Sentinel-1 Mission Overview and Status

ESA Polarimetry Course 2019
22 Jan 2019, ESRIN, Frascati

Copernicus – the European EO programme

European Earth Observation System, led by the EU

European response to global needs:

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

FULL, FREE AND OPEN ACCESS TO DATA

- ATMOSPHERE MONITORING
- MARINE ENVIRONMENT MONITORING
- LAND MONITORING
- CLIMATE CHANGE
- EMERGENCY MANAGEMENT
- SECURITY

copernicus
Europe's eyes on Earth

Sentinel Launches

Sentinel-1 Constellation Mission Facts & Status

- Constellation of two identical SAR C-band (5.405 GHz) satellites (A & B units)

- *Sentinel-1A* launched on 3 April, 2014 & *Sentinel-1B* on 25 April, 2016

- Near-Polar, sun-synchronous (dawn-dusk) orbit at 698 km

- Instrument duty cycle of 25 min/orbit in High Bit Rate modes and 75 min/orbit in Low Bit Rate mode (Wave)

- *12-day* repeat cycle (each satellite), *6 days* for the constellation

- Systematic SAR data acquisition using a predefined observation scenario

- 7 years lifetime, consumables for 12 years at least
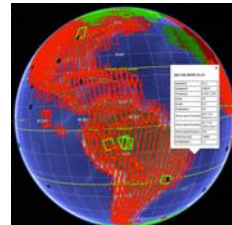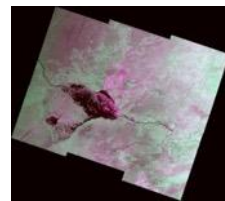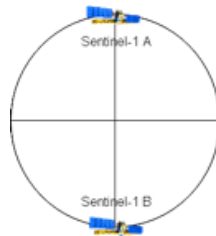
- Sentinel-1A and Sentinel-1B mission operations → **nominal**

- Sentinel-1 is operated close to its **full mission capacity**
  (i.e. difficulty to accommodate additional observations)

Sentinel-1 SAR Operational Modes
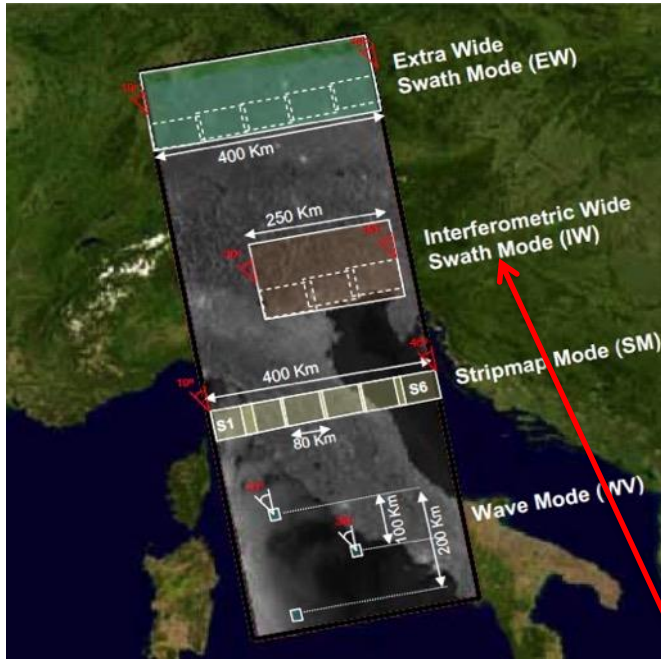
GRD Level 1 product resolution	Swath Width	Polarisation
EW — 50m (3 ENL)	> 400 km	HH+HV or VV+VH
IW — 20m (5 ENL)	> 250 km	HH+HV or VV+VH
SM — 9m (4 ENL)	> 80 km	HH+HV or VV+VH
WV — 50m (140 ENL)	20 x 20 km² at 100 km spacing	HH or VV

IW: main mode over land and coastal areas

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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.

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Sentinel-1 Constellation systematic processing

GLOBAL & Regional Production & Dissemination Operations Scenario

Global Production scenario			
Processing scenario	**Instrument mode**	**Systematic Product Type**	**Timeliness**
Systematic Global	SM IW EW	L0, L1 GRDH L0, L1 GRDH L0, L1 GRDM	Fast-24h
	WV	L2 OCN	Fast-24h

Regional Production scenario status			
Processing scenario	**Instrument mode**	**Systematic Product Type**	**Timeliness**
Systematic Regional NRT	EW	L1 GRDM L1 SLC	NRT Fast24h
Systematic Regional SLC	IW, SM	L1 SLC	Fast24h
Systematic Regional L2 OCN	SM, EW, IW	L2 OCN	Fast24

GLOBAL & Regional Production & Dissemination Operations Scenario

Global Production scenario			
Processing scenario	**Instrument mode**	**Systematic Product Type**	**Timeliness**
Systematic Global	SM IW EW	L0, L1 GRDH, L1 SLC, **L2 OCN** L0, L1 GRDH, L1 SLC, **L2 OCN** L0, L1 GRDM, **L2 OCN**	Fast-24h
	WV	**L1 SLC**, L2 OCN	Fast-24h

Regional Production scenario status			
Processing scenario	**Instrument mode**	**Systematic Product Type**	**Timeliness**
Systematic Regional NRT	EW	L1 GRDM L1 SLC	NRT Fast24h
Systematic Regional SLC	IW, SM	L1 SLC (=> global)	Fast24h
Systematic Regional L2 OCN	SM, EW, IW	L2 OCN (=> global)	Fast24

Sentinel-1 Constellation Observation Scenario:
Mode - Polarisation - Observation Geometry

sentinel-1

validity start: 02/2018

esa

Baseline starting Feb 2018

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

POLARISATION SCHEMA

HH or HH-HV

VV or VV-VH

HH or HH-HV

MODE / POLARISATION

- IW mode / dual polarisation (green)
- IW mode / single polarisation (black)
- EW mode / dual polarisation (red)
- EW mode / single polarisation (orange)

▲ SM mode / dual-polarisation
▲ SM mode / single-polarisation

★ Calibration Site

(locally different modes or polarisations possible)

PASS

ASCENDING
DESCENDING

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Sentinel-1 Constellation Observation Scenario: Revisit & Coverage Frequency

sentinel-1

esa

validity start: 02/2018

Baseline starting Feb 2018

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

PASS	REVISIT	FREQUENCY *
ASCENDING	6 days	12 days
DESCENDING		

COVERAGE FREQUENCY *

COVERAGE	FREQUENCY **
1 days	
1-3 days	
2-4 days	

REFERENCE DATA SITES (6d repeat)

- ▲ Highly active volcanism
- ▼ Fast subsidence
- ▲ Short growth cycle, intensive agriculture
- ▼ Fast changing wetlands
- ★ Fast moving outlet glaciers
- ■ Permafrost & glaciers

* coverage ensured from same, repetitive relative orbits
** coverage not considering repetitiveness of relative orbits

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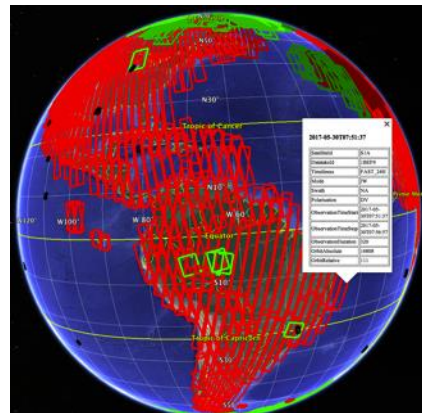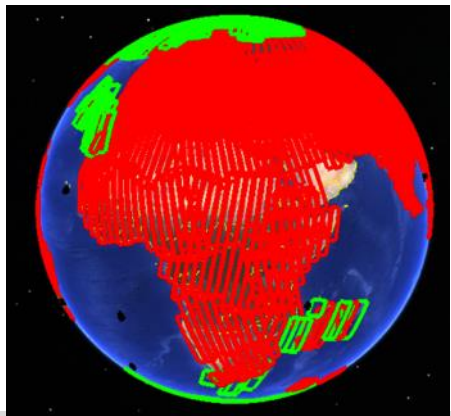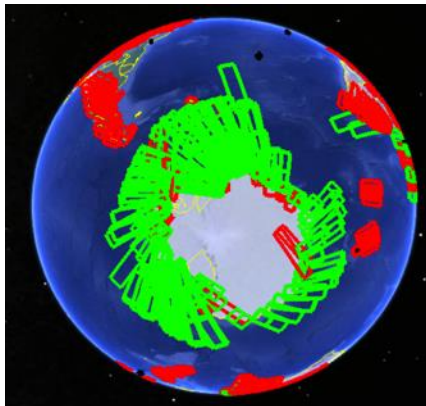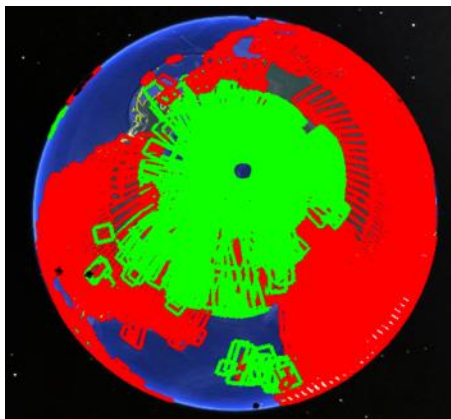
KML files providing detailed information on the planned acquisitions, regularly published on Sentinel Online

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

SAR daily production volume evolution

Sentinel-1 Daily Total Production Volume [TB]

