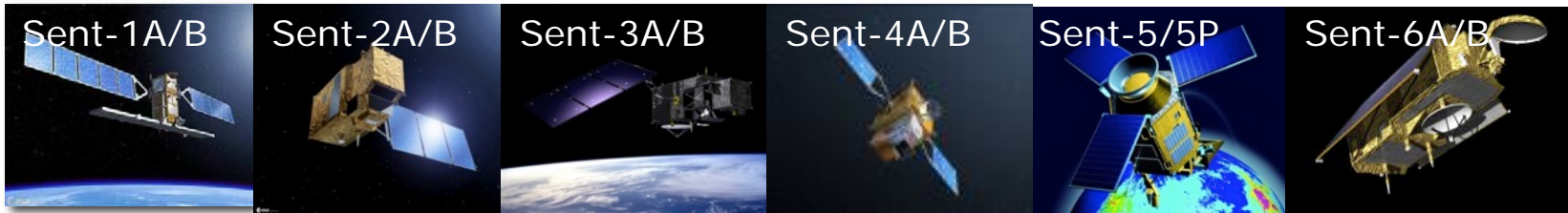


Sentinel-1 Mission Overview

*Yves-Louis Desnos Head R&D - SEOM program manager ,
Pierre Potin Sentinel 1 mission manager
European Space Agency - ESRIN*

MUAS Workshop, 3-4 November 2015, ESRIN



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



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

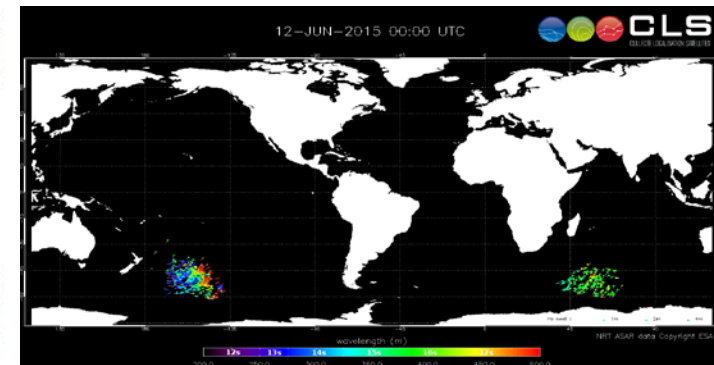
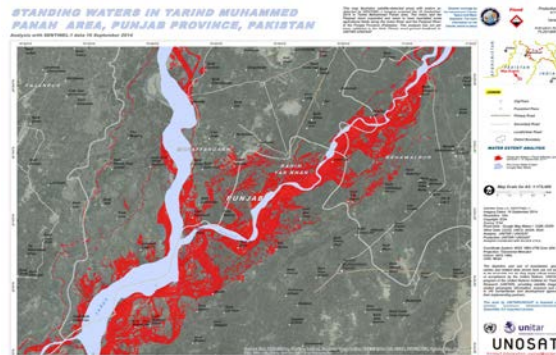
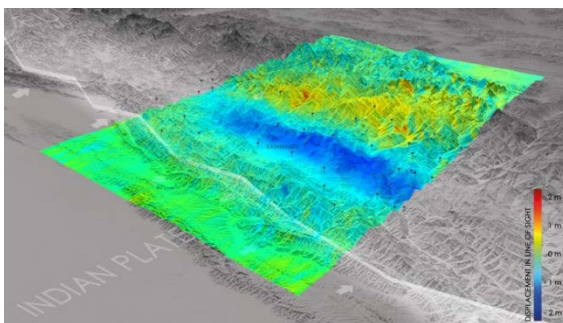
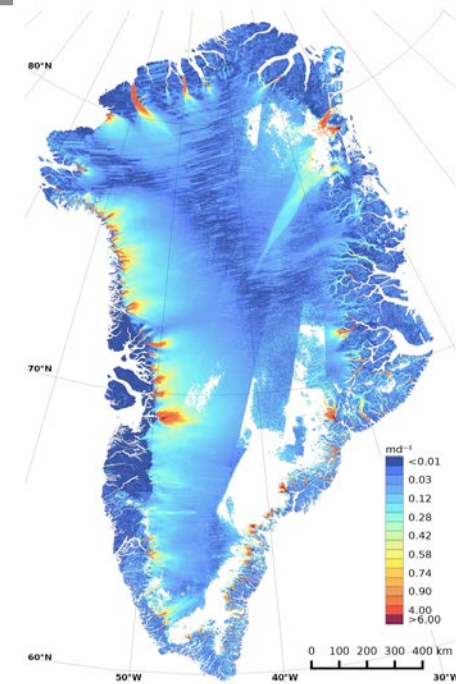


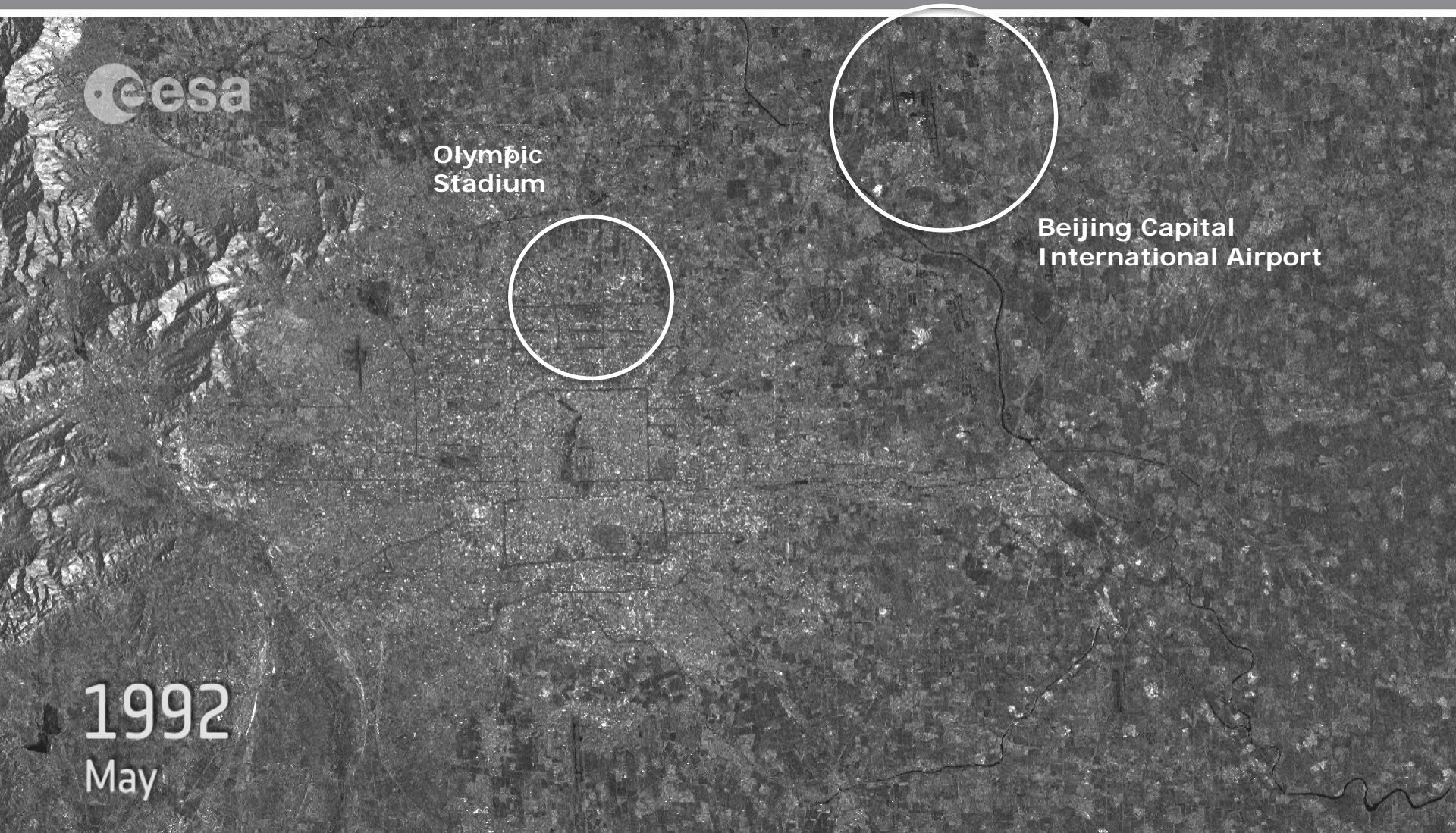
S6 (Jason-CS): Altimetry Mission

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



- ✓ **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)
 - maritime security (e.g. ships)
 - wind, wave, current monitoring
 - monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.)
 - support to emergency / risk management and humanitarian aid in crisis situations
 - mapping of land surfaces: forest, water and soil, agriculture, urban etc.

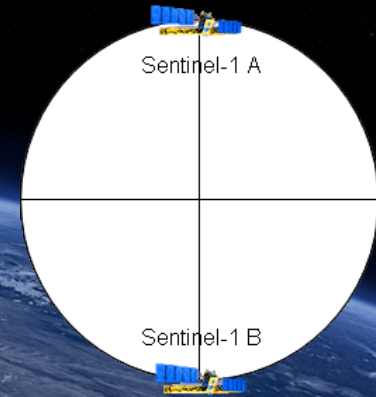


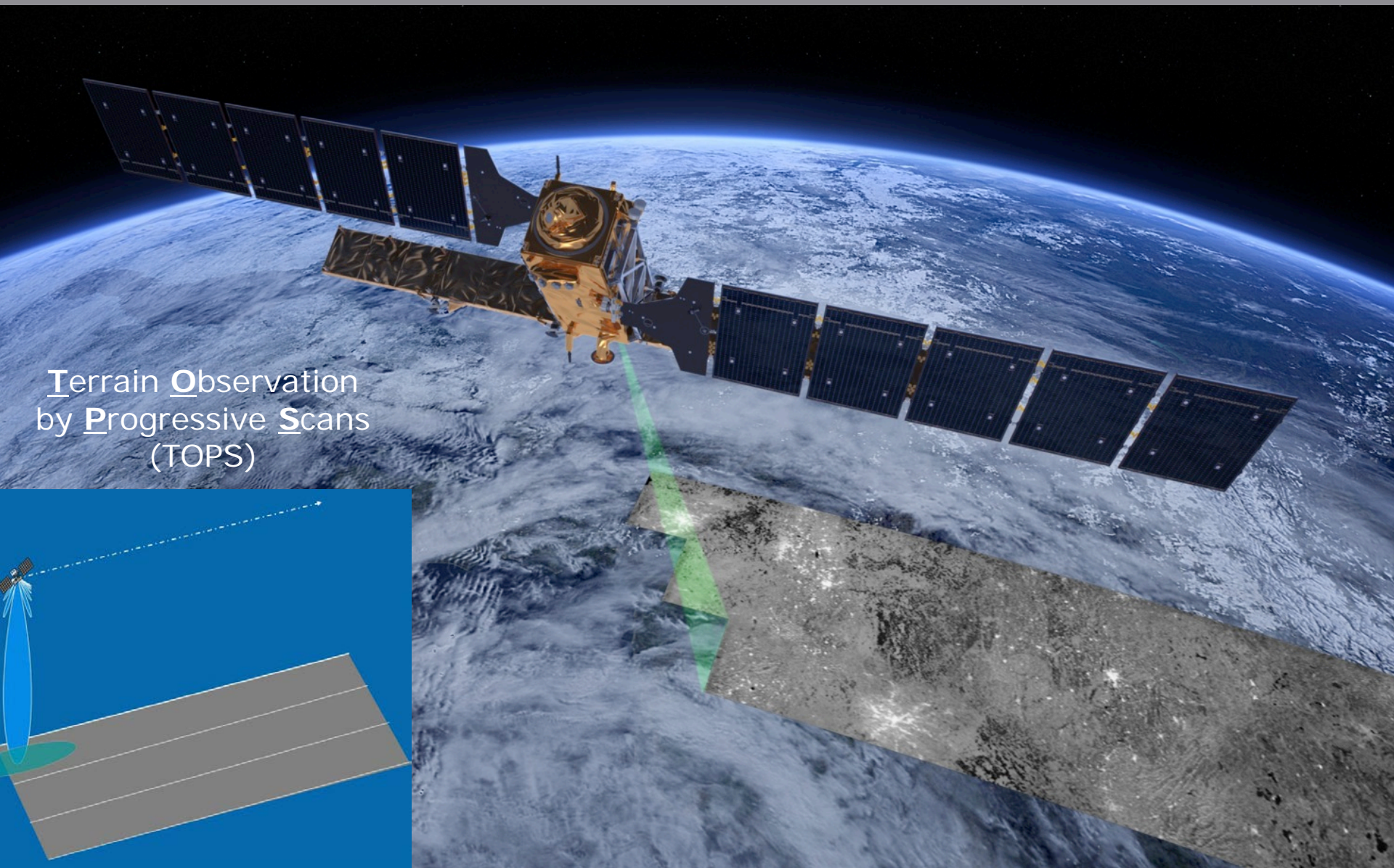




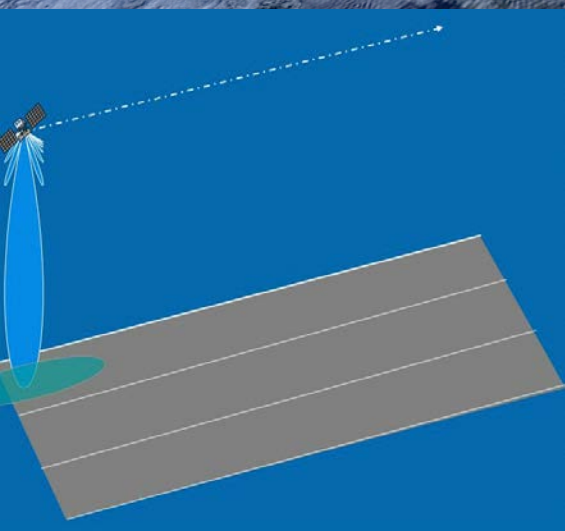
ENVISAT SAR
08/06/2003

- 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)

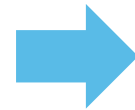
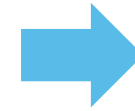
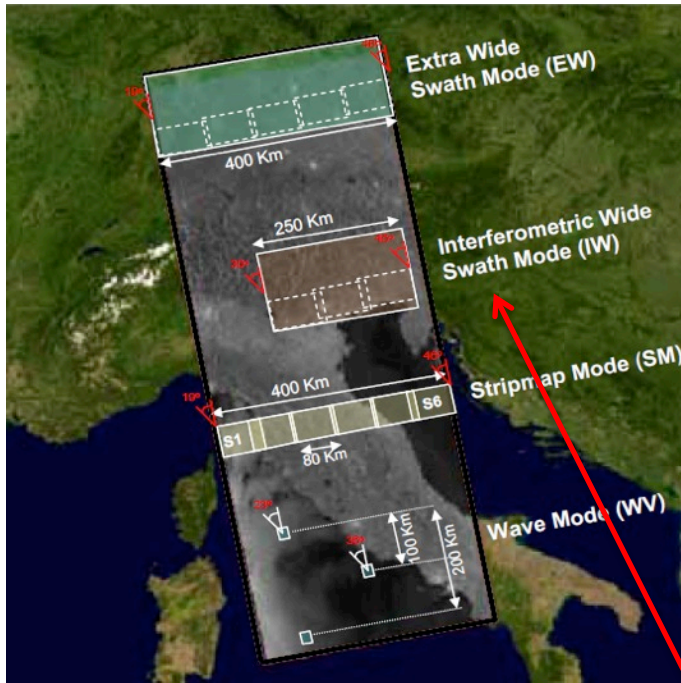




