Examples of Earth Observation Applications to Natural Hazards

Francesco Sarti, ESA

GIFT Workshop & 9th EGU AvH International Conference,
Istanbul, 27 March 2014

Outline

1. Introduction to ESA and EO programmes
2. Examples of applications to Disaster Monitoring
3. International Charter “Space and Major Disasters”
4. Preparing for the future: Global Monitoring for Environment and Security (GMES)

ABOUT THE EUROPEAN SPACE AGENCY (ESA)

PURPOSE OF ESA

"To provide for and promote, for exclusively peaceful purposes, cooperation among European states in **space research** and **technology** and their **space applications.**"

Article 2 of ESA Convention

19 MEMBER STATES AND GROWING

ESA has 20 Member States: 18 states of the EU (AT, BE, CZ, DE, DK, ES, FI, FR, IT, GR, IE, LU, NL, PL, PT, RO, SE, UK) plus Norway and Switzerland.

Other EU states have Cooperation Agreements with ESA: Estonia, Slovenia, Hungary, Cyprus, Latvia, Lithuania and the Slovak Republic. Bulgaria and Malta are negotiating Cooperation Agreements.

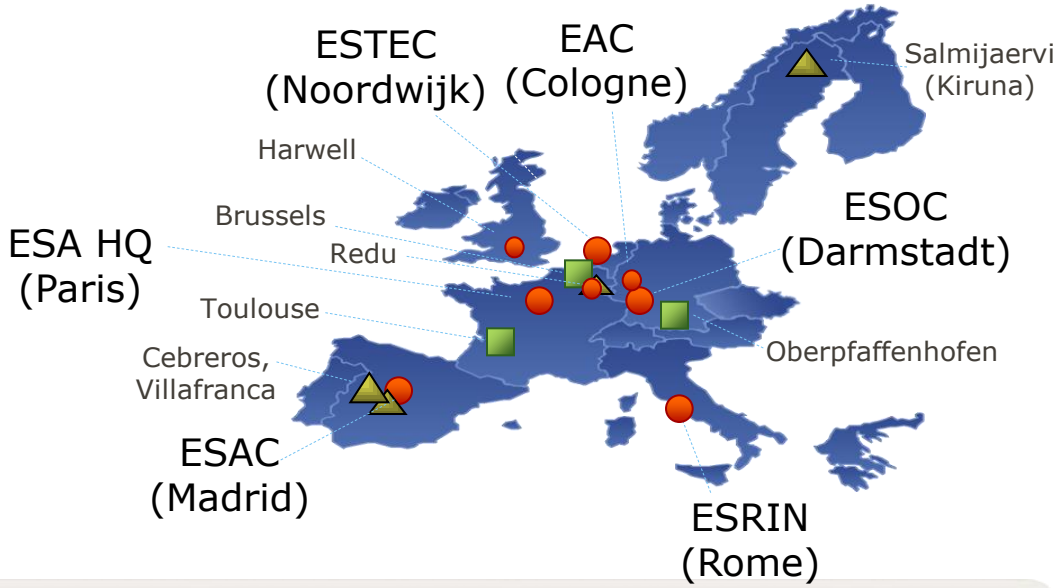
Canada takes part in some programmes under a Cooperation Agreement.

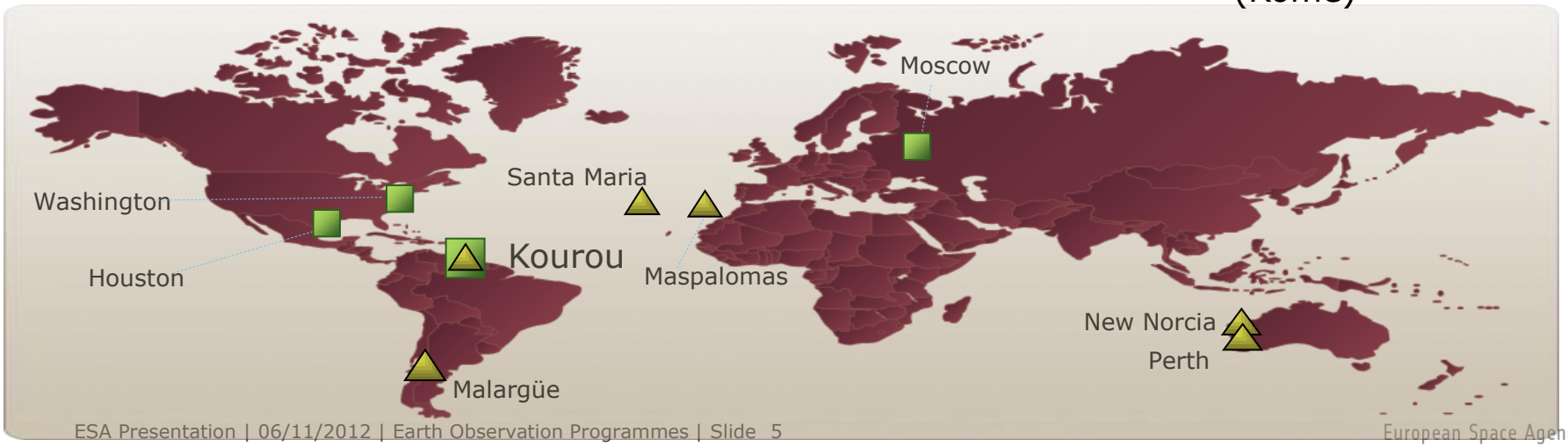
ESA'S LOCATIONS

ESA sites/facilities

Offices

ESA ground stations



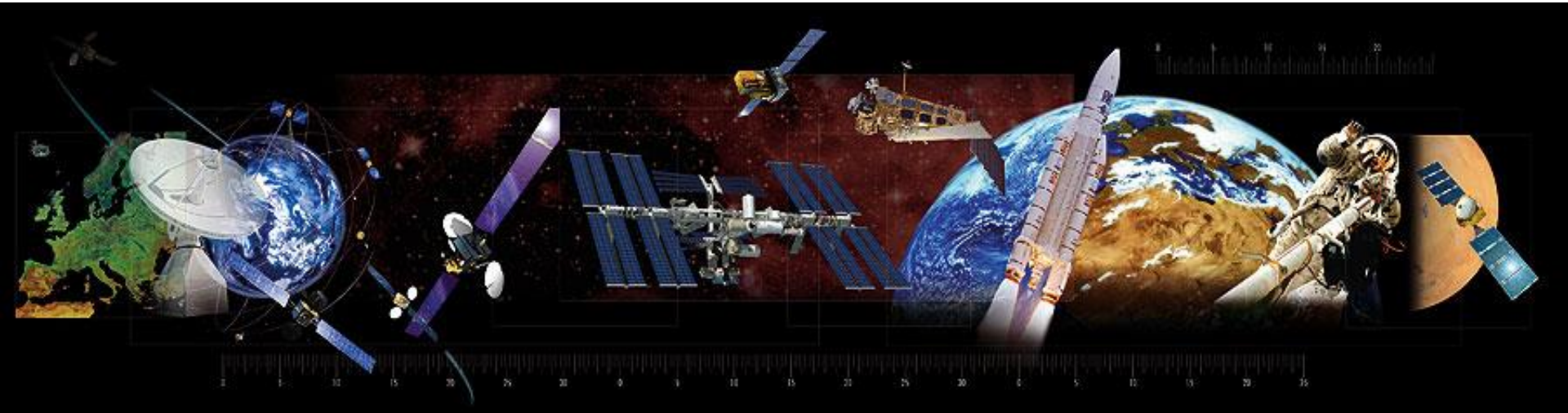


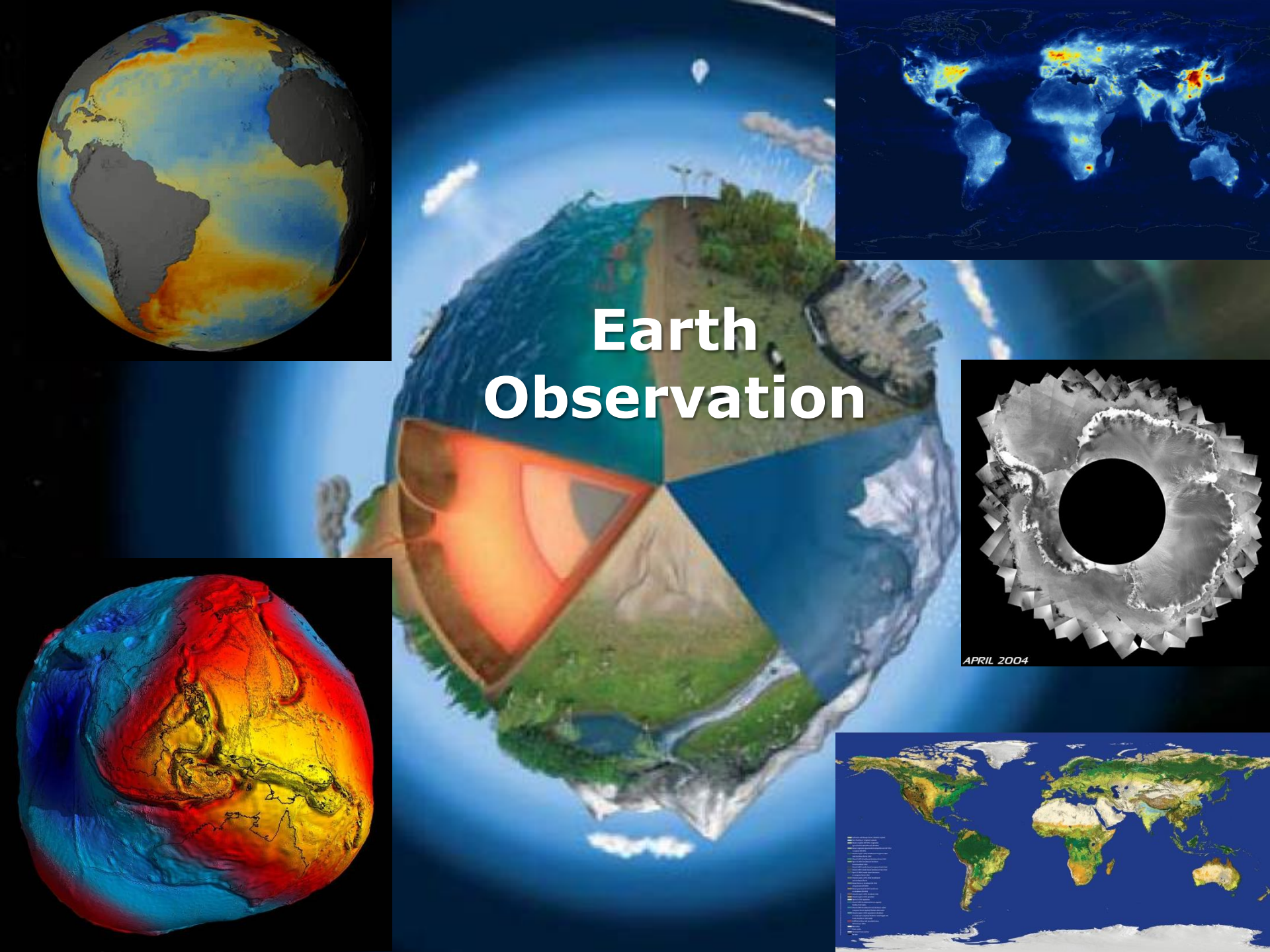
ACTIVITIES

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
APRIL 2004

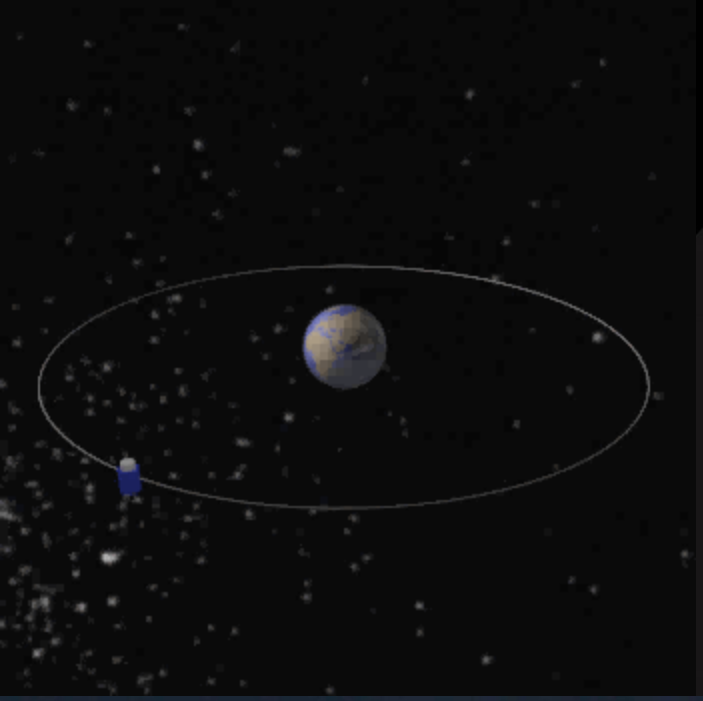
What is Earth Observation?

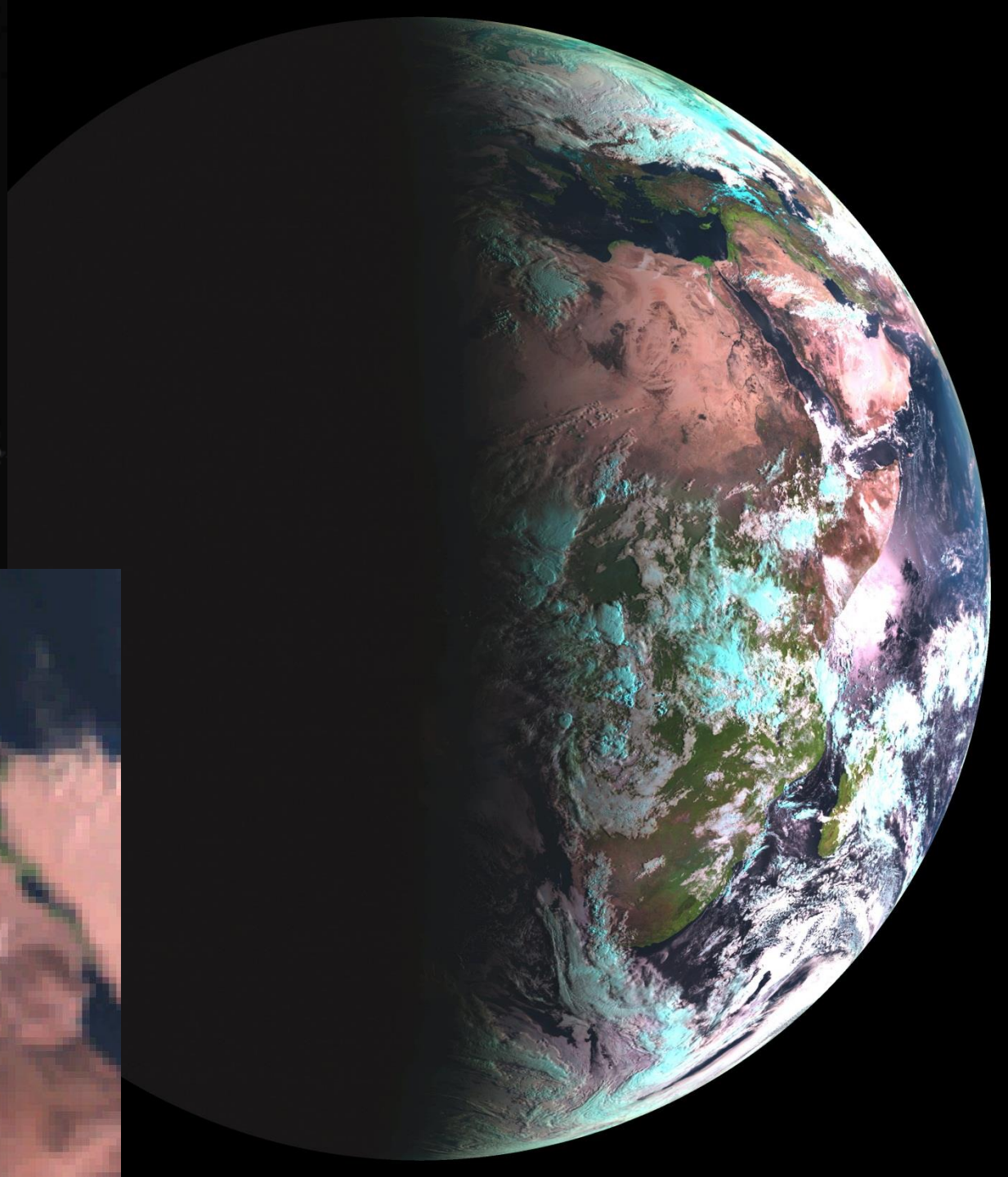
What is Earth Observation? …**Observing** the **Earth remotely**

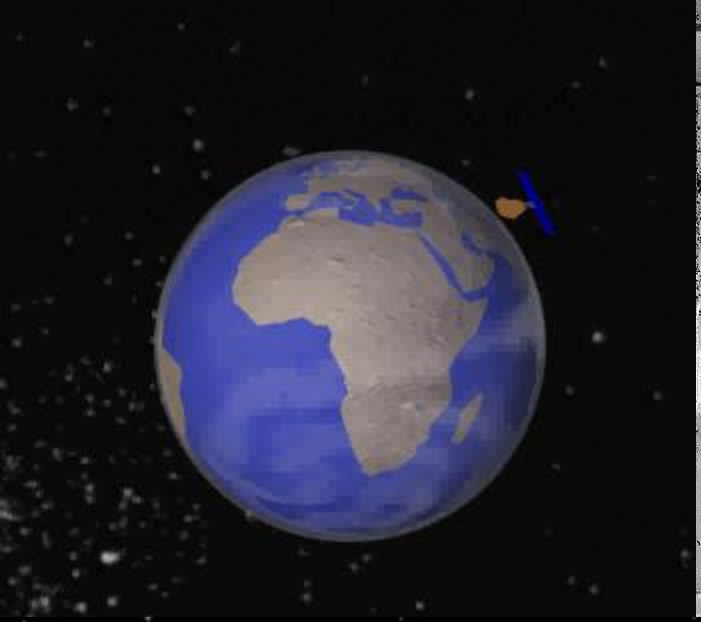
Observing = acquiring data and information using instruments called "sensors" (e.g. cameras, radiometers, spectrometers, radars)

The **Earth** = includes the Earth's surface (oceans, land), the Earth's core (gravity sphere – geoid), the Earth's atmosphere

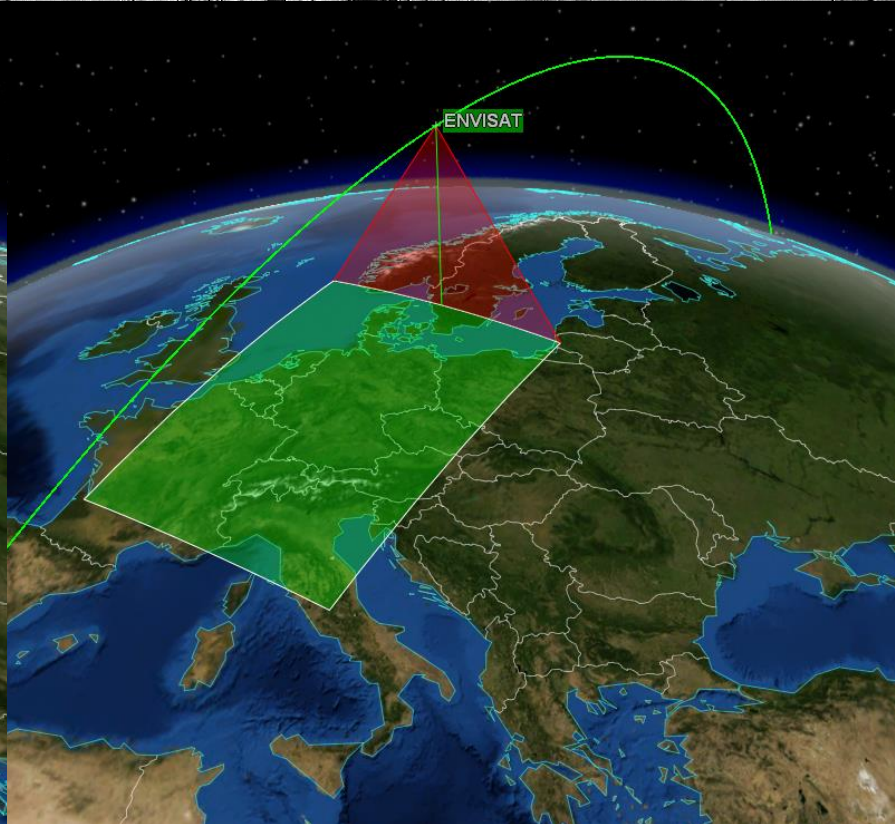
Remotely = without being in physical contact with the Earth







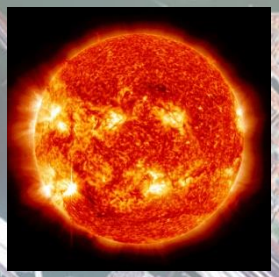

QUICKBIRD-2


ENVISAT


Range : 13923 km
Altitude : 13923 km
Intersection Mode ON
Auto Steering ON
ENVISAT
RapidEye-5
SPOT-5
RapidEye-4

