



Earth Observation Principles and Applications

**ESA Earth Observation Programme and related educational programme.
Data access**

8th ESA Training Course on Radar and Optical Remote Sensing, 5 - 9 September, 2016, Cesis, Latvia

Francesco Sarti, ESA

22 MEMBER STATES AND GROWING



ESA has 22 Member States: 20 states of the EU (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Poland, Portugal, Romania, Spain, Sweden, UK) **plus Norway and Switzerland.**

Other EU states have Cooperation Agreements with ESA, such as Bulgaria, Cyprus, Lithuania and Malta. **Latvia**, Slovenia and Slovakia are participating in the Plan for European Cooperating States (PECS).

Canada takes part in some programmes under a Cooperation Agreement.

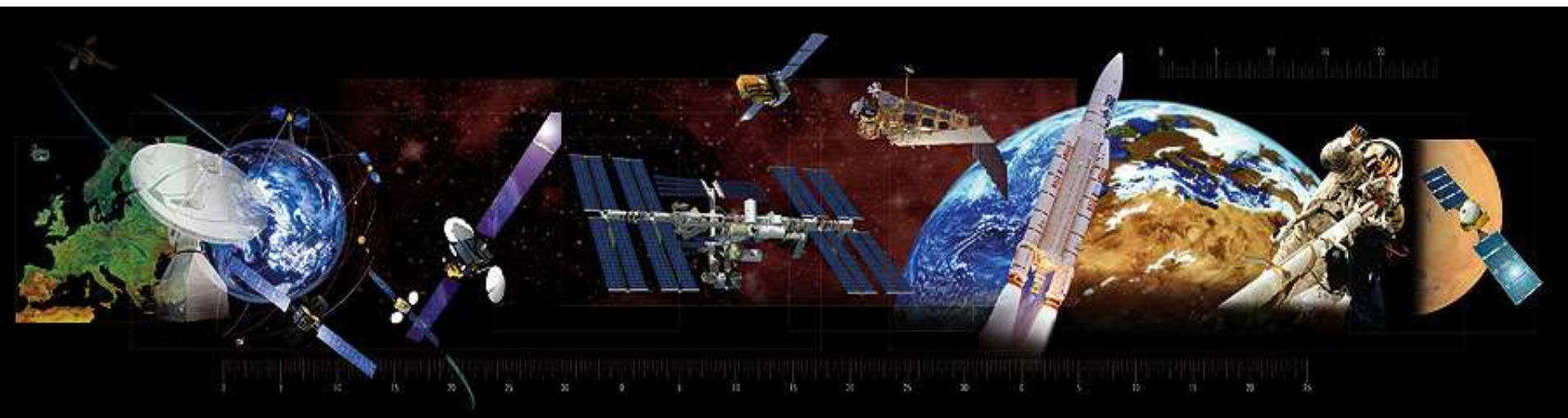


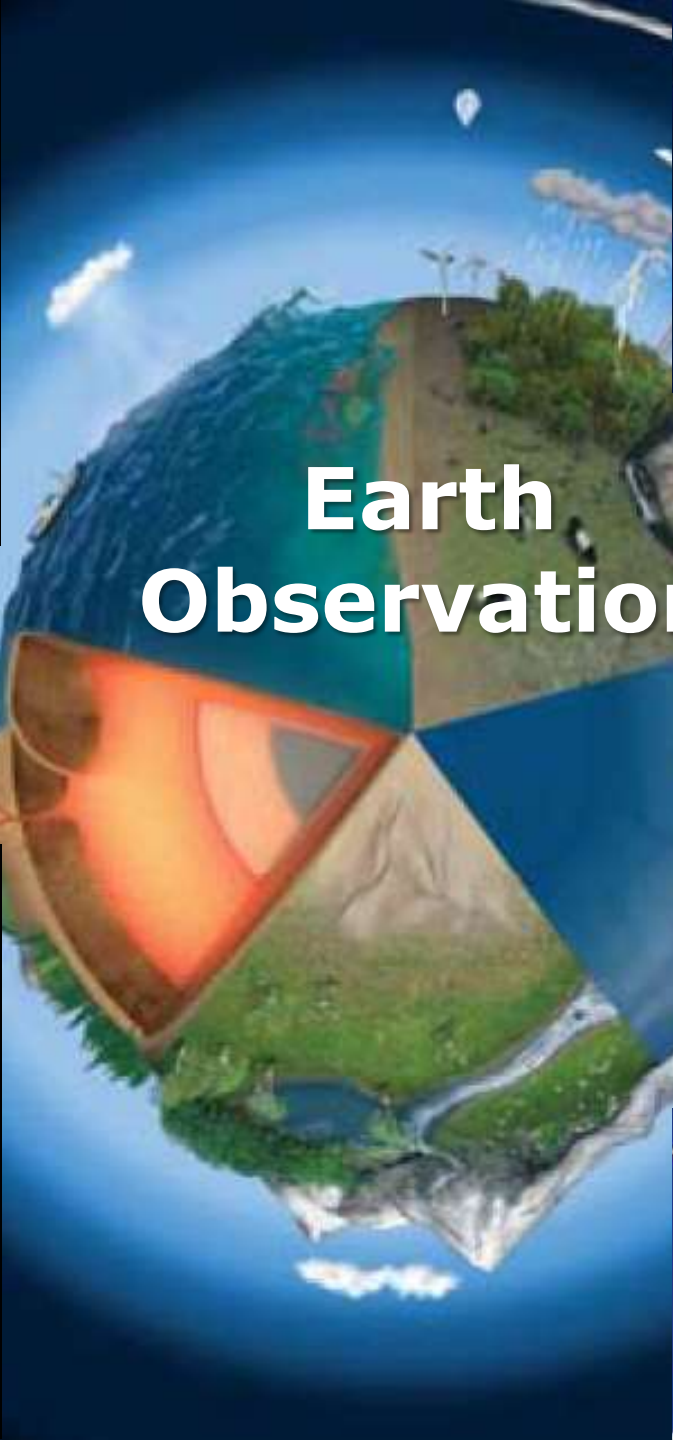
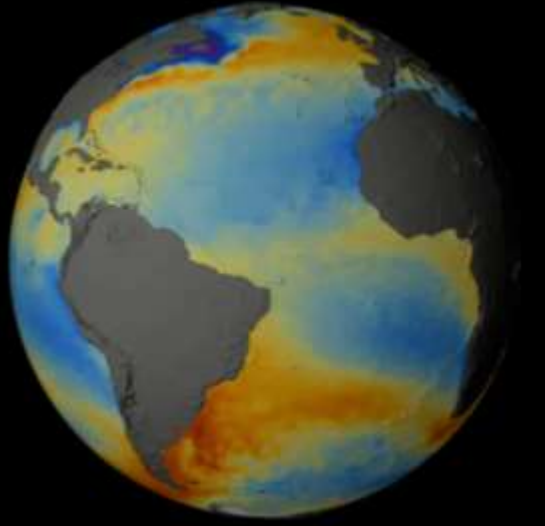
ACTIVITIES



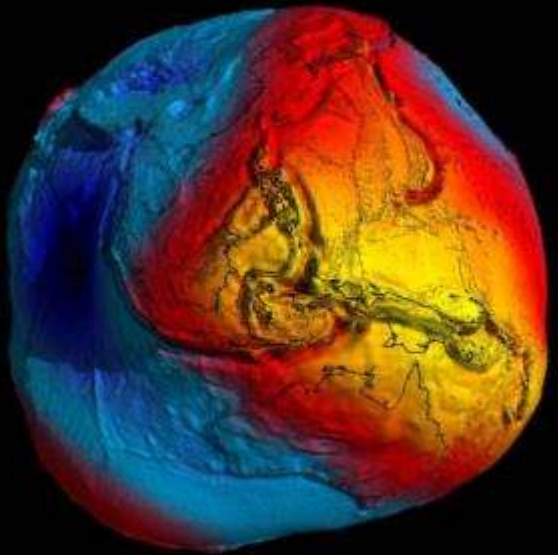
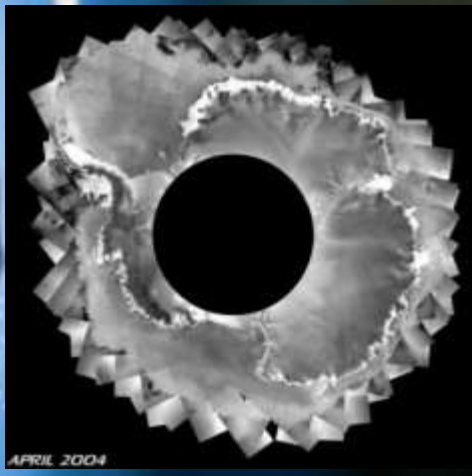
ESA is one of the few space agencies in the world to combine responsibility in nearly all areas of space activity.

- 1. Space science**
 - 2. Human spaceflight**
 - 3. Exploration**
 - 4. Earth observation**
 - 5. Launchers**
- Navigation**
 - Telecommunications**
 - Technology**
 - Operations**



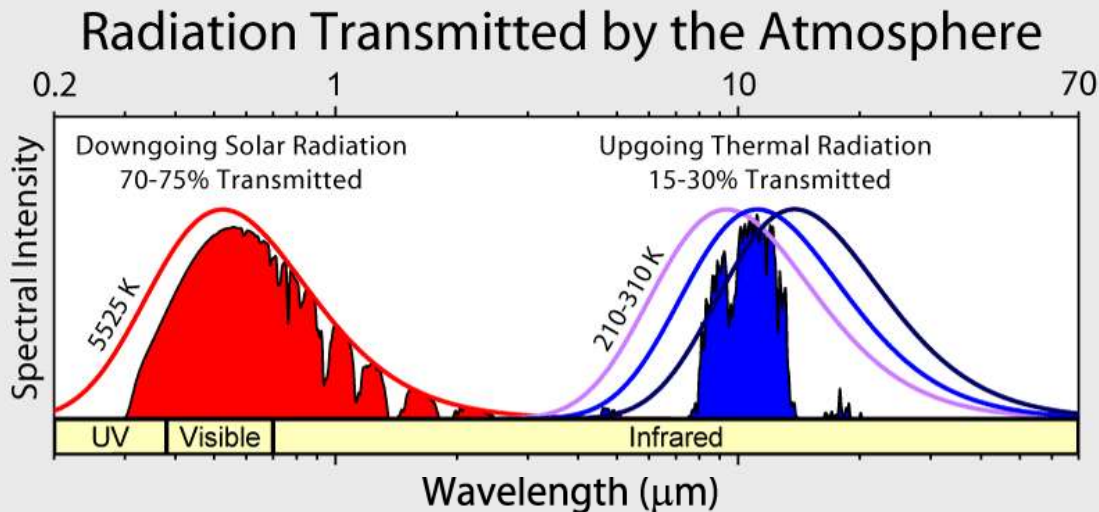
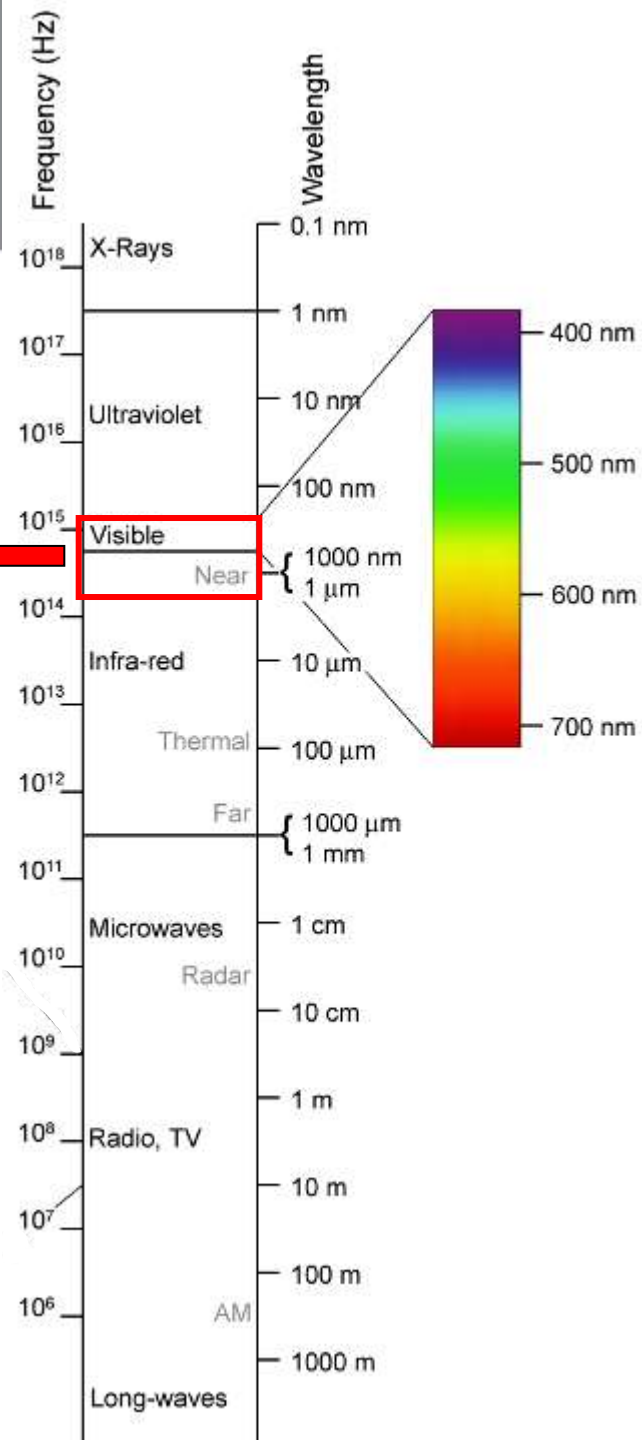


Earth Observation



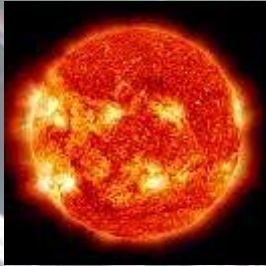
The electromagnetic spectrum

Visible (VIS) + Near Infrared (NIR) = Optical ←

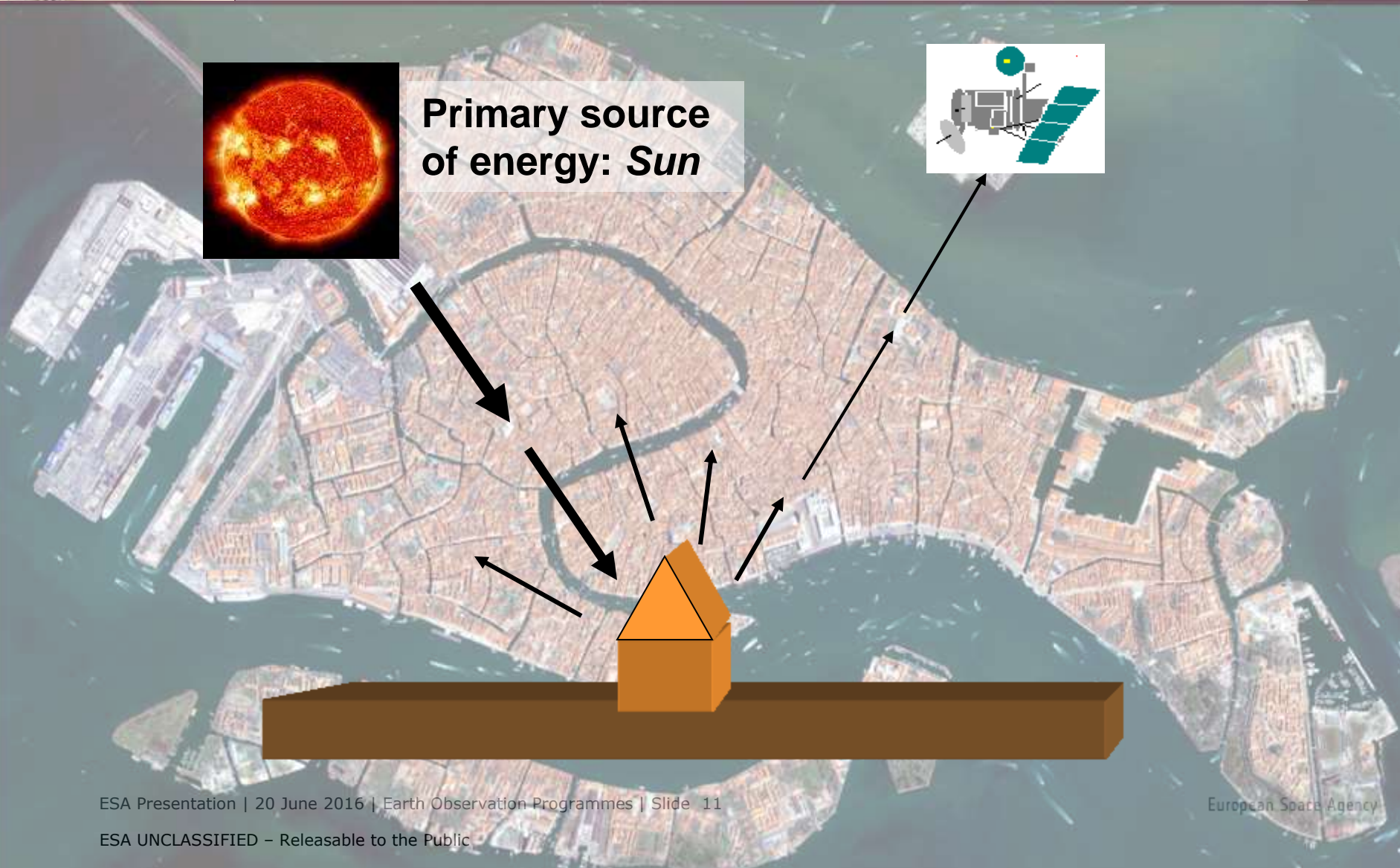
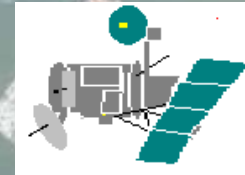




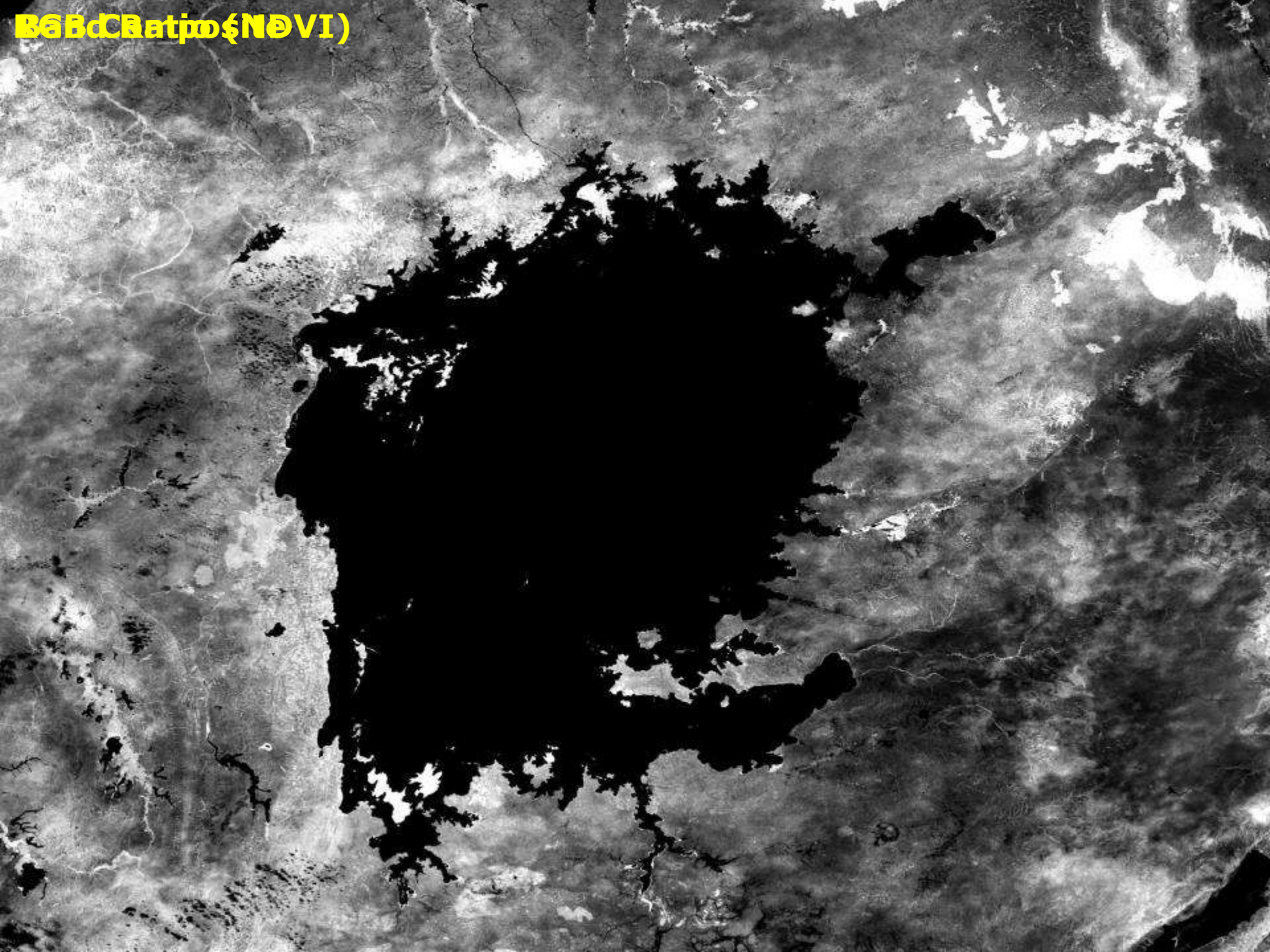
Passive Sensors



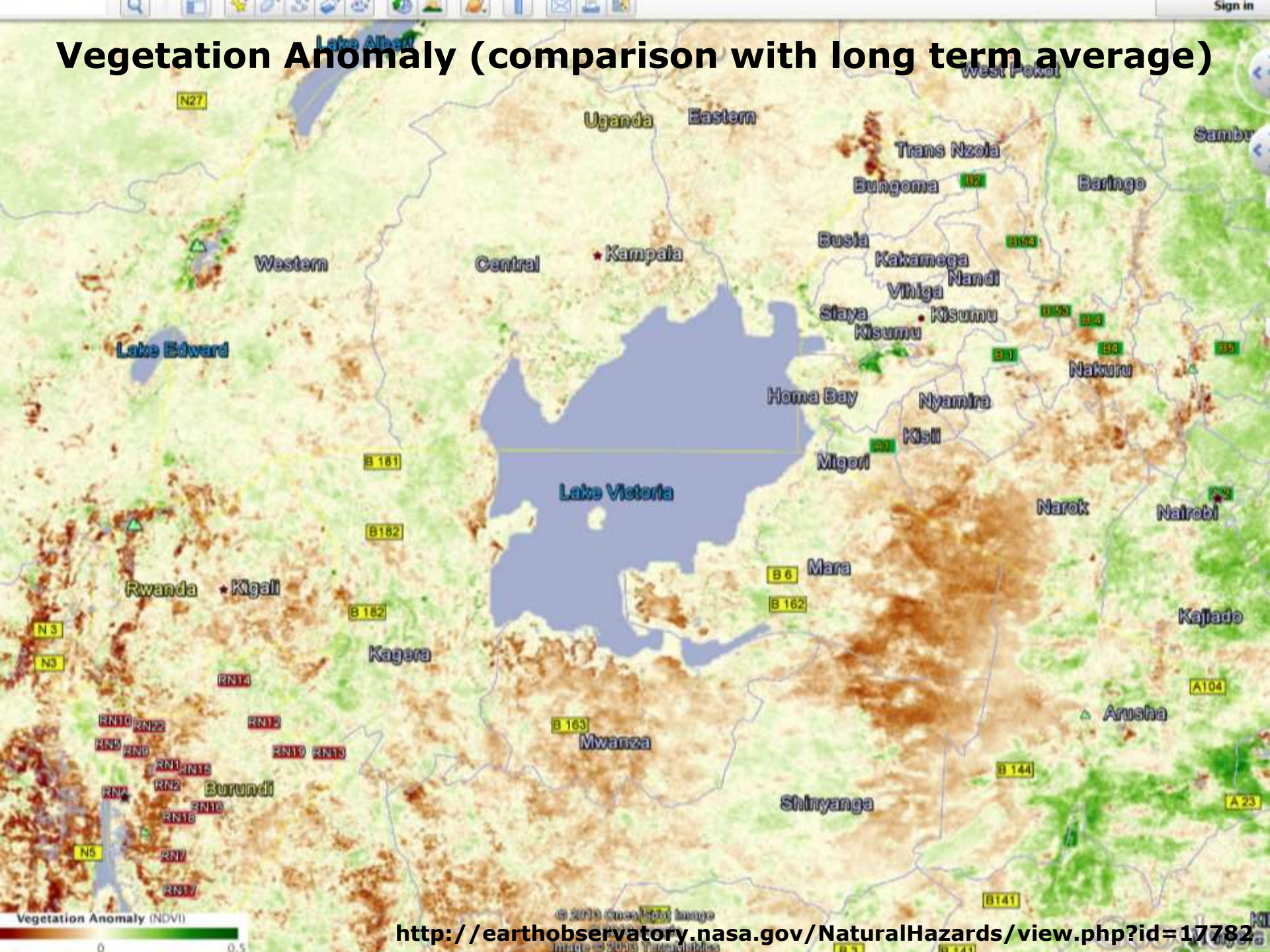
Primary source
of energy: *Sun*



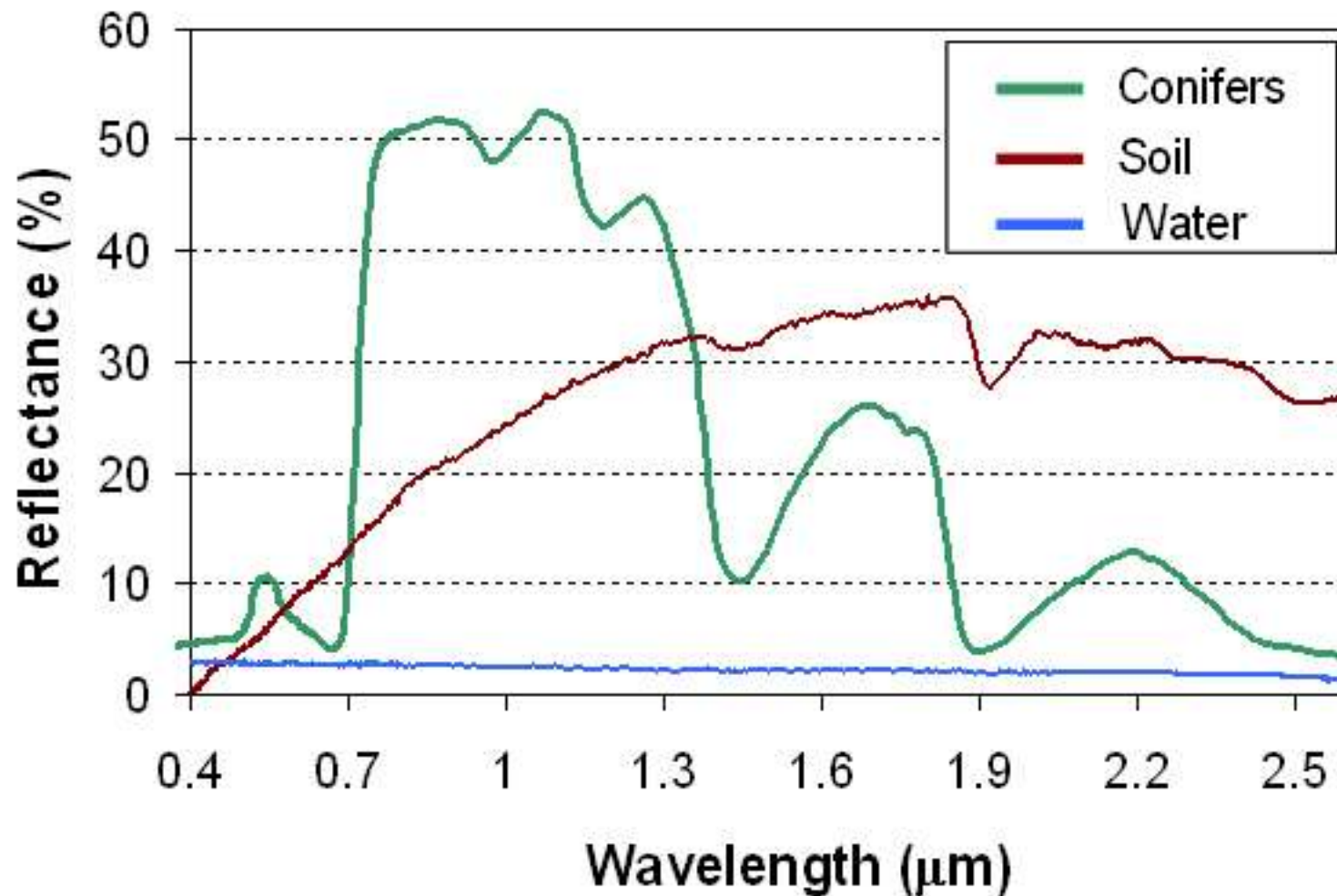
B&BdCBatp(\$NDVI)

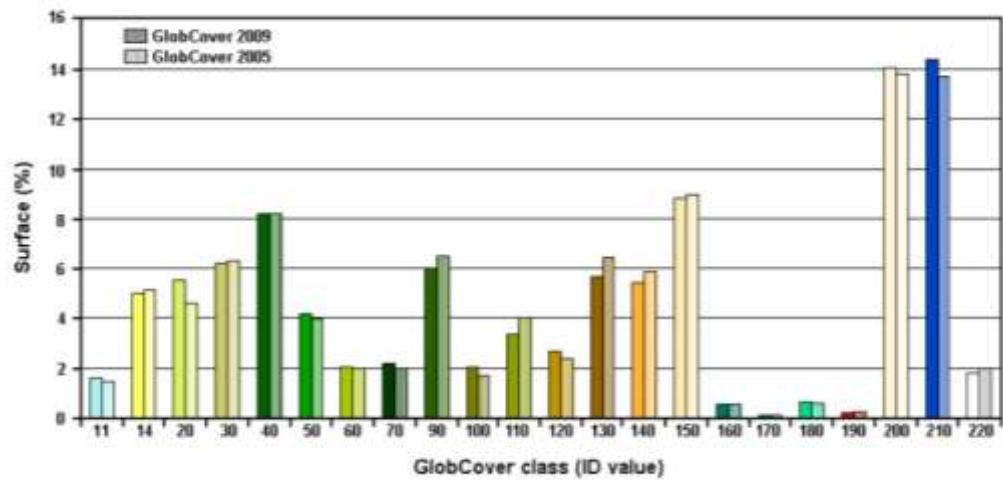
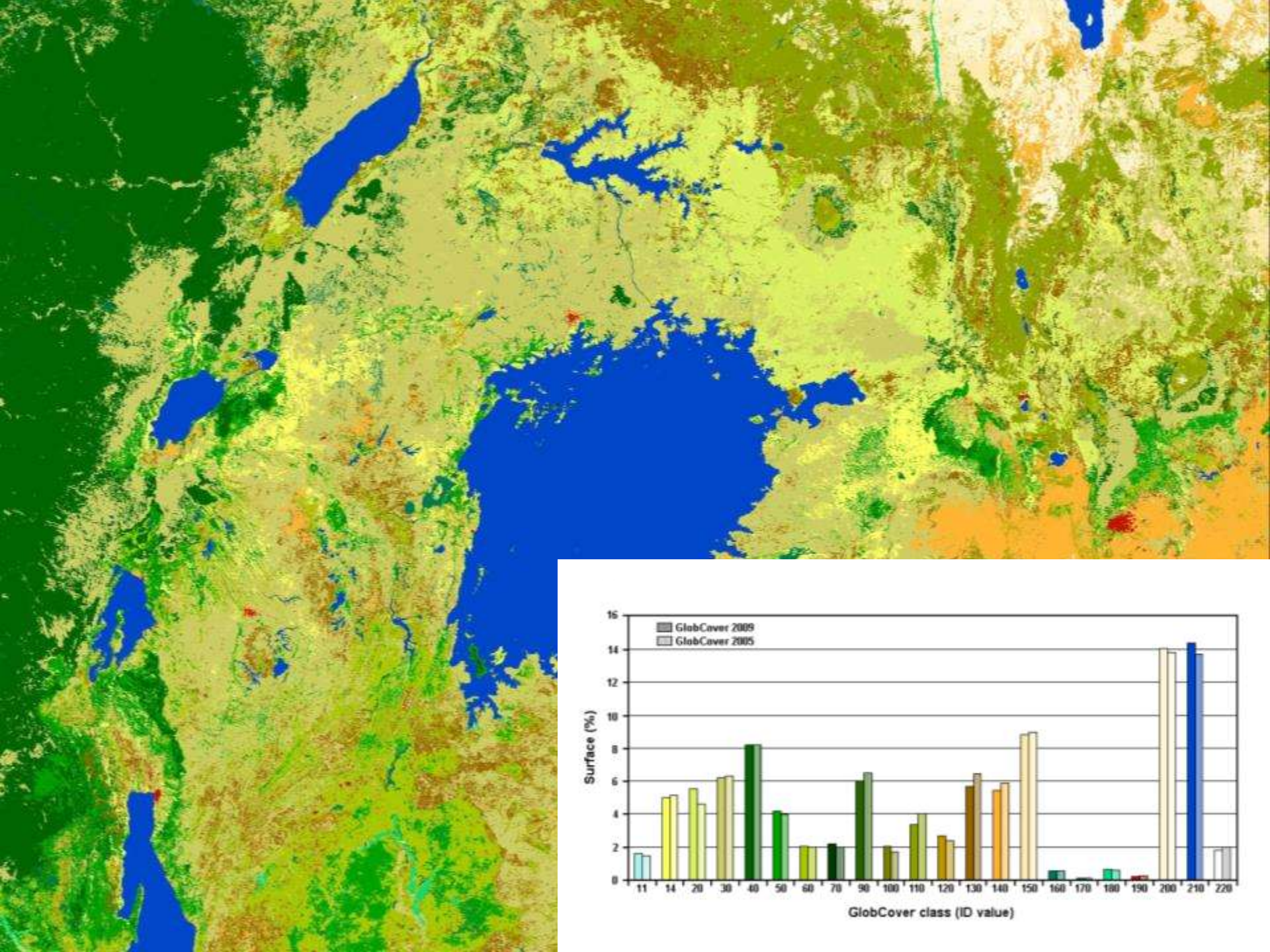


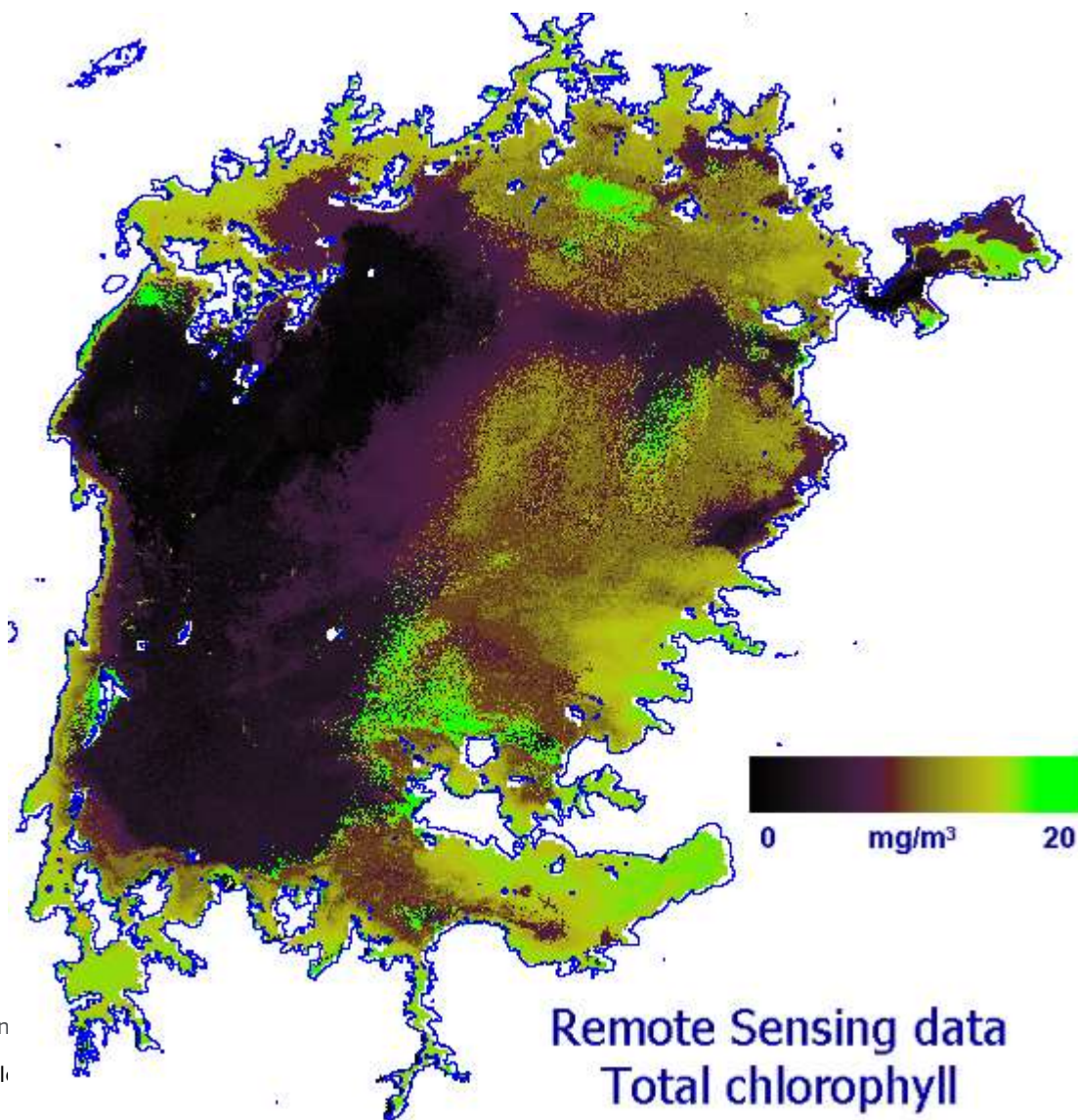
Vegetation Anomaly (comparison with long term average)