Terrain Observation
by Progressive Scans
(TOPS)

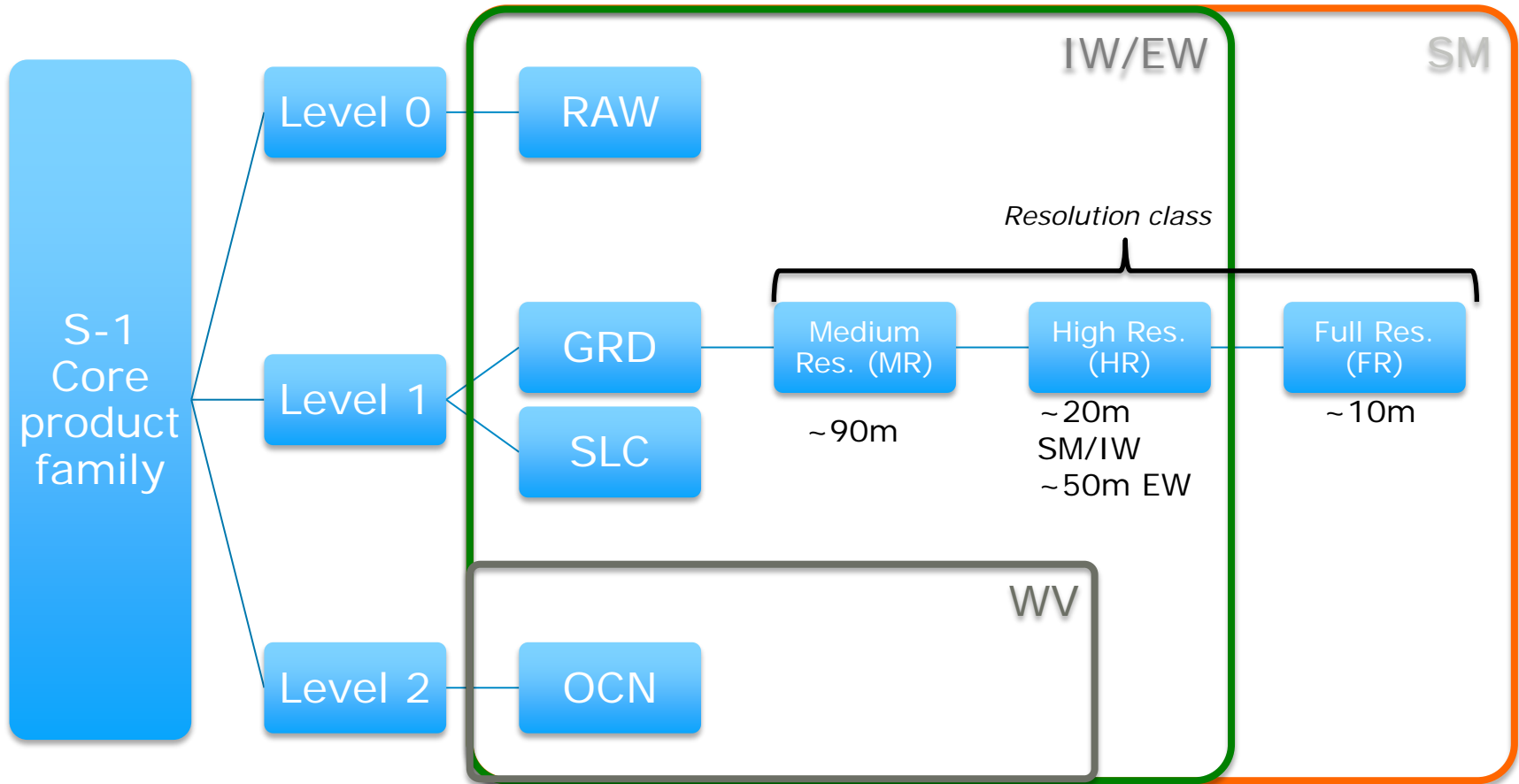


Operational Modes

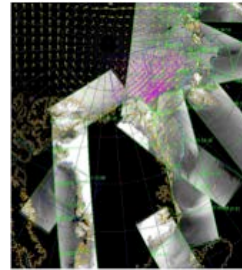
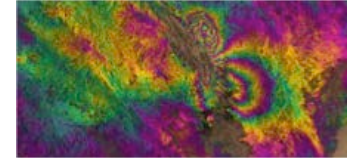
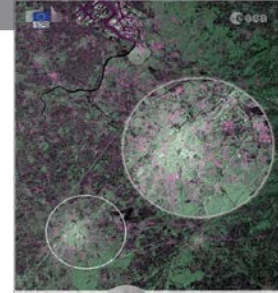


GRD Level 1 product resolution	Swath Width	Polarisation
50m (3 ENL)	> 400 km	HH+HV or VV+VH
20m (5 ENL)	> 250 km	HH+HV or VV+VH
9m (4 ENL)	> 80 km	HH+HV or VV+VH
50m (140 ENL)	20 x 20 km ² at 100 km spacing	HH or VV

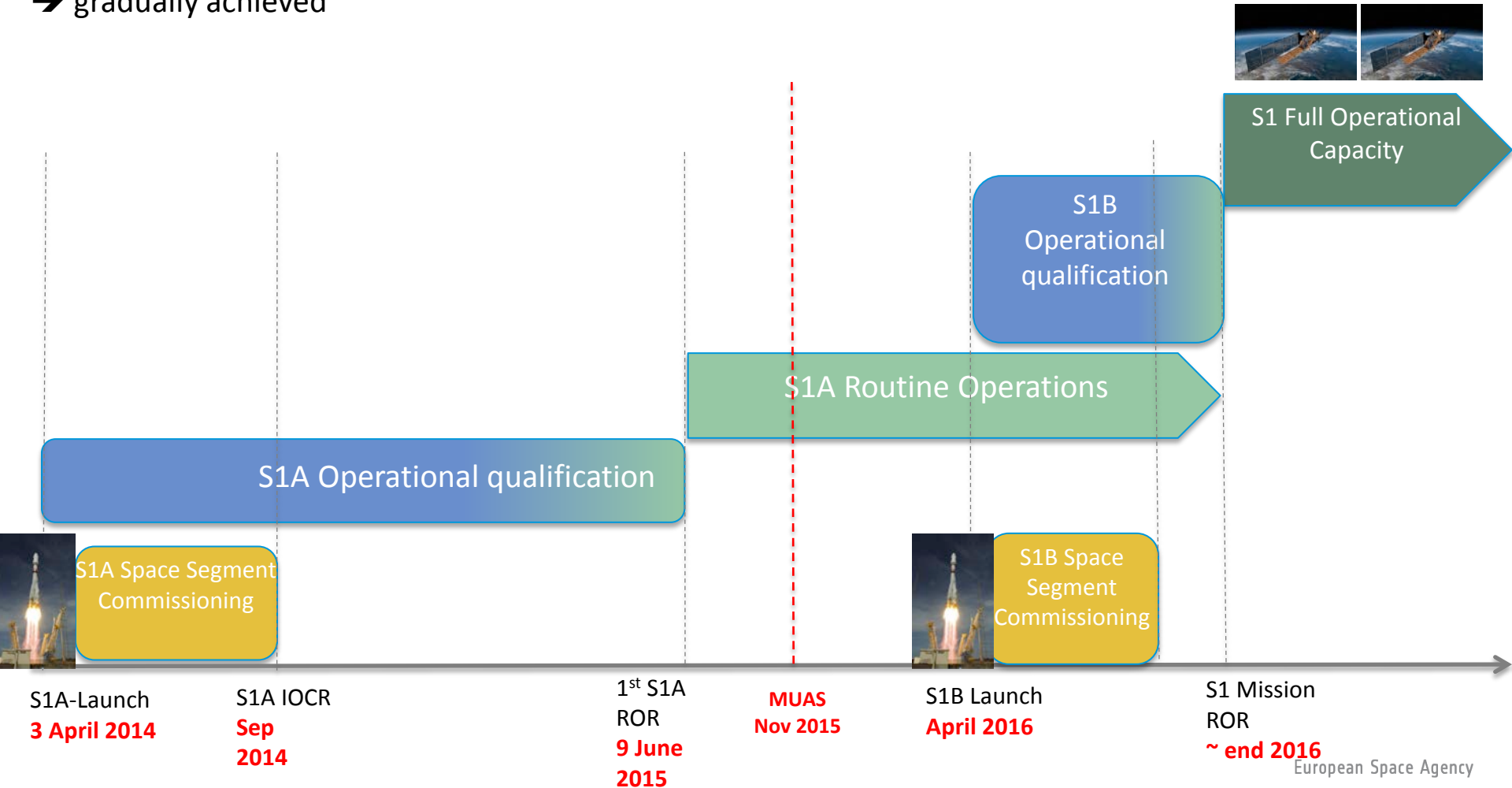
Main mode over land and coastal areas



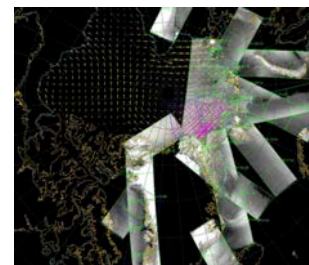
- ✓ Sentinel-1A launched on 3 April 2014 on Soyuz from Kourou
- ✓ Nominal orbit reached on 7 August 2014
- ✓ Sentinel-1A commissioning phase completed on 23 September 2014
- ✓ Data flow opened to all users worldwide on 3rd October 2014
- ✓ Copernicus services (Marine and Emergency in particular) are operationally using Sentinel-1 data
- ✓ Sentinel-1A Operational Qualification phase (ramp-up) completed with the 1st Yearly Routine Operations Review on 9 June 2015
- ✓ Sentinel-1B satellite under development, launch foreseen in April 2016



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



- ✓ Overall very good performance of the satellite
- ✓ Flight Operations Segment (FOS) performance nominal, operations migrated to the full Routine set-up and working practice, achieved by mid February 2015
- ✓ Very good performance of the Payload Data Ground Segment (PDGS), operations run smoothly, very high data throughput achieved already in early stages of the mission: **more than 3 TB of products generated daily**
- ✓ Level-0 and Level 1 products operationally qualified, level-2 products (Ocean Products) full operational qualification on-going (geophysical validation)
- ✓ First inter-orbit optical link campaign between Sentinel-1 and Alphasat Technology Demonstration Payload TDP-1 successfully performed in Autumn 2014. Routine characterisation phase currently on-going



Sentinel-1A observation scenario

Main components & thematic domains

Agriculture

European coverage

Forestry

Calibration/validation



Maritime surveillance

Zonal mapping



Emergency

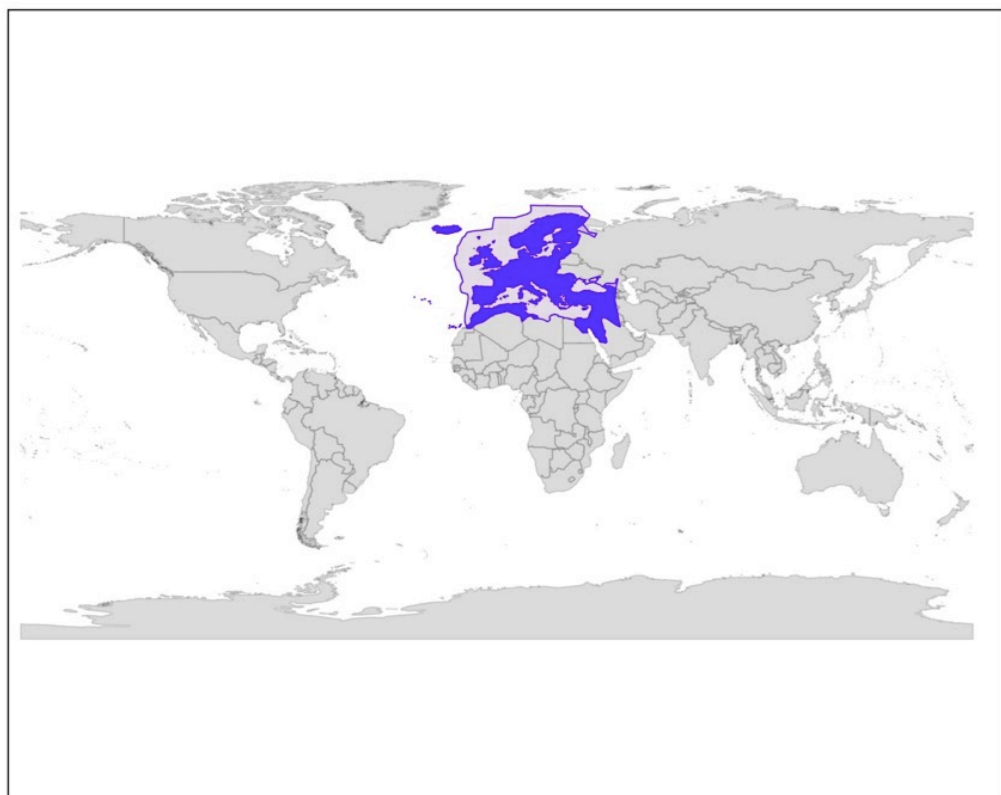
Tectonic active areas and volcanoes / landslides and subsidence

Security

Sea state

Sea-ice, icebergs, lake-ice

Ice sheets, glaciers, permafrost and snow



- 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

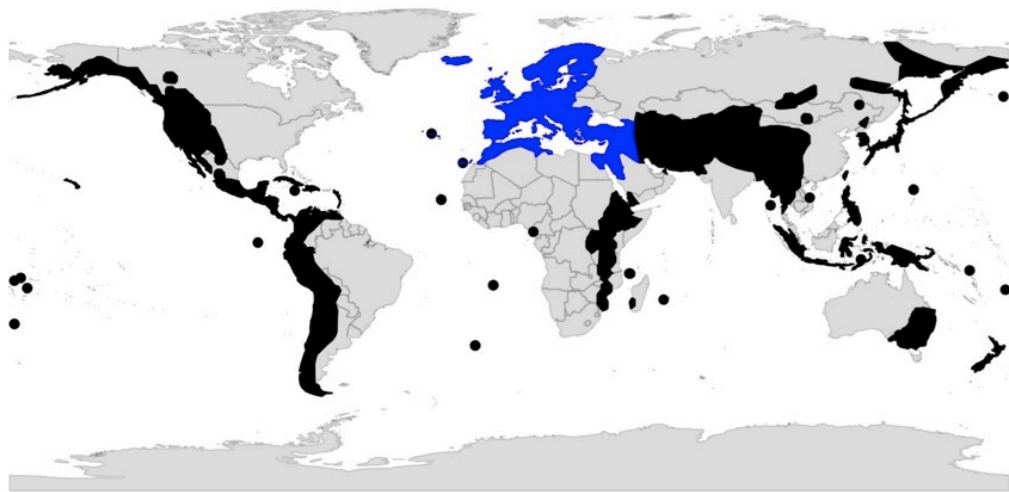
Contains modified Copernicus Sentinel data [2014]