Passive Sensors

esa

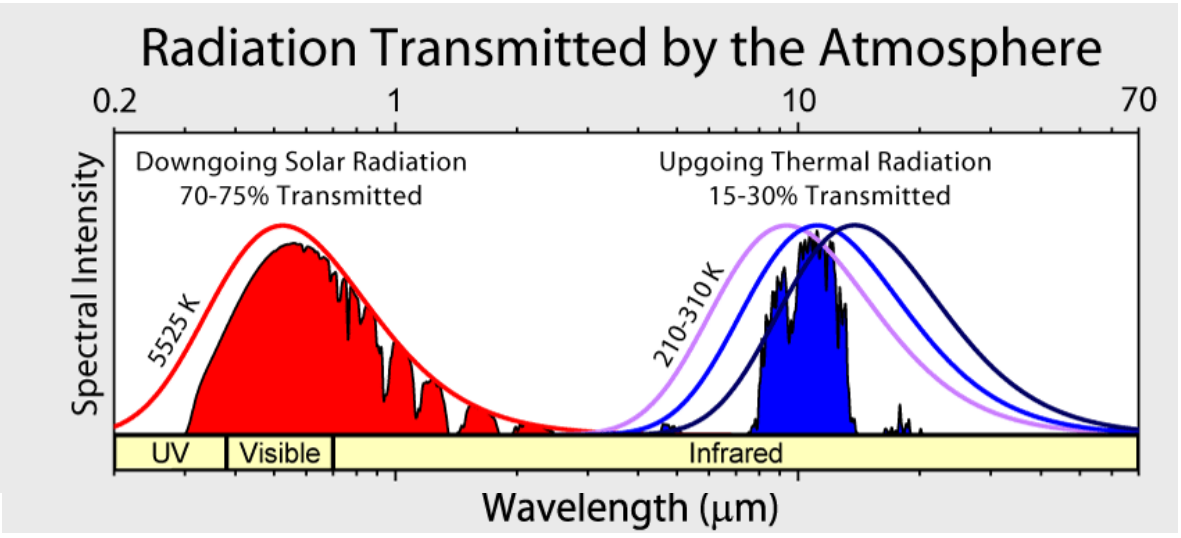


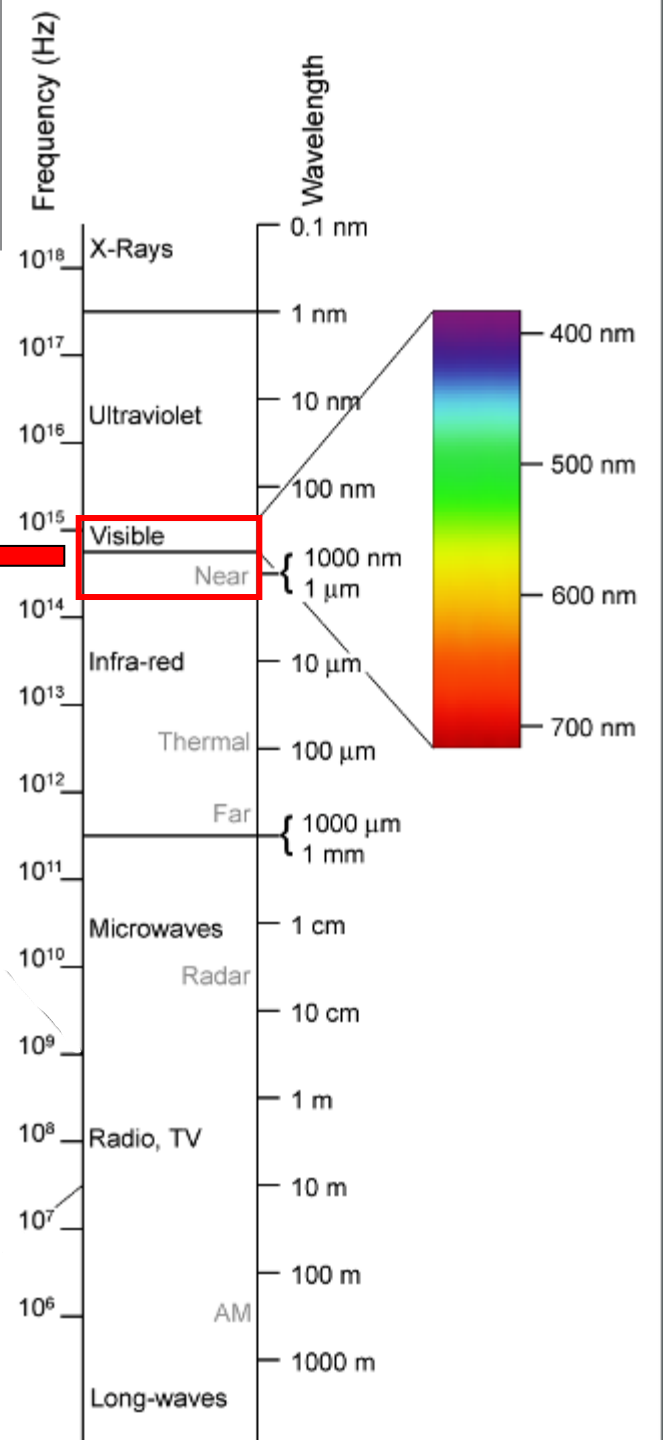
Primary source of energy: *Sun*

ESA UNCLASSIFIED – Releasable to the Public

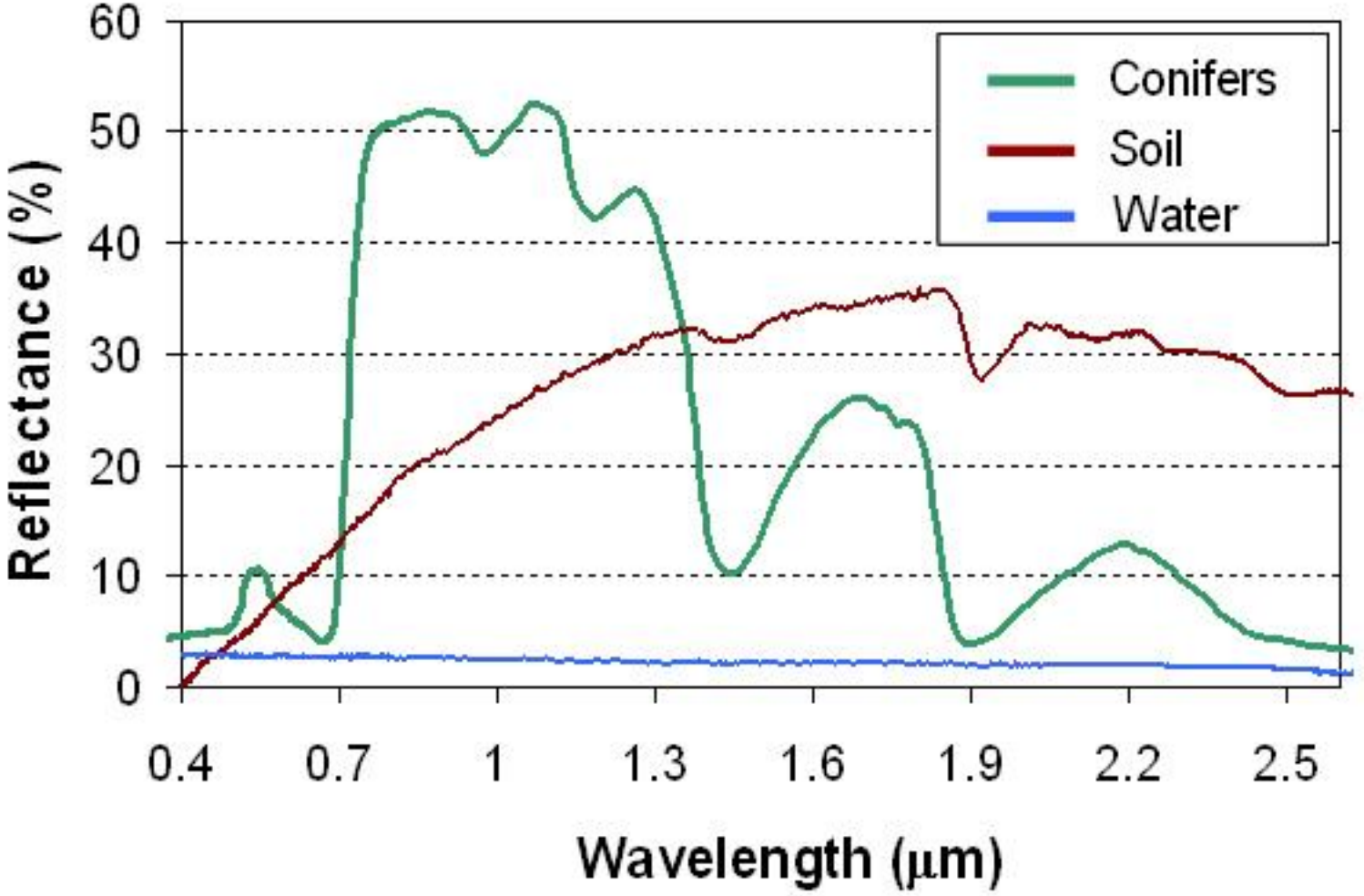
The electromagnetic spectrum

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





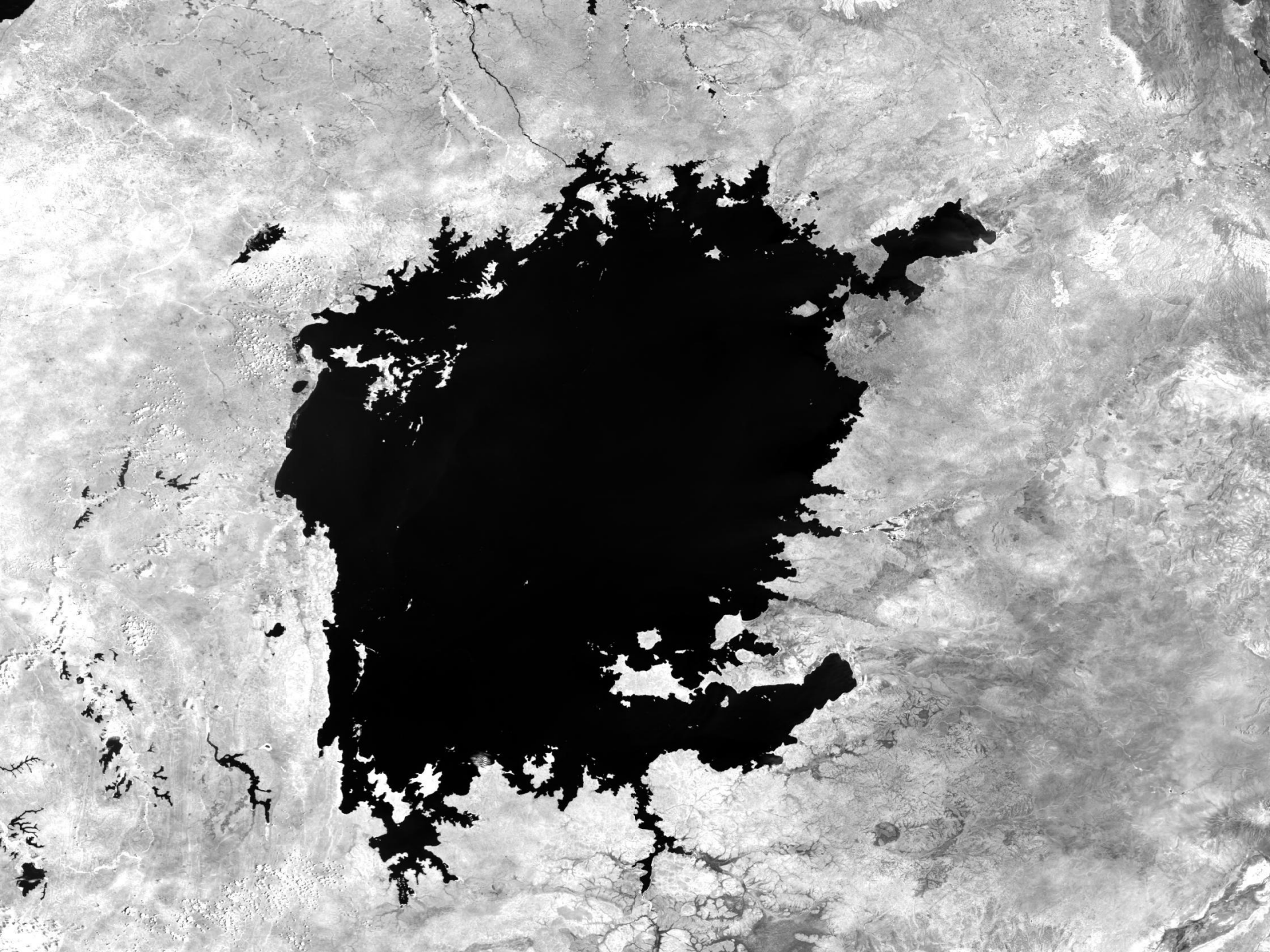
Spectral signatures



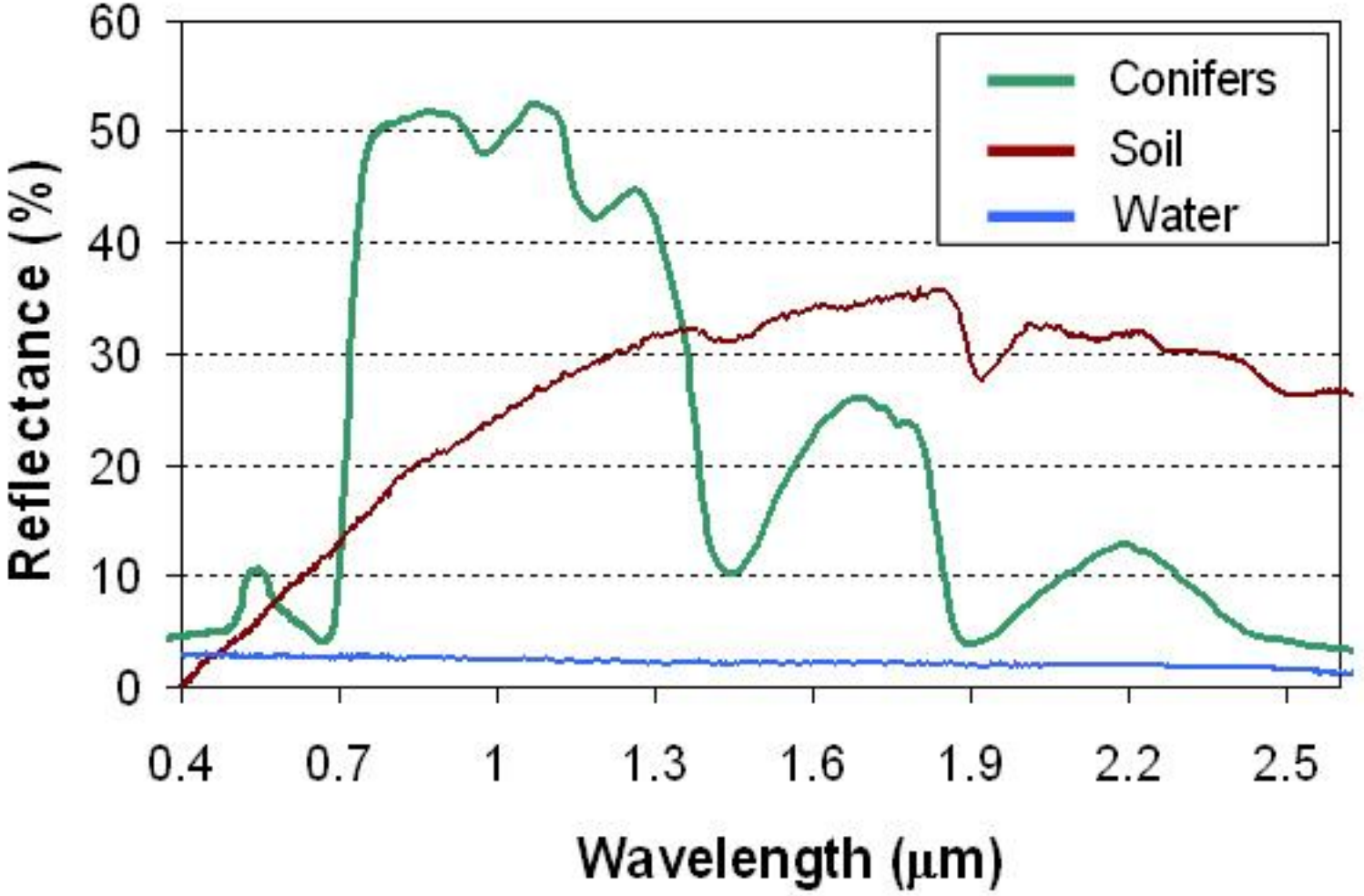
USGS
science for a changing world

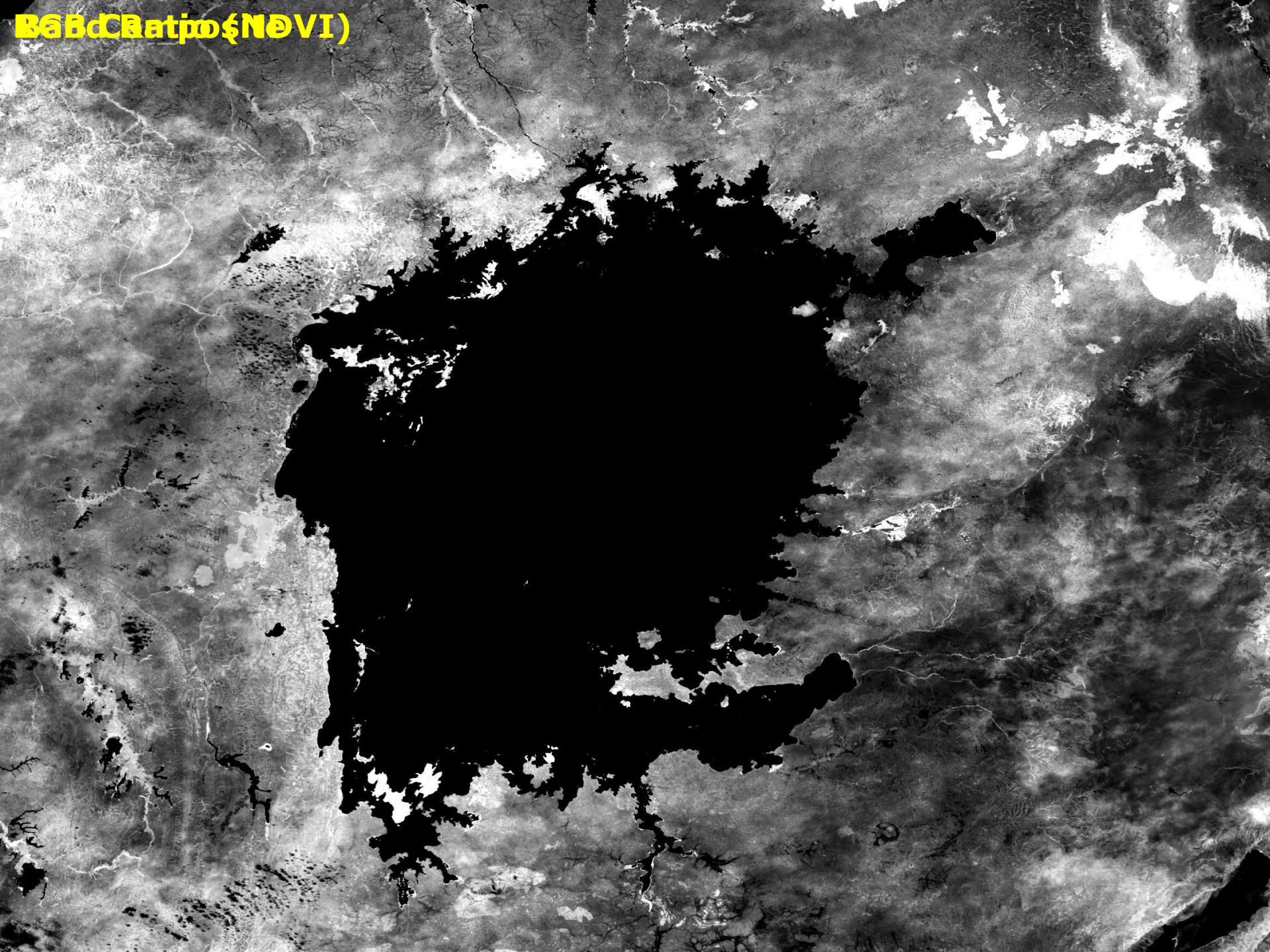
Rondônia, Brazil: 1975–2011

U.S. Department of the Interior
U.S. Geological Survey

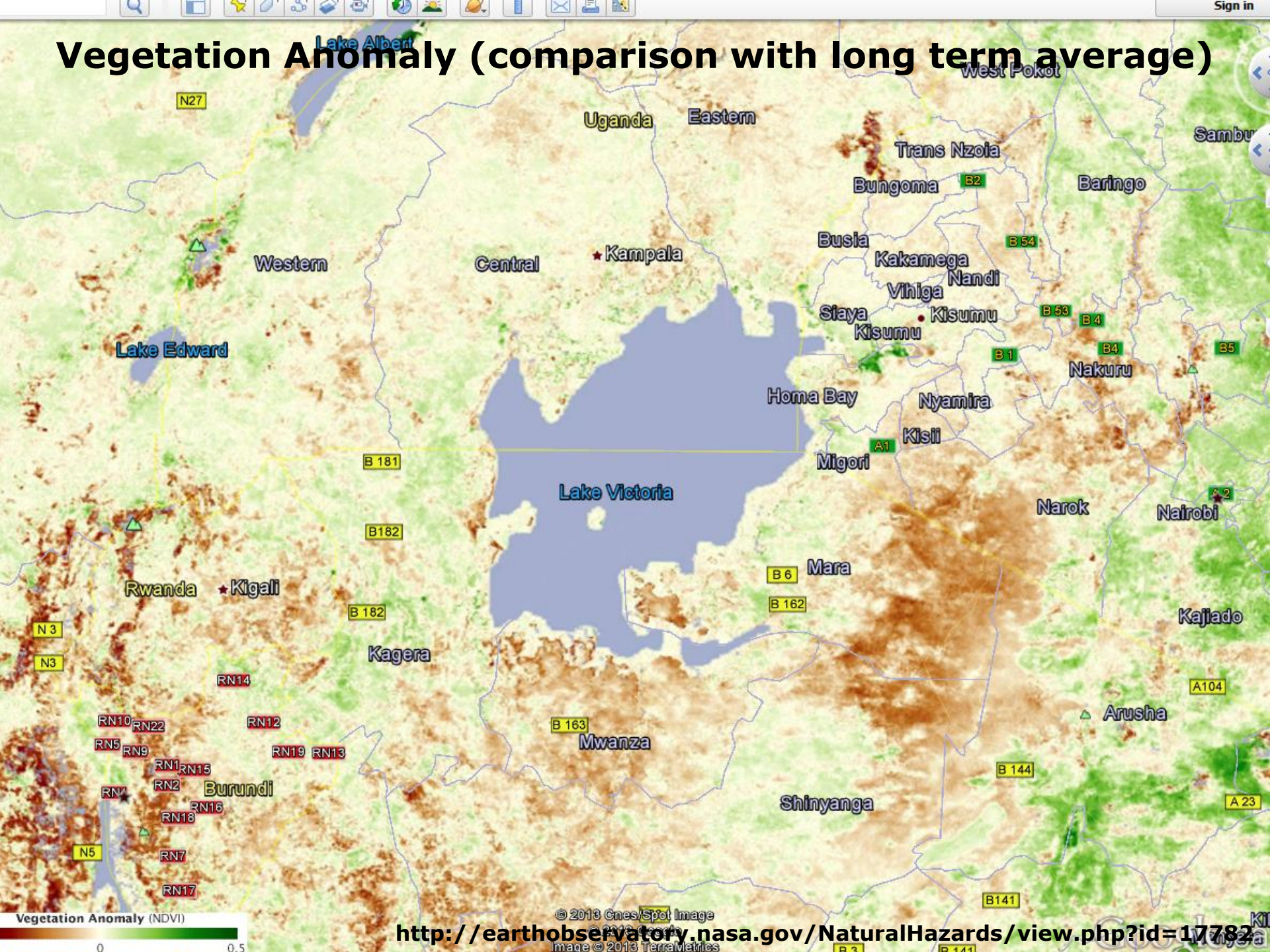


Spectral signatures

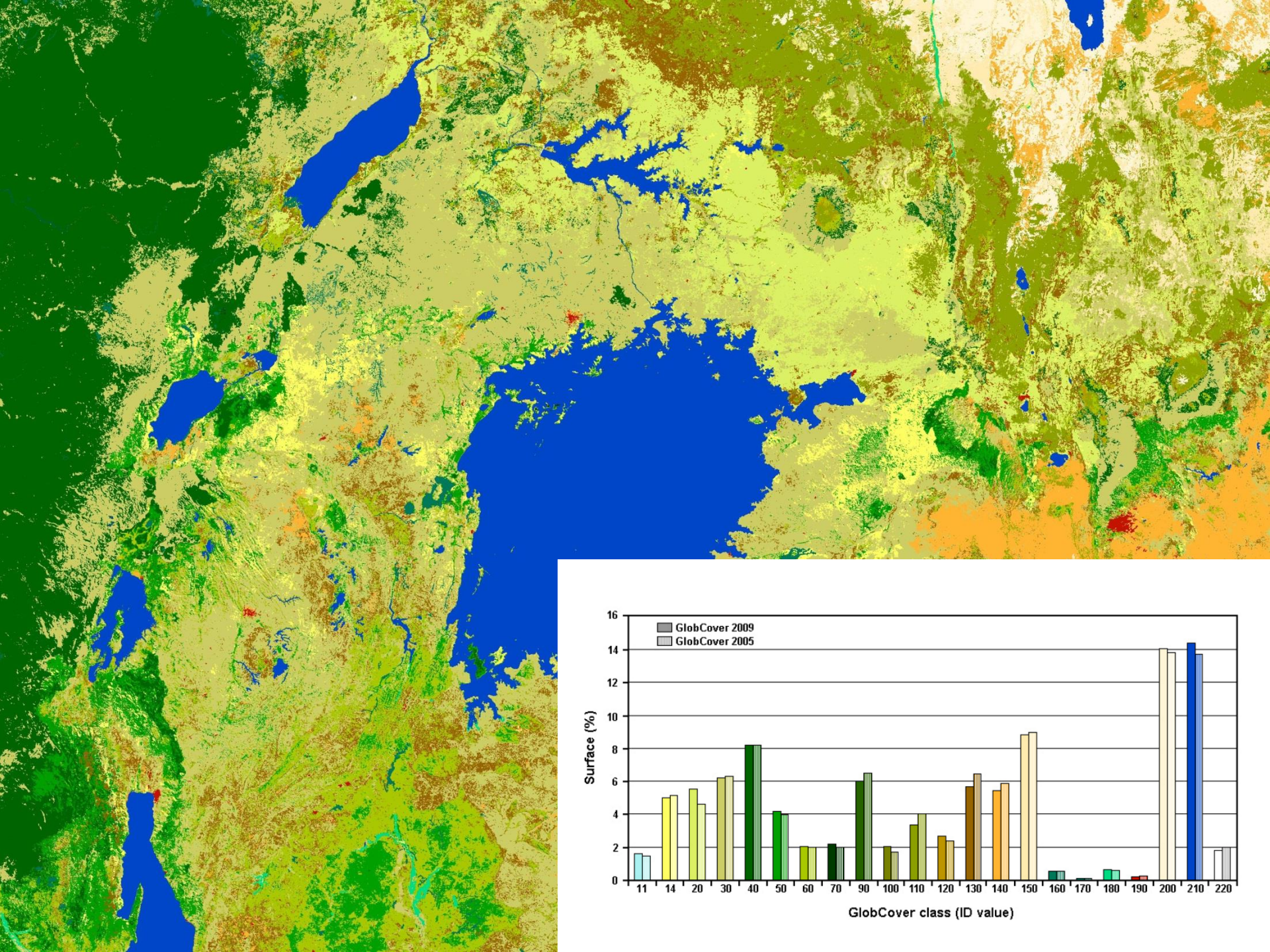


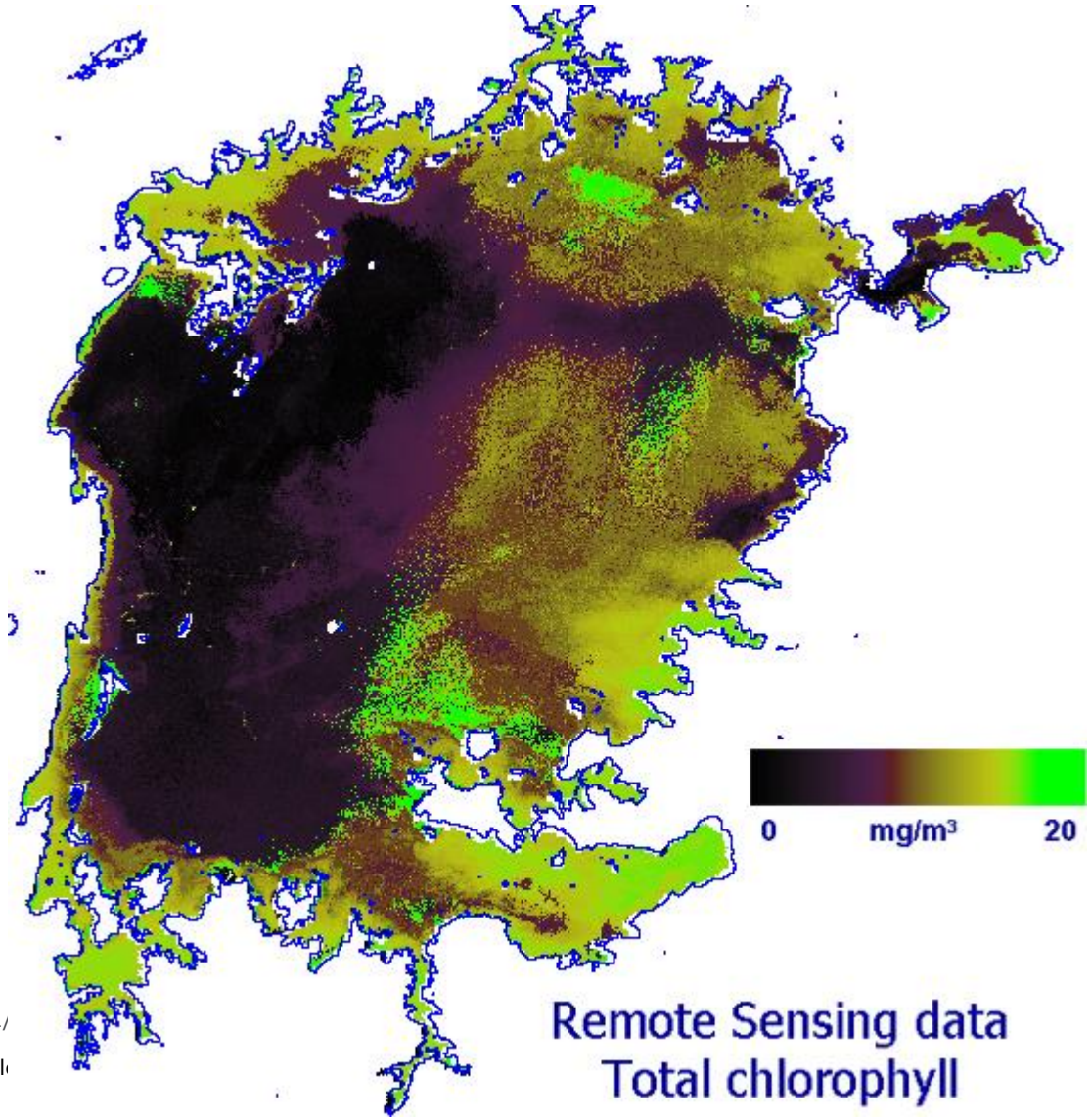

Band Ratio (NDVI)

