THE EUROPEAN SPACE AGENCY

EO Missions and their Exploitation for Land Science & Applications

Yves-Louis DESNOS, Peter REGNER, Steven Delwart, Marcus ENGDAHL
Jerome BENVENISTE, Michael FOUMELIS, Simon PINNOCK et al

European Space Agency ESRIN/ESTEC/HARWELL

ESA FACTS AND FIGURES

- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2200 staff
- 4.4 billion Euro budget (2015)
- Over 80 satellites designed, tested and operated in flight
- Over 20 scientific satellites in operation
- Six types of launcher developed

PURPOSE OF ESA

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

Article 2 of ESA Convention


2-4

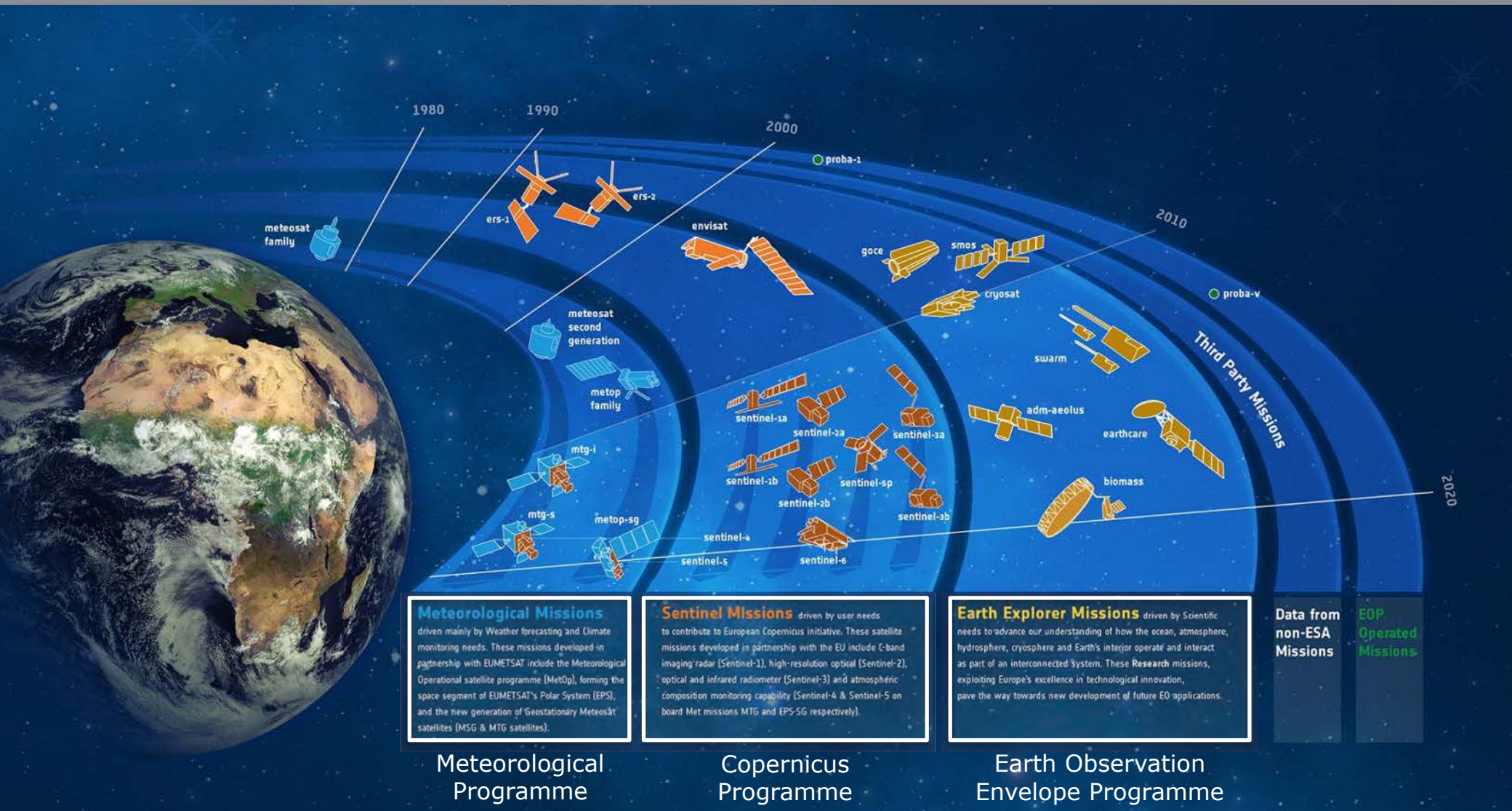
OVER 20 MEMBER STATES

ESA has 22 Member States: 18 states of the EU (AT, BE, CZ, DE, DK, ES, FI, FR, IT, GR, IE, LU, NL, PT, PL, RO, SE, UK) plus Norway and Switzerland. Estonia and Hungary are joining ESA in 2015.

Seven other EU states have Cooperation Agreements with ESA: Bulgaria, Cyprus, Latvia, Lithuania, Malta, Slovakia and Slovenia. Discussions are ongoing with Croatia.

Canada takes part in some programmes under a long-standing Cooperation Agreement.

ESA Earth Observation Programmes

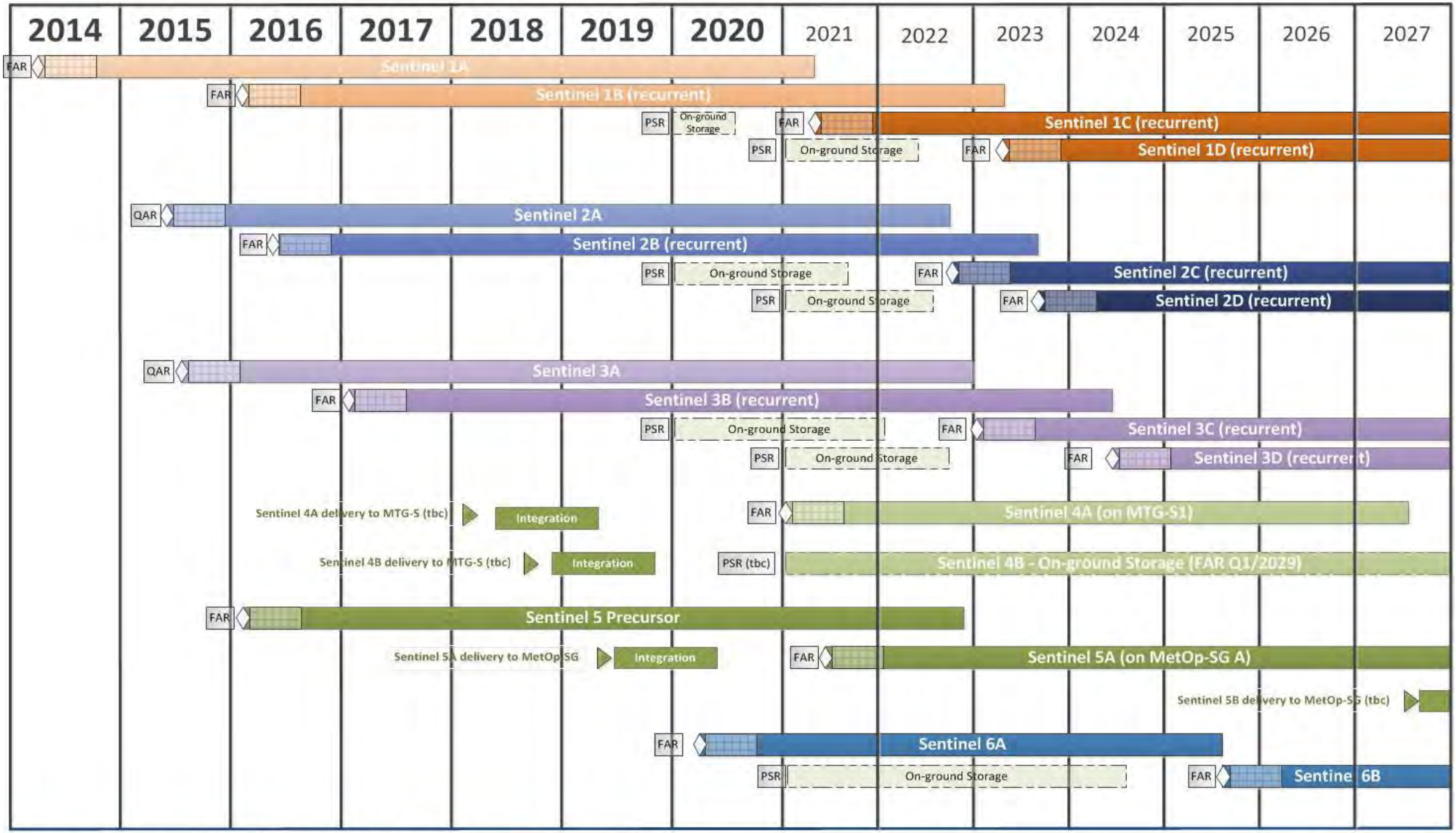


Copernicus: A New Generation of Data Sources

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
- ESA coordinates the space component
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security
- Free and open data policy

Tentative Sentinel Schedule



Launch Sentinel-1A

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

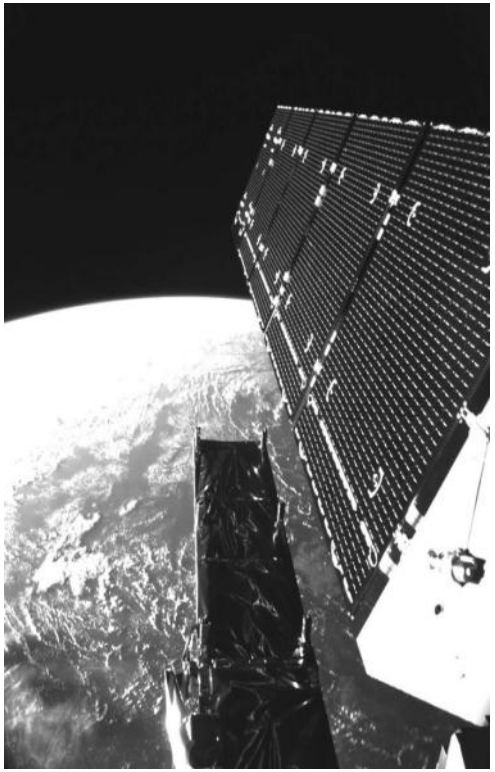
First Image Campaign

Credits: ESA

Sentinel-1 C-band SAR mission

Mission profile:

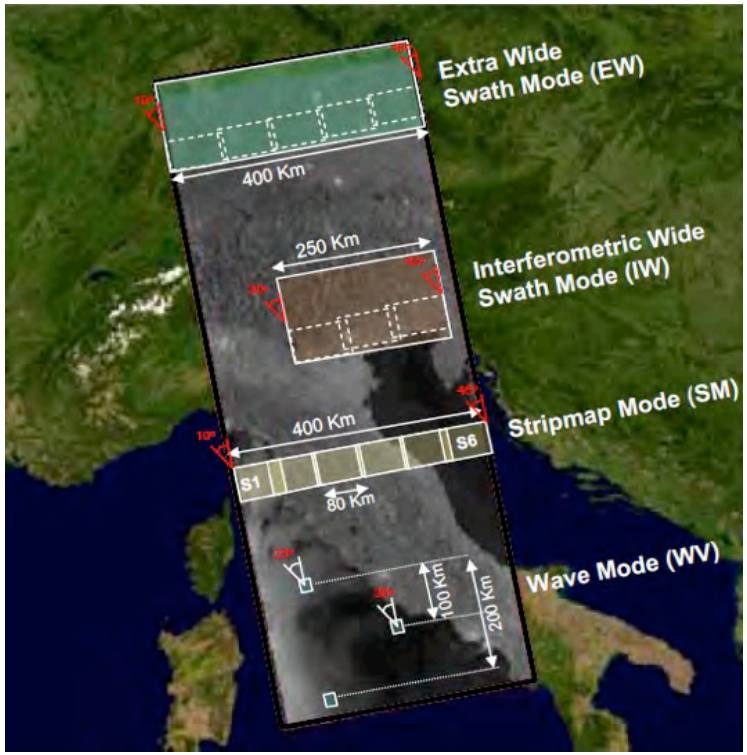
- **C-Band SAR** at 5.4 GHz, multi-polarisation
- Sun synchronous orbit at **693 km** mean altitude
- **250 km** swath width (Interferometric Wide-swath mode)
- **6 days** repeat cycle at Equator with 2 satellites
- **7 years** design life time, consumables for 12 years
- **4** nominal mutually exclusive operation modes



'Selfie' April 4th 2014

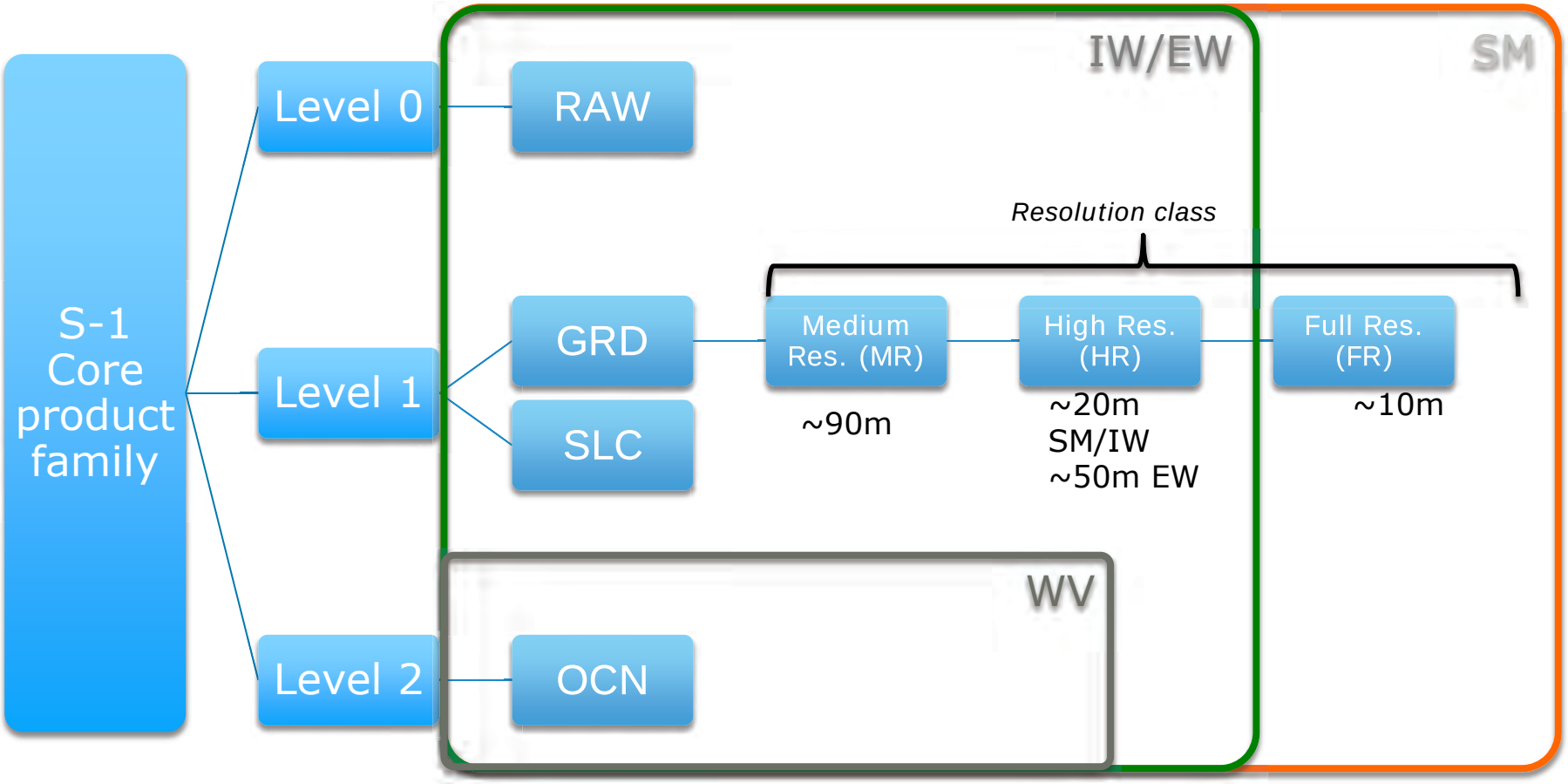
Sentinel-1 Operational Modes

Operational Modes



Resolution (1 look)	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

S-1 operational product family

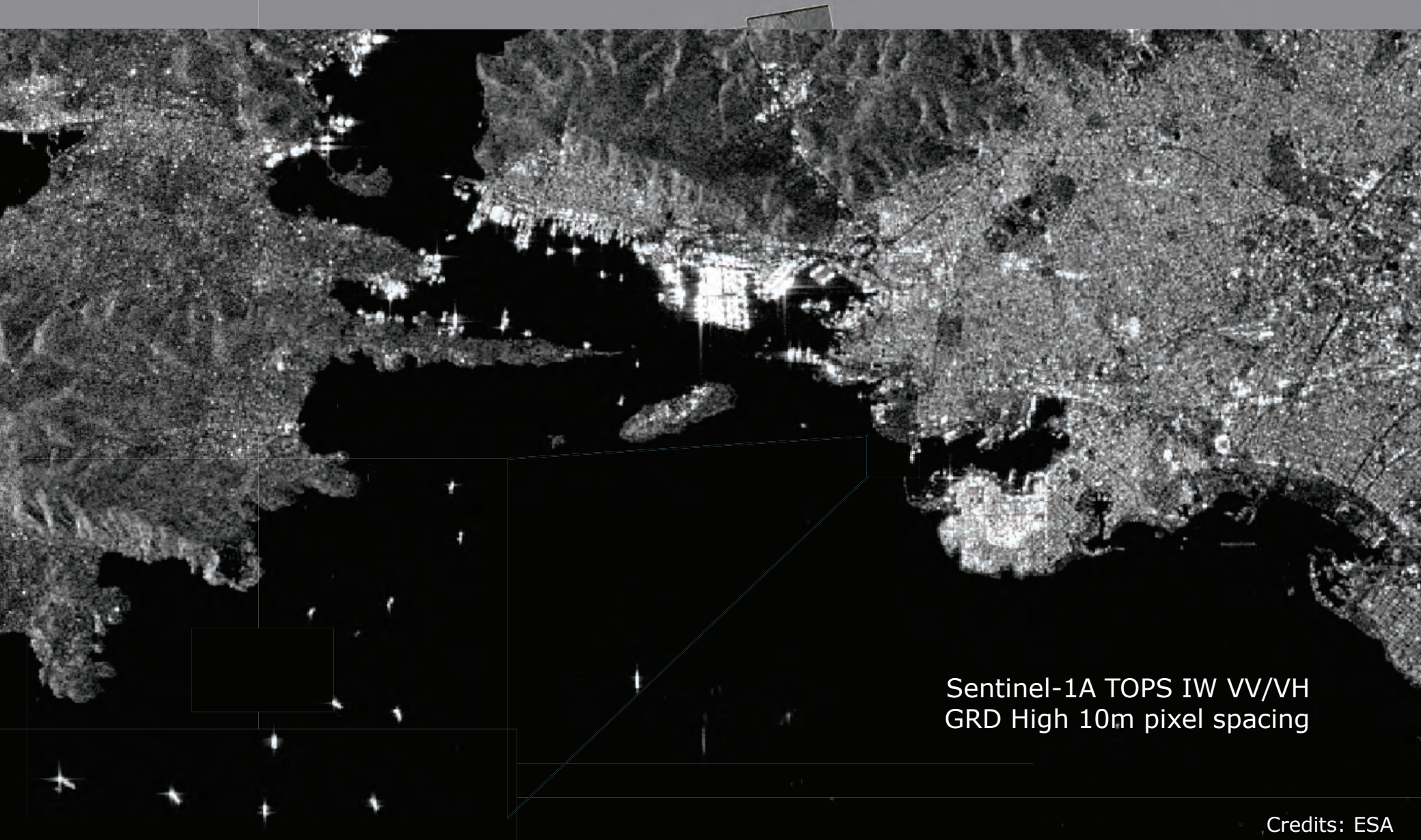


Marine / Oceans

Maritime Surveillance
(Oil Spill Detection, Ship Detection, Illegal Fisheries, etc.)

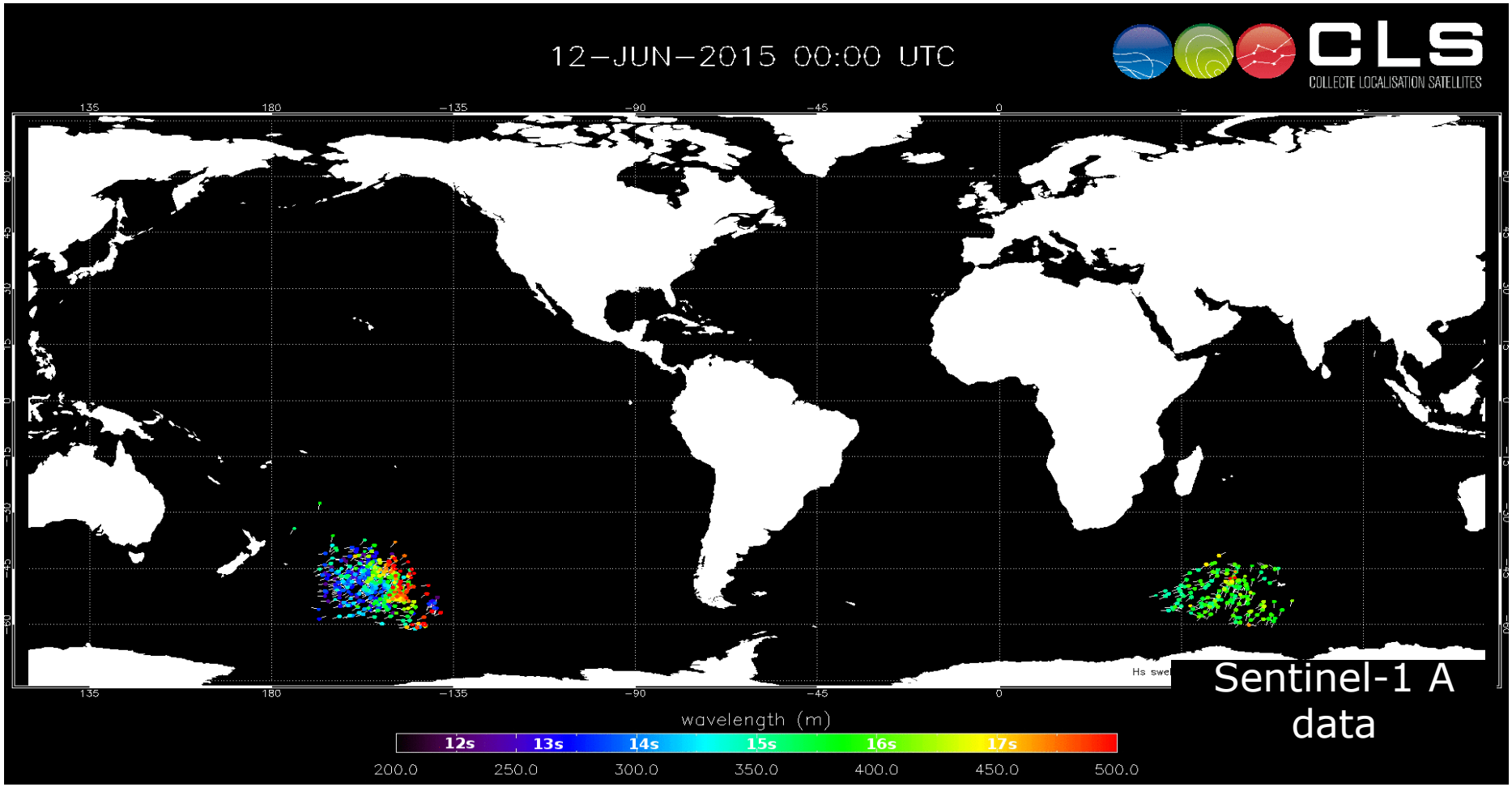
Sentinel-1 TOPS Polarimetric Composite

Sentinel-1A TOPS over Greece



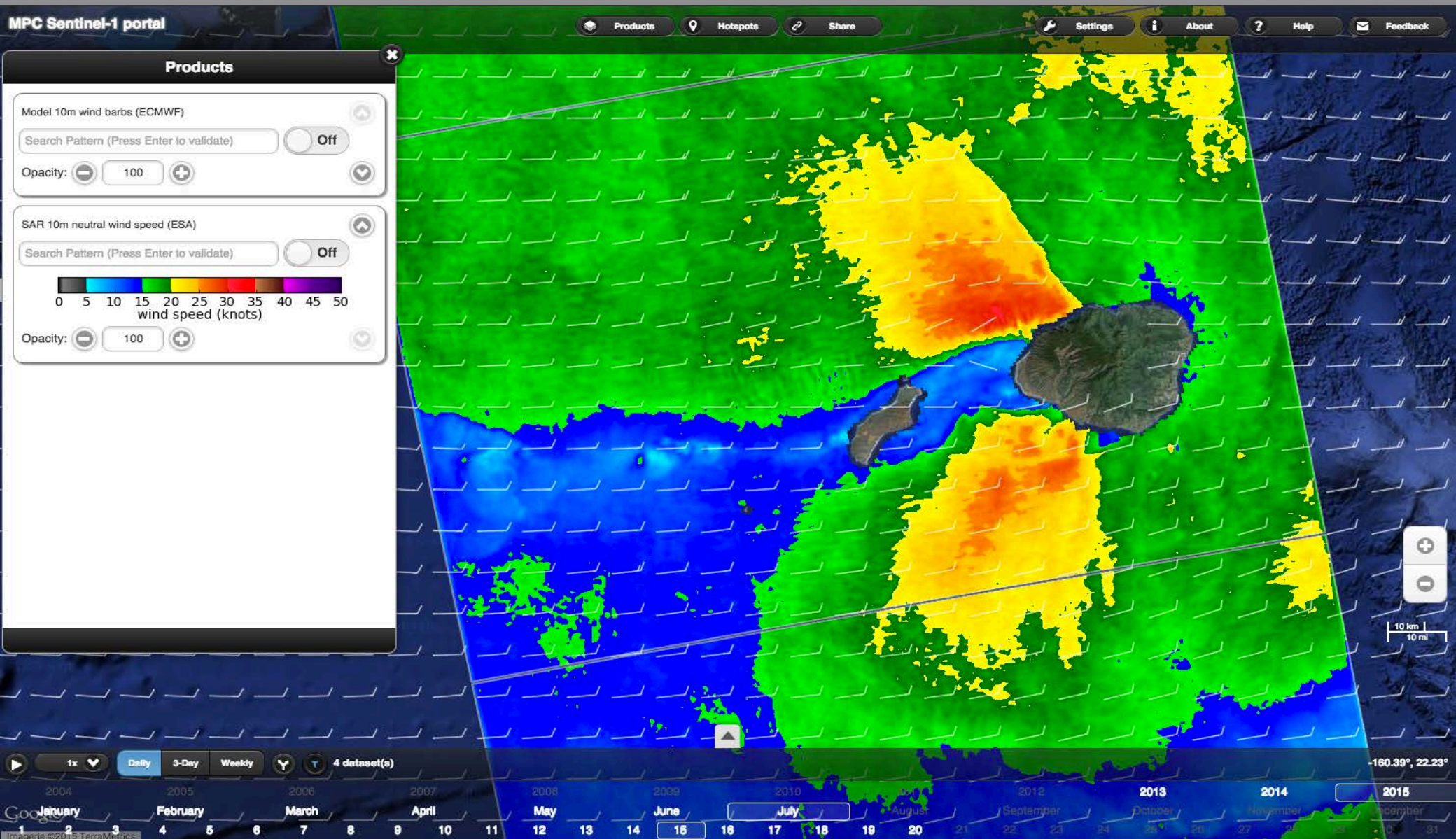
Credits: ESA

Sentinel-1 A for Sentinel-1 B Cal/Val

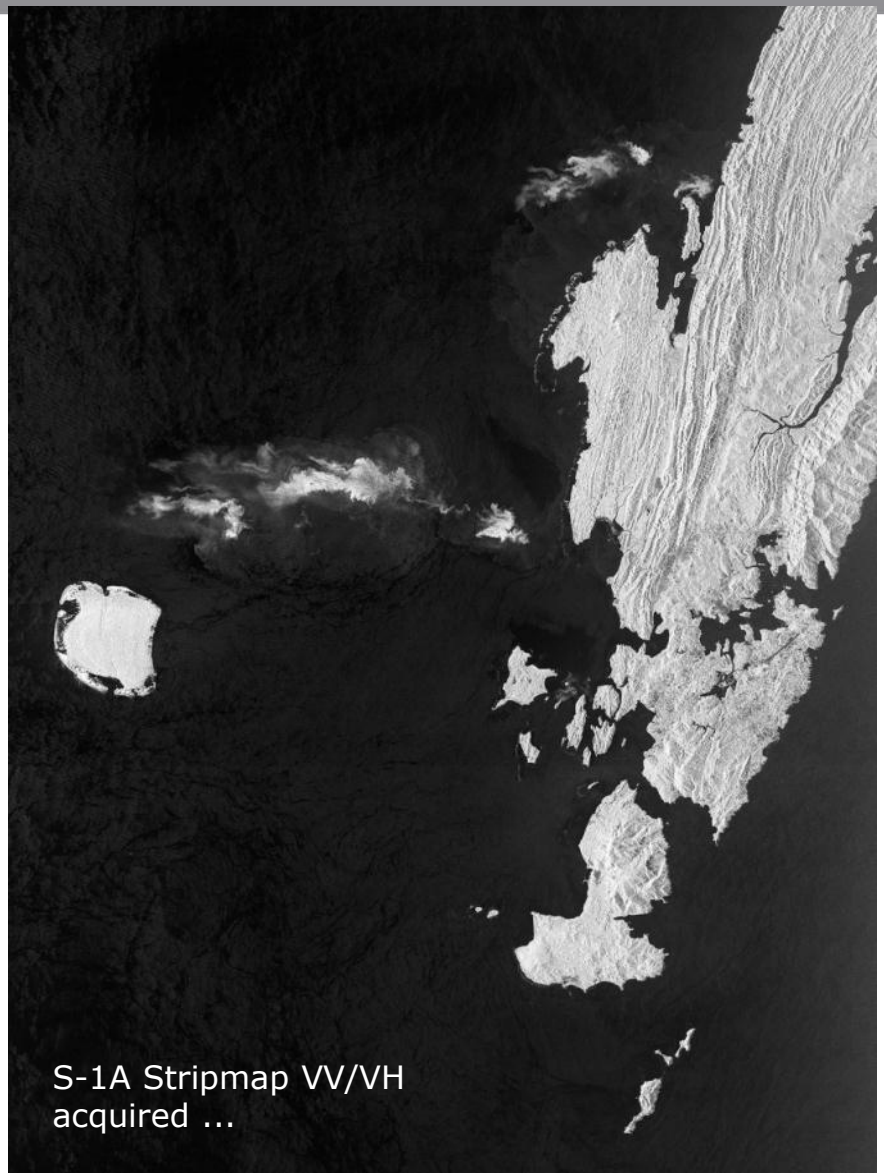


Sentinel-1 A data propagated in time and space from the source storm to the coast

Sentinel1 wind speed ventury effect around hawaiian islands

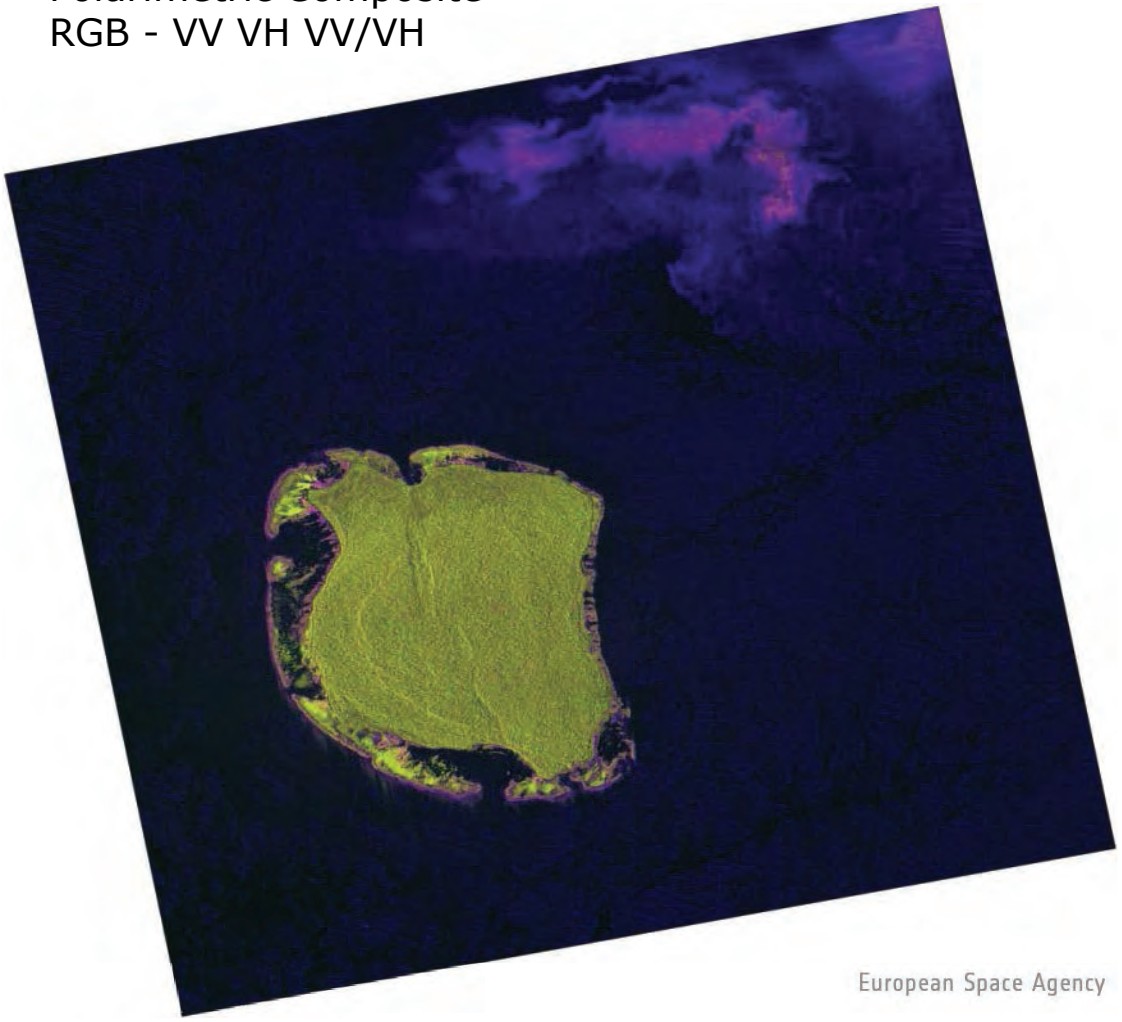


Sentinel-1A Island



S-1A Stripmap VV/VH
acquired ...

