→ 6th ESA ADVANCED TRAINING COURSE
ON LAND REMOTE SENSING

Floods & Lakes Monitoring

Dr Hervé YESOU

UNIVERSITÉ DE STRASBOURG

ECOLE D'INGENIEURS TELECOM PHYSIQUE STRASBOURG

D4T1a

Wenesday 16 of September 2015

SERTIT

Technological and services platform of Icube lab from Strasbourg University
Valorisation and technological transfert in space techniques and E.O. applications

Activities

- Image processing
- Remote Sensing
- GIS
- Expertise
- Training

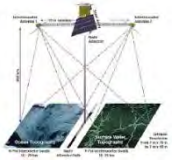
Applications

- Land management and urban planning
- Natural resources monitoring
- Environmental survey
- Epidemiology
- *Natural disaster and risk management*


Western Europe
esa
Paris
esa
cnes
Strasbourg
sertit
Munich
Toulouse
cnes
Roma
esa

Water bodies and Flood mapping and monitoring based on EO data

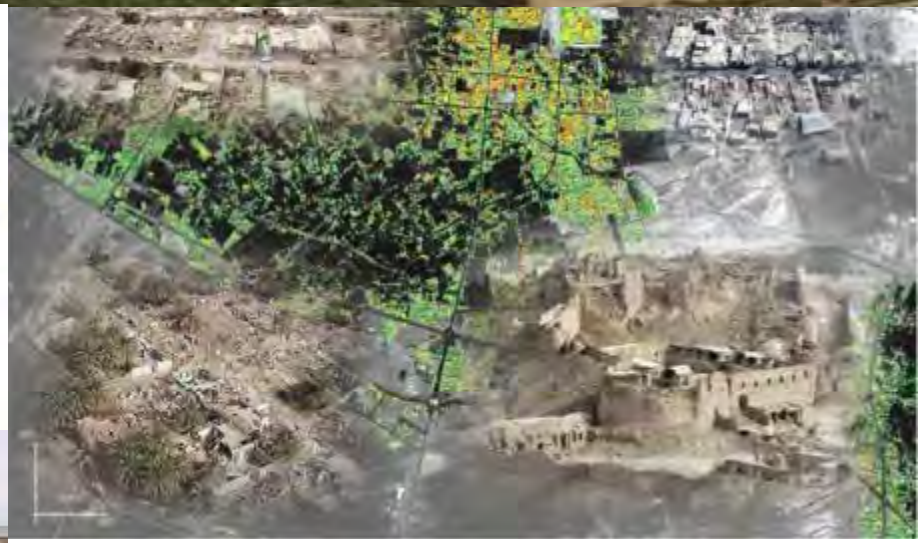
- **ESA Programmes**
  - AO and CAT1 ERS/ Radarsat SOAR
  - EOMD Plain flood project
  - Water an Fire project
  - GMES- ESA GSE projects (Riskeos, Respond)
  - DRAGON ESA MOST
- **CNES projects**
  - SPOT2 to SPOT5 preparatory and validation programmes
  - Pactes
  - Pléiades / Orfeo thematic programme
  - Post Pléiades: SWIR /VHR trade off and synergy
  - SWOT SDT
- **Others projects**
  - CSK ASI
  - TerraSAR AOs
- **International Charter Space and Major Disasters**
- **Former GMES SAFER and EMS Copernicus**
  more than 120 actions of flood rapid mapping

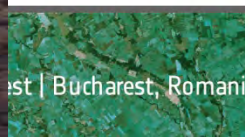
http://sertit.u-strasbg.fr

Rapid mapping service

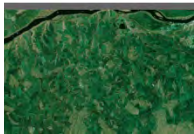
International Charter Space & Major Disasters
Charte Internationale Espace et Catastrophes Majeures



afaq ISO 9001 Qualité AFNOR CERTIFICATION

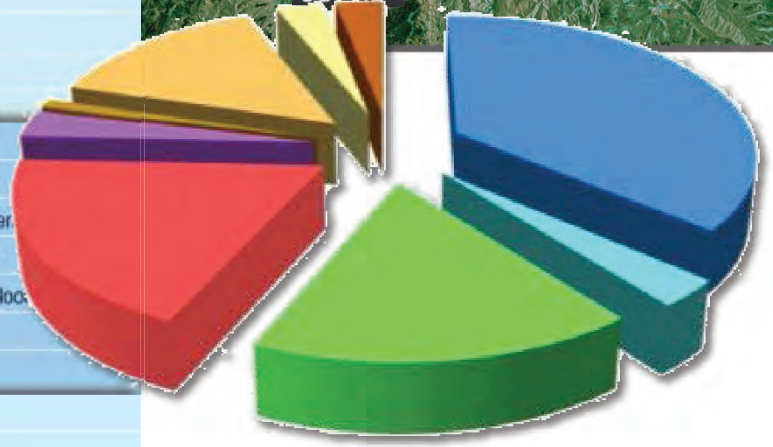


Copernicus
Europe's eyes on Earth



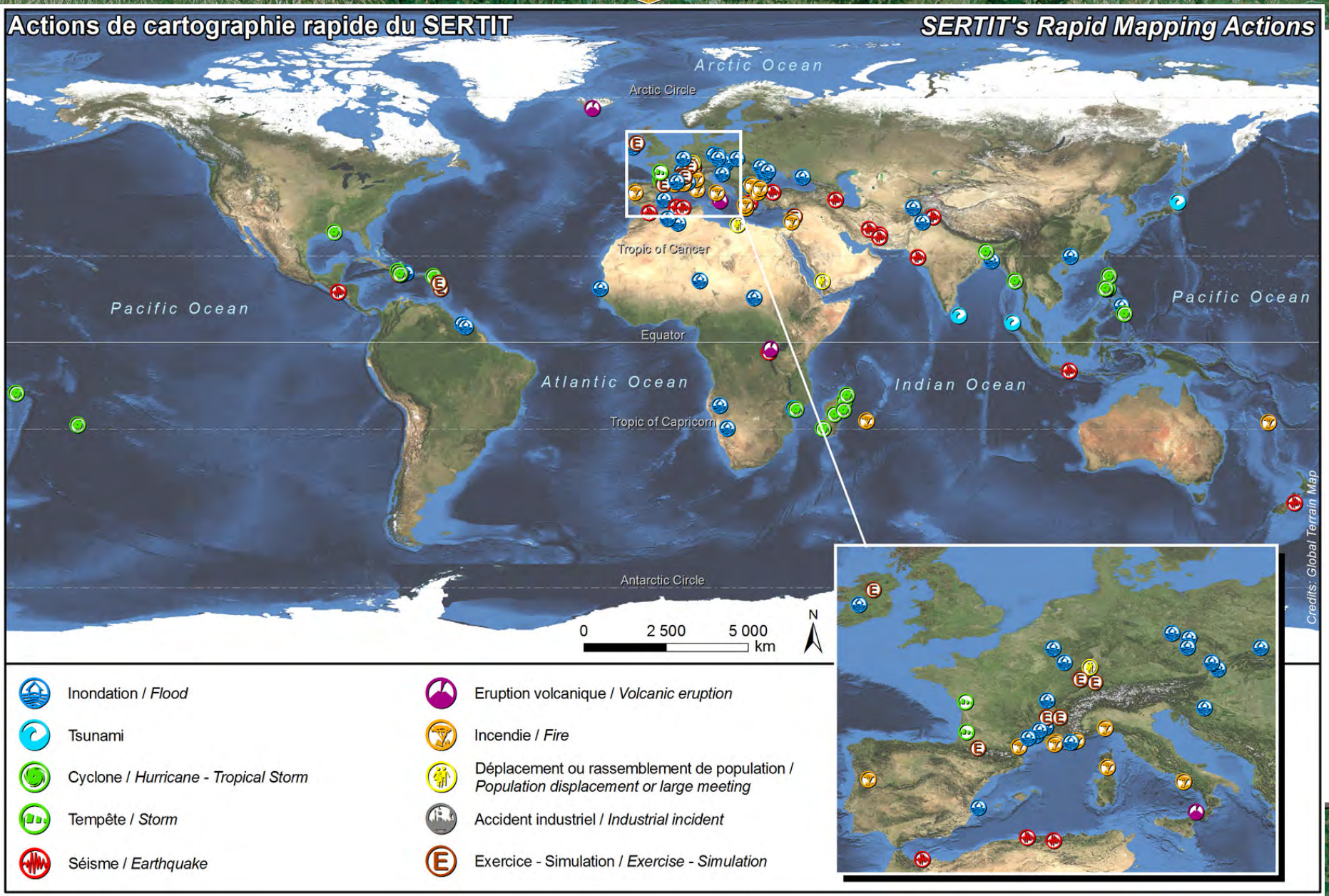
Plus de 150 opérations au SERTIT

60	2008	November	France - Martinique	Simulation : Earthquake
59		October	[illegible]	[illegible]
58			Algeria - Ghardaia	Floods
57		August - September	Haiti	Hurricanes & Floods
56		August	France - Aude	Forest fires
55		July	Romania, Ukraine	Floods
54		June	French Guiana - Maroni	Floods
53		May	Myanmar	Cyclone & Floods
76	2009	December	Ireland - Shannon river	Floods
75		November	Philippines - Lagune de Bay	Typhoon & Floods
74		October	Yemen	Population displacer.
73			Philippines - North of Luzon	Typhoon & Floods
72			Philippines - Manille	Tropical storm & Floo
71		September	Southern Italy - Naples	Forest fires
70			Northern Italy - Genoa	Forest fires
96	2010	December	Iran	Earthquake
95			Israel	Forest fires
94		November	Bulgaria	Forest fires
93		September	Croatia	Floods
92		August	France - South	Forest fires
91			Czech Republic	Floods
90		July - August	Pakistan	Floods
89		July	Moldova	Floods
88		June	France - Draguignan	Floods
87		May - June	Poland	Floods
86			France - Aude	Simulation : Earthquake
85		May	France - Nice	Large gathering
84		April - May	Iceland	Volcanic Eruption
83			Bangladesh	Storm & Floods
82		March	Wallis & Futuna	Cyclone
81			Mozambique	Floods
103	2011	May	France	G8 summit
102		April	France	Simulation : Earthquake
101		March	Japan	Tsunami
100		February	Libya	Humanitarian crisis
99			New Zealand	Earthquake
98			Madagascar	Cyclone
97		January	Belgium	Floods



- Floods
- Tsunami
- Cyclone / Hurricane / Tropical Storm / Storm & Floods
- Earthquake
- Volcanic Eruption
- Landslide
- Forest fires
- Population displacement or Large meeting
- Exercise / Simulation

15 years of rapid mapping at SERTIT



Recent mapping action Krymsk, Russia, July 2012

Charter Call 399
Glide No. FF-2012-000115-RUS
Product No. 03

Russian Federation - Krasnodar
Southern part of Krymsk
Damage assessment map
Observation the 16/07/2012

Location Diagrams

Legend

- Potentially affected urban area
- Emergency camp
- Broken bridge

Interpretation

The floods began on the 7th of July 2012 in southwest Russian Federation, mainly in Krasnodar Krai. More than 150 people have died during the floods and nearly 13 000 people are affected. Most of the victims lived in the city of Krymsk.
This cartographic product shows the potentially affected area, the broken bridges, the emergency camps over Krymsk with a Pléiades HR1 image (50cm) acquired the 16th of July 2012.

Cartographic Information

0 100 200 m N

Local projection: UTM Zone 37 North , Datum: WGS 84
Geographic projection: Lat/Lon (DMS), Datum: WGS 84

Scale: 1:5 000 for A1 prints

Geometric references:
Horizontal: Landsat-7 ETM+, EarthSat Ortho GeoCover, RMSe 50m

Data Sources

Background layers
Pléiades 1A - 16 07 2012, © CNES 2012, distribution Astrium Services / Spot Image S.A., all rights reserved

Affected urban areas, emergency camps & broken bridges are derived from Pléiades HR1 data (0.5 m) acquired the 16th of July 2012
© SERTIT

Roads
© 2012 OpenStreetMap

Framework

The products elaborated for this Rapid Mapping Activity are realised to the best of our ability, within a very short time frame, during a crisis/exercice, optimising the material available.
All geographic information has limitations due to the scale, resolution, date and interpretation of the original source materials. No liability concerning the content or the use thereof is assumed by the producer.

Map produced the 18 07 2012 by SERTIT
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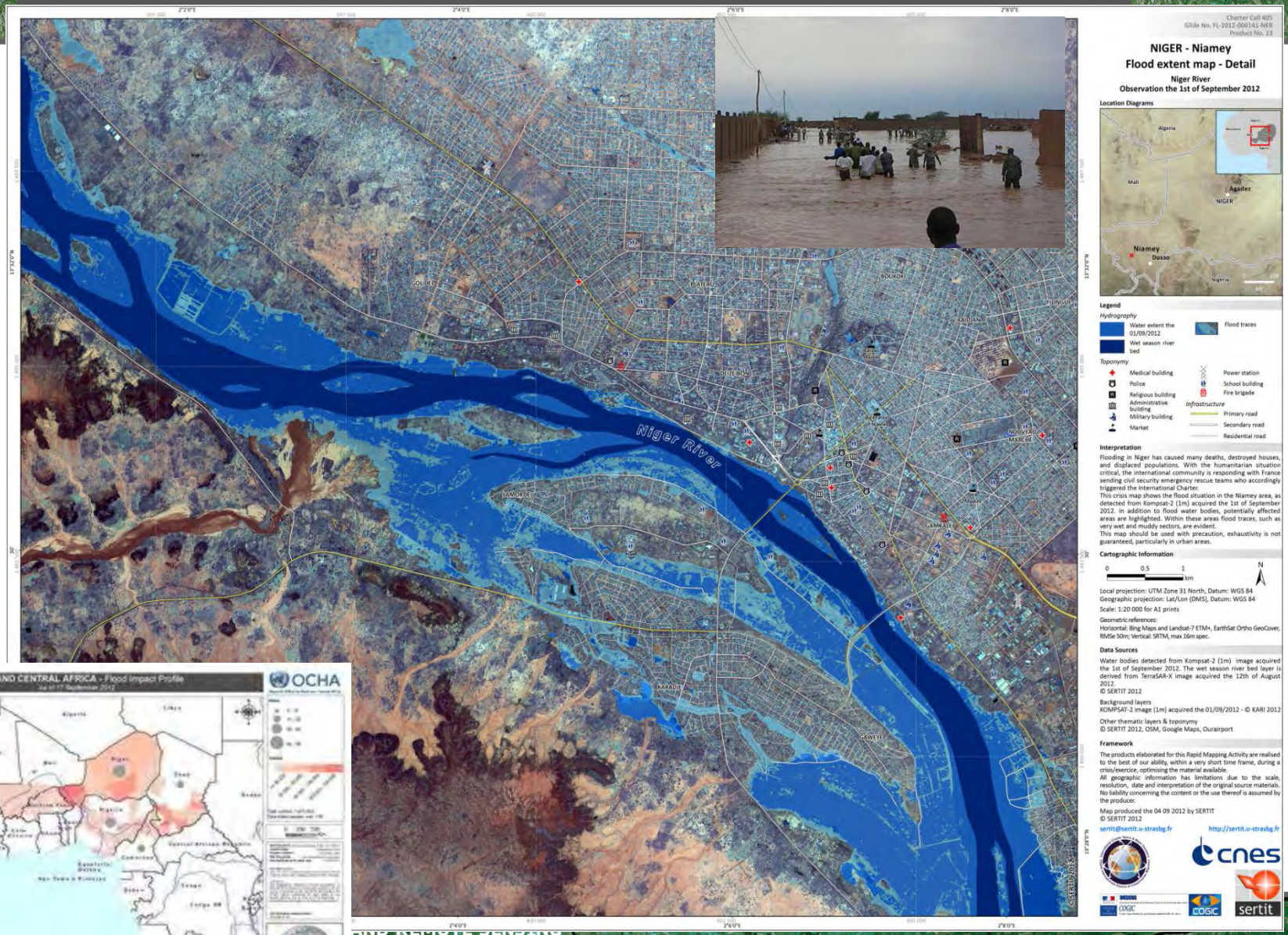
http://sertit.u-strasbg.fr

Recent rapid mapping action Niamey, Niger, September 2012



Science and Veterinary Medicine Bucharest | Bucharest, Romania

Recent rapid mapping action Madagascar Haruna Cyclone, February 2013

Morombe, affected individual housing Viewed with Pleiades HR

Recent rapid mapping action Madagascar
Haruna Cyclone, February 2013

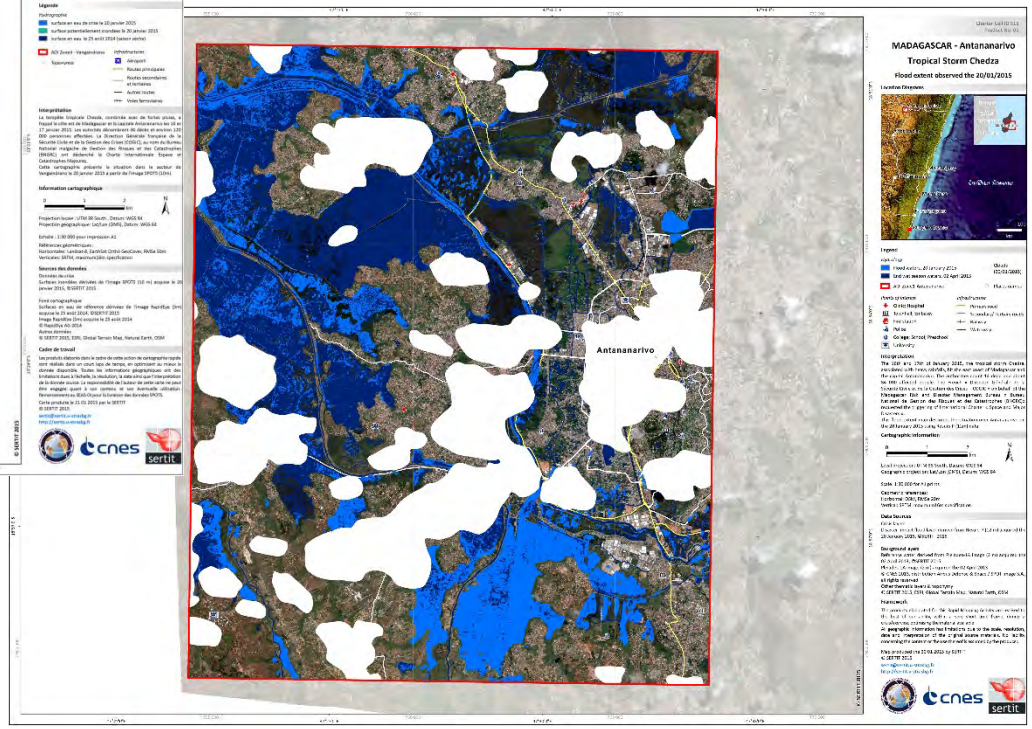
Tolaria, affected individual housing Viewed with Pleiades HR

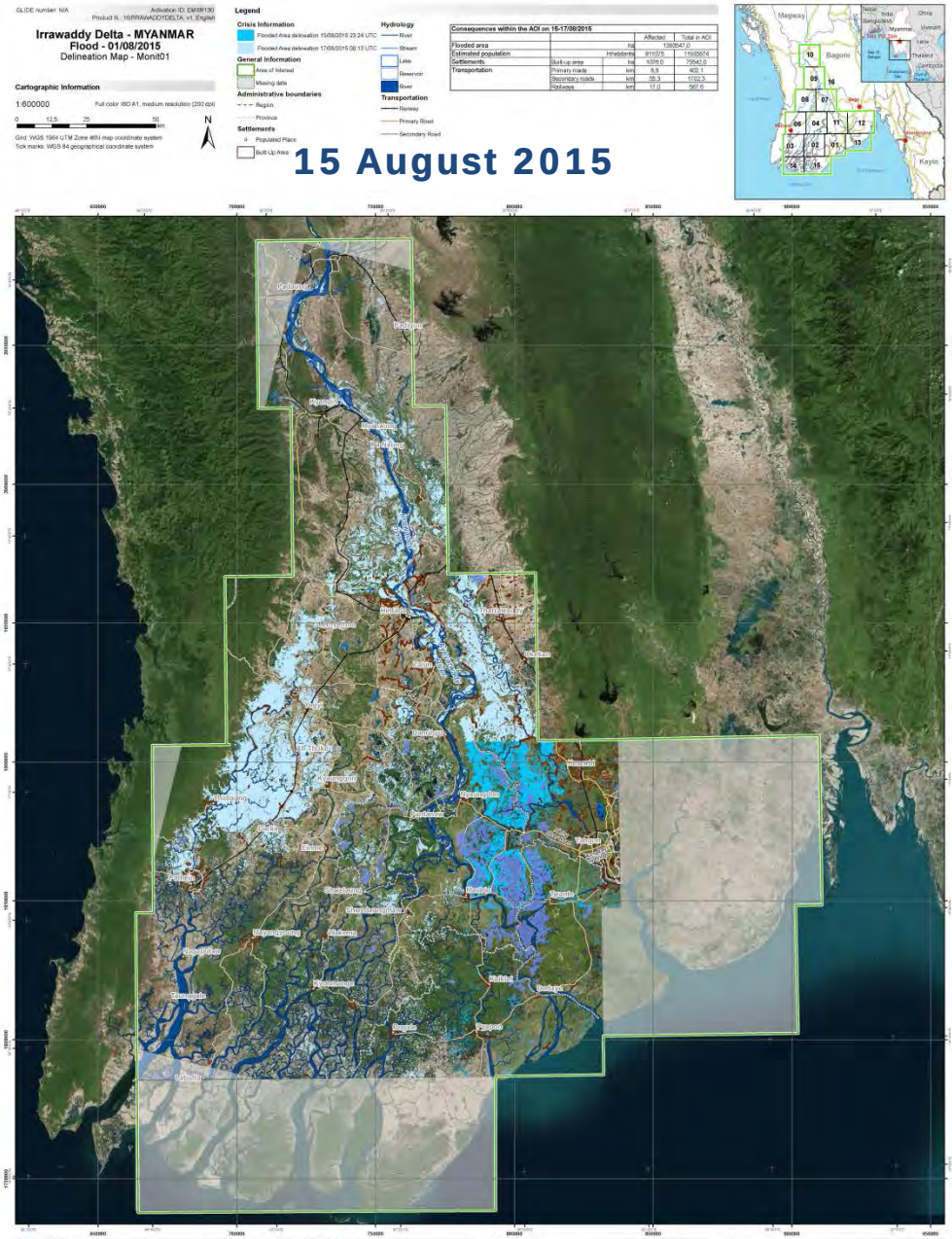
Andranogadra

Rapid mapping acti
Marne flood, Ma

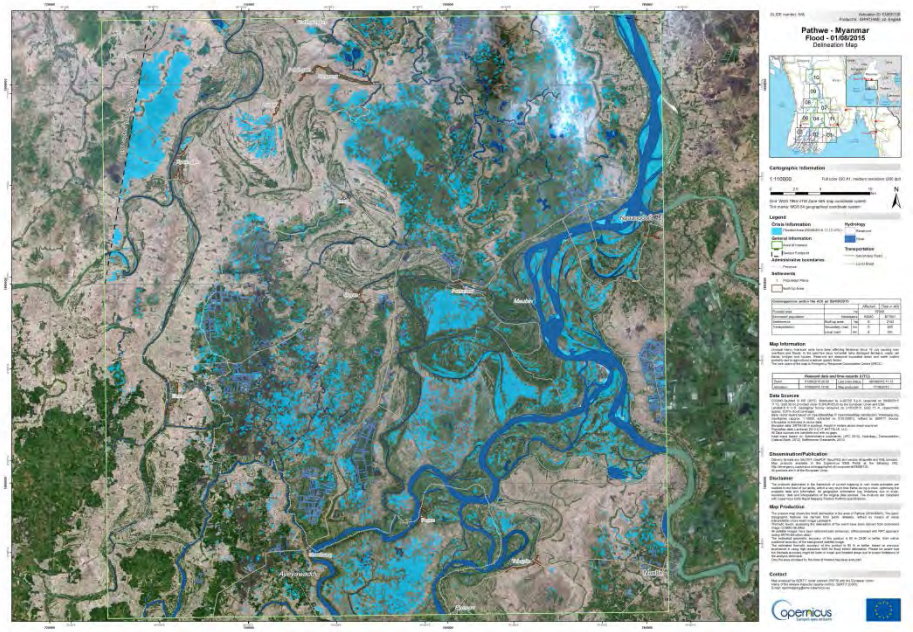
Marne flood in
Jionville vicinity
Viewed with
Pleiades HR

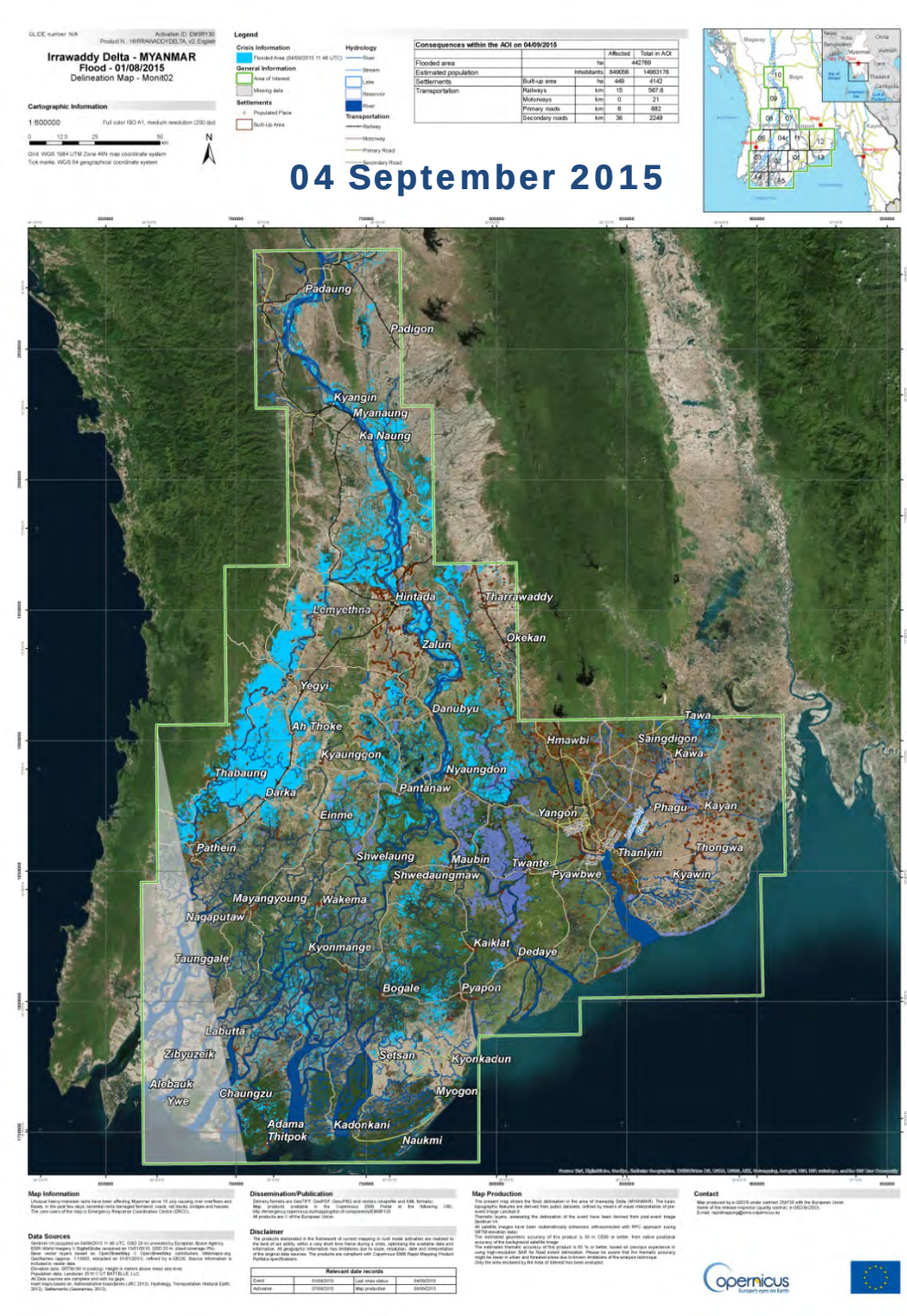
Tropical storm Chezda
Madagascar
January 2015

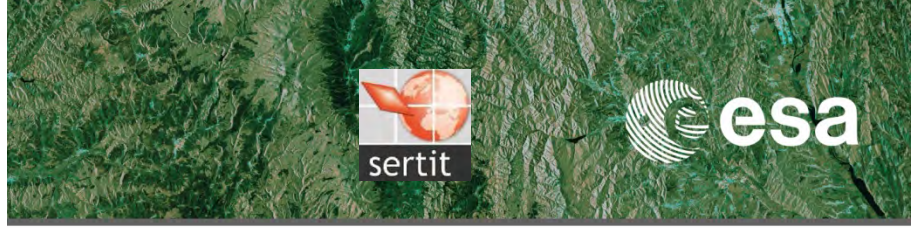




Myanmar
Heavy monsoon rain caused river overflow and flooding in August 2015







Myanmar
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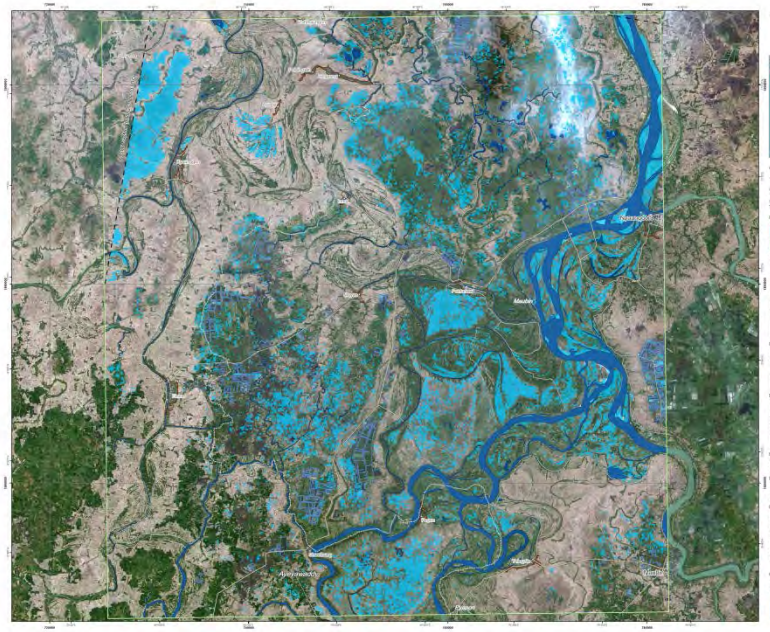


Copernicus
Europe's eyes on Earth

Presentation outline

Introduction: Why water bodies and flood mapping and monitoring

Flood mapping exploiting SAR data

- Basis physical principles
- From ERS to ASAR towards Sentinel
- New generation of ASAR: VHR SAR

Flood mapping exploiting optical data (short overview)

- PIR and SWIR bands exploitation
- From Medium to VHR data

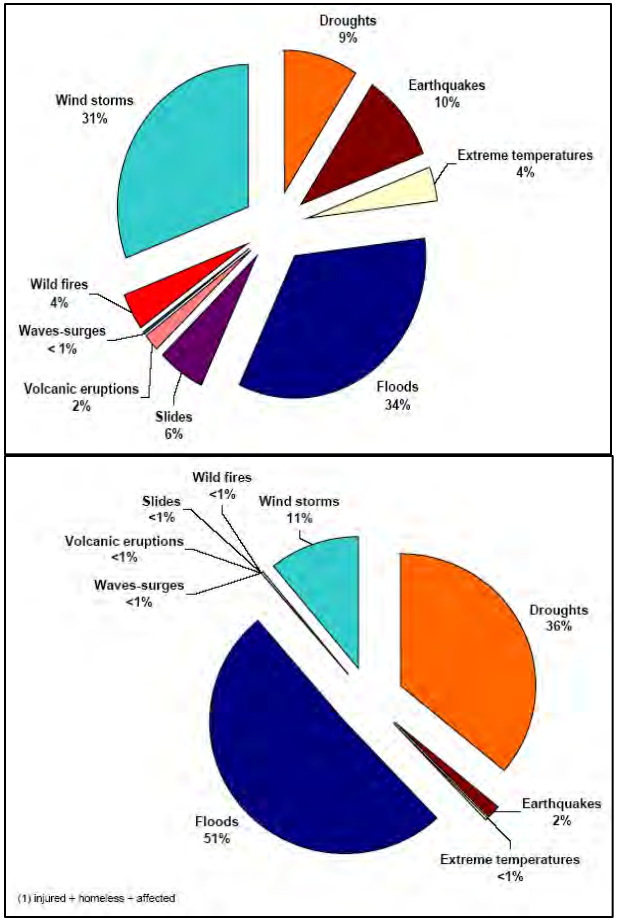
Floods and lakes monitoring

- Long term monitoring
- Meteo climato parameters

Concluding remarks, new trends and recommendations

Why it is relevant to map and monitor flood events?

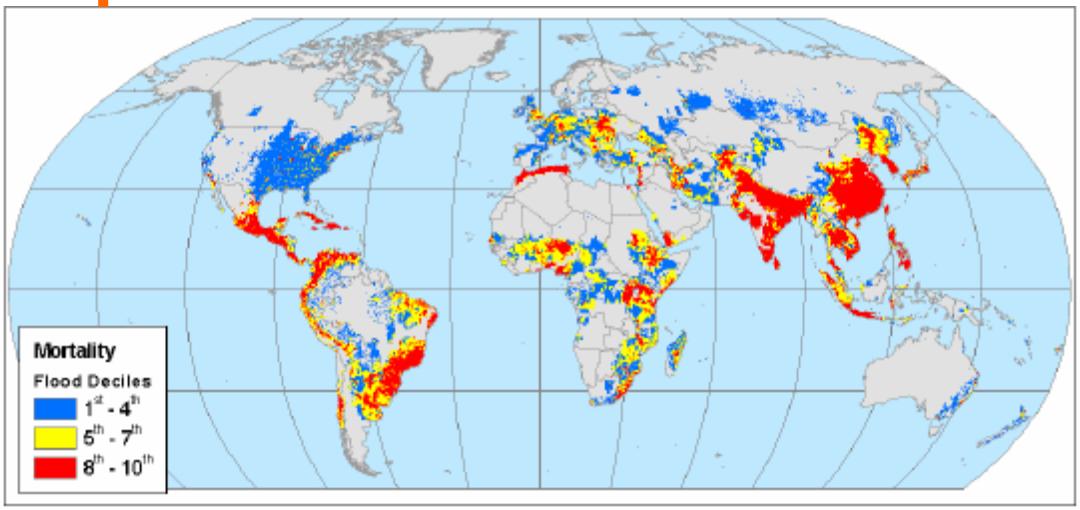
- **Floods: 34% world natural hazards between 1974-2003**
- **Near 200 millions of affected people each year (more than half of affected people by a natural hazards)**
- **More than 170 000 deceases from 1980 to 2000**
- **With climate change it would become worse**
- **Fitting floods is one of the most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

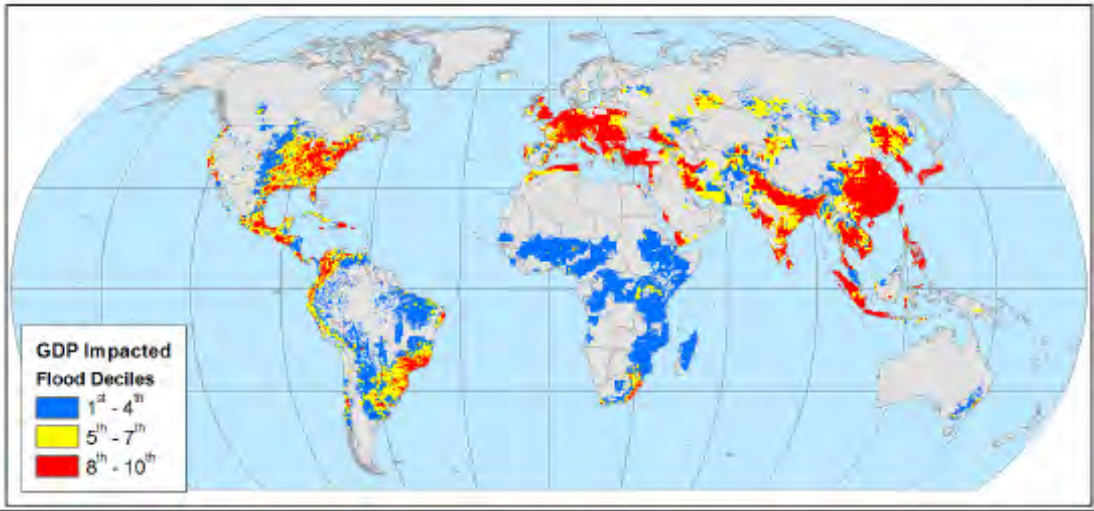


Source:EM-DAT - International Disaster Database

Why it is relevant to map and monitor flood events?

- **Floods: worldwide**
- **Important mortality in Asia, Central- South America, Eastern Africa**
- **Important economic losse 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**



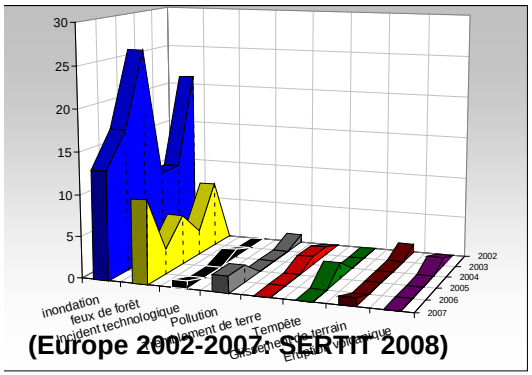


Global Distribution of Flood Risk
(Source: Columbia University, UNDP, CRED)

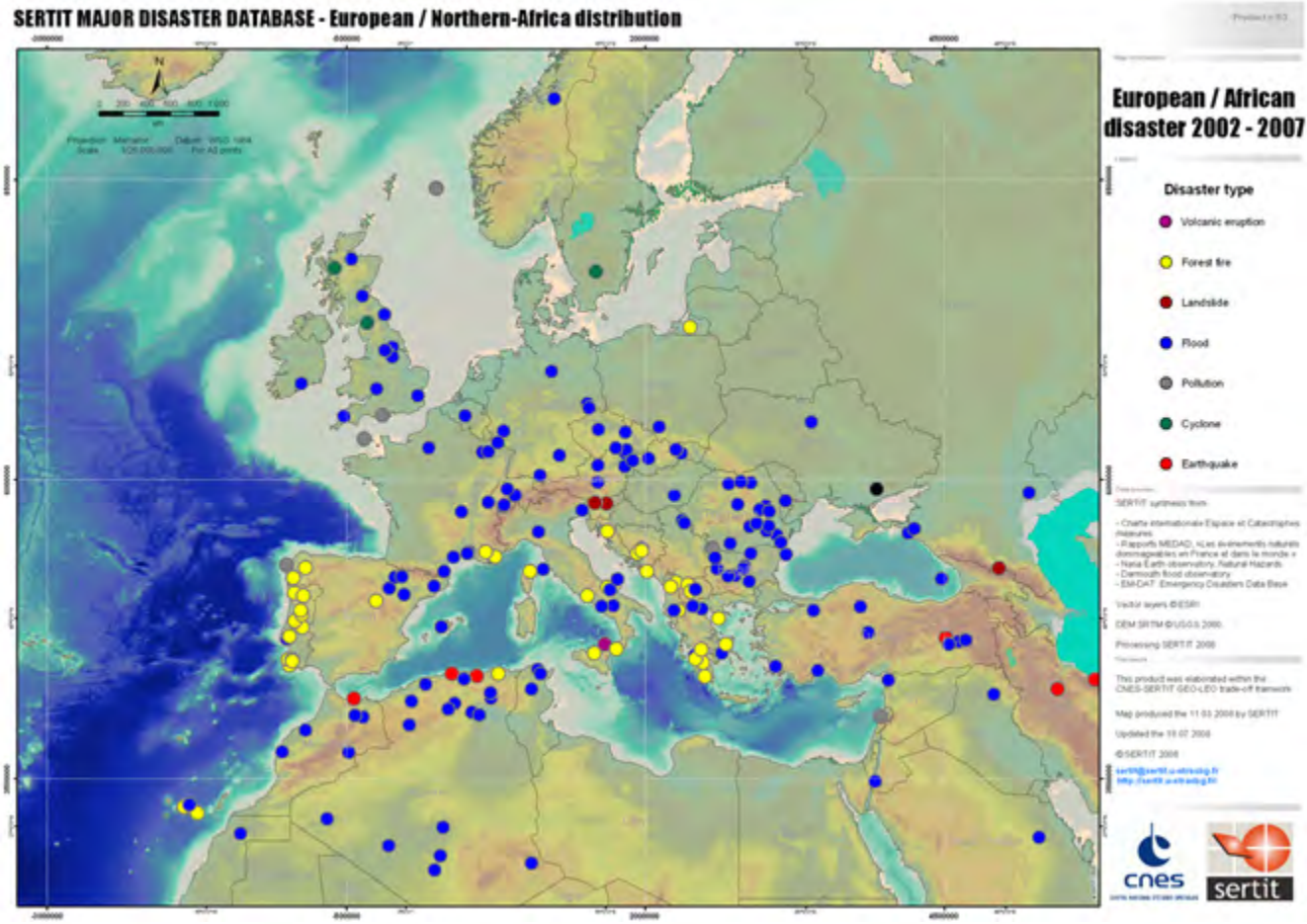
Why it is relevant to map and monitor flood events?

- Floods: Europe

- Central Europe
- British Islands
- South France

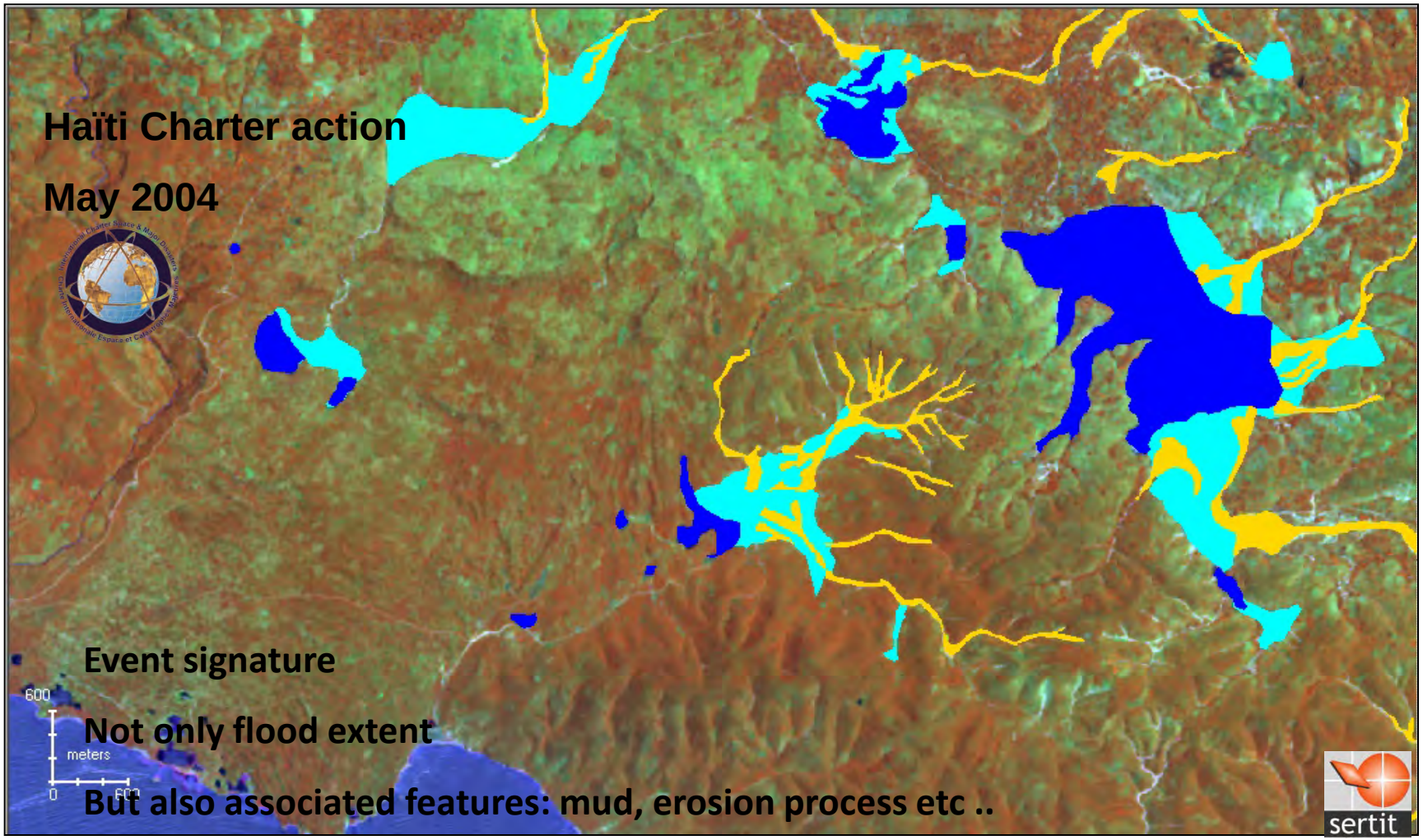


(Europe 2002-2007, SERTIT 2008)

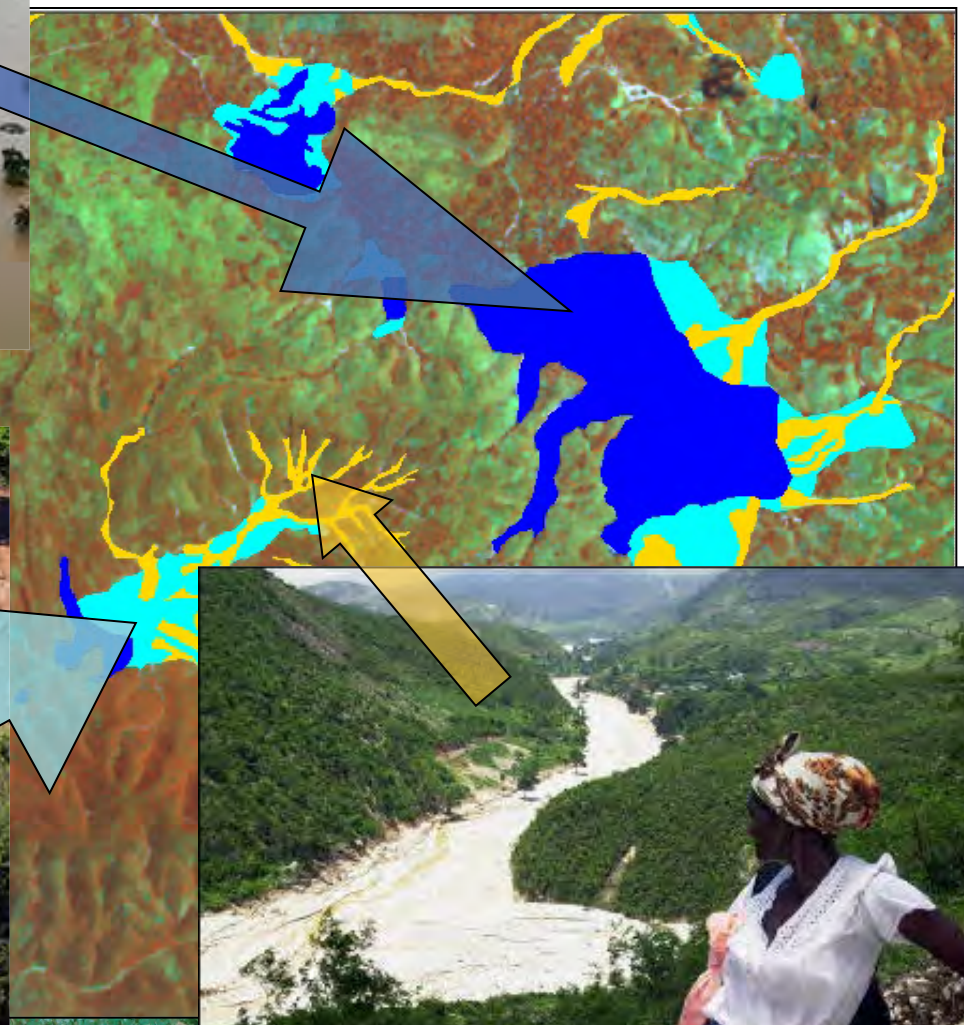


(SERTIT 2008)

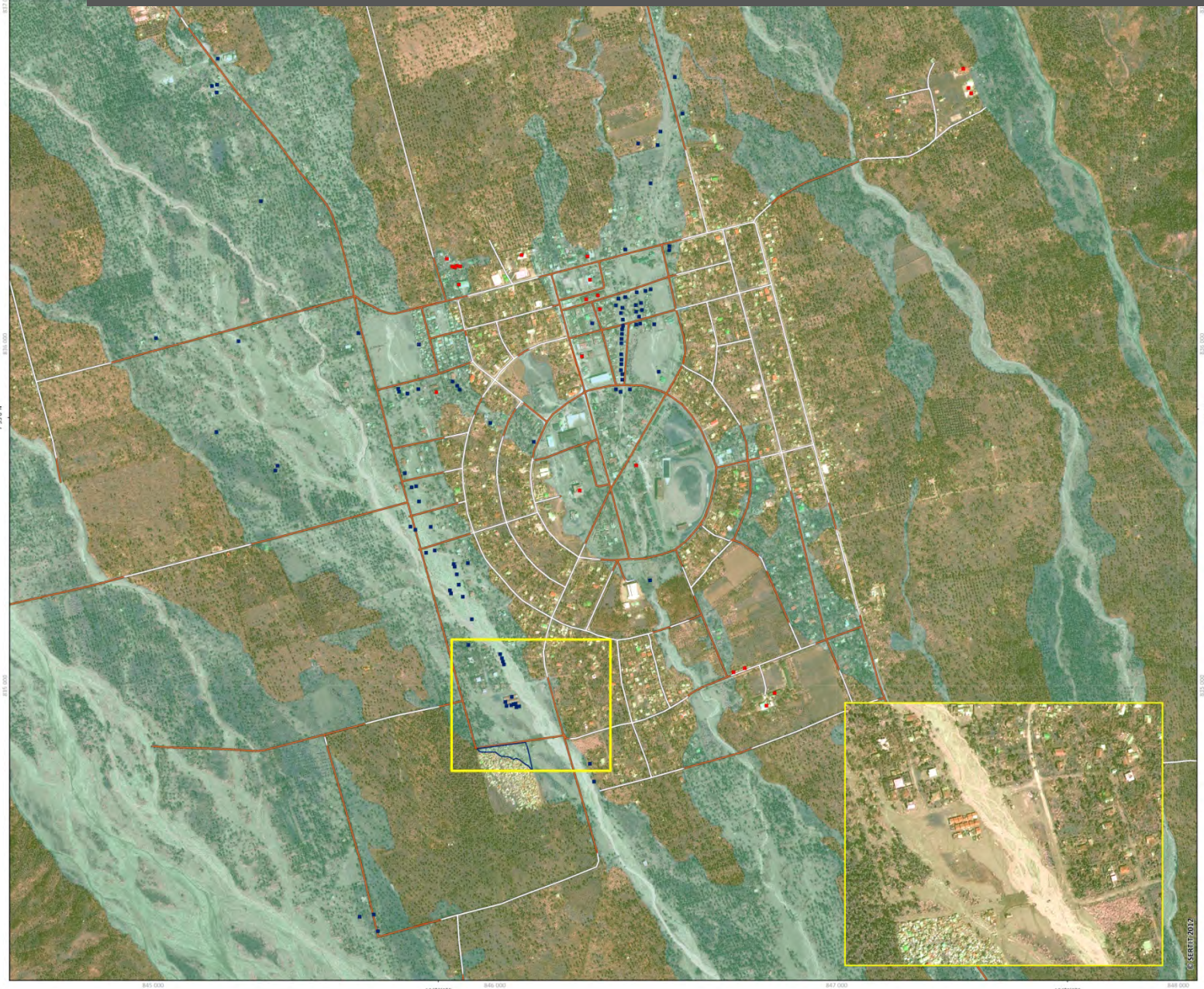
Flood patterns recognition



Event signatures



Flood patterns recognition



Charter Call ID No. 423-424
TC-2012-000197-PHL
Product No. 03

PHILIPPINES - Mindanao Island
New Bataan - Damage assessment
Typhoon Bopha/Pablo
Observed the 10/12/2012

Location Diagrams

Legend

Building damage (probable)	*Road Infrastructure (probable)*
Probable flood	Flood affected
Probable wind	Unaffected
Flooded slum area	

Other Typhoon damage

Flood traces (water/mud) — Tree windfall damage

Interpretation

Bopha Typhoon which devastated Midanao's island, in southern Philippines, on Wednesday 05 December 2012. The authorities count around 700 dead, 400 missing and 250,000 homeless after its passage.
The typhoon has badly hit the New Bataan area: many buildings are flooded and wind damaged, with a slum area being swept away, a number of roads also seem seriously affected and the trees in the area have been hit. This is evidenced after analysing Pléiades imagery acquired the 10 December 2012 (0.50m).

