Floods & Lakes Monitoring

OPTICAL PART

ESA–MOST Dragon 4 Cooperation

ADVANCED LAND REMOTE SENSING
INTERNATIONAL TRAINING COURSE

“龙计划4”高级陆地遥感国际培训班

Dr Hervé YESOU

D3OT -L2

Wenesday 26 of November 2017

20–25 November 2017 | Yunnan Normal University
Kunming, Yunnan Province, P.R. China

2017年11月20日——11月25日
云南师范大学，中国, 昆明

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
- Interest for SWIR bands

Elements for water bodies extraction based on optical imagery

Optical sensors for water bodies and/or flood mapping
- Medium
- High resolution
- VHR sensors

Water level from space
- Principles of altimetry
- Altimetry missions past, present futures
- Altimetry database

Flood plain and lakes monitoring
- Short term Monitoring
- Long term monitoring
- Meteo climato parameters

Concluding remarks

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
DLR
Toulouse
cnes
Roma
esa

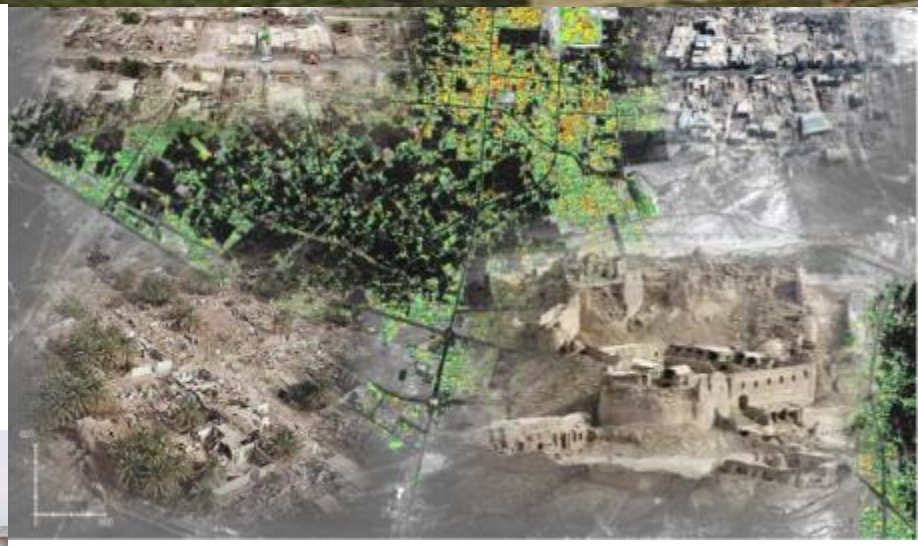
Water bodies and Flood mapping and monitoring based on EO data

- **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 I, II, III & IV
- **CNES projects**
  - SPOT2 to SPOT5 preparatory and validation programmes
  - Pactes
  - Pléiades / Orfeo thematic programme
  - Post Pléiades: SWIR /VHR trade off and synergy
  - SWOT SDT ADT
  - RT CNES Dtata flow&water bodies mapping/monitoring
- **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

OURSE

Copernicus Europe's eyes on Earth

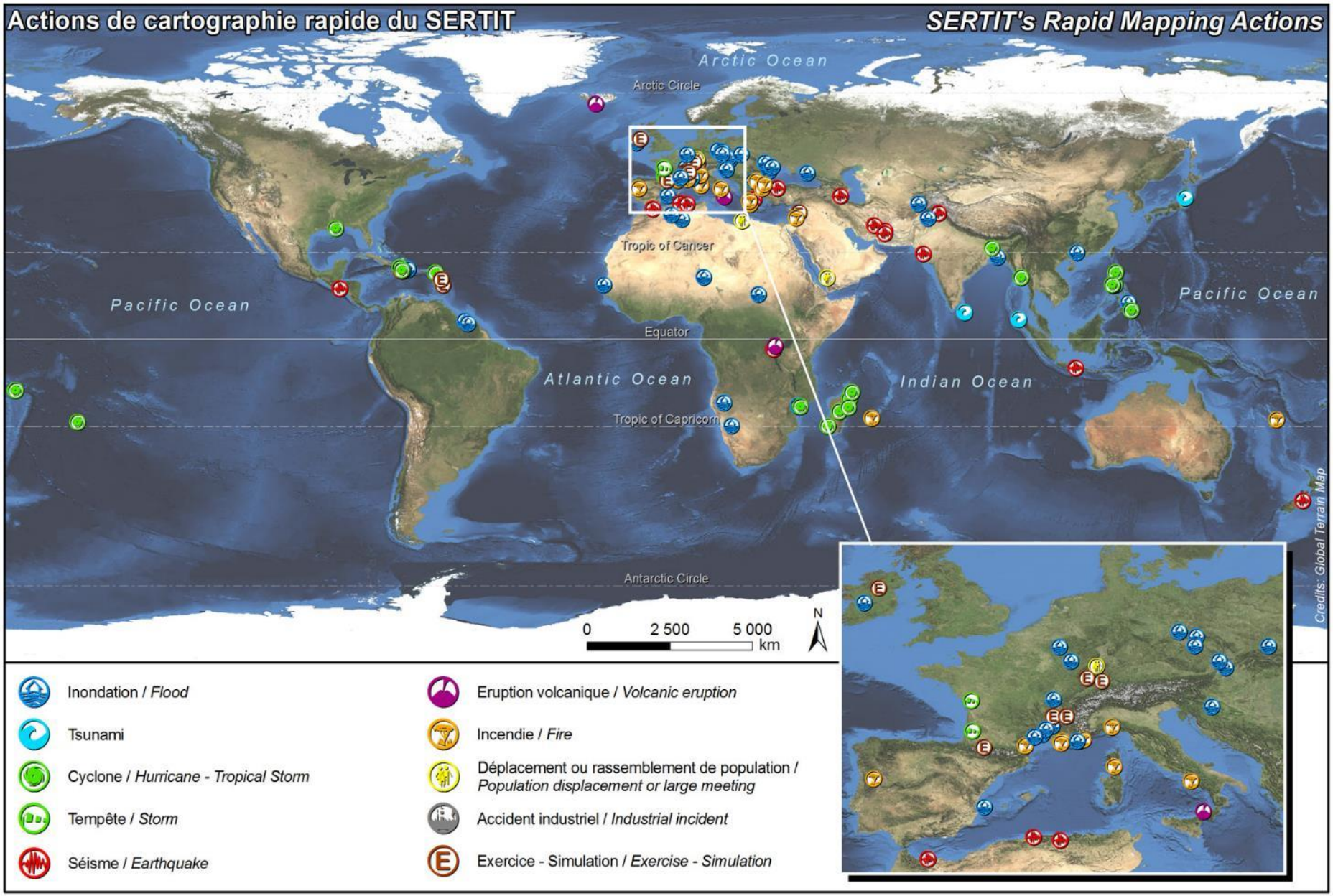
际培训班
范大学，中国，昆明

Plus de 150 opérations au SERTIT

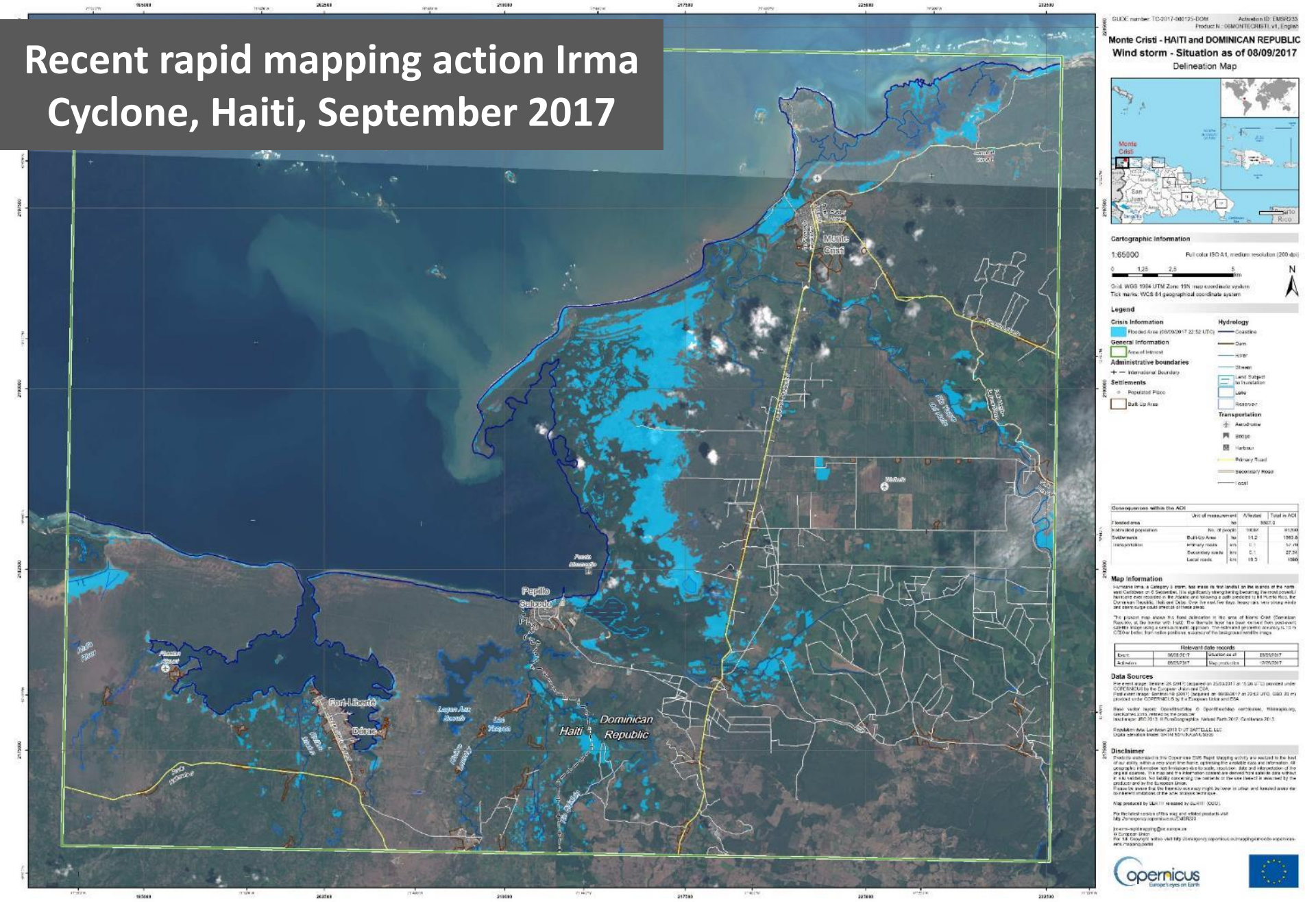
60	2008	November	France - Martinique	Simulation : Earthquake
59		October	[illegible]	[illegible]
58			Algeria - Ghardaia	Floods
57		August - September	Haiti	Hurricanes & Floods
56		August	France - Aude	Forest fires
55		July	Romania, Ukraine	Floods
54		June	French Guiana - Maroni	Floods
53		May	Myanmar	Cyclone & Floods
76		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		September	Philippines - Manille	Tropical storm & Floc
71			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

18 years of rapid mapping at SERTIT



Recent rapid mapping action Irma Cyclone, Haiti, September 2017



Recent rapid mapping action Irma Cyclone, San Barthelemy , September 2017

Charter Call ID 627
Product No. 01

FRANCE - Saint-Barthélémy - Saint Jean Bay

Hurricane Irma
Impact map
Observed the 08/09/2017

Location Diagrams

Legend

Damage on buildings
- Highly affected building
- Moderately affected

Damage on communication network
- Highly affected road
- Potentially affected road
- Road with no visible damage
- Highly affected airport area
- Potentially affected airport area

Other damage
- Sand deposits

Other information
- Cloudy area

Interpretation

On September 6, 2017, hurricane Irma, a powerful category 5 storm, has started to strike the Caribbean, in particular the French islands of Saint-Martin and Saint-Barthélémy which have been devastated.
This map presents the hurricane damage assessment over the Baie de Saint Jean area in Saint-Barthélémy, derived from the Pléiades imagery acquired the 08/09/2017. Highly and moderately affected buildings are reported, as well as damage on road network and airport infrastructure.

Cartographic Information

0 50 100 m

N

Local projection: UTM Zone 20 North, Datum: WGS 84
Geographic projection: Lat/Lon (DMS), Datum: WGS 84
Scale: 1:2 000 for A1 prints
Geometric references:
Horizontal Landsat-7 ETM+, EarthSat Ortho GeoCover, RMSe 50m

Data Sources

Crisis layers
Disaster impact assessment (affected buildings, roads, harbour banks and sand deposits) derived from Pléiades image acquired the 08/09/2017
© SERTIT 2017
Background layers
Roads derived from IGN BD TOPO, updated by SERTIT using Pléiades pre-event image acquired the 22/05/2016
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Pleiades-HR 1B acquired the 08/09/2017
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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/exercise, 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 09 09 2017 by SERTIT
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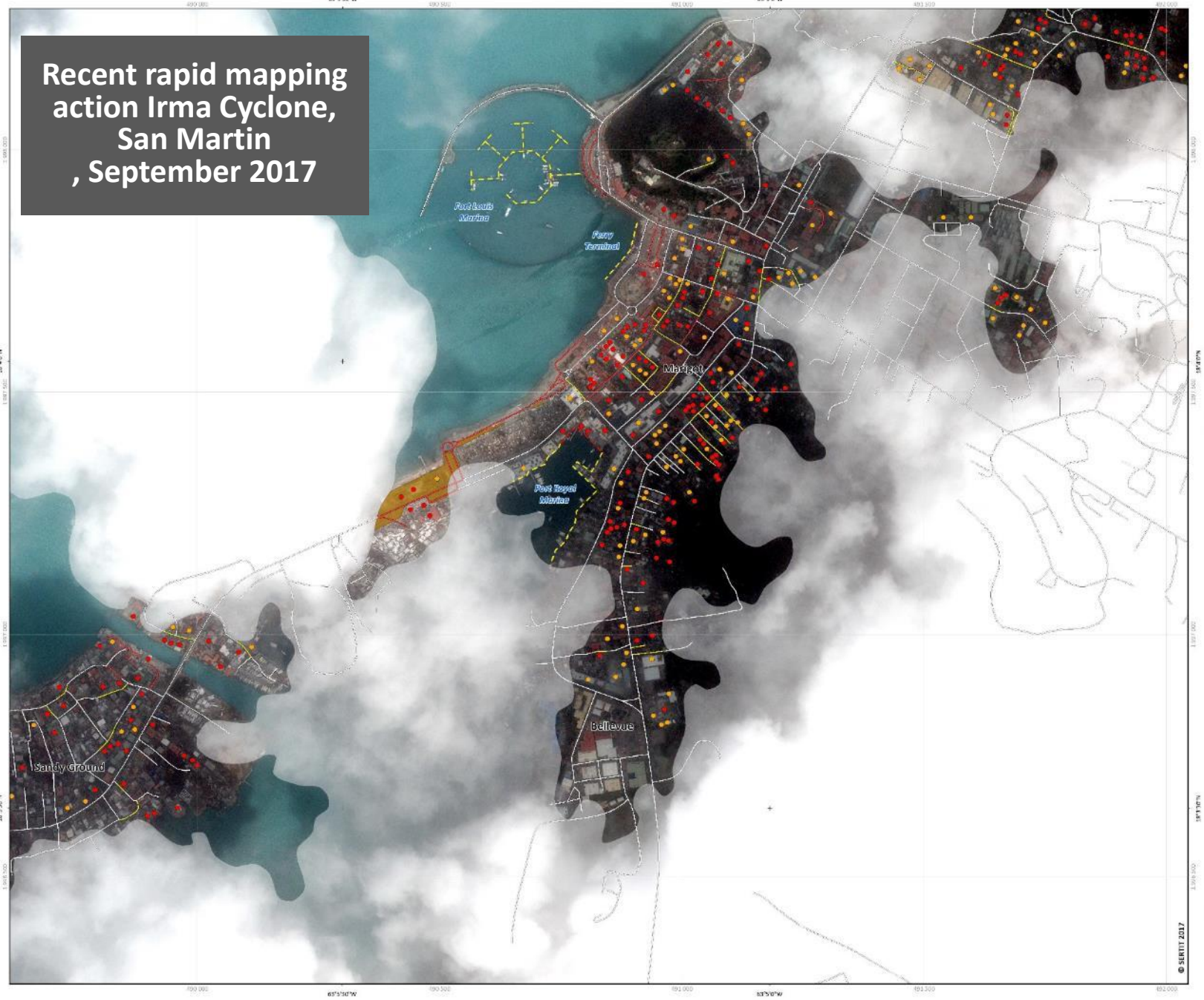
http://sertit.u-strasbg.fr

COGIC
cnes
sertit

Recent rapid mapping action Irma Cyclone, San Martin , September 2017



Charter Call ID 627
Product No. 02

FRANCE - Saint-Martin - Marigot Hurricane Irma Impact map

Observed the 08/09/2017

Location Diagrams

Legend

Damage on buildings
- Highly affected building
- Moderately affected

Other damage
- Sand deposits

Damage on communication network
- Highly affected road
- Potentially affected road
- Road with no visible damage
- Highly affected harbour bank
- Potentially affected harbour bank

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- Cloudy area

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On September 6, 2017, hurricane Irma, a powerful category 5 storm, has started to strike the Caribbean, in particular the French islands of Saint-Martin and Saint-Barthélémy which have been devastated.

This map presents the hurricane damage assessment over Marigot area in Saint-Martin, derived from the Pléiades imagery acquired the 08/09/2017. Highly and moderately affected buildings are reported, as well as damage on road network and harbour banks.

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Scale: 1:3 500 for A1 prints

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

Data Sources

Crisis layers
Disaster impact assessment [affected buildings, roads, harbour banks and sand deposits] derived from Pleiades image acquired the 08/09/2017
© SERTIT 2017

Background layers
Roads derived from IGN BD TOPO, updated by SERTIT using Pléiades pre-event image acquired the 12/02/2017
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Pléiades HR 1B acquired the 08/09/2017
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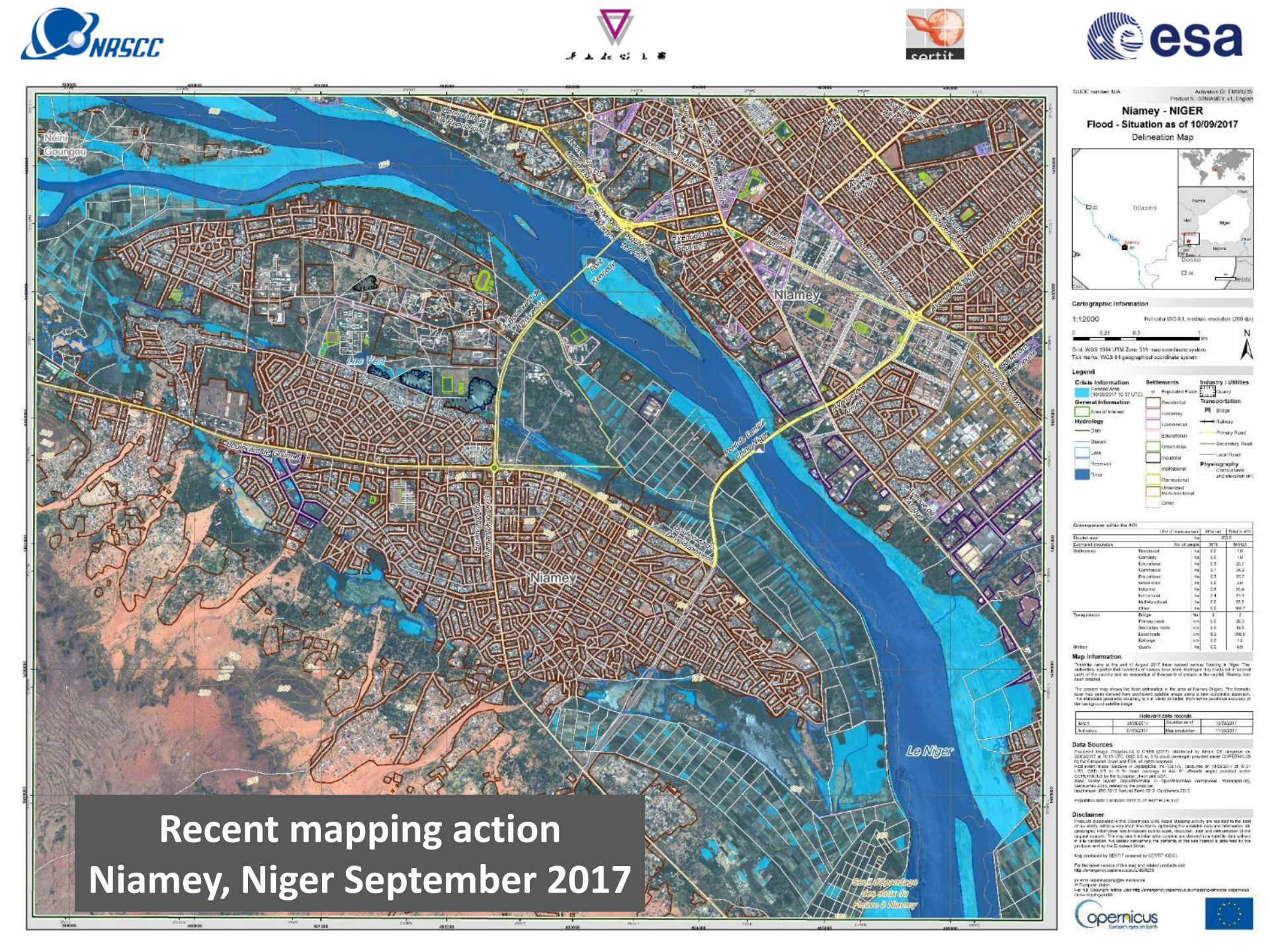
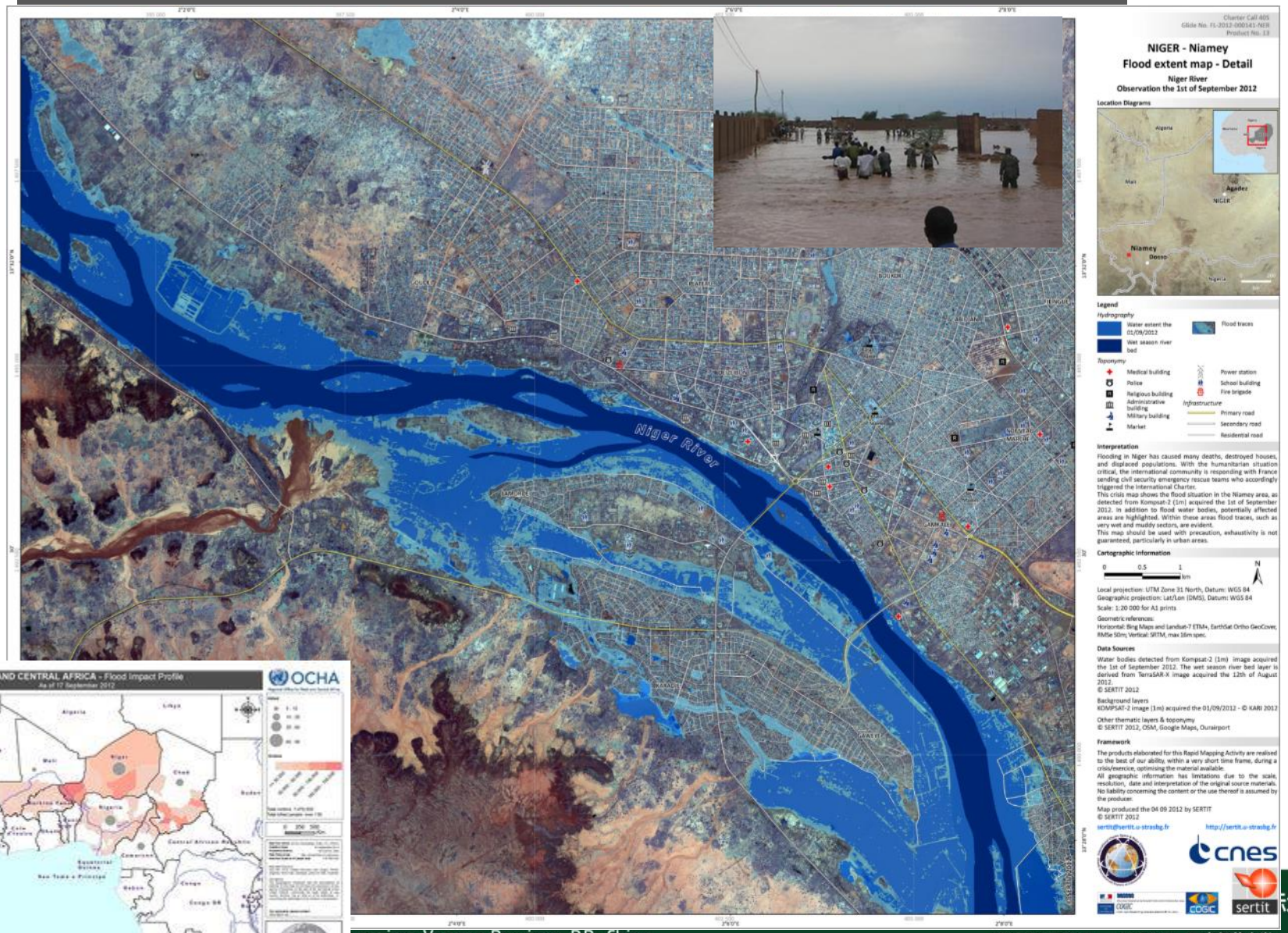

Niamey - NIGER
Flood - Situation as of 10/09/2017
Delineation Map
Cartographic Information
1:12000
Legend
Map Information
Data Sources
Disclaimer
Niamey
Le Niger
Recent mapping action
Niamey, Niger September 2017

Old rapid mapping action Niamey, Niger, September 2012



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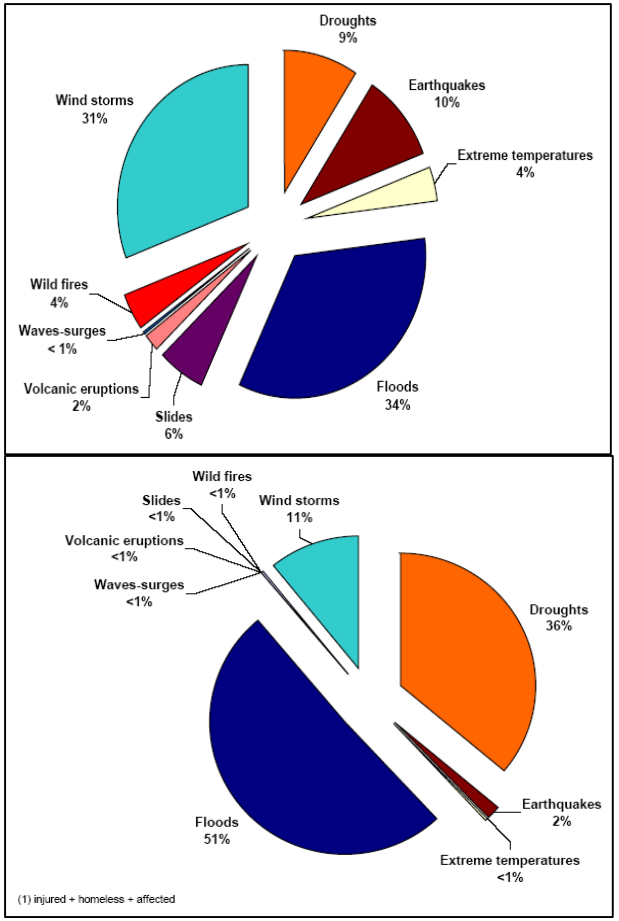
Concluding remarks

Why it is relevant to map and monitor flood events?

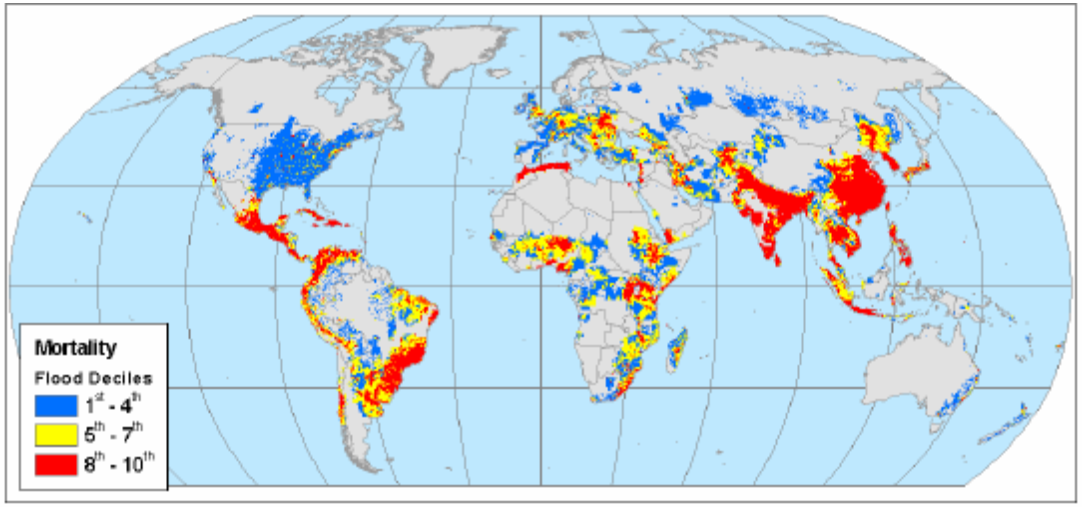
- Floods: 34% world natural hazards between 1974-2003
- Near 200 millions of affected people each year (more than half of affected people by a natural hazards)
- More than 170 000 deceases from 1980 to 2000
- With climate change it would become worse
- Fitting floods is one of the most important environmental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

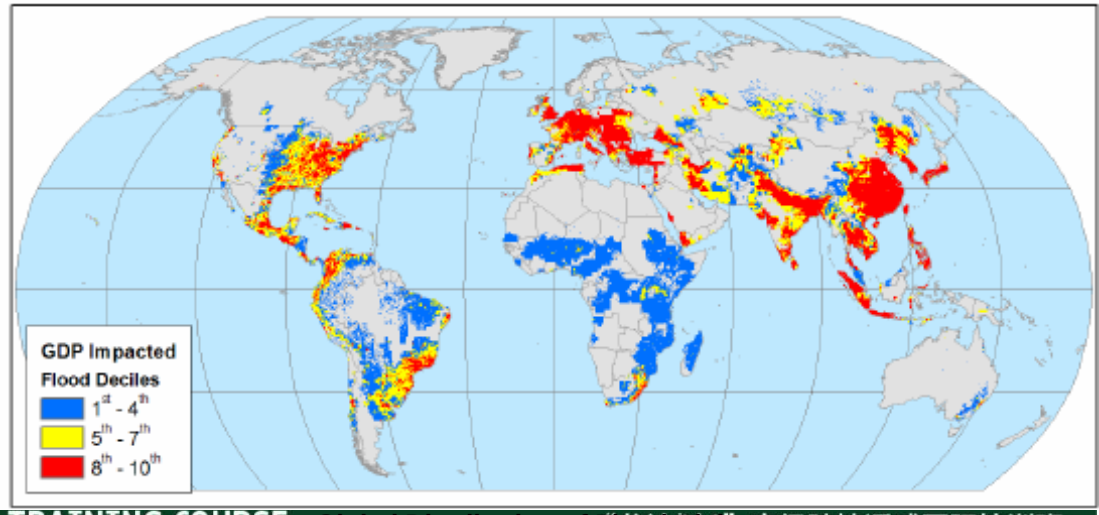


Source:EM-DAT - International Disaster Database

Why it is relevant to map and monitor flood events?

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



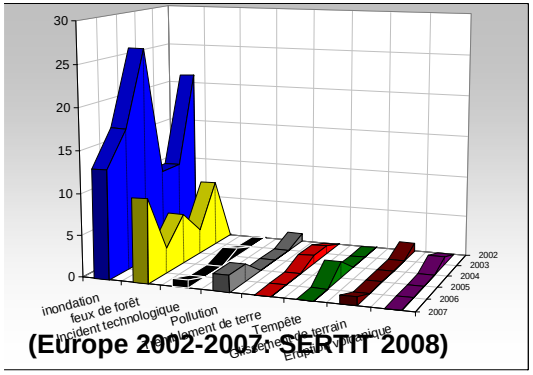


Global Distribution of Flood Risk
(Source: Columbia University, UNDP, CRED)

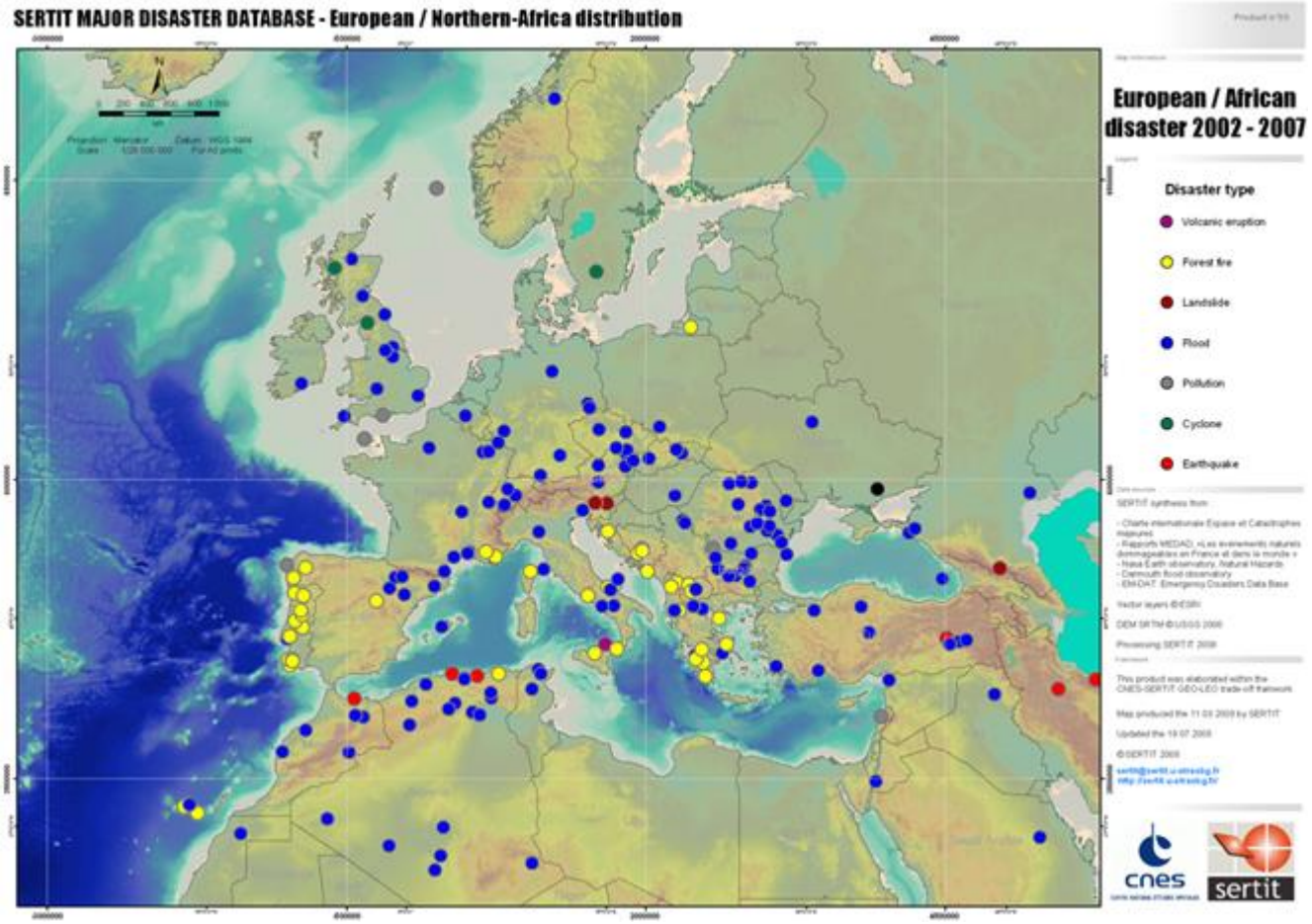
Why it is relevant to map and monitor flood events?

- **Floods: Europe**

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



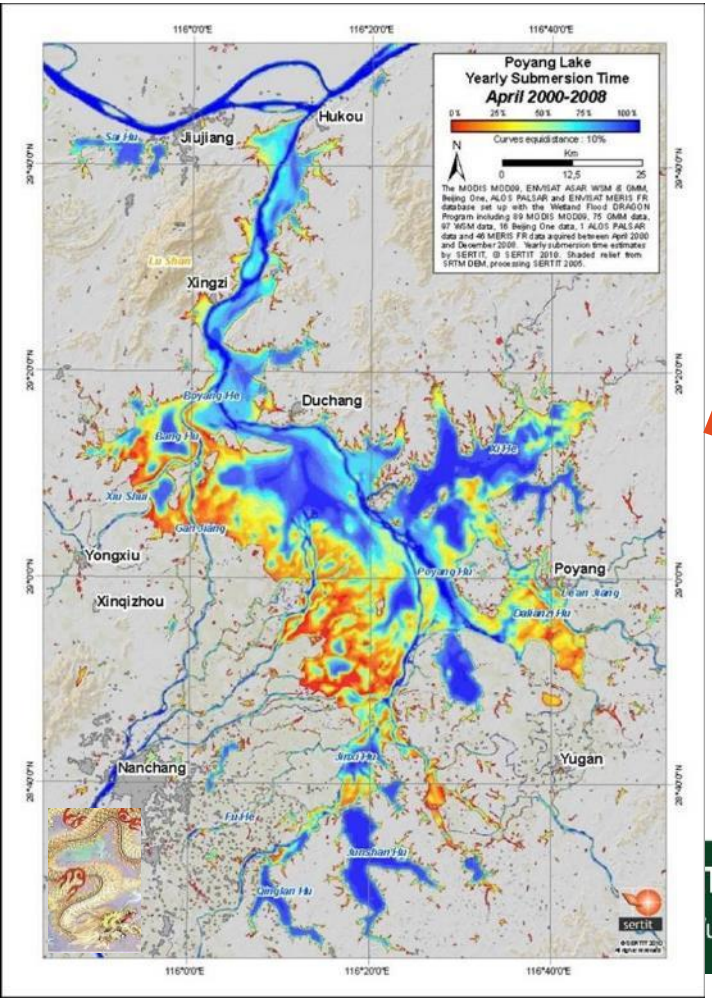
(Europe 2002-2007, SERTIT 2008)

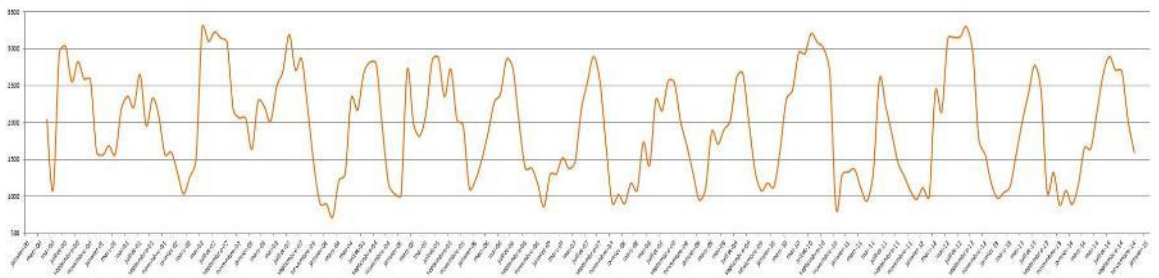


(SERTIT 2008)

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

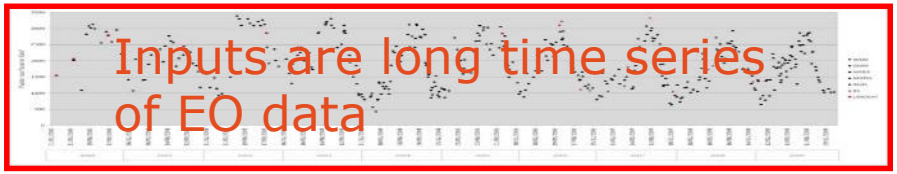
15 years of monitoring

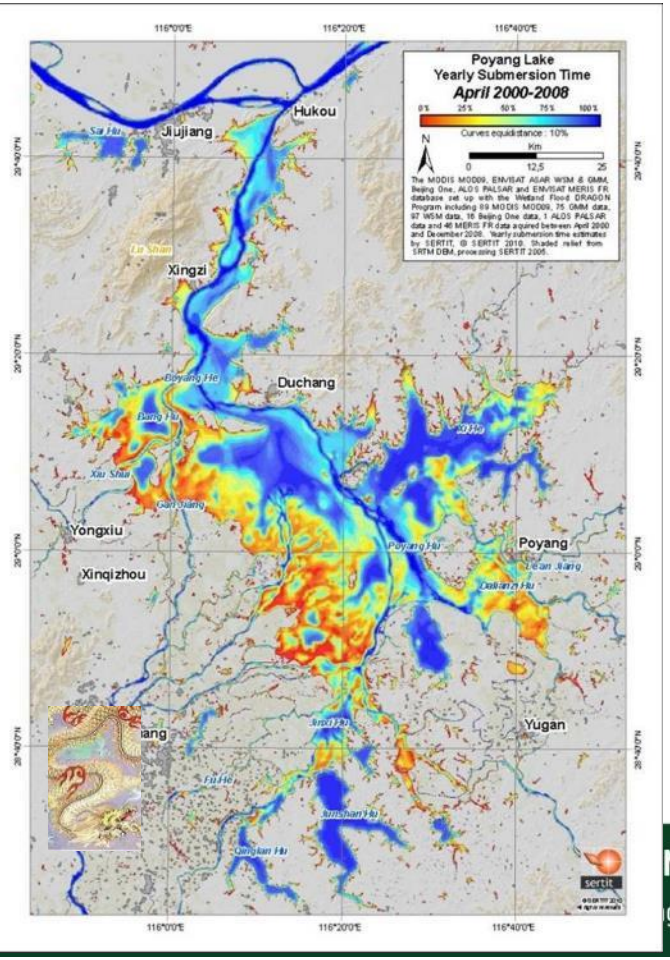
Important to monitor water resource as water is a key element for human being and life

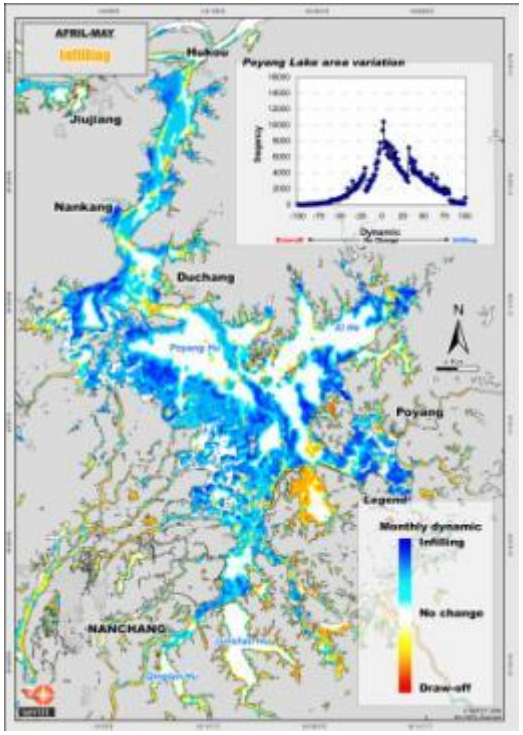
Better understanding of water cycle

Why it is important to monitor water bodies?

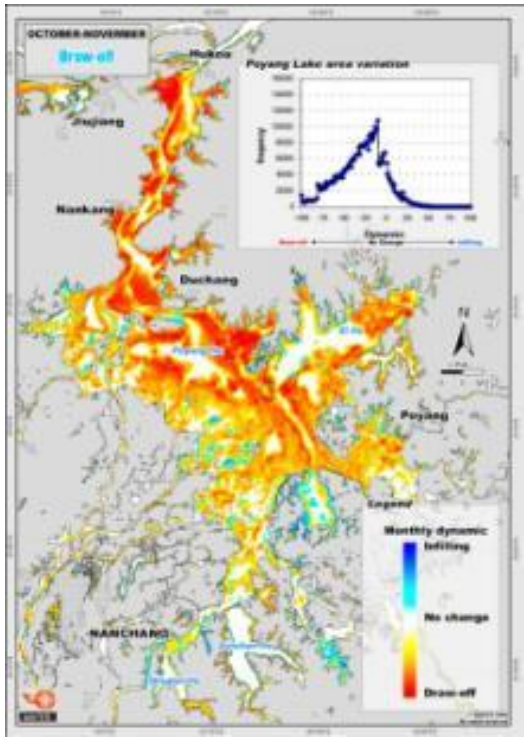
Monitoring : keys for **hydrological modeling**







Water mass movement: infilling



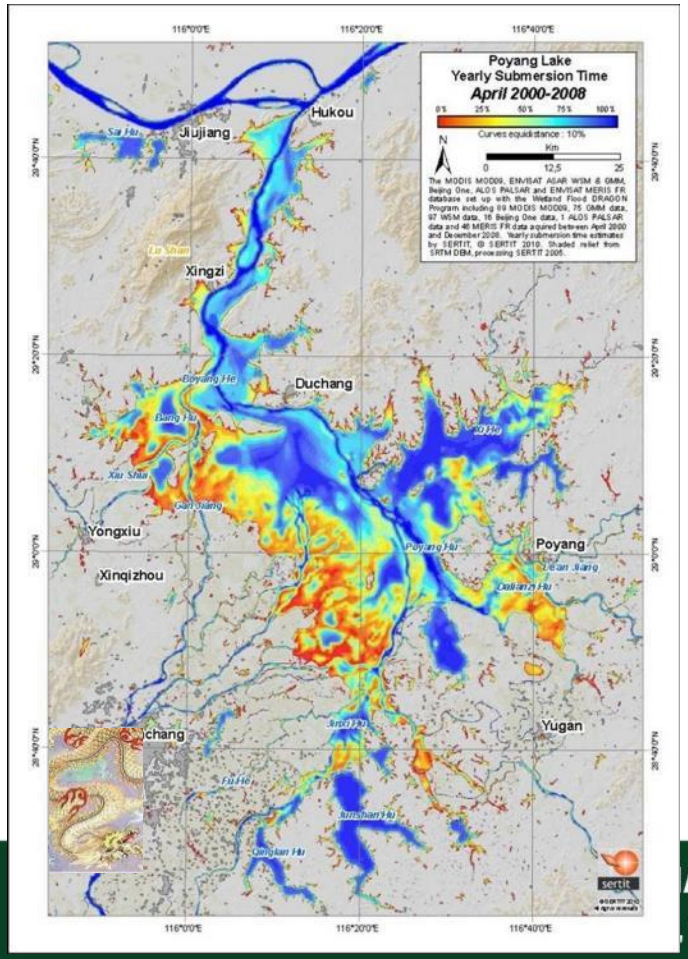
Water mass movement draw off

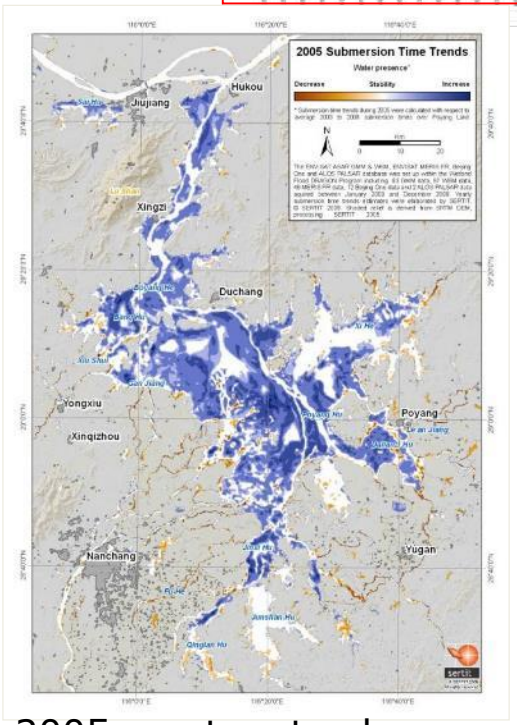
Why it is important to monitor water bodies?

Monitoring：keys for

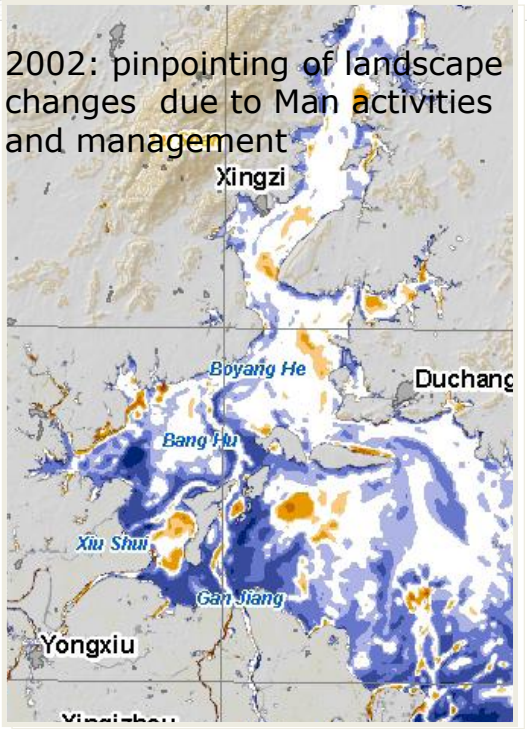
long term change : lakes are climate sentinels

Inputs are long time series of EO data





2005：water stay longer period due to the February flood



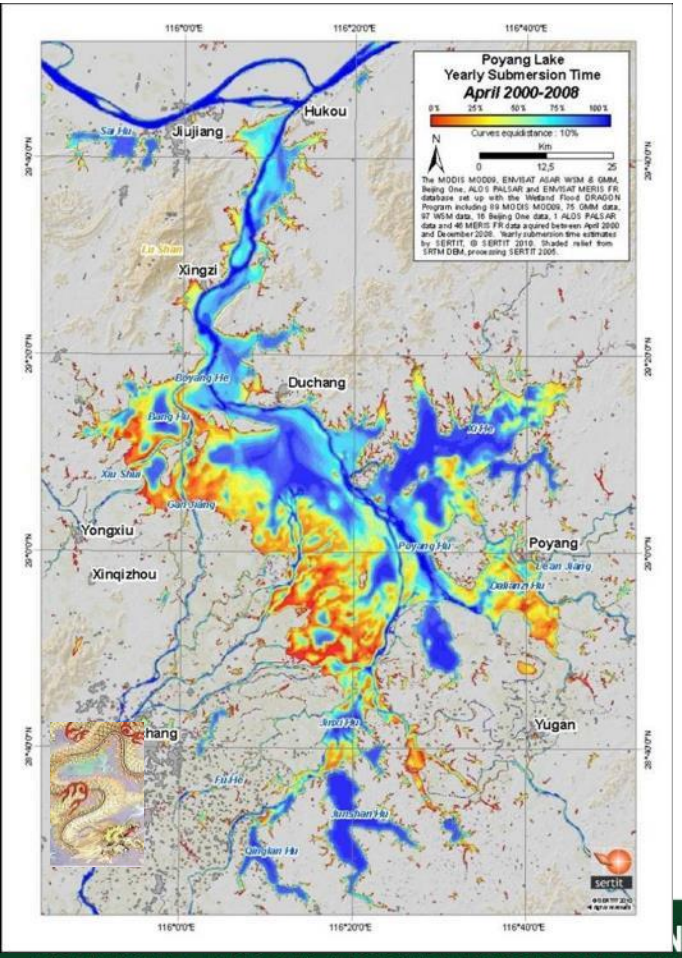
2002: pinpointing of landscape changes due to Man activities and management

2008：Deficit of water stay in the delta part

Why it is important to monitor water bodies?

