

Earth Observation Applications: Examples in Cyprus, Europe and Elsewhere

Cyprus/ESA ECS Agreement Earth Observation Downstream Applications for Public Sector Workshop
2022 September 21, Cleopatra Hotel, Nicosia, Cyprus

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Directorate of Earth Observation Programmes
Science, Applications and Climate Department

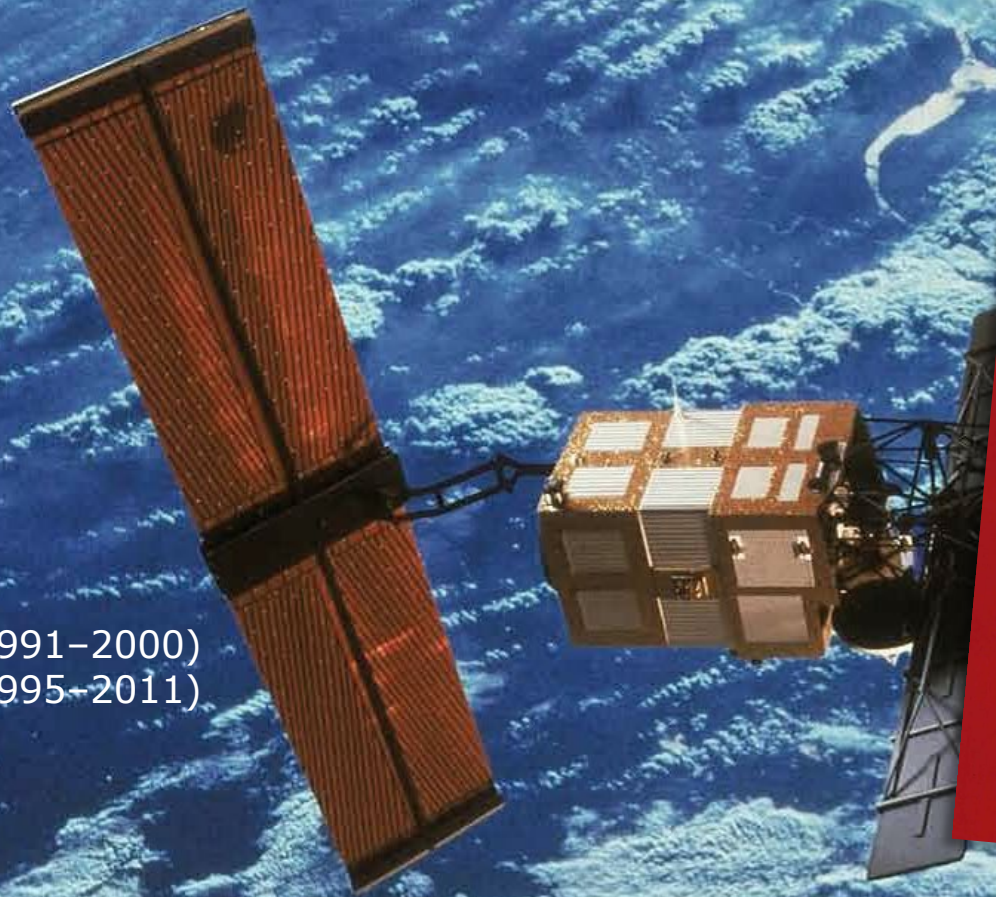
This Presentation

- ESA Earth Observation (EO) – a high-level overview
- ESA EO exploitation: science and (especially) applications, including those based on Copernicus
- Opportunities for Cyprus in EO



Earth Observation at ESA





ERS-1 (1991-2000)
ERS-2 (1995-2011)



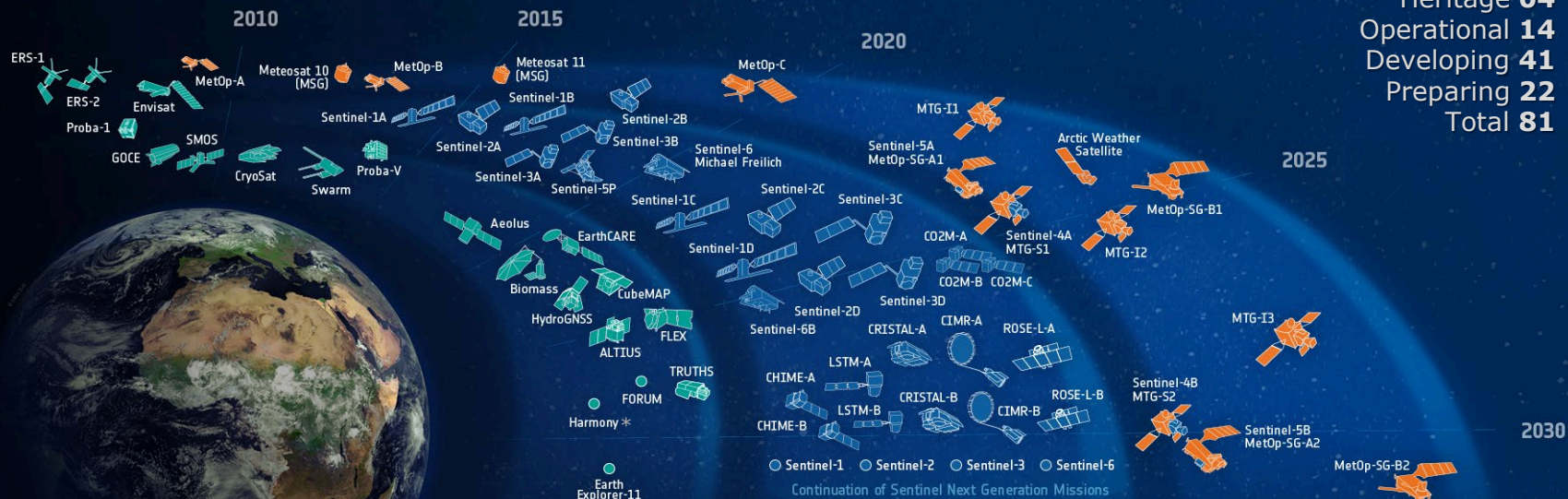


Envisat (2002–2012)

ESA-Developed Earth Observation Missions

Satellites

Heritage **04**
 Operational **14**
 Developing **41**
 Preparing **22**
 Total **81**



Science

Copernicus

Meteorology

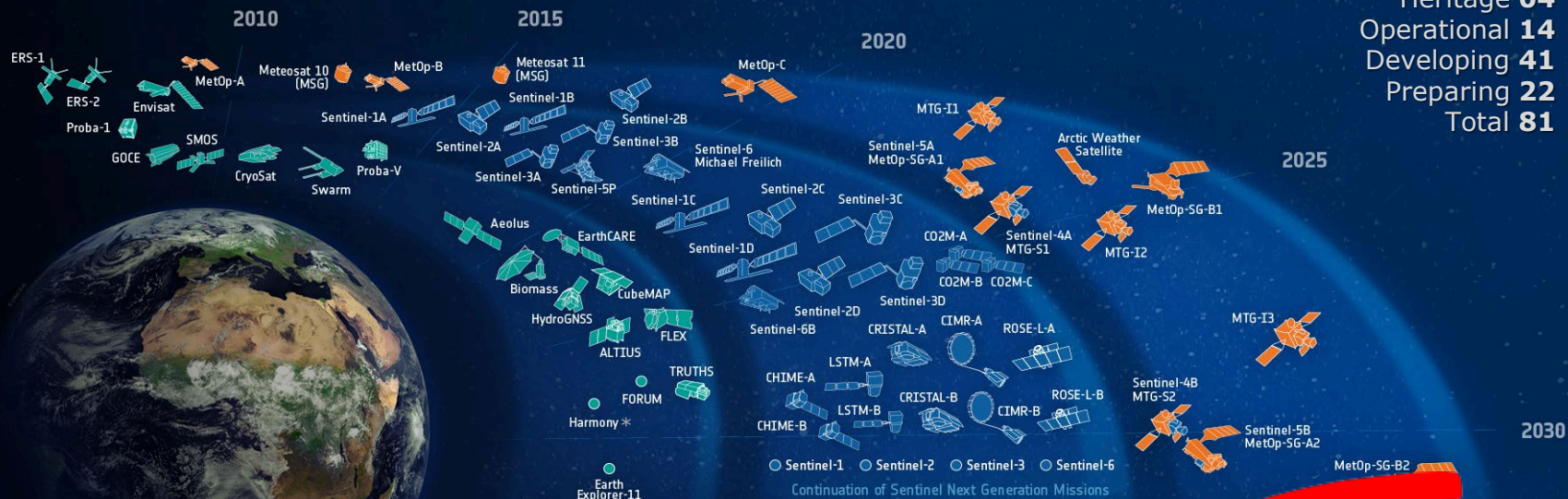
*Pending final mission selection



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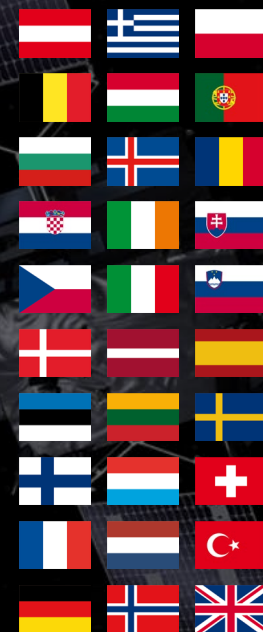
*Pending final mission selection

EUMETSAT: European Organization for the Exploitation of Meteorological Satellites



EUMETSAT

- EUMETSAT is the leading European operational agency for monitoring weather from space, since 1977.
- EUMETSAT operates the geostationary satellites **Meteosat** -10, and -11 over Europe and Africa, and Meteosat-9 over the Indian Ocean.
 - Meteosat satellites provide detailed full disc imagery over Europe and Africa every 15 minutes and rapid scan imagery over Europe, every 5 minutes.
- Also operates two **Metop** polar-orbiting satellites as part of the Initial Joint Polar System (IJPS) shared with the US National Oceanic and Atmospheric Administration (NOAA).
 - Also a partner in the cooperative sea level monitoring Jason missions (Jason-3 and Jason-CS/Sentinel-6) involving Europe and the US.
- The EU has entrusted EUMETSAT with exploiting the four Sentinel missions dedicated to the monitoring of atmosphere, ocean and climate on its behalf. EUMETSAT carries out these tasks in cooperation with ESA.
 - ESA develops the satellites and procures their recurrent versions.
 - EUMETSAT is responsible for the overall user and mission requirements, the development of the ground segment (incl. data dissemination) and the satellite operations.



Meteosat-1 (1977)

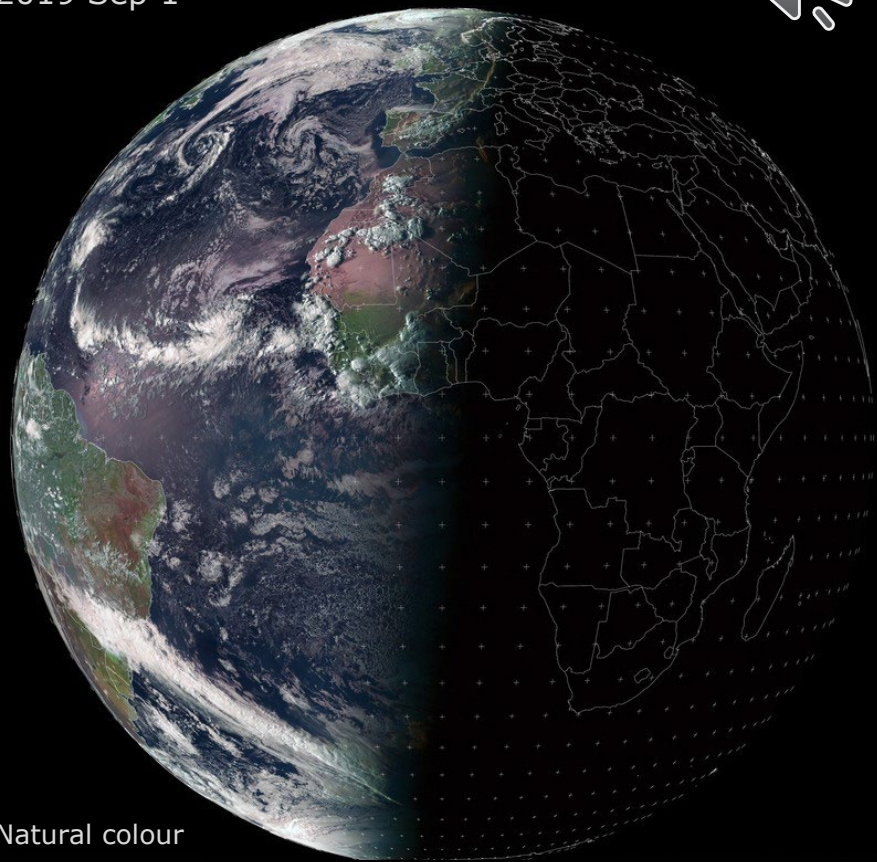


METEOSAT-1

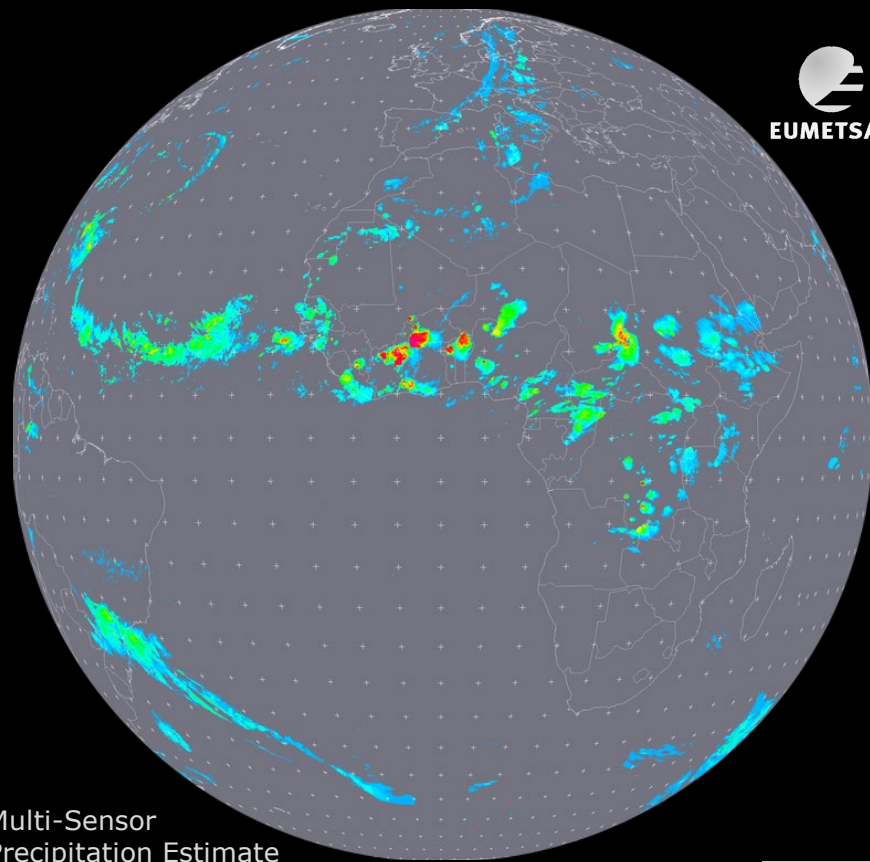
FIRST IMAGE: 9 DEC 1977
COPYRIGHT ESA



Meteosat-11
2019 Sep 1



Natural colour



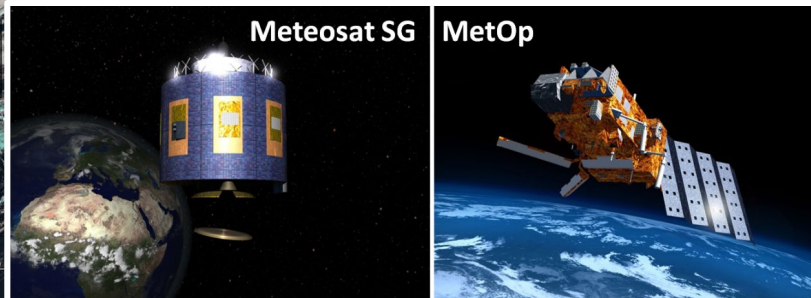
Multi-Sensor
Precipitation Estimate

2019-09-01 17:00:00 UTC

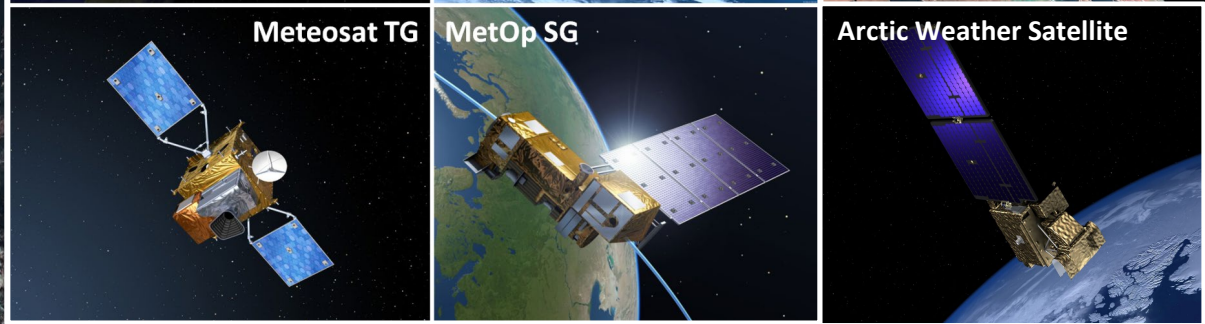


European Space Agency

Current Systems



Post-2022 Systems will continue into the 2040s



ECMWF: European Centre for Medium-Range Weather Forecasts



- ECMWF was established in 1975, in recognition of the need to pool the scientific and technical resources of Europe's meteorological services and institutions for the production of weather forecasts.
- Aims to provide accurate global weather forecasts up to 15 days (medium-range), to monthly and seasonal, and up to a year ahead.
- Provides current forecasts, climate reanalyses, and specific datasets.
- Has one of the largest supercomputer facilities and meteorological data archives in the world.
- Through the EU's Destination Earth initiative, develops prototype digital twins of the Earth.



Search products...

Range

- Medium (15 days)
- Extended (42 days)
- Long (Months)

Type

- Forecasts
- Verification

Component

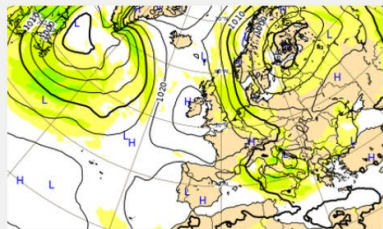
- Surface
- Atmosphere


Product type

- High resolution forecast (HRES)
- Ensemble forecast (ENS)
- Combined (ENS + HRES)
- Extreme forecast index
- Point-based products

Parameters

- Wind
- Mean sea level pressure
- Temperature
- Geopotential
- Precipitation
- Cloud
- Water vapour
- Indices
- Snow

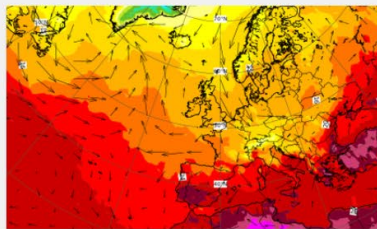


Latest forecast 

Mean sea level pressure and 850 hPa wind speed

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

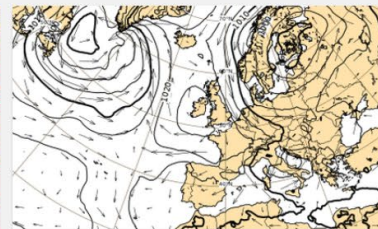



Latest forecast 

2 m temperature and 30 m wind

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

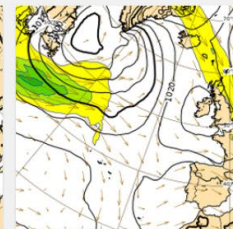



Latest forecast 

100 m wind and mean sea level pressure

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

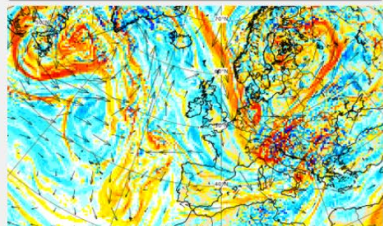



Latest forecast 

Mean sea level pressure and 850 hPa wind speed

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

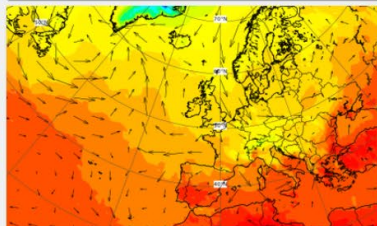



Latest forecast 

Vorticity and 700 hPa wind

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

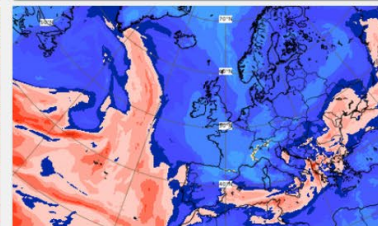


Latest forecast 

2 m temperature and 10 m wind

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

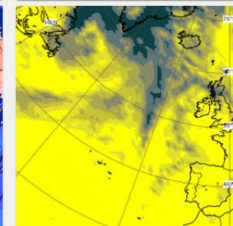



Latest forecast 

Total column water

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

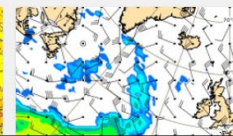
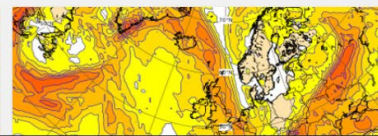
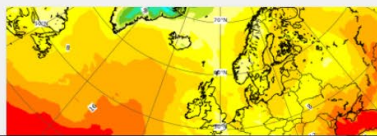
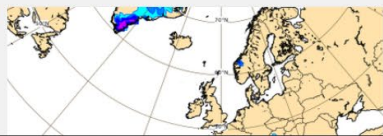


Latest forecast 

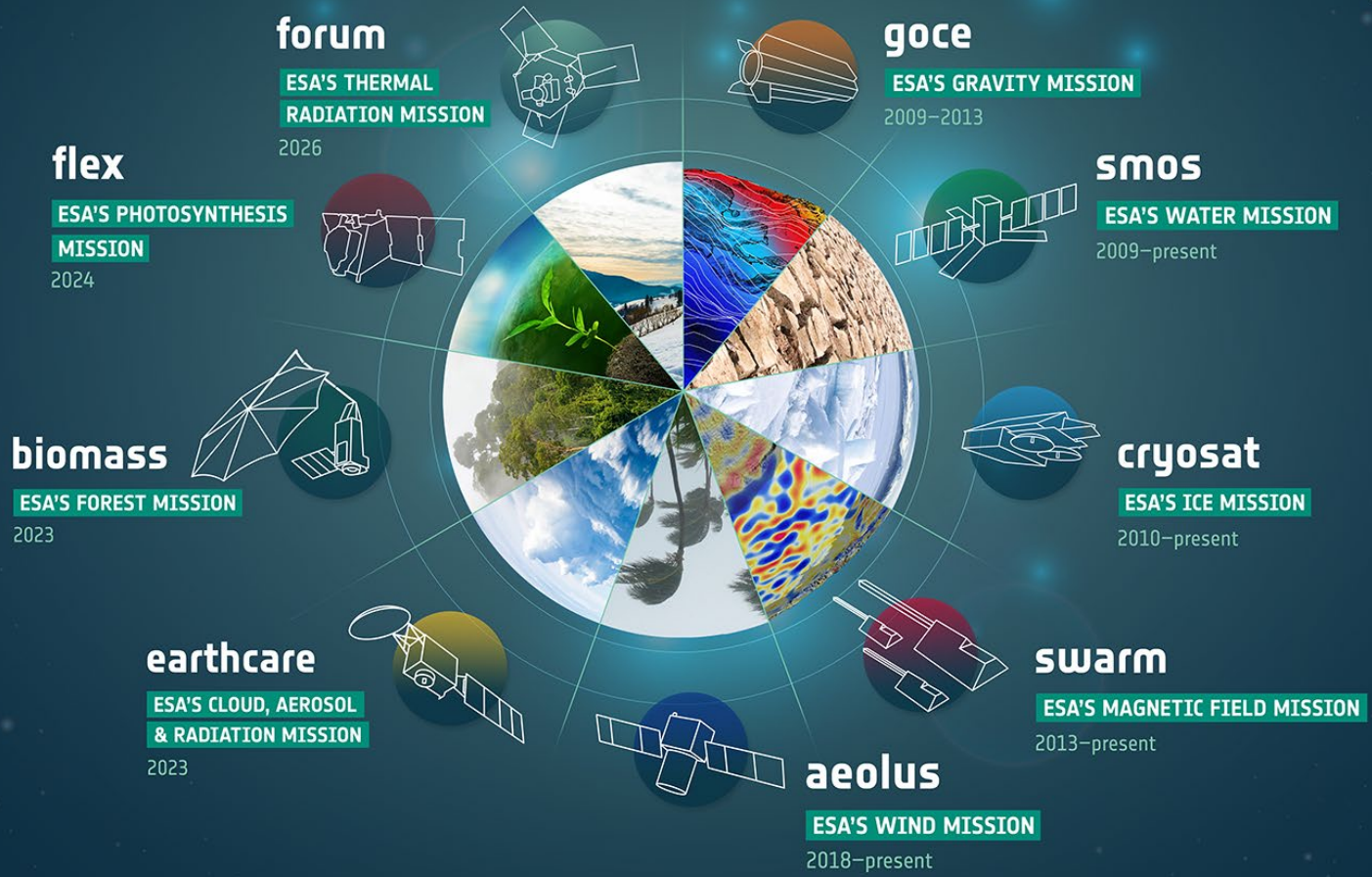
Sunshine duration, last 24 hours

These charts are from the ECMWF high resolution forecast (HRES). [A](#) Select desired times and ...

