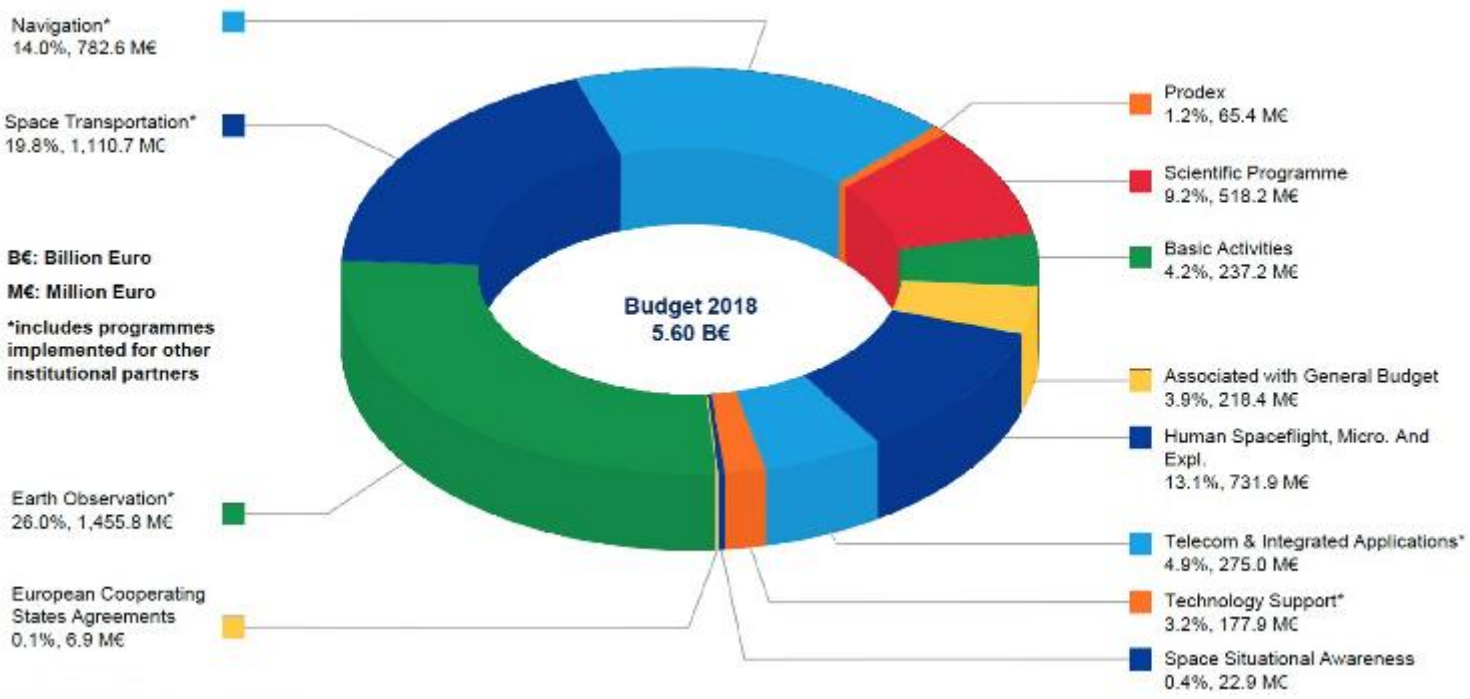
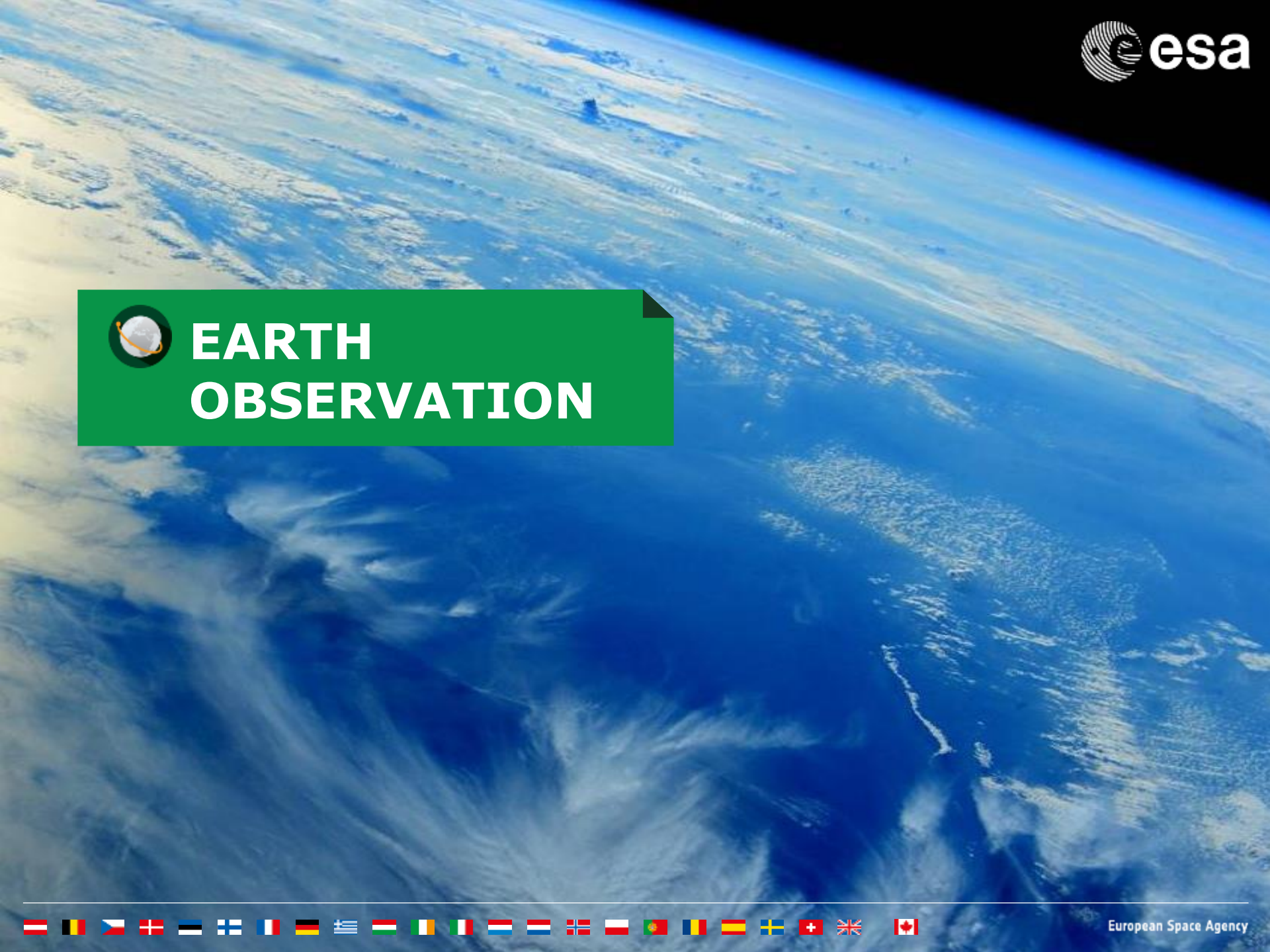
ESA Earth Observation Introduction

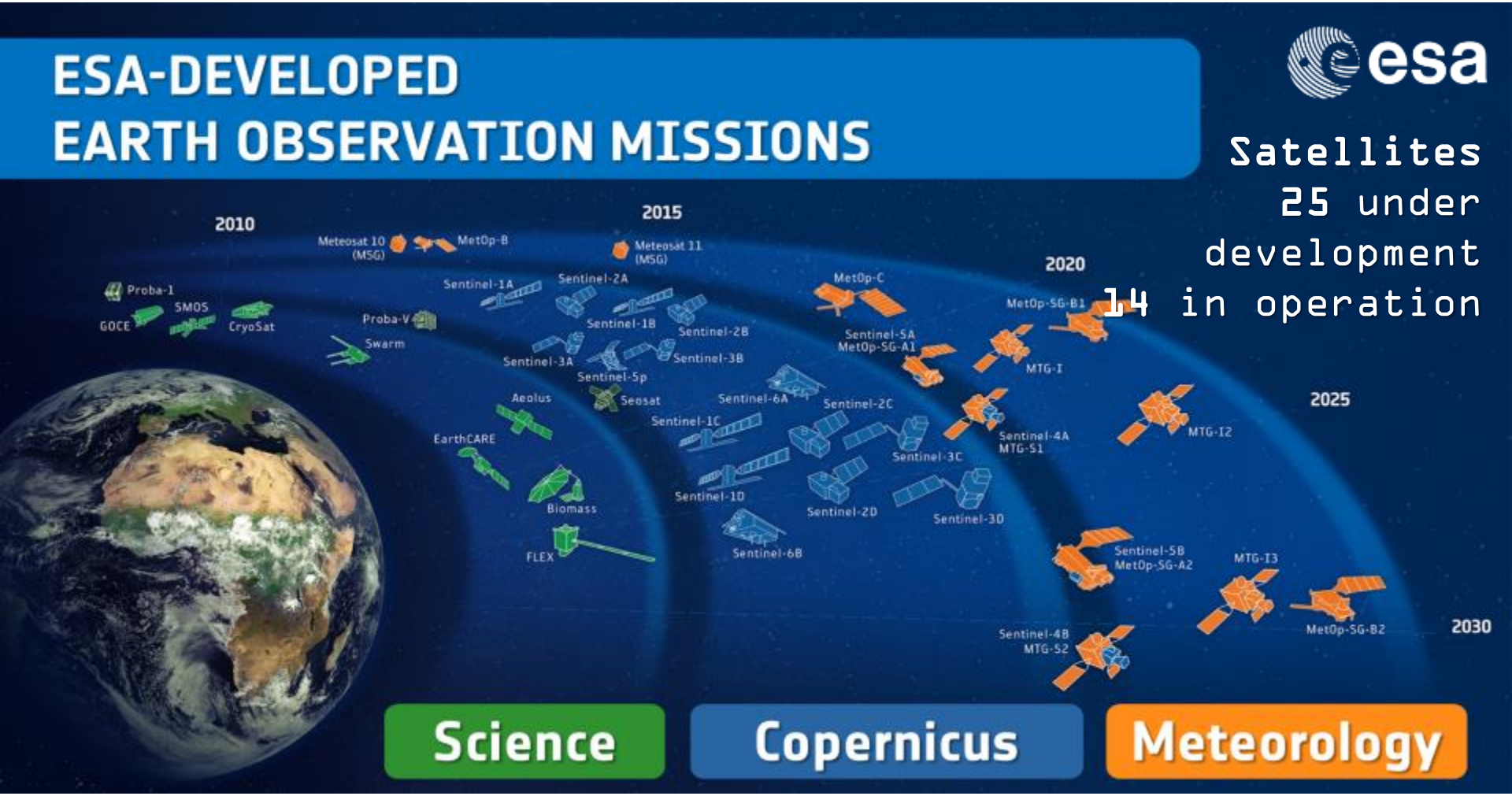
Francesco Sarti

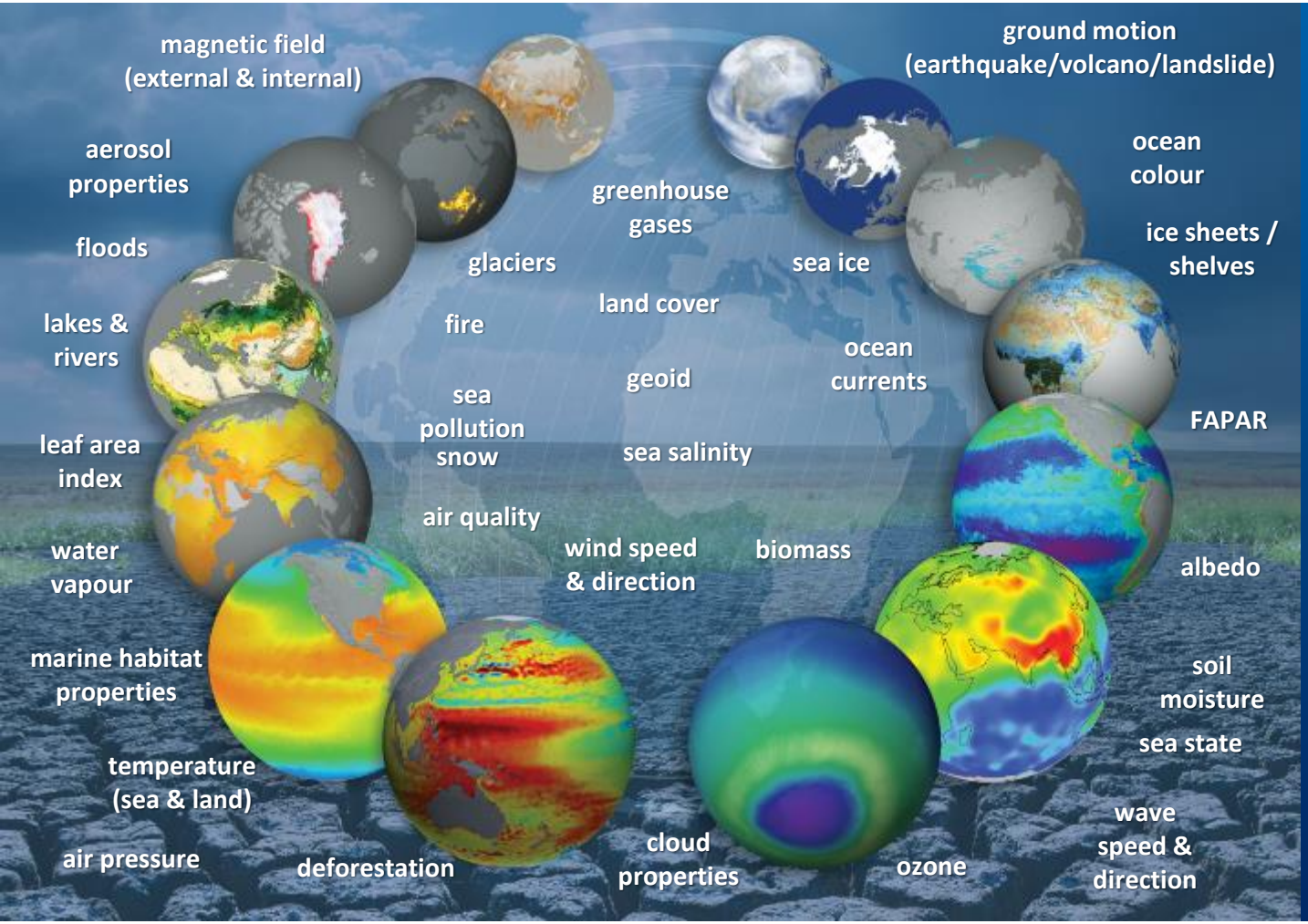
Buenos Aires, 12 Nov 2018

- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2200 staff
- 5.6 billion Euro budget (2018)
- Over 80 satellites designed and operated in flight




esa
EARTH
OBSERVATION
European Space Agency


ESA-DEVELOPED
EARTH OBSERVATION MISSIONS
Satellites
25 under development
14 in operation
2010
2015
2020
2025
2030
Proba-1
GOCE
SMOS
CryoSat
Meteosat 10 (MSG)
MetOp-B
Proba-V
Swarm
Sentinel-1A
Sentinel-2A
Meteosat 11 (MSG)
Sentinel-1B
Sentinel-2B
Sentinel-3A
Sentinel-3B
Sentinel-5p
Aeolus
Seosat
EarthCARE
Biomass
FLEX
Sentinel-1C
Sentinel-6A
Sentinel-2C
Sentinel-3C
Sentinel-1D
Sentinel-2D
Sentinel-3D
Sentinel-6B
MetOp-C
Sentinel-5A
MetOp-SG-A1
MetOp-SG-B1
MTG-I
Sentinel-4A
MTG-S1
MTG-I2
Sentinel-5B
MetOp-SG-A2
MTG-I3
MetOp-SG-B2
Sentinel-4B
MTG-S2
Science
Copernicus
Meteorology



ESA provides EO mission data addressing almost **all** parameters retrievable by EO satellites

➔ **Extreme user diversity**

Copernicus – a new Phase in EO

European Earth Observation System, led by the EU

European response to global needs:

- to manage the environment
- to mitigate the effects of climate change
- to ensure civil security

European independence, contribution to global system (GEOSS)

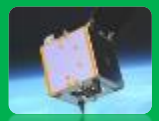
CSC: Sentinel Satellites

	**Sentinel 1** (A/B/C/D) **SAR Imaging**	All weather, day/night applications, interferometry
	**Sentinel 2** (A/B/C/D) **Multispectral Imaging**	Land applications: urban, forest, agriculture, … Continuity of Landsat, SPOT
	**Sentinel 3** (A/B/C/D) **Ocean & Global Land Monitoring**	Wide-swath ocean colour, vegetation, sea/land surface temperature, altimetry
	**Sentinel 4** (A/B) **Geostationary Atmospheric**	Atmospheric composition monitoring, pollution; instrument on MTG satellites
	**Sentinel 5** (A/B/C) & Precursor **Low-Orbit Atmospheric**	Atmospheric composition monitoring; instrument on MetOp-SG satellites
	**Sentinel 6** **Jason CS (A/B)**	Altimetry reference mission

Contributing Missions

Optical High & Very High Resolution

DMC



Pléiades

RapidEye

Deimos-2

SPOT (HRS)

Optical Medium & Low Resolution

SPOT

PROBA-V

Synthetic Aperture Radar

Cosmo SkyMed

Radarsat

TerraSAR-X Tandem-X

Altimetry

Cryosat

Jason

Atmosphere

MetOp

MSG

and many more …

Sentinel Status

S-1

Radar

- **A** 3 Apr. 2014
- **B** 25 Apr. 2016
- **C** 2022/23
- **D** > 2022/23

S-2

High Res. Optical

- **A** 23 Jun. 2015
- **B** 6 Mar. 2017
- **C** 2022/23
- **D** > 2022/23

S-3

Medium Res. Optical & Altimetry

- **A** 16 Feb. 2016
- **B** 25 Apr. 2018
- **C** 2023
- **D** > 2023

S-4

Atmospheric Chemistry (GEO)

- **A** 2021
- **B** 2027

S-5P

Atmospheric Chemistry (LEO)

- **A** 13 Oct. 2017

S-5

Atmospheric Chemistry (LEO)

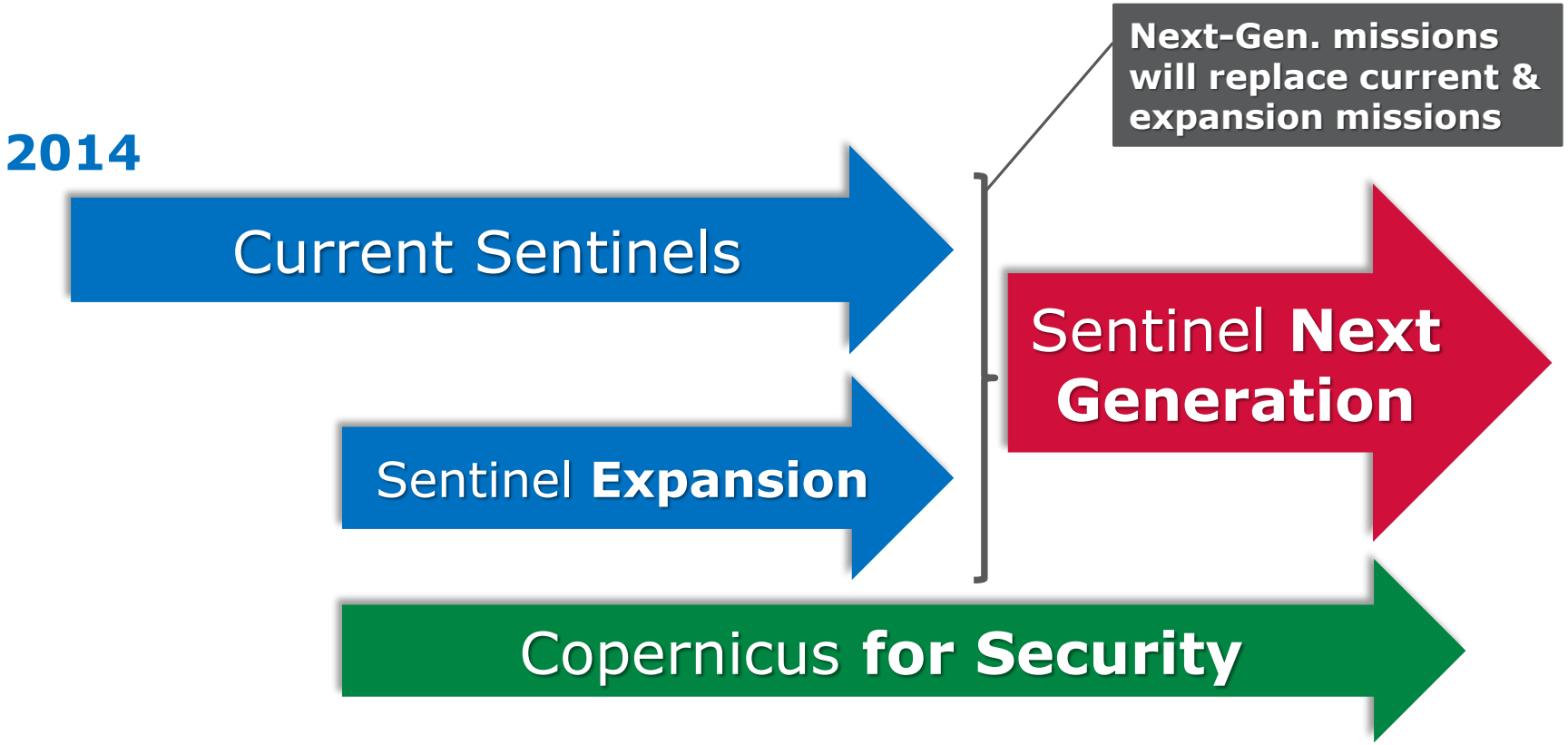
- **A** 2021
- **B** 2027
- **C** > 2027

S-6

Altimetry

- **A** 2020
- **B** 2025

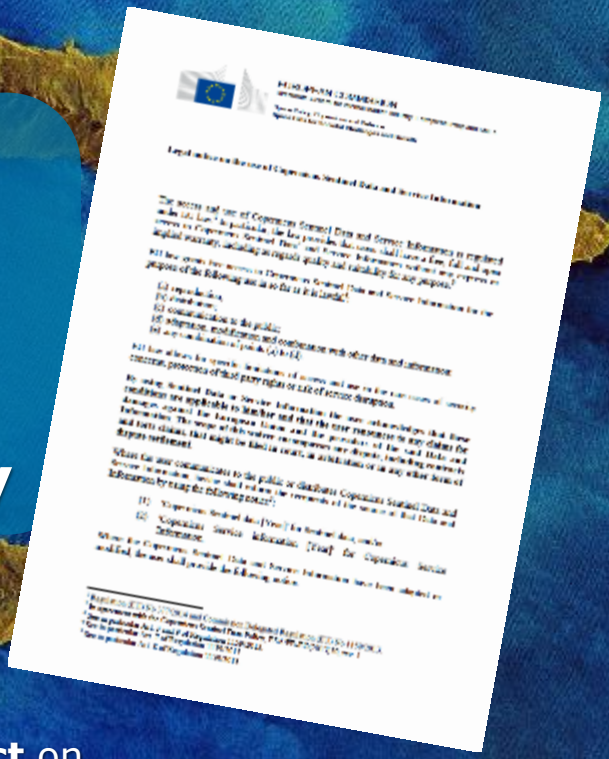
Copernicus Space Component Evolution



Copernicus Sentinel Data Policy

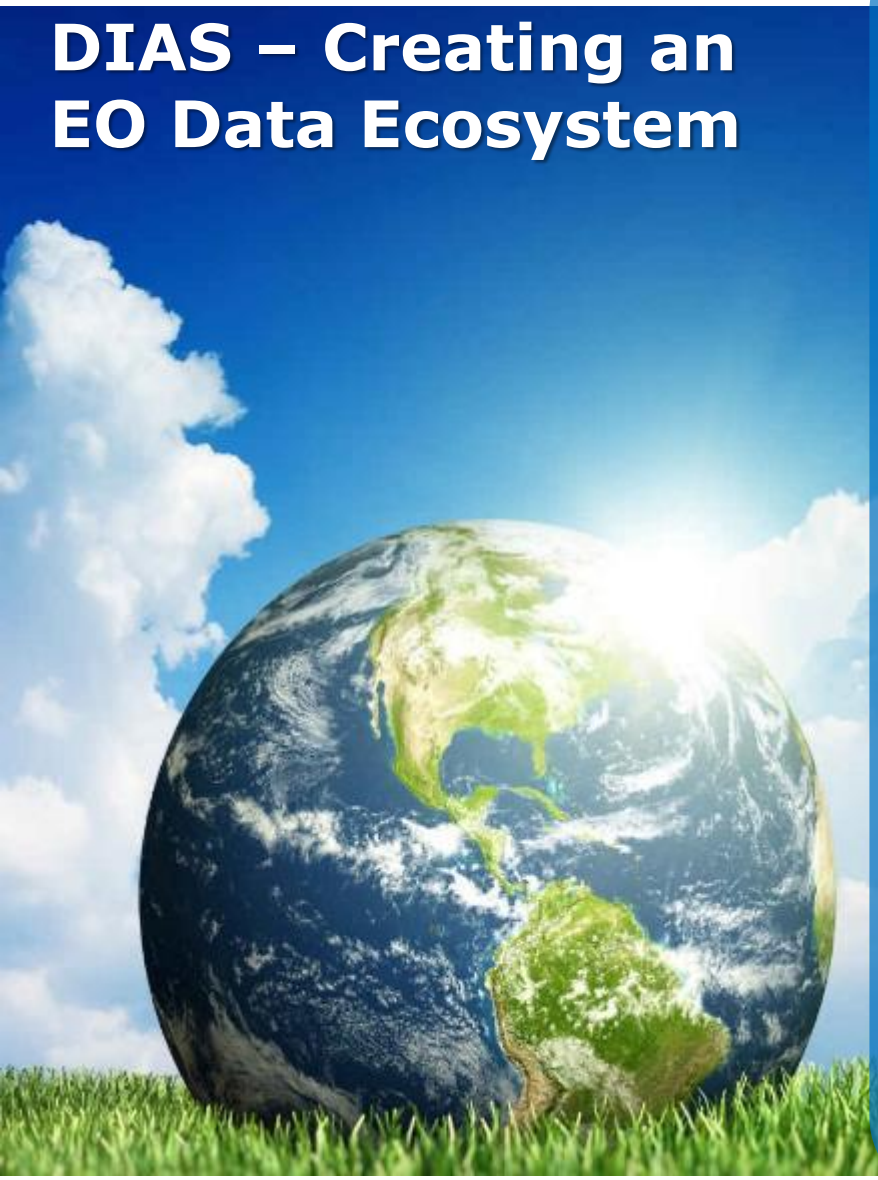
Sentinel data are available:

- ✓ **Free, Full and Open***
- ✓ **Over very long term**
- ✓ **Systematically, Operationally**



*** ESA Sentinel Data Policy** (Sep 2013) and **EU Delegated Act** on Copernicus Data and Information Policy (Dec 2013)

DIAS – Creating an EO Data Ecosystem



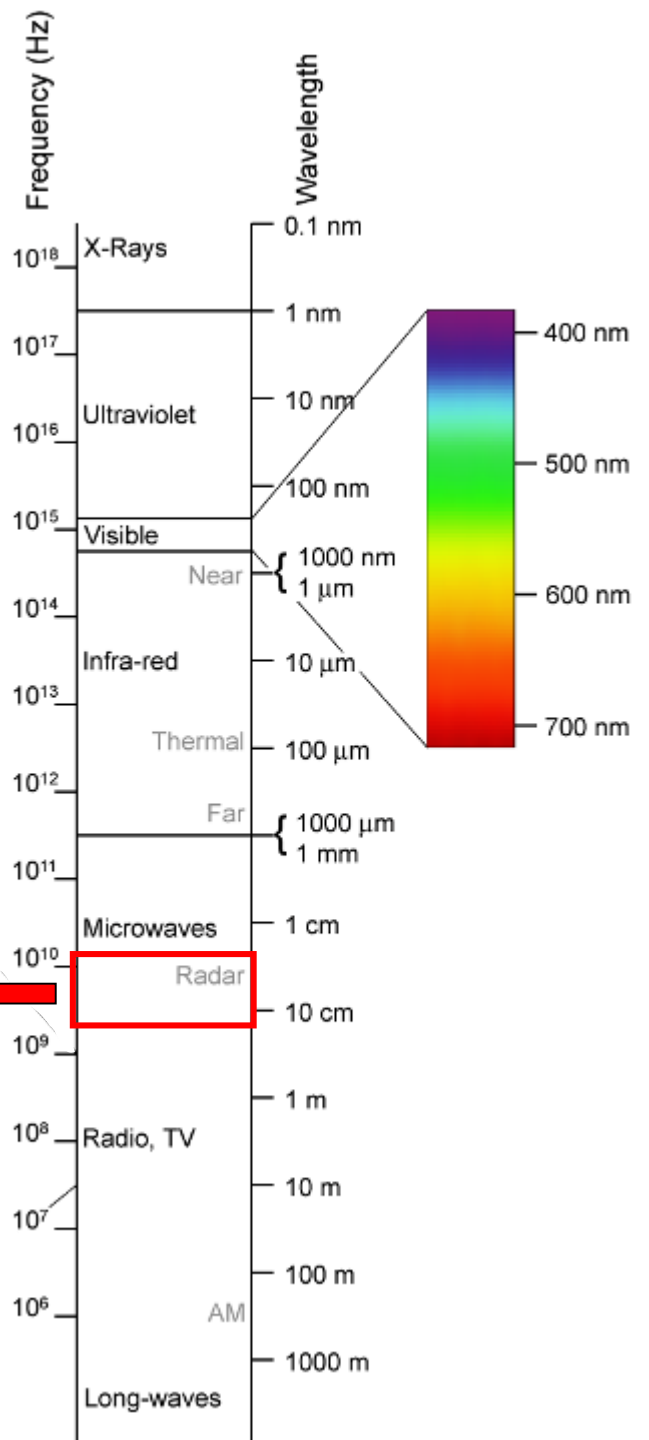
- Copernicus **D**ata and **I**nformation **A**ccess **S**ervices
- Common DG-GROW-ESA approach to EO data exploitation with Copernicus at its core
- Create & enable European EO Data ecosystem for research & business
- Starts in June 2018

Earth Observation with SAR

Reminders:

- The electromagnetic spectrum
- All weather
- day and night (active system)
- SAR geometry
- Intensity and Phase (Complex):
  - Coherent signal
  - Phase information
- Band (X, C, L, P)
- Polarisation (VV, VH, HH, HV)

Synthetic Aperture Radar (SAR)



Introduction

Why SAR

Single channel SAR

Multi temporal SAR

Polarimetry

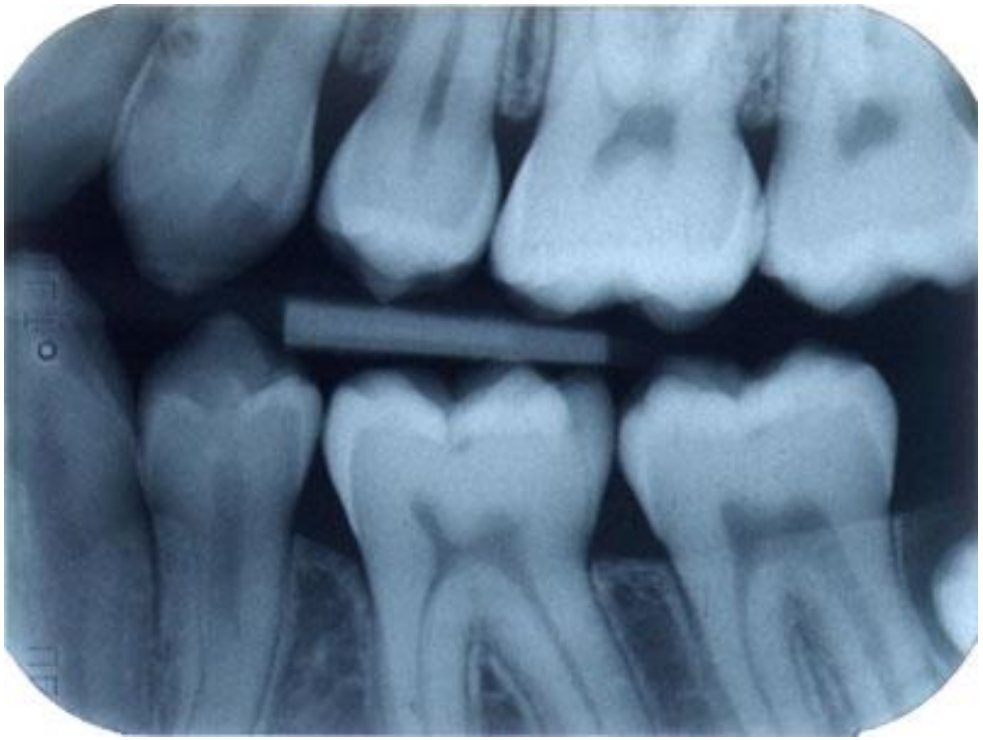
Interferometry

Introduction

SAR extends vision from the 'normal' visible light to invisible light using waves invisible to the human eye

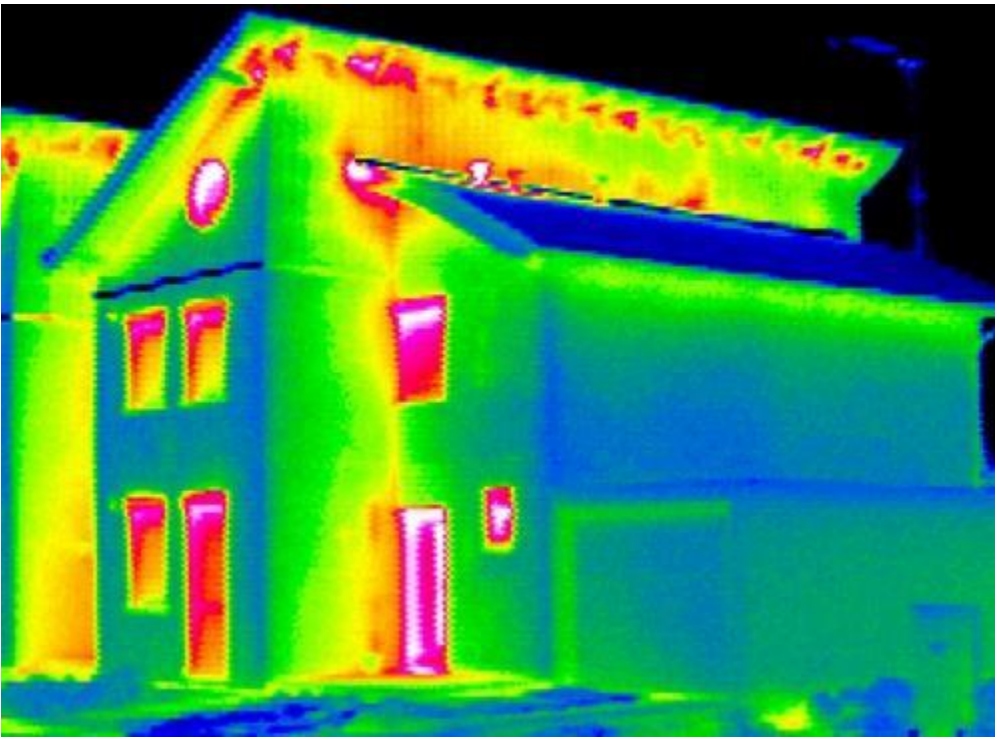
Not unique to SAR

X-rays



Introduction (cont.)

Infra-red



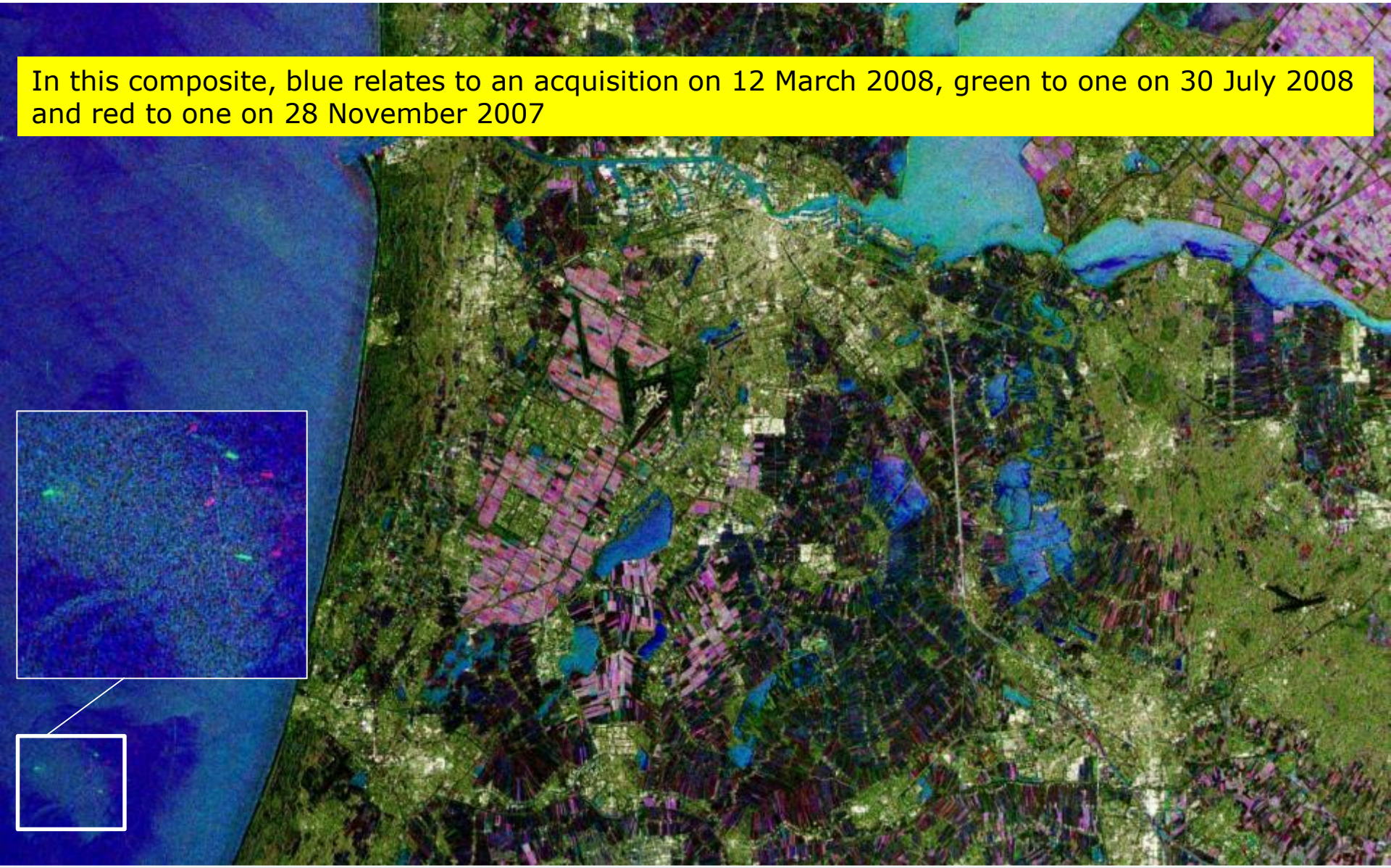
Introduction (cont.)

Ultra-sound

Single channel SAR

Left image: COSMOSkyMed 1 Spotlight-2 X-band acquisition (1m resolution) over the Flevoland region in the Netherlands (3 February 2008)

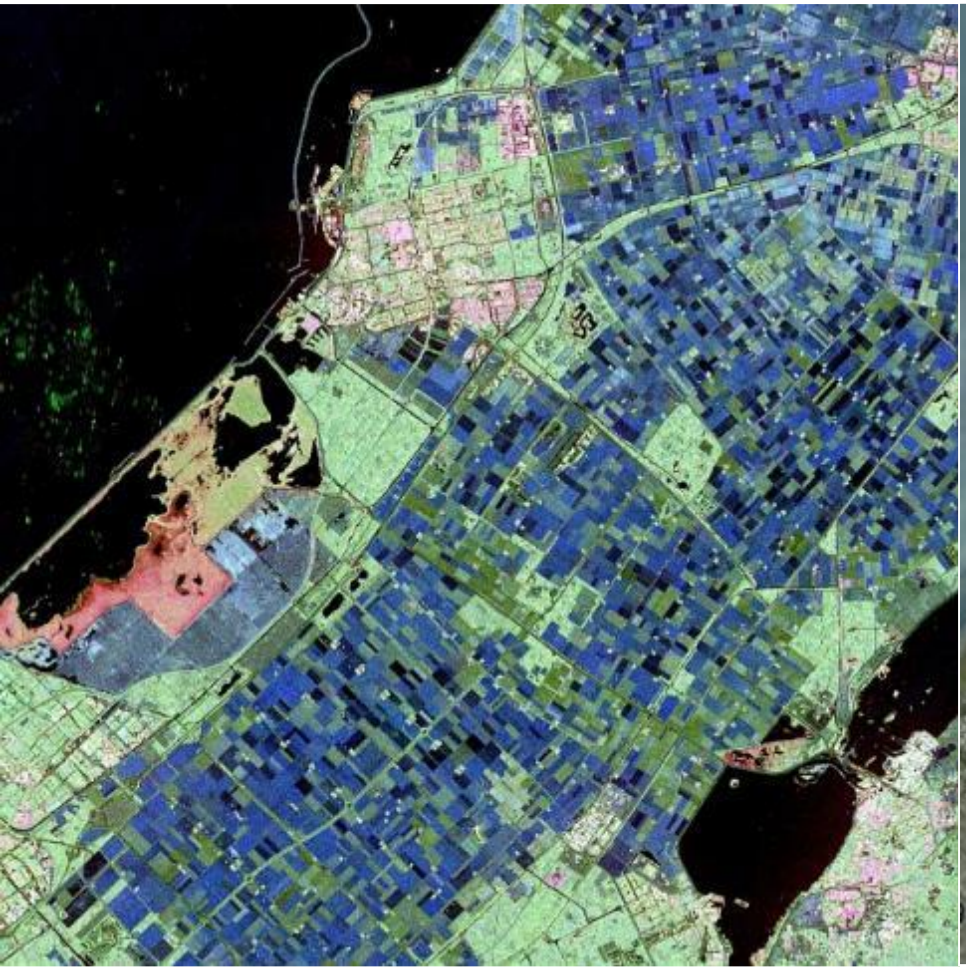
Multi temporal SAR

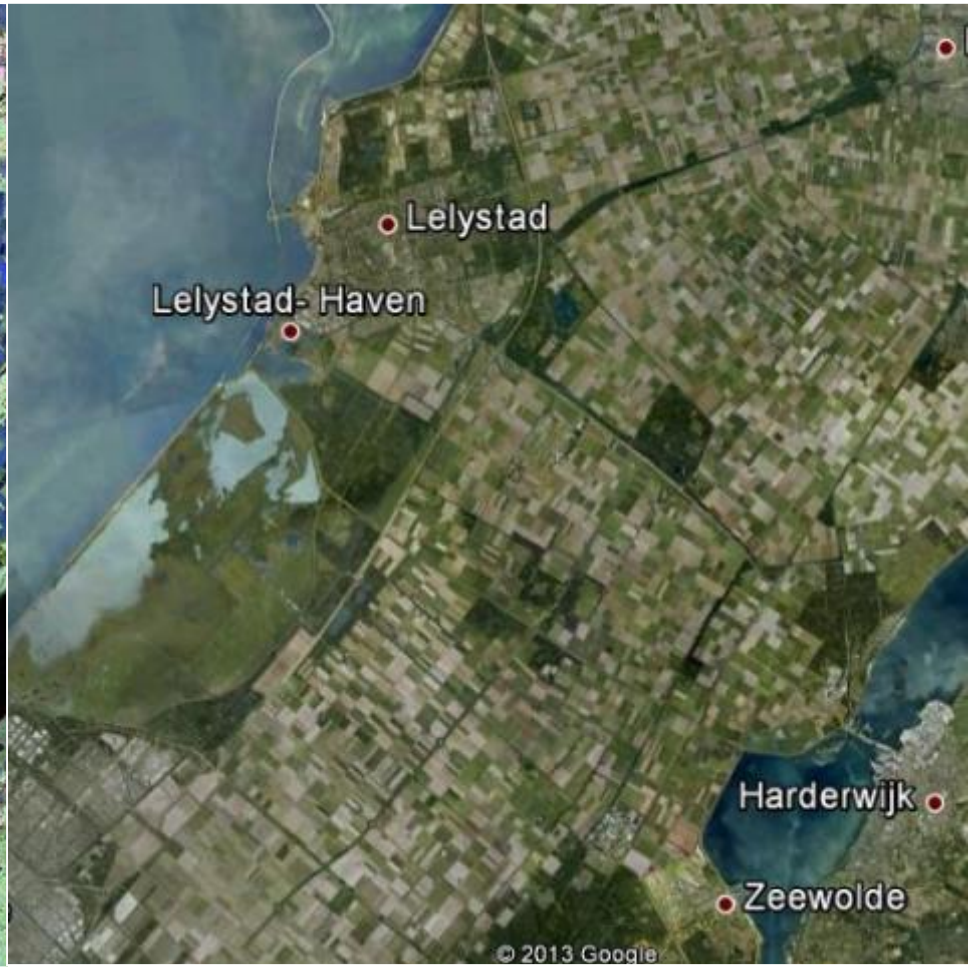


Multi wavelength SAR

The three-frequency false-colour SAR image was recorded on April 18, 1994 and was made with L-band total power in the red channel, C-band total power in the green channel, and X-band VV polarization in the blue channel

Polarimetry





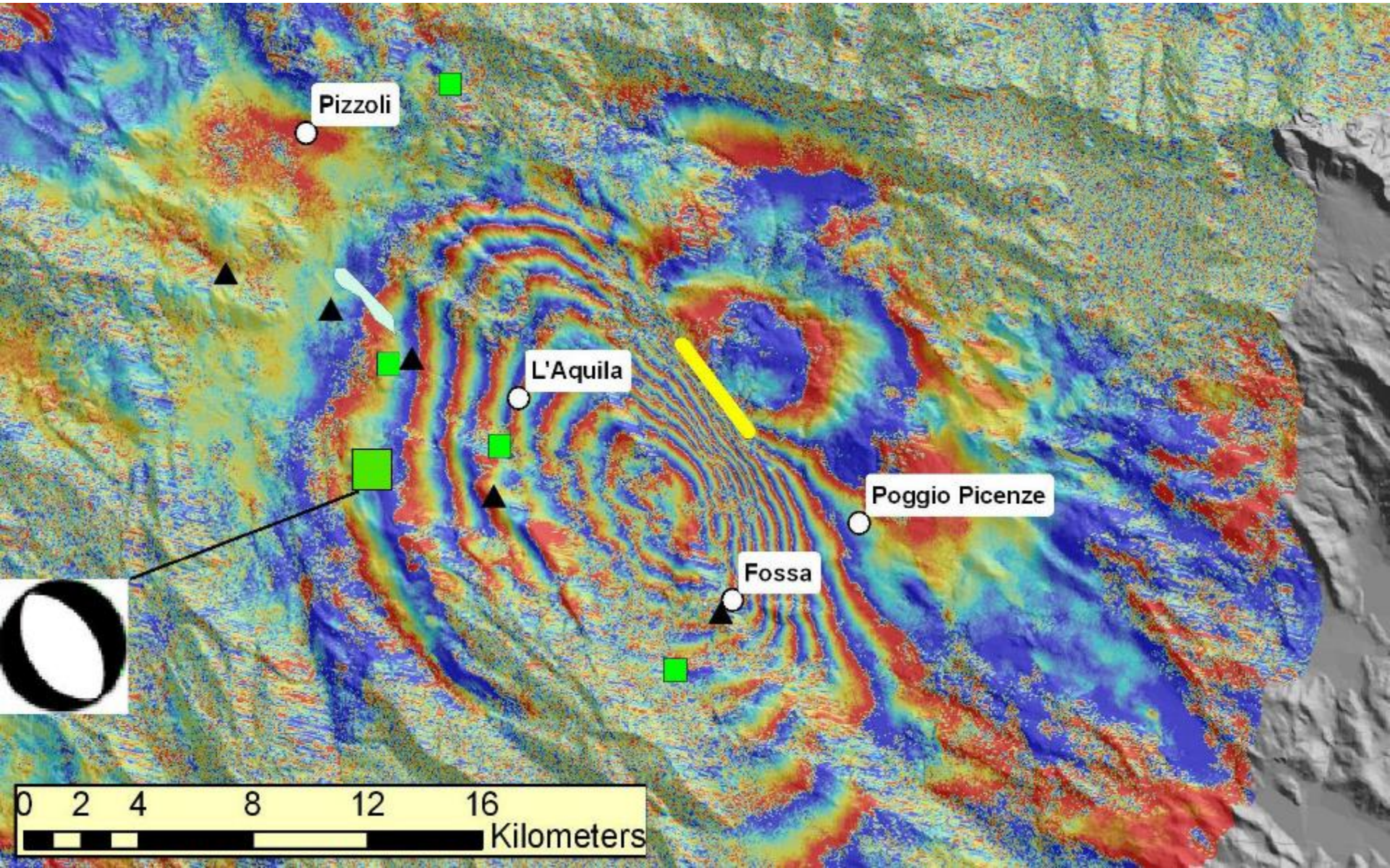
Interferometry

Observation with two eyes
- 3D vision
- Distance estimation

Looking more than once
- Detect changes
- Detect movements

Same with SAR
- Two or more SARs
- Revisiting the same site
- Surface elevation, classification and sub

Interferometry (cont.)
SAR sees earthquakes



Some history about SAR missions….