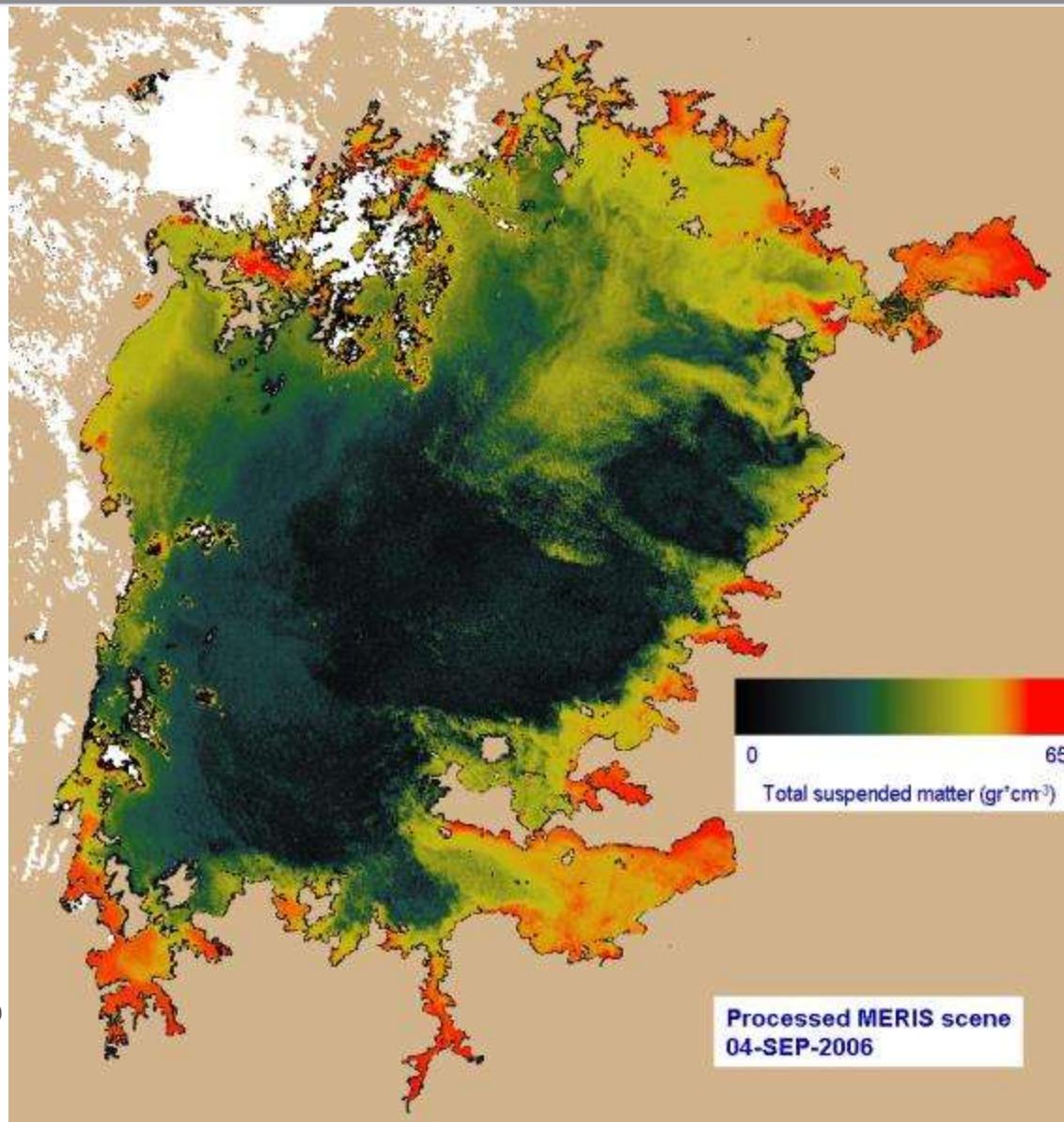


Spectral signatures

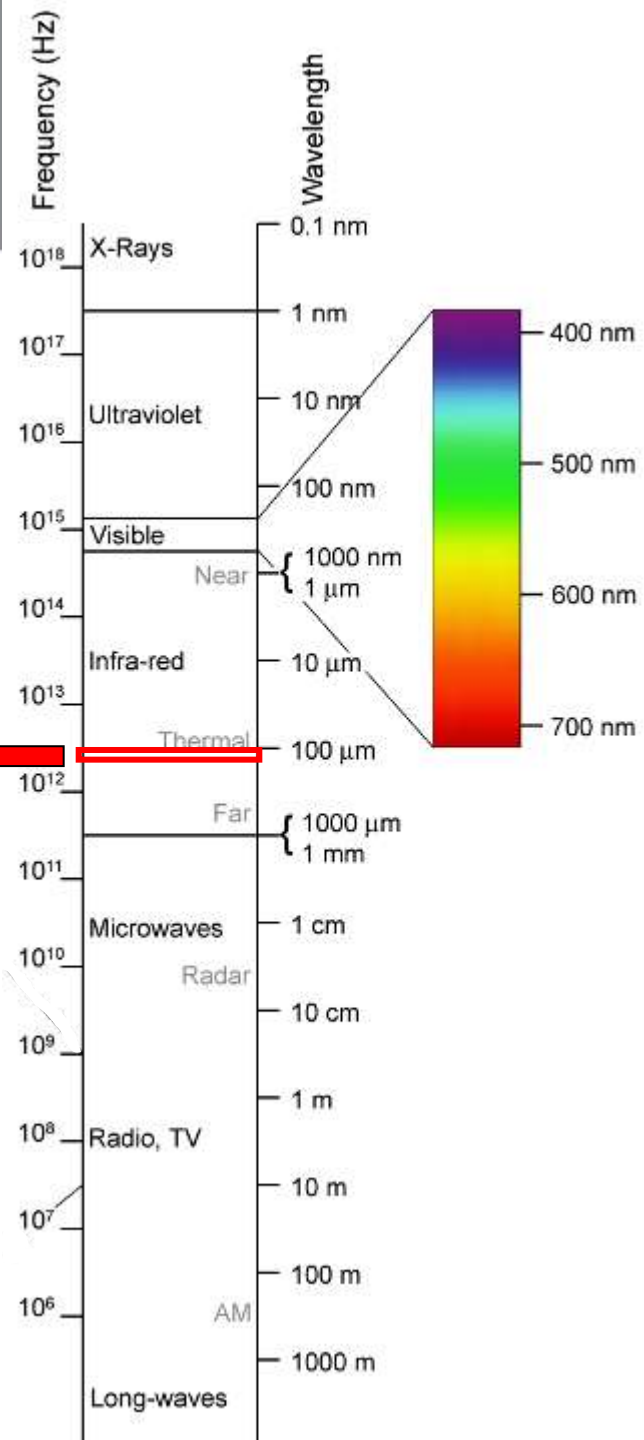




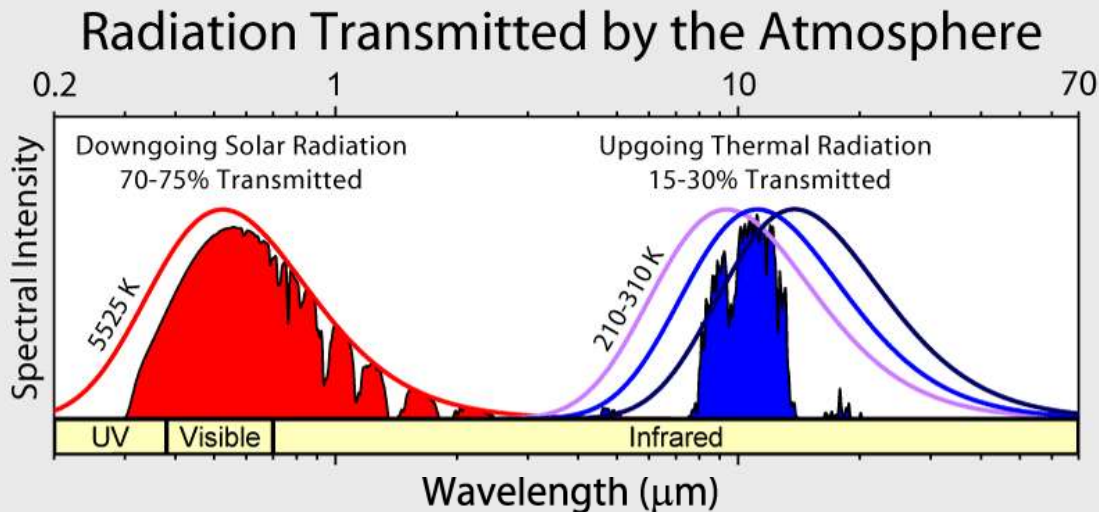




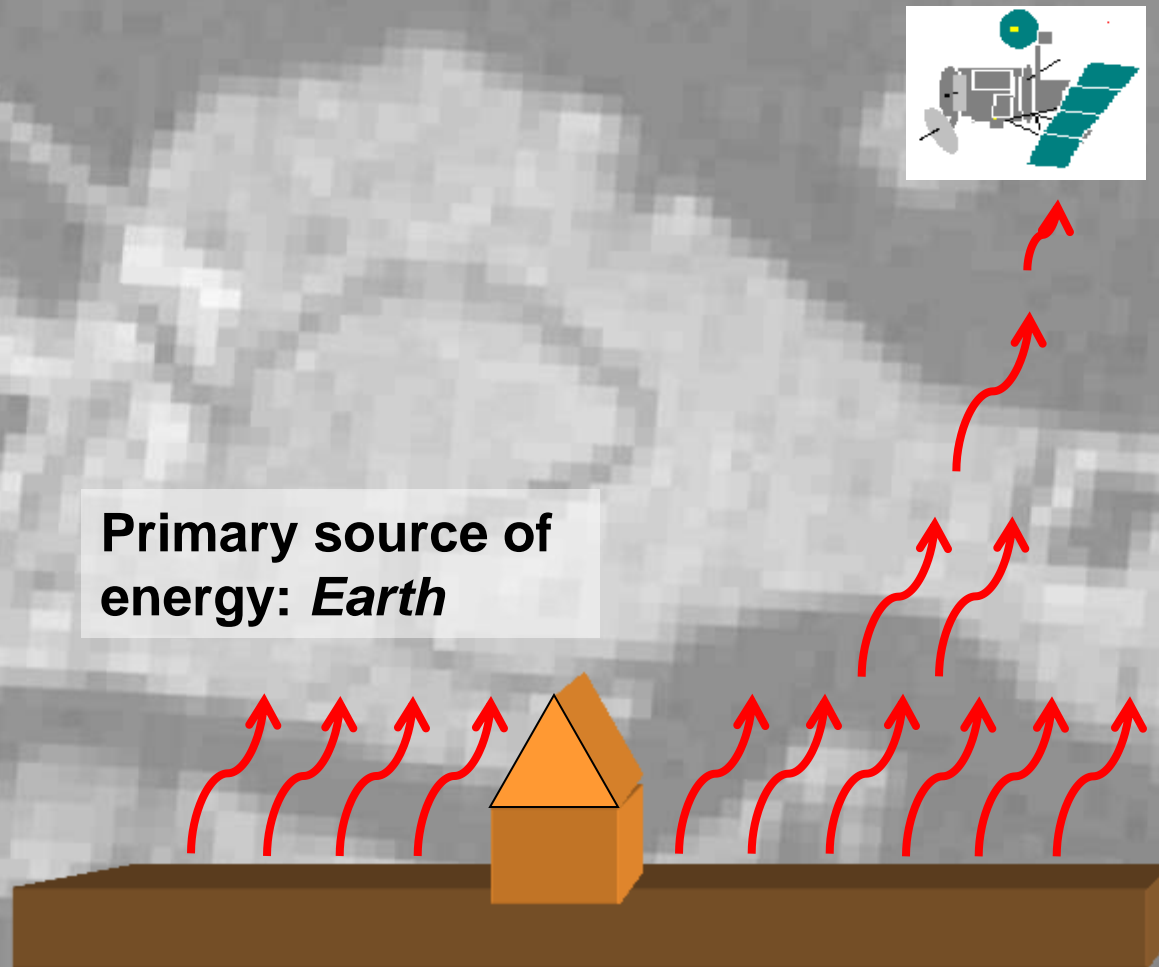
The electromagnetic spectrum



Thermal Infrared (TIR) ←



Passive Sensors



Derived from 3
AATSR scenes:

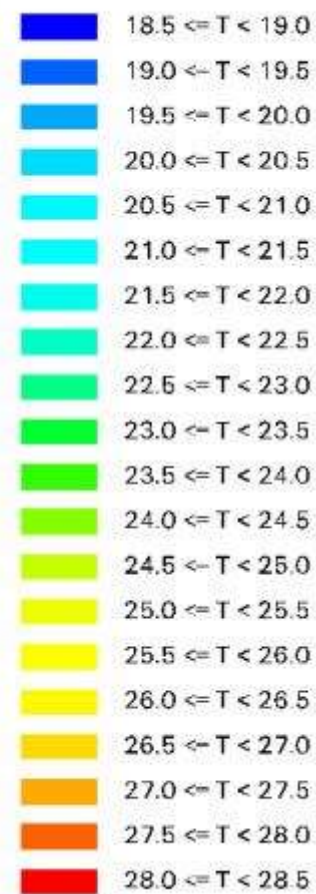
16-AUG-2006

19-AUG-2006

24-AUG-2006

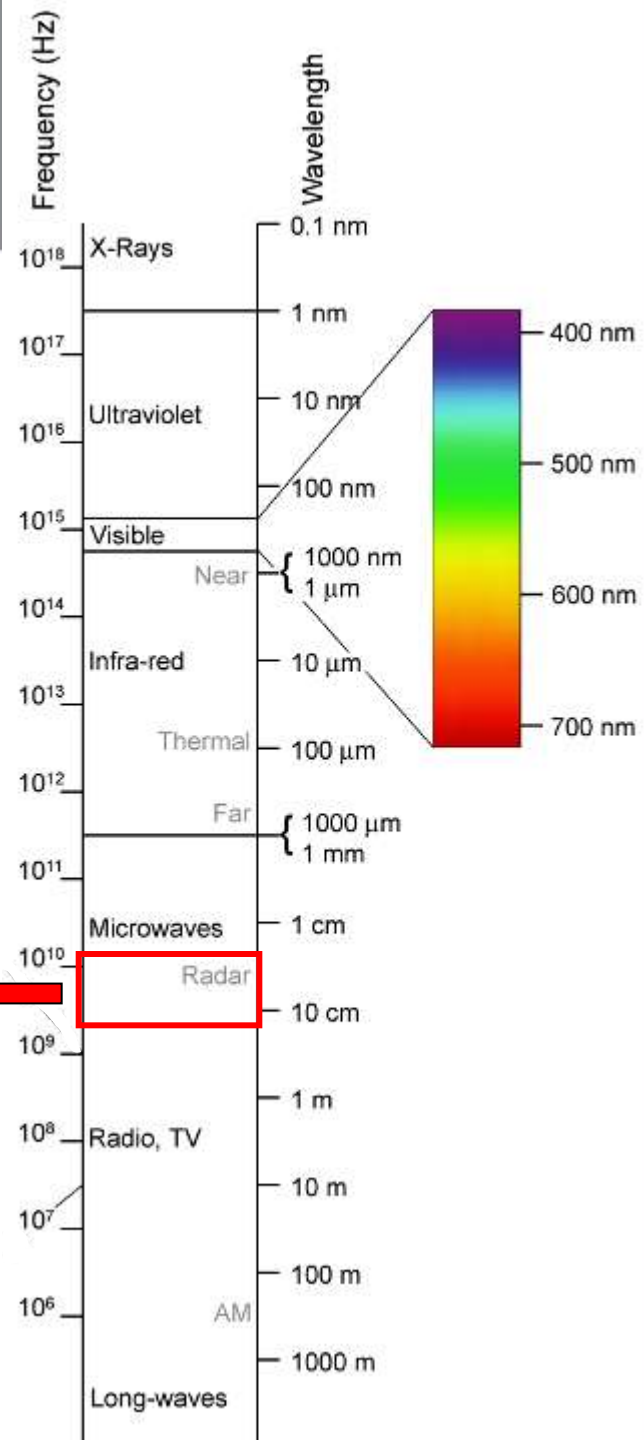
Legend

Temperature ($^{\circ}\text{C}$)



The electromagnetic spectrum

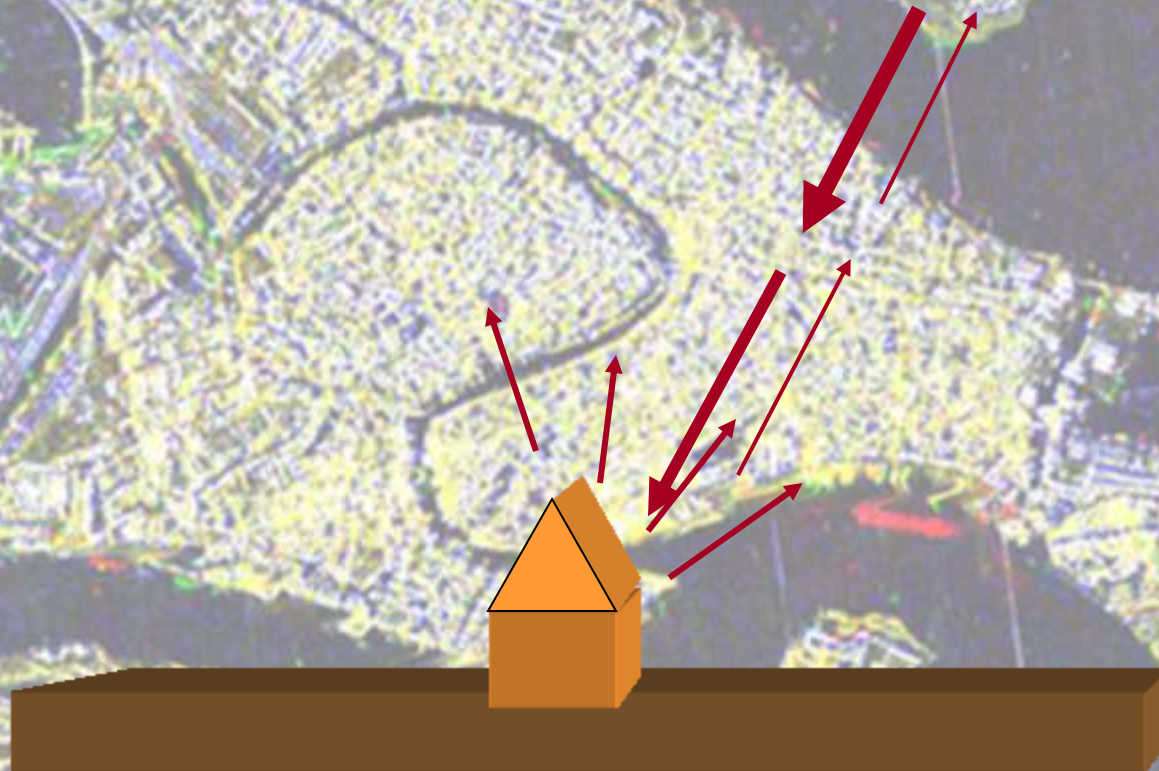
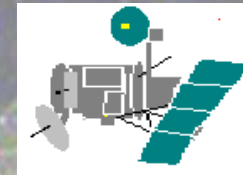
Synthetic Aperture Radar (SAR)





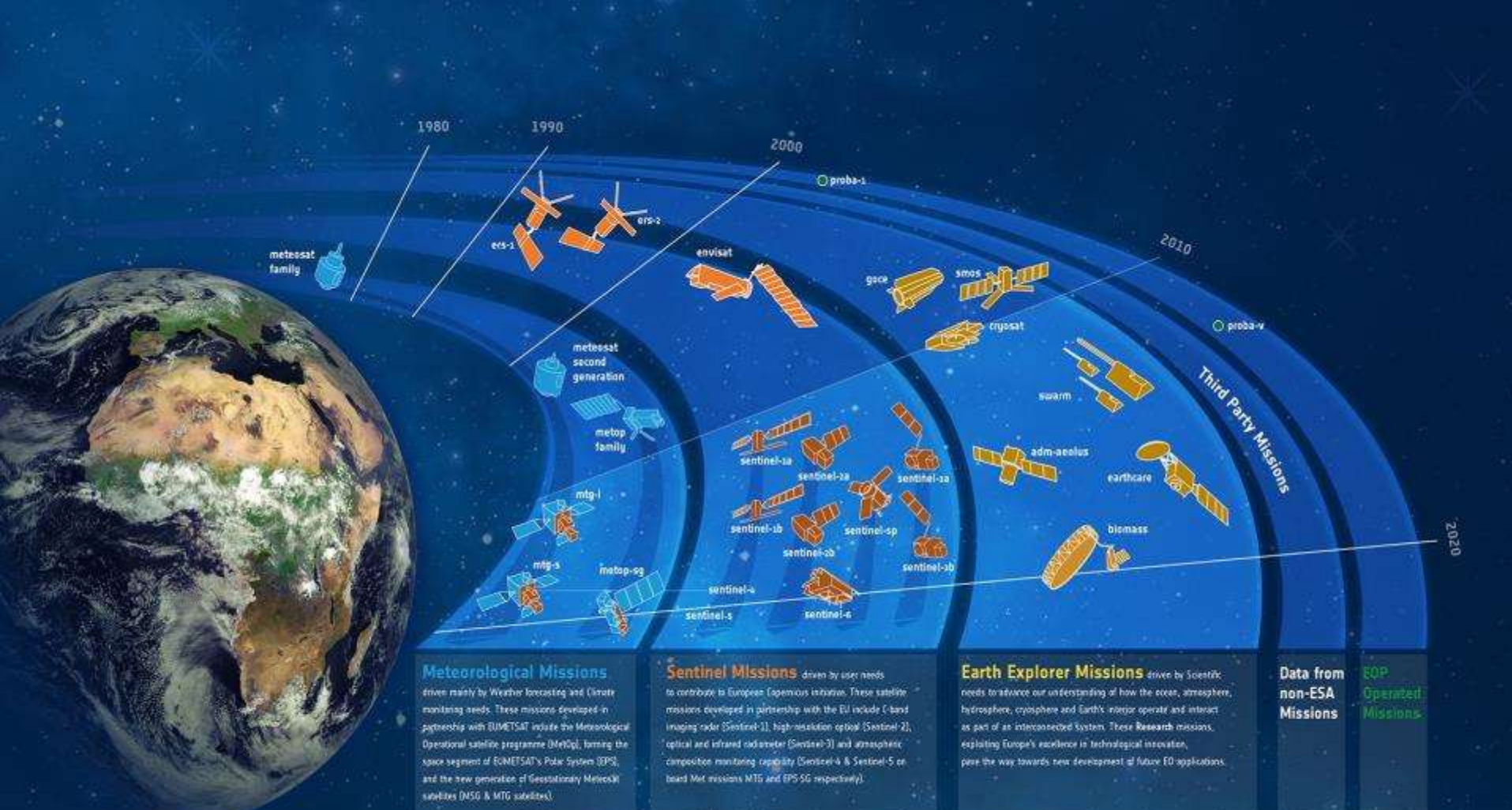
Active Sensors

Source of energy:
Satellite

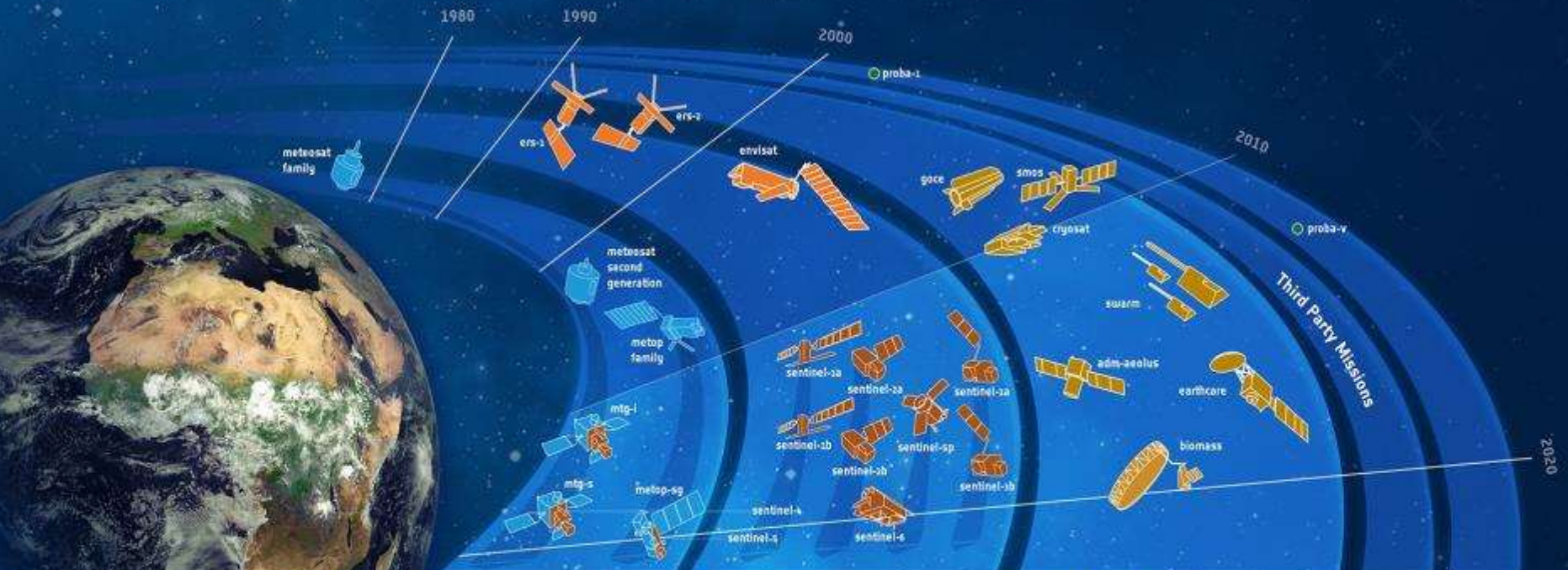




ESA Earth Observation Programmes



ESA Earth Observation Programmes



Meteorological Missions
 driven mainly by Weather forecasting and Climate monitoring needs. These missions developed in partnership with EUMETSAT include the Meteorological Operational satellite programme (MetOp), forming the space segment of EUMETSAT's Polar System (EPS), and the new generation of Geostationary Meteosat satellites (MSG & MTG satellites).

Meteorological Programme

Sentinel Missions driven by user needs to contribute to European Copernicus initiative. These satellite missions developed in partnership with the EU include C-band imaging radar (Sentinel-1), high-resolution optical (Sentinel-2), optical and infrared radiometer (Sentinel-3) and atmospheric composition monitoring capability (Sentinel-4 & Sentinel-5 on board Met missions MTG and EPS-SG respectively).

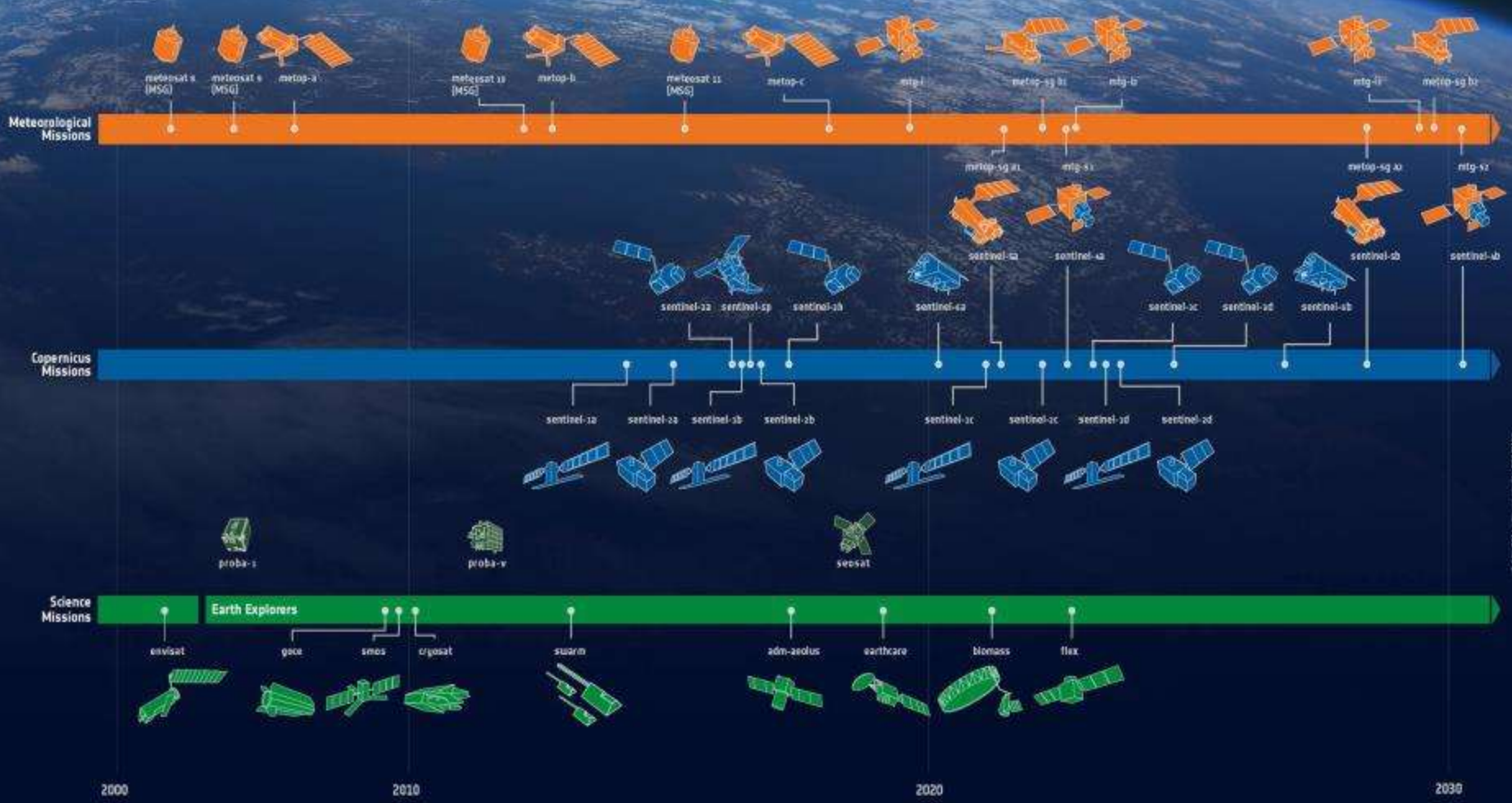
Copernicus Programme

Earth Explorer Missions driven by Scientific needs to advance our understanding of how the ocean, atmosphere, hydrosphere, cryosphere and Earth's interior operate and interact as part of an interconnected system. These Research missions, exploiting Europe's excellence in technological innovation, pave the way towards new development of future EO applications.

Earth Observation Envelope Programme

Data from non-ESA Missions
 EOP Operated Missions

→ ESA DEVELOPED EARTH OBSERVATION MISSIONS



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The Heritage: ERS and Envisat data



- ERS and Envisat missions 1991-2012
- More than 2 Petabytes of data
- Two decades of global change records
- Need for preservation, availability and exploitation



Michelson Interferometric Passive

Atmospheric Sounder

MIPAS

MERIS

Medium Resolution Imaging Spectrometer

GOMOS

Global Ozone Monitoring by Occultation of Stars

RA-2 Antenna

Radar Altimeter 2

LRR

AATSR Advanced Along Track Scanning Radiometer

SCIAMACHY Scanning Imaging Absorption Spectrometer for Atmospheric Cartography

MWR Microwave Radiometer

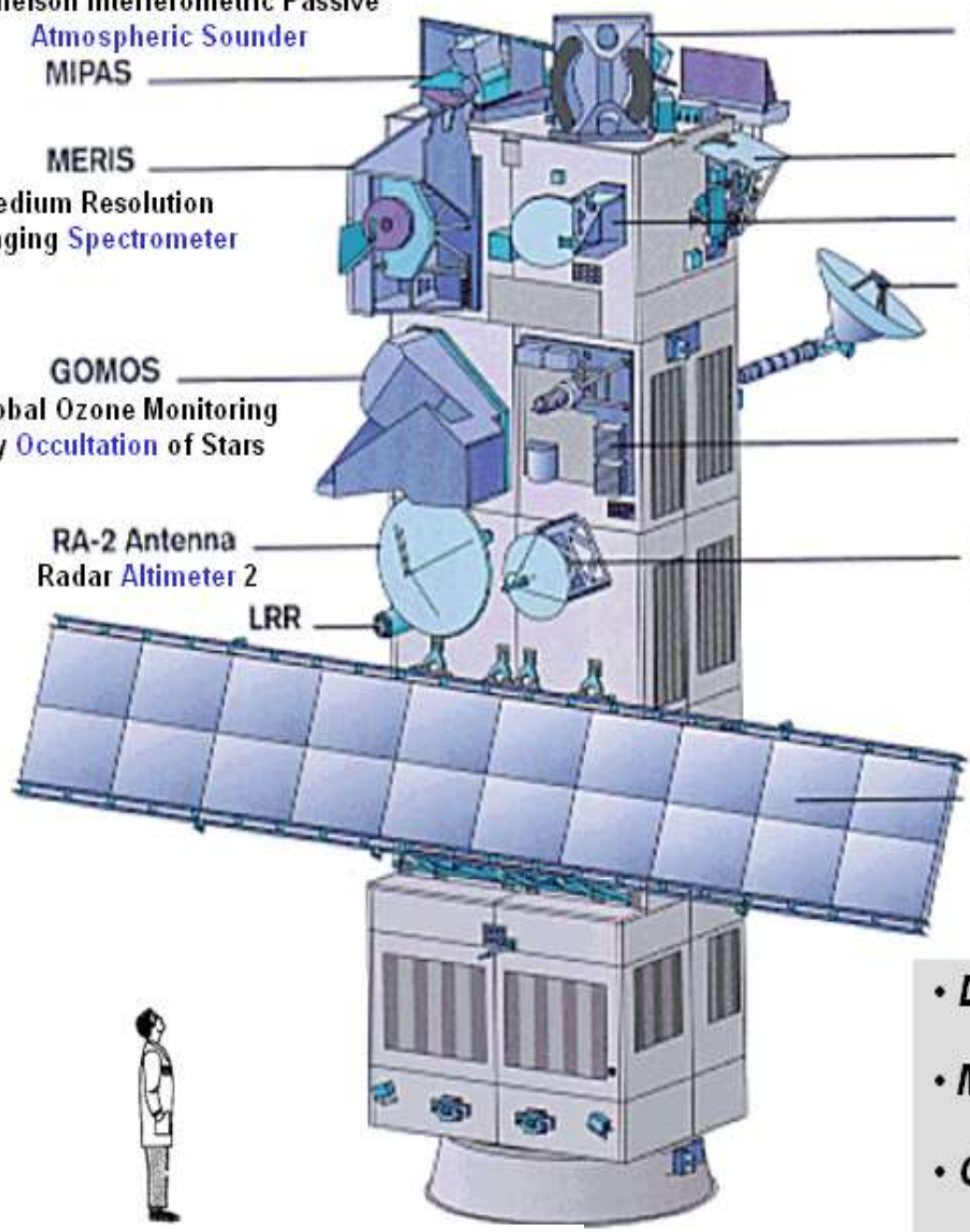
Ka-band Antenna

DORIS Doppler Orbitography and Radio-positioning Integrated by Satellite

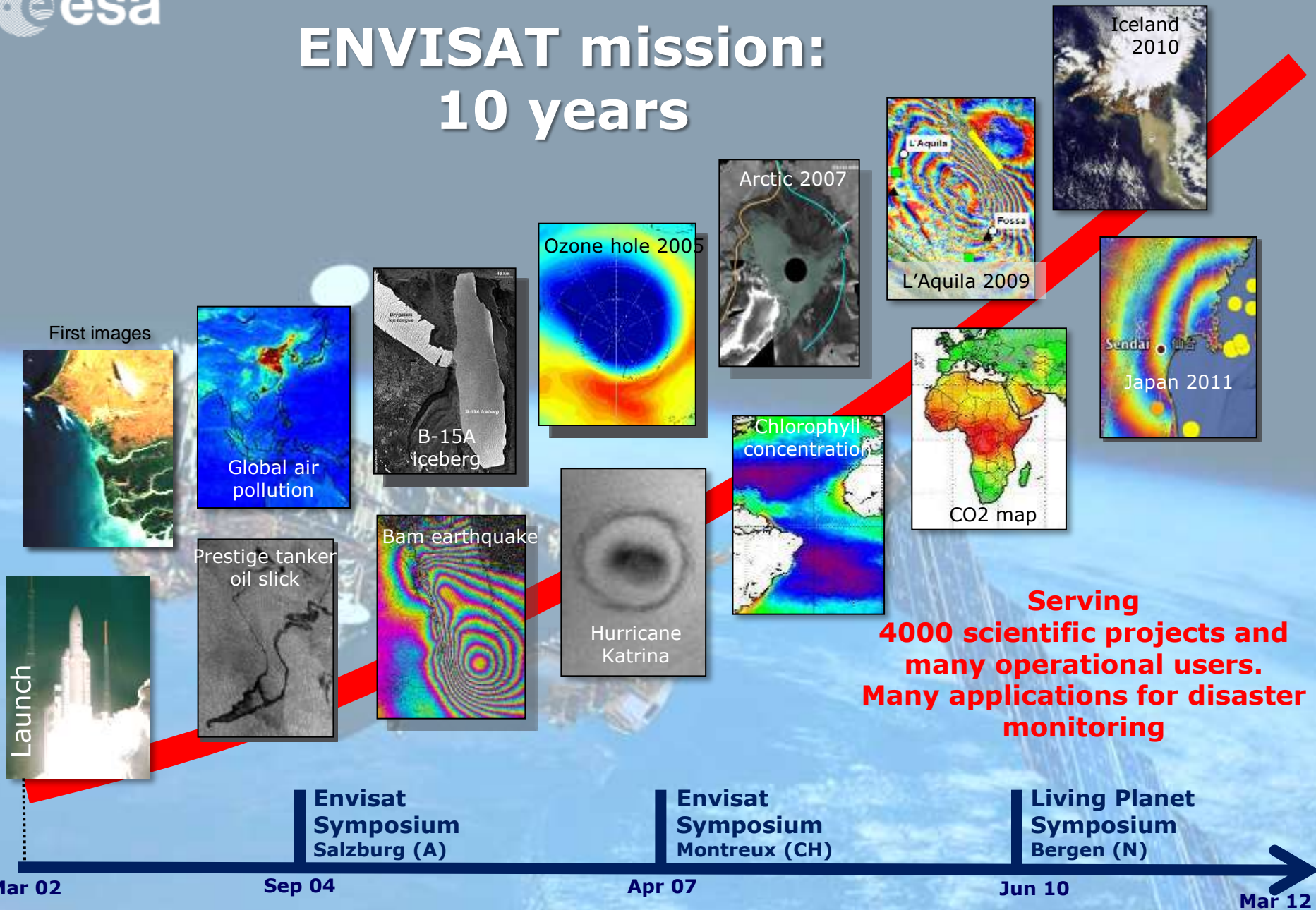
X-band Antenna

ASAR Advanced Synthetic Aperture Radar Antenna

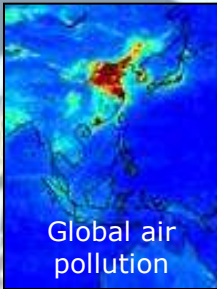
- **Dimensions (in orbit)**
26m x 10m x 5m
- **Mass**
8140 Kg
- **Orbit**
800 km as ERS, sun synchronous
10:00, i.e. 30 minutes before ERS-2



ENVISAT mission: 10 years



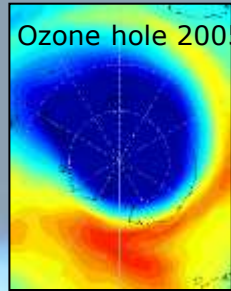
First images



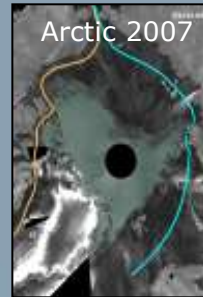
Global air pollution



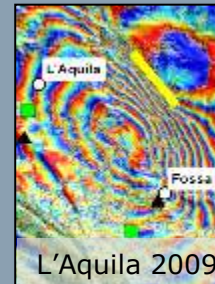
B-15A iceberg



Ozone hole 2005



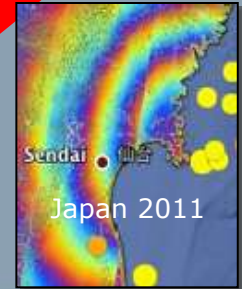
Arctic 2007



L'Aquila 2009



Iceland 2010



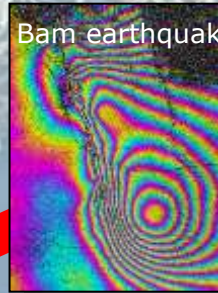
Japan 2011



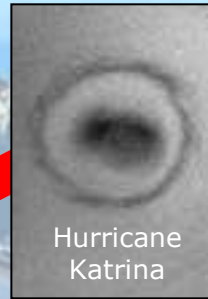
Launch



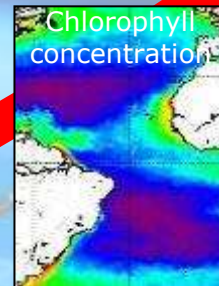
Prestige tanker oil slick



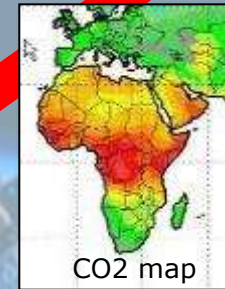
Bam earthquake



Hurricane Katrina



Chlorophyll concentration



CO2 map

**Serving
4000 scientific projects and
many operational users.
Many applications for disaster
monitoring**

**Envisat
Symposium
Salzburg (A)**

Sep 04

**Envisat
Symposium
Montreux (CH)**

Apr 07

**Living Planet
Symposium
Bergen (N)**

Jun 10

Mar 12

and many workshops dedicated to specific Envisat user communities


ENVISAT

An example of multisensor application: Risk Management

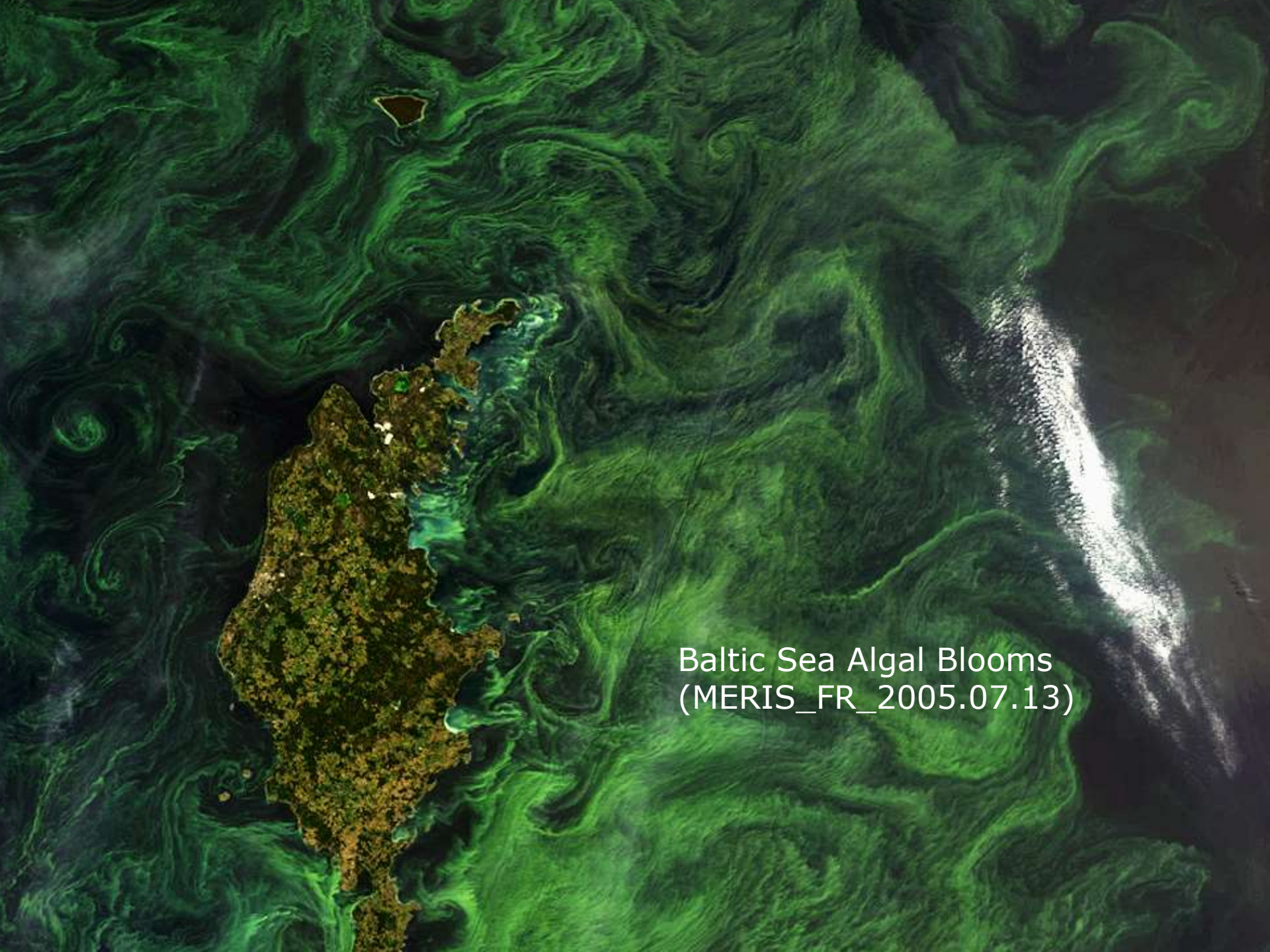


1) Use of optical data for Risk Management



An aerial photograph of a large reservoir with a complex, dendritic shoreline. The water is dark blue, and the surrounding land is a mix of brown and green, indicating a mix of forest and open land. A large, white, plume-like feature, likely smoke or ash from a fire, is visible on the left side of the image, partially obscuring the reservoir's edge. The text "Moscow Fires (Meris FR 2011)" is overlaid in white in the upper right quadrant.