S1B Satellite Commissioning operations

S1 constellation operations

Start of S1A-EDRS operations

Start of S1B-EDRS operations

S1B   S1A

May 2017   May 2018
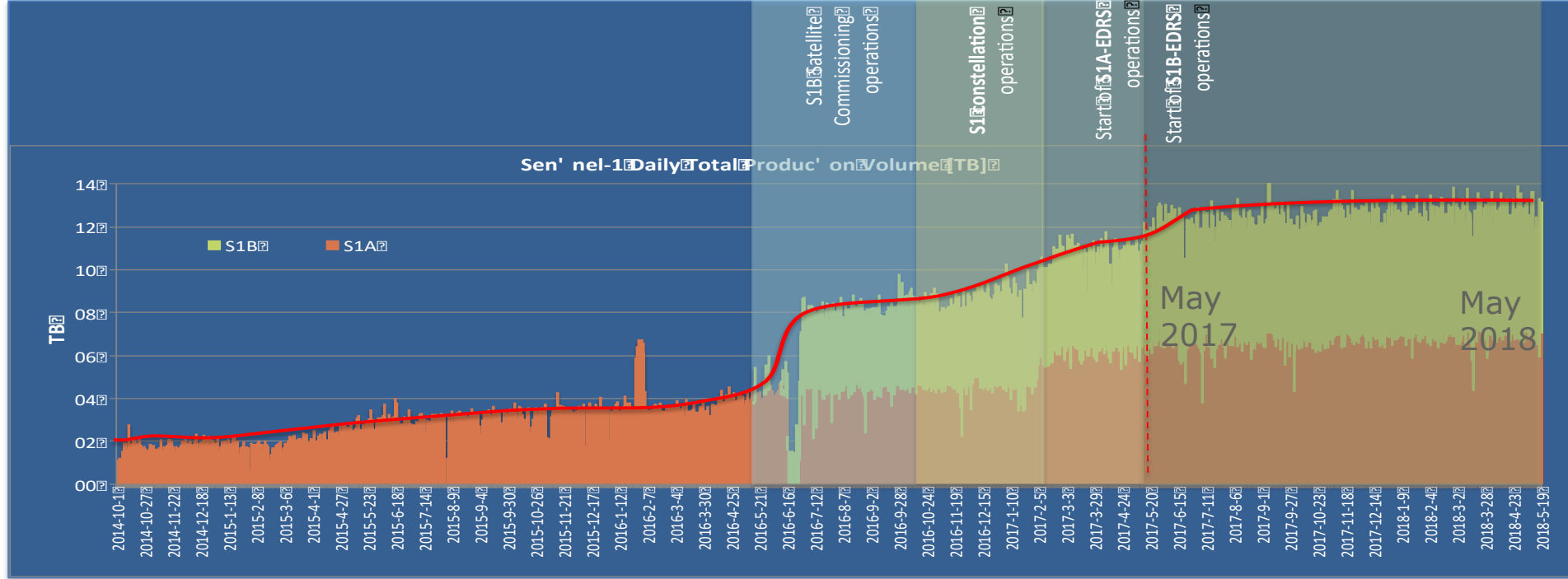
Sentinel-1 operational daily production volume is now exceeding 12 TB/day

ESA UNCLASSIFIED - For Official Use

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Sentinel-1 Constellation operations are based on a set of operational services

There is a large committed team and a set of efficient operational services contributing to the Sentinel-1 operations performance:

- COPERNICUS WAN Service
- Svalbard X-Band Acquisition Service
- Matera X-Band Acquisition Service
- Maspalomas X-Band Acquisition Service
- UK-PAC Long Term Archiving Service
- DLR-PAC Long Term Archiving Service
- Mission Performance Service
- Precise Orbit Determination Service
- Data Access Service
- E2E Production Operations Service

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Operational use of European Data Relay System (EDRS)

The European Data Relay System service provides for the Sentinel-1 mission the following assets:

- **increased data download capacity**
- **increased coverage**
- **enhanced timeliness**

EUTELSAT 9B hosting EDRS-A
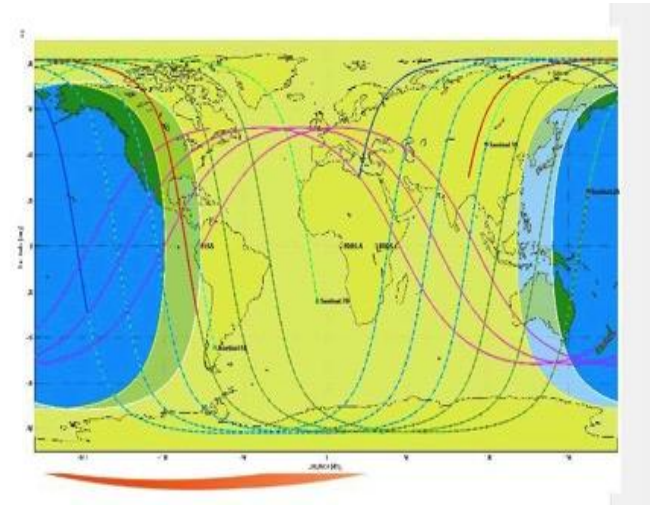
EDRS-Sentinels indicative geometrical visibility map

The operational use of EDRS-A in the Sentinel-1 routine operations has resulted in:

- ✓ Significant **increase of production volume** thanks to the additional downlink capabilities. Sentinel-1 products are being made available through the standard on-line data access mechanisms

- ✓ **Increased observations** (e.g. revisit) and SAR dual polarisation acquisitions

- ✓ significant **increase of Sentinel-1 pass-through acquisitions in X-Band over Europe**

Sentinel Open Access Hub: Free and Open Access to Sentinel data
(previously called "Scientific" Hub)

https://scihub.copernicus.eu/
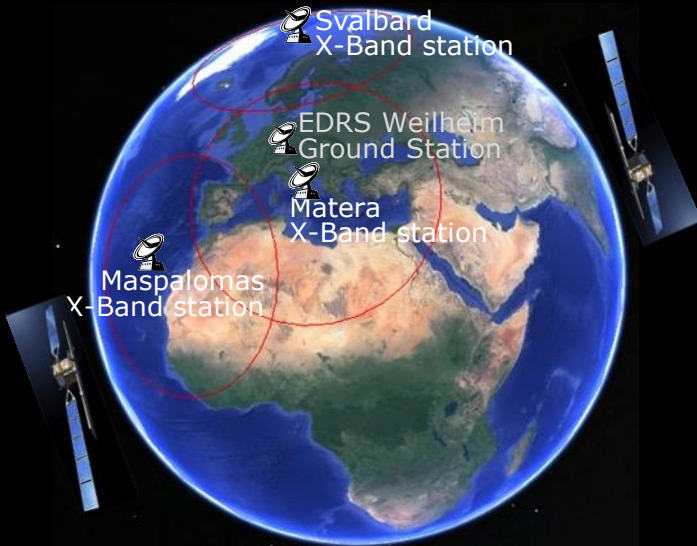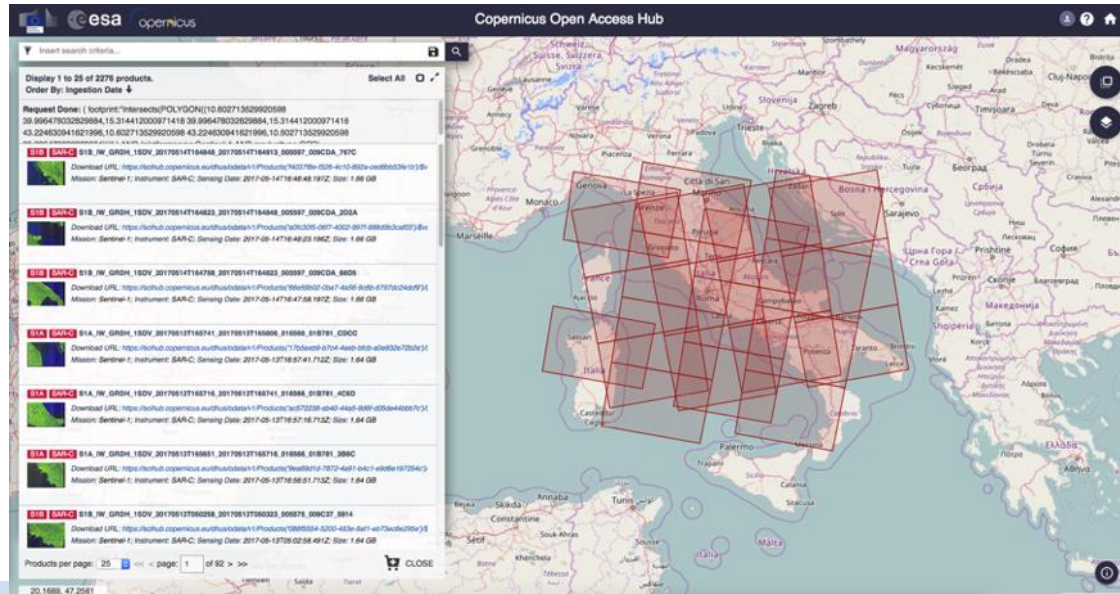
- Access through self-registration
- Automated download scripting capability and dedicated API-Hub
- Restriction on concurrent downloads

More than 200,000 users registered (all Sentinels)
3.4 Million Sentinel-1 products are available on-line for download,
representing 5.5 PB of data.
23 PB of data downloaded by users.

Sentinel-1 observation scenario
Main thematic domains & components

Land cover:
agriculture, forestry,
hydrology, etc.

