



→ RADAR VISION FOR COPERNICUS



Sentinel-1 Mission Overview and Status

*ESA Polarimetry Course 2019
22 Jan 2019, ESRIN, Frascati*

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European Space Agency

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



Sentinel Launches



S-1



Radar

A



3 Apr. 2014

B



25 Apr. 2016

C

2022/23

D

> 2022/23

S-2



High
Resolution
Optical

A



23 Jun. 2015

B



6 Mar. 2017

C

2022/23

D

> 2022/23

S-3



Medium
Resolution
Optical &
Altimetry

A



16 Feb. 2016

B



25 Apr. 2018

C

2023

D

> 2023

S-4



Atmospheric
Chemistry
(GEO)

A

2021

B

2027

S-5P



Atmospheric
Chemistry
(LEO)

A



13 Oct. 2017

S-5



Atmospheric
Chemistry
(LEO)

A

2021

B

2027

C

> 2027

S-6



Altimetry

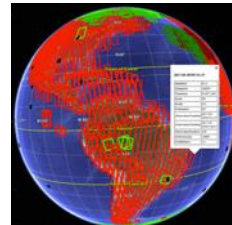
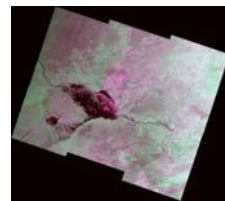
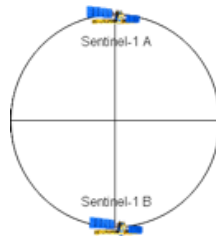
A

2020

B

2025

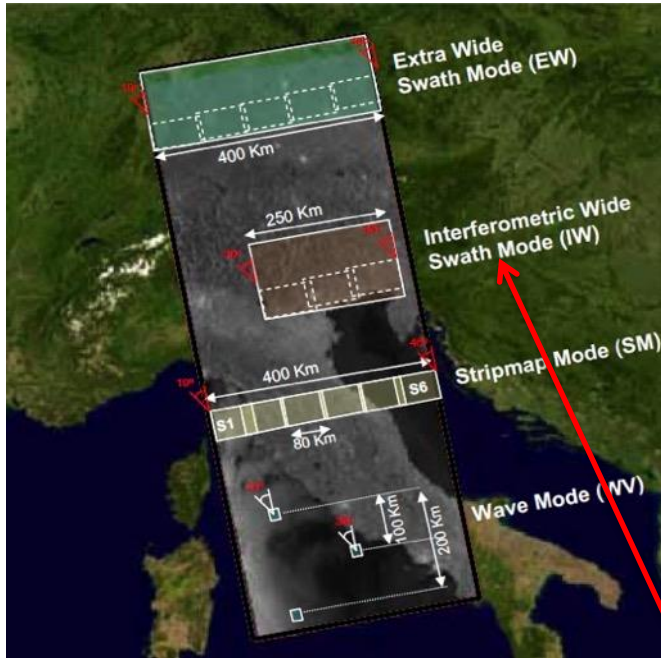
- Constellation of two identical SAR C-band (5.405 GHz) satellites (A & B units)
- **Sentinel-1A** launched on 3 April, 2014 & **Sentinel-1B** on 25 April, 2016
- Near-Polar, sun-synchronous (dawn-dusk) orbit at 698 km
- Instrument duty cycle of 25 min/orbit in High Bit Rate modes and 75 min/orbit in 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



EW

IW

SM

WV

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

IW: main mode over land and coastal areas

Sentinel-1 Operational Products available to users

LEVEL-0 PRODUCTS

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

LEVEL-1 PRODUCTS

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

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

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

Focused data projected to ground range, detected and multi-looked.

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

LEVEL-2 PRODUCTS

Level-2 Ocean products

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

Sentinel-1 Level 1 Operational Product characteristics

Acq. Mode	Product Type	Resolution Class	Resolution [Rng x Azi] [m]	Pixel Spacing [Rng x Azi]	No. Looks [Rng x Azi]	ENL
SM	SLC	-	1.7 x 4.3 to 3.6 x 4.9	1.5 x 3.6 to 3.1 x 4.1	1 x 1	1
	GRD	FR	9 x 9	4 x 4	2 x 2	3.9
		HR	23 x 23	10 x 10	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 WV1 and WV2.
- For SLC products, the range coordinate is in slant range. All the other products are in ground range.

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

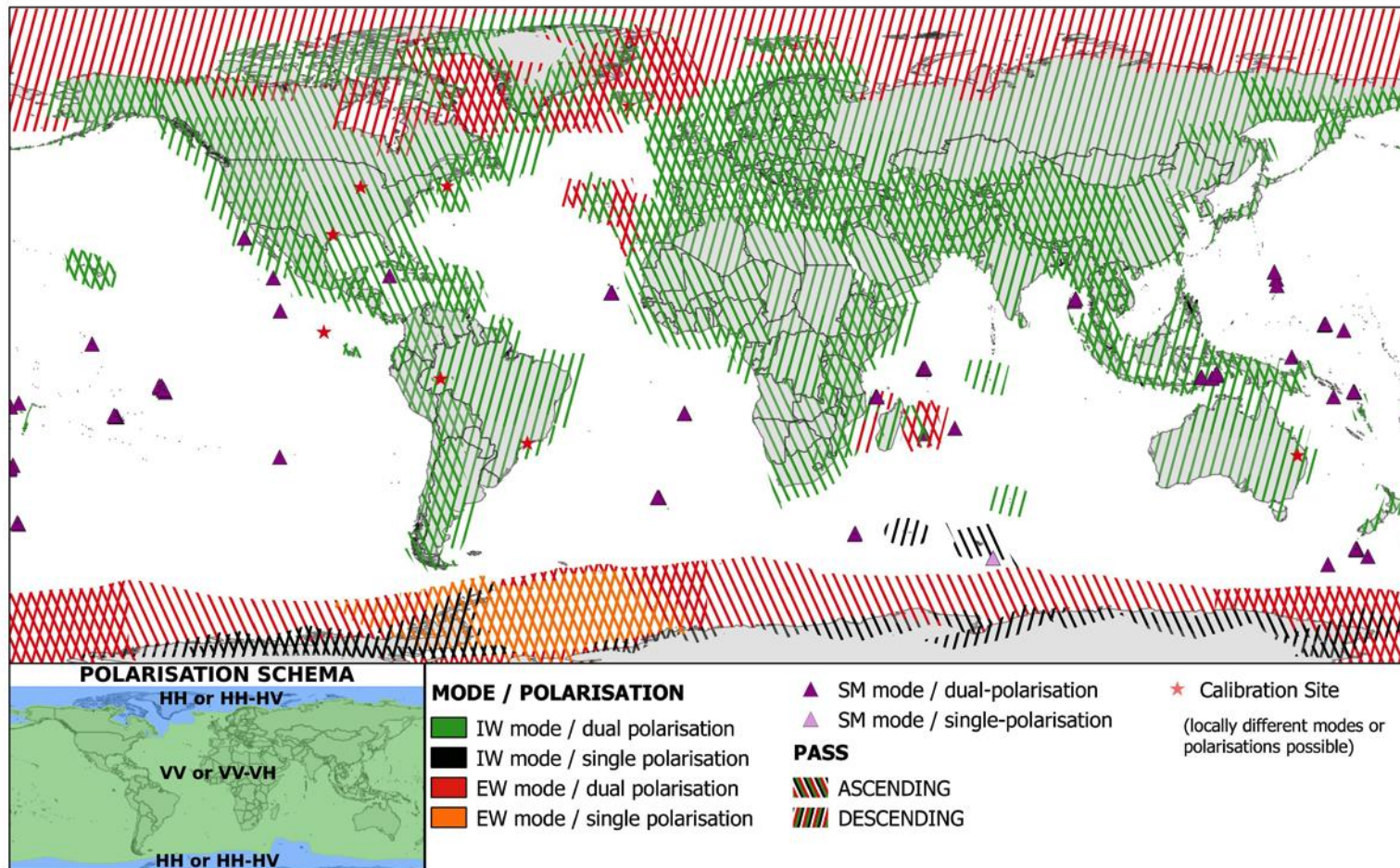


validity start: 02/2018



Baseline
starting
Feb 2018

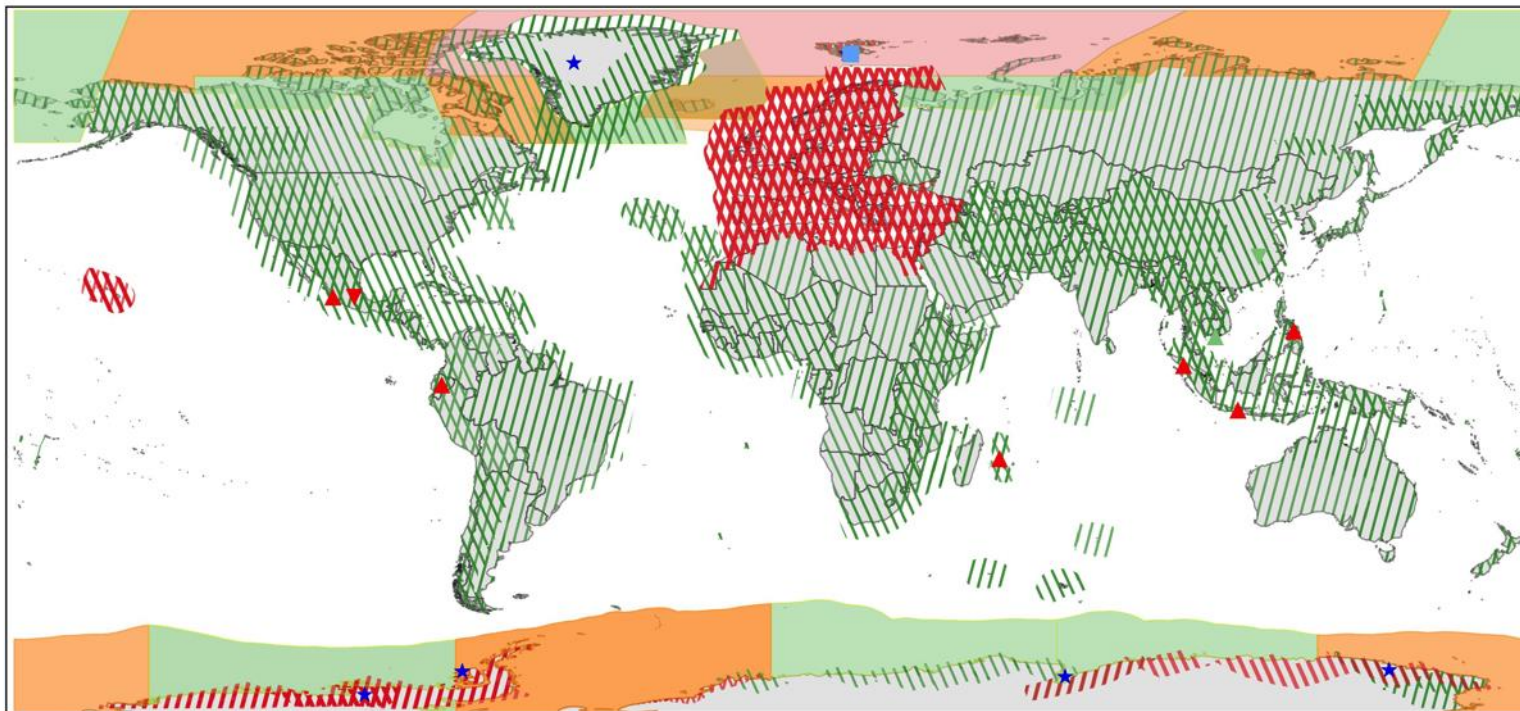
This map is
related to SAR
High Rate
modes only.
Wave mode
operated by
default over
open oceans
(not shown)