Vegetation Anomaly (comparison with long term average)

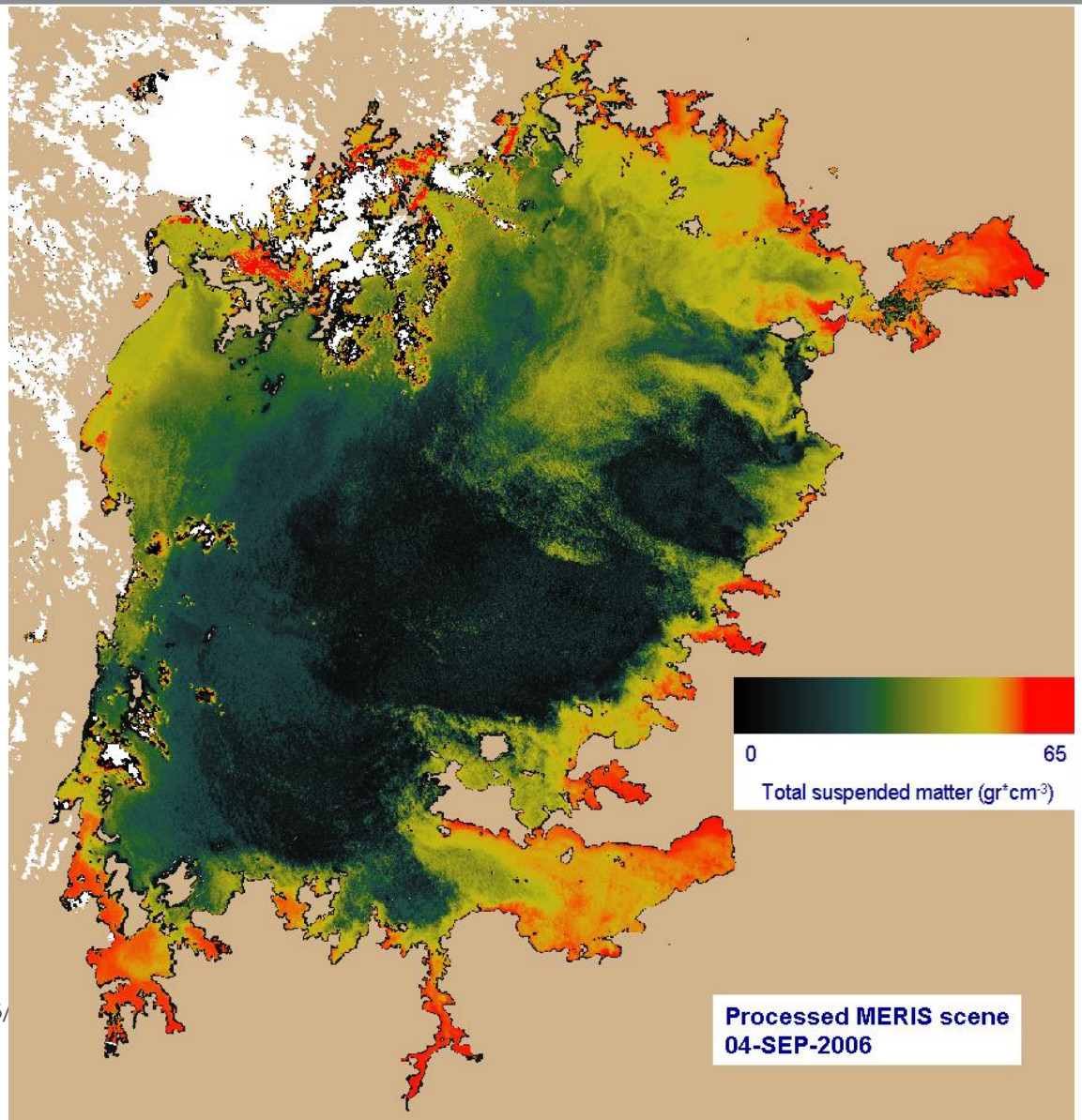


http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=17782

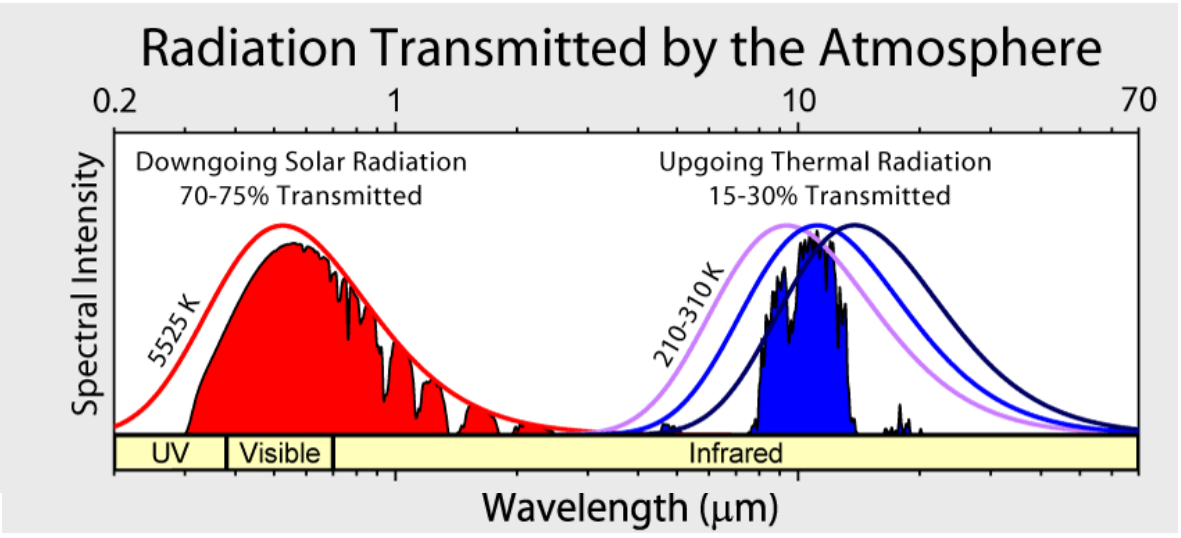

GlobCover 2009
GlobCover 2005
Surface (%)
0
2
4
6
8
10
12
14
16
11
14
20
30
40
50
60
70
90
100
110
120
130
140
150
160
170
180
190
200
210
220
GlobCover class (ID value)



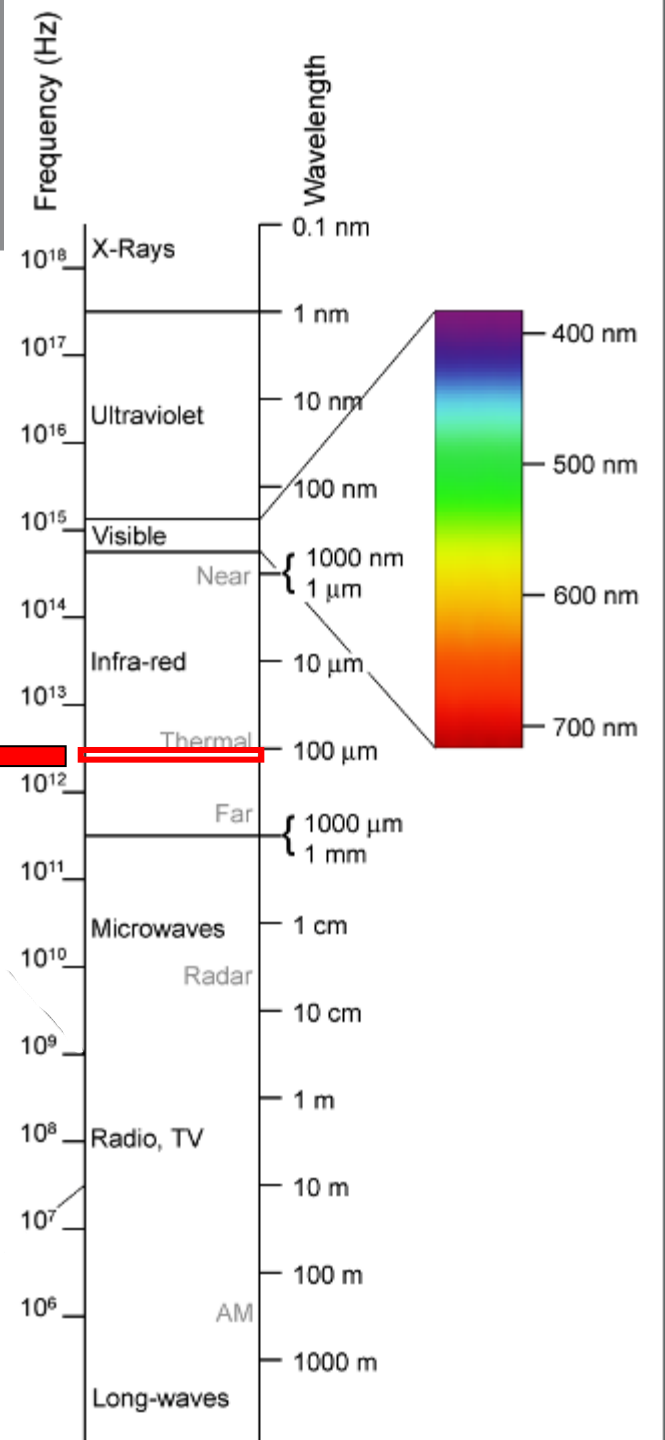
Remote Sensing data
Total chlorophyll


0
65
Total suspended matter (gr*cm-3)
Processed MERIS scene
04-SEP-2006

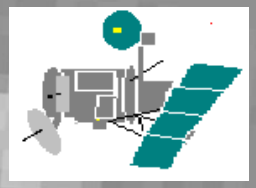
The electromagnetic spectrum



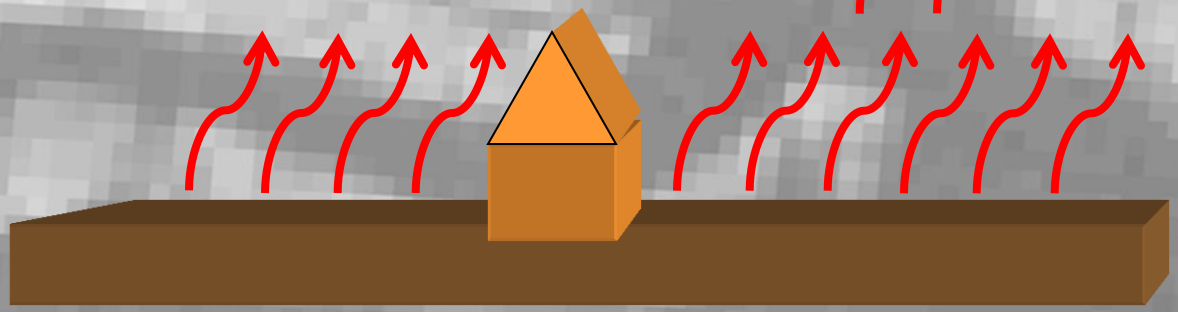
Thermal Infrared (TIR)



Passive Sensors



Primary source of energy: *Earth*



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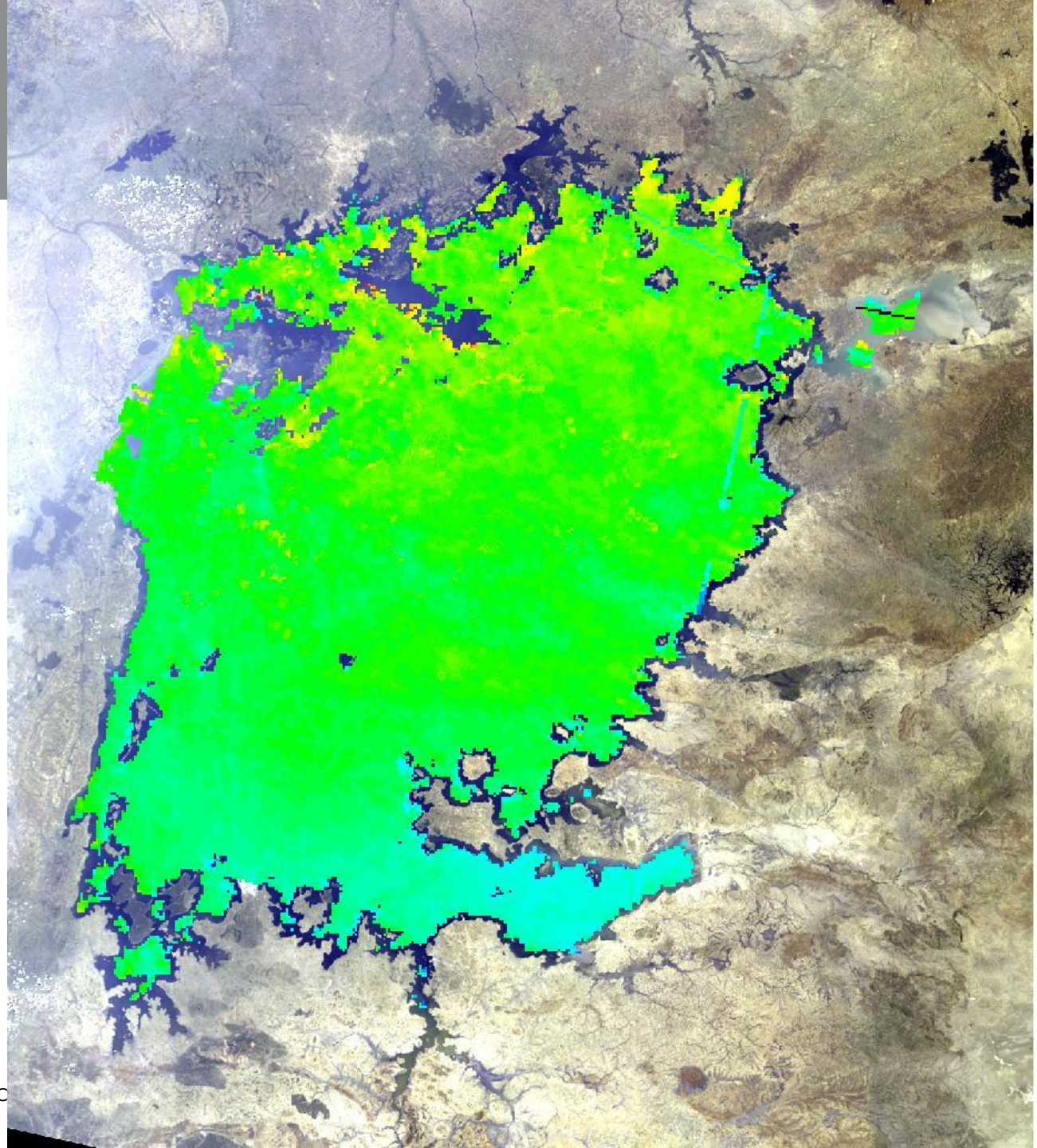


Derived from 3 AATSR scenes:

16-AUG-2006
19-AUG-2006
24-AUG-2006

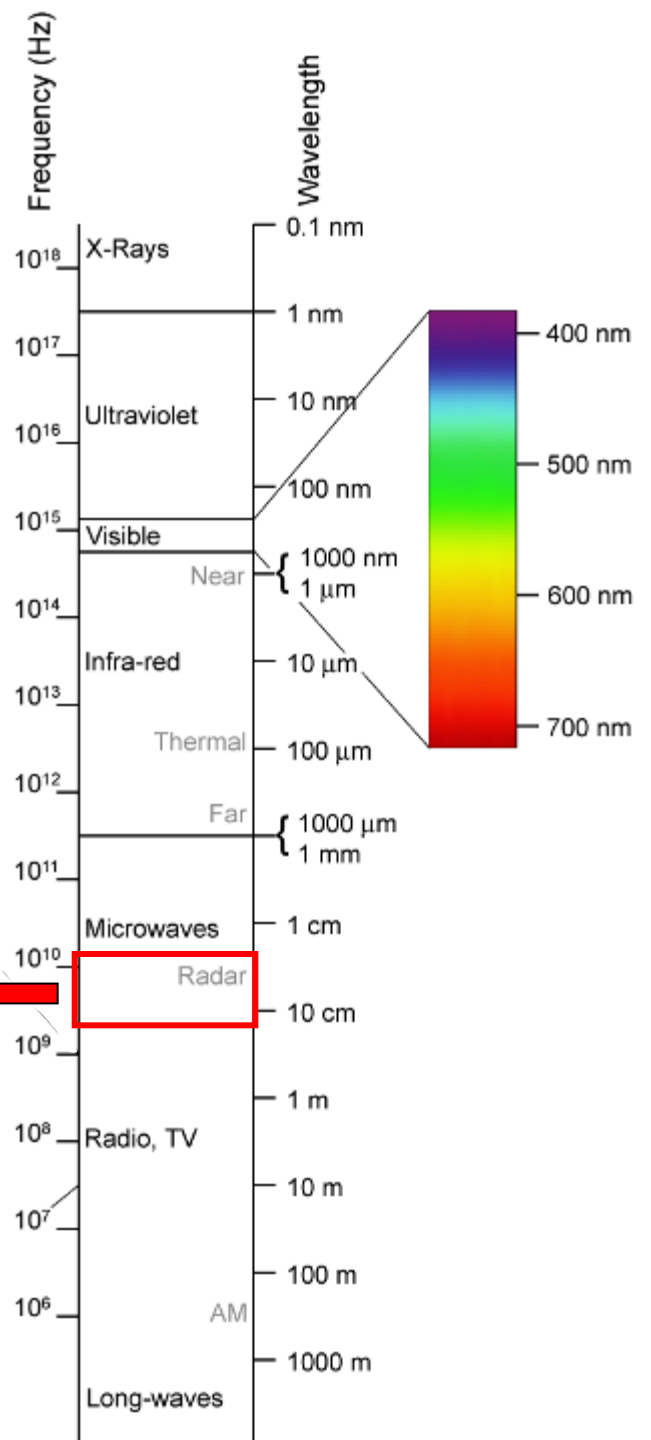
Legend

Temperature (°C)

- 18.5 <= T < 19.0
- 19.0 <= T < 19.5
- 19.5 <= T < 20.0
- 20.0 <= T < 20.5
- 20.5 <= T < 21.0
- 21.0 <= T < 21.5
- 21.5 <= T < 22.0
- 22.0 <= T < 22.5
- 22.5 <= T < 23.0
- 23.0 <= T < 23.5
- 23.5 <= T < 24.0
- 24.0 <= T < 24.5
- 24.5 <= T < 25.0
- 25.0 <= T < 25.5
- 25.5 <= T < 26.0
- 26.0 <= T < 26.5
- 26.5 <= T < 27.0
- 27.0 <= T < 27.5
- 27.5 <= T < 28.0
- 28.0 <= T < 28.5

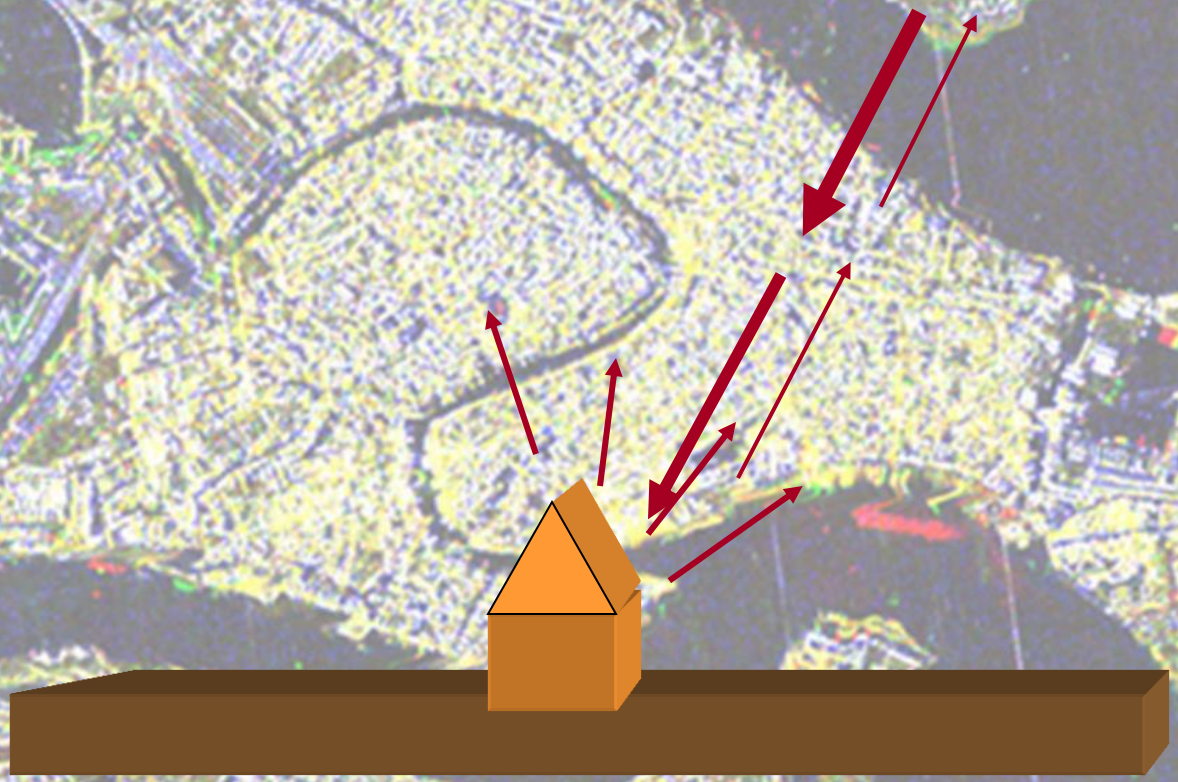
The electromagnetic spectrum

Synthetic Aperture Radar (SAR)