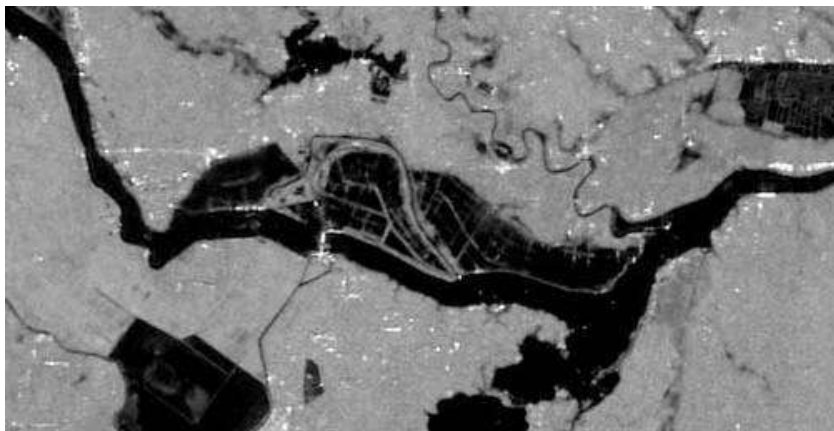
Moscow Fires (Meris FR 2011)



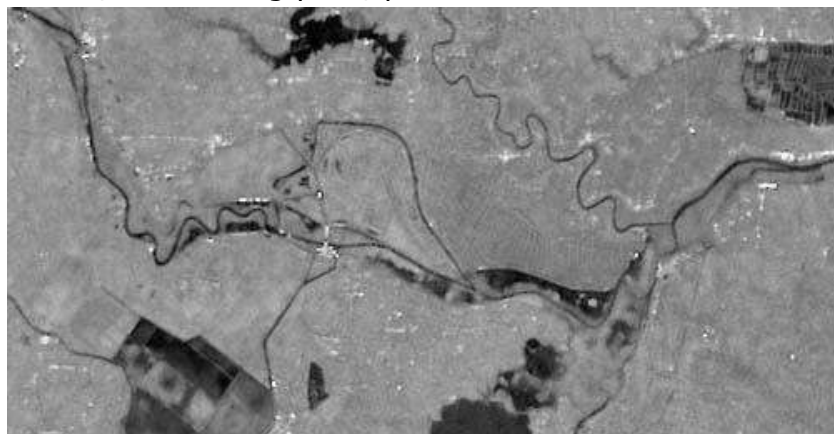
Baltic Sea Algal Blooms
(MERIS_FR_2005.07.13)

2) Use of radar backscatter for Risk Management





ASAR WSM 150m spatial resolution acquired 15th July 2007, descending pass, polarisation HH.



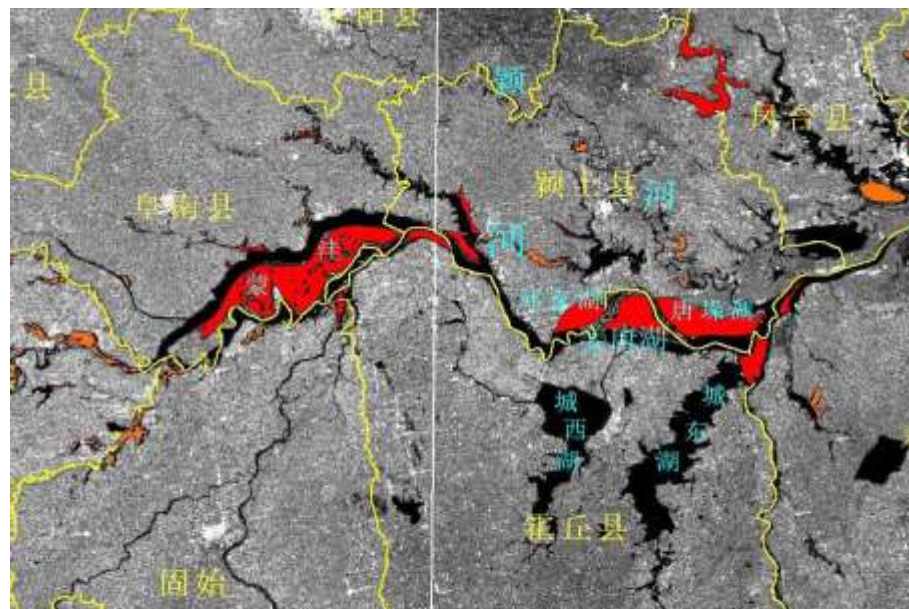
ASAR WSM 150m spatial resolution acquired 12th August 2006, descending pass, polarisation HH.

Inundated areas are clearly visible in this Envisat ASAR image acquired during floods in China in July 2007.

FLOODING IN CHINA

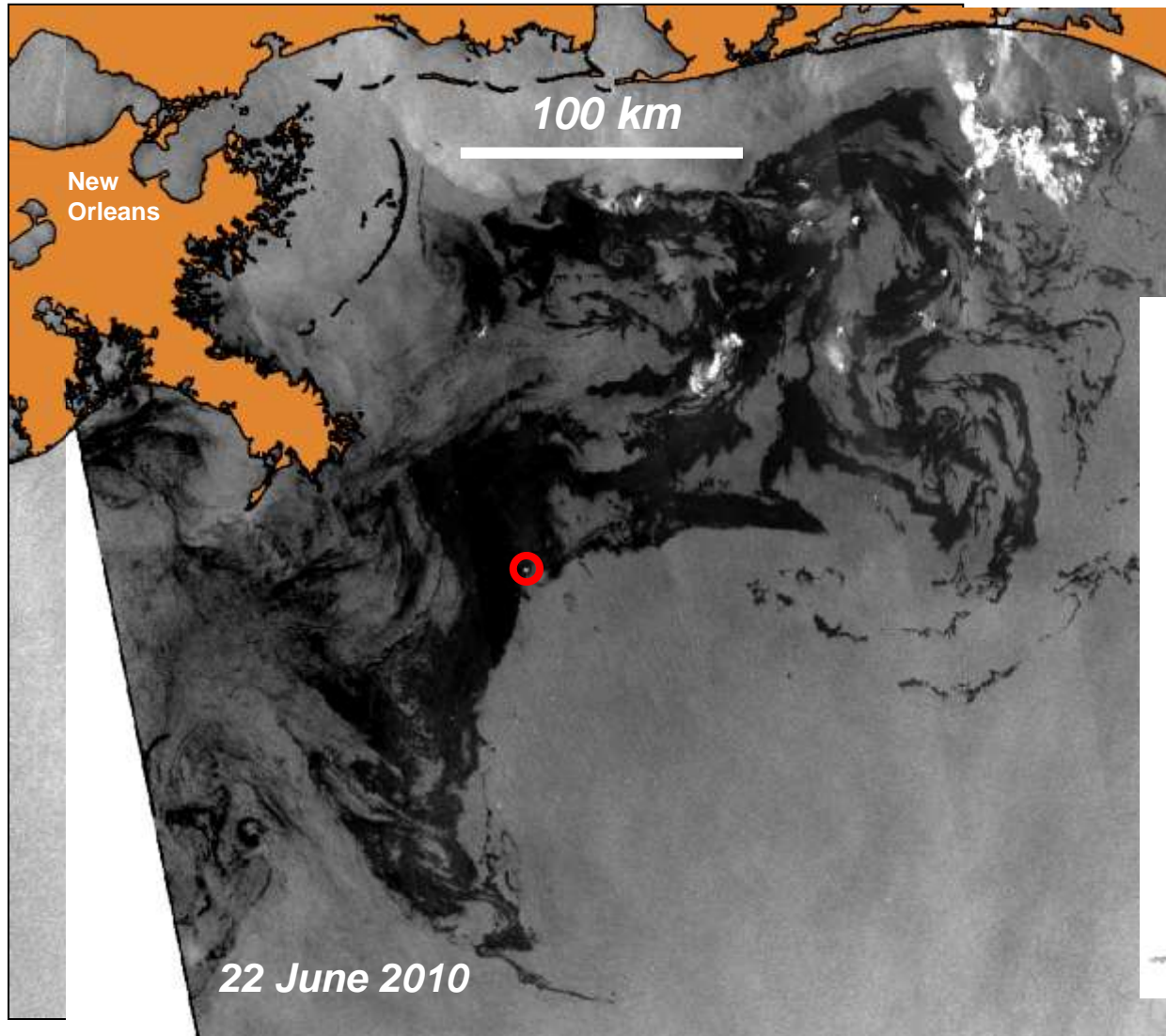
(JULY 2007)

The two images were acquired during the same season but different years, one during the flooding, the other the year before. By comparing the two images, both with the same geometry (Wide Swath Mode, descending pass) and same polarisation (HH) it is possible to assess the extent of the flooding.

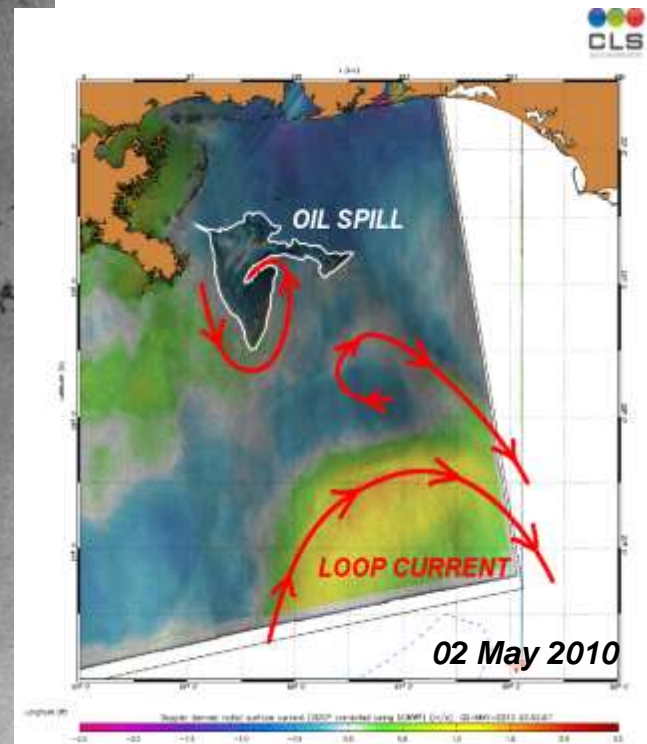


Courtesy of IWHR, Beijing

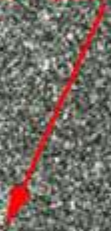
Oil spill monitoring using radar satellite



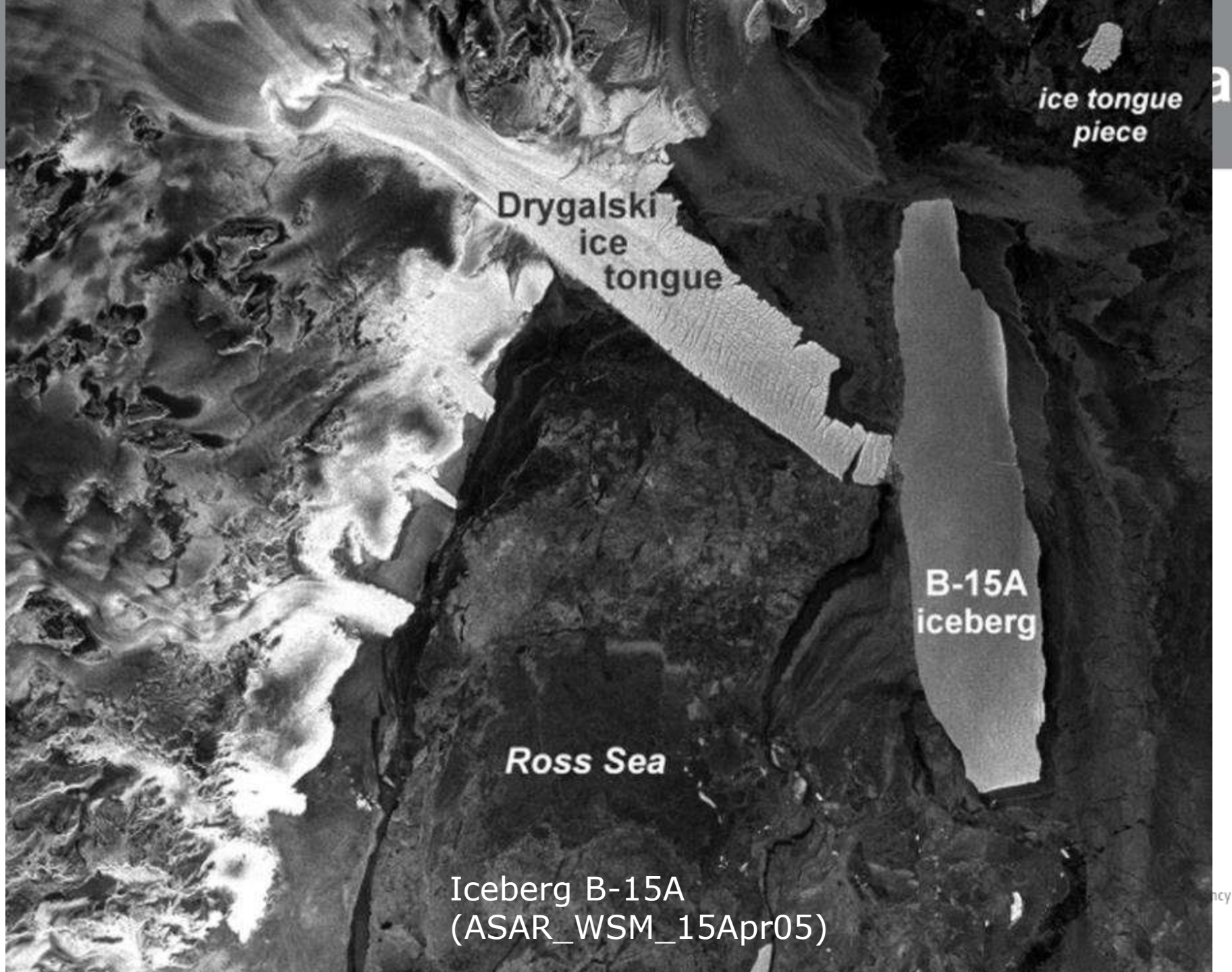
The Louisiana Oil Spill disaster from space (Envisat ASAR)



Costa "Concordia" Ship



Costa Concordia (ASAR IMP 10.Feb.2012)



ice tongue
piece

Drygalski
ice
tongue

B-15A
iceberg

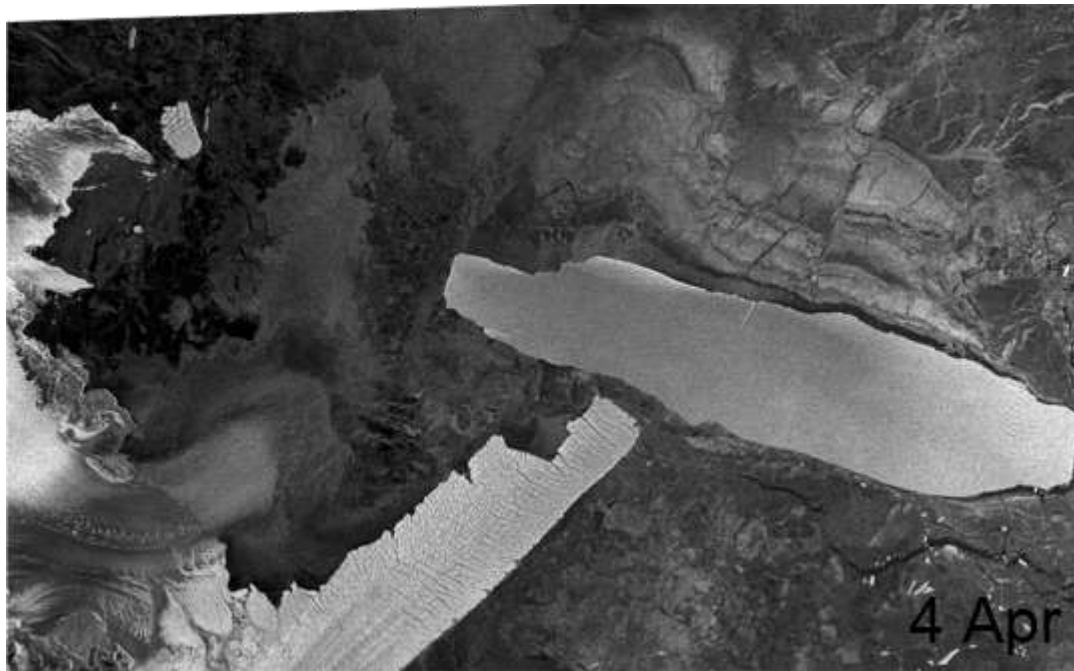
Ross Sea

Iceberg B-15A
(ASAR_WSM_15Apr05)

a

ncy

Iceberg B-15A Antarctic (ASAR_WSM from 4th to 20th Apr 05)



Use of radar phase (InSAR, PS) for Risk Management

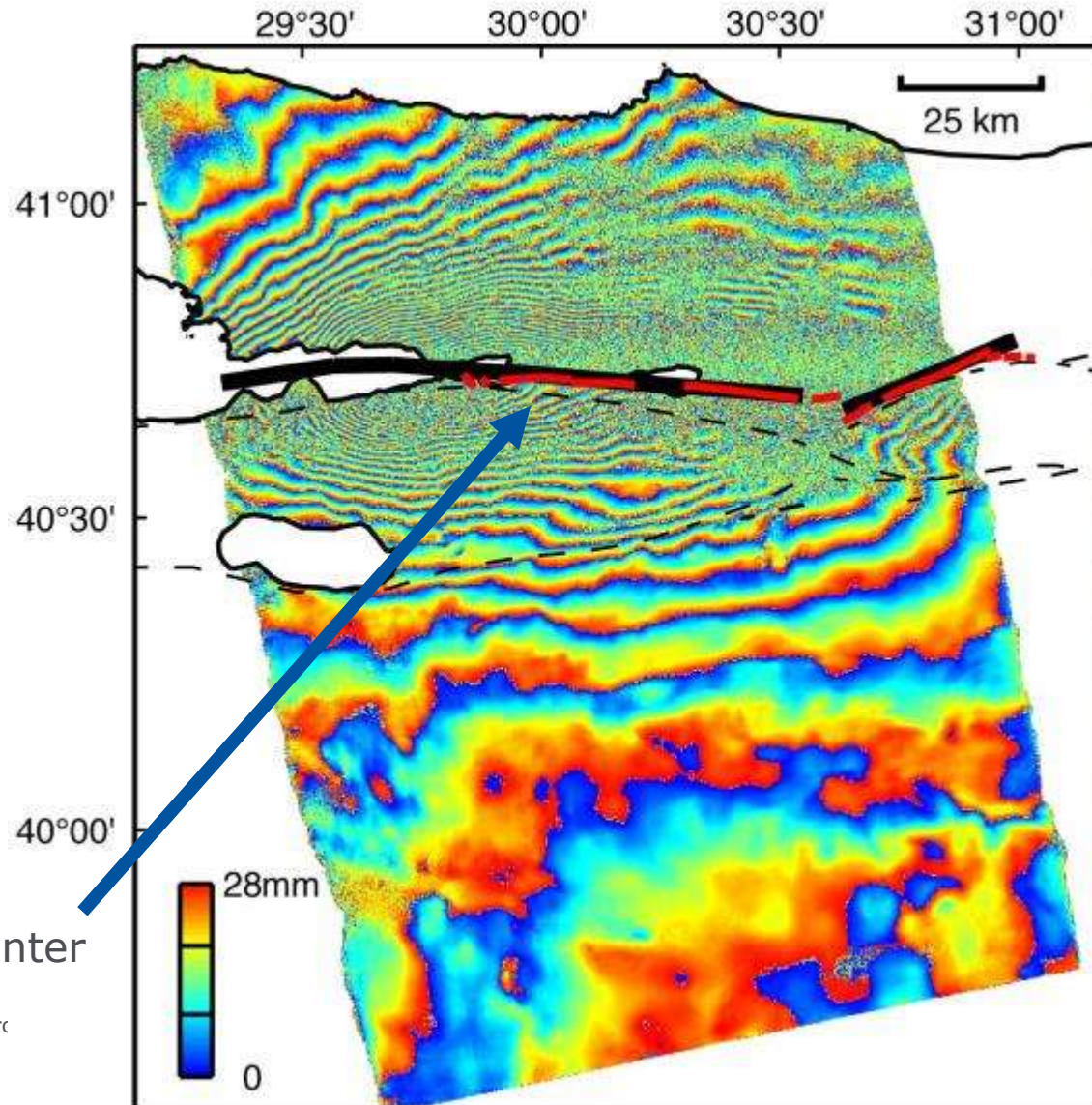


Earthquake in Izmit, Turkey (1999)

Post-seismic deformation measured by Interferometric SAR

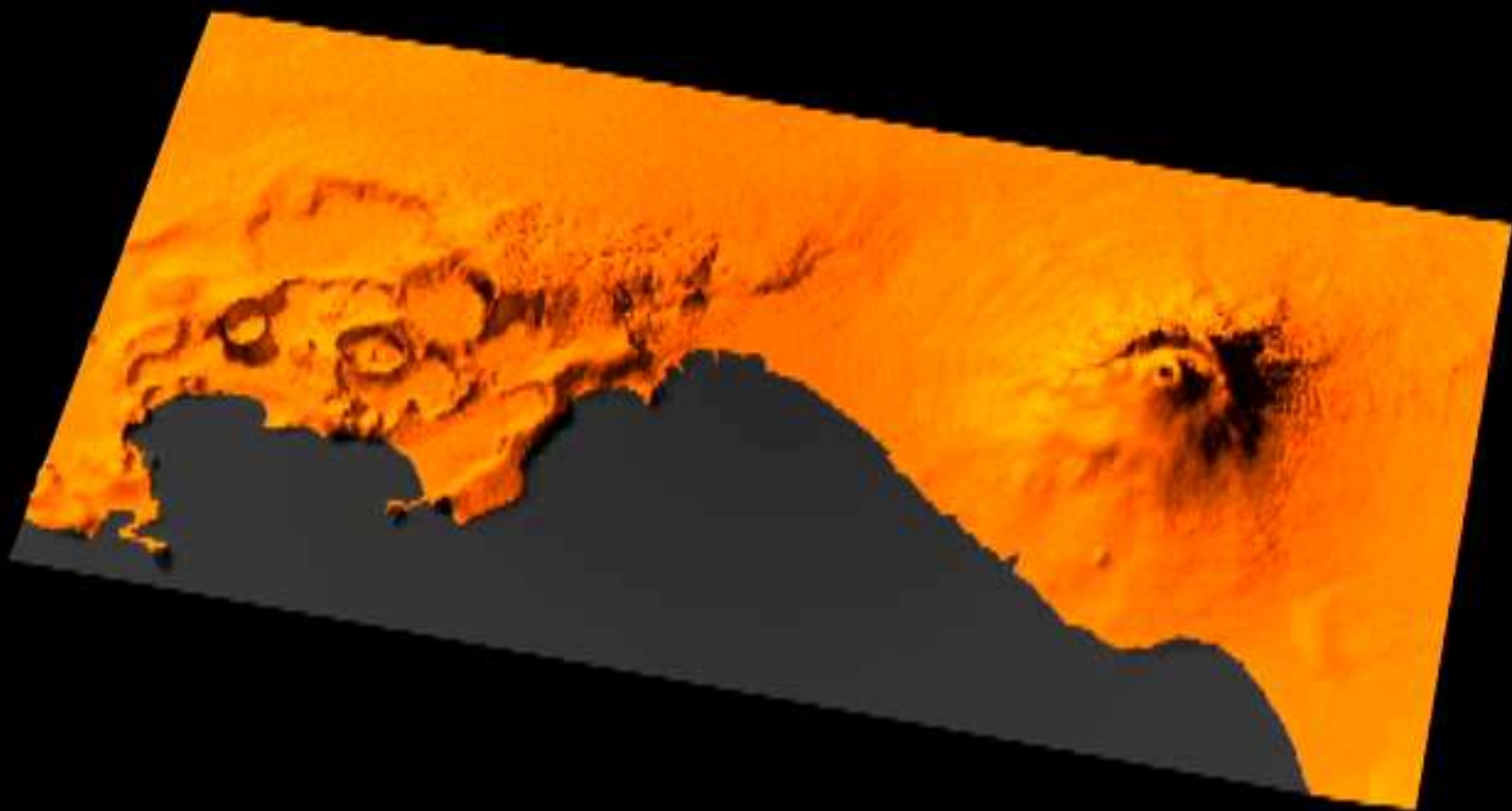
- Synthetic Aperture Radar (ERS-1, ERS-2)
- Generation of Interferogram (phase difference between two SAR images)
- One colour pattern (fringe) corresponds to 28 mm deformation along the line of sight
- This works through clouds or darkness (Radar Data)

Epicenter



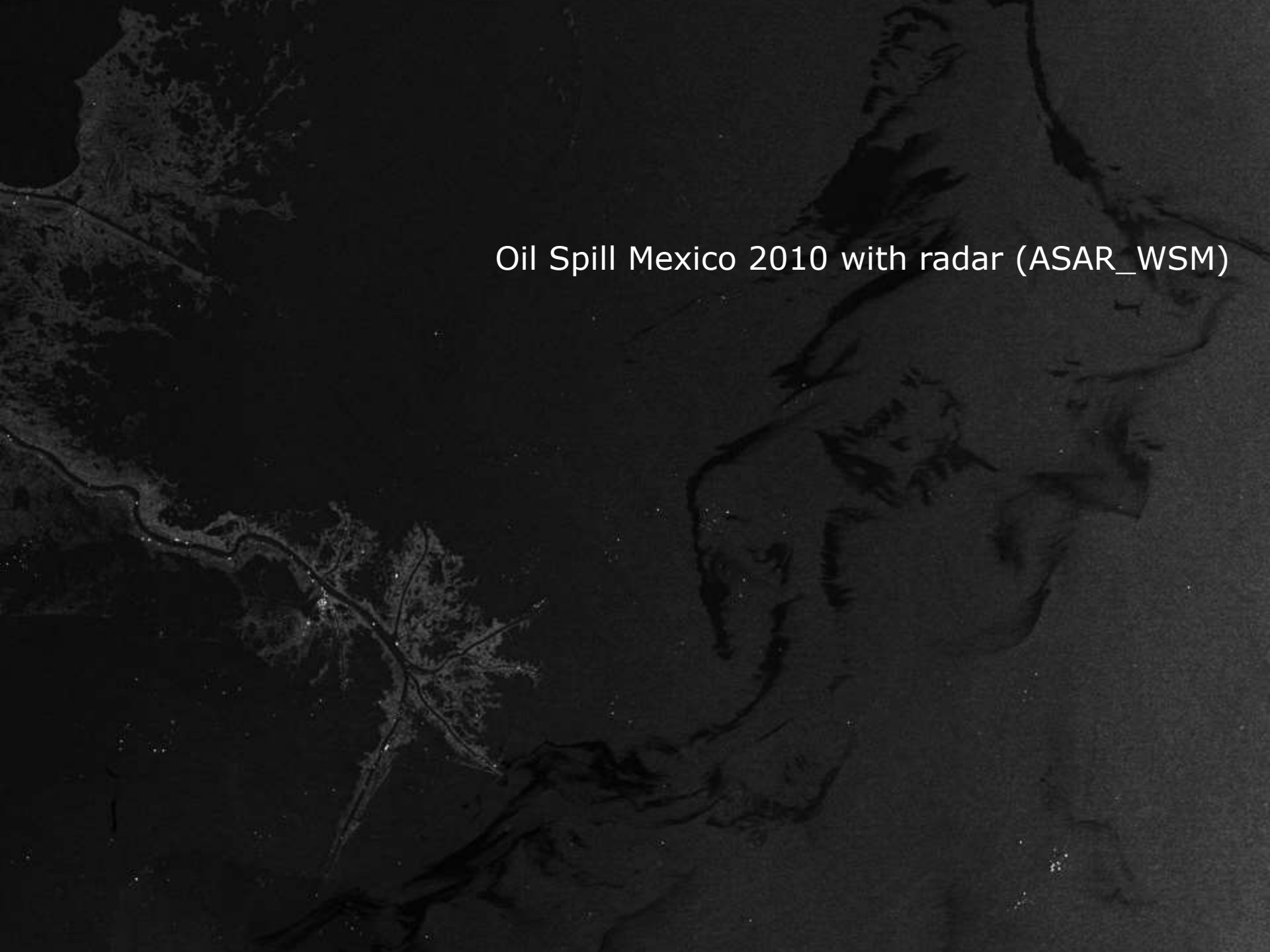
Campi Flegrei: observation by InSAR





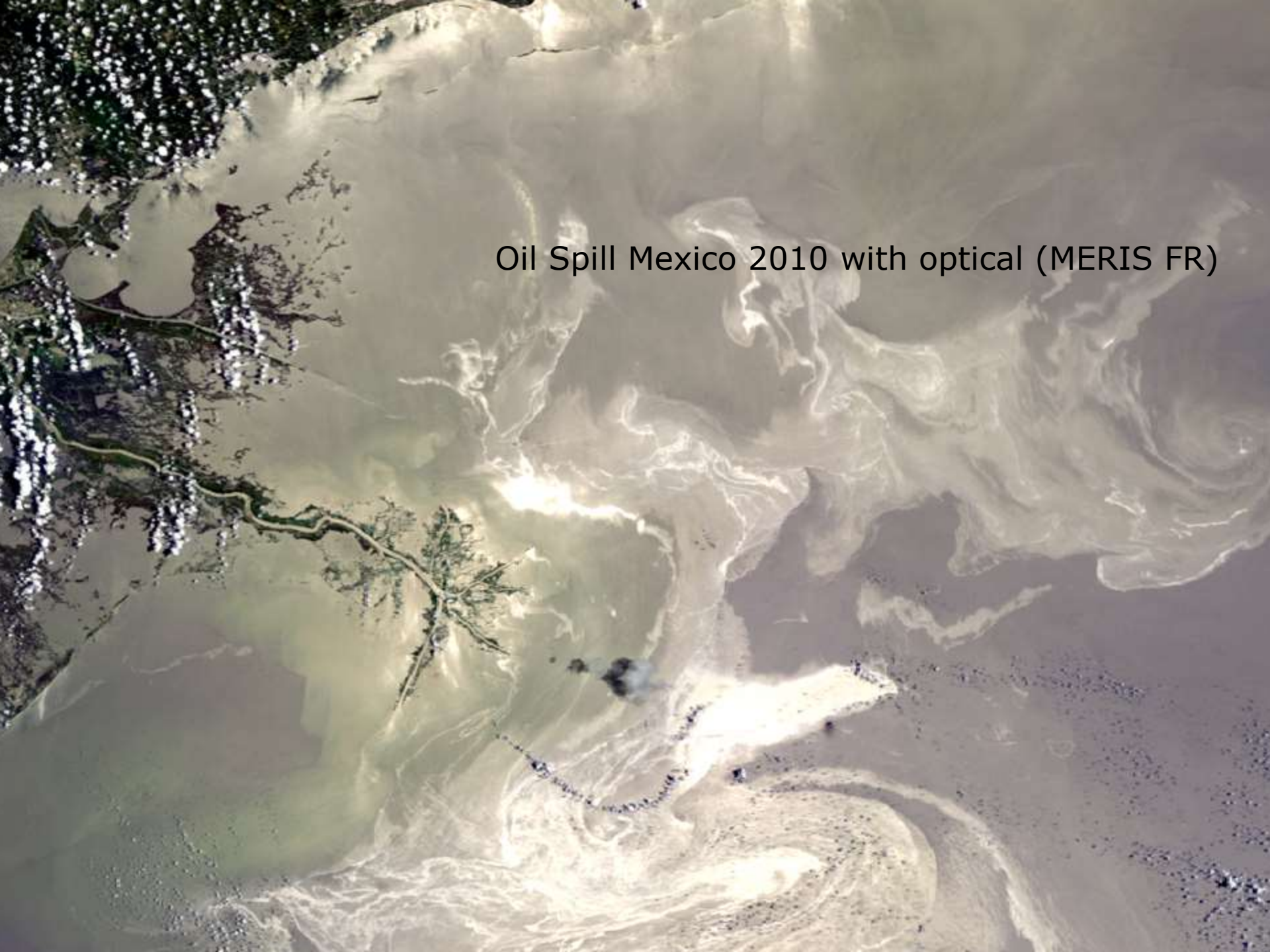
3) Use of radar backscatter, combined with optical data, for Risk Management





Oil Spill Mexico 2010 with radar (ASAR_WSM)

Oil Spill Mexico 2010 with optical (MERIS FR)





Hurricane Earl (Caribbean
Sea)_Meris_FR_September 2010

Hurricane Earl



Hurricane Earl (Caribbean Sea)_ASAR_WSM_September 2010

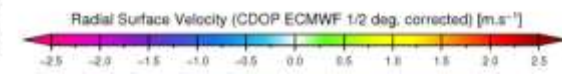
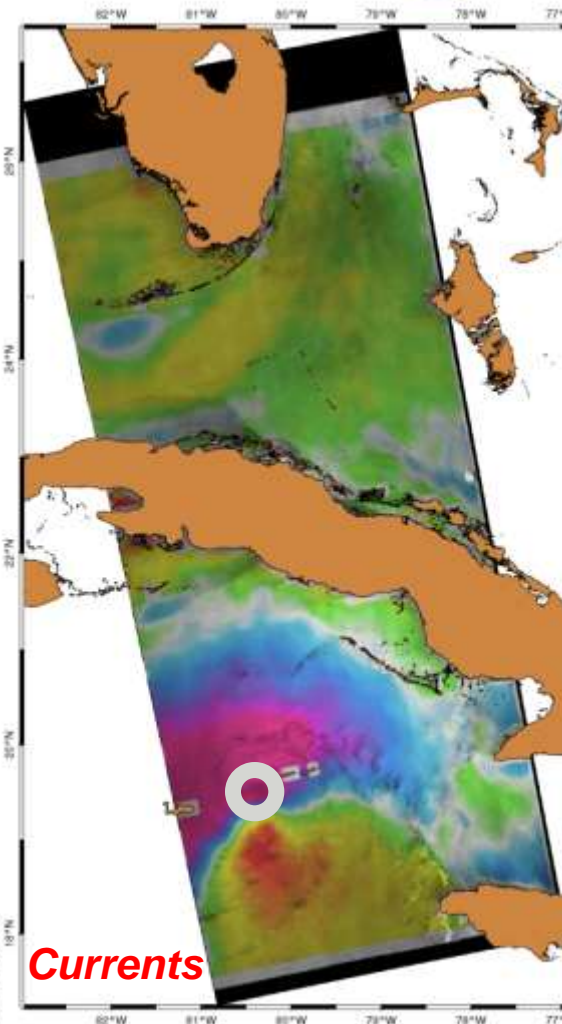
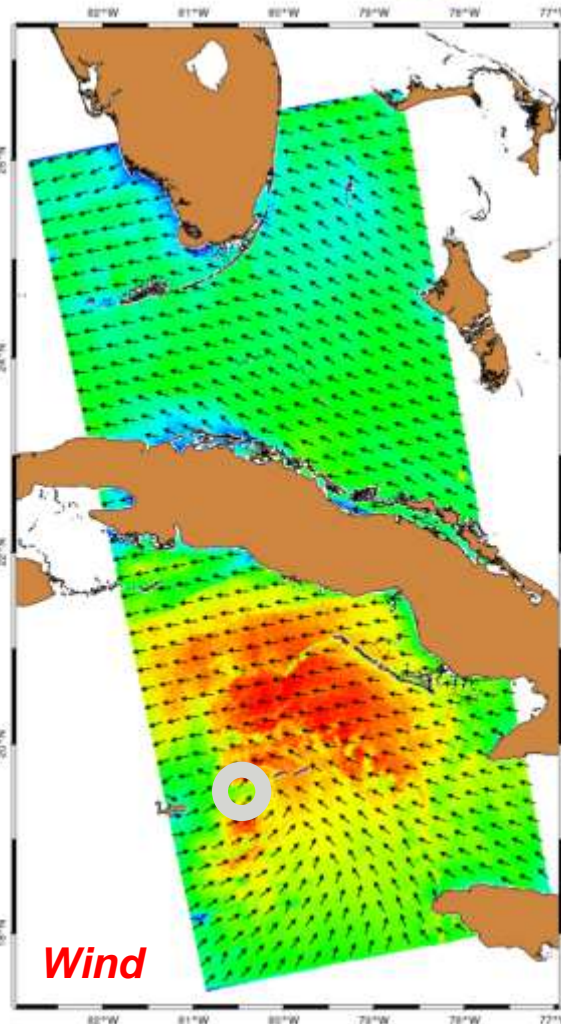
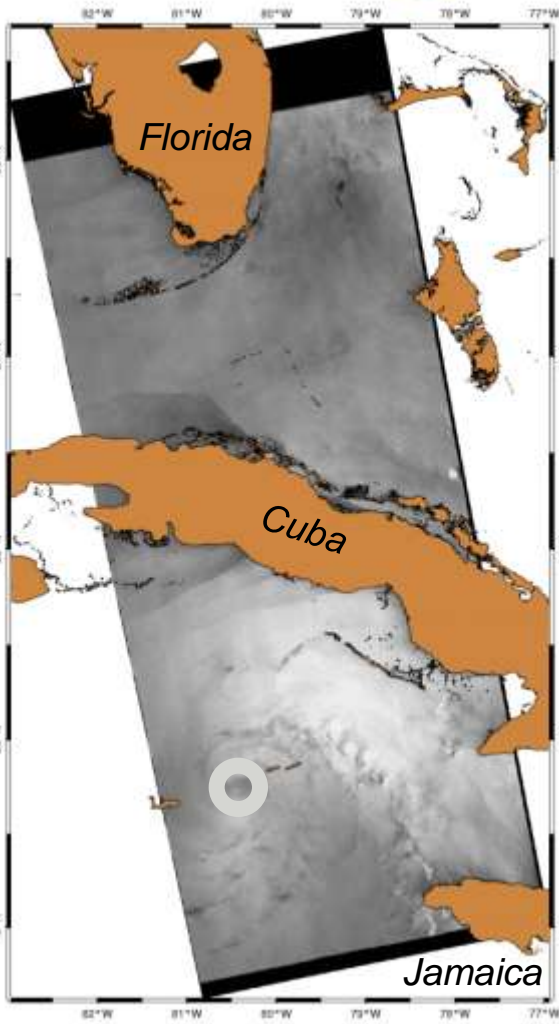
Hurricane Gustav: wind and currents



30-August-2008 03:21:37 (UTC)
ENVISAT WSM Product



30-August-2008 03:21:37 (UTC)
ENVISAT WSM Product



International Charter Space & Major Disasters



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

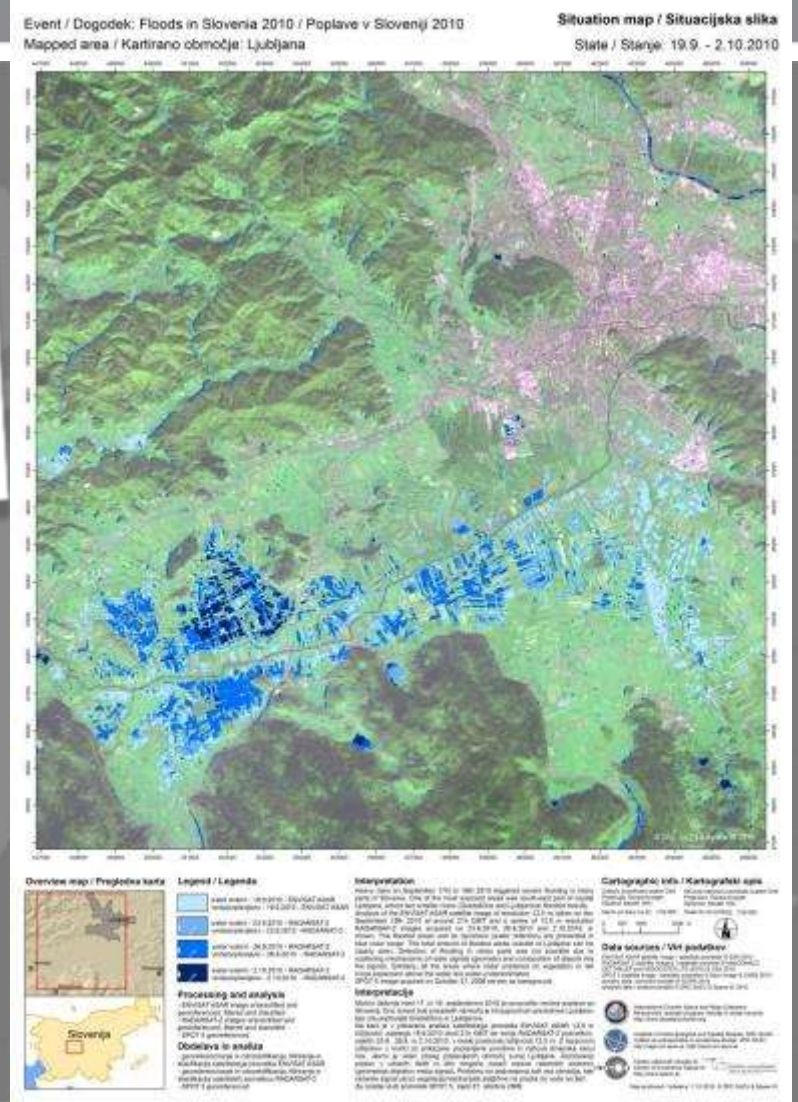
CHARTRE INTERNATIONALE

Partners / Partenaires

- esa - European Space Agency / Agence Spatiale Européenne
- cnes - Centre National d'études Spatiales
- Canadian Space Agency / Agence Spatiale Canadienne
- Agence Spatiale et Atmosphérique
- Agencia Espacial Brasileira / Agência Espacial Brasileira
- Indian Space Research Organisation



More than 400 activations in 110+ countries since 2000 !



