The European Space Agency: Space Infrastructure for Polar Applications

Dr. Craig Donlon- European Space Agency

EU Arctic policy

Within Copernicus the European Space Agency:

- ***Works in Partnership*** with the European Commission
- ***Responds to User Needs*** provided by the European Commission *eg. Arctic Policy needs*
- ***The Technical Architect*** of the Copernicus Space Segment (CSC) to meet those needs
- ***Develops, Launches, Maintains and Operates Copernicus Sentinel satellites*** - together with EUMETSAT - on behalf of the European Commission
- ***Strives to maintain Europe as a world leader in Earth Observation*** (jobs, growth, innovation, leadership, value for money, science…)

Copernicus Space Segment (CSC) Sentinel Satellites

European Commission

esa

S-1

Radar

A	3 Apr. 2014
B	25 Apr. 2016
C	2022/23
D	> 2022/23

S-2

High Res. Optical

A	23 Jun. 2015
B	6 Mar. 2017
C	2022/23
D	> 2022/23

S-3

Medium Res. 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

ESA CSC Ground Segment

Sentinel Data Dashboard

opernicus | esa | Sign out

Copernicus Open Access Hub

LATEST NEWS

181,371
Self registered Users

59,695,028 Products Downloaded
41.95 PB Volume Downloaded

No Rolling Policy

Sentinel-1 NTC
Sentinel-2
Sentinel-3 (preops)
Sentinel-5P (preops)

Max 2 concurrent Downloads

Collaborative Hub

LATEST NEWS

18 Collaborative GS
7 Data Hub Relays

34,866,788 Products Downloaded
27.02 PB Volume Downloaded

Node1: 30 days
Node2: 2 weeks
Node3: 3 weeks

Sentinel-1 NRT & NTC
Sentinel-2
Sentinel-3 SRAL

Max 10 concurrent downloads per Node

International Hub

LATEST NEWS

4 International Agreements

10,211,842 Products Downloaded
7.88 PB Volume Downloaded

3 weeks

Sentinel-1 NTC
Sentinel-2 L1C
Sentinel-3 SRAL

Max 10 concurrent downloads

Copernicus Services Hub

LATEST NEWS

217 Registered Users

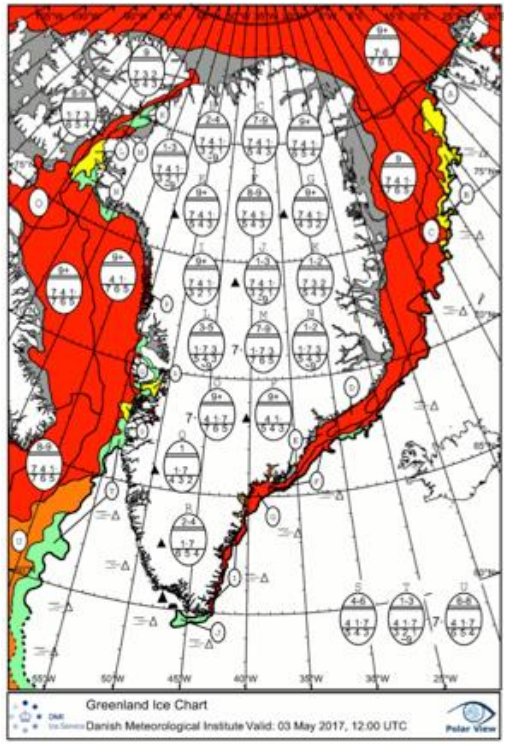
33,348,191 Products Downloaded
21.27 PB Volume Downloaded

No Rolling Policy

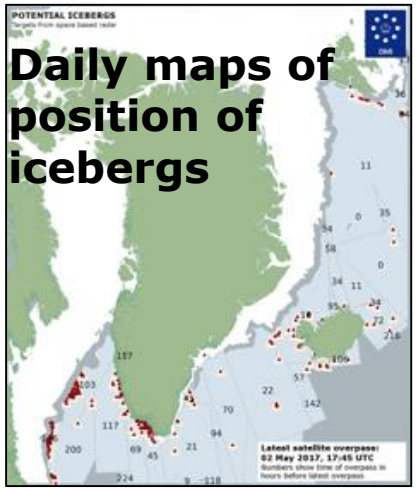
Sentinel-1 NRT & NTC
Sentinel-2
Sentinel-3 SRAL

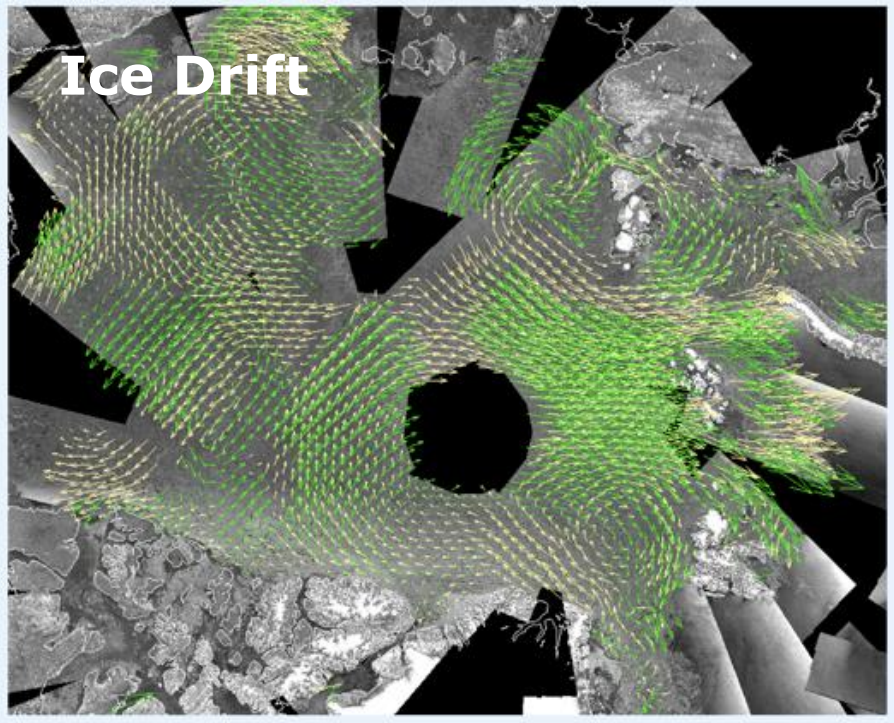
Max 10 concurrent downloads

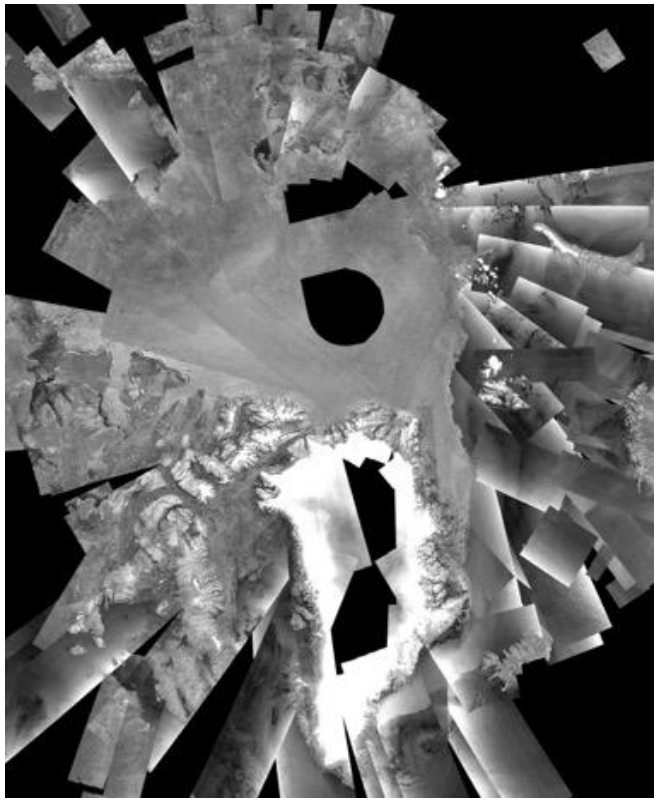
Since Sep 2014, **Sentinel-1** has become the main source of data for the operational **Copernicus Marine Environment Monitoring Service (CMEMS) for sea-ice and iceberg monitoring**



Ice Charts

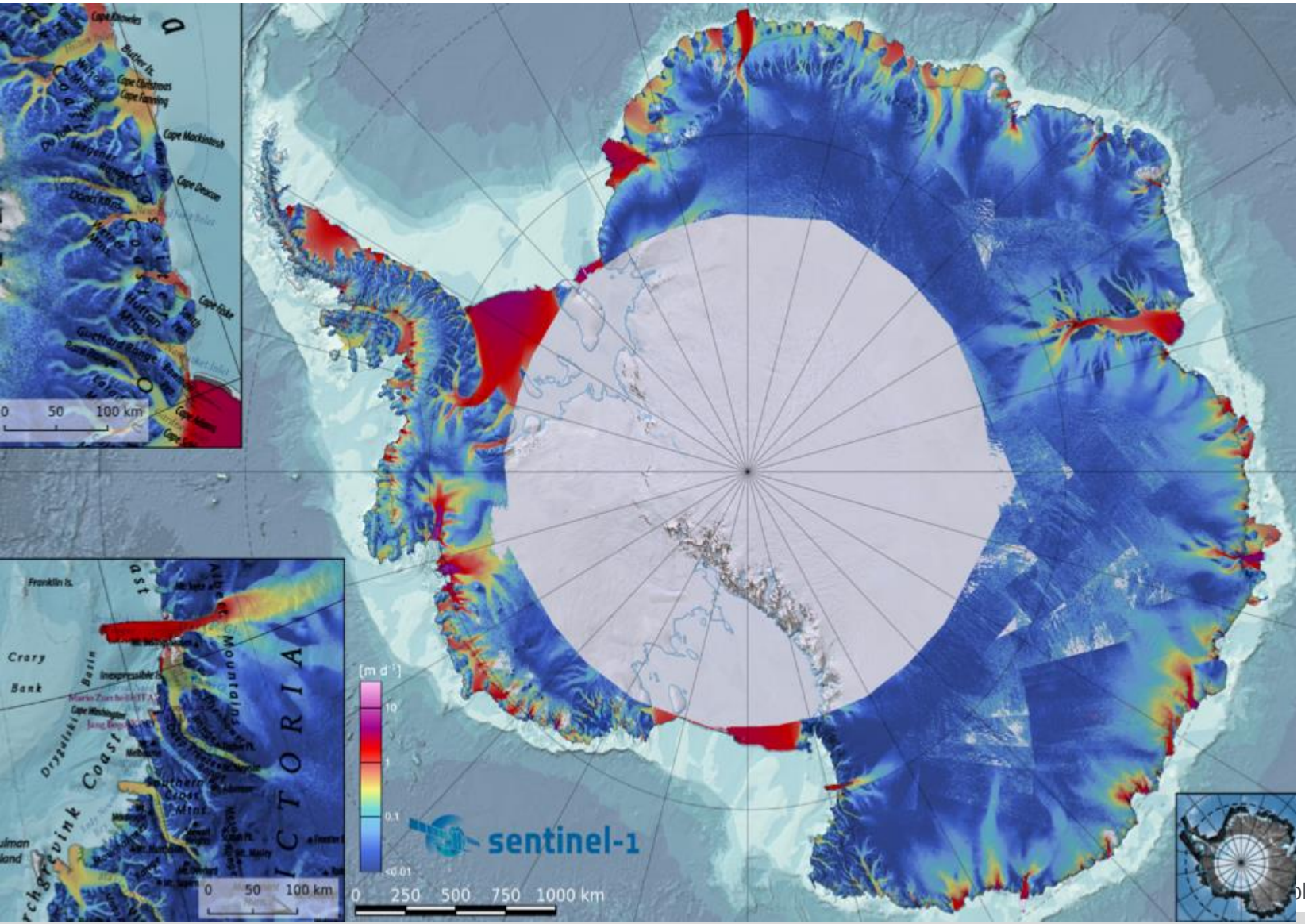


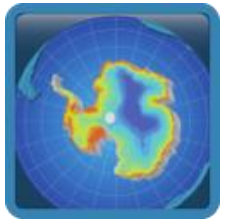




3-day Mosaic 29-30-31 Oct 2018
http://www.seaice.dk/

Antarctica Ice velocity map from S-1





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

[m d^{-1}]