The Golden Age of SAR

Mission	Band	Launch
SEASAT	L	1978
SIR-A	L	1981
SIR-B	L	1984
ERS-1 & ERS-2	C	1991 & 1995
J-ERS-1	L	1992
SIR-C/X-SAR	X/C	1994
RADARSAT-1 & -2	C	1995 & 2001
SRTM	X/C	2000
ASAR/Envisat	C	2002
PALSAR/ALOS-1 & -2	L	2002 & 2014
COSMO-SkyMed	X	2007
TerraSAR-X	X	2007
RISAT-2 & -1	X	2009 & 2012
Tandem-X	X	2010
Sentinel-1A & B	C	2014 & 2016
SAOCOM 1A	L	2018
Plus many airborne campaigns….	X, L, C	

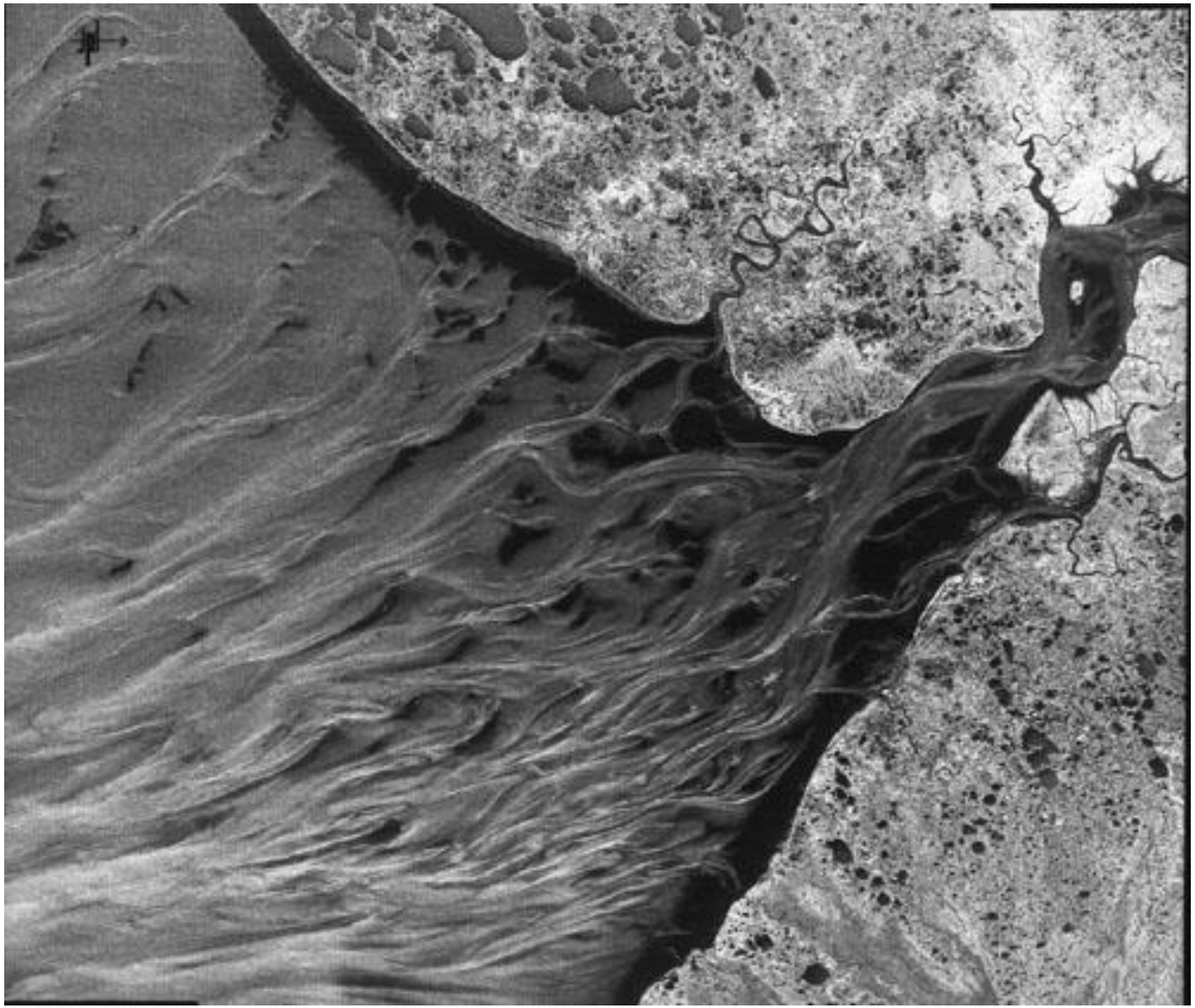
SEASAT the First Civilian Spaceborne SAR 1978

Orbit Parameters
Altitude:805 km circular
Inclination:108 degrees
Repeat Period:100 min (14 orbits a day)

Spacecraft Statistics
Weight:2,290 kg
Length:12.2m
Diameter: 1.5m max.
SAR antenna: 2.1 x 10.7m

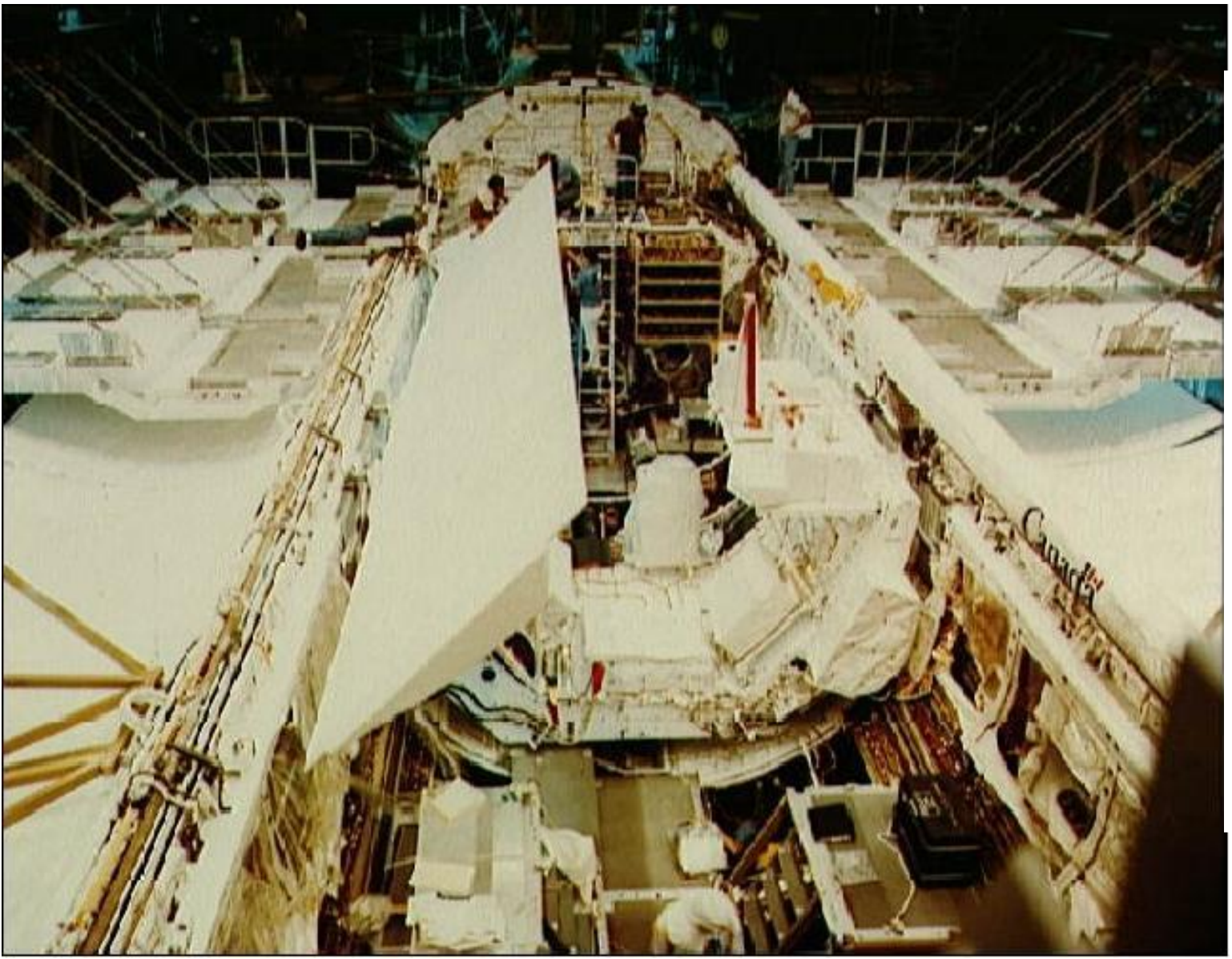
Instrument :
L Band (23 cm-1.27Ghz)
Polarization : HH
Central Incidence : 20˚
Ground resolution : 25 m (4 looks)
Swath Width: 100 km

SEASAT



This SAR image is of the Kuskokwim River delta, Western Alaska. It was taken by Seasat on July 13, 1978. The patterns are formed by river water flowing around sand bars. The pock-marked land is covered by small permafrost lakes.

SIR-A 1981



SIR-A

L-band

Polarisation
HH

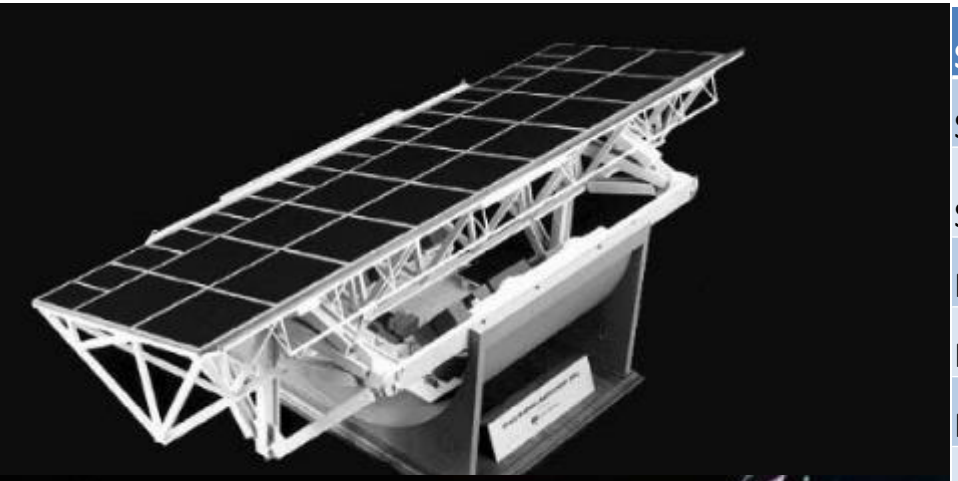
Look Angle
47º

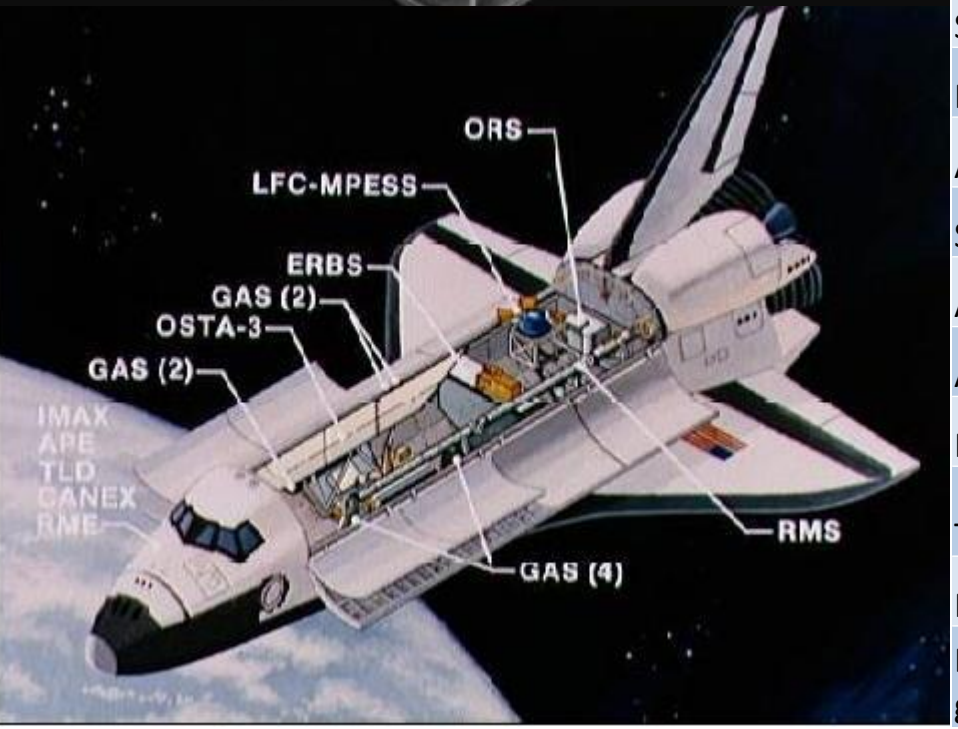
Pixel size
40 x 40 m

Data recorded onto an optical medium (film)

SIR-A sees Bedrock in Egypt

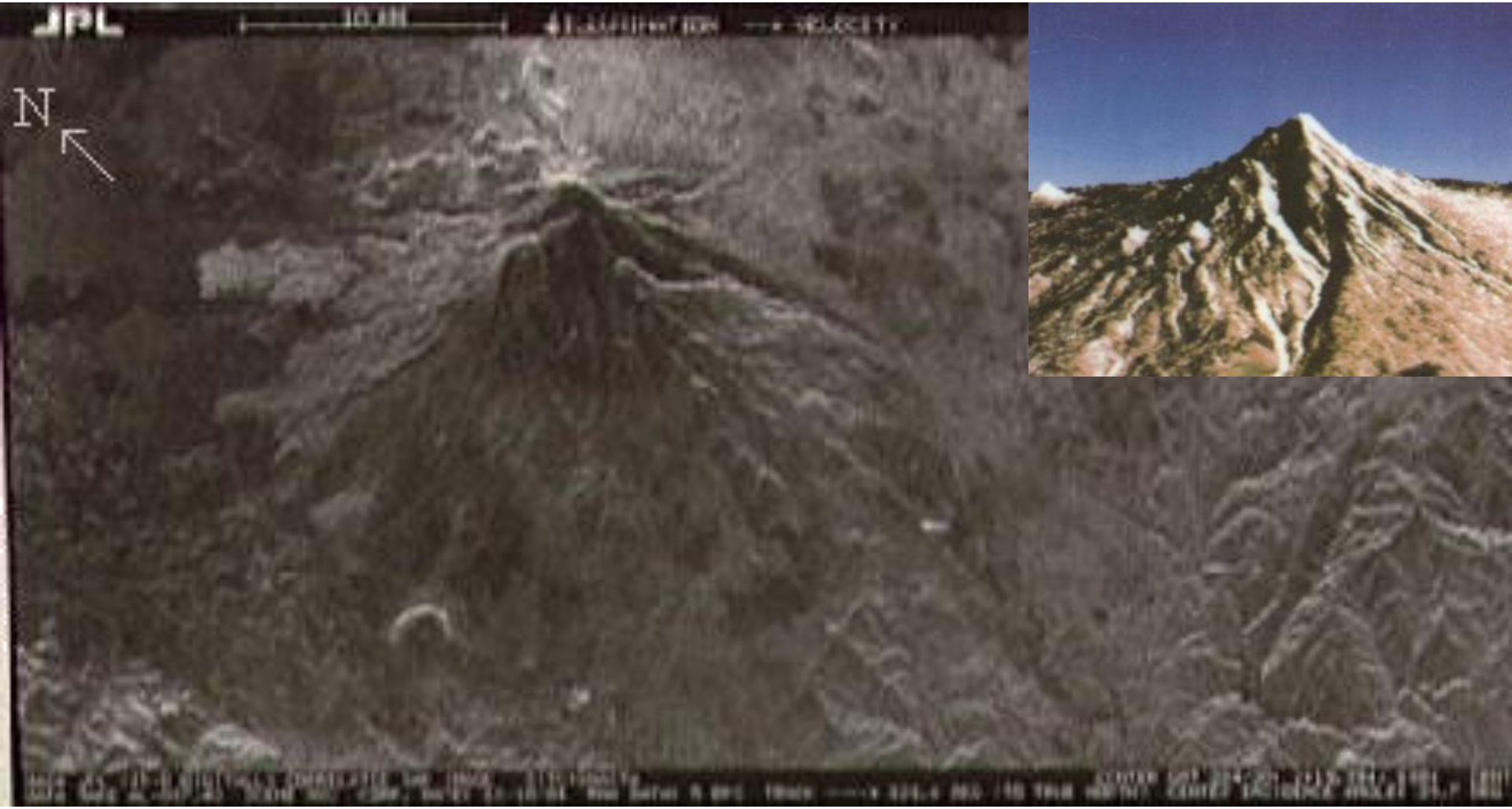
SIR-B 1984



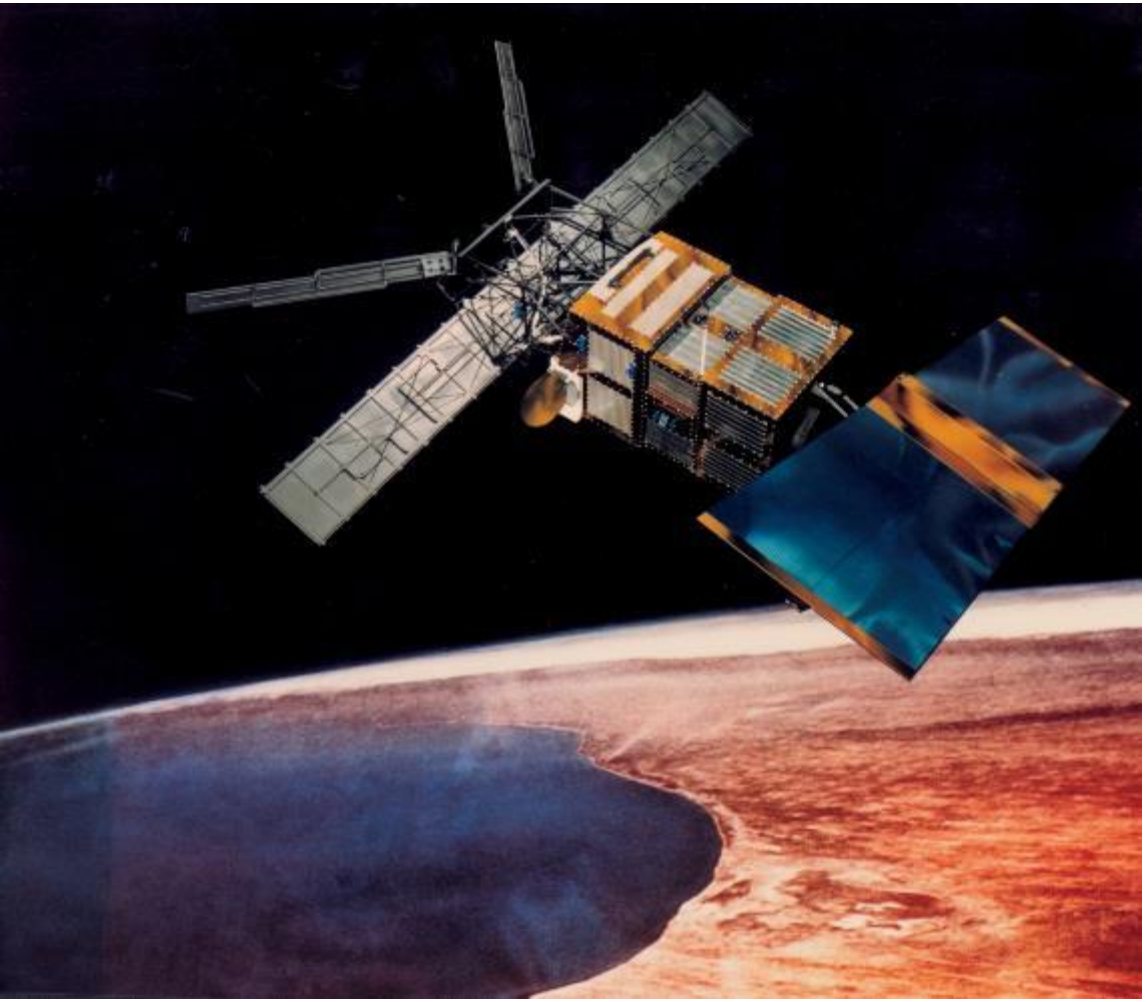


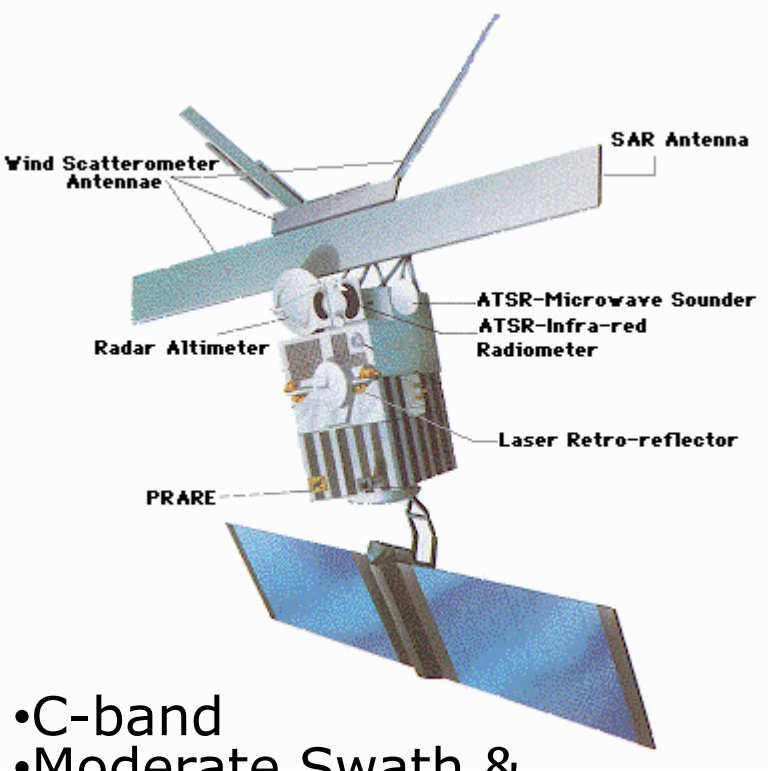
SIR-B	Parameters
Shuttle Orbital Altitudes	360, 257, 224 km
Shuttle Orbital Inclination	57 degrees
Mission Length	8.3 days
Radar Frequency	1.275 GHz (L-band)
Radar Wavelength	23.5 cm
System Bandwidth	12 MHz
Range Resolution	58 to 16 m
Azimuth Resolution	20 to 30 m (4-look)
Swath Width	20 to 40 km
Antenna Dimensions	10.7 m x 2.16 m
Antenna Look Angle	15 to 65 degrees from vertical
Polarization	HH
Transmitted Pulse Length	30.4 microseconds
Minimum peak power	1.12 kW
Data recorder bit rate (on the ground)	30.4 Mbits/s

SIR-B Radar Image of Mount Shasta



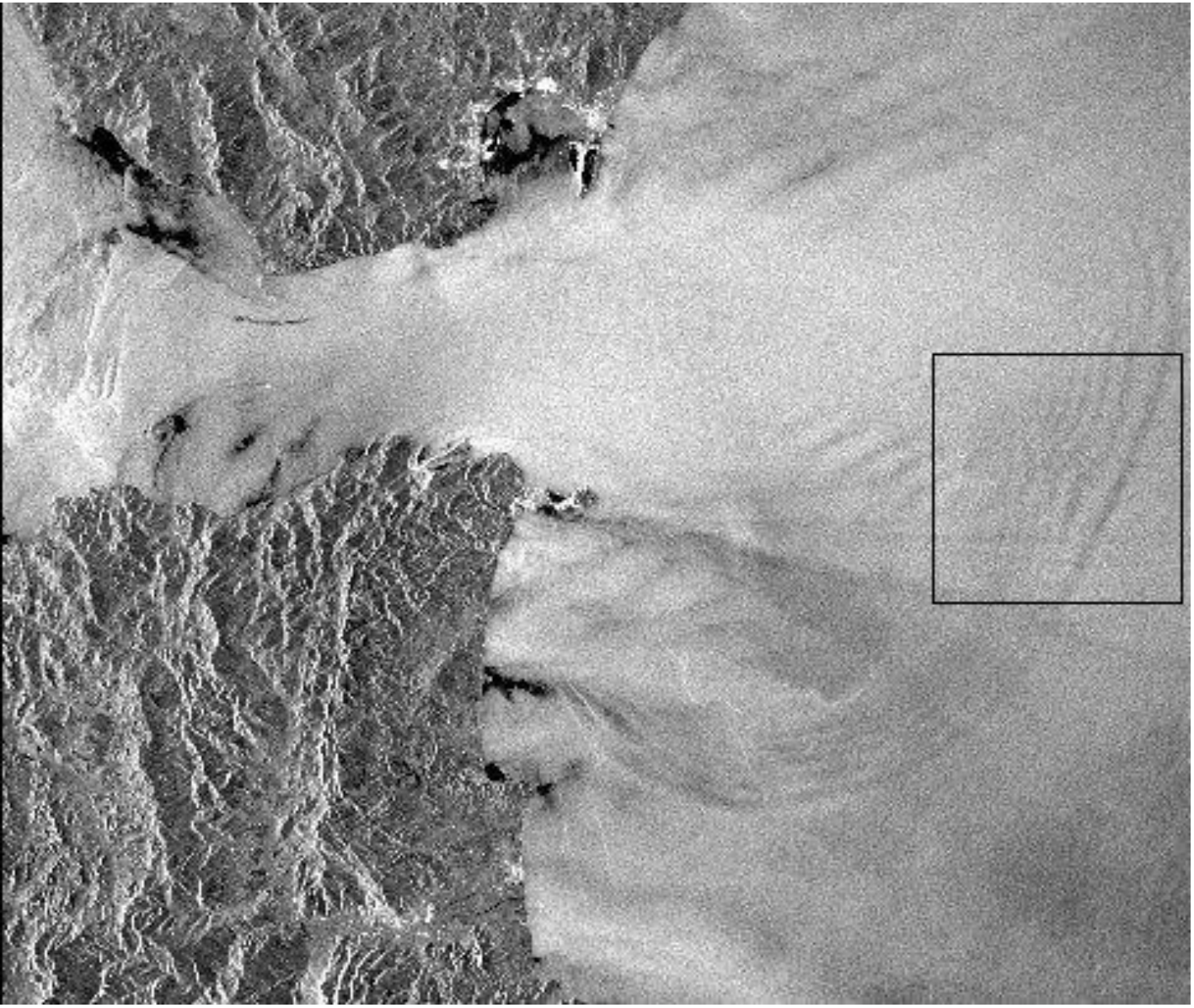
ERS-1 (ESA 1991-2000)





- C-band
- Moderate Swath & Resolution
- Single Polarisation (VV)
- Successful Operations
- Excellent Data Quality
- Application Development
- Emerging Market

ERS-1

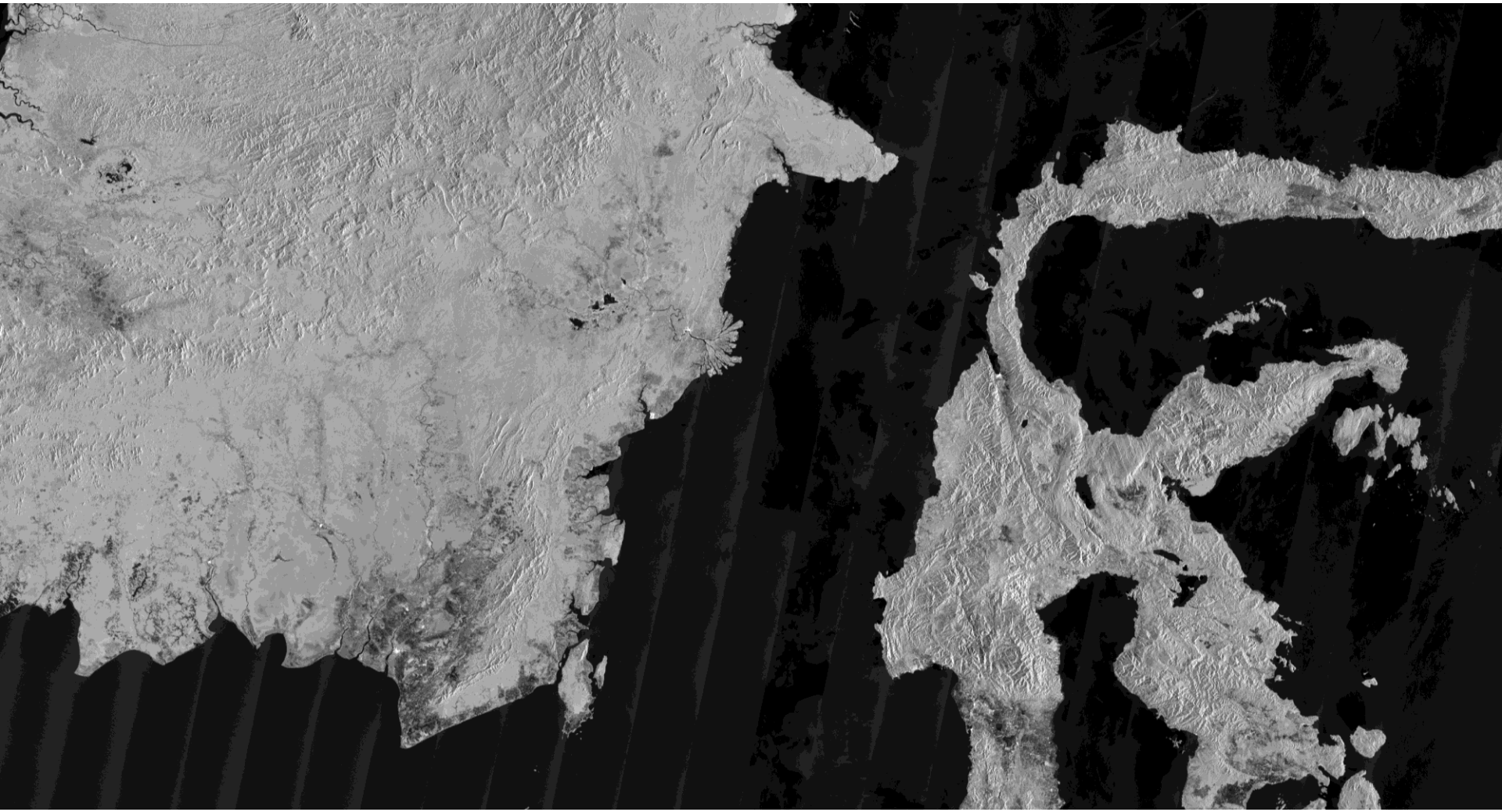


The ERS-1 SAR scene below is from the Strait of Gibraltar, and was acquired on 22:39 UTC on July 30, 1993.

JERS-1 (NASDA, Japan 1992)

Instrument :	**Orbit :**
L Band (1.2 GHz)	Repeat Period : 44 days
Polarization : HH	Local crossing time : 10:45
Central Incidence : 35°	
Ground resolution : 18 m (3 looks)	
Swath Width: 75 km(offset from Nadir: 400km)	

J-ERS-1 Kalimantan Sulawesi



Shuttle Imaging Radar Missions (JPL USA 1981-2000)

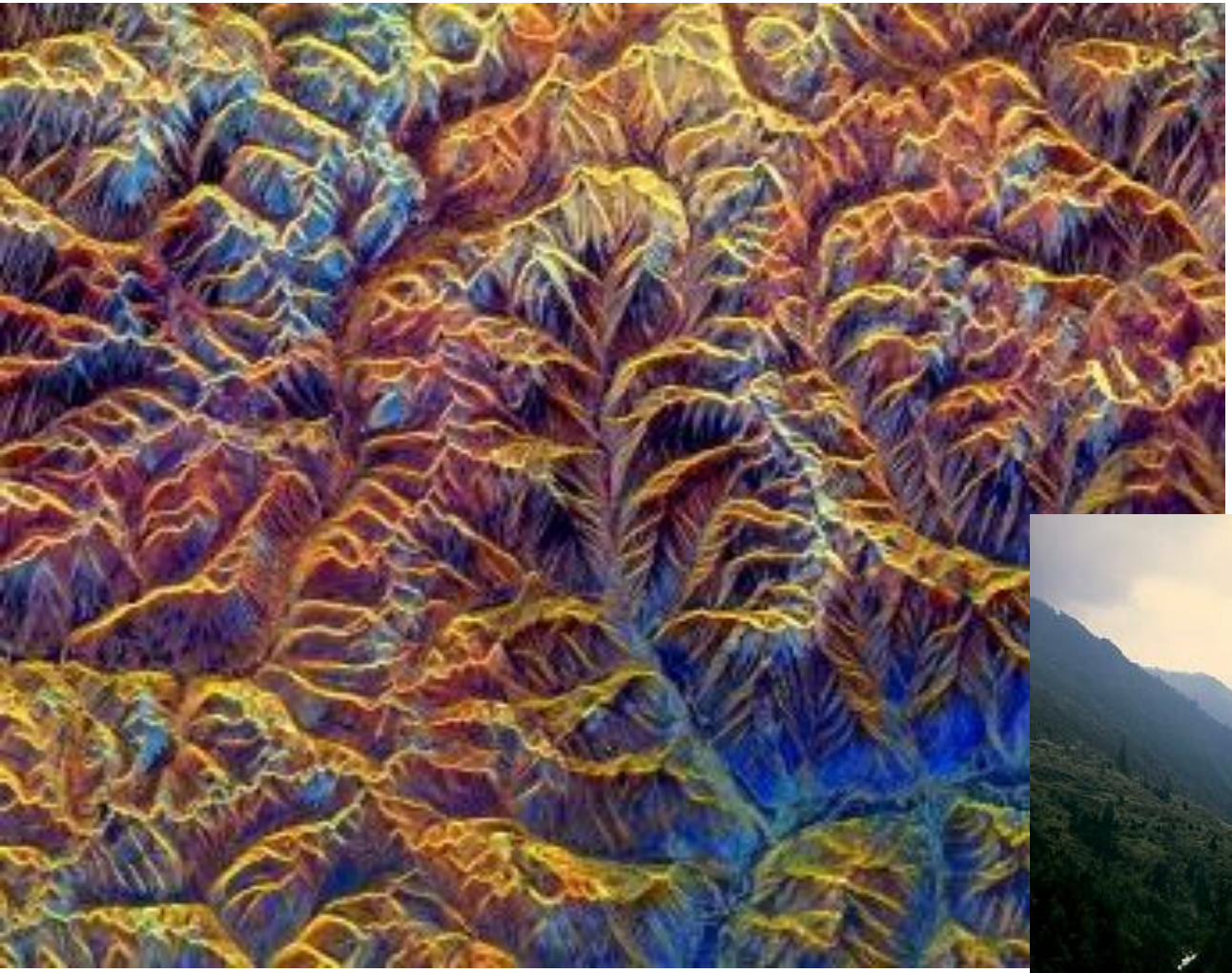
SIR-C/X-SAR (Endeavour shuttle, 1994)

<u>Instrument :</u>

L Band (1.25 GHz)
C Band (5.3 GHz)
Polarisation : Fully Polarimetric
Incidence : 20° -55°

X Band (9 GHz)
Polarisation : VV
Incidence : 20° -55°

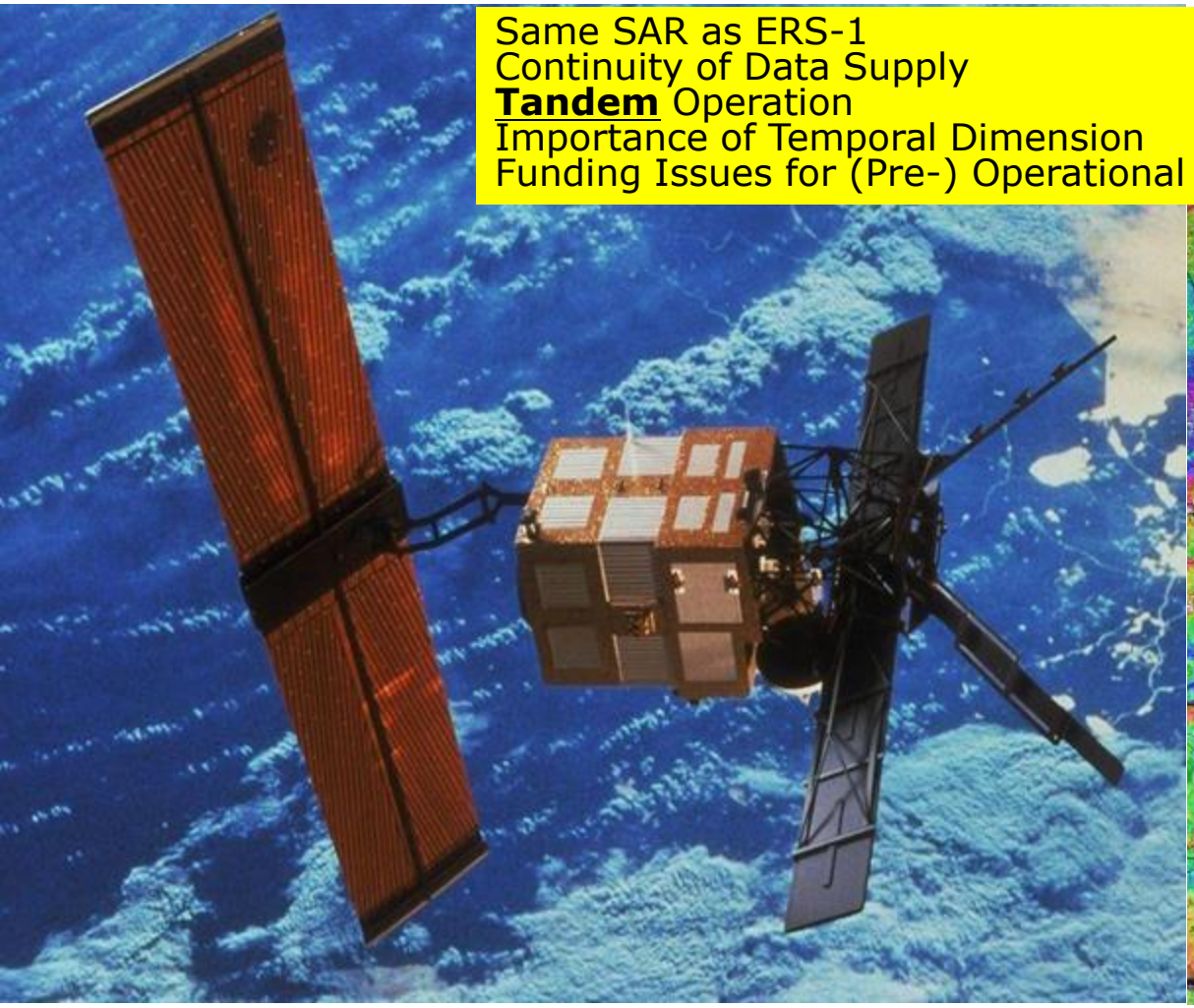
SIR-C/X-SAR

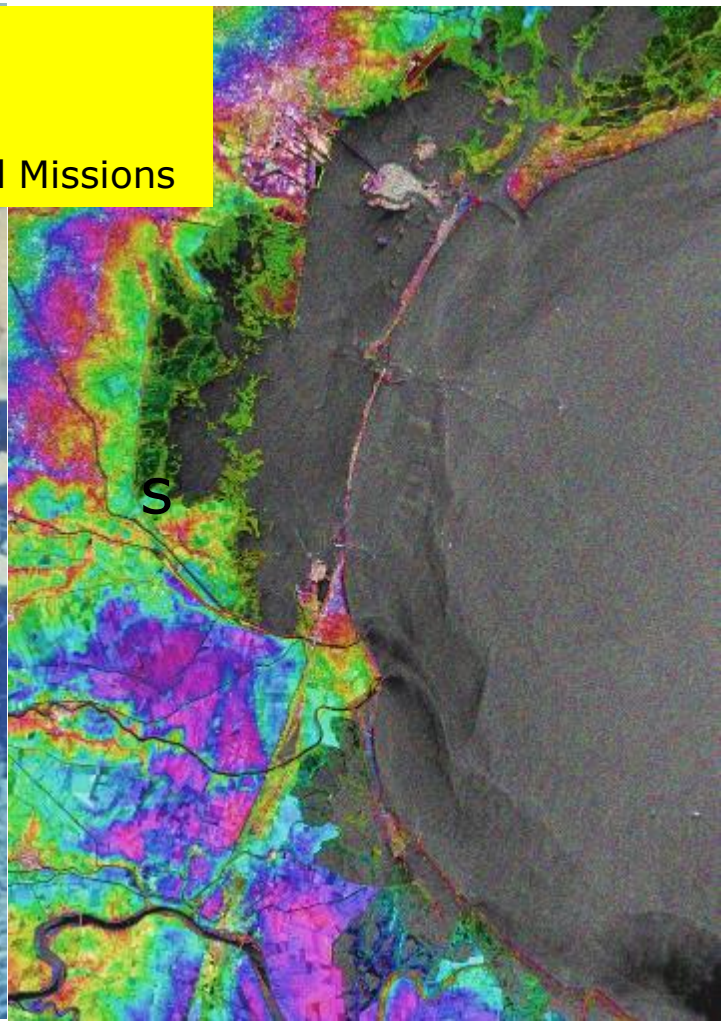


Tibet seen by SIR-C/X-SAR). The various colors assigned to the radar frequencies and polarizations are to map the distribution of different rock types.

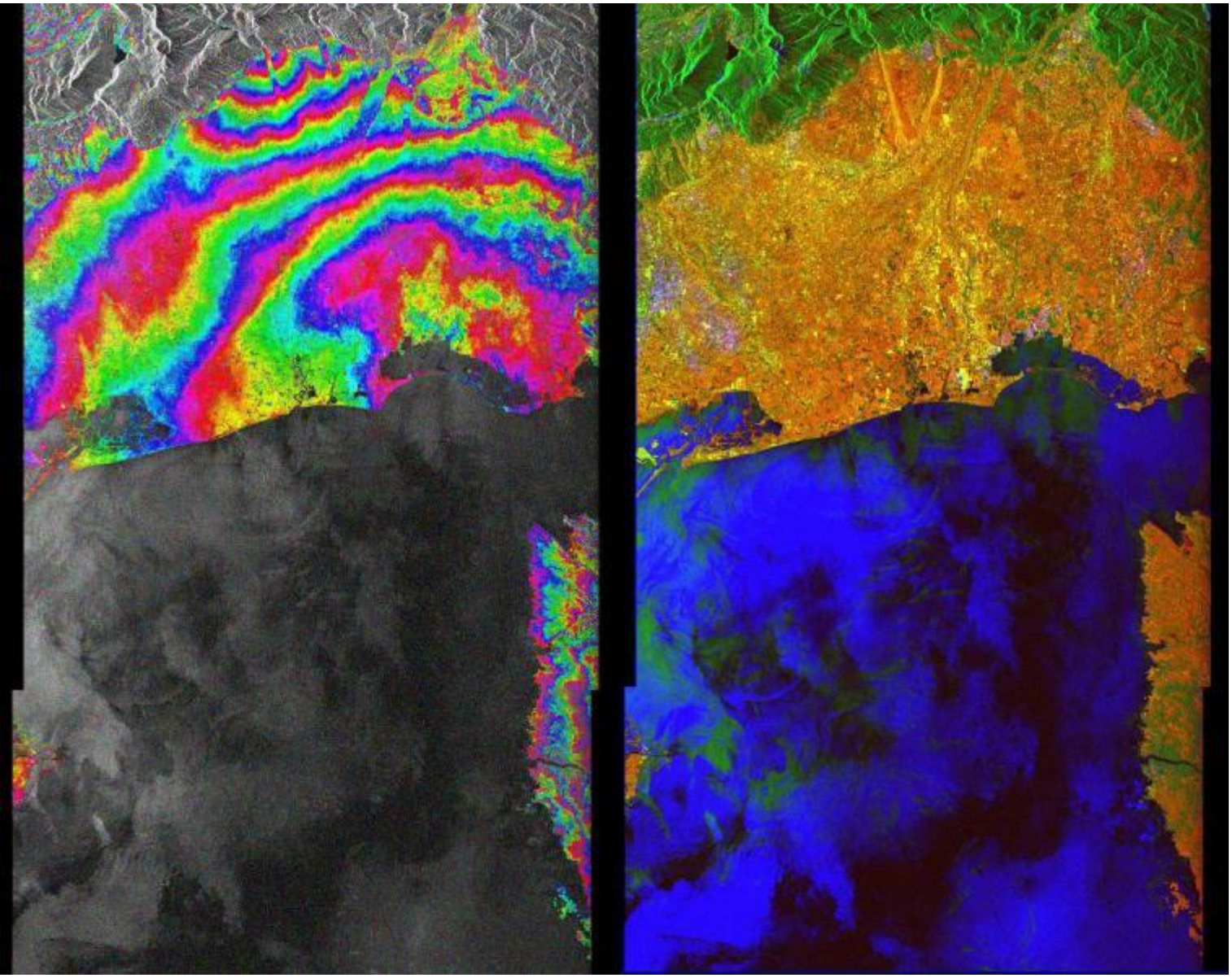
ERS-2 1995-2011

Same SAR as ERS-1
Continuity of Data Supply
Tandem Operation
Importance of Temporal Dimension
Funding Issues for (Pre-) Operational Missions



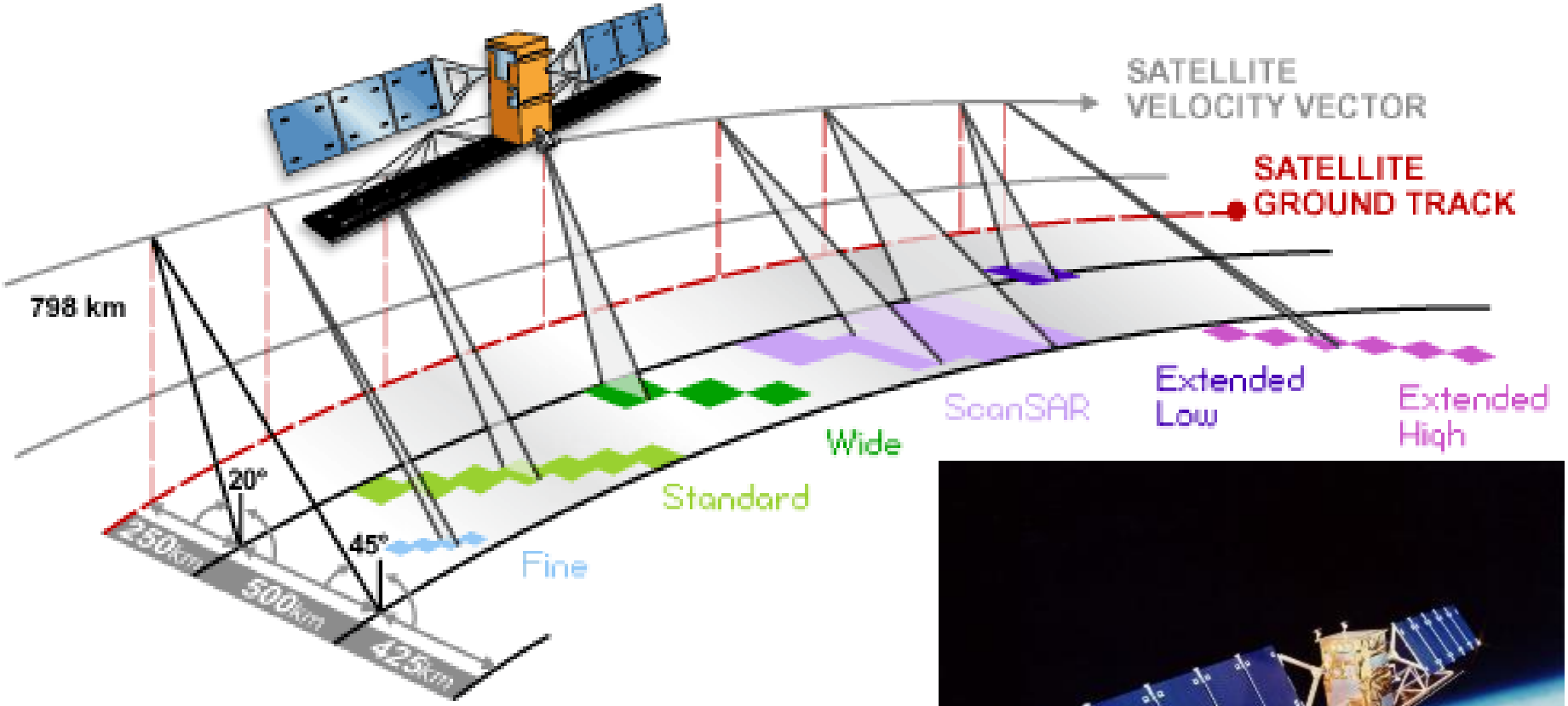


ERS-2 SAR Interferometry

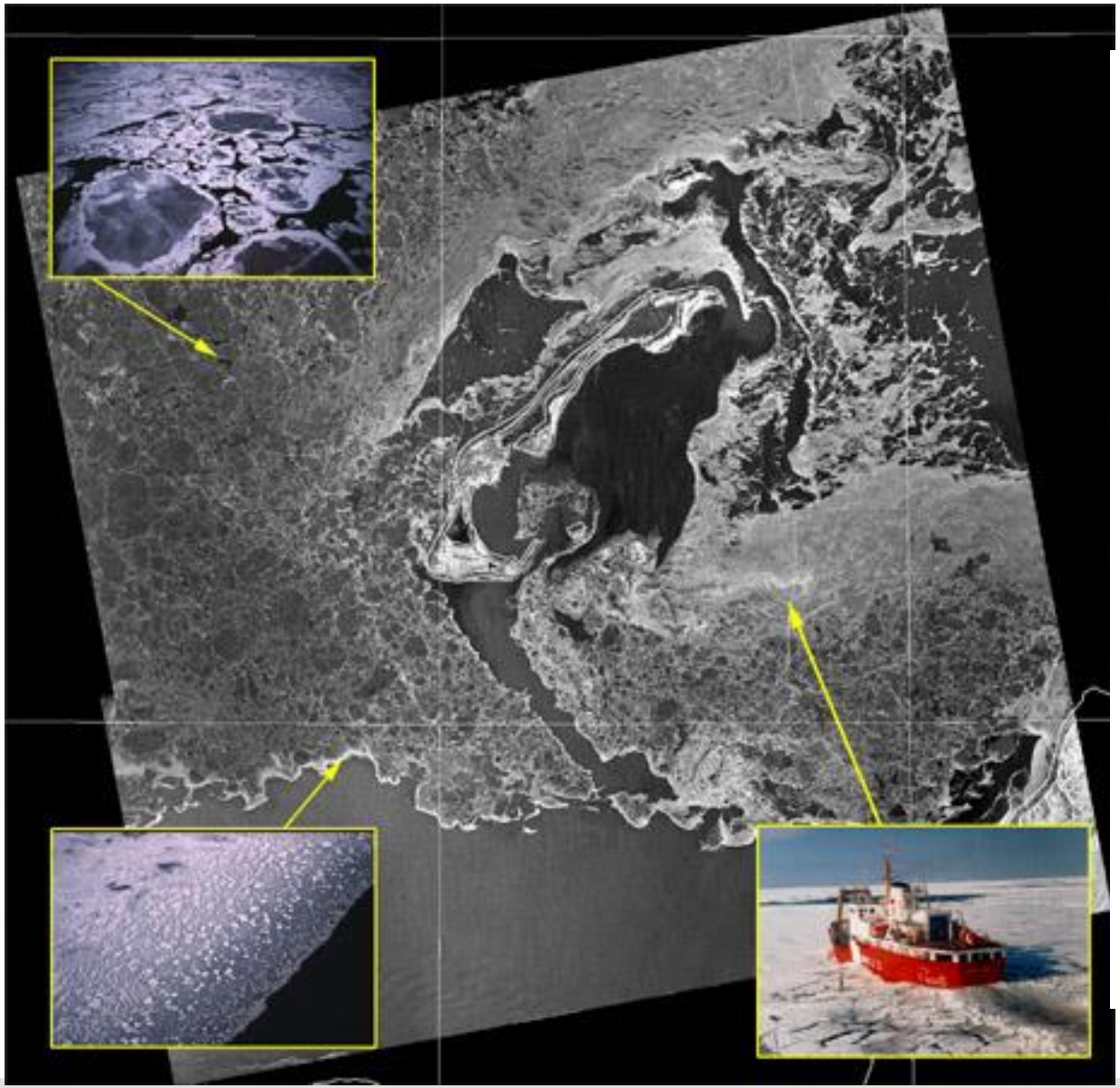


The image shows a sample of ERS-2 SAR Interferometry

RADARSAT-1, Canada CSA 1995



RADARSAT-1 Ice Monitoring

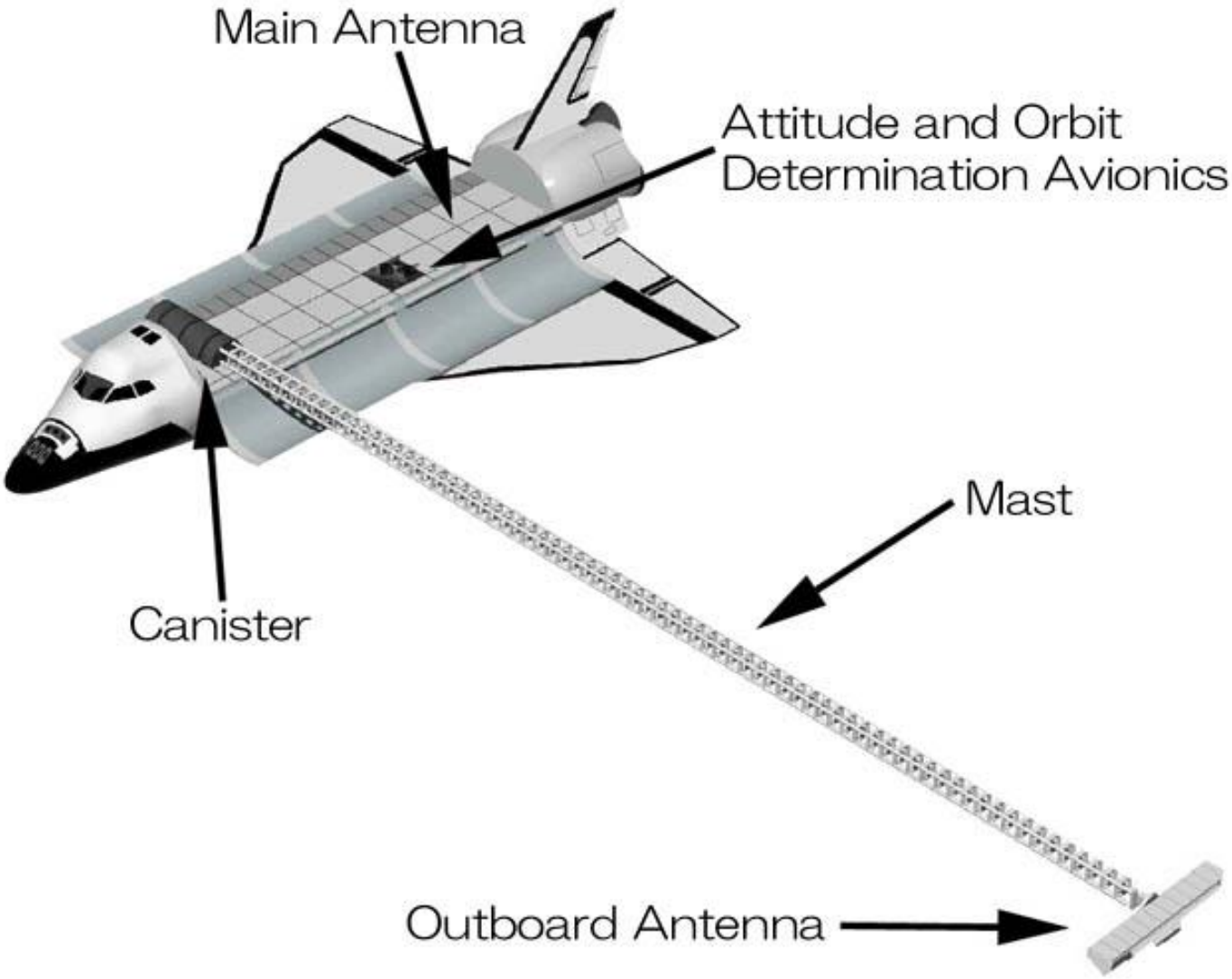


RADARSAT provides routine surveillance of the entire Arctic region.

This helps track sea ice distribution, identify various types of ice, and produce daily ice charts.

The information is used for planning safe shipping routes and supply operations for offshore exploration platforms or ocean research stations.