Active Sensors

Source of energy:
Satellite



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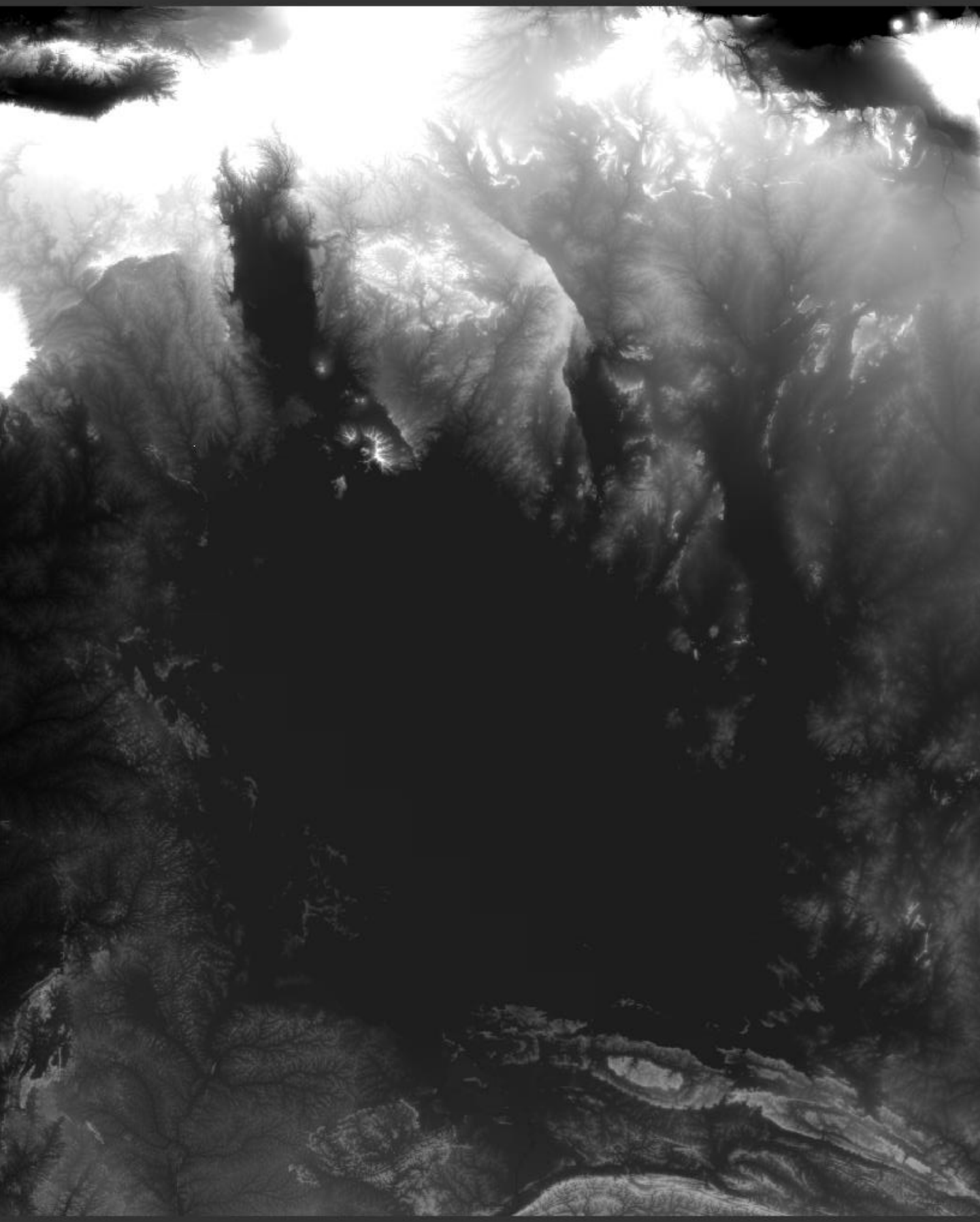
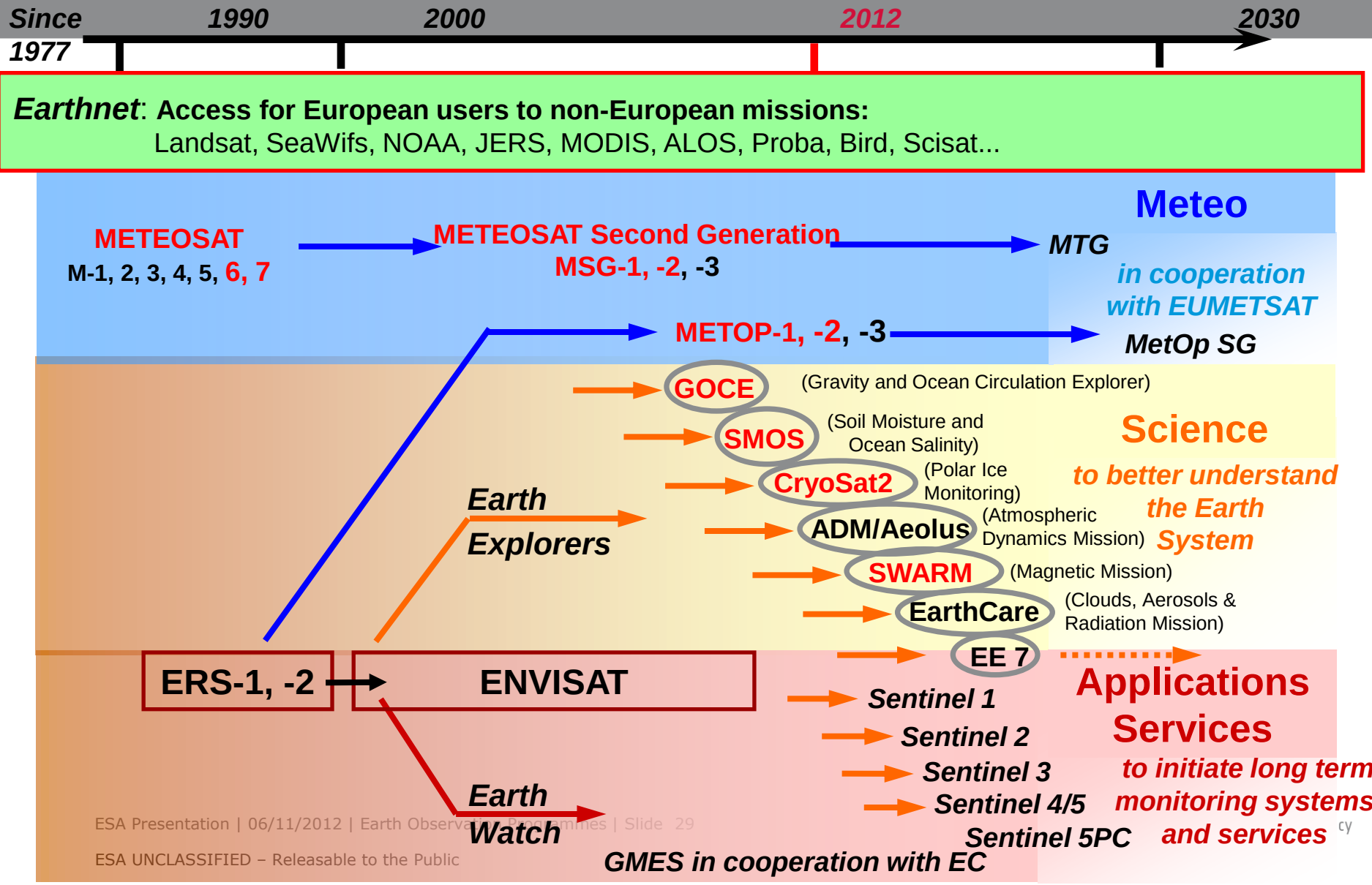
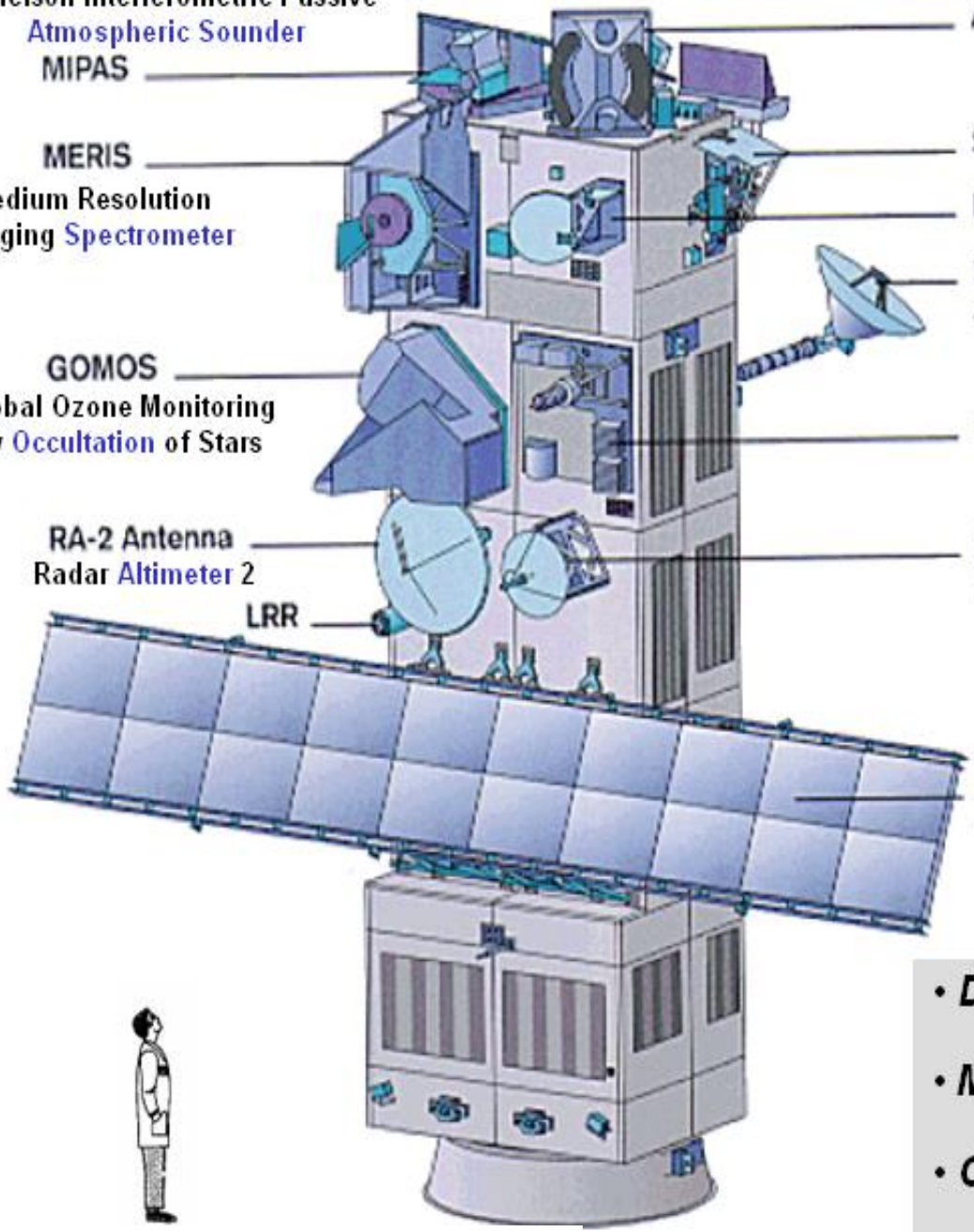


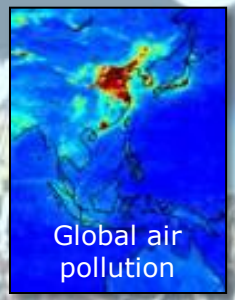
The development of Earth observation in Europe

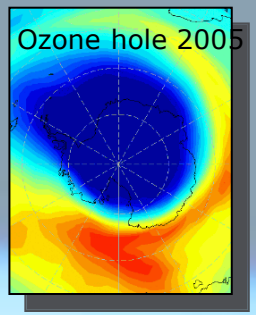


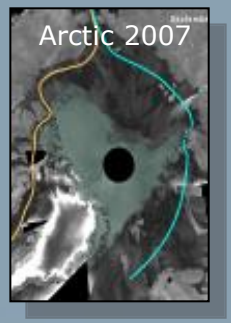


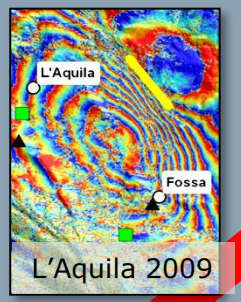
- ***Dimensions*** *(in orbit)*
  26m x 10m x 5m
- ***Mass***
  8140 Kg
- ***Orbit***
  800 km as ERS, sun synchronous
  10:00, i.e. 30 minutes before ERS-2

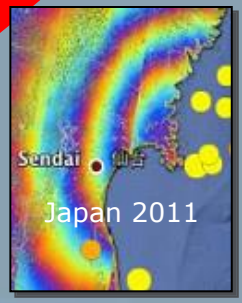
ENVISAT mission: 10 years

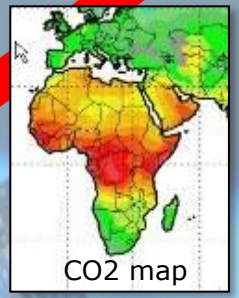


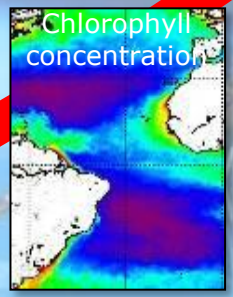


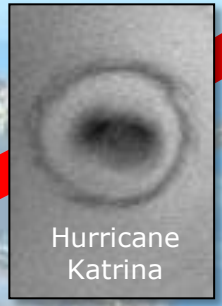


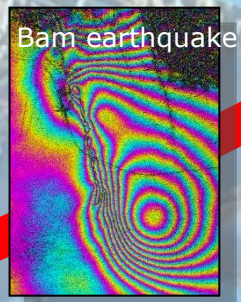












Serving 4000 scientific projects and many operational users. Many applications for disaster monitoring

Envisat Symposium Salzburg (A)

Envisat Symposium Montreux (CH)

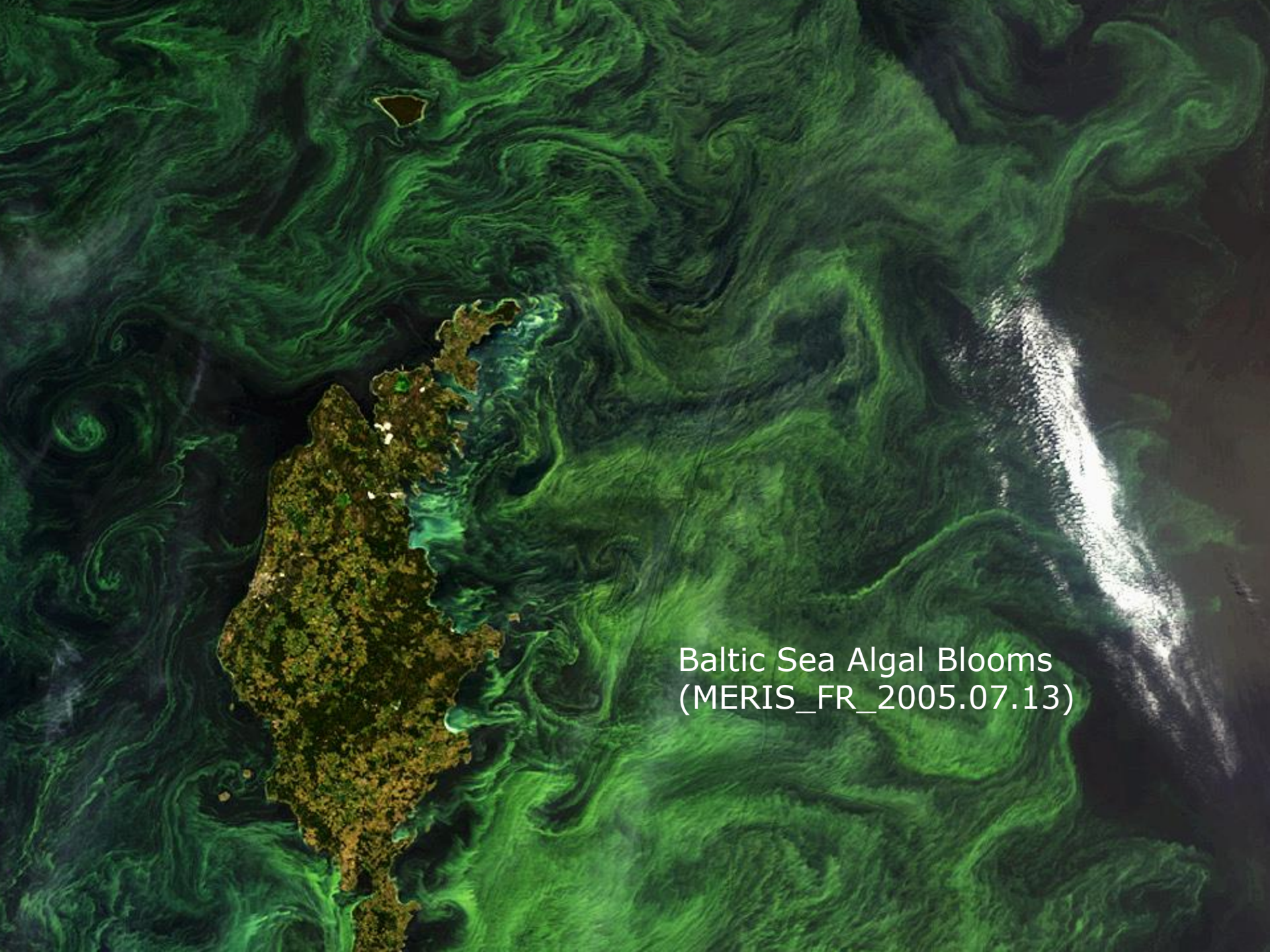
Living Planet Symposium Bergen (N)

Mar 02 | **Sep 04** | **Apr 07** | **Jun 10** | **Mar 12**

and many workshops dedicated to specific Envisat user communities

1) Use of optical data for Risk Management


Moscow Fires (Meris FR 2011)


Baltic Sea Algal Blooms
(MERIS_FR_2005.07.13)

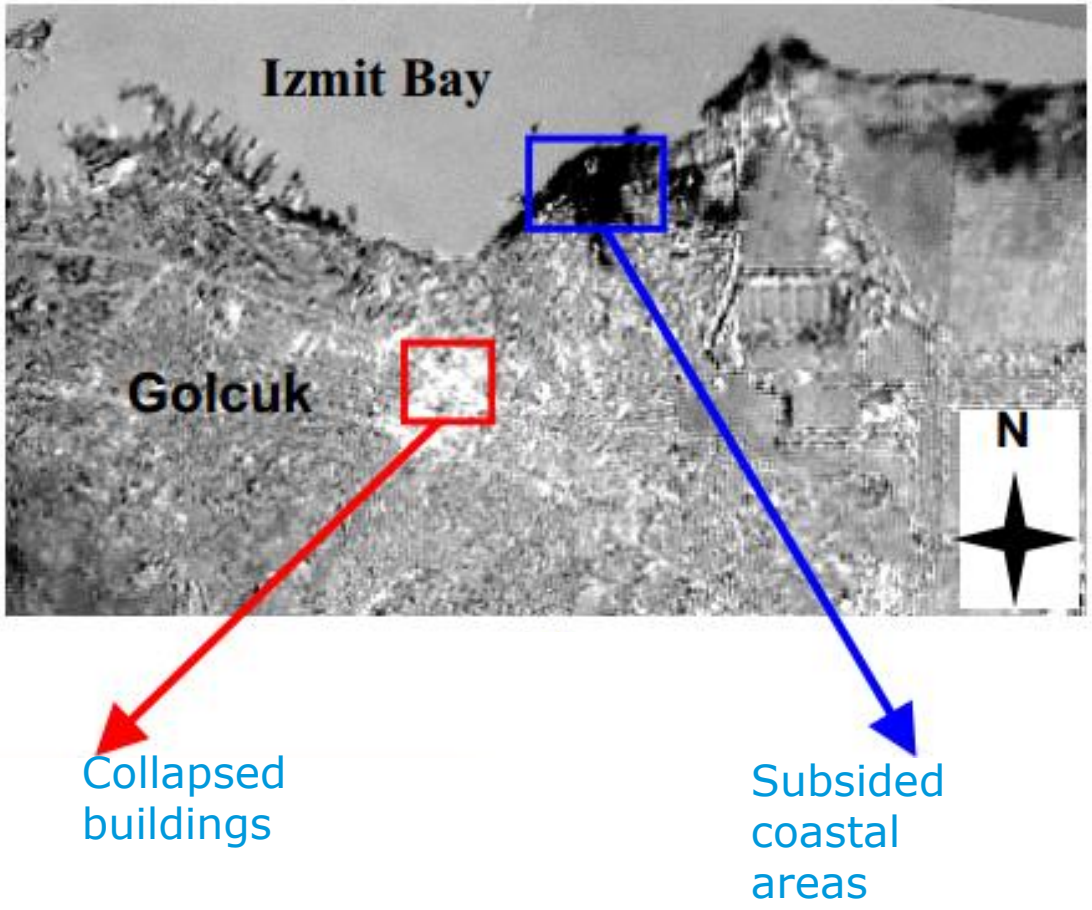
Earthquake in Izmit, Turkey (1999)

Change detection from space, using Multispectral optical images (SPOT HRV XS, PAN)

- Image of the differences (using several bands)
- ~95% accuracy in the detection (*)
- This works only by day time and clear sky (Optical Data)

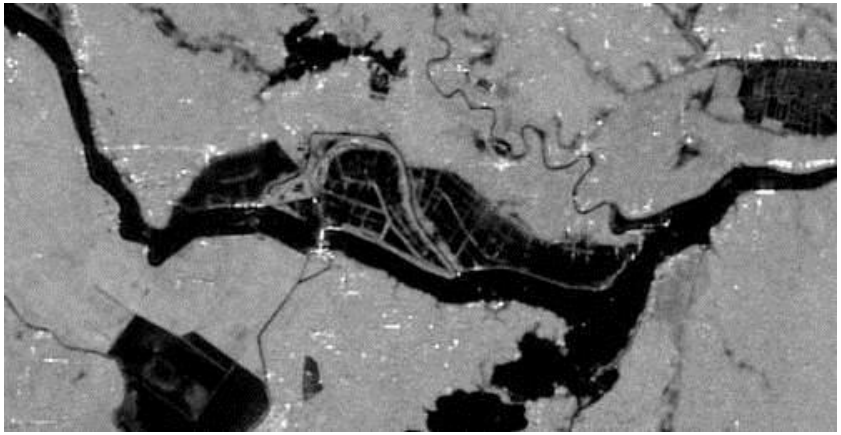
(*) by comparison to a detection based on airborne images using building shadows

Turker, 2002

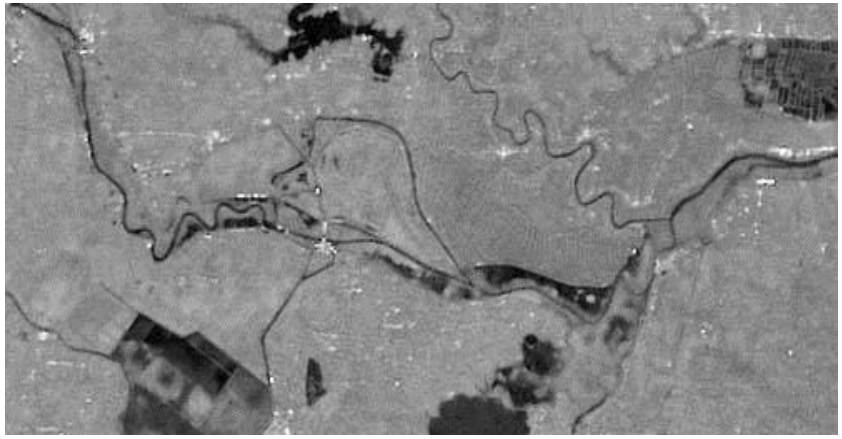


2) Use of radar backscatter for Risk Management

Flood mapping using satellite radar



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

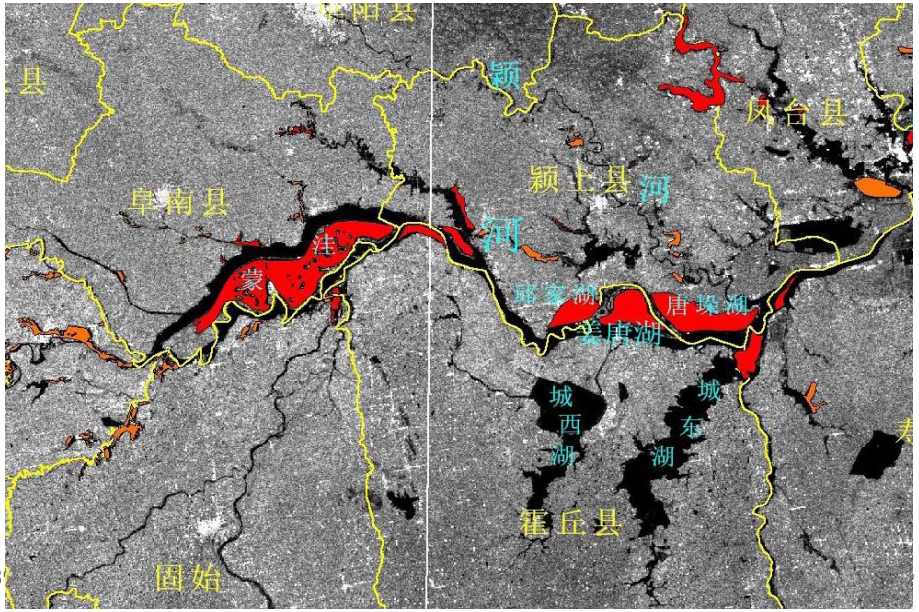


ASAR WSM 150m spatial resolution acquired 12th August 2006, descending pass, polarisation HH.

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

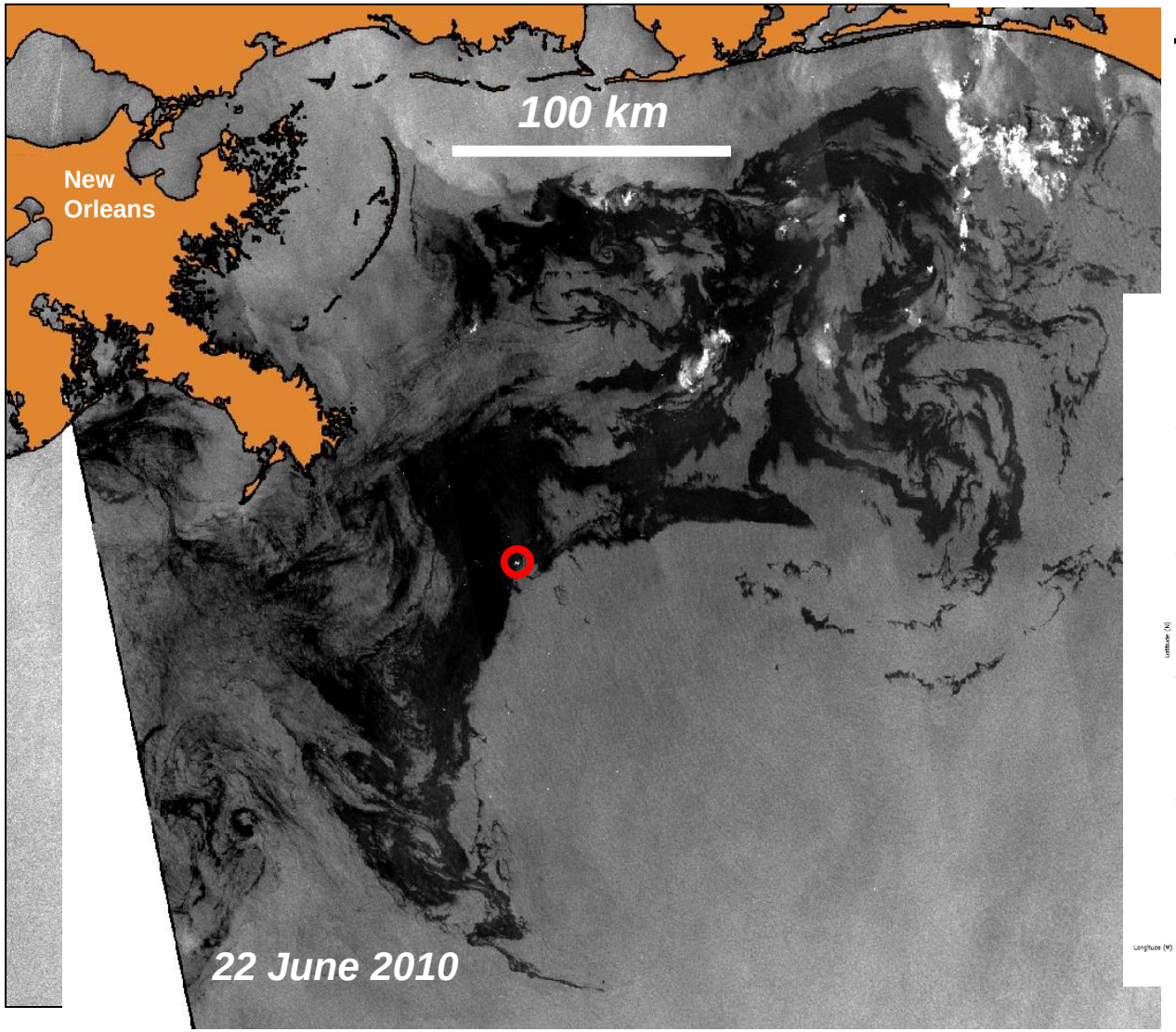
FLOODING IN CHINA JULY 2007

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.