[+](#) ADD TO CHARTSET

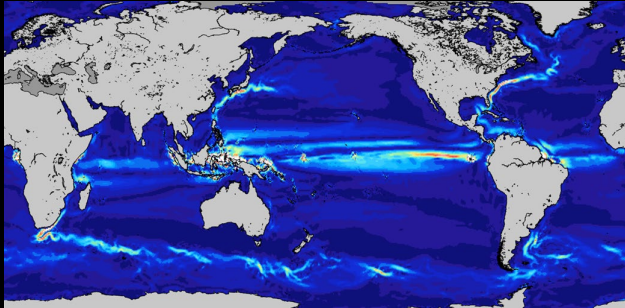


Science: Earth Explorers

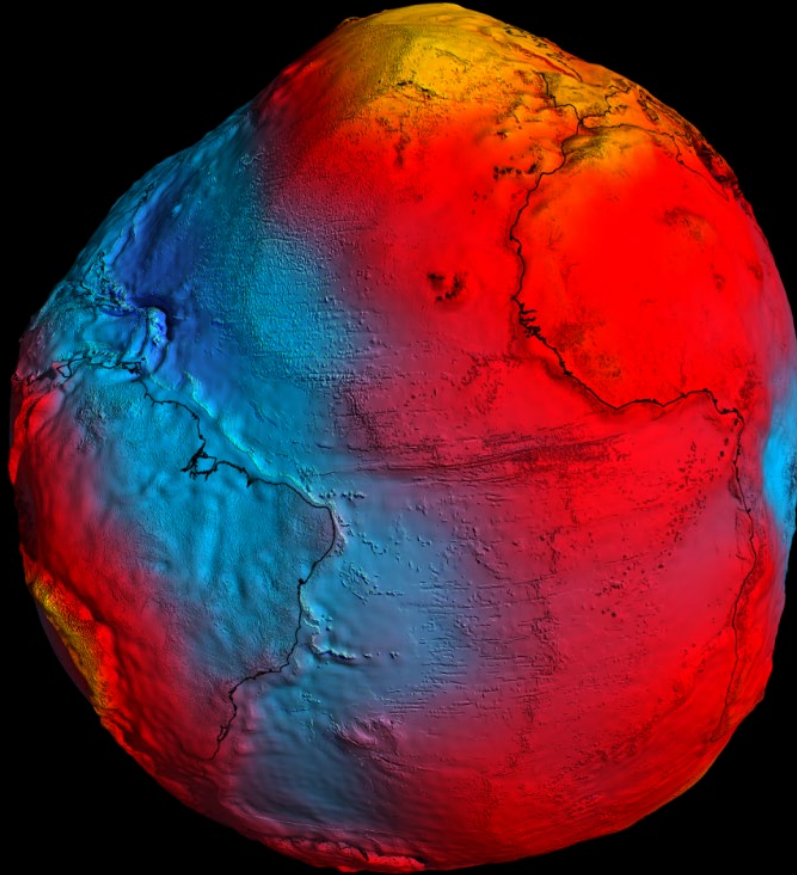


The GOCE Geoid

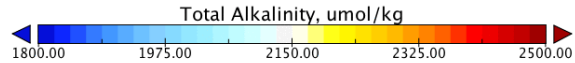
- First ever gradiometer in space
- Best ever static geoid



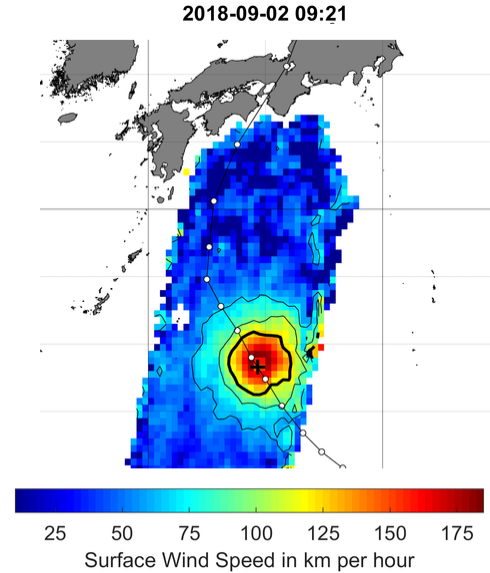
Mean ocean circulations from GOCE geoid and sea altimetry



Unexpected Science Results



SMOS: Ocean acidification



SMOS: Surface wind in intense storms

Sustainable
Development

UN SDGs

Climate Change

UNFCCC

Climate Change

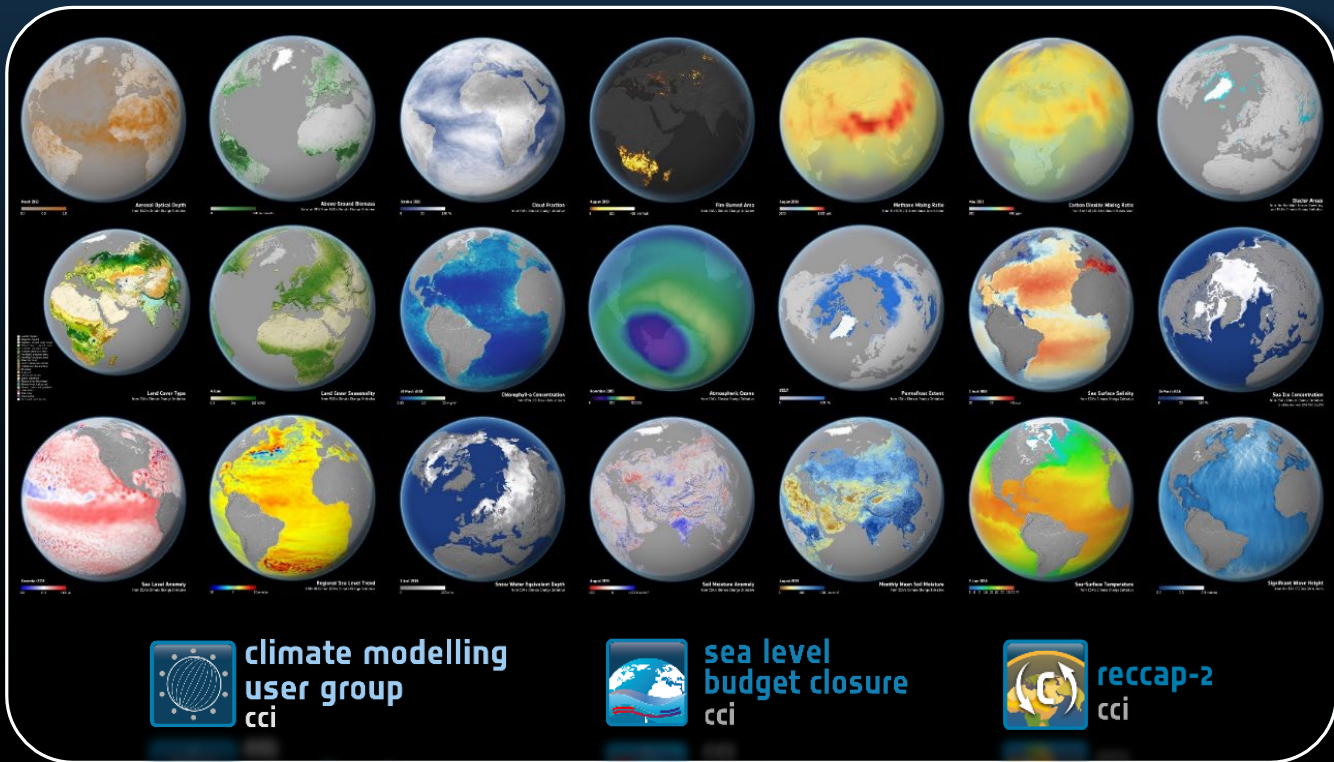
*SPACE CLIMATE
OBSERVATORY*

The **Sendai Framework** - Mitigating environmental threats to society and strengthen Global Resilience through novelty

The **European Green Deal** - Benefitting strongly from ESA Earth Observation capabilities, both now and in the future

21 Essential Climate Variable (ECV) Being Monitored

- CCI is a response to UNFCCC's need for **systematic global climate observation**
- ECV datasets provide **long-term empirical evidence** to predict & understand key parts of the climate
- 54 defined ECVs, 36 monitored from space, **21 under development** by ESA



ESA-Developed Earth Observation Missions

Satellites

Heritage **04**
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Science **Copernicus** Meteorology

*Pending final mission selection

> 585.000

registered users
= tip of the iceberg



Land

6 operational services



Atmosphere



Ocean



Climate



Disaster



Security



250 TB satellite data
distributed per day



full, free & open
data policy

7 Copernicus Sentinels flying



6 Copernicus Expansion missions



Preparing Copernicus 4.0

Copernicus Sentinels Status

S-1



Radar

A

3 Apr 2014

B

25 Apr 2016

C

2022

D

2028

S-2



High Res.
Optical

A

23 Jun 2015

B

6 Mar 2017

C

2024

D

2028

S-3



Medium Res.
Optical &
Altimetry

A

16 Feb 2016

B

25 Apr 2018

C

2024

D

2028

S-4



Atmospheric
Chemistry
(GEO)

A

2024

B

2032

S-5P



Atmospheric
Chemistry
(LEO)

A

13 Oct 2017

S-5



Atmospheric
Chemistry
(LEO)

A

2024

B

2031

C

2038

S-6



Altimetry

MF

21 Nov 2020

B

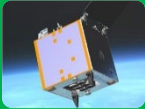
2025

Contributing Missions are key to Copernicus

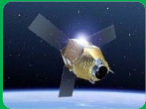


Optical High & Very High Resolution

DMC



Pléiades



RapidEye



WorldView



Deimos-2



SPOT (HRS) SkySat



Doves



Optical Medium & Low Resolution

SPOT



PROBA-V



and many more ...

Synthetic Aperture Radar

Cosmo SkyMed



Radarsat



TerraSAR-X Tandem-X



Altimetry

Cryosat



Jason



Atmosphere

MetOp



MSG



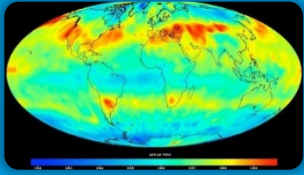
ESA buys large volumes of non-ESA EO data



Copernicus Sentinel Expansion Missions

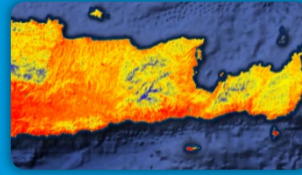


CO₂M – Anthropogenic CO₂ Monitoring



Causes of
Climate Change

LST – Land Surface Temperature



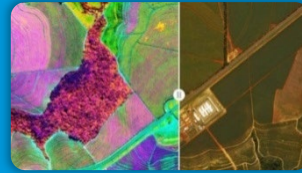
Agriculture,
Water Productivity

CRISTAL – Polar Ice/Snow Topography



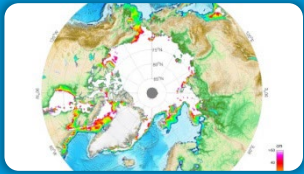
Effects of
Climate Change

CHIME – Hyperspectral Imaging Mission



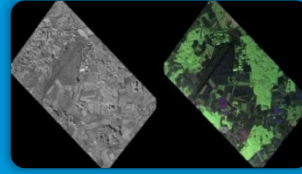
Food Security, Soil,
Biodiversity

CIMR – Passive Microwave Radiometer



Sea Surface Temperature,
Ice Concentration

ROSE-L – L-band SAR Mission

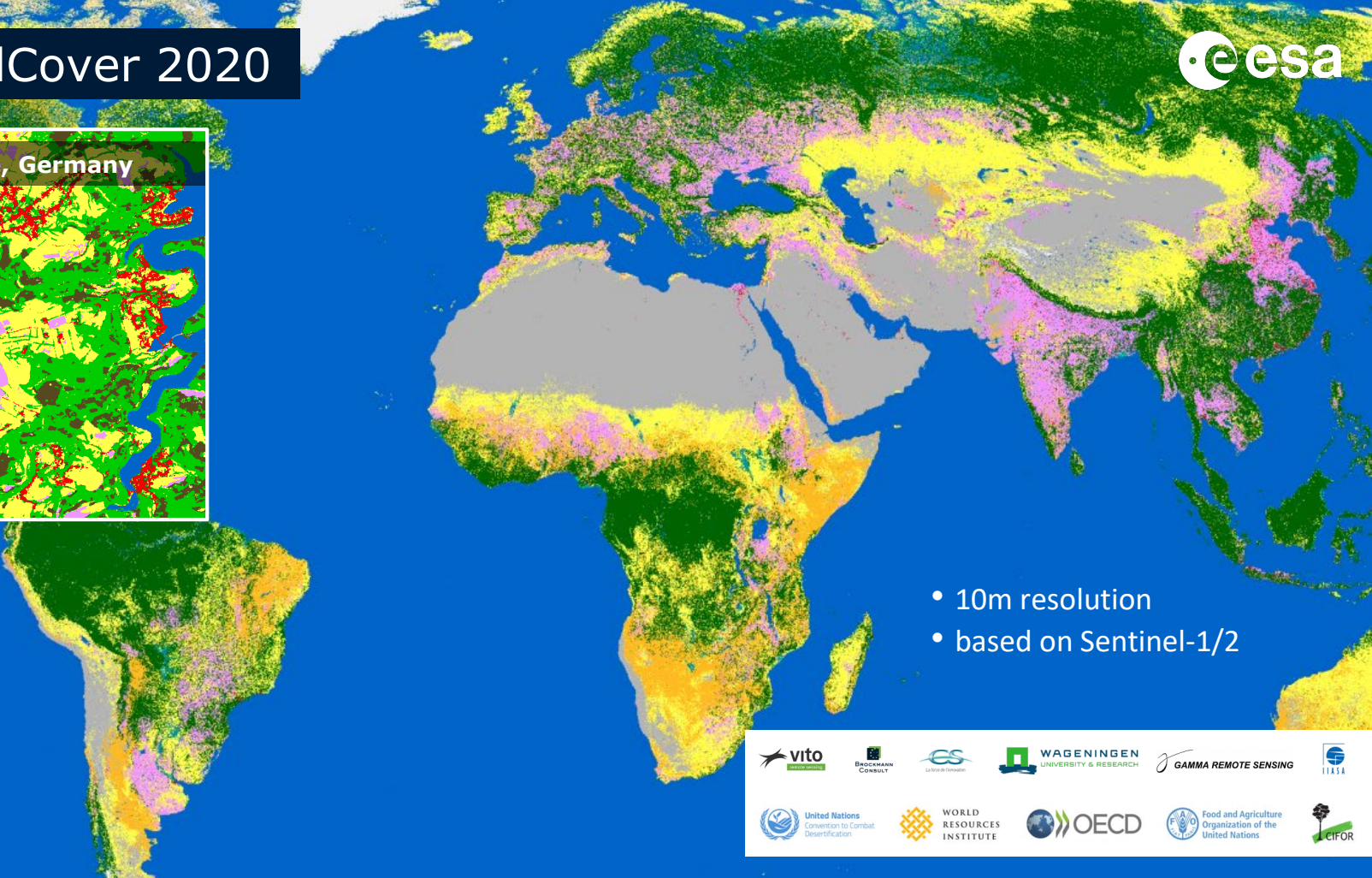
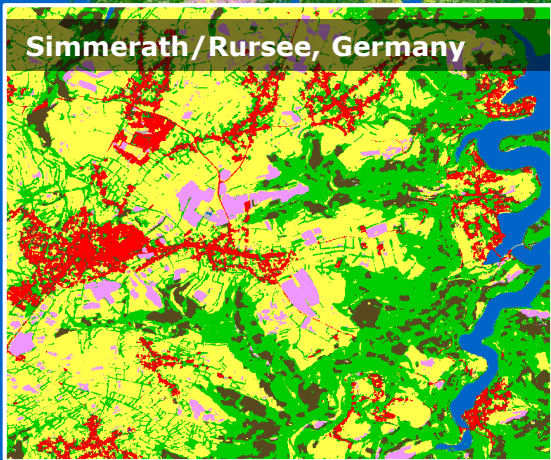


Vegetation, Ground
Motion, Soil Moisture

ESA WorldCover 2020



Simmerath/Rursee, Germany



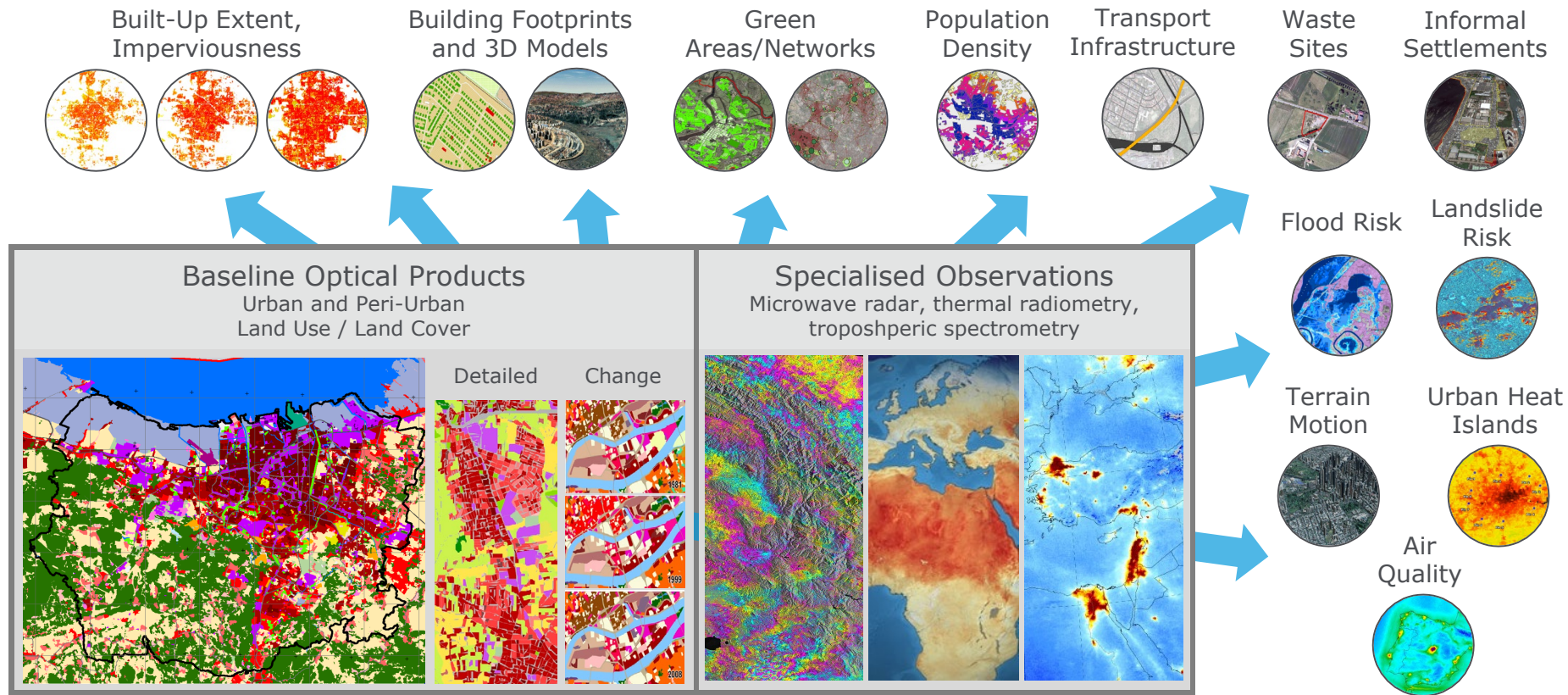
- 10m resolution
- based on Sentinel-1/2

