Sentinel-1 Mission Overview

Pierre Potin, Sentinel-1 Mission Manager, ESA

Workshop "Dark side of Remote Sensing"
BELSPO, Brussels, 9 Dec 2015

Copernicus:
A New Generation of Data Sources

Sent-1A/B Sent-2A/B Sent-3A/B Sent-4A/B Sent-5/5P Sent-6A/B

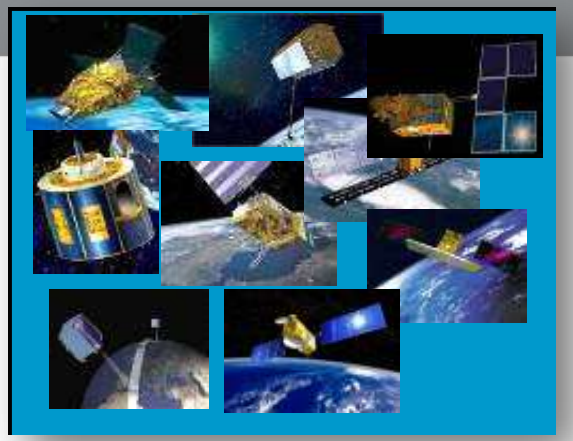
- Copernicus is a European space flagship programme led by the European Union
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security
- ESA coordinates the space component
- Free and open data policy

Copernicus Space Component: Dedicated Missions: the Sentinels

- **S1:** Radar Mission — FIRST LAUNCH 3.04.2014
- **S2:** High Resolution Optical Mission — FIRST LAUNCH 23.06.2015
- **S3:** Medium Resolution Imaging and Altimetry Mission
- **S4:** Geostationary Atmospheric Chemistry Mission
- **S5P:** Low Earth Orbit Atmospheric Chemistry Precursor Mission
- **S5:** Low Earth Orbit Atmospheric Chemistry Mission
- **S6 (Jason-CS):** Altimetry Mission

Copernicus architecture

6 services use Earth Observation data to deliver …



Sentinels

Contributing missions

Other use (e.g science)

…added-value products

in-situ

Copernicus Sentinel Data Policy

Sentinel Data Policy =
FREE and OPEN access

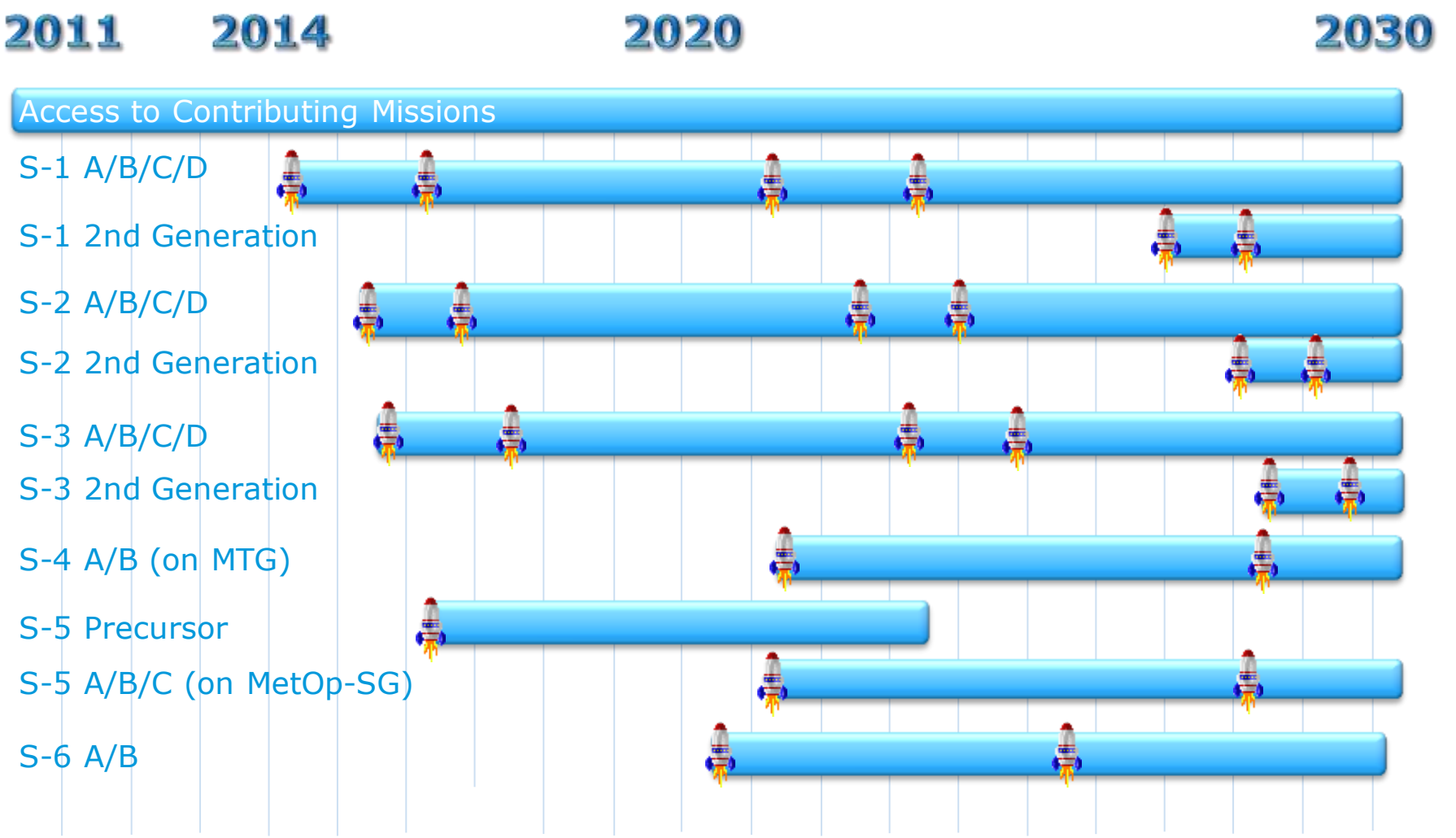
The Delegated Regulation on Data and Information Policy from the European Commission entered into force in December 2013

This Regulation stipulates:

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

Copernicus Contributing Missions data access follow their owners data policies.

Copernicus: a long-term operational perspective

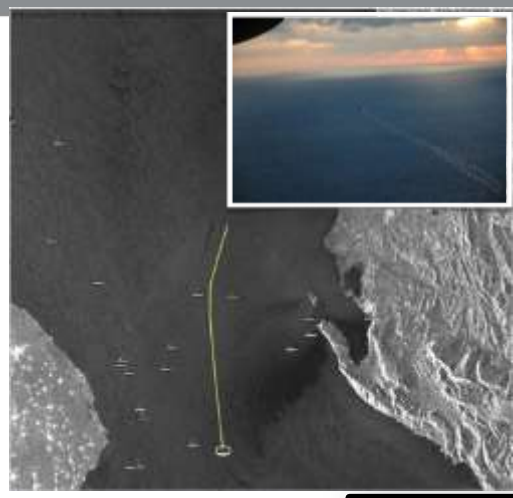


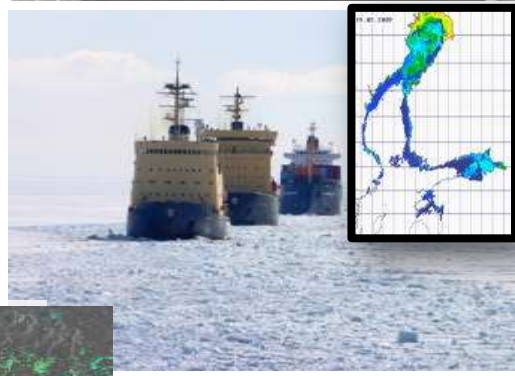
Launch Sentinel-1A

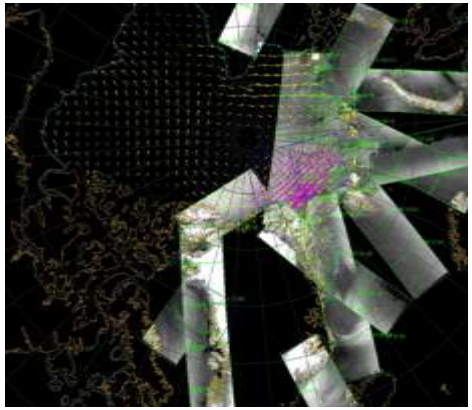
- 3 April 2014
- Kourou spaceport
- Soyuz-2 rocket
- New era of Earth observation

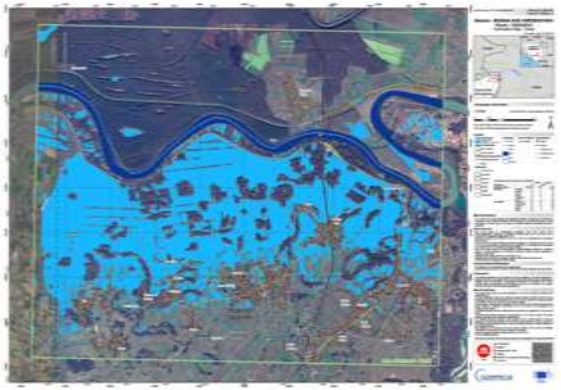
Sentinel–1: C-band SAR mission

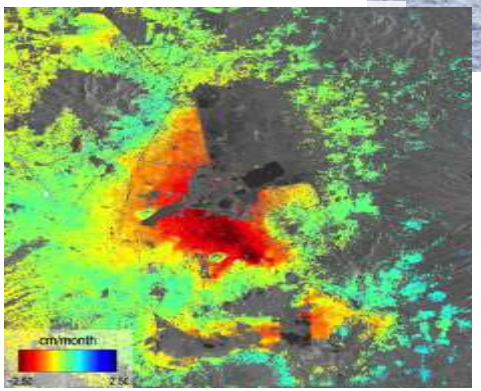
- ✓ **Data continuity of ERS and ENVISAT missions**
- ✓ **Copernicus radar imaging mission for ocean, land, emergency**
- ✓ **Applications:**
  - monitoring sea ice zones and the arctic environment
  - surveillance of marine environment (e.g. oil spill monitoring)
  - maritime security (e.g. ship detection)
  - wind, wave, current monitoring
  - monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.)
  - support to emergency / risk management (e.g. flooding, etc.) and humanitarian aid in crisis situations
  - mapping of land surfaces: forest, water and soil, agriculture, etc.





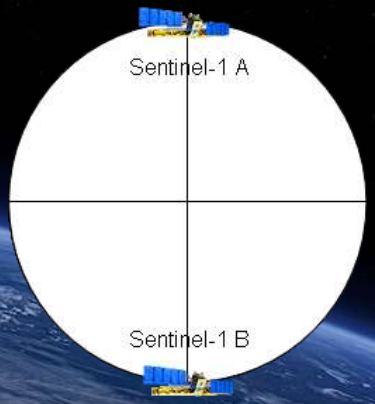






Sentinel-1: Mission Profile

- Mission based on 2 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 (6 days with 2 satellites)



Launch and Mission Operations Phases

Sentinel-1 full mission exploitation capacity based on the routine operations of the 2-satellite constellation
➔ gradually achieved

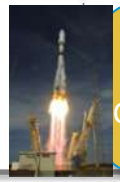
S1 Full Operational Capacity

S1B Operational qualification

S1A Routine Operations

S1A Operational qualification

S1A Space Segment Commissioning



S1B Space Segment Commissioning

S1A-Launch
3 April 2014

S1A IOCR
Sep 2014

1st S1A ROR
9 June 2015

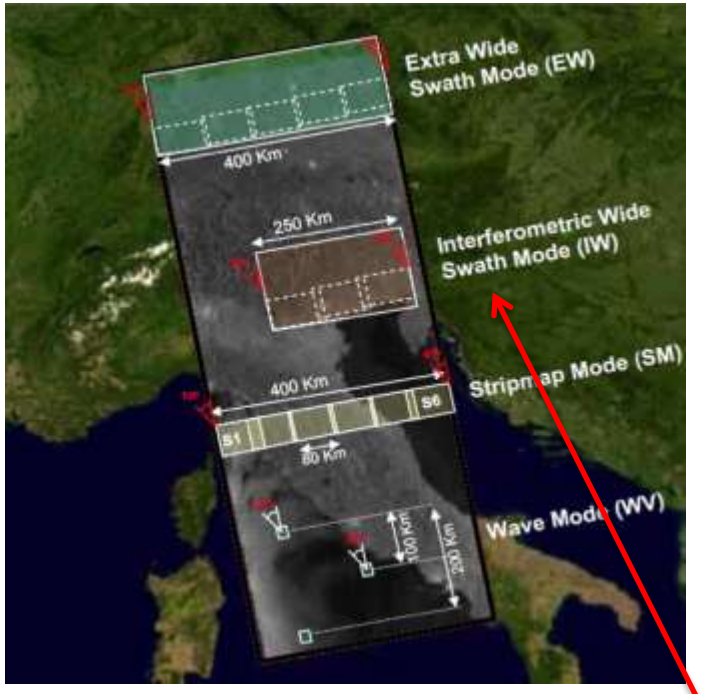
Dec 2015

S1B Launch
April 2016

S1 Mission ROR
~ end 2016

Sentinel-1 SAR Operational Modes

Operational Modes



GRD Level 1 product resolution	Swath Width	Polarisation
50m (3 ENL)	> 400 km	HH+HV or VV+VH
20m (5 ENL)	> 250 km	HH+HV or VV+VH
9m (4 ENL)	> 80 km	HH+HV or VV+VH
50m (140 ENL)	20 x 20 km² at 100 km spacing	HH or VV

Main mode over land and coastal areas

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.

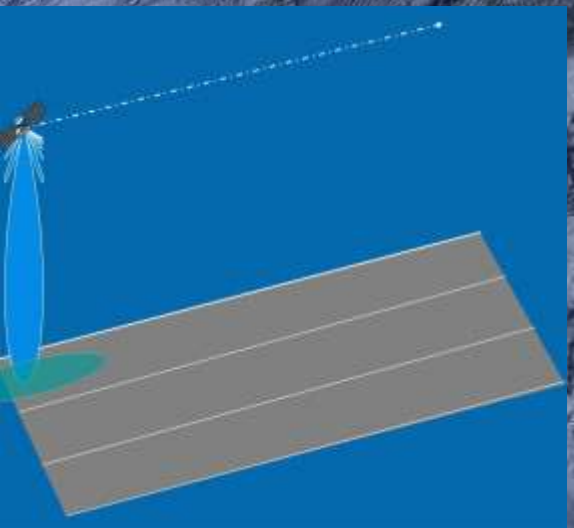
Sentinel-1 Level 1 Operational Product characteristics

Acq. Mode	Product Type	Resolution Class	Resolution [Rng x Azi] [m]	Pixel Spacing [Rng x Azi]	No. Looks [Rng x Azi]	ENL
SM	**SLC**	-	**1.7 x 4.3 to 3.6 x 4.9**	**1.5 x 3.6 to 3.1 x 4.1**	1 x 1	1
	GRD	FR	9 x 9	4 x 4	2 x 2	3.9
		HR	23 x 23	10 x10	6 x 6	34.4
		MR	84 x 84	40 x 40	22 x 22	464.7
IW	**SLC**	-	**2.7 x 22 to 3.5 x 22**	**2.3 x 17.4 to 3 x 17.4**	1	1
	GRD	HR	20 x 22	10 x 10	5 x 1	4.9
		MR	88 x 89	40 x 40	22 x 5	105.7
EW	**SLC**	-	**7.9 x 42 to 14.4 x 43**	**5.9 x 34.7 to 12.5 x 34.7**	1 x 1	1
	GRD	HR	50 x 50	25 x 25	3 x 1	3
		MR	93 x 87	40 x 40	6 x 2	12
WV	**SLC**	-	**2.0 x 4.8 and 3.1 x 4.8**	**1.7 x 4.1 and 2.7 x 4.1**	1 x 1	1
	GRD	MR	52 x 51	25 x 25	13 x 13	139.7

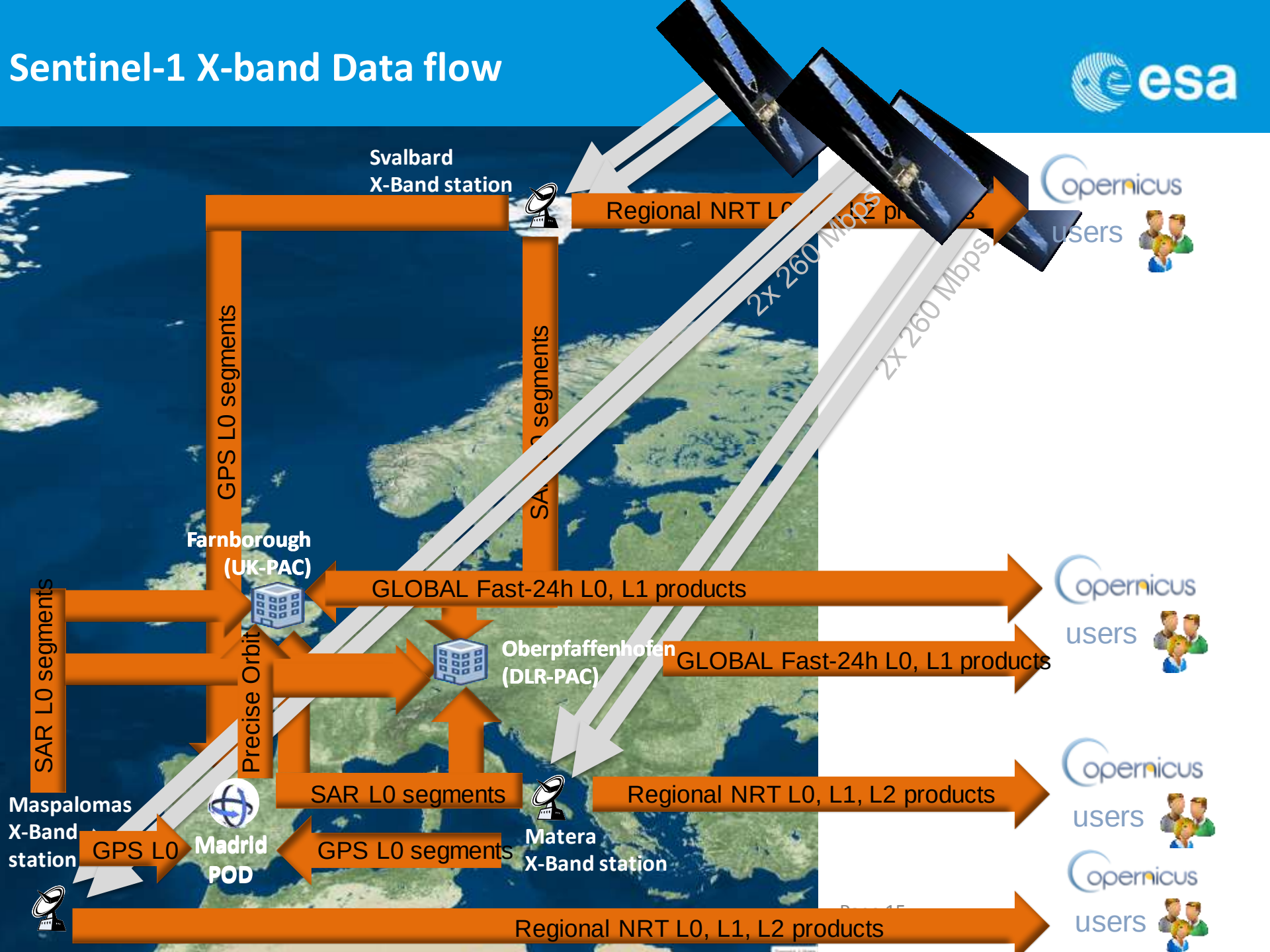
- **For Ground Range Products, the resolution corresponds to the mid range value at mid orbit altitude, averaged over all swaths.**
- **For SLC SM/IW/EW products, the resolution and pixel spacing are provided from lowest to highest incidence angle. For SLC WV products, the resolution and pixel spacing are provided for beams WV1and WV2.**
- **For SLC products, the range coordinate is in slant range. All the other products are in ground range.**

Image Acquisition in Interferometric Wide Swath mode (IW)

Terrain **O**bservation by **P**rogressive **S**cans (TOPS)



Sentinel-1 X-band Data flow



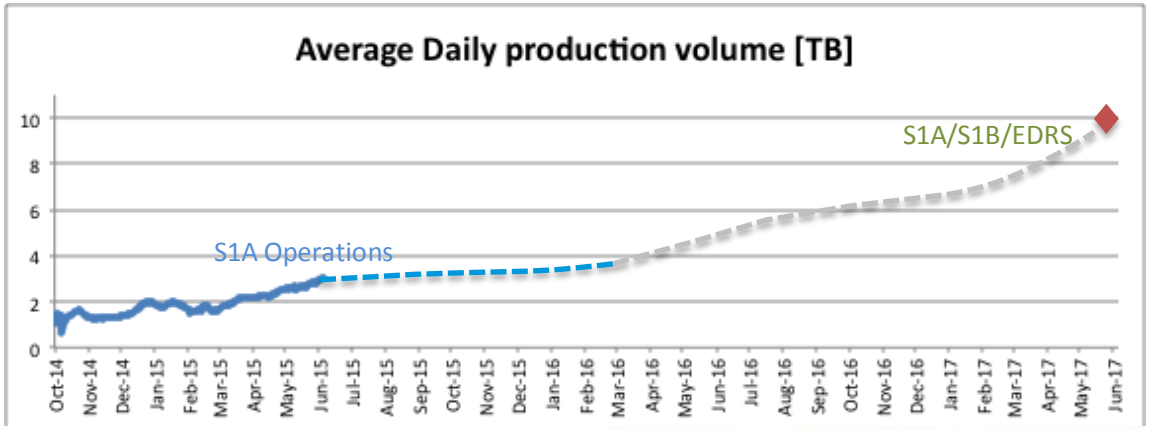
Mission operations perspectives

- S1 operations are nominally performing since S1A Launch: observation, production, product qualification and data access being gradually enhanced to maximize the mission exploitation

- S1 L0/L1 user products are operationally qualified. S2 L2 OCN products geophysical validation is in progress

- S1 operations paradigm with systematic processing of all data and open & free data access to all users is a major challenge but… it is being made possible

- S1A operations qualification being completed… S1B operations arriving soon.



Sentinel-1 observation scenario Main components & thematic domains

Agriculture

European coverage

Forestry

Calibration/validation

Maritime surveillance

Zonal mapping

Emergency

Tectonic active areas and volcanoes / landslides and subsidence

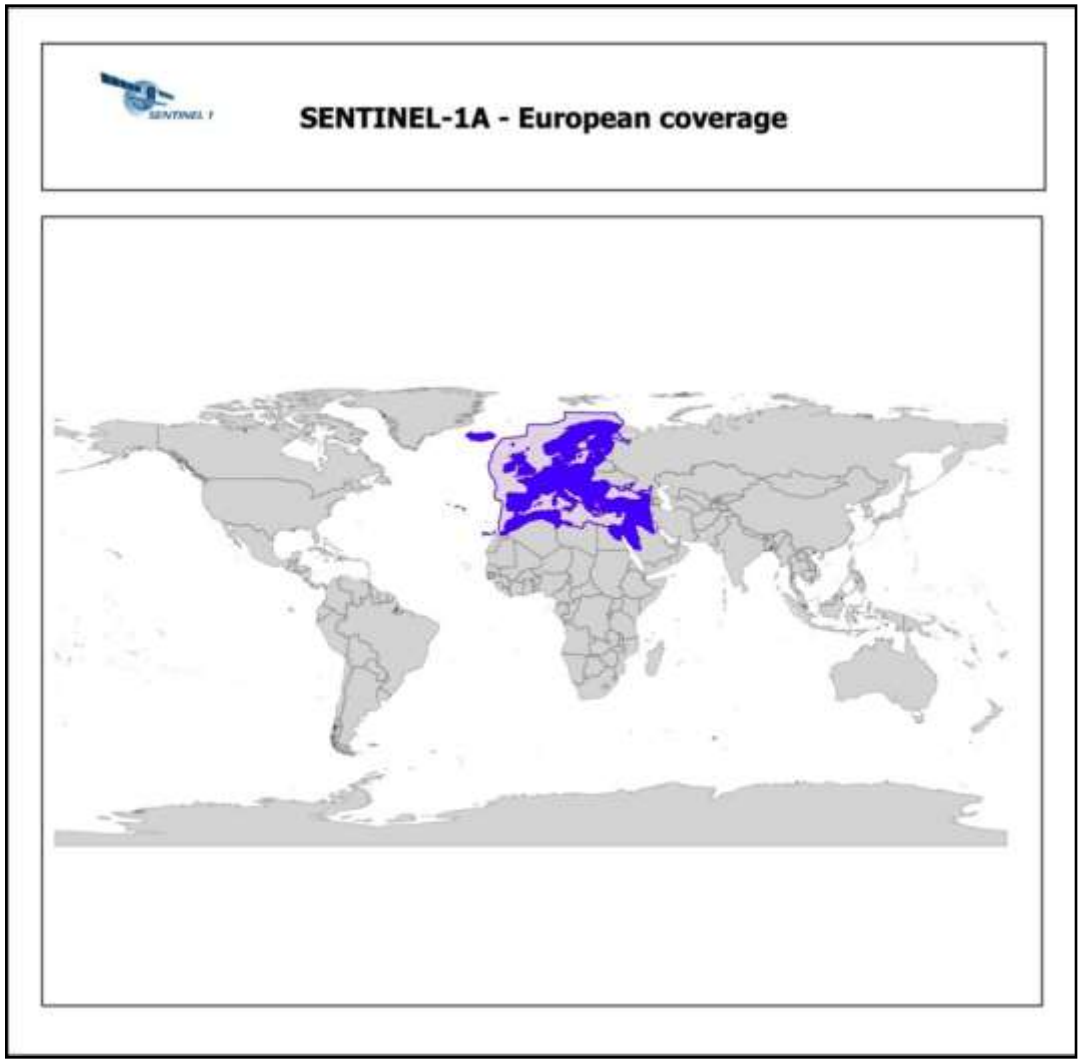
Security

Sea state

Sea-ice, icebergs, lake-ice

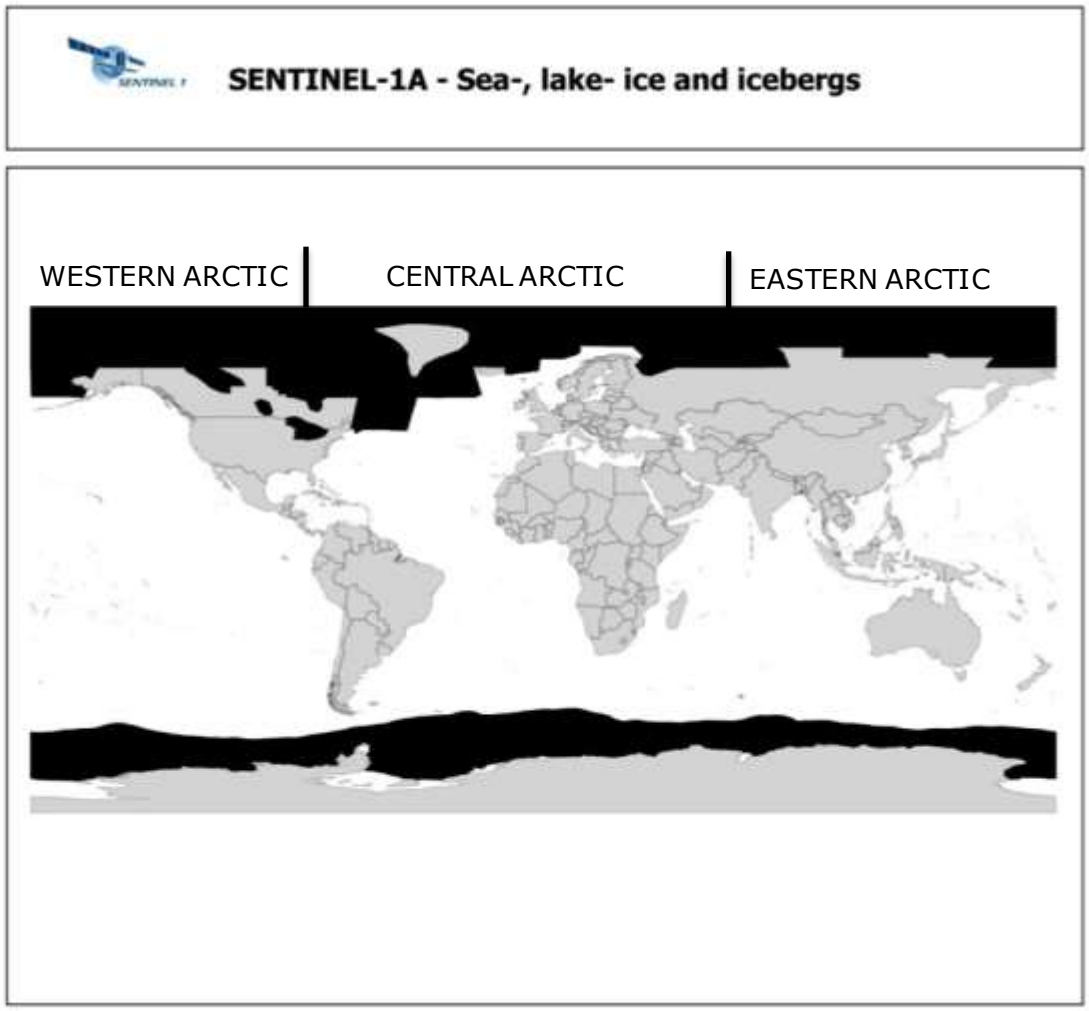
Ice sheets, glaciers, permafrost and snow

Sentinel-1 observation scenario
European coverage



- Full consistent coverage in ascending and descending passes every 12 days
- IW mode, VV+VH polarisation
- Including Mediterranean Sea, Black Sea, Baltic Sea and North Sea, EEZ of continental Europe in the Atlantic Ocean
- Europe defined as EU-/ESA-/EEA-38 member states
- Including (especially tectonic active) parts of the Maghreb and Middle East to avoid coverage fragmentation due to instrument switches
- Main observation area, resulting from various requirements

Sentinel-1 observation scenario
Sea-ice, icebergs, lake-ice



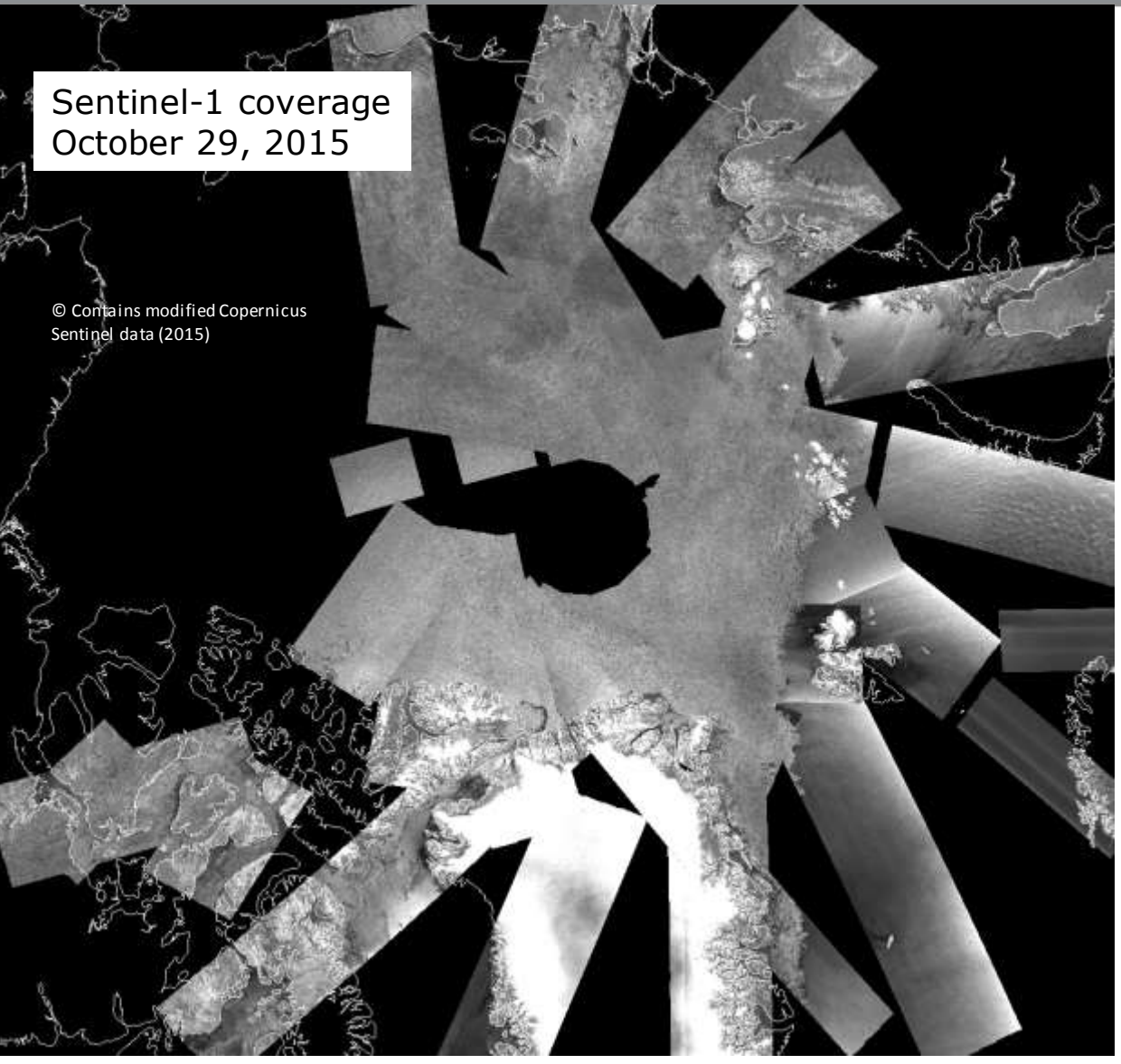
Central Arctic:

- Acquisitions in EW mode, HH+HV polarisation
- Very high repeat frequency, to respond mainly to CMEMS requirements

Eastern/Western Arctic:

- Acquisitions in EW mode, HH+HV polarisation up to ~ 78 deg N
- Acquisitions in EW mode, HH polarisation further north

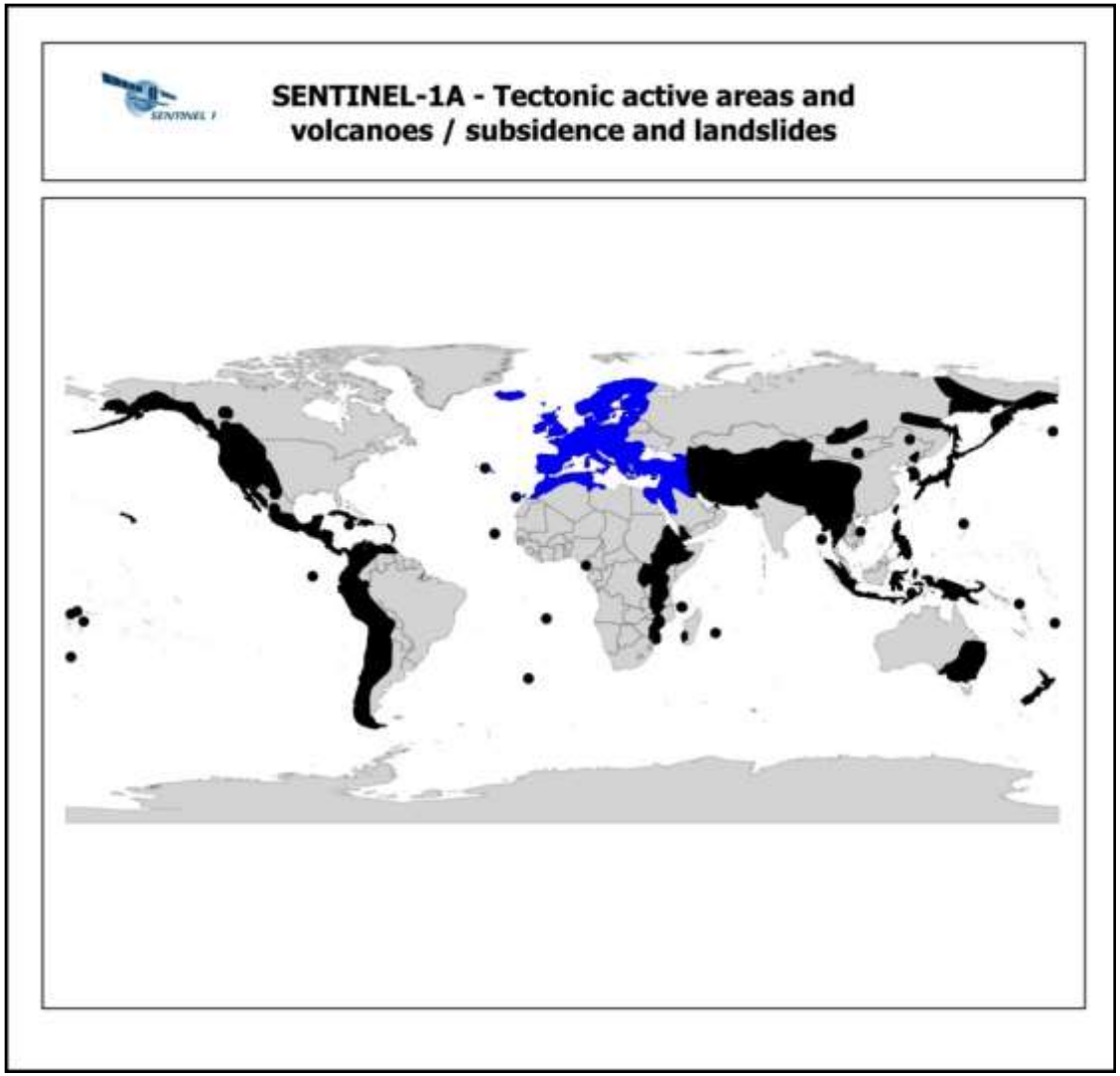
Operational Sentinel-1 data provision to CMEMS
Example of daily coverage