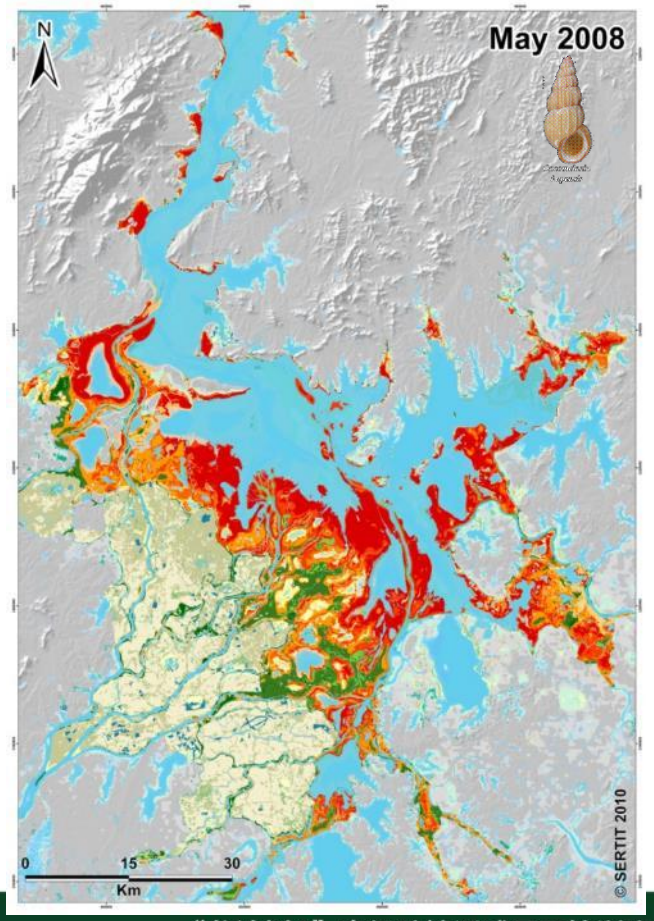
Monitoring：keys for epidemiology

Inputs are long time series of EO data



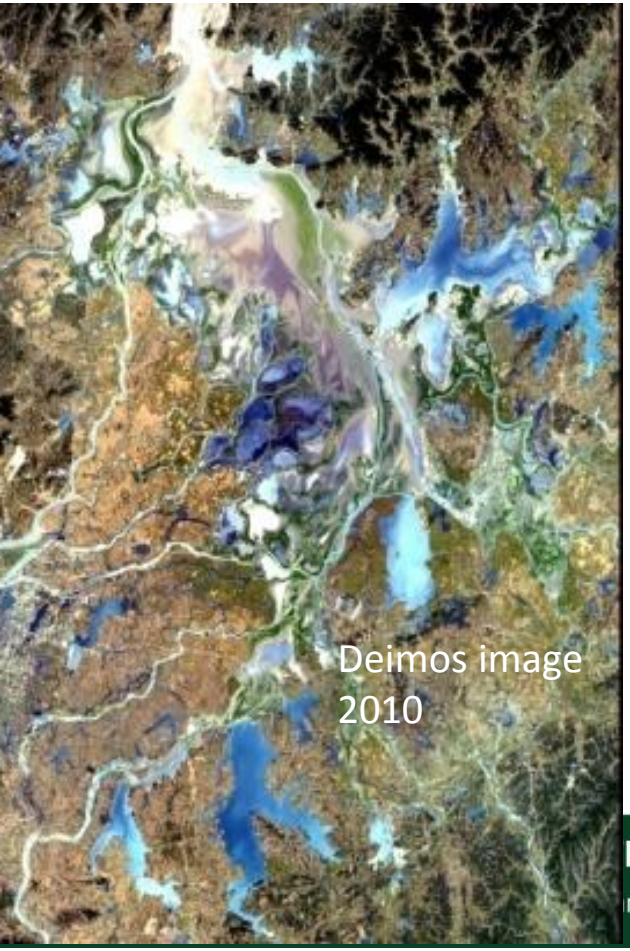
Water = key element in epidemiologyift Malaria,
Rift valley fever,
Schistosiomasis
Etc …

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

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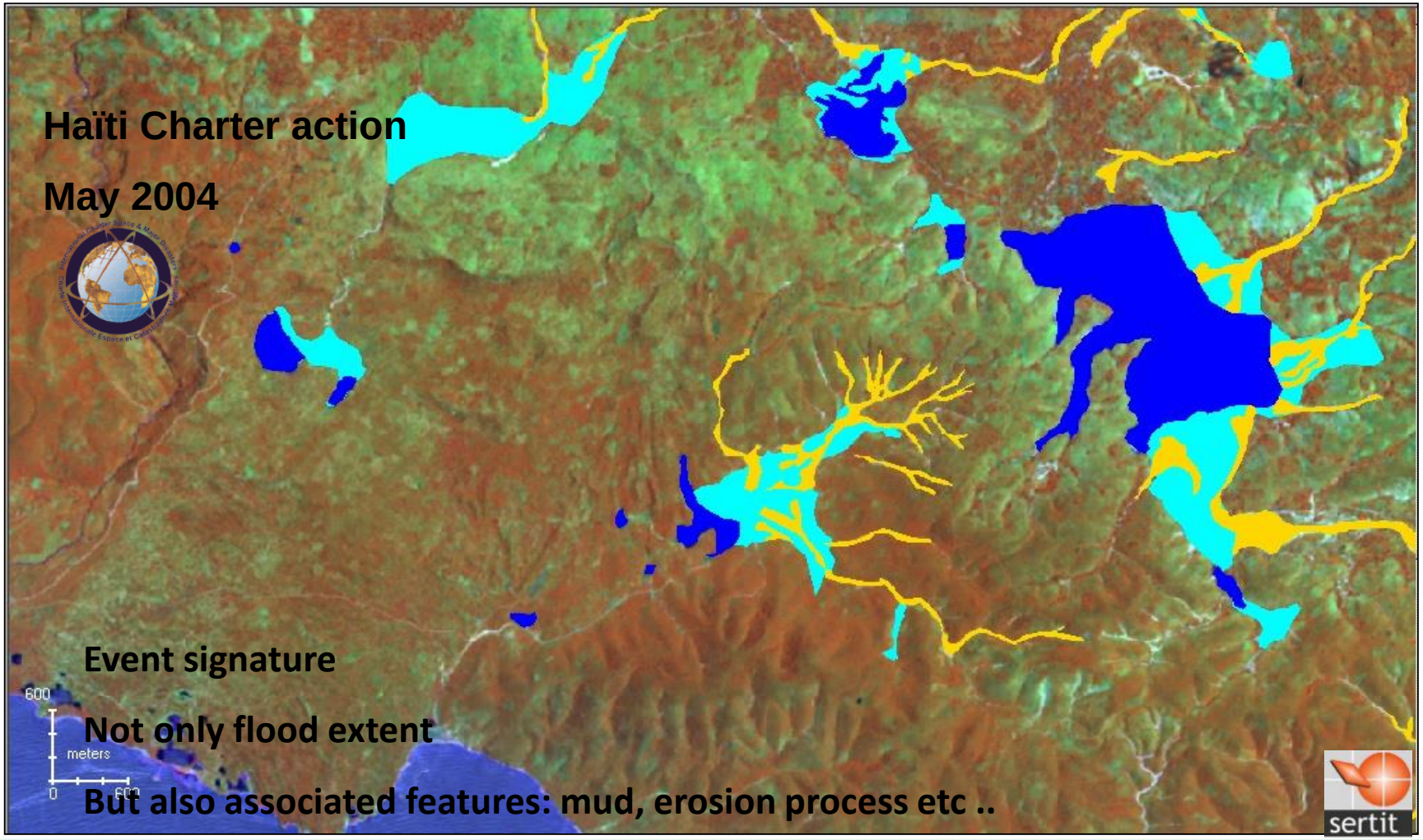
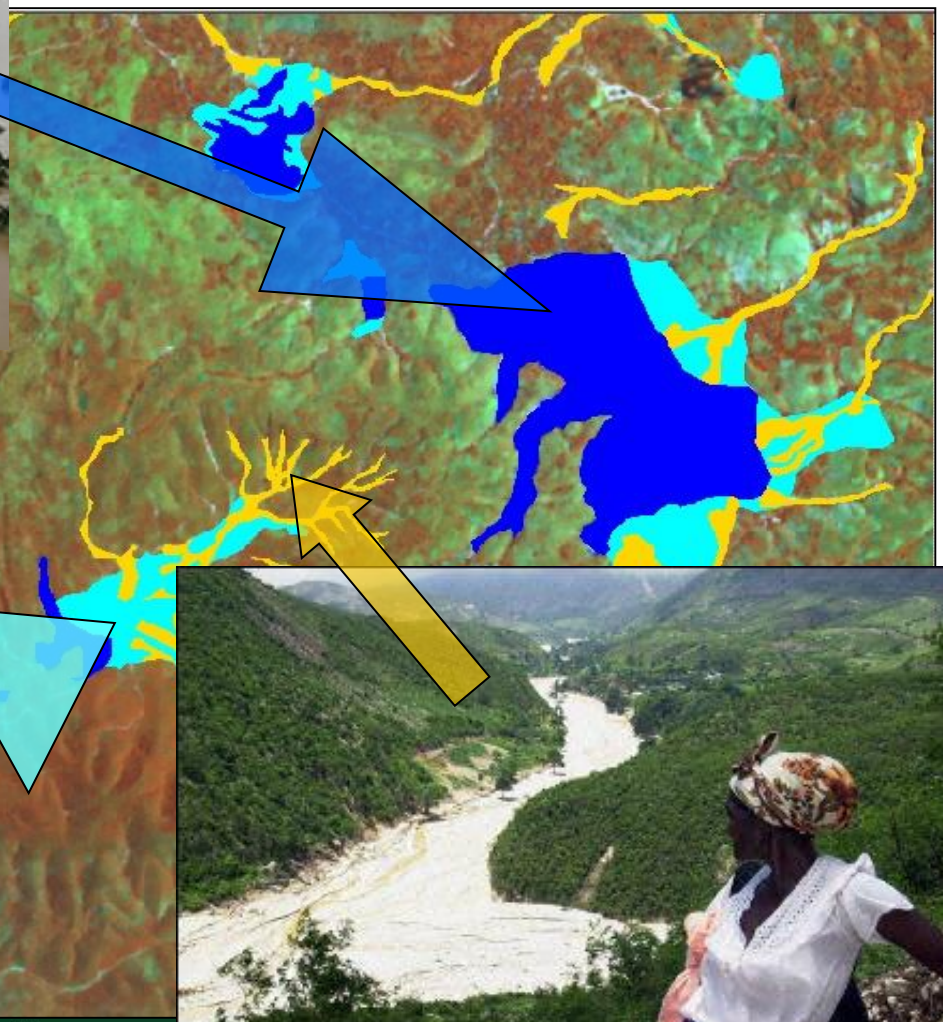
Flood patterns recognition



Event signatures



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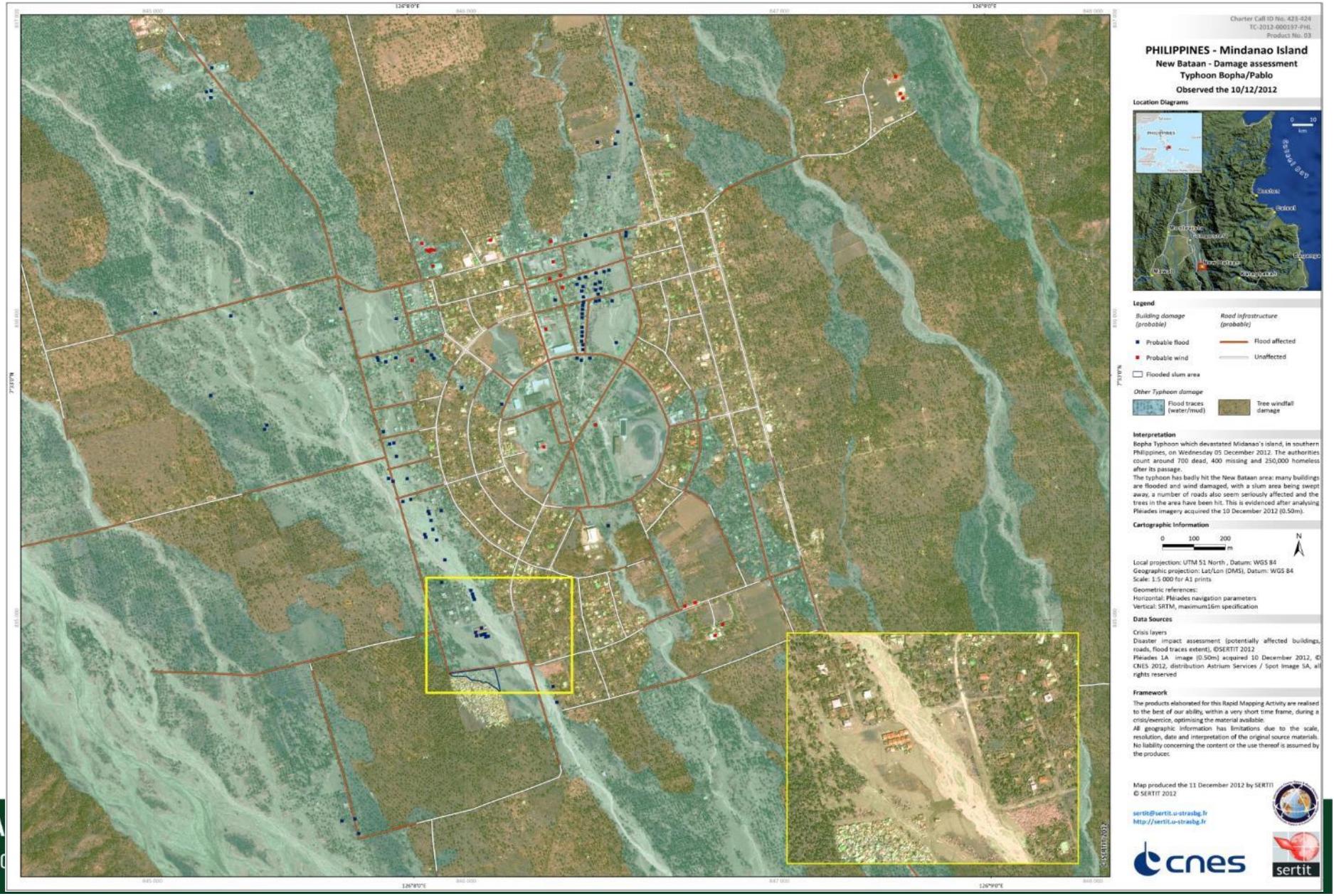

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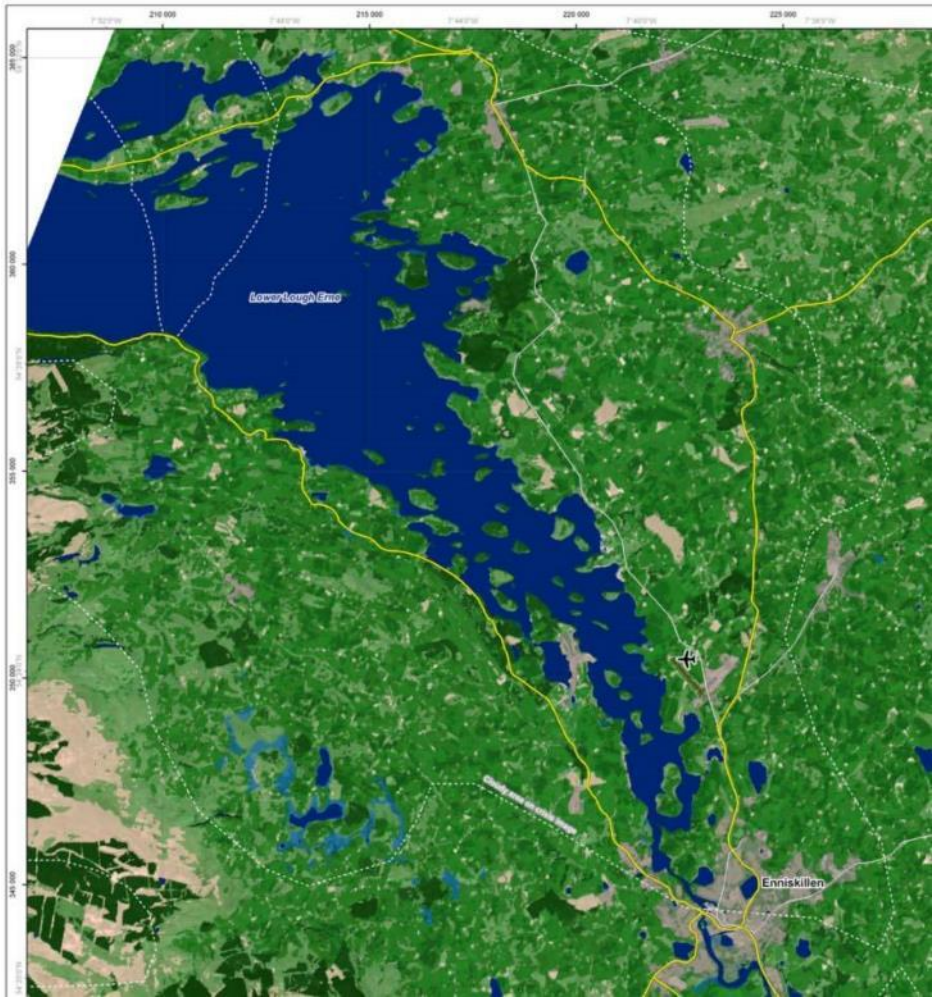
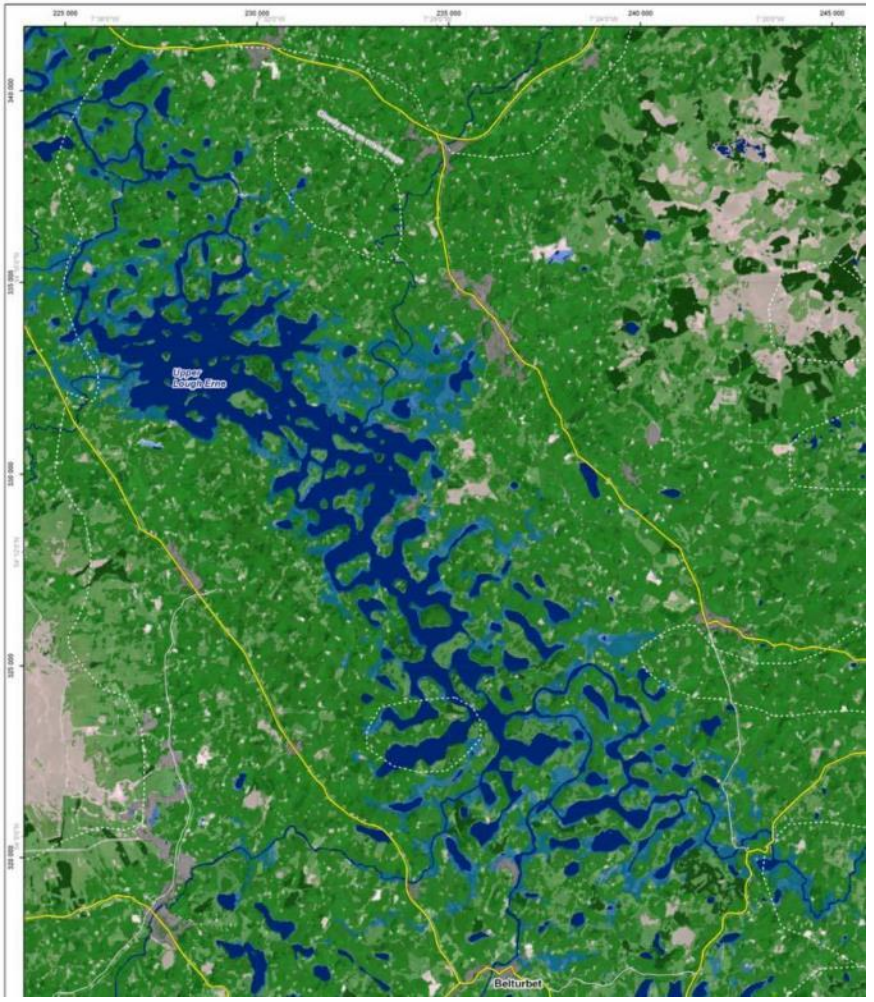
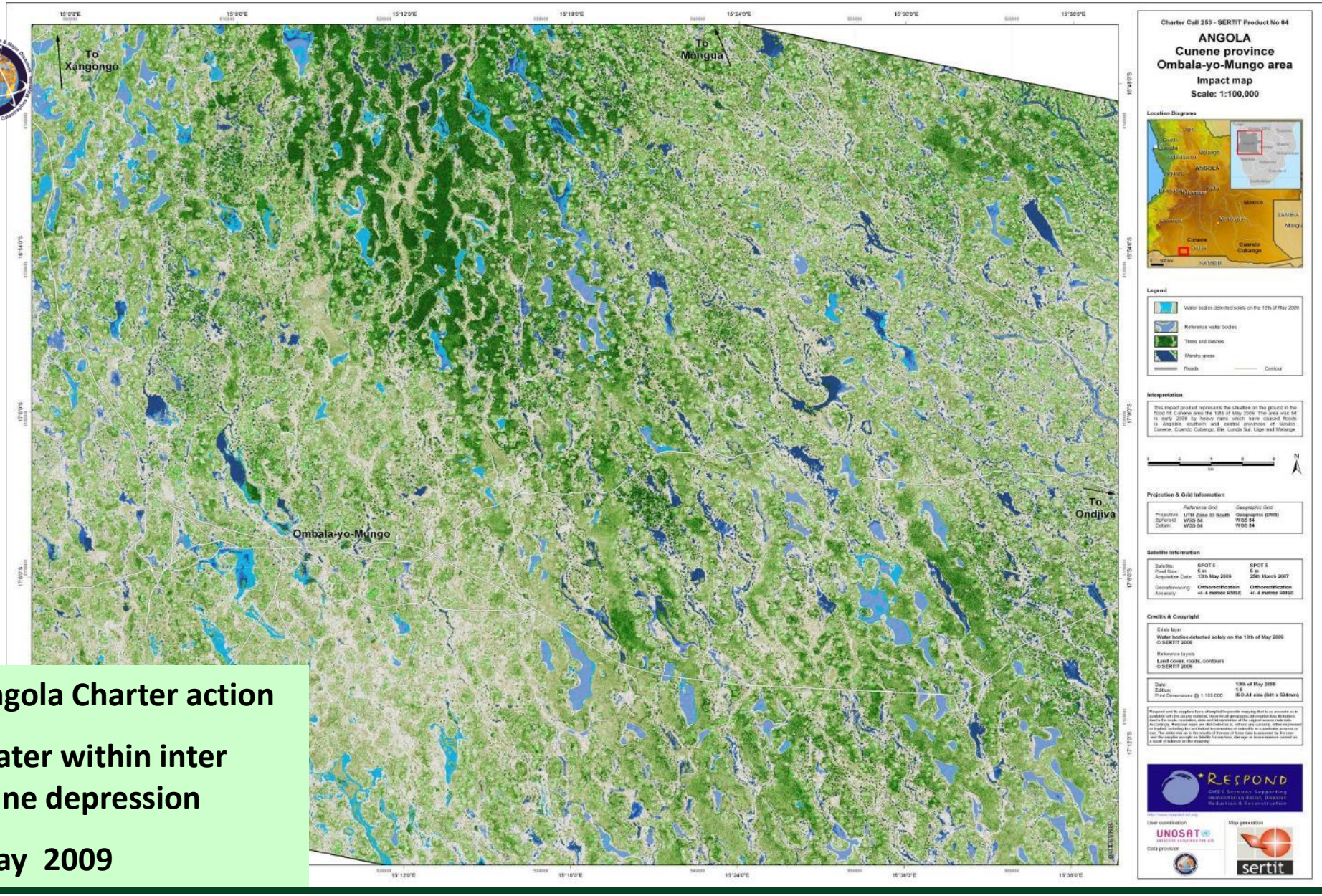




Ireland SAFER 027, 2010: Water within bogs

Flood patterns recognition



Angola Charter action

Water within inter dune depression

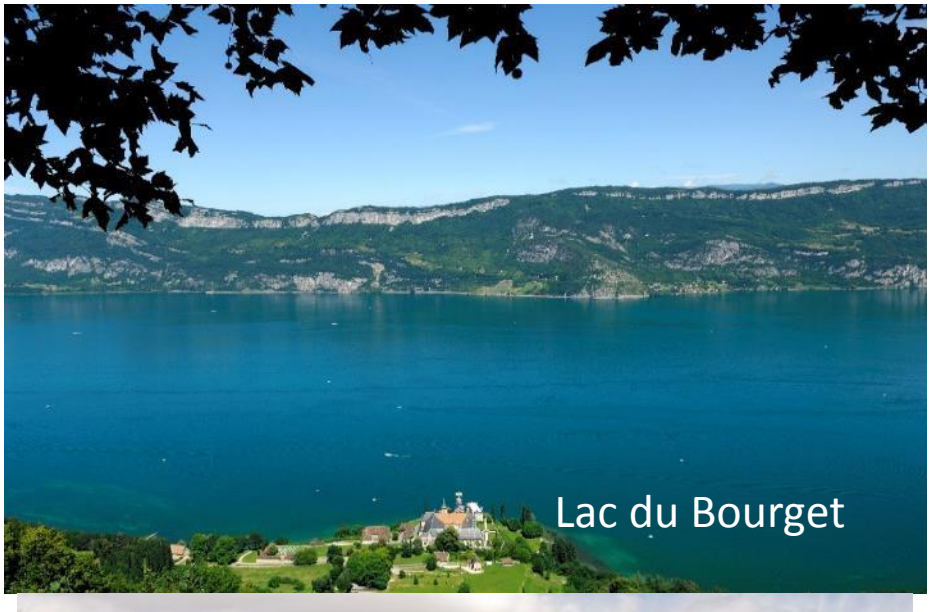
May 2009

Lakes and water bodies: Landscape variability


Okavongo delta and river

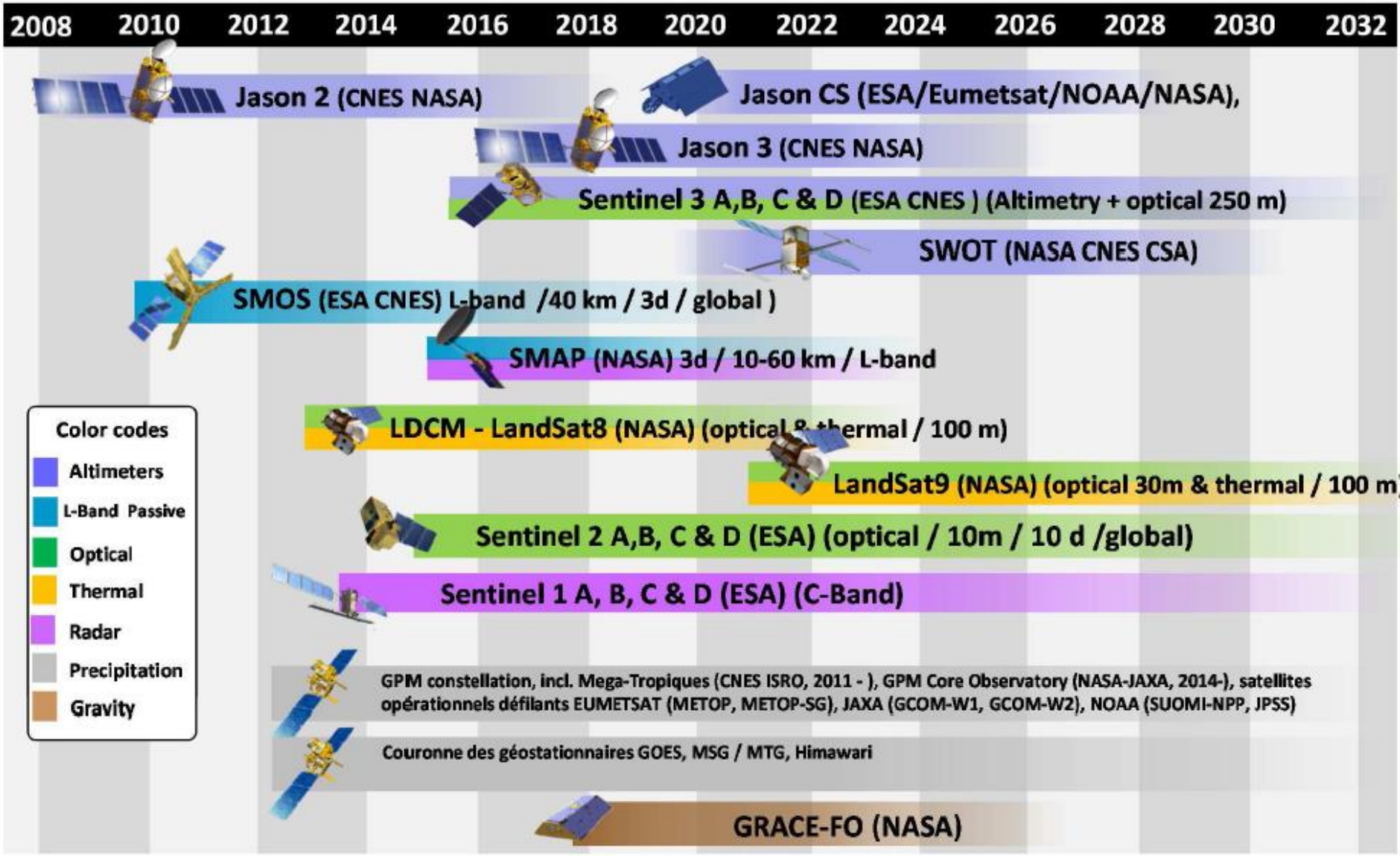

Niger Inner delta and river

Lakes and water bodies: Landscape variability

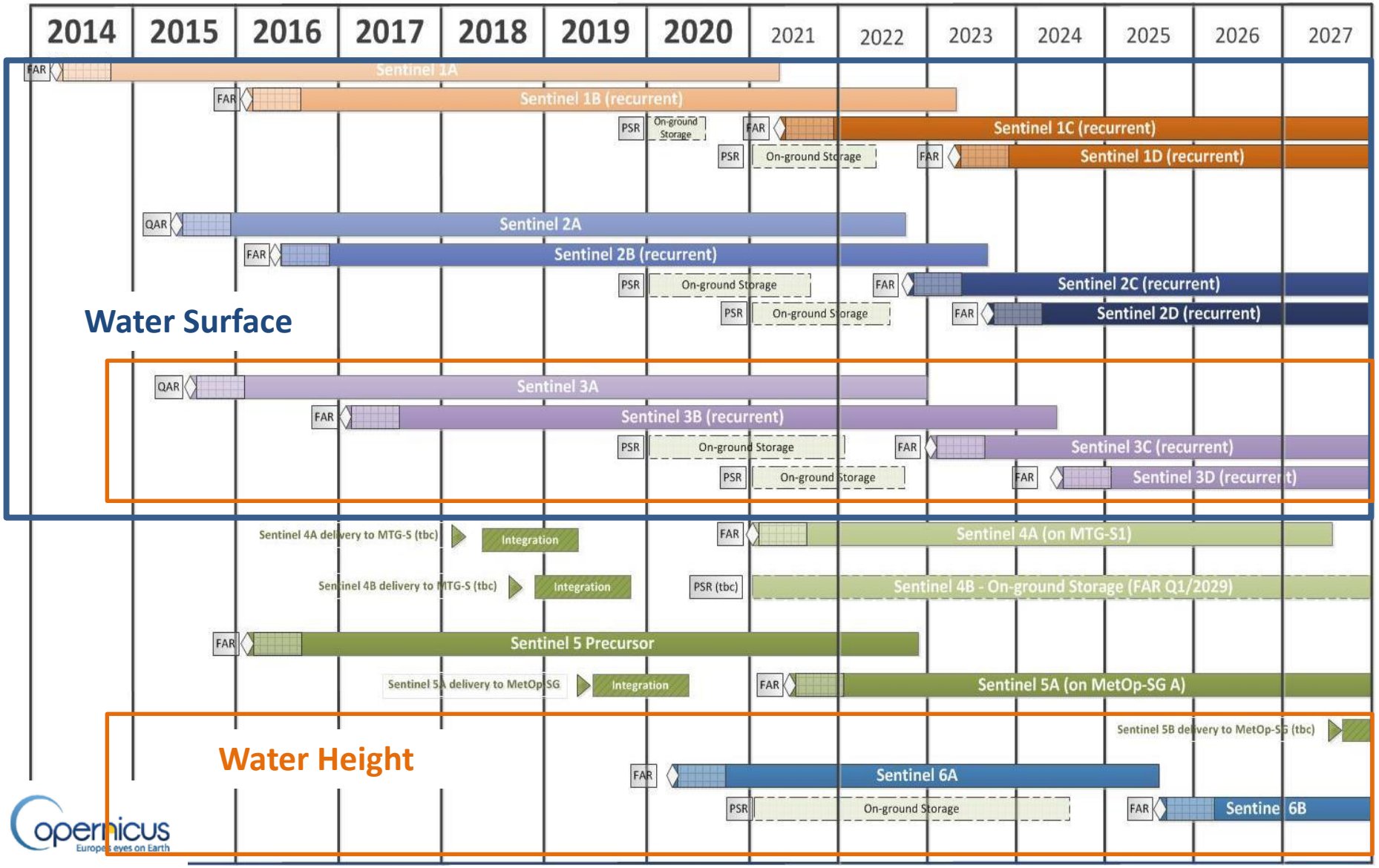


Lakes and water bodies: Landscape variability

EO sensors for hydrology



Copernicus missions (ESA) exploitable for hydrology



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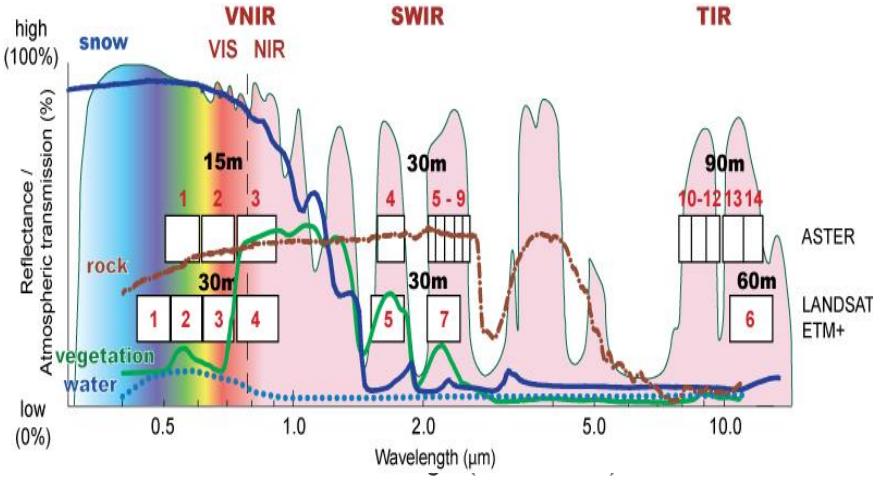
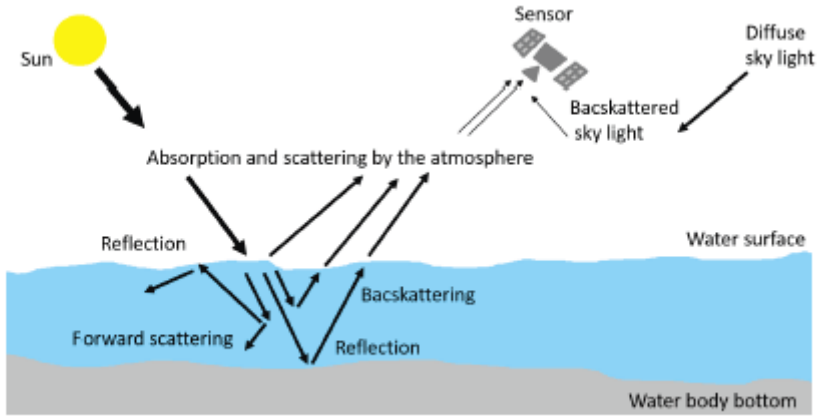
Short cut of Physical basis for Water bodies mapping

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



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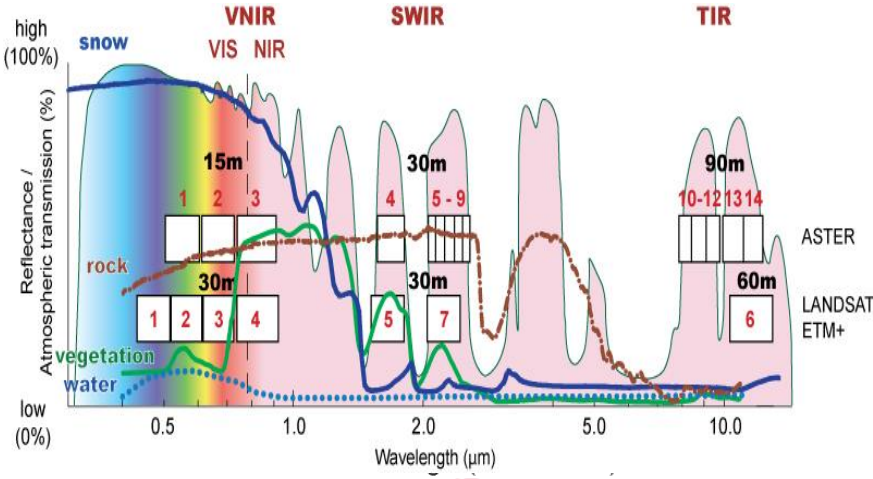

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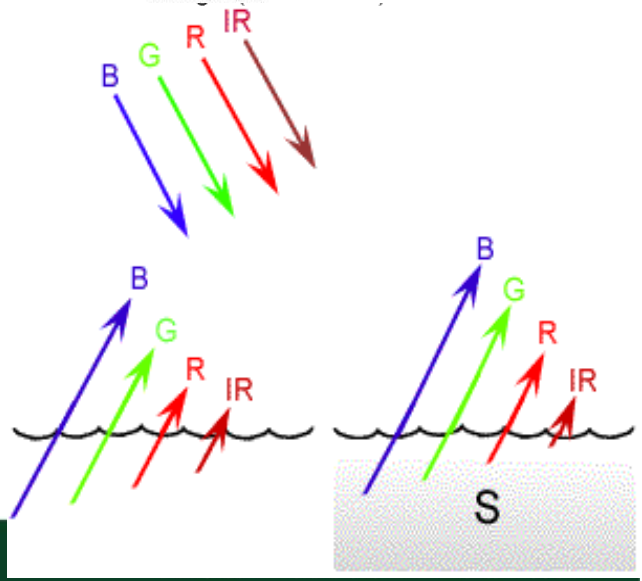

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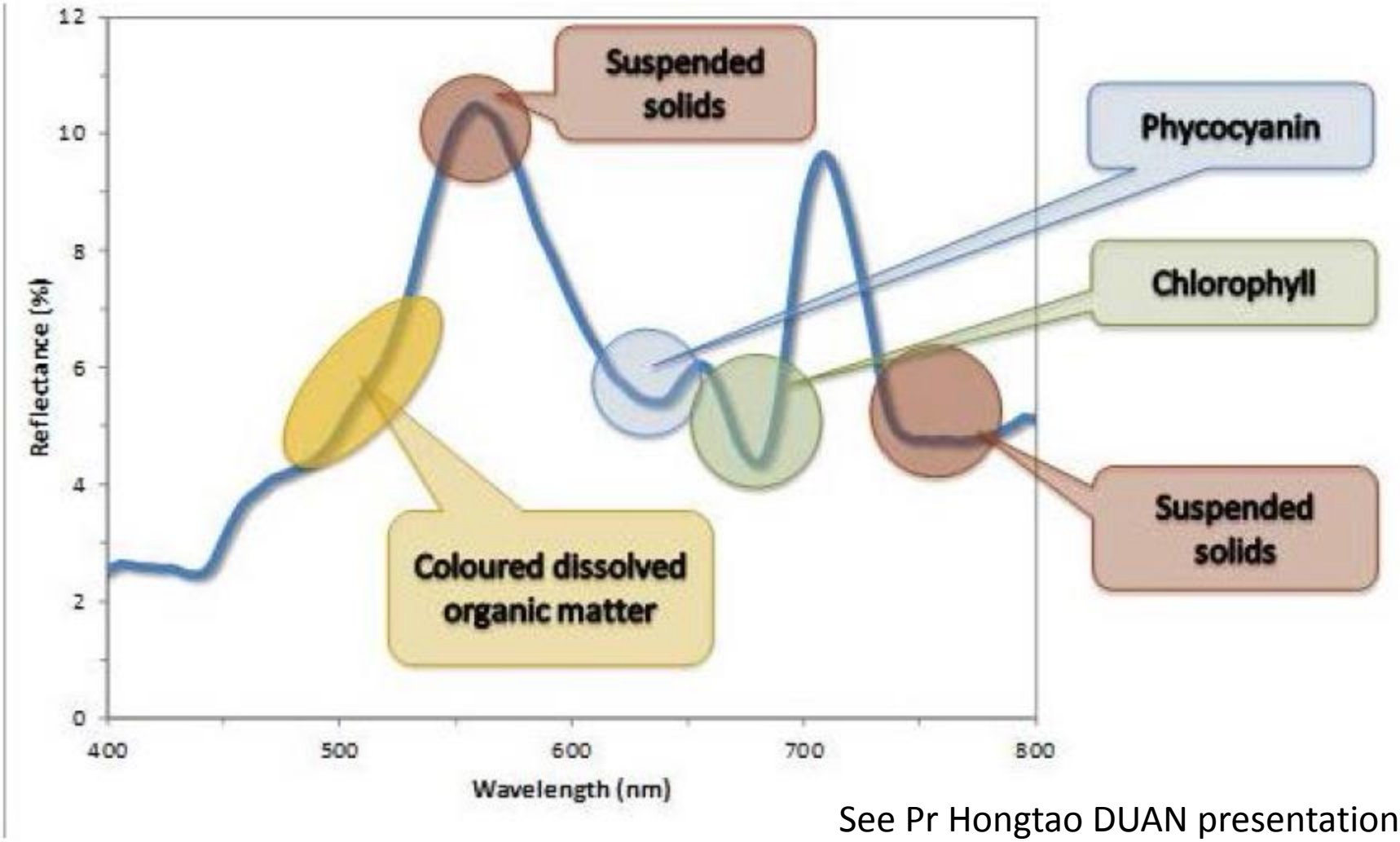
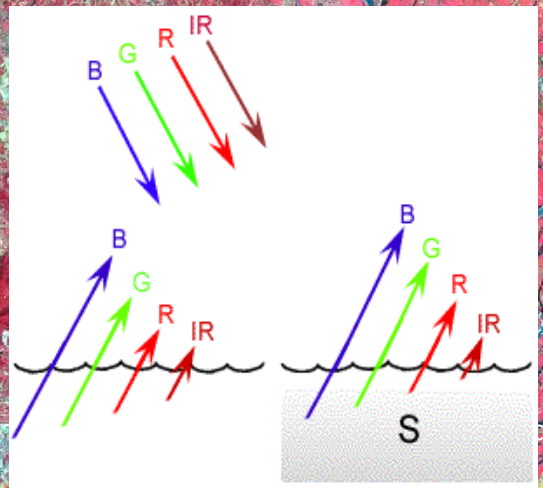


See Pr Hongtao DUAN presentation

Water bodies: optically complex system

Water bodies: spatially complex system

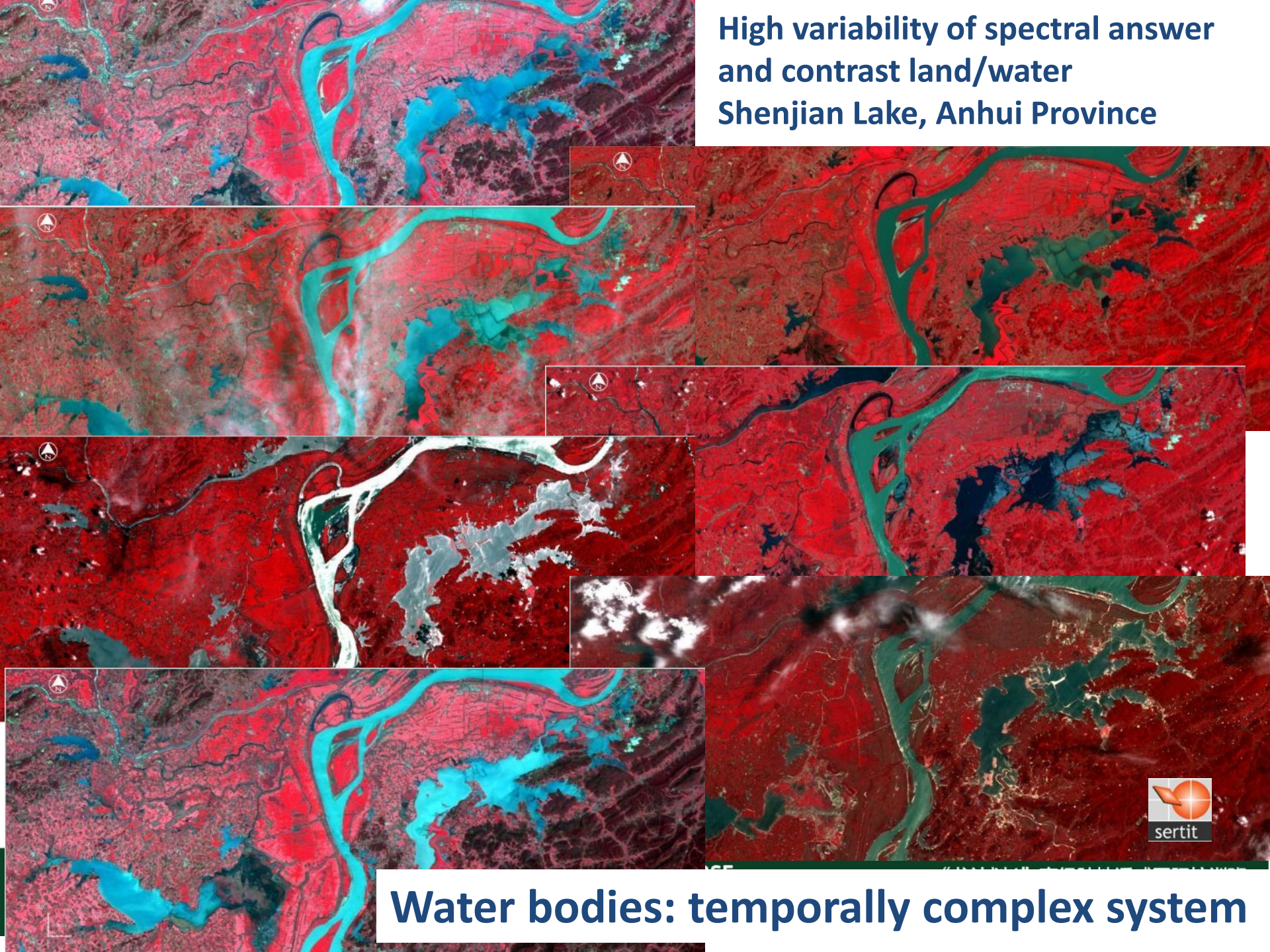
15 km



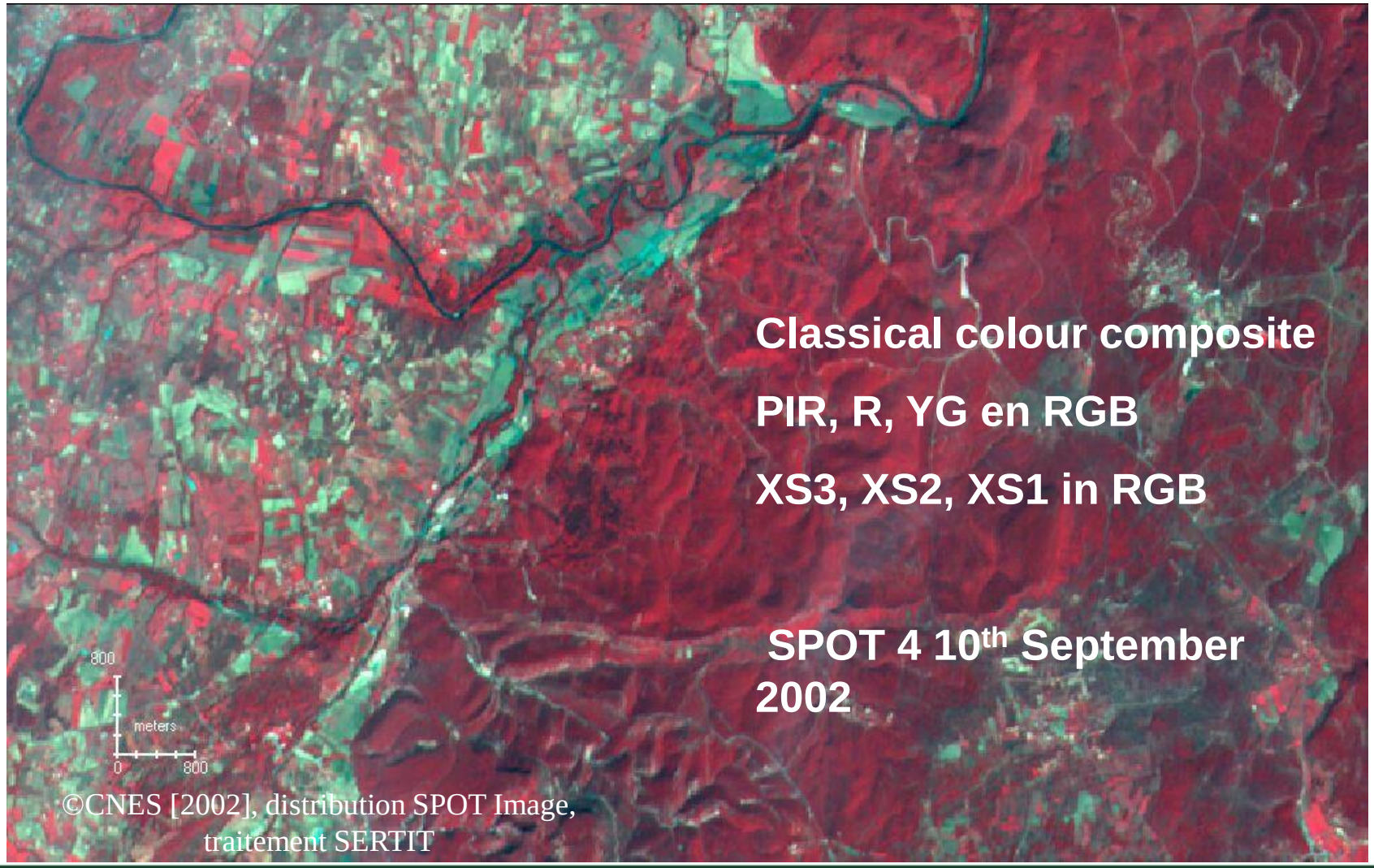
Sentinel2

2015-10-20

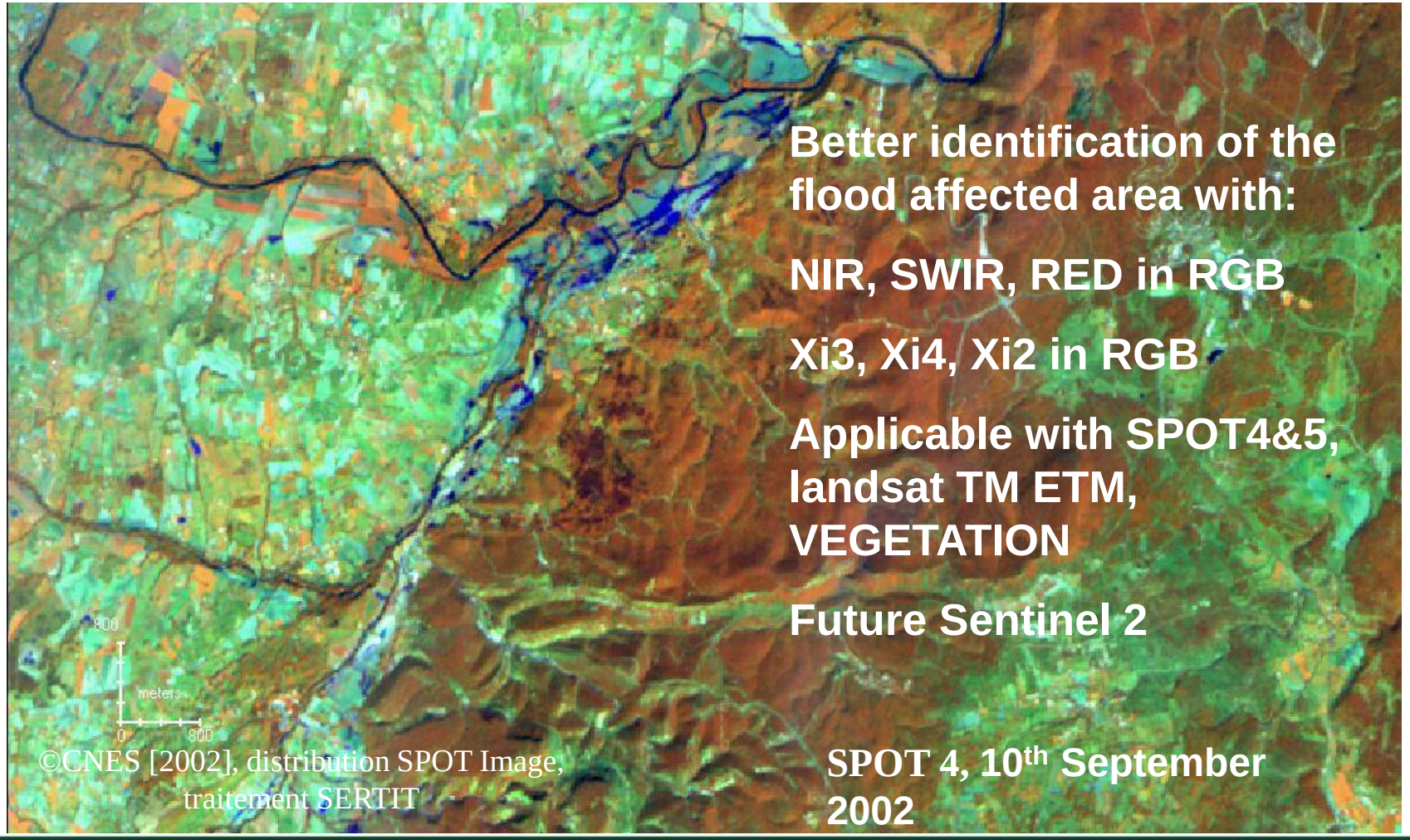
10 m


High variability of spectral answer
and contrast land/water
Shenjian Lake, Anhui Province
sertit
Water bodies: temporally complex system