Polarimetric Composite
RGB - VV VH VV/VH



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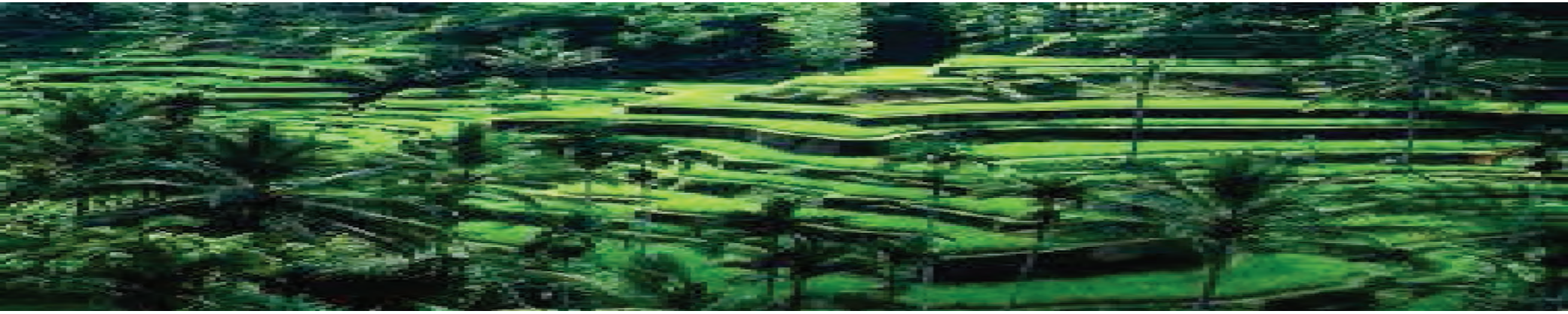
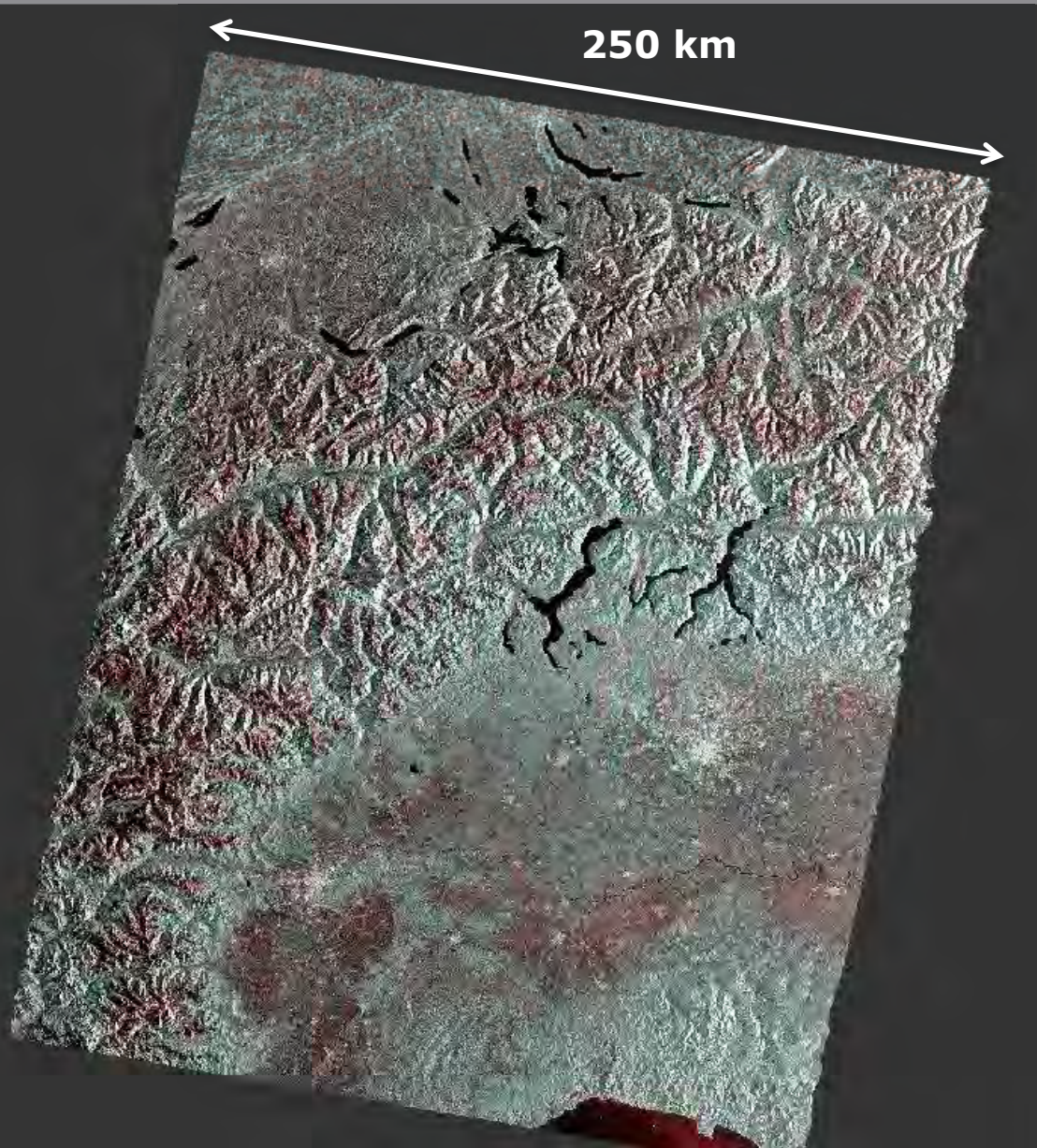
Land cover



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

Northern Italy



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

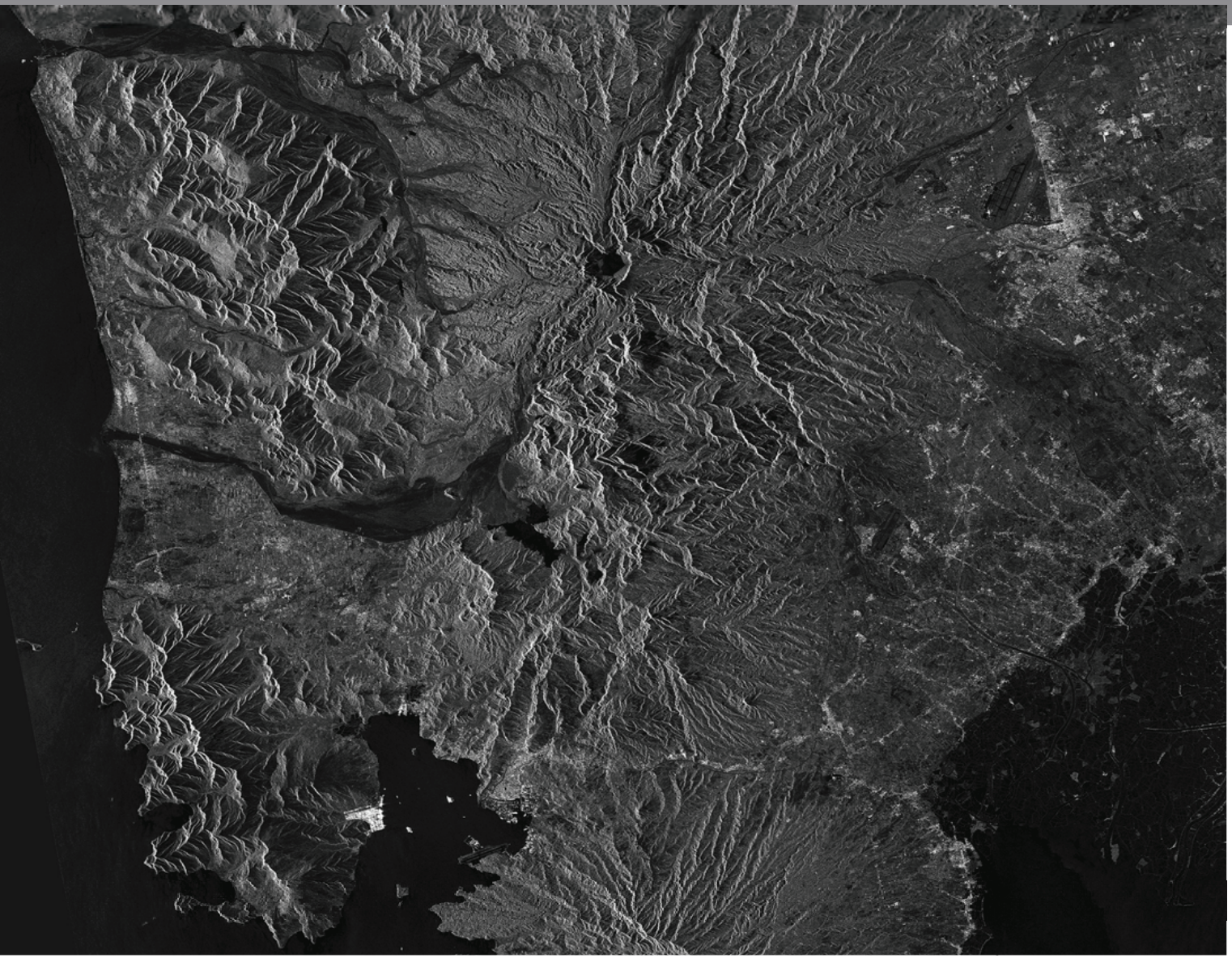
S1A Country Mosaics

Data from SciHub - processed with S1TBX

S1A Mosaic of Romania

European Space Agency

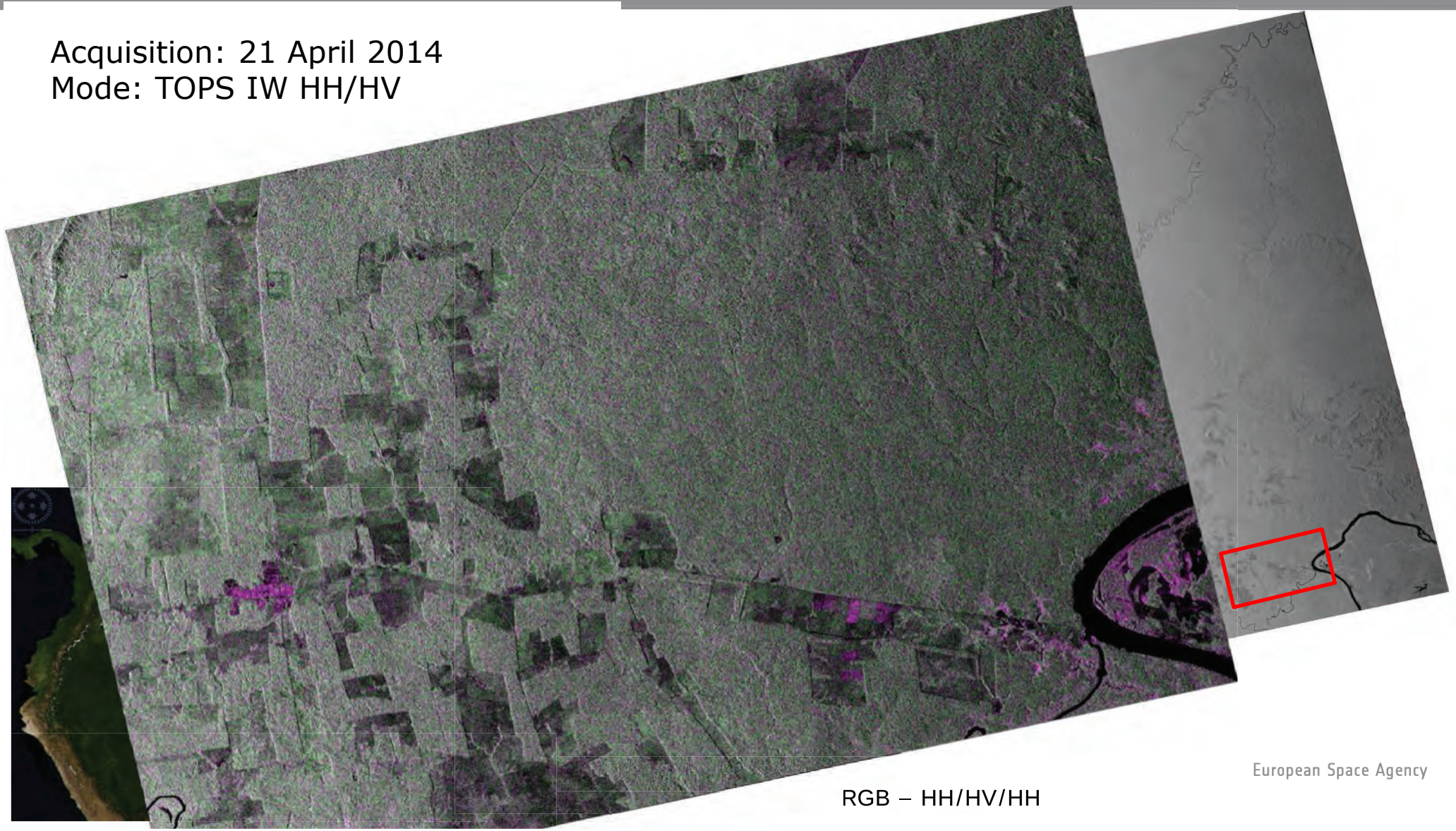
Philippine island of Luzon with Mount Pinatubo



European Space Agency

Sentinel-1A Deforestation over Brazil

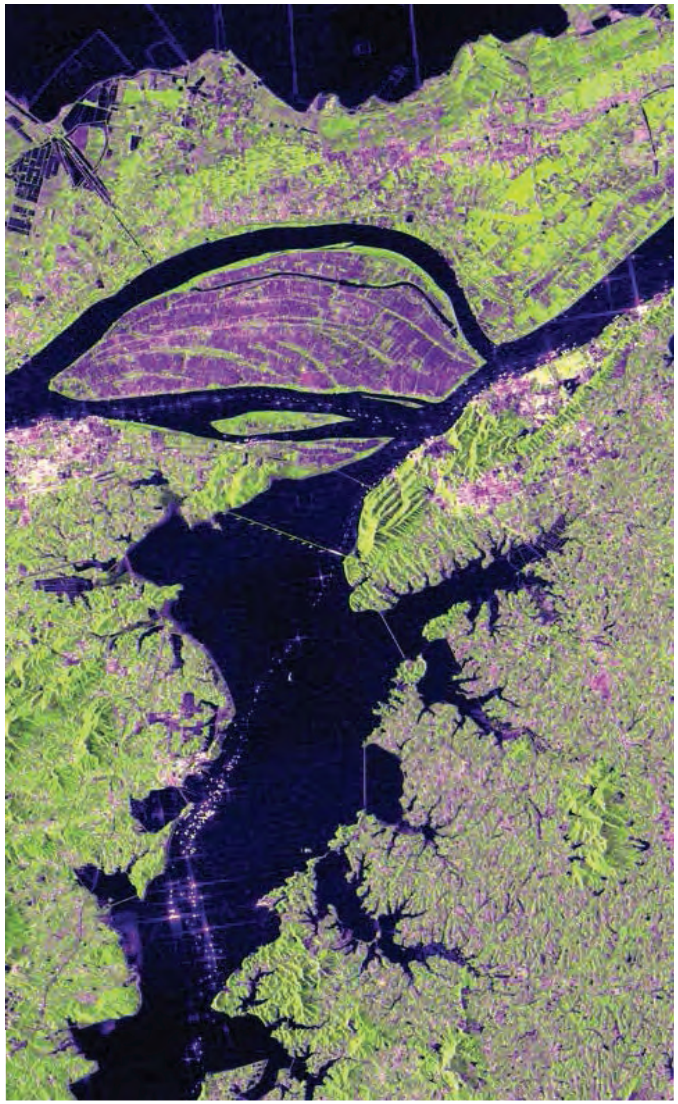
Acquisition: 21 April 2014
Mode: TOPS IW HH/HV

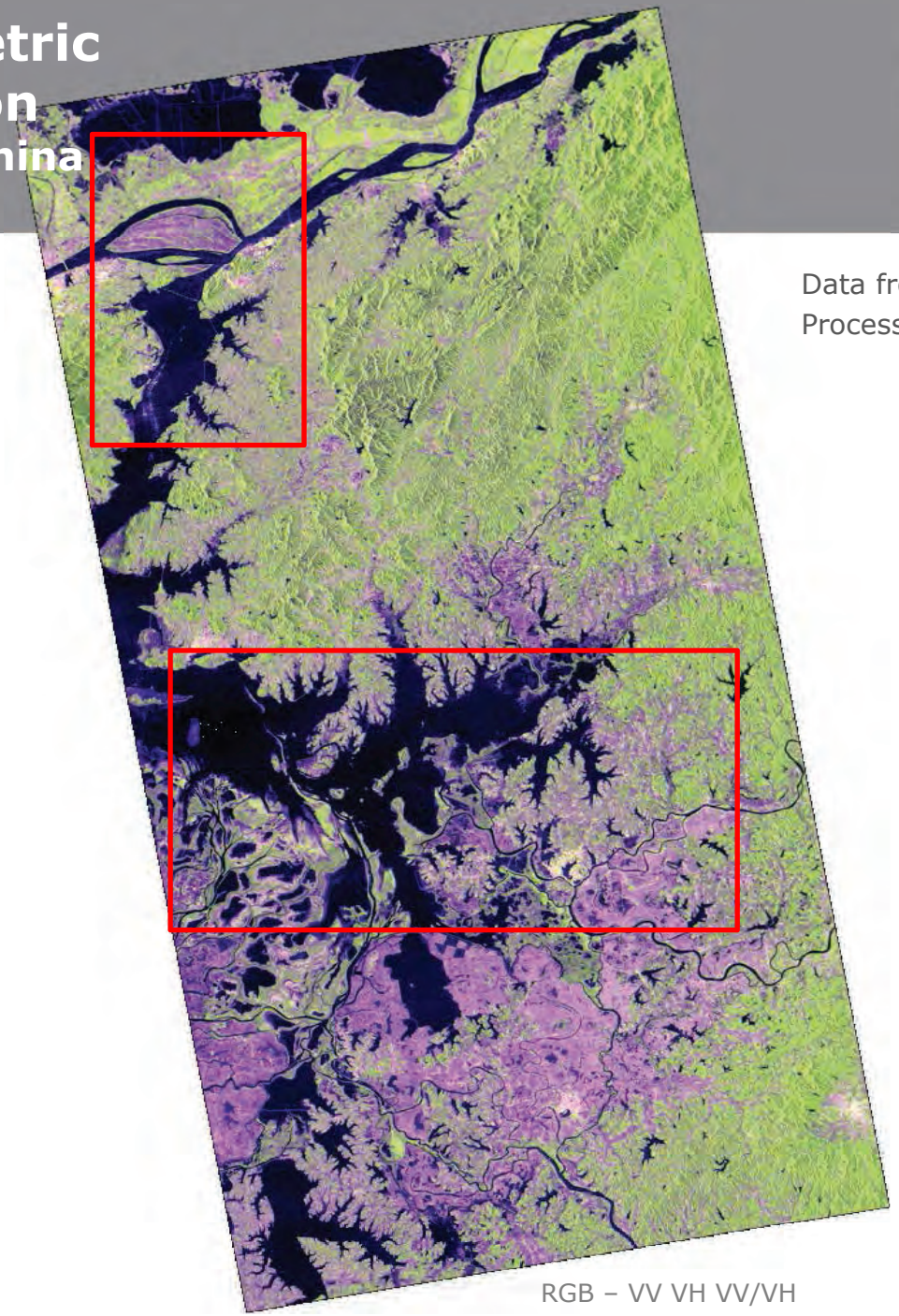


RGB – HH/HV/HH

S1A Polarimetric Composition

Poyang Lake, China





Data from SciHub
Processed with S1TBX

RGB – VV VH VV/VH

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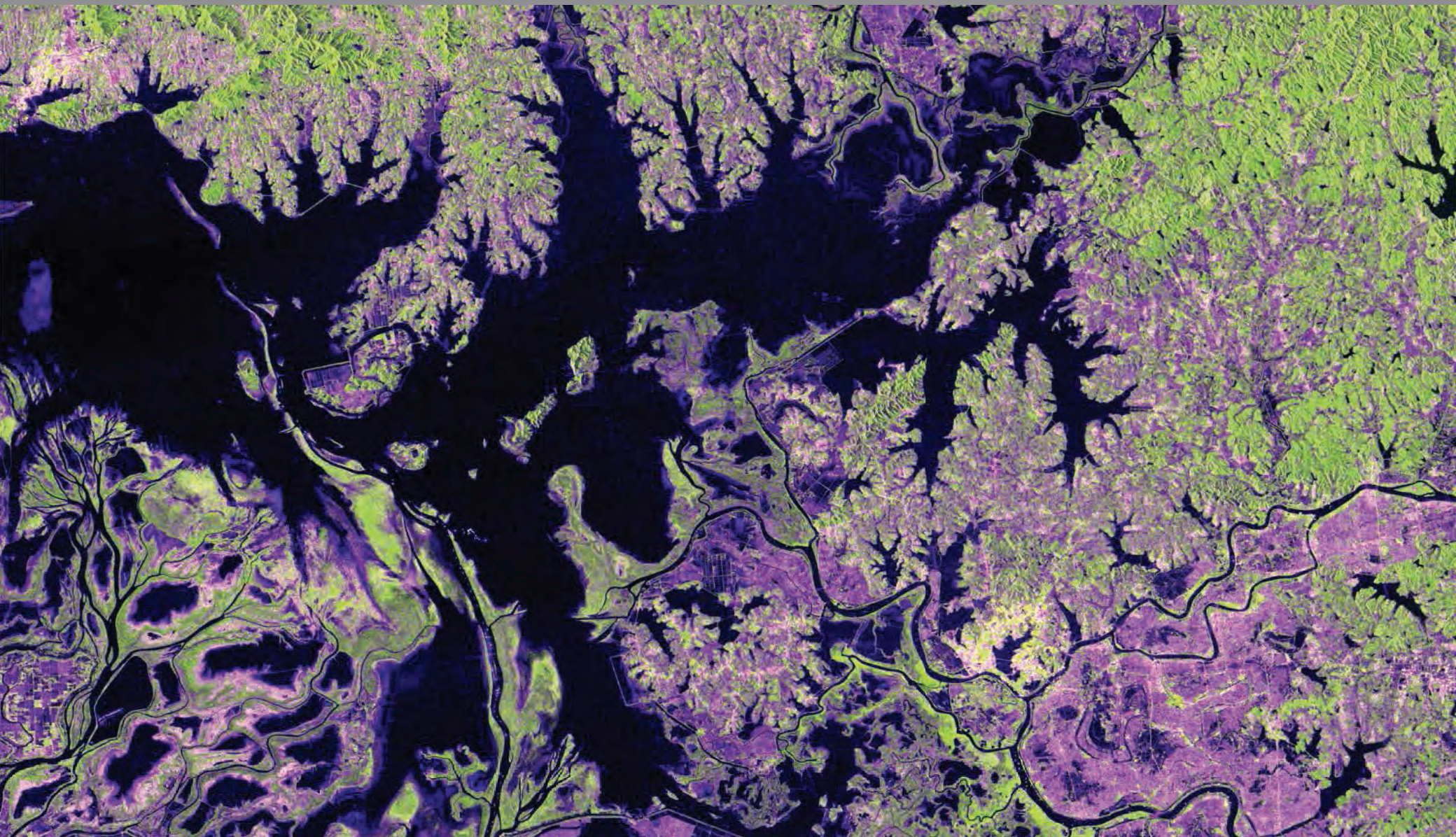
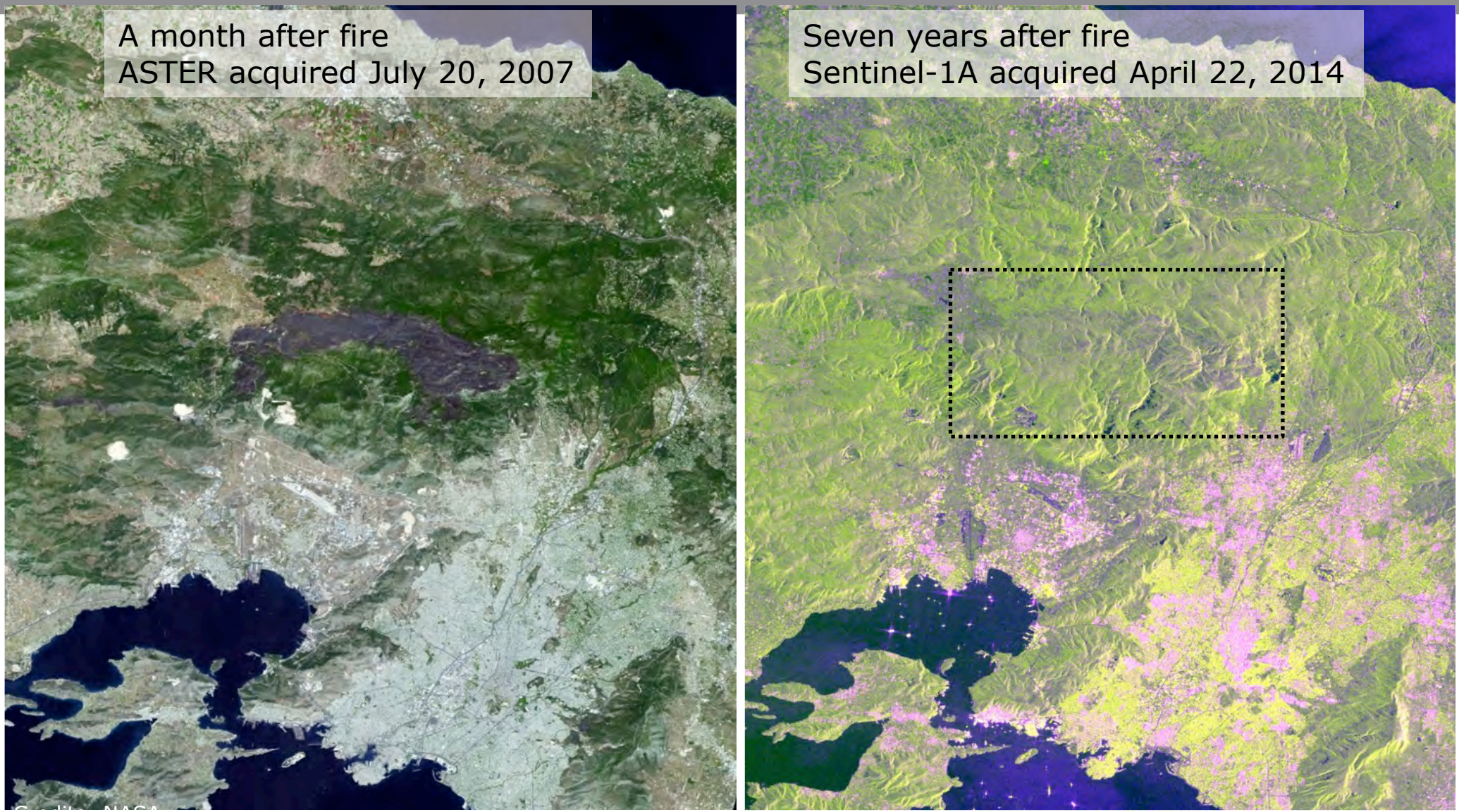
scientific exploitation of operational missions

European Space Agency

S1A Polarimetric Composition – Poyang Lake, China

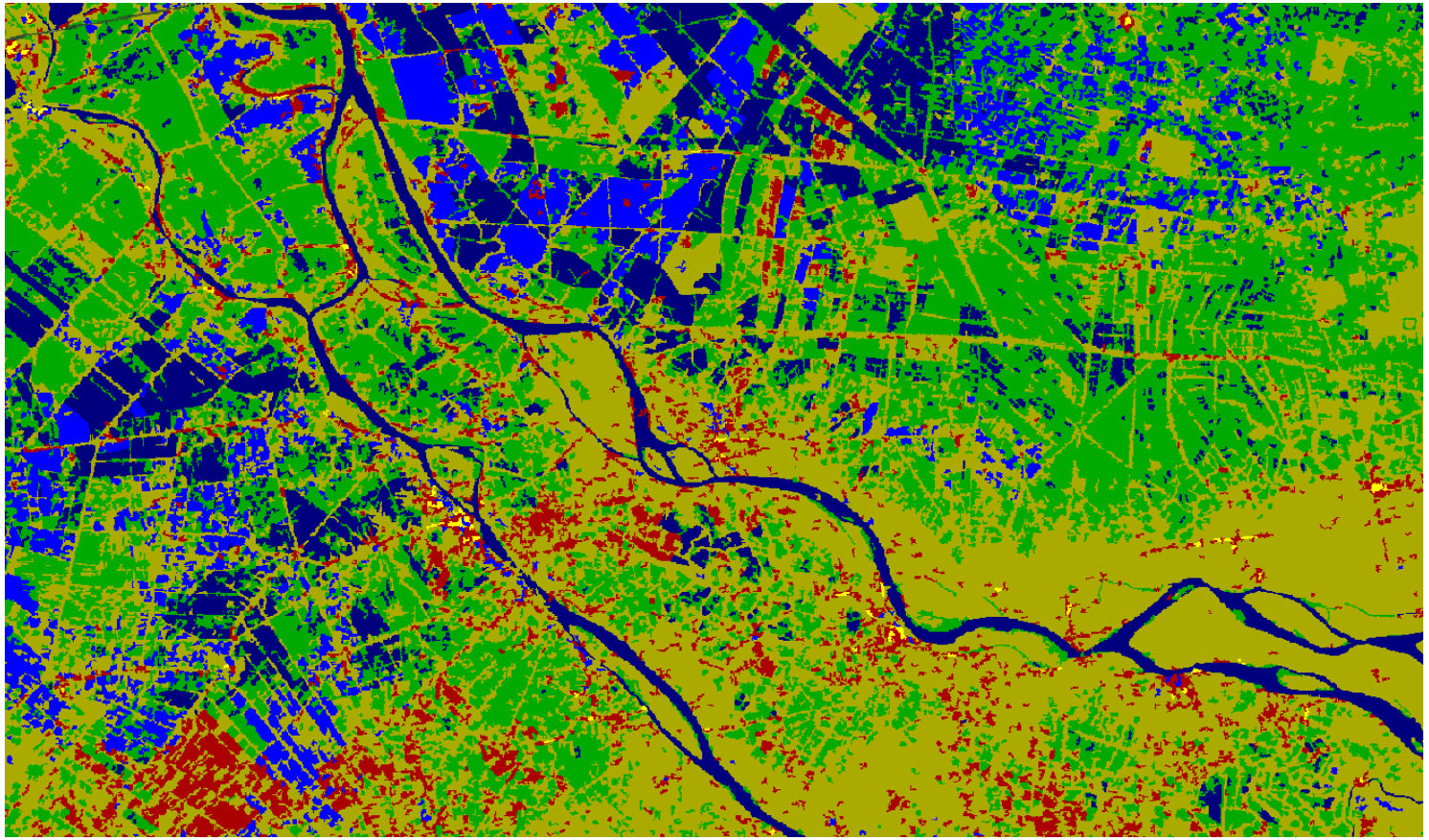


Vegetation Regeneration
Burn Scar over Parnitha Mt. (Greece)



PRELIMINAY RESULTS
RICE MONITORING

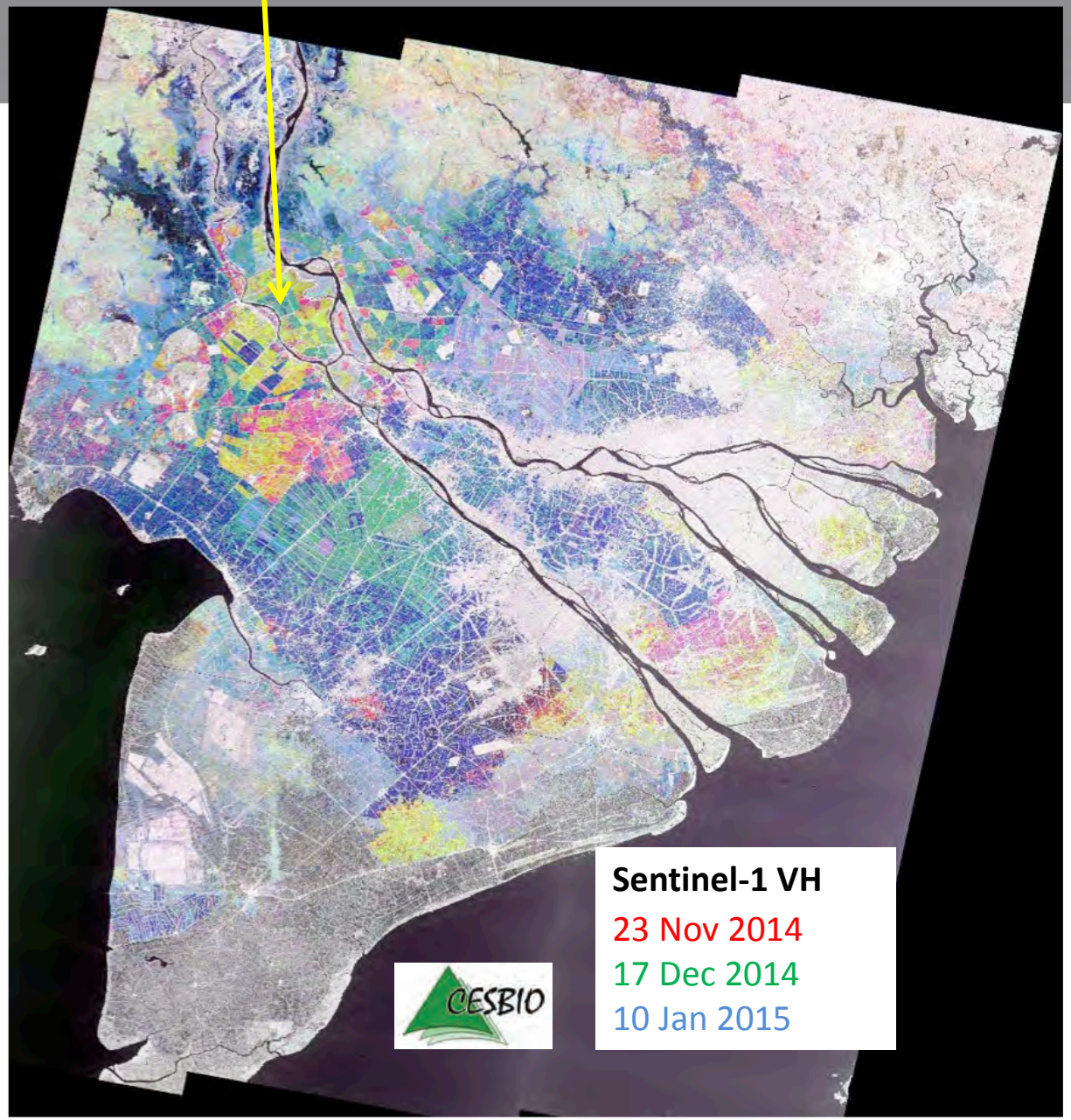
S-1A geocoded – 8 & 20 Aug, 80m (detail) – Vietnam



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

Courtesy SARMAP

PRELIMINAY RESULTS
RICE MONITORING



Asia- RICE
Technical Demonstration Site:
The Mekong River Delta
(~250 x 300 km)

Sentinel-1 data acquired every 12 days (resolution 40m or 10m):

1 - 30 Oct 2014
2 - 11 Nov 2014
3 - 23 Nov 2014
4 - 5 Dec 2014
5- 17 Dec 2014
6- 10 Jan 2015

The period corresponds to
. Recession of flood waters
. For fields protected by dykes: the end of Autumn-Winter crop and the beginning of Winter-Spring crop
(e.g. in the An Giang Province)

Bouvet & Le Toan

PRELIMINAY RESULTS
RICE MONITORING
Rice crop calendar for local/regional survey and inputs to rice growth models

The An Giang province (80 km x 80 km)

Crop calendar in the An Giang Province

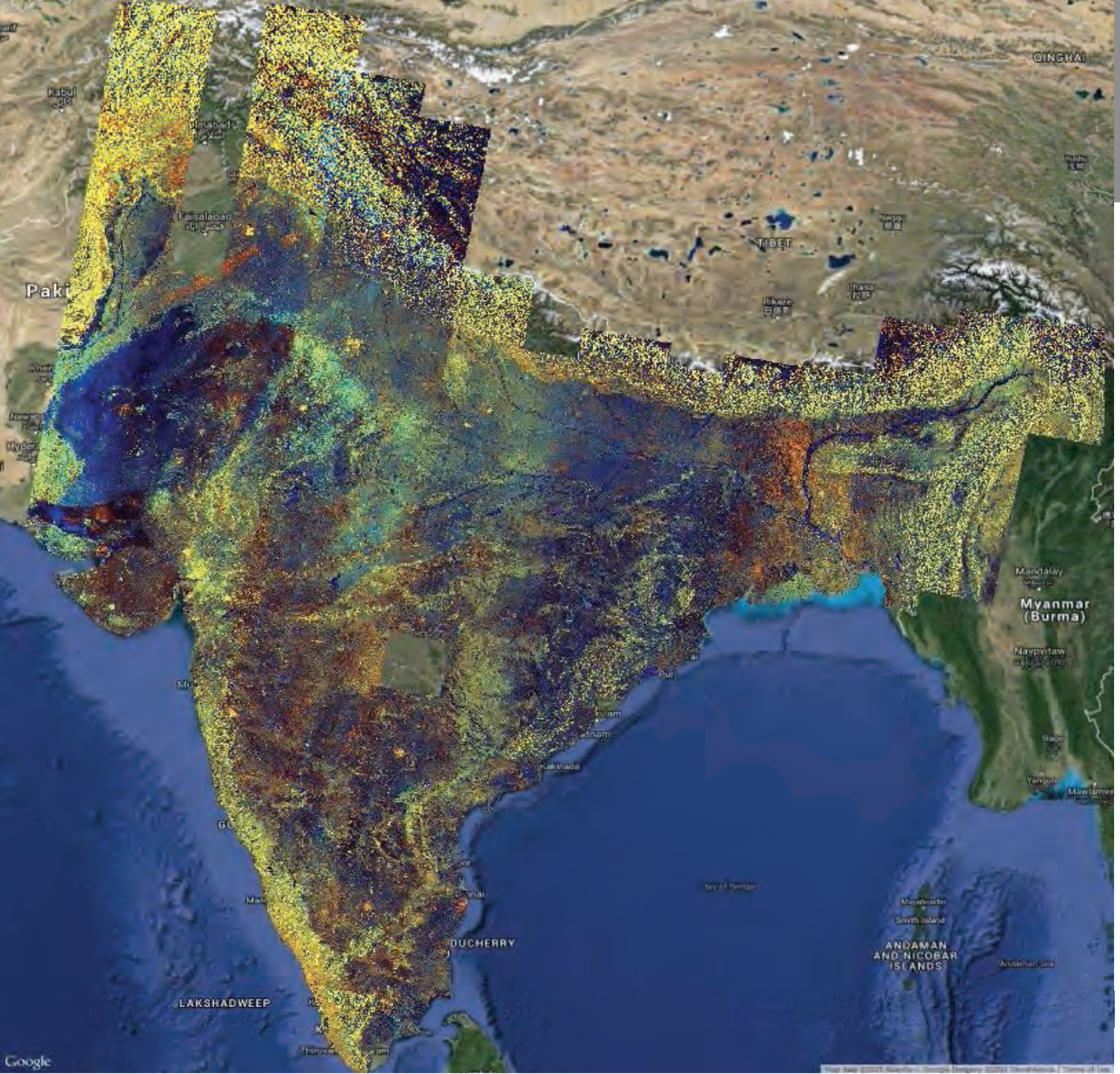
Crop season	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Winter-Spring crop														
Summer-Autumn crop														
Autumn-Winter crop														

November-December: end of Autumn-Winter crop and beginning of Winter-Spring crop

Crop calendar using the first Sentinel-1 data

- Planted around 11-12- 2014
- Planted between 11-11 and 23-11
- Planted on 23 -11
- Harvested between 23-11 and 5 -12, and planted again around 5-12
- Harvested between 23-11 and 5-12, and planted again between 5 and 17 -12
- Harvested between 17 -12 and 10 -01-2015

Bouvet & Le Toan



Sentinel-1 Mosaic of India

Courtesy SARMAP

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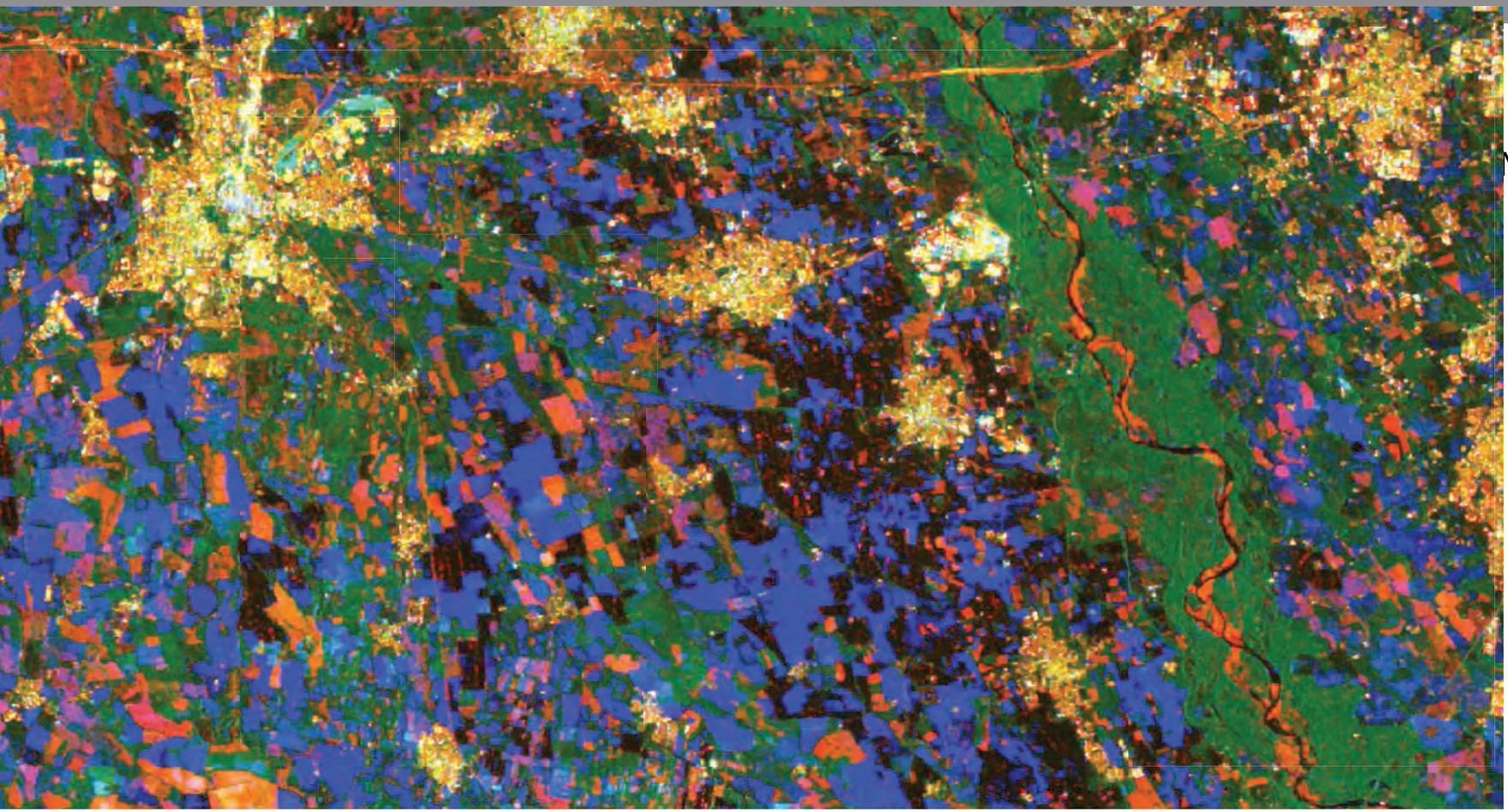
Great potential for rice mapping and land classification Demonstration North Italy



Multitemporal 8-20 Apr 2015 with coherence

Courtesy SARMAP

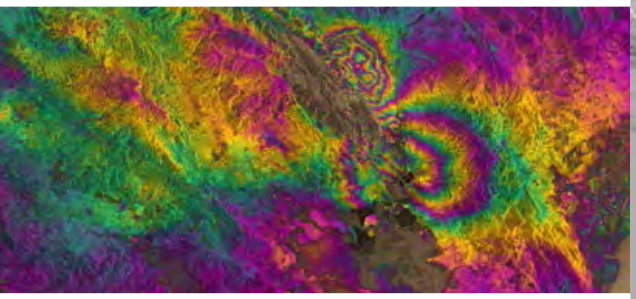
RED/ORANGE: coherence, object not changing: bare soil rough

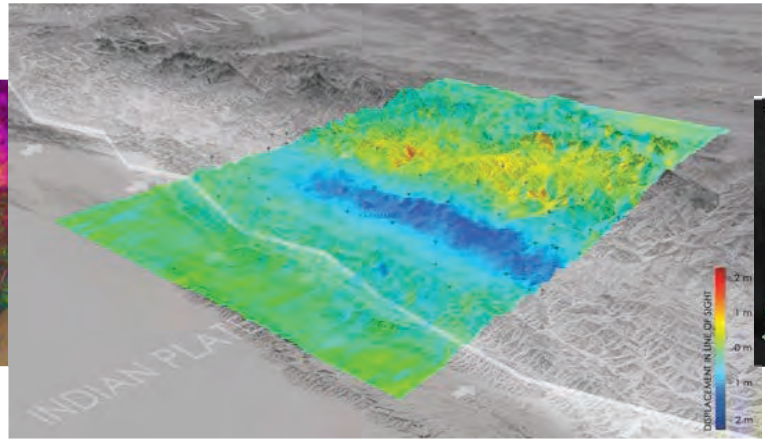
GREEN: average of the two sigma0 VV Forest mainly

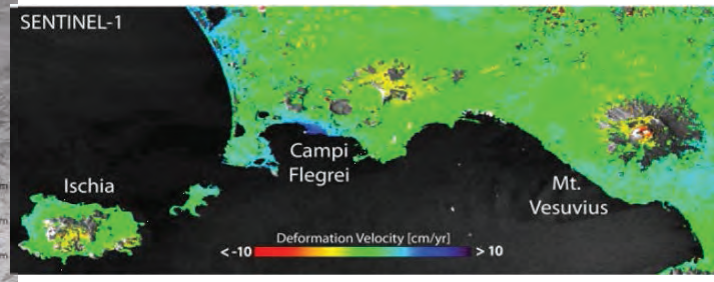
BLUE: difference of the two sigma0 VV objects changing within 12 days (here ploughing activities)