10

1

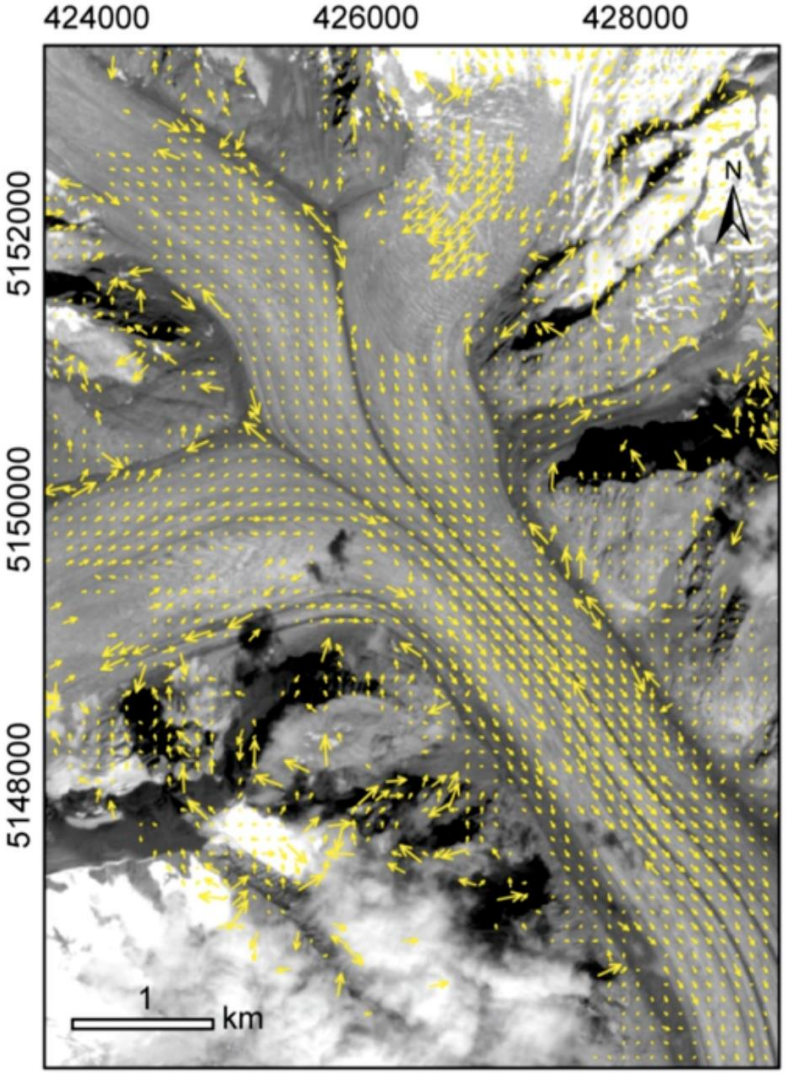
0.1

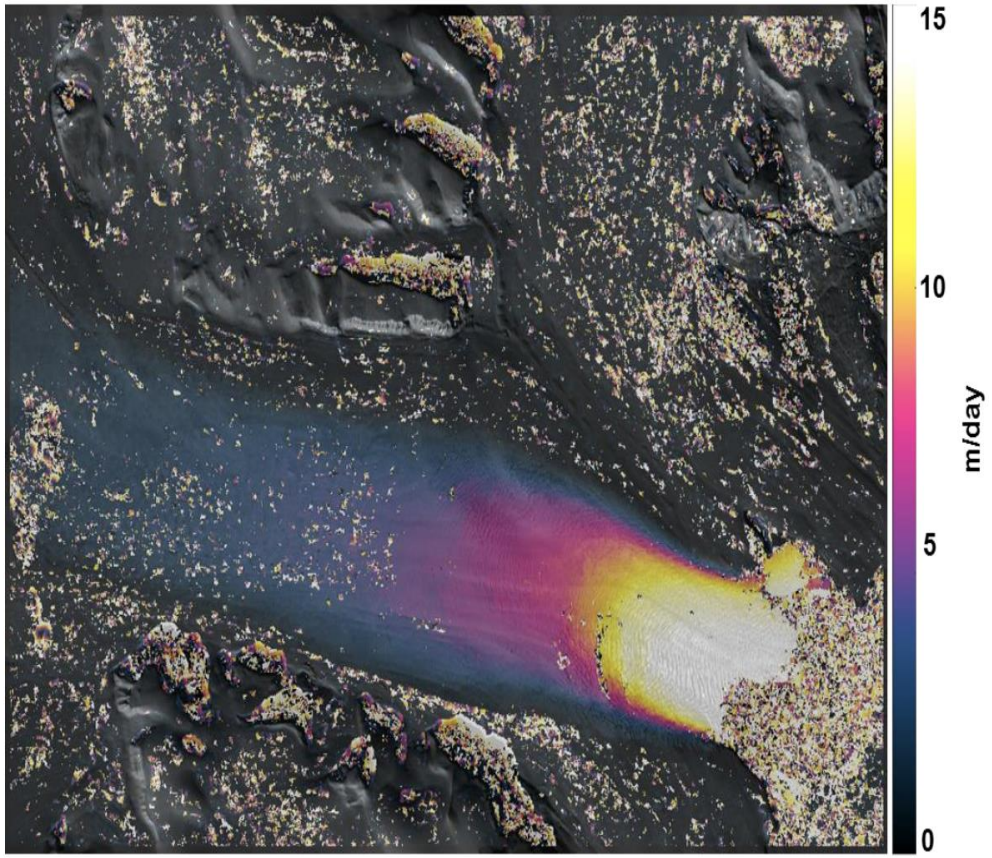
<0.01

Sentinel-2: Glacier Monitoring

Kääb et al., 2016

For Aletsch Glacier, Swiss Alps, tracked displacements using Sentinel-2A band 8 data from 30 July and 8 September 2015, i.e. over 40 days.

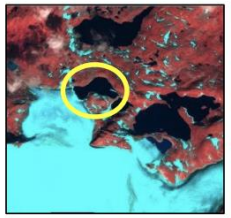




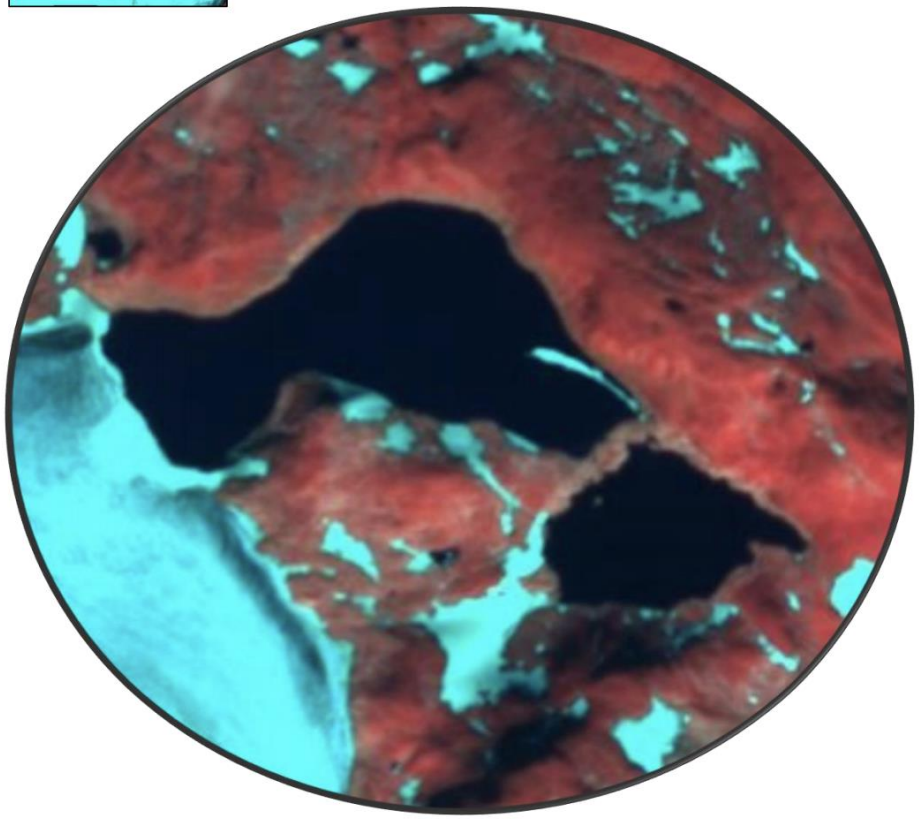
Negribreen, Svalbard. 10m resolution velocity map of glacial surge in spring 2017 doem Sentinel-2 measurement pair

