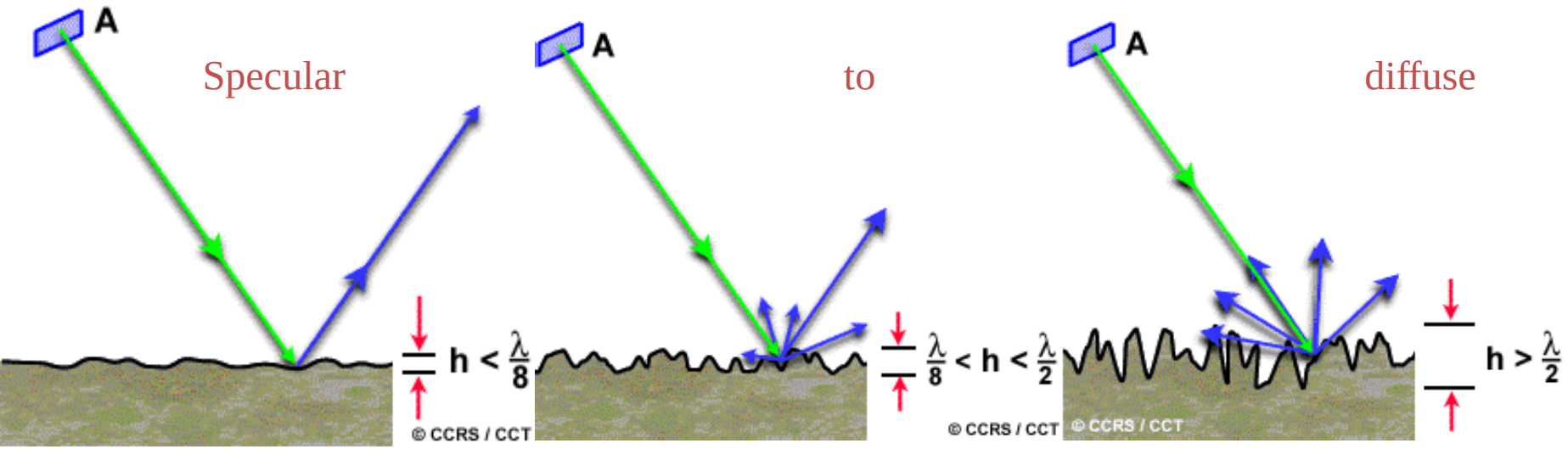
3cm C

5.6cm S

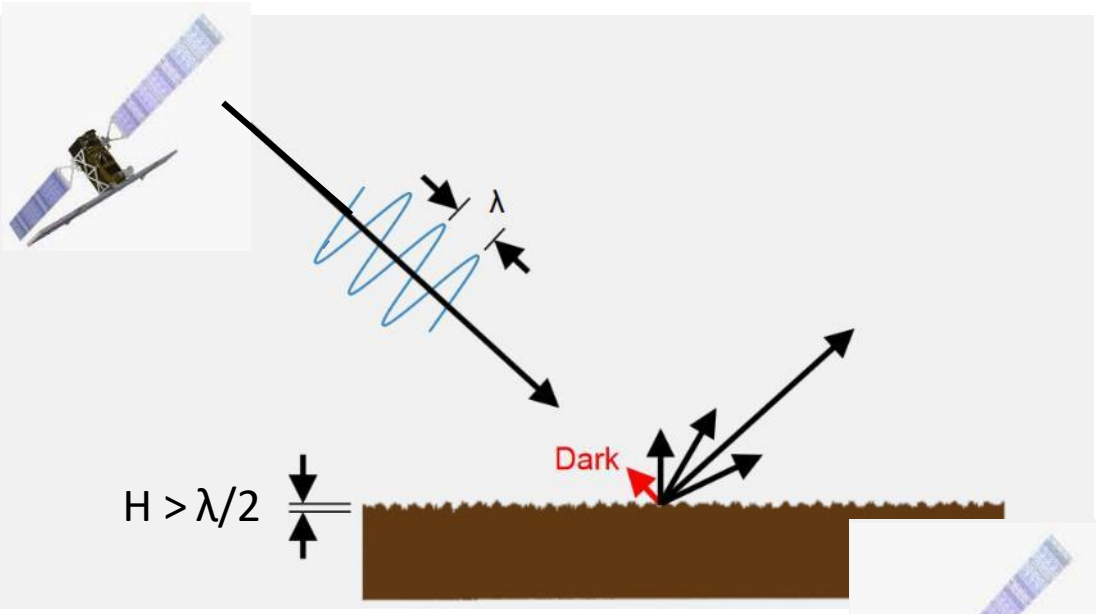
10cm L ← HJ-C ALOS PALSAR

23cm P

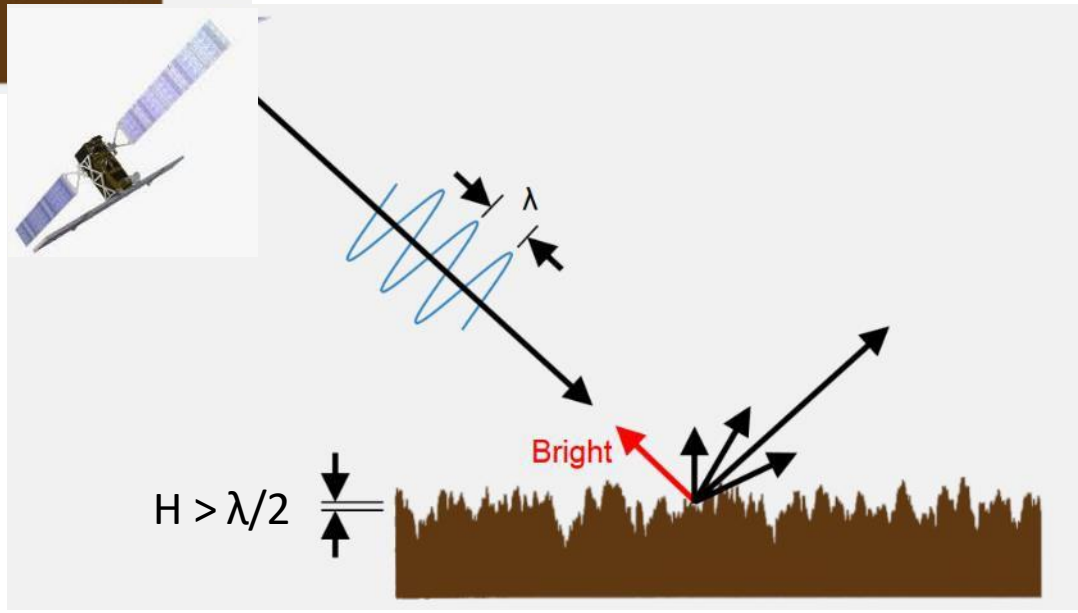
70cm



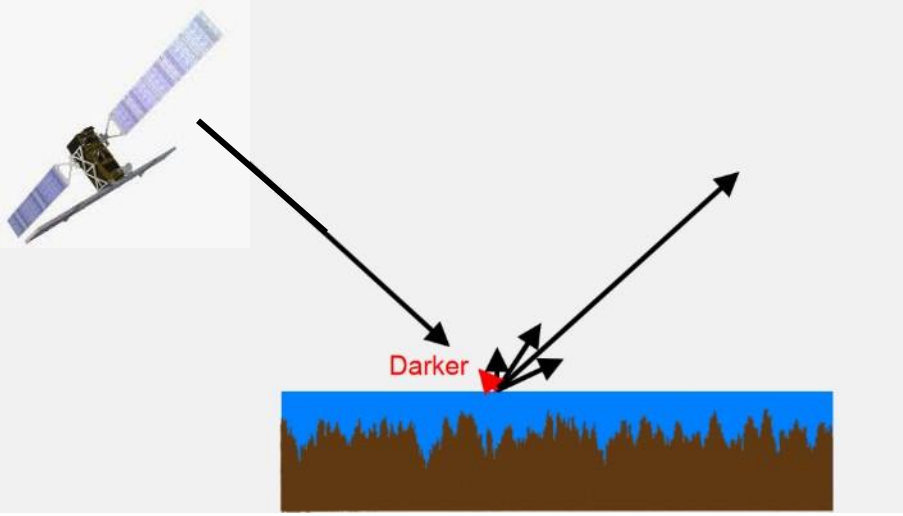
Water backscattering in function of surface roughness



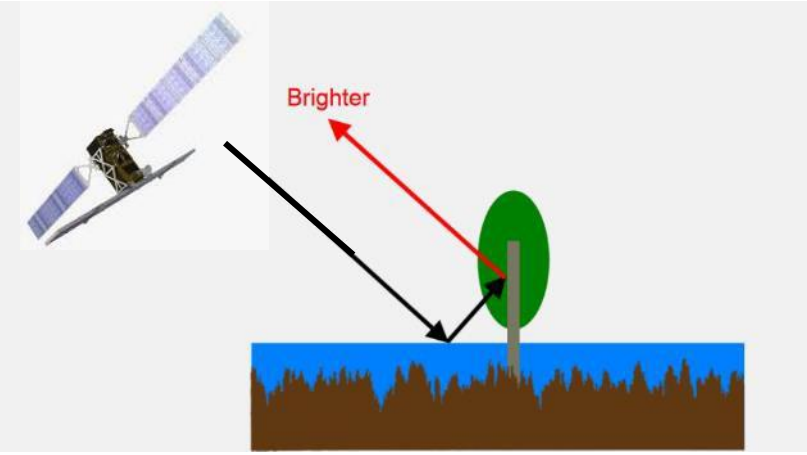
Case of soil surface

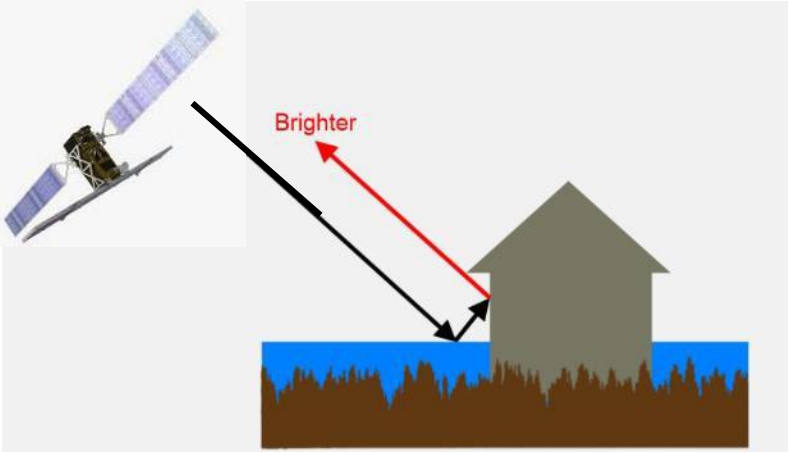


Adapted from Sang-Ho Yun, NASA JPL



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:

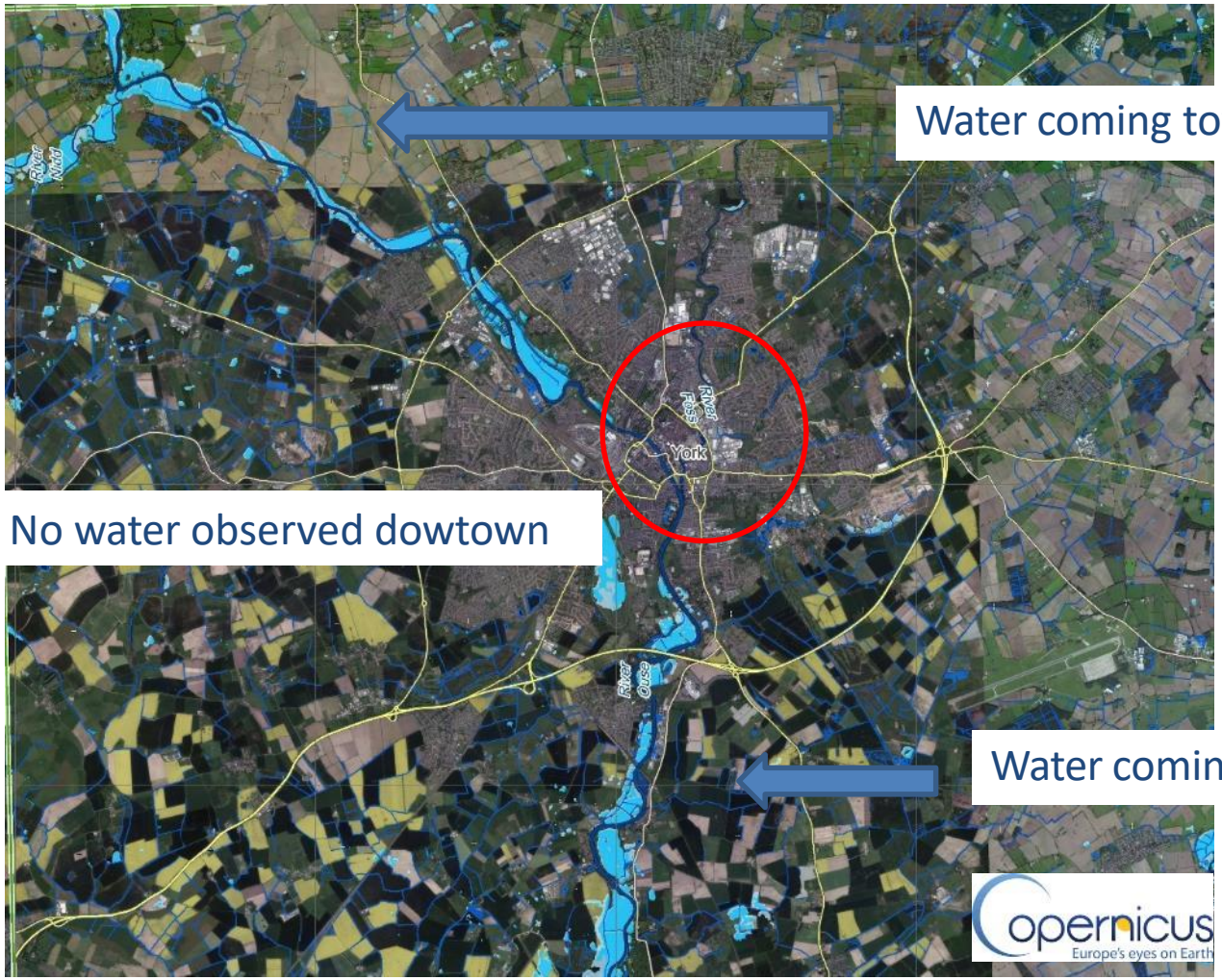
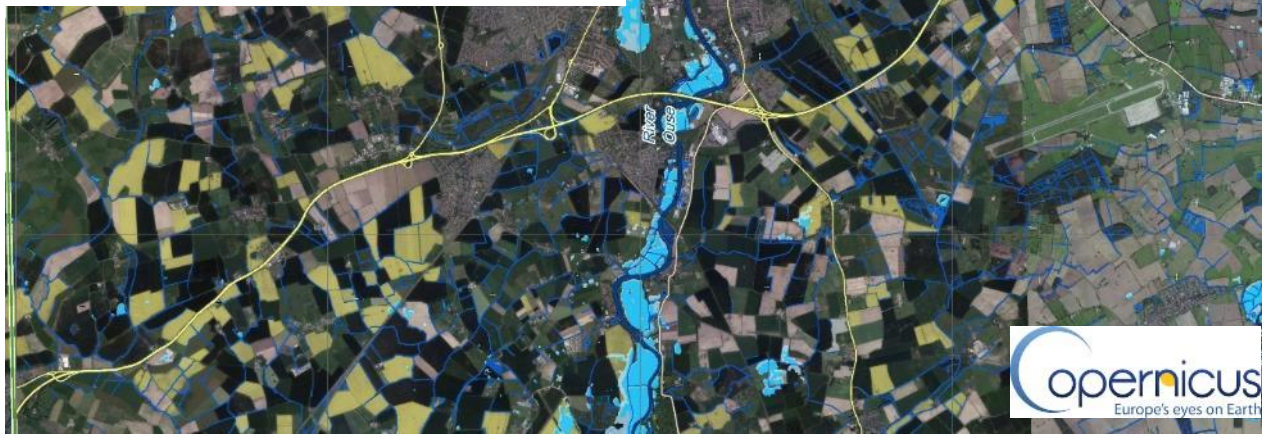


Illustration of SAR limitation in Urban area

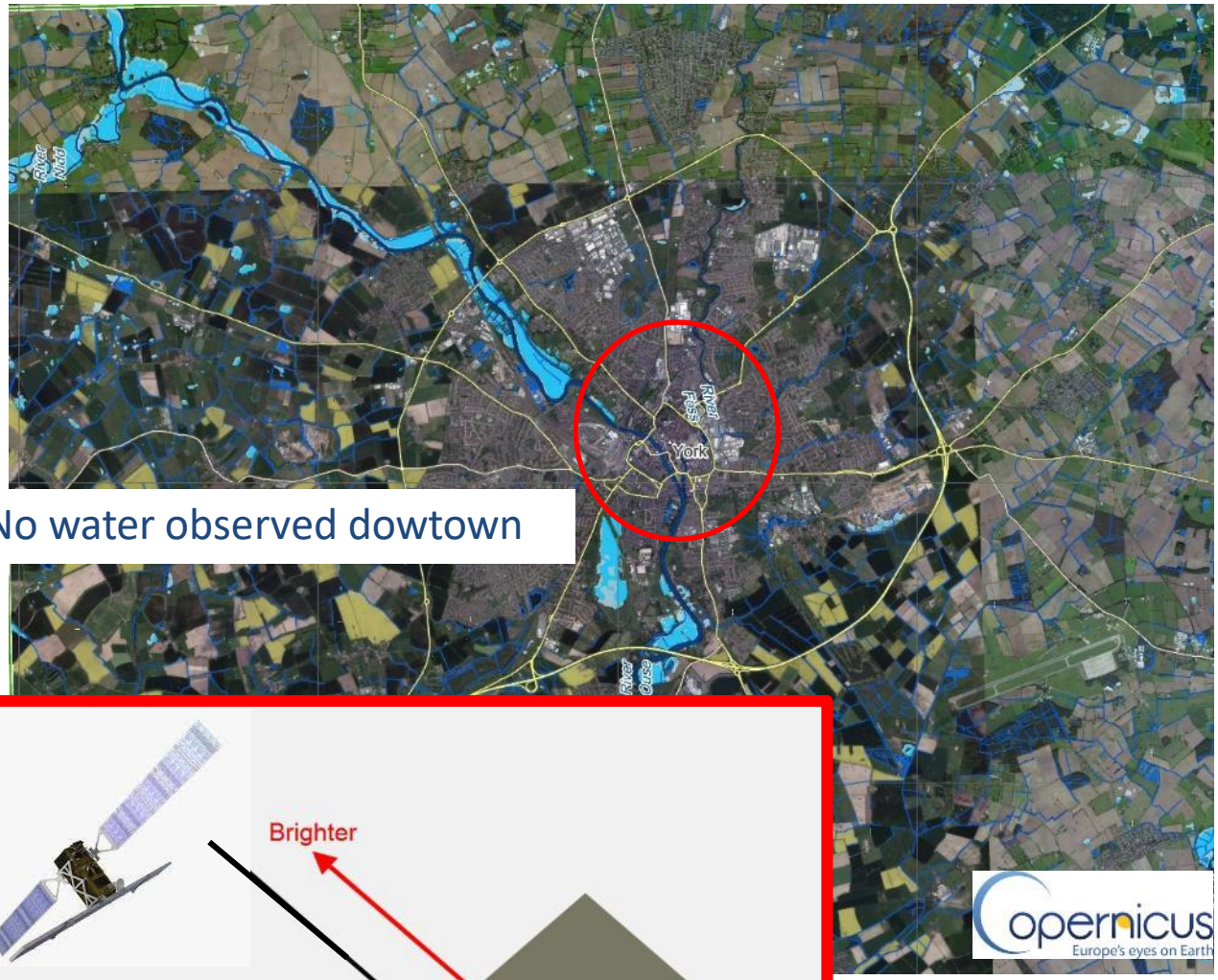
SAR and Urban area: December 2016 Flood in York, England, based on Radarsat 2 imagery:

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:



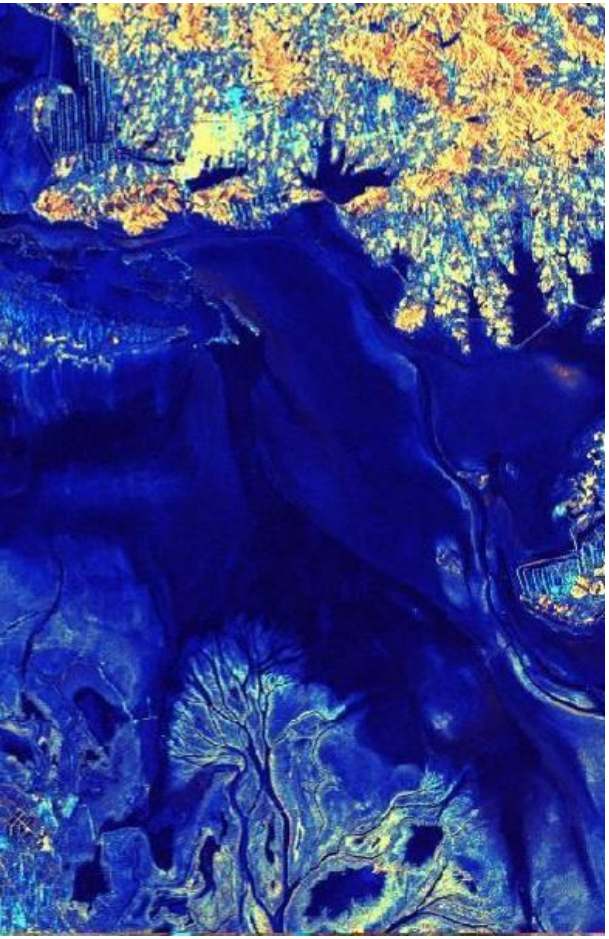
No water observed dowtown

Strong SAR signal in urban environment no capability for water recognition

Water backscattering in function of surface roughness

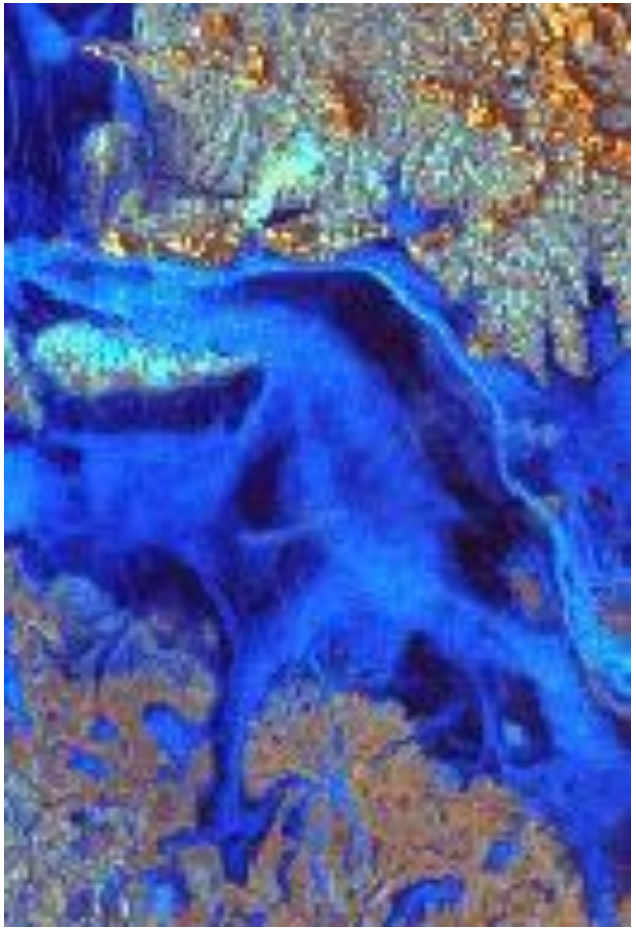
PALSAR bande L HH/HV

Low level of water
Commision between mud banks and open water



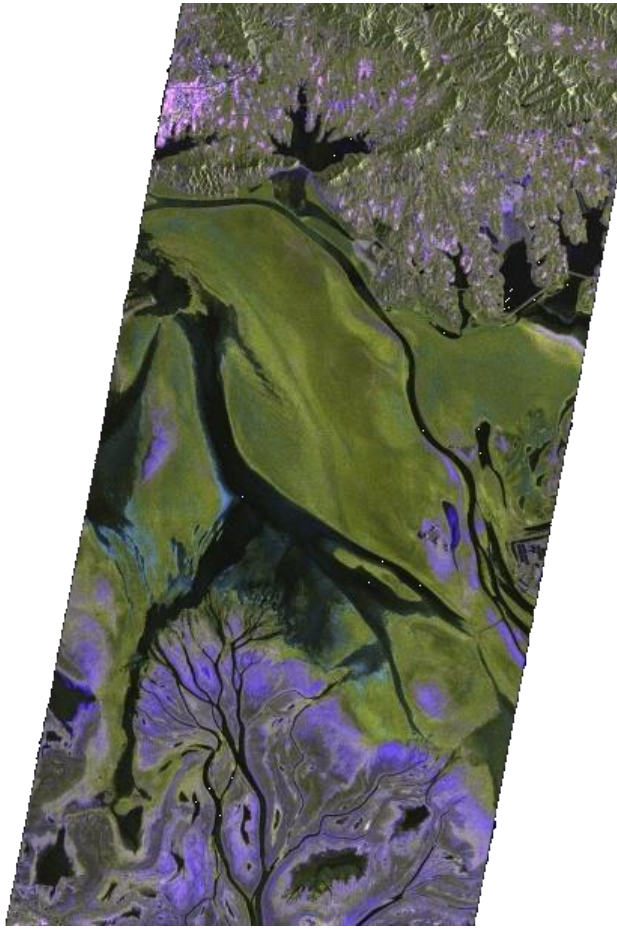
ASAR bande C HH/HV

Intermediate level of water



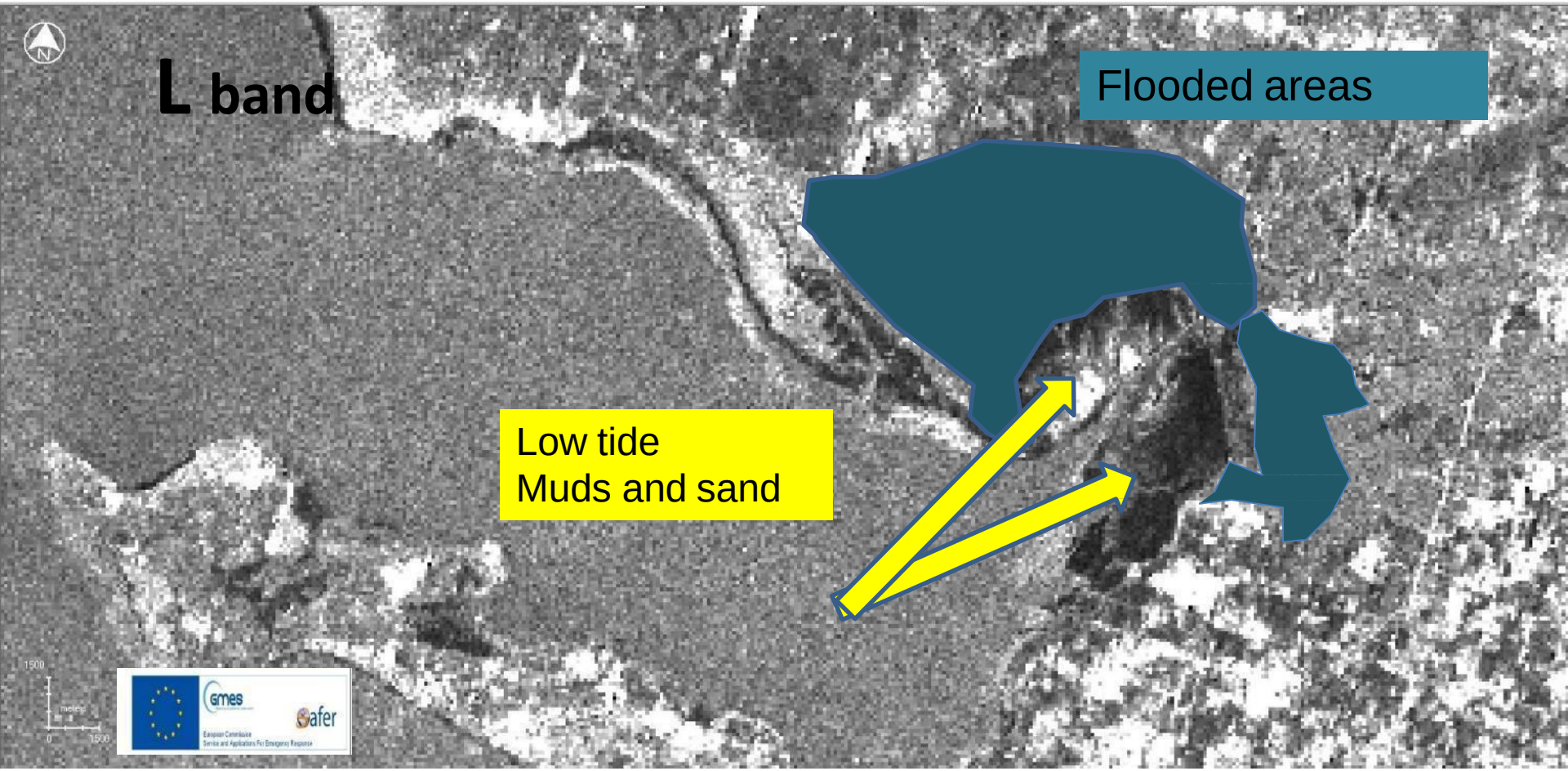
TerraSar bande X HH/HV

Low level of water
Good différenciation between mud/water



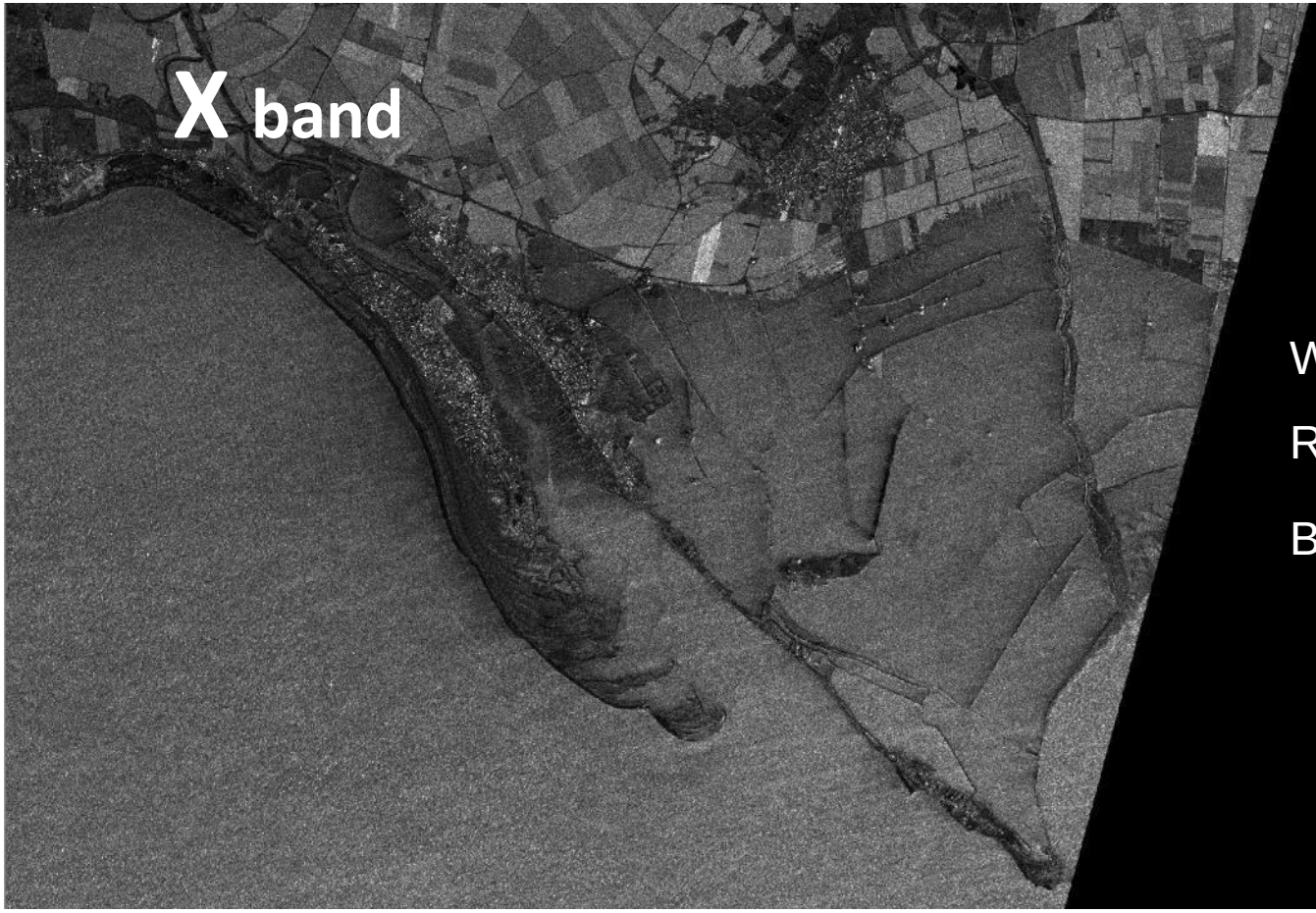
PALSAR bande L HH,
ScanSAr mode,
10h56 the 2010 03 01

Water backscattering in function of surface roughness



TerraSAR X: 2010 03 03

Water backscattering in function of surface roughness



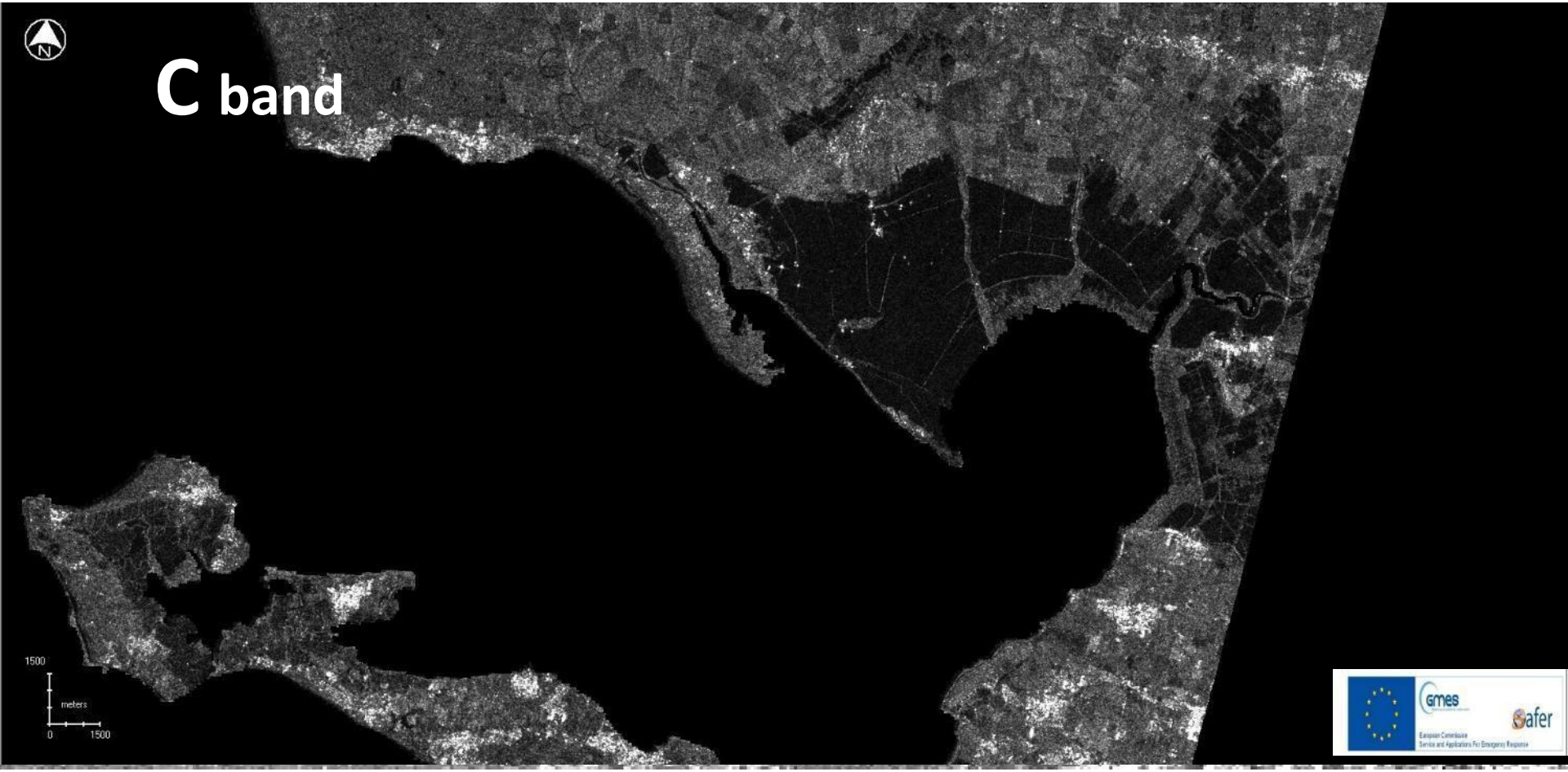
Windy Condition

Rough water surface

Backscaterring increase

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

SAR: All weather system
Yes but !!!!

Distortions in the SAR observational data come from various factors.

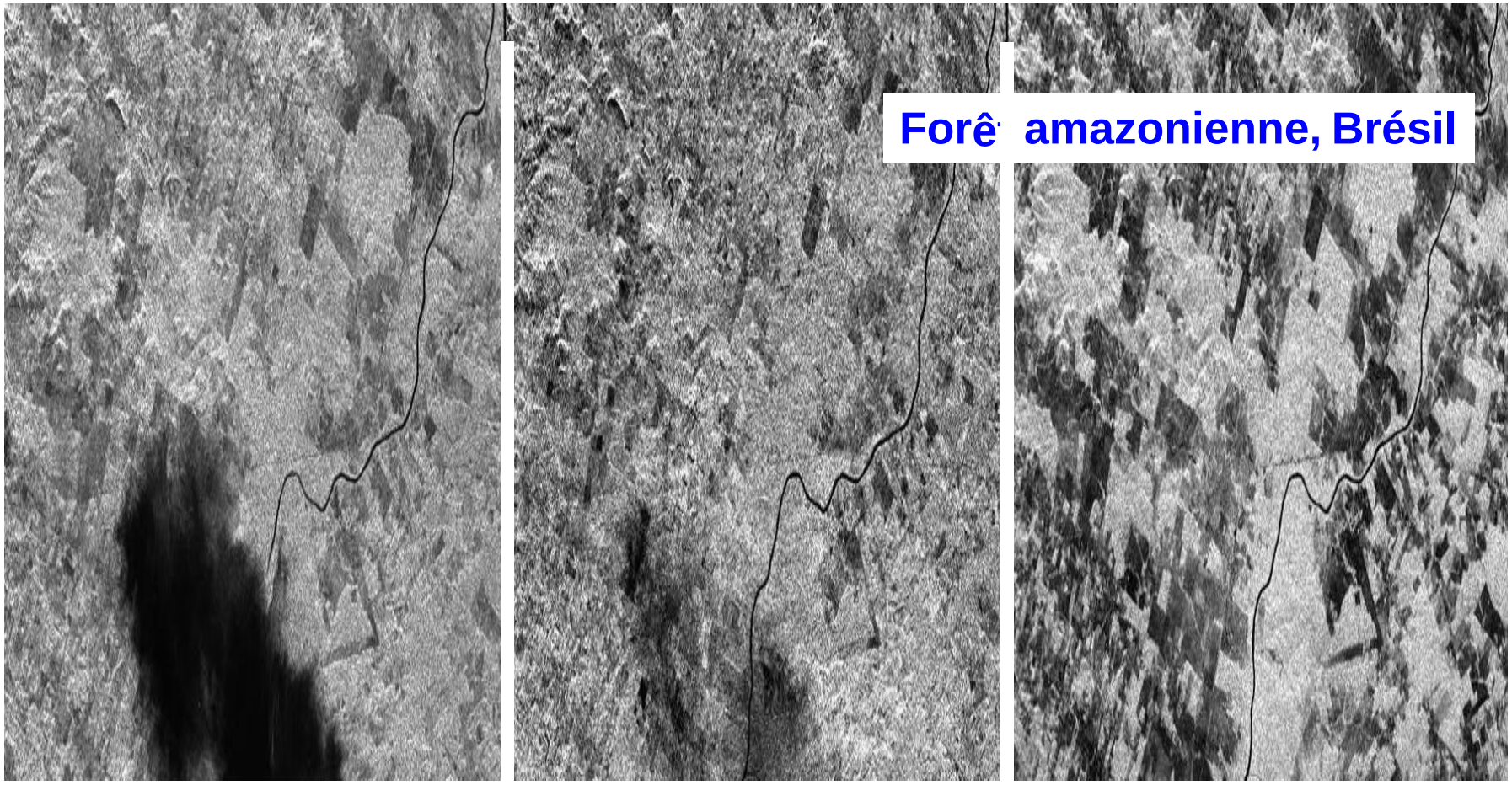
Absorption by the atmosphere
(oxygen, water vapor, and so on.)