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

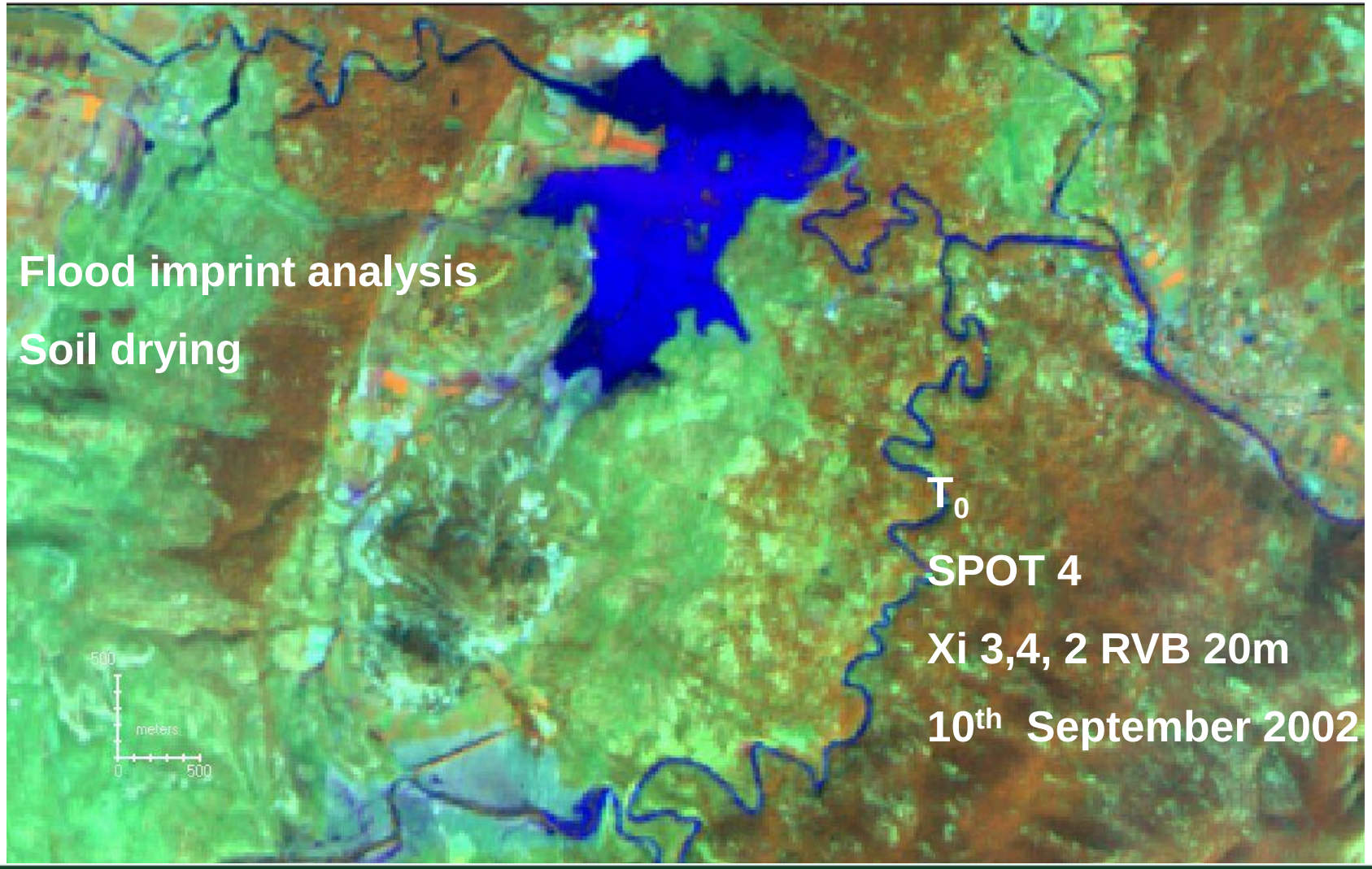
Applicable with SPOT4&5, landsat TM ETM, VEGETATION

Future Sentinel 2

SPOT 4, 10th September 2002

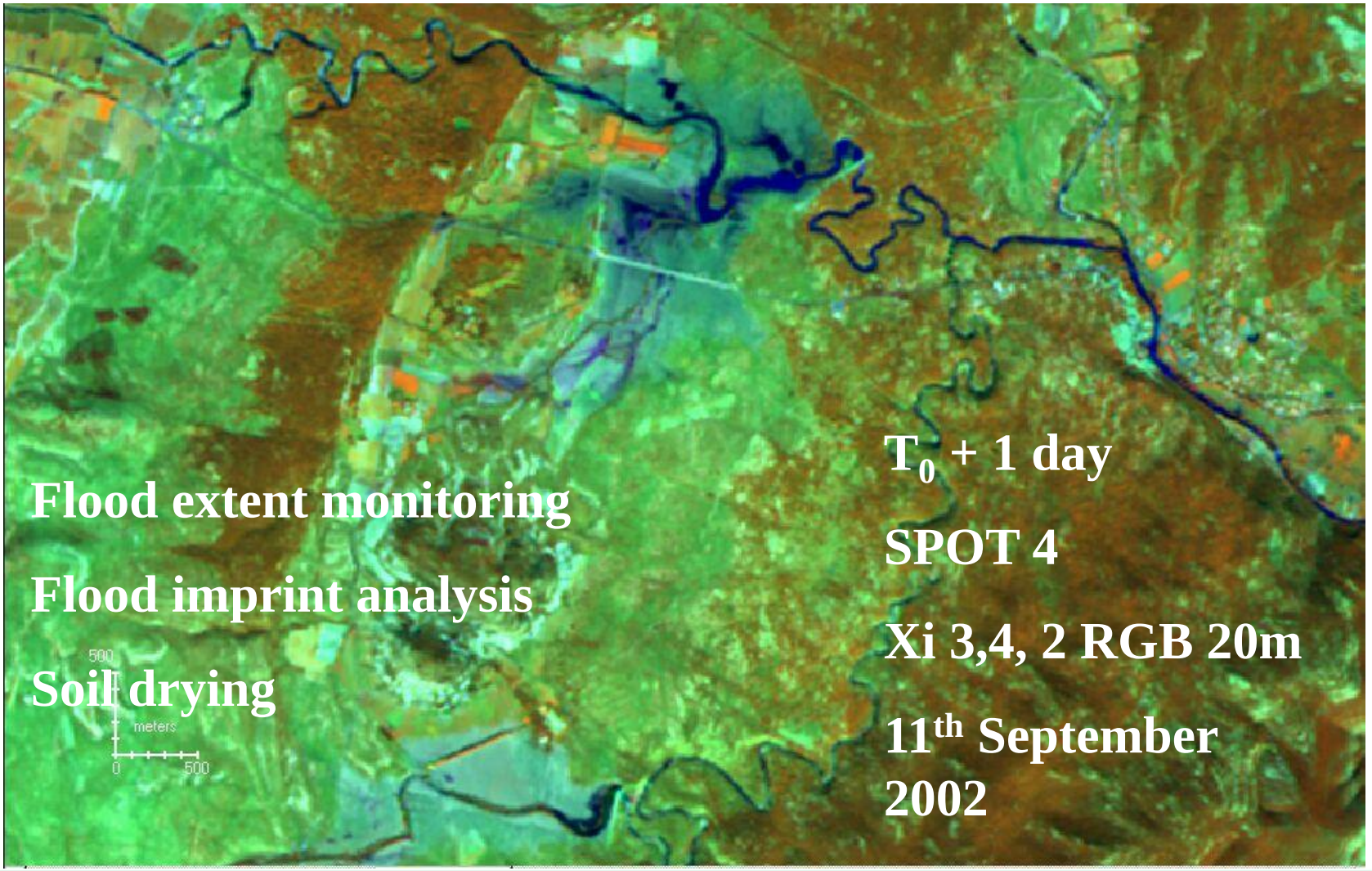
Multitemporal approach:

contribution of the SWIR channel for flood imprint mapping



Multitemporal approach:

contribution of the SWIR channel for flood imprint mapping



Spectral basis for flood / water bodies mapping: VIS & SWIR

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

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
- Interest for SWIR bands

Elements for water bodies extraction based on optical imagery

Optical sensors for water bodies and/or flood mapping
- Medium
- High resolution
- VHR sensors

Water level from space
- Principles of altimetry
- Altimetry missions past, present futures
- Altimetry database

Flood plain and lakes monitoring
- Short term Monitoring
- Long term monitoring
- Meteo climato parameters

Concluding remarks

Water bodies mapping based on Optical data

Extraction of water bodies on:

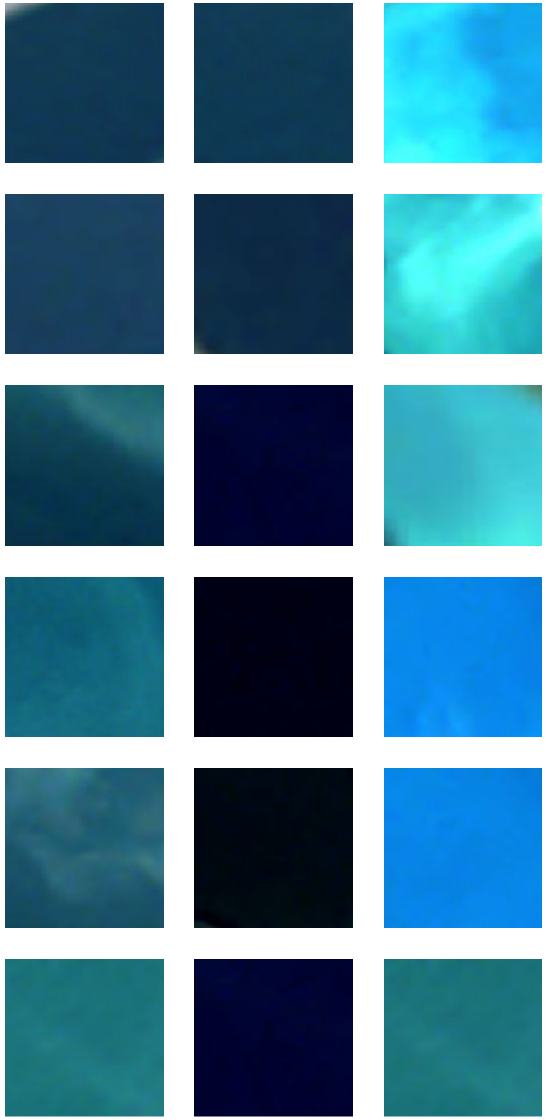
- raw channels, particularly the NIR, SWIR ones
- Indices, NDWI, , AWEI, INH, SBI
- Saturation or Hue indices of a HIS transformation

Methods of thresholding

- Simple/double
- Otsu
- Kalman, Hysteresis filters
- …

Methods of classification

- Supervised
- None supervised
- Oriented object methods
- SVM
- …



Variations in space of water bodies spectral signatures

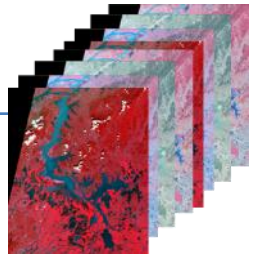
Processing chain for Sentinel-2

PreProcessing

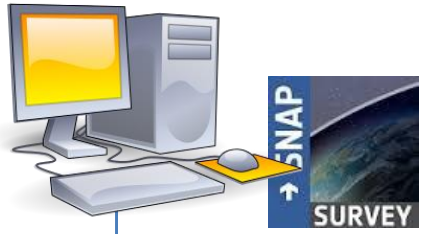
DEM

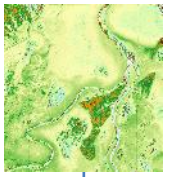
Data ingest

ESA SciHub



Sentinel-2





Band selection
Meta data

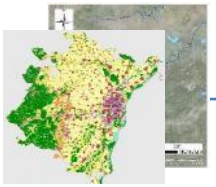
Masks
Metadata
+ métas

Primitives Image features/ patterns

Images
Features
characterisation

Methods

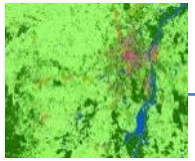
Database



Extraction

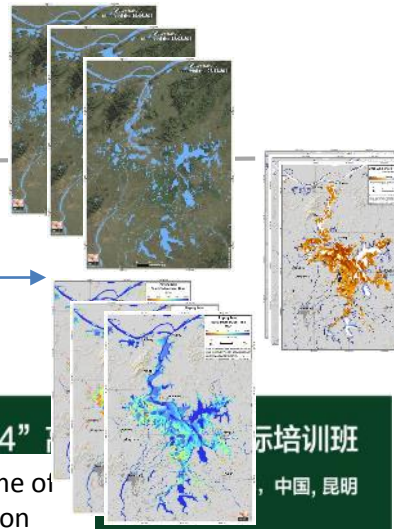
Validation

Database



Validation

Water products



Yearly time of submersion

Processing chain for Sentinel-2

PreProcessing

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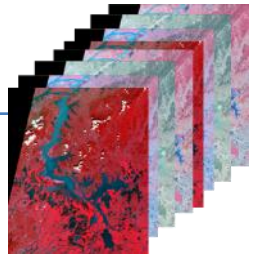
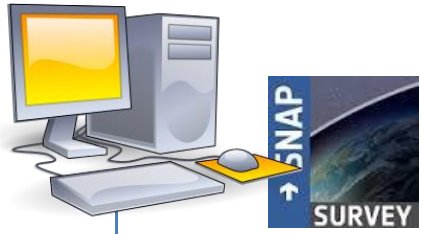
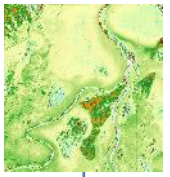
Data ingest

ESA SciHub



Sentinel-2





Band selection
Meta data

Masks
Metadata
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Images
Features
characterisation

Methods

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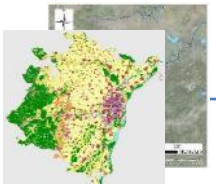

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Validation

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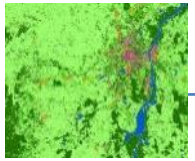

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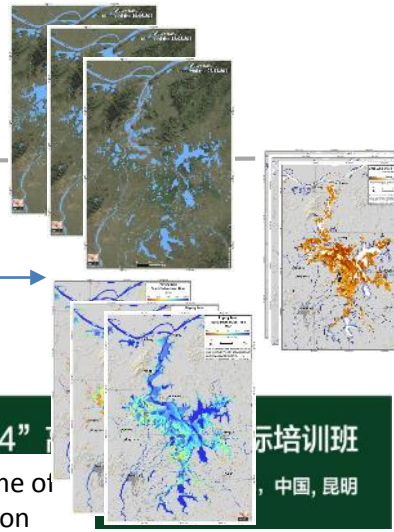
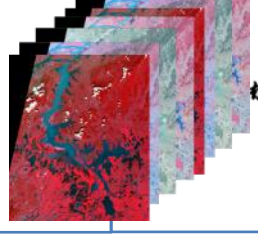


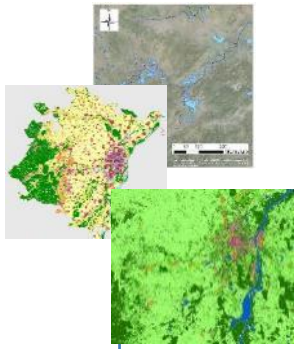
Yearly time of submersion

S2 primitives' image extraction



Indices:
NDVI, NDWI, ,
AWEI, INH, SBI

Spectral space
IHS, ...



Binary mask
+ métas
(GeoTiff)

Primitives,
features

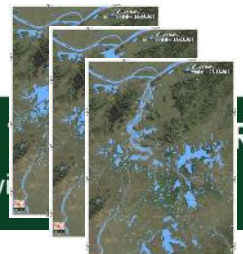
Binary mask
+ métas
(GeoTiff)

Thematic extraction

Simple or
multiple
thresholds

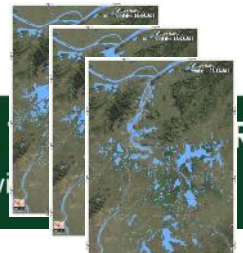
SVM,
classification

Water mask
+ metadata

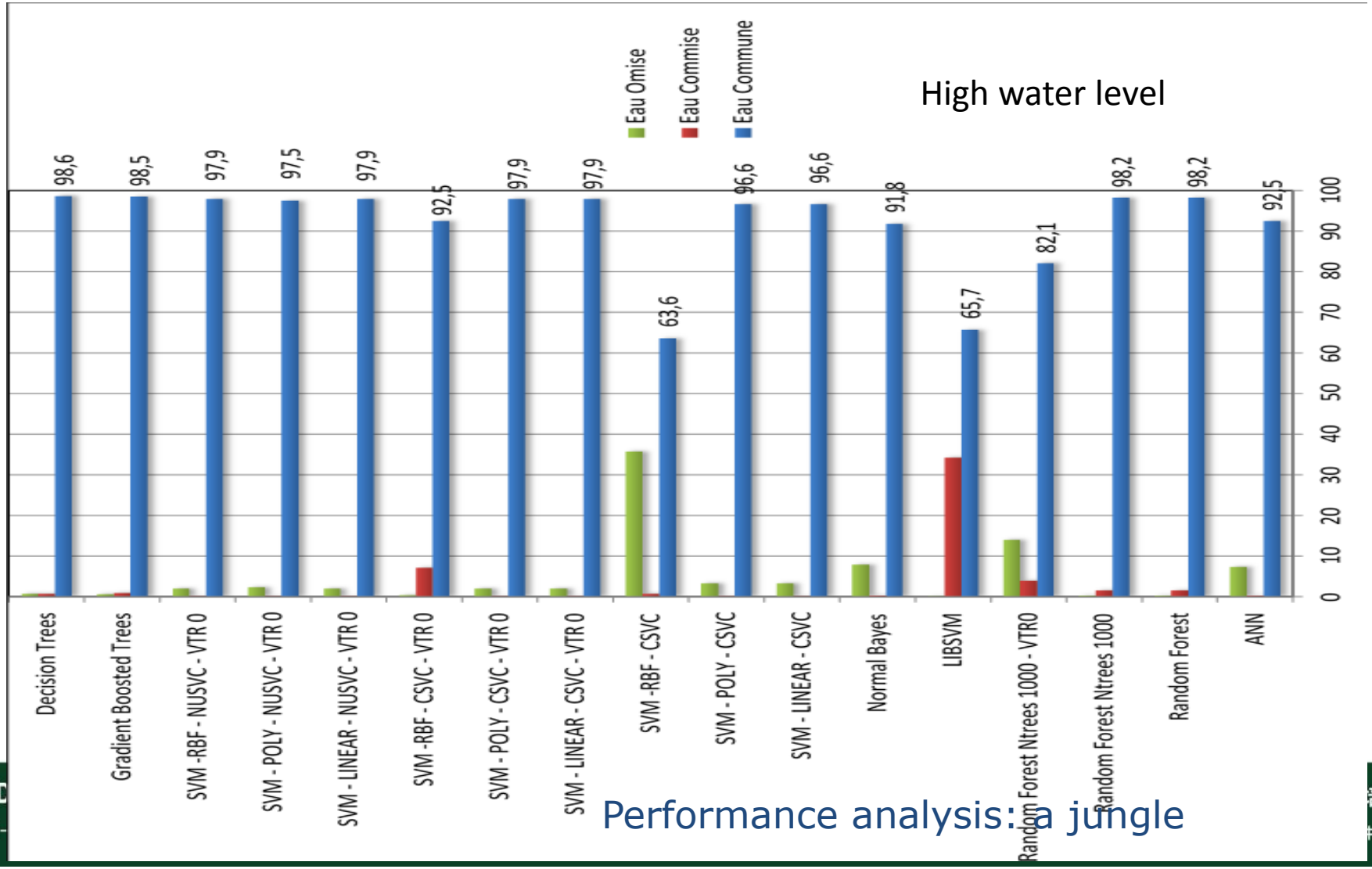


Index	Equation	Remark
Normalized Difference Water Index	NDWI = (Green − NIR)/(Green + NIR)	Water has positive va
Normalized Difference Moisture Index	NDMI = (NIR − MIR)/(NIR + MIR)	Water has positive va
Modified Normalized Difference Water Index	MNDWI = (Green − MIR)/(Green + MIR)	Water has positive va
Water Ratio Index	WRI = (Green + Red)/(NIR + MIR)	Value of water body greater than 1
Normalized Difference Vegetation Index	NDVI = (NIR − Red)/(NIR + Red)	Water has negative va
Automated Water Extraction Index	AWEI = 4 × (Green-MIR) − (0.25 × NIR + 2.75 × SWIR)	Water has positive va

Water mask
+ metadata

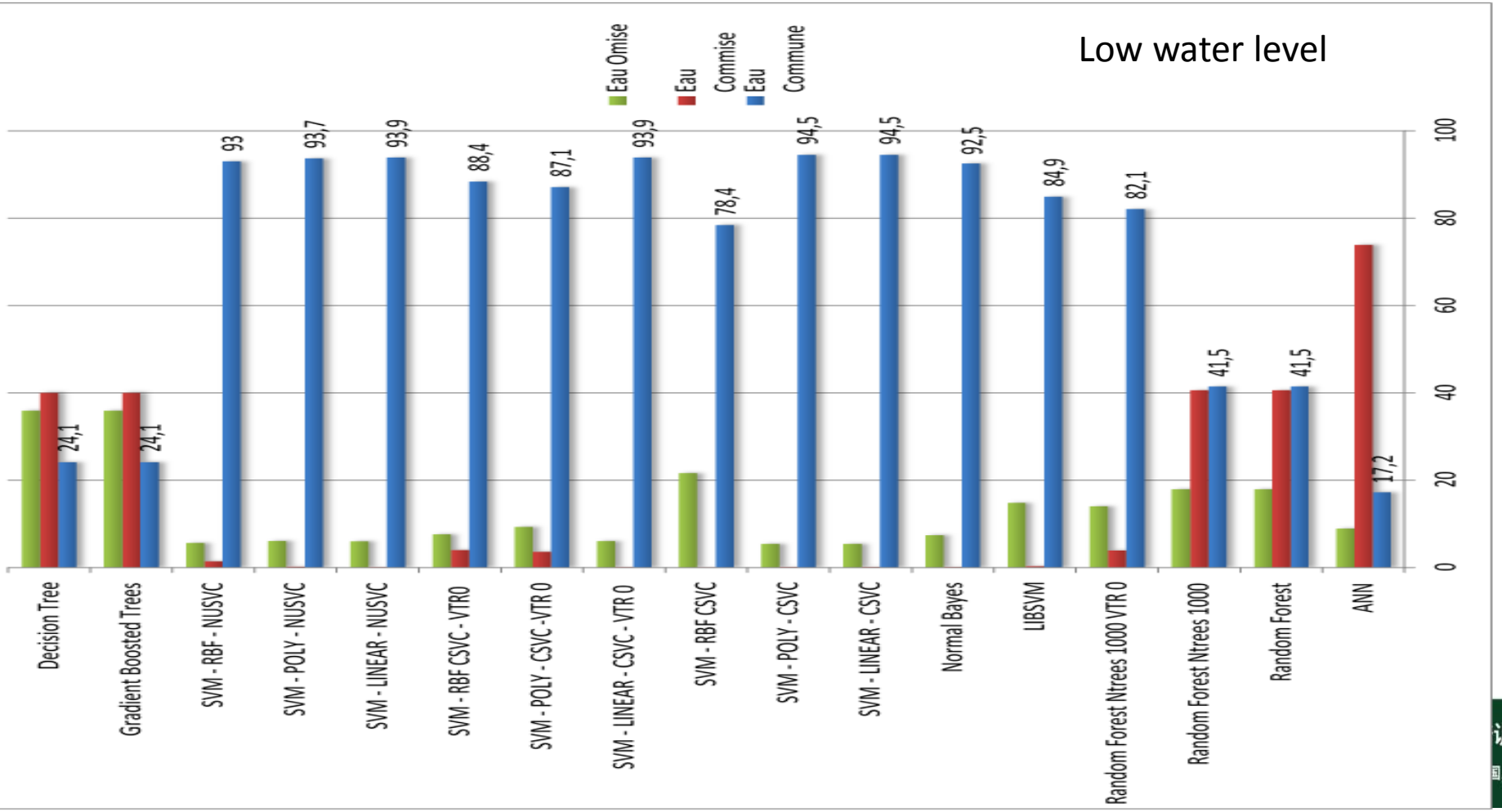


Flood mapping based on classification from test areas



Performance analysis: a jungle

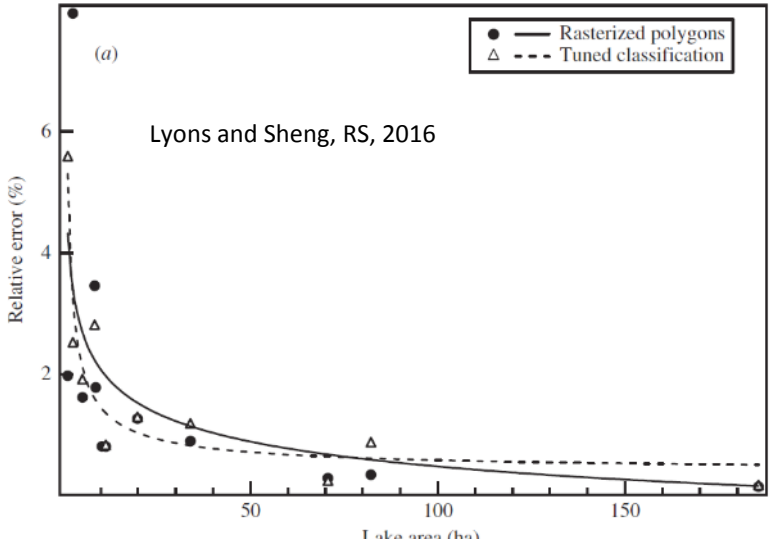
Flood mapping based on classification from test areas



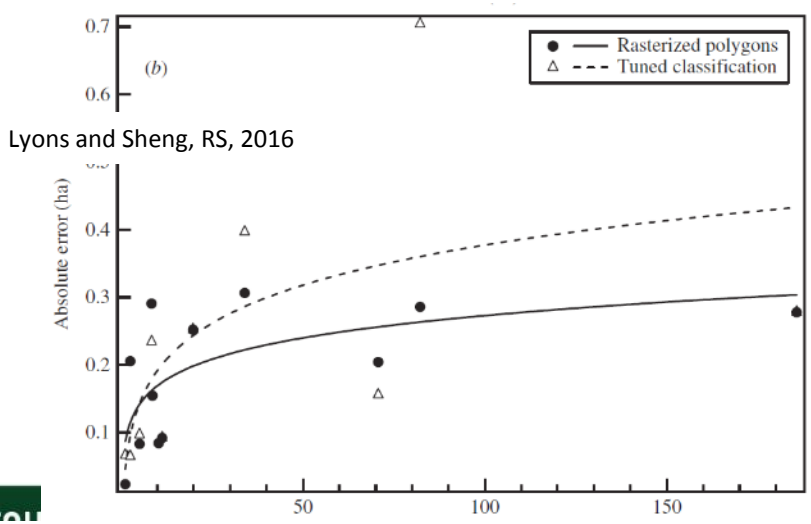
Errors and sources of errors in water surfaces mapping

	Sensors properties	Lakes Characteristics	Data processing
Spatial	**Spatial resolution**	**Size and Shape** **Size of the transition zones between dry and flooded areas.. Ice..**	**Spatial sampling**
Radiometric	**Radiometric resolution** **Spectral coverage (bands)**	**Spectral response of water/land, floating or submerged vegetation**	**Radiometric sampling** **Sensitivity of the descriptors**
Temporal	**Temporal resolution** **Acquisition date**	**Seasonal water surfaces fluctuations** **Periodic/recurrent inundations**	**Co registration** **Nb exploitable images**

Factors, spatial, radiometric and temporal, factors contributing to errors in water surface mapping



Lyons and Sheng, RS, 2016

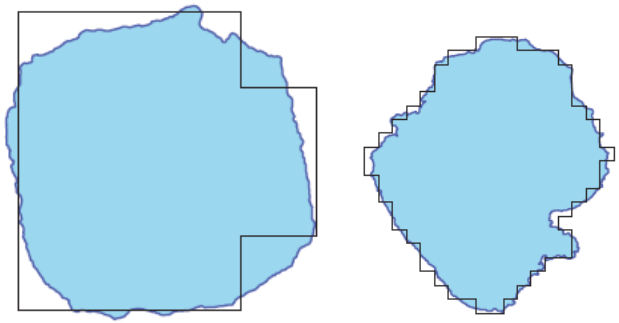


Lyons and Sheng, RS, 2016

Errors distribution in function of water bodies size

Errors and sources of errors in water surfaces mapping

Definition of limits of flooded areas



Shape /resolution

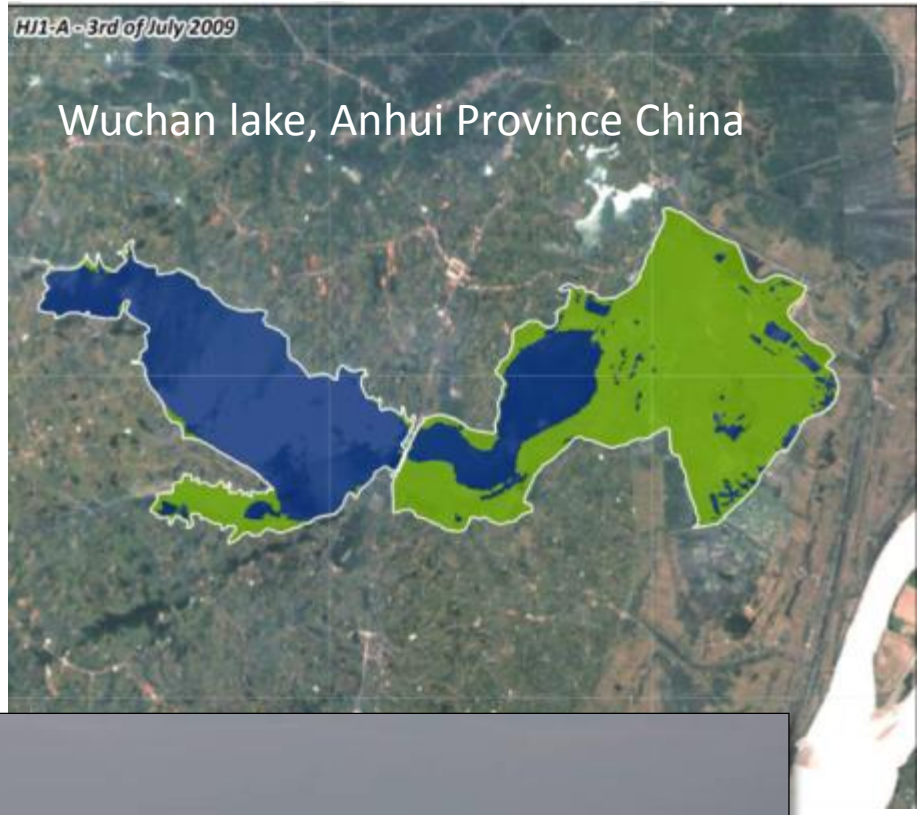
Floating vegetation

Presence of vegetation/alga bloom
Presence of Ice

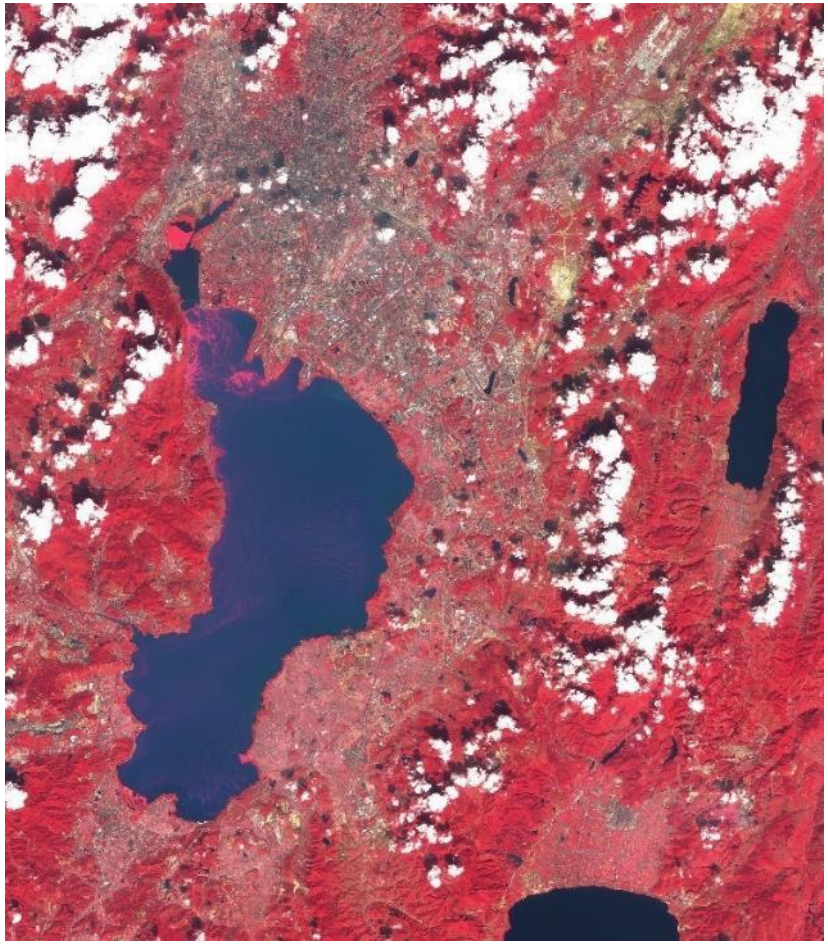
Potential limitation on water surface regognition water flooded vegetation and floating vegetation

Azolla filiculoides

Potential limitation on water surface regognition water flooded vegetation and floating vegetation



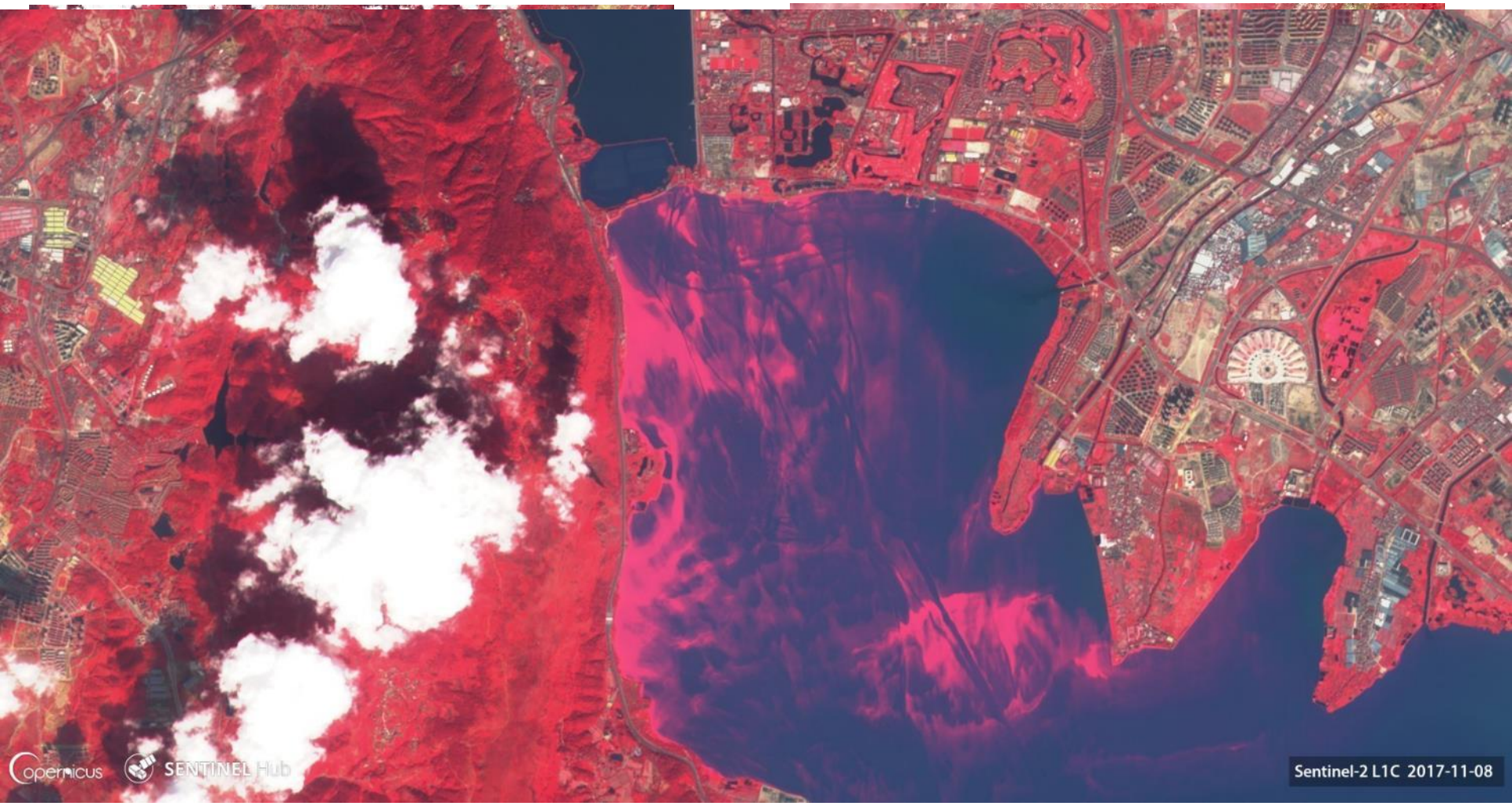
Potential limitation on water surface regognition water: alga bloom



S2 8 November 2017

S2 13 November 2017

Potential limitation on water surface regognition water: alga bloom



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- **High resolution**
- **VHR sensors**

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Concluding remarks

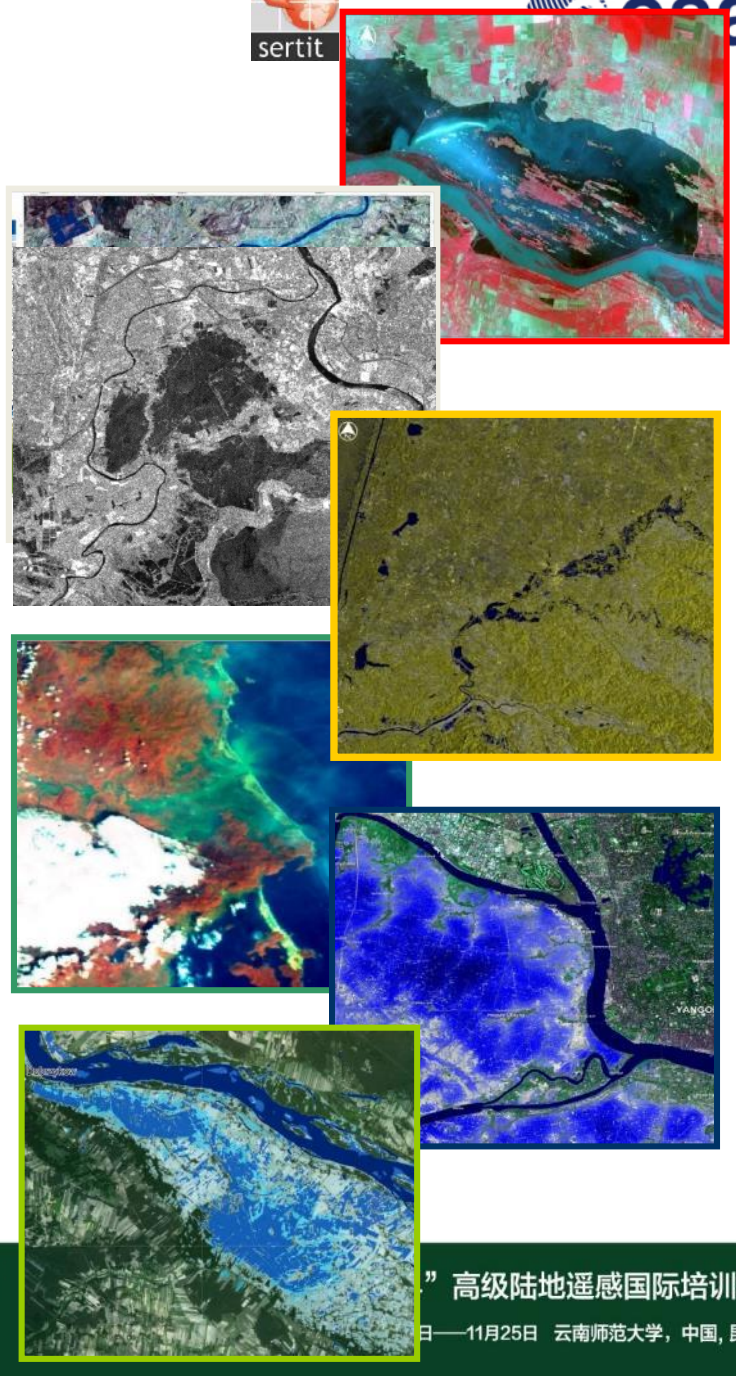
Near 30 years of exploitation of EO data for water bodies mapping and monitoring

Improvement from one generation to another one

- SPOT1-3 to SPOT4-5=> SPOT 6-7
- SPOT => Pleaides VHR
- MODIS => MERIS=> OCLI
- ERS =>ENVISAT=> Sentinel 1A/B
- HJ 1C => Chang Zheng 4C
- Radarsat 1 => Radarsat 2
- VHR SAR TerraSar X and CSK
-

Improvement in term of

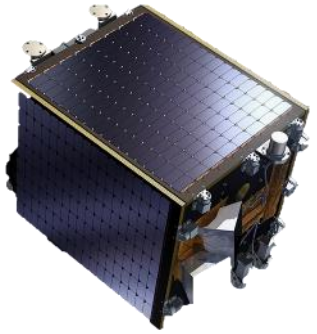
- Swath
- Resolution
- Radiometric quality
- Revisiting time
- Access to images
- Derived products



caroussel_1.png

PROBA V

Following of SPOT Vegetation (SPOT4 &SPOT5)
with improved spatial resolution

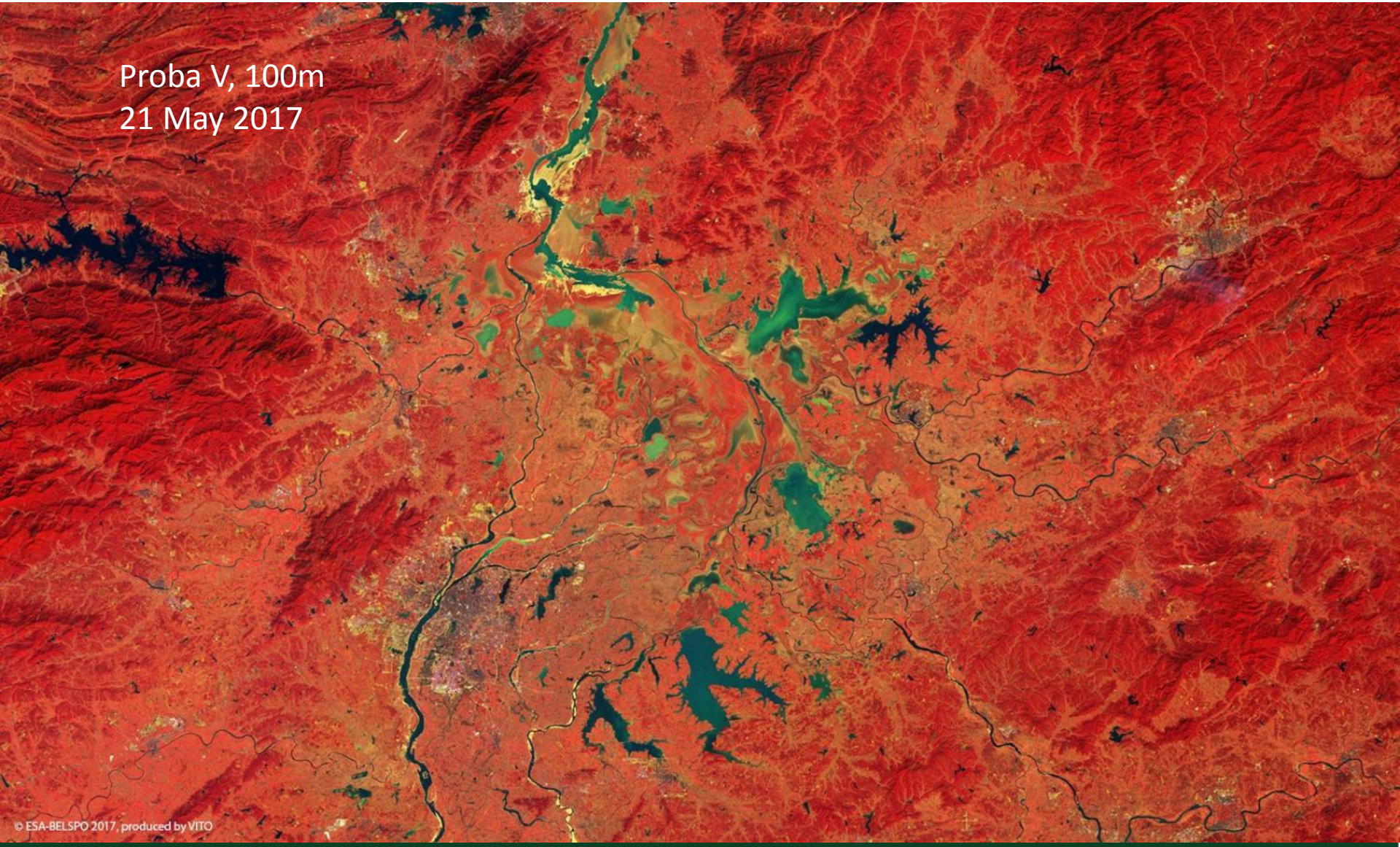


Launch 7 of Mai 2013

4 bands
VNIR B0: 0.415-0.500 µm (Blue)
VNIR B1: 0.580-0.770 µm (Red)
VNIR B2 : 0.730-0.960 µm (NIR)
SWIR:1.480-1.760 µm