Sentinel2: Ephemeral Glacier Lakes

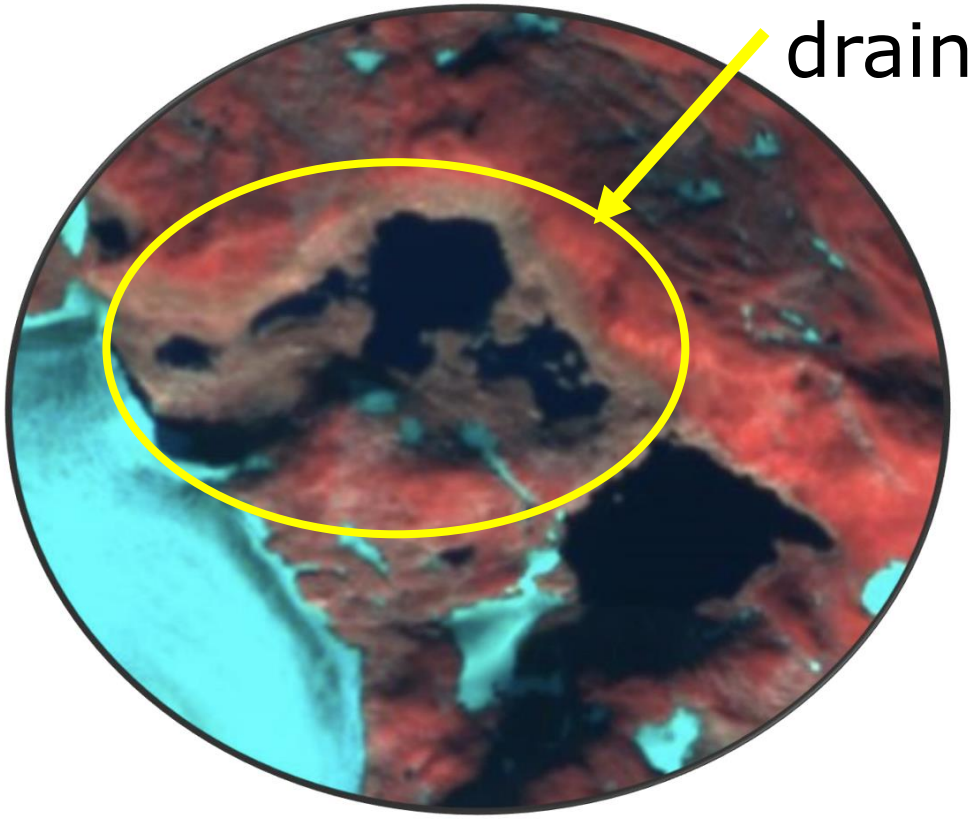
Jøkulhlaup from Blåmannsisen



14 August 2018

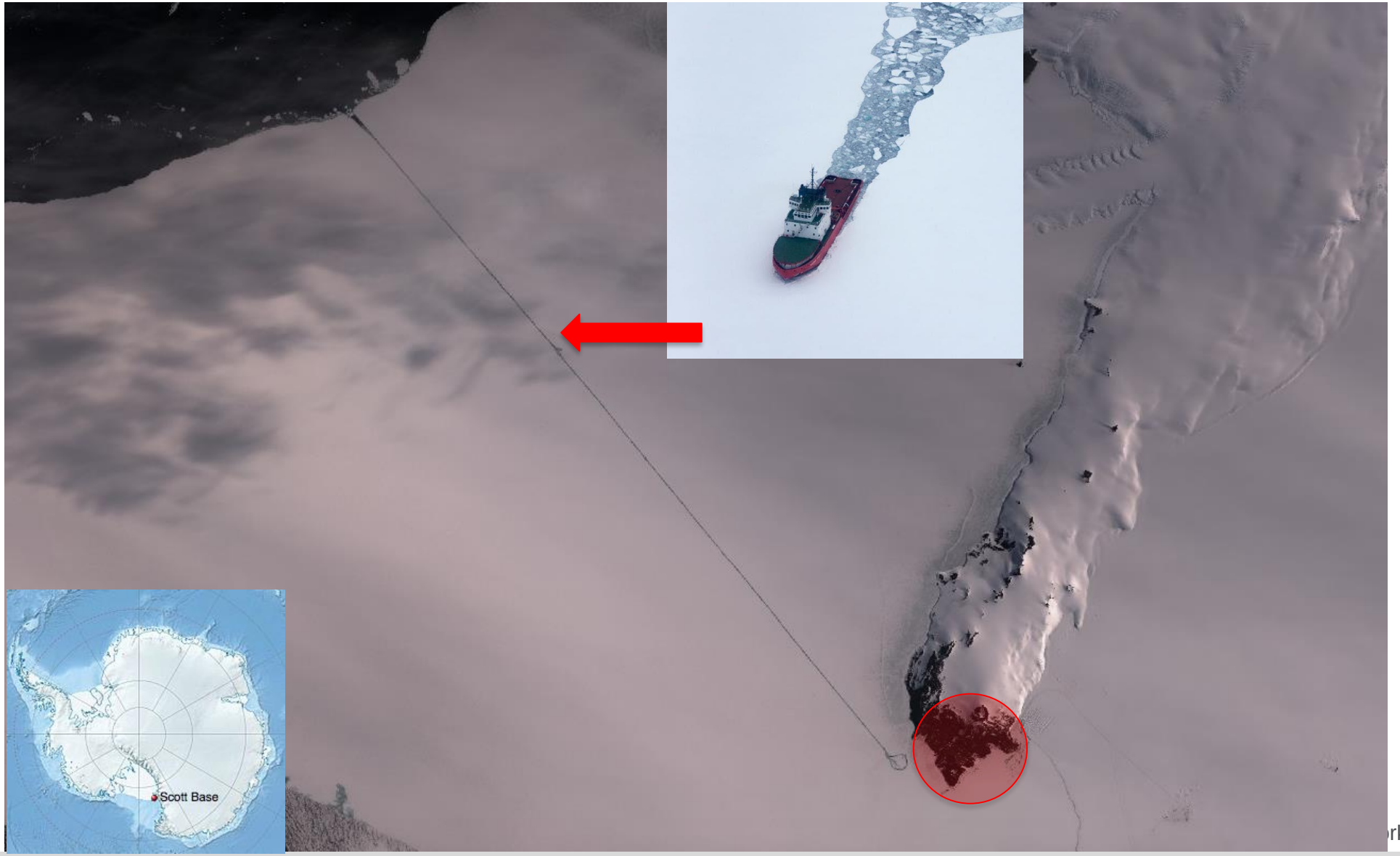


1 September 2018



Water has drained

Sentinel-2: Antarctic Shipping



Icebreakers opened a passage through the ice for providing supplies to the Scott research base (New Zealand).

S2B Siberia 09/05/2018

Polar View

Click for more information

Available datasets

SAR imagery

- Sentinel-1 — Select image
- Radarsat 2 — Select image

Showing data for the last 72 hours (default)

Sea ice concentration

- AMSR2 Sea ice edge (15%) — 2018-11-05
- AMSR2 Sea ice map — 2018-11-05

Ice charts

- Ice chart (NIC, MIZ) — 2018-06-07
- Ice chart (NIC, Con)
- Ice chart (NIC, SoD)

IMO Polar Code Polaris

Summer ice / Winter ice

- PC1

Sentinel 3 Mosaics

- Sentinel 3 Mosaic — 2018-11-04

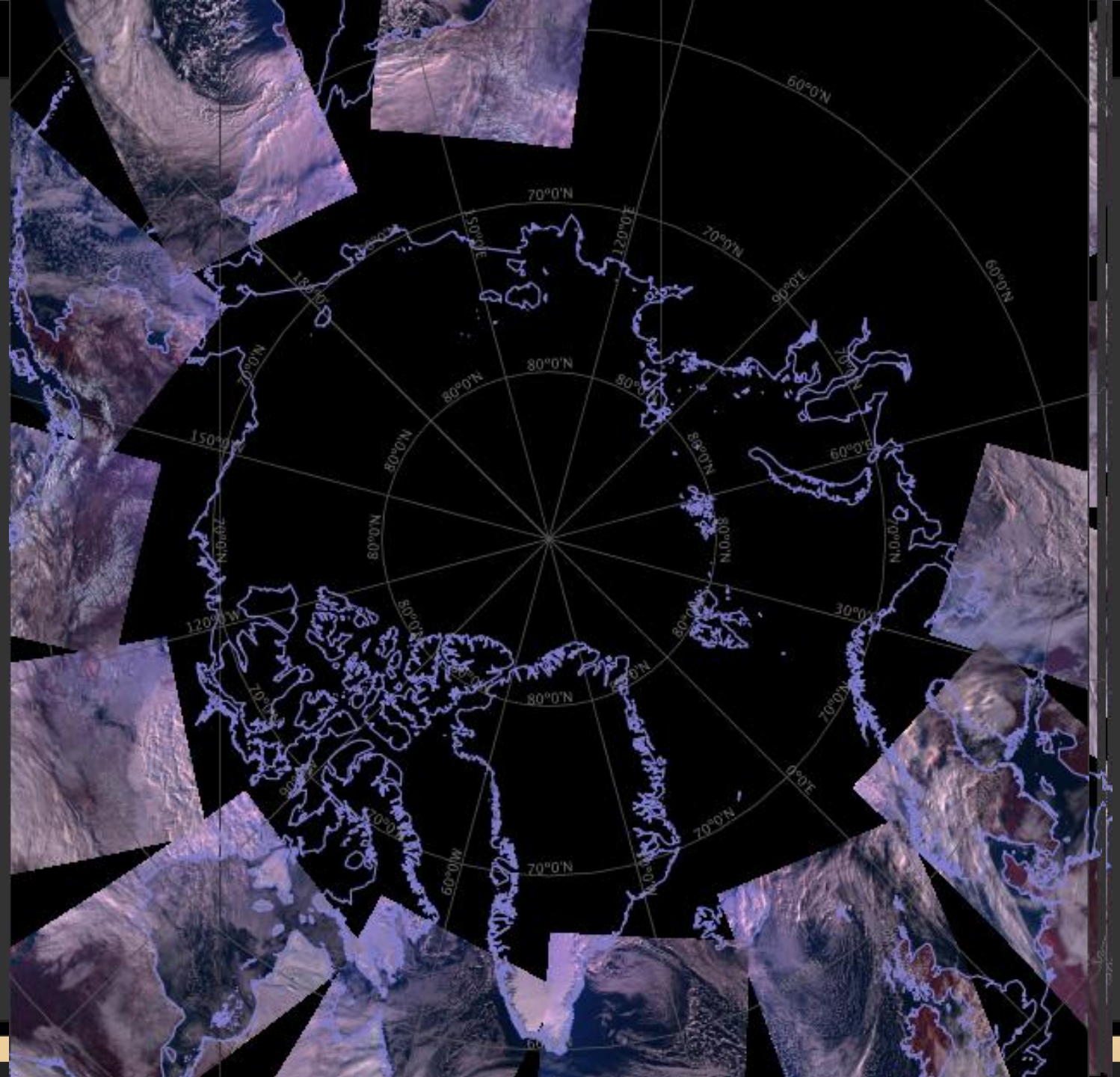
MODIS Mosaics

- MODIS Mosaic (yesterday) — 2018-11-04

S1 Future Acquisitions

- S1 Foresight — unknown

Showing data for the next 48 hours (default)



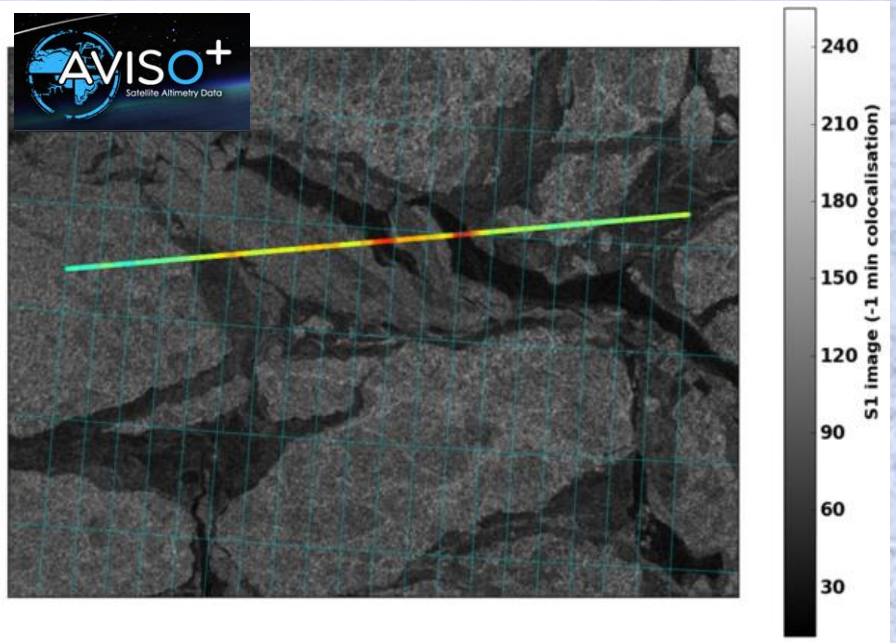
1000 km
500 mi

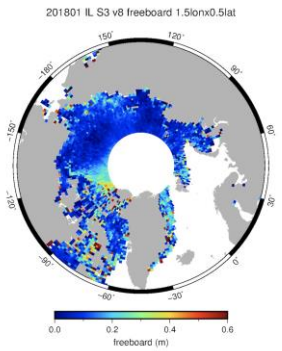
Long: 85.43, Lat: 28.46

S3 | 06-10-18 | 03-11-18

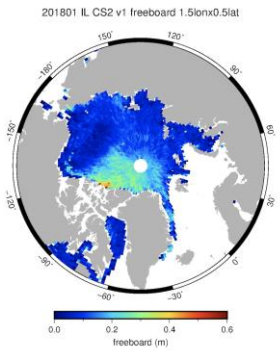
Click to expand the carousel

Image preview


AVISO+
Satellite Altimetry Data
240
210
180
150
120
90
60
30
S1 image (-1 min colocalisation)