Sentinel-1 Constellation Observation Scenario: Revisit & Coverage Frequency



validity start: 02/2018

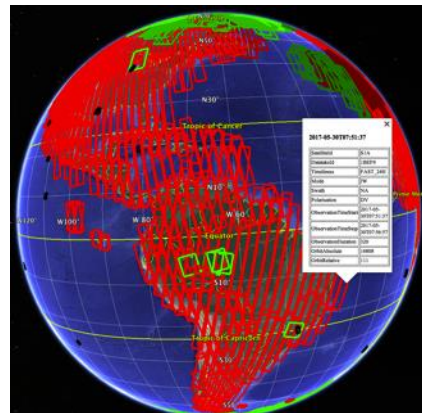
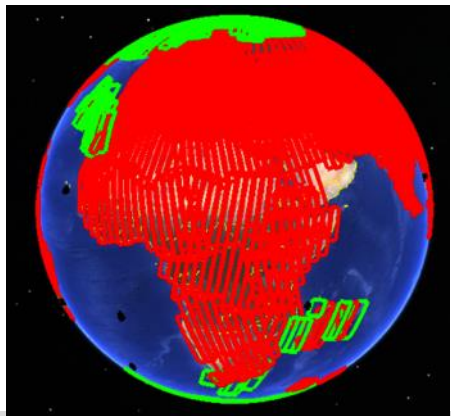
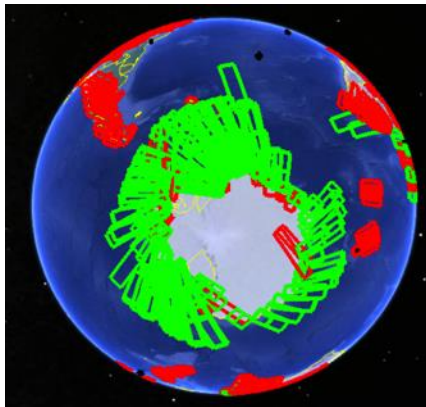
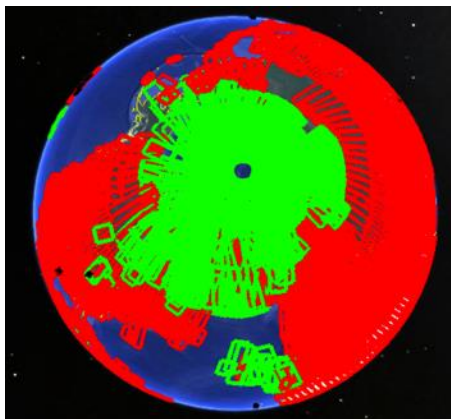


Baseline
starting
Feb 2018

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

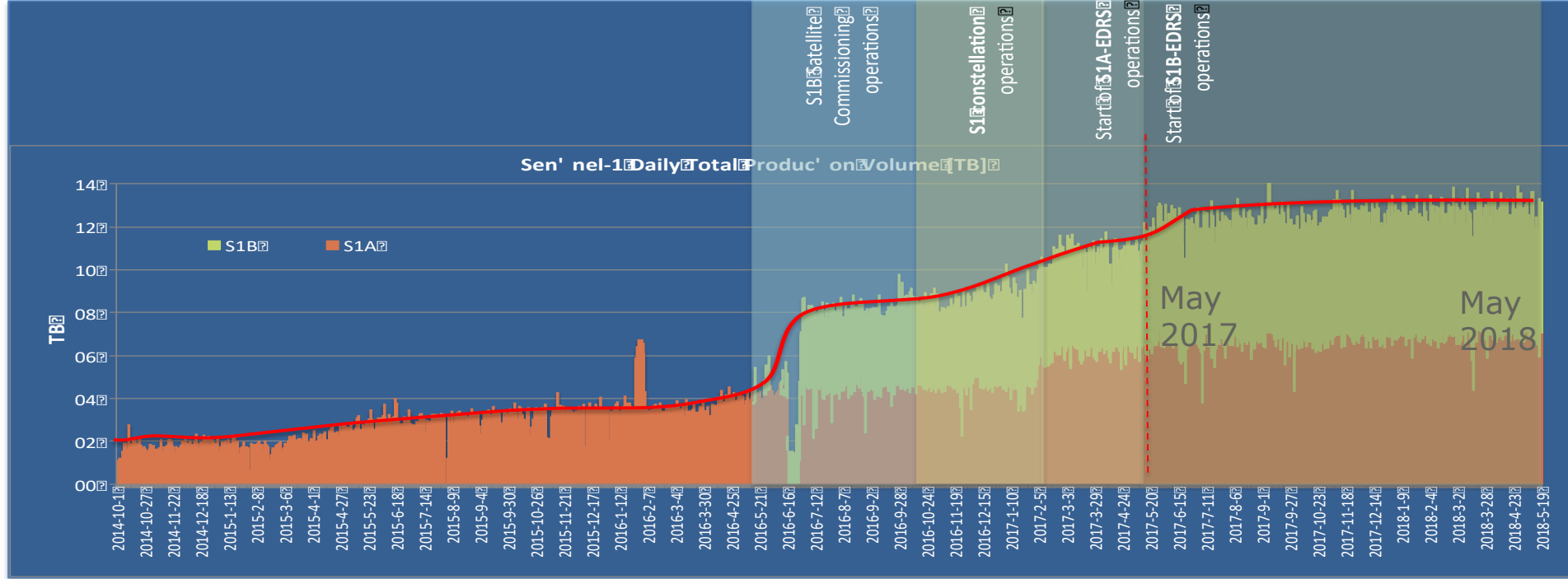
PASS	REVISIT	FREQUENCY *	COVERAGE	FREQUENCY **	REFERENCE DATA SITES (6d repeat)
ASCENDING DESCENDING	6 days 12 days	12 days 12 days	1 days 1-3 days 2-4 days	6 days 12 days	▲ Highly active volcanism ▼ Fast subsidence ▲ Short growth cycle, intensive agriculture ▼ Fast changing wetlands ★ Fast moving outlet glaciers ■ Permafrost & glaciers

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



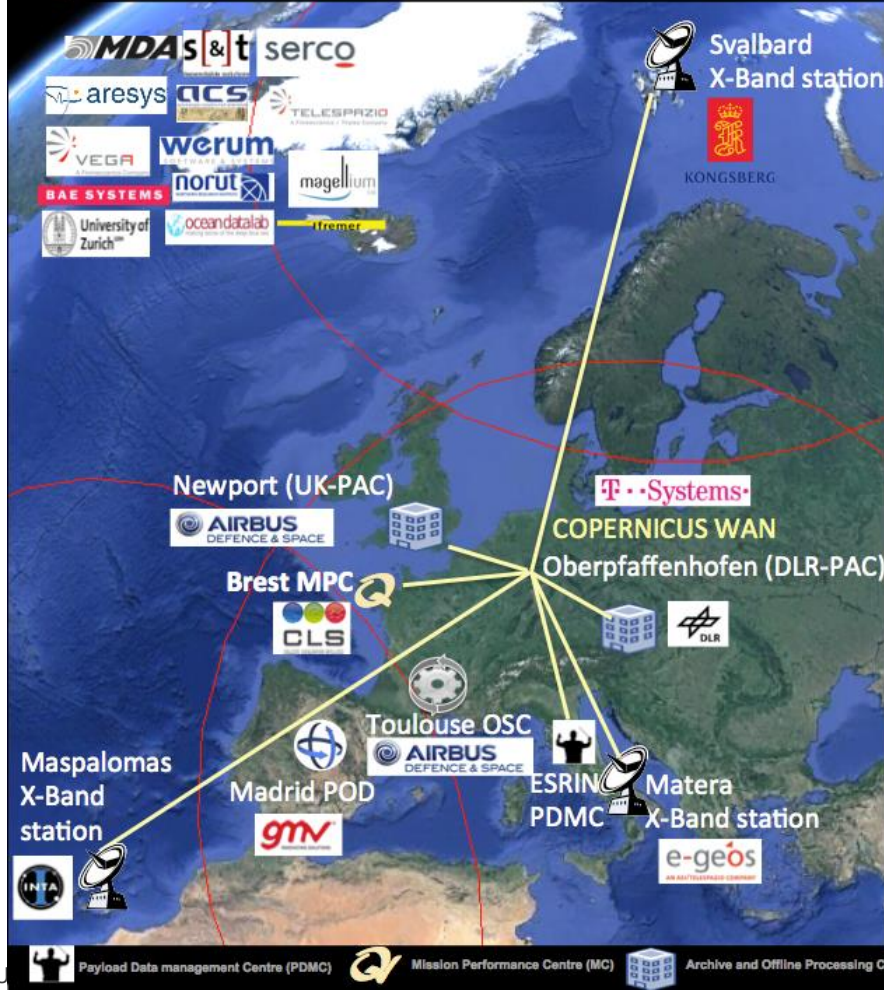
KML files providing detailed information on the planned acquisitions, regularly published on Sentinel Online

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



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

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:

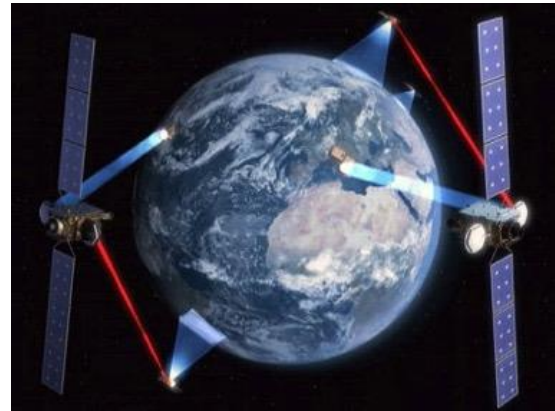
- COPERNICUS WAN Service
- Svalbard X-Band Acquisition Service
- Matera X-Band Acquisition Service
- Maspalomas X-Band Acquisition Service
- UK-PAC Long Term Archiving Service
- DLR-PAC Long Term Archiving Service
- Mission Performance Service
- Precise Orbit Determination Service
- Data Access Service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

Operational use of European Data Relay System (EDRS)



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

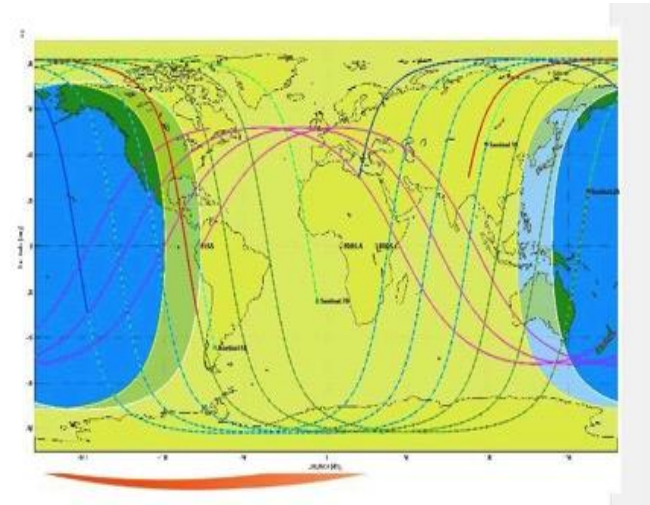
- **increased data download capacity**
- **increased coverage**
- **enhanced timeliness**



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EUTELSAT 9B hosting EDRS-A



EDRS-Sentinels indicative geometrical visibility map

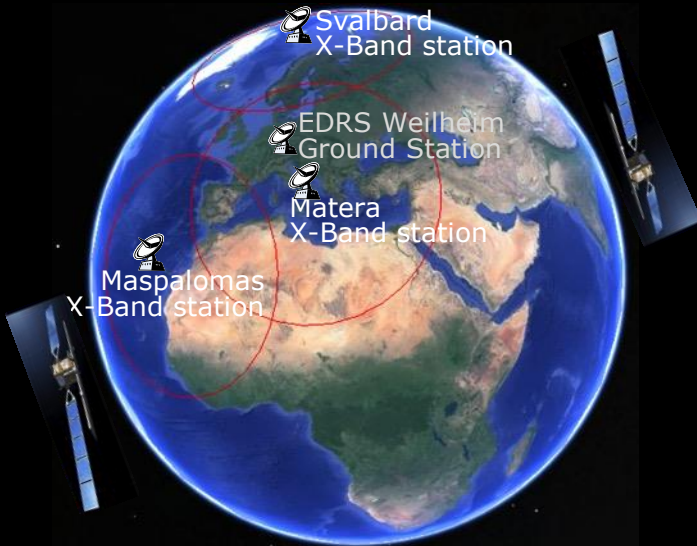
Sentinel-1/EDRS-A Operations

S1 Operations enhancements



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

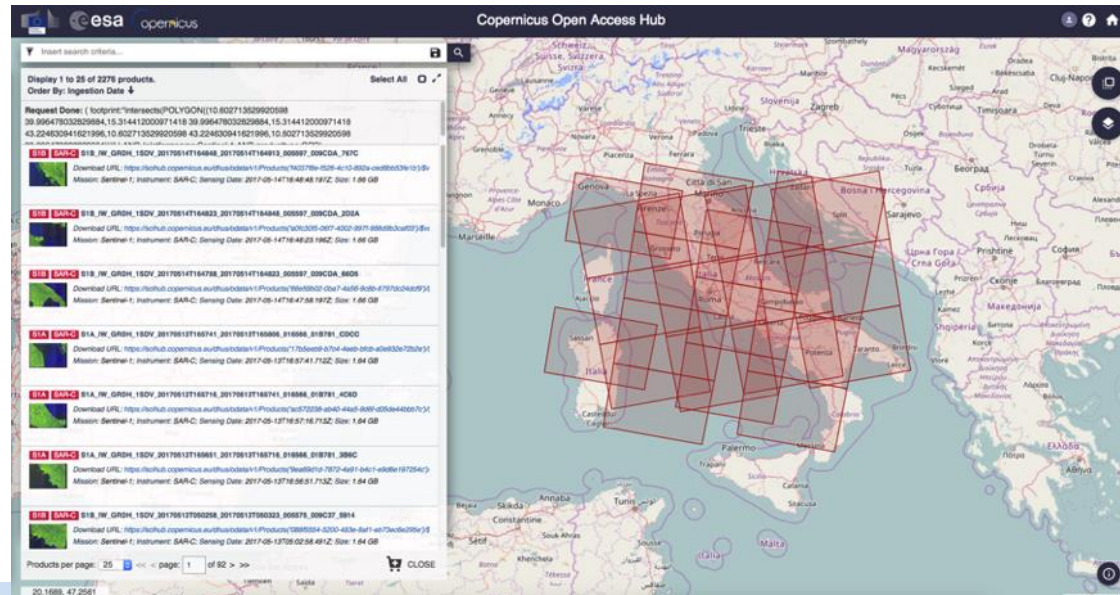
- ✓ Significant **increase of production volume** thanks to the additional downlink capabilities. Sentinel-1 products are being made available through the standard on-line data access mechanisms
- ✓ **Increased observations** (e.g. revisit) and **SAR dual polarisation acquisitions**
- ✓ significant **increase of Sentinel-1 pass-through acquisitions in X-Band over Europe**



<https://scihub.copernicus.eu/>

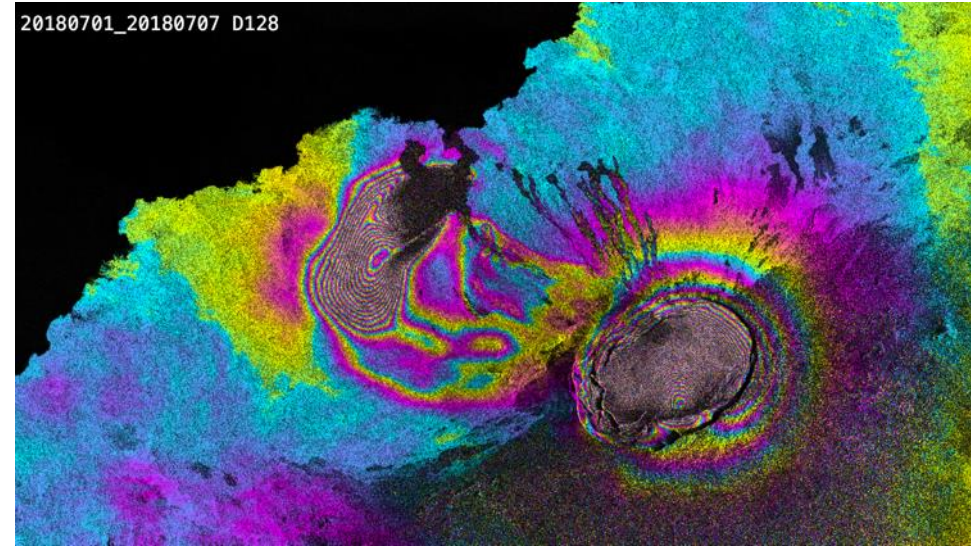
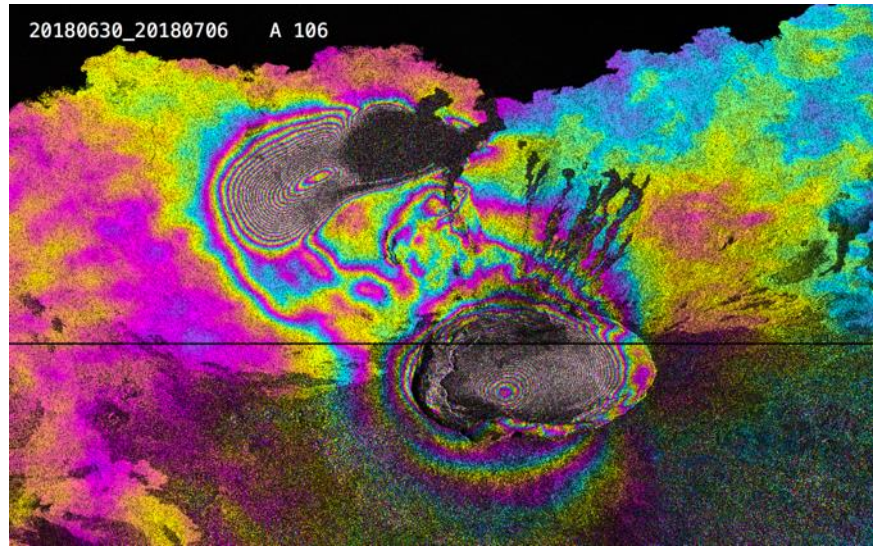


Open Hub



- Access through self-registration
- Automated download scripting capability and dedicated API-Hub
- Restriction on concurrent downloads

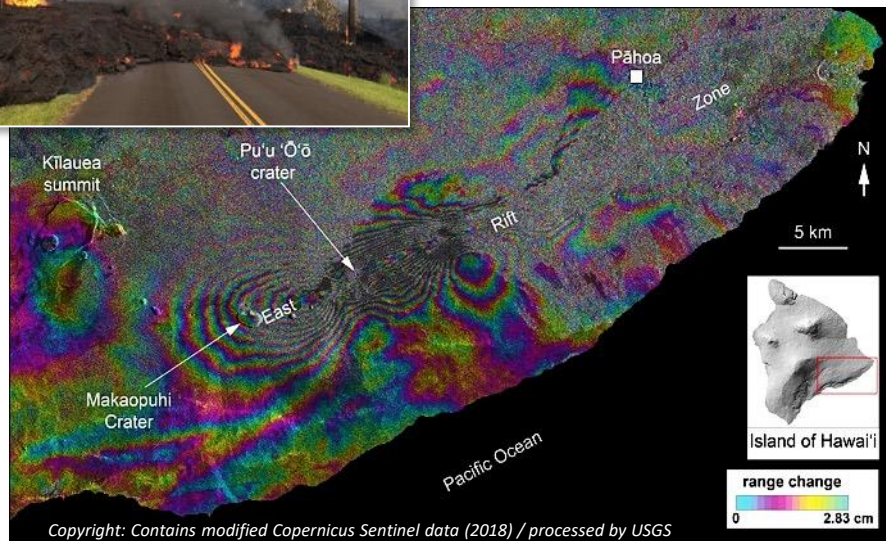
More than 200,000 users registered (all Sentinels)
3.4 Million Sentinel-1 products are available on-line for download,
representing 5.5 PB of data.
23 PB of data downloaded by users.