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 wavelenghts

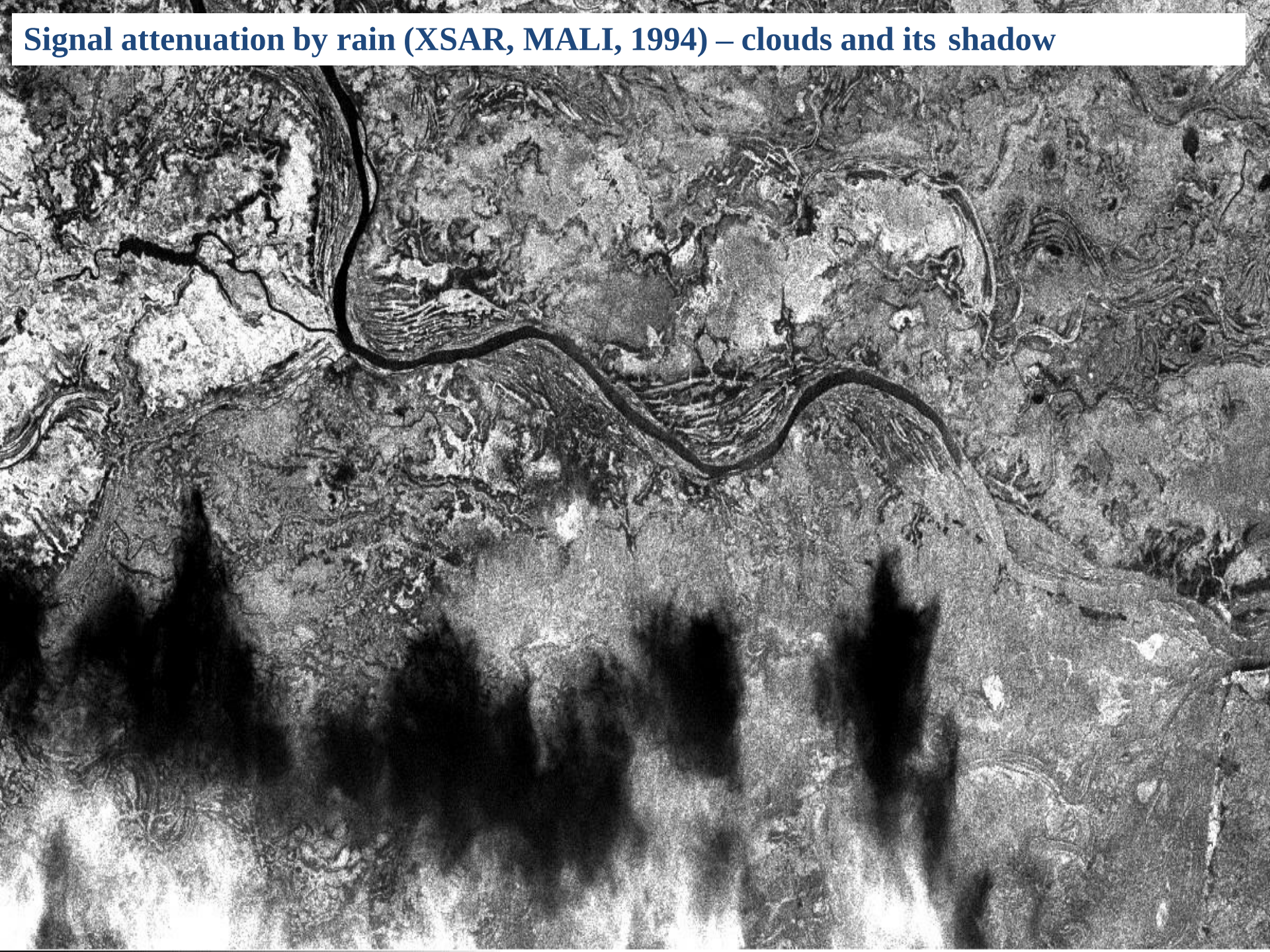


Bande X (3 cm)

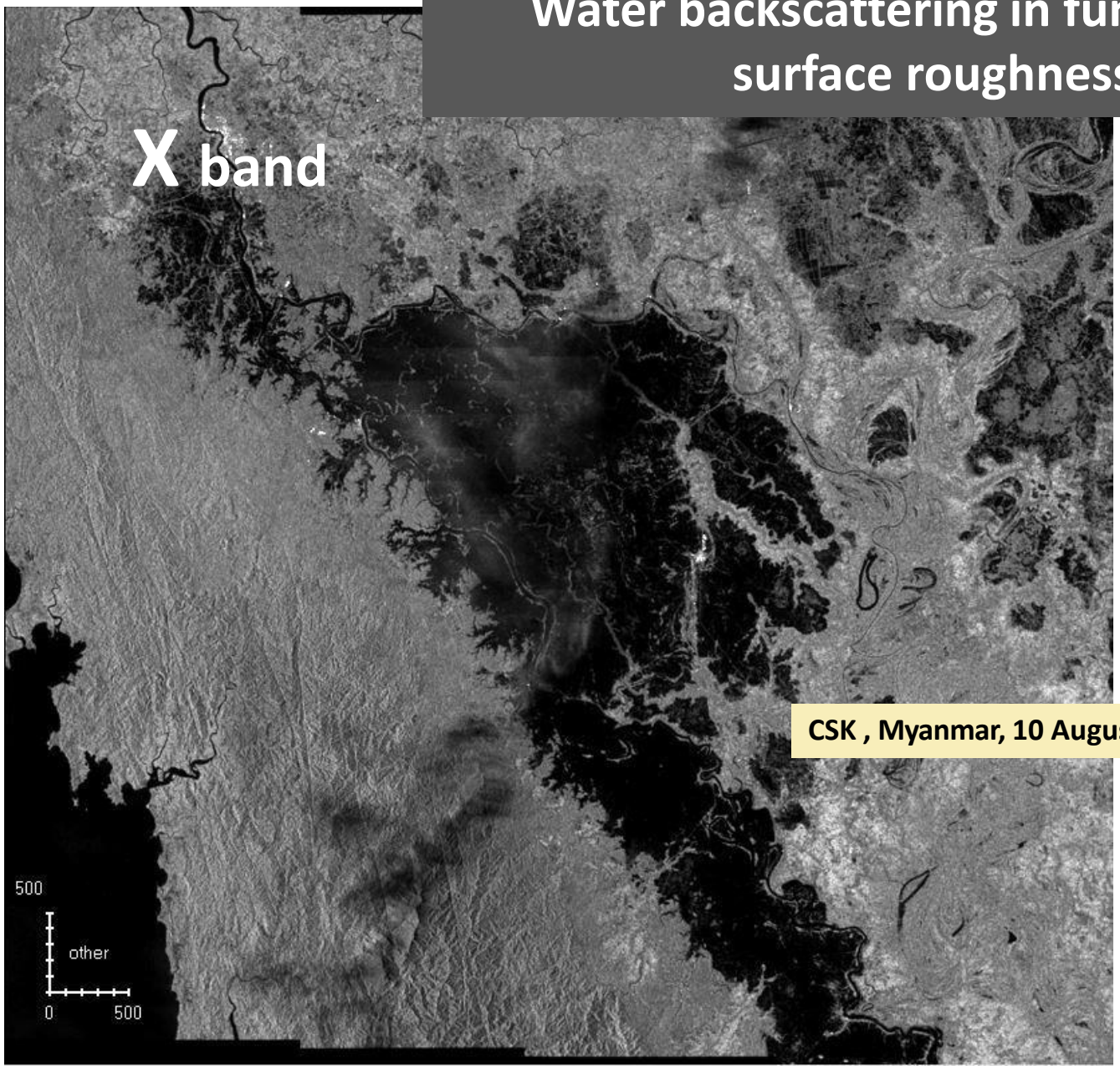
Bande C (5.6 cm)

Bande L (25 cm)

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

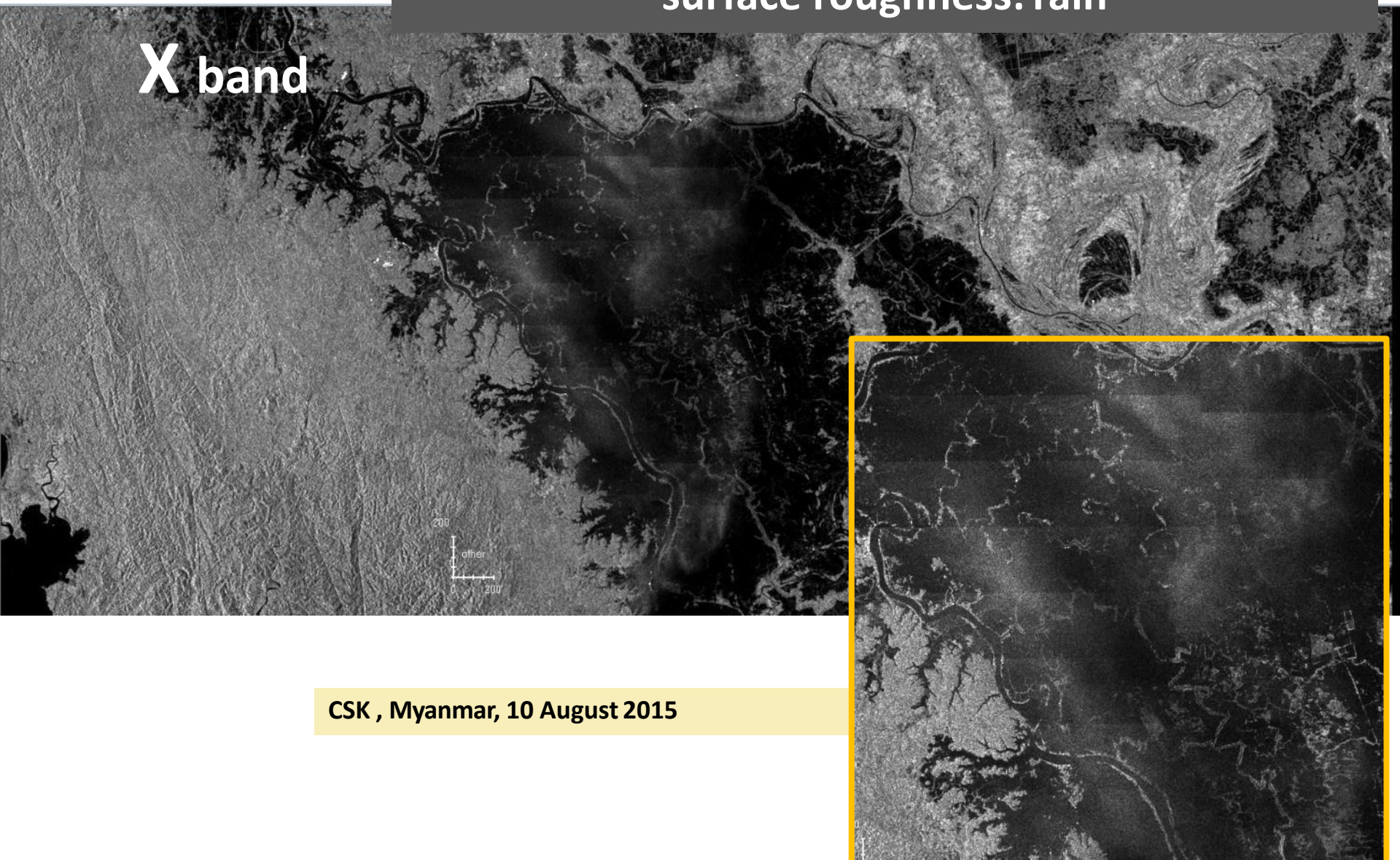


Water backscattering in function of water surface roughness: rain



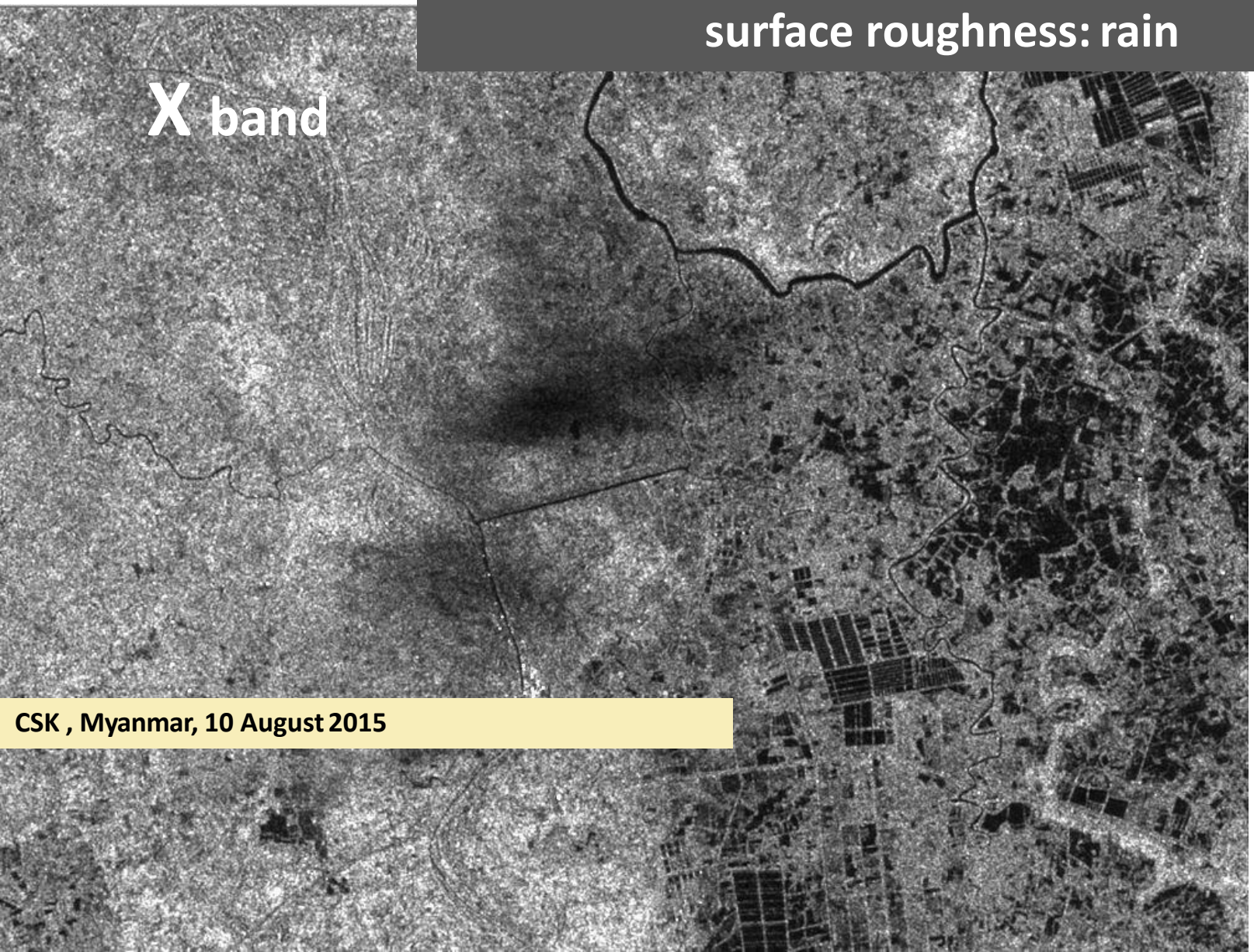
CSK , Myanmar, 10 August 2015

Water backscattering in function of water surface roughness: rain

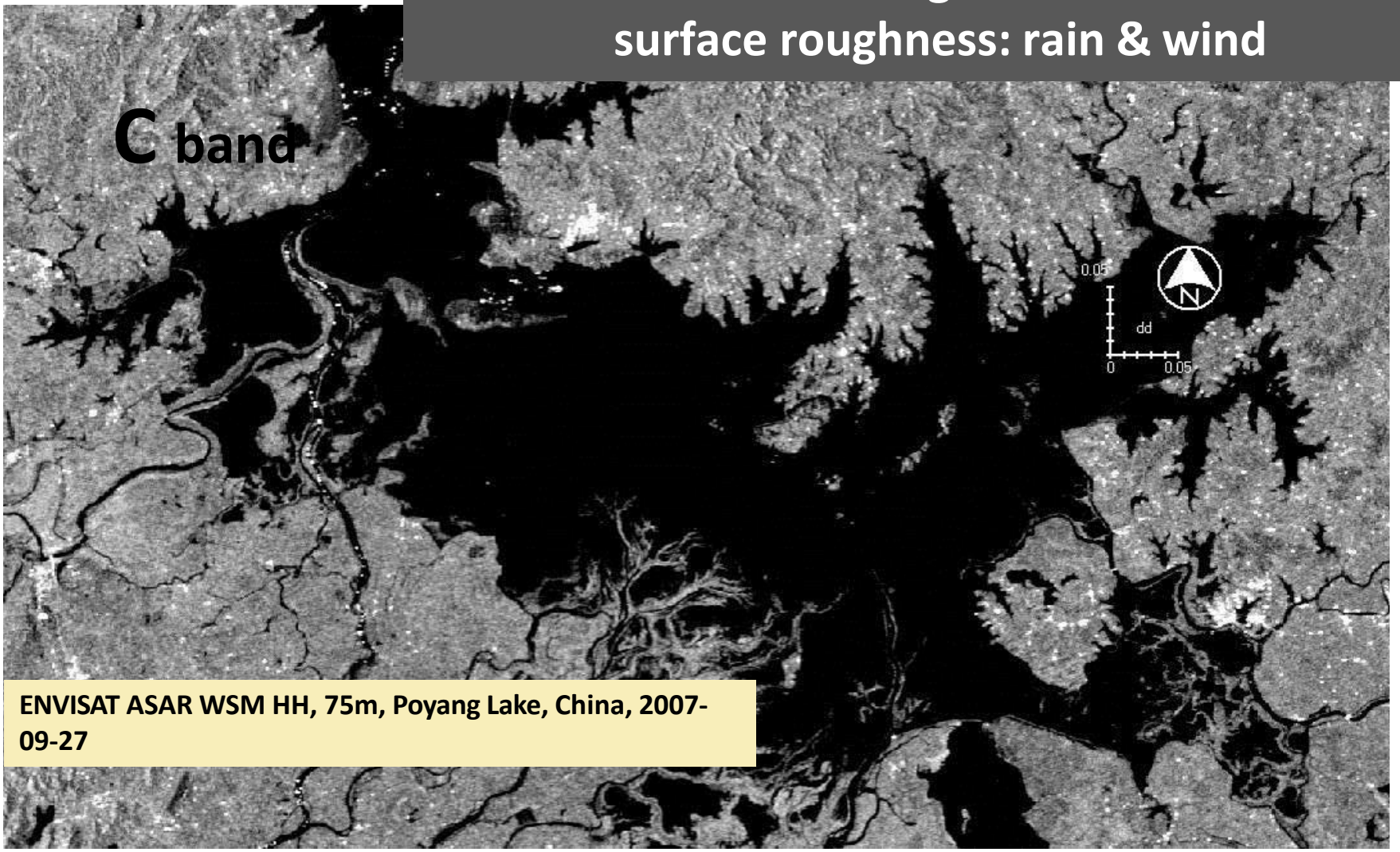


CSK , Myanmar, 10 August 2015

Water backscattering in function of water surface roughness: rain

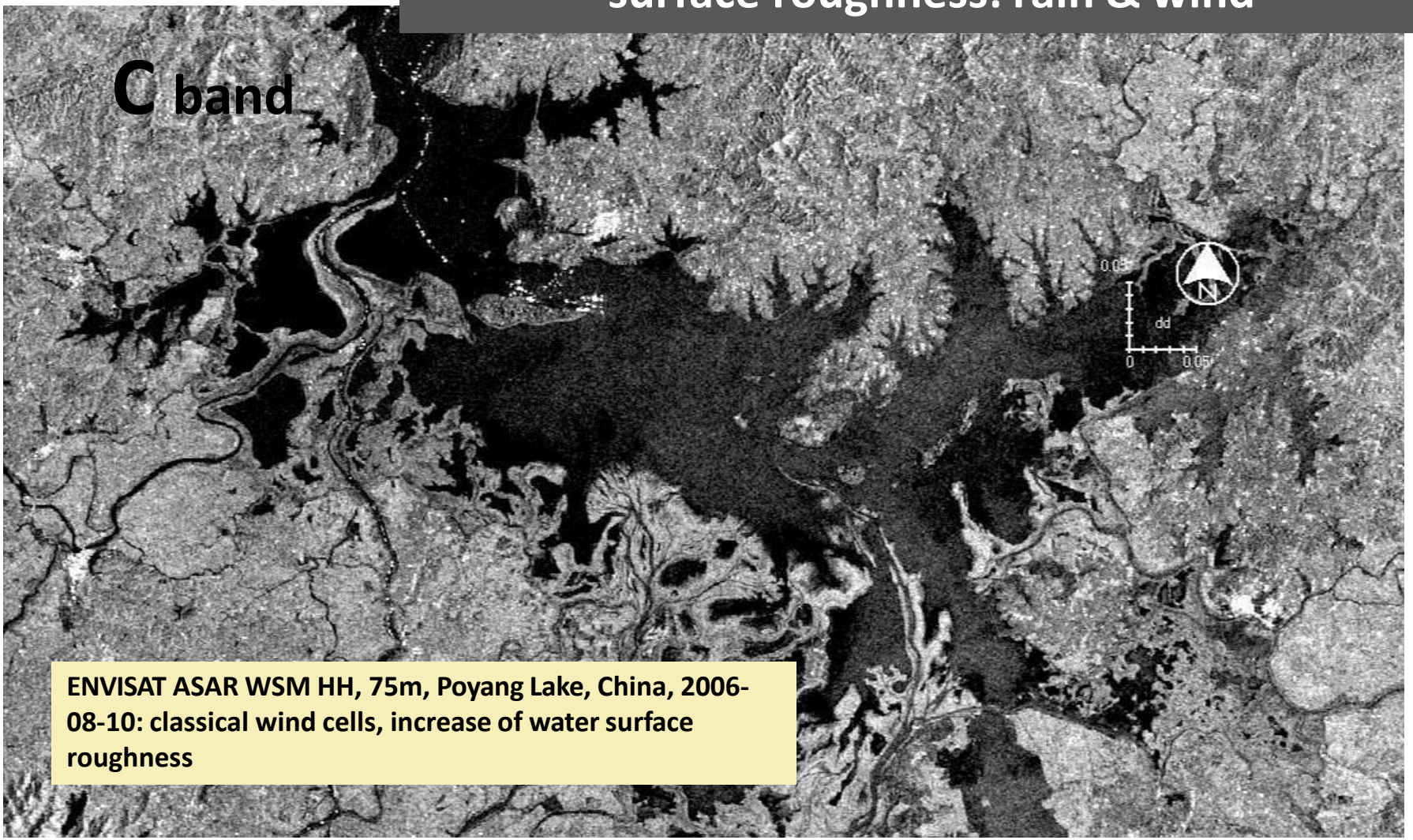


Water backscattering in function of water surface roughness: rain & wind



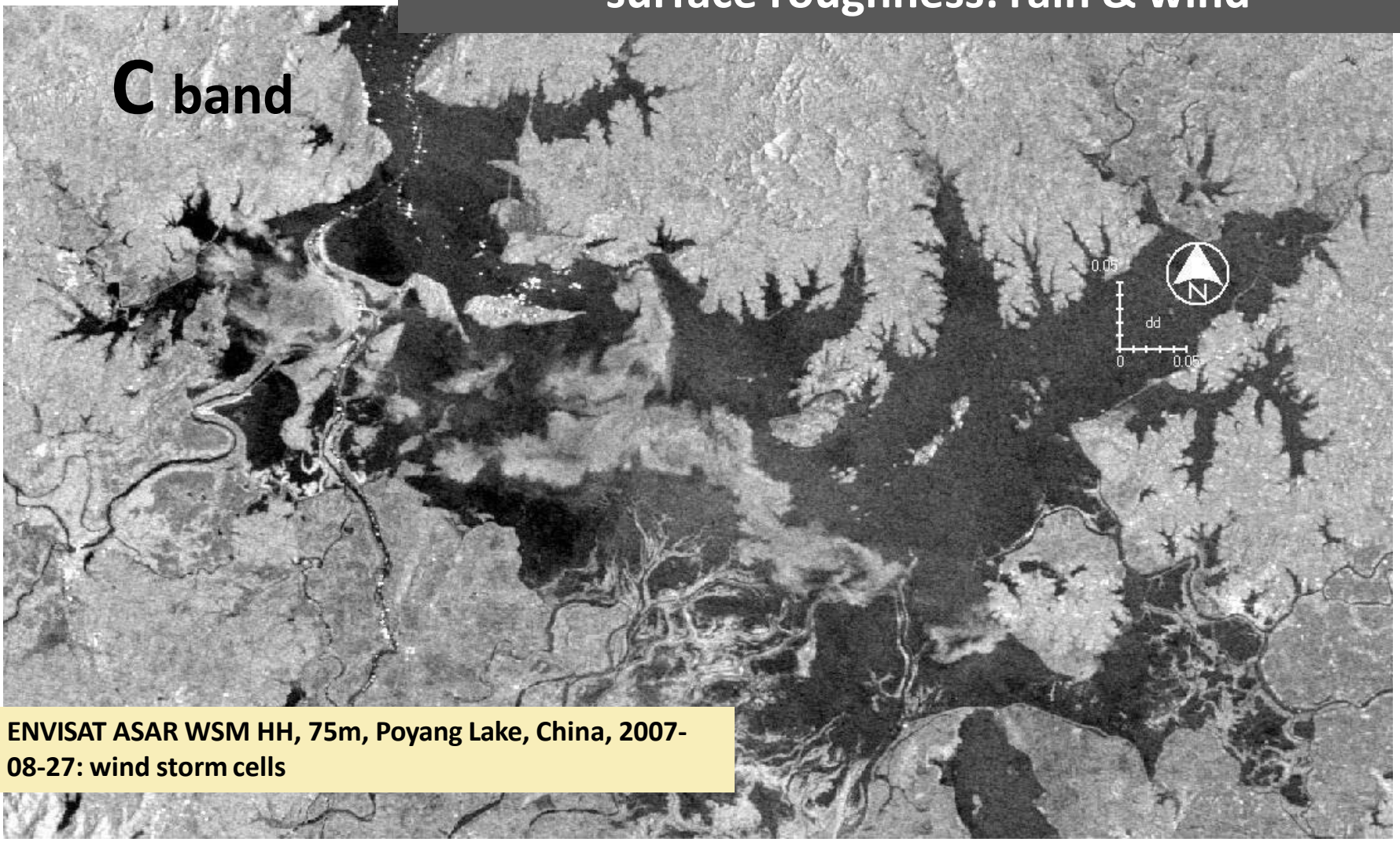
ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-09-27

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



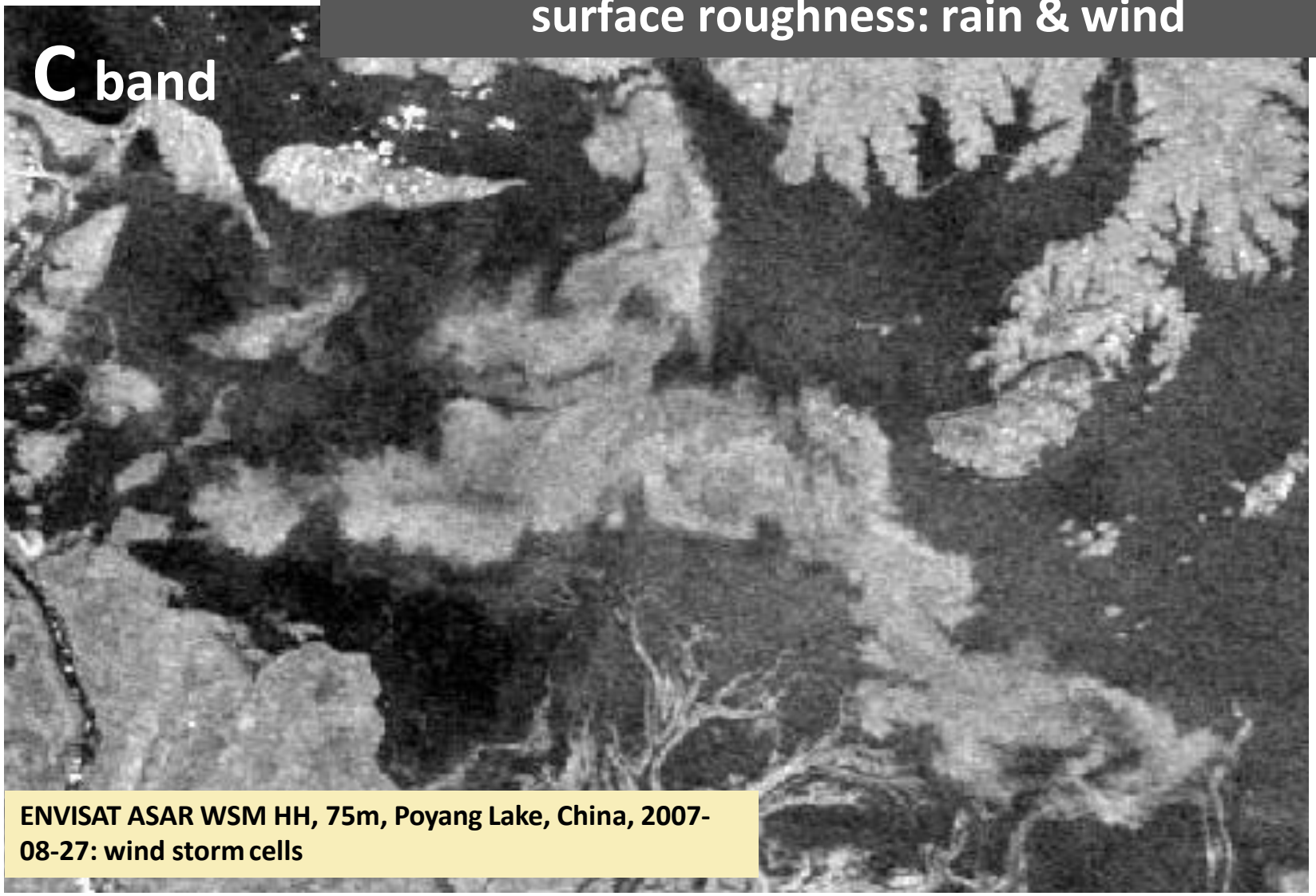
ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2006-08-10: classical wind cells, increase of water surface roughness

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



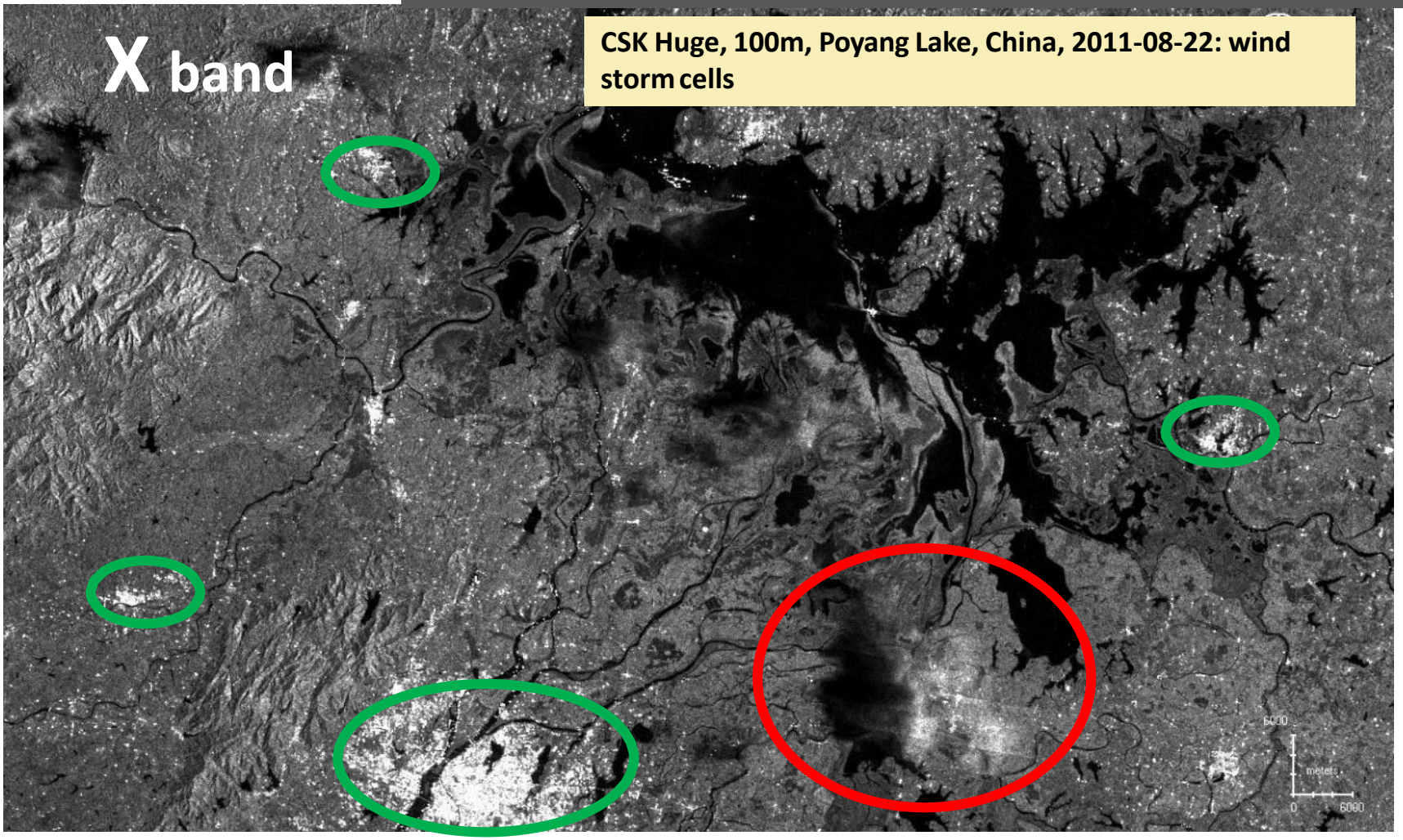
ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-08-27: wind storm cells

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

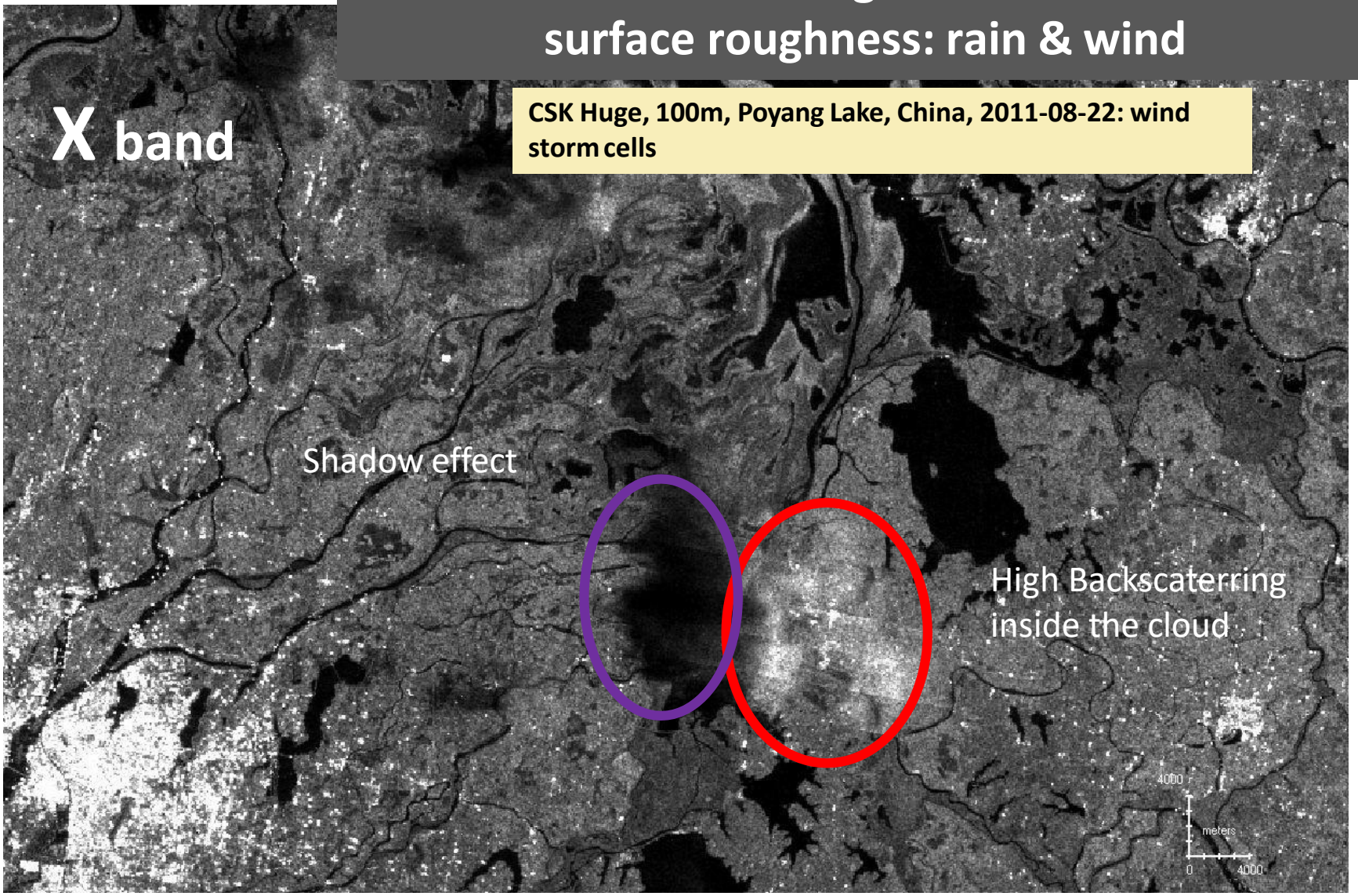


ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-08-27: wind storm cells

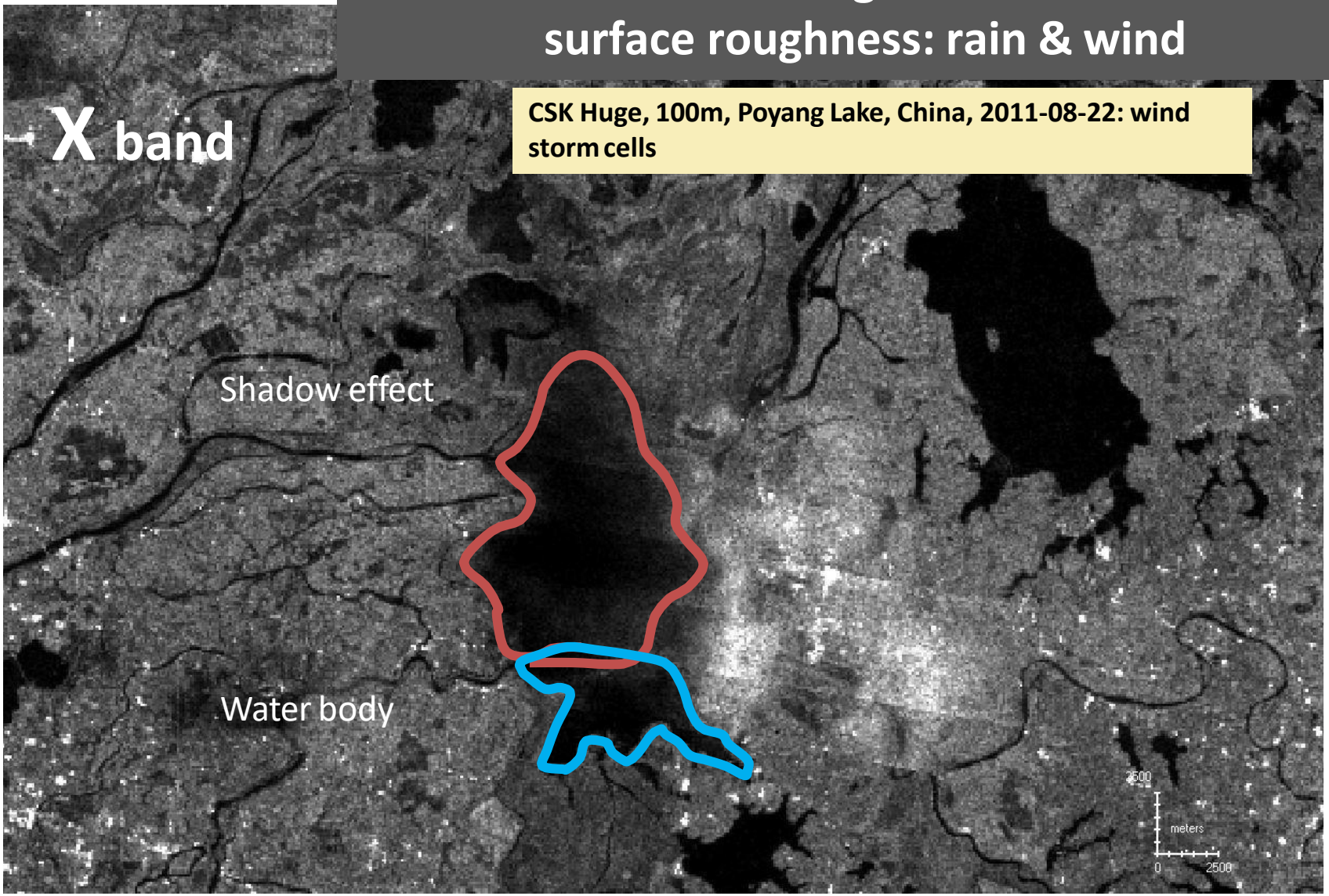
Water backscattering in function of water surface roughness: rain & wind



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



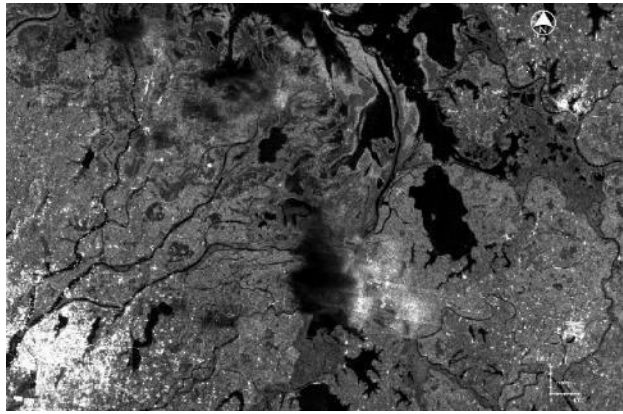
Water backscattering in function of water surface roughness: rain & wind



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

China: Poyang lake case

- 1 image ASAR ENVISAT en bande C, over more than 200 analyzed
- 1 image CSK Huge, bande X, over 15 analyzed…



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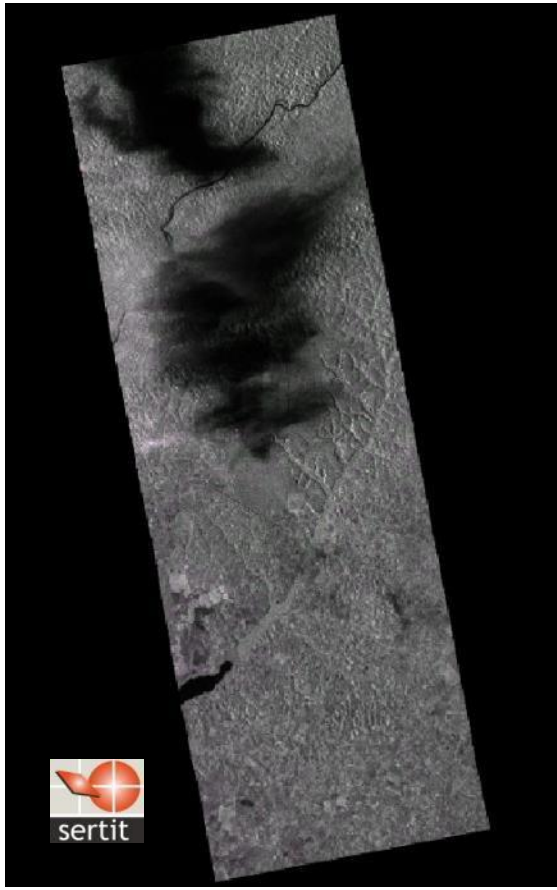
Ivory coast

1 TerraSAr Stripmap, X band, over 5 analysed

Attenuation due to the rain fall



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Ivory coast

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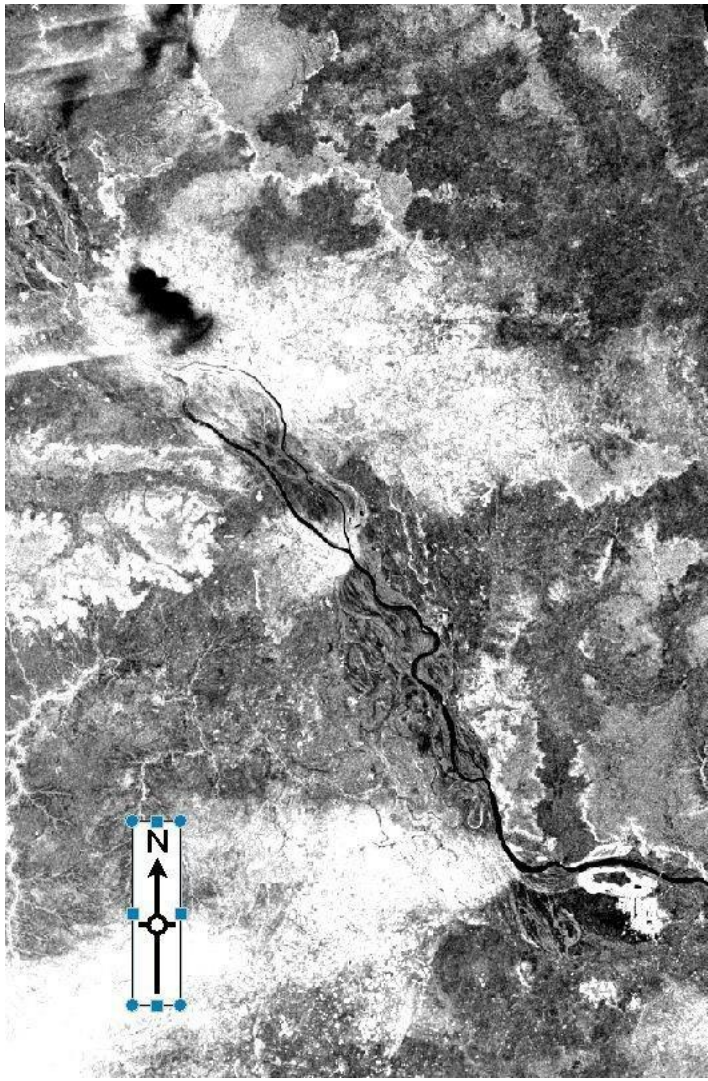
Niger:

1 TerraSAR X ScanSAR, X band, over 3 analysed



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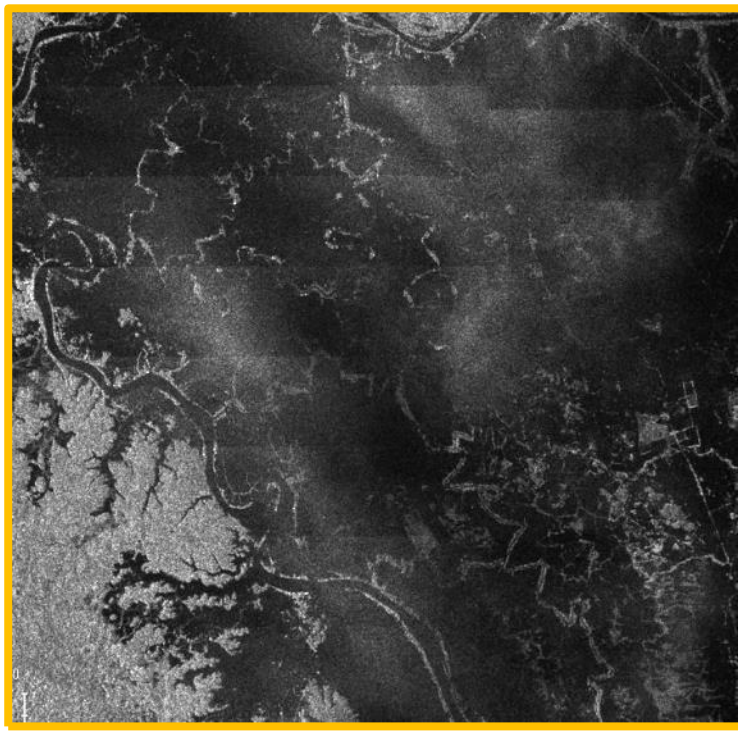


Ivory coast

1 TerraSAR X Stripmap, X band, over 5 analysed..

Niger:

1 TerraSAR X ScanSAR, X band, over 3 analysed
Attenuation and huge ackscaterring

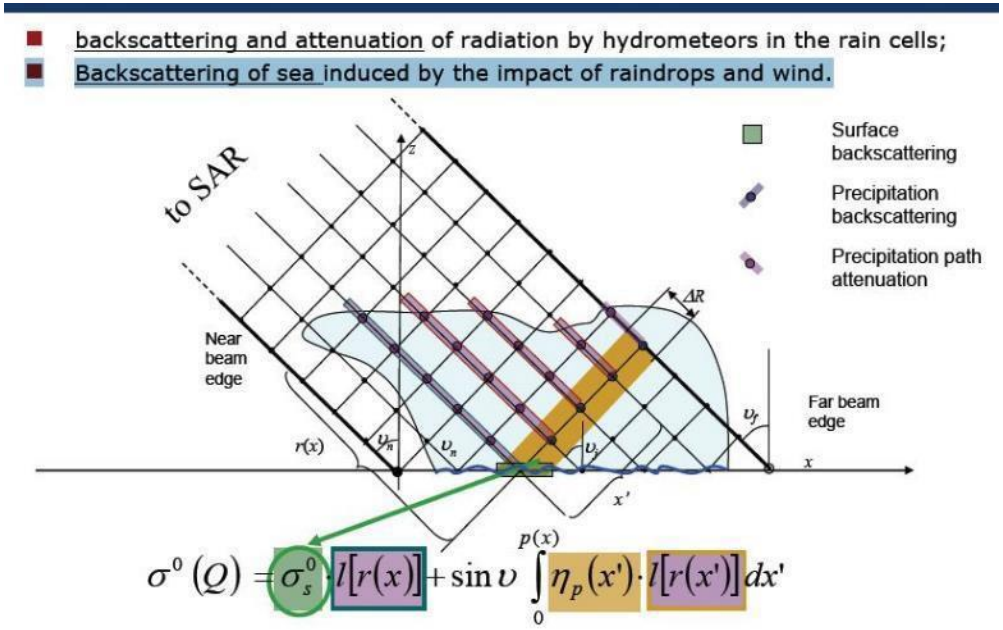
Myanmar

1 CSK, X band

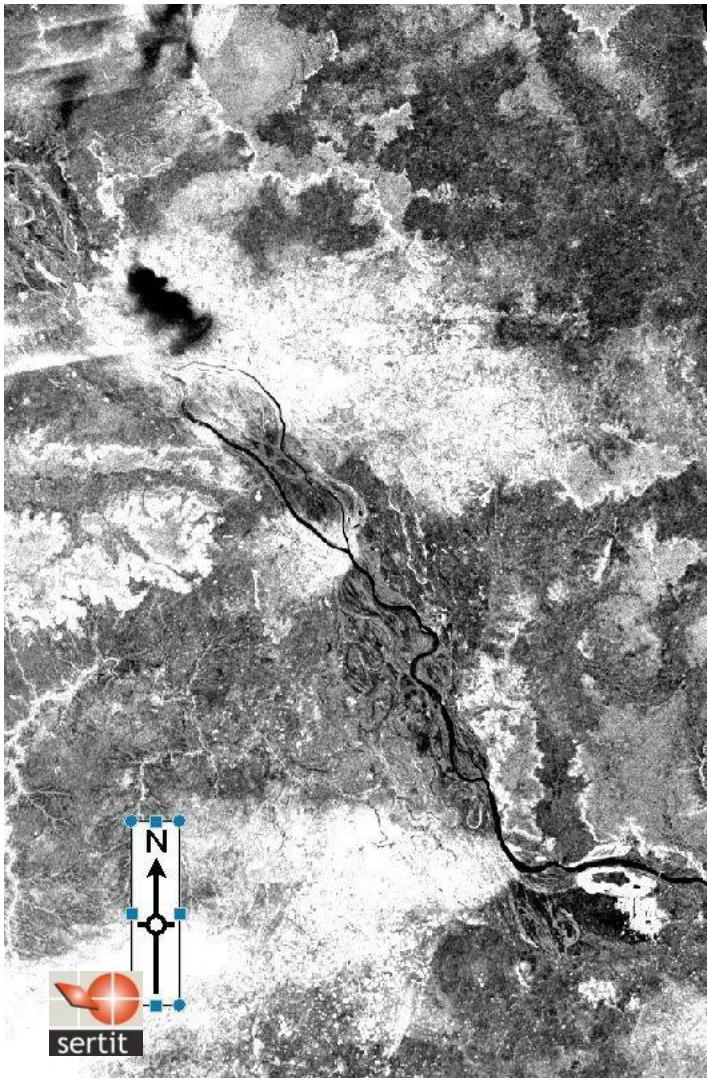
Water backscattering in function of cloud /precipitation : country with contrasted rainy/dry season

Very high sensibility to rainfall and clous in X band

Be careffull!!