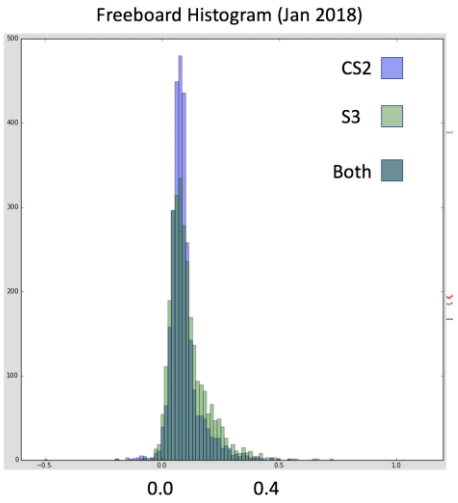


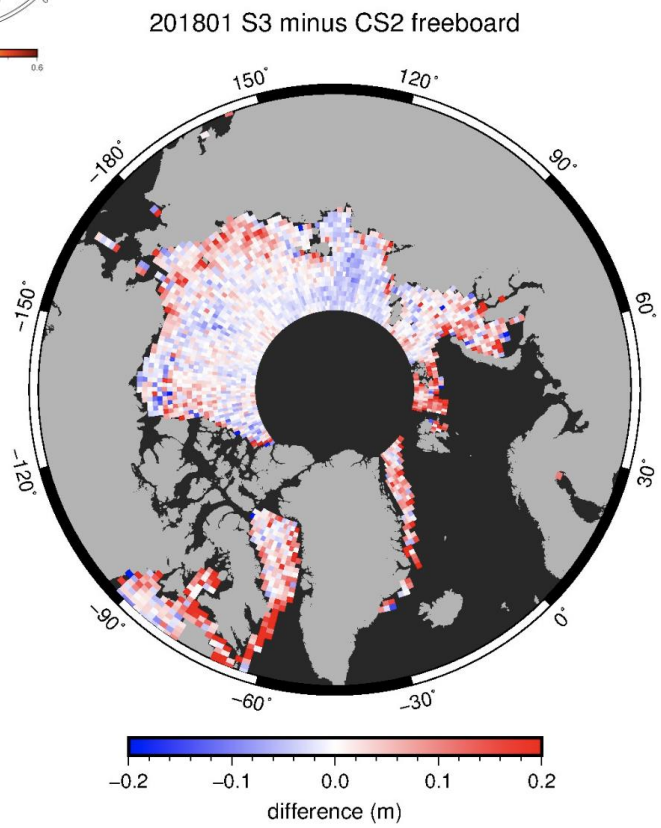
S3 Freeboard



CS2 Freeboard

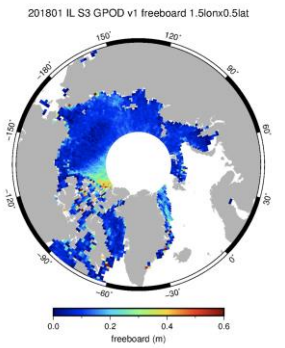
Next IPF (Nov/Dec 2018) Shown with L2 Evolutions Implemented



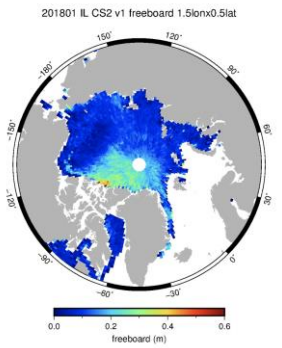


Processed from S3 L1b: IPF PB 2.32 with Next IPF prototype (CPOM/UCL)

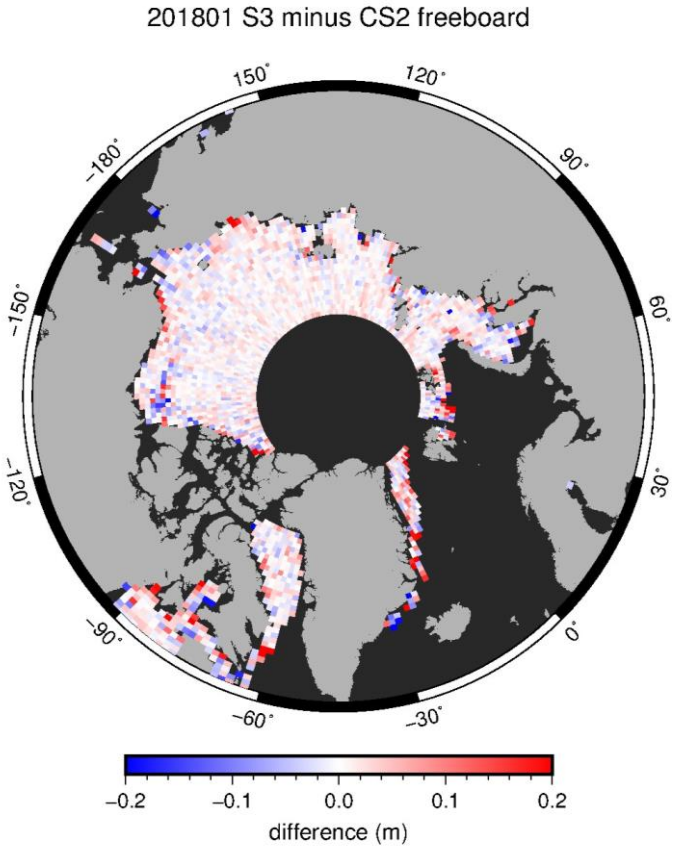
Further Significant Improvements Possible with L1 Update

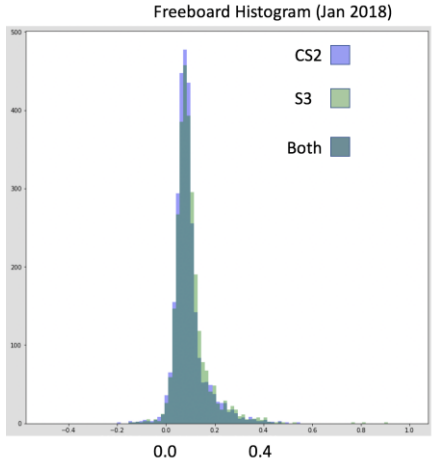


S3 Freeboard



CS2 Freeboard

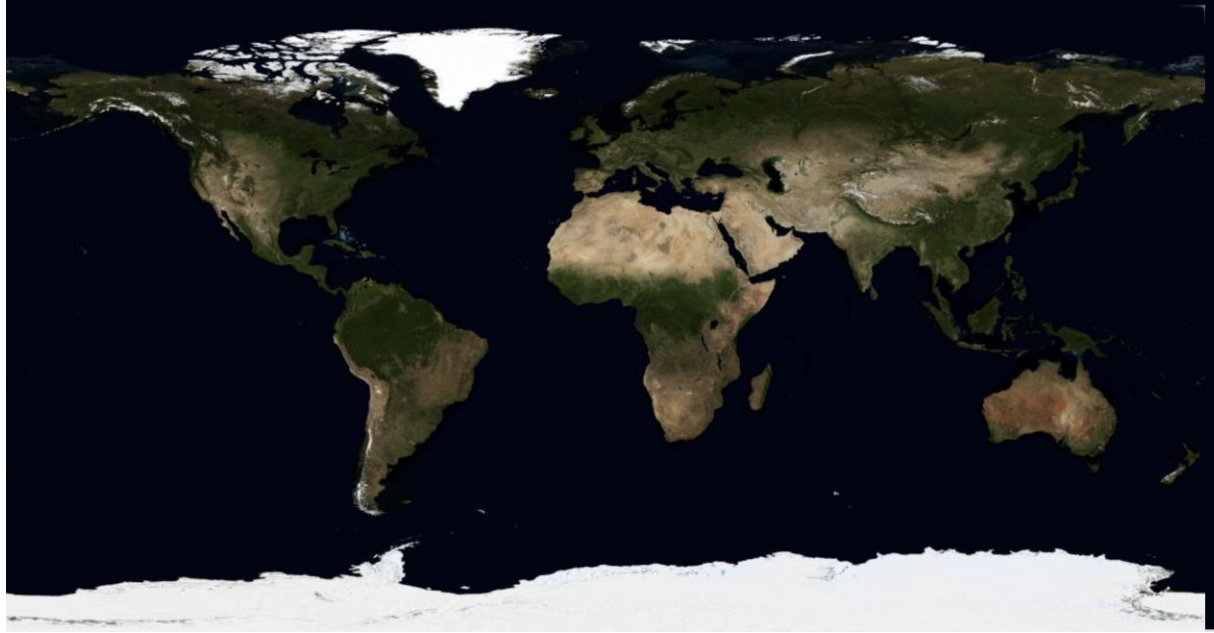




Processed from GPOD L1b, using UCL L2 prototype: (with Hamming Weighting, Zero Padding)

Seasonal Snow

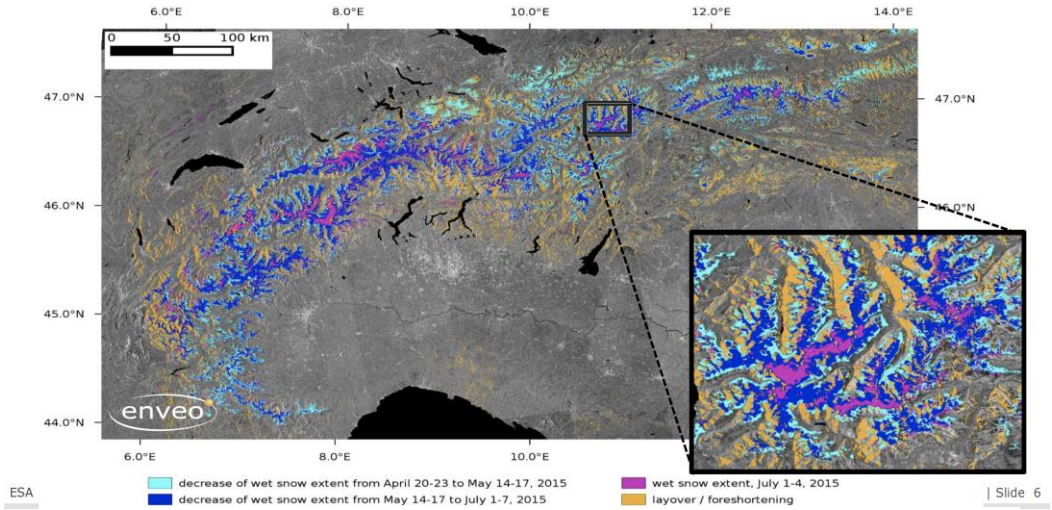
- covers up to ~47 Mio km^2 in extent and has a mass of ~3000 Gt
- ~98% of seasonal snow cover occurs in the Northern Hemisphere
- highly variable in space and time
- very sensitive to weather on short term and to climate change on long term



- **How is the snow-albedo feedback changing?**
- **How much water is stored as seasonal snow and where has it changed?**
- **Amount and duration of snow cover influences carbon cycle by insulating soil and influencing vegetation phenology**