Tree cover
Shrubland
Grassland
Cropland
Built-up
Bare/sparse vegetation
Snow and ice
Permanent water bodies
Herbaceous wetland
Mangroves
Moss and lichen



Urban Development

EO Products for Urban Development



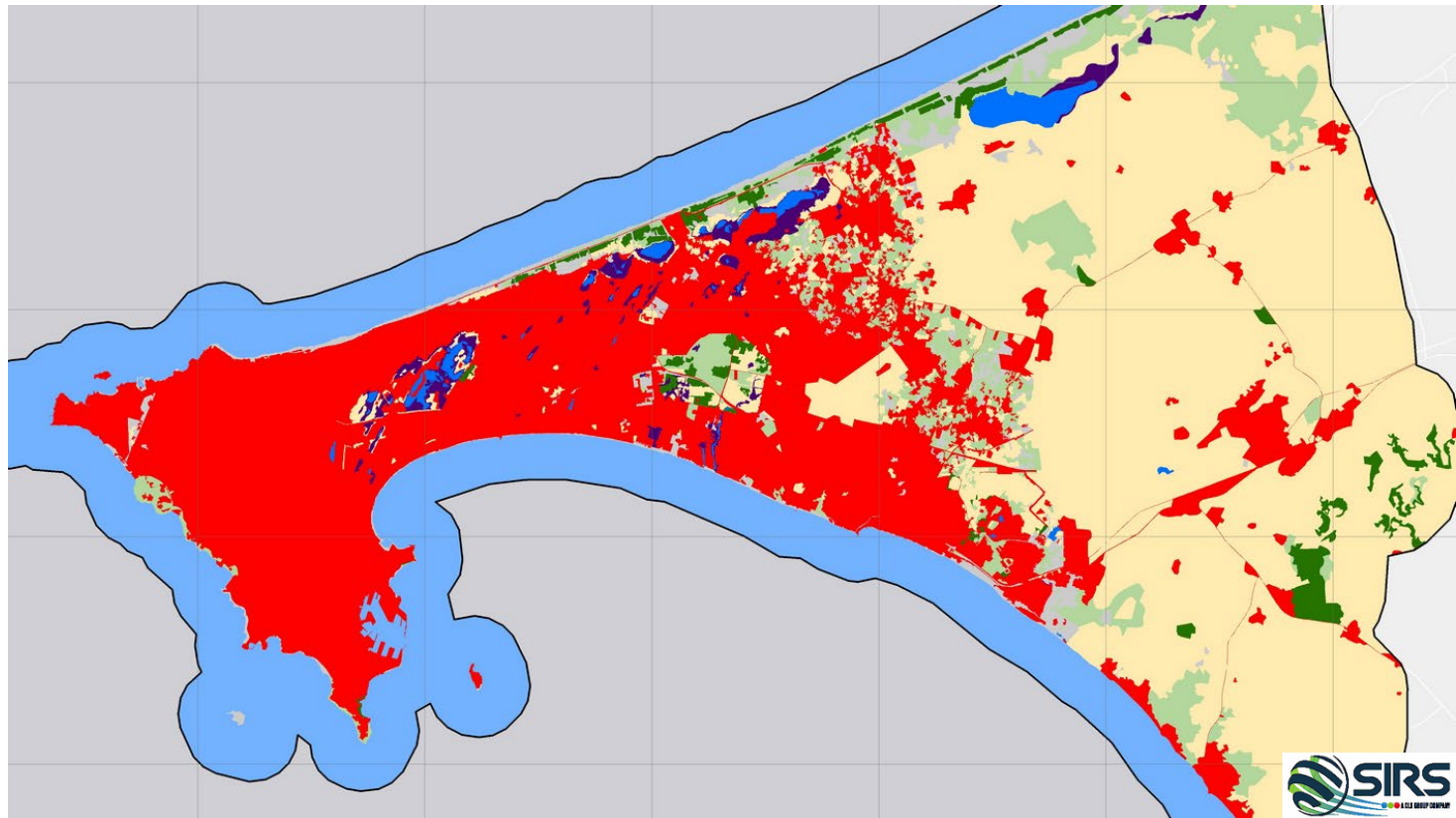
Example: Land Use/Land Cover

Dakar, Senegal

2015

Land Use / Land Cover

- Artificial Surfaces
- Agricultural Areas
- Forest and Shrublands
- Natural Areas (Grassland)
- Bare Soil
- Wetlands
- Inland Water
- Marine Water



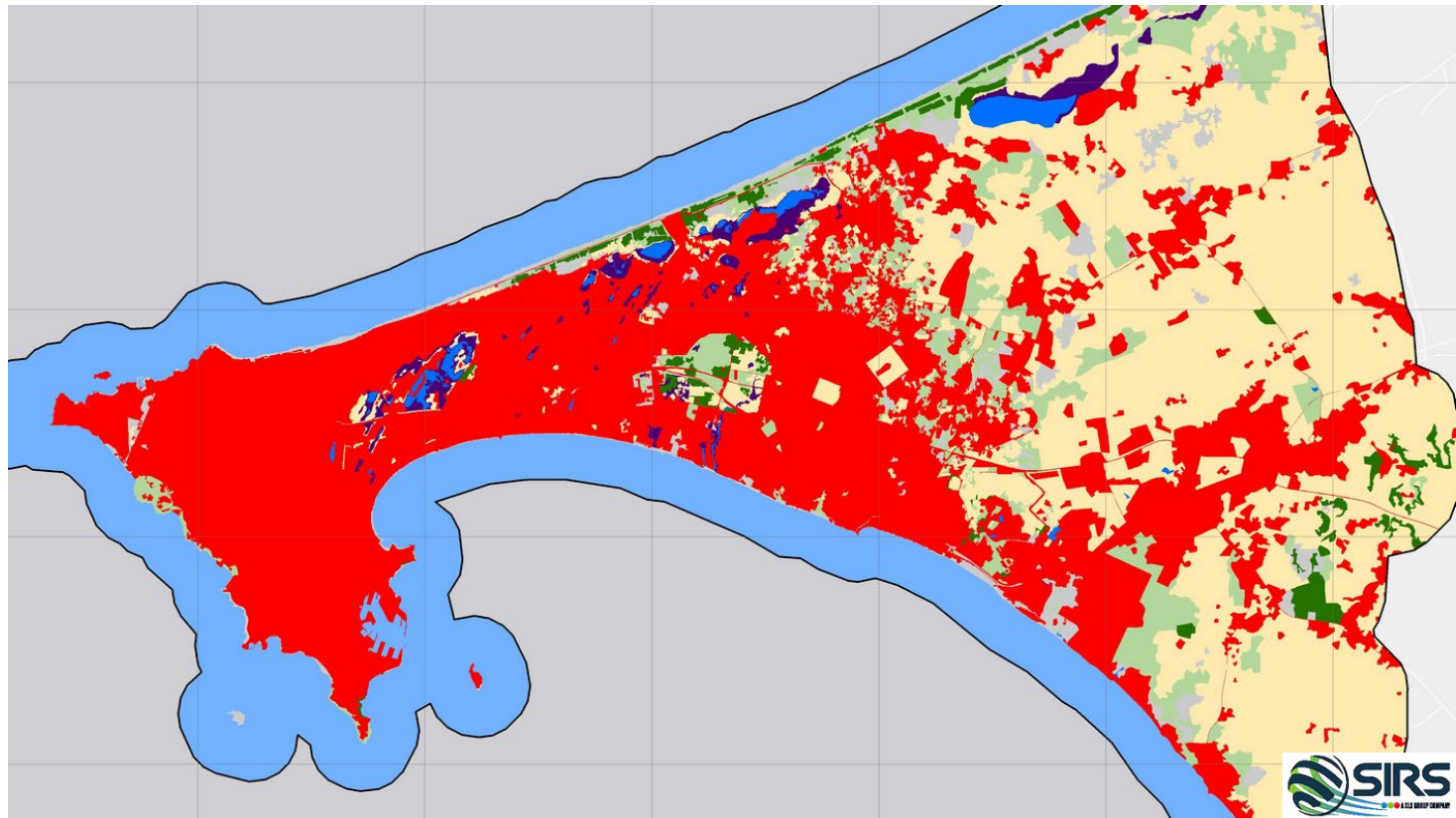
Example: Land Use/Land Cover

Dakar, Senegal

2018

Land Use / Land Cover

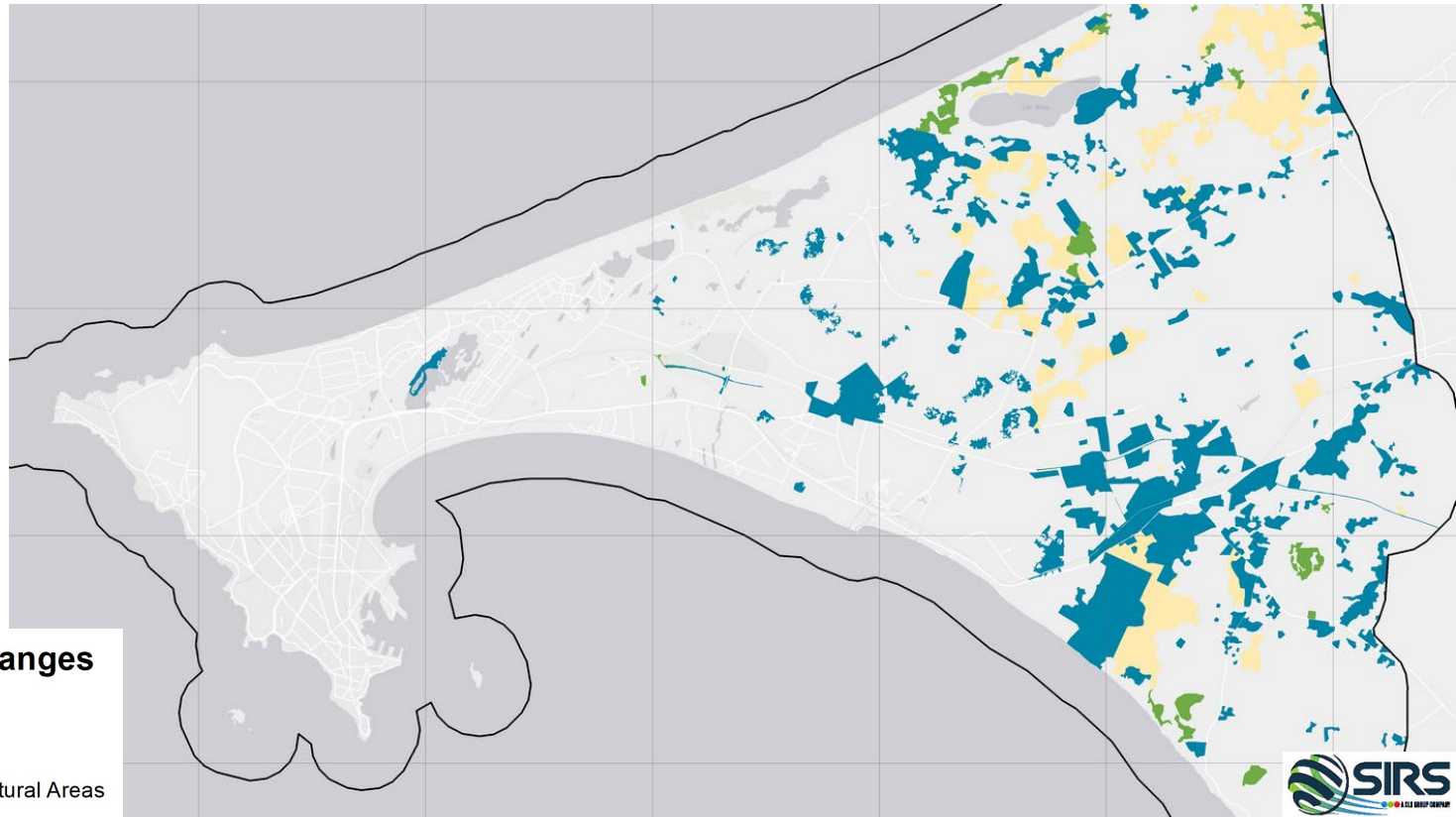
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Example: Land Use/Land Cover

Dakar, Senegal

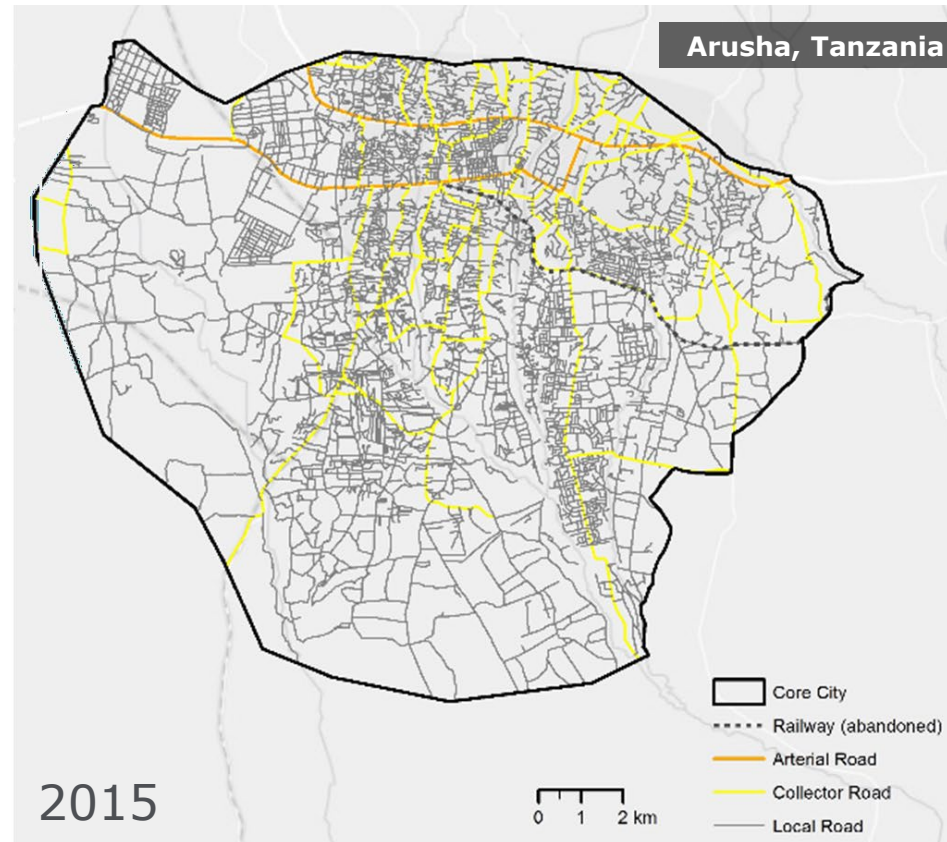
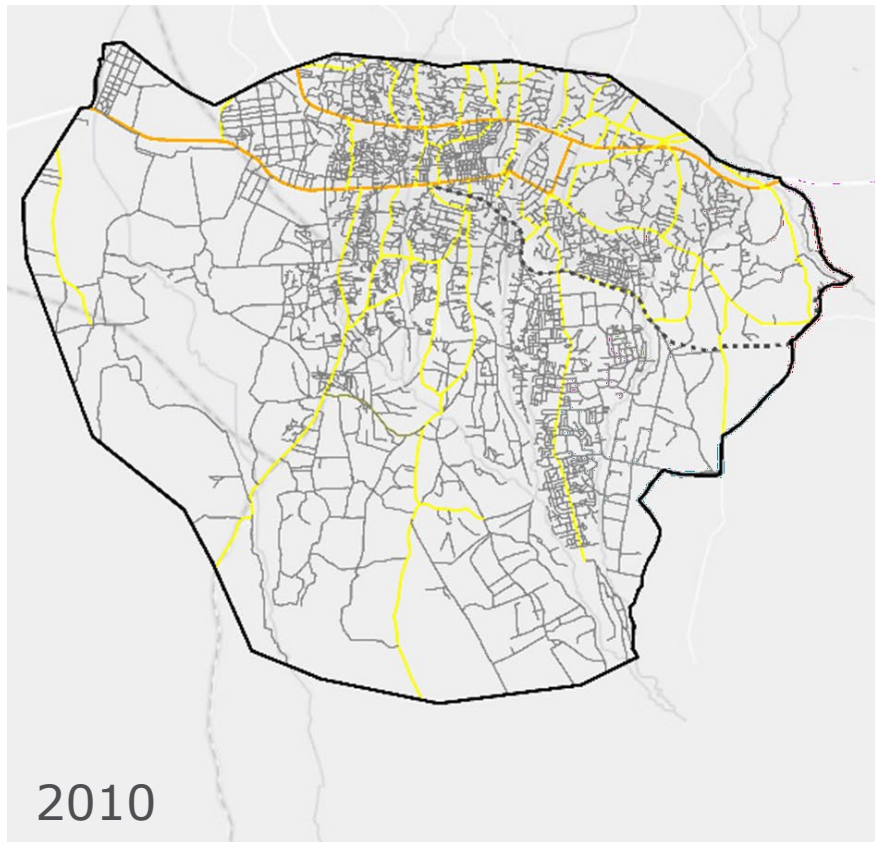
2015–2018



Land Use / Land Cover Changes

- Artificial Surface Expansion
- Agriculture development
- Change within Natural and Semi-Natural Areas

Example: Transport Network 2010–2015



Example: Urban Green Areas







Bhopal, India

2005-2017

Upper Lake



-  Non-Urban Green Area
-  Permanent Urban Green Area
-  Loss of Urban Green Area
-  New Urban Green Area