Sentinel-1 provides unprecedented radar coverage of the Polar Regions

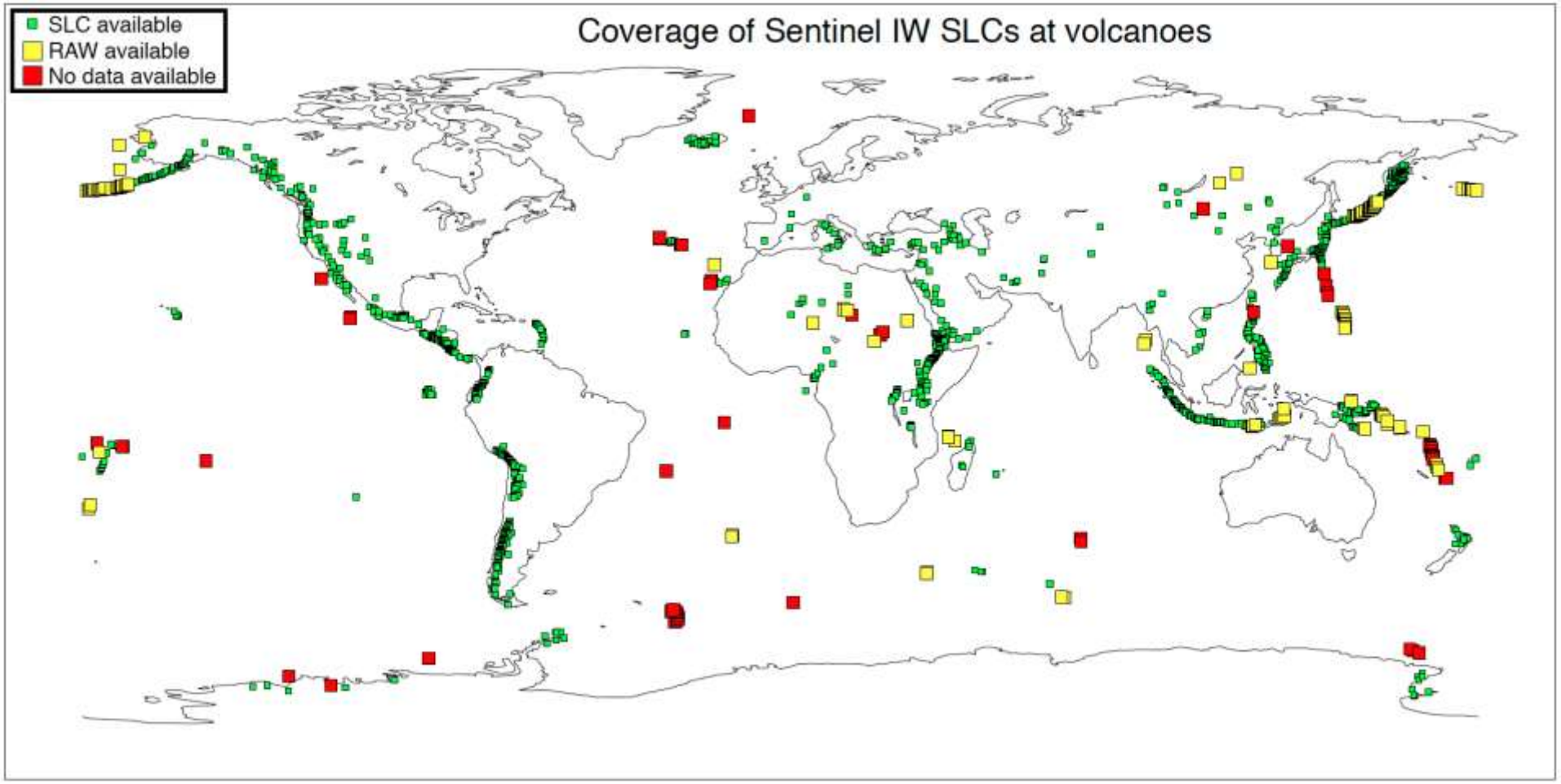
Data are delivered in near real time to the Copernicus Marine Environment Monitoring Service and constitutes the key input data to sea ice and iceberg monitoring

Sentinel-1 observation scenario
Global tectonic and volcanic areas



- **BLUE**: Acquisitions in IW mode, VV+VH polarisation, every 12 days ascending and descending
- **BLACK**: Acquisitions in IW mode, VV polarisation, every 24 days ascending and descending, alternating asc and desc passes every 12 days (i.e. repeat on the same track every 24 days)
- **Stripmap mode** (SM) acquisitions over selected small volcanic islands
- Increased sampling density over supersites outside Europe
- About one third of global landmass covered regularly under this frame

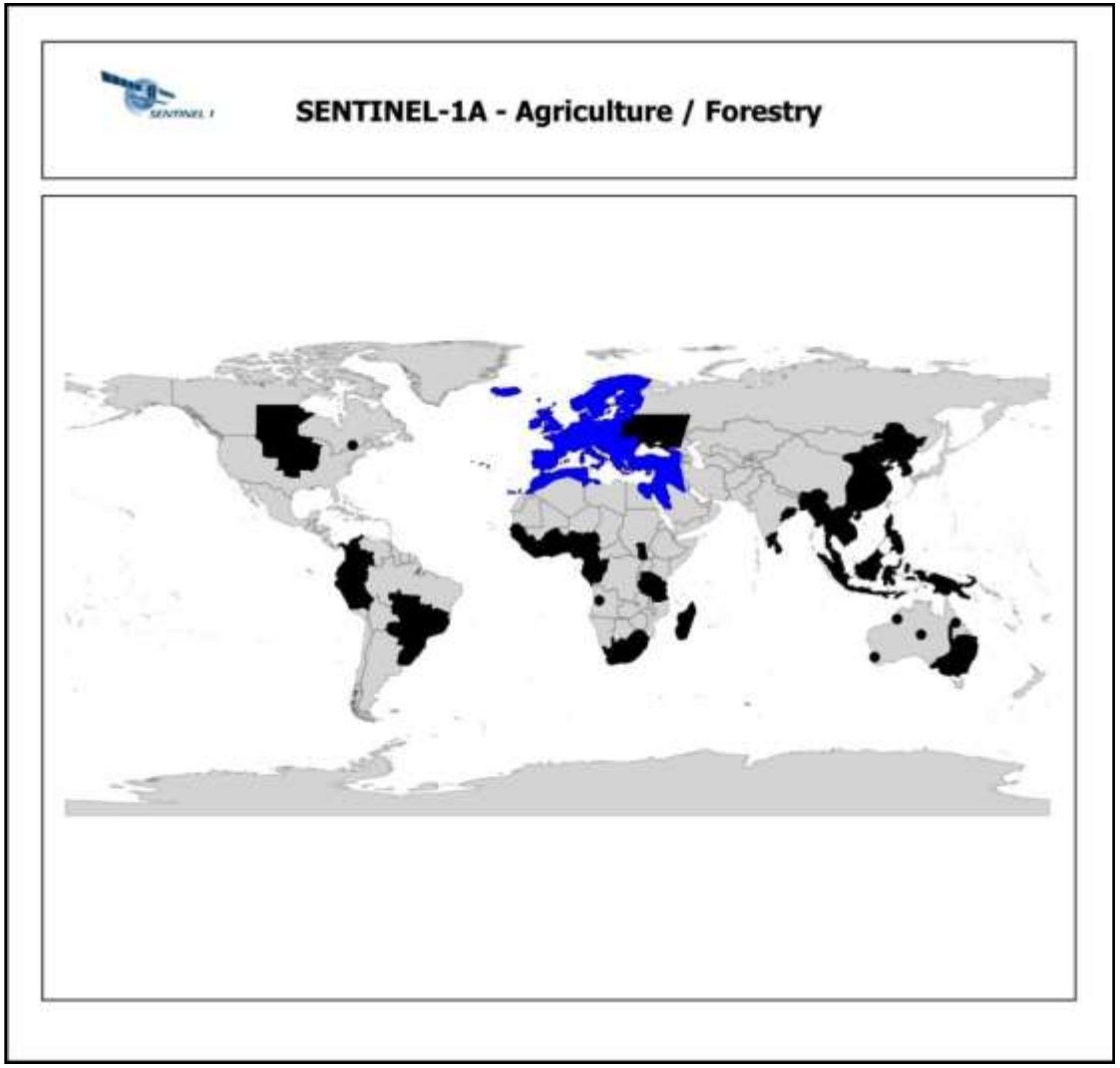
Assessment of worldwide volcano coverage



"Overall, the coverage is excellent with ~1180 of the 1370 subaerial volcanoes listed in the Global Volcano Programme having coverage already"

Statement from Juliet Biggs, University of Bristol (28 Sep 2015)

Sentinel-1 observation scenario
Agriculture and forestry priority areas



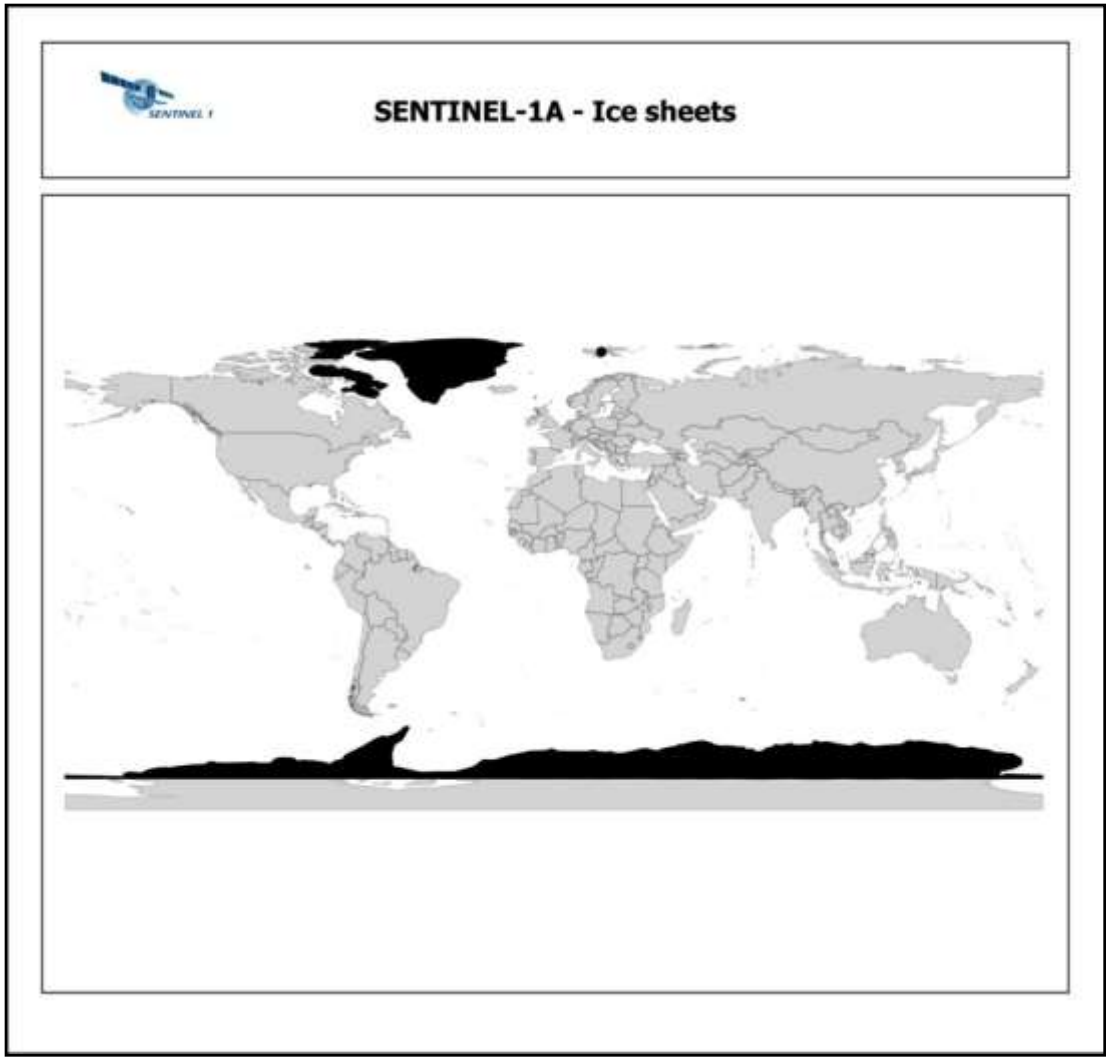
- **BLUE**: Acquisitions in IW mode, VV+VH polarisation, every 12 days ascending and descending

- **BLACK**: Acquisitions in IW mode, VV+VH polarisation, every 12 days in one pass
  - Repeat over parts of SE-Asia IW VV+VH currently every 24 days, plus complementary acquisitions in IW VV
  - North Andes and Tanzania covered with lower frequency (dedicated campaigns for forestry monitoring)

- **Agriculture focus**: mainly based on requirements from
  - wet rice crop monitoring (e.g. GEOGLAM)
  - soil moisture retrieval

- **Forestry focus**: mainly based on requirements from
  - GFOI
  - regions with high risk for illegal logging
  - Mostly cloudy tropical rainforests

Sentinel-1 observation scenario
Ice sheets

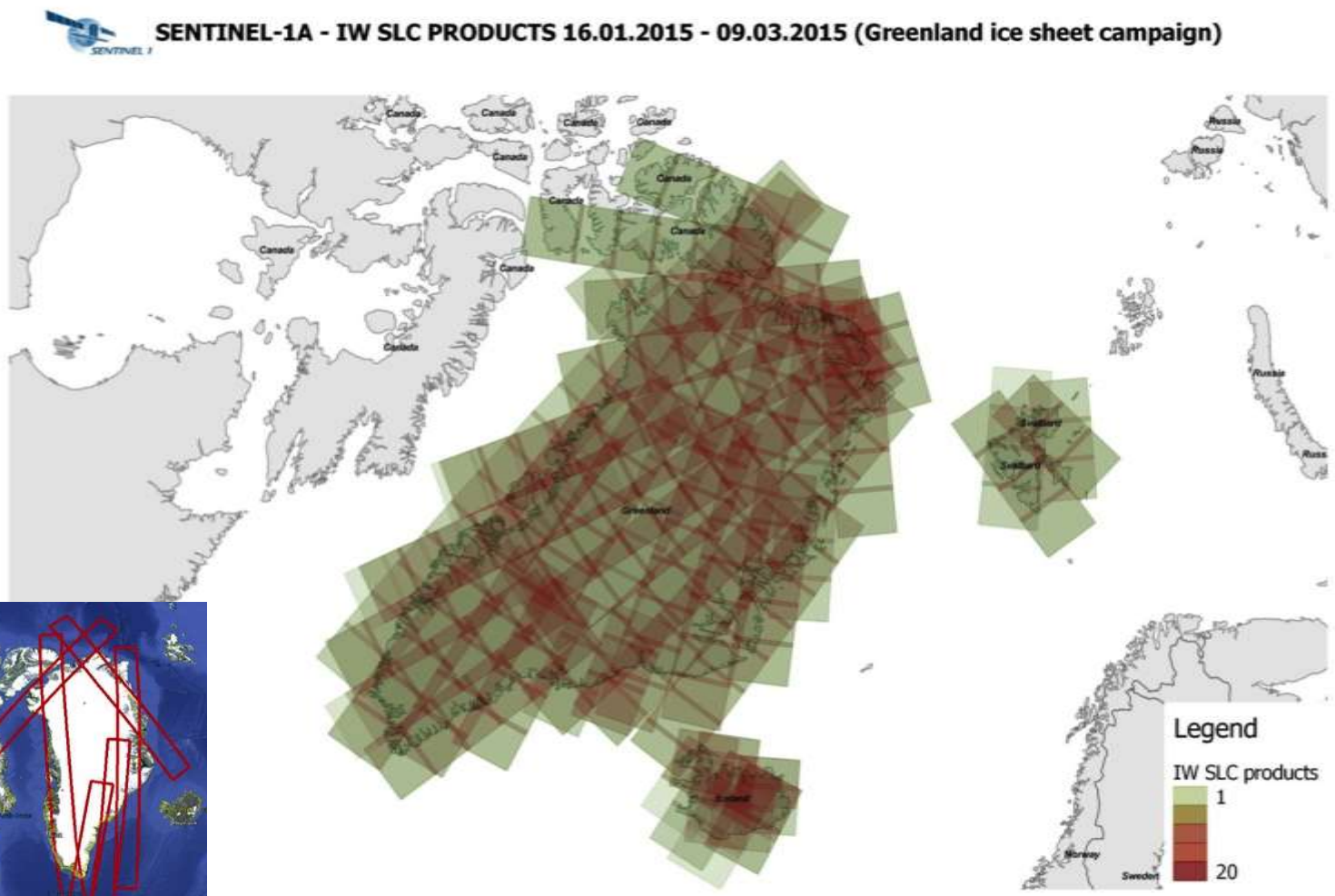


- **All year**: Acquisitions in IW mode, HH polarisation, every 12 days on selected tracks over the complete Greenland shore, the Antarctic Peninsula and the main outlet glaciers of Western Antarctica (Thwaites and Pine Island glaciers)

- **Frequent**: Acquisitions over Svalbard in IW mode, HH polarisation

- **Campaigns**: IW mode, HH polarisation, 3-4 consecutive repeats on the same tracks.
  - Greenland: ASC + DSC tracks. Including Baffin and Ellesmere islands. Ideally twice a year
  - Antarctica: ASC or DSC. S1A can see up to 78.5 deg. S. One full campaign during Antarctic winter, one potential campaign (ice edge only) during Antarctic summer

Sentinel-1 observation scenario Greenland Ice Sheet Campaign



In addition, continuous monitoring of coastal areas every 12-day repeat cycle with 6 tracks

Greenland campaign:

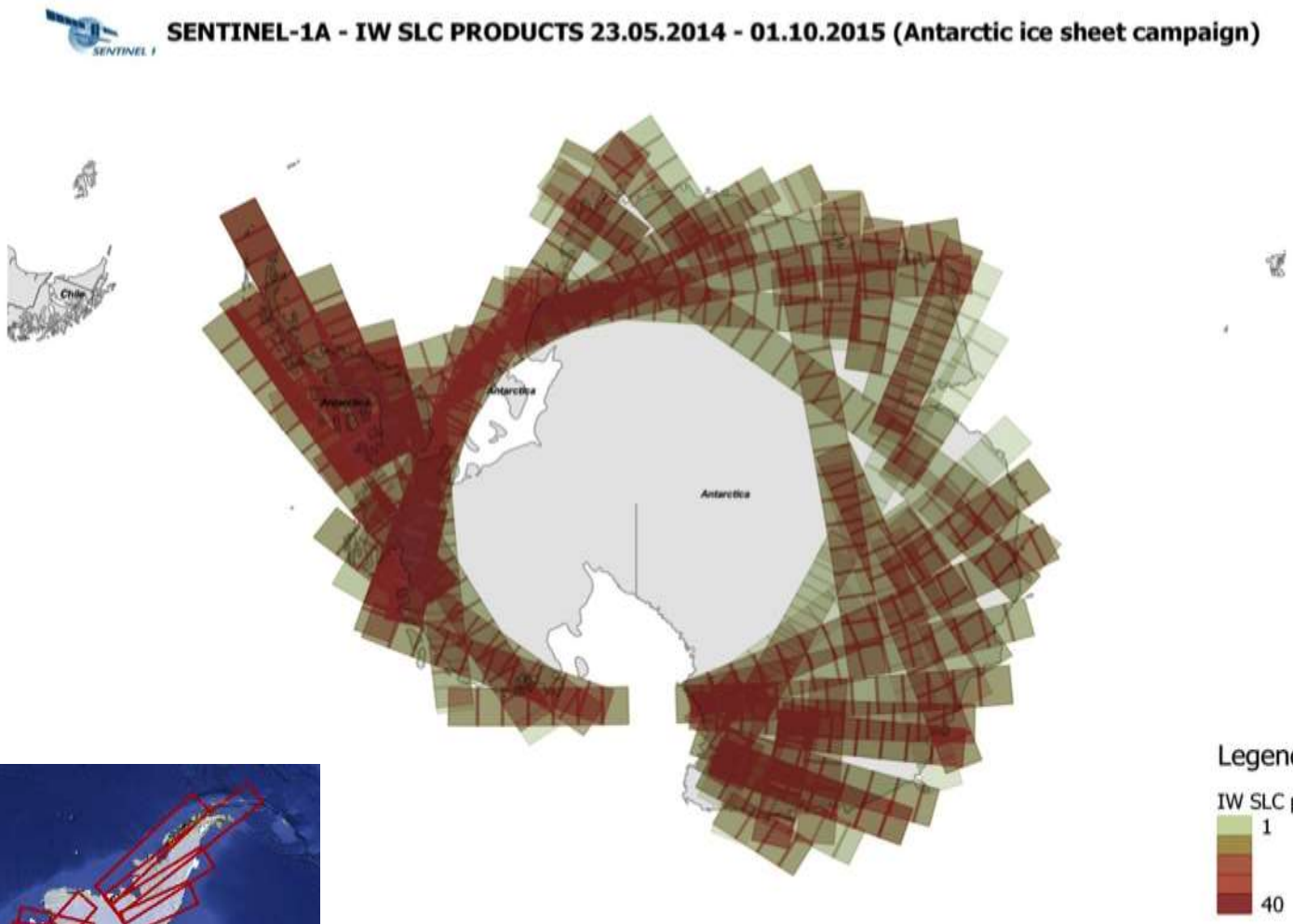
- ✓ ~750 IW SLC scenes from 16.01.2015 to 09.03.2015
- ✓ Cumulative SAR operation time of > 5 hours

Greenland overall:

- ✓ > 1300 GRDH and 1300 SLC products since Oct 2014
- ✓ ~ Cumulative SAR operation time of > 9 hours

European Space Agency

Sentinel-1 observation scenario
Antarctica Ice Sheet Campaign



Antarctic campaign:

- ✓ ~2200 IW SLC scenes since 23.05.2015
- ✓ Cumulative SAR operation time of 15.5 hours

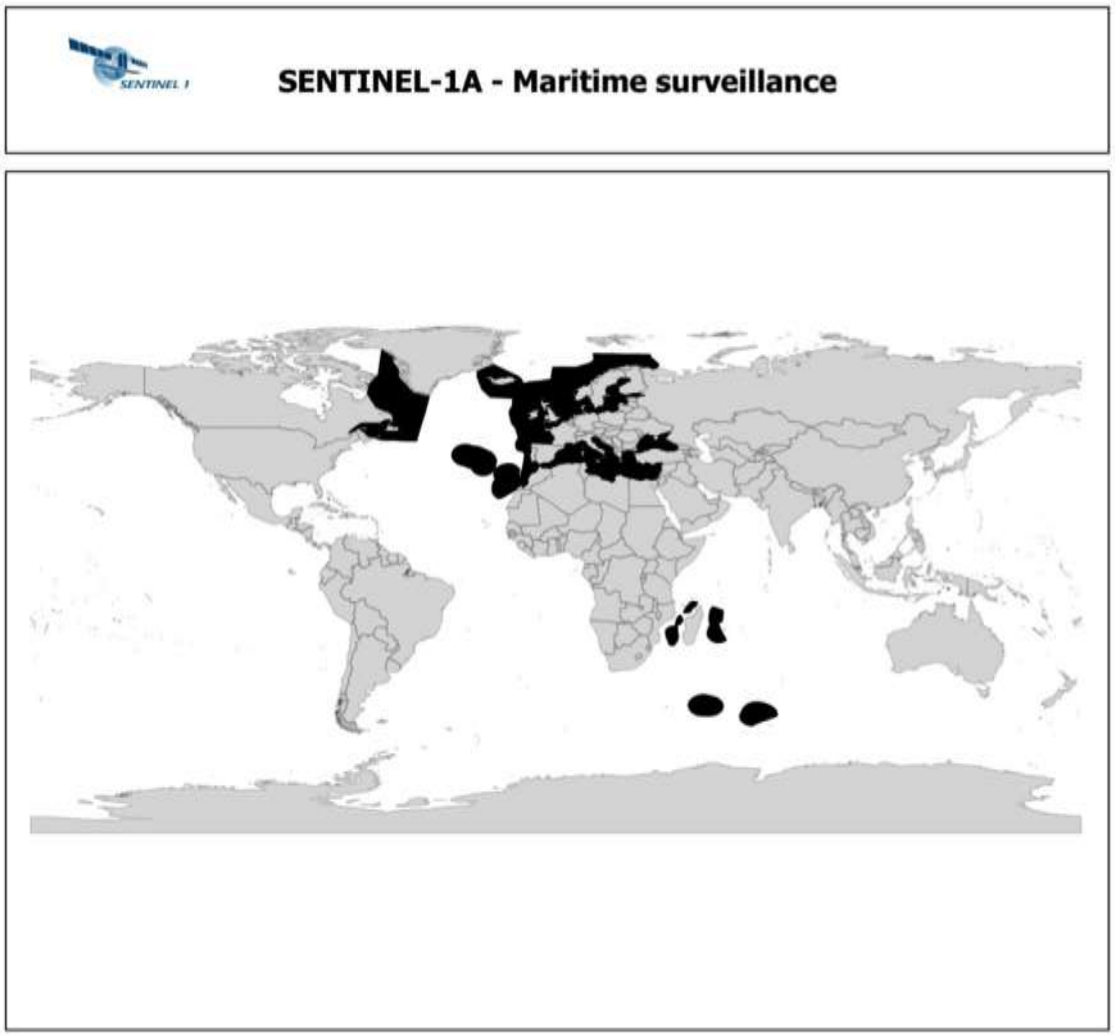
Antarctica overall:

- ✓ 2656 GRDH and 2610 SLC products between 03.10.2014 and 03.10.2015
- ✓ Cumulative SAR operation time of 18.75 hours

In addition, continuous monitoring of Peninsula and critical glaciers every 12-day repeat cycle

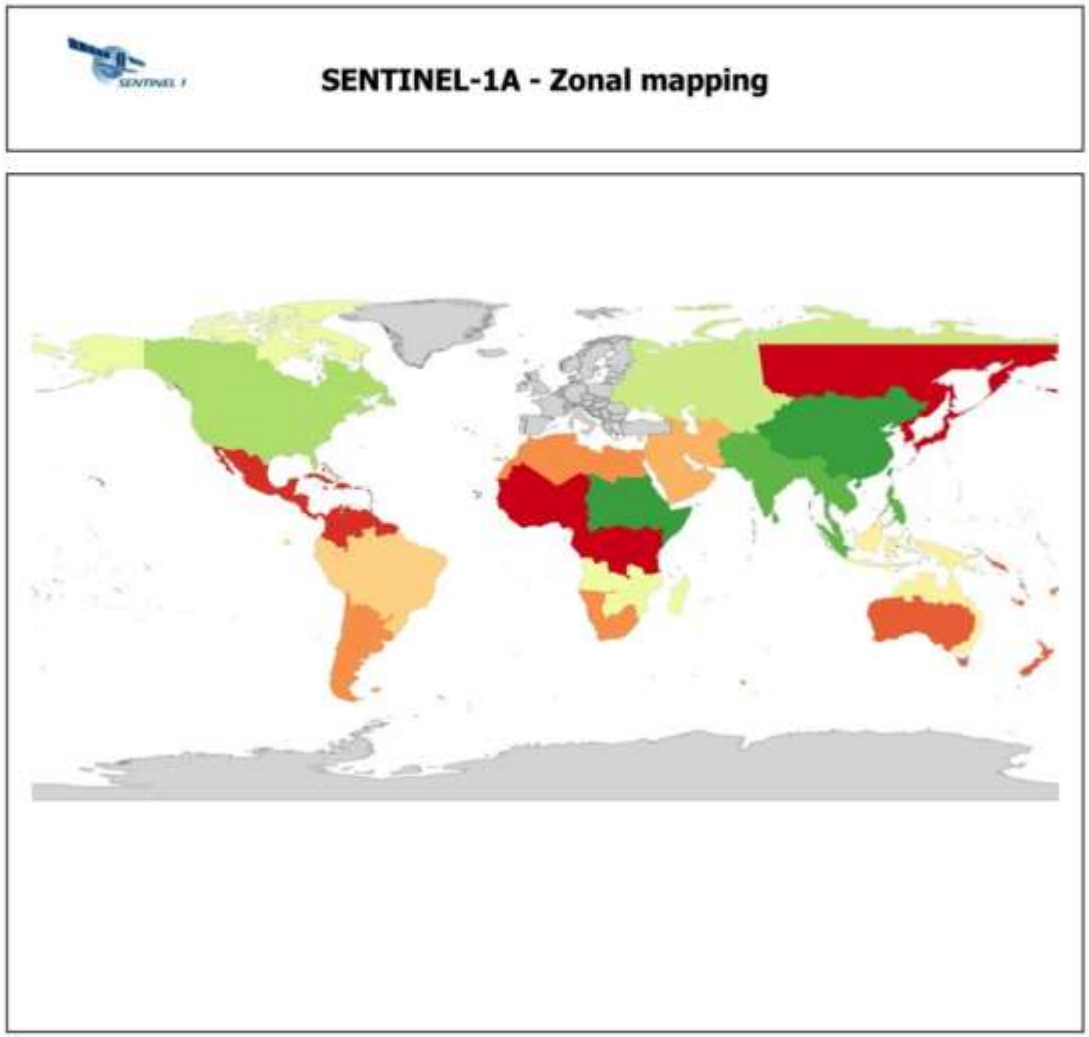
European Space Agency

Sentinel-1 observation scenario
Maritime surveillance



- Frequent acquisitions in IW mode, dual polarisation ASC + DSC, over North Sea, Baltic Sea, European coastal waters
- Frequent acquisitions in IW and EW mode, ASC + DSC around Iceland, Azores and Canary islands
- One pass coverage of EEZ in IW mode over French Islands in the Indian Ocean and around Newfoundland

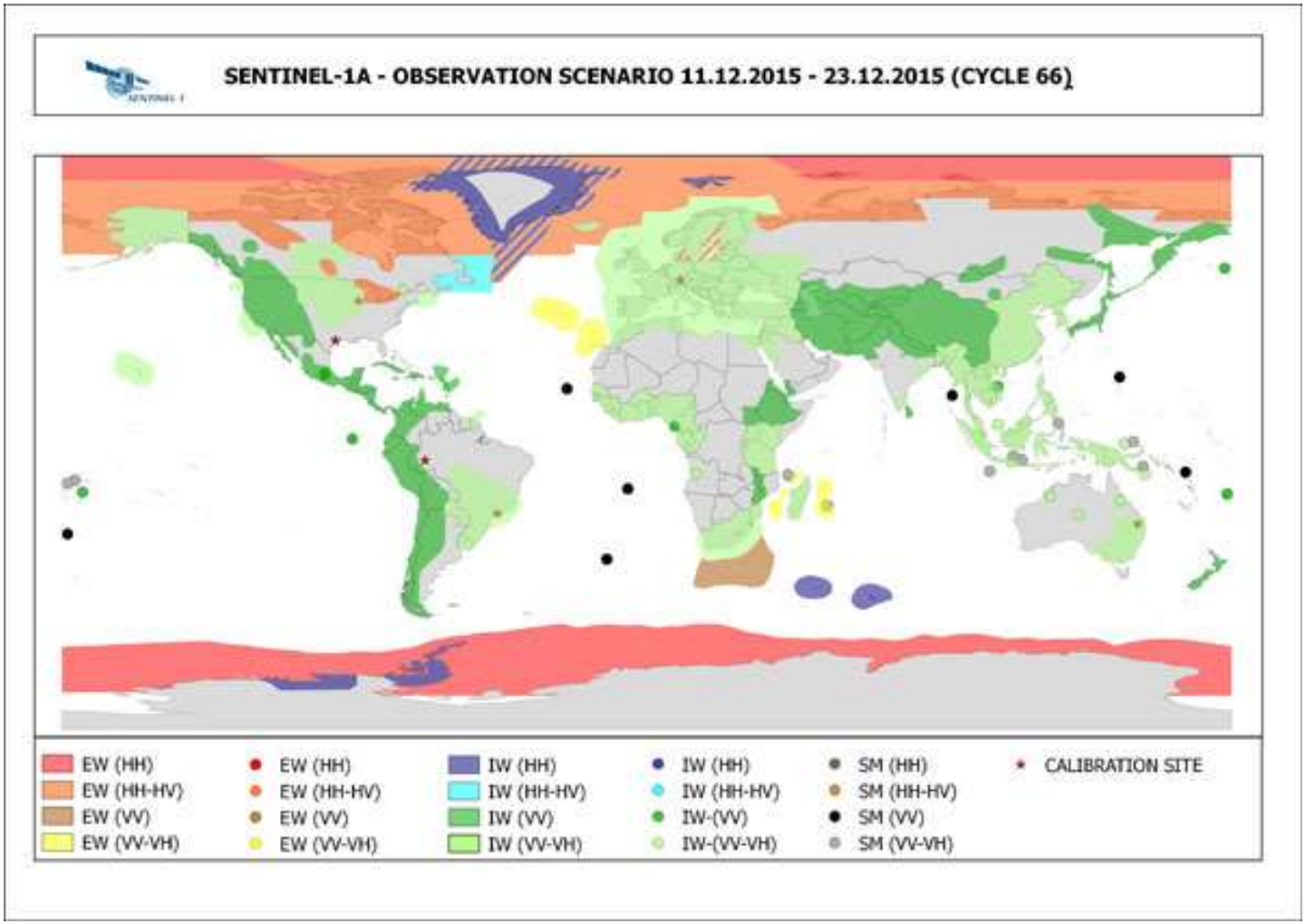
Sentinel-1 observation scenario
Zonal mapping



- IW mode, VV+VH polarisation, one pass
- Acquisitions following a zonal approach, prime acquisition windows prevailing regional dry season conditions
- Continuous acquisition zones (e.g. Tectonic active areas) become upgraded to dual polarisation whenever they fall into a regional zonal acquisition window
- Revisit per zone **several times a year**
- Main driver: emergency reference mapping, low frequency global applications (e.g. forest mapping, land use, urban area mapping…)

Sentinel-1 observation scenario regularly published online

(current repeat cycle 66: from 11 to 23 December 2015)

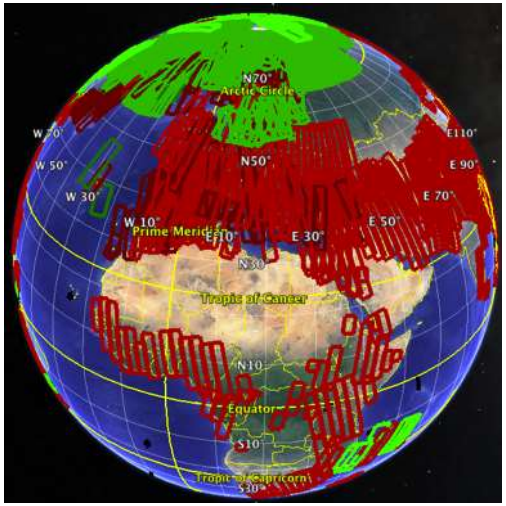


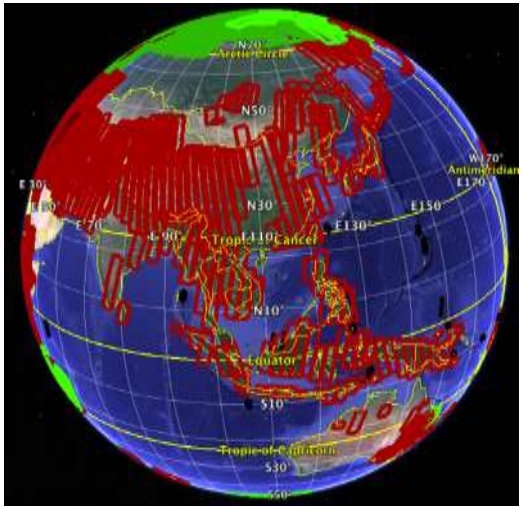
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario

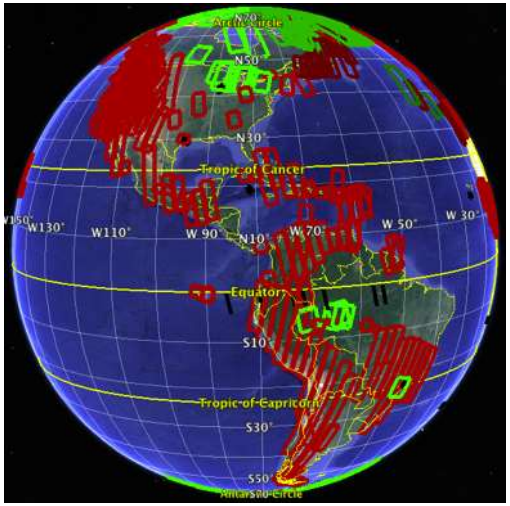
European Space Agency

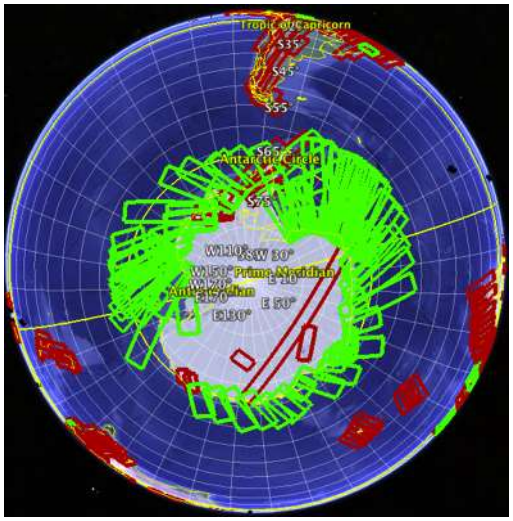
Sentinel-1 acquisition segments regularly published online

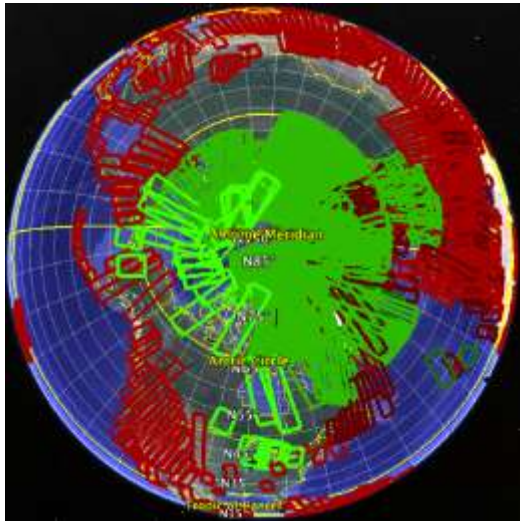
(12-days repeat cycle: example cycle 66, from 11 to 23 December 2015)







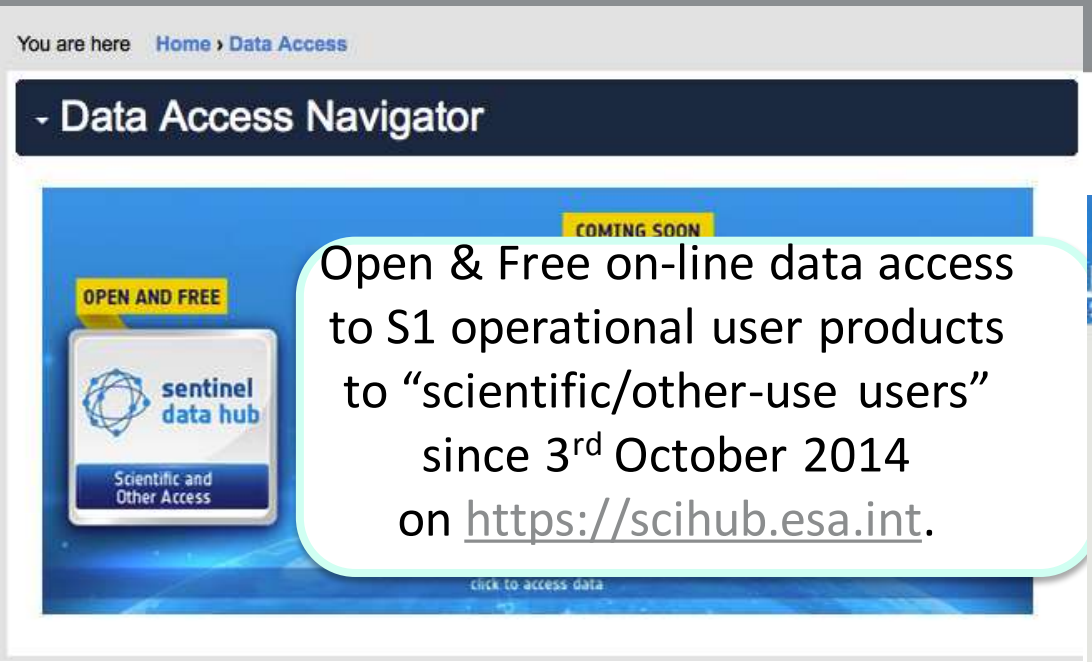




European Space Agency

https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/acquisition-segments

Open and Free On-Line data access



Open & Free on-line data access to S1 operational user products to "scientific/other-use users" since 3rd October 2014 on https://scihub.esa.int.