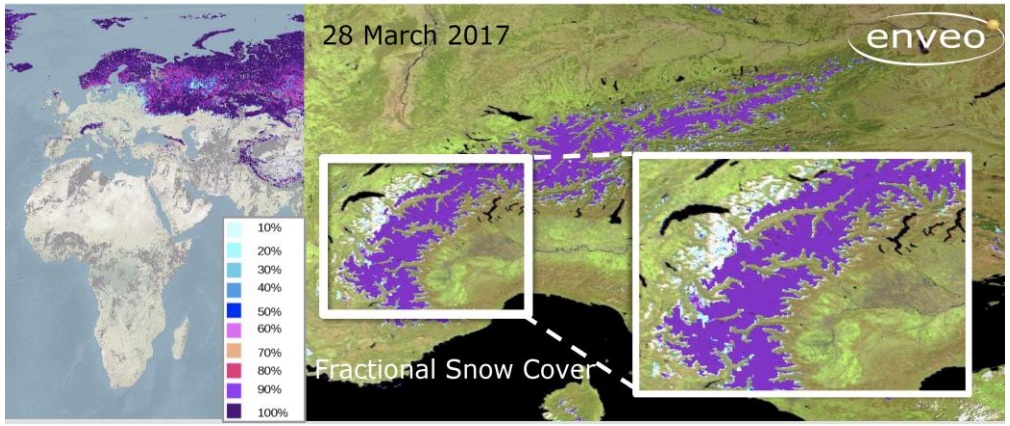
Sentinel and snow measurements

Mountain Wet Snow Maps - Sentinel-1 SAR



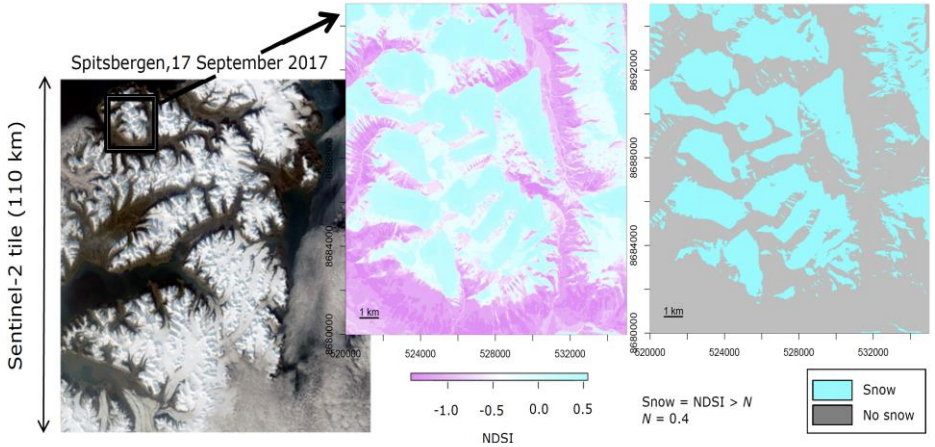
Fractional Snow Cover - Sentinel-3 SLSTR

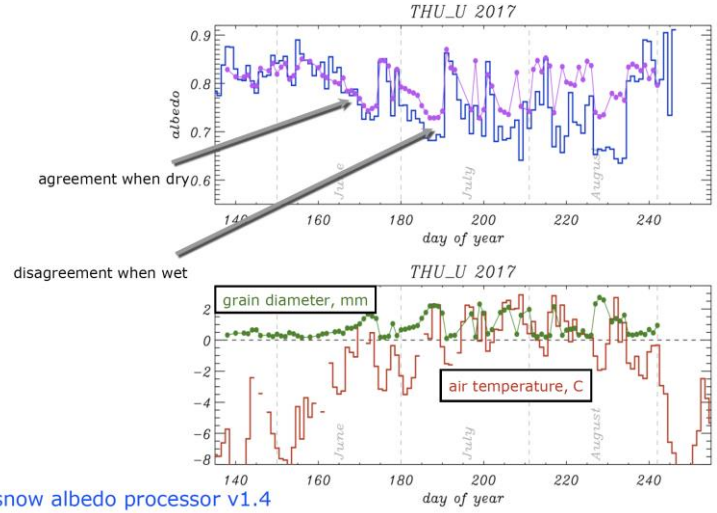
Snow Extent product



Snow Cover - Sentinel-2 MSI

Snow cover maps area at 20 m spatial resolution.





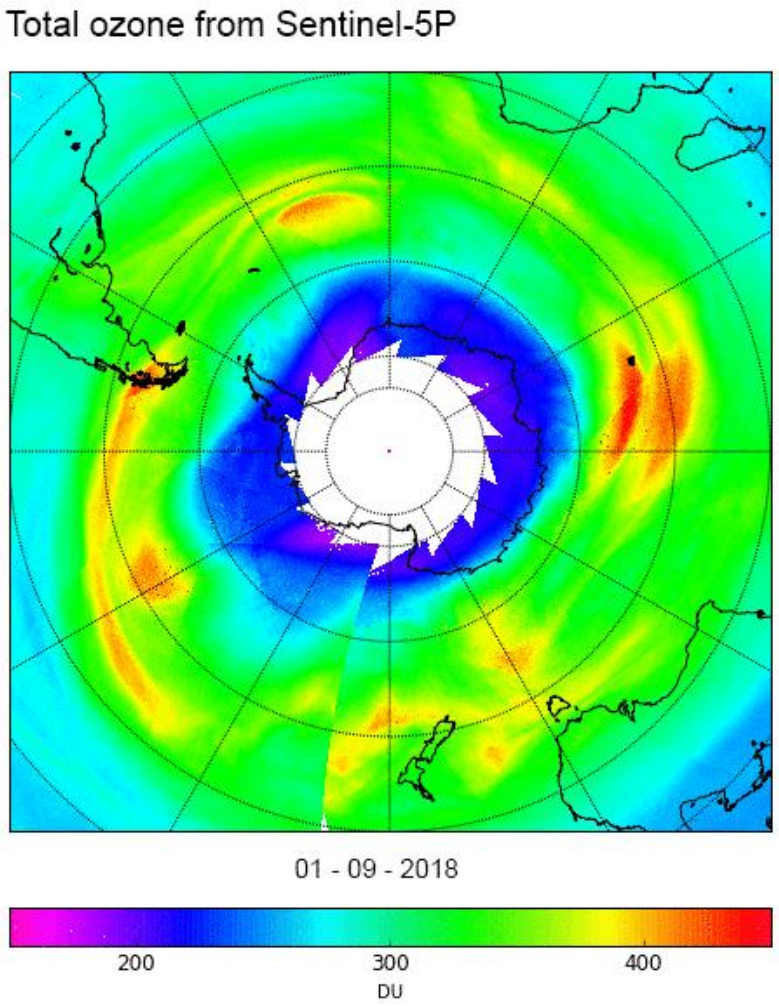
Snow albedo

snow albedo processor v1.4

Sentinel-5p: Antarctic O3 Hole

Measurements of total ozone for 1–13 September 2018 over Antarctica from the Copernicus Sentinel-5P satellite, showing the ozone hole over the South Pole.

UVB radiation impacts on Ecosystems and Society



Motivation

- The European Copernicus system, including the Copernicus Space Component (CSC), has been established as **the largest and most proficient EO system in the world**.
- The current Sentinels provide **~10 Tb/day** of world-class data to over **180,000 registered users** – fuelling Copernicus.
- **Service application dependencies** are now in place and there are **great expectations for the future** Copernicus system.
- **User needs and requirements have also evolved** in the new Copernicus paradigm

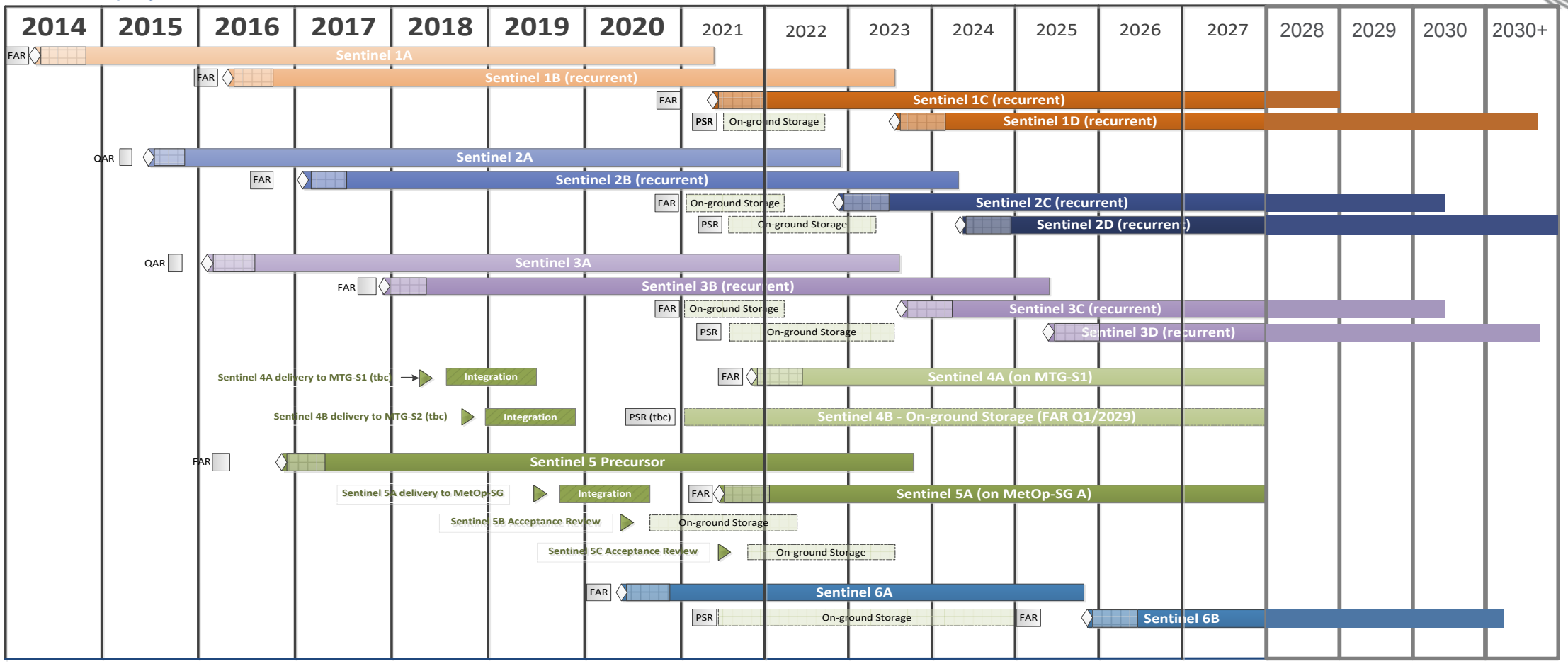
- **How might the CSC build on the current Sentinel series?**
  - How might the system ***extend*** to provide ***enhanced continuity***?
  - How might the system ***expand*** to address ***new user needs***?