Maritime
surveillance

European coverage

Sea-ice, icebergs,
lake-ice

Emergency

Calibration/validation

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

Security

Global land mapping

PR actions
(infrequent)

Sea state

Ice sheets, glaciers,
permafrost, snow, etc

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Sierra Negra and Fernandina volcano eruption, Galapagos
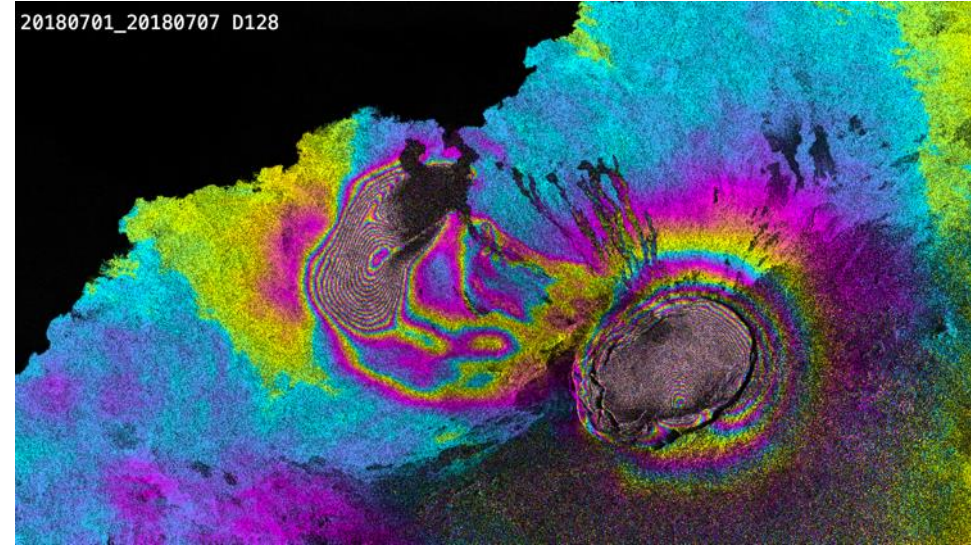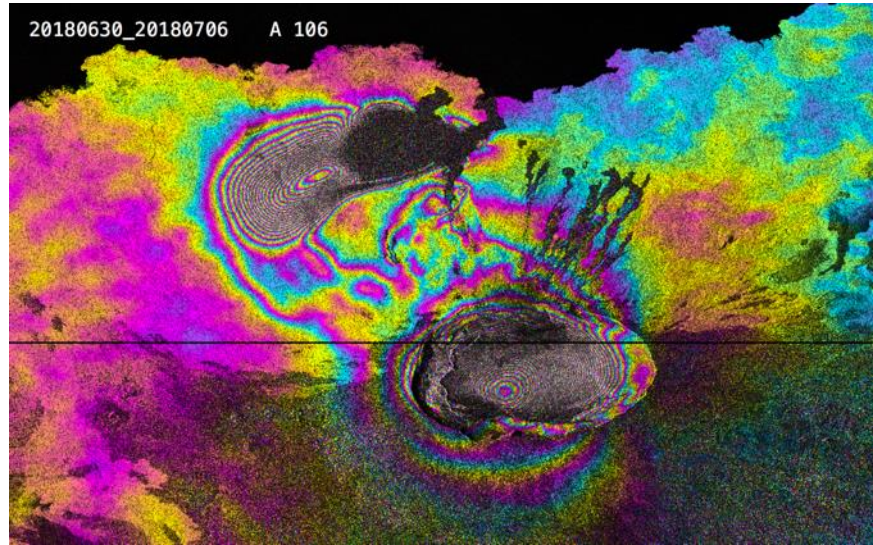
6-day Interferograms showing ground deformation of Sierra Negra and Fernandina volcano eruption, Galapagos

© Contains modified Copernicus Sentinel data [2018], University of Miami / Courtesy Falk Amelung

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Kīlauea volcano eruption and earthquake, Hawaii

Eruption and earthquake near Kilauea volcano, Hawaii (3 May 2018)
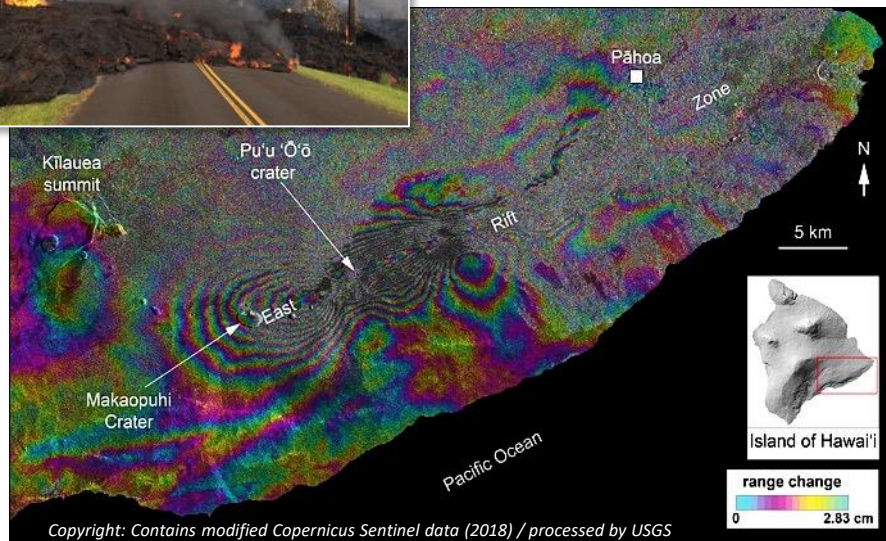
Sentinel-1 interferogram (19 April – **1 May 2018**)
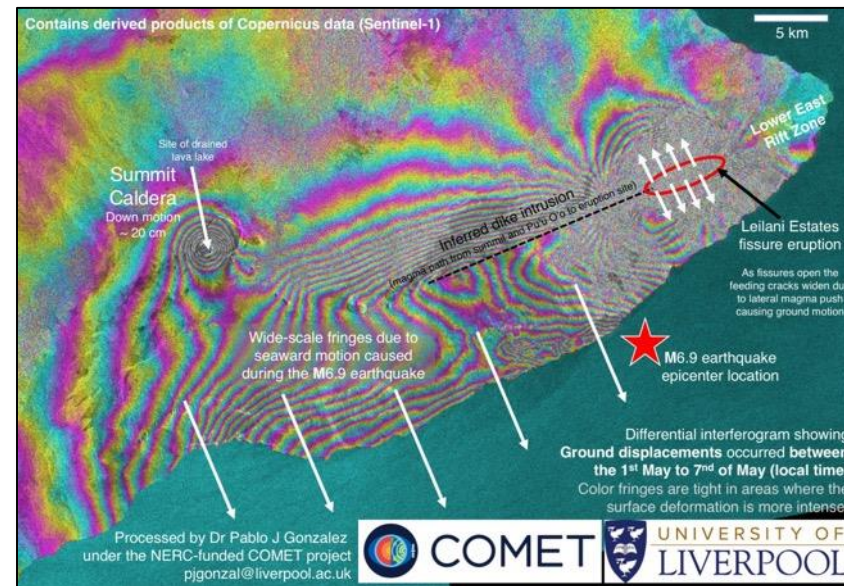
Sentinel-1 interferogram (**1 May – 7 May 2018**)

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

Sentinel-1: a major tool for geophysicists
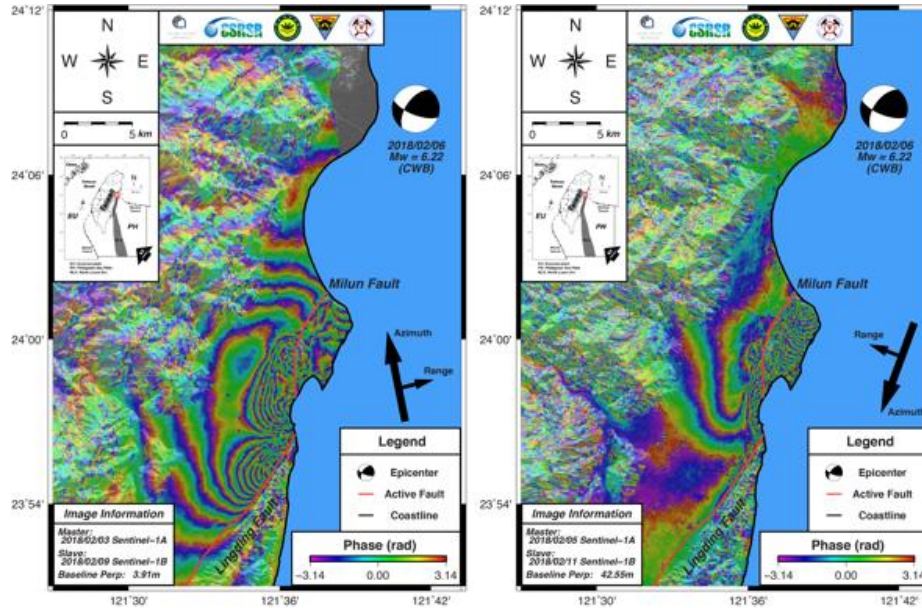
6.0 magnitude Taiwan's earthquake, 6 Feb 2018
Surface deformation of Hualien area

© Contains modified Copernicus Sentinel data [2018], processed by the Eastern Taiwan Earthquake Center (ETEC)
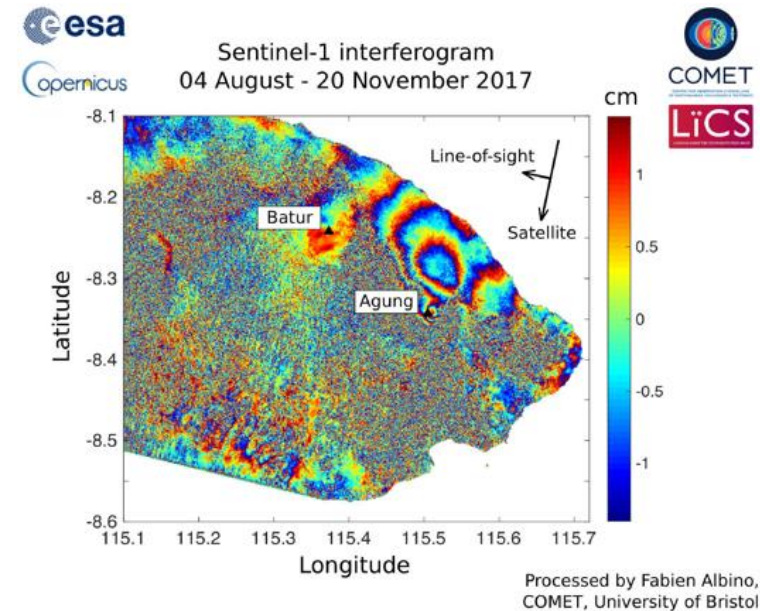
Mount Agung Volcano eruption