Bakldini 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

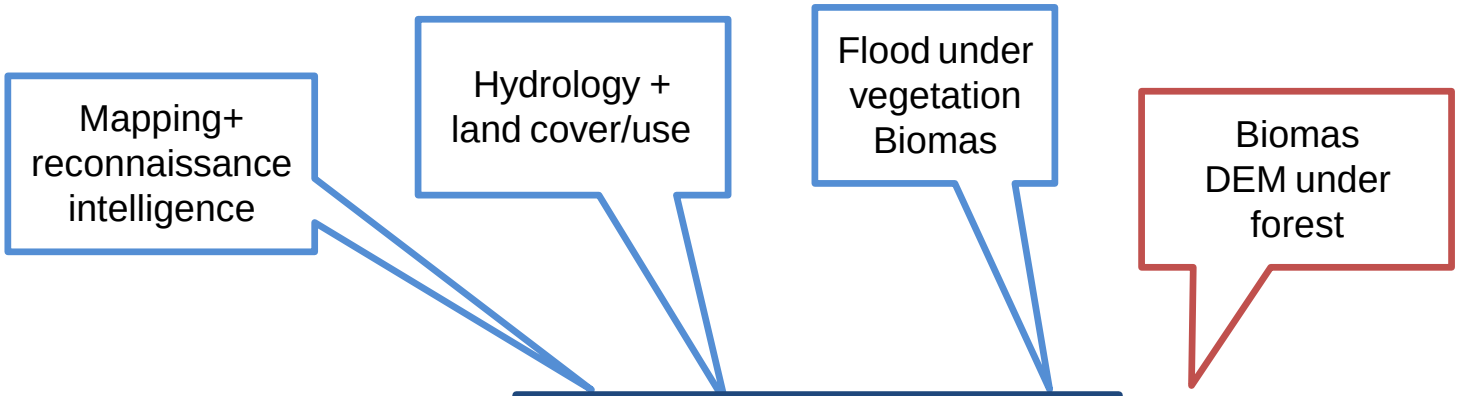
- **Past mission**
- **On going missions**
- **Future missions**

Flood plain and lakes monitoring

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

Concluding remarks

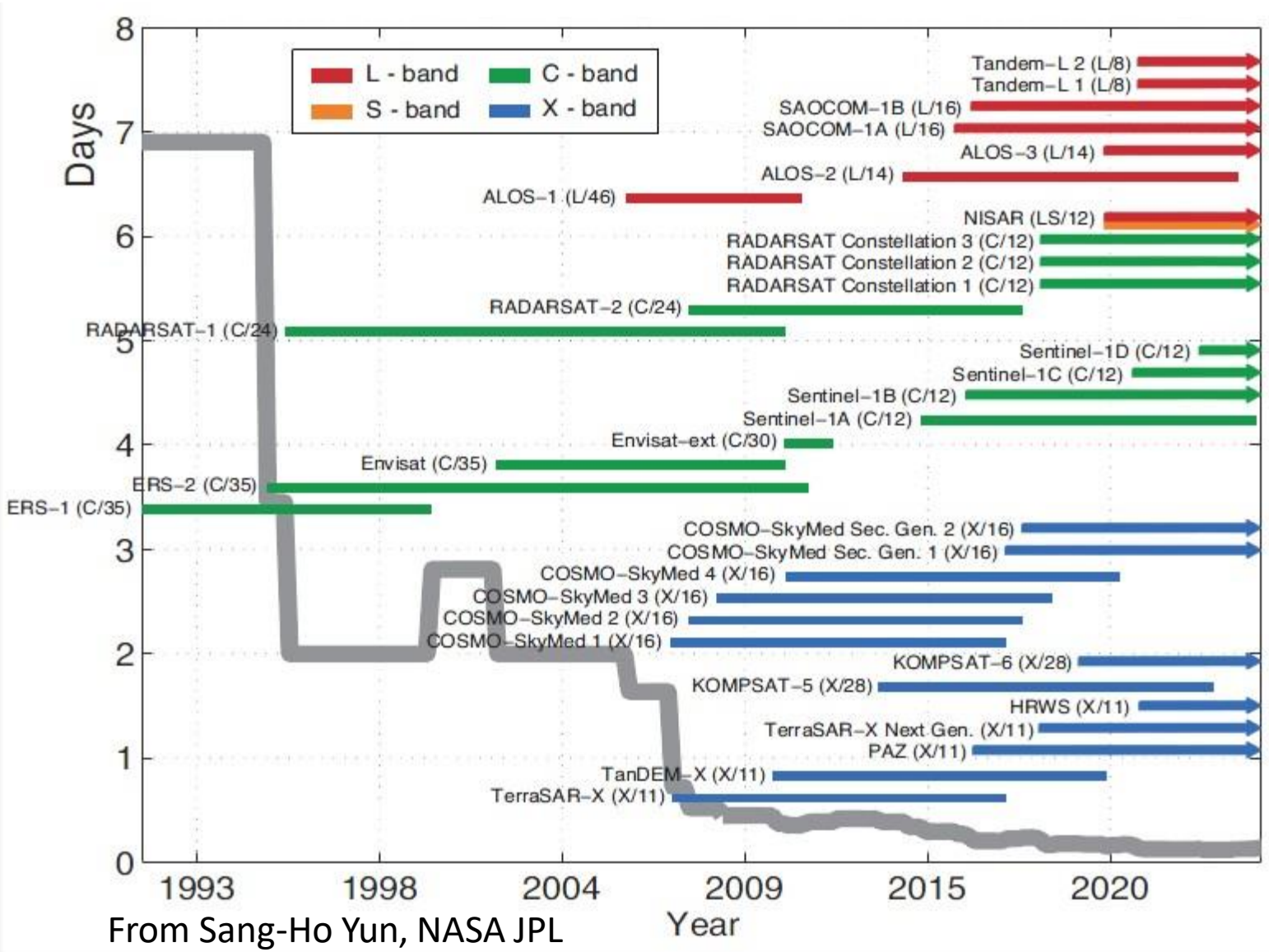
Former, actual and future SAR missions valuable for water surface mapping/monitoring



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



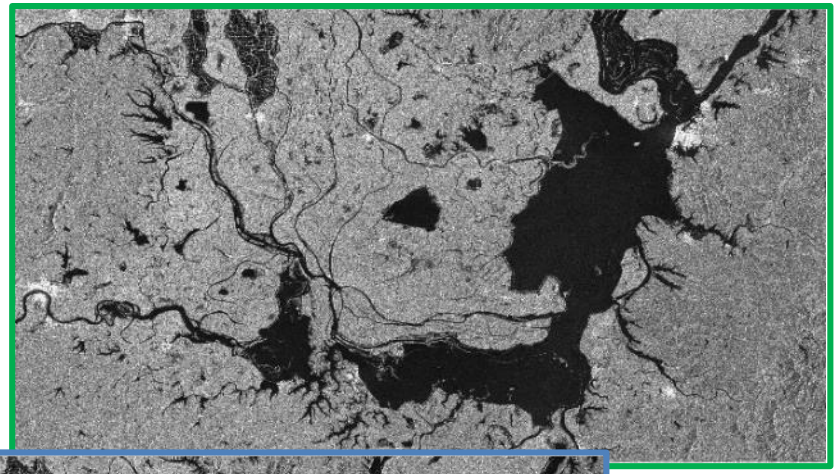
From Sang-Ho Yun, NASA JPL

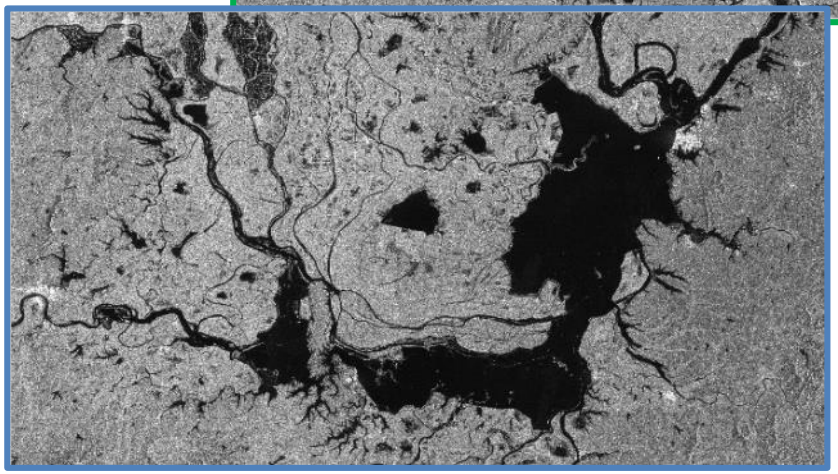
Former & old missions: precursors and rich archive

- **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)

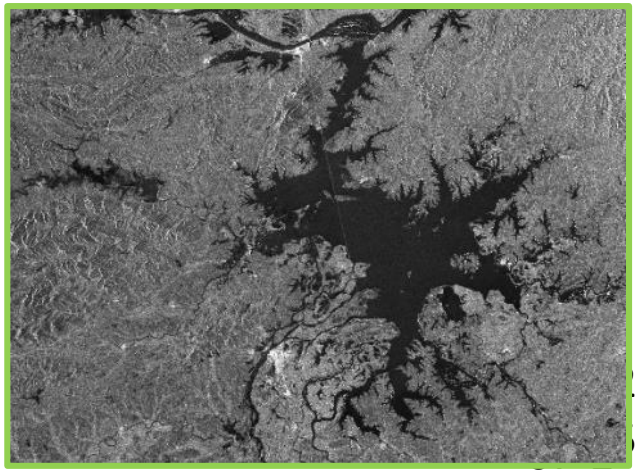
Importance of the Archive: Flood memory
Radarsat over 1998 Yangtze historical flood

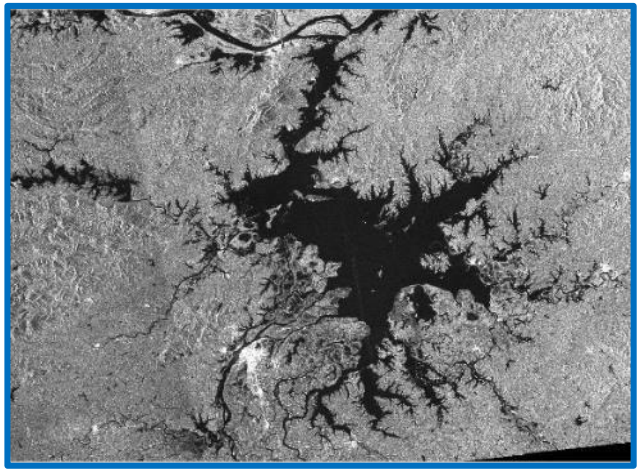




Dongting 1998: SCN, SCW, SGF

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

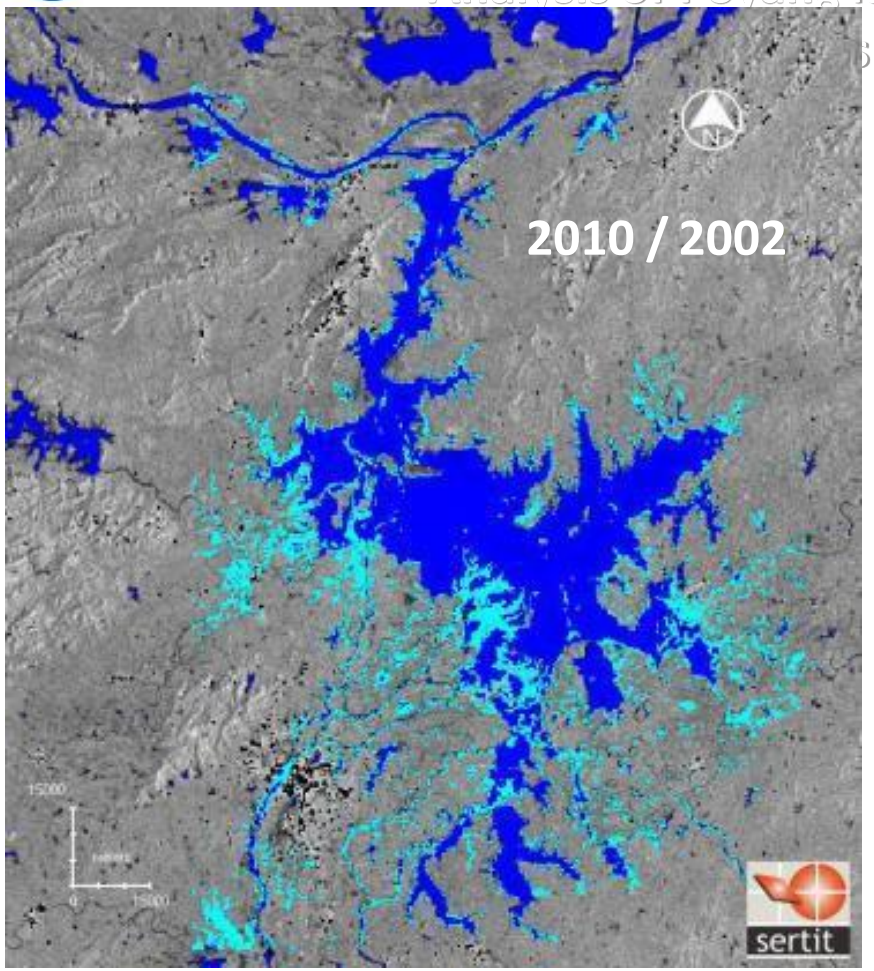


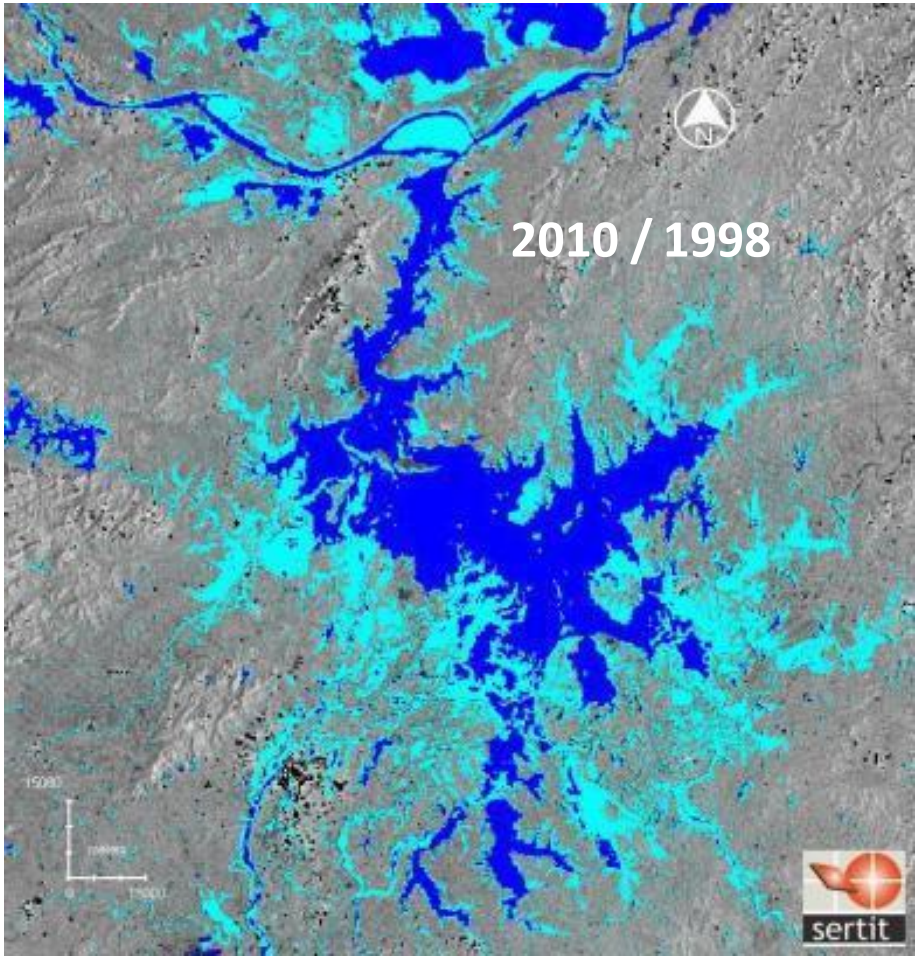


Poyang 1998: SGF, SCW,

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

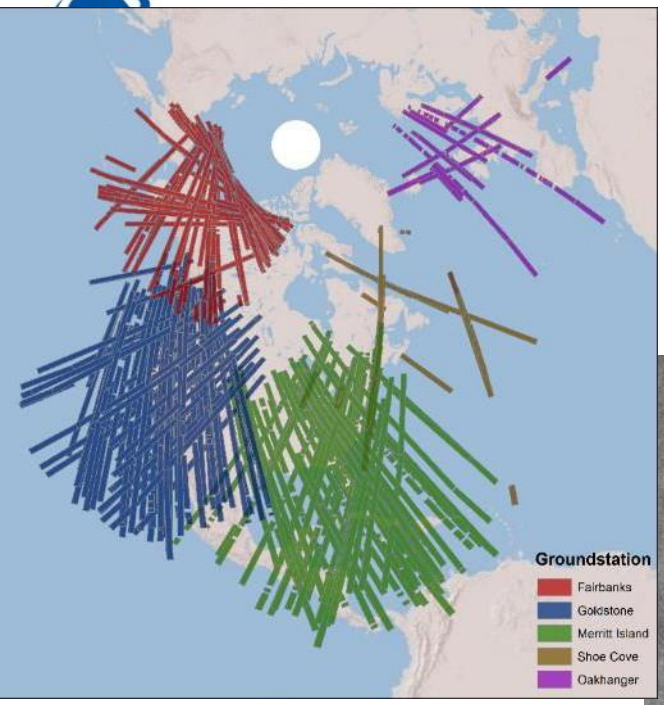
Analysis of Poyang lake Summer 2010 flood

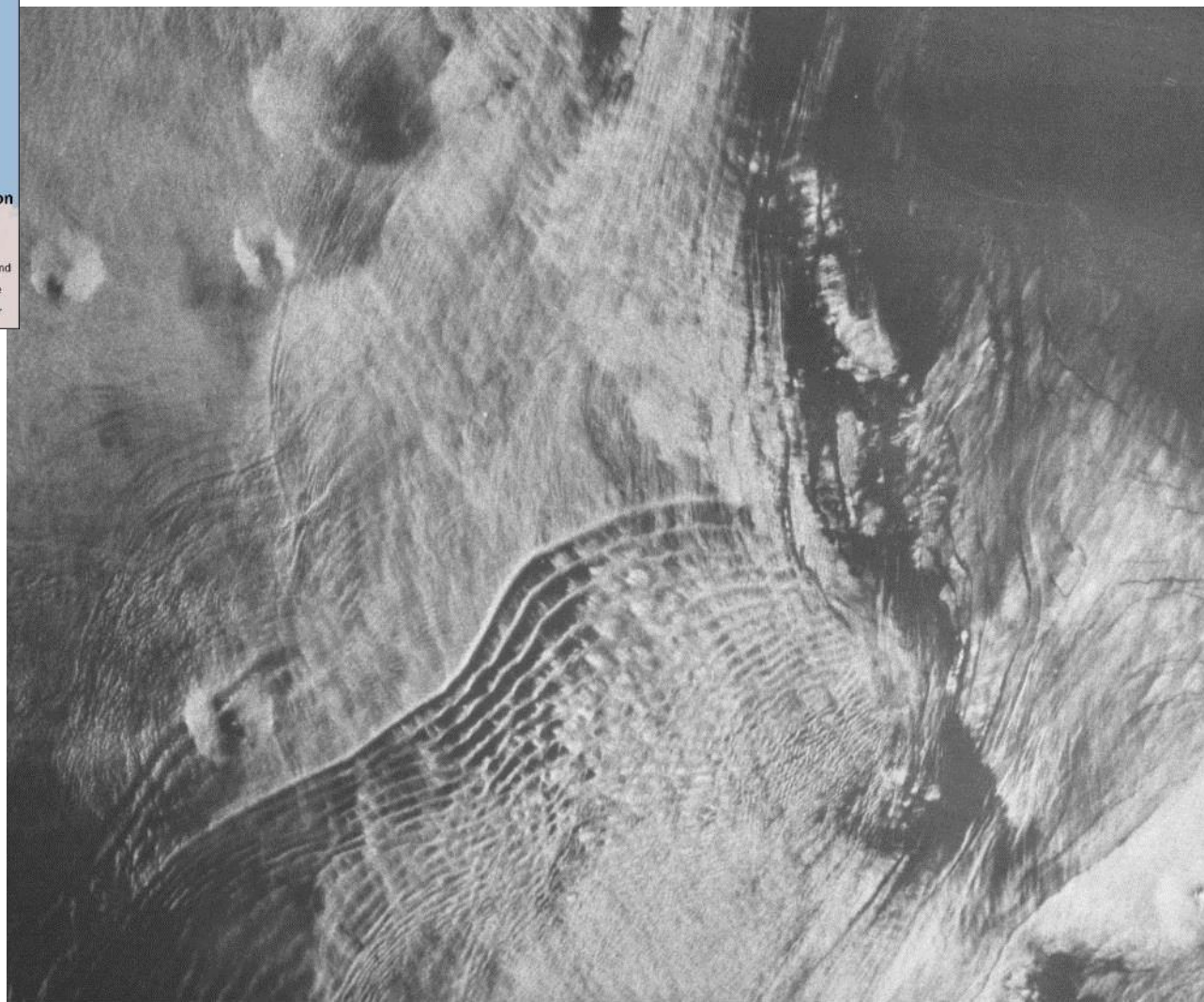




2010 flood event is an important one in Poyang last decade history
2010 extent (3354 km²) no far to the 2002 extent (3392 km²)
2010 much smaller in term of extent than 1998 (4116 km2)

Seasat: L Band

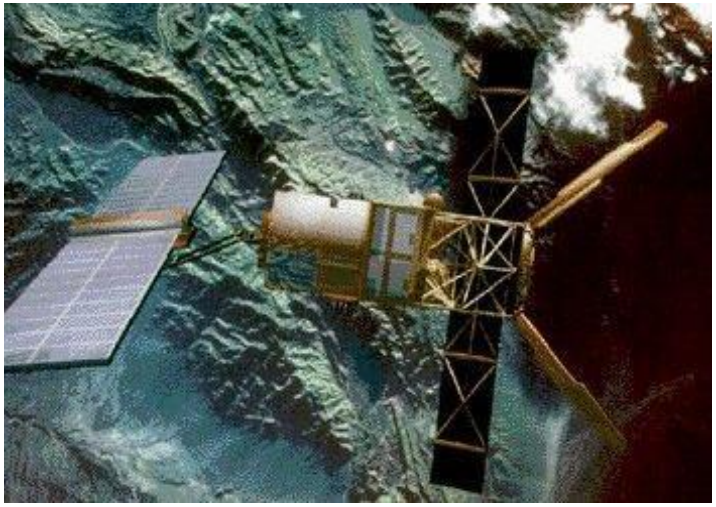




Brittany
West part of France

1978-08-20

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

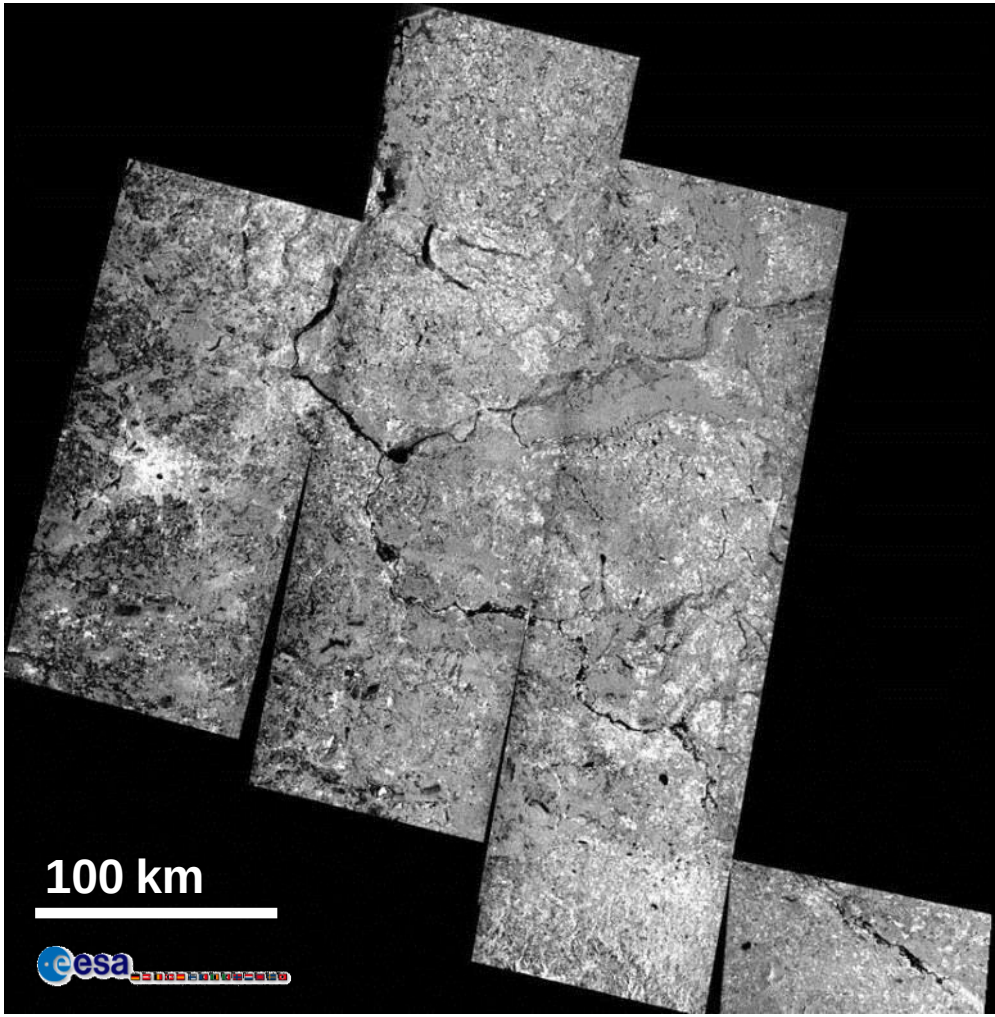
ERS 1 - 2

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…

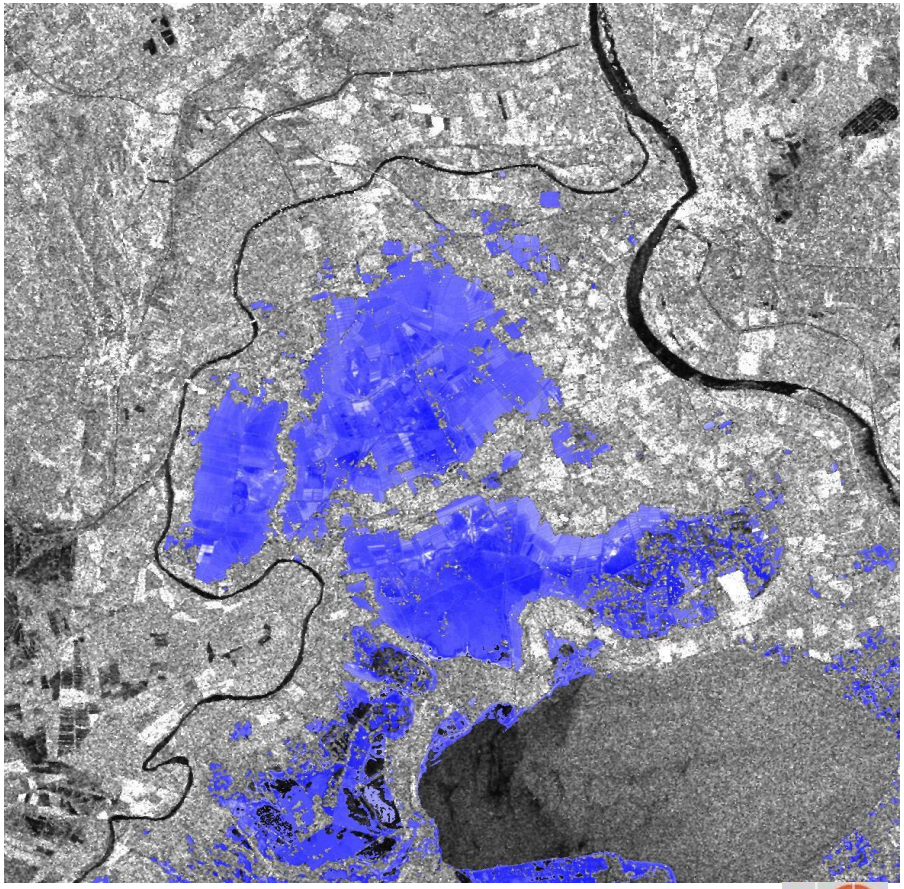
Exploiting mostly the Amplitude



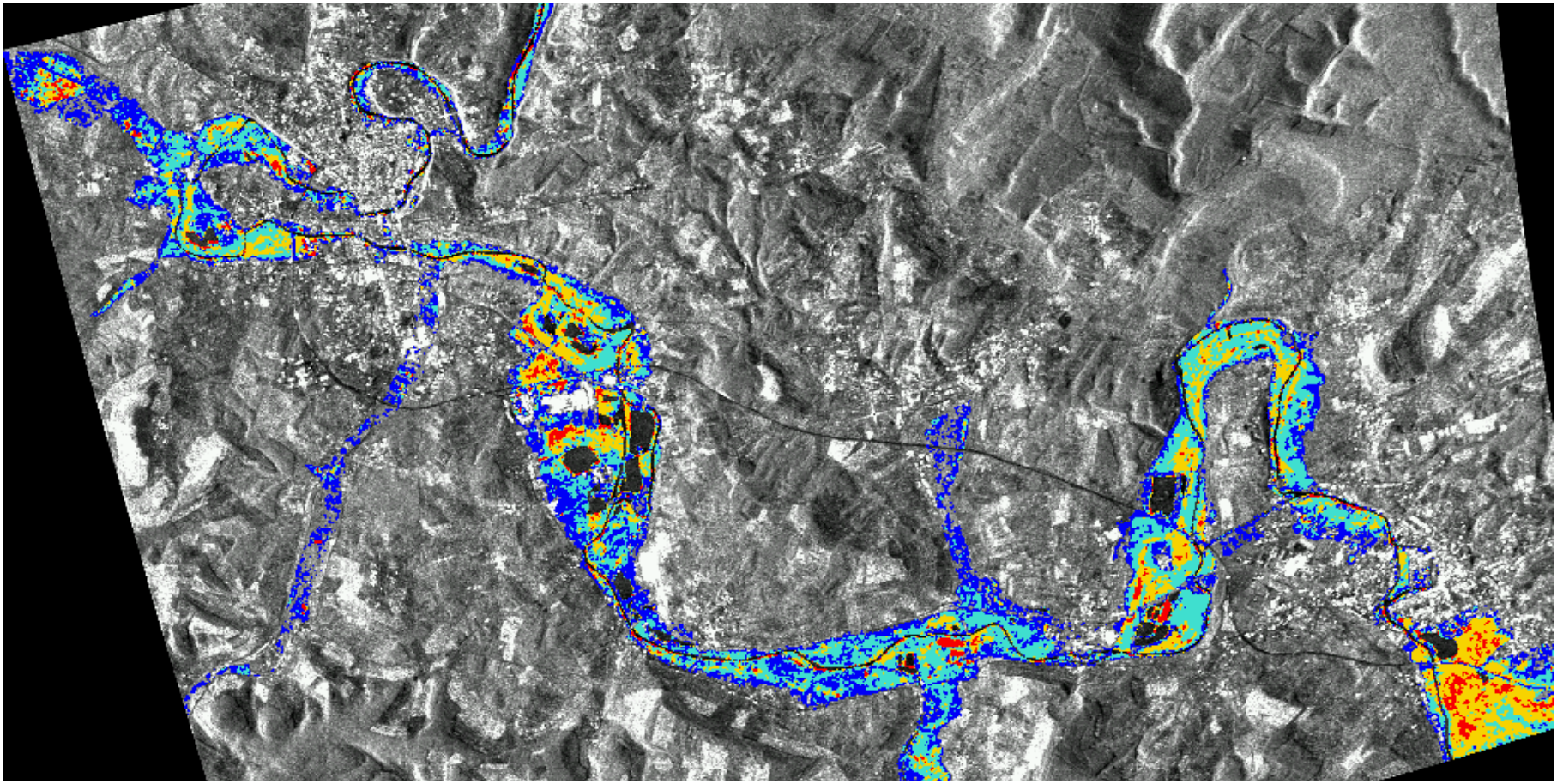
ERS Mosaïque over the Oder river : Acquired 30-07 to 9-08-97

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)

Flood mapping based on ERS 1 - 2 INSAR

Few examples of Coherence exploitation

Aude 96 flood event

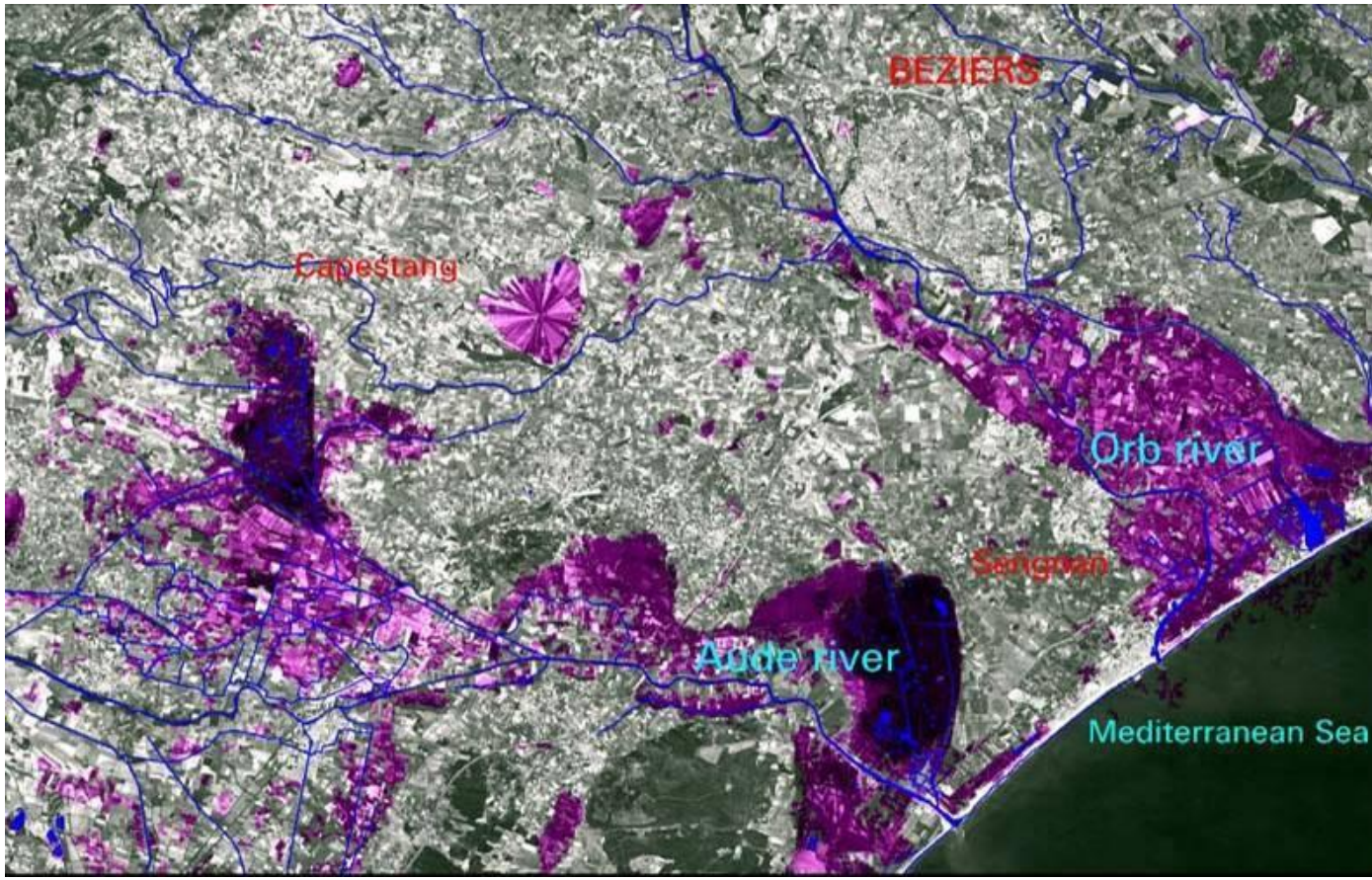
ERS-2: 7 8 1995
ERS-2: 29 01 1996
ERS-1: 28 01 1996

Acquisition near the maximum of the flood

2 consecutives images

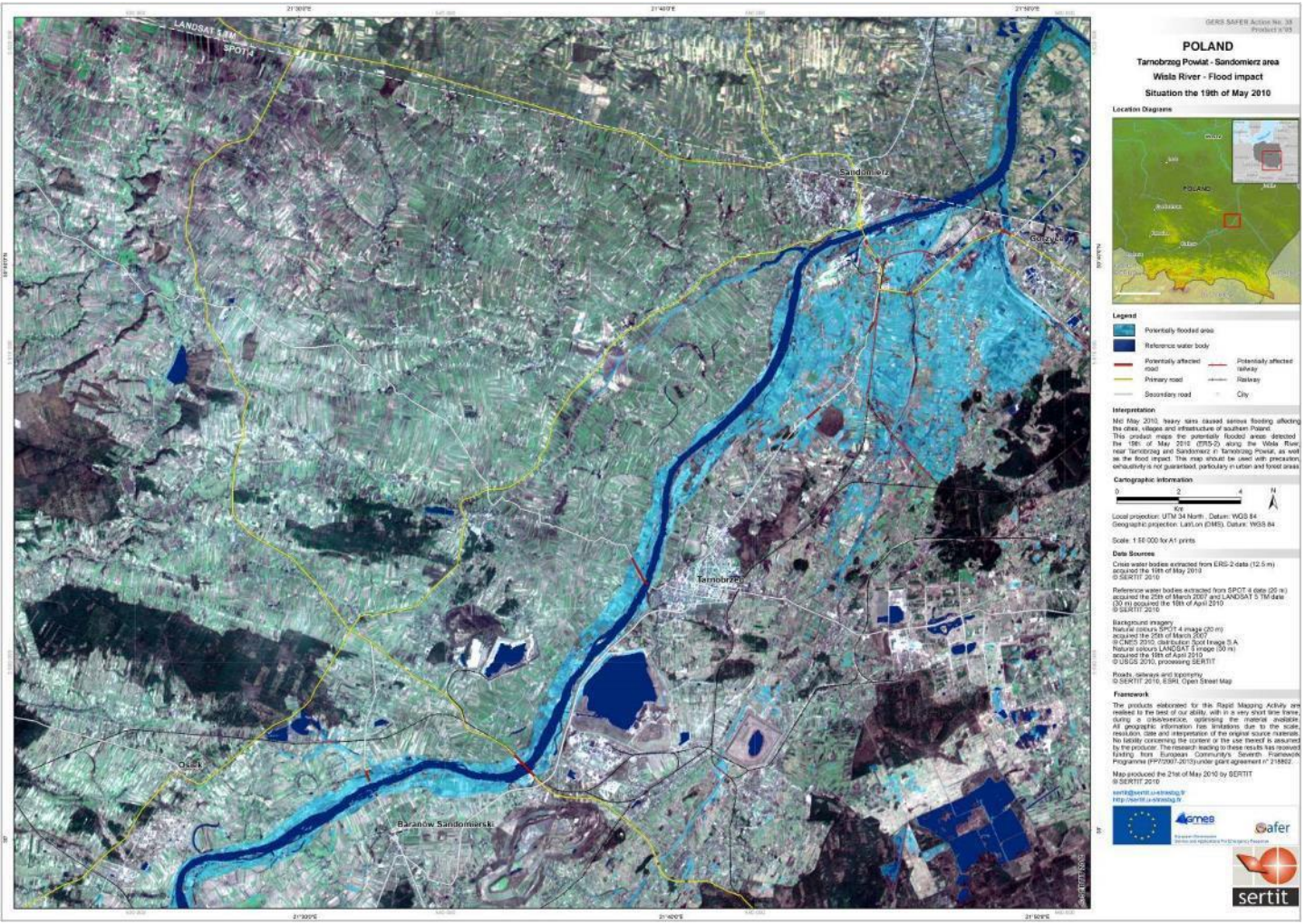
Exploitation of the phase information: lost of coherence on water surface

(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

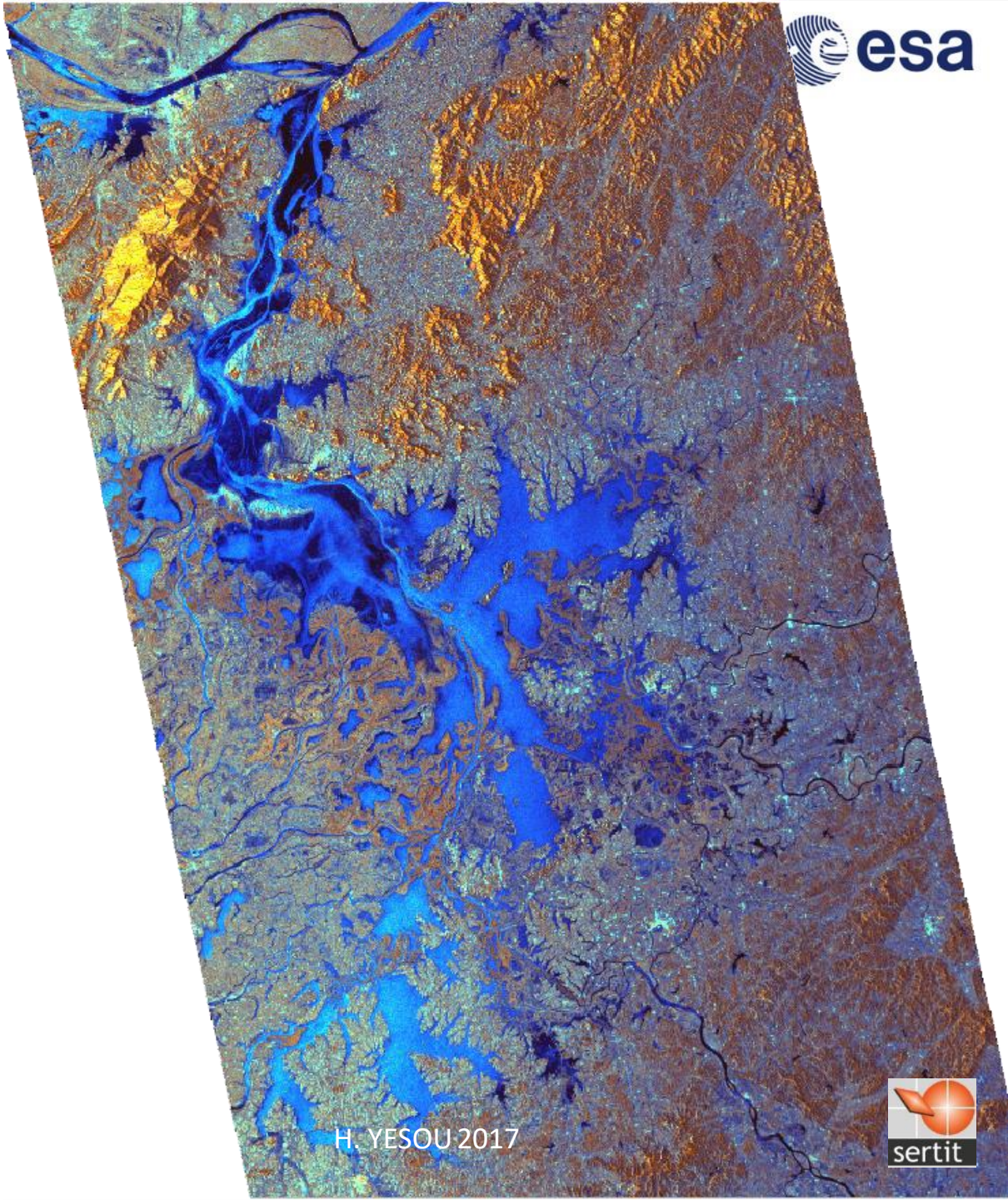
DRAGON ESA MOST

APP image

Stripe of two images

HH-HV (diff HH-HV)

20-02-05

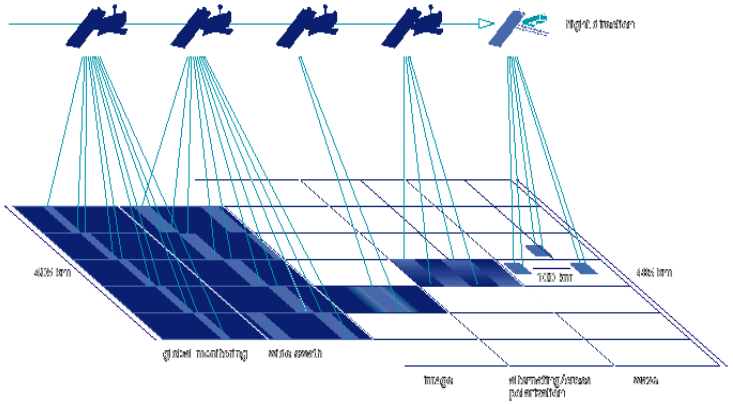


H. YESOU 2017

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:

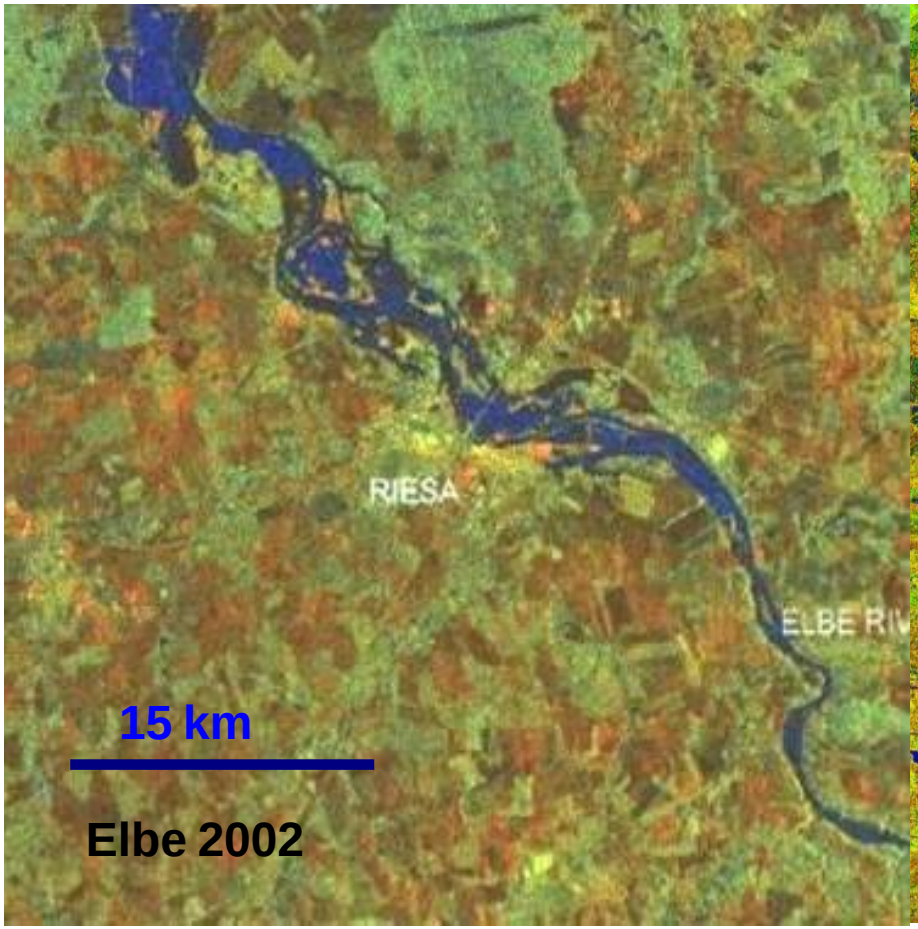
- **Multi beams**
- **Wide Swath mode**

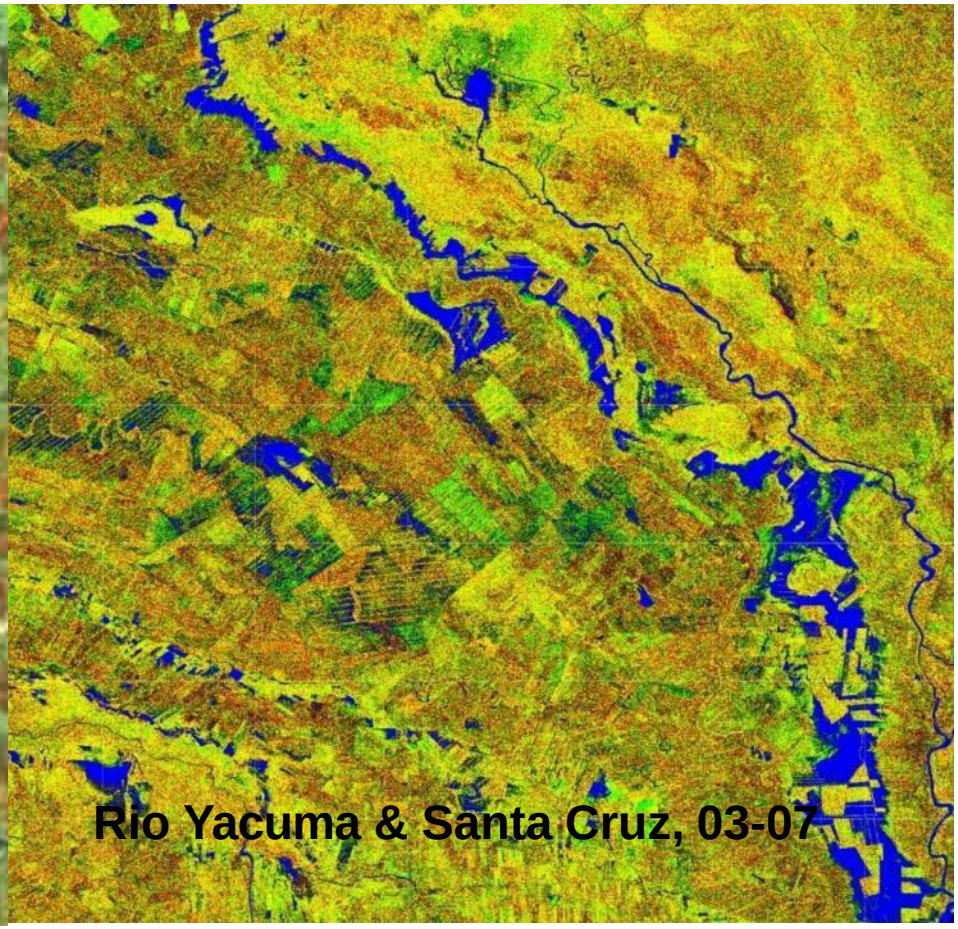
3 – Flooded low vegetation recognition

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

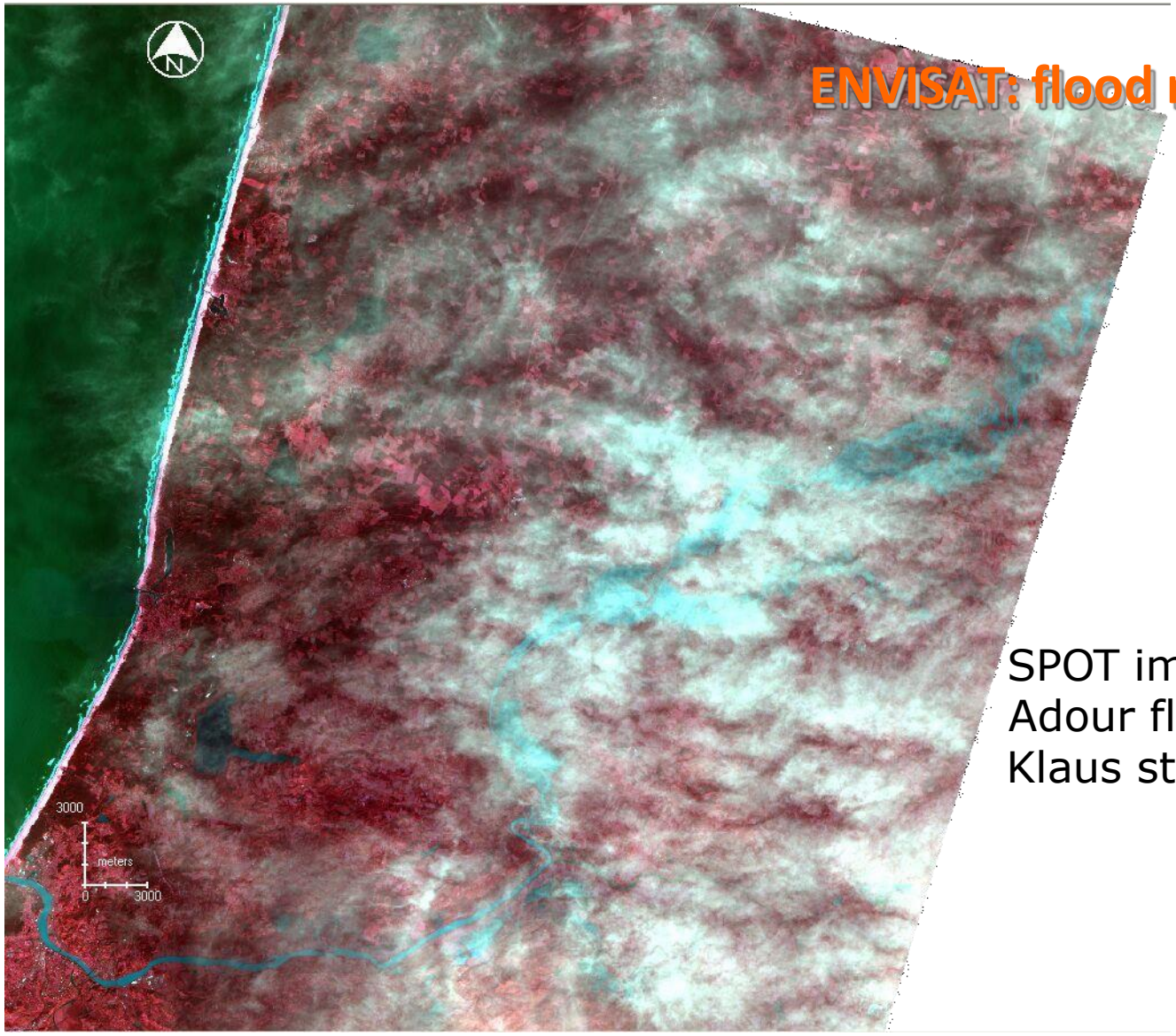
ENVISAT: flood rapid mapping



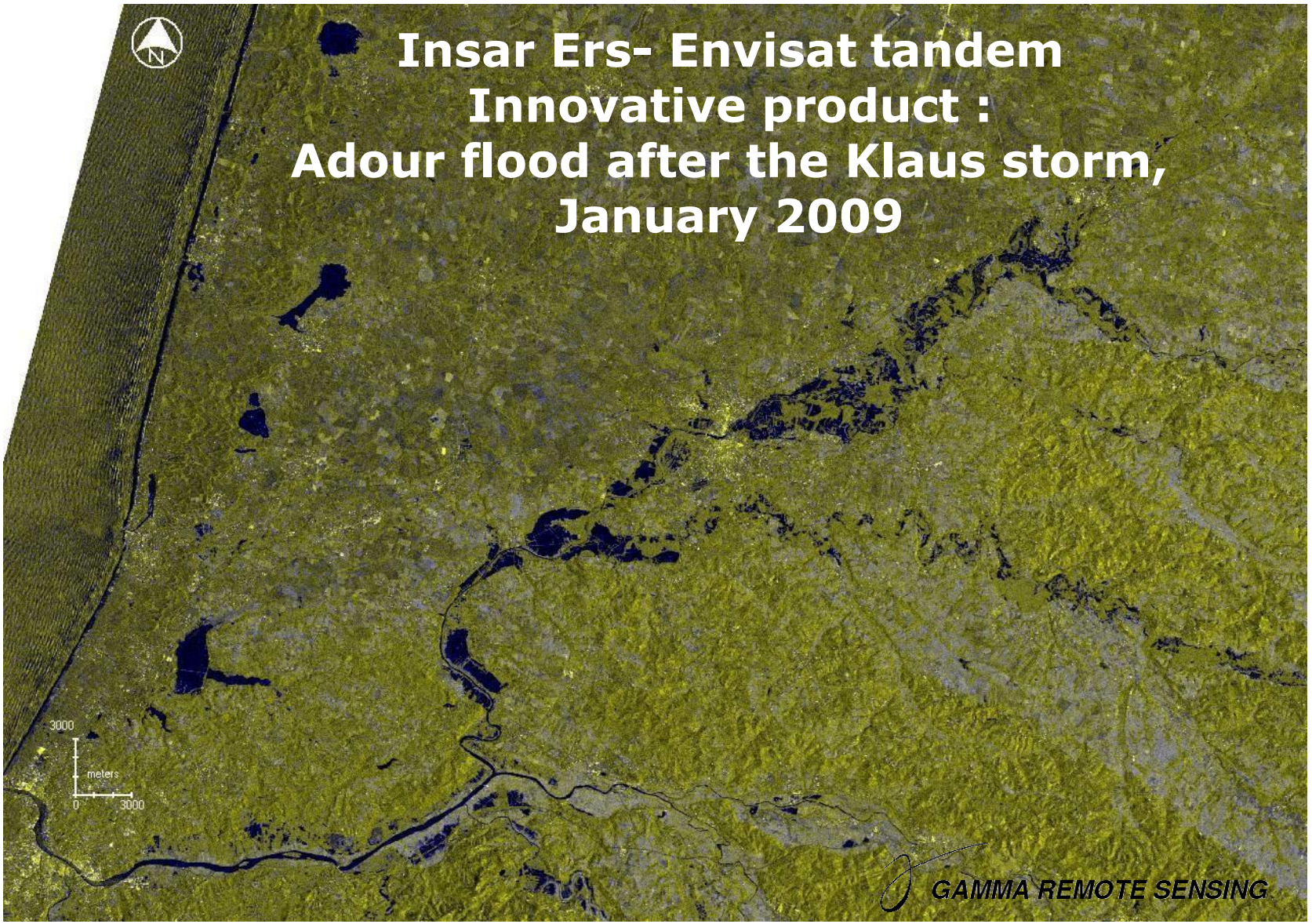


Very few failures: Katrina: New Orleans,

ENVISAT: flood rapid mapping



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

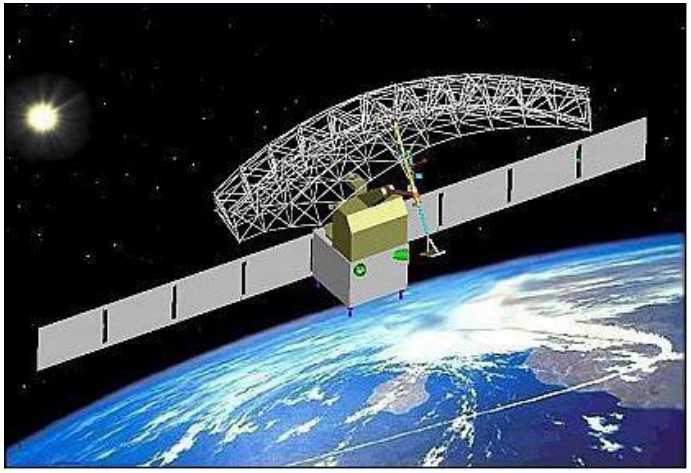

Insar Ers- Envisat tandem
Innovative product :
Adour flood after the Klaus storm,
January 2009
N
3000
meters
0
3000
GAMMA REMOTE SENSING

HJ1C:

(Huan Jing-1: Environmental Protection

& Disaster Monitoring Constellation

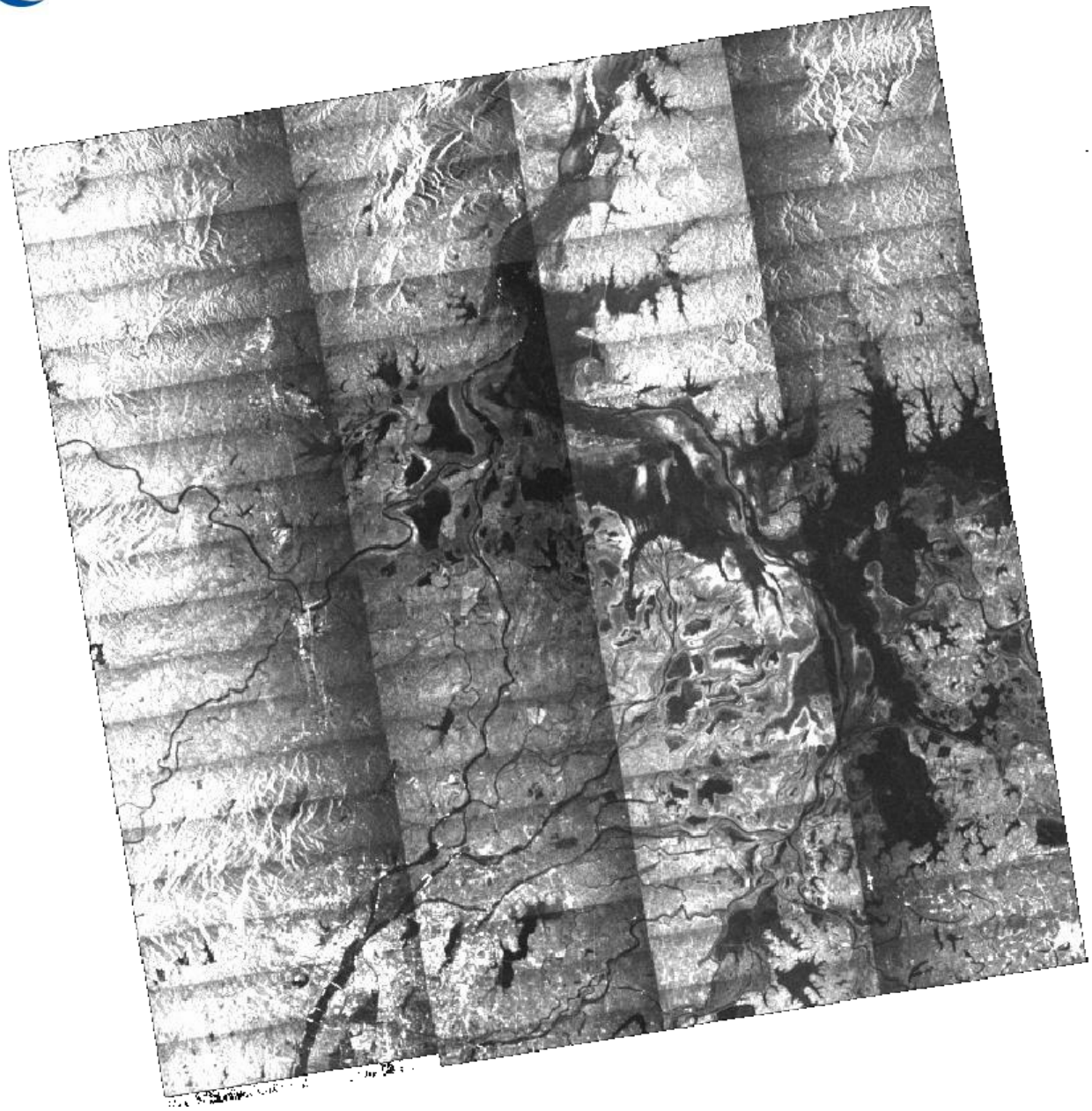
Chinese



Launch: 18-11-2012

- strip map modes: 25m / 5 m
- S band
- Swath: 100 / 40 km
- Single Pol HH or VV
- Cycle 31 days, revisit 4 days
- Lifetime : 3 years with Limited functionality due to damaged antenna

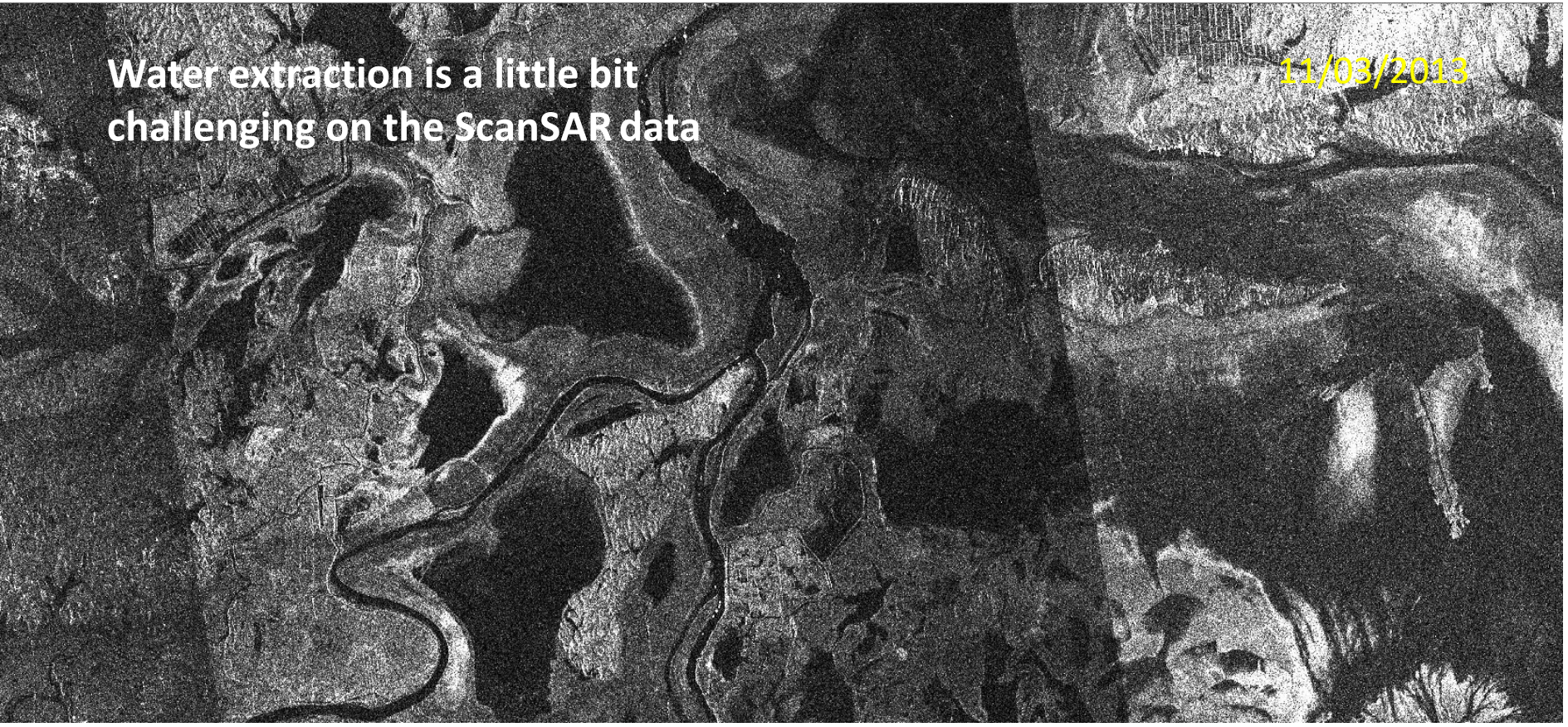
Reportedly the satellite suffered from an antenna problem, which caused a lower than planned resolution. As a remedy, the orbit was lowered.

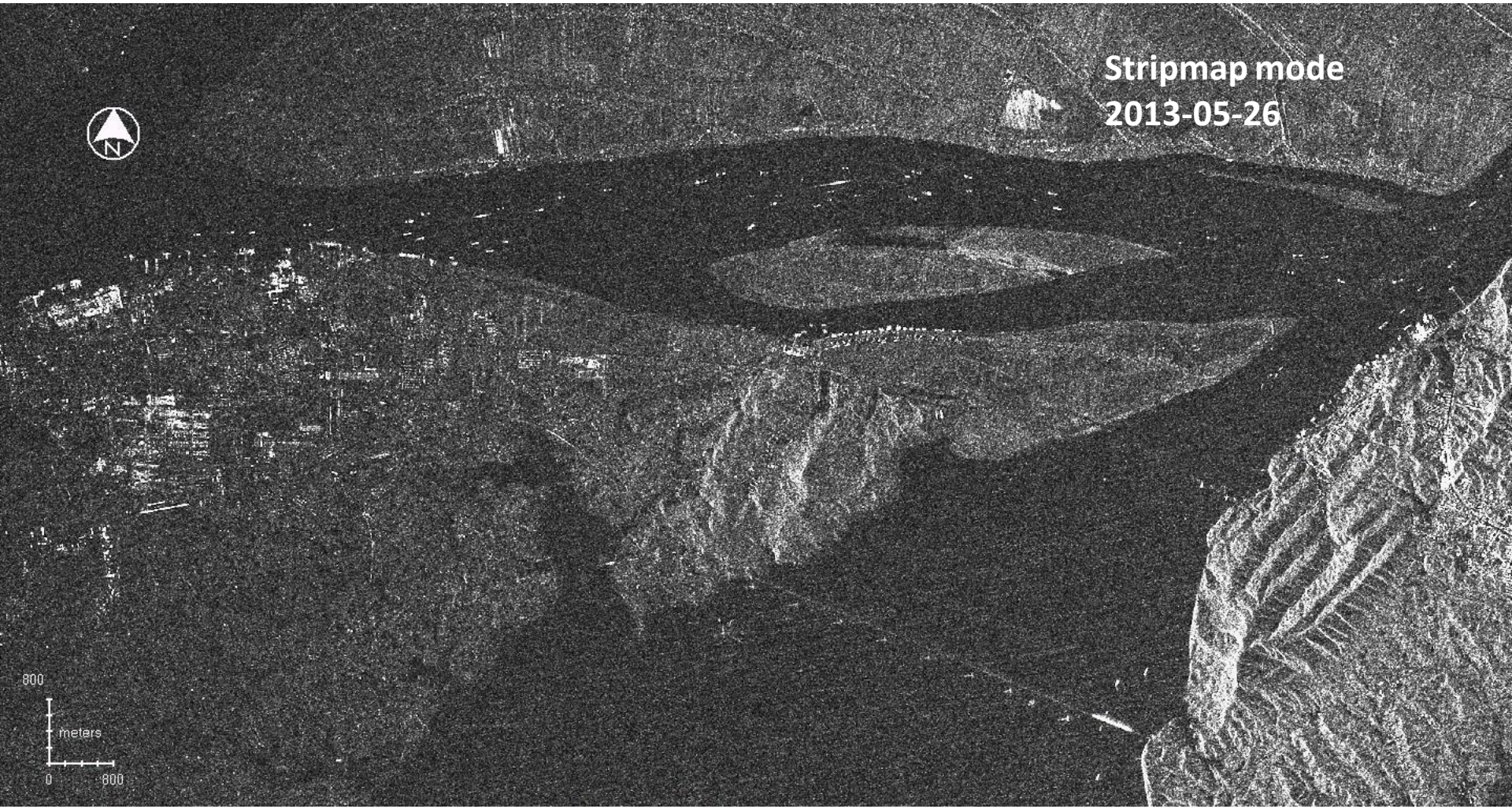


HJ 1C ScanSAR mode 11/03/2013

Relatively high level of noise: 15-17 db

Lack of radiometric compensation during mosaicing phase + blocs processing => patchwork of strips


Water extraction is a little bit challenging on the ScanSAR data
11/03/2013


Stripmap mode
2013-05-26
N
800
meters
0
800

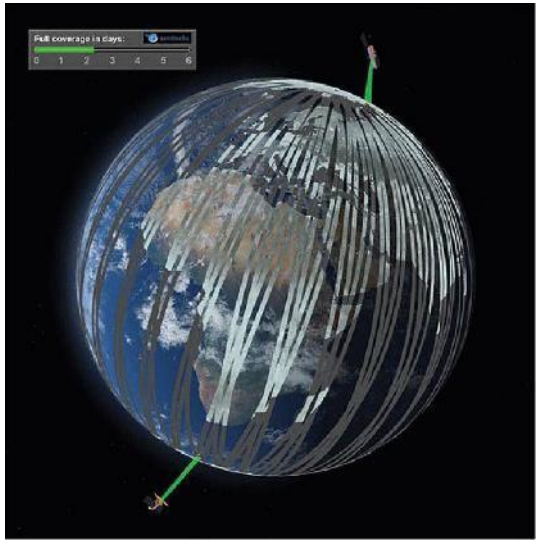
On going SAR Missions

- **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)



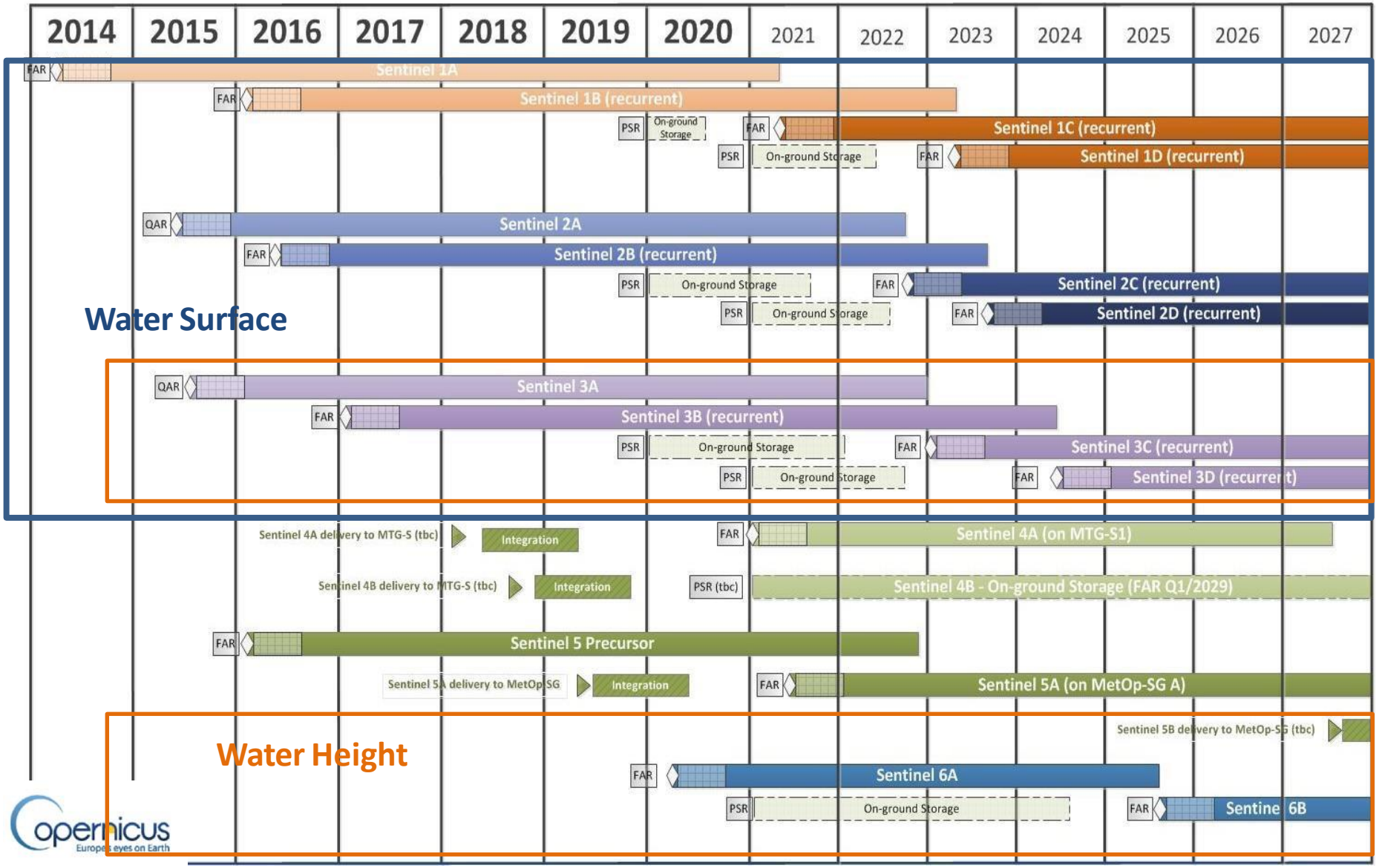
Multi mode

- 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

Copernicus missions (ESA) exploitable for hydrology



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

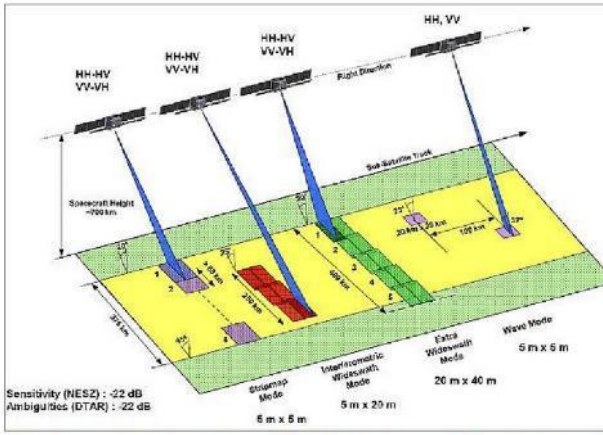
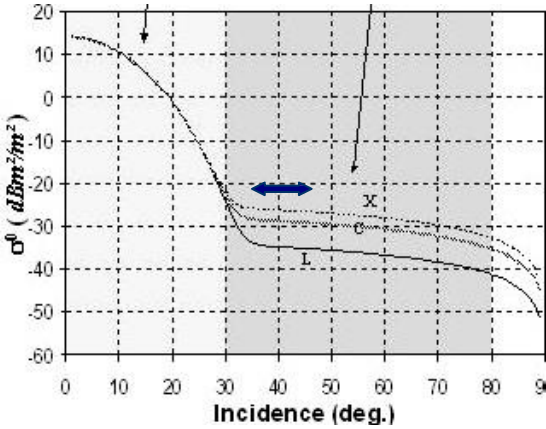
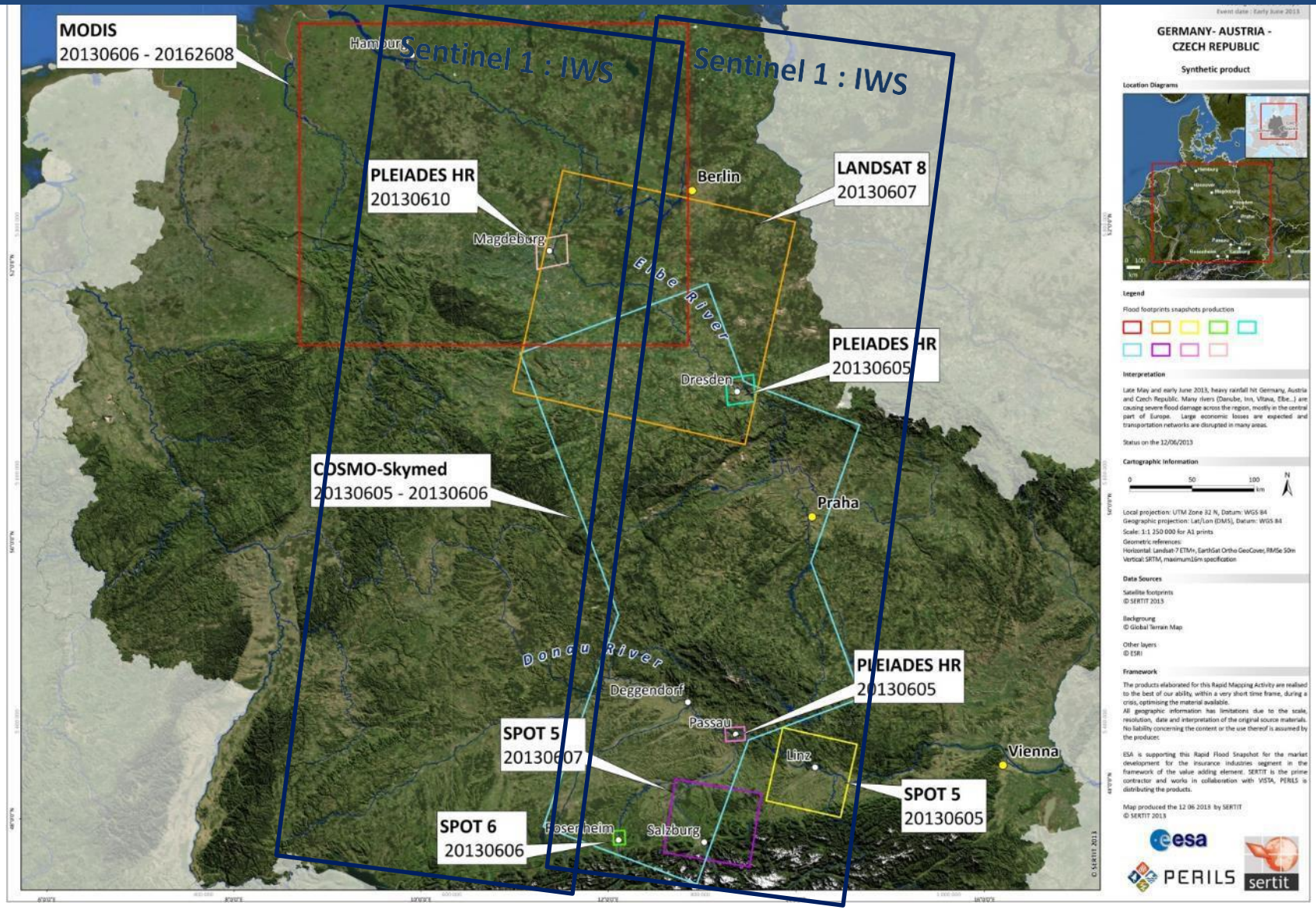


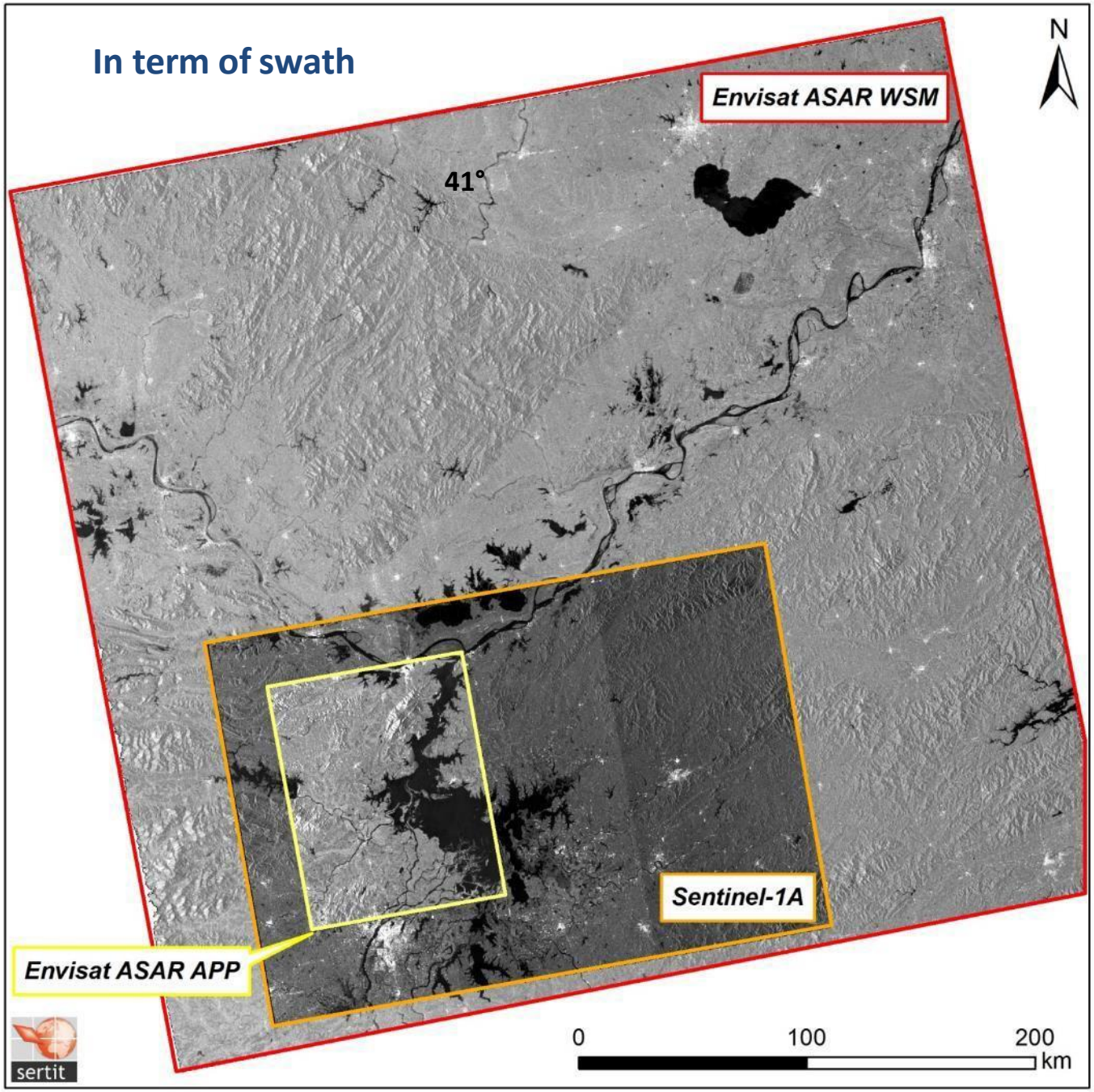
Figure 129: Overview of the Sentinel-1 C-SAR instrument observation scheme and operational support (image credit: ESA)