- Access through self-registration
- Automated download scripting published
- Restriction on concurrent downloads
- **All data published since 3rd October 2014 still available on line**
- **Data access will be enabled for archive data when roll-out will be activated (before end 2015)**

Currently on-line available products:

- IW, EW, SM L0 & L1 systematic products
- WV L2 OCN products
- IW/EW L2 OCN products

https://scihub.esa.int/dhus/

Sentinel-1 Scientific Data Hub

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Welcome cstewart ! Logout

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Search | advanced search

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Display 1 to 23 of 23 products

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https://scihub.esa.int/dhus/odata/v1/Products('6359f2bc-42f8-47cc-bf4e-46b7df638d86')/$value
Date : 2014-10-04T04:45:22.460Z, Instrument : SAR-C, Mode : IW, Satellite : Sentinel-1, Size : 1 GB

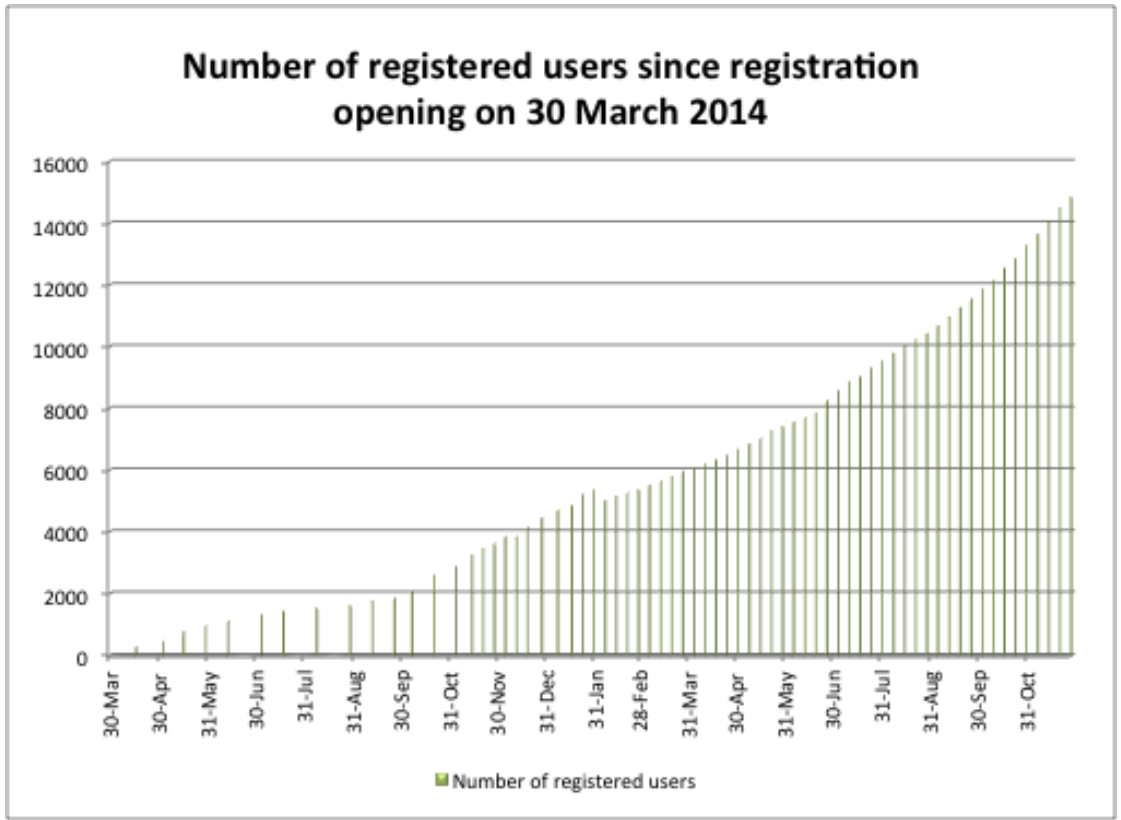
S1A_IW_GRDH_1SDV_20141004T044547_20141004T044612_002675_002FBB_FD20
https://scihub.esa.int/dhus/odata/v1/Products('5b4c06d2-206e-4de6-ad2f-07bc10bbe5c0')/$value
Date : 2014-10-04T04:45:47.460Z, Instrument : SAR-C, Mode : IW, Satellite : Sentinel-1, Size : 1 GB

S1A_IW_GRDH_1SDV_20141004T044612_20141004T044637_002675_002FBB_925F
https://scihub.esa.int/dhus/odata/v1/Products('188eada4-1ab4-4ece-a182-879334d023d9')/$value
Date : 2014-10-04T04:46:12.460Z, Instrument : SAR-C, Mode : IW, Satellite : Sentinel-1, Size : 1 GB

Sentinels User Statistics Overview

By 26 November 2015:

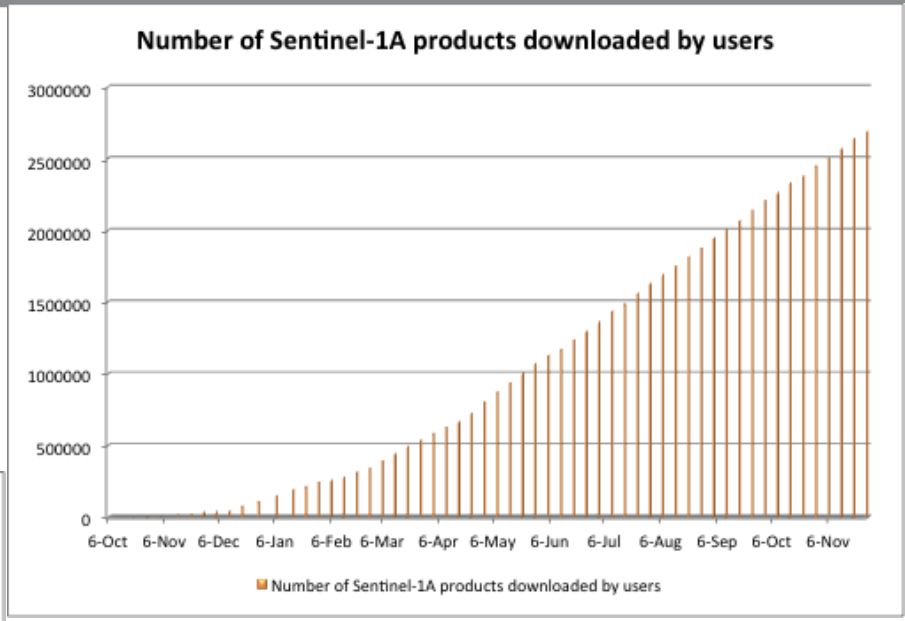
- **14,869 users** registered on the scientific/open access data hub
- **2.7 million products** downloaded by users, representing more than **3.2 Petabytes** of data
- Currently more than **340,000** Sentinel-1 core products available for download

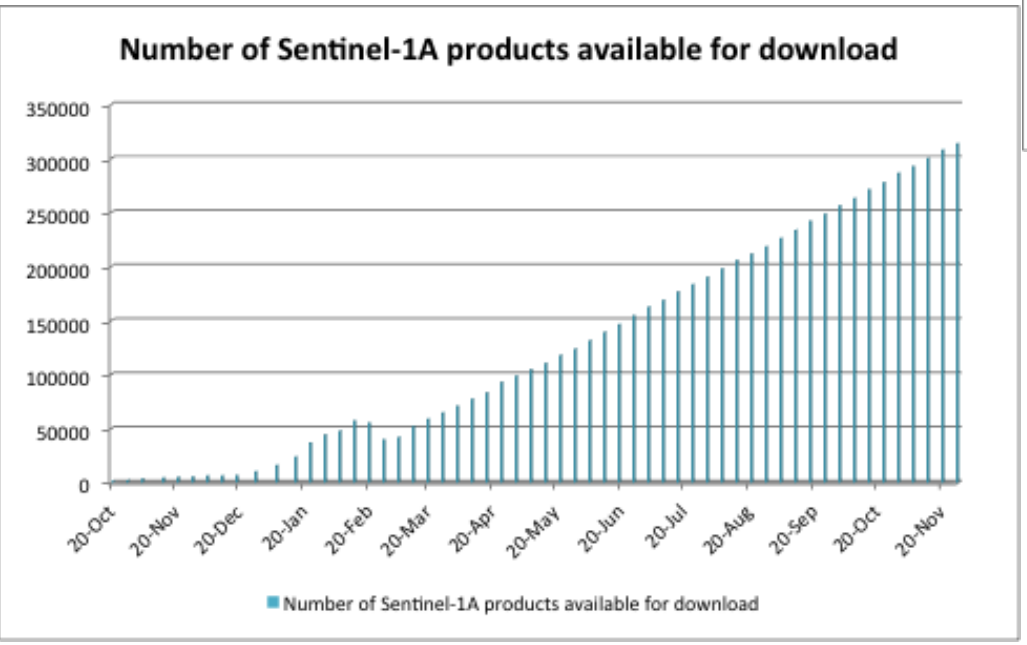


Sentinels Data Statistics Overview

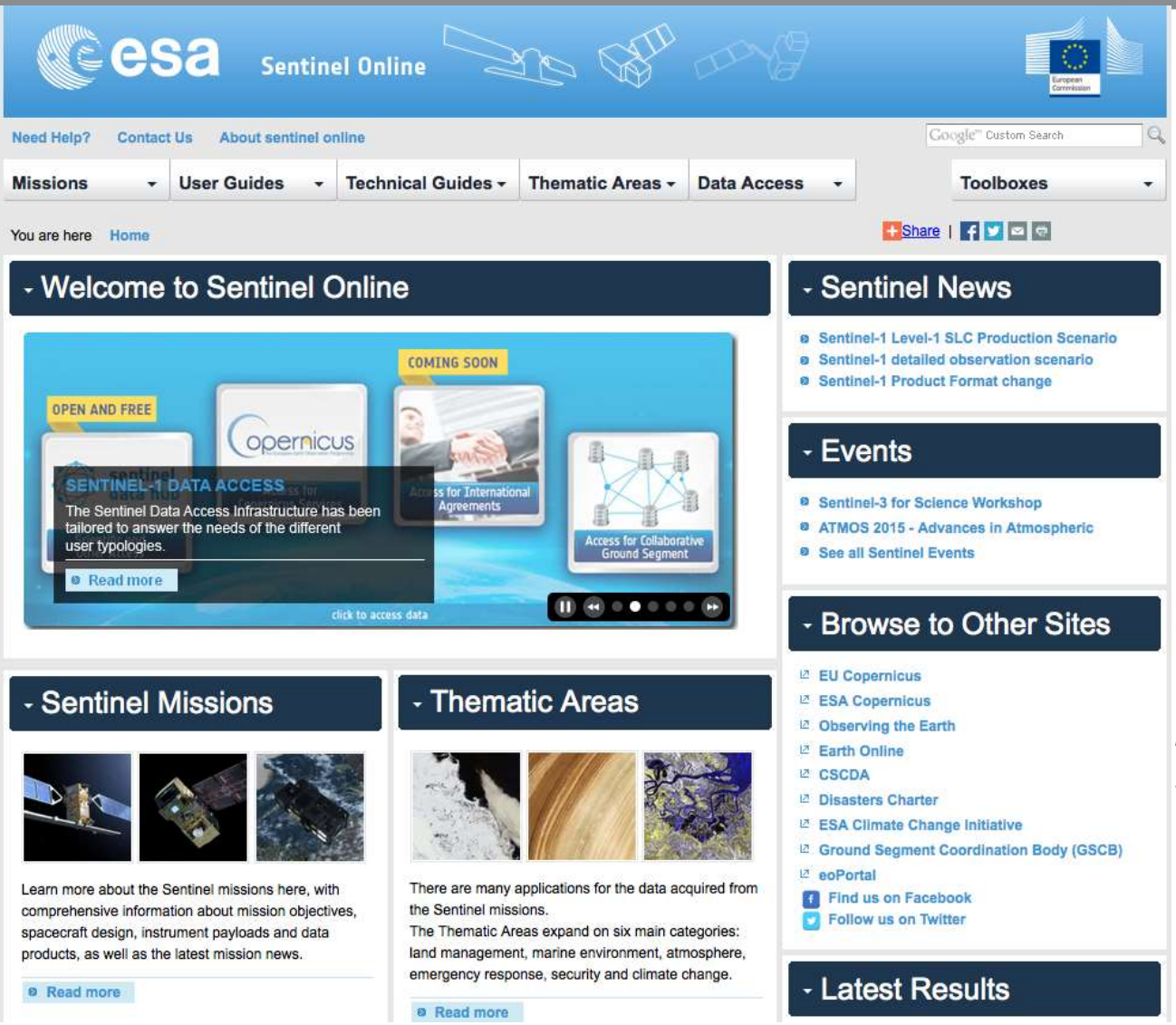
Sentinel data access online at

sentinels.copernicus.eu





Sentinel Online web portal



http://sentinels.copernicus.eu

Sentinel-1 related documentation and technical notes are available, e.g.:

"*Definition of the TOPS SLC deramping function for products generated by the Sentinel-1 IPF*"

step.esa.int
Science Toolbox Exploitation Platform

SNAP download page
Access to Beta versions for testing

Sentinel-1 Toolbox
step.esa.int

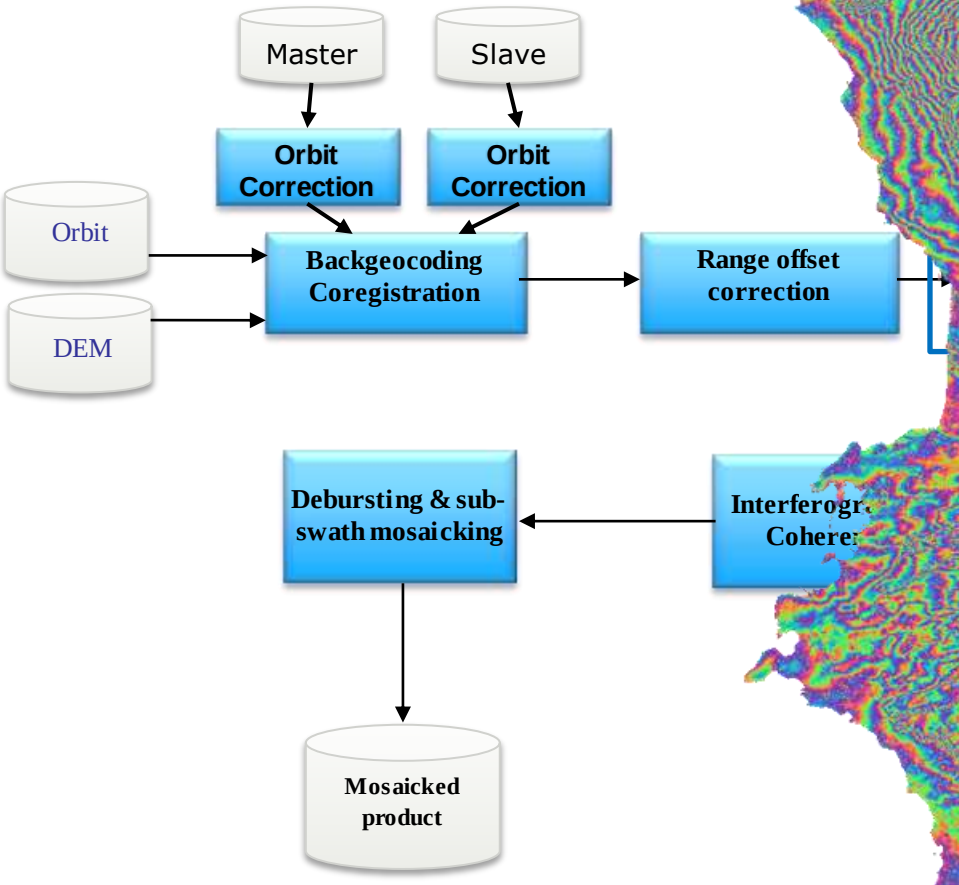
1. Sentinel 1 data readers : L1, L2
    a. Multi-mission : ALOS PALSAR, ALOS 2, Cosmo-Skymed, ENVISAT, ERS-1/2, JERS RADARSAT-1, RADARSAT-2, SENTINEL-1, TerraSAR-X & TanDEM-X
    b. Import/Export of PolSARpro, GAMMA, RAT product formats
2. Sentinel 1 scientific tools
    a. Automatic Orbits update
    b. Automatic DEM download (ACE 5Min, Ace30, GETASS30, SRTM 1sec HGT, SRTM 3sec)
    c. S1 TOPS Utilities (Thermal noise removal, Slice Assembly, TOPS Split, Deburst, Sub-swath merge, remove border noise etc.)
    d. S1 TOPS Coregistration
    e. Terrain flattening
    f. Texture analysis
    g. Feature Extraction (Ocean object and oil spill detection, Wind field estimation)

TOPS InSAR for Sentinel-1 Toolbox

https://sentinel.esa.int/web/sentinel/toolboxes/sentinel-1

S1A TOPS Interferogram
Mt. Etna

TOPSAR Chain



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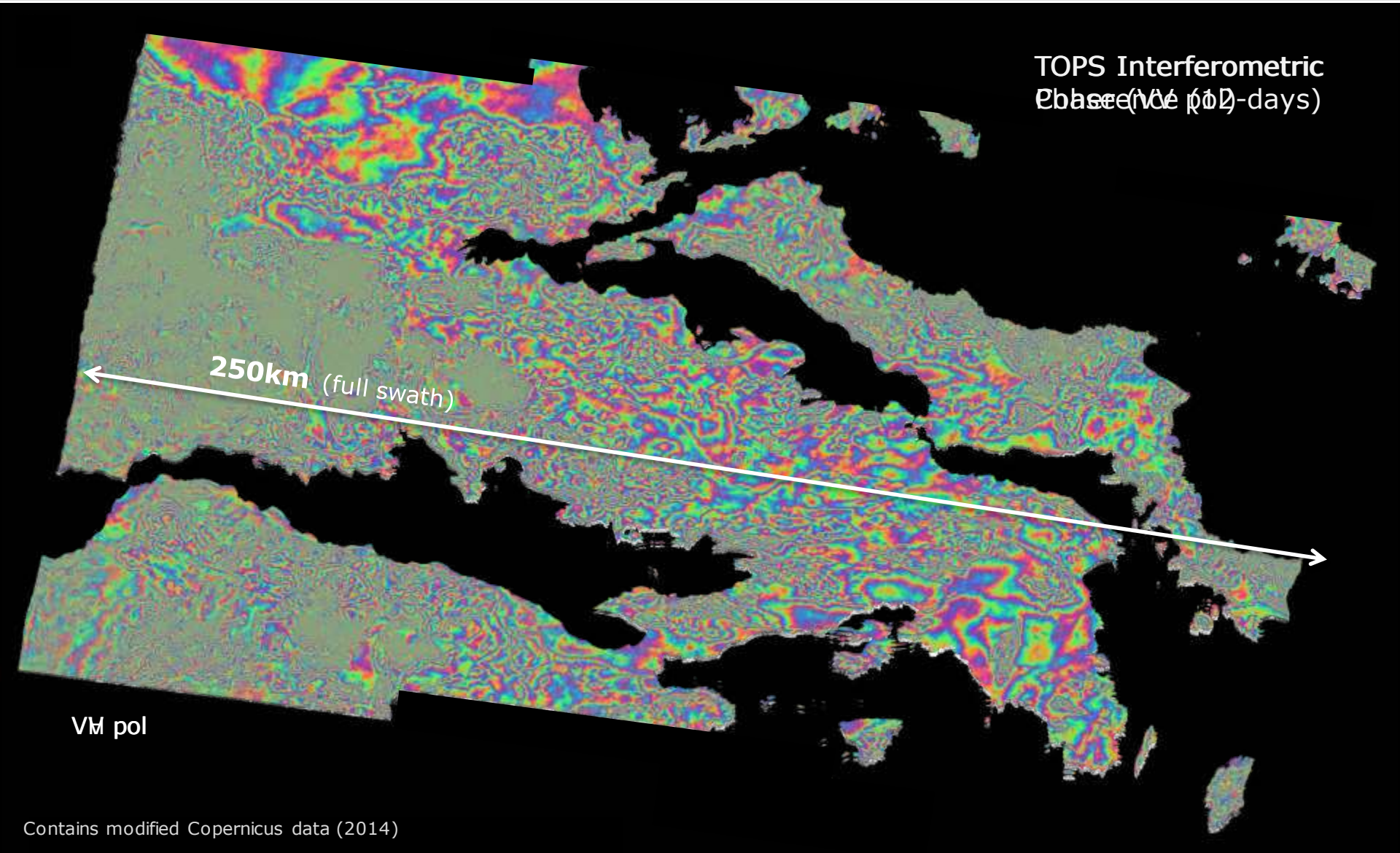
European Space Agency

TOPS InSAR for Sentinel-1 Toolbox



Weekly Mission Status Reports published online
(83 reports issued since Launch)

https://sentinel.esa.int/web/sentinel/missions/sentinel-1/mission-status

sentinel-1

→ RADAR VISION FOR COPERNICUS

Mission Status Report 1

Reference Period: 3 April - 7 April 2014

Mission Status

- Sentinel-1A was successfully launched from Kourou on 3 April 2014, 21:02 UTC
- The Launch and Early Orbit Phase (LEOP) was successfully performed according to the planned timeline and declared closed on 6 April at 16:00 UTC
- The Commissioning Phase has started

Satellite

The LEOP covered the main following key activities:

- Deployments of the solar panels (including rotation) and of the Synthetic Aperture Radar (SAR) antenna
- Achievement of Satellite Nominal Mode and AOCS Nominal Pointing Mode
- Switch ON and initial checks of the spacecraft sub-systems
- First operations of the X-Band Transmitter and the SAR instrument (3 min of Wave mode)

In addition, a collision avoidance manoeuvre was performed on 5 April

Ground Segment

- The Flight Operations Segment performed nominal during the complete 3 days of LEOP
- First X-band data acquisition took place at the Matera ground station on 6 April, early morning
- First SAR instrument data acquisition was performed on 6 April. The related measurement was successfully processed at UK-PAC
- The FOS and the PDGS were declared ready to support the commissioning phase

Outlook

- Start of platform and payload commissioning activities
- First SAR acquisitions driven by the operational PDGS mission planning system are planned to start on 9 April, as part of the initial verification and calibration activities
- Start of orbit manoeuvre sequence to acquire the target reference orbit.

Report prepared by the ESA Sentinel-1 Team -

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sentinel-1

→ RADAR VISION FOR COPERNICUS

Mission Status Report 80

Reference Period: 3 November 2015 – 9 November 2015

Mission status

- The Sentinel-1A routine operations are on-going
- Sentinel-1 data can be accessed from: https://sentinels.copernicus.eu
- The observation scenario supports the systematic coverage of a first set of Copernicus Services areas of interest, of European land and coastal waters, of global tectonic/volcanic areas, as well as of other specific targets worldwide for various applications. The observation plan also includes regular mapping of all land areas worldwide. The dedicated campaign for Antarctica ice sheet monitoring, performed during local winter, has been completed. An overview of the observation scenario is available at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario
- The detailed observation plan in the form of instrument acquisition segments is published on Sentinel Online at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/acquisition-segments
- The operational use of Sentinel-1A data by the Copernicus Marine Environment Monitoring Service for sea-ice and iceberg monitoring activities is on-going
- The European Maritime Safety Agency (EMSA) is gradually introducing in the CleanSeaNet service the use of Sentinel-1 imagery in quasi-real time. Preliminary operations with first EMSA local stations are on-going
- A Sentinel-1A in-Orbit Performance Review took place on 3-4 November in TAS-I Rome, Italy. The overall satellite health was confirmed to be nominal
- Numerous Sentinel-1 presentations were made at the CEOS Working Group on Calibration and Validation (WGCV - SAR Subgroup) workshop that took place on 27-29 October in ESA-ESTEC, Noordwijk, The Netherlands
- The Sentinel-1A spacecraft is in a stable state, operating in Nominal Mission Mode (NMM). The Flight Operations Segment (FOS) ensuring the monitoring, control and commanding of the satellite is operating nominally. Orbit control manoeuvres are performed once a week typically
- Data unavailability took place from 5 November 18:00 UTC to 6 November 12:30 UTC due to a misconfiguration in the PDGS planning files provided to FOS for satellite commanding
- A satellite unavailability occurred between 7 November 17:53 UTC and 8 November 12:10 UTC (nominal SAR operations resumed at 12:30 UTC) due to a PDHT software anomaly
- X-Band data acquisitions are routinely performed over Matera, Svalbard and Maspalomas X-band core stations. The acquired data are circulated within the PDGS, systematically processed to Level-0 and Level-1 products and archived
- Wave Mode data are regularly acquired over open oceans, systematically processed to Level-2 OCN products and made available. Sentinel-1 IW and EW Level-2 OCN products over regional ocean areas are available on the Scientific Data Hub since 26 July 2015. The operational qualification of Level-2 OCN products is on-going (geophysical validation)
- Operations are performed regularly at the Processing and Archiving Centres (DLR-PAC and UK-PAC). All other PDGS operational services (i.e. Mission Performance, Precise Orbit Determination, Wide Area Network) are operating nominally
- Testing activities with direct receiving collaborative stations are on-going
- Since 21 July, 100% of the IW data acquired over land are systematically produced to level 1 SLC, as shown at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/production-scenario
- By 5 November, a total of 13,000 users have self-registered on the Sentinels Scientific Data Hub; 2,502,024 product download have been made by users, corresponding to 2.95 PB of data. At the time of publishing this report, more than 311,000 Sentinel-1A products are available on-line for download, representing 387 TB of data. Statistics of last 24 hours are available in real time at the Data Hub home page (https://scihub.copernicus.eu)

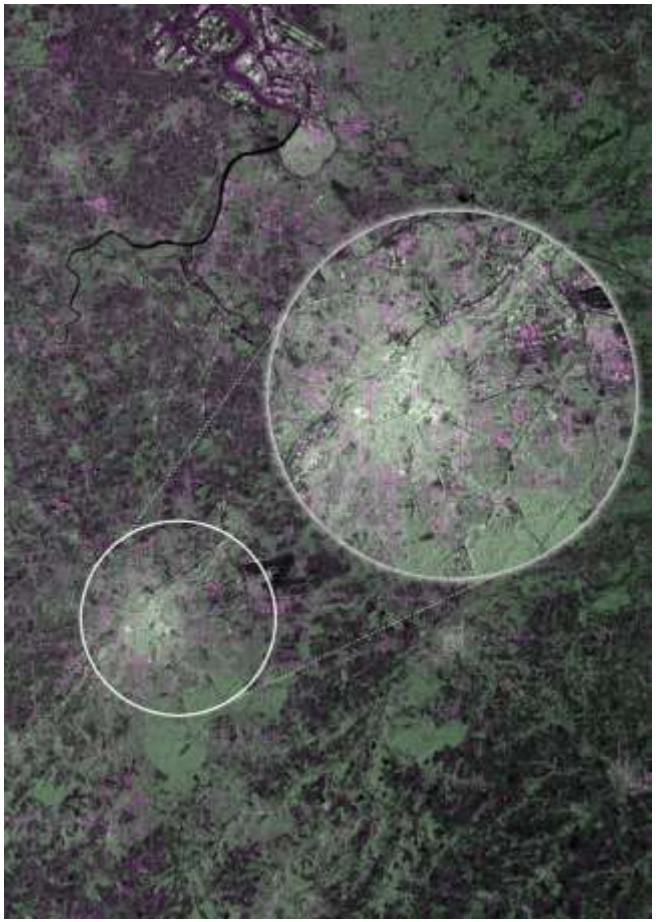
Outlook

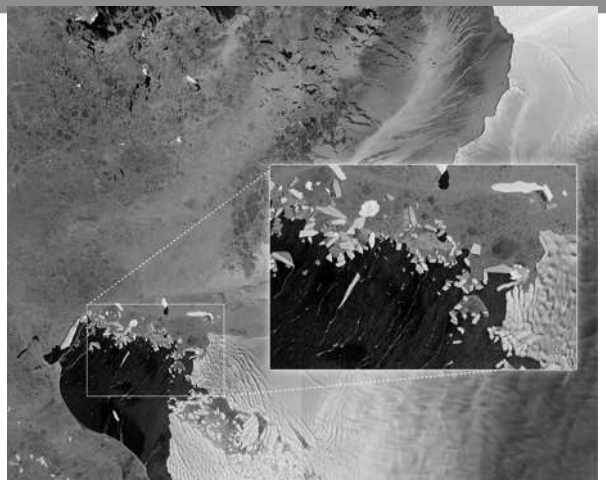
- Continuation of routine mission operations
- Resume of Sentinel-1A - Alphasat TDP-1 inter-orbit link characterisation campaign

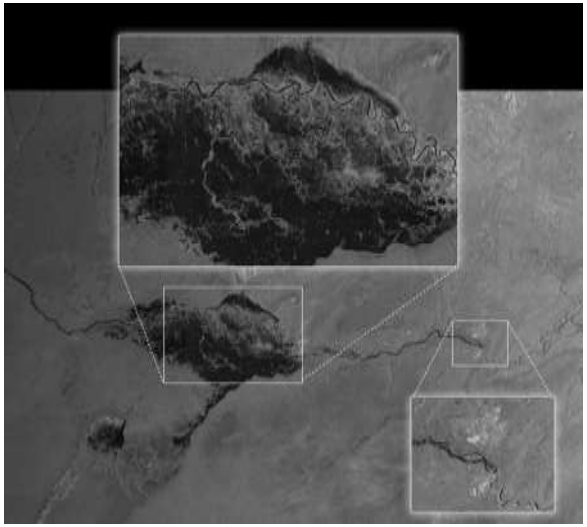
Report prepared by the ESA Sentinel-1 Team -

Examples of Sentinel-1A images, applications and results

SENTINEL-1A FIRST IMAGES



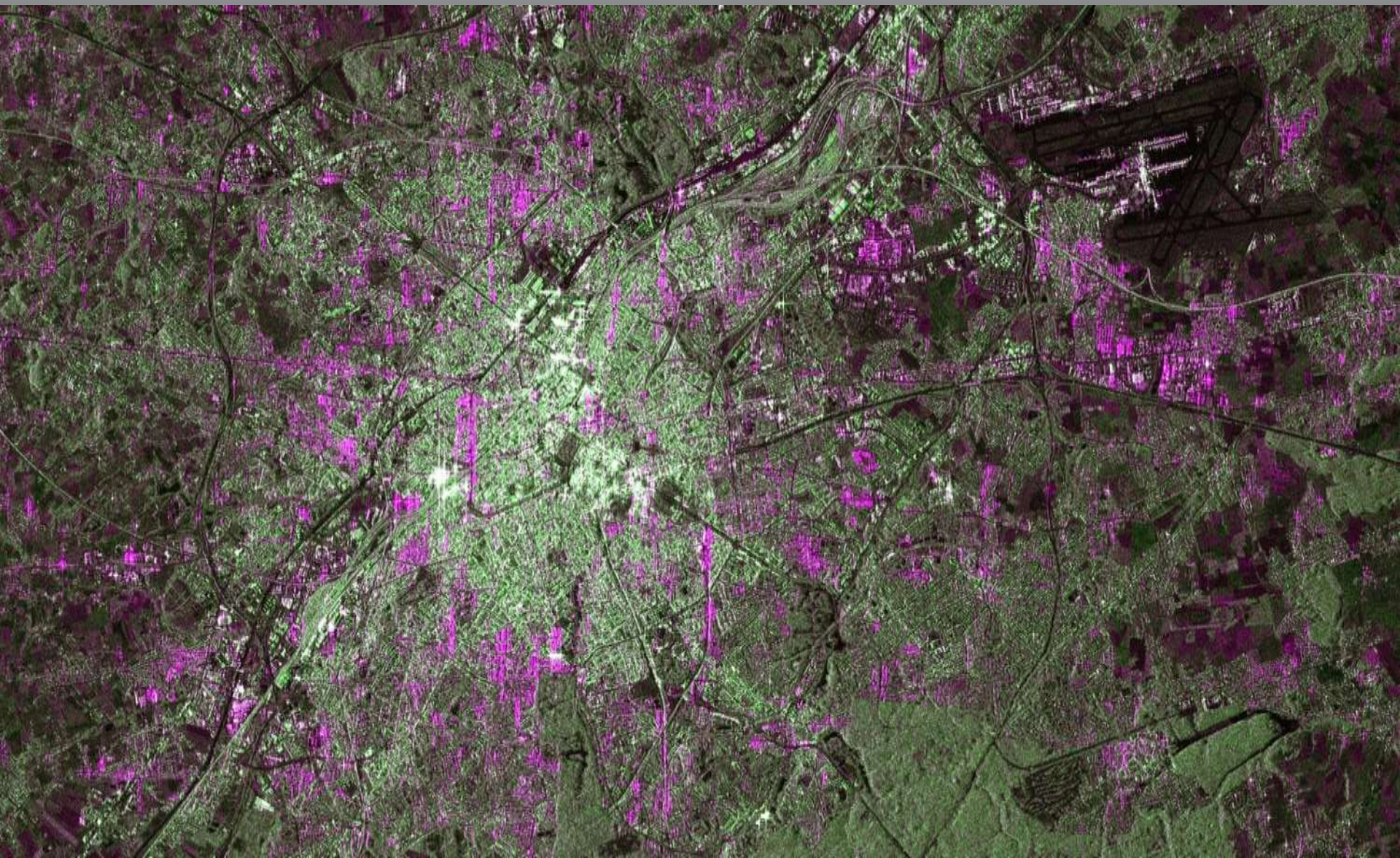




Land

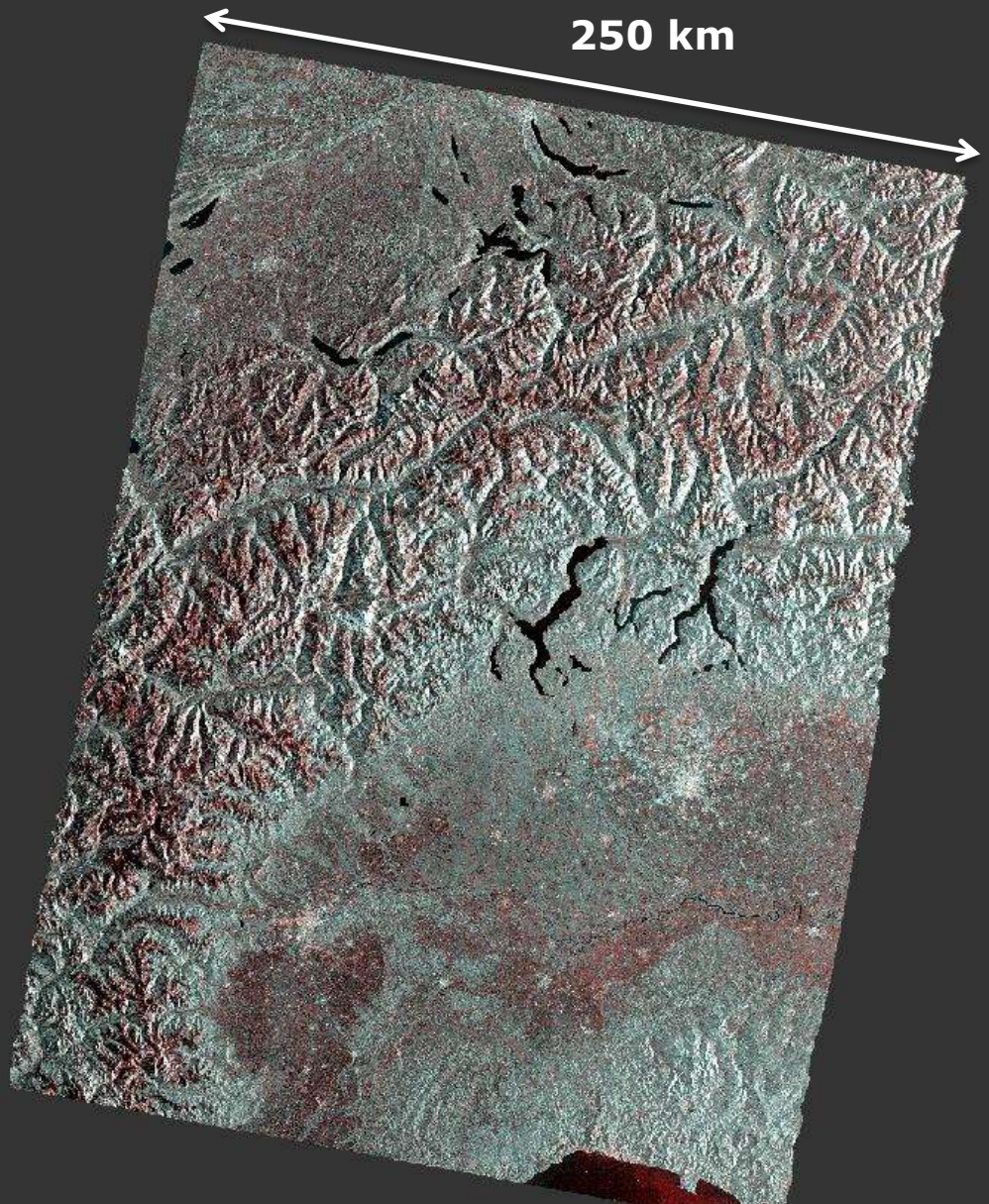
Land Cover
Crop monitoring, Forest, Food Security
… and New Promising Land Applications …