Cartographic Information

0 100 200 m — N

Local projection: UTM 51 North , Datum: WGS 84
Geographic projection: Lat/Lon (DMS), Datum: WGS 84
Scale: 1:5 000 for A1 prints

Geometric references:
Horizontal: Pléiades navigation parameters
Vertical: SRTM, maximum16m specification

Data Sources

Crisis layers
Disaster impact assessment (potentially affected buildings, roads, flood traces extent), ©SERTIT 2012
Pléiades 1A image (0.50m) acquired 10 December 2012, © CNES 2012, distribution Astrium Services / Spot Image SA, all rights reserved

Framework

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Map produced the 11 December 2012 by SERTIT
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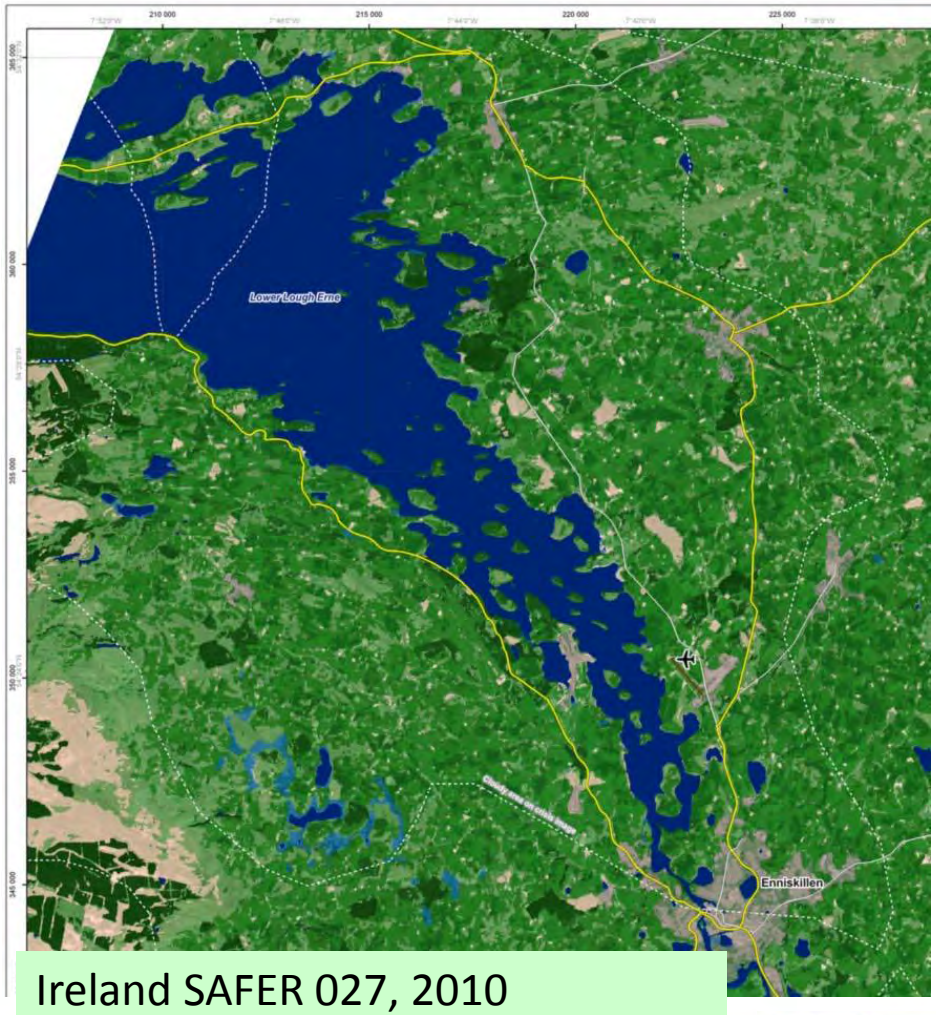
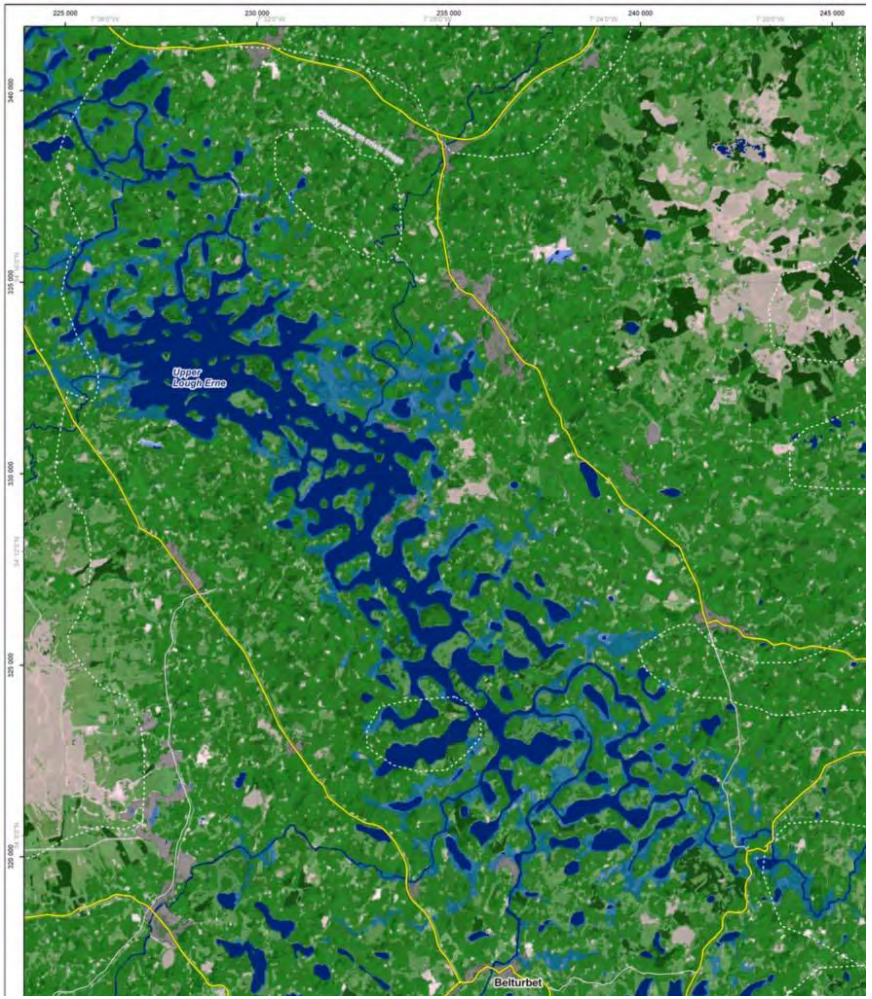
Flood patterns recognition

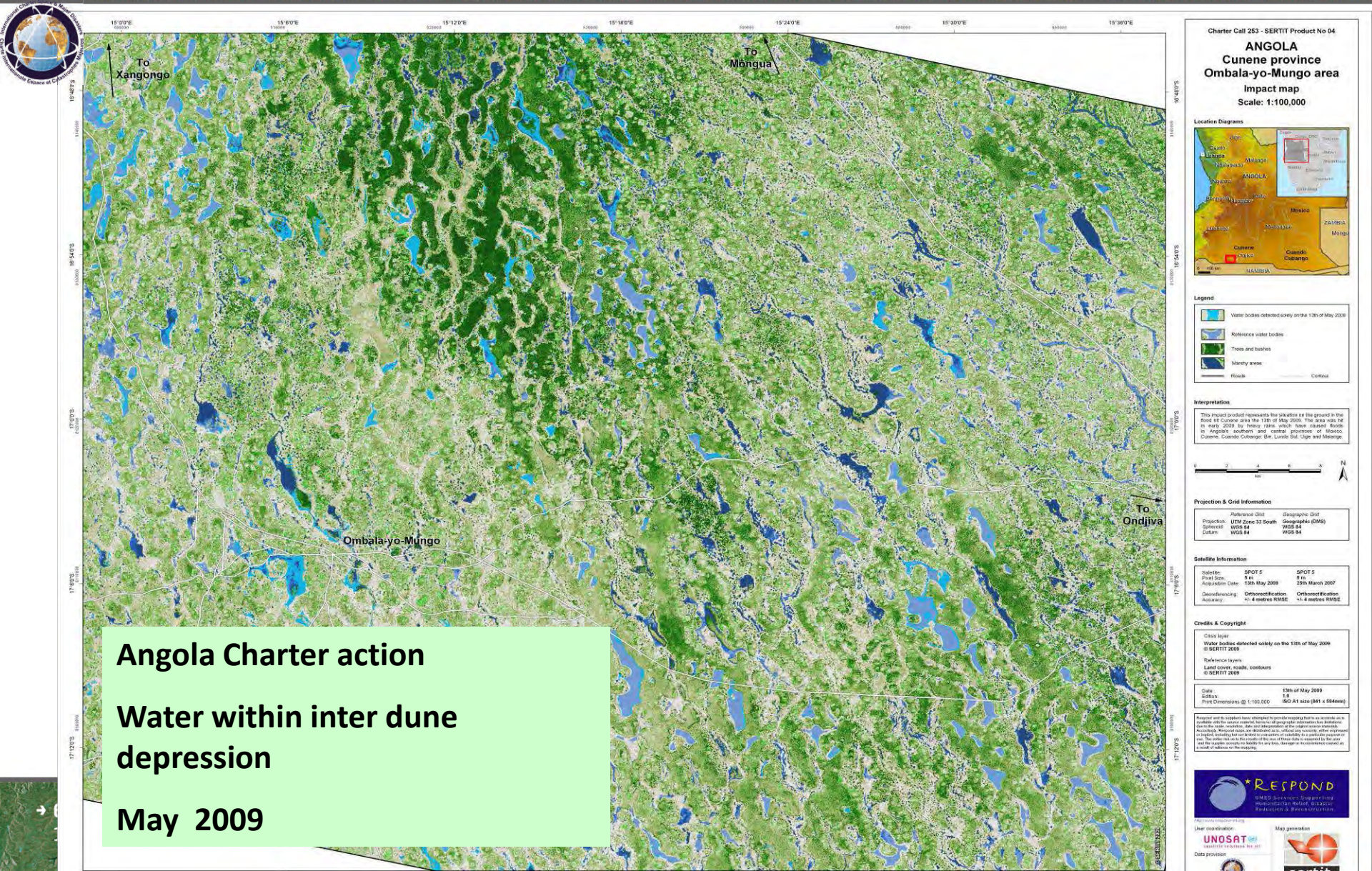




Ireland SAFER 027, 2010

Water within bogs

Flood patterns recognition



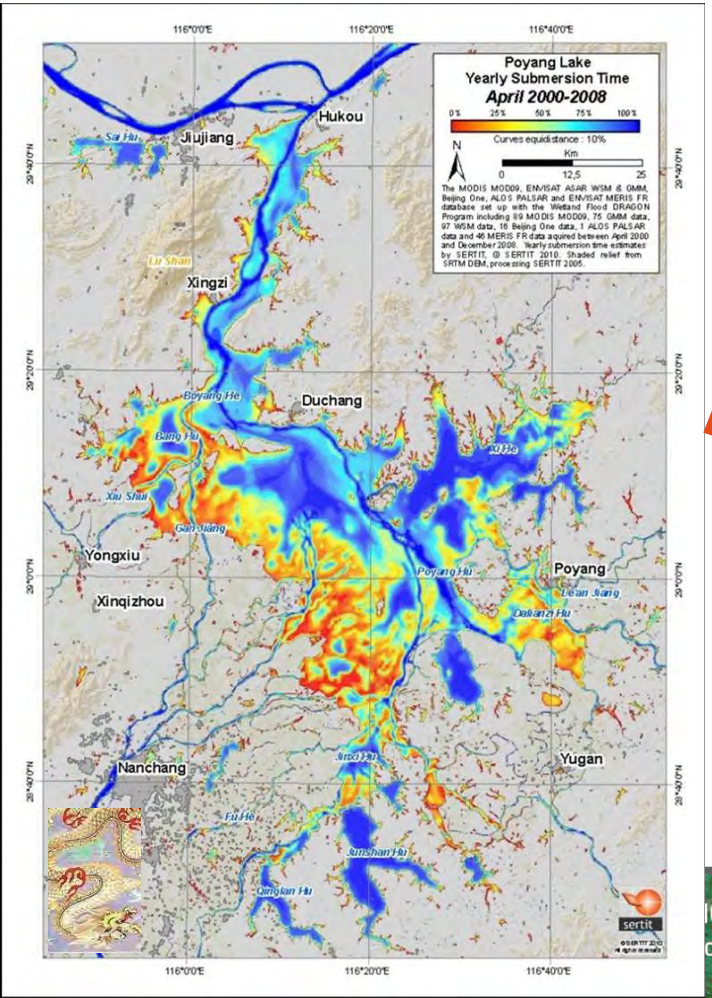
Angola Charter action

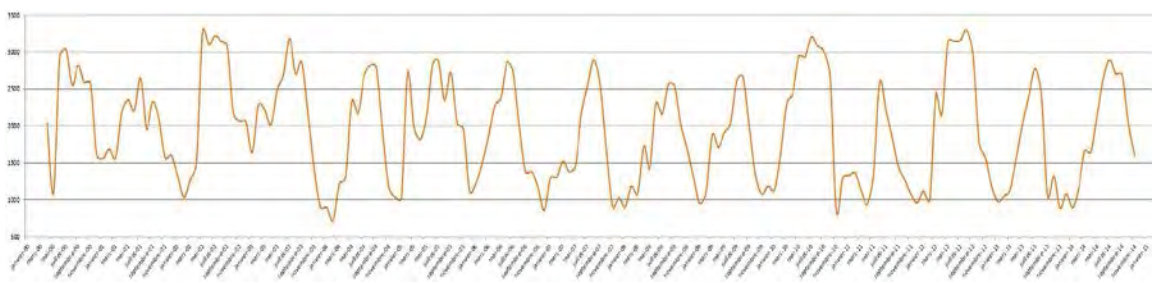
Water within inter dune depression

May 2009

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

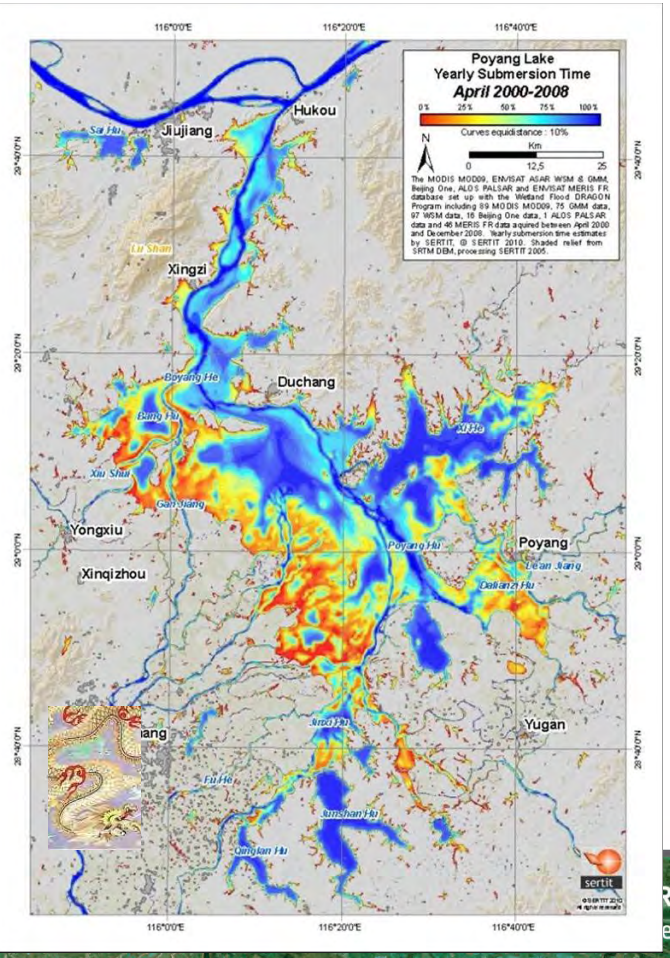
Important to monitor water resource as water is a key element for human being and life

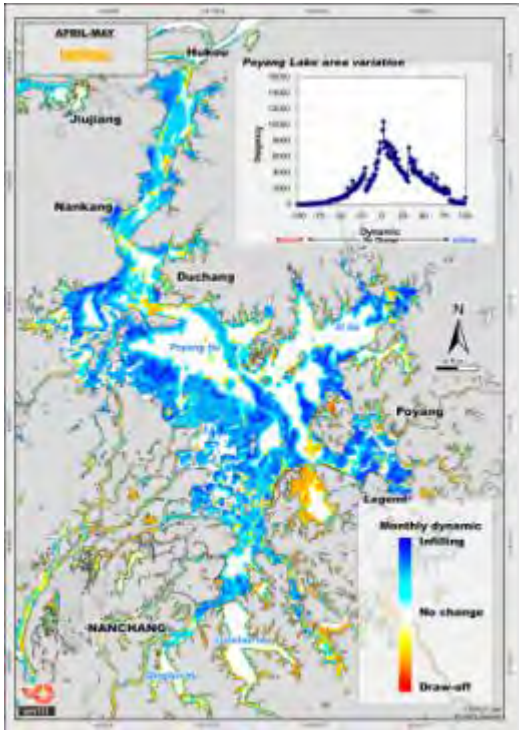
Better understanding of water cycle

Why it is important to monitor water bodies?

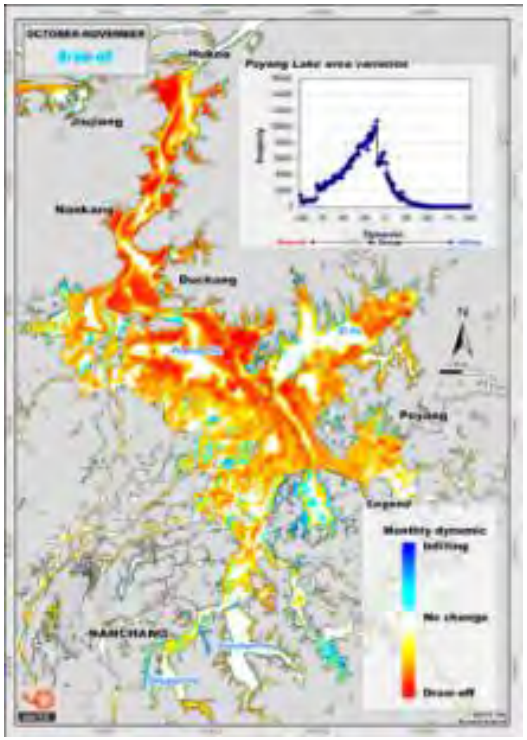
Monitoring : keys for
hydrological modeling

Inputs are long time series of EO data





Water mass movement: infilling



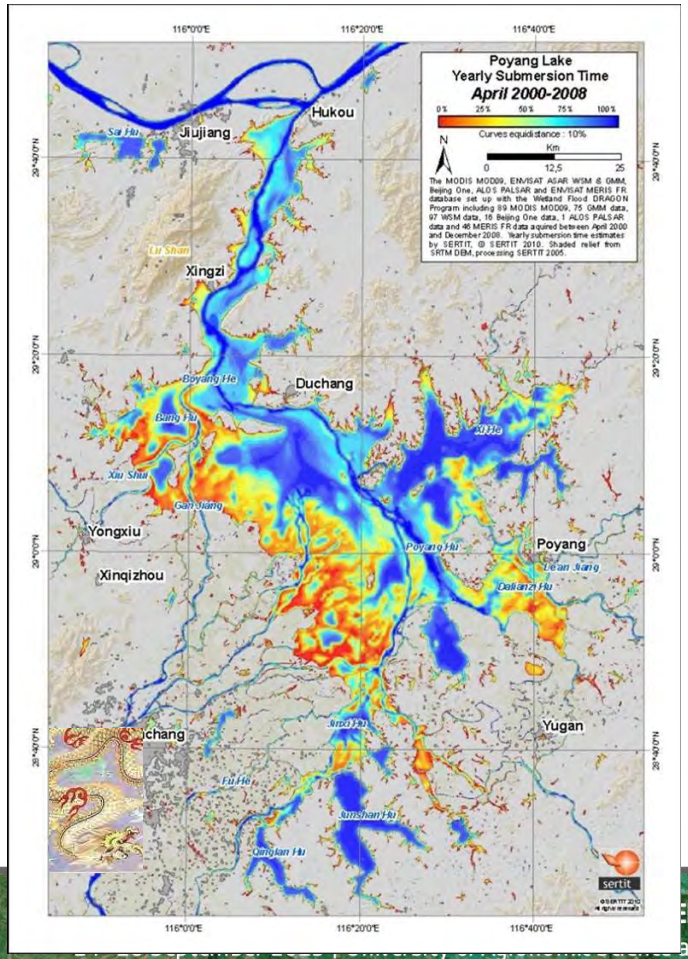
Water mass movement draw off

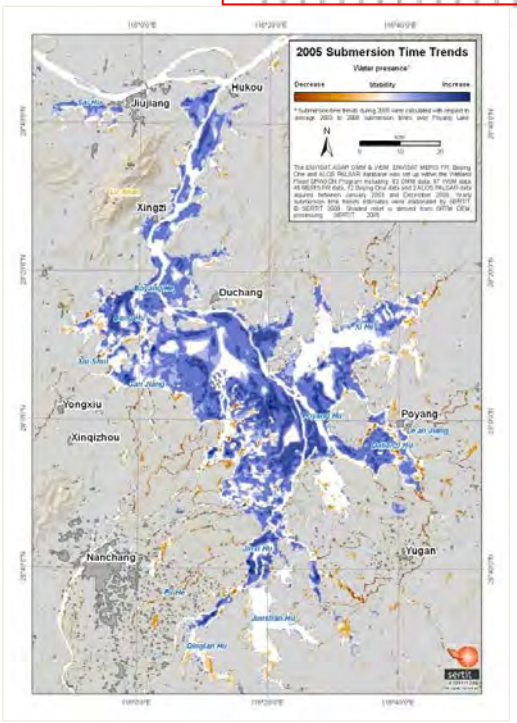
Why it is important to monitor water bodies?

Monitoring : keys for

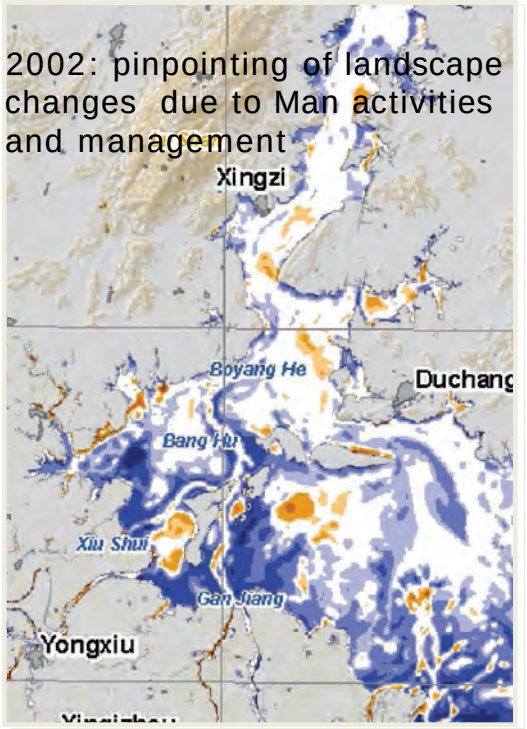
long term change

Inputs are long time series of EO data





2005 : water stay longer period due to the February flood



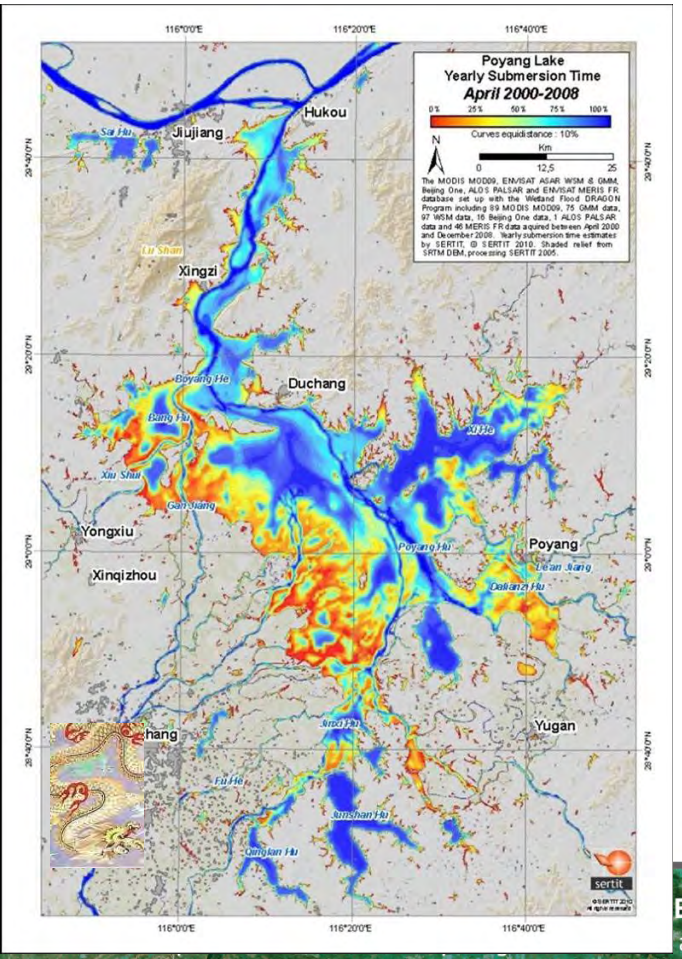
2002: pinpointing of landscape changes due to Man activities and management

2008 : Deficit of water stay in the delta part

Why it is important to monitor water bodies?

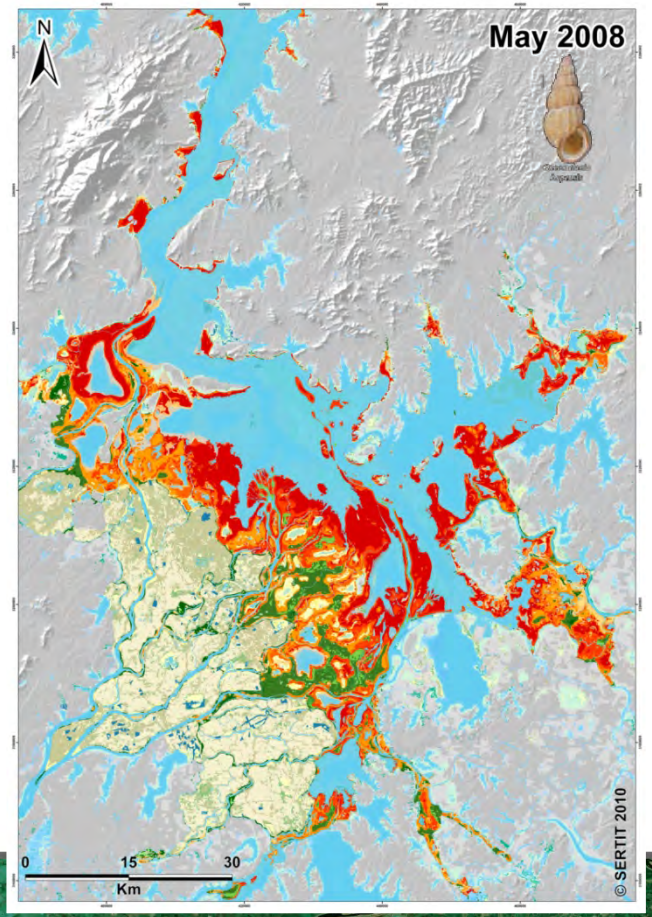
Monitoring : keys for epidemiology

Inputs are long time series of EO data



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

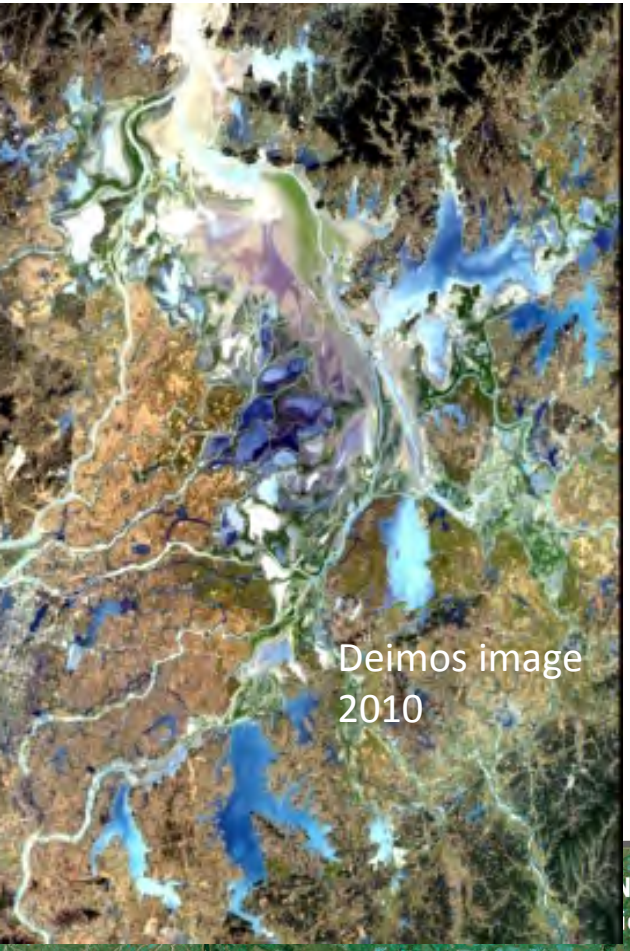
Dynamic element=> need to be monitor



Why it is important to monitor water bodies?

Monitoring : keys for **Biodiversity**

Inputs are long time series of EO data

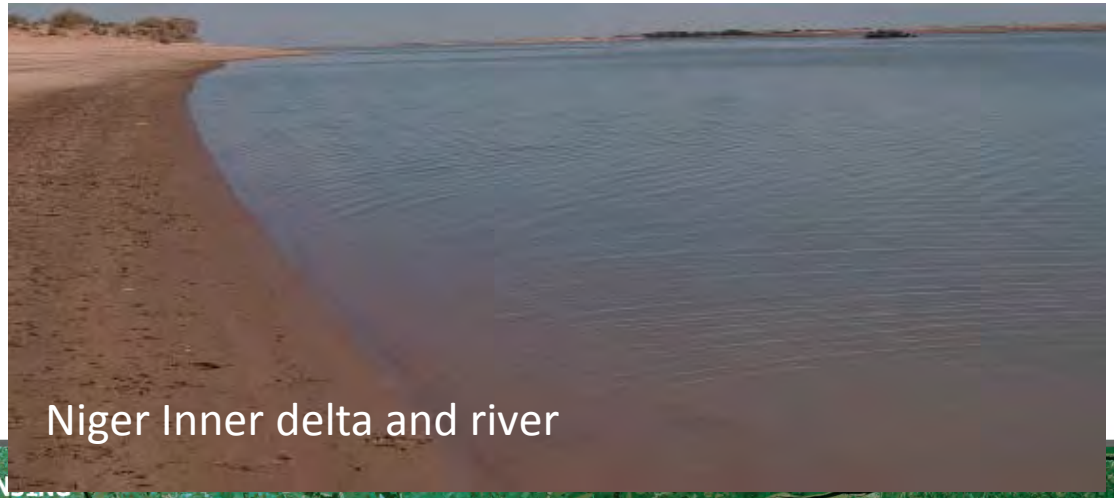


Water = key element
driving force of
sensible ecosystem
Etc …

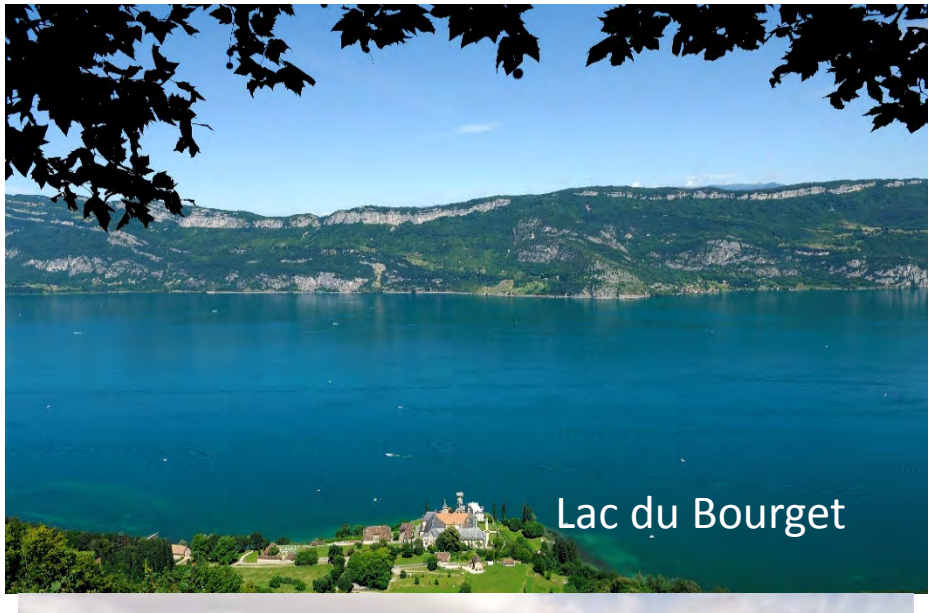
Input for oriented
field survey

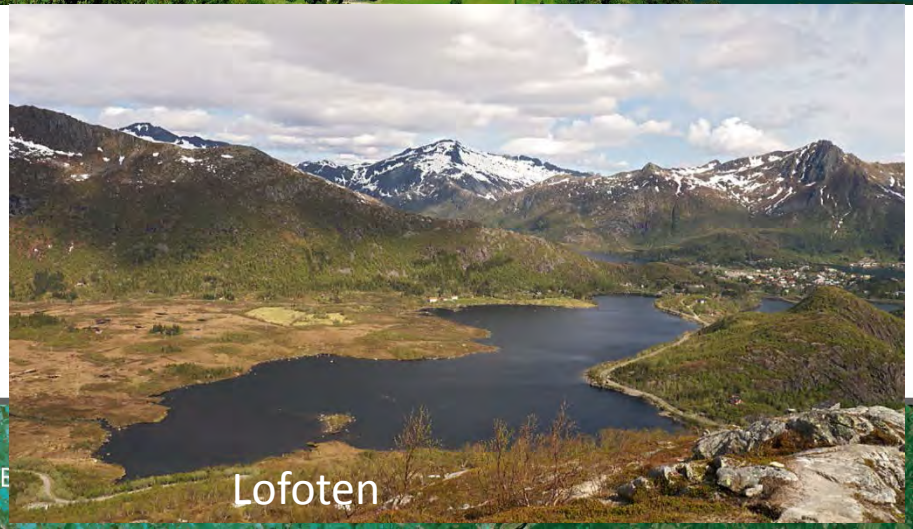
Lakes and water bodies: Landscape variability


Okavongo delta and river

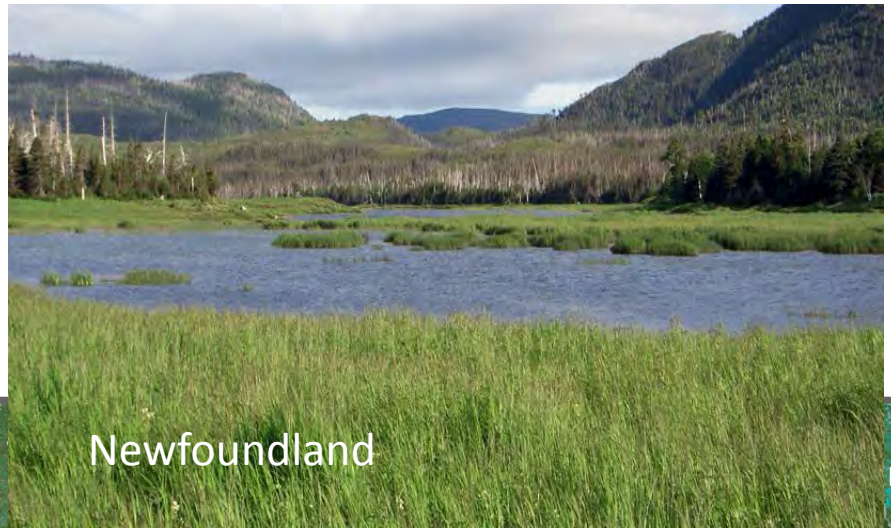

Niger Inner delta and river

Lakes and water bodies: Landscape variability





Lakes and water bodies: Landscape variability



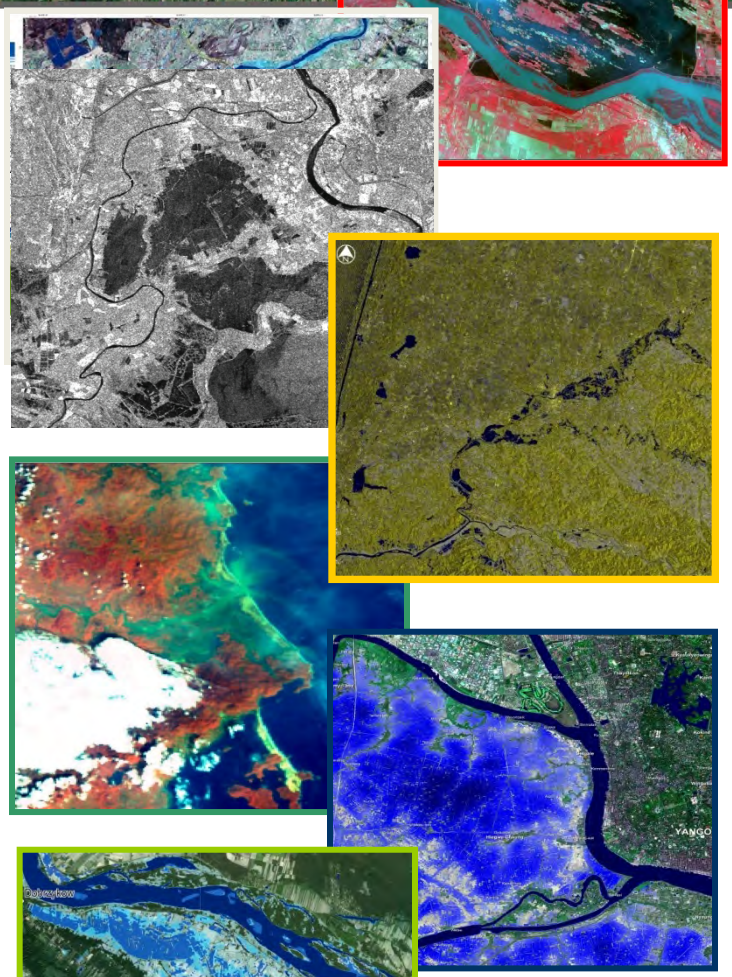
Near 30 years of exploitation of EO data for water bodies mapping and monitoring

Improvement from one generation to another one

- SPOT1-3 to SPOT4-5
- SPOT => VHR
- MODIS => MERIS
- ERS =>ENVISAT
- Radarsat 1 => Radarsat 2
- VHR SAR TerraSar X and CSK
- Sentinel 1 A and coming B

Improvement in term of

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



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

Presentation outline

Introduction: Why water bodies and flood mapping and monitoring

Flood mapping exploiting SAR data

- **Basis physical principles**
- **From ERS to ASAR towards Sentinel**
- **New generation of ASAR: VHR SAR + Sentinel**

Flood mapping exploiting optical data (short overview)

- PIR and SWIR bands exploitation
- From Medium to VHR data

Floods and lakes monitoring

- Long term monitoring
- Meteo climato parameters

Concluding remarks, new trends and recommendations

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

Near all weather capability

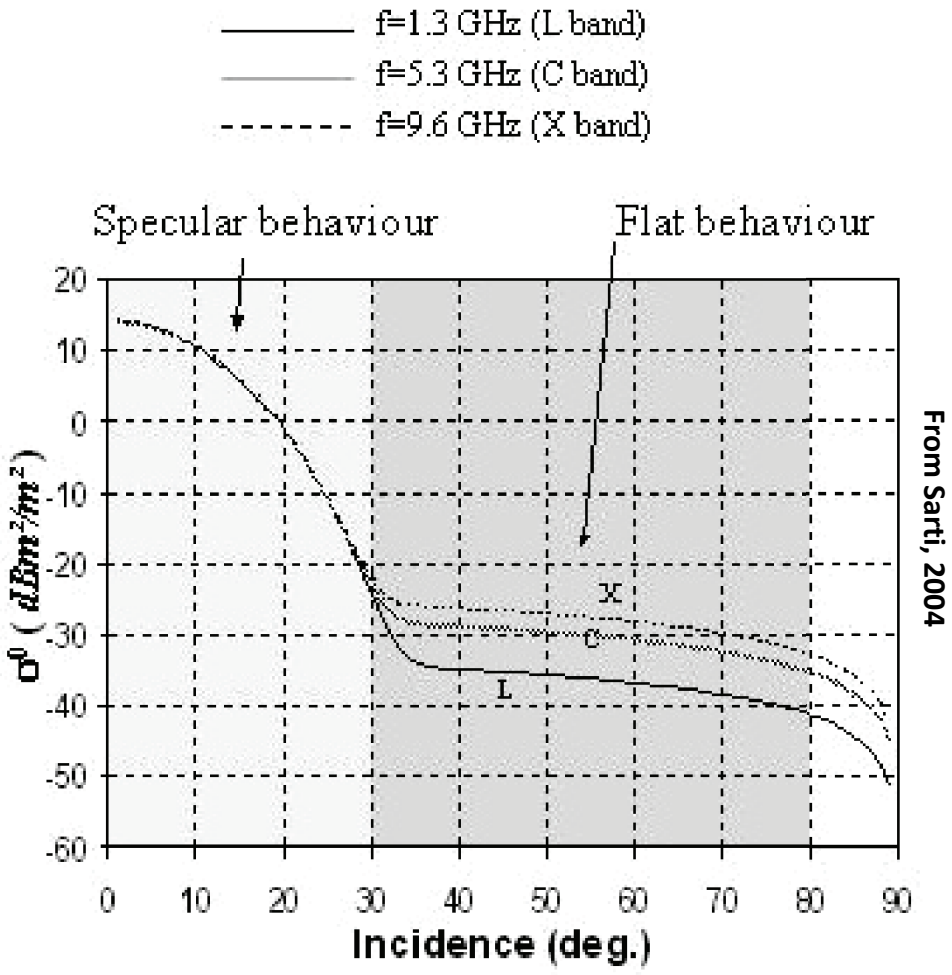
Day & night capabilities

Relative large swath

Relative good revisit

On SAR data water surfaces have low values of BS

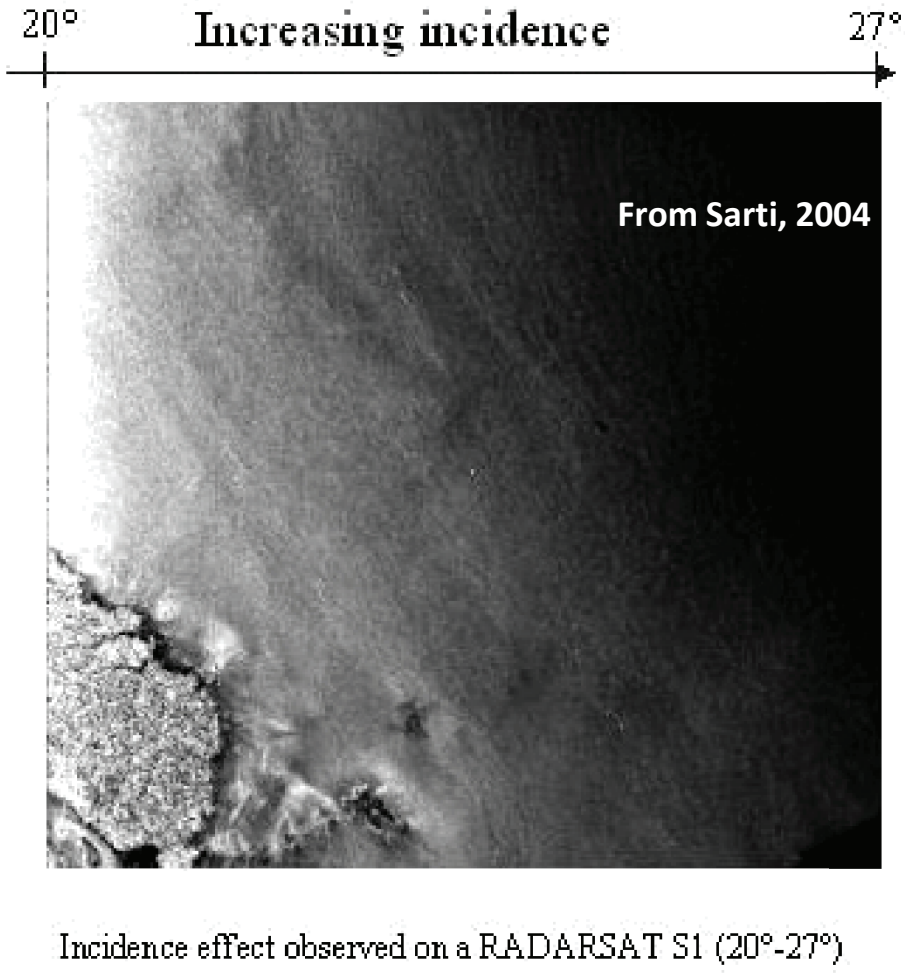
But local weather (wind/rain) effect altering the signal



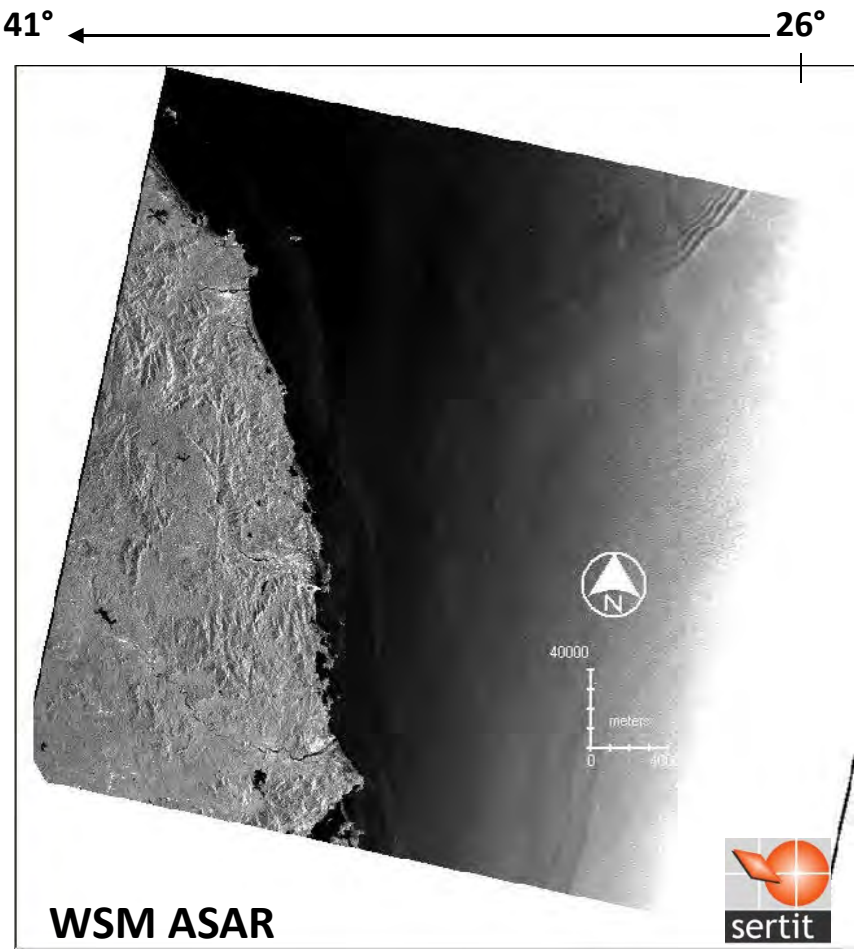
From Sarti, 2004

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

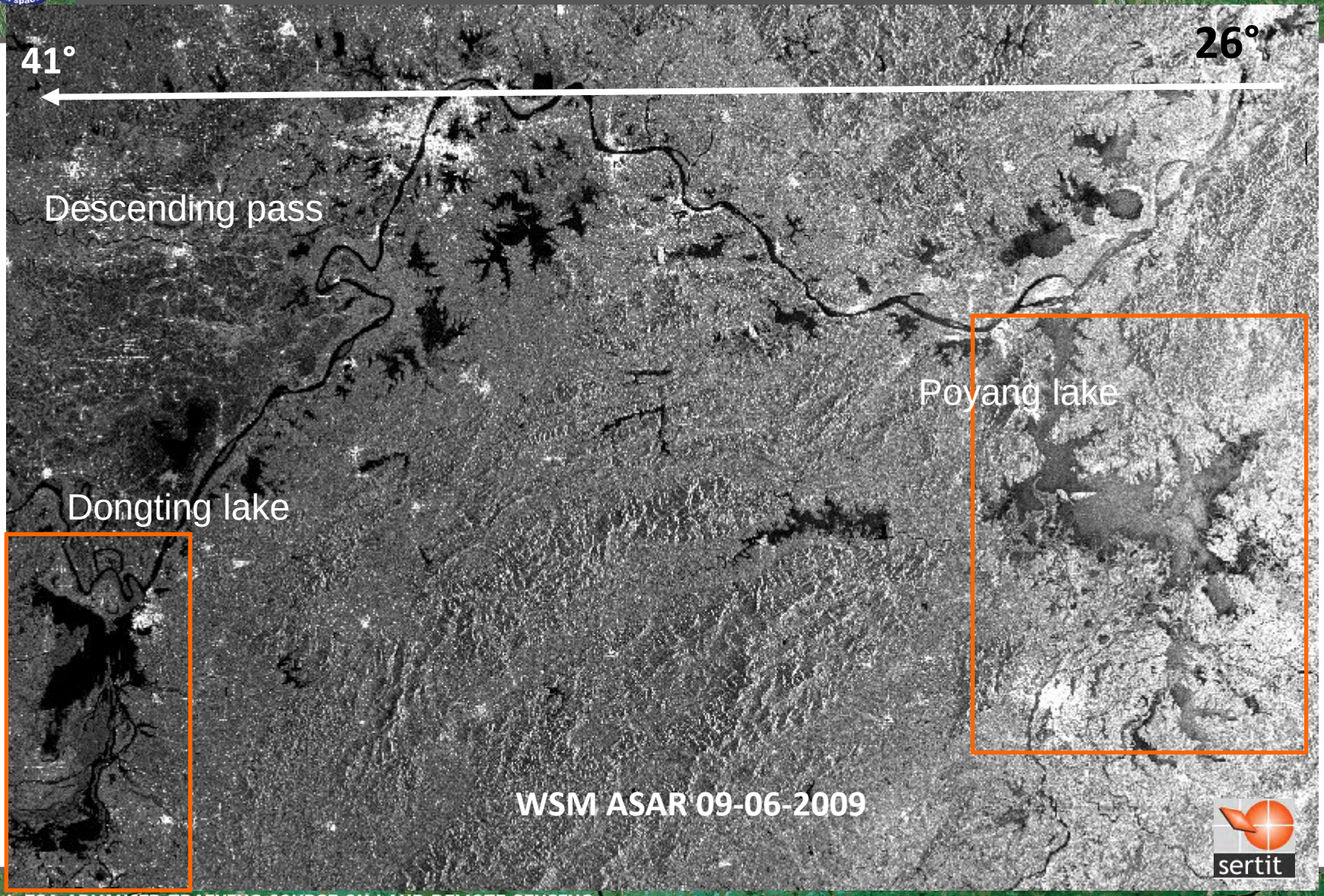
Water backscattering in function of incidence angle



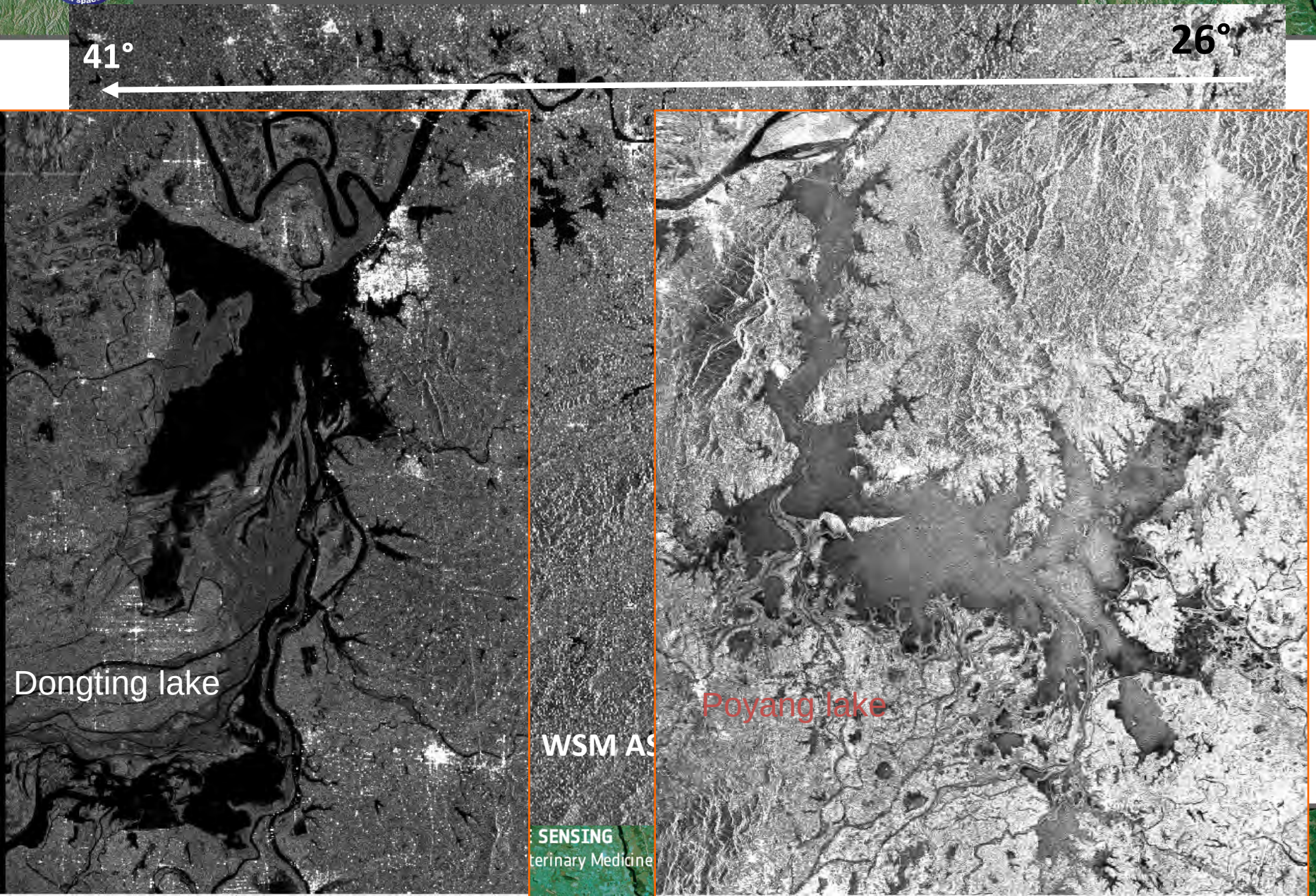
Incidence effect observed on a RADARSAT S1 (20°-27°)