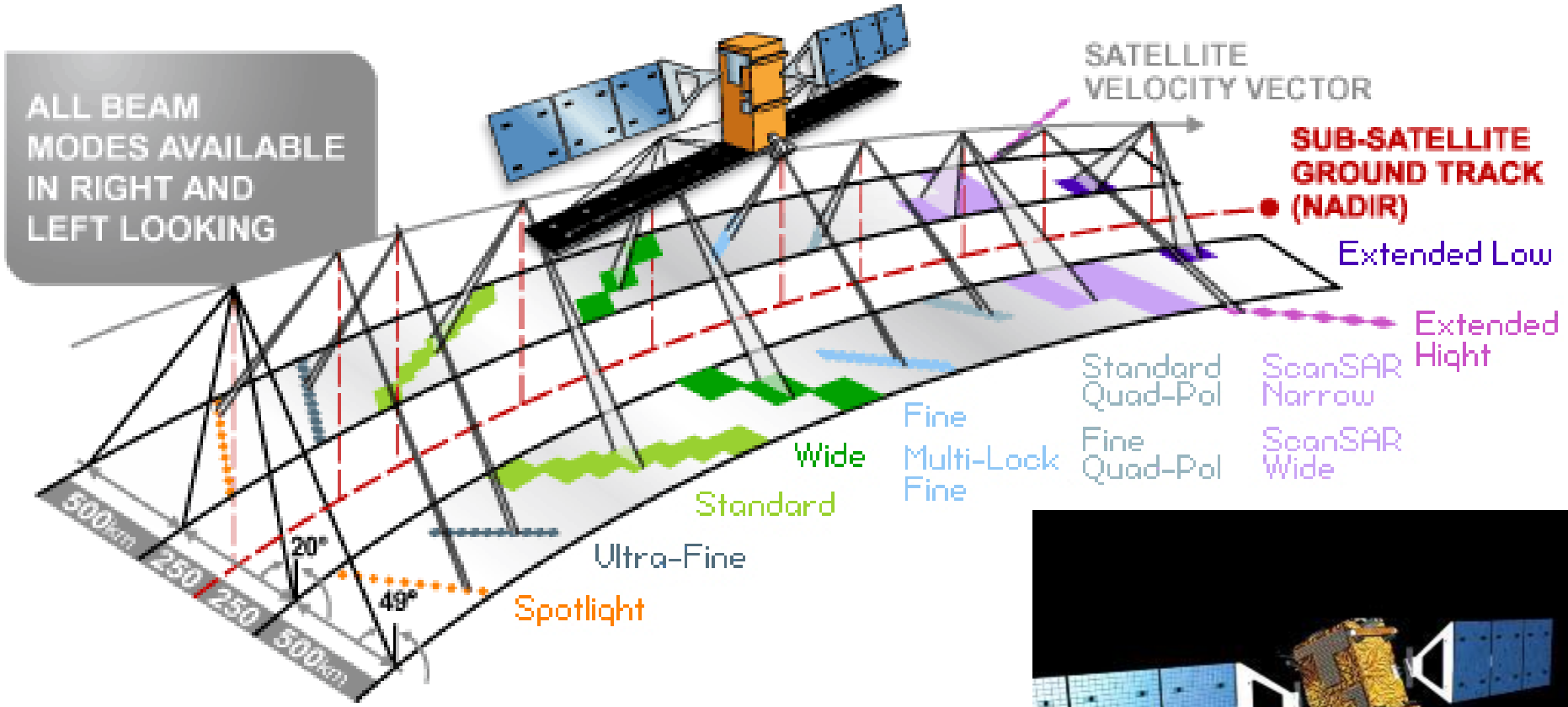
Shuttle Radar Topographic Mission 2000

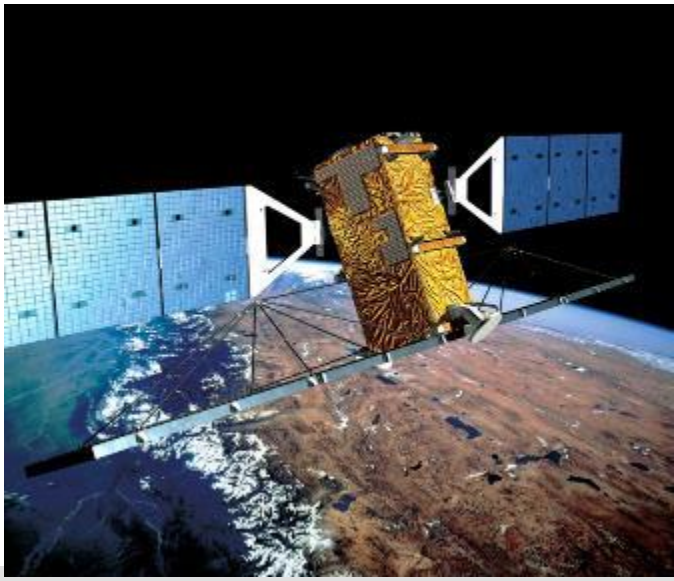


The Shuttle Radar Topography Mission (SRTM) obtained elevation data for a high-resolution digital topographic database of Earth.
SRTM flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000.

SRTM 3D Processed Data

RADARSAT-2 (Canada 2001)

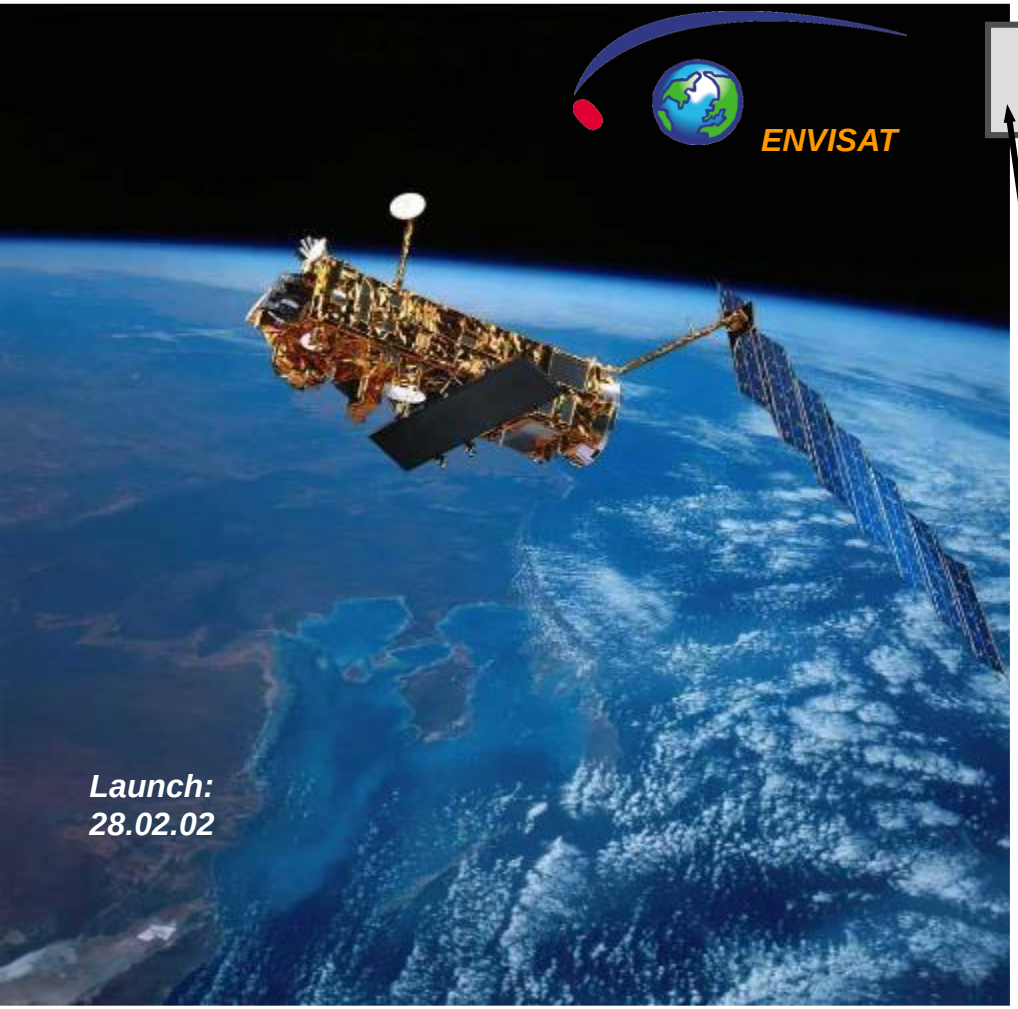


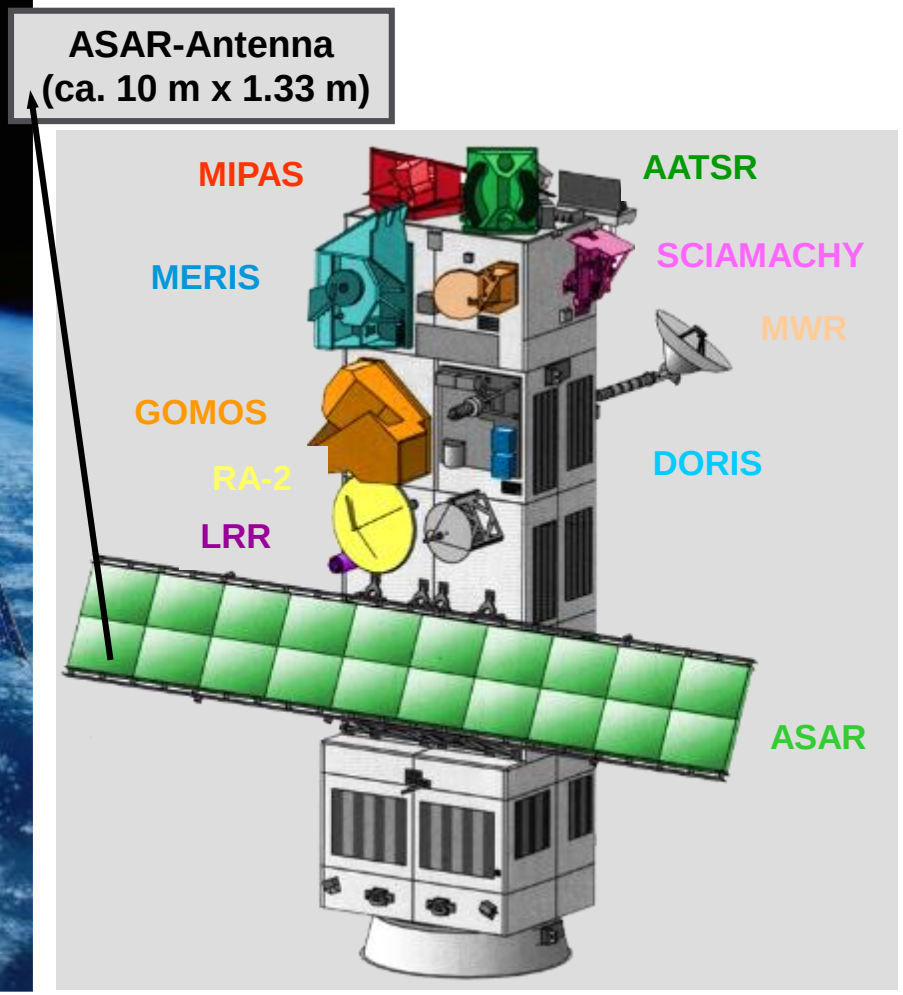


RADARSAT-2 Quad Polarisation

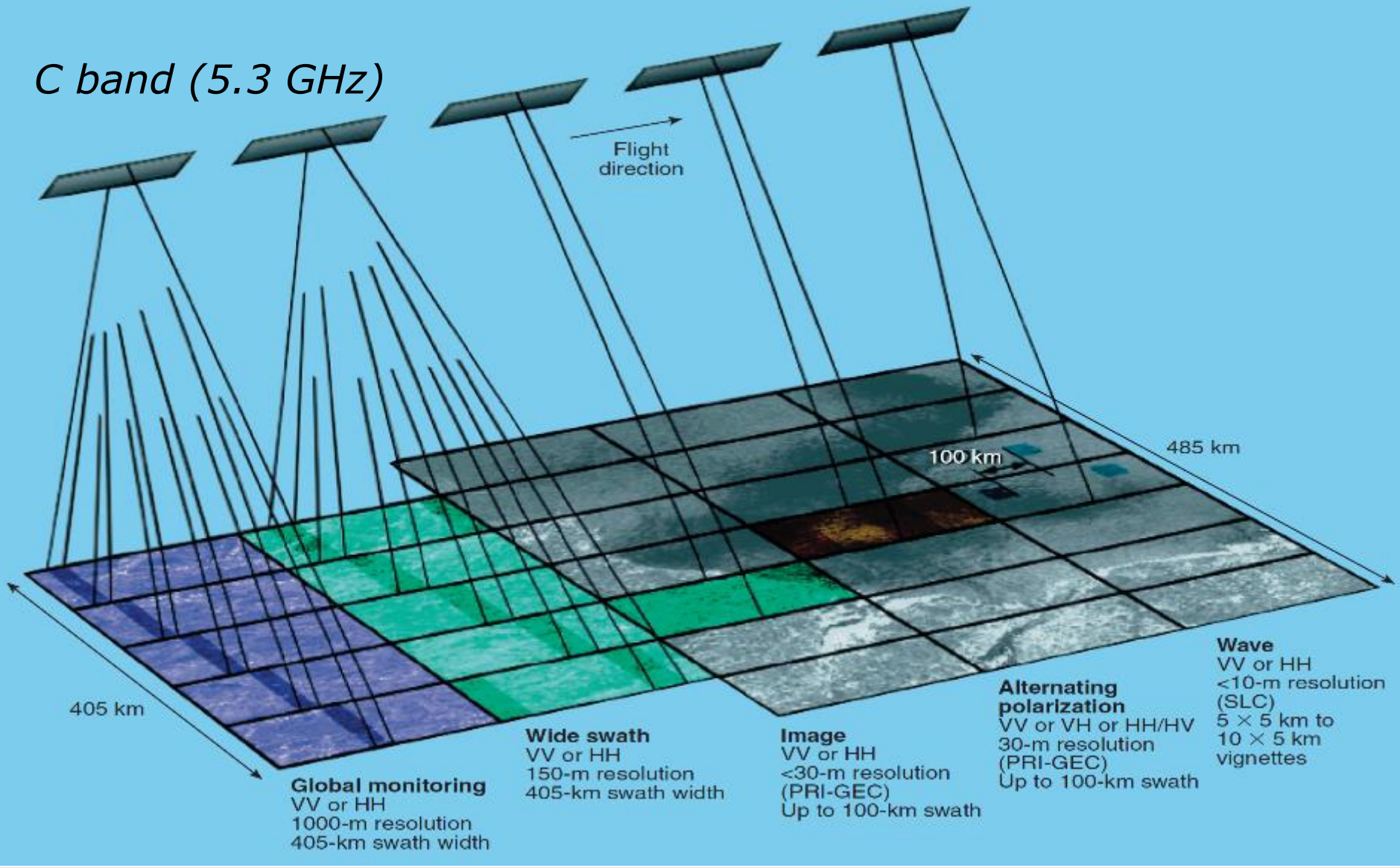
RADARSAT-2 Quad Pol image of Devon Island in the Canadian Arctic Archipelago (image credit: MDA)

ENVISAT / ASAR (ESA 2002)

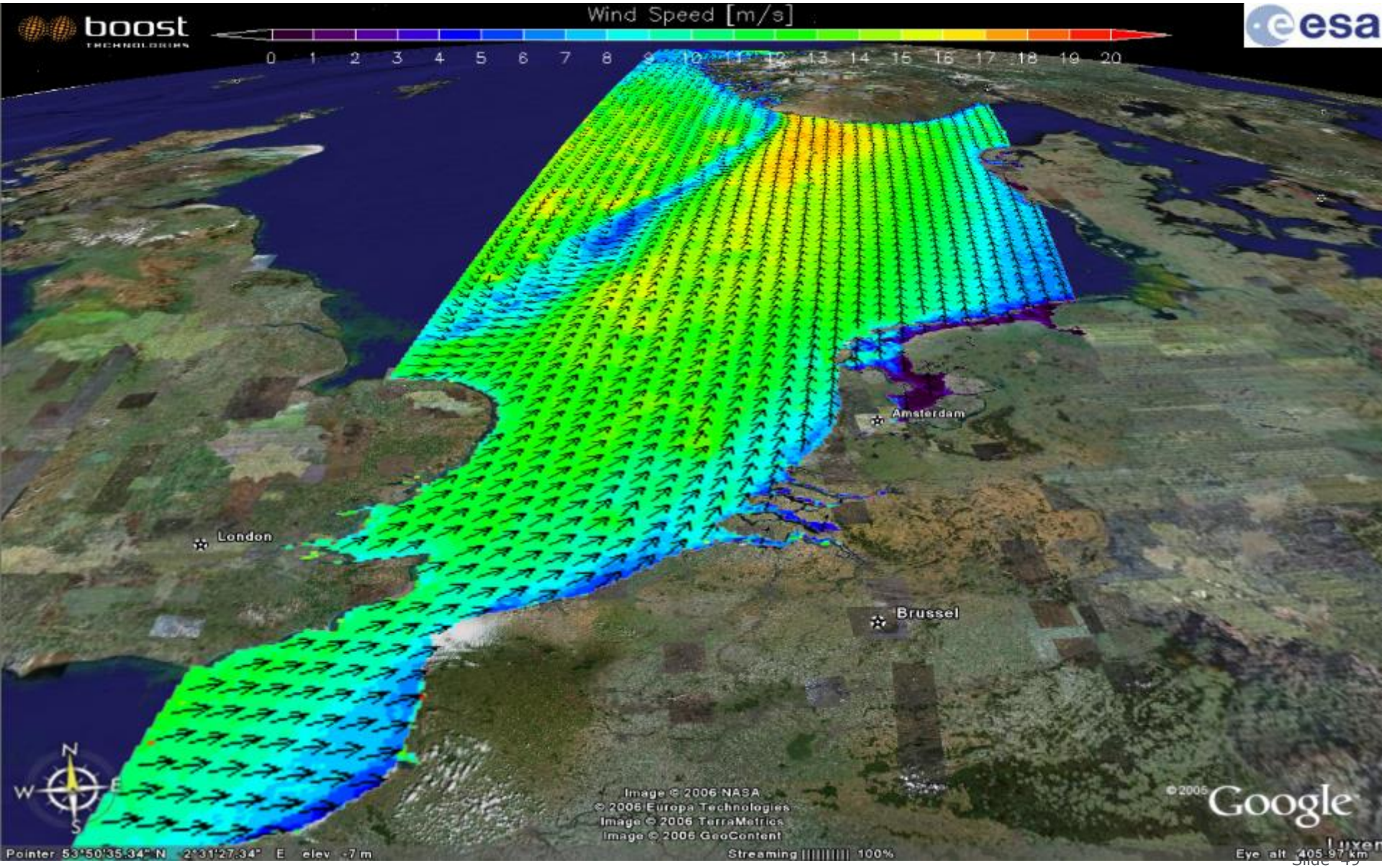




ENVISAT / ASAR (ESA 2002)



ASAR Envisat Wind Mapping

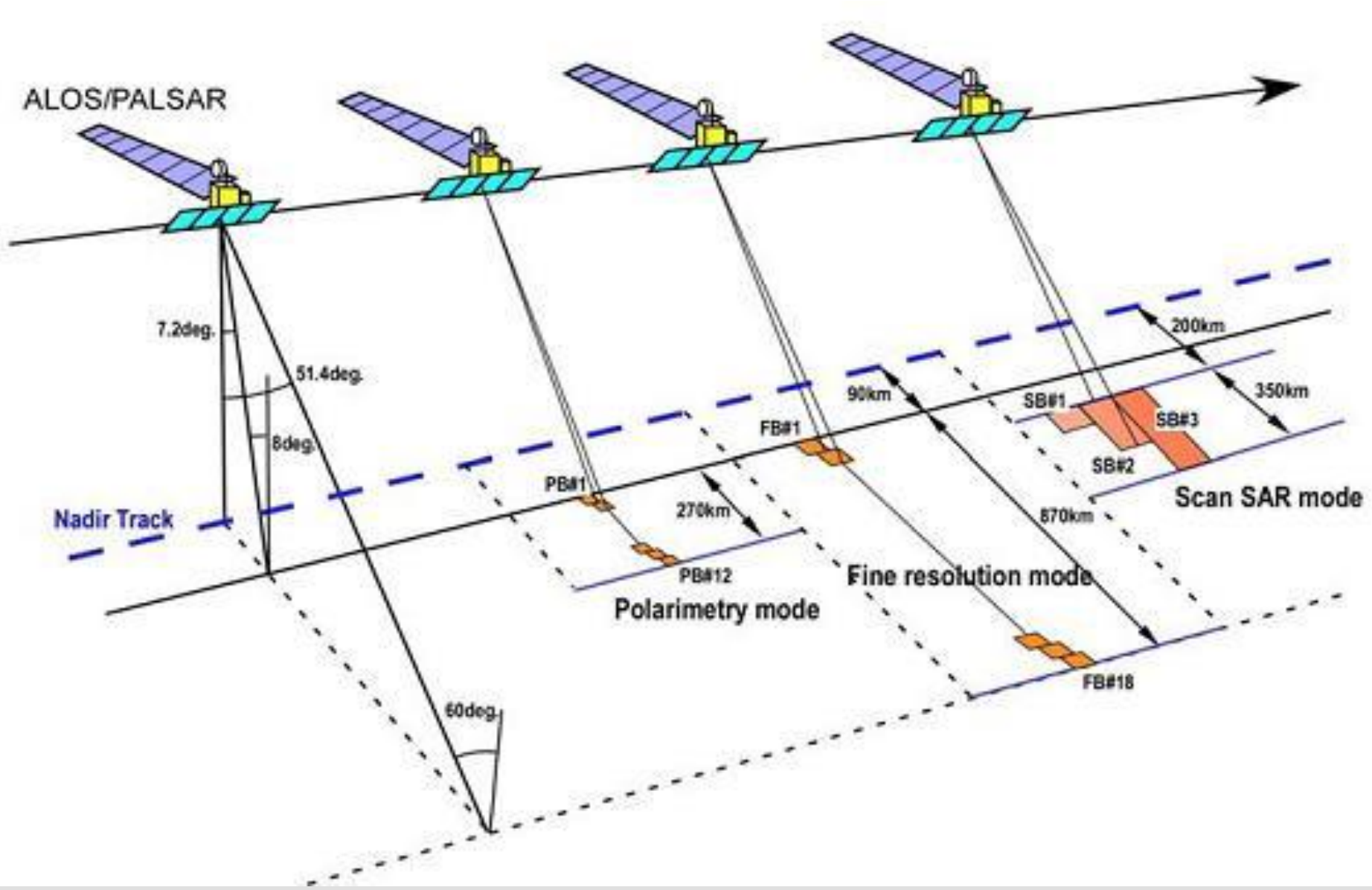


With ERS-1, ERS-2, Envisat ASAR, ESA has been constantly supporting the SAR Interferometry (InSAR) communities for over two decades with:

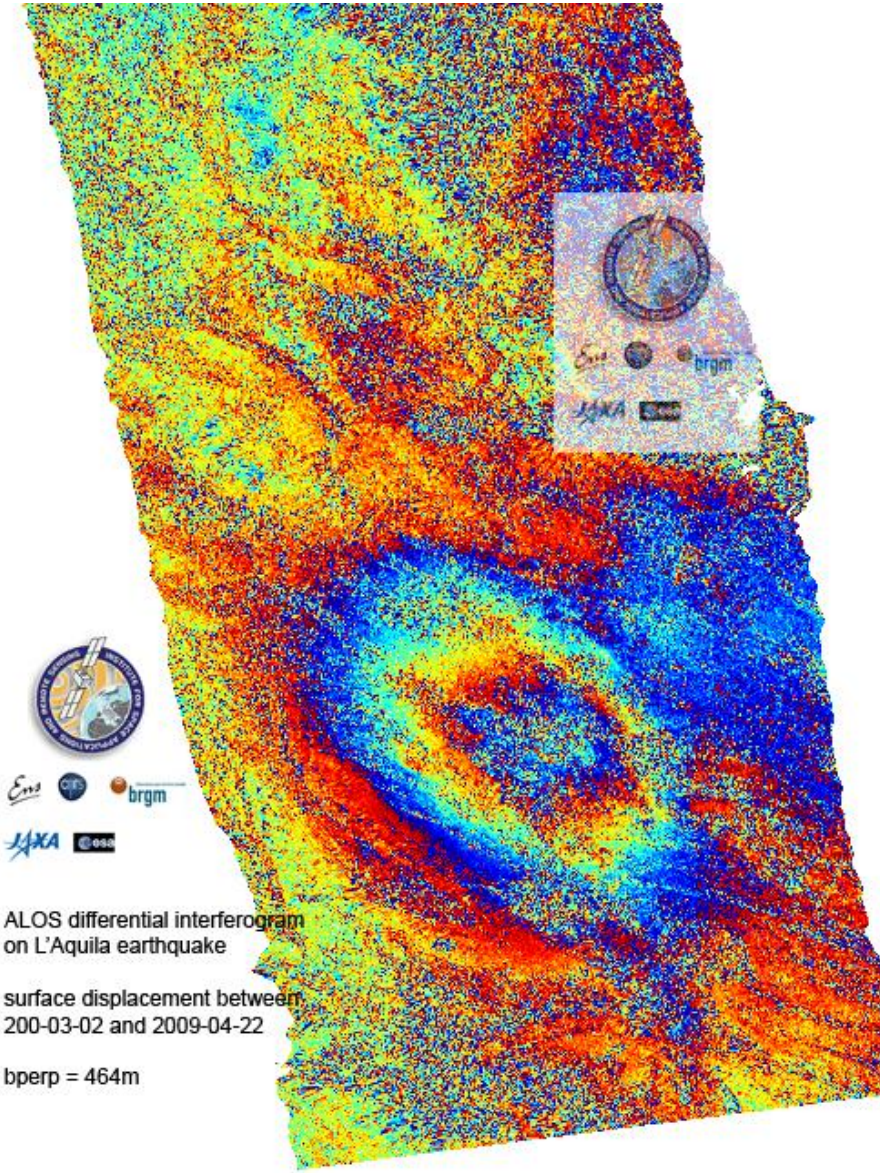
- the **provision of InSAR data**, through:
  - the development and operations of SAR satellites (ERS-1, ERS-2, Envisat)
  - a precise satellite orbital maintenance including InSAR tandem campaigns (ERS-1/ERS-2 tandem, ERS-2/Envisat tandem)
  - the development of a large and consistent InSAR data archive
  - a constant effort in facilitating the use of SAR data
- the **development of InSAR science and InSAR applications**,
- bringing together the InSAR communities through **Fringe & Living Planet workshops**.

PALSAR on ALOS-1 (NASDA 2002)

PALSAR Measurement Geometry



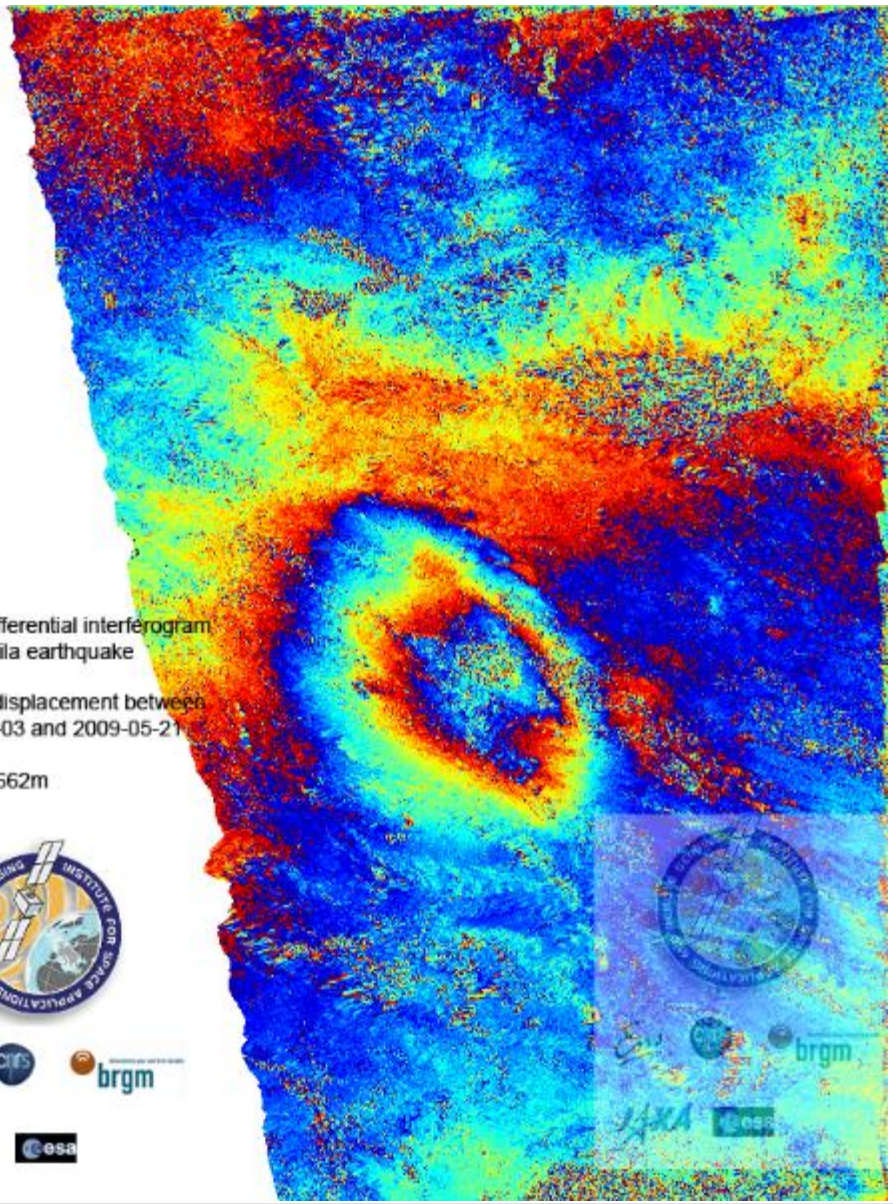
PALSAR & L'Aquila Earthquake



ALOS differential interferogram
on L'Aquila earthquake

surface displacement between
200-03-02 and 2009-04-22

bperp = 464m



ALOS differential interferogram
on L'Aquila earthquake

surface displacement between
2008-07-03 and 2009-05-21

bperp = 662m

COSMO-SkyMed (ASI 2007)

First generation
- Four COSMO-SkyMed X band satellites

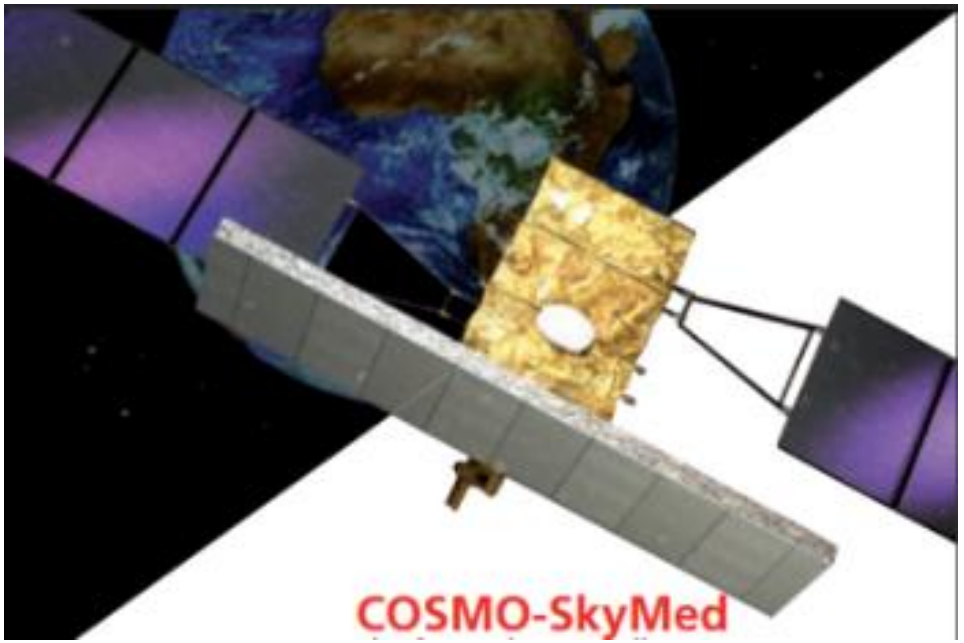
Integration with other missions
- Two SAOCOM L-band satellites

Second Generation
- COSMO-SkyMed second generation being developed by ASI and Italian Ministry of Defense (launching by 2014), will guarantee innovation and continuity with the current system

- 400 MHz chirp bandwidth
- 1m resolution from 25° to 59° incidence angle
- Image size 10 x 10 km @ 1m resolution

With 4 satellites
- At equator 4 images per day
- At 40° latitude, every 7 hours (average)

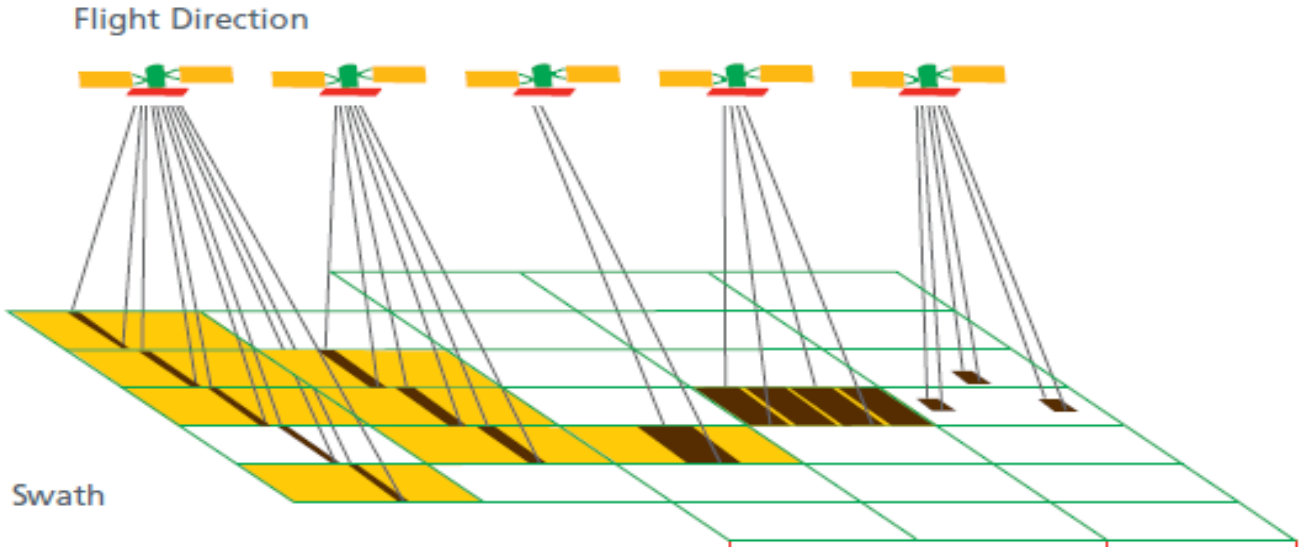
An image will be made available 24 to 48 hours after the request has been approved



With 4 satellites up to 1800 images per day
Daily scenario example:
- 300 Spotlight-2 = 30,000 km² at 1m resolution

And
- 1,500 Stripmap = 2,400,000 km² at 3m resolution

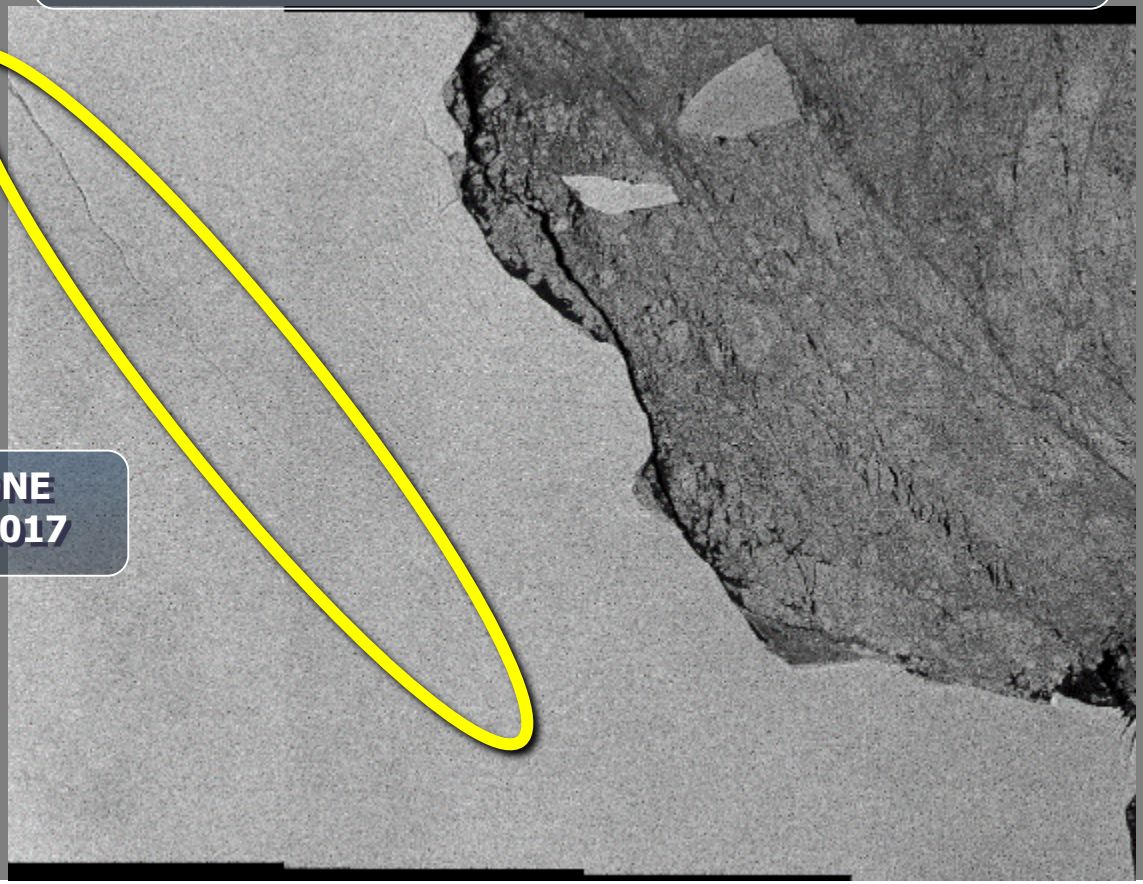
COSMO-SkyMed (ASI 2007)



	Hugeregion	Wideregion	Himage	Pingpong	Mode-2
Resolution - Multi Look	100 m	30 m	5 m	20 m	
Single Look	30 m	16 m	3 m	15 m	1 m
Swath	200 km	100 km	40 km	30 km	10x10 km
Strip Length	2000 km	2000 km	2000 km	2000 km	
	ScanSAR		StripMap		Spotlight -2

COSMO-SkyMed & San Francisco

COSMO-SkyMed & LARSEN C

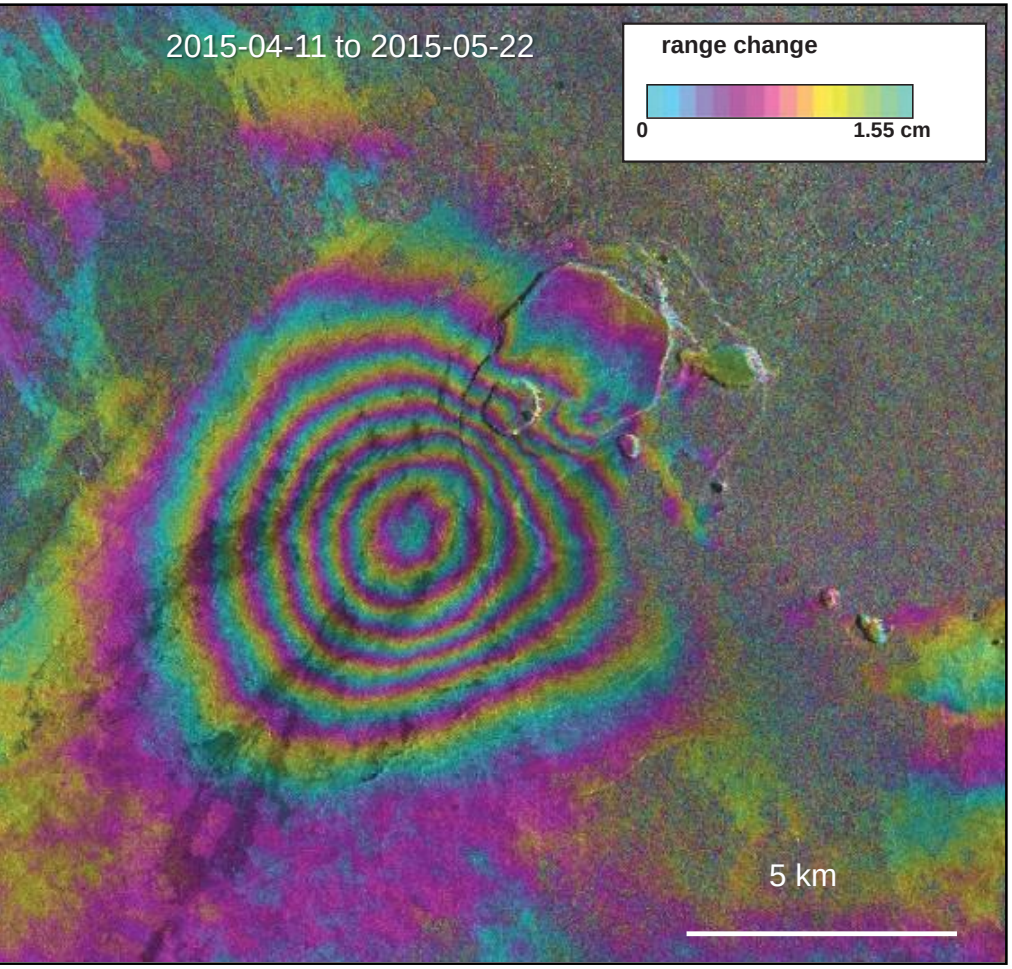


ACQUISIZIONE
10 GIUGNO 2017

COSMO-SkyMed & LARSEN C

ACQUISIZIONI
21 LUGLIO 2017

The importance of low latency at Kīlauea



The low latency of Cosmo-SkyMed data (available within hours of acquisition) has been particularly valuable for responding to volcanic crises at Kīlauea, where changes in eruptive activity threaten tourists and residents alike.

As an example, an intense seismic swarm in May 2015 signaled the intrusion of new magma in the summit area of the volcano. Cosmo-SkyMed data provided a clear view of the associated deformation and allowed scientists to determine the magma's depth while the crisis was ongoing (the magma did not reach the surface to erupt).

The combination of low latency (hours), rapid repeat times, and high resolution provided by Cosmo-SkyMed data is unique among past and current SAR systems.

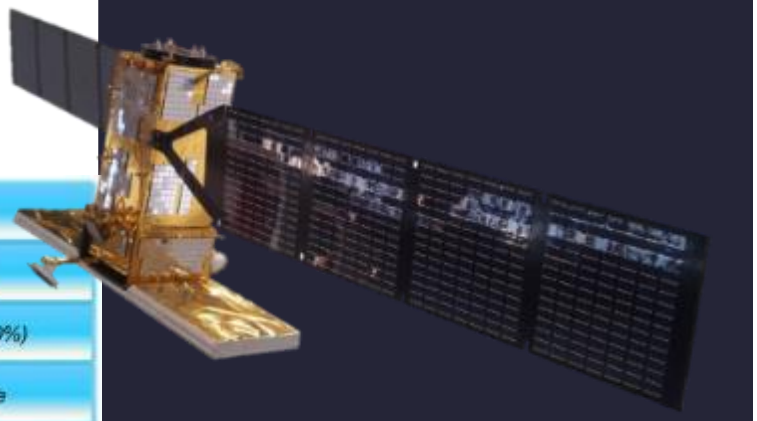
Courtesy of M. Poland

COSMO-SkyMed SECOND GENERATION

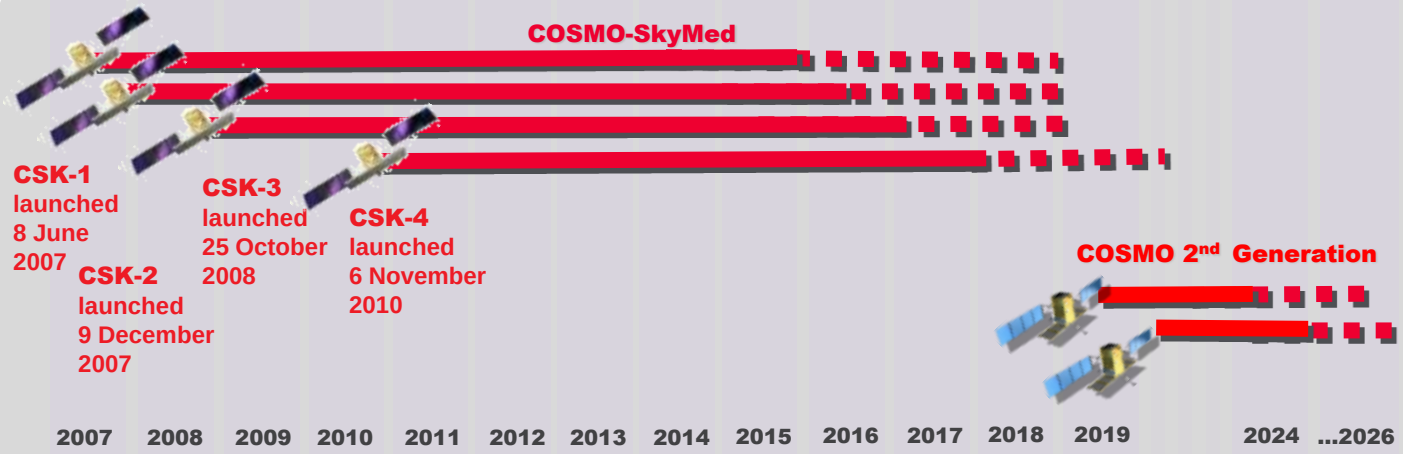
Improvement w.r.t. CSK

- Enhanced geometric resolution
- Enhanced geolocation accuracy
- 7 years lifetime
- Higher agility of the platform
- Lessons Learned from CSK
- Easier interoperability with other systems
- HMI redesigned with users

Access Capability	*+/- 90° latitude*
Revisit Time	*13 hours (90%)*
Response Time	*from 25 to 37 hours (90%)*
Images per day	*Up to 553 per satellite*
Images Dimension	*from 10x10 to 200x200 km2*
Images Resolution	*from sub-metric to 100 m*
Geolocation	*from 1,25 m to 25 m*
Autonomy	*24 hours*

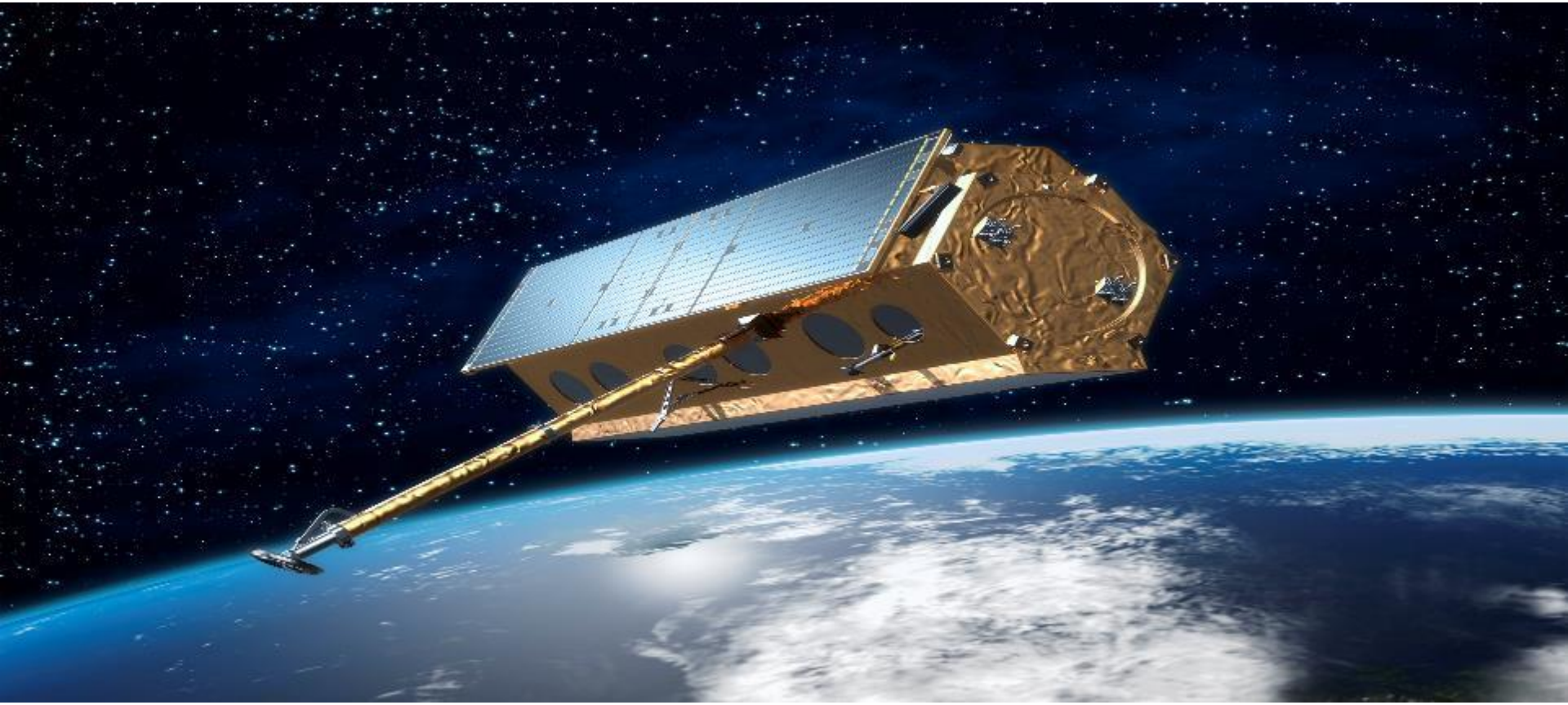


DEPLOYMENT SCENARIO



- COSMO-SkyMed constellation is fully deployed and operational since **mid-2011**
- CSG satellites will replace the CSK satellites that reached the end of life
- With the launch of the first CSG satellite planned for **mid-2019** and the second **one year later.**

TerraSAR-X Satellite

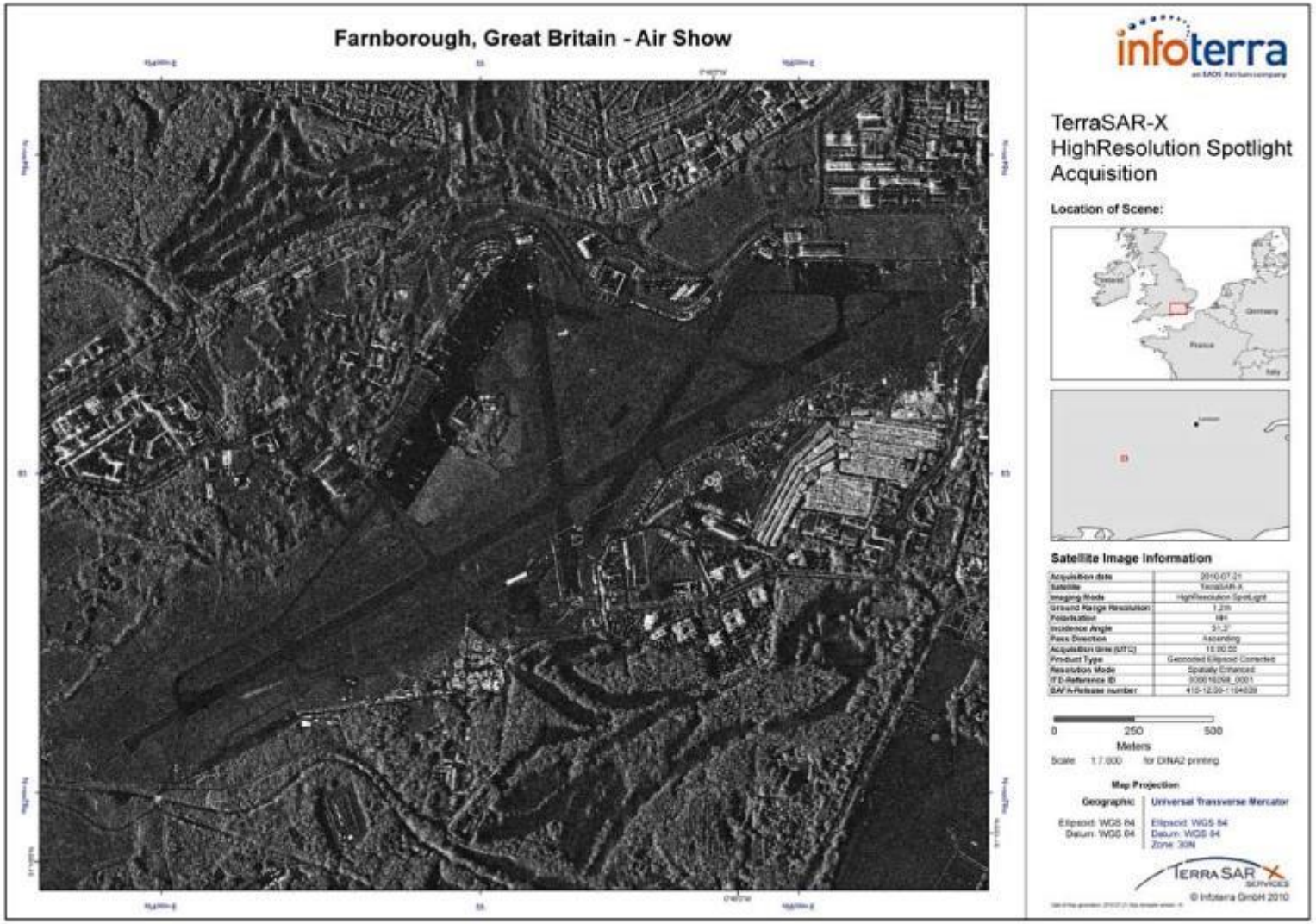


Dusk/down orbit`514.8 km altitude at equator Inclination 97.44˚ ;