© Contains modified Copernicus Sentinel data [2018], processed by COMET, University of Bristol

Etna eruption that started 24 Dec 2018 and earthquake of 26 Dec 2018

Example of contribution of Sentinel-1

Interferograms in Line Of Sight (LOS) and deformation maps

(A1) interferogram map obtained from ascending pass between 22/12/2018 and 28/12/2018

(A2) interferogram obtained from descending pass between 22/12/2018 and 28/12/2018

(B1) ground deformation map in LOS corresponding to interferogram (A1)

(B2) ground deformation map in LOS corresponding to interferogram (A2)

© Contains modified Copernicus Sentinel data [2018] / processed by CNR IREA and INGV

Courtesy CNR IREA / INGV / ASI

S1A & S1B Orbit Maintenance
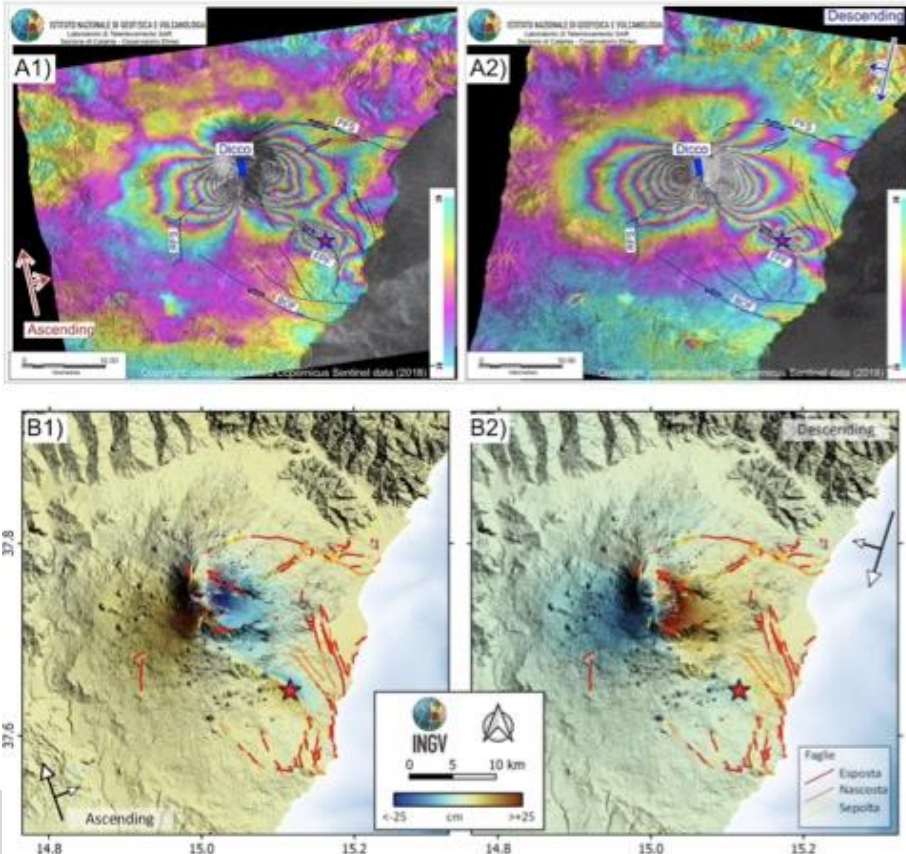
S1A
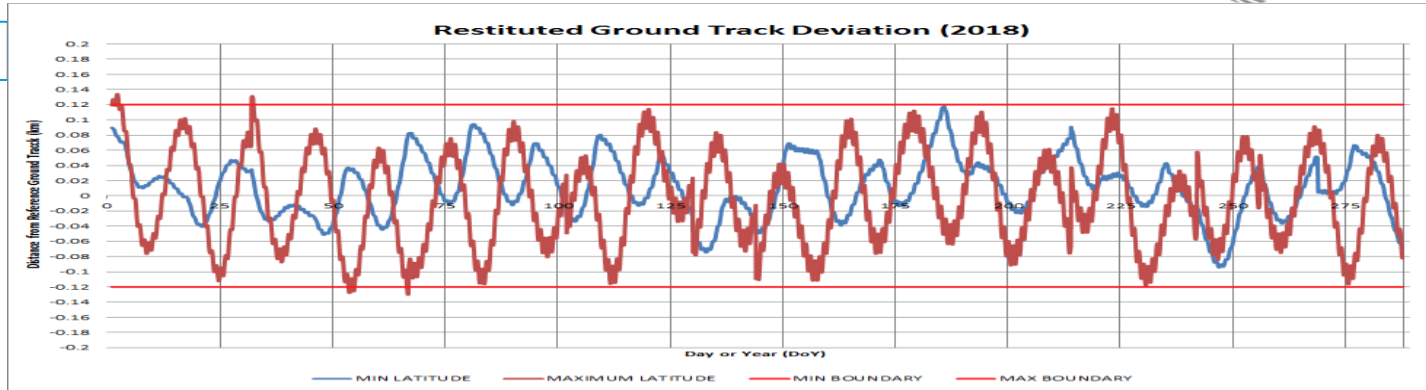
Both satellites are maintained within +/- 120m ground track

S1B

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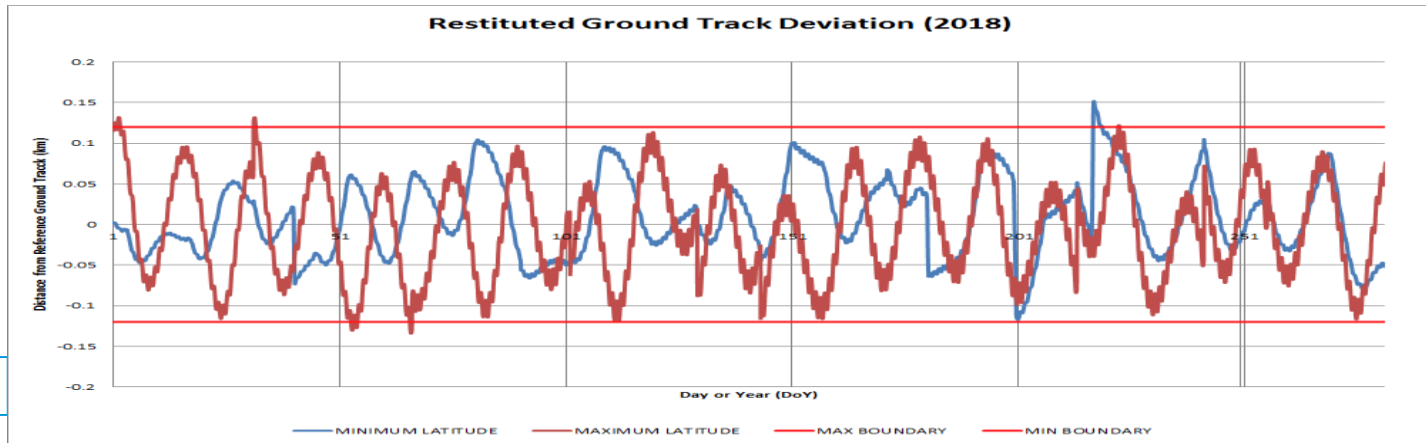
Operational support to the
Copernicus Marine Environment Monitoring Service (CMEMS),
since start of Sentinel-1A operations

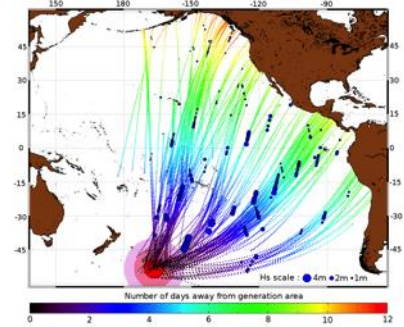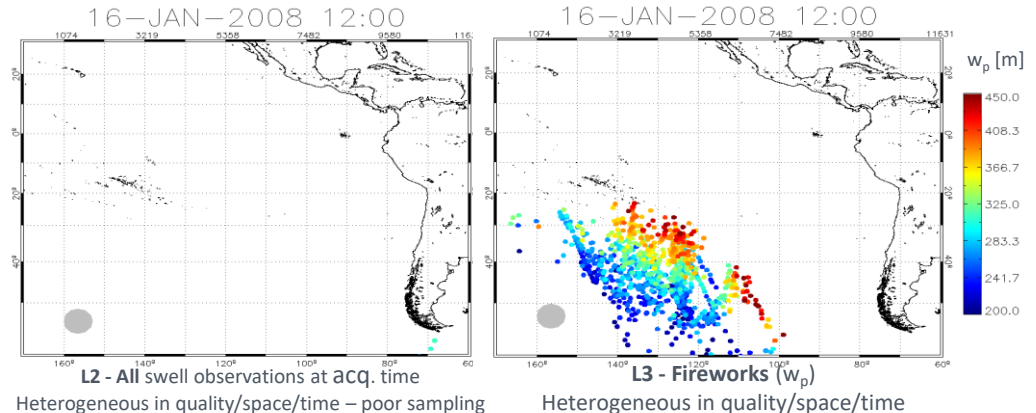Daily maps of position of icebergs