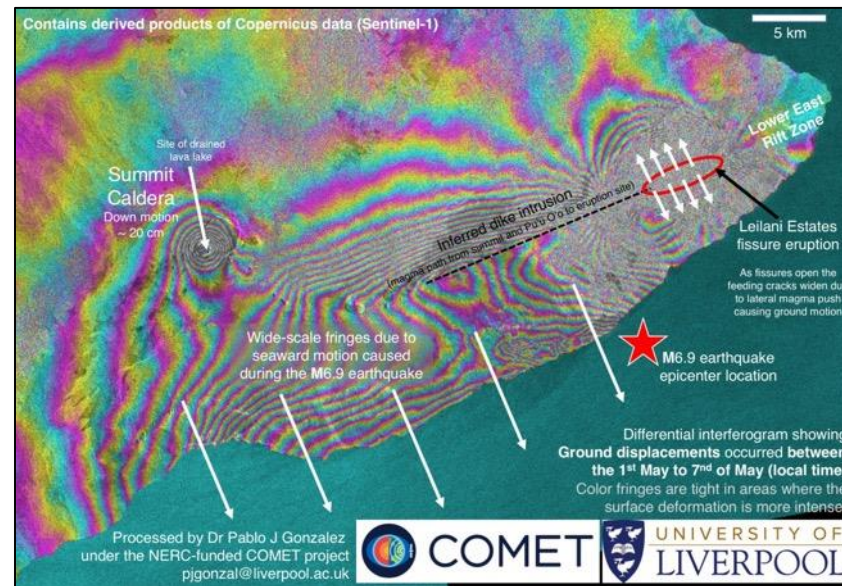
6-day Interferograms showing ground deformation of Sierra Negra and Fernandina volcano eruption, Galapagos



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

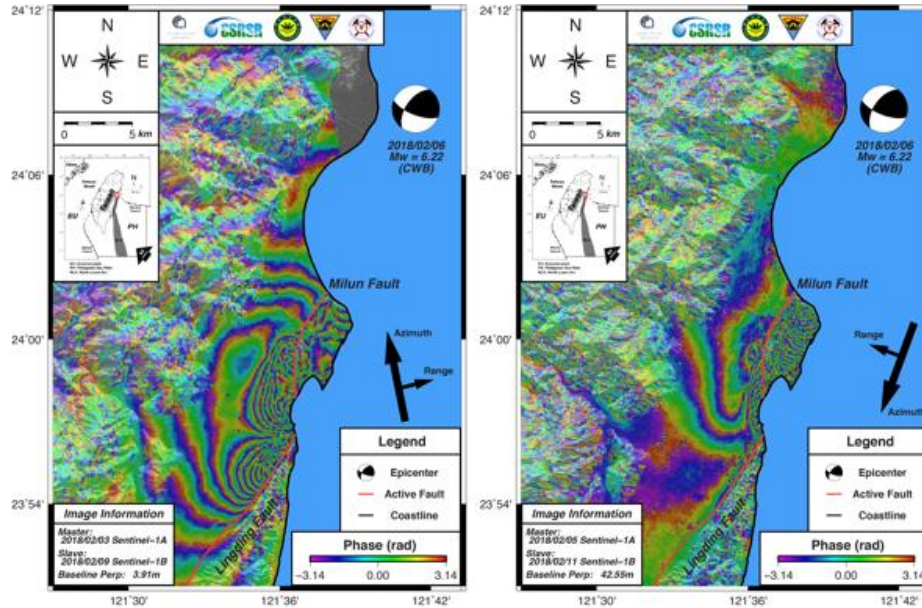


Sentinel-1 interferogram (19 April – 1 May 2018)



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

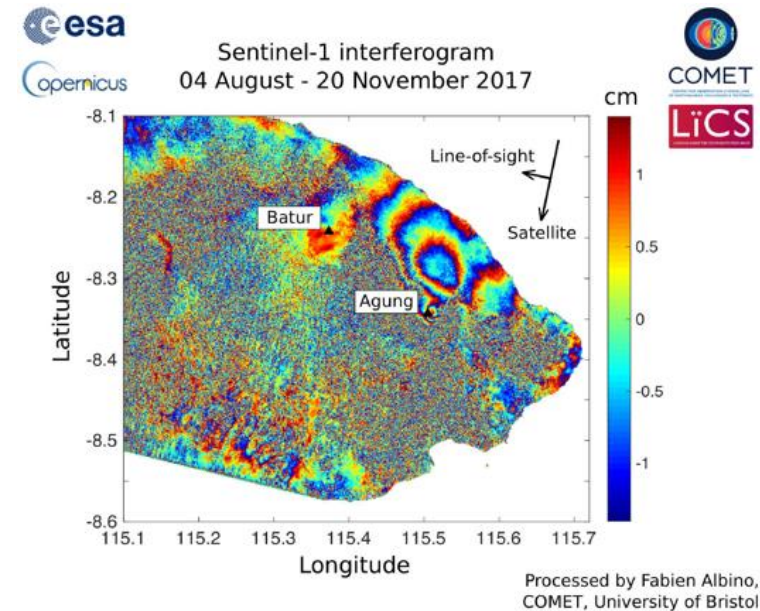
Deformation due to magmatic intrusion → magma withdrawn from middle East Rift Zone and intruded beneath lower East Rift Zone.



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 map obtained from descending pass between 22/12/2018 and 28/12/2018

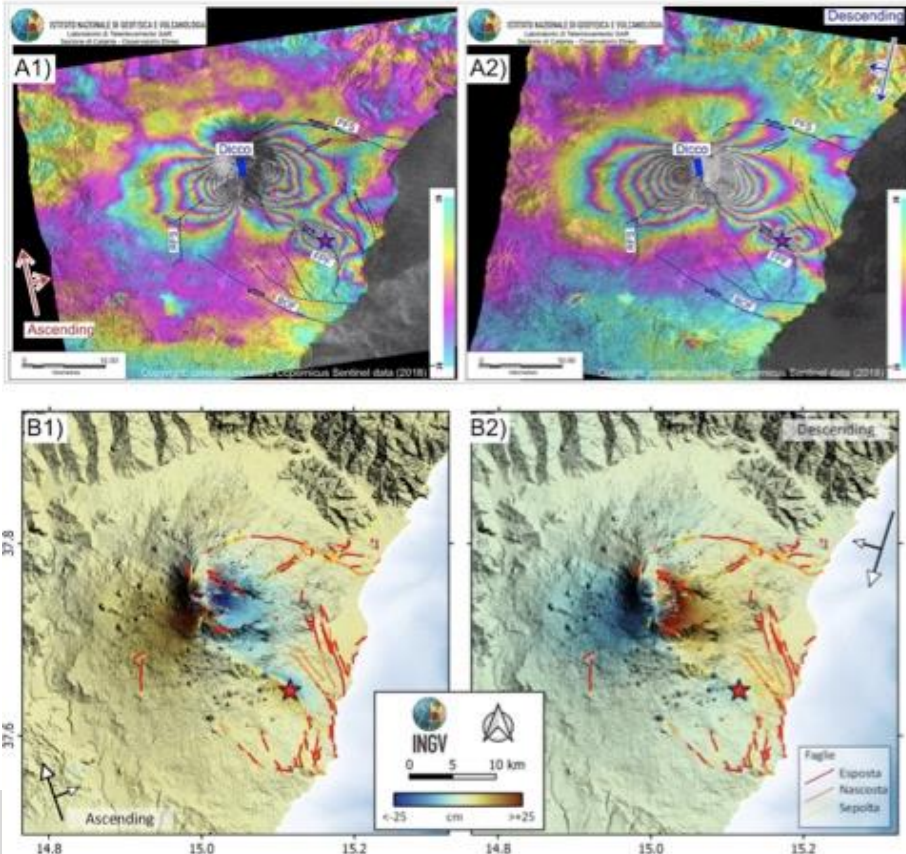
(B1) ground deformation map in LOS corresponding to interferogram (A1)

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

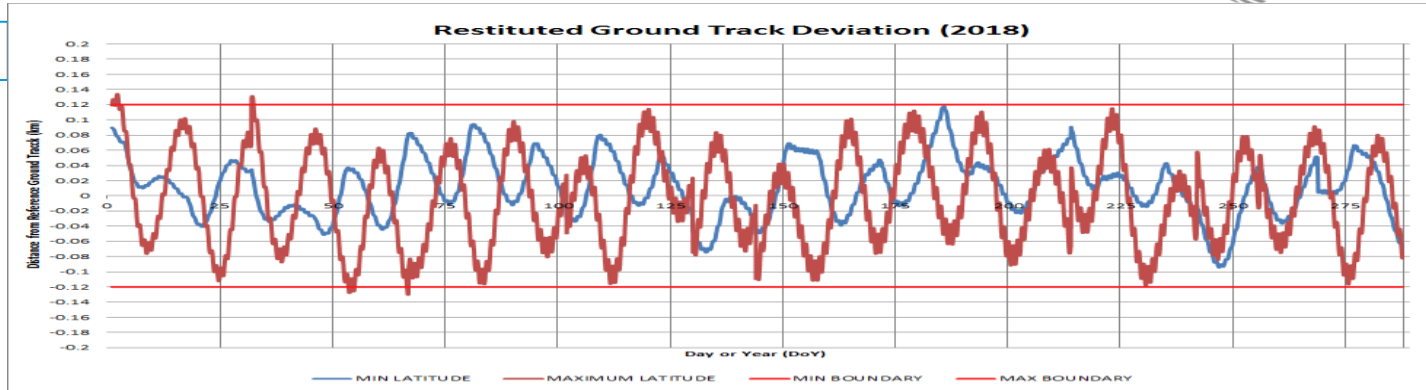
© Contains modified Copernicus Sentinel data [2018] / processed by CNR IREA and INGV