A Long Term Scenario (LTS)

- Fundamental aspects of a LTS:
  - **assure user-driven continuity** and increase the **robustness** of the existing CSC in the future (Priority)
  - **increase the quality and quantity** of the existing measurements
  - **expand observation** types according to policies and user needs
  - employ **latest technologies** for maximum efficiency
  - **Partnerships and cooperation** are essential to success

- **Key driver is the evolving needs of the services prioritized by EC** through various consultative processes over the last year

CSC Segment-4 (2020-2029)



Legend: Qualification Acceptance Review (QAR) Flight Acceptance Review (FAR) or PreStorage Review (PSR) | On-ground Storage | Tentative launch date | In-orbit Commissioning

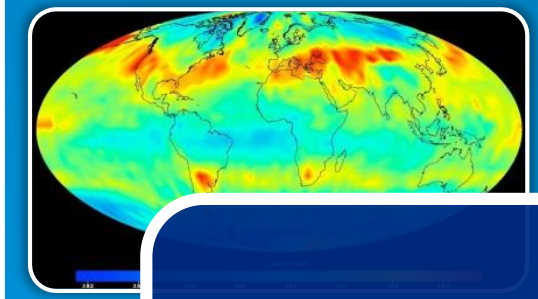
Status: 22 March 2016

Copernicus Extension: Copernicus-NG

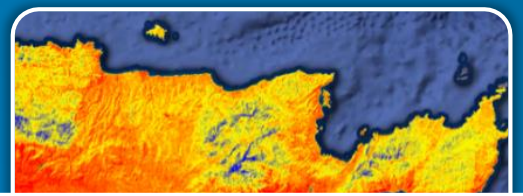
Copernicus Expansion: High Priority Candidate Missions

Copernicus 2.0: Expansion

6 High Priority Candidate Missions



Anthropogenic CO_2 Imaging

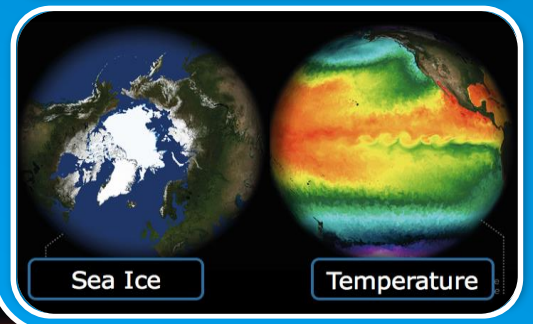


High Resolution Agriculture & Water Surface Temp

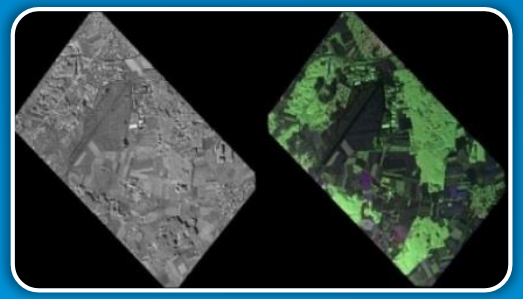
Phase A/B1 HPCM Studies are ongoing

Climate Change (Arctic sea ice volume)

Biodiversity



Sea Ice & SST Imaging Microwave Radiometer (Arctic situational awareness)

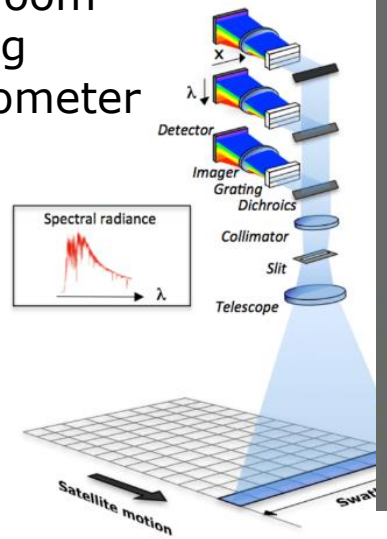


Soil Moisture, Vegetation & Ground Motion L-band SAR

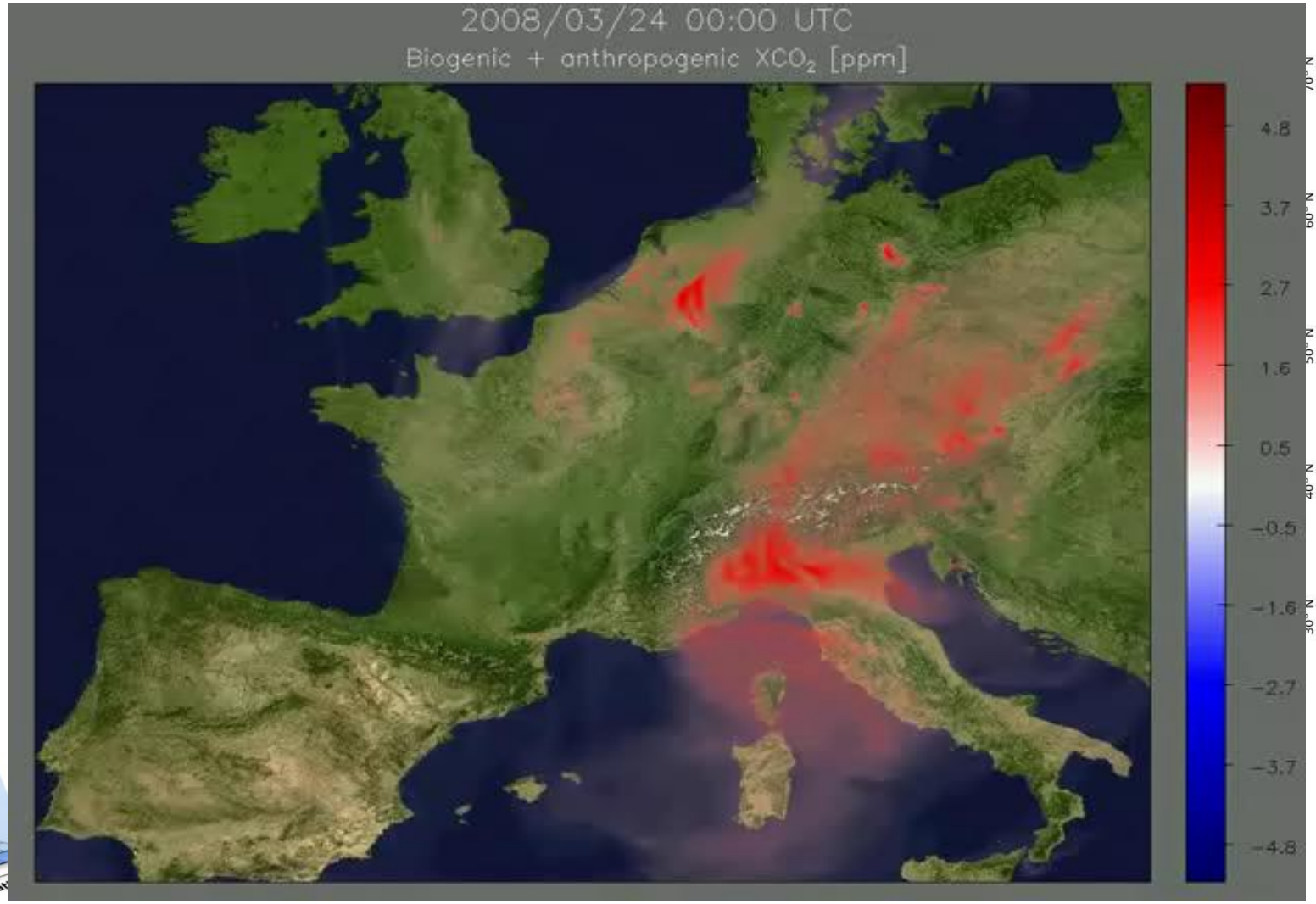
Anthropogenic CO2 monitoring mission

This mission aims to analyse through the use of CO2 satellite imagers the **man-made CO2 emissions and overall CO2 budget** at country and regional/megacity scales and assess the effectiveness of the relevant COP21 decisions.

Pushbroom imaging spectrometer



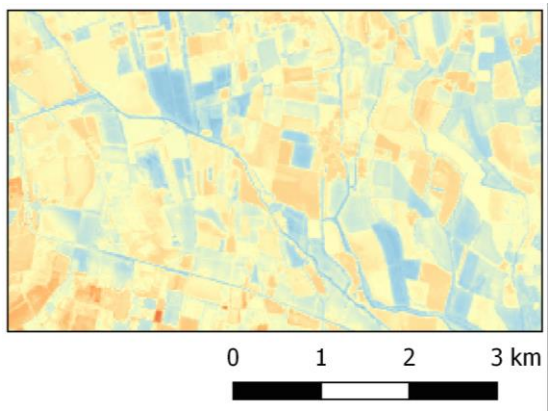
<u>Observation Requirement:</u>
XCO2 precision: 0.5 – 0.7 ppm
Systematic bias < 0.5 ppm
Spatial resolution about 4 km^2
Continuously sampled swath width > 200 km



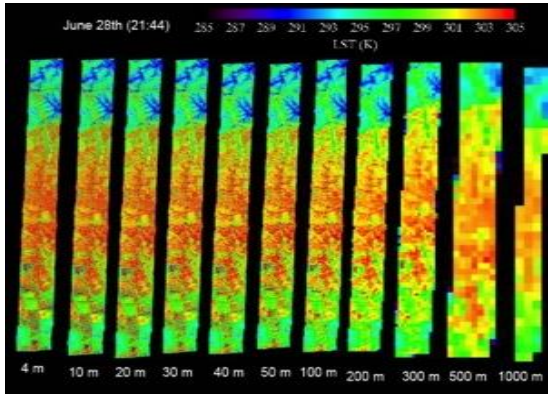
High Spatial and Temporal Resolution Land Surface Temperature (LST) Monitoring Mission

A complement to the current visible (VIS) and **near-infrared (NIR) Copernicus observations with high spatial and temporal resolution Thermal Infrared observations** over land and coastal regions in support of agriculture management services **(CAP)** and a range of additional services.

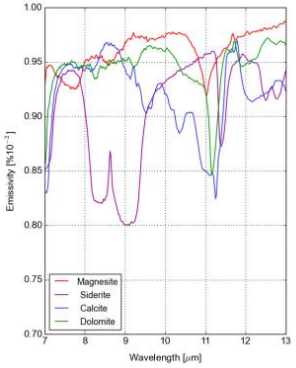
<u>Observation Requirement:</u>
30-50 m to match European/African field scale variability
LST observations should optimally be acquired daily (goal), with a minimum threshold of 3-4 days



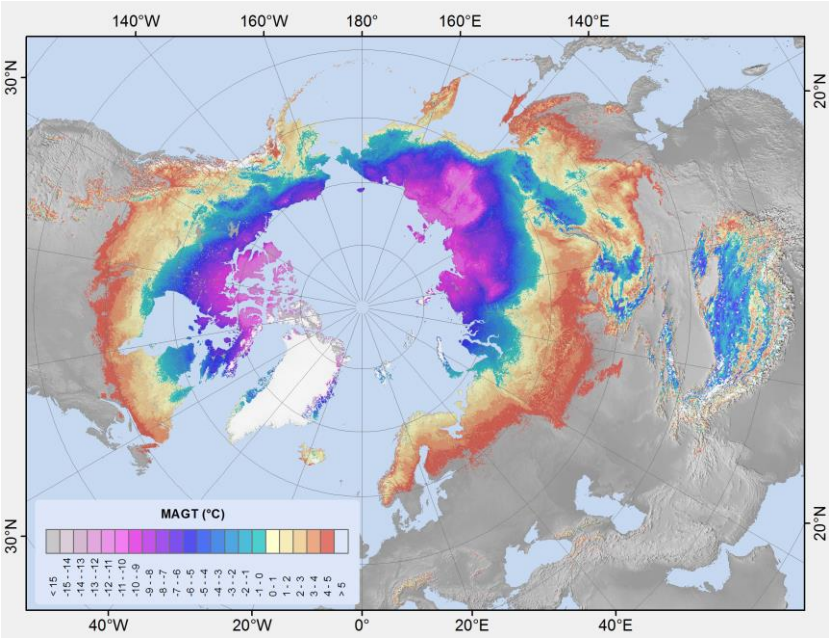
Water stress



Urban heat island



Minerology



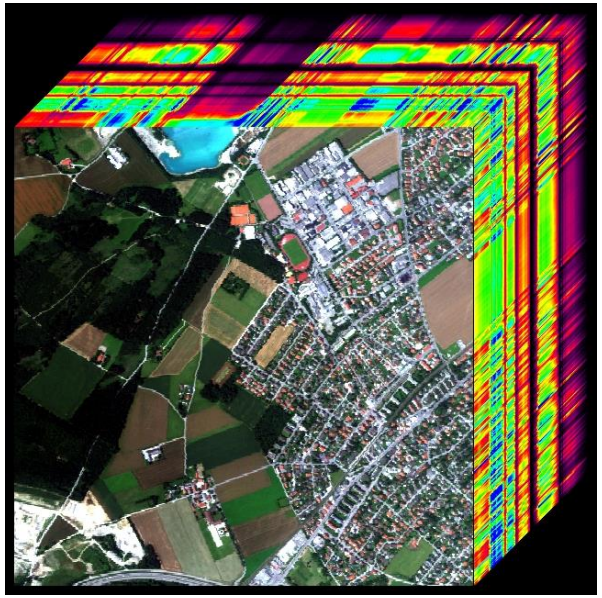
Copernicus Hyperspectral Imaging Mission (CHIME)

"To provide routine hyperspectral measurements in support of EU- and related policies for the management of natural resources, assets and benefits.