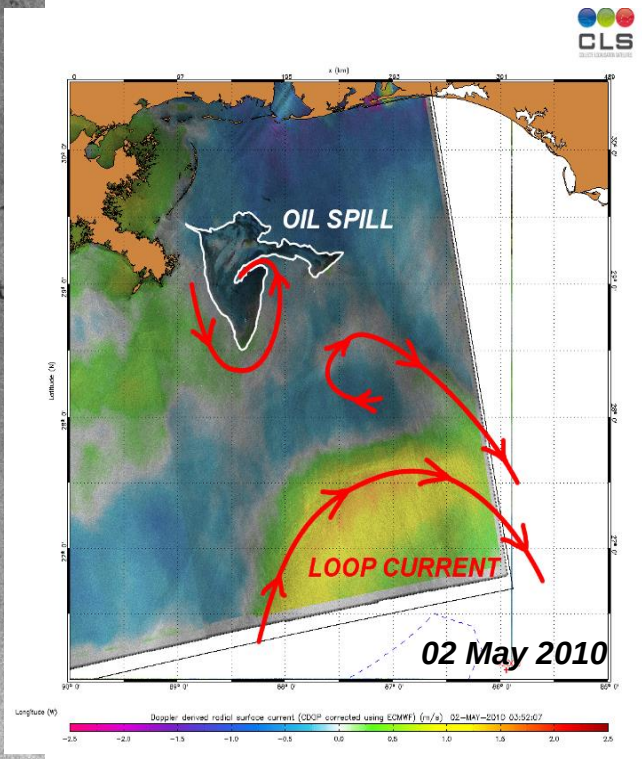


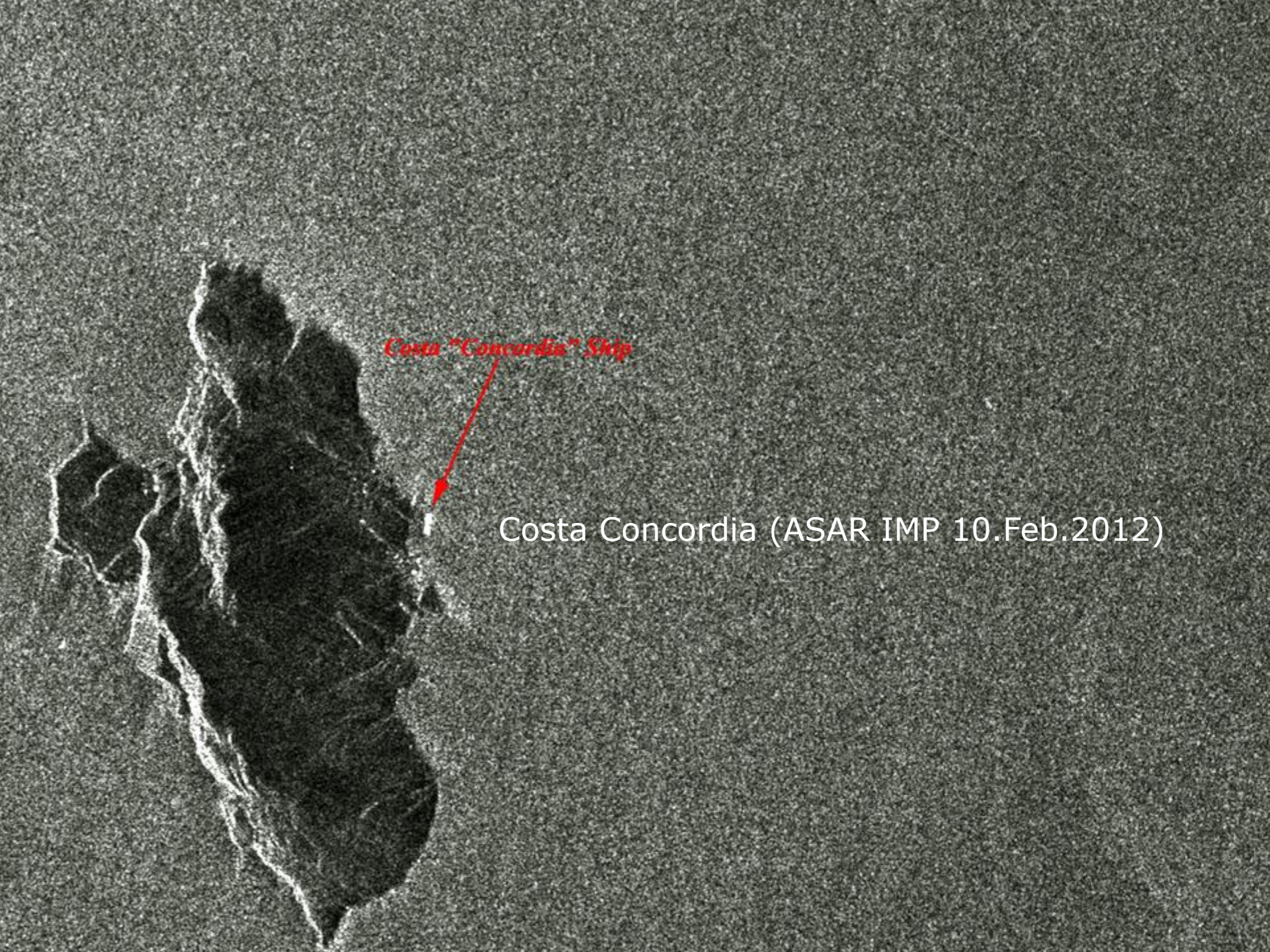
Courtesy of IWHR, Beijing

Oil spill monitoring using radar satellite



The Louisiana Oil Spill disaster from space
(Envisat ASAR)





Costa Concordia (ASAR IMP 10.Feb.2012)

Iceberg B-15A
(ASAR_WSM_15Apr05)

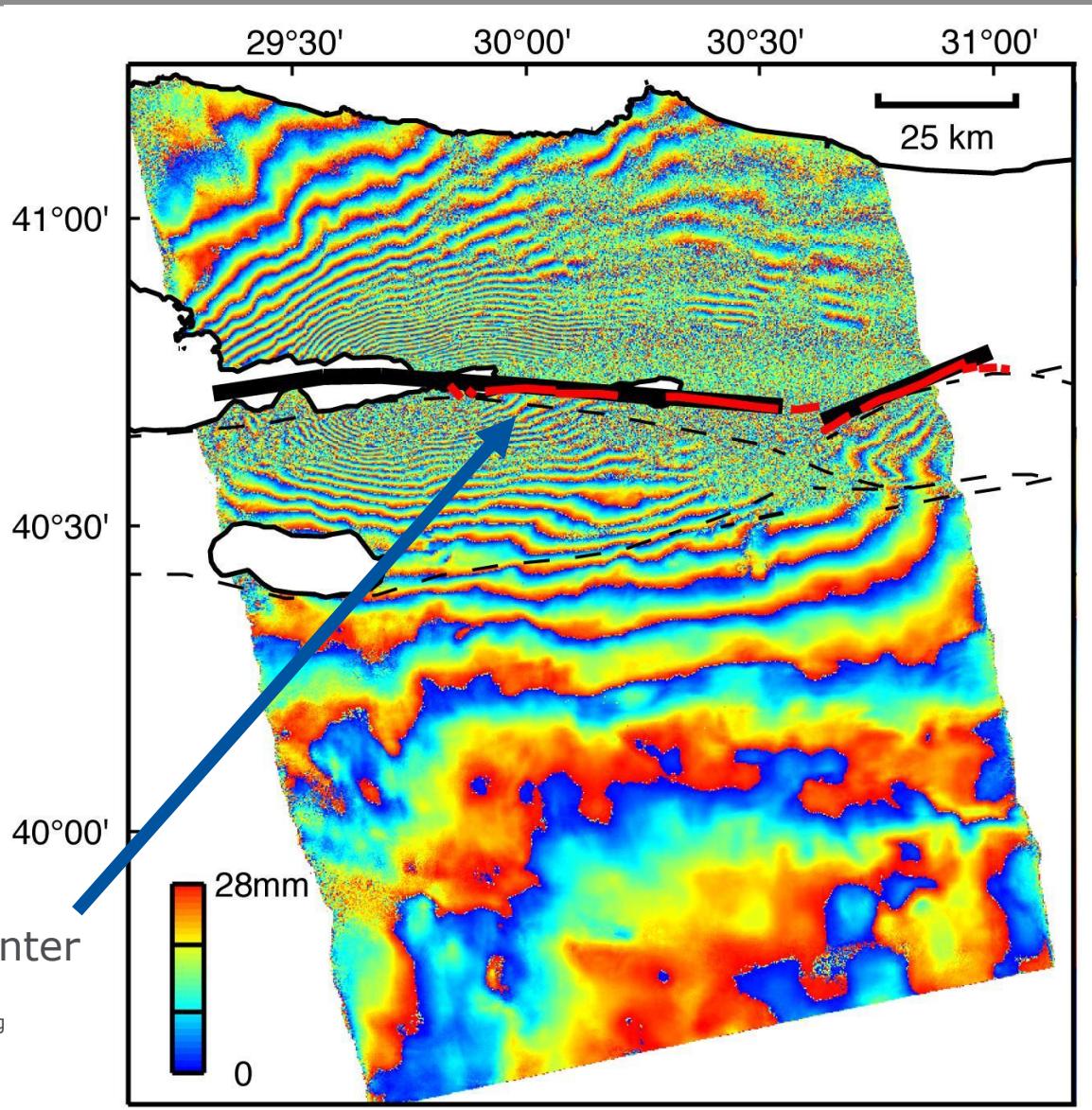
Iceberg B-15A Antarctic (ASAR_WSM from 4th to 20th Apr 05)

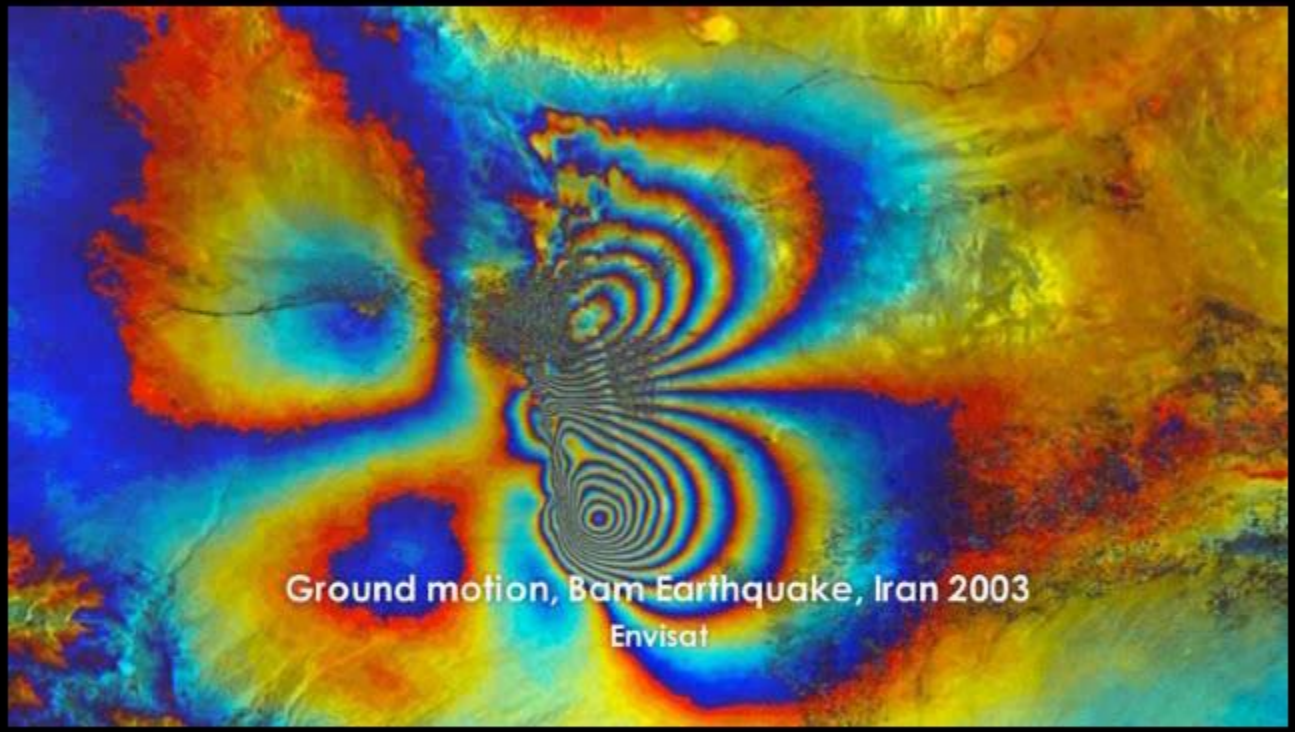
Use of radar phase (InSAR, PS) for Risk Management

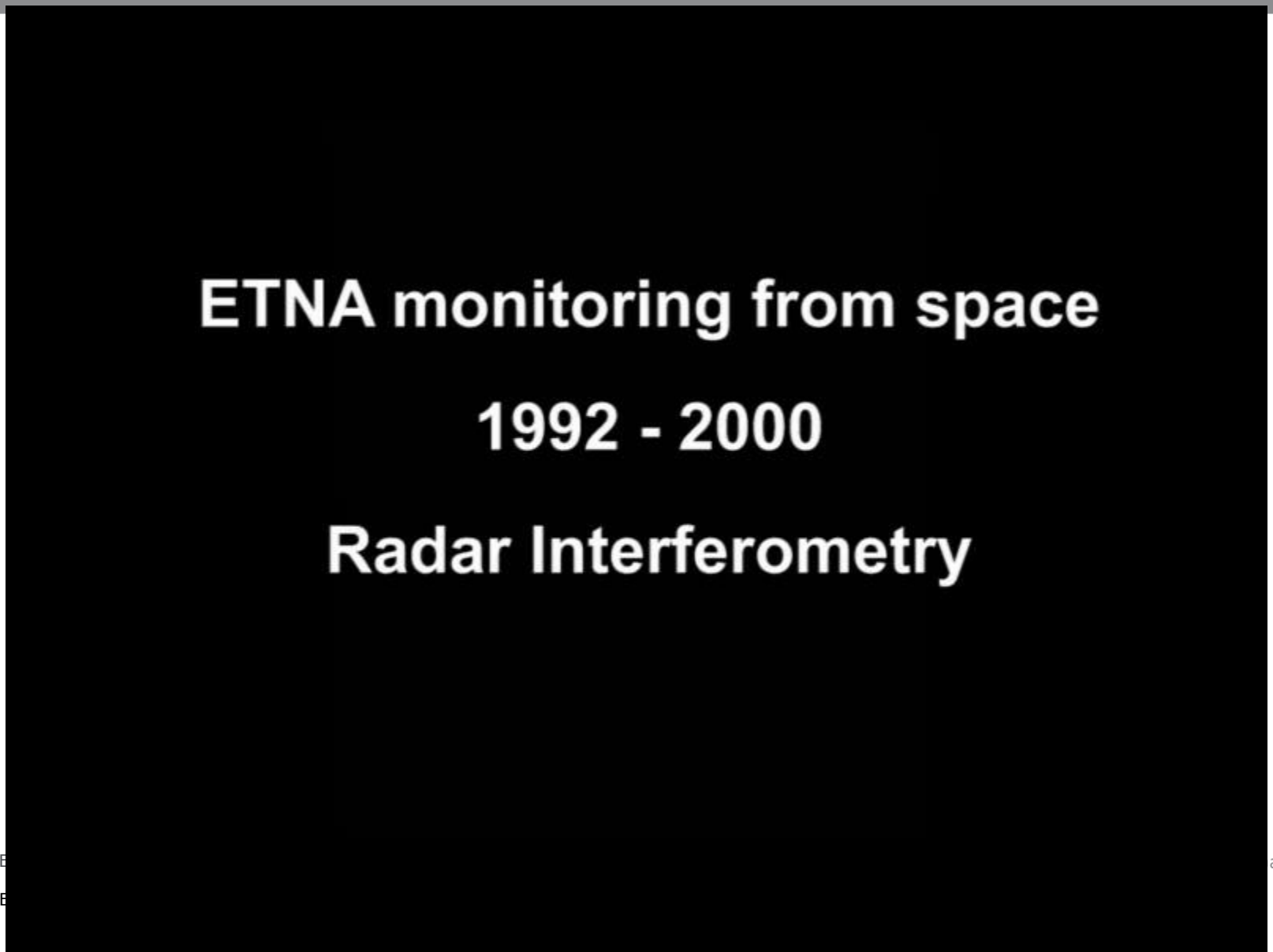
Earthquake in Izmit, Turkey (1999)

Post-seismic deformation measured by Interferometric SAR

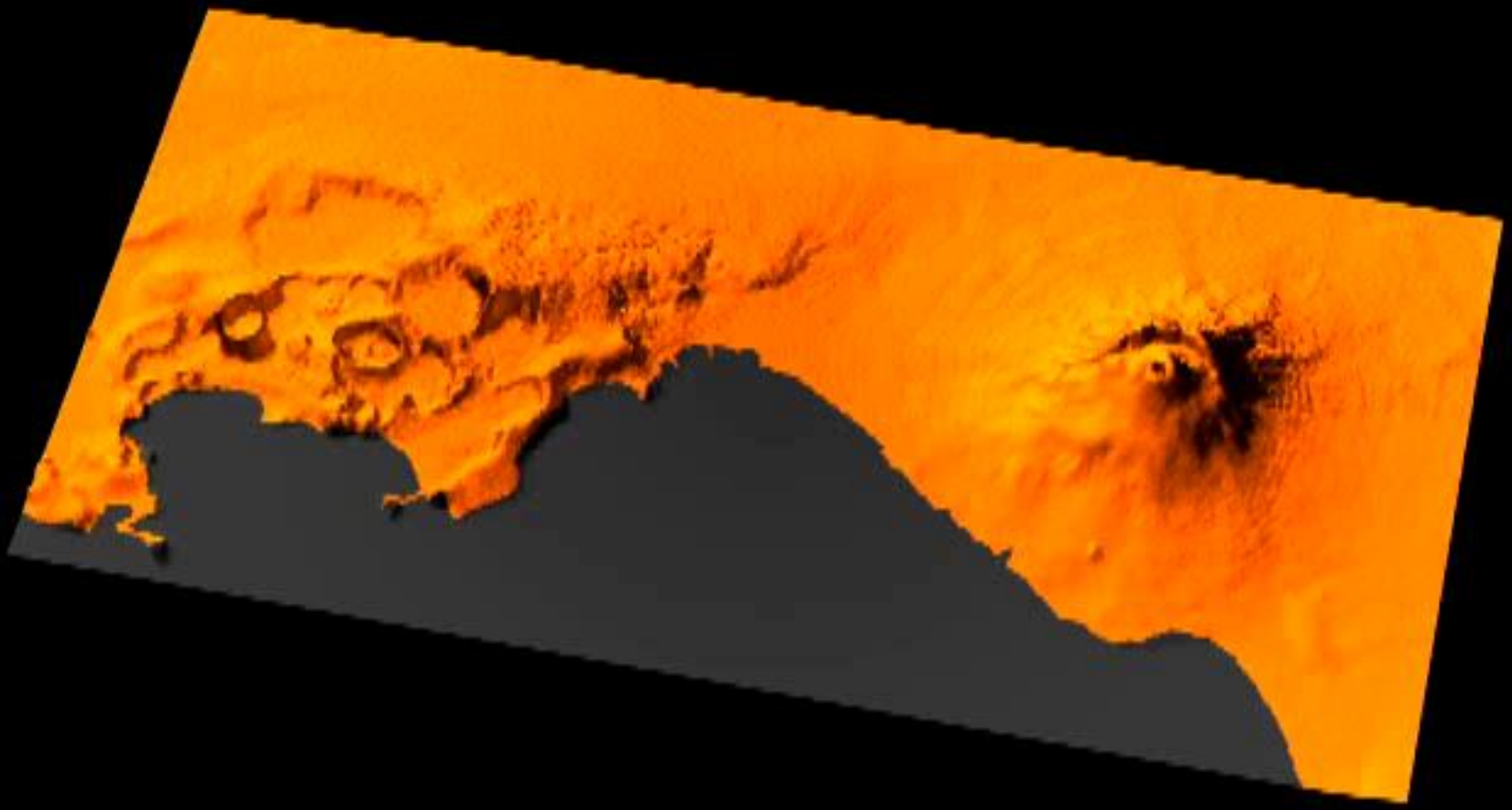
- Synthetic Aperture Radar (ERS-1, ERS-2)
- Generation of Interferogram (phase difference between two SAR images)
- One colour pattern (fringe) corresponds to 28 mm deformation along the line of sight
- This works through clouds or darkness (Radar Data)