Brussels and Surroundings



Harbour of Antwerp, Belgium

Northern Italy



RBG – VV/VH/VH
Pixel spacing 10m
250x340 km
Date: 15.11.2014

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Scientific Toolboxes
RESULT

Sentinel-1A
Mosaic of EUROPE

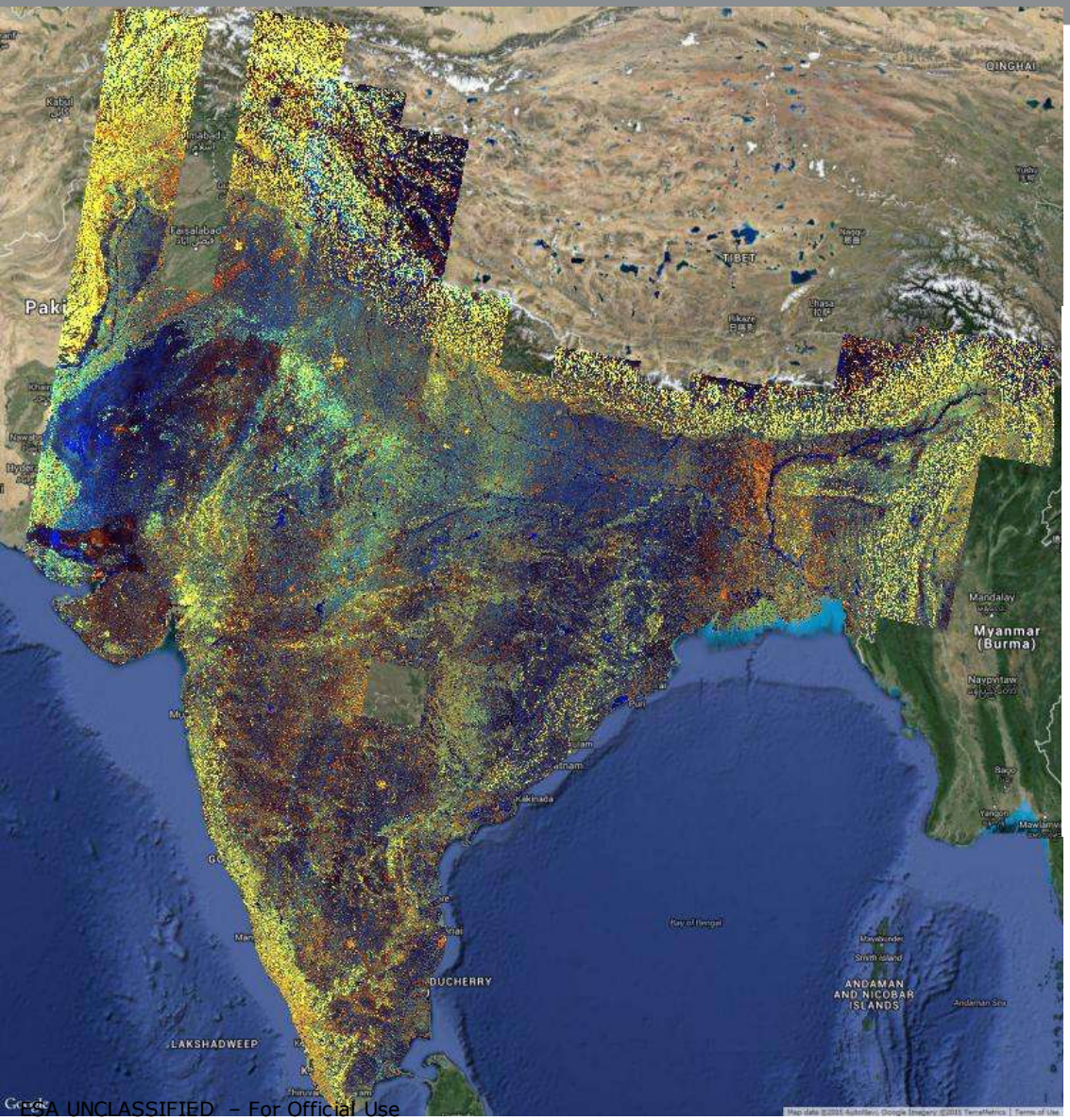
esa

Contains modified Copernicus Sentinel data [2014]

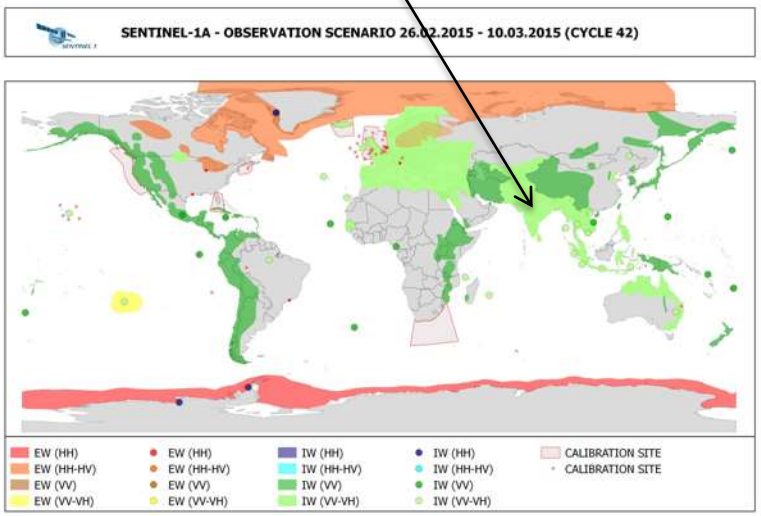
Europe Mosaic
(R:VH G:VV dB B:VV)
processed by
S1TBX/SNAP

"This is amazing job guys - this will set new ground for a wide community of (new) users"

Example of Zonal mapping results
- Mosaic of India -

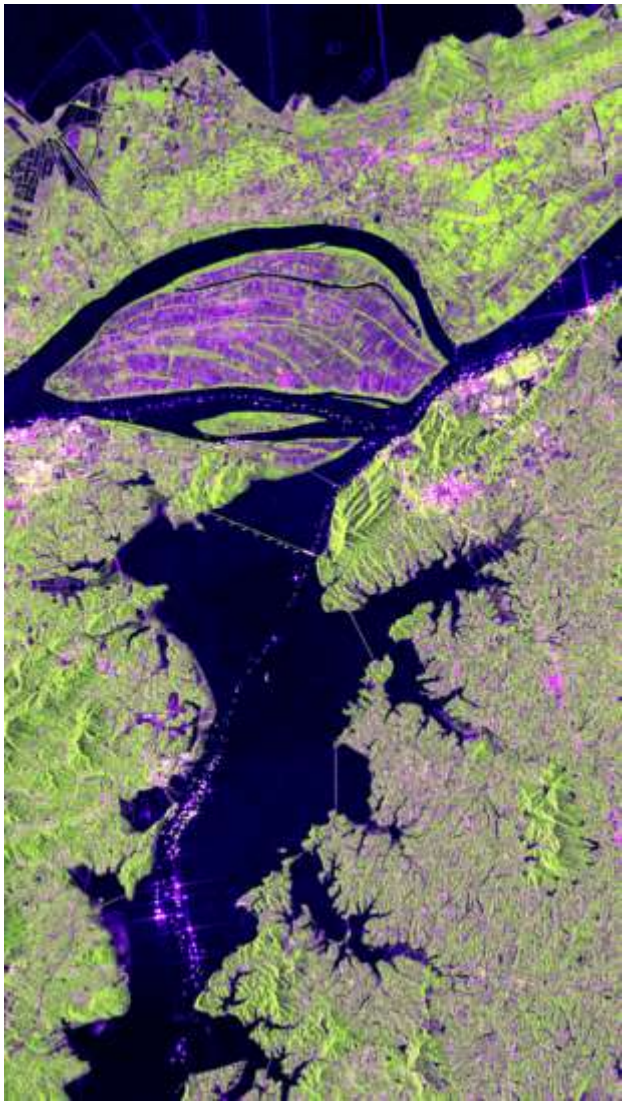


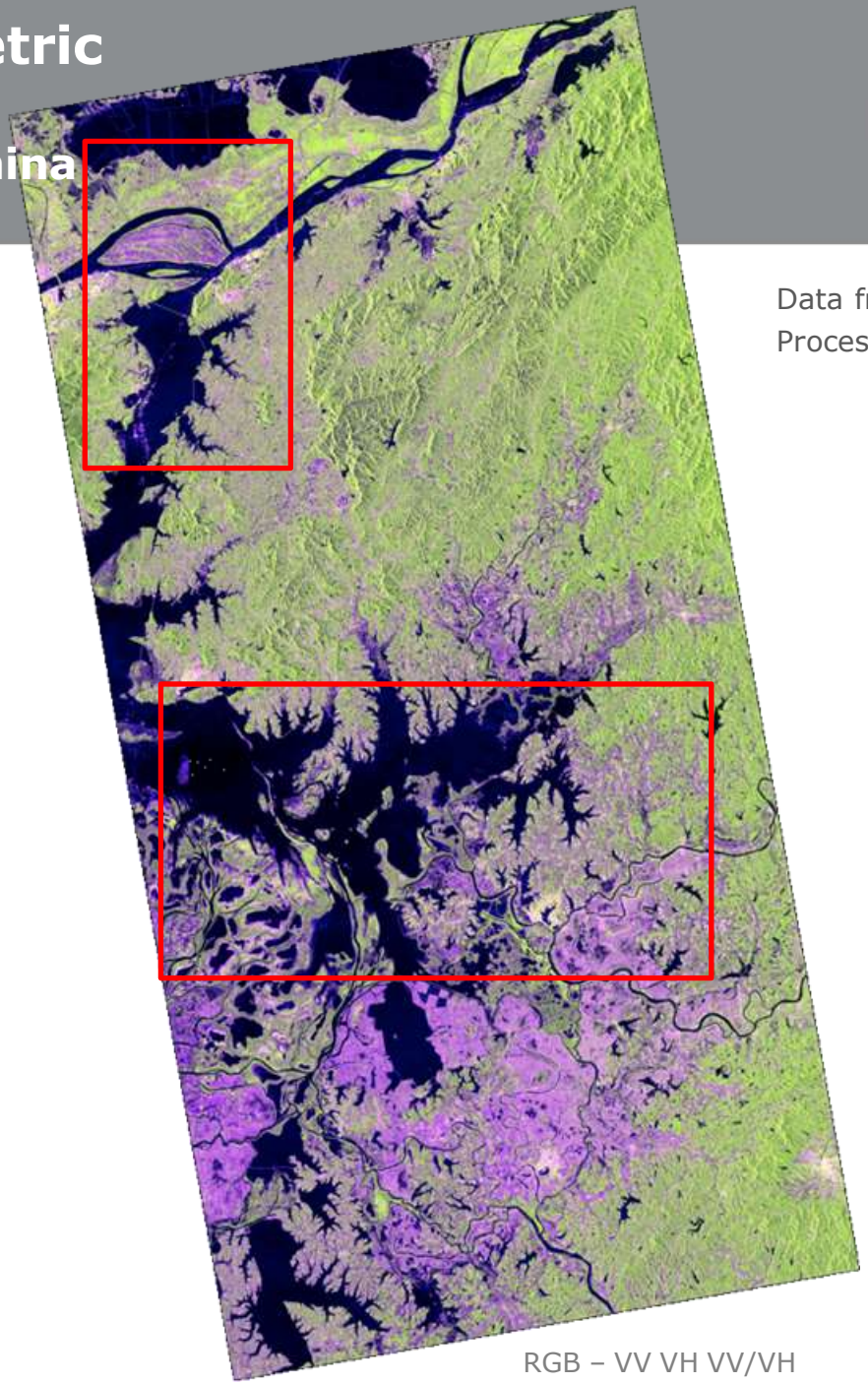
Sentinel-1 IW mode, VV+VH polarisation, acquired end February / beg March 2015



Courtesy of SARMAP

S1A Polarimetric Composition
Poyang Lake, China





Data from SciHub
Processed with S1TBX

RGB – VV VH VV/VH

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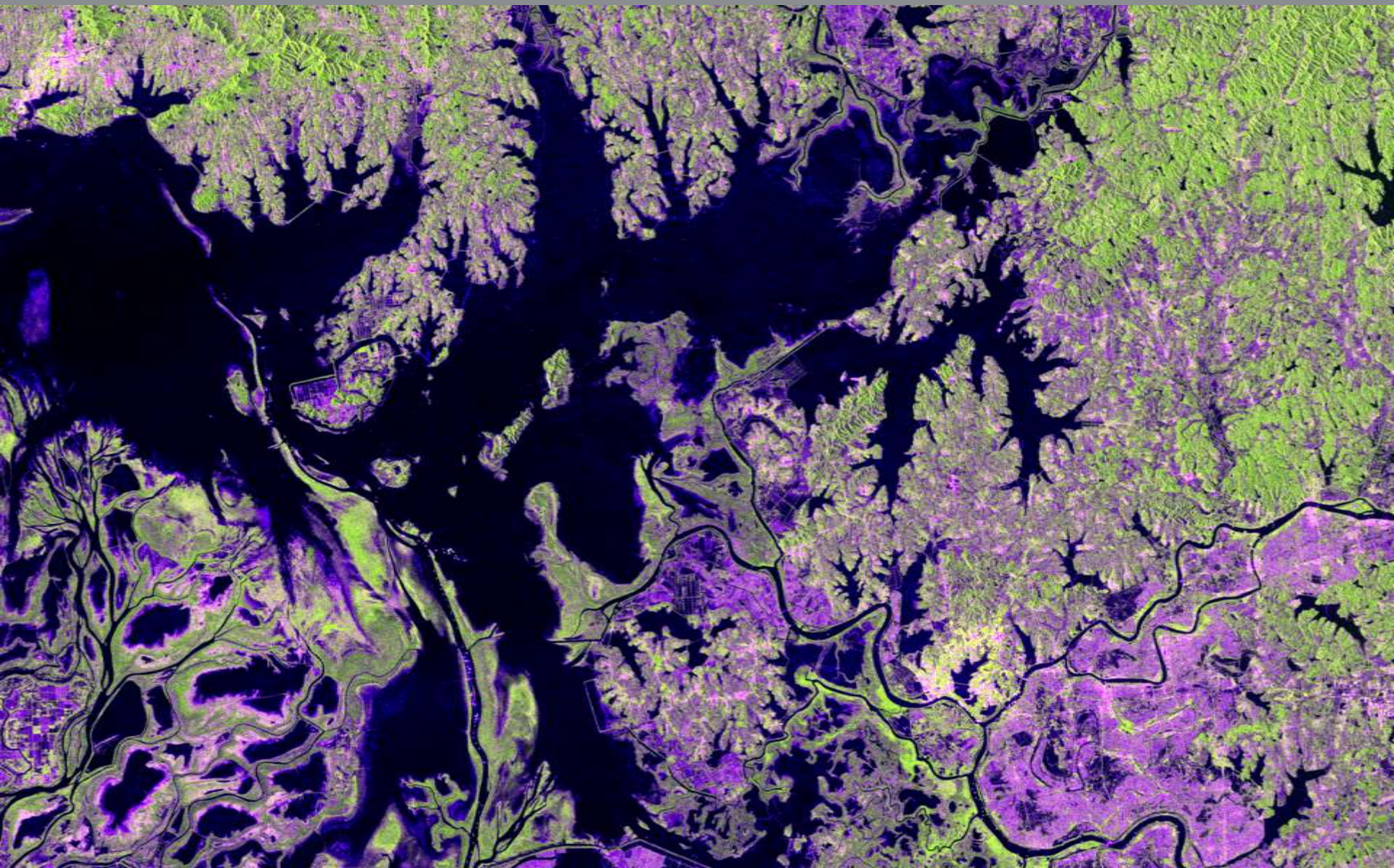
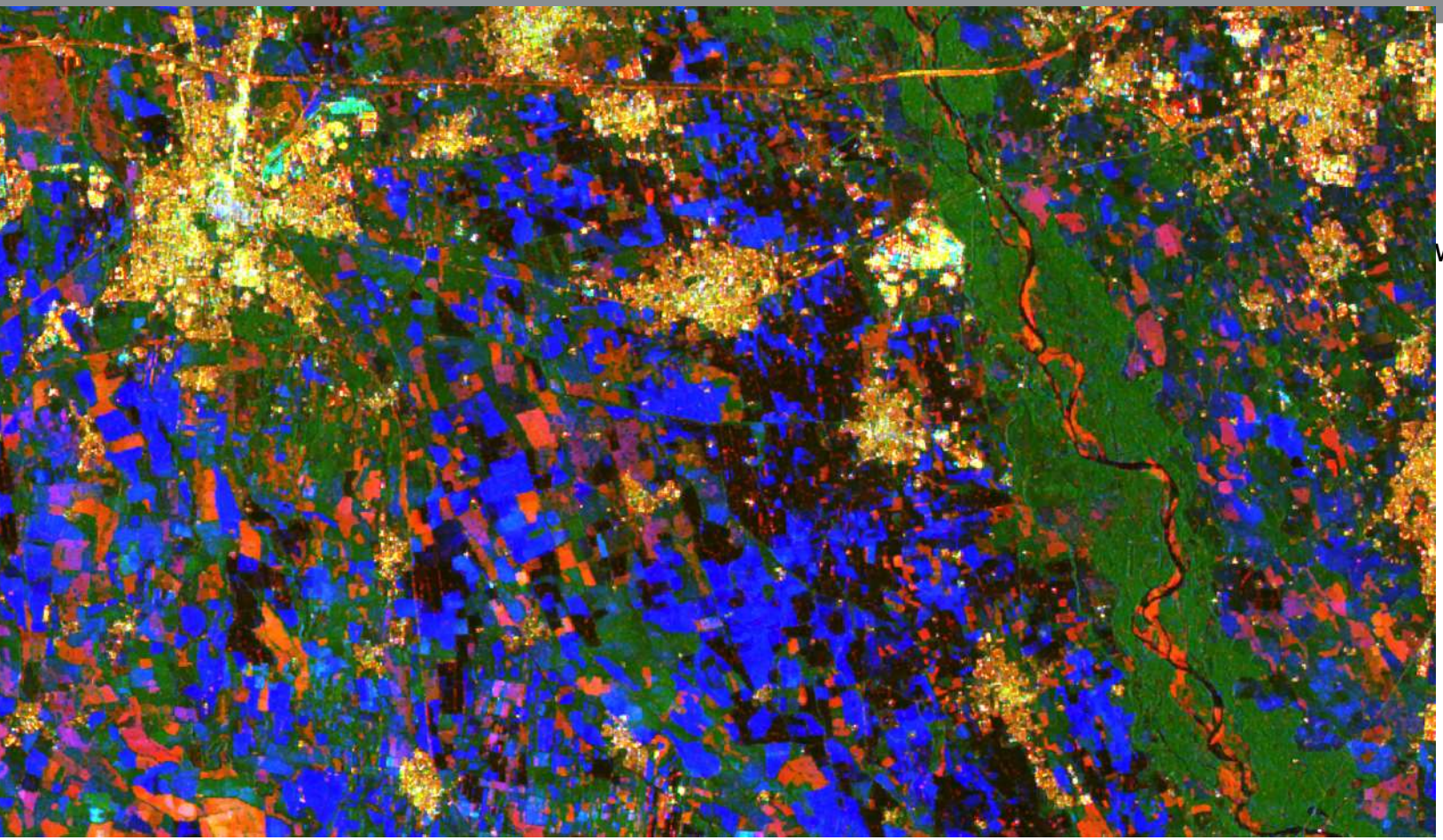
scientific exploitation of operational missions
European Space Agency

S1A Polarimetric Composition
Poyang Lake



Great potential for rice mapping and land classification Demonstration North Italy



Multitemporal 8-20 Apr 2015 with coherence

Courtesy SARMAP

RED/ORANGE: coherence, object not changing: bare soil rough

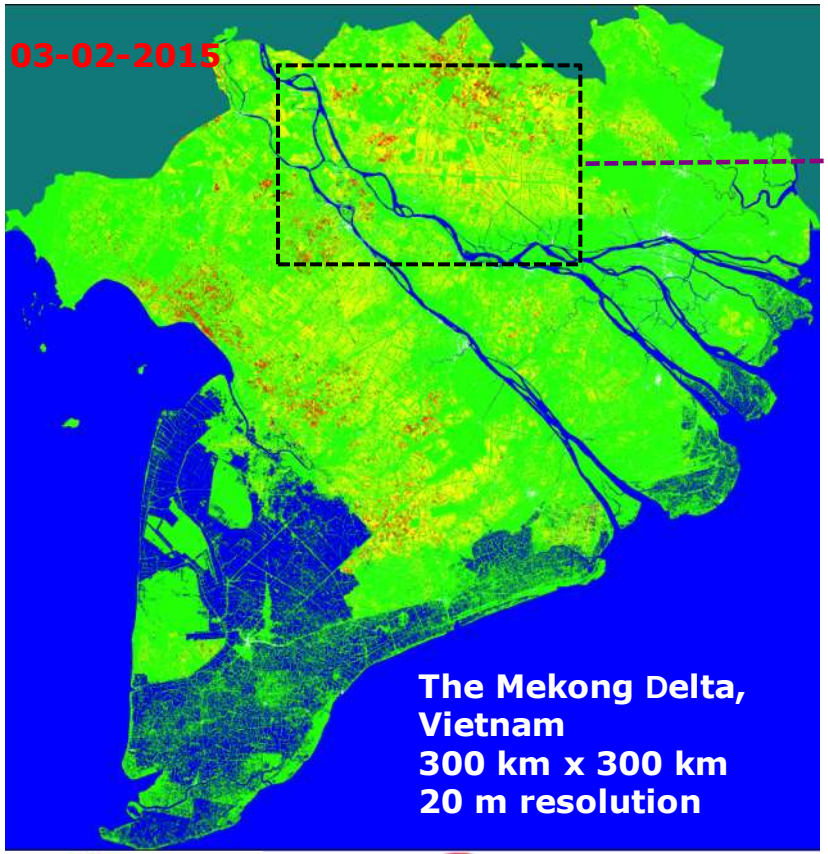
GREEN: average of the two sigma0 VV Forest mainly

BLUE: difference of the two sigma0 VV objects changing within 12 days (here ploughing activities)

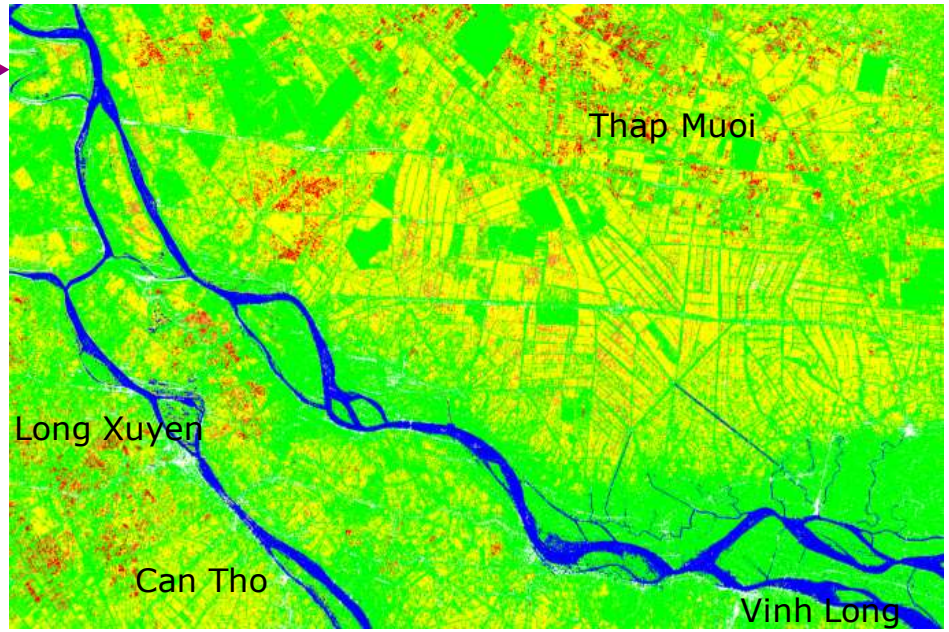
BLACK: objects not reflecting: water or very smooth bare soil areas

Agriculture application examples resulting from regular Sentinel-1 acquisitions - Rice monitoring, Mekong Delta, Vietnam -

Monitoring of Winter-Spring rice



100 km x 70 km, 20 m resolution



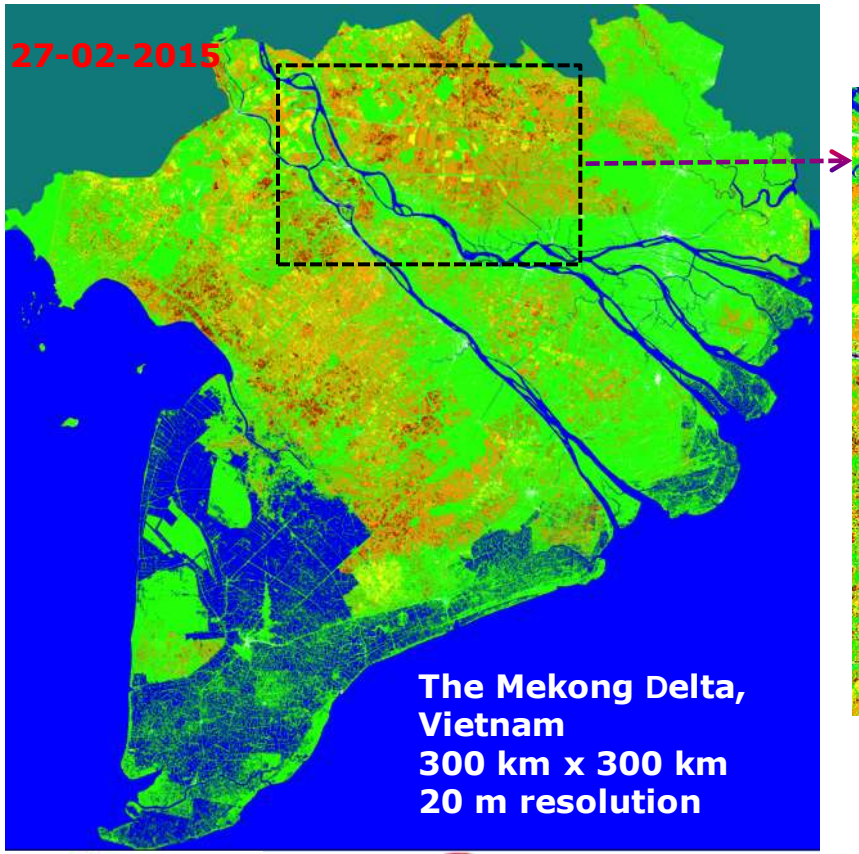
- Rice: early stage
- Rice: tillering stage
- Rice: reproductive stage
- Rice: maturity stage
- Non rice (forest, other LULC)
- Water (ocean, river, aquaculture)
- Land outside the Vietnam Mekong delta

CESBIO V.A.S.T Asia-RiCE Crop Estimation and Monitoring innovators georice

European Space Agency

Agriculture application examples resulting from regular Sentinel-1 acquisitions - Rice monitoring, Mekong Delta, Vietnam -

Monitoring of Winter-Spring rice



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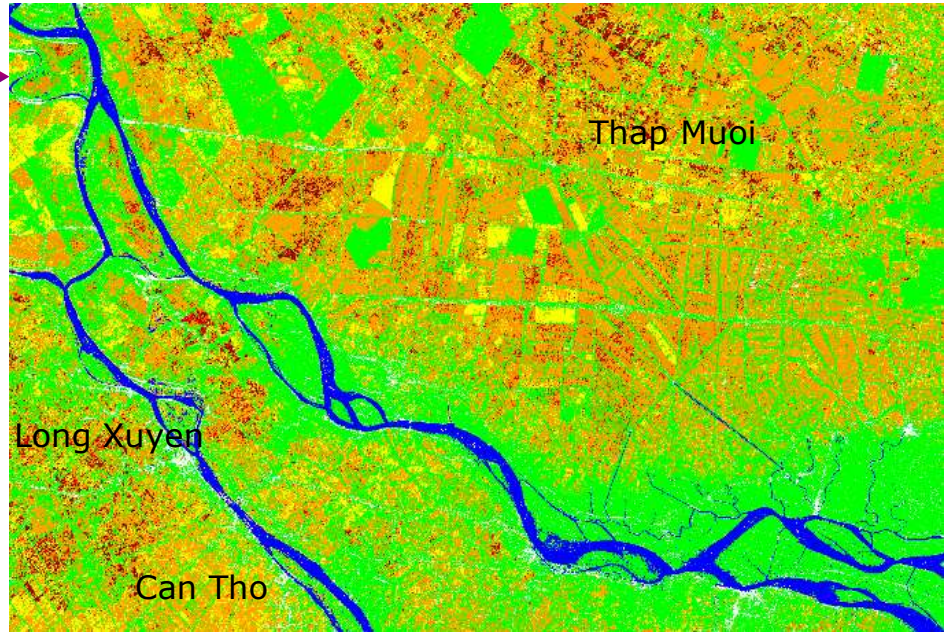

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European Space Agency

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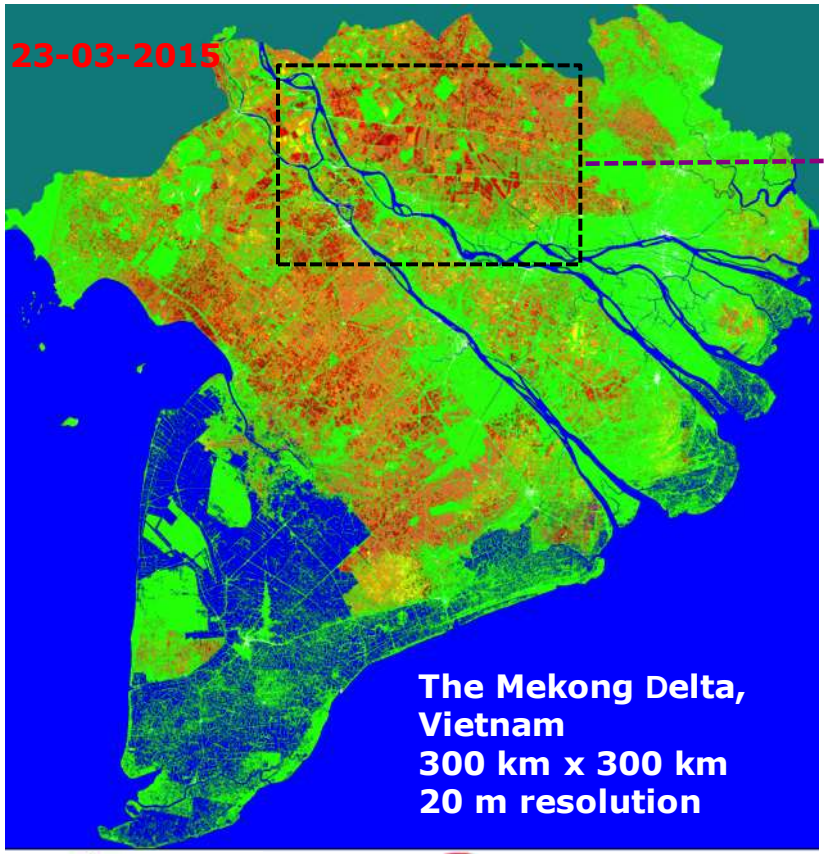

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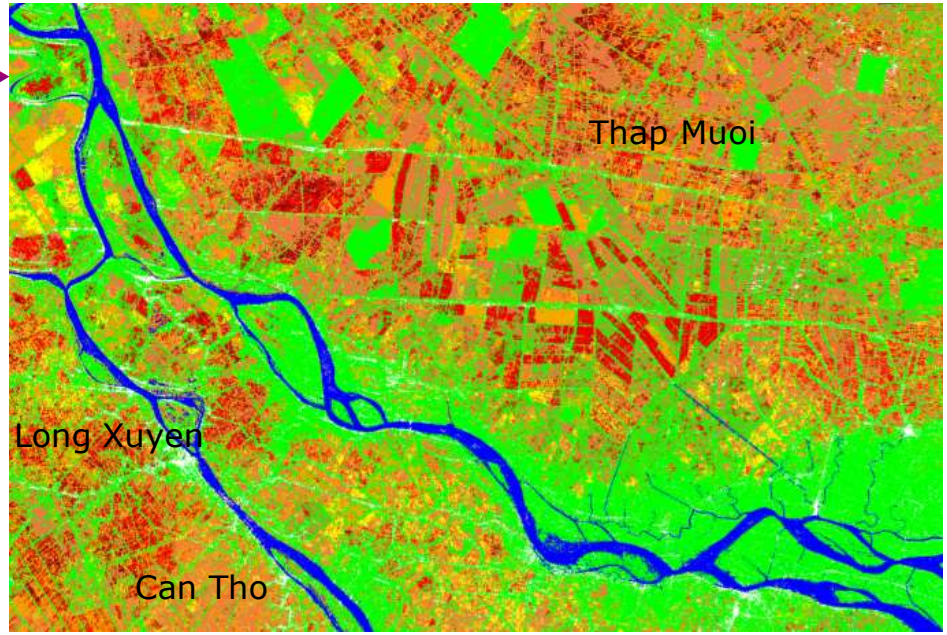