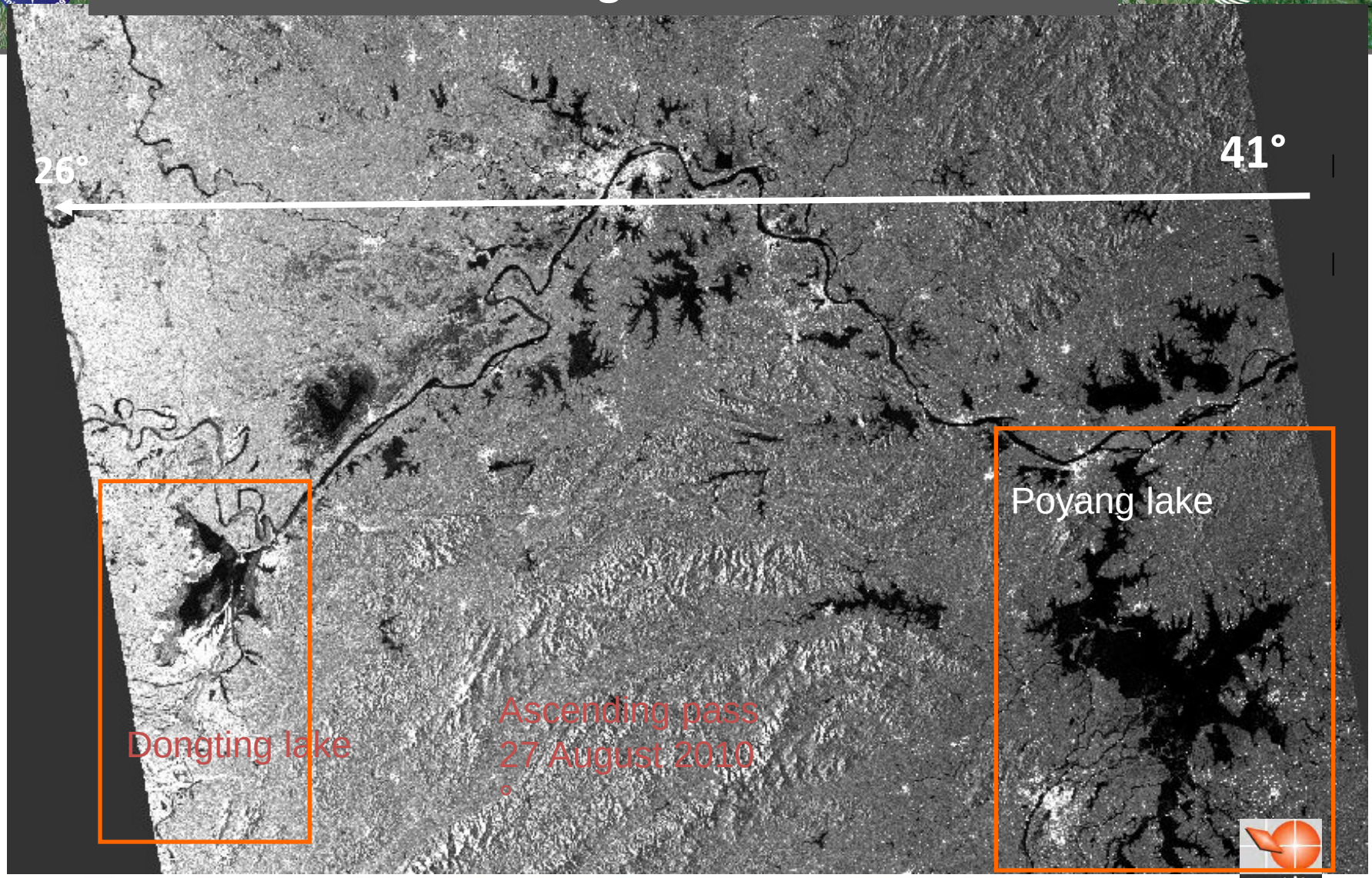
Water backscattering in function of incidence angle



Water backscattering in function of incidence angle

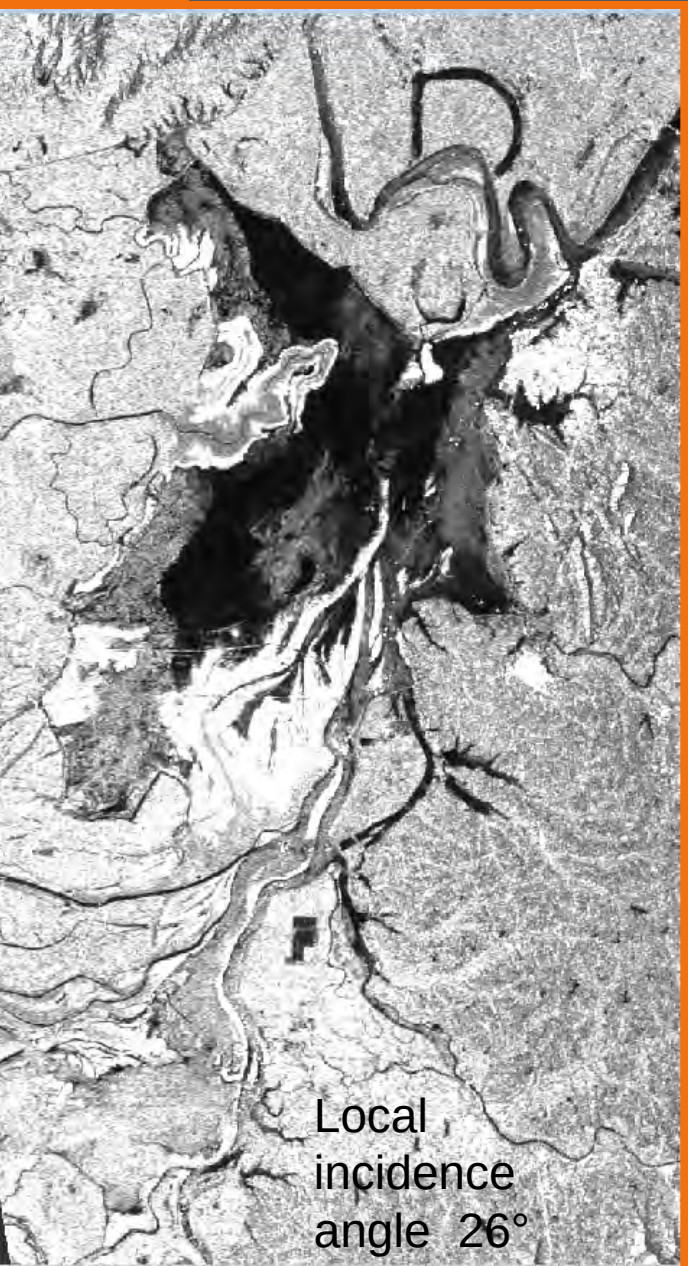


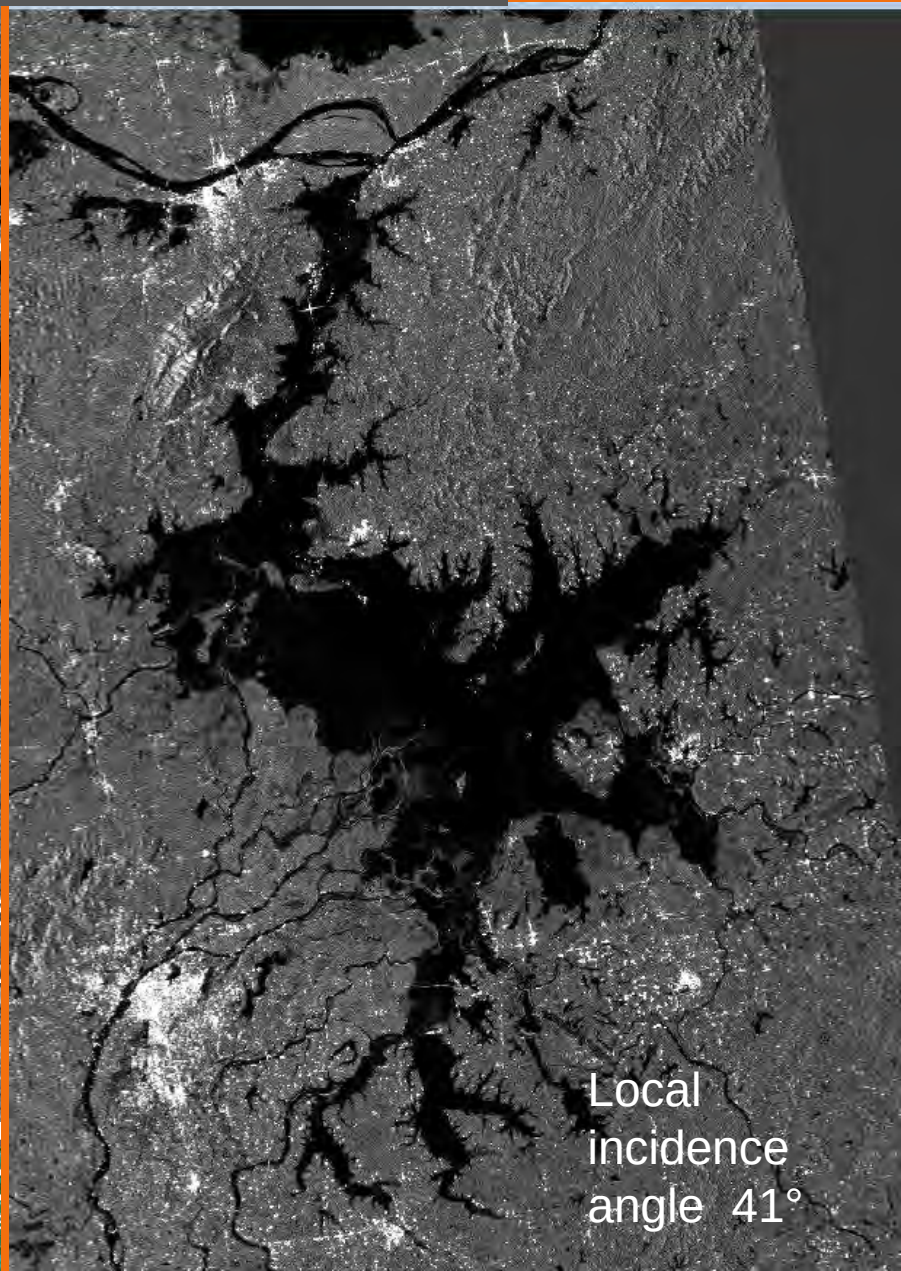
Water backscattering in function of incidence angle



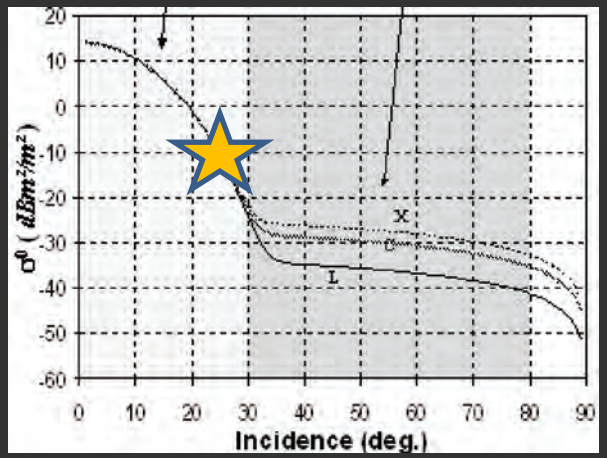
WSM ASAR 09-06-2009

Water backscattering in function of incidence angle



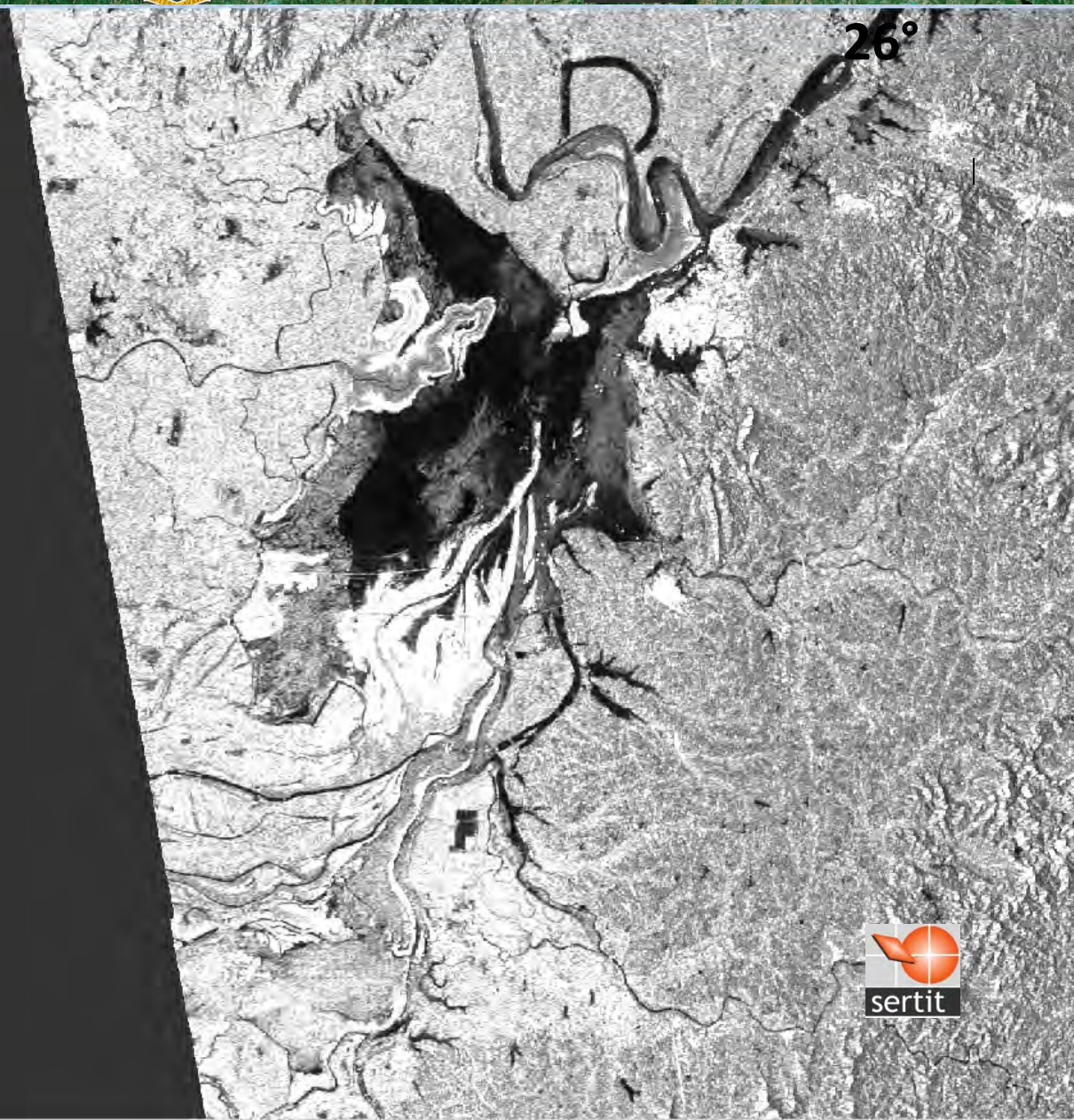


Water backscattering in function of incidence angle

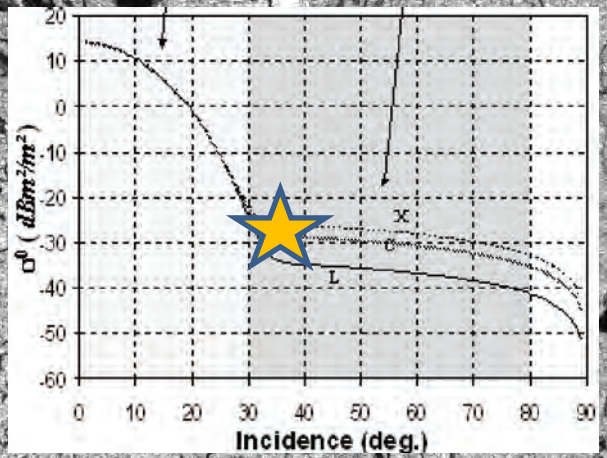


Dongting lake

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



Water backscattering in function of incidence angle



26°

Dongting lake

Ascending pass
30 August 2010
Local incidence angle = 32-33 °

Water backscattering in function of surface roughness

Signal - Surface interactions Rayleigh criterion

Specular reflection (smooth surface)

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

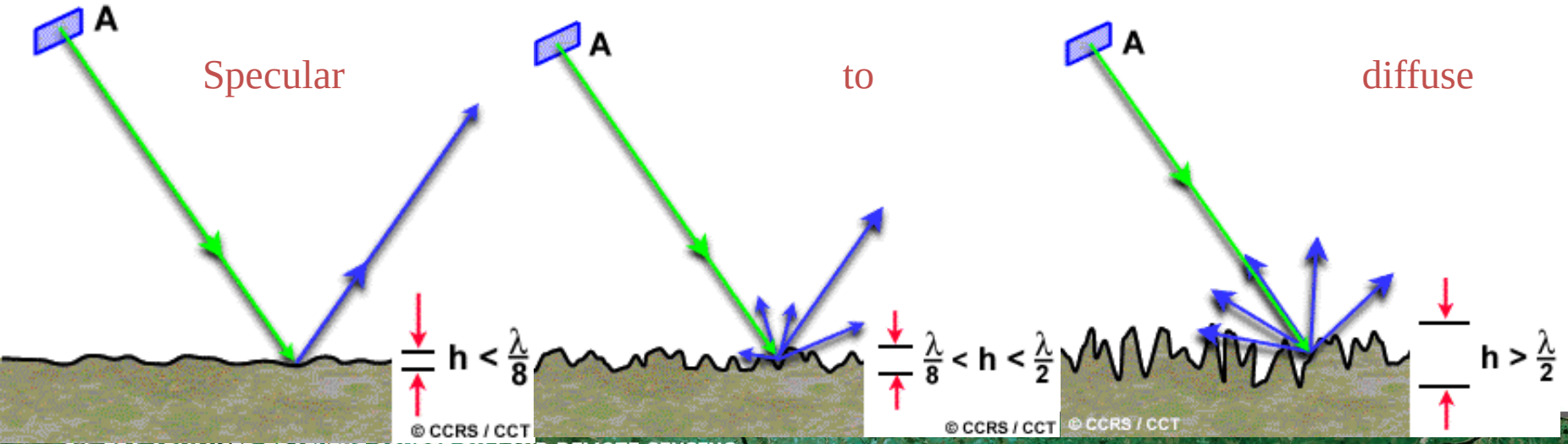
Diffuse reflection (rough surface)

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

λ varies from

- **K 1cm**
- **X 3cm**
- **C 5.6cm**
- **S 10cm**
- **L 23cm**
- **P 70cm**

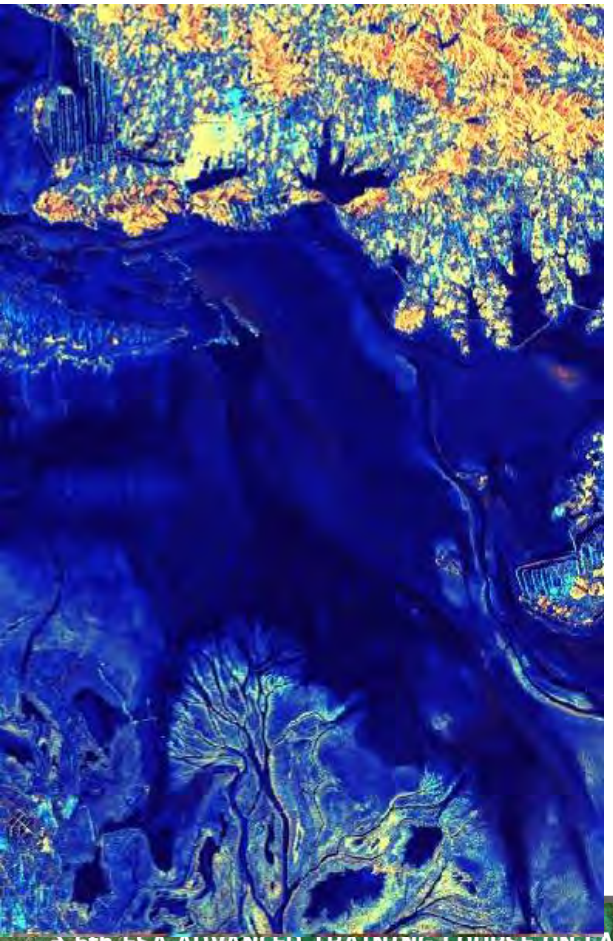
HJ-C
ALOS PALSAR



Water backscattering in function of surface roughness

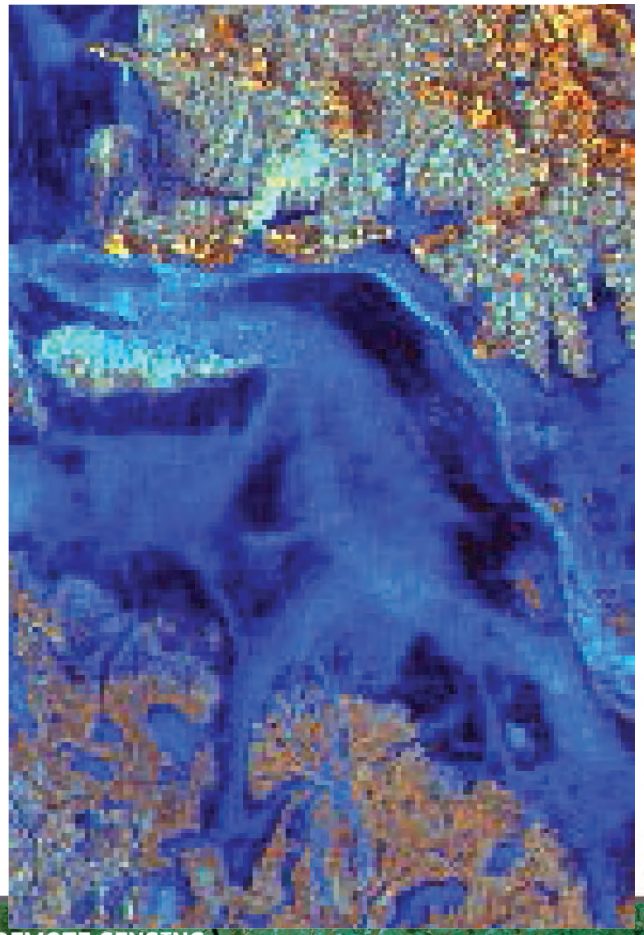
PALSAR bande L HH/HV

Low level of water



ASAR bande C HH/HV

Intermediate level of water

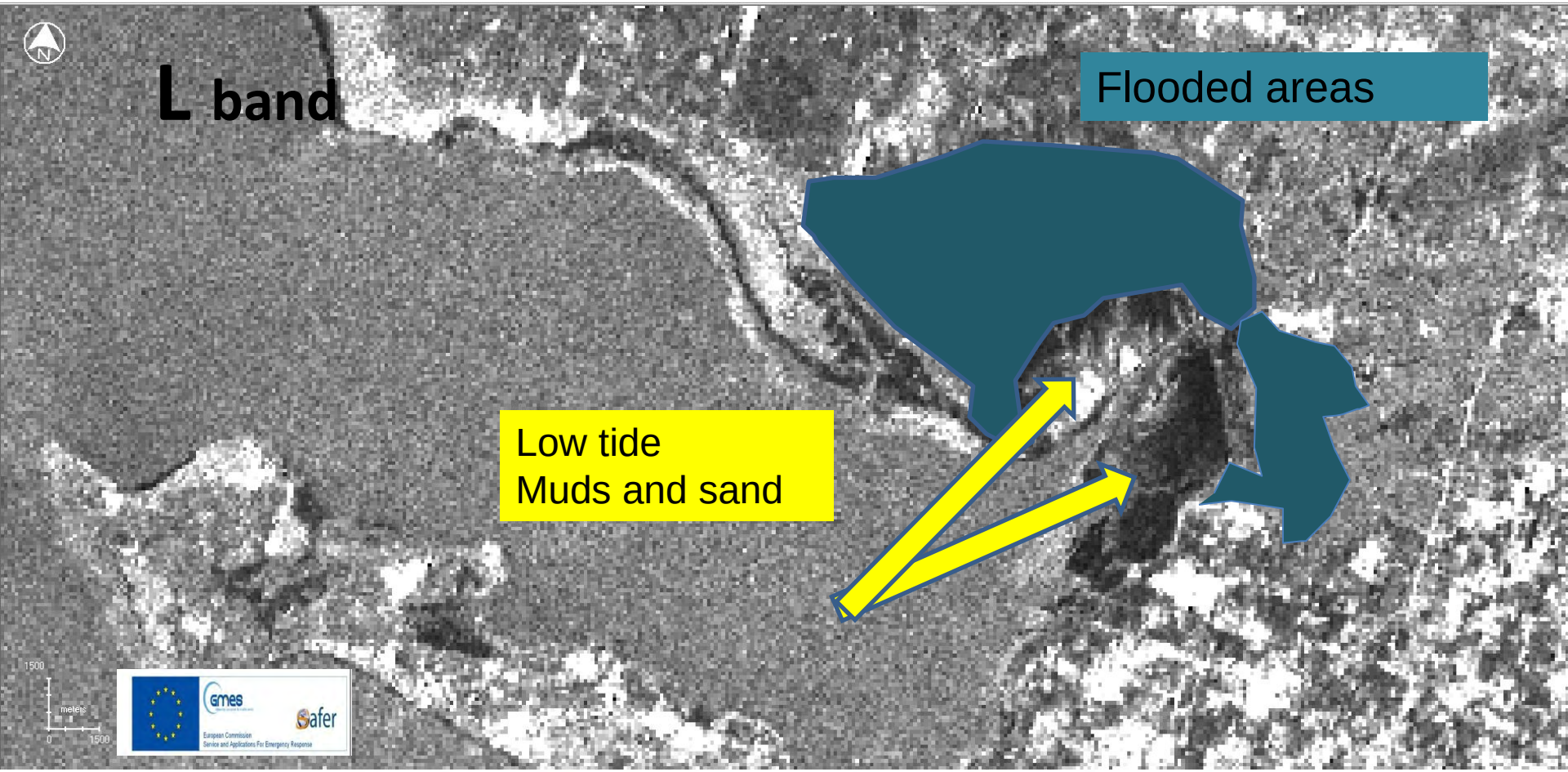


TerraSar bande X HH/HV

Low level of water

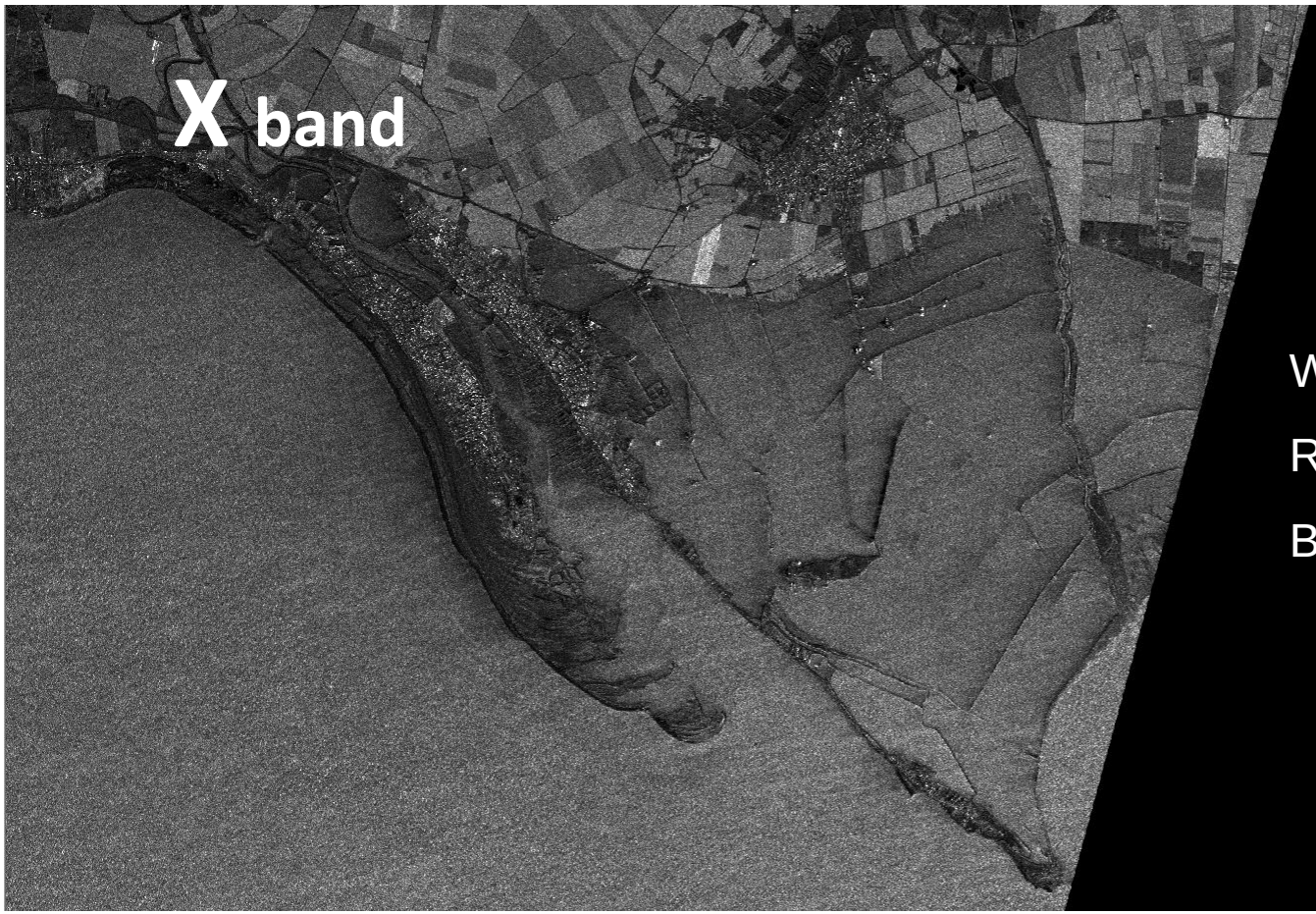
Water backscattering in function of water/soil surface roughness

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



Water backscattering in function of surface roughness

TerraSAR X the 2010 03 03



Windy Condition

Rough water surface

Backscaterring increase

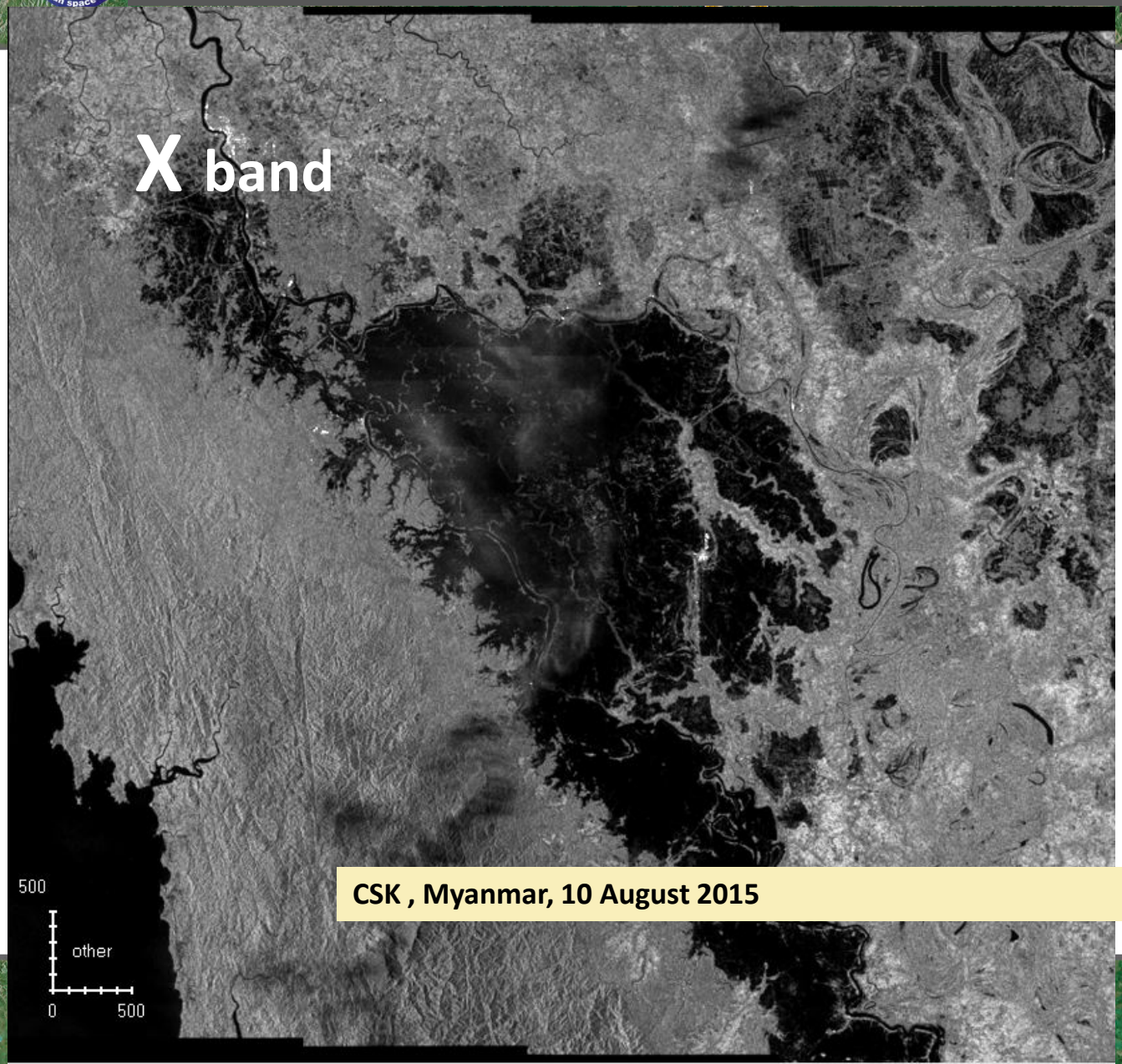
Water backscattering in function of surface roughness

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

Water backscattering in function of surface roughness

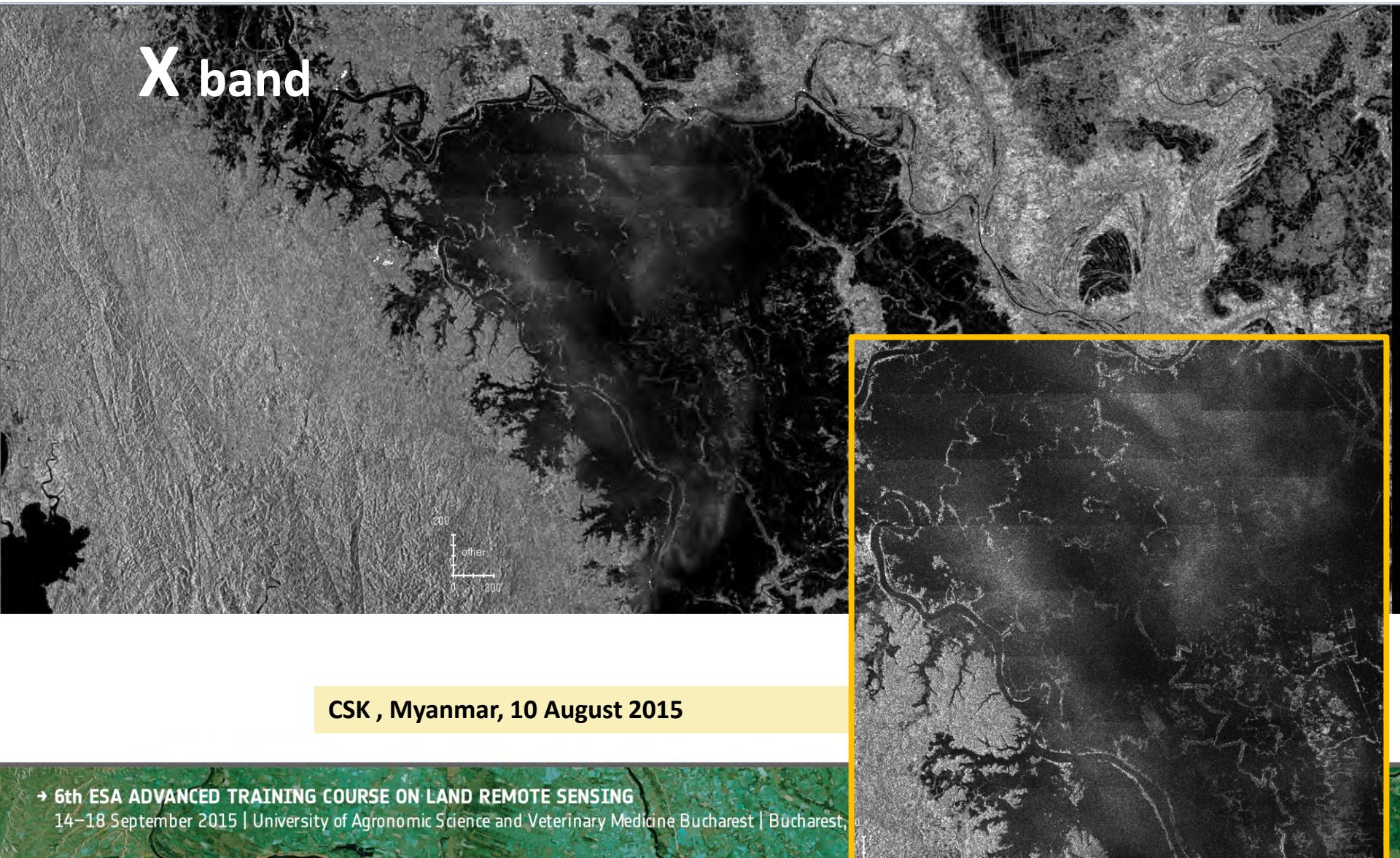
TerraSAR X the 2010 03 06

Water backscattering in function of water surface roughness: rain



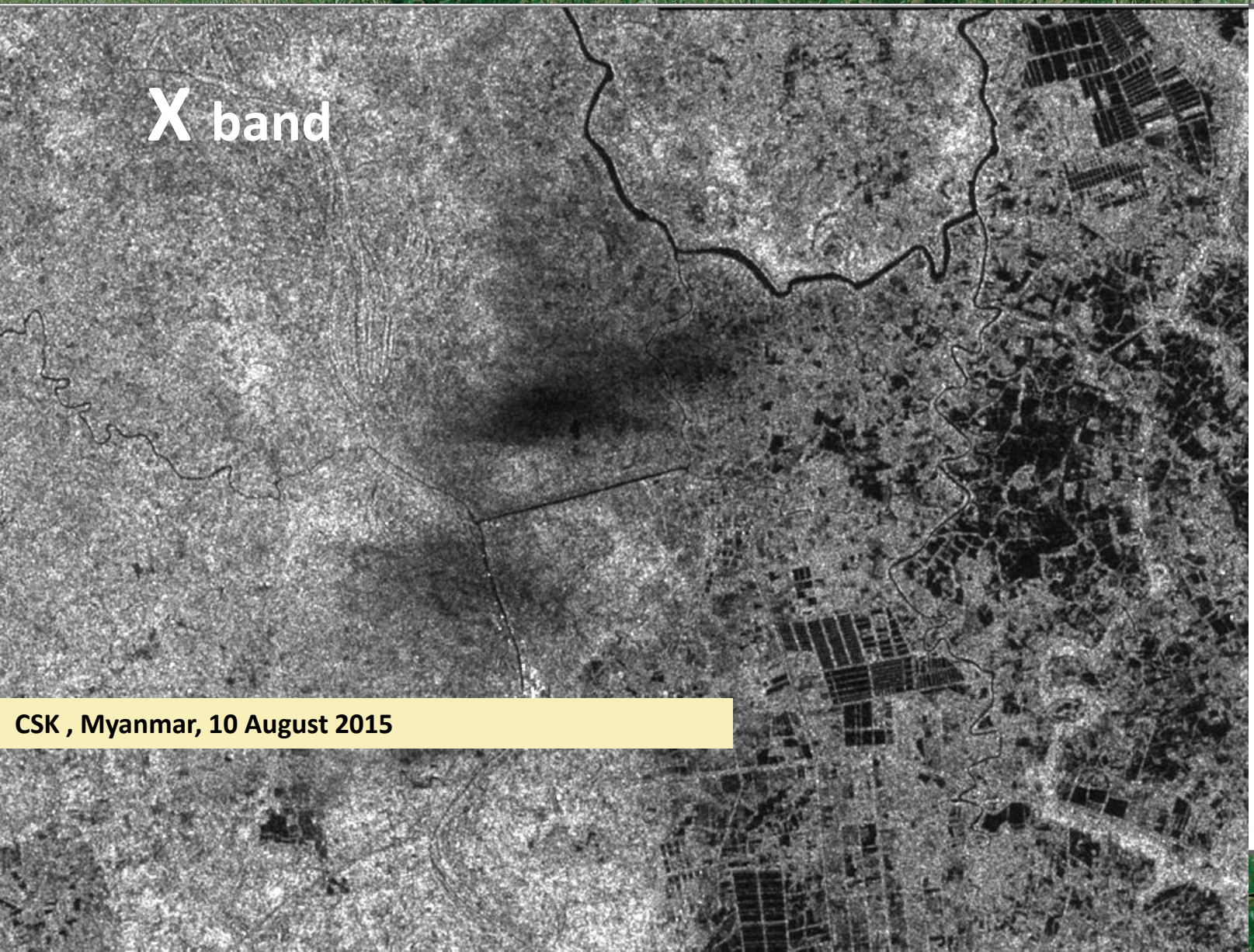
CSK , Myanmar, 10 August 2015

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



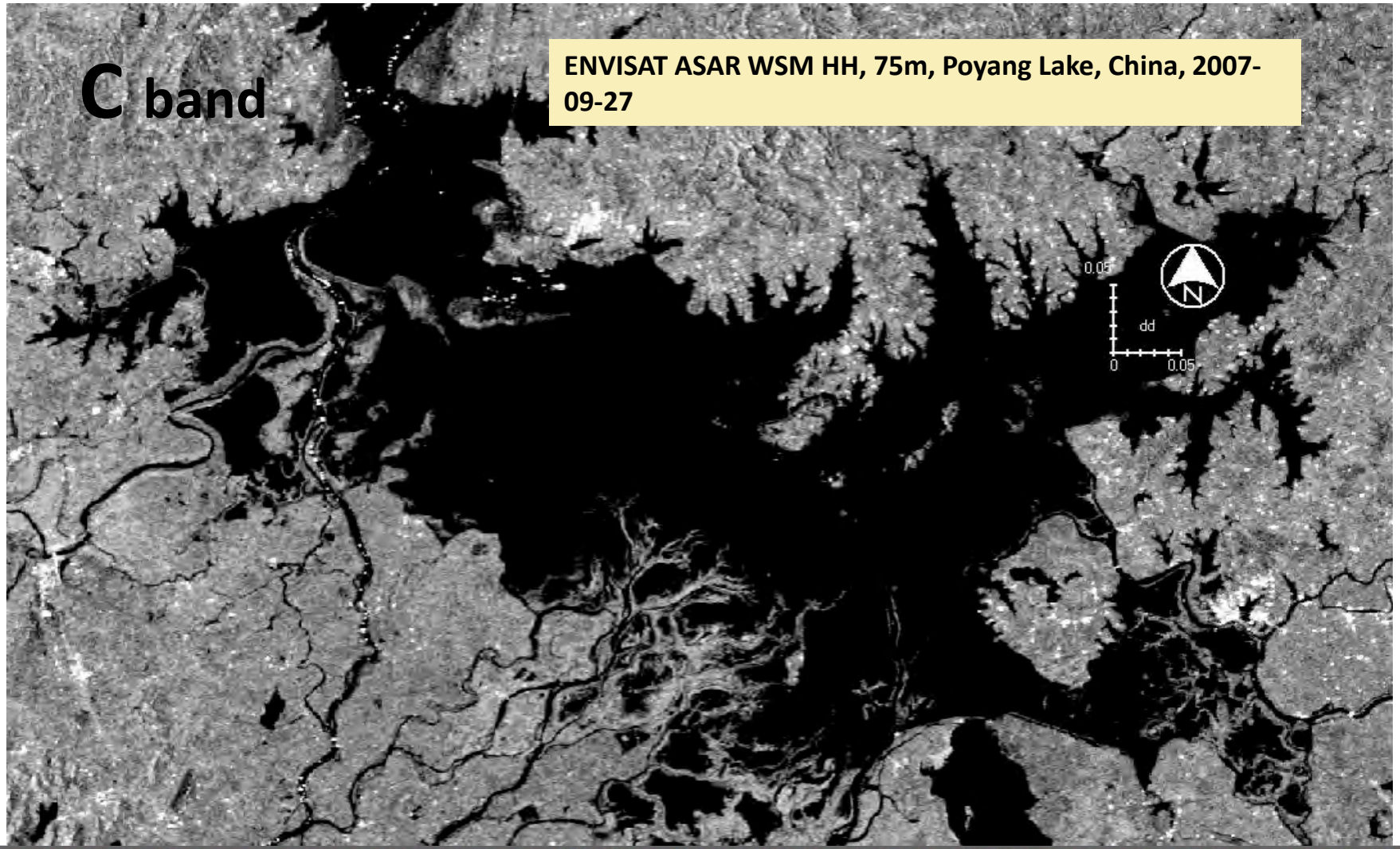
CSK , Myanmar, 10 August 2015

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

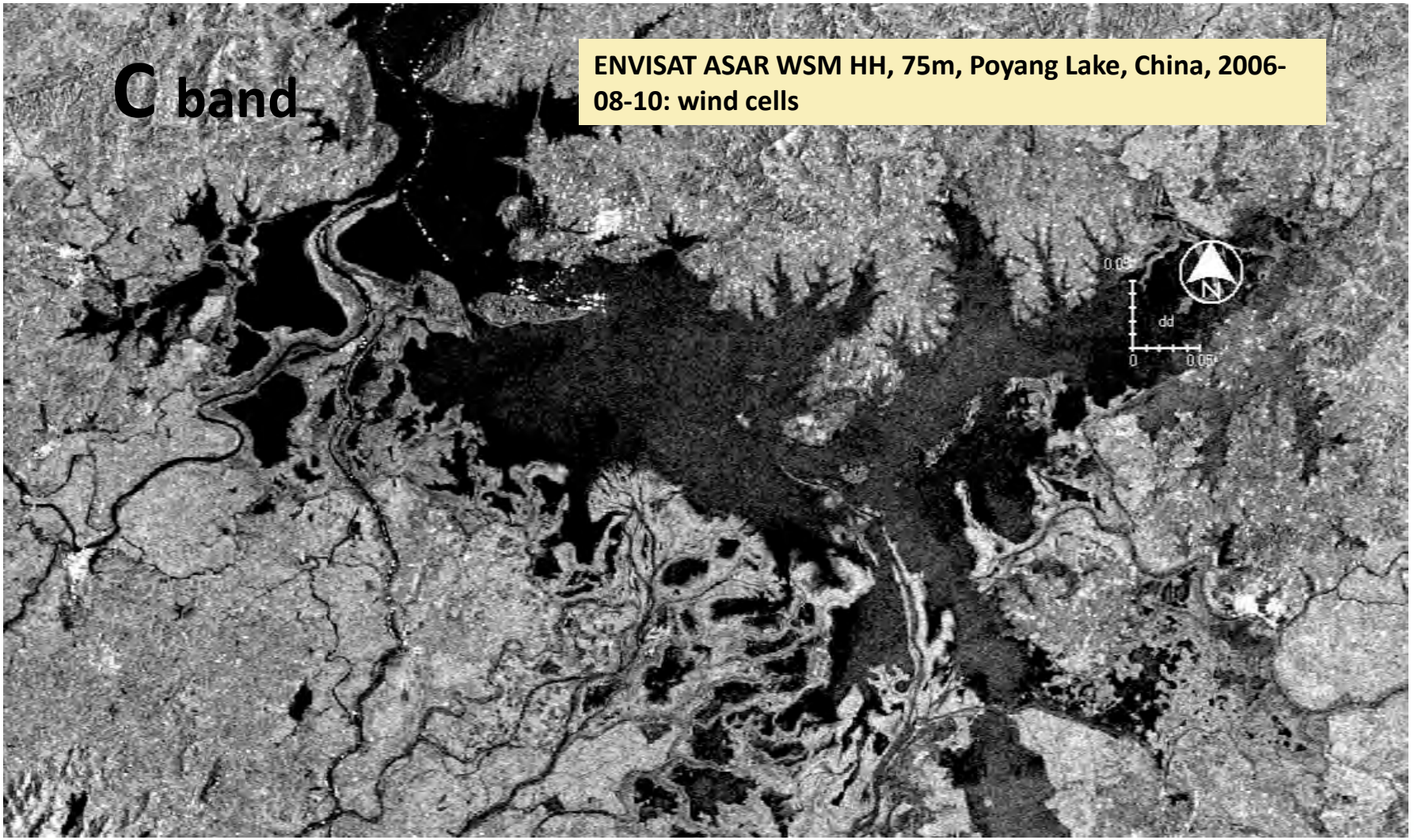


CSK , Myanmar, 10 August 2015

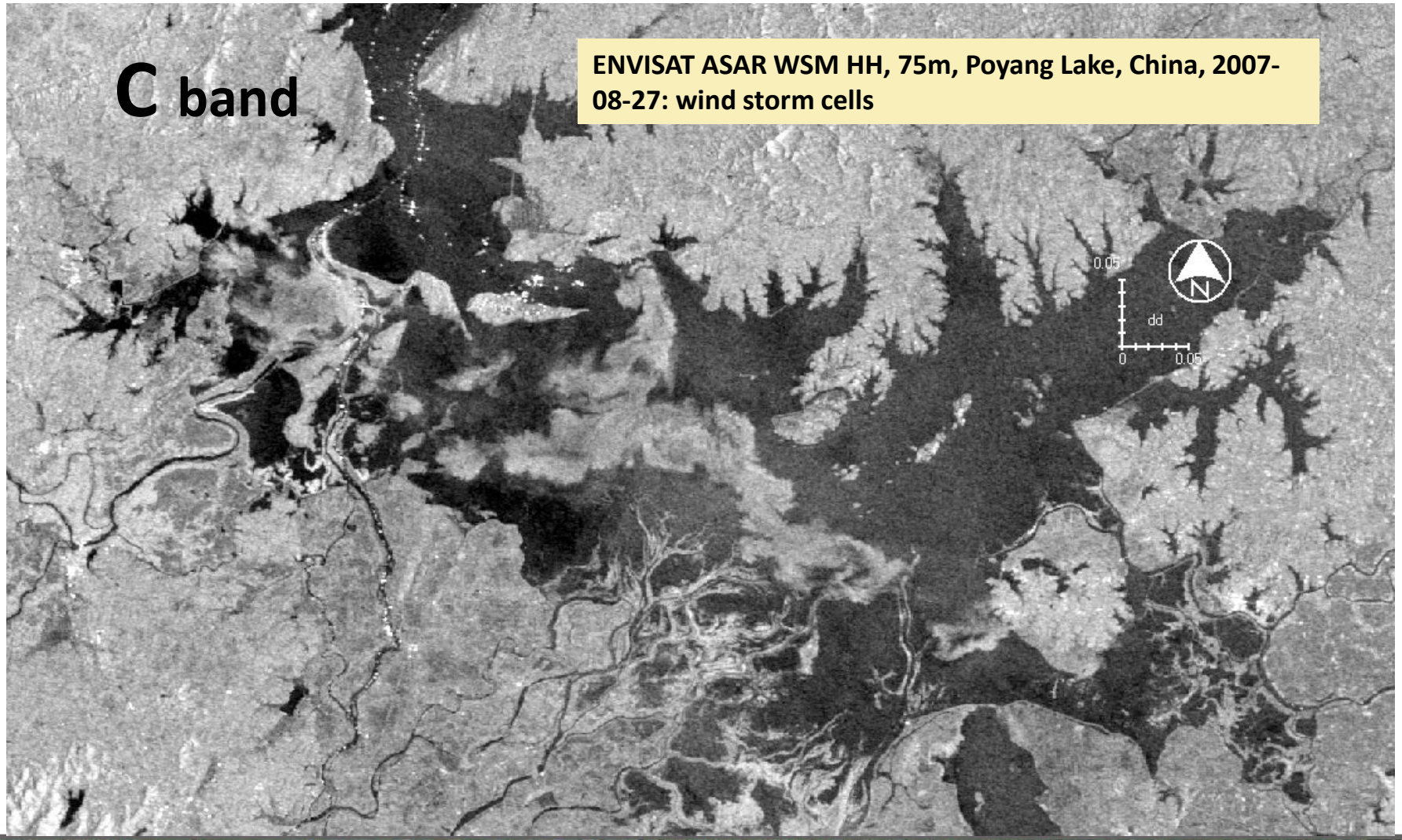
Water backscattering in function of water surface roughness: rain & wind



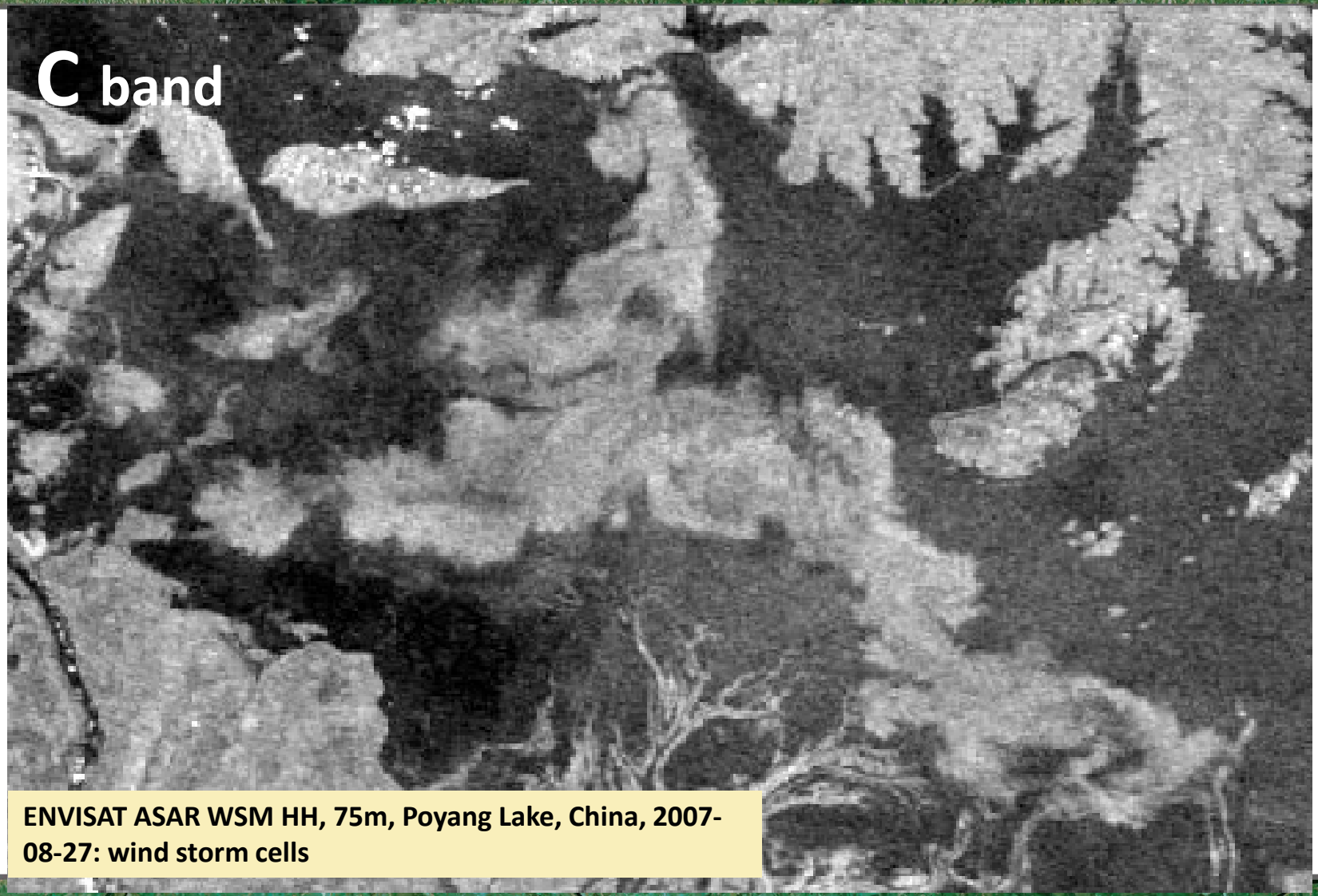
Water backscattering in function of water surface roughness: rain & wind