The example of the 2010 Slovenia Floods (from Envisat ASAR, Radarsat-2)

Universal Access since Sept. 2012

Disasters types supported



The International Charter makes priority tasking of different EO missions in a rapid fashion; it is designed to address sudden requests concerning major disasters caused by:

Natural events

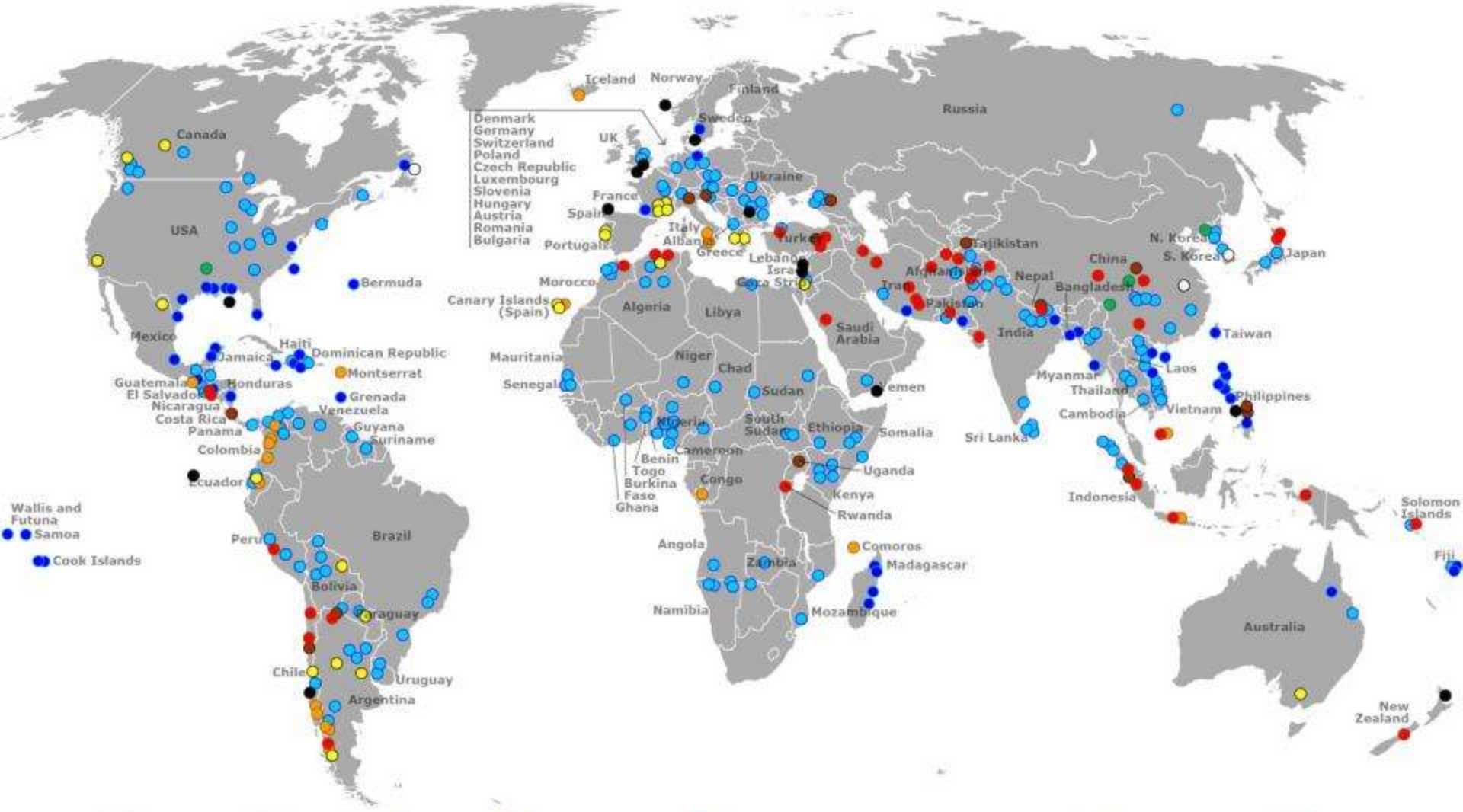
- Earthquakes
- Fires
- Floods
- Ice jams
- Landslides
- Tsunamis
- Ocean storms
- Volcanic eruptions

Man-made events

- Oil spills
- Industrial accidents



Activation Distribution



Legend: ● Earthquake ● Landslide ● Volcano ● Storm/hurricane ● Flood/ocean wave ○ Ice/snow hazard ● Fire ● Oil spill ● Other

Charter website



INTERNATIONAL CHARTER SPACE AND MAJOR DISASTERS

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[FAQ](#)

[Text of the Charter](#)

[Activating the Charter](#)

[Charter Members](#)

[Charter for Schools](#)

[Charter Geographical
Tool](#)

[Disaster Statistics](#)

[Movie of the Charter](#)

[Presentation of the
Charter](#)

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Activating the Charter

There are several [mechanisms to activate the Charter](#). It is based on a pre-defined list of appointed users, known as 'Authorized Users' (AUs). Until now AUs are typically disaster management authorities, from countries of Charter member agencies, able to request Charter support for emergencies in their own country, or in a country with which they cooperate for disaster relief.

Since its inception, the Charter has demonstrated a strong commitment to expanding its number of users. Initiatives include collaboration with UNITAR/UNOSAT and UN OOSA, active in many countries and who can submit requests to support in-country UN relief agencies, and Sentinel Asia, a regional network for Earth observation-based Emergency Response in 32 countries.

Universal Access

Building on a decade of success in making satellite data available for disaster response, the International Charter is now opening its doors even wider. The Charter Members have adopted the principle of Universal Access to further strengthen the Charter's contribution to disaster management worldwide. Any national disaster management authority will be able to submit requests to the Charter for emergency response. Proper procedures will have to be followed, but the affected country will not have to be a Charter member.

Universal Access benefits national disaster management authorities in countries beyond those of the Charter members, previously unable to make direct requests to the Charter.

A registration process is in place for national authorities interested in participating in the Charter as an "Authorized User". This process will validate the ability of national authorities to access and use Charter assets for disaster response, in accordance with Charter operational procedures. Steps and applicable conditions are explained in the Charter's [Universal Access Information Brochure](#) available together with its [Registration form](#).

Copernicus: A New Generation of Data Sources



Sent-1A/B



Sentinel-2A/B



Sentinel-3A/B



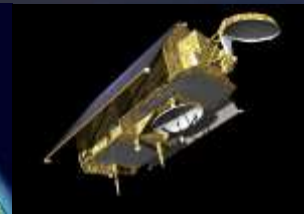
Sentinel-4A/B



Sentinel-5/5P



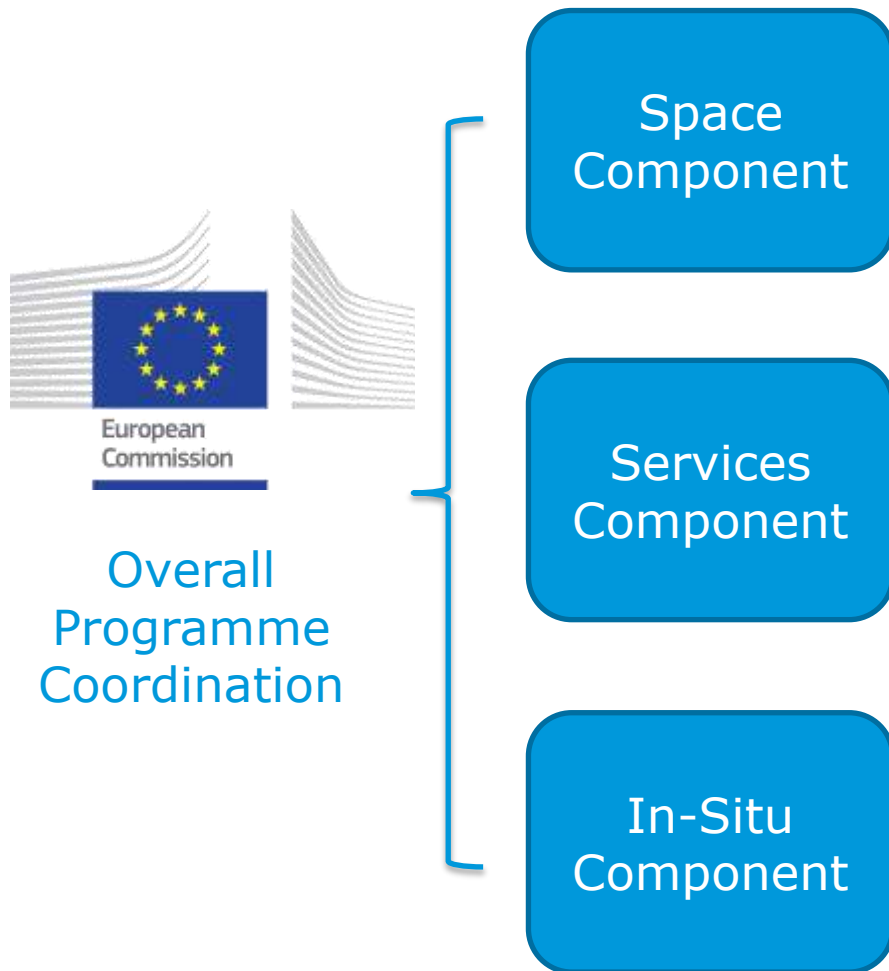
Sentinel-6A/B



- Copernicus is a European space flagship programme led by the European Union
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security
- ESA coordinates the space component



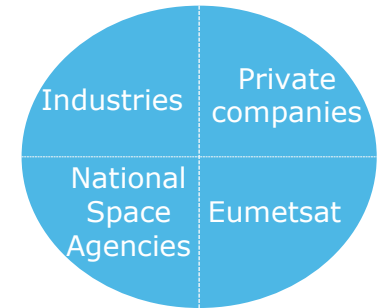
Components & Competences



Coordinators:



Partners:



Sentinel Data Policy = **FREE and OPEN access**

- Main principles of Sentinel data policy:
 - **Open** access to Sentinel data by anybody and for any use
 - **Free** of charge data licenses
 - Restrictions possible due to technical limitations or security constraints

Copernicus dedicated missions: the ESA Sentinels...



S1A/B: Radar Mission



2014/2016



S2A/B: High Resolution Optical Mission

2016/2017



S3A/B: Medium Resolution Imaging and Altimetry Mission

2016/2017



S4A/B: Geostationary Atmospheric Chemistry Mission

2019/2027



S5P: Low Earth Orbit Atmospheric Chemistry Mission

2016



S5A/B/C: Low Earth Orbit Atmospheric Chemistry Mission

2020/2027



S6-(Jason-CS) A/B: Altimetry Mission

2019/2025

... with a long-term operational perspective



2011

2014

2020

2030

Access to Contributing Missions

S-1 A/B/C/D



S-1 A/B 2nd Generation



S-2 A/B/C/D



S-2 A/B 2nd Generation



S-3 A/B/C/D



S-3 A/B 2nd Generation



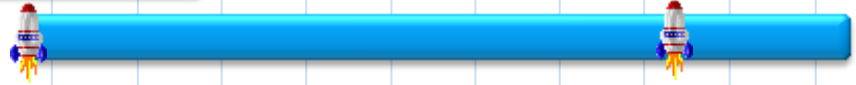
S-4 A/B (on MTG)



S-5 Precursor



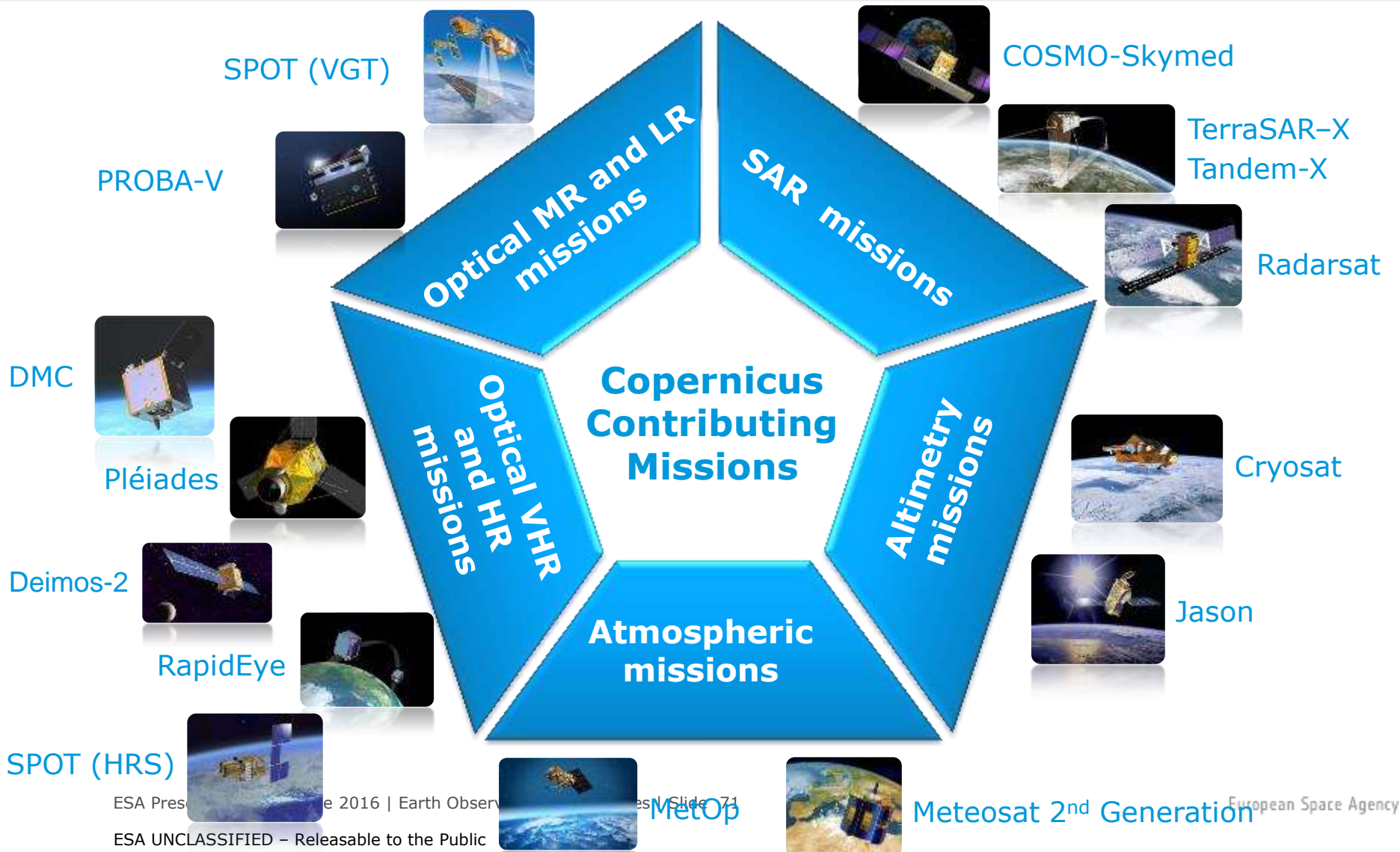
S-5 A/B/C (on MetOp-SG)



S-6 A/B



Copernicus Contributing Missions



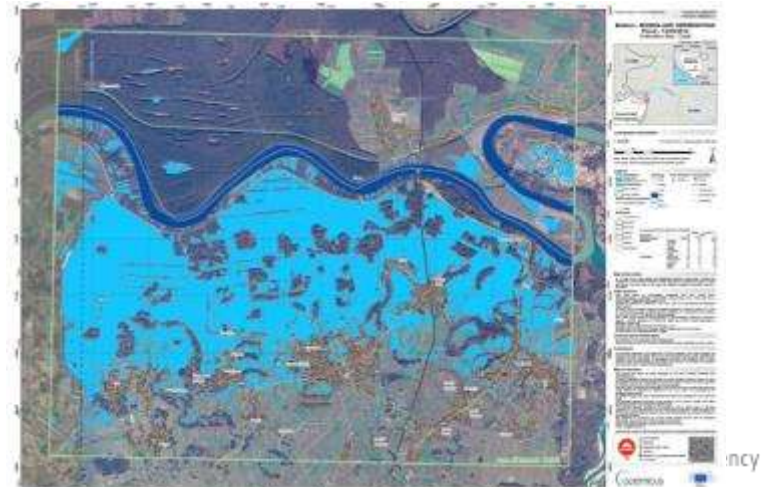
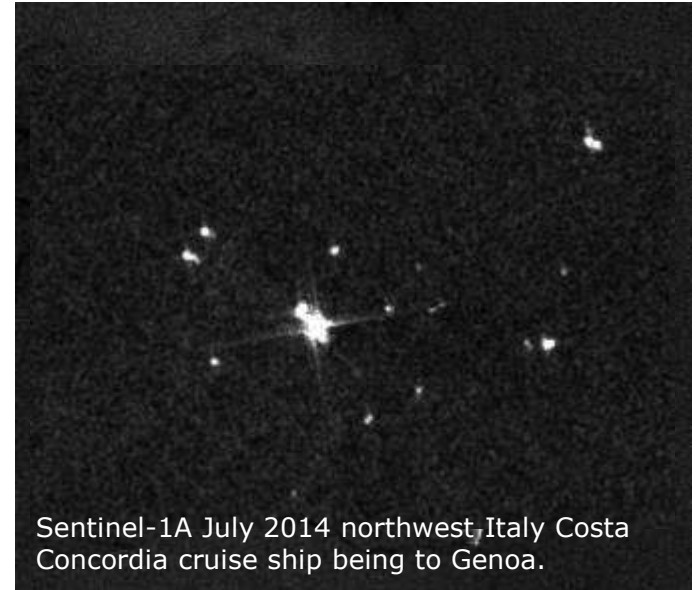
Sentinel-1 (A: launched April 2014, B: launched April 2016) is the first of a series of operational radar satellites that will provide data continuity until 2030



✓ Data continuity of ERS and ENVISAT missions

✓ Copernicus imaging radar mission for ocean, land, emergency applications:

- monitoring sea ice zones and the arctic environment
- surveillance of marine environment (oil spill monitoring)
- maritime security (e.g. ship detection)
- wind, wave, current monitoring
- monitoring of land surface motion (subsidence, tectonics, volcanoes)
- support to emergency / risk management and humanitarian aid in crisis situations
- mapping of land surfaces: forest, water and soil, agriculture, etc.



Sentinel-1

Mission Overview



- Two satellites
- C-band Radar instrument
- Sun-synchronous orbit at 693 km altitude
- Inclination: 98.18°
- 7 years lifetime
- Consumables for 12 years
- Mean LST: 18:00h at ascending node
- 12-day repeat cycle at Equator (with 1 satellite)



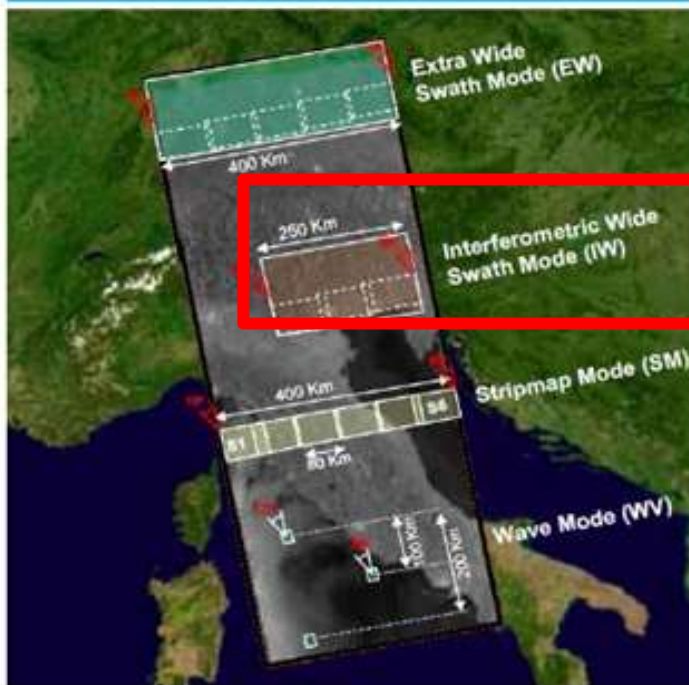
6-day repeat cycle at Equator (with 2 satellites)

Sentinel-1

SAR Operational Modes



Operational Modes



Resolution	Swath Width	Polarisation
20 x 40 m ²	> 400 km	HH+HV or VV+VH



5 x 20 m ²	> 250 km	HH+HV or VV+VH
-----------------------	----------	----------------



5 x 5 m ²	> 80 km	HH+HV or VV+VH
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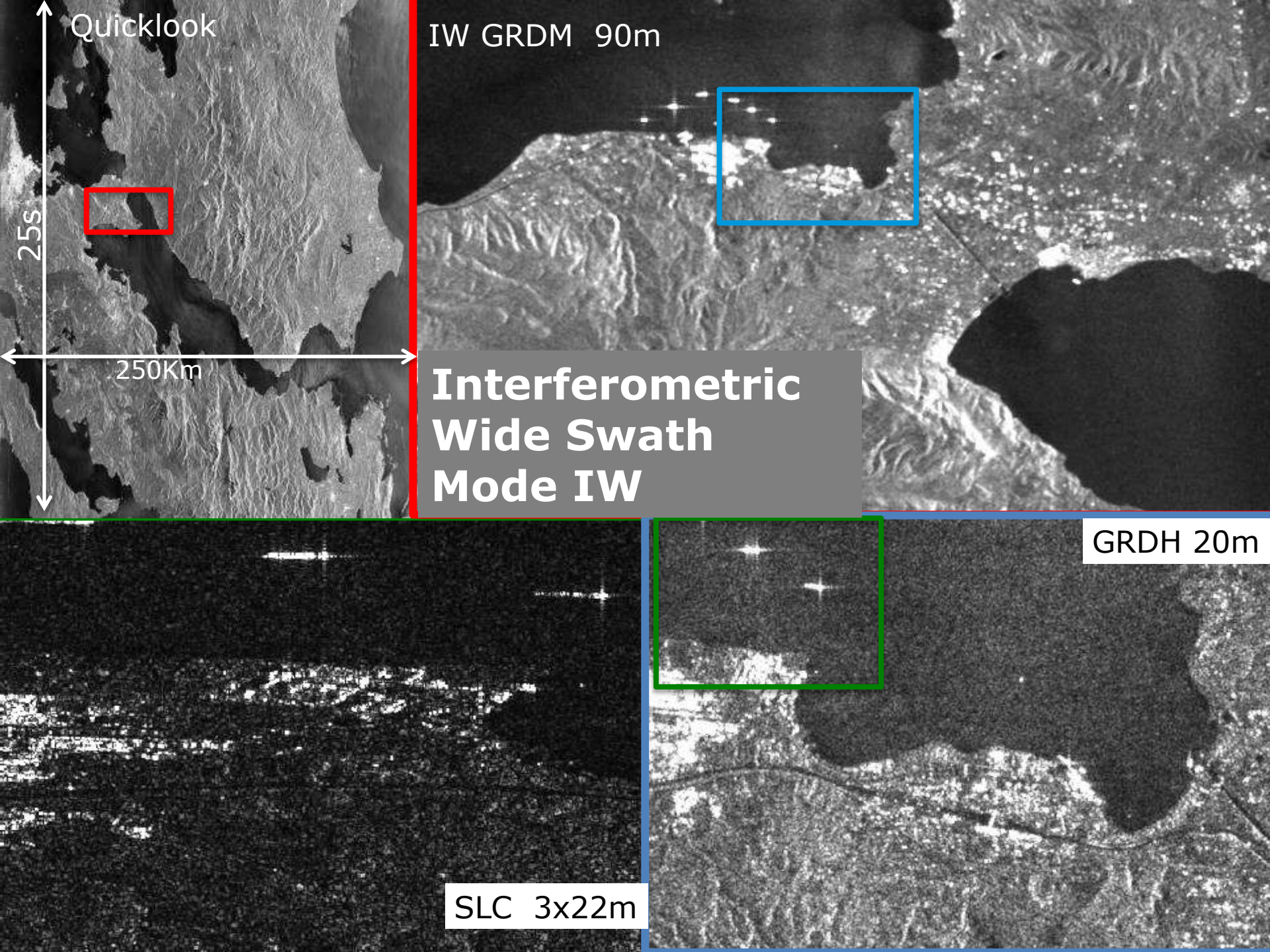
5 x 5 m ²	20 x 20 km ² at 100 km spacing	HH or VV
----------------------	---	----------

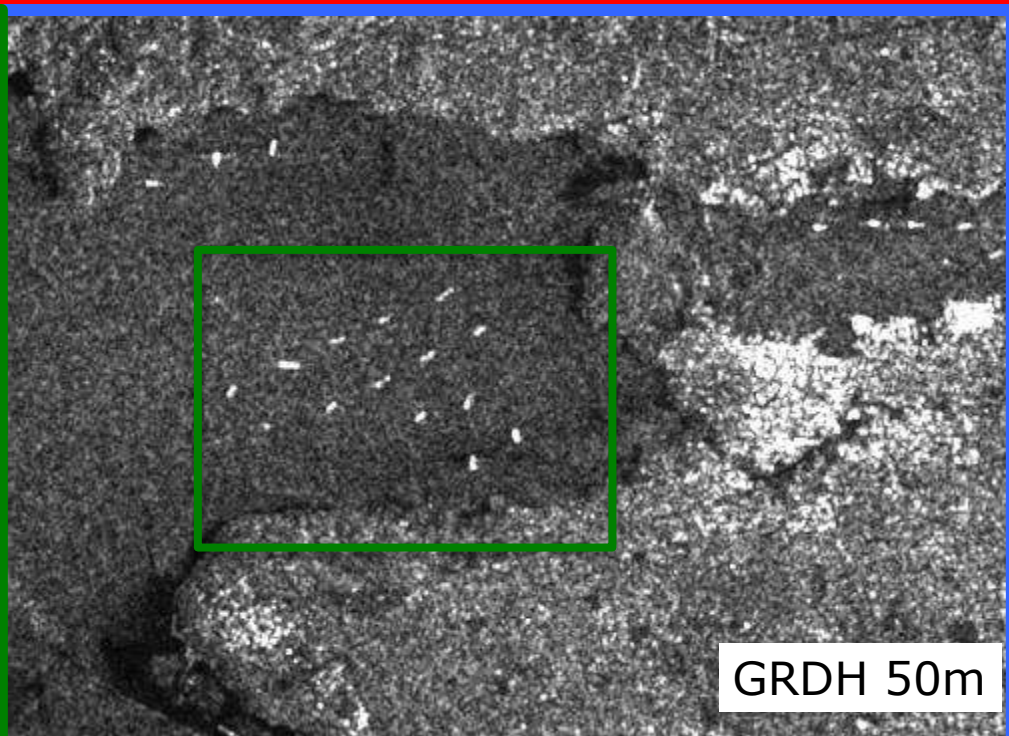
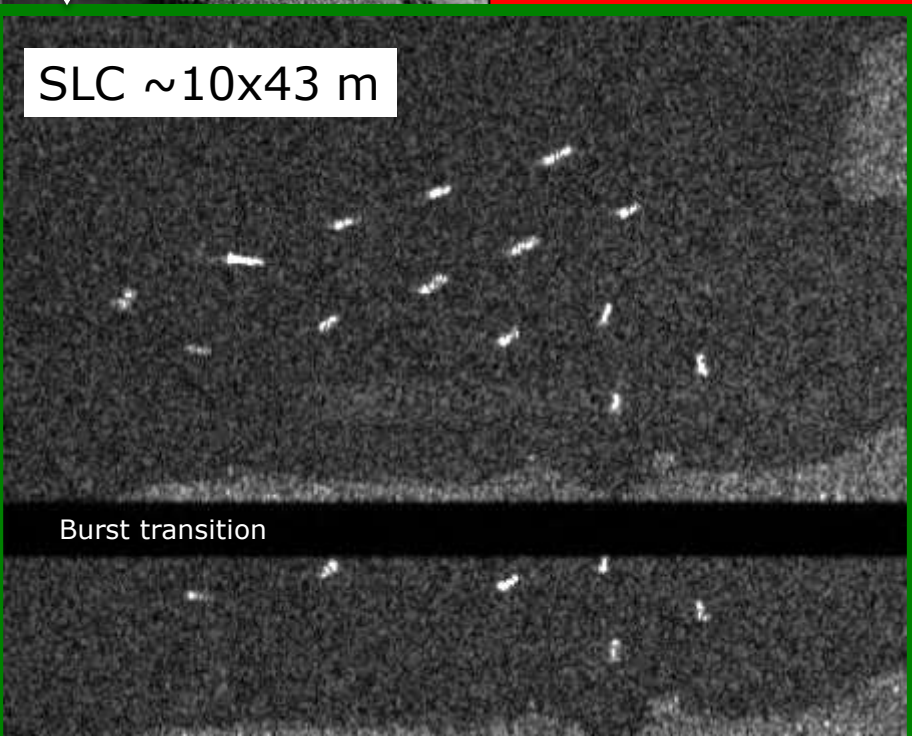
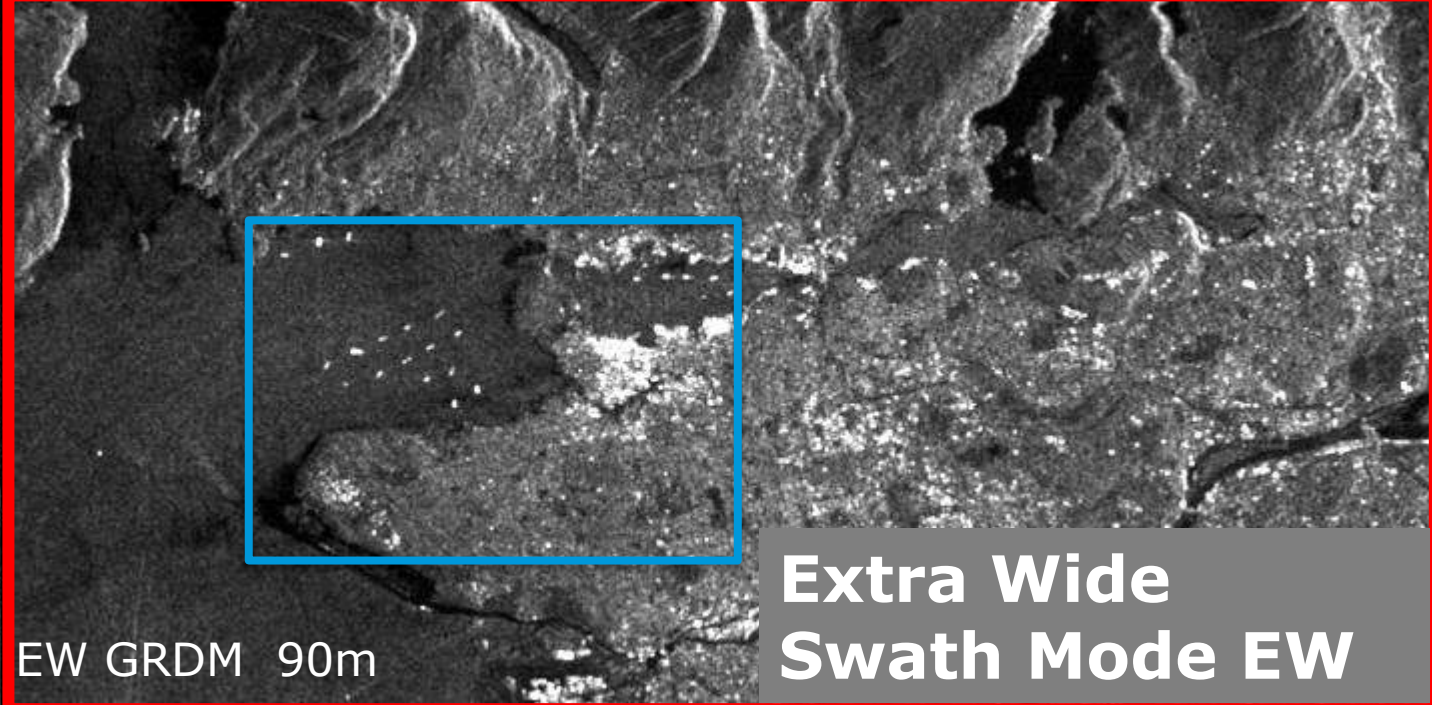
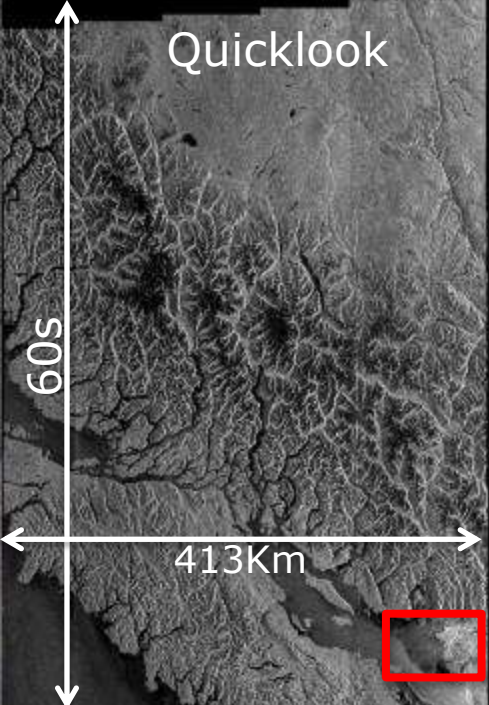
➤ Daily coverage of high priority areas, e.g. Europe, Canada, shipping routes

Main modes of operations:

- IW over land and coastal waters (normally VV or VV-VH polarization)
- EW over extended sea (VV or VV-VH) and sea-ice (HH or HH-HV) areas
- WV over open oceans







Sentinel-1 (SAR) versus Envisat ASAR



Sentinel-1

- **10 m** ground range resolution (stripmap mode)
- **250 km** swath width (Interferometric wide swath mode – 20m ground range resolution)
- **6 days** repeat cycle (with 2 satellites)
- **2 x 260 Mb/s** downlink data rate
- **7 years** design lifetime (consumables for 12 years)