Ice Drift
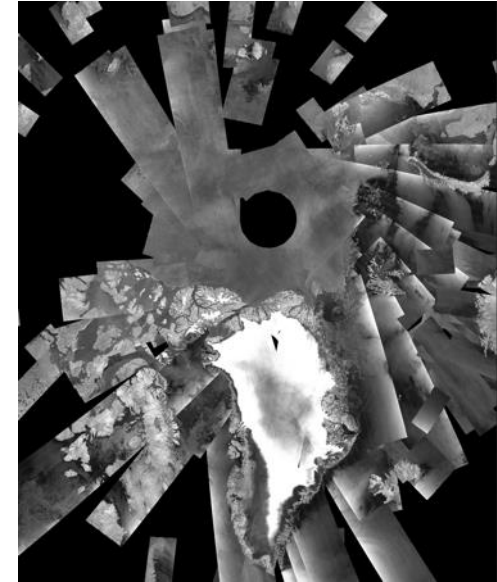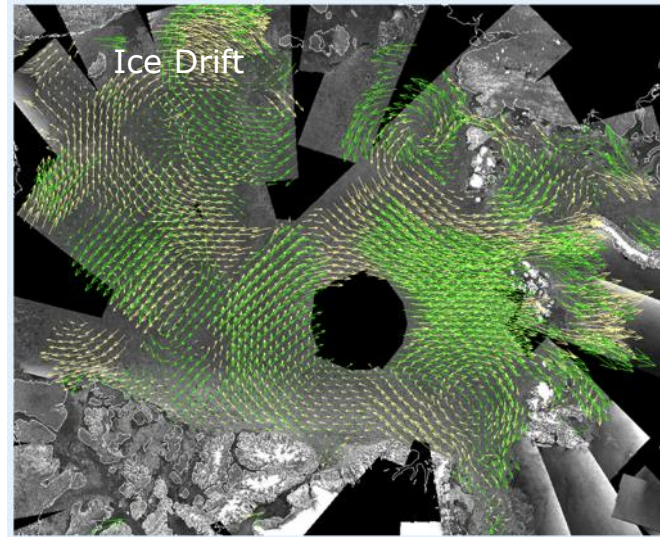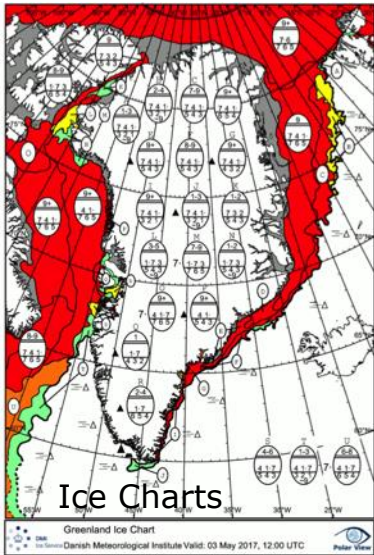
3-day Mosaic 20-21-22 July 2018
http://www.seaice.dk/

Ice Charts

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Operational generation of SAR Wave products recently implemented by CMEMS

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

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

Courtesy:

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

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

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CMEMS Waves product content from SAR

Sentinel-1A&B Level-3 demo NRT 26−NOV−2017 00:00 UTC
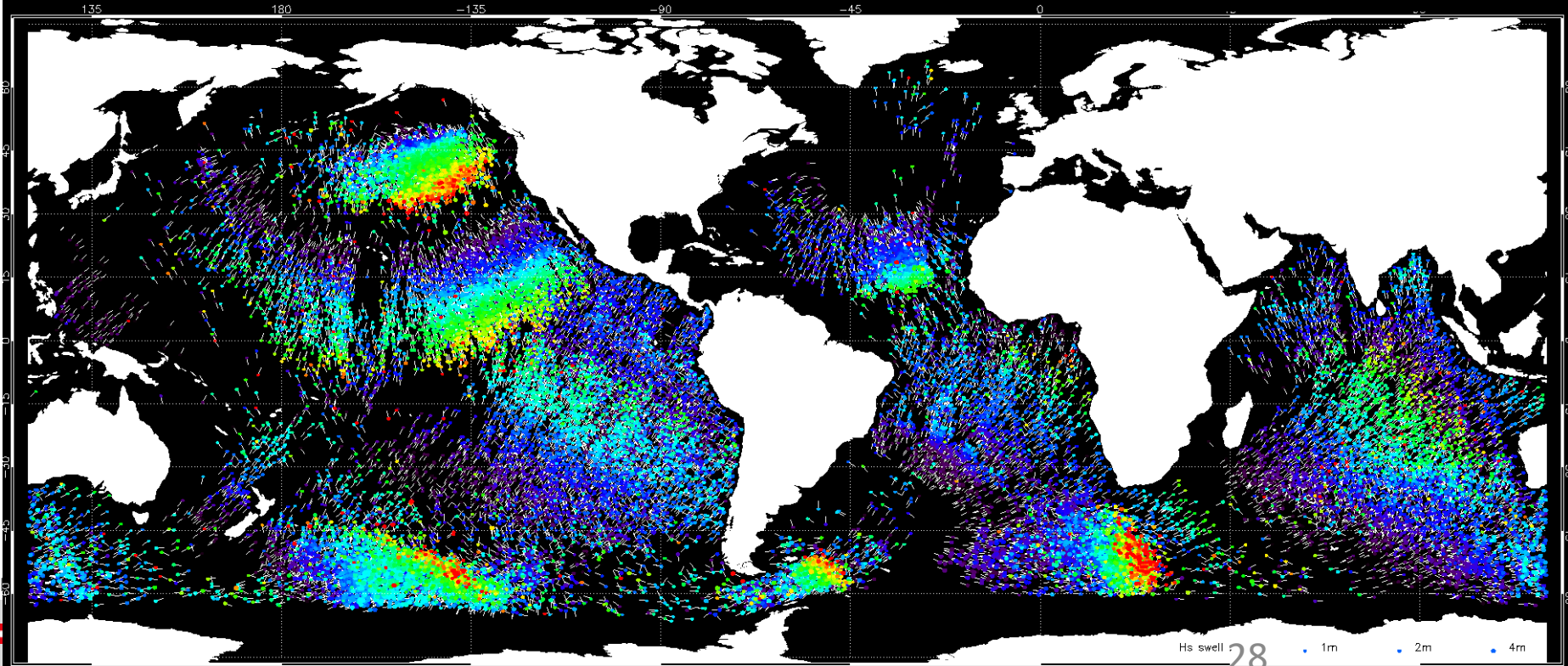
Wind fields

S1A evening and morning passes
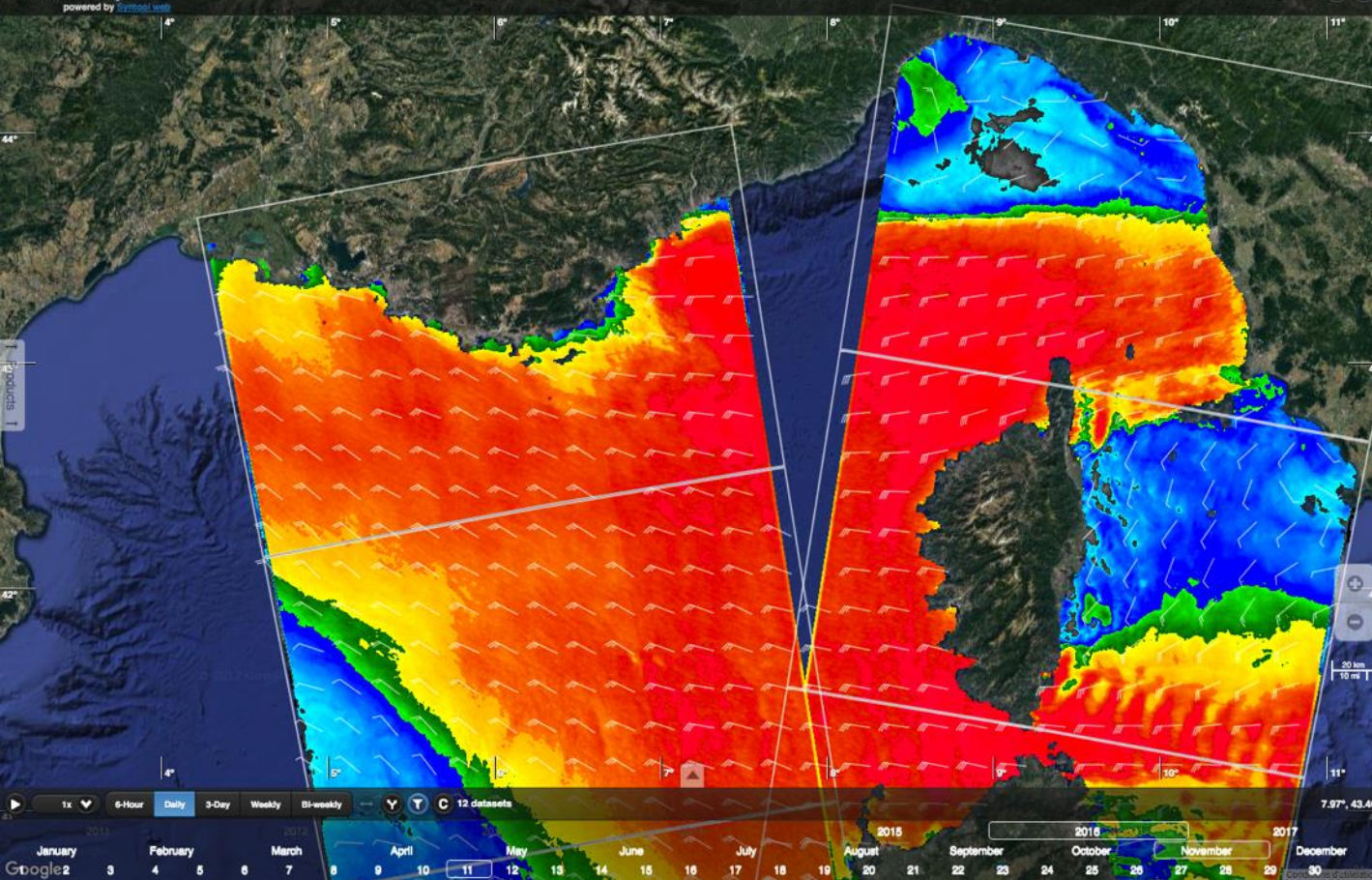
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Sentinel Hurricane Observation Campaign