Courtesy CNR IREA / INGV / ASI

Slide 24

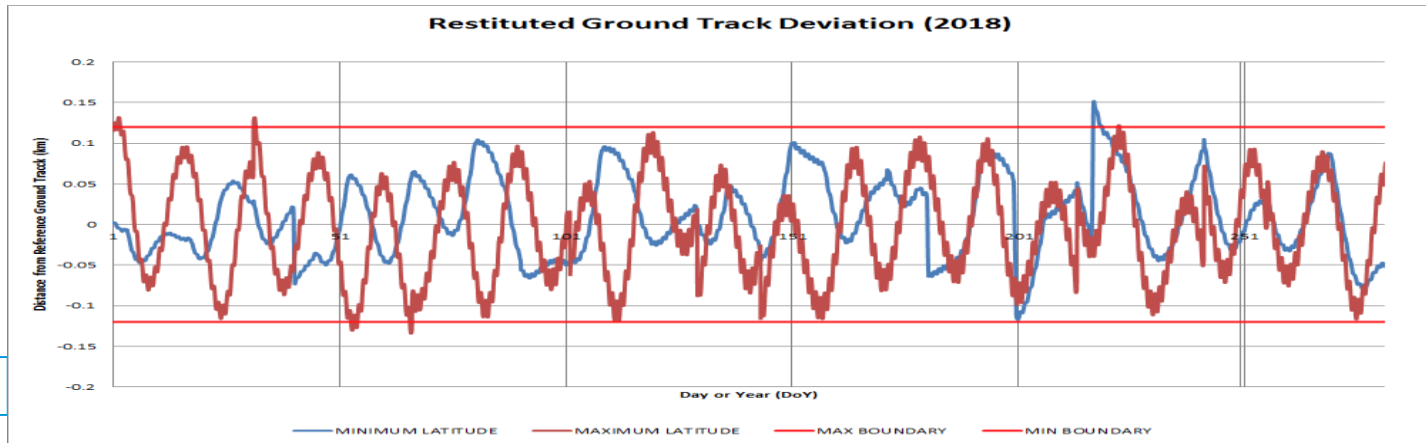


S1A

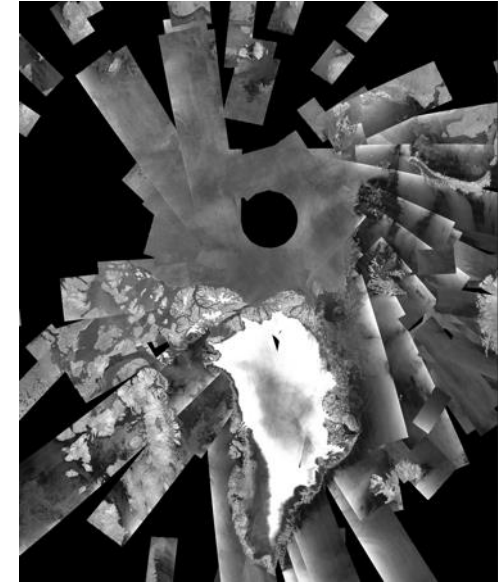
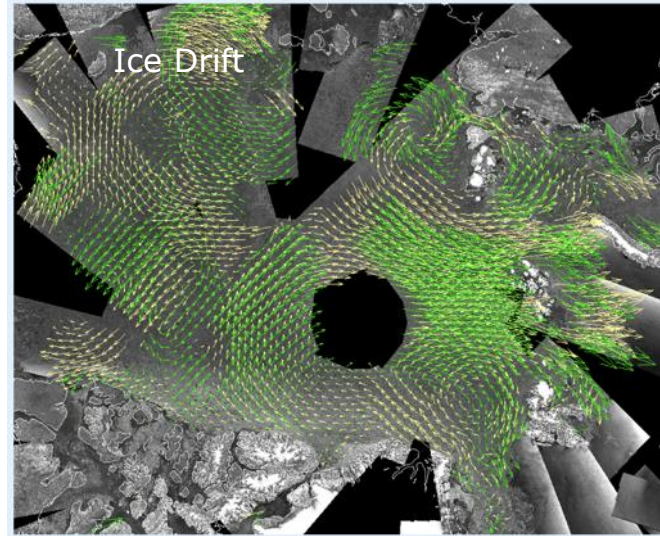
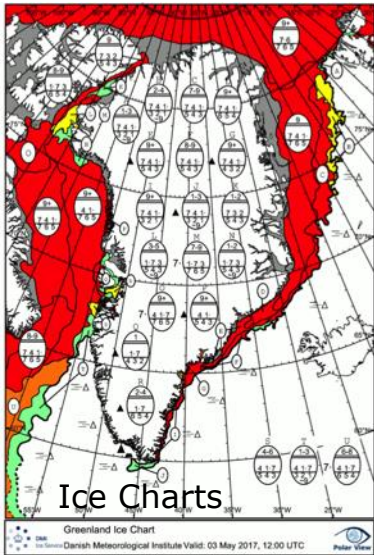
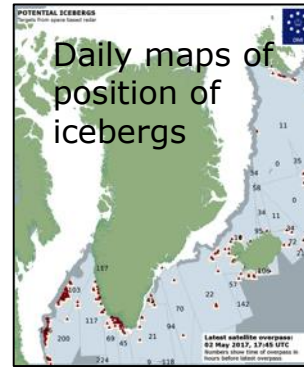


Both
 satellites are
 maintained
 within
 +/- 120m
 ground track

S1B



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



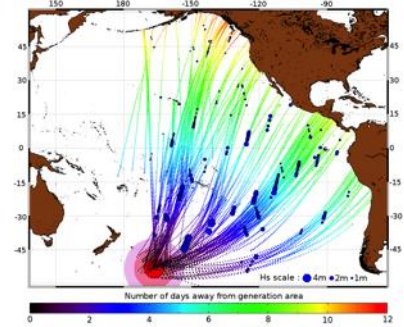
3-day Mosaic 20-21-22 July 2018
<http://www.seaice.dk/>



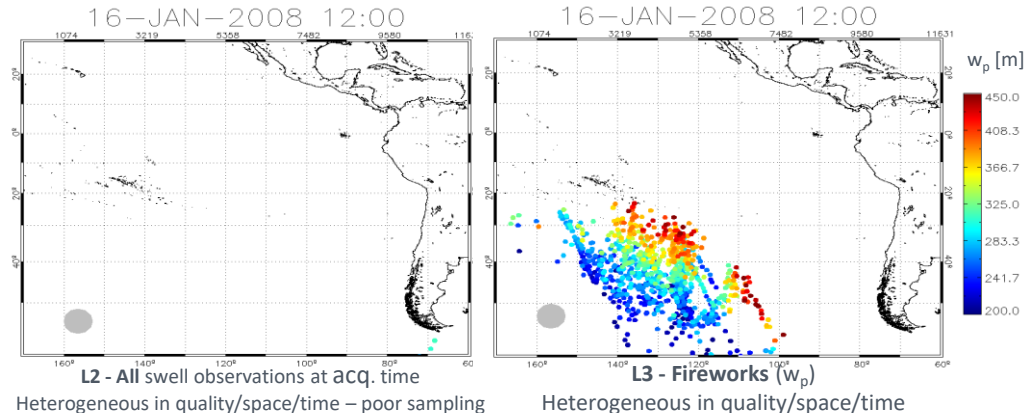
Slide 26

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

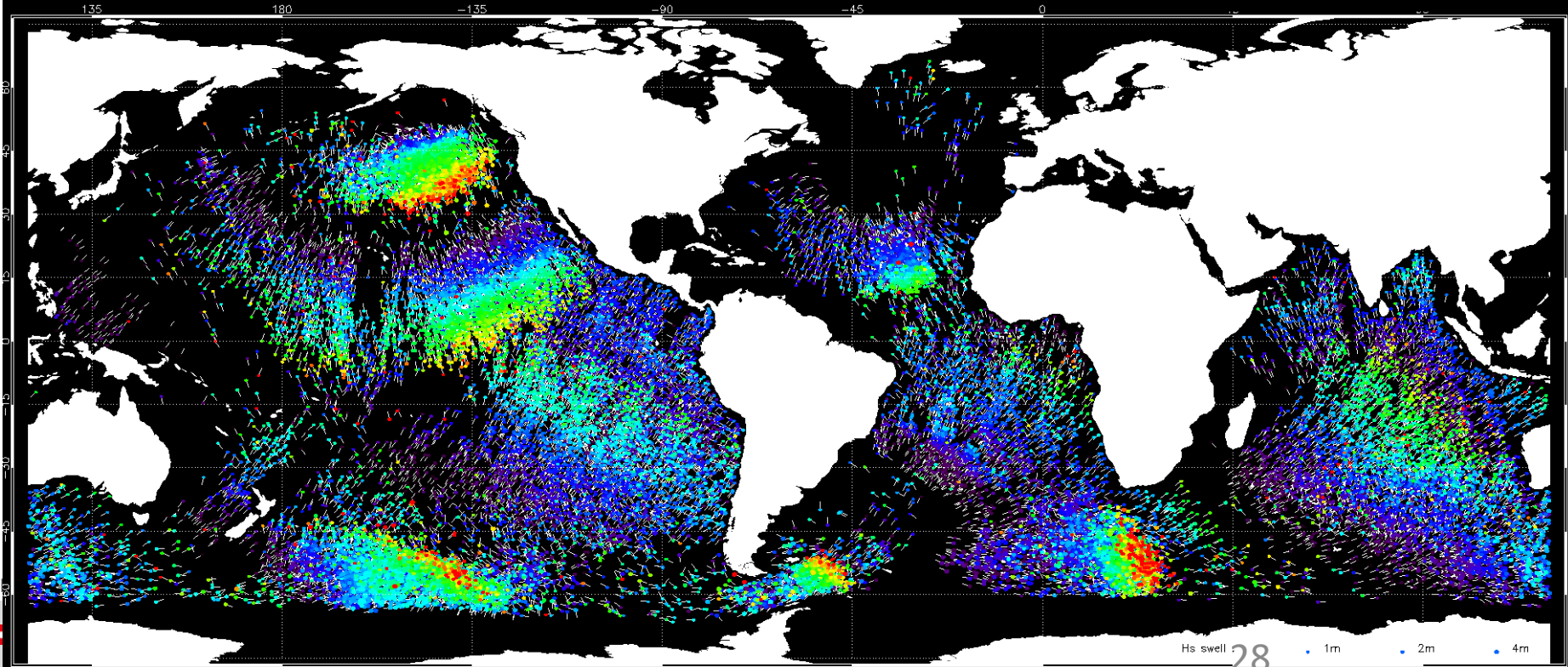


SAR-derived swell measurement trajectories from the source to the coast. Measured H_s shown by blue dots