Envisat ASAR

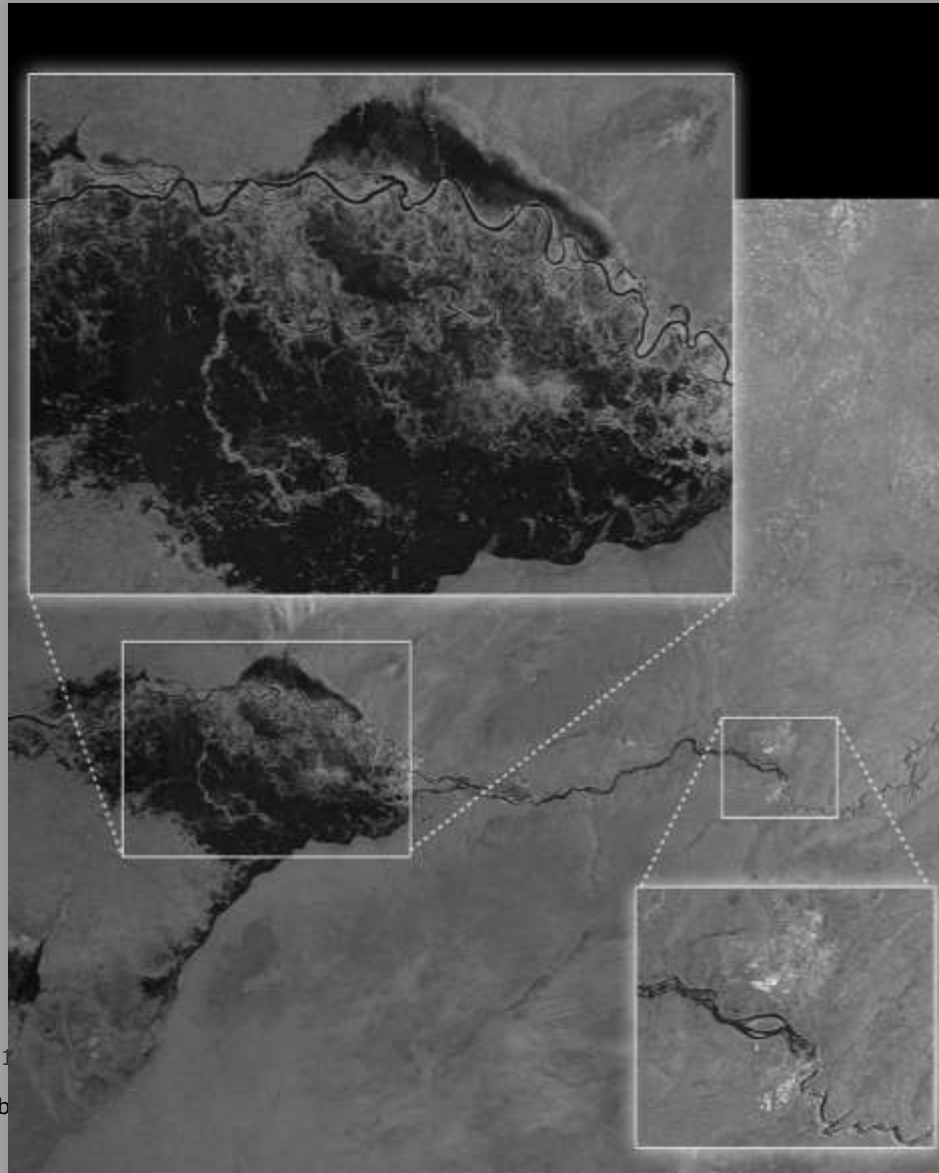
- **20 m** ground range resolution
- **100 km** swath width (Imaging mode)
- **35 days** repeat cycle
- Up to **100 Mb/s** space to ground data rate
- **5 years** design lifetime

First Images of Sentinel-1A

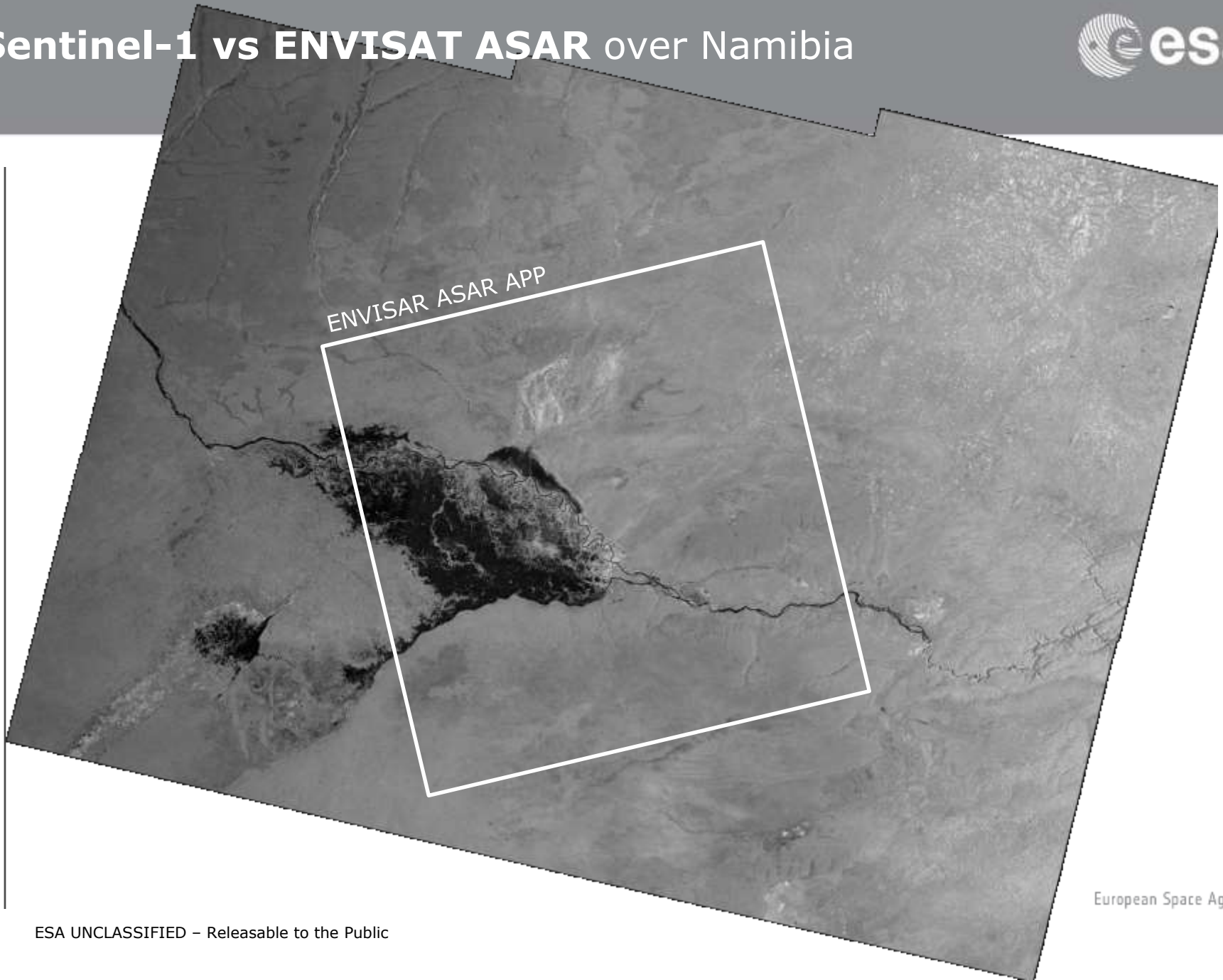


Zambezi River Flooding
and Victoria Falls,
Namibia

13 April 2014



Sentinel-1 vs ENVISAT ASAR over Namibia



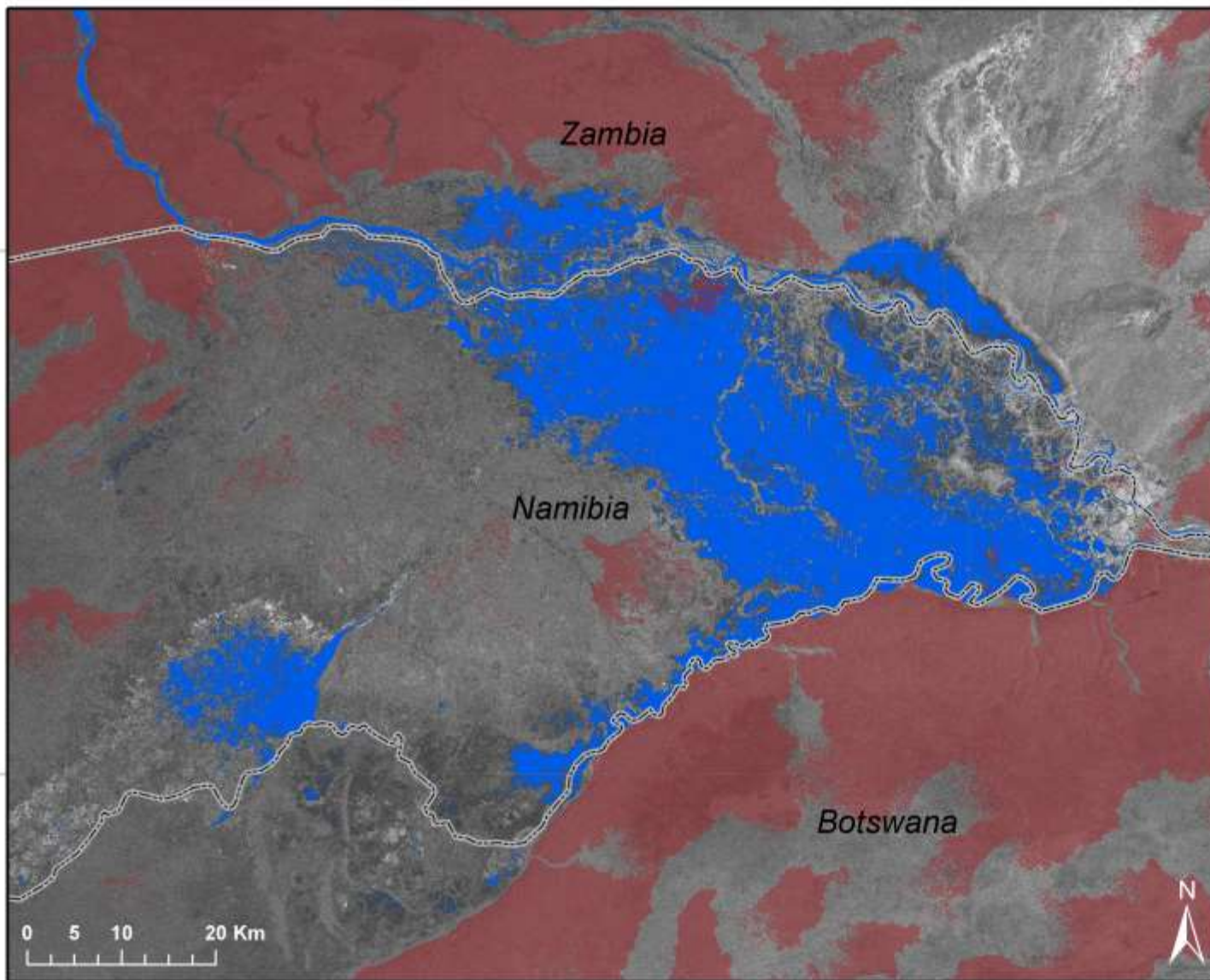
European Space Agency

Sentinel-1 Flood Monitoring of Caprivi Flood Plain, Namibia



24°30'0"E

25°0'0"E



Legend

- Country border
- Derived HAND Index > 10 m
- Flooded areas

Description:

This map shows the flooding situation in the Caprivi flood plain of Zambezi River on 13th of April, 2014. The flood was delineated with the Water Observation and Information System (WOIS) based on SENTINEL-1A satellite data.

Source data:

SENTINEL-1A IW mode, 20 m resolution, acquired on 13th of April, 2014 at 03:50 GMT. SENTINEL-1 image was provided by the European Space Agency.

Cartographic Reference
Projection: EPSG:4326
Datum: WGS 84



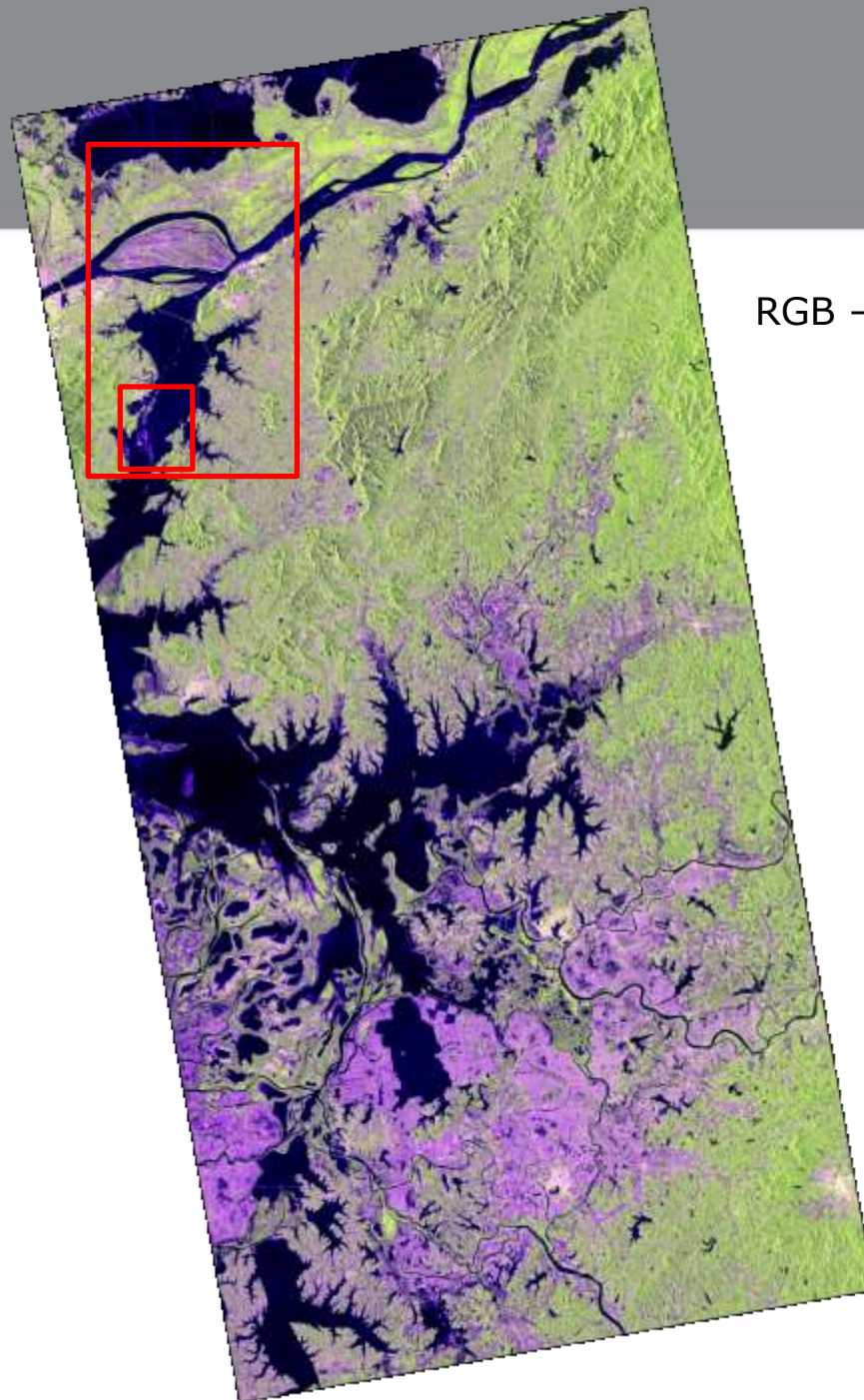
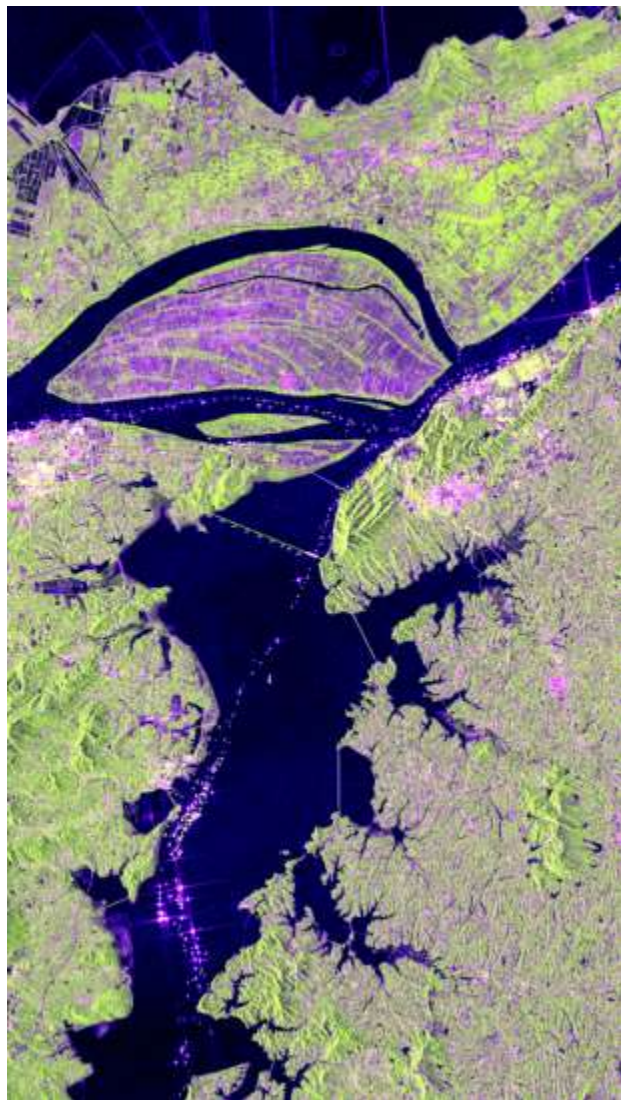
24°30'0"E

25°0'0"E

17°30'0"S

18°0'0"S

S1A Polarimetric Composition Poyang Lake



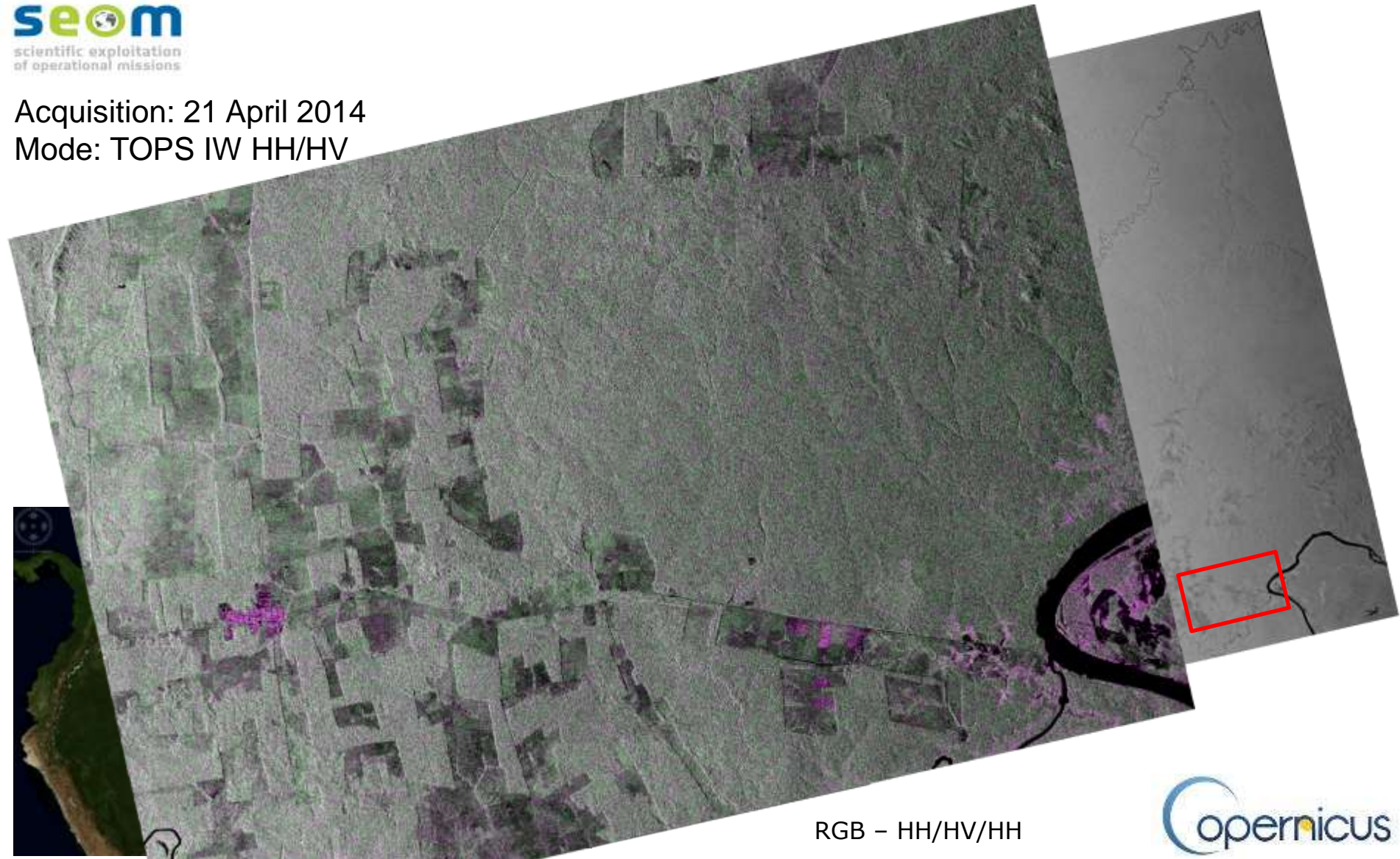
RGB – VV VH VV/VH

Sentinel-1

Deforestation over Brazil



Acquisition: 21 April 2014
Mode: TOPS IW HH/HV



RGB – HH/HV/HH



Sentinel-1

Vegetation Regeneration – Burn Scar (Greece)



A month after fire (Parnitha Mt.)
ASTER acquired July 20, 2007

Seven years after fire (Parnitha Mt.)
Sentinel-1A acquired April 22, 2014



Icebergs Antarctica Peninsula Sentinel-1A (RGB HV-HH-HH)

Post processing with Sentinel 1 Toolbox



Sentinel-1

Land Classification Dual Pol HH-HV (Germany)



Class. Method:
Random Forest

Classes:

Forest

Water

Urban

Winter crops

Bare fields

Location: Thuringia,
Central Germany

Acquisition Date:
26-April-2014

Credit Univ. of Jena
European Space Agency
Chris Schnmullius

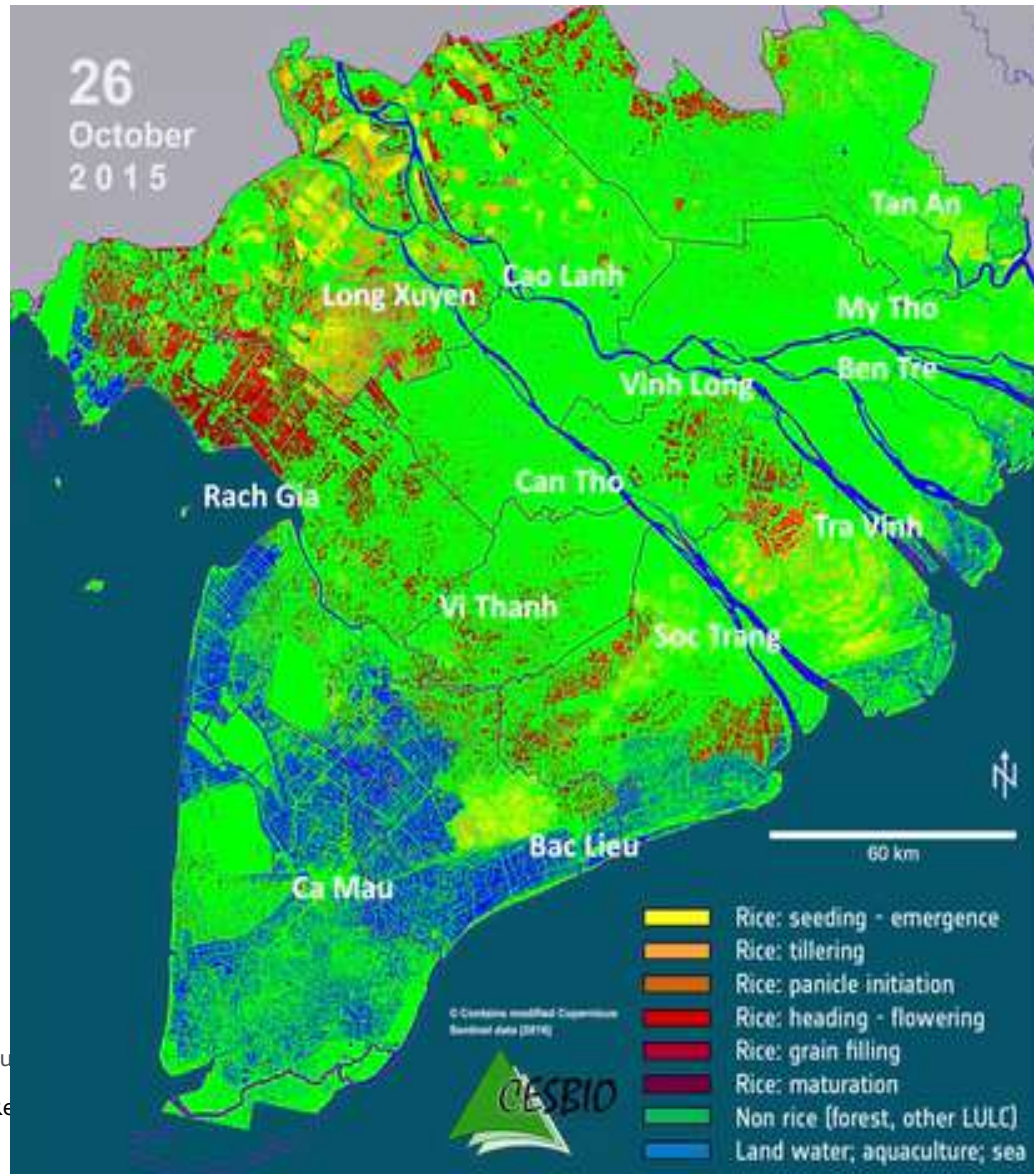
S-1A geocoded – 8 & 20 Aug, 80m (detail) – Vietnam



rice stage 1
rice stage 2
rice stage 3
non-rice

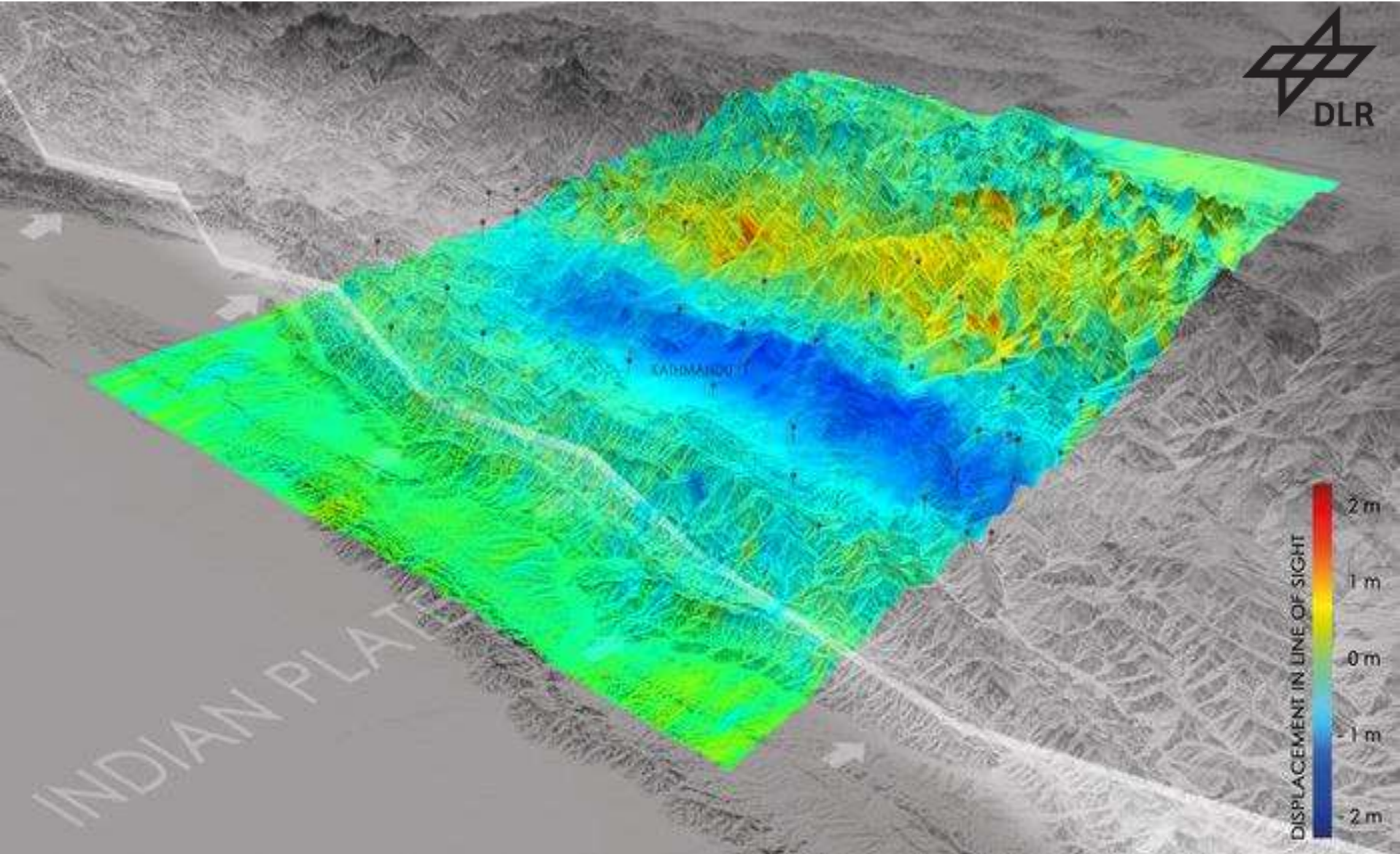
Courtesy SARMAP

Sentinel-1: Mekong Delta Rice Crops



contains modified Copernicus Sentinel data (2015-16) /CESBIO/ESA DUE GEO-Rice Innovator project

Sentinel-1A: Nepal Earthquake



Sentinel-1 Napa Valley Earthquake INSARAP (NORUT-PPO.labs-Univ. Leeds-COMET)



Sentinel-1 maps earthquake

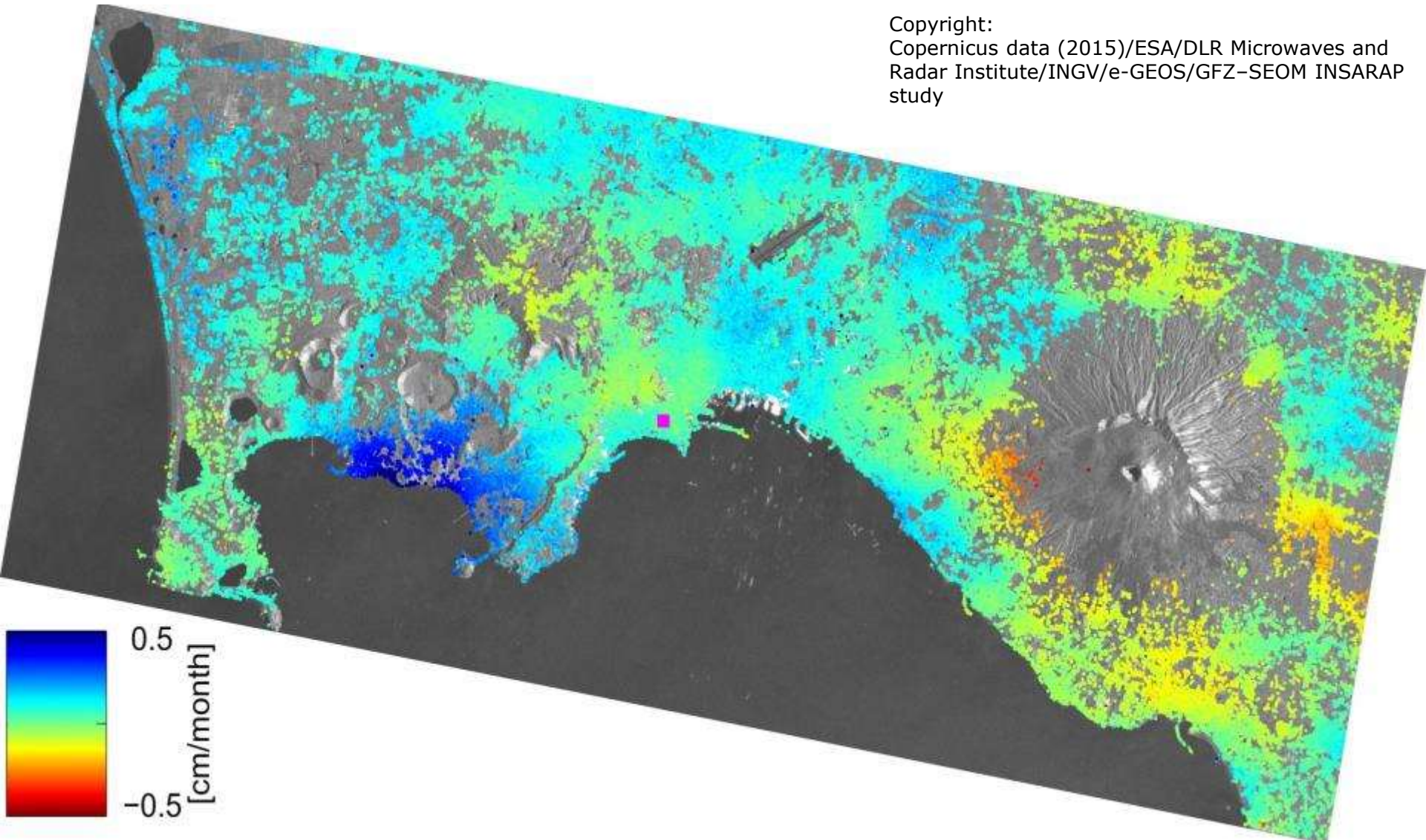
The biggest earthquake in 25 years struck California's Napa Valley in the early hours of 24 August 2014. By processing two Sentinel-1A images, acquired on 7 August and 31 August 2014 an interferogram was generated. Deformation on the ground causes phase changes in radar signals that appear as the rainbow-coloured patterns around the Napa Valley. Each colour cycle corresponds to a deformation of 28 mm deformation. The maximum deformation is more than 10 cm, and an area of about 30x30 km was affected significantly.

Copyright: Copernicus data (2014)/ESA/PPO.labs/Norut/COMET-SEOM Insarap study

Campi Flegrei seen by Sentinel-1A



Copyright:
Copernicus data (2015)/ESA/DLR Microwaves and
Radar Institute/INGV/e-GEOS/GFZ-SEOM INSARAP
study

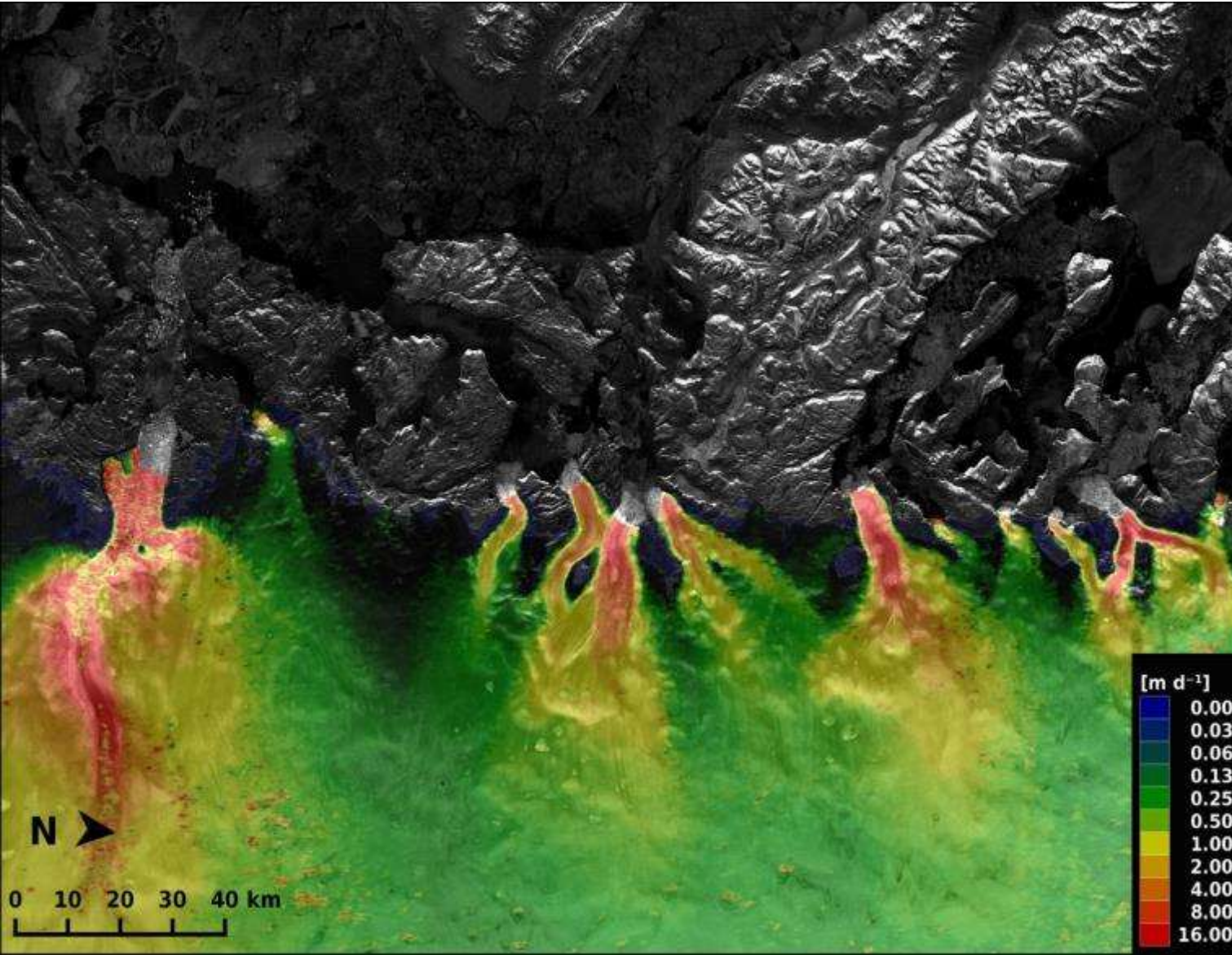


Ice Streams seen by Sentinel-1A



Greenland,
West Coast

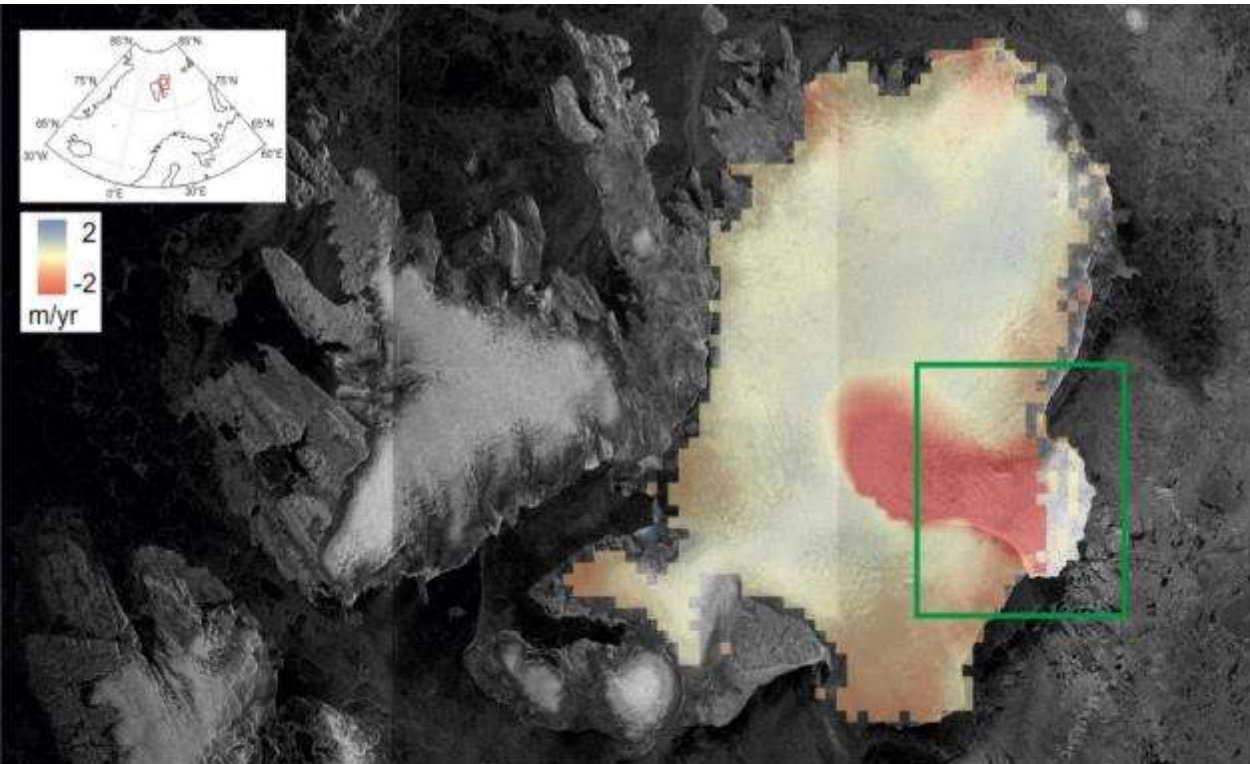
January 2015



Copyright:
Copernicus data (2015)/
ESA/Enveo

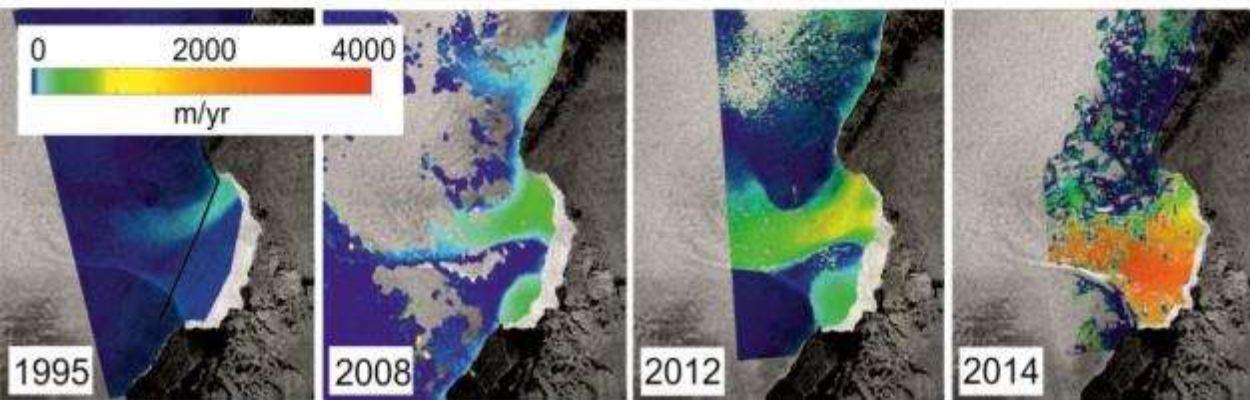
European Space Agency

Sentinel-1A: Austfonna Ice Loss



Rapid ice loss in a remote Arctic ice cap:

Combined observations from eight satellite missions, including **Sentinel-1A** and **Cryosat**



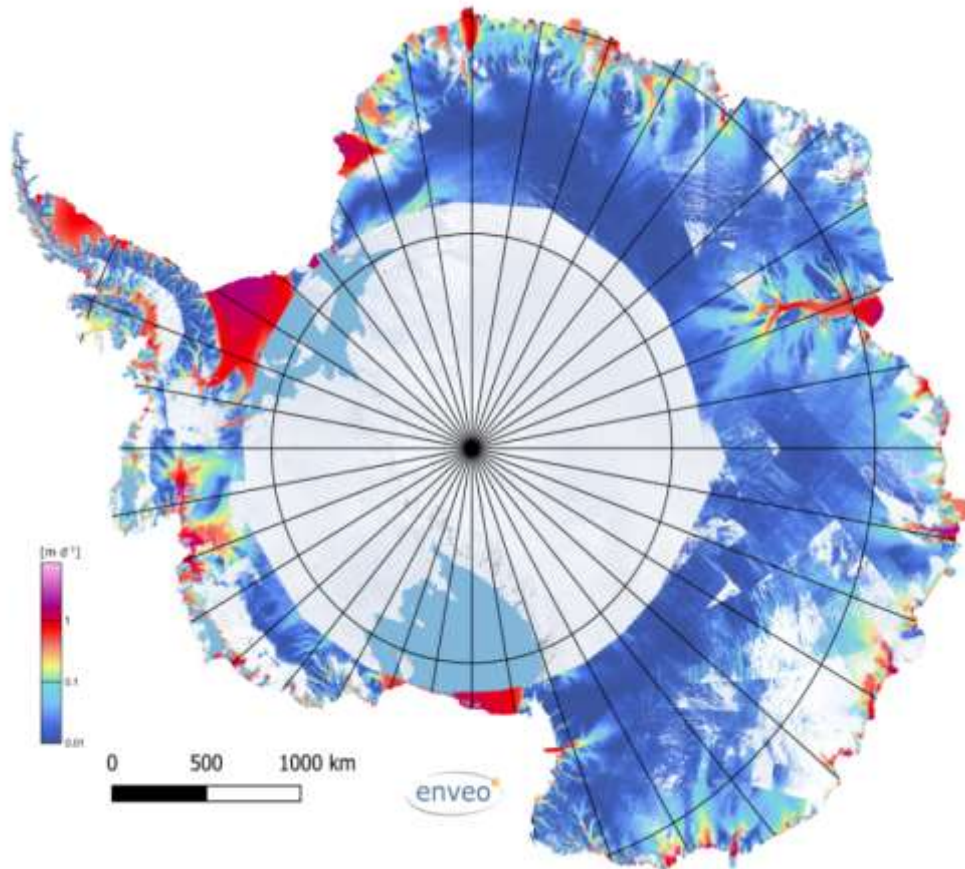
Sentinel-1: Ice Velocity Maps



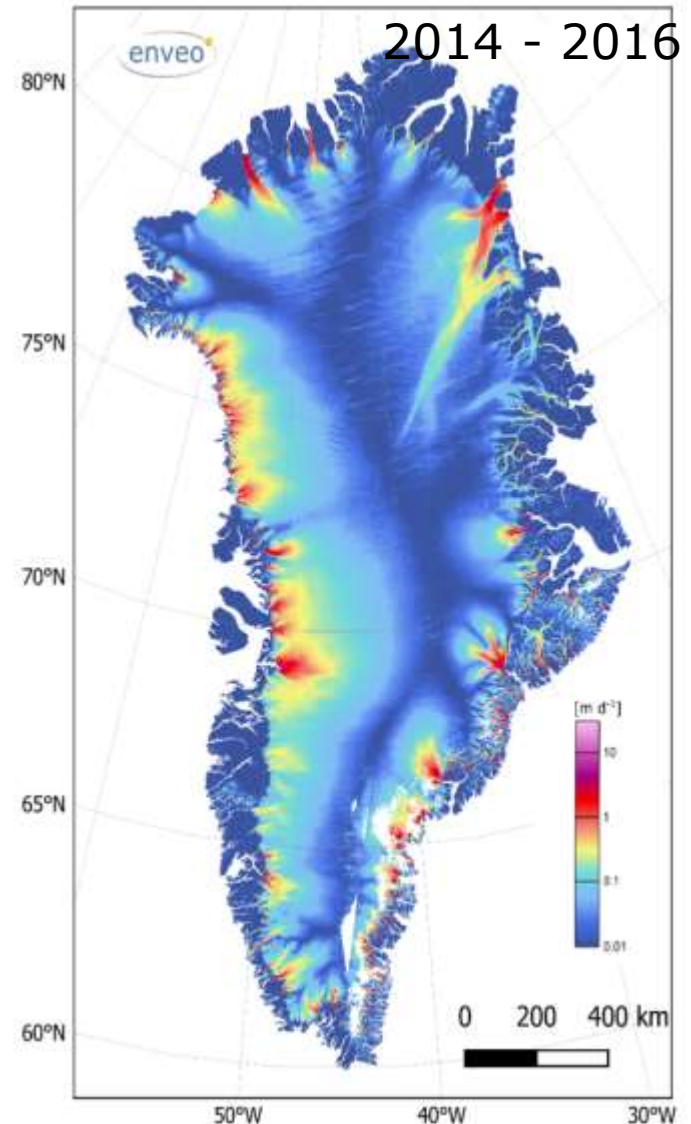
Study climate change impact on ice melting. Large ice sheets such as Greenland and Antarctica substantially contribute to the global sea level rise

2015/2016

Nagler et al.



2014 - 2016



ESA UNCLASSIFIED - Releasable to the Public

Copyright: contains modified Copernicus Sentinel data [2014-2016]

/ ENVEO / ESA CCI

36 Years of Radar Vision



Upper glacier
receded by about
5.5 km over the past
36 years,
contributing to sea-
level rise

→ **36 YEARS OF GLACIER RETREAT**
southeast Greenland

5 km

Sentinel-1B's First Image



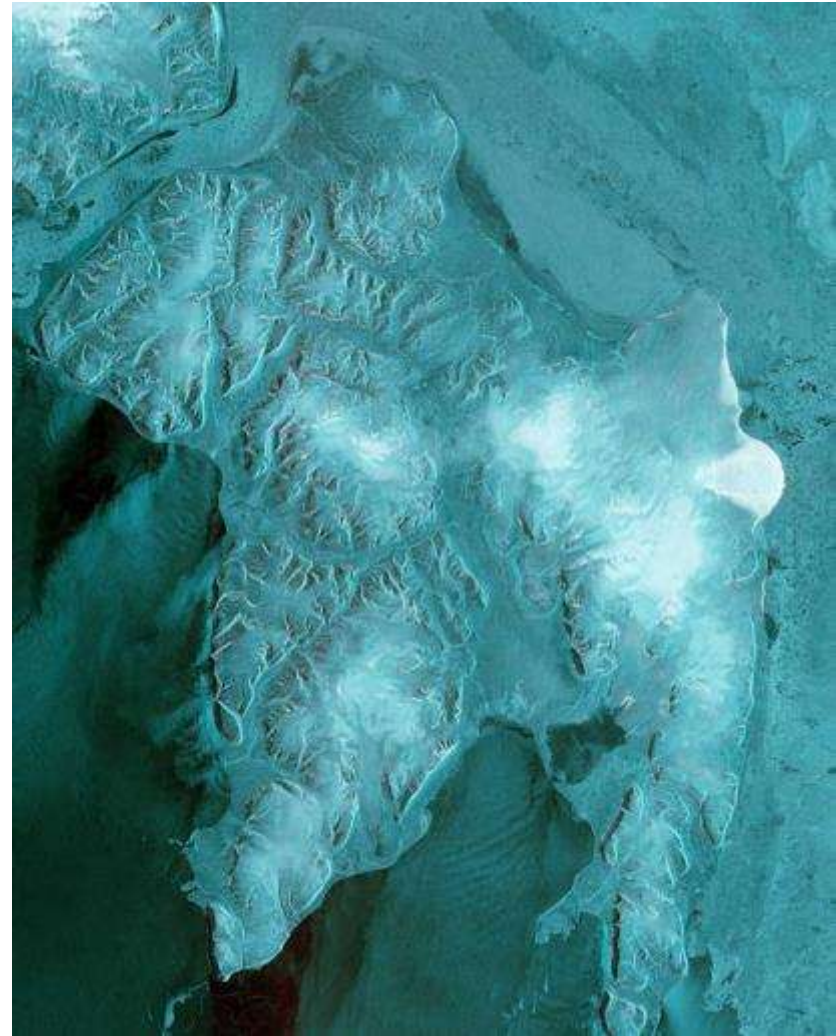
Svalbard Archipelago,
28 April 2016



full scene



subset



European Space Agency

ble to the Public

Contains modified Copernicus Sentinel data [2016], processed by ESA

Sentinel-2A launch



- 22 June 2015
- Kourou
- Vega VV05

Sentinel-2



- Wide swath high resolution super-spectral imaging mission
- Land and Security Services
- Data continuity Landsat and SPOT-type missions

Mission profile

- Multispectral instrument with **13** spectral bands (VIS, NIR & SWIR)
- Sun synchronous orbit at **786 km** mean altitude
- **290 km** swath width
- **5 days** repeat cycle at Equator (cloud free) with 2 satellites
- **7 years** design life time, consumables for 12 years
- **10, 20** and **60 m** spatial resolution

Mission objectives:

- Generic land cover maps
- Risk mapping and disaster relief

Sentinel-2

The European "Super Landsat"



SPOT 5

Landsat 8

Sentinel-2

Coverage (d)	26	16	5 (2 satellites)
Swath (km)	60	185	290
Spectral bands	4+1	8+1	13
Resolution (m)	2.5	30,(15)	10,20,(60)

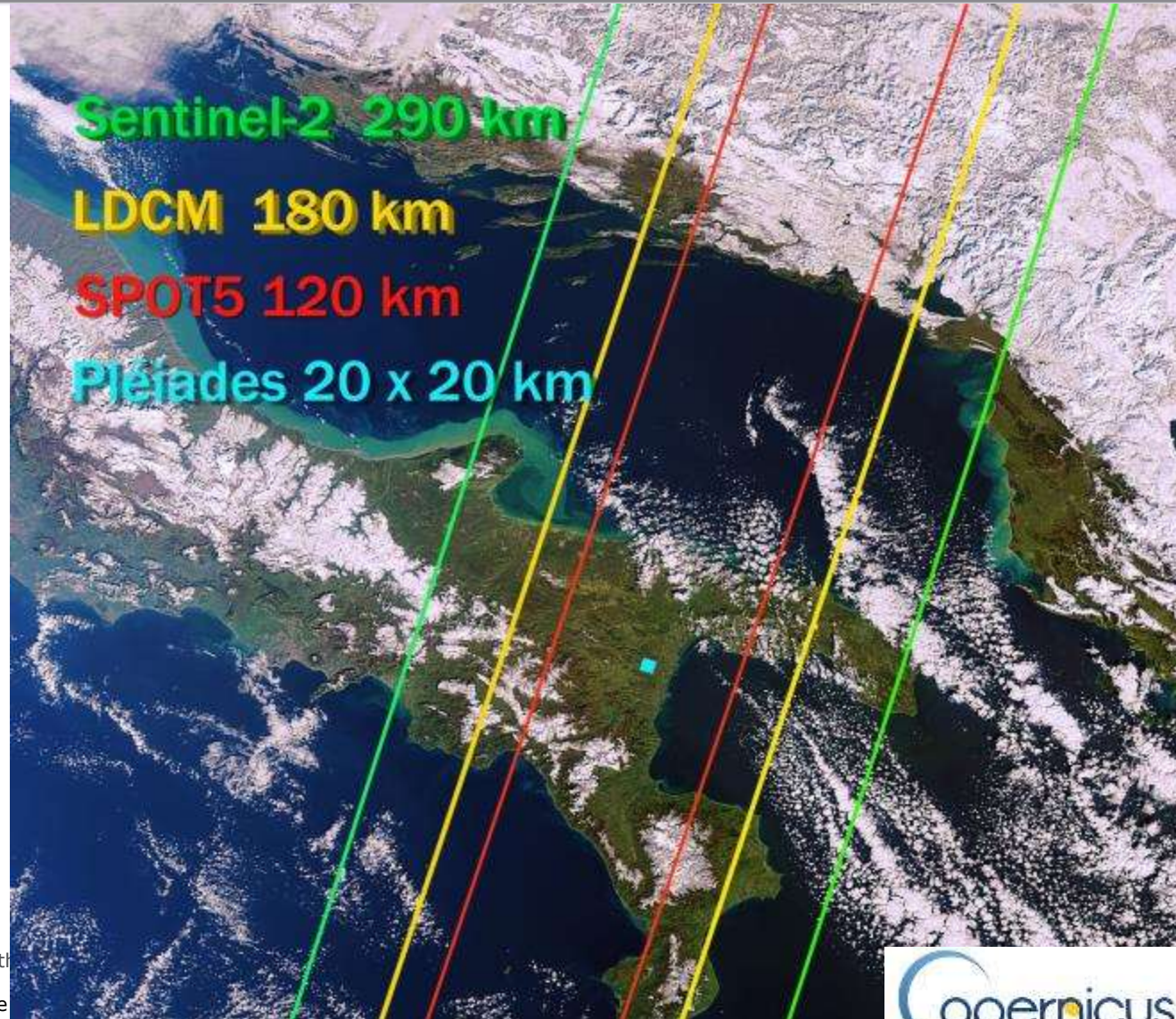
Sentinel-2

Swath width



Sentinel-2 (A+B):
Full Earth Coverage
(at Equator) in 5 days

Sentinels are
complementary to
High-Res commercial
and national missions

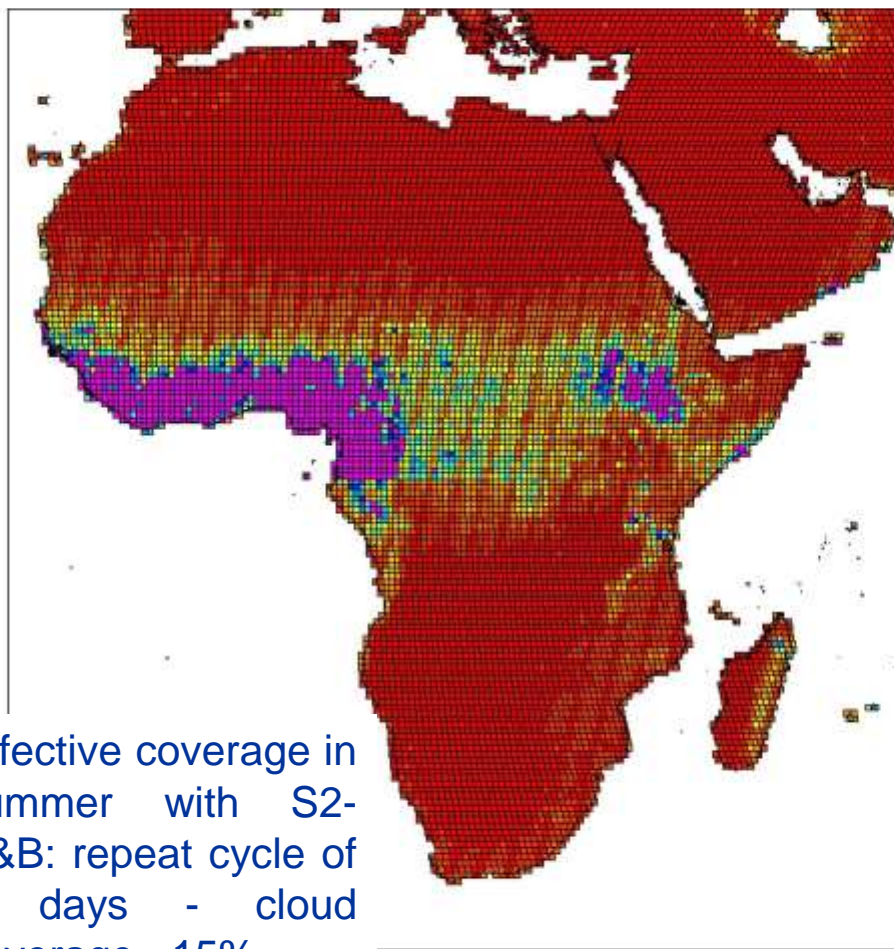


Sentinel-2 Revisit Time Capability

5 days revisit for crop dynamics

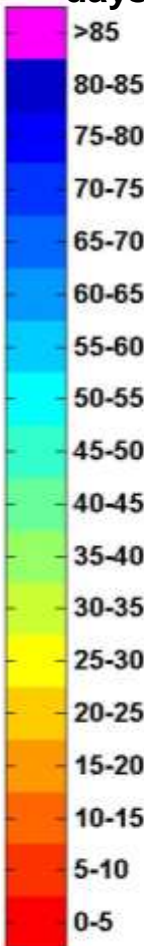


[Sentinel-2 for agriculture](http://www.esa-sen2agri.org/SitePages/Home.aspx) <http://www.esa-sen2agri.org/SitePages/Home.aspx>



Effective coverage in summer with S2-A&B: repeat cycle of 5 days - cloud coverage <15%

days



South Africa JECAM site: 5 days revisit, February-June 2013 - RapidEye



Monthly cloud free composites possible for most areas

Sentinel-2A: First images



**Northwest Italy
and Southern
France**



French Riviera



Po Valley

Sentinel-2A: Mapping Water Bodies

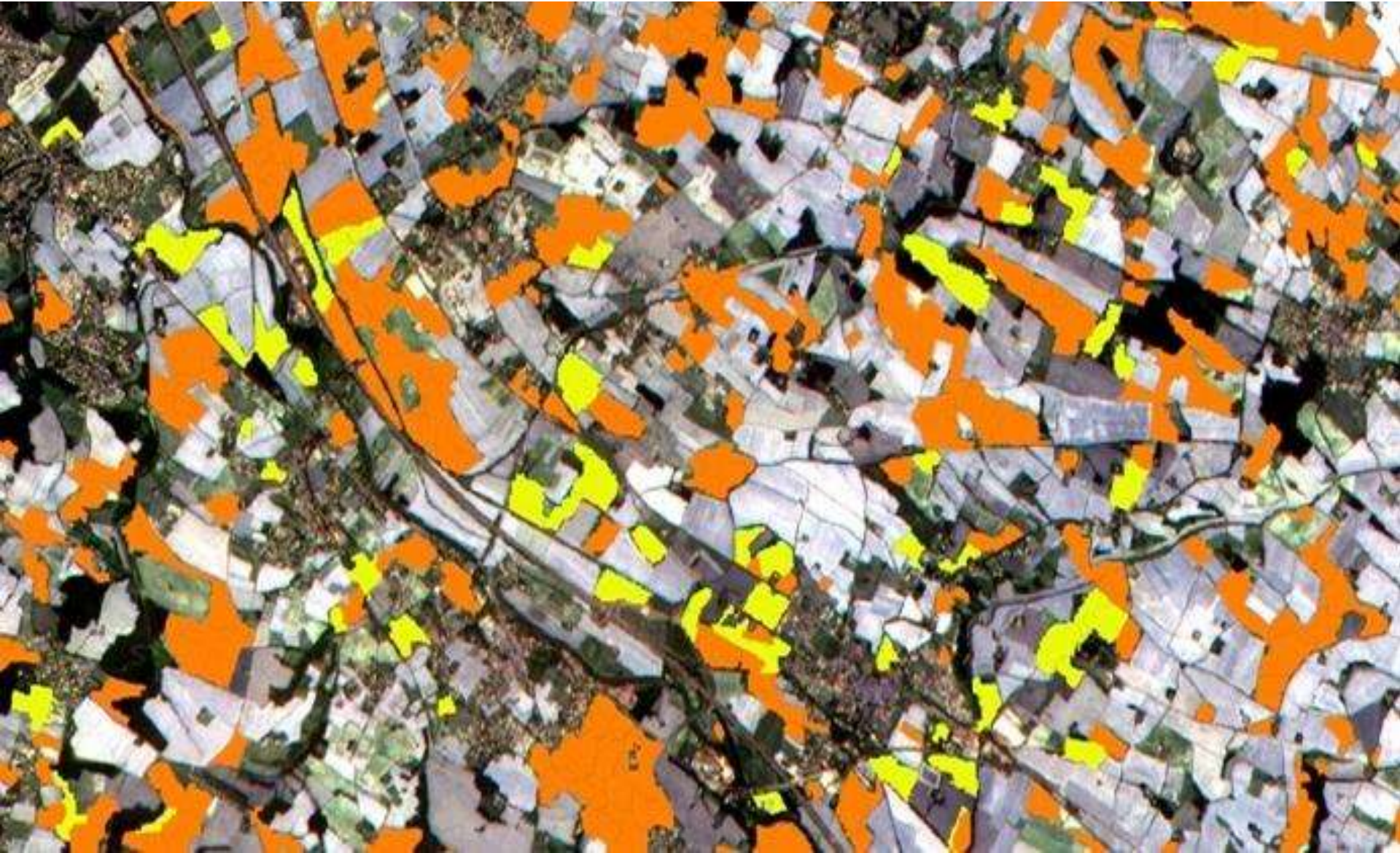


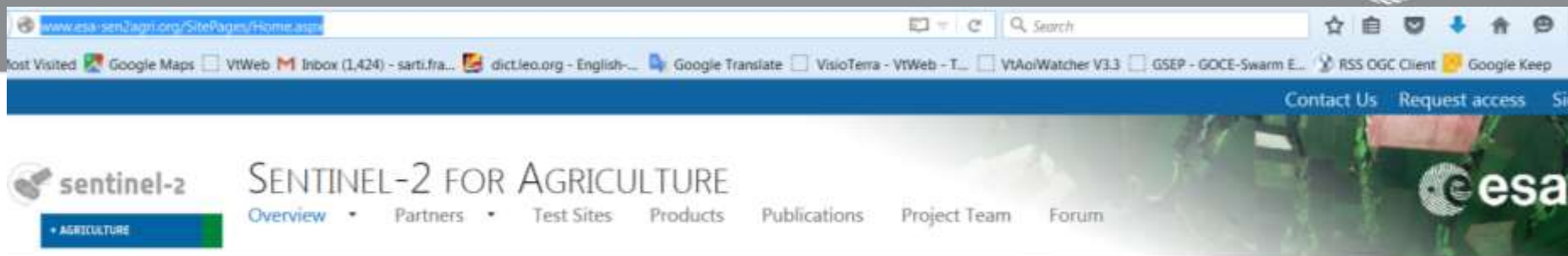
This animation shows a Sentinel-2 image over southern Spain from 12 July 2015, and how information on inland water bodies can be isolated to help better detect changes. By providing measurements of water quality and detecting changes, Sentinel-2 can support the sustainable management of water resources

Sentinel-2A: Agricultural Monitoring

See also: S-2 for vegetation
<http://www.esa-sen2agri.org/SitePages/Home.aspx>

Sentinel-2 is the first optical mission to include 3 bands in the 'red edge', providing information on the state of vegetation. In this image (6 July 2015 near Toulouse) the multispectral instrument was able to discriminate between two types of crops: sunflower (in orange) and maize (in yellow).



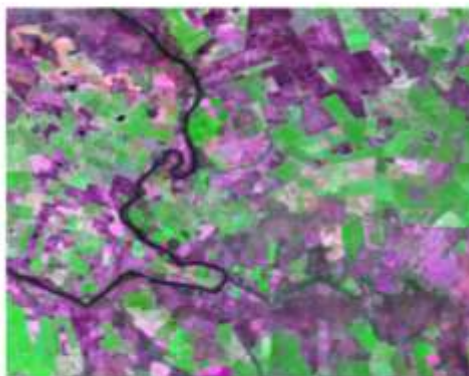


PREPARING SENTINEL-2 EXPLOITATION FOR AGRICULTURE MONITORING

Agriculture is a key remote sensing application with high requirements. Short-term observation requirements in a global perspective for agriculture monitoring were tentatively defined by the GEO Agricultural Monitoring Community of Practice. The critical importance of the decameter resolution capabilities was highlighted to cover the whole diversity of the agricultural landscapes.

In this respect, the up-coming Sentinel-2 mission is a unique opportunity. Its 10-20m spatial resolution, its 5-day revisit frequency, its global coverage and its compatibility to the Landsat missions offer new opportunities for regional to global agriculture monitoring.

In this context, the Sentinel-2 for Agriculture (Sen2-Agri) project has recently been launched by ESA, as a major contribution to the R&D component of the GEOGLAM initiative and to the JECAM network activities. The project will demonstrate the benefit of the Sentinel-2 mission for the agriculture domain across a range of crops and agricultural practices. The intention is to provide the international user community with validated algorithms to derive



Earth Observation products relevant for crop monitoring.



SPOT5 TAKES to acquire a new Sentinel-2 like dataset

UPCOMING EVENTS

Sen2-Agri project at IGARSS 2015

7/26/2015, Milano, Italy

Sen2-Agri project presented at IGARSS 2015, in Milano.

Sentinel-2 for Science Workshop

5/20/2014, Frascati, Italy

Sentinel-2 for Science Workshop hosted by ESA-ESRIN between May 20th and 22nd, 2014.

Sentinels in Co-Operation

Using both S1 and S2 data (and Landsat-8). Innovative crop type map at national scale: pilot project for potential future Copernicus service agricultural components



→ CZECH AGRICULTURE FROM SPACE

contains modified Copernicus Sentinel data [2016]

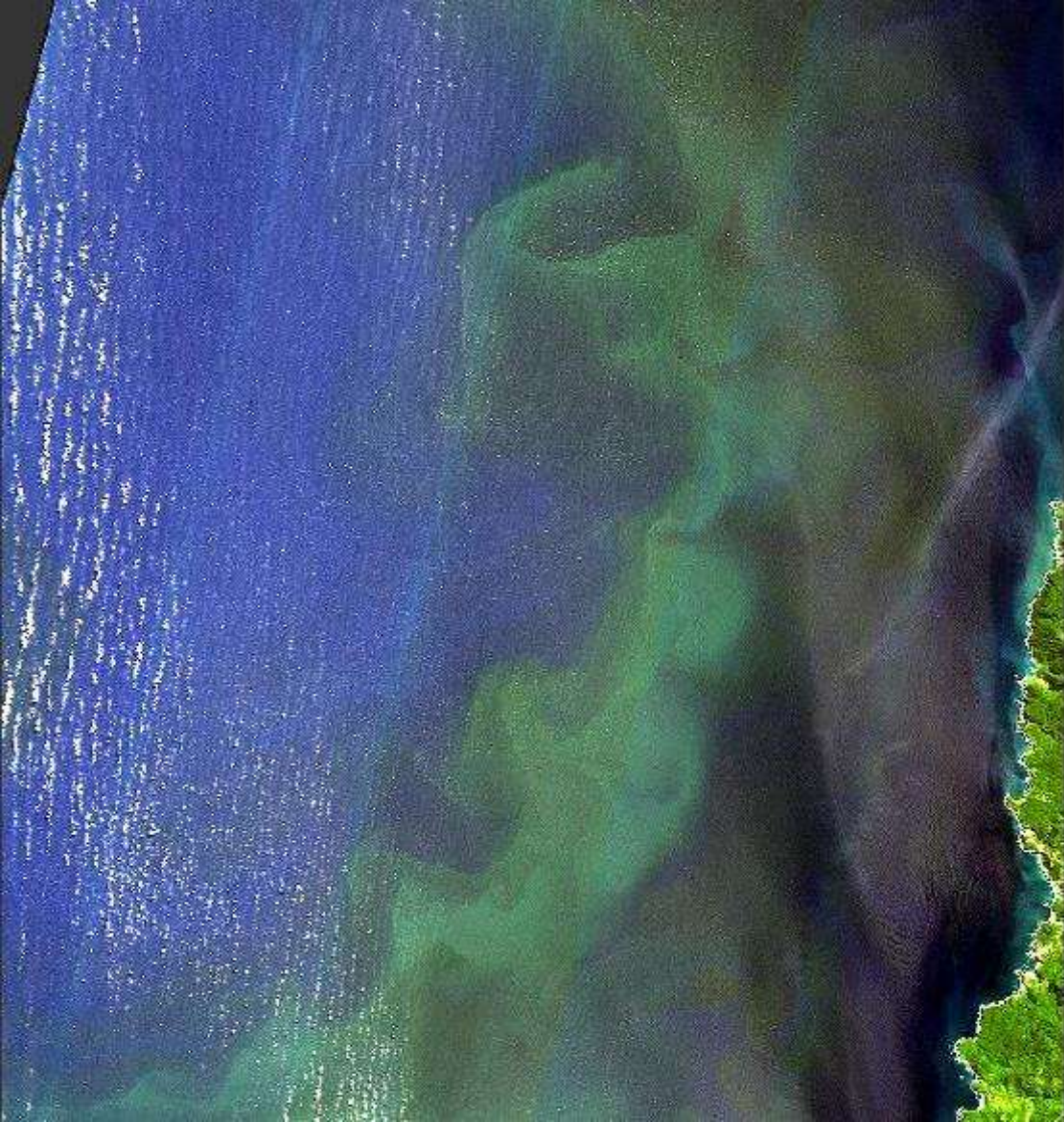


**CZECH CROP TYPE
MAP 2015**

- winter rapeseed
- winter cereals
- spring cereals
- sugarbeet
- maize
- potatoes
- fodder crops
- other annual crops

Data sources:
Sentinel-1, Sentinel-2,
Landsat-8, Dvorník 2015

Sentinel-2A: Algal Bloom



Algal bloom along the coast of Valdivia, Chile

Extreme economic impact: more than 24 Million of salmon died, more than 800 Millions of USD loss

Sentinel-2A,
5 March 2016

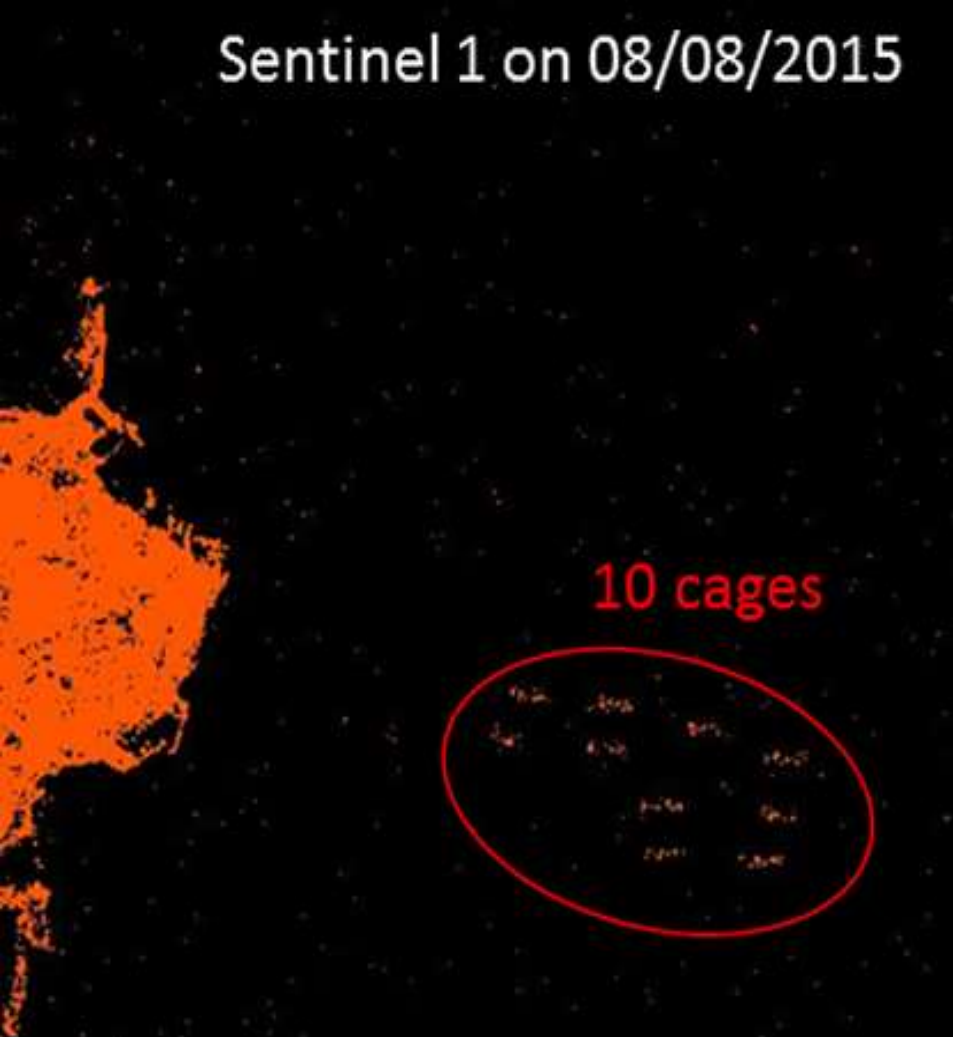


contains Copernicus Sentinel data [2015]

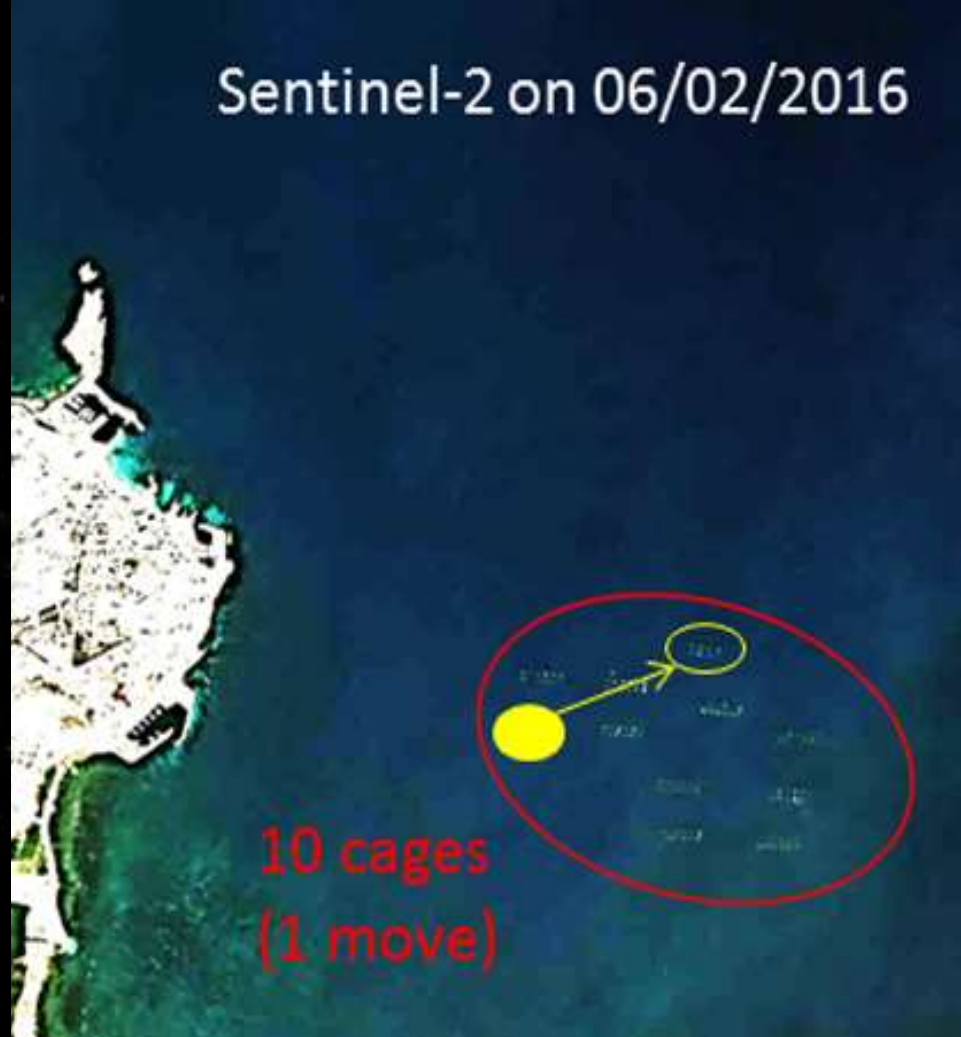
Sentinels in Co-Operation



Sentinel 1 on 08/08/2015



Sentinel-2 on 06/02/2016



A specific commercial serviced developed in France for precision farming is FARMSTAR:
https://www.farmstar-conseil.fr/agriculture_teledection.html



FARMSTAR expert
Vos parcelles vues du ciel

Services ▾ | Conseils ▾ | Avantages | Réseau

Accueil / Agriculture durable / Les images satellite au service de l'agriculture de précision

Les images satellite au service de l'agriculture de précision

Les satellites tournent autour de la Terre à environ 900 km d'altitude et enregistrent des images en tout point du globe. Les trajectoires qu'ils suivent leur permettent de passer régulièrement au-dessus des mêmes zones et donc de suivre dans le temps l'évolution des cultures.

Les informations que l'on déduit de ces images, pour l'agriculture de précision, concernent le couvert végétal. En effet, suivant l'avancement du développement de la végétation, l'énergie solaire réfléchi par les plantes n'est pas la même. C'est cette réflectance que mesurent les satellites. Celle-ci permet de déduire la teneur en chlorophylle des plantes grâce à des modèles de réflectances, et ainsi estimer les besoins en engrais et produits phytosanitaires.

Cette correspondance entre réflectance et besoin des végétaux est le fruit de longues années de recherches et de développements qui permettent aujourd'hui de caractériser en temps réel l'état du végétal.

Ces données sont ensuite combinées à des modèles agronomiques, qui intègrent les conditions météorologiques et les caractéristiques culturales des parcelles pour générer des cartes de préconisation directement utilisables par l'agriculteur.

FARMSTAR Expert est le seul service opérationnel de télédétection au monde capable d'une telle prouesse technologique !