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European Space Agency

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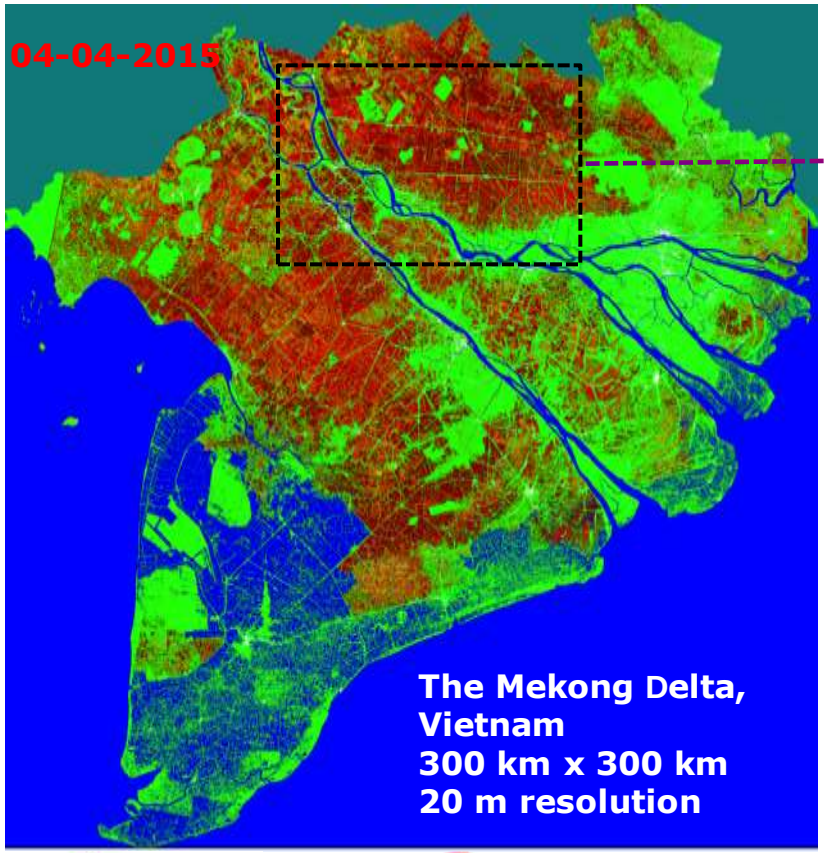
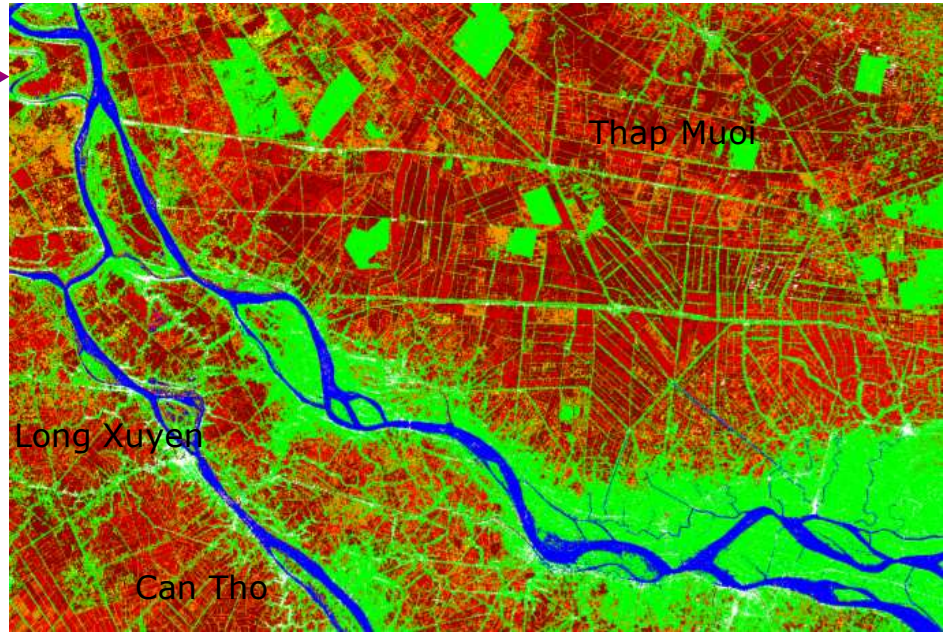


100 km x 70 km, 20 m resolution



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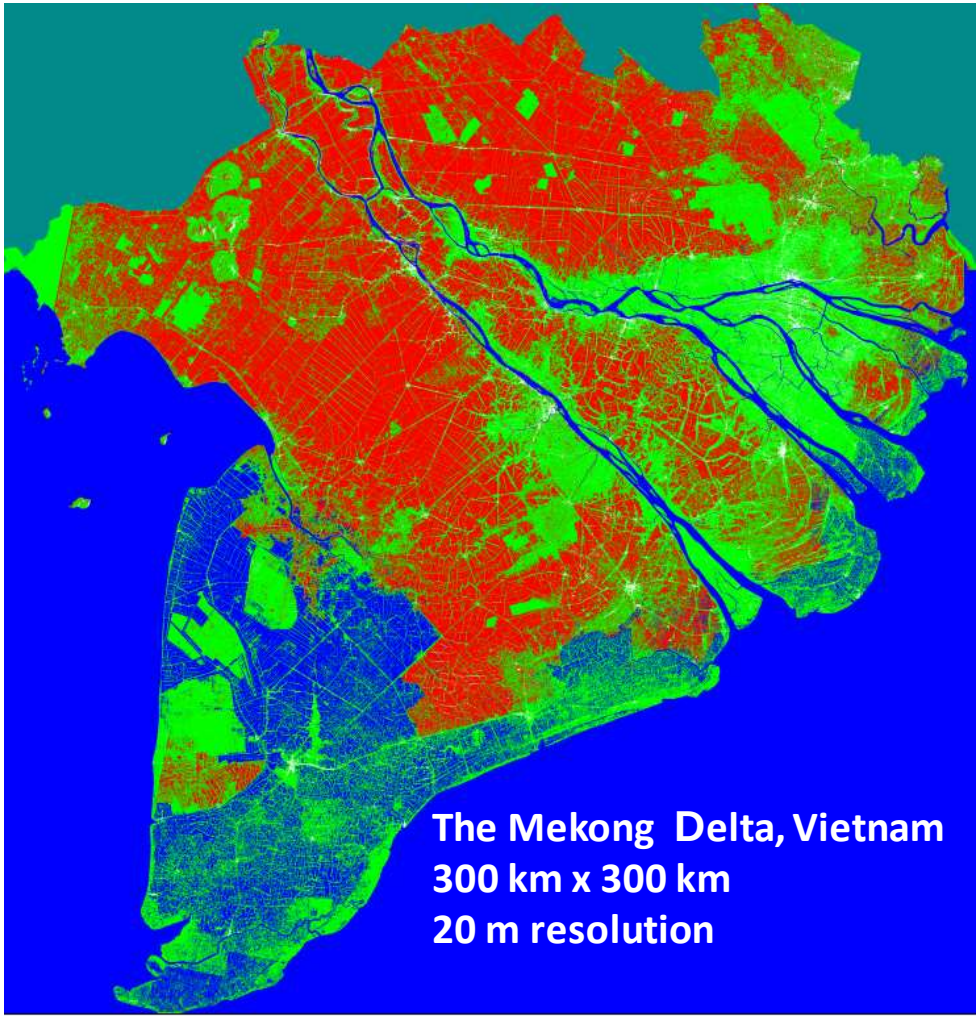
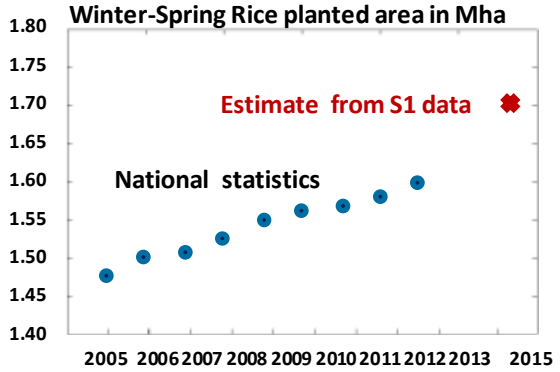
CESBIO V.A.S.T Asia-RiCE Crop Estimation and Monitoring innovators georice

European Space Agency

Agriculture application examples resulting from regular Sentinel-1 acquisitions - Rice monitoring, Mekong Delta, Vietnam -

Estimate and map of Winter-Spring Rice (January-April) 2015





Estimated Winter-Spring planted area in 2015: 1.704 Mha

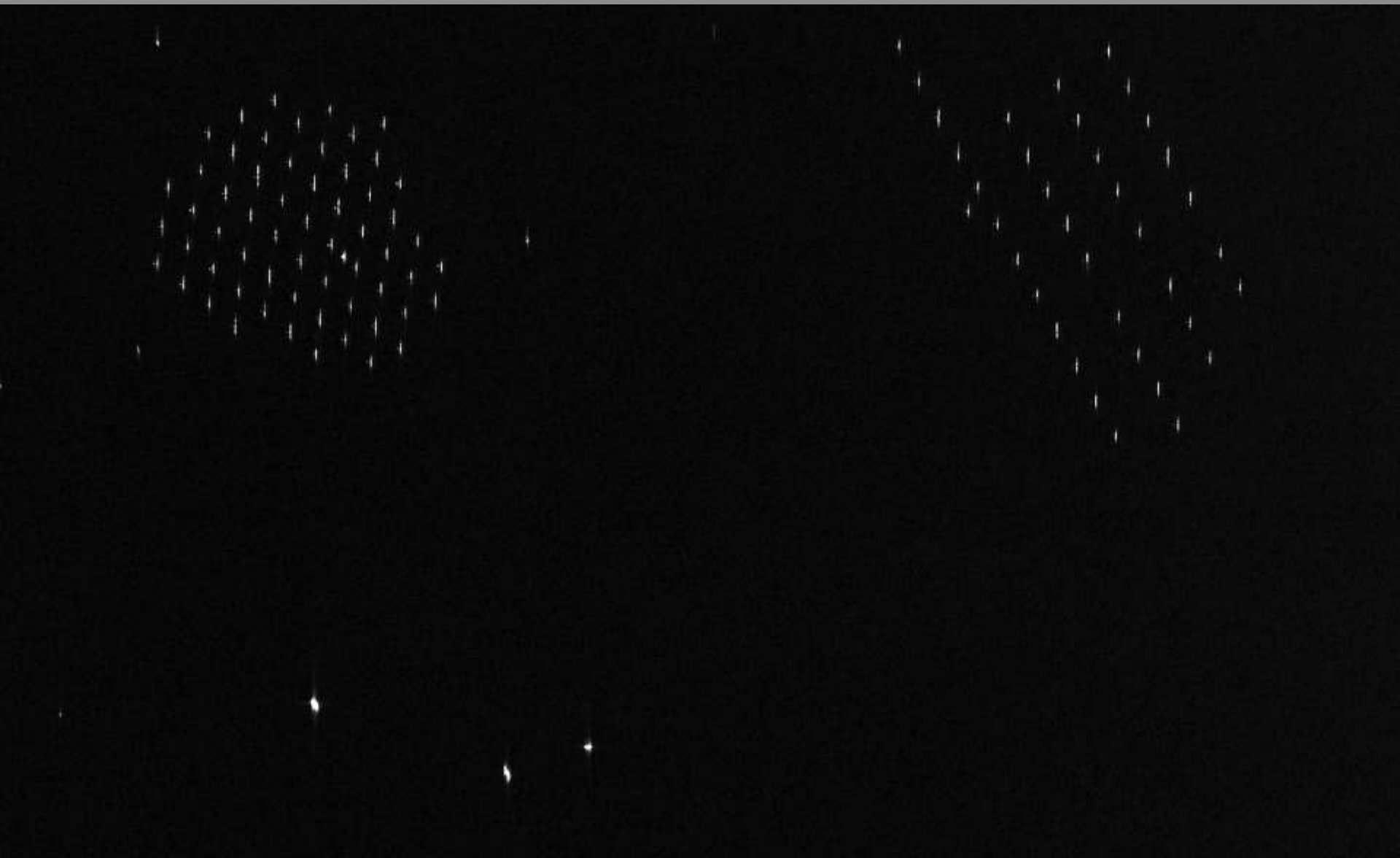
- Rice (Winter-Spring)
- Non rice (forest, other LULC)
- Water (ocean, river, aquaculture)
- Land outside the Vietnam Mekong delta

IW S1 Data: 10 January, 03 February, 27 February, 11 March, 23 March, 04 April, 16 April 2015

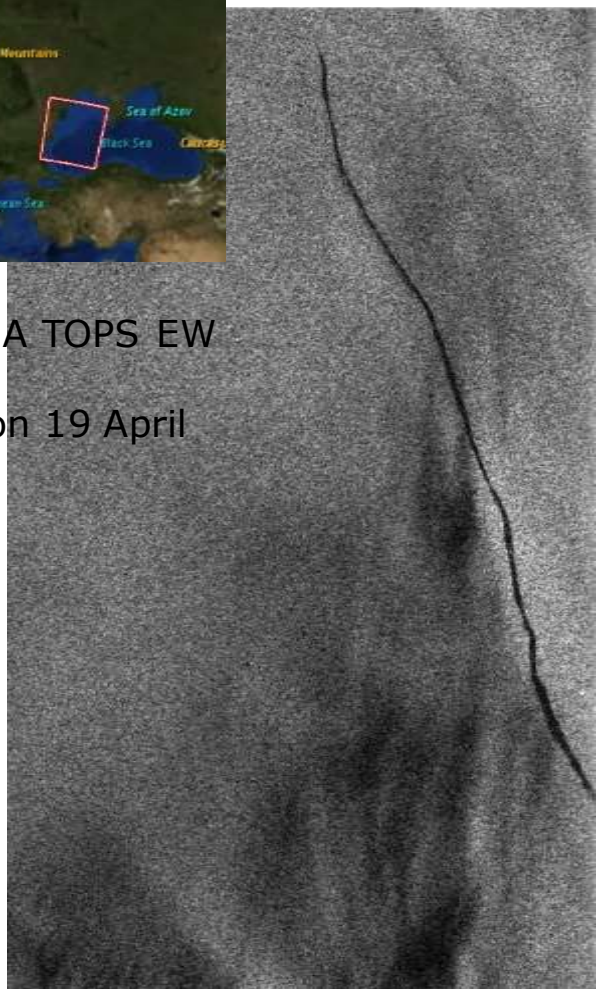
Marine / Oceans

Maritime Surveillance
(Oil Spill Detection, Ship Detection, Illegal Fisheries, etc.)
Wind / Wave / Current

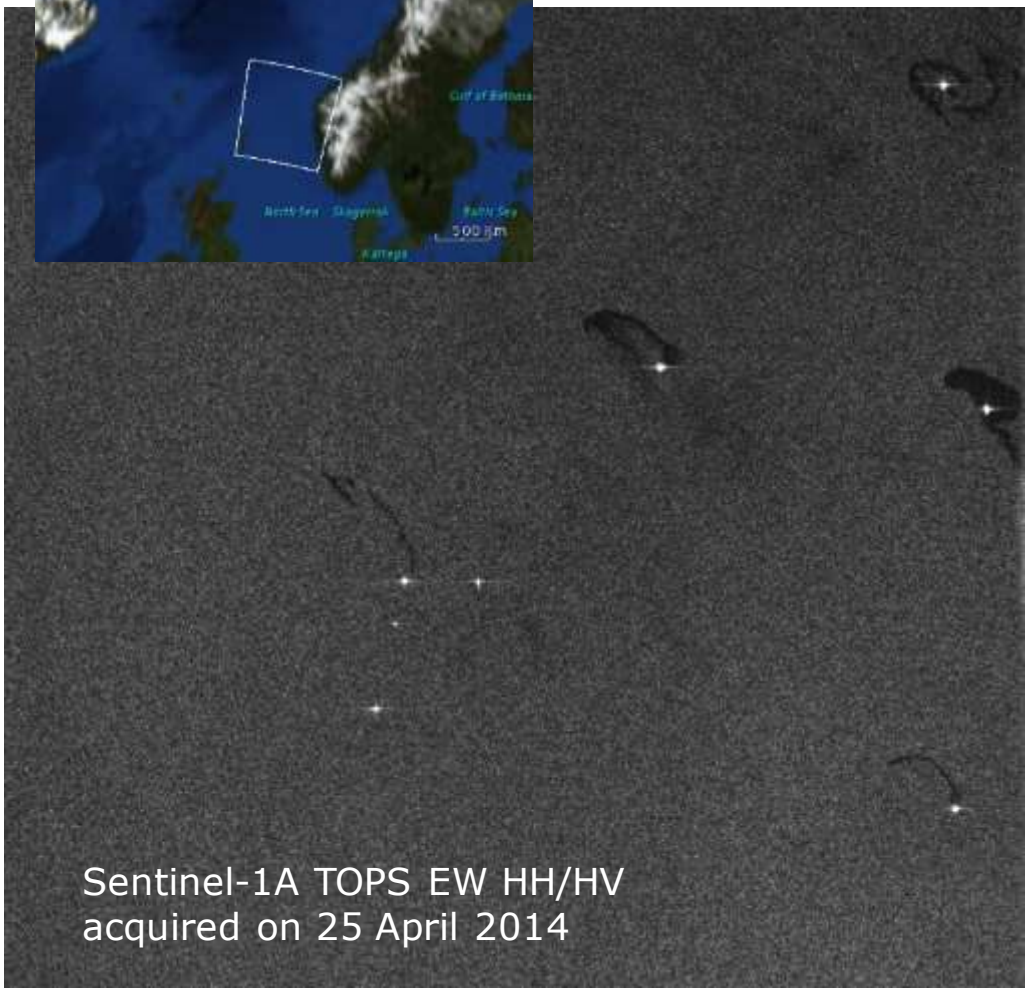
Windfarms of the Dutch Coast



First Oil Spills Detected by Sentinel-1

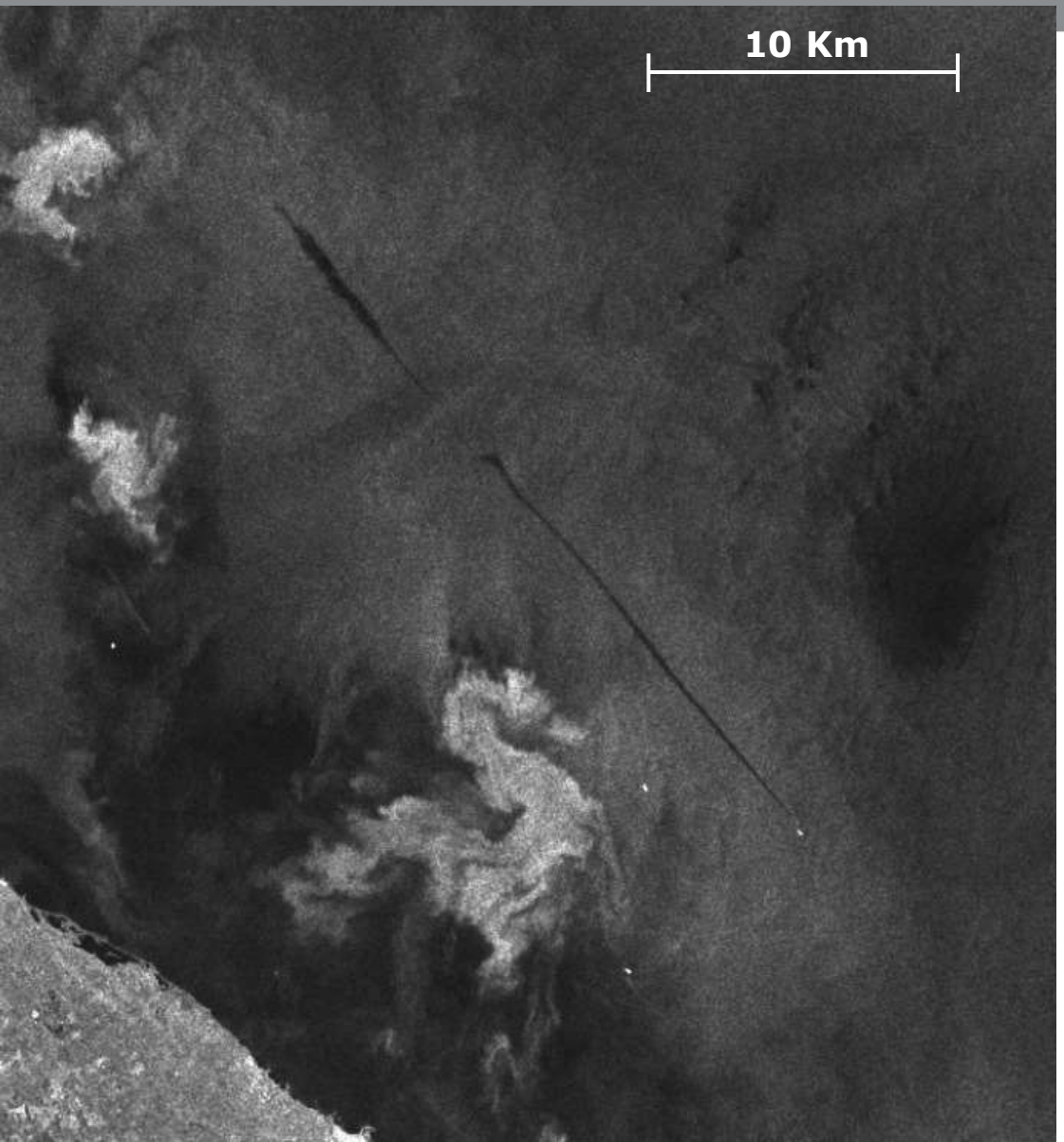


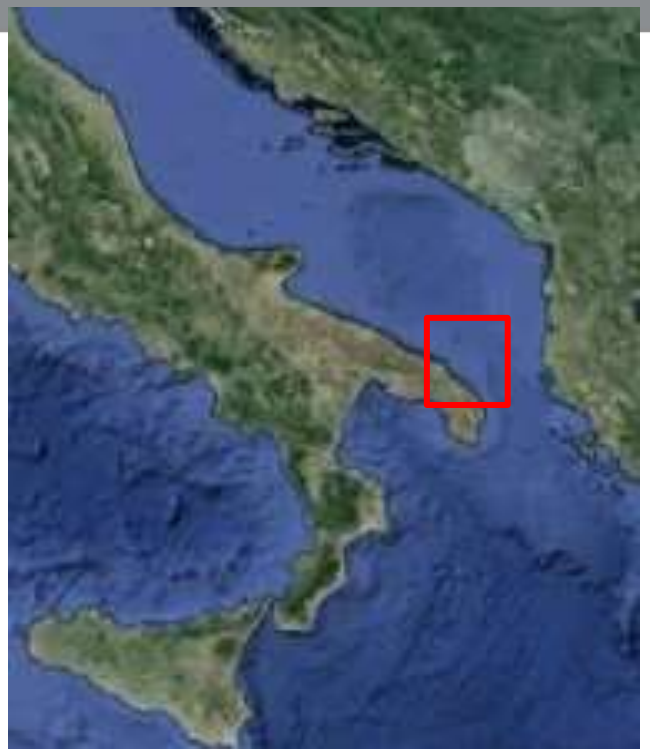
Sentinel-1A TOPS EW VV/VH acquired on 19 April 2014



Sentinel-1A TOPS EW HH/HV acquired on 25 April 2014

Oil discharge





IW mode

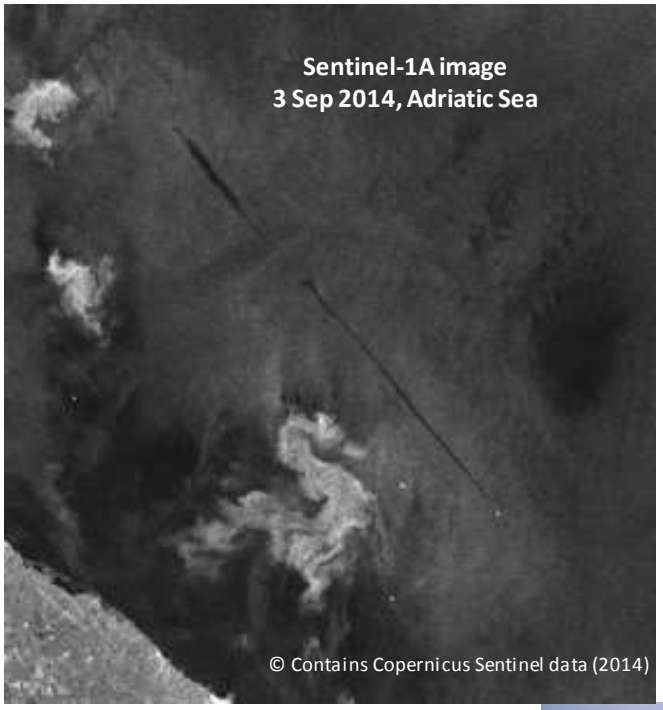
Vertical Polarization

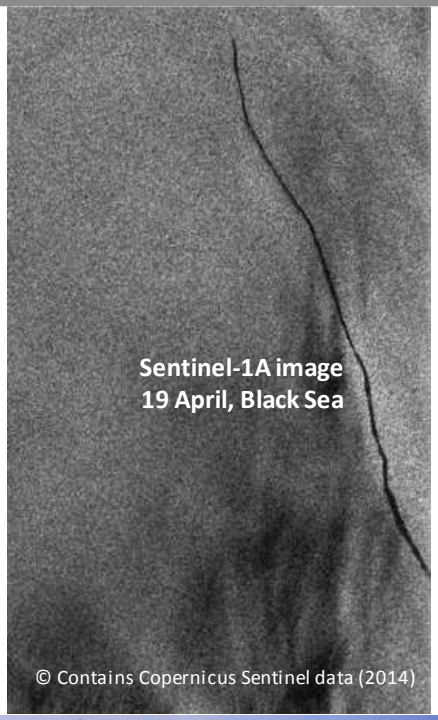
Date: 3.09.2014

Sentinel-1 supports the EMSA CleanSeaNet service

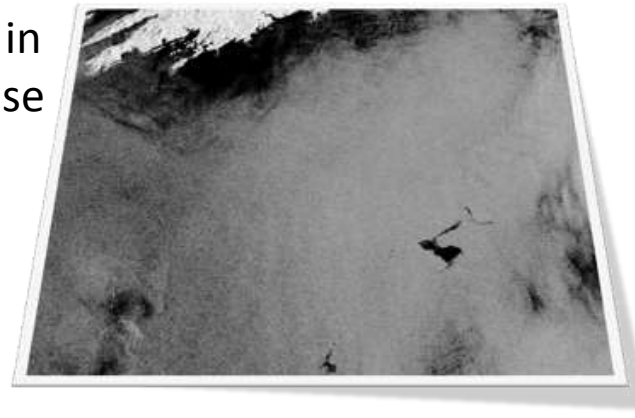
CleanSeaNet: the European satellite-based **oil pollution and vessel detection monitoring system**

→ Operated by the European Maritime and Safety Agency (EMSA)





EMSA is gradually introducing in the CleanSeaNet service the use of Sentinel-1 imagery

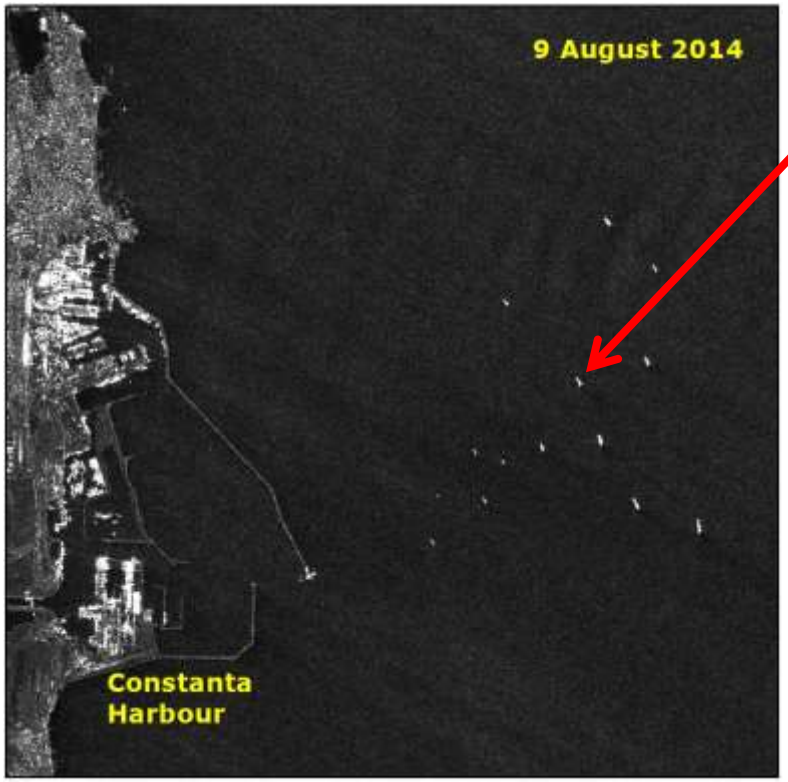


Sentinel-1A single acquisition over Greece and ship detection

Credits: ESA

Sentinel-1
Ship detection demonstration

Sentinel-1 image



Santa Barbara

Flag: Barbados

Home port: Bridgetown

Build: 1984

Type: Cargo

Gross Tonnage: 24844

Deadweight: 40907 t

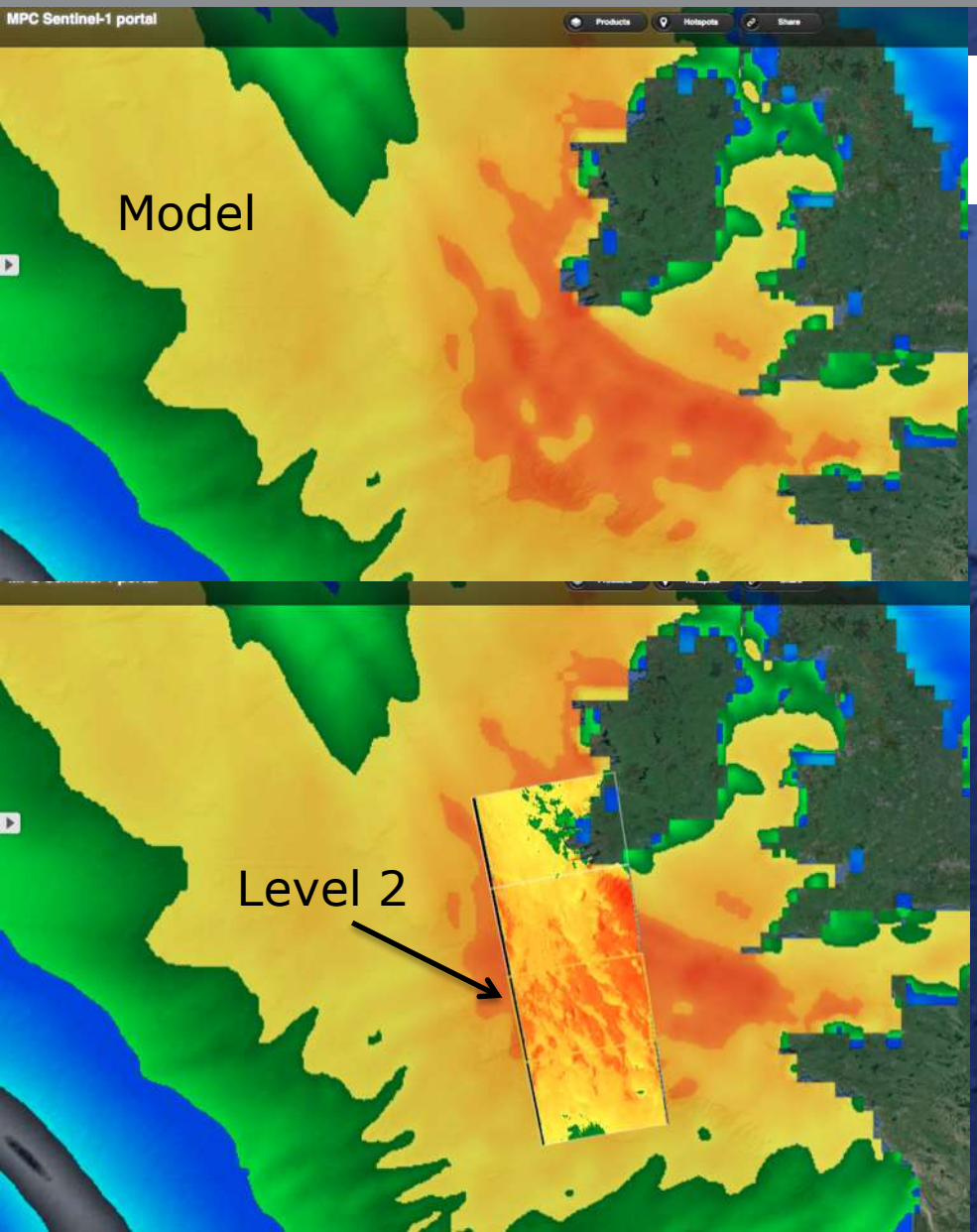
Length and Breath: 182.81m x30.54m

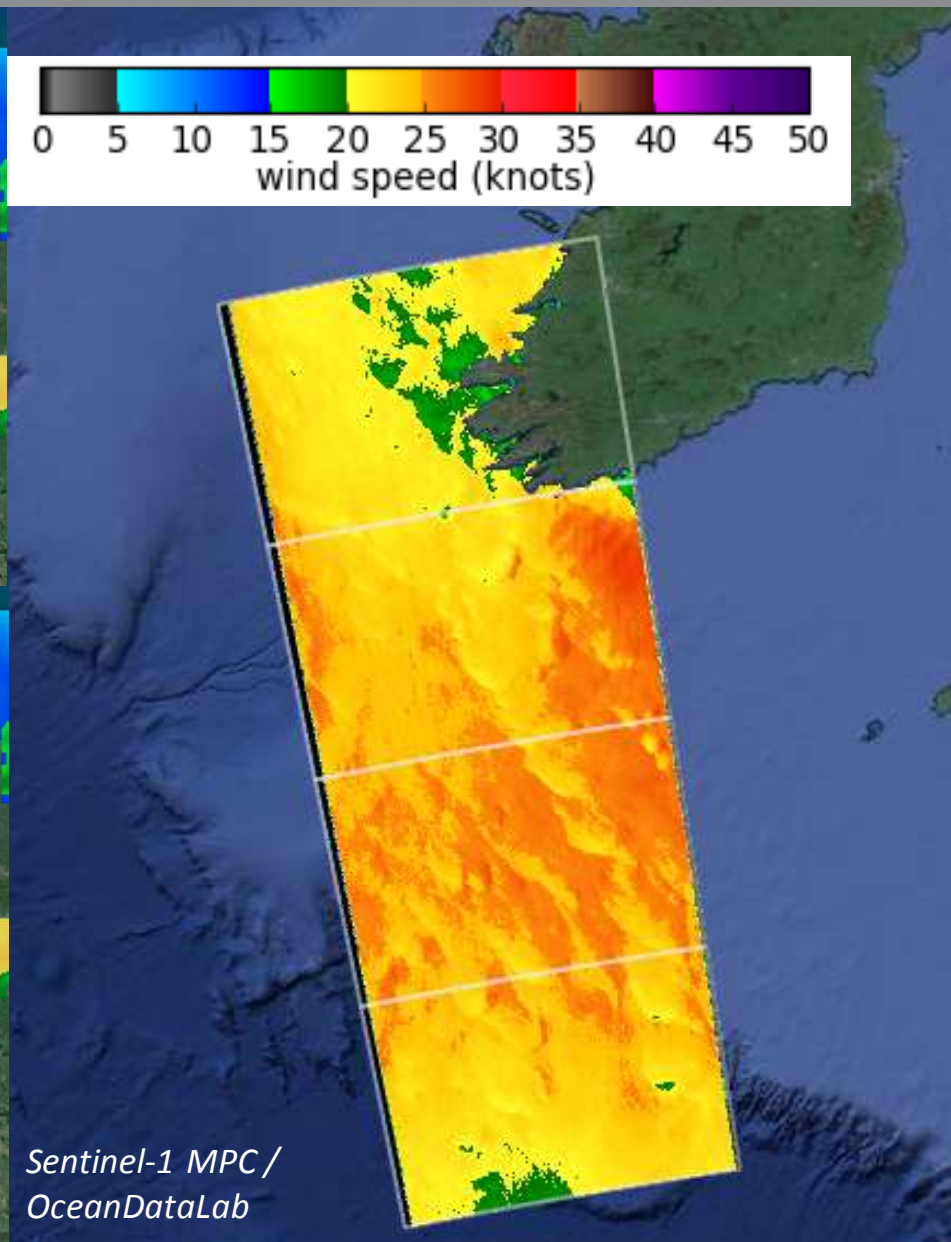
Status: Active

Correlation with AIS (Automatic Identification System) data*

*data acquired from www.marinetraffic.com

Sentinel-1 Level-2 product
Wind speed measurement



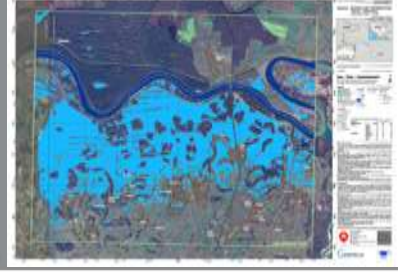
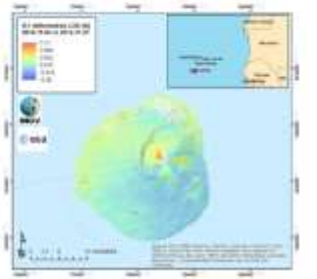
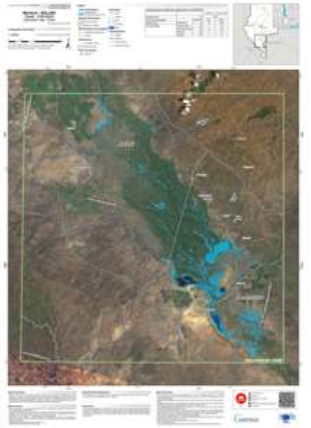
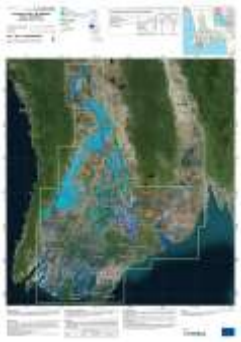


Emergency Disaster Management

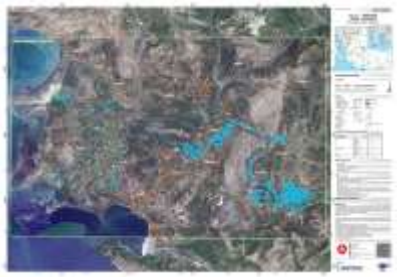
Flooding
Geohazards
Natural / Man-made Disasters
etc