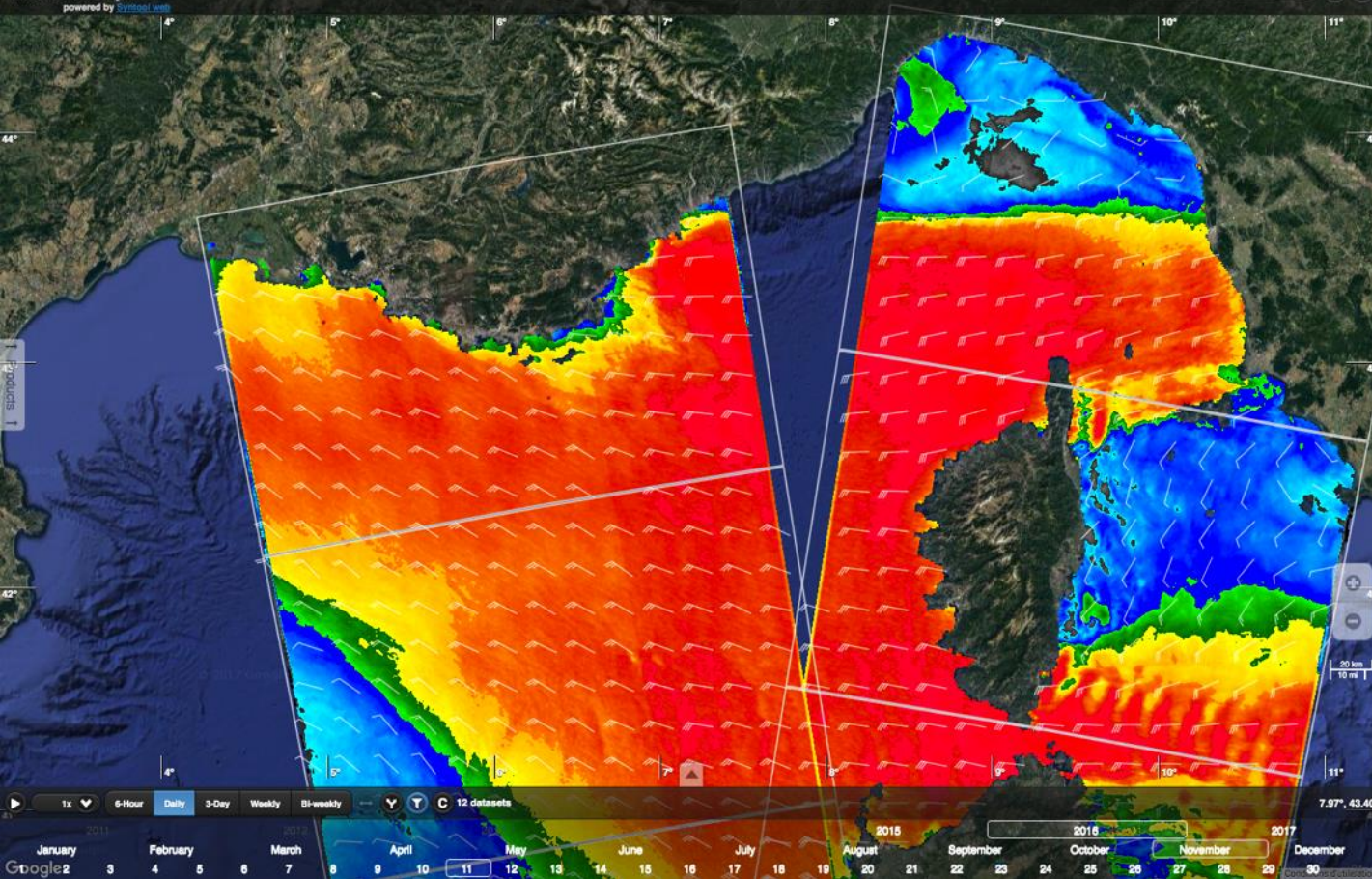
Sentinel-1A&B Level-3 demo NRT

26-NOV-2017 00:00 UTC



Wind fields

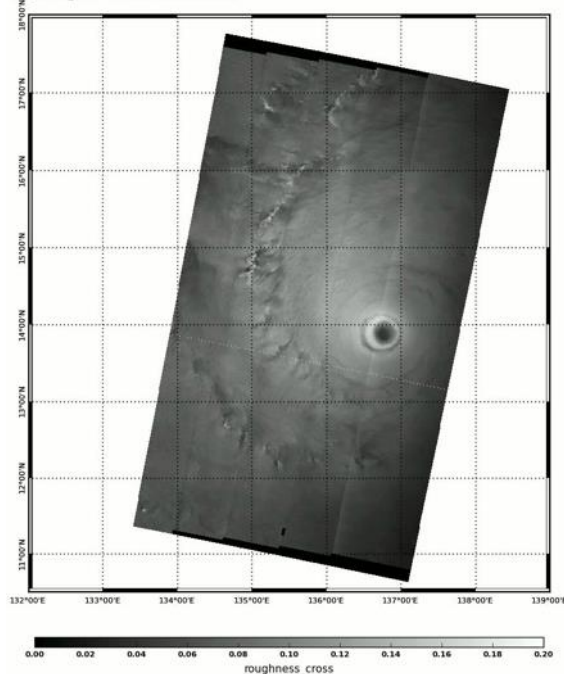
S1A evening
and morning
passes



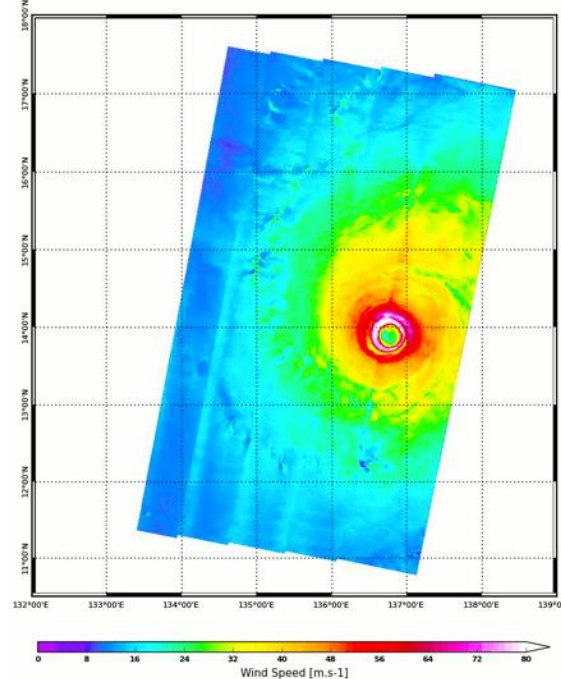
Typhoon Mangkhut

<https://datastore.cls.fr/monitoring-typhoon-mangkhut-from-space/>

Sentinel-1B
roughness_cross - 2018-09-11T20:49:16Z



Sentinel-1B
Wind field - 2018-09-11T20:49:16Z

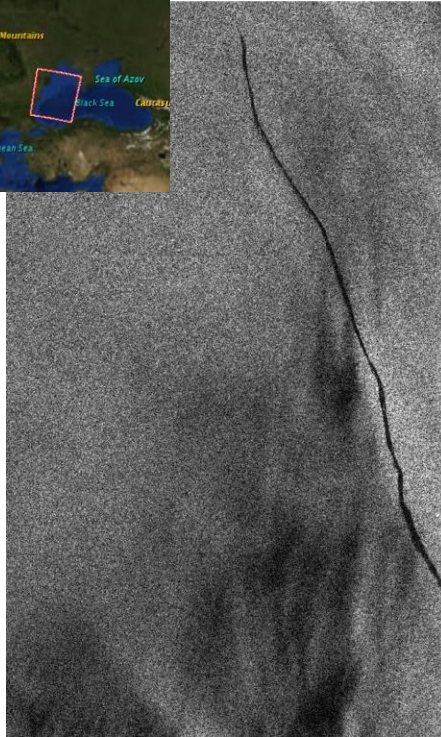


SAR: the only sensor able to characterize extreme winds (greater than 70 m/s) at very high resolution.

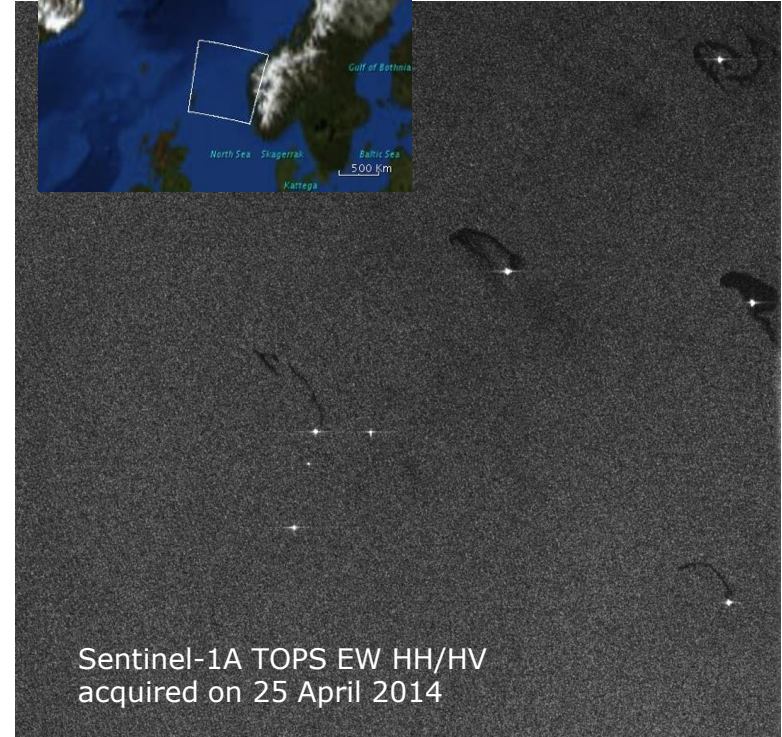
These activities may become part - at a later stage - of a Copernicus Service, e.g. CMEMS or CEMS...