Agriculture durable

- L'agriculture: l'affaire de tous
- Les agriculteurs éco-acteurs
- Nos distributeurs FARMSTAR Expert
- FARMSTAR Expert: 10 ans d'agriculture plus responsable
- FARMSTAR Expert: une histoire d'hommes et d'innovations
- Les images satellite au service de l'agriculture de précision

Process FARMSTAR

Sentinel-3 (3-A launched)



March 2016

- Medium resolution imaging and altimetry mission
- Land and ocean applications



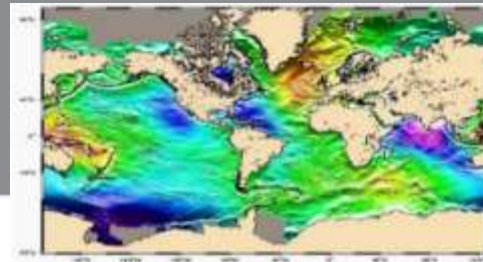
Sentinel-3 Payload

Optical Mission Payload

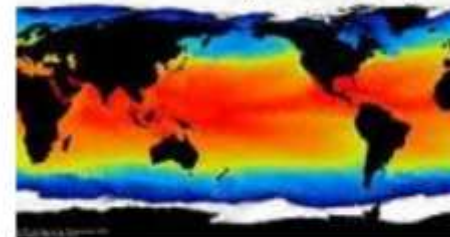
- Ocean and Land Colour Instrument (OLCI)
- Sea and Land Surface Temperature Radiometer (SLSTR)

Topography Mission Payload

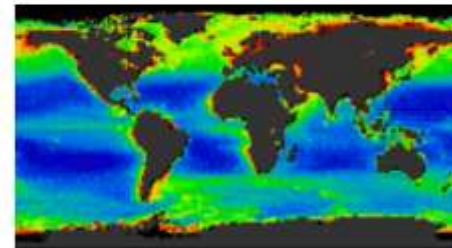
- Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL)
- MicroWave Radiometer (Bi-frequency)
- Precise Orbit Determination (POD) including:
 - GNSS Receiver
 - DORIS
 - Laser Retro-Reflector



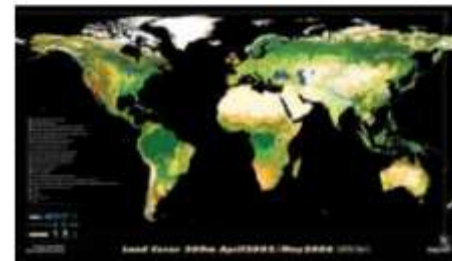
Sea Surface Height products
(Credit: CLS)



Sea Surface Temperature products
(Credit: Met Office)



Ocean colour products
(Credit: MyOcean)



Land cover products
(Credit: ESA)

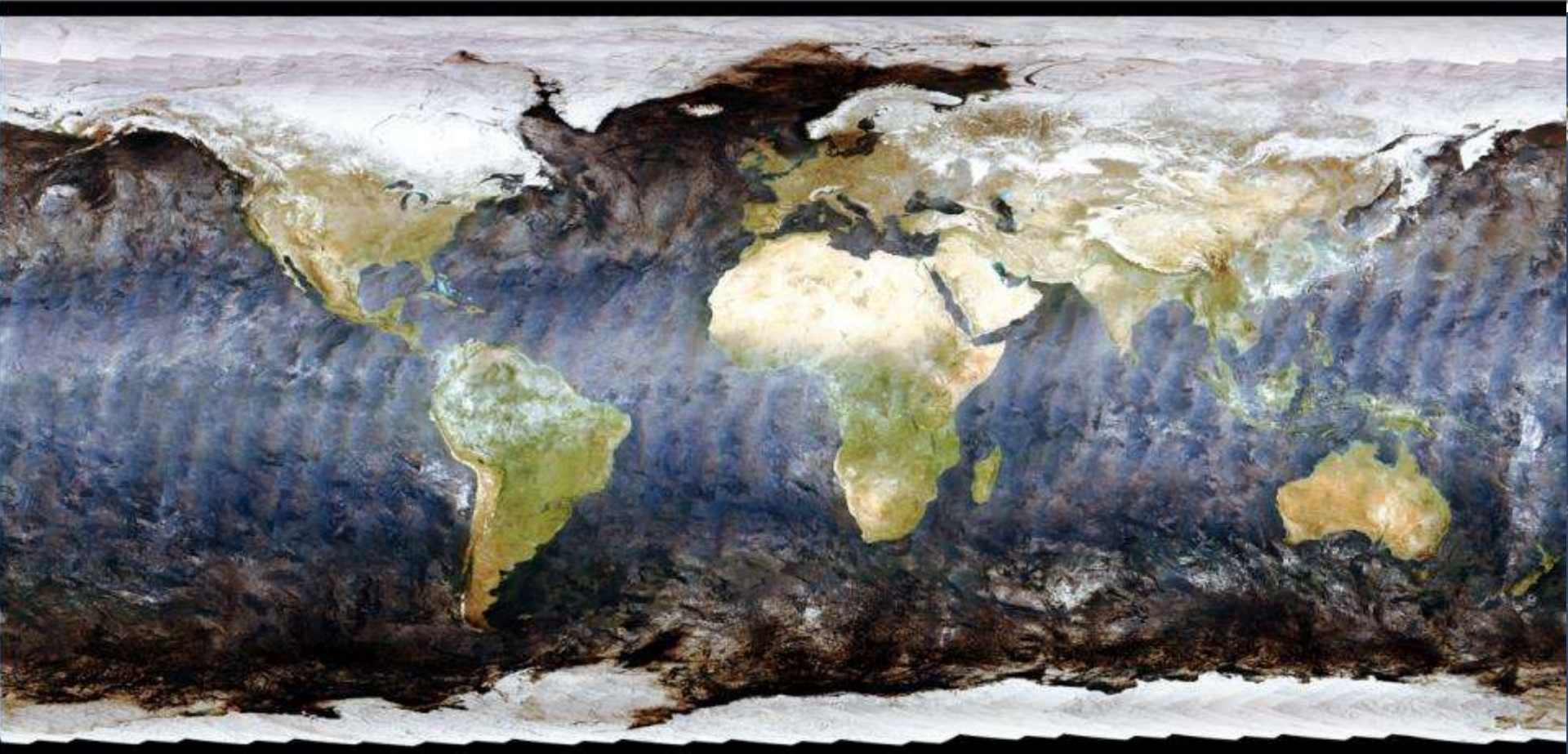
Sentinel-3 Revisit Time & Coverage: Optical Mission



	Number of Satellites	Revisit at Equator	Revisit for latitude >30°	Spec.
Ocean Colour (Sun-glint free, day only)	2 Satellites	< 1.9 days	< 1.4 days	< 2 days
Land Colour (day only)	2 Satellites	< 1.1 day	< 0.9 day	< 2 days
SLSTR dual view (day and night)	2 Satellites	< 0.9 day	< 0.8 day	< 4 days

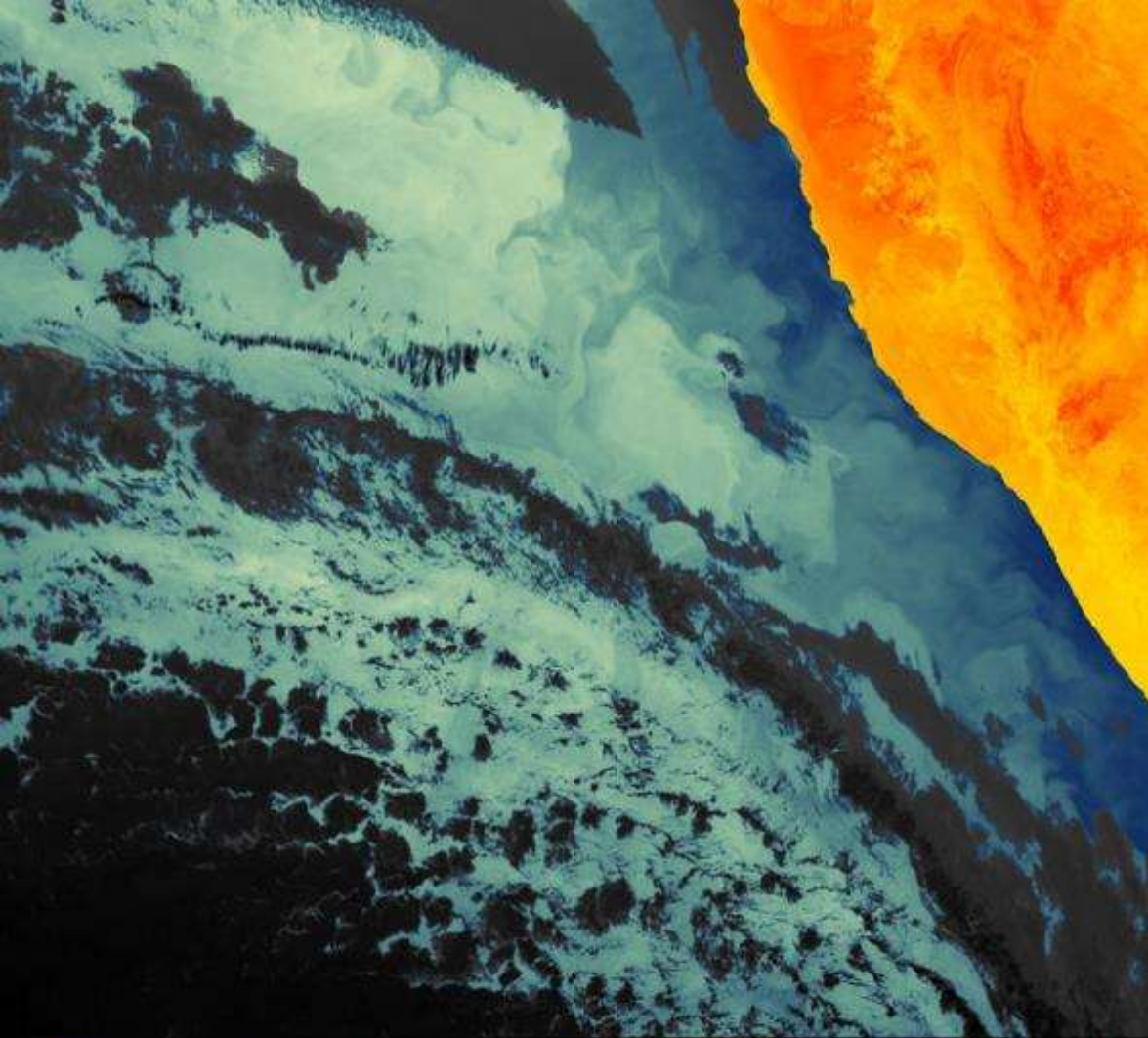
➤ **Short Revisit times for optical payload**

Sentinel-3 Applications



True colour composite mosaic of MERIS data for March 2003. OLCI will provide global coverage data for 21 spectral bands (400 -1020nm) at a spatial resolution of ~300m

Sentinel-3A: Thermal Signatures



Namibian Coastline,
29 March 2016



Contains modified
Copernicus Sentinel data
[2016]

European Space Agency

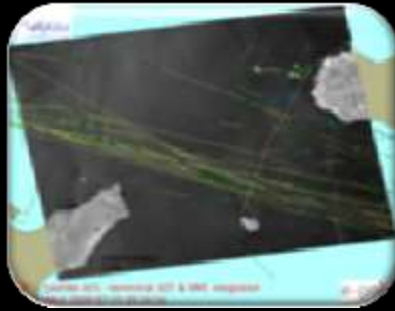


Sentinel-4/5/5p

- Atmospheric chemistry missions
- Instruments to be flown on
 - MTG (Sentinel 4)
 - MetOp SG (Sentinel 5)
- Separate precursor mission for Sentinel 5



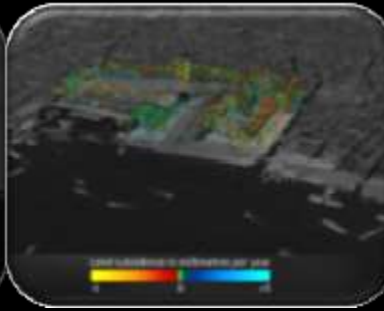
Some Sentinel Application Areas



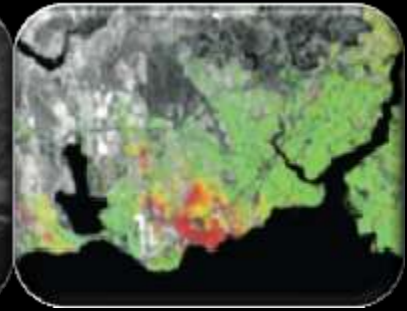
Maritime surveillance



Oil spills



Land subsidence



Tectonics



Volcanoes



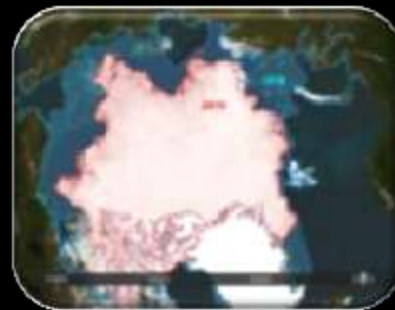
Floods



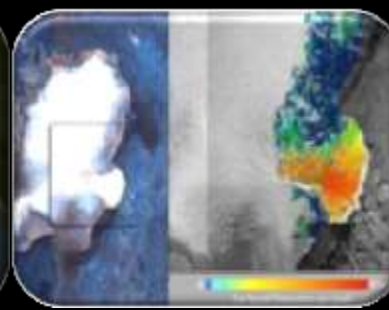
Deforestation



Vegetation



Sea ice extent



Ice speed

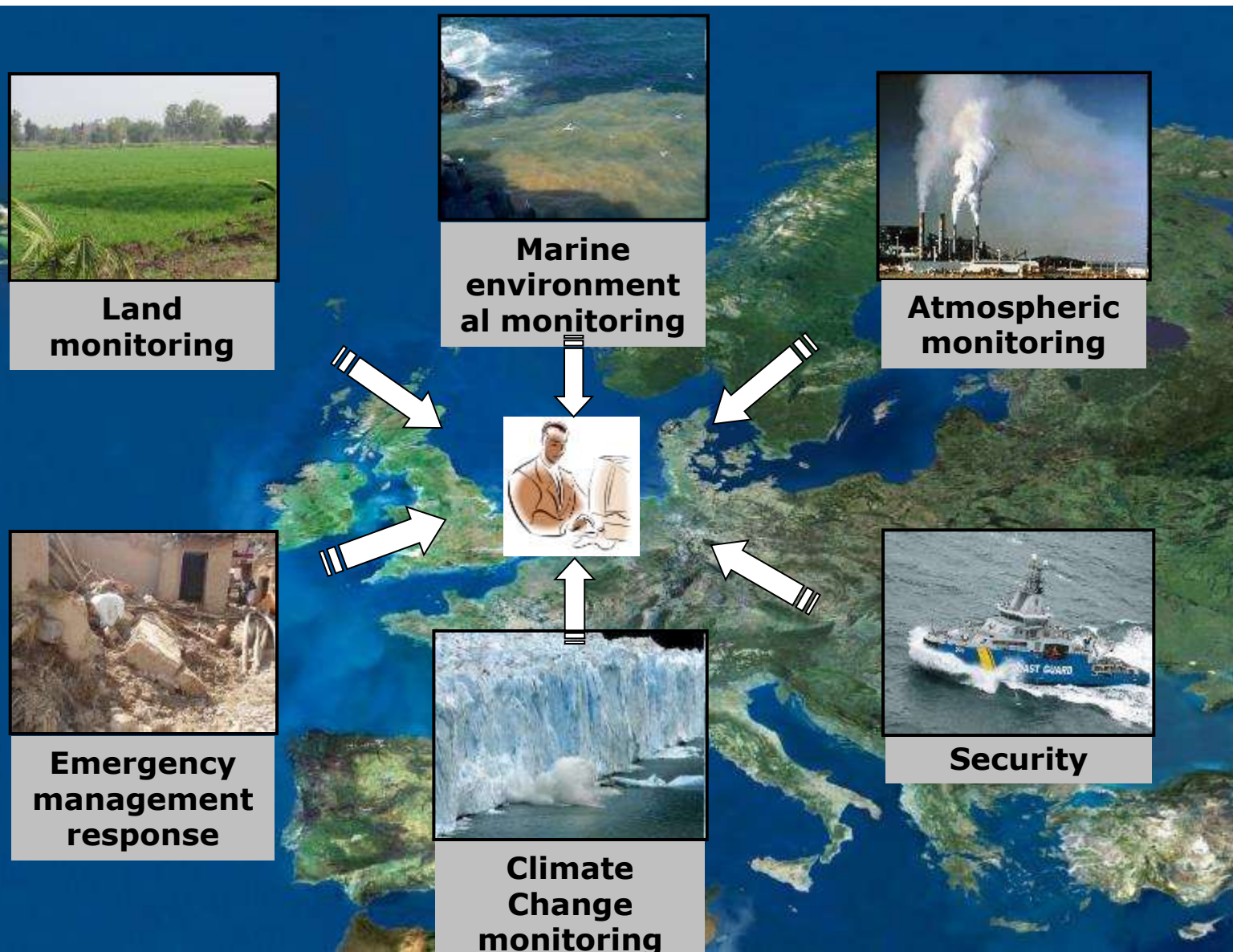


Atmosphere

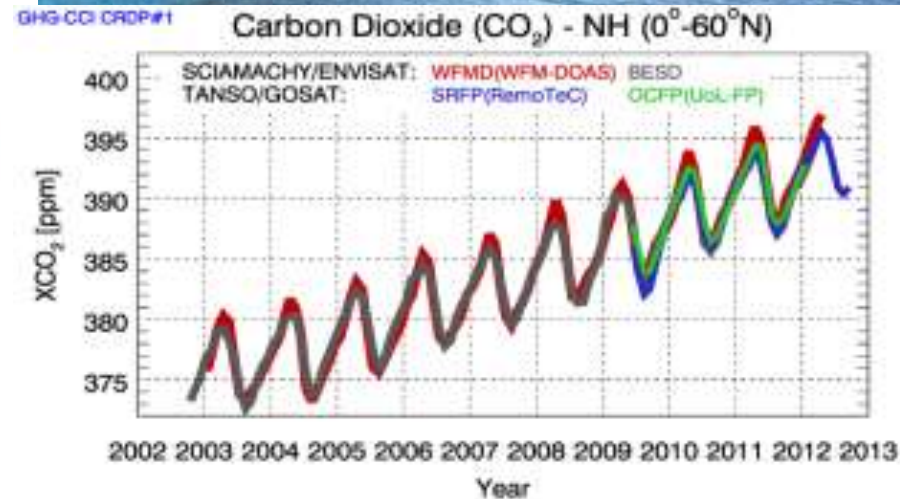
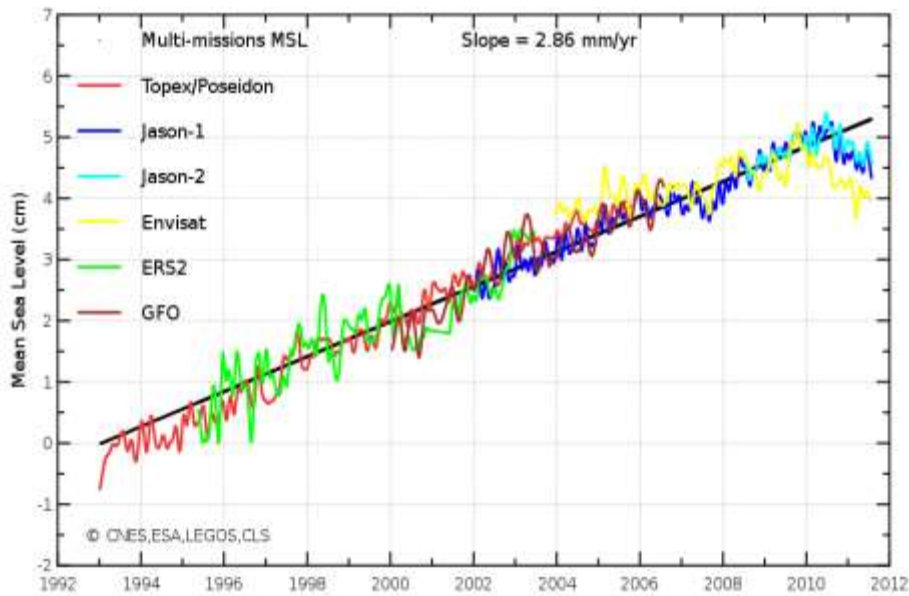


Ocean colour

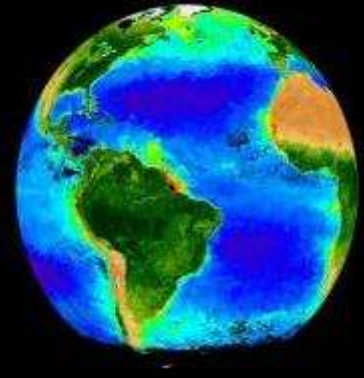
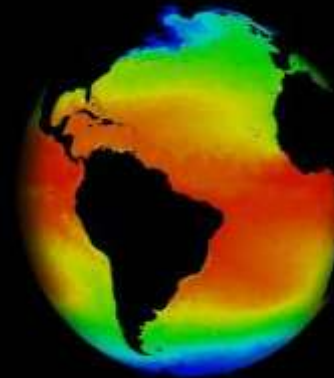
GMES/ Copernicus Services domains



The ESA Climate Change Initiative (CCI)



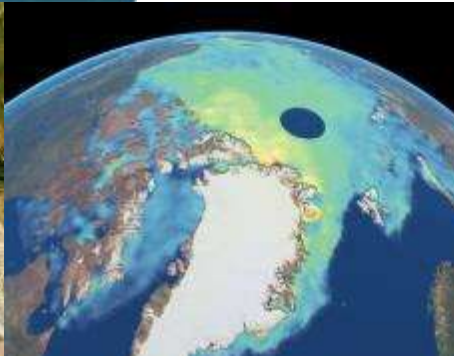
- Cloud Properties
- Carbon Dioxide, Methane & other GHGs
- Ozone
- Aerosol properties
- Sea Surface Temperature
- Sea Level; Sea Ice
- Ocean Colour
- Glaciers and ice caps
- Land cover
- Fire disturbance
- Soil moisture



EOEP Impact on IPCC



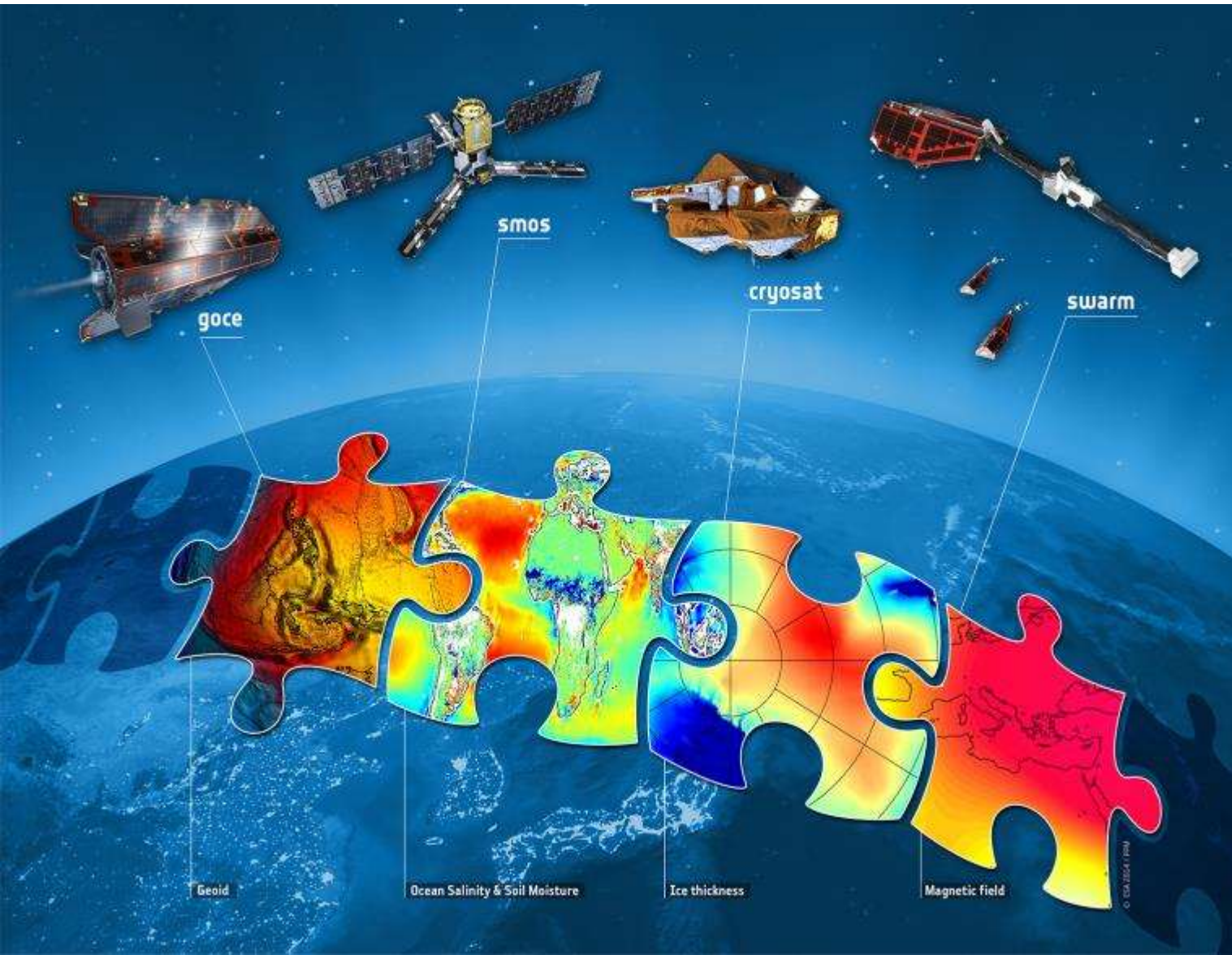
- “Satellites have improved the capabilities of observations for climate science, in terms of volume and quality”
- Chapter 2: Observations: Atmosphere and Surface
 - ATSR series
- Chapter 4: Observations: Cryosphere
 - Altimetry/SAR (ERS-1/2; Envisat); Cryosat-2; IMBIE
- Chapter 13: Sea Level Change
 - Altimetry (ERS-1/2; Envisat)



Science – the Earth Explorers

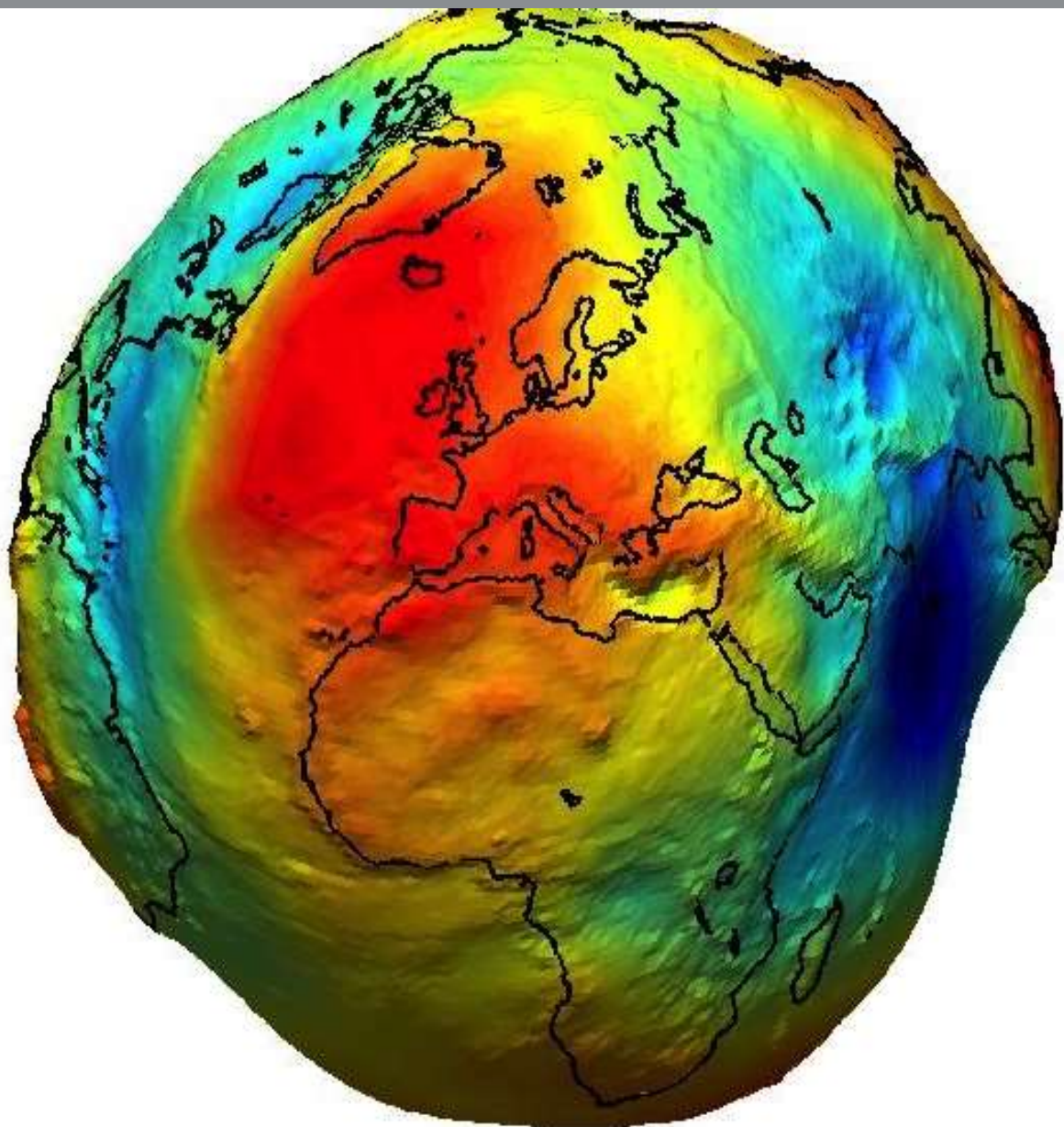


Science – the Earth Explorers



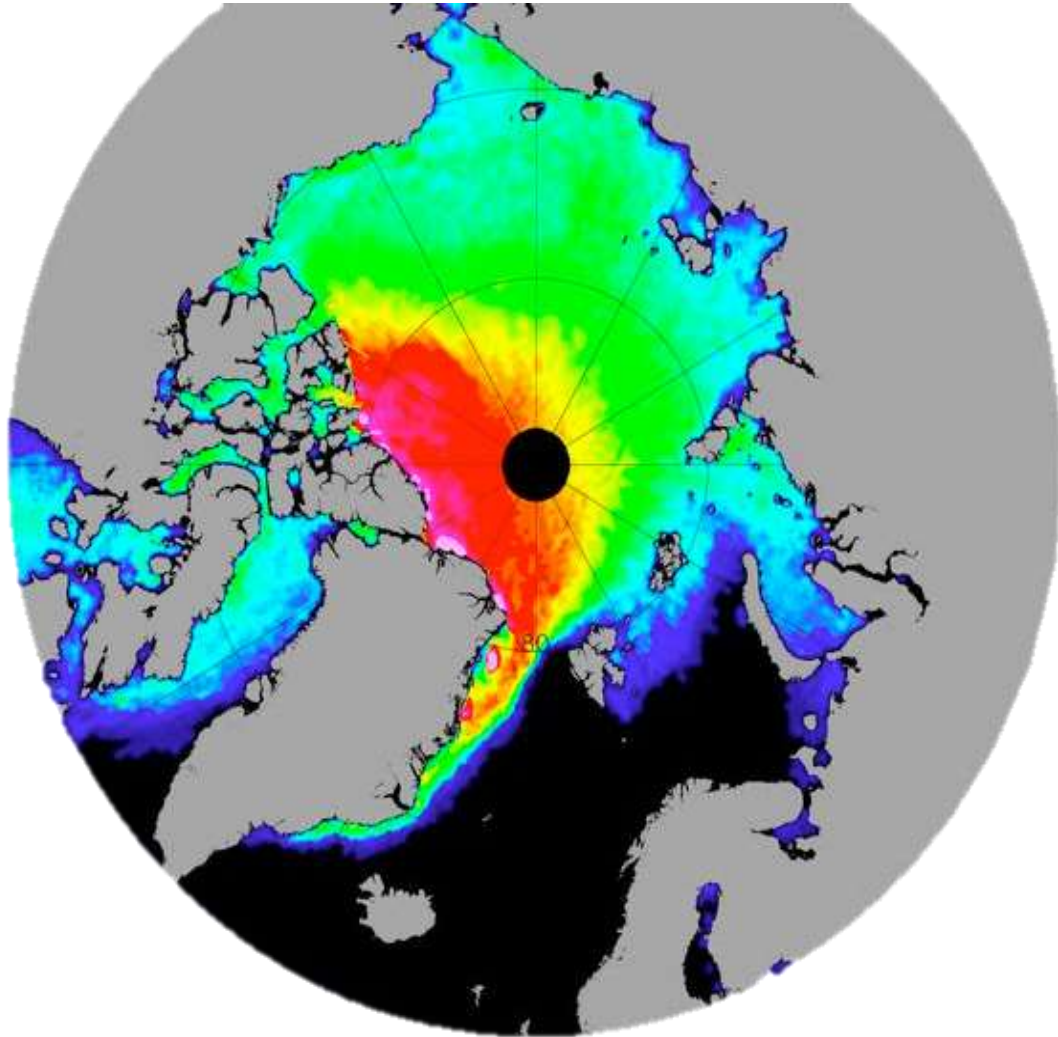
Earth Explorers launched so far

GOCE: Mission accomplished



Most precise geoid to date

Cryosat: Mission accomplished and ongoing

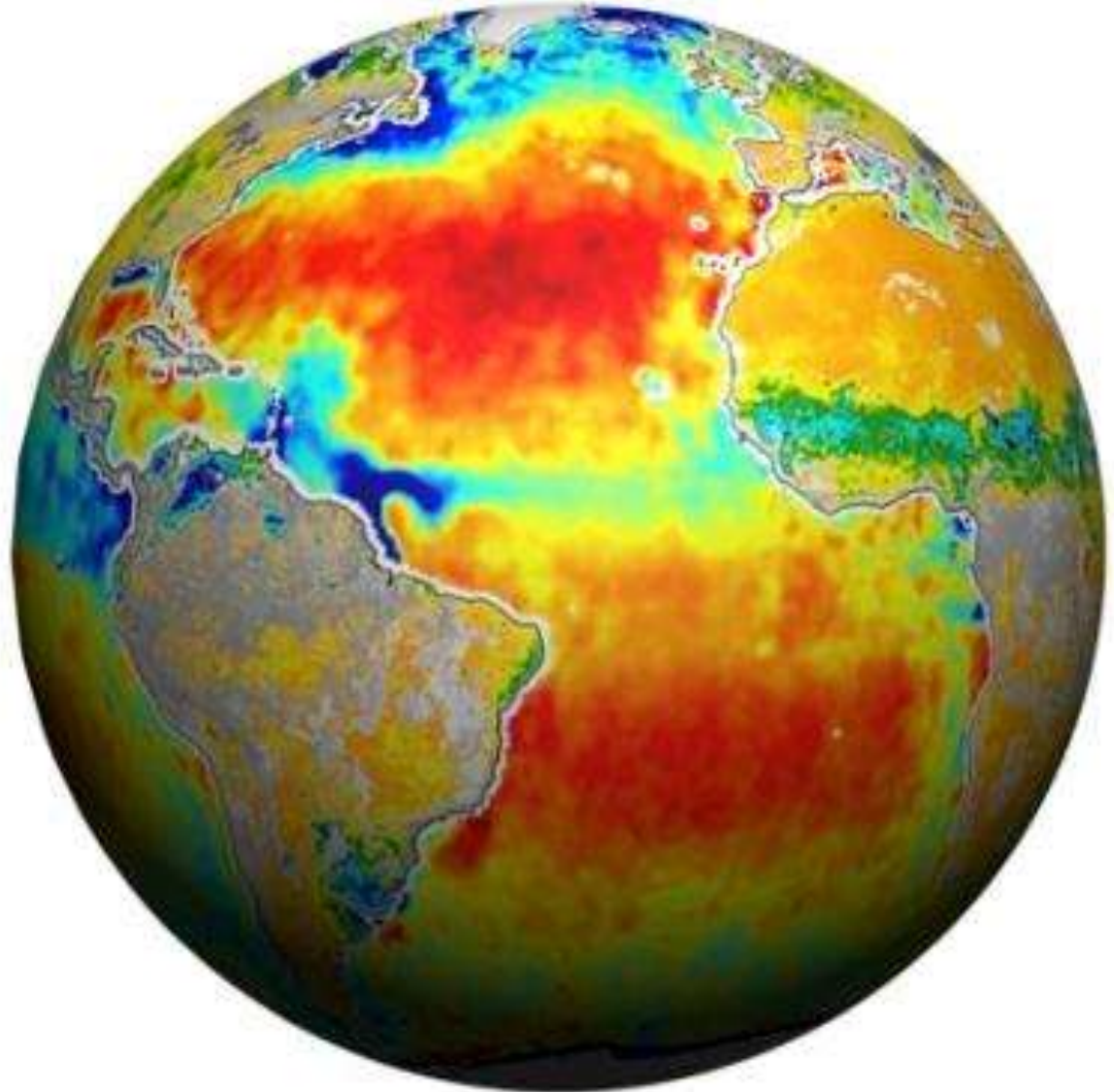


Surveyed sea ice thickness

Average spring sea ice thickness 2010-2015

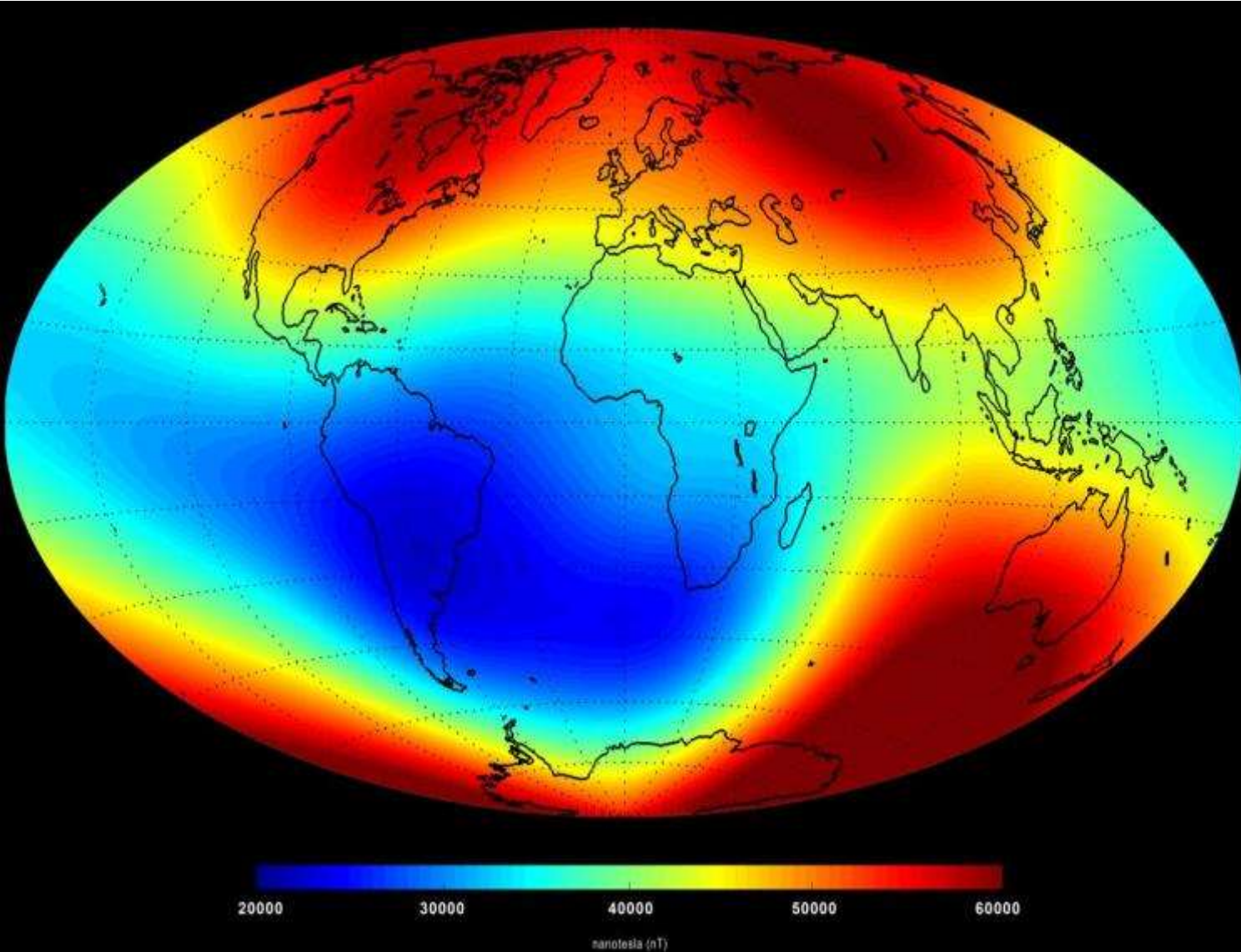


SMOS: Mission accomplished and ongoing



Monitoring soil moisture and ocean salinity. Globally.