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

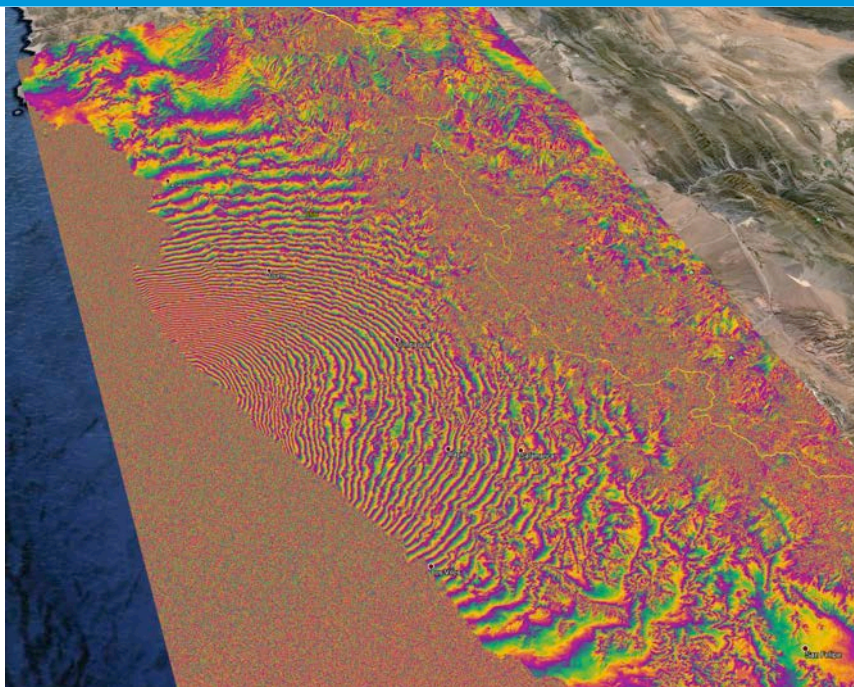
"This is amazing job guys - this will set new ground for a wide community of (new) users"



SENTINEL-1A - Tectonic active areas and volcanoes / subsidence and landslides



- **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



Chile Earthquake, September 2015

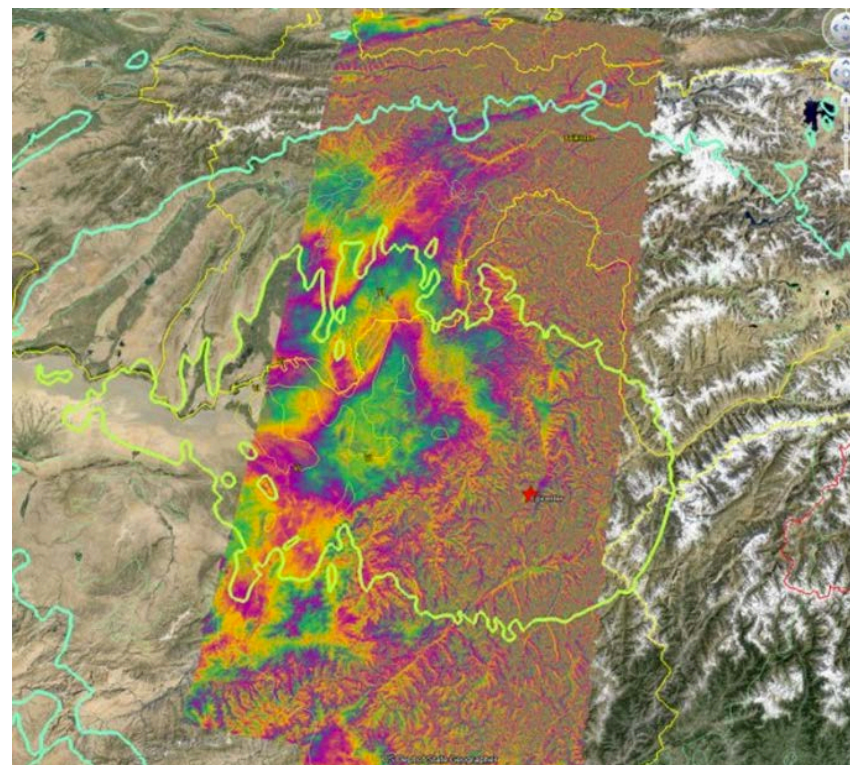
- 8.3 M earthquake, central Chile, 16 Sep 2015
- Interferogram with Sentinel-1 IW acquisitions on 24 Aug and 17 Sep 2015
- Estimated displacement of 1.4 m along the viewing direction of the radar observation

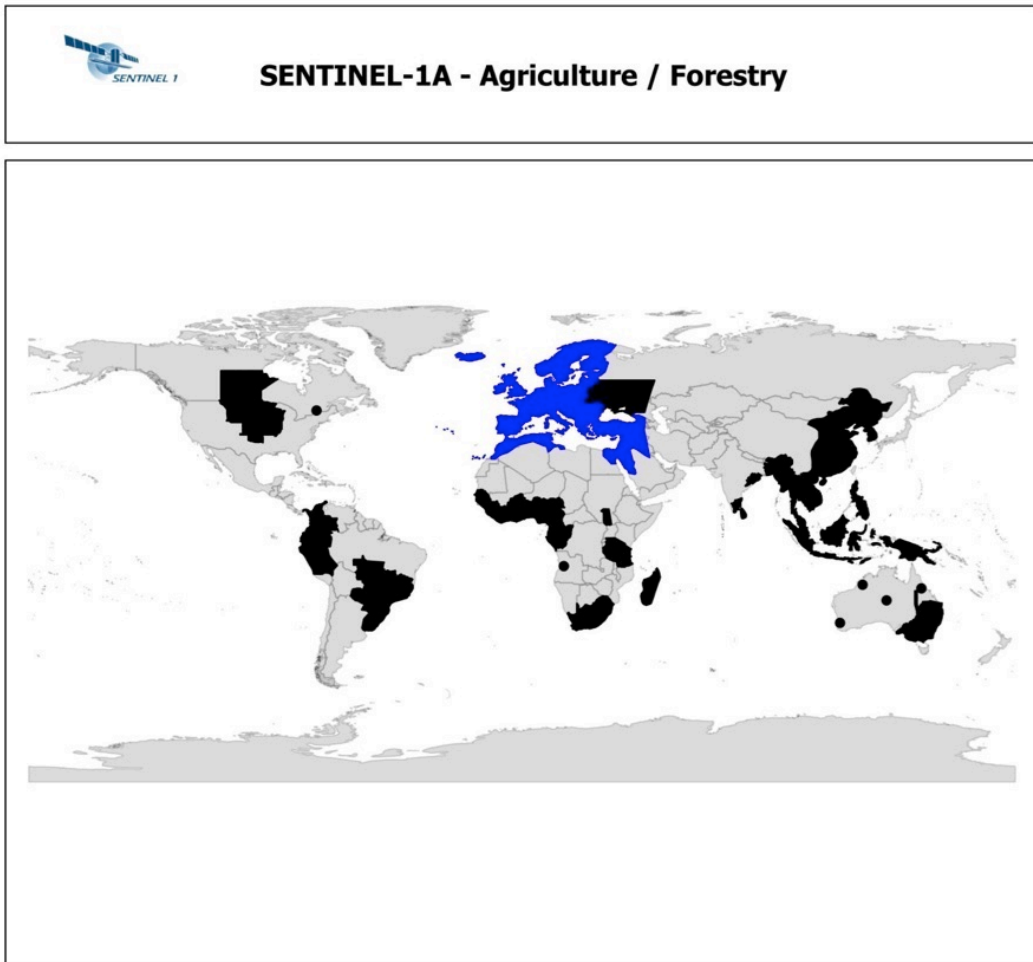
© Contains modified Copernicus Sentinel data (2015)/ESA
SEOM INSARAP study PPO.labs/NORUT

Afghanistan Earthquake October 2015

- Interferogram with Sentinel-1 IW acquisitions on 06 and 30 October 2015
- Ground deformation

Courtesy of Petar Marinkovic PPO Labs SEOM INSARAP
© Contains modified Copernicus Sentinel data (2015)/PPO Labs

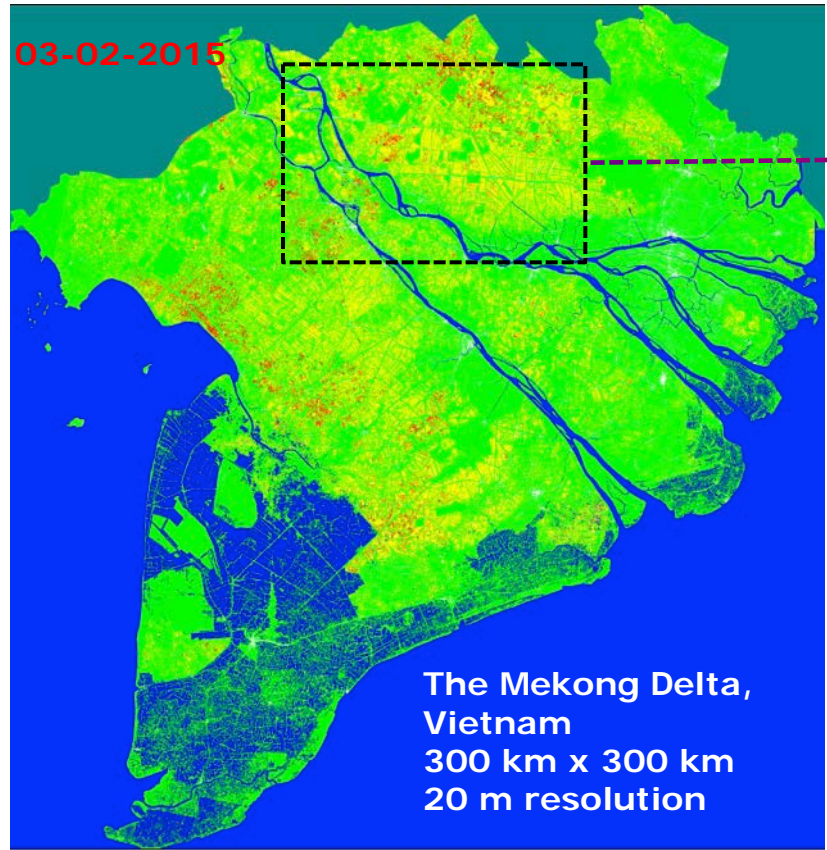




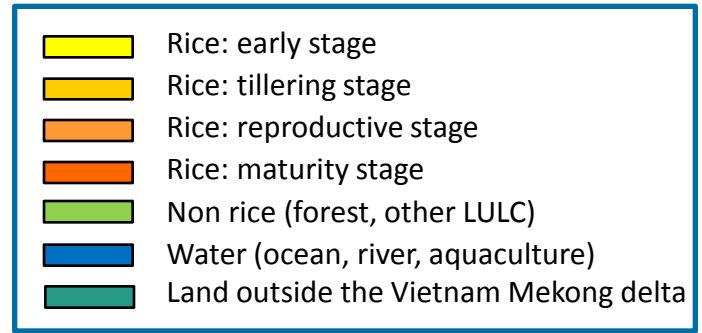
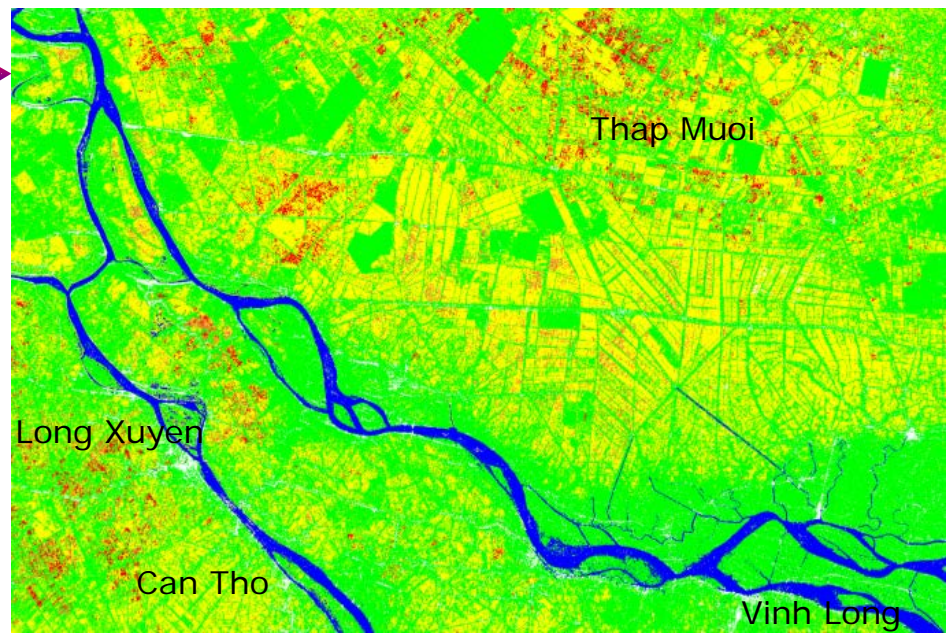
- **BLUE:** Acquisitions in IW mode, VV+VH polarisation, every 12 days ascending and descending
- **BLACK:** Acquisitions in IW mode, VV+VH polarisation, every 12 days in one pass
 - Repeat over parts of SE-Asia IW VV+VH currently every 24 days, plus complementary acquisitions in IW VV
 - North Andes 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

Monitoring of Winter-Spring rice

© Contains modified Copernicus Sentinel data (2015)