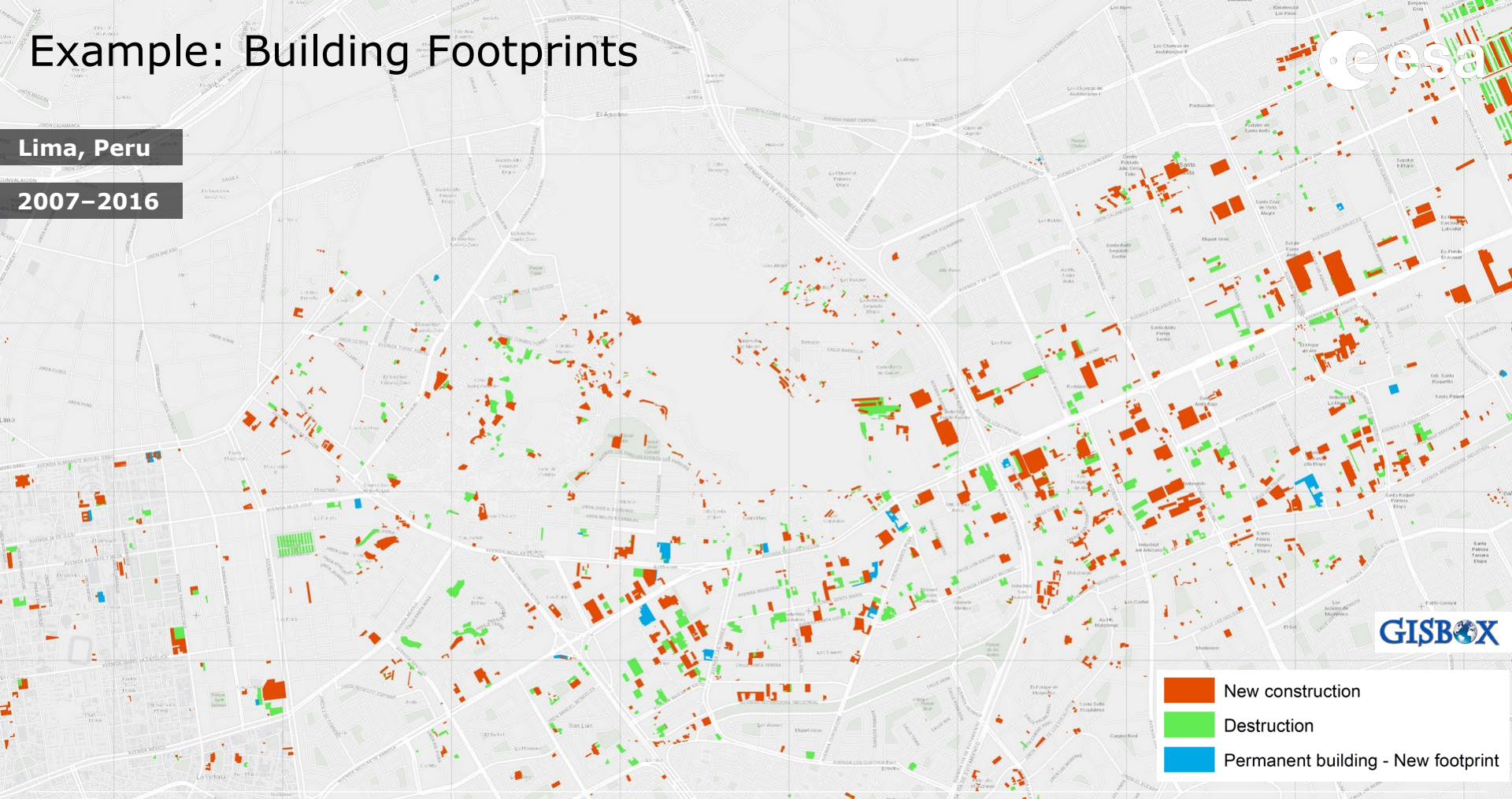


Example: Building Footprints






Lima, Peru

2007-2016



GISBOX

-  New construction
-  Destruction
-  Permanent building - New footprint



Example: Yearly Urban Expansion 1985–2015

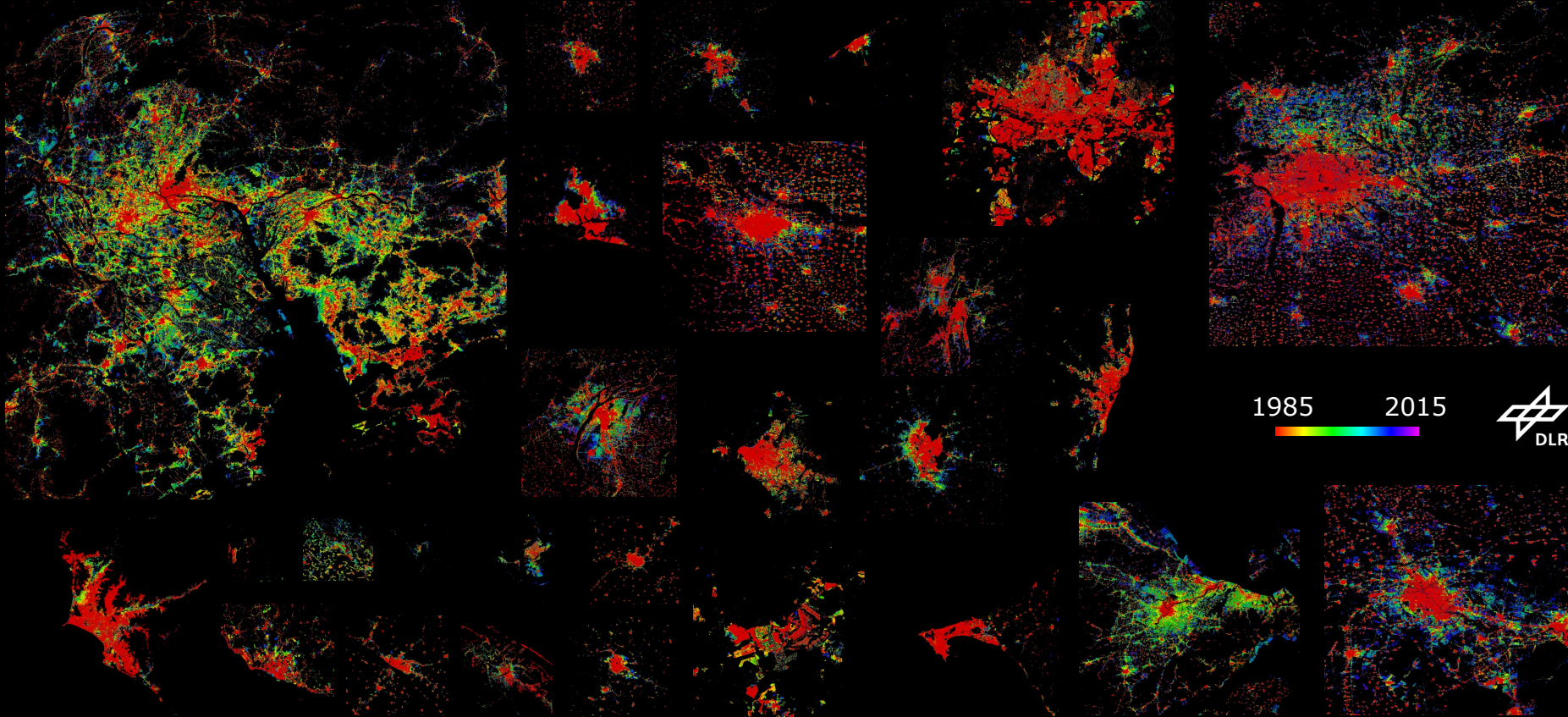


Globale Siedlungsspuren

WORLD SETTLEMENT FOOTPRINT



Example: Yearly Urban Expansion 1985-2015



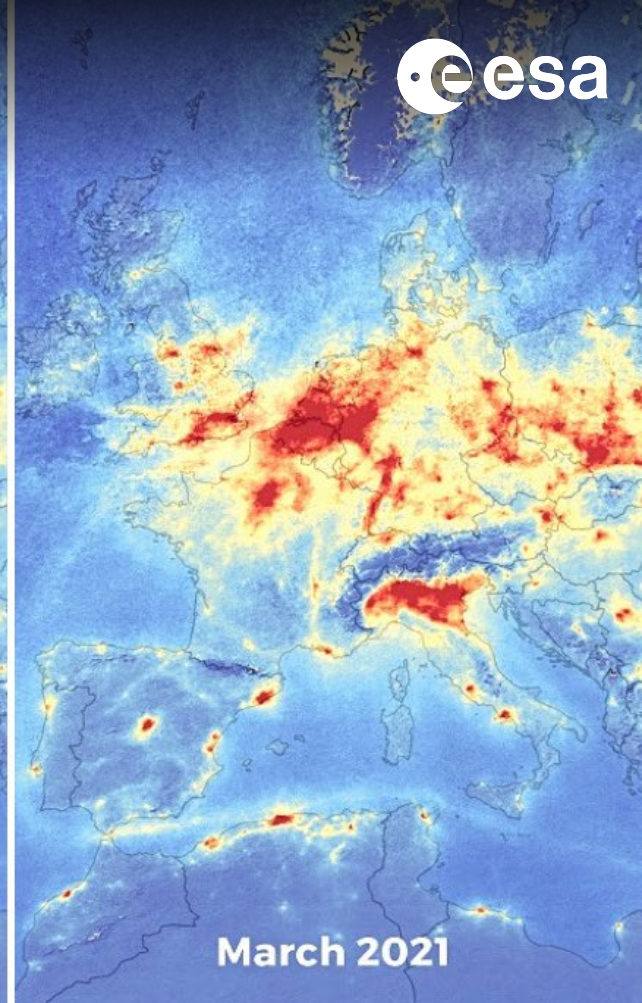
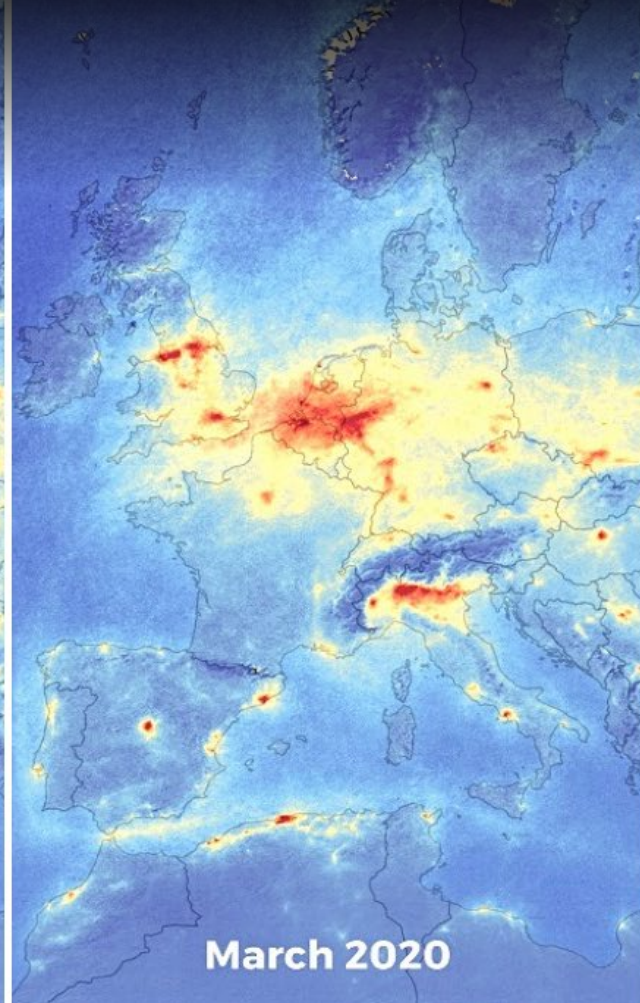
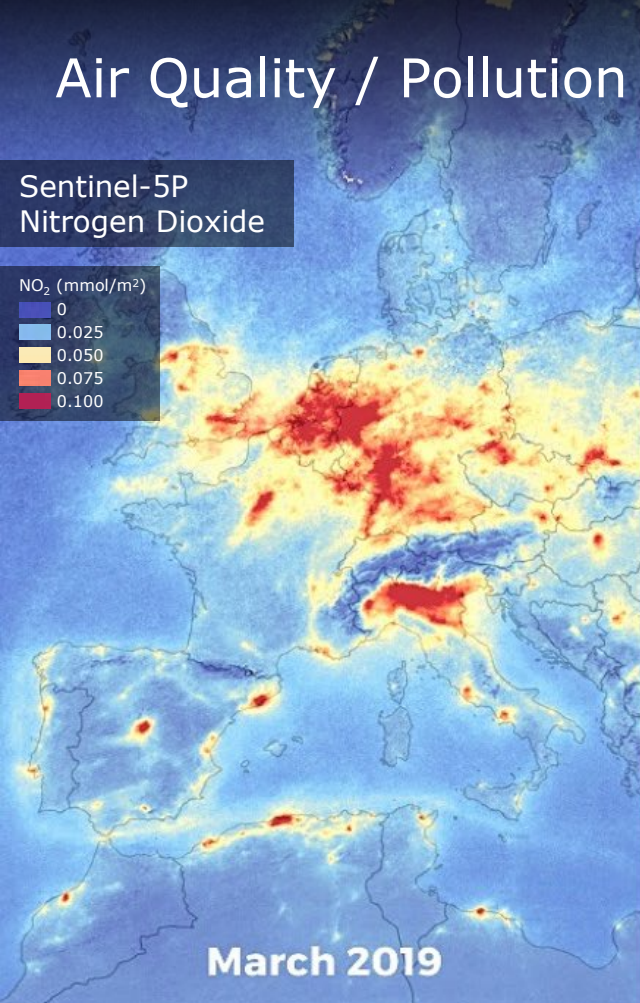
Air Quality / Pollution



Sentinel-5P
Nitrogen Dioxide

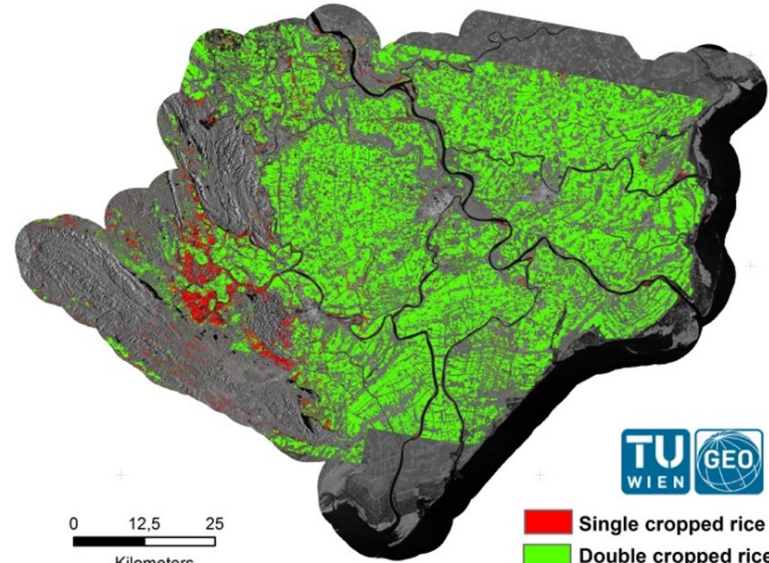
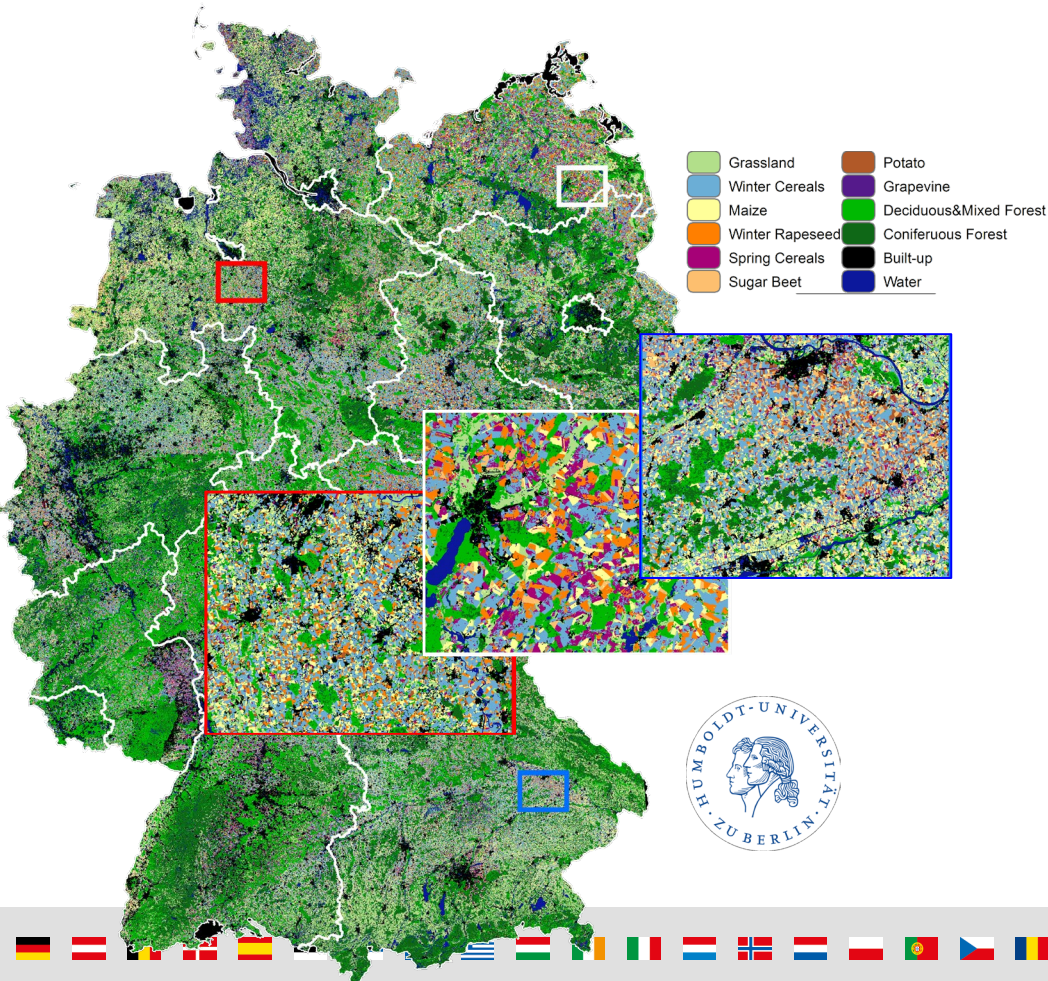
NO₂ (mmol/m²)

0
0.025
0.050
0.075
0.100



→ THE EUROPEAN SPACE AGENCY

Agriculture



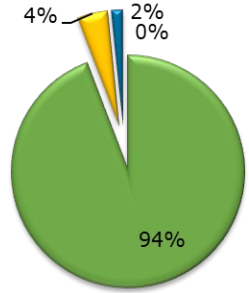
Revolutionising the EU Common Agricultural Policy (CAP): Technology Meets Policy

Crop type mapping for crop diversification monitoring – Netherlands, 2017

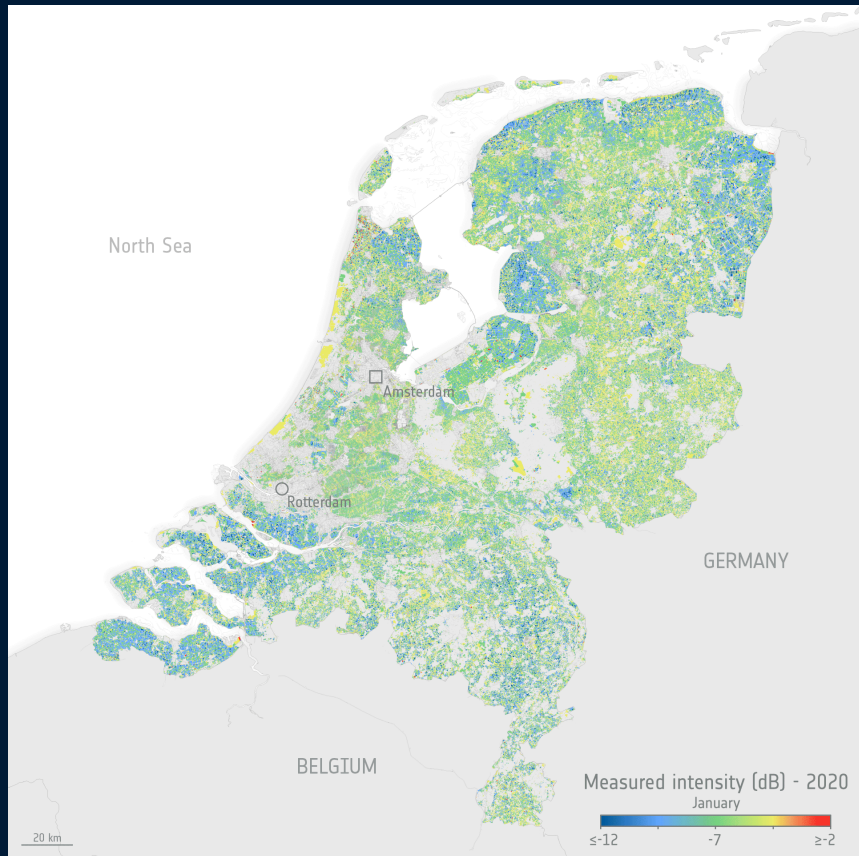
Observed crop type

Compliance indicator

- Compliant
- Expert-judgement required
- Insufficient evidence
- Non-Compliant

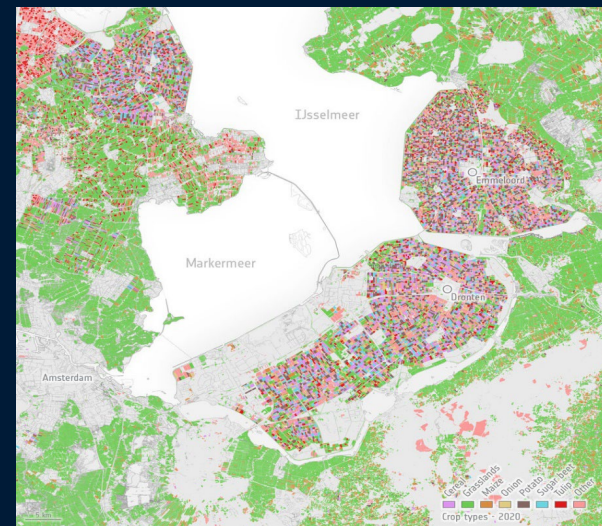


Monitoring crop health across the Netherlands



Thanks to the combination of Sentinel-1 radar and Sentinel-2 optical data and a newly developed dataset tool, called Agricultural Sandbox NL, people working in the agriculture sector, but who are not satellite data experts, can monitor the health and development of crops, right down to each crop in individual fields.

Animation of highlighting crops between January and December 2020

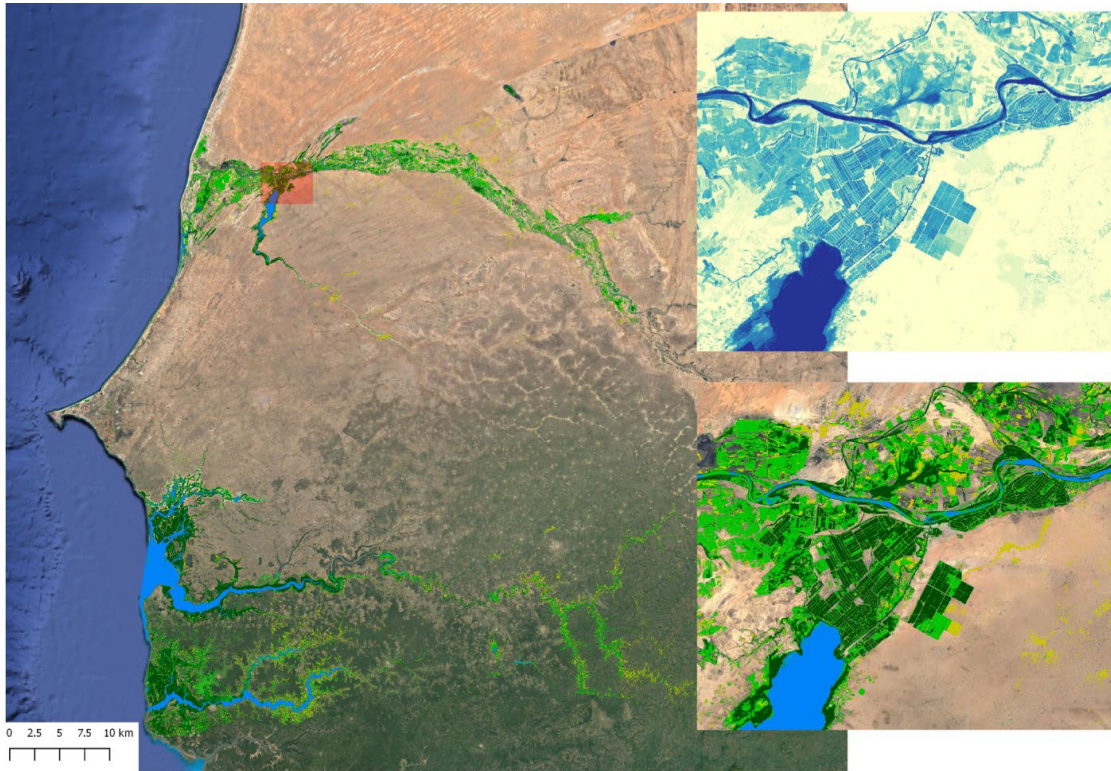


Crop type for all agricultural parcels Flevoland in the Netherlands

Ecosystems

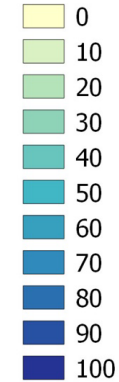
Wetlands Inventories

Senegal vegetated wetlands pre-inventory

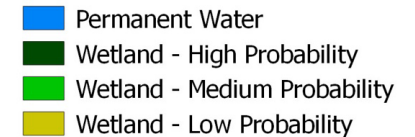


Legend

WWPI [%]