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

Land motion







Interferometry Applications
Ground deformation

ESA's SEOM INSARAP Studies

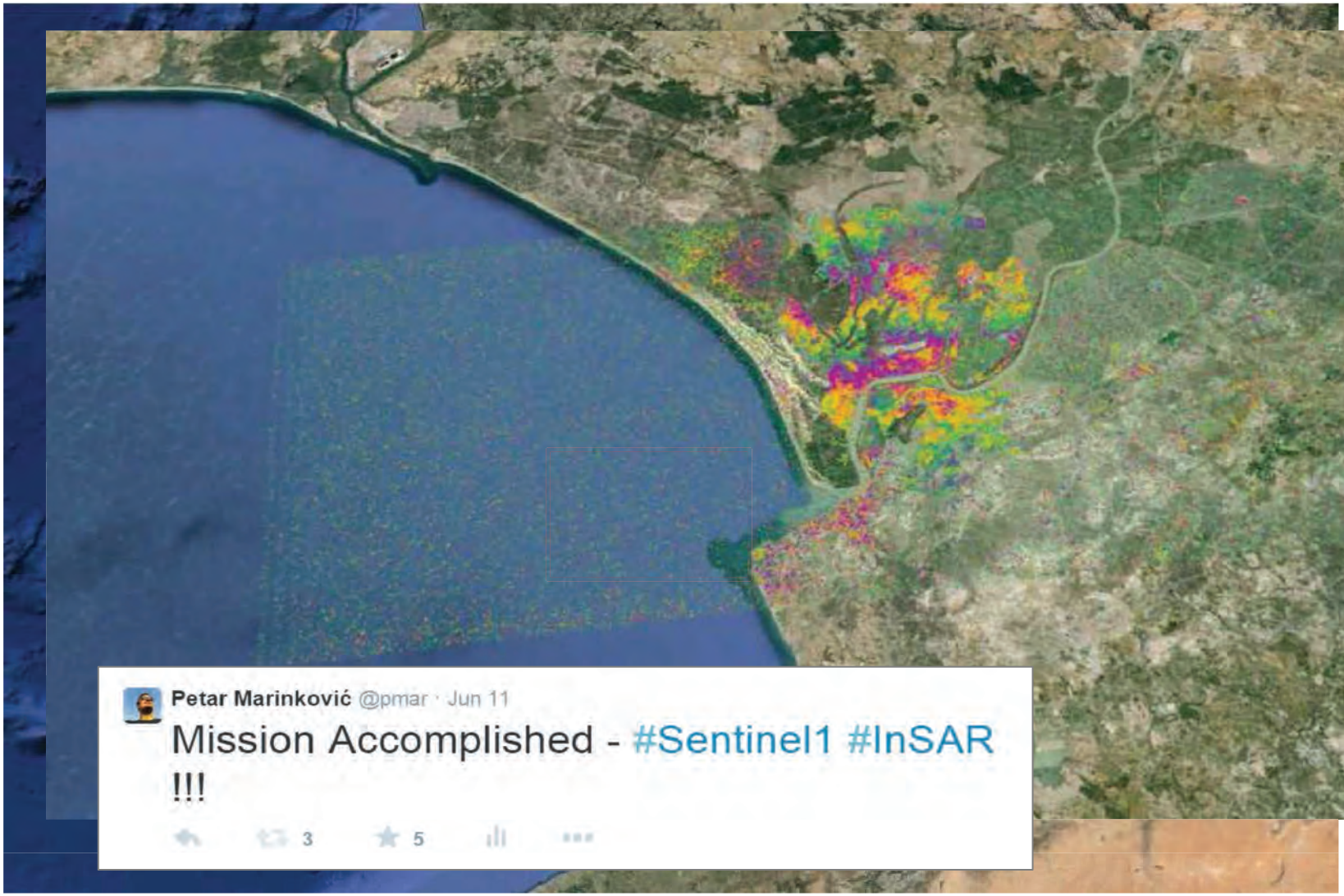
Objective

"Validation and scientific exploitation of the interferometric performance of TOPS mode on Copernicus Sentinel-1 mission"

- Full exploitation of S-1 mission capacity (DInSAR, PSI, multi-reference SBAS-like, processing full IW extend etc.)
- Development of advanced algorithms and novel products
- Supporting the scientific community
- Demonstrate continuity of ESA's C-band SAR observations

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

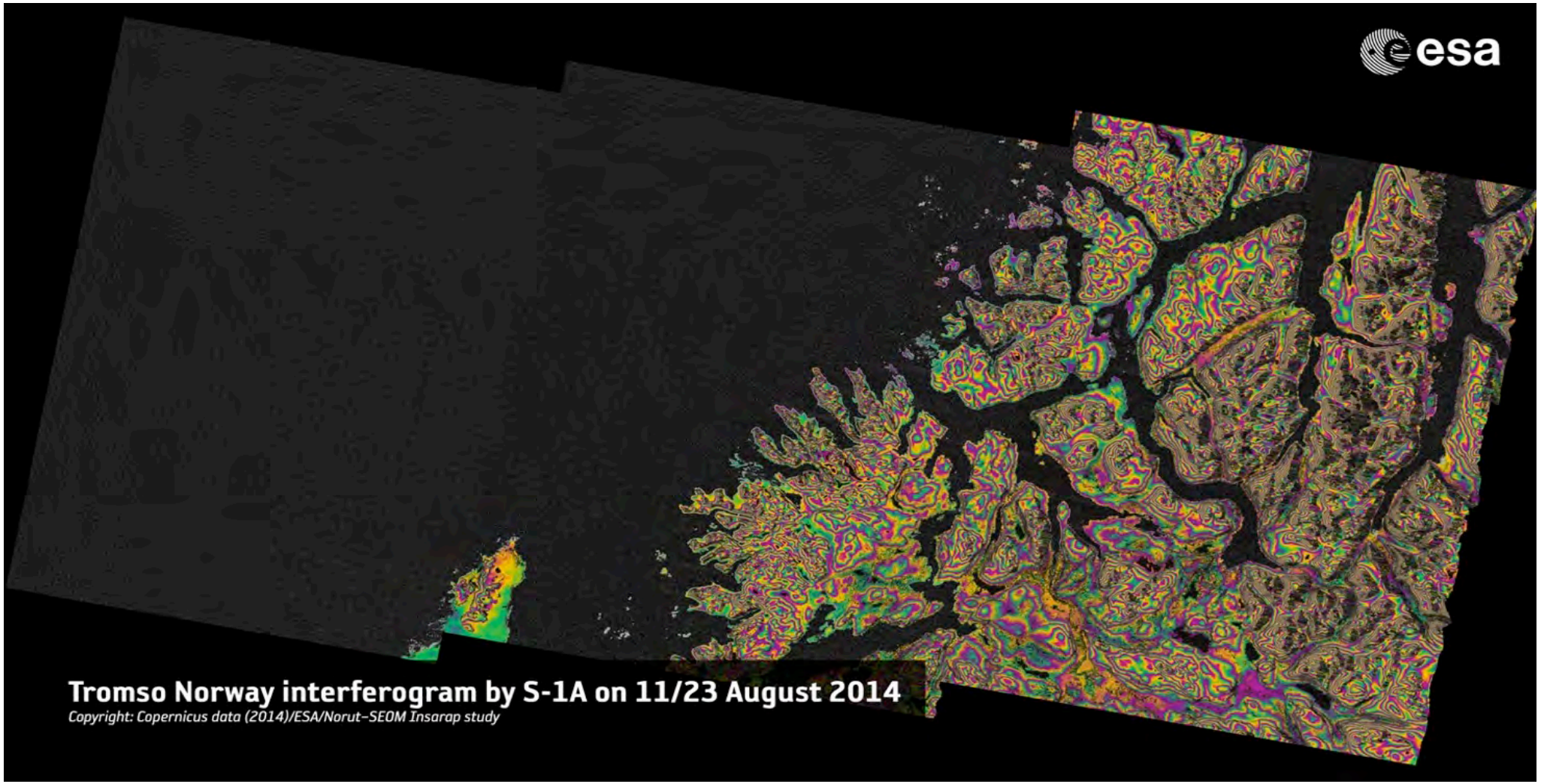
First Sentinel-1 Interferogram !



European Space Agency

Sentinel-1 TOPS Interferogram - Norway Relief

Nominal Orbit Reached



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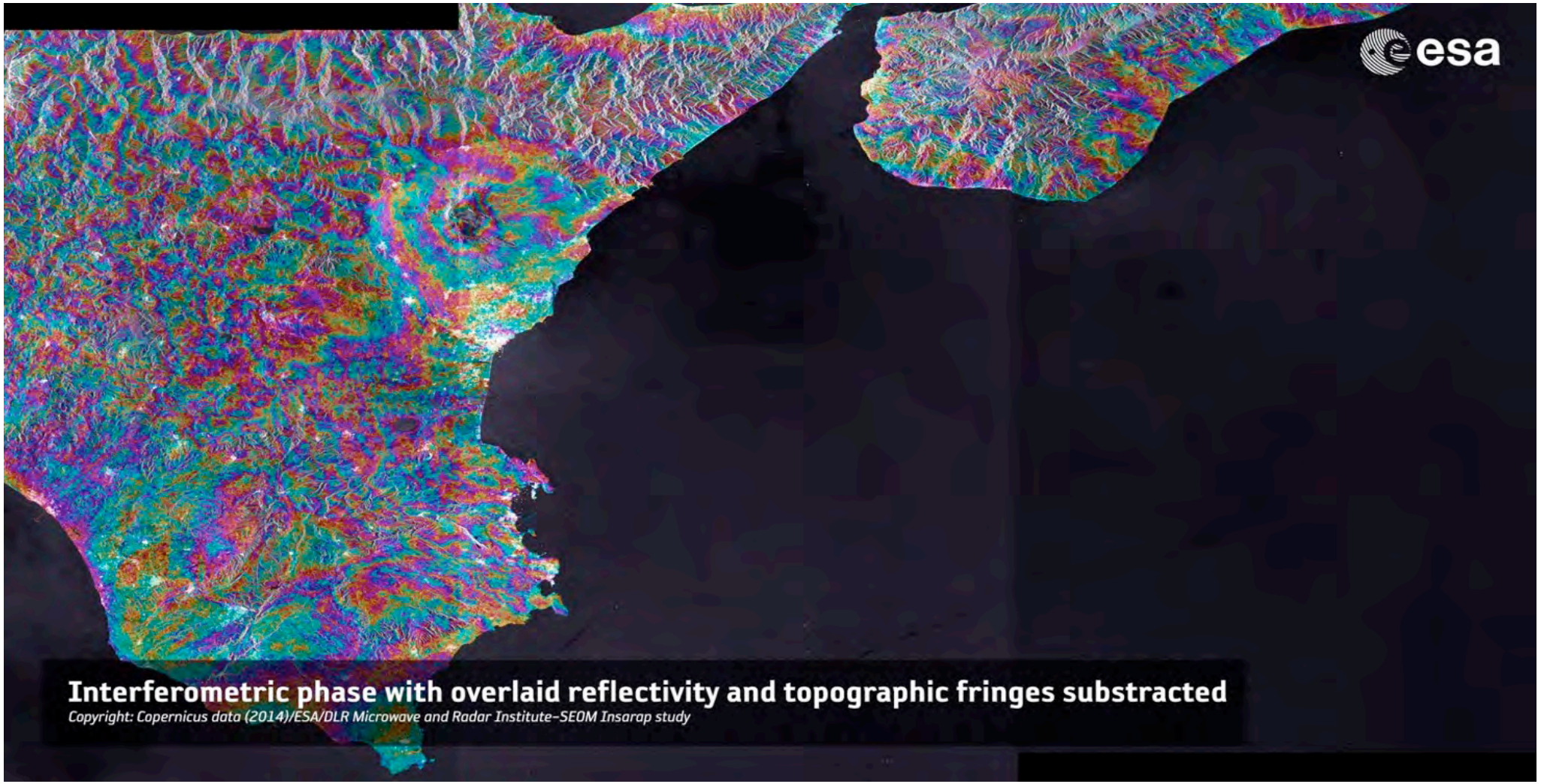
Sentinel-1 TOPS Interferogram
Mt. Etna (Sicily)
Nominal Orbit Reached



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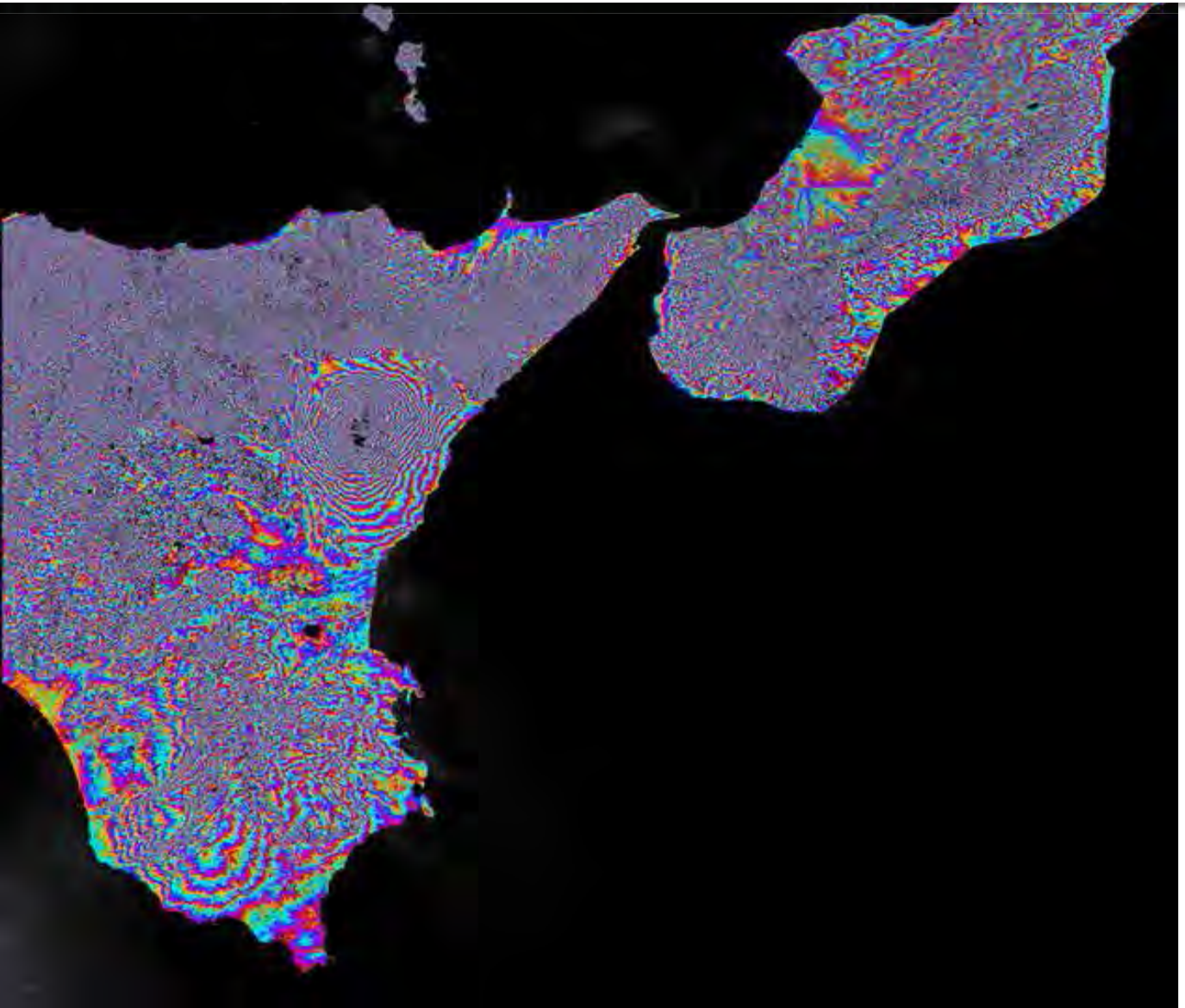
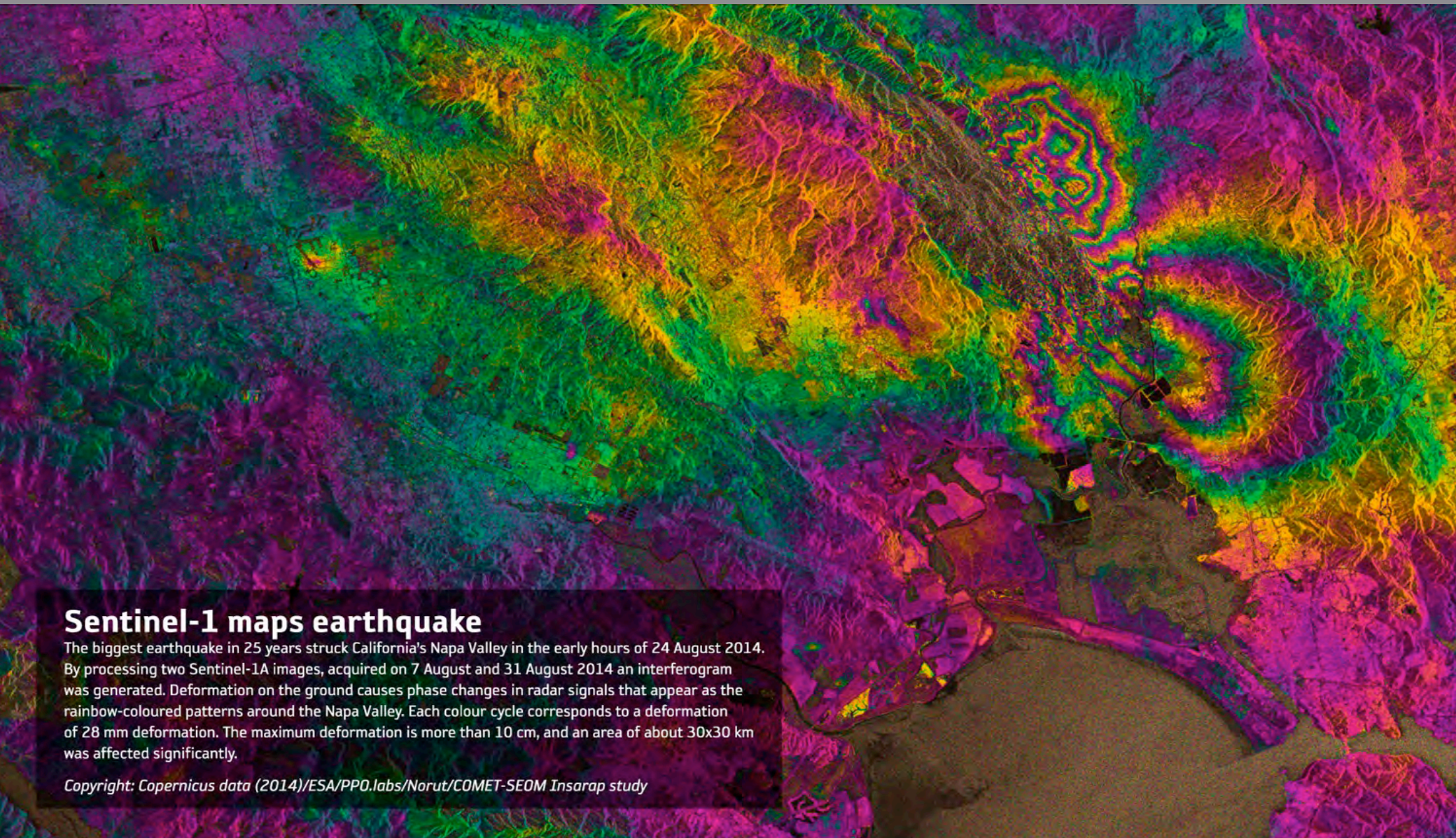
Large Scale Interferogram over Italy

@ In-Orbit Commissioning Review (IOCR)



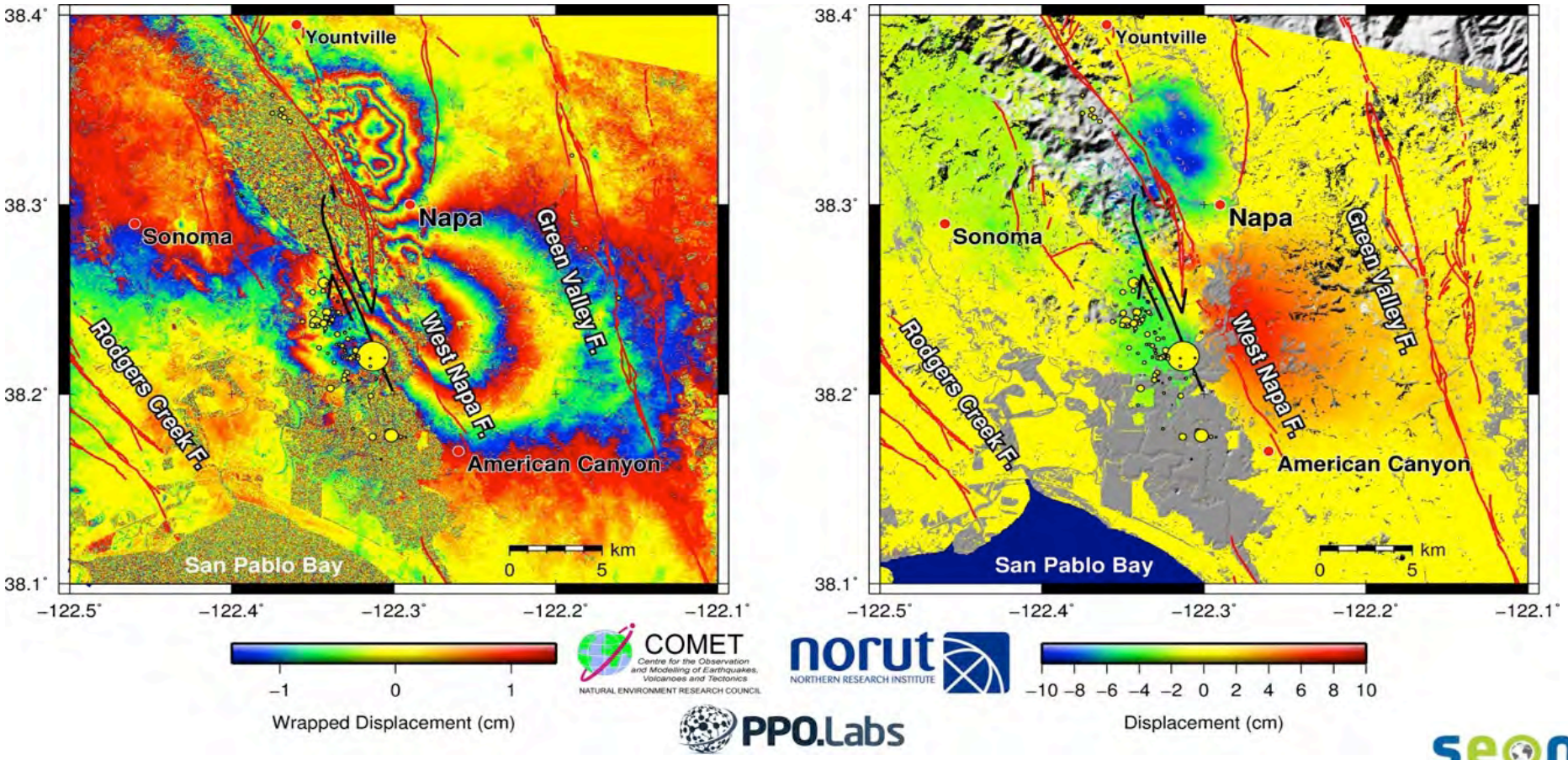
First Capture of an Earthquake by Sentinel-1 Napa Valley (California) M6.0R



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



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

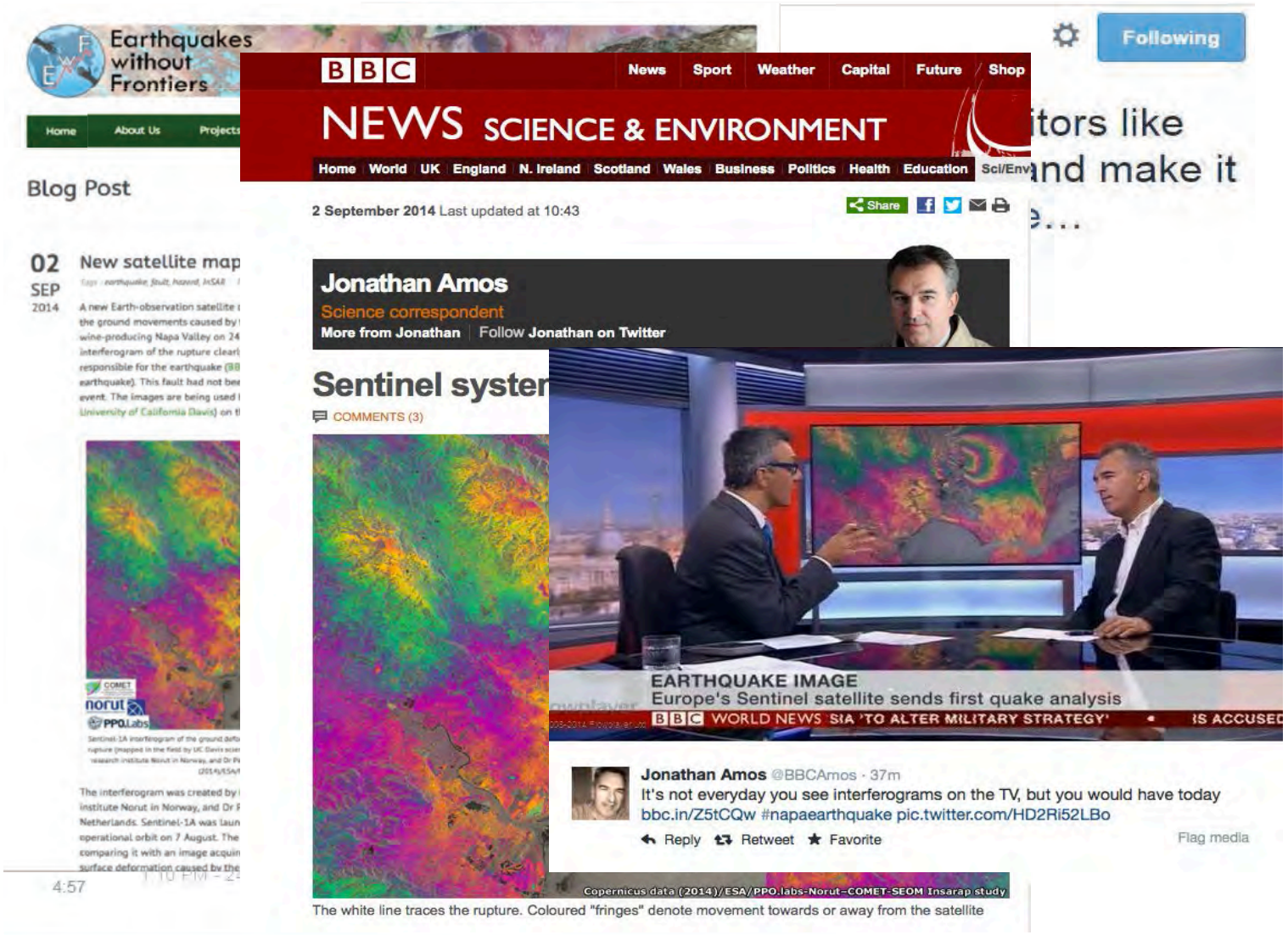
norut NORTHERN RESEARCH INSTITUTE

PPO.Labs

seom scientific exploitation of operational missions

European Space Agency

Napa Valley Earthquake
Promoting Science Data Use and Results



esa

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

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NORTHERN RESEARCH INSTITUTE

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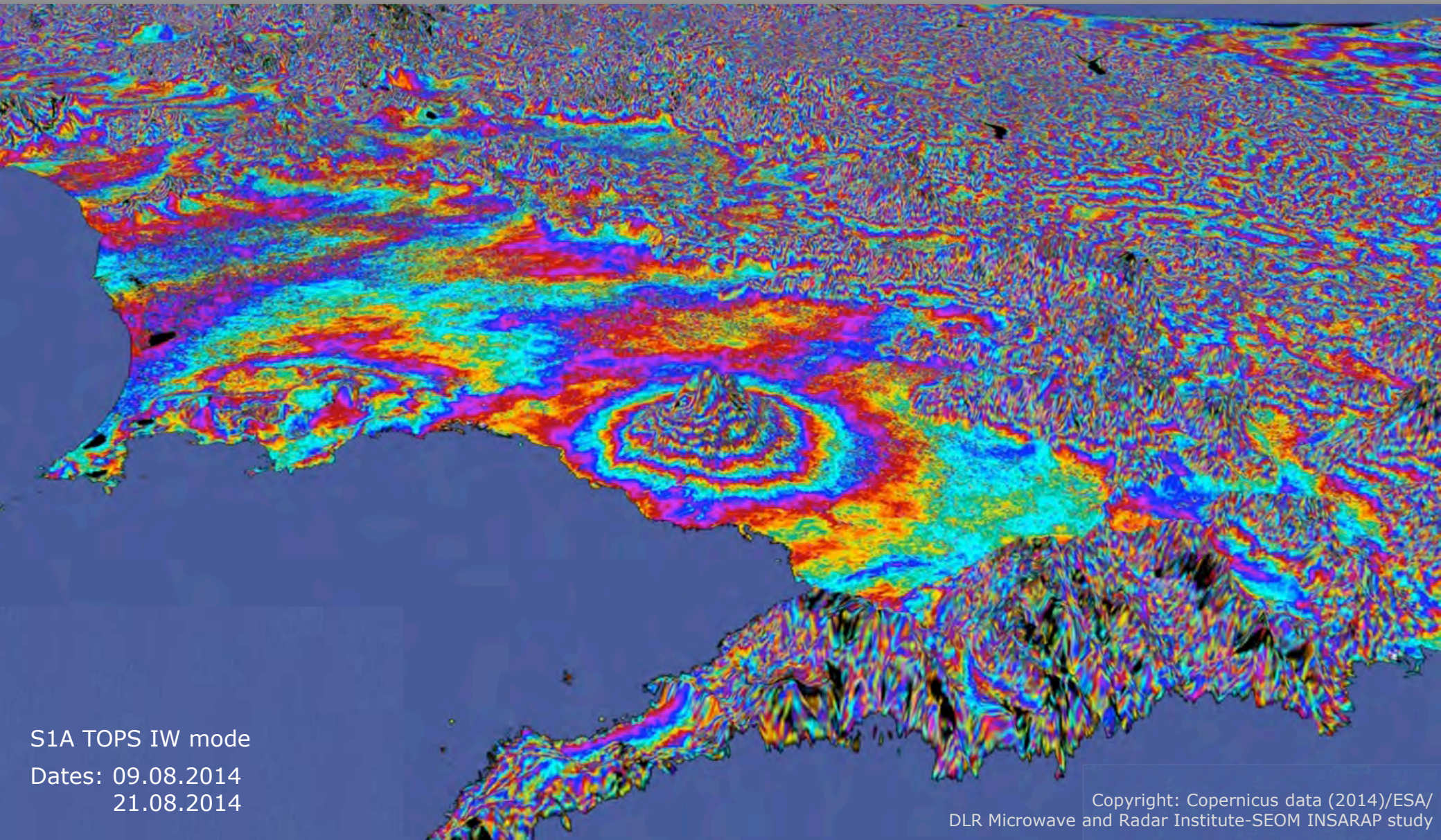
Mount Vesuvius and Campi Flegrei
Nominal Orbit Reached



S1A TOPS IW mode

Dates: 09.08.2014
21.08.2014

Release of Sentinel Toolboxes

ARRAY SYSTEMS COMPUTING INC.

La force de l'innovation

BROCKMANN CONSULT

Sentinel To

- Multi-mission lboxes
- Developed as open re
- Common architecture (SI
- Java/Python API and Java/Pyth
- Portable engine to a Cloud infrastruct

Download https://sentinel.esa.int

Open source scientific toolboxes
3000+ users in 70 countries

STEP

- EO science collaborative m
- Technical forum and commun nation
- Gathering user feedback and usag
- Communicating on results
- Cloud demonstrator (e.g. Land Training 201

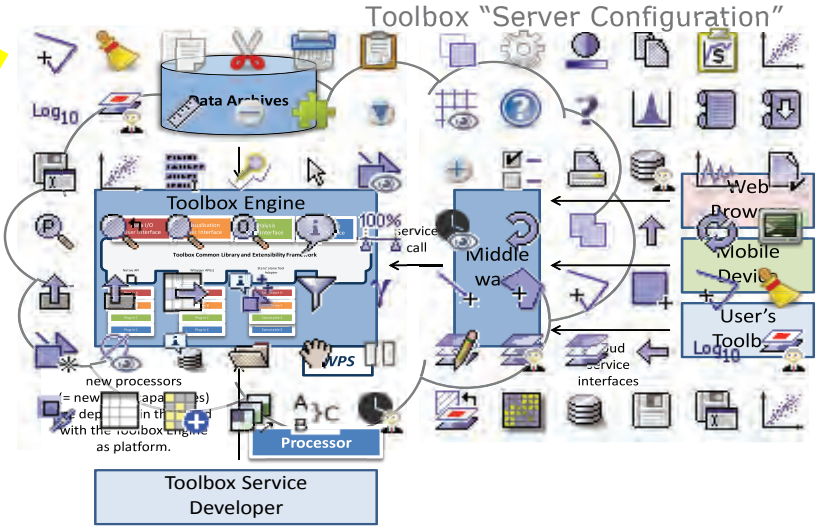
Under preparation http://step.esa.int/

STEP opening 15 June 2015

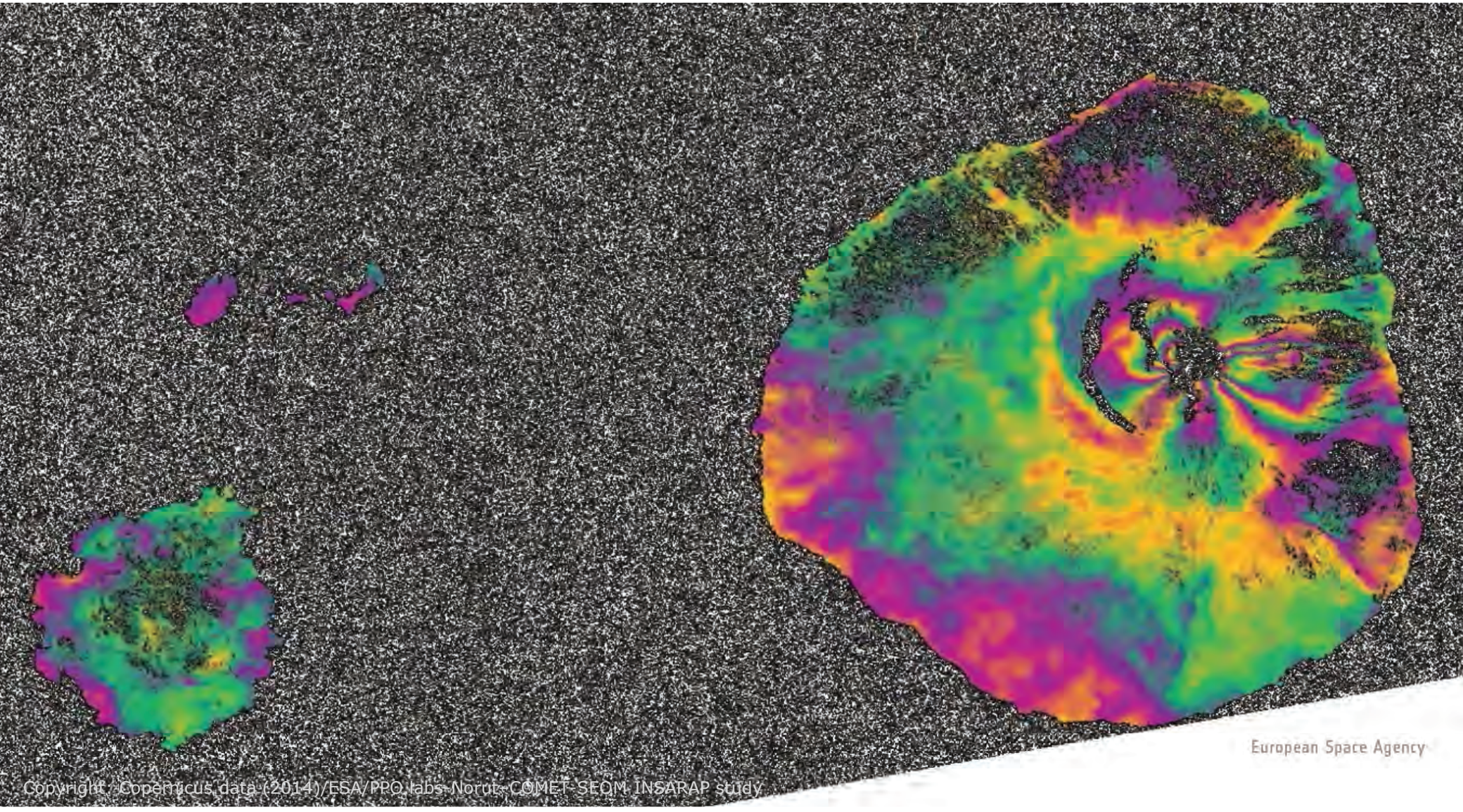
SNAP

SentiNel Application Platform

SOCIAL CODING

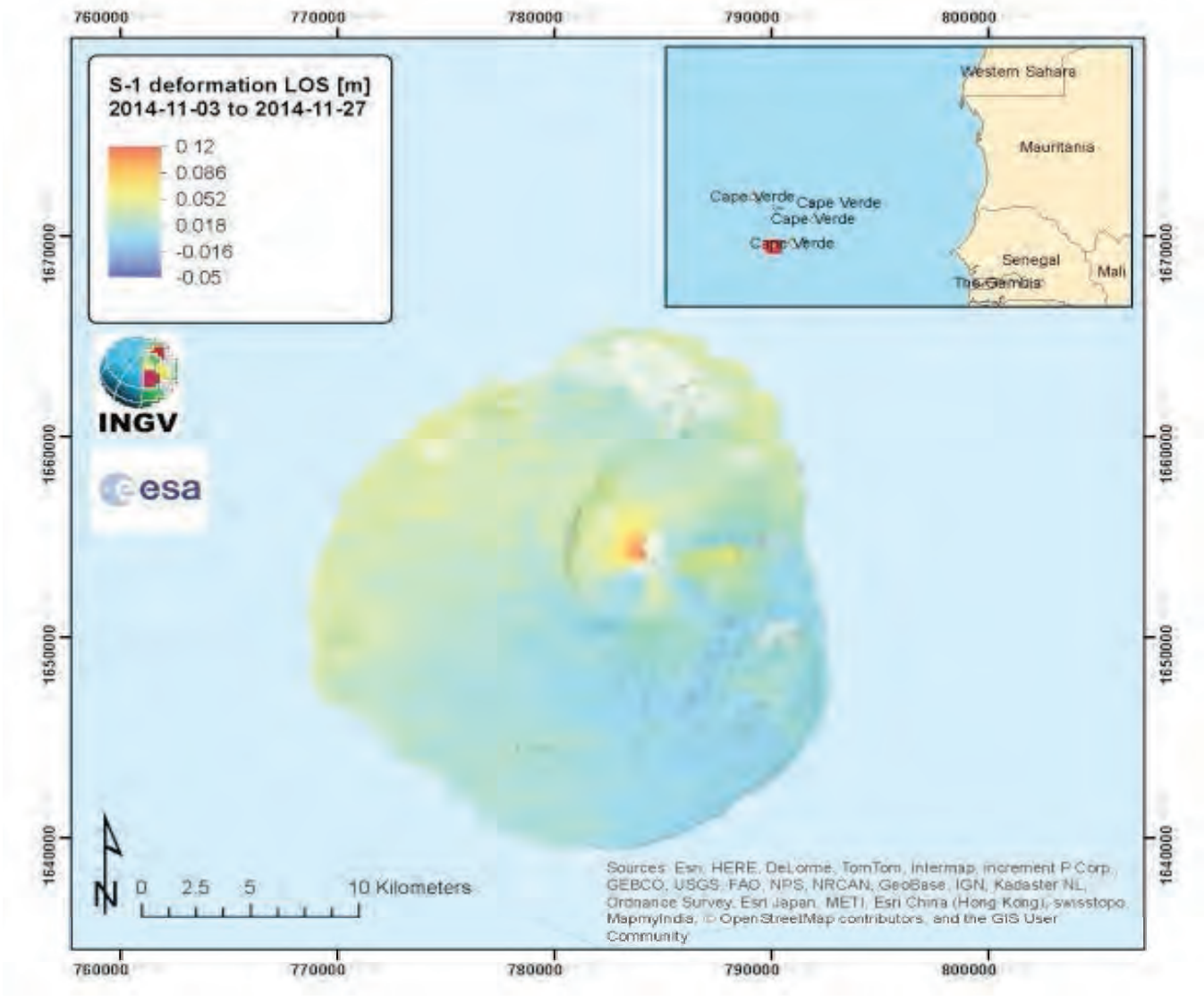


Sentinel-1 Maps Fogo Volcano Eruption



European Space Agency

Fogo Volcano Eruption
Displacement Field



INSARAP 2014 Workshop

seom
scientific exploitation of operational missions

INSARAP | SEOM | ESA

NAVIGATION
Home
Participation and Registration
Programme
Committee and Contact
Workshop Flyer

Programme and Presentations

11 December 2014

Session 3 - Sentinel-1 TOPS InSAR results

Chairs: *P. Prats & Y. Larsen*

09:00 Sentinel-1 InSAR Capabilities: Results from the Sentinel-1A Commissioning Phase - *D. Geudtner, ESA*

09:15 Adaptation of DIAPASON processing software to Sentinel-1 TOPS interferometry - *J. Duro, Altamira*

09:45 Sentinel-1 InSAR progress and experience at GAMMA - *U. Wegmüller, Gamma Remote Sensing AG*

10:15 Enabling the processing of Sentinel-1 TOPS data with the open-source DORIS software - *F. van Leijen, Delft University of Technology*

10:45 *Coffee Break*

11:00 SBAS-DInSAR processing chain for Interferometric Wide Swath Sentinel-1 data - *M. Manunta, IREA-CNR*

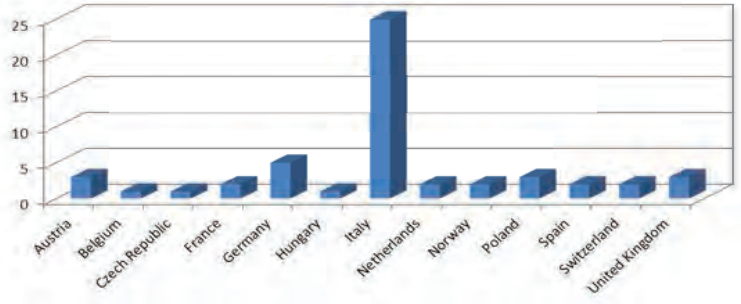
11:30 Sentinel-1a Interferometry using the Integrated Wide Area Processor – First Experiences -*R. Brcic, DLR*

12:00 *Lunch Break*

Round Table Discussion

Participation

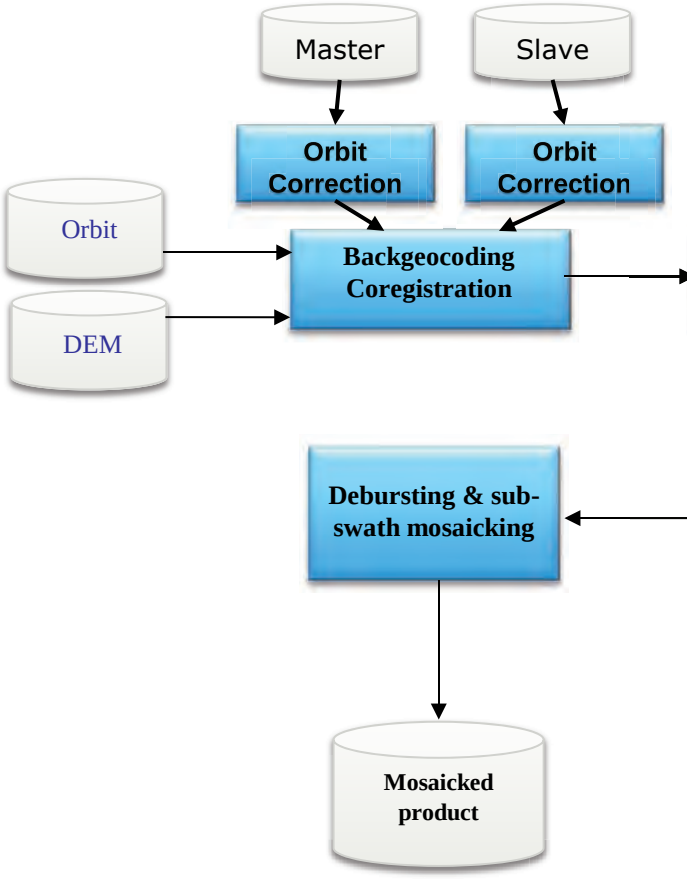
- The workshop was **open** to scientists and results in TOPS mode.
- Adapt InSAR and PSI processing techniques to TOPS SAR data.