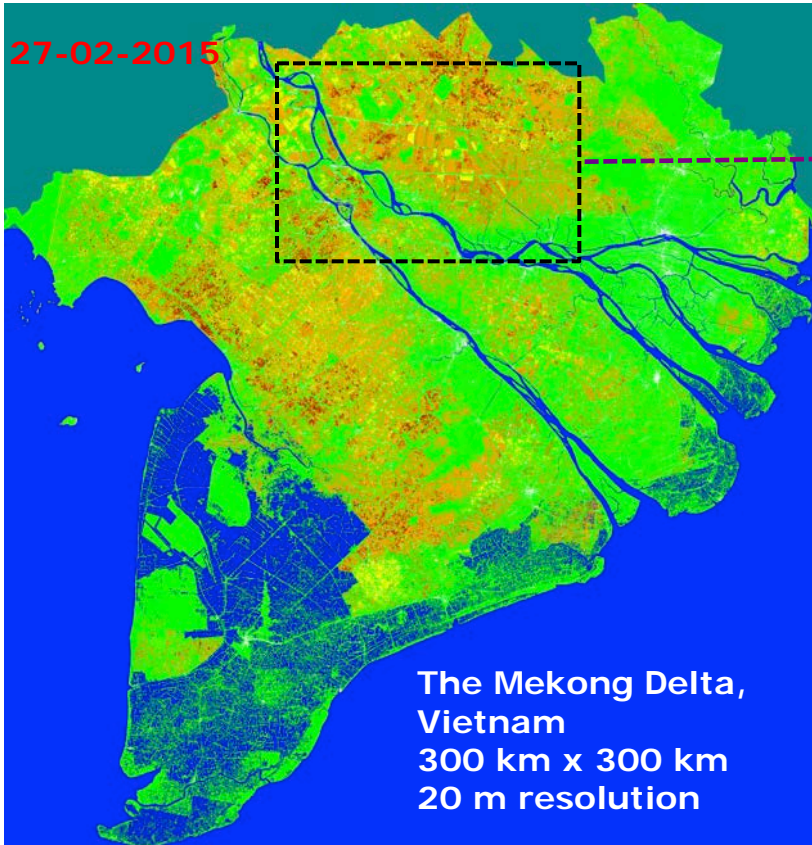


100 km x 70 km, 20 m resolution

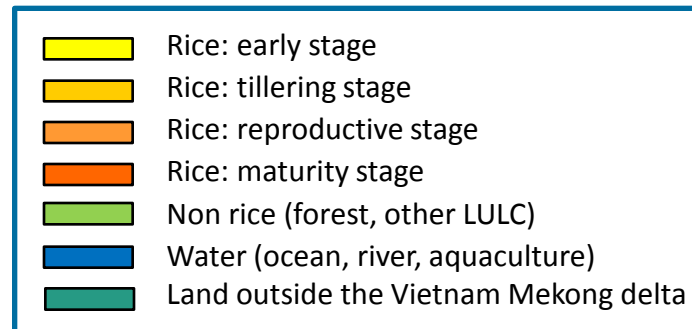
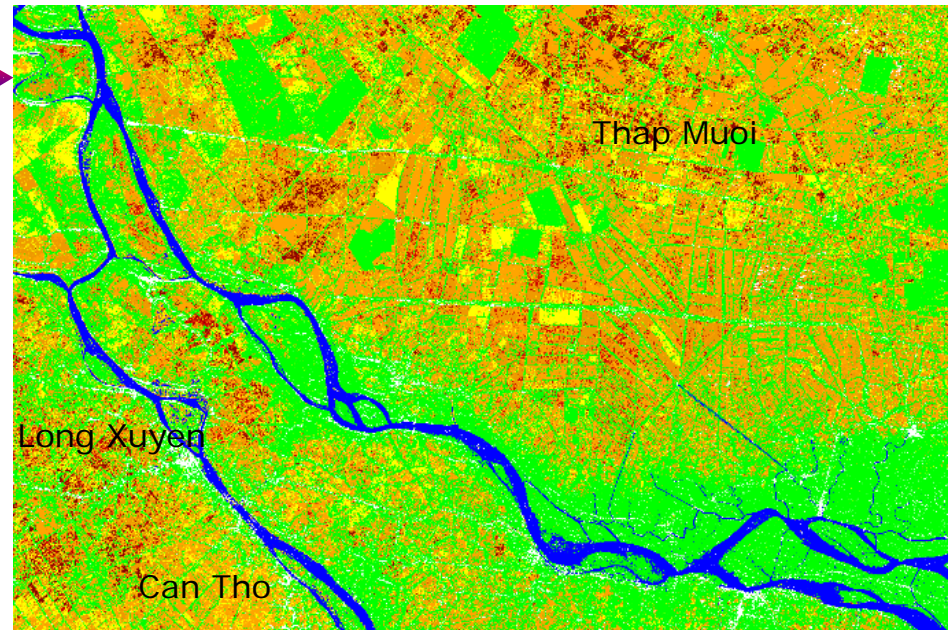


Monitoring of Winter-Spring rice

© Contains modified Copernicus Sentinel data (2015)

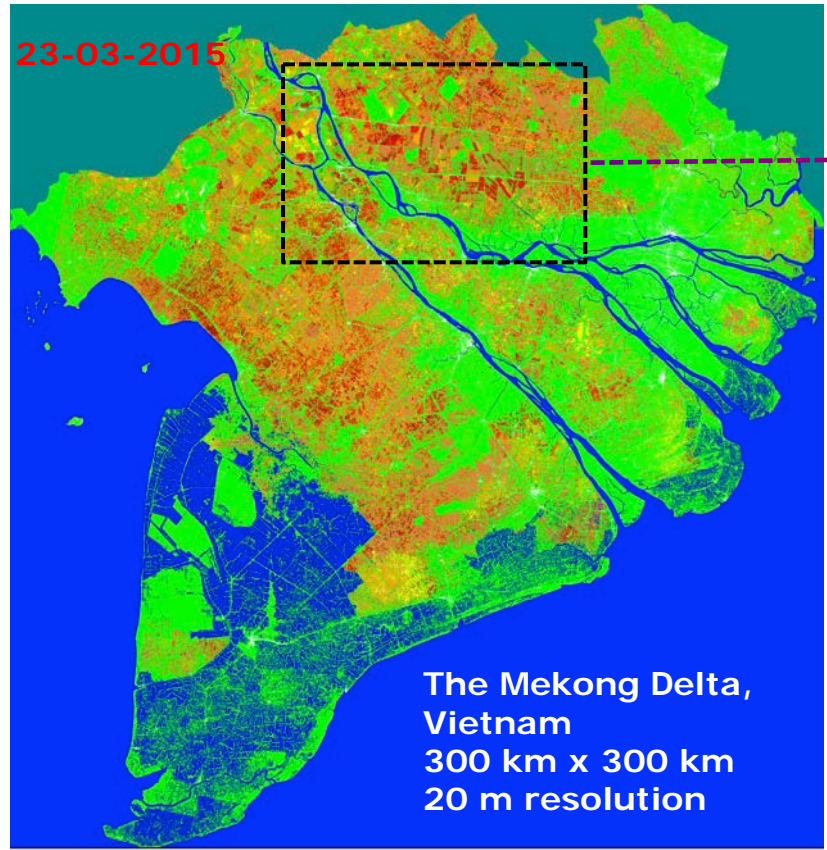


100 km x 70 km, 20 m resolution

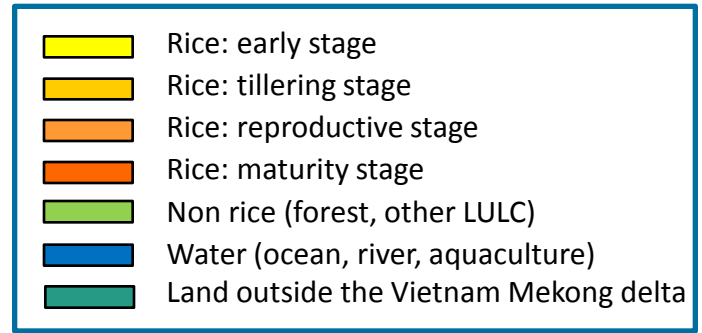
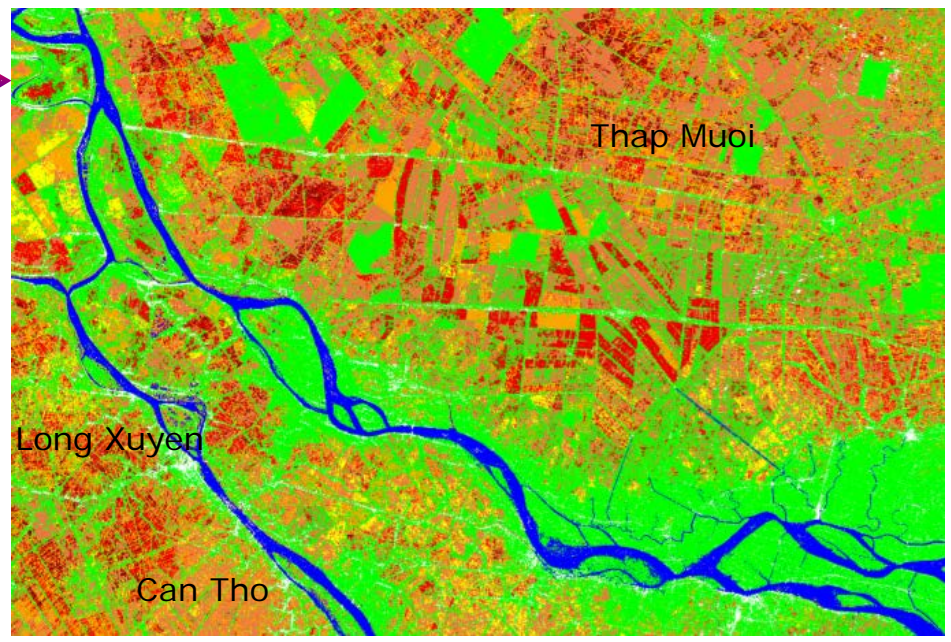


Monitoring of Winter-Spring rice

© Contains modified Copernicus Sentinel data (2015)

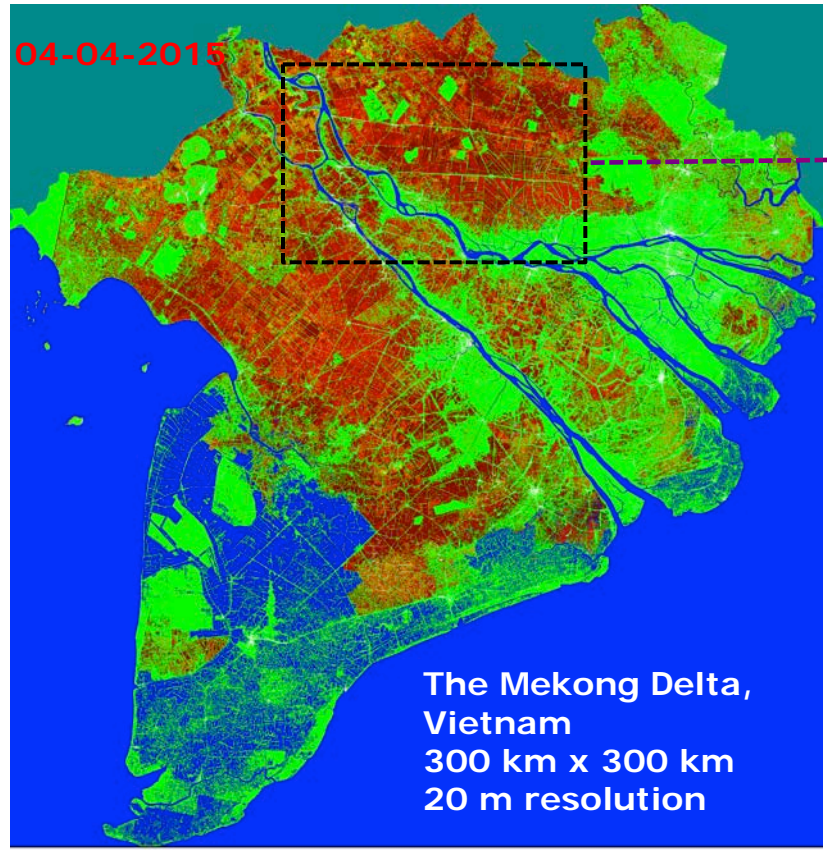


100 km x 70 km, 20 m resolution

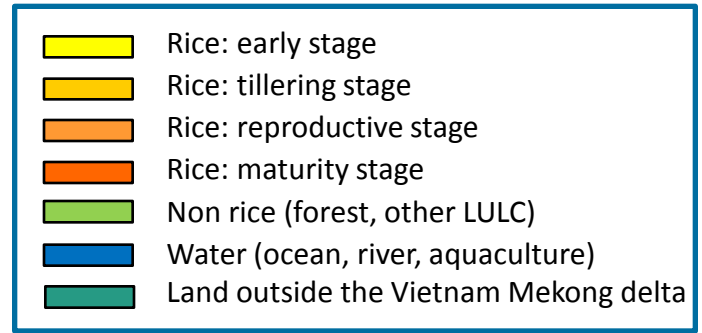
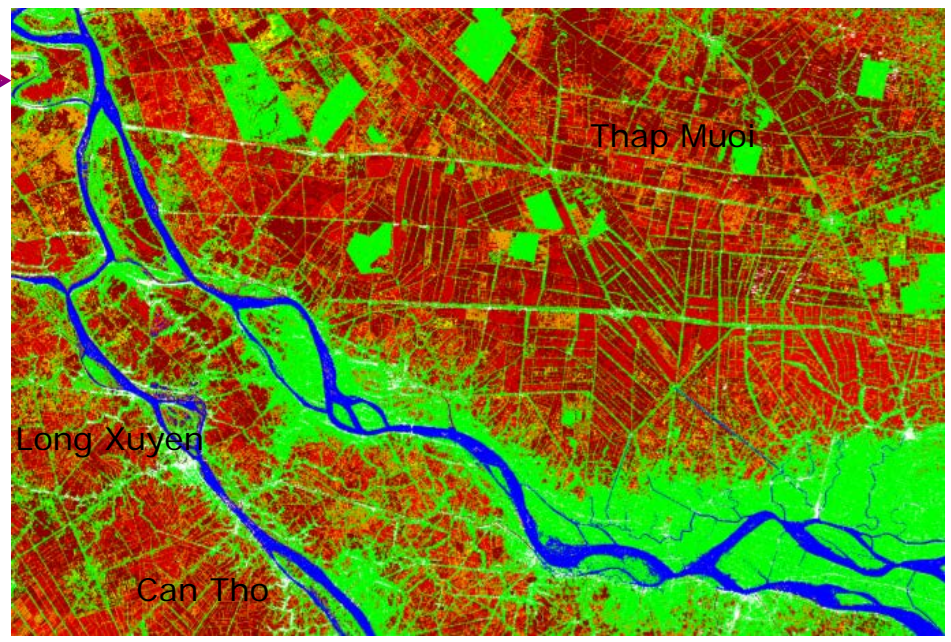


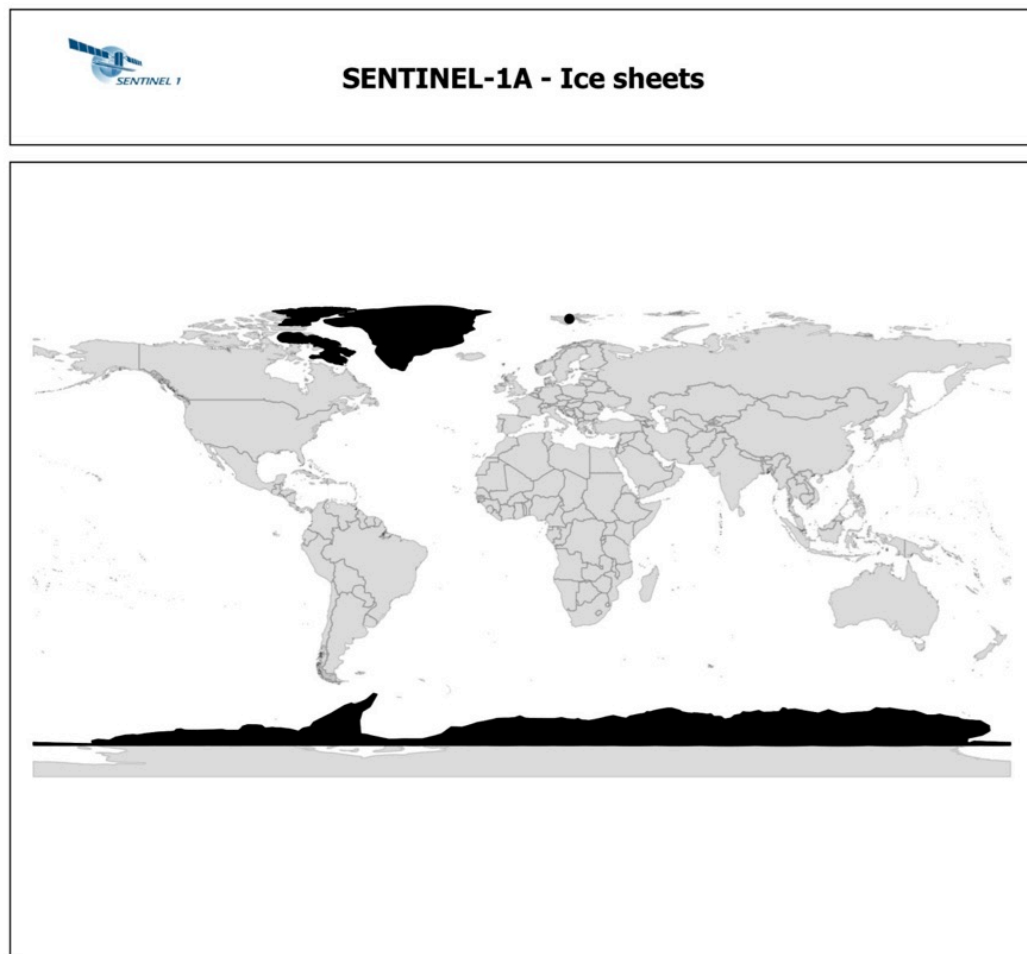
Monitoring of Winter-Spring rice

© Contains modified Copernicus Sentinel data (2015)