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

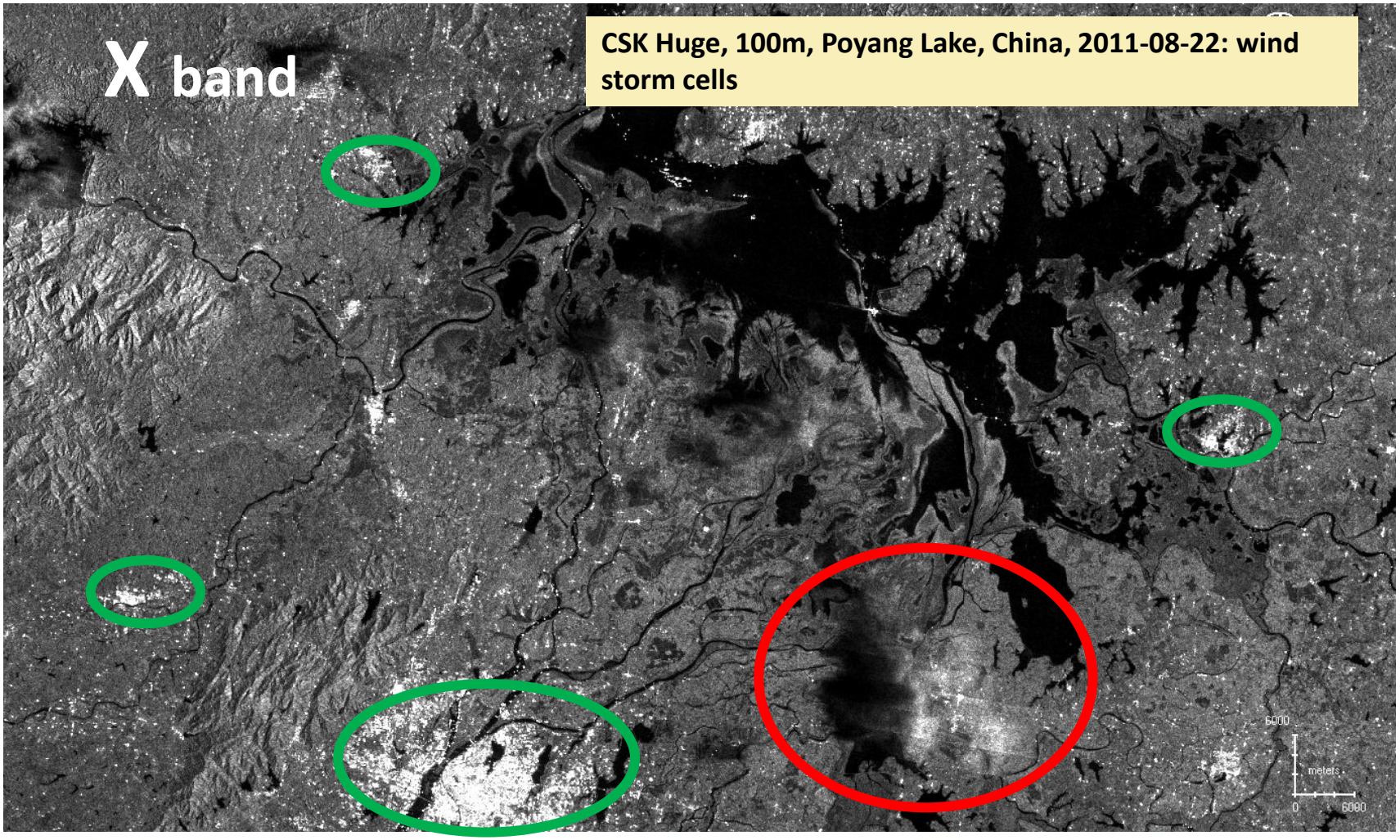


Water backscattering in function of water surface roughness: rain & wind

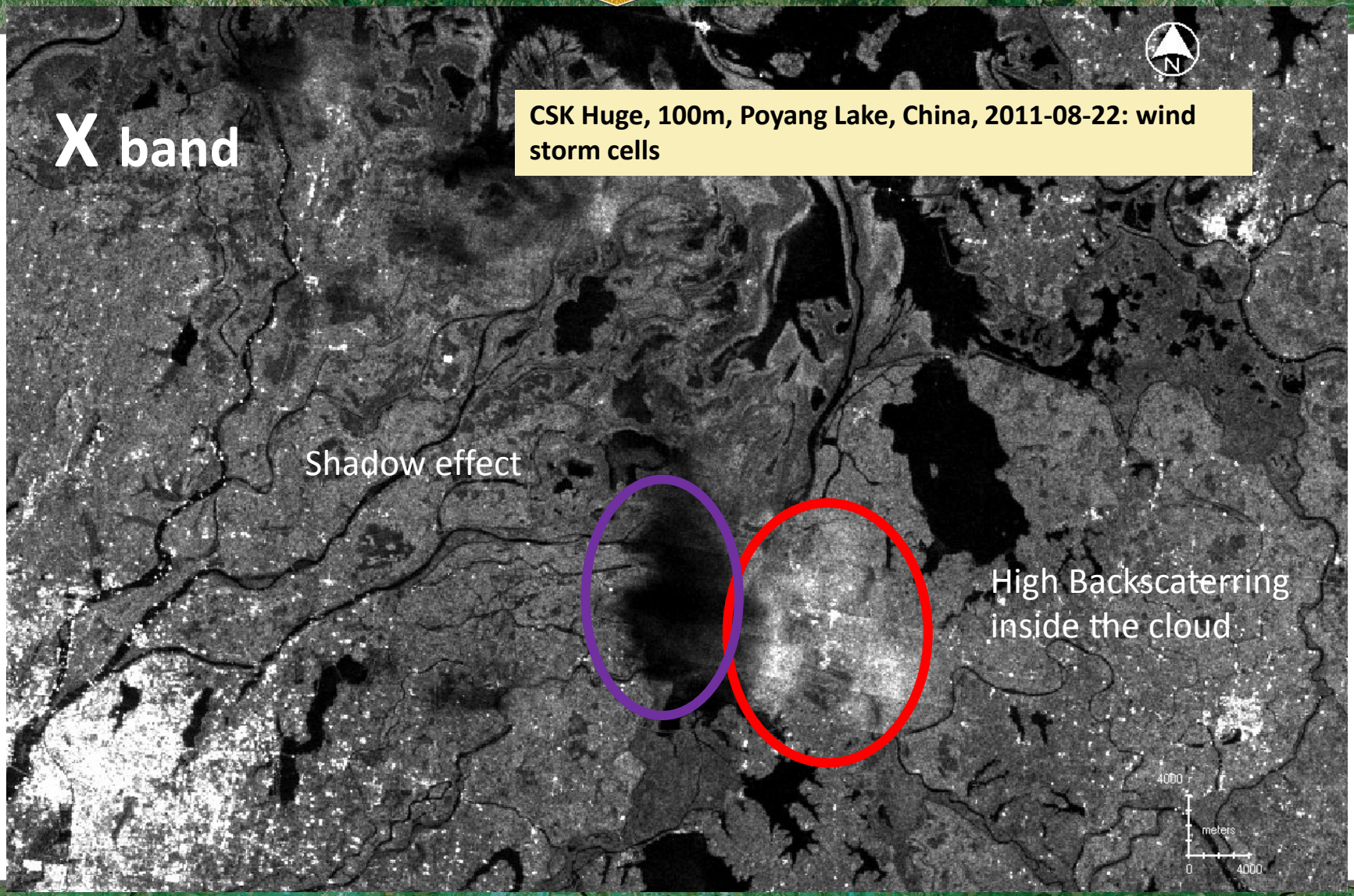


ENVISAT ASAR WSM HH, 75m, Poyang Lake, China, 2007-08-27: wind storm cells

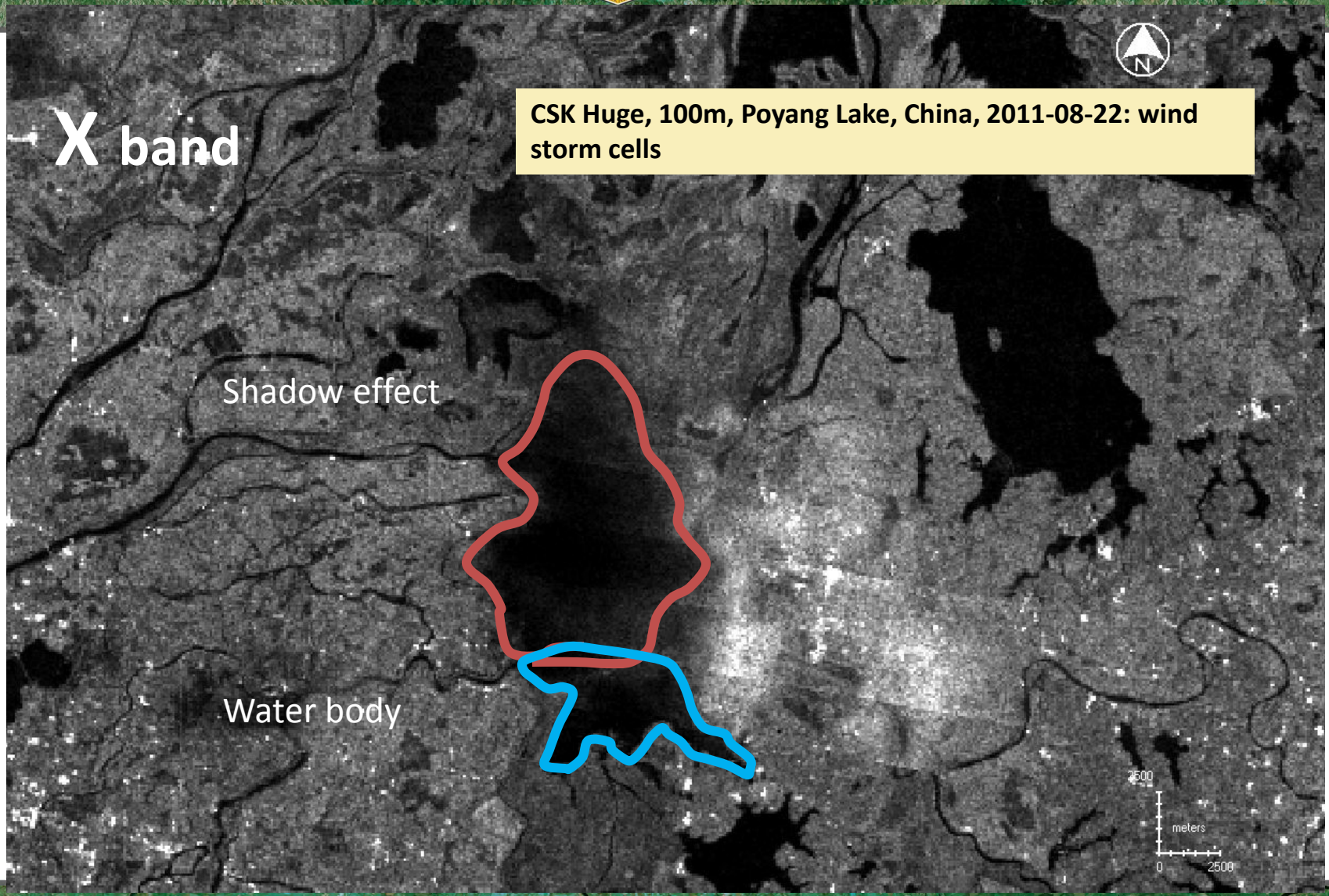
Water backscattering in function of water surface roughness: rain & wind



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



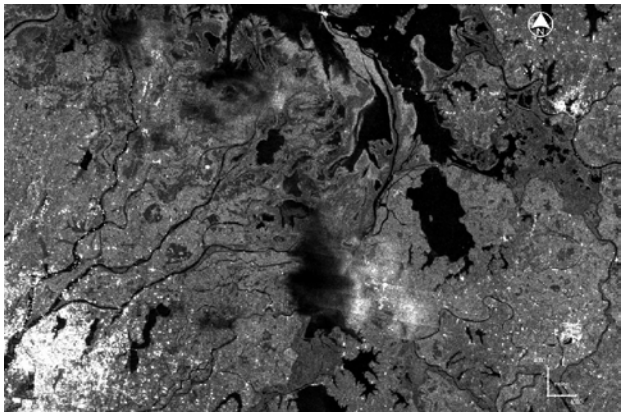
Water backscattering in function of water surface roughness: rain & wind



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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- 1 image ASAR ENVISAT en bande C, over more than 200 analyzed
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Ivory coast

1 TerraSAr Stripmap, X band, over 5 analysed

Attenuation due to the rain fall

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

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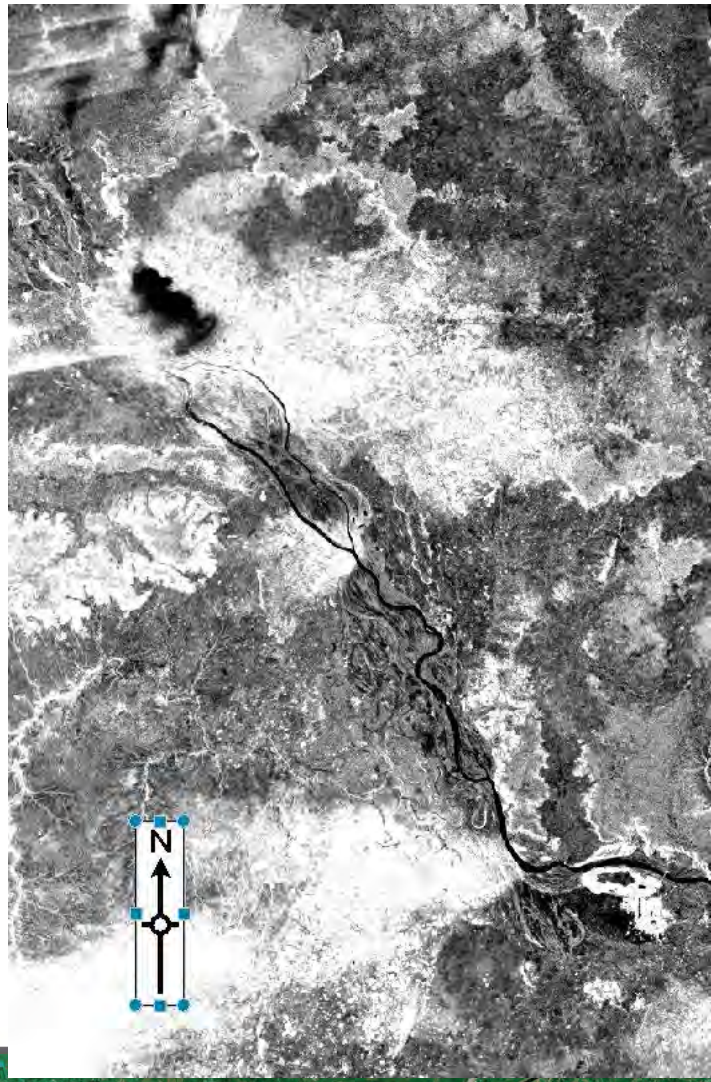
- 1 image CSK Huge, bande X, over 15 analyzeds…

Ivory coast

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

Niger:

1 TerraSAR X ScanSAR, X band, over 3 analysed



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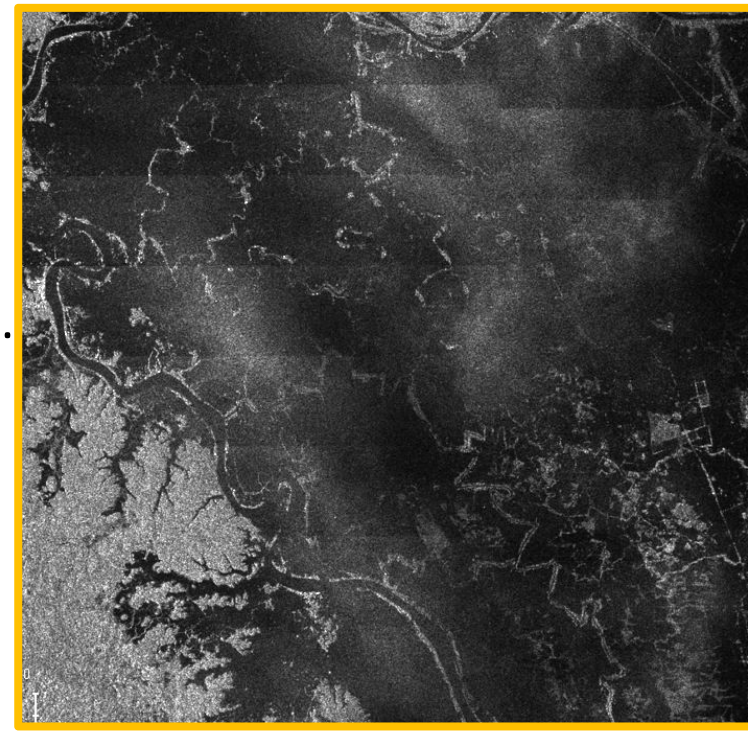


Ivory coast

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

Niger:

1 TerraSAR X ScanSAR, X band, over 3 analysed

Attenuation and huge ackscaterring

Myanmar

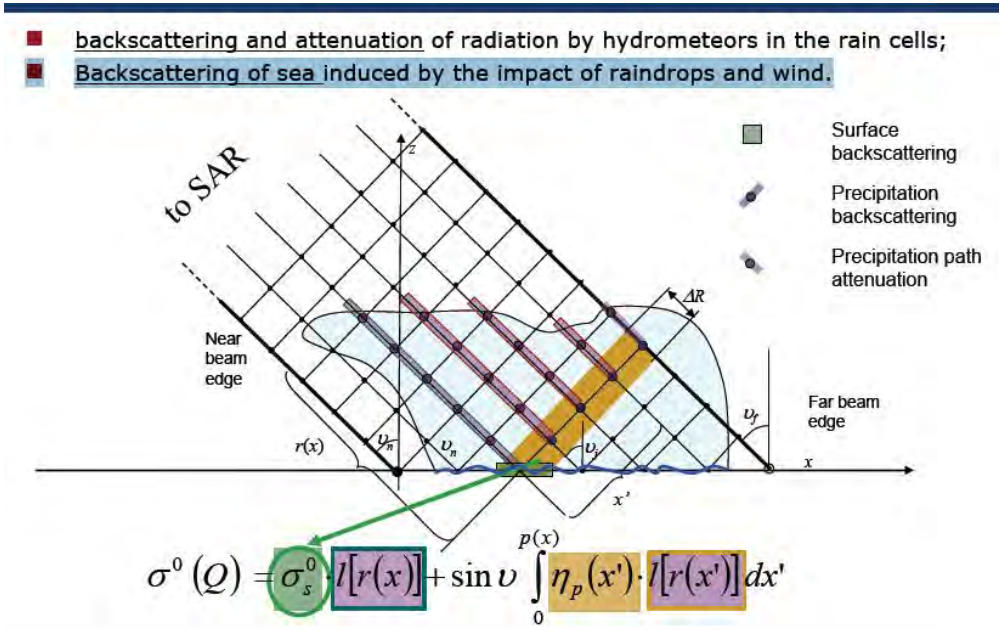
1 CSK, X band

sertit

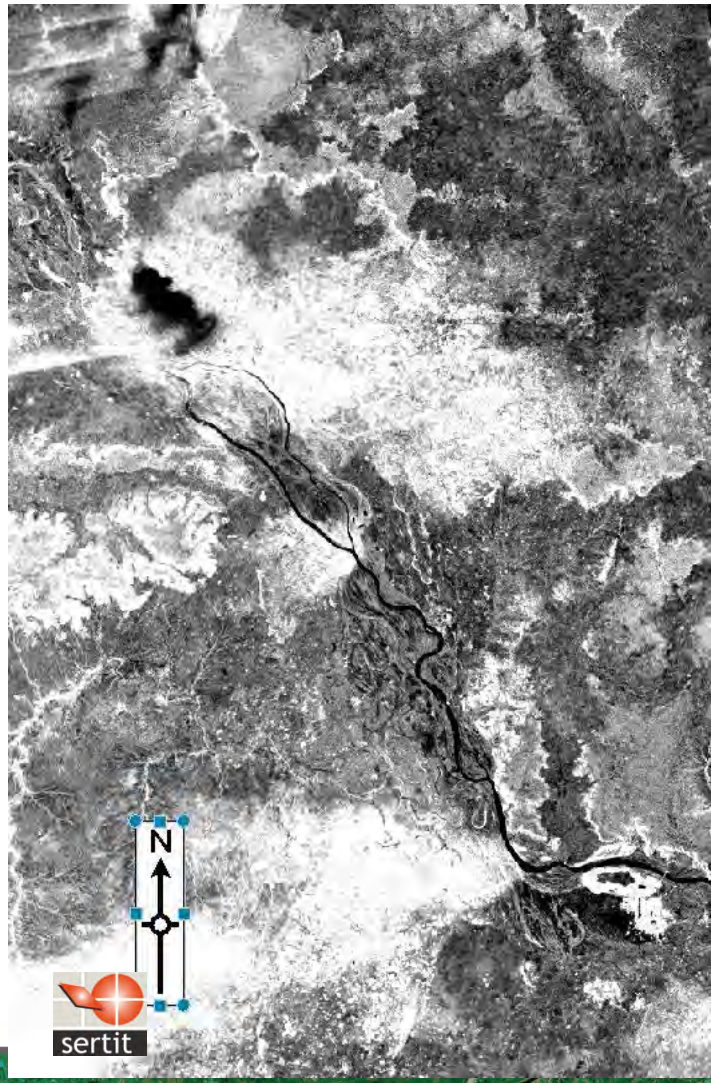
Water backscattering in function of cloud /precipitation : country with contrasted rainy/dry season

Very high sensibility to rainfall and clous in X band

Be careffull!!



Bakldini et al., 2012, from Meteo Italy



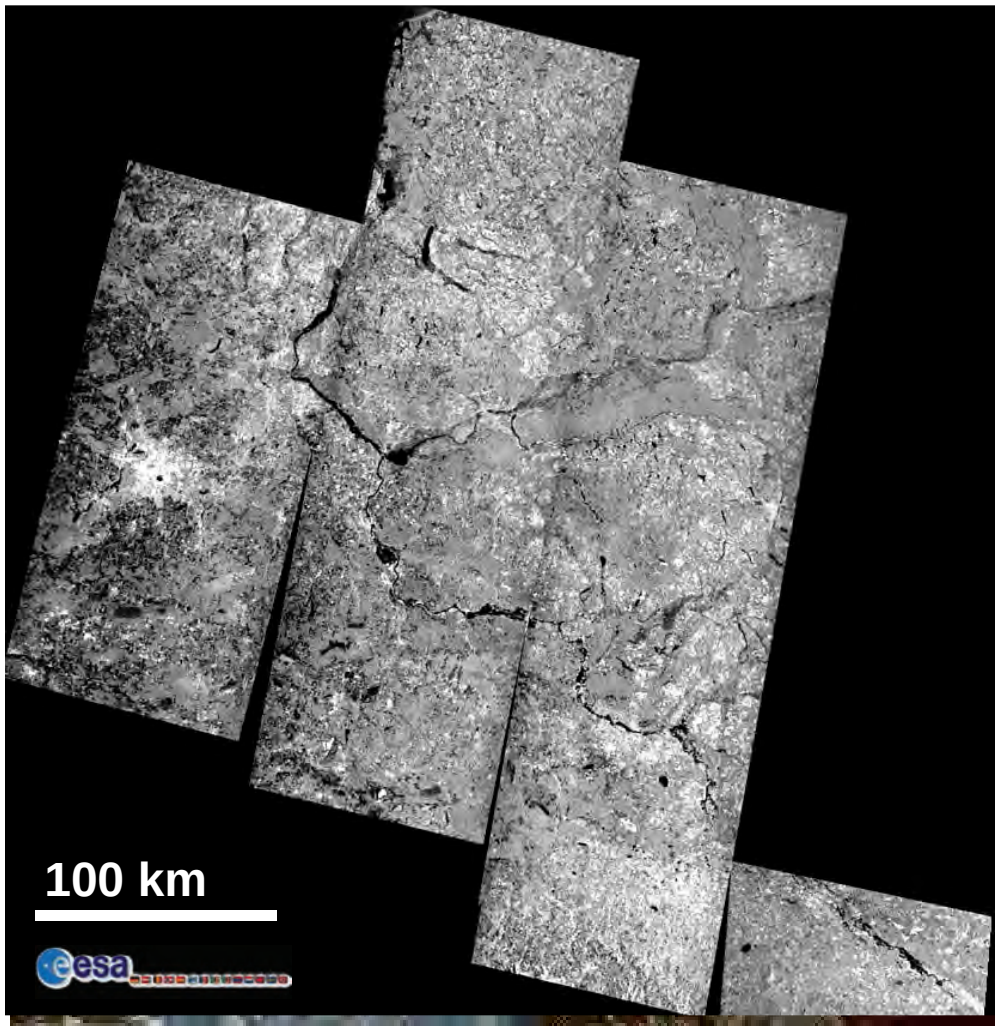
Flood mapping based on ERS 1 - 2

Since ERS 1 launch, 1991, followed by ERS 2 in 1995, 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…

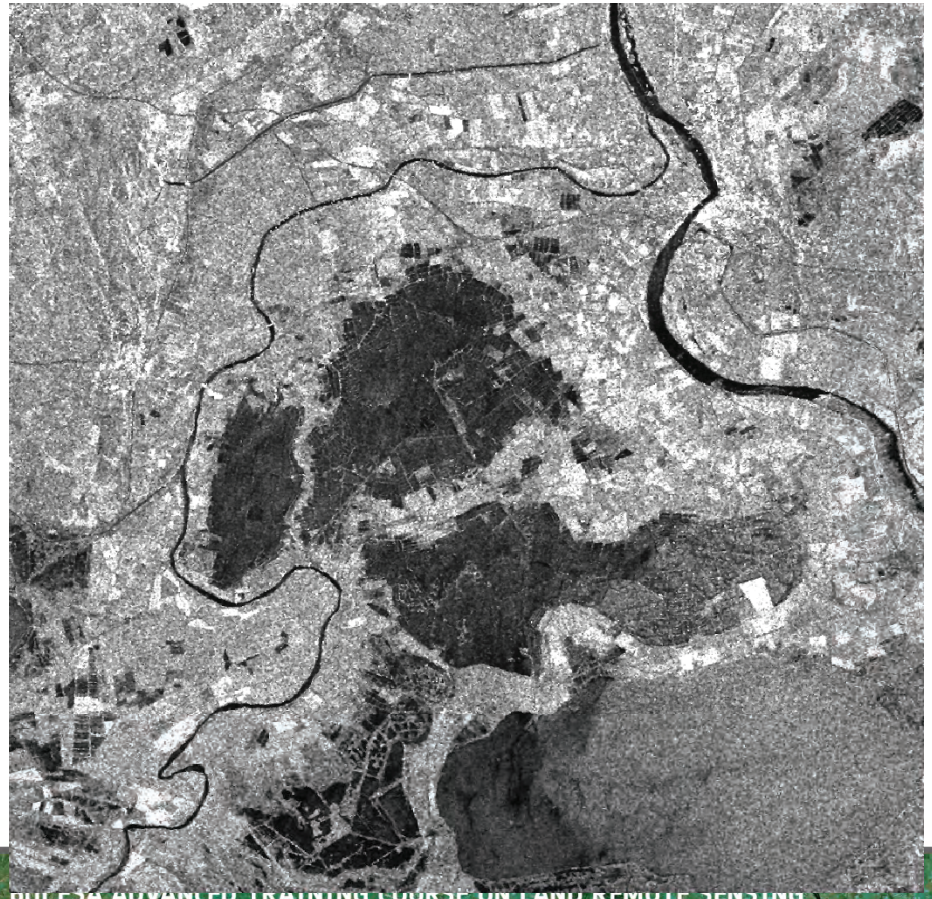
Exploiting mostly the Amplitude

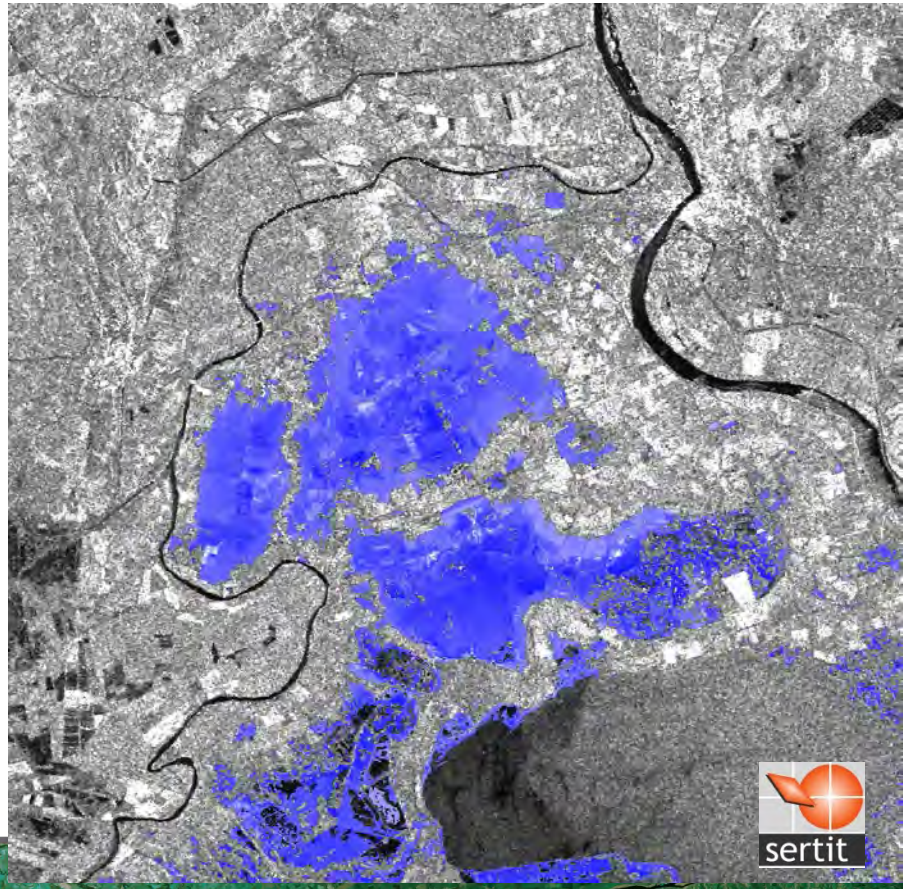


ERS Mosaïque over the Oder river : Acquired 30-07 to 9-08-97

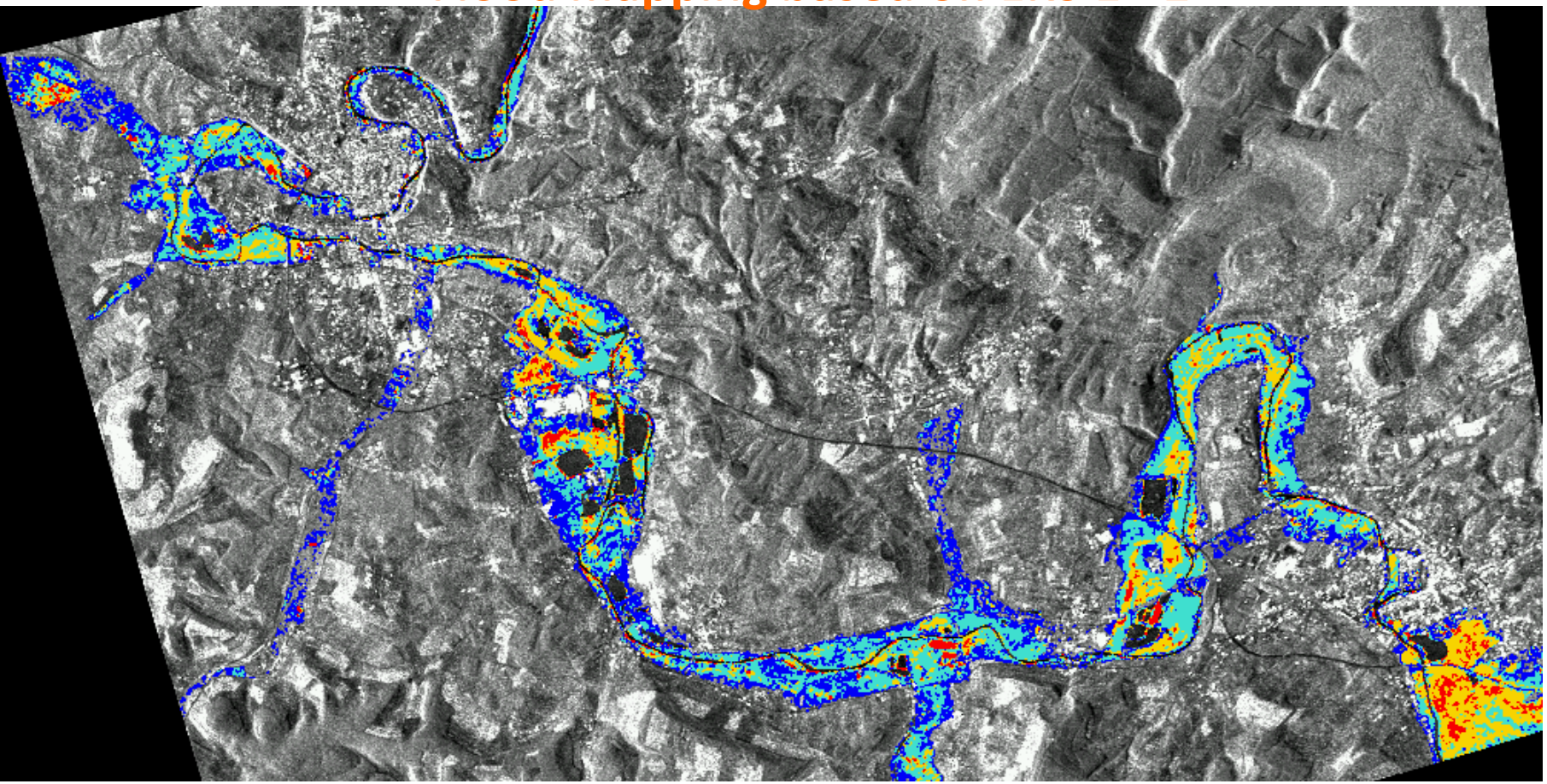
Flood mapping based on ERS 1 - 2

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

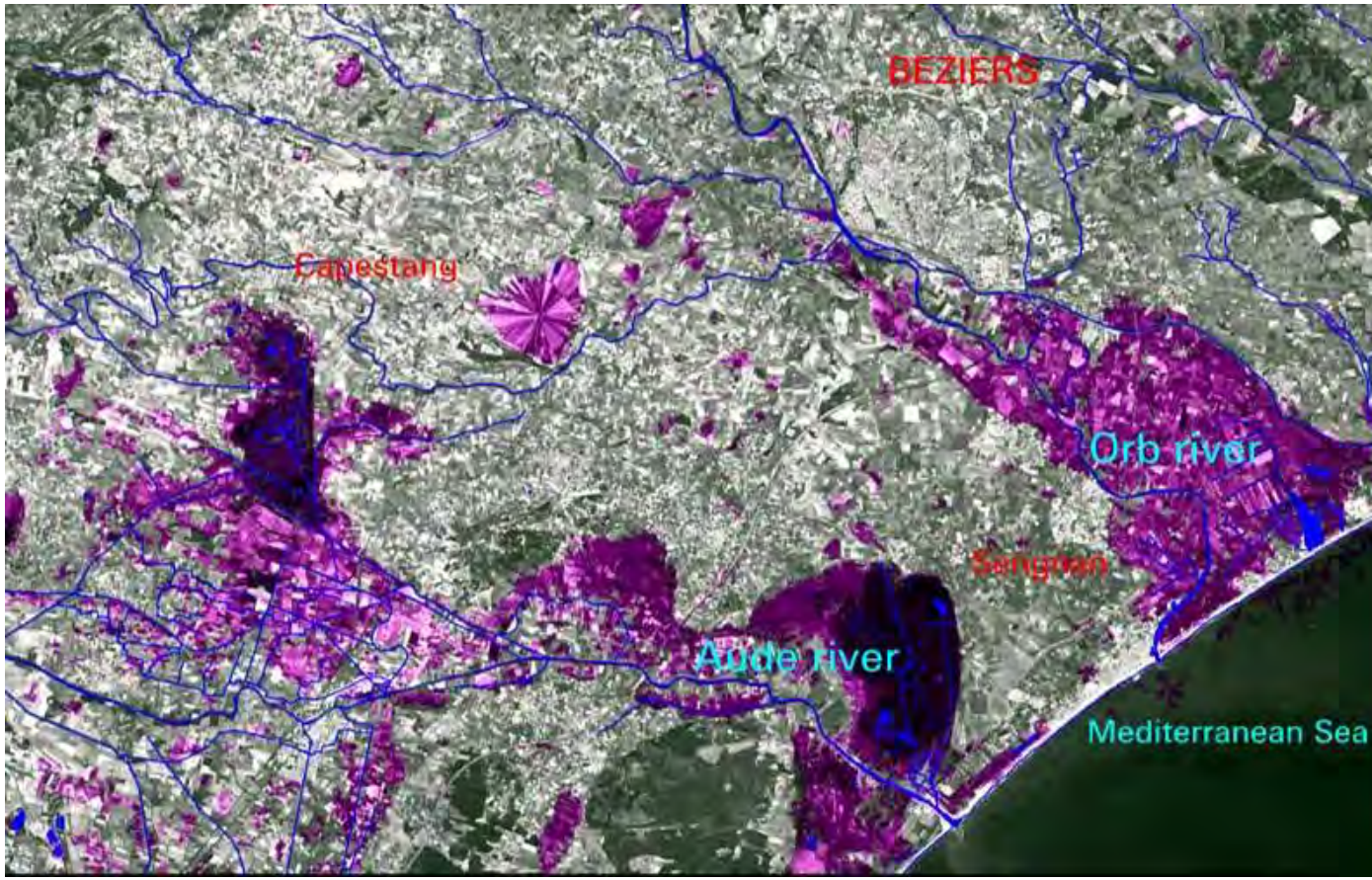
ERS-2: 7 8 1995
ERS-2: 29 01 1996
ERS-1: 28 01 1996

Acquisition near the maximum of the flood

2 consecutives images

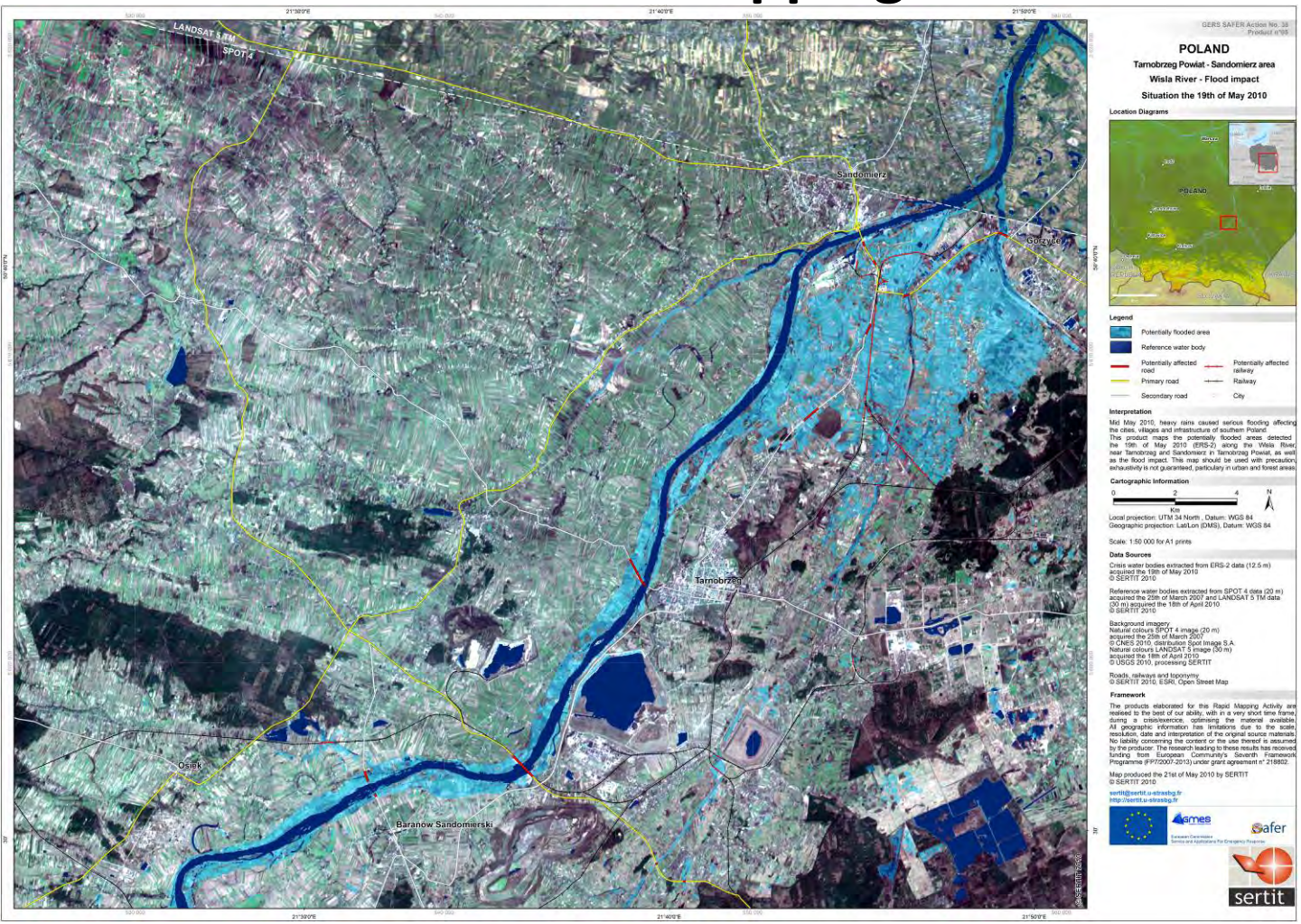
Exploitation of the phase information: lost of coherence on water surface

(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

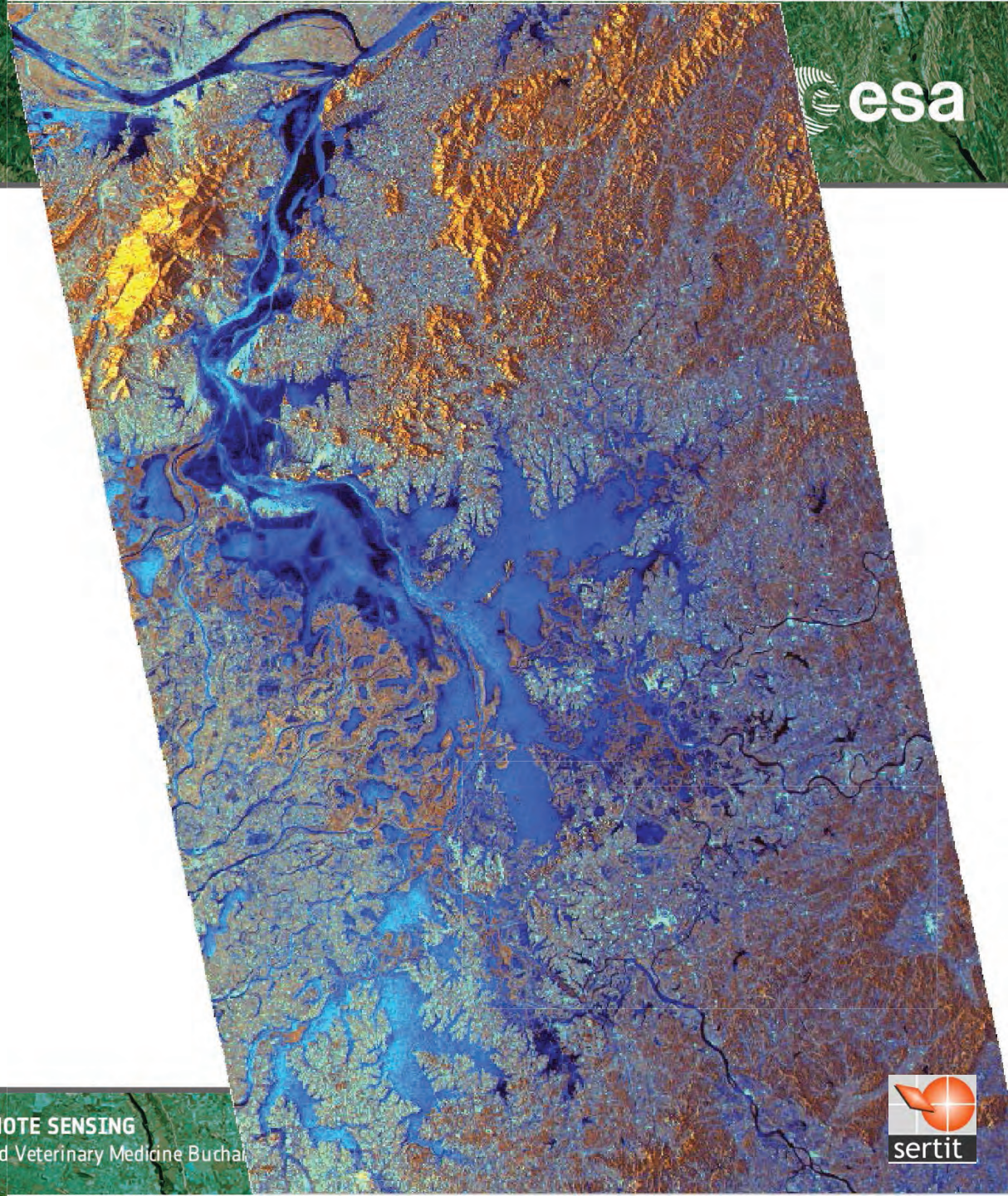
DRAGON ESA MOST

APP image

Stripe of two images

HH-HV (diff HH-HV)

20-02-05

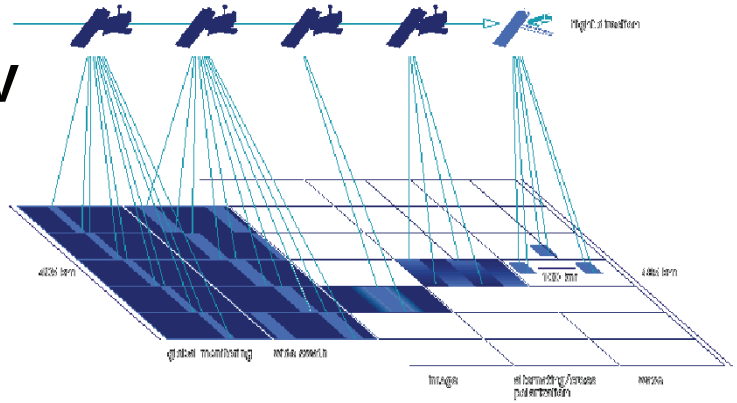


ASAR ENVISAT: flood mapping

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**



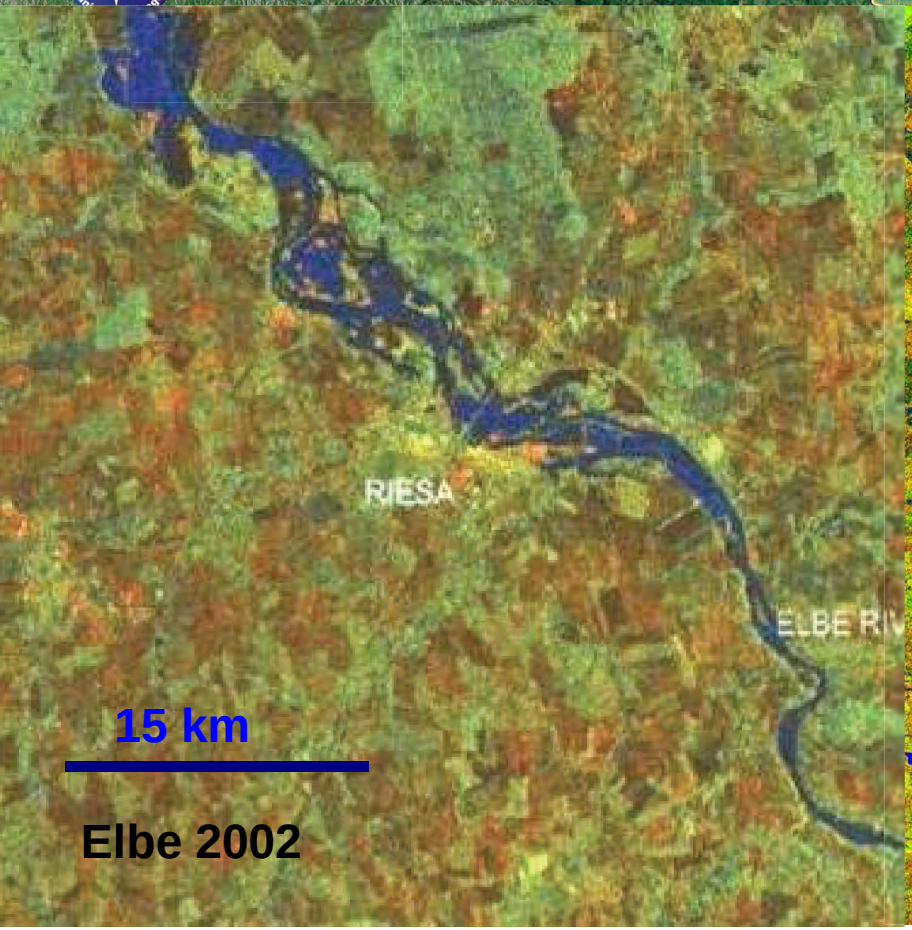
2- Better revisit thanks to:

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

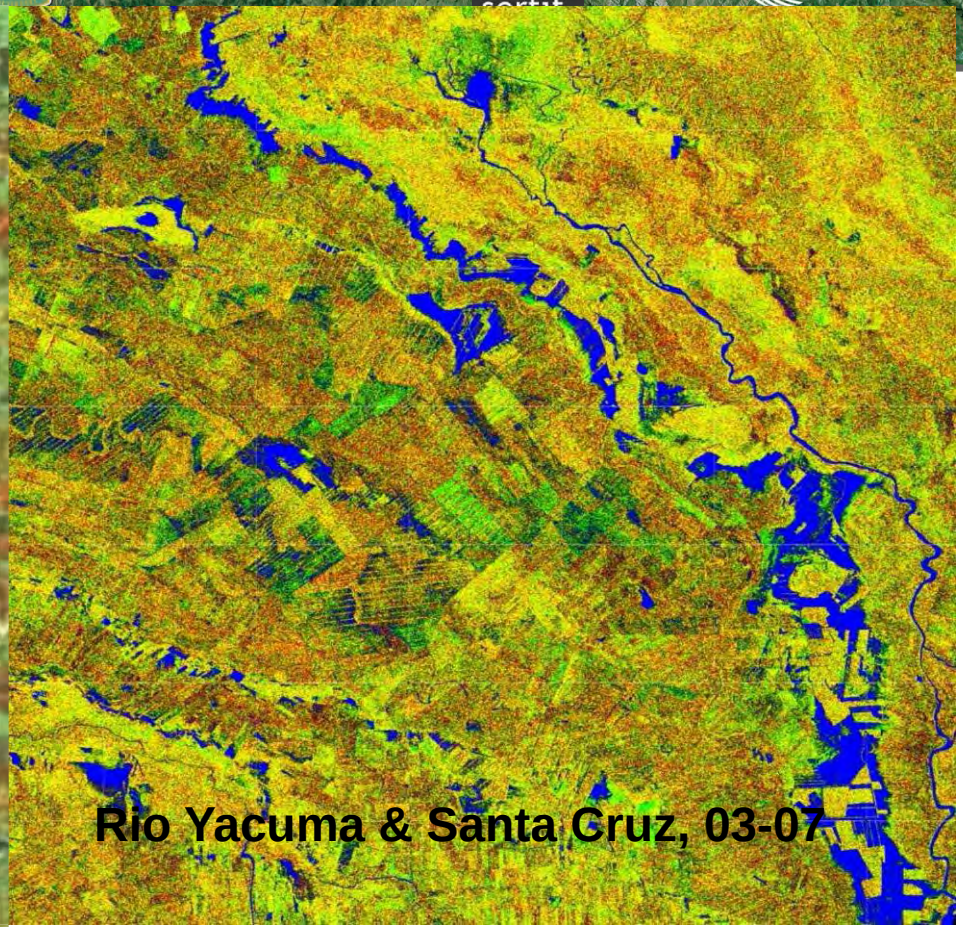
3 – Flooded low vegetation recognition

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



Elbe 2002



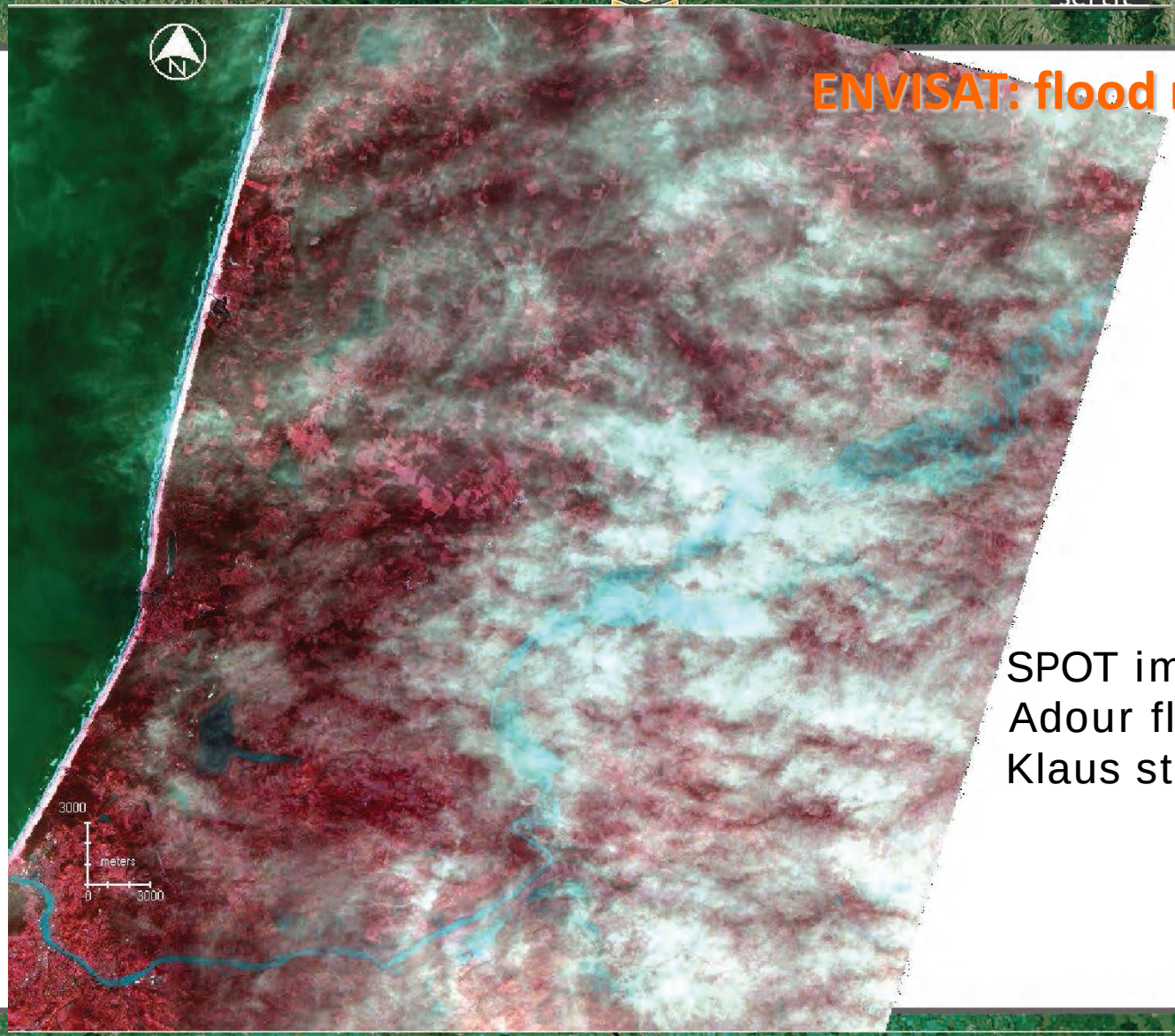
Rio Yacuma & Santa Cruz, 03-07

- China, 2010

Very few failures: Katrina: New Orleans

=> Great potential for flood mapping

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

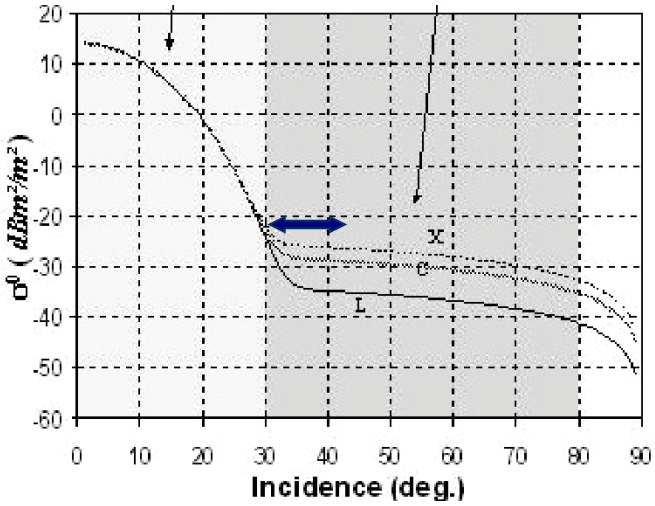
From ENVISAT towards SENTINEL 1

The Sentinel-1 series : part of the GMES programme

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
- Extra wide EW Swath , 400 km , 25x100 m
- Wave mode, WV, low data rate, 5x20m
- Swath 250 km