Swath 2285 km
300 m (baseline)
- VNIR : 100 m at nadir, 360 m at edge of swath
- SWIR : 200 m at nadir, 600 m at edge of swath

=> Daily coverage


Proba V, 100m
21 May 2017
© ESA-BELSPO 2017, produced by VITO

ALOS AVNIR

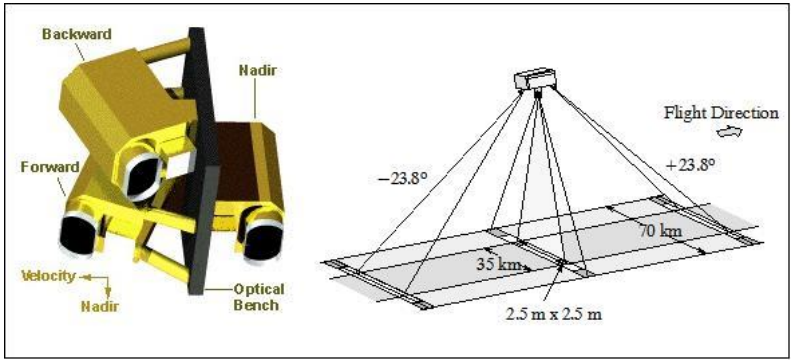
ALOS= DAICHI
PRISM: 2,5m
AVNIR-2: 10m
+ SAR=PALSAR

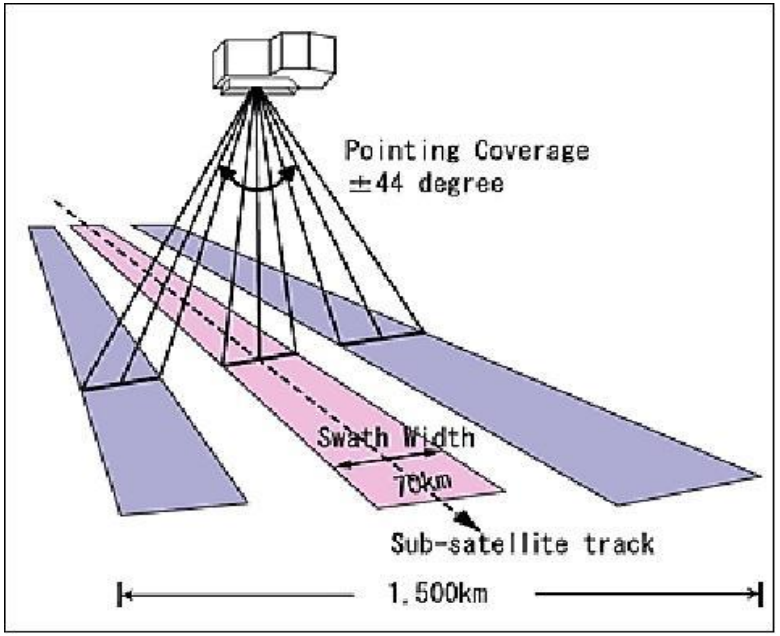
Launch September 2012 and June 2014

4 bands + Pan
Blue: 0.42-0.50 µm
Green: 0.52-0.60 µm
Red: 0.61-0,69 µm
NIR: 0.76-0,89 µm

PAN: 0.52-0,77 µm

Swath 35 km (triplet) or 70 km (nadir) for PRISM
Swath AVNIR: 70 km





ALOS AVNIR

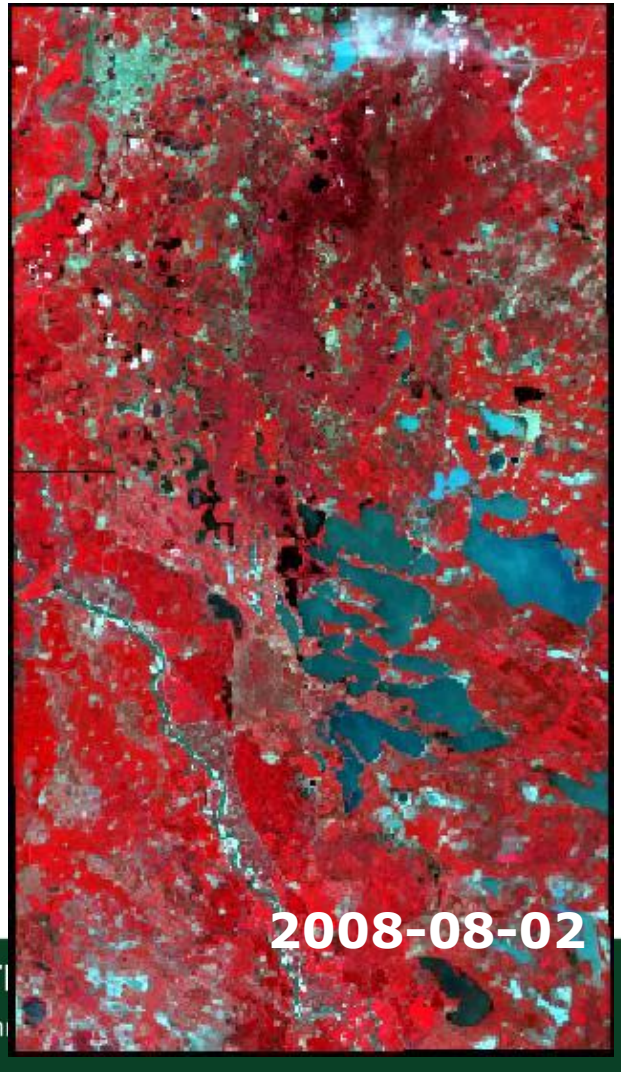
Alos AVNIR Strip over

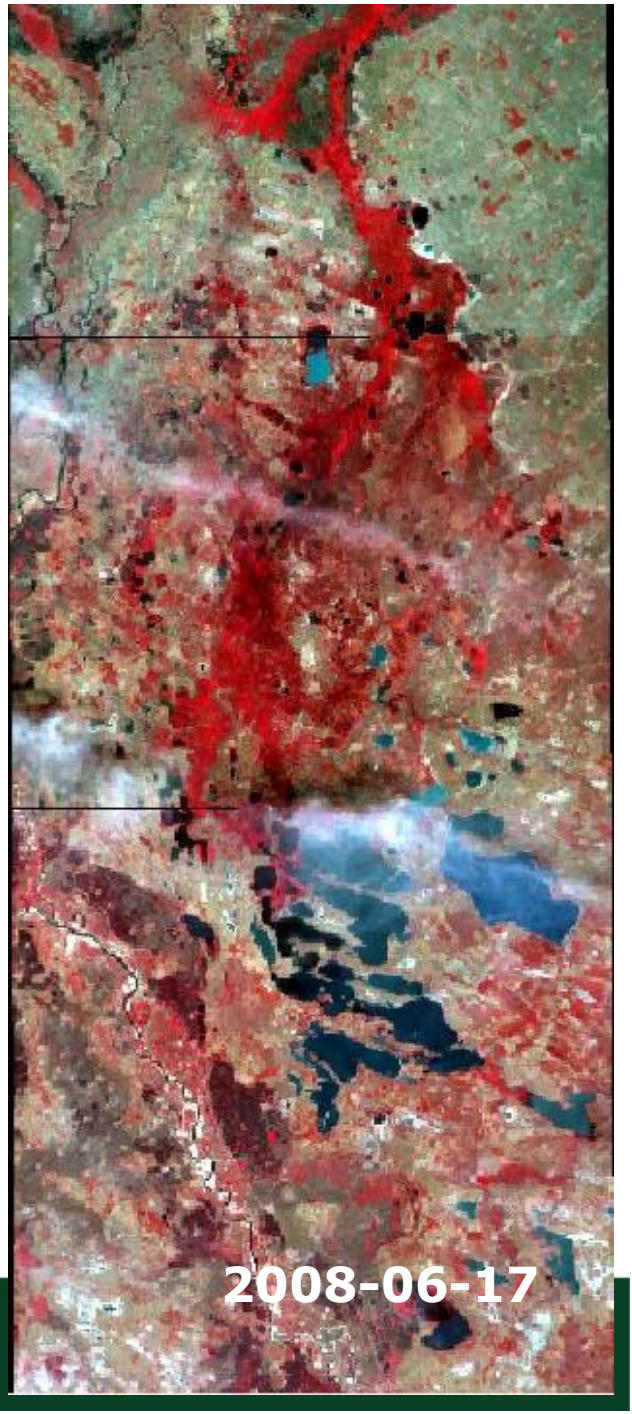
Nen river

and

Zhalong Natural Reserve

Heilongjiang and Jiling Provinces



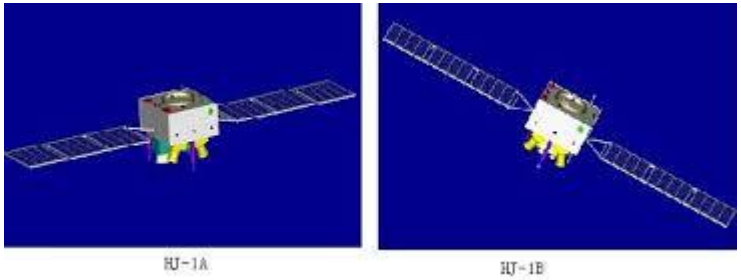


caroussel_1.png

HJ 1A – HJ 1G

HJ-1A : CCD camera + infrared camera
HJ-1B: CCD camera +hyperspectral camera

Launch: 5 September 2008

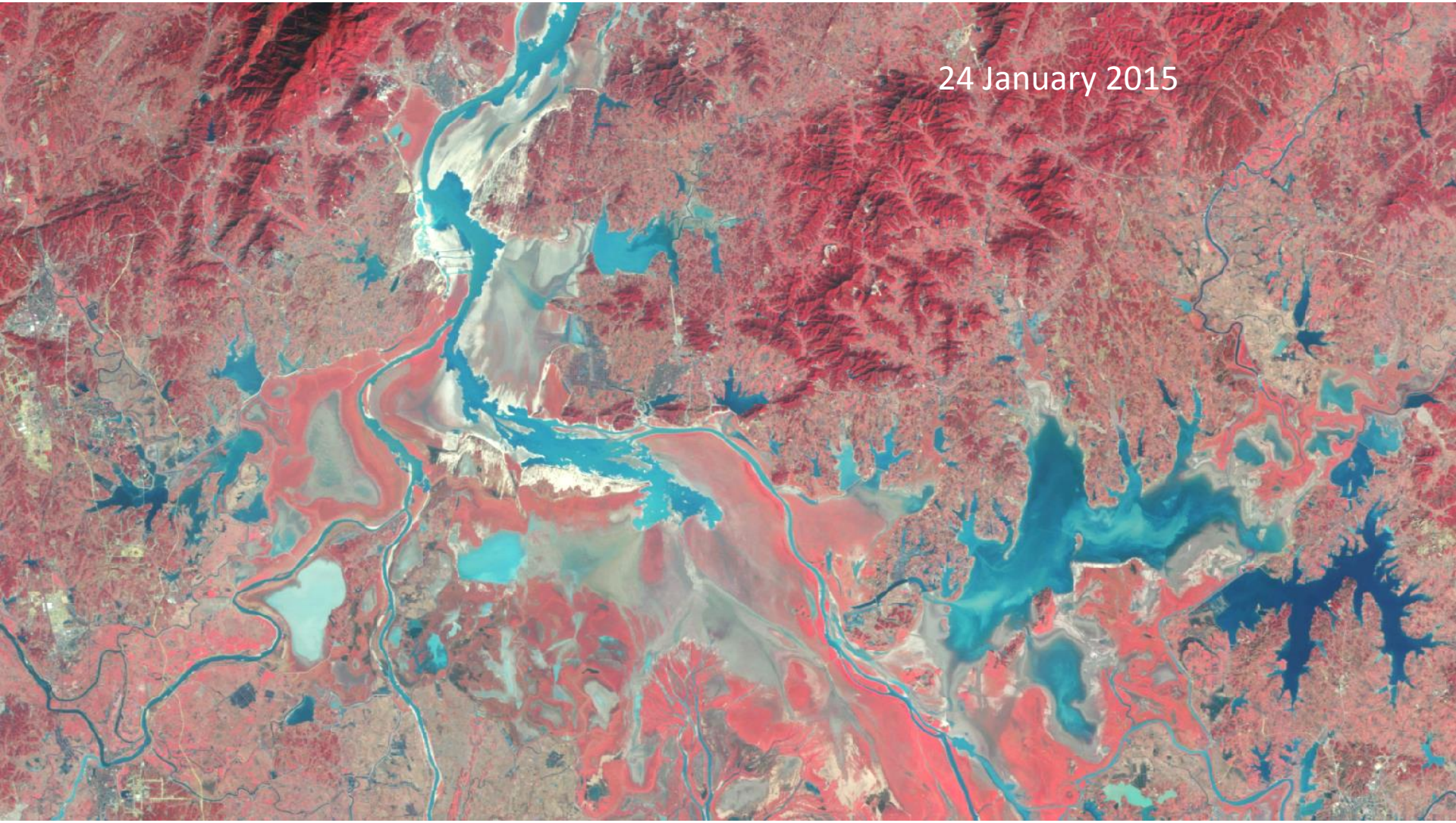


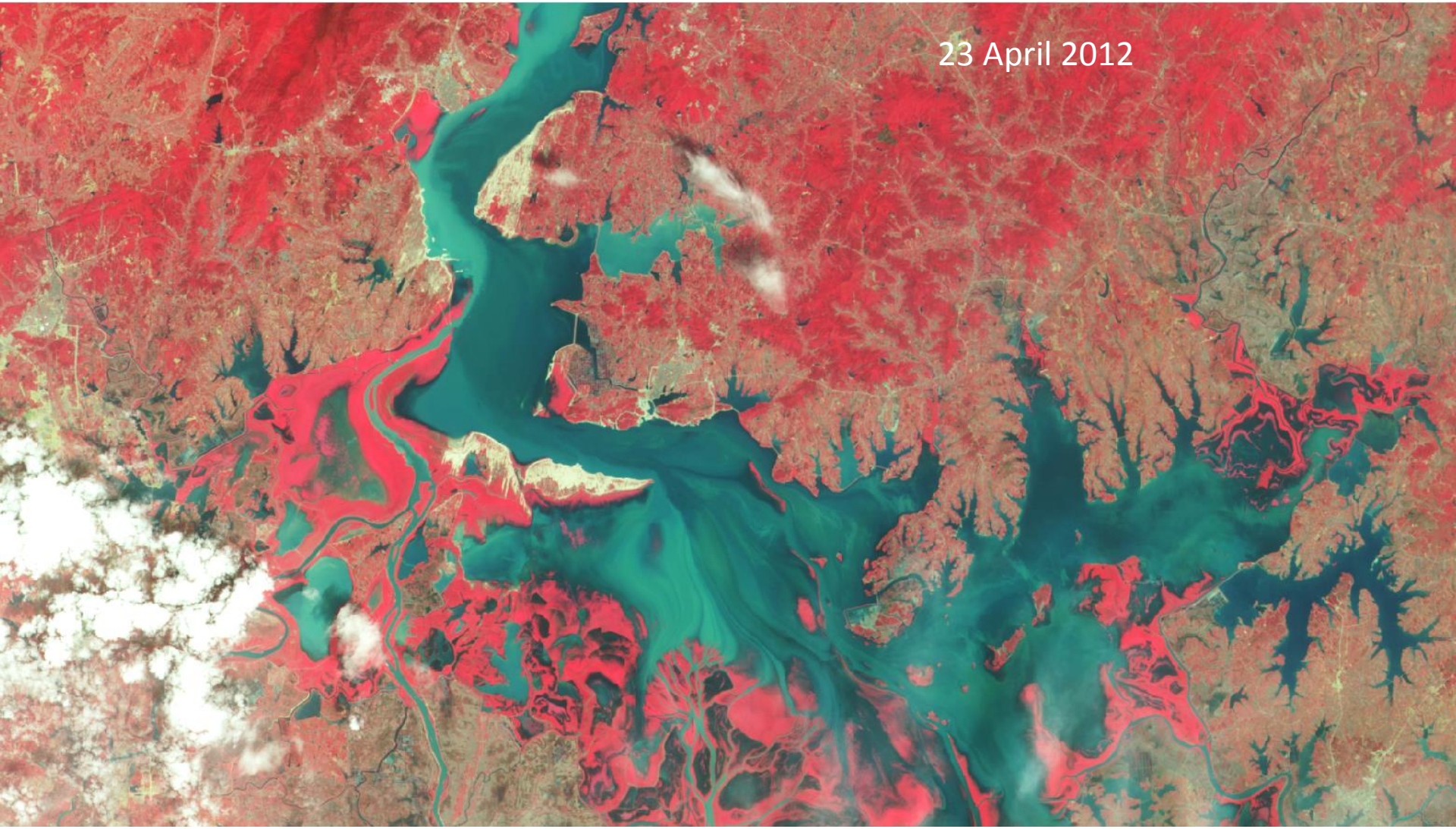
Wide View CCD Camera 4 bands
Blue: 0.43-0.52 µm
Green: 0.52-0.60 µm
Red: 0.63-0.6 µm
NIR: 0.76-0.90 µm

Resolution: 30m

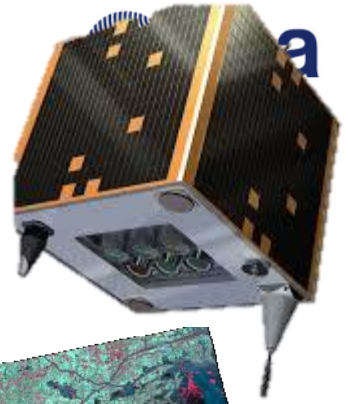
Swath 700 km= 2 * 360 km

=> Daily coverage


24 January 2015


23 April 2012

DMC Familly: DEIMOS 1 – Beijing 1



DMC 2G:
2005 October 27: Beijing 1
2009 July 29 : Deismos 1
2009 July 29: UK DMC 2
2011 August 17: Nigeria Sat 2

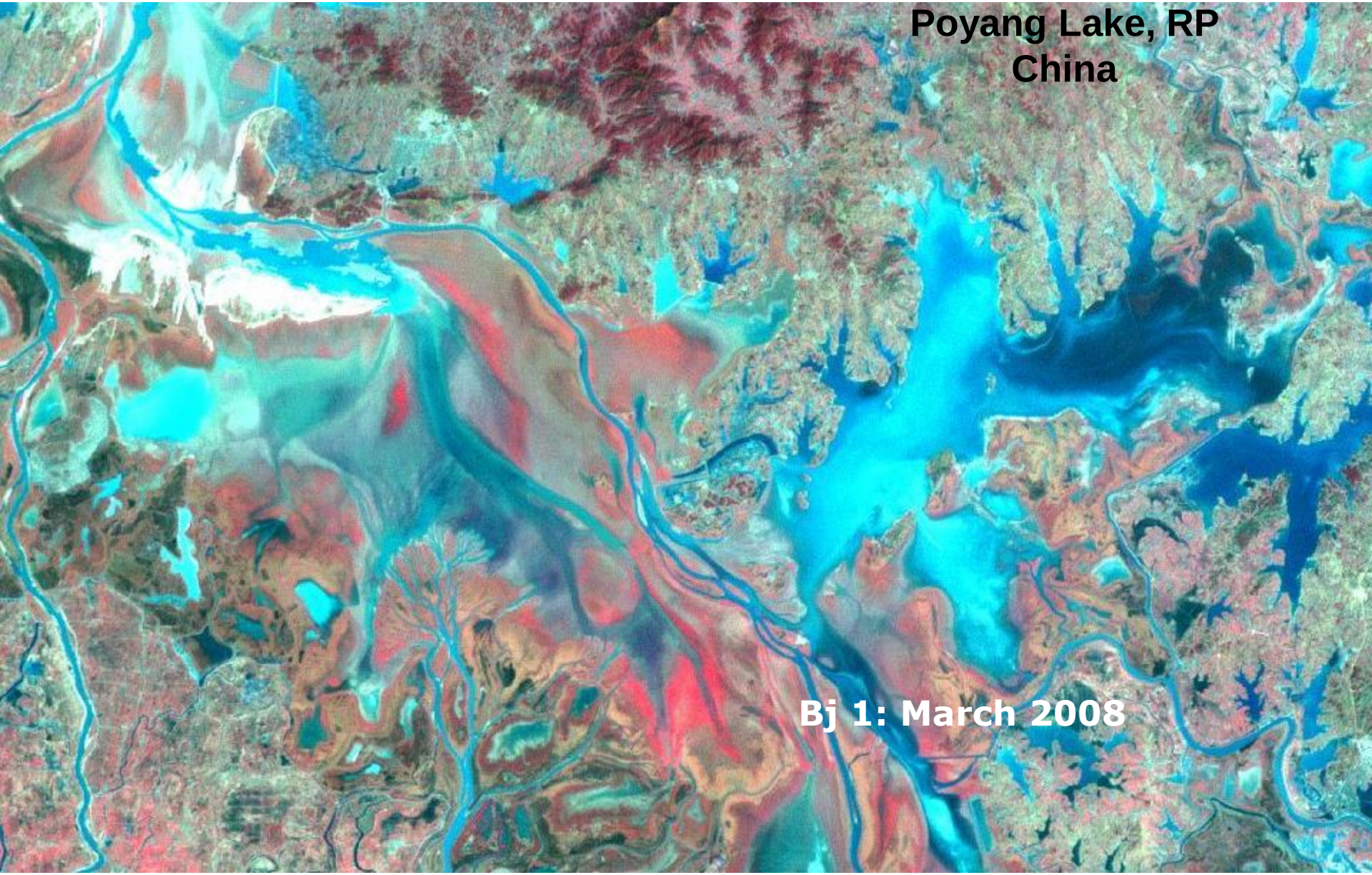
22m 650 km swath
DMC 1G:

Beijing 1 :
32 m, 600 km swath

3 bands
Green: 0.52-0.60 µm
Red: 0.63-0,69 µm
NIR: 0.77-0,90 µm

Daily revisit for constellation

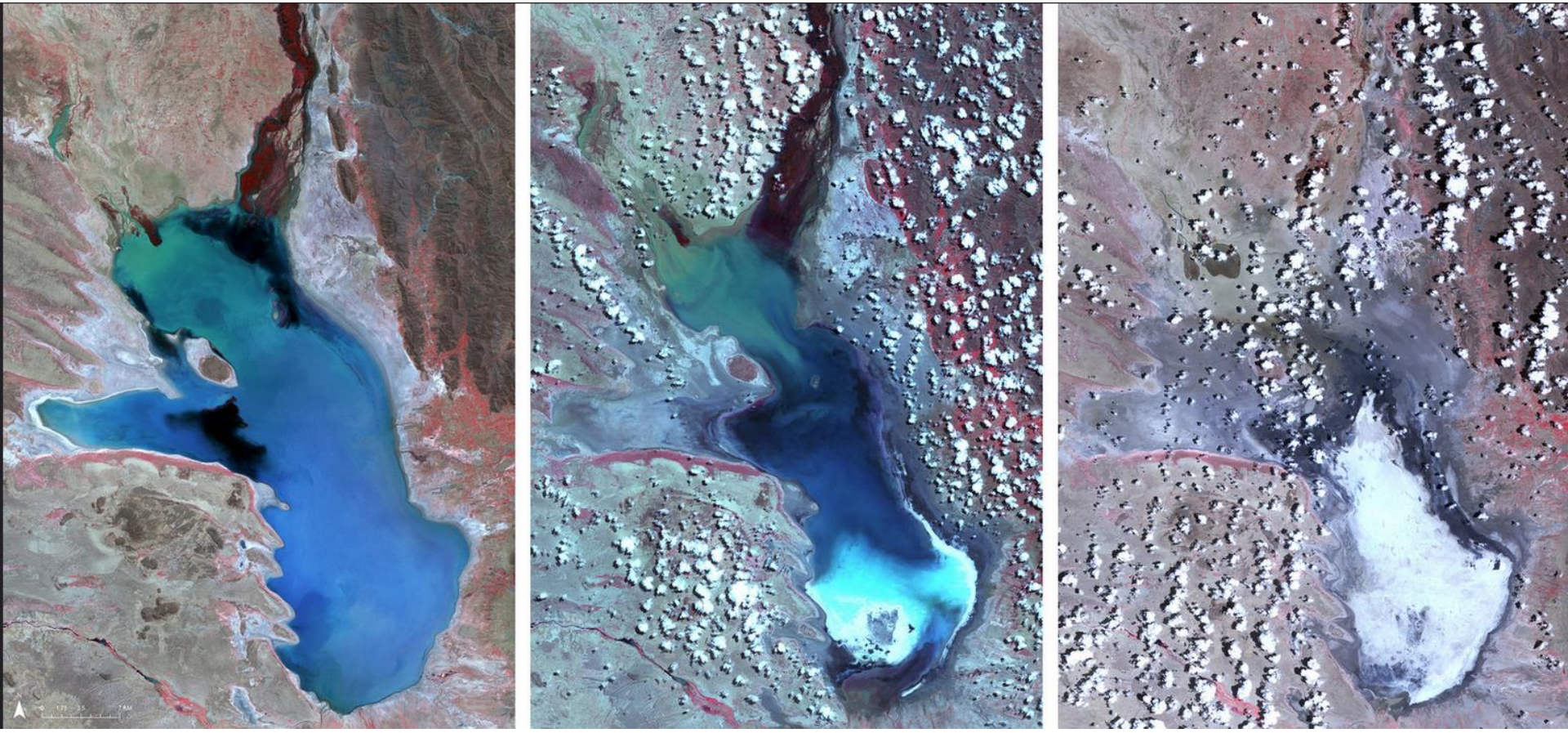
DMC Family: Beijing 1



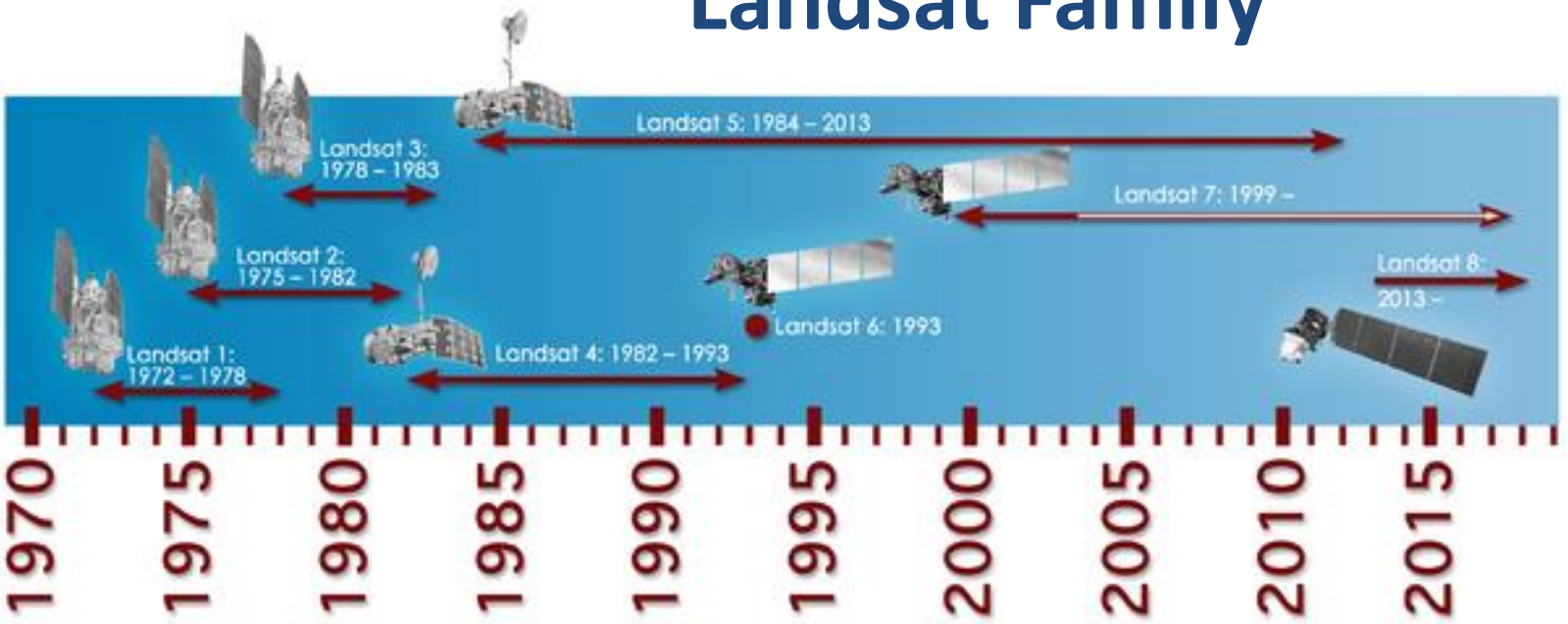
DMC Family: DEIMOS

Poopo Lake, Bolivia

2013-2016



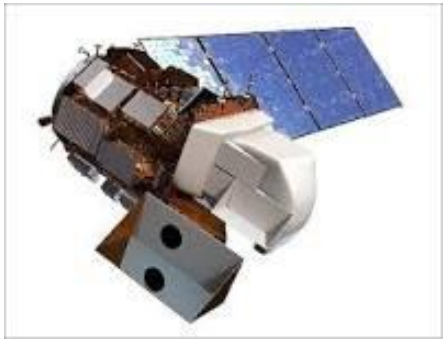
Landsat Family



Systematic acquisition
16 days revisit
Huge archive

Since Landsat 4-5 . SWIR band
30 m

Landsat 8



OLI Spectral bands (30+15m)
B1, Coastal/ Aerosol 0,433-0,453 µm
B2, Blue: 0,45-0,515 µm
B3, Green: 0,525-0,6 µm
B4, Red: 0,63-0,68 µm
B5, NIR: 0,845-0,885 µm
B6, SWIR1: 1,56-1,66 µm
B7, SWIR2: 2,1-2,3 µm
B8, Pan: 0,5-0,68 µm
B9: Cirrus: 1,36-1,39 µm

Plus thermal InfraRed Sensor (100m)
B10, LWIR1: 10,3-11,3 µm
B11, LWIR2: 11,5-12,5 µm

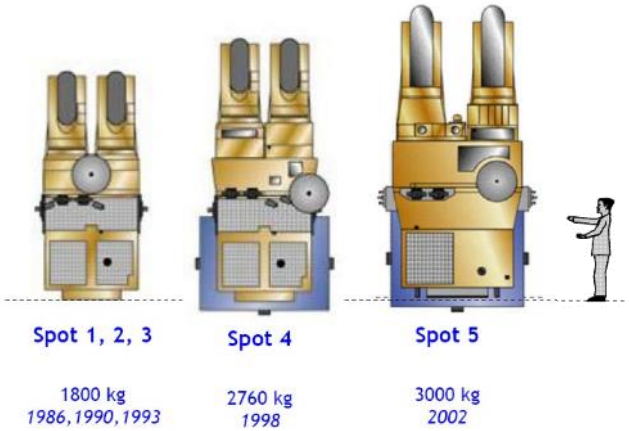
Swath: 185 km
Revisit 16 days
Launch: 11 February 2013

caroussel_1.png

SPOT 1-5

SPOT1-3 3XS + 1 PAN
20m -10 m

SPOT4-5 4XS + PAN
20 m + 10m (red band)
10 m + 2,5m



Green: 0.53-0.60 µm
Red: 0.61-0,68 µm
NIR: 0.78-0,89 µm
SWIR: 1.58-1,75 µm

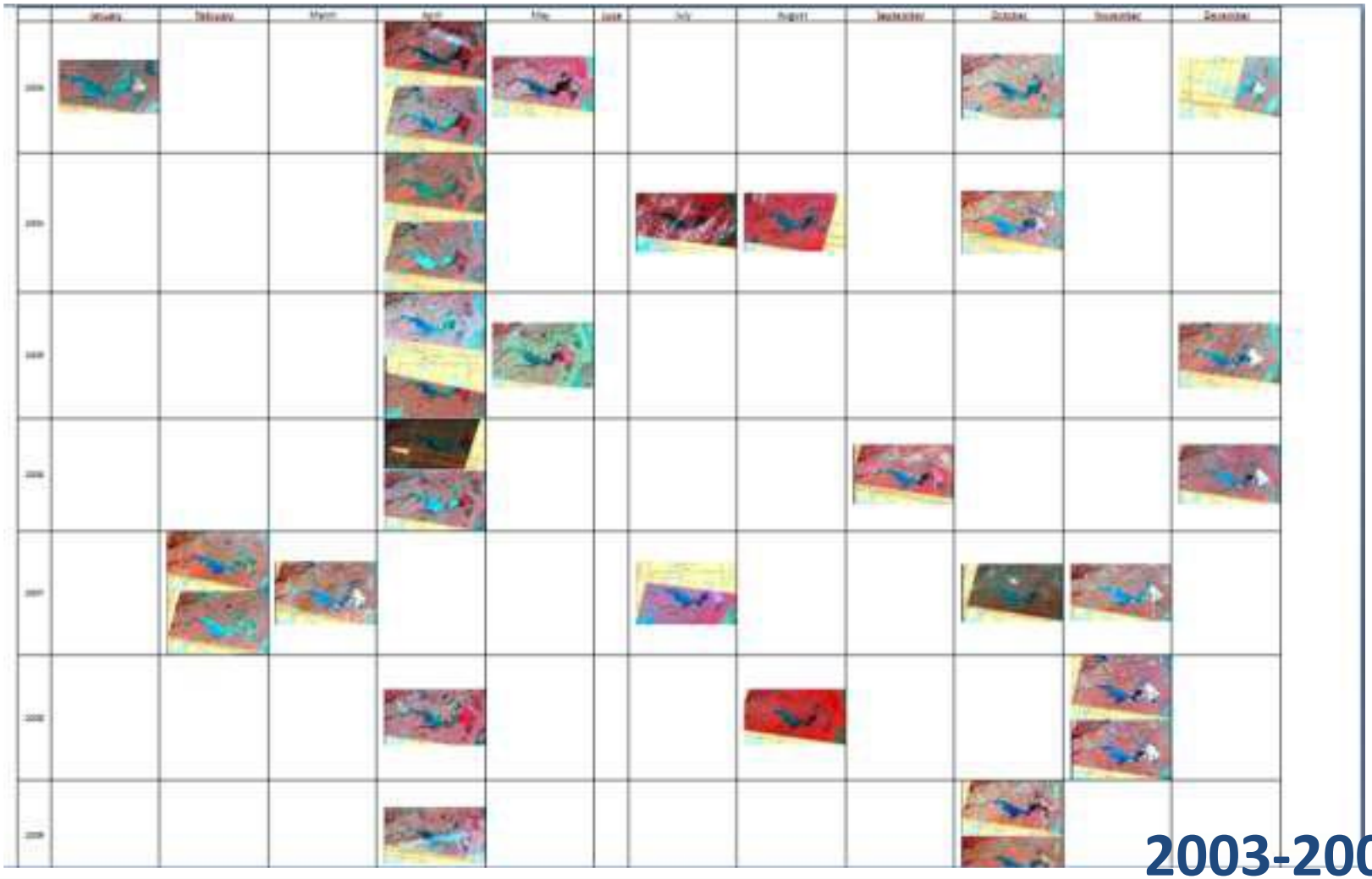
PAN: 0.48-0,71 µm

Swath 60 km

- **SPOT 1**: 22 February 1986 / 17 November 2003
- **SPOT 2**: 22 January 1990 / July 2009
- **SPOT 3**: 26 September 1993 / November 1996
- **SPOT4**: 26 March 1998 /
- **SPOT5**: 4 May 2002 /31 March 2015

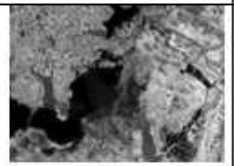
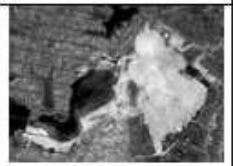
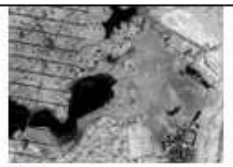
- => Very rich archive, no so well known and exploited

SPOT archive over Wuchen lake, Anhui Province



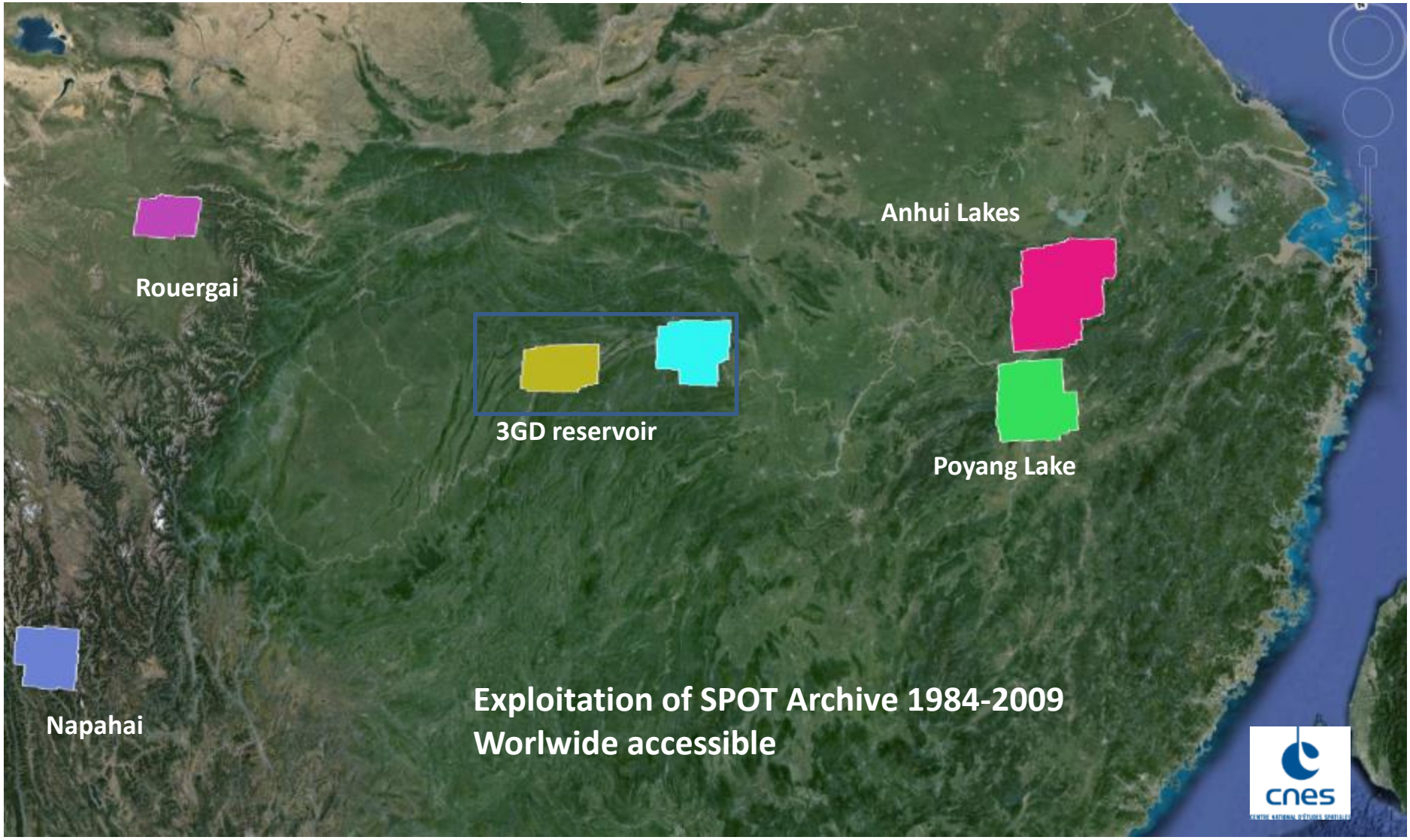
2003-2009

Landsat archive over Wuchen lake, Anhui Province

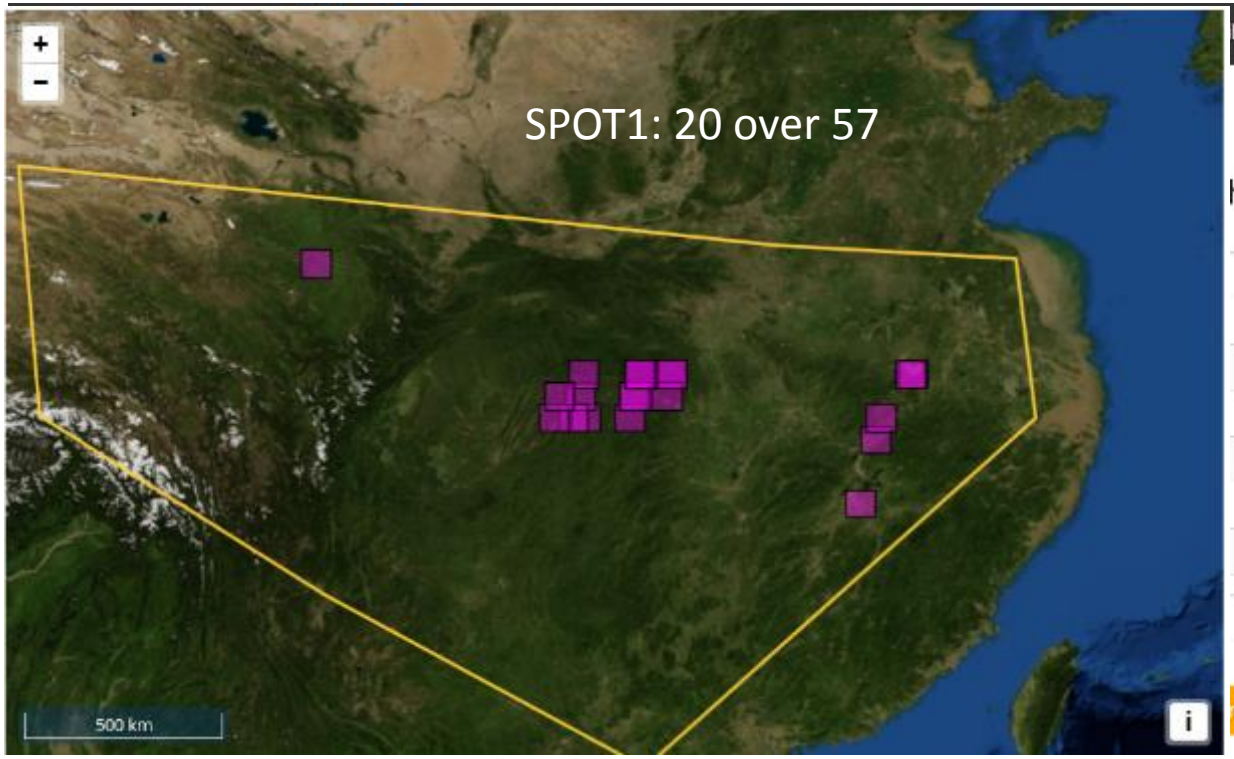
					0918		
2005							
					 0909		
2006					 0924		
2007		 0607					
2008				 0812			
2009	 0511						

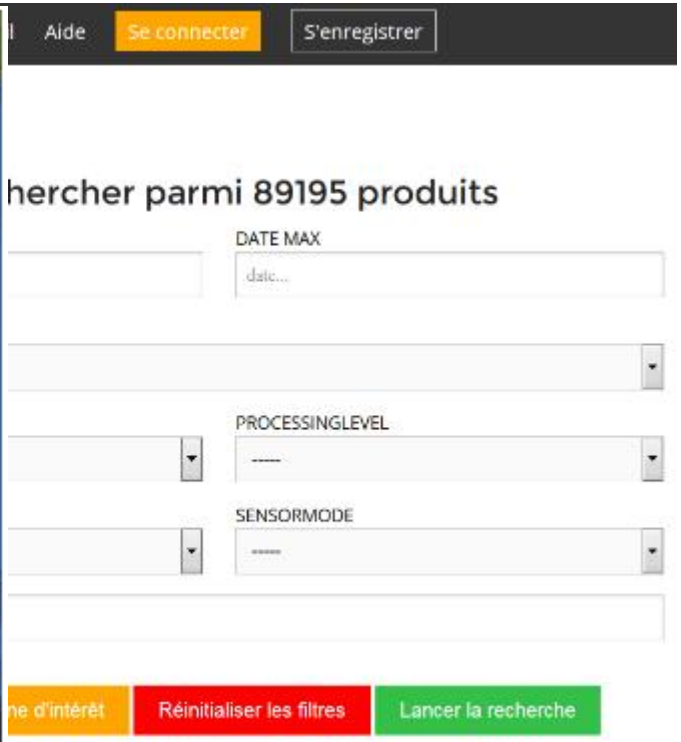
2003-2009

SPOT World Heritage over Yangtze



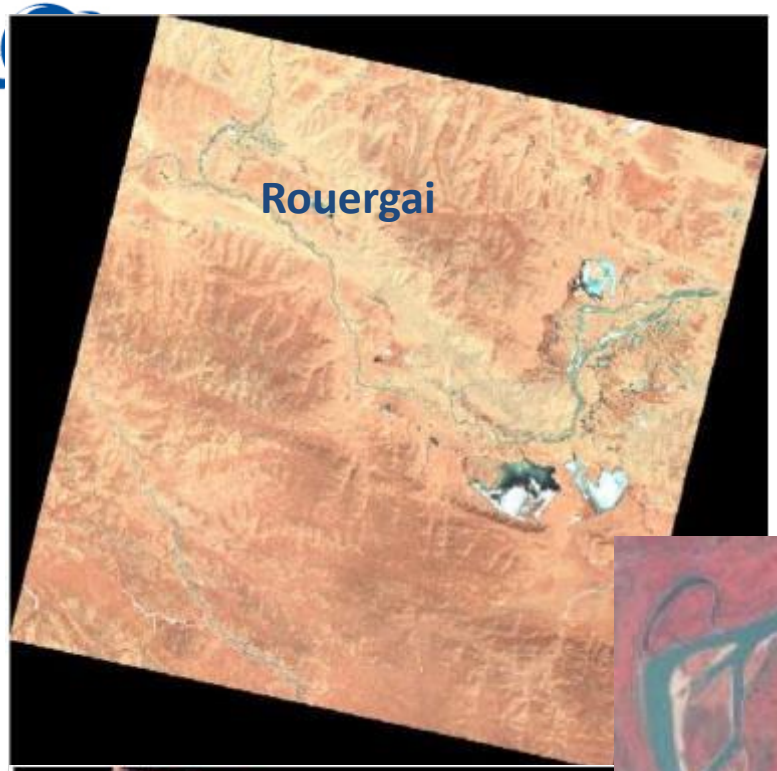
SPOT World Heritage over Yangtze

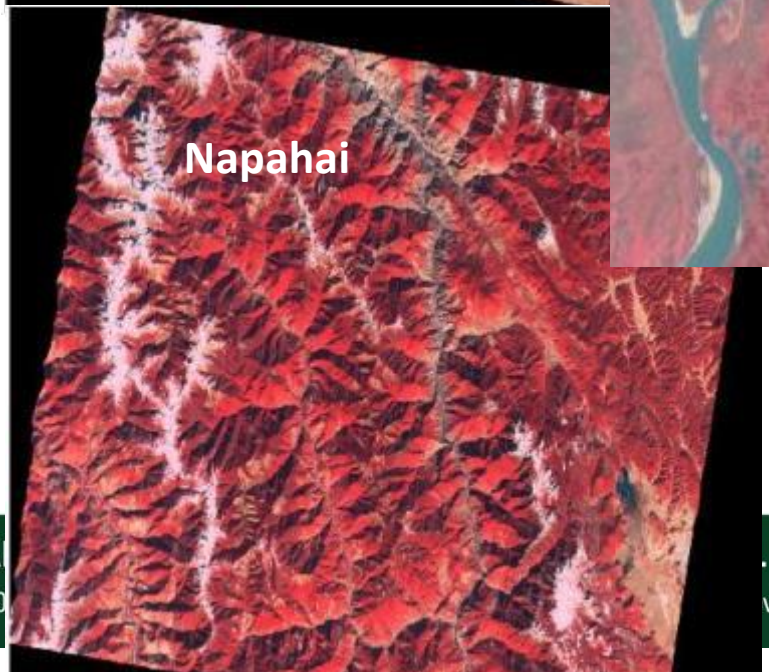


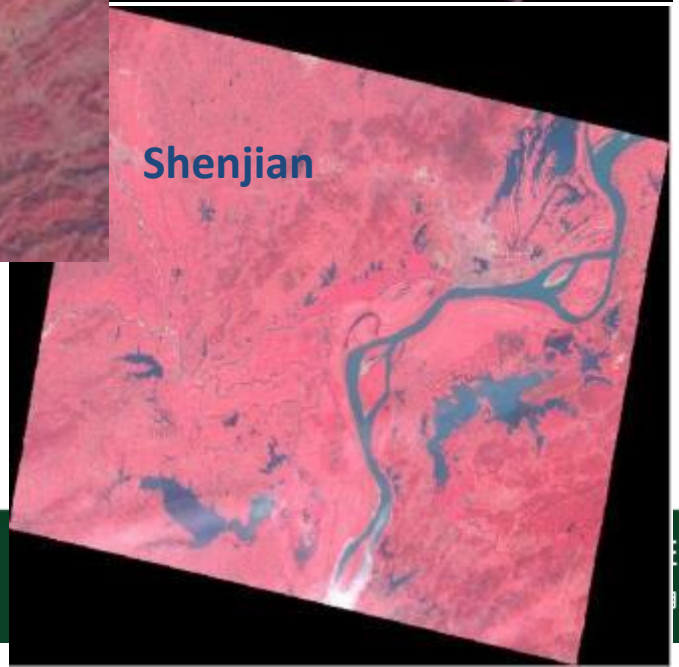


https://theia.cnes.fr/

Spot Family older than 6 years
948 SPOT images available







TRAINING COURSE

vince, P.R. China

caroussel_1.png

SPOT 6-7

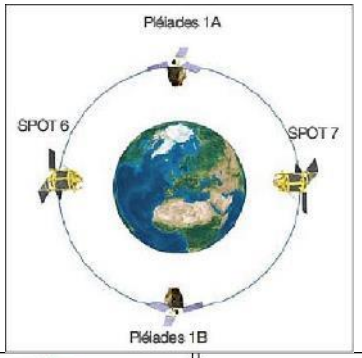
Following of SPOT 5
with improved spatial resolution 1,5-6m at nadir
2 satellites in constellation with Pleaides

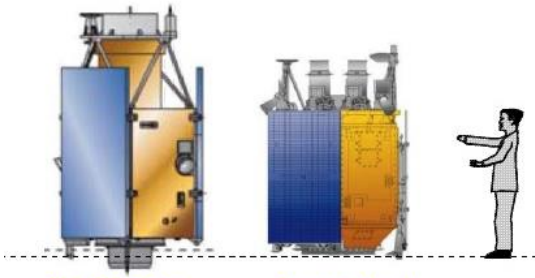
Launch September 2012 and June 2014

4 bands + Pan
Blue: 0.45-0.52 µm
Green: 0.53-0.60 µm
Red: 0.76-0,69 µm
NIR: 0.76-0,89 µm
PAN: 0.45-0,75 µm