Courtesy
CLS / Ifremer

First Oil Spills Detected by Sentinel-1



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



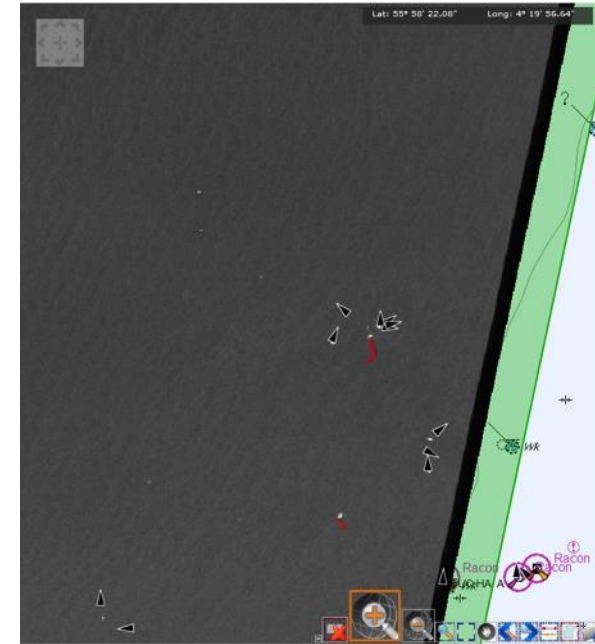
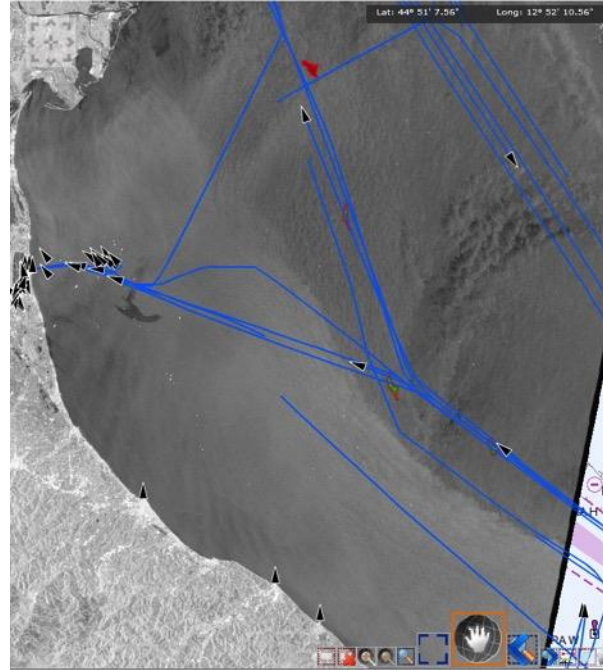
Sentinel-1A TOPS EW HH/HV
acquired on 25 April 2014



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

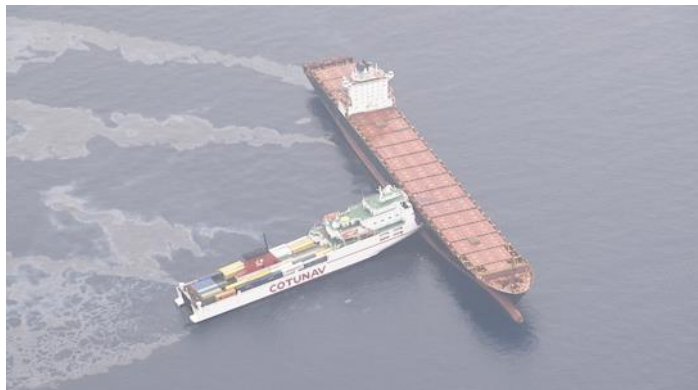
→ Operated by the **European Maritime and Safety Agency (EMSA)**