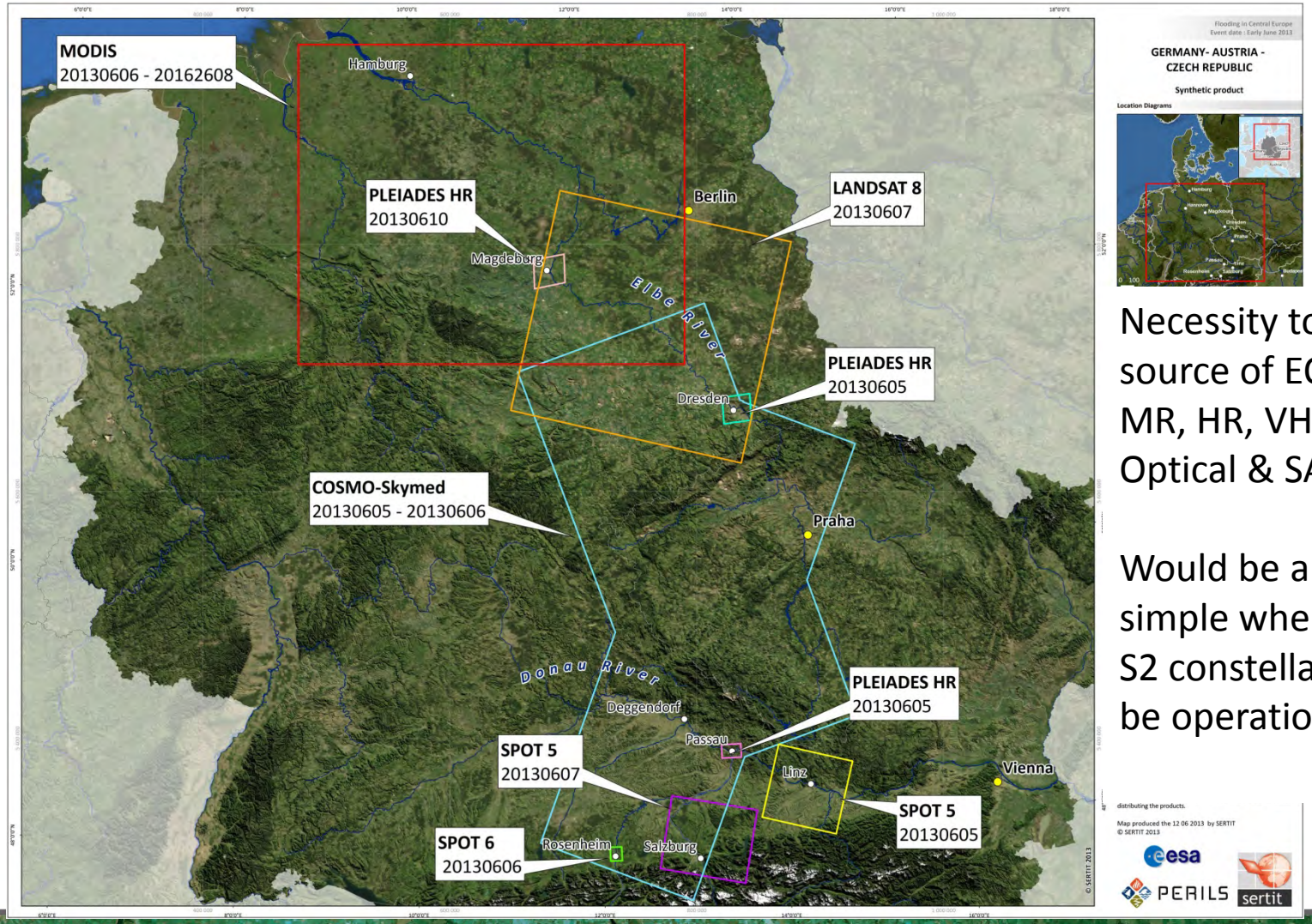


Polarisation modes:

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

(See Dr YL DESNOS presentations for more details)

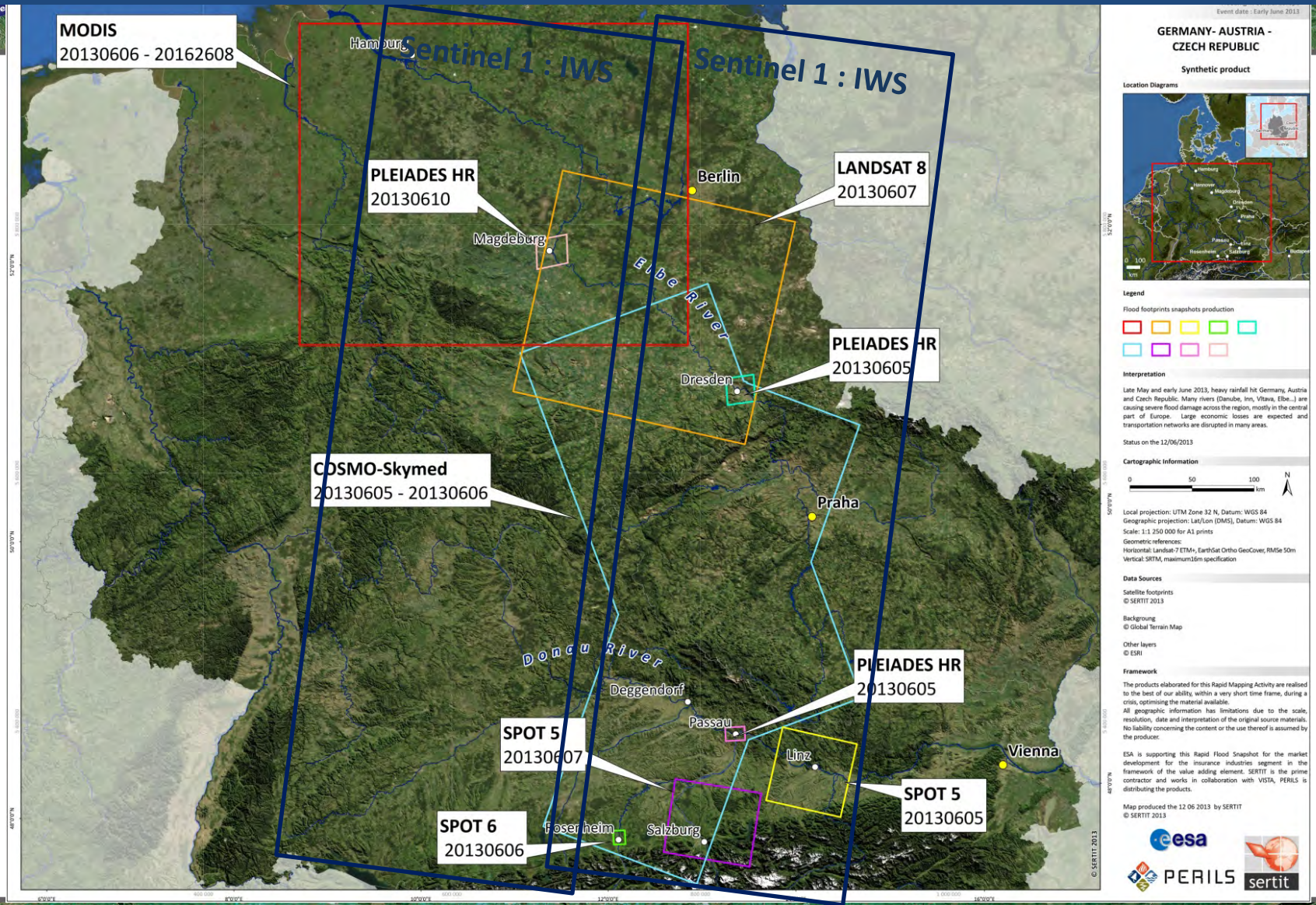
2013 Elbe flood: Areas and EO data



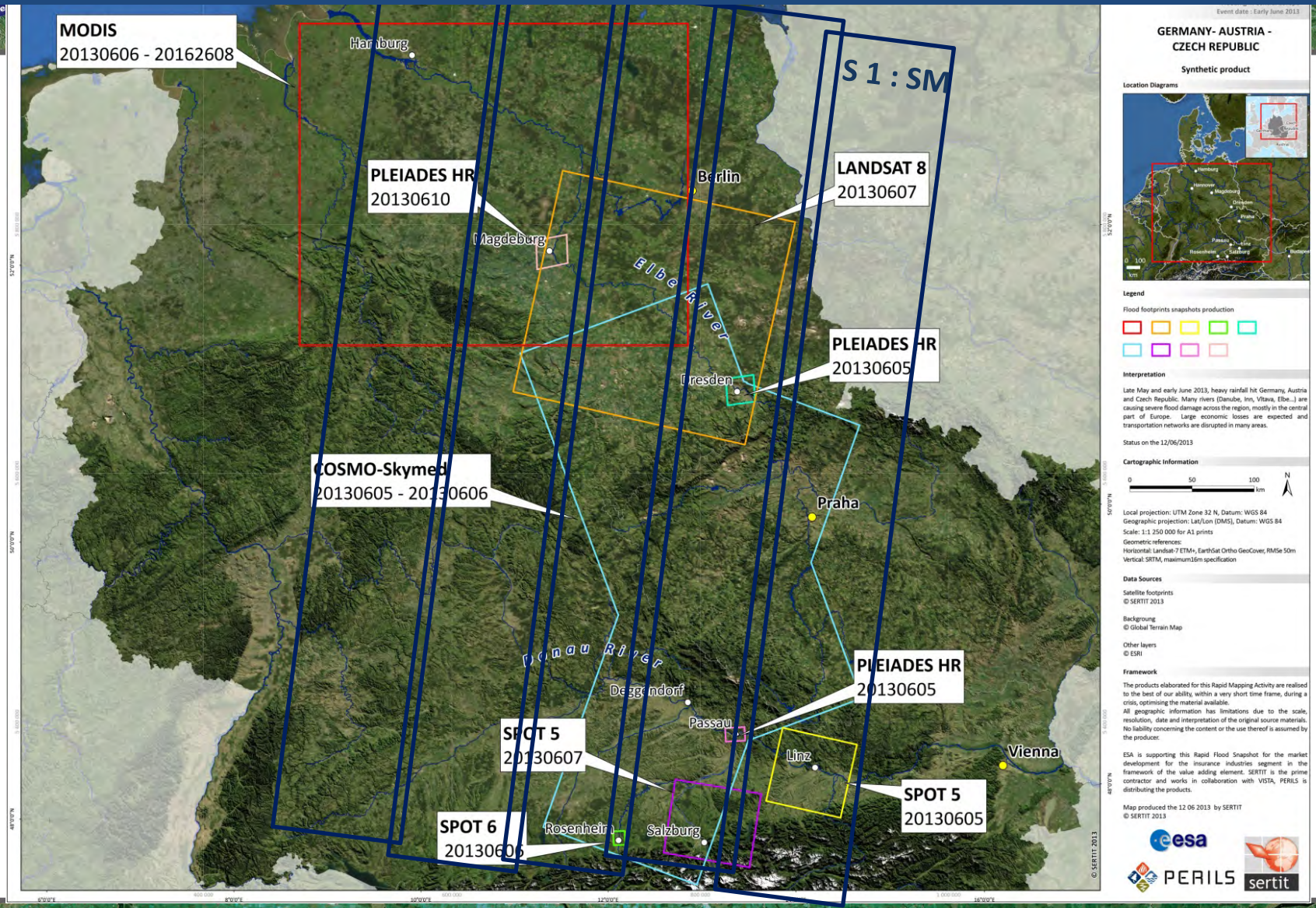
Necessity to exploit all source of EO
MR, HR, VHR
Optical & SAR

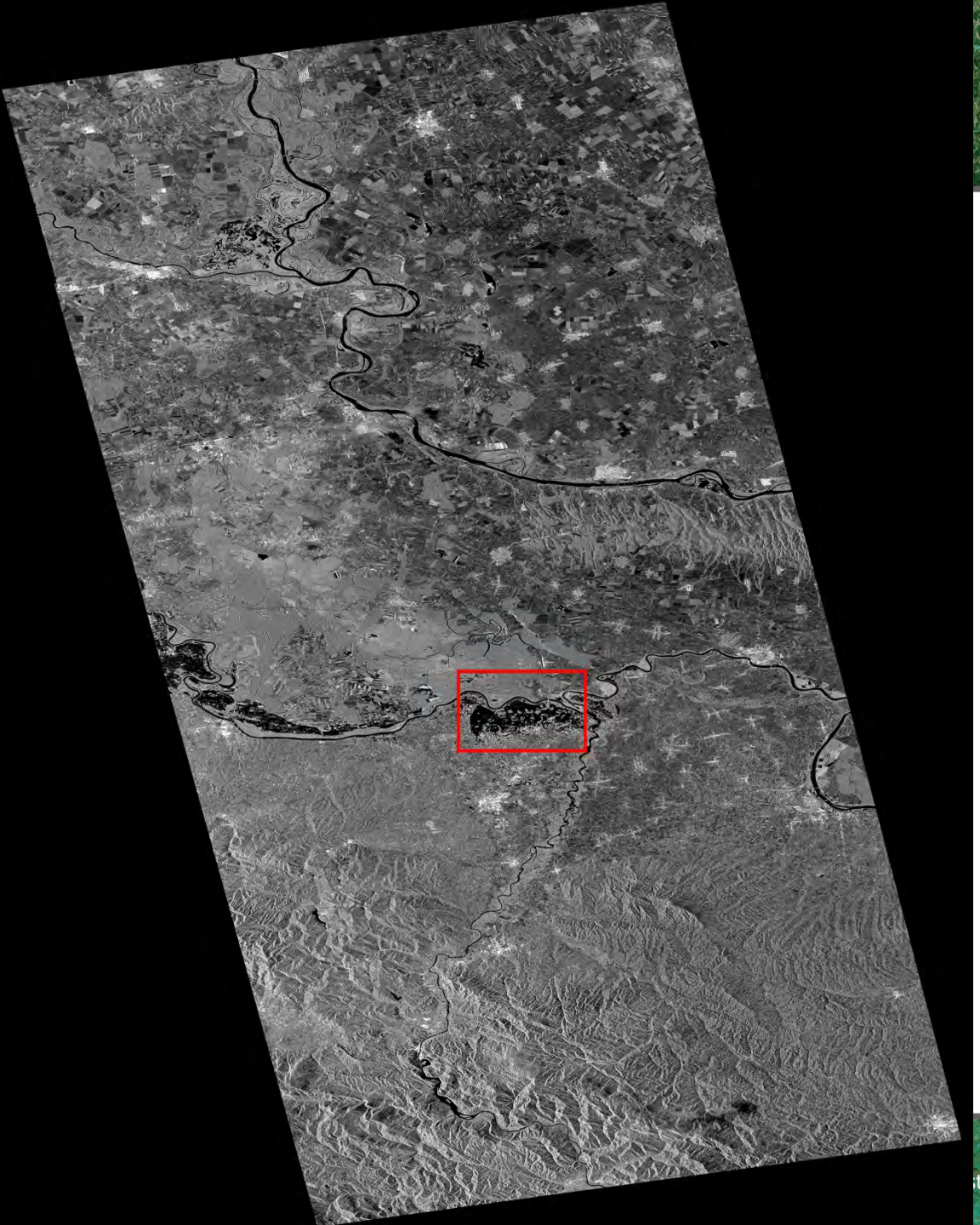
Would be a little more simple when S1 and S2 constellation will be operationnal

Sentinel 1 expect in term of swath coverage : standard mode



Sentinel2 expect in term of swath coverage: strip map mode



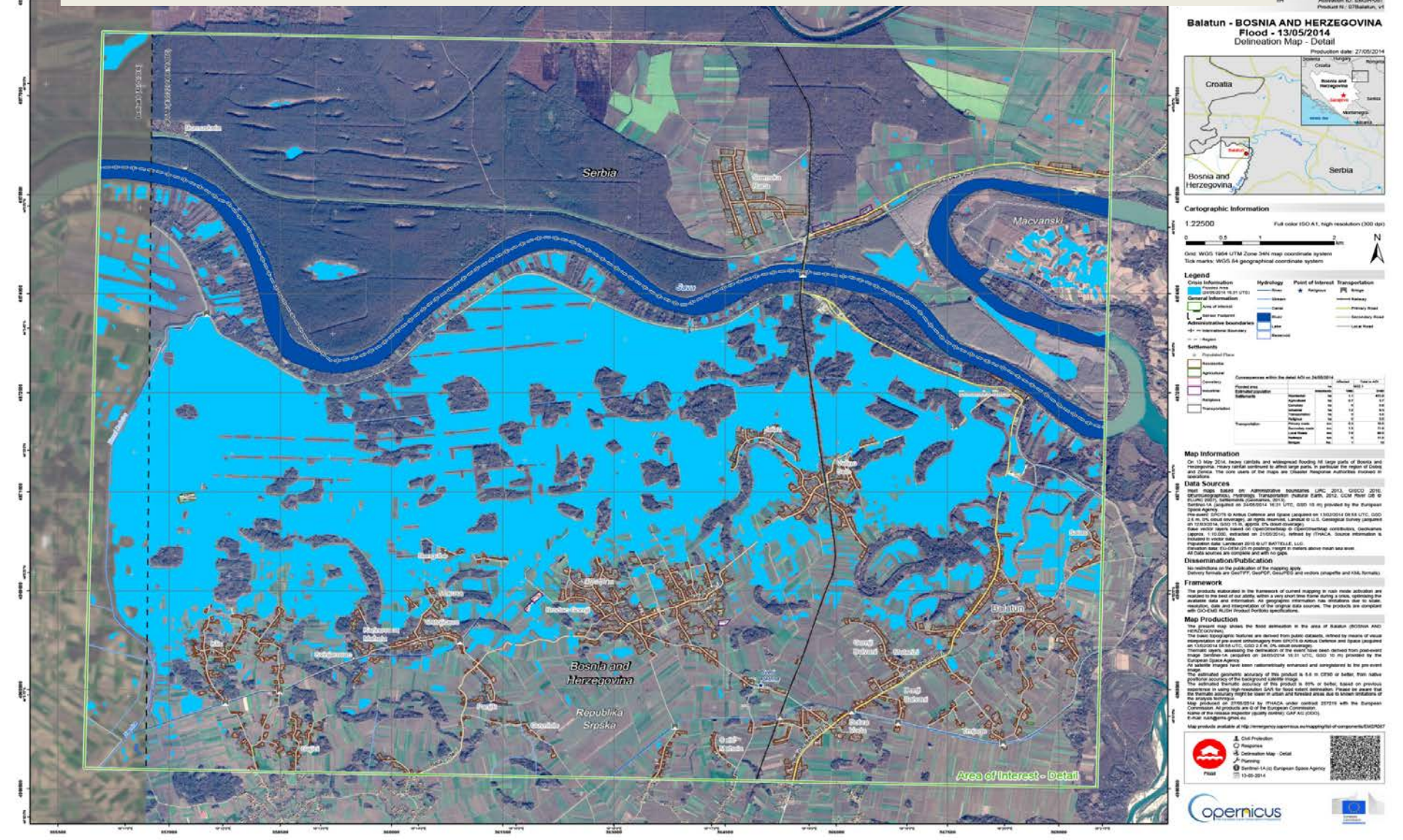


Sentinel Flood mapping: a rare example of strip map exploitation

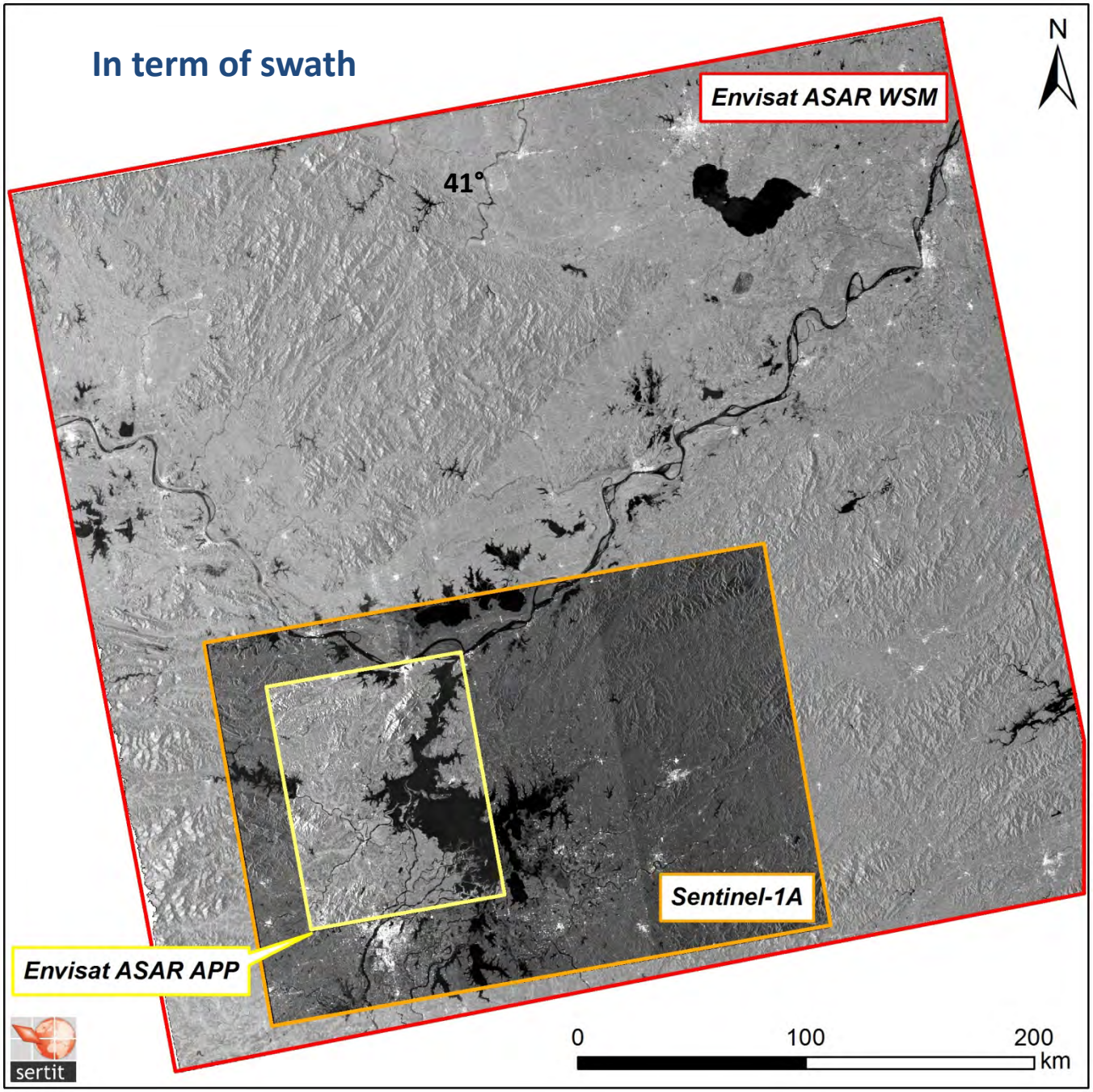
Bosnia and Herzegovina

May 2014

Sentinel Flood mapping: a rare aexample of strip map exploitation



In term of swath



ASAR WSM ENVISAT

400 km

26° - 41° ENL 10.5

Sentinel 1

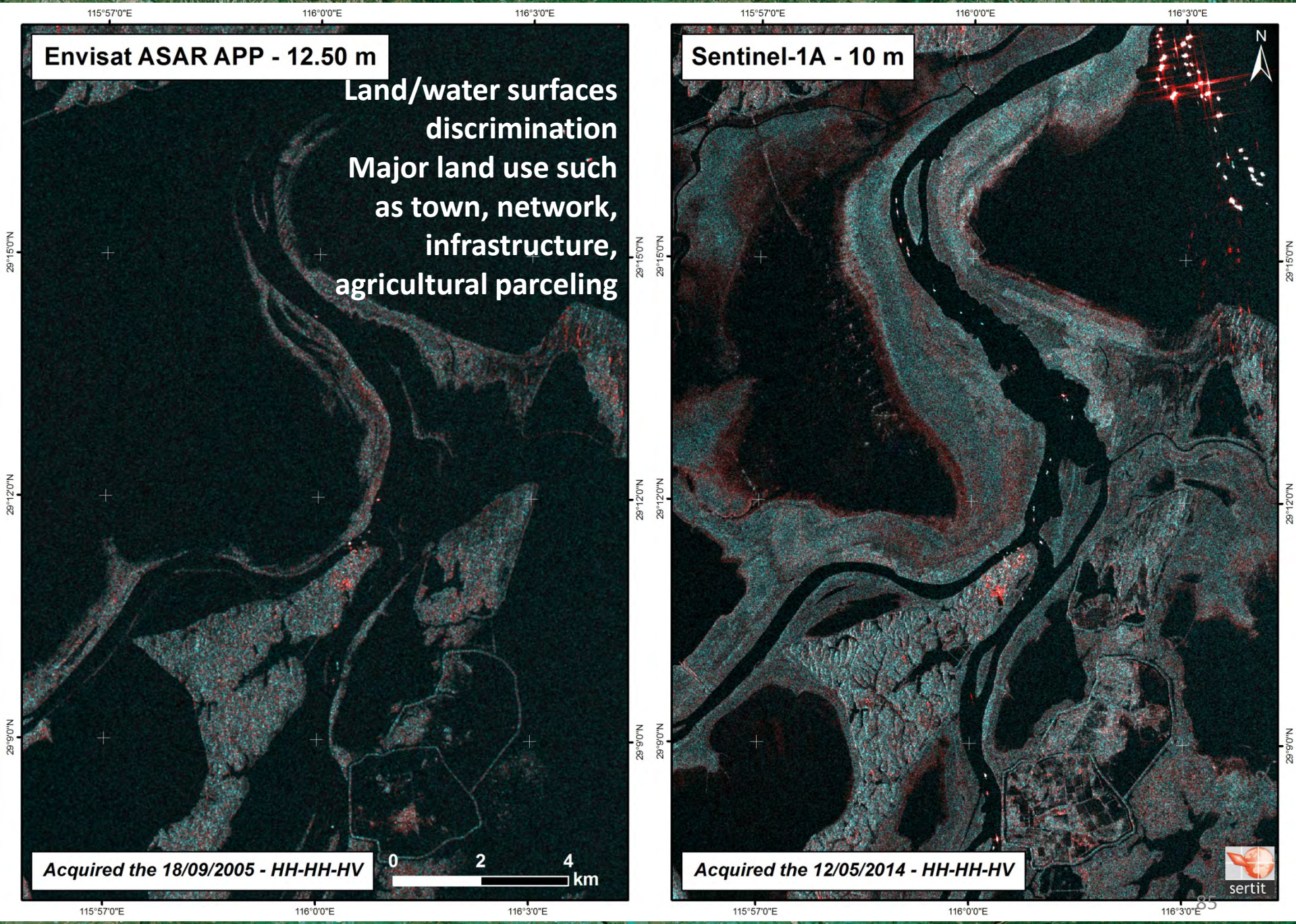
250 km

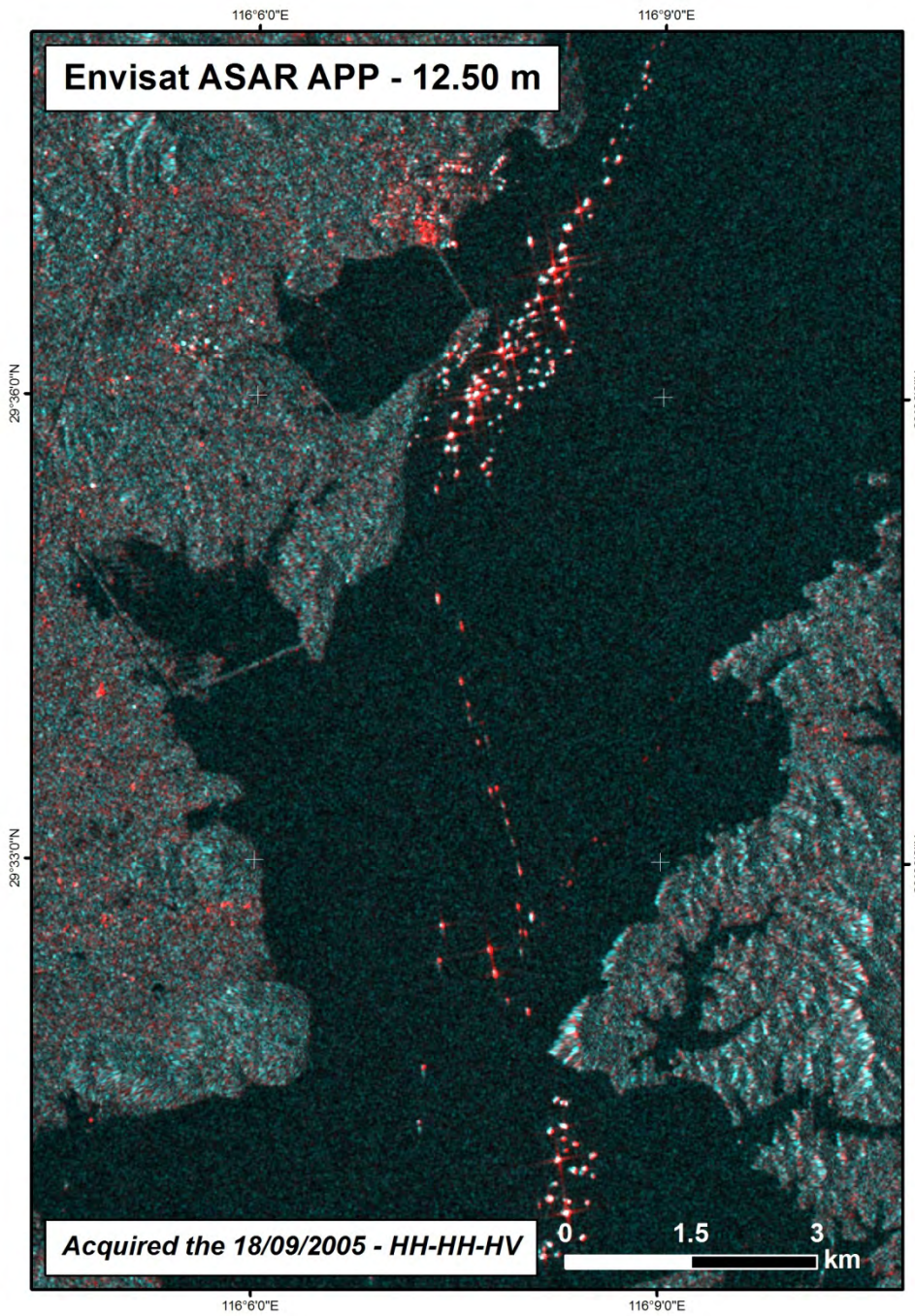
30° - 45 ENL: 4.9

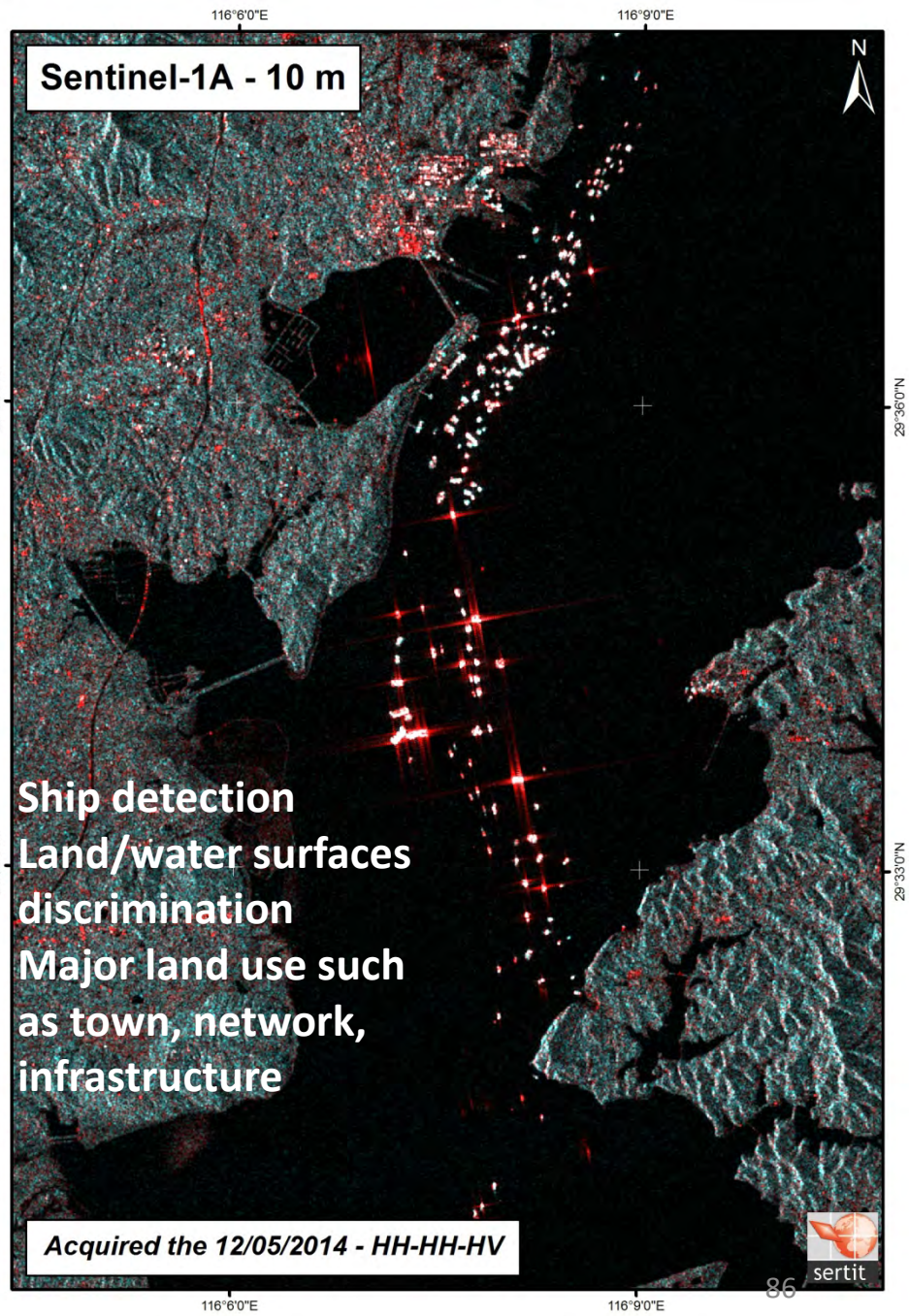
ASAR APP S4 ENVISAT

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
Acquired the 18/09/2005 - HH-HH-HV
0
2
4
km
Sentinel-1A - 10 m
N
Acquired the 12/05/2014 - HH-HH-HV
sertit
115°57'0"E
116°0'0"E
116°3'0"E
29°15'0"N
29°12'0"N
29°9'0"N


Envisat ASAR APP - 12.50 m
116°6'0"E
116°9'0"E
29°36'0"N
29°33'0"N
0
1.5
3
km
Acquired the 18/09/2005 - HH-HH-HV


Sentinel-1A - 10 m
N
116°6'0"E
116°9'0"E
29°36'0"N
29°33'0"N
Ship detection
Land/water surfaces discrimination
Major land use such as town, network, infrastructure
Acquired the 12/05/2014 - HH-HH-HV
sertit

Sentinel 1: High temporal revisit T0 , +5, +7

2014092

20140926

20141003

2014100

2014101

20141020

20141108

20141101

20141113

20141120

20141125

20141202

20141207

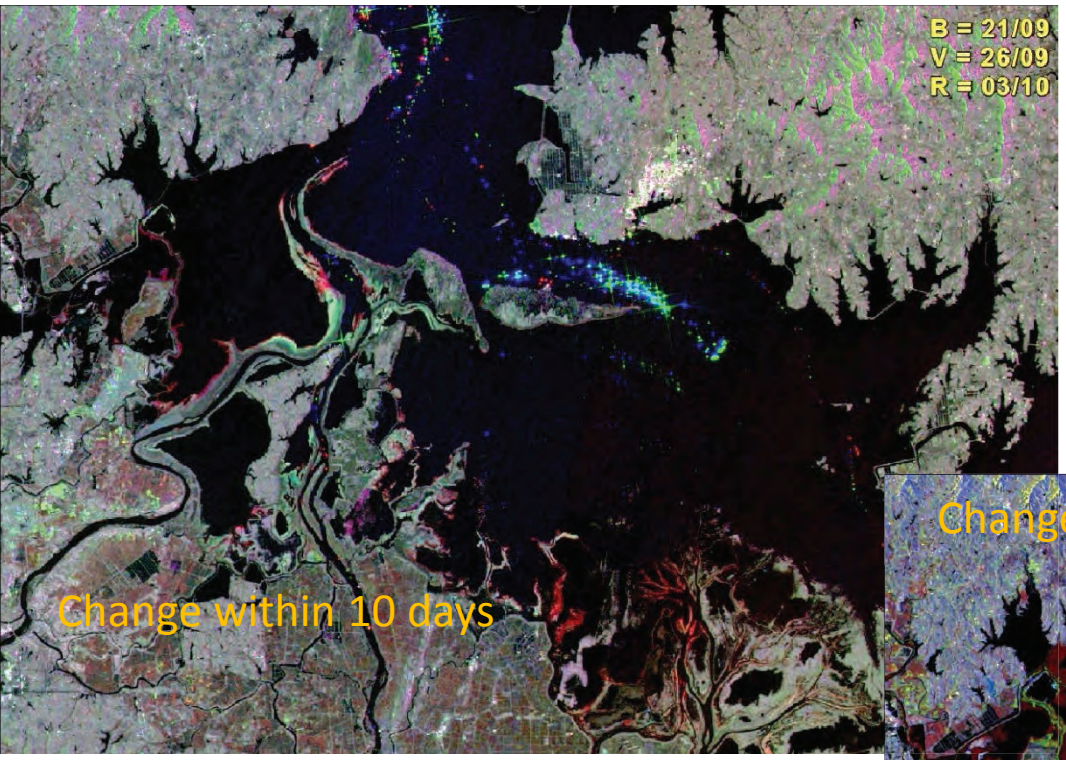
20141214

20141219

20141226

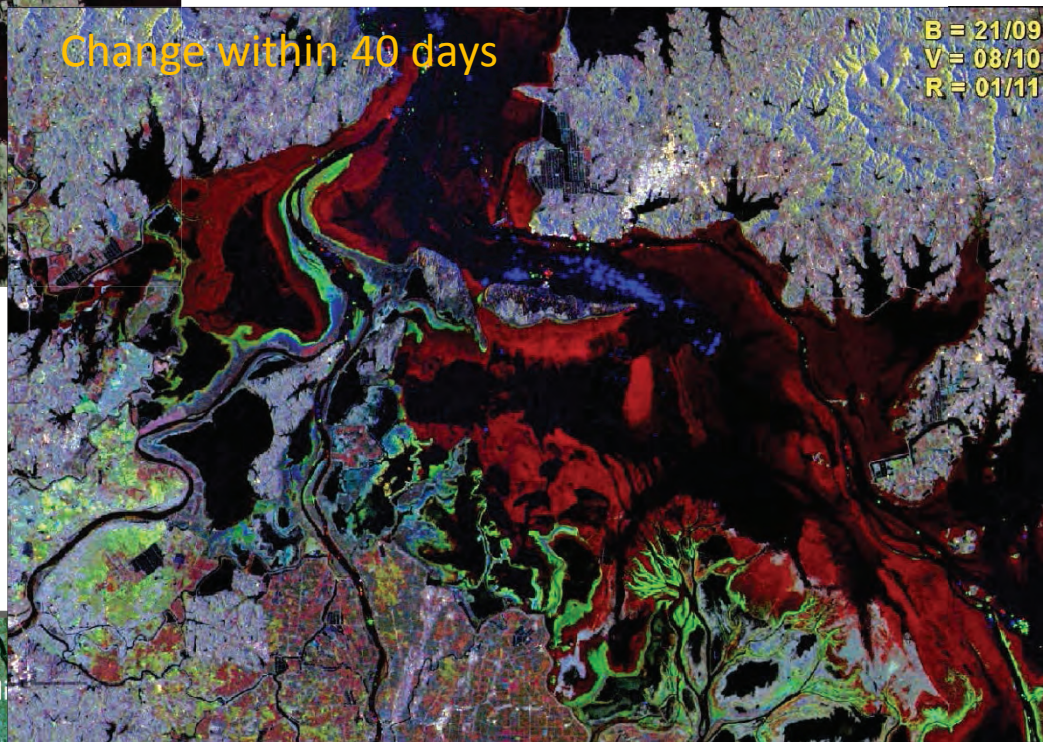
→ 6th ESA AD

14–18 Septe



Interest of High temporal revisit for monitoring hydrological behaviors

Intra annual changes



The VHR and polarimetric SAR:

X band VHR SAR: TerraSAR, CosmoSkymed

C BAND: RadarSAT II: VHR and Full Pol

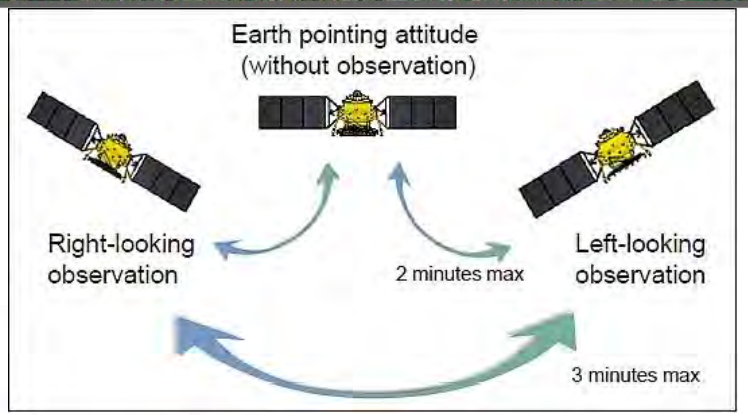
L Band : PALSAR II bi & Full Pol, large swath ScanSAR mode

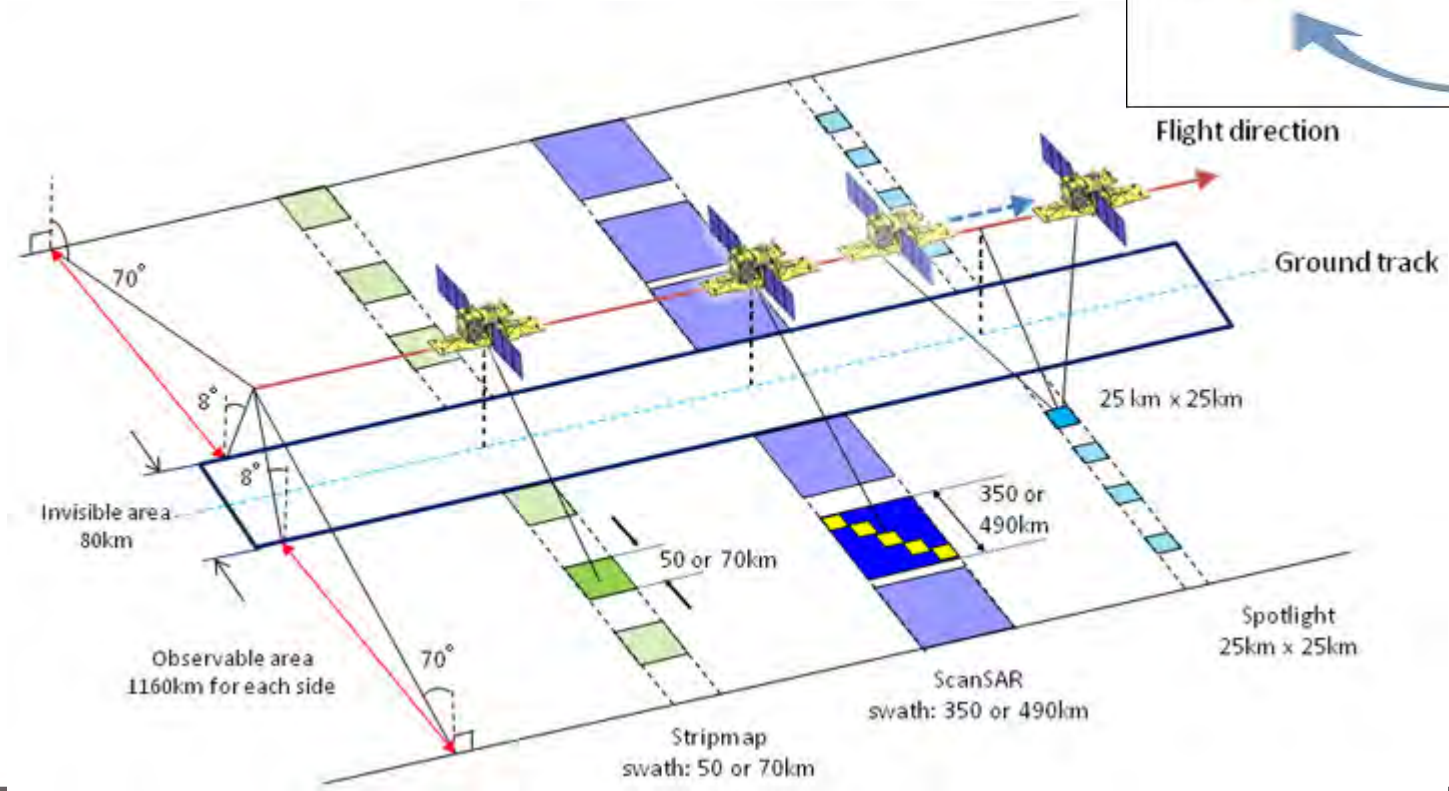
Advanced Land Observing Satellite (ALOS II)

- ALOS II
- the Phased Array type L-band Synthetic Aperture Radar (PALSAR)
- Left/right looking
- WS to ultra fine (490 to 25km => 60 to 1m)

- 24 May 2014

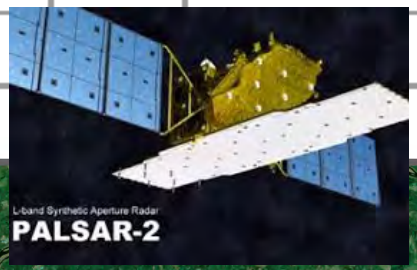

L-band Synthetic Aperture Radar
PALSAR-2


Earth pointing attitude
(without observation)
Right-looking
observation
2 minutes max
Left-looking
observation
3 minutes max


Flight direction
Ground track
70°
8°
8°
Invisible area
80km
25 km x 25km
350 or
490km
50 or 70km
Observable area
1160km for each side
70°
Spotlight
25km x 25km
ScanSAR
swath: 350 or 490km
Stripmap
swath: 50 or 70km

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	-23	-26
S/A (dB)	Rg	25	25	23	23	25	20	25	25	20
	Az	20	25	20	20	23				

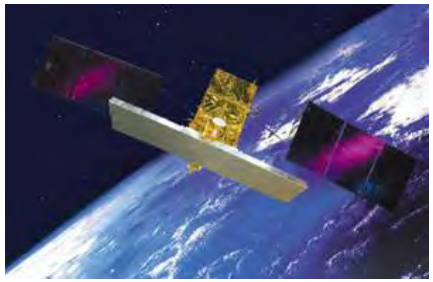
* SP: HH or HV or VV, DP: HH+HV or VV+VH, FP: HH+HV+VH+VV, CP: compact pol. (experimental)



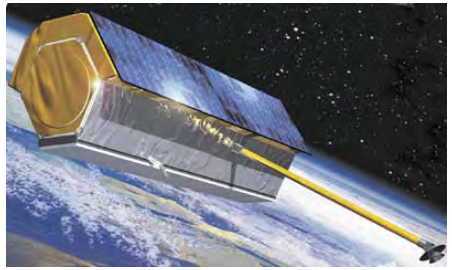
The VHR and polarimetric SAR: TerraSAR, CSK

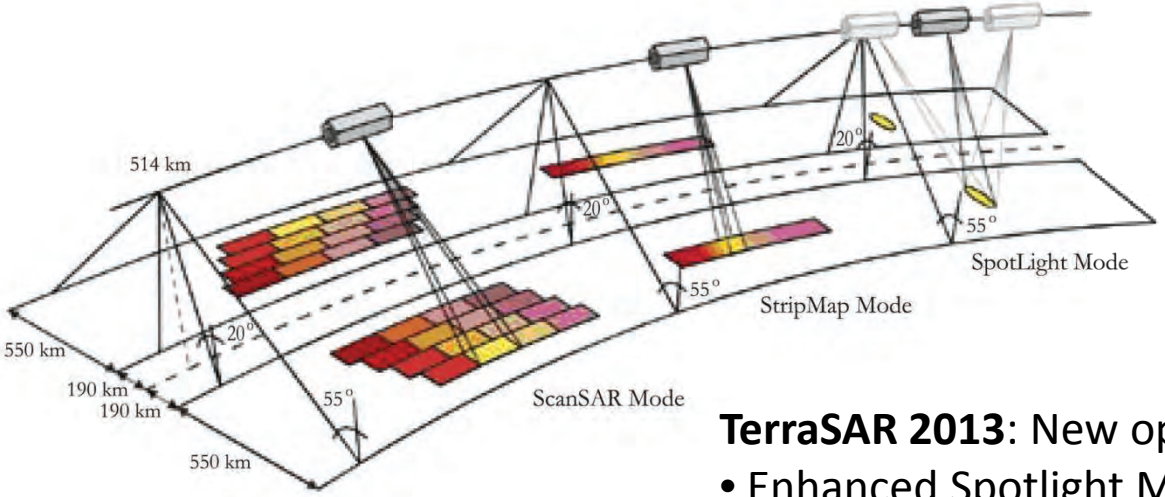
X band VHR satellites

- **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

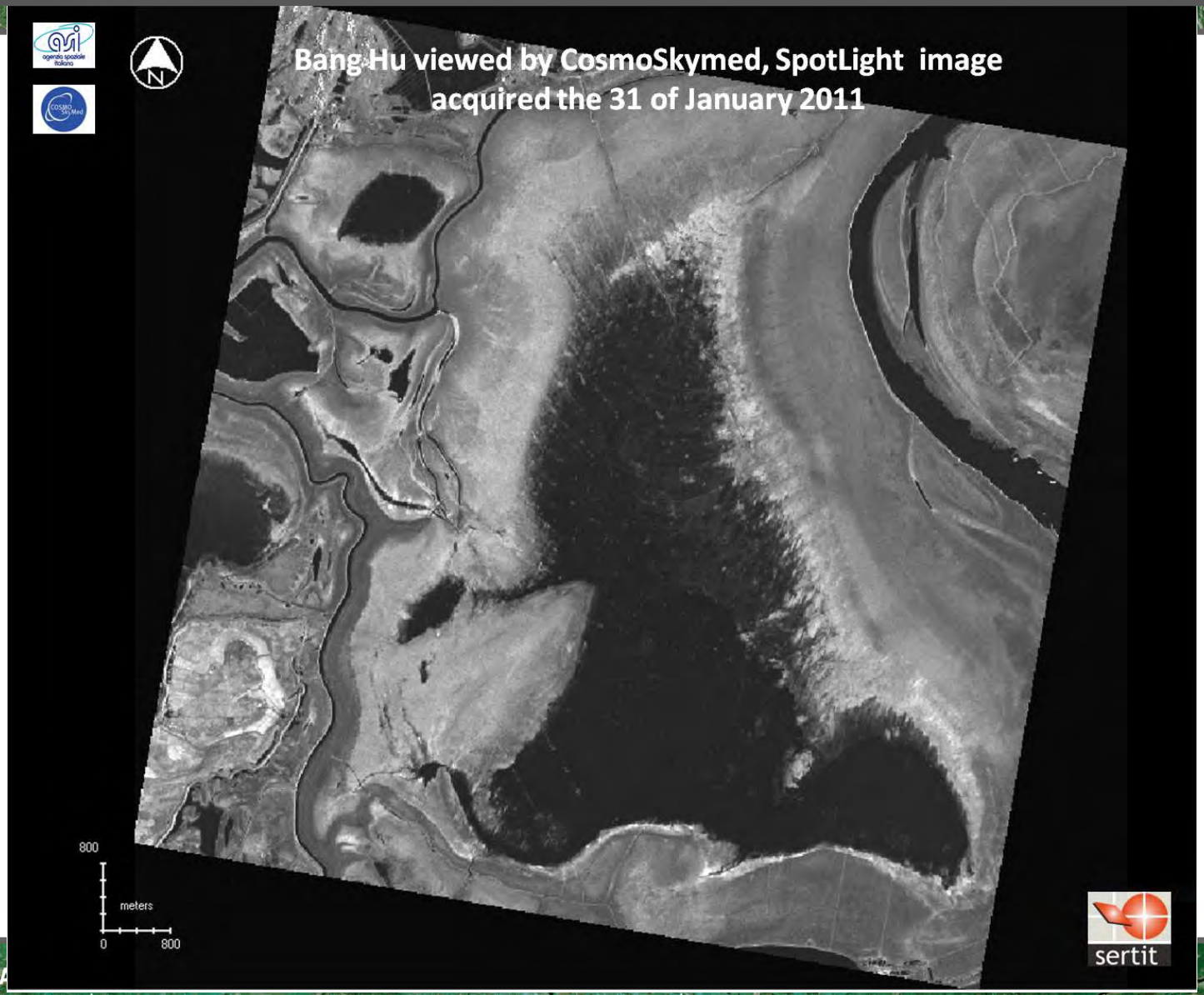
- Enhanced Spotlight Mode (Starring Spotlight).
- ScanSAR :expanded swath width (200 instead of 100km).