TOPS InSAR for Sentinel-1 Toolbox

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

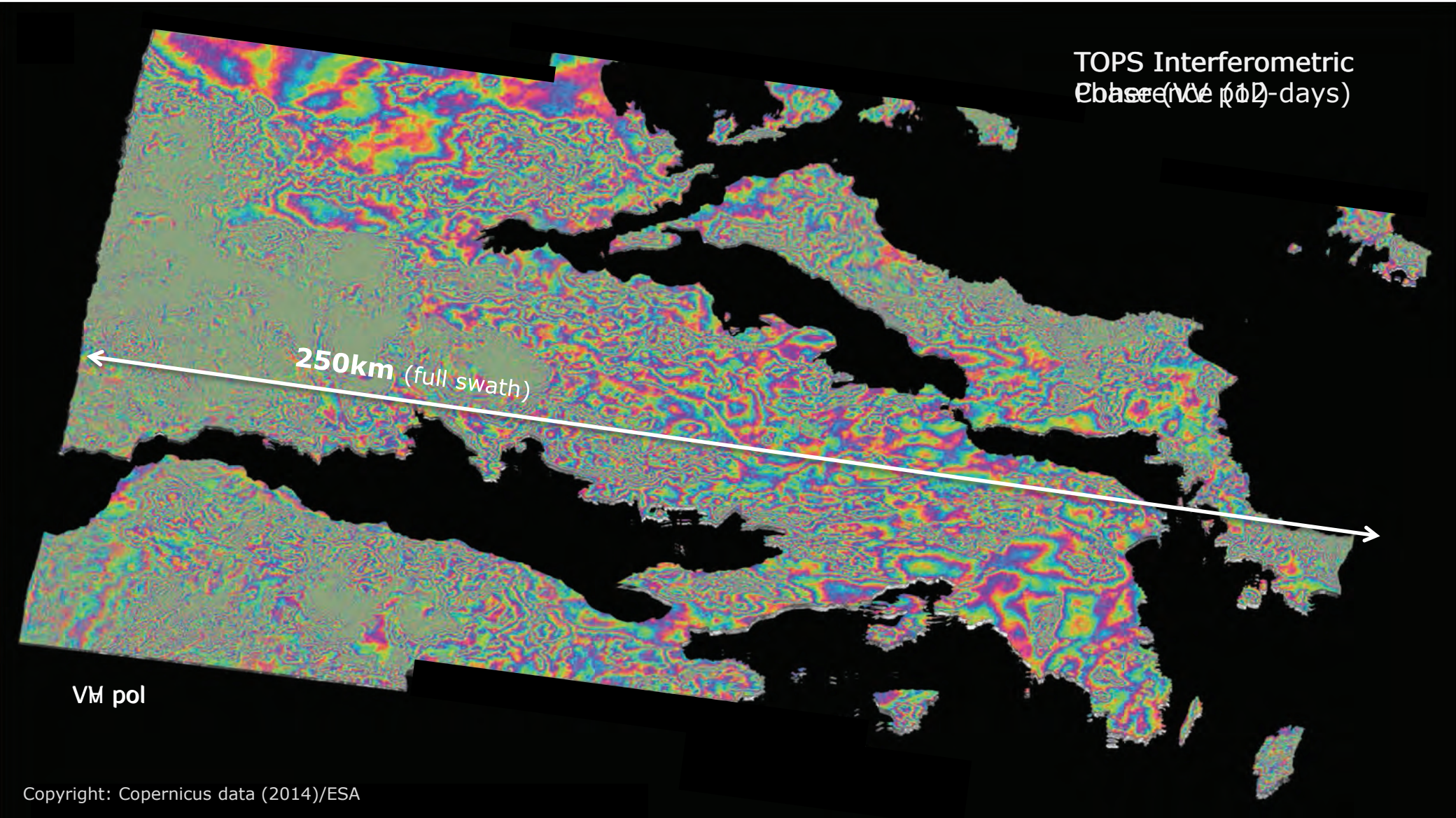
TOPSAR Chain



S1A TOPS Interferogram
Mt. Etna

TOPS InSAR for Sentinel-1 Toolbox

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



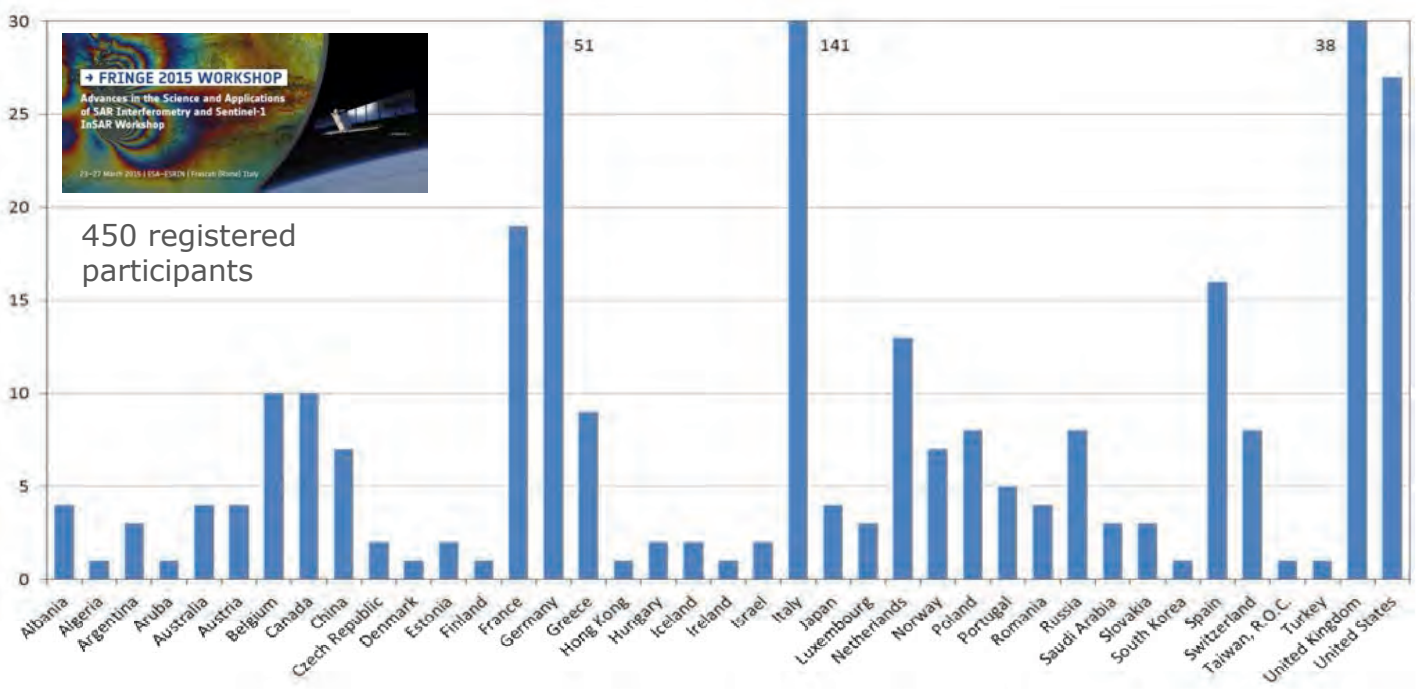
FRINGE 2015 Workshop

12 Thematic Sessions with 146 oral presentations

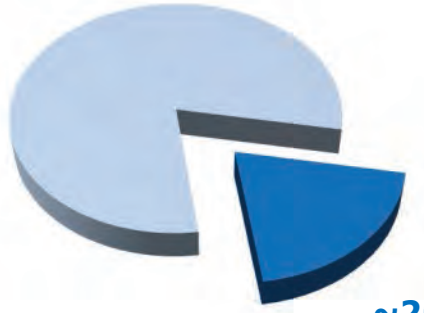
General
- Opening/ESA Session
- Copernicus Overview
- International Initiatives
- Mission Exploitation

Methods
- **InSAR with Sentinel-1 (TOPS)**
- Coherence Exploitation
- Theory and Techniques
- PSI and DInSAR

Applications
- Cryosphere
- Mapping
- Earthquakes and Tectonics
- Subsidence and Landslides
- Volcanoes



Oral presentations

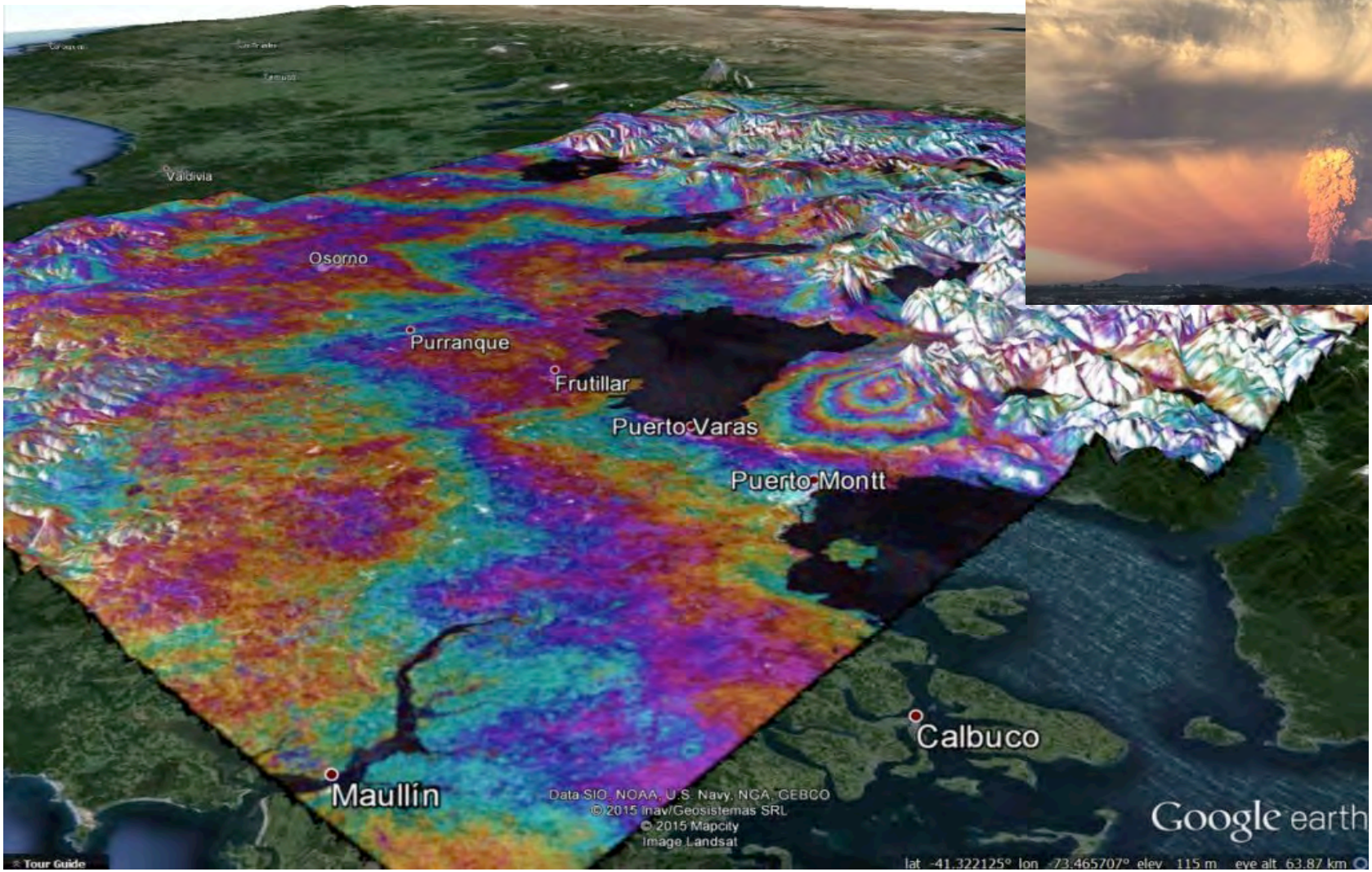


~20%
Sentinel-1A data

seom
scientific exploitation of operational missions

European Space Agency

Calbuco Volcano, Chile
Eruption on April 24th, 2015



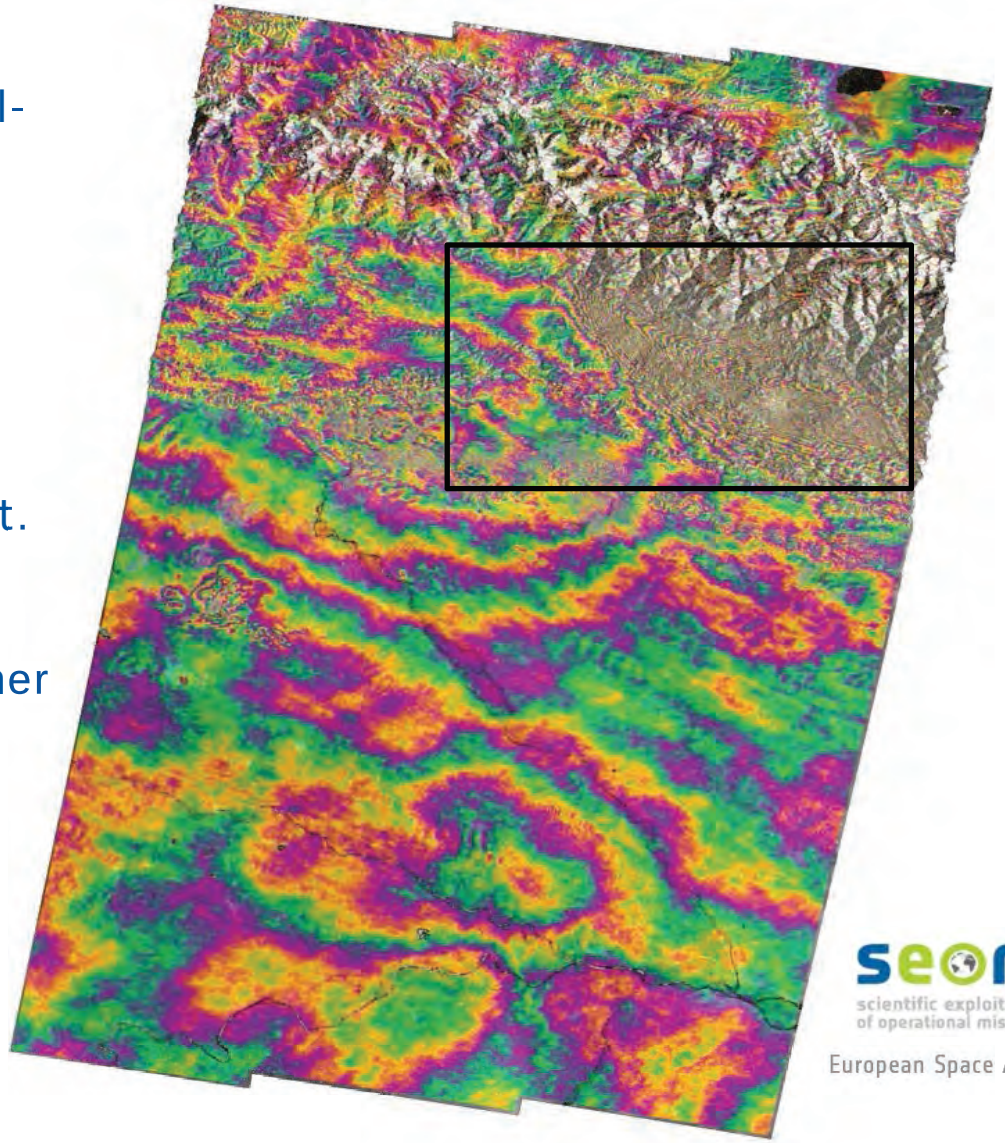
European Space Agency

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.

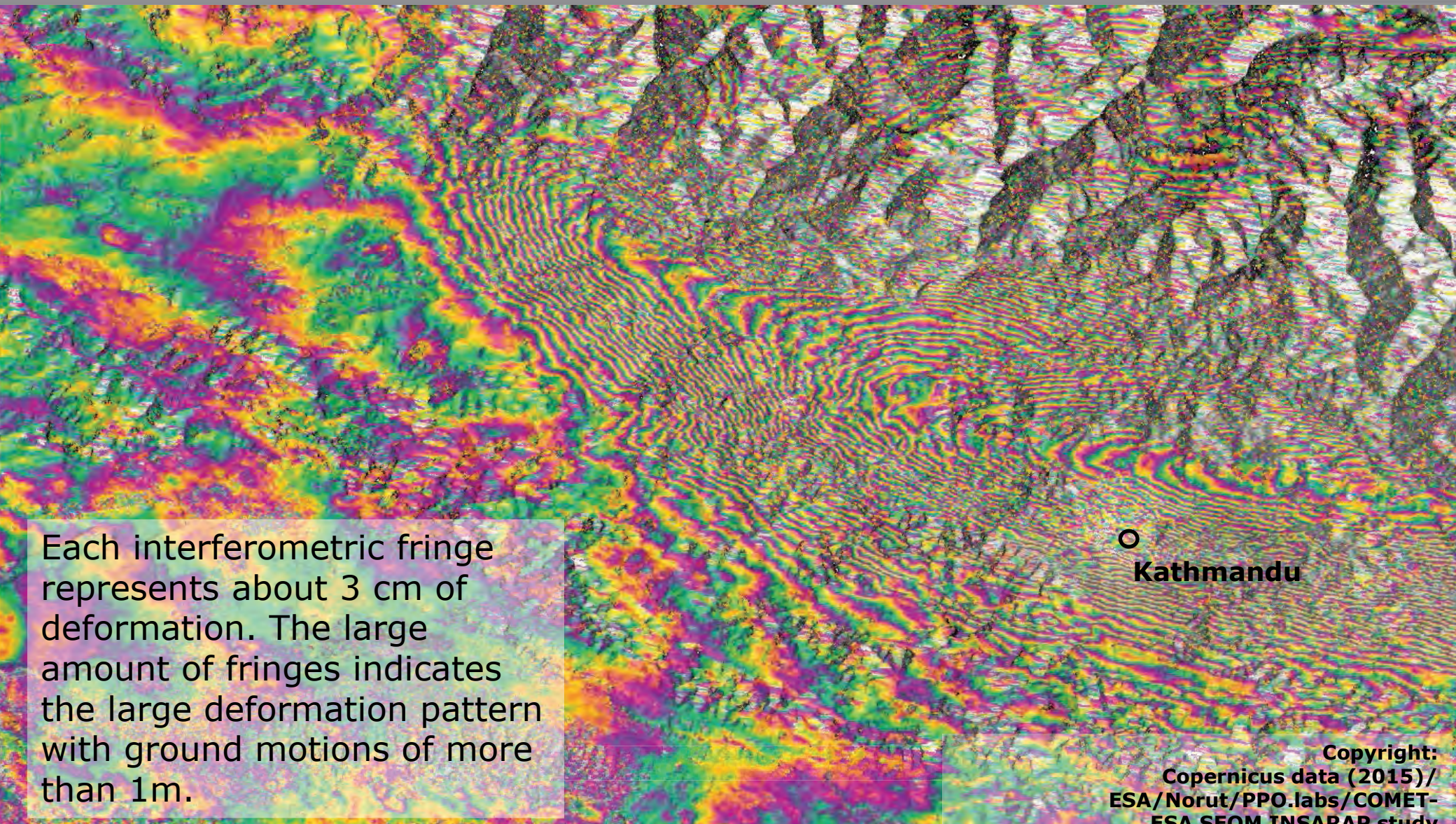
An overall area of 120x100 km has moved, half of that uplifted and the other half, north of Kathmandu subsided.



seom
scientific exploitation of operational missions

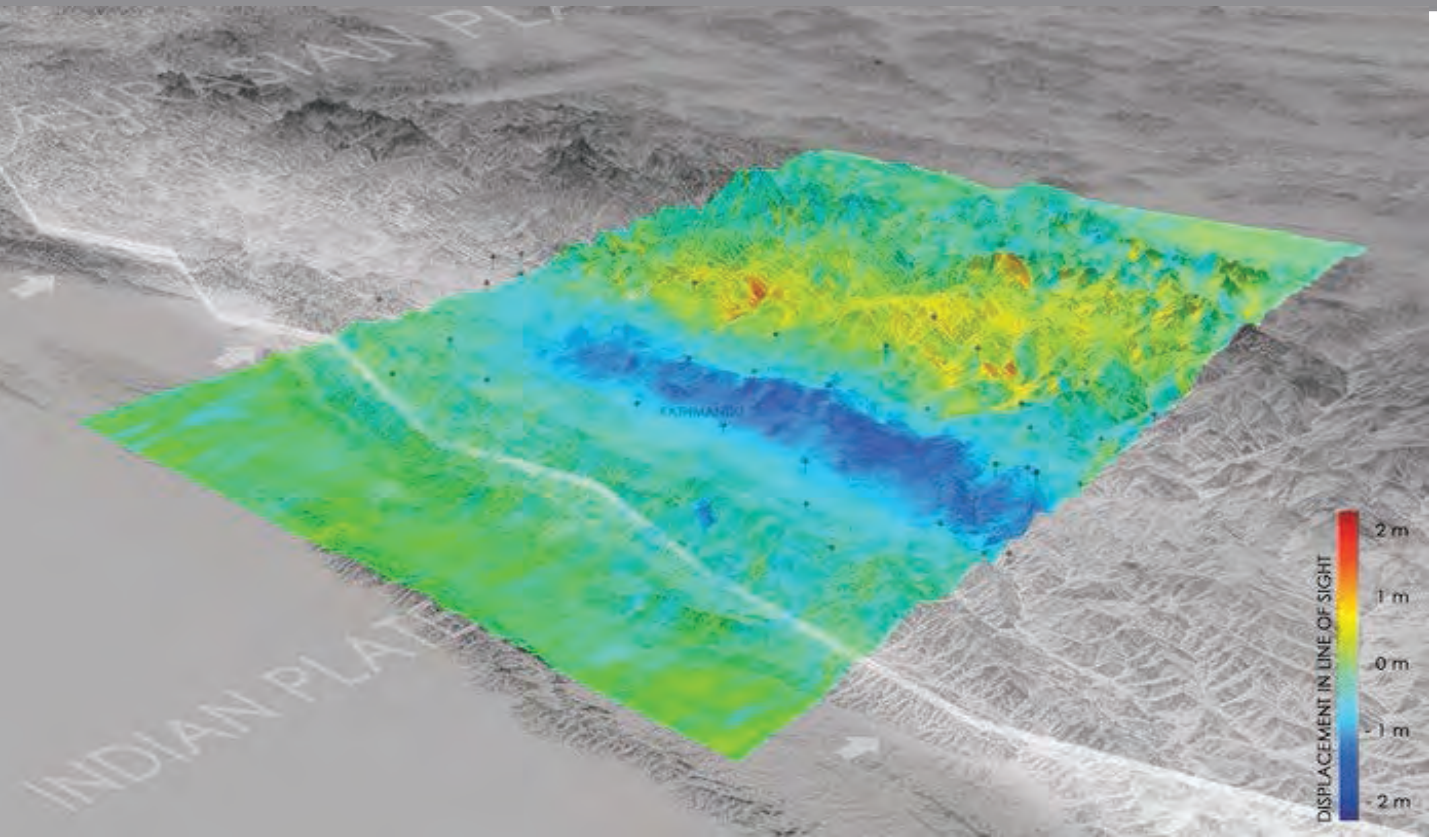
European Space Agency

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

Nepal Earthquake
Promoting Science Data Use and Results

Geophysical data pack downloaded 150 times

ESA web news 21500 views

EARTHQUAKE: SENTINEL-1 INSAR ANALYSIS

APRIL 2015

COSEISMIC INTERFEROGRAMS

02 Apr - 26 Apr
23 Mar/04 Apr - 28 Apr
17 Apr - 29 Apr
09 Apr - 03 May
21 Apr - 03 May

- Range offsets, masked, in KMZ format
- Azimuth offsets, masked, in KMZ format

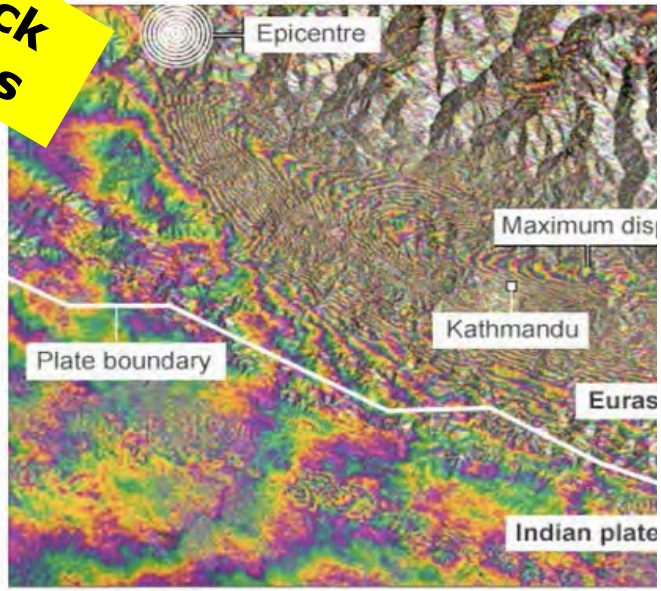
S1_Nepal_Coseismic_2....zip

Show All

Sentinel satellite reveals Nepal quake movement

By Jonathan Amos
BBC Science Correspondent

29 April 2015 | Science & Environment



Source: ESA SEOM InSARap Study

Tim Wright @timwright_leeds · 3h3 hours ago

6. Overall, area at least 120 x100 km moved. ntinel-1 data invaluable at this scale. Earthquake #insarap #Sentinel1 (7/7)

5. A f Kathmandu subsides. Consiste stic rebound from shallow thrust #Nepa e #insarap #Sentinel1 (6/7)

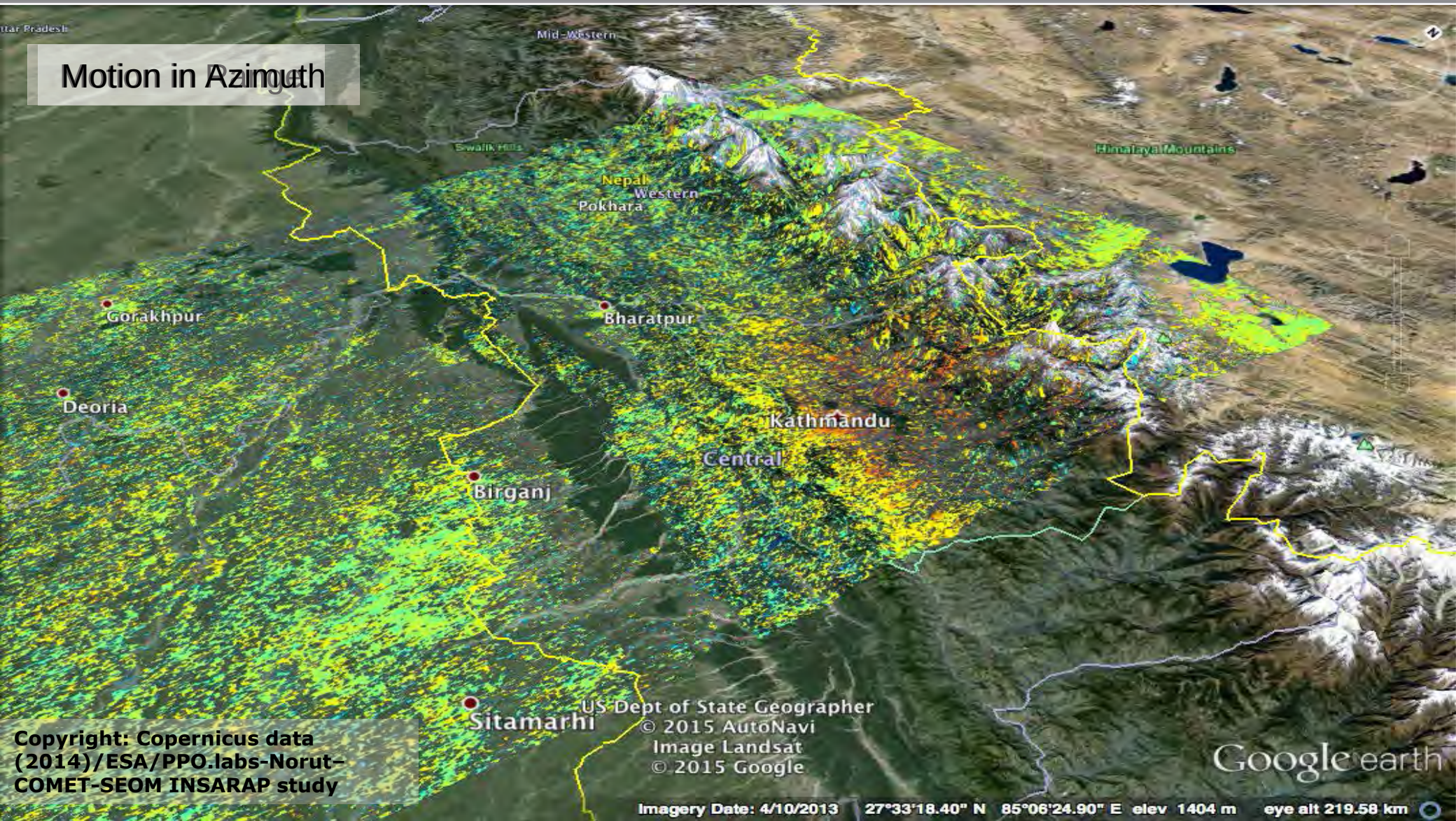
4. The fault did not ruptu face. #NepalEarthquake #insarap tinel1 (5/7)

3. An area at least 120x50 km uplifted, with a maximum greater than 1m. #NepalEarthquake #insarap #Sentinel1 (4/7)

2. Peak displacement is very close to Kathmandu; fault under the city slipped significantly. #NepalEarthquake #insarap #Sentinel1 (3/7)

1. Quake ruptured east from Epicentre, confirming seismology #NepalEarthquake #insarap #Sentinel1

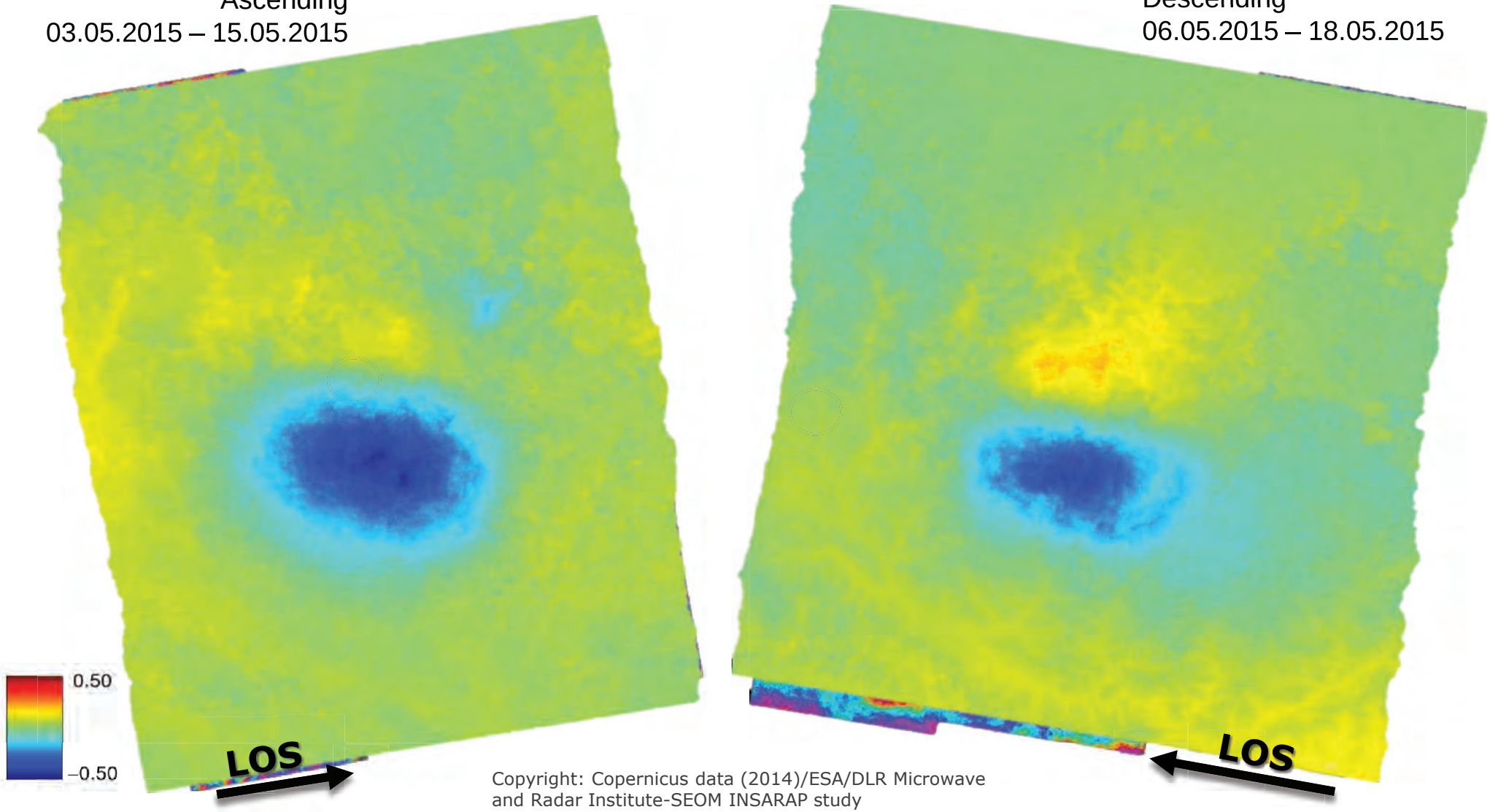
Nepal Earthquake
Motion using Speckle Tracking



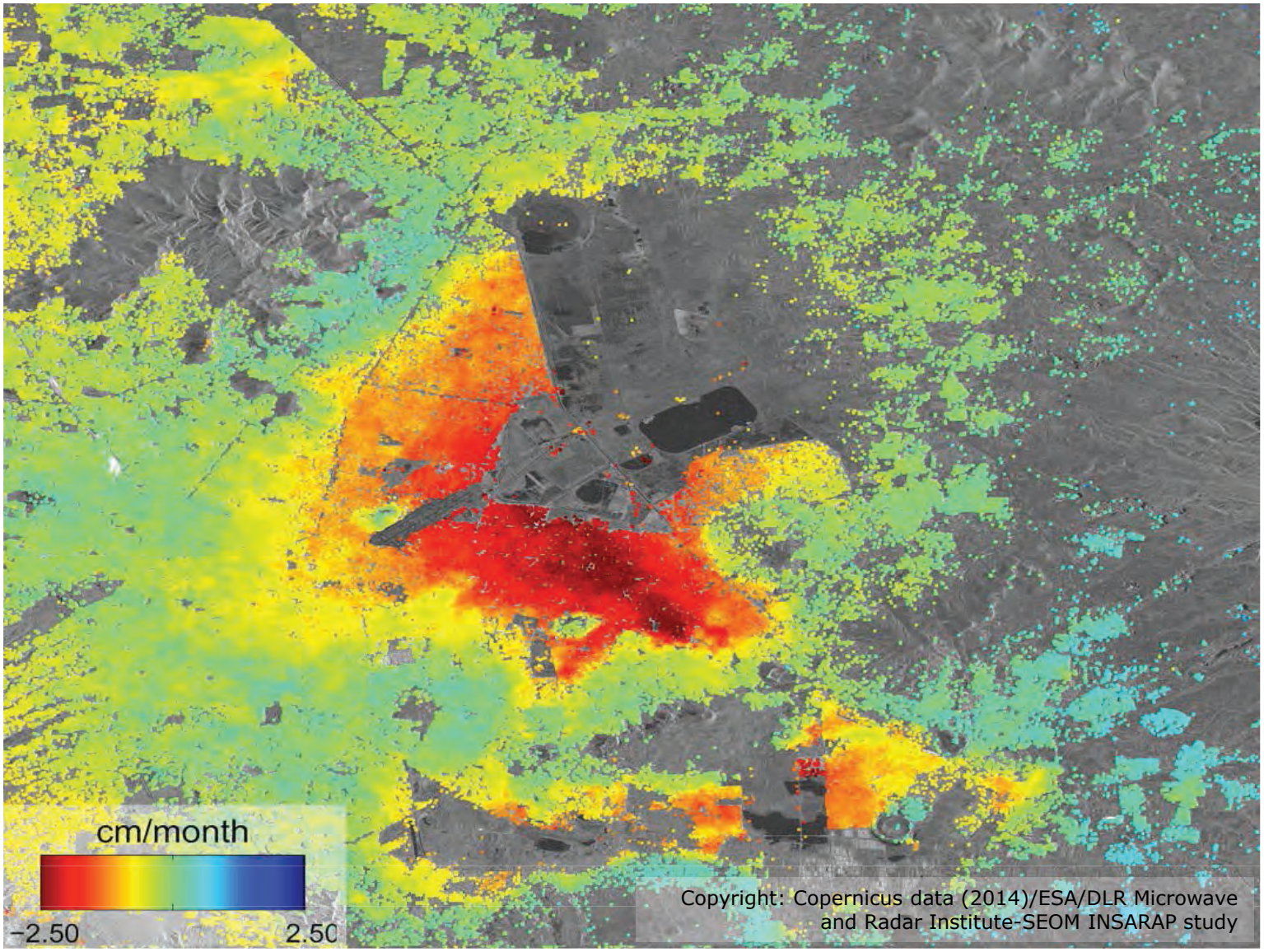
Nepal After-Shock (12 May 2015)

Ascending
03.05.2015 – 15.05.2015

Descending
06.05.2015 – 18.05.2015



Sentinel-1 First Subsidence Monitoring
Mexico City



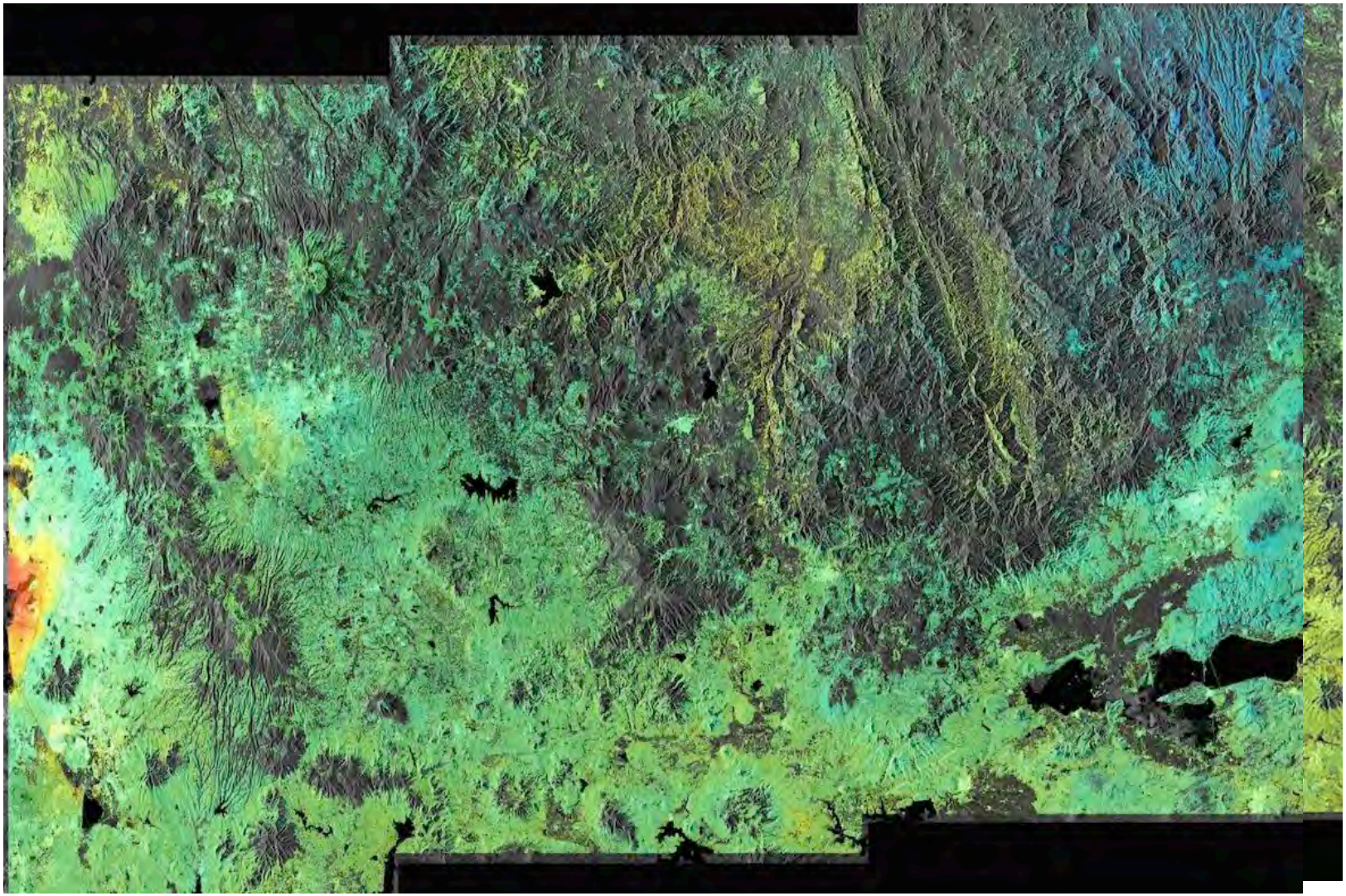
Five Sentinel-1A radar TOPS scans acquired between 3 October and 2 December 2014 were combined to create this image of ground deformation in Mexico City.