Swath 60 km (agil)

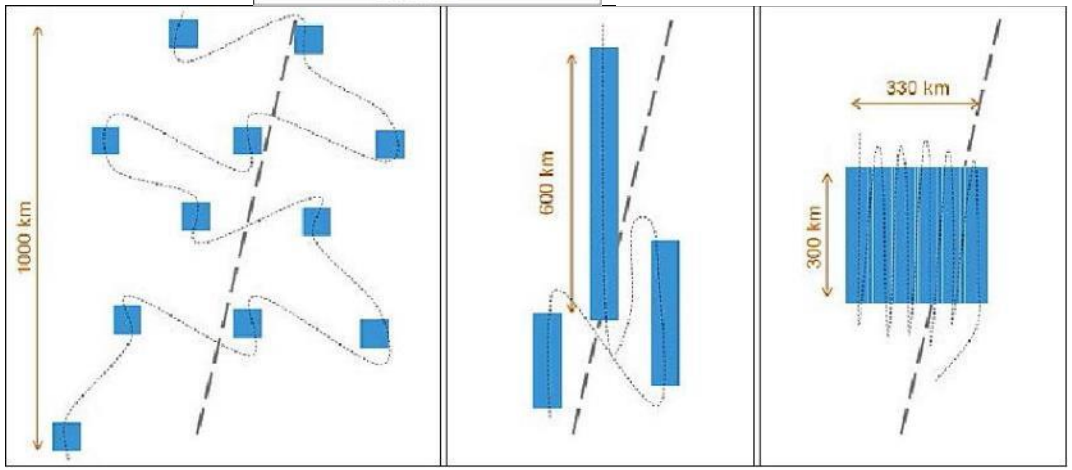
=> Daily coverage capacity





Pléiades 1A et 1B
1000 kg
2011 et 2012

Spot 6 et Spot 7
800 kg
2012 et 2014



esa

SPOT 6-7

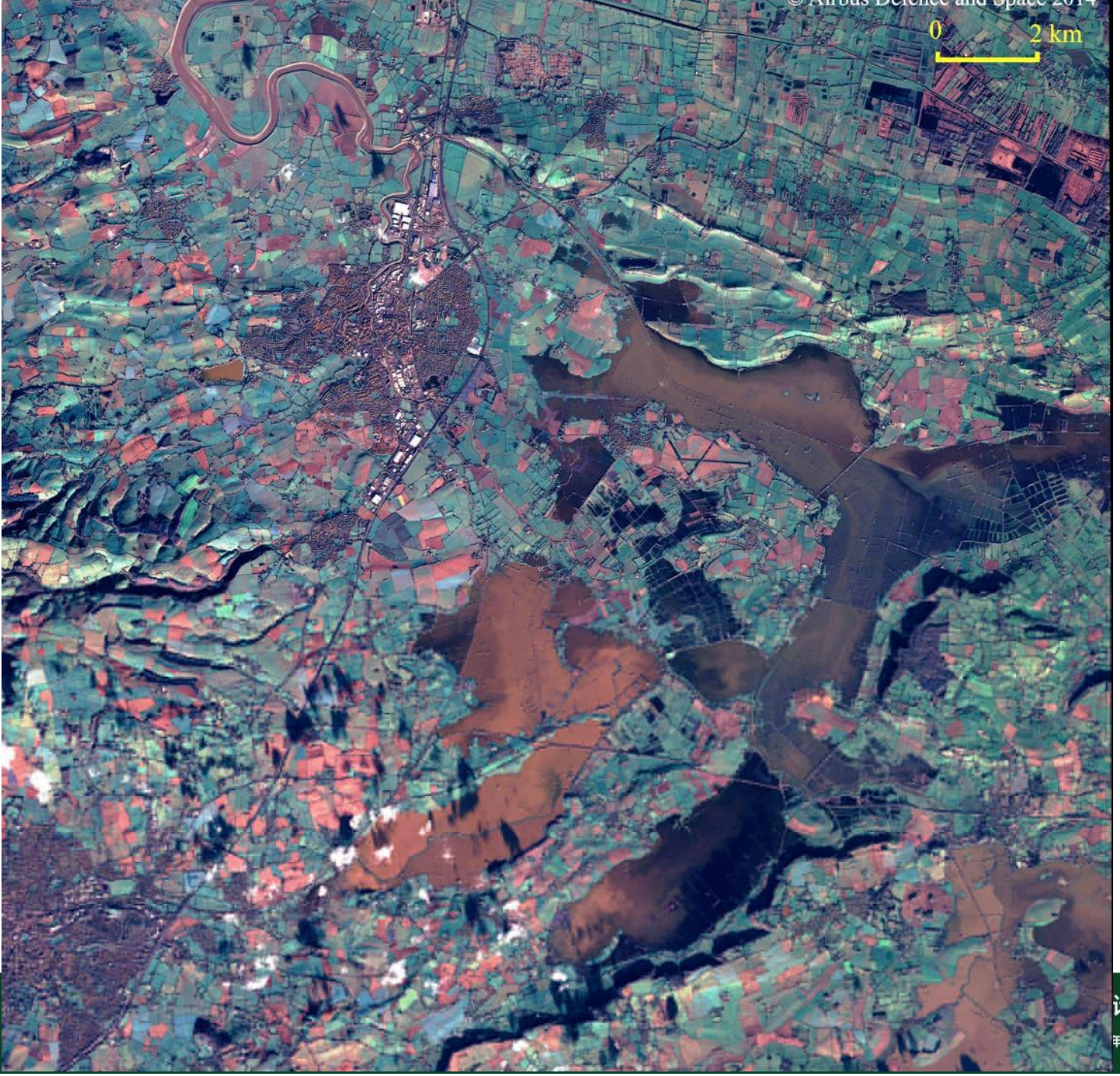
Flood in
Bridgewater,
England,
Before event

SPOT IMAGE

AIRBUS
DEFENCE & SPACE

计划4”高级陆地遥感国际培训班

年11月20日——11月25日 云南师范大学，中国，昆明



esa

SPOT 6-7

Flood in
Bridgewater,
England,
11 January 2014

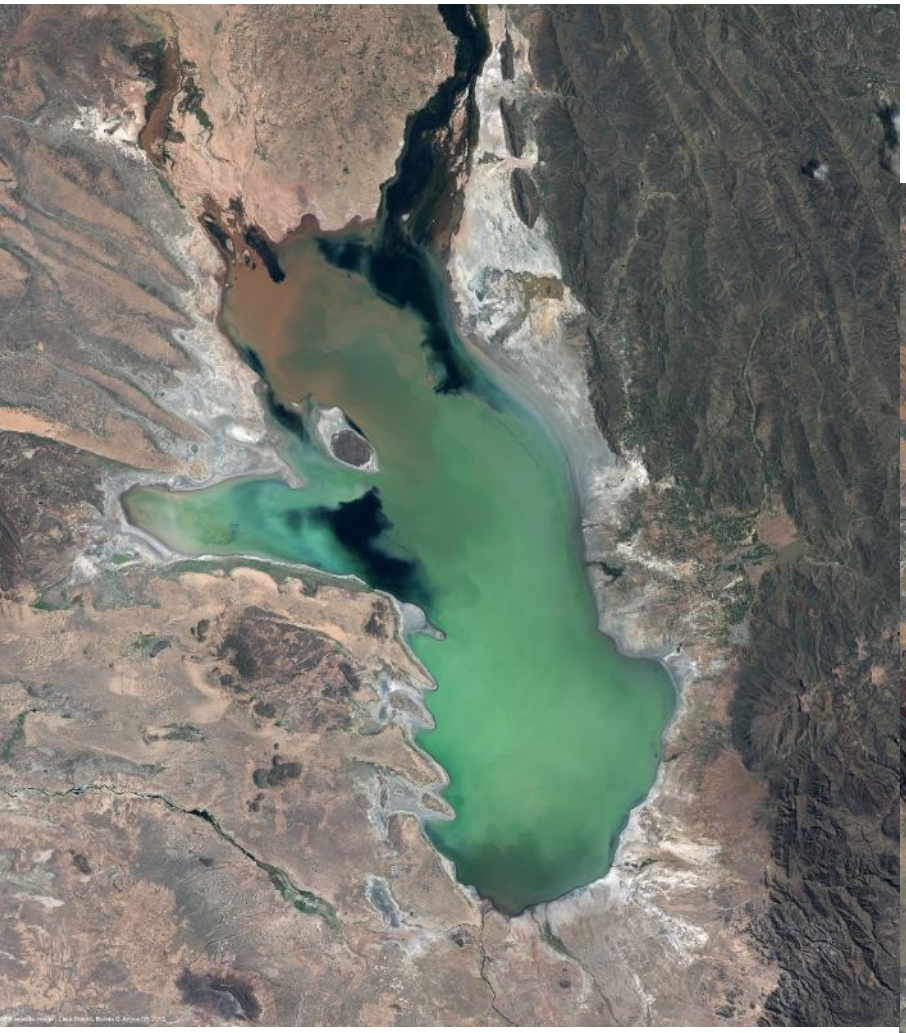
SPOT IMAGE

AIRBUS DEFENCE & SPACE

SPOT 6-7

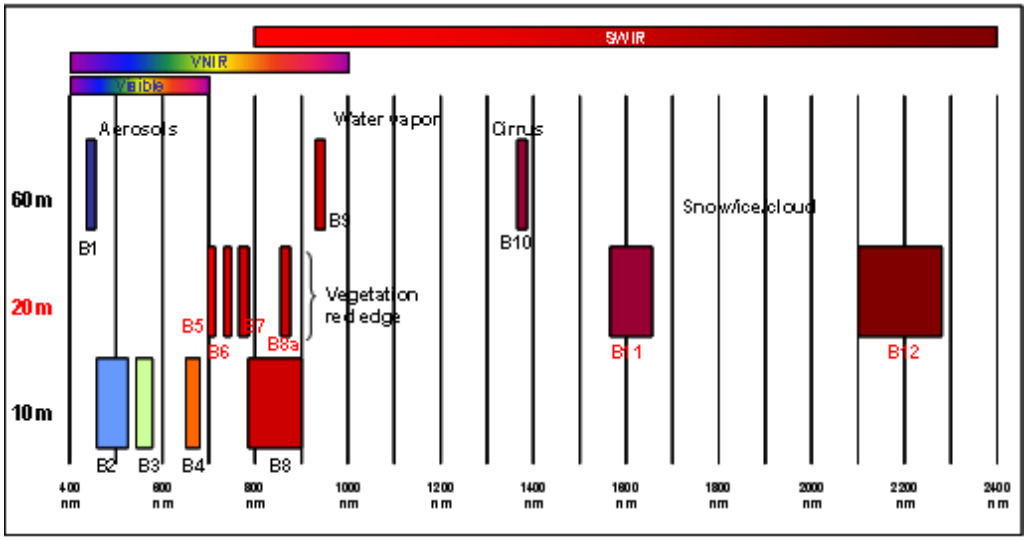
Flood in Bridgewater,
England,
11 January 2014

SPOT 6-7



Lake Poopo, Bolivia
24 March 2013- Spot 6
16 January 2016 – SPOT 7

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 like: Applicable to others optical sensors

Sentinel 2

- **Resolution depending of the spectral coverage**

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

10 metre spatial resolution:

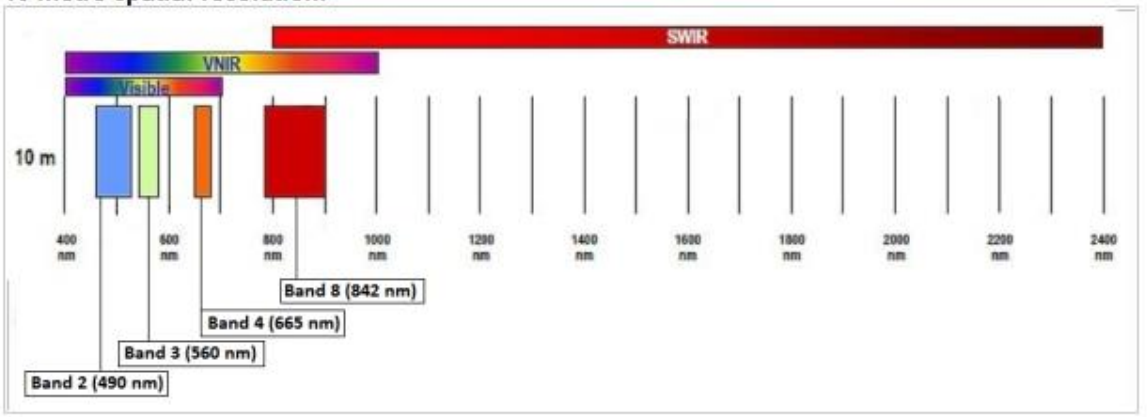


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

20 metre spatial resolution:

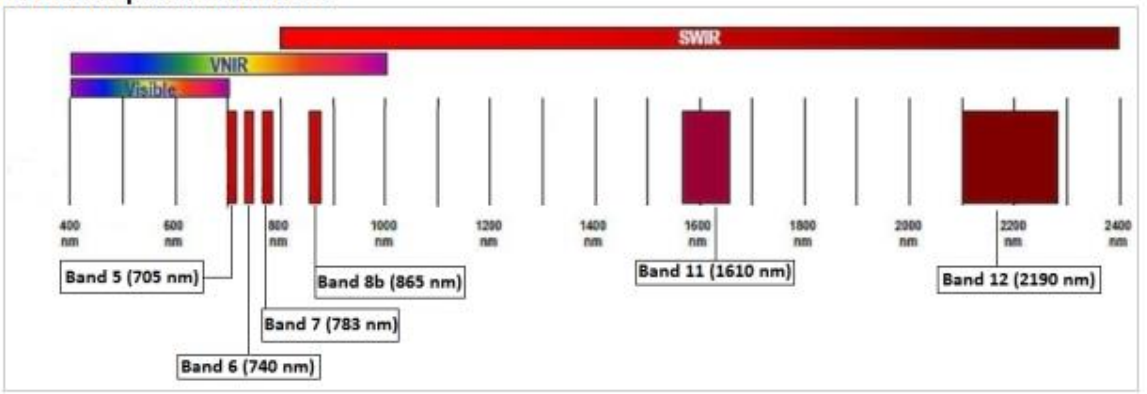


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8b (865 nm), B11 (1610 nm) and B12 (2190 nm)

60 metre spatial resolution:

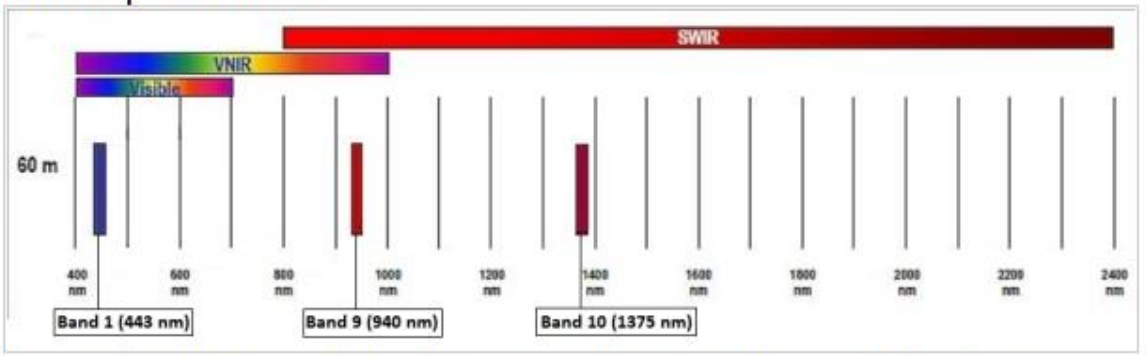
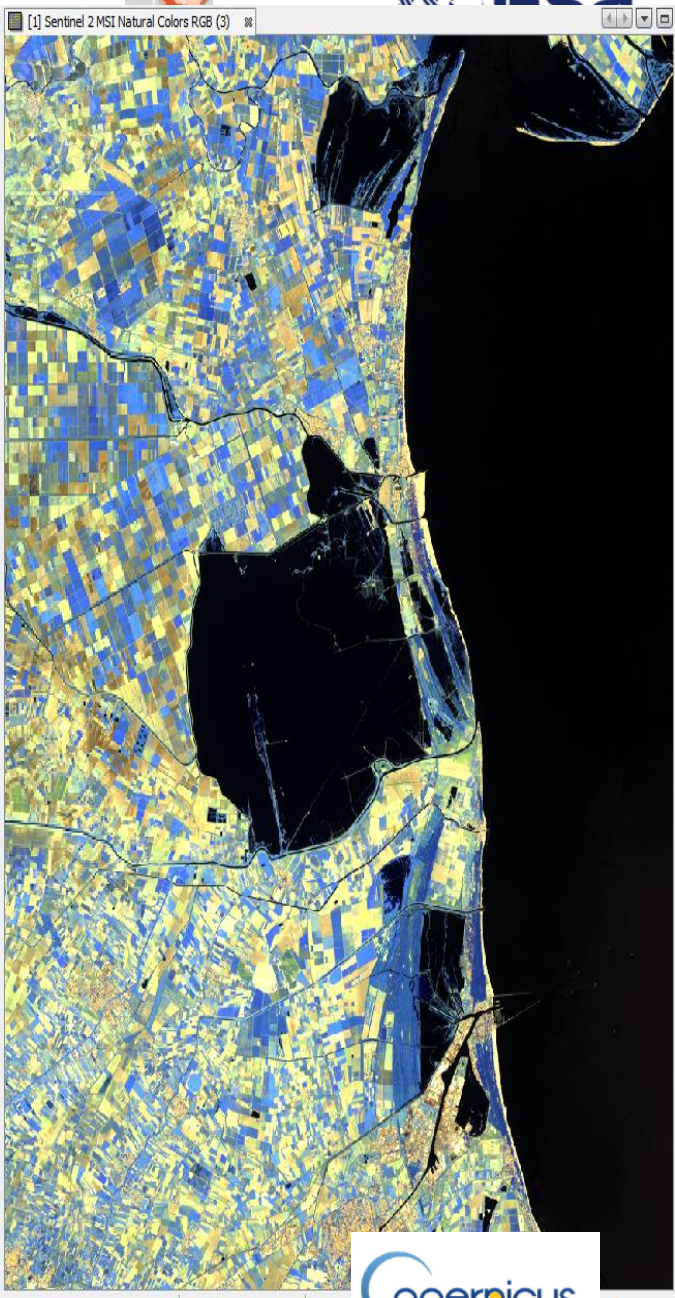
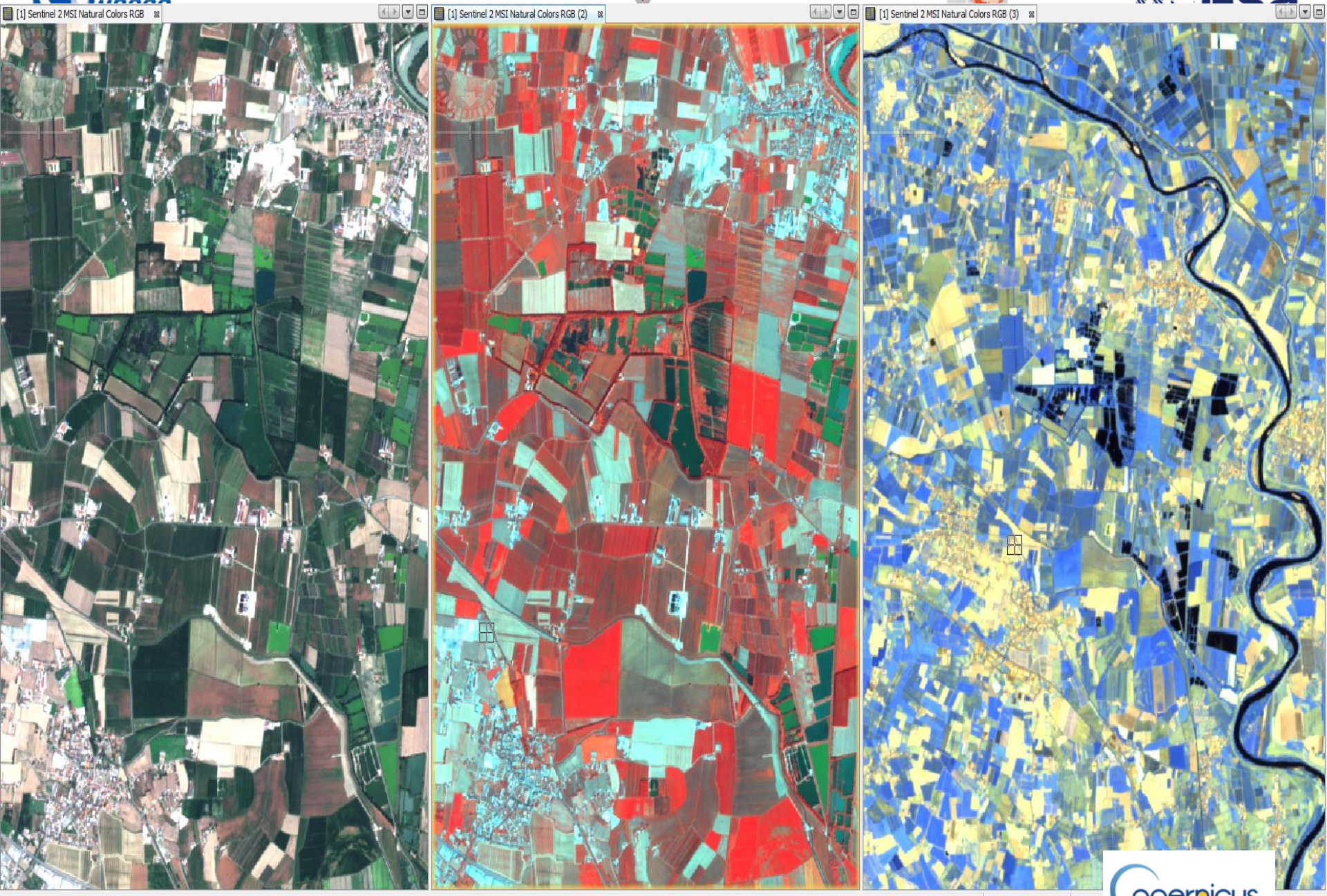


Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)



X -- Y --

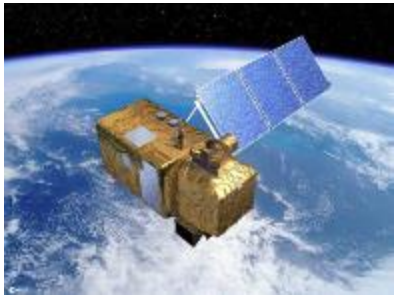
Copernicus
Europe's eyes on Earth


[1] Sentinel 2 MSI Natural Colors RGB
[1] Sentinel 2 MSI Natural Colors RGB (2)
[1] Sentinel 2 MSI Natural Colors RGB (3)
X 7215 Y 8122
Level 0
Copernicus
Europe's eyes on Earth

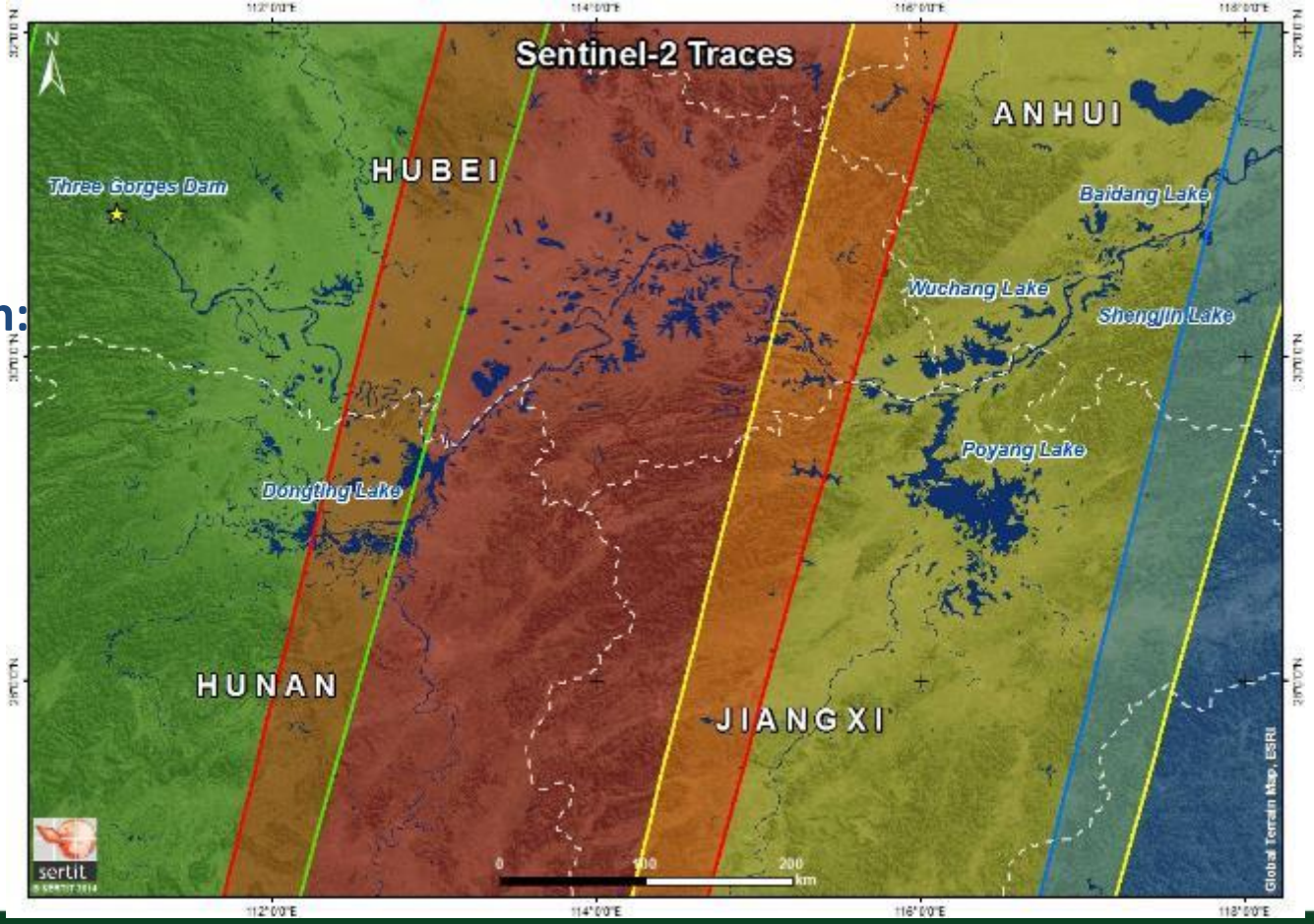
X 3856 Y 10001

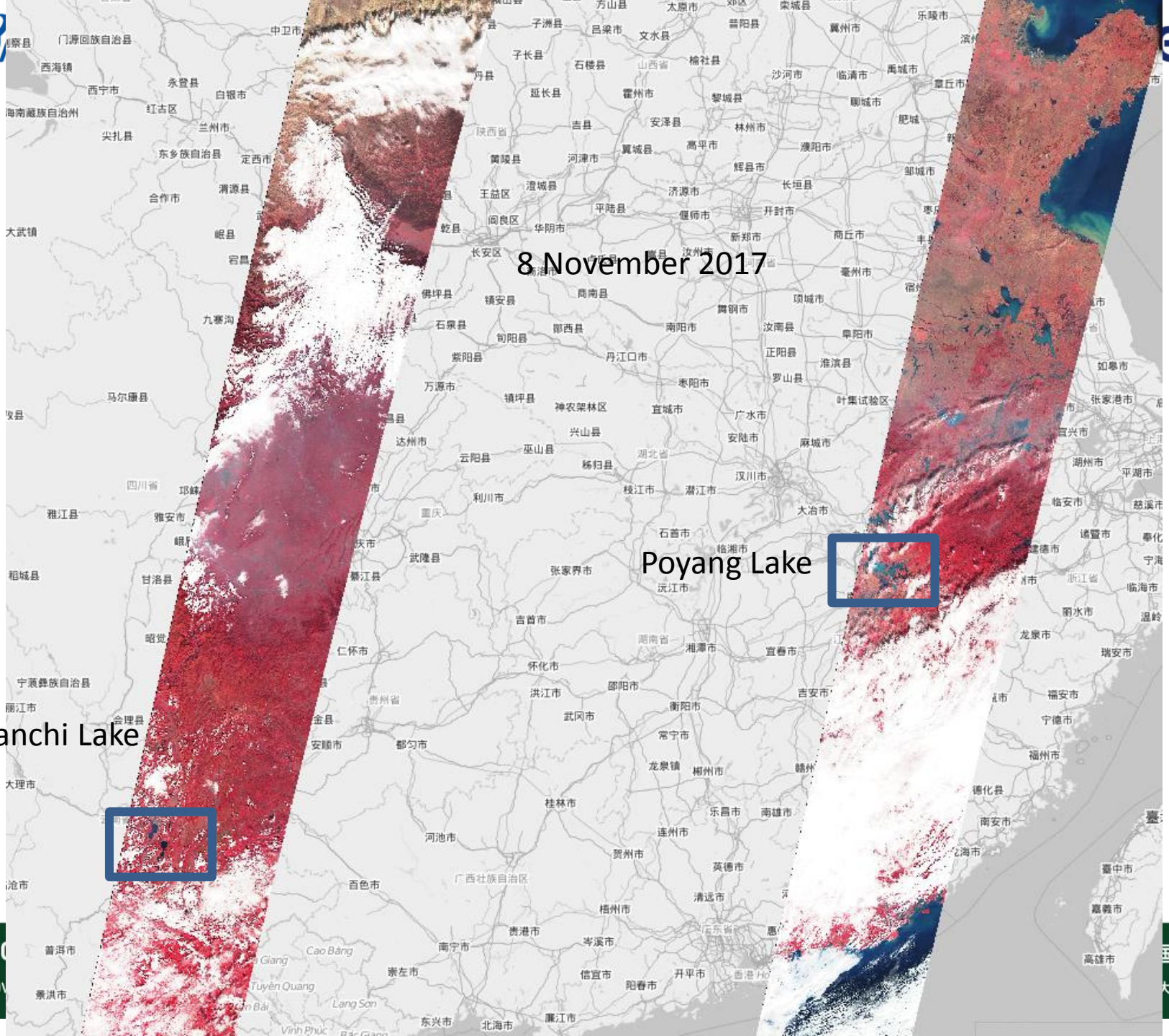
Copernicus
Europe's eyes on Earth

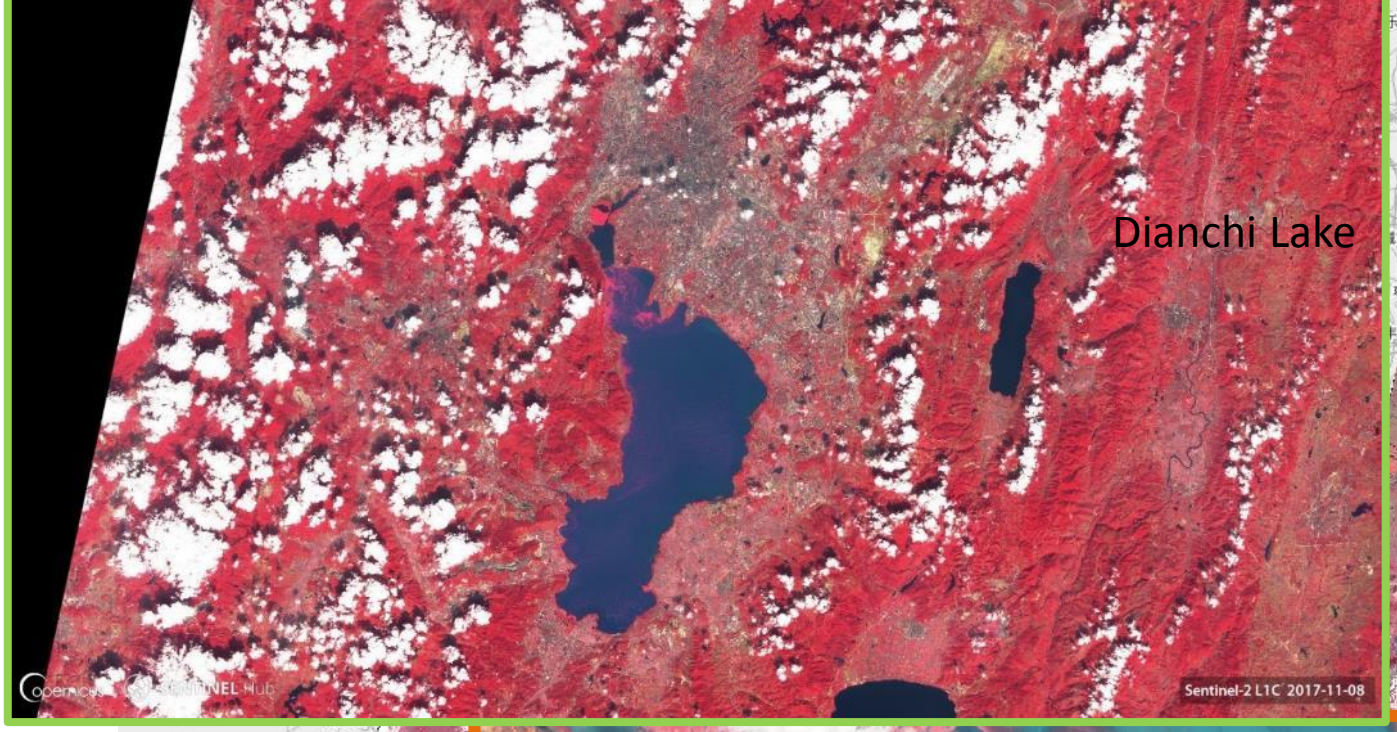
Sentinel 2 observation over Yantgze middle watershed



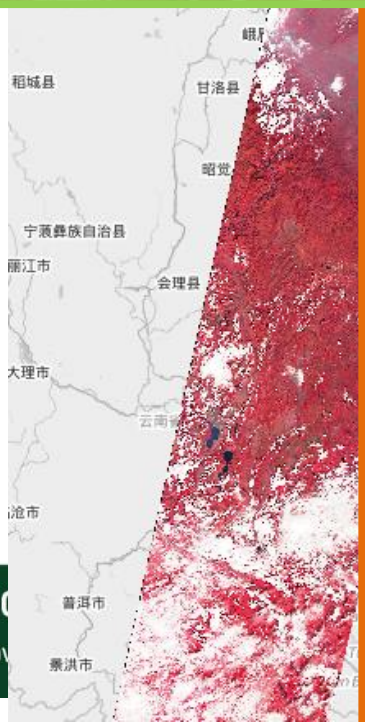
one cycle of acquisition:
Red: Day 3,
Green: Day 6,
Blue: Day 7,
Yellow: Day 10.

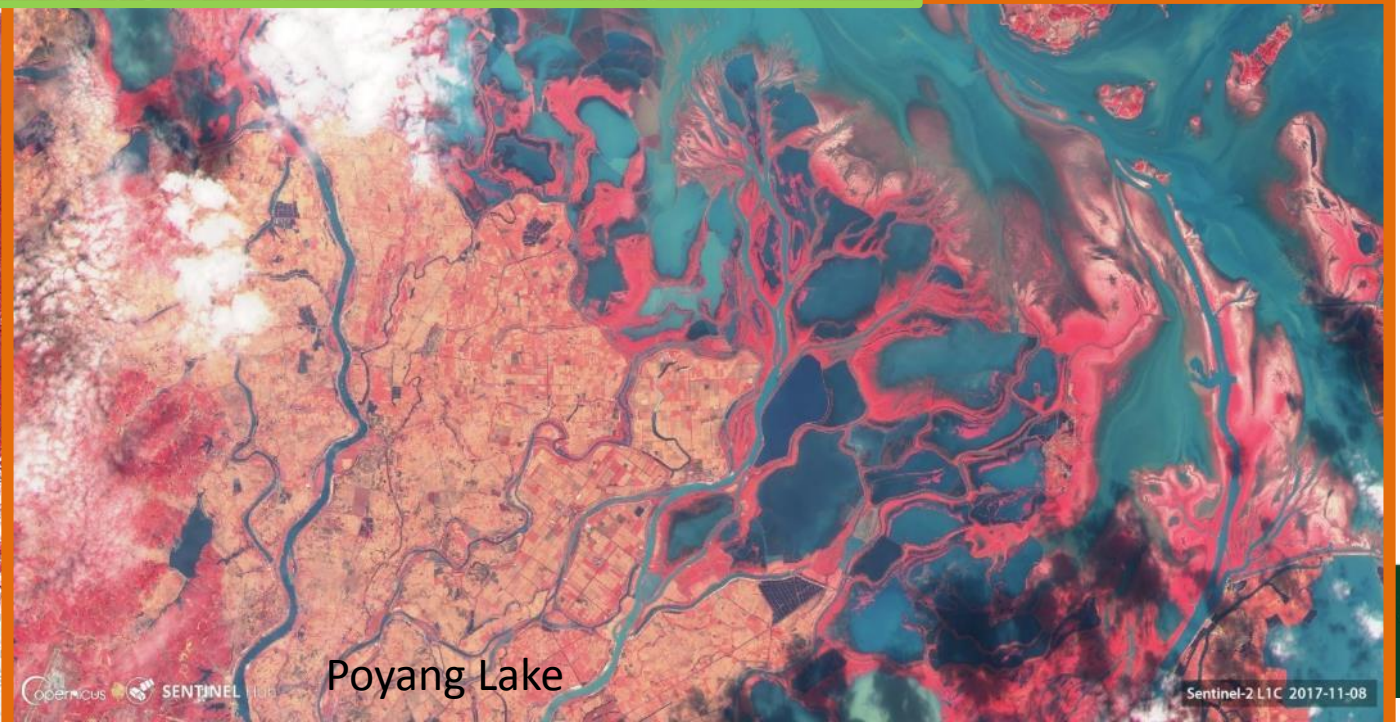



8 November 2017
Poyang Lake
Dianchi Lake

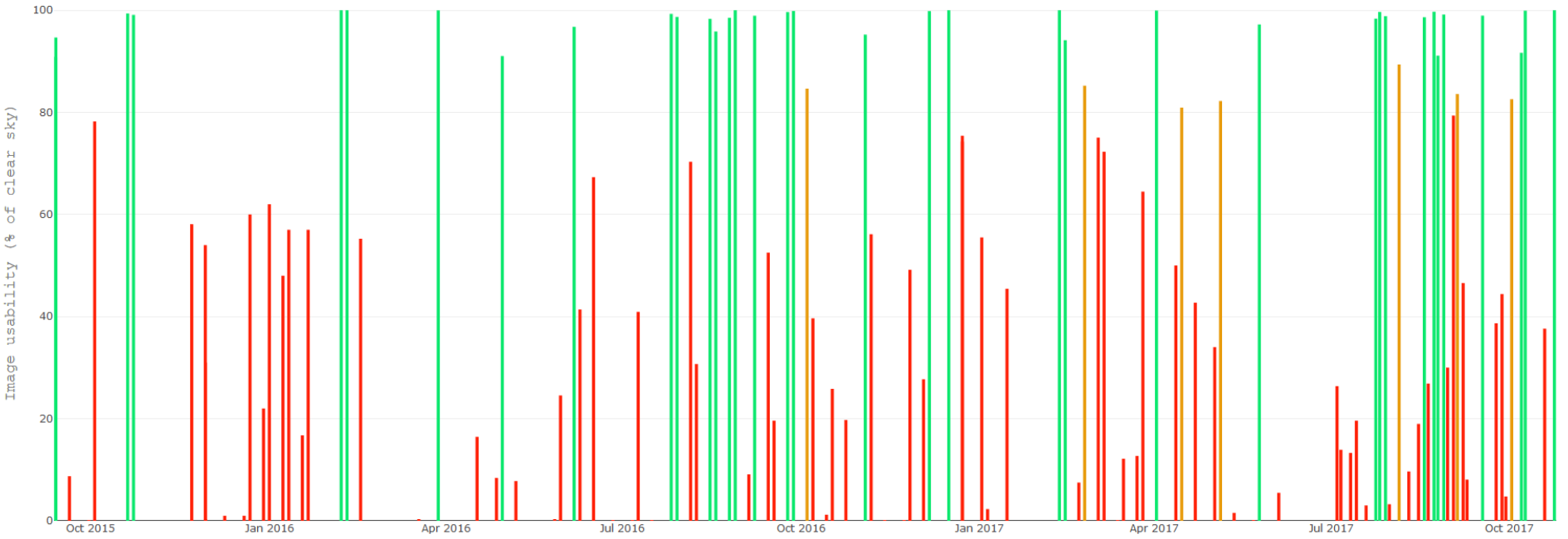

Dianchi Lake
Sentinel-2 L1C 2017-11-08


如皋市
张家港市
宜兴市
湖州市
平湖市

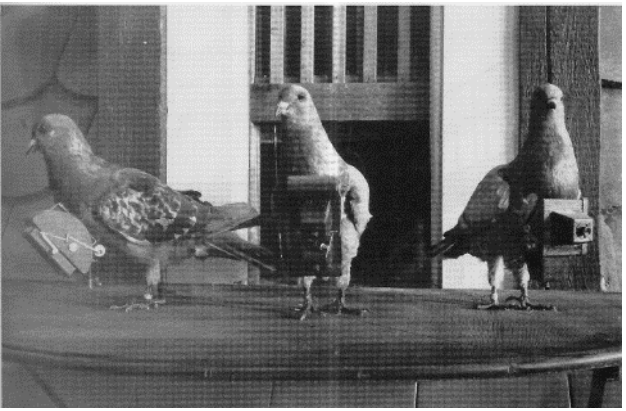

甘洛县
宁蒗彝族自治县
丽江市
会理县
大理市
普洱市
景洪市


Poyang Lake
Sentinel-2 L1C 2017-11-08

Sentinel2 images acquired over Poyang Lake area



155 images S2 acquired since October 2015 (at the 11-11-2017)
Increase of acquisitions since the rump up phase of Sentinel 2B

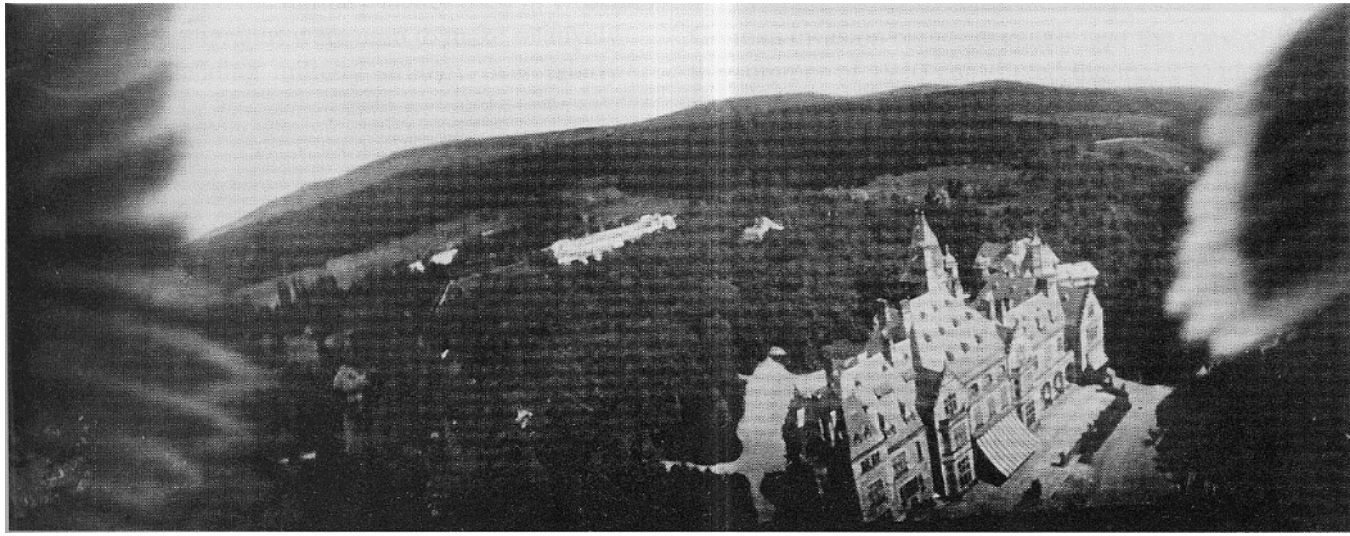


High resolution: military heritage

Spy dove escadron: 1903

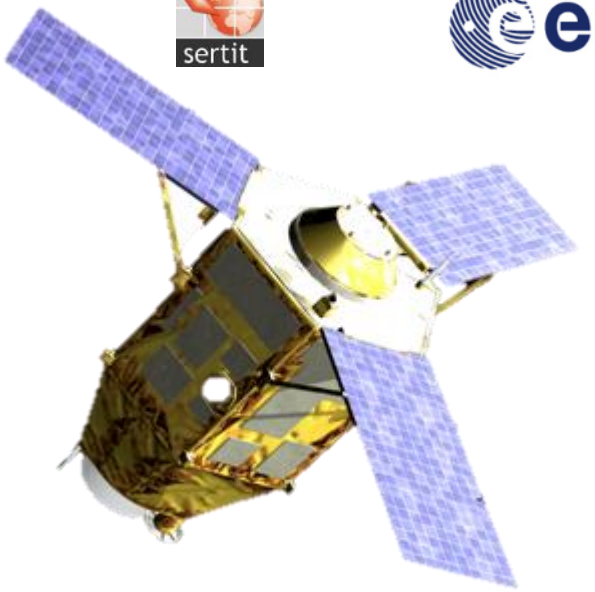
Deutsches Museum Munich

http://flightlessboyds.blogspot.fr/2011/07/spies-in-sky.html



caroussel_1.png

PLEIADES



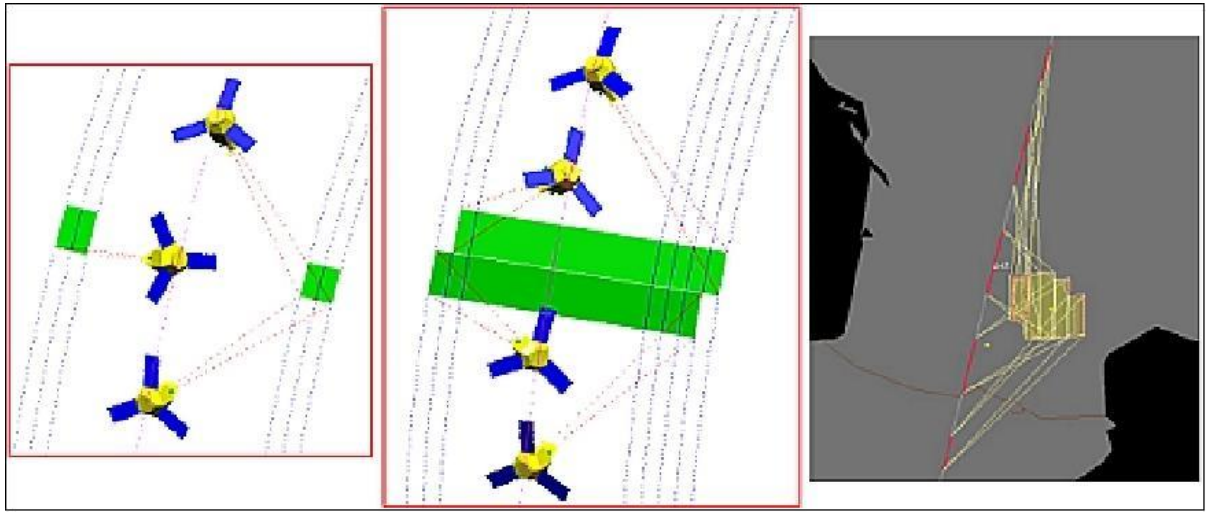
2 satellites in constellation
Launch December 2011 and 2012

0,70 cm in PAN
2,8 in XS

4 bands + Pan
Blue: 0.43-0.55 µm
Green: 0.50-0.62 µm
Red: 0.59-0,71 µm
NIR: 0.70-0,94 µm
PAN: 0.47-0,83 µm

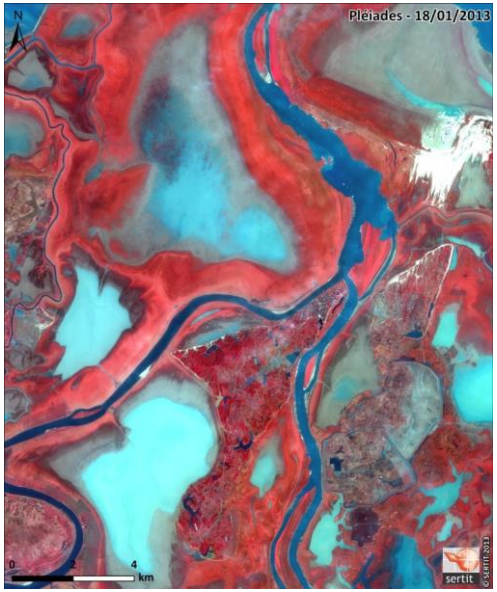
Swath 20 km (agil)