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



Sentinel-1 mission status

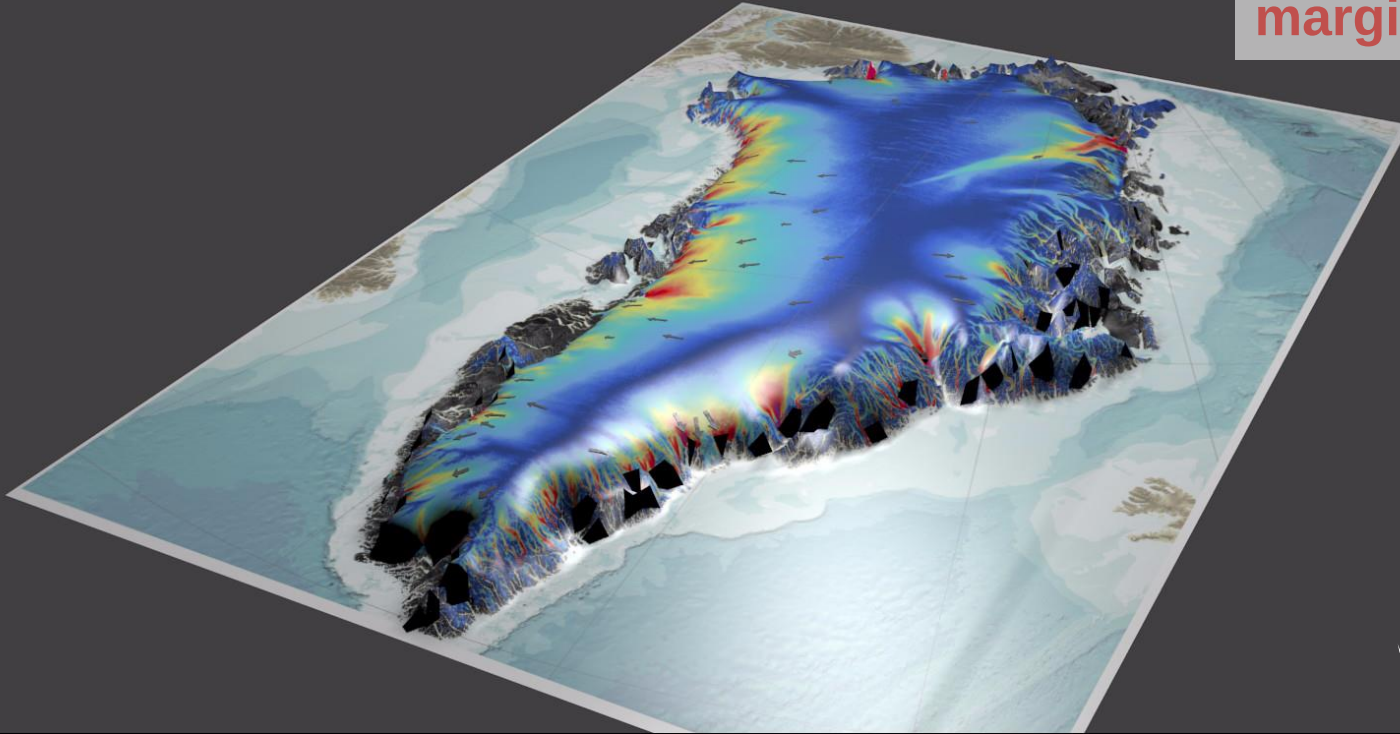
Oil Spill North of Corsica, 8 September



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

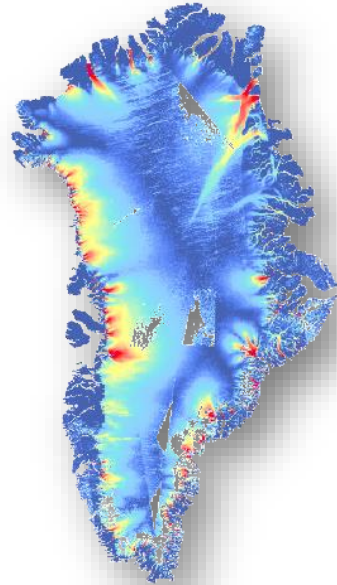


A routine
observatory of
ice sheet
margins

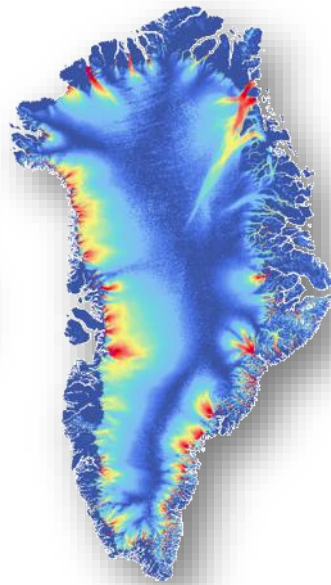




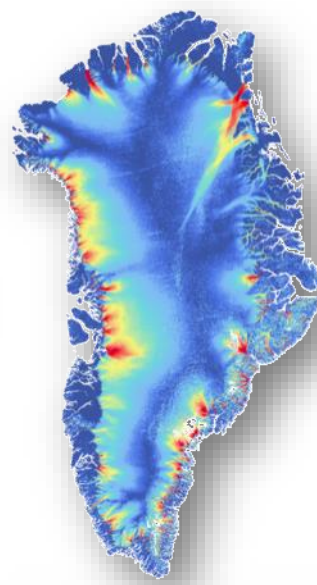
2014/15



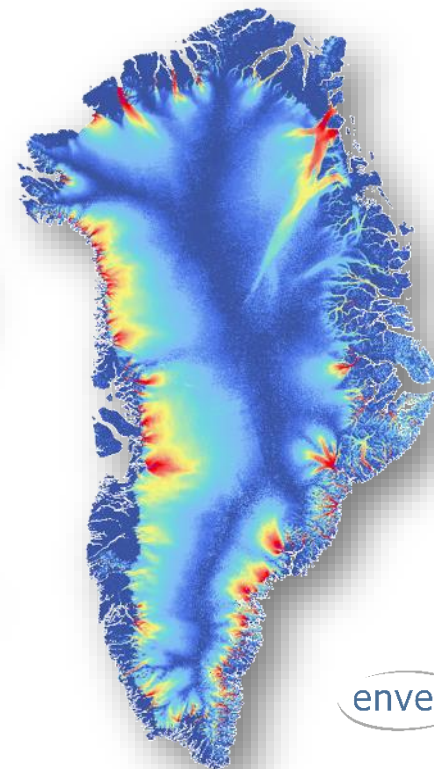
2015/16



2016/17

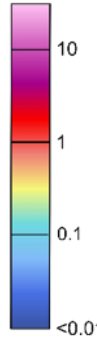


2017/18

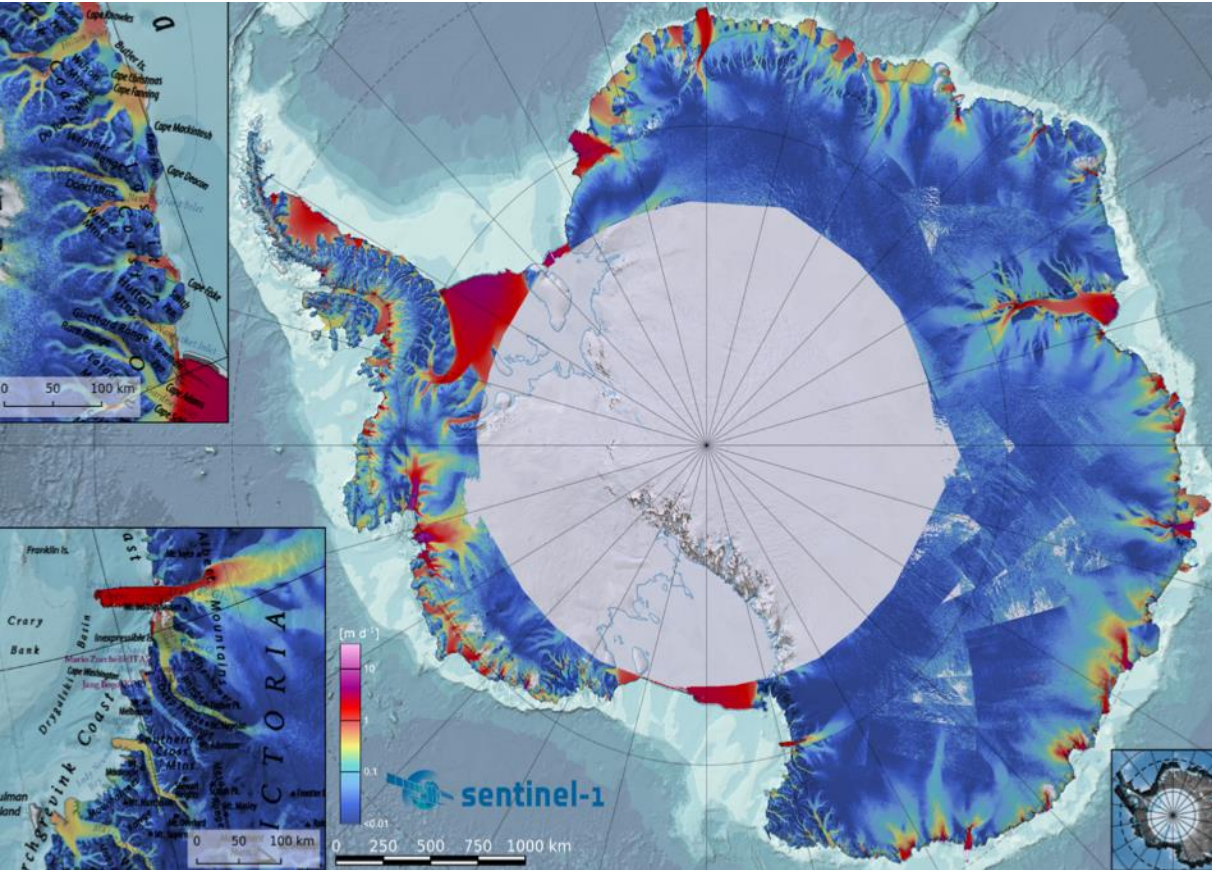


Annual Ice Velocity Maps for Greenland derived from Sentinel-1 Data for the years 2014/15 to 2017/18.

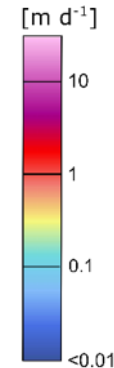
[m d⁻¹]



Antarctica Ice velocity map from S-1

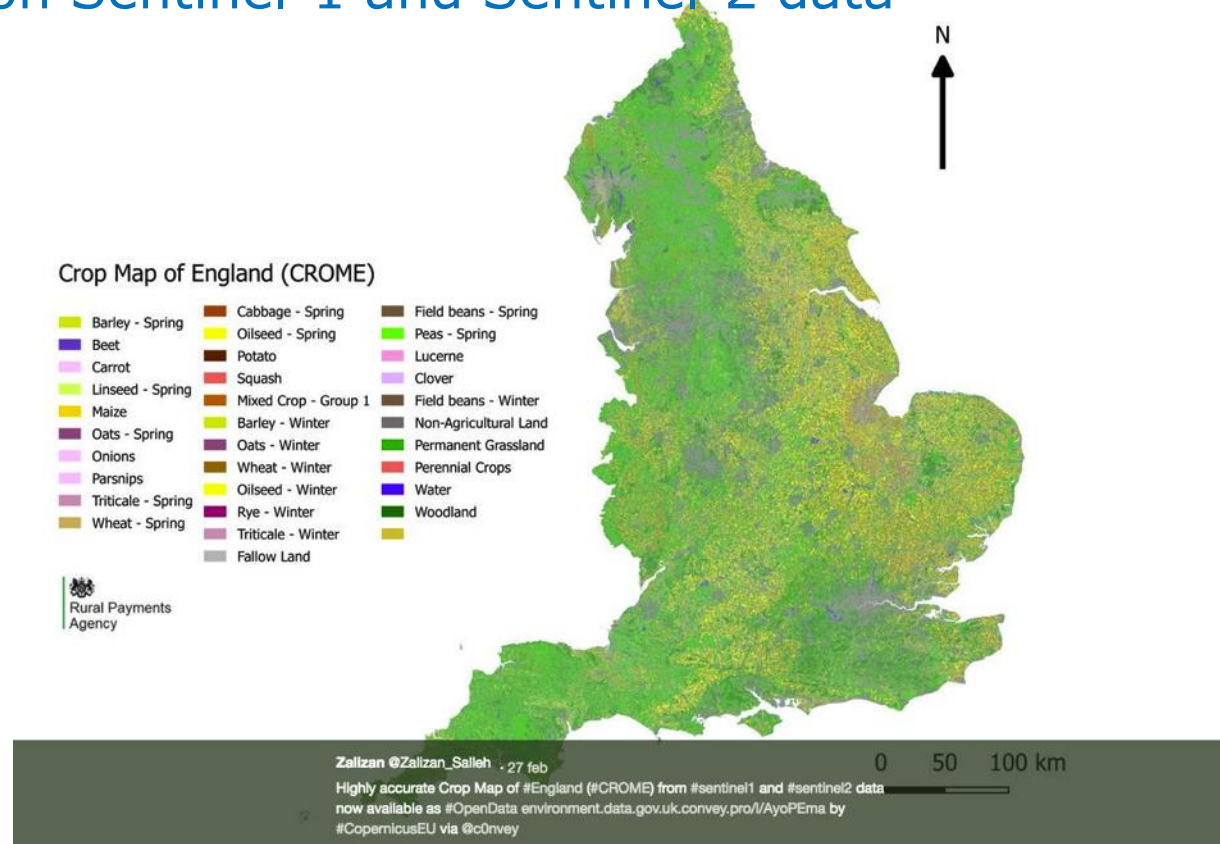


Antarctic Icesheet Wide
Velocity Map from
Sentinel-1 (2015 to 2018)



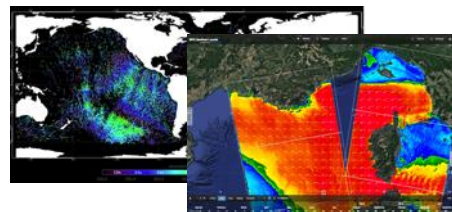
Example of UK map of crop classification based on Sentinel-1 and Sentinel-2 data

Example of Land Cover application



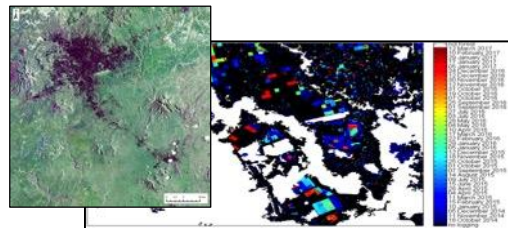
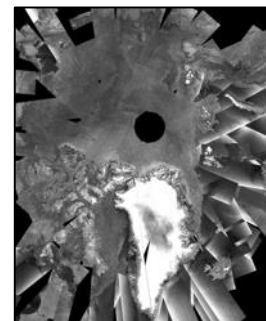


Maritime surveillance: oil spill monitoring, ship detection, illegal fisheries, etc.

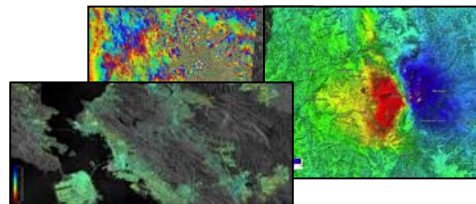


Sea state: wind, wave

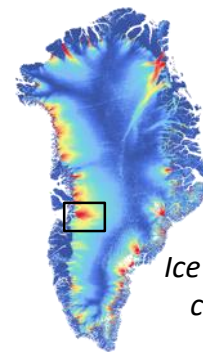
Sea ice and iceberg monitoring



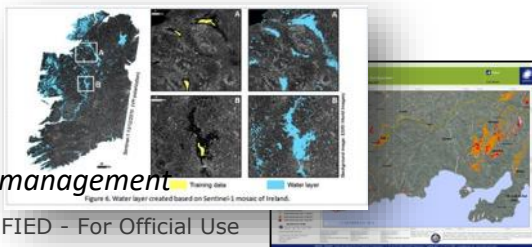
Land use, agriculture, forestry, logging, land classification, urban planning



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

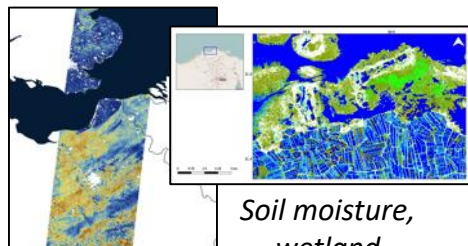


Ice sheets, glaciers, climate change

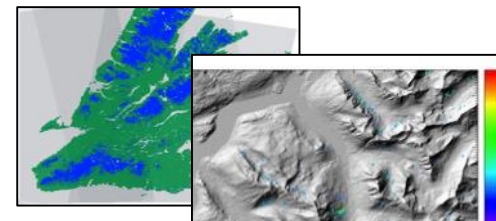


Emergency management

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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