The deformation is caused by ground water extraction, with some areas of the city subsiding at up to 2.5 cm/month (red).

seom
scientific exploitation of operational missions

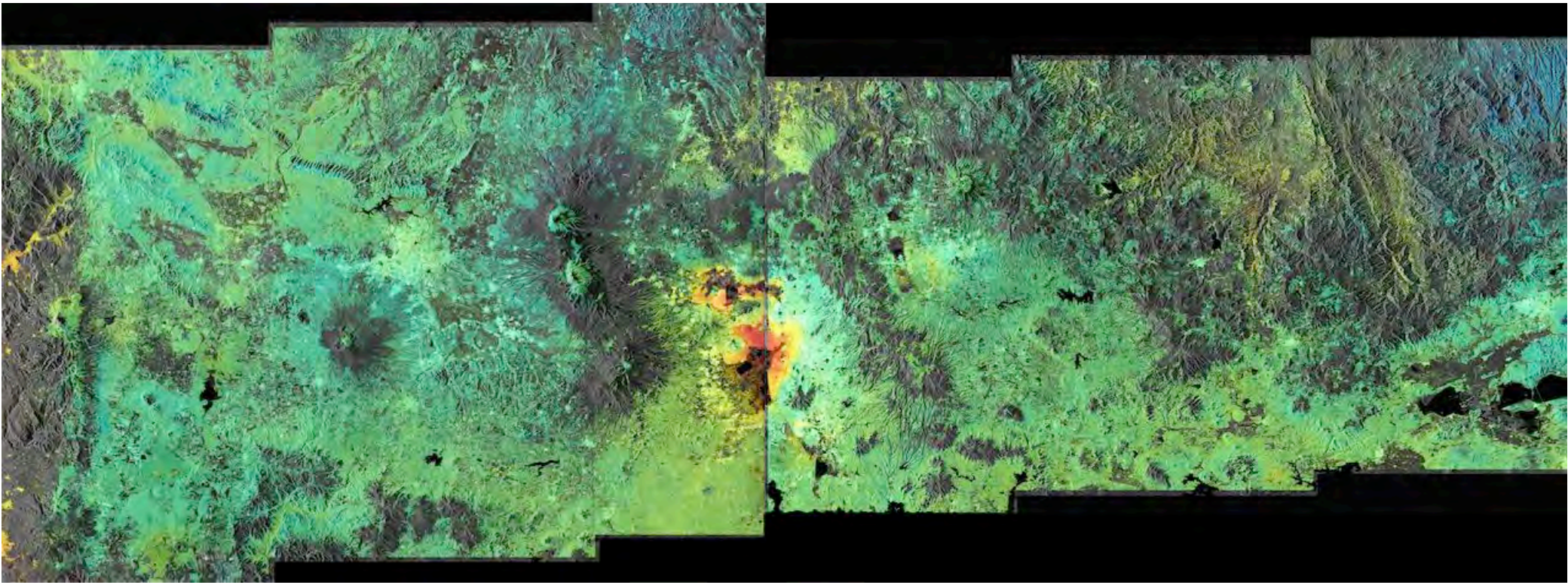
European Space Agency

‘Big Deformation’
Mexico City - Recap



European Space Agency

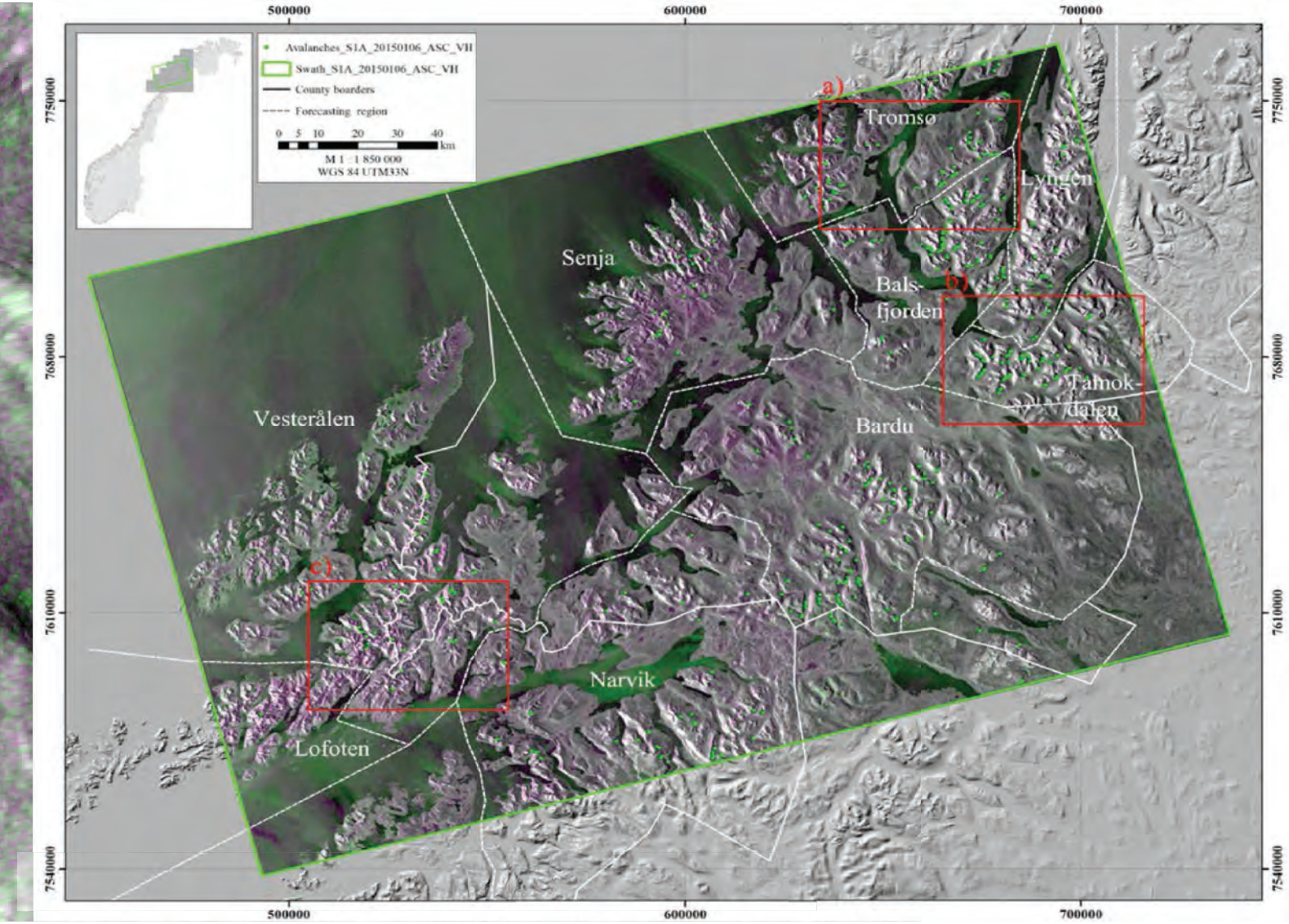
‘Big Deformation’
Mexico City - Recap

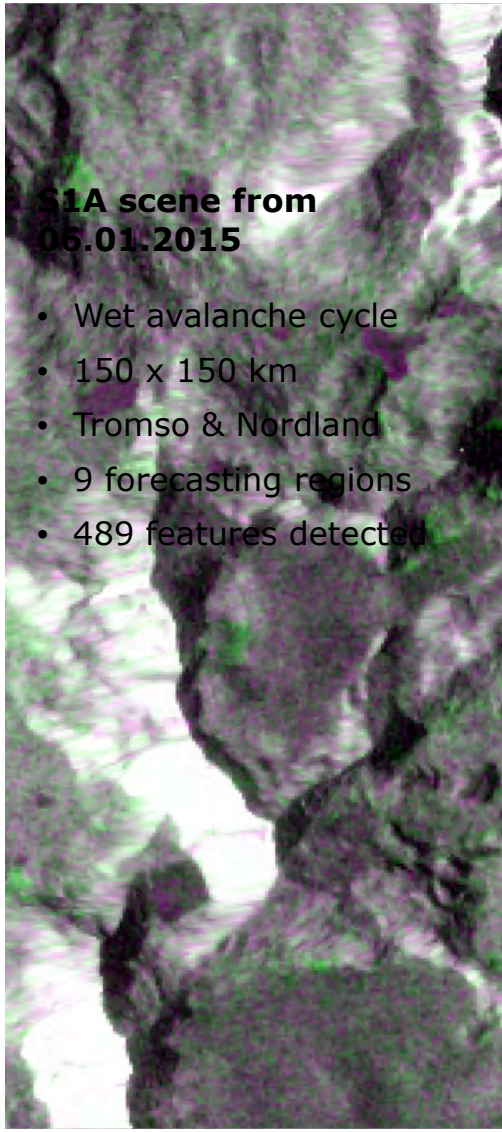


~500km (longitude)

European Space Agency

Sentinel-1 Avalanche Debris Detection
ESA Living Planet Fellowship "AVISENT" - NORUT

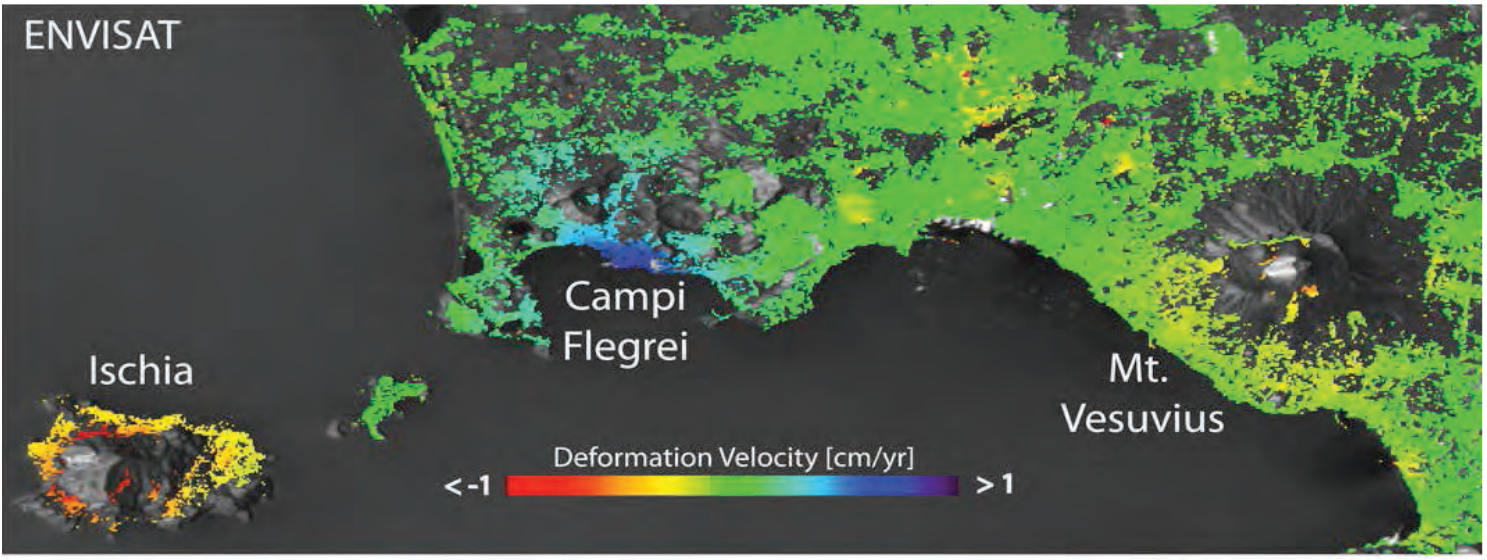


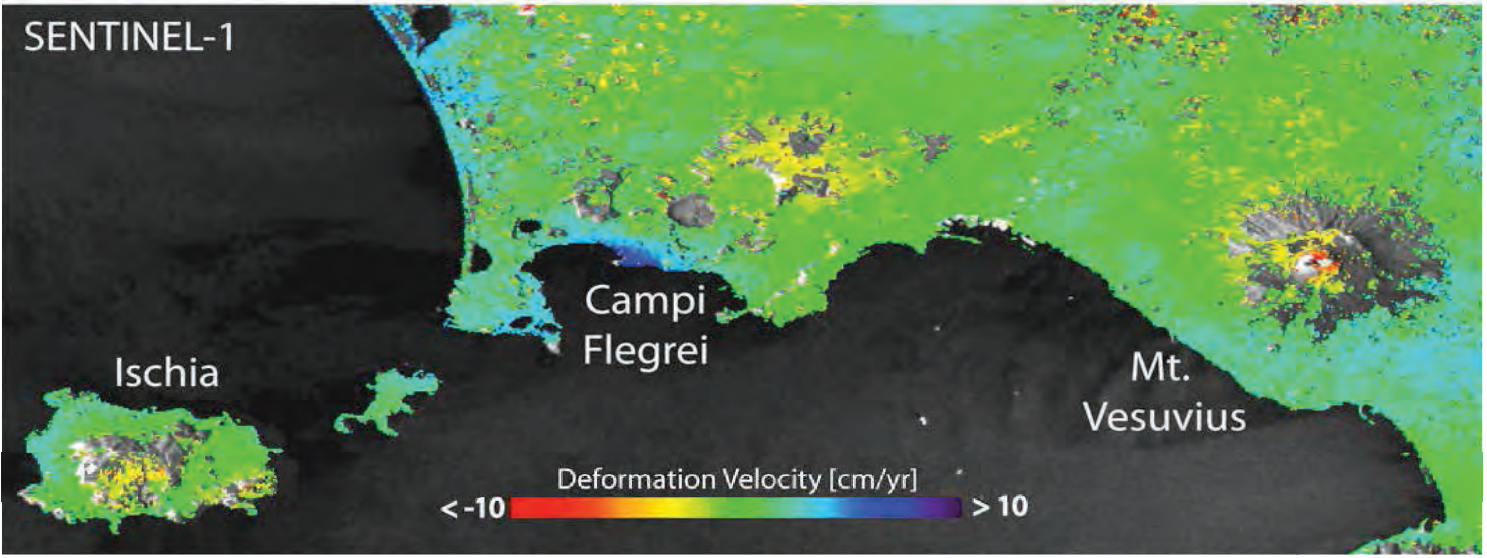


S1A scene from 06.01.2015

- Wet avalanche cycle
- 150 x 150 km
- Tromso & Nordland
- 9 forecasting regions
- 489 features detected

Phlegraean fields monitored by Sentinel-1 – Surface deformation velocity





TOP: based on Envisat data acquired in 2002-2010

BOTTOM: based on Sentinel-1A data acquired in 2014-2015.

Drastic improvement of the point density obtained through the Sentinel-1A InSAR analysis

Small BAseline Subset (SBAS) interferometry technique, based on small spatial and temporal orbital separation between the radar images

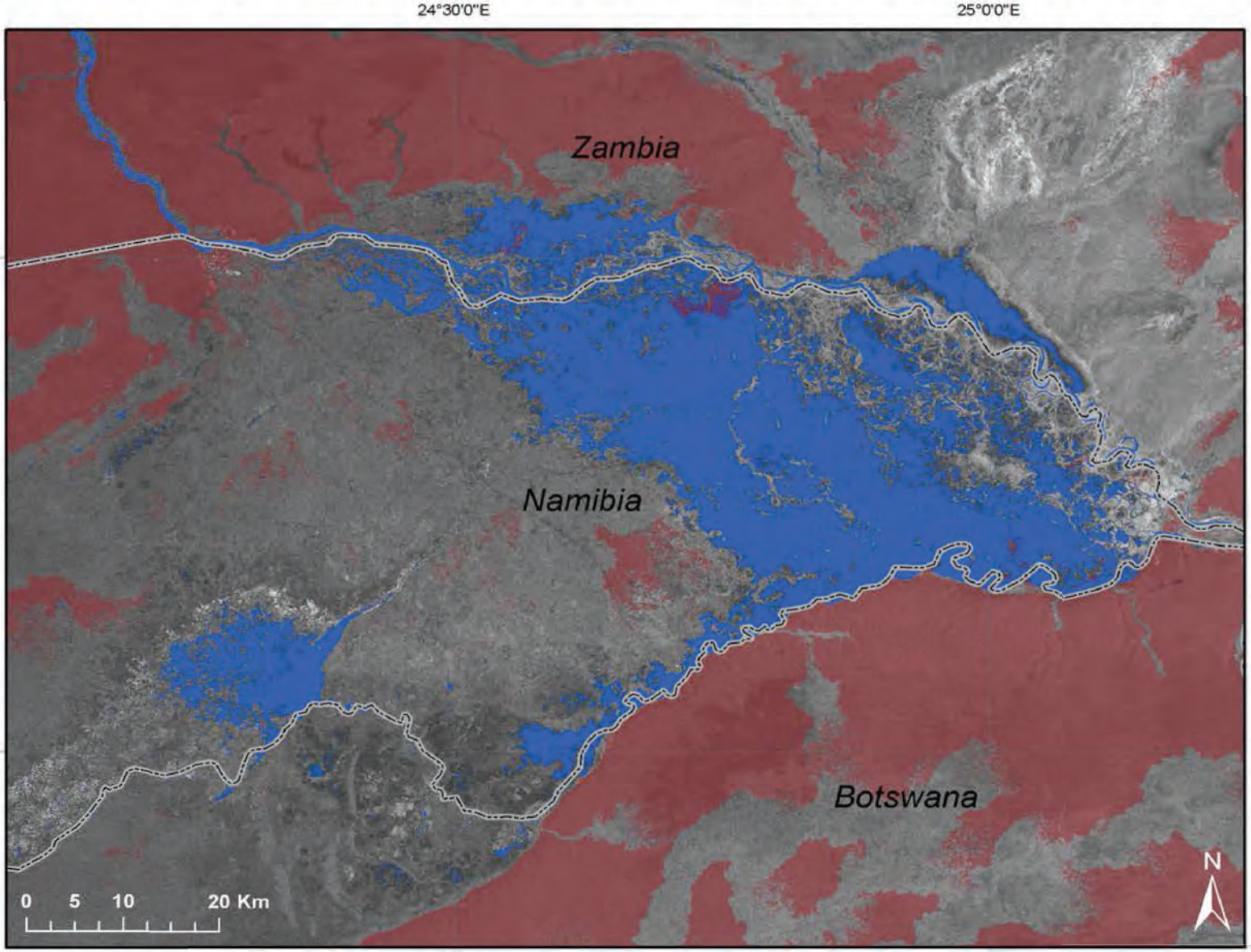
Courtesy CNR / IREA

Emergency Disaster Management

Flooding
Geohazards
Natural / Man-made Disasters
etc

Sentinel-1 Flood Monitoring of Caprivi Flood Plain, Namibia

TIGER NET



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

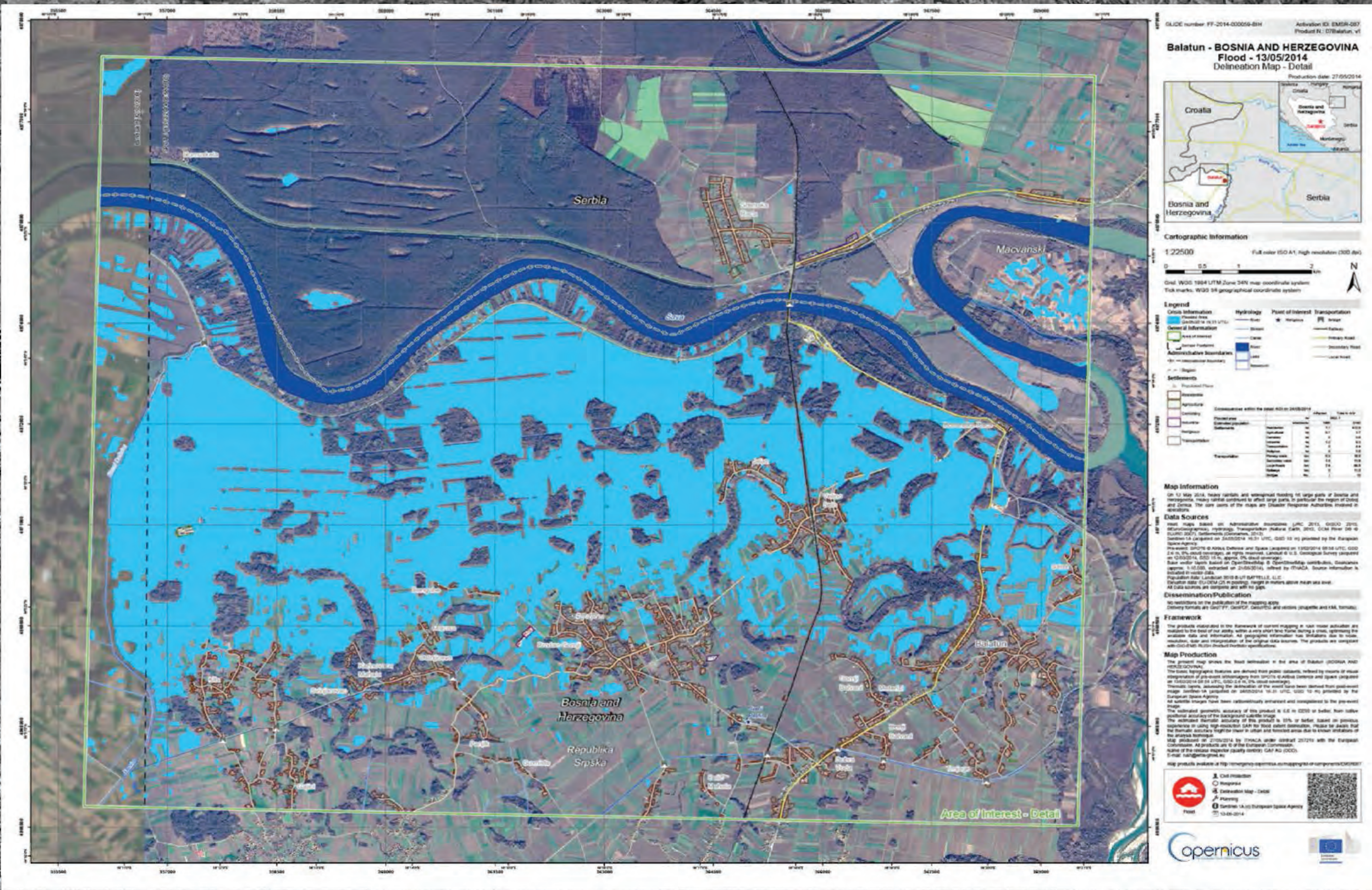
Department of Water Affairs

esa

GeoVille Group

DHI GRAS

TU WIEN GEO



Balatun - BOSNIA AND HERZEGOVINA
Flood - 13/05/2014
Delineation Map - Detail
Croatia
Bosnia and Herzegovina
Serbia
Cartographic Information
1:22500
Legend
Crisis Information
General Information
Hydrology
Point of Interest
Transportation
Settlements
Map Information
Data Sources
Dissemination/Publication
Framework
Map Production
Sava
Macvanski
Bosnia and Herzegovina
Republika Srpska
Balatun
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.

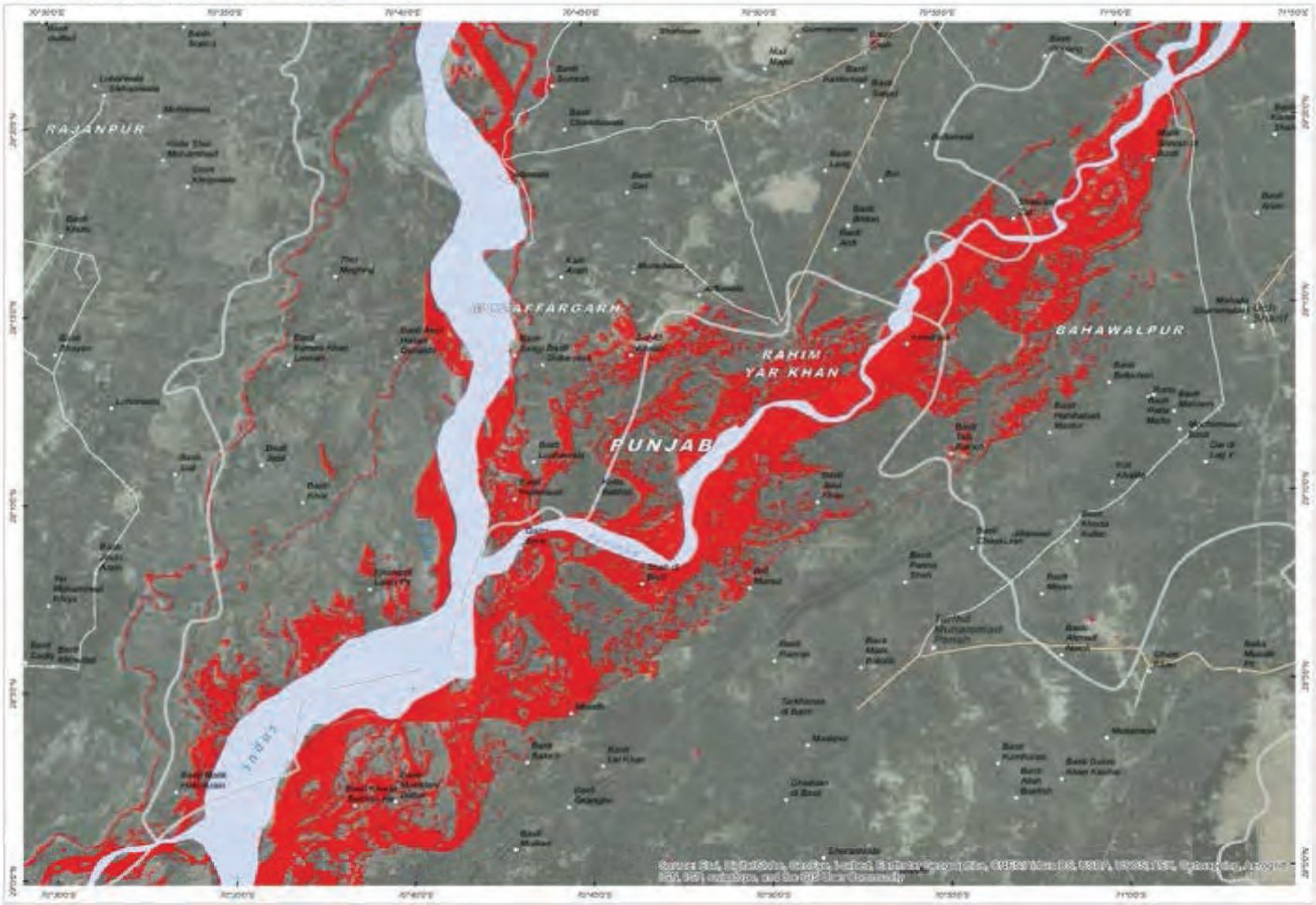
Disaster coverage by the International Charter 'Space and Major Disasters'. For more information on the Charter, which is about

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

Km

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

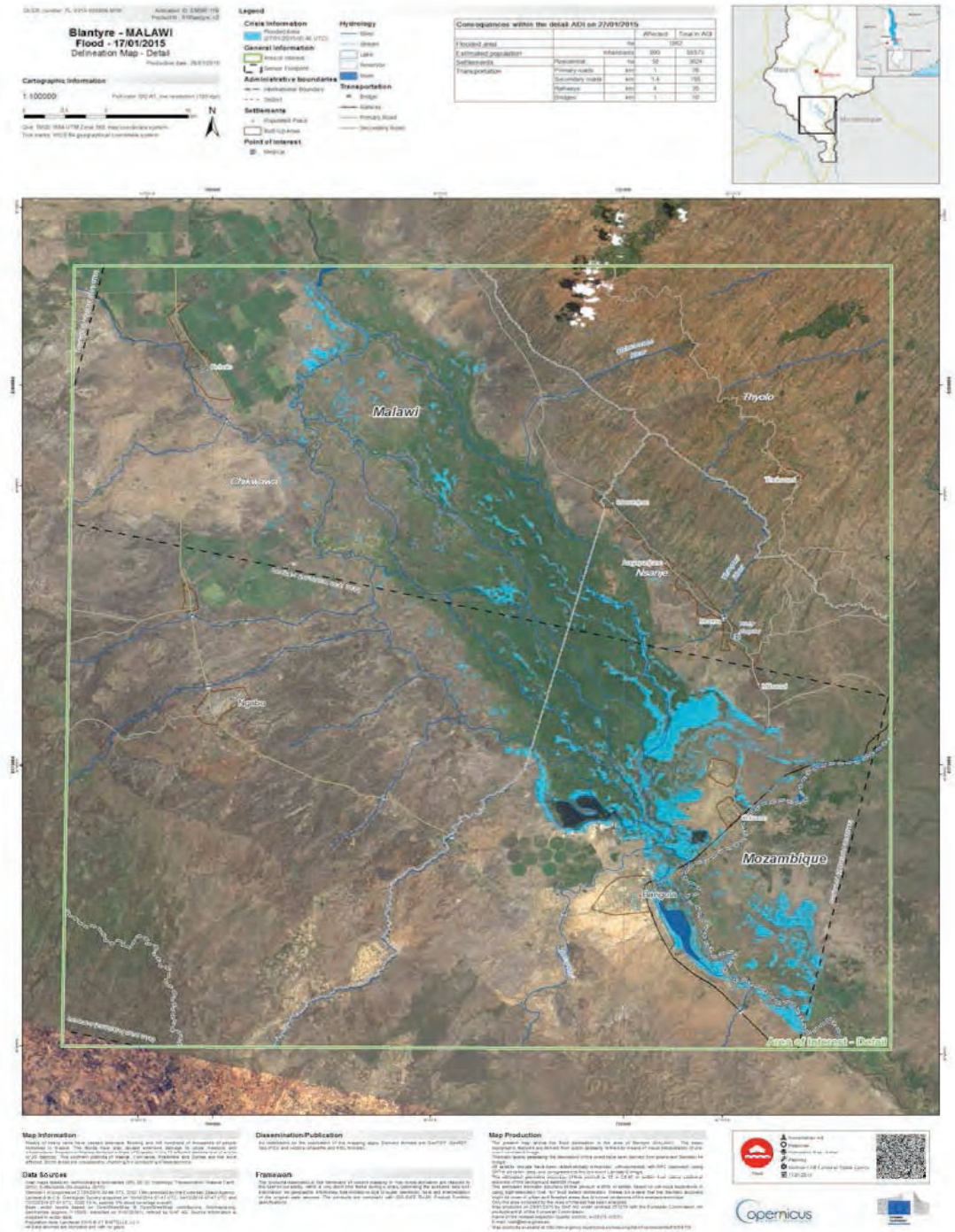
Coordinate System: WGS 1984 UTM Zone 42N
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

unitar

UNOSAT

Contact information: unosat@unitar.org
24/7 Hotline: +41 76 487 4088
www.unitar.org/unosat