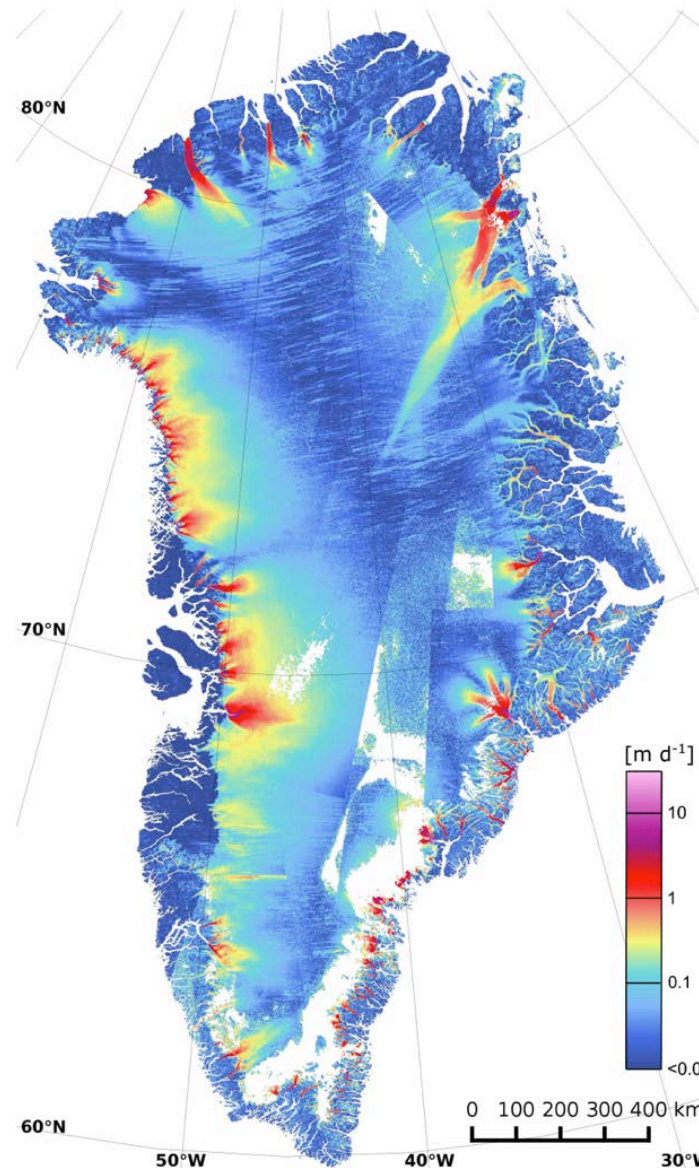


100 km x 70 km, 20 m resolution

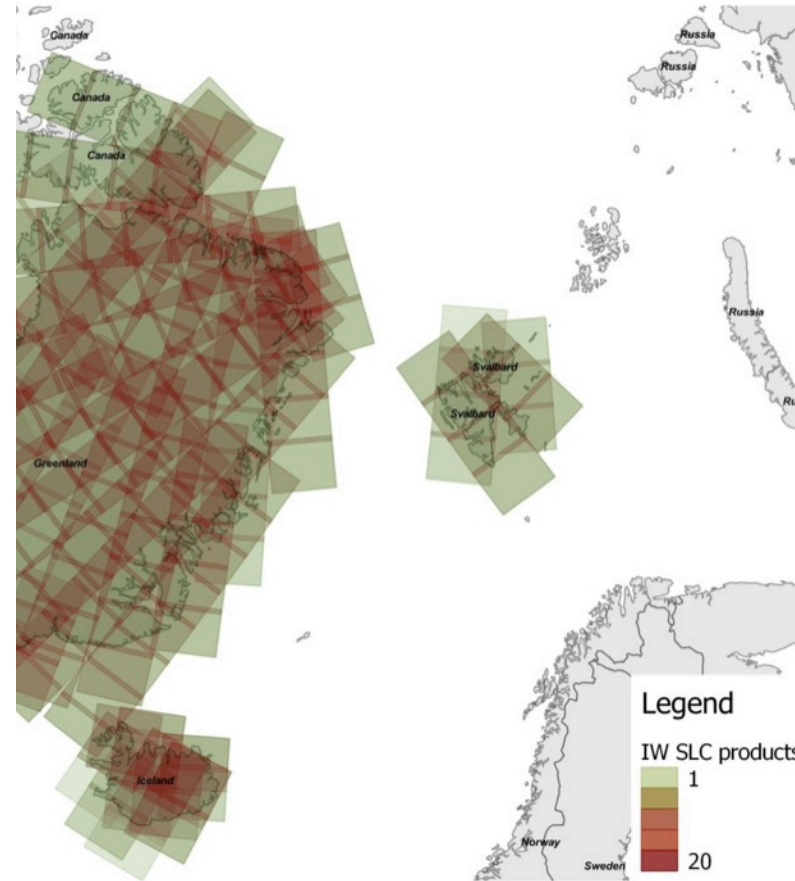




- **All year:** Acquisitions in IW mode, HH polarisation, every 12 days on selected tracks over the complete Greenland shore, the Antarctic Peninsula and the main outlet glaciers of Western Antarctica (Thwaites and Pine Island glaciers)
- **Frequent:** Acquisitions over Svalbard in IW mode, HH polarisation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



01.2015 - 09.03.2015 (Greenland ice sheet campaign)



Monitoring of coastal
ice cycle with 6 tracks

Greenland campaign:

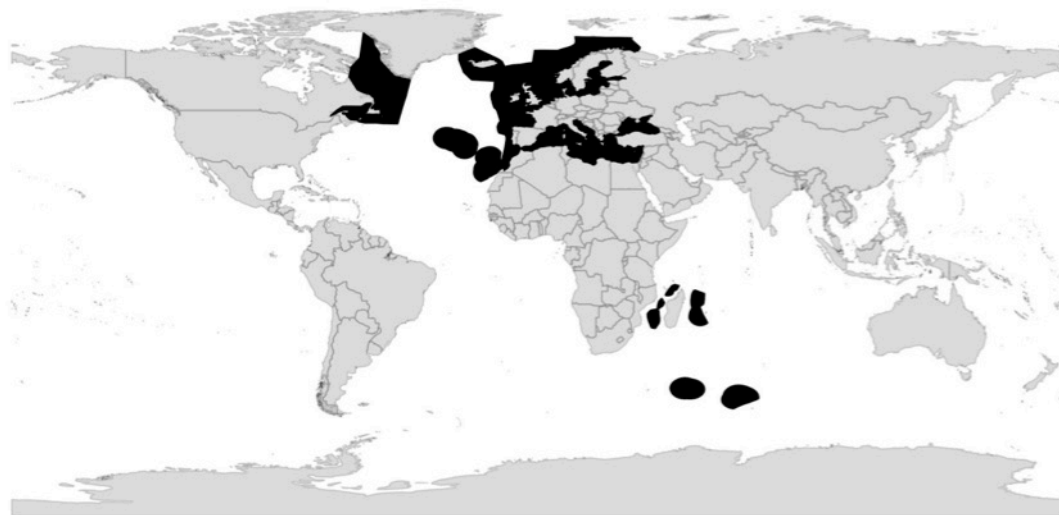
- ✓ ~ 750 IW SLC scenes from 16.01.2015 to 09.03.2015
- ✓ Cumulative SAR operation time of > 5 hours

Greenland overall:


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



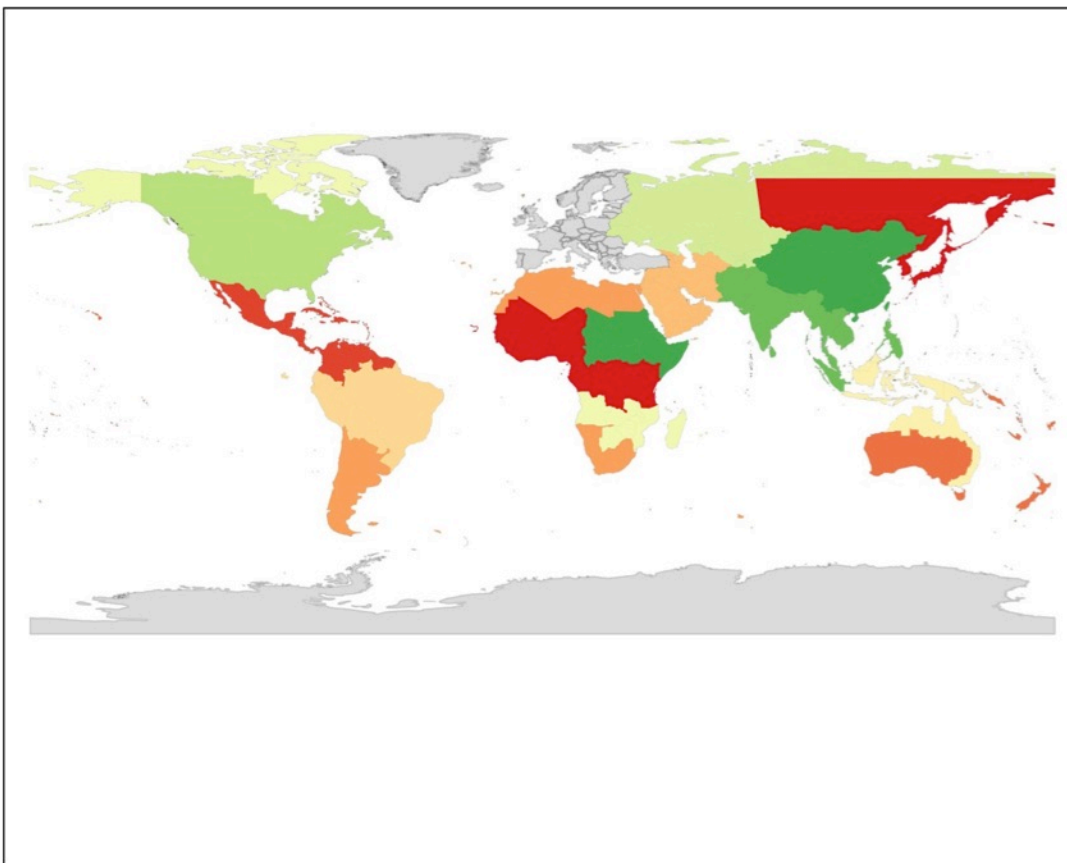
SENTINEL-1A - Maritime surveillance



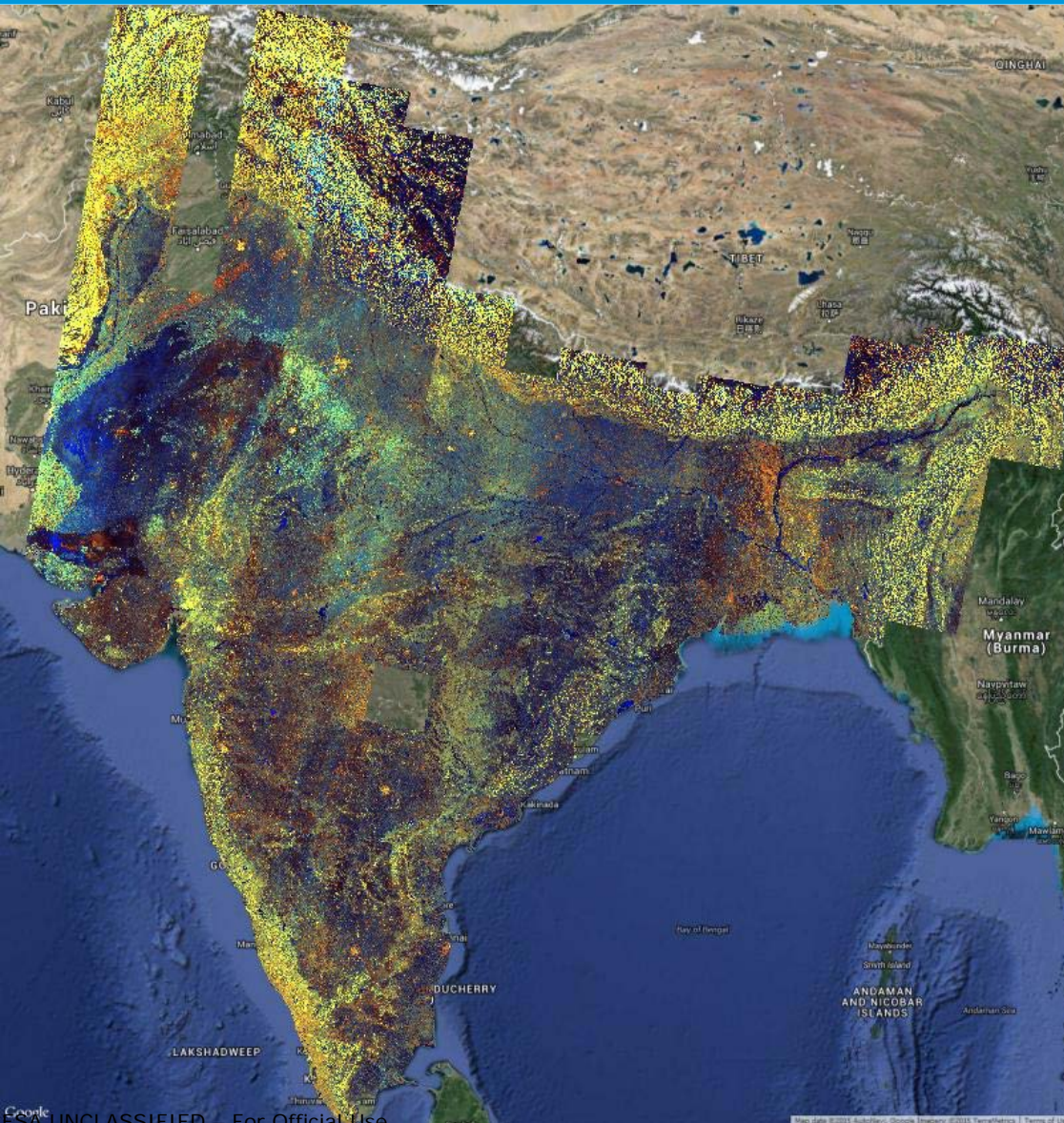
- Frequent acquisitions in IW mode, dual polarisation ASC + DSC, over North Sea, Baltic Sea, European coastal waters
- Frequent acquisitions in IW and EW mode, ASC + DSC around Iceland, Azores and Canary islands
- One pass coverage of EEZ in IW mode over French Islands in the Indian Ocean and around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