Swarm: Mission accomplished and ongoing



Tracking Earth's dynamic magnetic field. European Space Agency

ADM-Aeolus and EarthCARE



ADM-Aeolus

- Global observations of wind profiles for analysis of global 3D wind field
- Launch end 2017



EarthCARE

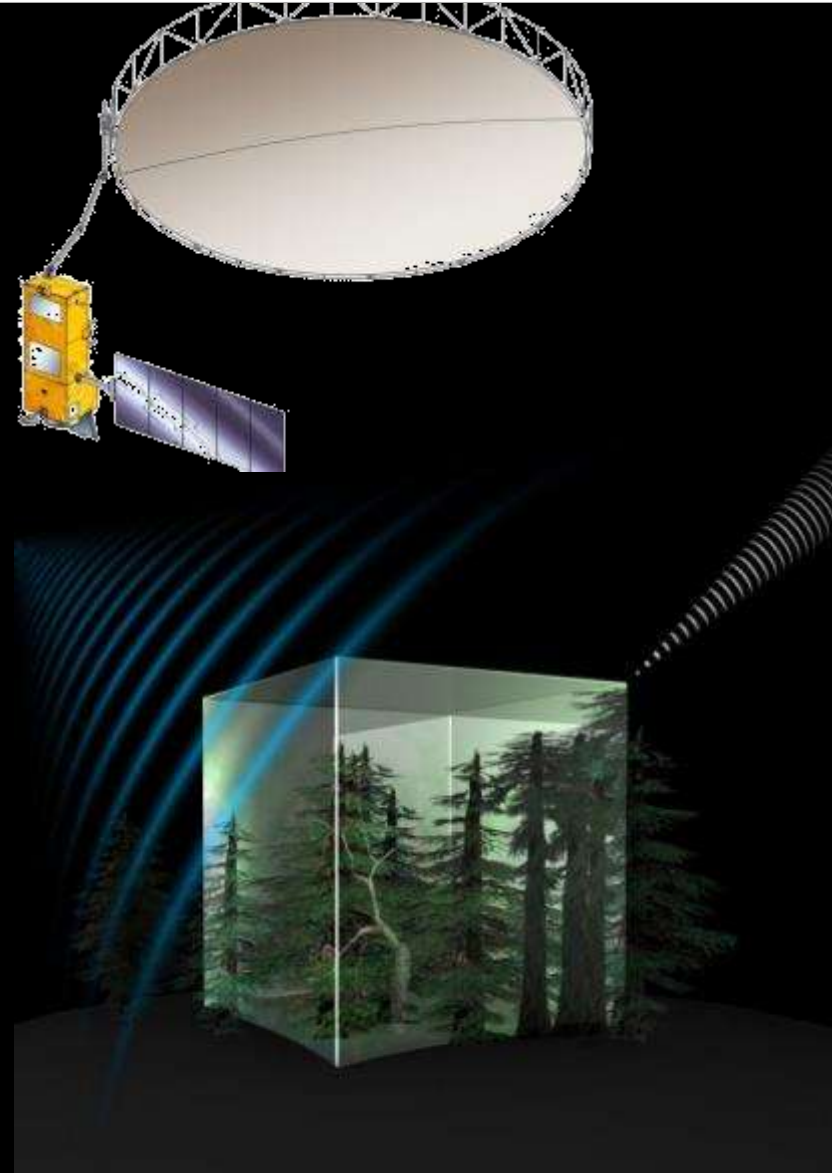
- Global observations of clouds, aerosols and radiation
- Launch planned for 2018



Biomass, the 7th Earth Explorer



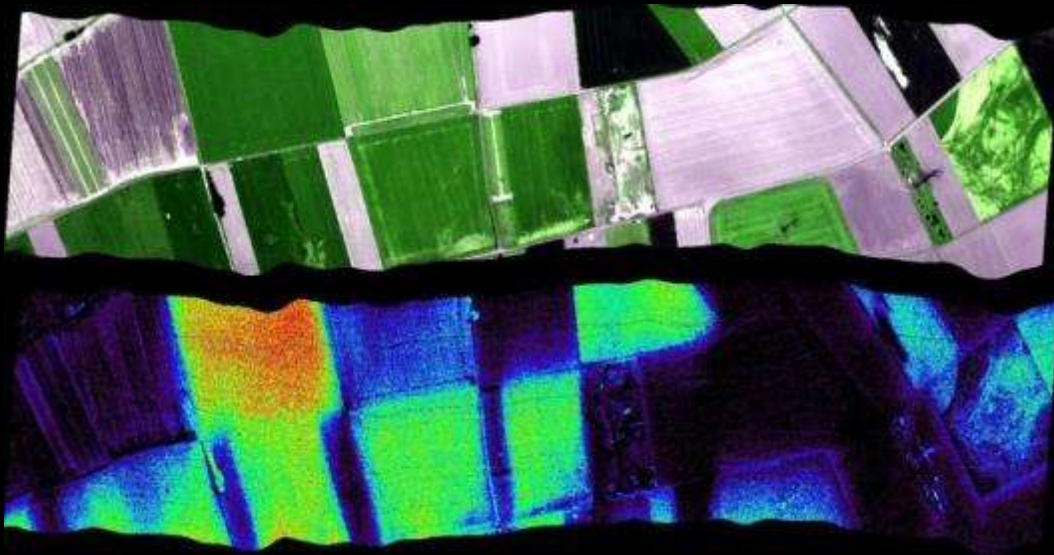
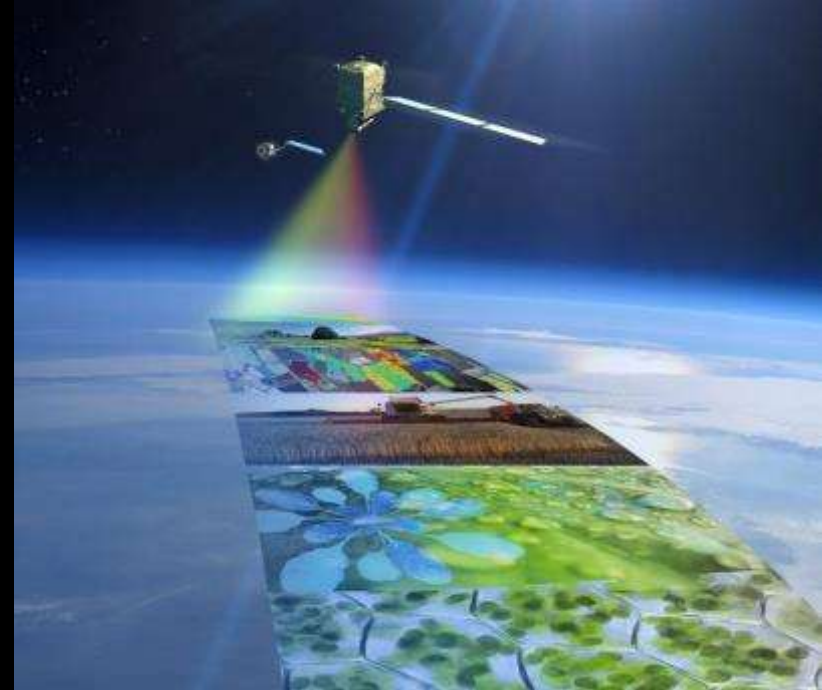
- Implementation decided by ESA's Earth Observation Programme Board in February 2015
- Biomass estimates based on global interferometric and polarimetric P-Band Radar observations
- Essential to understand the Earth's carbon cycle
- To be launched in 2020



FLEX, the 8th Earth Explorer



- decision by PB-EO in November 2015
- global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity



ESA LPS 2016



PRAGUE 09-13 MAY 2016

Main Objective: Presentation of Exploitation Results based on ESA
Earth Observation Measurements



living planet symposium | PRAGUE 09-13 May 2016



<http://lps16.esa.int>

European Space Agency



A satellite image showing a large river delta system with a complex network of channels and distributaries. The surrounding land is a mix of green and brownish-yellow, indicating different vegetation and terrain types. A blue banner with white text is overlaid on the image.

EO Tools for Education

- ❑ E-learning tools
 - ESA kids (*primary*)
 - Eduspace (*secondary*)
 - SEOS (*secondary*)
 - LearnEO! (*secondary/undergraduate*)
 - Bilko (*secondary/undergraduate*)
- ❑ Printed resources
 - ESA School Atlas and Water Atlas (*secondary*)
 - ESA EO Teacher's Pack (*secondary*)
- ❑ Training courses
 - EO summer schools (*graduate*)
 - Advanced training courses (land, ocean, atmosphere) (*graduate*)
 - Other EO training Courses (*graduate and undergraduate*)
- ❑ Training within programmes
 - DRAGON
 - TIGER

- EO Education News

Participate in the ESA LearnEO! competition
 23 September 2013

Participate in the ESA LearnEO! lesson-writing competition, bring your work to a world audience and take a chance to win up to 5,000 euros!

Find out more on the [LearnEO! competition website](#).

EO Education and Training

[EO Education and Training Home](#)
[EO Education for Schools](#)
[Advanced EO Training for PIs](#)
[Other EO Training](#)

- EO Education and Training



Overview of Earth Observation Training at ESA.

ESA undertakes a wide range of activities in the field of Earth Observation education, training and capacity building. The scope of these activities ranges from high level training in state-of-the-art processing for the next generation of Principal Investigators to more general outreach activities and Earth Observation education for schools.

The aim of this website is to provide a single portal that supplies information about these activities, and enables access to resources produced in their framework.

- ### - EO data
- EO data distributed by ESA
 - Access data online
 - Access GMT's data
 - How to apply for data
 - EO Catalogue
 - ESA Multimedia Gallery

- ### - EO training activities
- Education for Schools
 - EO Summer Schools
 - Dragon Programme
 - Tiger initiative
 - Advanced Training
 - Other EO Training
 - Upcoming / Past Events

- ### - EO software
- HEET Training
 - LEOWorks Download (10.5MB)
 - Elko
 - SVRT

- LearnEO!



LearnEO! is an Earth observation education project funded by ESA. Its aim is to increase the understanding of satellite data from ESA missions and show how these can be used to tackle environmental problems in the real world.

[Read more](#)

- Education for Schools



ESA has developed an EO educational website "EduSpace" that mainly targets secondary schools. In addition to this, ESA provides workshops for teachers and has funded the development of many tools for EO education.

[Read more](#)

- Key Resources

- Sample data
- Auxiliary data
- Catalogue access
- Document Library
- Upcoming Events
- Events Catalogue
- Software Tools
- Online Archives
- EO Software Toolboxes

- EO Summer Schools



- TIGER Training



1. LeanEO! is an Earth observation education project funded by the European Space Agency. Its aim is to increase the understanding of satellite data from ESA missions and show how these can be used to tackle environmental problems in the real world.

2. Lessons use Bilko software.

3. The Amazon river plume
4. Monitoring oil pollution at sea
5. El Niño and the Southern Oscillation (ENSO)
6. Monitoring Atlantic storms
7. Observing Earth gravity:
8. Monitoring Arctic sea ice
9. Forest monitoring
10. Monitoring urban growth
11. Land cover mapping
12. Monitoring soil moisture

SNAP = Sentinels Application Platform

<http://step.esa.int/main/toolboxes/snap/>

- **Optical exercise (S-2):**
 - a. Application: spectral analysis & vegetation mapping
 - b. Data: Sentinel-2
 - c. Processing steps:
 - Sentinel-2 metadata
 - Band visualisations
 - Spectral analysis
 - Band maths (NDVI)
- **SAR exercise (S-1):**
 - a. Application: Flood mapping
 - b. Data: Sentinel-1
 - c. Processing steps:
 - Sentinel-1 import
 - Multilook
 - Calibrate
 - Geocode
 - Stack
 - Flood map creatio
 - Export to Google Earth

Thanks for your attention!!!



Web sites of interest for EO Education:

International Charter: www.disasterscharter.org

GMES / Copernicus: <http://copernicus.eu/>

ESA Earth Watching: <http://ew.eo.esa.int/web/guest/home>

ESA Education: <http://www.esa.int/Education>

ESA Earth Observation:

[http://www.esa.int/Our Activities/Observing the Earth](http://www.esa.int/Our_Activities/Observing_the_Earth)

ESA Earth Observation Education: <https://earth.esa.int/web/guest/eo-education-and-training>

Eduspace: [http://www.esa.int/SPECIALS/Eduspace EN/](http://www.esa.int/SPECIALS/Eduspace_EN/)

SEOS Project: <http://www.seos-project.eu/home.html>

8th ESA Training Course on Radar and Optical Remote Sensing, 5 - 9 September, 2016



1. An Introduction on SAR remote sensing and its applications to forestry
– *Christian Thiel*
2. Optical land applications, focus on agriculture - *Pierre Defourny*
3. Practical exercises on Sentinel 1 and Sentinel 2 application using SNAP Toolbox - *Chris Stewart*
4. SAR land applications - *Francesco Holecz*
5. SAR marine applications - *Martin Gade*

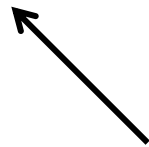
Several social events organised by our host

What is Remote Sensing/Earth

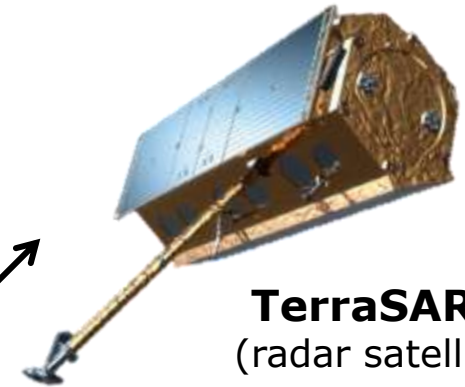


SPOT 5
(optical satellite)

passive



active



TerraSAR-X
(radar satellite)

Further Examples:

Non-imaging: radiometer, magnetic sensor

Imaging: cameras, optical mechanical scanner, spectrometer, radiometer

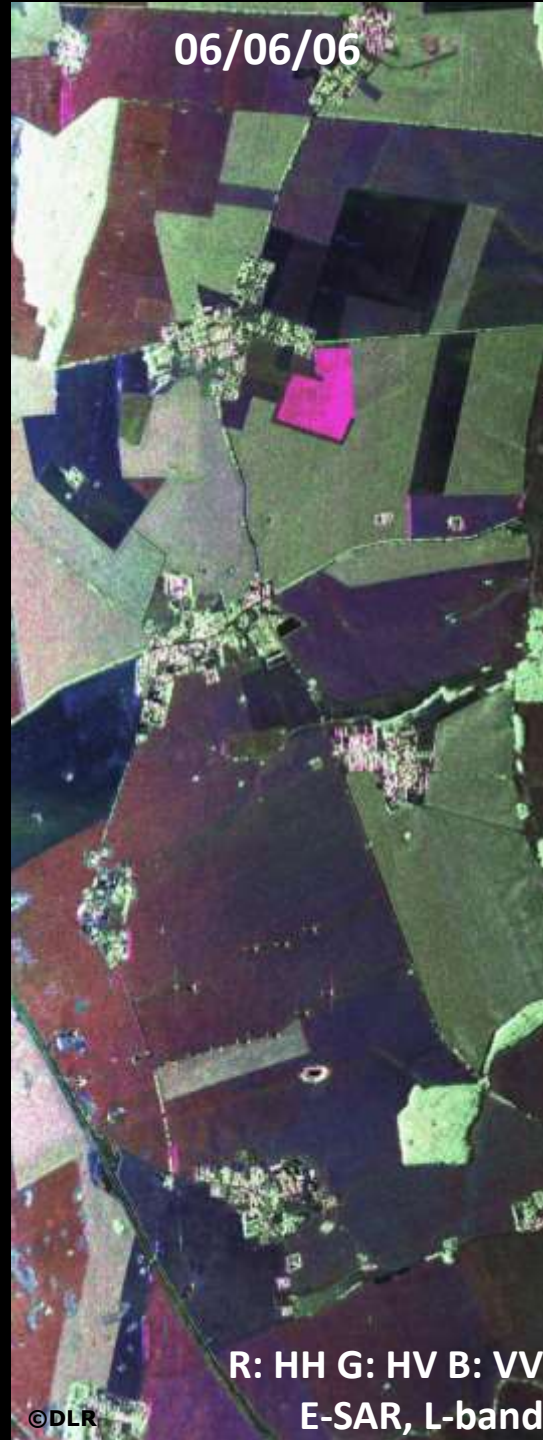
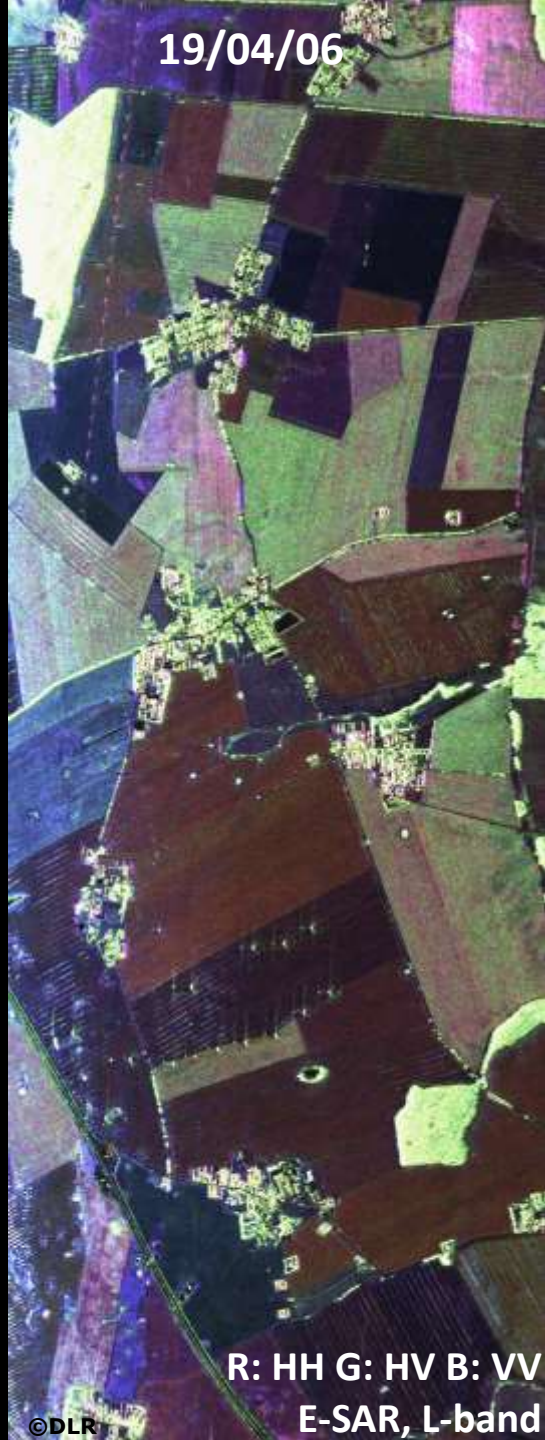
Further Examples:

Non-imaging: scatterometer, altimeter, laser

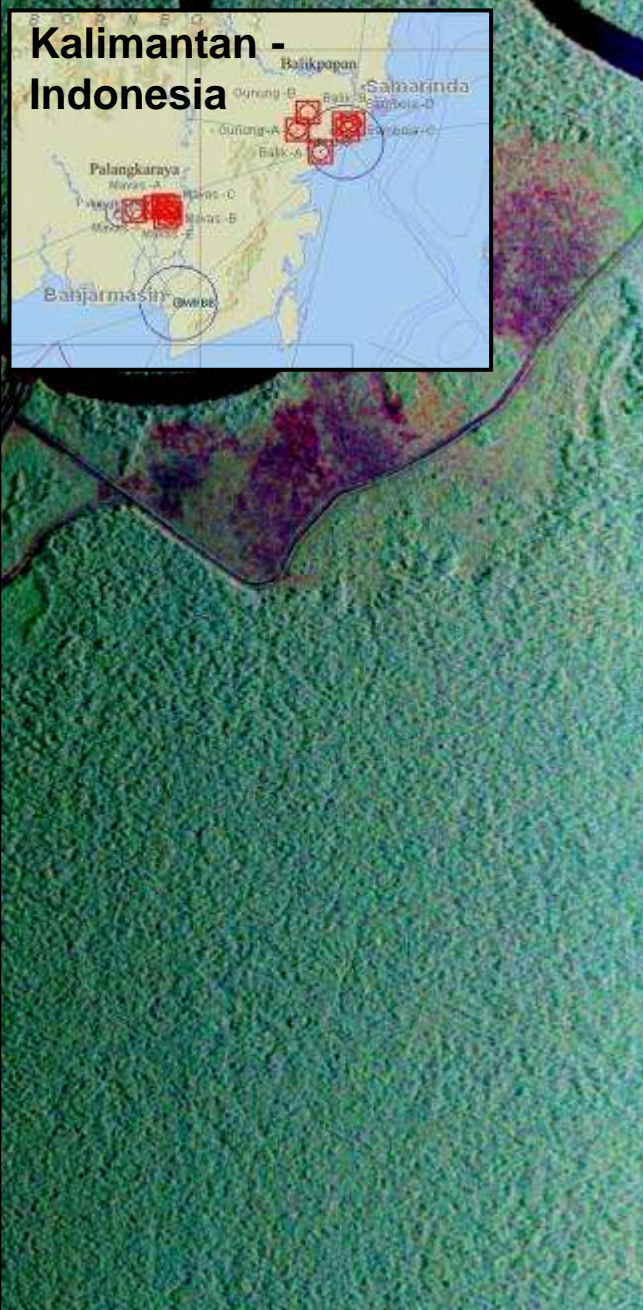
Imaging: Real Aperture Radar, Synthetic Aperture Radar



Crop monitoring with several observations



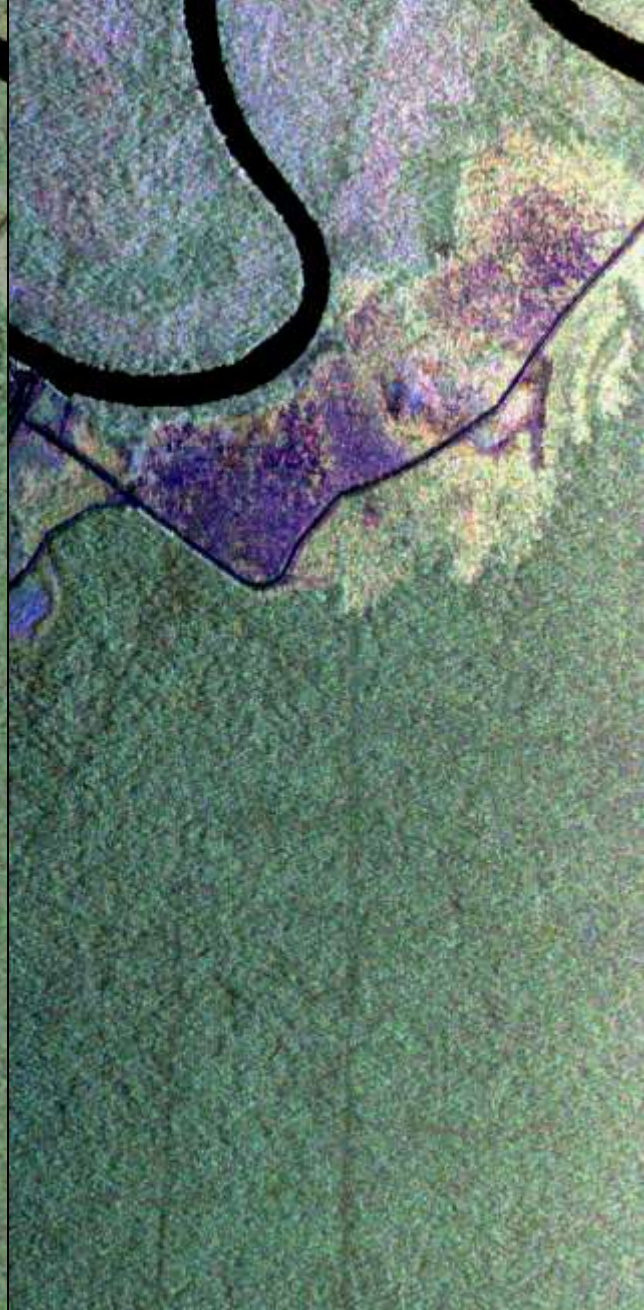
Kalimantan - Indonesia



E-SAR, C-band
R: HH G: HV B: VV

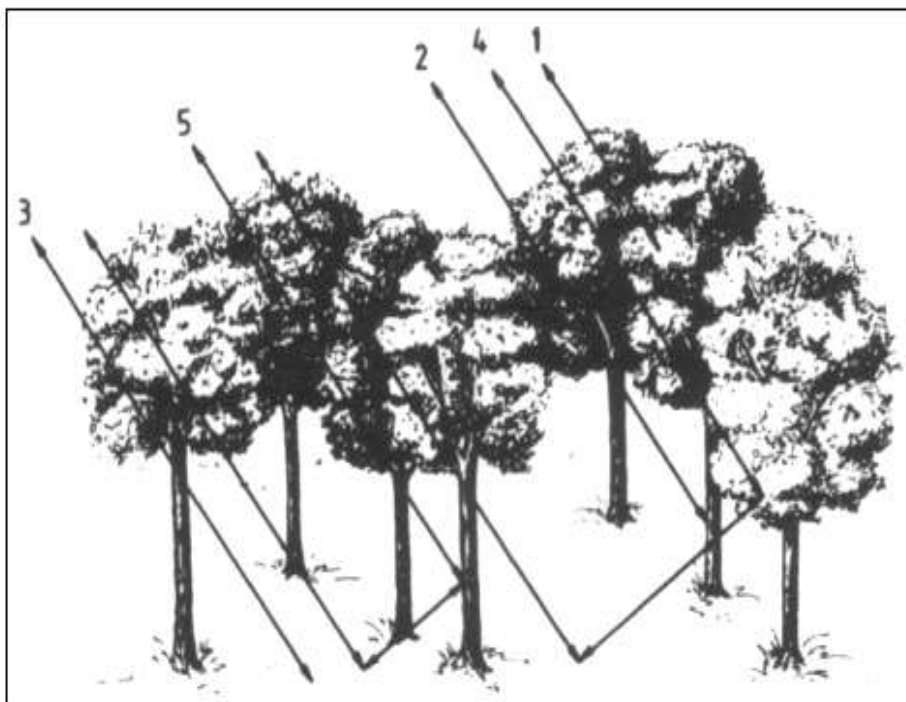


E-SAR, L-band
R: HH G: HV B: VV



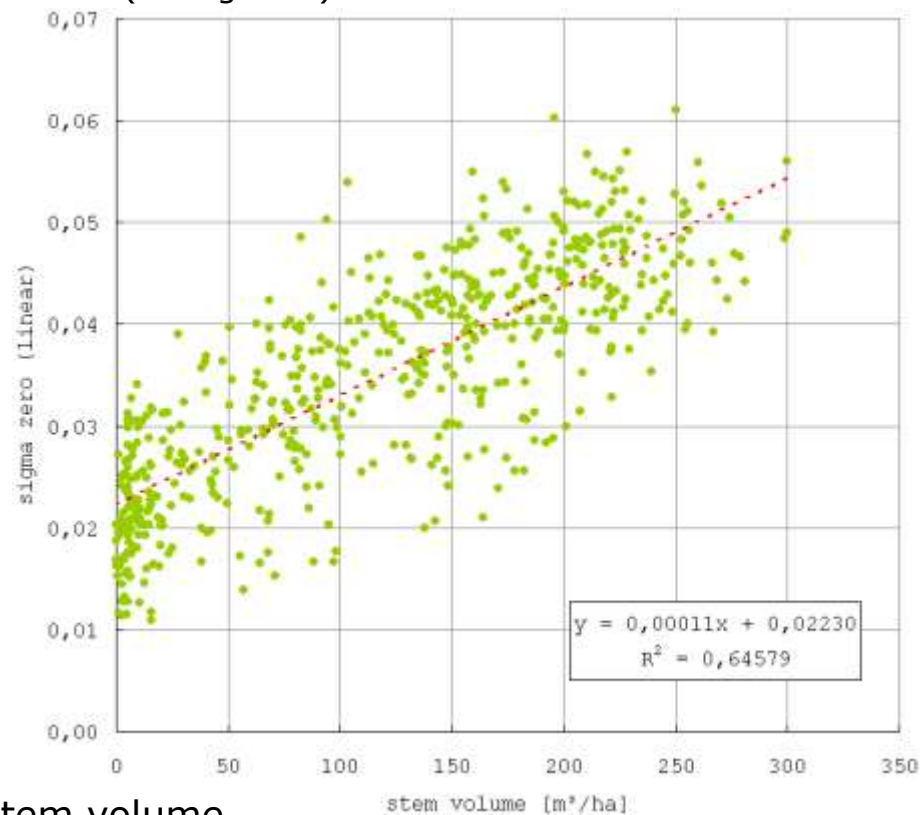
E-SAR, P-band
R: HH G: HV B: VV

SAR Techniques: Backscatter analysis



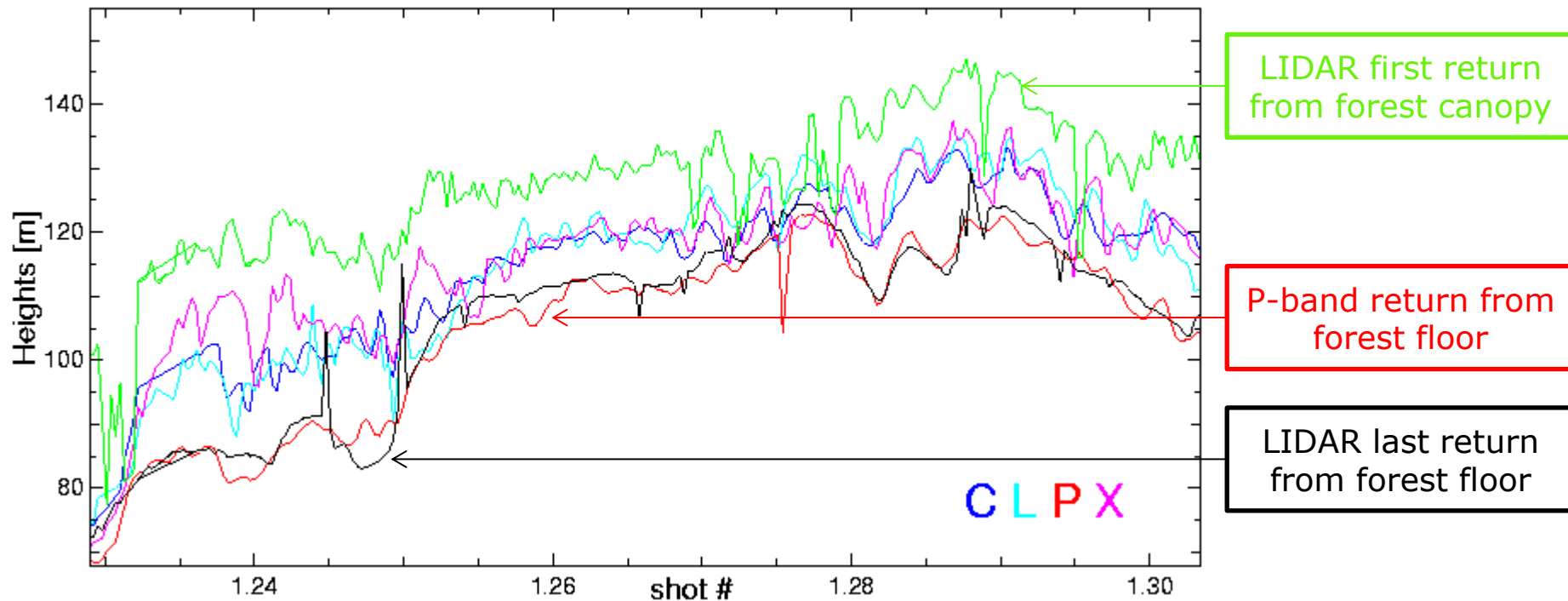
Correlation between SAR data and stem volume

Stem volume vs. backscatter (HV)
(05aug2007) – 12.5 m data



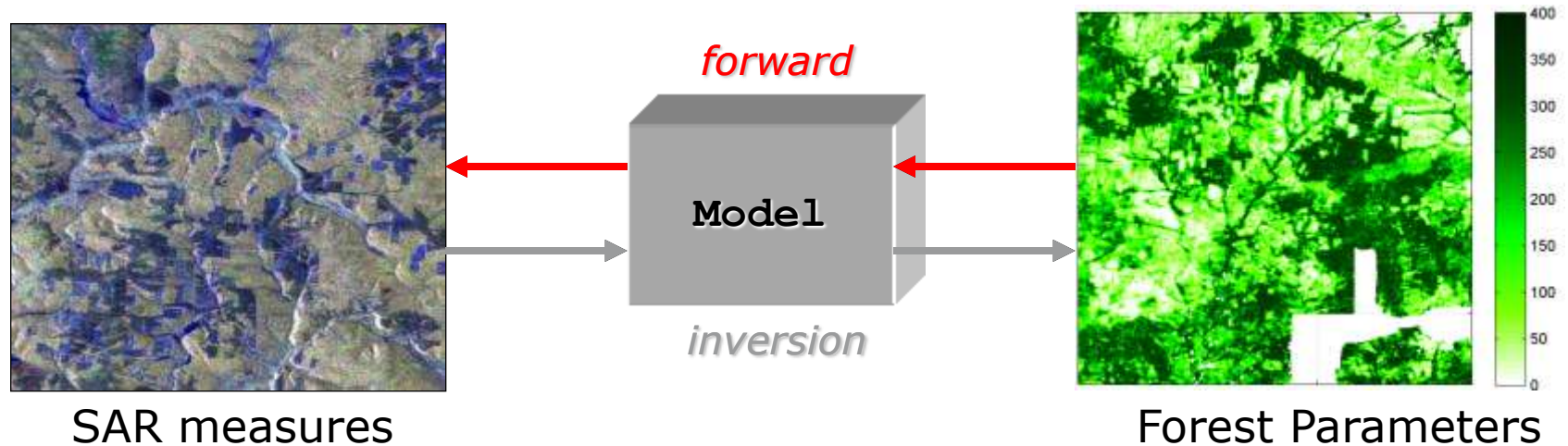
Forest Height based on EO Data

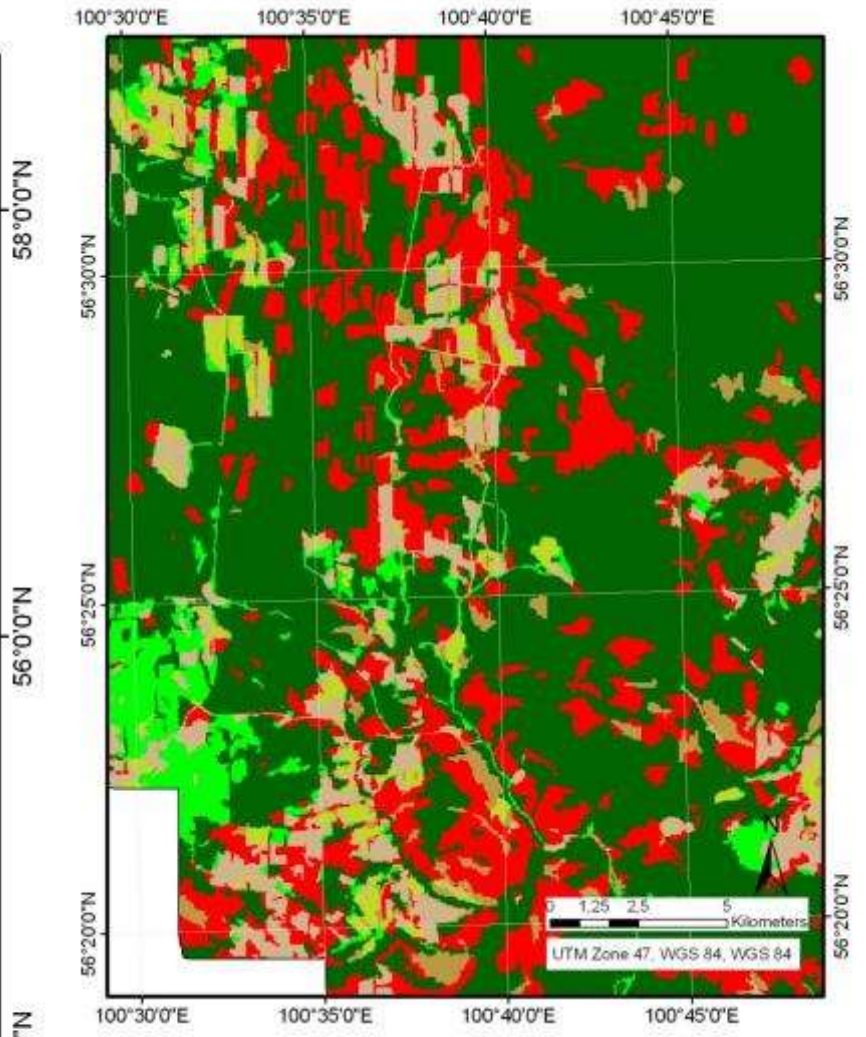
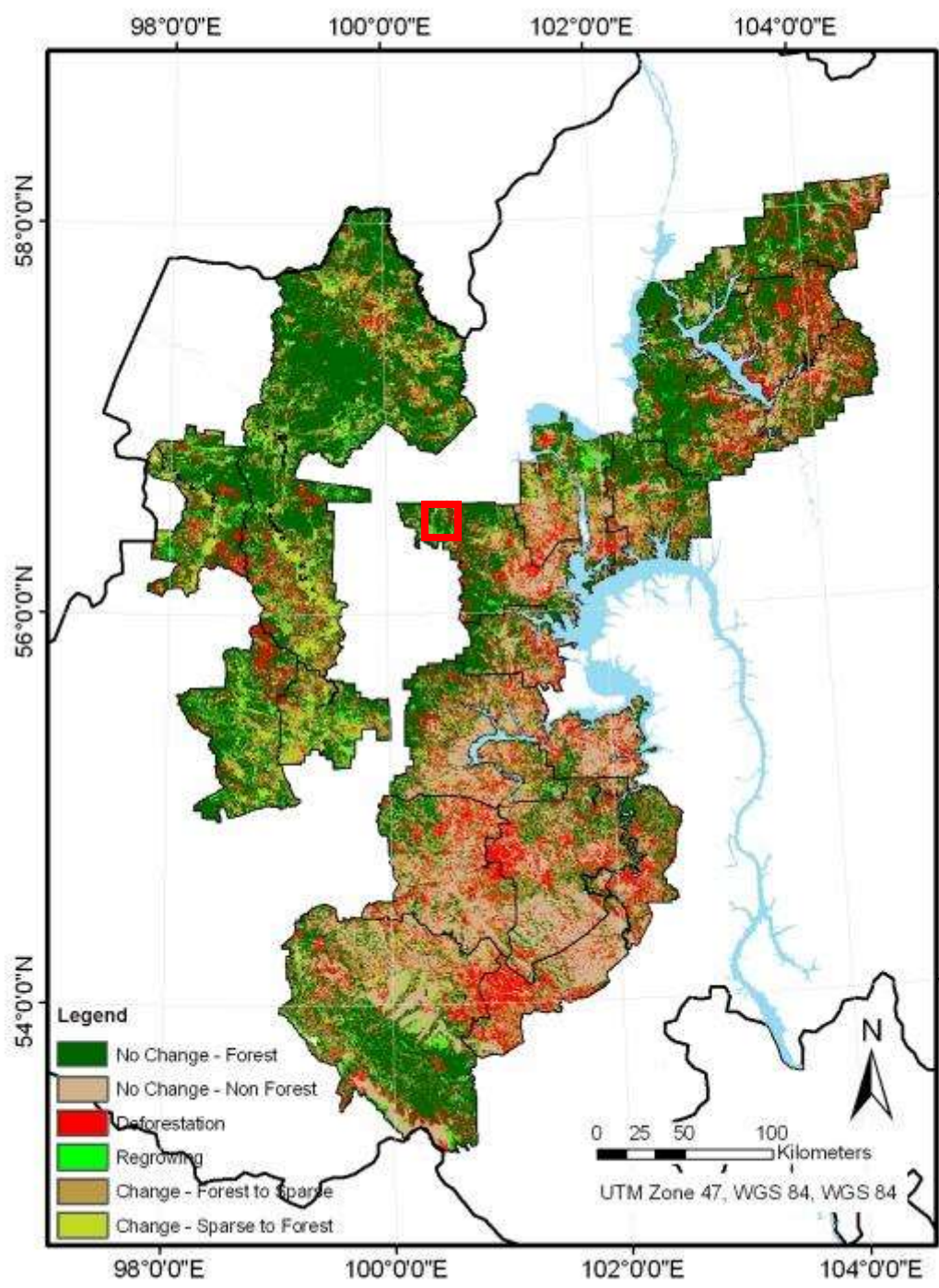
HGT on slicer track 506 top(green) and grnd(black) heights



(WOODHOUSE; Data from SASSAN SAATCHI, JPL).

Linking SAR measures and Forest Parameters





Final Map Product of ESA-Project GSE Forest Monitoring