Sentinel-1 Data Provision to Copernicus Emergency Management Service

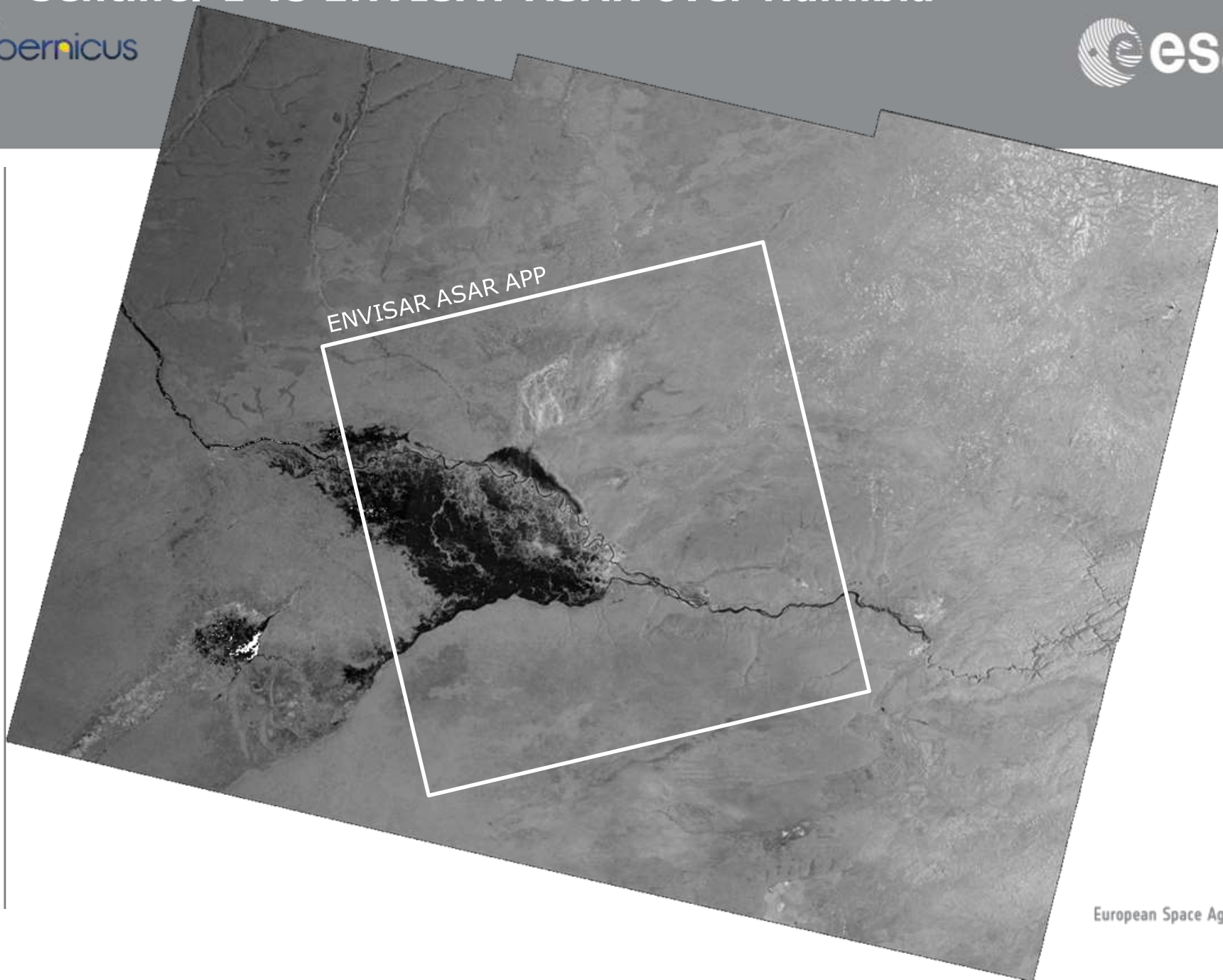
- ✓ Sentinel-1 responded to a number of activations from the Copernicus Emergency Management Service (as well as from the International Charter Space and Major Disasters):
  - ✓ EMSR87 for floods in Bosnia-Herzegovina (May 2014)
  - ✓ EMSR100 for floods and landslides in Italy (Sep 2014)
  - ✓ EMSR107 for floods in Slovenia (Nov 2014)
  - ✓ EMSR108 for floods and landslides in Italy (Nov 2014)
  - ✓ EMSR111 related to the volcanic eruption at Fogo Island (Cape Verde) (Nov 2014)
  - ✓ EMSR116 for floods in Malawi (Jan 2015)
  - ✓ EMSR117 for floods in Greece (Feb 2015)
  - ✓ EMSR118 for floods in Spain (Feb 2015)
  - ✓ EMSR122 for floods in Greece (Mar 2015)
  - ✓ EMSR125 for Earthquake in Nepal
  - ✓ EMSR126 for algae bloom in French Guiana (May 2015)
  - ✓ EMSR130 for major floods in Myanmar (Aug-Sep 2015)

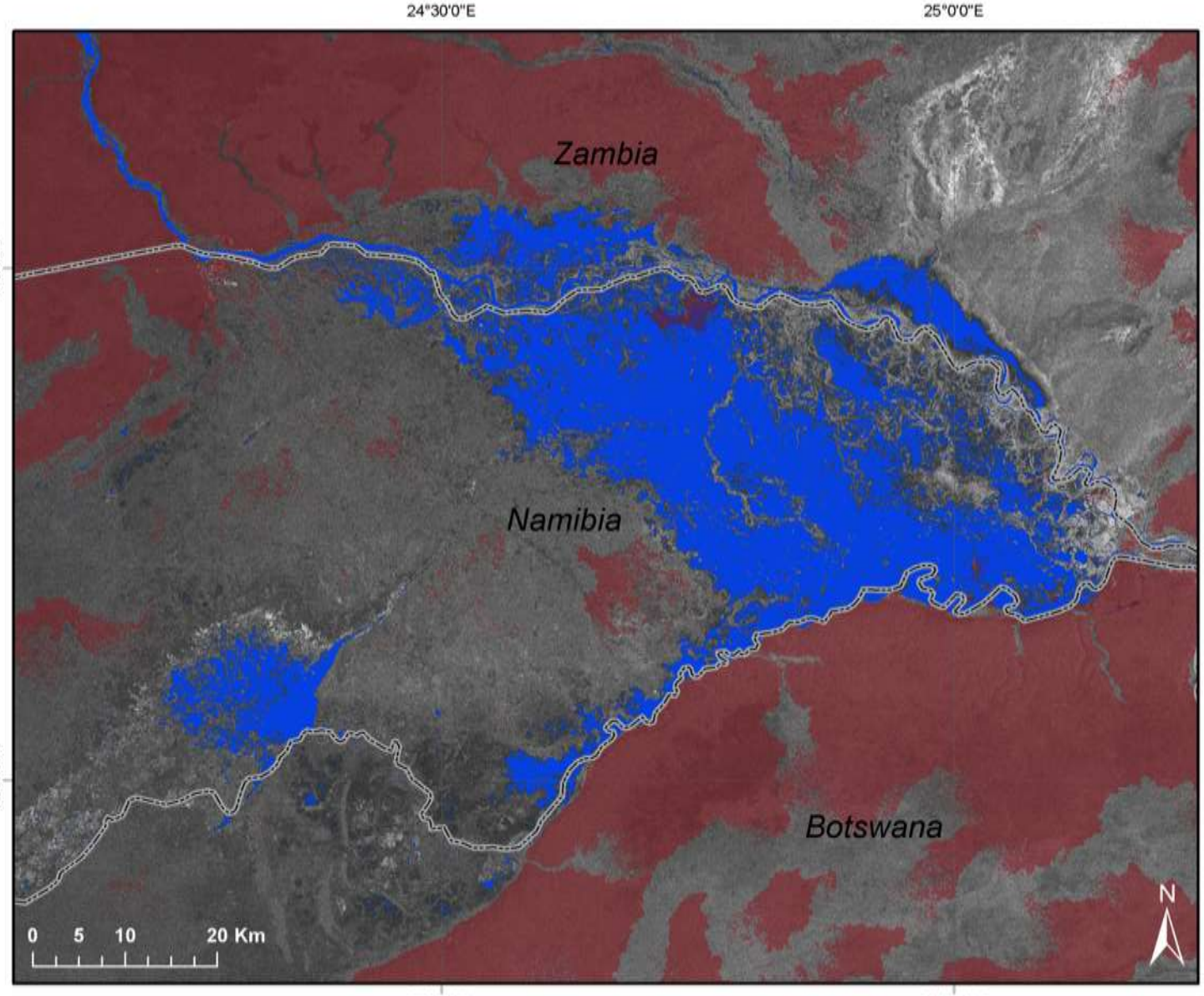




Sentinel-1 vs ENVISAT ASAR over Namibia



Sentinel-1 Flood Monitoring of Caprivi Flood Plain, Namibia



Legend

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

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

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

Cartographic Reference
Projection: EPSG:4326
Datum: WGS 84


Balatun - BOSNIA AND HERZEGOVINA
Flood - 13/05/2014
Delineation Map - Detail
Croatia
Bosnia and Herzegovina
Serbia
Legend
Map Information
Data Sources
Dissemination/Publication
Framework
Map Production
Area of Interest - Detail
Copernicus

Flood in Panah, Pakistan, 16 Sep 2014 – International Charter / Unosat

STANDING WATERS IN TARIND MUHAMMED PANAH AREA, PUNJAB PROVINCE, PAKISTAN

Analysis with SENTINEL-1 data 16 September 2014

This map illustrates satellite-detected areas with waters as detected by SENTINEL-1 imagery acquired the 16 September 2014 in Tarind Muhammad Panah area. The Indus and the Panjnad rivers expanded and seem to have inundated some agricultural fields along the Indus River and the Panjnad River in the Punjab Province (Pakistan). This analysis has not yet been validated in the field. Please send ground feedback to UNITAR /UNOSAT.

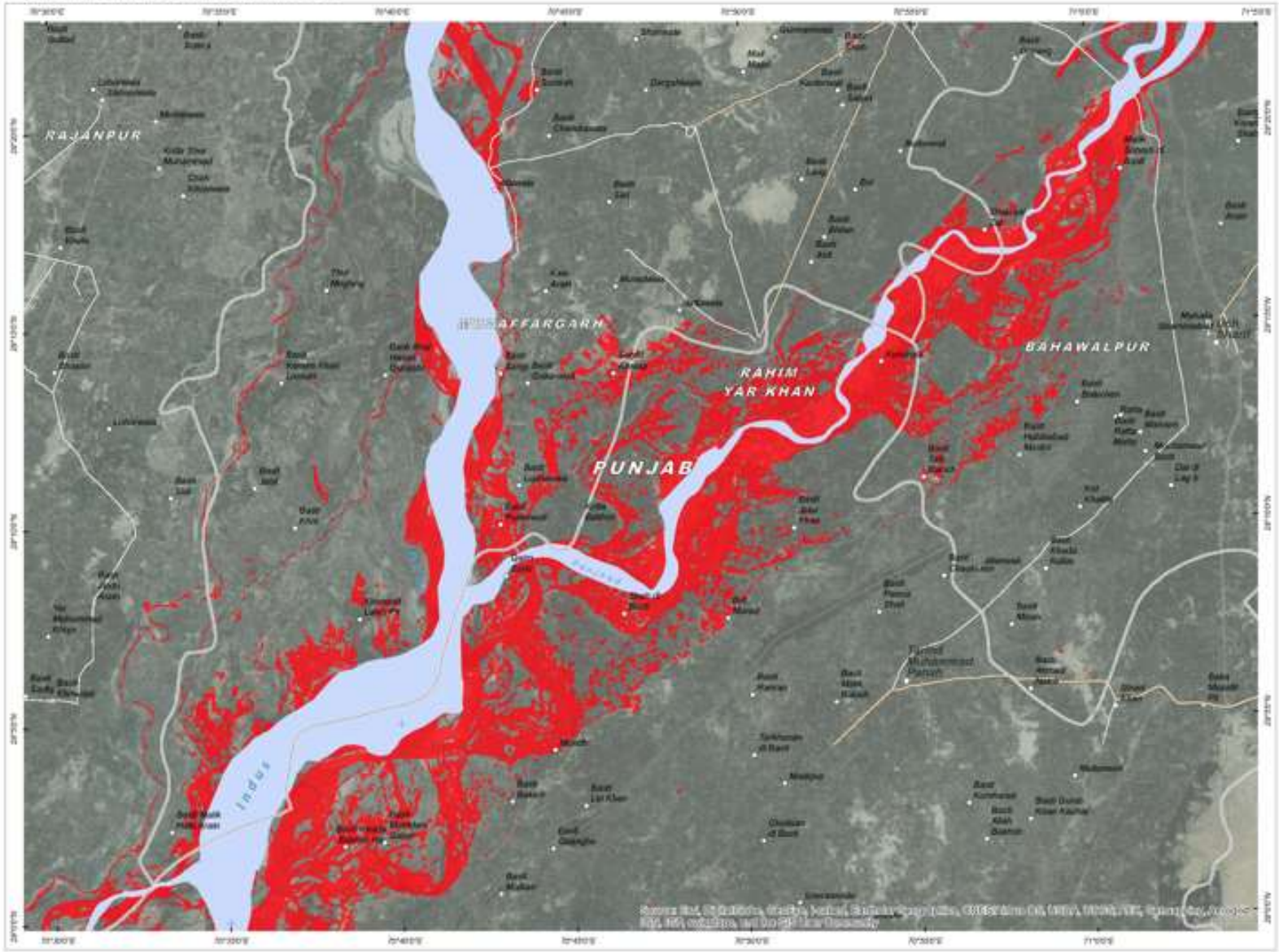
Disaster coverage by the International Charter Space and Major Disasters. For more information on the Charter, which is about

Flood

Production Date: 9/17/2014

Version 1.0

Activation Number: FL20140910PAK



LEGEND

- City/Town
- Populated Place
- Primary Road
- Secondary Road
- Local/Urban Road
- District Boundary

WATER EXTENT ANALYSIS

- Observed Waters / Flood Affected Lands Sentinel-1 16 September 2014
- Pre-Crisis Water Extent Google Map Maker

Map Scale for A3: 1:175,000

Satellite Data (1): SENTINEL-1
Imagery Dates: 16 September 2014
Resolution: 10m
Copyright: ESA
Source: ESA
Road Data : Google Map Maker / OSM / ESRI
Other Data: USGS, UNCS, NASA, NGA
Analysis : UNITAR / UNOSAT
Production: UNITAR / UNOSAT
Analysis conducted with ArcGIS v10.2

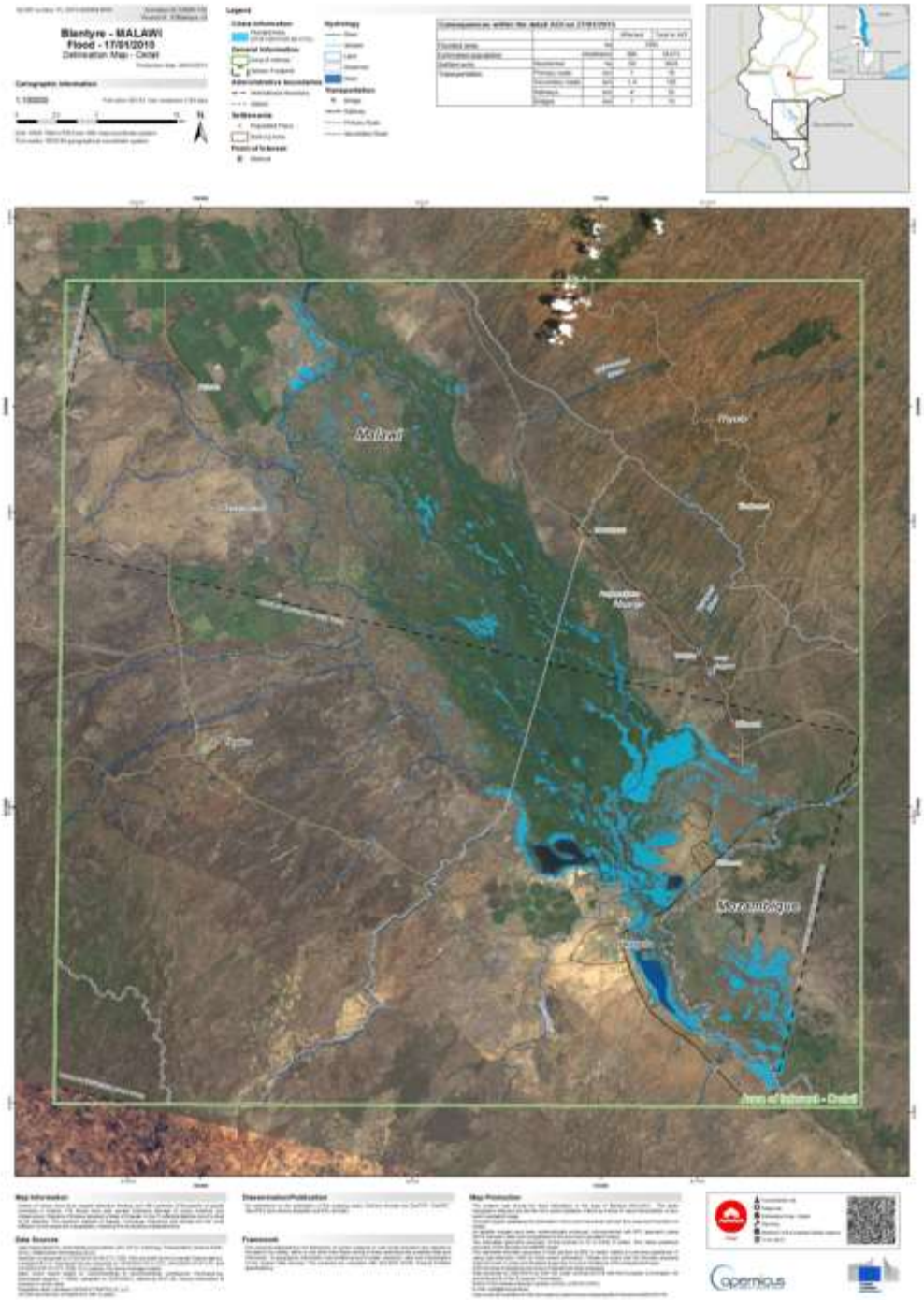
Coordinate System: WGS 1984 UTM Zone 42N
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

unitar

UNOSAT

Contact information: unosat@unitar.org
24/7 Hotline: +41 76 487 4998
www.unitar.org/unosat

Flood in Zaragoza, Spain, 2 Feb 2015 – Copernicus Emergency Service



Flood in Malawi

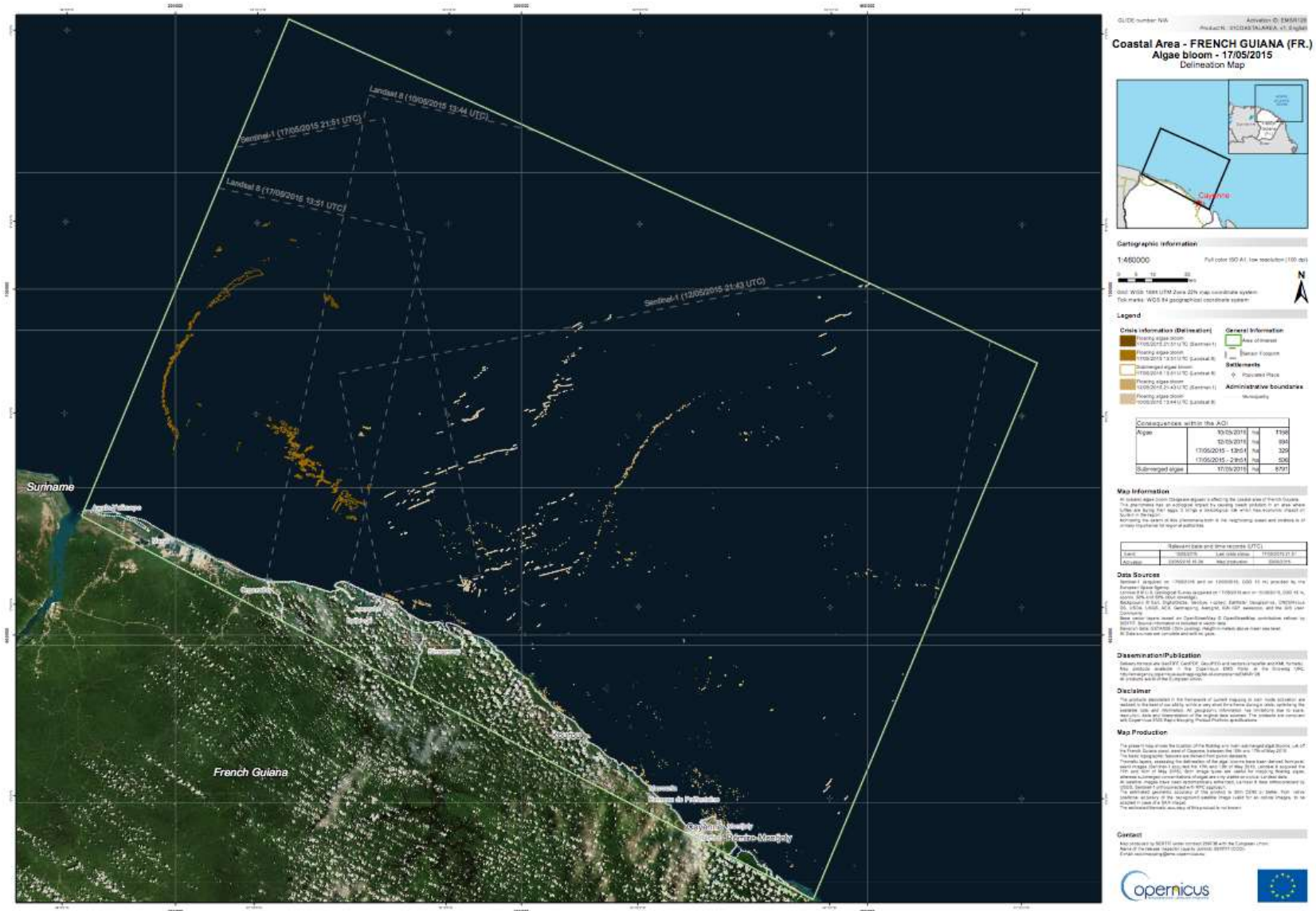
January 2015 -

Flood delineation map based on Sentinel-1 data

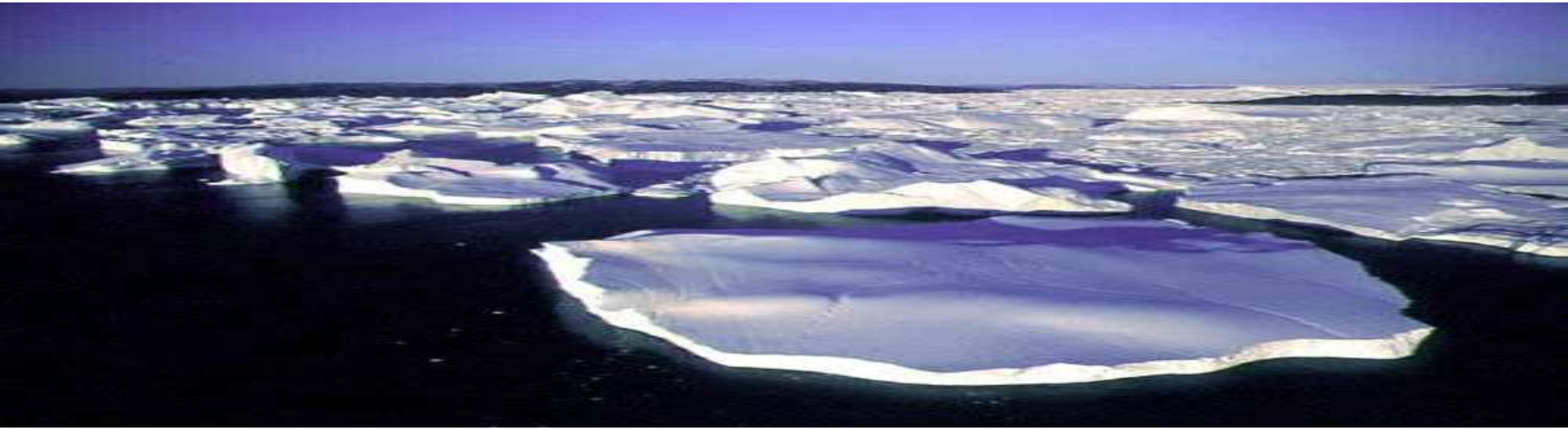
Copernicus Emergency Management Service

European Space Agency

Algae bloom detected by Sentinel-1, French Guiana
Use by the Copernicus Emergency Management Service

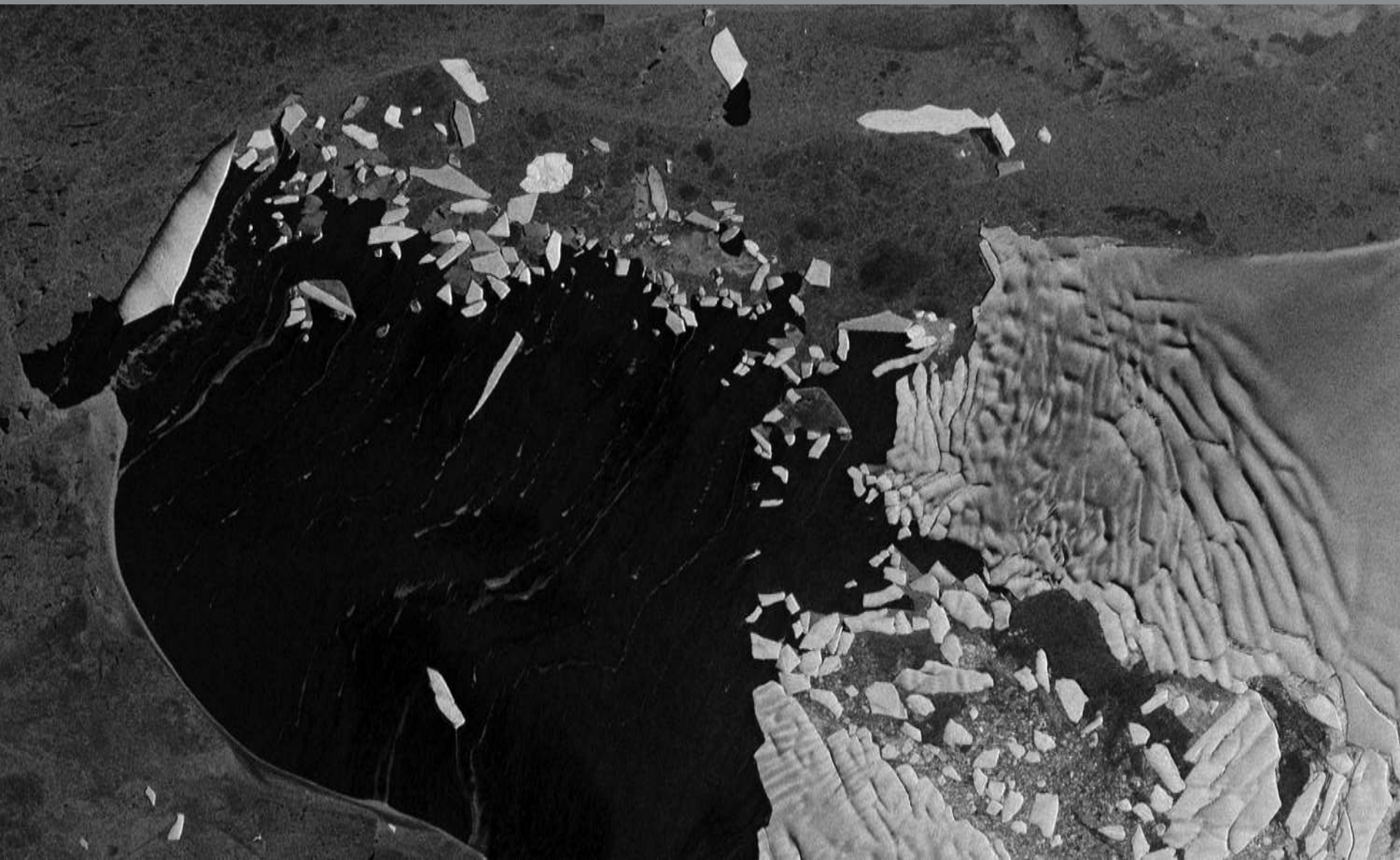


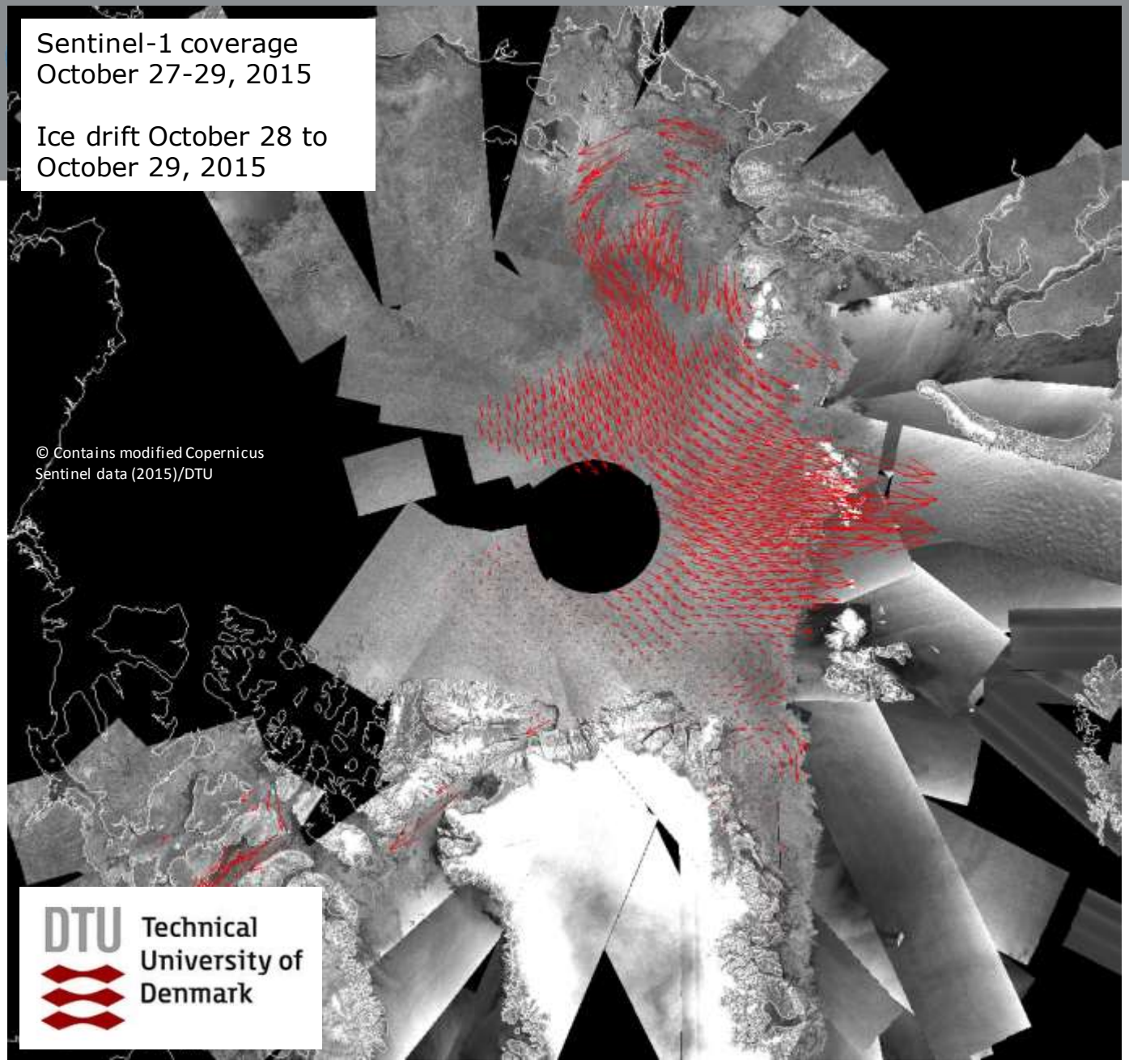
Ice / Cryosphere / Climate



Sea Ice / Iceberg
Ice Sheets
Polar Monitoring
Snow

Thwaites Glacier, Antarctica





esa

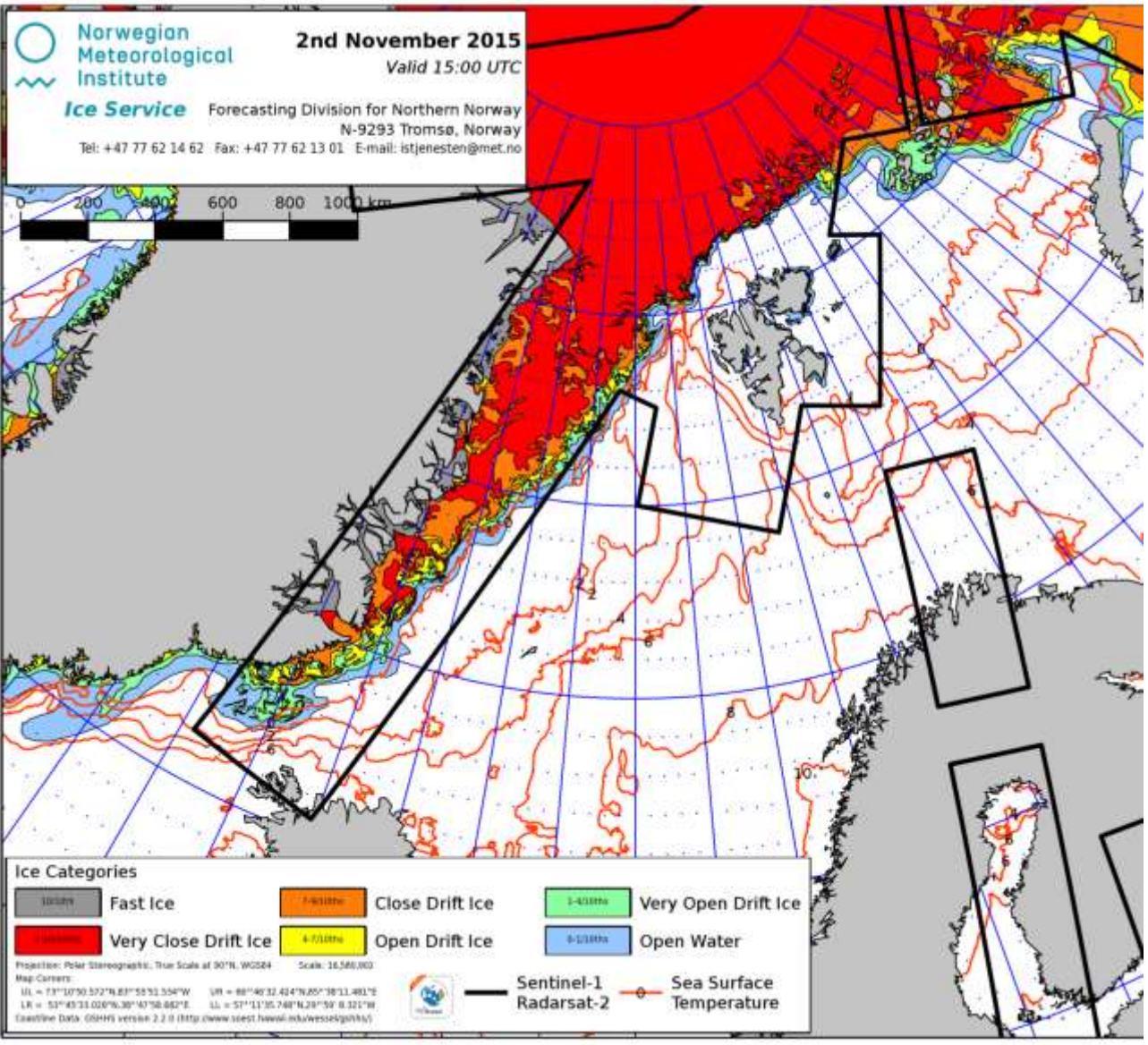
Sentinel-1 provides unprecedented radar coverage of the Polar Regions

Daily ice drift is derived from consecutive overlapping scenes

To validate and tune ice drift forecast models

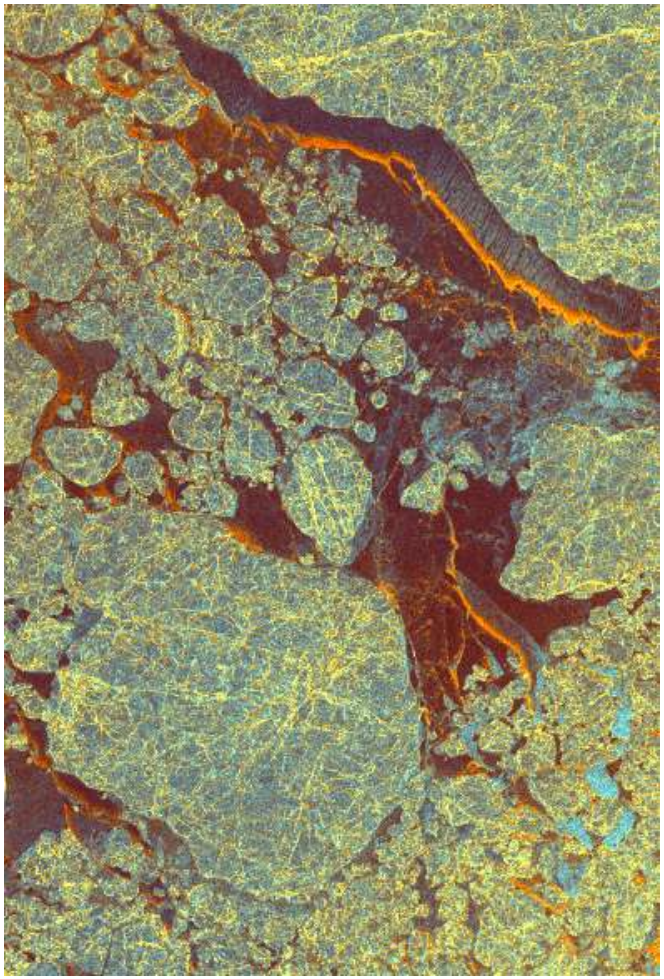
sentinel copernicus
The European Earth Observation Programme