Wetland classification



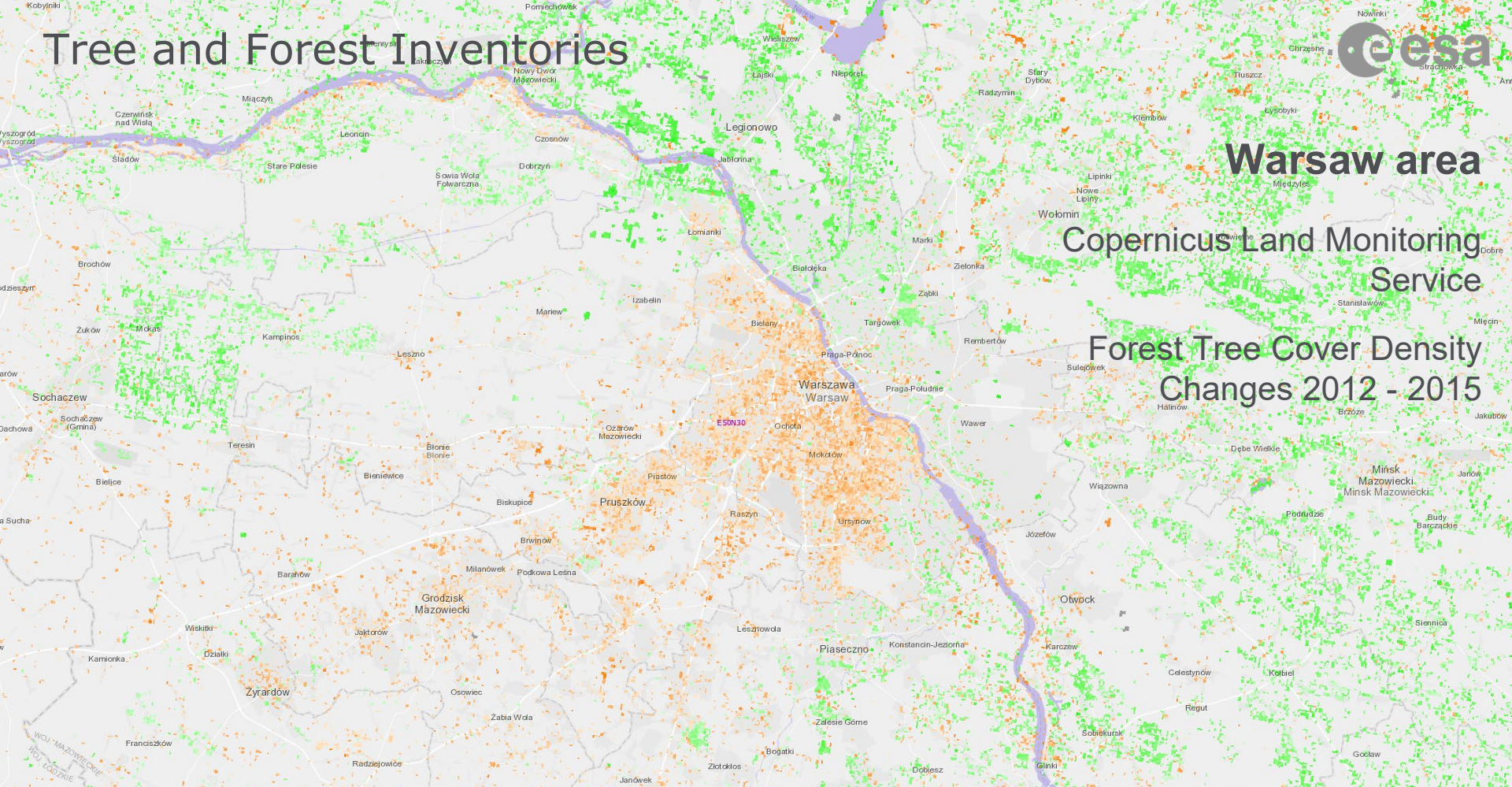
Tree and Forest Inventories



Warsaw area

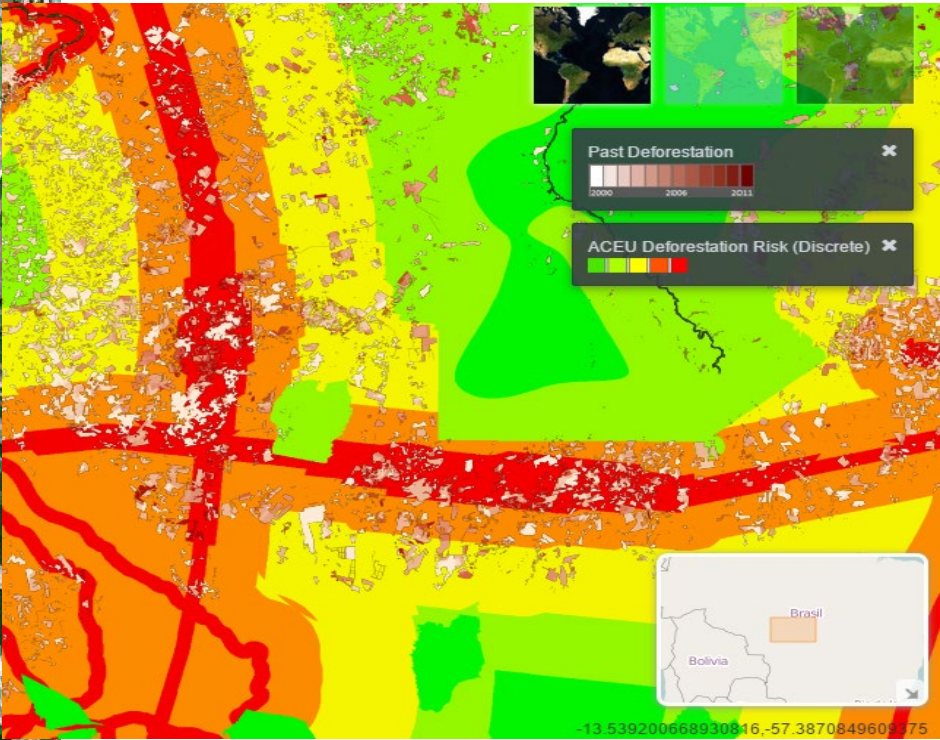
Copernicus Land Monitoring Service

Forest Tree Cover Density Changes 2012 - 2015



→ THE EUROPEAN SPACE AGENCY

Forest Ecosystem Management



Multi-Scale and Multi-Purpose Land Information Systems



Maps

LandMonitoring.Earth

5-2 monthly phenology 2016-2018 (LIC beta) ⓘ

Opacity 100%

Let's Timeseries

2017	2017	2018	2018	2018	2018	2018	2018	2018
11	12	01	02	03	04	05	06	07

⏪ ⏩

CadasterENV 5-2 Land Cover Austria 2016 ⓘ

Landcover Dynamics 2016-2018 (v1.0.2) ⓘ

Copernicus Land Monitoring

HRL Imperviousness 2006-2015 ⓘ

HRL Water and Wetness 2015 ⓘ

HRL Grassland 2015 ⓘ

HRL Forest, Tree Cover Density 2015 ⓘ

CORINE Land Cover 2012 ⓘ

Global Land Cover

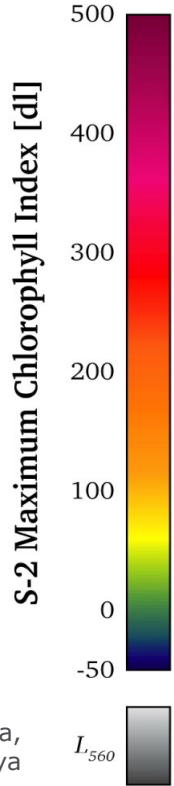
CCI Land Cover 2015 ⓘ

Basemaps

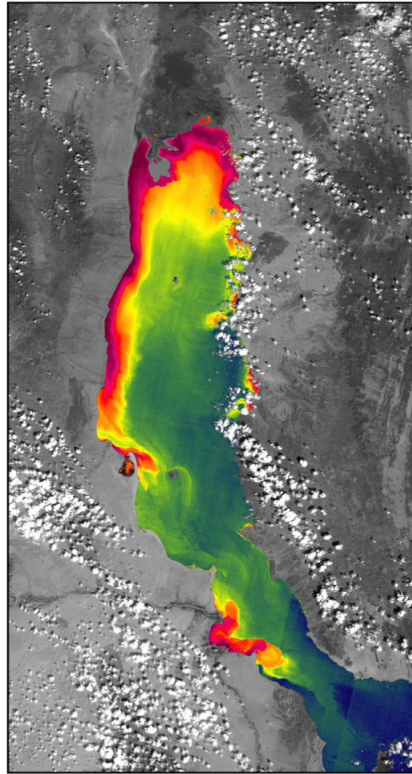


Water Resources Management

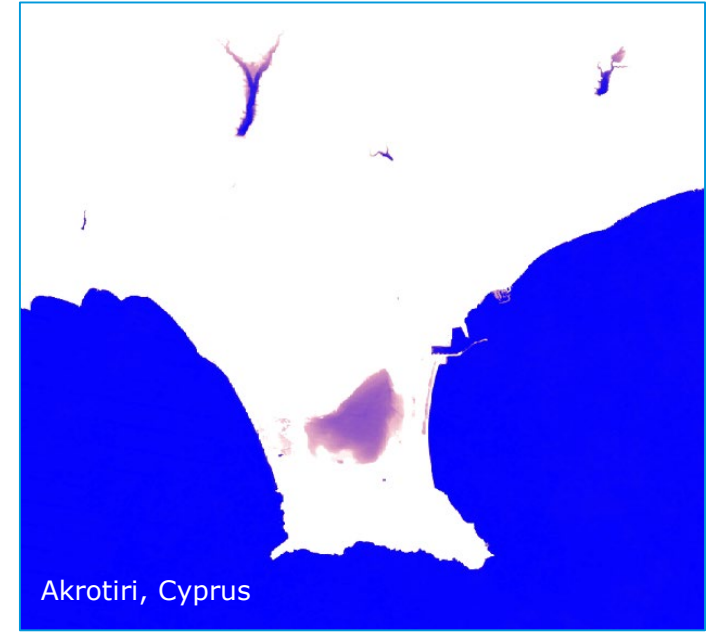
Monitoring of Water Quality and Water Extent



Lake Turkana, Kenya



2015-12-09



Akrotiri, Cyprus

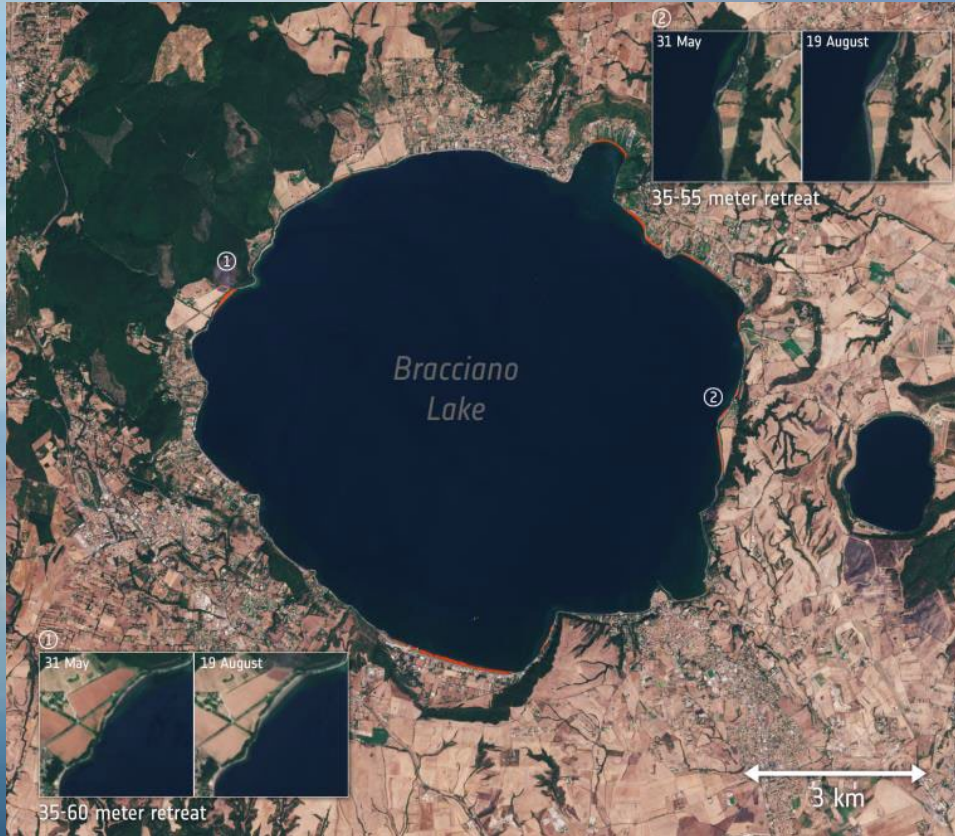


Water Occurrence (1984-2020)



Global Surface Water Explorer

Water Level Changes



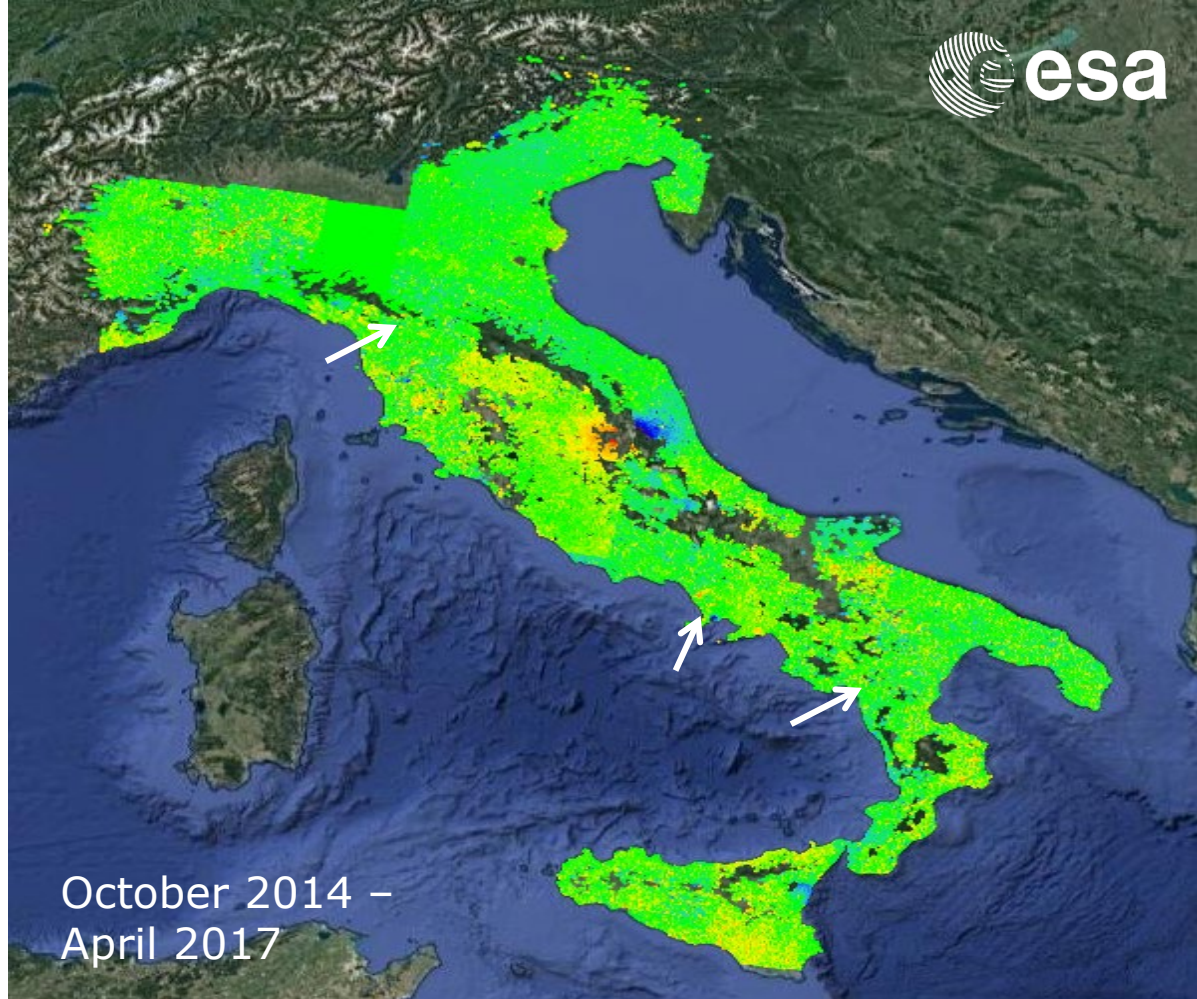
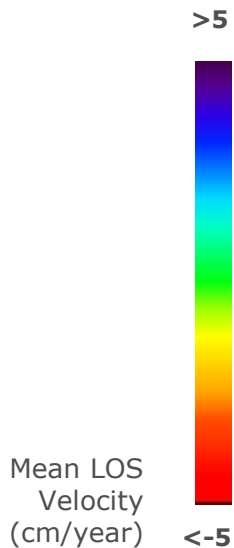
Lake Bracciano, Italy
Summer 2017 Drought

Based on Sentinel-2

Disaster Risk Management

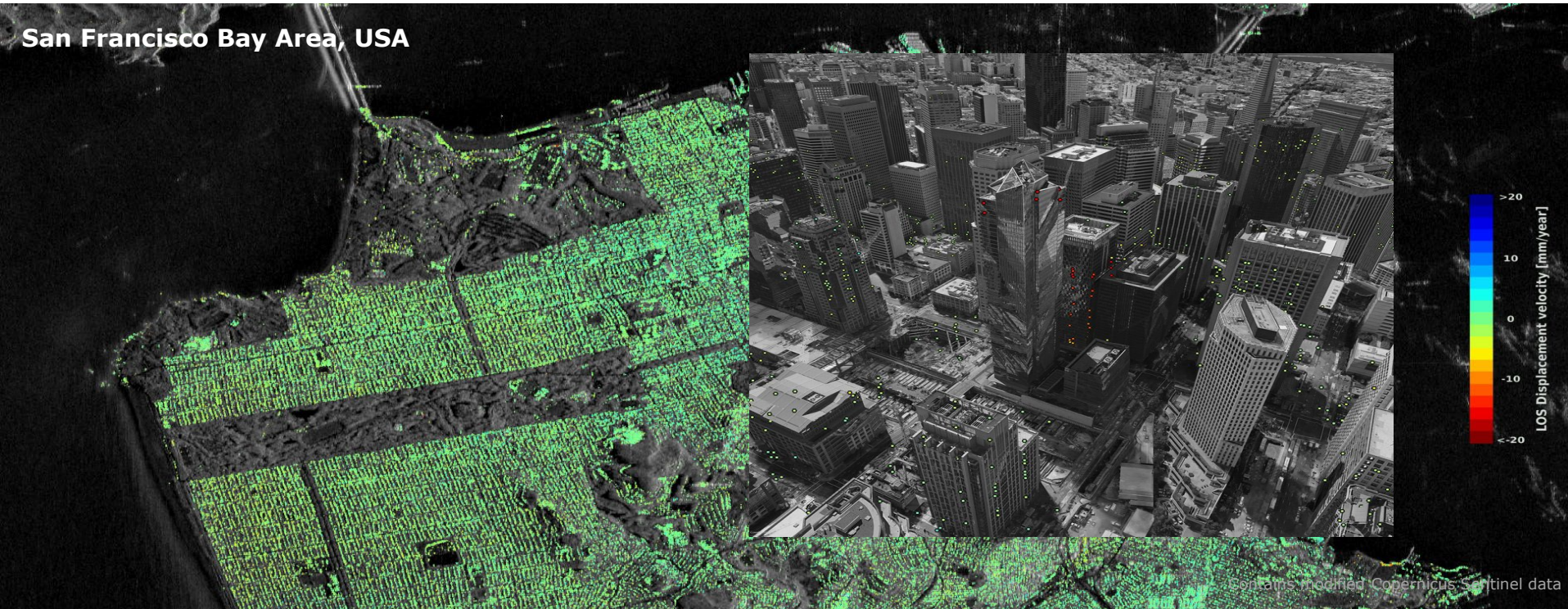
Country-Level Land Motion Products

Towards national- and regional-scale disaster risk management information with Interferometric SAR



Subsidence Risk at Building Level

San Francisco Bay Area, USA

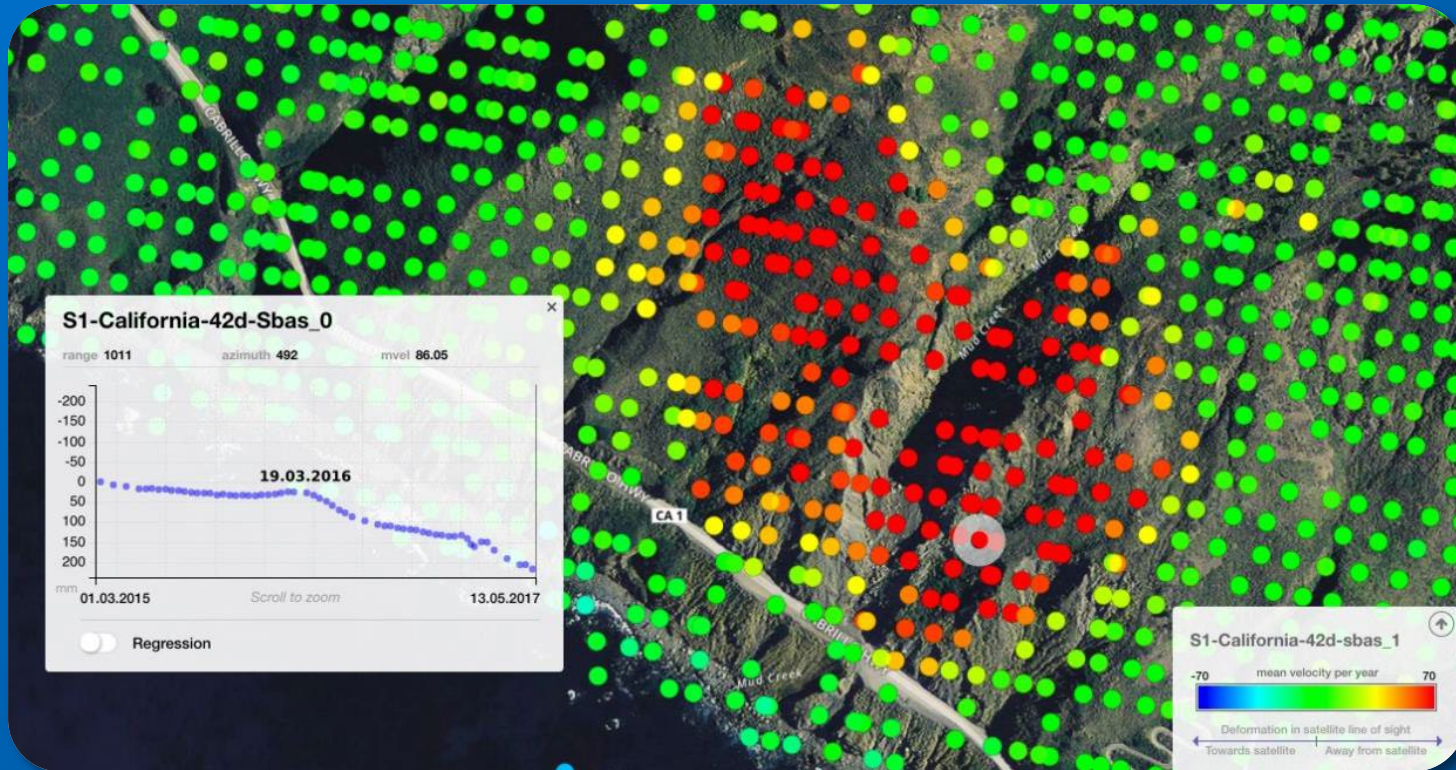


Contains modified Copernicus Sentinel data

<http://insarap.org>



Landslides



Highway 1
California, USA

Based on Sentinel-1 data
(2015–17), processed by
Norut

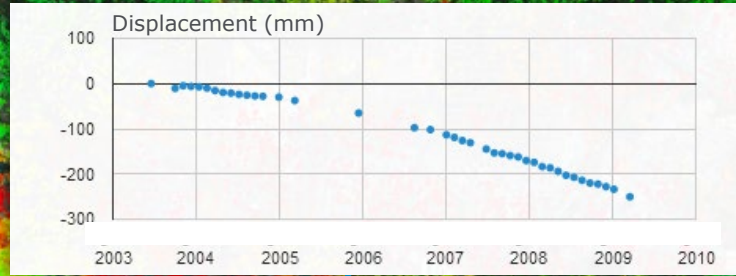
Land Motion Due To Freshwater Extraction

Permanent Scatterer Interferometry: a radar technique able to measure millimetre-range terrain deformations over time. Subsidence due to water extraction can be closely monitored in space and time.