- *Visible-to-shortwave infra-red spectroscopy for food security, agriculture and raw materials, soil properties…*
- **Polar Regions: snow grain size, light-absorbing impurities, albedo, ice roads and urban security, snow cover dynamics, coastal ecosystems biology…**

Concept:
Routine spectroscopic observations in contiguous spectral bands conducted at:

- Sun synchronous orbit (LTDN 10:30 – 11:30),
- Revisit 10-15 days,
- GSD: 20-30m,
- Nadir view covering land and coastal areas,
- Instrument: Pushbroom Imaging Spectrometer 400 – 2500 nm, $\Delta\lambda \leq$ 10nm,
- High radiometric accuracy, low spectral/spatial mis-registration.



Hyperspectral data cube (courtesy DLR)

Copernicus L-band SAR mission (ROSE-L)

Mission Objective: New information for services in Disasters and Geohazards, Forests and Agriculture and high-resolution monitoring of Arctic and Cryosphere

…to support the ***EU Integrated Arctic Policy***

Mission Concept: L-band SAR payload (reflector or planar array) with high-resolution & high-duty cycle

Heritage through current and historical L-band SAR missions (JERS-1, ALOS PALSAR). New or improved information from mission include:

- **Sea ice mapping** (e.g. deformed ice, icebergs) and ice drift information to support Arctic ship navigation
- Robust **ice sheet velocity information**
- New **Snow Water Mass** (SWE) information with applications to hydrology, meteorology and climate

EC Polar Expert Group High Priority Information Products
(red = new information through L-band SAR)

Copernicus Polar Ice and Snow Topographic Mission

Aim: **To measure and monitor variability of Arctic and Southern Ocean sea-ice thickness and its snow depth.**

PRIMARY

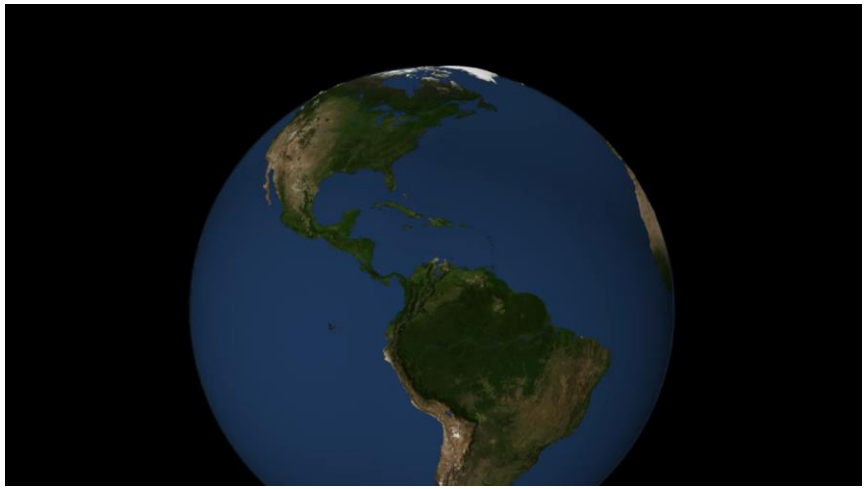
To measure and monitor the surface elevation and changes of glaciers, ice caps and the Antarctic and Greenland ice sheets.

Secondary

To contribute to the observation of global ocean topography as a continuum up to the polar seas.

To support applications related to coastal and inland waters.

To support applications related to snow cover and permafrost.



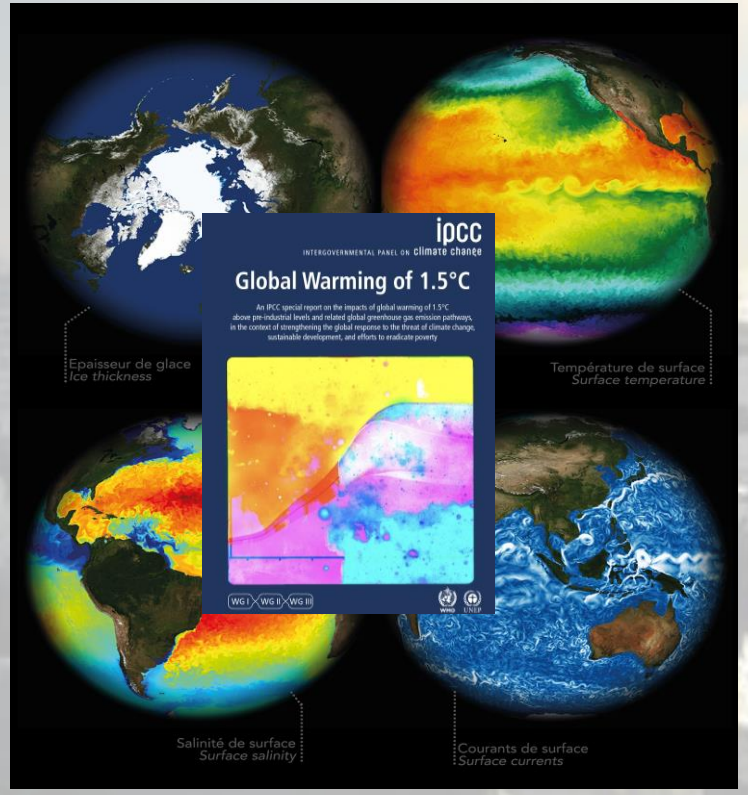
Mission Concept: A) The satellite embarks a payload forming a complete measurement system, comprising of a high spatial resolution Ku-band and Ka-band interferometric radar altimeter, a laser retro-reflector array, a GNSS receiver and a microwave radiometer. B) The mission draws from the heritage experience of several in-orbit missions and from the on-going development of the Sentinel-6 and MetOp-SG programmes.

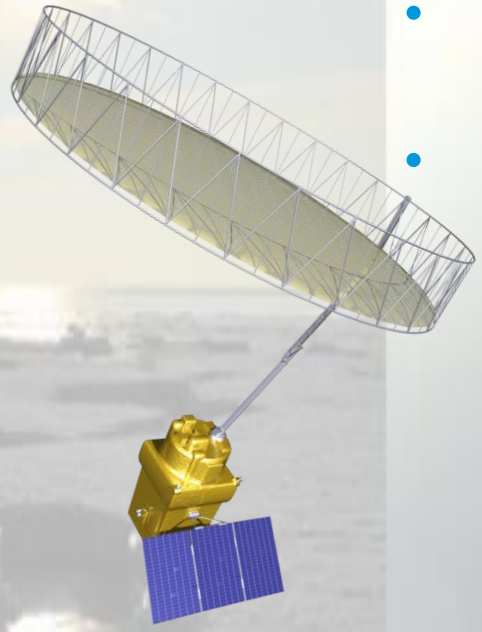
Mission status and launch date: Currently in Phase A/B1. Anticipated launch date is 2025.

Possible Support through coordinated CEOS actions: Potential cross calibration/validation activities with Sentinel-3, Sentinel-6, CryoSat-2, Altika and IceSat-2 (if operational)

Why do we need **High Priority** Copernicus Missions?

HPCM Example: The Copernicus Imaging Microwave Radiometer (CIMR)