Typhoon Mangkhut
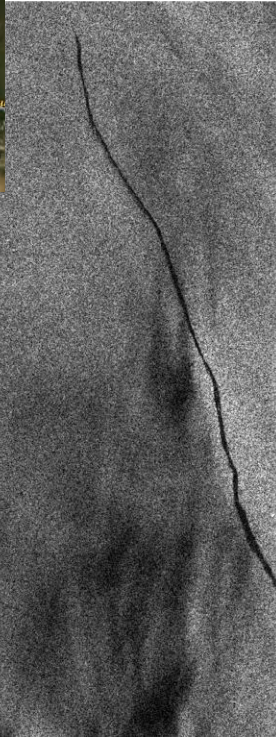https://datastore.cls.fr/monitoring-typhoon-mangkhut-from-space/
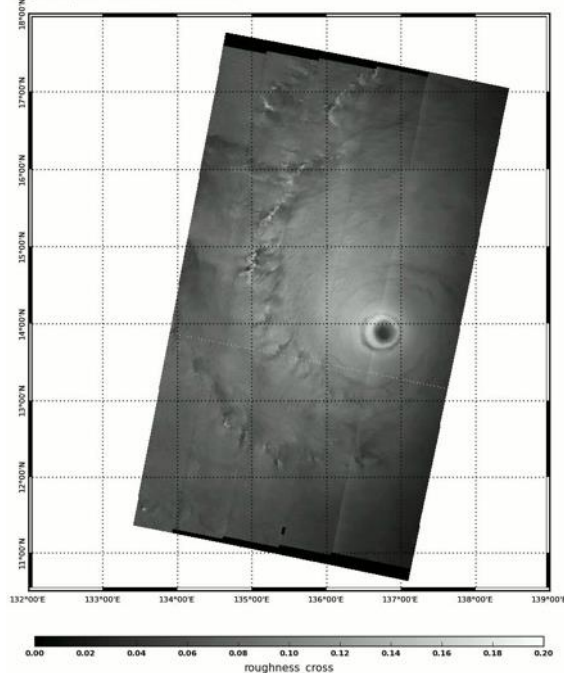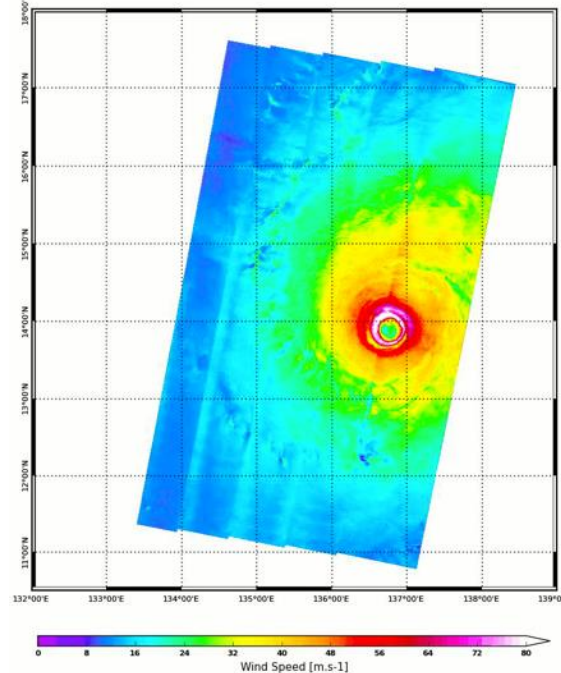
SAR: the only sensor able to characterize extreme winds (greater than 70 m/s) at very high resolution.

These activities may become part - at a later stage - of a Copernicus Service, e.g. CMEMS or CEMS…

Courtesy
CLS / Ifremer

First Oil Spills Detected by Sentinel-1

Sentinel-1A TOPS EW
VV/VH
acquired on 19 April
2014
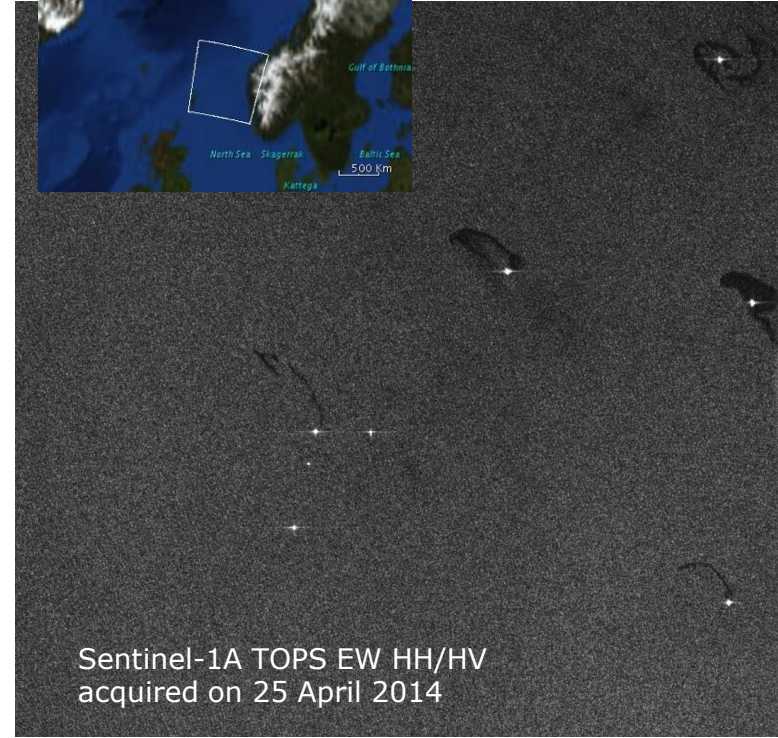
Sentinel-1A TOPS EW HH/HV
acquired on 25 April 2014

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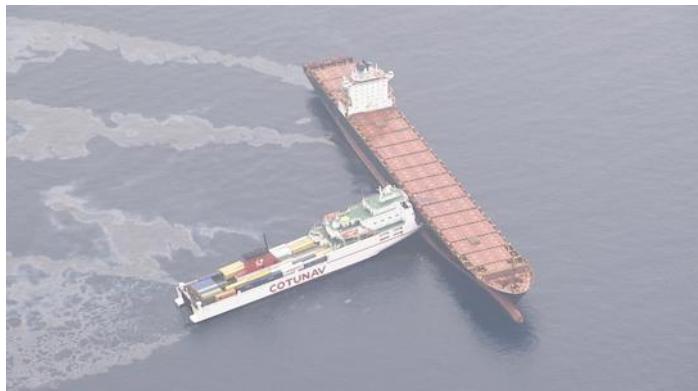CleanSeaNet: the European satellite-based **oil pollution and vessel detection monitoring system**

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

Sentinel-1 currently represents 85 % of satellite imagery used for CleanSeaNet

acquired on 25 April 2014
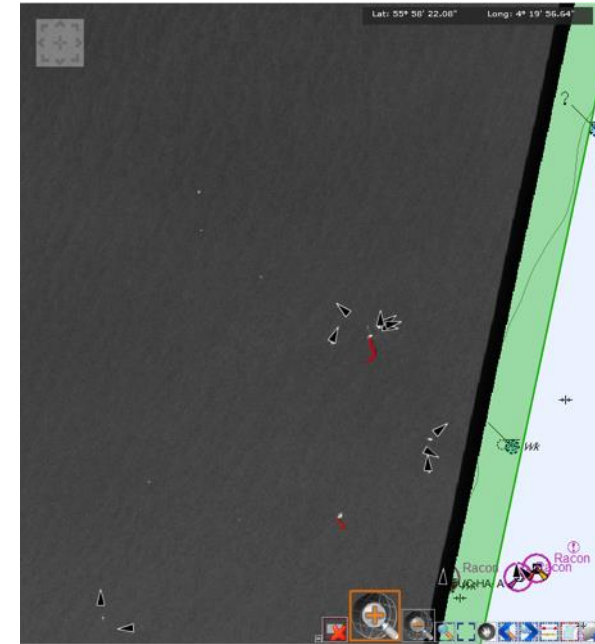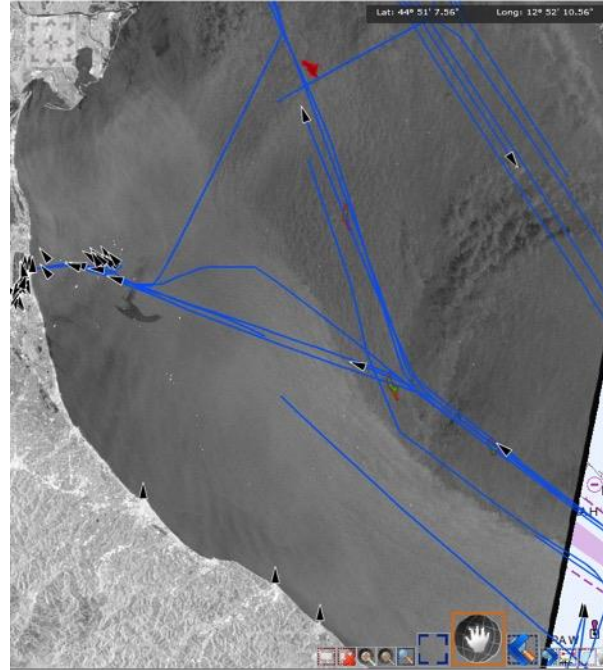
Sentinel-1 mission status
Oil Spill North of Corsica, 8 September