The VHR and polarimetric SAR: TerraSAR, CSK

The VHR and polarimetric SAR: TerraSAR, CSK

Shenjiang lake
CSK time series
2014

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



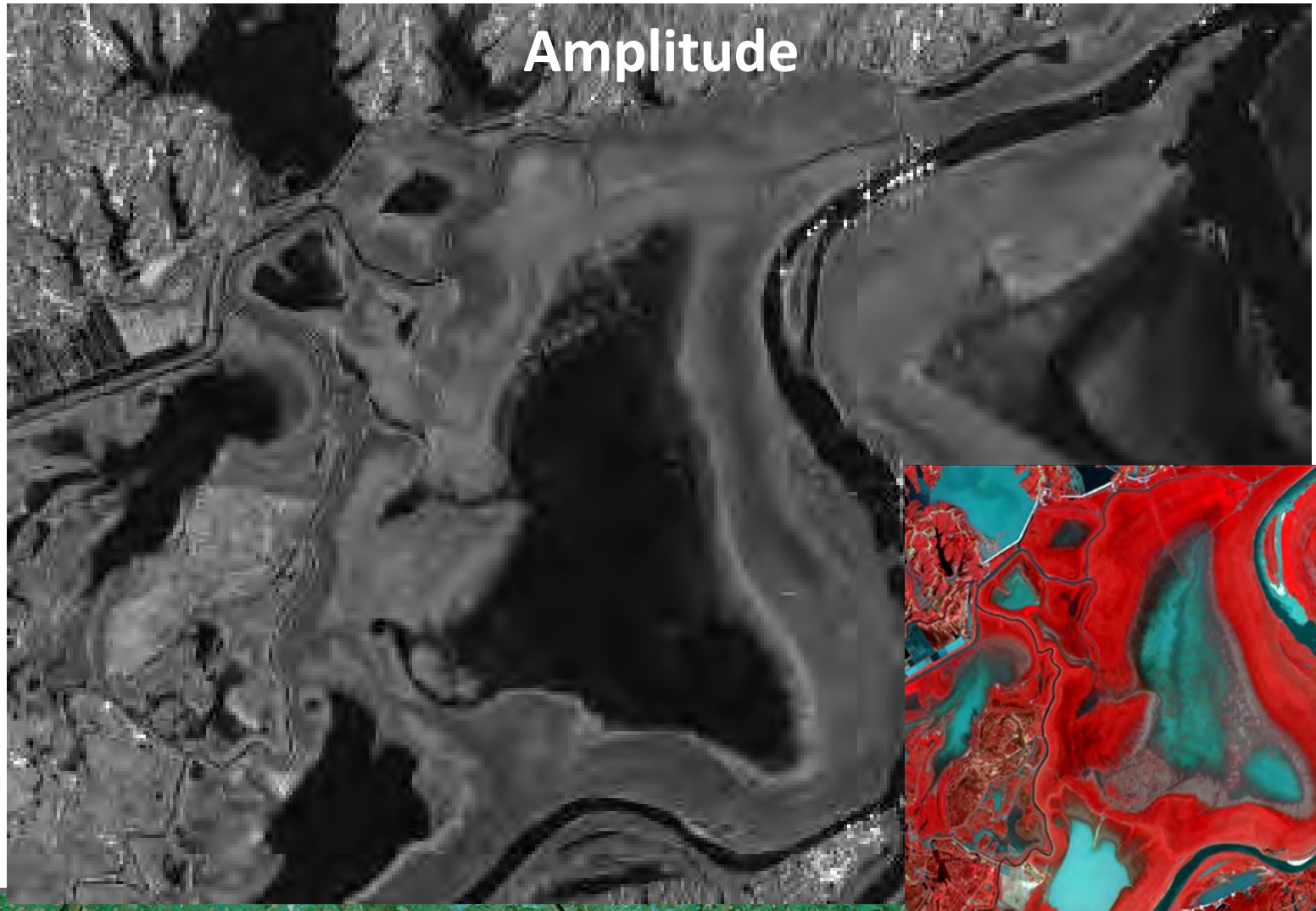
Water bodies mapping based on Cosmo Skymed Data: Poyang lake China

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

30
meters
0

sertit

Water bodies mapping based on Tandem X INSAR

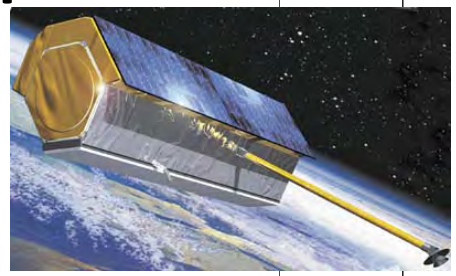


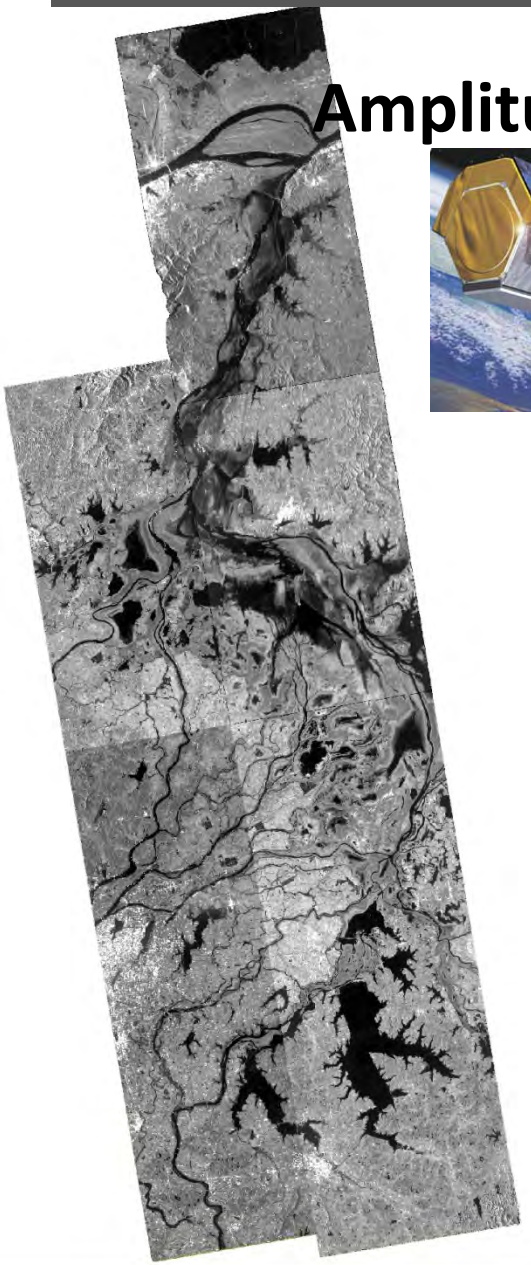
Water bodies mapping based on Tandem X INSAR

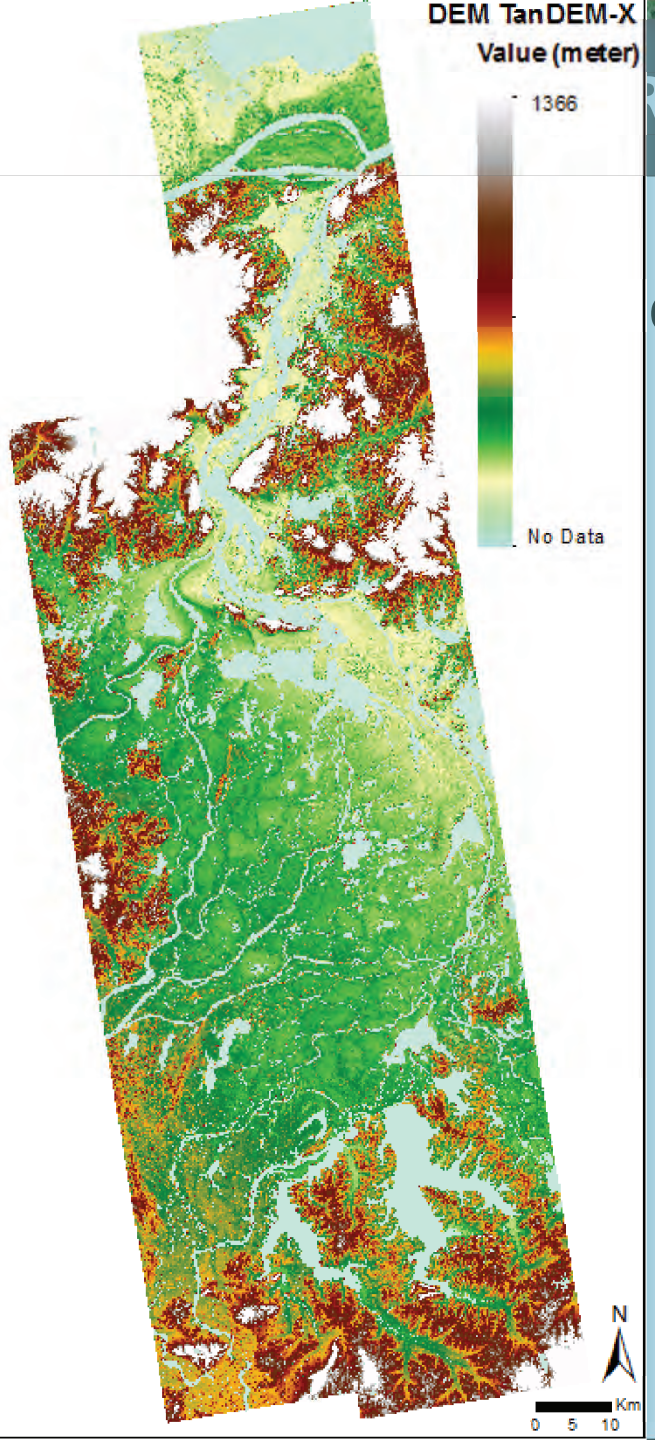
Cohérence

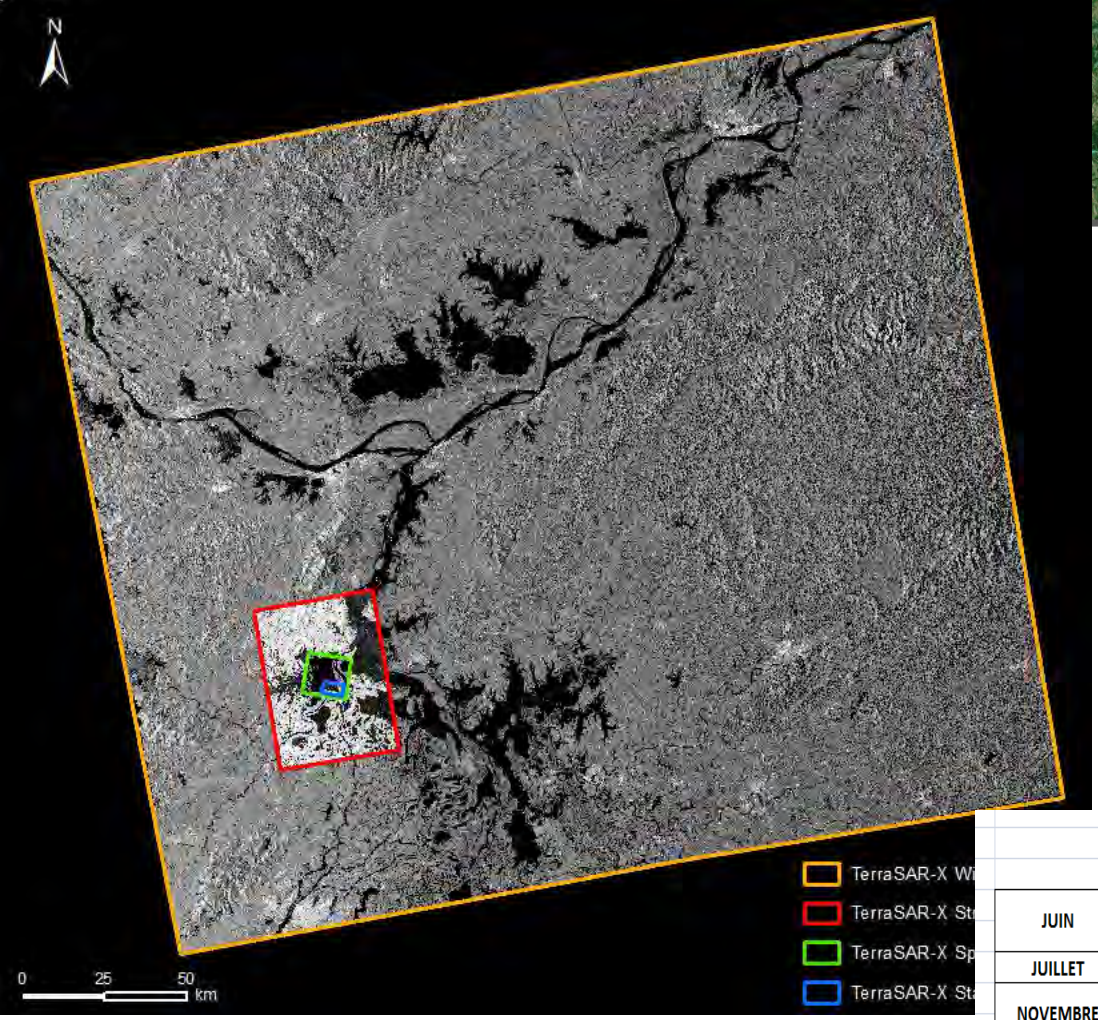
Water bodies mapping ba

Amplitude





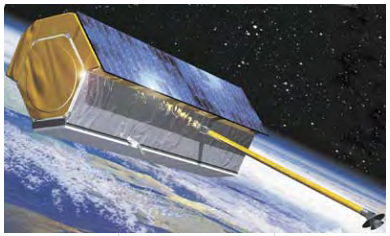




sertit esa

Muti resolution approach exploiting TerraSAR New modes

DLR



Wide Scan SAR 200*200 km^2, 30 m

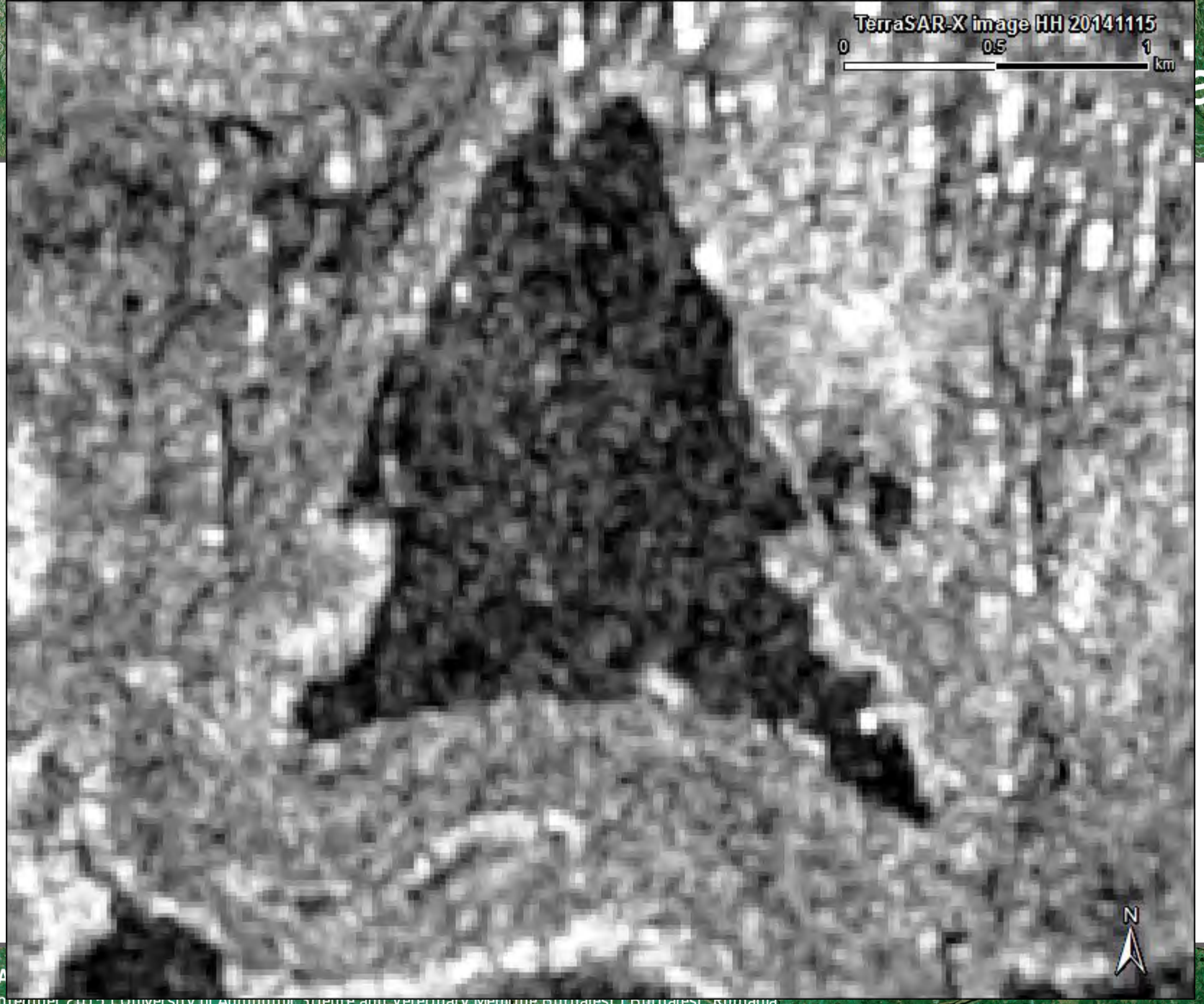
Strip Map mode : 30*50 km^2, 3m

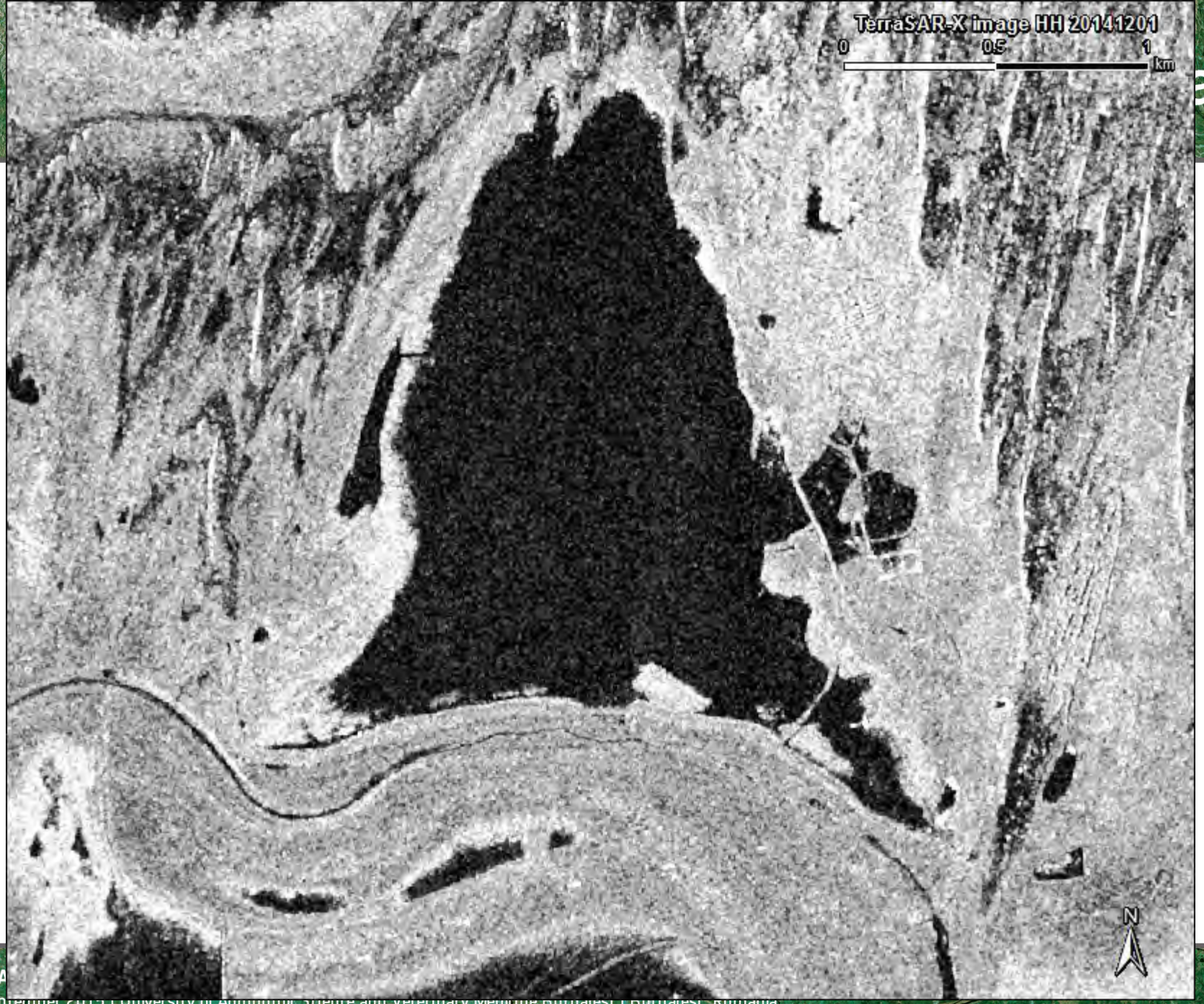
SpotLight mode : 5*10 km^2, 1m

Staring SpotLight : 3*4 km^2, 25 cm

	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					


TerraSAR-X image HH 20141113
0
0.5
1
km
N


TerraSAR-X image HH 20141115
0
0.5
1
km
N

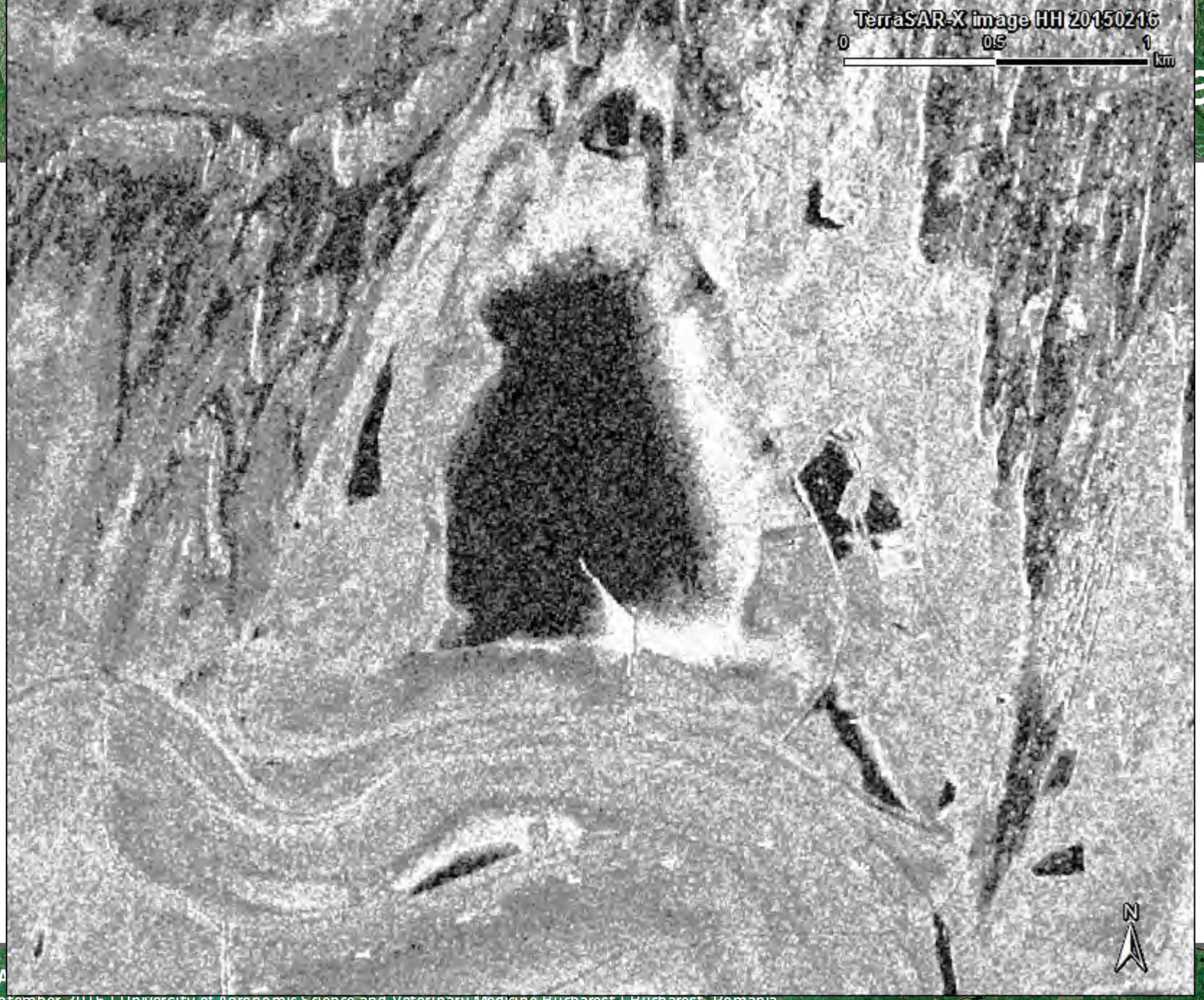

TerraSAR-X image HH 20141201
0
0.5
1
km
N


TerraSAR-X image HH 20141216
0
0.5
1
km
N

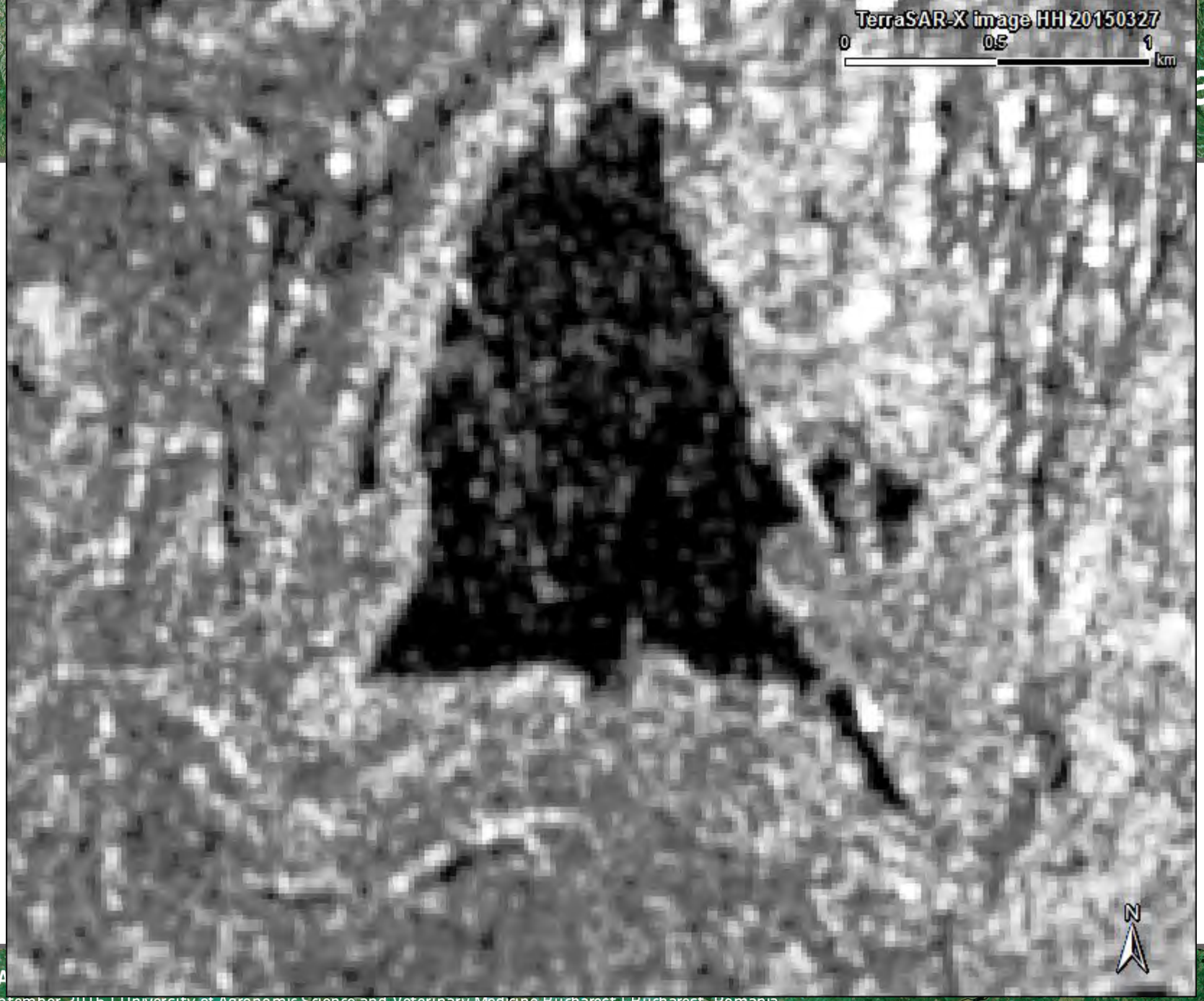

TerraSAR-X image HH 20150114
0
0.5
1
km
N


TerraSAR-X image HH 20150118
0
0.5
1
km
N


TerraSAR-X image HH 20150209
0
0.5
1
km
N


TerraSAR-X image HH 20150216
0
0.5
1
km
N


TerraSAR-X image HH 20150314
0
0.5
1
km
N


TerraSAR-X image HH 20150327
0
0.5
1
km
N


TerraSAR-X image HH 20150412
0
0.5
1
km
N

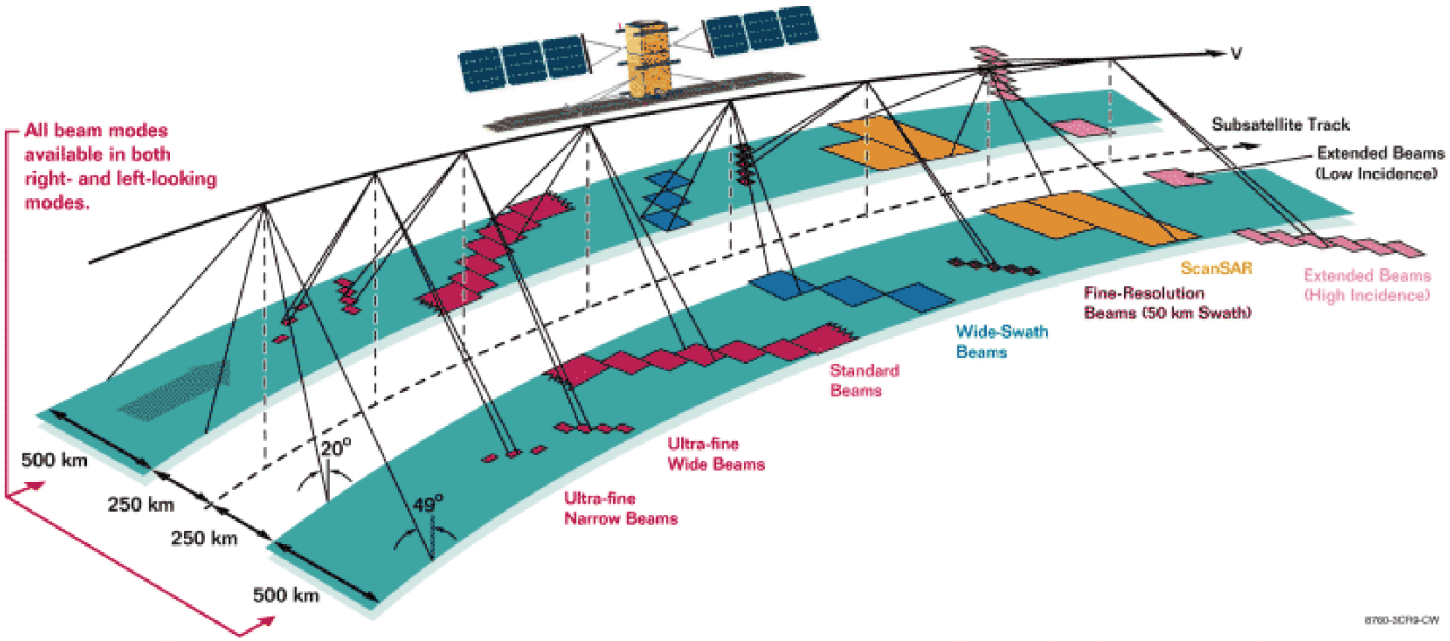

TerraSAR-X image HH 20150416
0
0.5
1
km
N


TerraSAR-X image HH 20150519
0
0.5
1
km
N

VHR and polarimetric SAR : Radarsat II

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

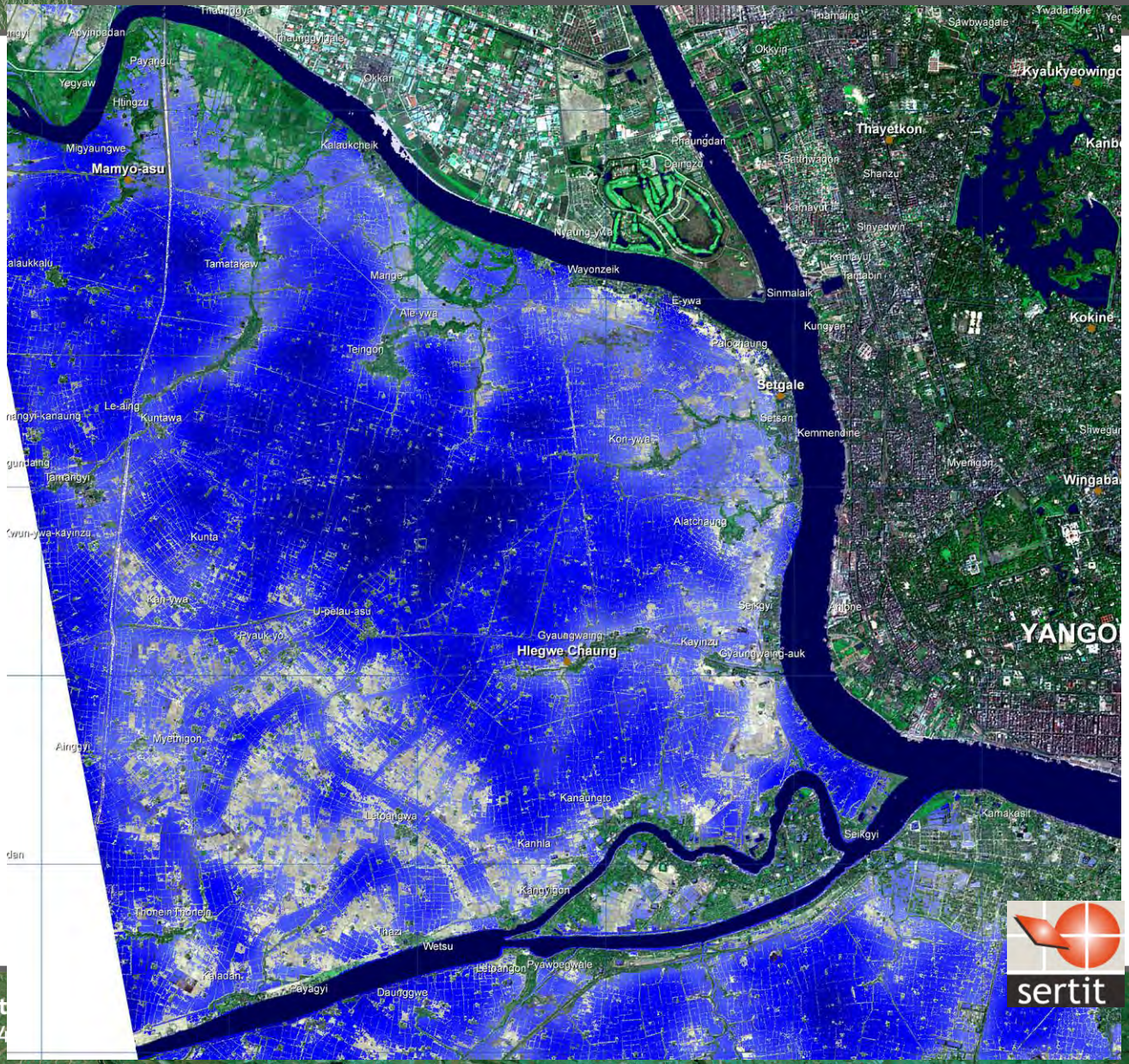
Exploitation of VHR SAR: Radarsat II
Nargis typhoon Maynmar

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

Rremember E. Pottier presentation

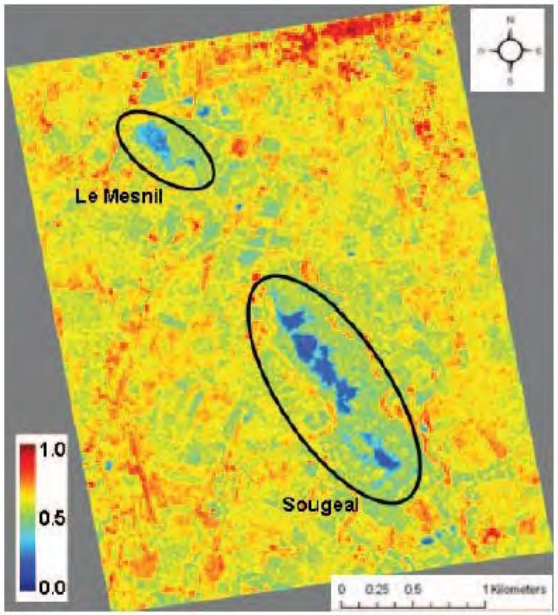


Figure 3- *The normalized Shannon Entropy (SE) image.*

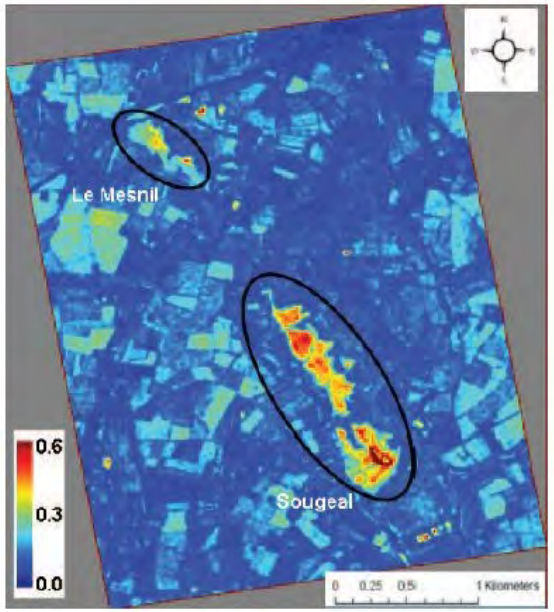


Figure 4- *Temporal coefficient of variation of the SE parameter*

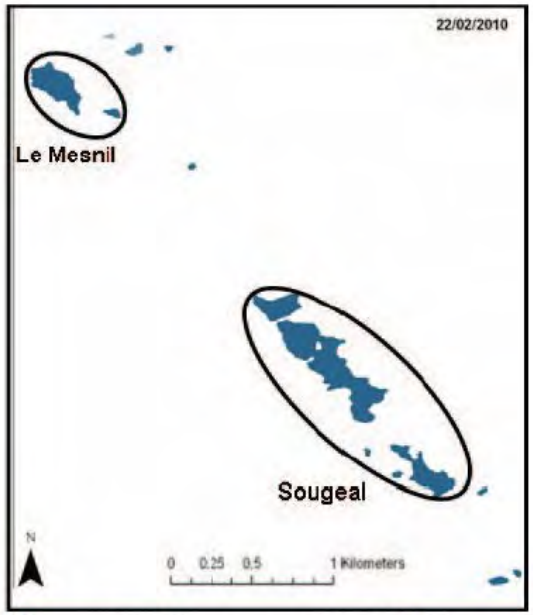


Figure 5-*The segmented SE image with the open water in blue*

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

Presentation outline

Introduction: Why water bodies and flood mapping and monitoring

Flood mapping exploiting SAR data

- Basis physical principles
- From ERS to ASAR towards Sentinel
- New generation of ASAR: VHR SAR and Sentinel

Flood mapping exploiting optical data (short overview)

- **PIR and SWIR bands exploitation**
- **From Medium to VHR data**

Floods and lakes monitoring

- Long term monitoring
- Meteo climato parameters

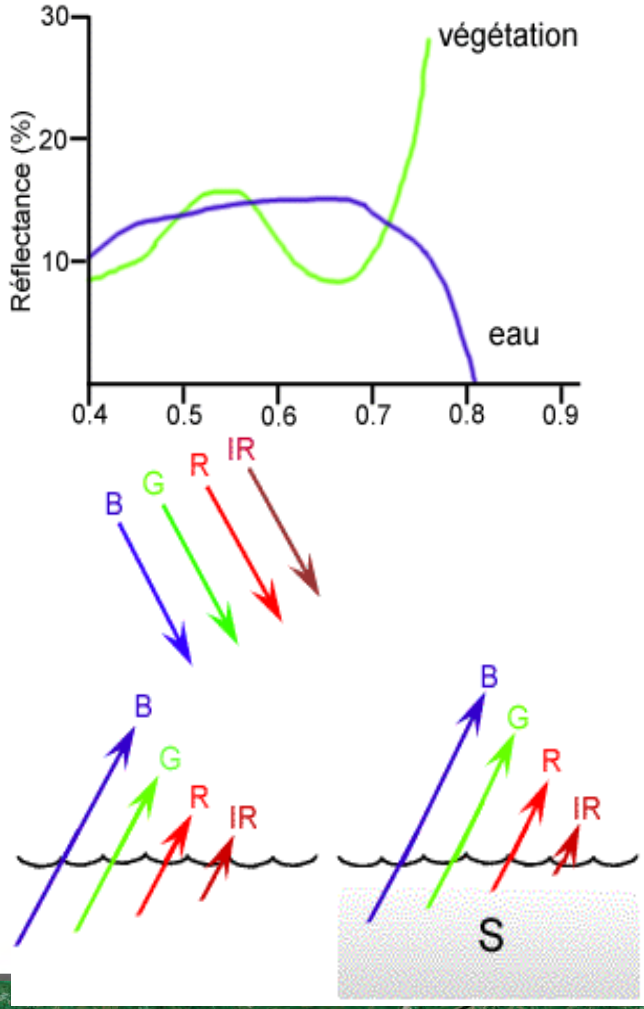
Concluding remarks, new trends and recommendations

Optical Flood mapping

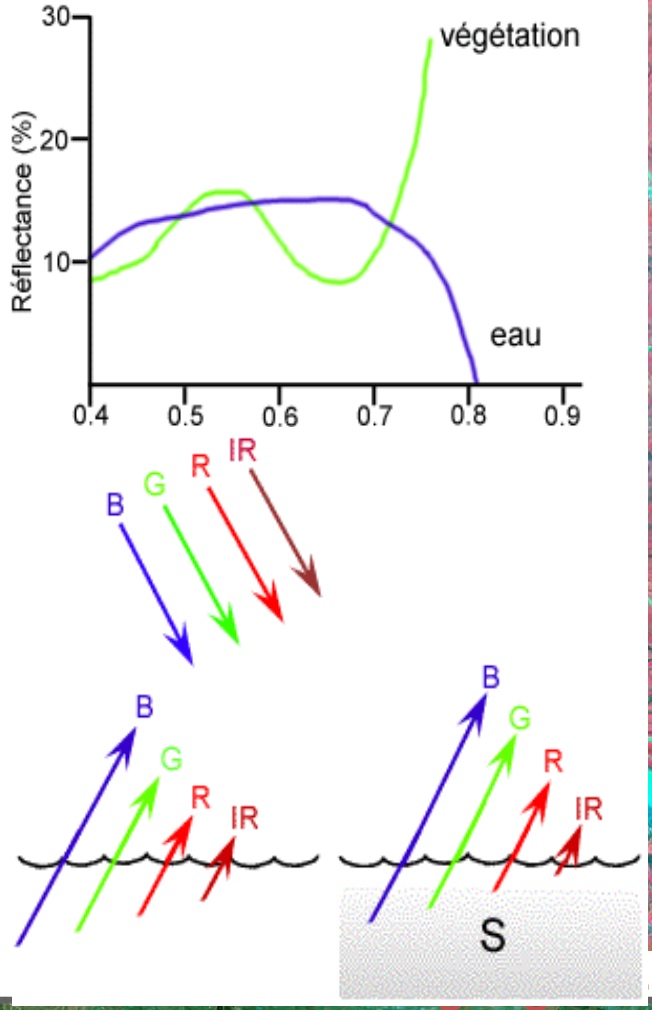
- Water absorbs the longer wavelengths of visible and NIR and SWIR domains Reflects the shorter wavelengths of the visible domain (blue, green)

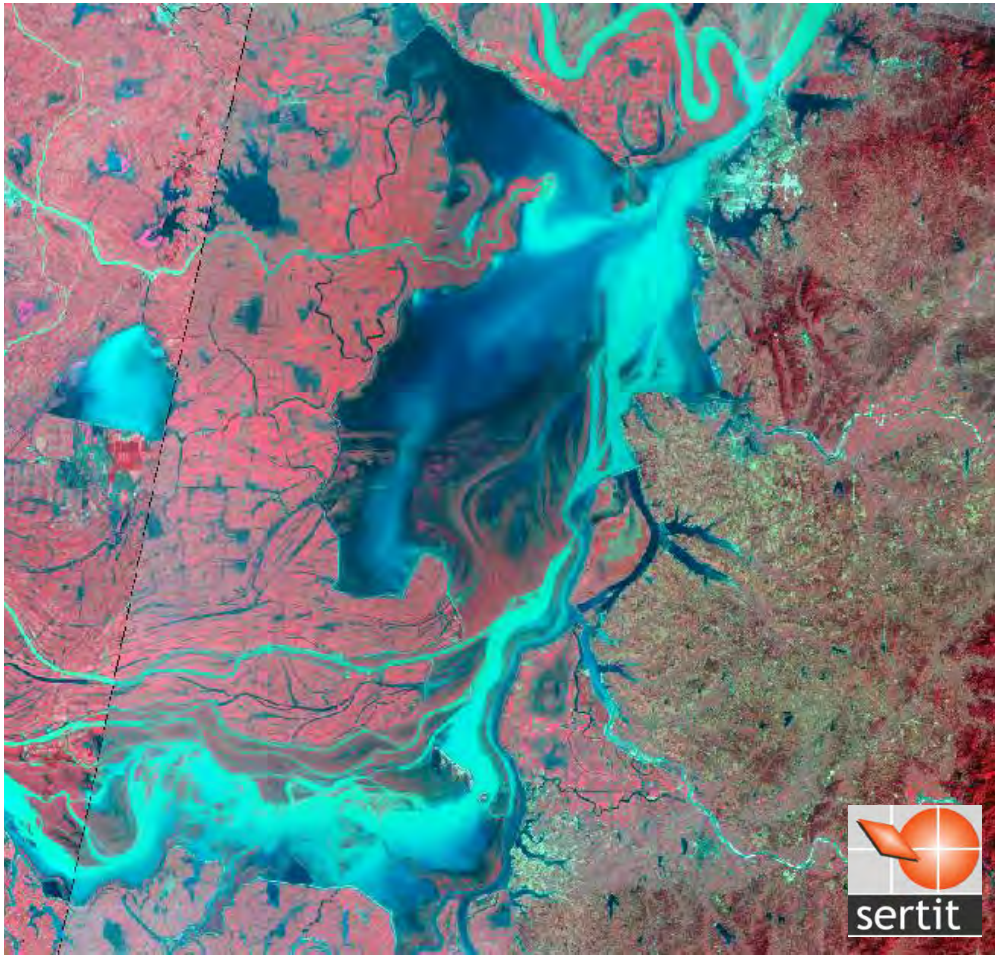
⇒ More precisely water color depends on:

- Depth (ground influence sand/rocks)
- Materials in suspension
- Vegetation or algae



Spectral basis for flood mapping



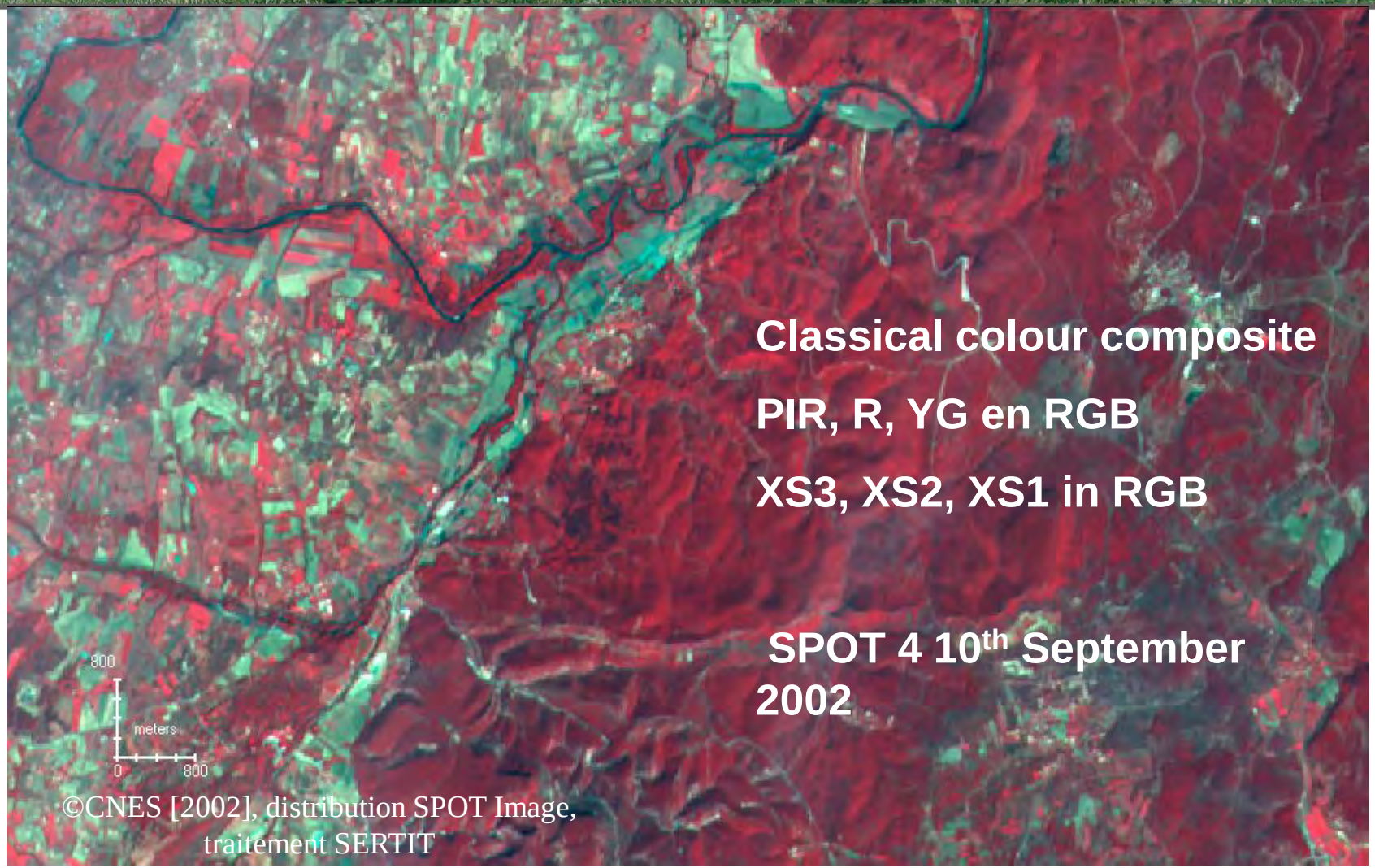


PR China, 1994 flood event

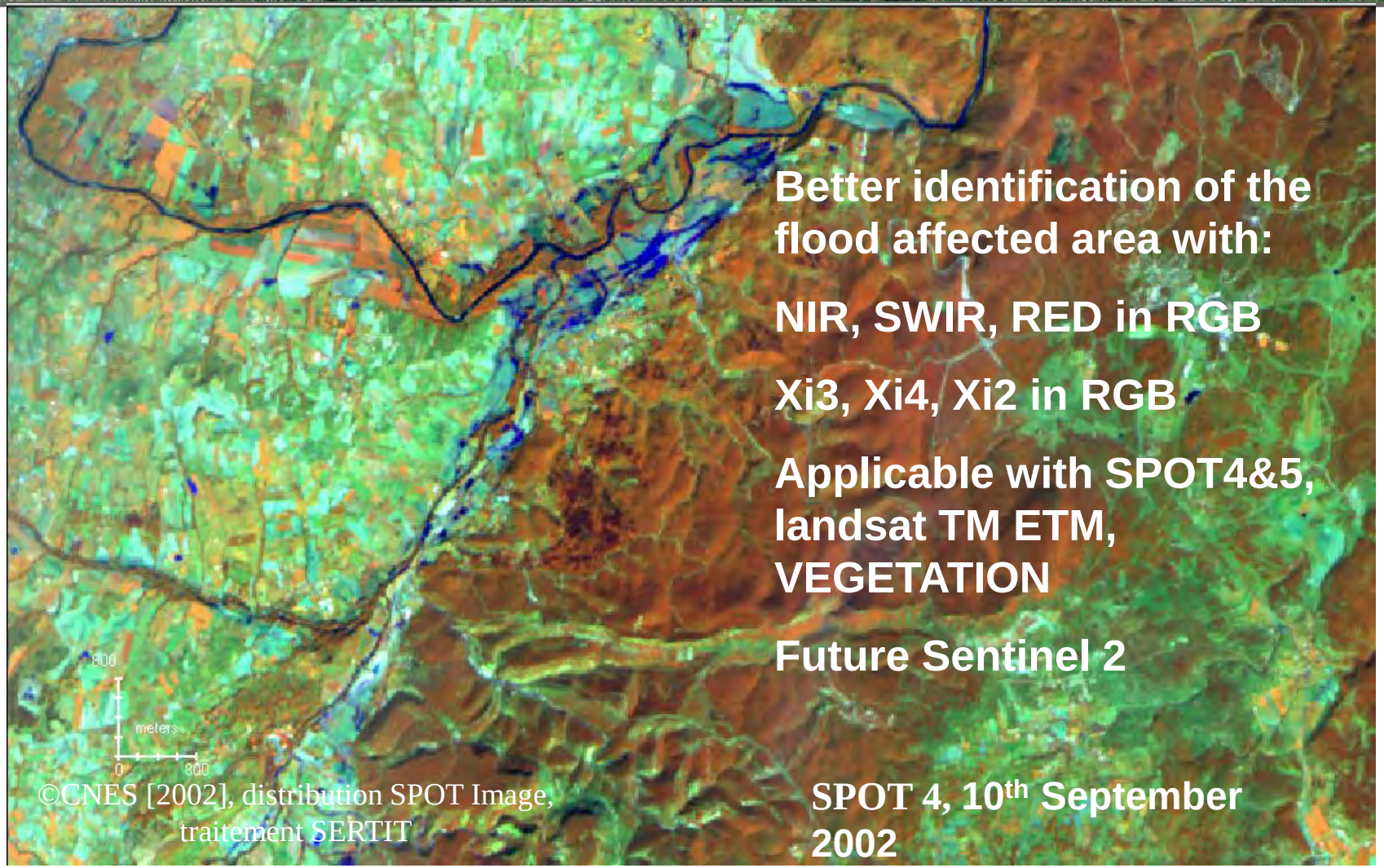
Spectral basis for flood mapping

Actual and future optical sensors more or less suitable for water surface mapping