Sentinel 1 expect in term of swath coverage : standard mode



In term of swath



ASAR WSM ENVISAT

400 km

26° - 41° ENL 10.5

Sentinel 1

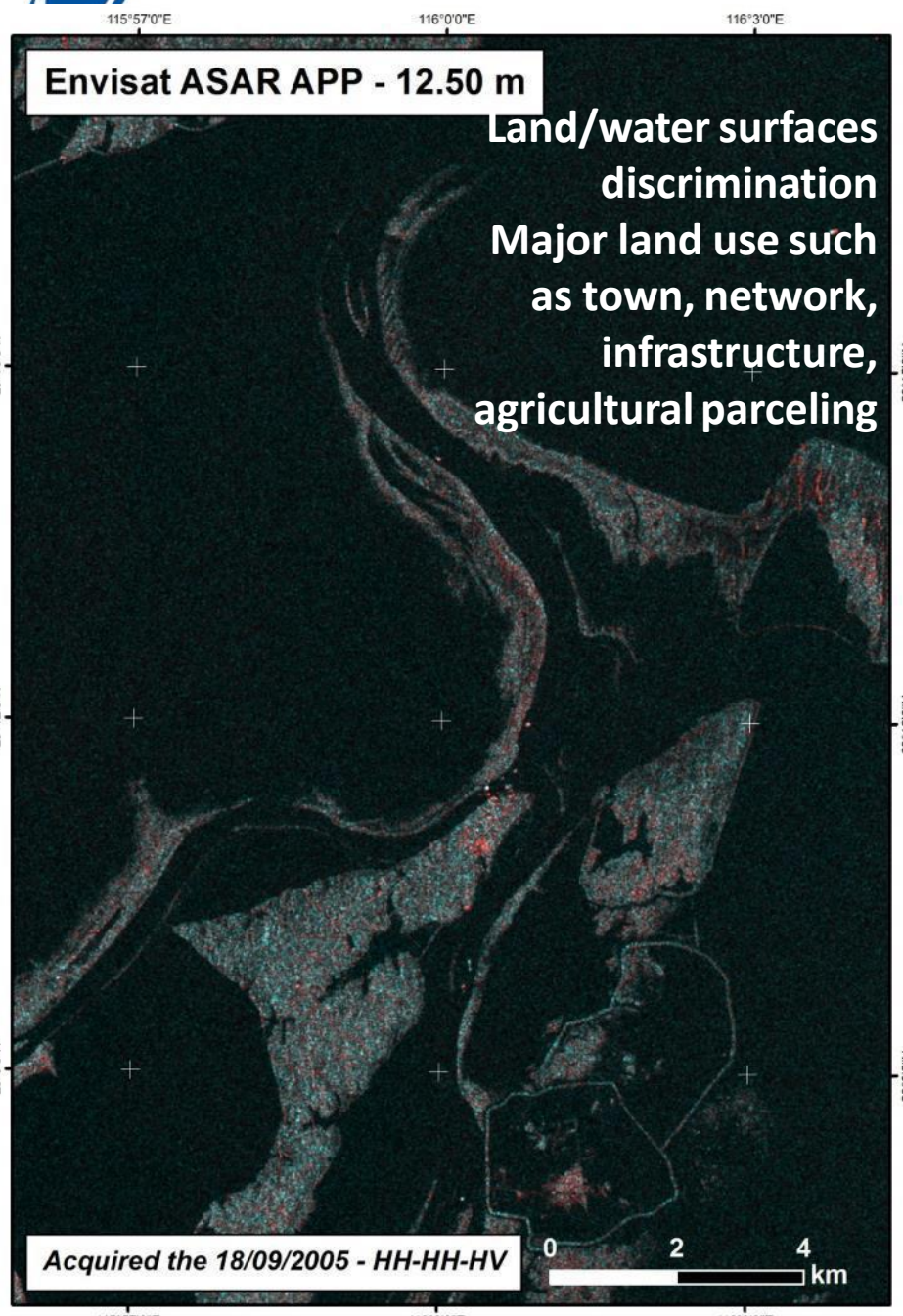
250 km

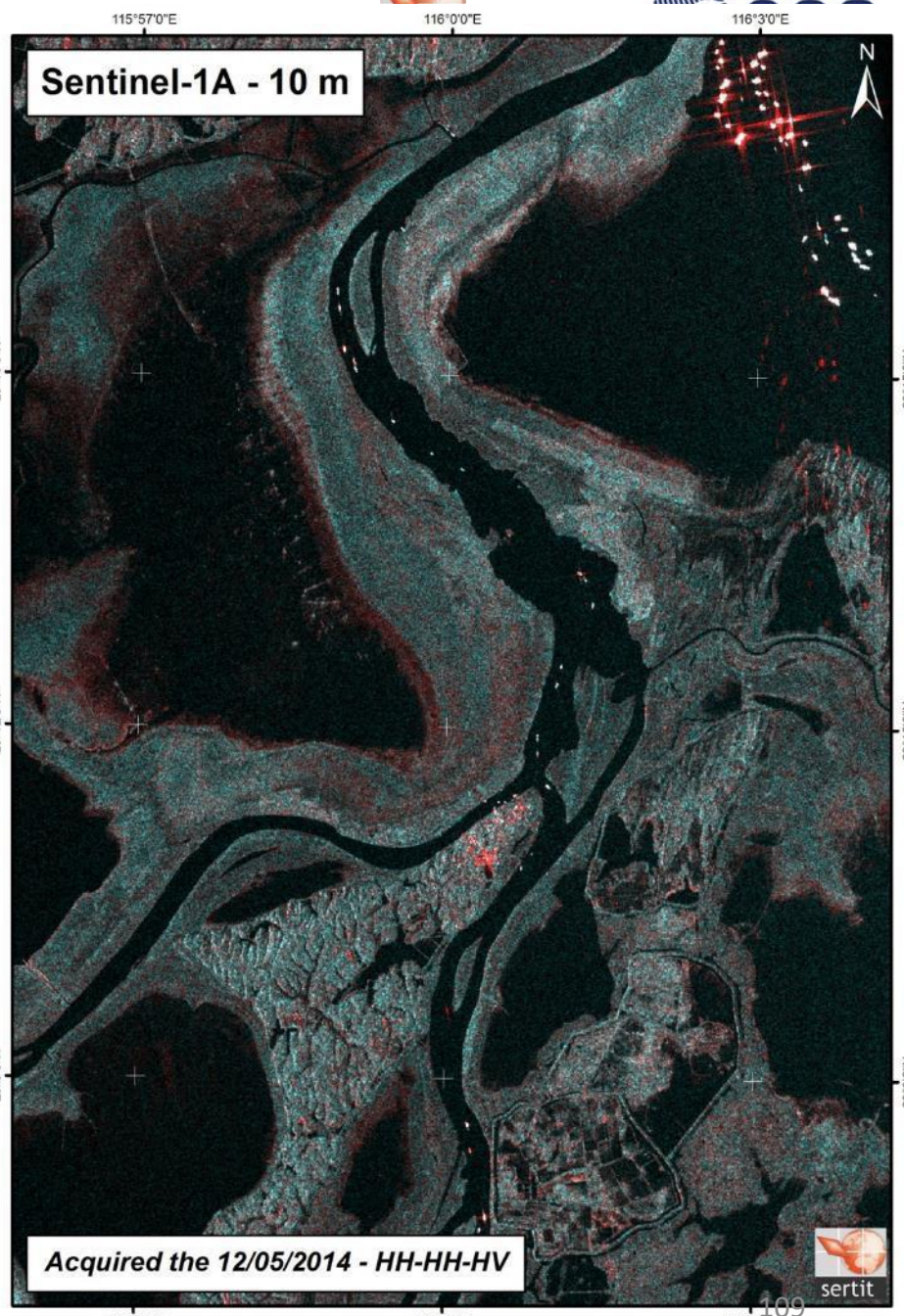
30° - 45 ENL: 4.9

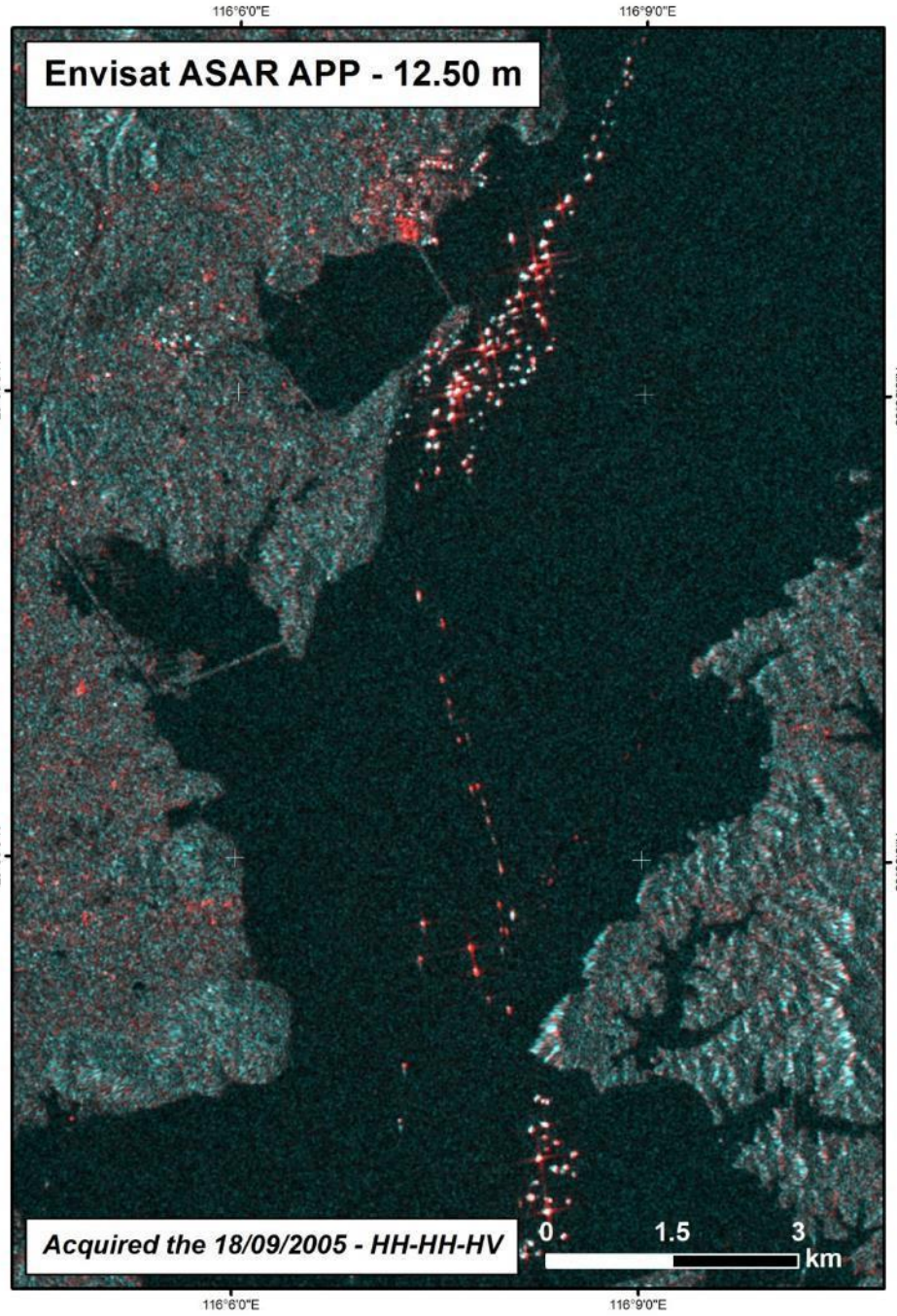
ASAR APP S4 ENVISAT

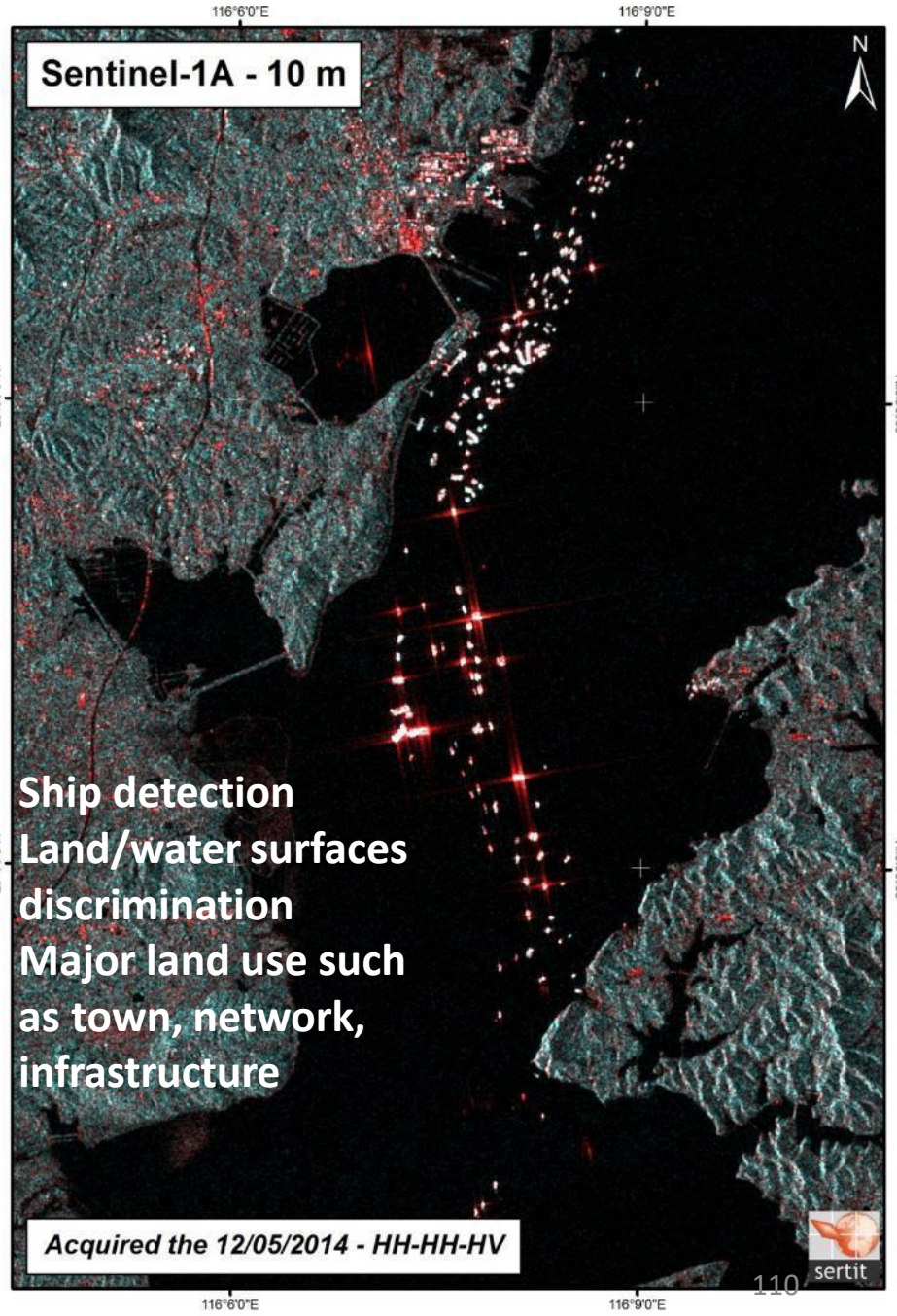
88 km

31-36° ENL 1.9

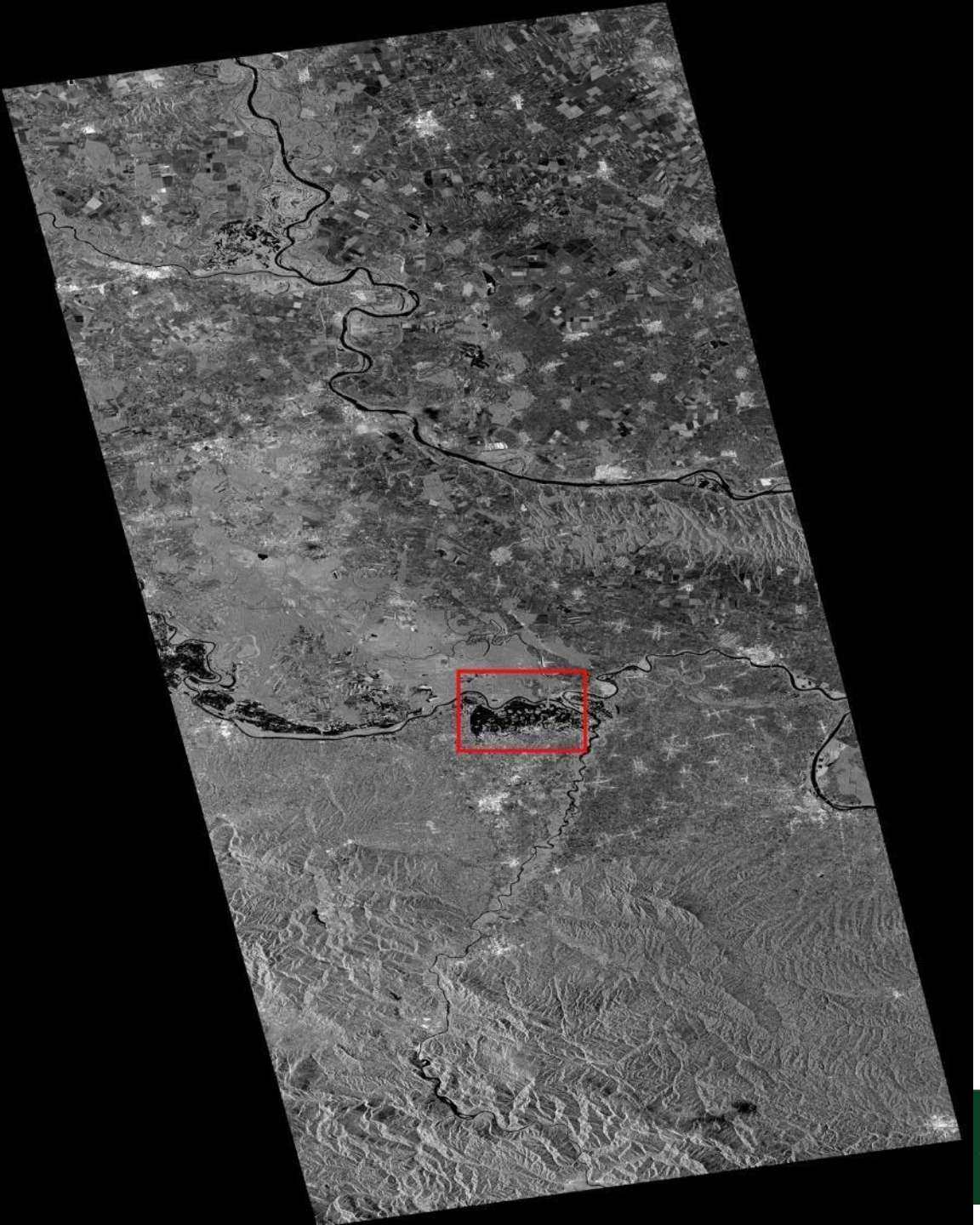

Envisat ASAR APP - 12.50 m
Land/water surfaces discrimination
Major land use such as town, network, infrastructure, agricultural parceling
115°57'0"E
116°0'0"E
116°3'0"E
29°15'0"N
29°12'0"N
29°9'0"N
Acquired the 18/09/2005 - HH-HH-HV
0
2
4
km


Sentinel-1A - 10 m
N
115°57'0"E
116°0'0"E
116°3'0"E
29°15'0"N
29°12'0"N
29°9'0"N
Acquired the 12/05/2014 - HH-HH-HV
sertit





Ship detection
Land/water surfaces discrimination
Major land use such as town, network, infrastructure

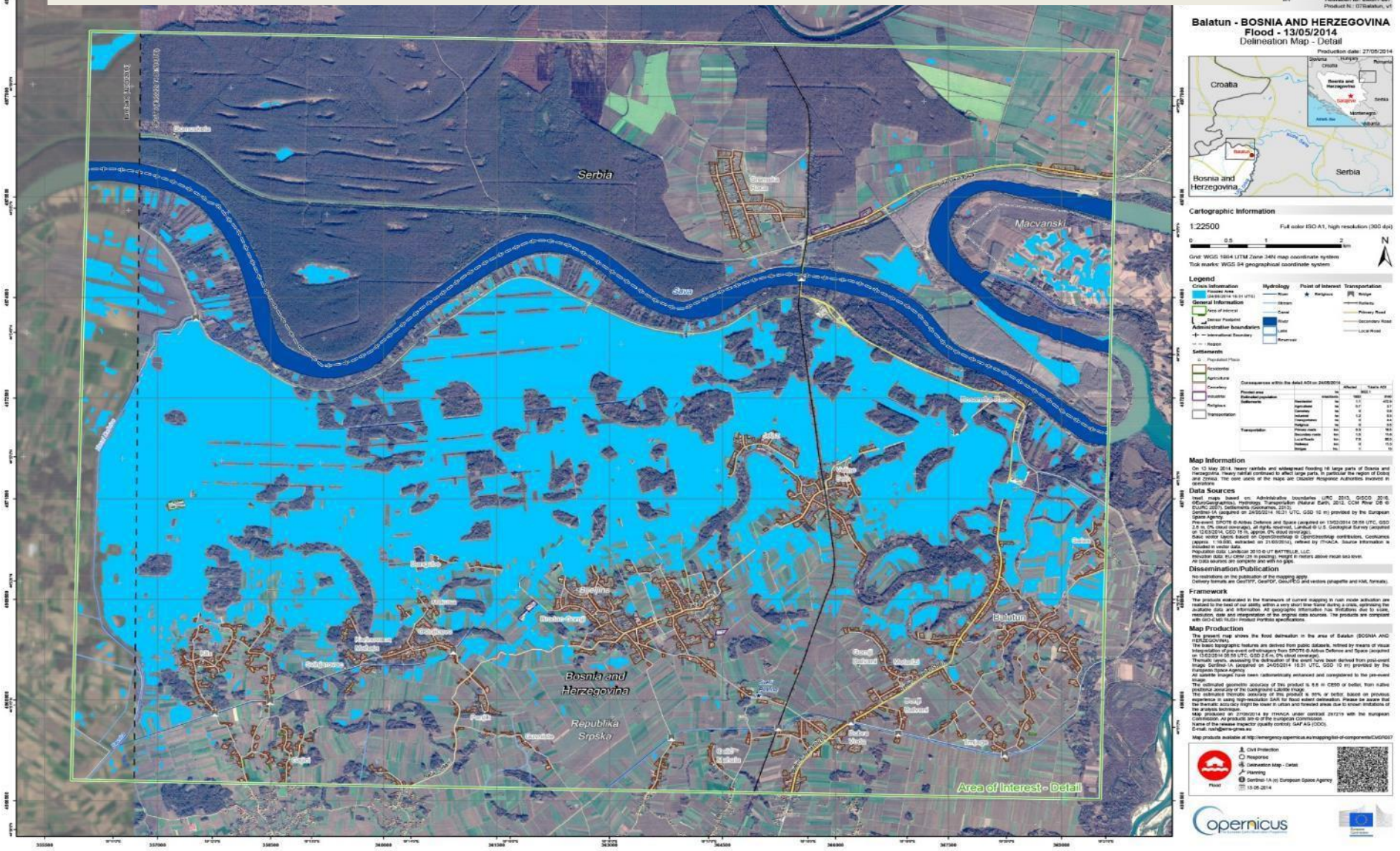


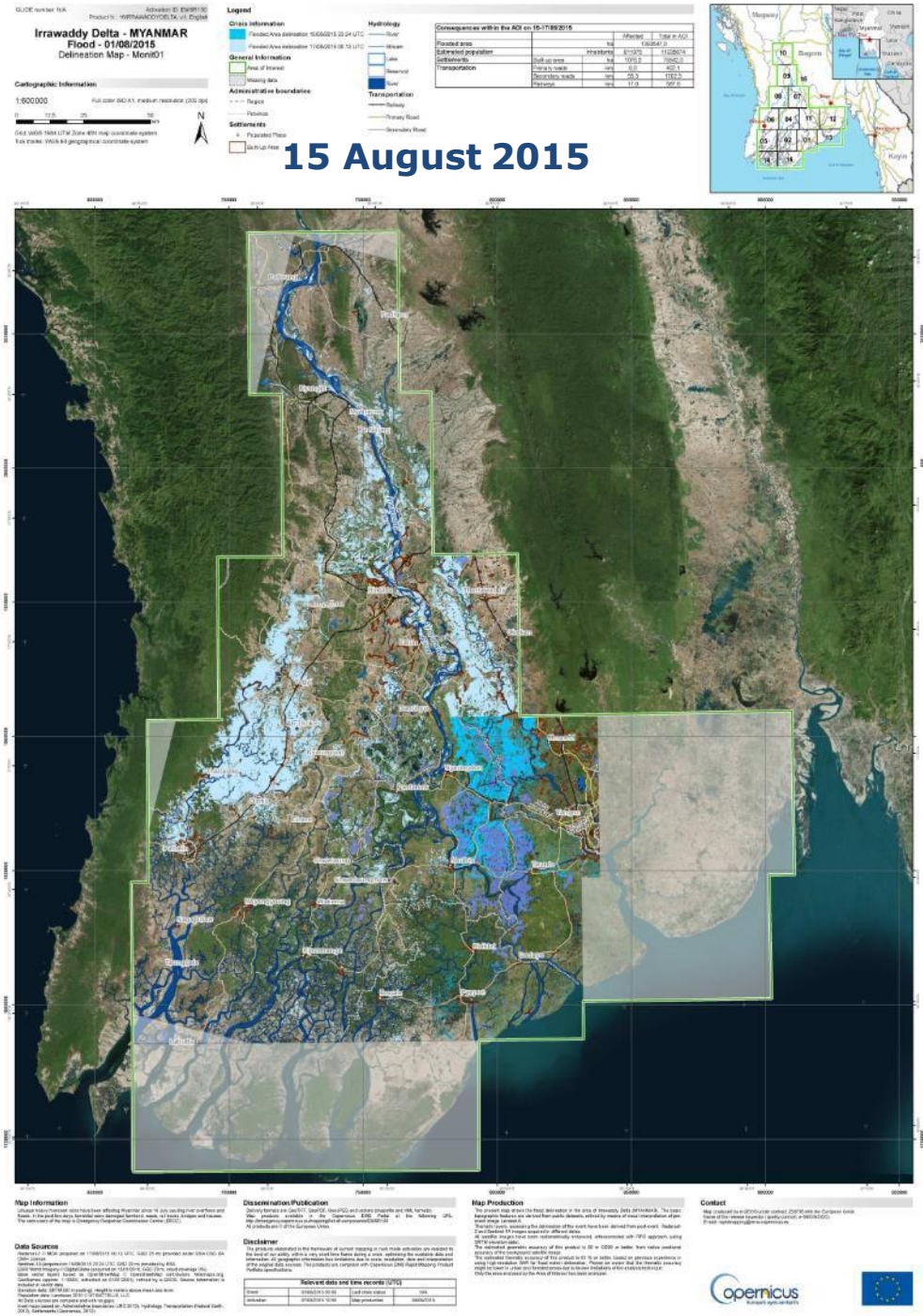
Sentinel Flood mapping: a rare example of strip map exploitation

Bosnia and Herzegovina

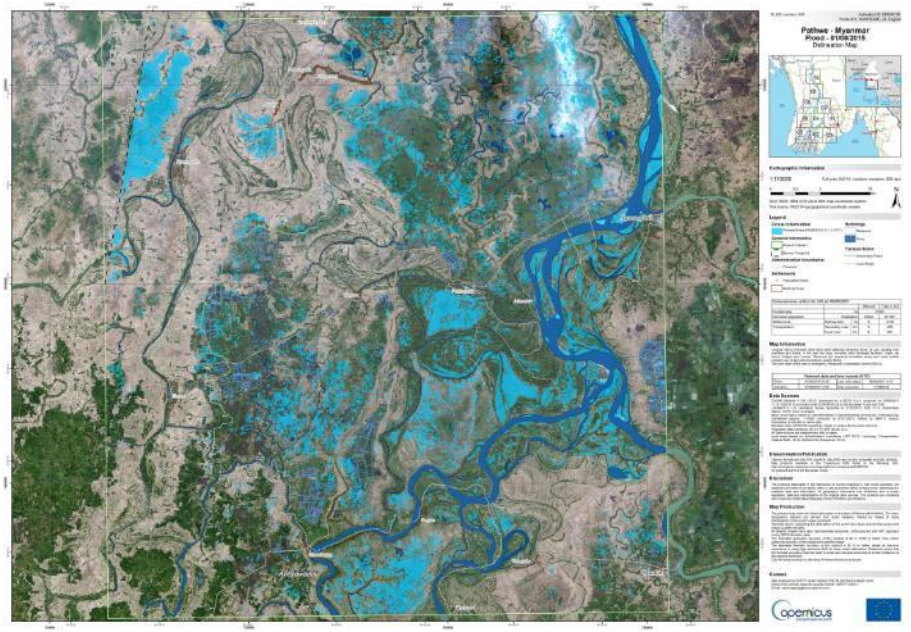
May 2014

Sentinel Flood mapping: a rare example of strip map exploitation

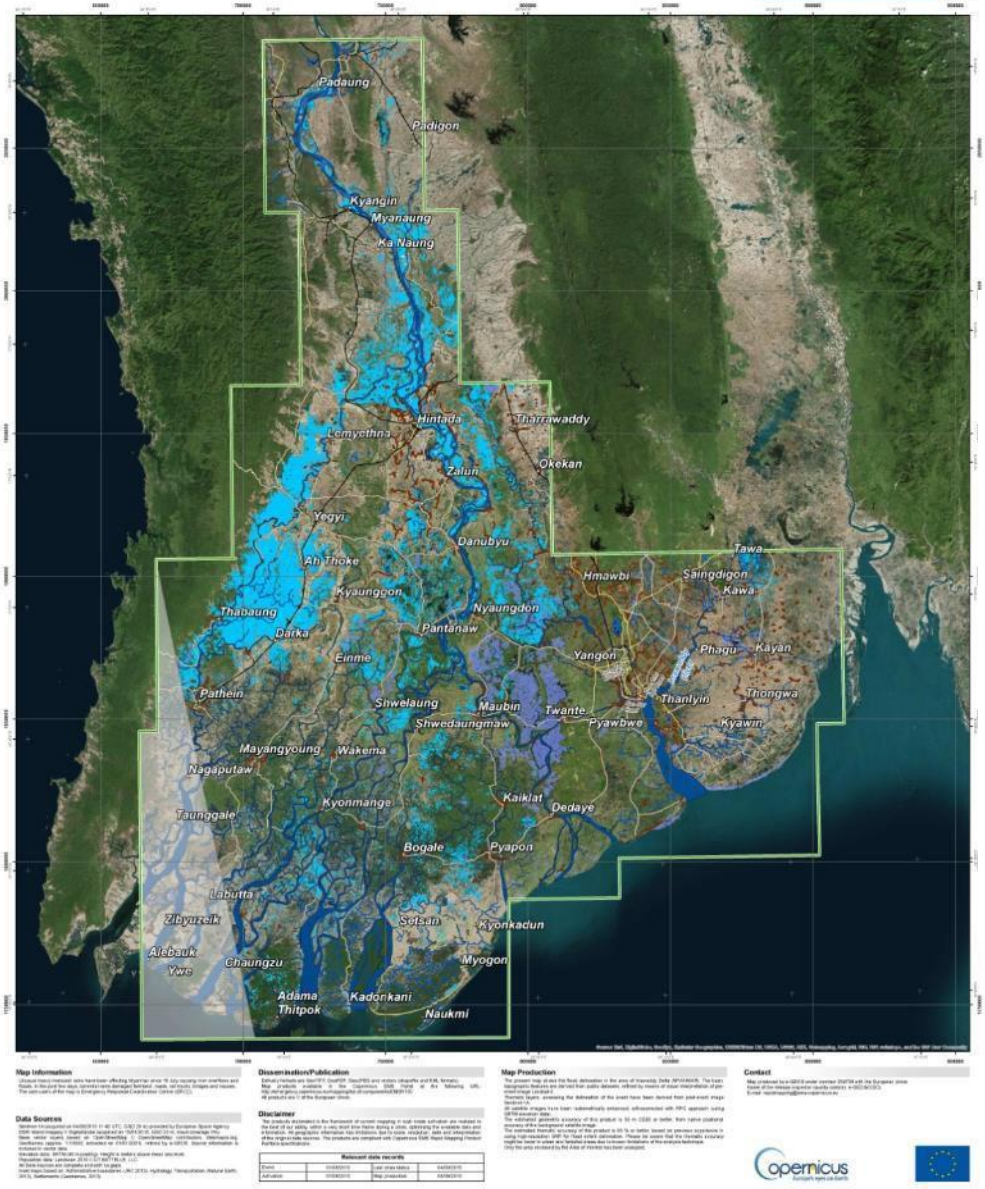




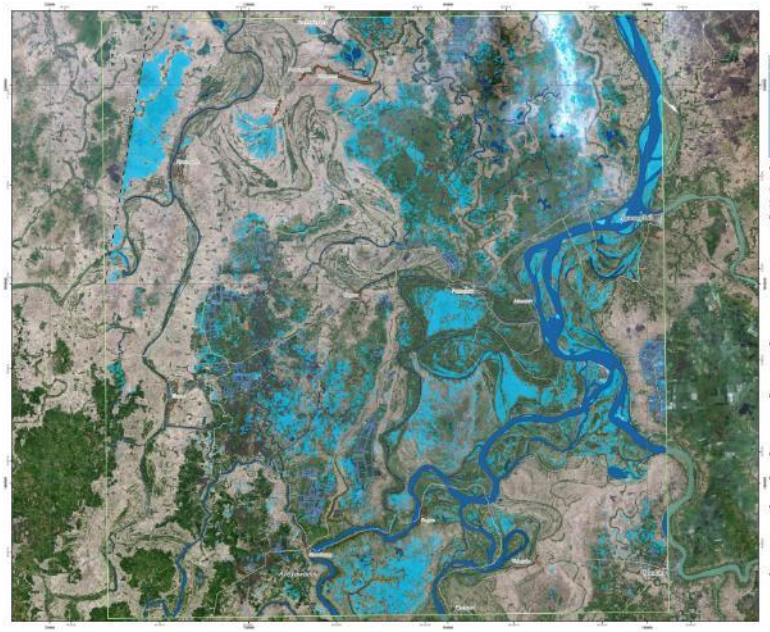
Myanmar
Heavy monsoon rain caused river overflow and flooding in August 2015



04 September 2015



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



RISAT

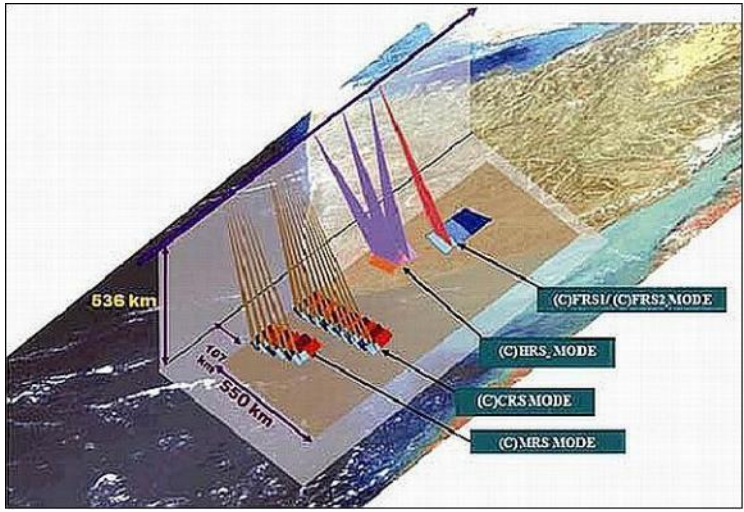
Indian satellite

C Band

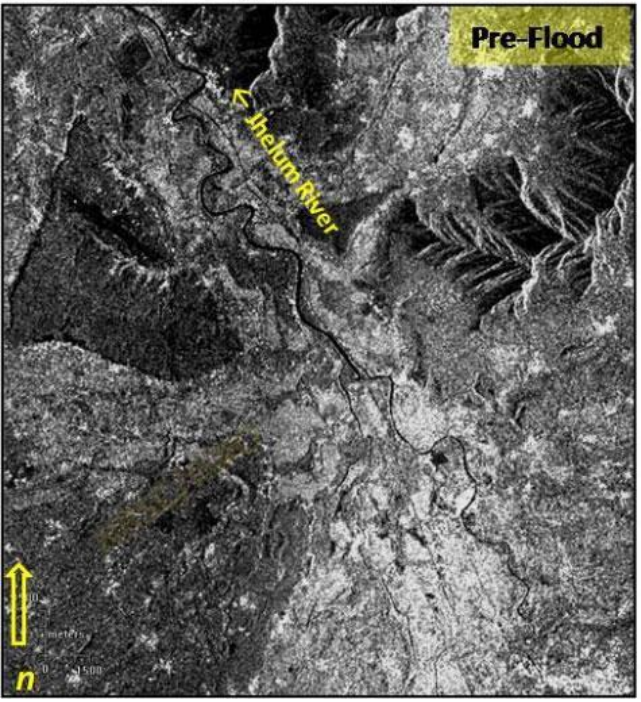
Launch: 01 May 2012

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

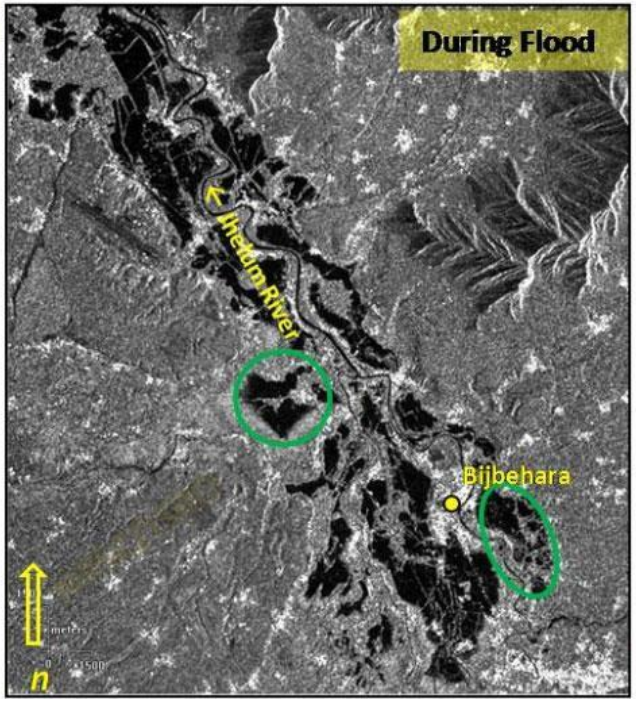
Mode		Resol (Az rang	Swath	Pol	Beam
SpotLight	HRS	>2m	10	Dual-hybrid	
Strip map 1	FRS-1	3*2m	25	Dual-hybrid	
Strip map 1	FRS-2	6*4m	25	Quad pol	
MediumScanSAR	MRS	25*8m	115	Dual-hybrid	6
Coarse ScanSAR	CRS	50*8	223	Dual-hybrid	12



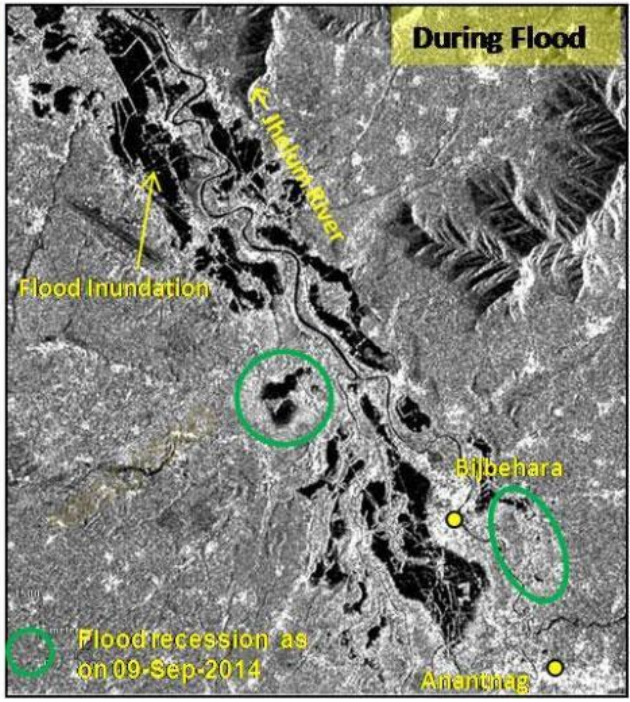
RISAT-1 image of 14-Aug-2014



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

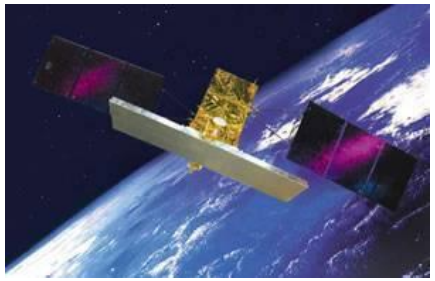
GAOFENG 3: VHR and Full Pol

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

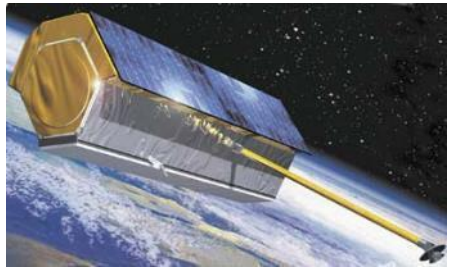
The VHR and polarimetric SAR: TerraSAR, CSK

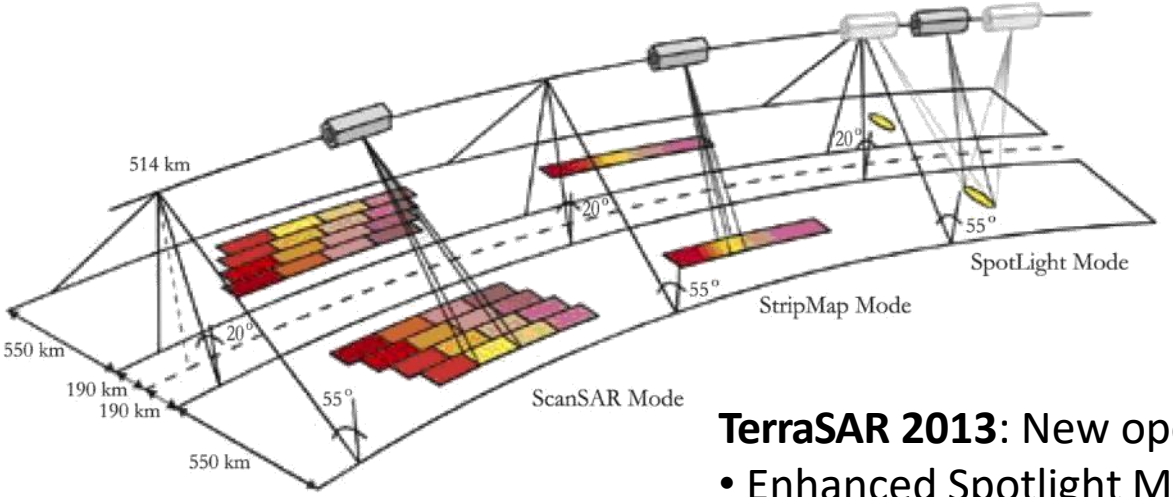
X band VHR satellites

- **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

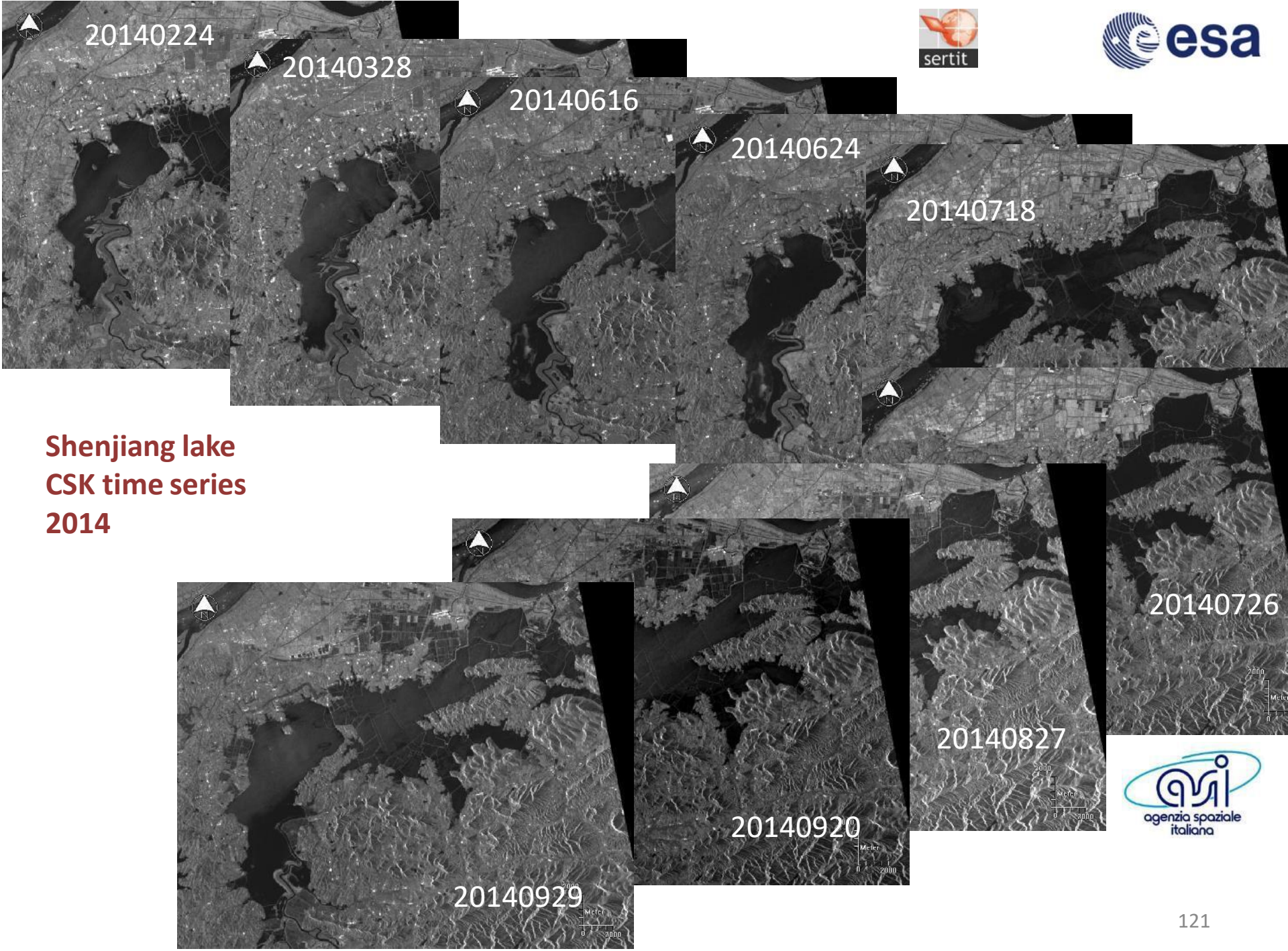




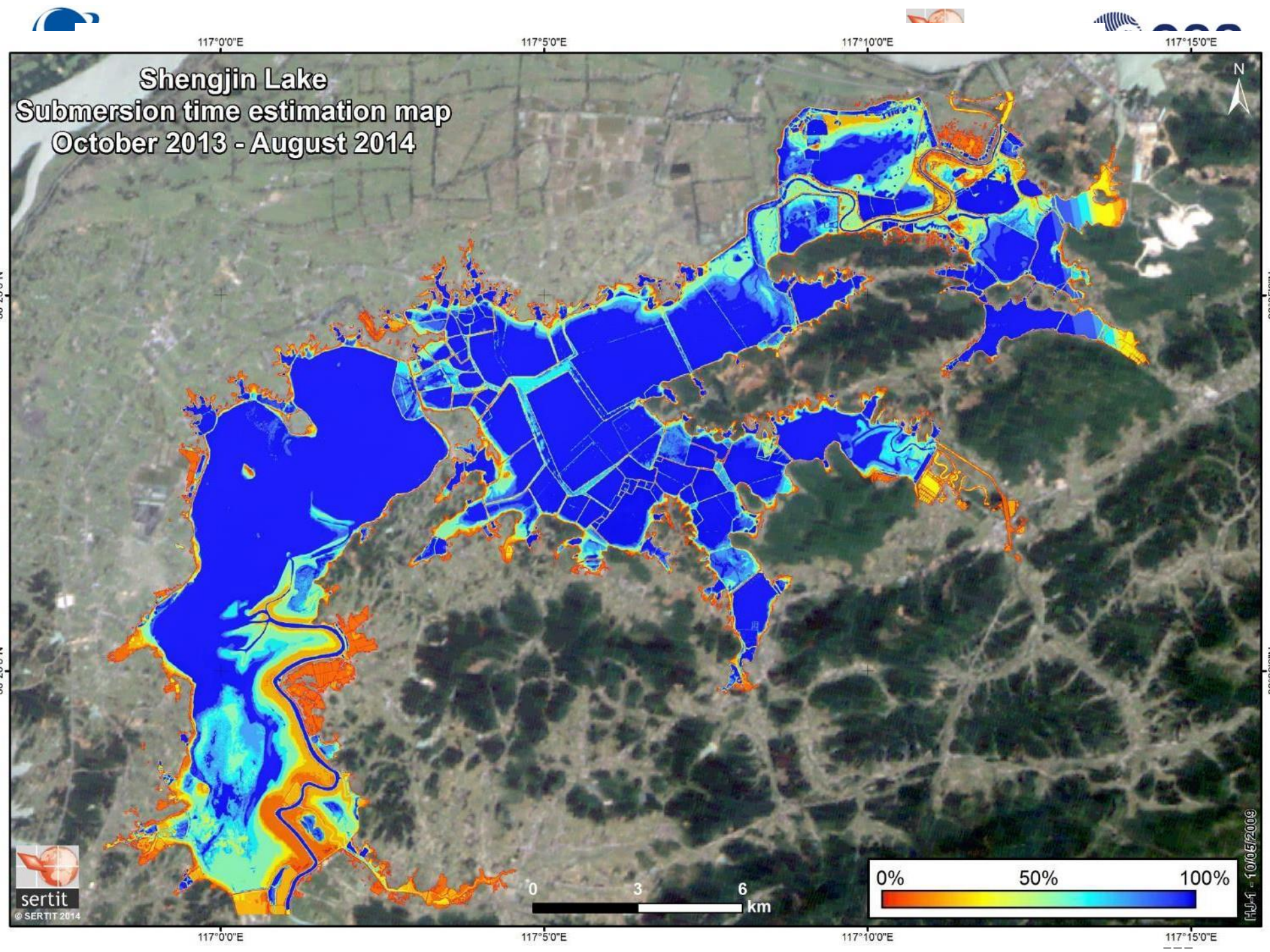
TerraSAR 2013: New operational Imaging Modes

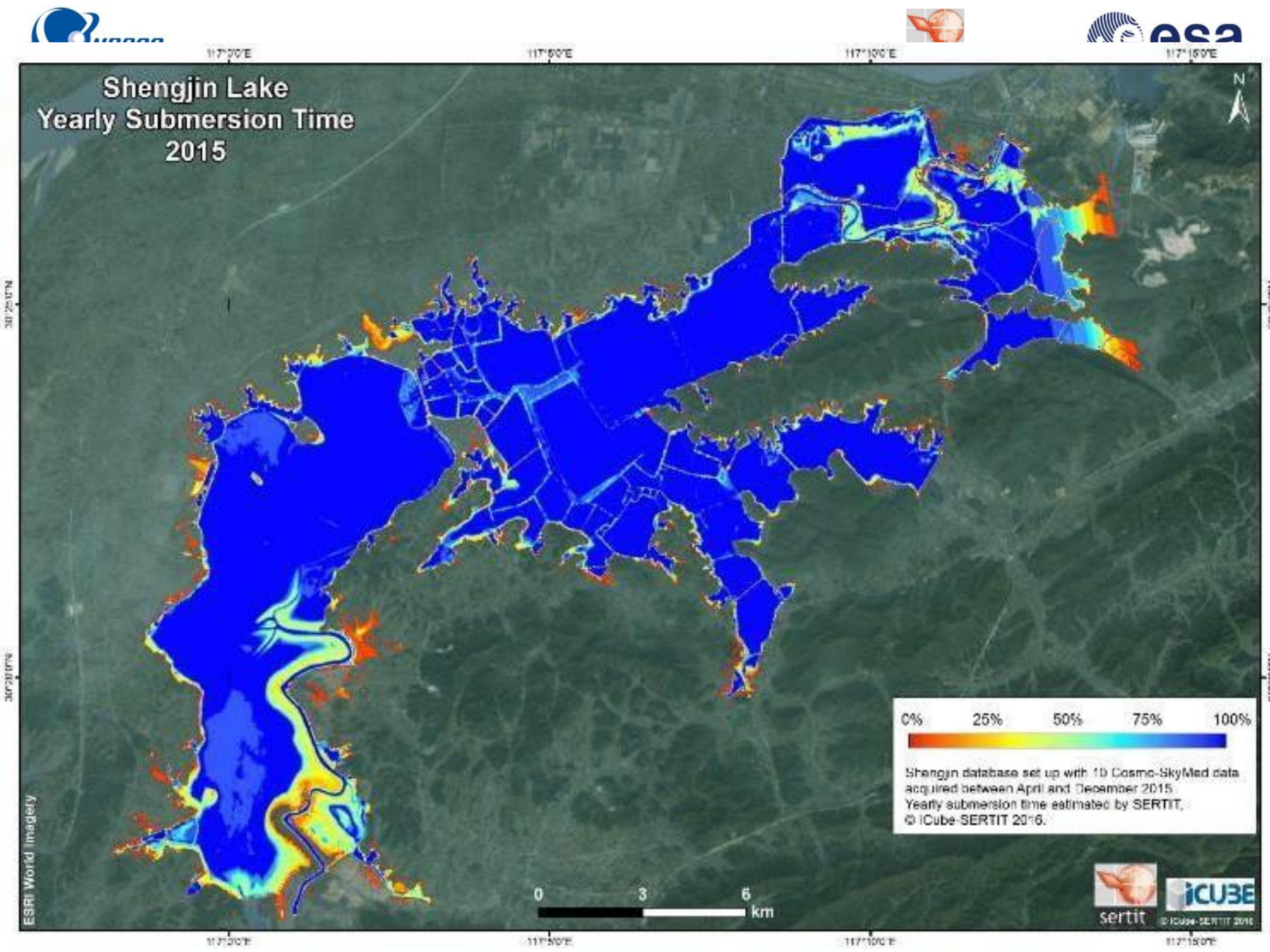
- Enhanced Spotlight Mode (Starring Spotlight).
- ScanSAR :expanded swath width (200 instead of 100km).