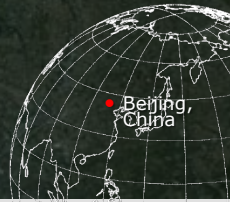
"The 800 water extraction wells within the fifth ring road areas in Beijing will be closed this year [2012] as part of an effort to conserve underground water."

Source: thewatchers.adorraeli.com

Beijing, China



Data: ERS, Envisat.
Processing: TRE.

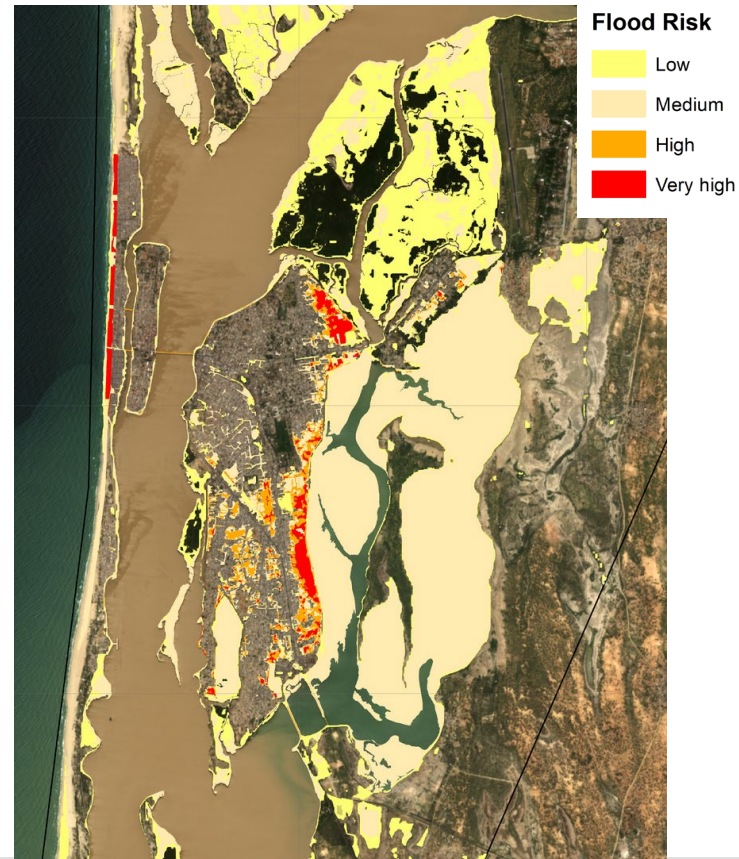
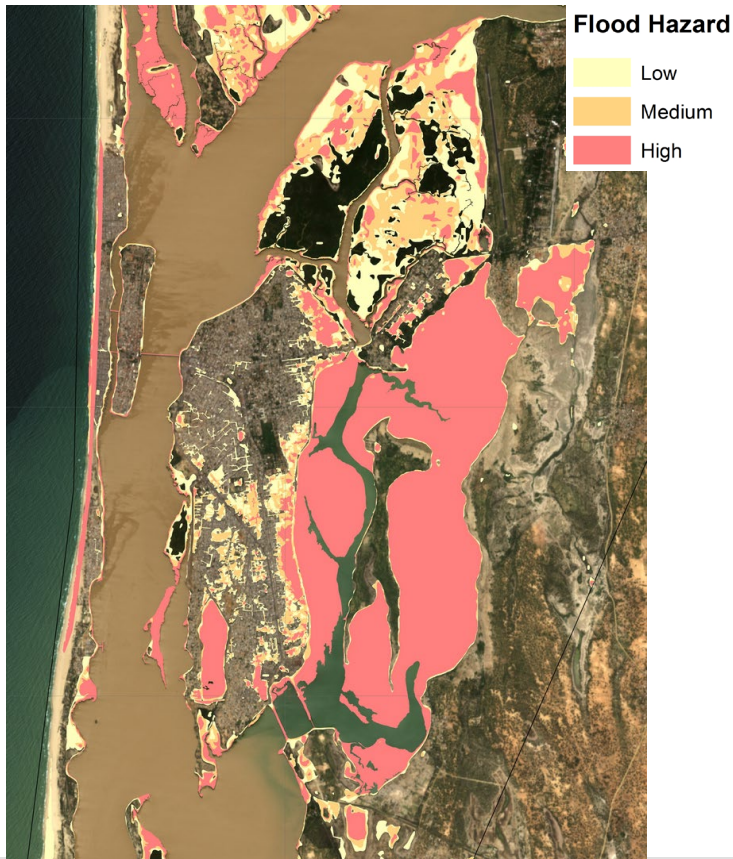


Flood Mapping



Example: Flood Hazard and Flood Risk

Saint-Louis, Senegal



Flood Risk

Requires:

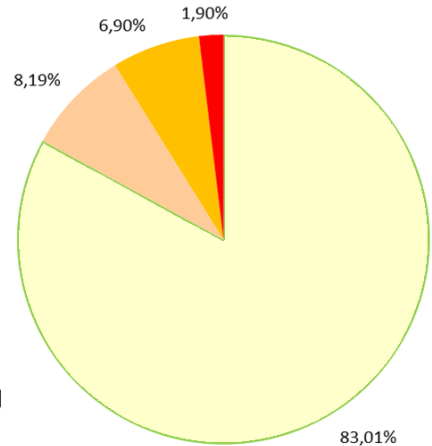
- precise Digital Terrain Model
- adequate EO archive data coverage



Semarang, Indonesia

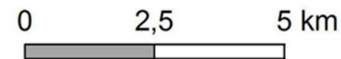


Residential and Public Urban Fabric in Flood Risk Zones



Flood Risk

- Low Risk
- Medium Risk
- High Risk
- Very High Risk



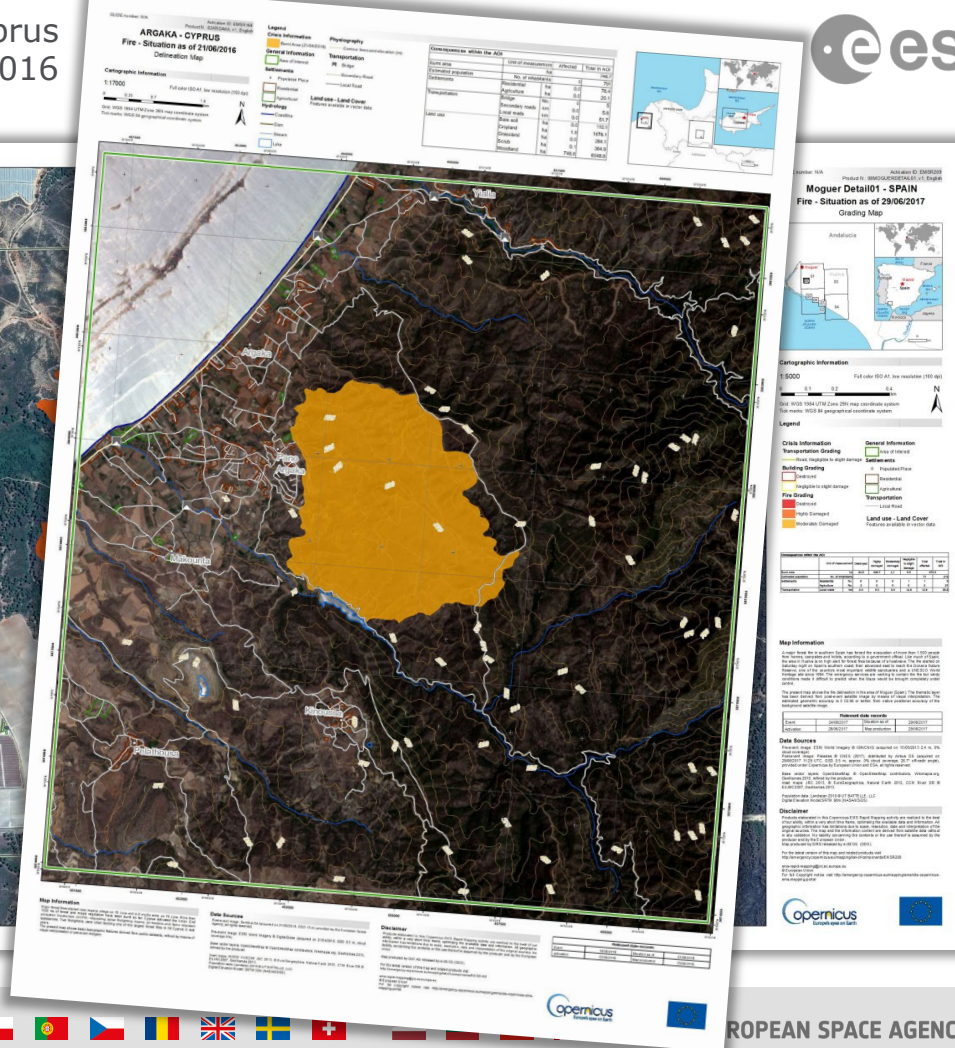
Wildfires, Fire Damage

Argaka, Cyprus
21 June 2016



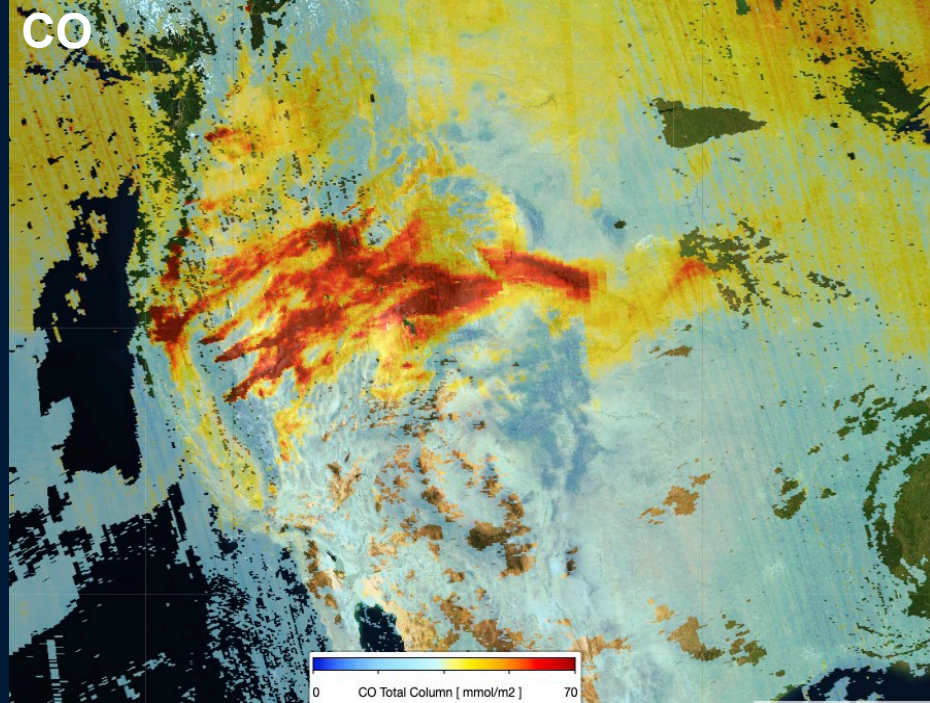
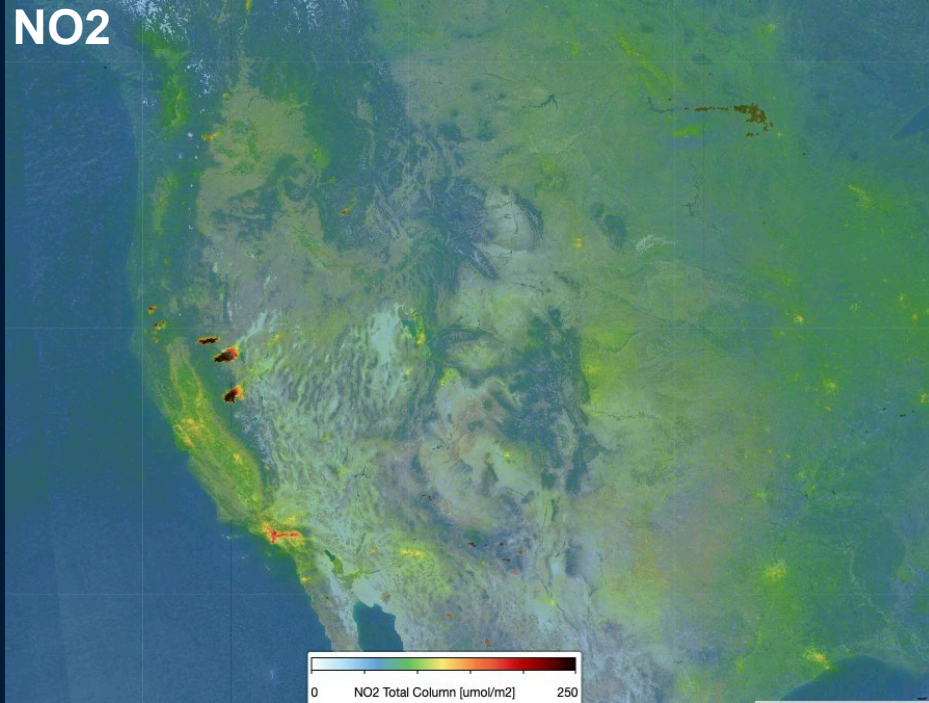
Moguer, Spain
29 June 2017

Copernicus Emergency
Management Service
Rapid Mapping

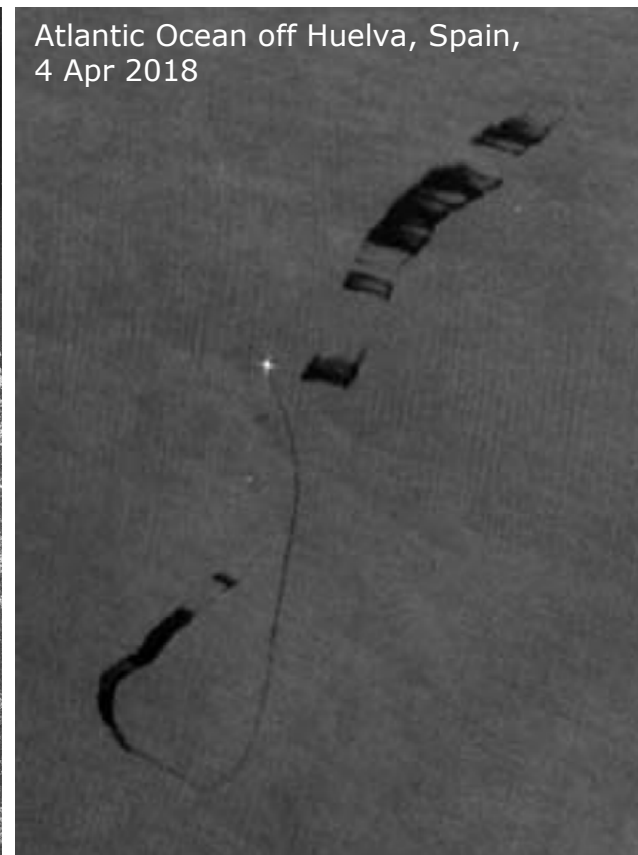
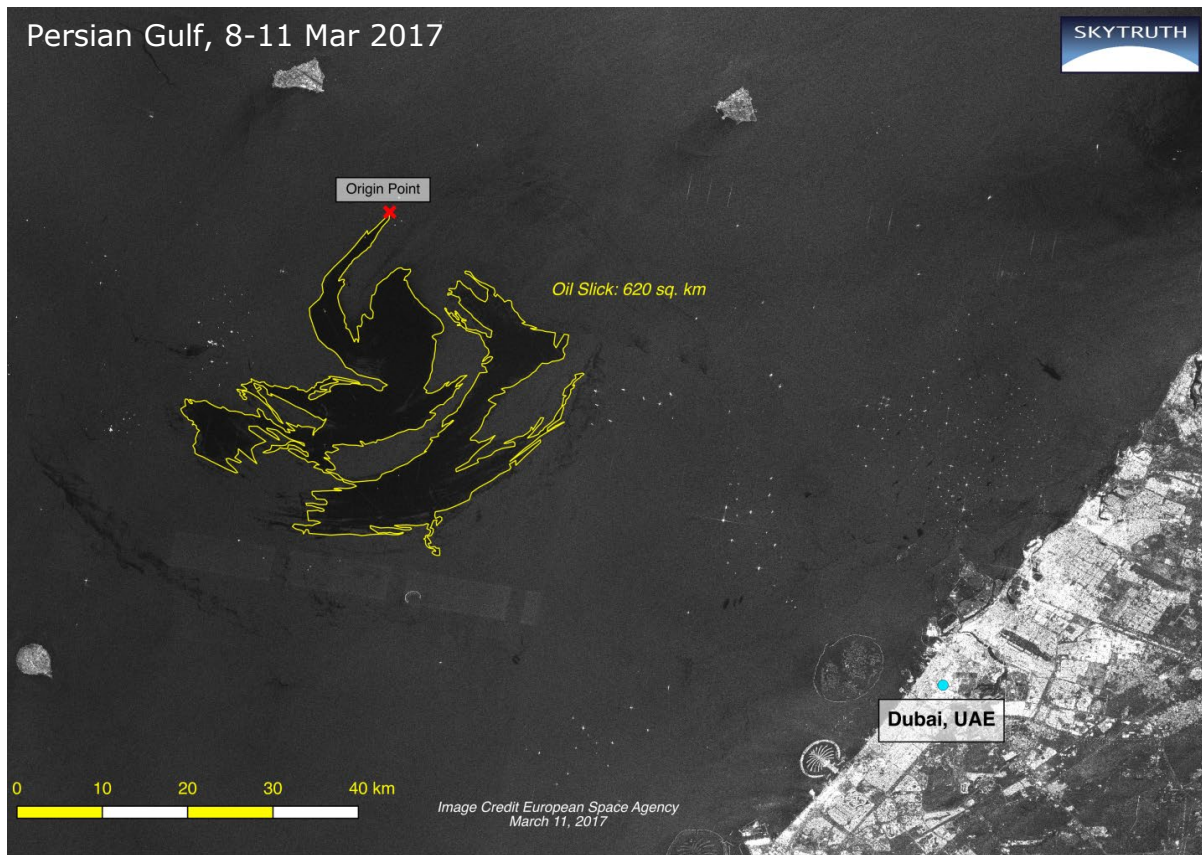


Sentinel-5p Applications during wildfires

Wildfire emission measurements over Western USA (30 Aug 2021)



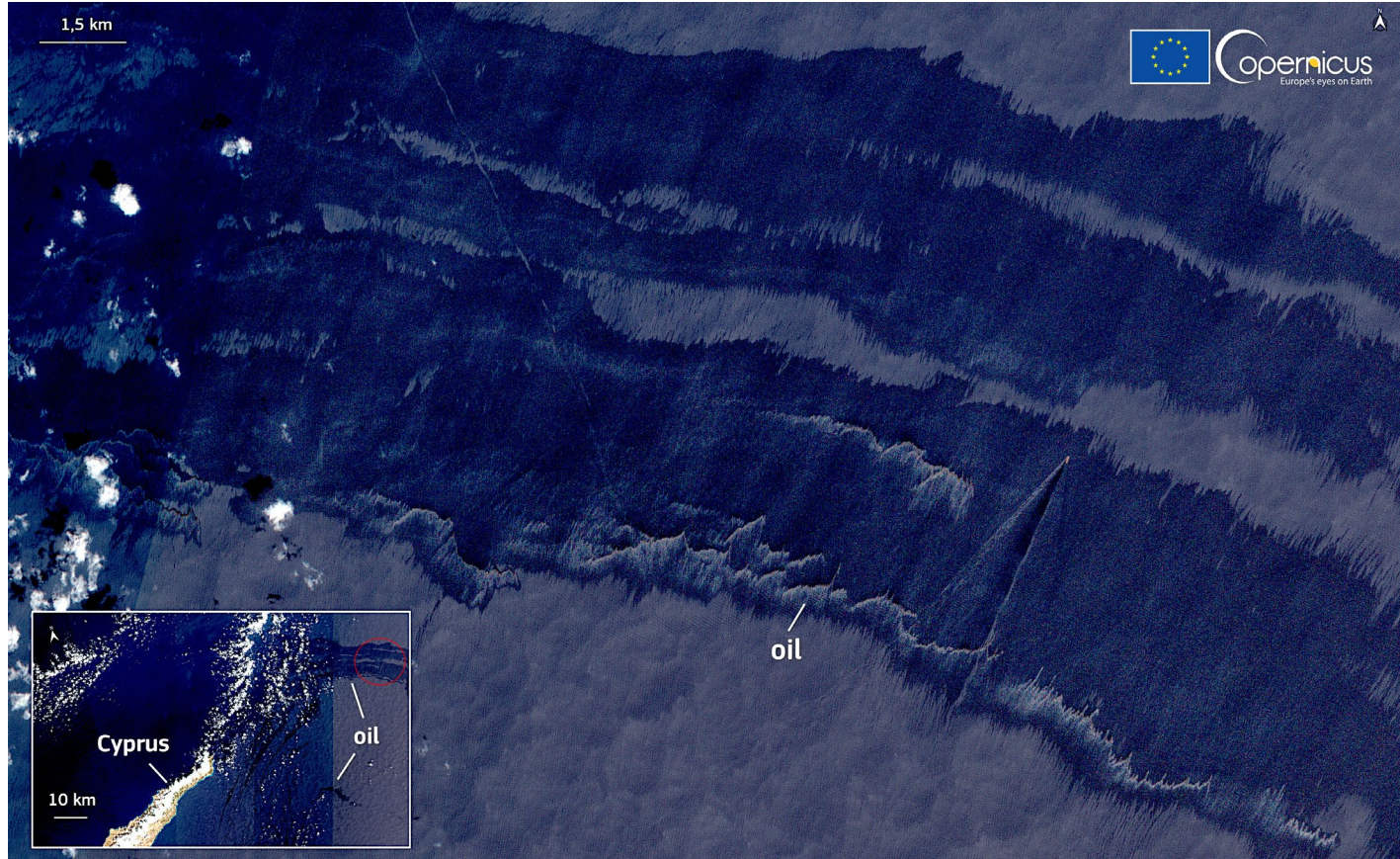
Oil Spill Detection and Monitoring



Oil Spill Detection and Monitoring

Off Karpas
Peninsula Cyprus
1 Sep 2021

Data from Copernicus satellite missions (such as Sentinel-2 here) as well as models and forecasts (currents, temperature, salinity etc.) from the Copernicus Marine Environment Monitoring Service are used to predict oil dispersion in case of accidents

