# Recent ESA Earth Observation Status Achievements

GEWEX SSG, WMO, Geneva

25 February 2019

Michael Rast

Senior Advisor

ESA Directorate of Earth Observation Programmes

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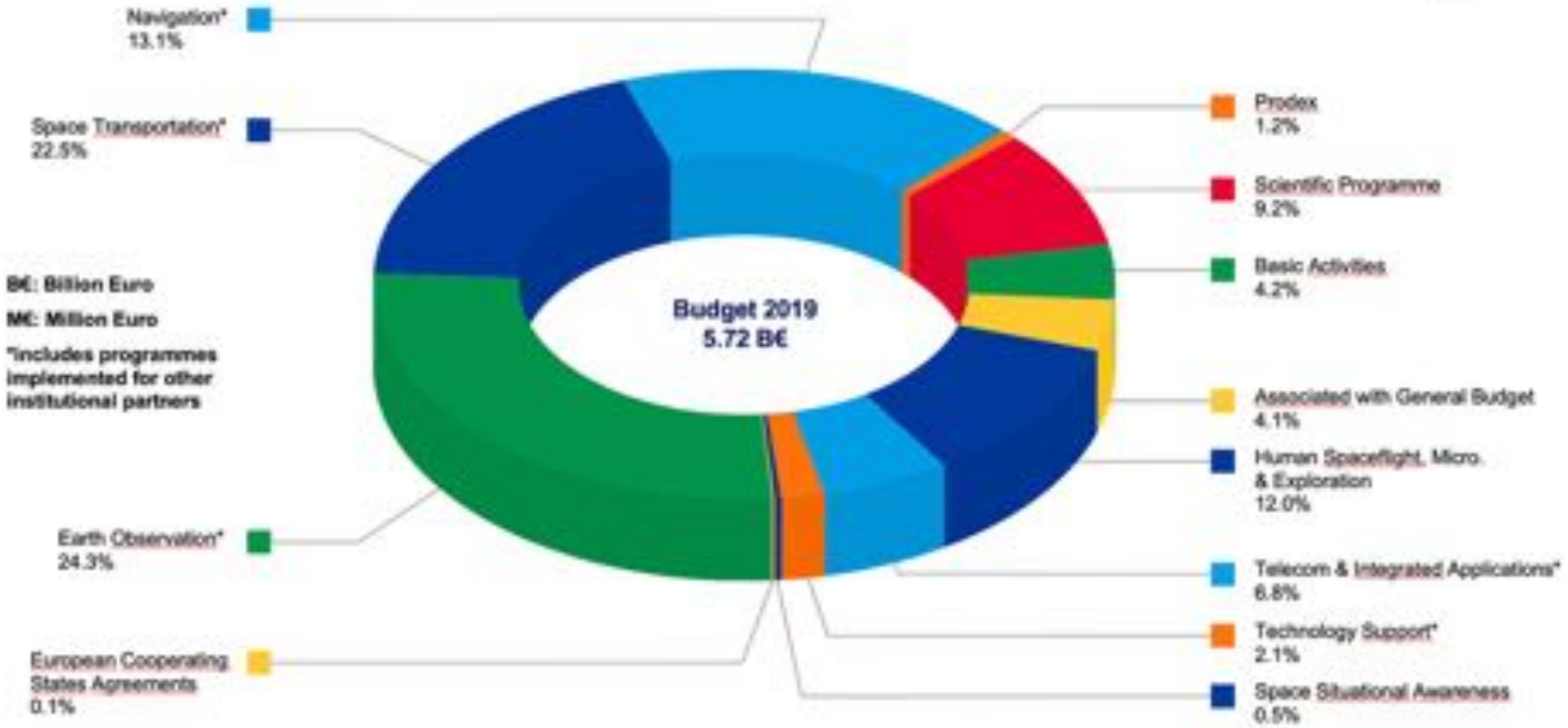
# ESA Vision for EO