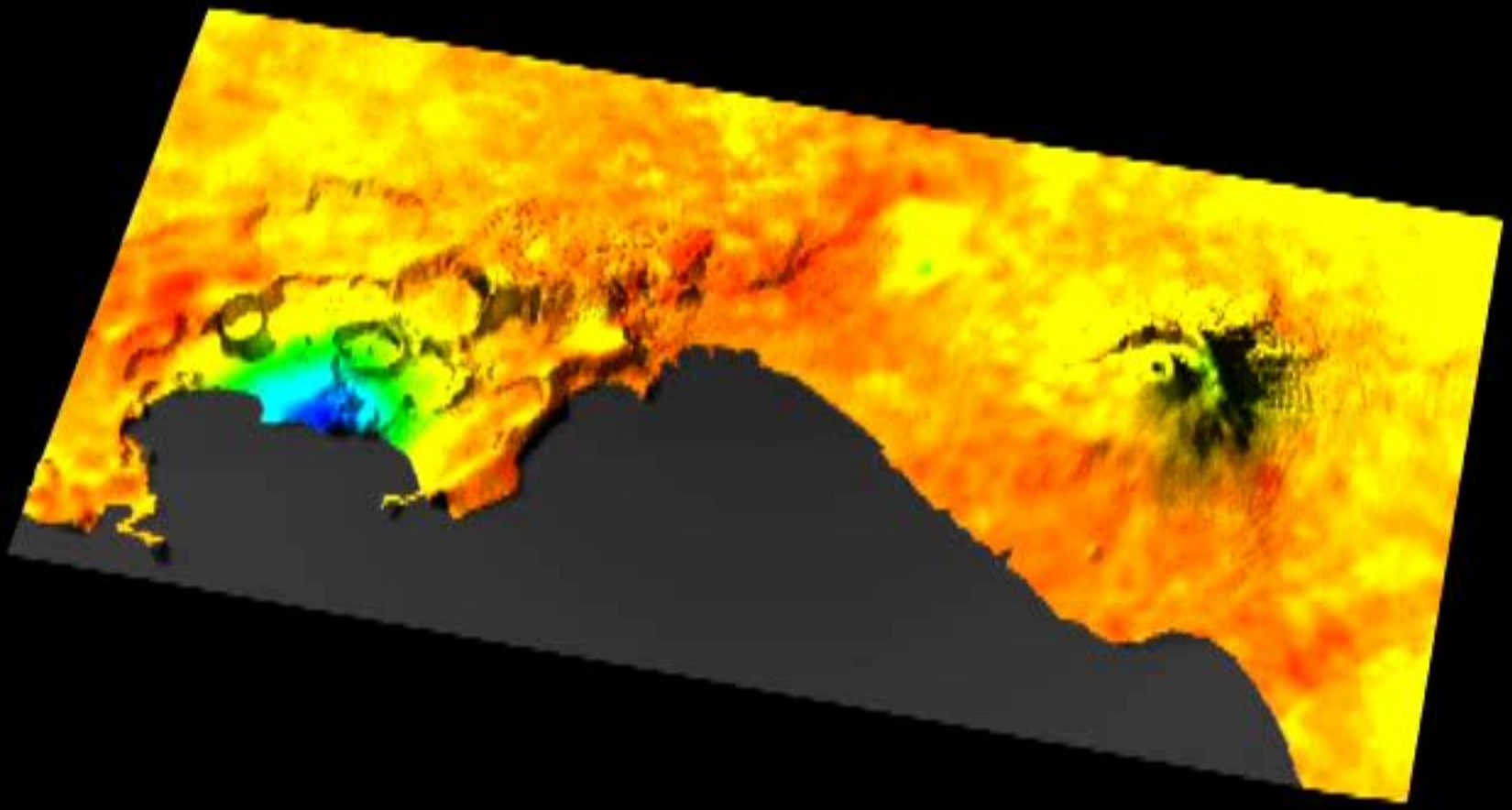

Ground motion, Bam Earthquake, Iran 2003
Envisat


ETNA monitoring from space
1992 - 2000
Radar Interferometry

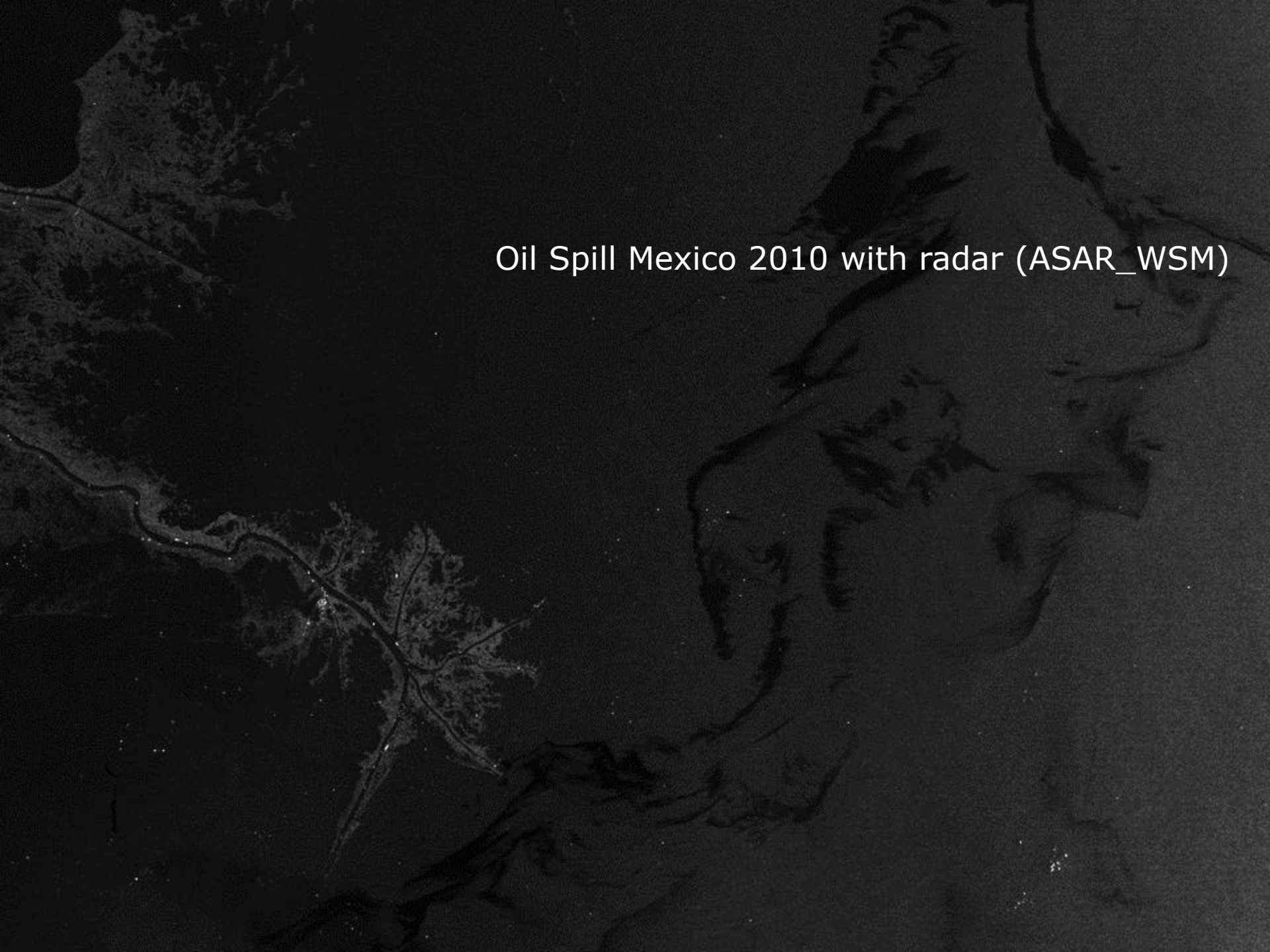
Campi Flegrei: observation by InSAR

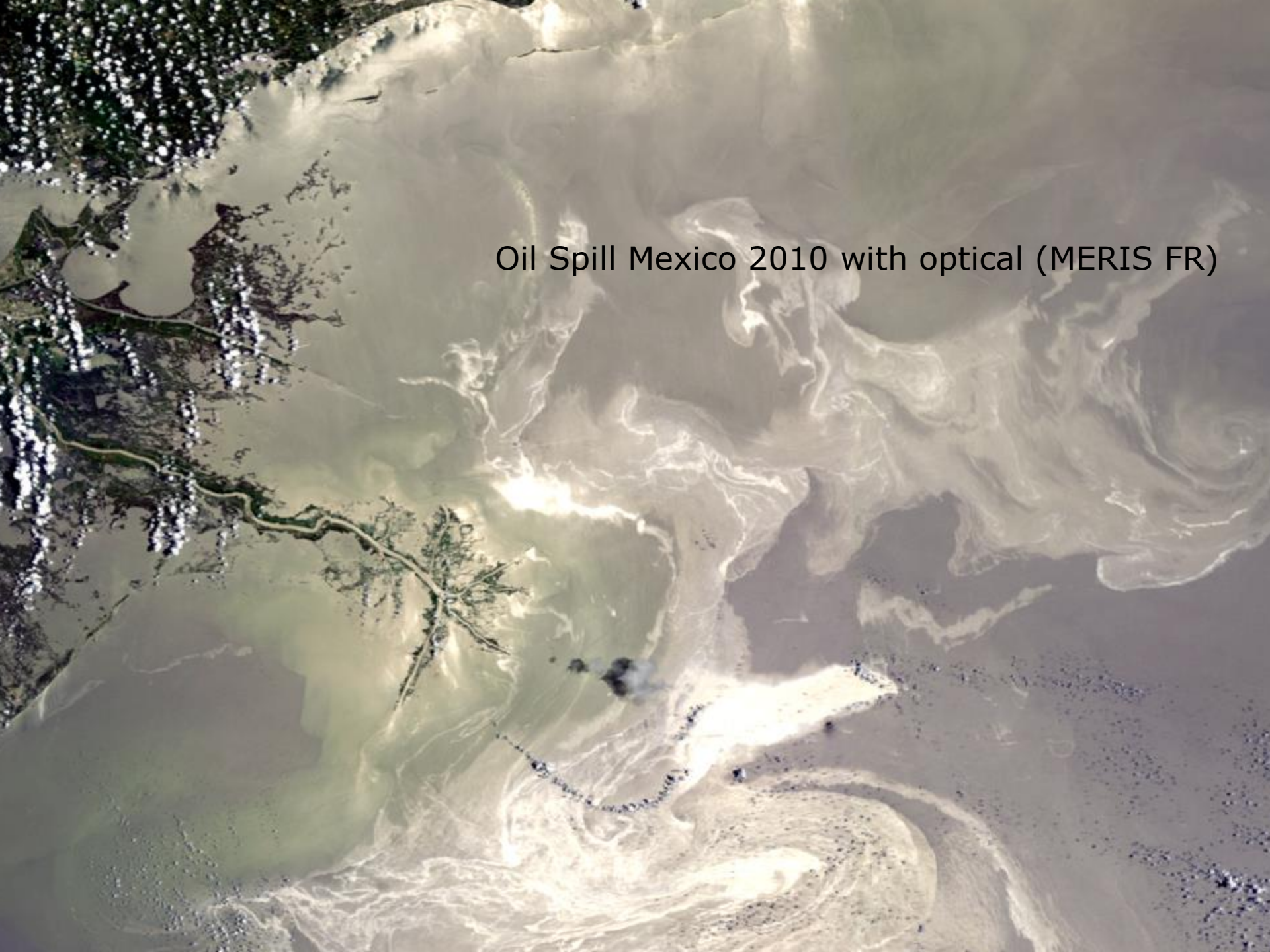


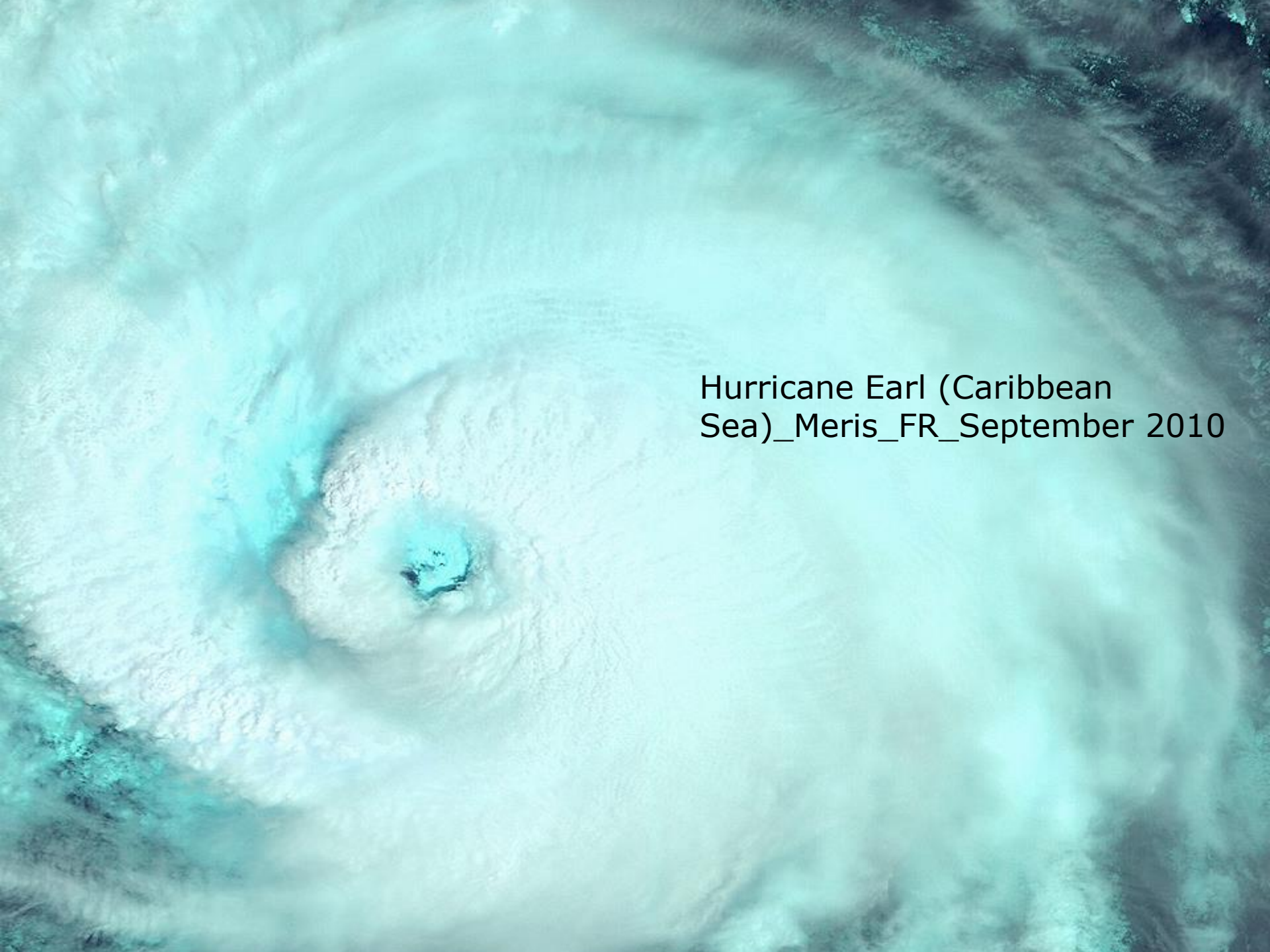
Campi Flegrei: geophysical interpretation

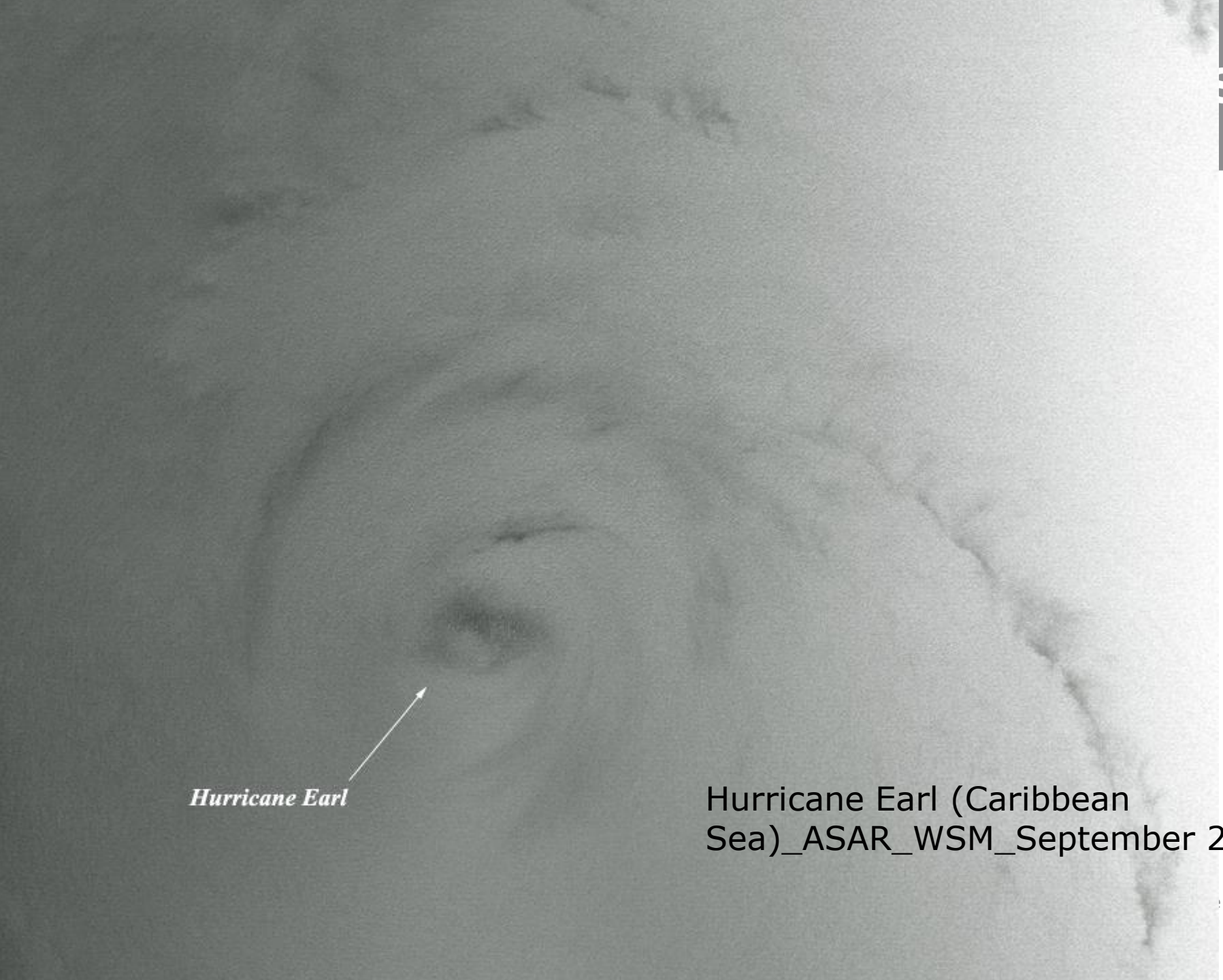


3) Use of radar backscatter, combined with optical data, for Risk Management


Oil Spill Mexico 2010 with radar (ASAR_WSM)


Oil Spill Mexico 2010 with optical (MERIS FR)

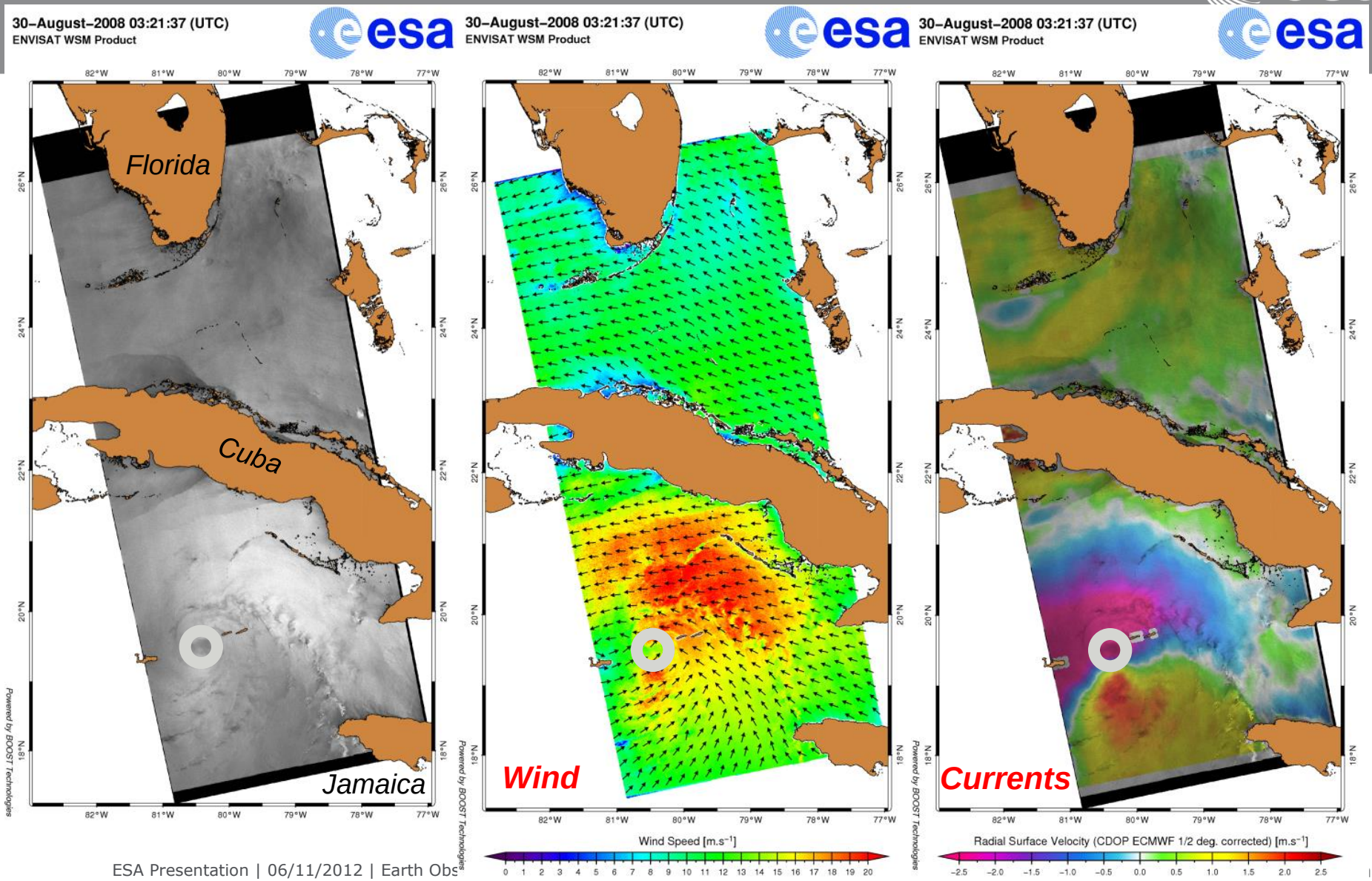

Hurricane Earl (Caribbean
Sea)_Meris_FR_September 2010



Hurricane Earl (Caribbean Sea)_ASAR_WSM_September 2010


esa
1 September 2008, 16:20 UTC
MERIS composite image
Hurricane Gustav
30 August 2008, 15:40 UTC
28 August 2008, 15:00 UTC
25 August 2008, 15:00 UTC
European Space Agency
Agence spatiale européenne
the Living Planet
© ESA Envisat

Hurricane Gustav: wind and currents

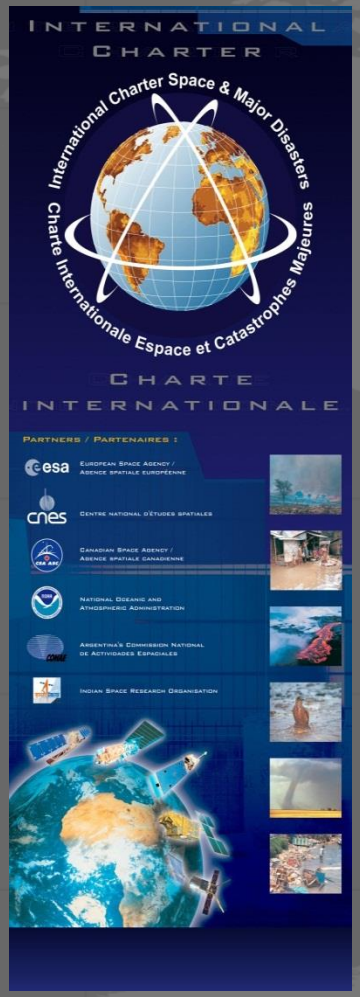


http://soprano.boost-technologies.com

Many more examples available at:

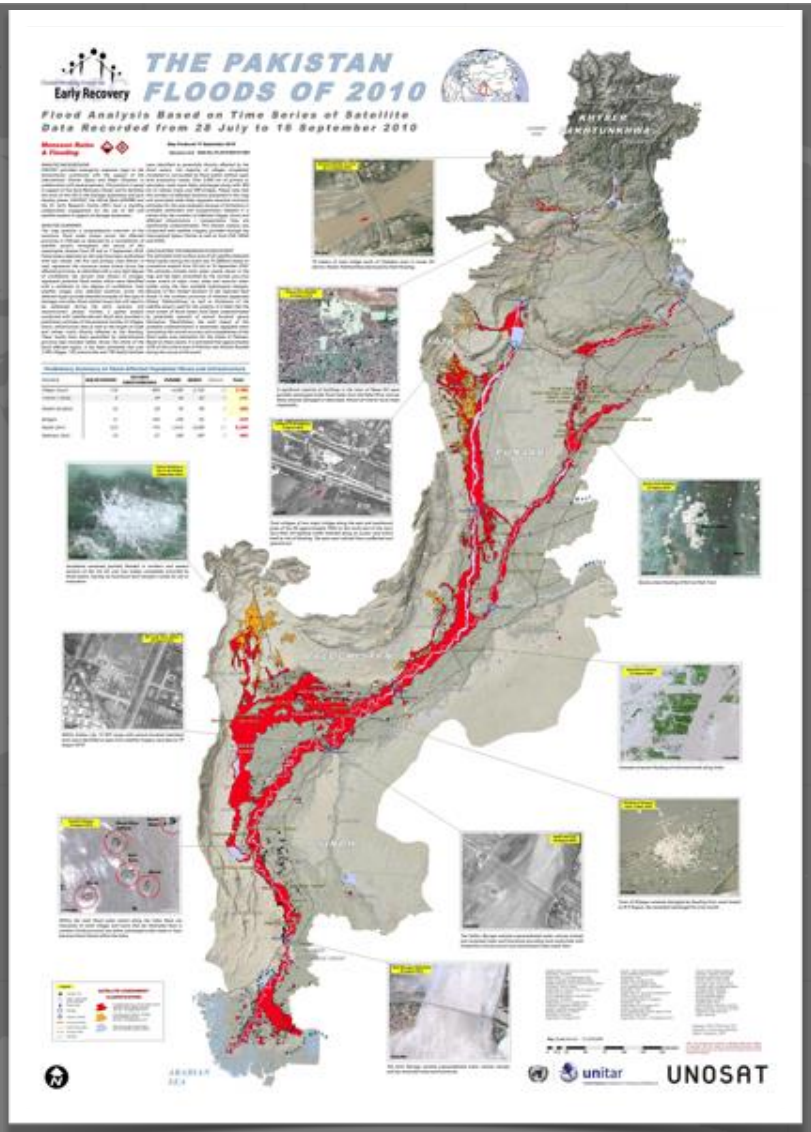
http://ew.eo.esa.int/web/guest/home

International Charter Space & Major Disasters



More than 350 activations in 110+ countries since 2000 !

Universal Access since Sept. 2012



The example of the 2010 Pakistan Floods

International Charter Space & Major Disasters – purpose:

An International agreement among Space Agencies to support with space-based data and information relief efforts in the event of emergencies caused by major disasters

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





Charter Activations (disaster types)

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Sub-totals	
Solid Earth	*Earthquake*		*3*	*1*	*3*	*5*	*3*	*2*	*5*	*4*	*3*	*5*	*6*	*2*	42	**76**
	Landslide	*1*	*1*	*2*	*2*			*1*			*4*	*2*	*1*		14	
	Volcano		*1*	*1*	*2*	*2*	*1*	*1*	*2*	*3*	*3*	*2*	*1*	*1*	20	
Weather / Atmospheric	*Storm/hurricane***			*1*	*2*	*3*	*6*	*1*	*8*	*8*	*8*	*11*	*3*	*2*	53	**260**
	Ice/snow hazard								*1*			*1*	*1*		3	
	*Flood/ocean wave**		*3*	*8*	*4*	*9*	*13*	*16*	*22*	*23*	*18*	*25*	*16*	*23*	180	
	Fire				*5*	*1*	*2*		*4*	*2*	*4*	*1*	*3*	*2*	24	
Technological	*Oil spill*		*3*	*2*				*4*	*3*			*1*	*1*		14	**18**
	Others					*1*						*3*			4	
	Total / year	**1**	**11**	**15**	**18**	**21**	**25**	**25**	**45**	**40**	**40**	**51**	**32**	**30**		

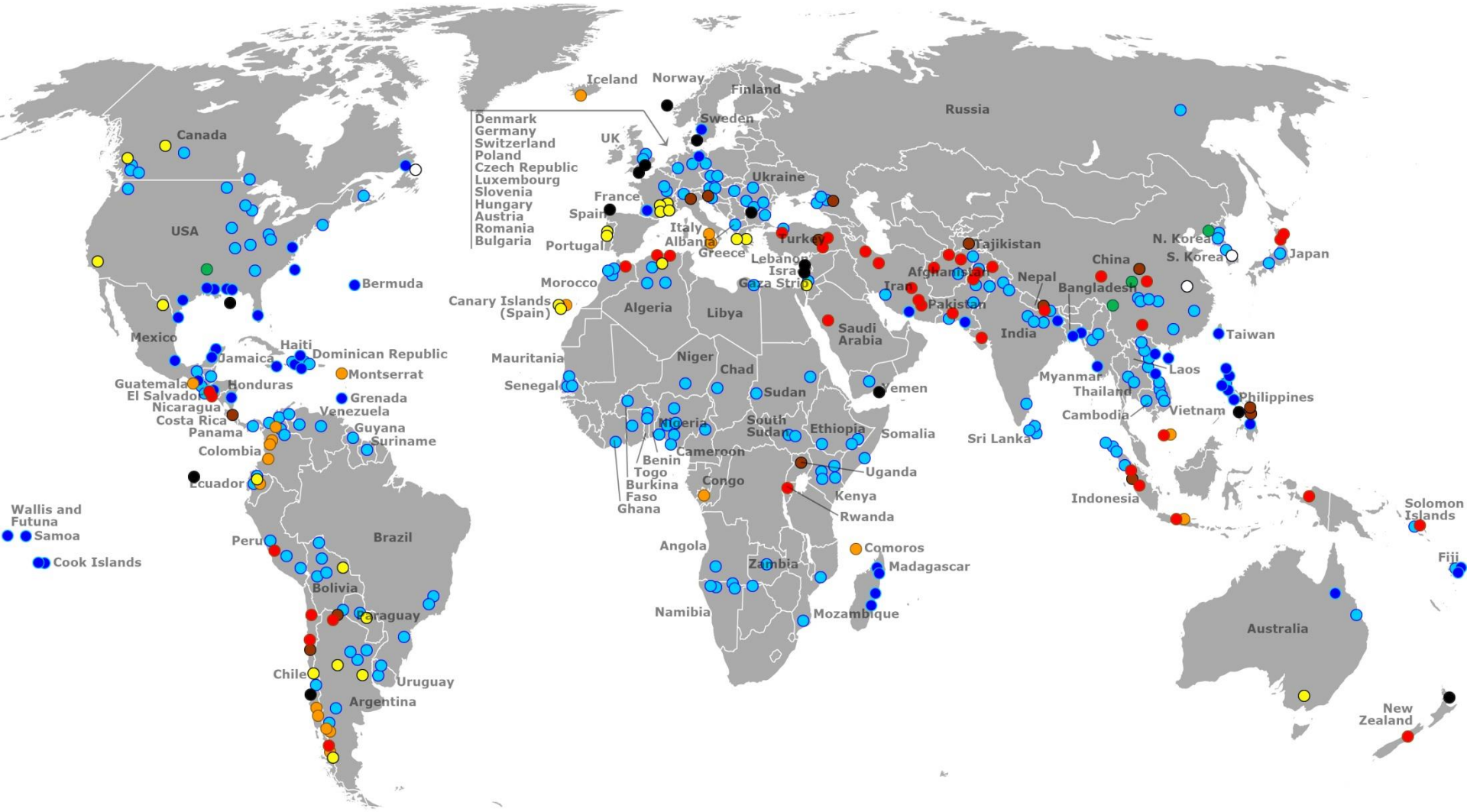
Total: 354

*includes solid earth related phenomenon of a tsunami

**includes all wind type storms (hurricane, cyclone, typhoon and tornado)

As of October 15, 2012

Activation Distribution

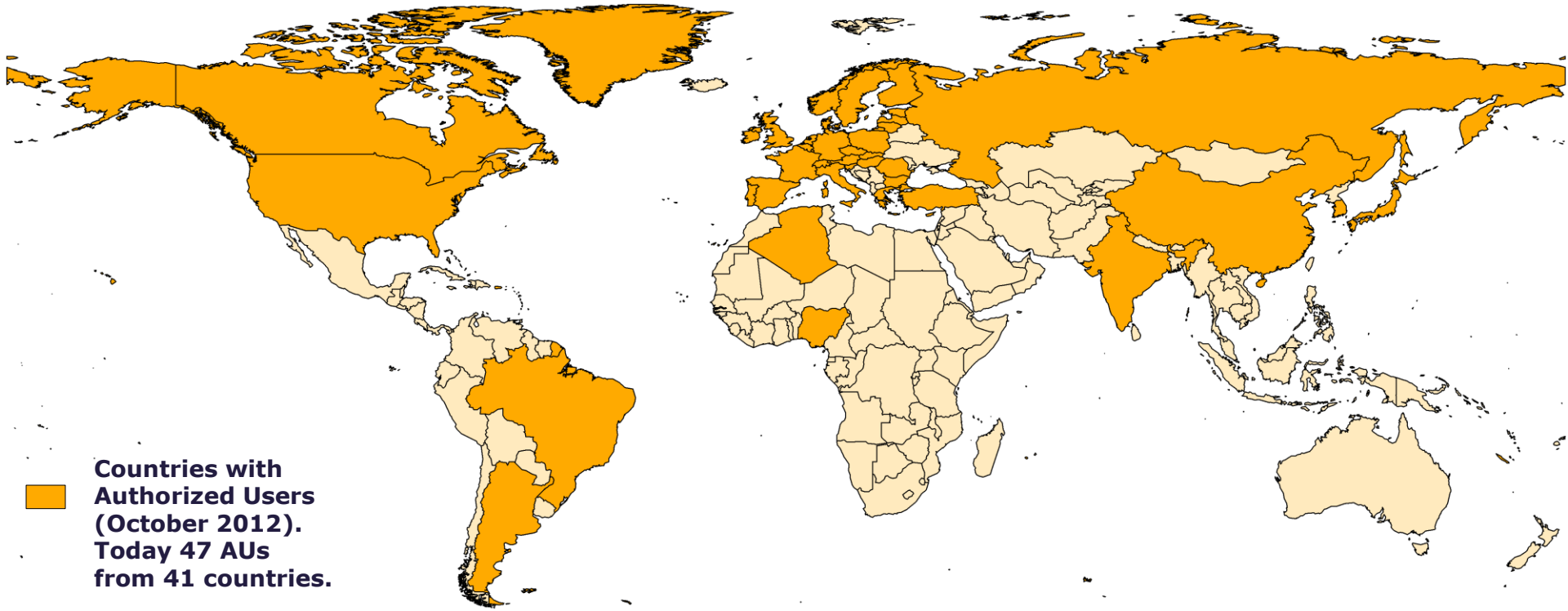


***Legend*:** ● Earthquake ● Landslide ● Volcano ● Storm/hurricane ● Flood/ocean wave ○ Ice/snow hazard ● Fire ● Oil spill ● Other

As of October 15, 2012

Activating the Charter: Authorized Users (AU)

The only bodies authorized to **directly** request the Charter to be activated are the **Authorized Users** - AUs (typically civil protection agencies, governmental relief organizations, or other authorities with a mandate related to disaster management).