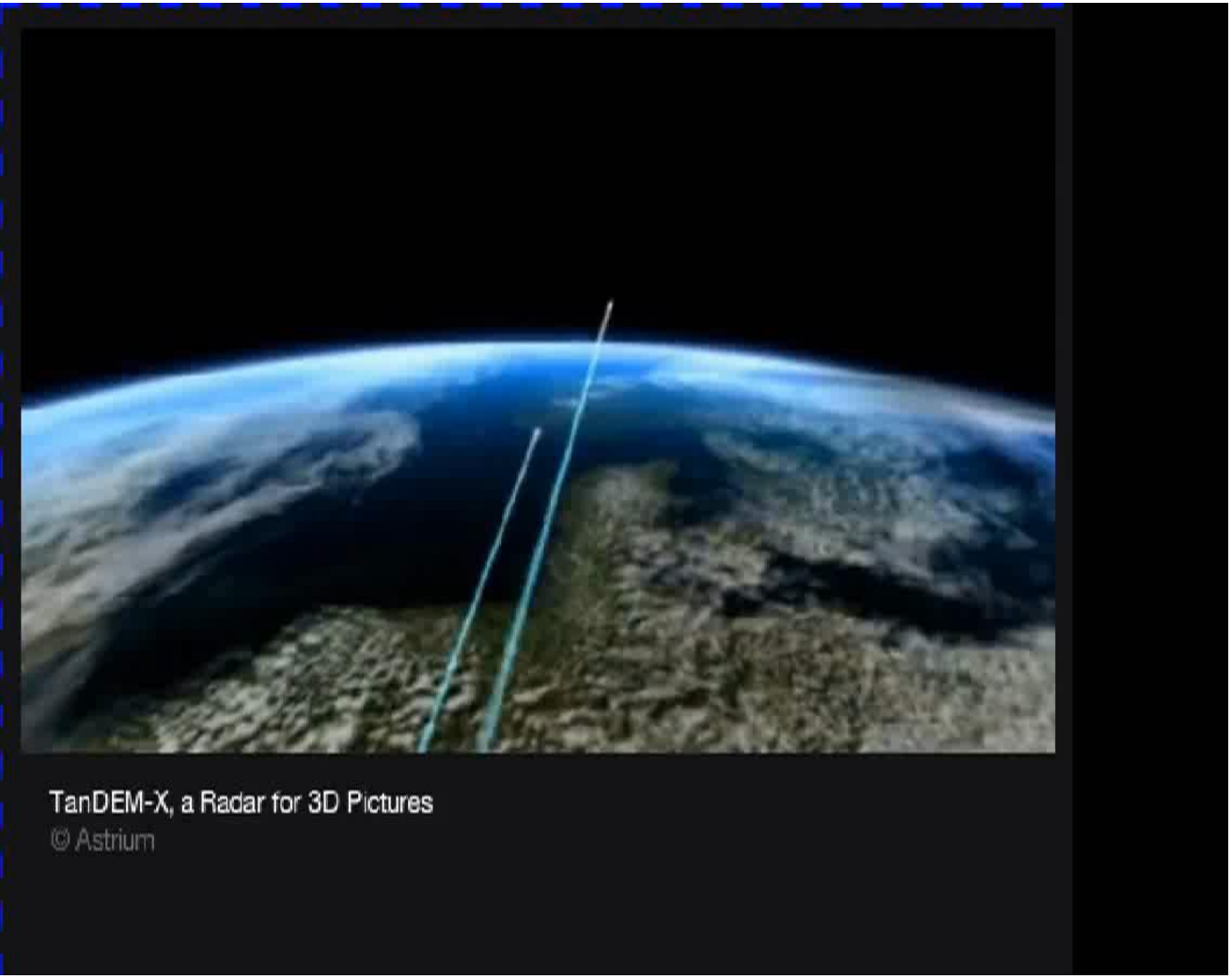
Sun-synchronous repeat orbit, period 11 days;

Revisit time: 4.5 days (100%) 2.5 days (95%) 15 2/11 Orbits per day

TerraSAR-X at Farnborough Airshow



Tandem-X (DLR)

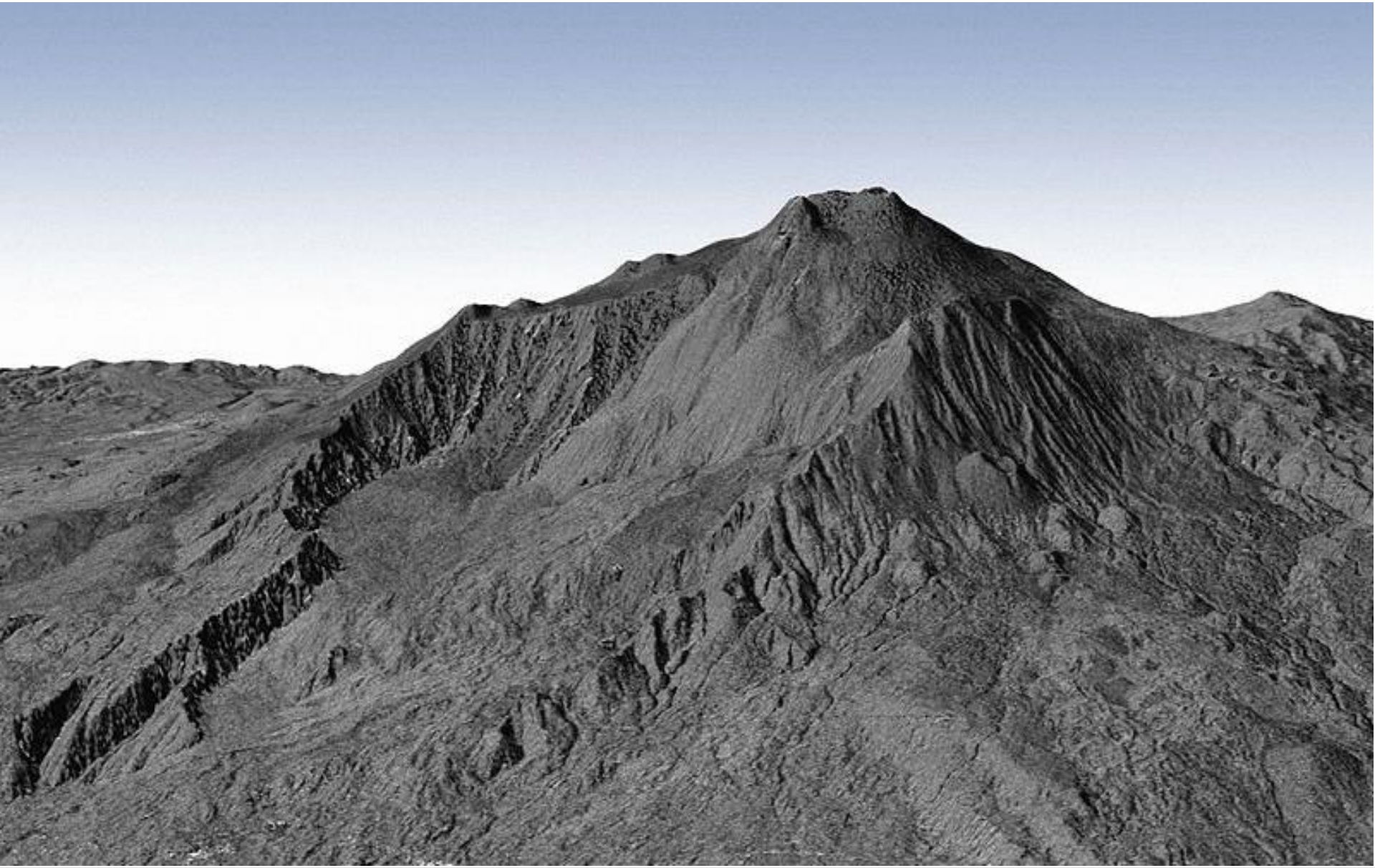


Acquisition of a global DEM according to HRTI-3 standard

Generation of local DEMs with HRTI-4 like quality

Demonstration of innovative techniques (formation flying, bistatic acquisiton, Pol-InSAR)

Etna SAR Image by Tandem-X



Application	Disaster, Land, Agriculture, Natural Resources, Sea Ice & Maritime Safety
L-band SAR (PALSAR-2)	Stripmap: 3 to 10m res., 50 to 70 km swath ScanSAR: 100m res., 350km/490km swath Spotlight: 1×3m res., 25km swath
Orbit	Sun-synchronous orbit Altitude: 628km Local sun time : 12:00 +/- 15min Revisit: 14days Orbit control: ≦+/-500m
Life time	5 years (target: 7 years)
Launch	May 24, 2014; H-IIA launch vehicle
Downlink	X-band: 800Mbps(16QAM) 400/200Mbps(QPSK) Ka-band: 278Mbps (Data Relay)
Experimental Instrument	Compact InfraRed Camera (CIRC) Space-based Automatic Identification System Experiment 2 (SPAISE2)

Japanese L-band SAR Satellites – 25-year Legacy

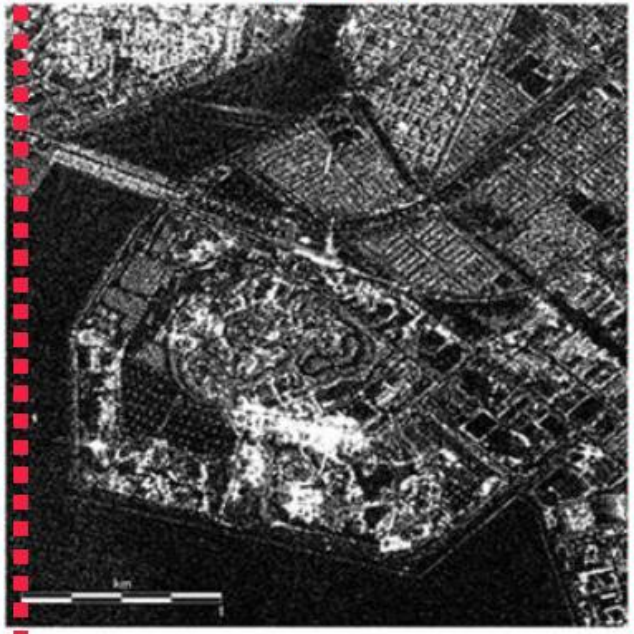
JERS-1
(1992-1998)

FUYO-1 SAR.
(Resolution: about 18 m)

ALOS
(2006-2011)

DAICHI PALSAR.
(Resolution: about 10 m)

ALOS-2
(2014-)



DAICHI-2 PALSAR-2.
(Resolution: about 3 m)

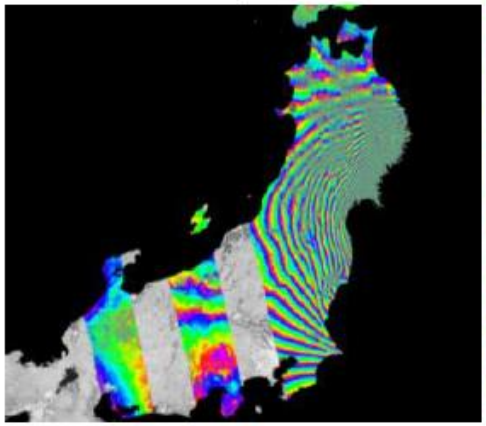
Improvement of Data Acquisition Abilities

"Daichi-2" (ALOS-2)

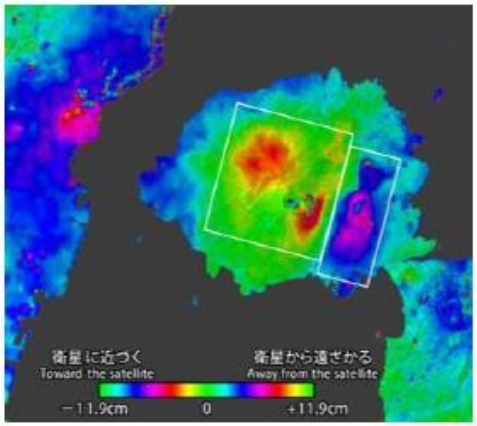
Mission Objectives:

Disaster monitoring

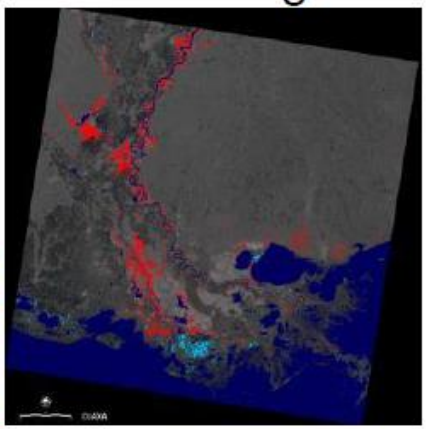
Earthquake



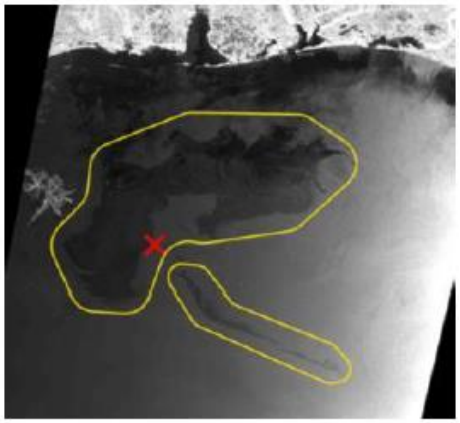
Volcano



Flooding

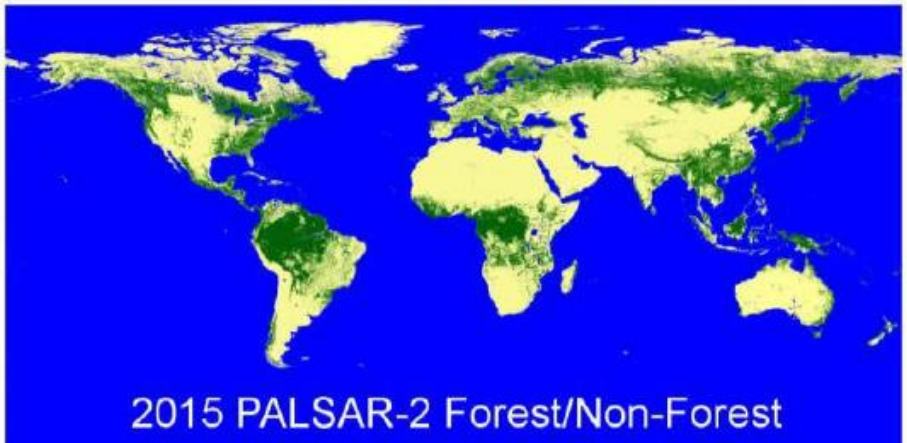


Ocean

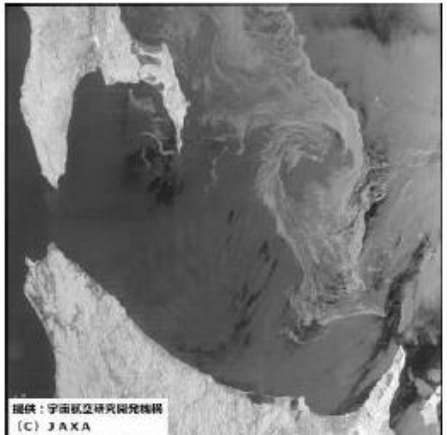


Environment and land management

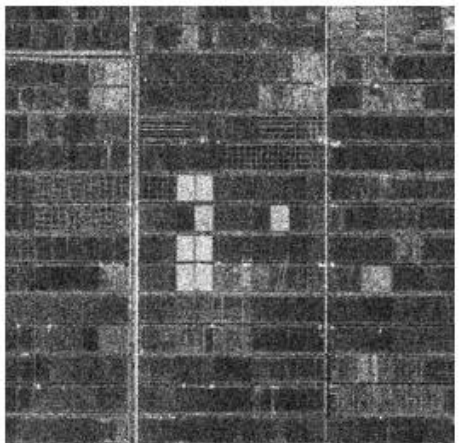
Forest and wetland



Ice



Agriculture & natural resources



Sentinel–1: SAR Mission (1A launched 2014, 1B launched 2016)

Ice and marine/land monitoring
Mapping in support to humanitarian aid crisis situations

Launch of Sentinel-1A

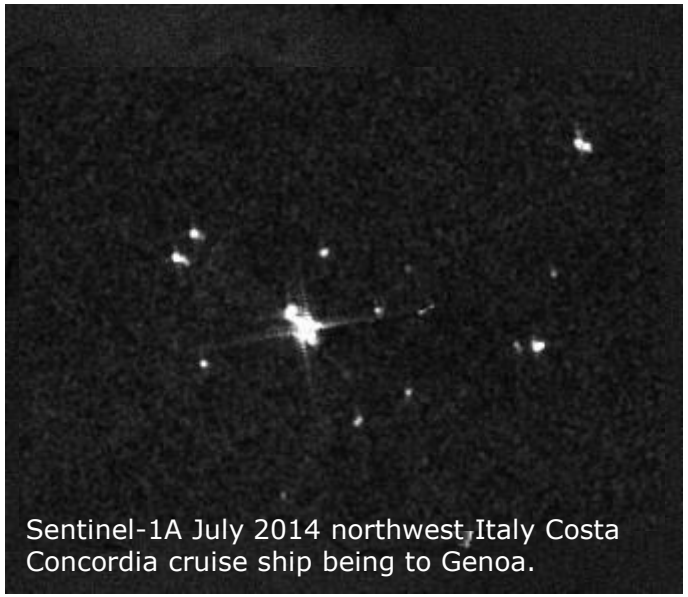
- April 3, 2014
- Launch from French Guiana Space Base
- Soyuz-2 rocket
- New era in Earth Observation

Sentinel-1
Mission objectives

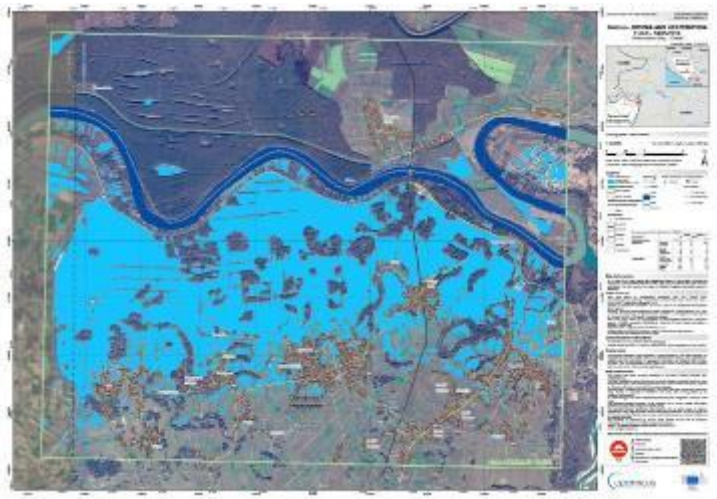
✓**Data continuity of ERS and ENVISAT missions**

✓ **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-1A July 2014 northwest Italy Costa Concordia cruise ship being to Genoa.



Flood delineation map over Balatun Bosnia and Herzegovina

Sentinel-1 observation scenario
Main thematic domains & components

Land cover: agriculture, forestry, hydrology, etc.

Maritime surveillance

European coverage

Sea-ice, icebergs, lake-ice

Emergency

Calibration/validation

Ground deformation: Tectonic, volcanoes, landslides, subsidence… (InSAR applications)

Security

Global land mapping

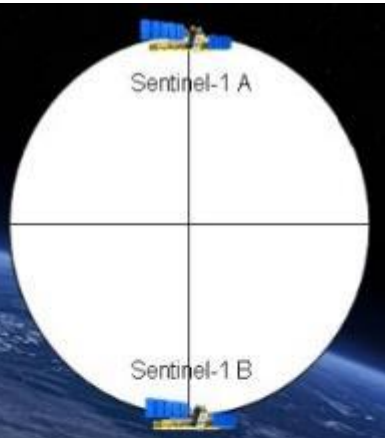
PR actions (infrequent)

Sea state

Ice sheets, glaciers, permafrost, snow, 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)

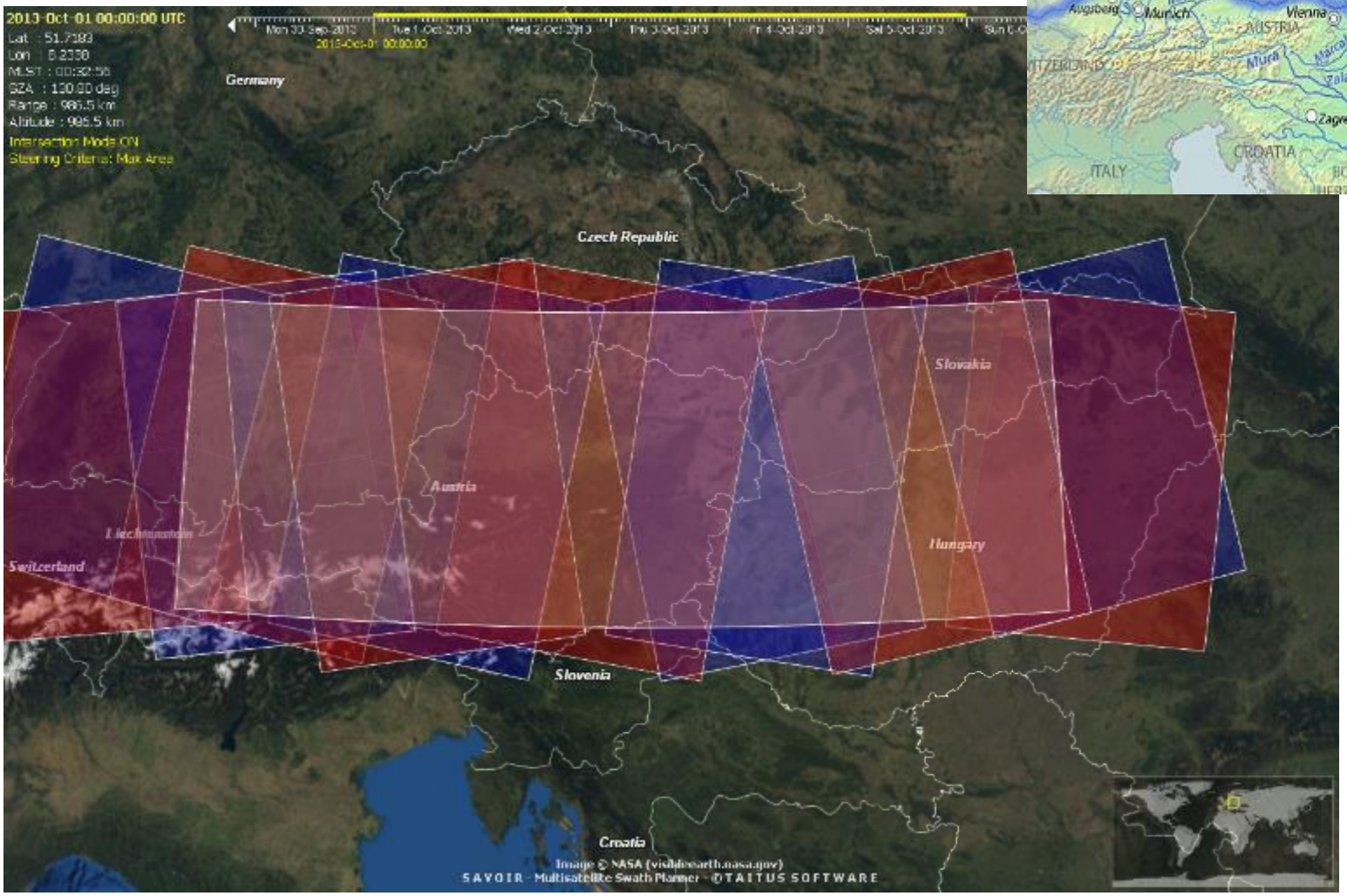


Laser data transmission via the geostationary data relay system EDRS was demonstrated for S-1

Now 6-day repeat cycle at Equator (with 2 satellites). Sentinel 1-B data distributed since 26 Sept 2016

Sentinel-1: Improved Spatial Coverage

Sentinel-1 vs ENVISAT 5-day coverage



Until 2012:
ENVISAT

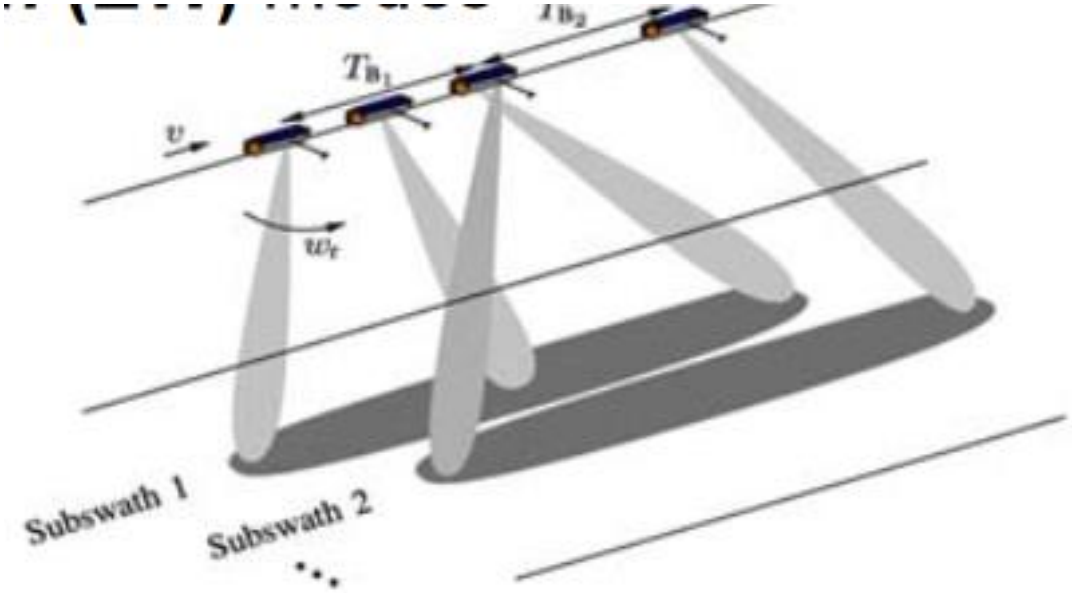
2014+:
Sentinel1A

2016+:
Sentinel1A/B

Image Acquisition in TOPS

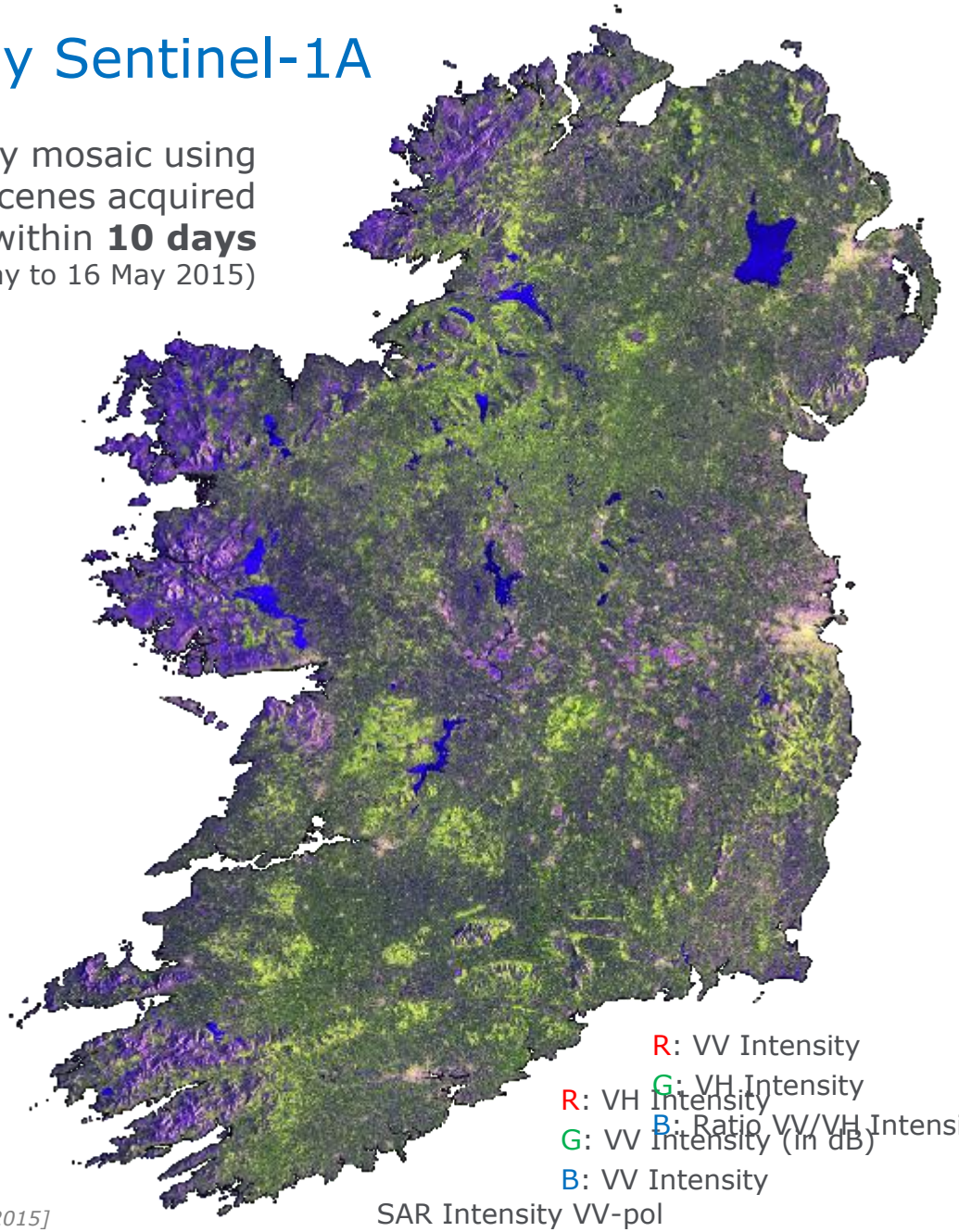
Interferometric Wide Swath mode (IW)

S-1 SAR TOPS Mode for IW and EW
TOPS = Terrain Observation with Progressive Scans in azimuth. Used for Sentinel-1 Interferometric Wide Swath (IW)
and Extended Wide Swath (EW) modes
It provides large swath width (ScanSAR) & and enhanced radiometric performance



Ireland by Sentinel-1A

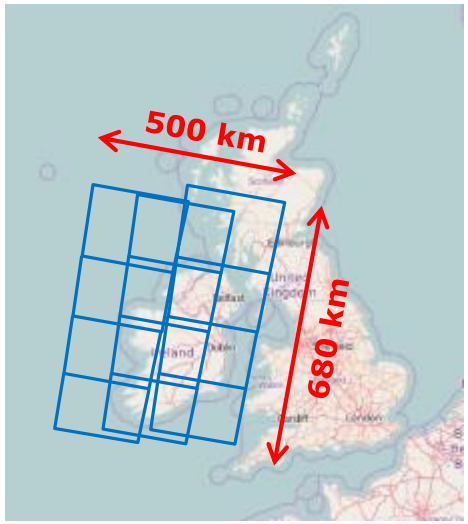
Country mosaic using
12 scenes acquired
within **10 days**
(from 06 May to 16 May 2015)



R: VV Intensity
G: VH Intensity
B: Ratio VV/VH Intensity

R: VH Intensity
G: VV Intensity (in dB)
B: VV Intensity

SAR Intensity VV-pol



Data accessed via the Sentinels Scientific Data Hub (scihub.copernicus.eu)

Processed by SNAP/S1TBX (step.esa.int)

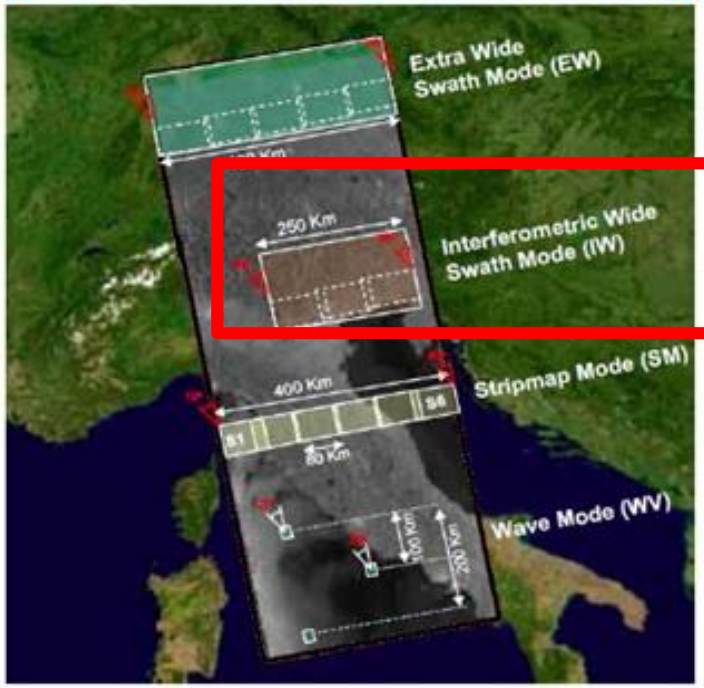
Contains modified Copernicus Sentinel data [2015]

Building Sentinel-1A Mosaic of EUROPE

Europe Mosaic
(R:VH G:VV dB B:VV)
processed by
S1TBX/SNAP

Contains modified Copernicus Sentinel data [2014]

Sentinel-1
SAR Operational Modes

Operational Modes	Resolution	Swath Width	Polarisation
	20 x 40 m²	> 400 km	HH+HV or VV+VH
	5 x 20 m²	> 250 km	HH+HV or VV+VH
	5 x 5 m²	> 80 km	HH+HV or VV+VH
	5 x 5 m²	20 x 20 km² at 100 km spacing	HH or VV

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

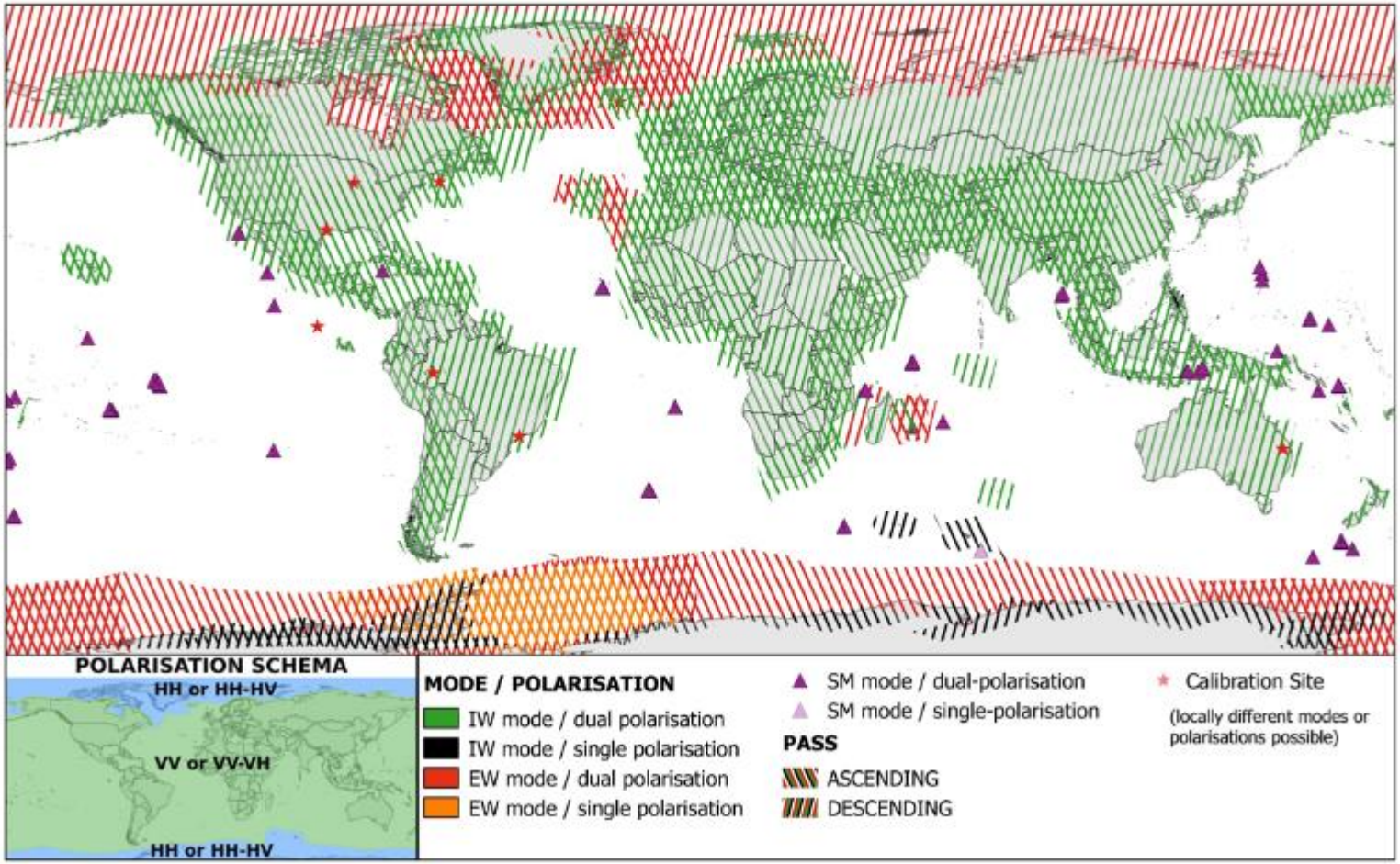
Main modes of operations:

- **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 Constellation Observation Scenario: Mode - Polarisation - Observation Geometry

sentinel-1

validity start: 02/2018



Updated Map

Baseline starting Feb 2018

This map is related to SAR High Rate modes only. Wave mode operated by default over open oceans (not shown)

Sentinel-1
Operational Products available to users

LEVEL-0 PRODUCTS

Compressed, unprocessed instrument source packets, with additional annotations and auxiliary information to support the processing.

LEVEL-1 PRODUCTS

Level-1 Slant-Range Single-Look Complex Products (SLC):

Focused data in slant-range geometry, single look, containing phase and amplitude information.

Level-1 Ground Range Detected Geo-referenced Products (GRD):

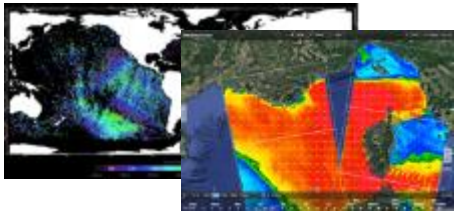
Focused data projected to ground range, detected and multi-looked.
Data is projected to ground range using an Earth ellipsoid model, maintaining the original satellite path direction and including complete geo-reference information.

LEVEL-2 PRODUCTS

Level-2 Ocean products
Ocean wind field, swell wave spectra and surface radial velocity information as derived from SAR data.

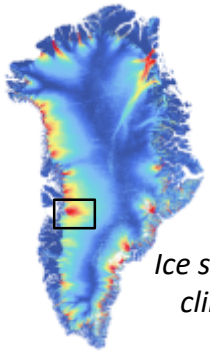
Sentinel-1 applications → ever increasing

Maritime surveillance: oil spill monitoring, ship detection, illegal fisheries, etc.

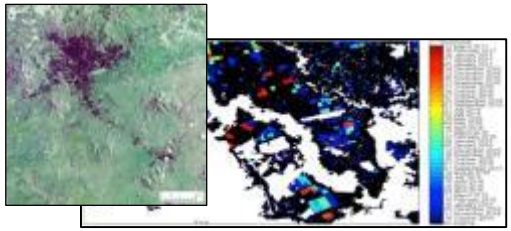


Sea state: wind, wave

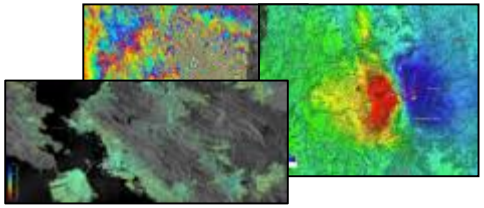
Sea ice and iceberg monitoring



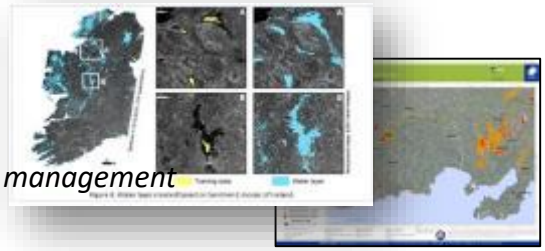
Ice sheets, glaciers, climate change



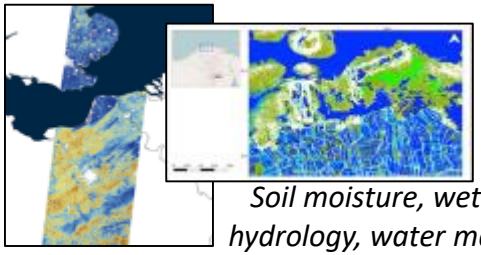
Land use, agriculture, forestry, logging, land classification, urban planning



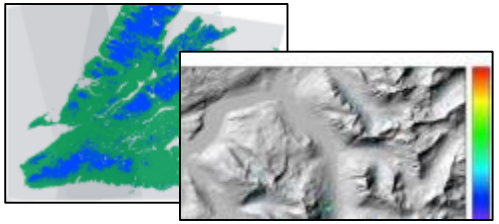
Ground deformation: subsidence, landslides, earthquakes, volcanoes, infrastructure monitoring



Emergency management



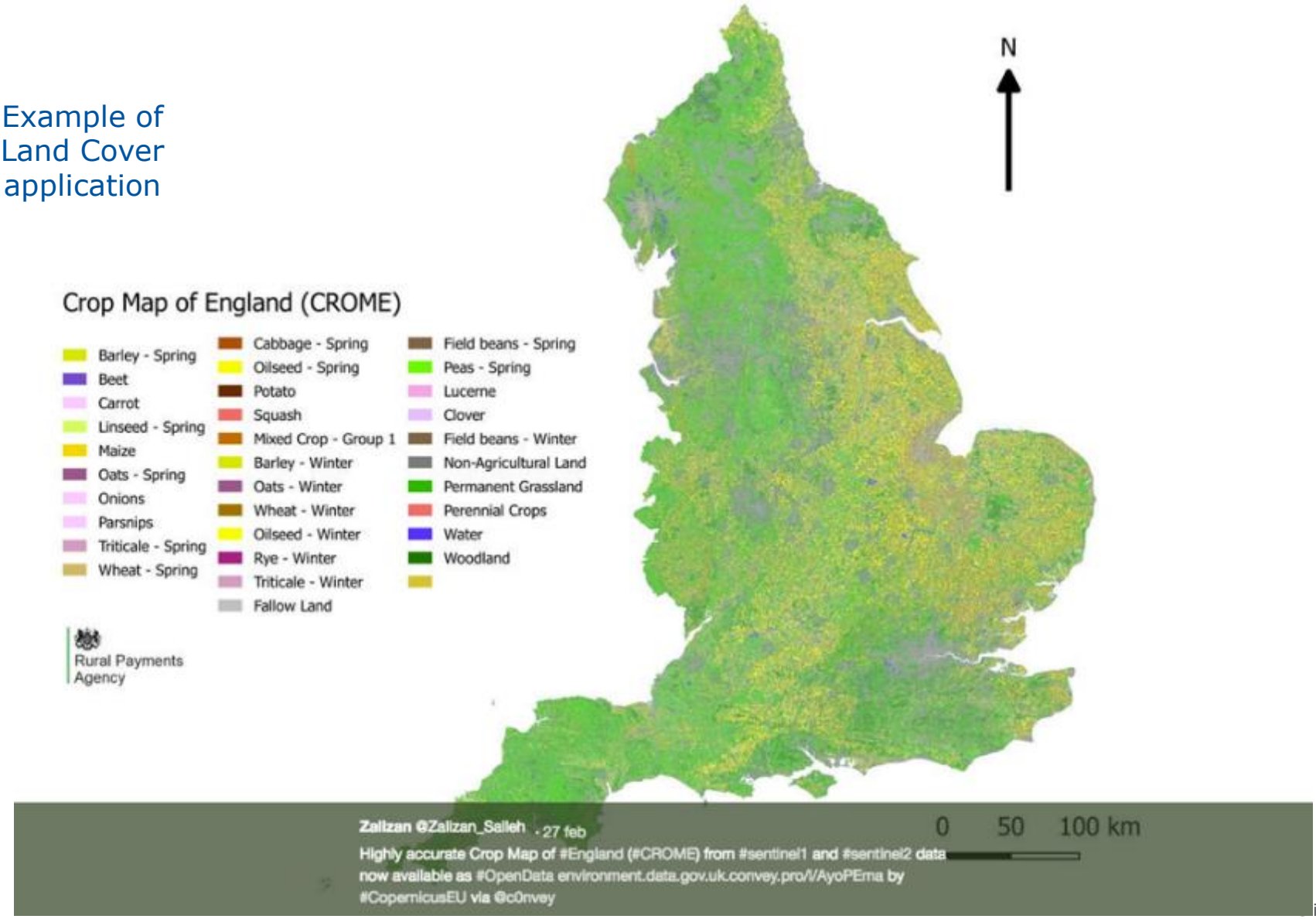
Soil moisture, wetland, hydrology, water mapping



Snow, permafrost, avalanches,…

Example of UK map of crop classification

Example of Land Cover application

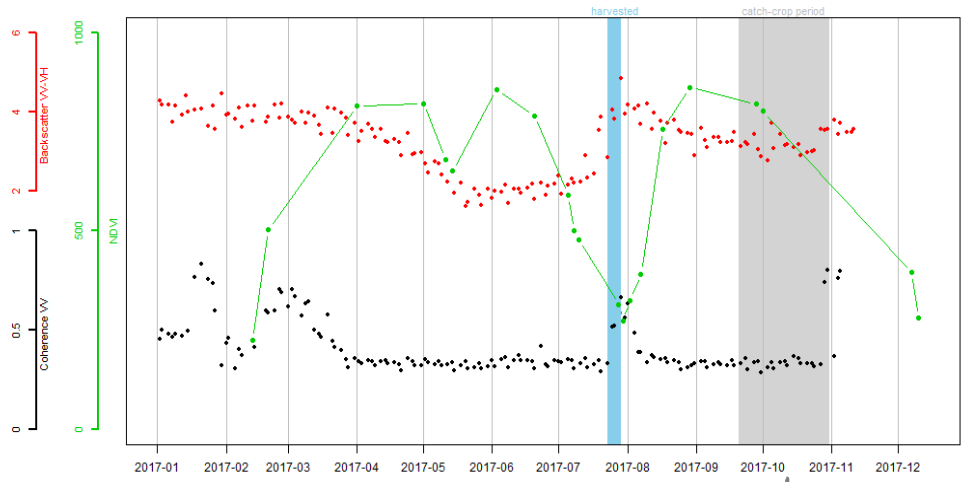


EU Common Agricultural Policy Monitoring
First Evidence of Sentinels Benefit

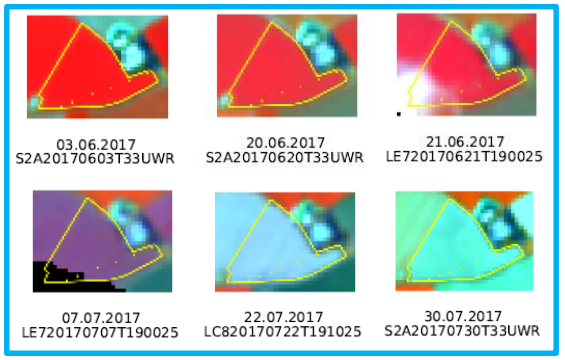
sen4cap common agricultural policy

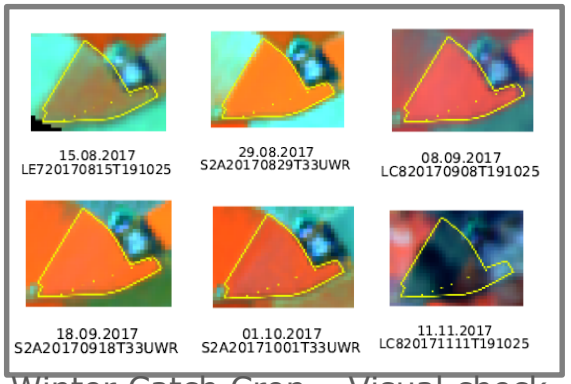
EFA Catch crop assessment – Czech Republic

RULE: Winter Catch Crop must be sown before 20 Sept. and must not be harvested before 31 Oct. During this period, crop coverage must not be mechanically or chemically removed or limited in growth.