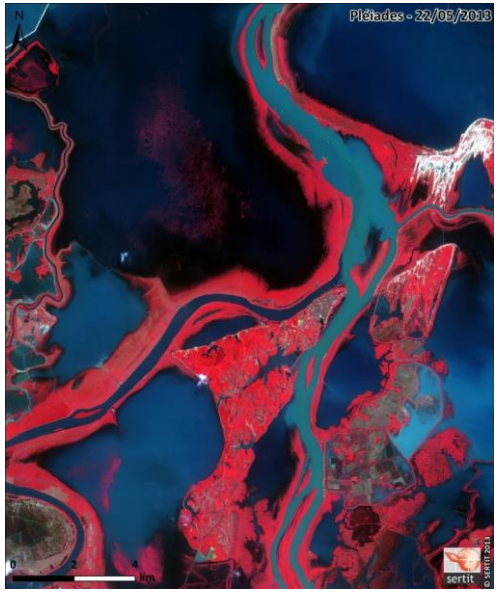
=> Daily coverage capacity

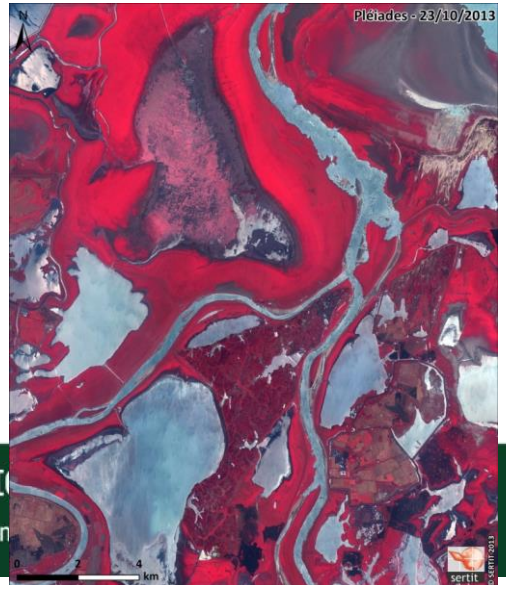


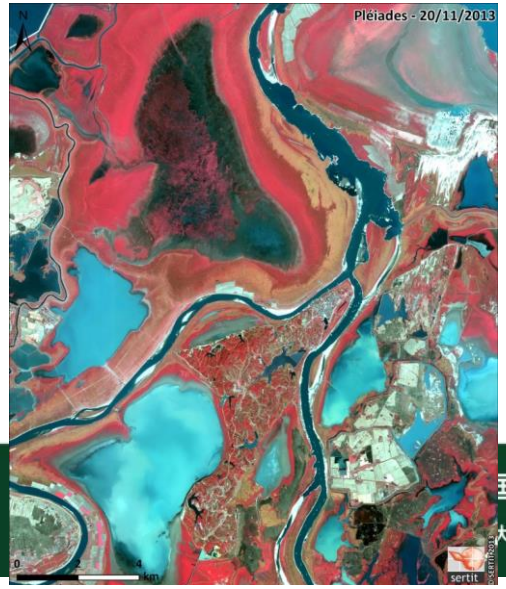
Water bodies: temporally complex system

POYANG LAKE





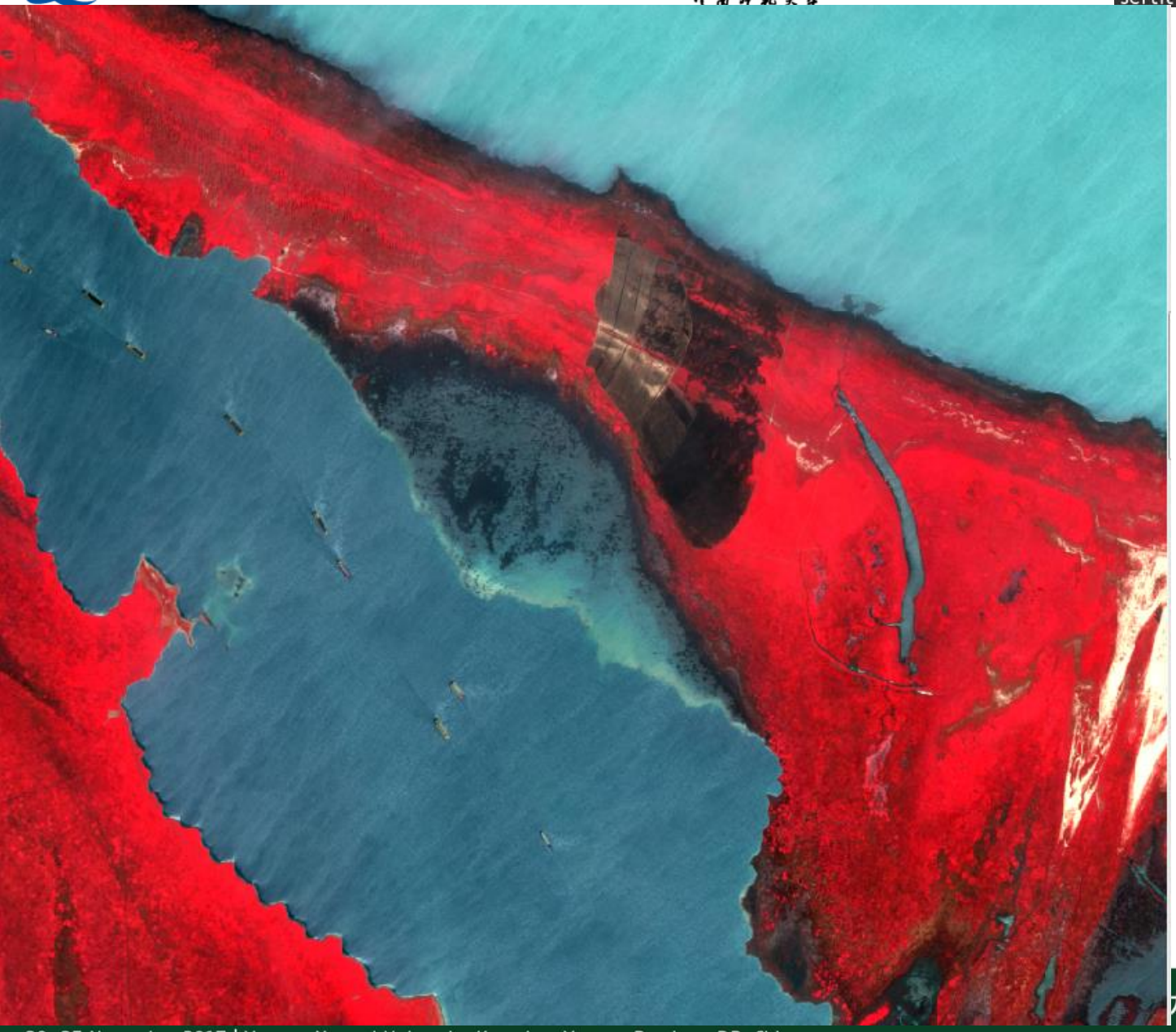




PLEIADES IMAGES

PLEIADES

Pléiades HR
acquired on the 12 April 2013
Over Poyang lake

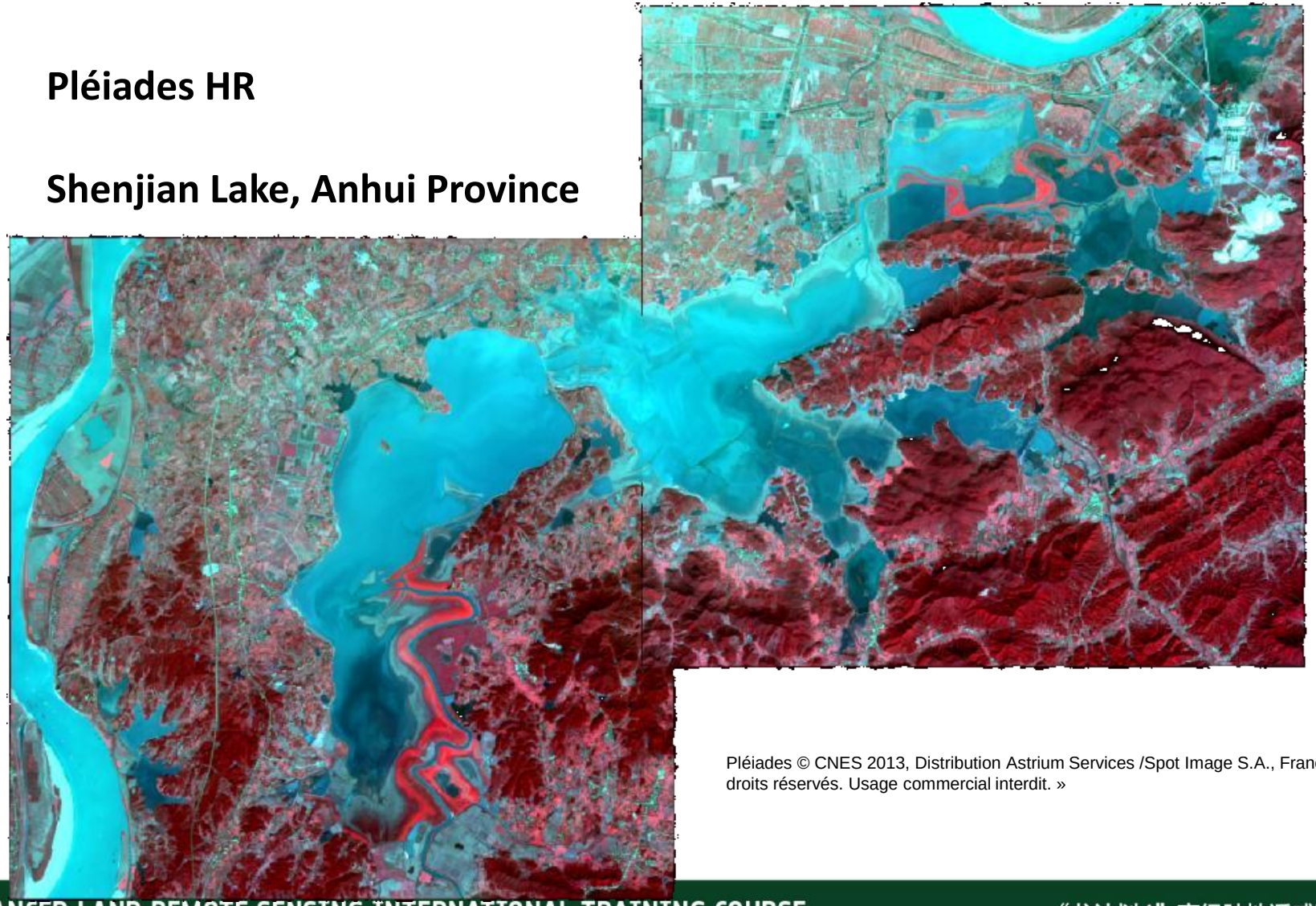


PLEIADES

Pléiades HR acquired on the 5th of August 2013 Over Poyang lake

Pléiades HR

Shenjian Lake, Anhui Province



Pléiades © CNES 2013, Distribution Astrium Services /Spot Image S.A., France tous droits réservés. Usage commercial interdit. »

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

Worldview 2
Safer action 42 Xynthia storm: coastal flooding

VHR &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)

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

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
- Interest for SWIR bands

Elements for water bodies extraction based on optical imagery

Optical sensors for water bodies and/or flood mapping
- Medium
- High resolution
- VHR sensors

Water level from space
- **Principles of altimetry**
- **Altimetry missions past, present futures**
- **Altimetry database**

Flood plain and lakes monitoring
- Short term Monitoring
- Long term monitoring
- Meteo climato parameters

Concluding remarks

Water level from space

Associate variation of extent of water with water height from Altimeter

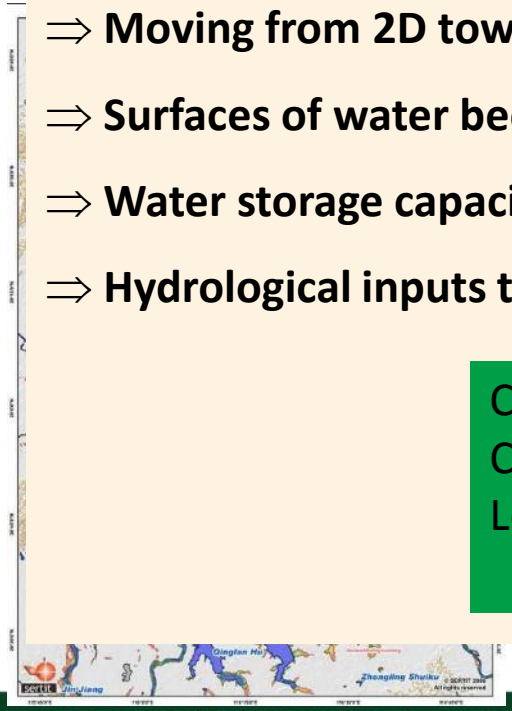
Access simultaneous of water surface and water height

⇒ Moving from 2D towards 3D observations / analysis

⇒ Surfaces of water become volumes of water

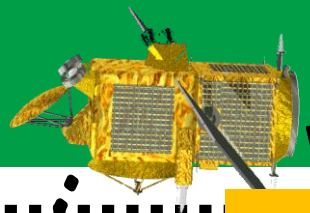
⇒ Water storage capacities=> water resource monitoring

⇒ Hydrological inputs towards hydraulical inputs for modelling



Courtesy of JC Souyris and J. Lambin, CNES, DSP/OT and JF Cretaux, CNES Legos

Radar altimetry



GPS

orbite

ionosphere

Mesure
bi-fréquence
(e.g. C/Ku)

Radiomètre

DORIS

troposphere

altitude
satellite

Radar altimeter emits a pulse towards the Earth's surface.
The time from the transmission of a pulse to the reception of its echo reflected off the Earth's surface is proportional to the satellite's altitude

hauteur mer

topographie
dynamique

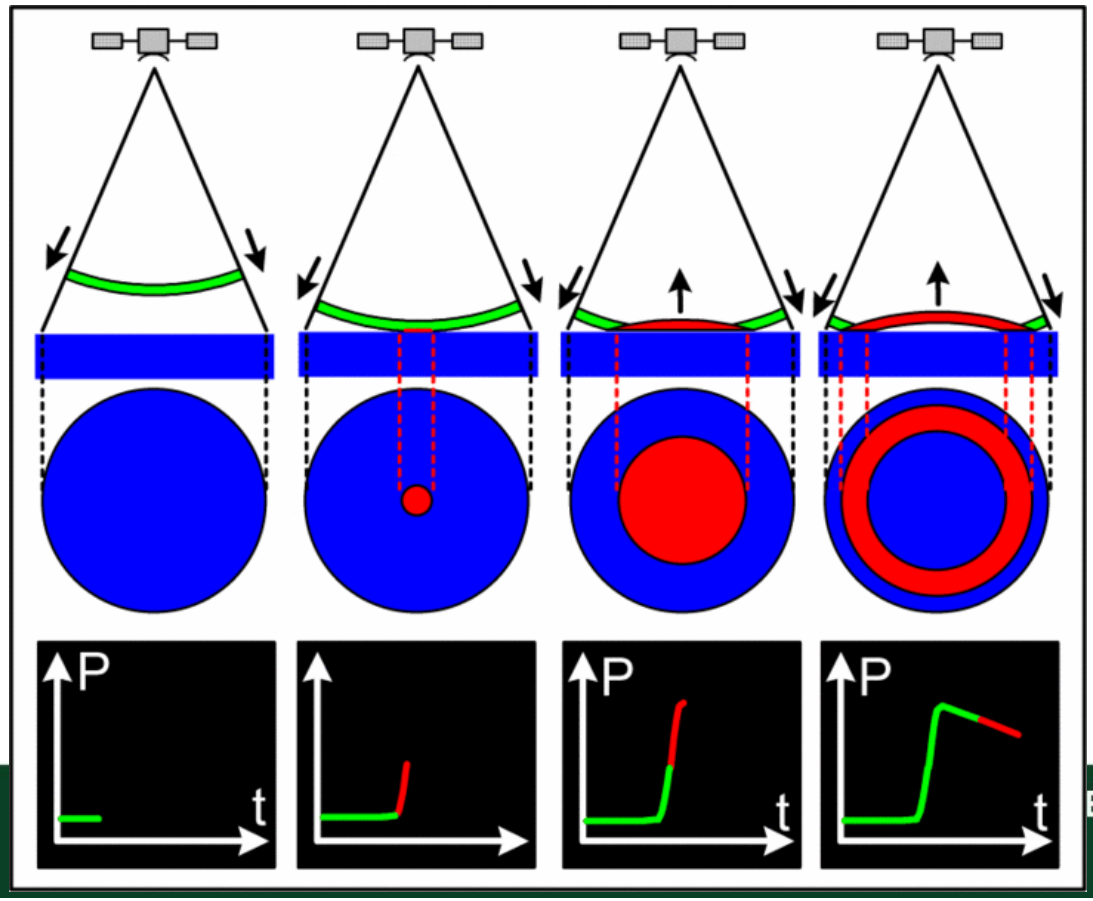
géoide

Ellipsoide – référence

Courtesy of JC Souyris and J. Lambin, CNES, DSP/OT and JF Cretaux, CNES Legos

Radar altimetry: echo waveform the Brown model

For a water surface, the echo waveform has a characteristic shape that can be described mathematically (the Brown model).



Where the sea surface is flat, the reflected wave's amplitude increases sharply from the moment the leading edge of the radar signal strikes the surface.

http://www.aviso.oceanobs.com/en/altimetry/principle/basic-principle.html

Radar altimetry: echo waveform the Brown model

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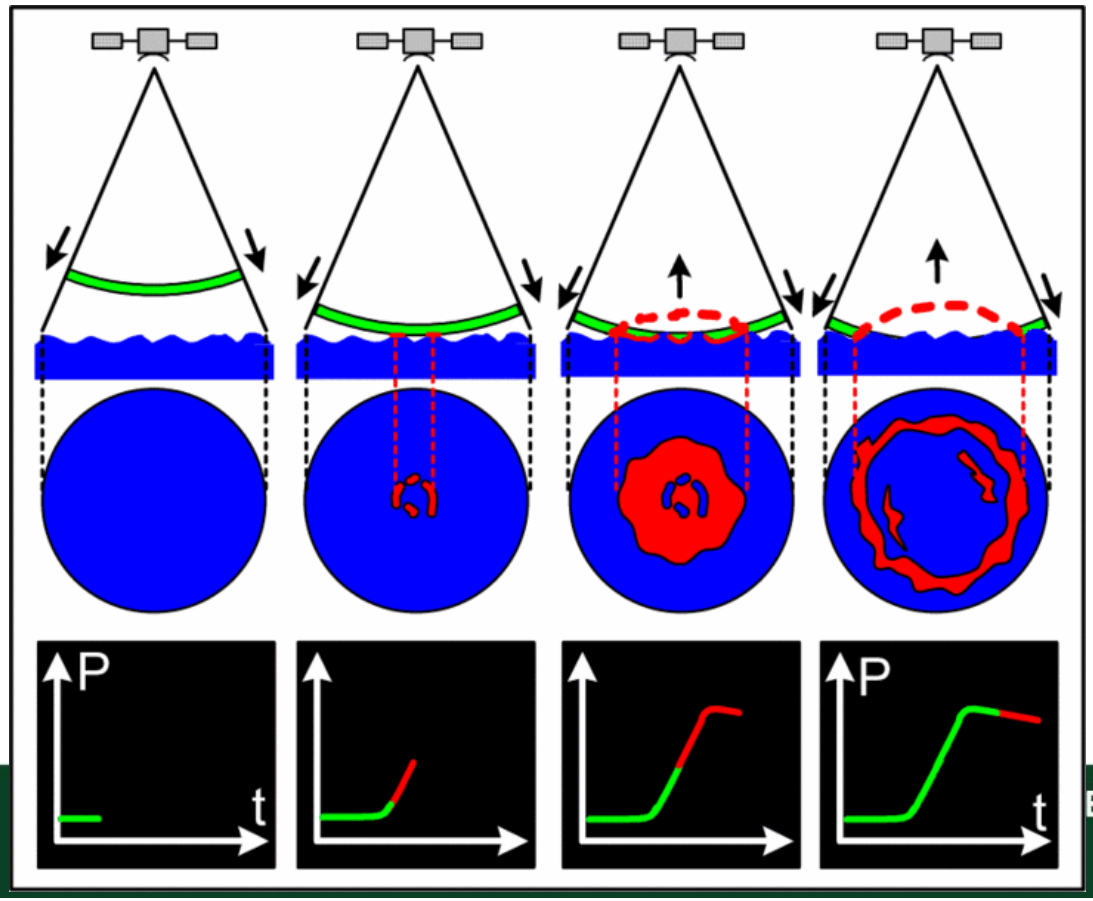
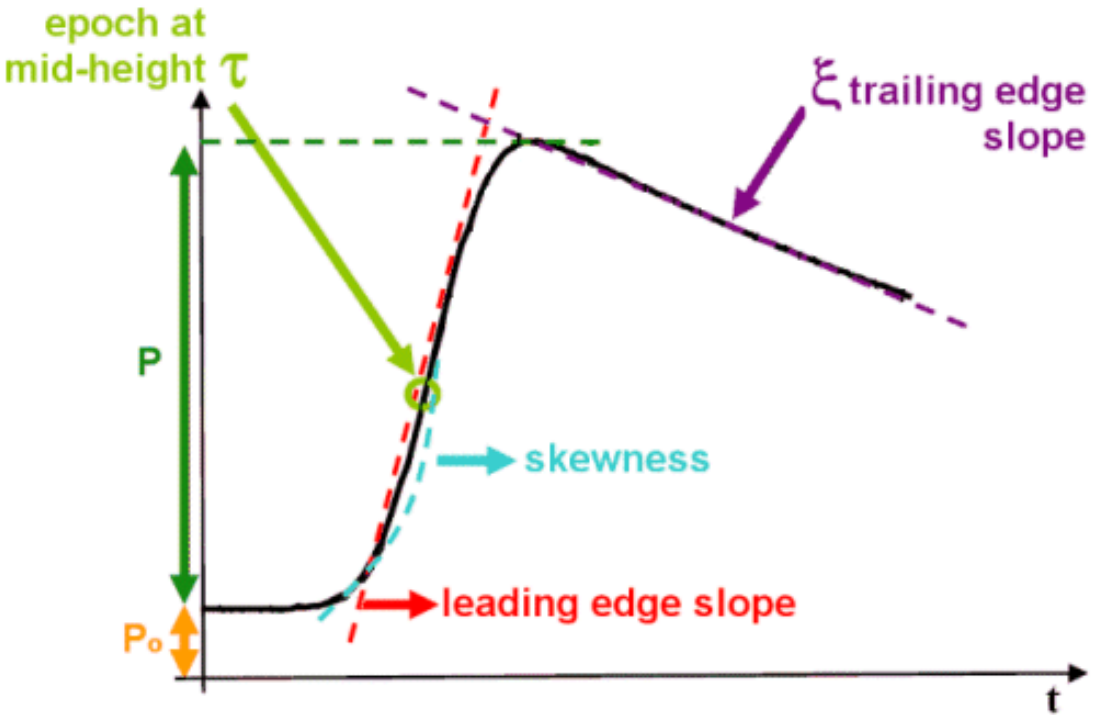


However, in sea swell or rough seas, the wave strikes the crest of one wave and then a series of other crests which cause the reflected wave's amplitude to increase more gradually

http://www.aviso.oceanobs.com/en/altimetry/principle/basic-principle.html

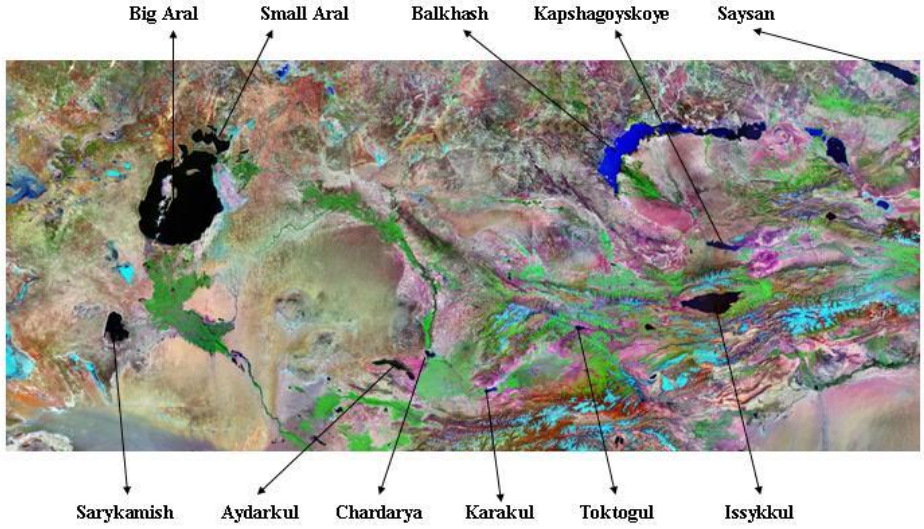
Radar altimetry: echo waveform the Brown model

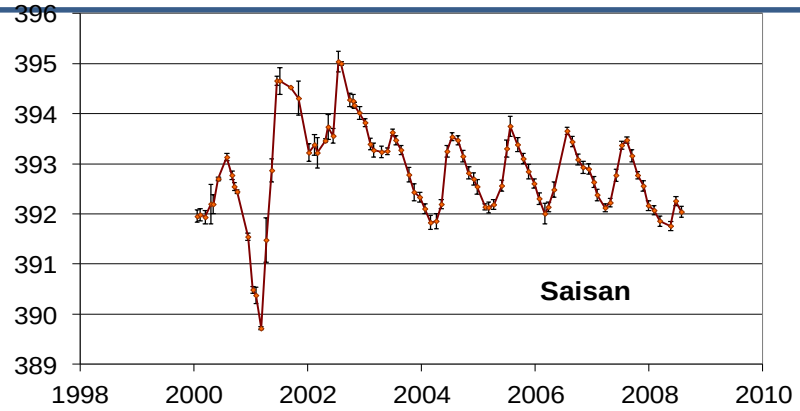
For a water surface, the echo waveform has a characteristic shape that can be described mathematically (the Brown model).

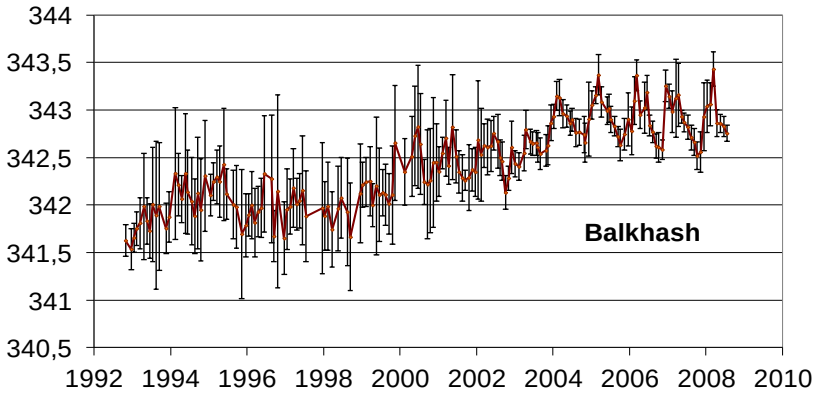


Ocean wave height can be derived from the information in this reflected wave, since the slope of the curve representing its amplitude over time is proportional to wave height

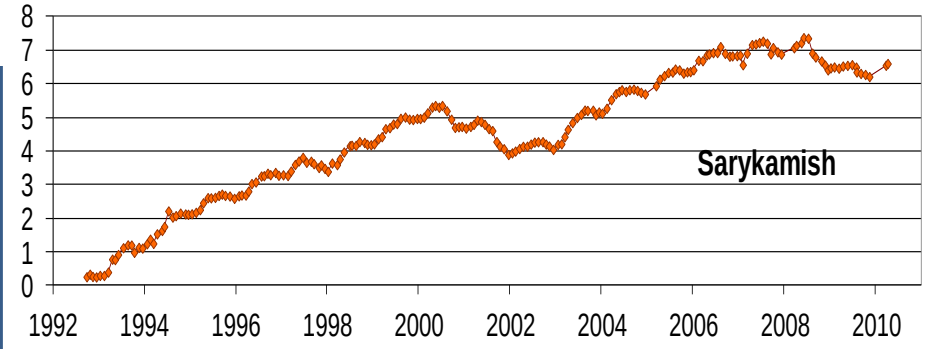
Central Asian is a complex system where river's flow is changed by variability of glaciers melting, variability in rain regime, irrigation and artificial reservoirs regulation under interstate agreements.

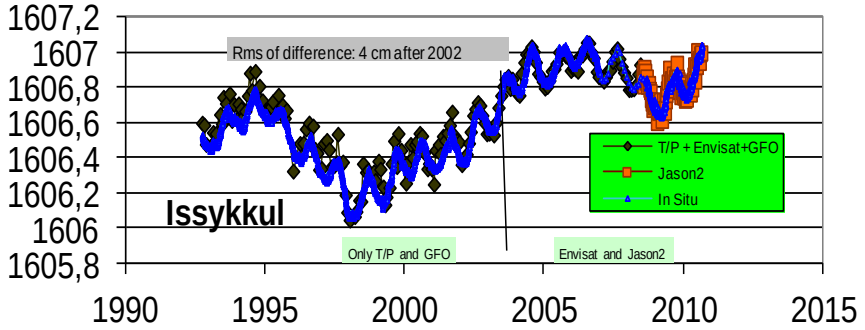






JF Cretaux, CNES-Legos

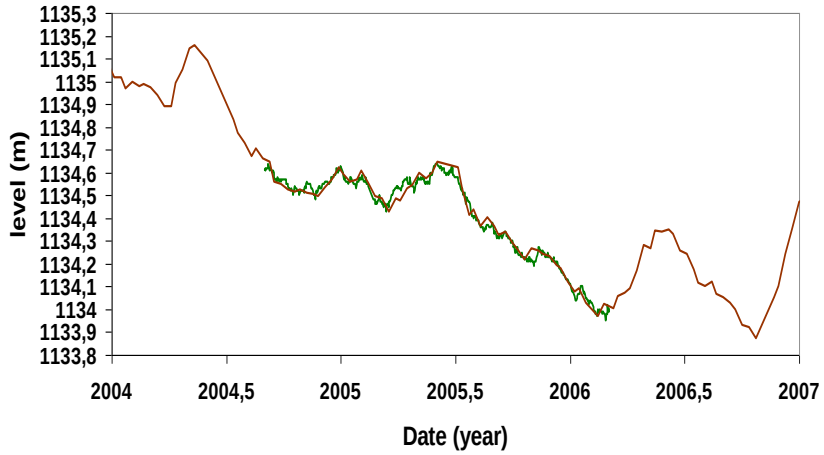




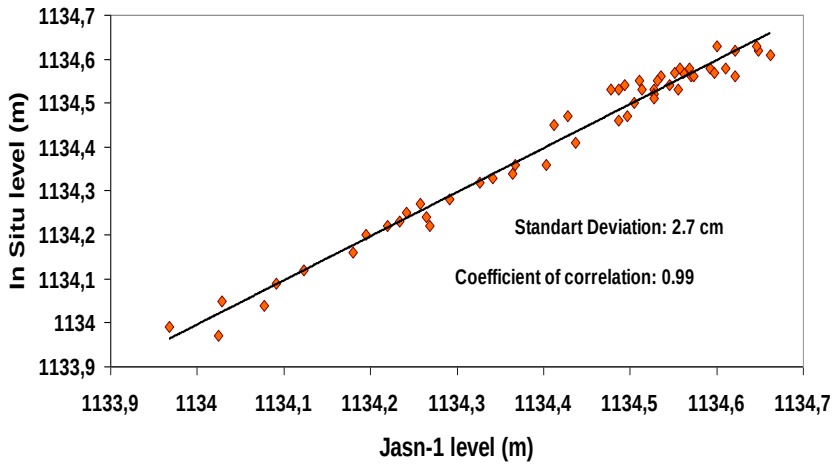
Altimetry over lakes: comparison with In Situ data (1/2)

JF Cretaux, CNES-Legos

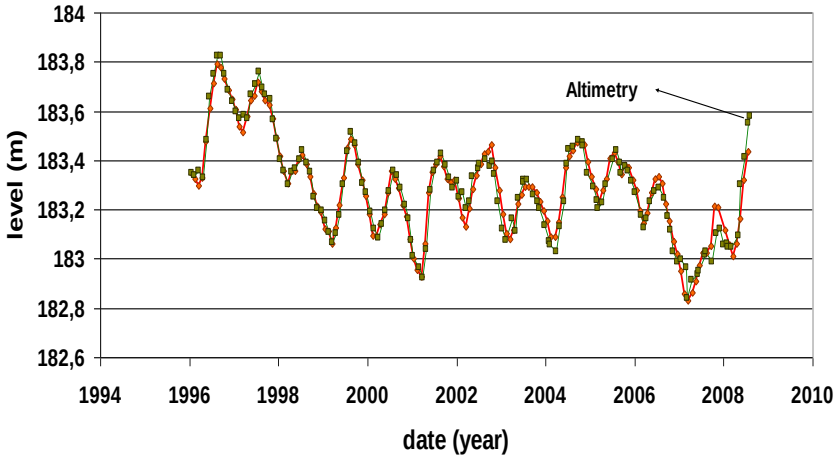
Lake Victoria, In Situ / Altimetry



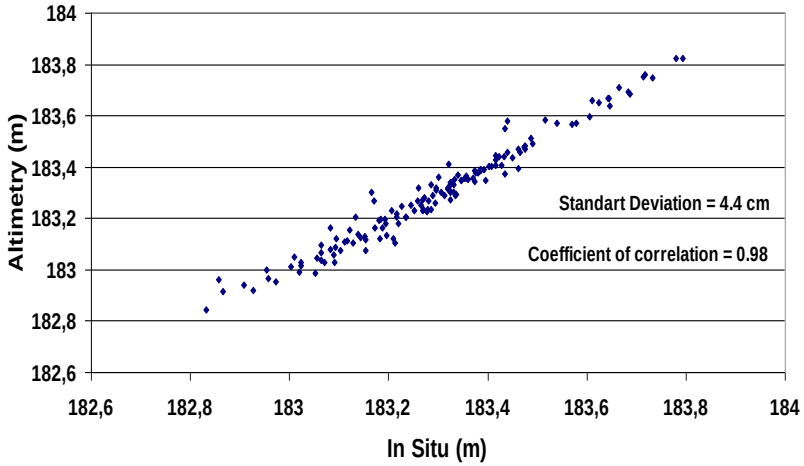
Lake Victoria, scatter of In Situ / Jason-1



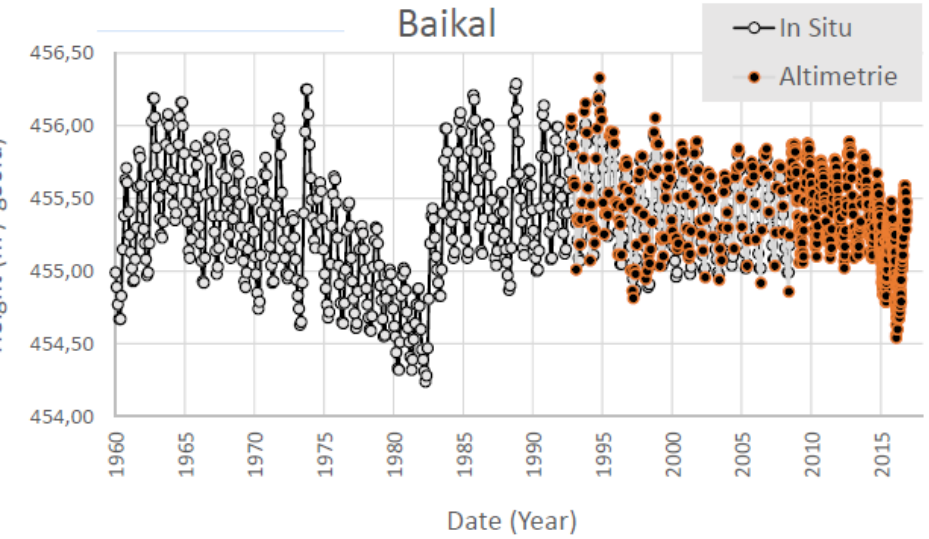
Lake Superior In Situ / altimetry

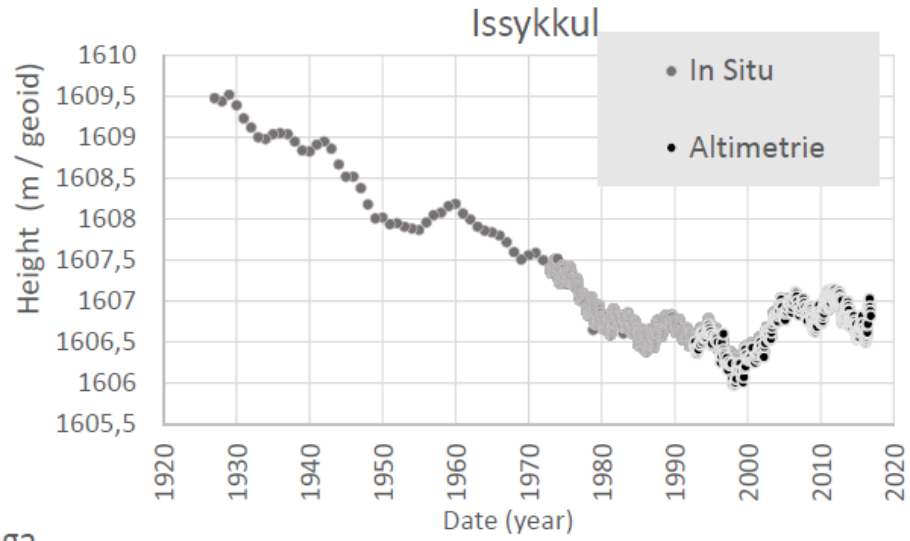


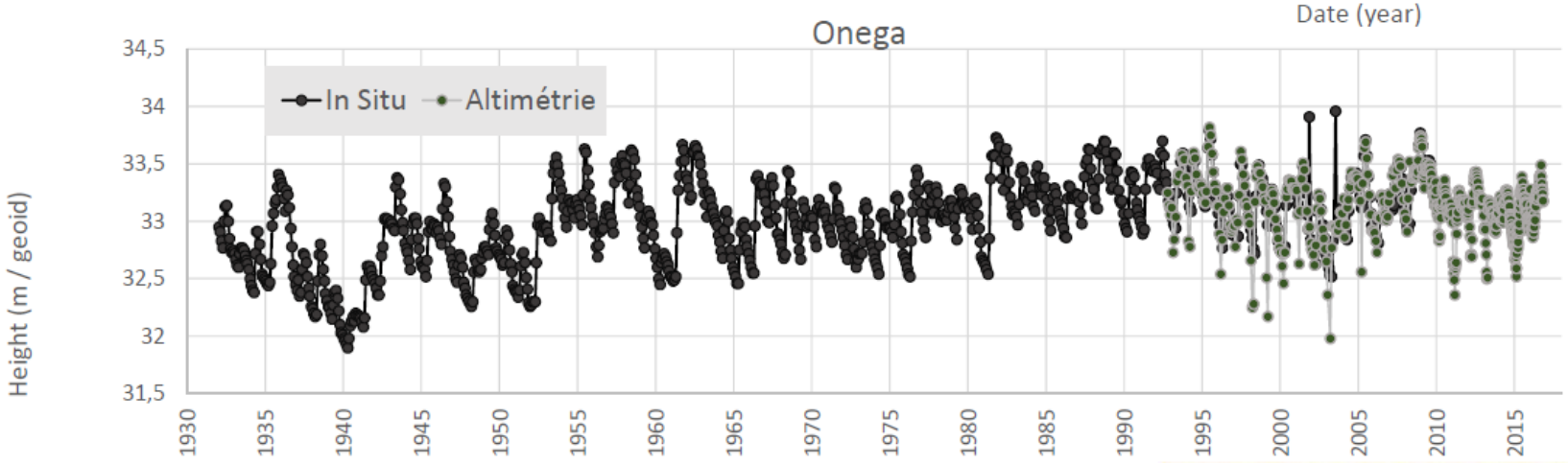
Lake Superior, Scatter In Situ / Altimetry



Exploitation of altimetry series in complement of ground gauge stations



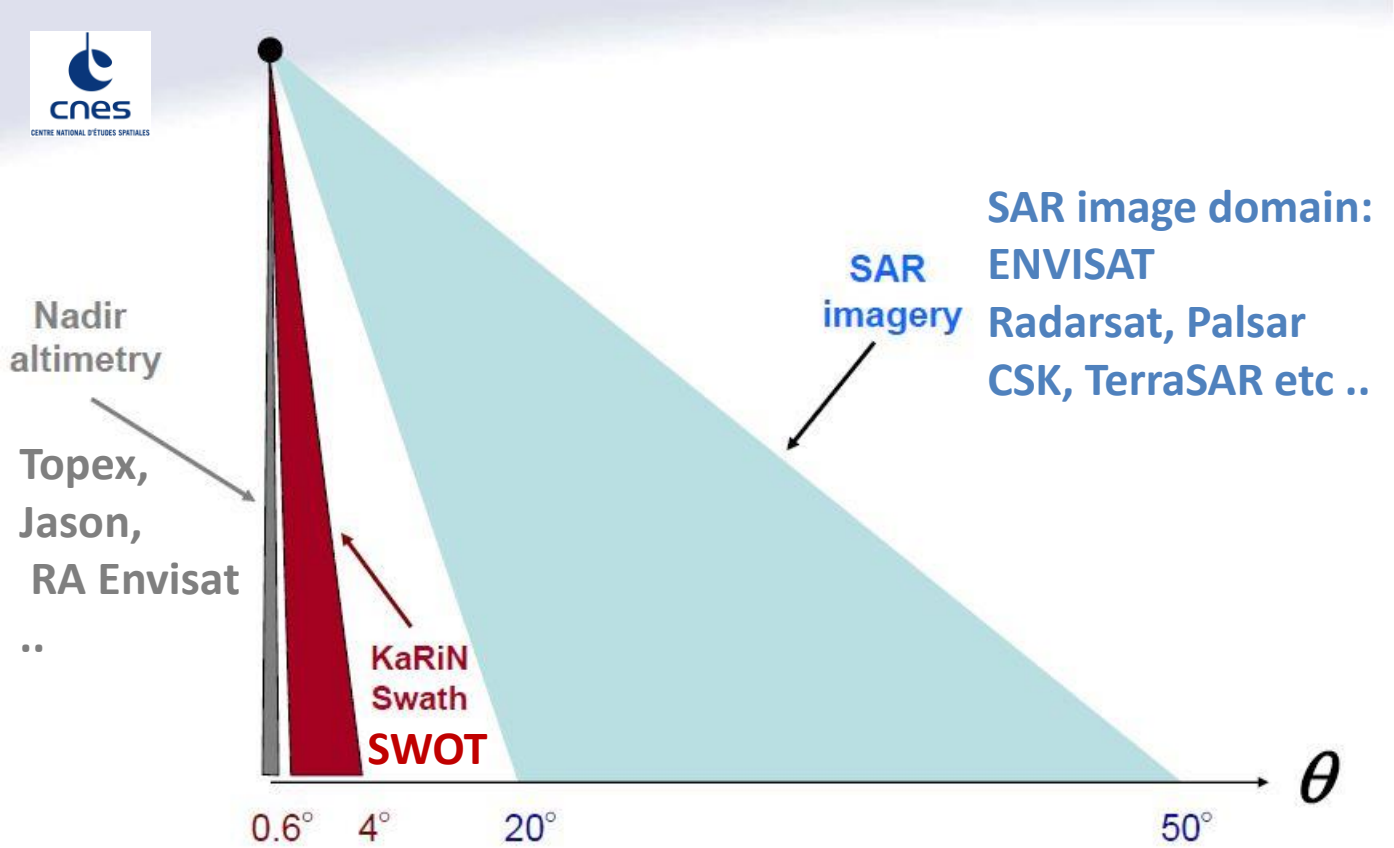




Radar altimetry: sensors types /SAR images

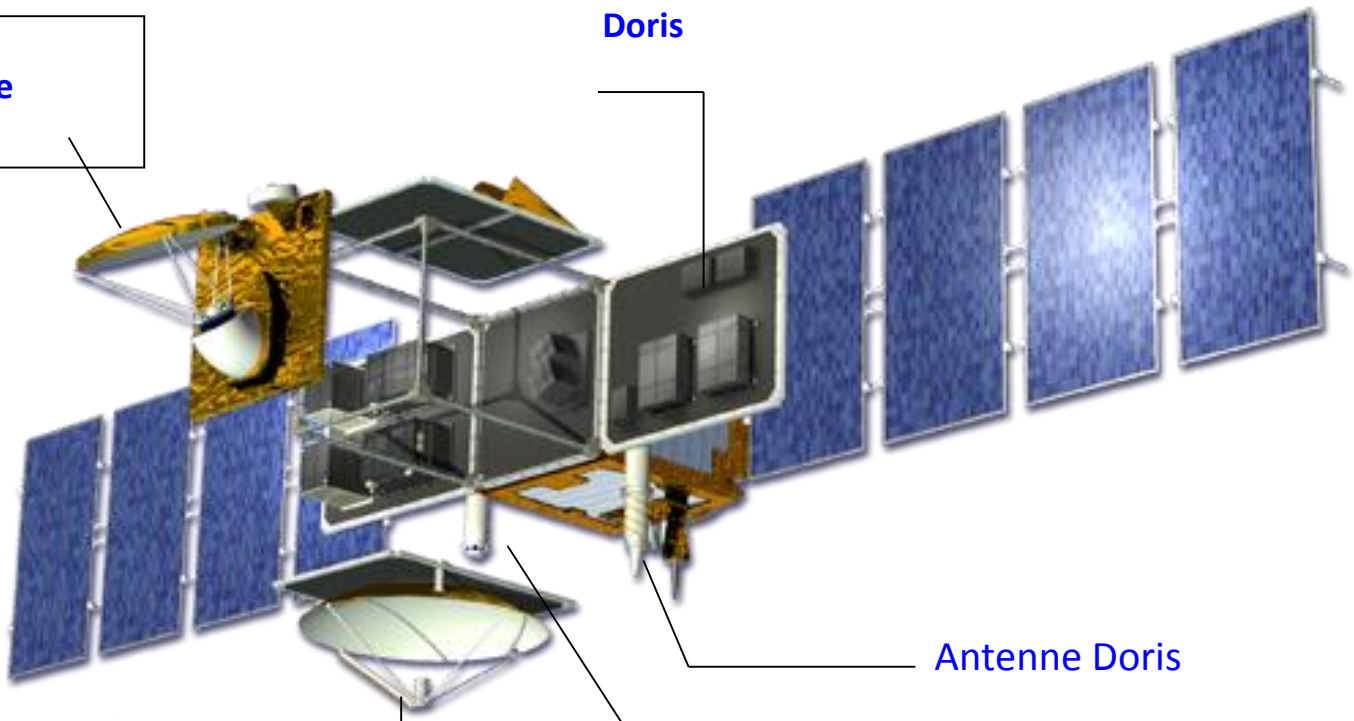
Sensors evolution

From Nadir to Ka_INterferometry



JASON: Payload (Jason-1)

2001



JASON-2 (2008)

- Operationnal Altimétry (cont. JASON-1 - 2001)
- CNES + JPL + NOAA + EUMETSAT
- Plateforme Proteus (CNES) orbite 1300 km
- Revisit: 10 days

HY-2 (2011)

- HaiYang
- Aug 2011
- Oceanographic satellite, with SAR, scatterometer altimeter
- Ku and C band
- Cycle: 14 days for 2 years and after 168 days with sub cycles of 5 days

Sentinel 3

Mission dedicated to OCEAN + continental hydrology

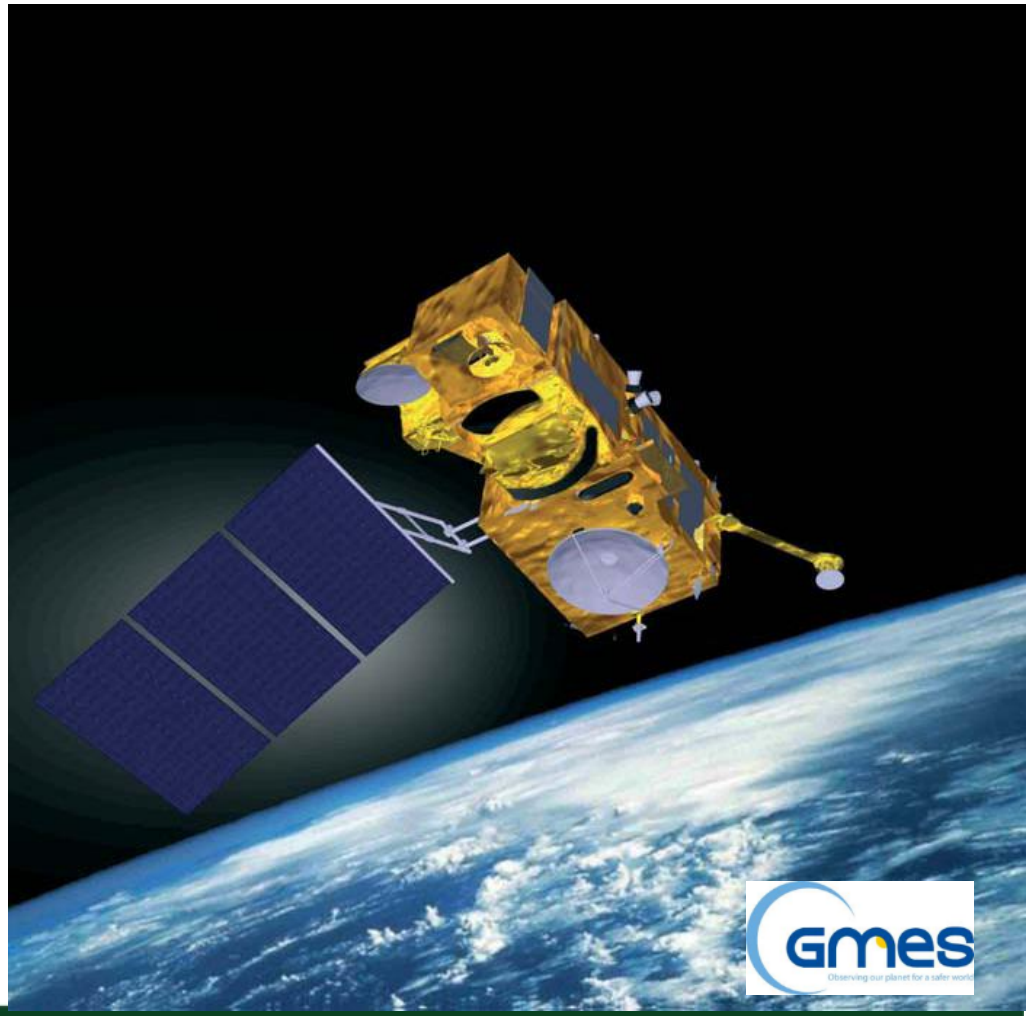
Instrument: SRAL (SAR Altimeter)
Ku and C-band