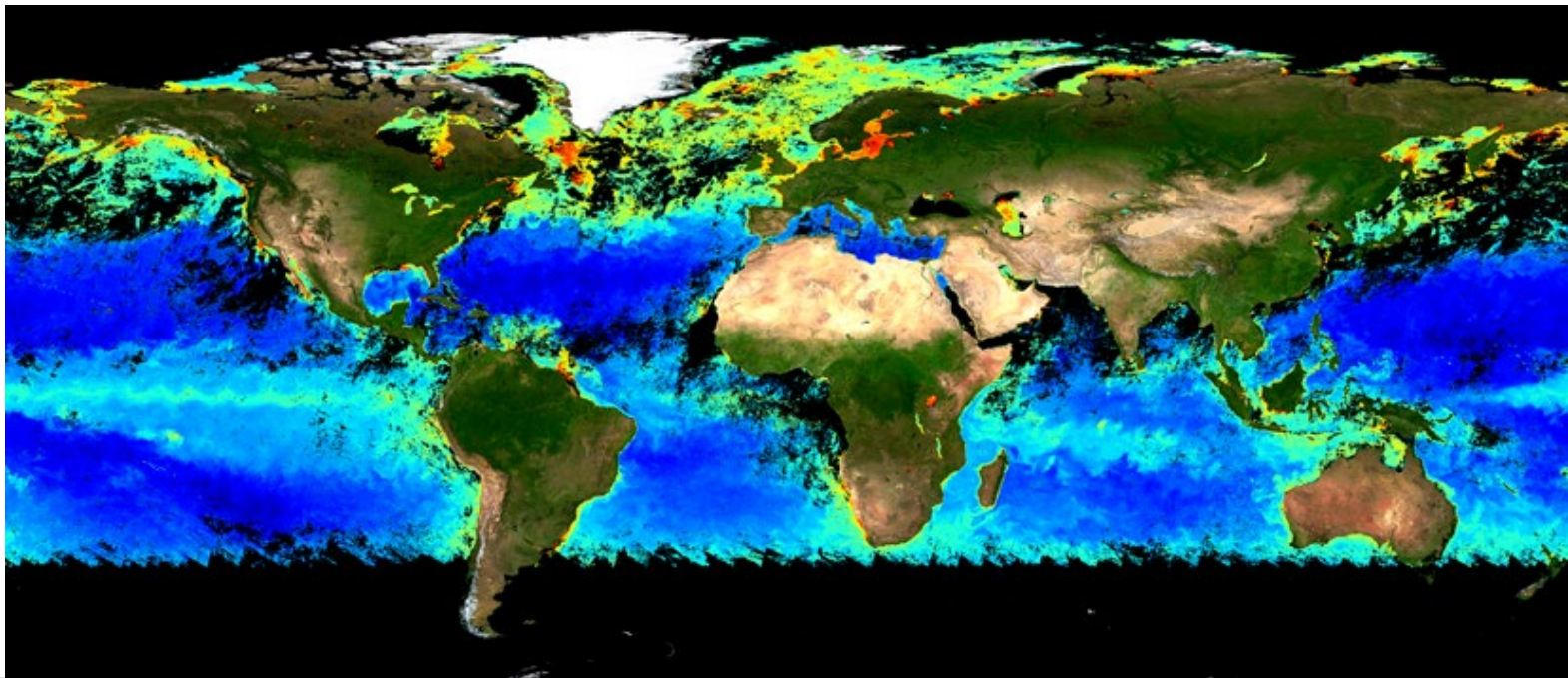


Marine and Coastal



Global Water Quality

Sentinel-3 OLCI Level 2 products were released in July 2017 simultaneously by Eumetsat (for ocean) and ESA (for land)



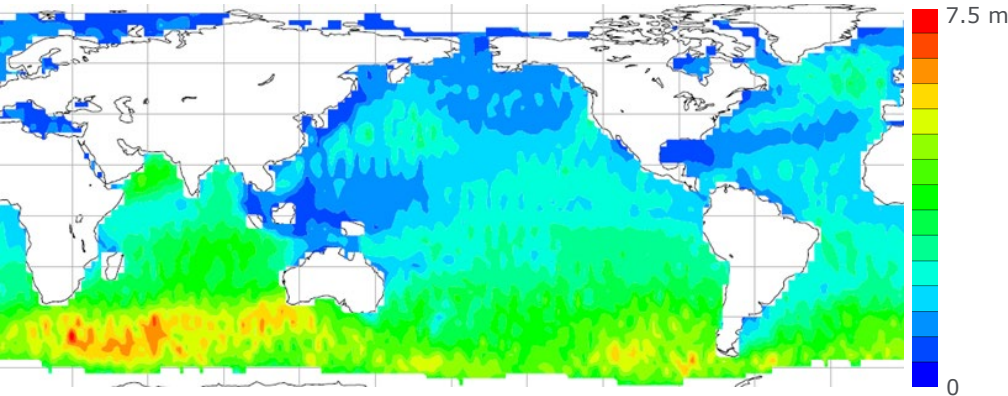
2017 June 14-27

Sentinel-3 OLCI Level-2
Algal pigment concentration
(mg/m³)



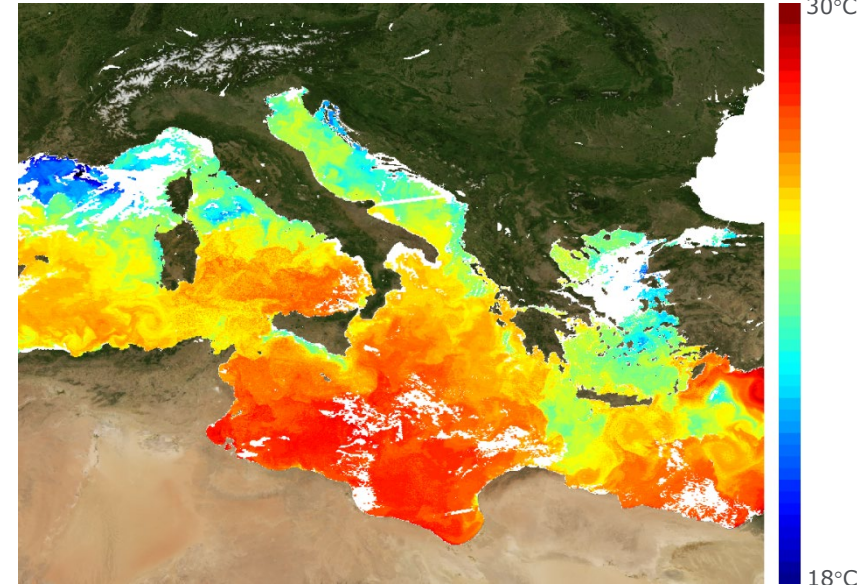


Significant Wave Height, 2017 July



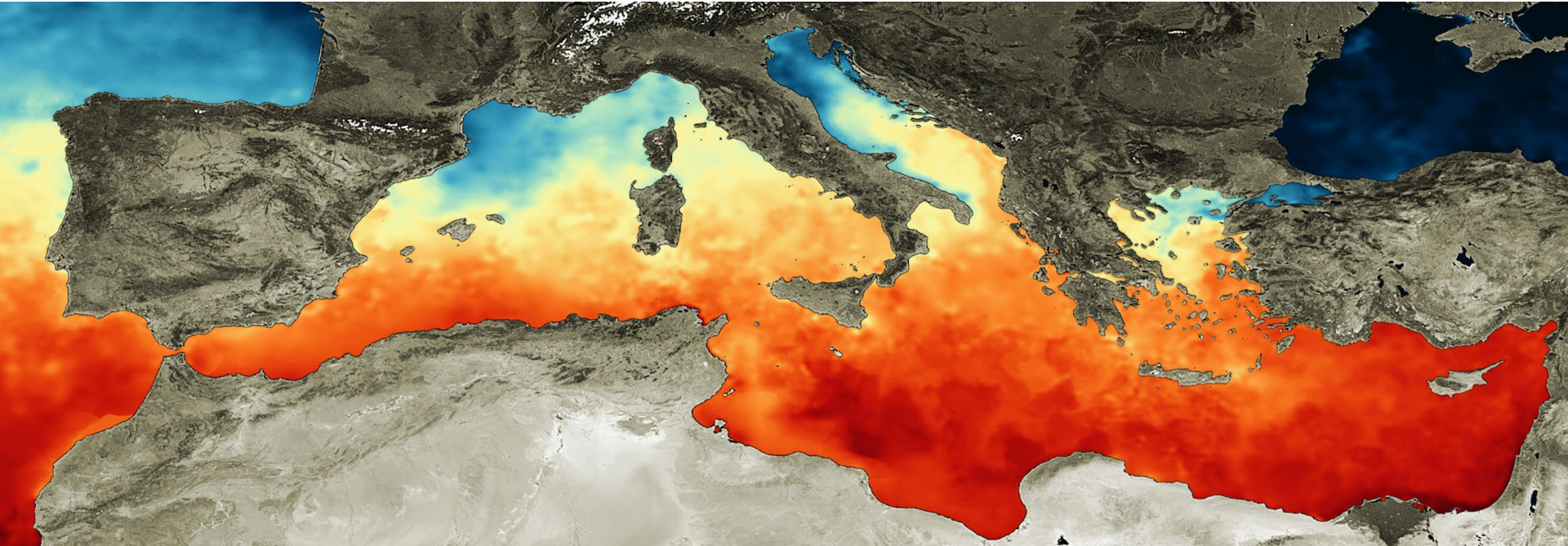
Since July 2017, the Copernicus Marine Environment Monitoring Service (CMEMS) provides a **real-time global wave product** based on satellite altimeter data (**Sentinel-3A** and Jason-3). After assimilation into the numerical real-time models, it allows CMEMS to provide wave forecasts with better accuracy.

Sea Surface Temperature, 2017 Sep 6



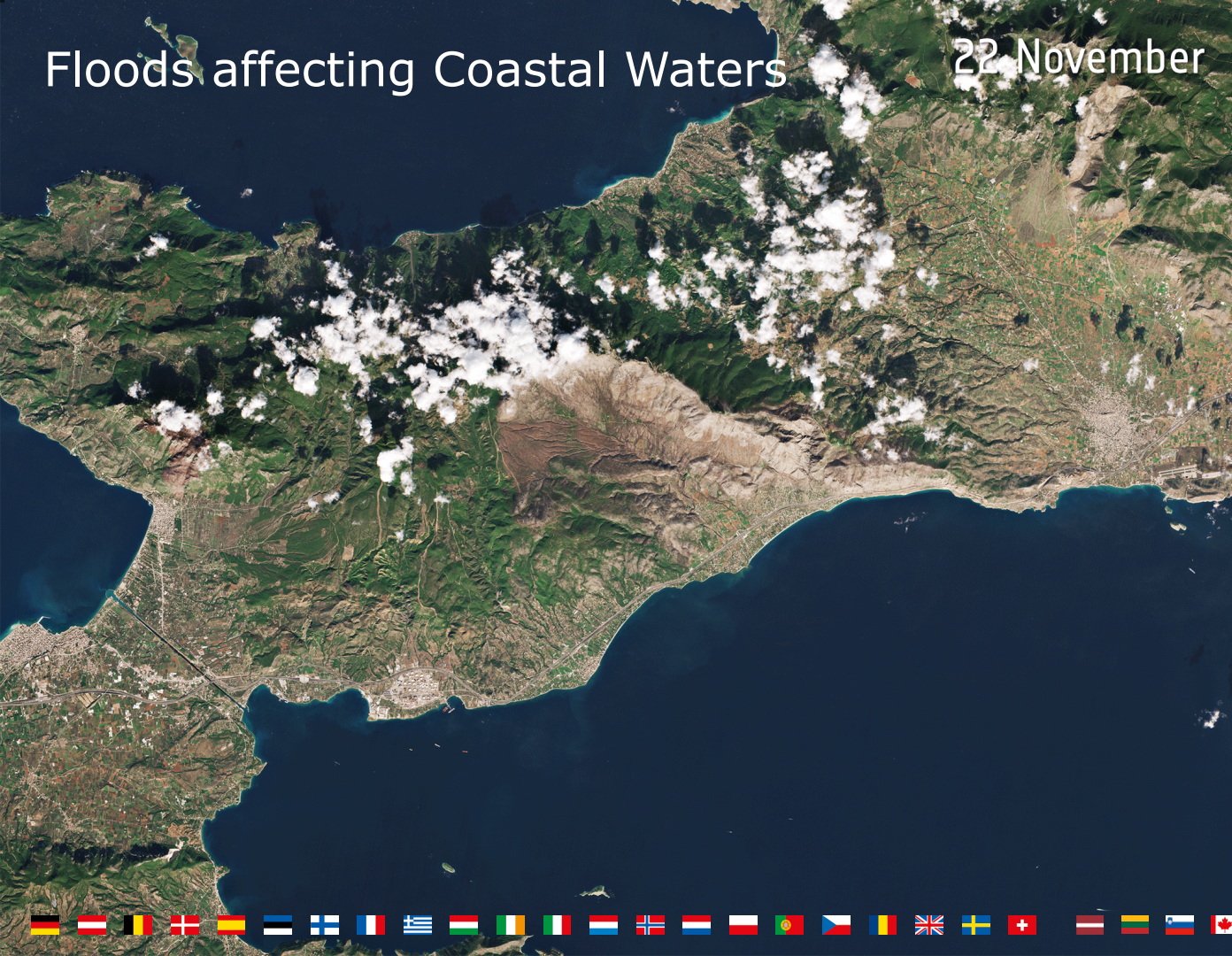
CMEMS also provides daily Mediterranean Sea surface temperature consisting of **merged multisensor data** to which **Sentinel-3A SLSTR** contributes.

Sea Surface Temperature



Floods affecting Coastal Waters

22 November

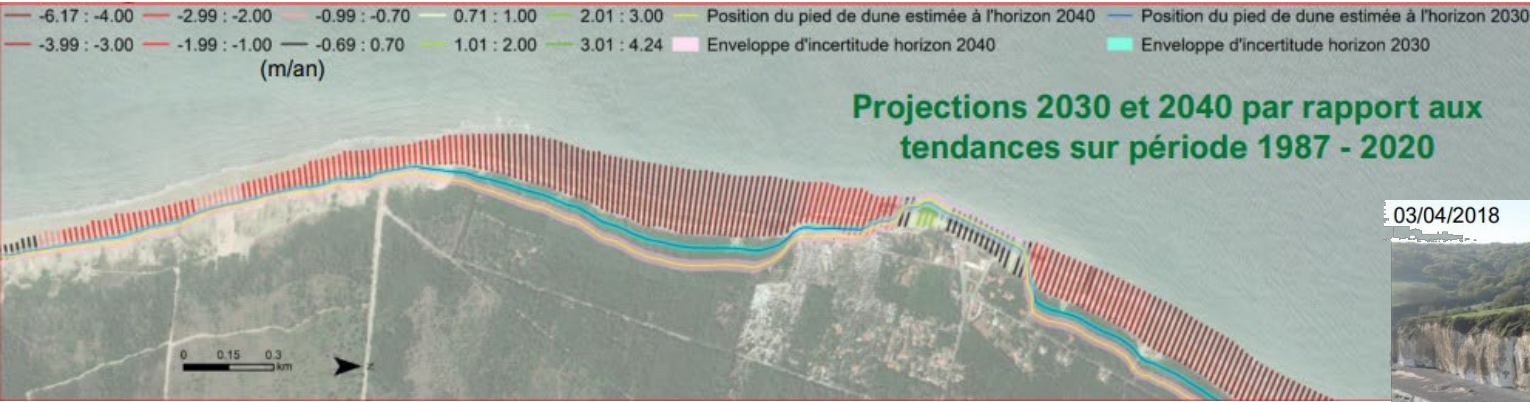


Attica, Greece, before and after floods, seen by Sentinel-2

22 and 25 November 2019



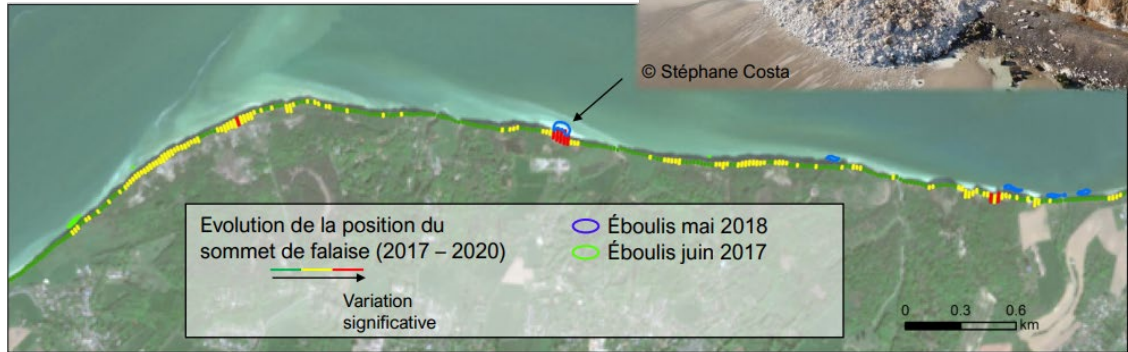
Coastal Charting and Erosion Monitoring



03/04/2018



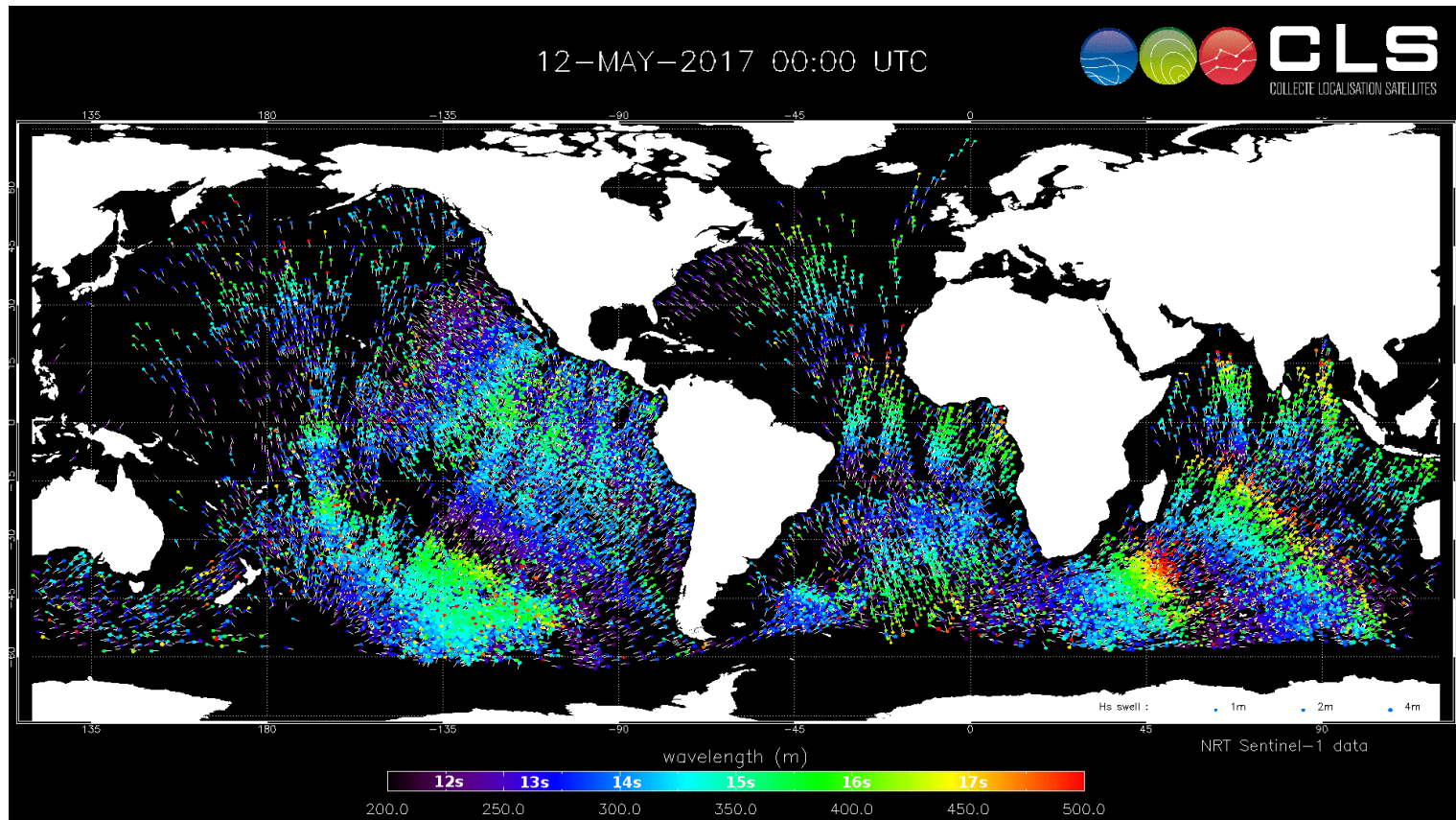
Monitoring of shoreline indicators and coastal erosion and accretion estimation.