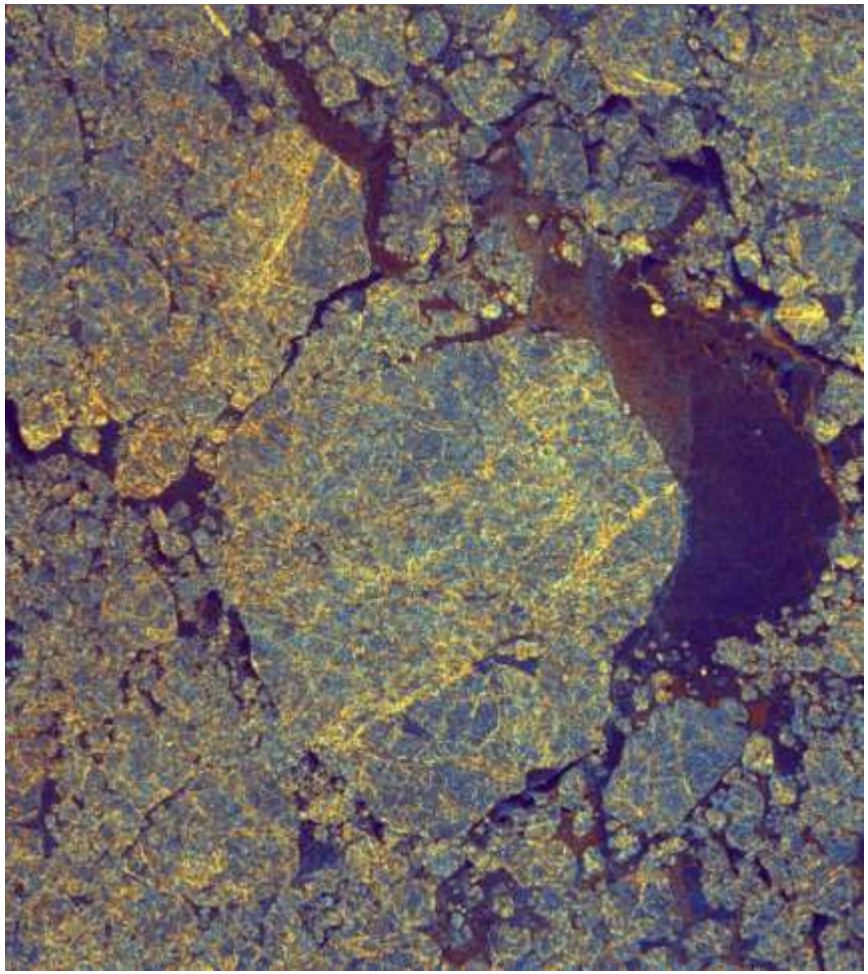
Operational Sentinel-1 data provision to CMEMS
Example of daily ice chart



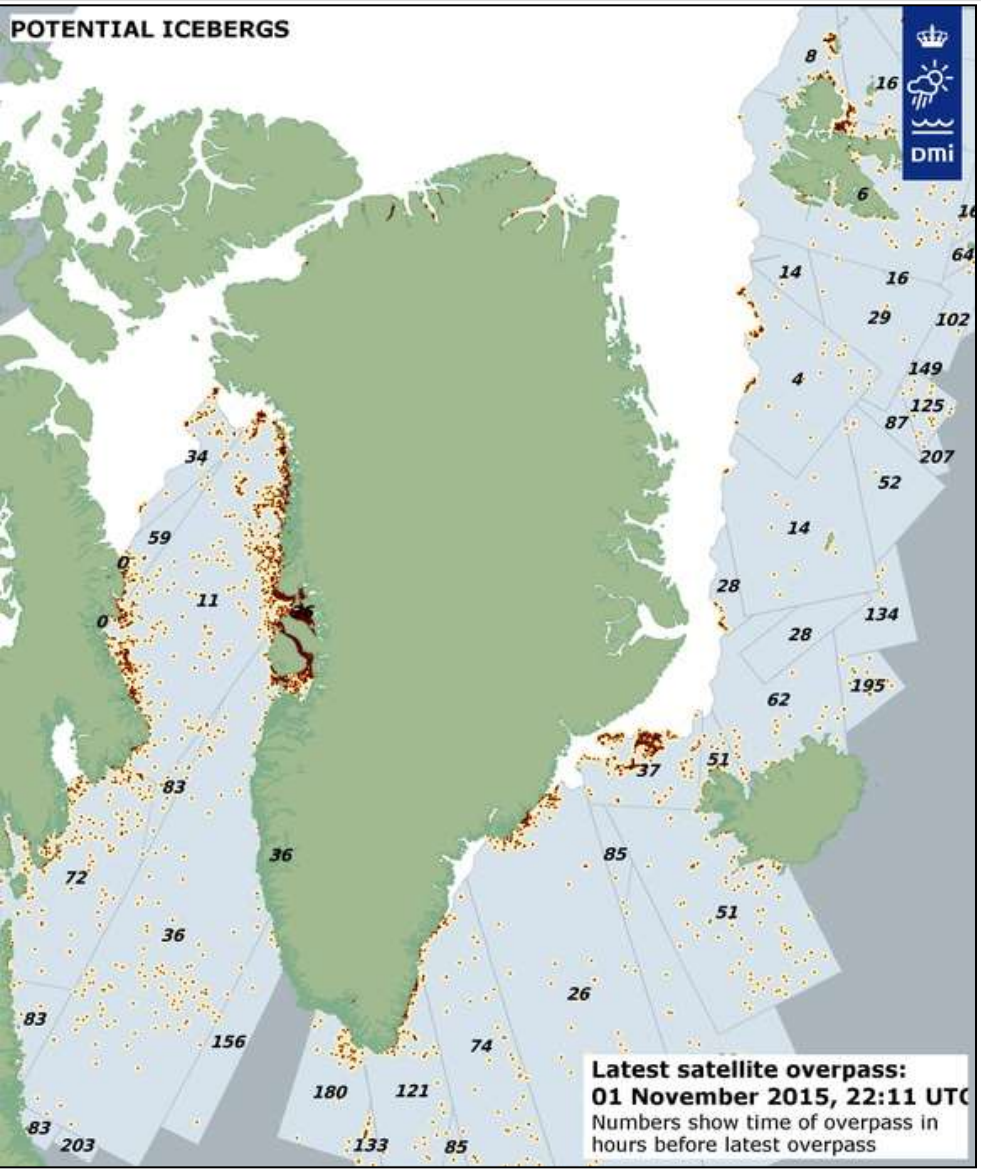
Daily Ice Charts are produced in support of navigation in the Arctic.

Sentinel-1A dual polarisation SAR for ice charting





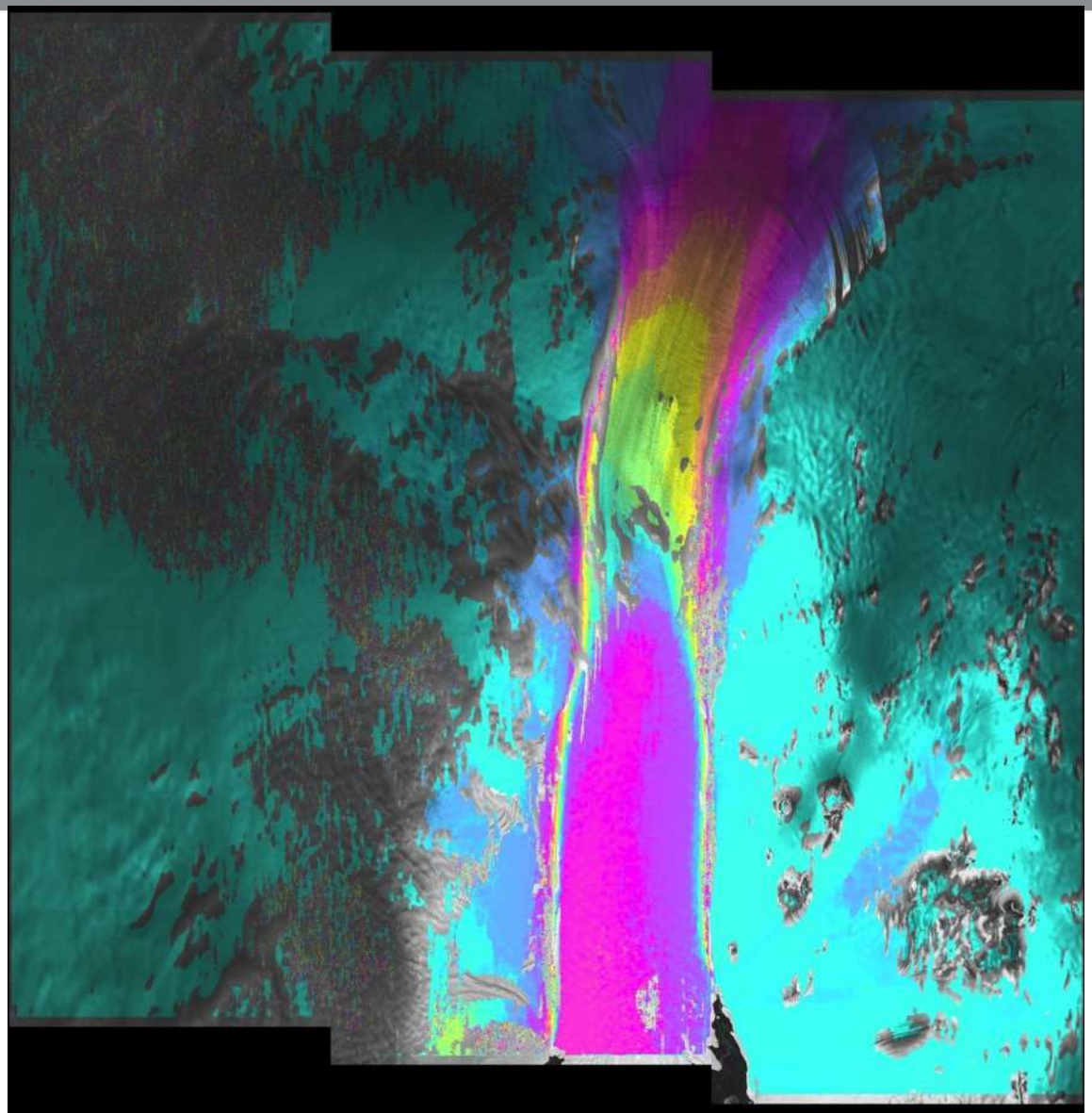
Operational Sentinel-1 data provision to CMEMS
Example of daily maps of icebergs



Daily maps of icebergs in Greenland Waters are produced

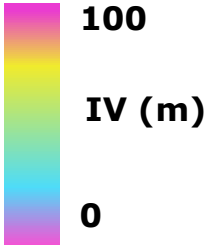
Note that some targets may be ships

Pine Island Glacier Ice Velocity

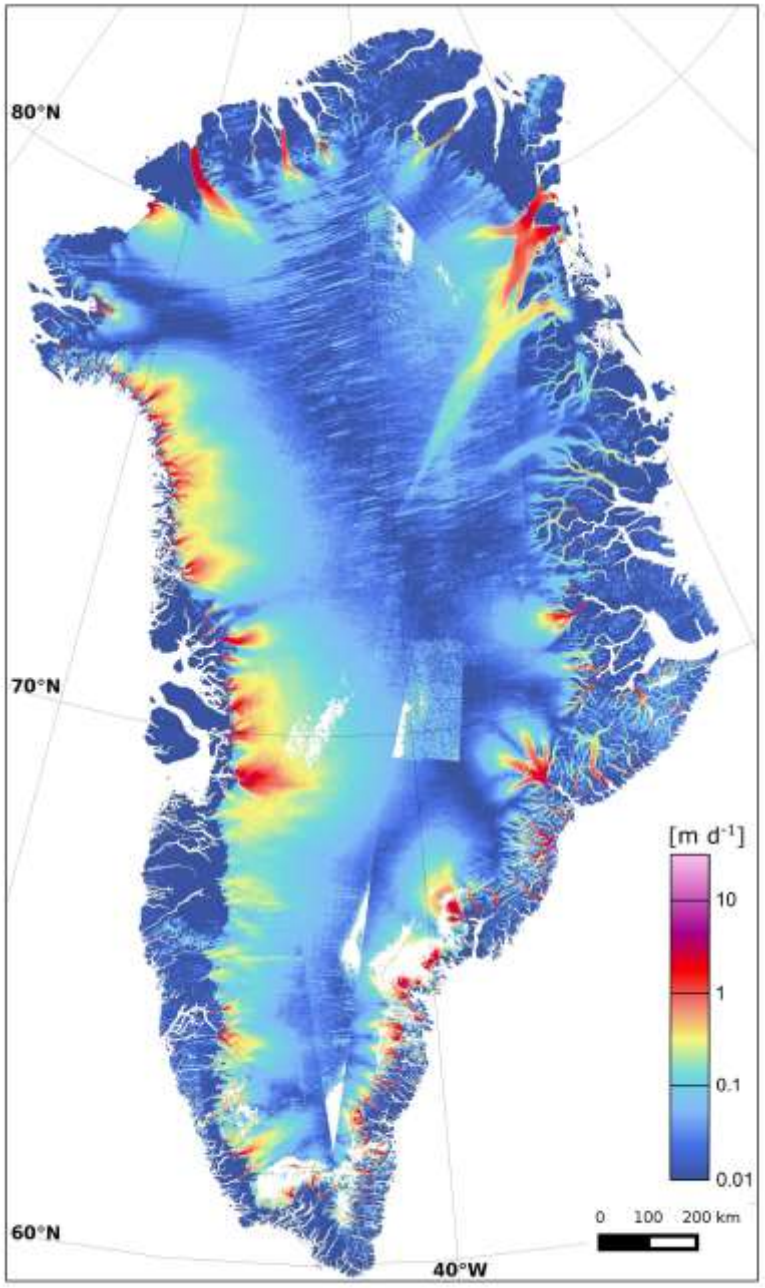


Ice velocity map made of 2 Sentinel-1A images acquired on:

- 3 March 2015
- 15 March 2015



Courtesy University of Leeds



Greenland Ice Sheet Campaign

esa

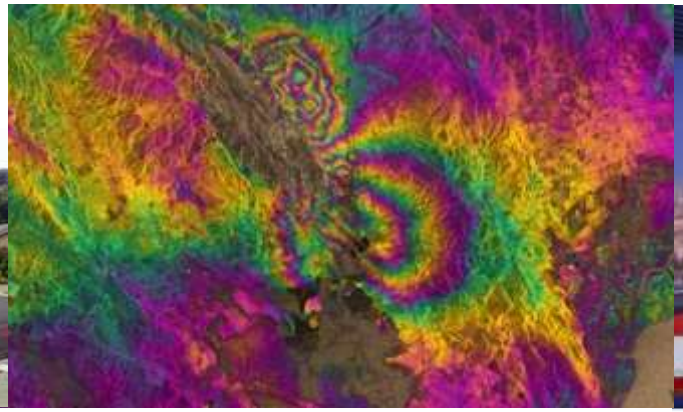
First Sentinel-1 Ice Velocity Map of Greenland

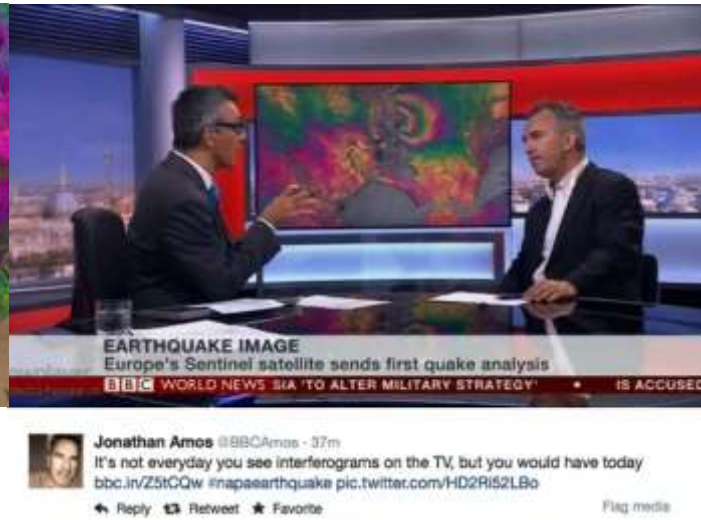
Data acquired between January and March 2015

Courtesy: T. Nagler, ENVEO

European Space Agency

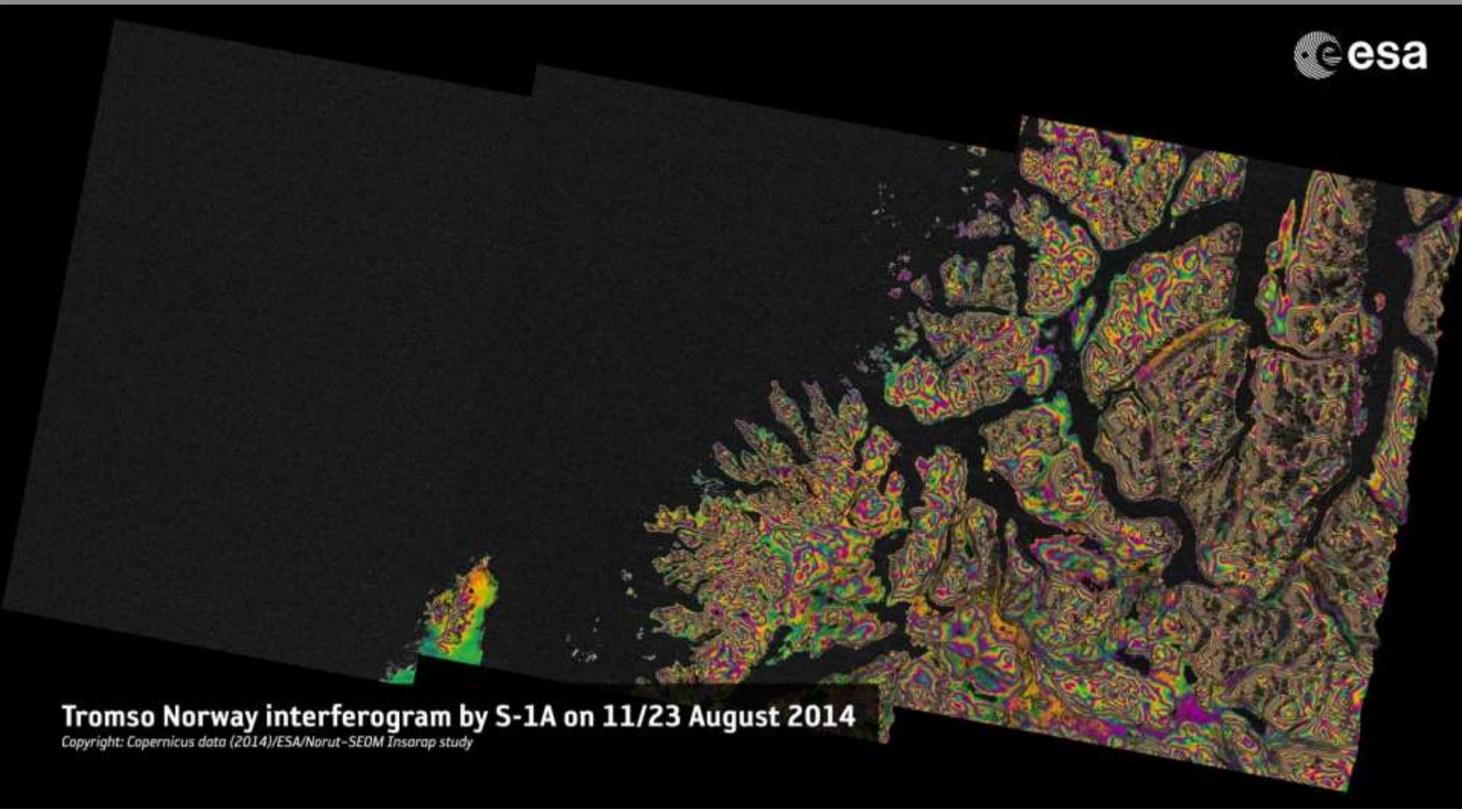
Land





Interferometry Applications
Ground Motion …

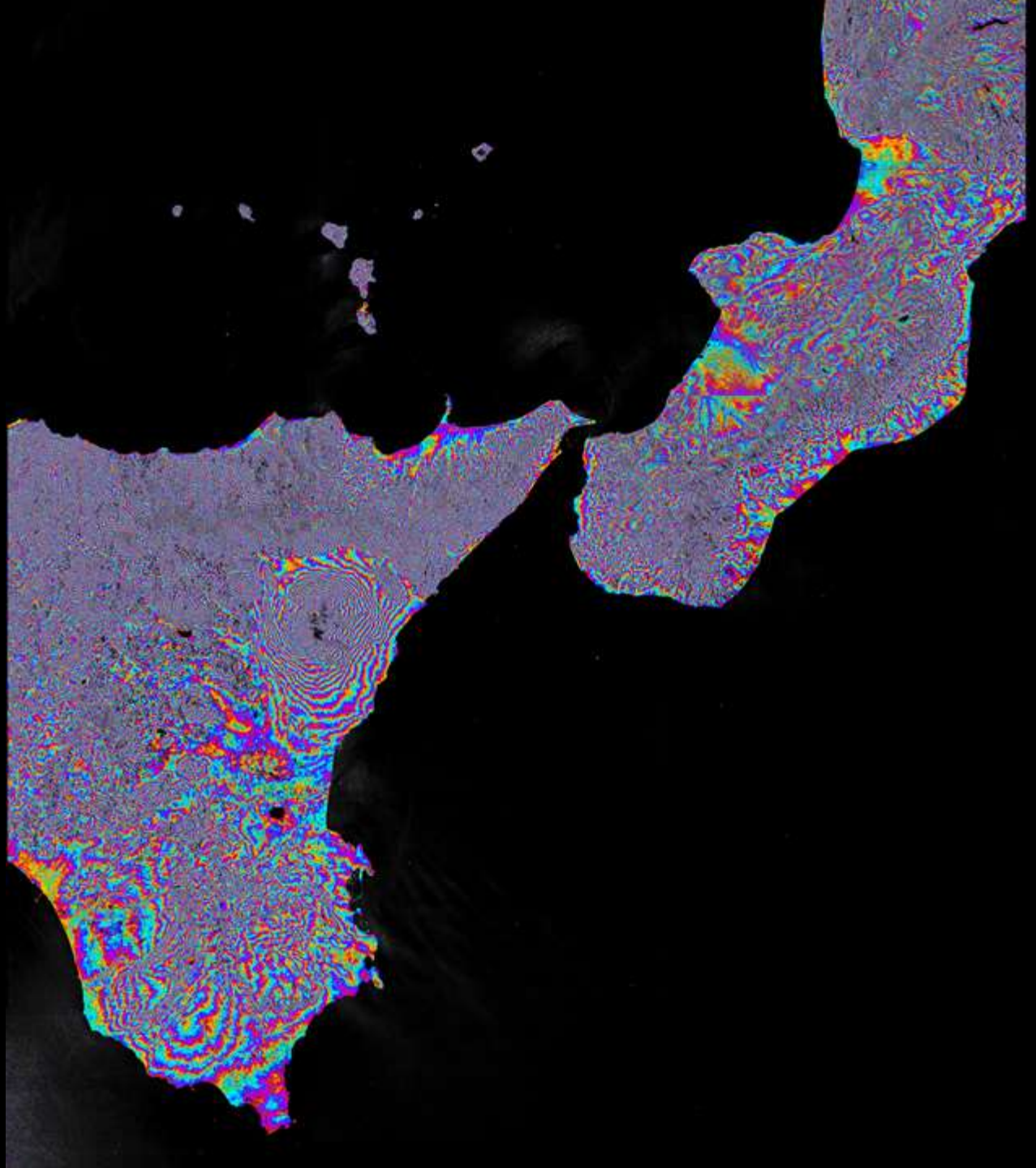
Sentinel-1 Interferogram Norway



Italy
1200 Km

Large scale Interferogram

Courtesy DLR



Datatake (7 slices): IW mode

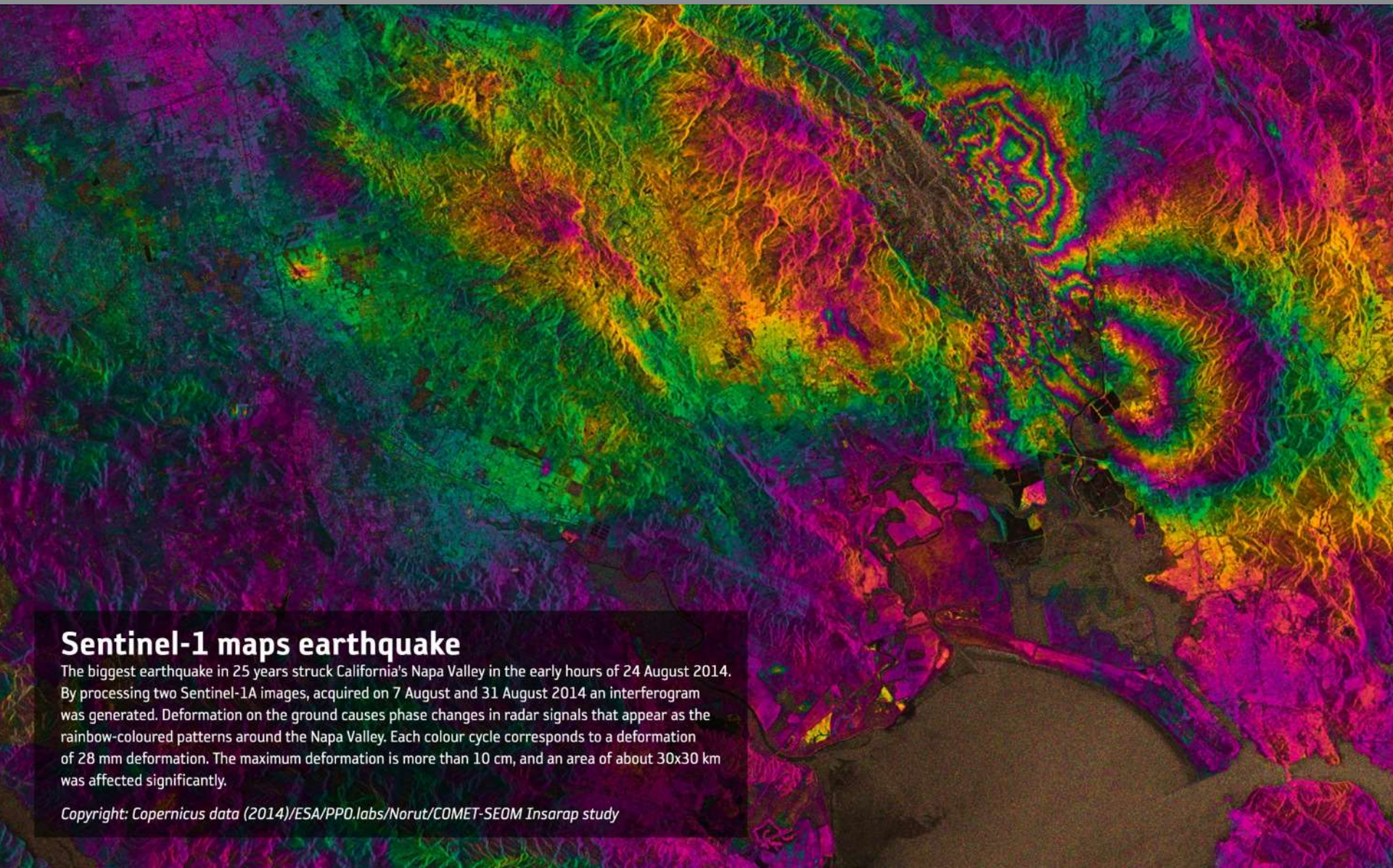
Vertical Polarization

Dates:

9.08.2014

21.08.2014

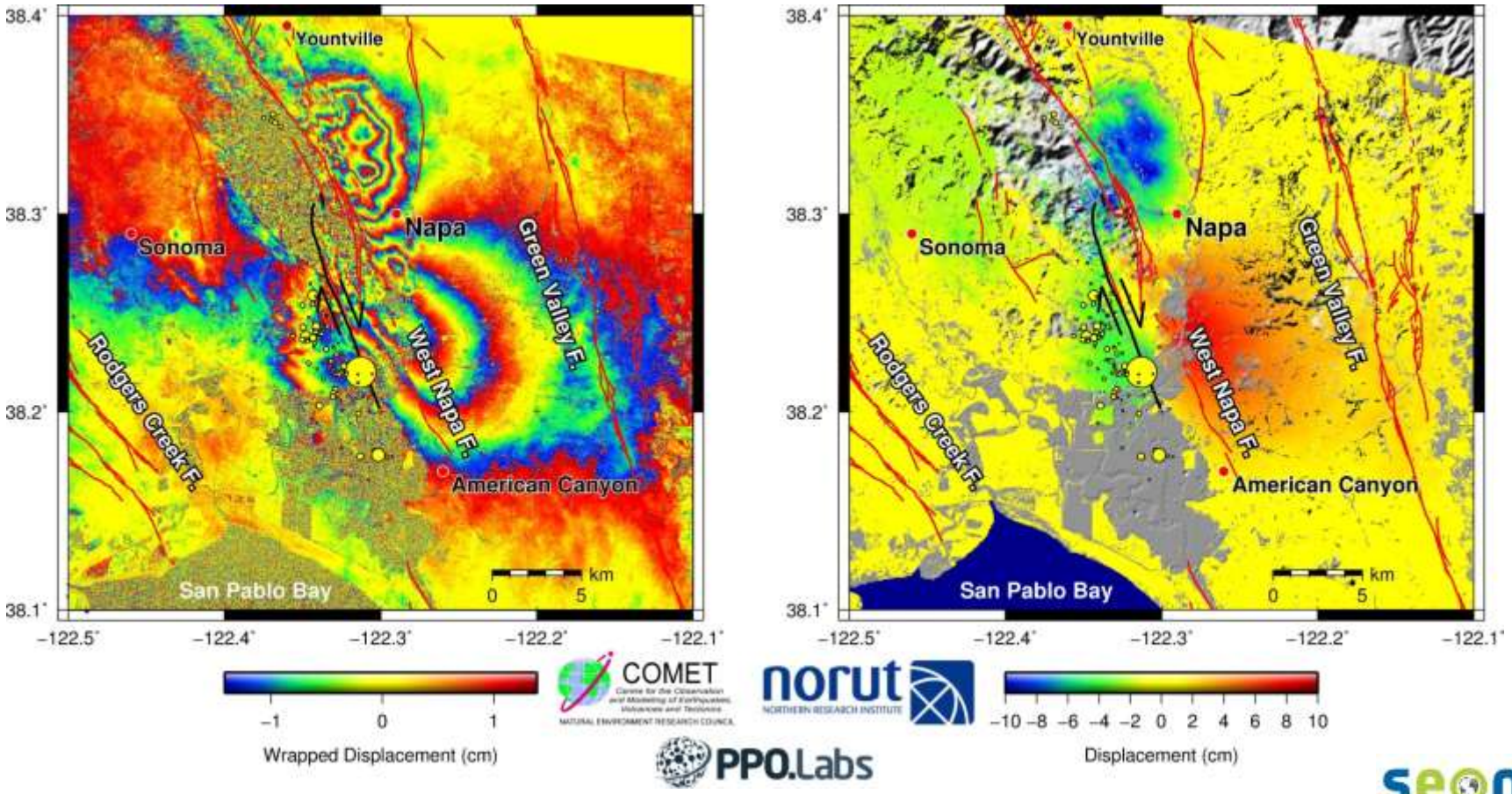
First Capture of an Earthquake by Sentinel-1 Napa Valley (California) M6.0R