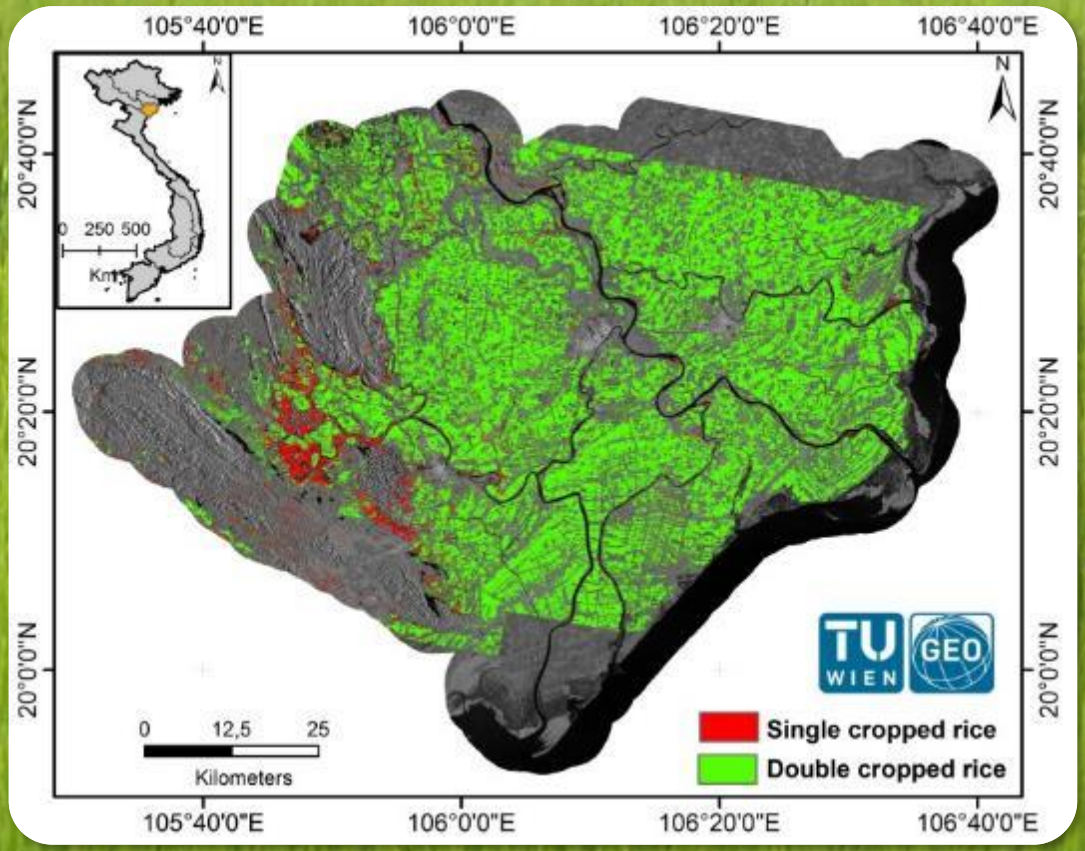
Harvest – Visual check





Winter Catch Crop – Visual check

Monitoring Rice Yields



Duong Delta
Nothern Vietnam

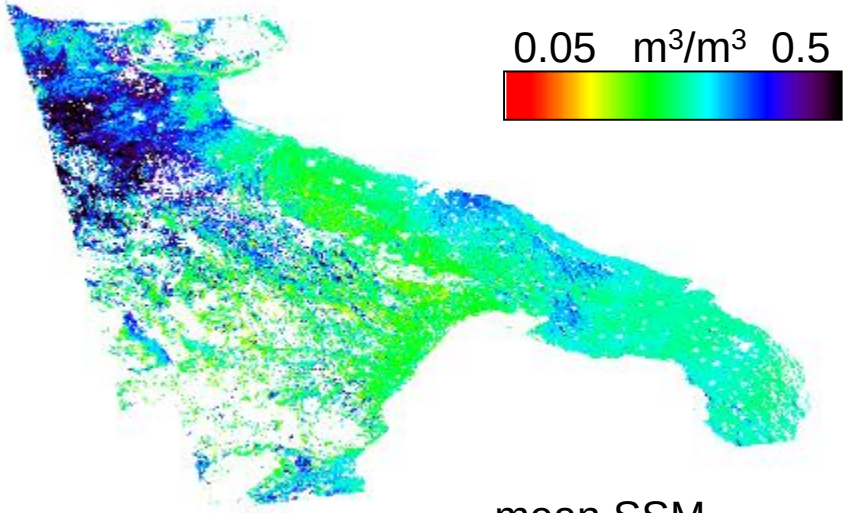
Based on Sentinel-1 Data

Sentinel-1 Surface Soil Moisture

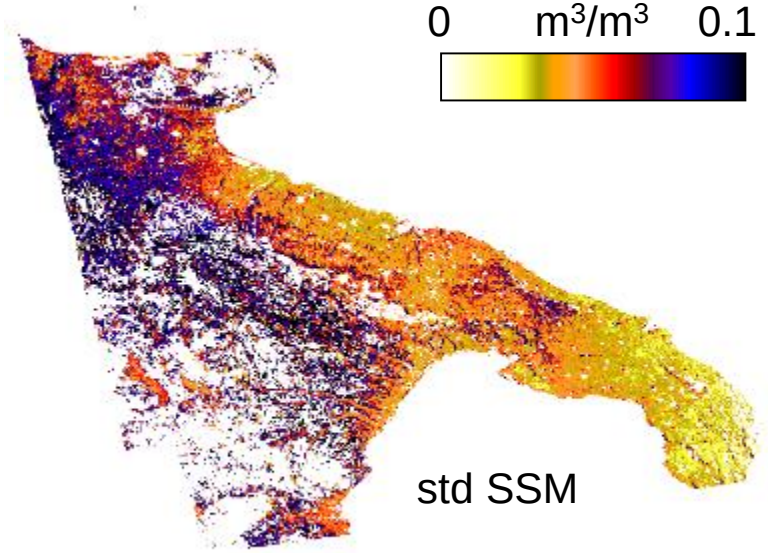
Example of 1km SSM resolution over in Southern Italy

S-1 SSM product includes mean & std at 520m pixels size (≈1 km res)

December 04, 2017



mean SSM

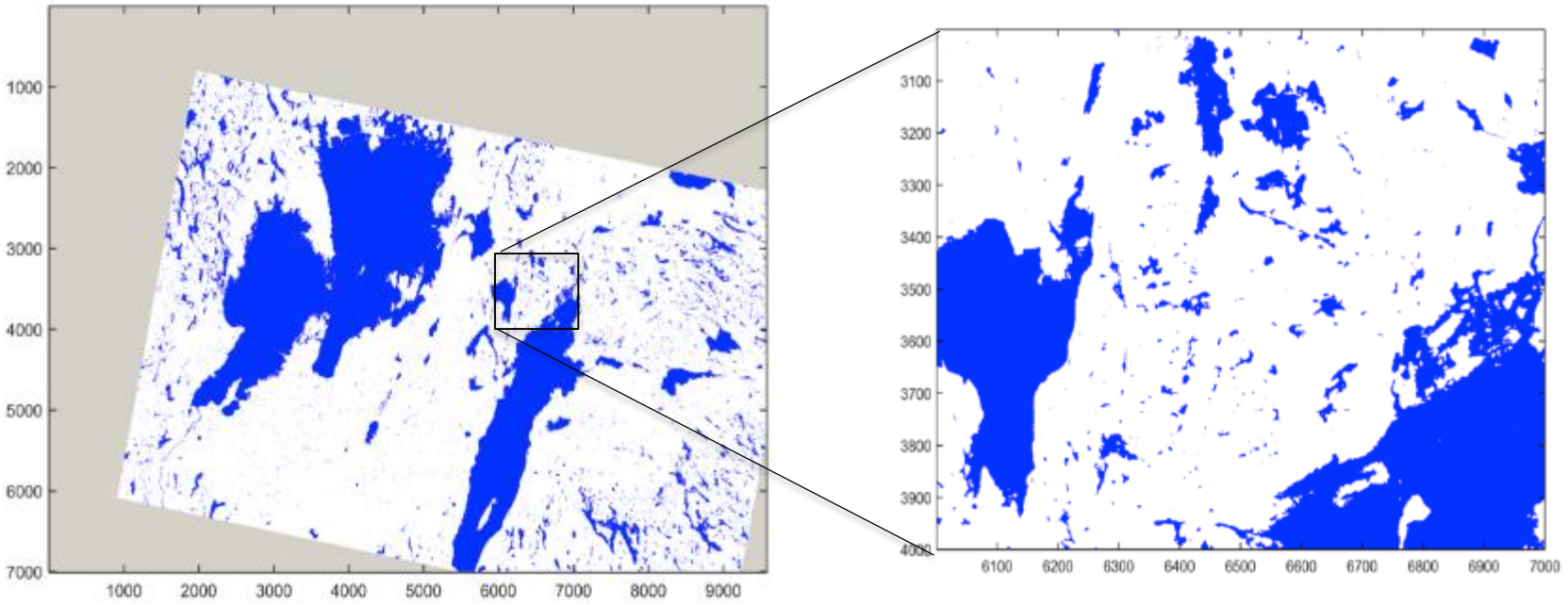


std SSM

Exploit-S-1

Courtesy: Francesco Mattia, CNR - ISSIA

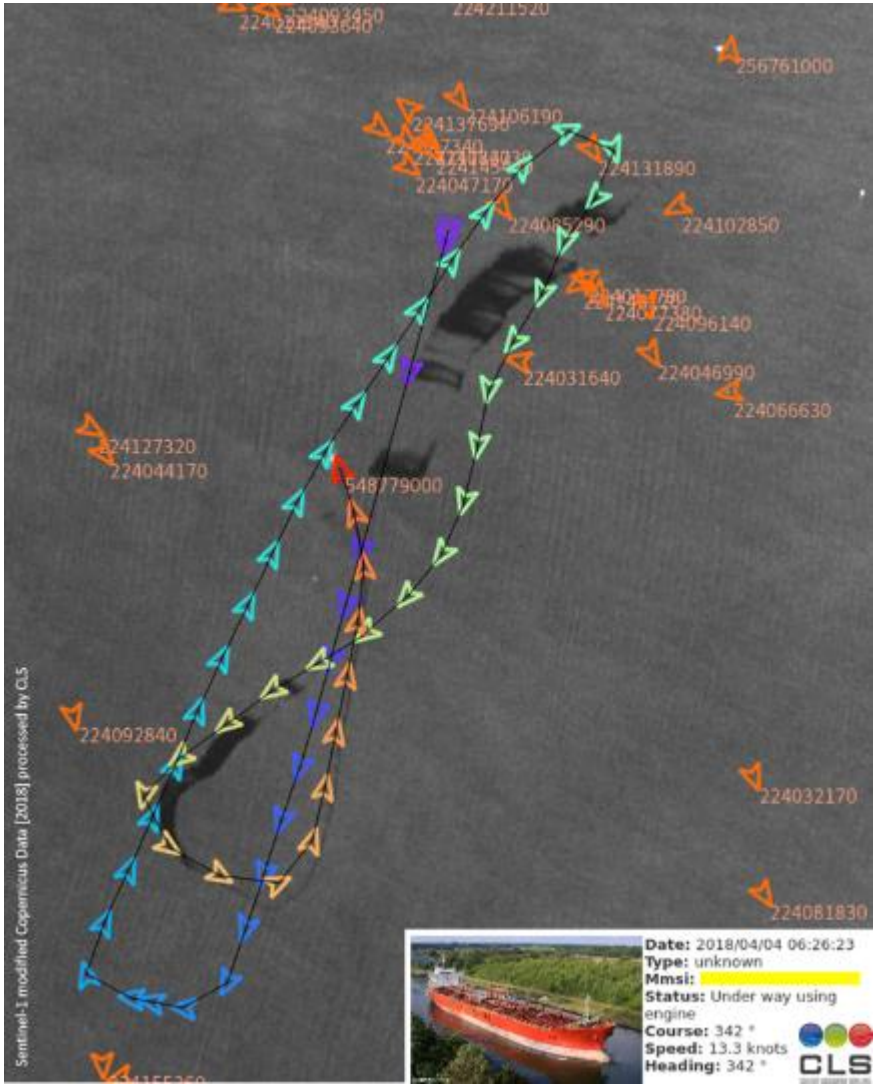
Sentinel-1 water body map of Southern Sweden



Sentinel-1 classification based on average VH-pol backscatter of August 2015 (3 images)

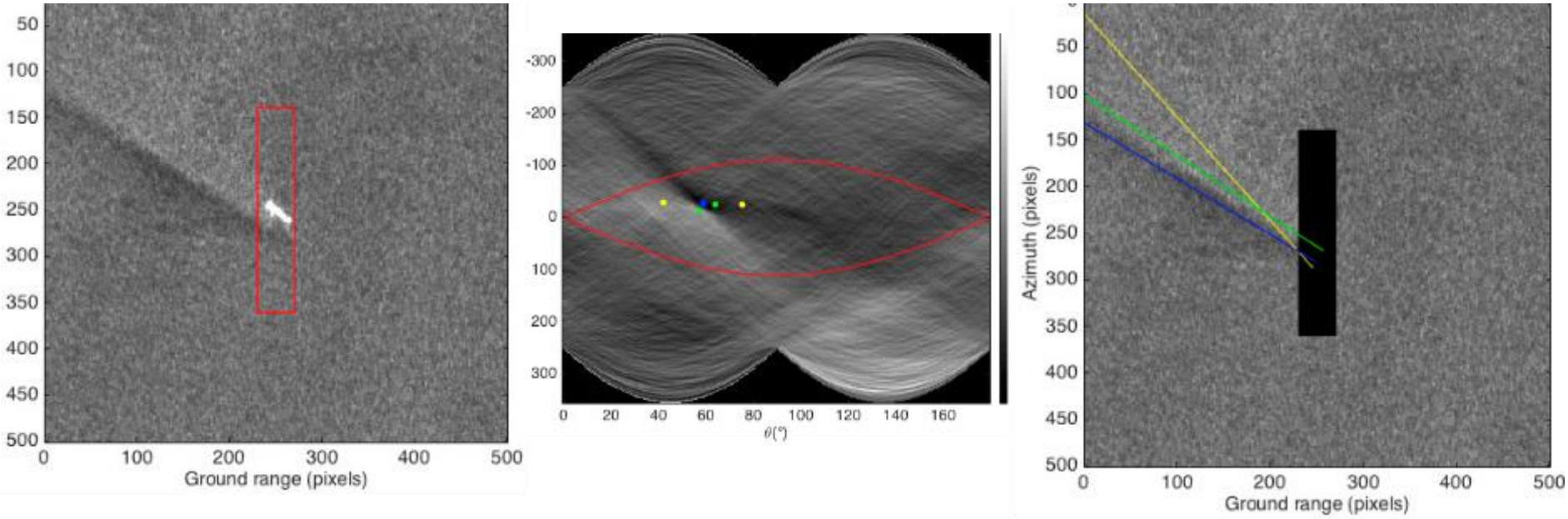
Courtesy: M. Santoro, GAMMA Remote Sensing

Oil spill detected by Sentinel-1B on 4th April 2018 in Spain, Huelva

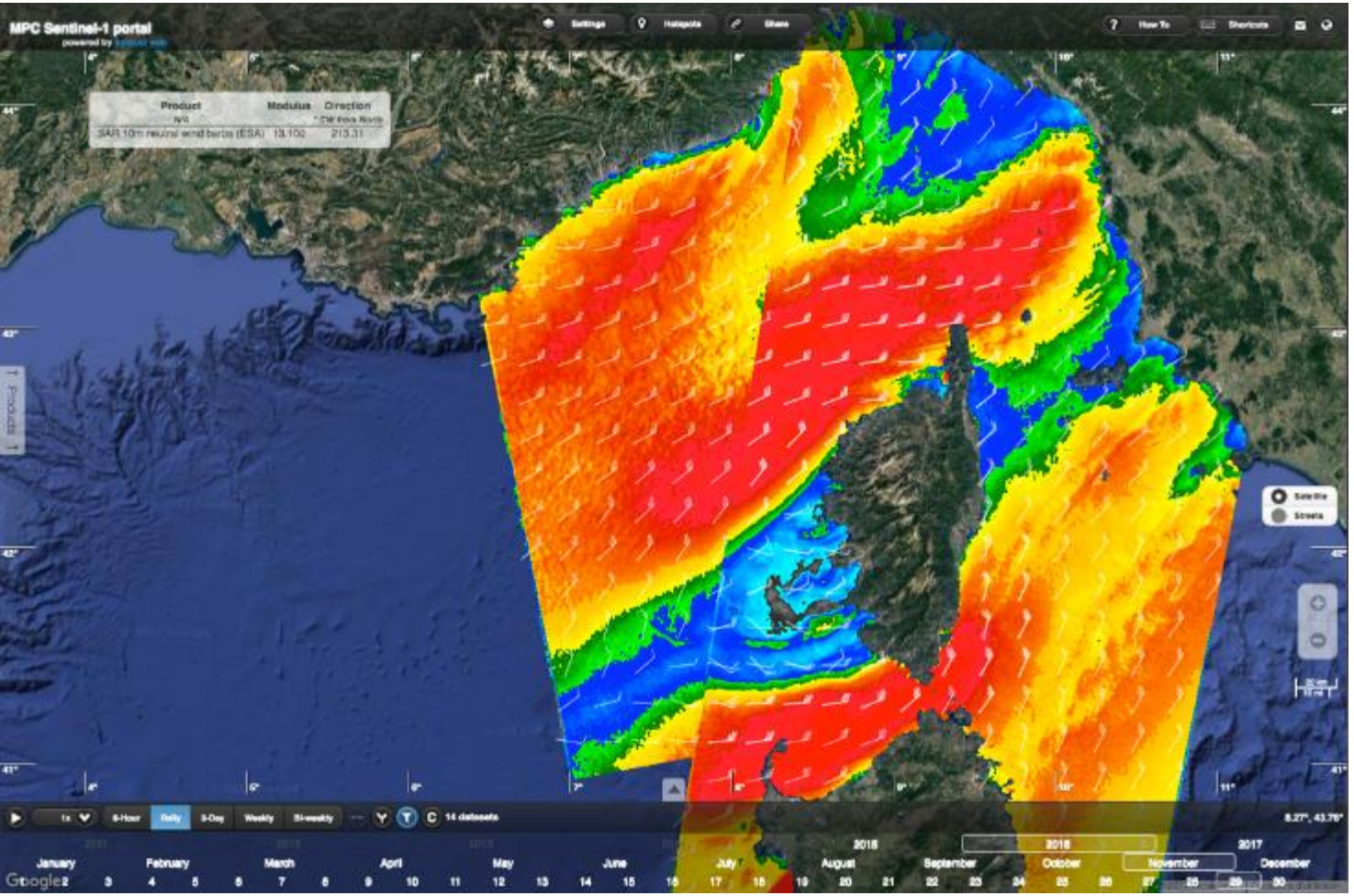


Wake Detection

"The most assessed algorithms for wake detection (Sentinel 1)"



[Graziano et al., 2017]



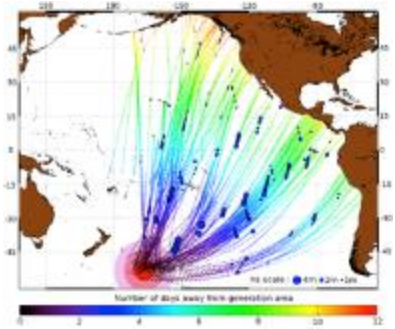
Wind fields

S1A morning pass S1B evening pass

oceandatalab

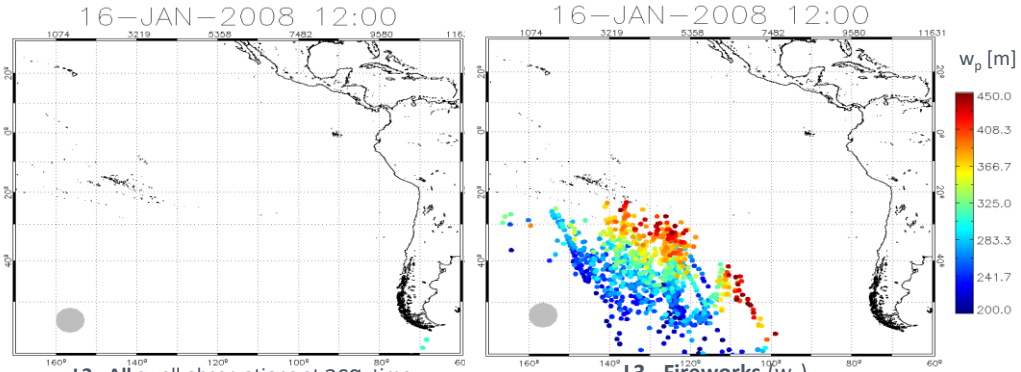
Operational generation of SAR Wave products recently implemented by CMEMS

Systematic generation of Level 3 products since end 2017, derived from the Sentinel-1A/B Level 2 Wave/OCN



SAR-derived swell measurement trajectories from the source to the coast. Measured H_s shown by blue dots

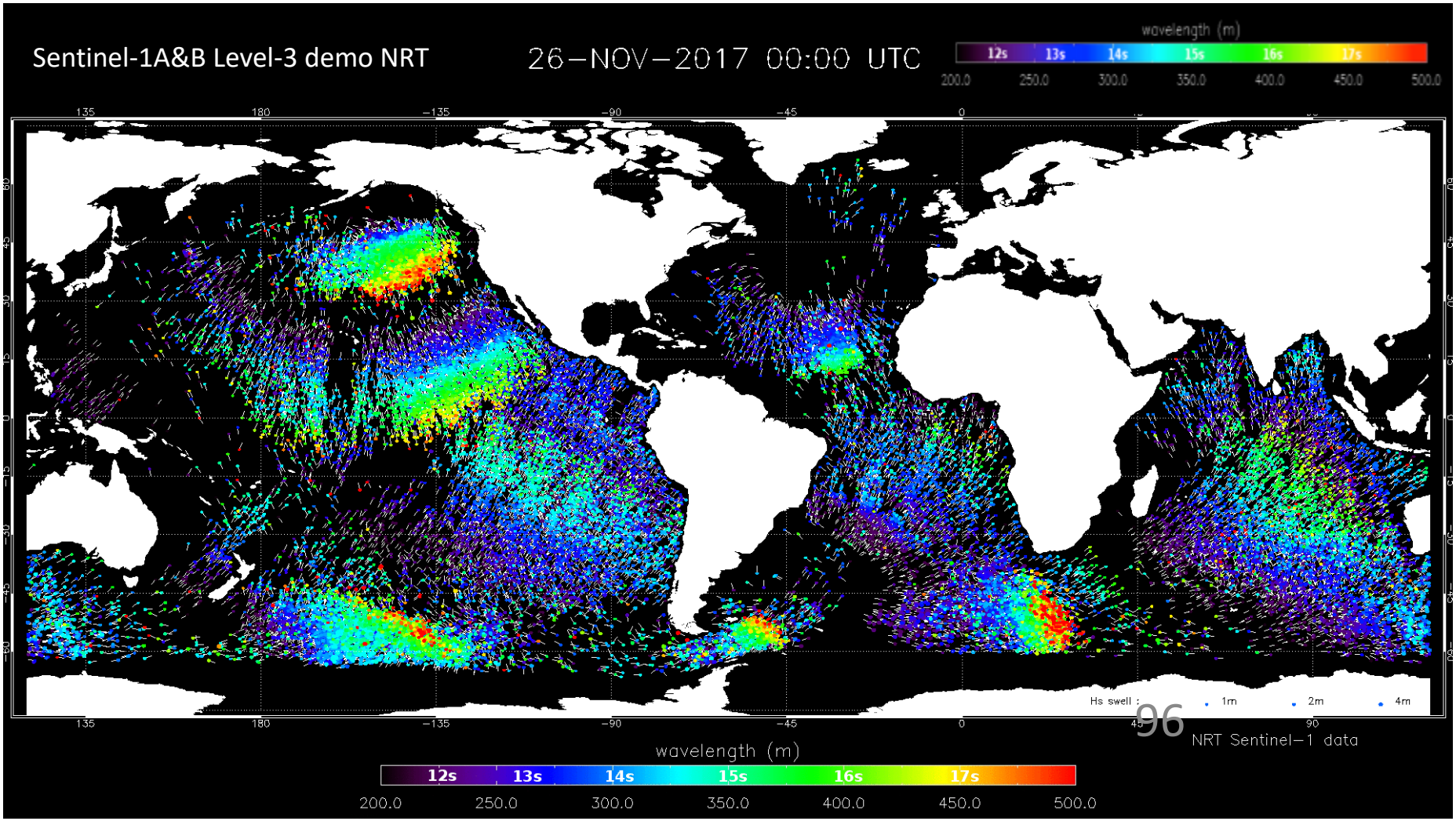
Courtesy:



L2 - All swell observations at acq. time
Heterogeneous in quality/space/time – poor sampling

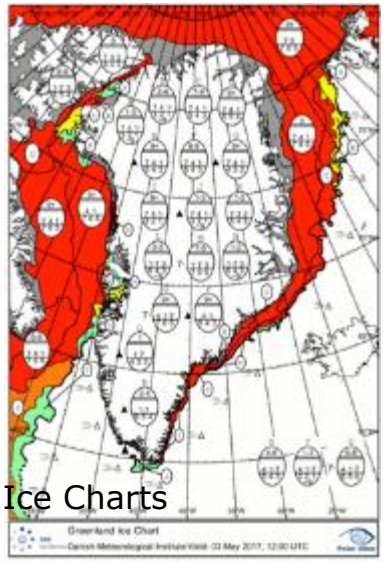
L3 - Fireworks (w_p)
Heterogeneous in quality/space/time

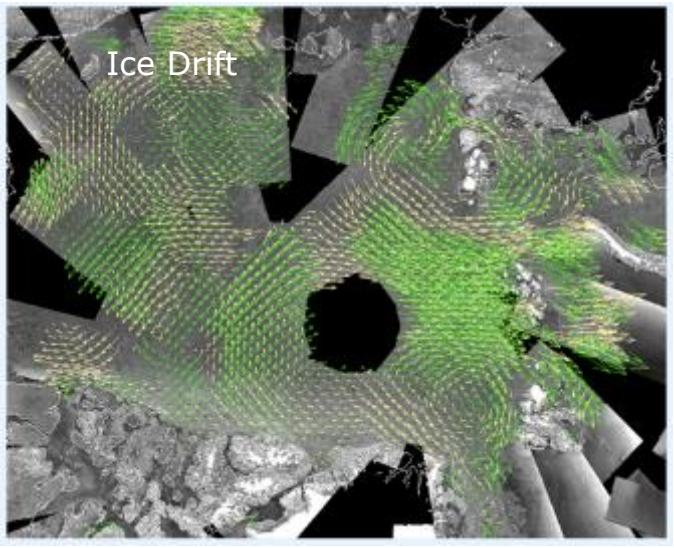
CMEMS Waves product content from SAR



Operational support to the Copernicus Marine Environment Monitoring Service (CMEMS) on-going, since start of Sentinel-1A operations

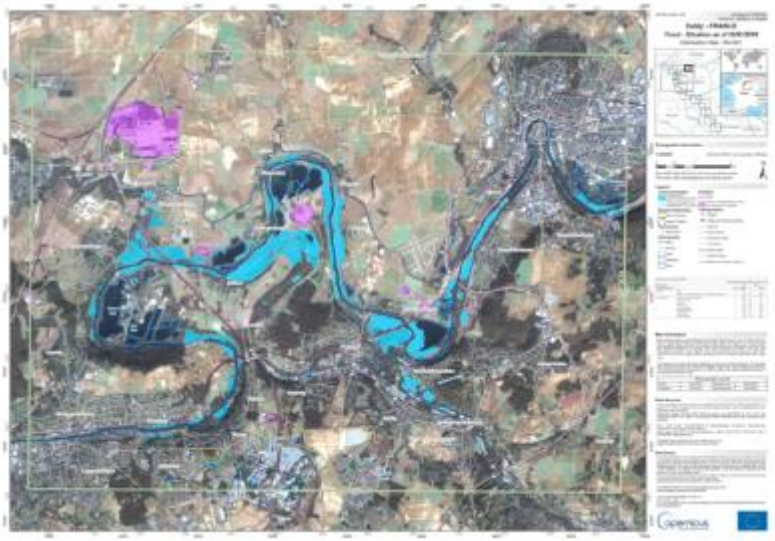
3-day Mosaic 2-3-4 June 2018
http://www.seaice.dk/

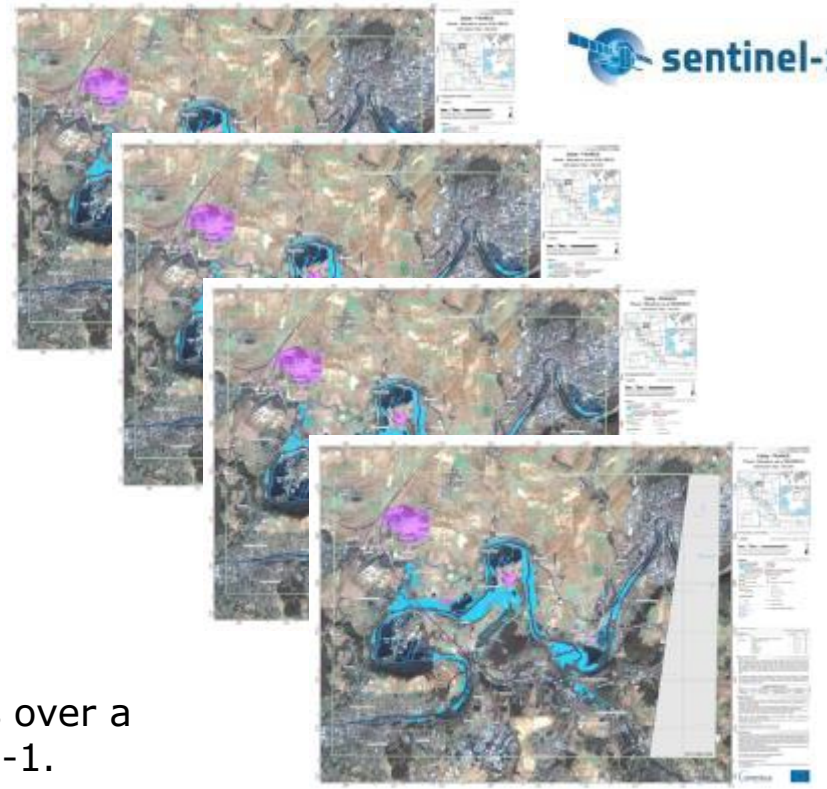




Strong increase of the Sentinel-1 contribution to the Copernicus Emergency Management Service

Example of Sentinel-1A/-1B contribution to the exceptional floods that occurred in Jan/Feb 2018 in Northern France

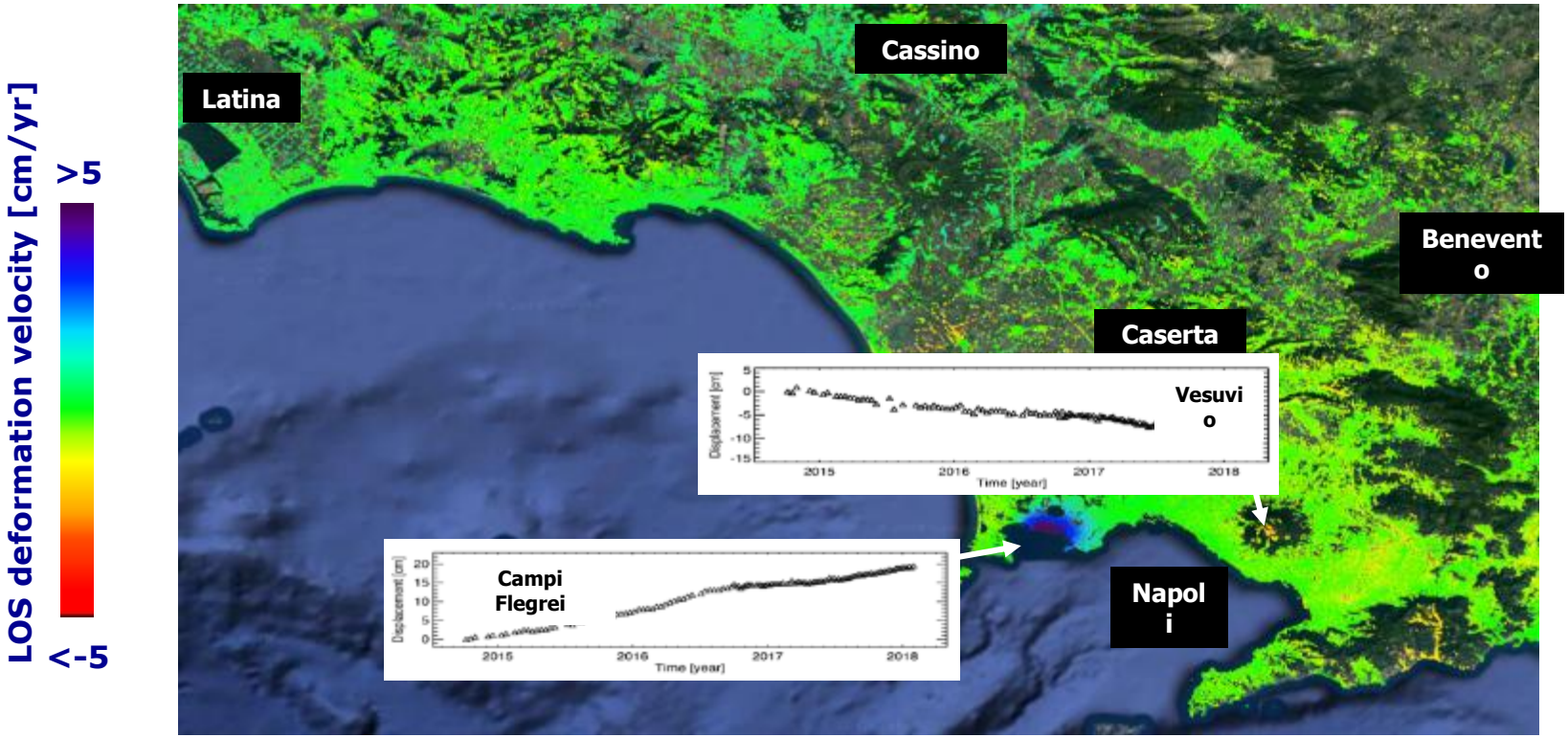




Same area (here Esbly) could be imaged several times over a long period thanks to the systematic revisit of Sentinel-1.

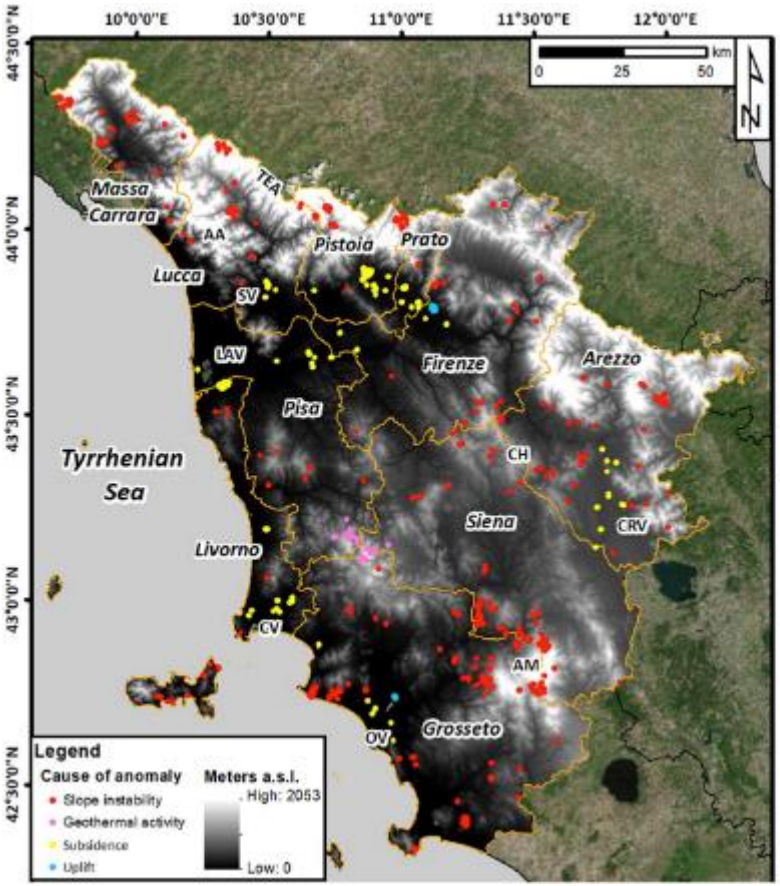
© Contains modified Copernicus Service information [2018], processed by CEMS

SBAS-DInSAR analysis: Sentinel-1 regional scale



IW Sentinel-1: 131 SAR images (October 2014-January 2018)

Routine use of Sentinel-1 time series for ground deformation – Tuscany



Update	Last acquisition (track 117)	# of Anomalies	# of ghost anomalies
2	07/11/2016	70	133
3	19/11/2016	90	104
4	01/12/2016	60	72
5	13/12/2016	95	76
6	25/12/2016	121	86
7	06/01/2017	130	55
8	18/01/2017	84	57
9	30/01/2017	94	86
10	11/02/2017	195	154
11	23/02/2017	304	86
12	07/03/2017	341	56
13	19/03/2017	803	109
14	31/03/2017	1.233	83
15	12/04/2017	1.024	68
16	24/04/2017	907	57
17	06/05/2017	2.314	174
18	18/05/2017	2.119	497
19	30/05/2017	2.034	642
Total	07/11/2016 - 30/05/2017	12.018	2.597

Province	Area (km²)	Total anomalies	Anomalies/10 km²			
			Slope instability	Subsidence	Uplift	Geothermal activity
Massa Carrara	1.158	79	0.68	0	0	0
Lucca	177	75	3.56	0.68	0	0
Pistoia	966	8.001	1.12	81.71	0	0
Prato	365	997	0.14	27.18	0	0
Firenze	3.520	103	0.25	0.01	0.03	0
Pisa	2.451	52	0.09	0.07	0	0.05
Livorno	1.218	71	0.24	0.34	0	0
Siena	3.820	618	1.40	0	0	0.01
Arezzo	3.235	338	0.80	0.15	0	0
Grosseto	4.510	1.684	2.43	0.04	1.25	0.02
Tuscany	21.412	12.018	1.12	4.21	0.27	0.01

TS **anomalies** classified according to the driving force as at Update #19. Anomalies related to **slope instabilities** are widespread in most of the mountain areas of the region. Anomalies related to **subsidence phenomena** are identified in the alluvial plains, along with two **uplifting areas** within the province of Grosseto and Firenze. Anomalies linked to **geothermal activities** straddle the provinces of Pisa, Siena and Grosseto.

TEA (Tuscan-Emilian Apennines); AA (Apuan Alps); SV (Serchio Valley); LAV (Lower Arno Valley); CH (Chianti Hills); CRV (Chiana River valley); AM (Amiata Mountain); CV (Cornia Valley); OV (Ombrone Valley).

University of Firenze,
TRE ALTAMIRA
University of Pisa

Results from UK wide ground motion map based on Sentinel-1 data

https://www.telegraph.co.uk/science/2018/04/12/devon-village-rising-2cm-year-scientists-have-no-idea/


The Telegraph

HOME | NEWS | SPORT | BUSINESS | ALL SECTIONS

News | Science

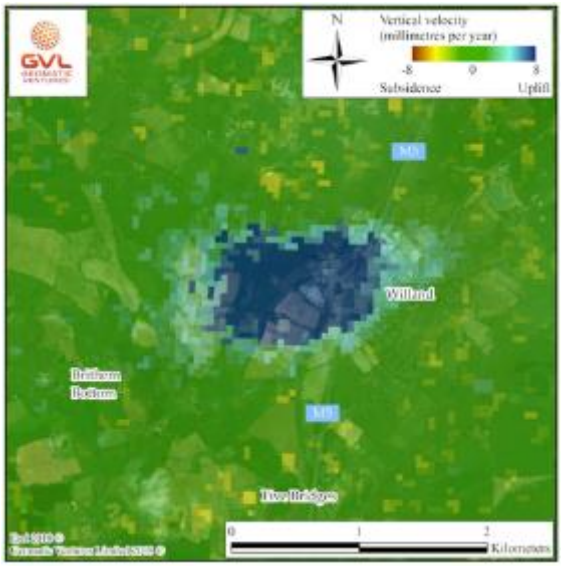
News · Science

Devon village is rising 2cm a year, and scientists have no idea why

FOLLOW THE TELEGRAPH

[The map] "*offers the most detailed look ever at the UK's shifting topography and highlights areas of hazards due to coal mining, soil compaction, landslides, coastal erosion, landfill subsidence and tunnelling for the London Underground*."

Dr Stephen Grebby, Assistant Professor in Earth Observation, at Nottingham University said, "***With the new map we are able to better understand how the entire UK landscape is being affected by various natural and anthropogenic processes. Whilst providing us with detailed information to study the individual mechanisms of these processes, the technique also offers a means of identifying and mitigating any potential risk that these may also pose to infrastructure, society and the environment***."

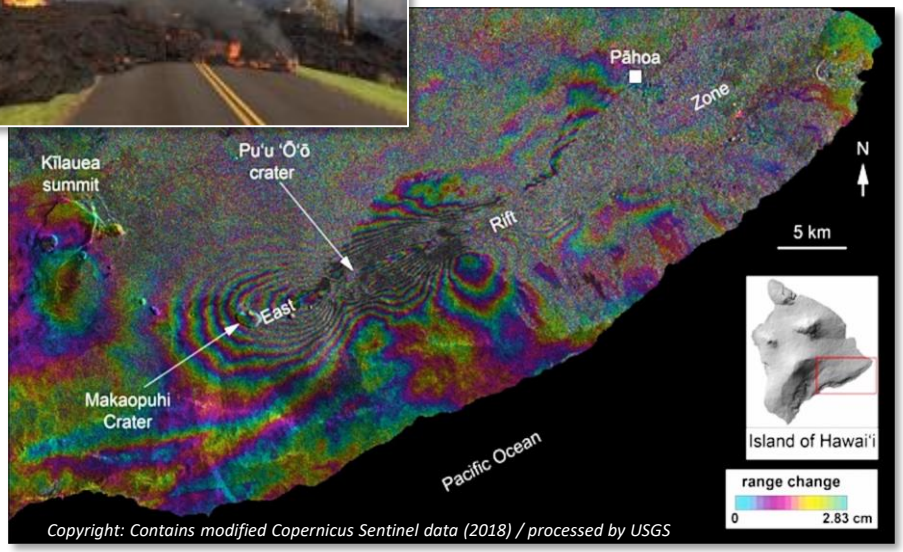


The area of Willand which is rising up Credit: GVL

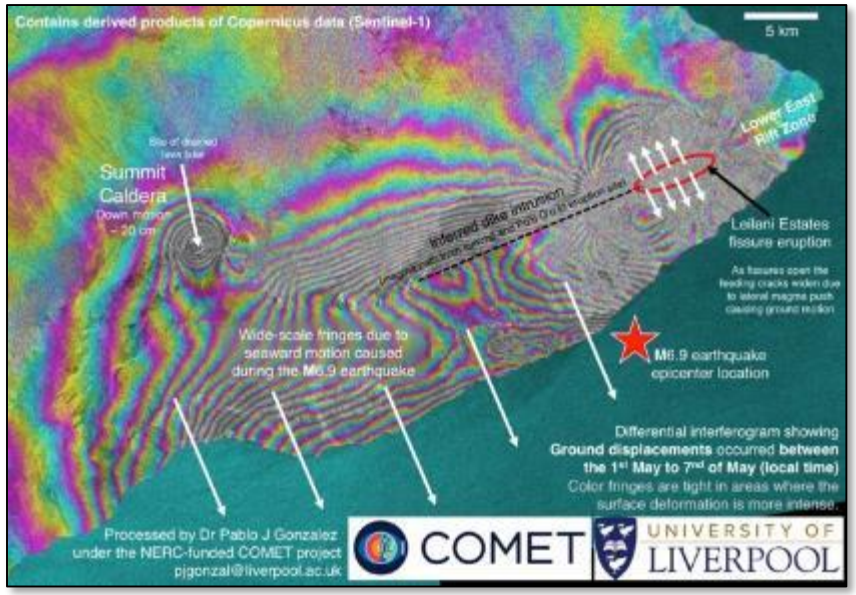
The team hope the map will be useful for policymakers and a wide range of industries, including onshore oil and gas, civil engineering, insurance, mining and carbon trading.

Sentinel-1: a major tool for geophysicists

Eruption and earthquake near Kilauea volcano, Hawaii (3 May 2018)



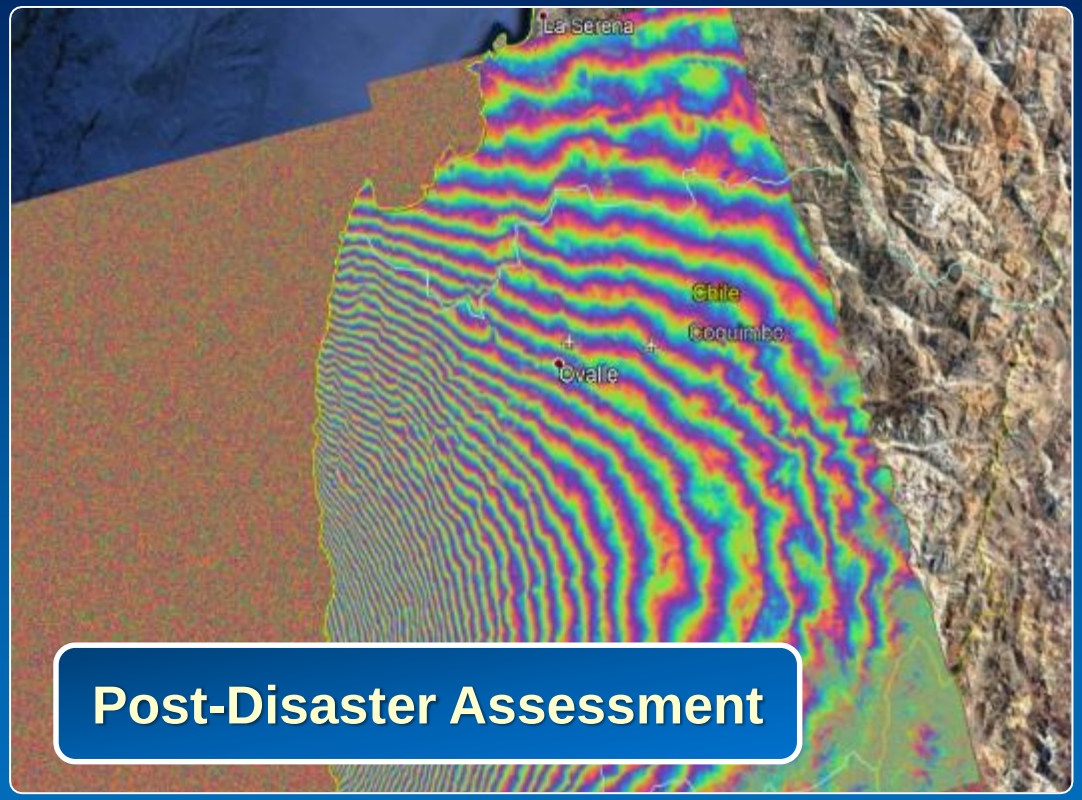
*Sentinel-1 interferogram (19 April – **1 May 2018**)*



*Sentinel-1 interferogram (**1 May – 7 May 2018**)*

Deformation due to magmatic intrusion → magma withdrawn from middle East Rift Zone and intruded beneath lower East Rift Zone.

Earthquake Ground Deformation in Chile



Post-Disaster Assessment

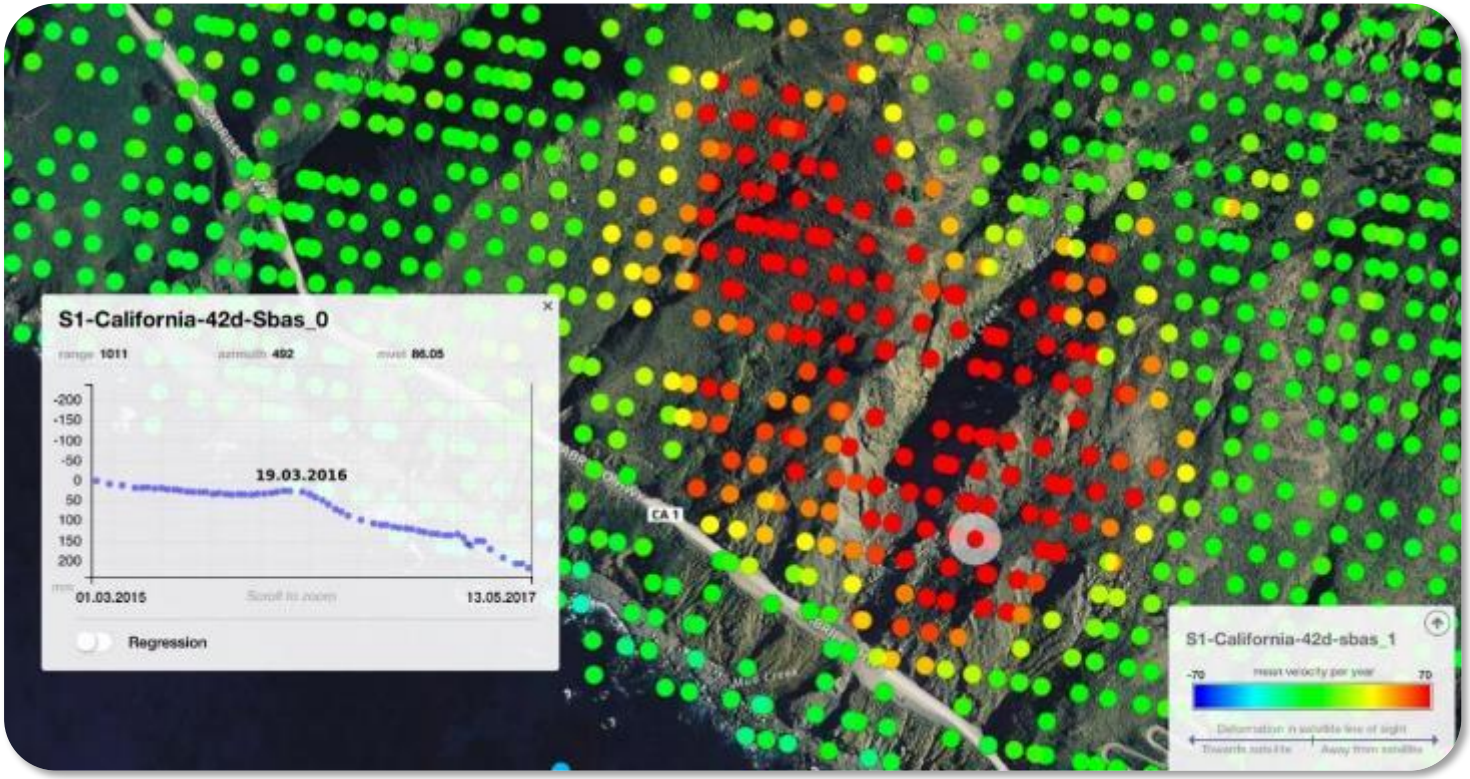
2015 Earthquake in the Chilean Nazca Plate region

Interferogram superimposed over optical image

ESA co-organises EO data processing capacity-building in Latin America

Data used: Sentinel-1 (C-band) Wrapped interferometric phase. To be complemented with ALOS-1/PALSAR-1 (L-band), TerraSAR-X (X-band) and Cosmo SkyMed (X-band)

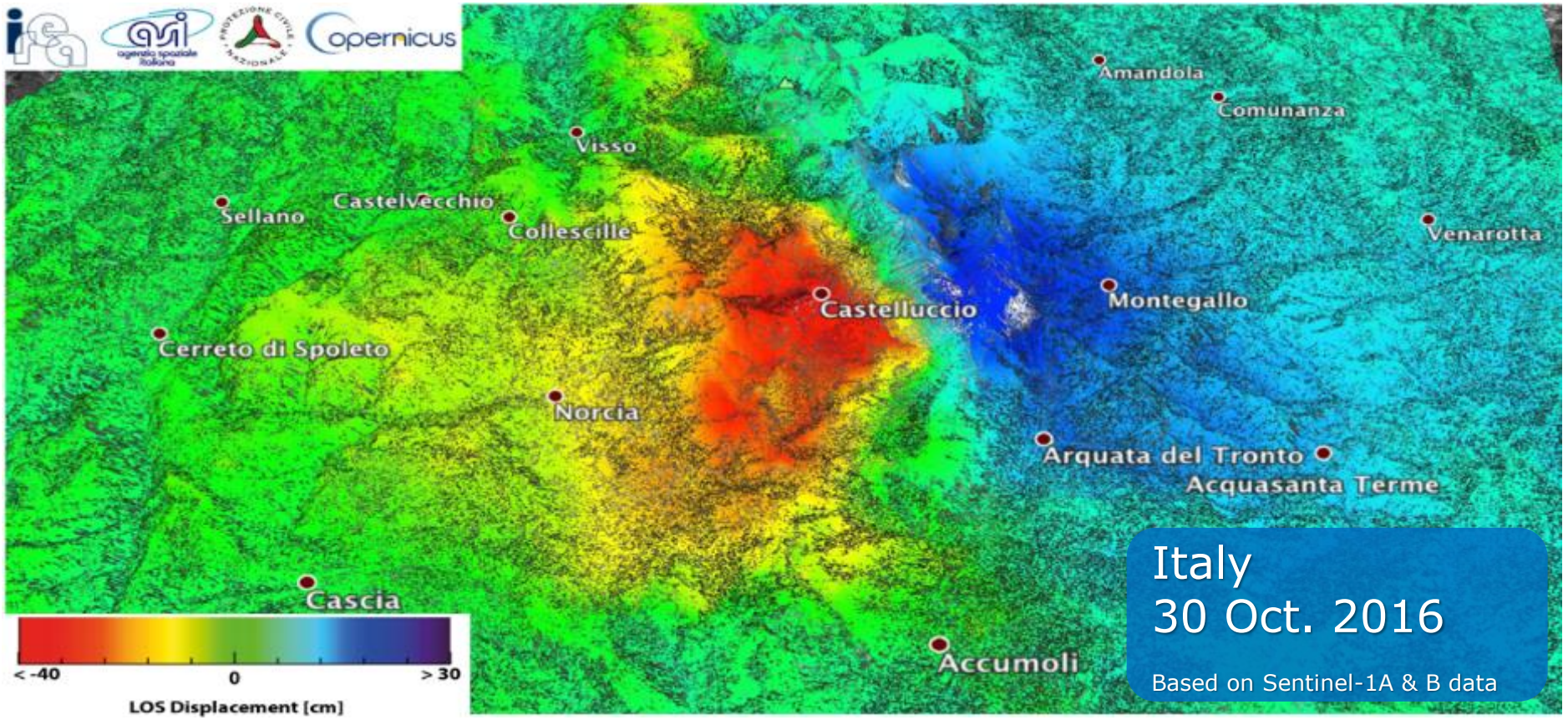
Landslides



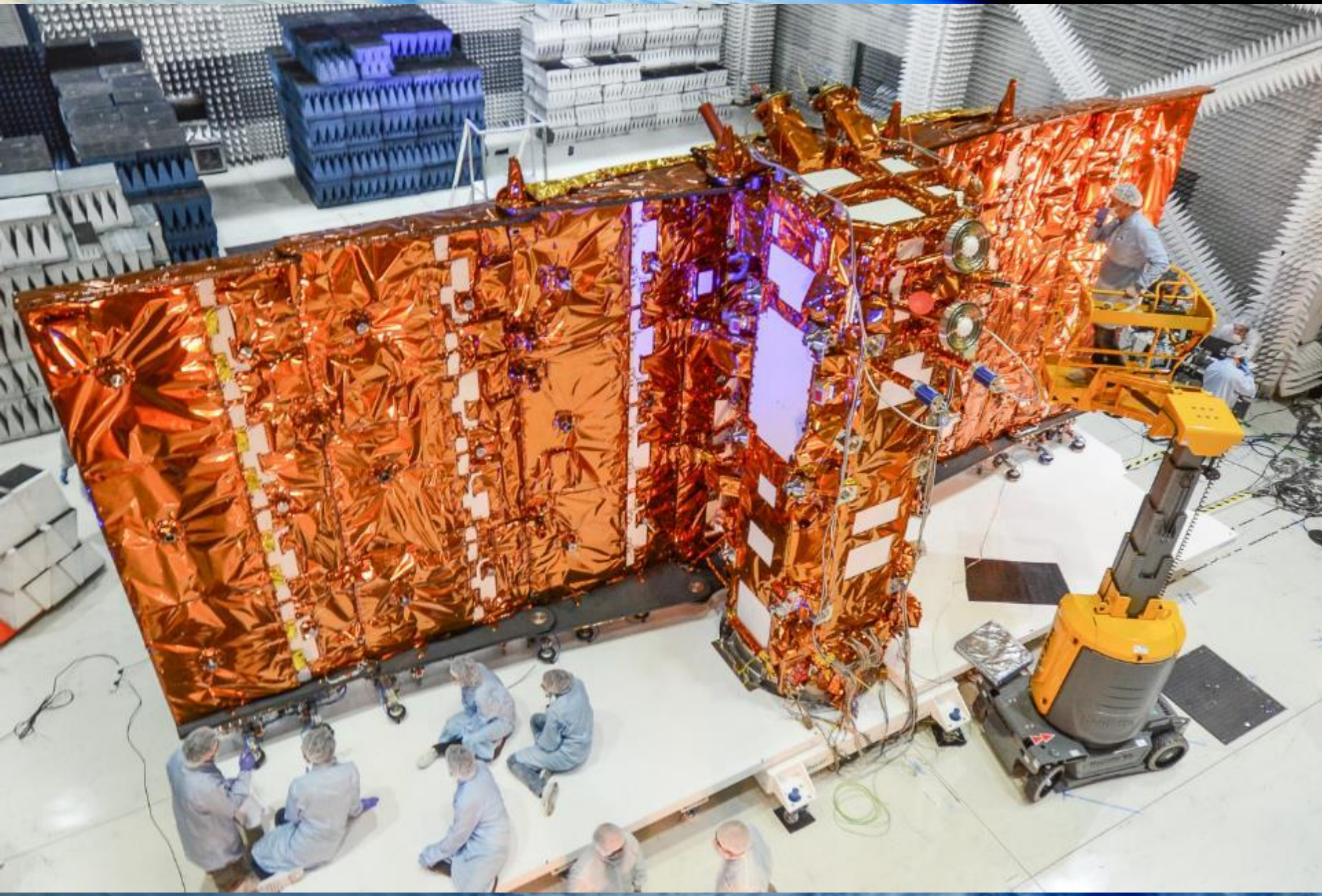
Highway 1
California
U.S.