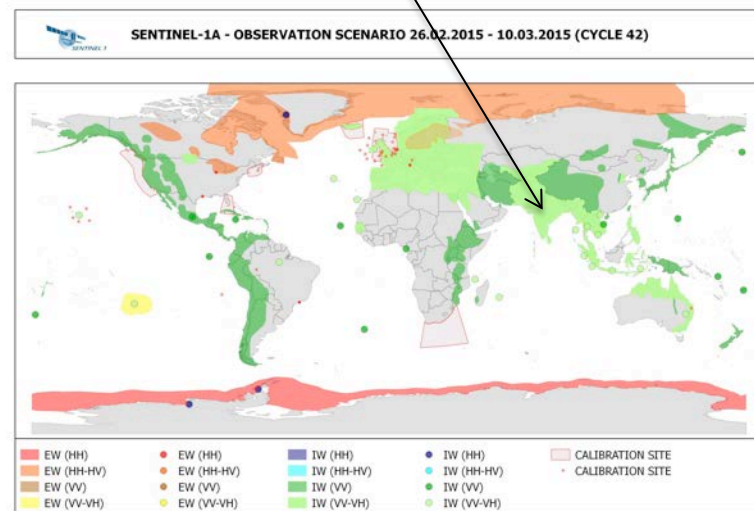
SENTINEL-1A - Zonal mapping



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

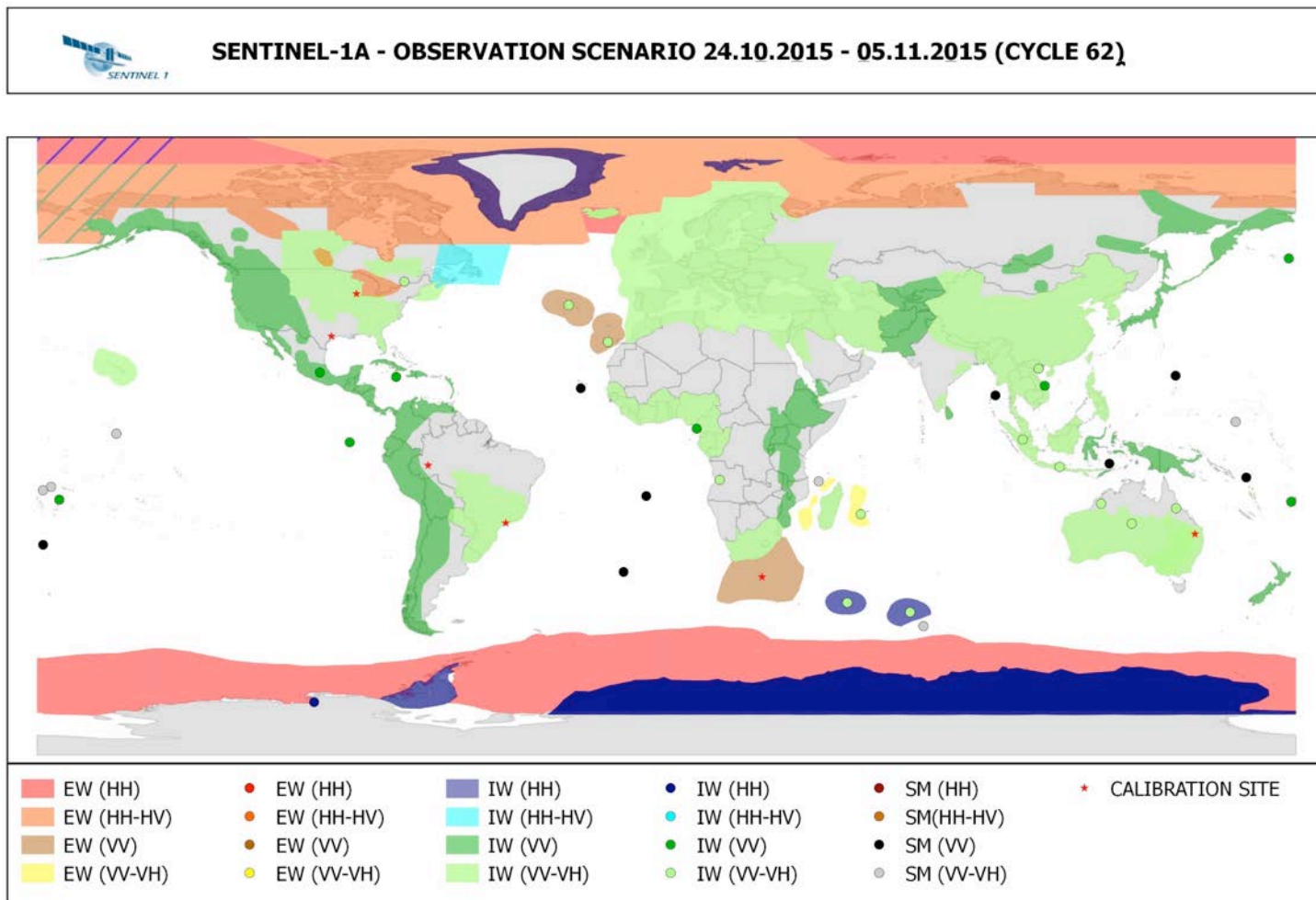


Courtesy of SARMAP

© Contains modified Copernicus Sentinel data (2015)

Sentinel-1 observation scenario regularly published online

(current repeat cycle 62: from 24 October to 5 November 2015)



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

You are here [Home](#) > [Data Access](#)

- Data Access Navigator

- 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:

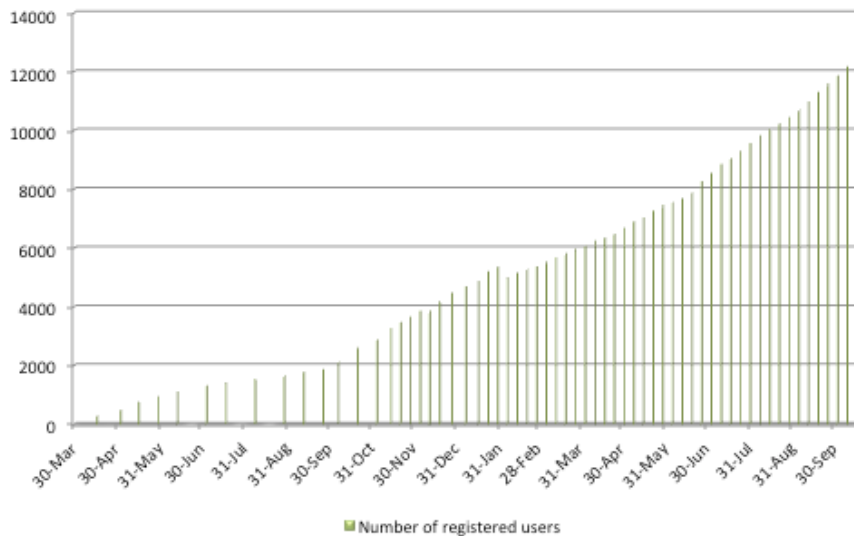
- IW, EW, SM L0 & L1 systematic products
- WV L2 OCN products
- IW/EW L2 OCN products

By 15 October 2015:

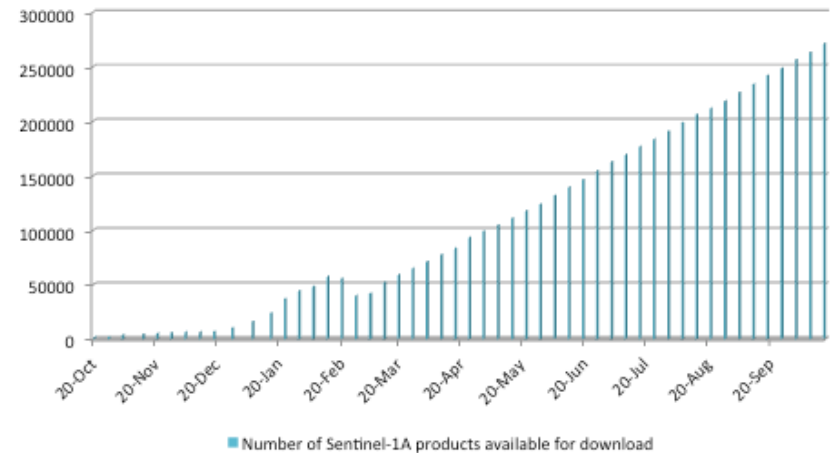
- ✓ 12,587 users registered on the scientific data hub
- ✓ 2.3 million products downloaded by users, representing 2.7 Petabytes of data

Currently more than 292,000 products available for download

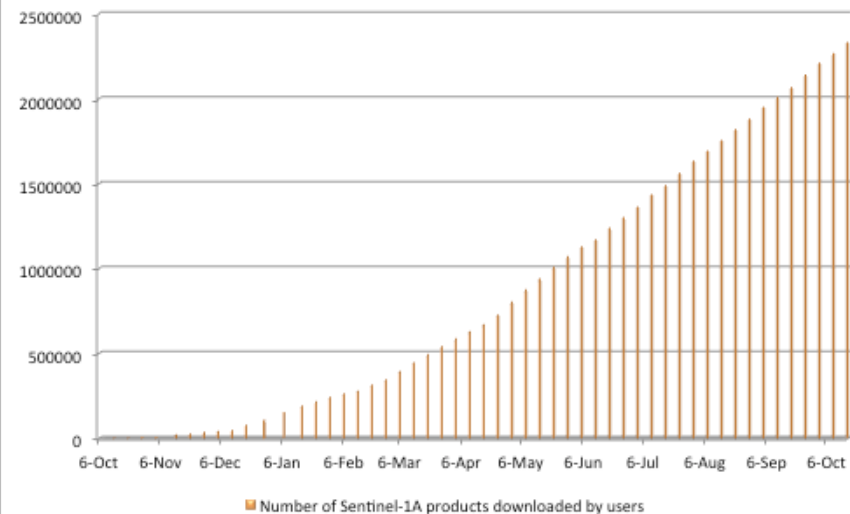
Number of registered users since registration opening on 30 March 2014



Number of Sentinel-1A products available for download



Number of Sentinel-1A products downloaded by users



Sentinel 1 Toolbox

- Multi-mission Scientific Toolboxes
- Developed as open source software
- common architecture
- Portable to a Cloud infrastructure

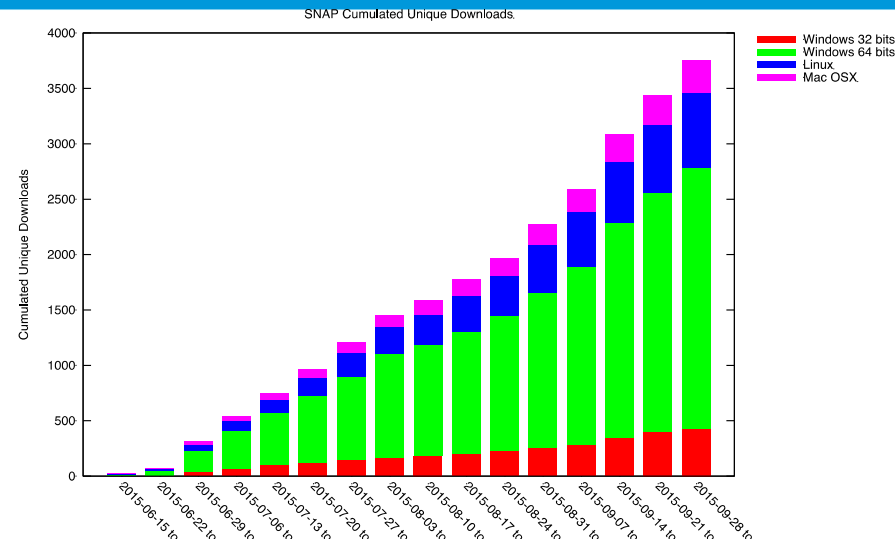
Download SNAP-S1TBX <http://step.esa.int/>

S1TBX: Array Systems
Computing (CANADA)

STEP (Science Toolbox Exploitation Platform)

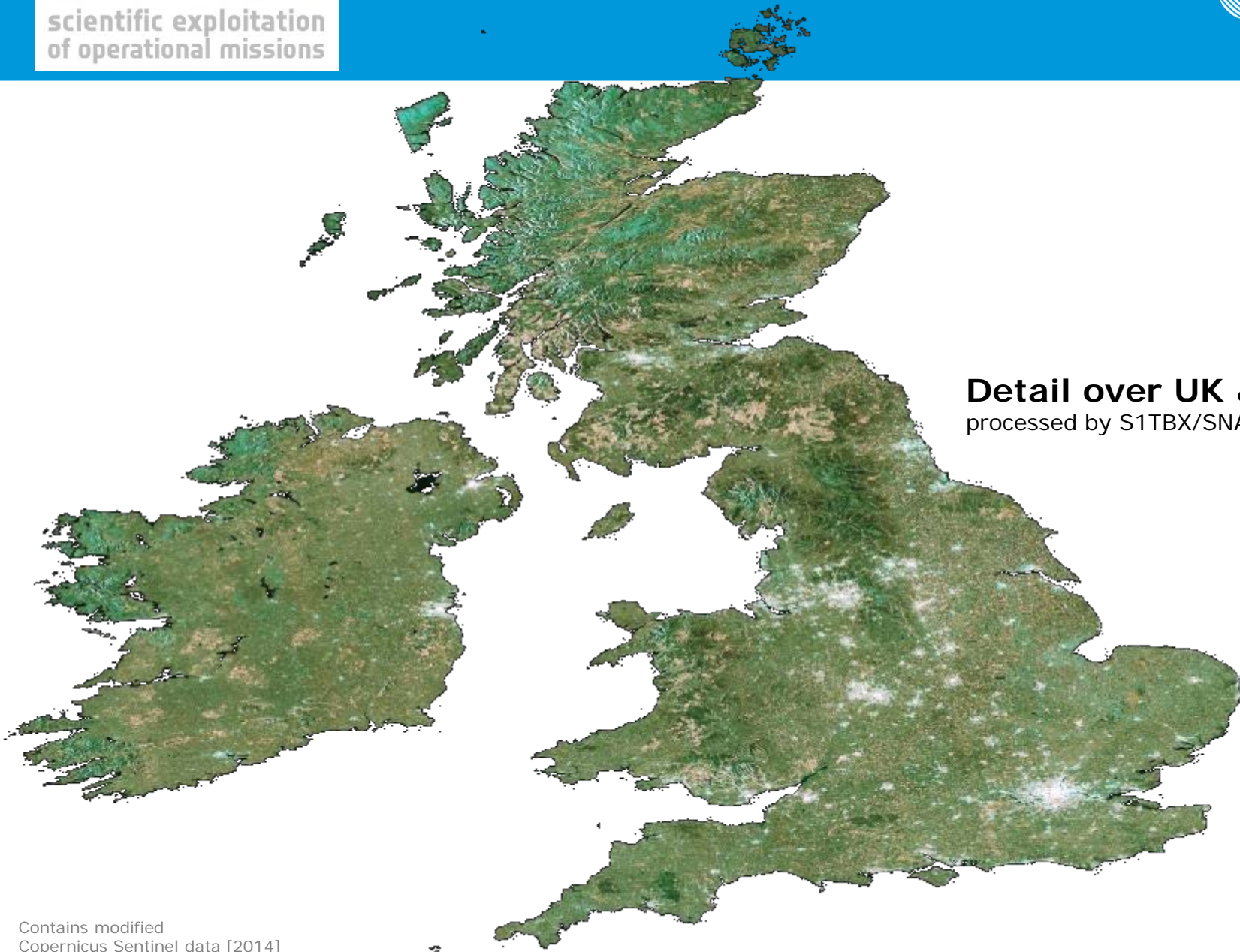
- ◆ EO science collaborative portal
- ◆ Technical forum and community animation
- ◆ Gathering user feedback and usage
- ◆ Communicating on results