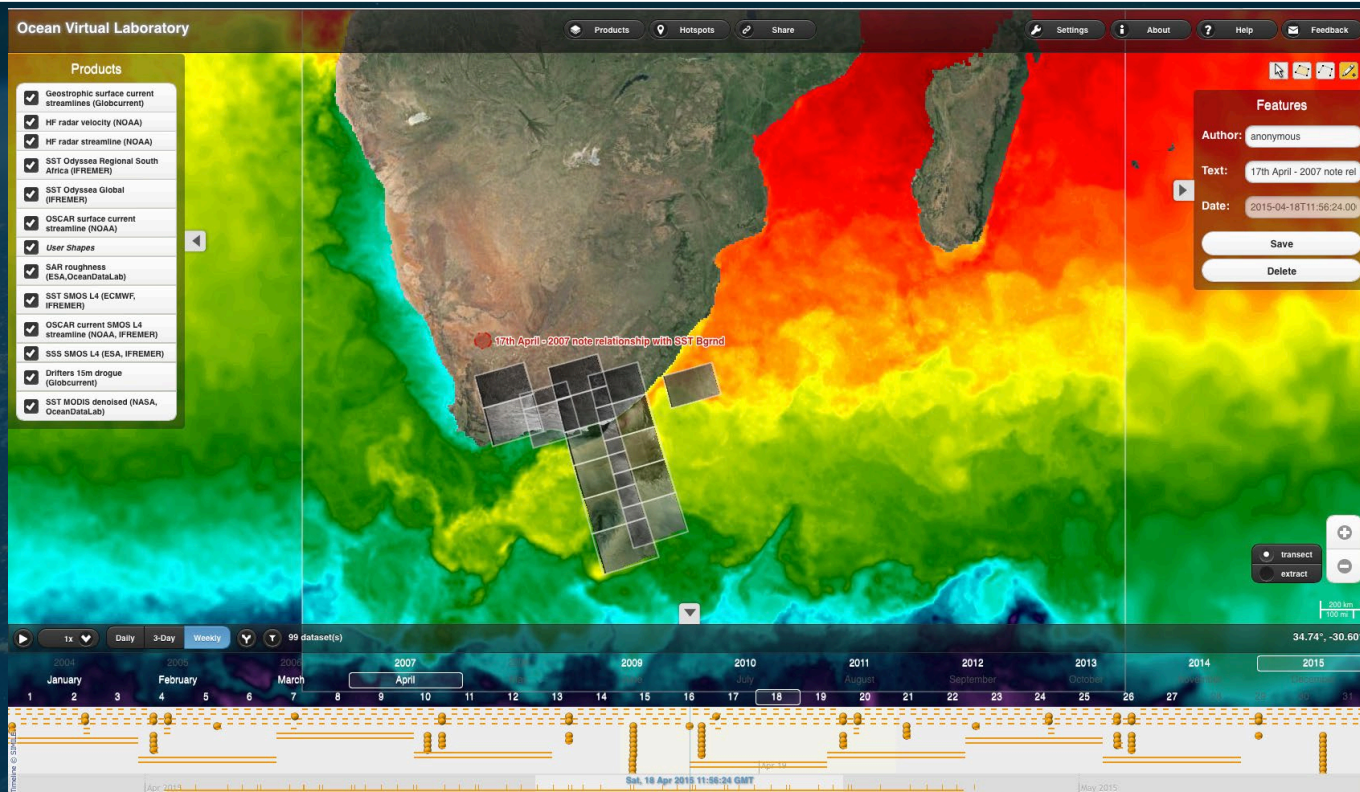


Global Near-Real Time Swell Tracking



Sentinel-1A and
Sentinel-1B
Wave Mode over
10 days





<https://ovl.oceandatalab.com>

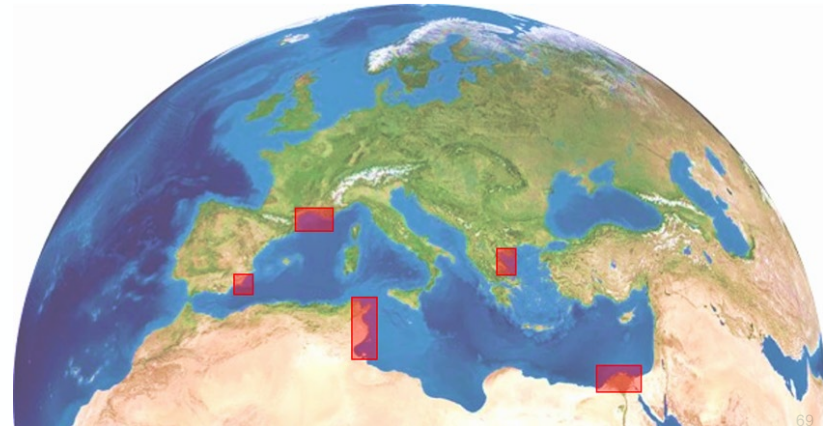
- Total Suspended Matter (TSM)
- Turbidity
- Chl-a Concentration
- Secchi Depth
- Colored Dissolved Organic Matter (CDOM)
- Fecal bacterial contamination indicators
- Eutrophication indicators
- Harmful Algal Blooms
- Global environmental anomaly detection
- River Plume Monitoring

Initial pilot areas:

- Bay of Marseille and French Mediterranean coast
- Gulf of Thermaikos, Thessaloniki
- Mar Menor and surrounding area
- Nile Delta
- Gulf of Tunis, Gulf of Hammamet, Gulf of Gabès



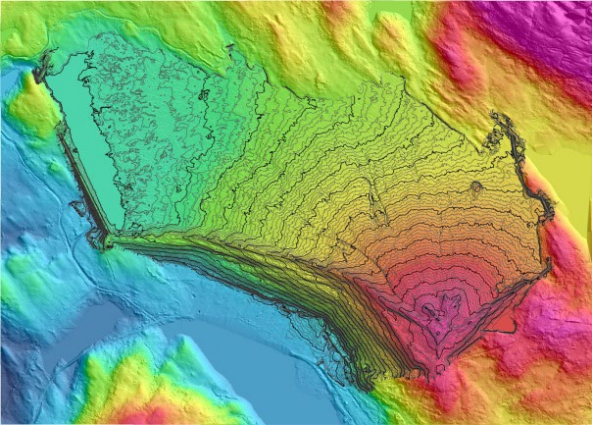
Maps of bacterial loads predicted by Marseille HR bacterial water quality model following a heavy rainfall event © SUEZ



Energy and Raw Materials



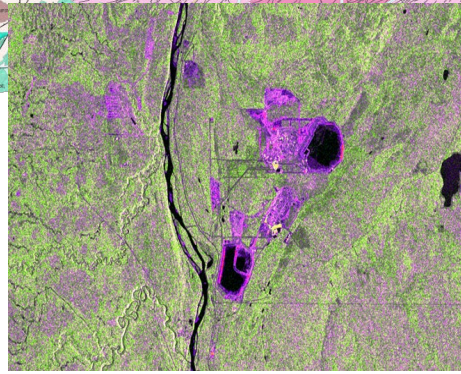
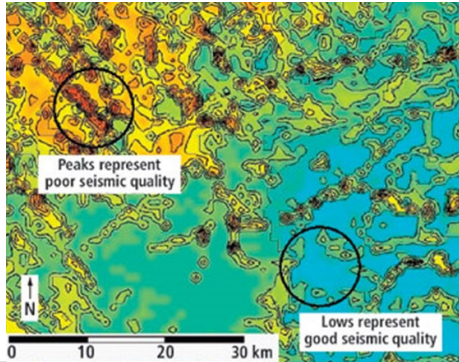
Geological Mapping, Extractives Management



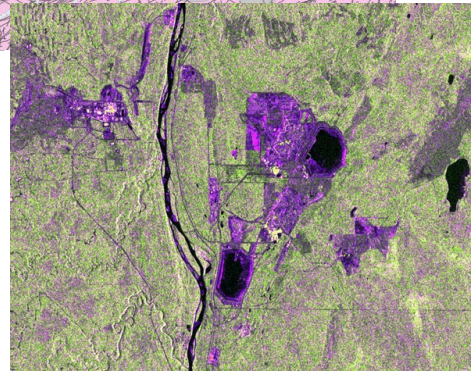
Tailings DEM



Geological map



2005



2006

- ICEYE: towards a constellation of 18 agile X-band SAR microsatellites with Daily Coherent Ground Track Repeat



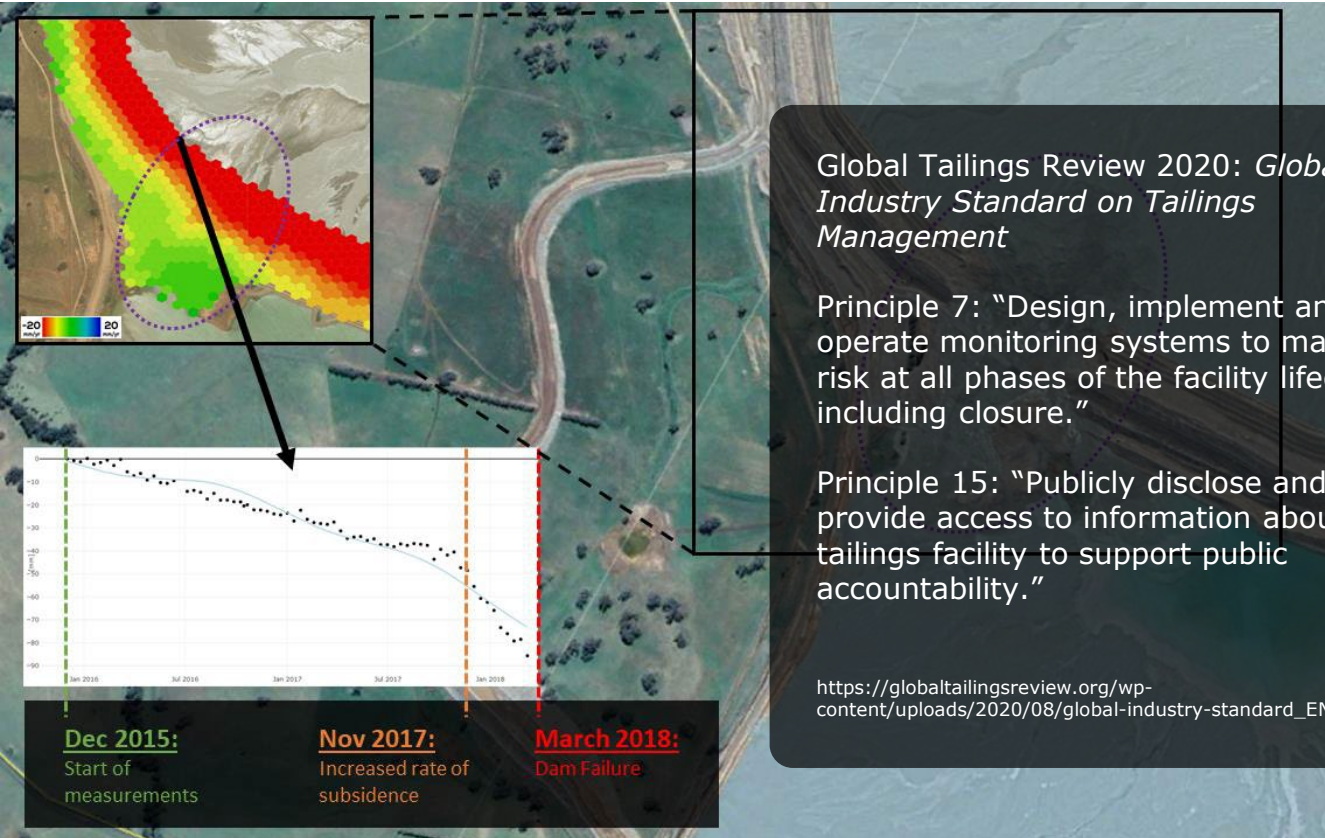
Time lapsed SAR images 2021 March 6–31 showing the movements of oil tank floating roofs and vessel traffic.



Time lapsed SAR images 2021 April–May showing lava accumulation dynamics.

Tailings Dam Stability Using Radar Interferometry

Cadia Hill gold/copper mine, Australia



Global Tailings Review 2020: *Global Industry Standard on Tailings Management*

Principle 7: "Design, implement and operate monitoring systems to manage risk at all phases of the facility lifecycle, including closure."

Principle 15: "Publicly disclose and provide access to information about the tailings facility to support public accountability."

https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard_EN.pdf

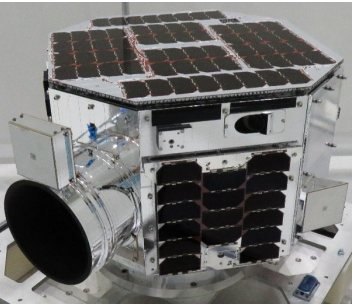
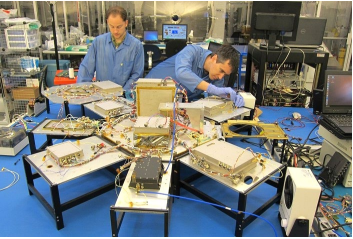


Accelerated surface deformation in the months preceding the embankment failure

Monitoring Activity Using Satellite Video



NEMO-HD: the first Slovenian microsatellite



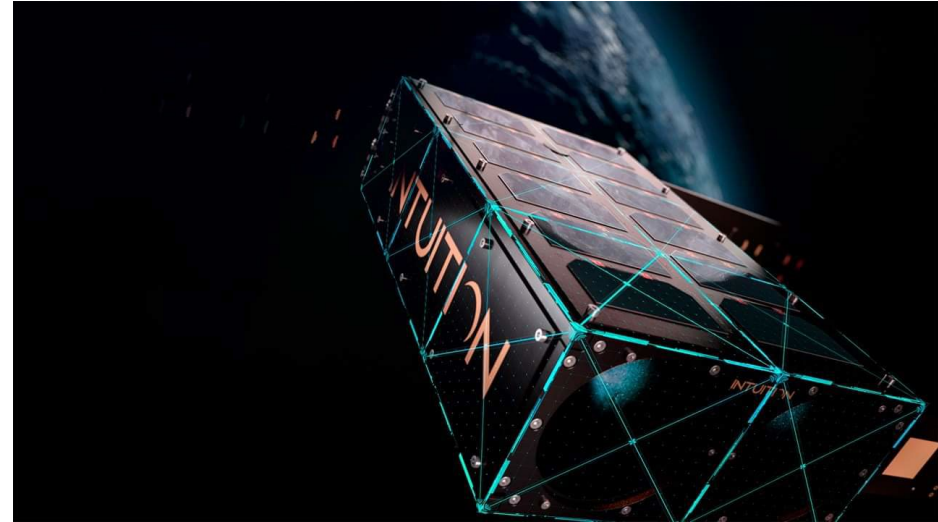
SPACE>SI
SLOVENIAN CENTRE OF EXCELLENCE
FOR SPACE SCIENCES AND TECHNOLOGIES



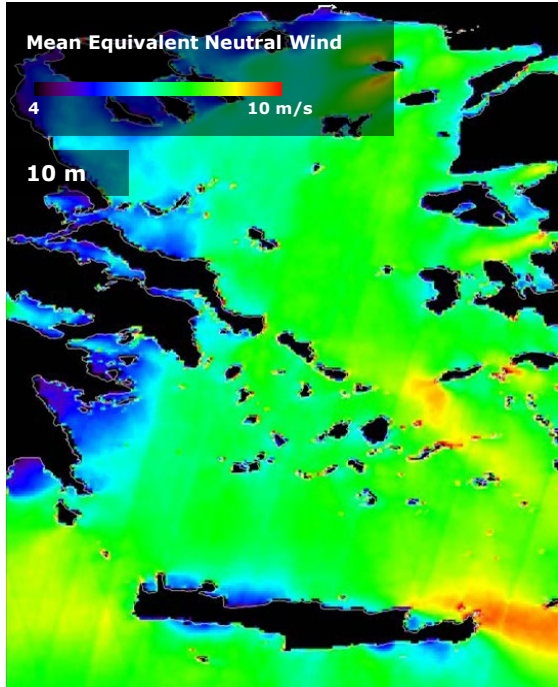
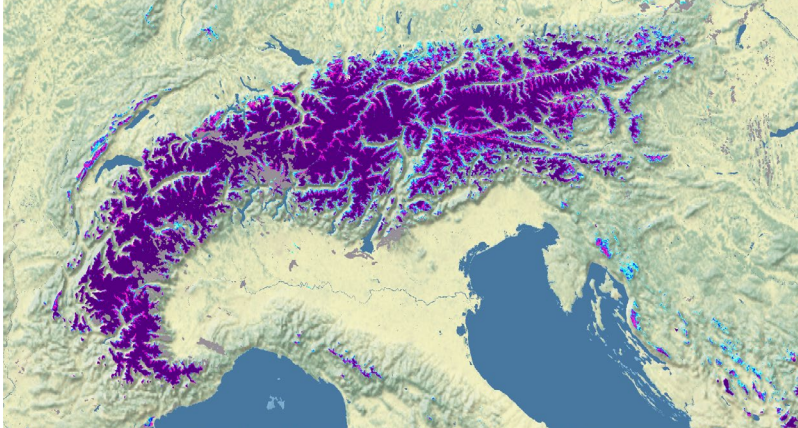
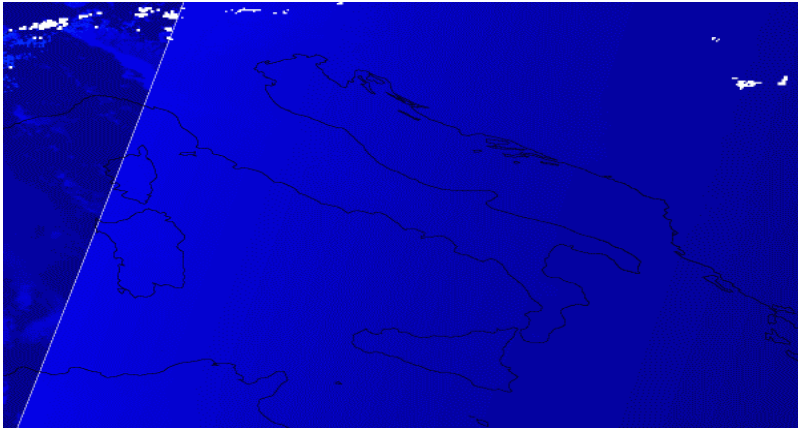
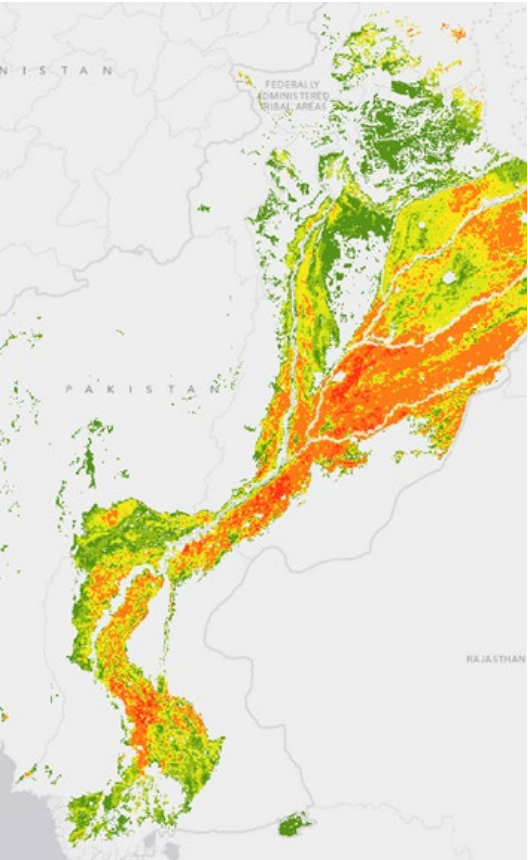
→ THE EUROPEAN SPACE AGENCY

SmallSats as Part of the "NewSpace" Paradigm

- **Intuition-1** by KP Labs (Poland): hyperspectral mission with *onboard processing*
 - 150 spectral bands in the range of 470 nm – 900 nm
 - Convolutional Neural Network-based advanced analysis and processing of images in orbit decreases download data volumes by a factor of 100
 - The applied neural networks can be reconfigured during the mission to ensure adjustment to evolving needs
 - In orbit in 2023

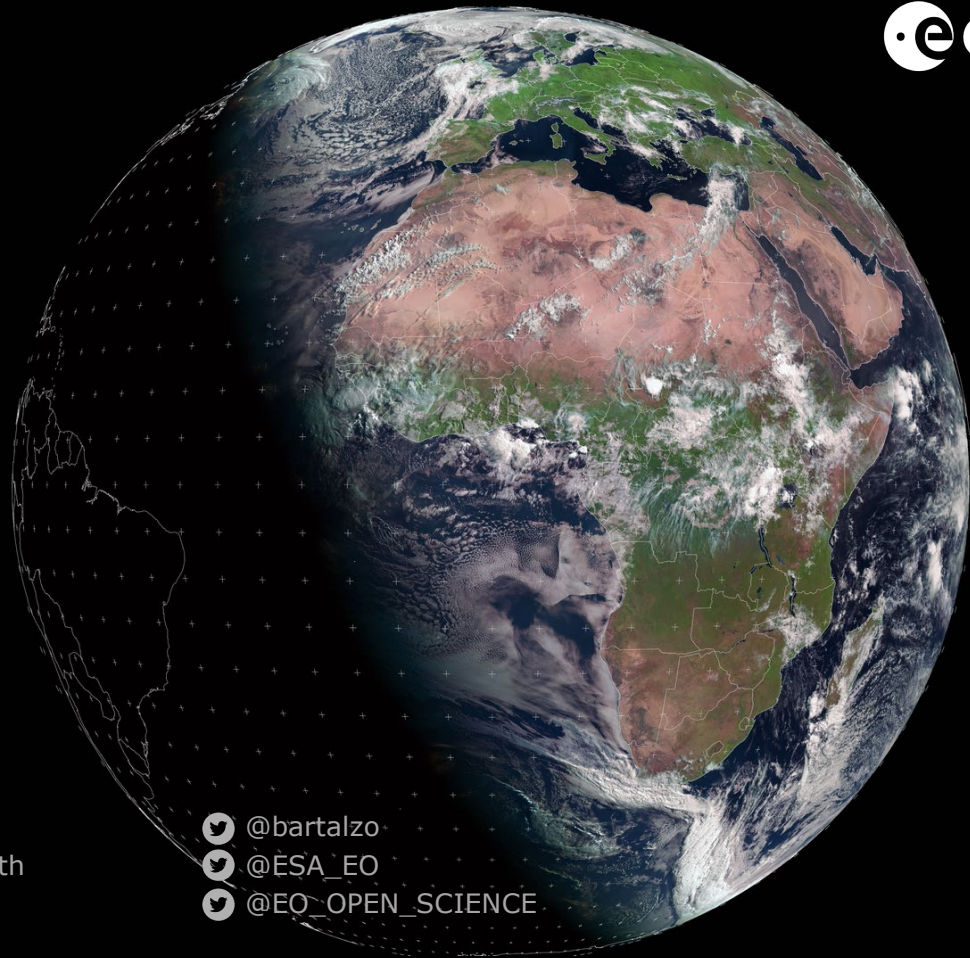


Renewable Resources, Renewable Energy



Earth Observation: A Necessity




Thank You!



Zoltan Bartalis

European Space Agency
Directorate of Earth Observation Programmes
Science, Applications and Climate Department
ESA ESRIIN, Frascati, Italy

Zoltan.Bartalis@esa.int
https://www.esa.int/Applications/Observing_the_Earth/eo4society.esa.int

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