Copyright: Contains modified Copernicus
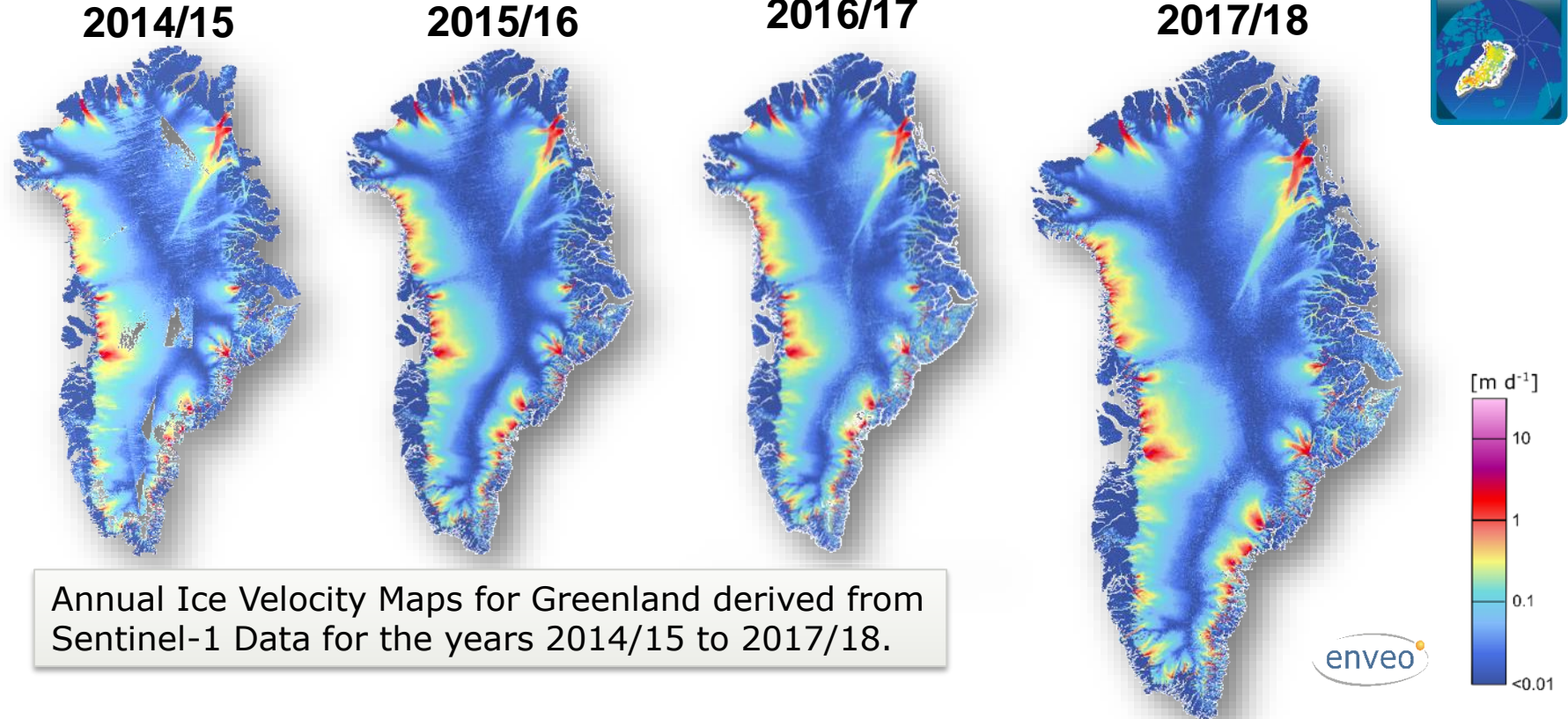Sentinel data (2018) / processed by ESA

35 km

8 October - 07:28 CEST

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A routine observatory of ice sheet margins

Greenland Ice velocity maps from S-1

Annual Ice Velocity Maps for Greenland derived from Sentinel-1 Data for the years 2014/15 to 2017/18.
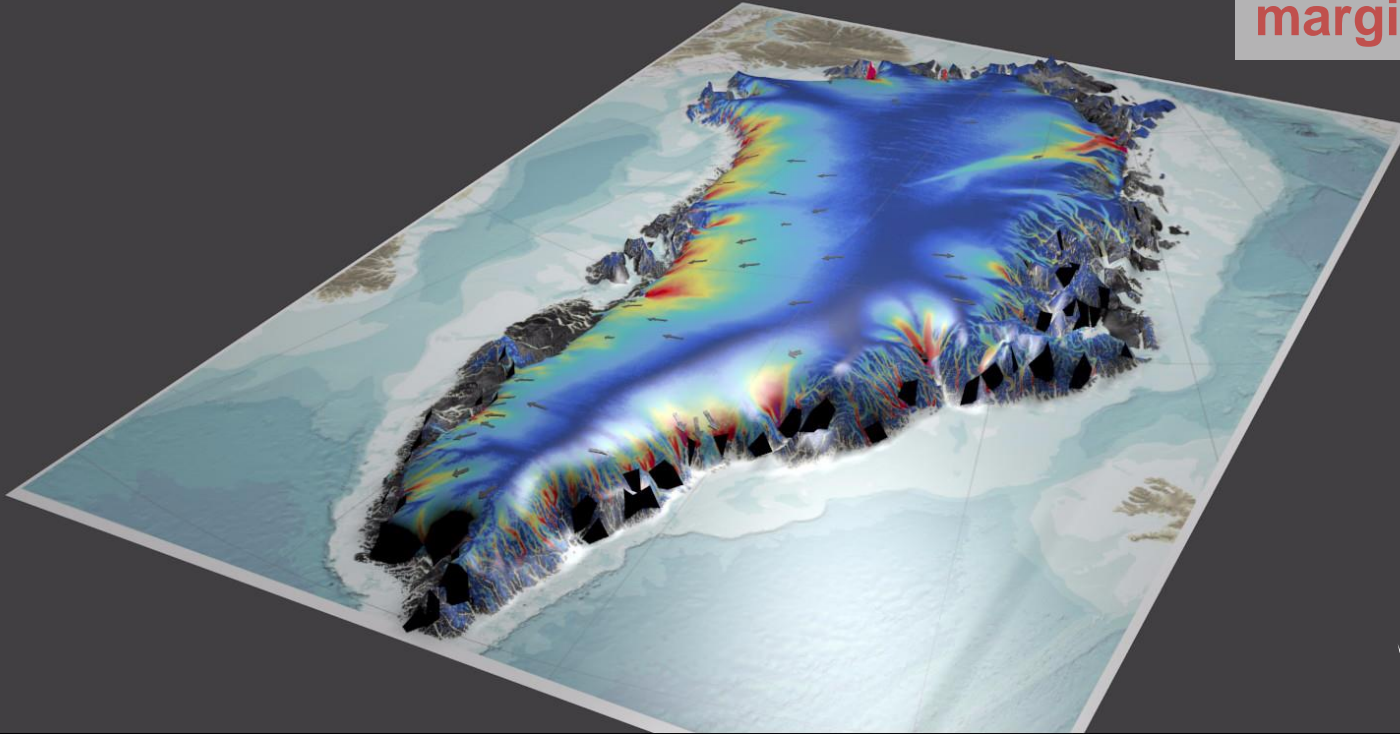
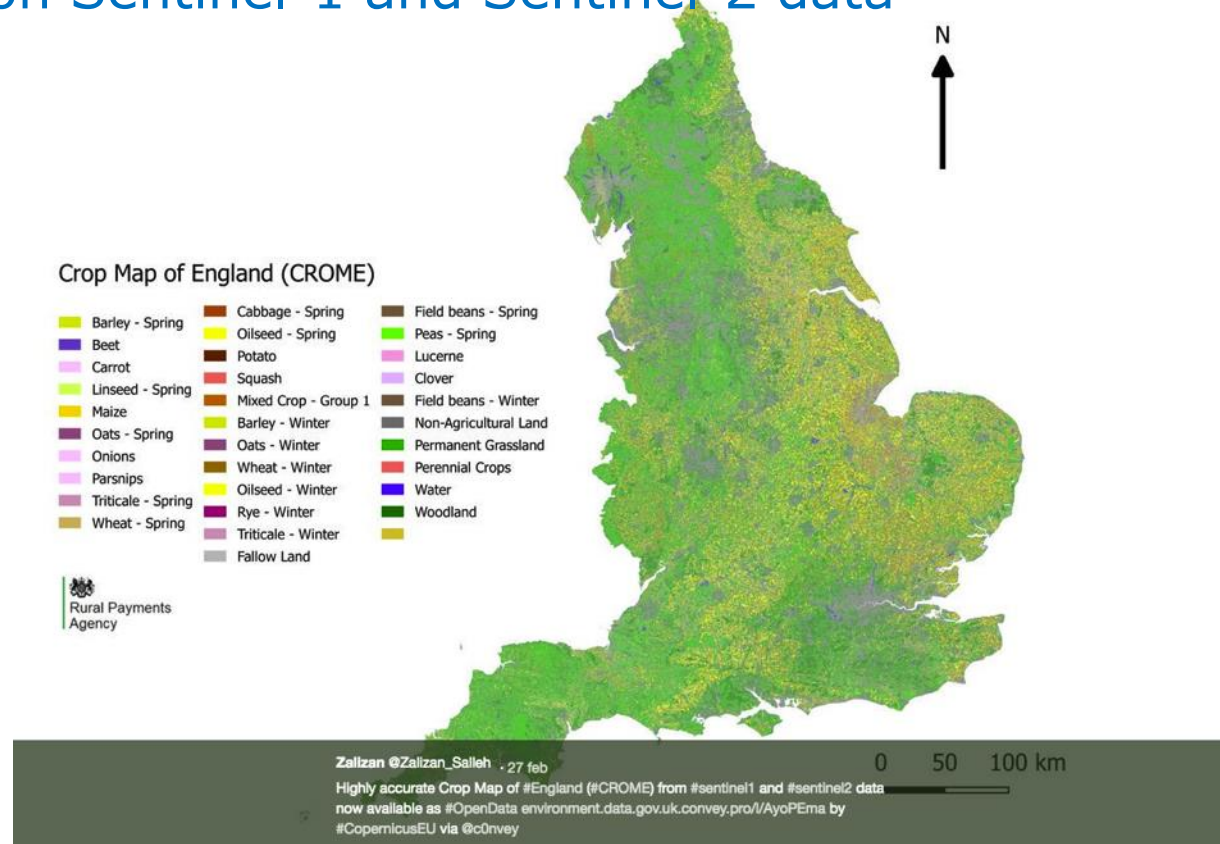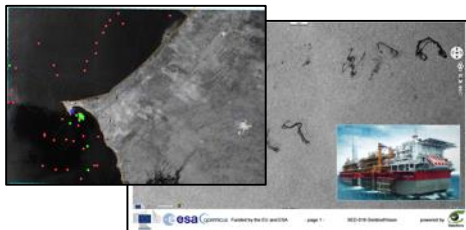Antarctica Ice velocity map from S-1
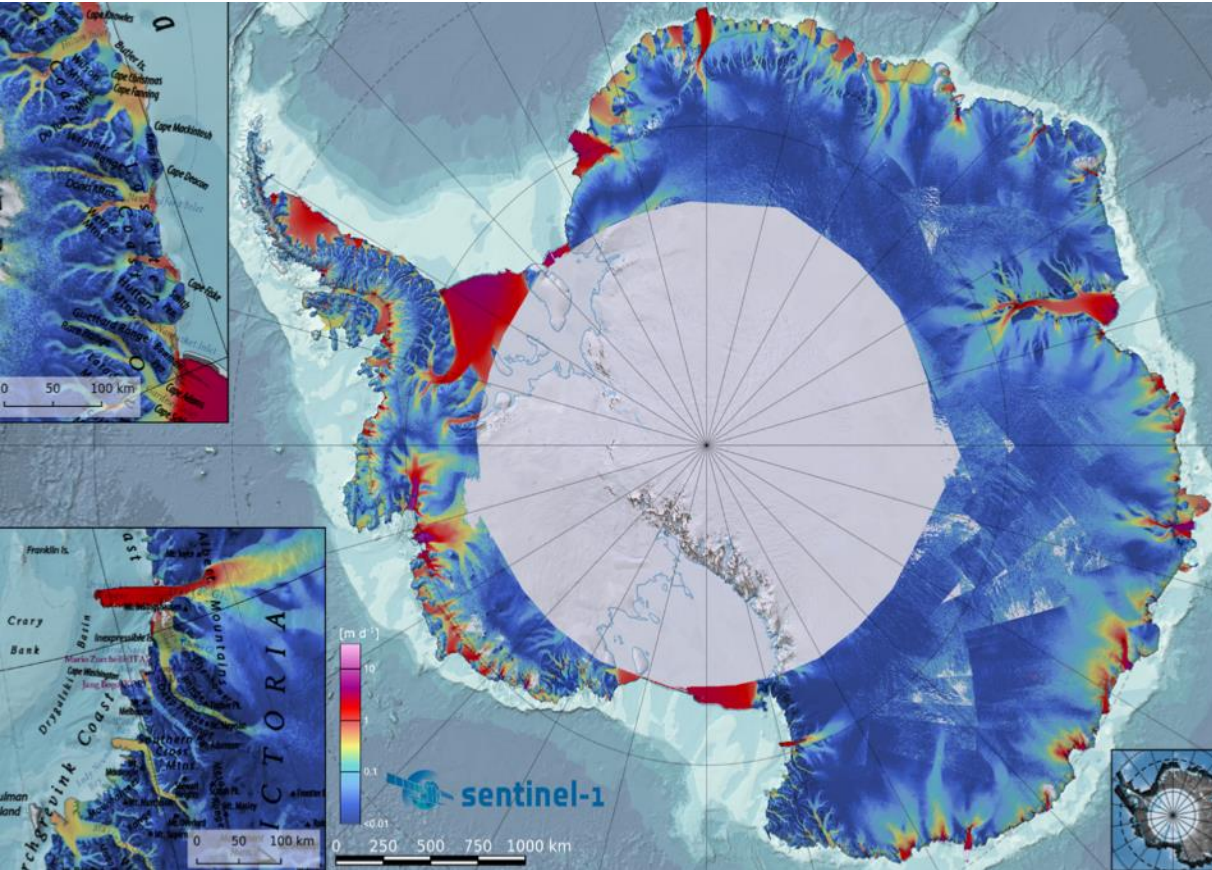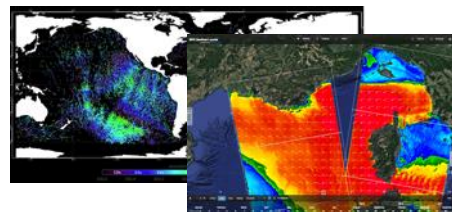
Antarctic Icesheet Wide Velocity Map from Sentinel-1 (2015 to 2018)
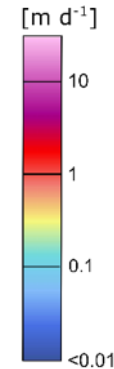
Example of UK map of crop classification based on Sentinel-1 and Sentinel-2 data