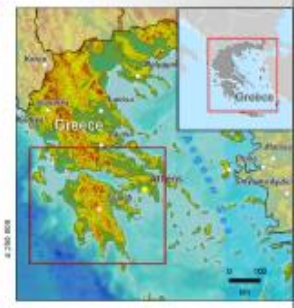


Burnt area mapping using IR satellite data

GREECE- Peloponnese - Forest fires - Regional Overview

Situation the 30th of August 2007

Charter Call 175
Product n°01



Legend

- Active fire observed the 30th of August 2007
- Burnt areas observed the 30th of August 2007
- Vegetation index (low to high)
- Mediterranean Sea
- Inland water
- Urban areas
- Major roads
- Secondary roads
- Other roads

Map Information

N

0 15 30
km

Projection : UTM Zone 34 North, Datum : WGS84
Scale : 1:500 000 (at A1 print)

Data sources

Processing SERTIT 2007

Vegetation index from the MERIS FR 1st date acquired the 30th of August 2007 (300m resolution).
Processing SERTIT 2007

Vector layers :
Mediterranean Sea : ORTHI
© UGGI
Roads, inland water, urban areas : ESRI
© ESRI

Topography : ARTM GRMS
© UGGI

Information

The products elaborated for this International Charter "Space and Major Disasters" call are realized on a best effort basis in crisis mode within a very short time scale.

Map produced the 30th of August 2007
by SERTIT
© SERTIT 2007

Map projection

cnes
esa
sertit

SERTIT, August 2007

Recent example: Super-storm Sandy, Haiti, October 2012

Charter Call 418
Glide N° TC-2012-000180-HTI
Product No. 05

Haiti - Port-au-Prince : Santo

Super-storm Sandy's impact along Grise River: affected buildings and displaced riverbanks Observation the 02/11/2012

Location Diagrams

Legend

Impact	*Situation before event (19 July 2012)*
Damaged building	
Affected road	Road
Water body 02 November 2012	Water body
New riverbank	Old riverbank
Riverbank displacement	

Interpretation

During the night of the 23-24 of October 2012, Hurricane Sandy hit Haiti with intense downpours and violent winds causing flooding and much damage. According to Civil Security, it left 51 dead and a number missing in its wake. Many dwellings, infrastructure and fields were destroyed. A country-wide state of emergency was declared on the evening of the 30th of October.
his map highlights impacts along the Grise River within the Santo neighbourhood, to the NE of Port-au-Prince's airport. In many places this flood provoked catastrophic riverbank changes sweeping away over 200 dwellings into the river waters.

Cartographic information

0 25 50 m

N

Local projection: UTM Zone 18 North , Datum: WGS 84
Geographic projection : Lat/Lon (DMS), Datum: WGS 84

Scale: 1:1 000 for A1 prints

Geometric references sourced from KAL-Haiti project:
Horizontal: Google images, RMSe < 5m
Vertical: SPOT HRS, RMSe < 10m

Data sources

Disaster impact assessment (affected buildings and roads, water bodies and riverbanks) mapped from the Pleiades image acquired the 02 November 2012
© SERTIT 2012

Situation before event mapped from the Pleiades image acquired the 19 July 2012 (water bodies and riverbanks) and KAL-Haiti project (roads)

Background layers
Pleiades 1A (50 cm) images acquired the 19 July 2012 and the 02 November 2012, © CNES 2012, distribution Astrium Services / Spot Image S.A., all rights reserved

Framework

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

Map produced the 08 November 2012 by SERTIT
© SERTIT 2012
sertit@sertit.u-strasbg.fr
http://sertit.u-strasbg.fr

cnes

sertit

Nyragongo Volcano

Examples of earthquake damage assessment in Turkey via the International Charter

Recent Earthquakes in Turkey, triggered activations of the "International Charter on Space and major Disasters"

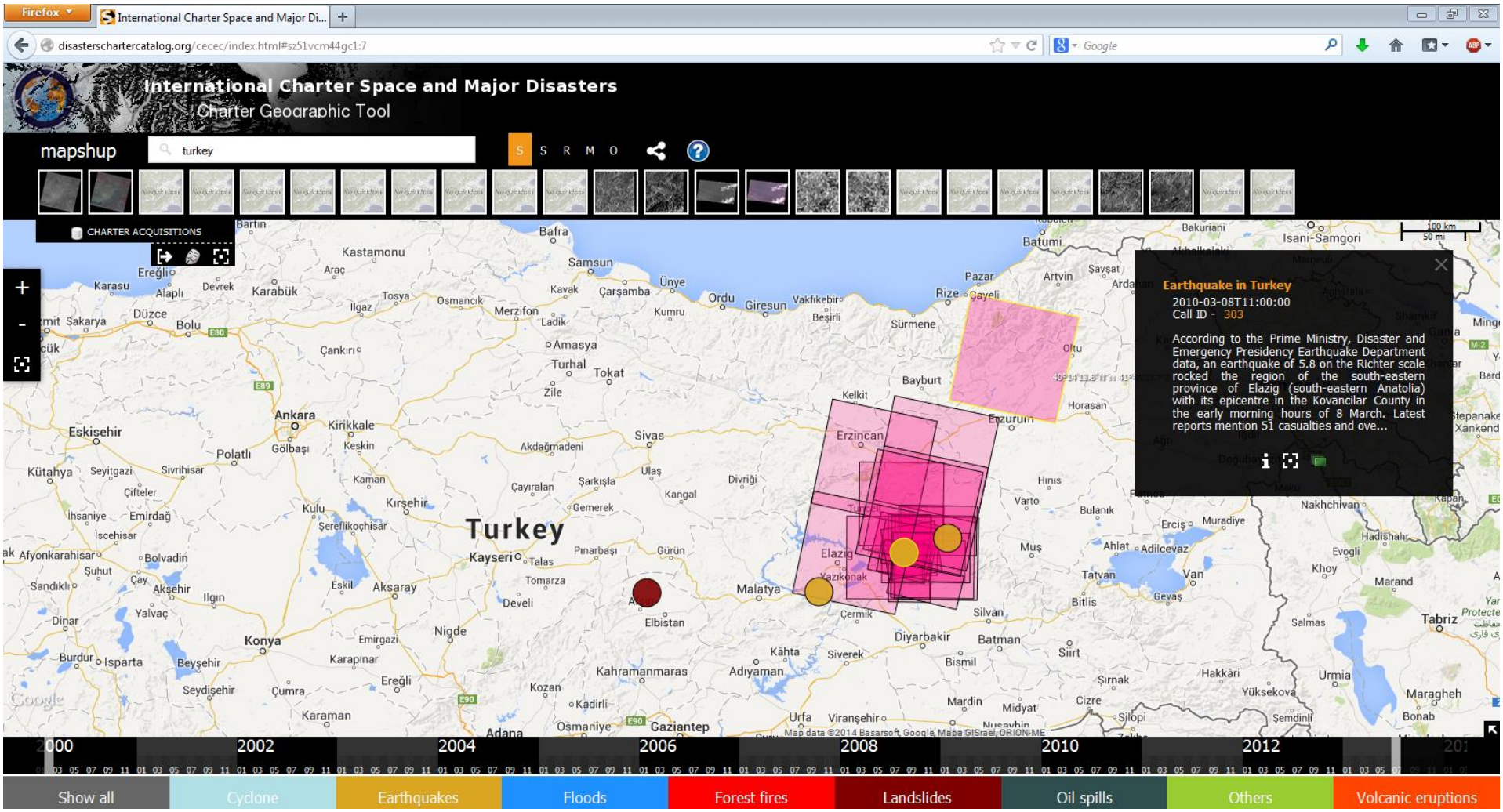
October 2011, an earthquake of magnitude of 7.2 shook Eastern Turkey (city of Ercis)

March 2010, an earthquake of magnitude of 5.8 shook the south-eastern province of Elazig (south-eastern Anatolia)

May 2003, an earthquake of magnitude of 6.1 shook Central Turkey near the town of Bingöl

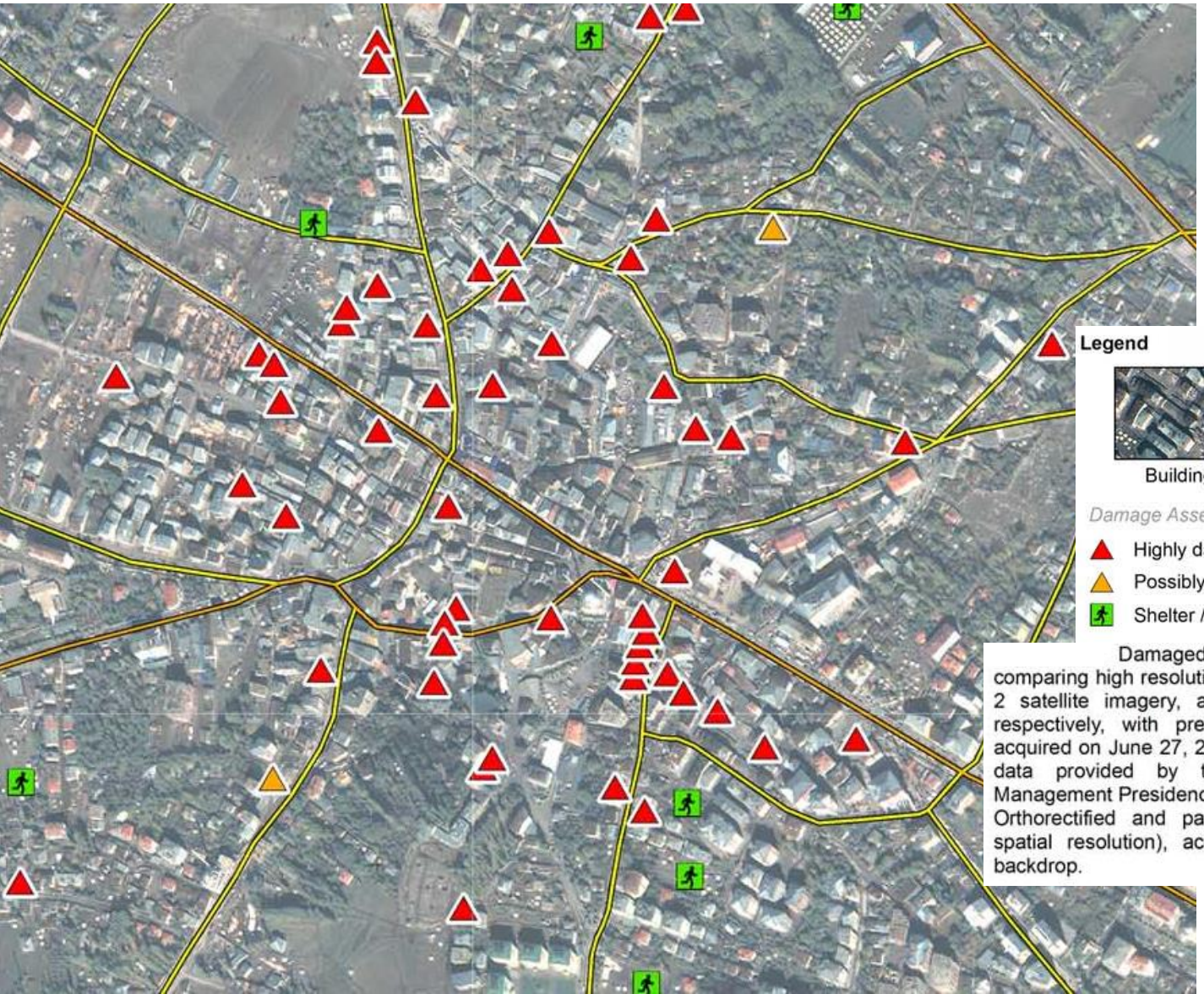
(see http://www.disasterscharter.org/web/charter/activations/tags/turkey)

Recent Earthquakes in Turkey



http://disasterschartercatalog.org/cecec/

Turkey, 2011 earthquake, Ercis , Eastern Turkey– Damage Assessment Map (International Charter)



TURKEY - ERCIS

Situation as of October 28, 2011

Damage Assessment Map - Detail

Scale: 1:6,000

Location Diagrams

Legend

Buildings


Cloud


Agriculture

Damage Assessment

- Highly damaged building
- Possibly damaged building
- Shelter / tents

Infrastructure

- Primary road
- Secondary road

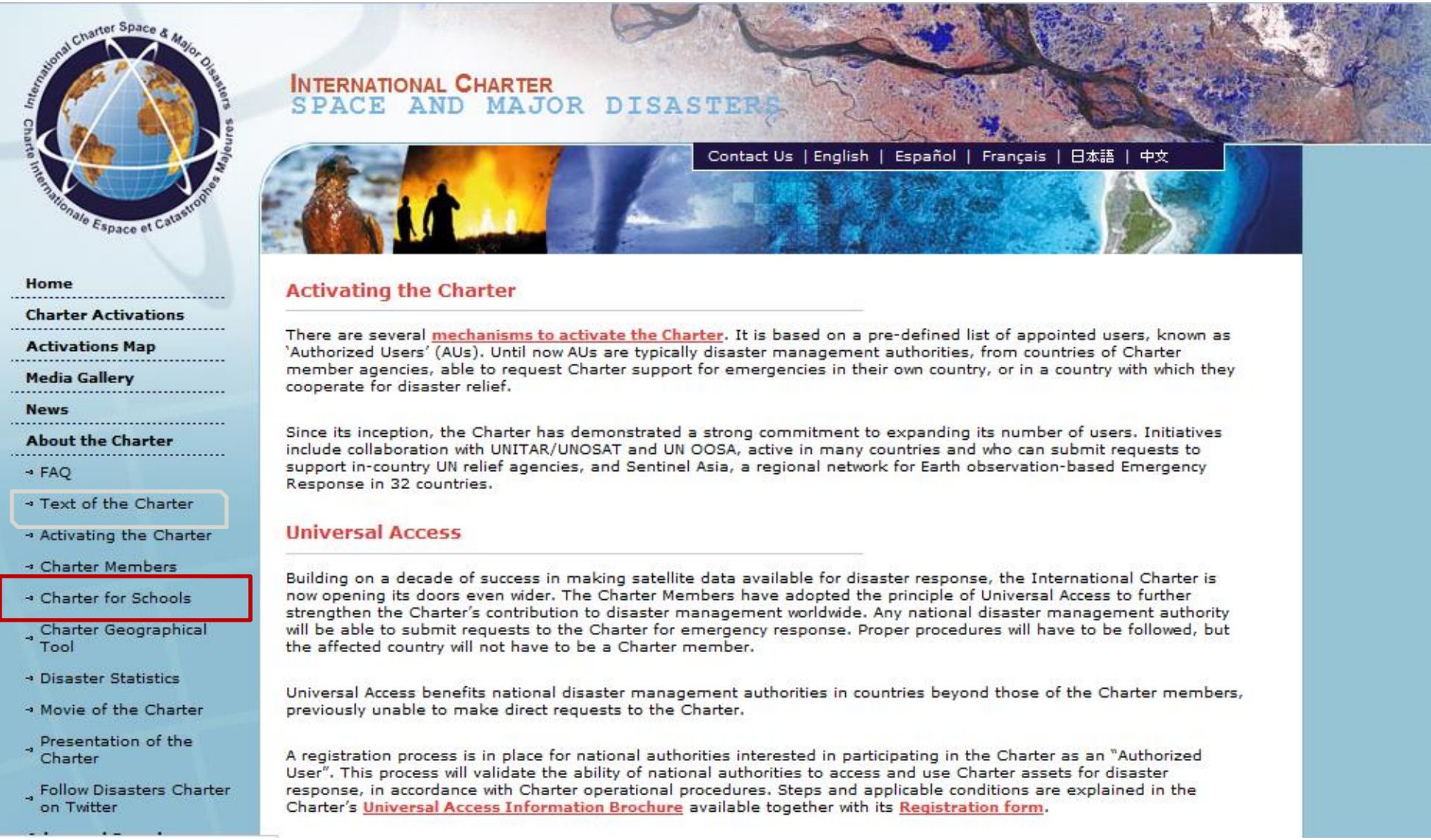
Damaged structures were derived by visually comparing high resolution post-disaster QuickBird-2 and IKONOS-2 satellite imagery, acquired on October 26 and 28, 2011, respectively, with pre-disaster WorldView-2 satellite imagery, acquired on June 27, 2011. Damage estimation was supported by data provided by the Turkish Disaster and Emergency Management Presidency AFAD.

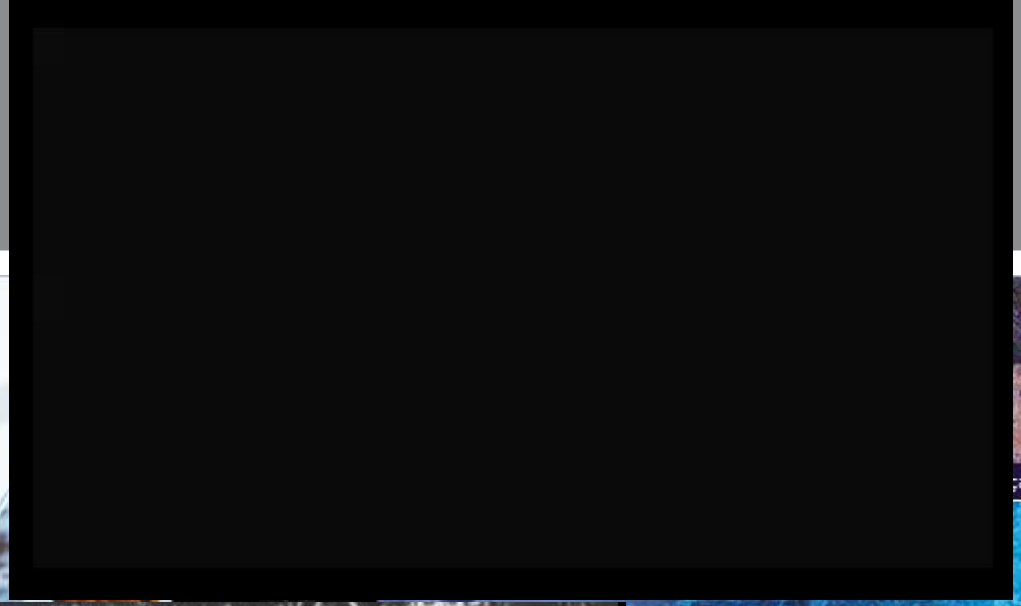
Orthorectified and pansharpened IKONOS-2 imagery (1.0 m spatial resolution), acquired on October 28, 2011 serves as backdrop.

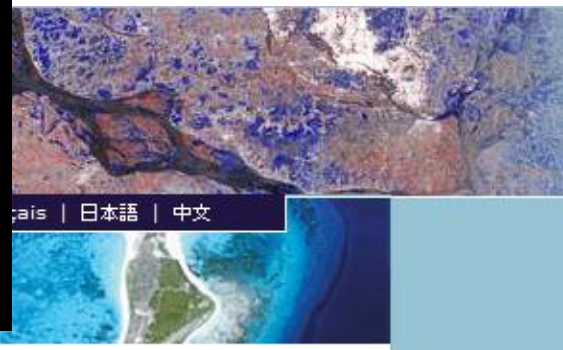
European Space Agency

www.disasterscharter.org

Charter website







- Tool
- Disaster Statistics
- Movie of the Charter
- Presentation of the Charter
- Follow Disasters Charter on Twitter

the affected country will not have to be a Charter mem

Universal Access benefits national disaster managemer
previously unable to make direct requests to the Chart

A registration process is in place for national authorities
User". This process will validate the ability of national a
response, in accordance with Charter operational proce
Charter's Universal Access Information Brochure avail

It is based on a pre-defined list of appointed users, known as
aster management authorities, from countries of Charter
mergencies in their own country, or in a country with which they

ng commitment to expanding its number of users. Initiatives

Global Monitoring for Environment and Security GMES - Copernicus

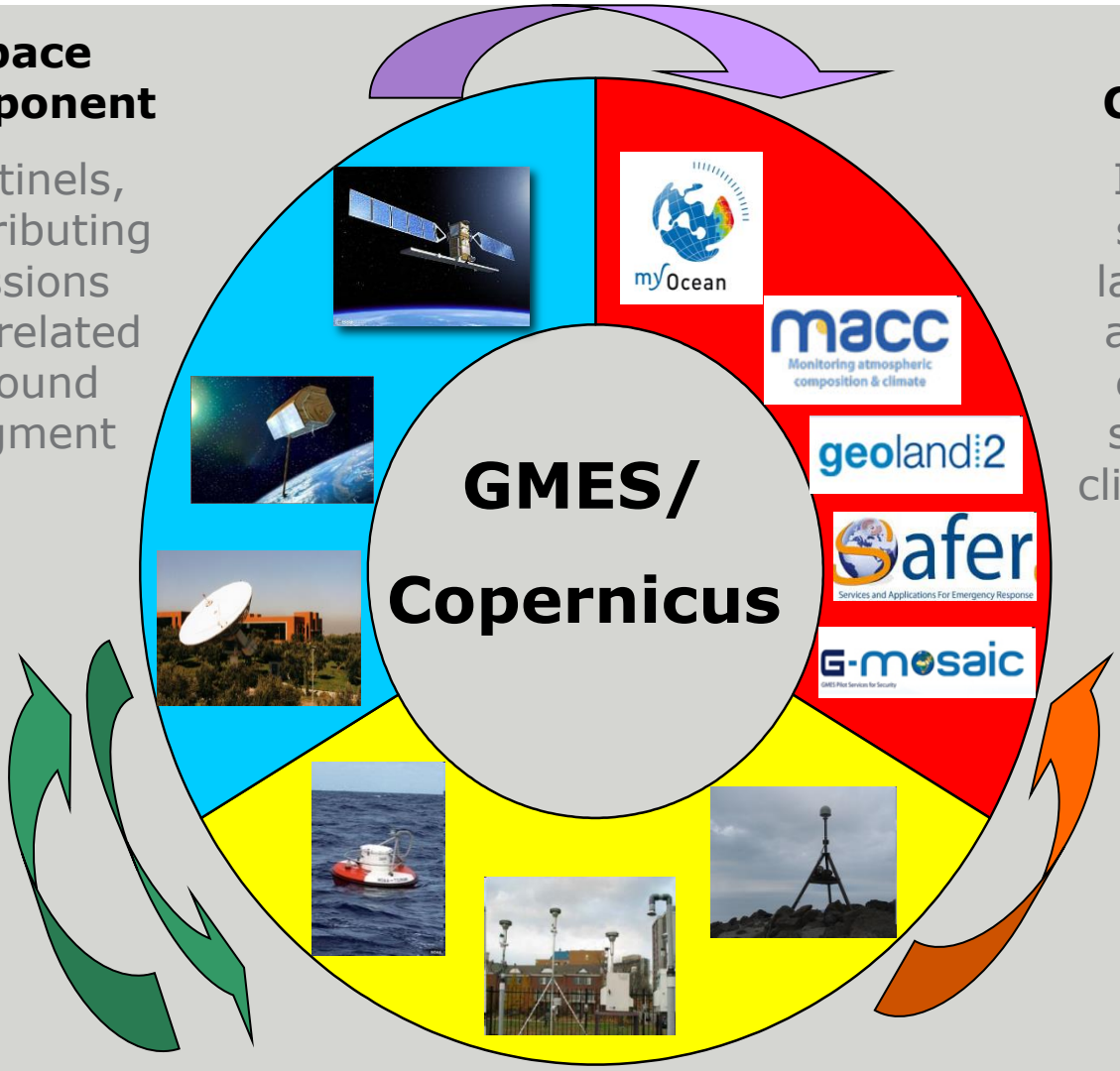
European independence in data sources for environment and security monitoring