Based on Sentinel-1 data (2015–17), processed by Norut

Earthquakes



SAOCOM 1A L-Band (launch 10/2018)



Additional SAR Applications

Ice Monitoring

Antarctica April 2005

Collision of B-15A iceberg with Drygalski ice tongue

Ross Sea

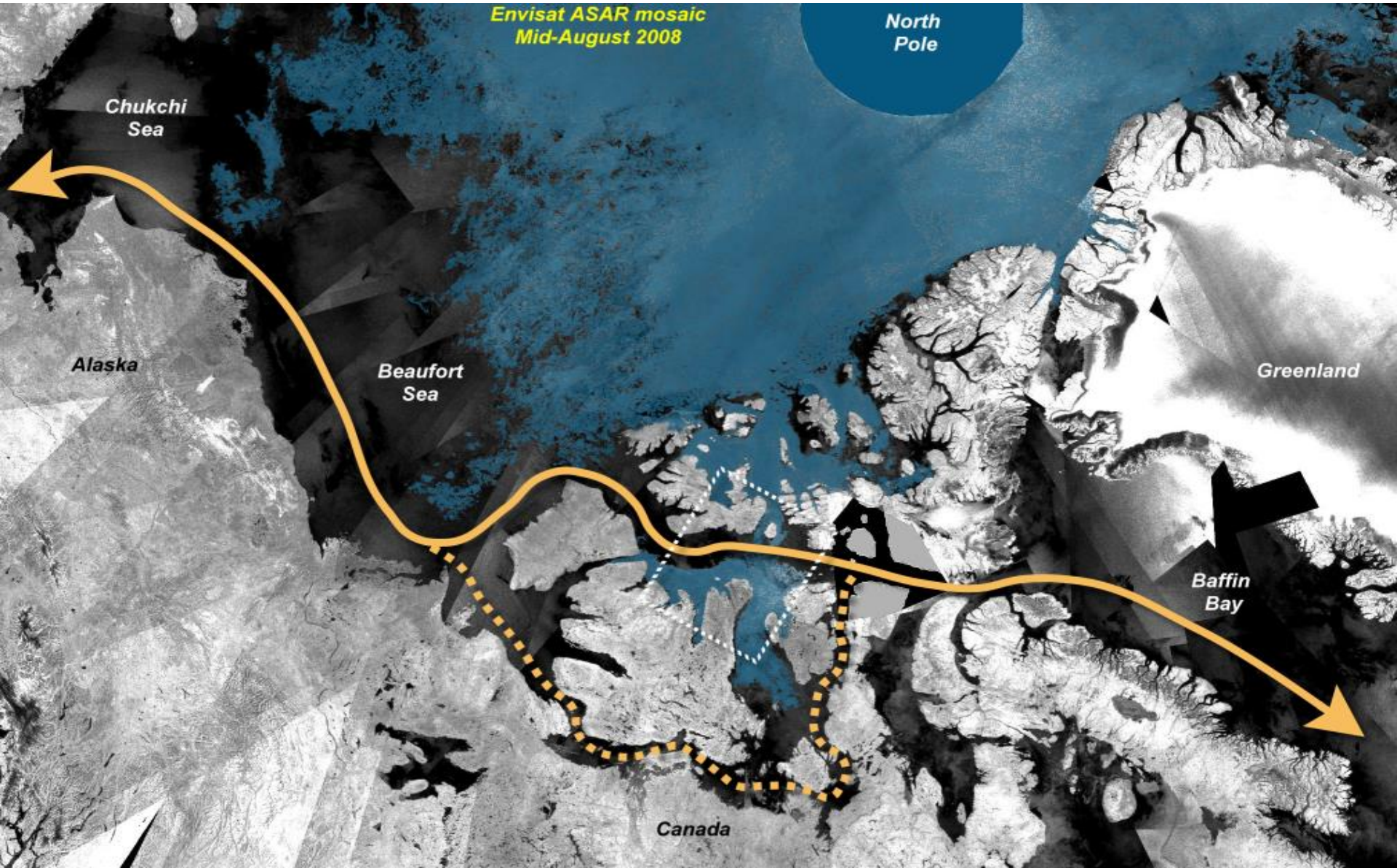
B-15A iceberg

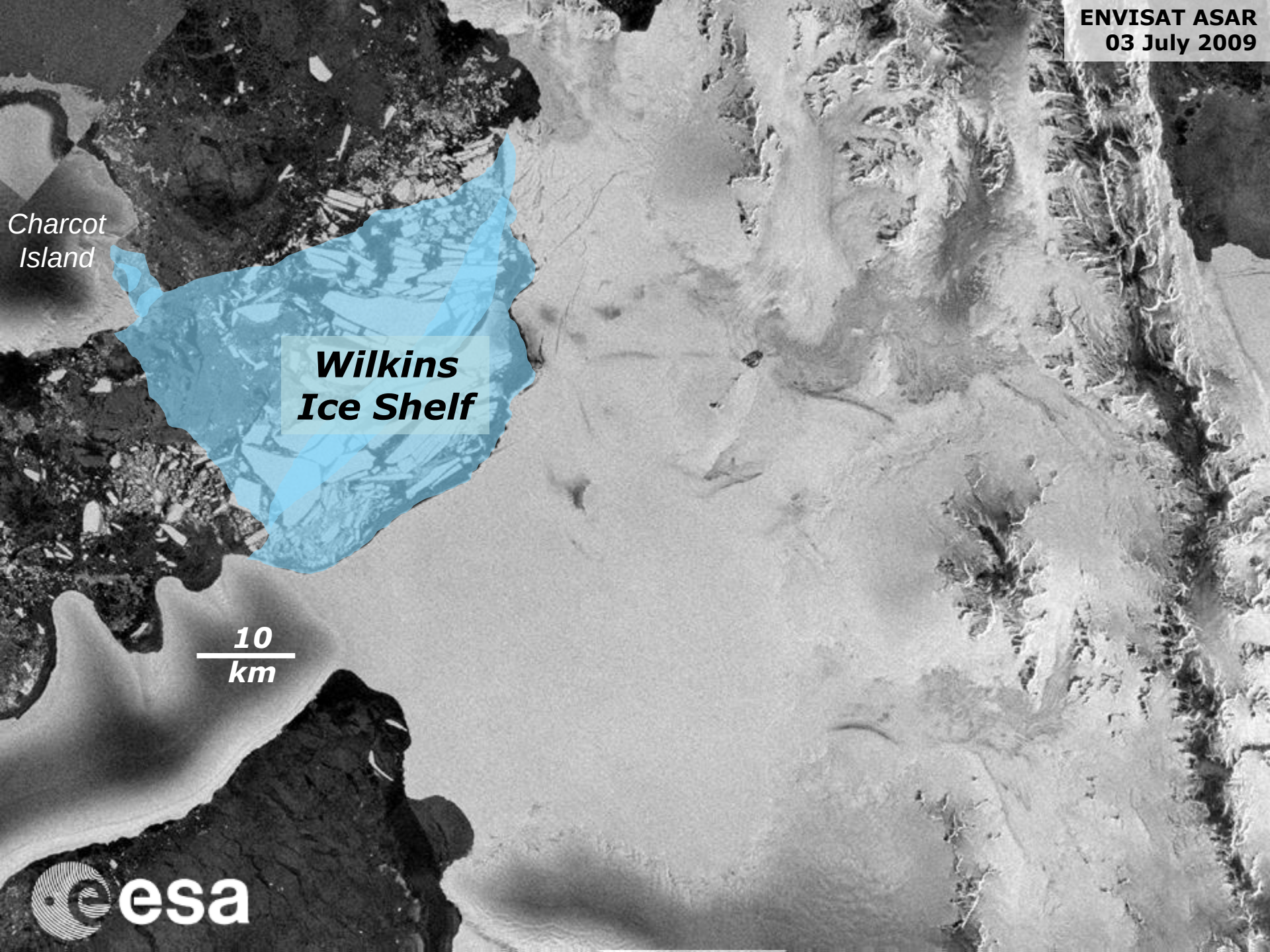
Drygalski ice tongue

4 Apr

100 km

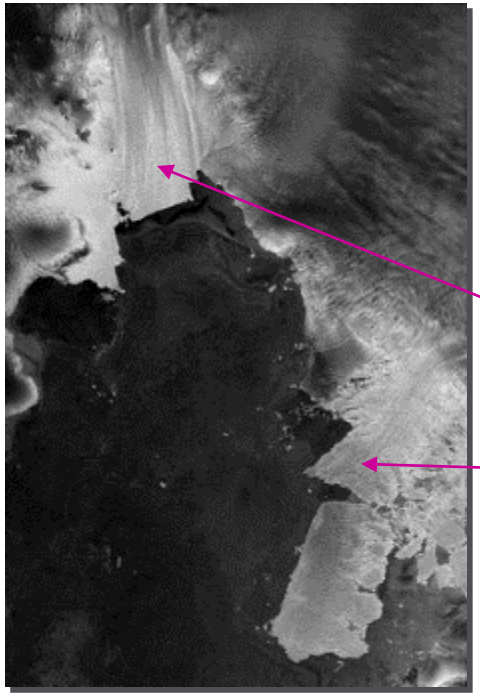
Ship Routing Support

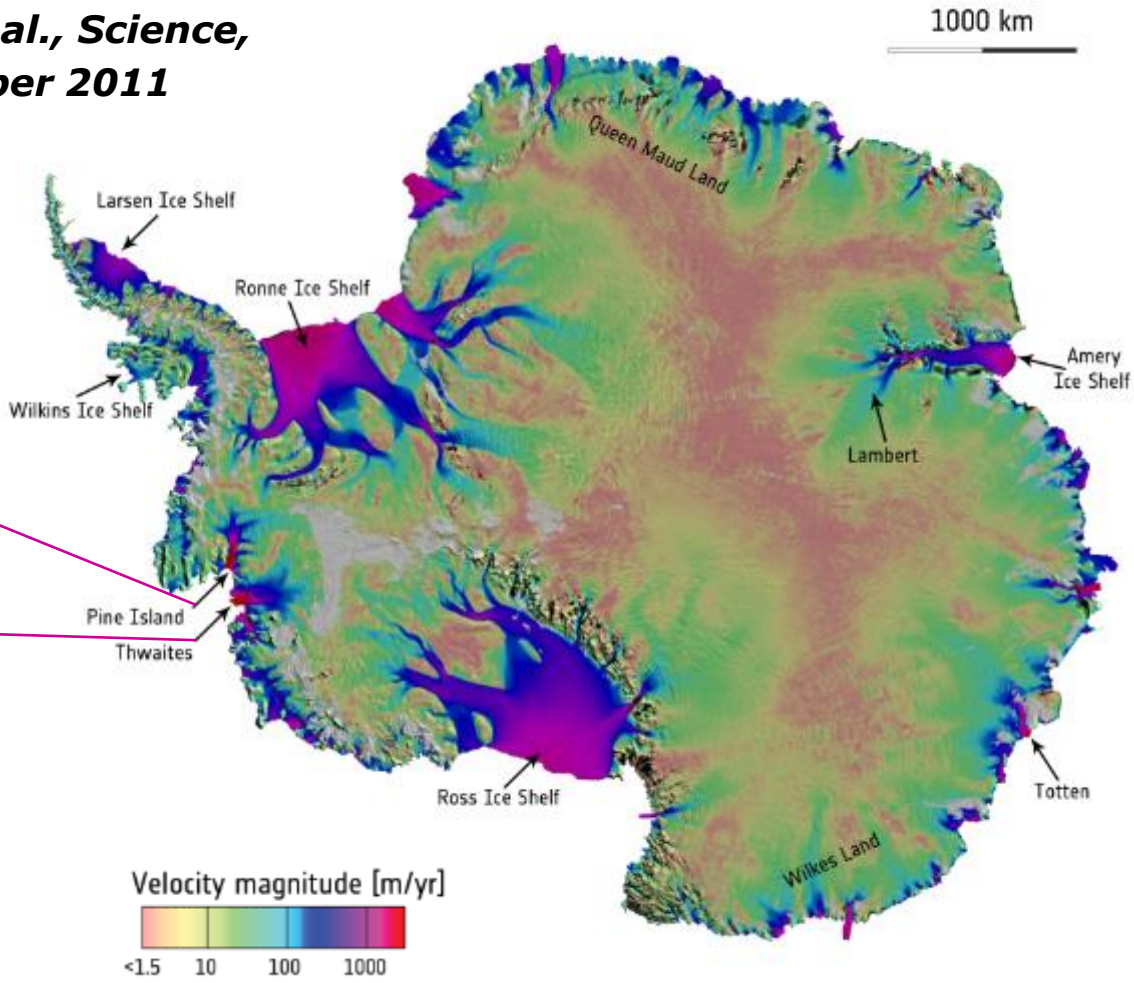



ENVISAT ASAR
03 July 2009
Charcot
Island
Wilkins
Ice Shelf
10
km
esa

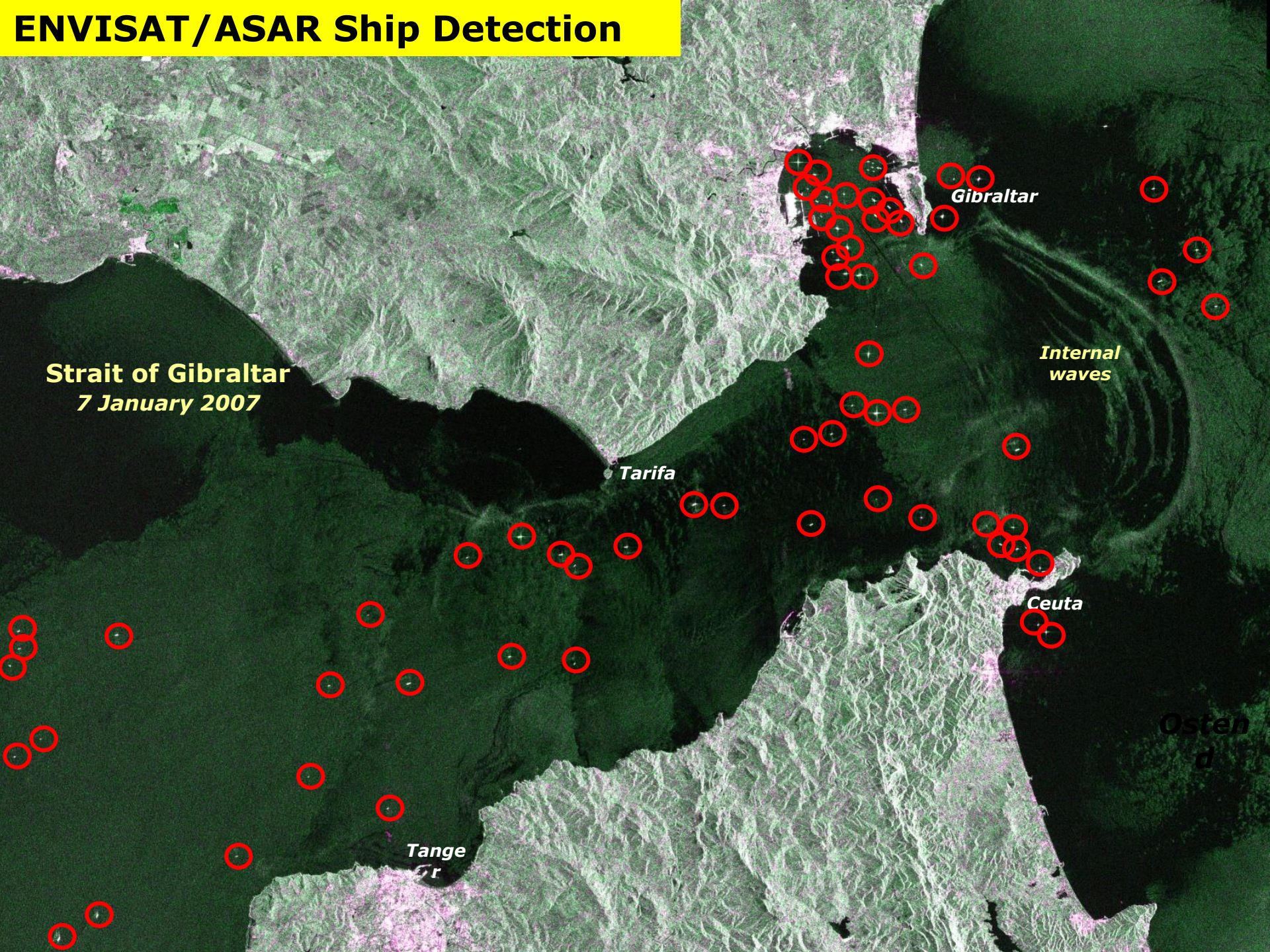
Ice Flow of the Antarctic Ice Sheet

E. Rignot et al., Science, September 2011

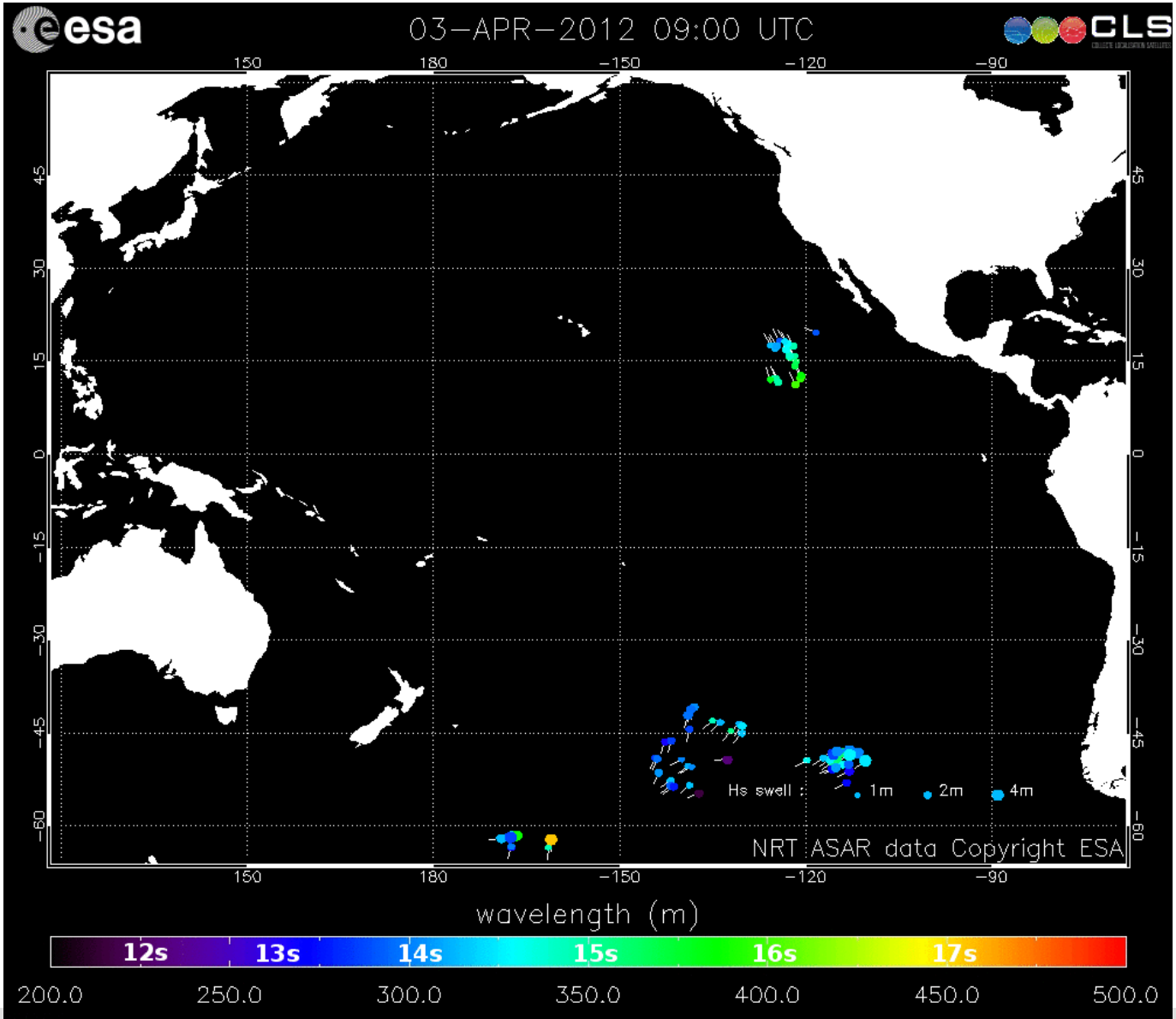


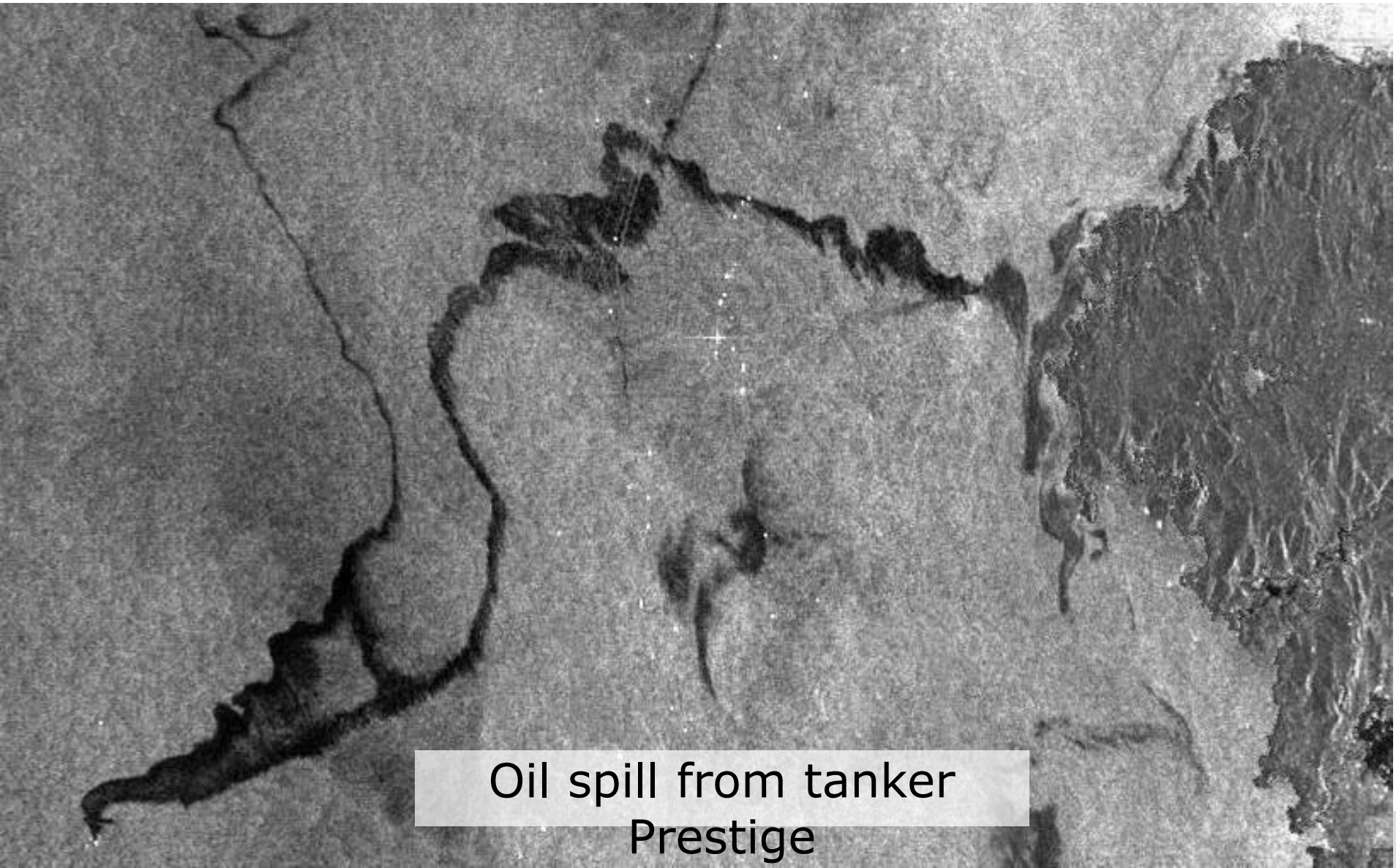


Marine Applications


ENVISAT/ASAR Ship Detection
Gibraltar
Strait of Gibraltar
7 January 2007
Internal waves
Tarifa
Ceuta
Tange r
Osten d

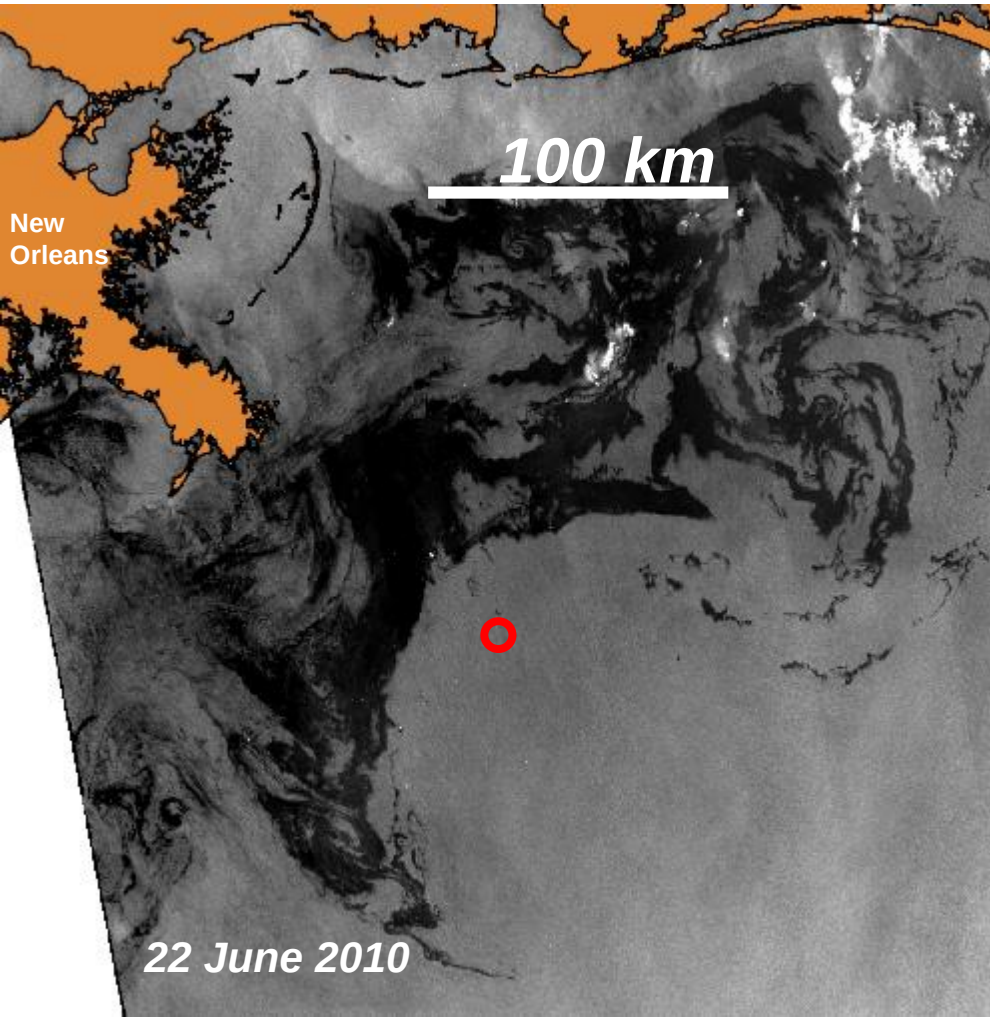
ASAR Ocean Wave Forecasting

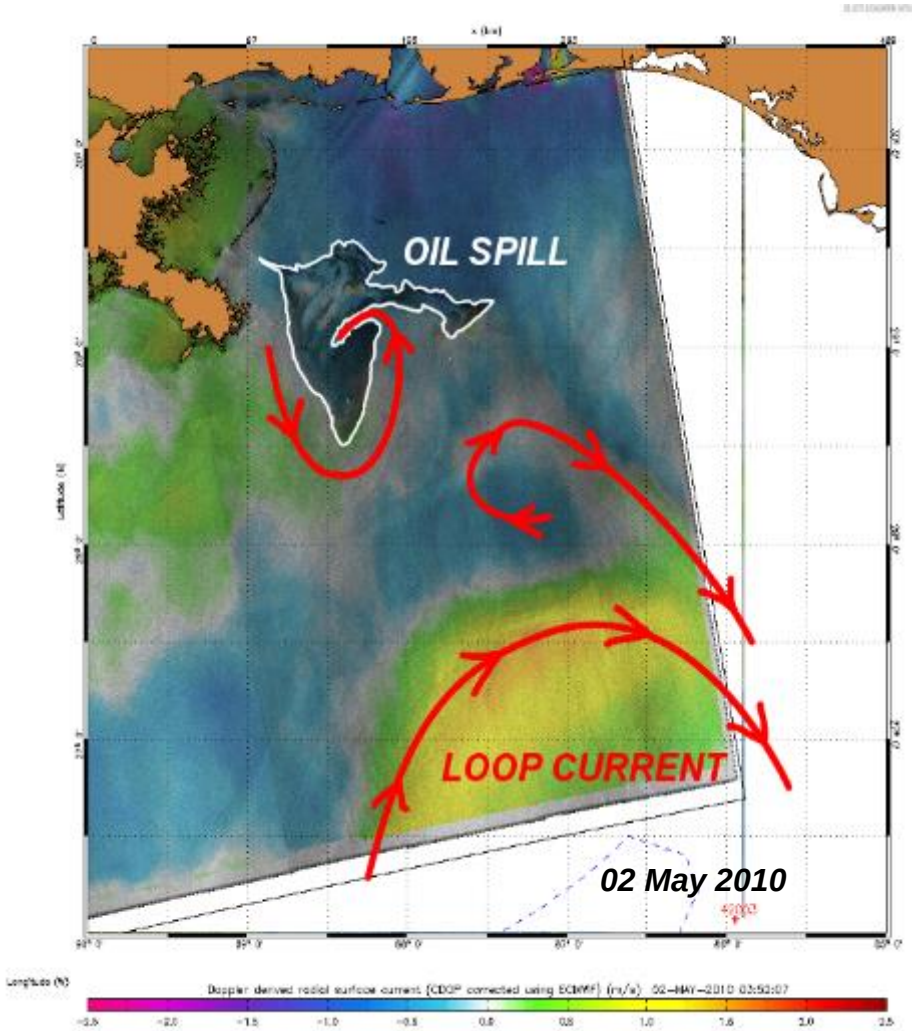




Oil spill from tanker Prestige

SAR applications for disaster management: Oil Spills





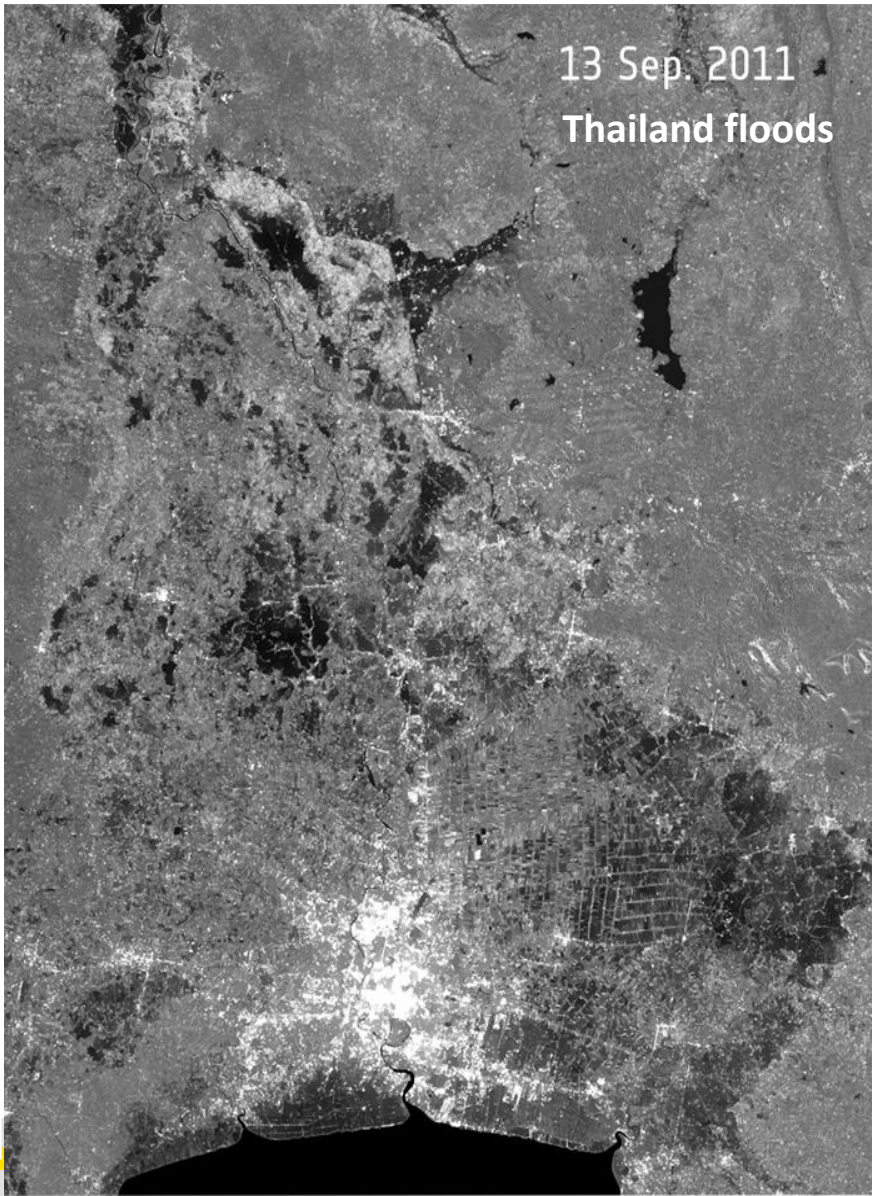
Floods

SAR Flood Monitoring

Envisat was activated 370 times for the Charter on Space and Major Disasters

Recent Envisat ASAR activation :

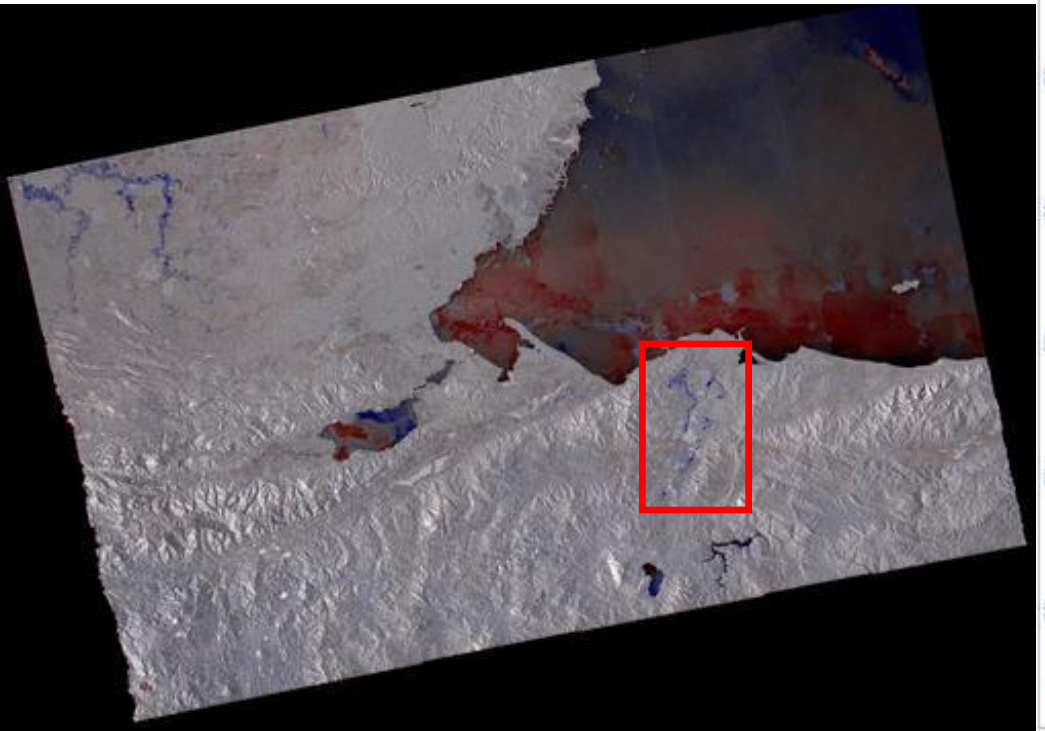
Emergency area	*Disaster type*	*Date*	*Authorized User*
Nigeria	Flood	29-Aug-11	National Emergency Management Agency (NEMA)
Japan	Flood/ Landslide	04-Sep-11	JAXA on behalf of Cabinet Office JAPAN
Cambodia	Flood	12-Oct-11	UNITAR/UNOSAT on behalf of UN OCHA
New Zealand	Oil Spill	12-Oct-11	USGS
Thailand	Flood	17-Oct-11	Asia Disaster Reduction Centre (ADRC)
Vietnam	Flood	17-Oct-11	Asia Disaster Reduction Centre (ADRC)
El Salvador	Flood	19-Oct-11	UNITAR/UNOSAT on behalf of UN OCHA
Chile	Volcano	27-Oct-11	SIFEM (Sistema Federal co Emergencias)
Ghana	Flood	28-Oct-11	UNOOSA
Philippines	Flood	19-Dec-11	Asia Disaster Reduction Center (ADRC)
Brazil	Flood	07-Jan-12	Ministry of Defense from Brazil
Madagascar	Flood	13-Feb-12	COGIC
Perú	Flood	21-Feb-12	SIFEM
Algeria	Flood	26-Feb-12	Algerian Space Agency
Madagascar	Flood	01-Mar-12	COGIC
Ecuador	Flood	09-Mar-12	USGS on behalf of SNGR/Ecuador

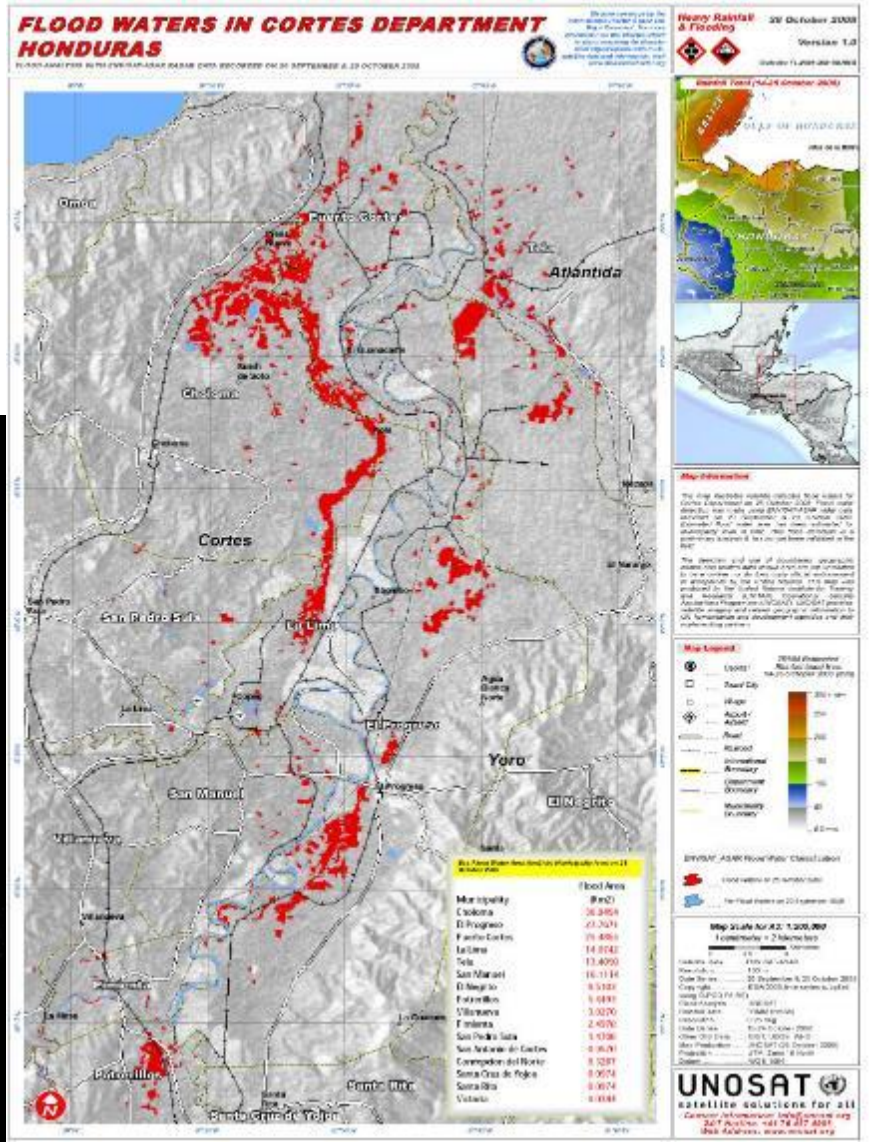


SAR Flood Monitoring

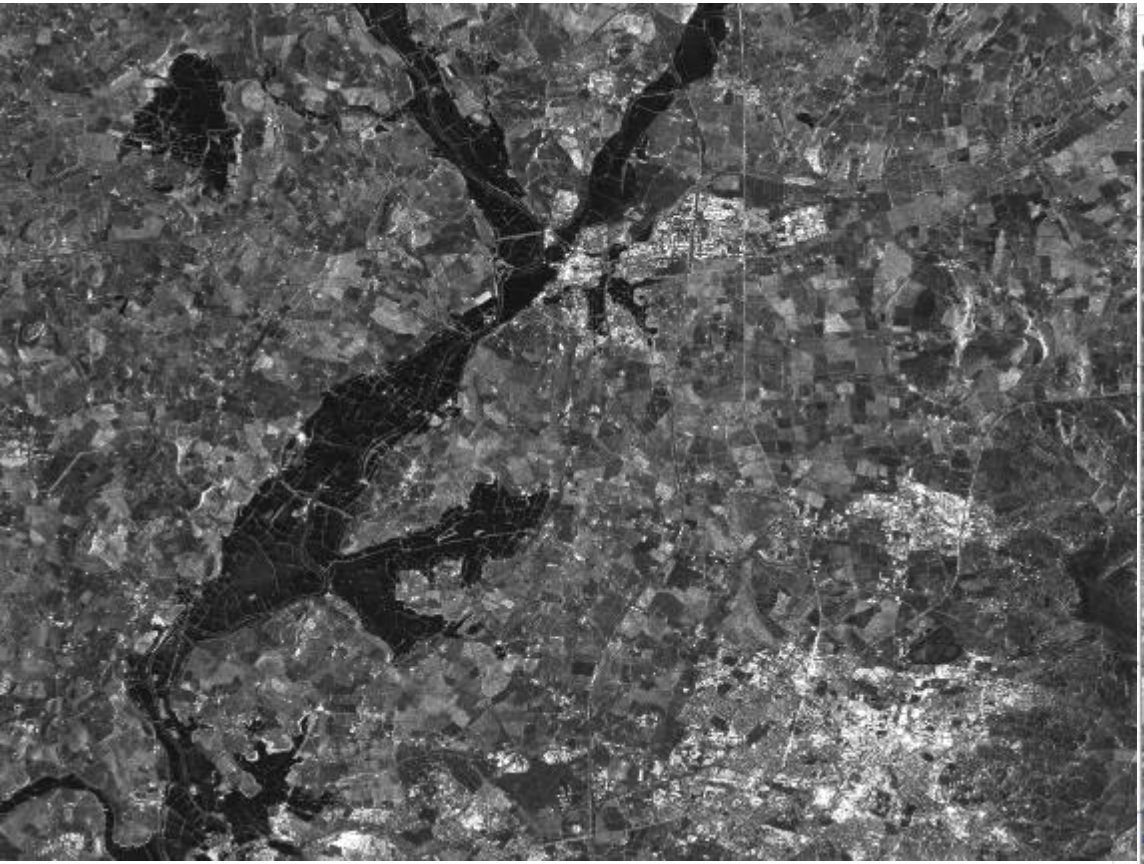
Flooding in Honduras. Charter activated 27th Oct 2008

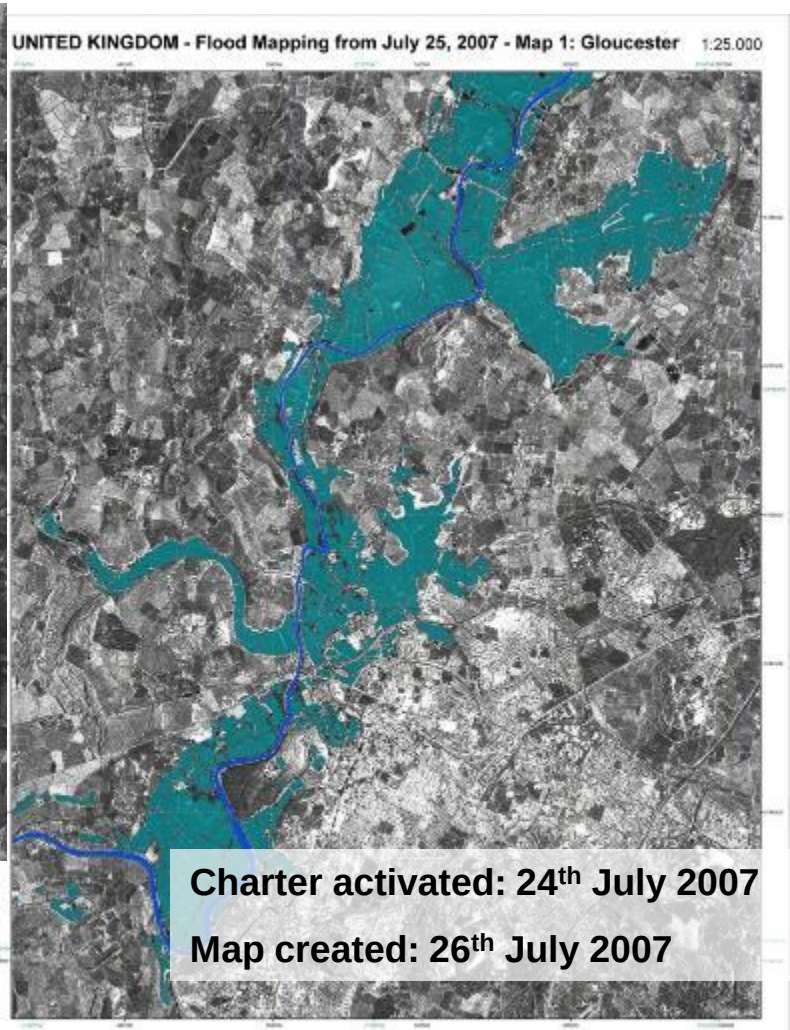
Map produced in **less than 3 hours after activation**





SAR Flood Monitoring

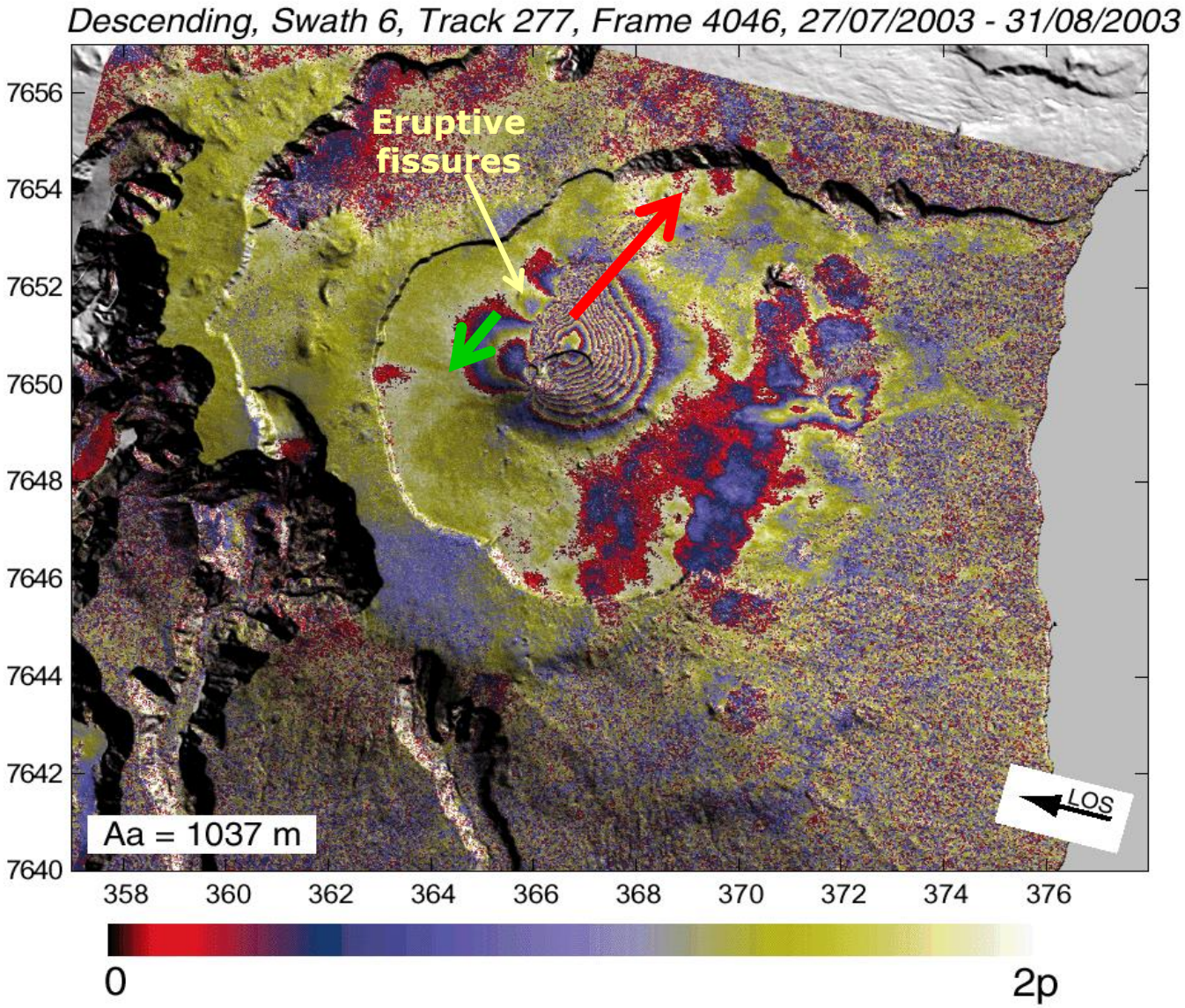




TerraSAR-X data (3m resolution) used in Charter Call

Volcanoes

SAR applications for disaster management: volcano monitoring



"Piton de la Fournaise" volcano (Reunion island) – August 2003 eruption

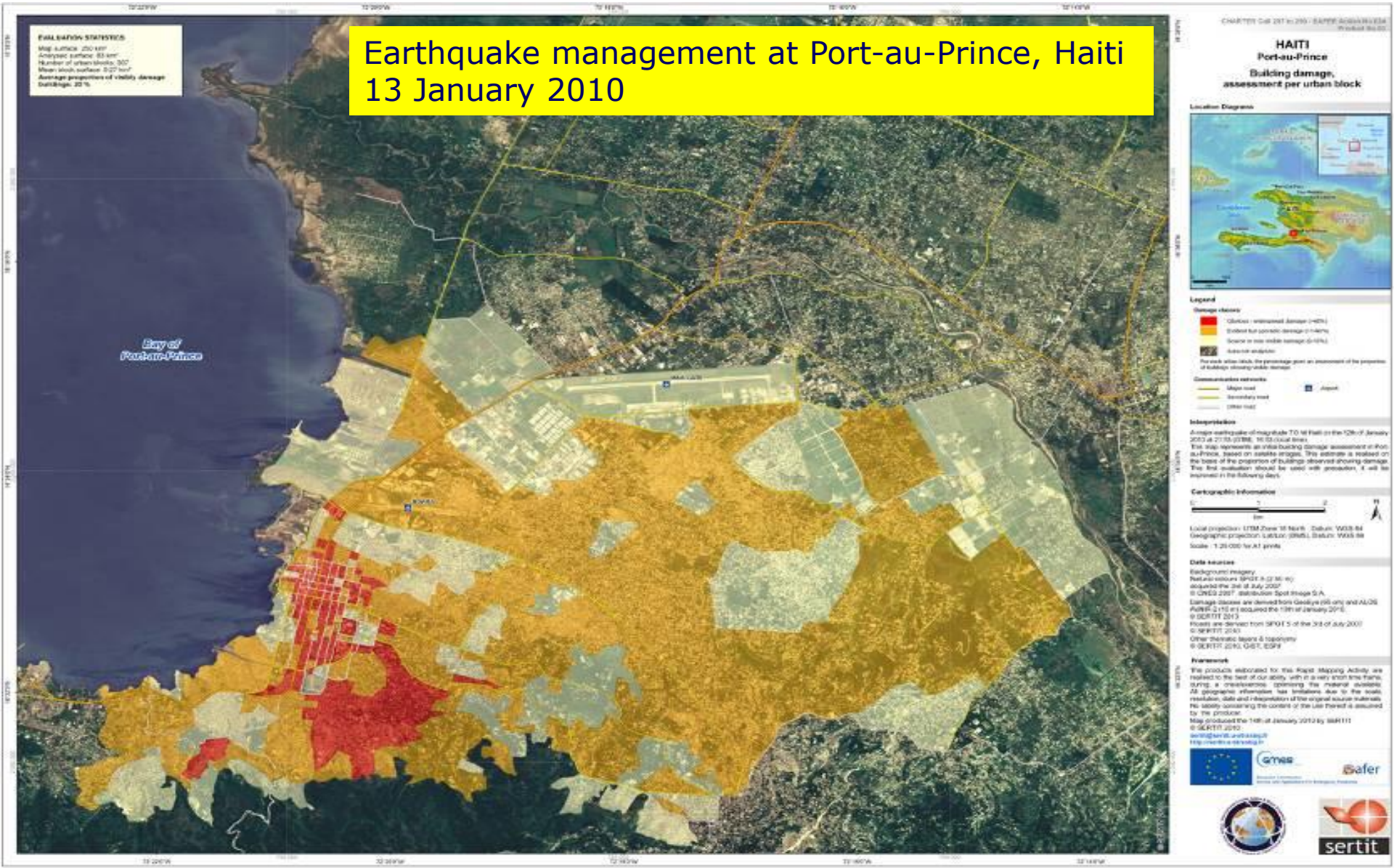
30 cm displacement toward satellite

7 cm displacement away from satellite

Courtesy:
- *Institut de Recherche pour le Développement (IRD), Clermont-Ferrand, France*
- *Université Blaise Pascal, Clermont-Ferrand, France*
- *Institut de Physique du Globe de Paris, Paris, France*
- *Université de la Réunion, Saint-Denis, France*