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



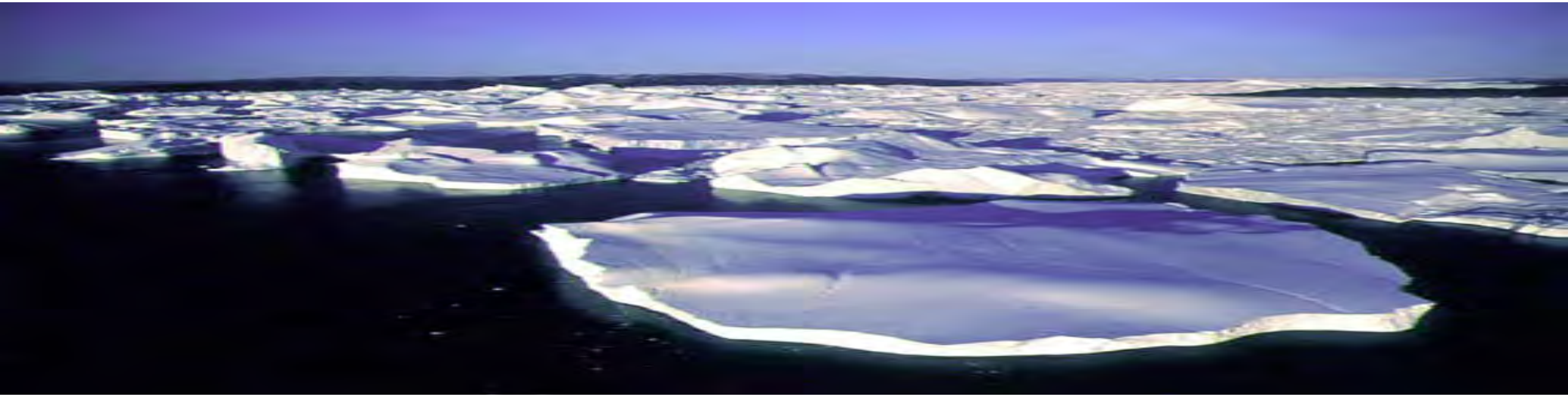
Flood in Malawi

January 2015 -

Flood delineation map based on Sentinel-1 data

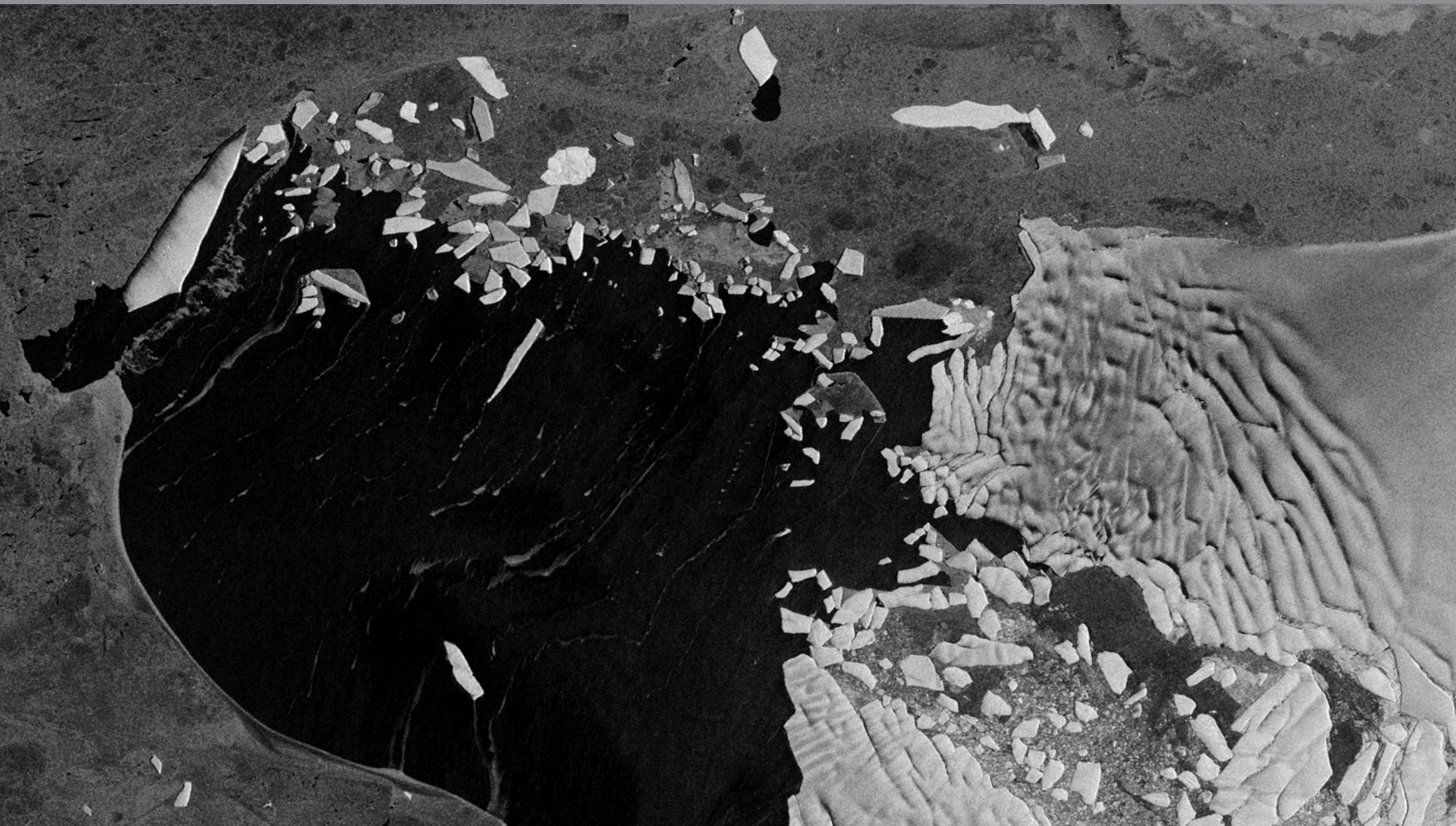
Copernicus Emergency Management Service

Ice / Cryosphere / Climate



Sea Ice / Iceberg
Ice Sheets
Polar Monitoring
Snow

Thwaites Glacier, Antarctica

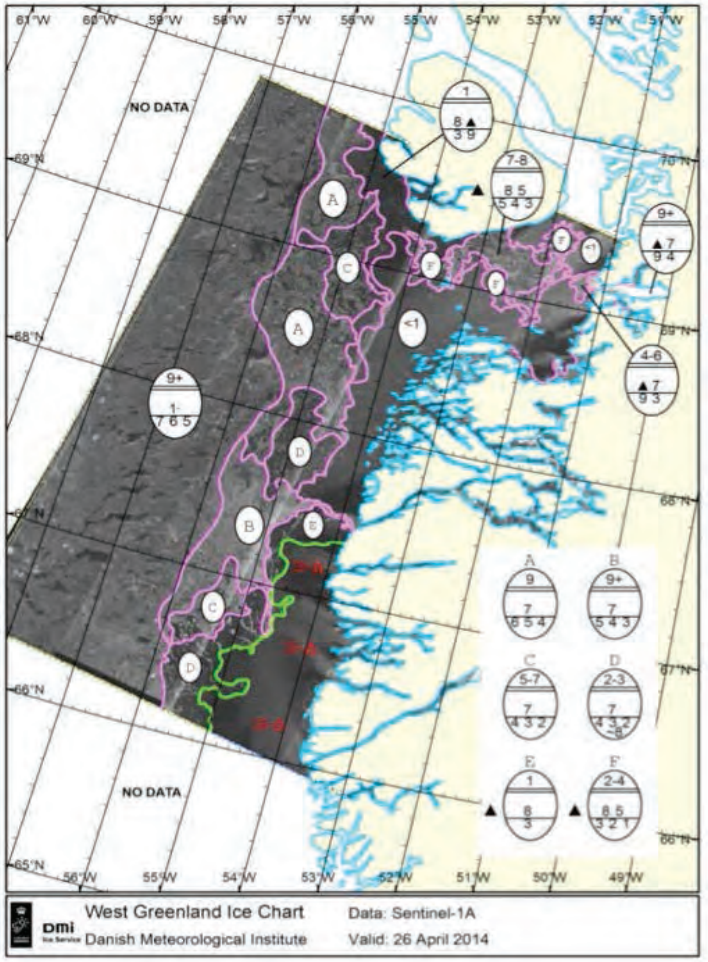


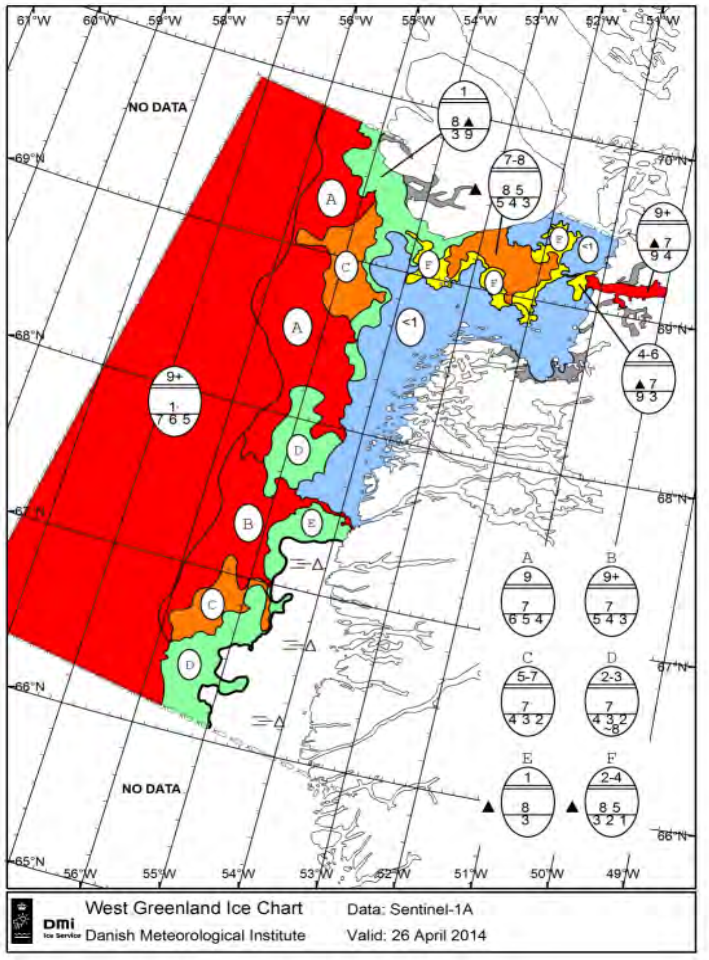
FIRST DEMONSTRATION OF SEA-ICE APPLICATIONS WITH SENTINEL-1A DATA

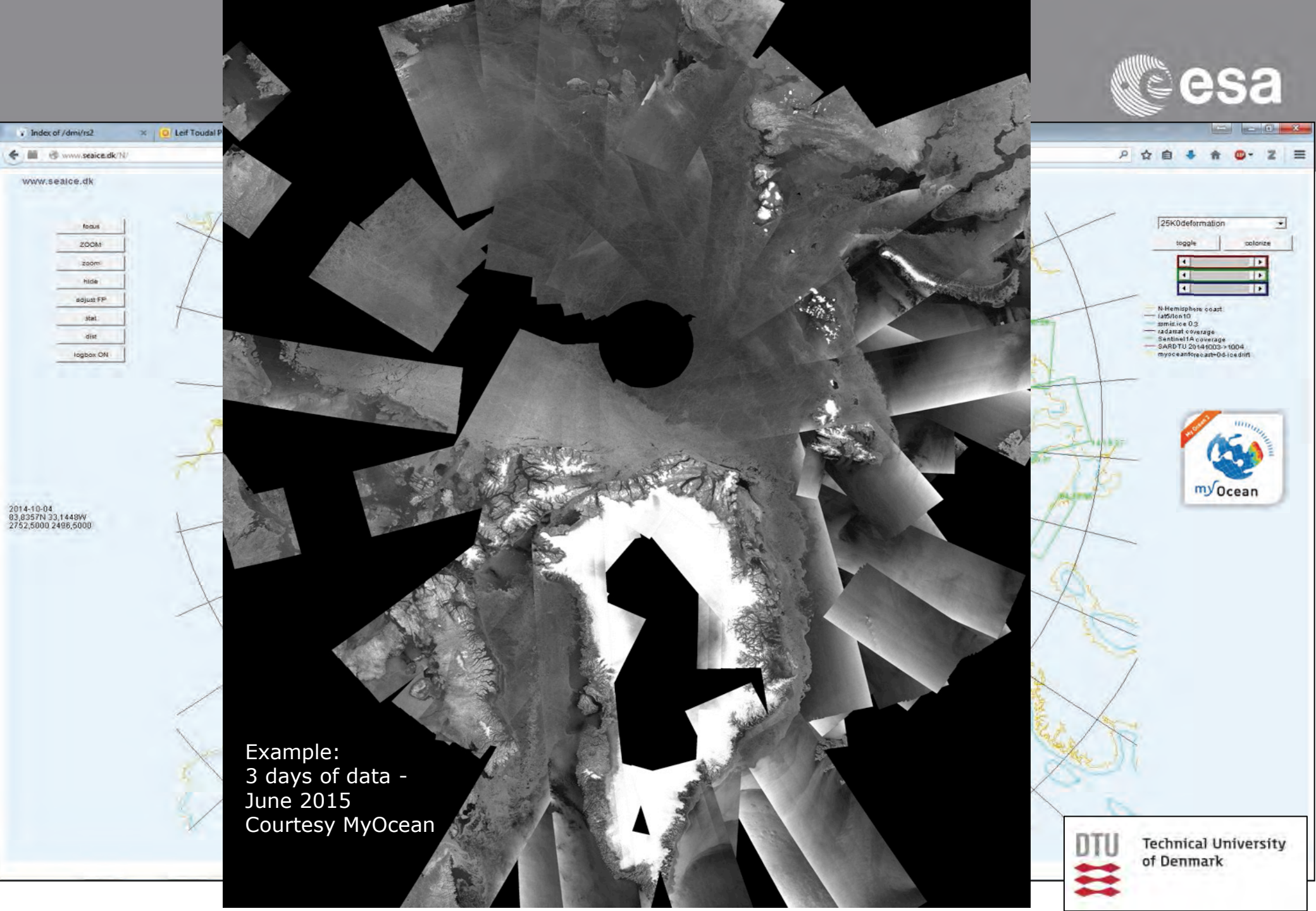
The first Sentinel-1 sea-ice chart

Courtesy of DMI, MyOcean

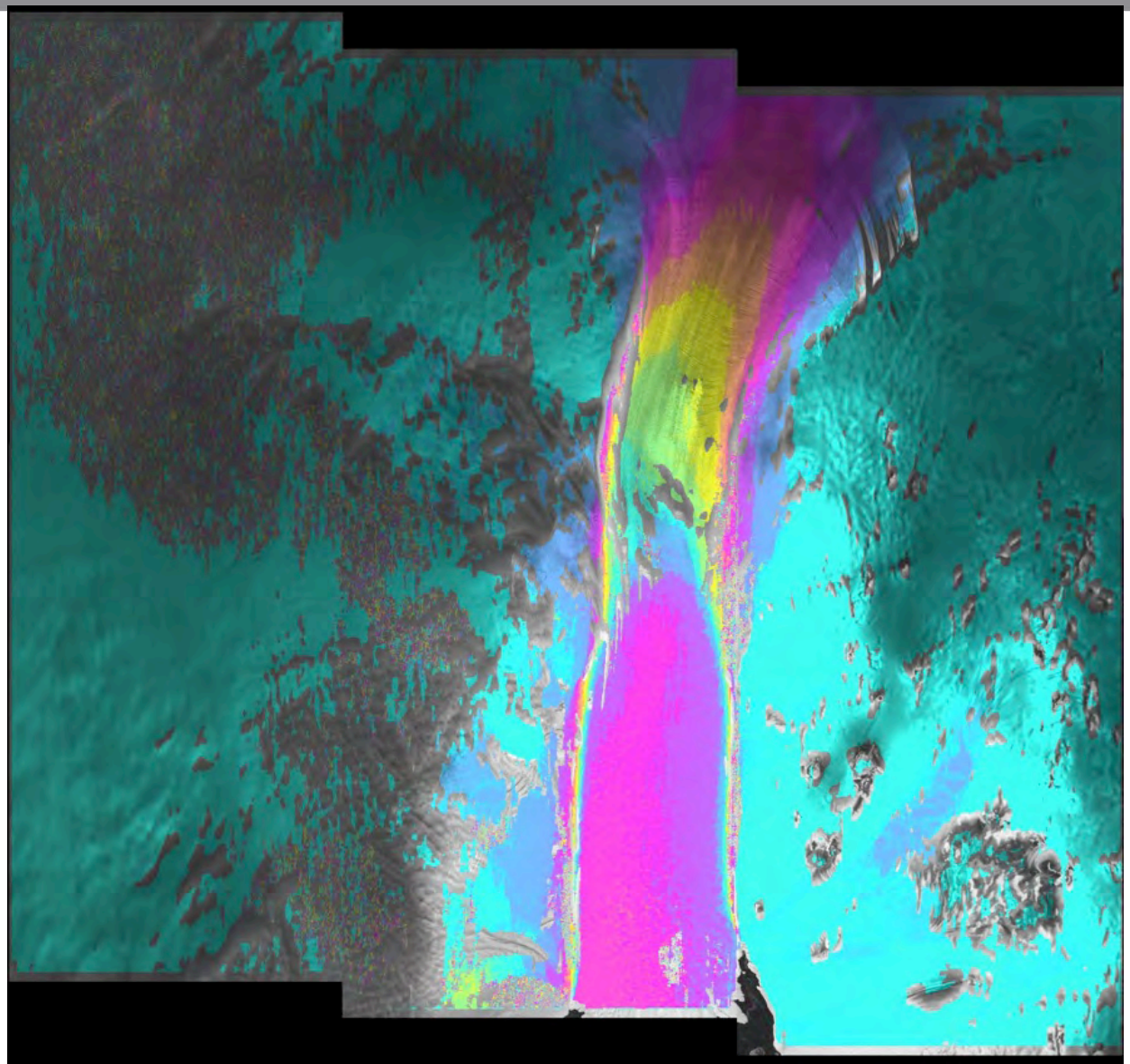
S1A image20140426 10:10 UTC, EWS, HH






esa
www.seaice.dk
focus
ZOOM
zoom
hide
adjust FP
stat
dist
logbox ON
2014-10-04
83,8357N 33,1448W
2752,5000 2496,5000
25K0deformation
toggle
colorize
N-Hemisphere coast
lat5/lon10
ssmis.ice 0.3
radarsat coverage
Sentinel1A coverage
SARDTU 20141003->1004
myoceanforecast+0d-ice drift
myOcean
Example:
3 days of data -
June 2015
Courtesy MyOcean
DTU
Technical University
of Denmark

Pine Island Glacier Ice Velocity



Ice velocity map made of 2 Sentinel-1A images acquired on:
- 3 March 2015
- 15 March 2015

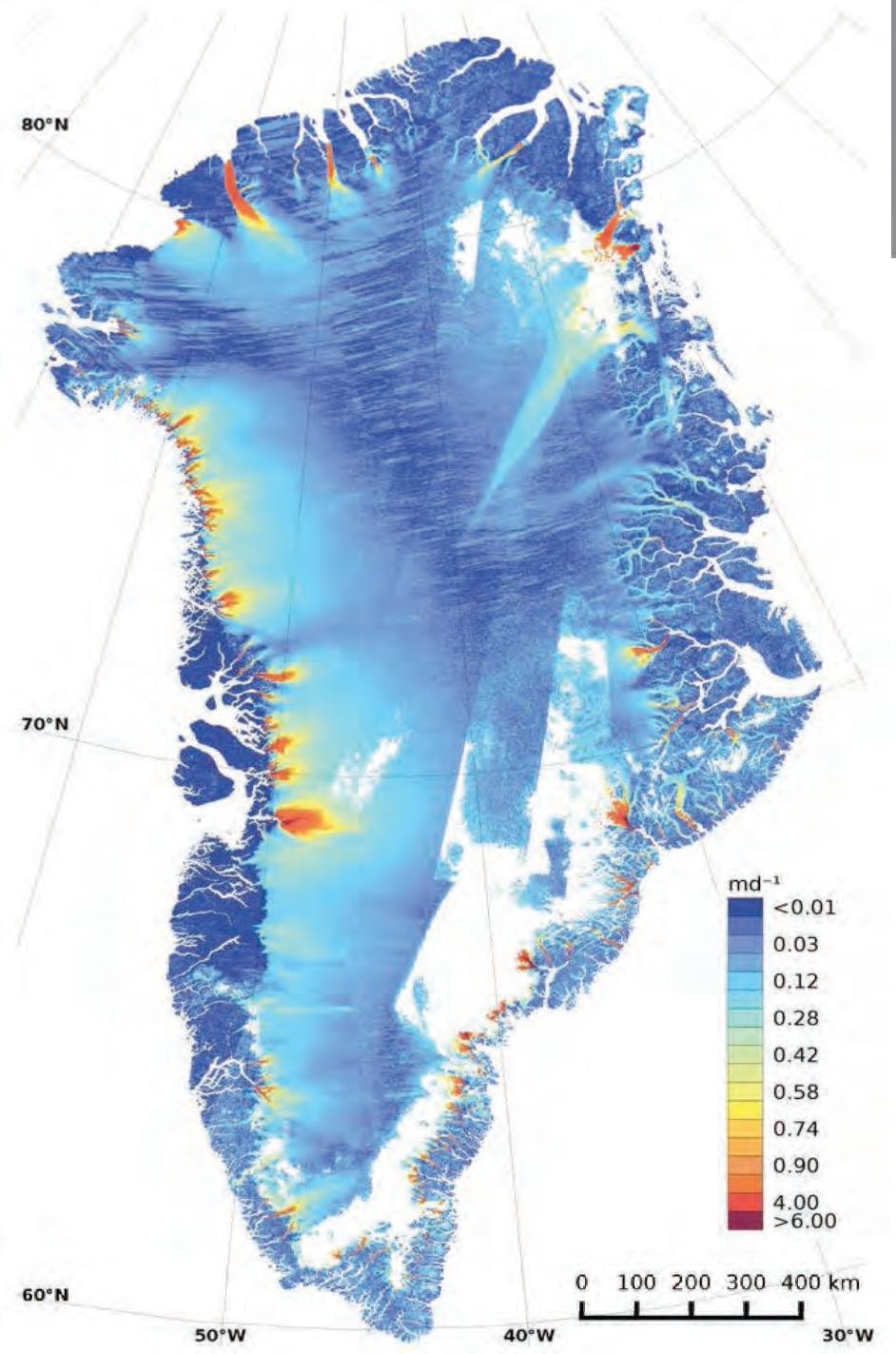
100

IV (m)

0

Courtesy University of Leeds

First Greenland Ice Sheet Ice Surface Velocity Map based on Sentinel-1 data



Based on SLC products from Sentinel-1 Interferometric Wide Swath mode

Period: Jan-Mar 2015
(some scenes from Oct-Dec 2014)

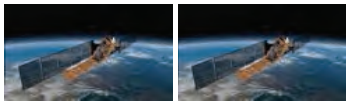
~ 800 scenes
~ 25 000 bursts
~ 2.7 TB of SLC data

Offset tracking technique

Courtesy ENVEO IT Gmbh / ESA CCI Ice Sheets Project

Operational Qualification phase leading to the Routine Operations

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

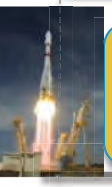


S1 Full Operational Capacity

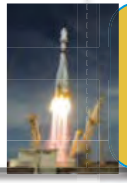
S1B Operational qualification

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

S1B Launch
March-May 2016

S1 Mission ROR
~ end 2016

Sentinel-2 Mission

Sentinel-2 in a nutshell

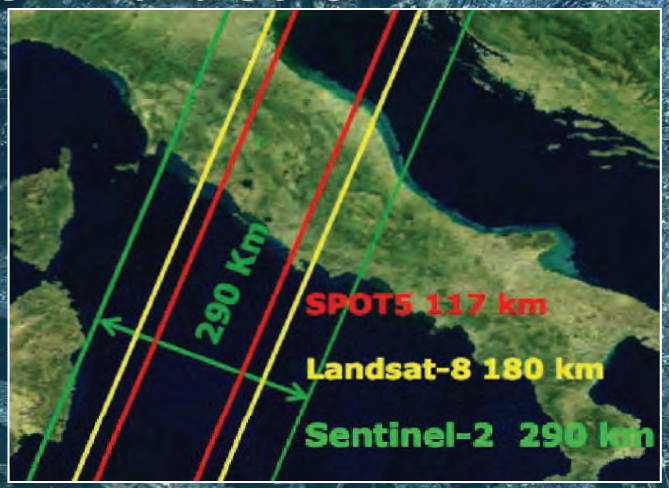
13 VIS/NIR/SWIR spectral bands: 3 new bands in the red edge tailored to vegetation monitoring

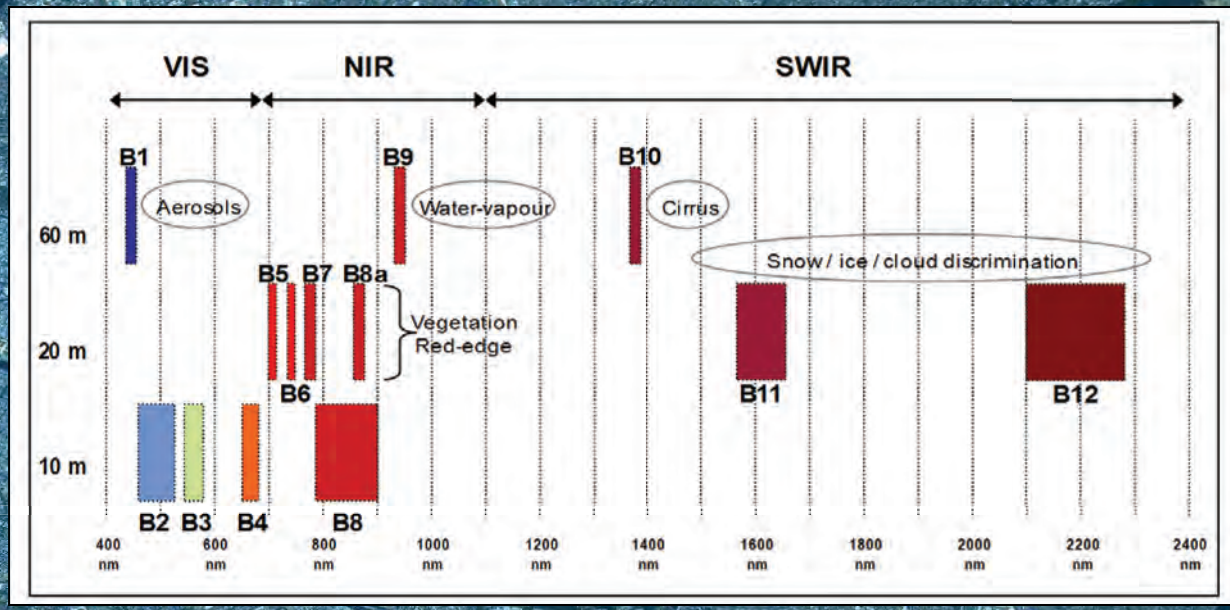
Spatial resolution: 10m / 20m (60 m for atmosphere calibration)

Swath: 290 km

2 spacecraft on same orbit, 180° apart: 5 days revisit at equator

Systematic coverage between 84°N and 56°S





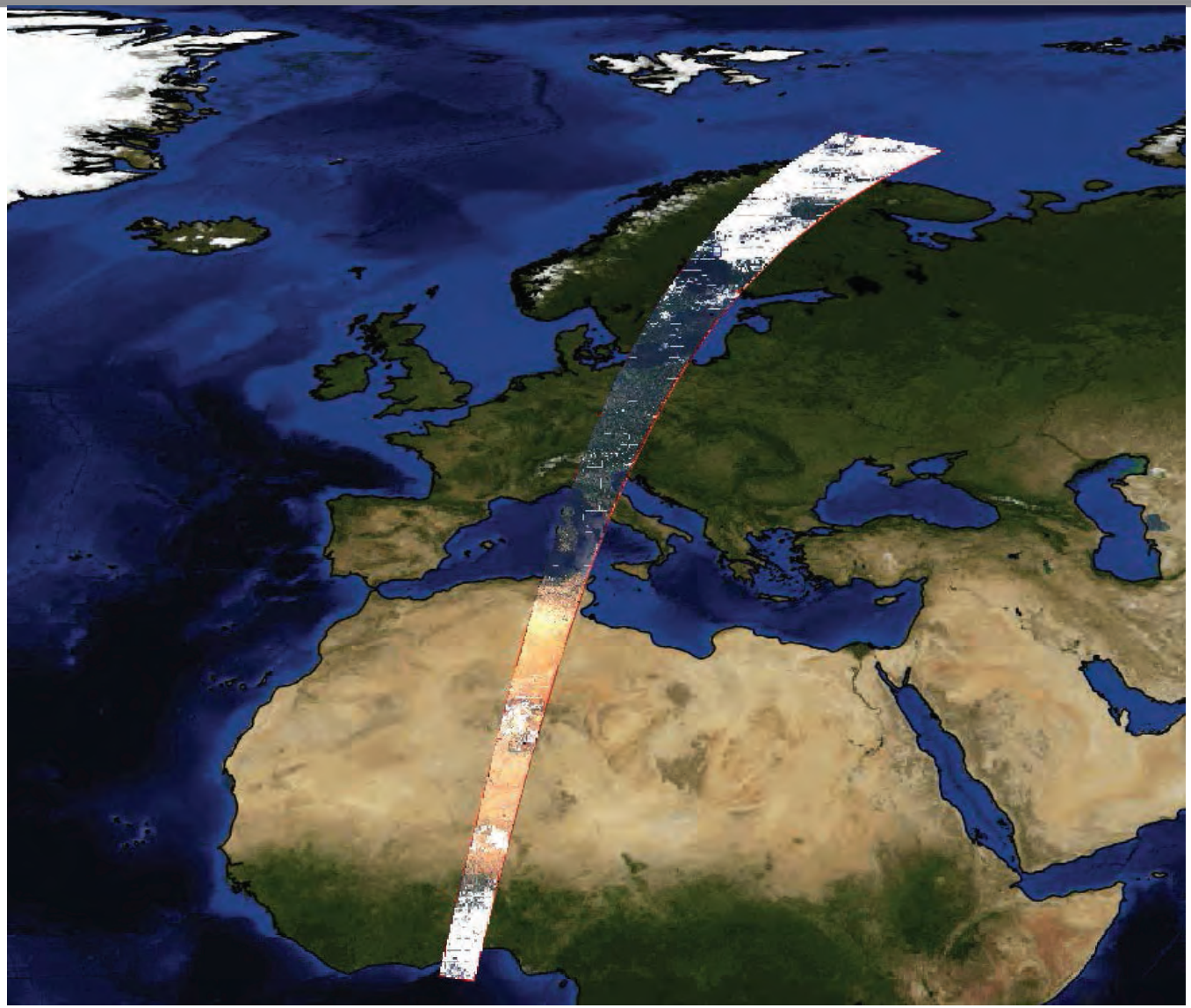
Capacity is key: systematic acquisition

4 July 2015: Longest orbit

8000km
from Sweden to Togo

±30% cloudy

<u>BUT:</u>
70% cloud-free =
2.3 Mio km2
successfully mapped in
20 minutes!



Sentinel-2 DOSTAG 4 Sep 2015

Irrigation and fires
in Tabuk, Saudi Arabia

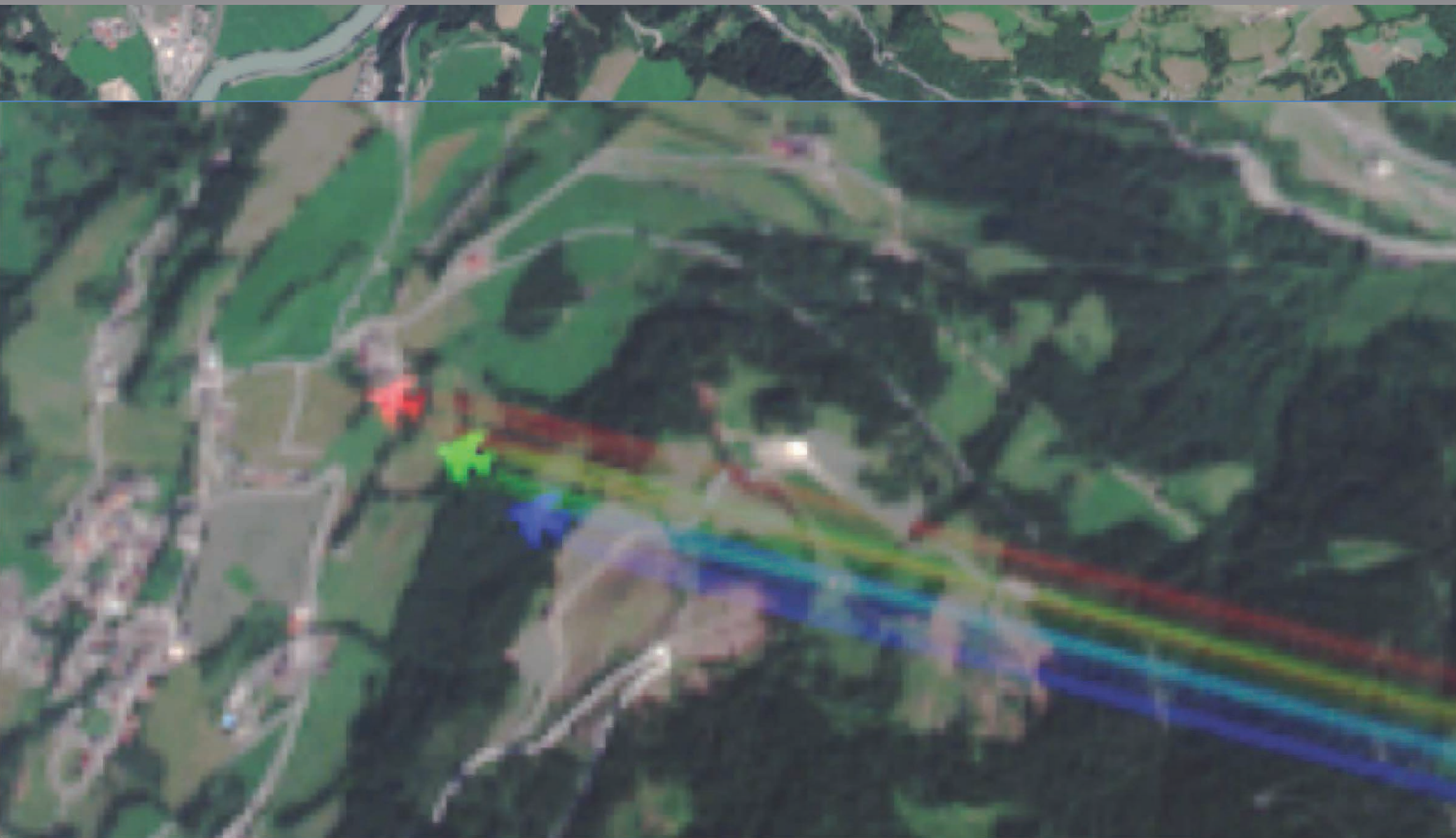
Sentinel-2 DOSTAG 4 Sep 2015

Urban Infrastructure and Motion
in Venice/Italy

Sentinel-2 DOSTAG 4 Sep 2015

European Space Agency

Spectacular details: airplane over the Alps

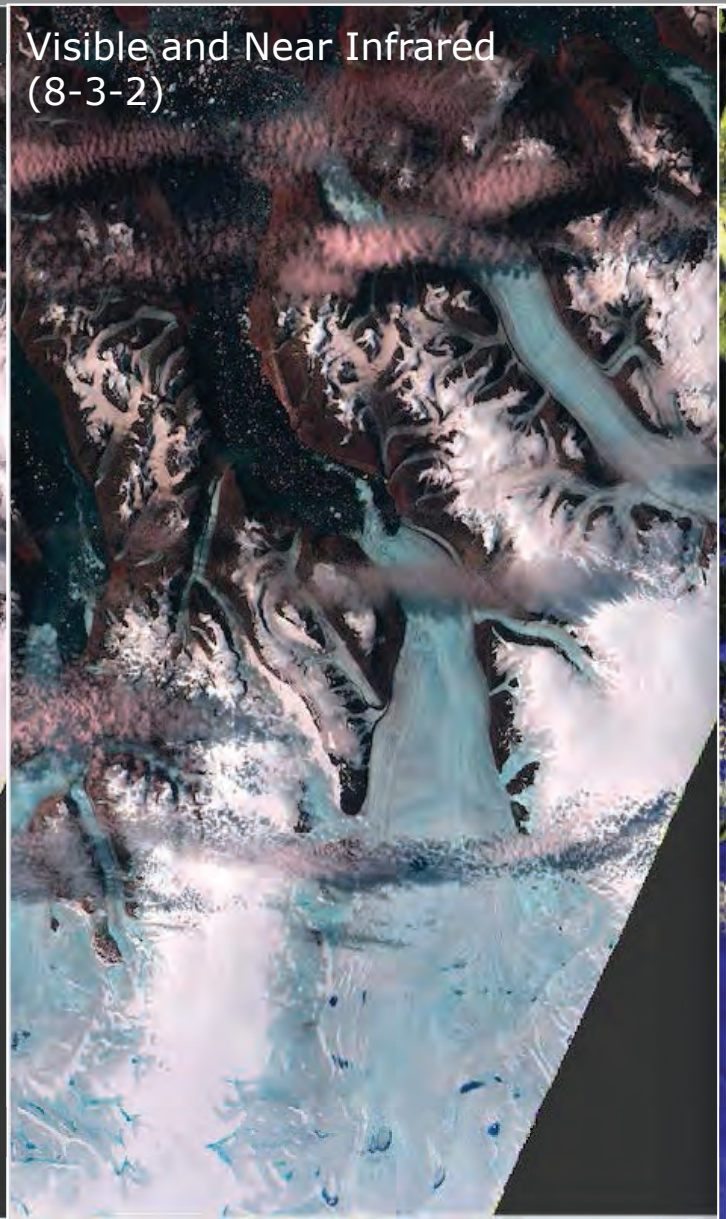


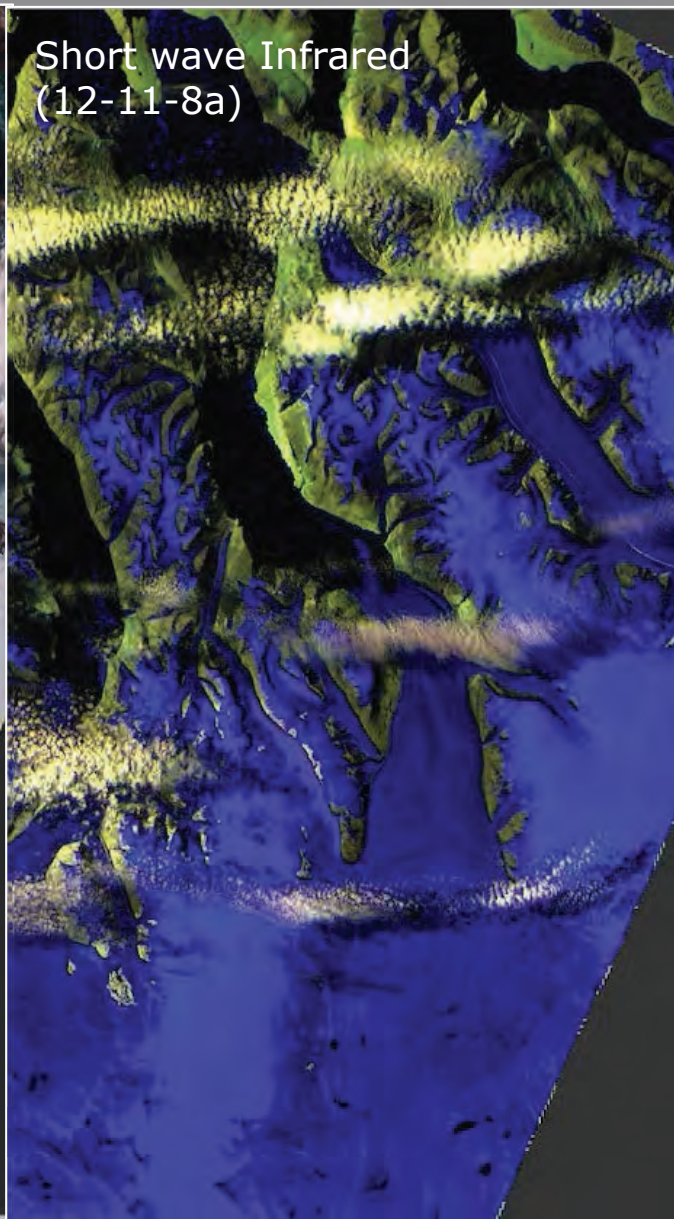
Athens/Orchomenos: 13 spectral banc

4-3-2, 8-3-2, 12-11-8a and 5-6-7

DOSTAG 4 Sep 2015

Greenland: Disko Bay
13 Spectral bands make the difference

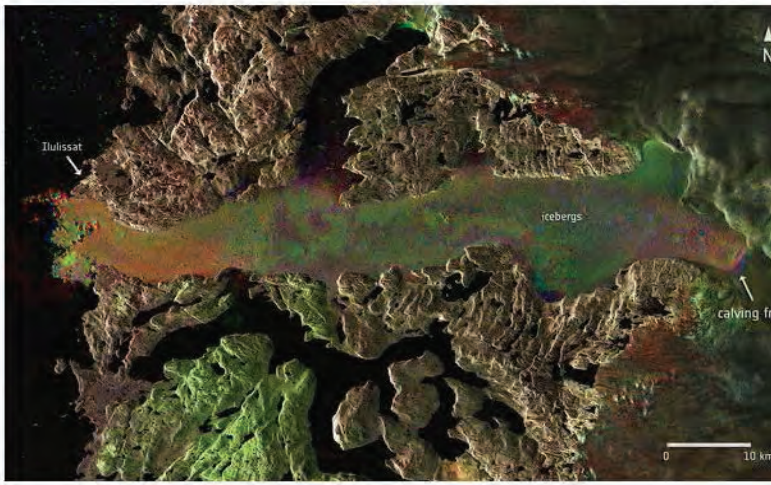




Sentinel-2 DOSTAG 4 Sep 2015

Calving icebergs (Greenland

ESA | OBSERVING THE EARTH | COPERNICUS | SENTINEL-1



Chasing glacier retreat

CHASING ICE

21 August 2015 Satellite images show that the fastest moving glacier in the world shed a chunk of measuring around 12.5 sq km this week – one of the most significant calving events on record.

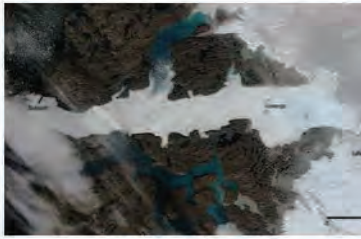
Radar images from Sentinel-1A captured the Jakobshavn glacier in western Greenland before and a the event, which took place between 14 and 16 August.

Comparing images taken on 27 July, and 13 and 19 August, the new face of the glacier has been pushed inland by several kilometres to what appears to be its furthest easterly location since monitoring began in the mid-1880s.

The image time series suggests that between 27 July and 13 August, the glacier advanced westwa before the calving caused rapid retreat of the ice front to its position on 19 August.

It is estimated that the glacier lost a total area of 12.5 sq km. Assuming the ice is about 1400 m d this equates a volume of 17.5 cubic km – which could cover the whole of Manhattan Island by a lay of ice about 300 m thick.

The history of this last calving event is also revealed in images taken by Sentinel-2A on 6 and 16 August.

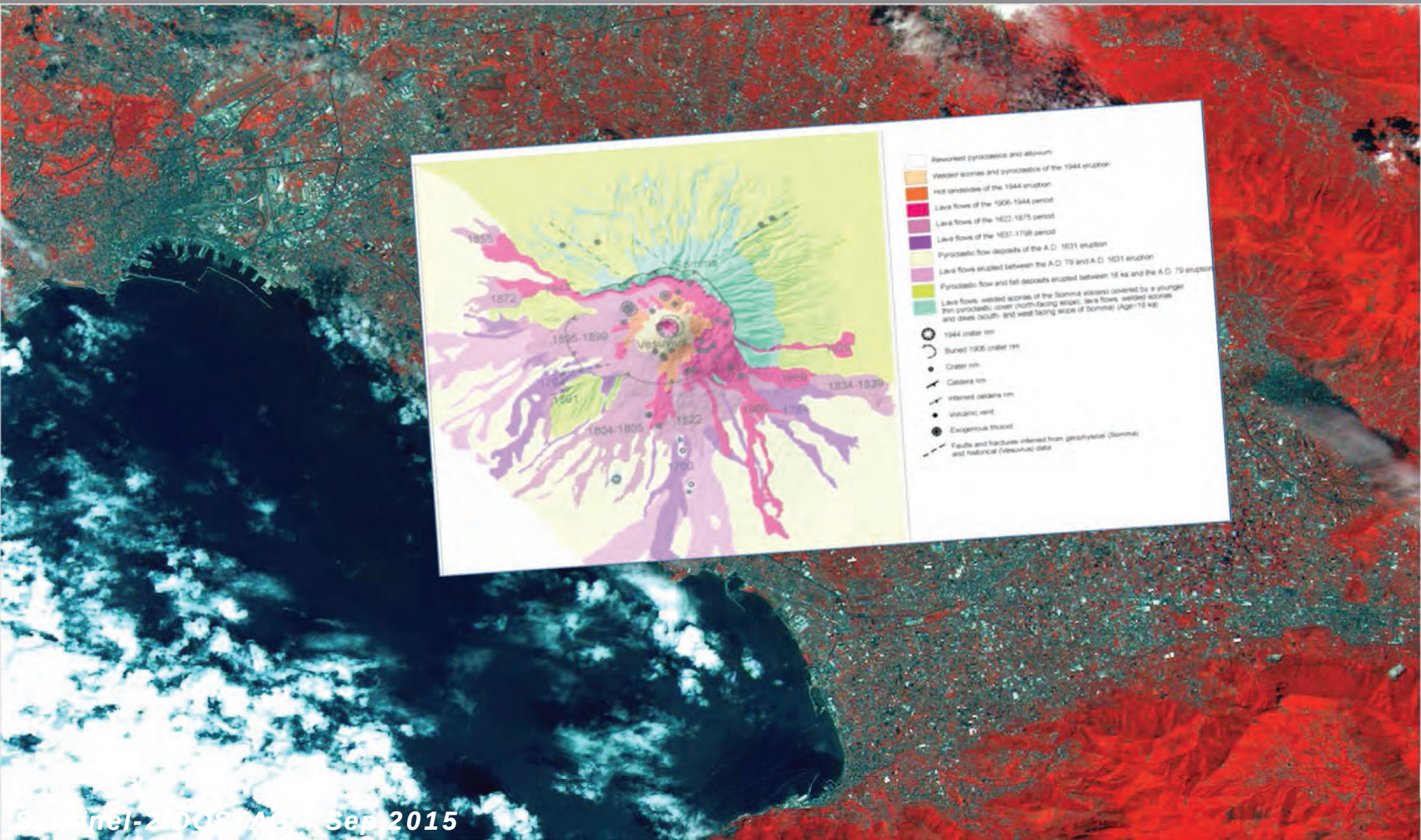


Jakobshavn glacier calving

Jakobshavn glacier drains 6.5% of the Greenland ice sheet, producing around 10% its icebergs. This amounts to some 35 billion tonnes of ice that calve every year.