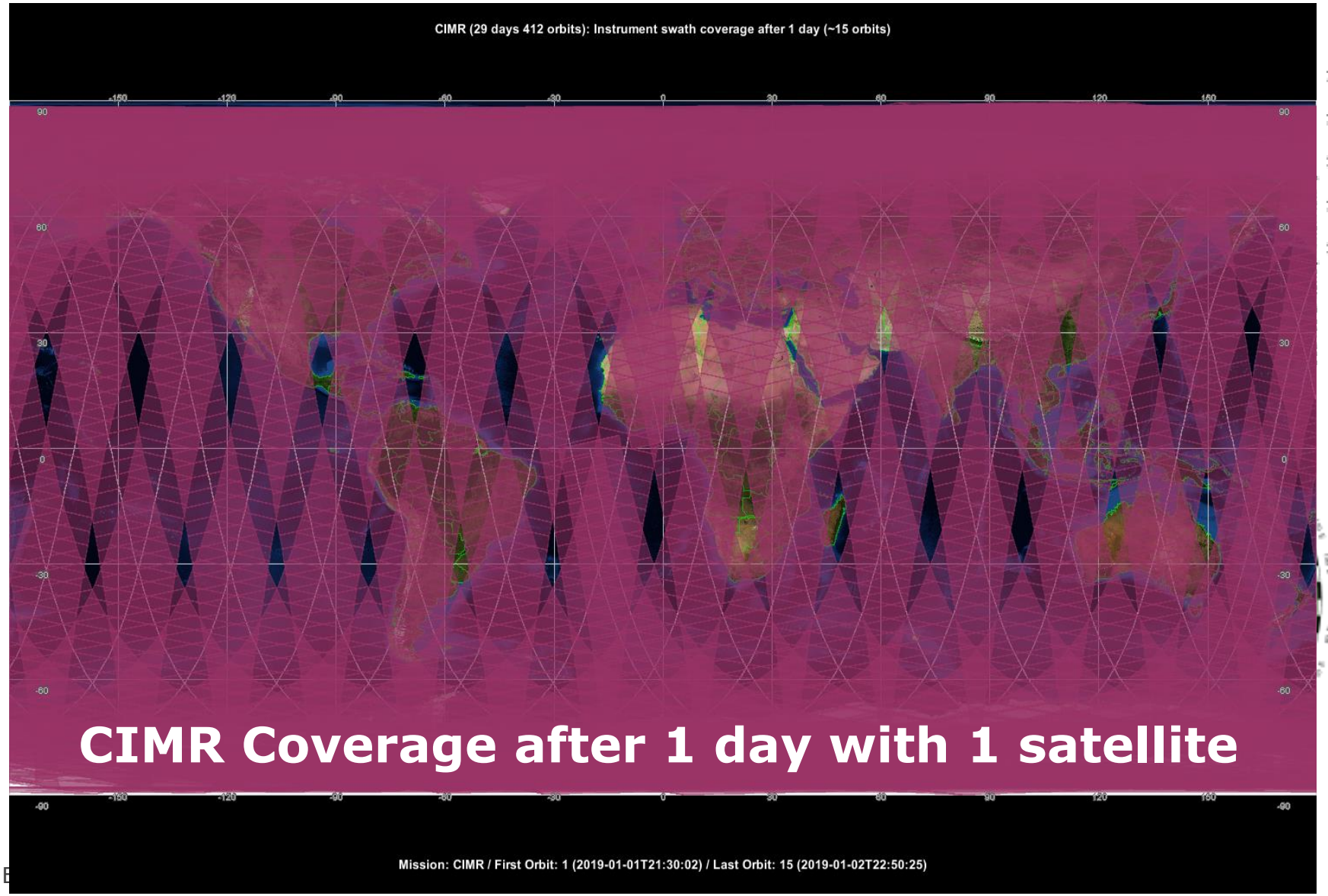


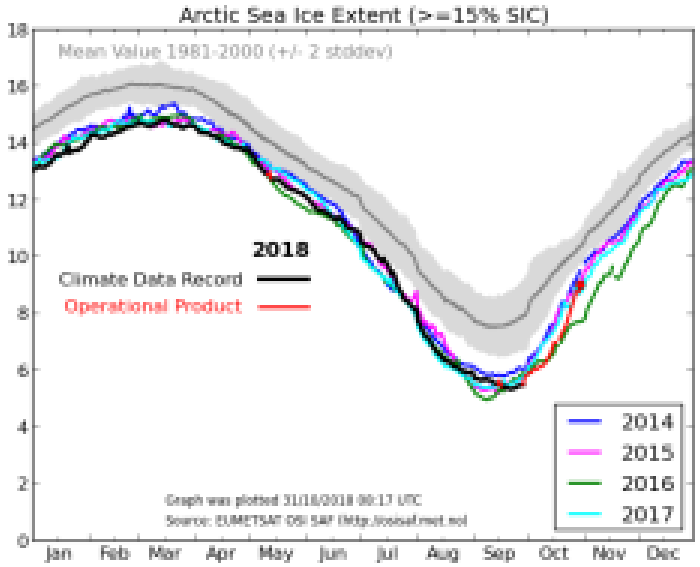


For Illustration purposes only. The final configuration for CIMR depends on the outcome of the Phase A/B1 studies of Thales-Alenia Space Italy and AIRBUS (Credit AIRBUS UK)

- **Polar Oceans are fundamental to understanding the global environment**
- **CIMR will:**
  - **Prevent the anticipated Gap in capability**
  - **Be "ready" for an ice free Arctic**
  - **Key variables:** *Sea Ice Concentration, Sea Surface Temperature, thin Sea Ice Thickness, Sea Surface Salinity, Wind Speed, soil moisture…*
  - Low frequency/High Spatial resolution (5–15 km)
  - **Measurements every ~6 hours** in the Polar regions, no hole at the pole
  - 95% global coverage every day for **application in all Copernicus Services**
- Directly addresses the EU Arctic Policy.
- **A 'Game Changer' for Copernicus**

Climate Change CIMR and Sea ice minima





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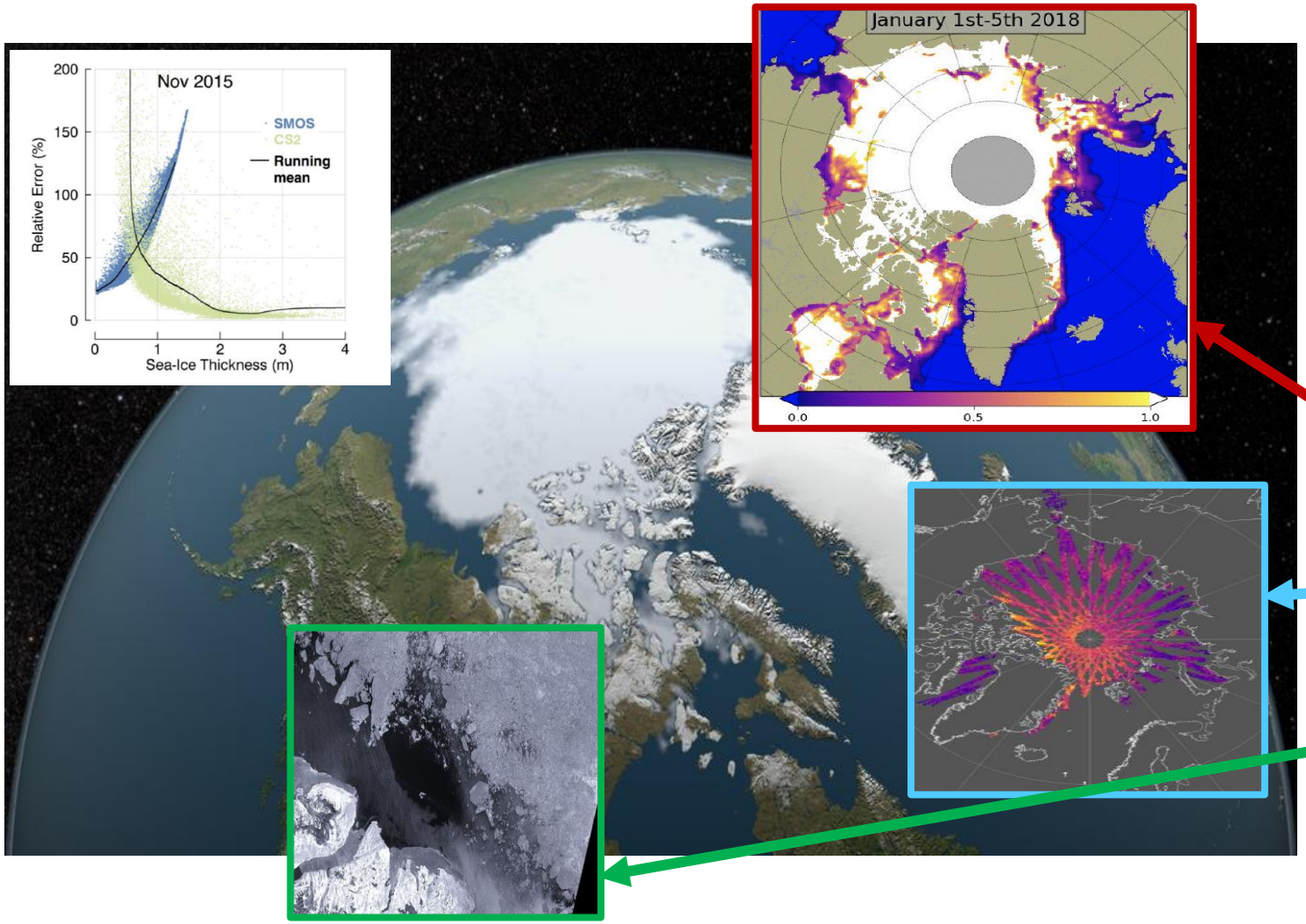
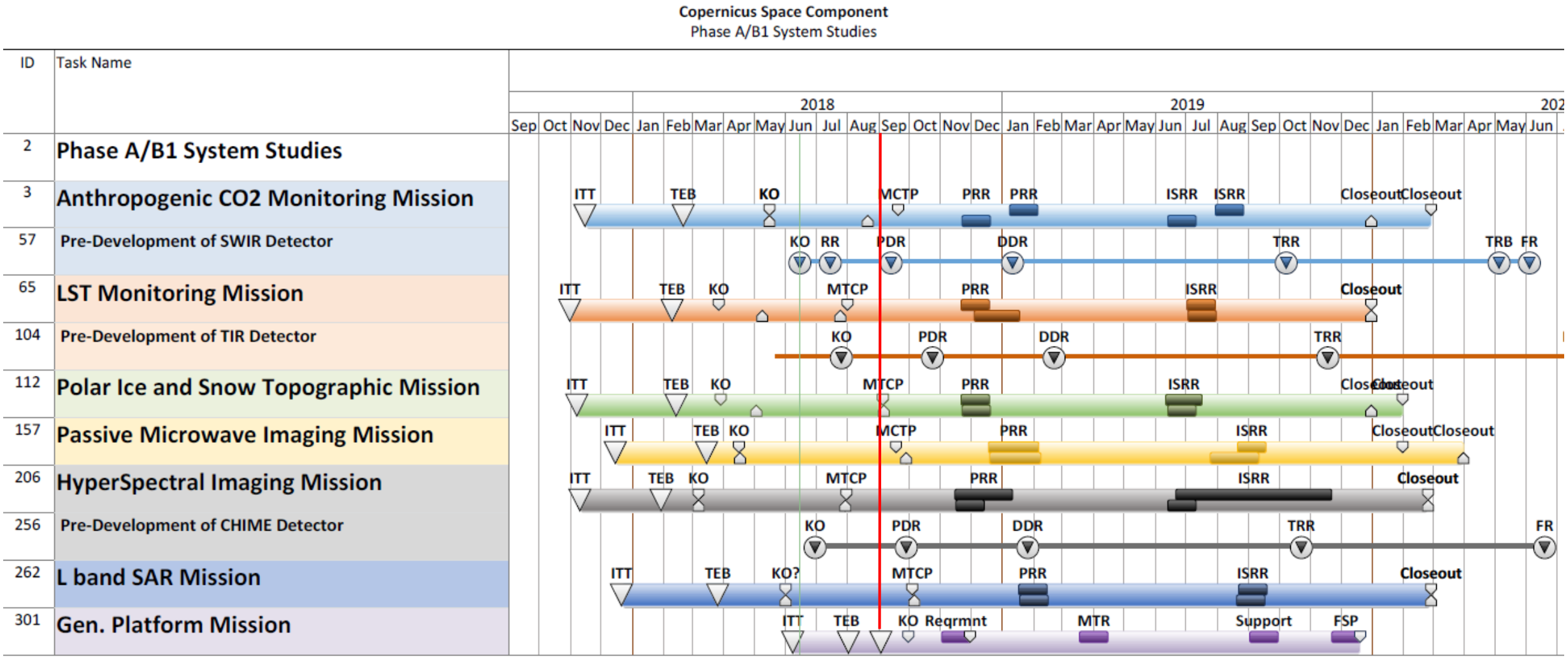
Copernicus Polar Constellation (CPC)



To underpin the Integrated EU Policy for the Arctic <u>different missions are used in synergy to meet all user needs</u>

- **CIMR:** Ocean and Ice foundation data set
- **P-ICE:** Precision SIT over sea ice and land masses (sea level)
- **ROSE-L:** Tactical information for ship routing through the Polar routes

Candidate Sentinels – Ph. A/B1 System Studies



Summary

- The European Copernicus system, including the Copernicus Space Component (CSC), has been established as **the largest and most proficient EO system in the world**

- **A user-driven Long Term Scenario (LTS) is in development** in close consultation with the EC, ESA and EUMETSAT
    - This will define the overall system architecture for the Copernicus Space Component and its evolution based on user requirements coordinated by the EC
    - **Near-term expansion to address High Priority user needs/gaps in existing observations**

- **The future CSC architecture is intended to meet expectations and needs in terms of:**
    - **Stability/Robustness**
    - **Continuity**
    - **Enhanced quantity and quality of CSC products and services**

- The LTS also addresses **emerging and urgent needs** for new types of measurements
    - **HPCM Phase A/B1 studies now I progress**
- The **LTS will continue to evolve**, with regular updates as the definition continues in close and continuous collaboration with all stakeholders

Copernicus

Europe's eyes on Earth

European Commission

EUMETSAT

esa

European Space Agency

Thank you very much for your attention.

Greenland glaciers by S2