at <http://step.esa.int/>



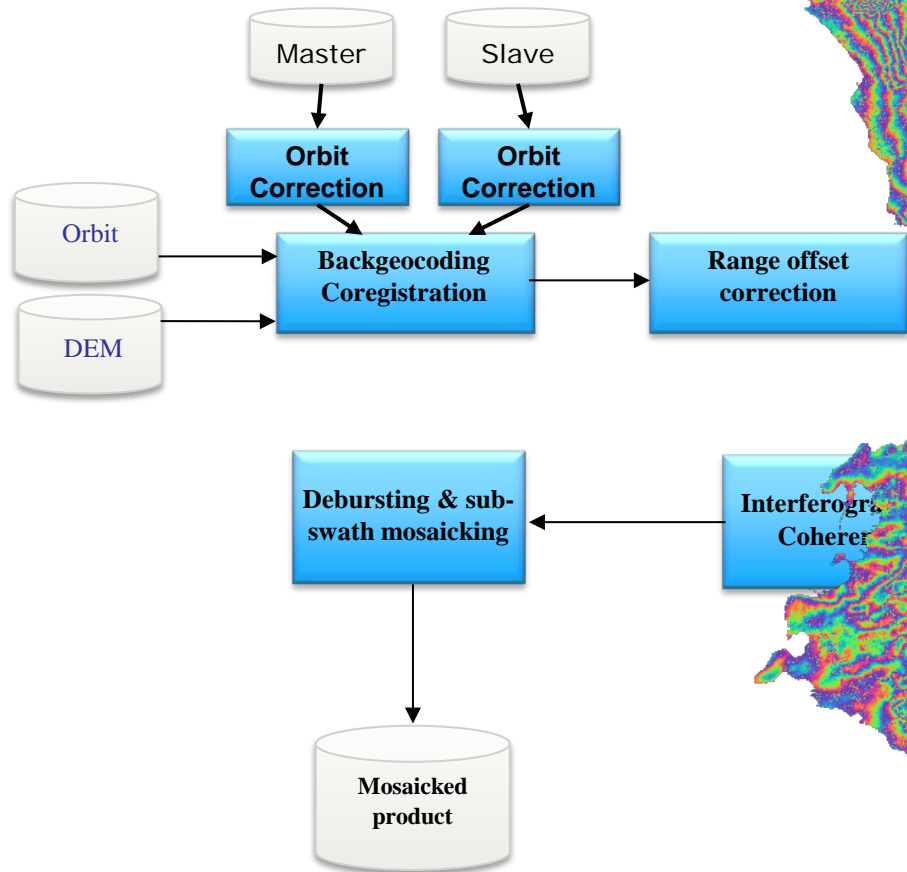
SNAP Cumulative weekly unique downloads by OS

The screenshot displays the user interface of the STEP platform. At the top, there are navigation tabs for 'EUROPEAN SPACE AGENCY', 'ABOUT US', 'OUR ACTIVITIES', 'FOR PUBLIC', 'FOR MEDIA', 'FOR EDUCATORS', and 'FOR KIDS'. The main header includes the 'step science toolbox exploitation platform' logo and the ESA logo. Below the header, a navigation menu lists 'ESA', 'STEP', 'TOOLBOXES', 'DOWNLOAD', 'DOCUMENTATION', 'COMMUNITY', and 'NEWS'. The 'TOOLBOXES' section is active, showing a list of toolboxes: Sentinel-1, Sentinel-2, and Sentinel-3. The 'Sentinel-1' toolbox is expanded, revealing a grid of icons for 'START USING STEP', 'STEP FEATURES', 'DOCUMENTATION', 'COMMUNITY', 'DEVELOPERS CORNER', 'MEDIA', 'EXTERNAL PROJECTS', and 'BLOG'. A prominent 'DOWNLOAD SENTINEL-1 TOOLBOX' button is located at the bottom of the page. A search bar is visible in the top right corner.

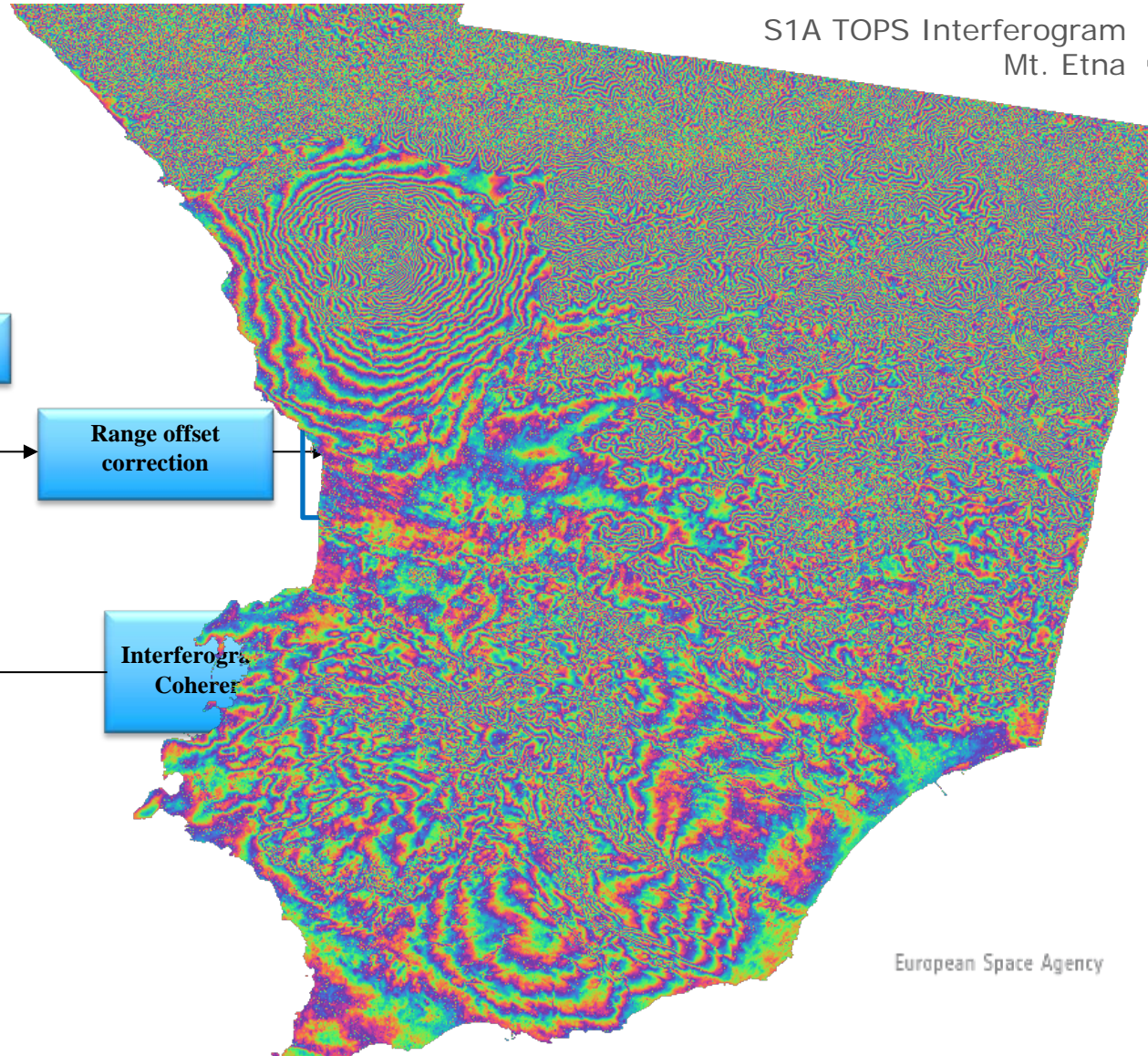


Detail over UK & Ireland
processed by S1TBX/SNAP

TOPSAR Chain



S1A TOPS Interferogram
Mt. Etna

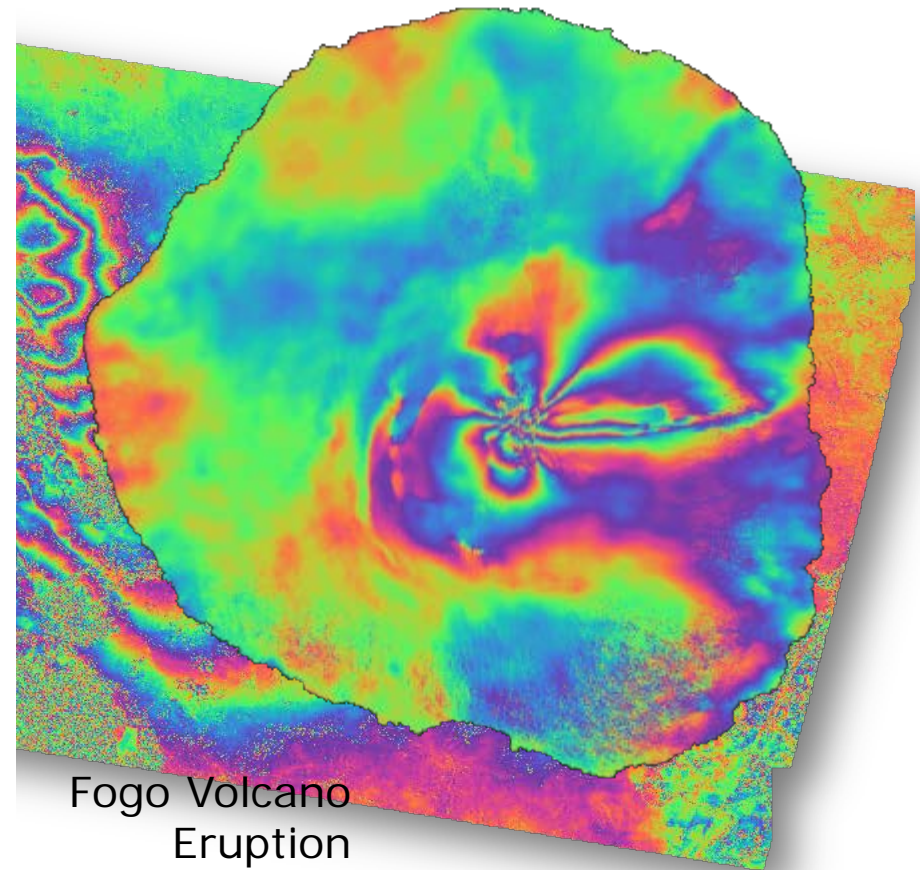


"I met with Scott last week and he showed me some really nice TOPS interferograms generated using the Sentinel-1 toolbox which is freely available from ESA. Scott said it could be easily scripted to bring it into a production environment. "

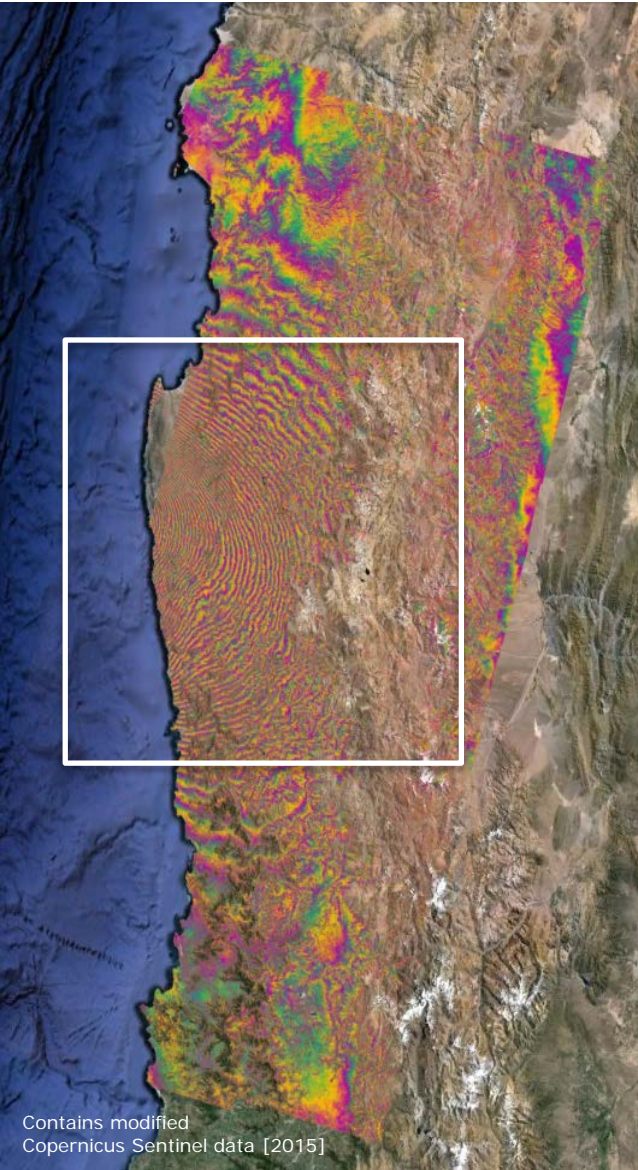
Prof. David Sandwell
COMET Board discussions

"I would like to thank the European Space Agency for making available to scientists with the Sentinel1 toolbox. I would like to inform you that the software is used in our University for educational purposes within the undergraduate and postgraduate courses. I would also like to thank you for the support given by the ESA team at all our questions about the operation of the software and we hope soon to have new versions that will increase our capabilities."

Prof. Issak Parcharidis
Harokopio University of Athens



**Fogo Volcano
Eruption**



September 16, 2015, earthquake of **magnitude 8.3** in Chile.

interferogram combining S1A from 24th August and 17th September

Fringe pattern suggests about **140 cm** Line-of-Sight ground displacement.