Optical Flood mapping : channel selection



Optical Flood mapping : Contribution of the SWIR channel



Better identification of the flood affected area with:

NIR, SWIR, RED in RGB

Xi3, Xi4, Xi2 in RGB

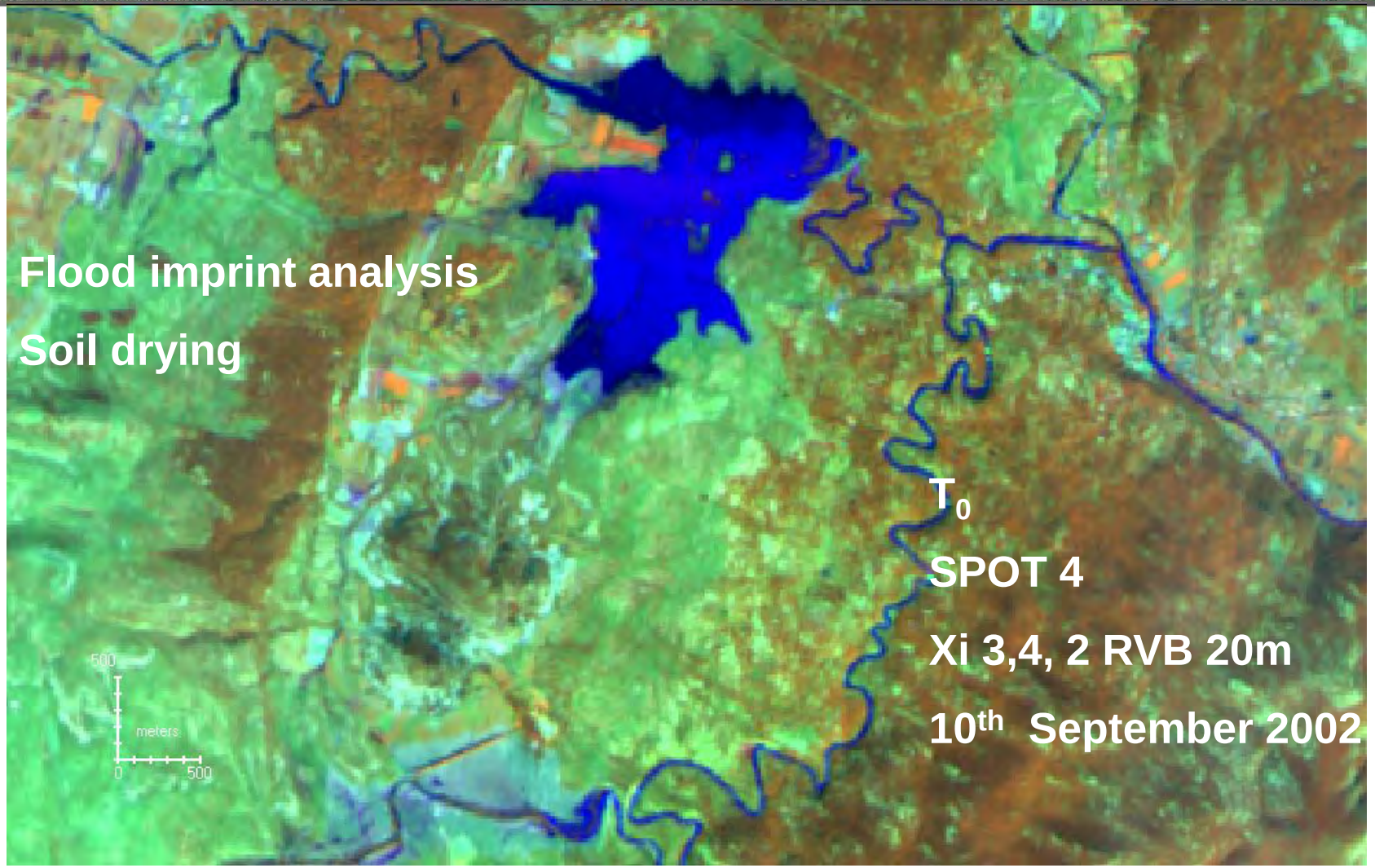
Applicable with SPOT4&5, landsat TM ETM, VEGETATION

Future Sentinel 2

SPOT 4, 10th September 2002

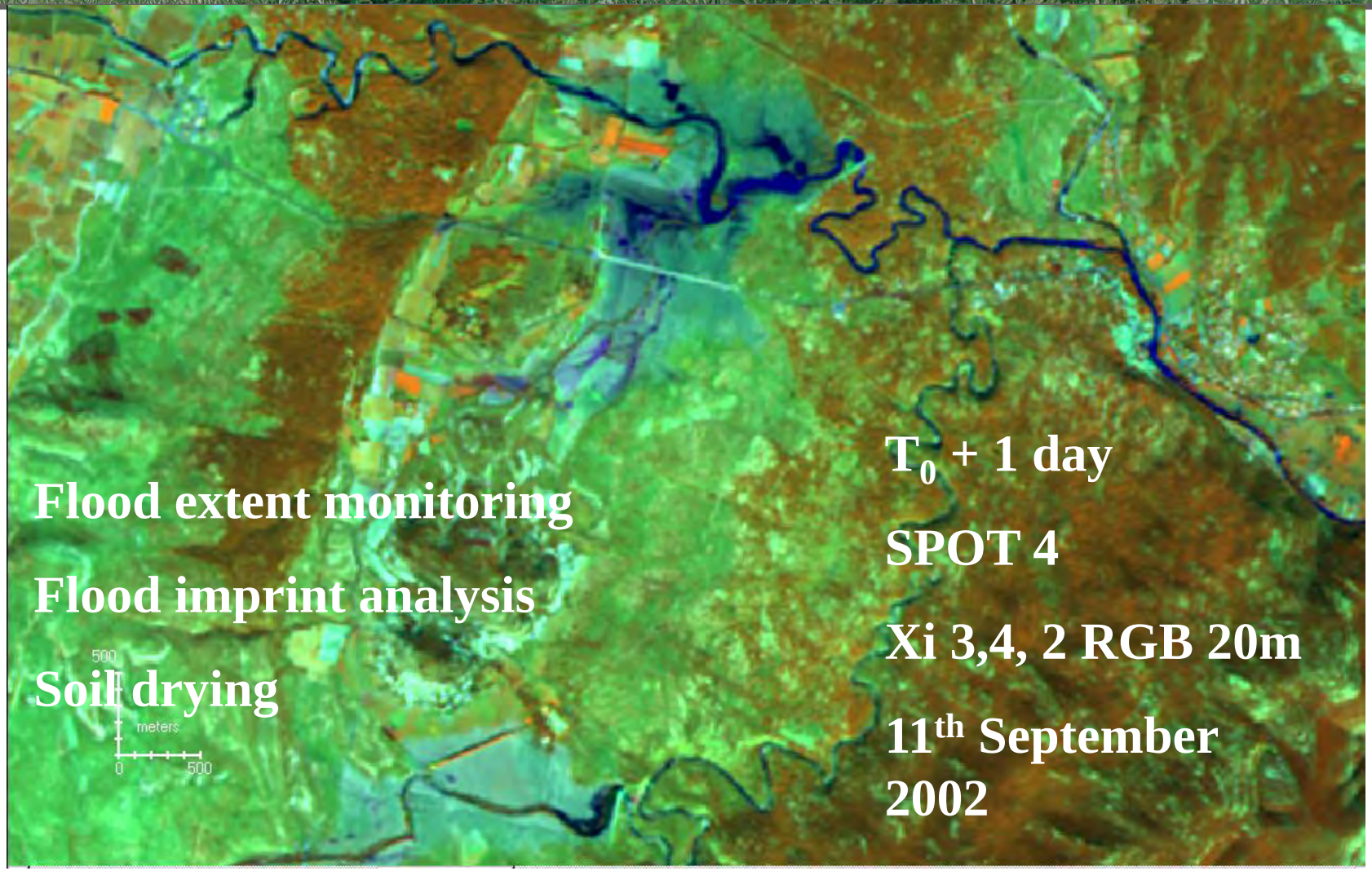
Multitemporal approach:

contribution of the SWIR channel for flood imprint mapping



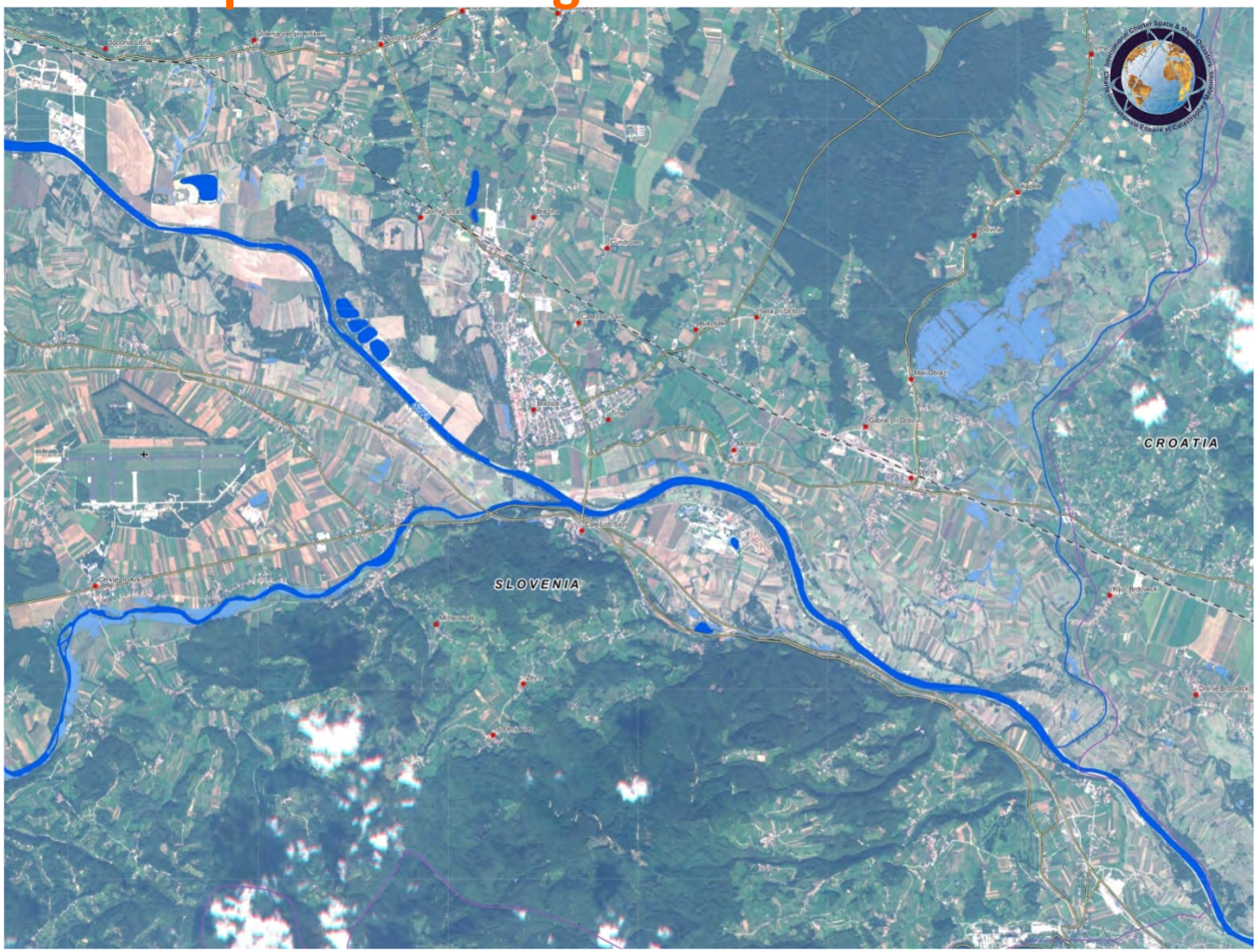
Multitemporal approach:

contribution of the SWIR channel for flood imprint mapping

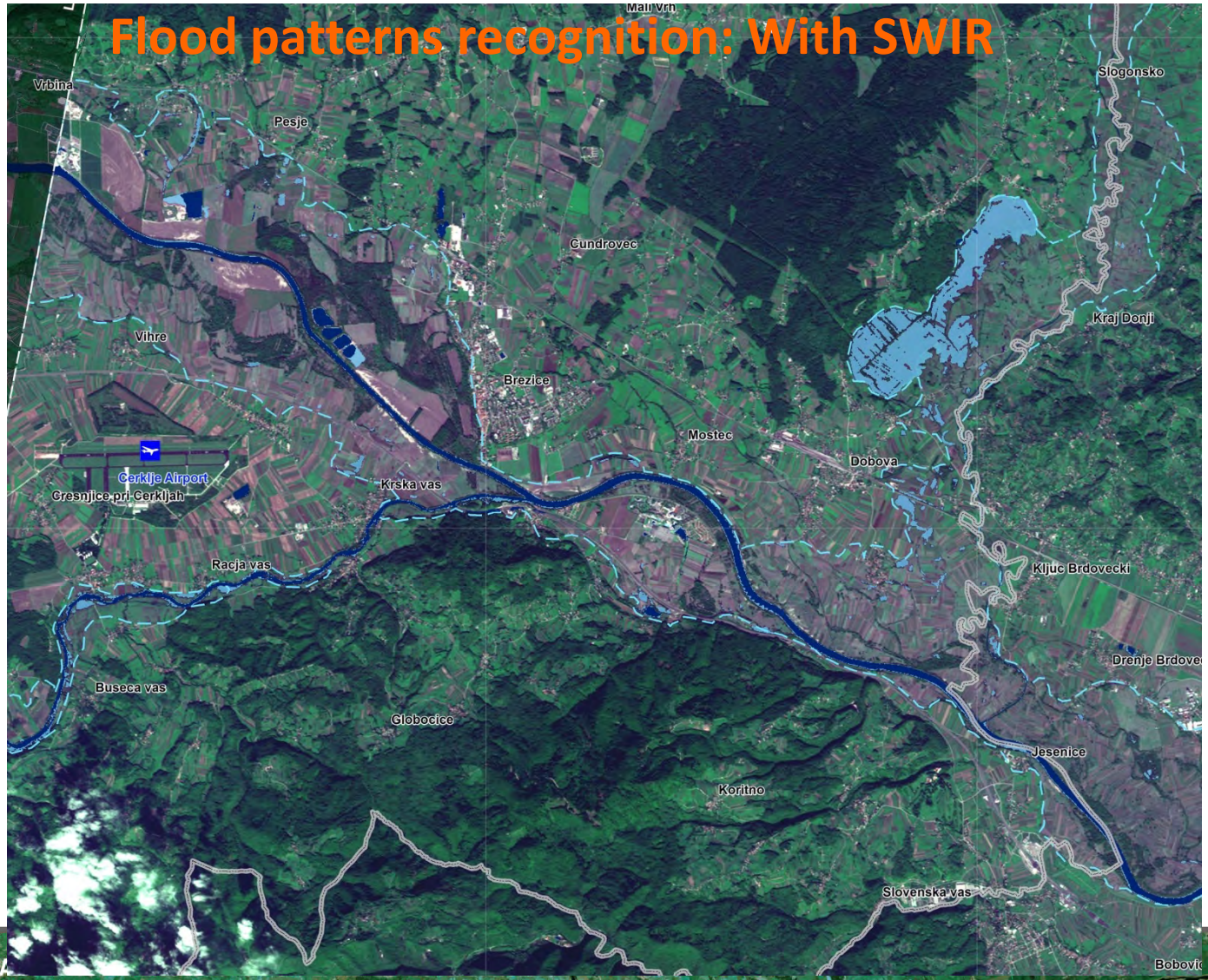


Optical Flood mapping : Contribution of the SWIR channel

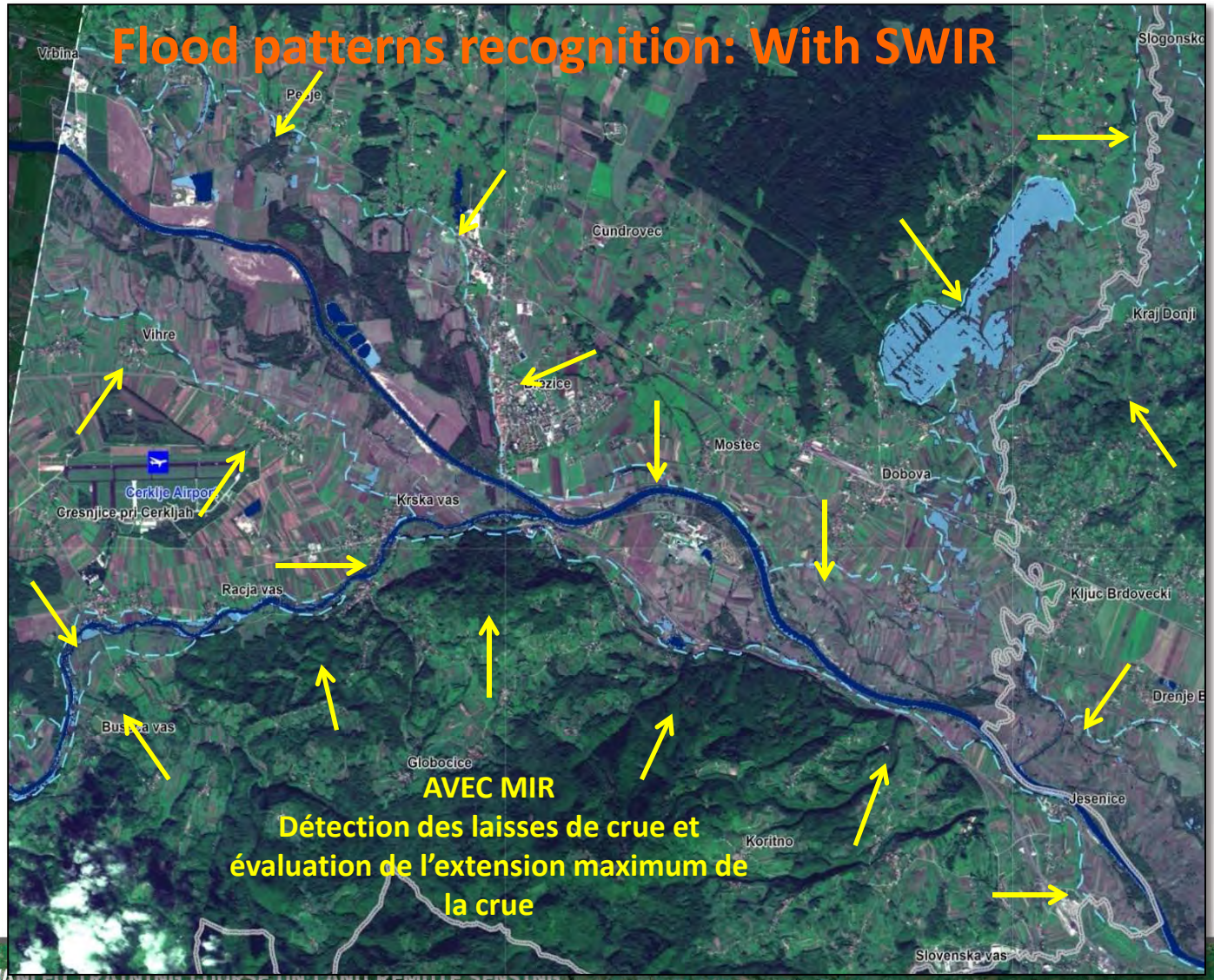
Flood patterns recognition: Without SWIR

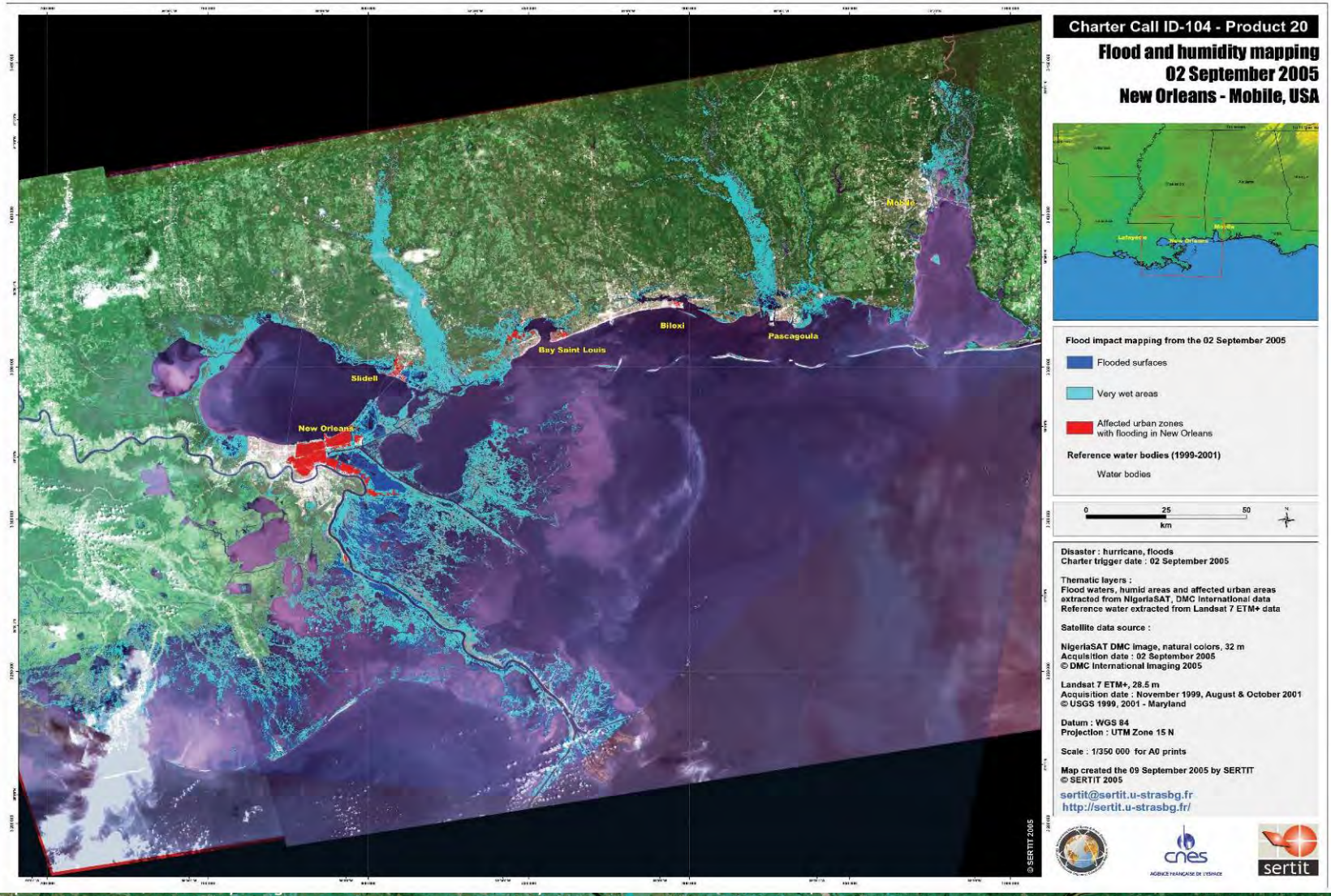


Optical Flood mapping : Contribution of the SWIR channel

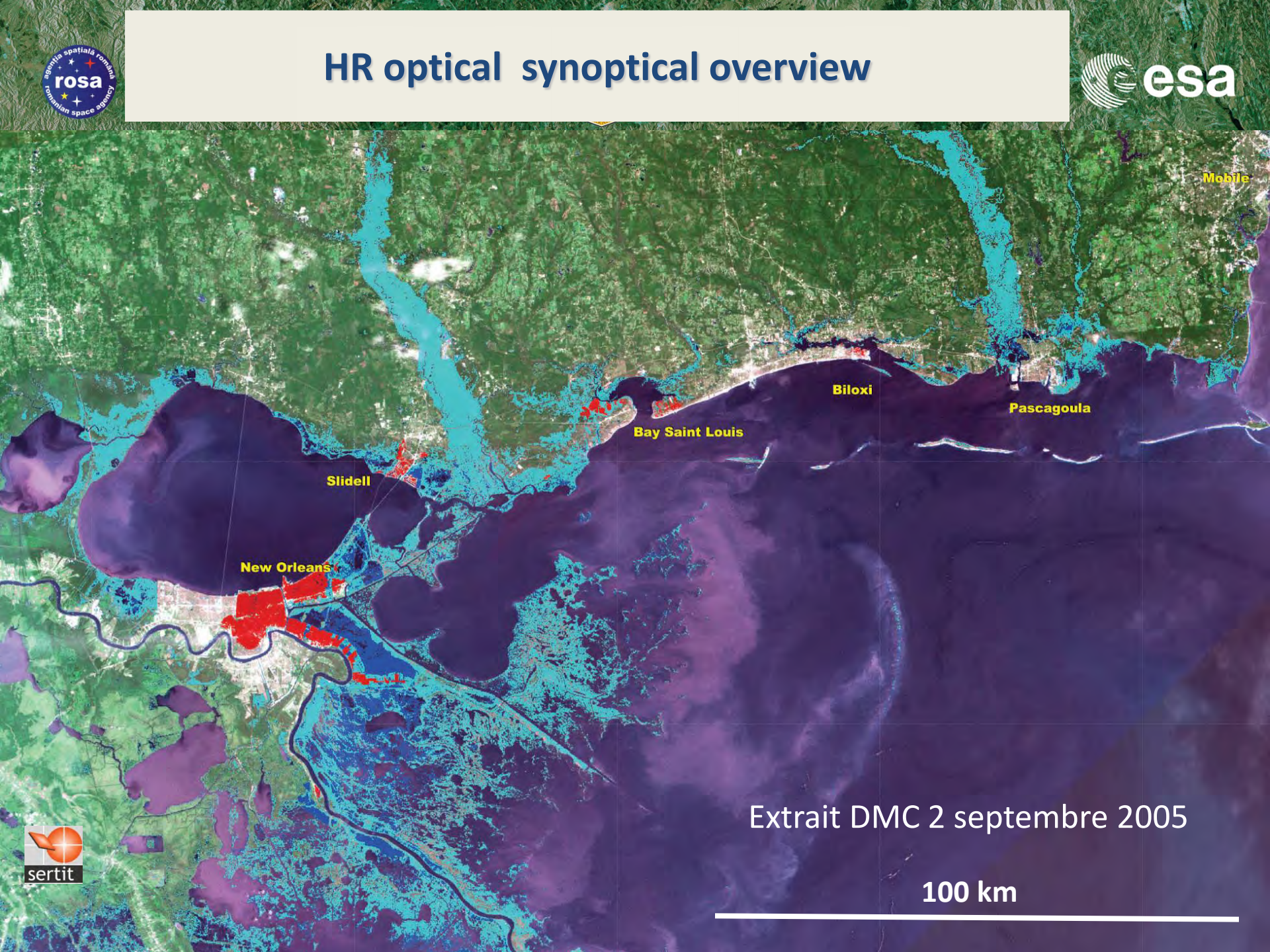


Optical Flood mapping : Contribution of the SWIR channel

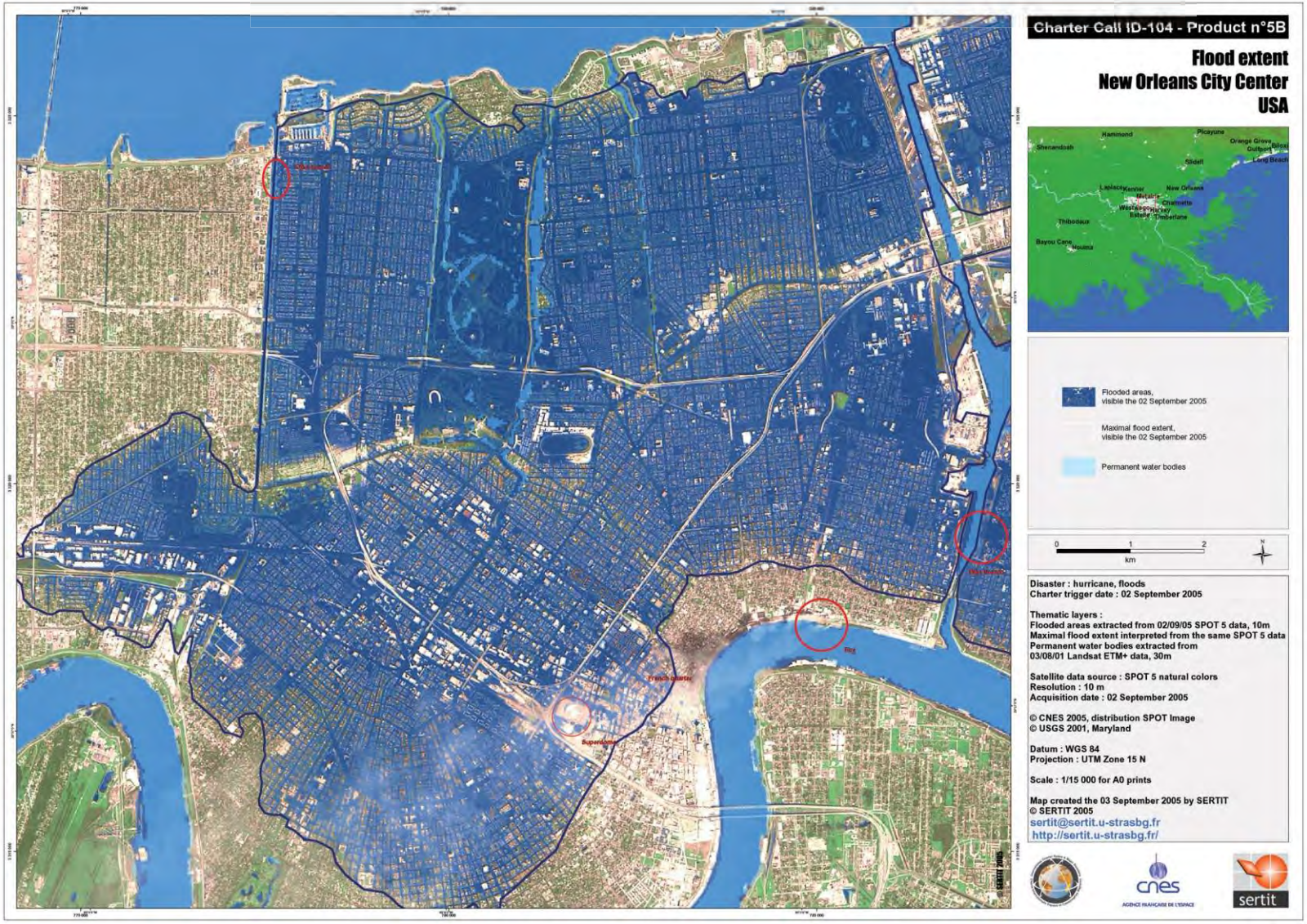



Charter Call ID-104 - Product 20
Flood and humidity mapping
02 September 2005
New Orleans - Mobile, USA
Mobile
Biloxi
Pascagoula
Bay Saint Louis
Slidell
New Orleans
Flood impact mapping from the 02 September 2005
Flooded surfaces
Very wet areas
Affected urban zones with flooding in New Orleans
Reference water bodies (1999-2001)
Water bodies
0 25 50
km
Disaster : hurricane, floods
Charter trigger date : 02 September 2005
Thematic layers :
Flood waters, humid areas and affected urban areas extracted from NigeriaSAT, DMC International data
Reference water extracted from Landsat 7 ETM+ data
Satellite data source :
NigeriaSAT DMC image, natural colors, 32 m
Acquisition date : 02 September 2005
© DMC International Imaging 2005
Landsat 7 ETM+, 28.5 m
Acquisition date : November 1999, August & October 2001
© USGS 1999, 2001 - Maryland
Datum : WGS 84
Projection : UTM Zone 15 N
Scale : 1/350 000 for A0 prints
Map created the 09 September 2005 by SERTIT
© SERTIT 2005
sertit@sertit.u-strasbg.fr
http://sertit.u-strasbg.fr/
© SERTIT 2005

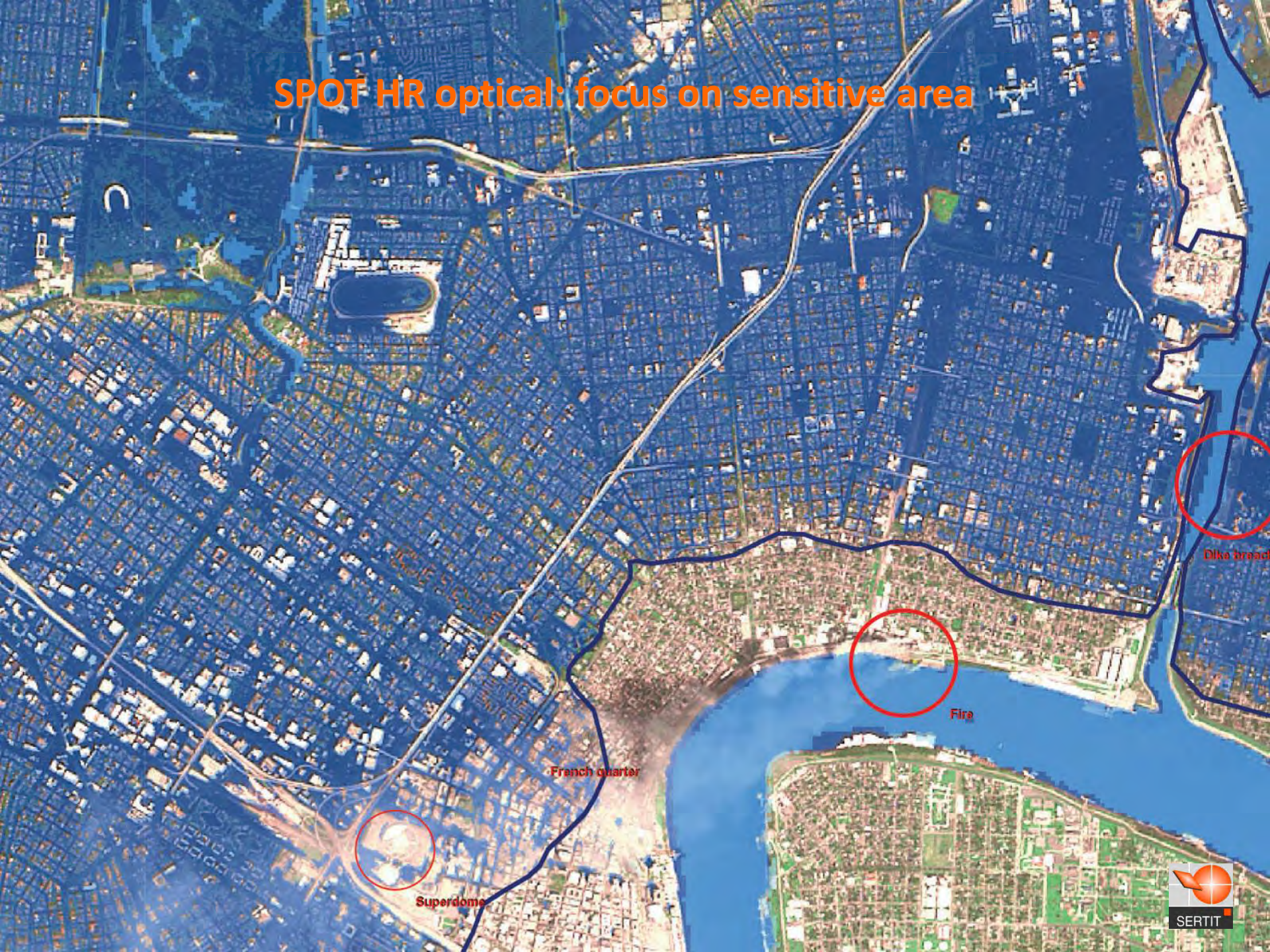
HR optical synoptical overview



SPOT HR optical: focus on sensitive area



SPOT HR optical: focus on sensitive area



Optical VHR and flood mapping

Since 2000 more and more VHR satellite

From Ikonos, Kompsat QuickBird, Worldview, Geoeye
Pléaides HR

Limitations:

- **Clouds and shadows**
- **Small swatch (incresed from the new and futures ones)**

Force:

- **Fast programming , agility**
- **Very High resolution (1 to 0.50 m)**
- **Scale 1.1500**
- **Flash flood**

Optical VHR and flood mapping: very fine description of the flood field

Worldview 2
Safer action 42 Xynthia storm: coastal flooding

Optical VHR and flood mapping: very fine description of the flood impact on sensitive places

Worldview 2: Nebraska flood, Juin 2012

Calhoum Power station
(Nebraska, juin 2012)

Optical VHR and flood mapping: very fine description of the flood impact on hydraulic elements

Optical VHR : Dike break

Agly 2013 flood event

Based on Pleiades HR

Pre event image

Post event image acquired on the 9 March 2013

Optical VHR and flood mapping: Impact on agricultural parcels

Optical VHR : parcelling and flood

- Extraction of narrow water bodies
- Identification of mud deposit
- Impact on river pathway
- Impact on agricultural field

Hautes-Pyrénées: flash flood of Gave de Pau (June 2013)

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

Concluding remarks, new trends and recommendations

long term monitoring of flood prone/lakes

Multisensors approach

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

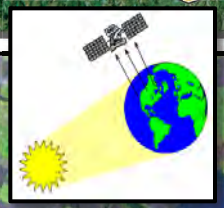
Great expect into the sentinel 1 and 2

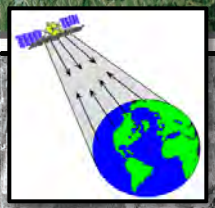
Worldwide applicable:
Asia : China, Mekong system (Tonle sap lake and Delta),
Africa: Niger iner delta, Okavango, etc
Australia: Eyre Lake and Diamanta River
South America: Argentina, Rio del Plata

Complementarity/synergy Optical / Radar

sertit

High Resolution Optical Image





High Resolution Radar Image

Day and night
Unaffected by cloud cover

Very High Resolution
Optical Image

Very High Resolution
Radar Image and polarimetry

Yangtze river's monsoons lakes monitoring

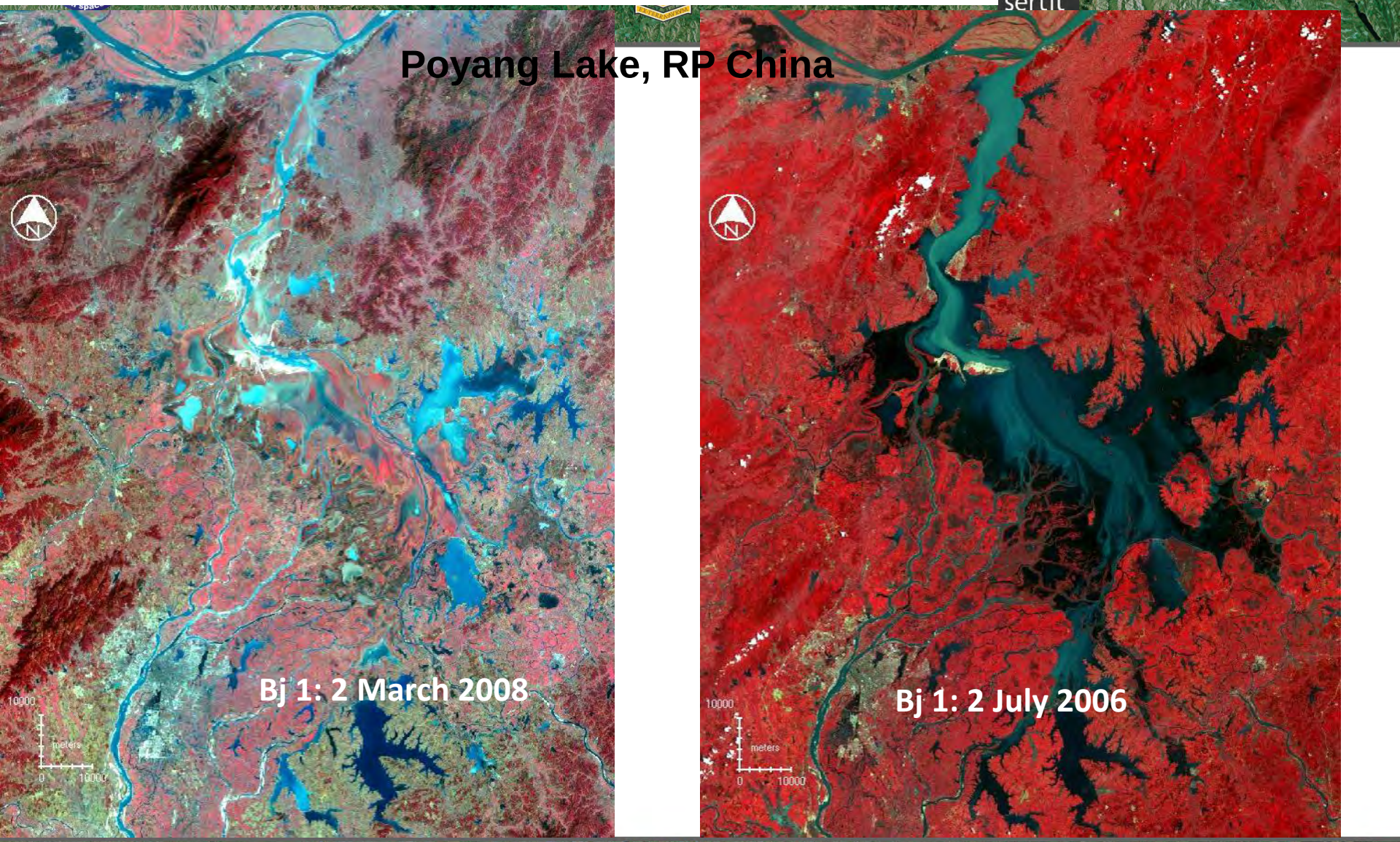
Health of Yangtze is a major concern for 400 000 000 of inhabitants as a fresh wa resource.

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

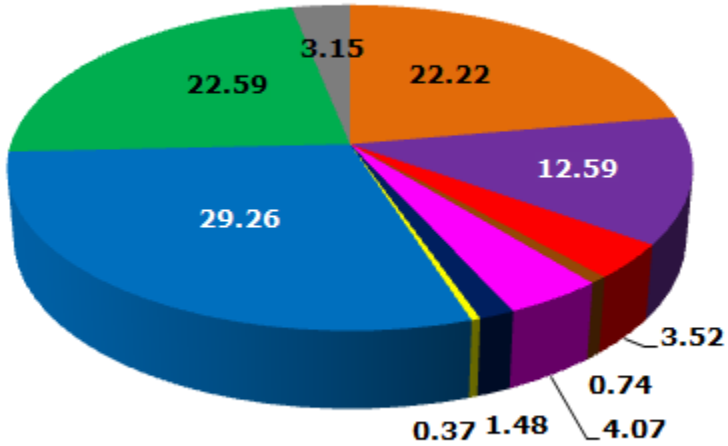
- Biodiversity stakes

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

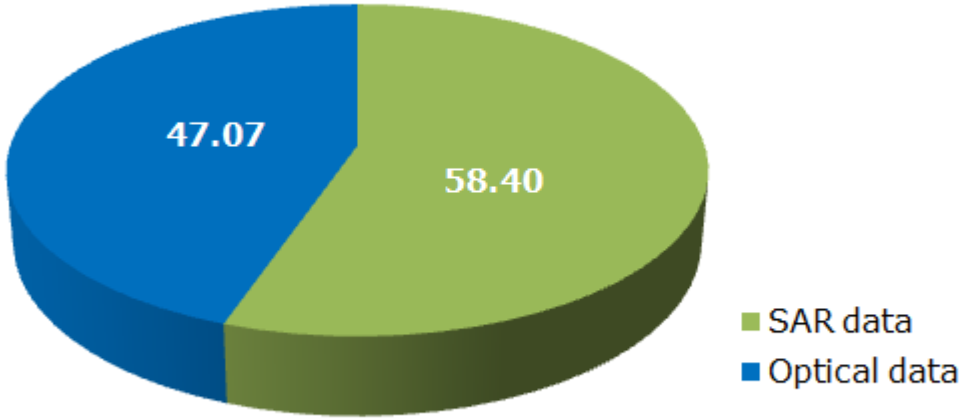


- MODIS
- ENVISAT MERIS FR
- Beijing-1
- Deimos
- HJ-1
- Landsat
- Alos Palsar
- ENVISAT ASAR WSM
- ENVISAT ASAR GMM

A mixed resource

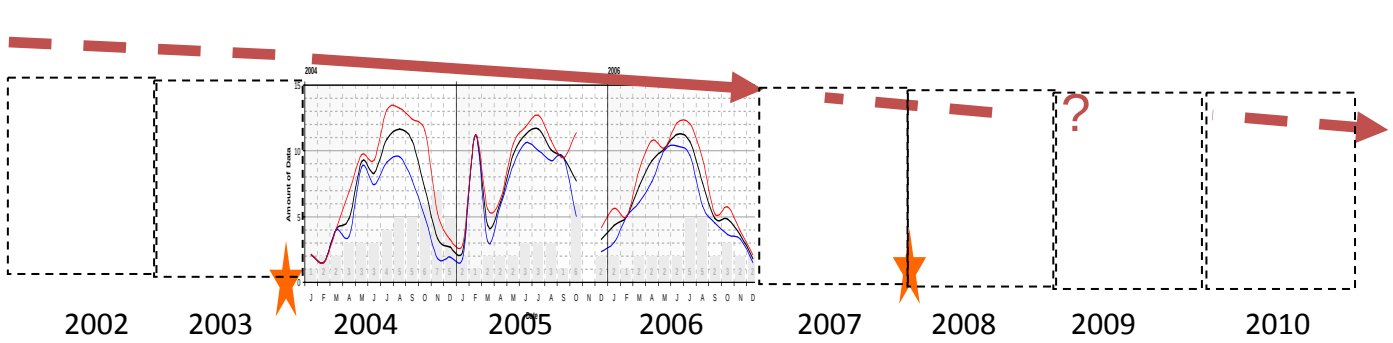
In the future two major resource Sentinel 1 et 2

+550 images



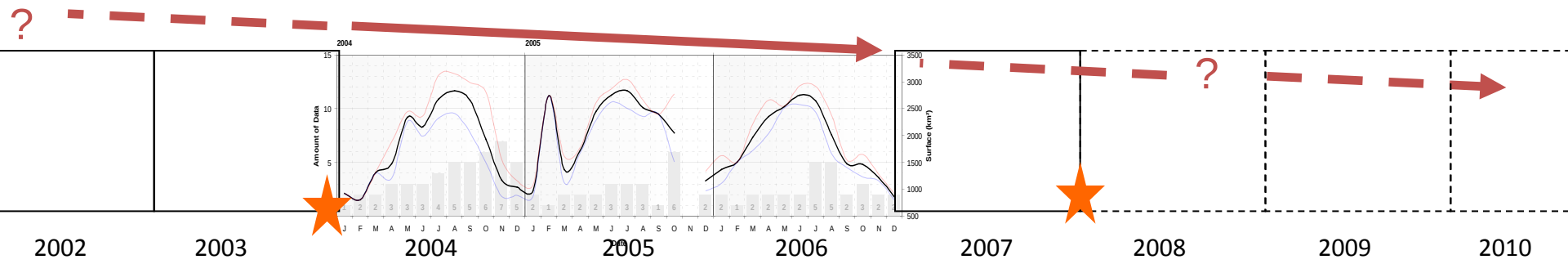
Water extent monitoring: Poyang

3GD event

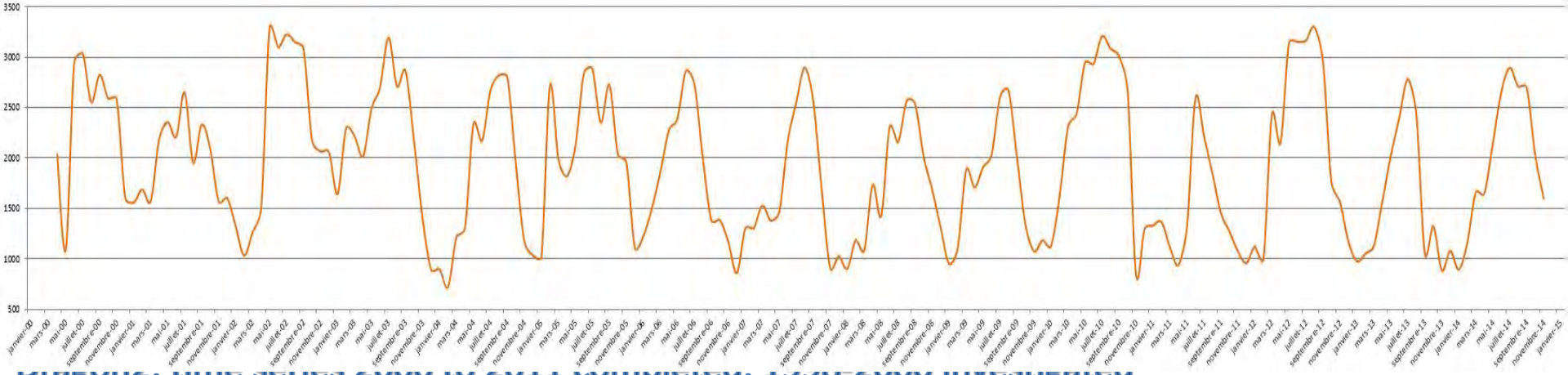


Dragon 2 objectives: Continue and complete water surfaces' monitoring

Water extent monitoring: Poyang



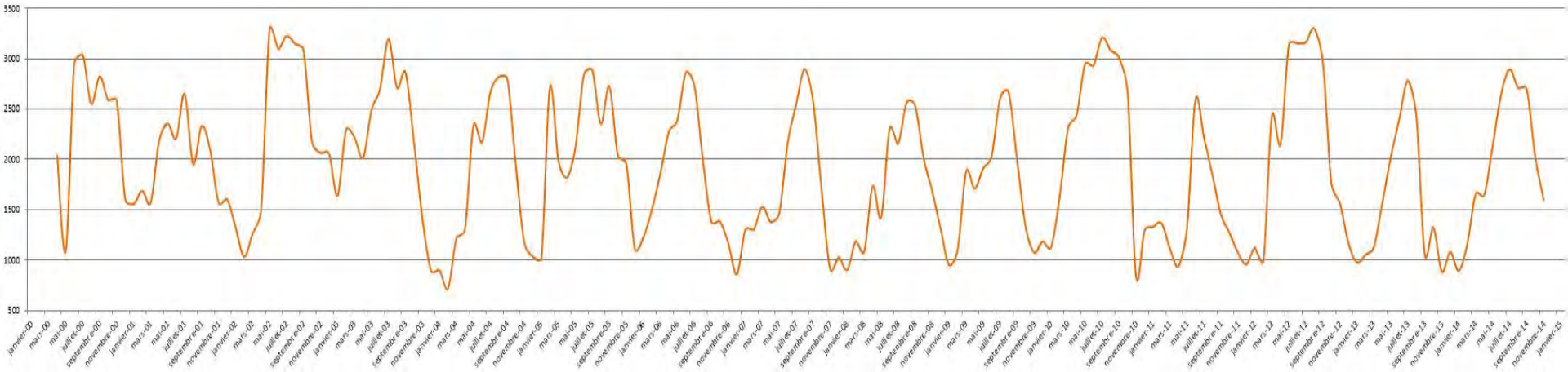
Dragon3objectives: Continue and complet water surface monitoring

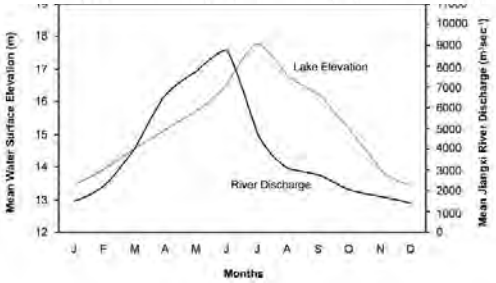


Dragon2: time series 2003 to 2011 completed, 1998-2003 investigated

Dragon 3: 2014 fully integrated

Projects' achievements: W1 Water extent monitoring: Poyang



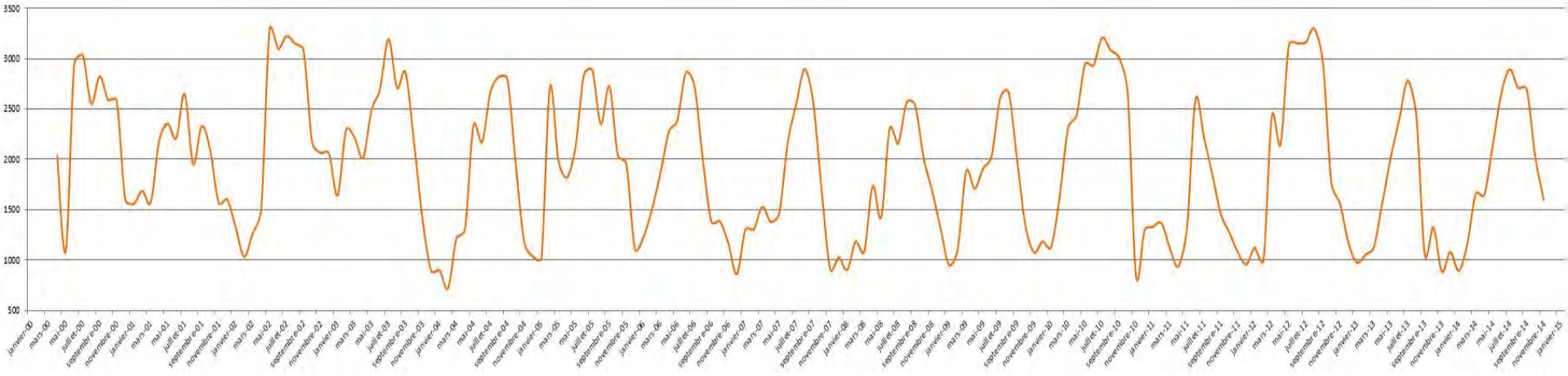


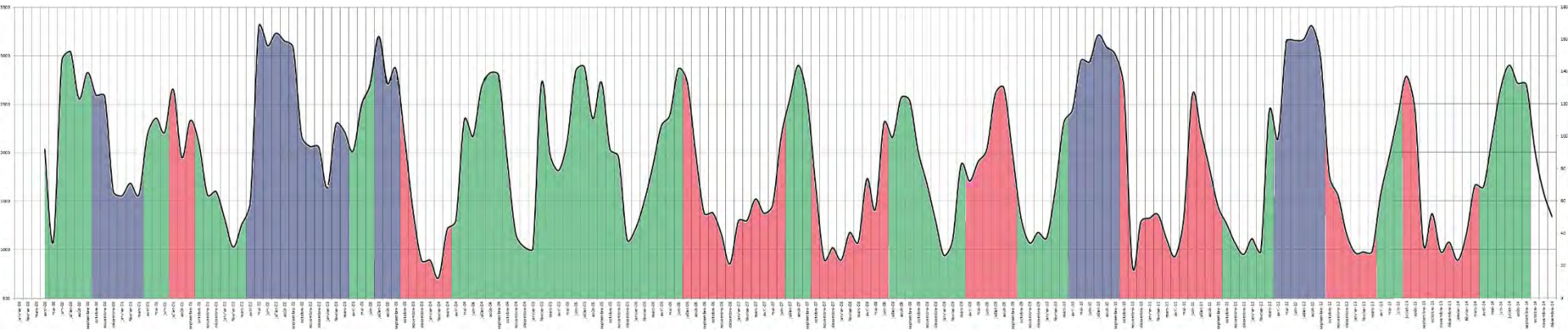
Very dynamic system: classical monsoon shape curves