Earthquakes

SAR Support for Earthquake Damage Assessment



L'Aquila earthquake (April 2009)

Envisat ASAR data

L'Aquila

Poggio Picenze

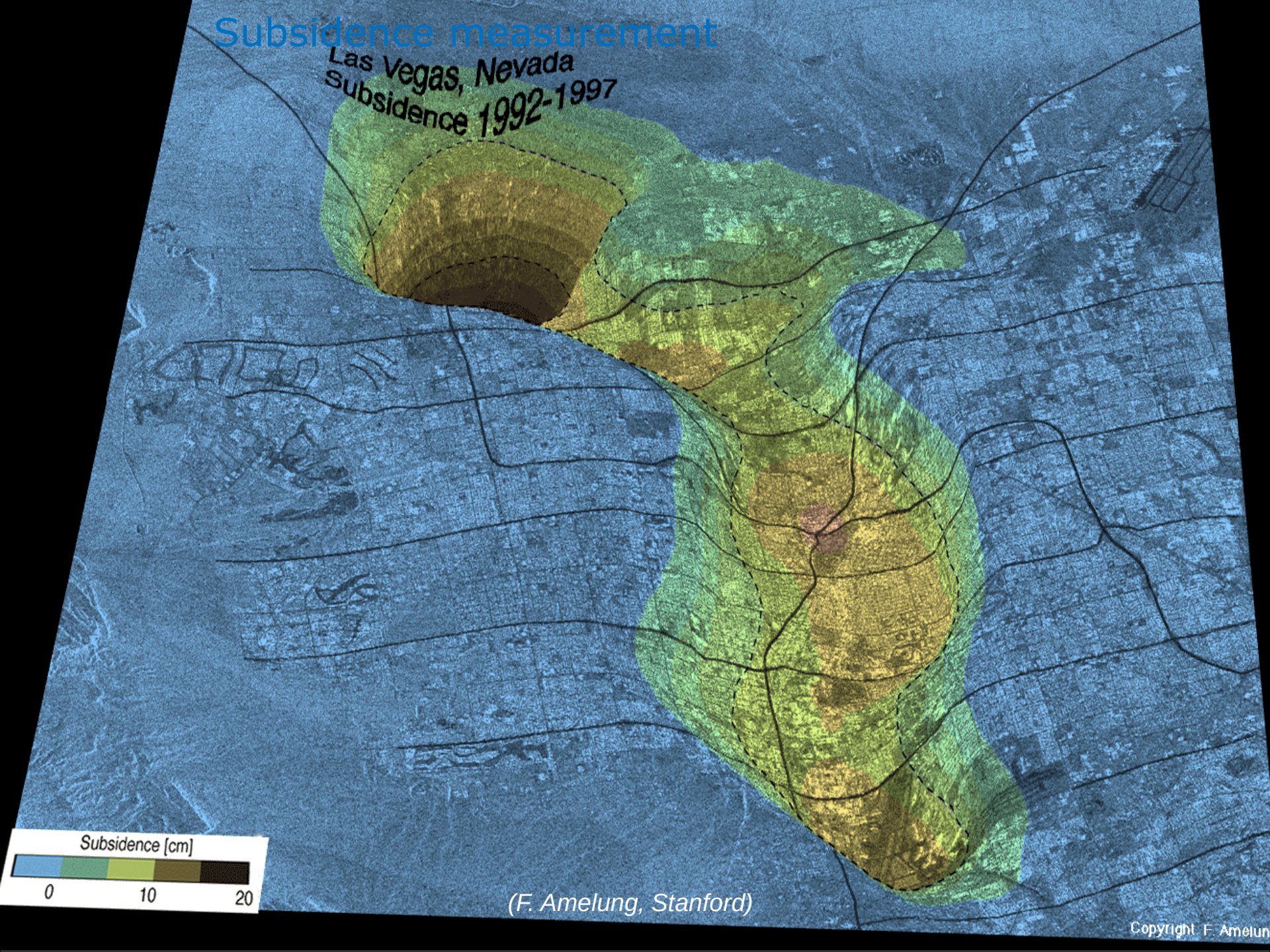
Fossa

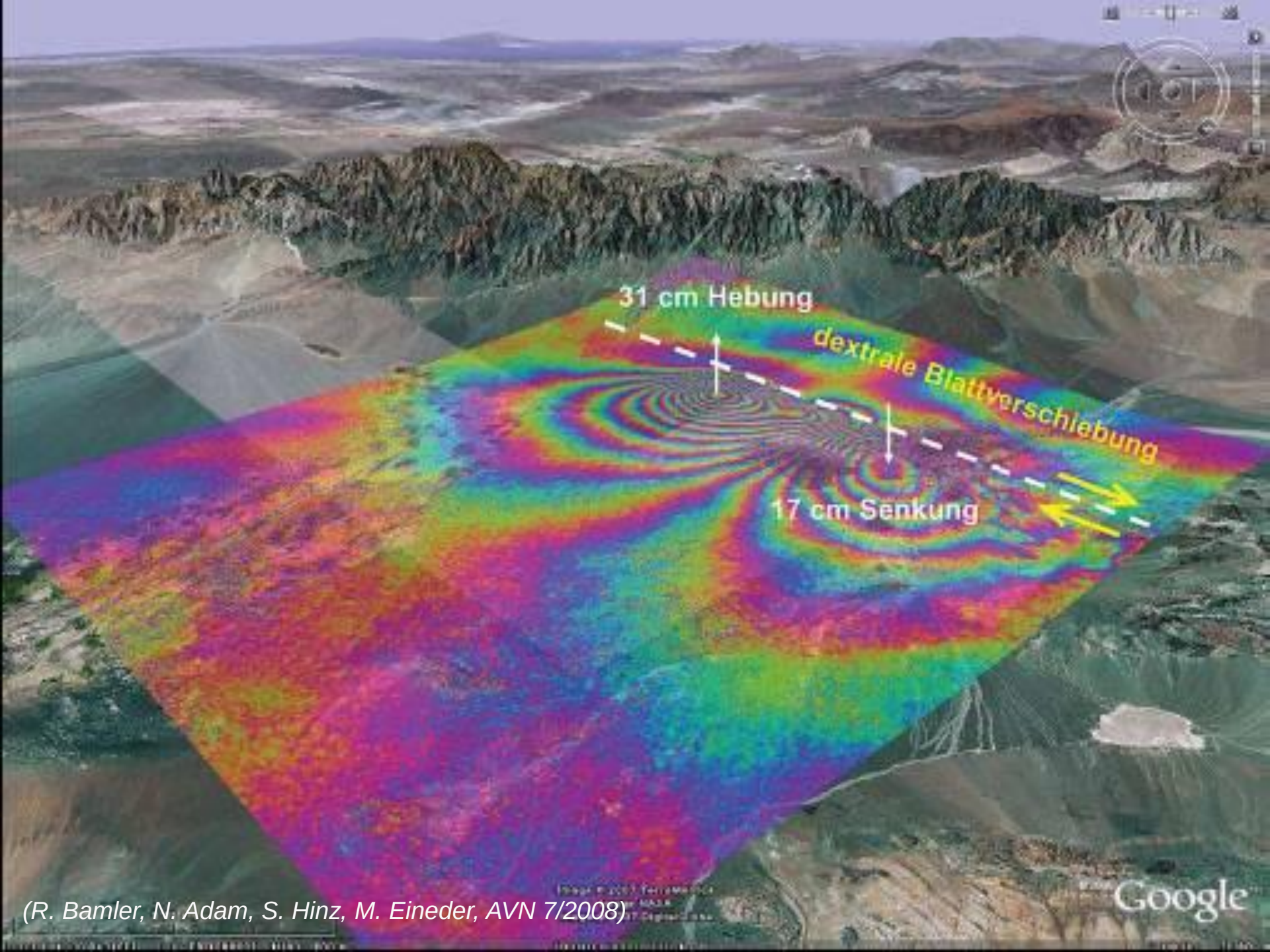
0 2 4 8 12 16 Kilometers

Each fringe (a colour cycle) of the interferogram is equivalent to a surface displacement of **2.8 cm** along the satellite direction.

Subsidence Measurement

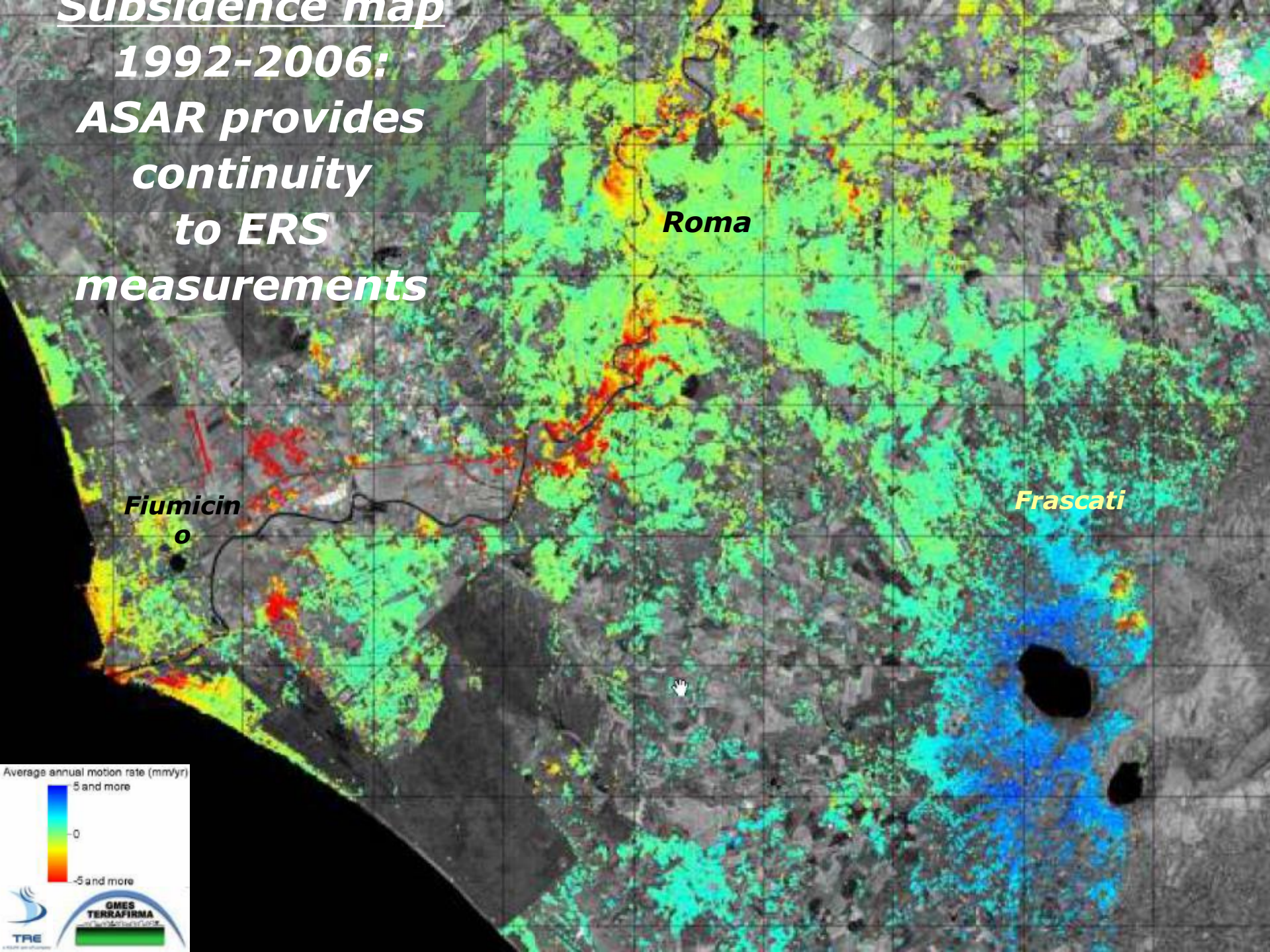
Subsidence measurement

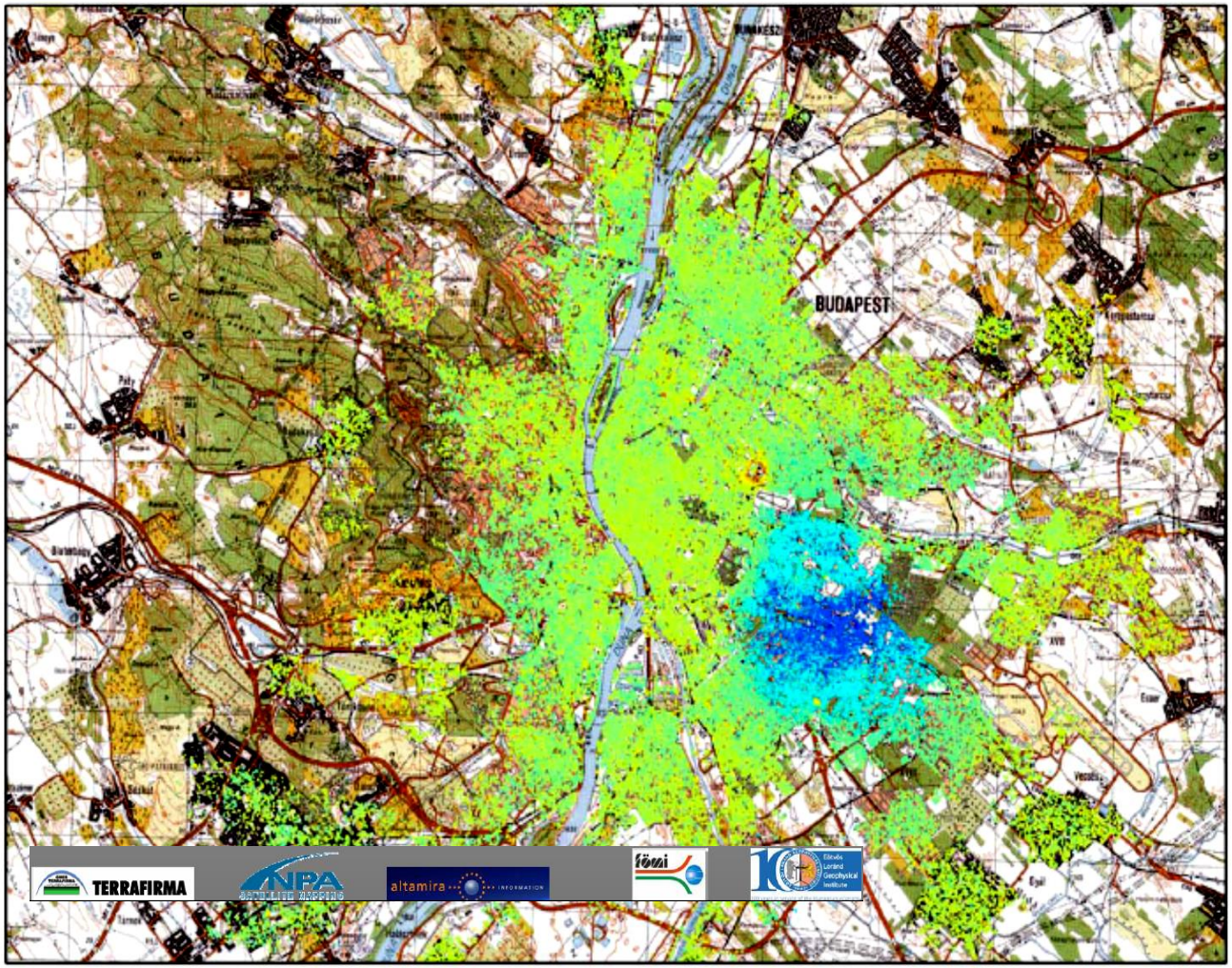




(R. Bamler, N. Adam, S. Hinz, M. Eineder, AVN 7/2008)

Subsidence map 1992-2006: ASAR provides continuity to ERS measurements





Legend

Velocity [mm/year]

- < -8.0
- -8.0 - -6.0
- -6.0 - -4.0
- -4.0 - -2.0
- -2.0 - 0.0
- 0.0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- > 8.0

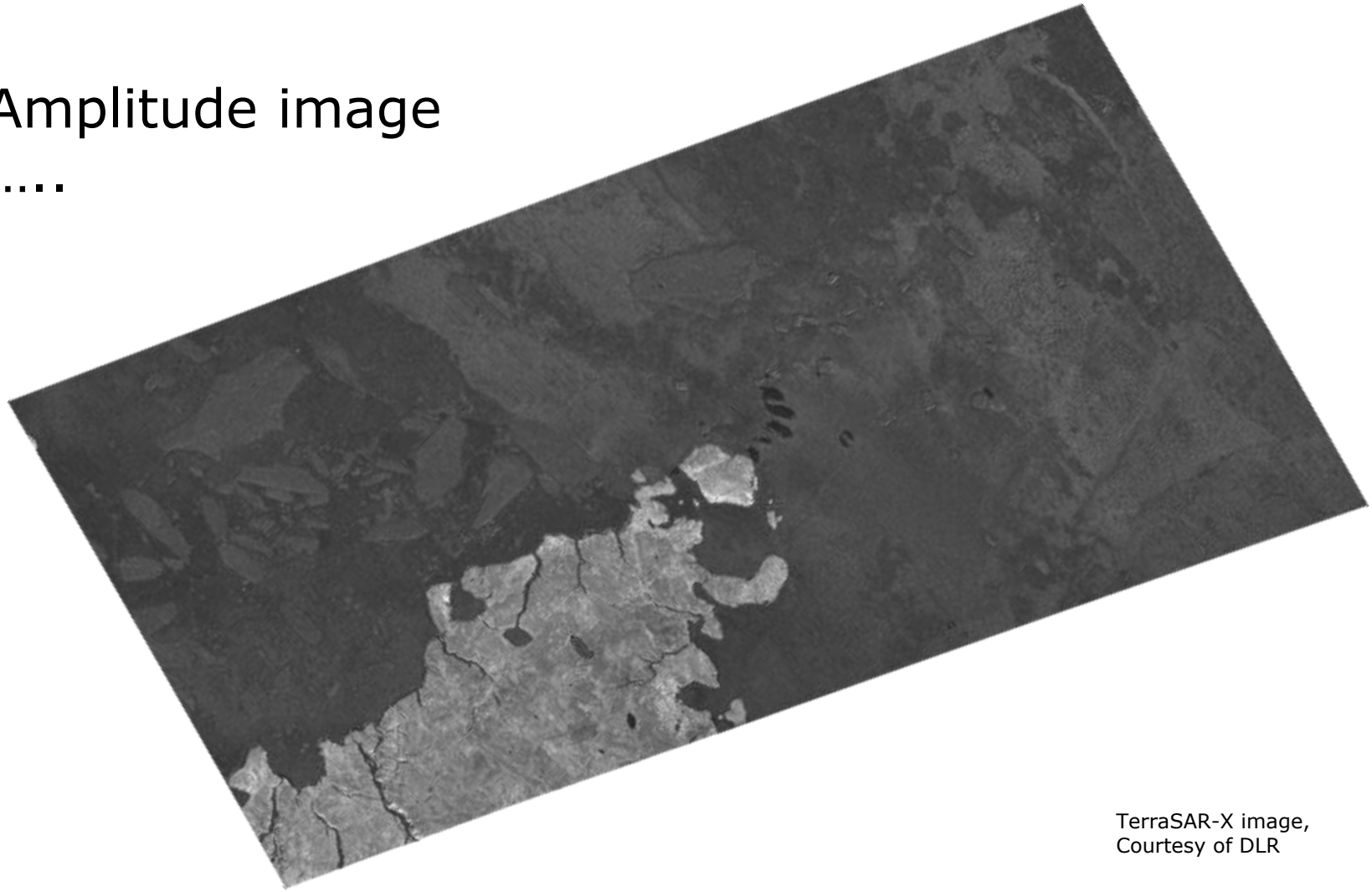
Terrafirma - Budapest PSInSAR dataset (velocity)

B.Füsi,Á.Gulyás,L.Vértesy: ELGI Eötvös Loránd Geophysical Inst.
G.Grenerczy,Z.Oberle: FÖMI Geodesy, Cartography and RS Inst.

Topography Applications

Amplitude image

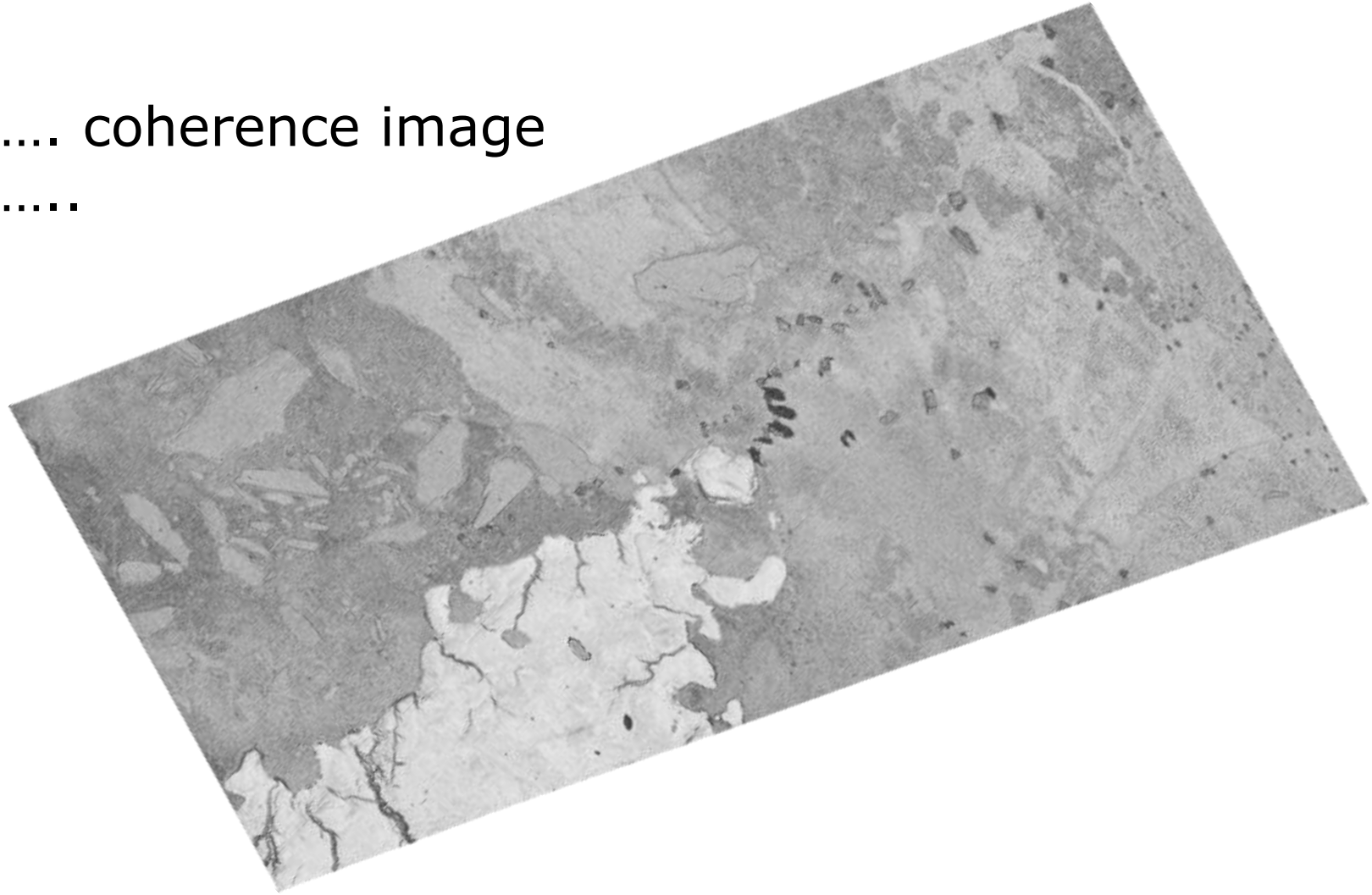
…..



TerraSAR-X image,
Courtesy of DLR

…. coherence image

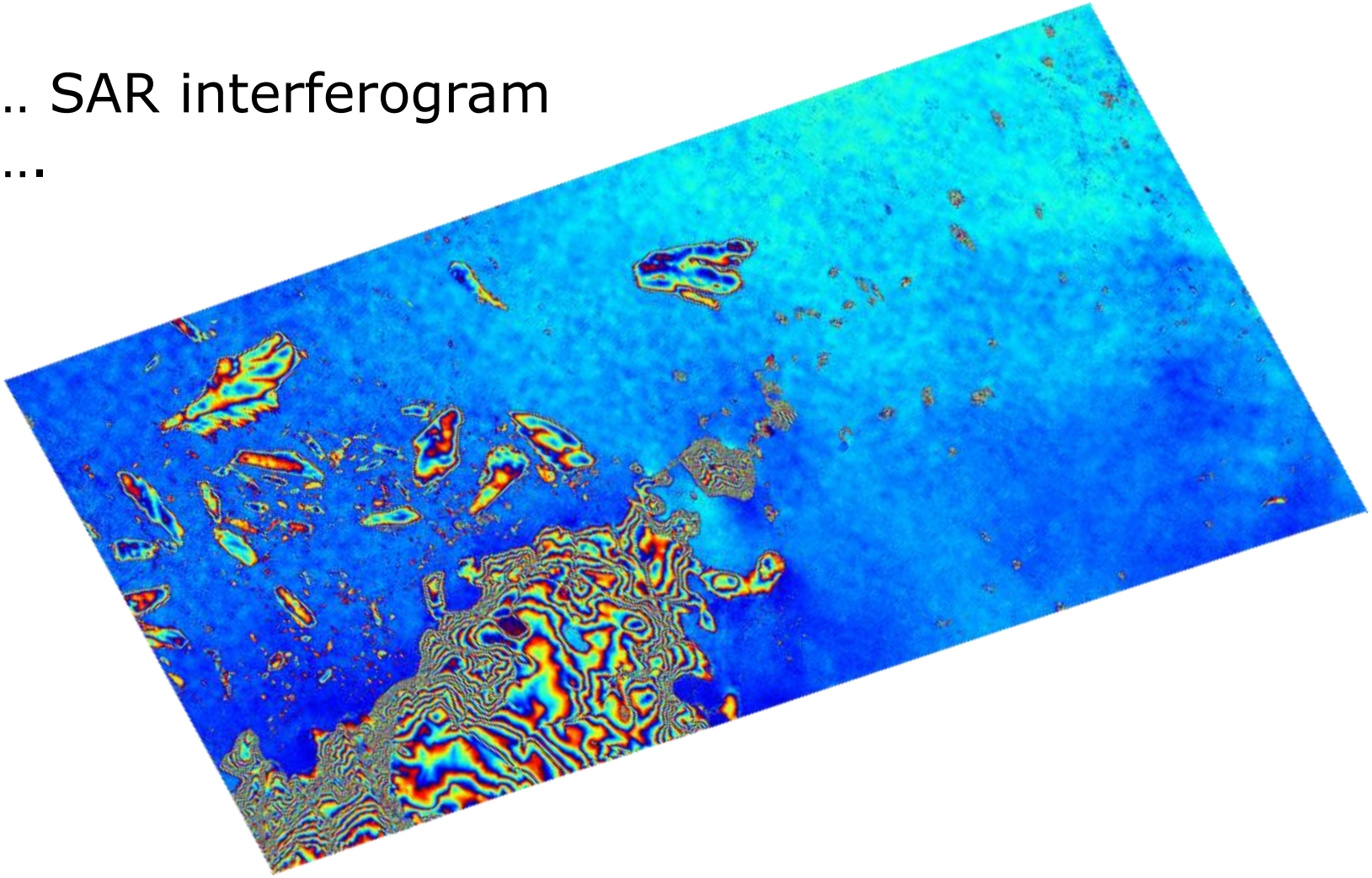
…..



TerraSAR-X image,
Courtesy of DLR

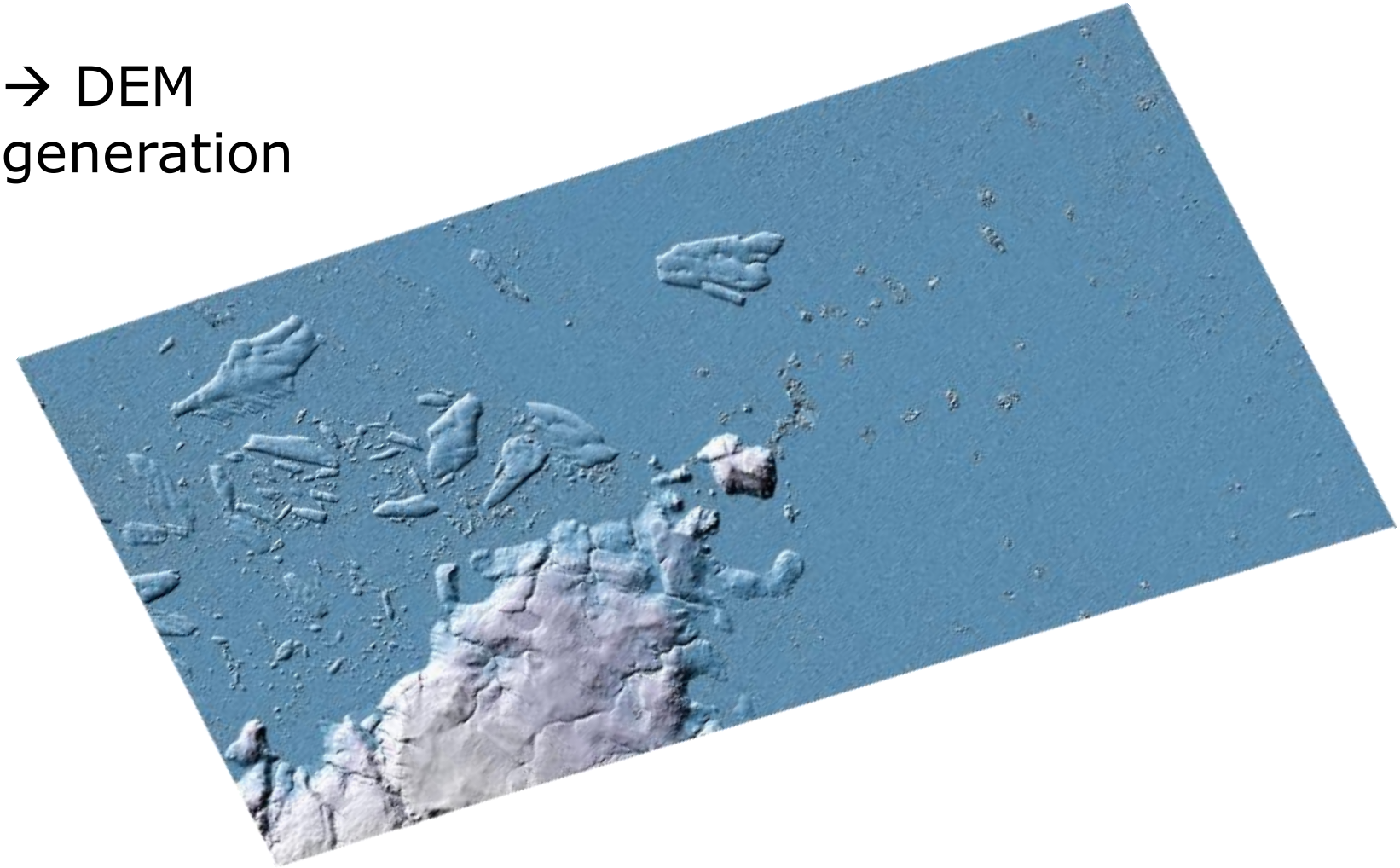
… SAR interferogram

….



TerraSAR-X image,
Courtesy of DLR

→ DEM generation



TerraSAR-X image,
Courtesy of DLR

Mineral Exploration

SAR "finds diamonds"

SIR-C/XSAR
South Africa
April 18, 1994

L-HH
L-HV
C-HV

Imaged area :
55 km * 60 km

Extracted from :
http://www.jpl.nasa.gov/radar/sircxsar

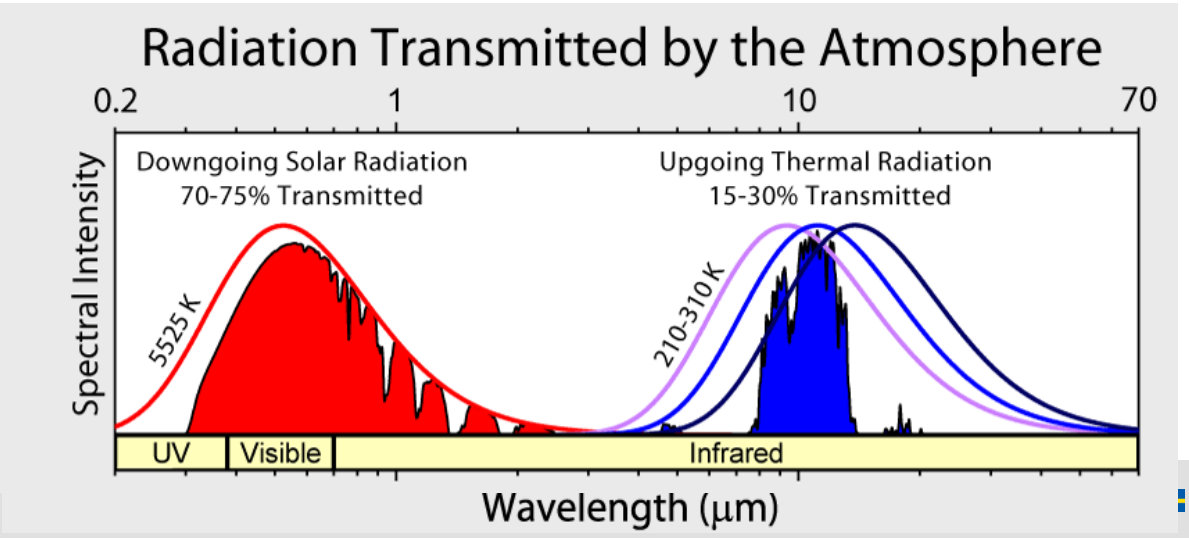
Courtesy of CNES

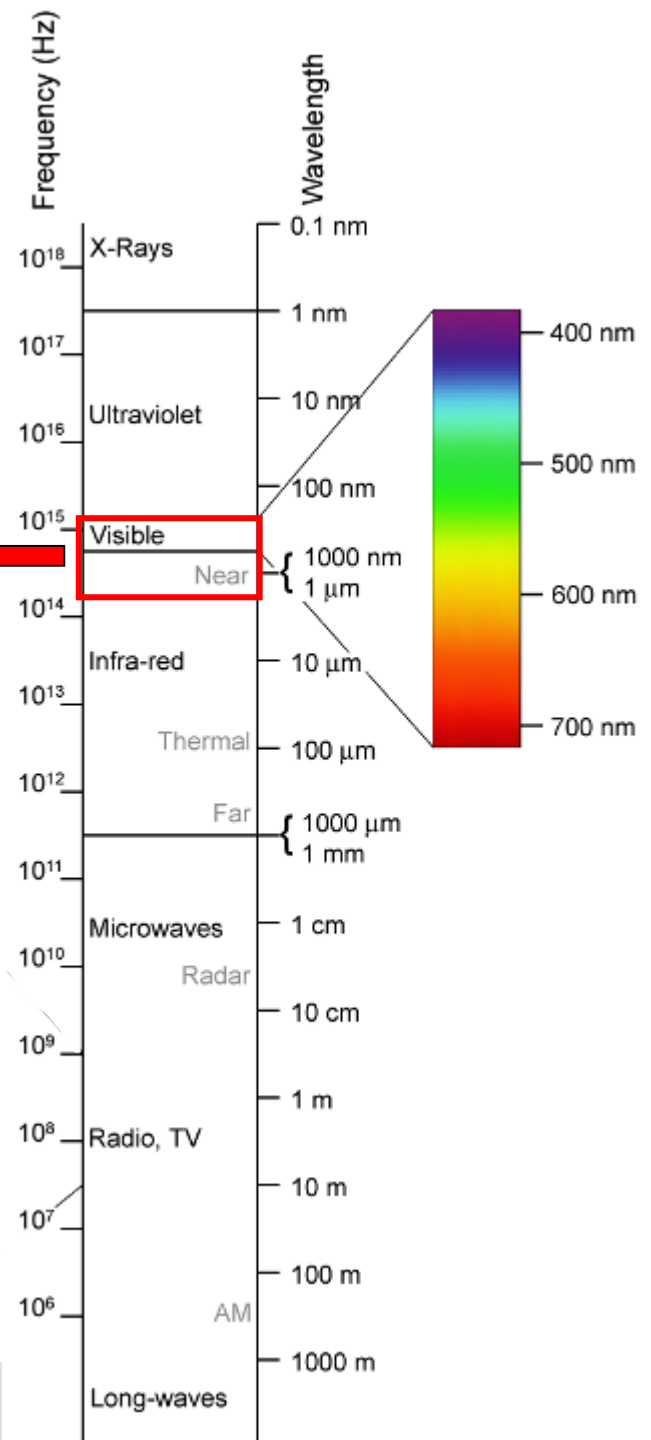
Namibia Diamond Deposits


SENTINEL-2

The electromagnetic spectrum

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





Launch of Sentinel-2A

- June 23, 2015
- Launch from French Guiana Space Base
- Vega rocket

Sentinel-2 Superspectral imaging mission

Mission profile

- Multispectral instrument with **13** spectral bands (VIS, NIR & SWIR)
- Sun synchronous orbit at **786 km** mean altitude and 98.5° inclinaison
- **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 m**, **20 m** and **60 m** spatial resolution (depending on the band) (1)

Mission objectives :

- Generic land cover maps
- Risk mapping and disaster relief

Sentinel-2
The European "Super Landsat"

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)**

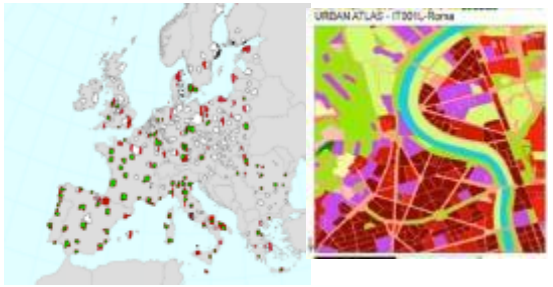
Sentinel-2
Imaging System : Multi Spectral Instrument (MSI)

Band name	Resolution (m)	Central wavelength (nm)	Band width (nm)	Purpose
B01	60	443	20	Aerosol detection
B02	10	490	65	Blue
B03	10	560	35	Green
B04	10	665	30	Red
B05	20	705	15	Vegetation classification
B06	20	740	15	Vegetation classification
B07	20	783	20	Vegetation classification
B08	10	842	115	Near infrared
B08A	20	865	20	Vegetation classification
B09	60	945	20	Water vapour
B10	60	1375	30	Cirrus
B11	20	1610	90	Snow / ice / cloud discrimination
B12	20	2190	180	Snow / ice / cloud discrimination

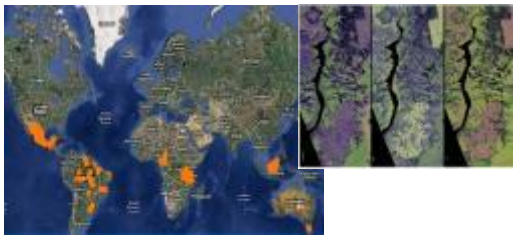
S-2: Large range of applications...

Agriculture, Forests & Carbon, Vegetation monitoring

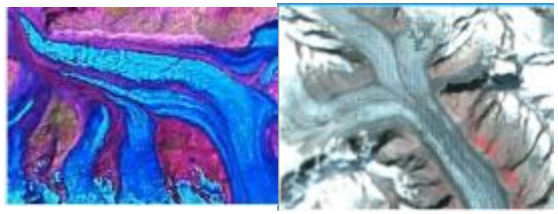
Land cover classification, high resolution layers & change.



Regional to Urban Applications



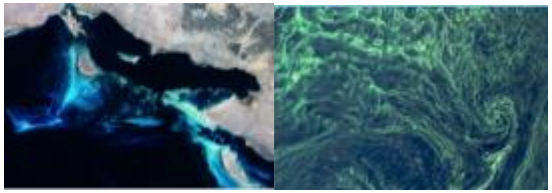
Emergency management



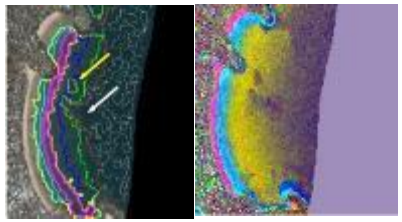
Glaciers & Ice

Global Land use & change

Geology



Water quality

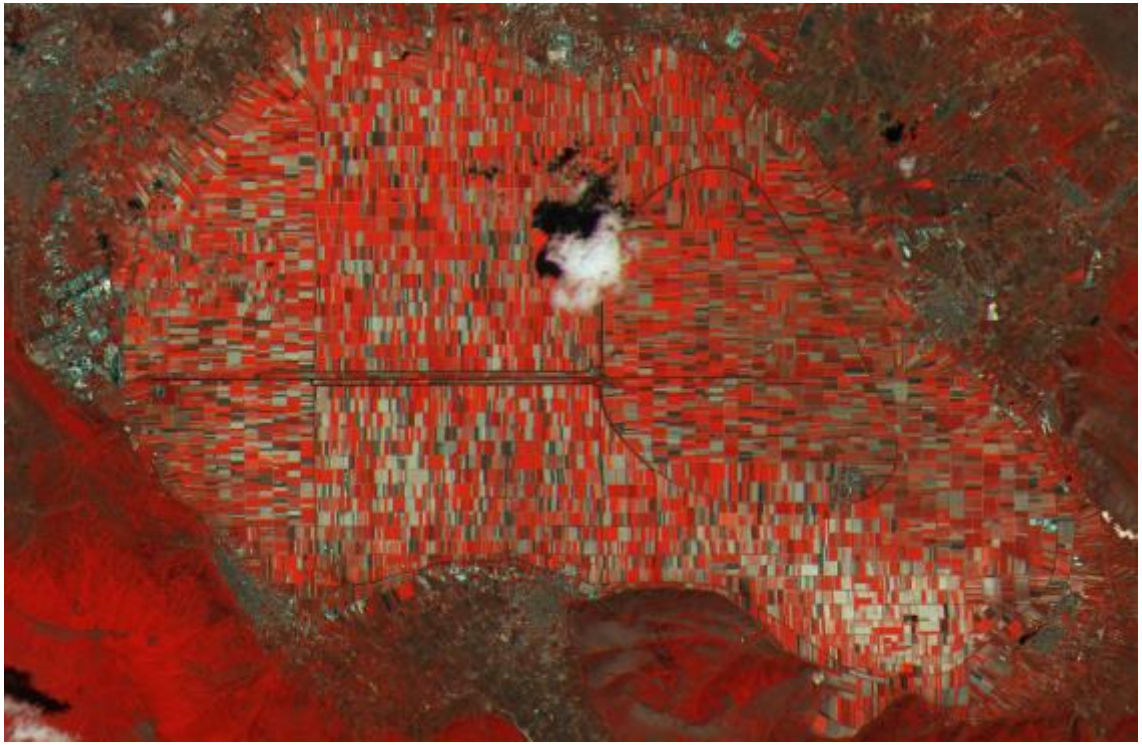


Coastal zones/bathymetry

Sentinel-2: Agriculture

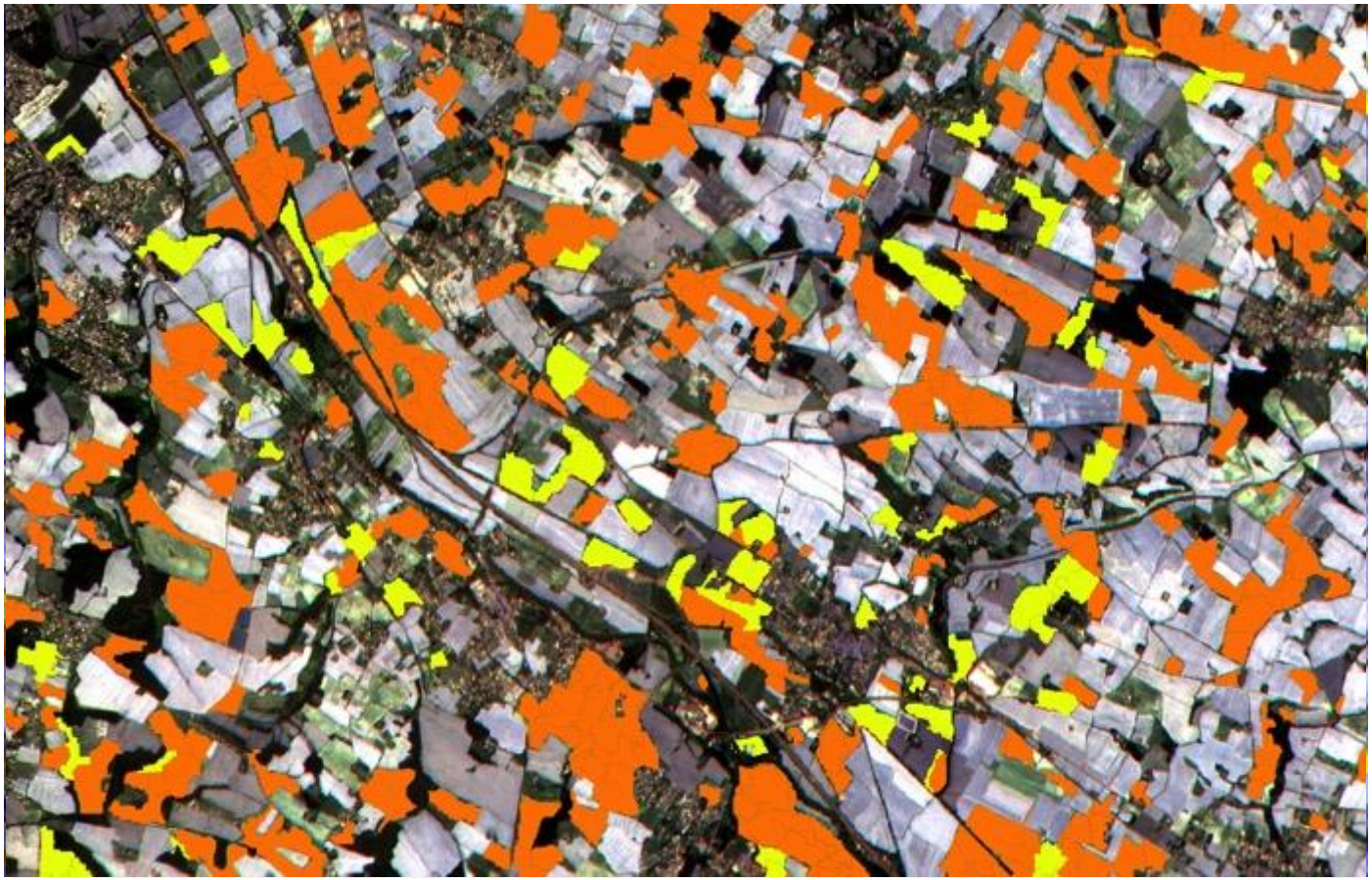
Sentinel-2 is the first optical mission to include 3 bands in the '**red edge**', providing information on the state of vegetation