The VHR and polarimetric SAR: TerraSAR, CSK



Shenjiang lake
CSK time series
2014

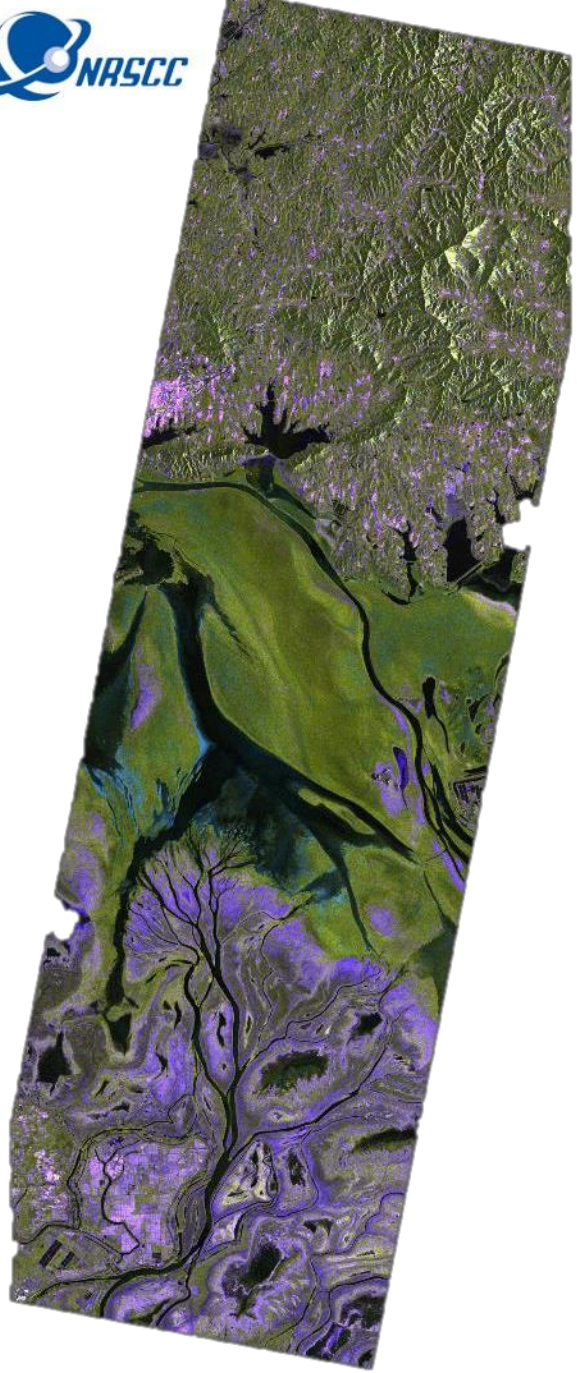

Shengjin Lake
Submersion time estimation map
October 2013 - August 2014
117°0'0"E
117°5'0"E
117°10'0"E
117°15'0"E
N
0
3
6
km
0%
50%
100%
HJ-1 - 10/05/2009
sertit
© SERTIT 2014


Shengjin Lake
Yearly Submersion Time
2015
N
0%
25%
50%
75%
100%
Shengjin database set up with 19 Cosmo-SkyMed data acquired between April and December 2015.
Yearly submersion time estimated by SERTIT.
© ICube-SERTIT 2016.
0
3
6
km
ESRI World Imagery
sertit
ICUBE

Water bodies mapping based on Cosmo Skymed Data:

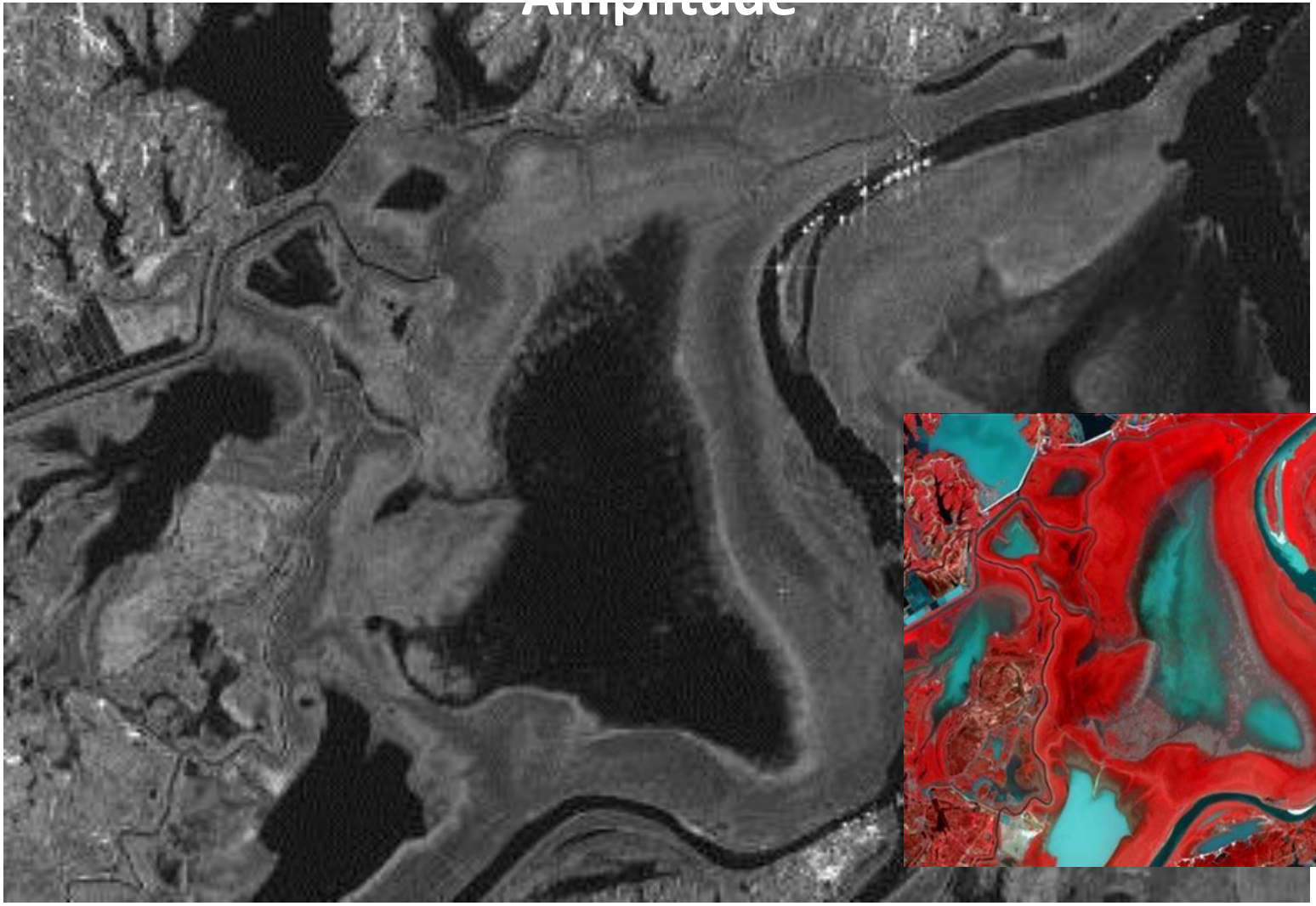
Water bodies mapping based on Cosmo Skymed Data: Poyang lake China

Fish traps on Bang Hu viewed by CosmoSkymed, SpotLight image acquired the 31 of January 2011



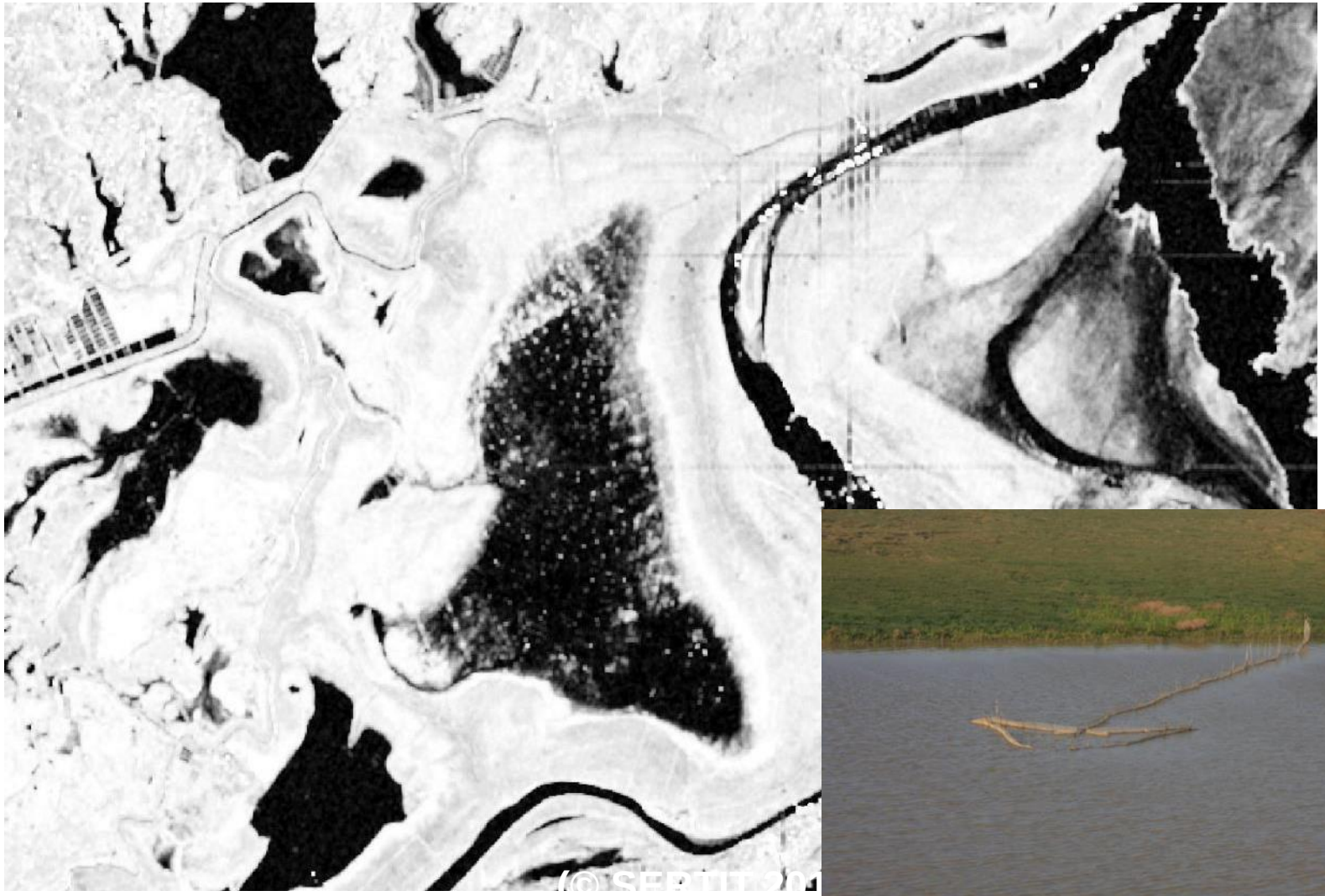
Water bodies mapping based on Tandem X INSAR

Water bodies mapping based on Tandem X INSAR



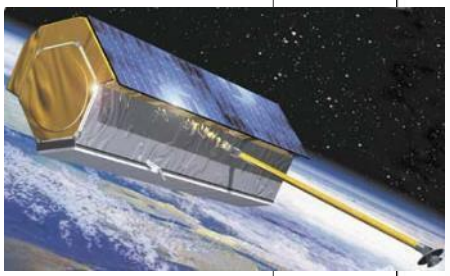
Water bodies mapping based on Tandem X INSAR

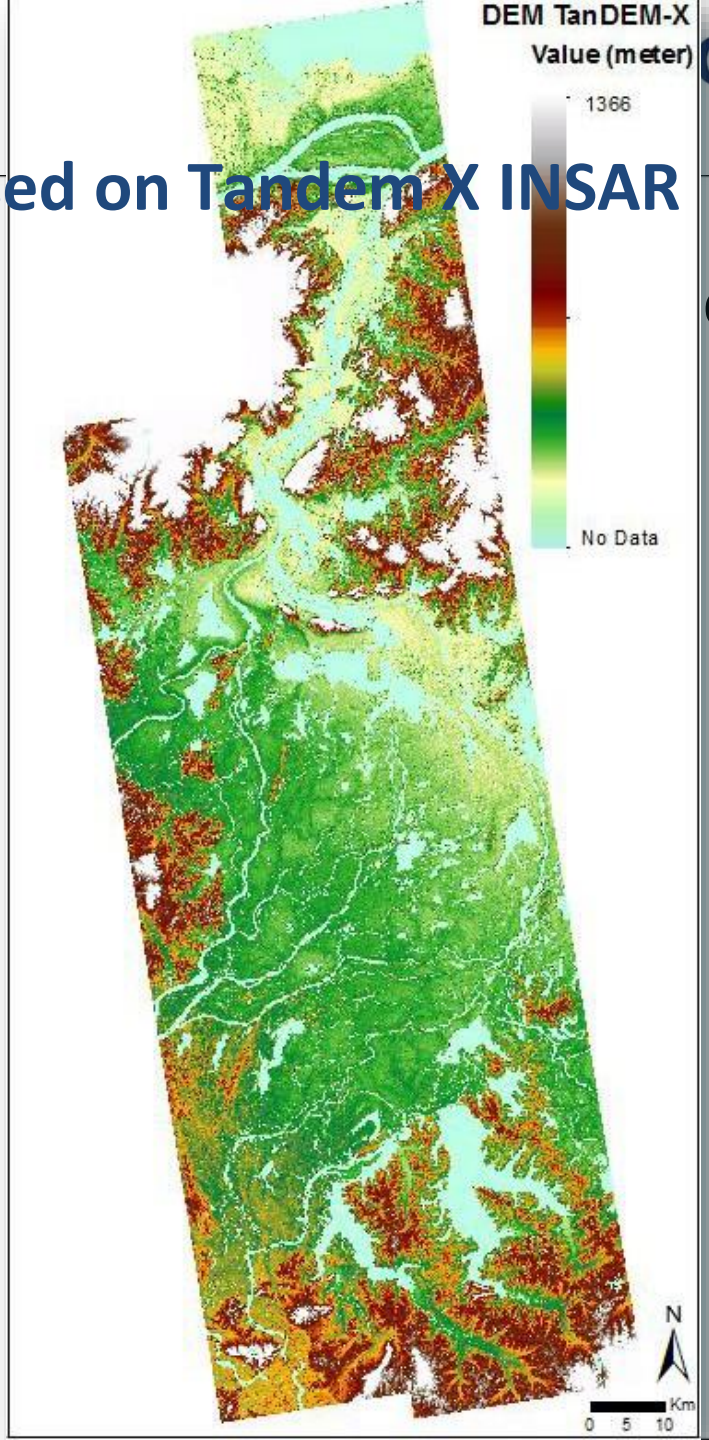
Cohérence

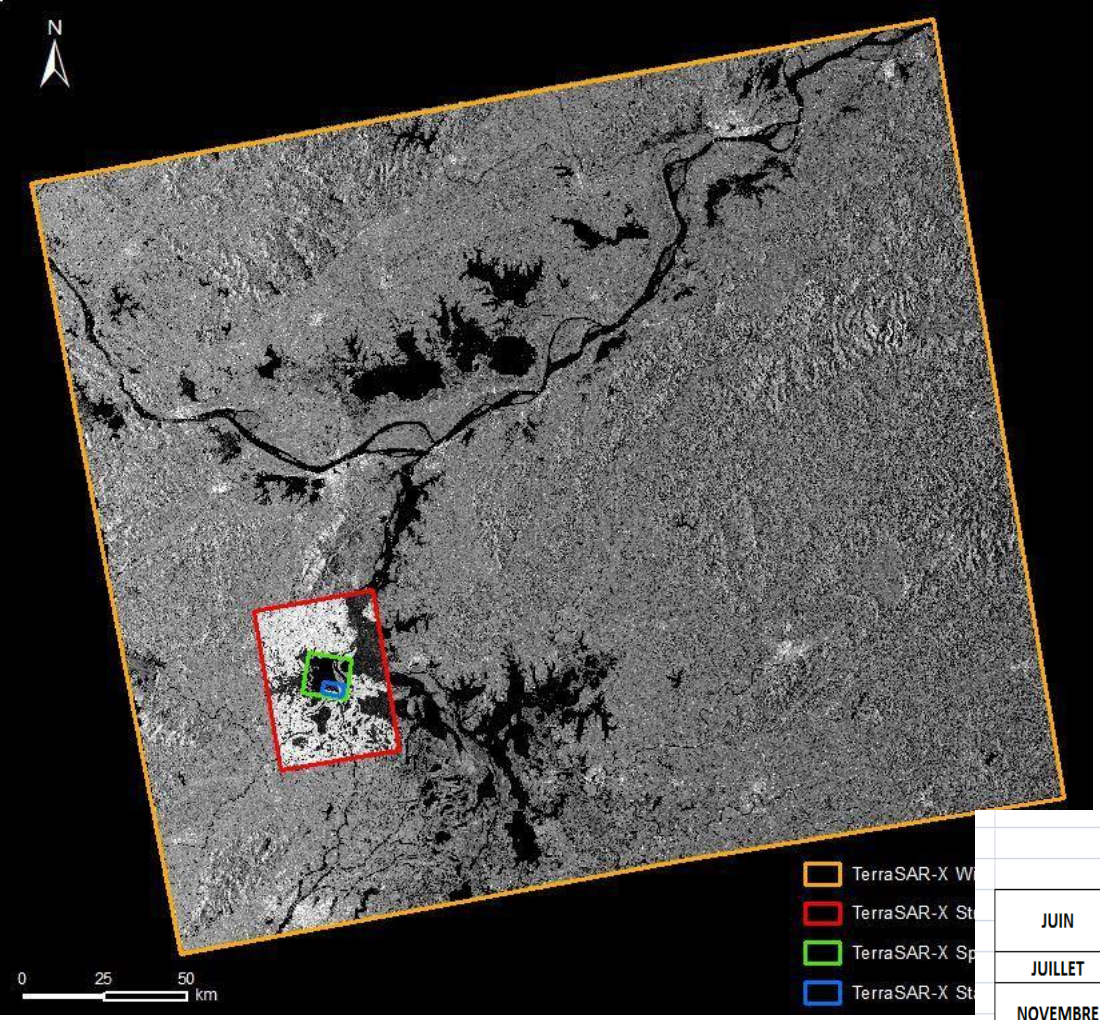


Water bodies mapping based on Tandem X INSAR

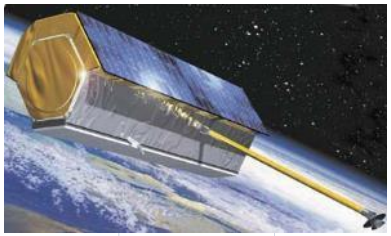
Amplitude







Muti resolution approach exploiting TerraSAR New modes



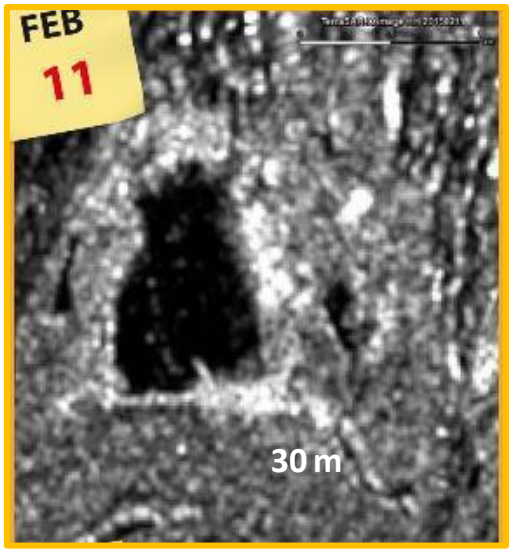
	CHINE				
	WSC	SM	SL	ST (BANG HU)	ST (MEIXI HU)
JUIN	3 25	8			
JUILLET			17		
NOVEMBRE	15	20	19 30		13
DÉCEMBRE	18 29	1 12		5	16
JANVIER	9 31	14	13	7	18
FÉVRIER	11	16	15	20	9
MARS	27	10	20	25	14
AVRIL		12	11	23	16
MAI		15	14		19
JUIN					

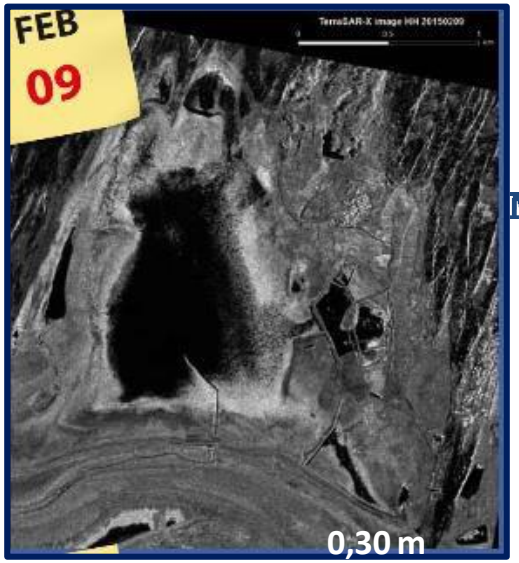
Wide Scan SAR 200*200 km², 30 m

Strip Map mode : 30*50 km², 3m

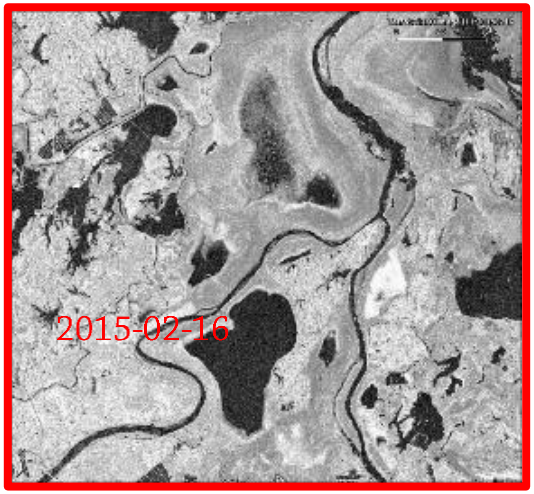
SpotLight mode : 5*10 km², 1m

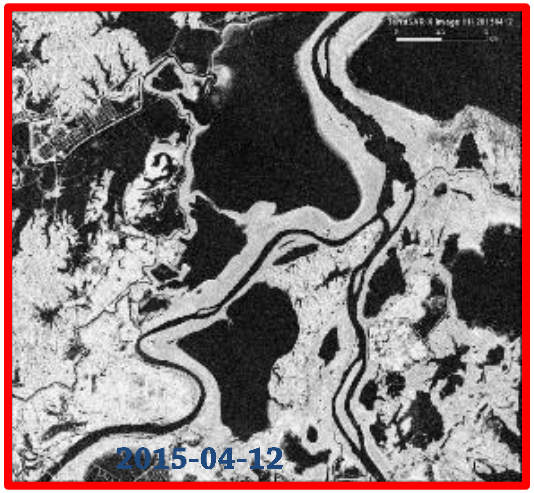
Staring SpotLight : 3*4 km², 25 cm

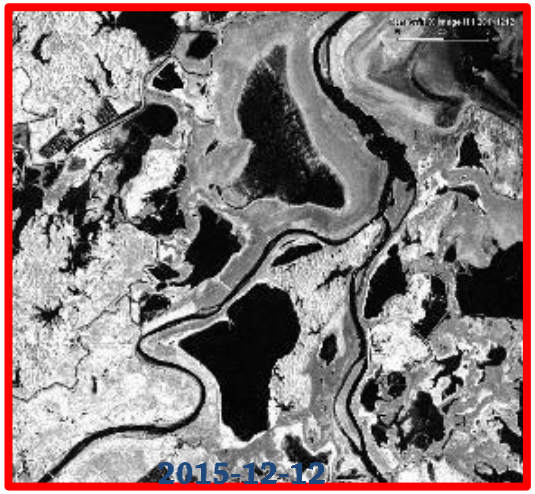




Multi resolution
Multi- temporelle



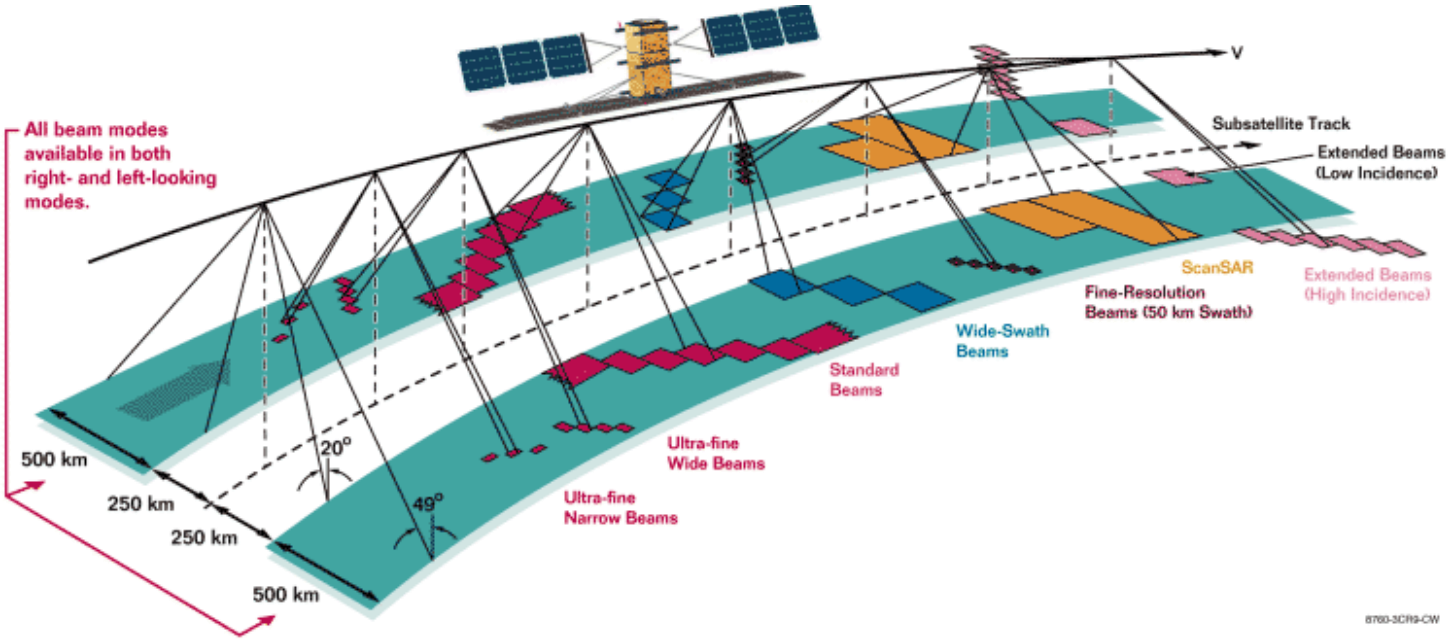




The VHR and polarimetric SAR: Radarsat

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

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



Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar

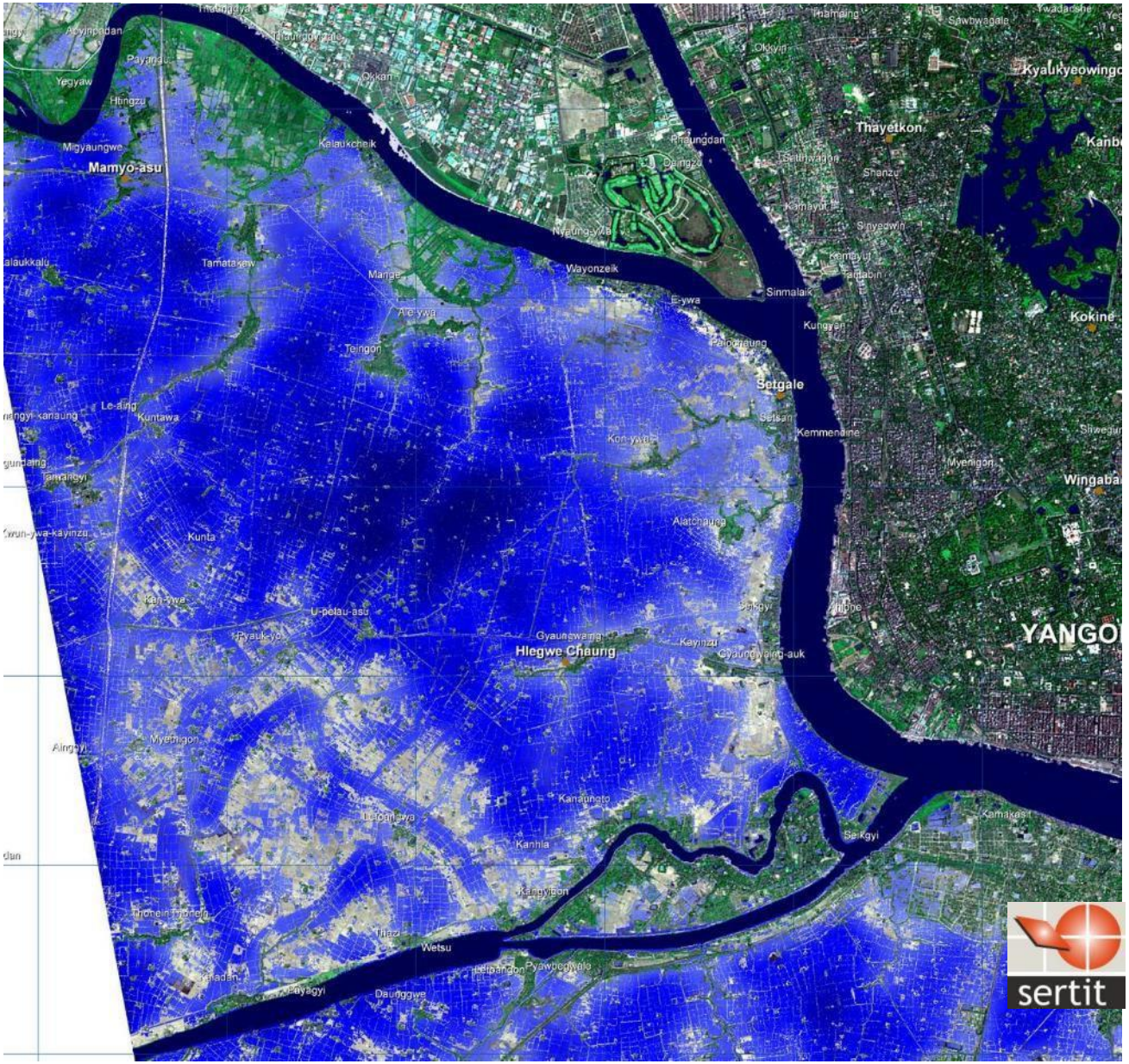
Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar

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)

Remember E. Pottier presentation

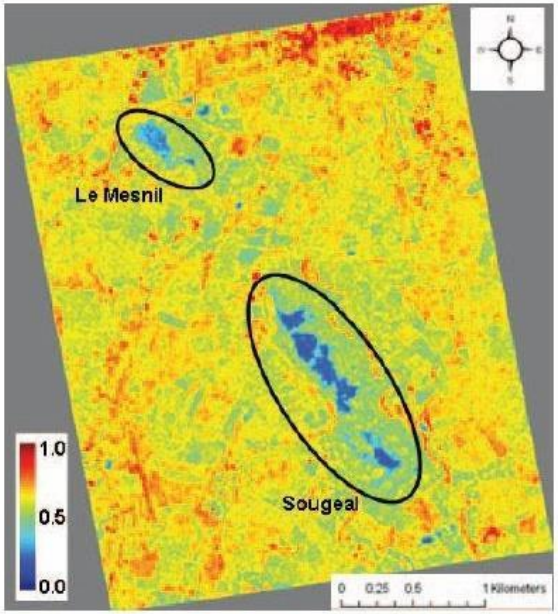


Figure 3- *The normalized Shannon Entropy (SE) image.*

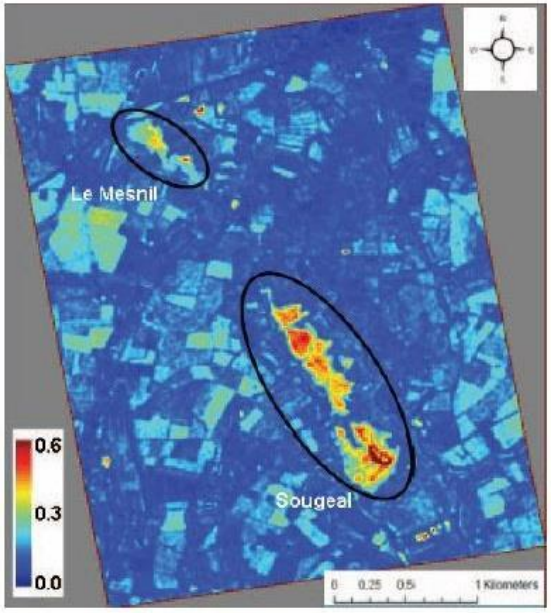


Figure 4- *Temporal coefficient of variation of the SE parameter*

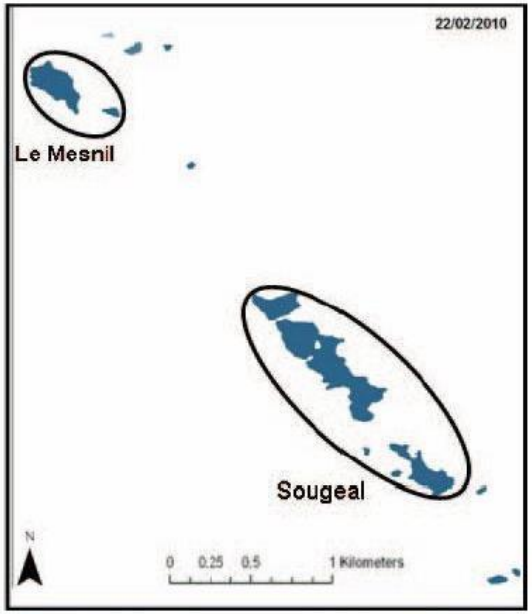


Figure 5-*The segmented SE image with the open water in blue*

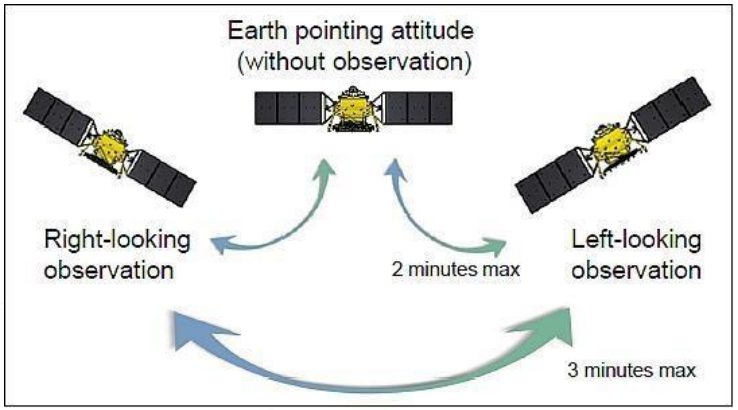
From Maréchal, Pottier et al., Igarss 2011; Pottier et al., Igarss Munich 2012

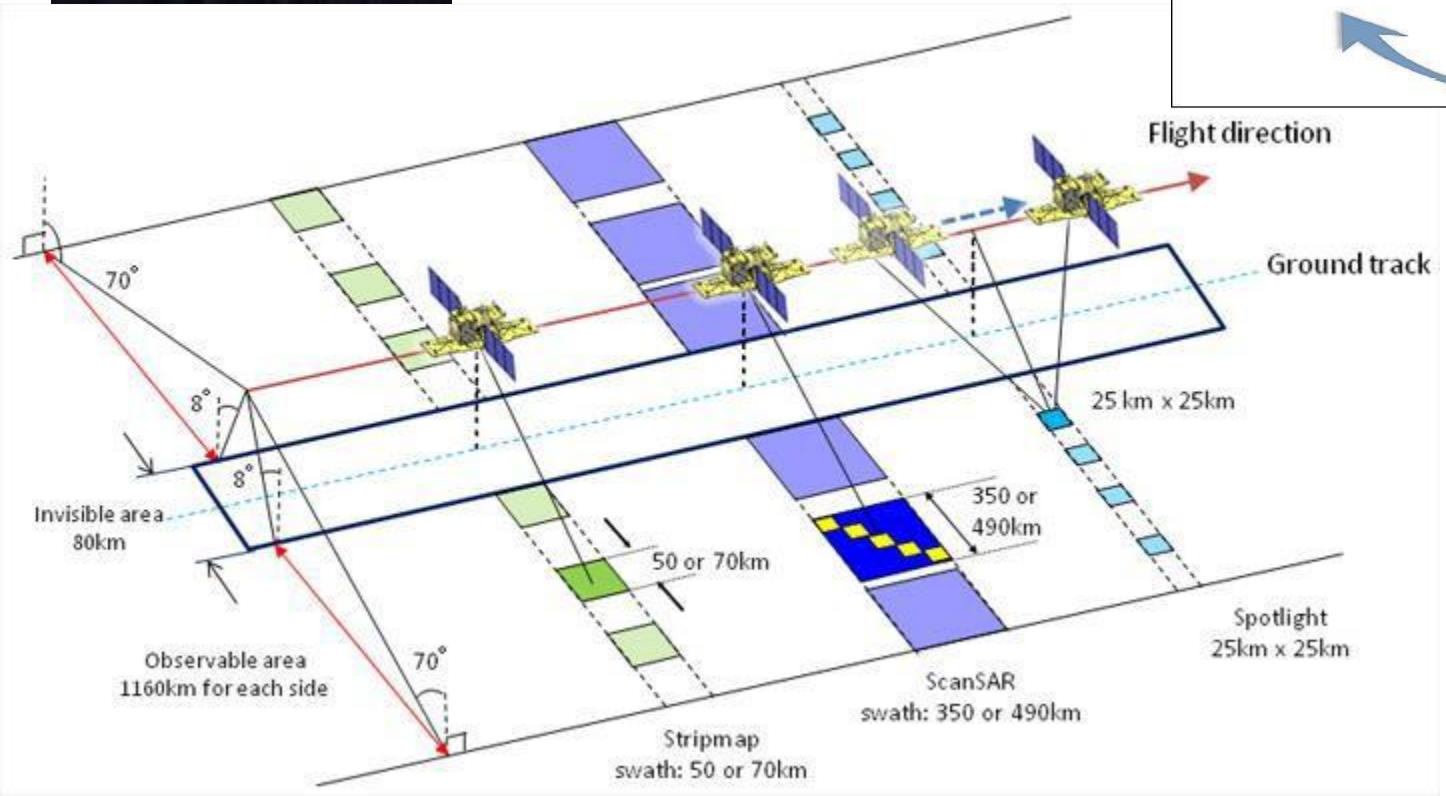
Advanced Land Observing Satellite (ALOS II) PALSAR

- 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



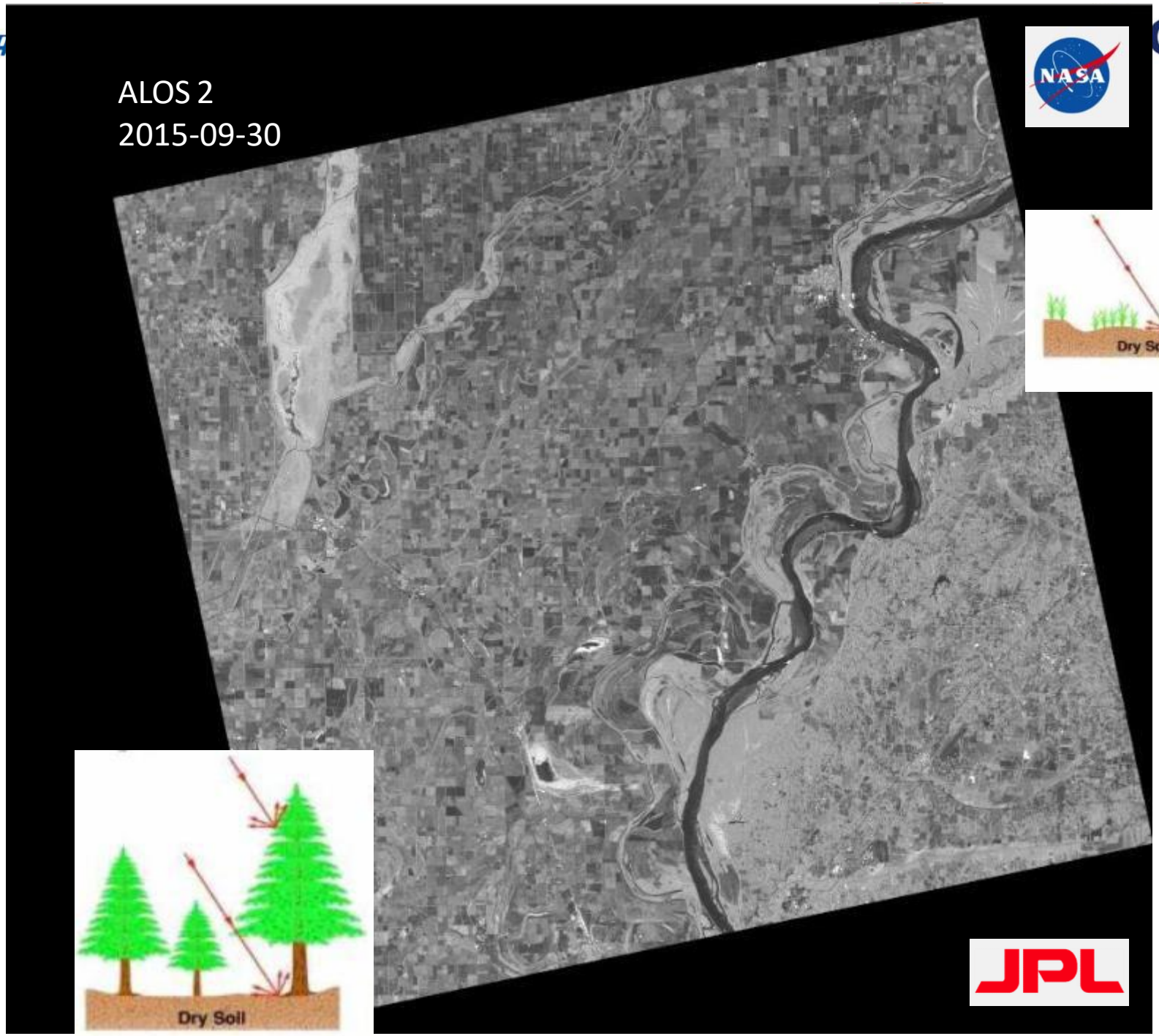


Advanced Land Observing Satellite (ALOS II) PALSAR

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	
	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

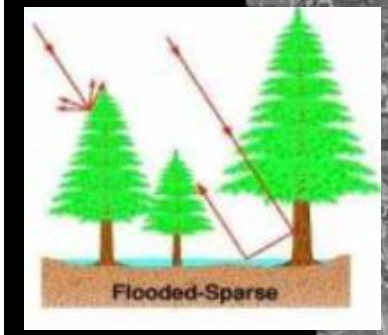


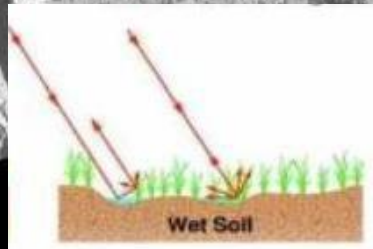
ALOS 2
2016-01-06

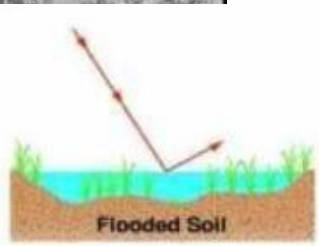
Flooded area under or with tall vegetation

Potentially flooded area

Potentially flooded area





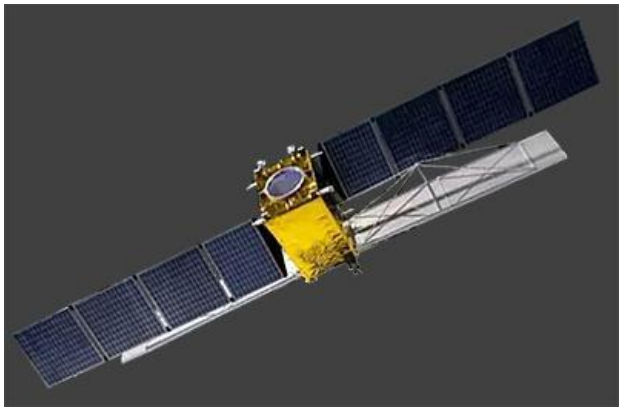


GAOFENG 3

- C band
- Full Pol SAR

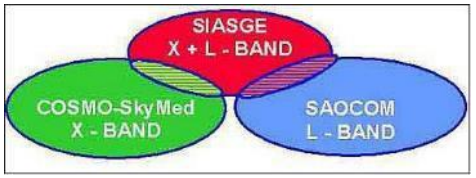
- 12 imaging modes WS to ultra fine mode with corresponding swath ranging from 650 km to 10 km

- 09 August 2016



Coming SAR missions

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



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

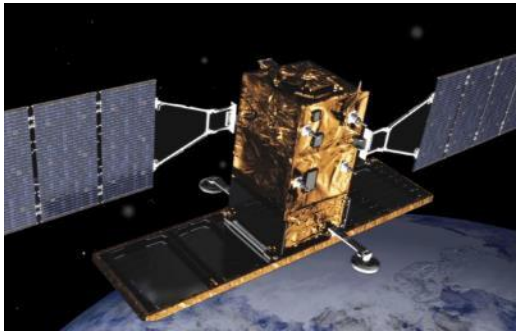
- **2021** : BIOMASS P band, not suitable for flood/lake mapping too coarse resolution (interest for DEM under forest)
- **2021** : NISAR , indo american mission, bande L et S

COSMO SKYMED SECOND GENRATION

Fleet of 3 satellites (small plateform)

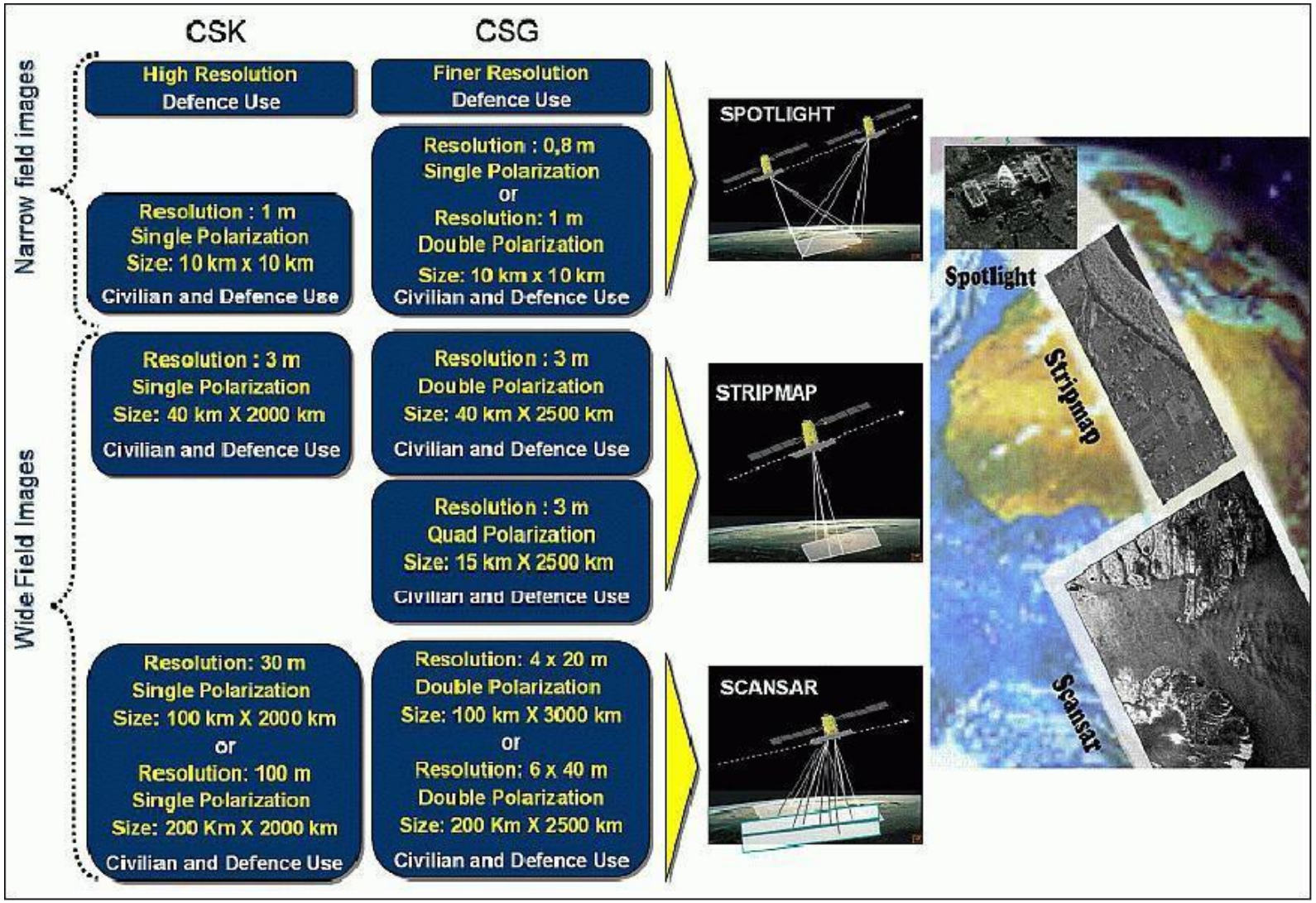
Gradual implementation with two launches separated by 16 months

First launch expected Q3 2018



4-day Coherent Change Detection using SAR interferometry

COSMO SKYMED SECOND GENERATION



COSMO SKYMED SECOND GENRATION

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	

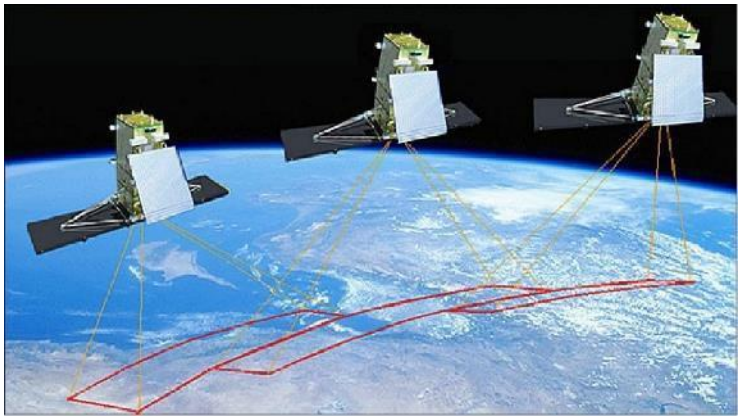
Radarsat Mission Constellation, RMC

Fleet of 3 satellites (small plateform)