Large inter annual and intra annual variations

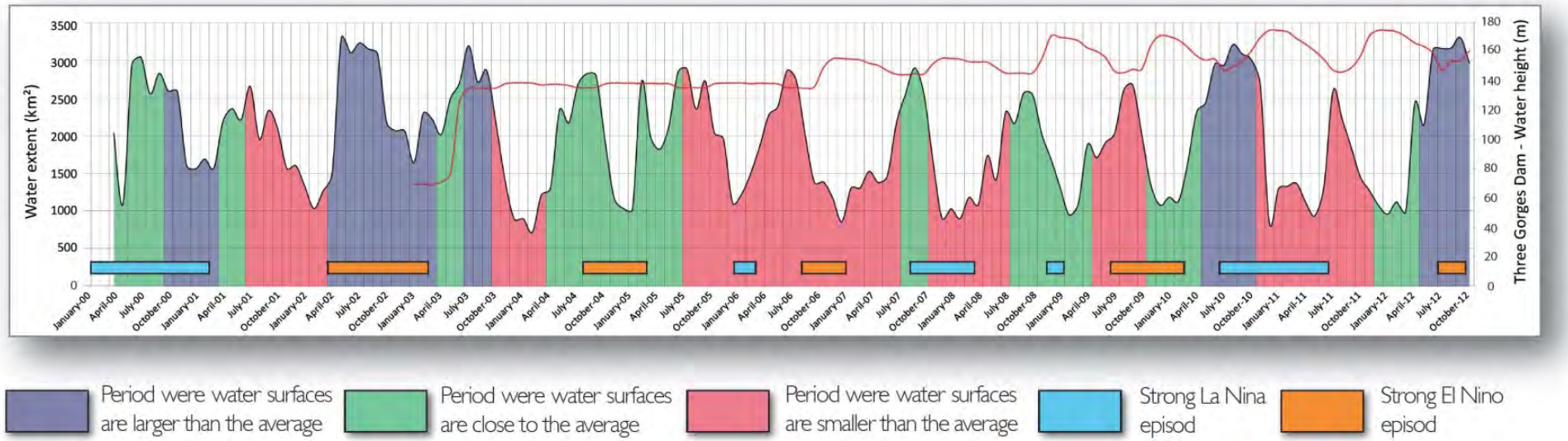
- Each year have an unique behaviors
- Some long flood period, 2002, 2010 (4 months)
- Some very weak flood period, 2006, 2007, redraw beginning in mid August…
- Very rapid inter annual transmission from a drought to a flood context (2009, 2010)
- Astonishing early flood event, first noticed in 2005, but also in 2009 and 2012

W1 Water extent monitoring



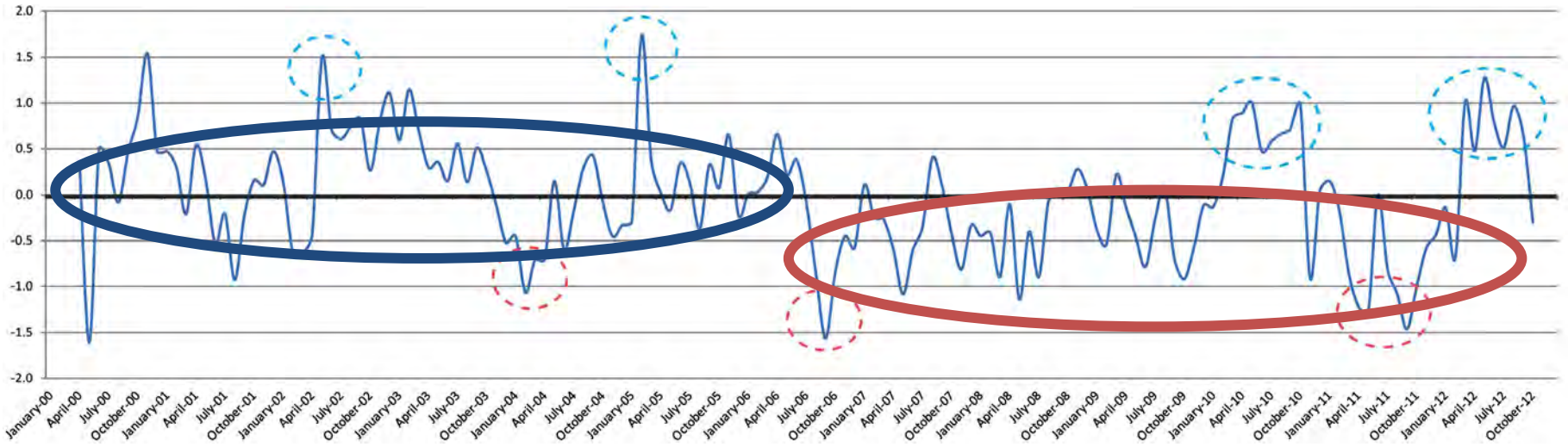


Analyse Regional and global interactions



Possibility to highlight normal, wetter or dryer during the hydrological cycle
=> 3 major long floods event, 2002, 2010 2011
=> Drought event, occurring at any period of the year, summer fall winter nor spring, with some long event July -2006 to july2009, fall 2010sprin 2012
=>Apparent increase of drought tendency since the mid 2000

Analysing Regional and global interactions



Removing of seasonal effect in order to quantify and rank the events

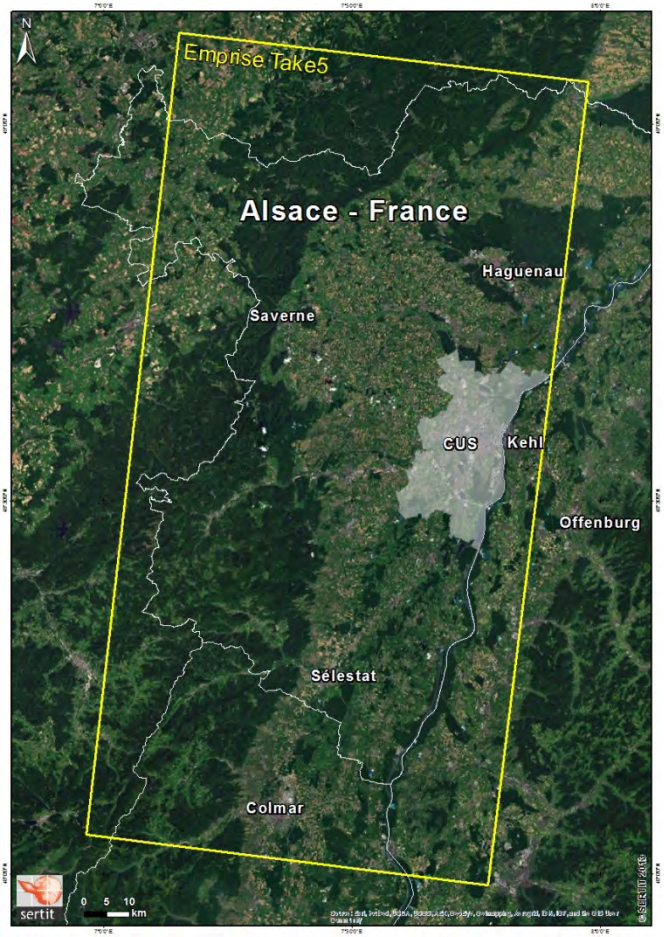
⇒Confirm the major floods event, and highlighting the February 2005 event

⇒More interesting for drought events, winter 2003-2004 , the Summer 2006 event and more impressive the spring 2011 October 2011 and the quasi systematic negative water extent from mid 2000

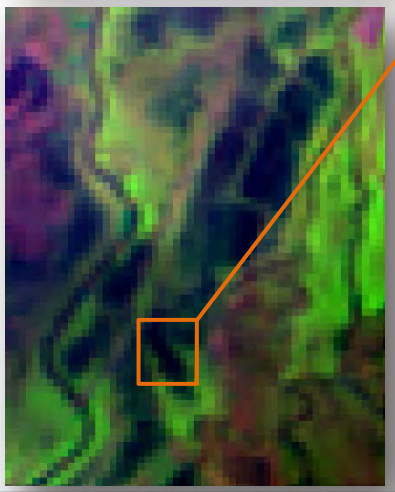
Monitoring sensitive areas based on EO data: preparation of Sentinel2 arrival

Take Five site in Alsatian Plain (France)

Plain flood monitoring
Biodiversity, sensitive agro natural systems



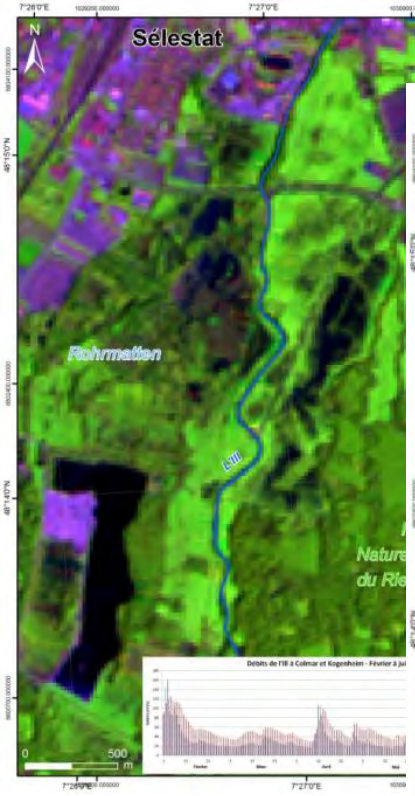
2 missions in field, synchronous with SPOT4 acquisition



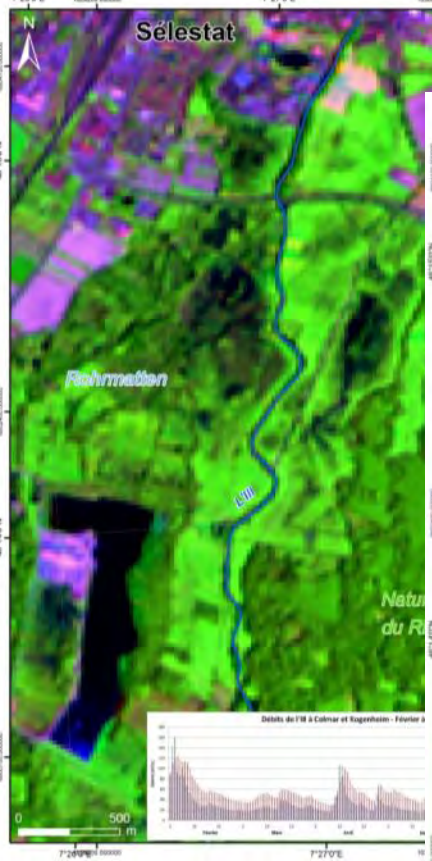
GPS track

TAKE5 SPOT4 exploitation

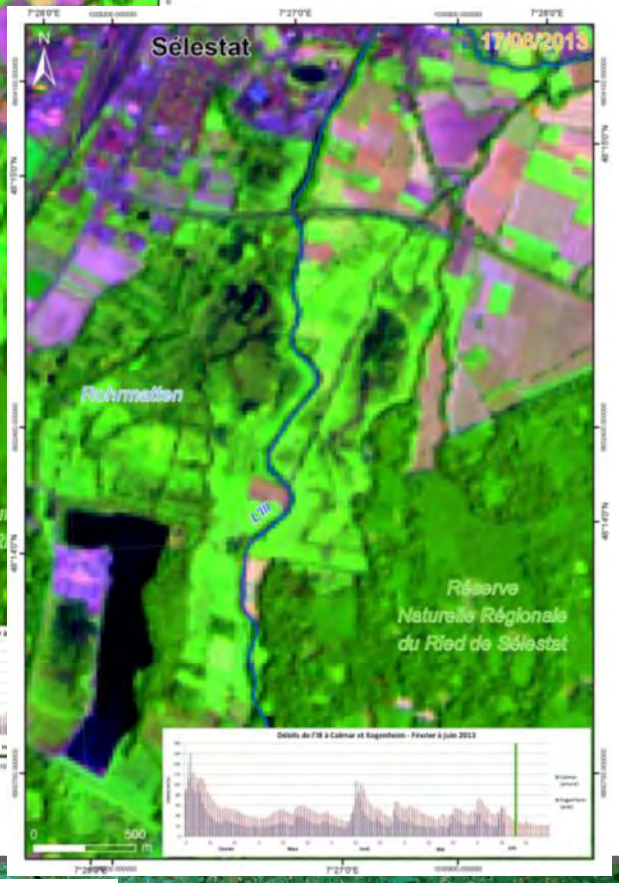
Relation between flooded areas observed and flow measured along the Ill river (area less than 25 km²)



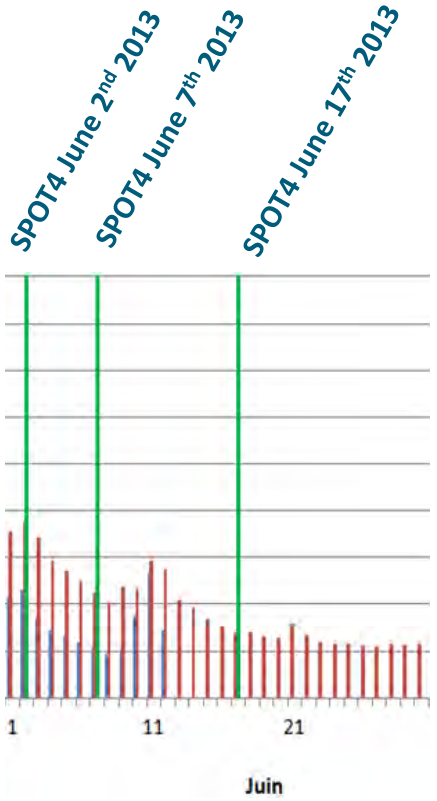
SPOT4 June 2nd 2013



SPOT4 June 7th 2013

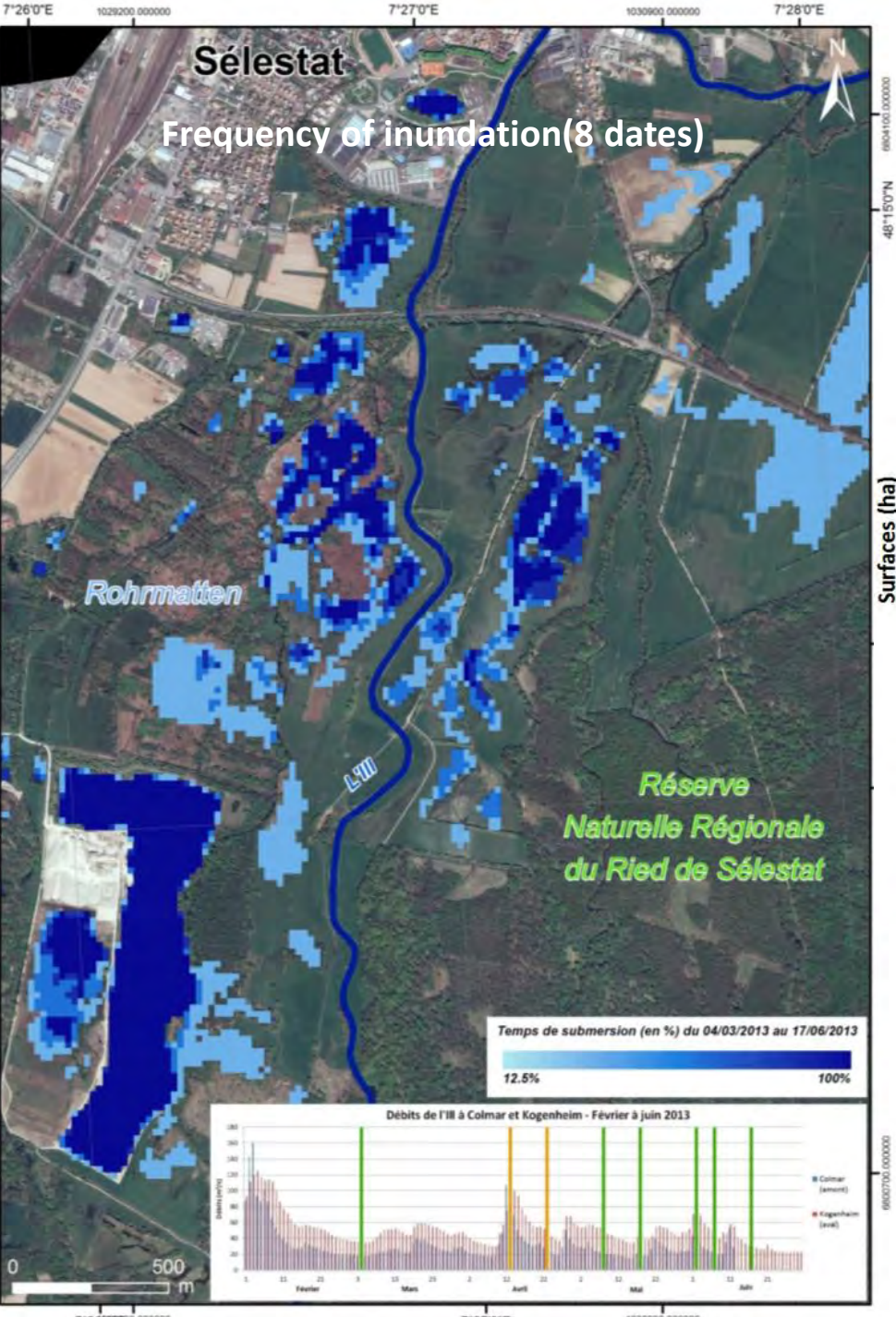


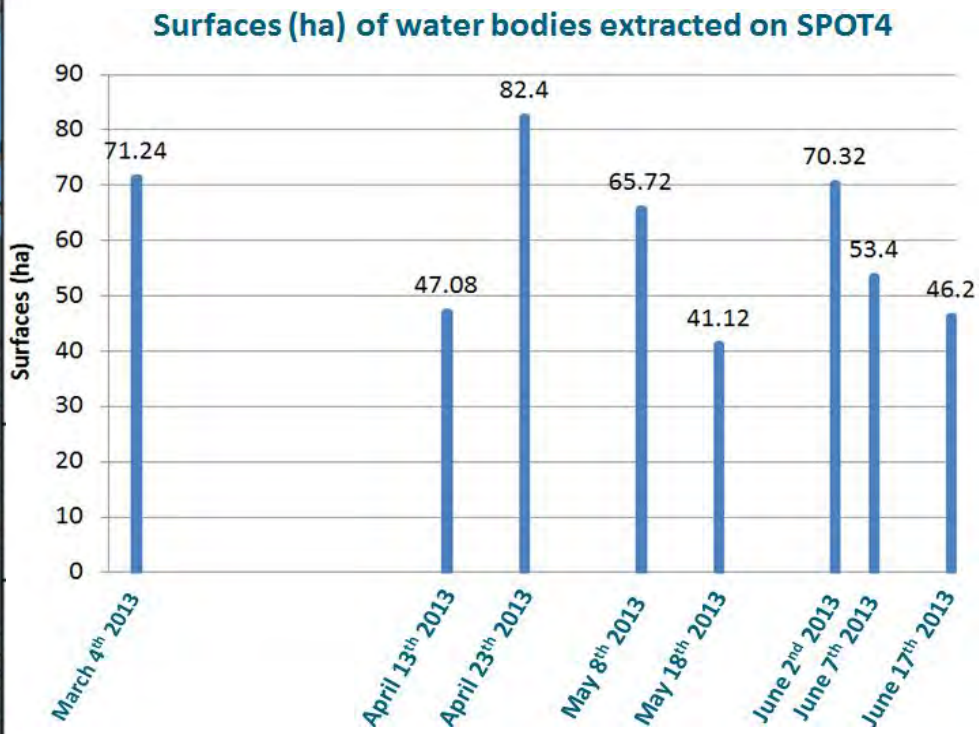
SPOT4 June 17th 2013



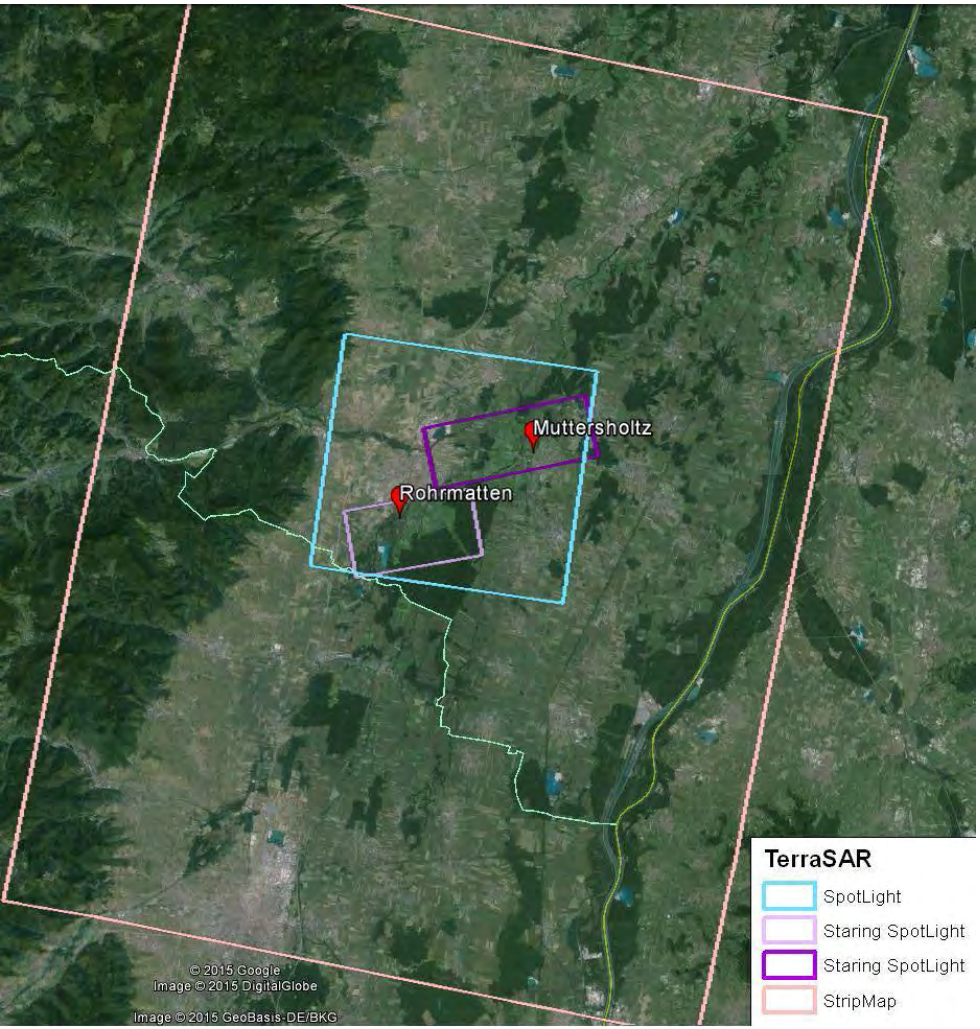
Visible decrease of water surface in 15 days

TAKE5 SPOT4 exploitation





Possibility to follow very small wetlands complex presenting in fact an unexpected/unknown (?) dynamic.



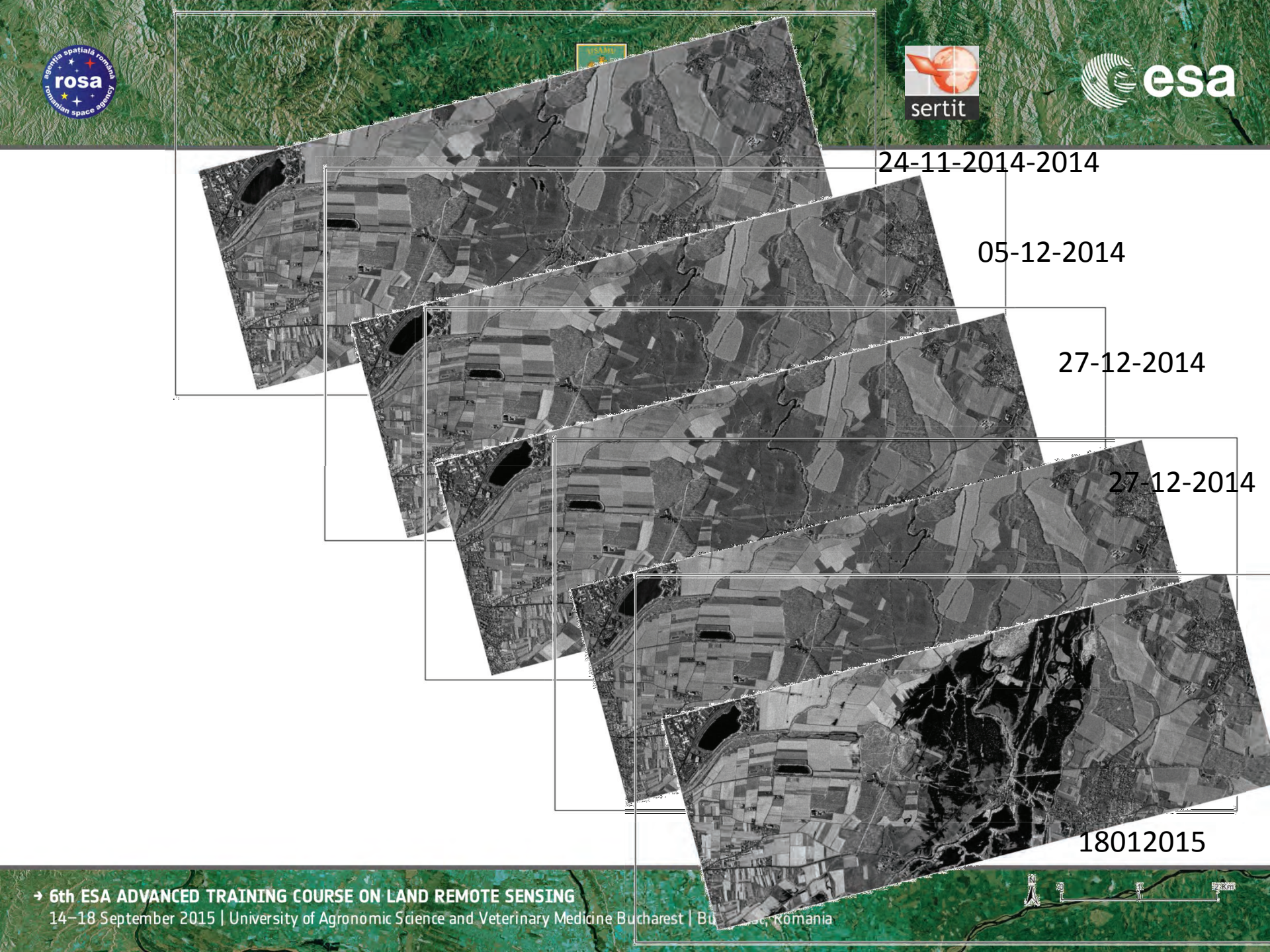
Monitoring sensitive areas based on EO data TerraSAR multimodes

Take Five site in Alsatian Plain (France)

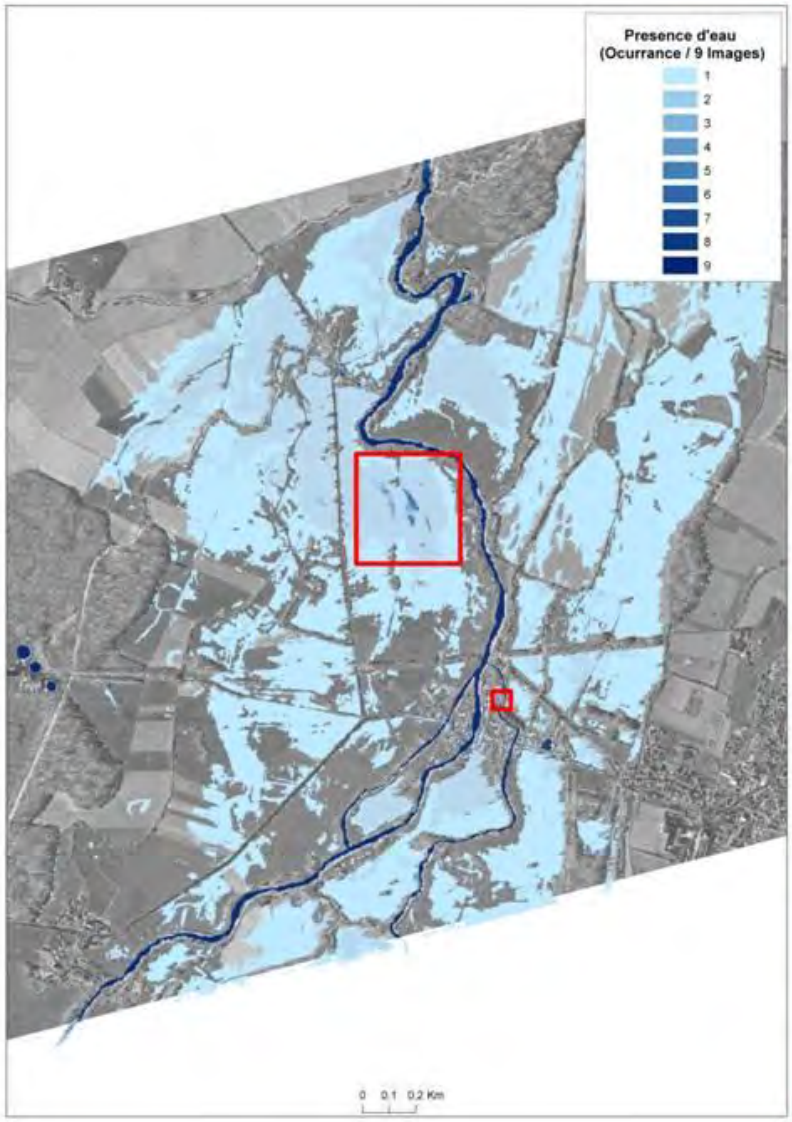
Strip Map mode : 30*50 km², 3m

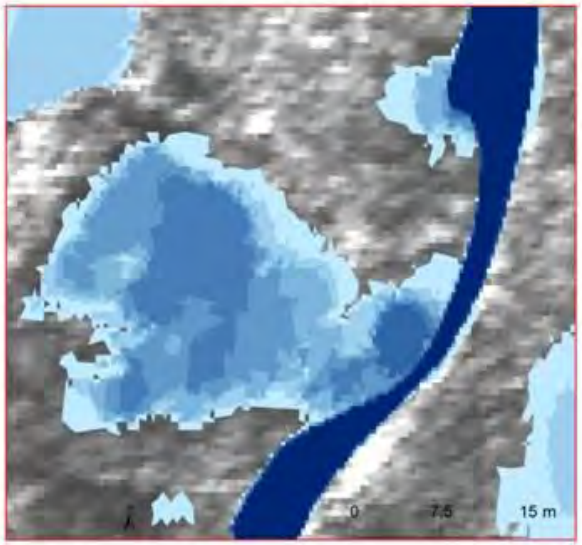
SpotLight mode : 5*10 km², 1m

Staring SpotLight : 3*4 km², 25 cm


24-11-2014-2014
05-12-2014
27-12-2014
27-12-2014
18012015

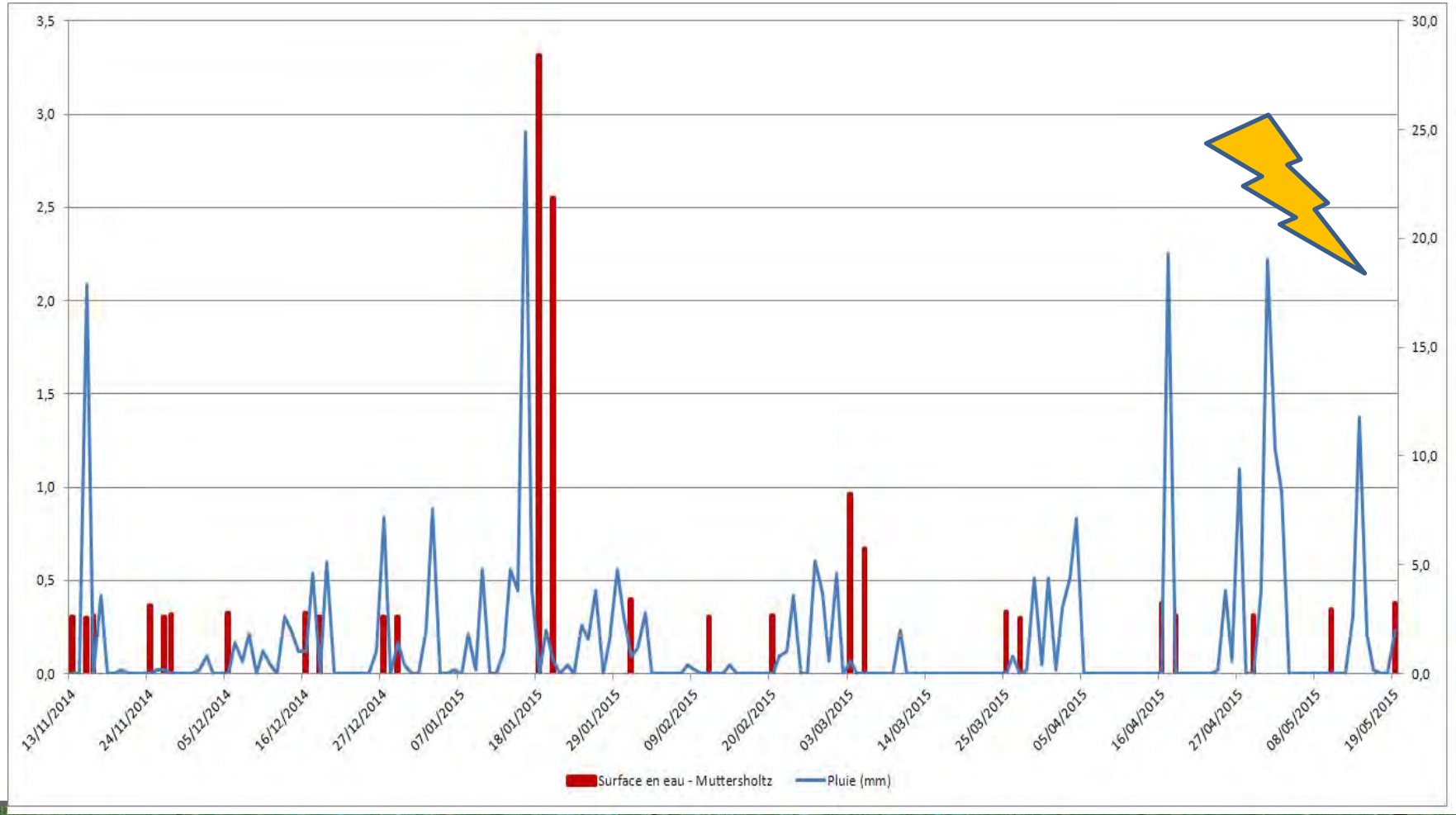
Flood occurrence map for very small wetland areas





Presence d'eau
(Ocurrance / 9 Images)
1
2
3
4
5
6
7
8
9

Water surface monitoring exploiting TerraSAR multimodes data




Sentinel image acquired on the 3 of May 2015

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Flood mapping exploiting SAR data

- Basis physical principles
- From ERS to ASAR towards Sentinel
- New generation of ASAR: VHR SAR and Sentinel

Flood mapping exploiting optical data (short overview)

- PIR and SWIR bands exploitation
- From Medium to VHR data

Floods and flood prones monitoring

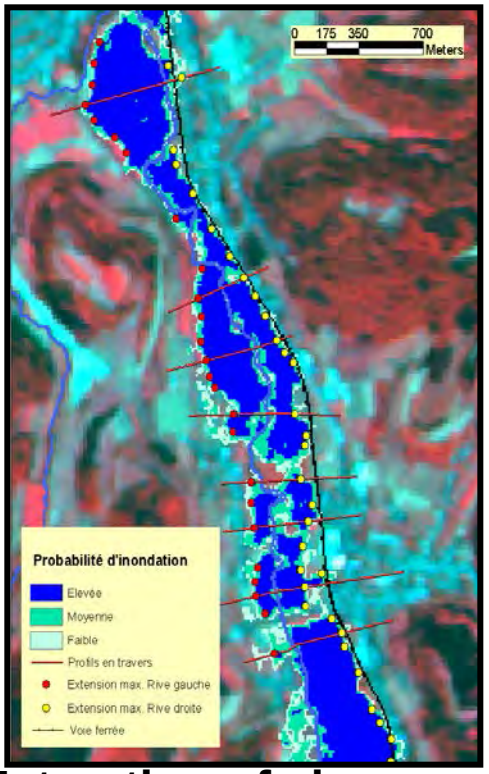
- Single event monitoring
- Long term monitoring

Concluding remarks, new trends and recommendations

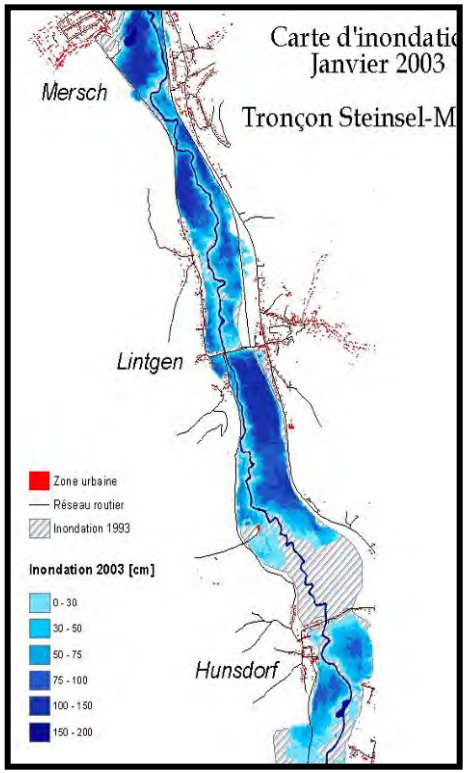
EO derived information and modelling

Envisat derived information as an input for validation of hydraulic models

ERS-2, Envisat



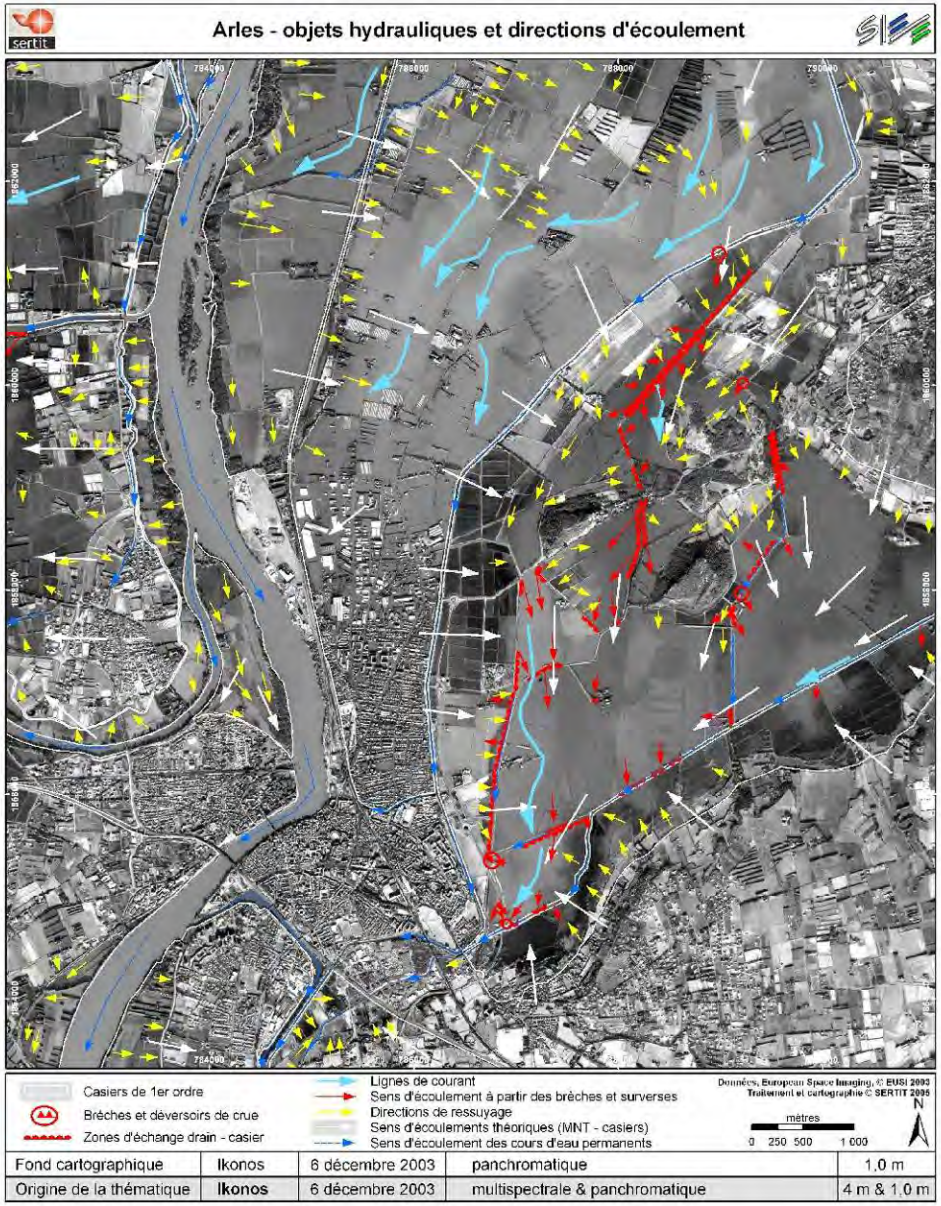
Extraction of classes of flood extent probabilities



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

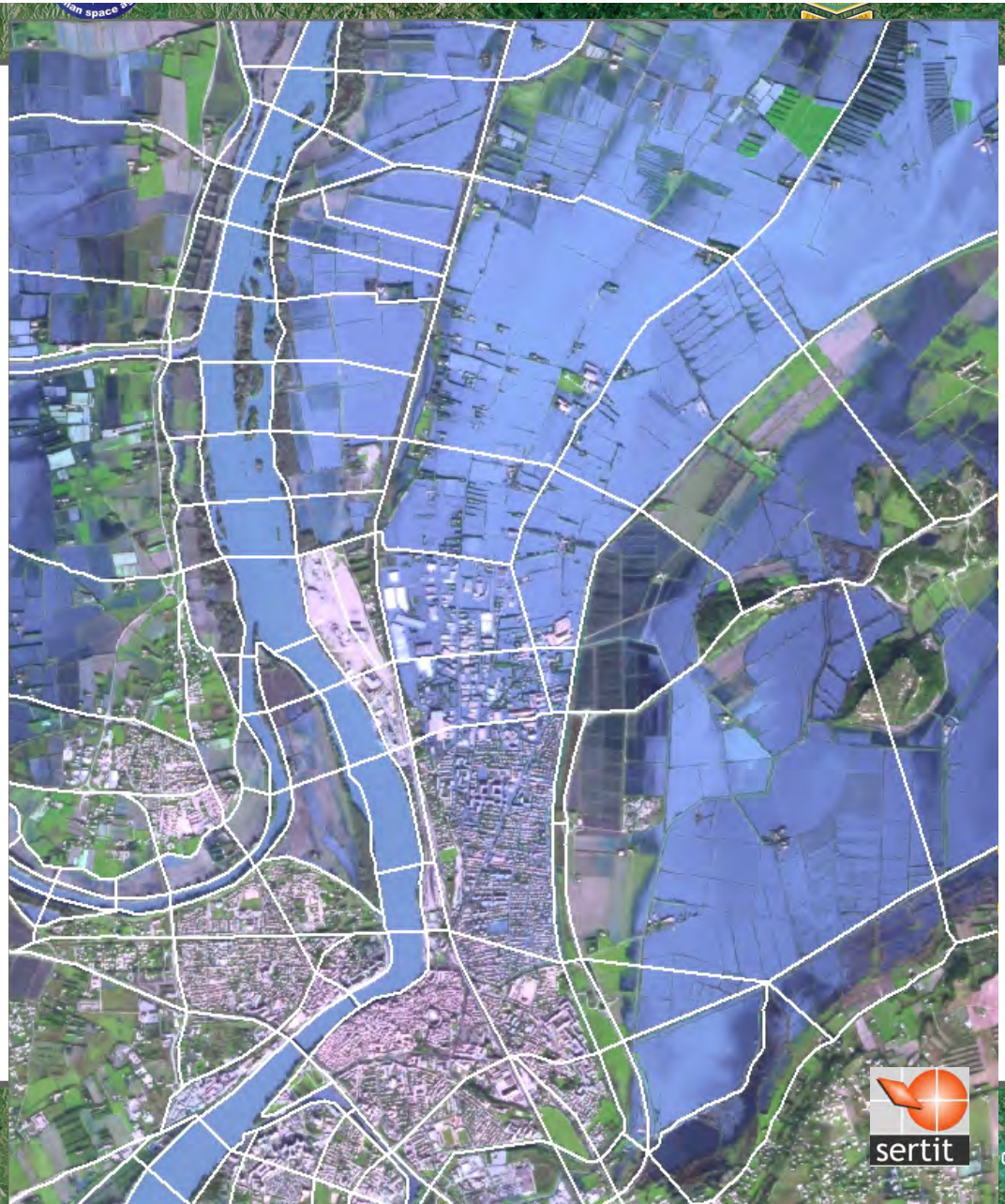
Post crisis exploitation of Ikonos crisis data

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

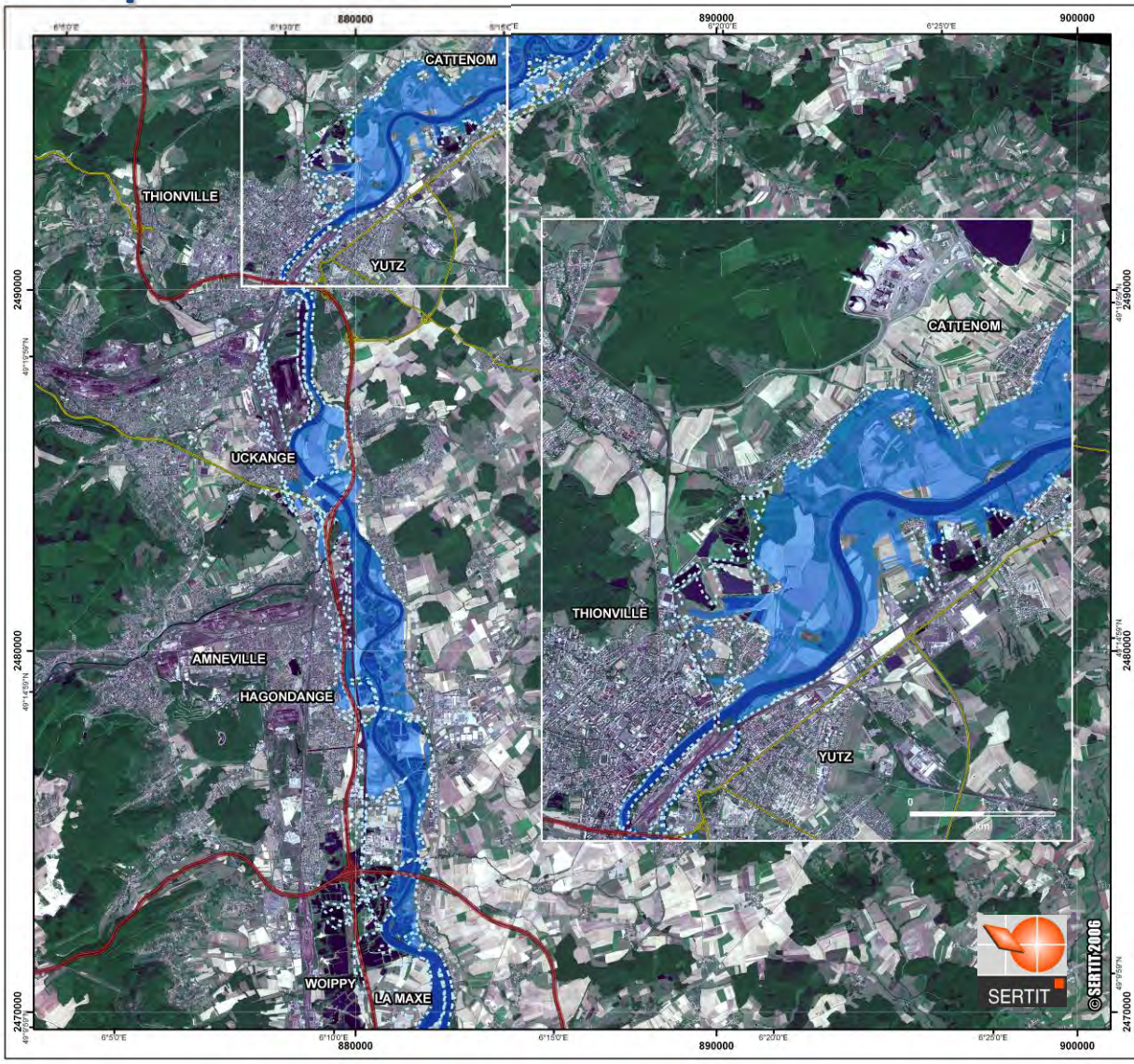
SPOT 5 :
functionnal ones

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:

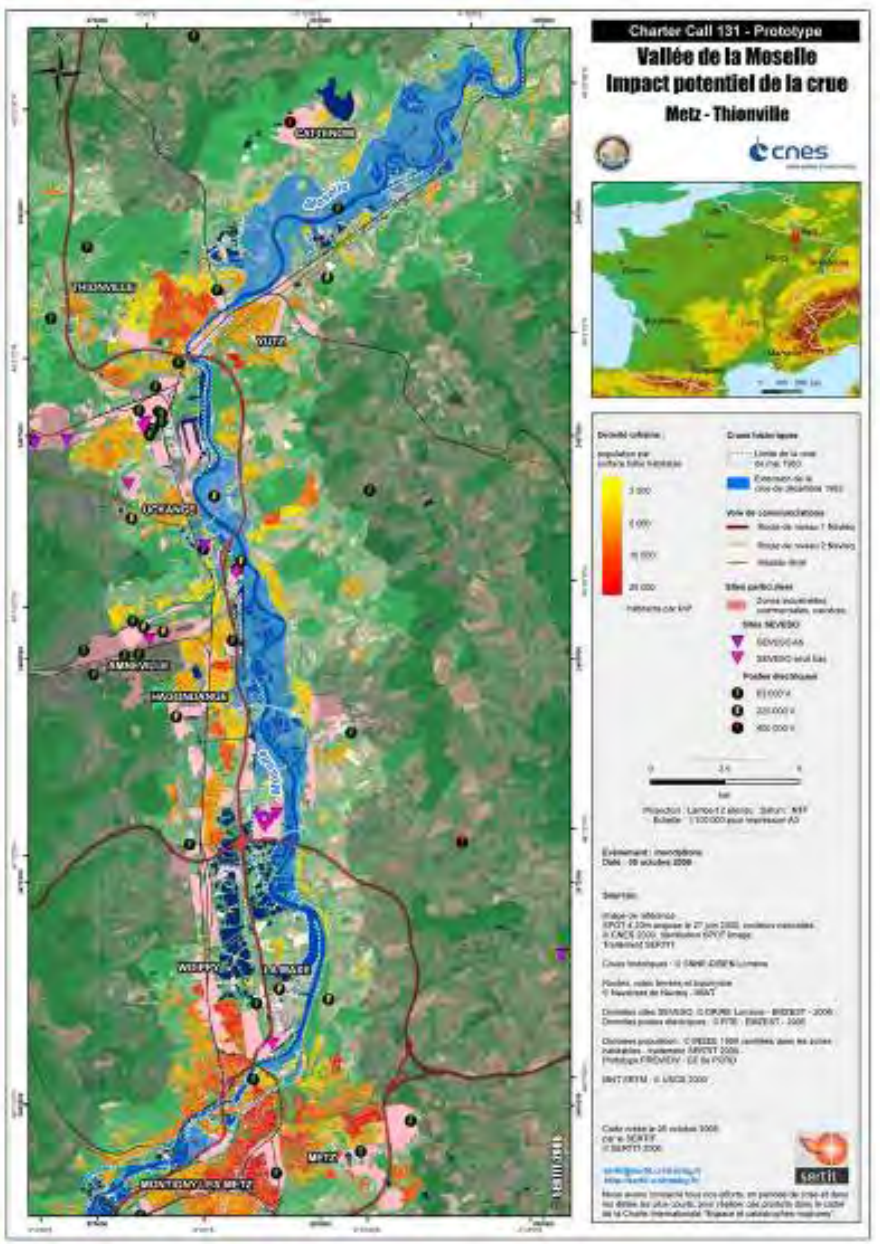
  . Affected population

  . 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

In a crisis situation the first arrived data has an unique value, therefore enhanced/improved products can be deliverable alter exploiting arriving data

Concluding remarks

Recommendations: been pro-active

- **Well prepare in advance the arrival of ESA Earth-watch mission such as Sentinel 1 and Sentinel 2**
- **Explore EO archive**
- **Realize a more systematic monitoring of flood prone areas**
- **Propose future scenarios exploiting Medium resolution products (ASAR WSM, MERIS) mode in synergy with VHR data (Cosmo Skymed, TerraSAR and Pleiades)**
  - **MR: identification and monitoring of water flow**
  - **VHR : focus on sensitive areas (urban areas, industrial sites)**

Sentinel 1 and Sentinel 2 forces in summary:

Improvement in term of

- Good swath compromise: fine

⇒SM mode it is fourth actual capability (ie strip of 80 km versus CSK sm of 40 by 40 km (Rapid Mapping)

⇒IWM & EWM: consistent for large areas monitoring .

- Resolution : convenient (two modes for continental areas)

- Radiometric quality: would be very good

- Revisiting time: a great advantage to have long term planning of acquisition, with a prioritary mode which is large swath

⇒a priori more compatible revisit (even if none daily one???)

⇒access to the defined planning

⇒no conflict between projects and/or commercial requests

→ 6th ESA ADVANCED TRAINING COURSE
ON LAND REMOTE SENSING

Floods & Lakes Monitoring

Dr Hervé YESOU

UNIVERSITÉ DE STRASBOURG

ECOLE D'INGENIEURS TELECOM PHYSIQUE STRASBOURG

D4T1a

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