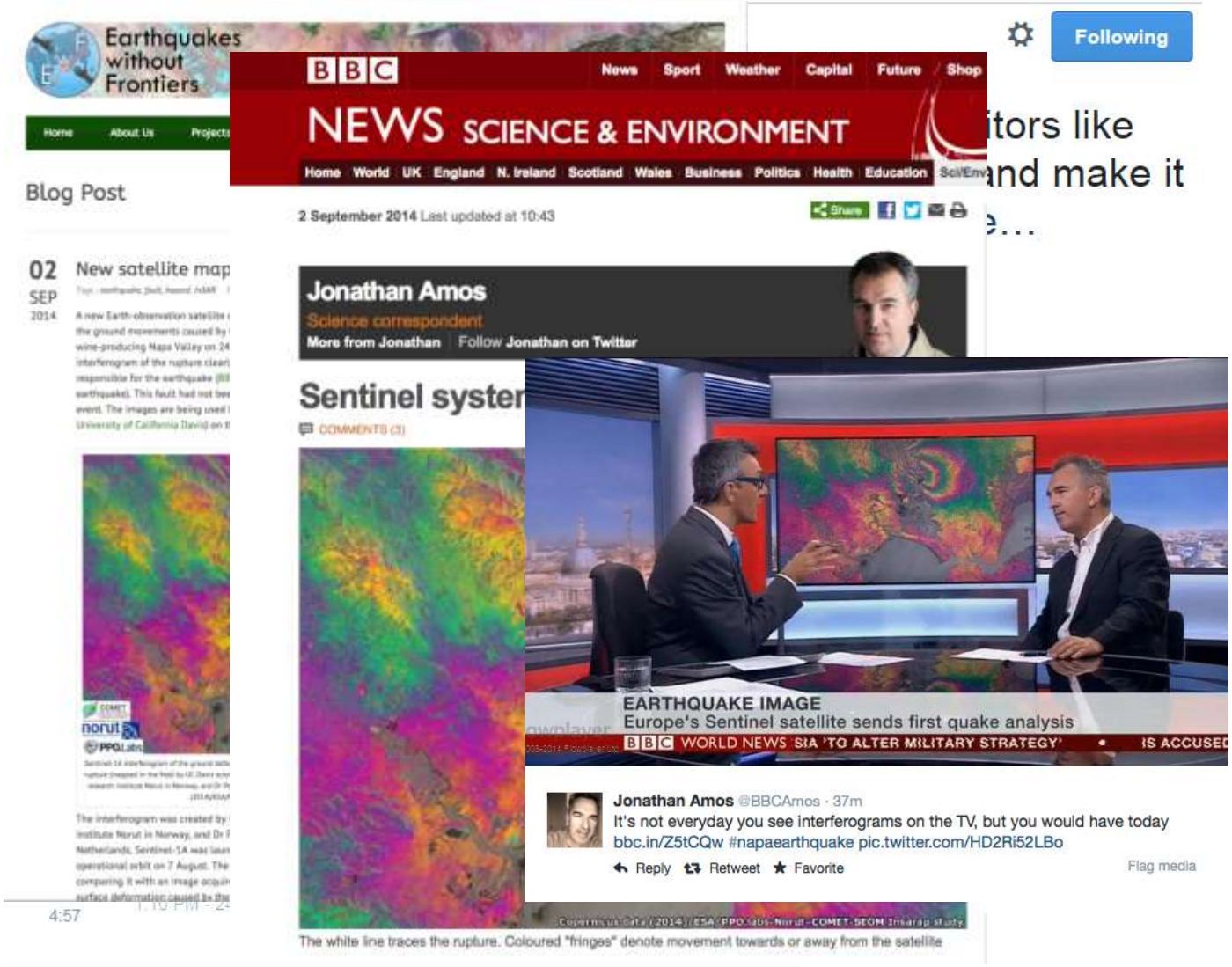
Sentinel-1 maps earthquake

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

Napa Valley Earthquake - Scientific Component



Napa Valley Earthquake
Promoting Science Data Use and Results



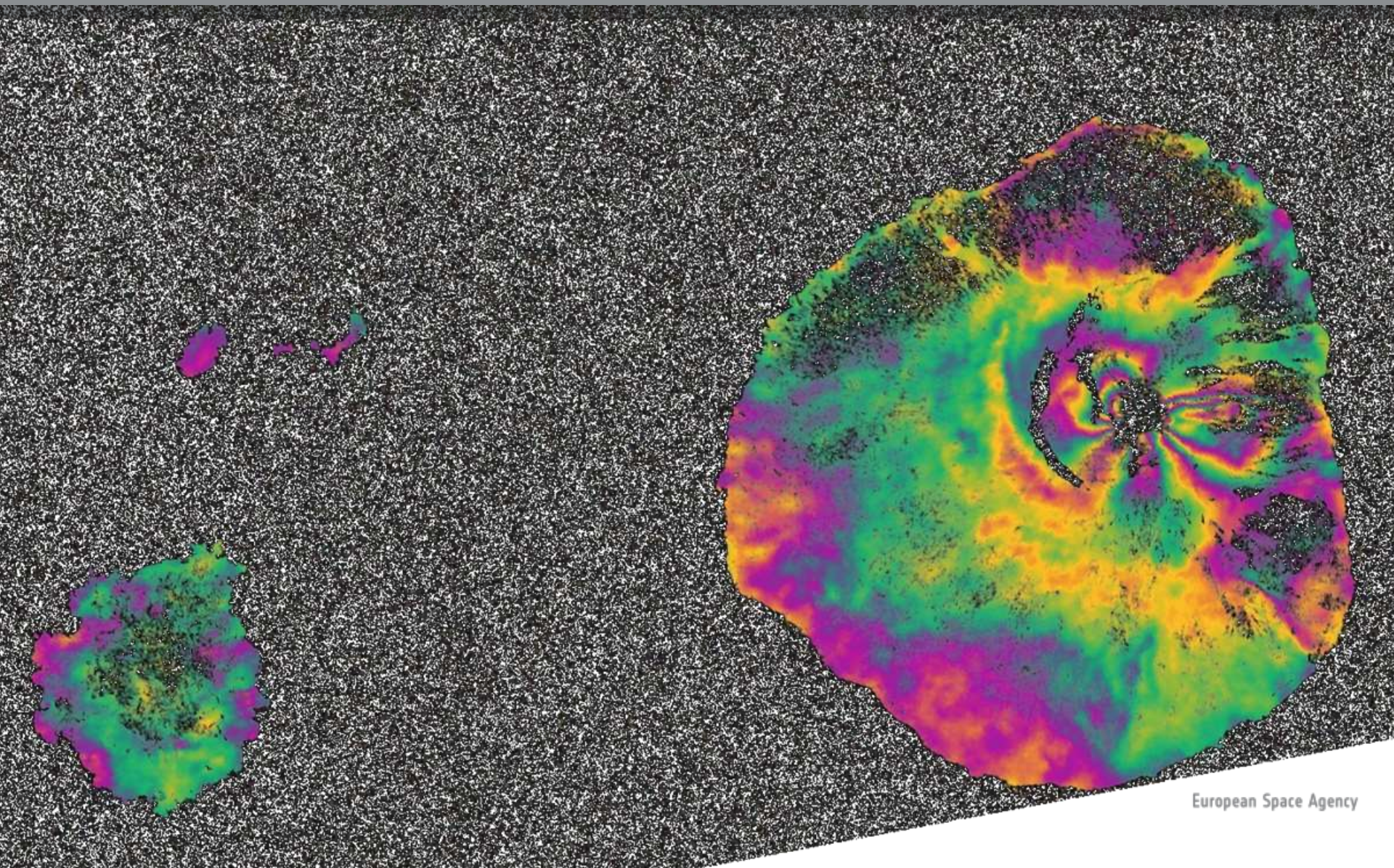
COMET
Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics
NATURAL ENVIRONMENT RESEARCH COUNCIL

norut
NORTHERN RESEARCH INSTITUTE

PPO.Labs

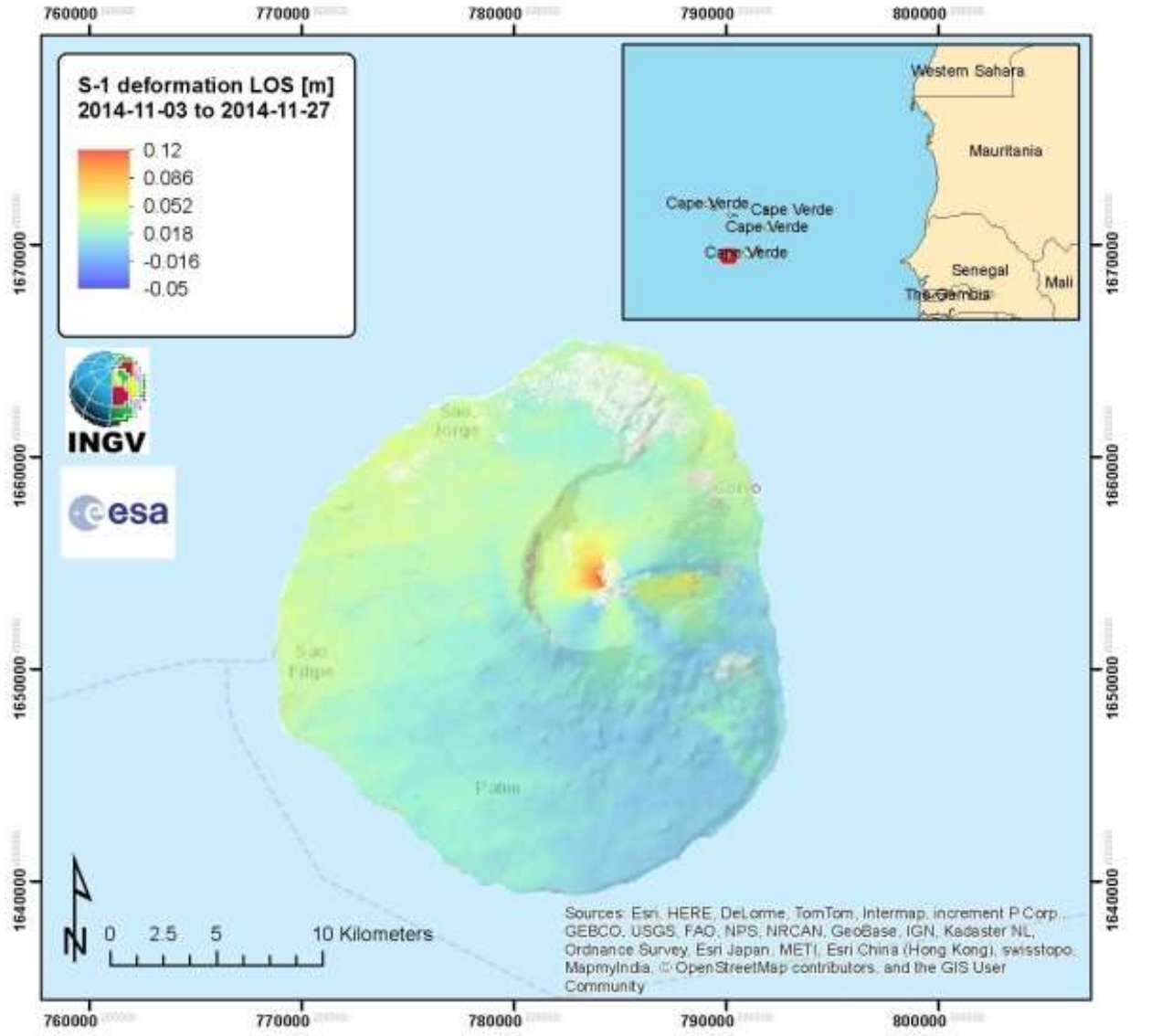
seom
scientific exploitation of operational missions
European Space Agency

Sentinel-1 Maps Fogo Eruption, Cape Verde



European Space Agency

Sentinel-1 Maps Fogo Eruption
Preliminary results

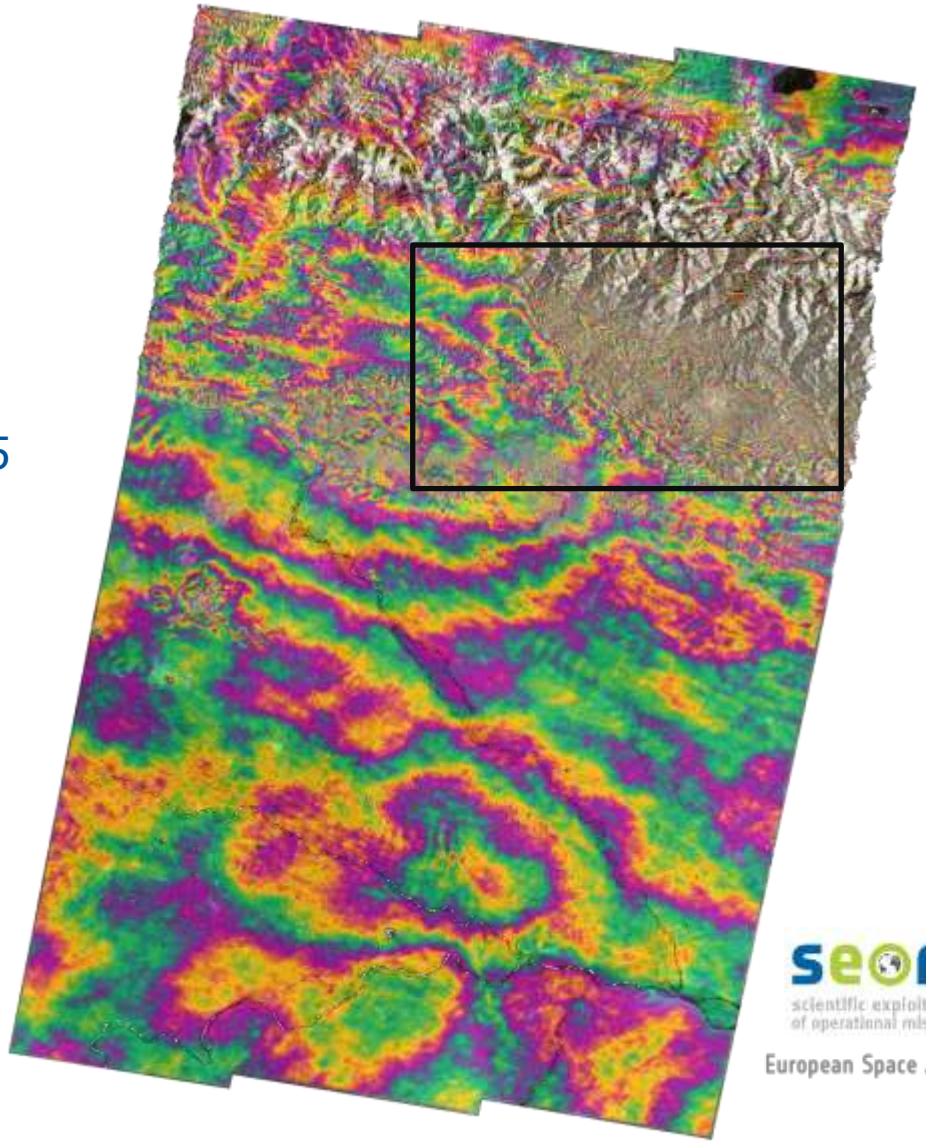


Nepal Earthquake (25 April 2015)

Differential interferogram from Sentinel-1A showing the ground deformation pattern of the 25 April 2015, M7.8R Nepal earthquake.

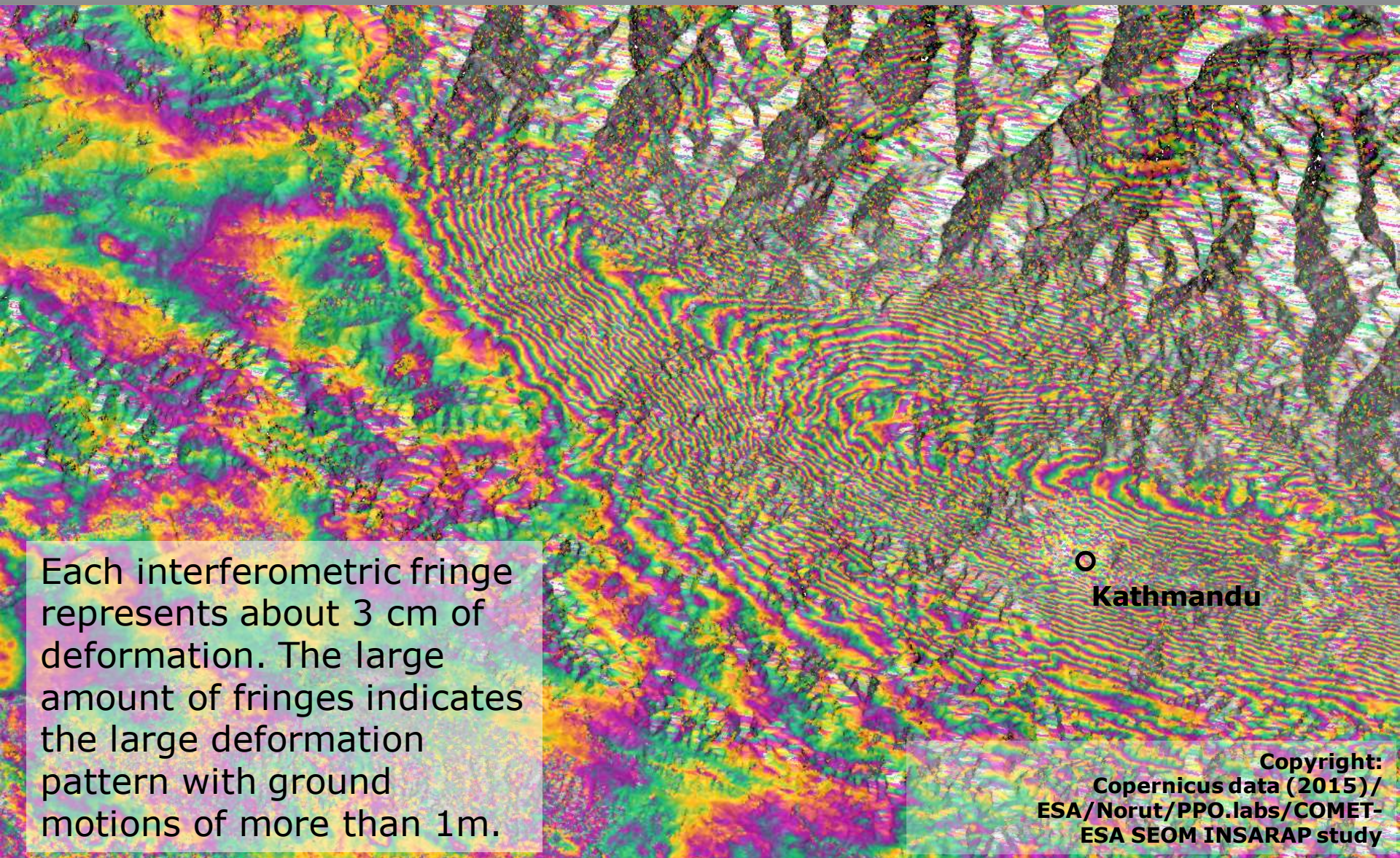
Generated based on Sentinel-1A acquisitions on 17 and 29 April 2015 – before and after the main seismic event.

An overall area of 120x100 km has moved, half of that uplifted and the other half, north of Kathmandu subsided.



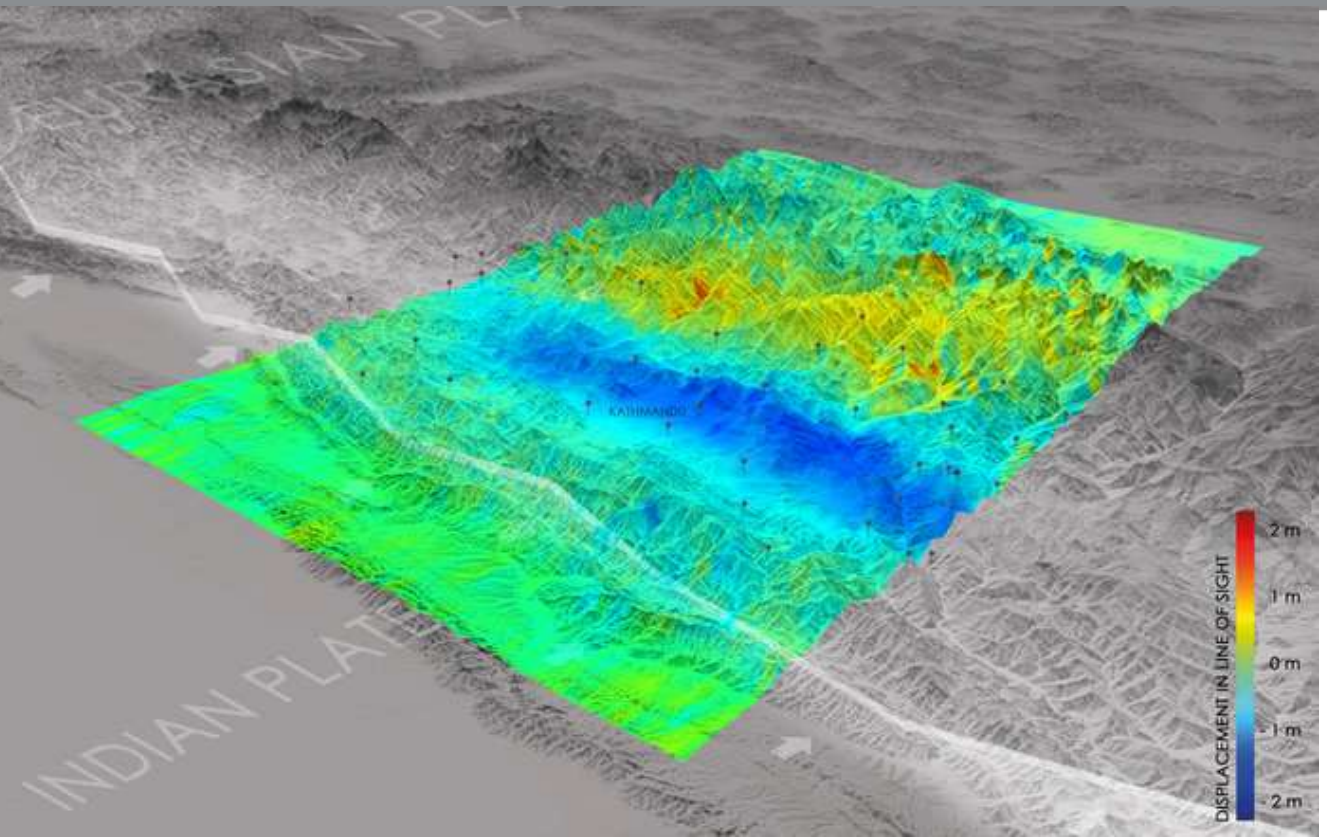
seom
scientific exploitation of operational missions
European Space Agency

Nepal Earthquake (25 April 2015)



Each interferometric fringe represents about 3 cm of deformation. The large amount of fringes indicates the large deformation pattern with ground motions of more than 1m.

Nepal Earthquake - 25 April 2015

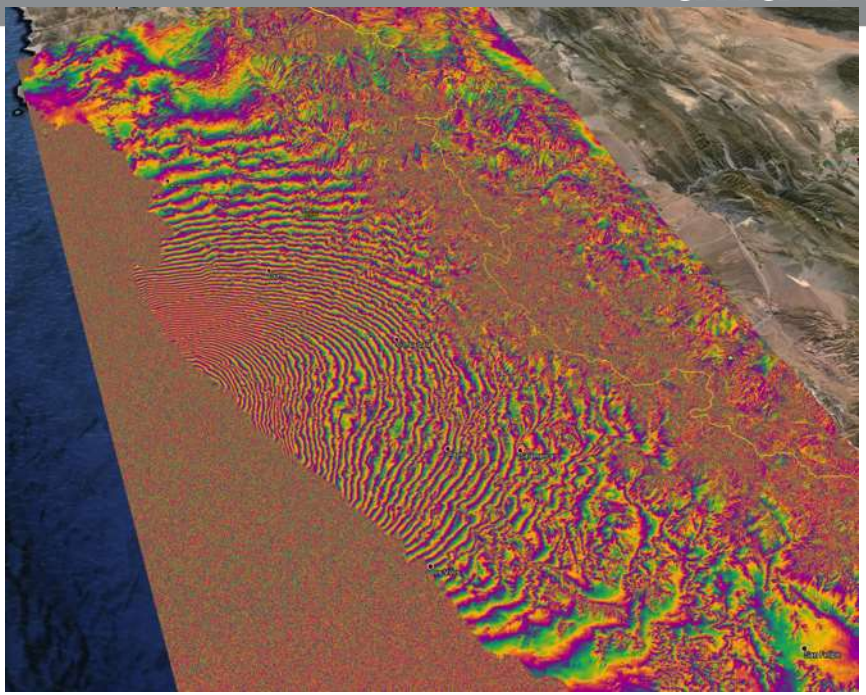


Based on Sentinel-1A acquisitions on 17 and 29 April 2015 (ie before and after the 25 April earthquake)

Courtesy DLR / EOC

- Near the boundary of the Indian and Eurasian tectonic plates
- Blue shows areas of uplift of up to 0.8 m towards the satellite (called 'line of sight') which could be caused by a vertical uplift of 1 m
- Yellow area depicts areas of subsidence,
- A horizontal north–south shift of up to 2 m was detected

Applications examples resulting from regular acquisitions of global tectonic and volcanic areas



Chile Earthquake, September 2015

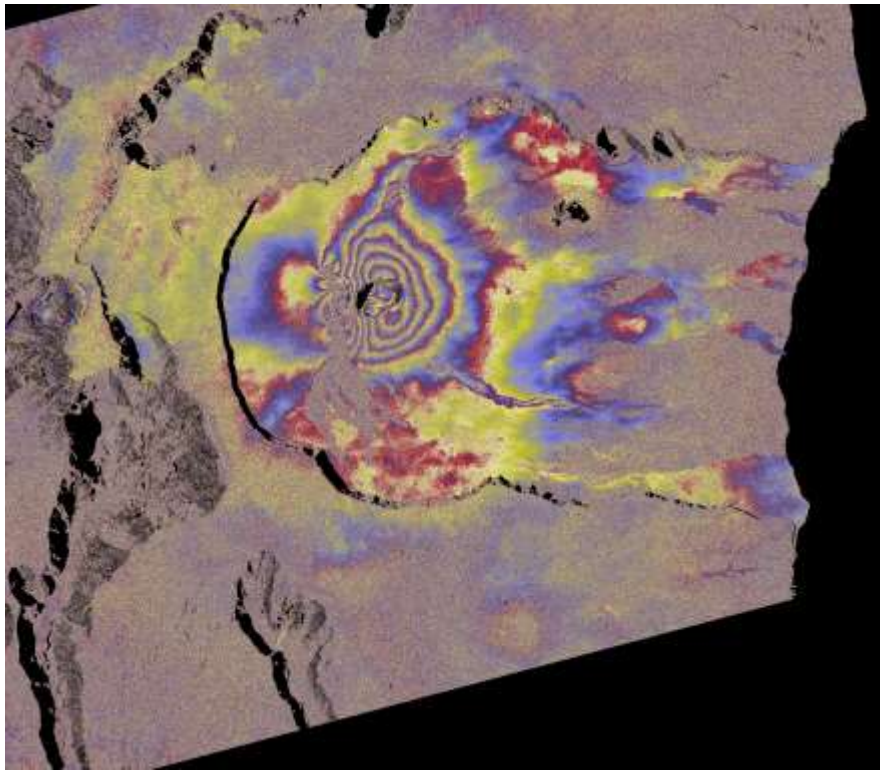
- 8.3 M earthquake, central Chile, 16 Sep 2015
- Interferogram with Sentinel-1 IW acquisitions on 24 Aug and 17 Sep 2015
- Estimated displacement of 1.4 m along the viewing direction of the radar observation
- Estimated 0.5 m horizontal movement along the flight direction of the satellite

SEOM INSARAP study PPO.labs/NORUT

Eruption of Le Piton de la Fournaise, August 2015

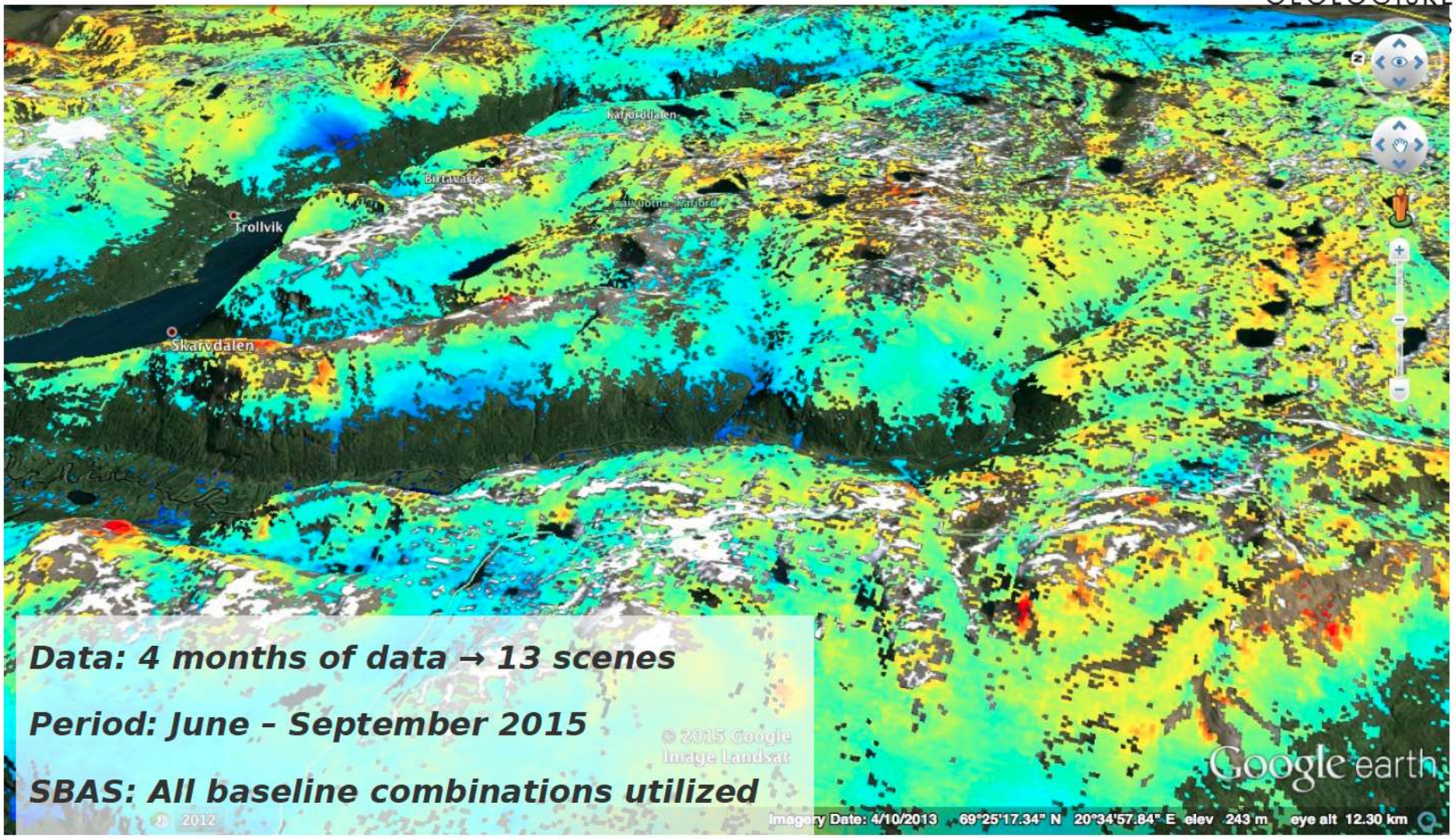
- Interferogram with Sentinel-1 SM acquisitions on 23 August and 28 September 2015
- Volcano deformation

Courtesy of JL. Froger, OPGC

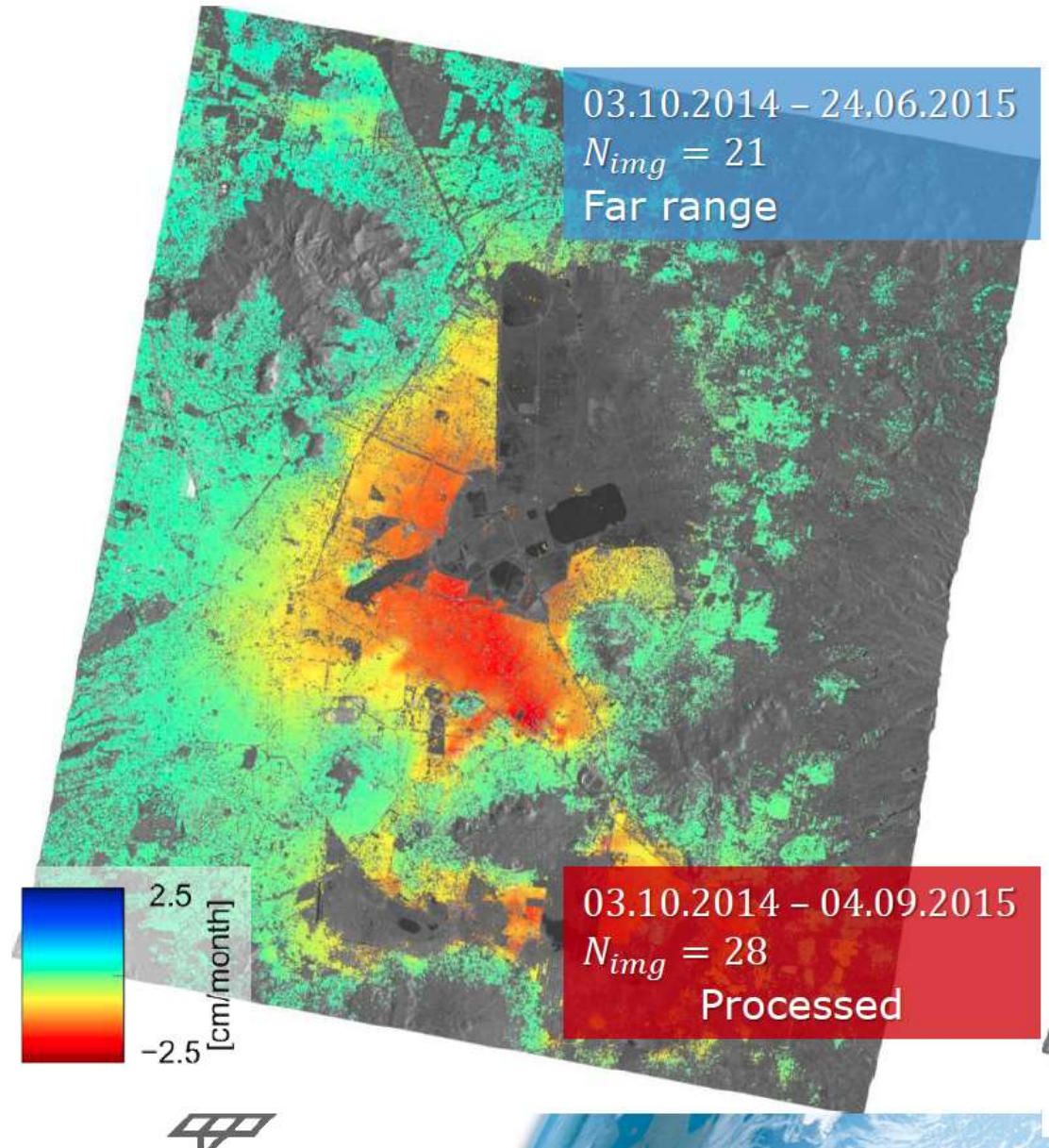


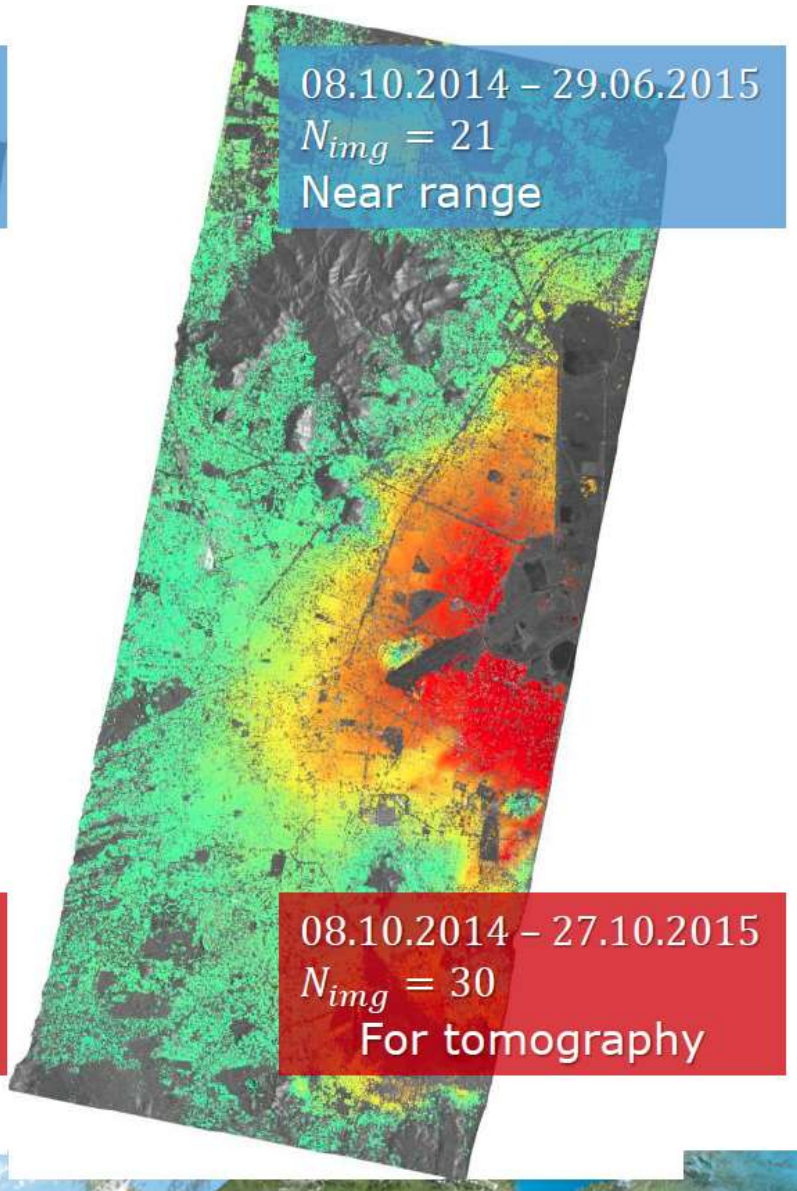
S-1 Time Series Results

NORGES GEOLOGISKE



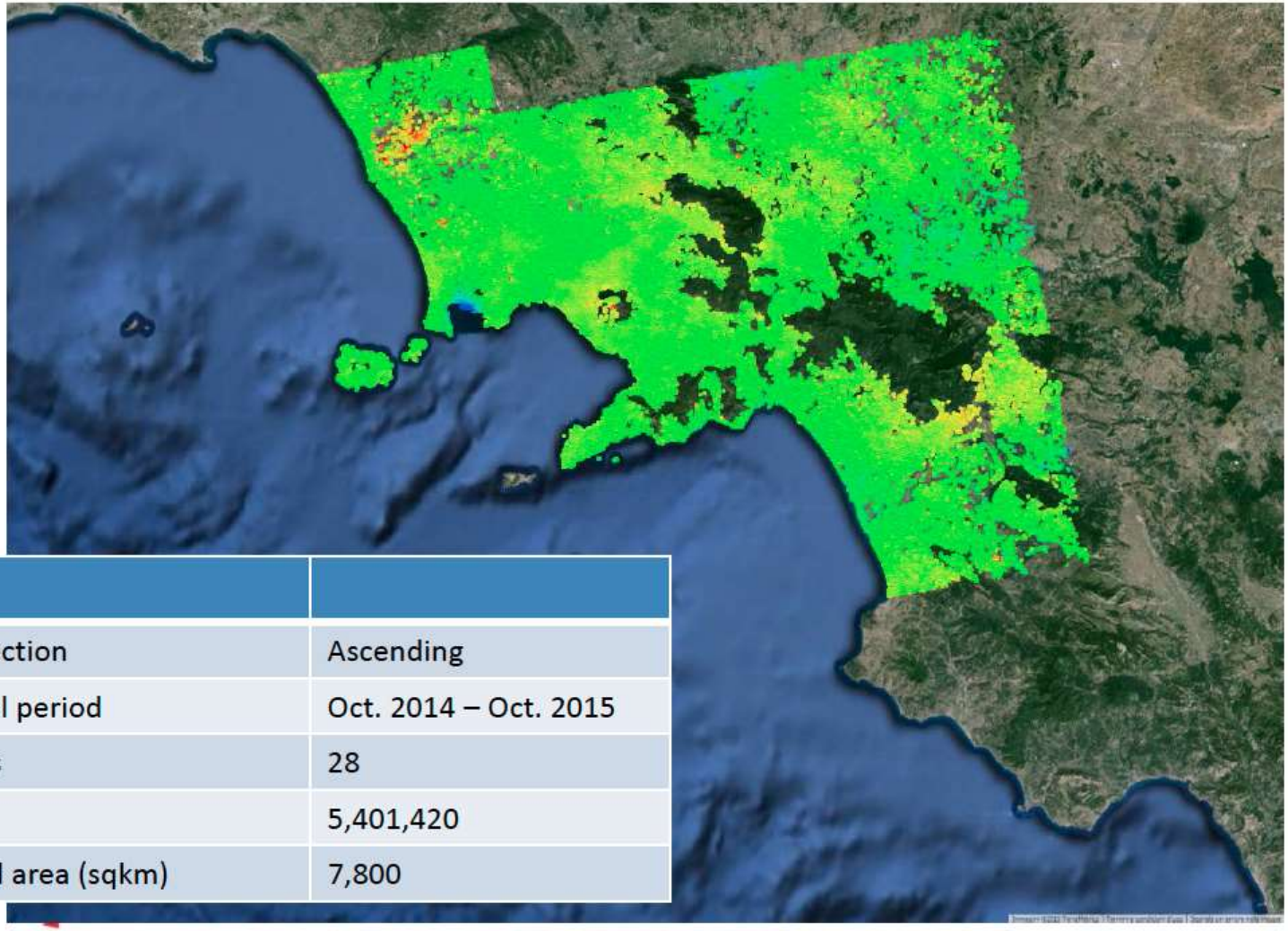
Mexico City: Descending (Dawn)





DLR

Campi Flegrei: PS mean velocity



Pass direction	Ascending
Temporal period	Oct. 2014 – Oct. 2015
# images	28
# PS	5,401,420
Analyzed area (sqkm)	7,800

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Thank you for your attention !

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