Global, timely and easily accessible information in Land, Marine, Emergency response, Atmosphere, Security and Climate Change domains

GMES/Copernicus: Components

Space Component

Sentinels, Contributing Missions and related Ground Segment



Services Component

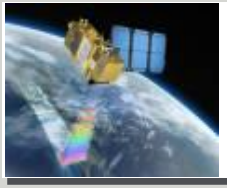
Information services for land, marine, atmosphere, emergency, security and climate change

In-situ Component Land, air and water monitoring sensors

GMES dedicated missions: Sentinels

Sentinel-1 (A/B) – SAR imaging
All weather, day/night applications, interferometry

2014 /2015



Sentinel-2 (A/B) – Multi-spectral imaging
Land applications: urban, forest, agriculture,…
Continuity of Landsat, SPOT

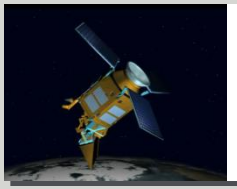
2014 /2016

Sentinel-3 (A/B) – Ocean and global land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

2014/2017

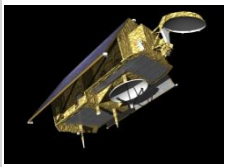
Sentinel-4 (A/B) – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

2019/2027



Sentinel-5 precursor/ Sentinel-5 (A/B) – Low-orbit atmospheric
Atmospheric composition monitoring

2015/2020/2027

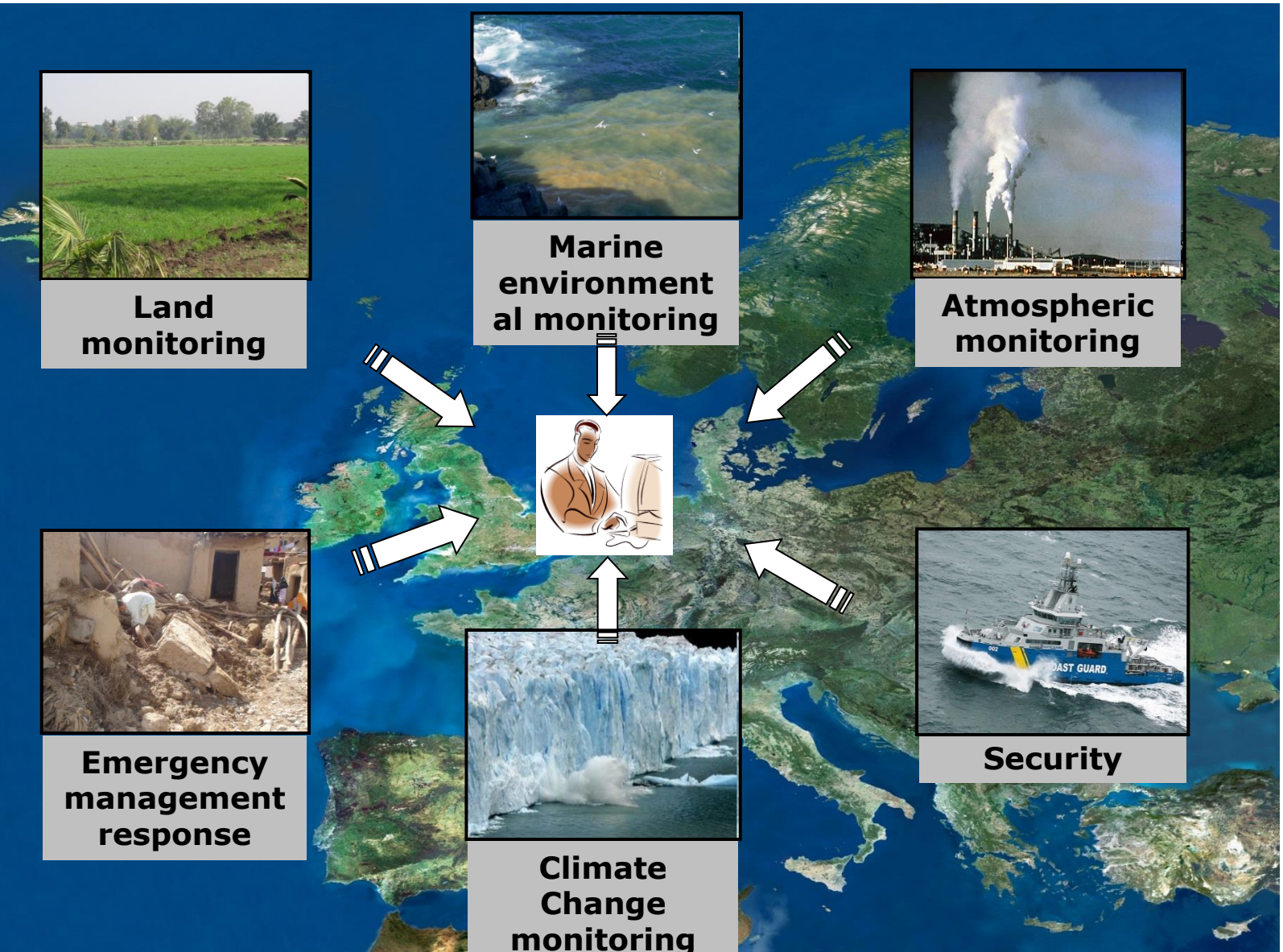


Jason-CS (A/B) – Low inclination Altimetry
Sea-level, wave height and marine wind speed

2018/2023


esa
P.CARRIL 2006

GMES/ Copernicus Services domains



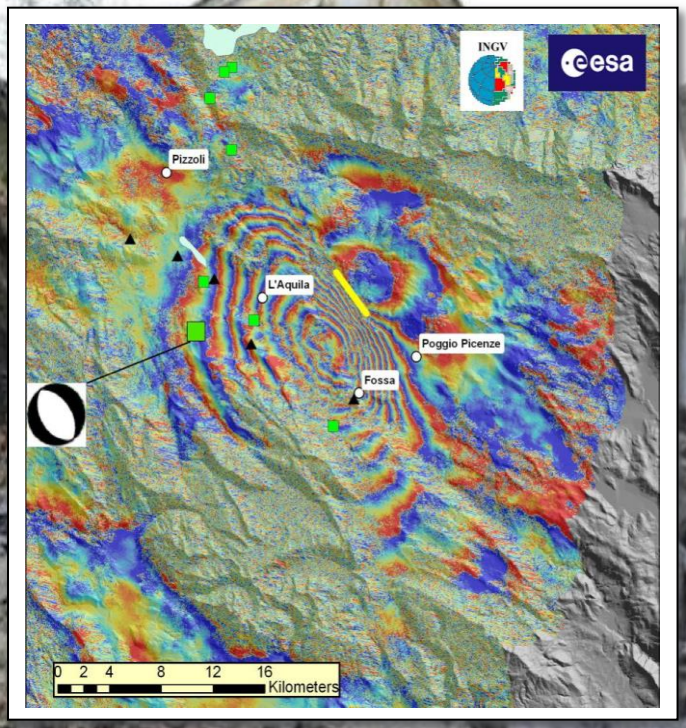
Several services can be linked to risk management

GMES/Copernicus in a video

Examples of Land monitoring service: Subsidence or ground displacement Monitoring

EnviSat ASAR interferogram of the Abruzzo earthquake (6 April 2009 – Magnitude 6.3)

Envisat interferometry pair:
1 February 2009 & 12 April 2009




Land subsidence - Venice, Italy
Venice has been subject to floodings for hundreds of years
and the problem is increasing due to sea level rise and a constant
subsidence of the city.
Radar data - like it will be delivered from the first GMES satellite -
are providing t

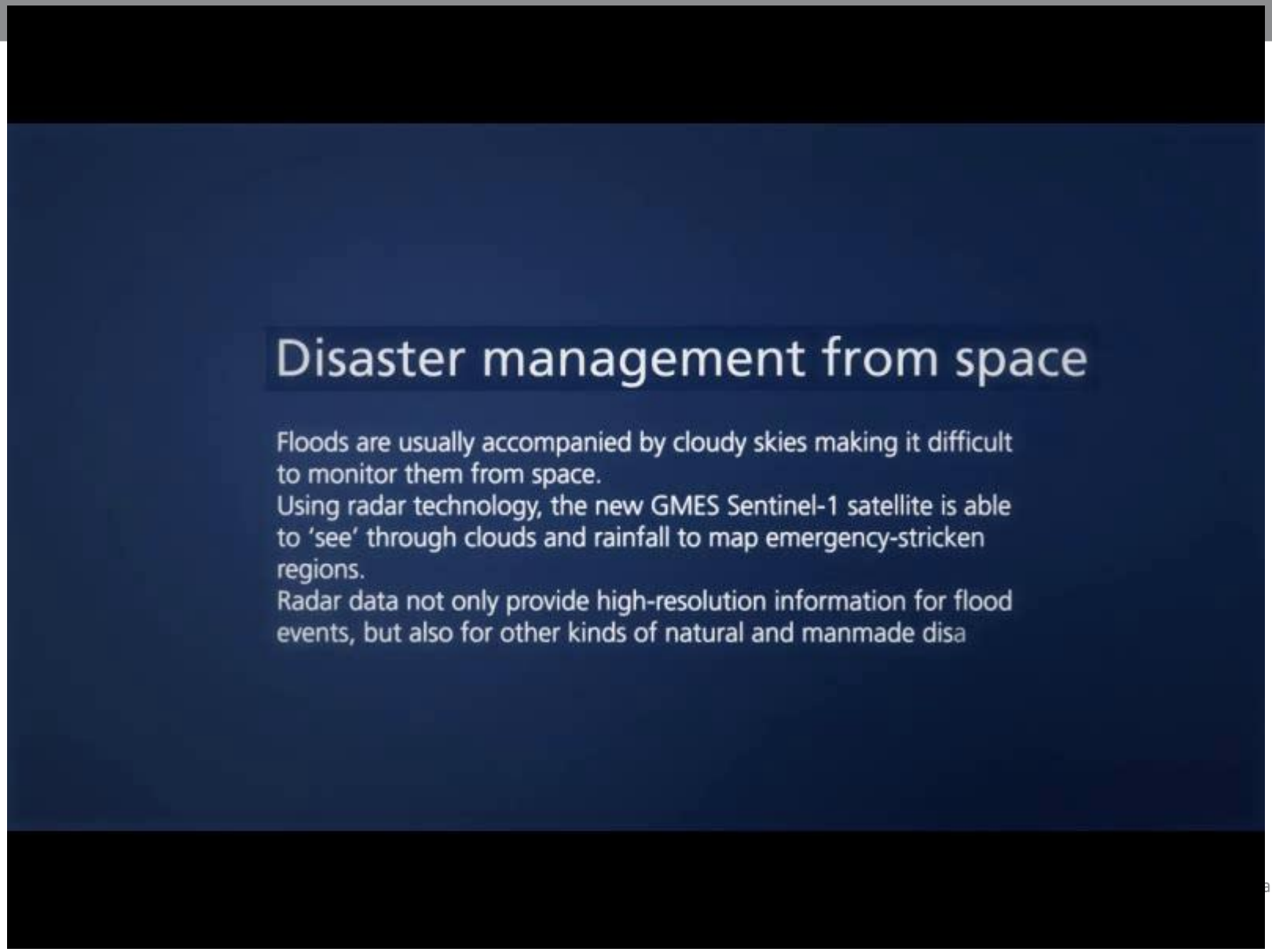
Examples of Marine monitoring service: oil spills

Example of Emergency management response service: 2010 Flood Crises in the Danube River basin

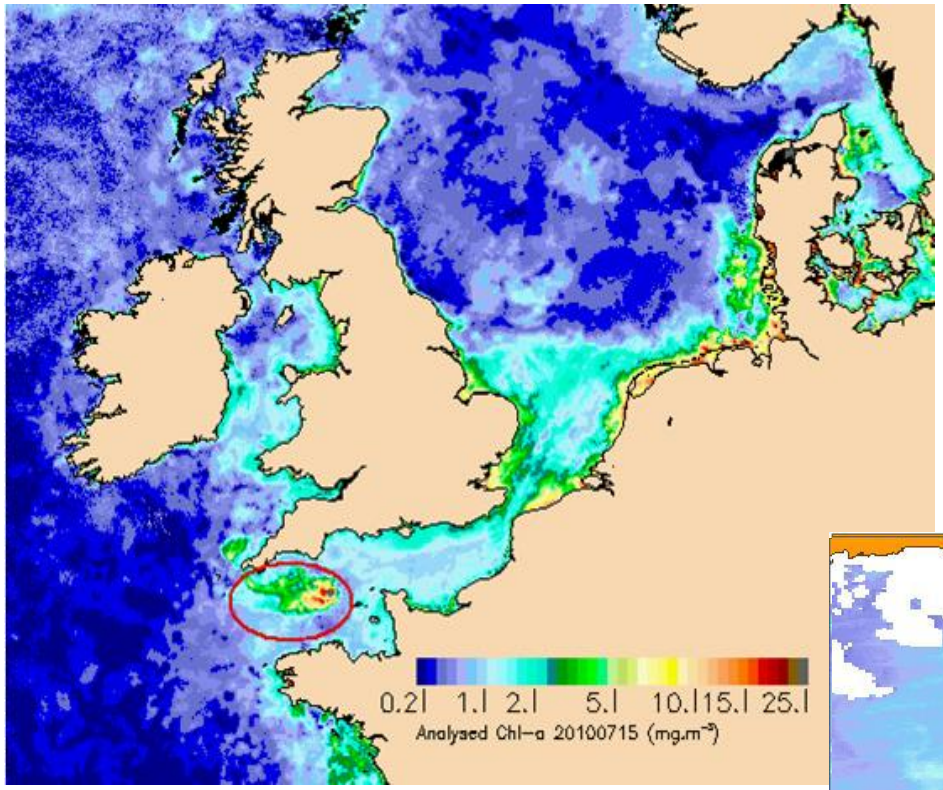
3 July flood extent Galati/Braila, Romania produced within 24 hours

Flooding in Passau, Germany, 3 June

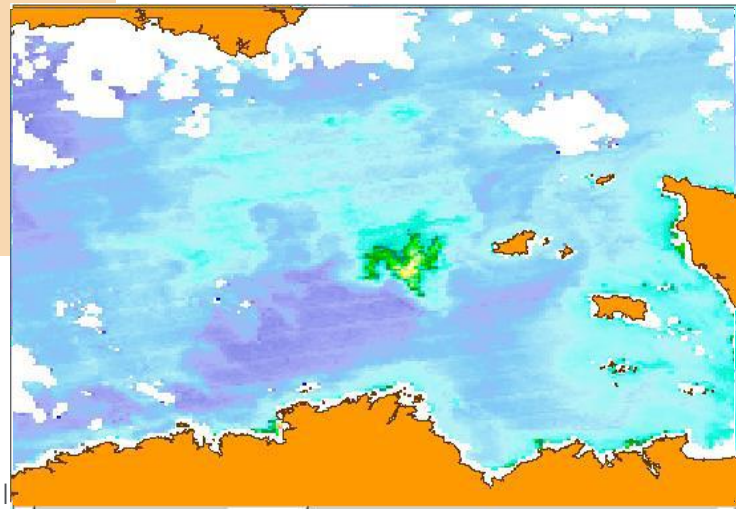
CHRISTOF STACHE/AFP/Getty Images


Disaster management from space
Floods are usually accompanied by cloudy skies making it difficult to monitor them from space.
Using radar technology, the new GMES Sentinel-1 satellite is able to 'see' through clouds and rainfall to map emergency-stricken regions.
Radar data not only provide high-resolution information for flood events, but also for other kinds of natural and manmade disa

Example of Marine environmental monitoring service: Coastal water quality – Algal Blooms

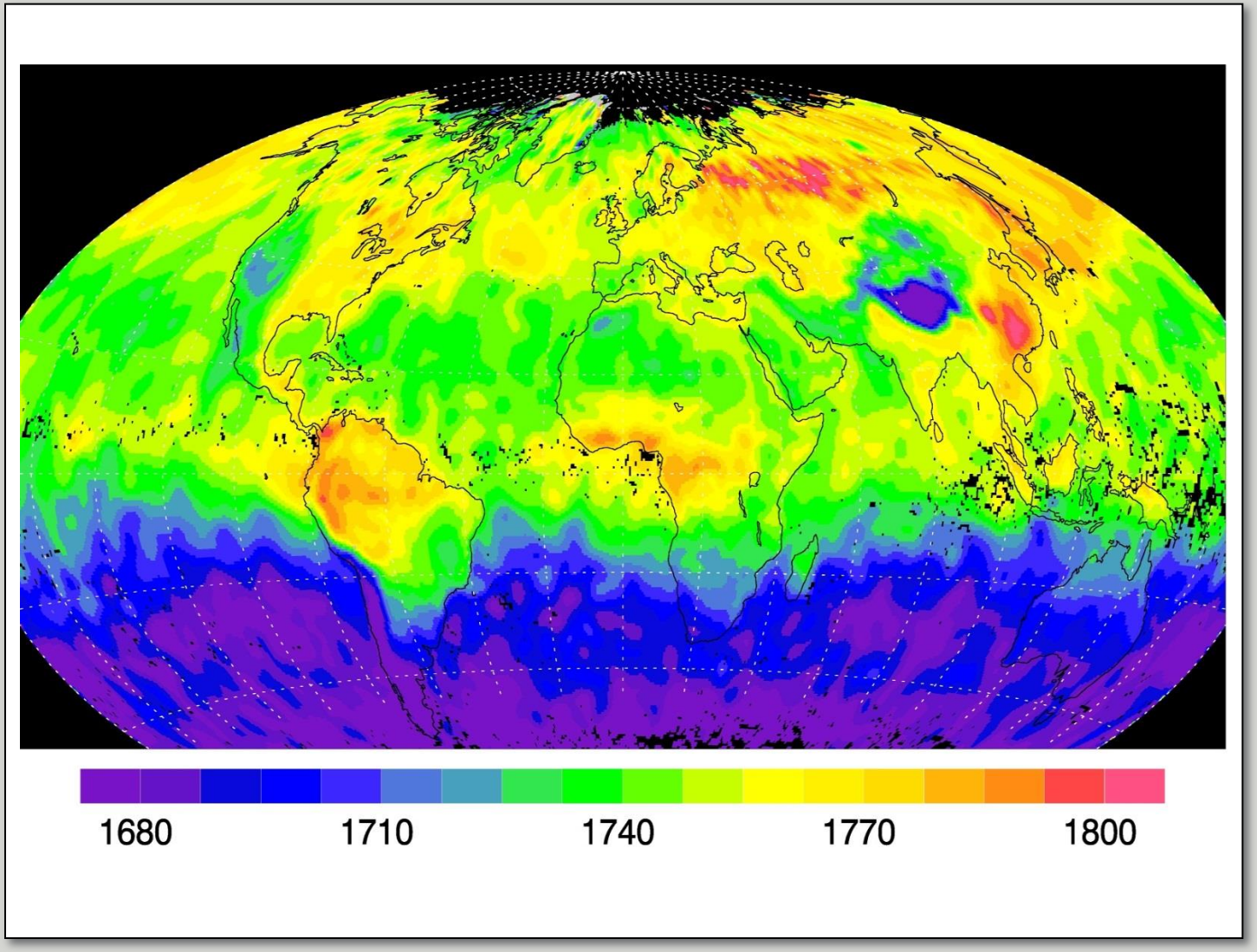


- **Detection of a significant algal bloom using Earth Observation data lead to in situ sampling**
- **The bloom was classified to be a type particularly harmful for aquaculture (*K. Mikimotoi*)**



26 July 2010

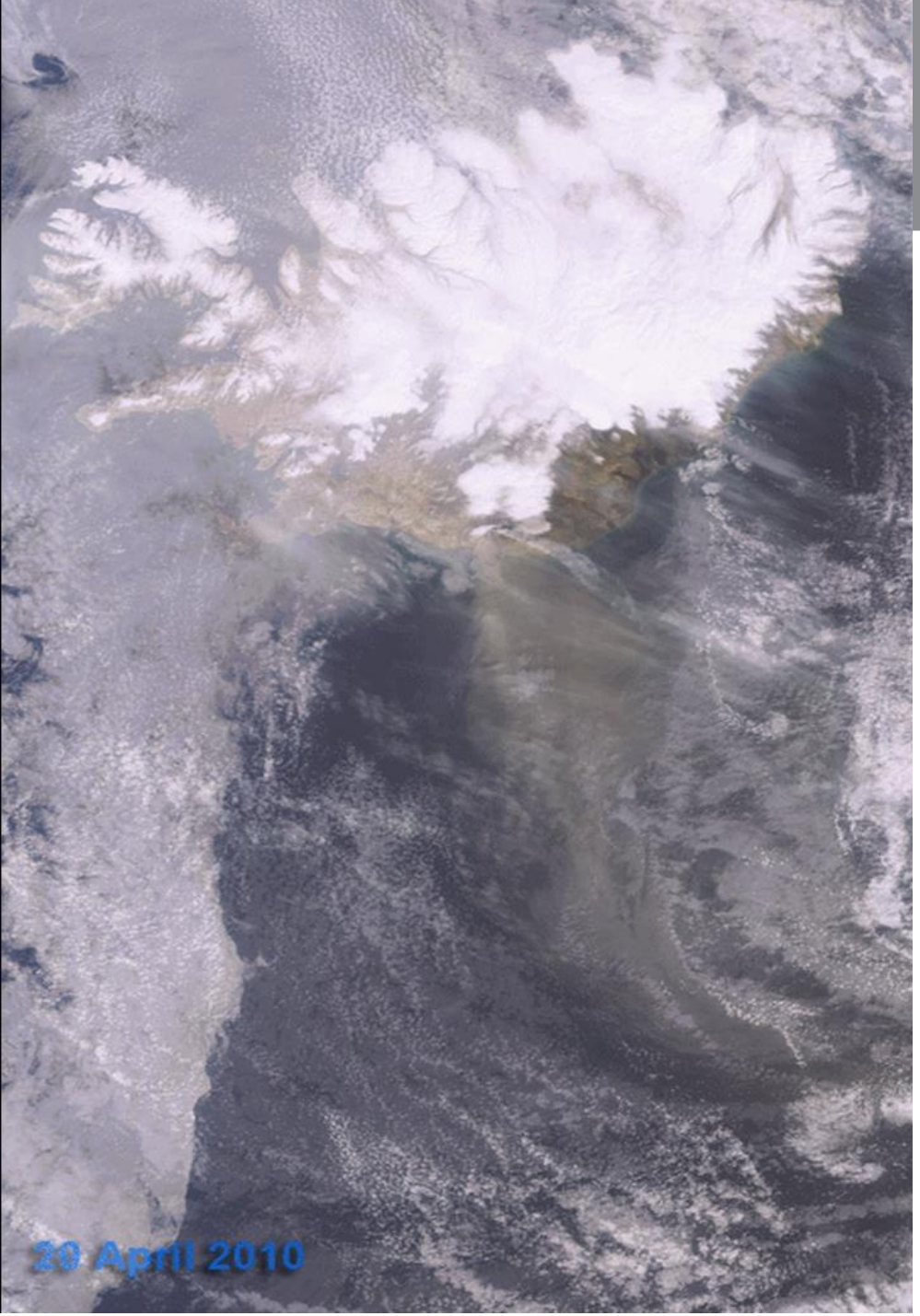
Example of Atmospheric monitoring service: CH_4 Concentration

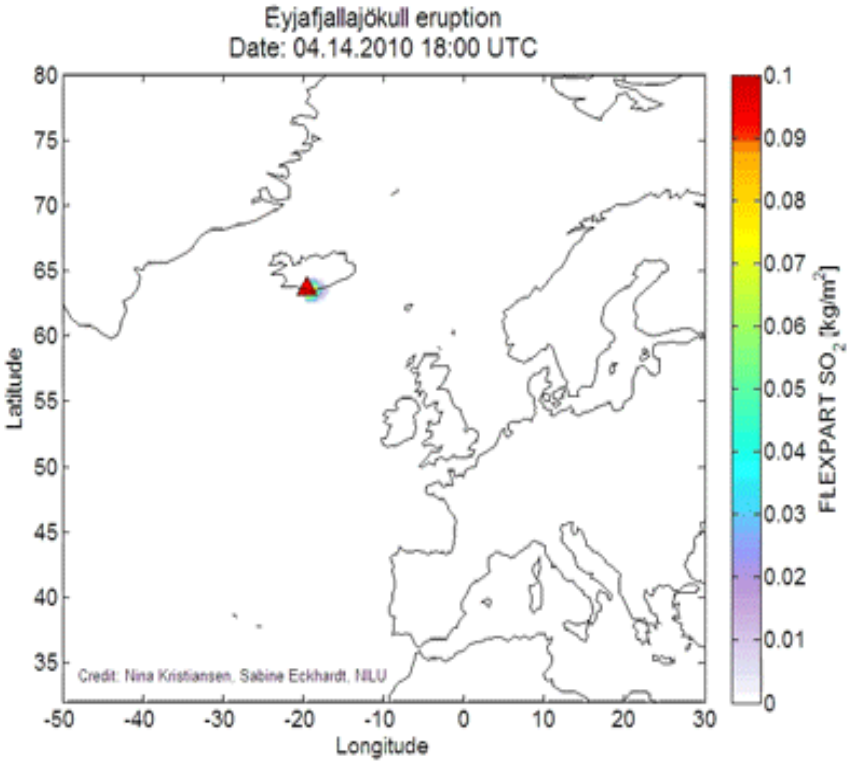


2003-2005 ESA's Envisat global atmospheric methane distribution (air mole fractions in parts per billion)

Credits: ESA and University of Bremen

Example of atmospheric monitoring application to risks





Norwegian Institute for Air Research

Ash cloud monitoring during volcanic eruption in Iceland April 2010

ESA/ENVISAT

Stakeholders in Disaster Risk Management

- National governments, Local authorities, Civil Protections Agencies (field teams and decision makers)
- The International Humanitarian community
- International Development Organisations
- GEO & CEOS
- Science community
- National agencies incl. Space agencies
- Mass media

Thanks for the 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

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

Eduspace: http://www.esa.int/SPECIALS/Eduspace_EN/

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