Continuity of ERS/ENVISAT missions

Nadir Locking SAR
Ku/C band
Repeat Cycle: 27 days

Two modes: low and high resolutions

Launch 16 February 2016
Now operational



From Nadir Ku/C to Ka (35 GHZ) : AltiKa

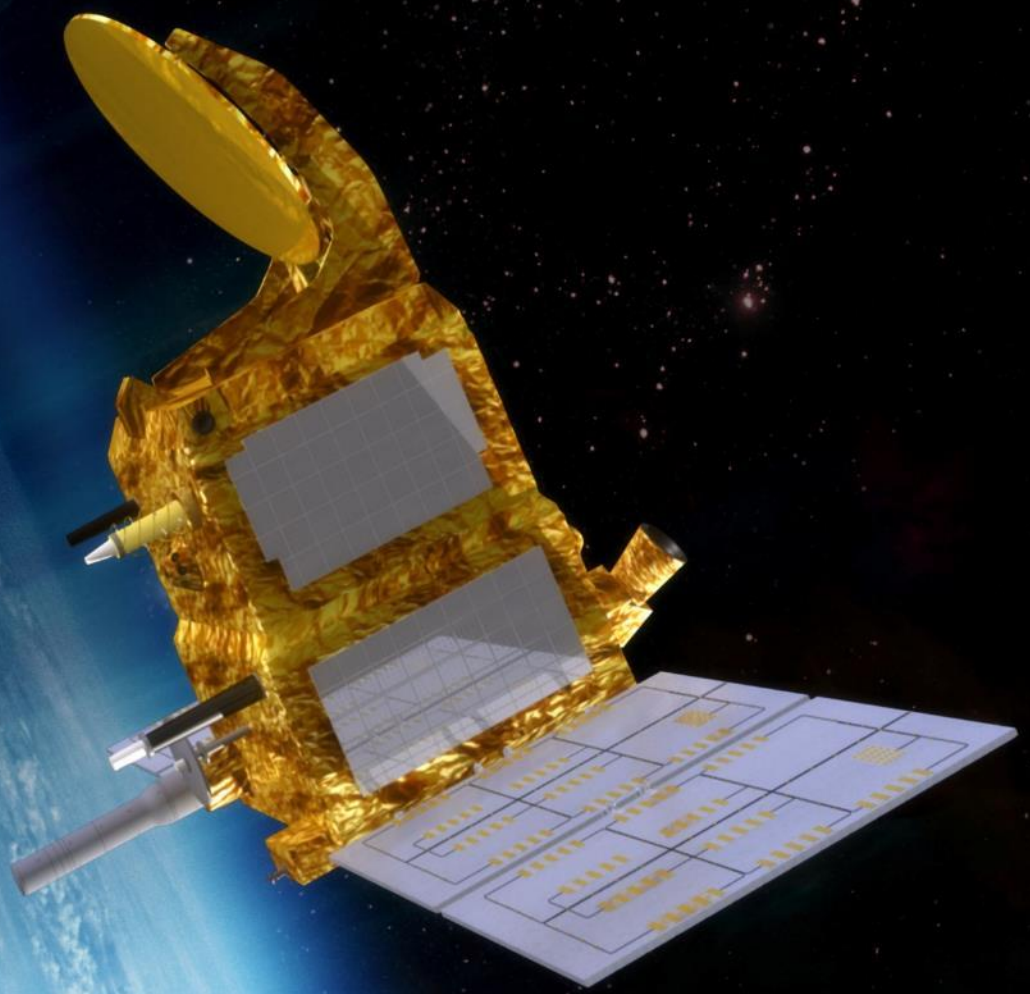
Ka : 8.5 mm
Reduced inospheric effects
→one single frequency
→Transition from Ku to Ka (Gain in height sensitivity : 2.6)

Ka : attenuation by rains, ice, snow .. ;
Very degraded if more than 1.5 mm/h

Same orbit as Envisat
-> ensure mission continuity

Revisit: 25 days

Launch 12/12/2012



ALTI-KA on SARAL

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

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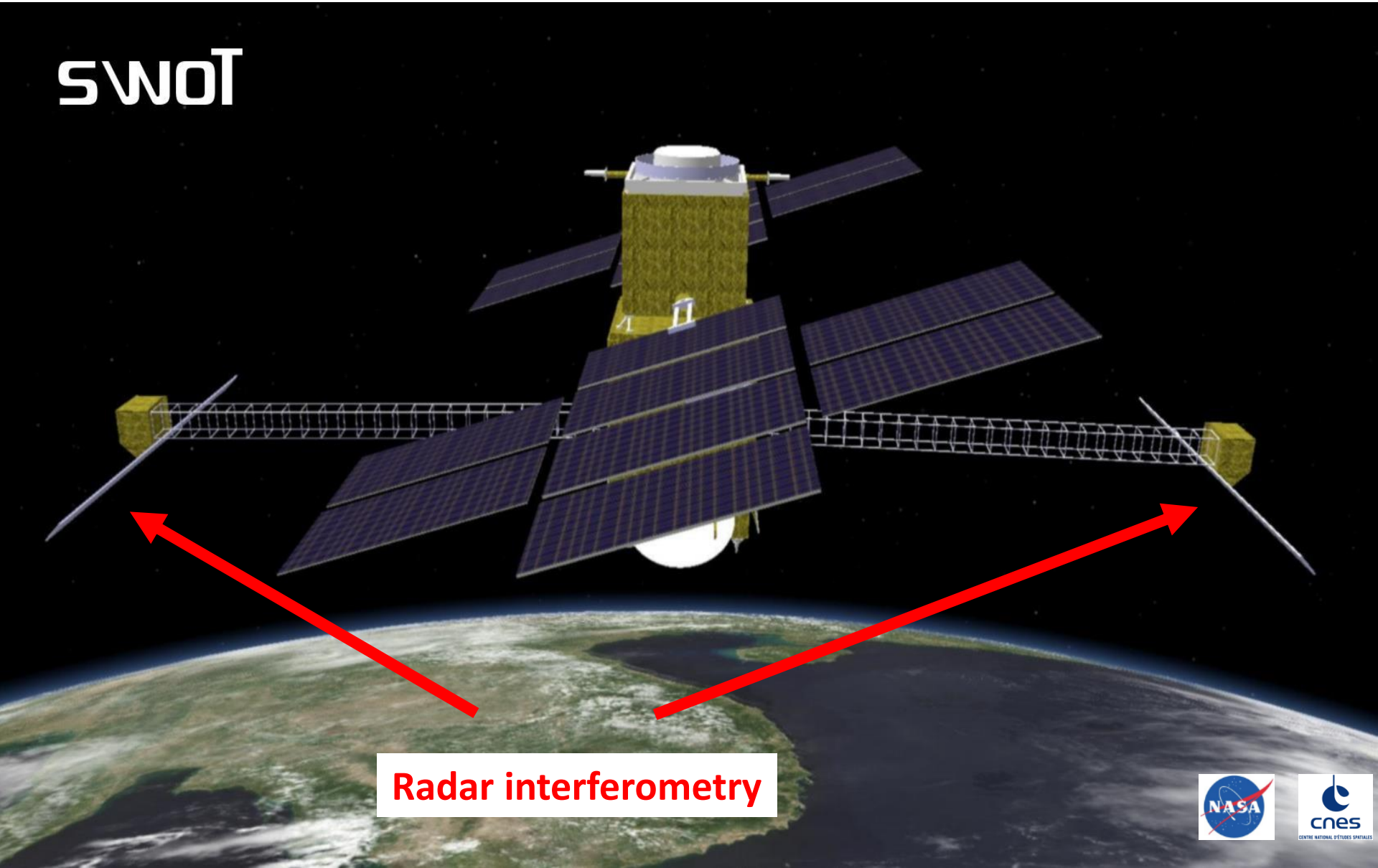
The future of radar altimetry : SWOT and large swath altimetry



SWOT: surface water topography

Interferometry large swath Ka band

2 swath of 50 km
(res. hor. ~50m & res. vert ~0.5m)

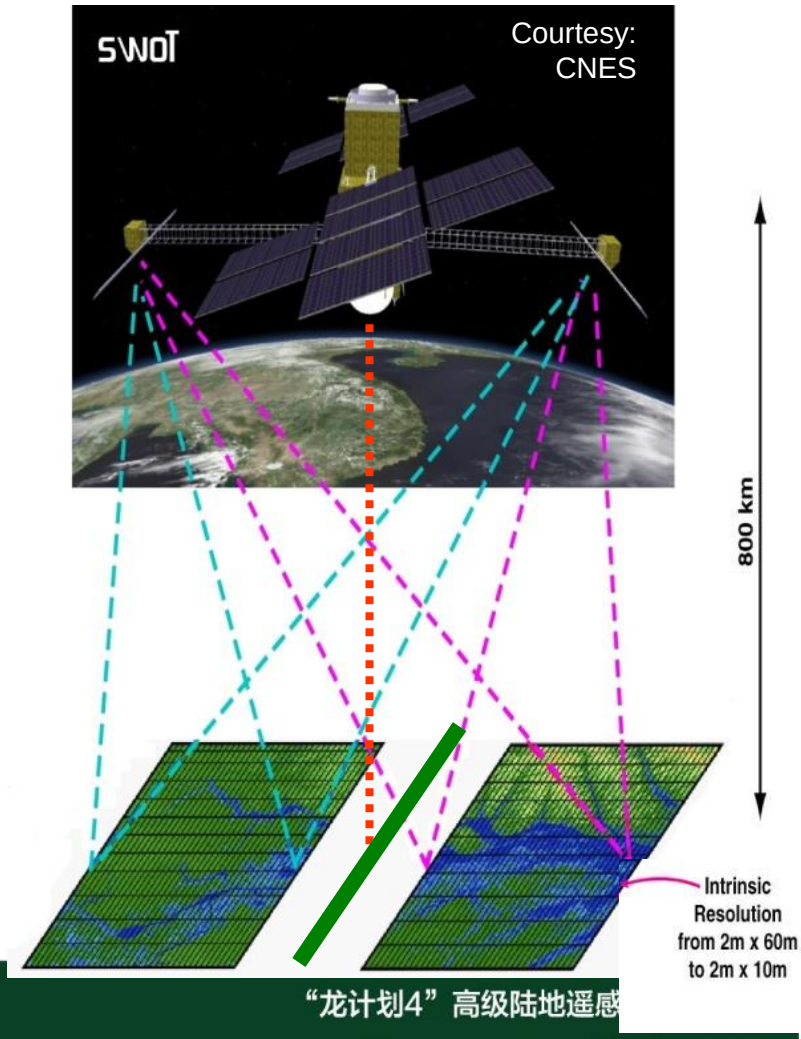
Revisit: 11 days (ccycle 21)

Lake about 4 ha (250*250m)

Measure: height (h), slope (dh/dx), temporal variation(dh/dt).

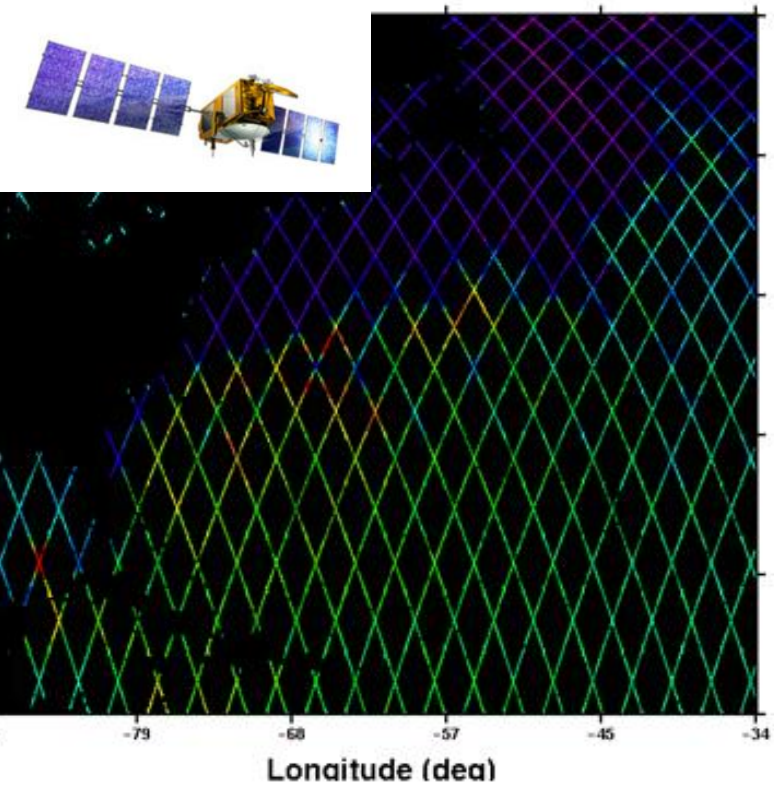
Water stock variations as well as rivers flow

Franco-US mission (CNES-NASA)
Launch 2021

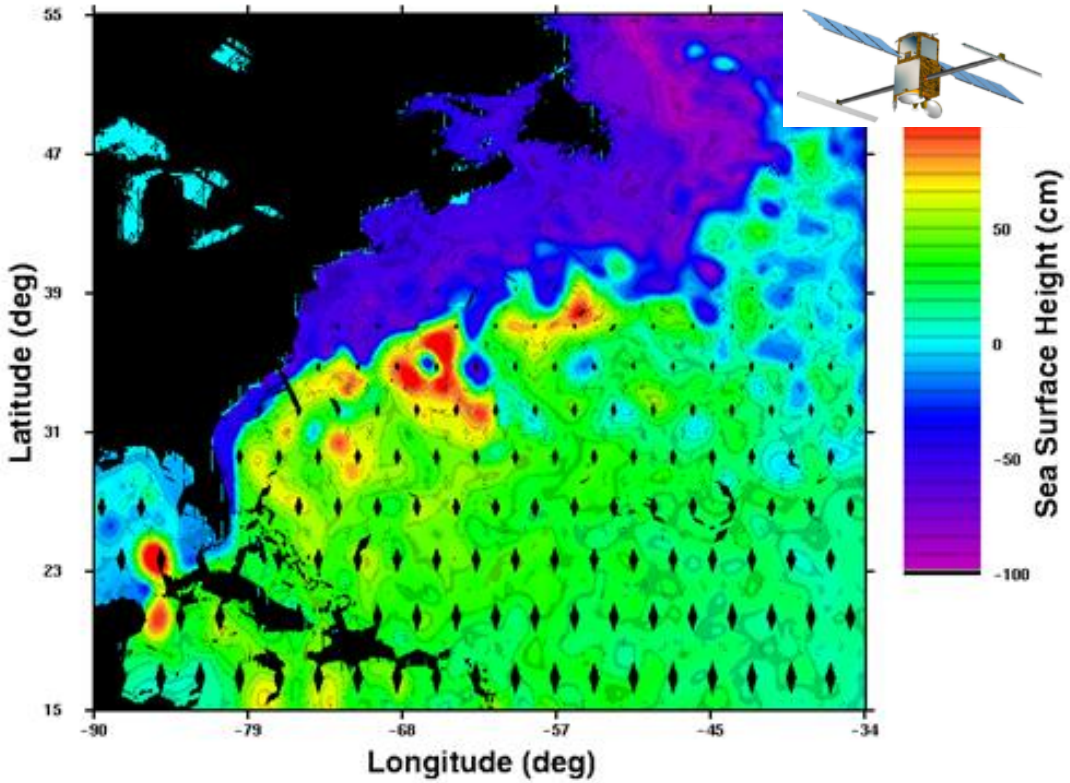


Advantage of Interferometric mission in term of global coverage…

Nadir Mission (Jason…)

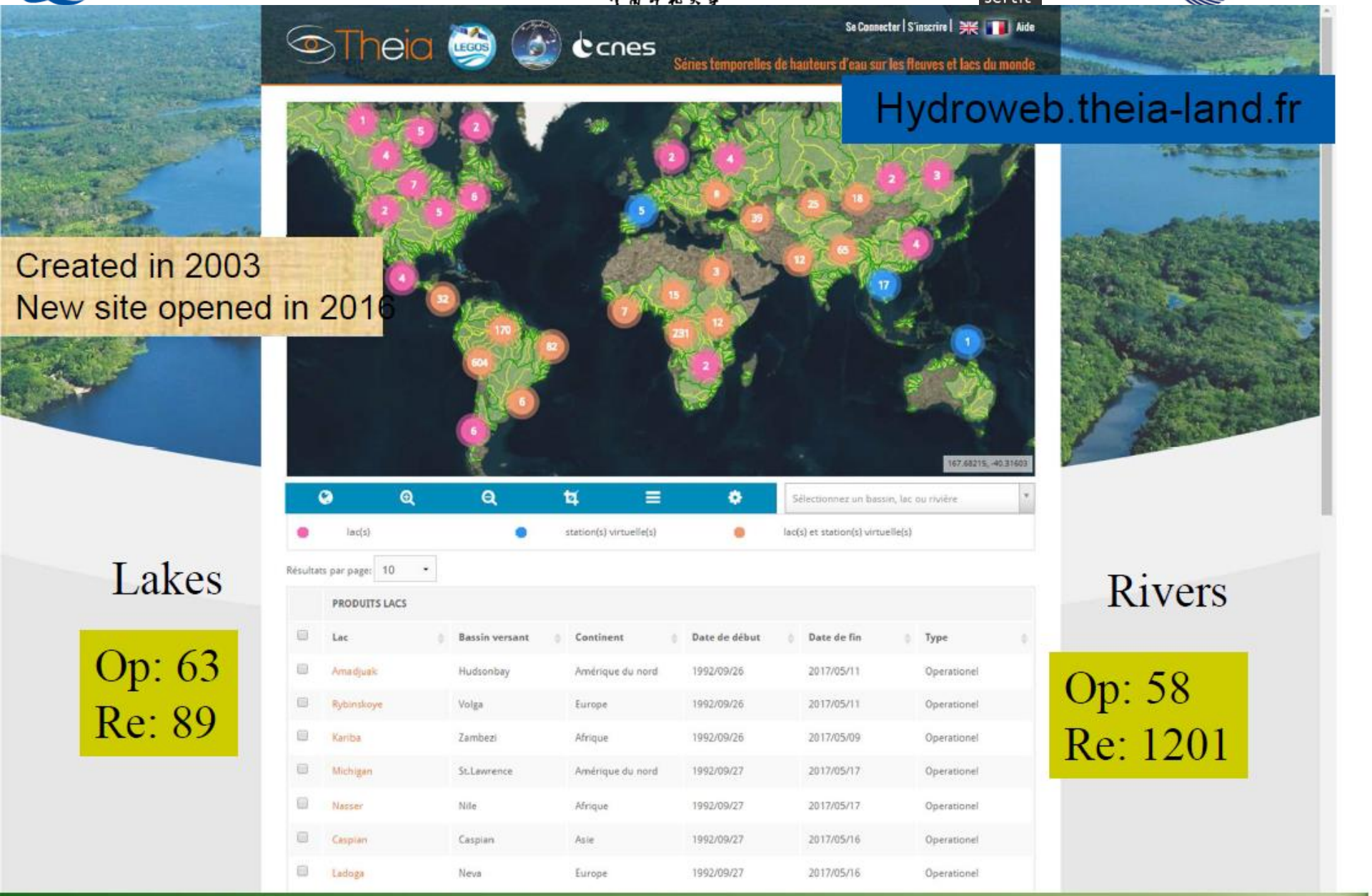


SWOT



Altimetric databases

- **GREALM** (lales/reservoirs) :
- 148 stations ENVISAT,
- 282 stations T/P, Jason-2/-3
- **Theia Hydroweb** :
- 163 stations lakes/rerservoirs.,
- 1280 stations rivers (T/P,J-2/-3, ERS-2,
- ENV, SARAL, S3)
- **DAHITI** :
- 136 stations lakes/resolutions
- 460 stations riv. (T/P,J-2/-3, ERS-2, ENV, SARAL, Cryosat-2)
- **HydroSat** :
- 435 « water storage anom. »,
- 860 « water levels », 18 « discharges »


Theia
LEGOS
cnes
Se Connecter | S'inscrire | Aide
Séries temporelles de hauteurs d'eau sur les fleuves et lacs du monde
Hydroweb.theia-land.fr
Created in 2003
New site opened in 2016
Sélectionnez un bassin, lac ou rivière
lac(s)
station(s) virtuelle(s)
lac(s) et station(s) virtuelle(s)
Résultats par page: 10
PRODUITS LACS
Lac
Bassin versant
Continent
Date de début
Date de fin
Type
Amadjuak
Hudsonbay
Amérique du nord
1992/09/26
2017/05/11
Operationel
Rybinskoye
Volga
Europe
1992/09/26
2017/05/11
Operationel
Kariba
Zambezi
Afrique
1992/09/26
2017/05/09
Operationel
Michigan
St.Lawrence
Amérique du nord
1992/09/27
2017/05/17
Operationel
Nasser
Nile
Afrique
1992/09/27
2017/05/17
Operationel
Caspian
Caspian
Asie
1992/09/27
2017/05/16
Operationel
Ladoga
Neva
Europe
1992/09/27
2017/05/16
Operationel
Lakes
Op: 63
Re: 89
Rivers
Op: 58
Re: 1201
Site developped by Legos, maintained and operated by CLS under CNES & Copernicus c

Theia | LEGOS | HydroWeb | cnes

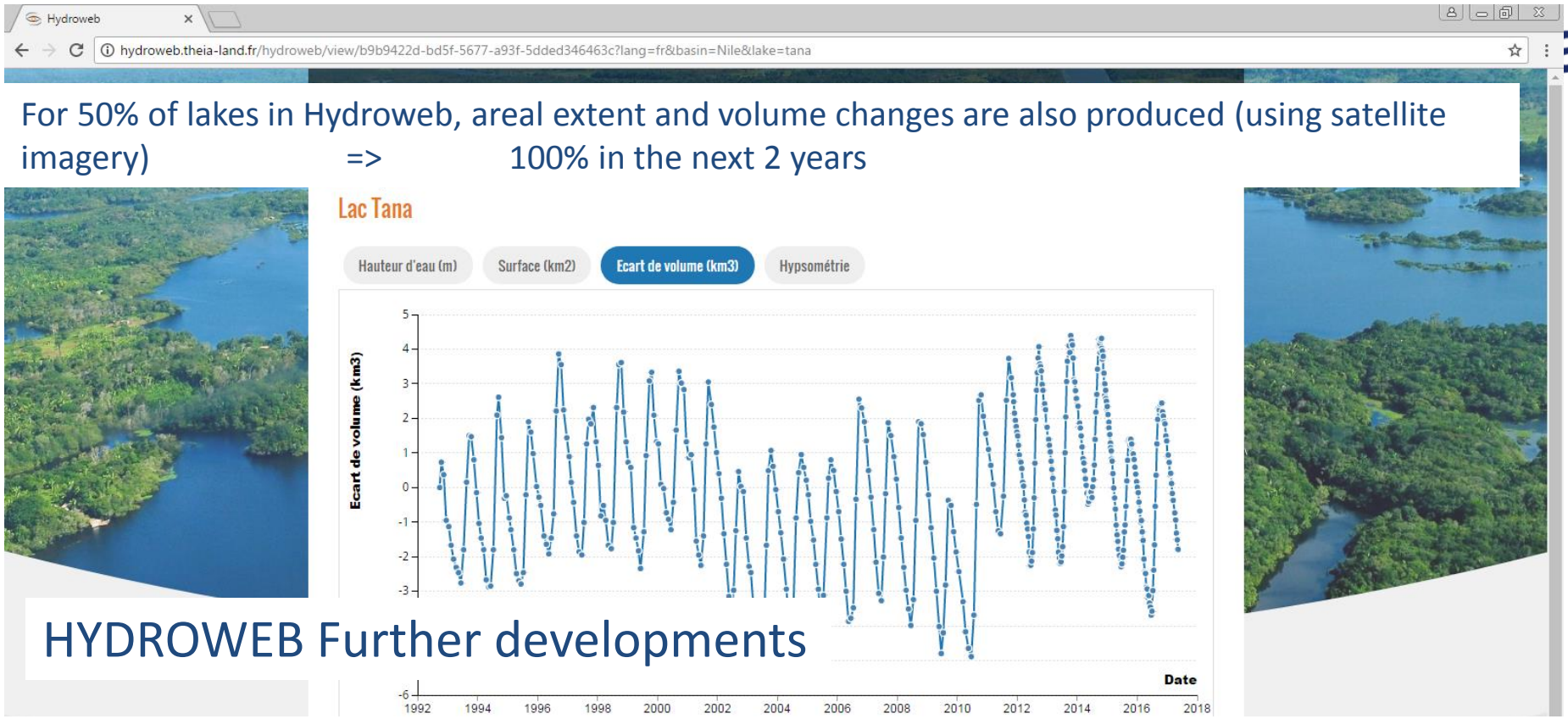
Sign In | Sign Up | Help

Time series of water levels in the rivers and lakes around the world

Select a basin, lake or river

lake(s) virtual station(s) lake(s) and virtual station(s)

Records per page: 10



HYDROWEB Further developments

- **Drastically increase the number of lakes in Hydroweb using the new missions Sentinel-3A & 3B, Jason-CS & SWOT**
- **Determination of near lake bathymetry using Laser ranging instruments & global lakes extent products (Peckel, Shen)**
- **Continue & Strenghen the participation in the Hydrolare project**
- **Include lake ice products (duration and date of ice formation and breakup)**

River&Lake

European Space Agency

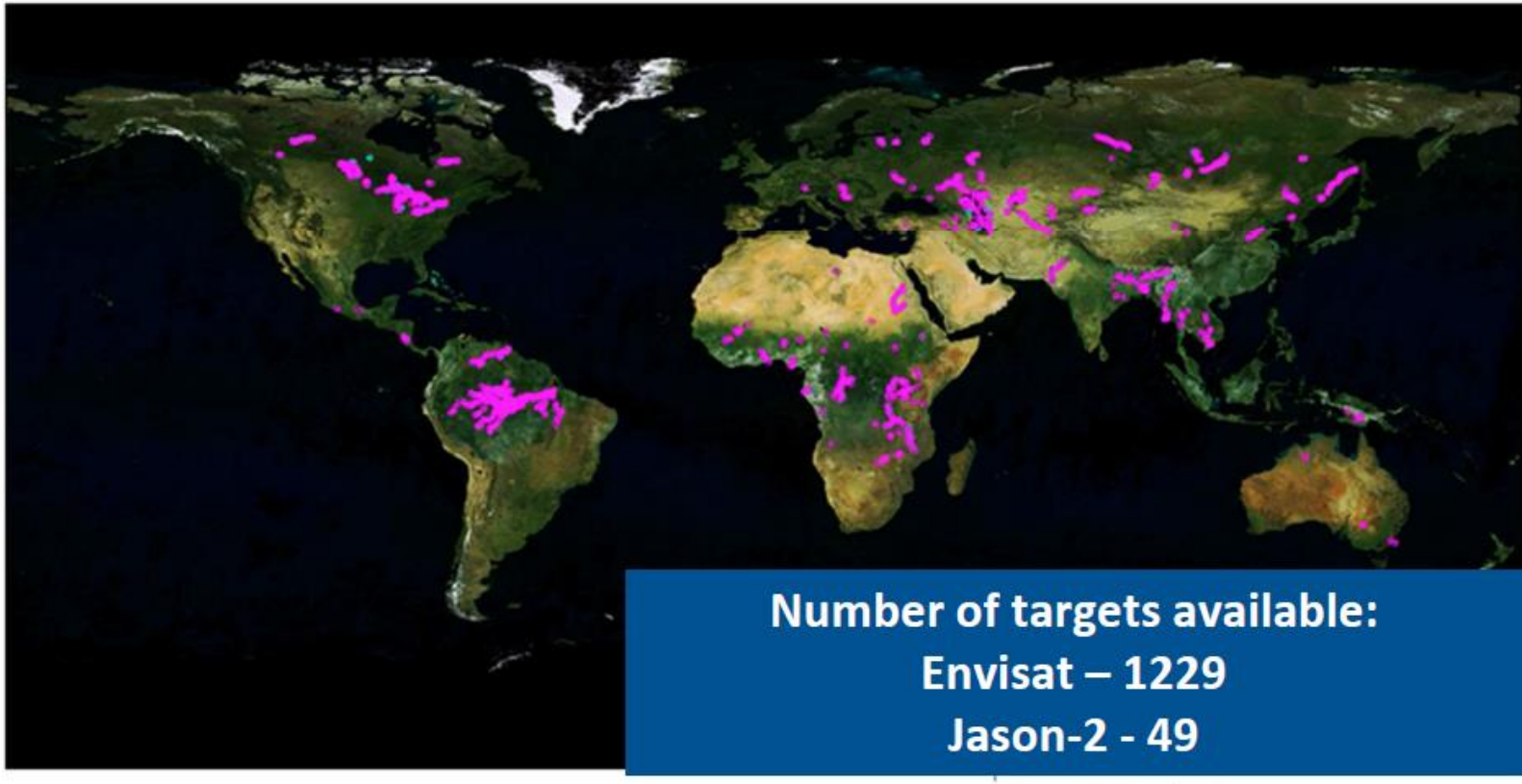
ESA | Observing The Earth

Login Register

- Main
- Products
- Africa
- Asia
- Europe
- North America
- South America
- Australia & Oceania
- Information
- Jason-2
- River Modelling
- Historical Review
- Current Capabilities
- Documents
- References
- Project Members
- Project Users
- F.A.Q.
- Quotes
- Contact

Global NRT Product Locations

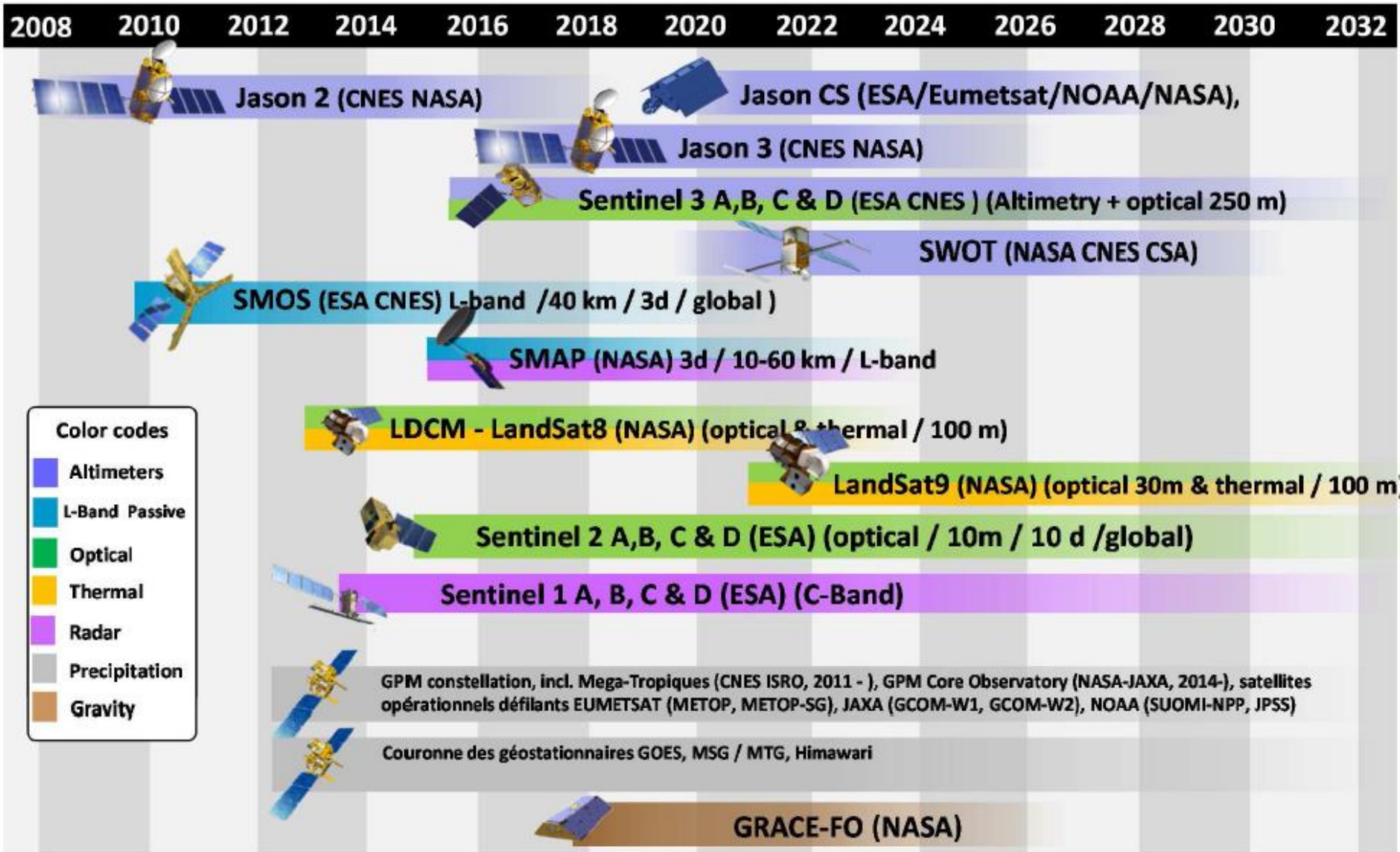
http://earth.esa.int/riverandlake



Number of targets available:
Envisat – 1229
Jason-2 - 49

River and Lake results now available without registration

Latest Products


2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
Jason 2 (CNES NASA)
Jason CS (ESA/Eumetsat/NOAA/NASA),
Jason 3 (CNES NASA)
Sentinel 3 A,B, C & D (ESA CNES) (Altimetry + optical 250 m)
SWOT (NASA CNES CSA)
SMOS (ESA CNES) L-band /40 km / 3d / global)
SMAP (NASA) 3d / 10-60 km / L-band
LDCM - LandSat8 (NASA) (optical & thermal / 100 m)
LandSat9 (NASA) (optical 30m & thermal / 100 m
Sentinel 2 A,B, C & D (ESA) (optical / 10m / 10 d /global)
Sentinel 1 A, B, C & D (ESA) (C-Band)
GPM constellation, incl. Mega-Tropiques (CNES ISRO, 2011 -), GPM Core Observatory (NASA-JAXA, 2014-), satellites opérationnels défilants EUMETSAT (METOP, METOP-SG), JAXA (GCOM-W1, GCOM-W2), NOAA (SUOMI-NPP, JPSS)
Couronne des géostationnaires GOES, MSG / MTG, Himawari
GRACE-FO (NASA)
Color codes
Altimeters
L-Band Passive
Optical
Thermal
Radar
Precipitation
Gravity

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
- Interest for SWIR bands

Elements for water bodies extraction based on optical imagery

Optical sensors for water bodies and/or flood mapping
- Medium
- High resolution
- VHR sensors

Water level from space
- Principles of altimetry
- Altimetry missions past, present futures
- Altimetry database

Flood plain and lakes monitoring
- **Short term Monitoring**
- **Long term monitoring**
- **Meteo climato parameters**

Concluding remarks

neighborhood

long term monitoring of flood prone/lakes

Multisensors approach based on synergy optical – SAR

- MERIS/ASAREnvisat
- CSK/TSX or Deimos_Beijing 1/HJ1A
_ Sentinel 1 and Sentinel 2

Worldwide applicable

1 - over large sensitive regions:

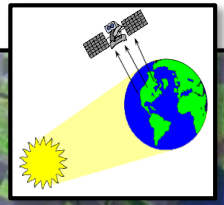
- Asia : China, Mekong system (Tonle sap lake and Delta),
- Africa: Niger iner delta, Okavango, etc
- Australia: Eyre Lake and Diamanta River
- South America: Argentina, Rio del Plata

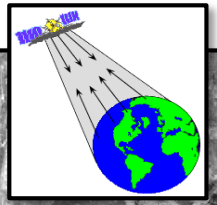
2- over small sensitive areas

- Every wetlands in your neighborhood

Complementarity/synergy Optical / Radar

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

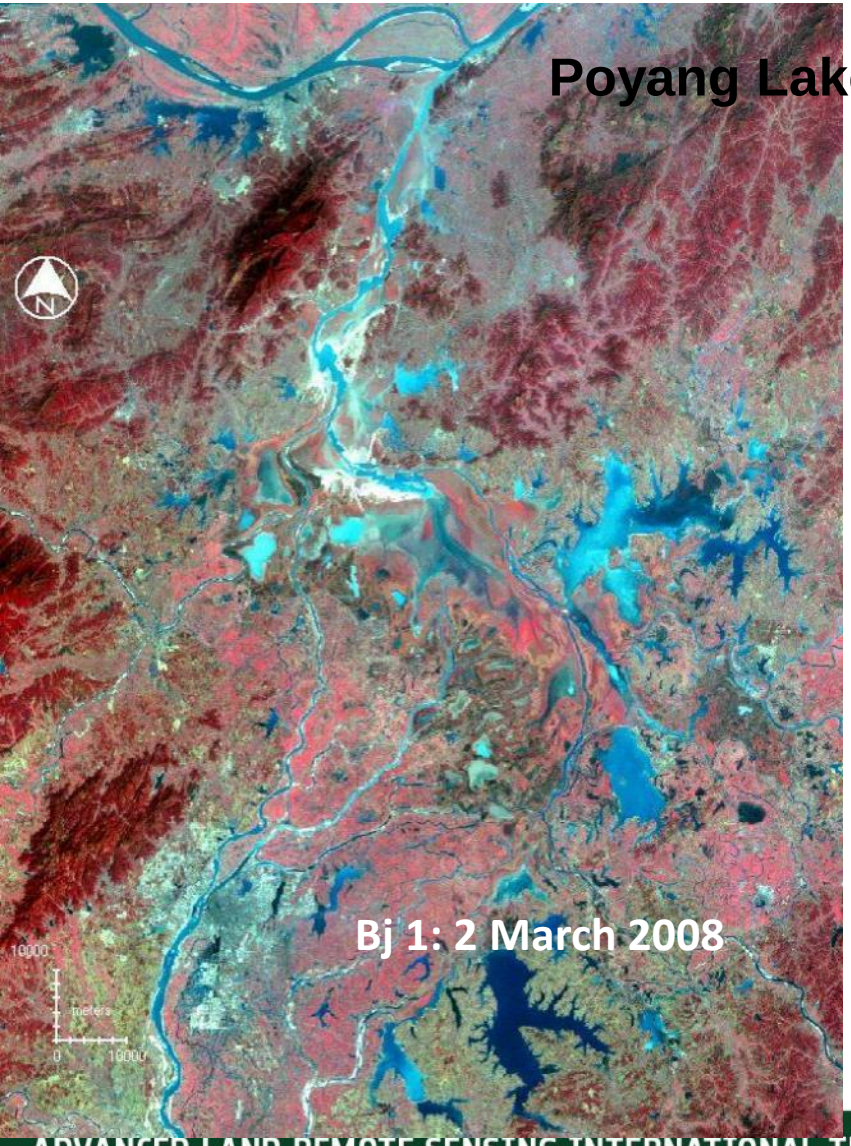
Health of Yangtze is a major concern for 400 000 000 of inhabitants as a fresh wa resource.

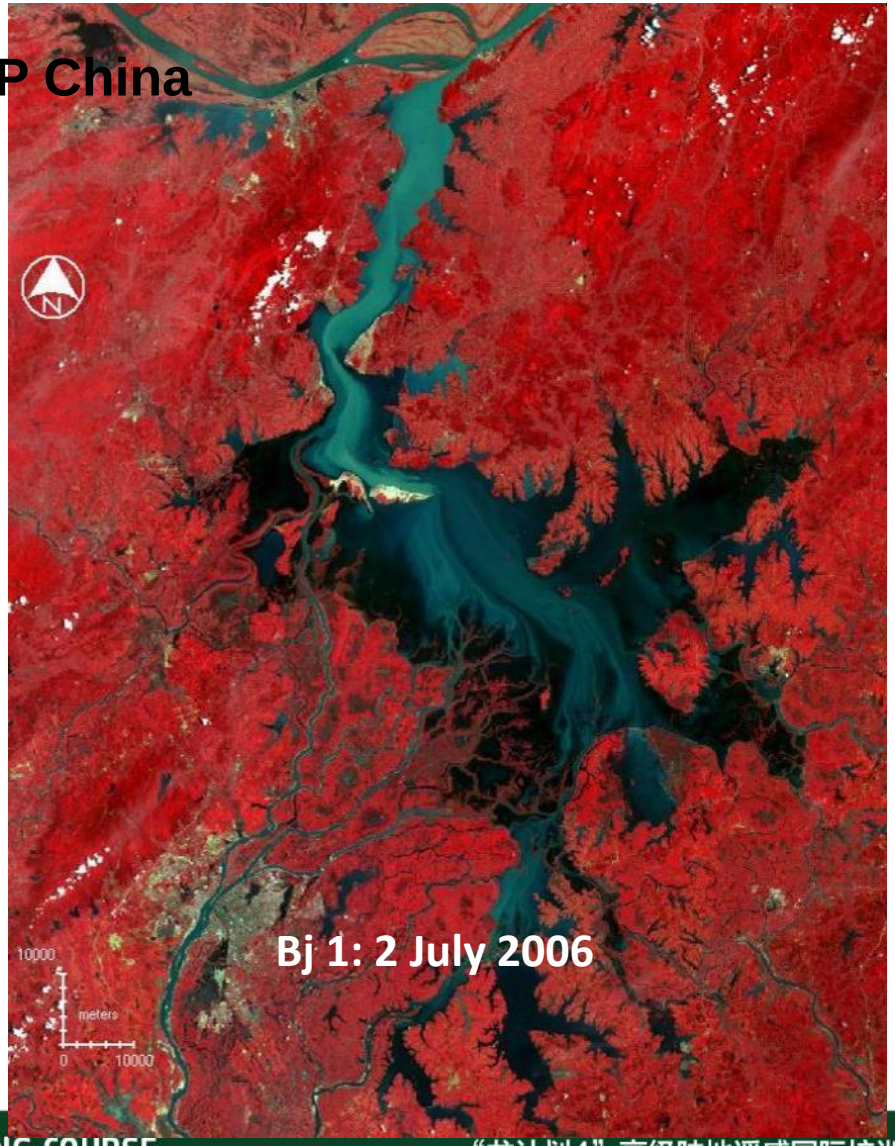
The river basin gives
- 70% rice production
- 40% cereal production
- 40% industry

- Biodiversity stakes

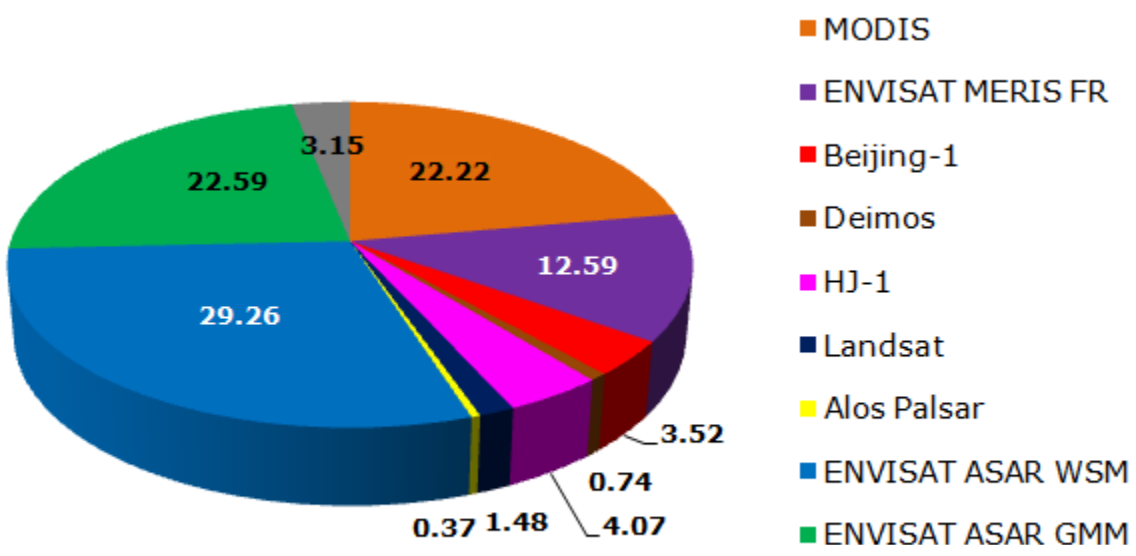
Climate fluctuation and man activities (ie Three Gorges dam) could have significant impact.

Monsoon lake: important annual variations of water surface





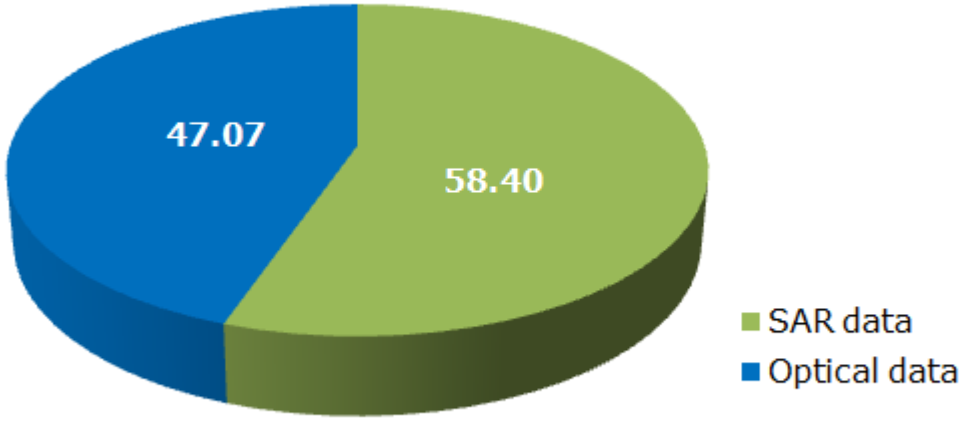
Example of water body monitoring: Poyang



A mixed resource

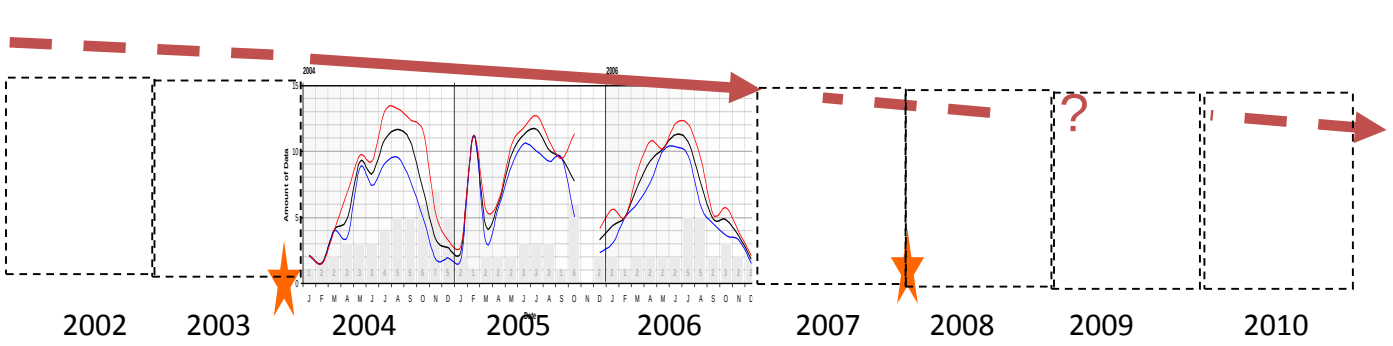
In the future two major resource Sentinel 1 et 2

+550 images



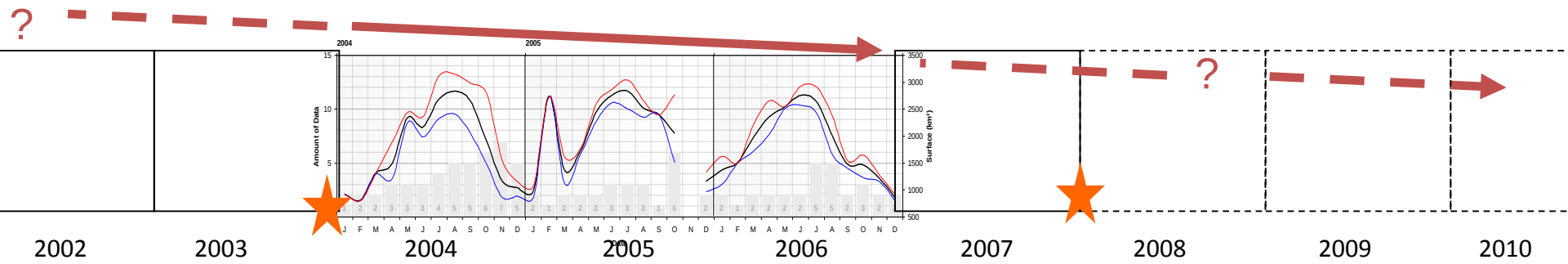
Water extent monitoring: Poyang

3GD event

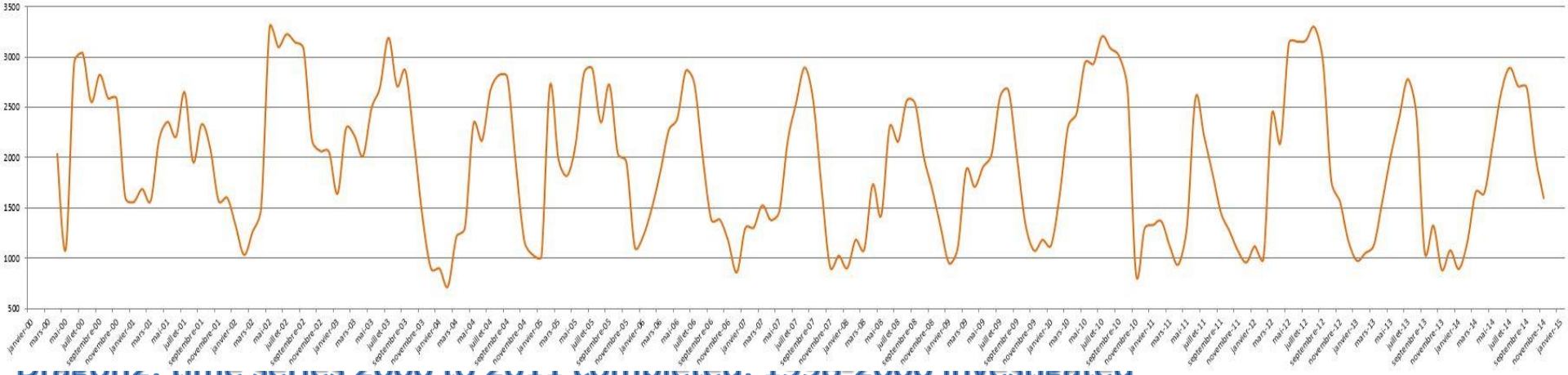


Dragon 2 objectives: Continue and complete water surfaces' monitoring

Water extent monitoring: Poyang



Dragon3objectives: Continue and complet water surface monitoring



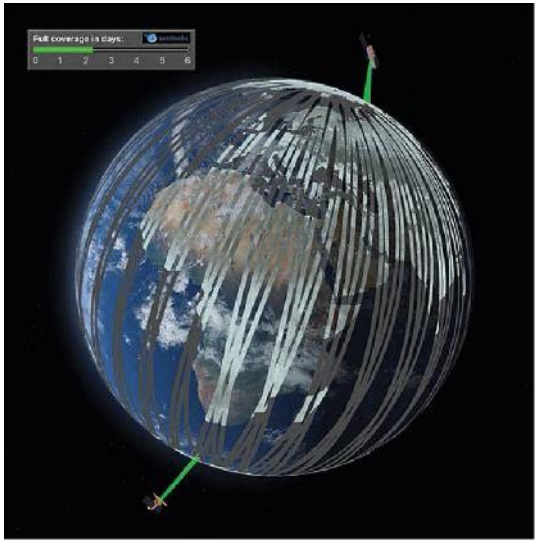
Dragon2: time series 2006 to 2011 completed, 1998-2006 investigated

Dragon 3: 2014 fully integrated

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
- 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