Gradual implementation with two launches separated by 16 months

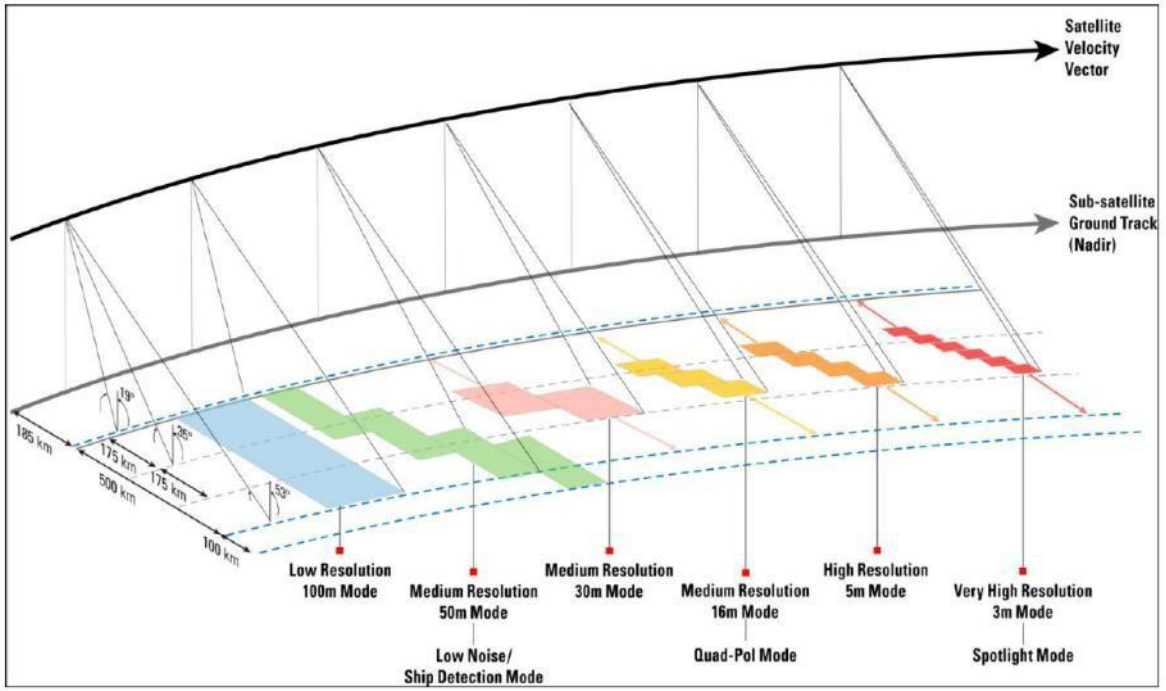
First launch expected Q3 2018

4-day Coherent Change Detection using SAR interferometry

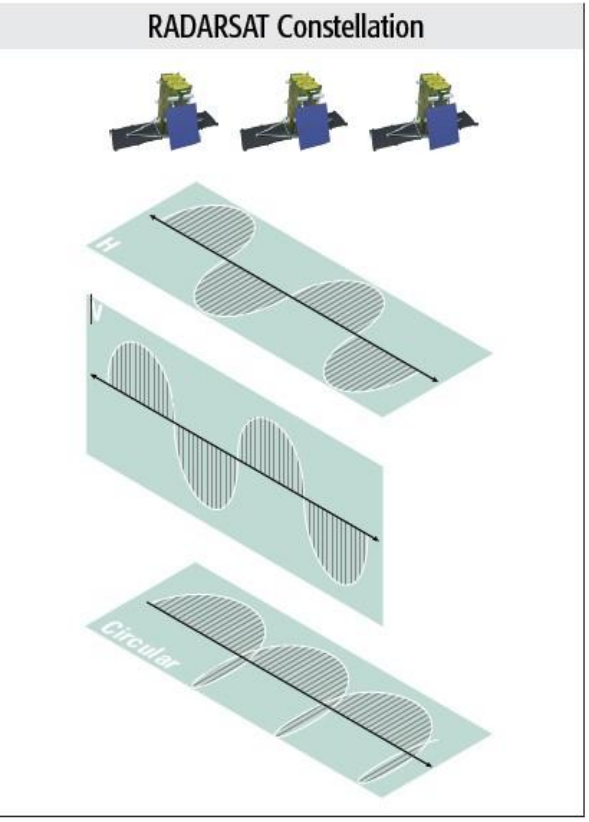


Radarsat Mission Constellation, RMC

Multi mode



Full Pol



Radarsat Mission Constellation, RMC

Multi mode

Mode	Nom. Res. m	Num Looks rng x az	Nominal Swath Width (accessible) km	Min Along Track Length km	Nom-inal NESZ dB	Polarization Options								
						Single Pol				Dual Pol				Quad Pol
						HH	VV	HV	VH	HH+HV	VV+VH	HH+VV	Compact	HH+VV+ HV+VH
Low Resolution 100m	100	8x1	500 (500)	10	-22	✓	✓	✓	✓	✓	✓	✓	✓	
Medium Resolution 50m	50	4x1	350 (500)	10	-22	✓	✓	✓	✓	✓	✓	✓	✓	
Medium Resolution 16m	16	1x4	30 (350)	10	-25	✓	✓	✓	✓	✓	✓	✓	✓	
Medium Resolution 30m	30	2x2	125 (350)	10	-24	✓	✓	✓	✓	✓	✓	✓	✓	
High Resolution 5m	5	1	30 (500)	10	-19	✓	✓	✓	✓	✓	✓	✓	✓	
Very High Resolution 3m	3 @35°	1	20 (500)	10	-17	✓	✓	✓	✓	✓	✓	✓	✓	
Low Noise	100	4x2	350 (500)	10	-25	✓	✓	✓	✓	✓	✓		✓	
Ship Detection	var.	var.	350 (600)	10	var.	✓	✓	✓	✓	✓	✓		✓	
Quad-Polarization	NR[1]	NR[1]	> 20 (NR[1])	10	NR[1]									✓
Spotlight	1 (az) x 3 (grd) @35°	1	20 (350)	5	-17	✓	✓	✓	✓	✓	✓		✓	

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

long term monitoring of flood prone/lakes

Multisensors approach

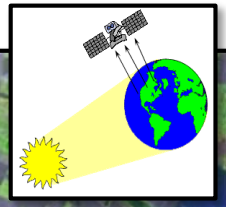
Synergy optical - SAR ie MERIS/ASAR
or CSK/HJ1 or Deimos

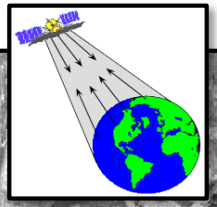
Great expect into the sentinel 1 and 2

Worldwide applicable for large systems but also smallest areas:
Asia : China, Mekong system (Tonle sap lake and Delta),
Africa: Niger iner delta, Okavango, etc
Australia: Eyre Lake and Diamanta River
South America: Argentina, Rio del Plata

Complementarity/synergy Optical / Radar

High Resolution Optical Image



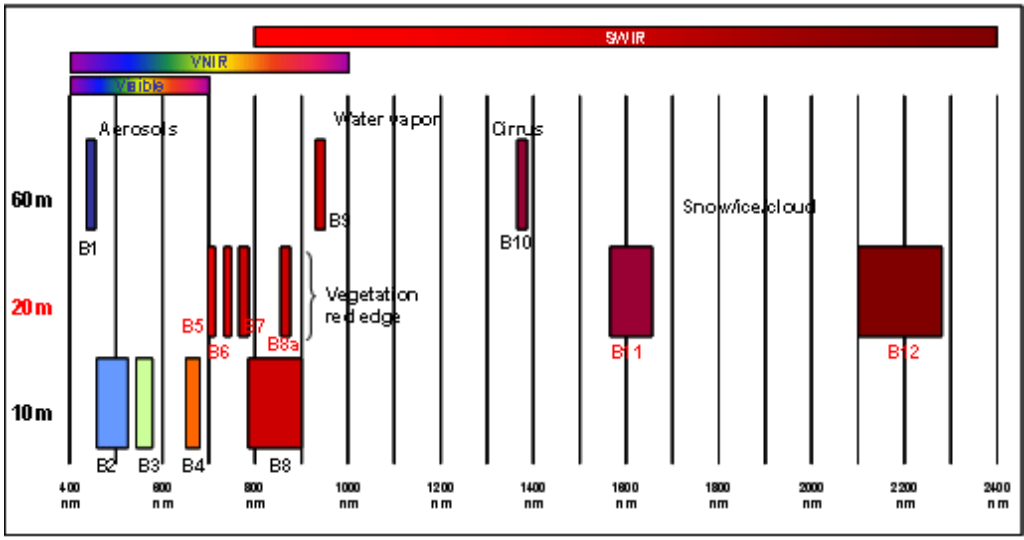


High Resolution Radar Image

Very High Resolution
Optical Image

Very High Resolution
Radar Image and polarimetry

Sentinel2



Sentinel 2

- Highest Resolution same as SPOT5 (10m)
- Presence of two SWIR bands (heritahe of landsat)
- Large swath (MERIS heritage)
- Revisiting time 10 – 5 days

Sentinel 2

- **Resolution depending of the spectral coverage**

Sentinel-2A : on 23 June 2015
Sentinel-2B : on 7 march 2017

10 metre spatial resolution:

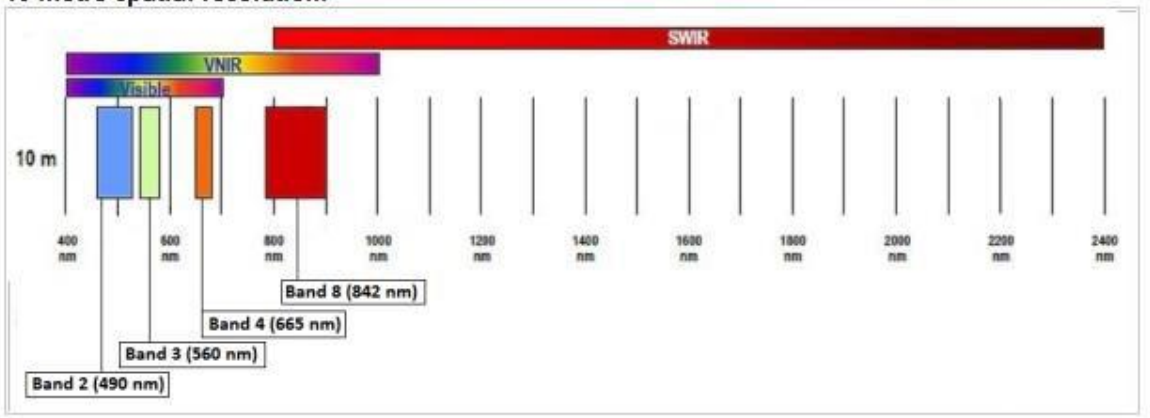


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

20 metre spatial resolution:

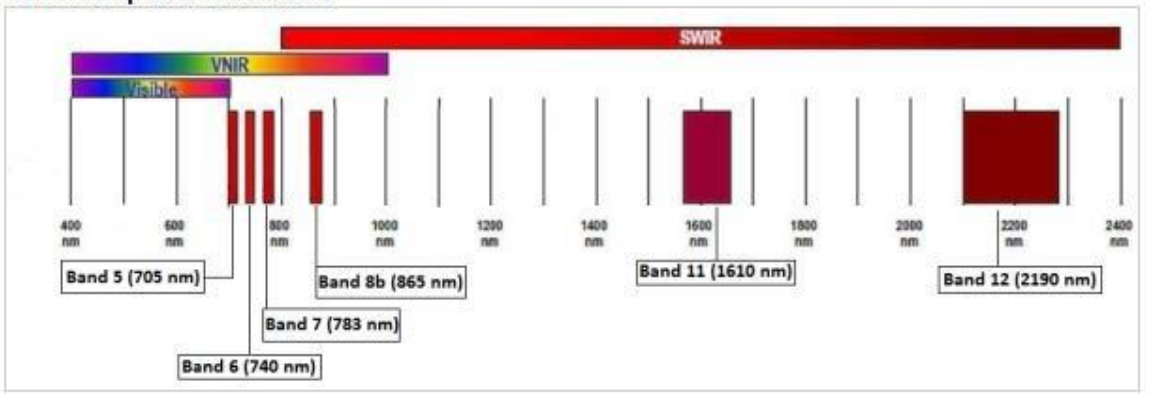


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8b (865 nm), B11 (1610 nm) and B12 (2190 nm)

60 metre spatial resolution:

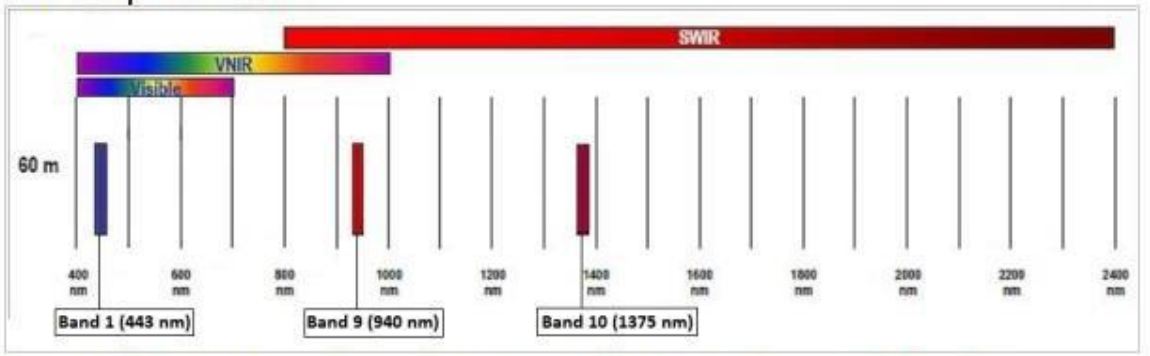
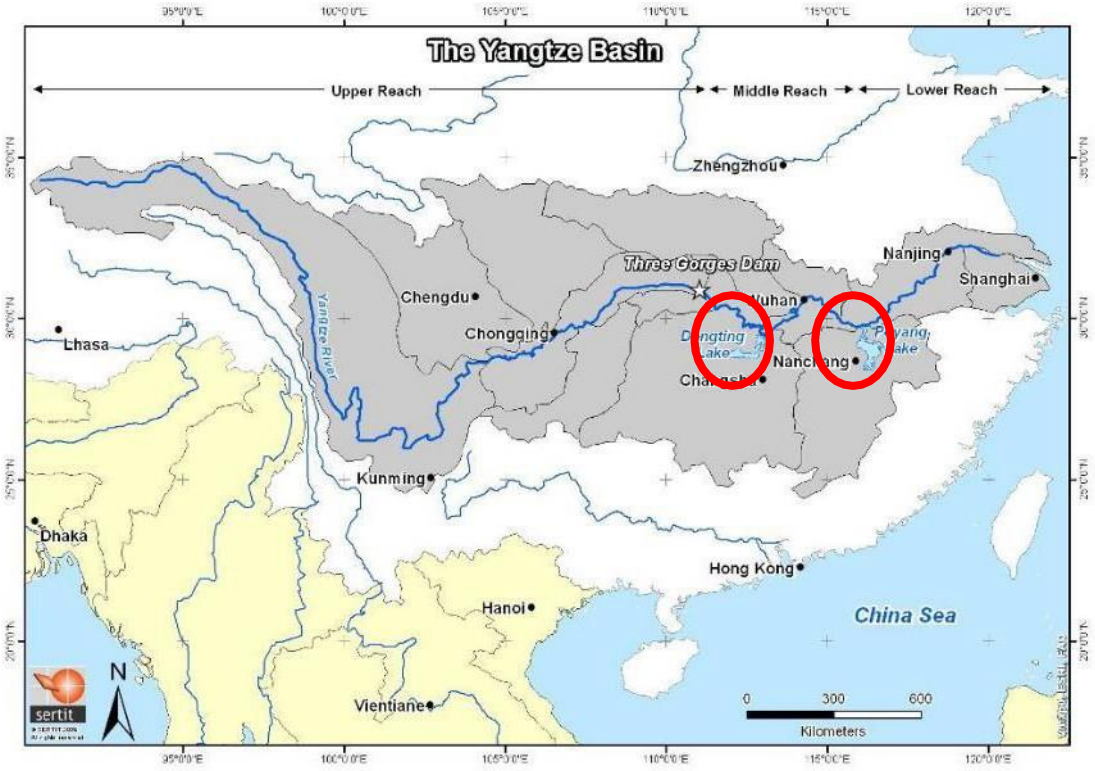


Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

Yangtze river's monsoons lakes monitoring



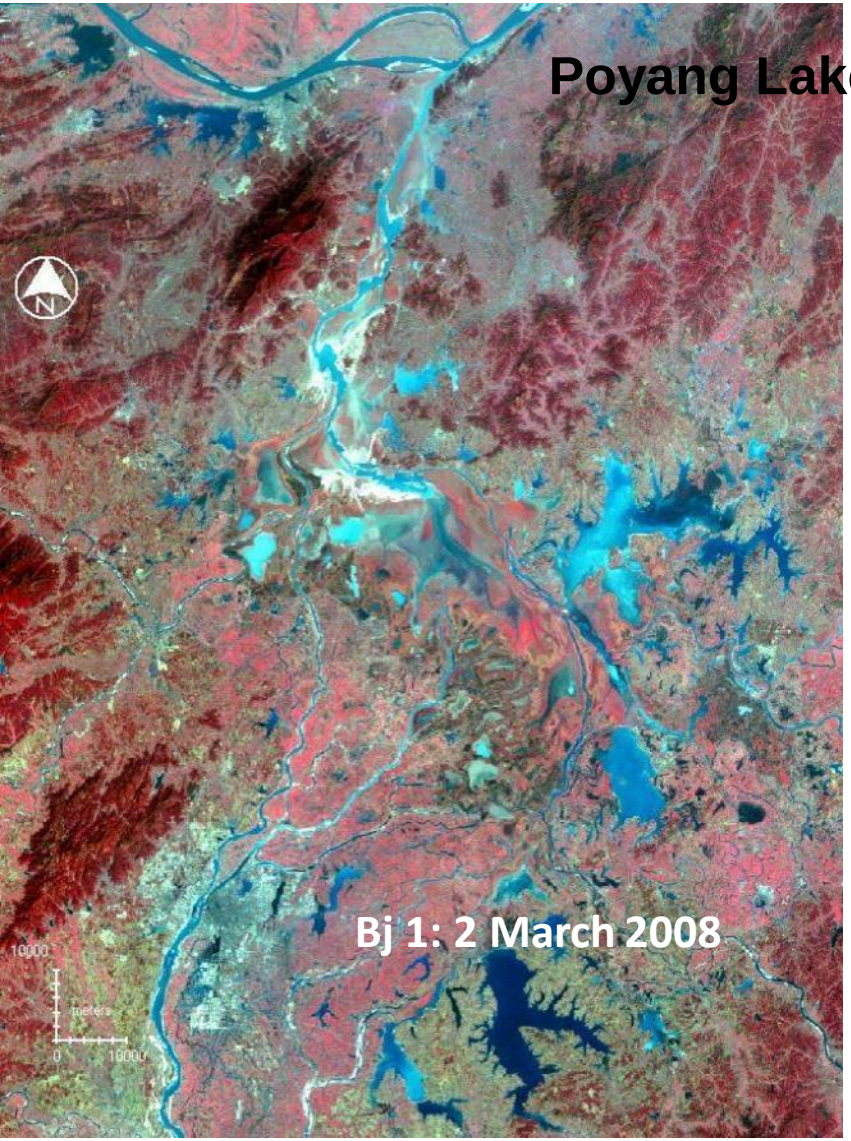
Health of Yangtze is a major concern for 400 000 000 of inhabitants as a fresh wa resource.

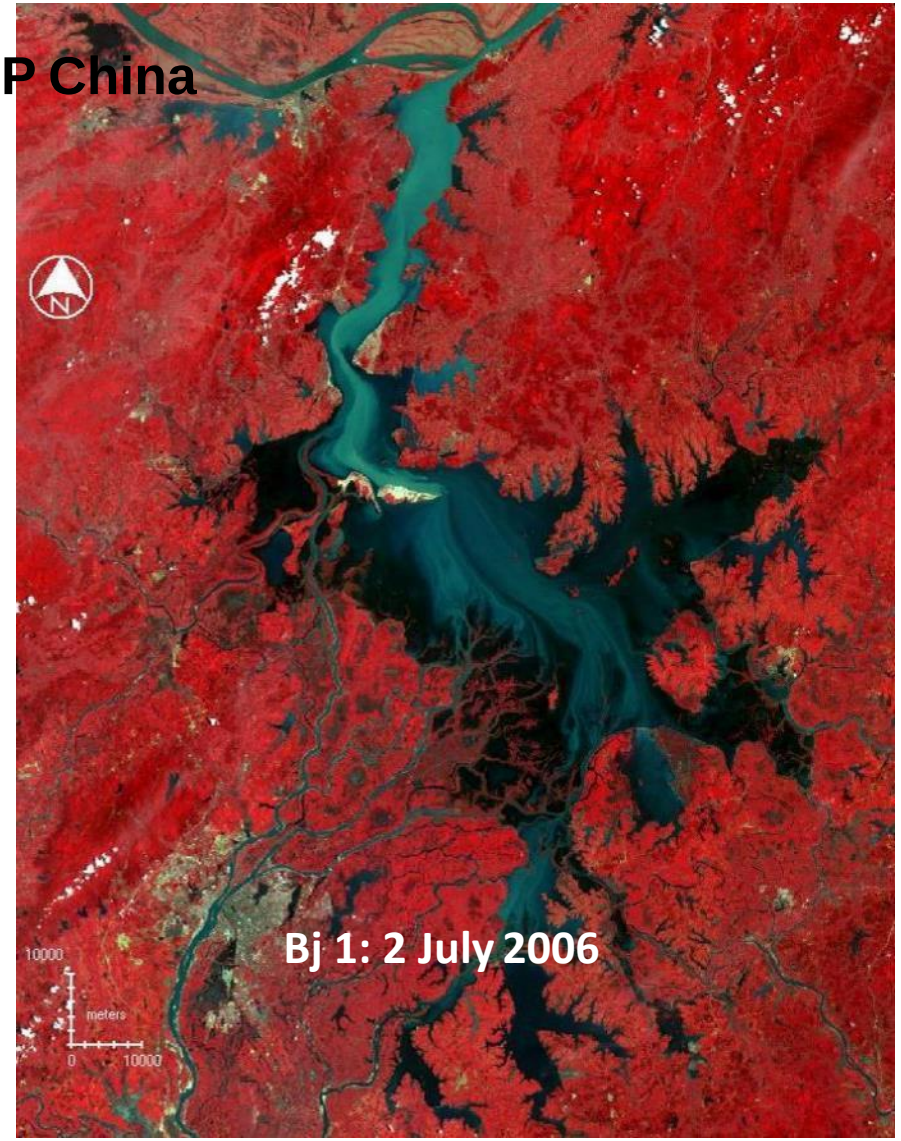
The river basin gives
- **70% rice production**
- **40% cereal production**
- **40% industry**

- **Biodiversity stakes**

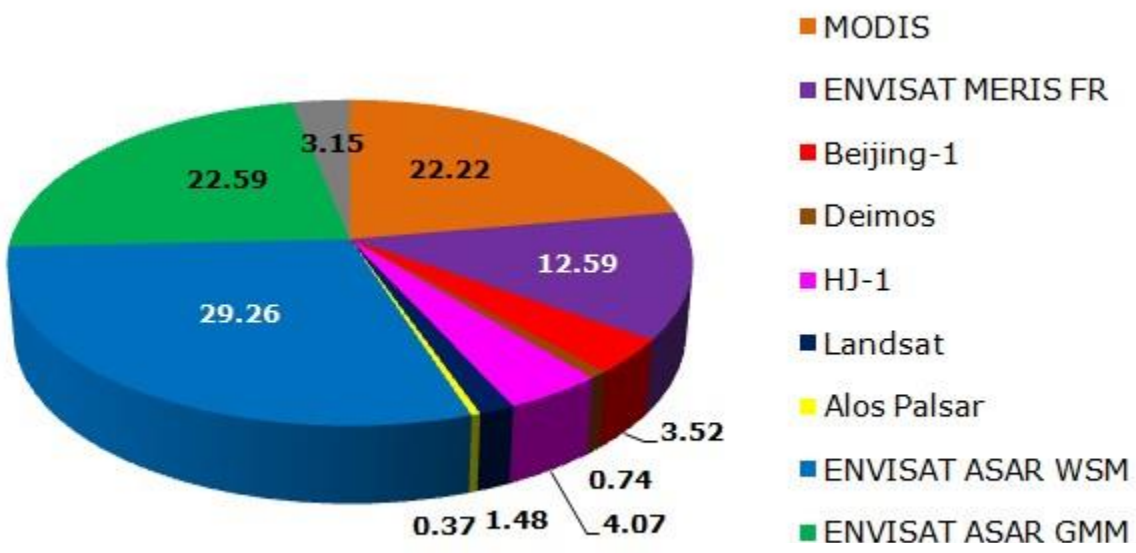
Climate fluctuation and man activities (ie Three Gorges dam) could have significant impact.

Monsoon lake: important annual variations of water surface





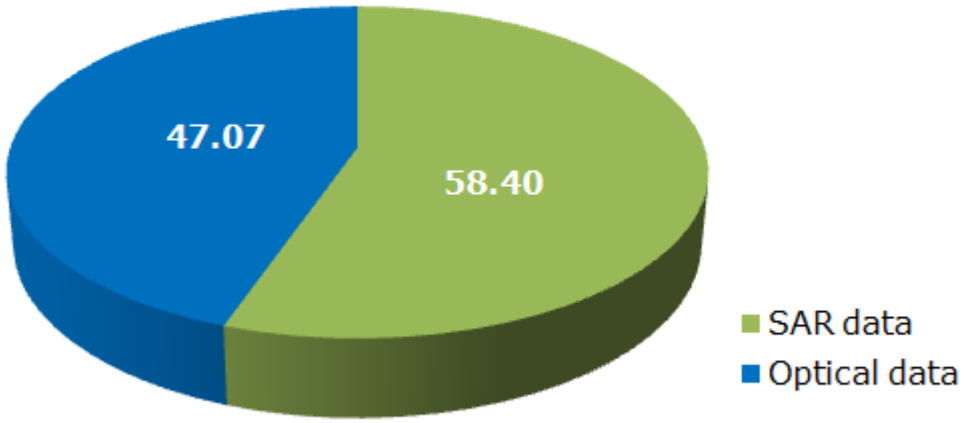
Example of water body monitoring: Poyang



A mixed resource

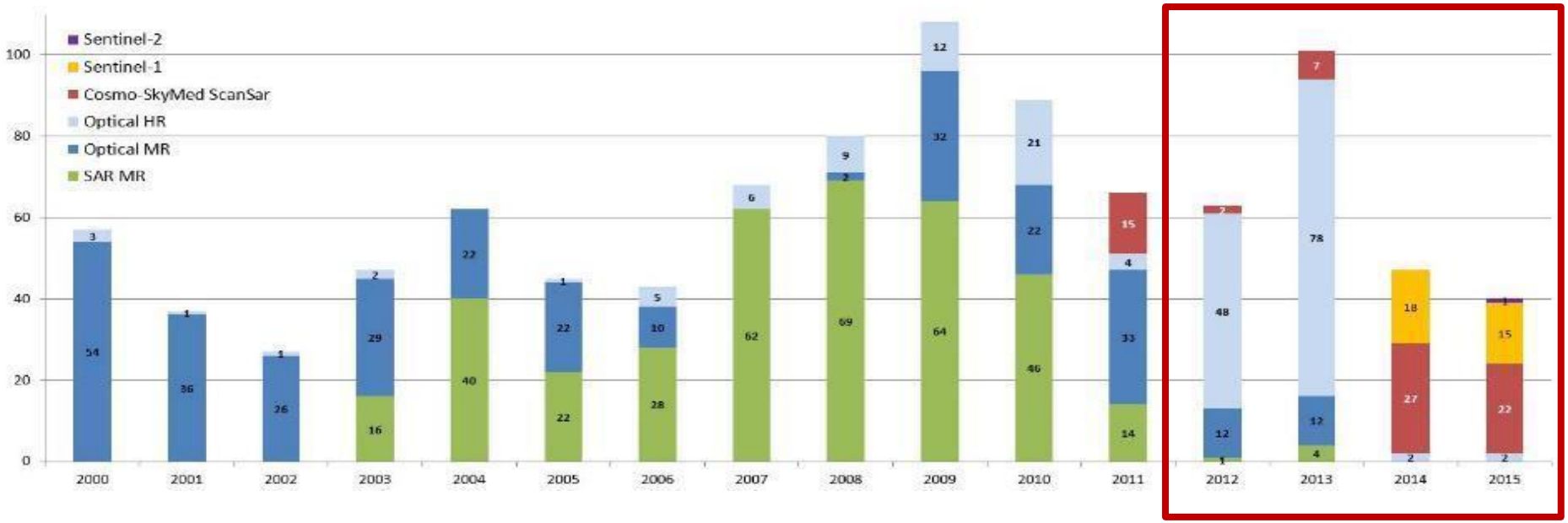
In the future two major resource Sentinel 1 et 2

+550 images



Request to a secured resource allowing to monitoring large areas with a reduced revisiting time (10 – 15 days)

Dragon 3



Moving from MR to HR

⇒ **SPOT 4&5 TakeFive, HJ1A, preparing Sentinel 2 venue**

⇒ **Archive TerraSAR, New modes TerraSAR TandemX**

⇒ **Cosmo Skymed from ASI (supporting Envisat Gap)**

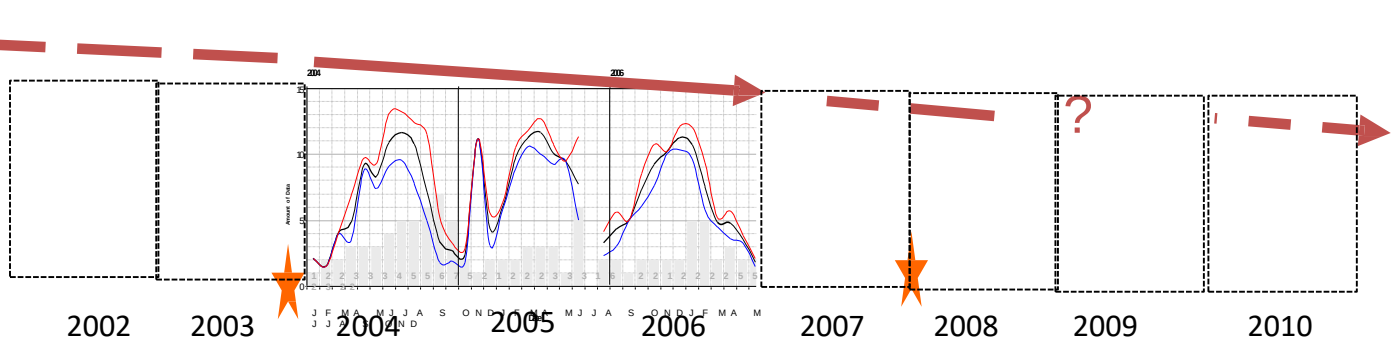
⇒ **Sentinel 1A**

⇒ **First Sentinel2**

⇒ **First Sentinel1B**

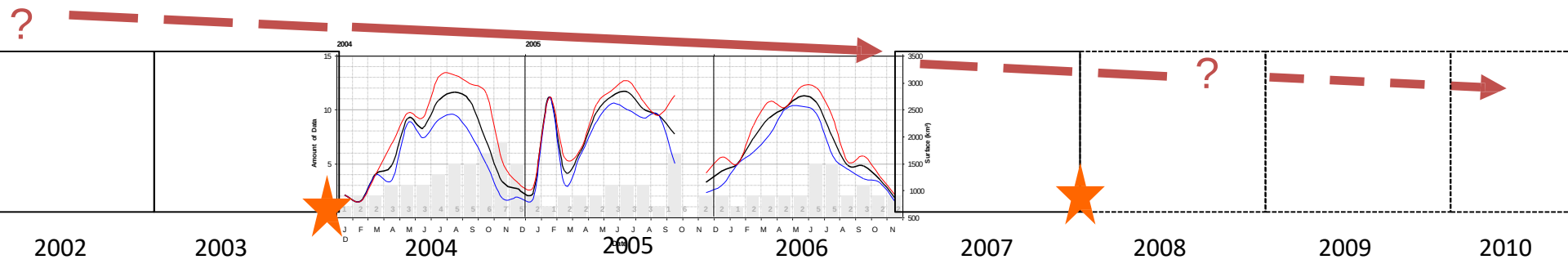
Water extent monitoring: Poyang

3GD event

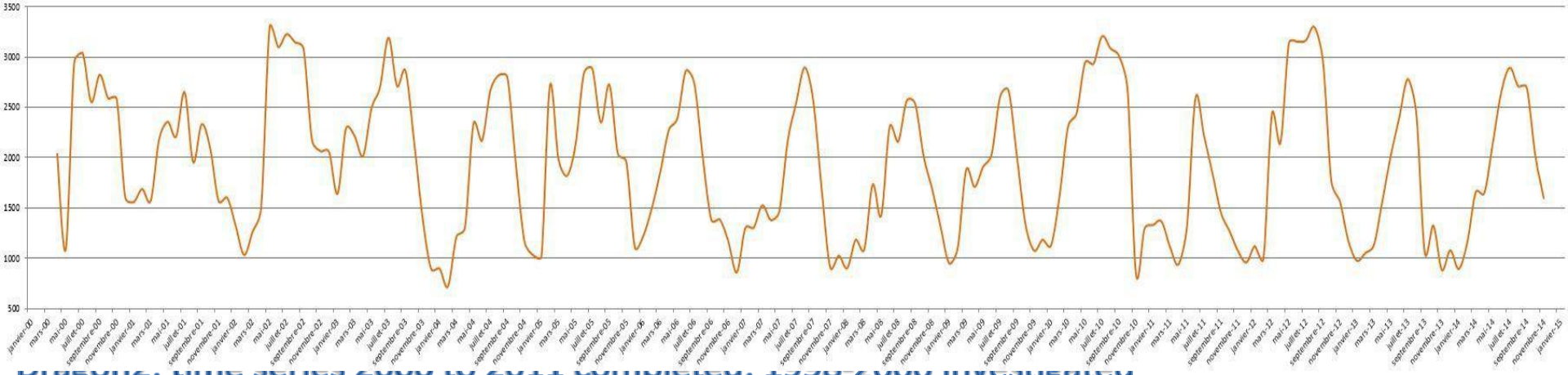


Dragon 2 objectives: Continue and complete water surfaces' monitoring

Water extent monitoring: Poyang



Dragon3objectives: Continue and complet water surface monitoring

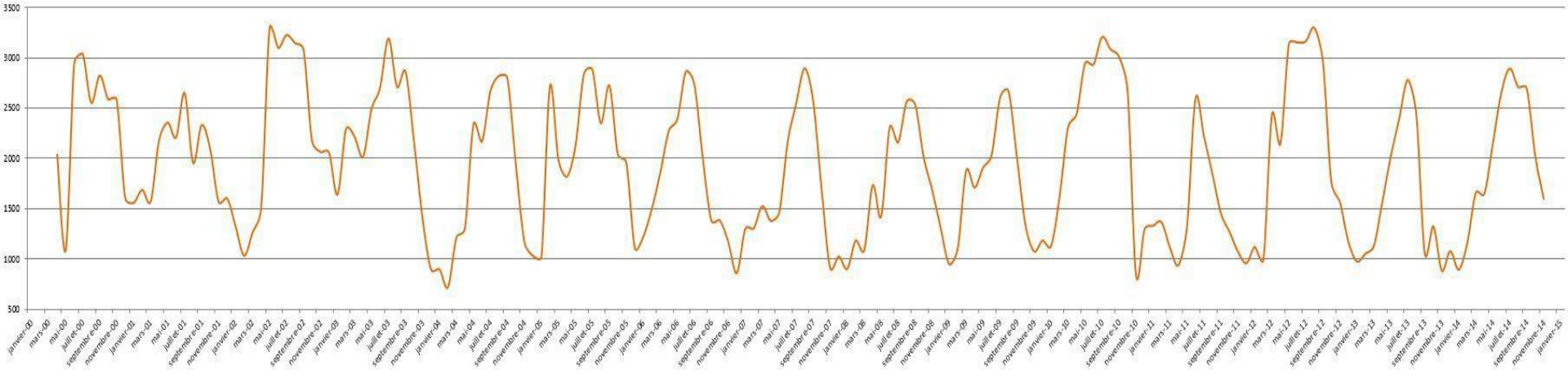


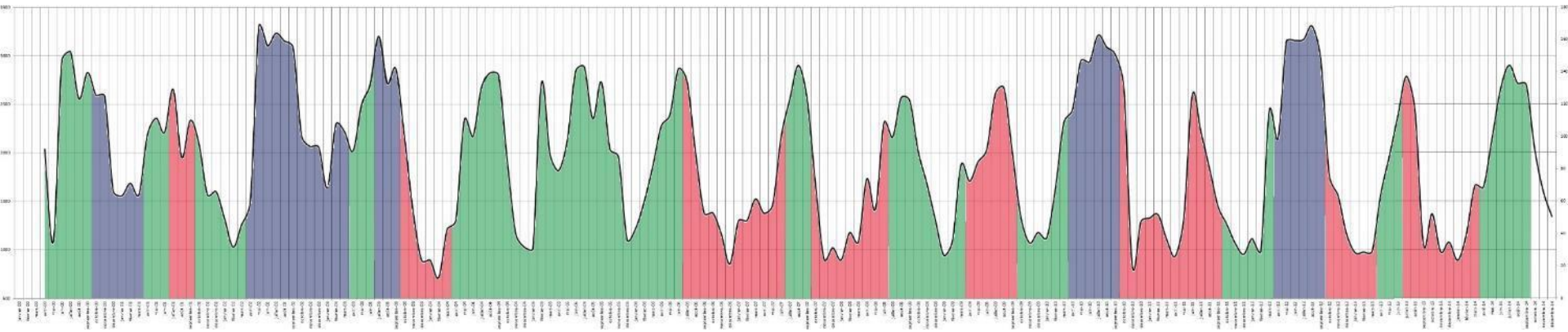
Dragon2: time series 2000 to 2011 completed, 1998-2000 investigated

Dragon 3: 2014 fully integrated

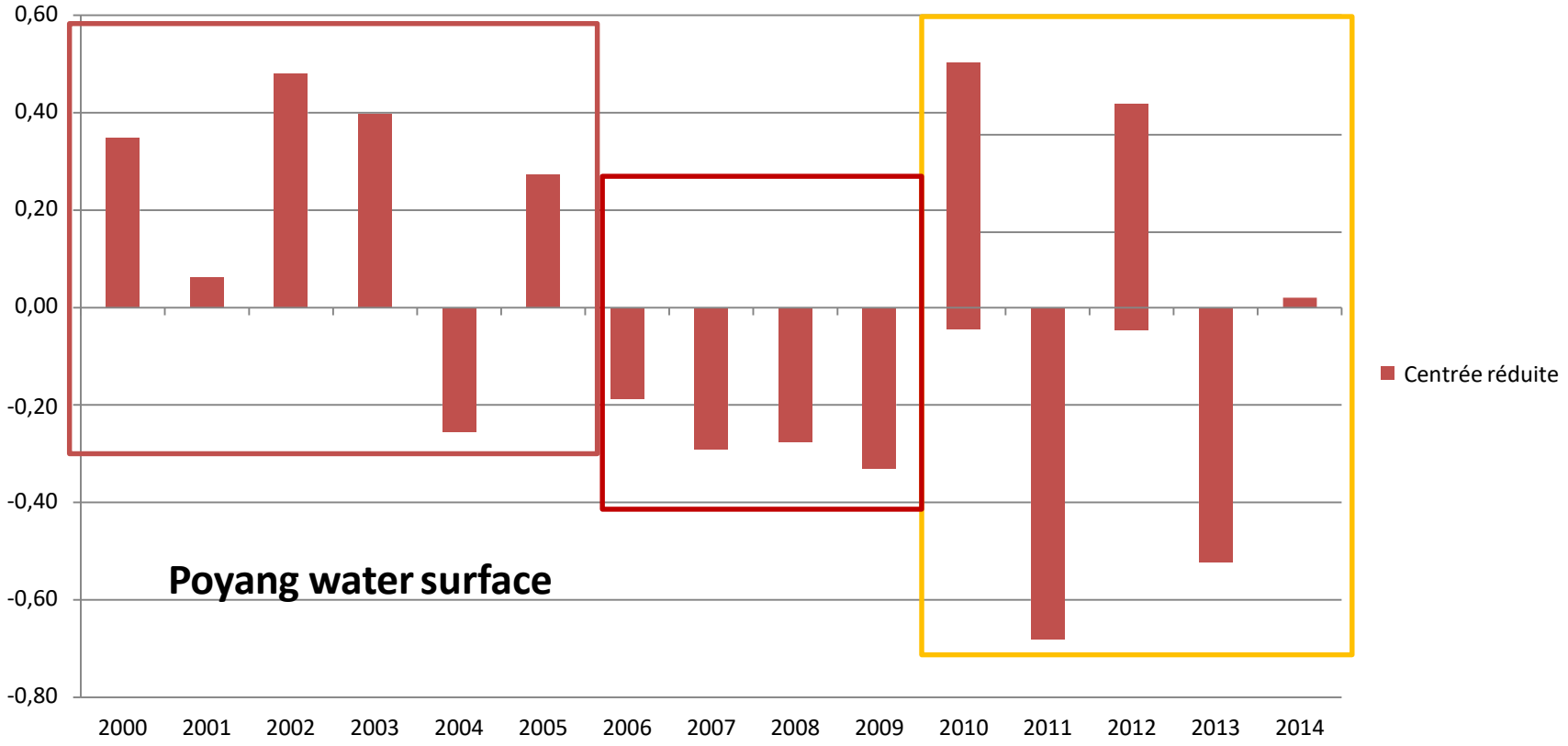
Poyang lake water surface monitoring:

Regional analysis and global interactions





WP7 : Regional and global interactions

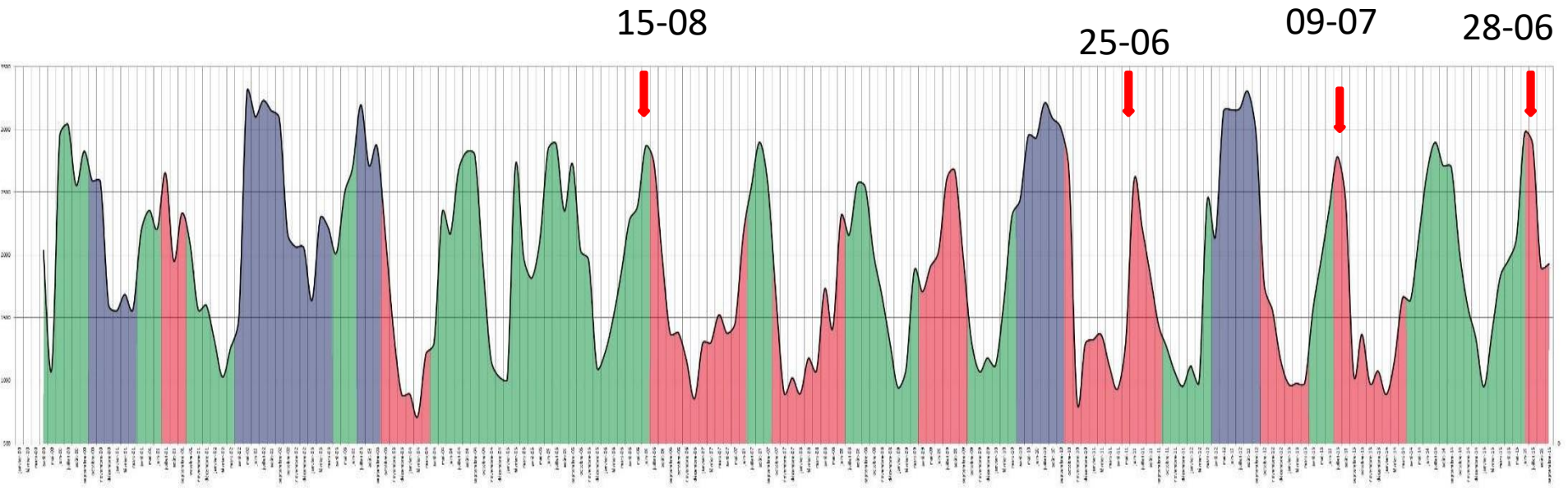


Water surface Statistical analysis

Centred reduced

2000-2005 : positive
2006-2009 : negative
2010_2015 : variations from one extreme to another

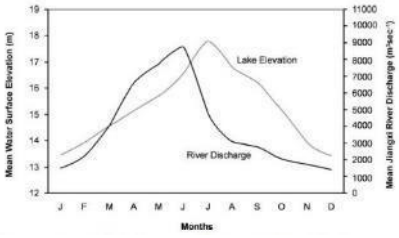
WP7 : Regional and global interactions



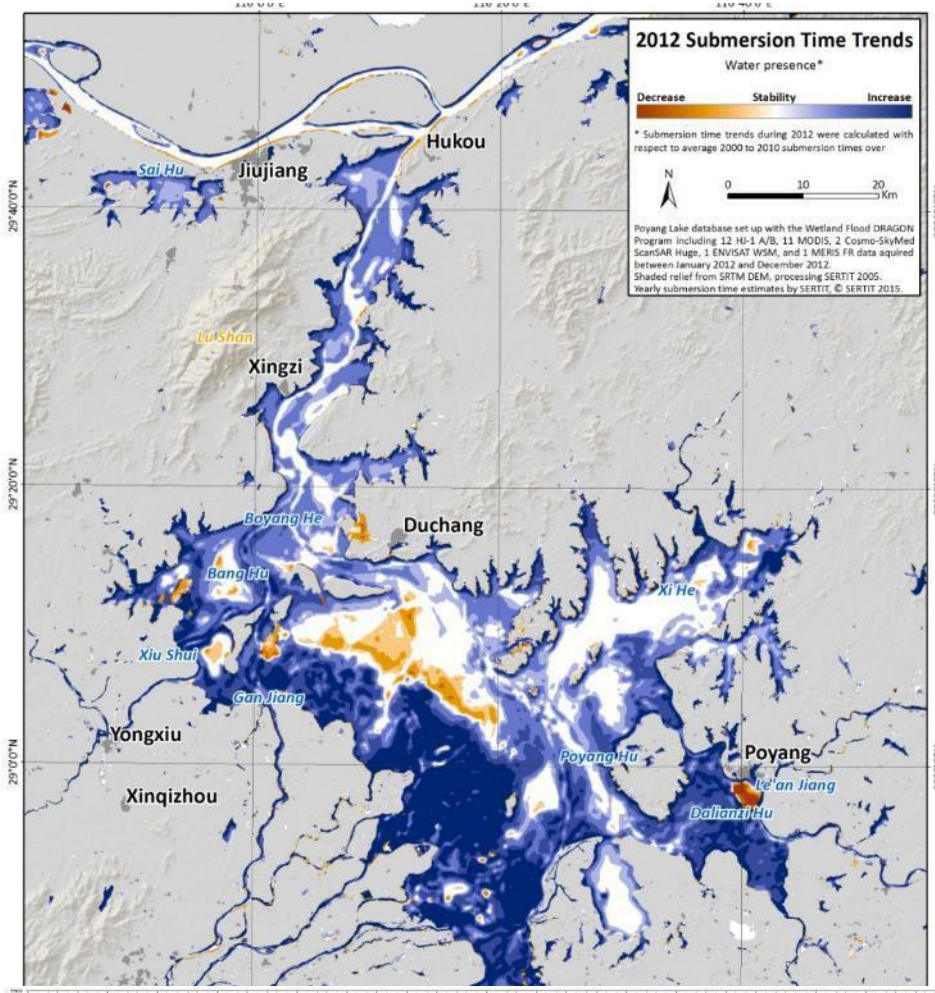
⇒ In literature draw off; Mid September, mid October