Other similar events have been documented where the glacier parted with 7 sq km of ice, both earlier this year and back in 2010.

Hazards: Vesuvius & Naples



Danube River Boat Jam – discovered by S1 and S2

Danube river traffic jam monitored with Sentinel satellites

10 Aug 2015, 20:00 • ENGLISH
218 views

The first two Sentinel satellites of the European Space Agency provided essential information for the monitoring of navigation along the Danube, which had its water levels receding considerably under the effect of the heat wave that gripped the country, informs a Romanian Space Agency (ROSA) release to AGERPRES.

Luisiana BIGEA / AGERPRES PHOTO

Using data from the two satellites, ROSA helped the Lower Danube River Administration spot a cluster of vessels jammed up near the town of Zimnicea, next to the river bank.

"About 120 vessels are now blocked on the Danube, 100 of which are not equipped with an Automatic Identification System," said Ion Nedelcu, director of the Romanian Space Agency's environmental and safety projects, cited in the release.

He said that "the main purpose was to identify the ships that are not equipped with such a system, and that it's particularly in these cases that the Sentinel images have proved extremely useful."

Sentinel-1A was the first satellite launched under the European Commission's Copernicus environment-monitoring programme, in April 2014; its all-weather, day-or-night radar imagery is particularly useful for maritime surveillance and ship safety.

As the radar regularly covers the entire Europe on a swath width of 250 km, it allows such critical events to be observed.

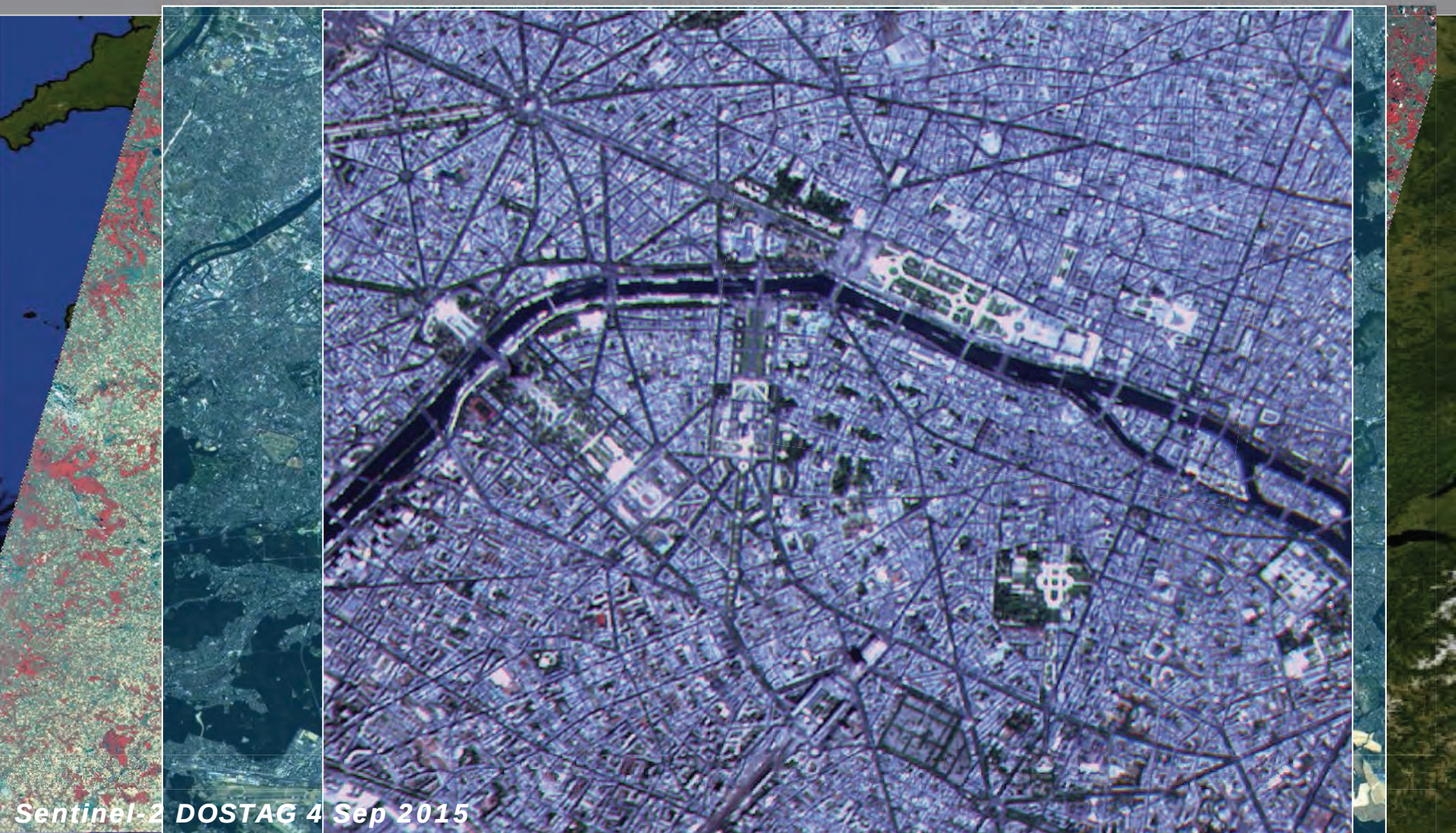
The younger Sentinel-2A has been in orbit only since June 23, with it multispectral camera supplying optical images of Earth's land and water bodies.

"We are pleased that we were able to support the request from Romania in the middle of the satellite's commissioning phase," said Bianca Hoersch, ESA's Sentinel-2 Mission Manager.

Pierre Potin, ESA's Sentinel-1 Mission Manager added that "the combined use of Sentinel-1 and Sentinel-2 opens new large-scale monitoring capabilities."

The satellites will continue to monitor the situation in the coming days. AGERPRES

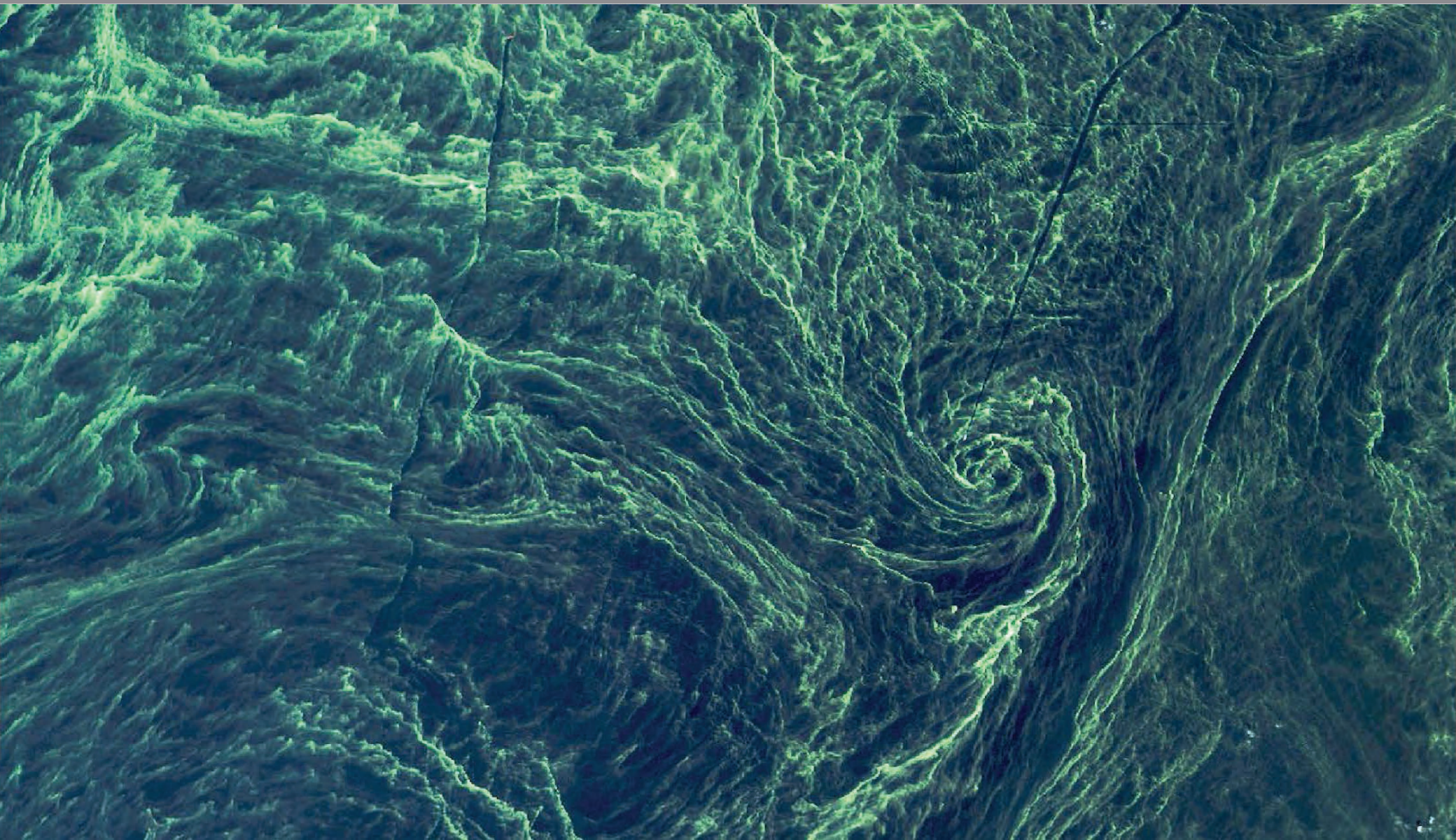
Enjoy the swath - Paris!



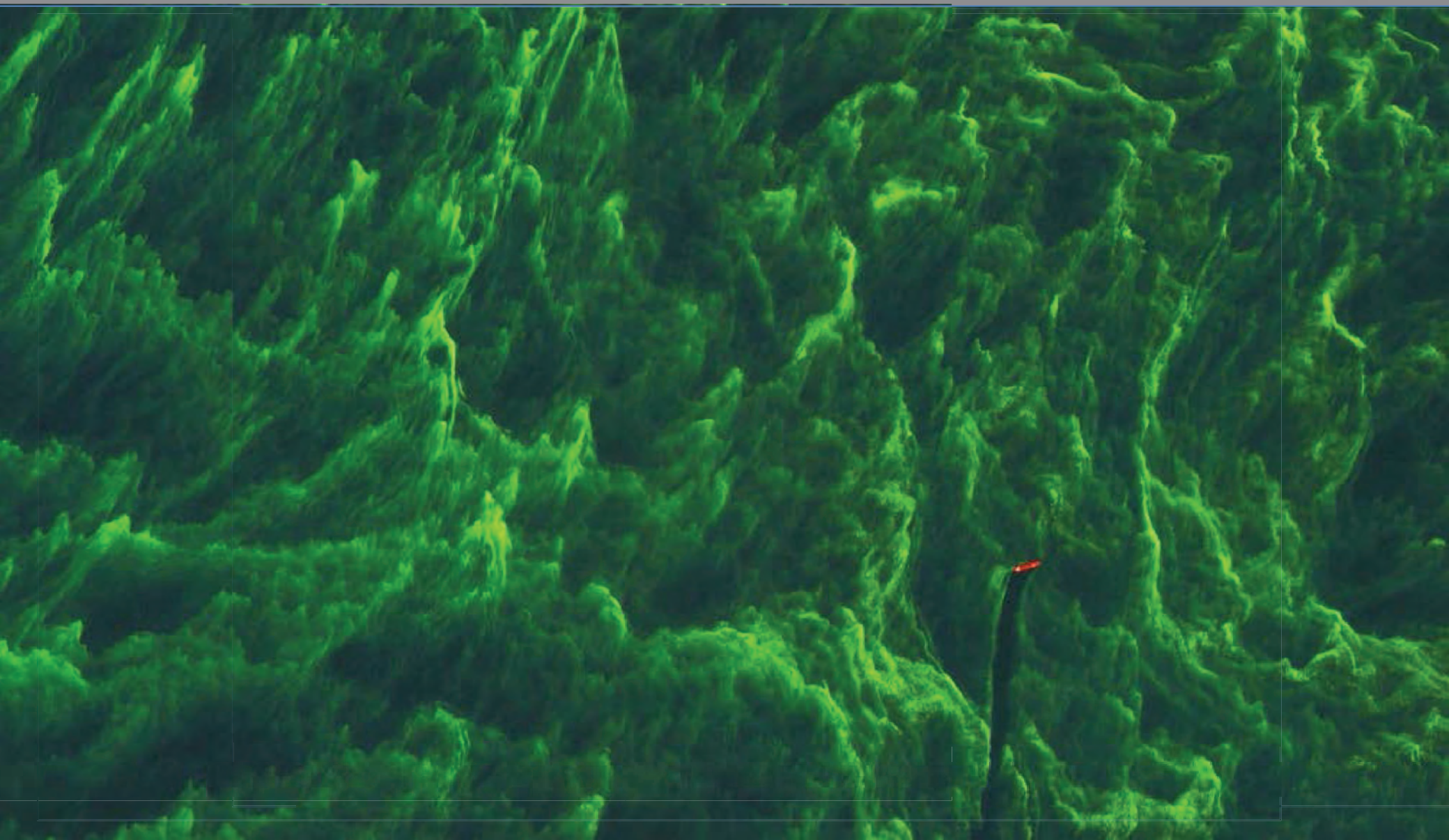
Sentinel-2 DOSTAG 4 Sep 2015

Baja California: dry land vs irrigated land (NIR-VIS), land discharge (red-edge) along a border

S2 & closed seas: Algal bloom in the Baltic Sea, august 2015



Stunning details: fronts and filaments of ocean biogeochemistry slashed open by shiptracks, wind blown structures…



Sentinel-2 Red Sea Coral Reefs - True Colour Saudi Arabian coast Gayal.jpg

Sentinel-2 Western Greenland glaciers 1

Sentinel-2 Western Greenland glaciers 2

Milestones reached…

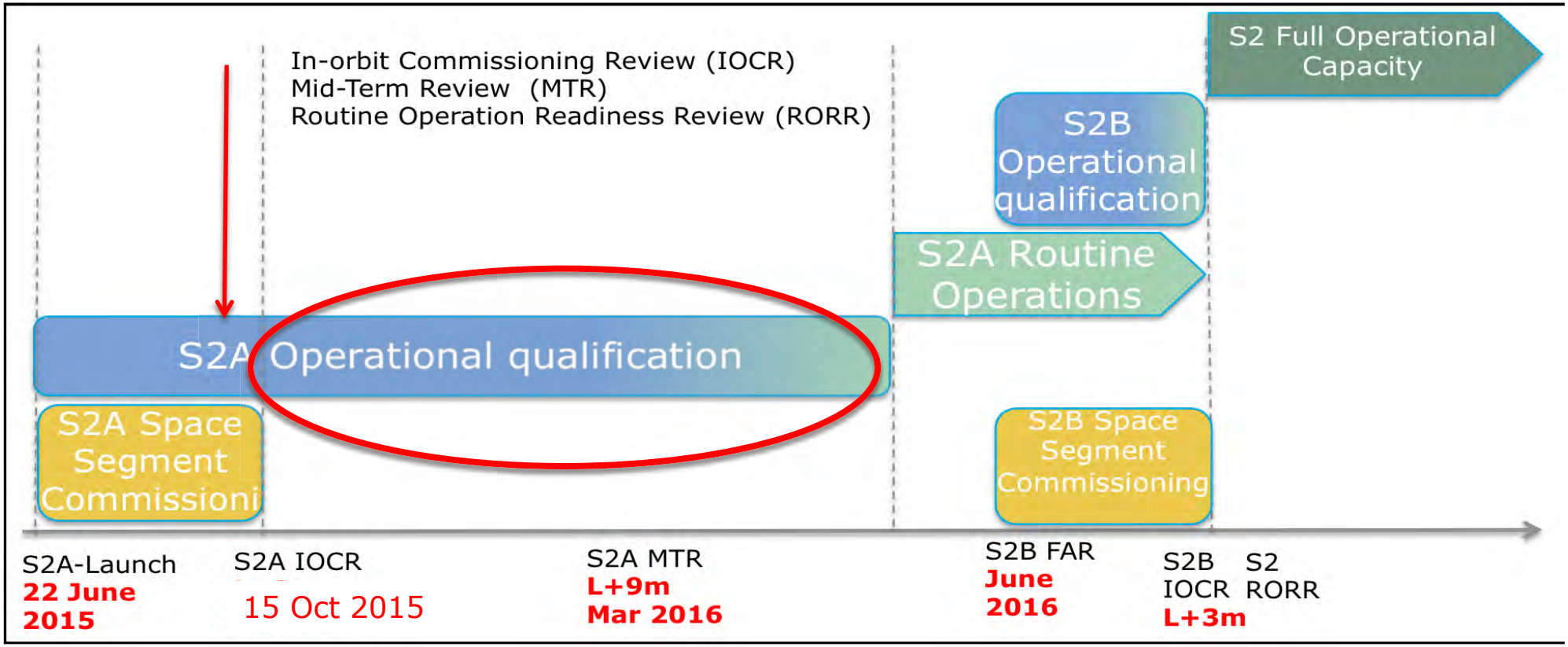
1. First image 4 days after launch
2. First sample published on SciHub 3 weeks after launch (pre-qualified)
3. First key user event at IGARSS'2015/Milano one month after launch (pre-qualified)
4. More sample published 18 Aug 2015 (pre-qualified)
5. Data quality steadily improving, currently IPF version 01.03

S2 nominal observation plan in Routine Operations

Baseline in full operations is systematic acquisition of:

- ✓ All land surfaces (-56° and +84° latitude);
- ✓ Major (greater than 100 km^2 size) and EU islands;
- ✓ Coastal (20km off the coast)
- ✓ inland waters, Mediterranean Sea and all closed seas;

Sentinel-2 Phases until Full Operational Capacity

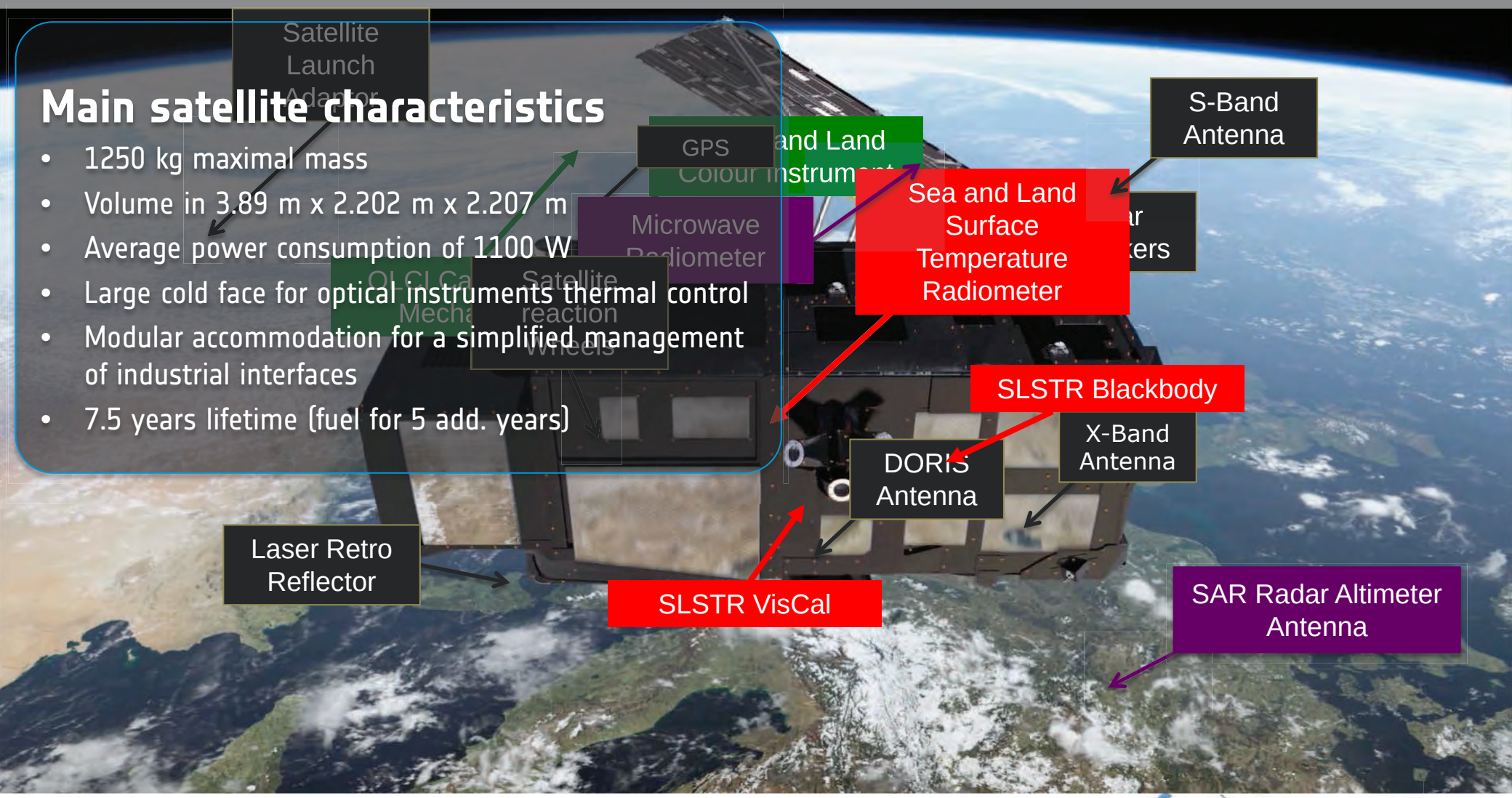


Sentinel-3

Sentinel-3: for Copernicus

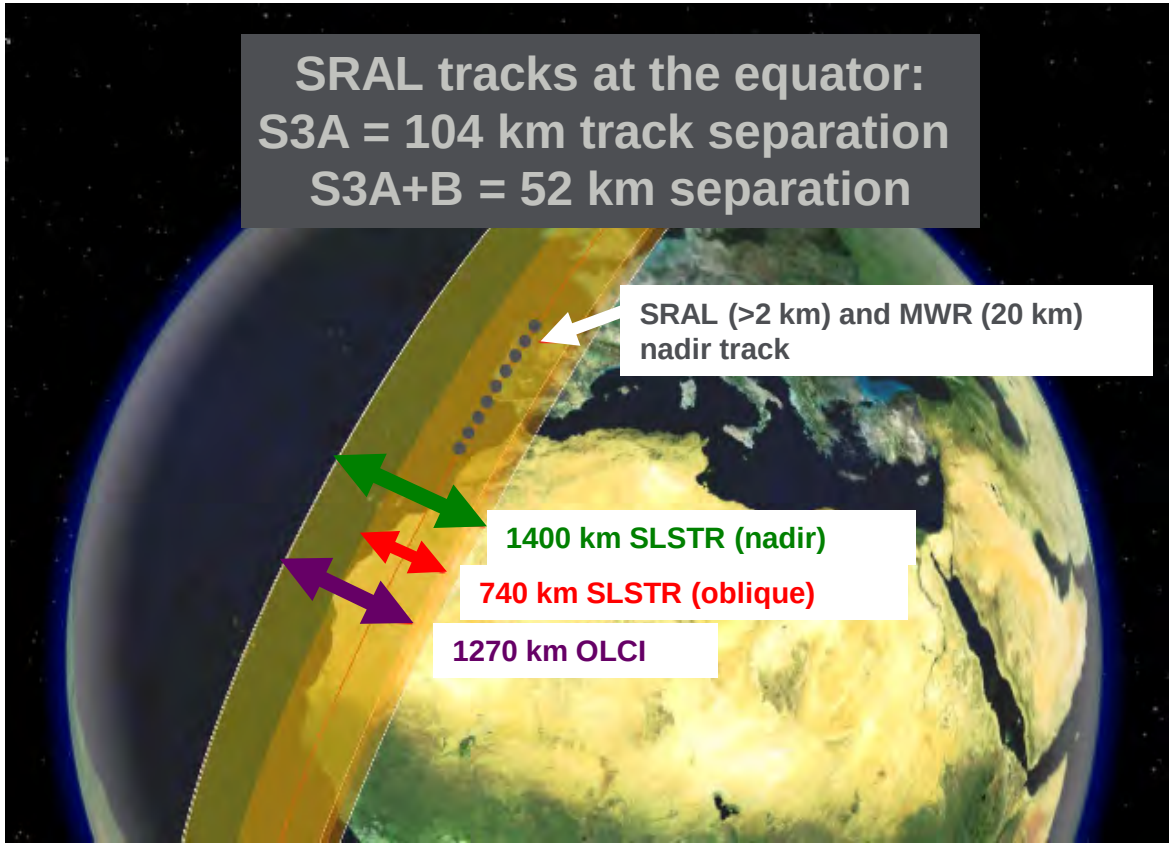
Main satellite characteristics

- 1250 kg maximal mass
- Volume in 3.89 m x 2.202 m x 2.207 m
- Average power consumption of 1100 W
- Large cold face for optical instruments thermal control
- Modular accommodation for a simplified management of industrial interfaces
- 7.5 years lifetime (fuel for 5 add. years)



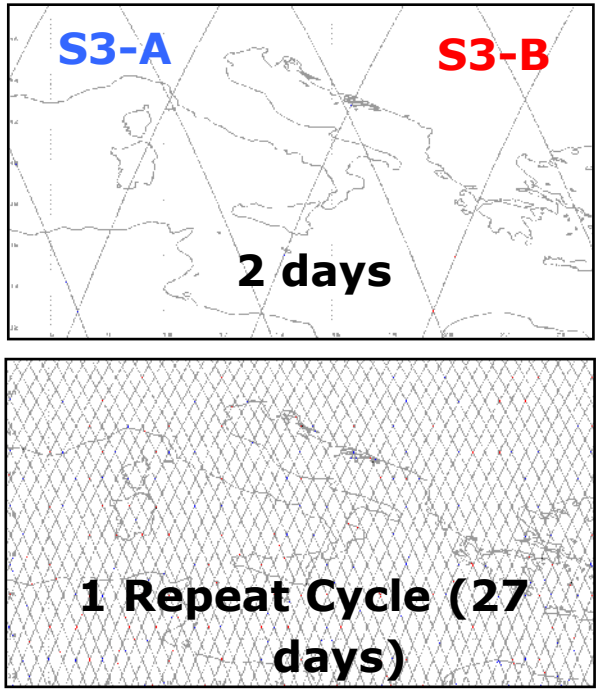
Sentinel-3: Satellite Orbit details

Instrument Swath Patterns



Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg

Ground Track Patterns

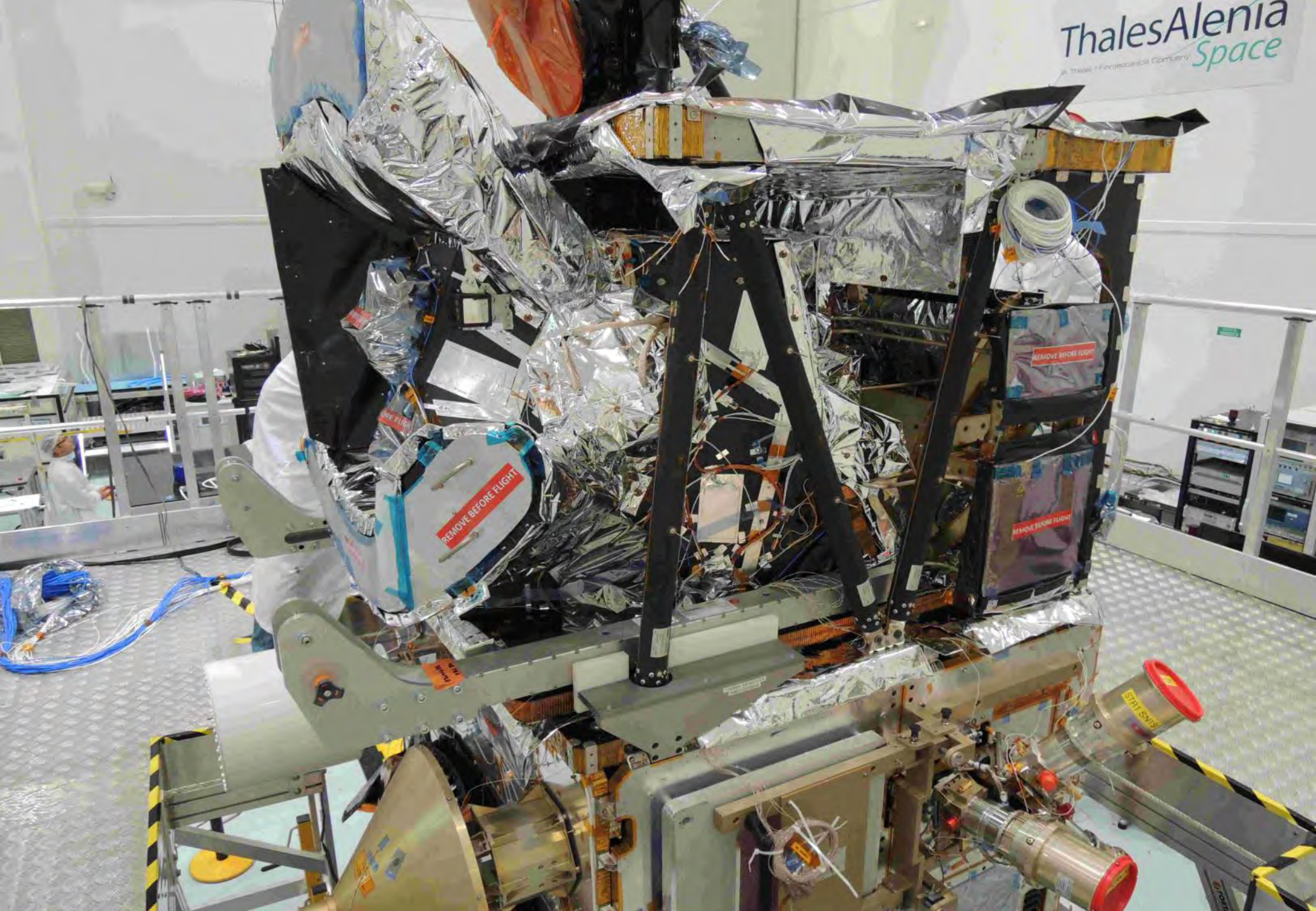


SRAL orbit drivers:

- **Ground track repeatability,**
- **Dense spatial sampling**

Orbit control requirement:

- **Ground track dead-band ±1km**


ThalesAlenia
Space
REMOVE BEFORE FLIGHT
REMOVE BEFORE FLIGHT
REMOVE BEFORE FLIGHT

The Sea and Land Surface Temperature Radiometer (SLSTR)

Key Improvements compared to AATSR:

- number of spectral bands from 7 to 9 (new 1.3 and 2.2um) for better Ci Cloud detection
- increased resolution for VIS and SWIR channels (0.5 km @ nadir, TIR 1 km @nadir)
- maintain along track scanning with increased swath of oblique view to 740 km
- increased nadir swath coverage to 1400 km
- 100% overlap with OLCI
- improved coverage Ocean < 4 days (practically ~ 2 days)
- dedicated Active Fire channels
- Timeliness: 3 hours NRT Level 2 product

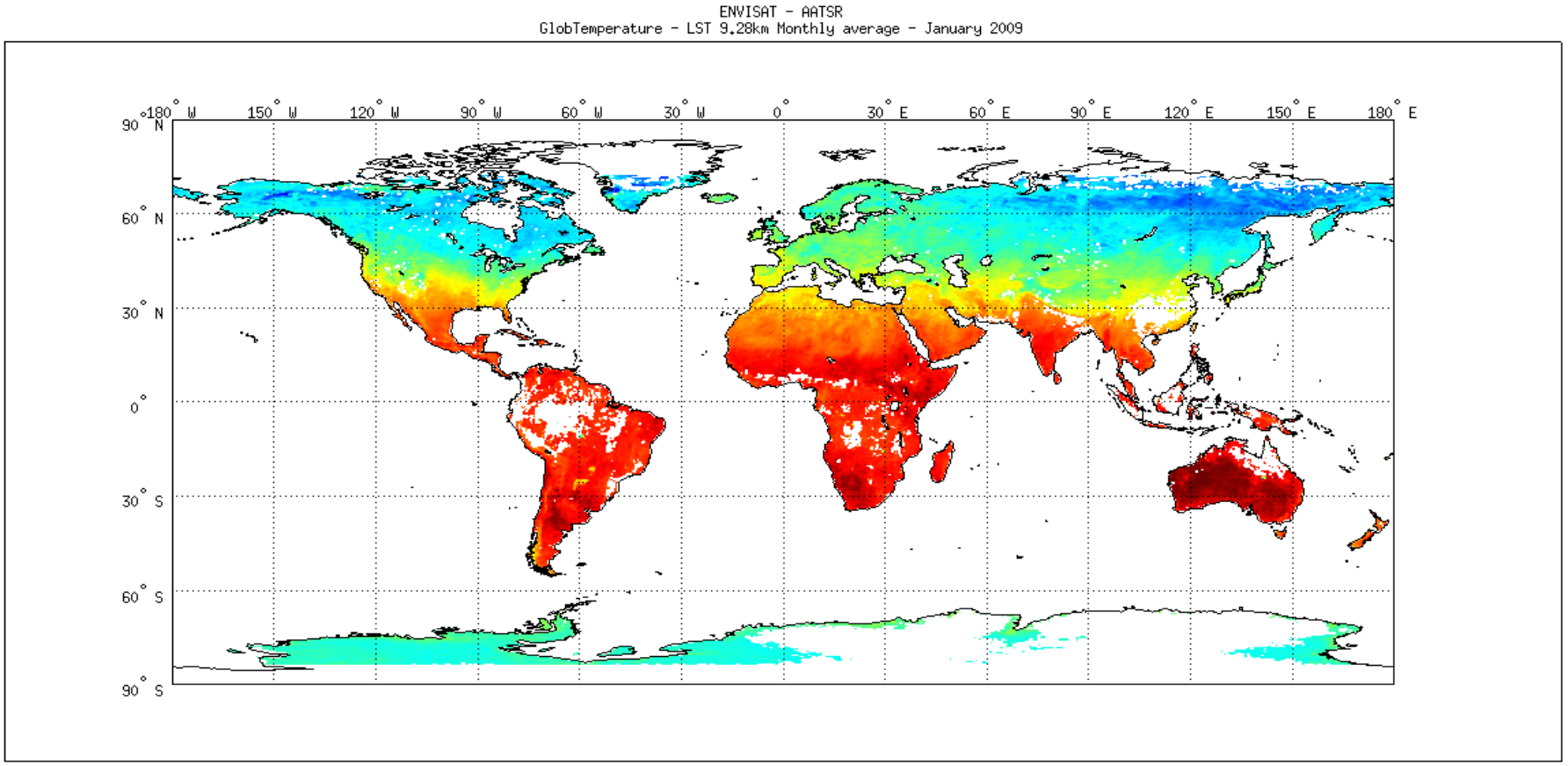
SLSTR FM2 emerging from Thermal Vacuum Chamber after characterization and calibration tests at RAL, UK May 2015

Spectral Channels: (A)ATSR & SLSTR

		ATSR-1	ATSR-2	AATSR	SLSTR
		ERS-1	ERS-2	ENVISAT	Sentinel3
Swath [km]	Nadir	500	500	500	1400
	oblique	500	500	500	740
SSI [km] VIS/SWIR	Resolution at sub sat point	1	1	1	0.5
SSI [km] IR		1	1	1	1
Band 1[12]	Chlorophyll	-	0.555	0.555	0.555
Band 2	Veg. Index	-	0.659	0.659	0.659
Band 3	Veg. Index	-	0.865	0.865	0.865
Band 4	Cloud clearing	-	-	-	1.375
Band 5	Cloud clearing	1.610	1.610	1.610	1.610
Band 6	Cloud clearing	-	-	-	2.250
Band 7	SST	3.740	3.740	3.740	3.740
Band 7 F	Fire	-	-	-	3.740
Band 8	SST	10.850	10.850	10.850	10.850
Band 8 F	Fire	-	-	-	10.850
Band 9	SST	12.000	12.000	12.000	12.000
Life time [years]	As designed	3	3	5	7.5
	As flown	1991-2000	1995-2008	2002-2012	

SENTINEL-3
Continuity to ENVISAT Projects

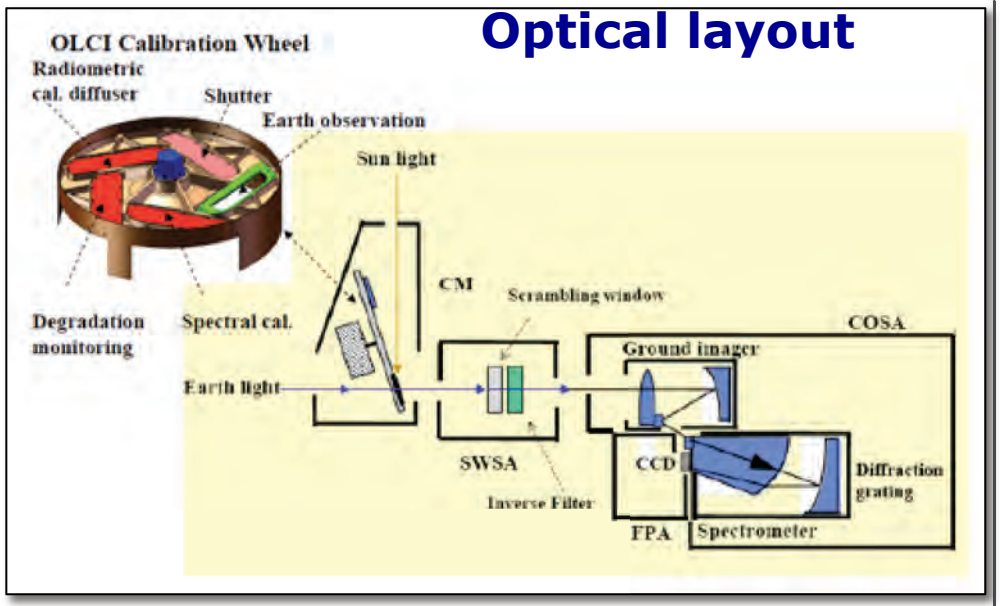
The **GlobTemperature** Project under the Data User Element of ESA's 4th Earth Observation Envelope Programme (2013-2017) aims to promote the wider uptake of global-scale satellite Land Surface Temperature by the research and operational user communities.