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

2014092

20140926

20141003

2014100

2014101

20141020

20141108

20141101

20141113

20141120

20141125

20141202

20141207

20141214

20141219

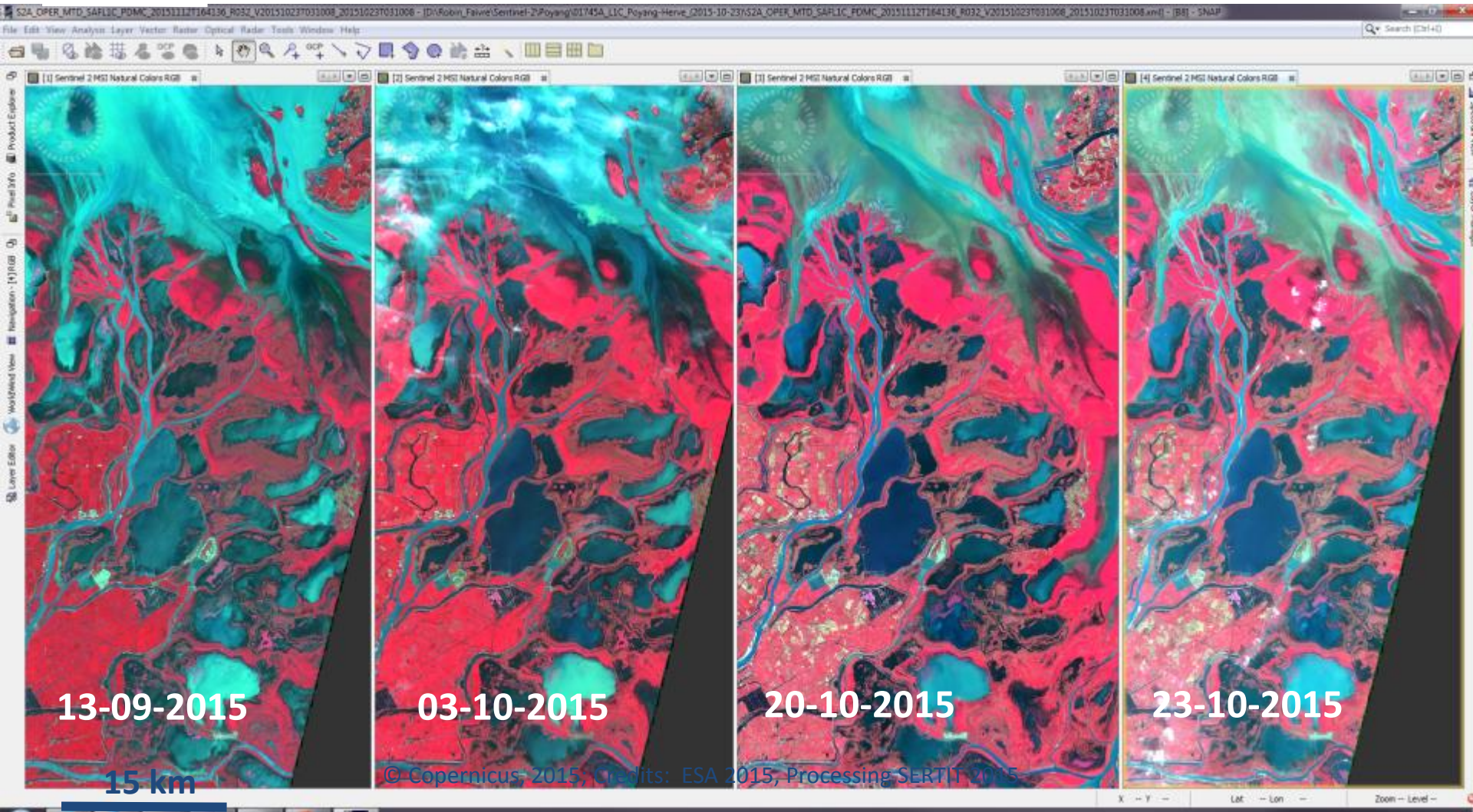
20141226

20–25 November

际培训班

中国, 昆明

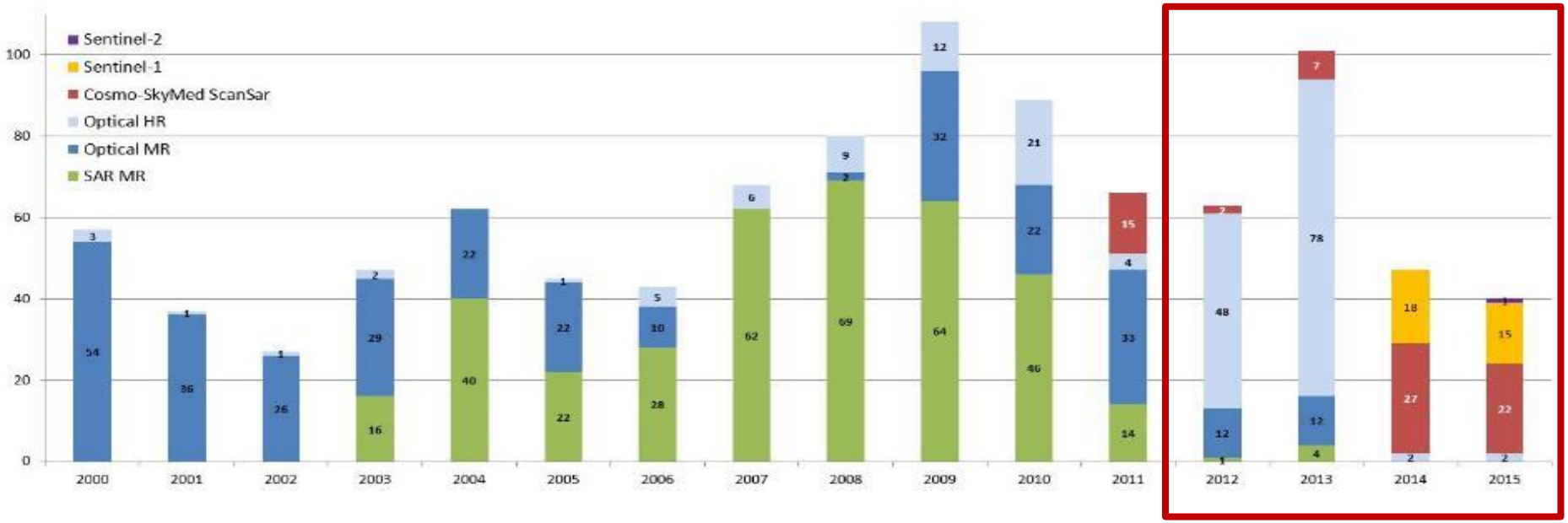
First Sentinel 2 Time series over Poyang



Water draw off over Nanjinshan natural reserve

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)

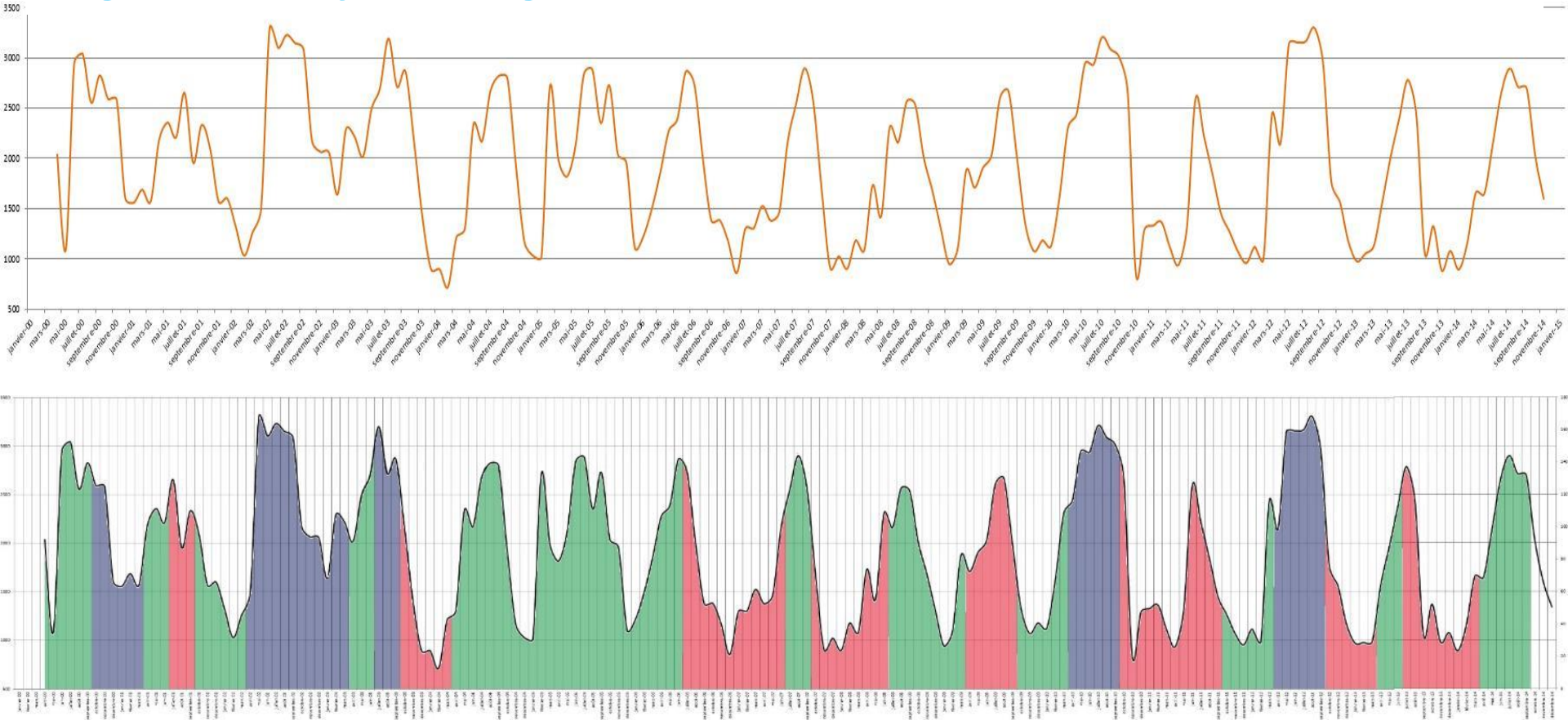
⇒ Sentinel 1A

⇒ First Sentinel2

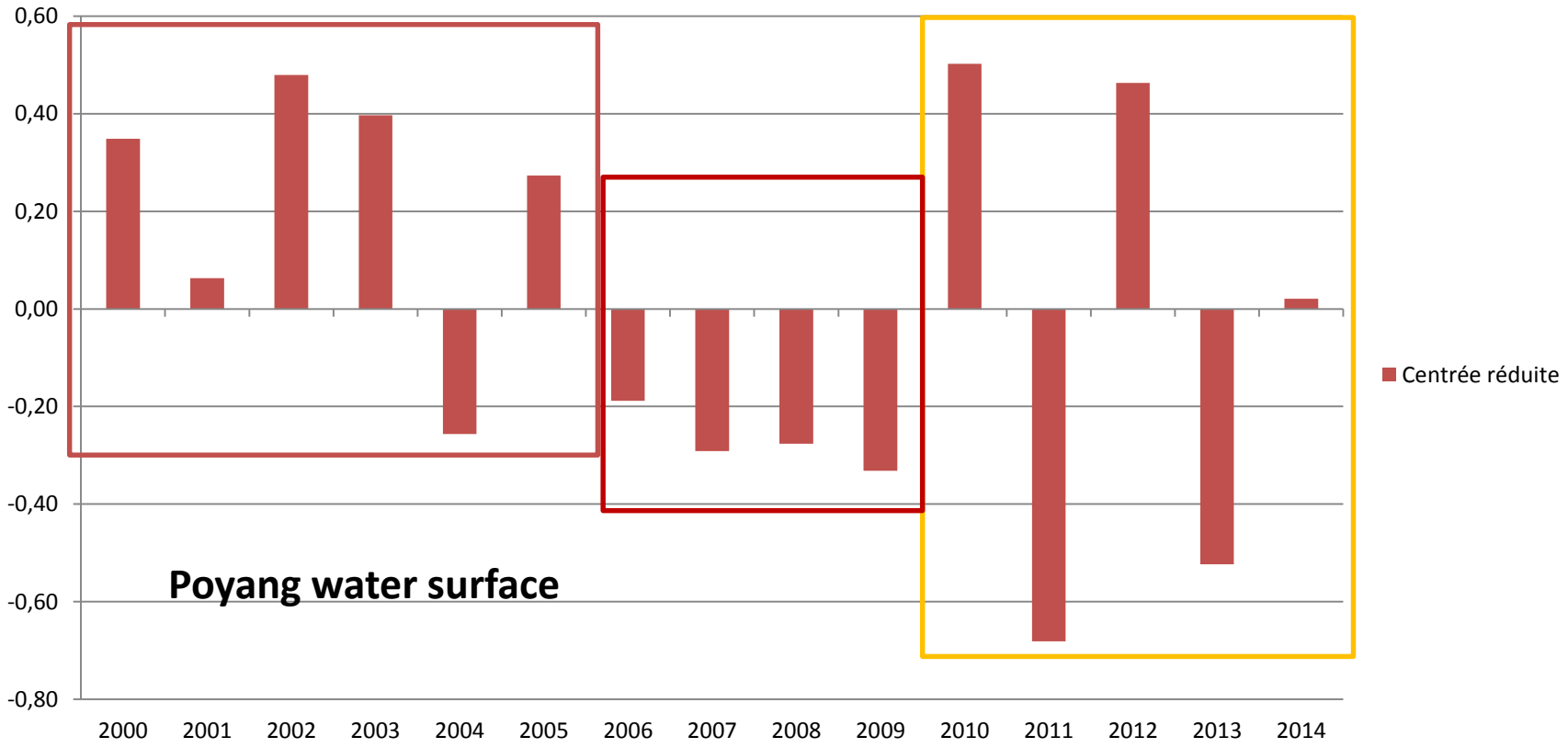
⇒ First Sentinel1B

Poyang lake water surface monitoring:

Regional analysis and global interactions



WP7 : Regional and global interactions

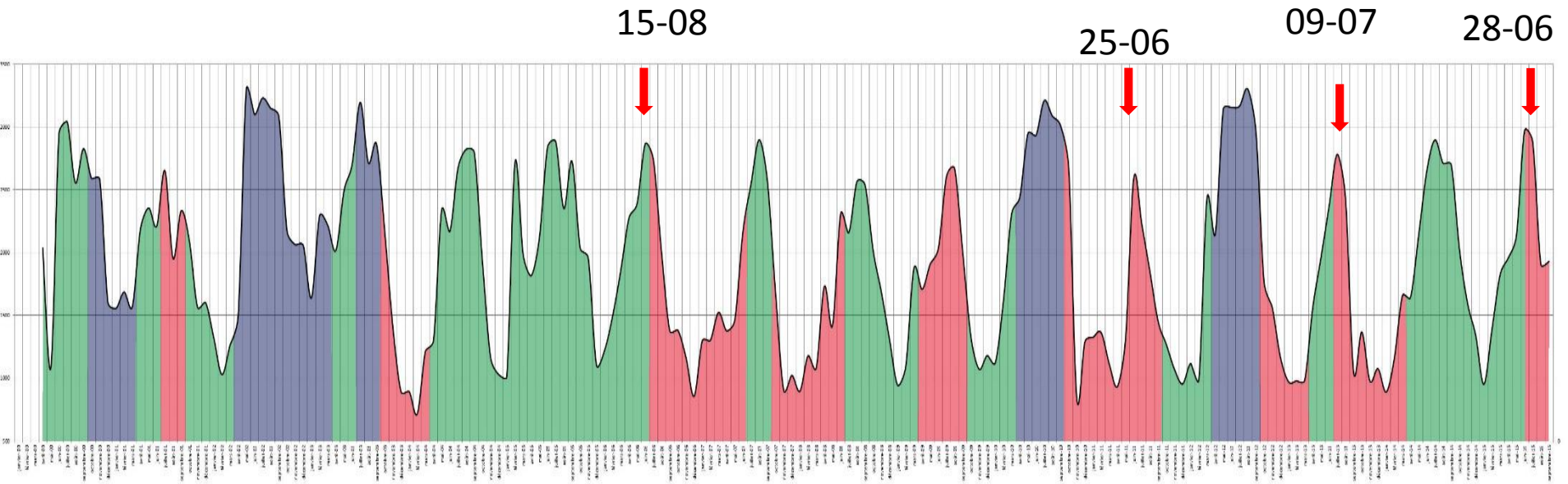


Water surface Statistical analysis

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

Centred reduced

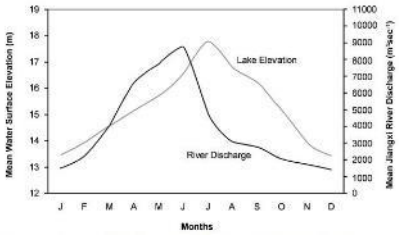
WP7 : Regional and global interactions



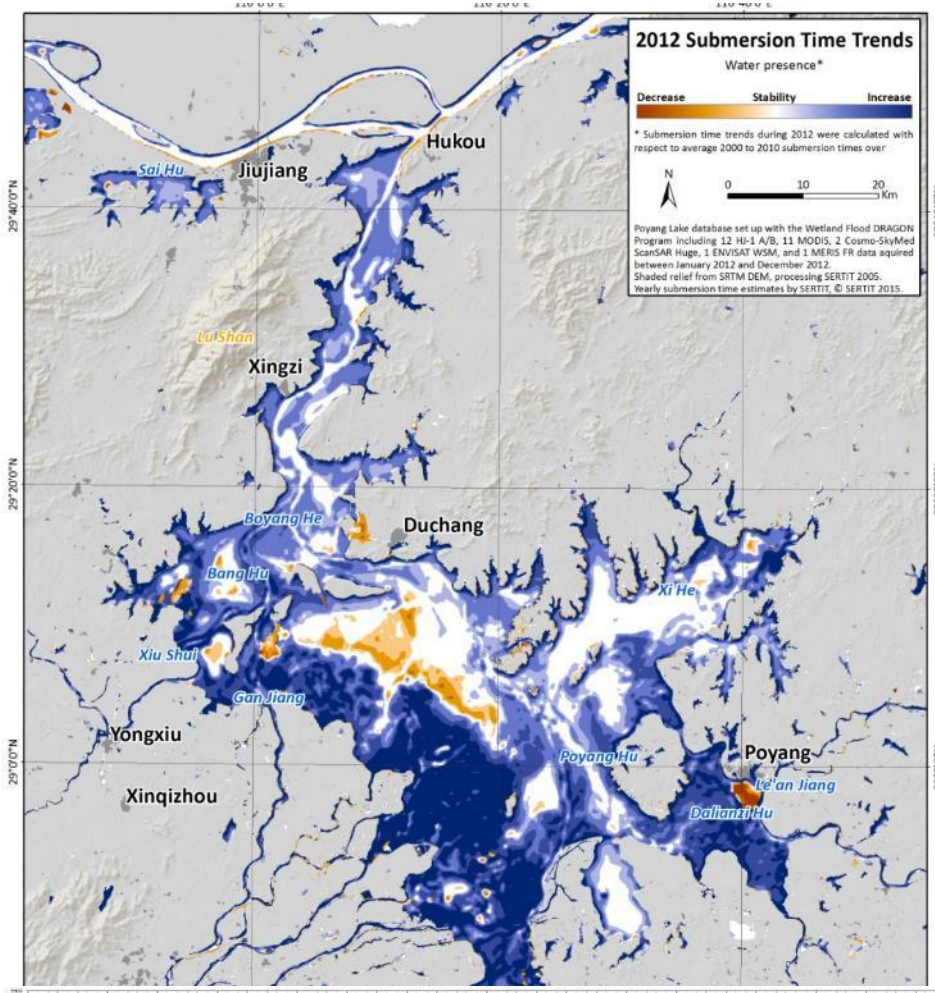
⇒ In literature draw off; Mid September, mid October

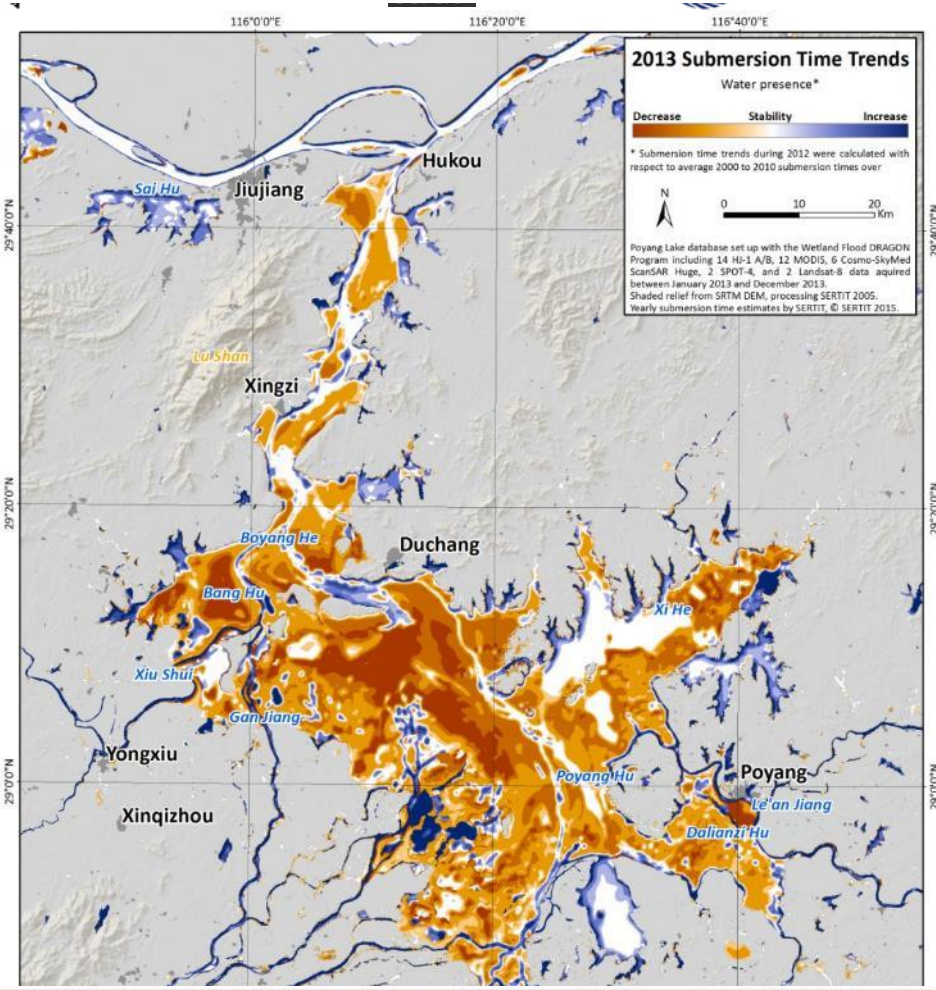
⇒ Draw off becomes very early over the years with a shortness of the inundation period

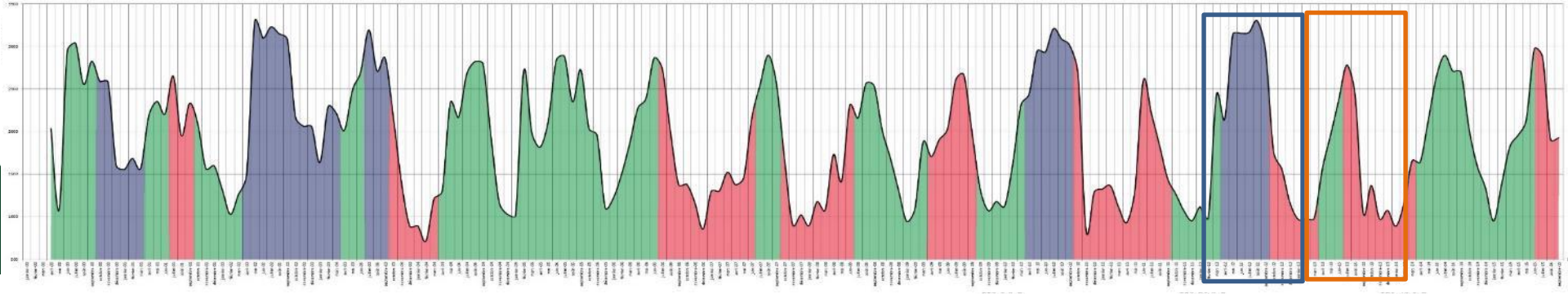
- ⇒ First time observed in mid August 2016
- ⇒ In 2011 very short flooding period, max in 25-06
- ⇒ In 2013, redraw in mid-July
- ⇒ In 2015 same behaviors, max flood extent in end of June



Water extent monitoring: Submersion time: residual analysis







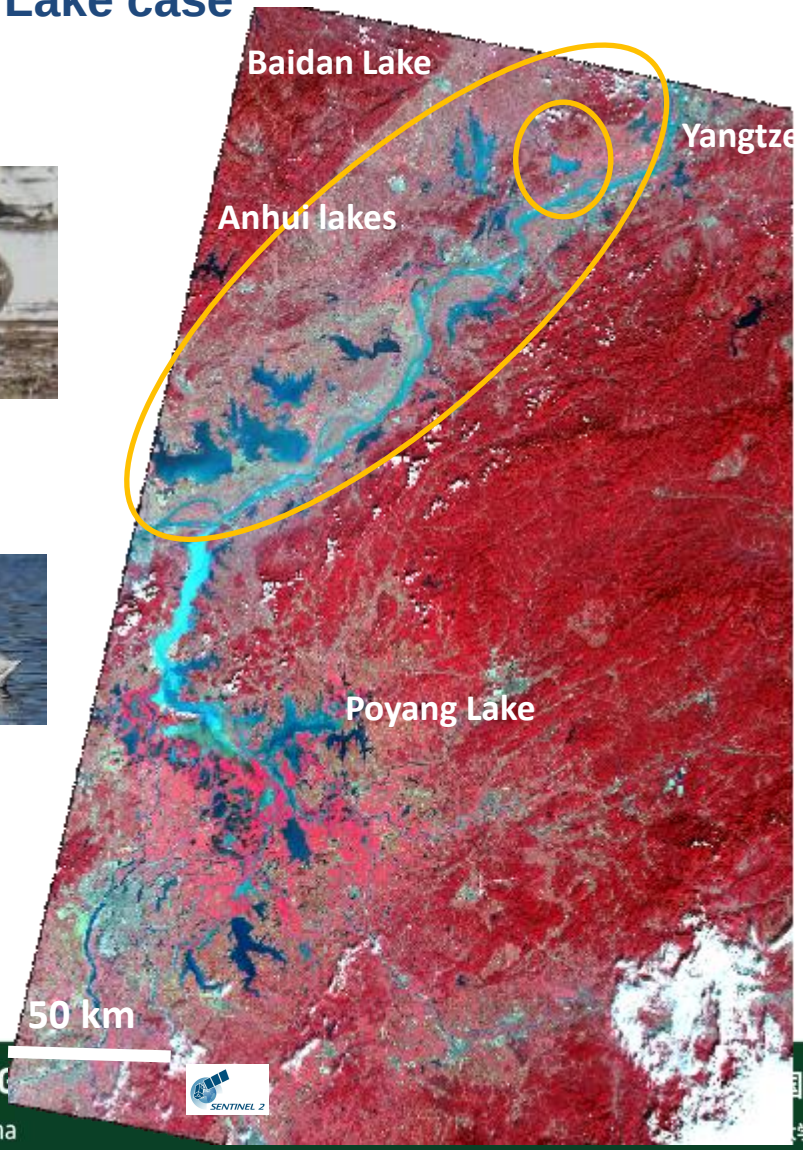
Monitoring aquatic vegetation of small lakes Anhui Province China: Baidan Lake case

Context:

Aquatic vegetation, generally existing in the shallow near-shore area, is a key component of lake ecosystems.

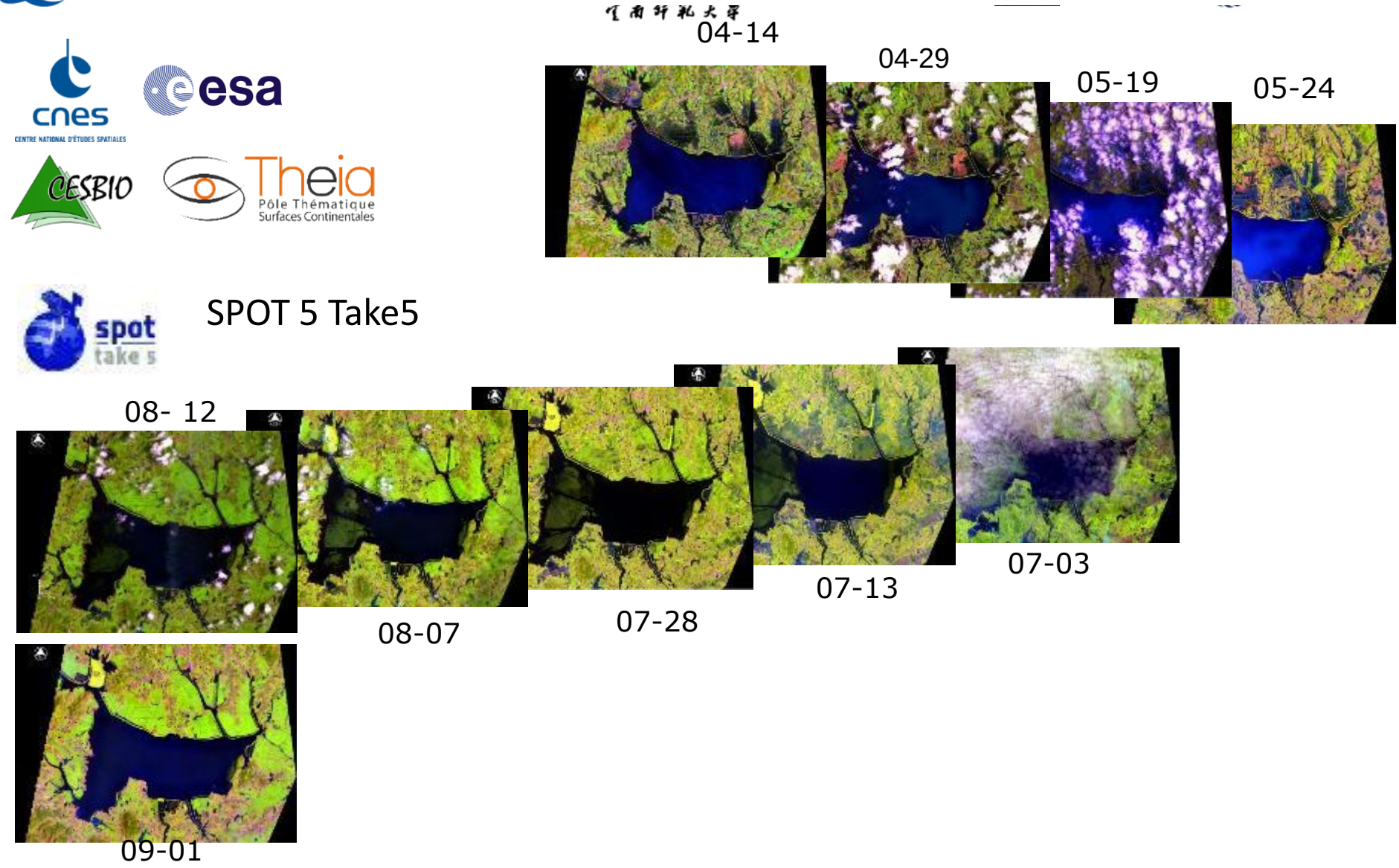
Providing food, shelter and breeding habitats for aquatic animals like invertebrates, fish and wading birds,

=>helps maintain the balance of the lake ecosystem.



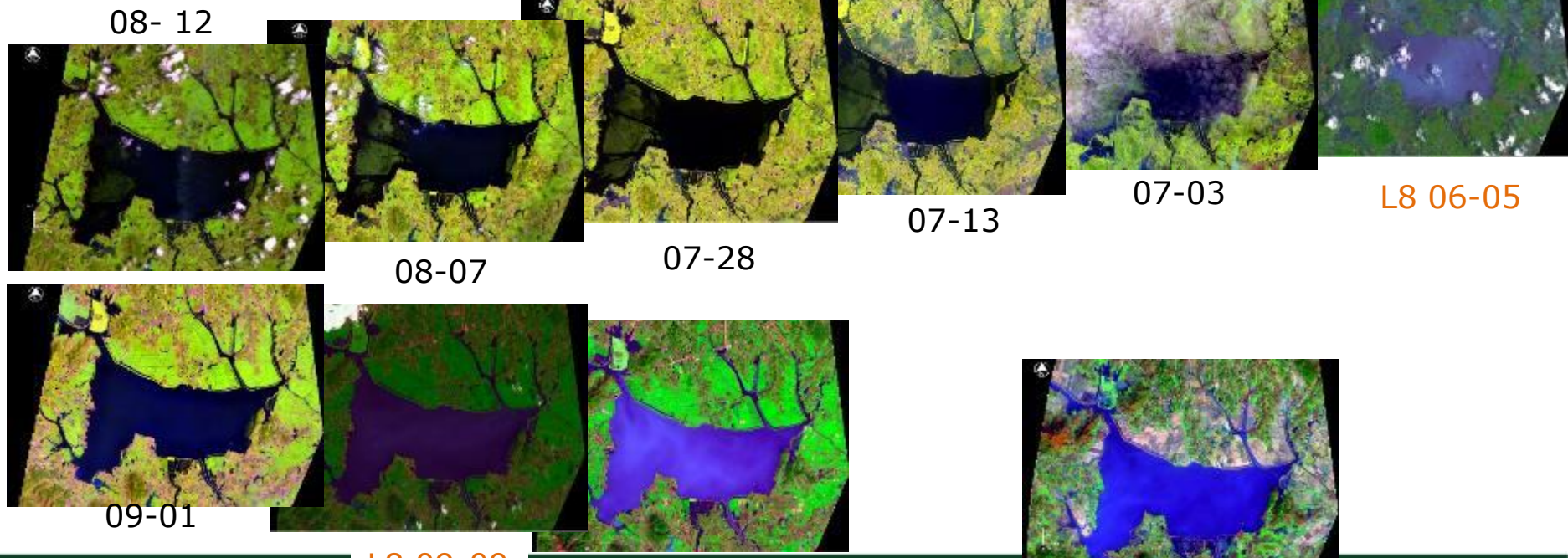
Exploitation of Sentinel2 and Sentinel2 like times series

SPOT 5 Take5

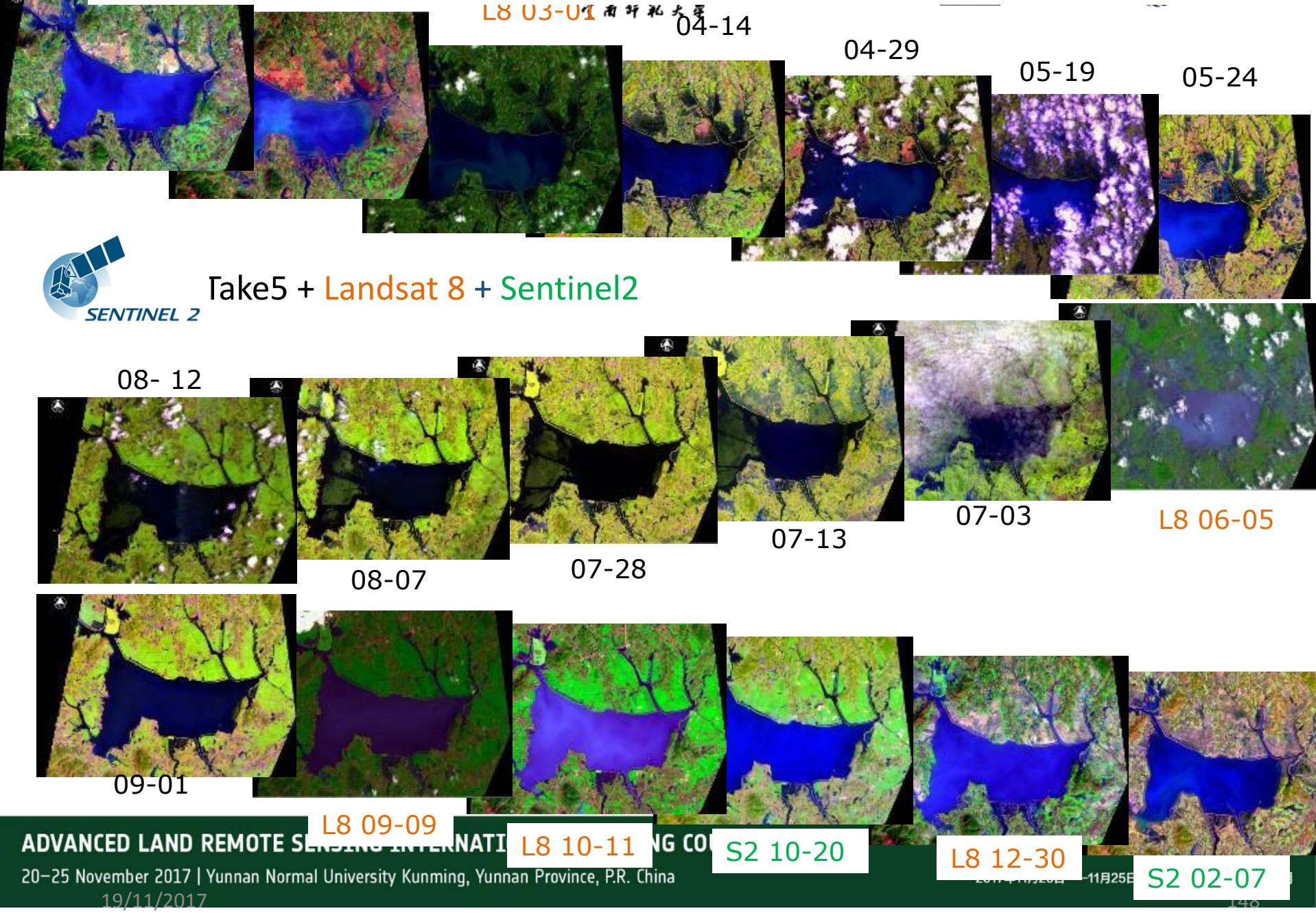


Exploitation of Sentinel2 and Sentinel2 like times series

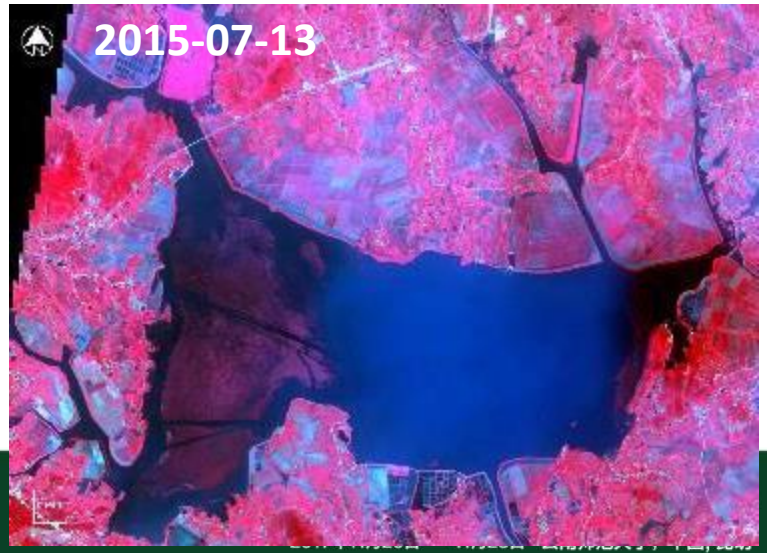
Take5 + Landsat 8



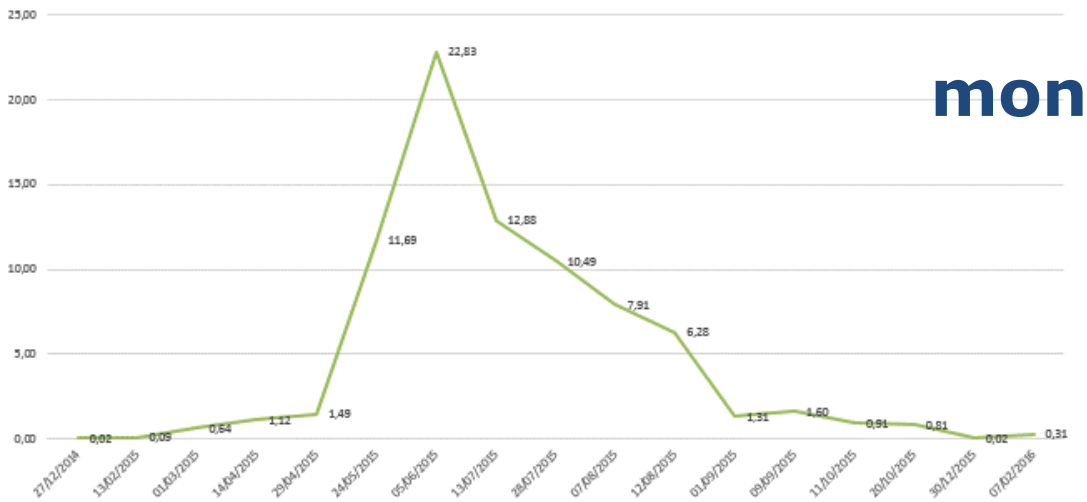
Exploitation of Sentinel2 and Sentinel2 like times series

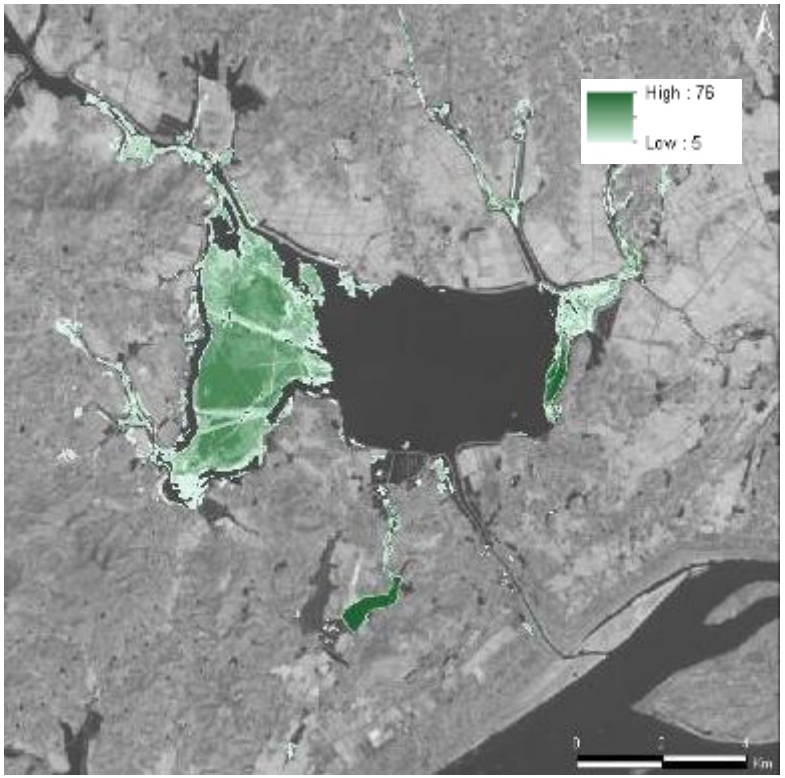


Acquatic vegetation monitoring: Baidan Lake



Aquatic vegetation monitoring: Baidan Lake





Very rapid onset of aquatic vegetation between the end of April (29 with 1,12 km²) and end of May (24 with 11,7 km²)

A peak on the 5 of June (22 km² ie near 50% of water surface)
=> correlated with the spring warm up

West part of the lake mostly affected and a lesser level the Eastern part

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
- Interest for SWIR bands

Elements for water bodies extraction based on optical imagery

Optical sensors for water bodies and/or flood mapping
- Medium
- High resolution
- VHR sensors

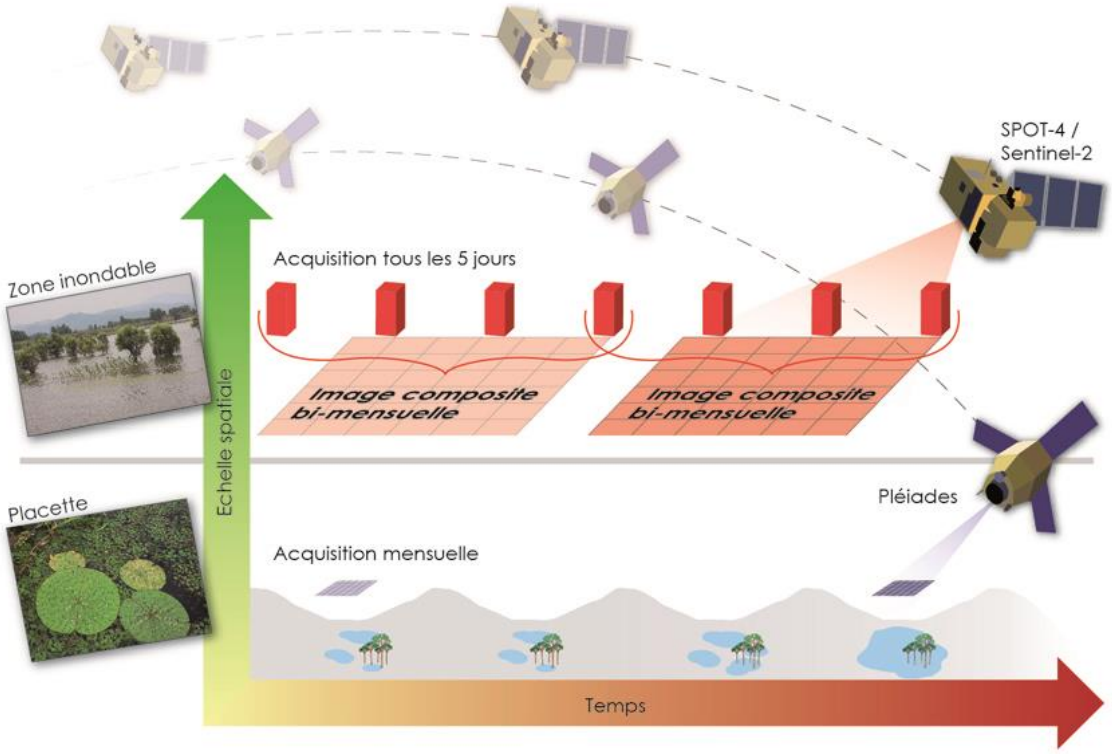
Water level from space
- Principles of altimetry
- Altimetry missions past, present futures
- Altimetry database

Flood plain and lakes monitoring
- Short term Monitoring
- Long term monitoring
- Meteo climato parameters

Concluding remarks

Exploited EO data for water bodies monitoring

Multi mission approach
MR; HR and VHR images
SAR & optical

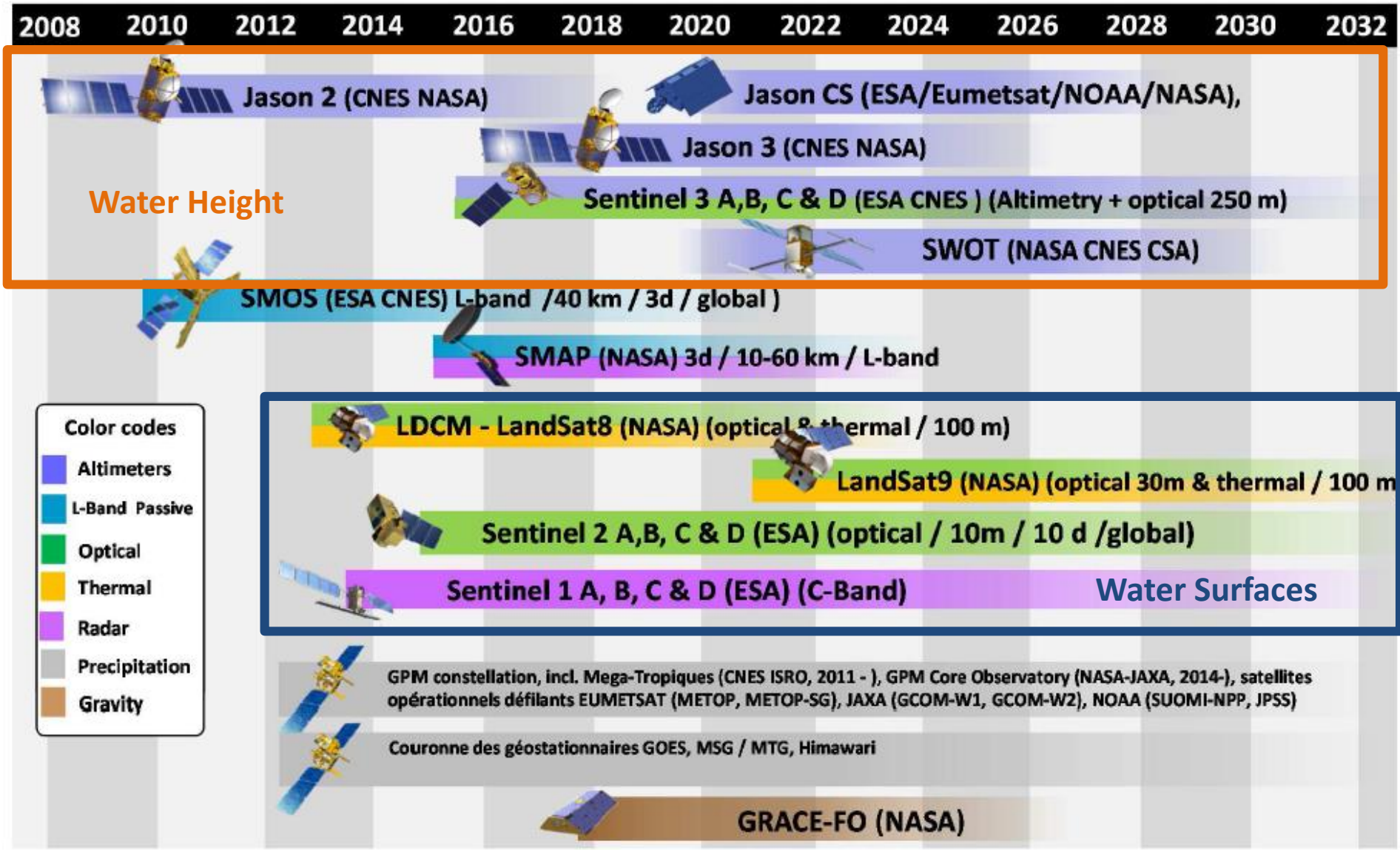


To derive

1. Detailed LC/LU maps
2. Vegetation maps
3. Water extent
4. Water path
5. Water quality
6. High precision DTM

Exploit the rich archives !!!!

EO sensors for hydrology



Floods & Lakes Monitoring

Optical Part

ESA–MOST Dragon 4 Cooperation

ADVANCED LAND REMOTE SENSING
INTERNATIONAL TRAINING COURSE

“龙计划4”高级陆地遥感国际培训班

Dr Hervé YESOU

D3OT -L2

Wenesday 26 of November 2017

20–25 November 2017 | Yunnan Normal University
Kunming, Yunnan Province, P.R. China

2017年11月20日——11月25日
云南师范大学，中国, 昆明