Example of Land Cover application

Crop Map of England (CROME)

Barley - Spring	Cabbage - Spring	Field beans - Spring
Beet	Oilseed - Spring	Peas - Spring
Carrot	Potato	Lucerne
Linseed - Spring	Squash	Clover
Maize	Mixed Crop - Group 1	Field beans - Winter
Oats - Spring	Barley - Winter	Non-Agricultural Land
Onions	Oats - Winter	Permanent Grassland
Parsnips	Wheat - Winter	Perennial Crops
Triticale - Spring	Oilseed - Winter	Water
Wheat - Spring	Rye - Winter	Woodland
	Triticale - Winter	
	Fallow Land	

Rural Payments Agency

Zalizan @Zalizan_Salleh · 27 feb
Highly accurate Crop Map of #England (#CROME) from #sentinel1 and #sentinel2 data now available as #OpenData environment.data.gov.uk.convey.pro/l/AyoPEma by #CopernicusEU via @c0nvey

N

0   50   100 km

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Sentinel-1 applications → ever increasing

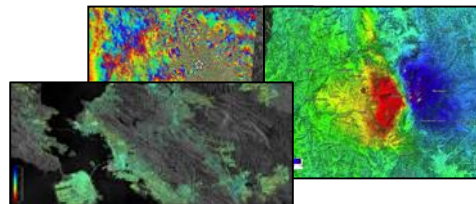*Maritime surveillance: oil spill monitoring, ship detection, illegal fisheries, etc.*
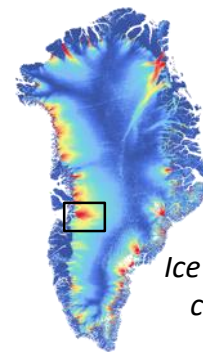

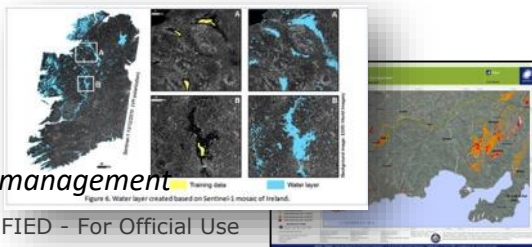*Sea state: wind, wave*

Sea ice and iceberg monitoring
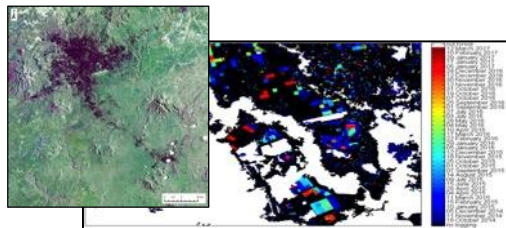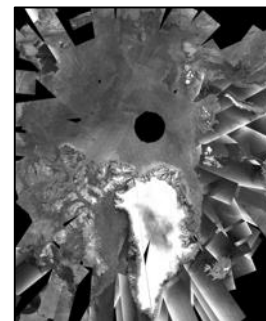
Land use, agriculture, forestry, logging, land classification, urban planning

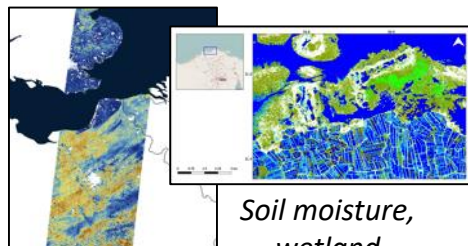*Ground deformation: subsidence, landslides, earthquakes, volcanoes, infrastructure monitoring*
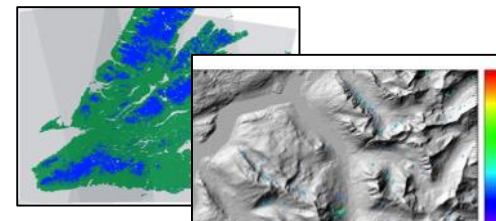
Ice sheets, glaciers, climate change

Emergency management

Soil moisture, wetland

Snow, permafrost, avalanches,…

Concluding remarks

- Sentinel-1 mission routine operations on-going, overall mission in a very good shape

- High quality data routinely provided to Copernicus Services, Member States / Copernicus Participating States, International partners and to a wide spectrum of user communities worldwide for various thematic applications

- The mission provides:

    - global and routine coverage, with a systematic production scenario,

    - open and free data access,

    - the long-term perspective,

    - complementarity to higher resolution SAR missions

    ➔ to further bring SAR applications into the operational domain, at local, national, regional, continental and global scale

Thank you for your attention!

Copernicus Programme: copernicus.eu

Sentinel Online: sentinels.copernicus.eu

CSC Data Access: spacedata.copernicus.eu

ESA Sentinel app: available for iOS and Android

European Space Agency