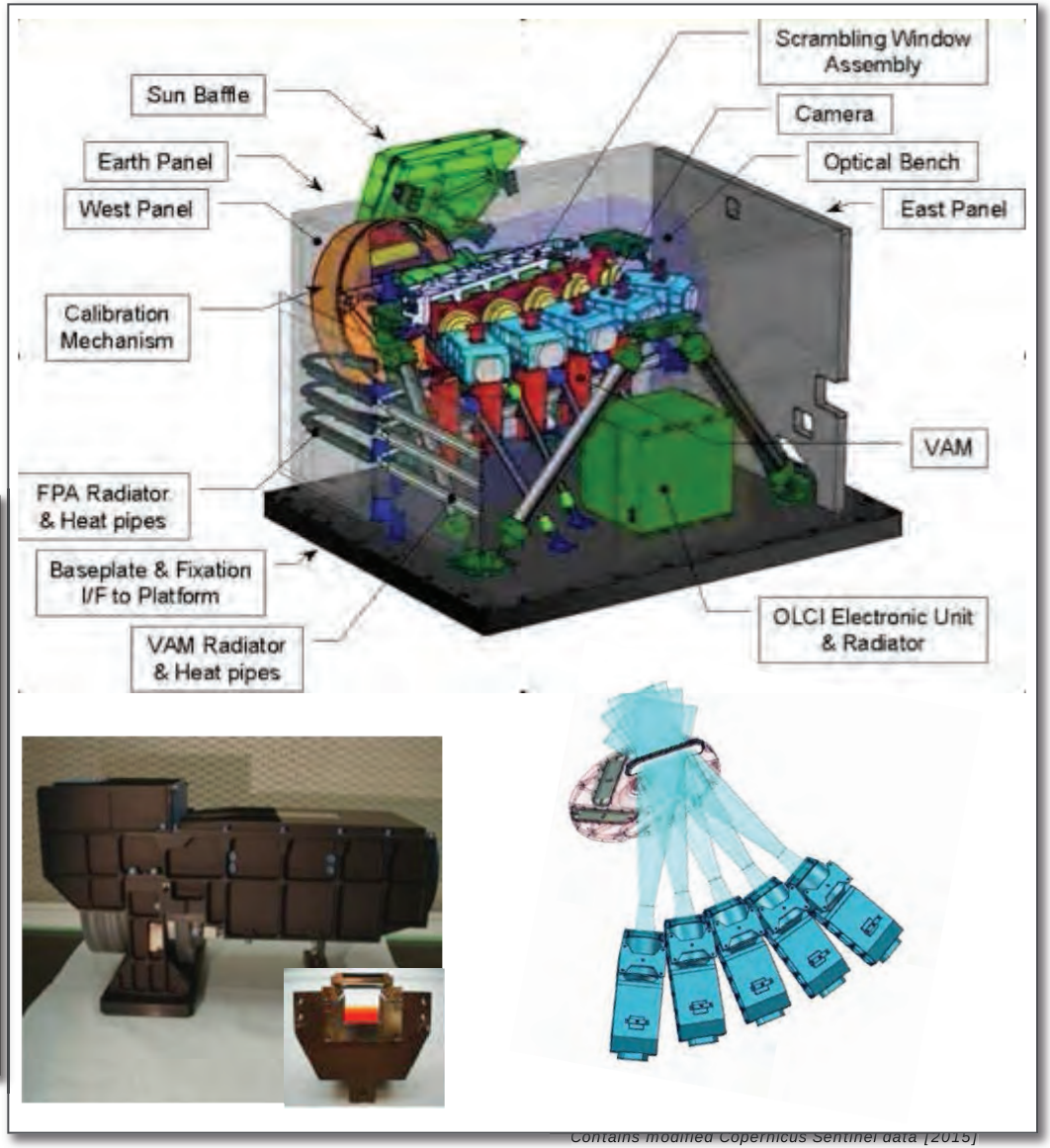


S3 OLCI: Technical details

Basic configuration similar to MERIS:

- 5 Camera Optical Sub Assemblies (COSA),
- 5 Focal Plane Assemblies (FPA),
- 5 Video Acquisition Modules (VAM),
- 1 Scrambling Window Assembly (SWA),
- 1 OLCI Electronic Unit (OEU) managing all the instrument functions,
- 1 calibration assembly allowing radiometric and spectral calibration.





Ocean and Land Colour Imager

Compared to MERIS:

- **100% overlap with SLSTR**
- **More spectral bands** (from 15 to 21): 400-1020 nm
- **Broader swath**: 1270 km
- **Full res. 300m acquired systematically** for land & ocean
- **Improved characterization**, e.g. straylight, camera boundary characterization
- Timeliness: 3 hours NRT Level 2 product

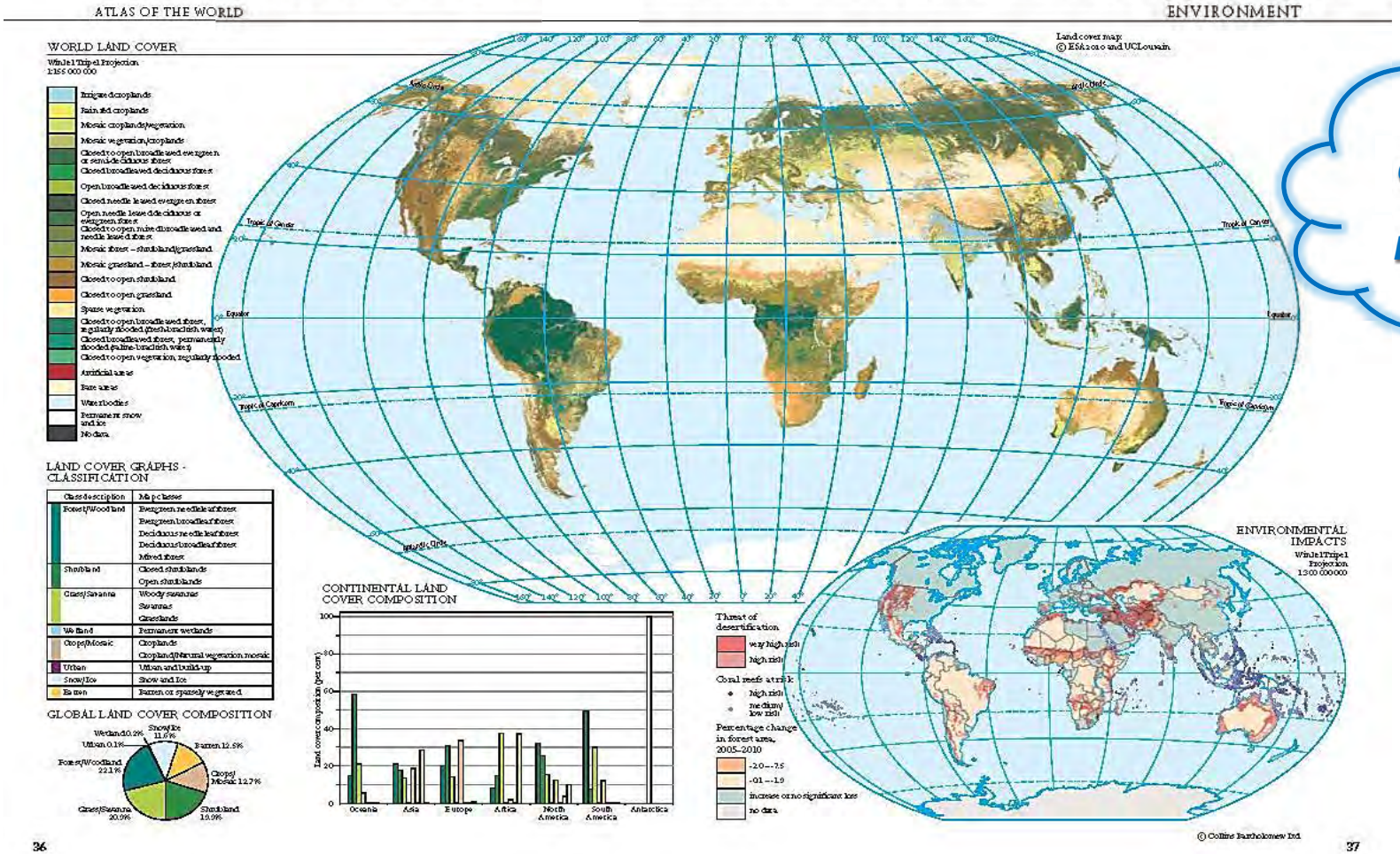
Reduced sun glint by camera tilt in west (12.6°)

MERIS Bands	λ center	Width
Yellow substanace/detrital pigments	412.5	10
Chl. Abs. Max	442.5	10
Chl & other pigments	490	10
Susp. Sediments, red tide	510	10
Chl. Abs. Min	560	10
Suspended sediment	620	10
Chl. Abs, Chl. fluorescence	665	10
Chl. fluorescence peak	681.25	7.5
Chl. fluorescence ref., Atm. Corr.	708.75	10
Vegetation, clouds	753.75	7.5
O_2 R-branch abs.	761.25	2.5
O_2 P-branch abs.	778.75	15
Atm corr	865	20
Vegetation, H_2O vap. Ref.	885	10
H_2O vap., Land	900	10

New OLCI bands	λ center	Width
Aerosol, in-water property	400	15
Fluorescence retrieval	673.75	7.5
Atmospheric parameter	764.375	3.75
Cloud top pressure	767.5	2.5
Atmos./aerosol correction	940	20
Atmos./aerosol correction	1020	40

SENTINEL-3
Continuity to ENVISAT Projects

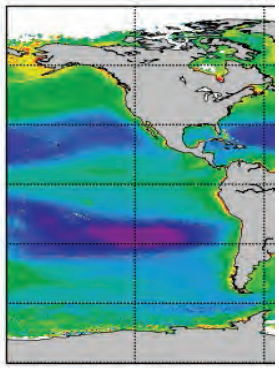
GlobCover on The Times 'Atlas of the World'

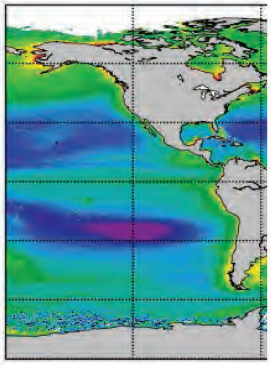


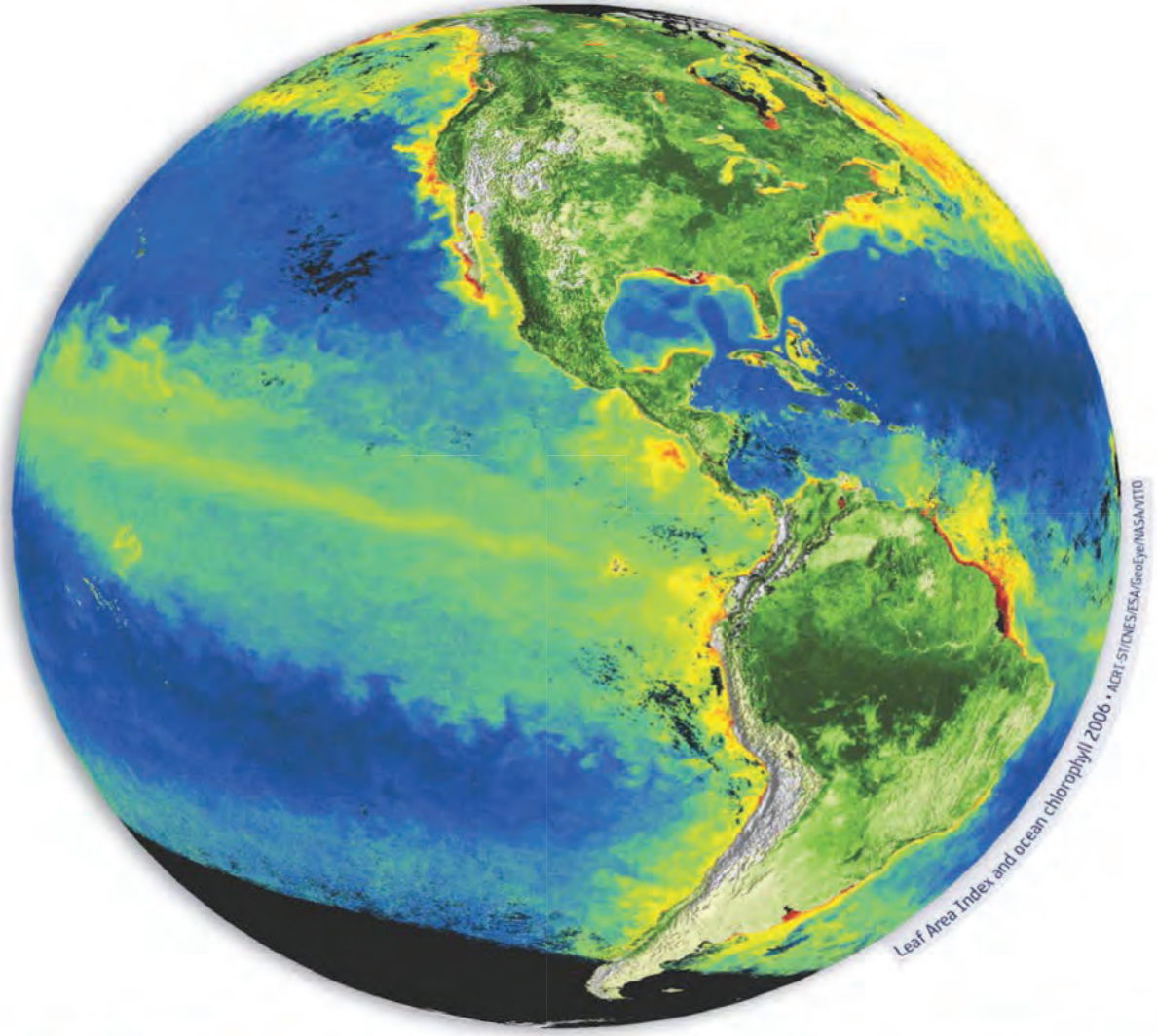
More than 14000 downloads for GlobCover Products since Jan 2012

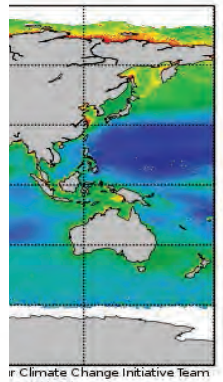
Contains modified Copernicus Sentinel data [2015]

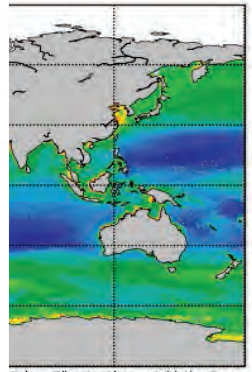
Global Ocean Colour
(ESA Ocean Colour Climate Change Initiative)





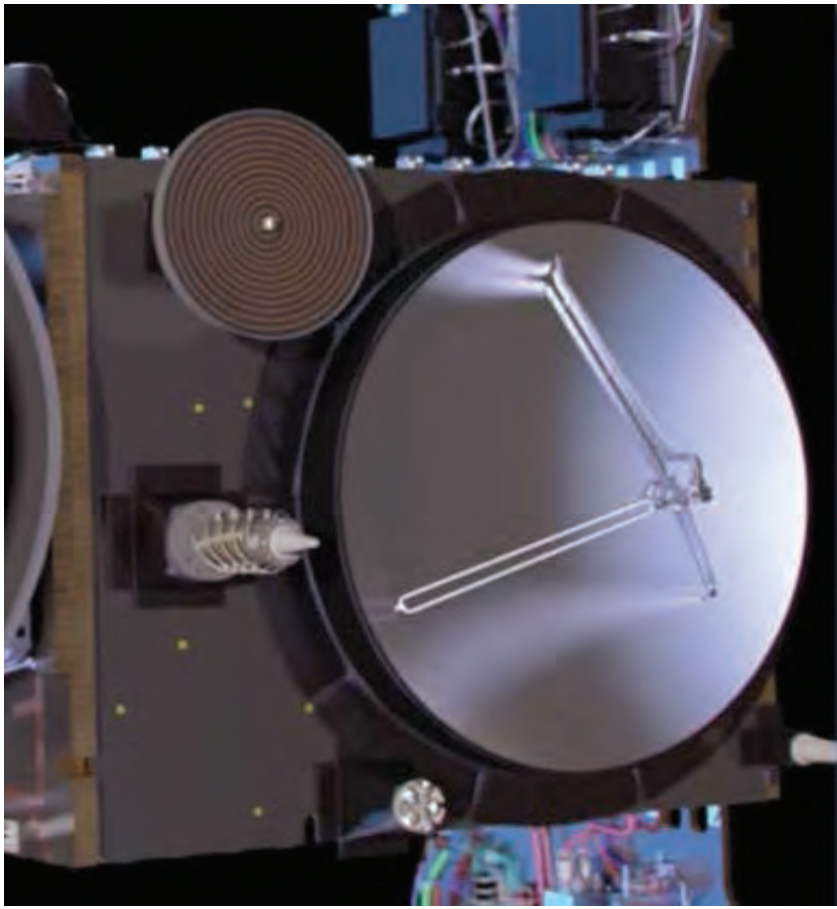






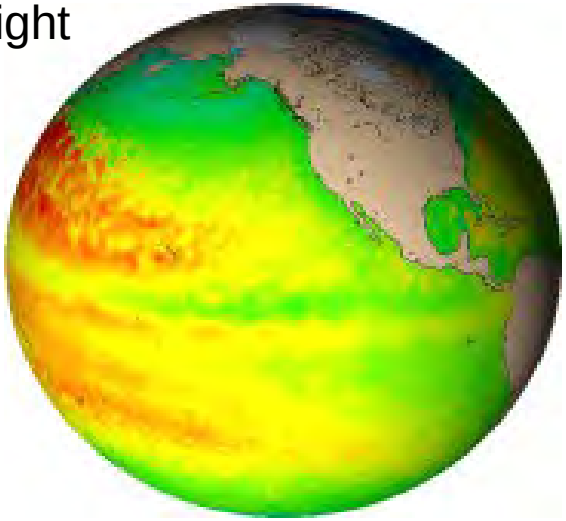
S3-A SAR Radar Altimeter (SRAL)

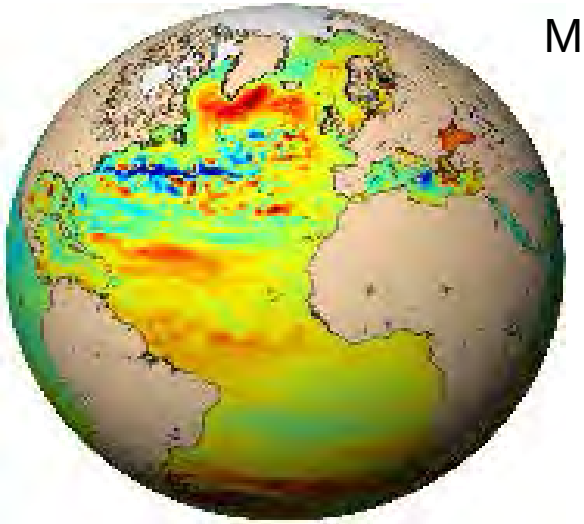
- **Dual frequency Ku/C band Radar Altimeter**
  - CryoSat and Jason heritage
  - High azimuth resolution (~300m in SAR mode)
- **SRAL Radar features:**
  - **Ku-Band** (13.575 GHz) : main frequency
  - **C-Band** (5.41 GHz) : ionosphere corrections
  - Fully redundant electronics
- **Measurement modes:**
  - **2 radar modes:**
    - **Low Resolution Mode (LRM) and**
    - **High Resolution SAR mode**
  - **2 tracking modes:**
    - Closed-loop (traditional) and
    - Open-loop tracking modes over rough surfaces
- **SRAL is Supported by dual channel microwave radiometer, DORIS, GPS and LRR**



Global SAR Sea Surface Altimetry

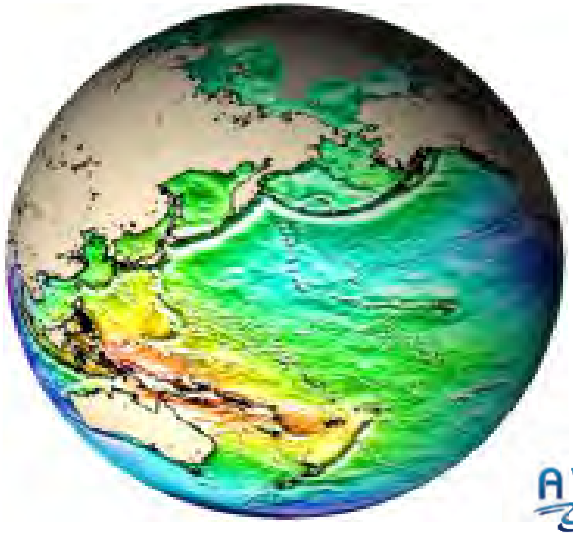
Sea Surface Height

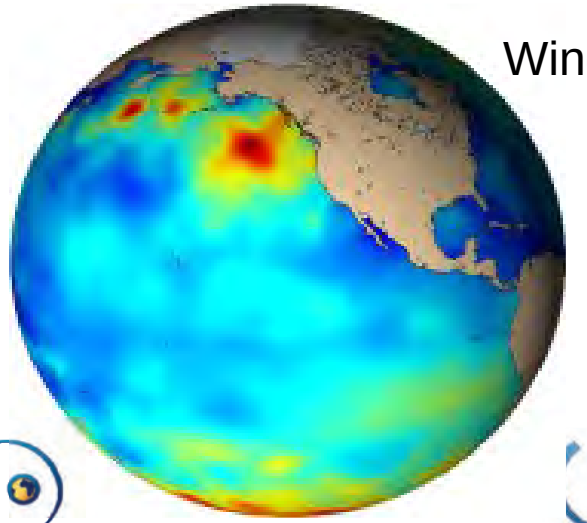




Mean Sea level

DEM, Tides, River and lake Heights, MSS …

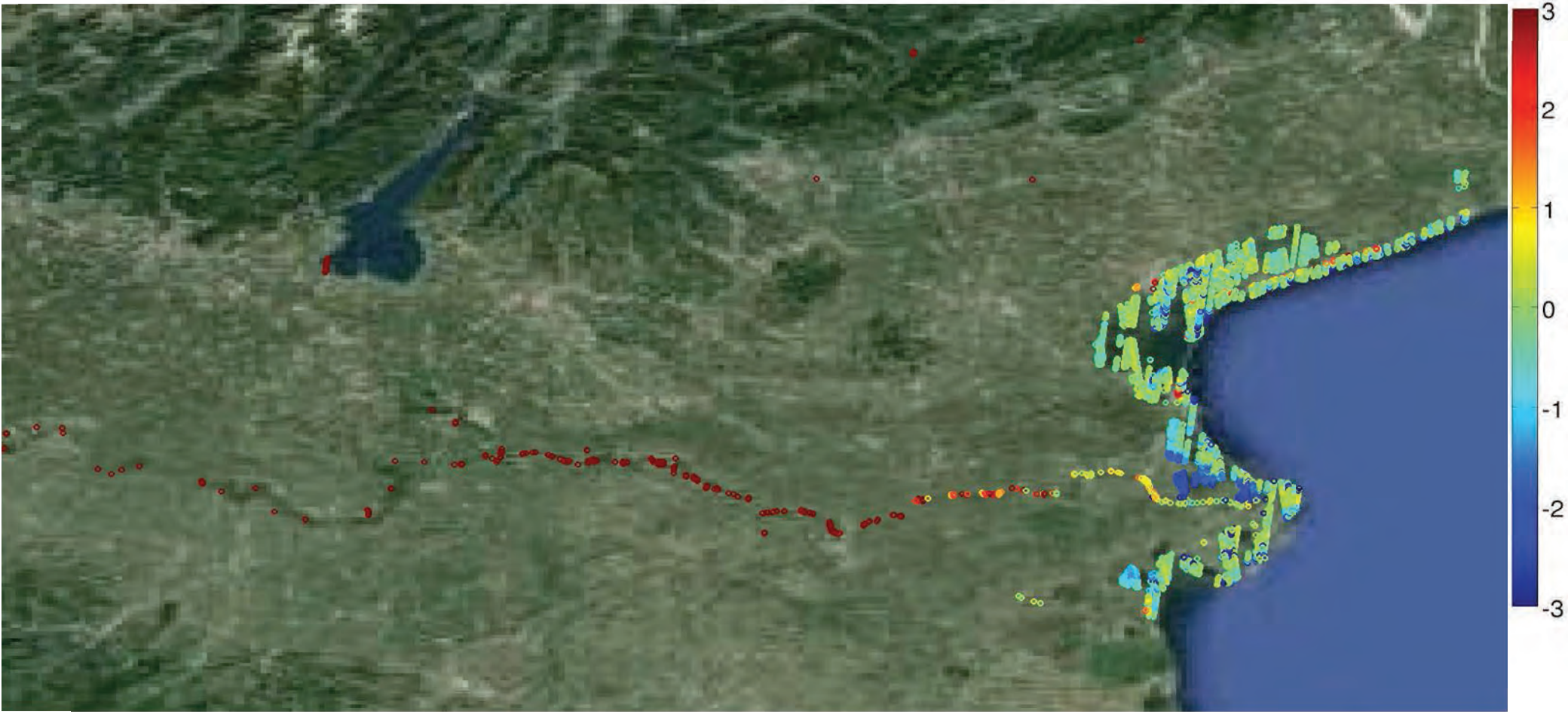




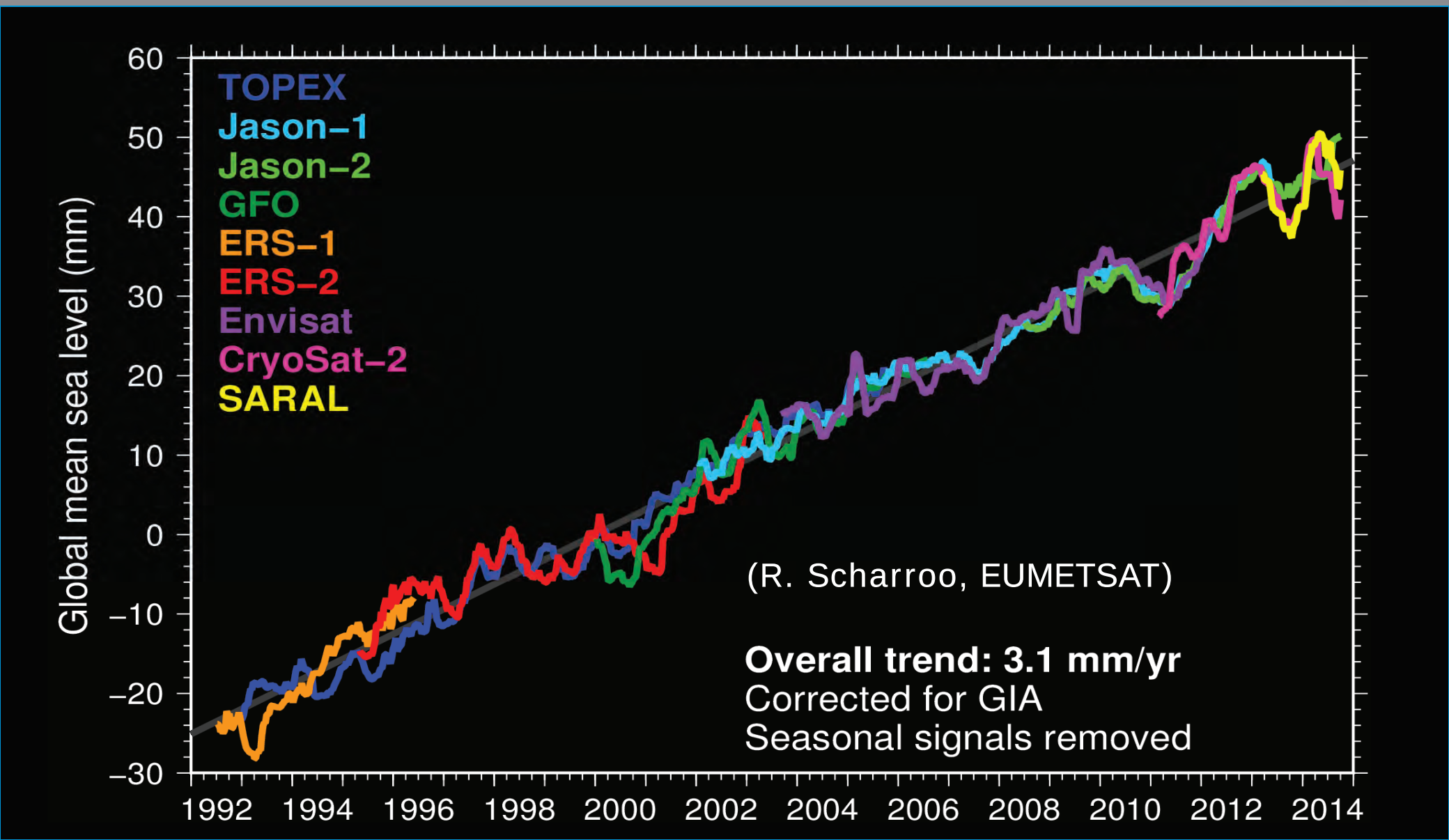
Wind and Waves

Altimetry of Po River and Venice Lagoon

CryoSat SAR mode with SAMOSA Retracker designed for Sentinel-3 over open oc



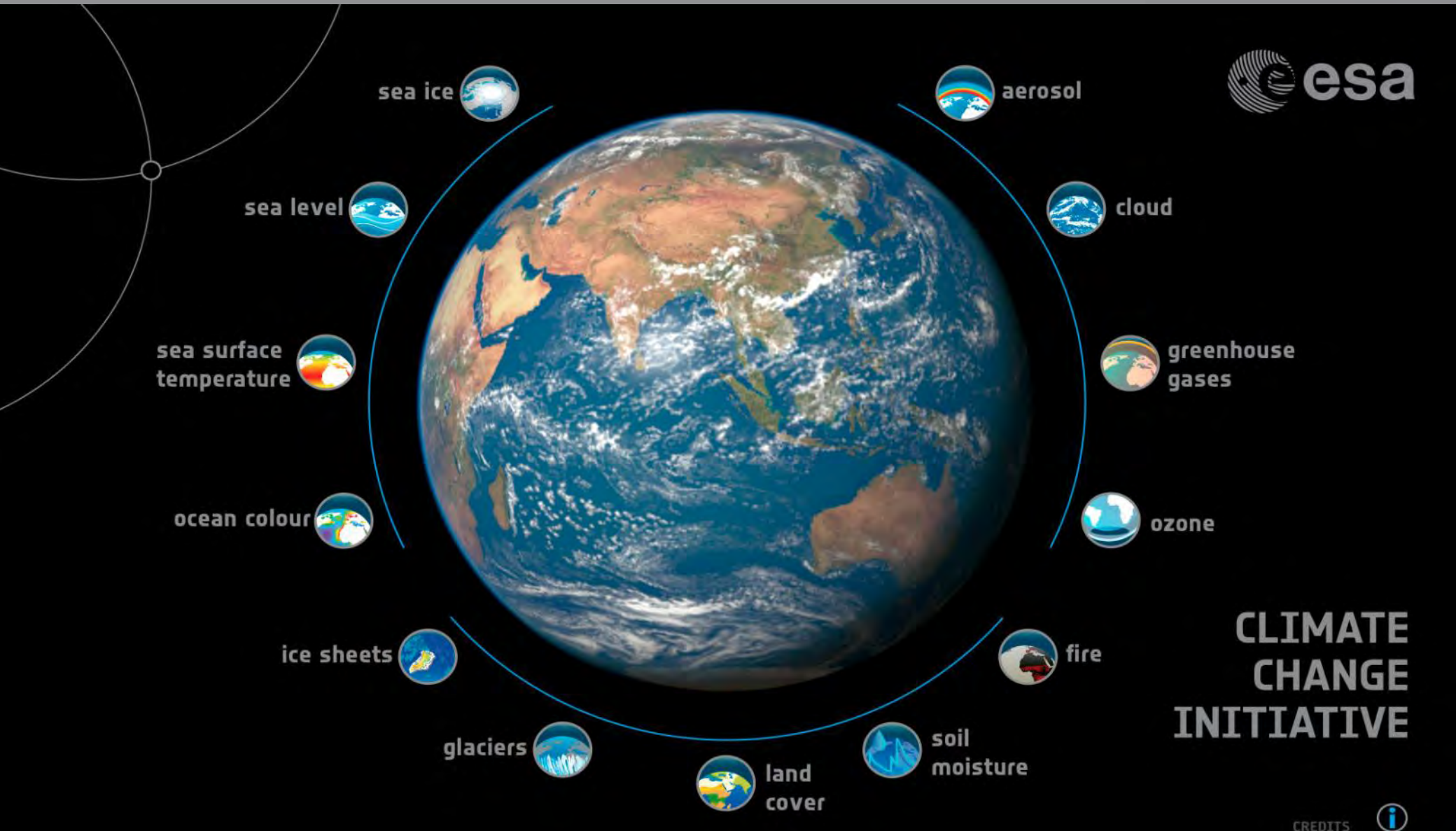
Sentinel-6/Jason-CS mission



Conclusions

- **Sentinel-3A Satellite on track for a launch November 2015!!**
- **All ground segment facilities supporting the Sentinel-3 commissioning** (predicted duration 5 months after launch) and operations are in place, both at ESA and EUMETSAT
- **Sentinel-3B Satellite integration well advanced**. On track for a launch approx. 18 months after Sentinel-3A (i.e. Q2-2017)
- **Procurement of Sentinel-3C and -3D Satellites started**
  - **of Sentinel-3 satellite, mission continuity is ensured for at least 25 years from the launch of the first Satellite**

CCI: Essential Climate Variables



land couer cci

www.esa-landcover-cci.org

UCL, Brockmann Consult, GAMMA, MPI-M, Met Office, LSCE, JRC, U. Wageningen, U. Jena, U. Pavia, Lippmann

esa

Phase 1 Achievements:

In consultation with international partners, IGBP, GOFC-GOLD, FAO, EEA and JRC, performed optical (MERIS, SPOT-VGT, Proba-V, AVHRR) and SAR (ASAR) image classification to provide:

- Global moderate resolution land cover maps for epochs: 2000 (1km), 2005 (300m), 2010 (300m)
- Legend compatible with plant functional types used in climate models.
- Land cover seasonality characterisation
- Global map of permanent water bodies
- Provision of a tool for subsetting, re-projecting and re-sampling the products for use in climate modelling.

Phase 2 Objectives:

- Improve Phase 1 products, processing systems and validation.
- Extend coverage to the 1990's and the 2013-2016 periods with AVHRR, Sentinel-3, and Proba-V data sets.
- Investigate potential to extend back to 1980's with AVHRR.
- Demonstrate the feasibility of higher resolution global land cover products (required as part of the ECV by GCOS) by generating a 10-20m land cover map over Africa, using Sentinel-2 supplemented by LandSat-8.

GCOS Req. for moderate resolution LC

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Maps of land-cover type	250m	N/A	1 year	15% (maximum error of omission and commission in mapping individual classes), location accuracy better than 1/3 IFOV with target IFOV 250m	15% (maximum error of omission and commission in mapping individual classes), location accuracy better than 1/3 IFOV with target IFOV 250m

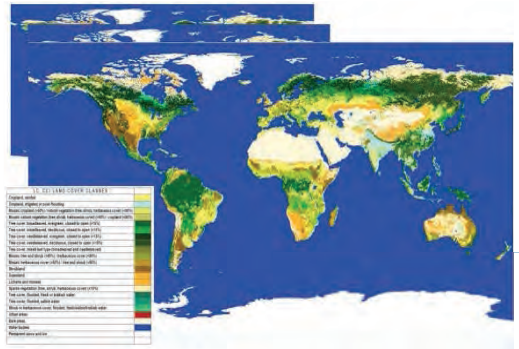


Figure: Landcover_cci Phase 1 has delivered three global land cover state products for 2000, 2005 and 2010 epochs, supplemented by global water bodies and phenology products.

ncy

Phase 1 Achievements:

Developed new processing algorithms for the ATSR-series, VEGETATION and MERIS sensors to overcome spatial and temporal inconsistencies in existing products.

- Prototype products over test sites in key biomes from ATSR-2, AATSR, VEGETATION and MERIS-300m.
- Global prototype products (2006-2008) for VGT and MERIS-300m.
- Unique validation database of high resolution optical satellite images collected over globally distributed sites for spatial and temporal validation.

Phase 2 Objectives (KO on 8 Sep 2015):

- Extend prototypes to full global coverage over 2000-2016
- Investigate potential to extend ECV back to 1980's using AVHRR
- Estimate small fire distribution for the African continent using Sentinel-2, plus Sentinel-1 SAR for persistently cloudy regions.
- Link small fires estimates to global products using Proba-V 300m and 100m data.
- Extend validation database to meet CEOS Level-3 spec.
- Develop a sustainable processing system.

GCOS Req. for Burnt Area

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Burnt area	250m	N/A	Daily detection	15% (error of omission and commission), compared to 30m observations	15% (error of omission and commission), compared to 30m observations

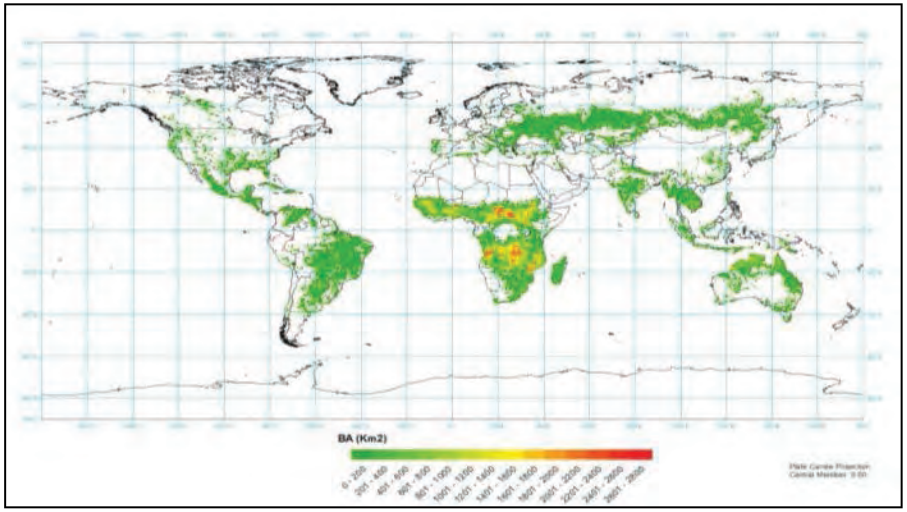


Figure: Gridded burned area derived from MERIS-300m for 2008

soil moisture cci

www.esa-soilmoisture-cci.org

EODC, TUW, GeoVille, AWST, Transmissivity, ETH, FMI, UCC, NILU

esa

Phase 1 Achievements:

- ECV products from merged active and passive microwave instruments covering 1978-2014:
  ERS 1/2, ASCAT, SMMR, SSM/I, TMI, AMSR-E, WindSat, and AMSR2.
- 1500 registered users
- Input to BAMS and WMO state of the climate assessments
- 24 peer-reviewed publications, including Nature.
- FCDR produced in collaboration with Level-2 data providers: ESA, EUMETSAT H-SAF, NASA, NOAA, NRL

Phase 2 Objectives:

- Integrate Sentinel-1 SAR and SMOS products into the ECV

GCOS Requirements

Product T.11 Global near-surface soil moisture maps (up to 5cm soil depth)

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Volumetric soil moisture	50km	NA	Daily	0.04m^3/m^3	0.01m^3/m^3 /year

- Improve algorithms and uncertainty characterisation with latest research:
  e.g. RFI, diurnal variability, vegetation modelling, land cover variability.
- Improve merging approaches and inter-instrument calibrations for multi-satellite products.
- Develop root-zone soil moisture products to better match climate user requirements.
- Reprocess to exploit new algorithm improvements and new sensor data.
- Transfer to sustainable operations at EODC

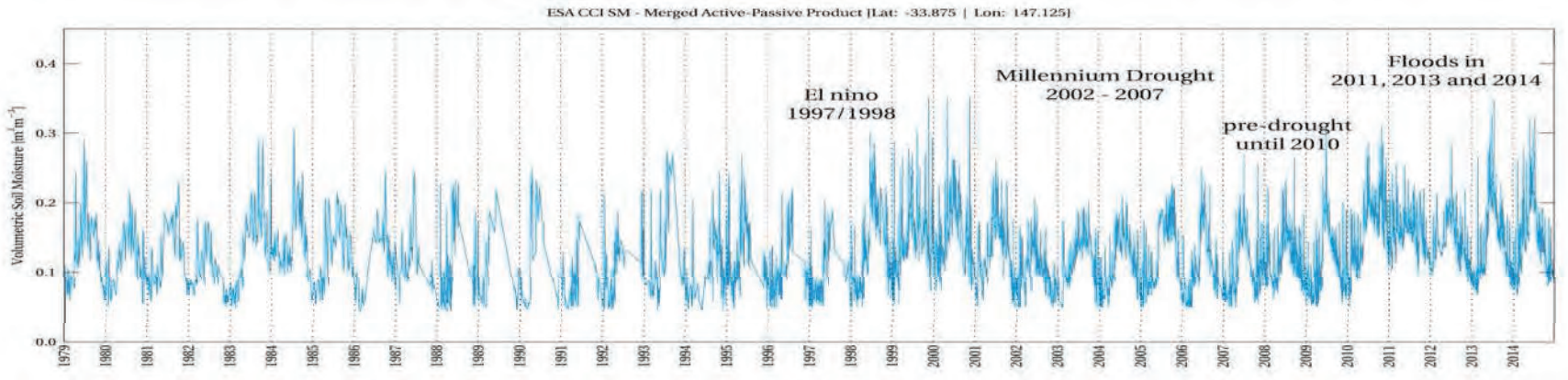


Figure:
Soil moisture active-passive merged product for Eastern Australia (1979-2014)

pean Space Agency