Sentinel-2 for agriculture :
esa-sen2agri.org



Usage of red-edge bands

Toulouse area (France) - Sentinel-2 – 06 July 2015



Summer Crops Map – 6 July 2015

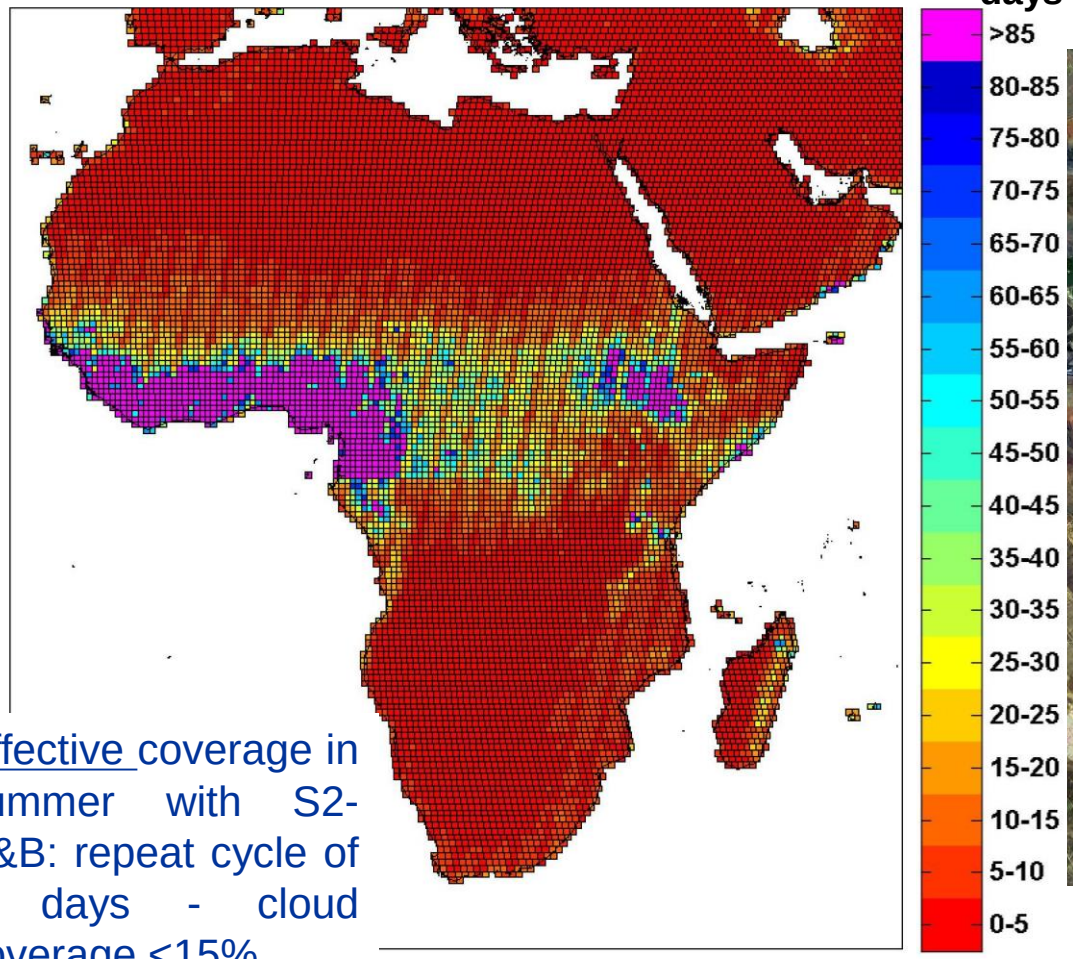
- Sunflower
- Maize

Courtesy: S2AGri, UCL, Cesbio, ESA

Vegetation monitoring

Sentinel-2: Agriculture

Sentinel-2 Revisit Time Capability
5 days revisit for crop dynamics



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

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

Monthly cloud free composites possible for most areas

S2 crop status monitoring over the season

18 Feb. 16

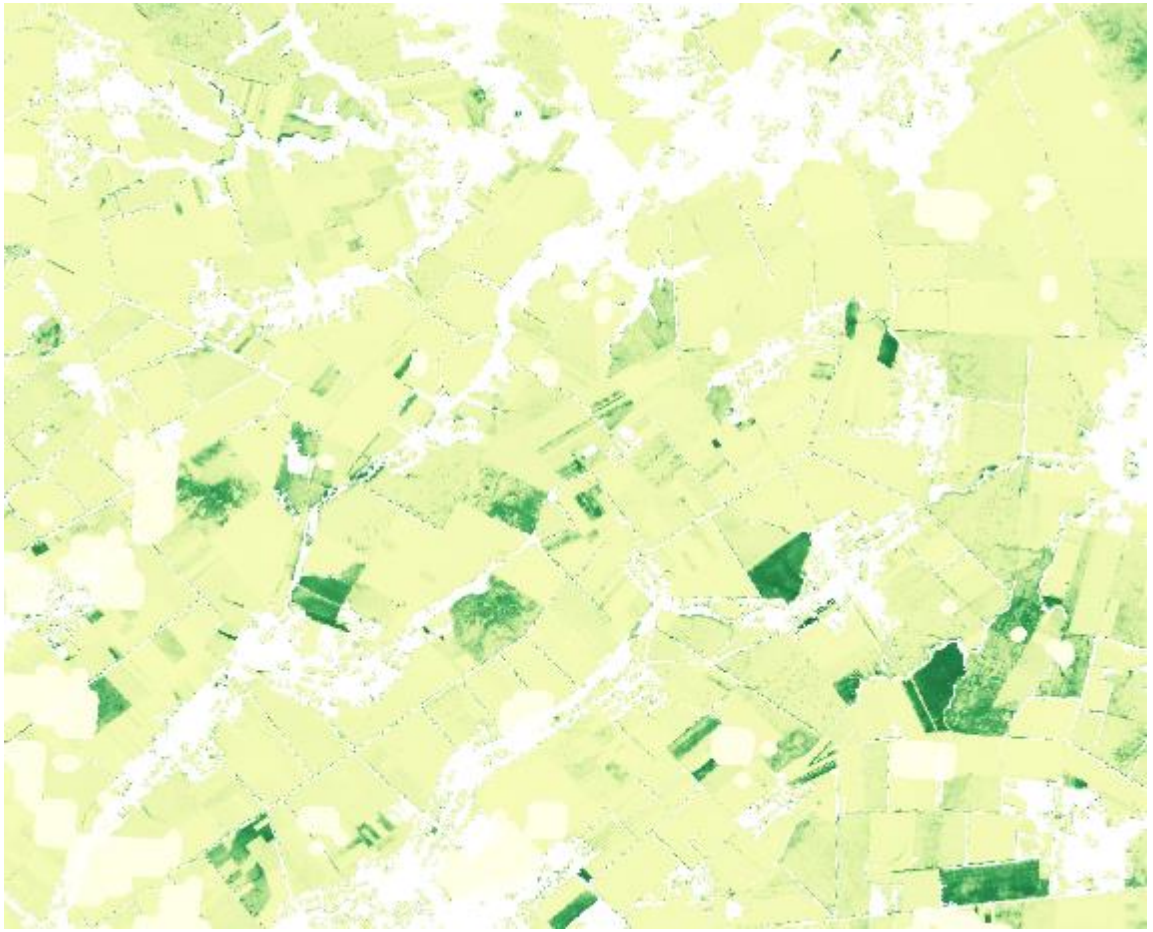
18 Apr. 16

28 Apr. 16

17 Jun. 16

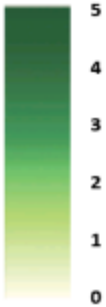
17 Jul. 16

8 Sept. 16



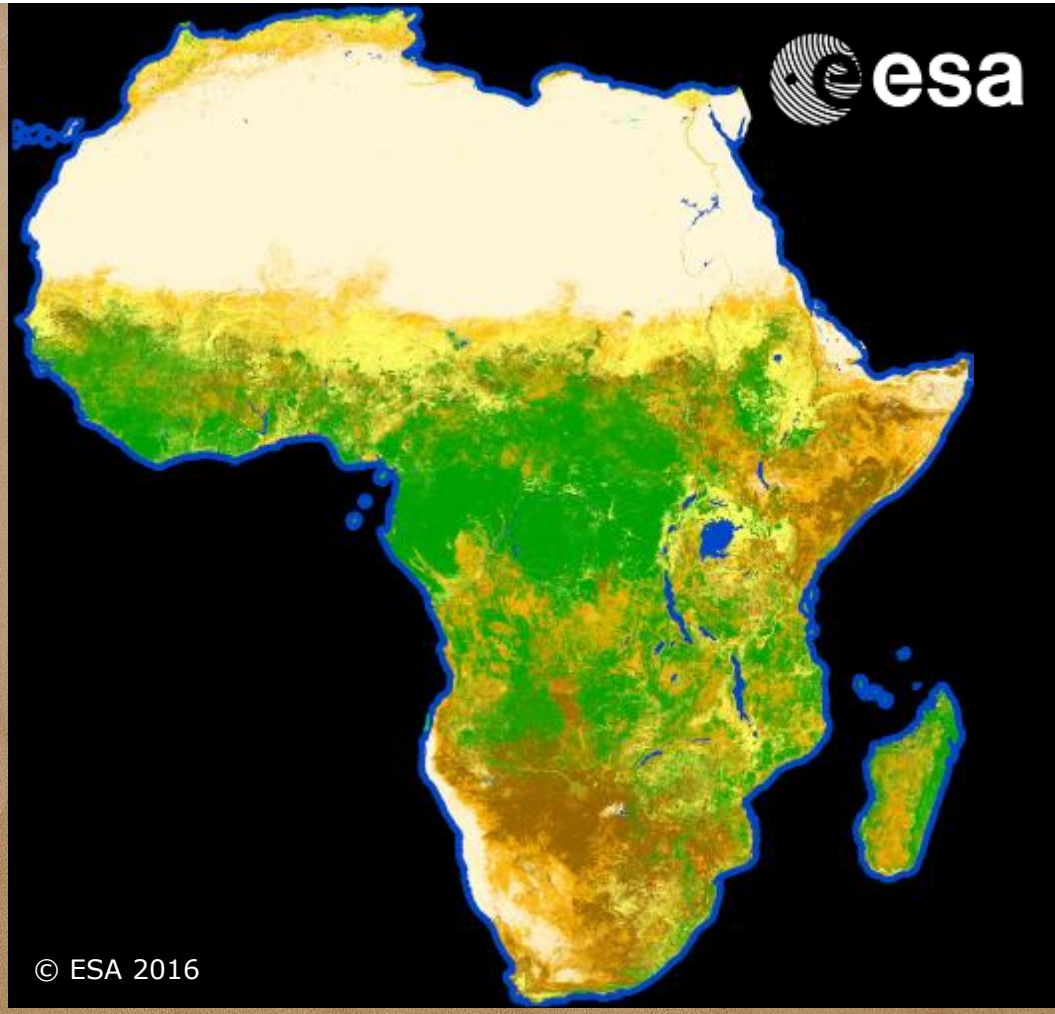
Ukraine 2016

Leaf Area Index

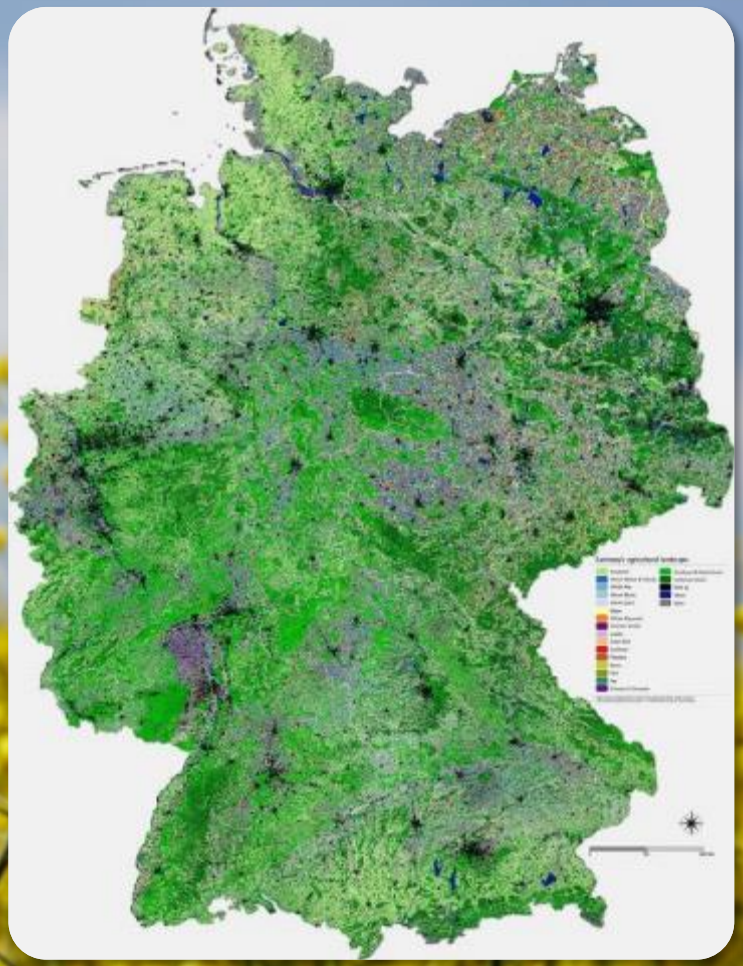


Land Cover Typology

180.000 Sentinel-2A images
Dec. 2015 – Dec. 2016



Agricultural Land Use



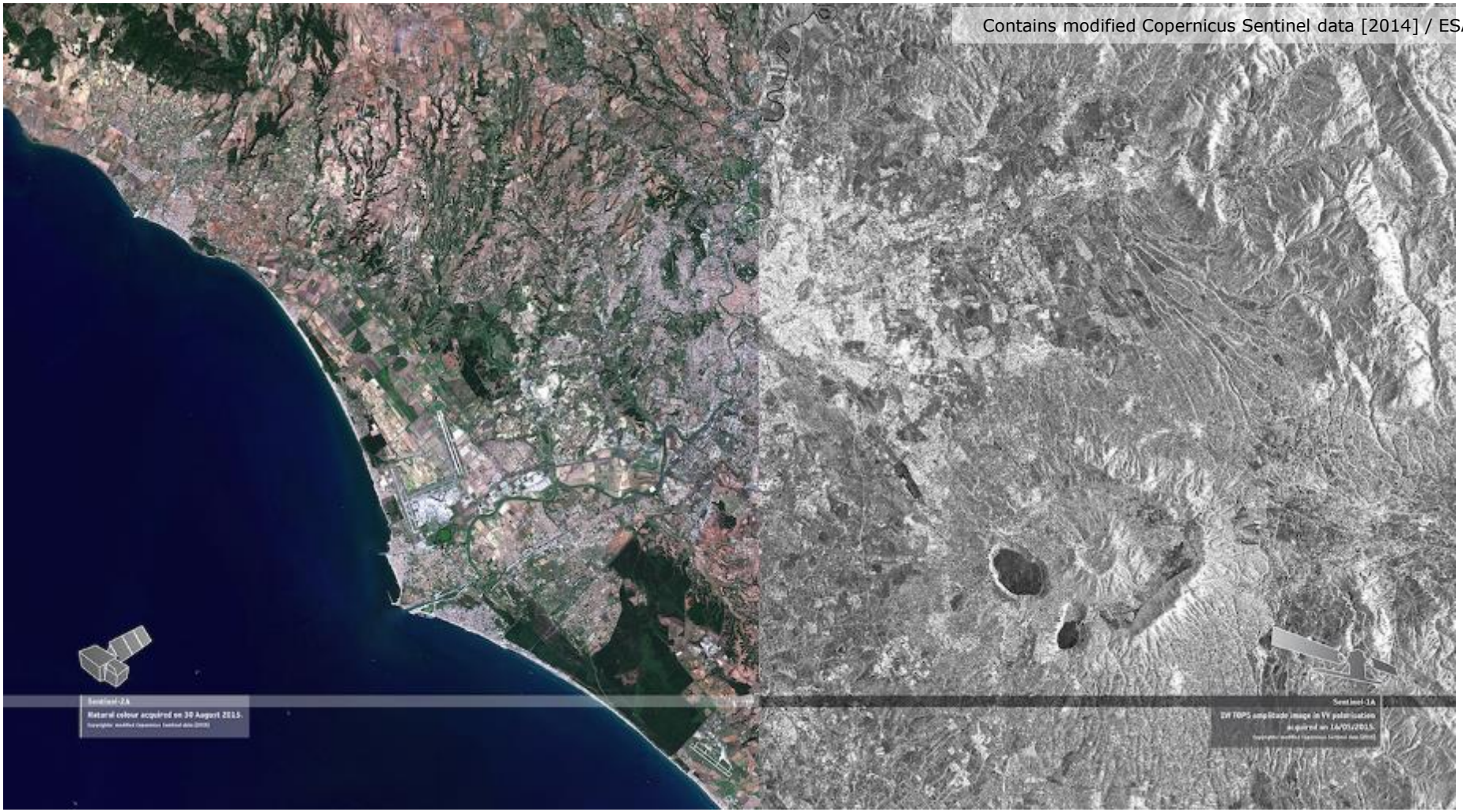
Distinguishing 15 crop types
Germany

Mixed Sentinel-2 and Landsat-8 Data

Sentinel-1, -2 and -3 Synergy

Contains modified Copernicus Sentinel data [2014] / ESA

Sentinel-1 & -2 **Synergy**




Contains modified Copernicus Sentinel data [2014] / ESA
Synergy of
Sentinel-1 & -2

Sentinels in Co-Operation

Using both S1 and S2 data (and Landsat-8).

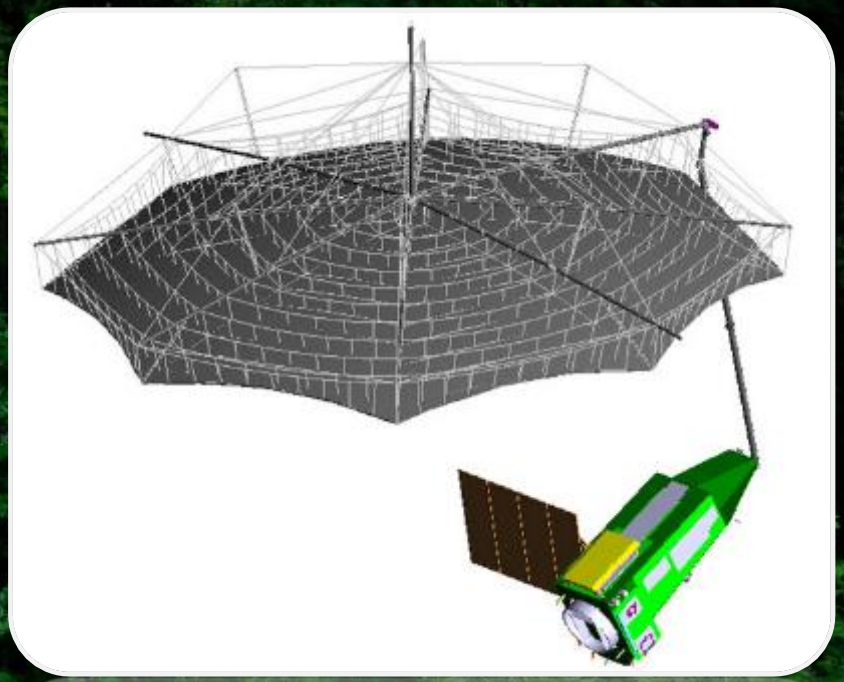
Innovative crop type map at national scale: pilot project for potential future Copernicus service agricultural components

Sentinel-1A und -2A: Traffic Jam on the Danube

Future Earth Explorers

BIOMASS

Mission	Measure of forest biomass and height (200 m. pixel resolution)
Payload	P-Band radar
Orbit	SSO, alt: 666 km; LTAN: 6h00
Satellite	1250 Kg
Consortium	Prime: ADS-UK, Instrument: ADS-DE
Launch date	2022
Lifetime	5.5 years



Biomass, what information will we get

Above-ground biomass (tons/hectare)

- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20%, or 10 t ha^{-1} for biomass < 50 t ha^{-1}

Upper canopy height (meter)

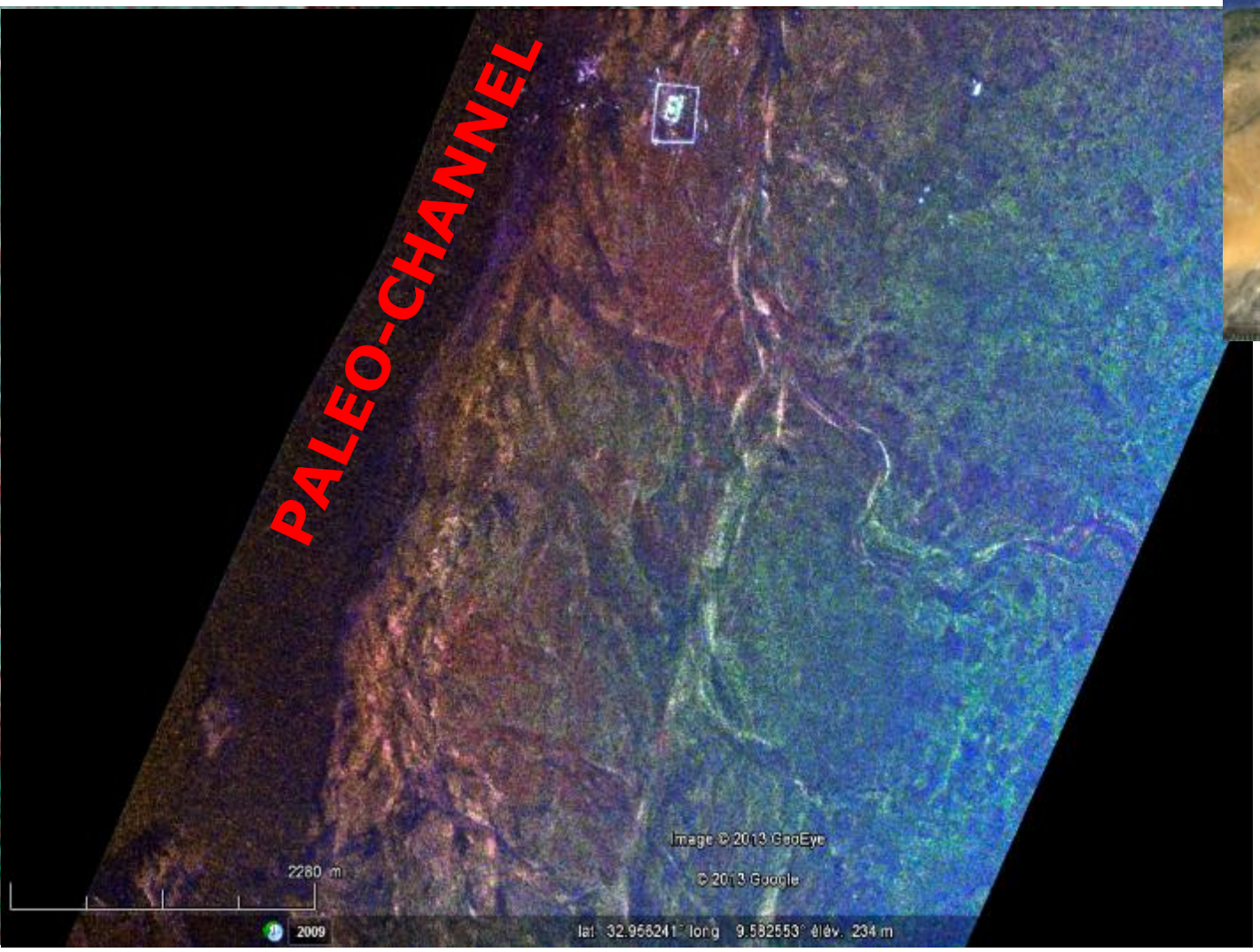
- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20-30%

Areas of forest clearing (hectare)

- 50 m resolution
- 1 map every 6 months
- global coverage of forested areas
- 90% classification accuracy

P-band enhances subsurface imaging in arid zones

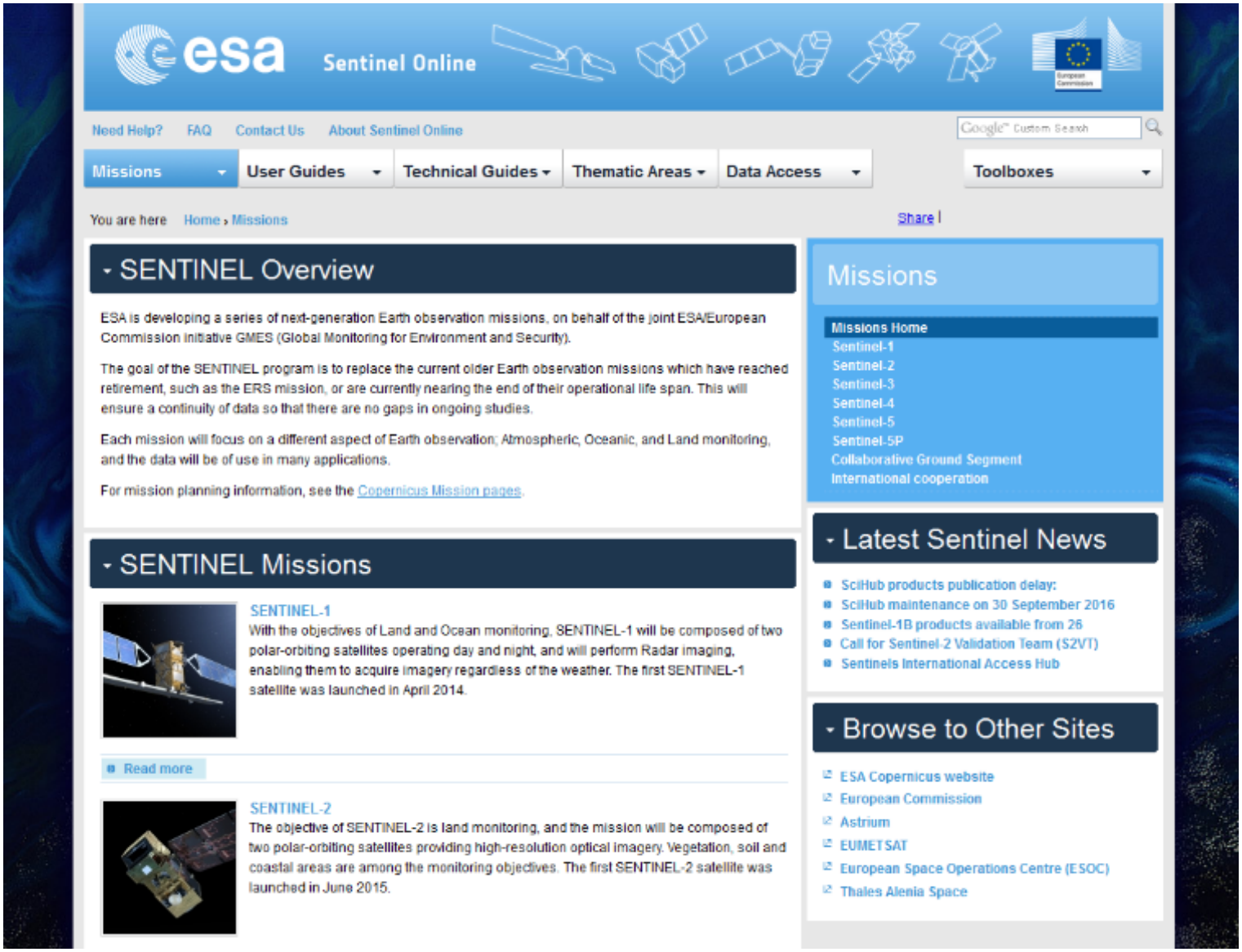
P-band SAR



ESA EO DATA ACCESS & RESOURCES

Sentinel Online | The Official Sentinel Website

https://sentinel.esa.int/web/sentinel/home



Sentinel-1 Data Access | Scientific Data Hub

https://scihub.copernicus.eu/

- open and free on-line access to Sentinel-1 products | Access through self-registration

ESA **SAR** Archive (ERS-1. 2, Envisat / ASAR))

ESA Data Access page

SNAP

- The common architecture for all **Sentinel Toolboxes** and **SMOS Toolbox** is called Sentinel Application Platform (SNAP).
- SNAP architecture is ideal for Earth Observation processing and analysis due the following technological innovations: Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management and a Graph Processing Framework.

Activity funded through SEOM element of ESA's EOEP-4 (www.seom.esa.int)

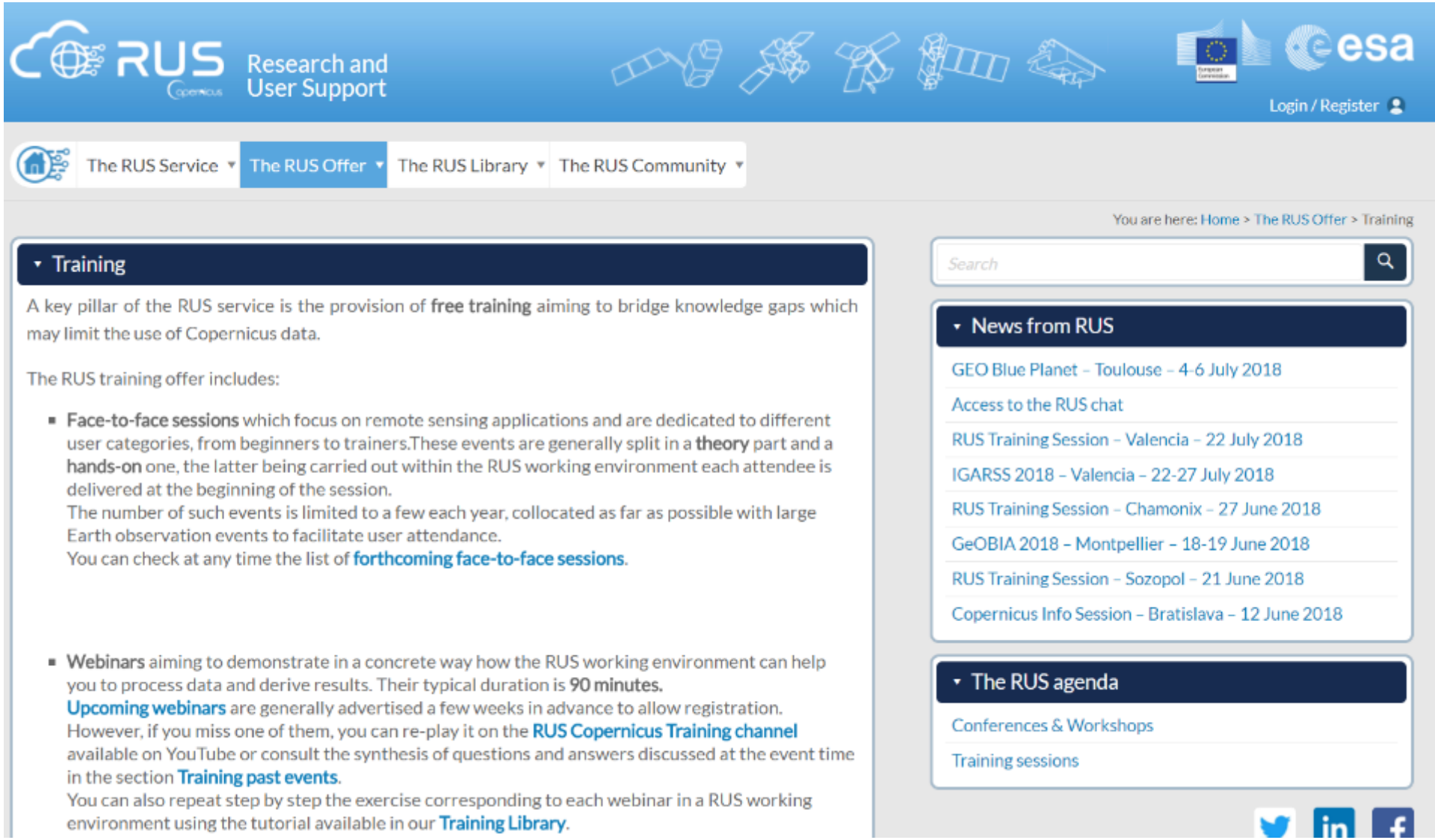
Opportunities for EO training

asdhttps://eo4society.esa.int/training-education/

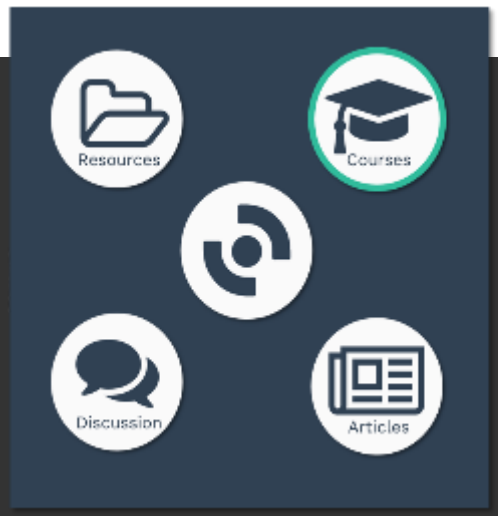
Training courses at University level in Europe:
Earth Observation Summer Schools in ESRIN

Usually organized every 2 years, open to students from worldwide, free tuition

https://rus-copernicus.eu/portal/the-rus-offer/training/



MOOC – First Radar Remote Sensing Course



HISTORY GEOMETRY
LAND WATER HAZARD

12 Τυτοριαλσ
5700 Στυδεντσ
15% Χομπλετιον ρατε
Φιναλ Χερτιφιχατε

esa FRIEDRICH-SCHILLER-UNIVERSITÄT JENA EOS eo college

http://eo-college.org

MOOC – First Radar Remote Sensing Course

MOOC Videos accessible on youtube all the time.
Exercises accessible via PDF tutorials prepared for CONAE and delivered to CONAE

esa FRIEDRICH-SCHILLER-UNIVERSITÄT JENA EOS eo college

http://eo-college.org

MOOC – First Radar Remote Sensing Course

To be followed in 2019 by an extensive re-run with more lessons and exercises (contribution from CSA) !!!!

Previous ESA EO MOOCs

Monitoring Climate from Space

Explore our planet from space and learn how Earth observation is used to monitor climate change, with this free online course.

Earth Observation from Space: the Optical View

Discover how optical Earth observation data is gathered and used in this free online course from the European Space Agency (ESA).

- **3rd ESA MOOC on Climate from Space "Greenland special"**

https://www.futurelearn.com/courses/climate-from-space

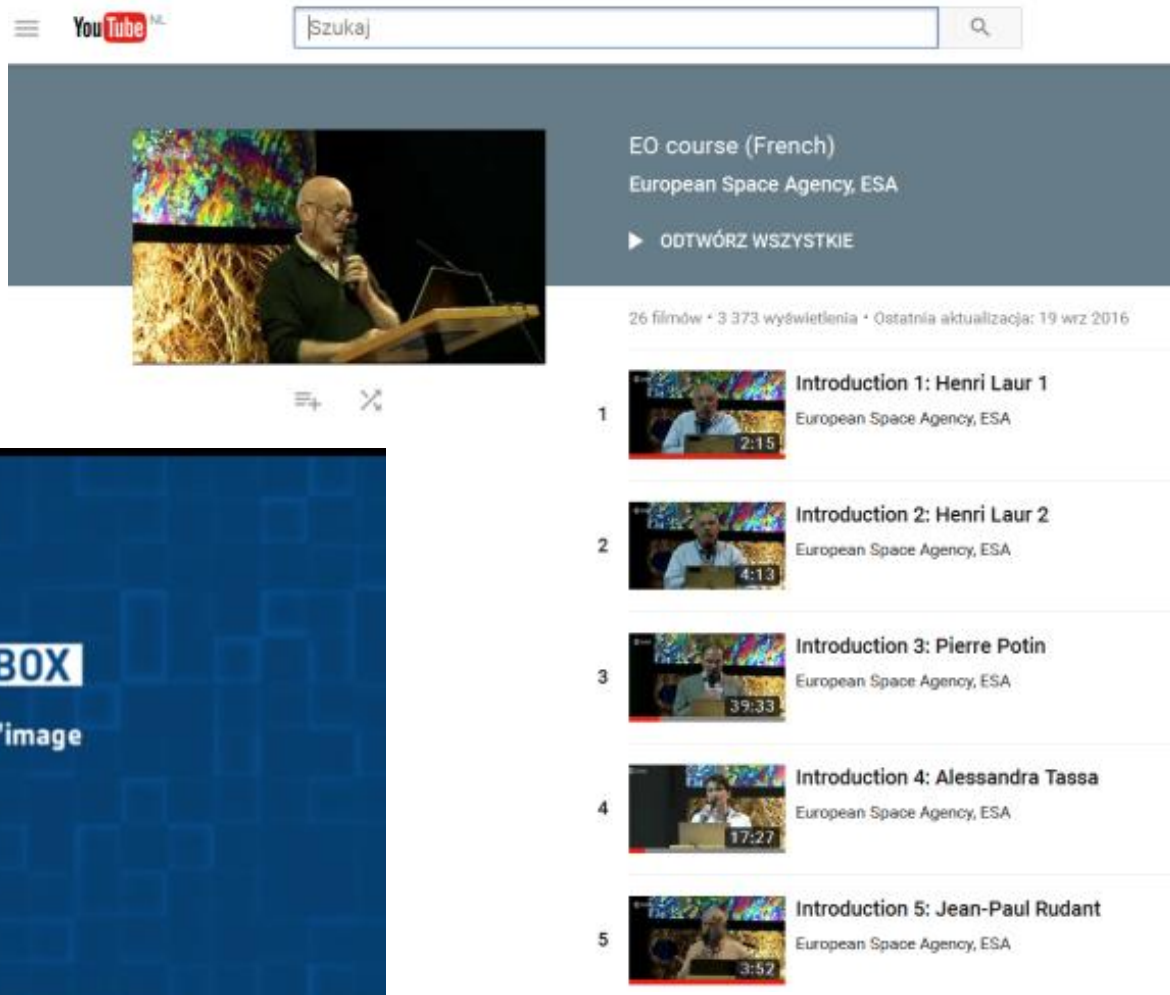
- **1st ESA MOOC on "EO from Space: The Optical View"**

https://www.futurelearn.com/courses/optical-earth-observation

- **1st ESA MOOC on "EO from Space: The Radar View"**
  Foreseen launch in October 2017

Recent SAR video lectures and SNAP tutorials (French, with Spanish / English Subtitles)

- SAR basic theory and practical exercises with SNAP (French version)
- Subtitles (Spanish, English) published in July 2017

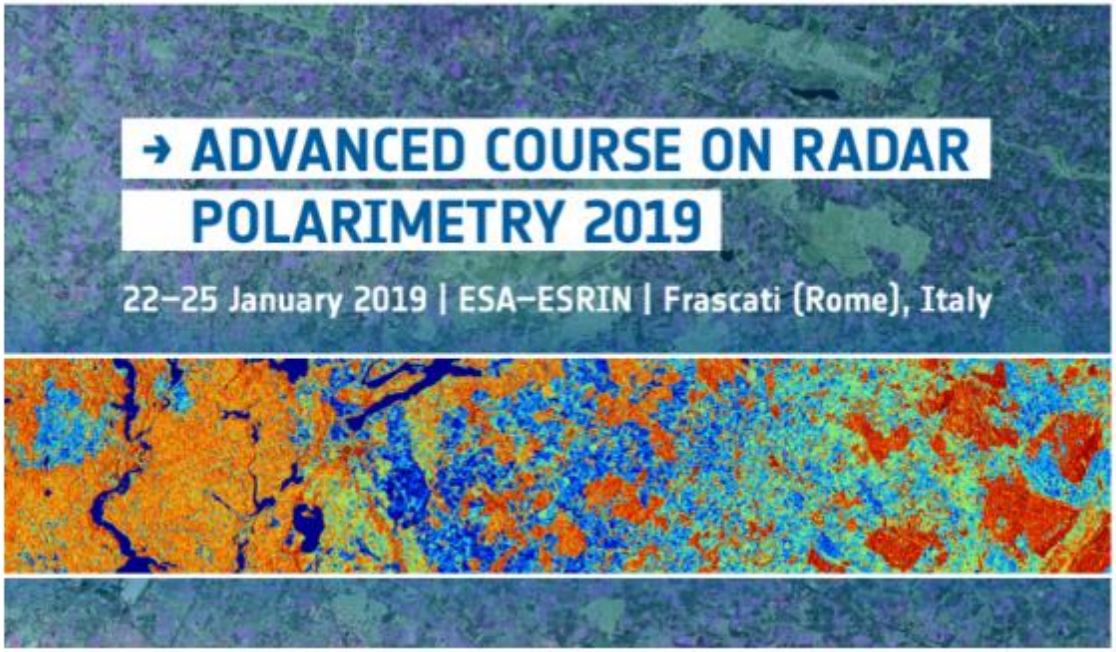


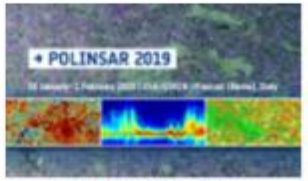
advanced course on radar polarimetry 2019

22–25 January | ESA–ESRIN | Frascati (Rome), Italy

esa

ESA





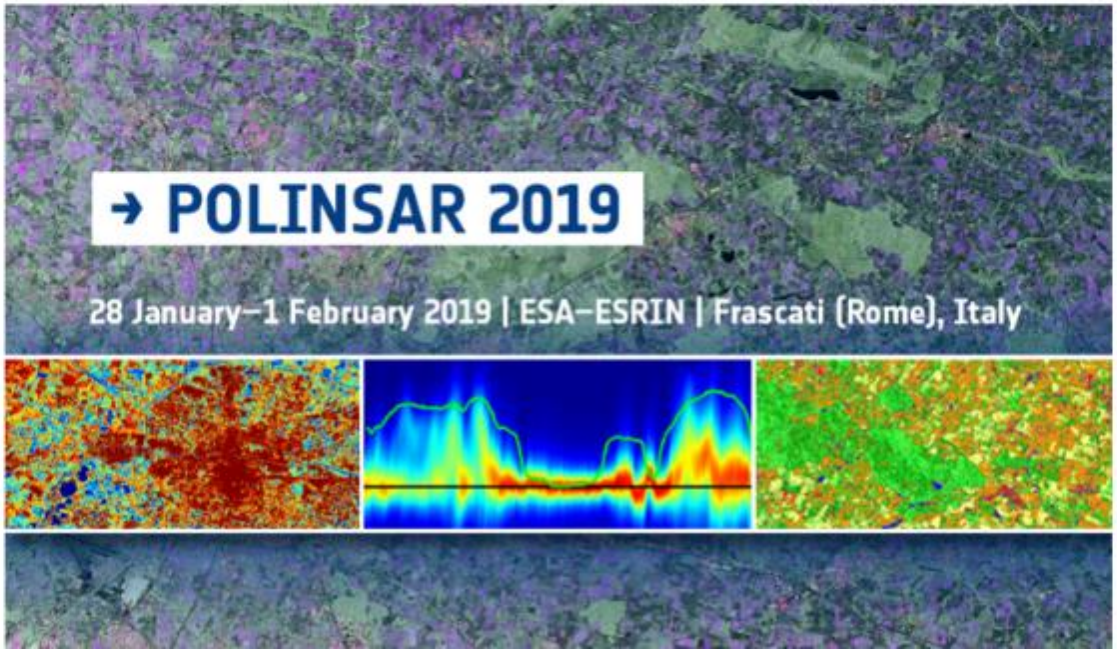
POLINSAR 2019 Workshop

polinsar 2019

28 January–1 February 2019 | ESA–ESRIN | Frascati (Rome), Italy

esa

ESA



Polarimetry Course 2019

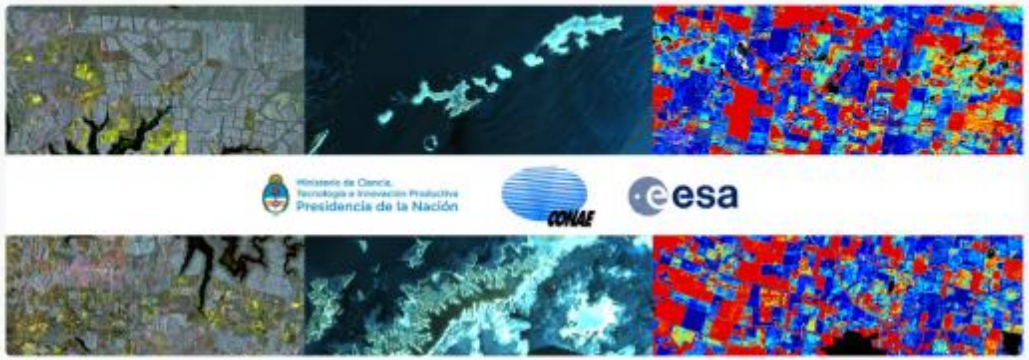

esa
living planet symposium
MILAN
13–17 May
2019
UNDERSTANDING THE EARTH SYSTEM
SPACE 4.0 AND EARTH OBSERVATION
BENEFITS FOR A RESILIENT SOCIETY
PUBLIC AND PRIVATE SECTOR INTERACTIONS
Deadlines
Session Proposals
17 June 2018
Abstracts
11 November 2018
Registration
April 2019
lps19.esa.int
European Space Agency

ESA/CONAE L/C/X band SAR Training Course

Buenos Aires, Argentina, 12 -17 November 2018

Jointly Organised by ESA & CONAE, in preparation of the exploitation of SAOCOM (L-band SAR) data, jointly with other C-band and X-band SAR missions
The course will include SAR theory & practice, with SAR techniques and applications to natural resource management (forestry, agriculture) and emergencies.

12 al 17 de Noviembre de 2018. Buenos Aires. Argentina



La Agencia Espacial Europea (ESA) en cooperación con la Comisión Nacional de Actividades Espaciales (CONAE) invitan a participar en el **"Curso ESA-CONAE de Formación SAR en Bandas L/C/X" ("ESA/CONAE L/C/X band SAR Training Course")** a desarrollarse del 12 al 17 de noviembre de 2018 en la Ciudad Autónoma de Buenos Aires, Argentina. El principal objetivo de este curso es promover entre los participantes la utilización de las imágenes SAR en diferentes áreas de aplicación relevantes para la Argentina. El temario abarca desde una introducción general en teoría SAR hasta la sinergia entre las diferentes bandas (L/C/X) para el desarrollo de aplicaciones.

Summary of the course

Topics:

- SAR theory, techniques and applications (including computers practicals):
- InSAR, PolinSAR
- Applications to Forestry and Vegetation
- Ship detection and surfactant detection
- Ground displacement mapping
- Disaster monitoring
- Snow and glaciers mapping

Teachers:

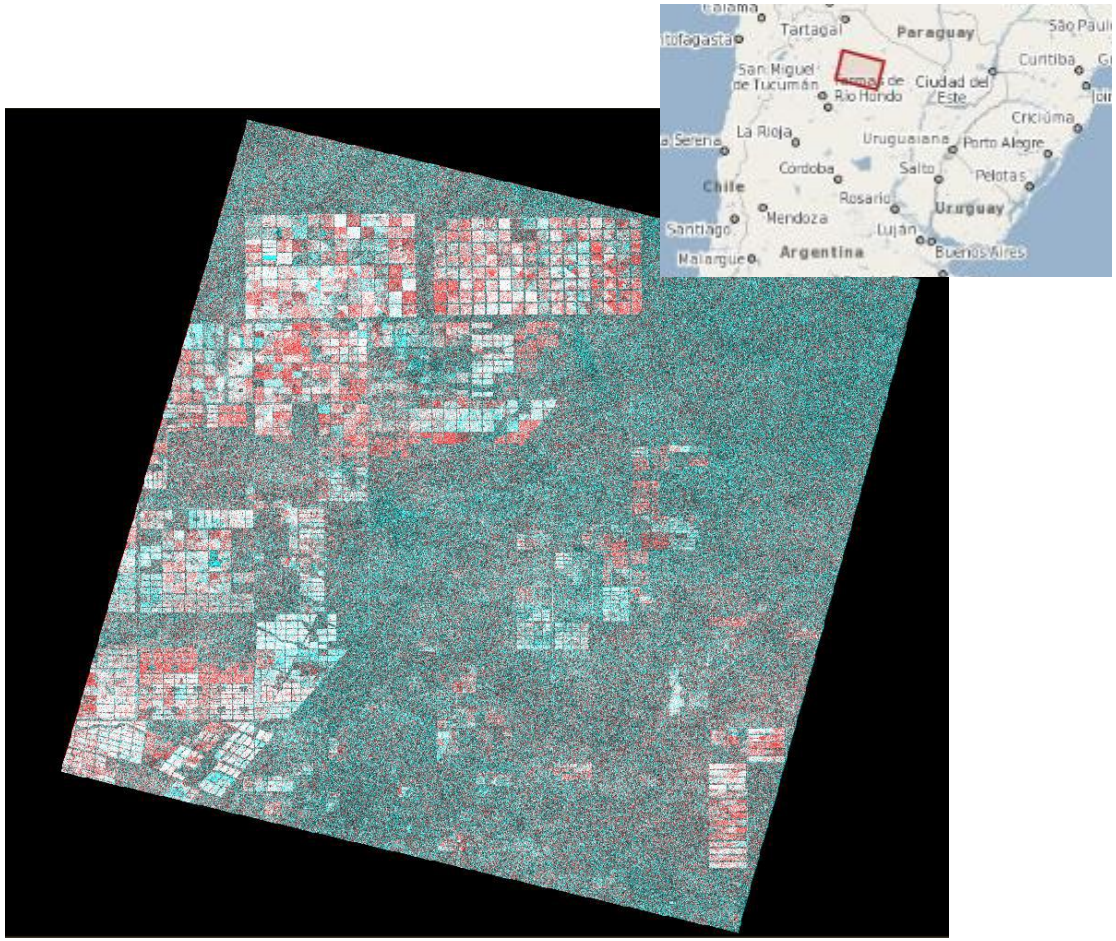
Renowned experts and scientists from European research institutes working with ESA

List of sensors used:

- Sentinel-1 and Radarsat-2 (C-band)
- ALOS-2/PALSAR-2 and ALOS/PALSAR (L-band)
- Cosmo SkyMed and TerraSAR-X (X-band)

Test-cases / practical exercises:

Deforestation in Gran Chaco Region, AR



Sentinel-1 (C-band) multi-temporal coherence analysis

Comparison of the interferometric coherence for two periods:

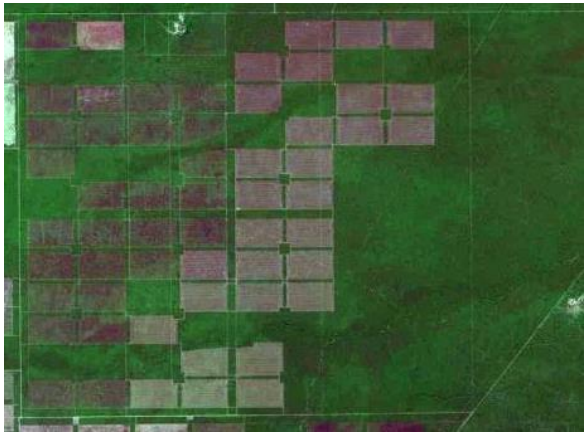
- Coherence between July & August 2016 (Cyan)
- Coherence between two dates of August 2018 (Red)

An increase in coherence indicates a decrease in vegetation.
Areas in Red indicate potential deforestation

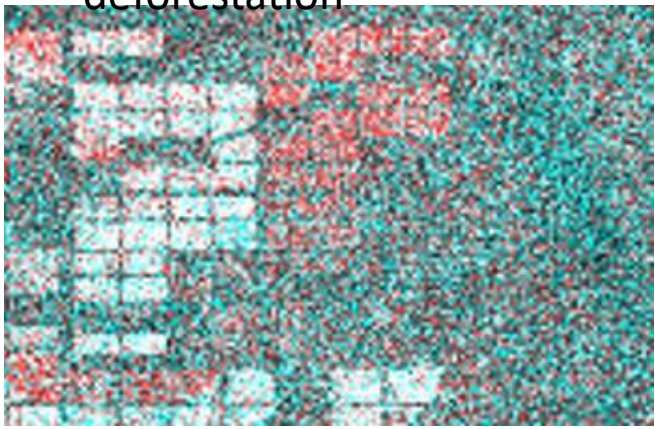
Test-cases / practical exercises: Deforestation in Gran Chaco Region, AR

Sentinel-2 (Optical) August 2016

Sentinel-2 (Optical) August 2018



Sentinel-1 (SAR) coherence analysis. Red: deforestation

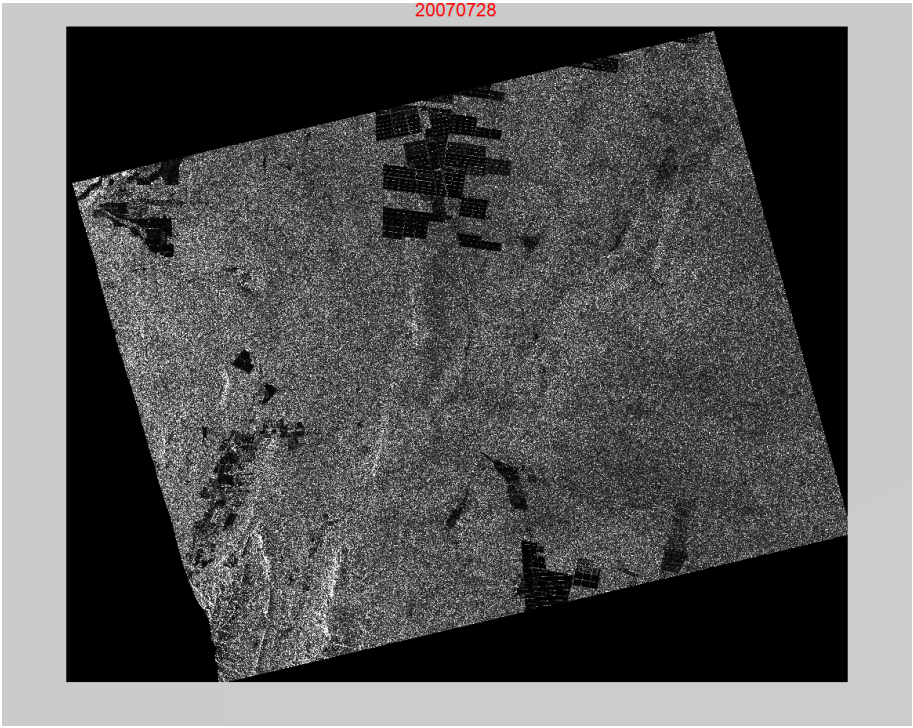


Sentinel-1 (C-band) analysis will be complemented with ALOS-2/PALSAR-2 (L-band)

Test-cases / practical exercises:

Deforestation in Salta Region, AR

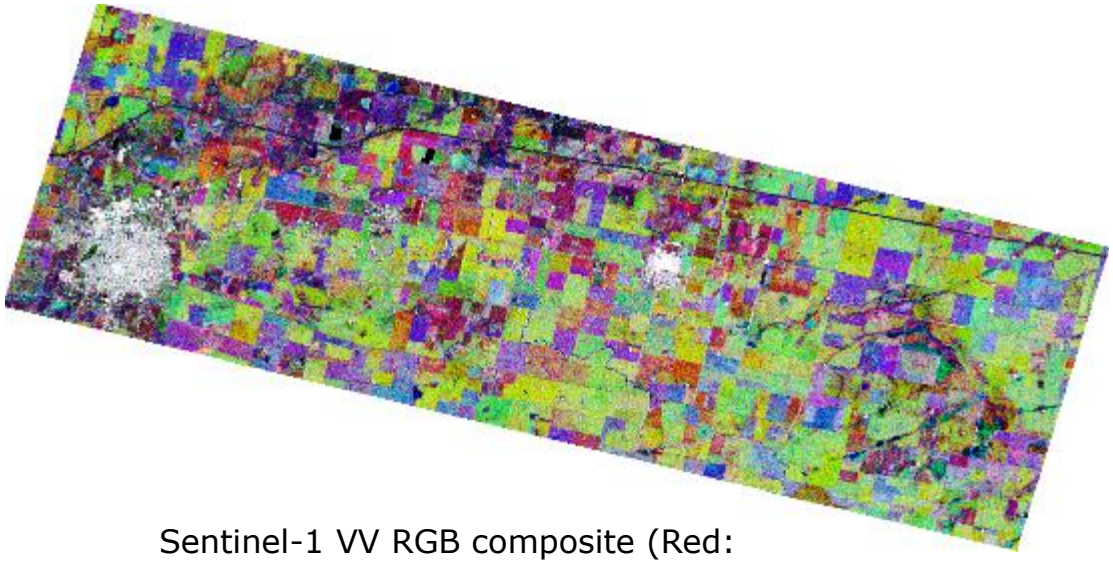
ALOS-1 (L-band) analysis will be complemented with Cosmo SkyMed (X-band) analysis



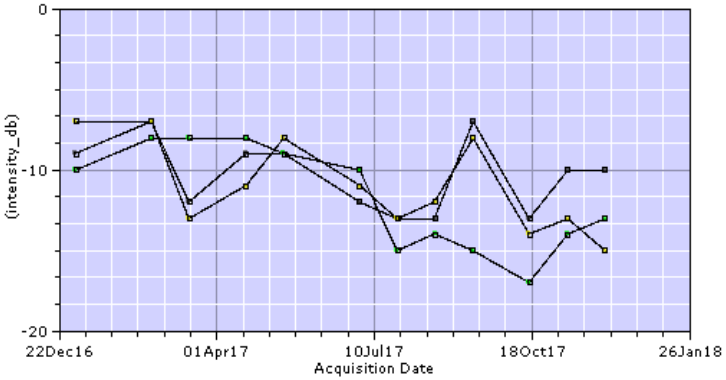
ALOS-1 animation (2007, 2009 and 2010)

Test-cases / practical exercises:
Agriculture in Cordoba Region, AR

Sentinel-1 (C-band) and Cosmo SkyMed (X-band) analysis,
to be complemented with ALOS-2/PALSAR-2 (L-band)



Sentinel-1 VV RGB composite (Red: January 2017, Green: March 2017, Blue: September 2017)



Plot of backscatter time series for different crop types using Sentinel-1. Green points: corn, yellow points : soya, brown points: pasture

Test-cases / practical exercises:
Ground deformation due to a major Earthquake in Chile

2015 Earthquake in Chile (Nazca Plate Region):
Sentinel-1 (C-band) Wrapped interferometric phase. To be complemented with ALOS-1/PALSAR-1 (L-band), TerraSAR-X (X-band) and Cosmo SkyMed (X-band)