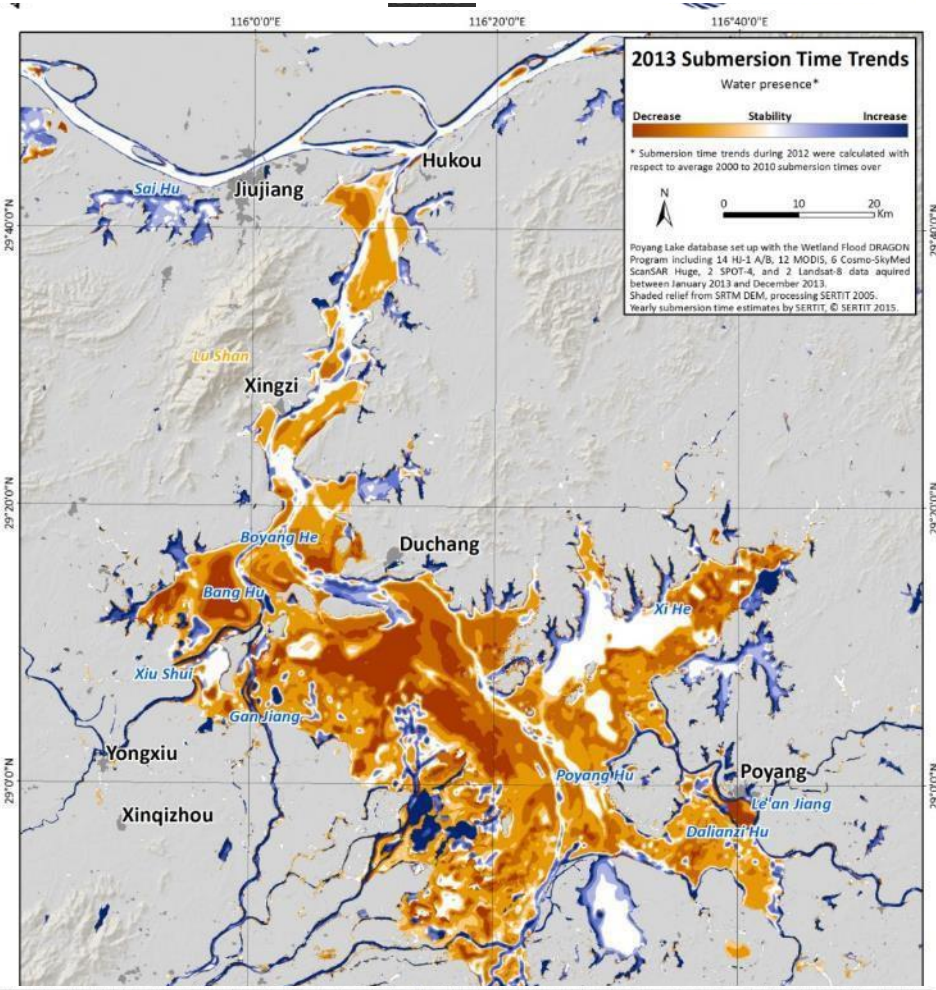
⇒ Draw off becomes very early over the years with a shortness of the inundation period

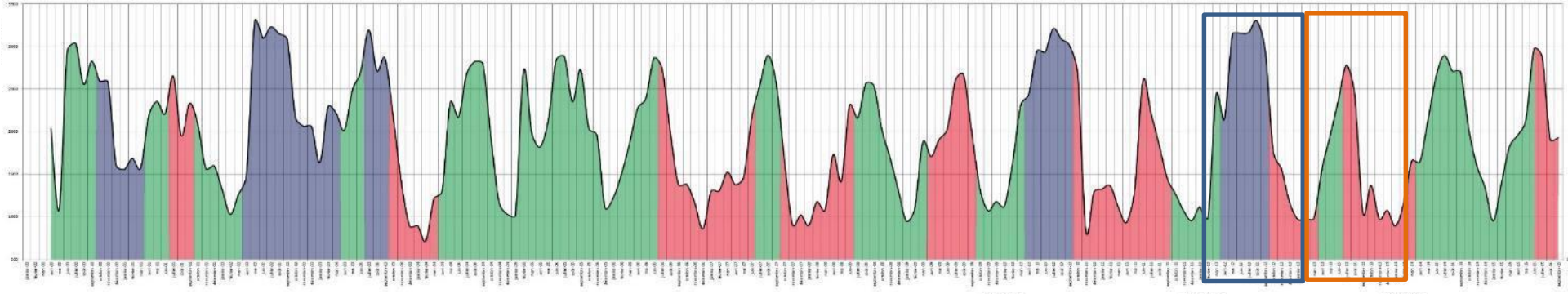
- ⇒ First time observed in mid August 2016
- ⇒ In 2011 very short flooding period, max in 25-06
- ⇒ In 2013, redraw in mid-July
- ⇒ In 2015 same behaviors, max flood extent in end of June



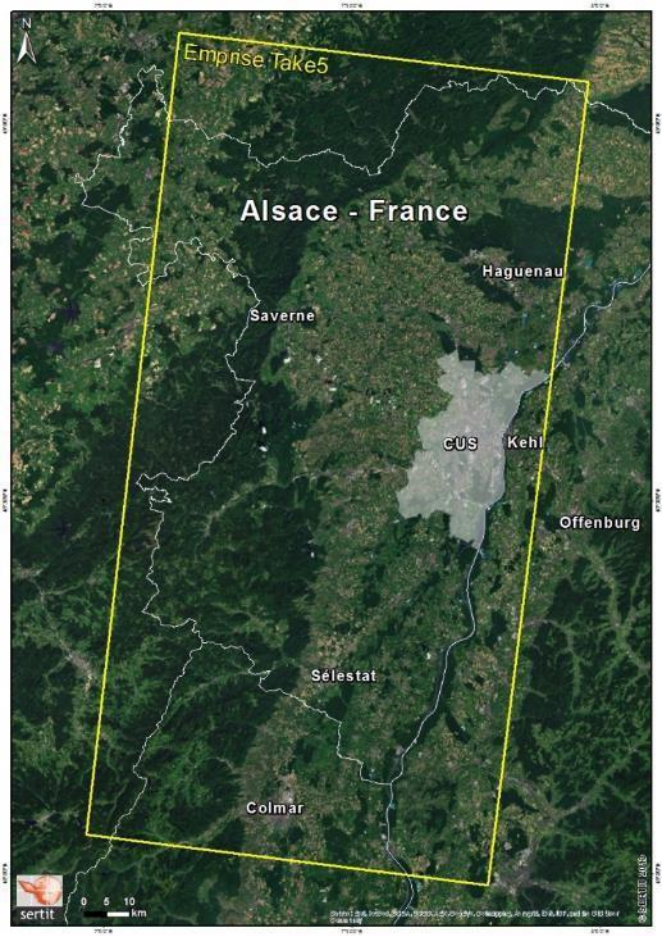
Water extent monitoring: Submersion time: residual analysis







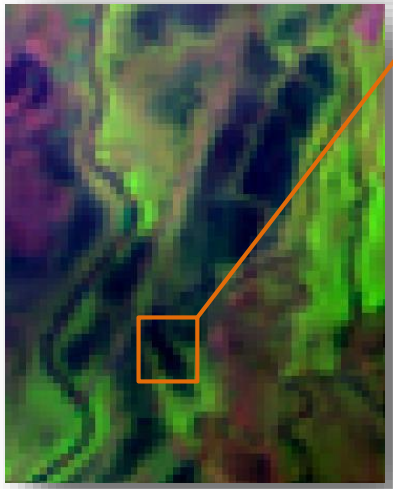
Monitoring sensitive areas based on EO SAR data: Alsatian Plain (France)



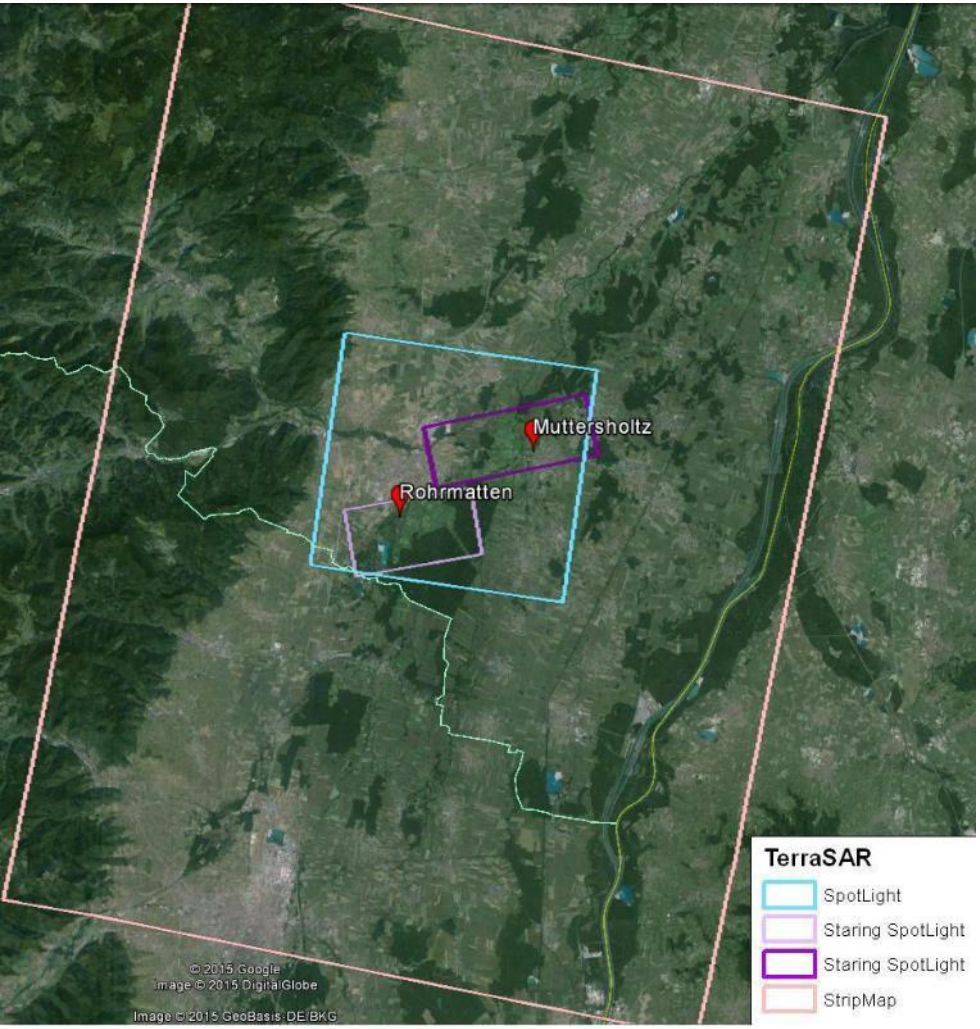
Plain flood monitoring

Biodiversity, sensitive agro natural systems

2 missions in field, synchronous with acquisition



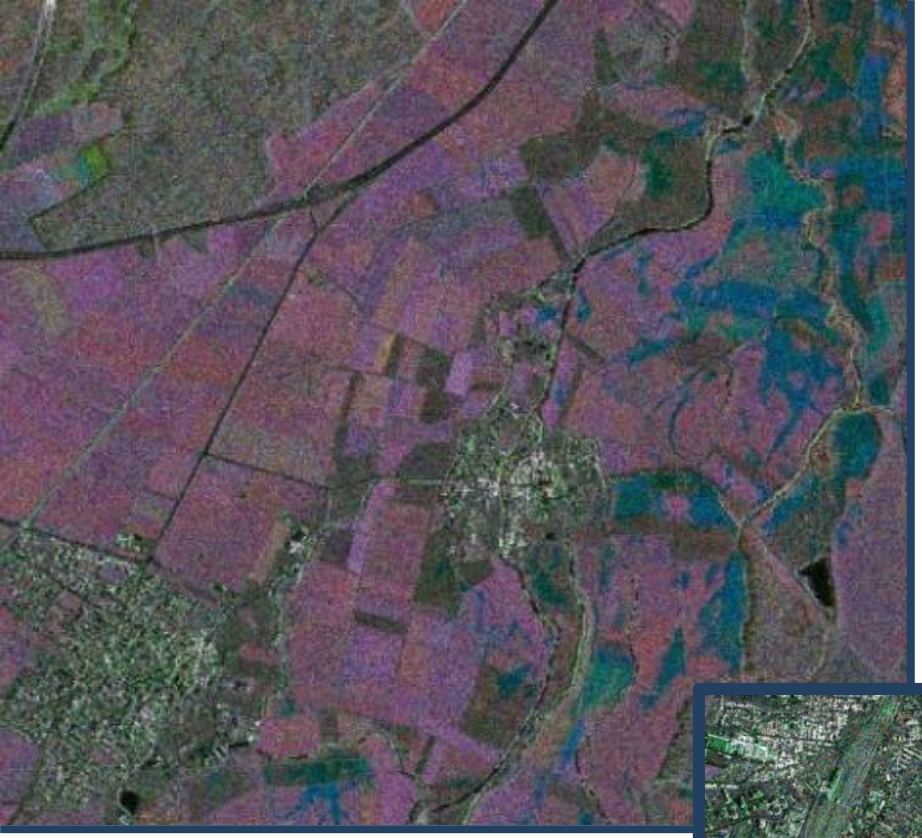
G PStrack



Monitoring sensitive areas based on EO data TerraSAR multimodes

Alsatian Plain (France)

Strip Map mode : 30*50 km², 3m
SpotLight mode : 5*10 km², 1m
Staring SpotLight : 3*4 km², 25 cm



Ebermunster

Muttersholtz

Rohrmatten

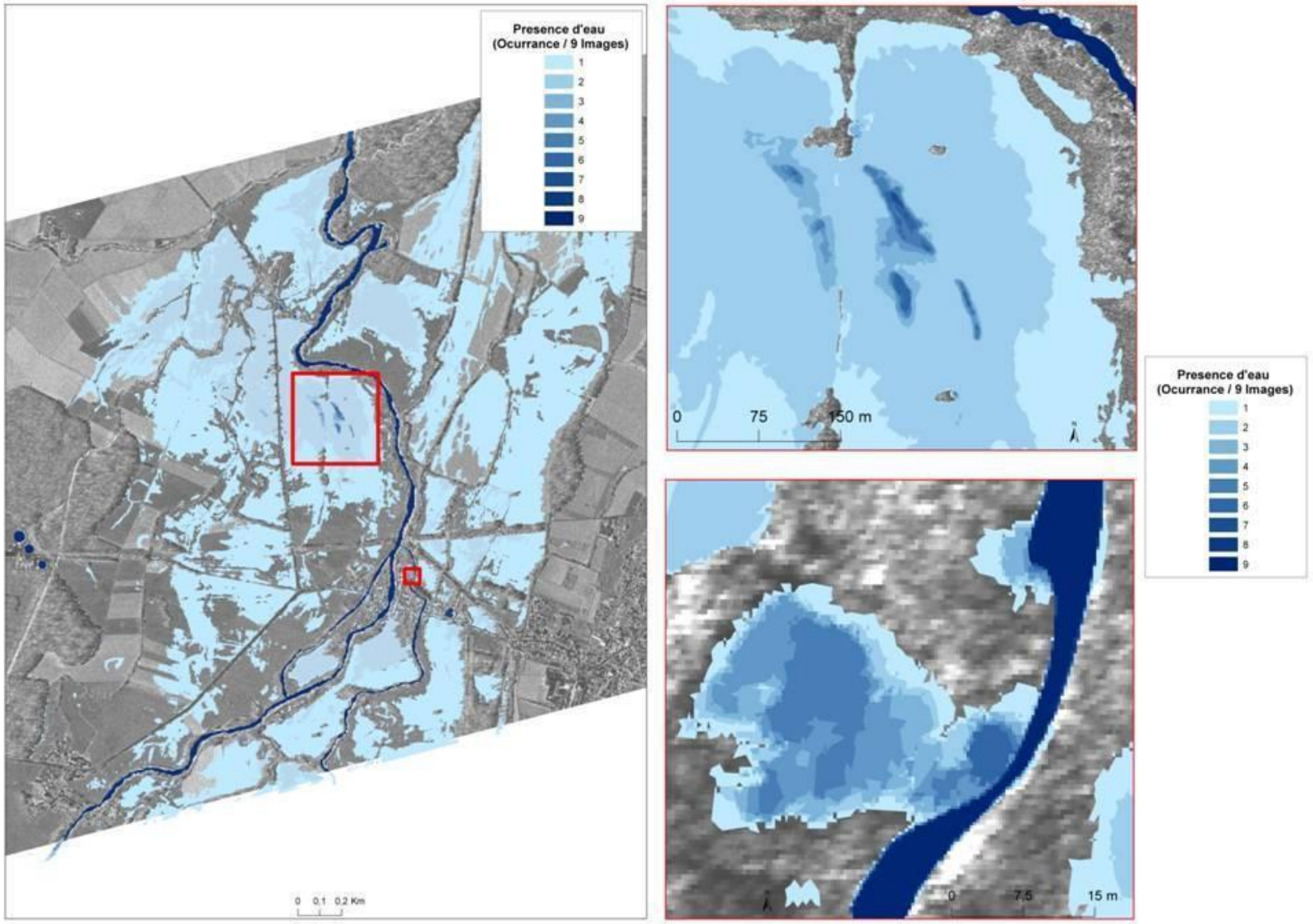
New TerraSAR X Staring Spot Light images

New TerraSAR X Staring Spot Light images

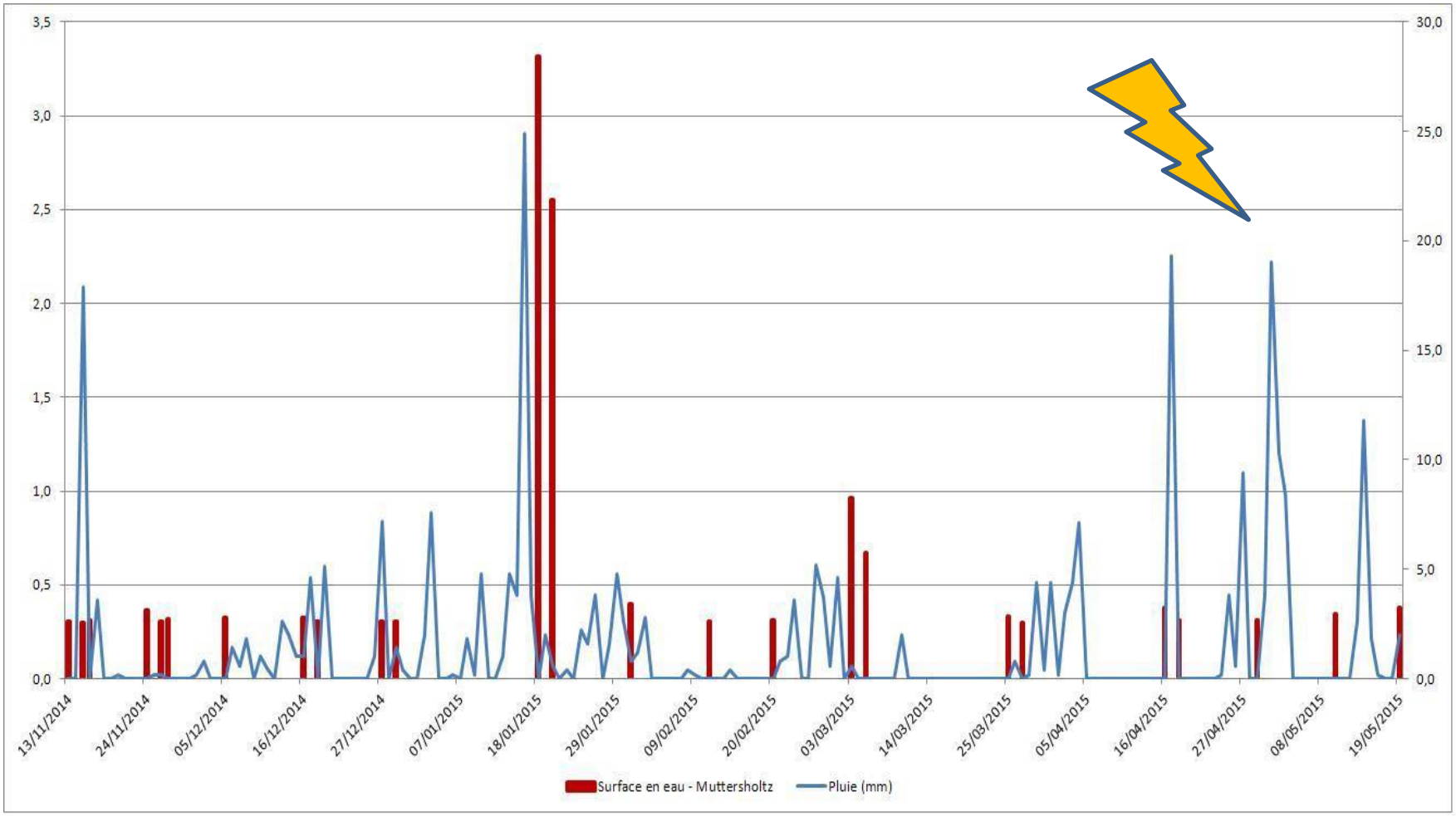
New TerraSAR X Staring Spot Light images


18-01-2015

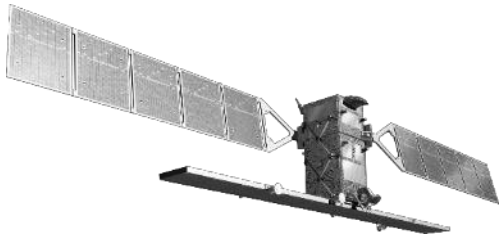
Flood occurrence map for very small wetland areas



Water surface monitoring exploiting TerraSAR multimodes data

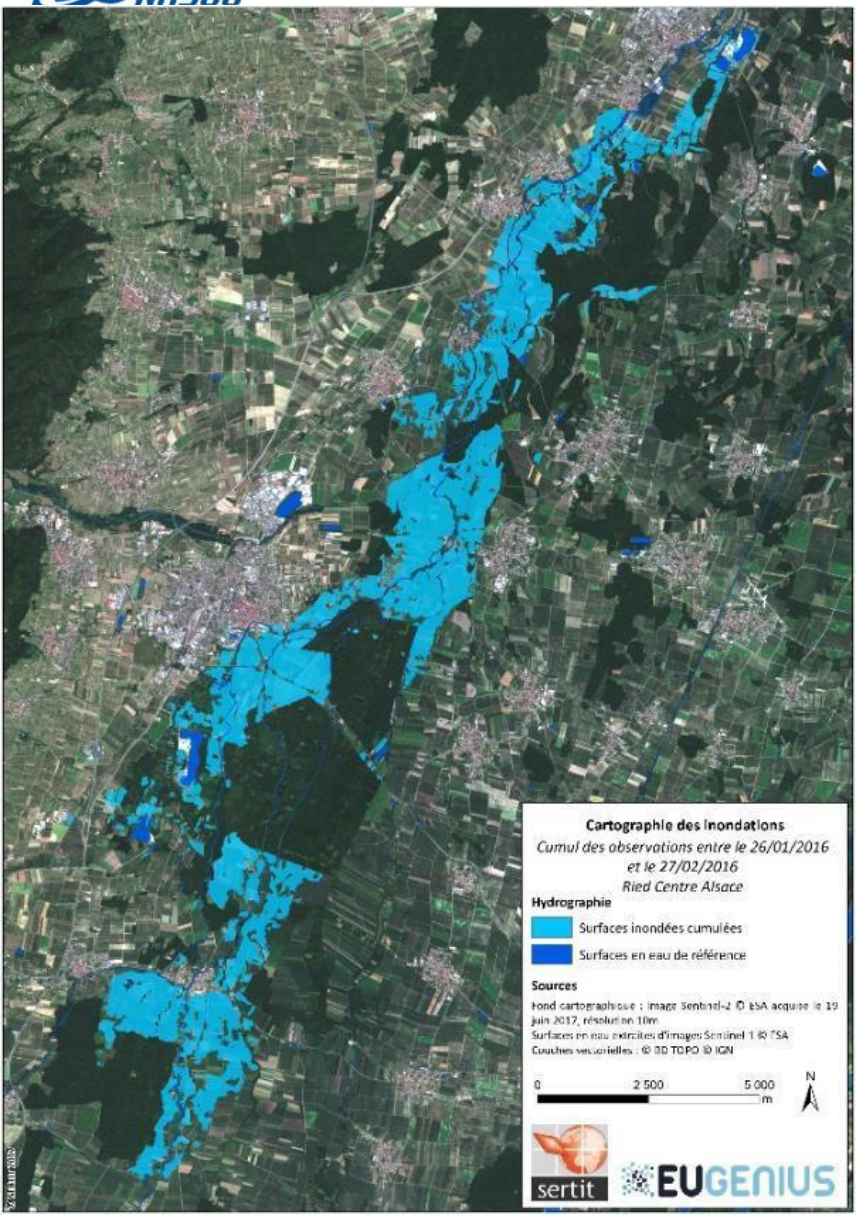


Exploiting Sentinel 1

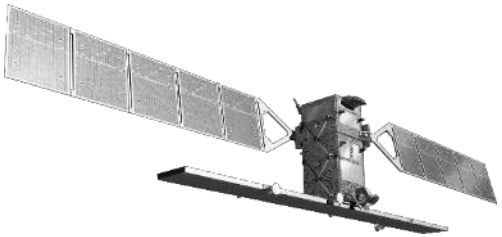


Flood maximal extent (over the period of observation, ie one month

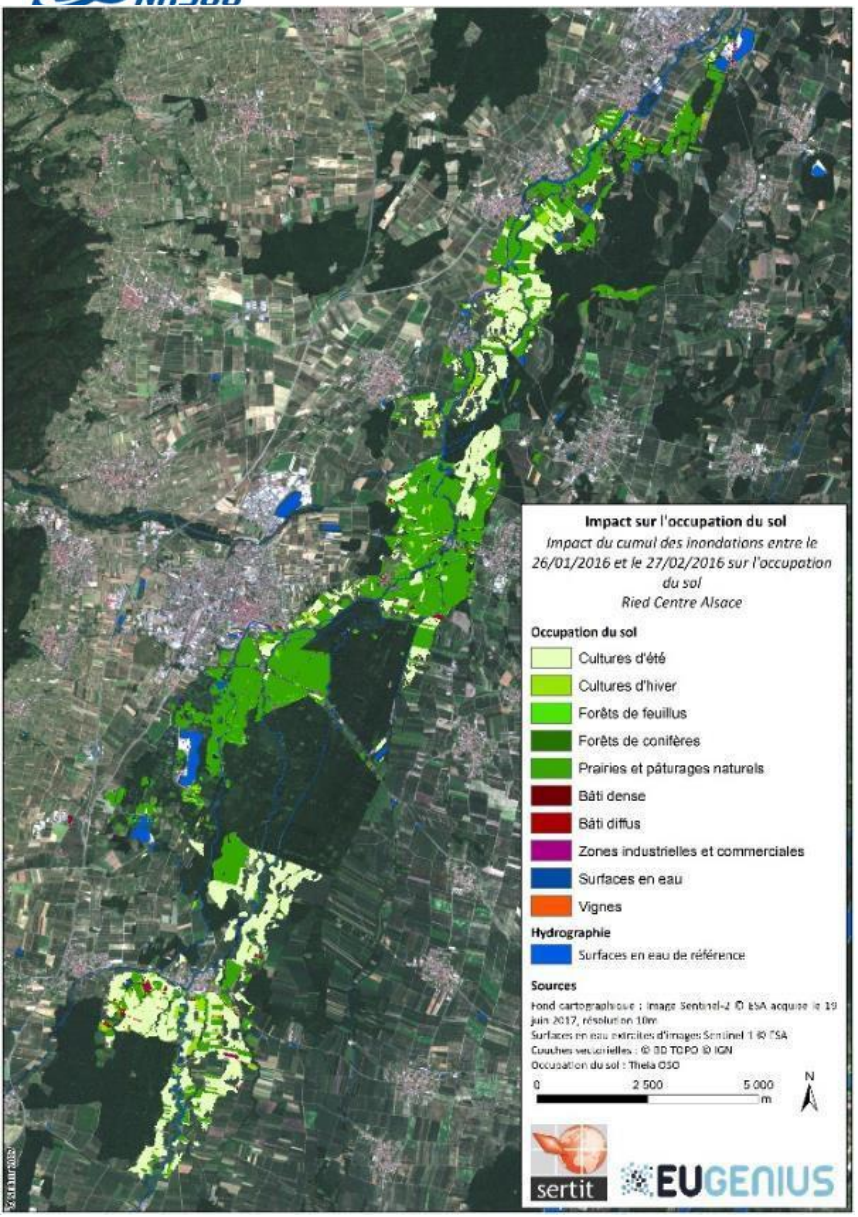
26-01-2016 to 27-02-2016



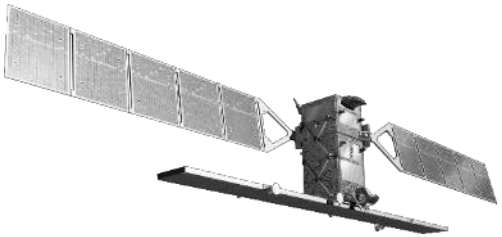
Exploiting Sentinel 1

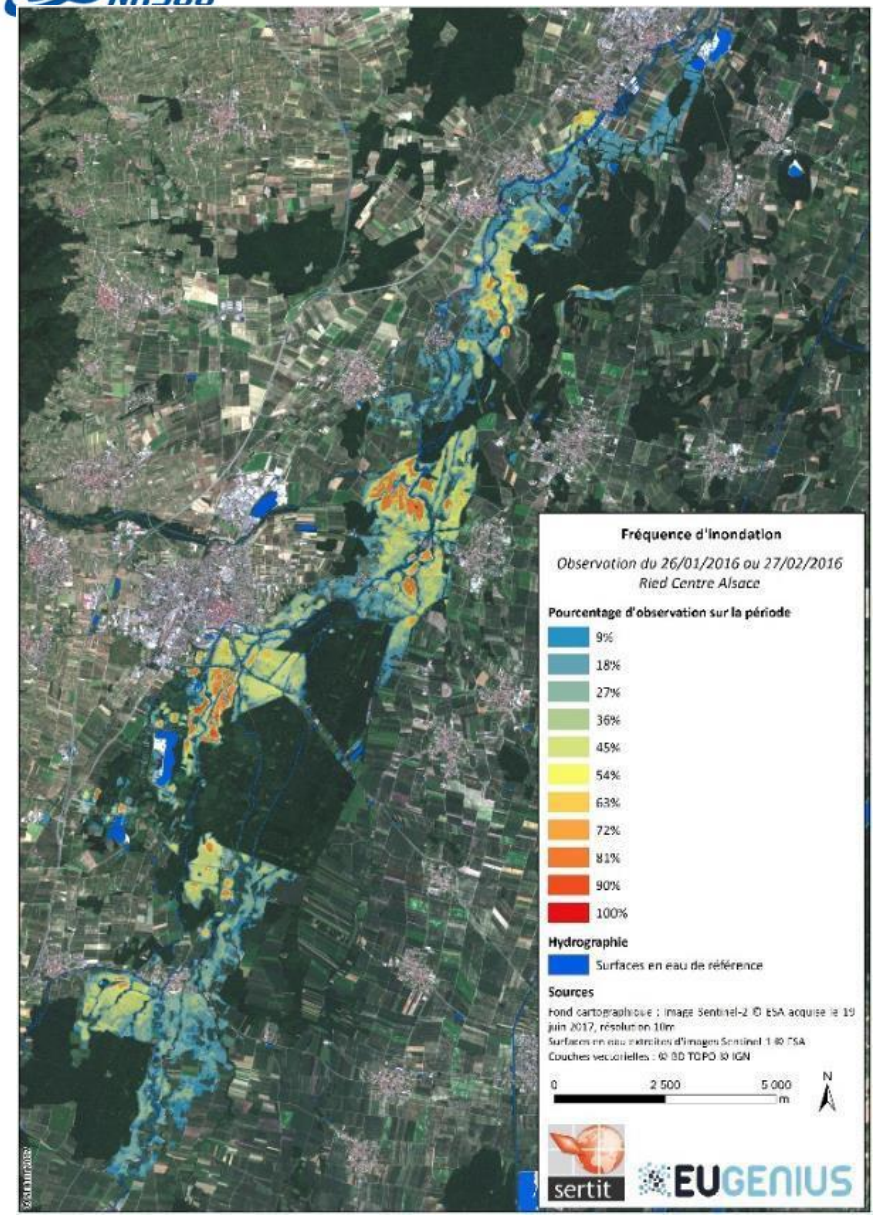


Flood Impact analysis



Exploiting Sentinel 1





Inundation frequency during the exploited data set (occurrence)

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

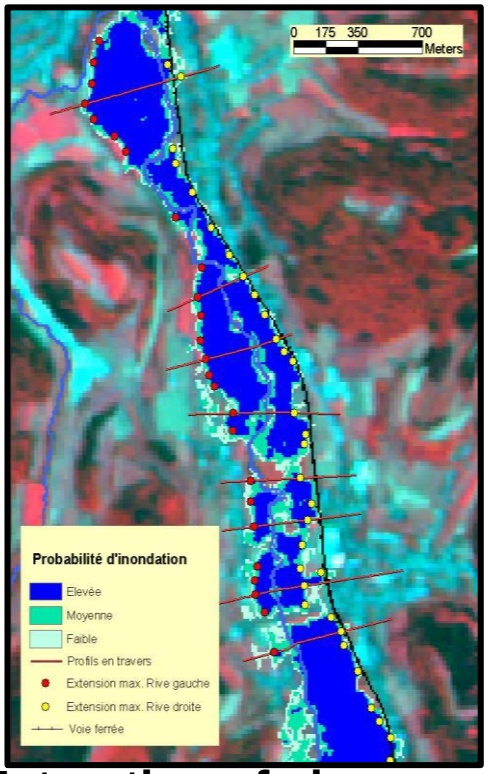
- Short term Monitoring
- Long term monitoring
- Meteo climato parameters

Concluding remarks

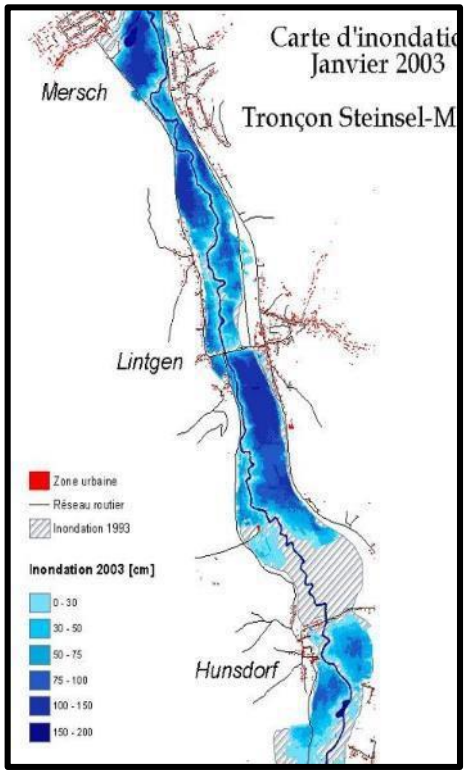
EO derived information and modelling

Envisat derived information as an input for validation of hydraulic models

ERS-2, Envisat



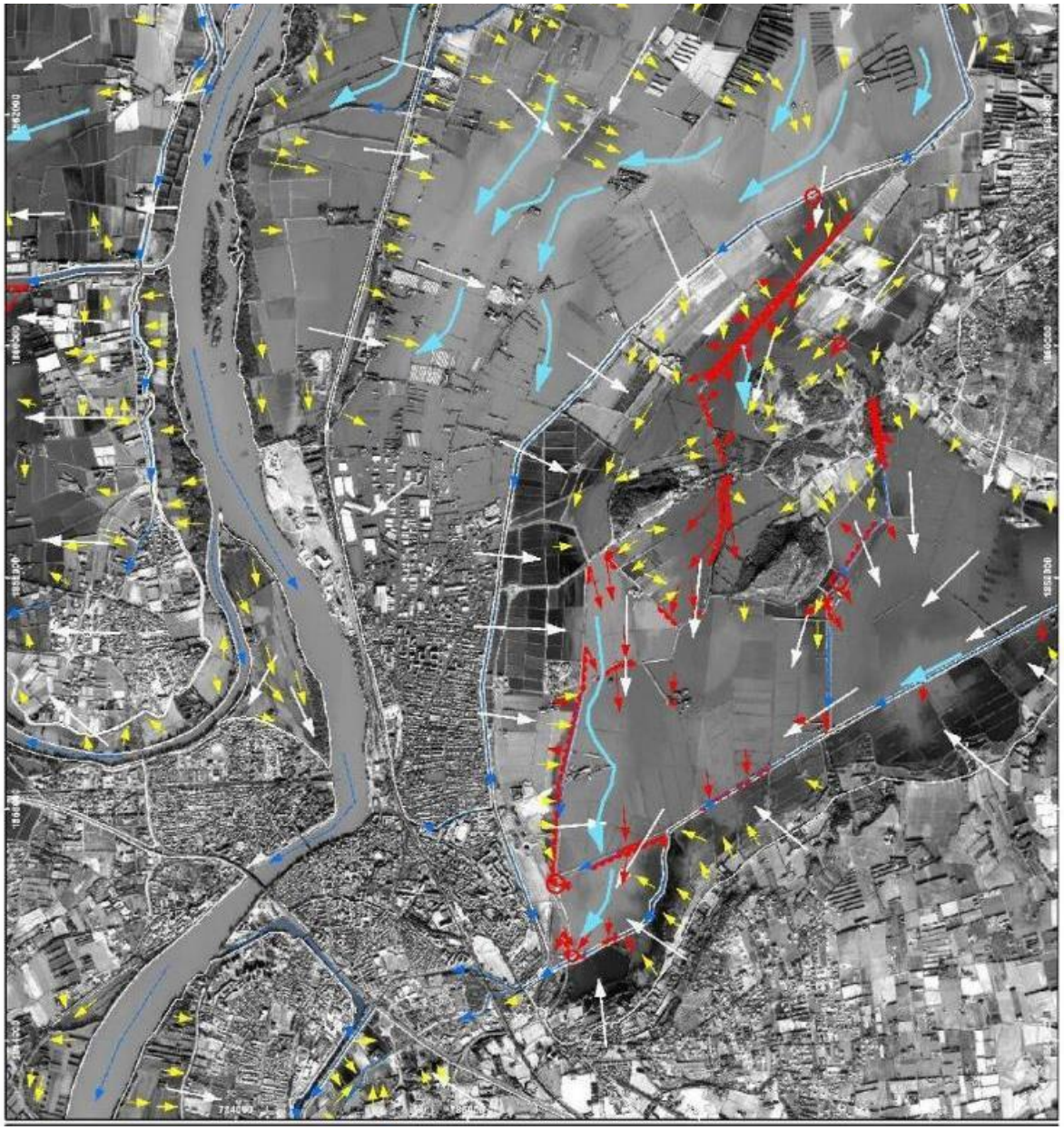
Extraction of classes of flood extent probabilities



Model calibration

Projet Tech Spin (Magten et al., 04 ; Henry, 04)

Optical VHR : post crisis hydrological analysis for modelling



South France flood event,

December 2003

Post crisis exploitation of Ikonos crisis data

Identification of

- **Water paths**
- **Flow trends**

Allenbach & Battiston 2005, MEDD

Optical VHR : post crisis hydrological analysis for modelling

South France flood event,
December 2003

Post crisis exploitation of SPOT5 crisis data

« casiers » hydraulical subdivisions

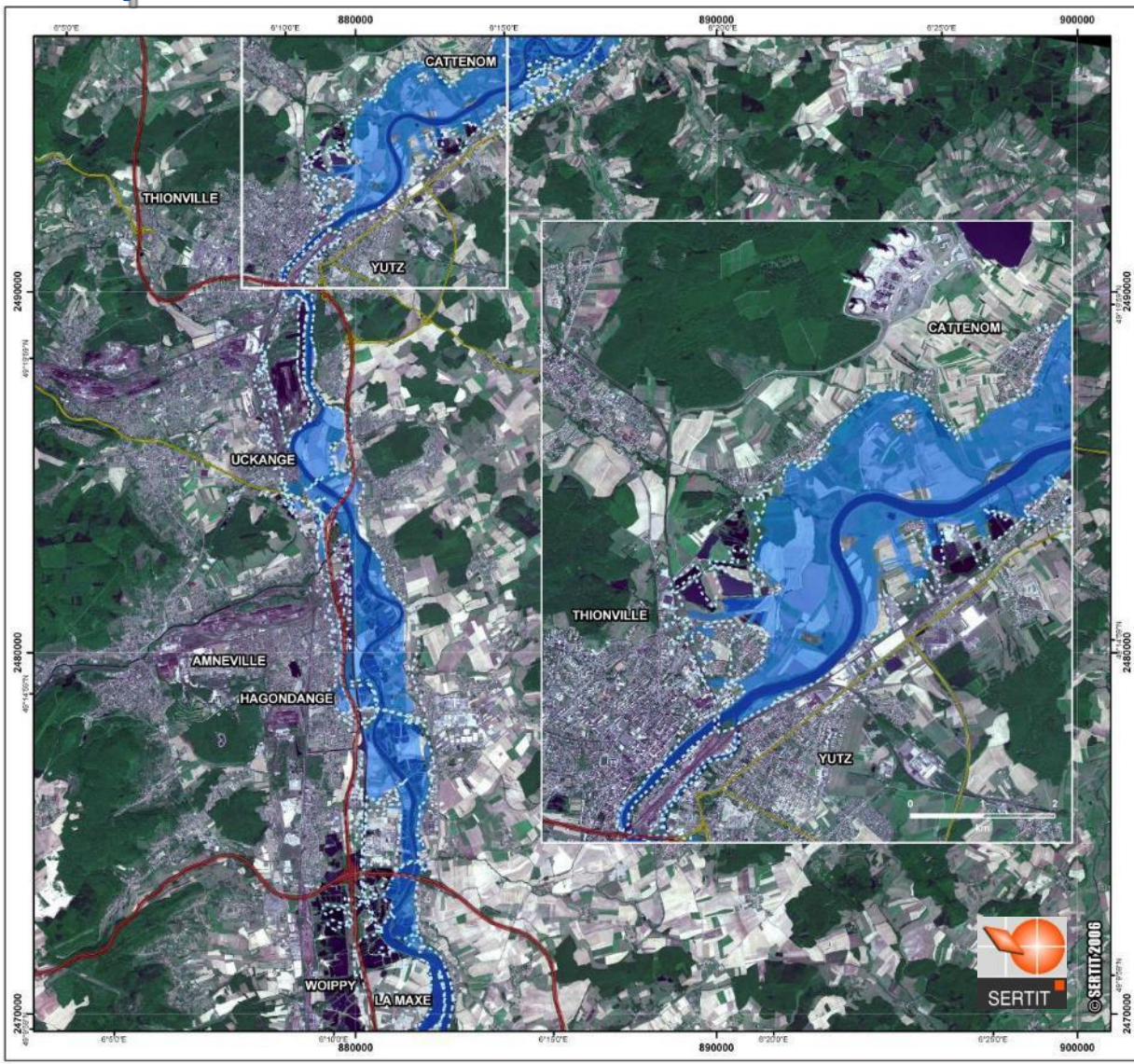
SPOT 5 :
functionnal ones

BCEOM box:
theorical ones

Allenbach & Battiston 2005, MEDD

EO derived information and impact forecast

Potential impact of the October 2006 extent



EO derived information and impact forecast

- 6 October – 11:00: Experimental product using PREVIEW dataset is received at COZ

  Estimation of:

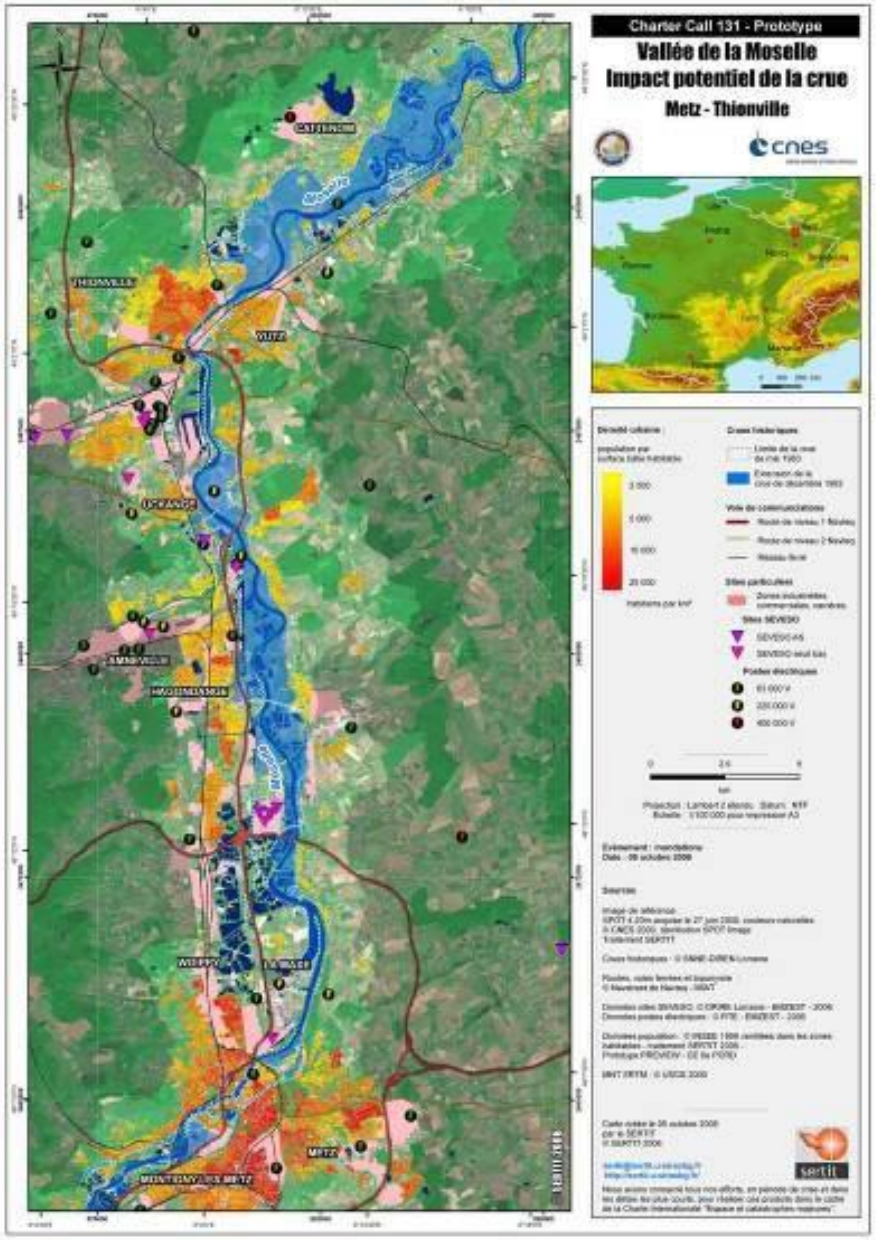
  . Affected population

  . Industrial Areas

  . Sensitive points as SEVESO and High Voltage Transformer

- Night of 6 to 7 October: the flood maximum crosses the border (France – Luxembourg – Germany)

- 7 October: 1st crisis EO data acquisition



Concluding remarks

EO data, optical/SAR can provide very valuable information on ongoing flood event

EO archive very rich for analyzing past event, particularly ESA archive

Not opposition/fight between optical/sar data these are to be exploited in synergy

Concluding remarks

Recommendations: been pro-active

- **Explore EO archive**
- **Realize a more systematic monitoring of flood prone areas**
- **Propose future scenarios exploiting Medium/High resolution products in synergy with VHR data (Cosmo Skymed, TerraSAR and Pleiades)**
  - **MR_HR: identification and monitoring of water flow**
  - **VHR : focus on sensitive areas (urban areas, industrial sites)**