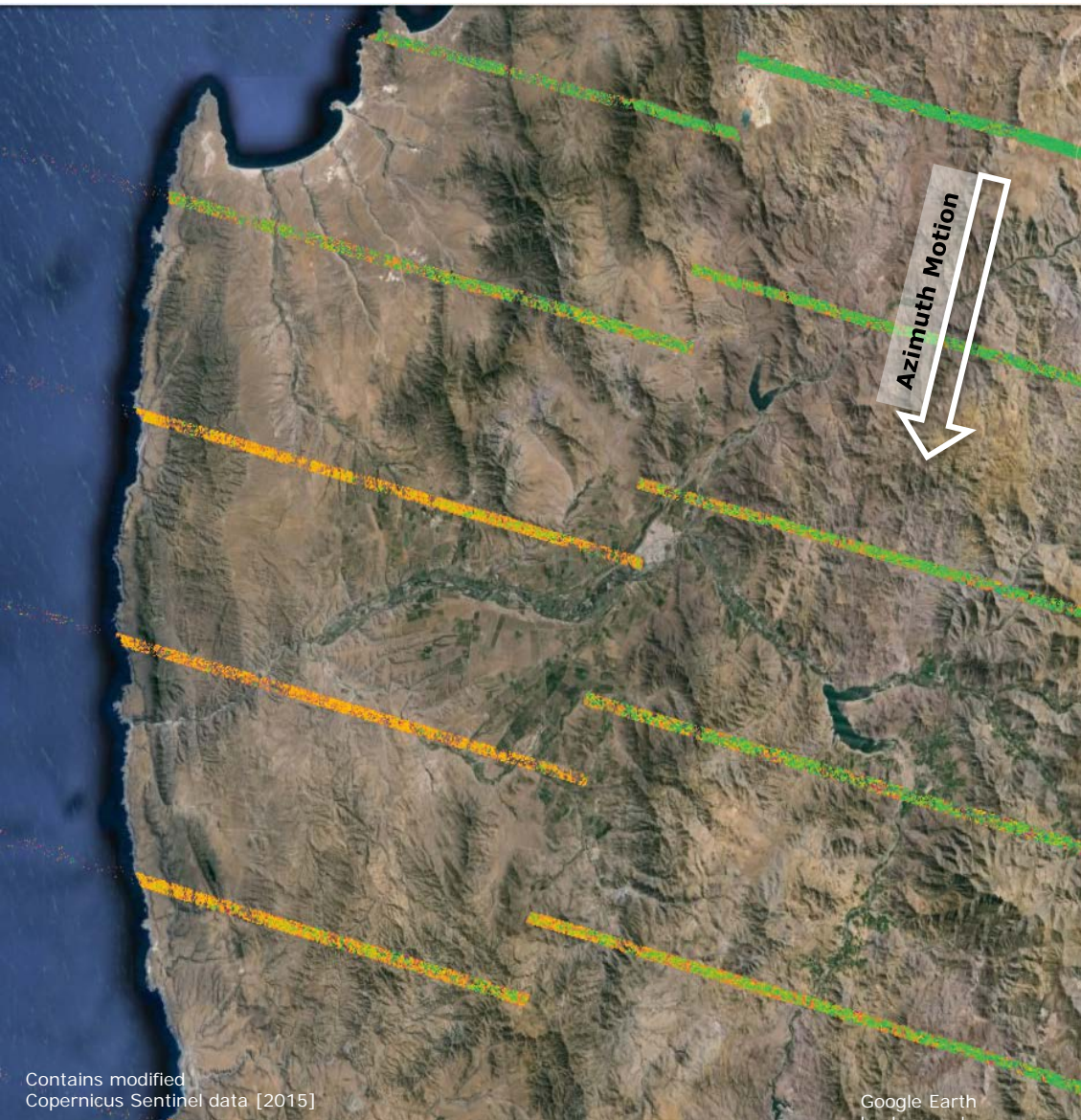
Geophysical product available at INSARAP.org
500+ downloads in 2days

Science blog 140K views

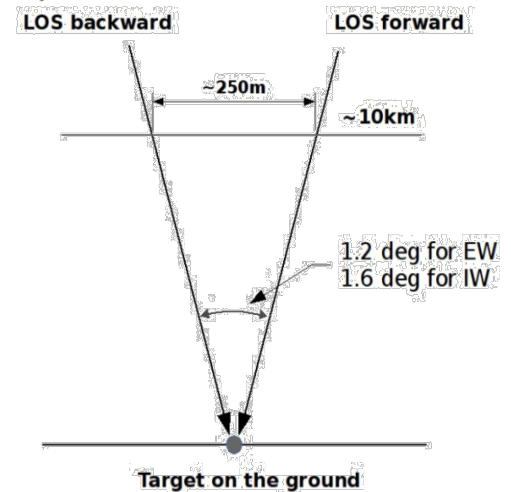
<http://space.io9.com/this-is-how-much-the-ground-moved-during-chiles-massive-1731767430>

ESA website Image -24105 views

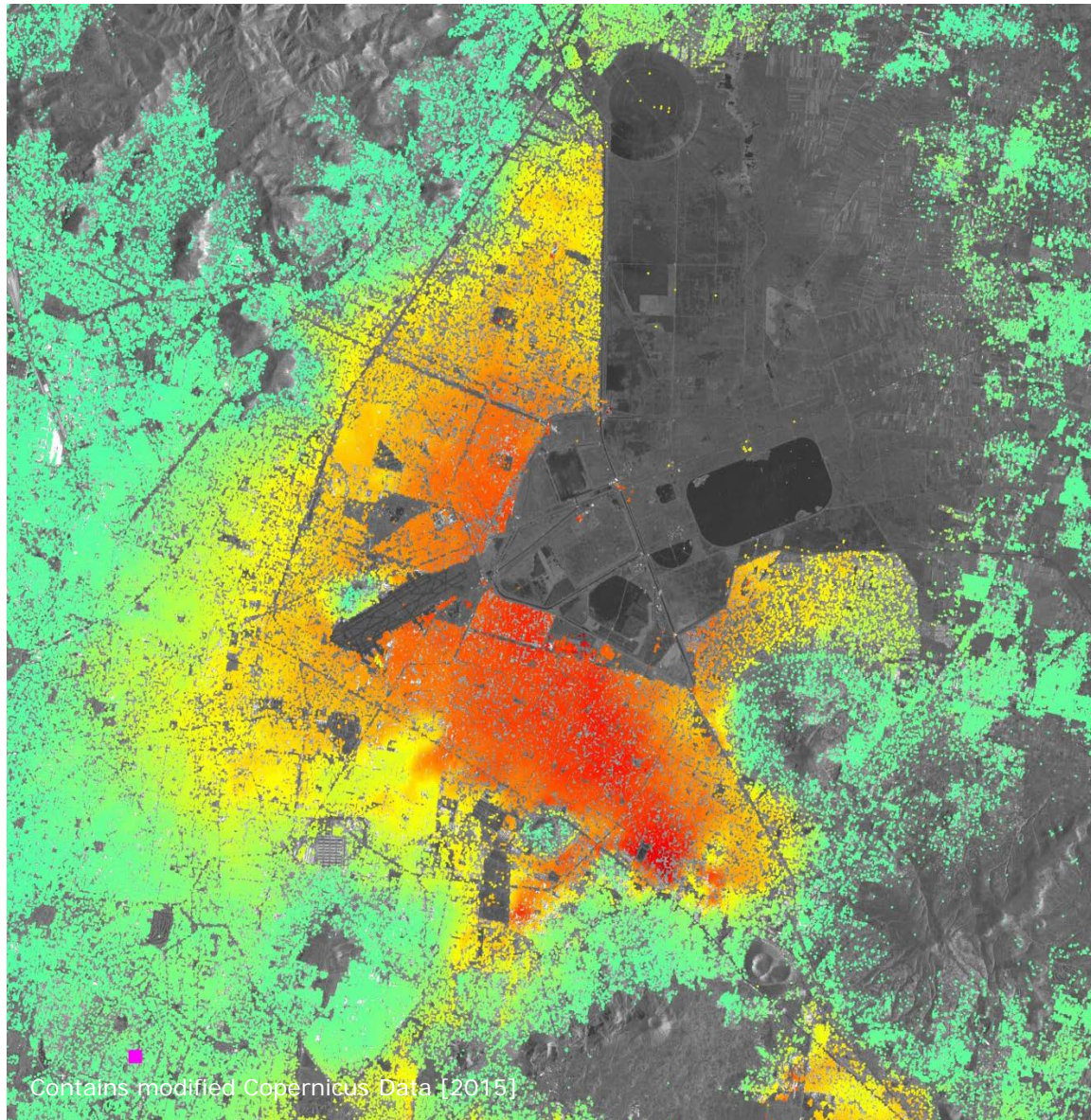
http://www.esa.int/spaceinimages/Images/2015/09/Chile_earthquake_on_the_radar



Study of the phase difference in the burst overlaps indicates about **50 cm** of horizontal (along track) motion.

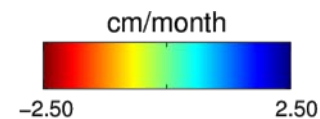


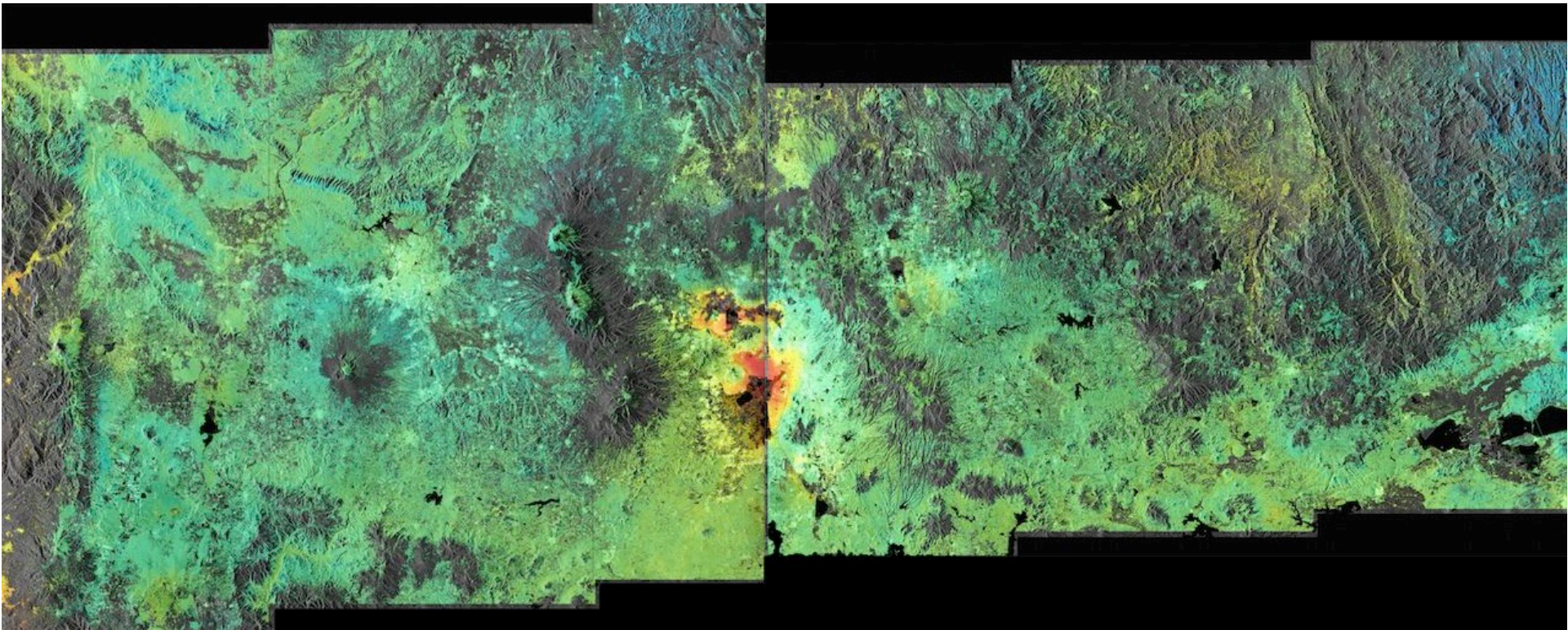
Motion along the azimuth direction can be measured from phase double difference of burst overlap regions (targets viewed from different angles within the 250km swath).



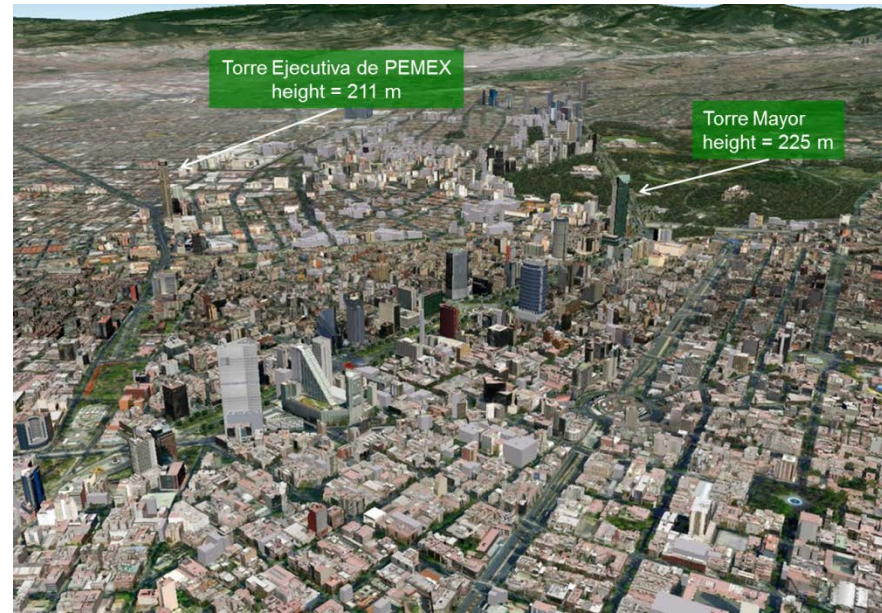
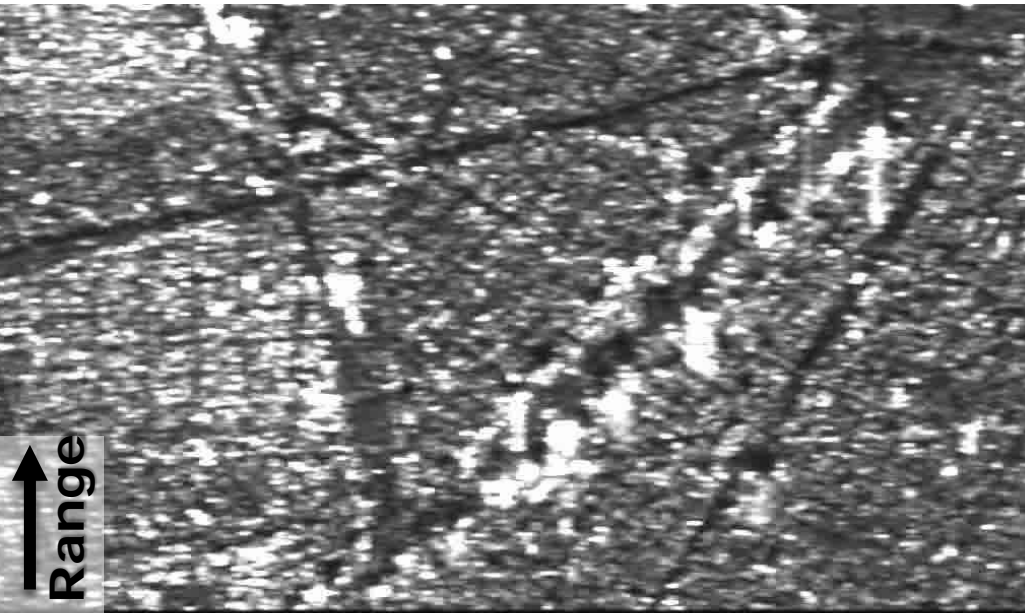
Sentinel-1A IW TOPS data acquired from October 3rd, 2014, until September 4th, 2015 were combined to measure ground deformation in Mexico City.

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





~500km (longitude)



Sentinel-1 Assessment of the Interferometric Wide-Swath Mode (InSARap Study)

Pau Prats et al IGARSS 2015



Thank you for your attention !

EU Copernicus web site:
<http://www.copernicus.eu/>

Sentinel Online web site:
<http://sentinels.copernicus.eu>