## Taking the Pulse of our Planet

# ESA budget by domain for 2019: 5.72 B€

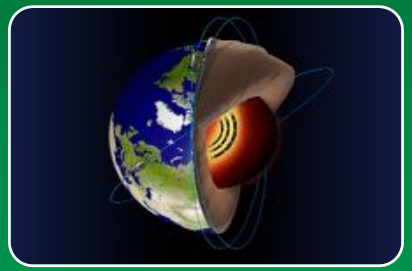


# Devising Earth Observation Missions

## Overall Target Feature: User Driven

### Member States

**Earth Explorers**



Defined by science partners in Member States (Open Calls)

### EU

**Copernicus**

### EUMETSAT

**Meteorology**

### Industry

**InCubed**

- Objectives come from partners & industry
- Mission Definition by ESA with industry, partners & users involved
- InCubed is a new PPP initiative for EO innovation

# ESA Developed Earth Observation Missions

esa

**Satellites**

**25** under development

**15** in operation

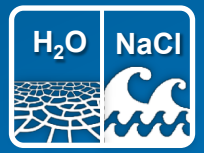
# Science: Earth Explorers

# Earth Explorers as EO S&T Flagships

## Flying Missions

**GOCE**
2009-2013

**SMOS**
2009




**Cryosat**
2010

**Swarm**
2013

**Aeolus**
2018

## Future Missions

**EarthCare**
2021

**Biomass**
2022

**FLEX**
2022

**EE-9**
2025

**2 Cand.**

**EE-10**
2027

**3 Cand.**

**Science & Innovation**

**4.700+ Reg. Users**

**300+ Publ. per Year**

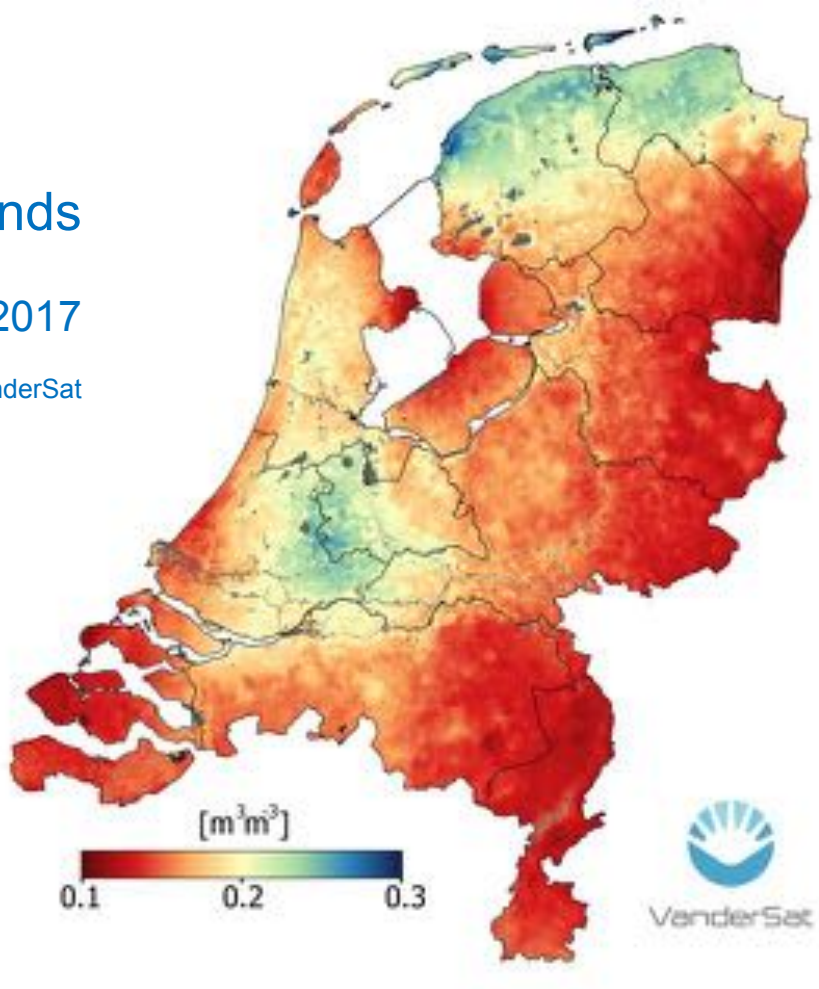
**High Risks for Great Rewards**

# SMOS: Soil Moisture

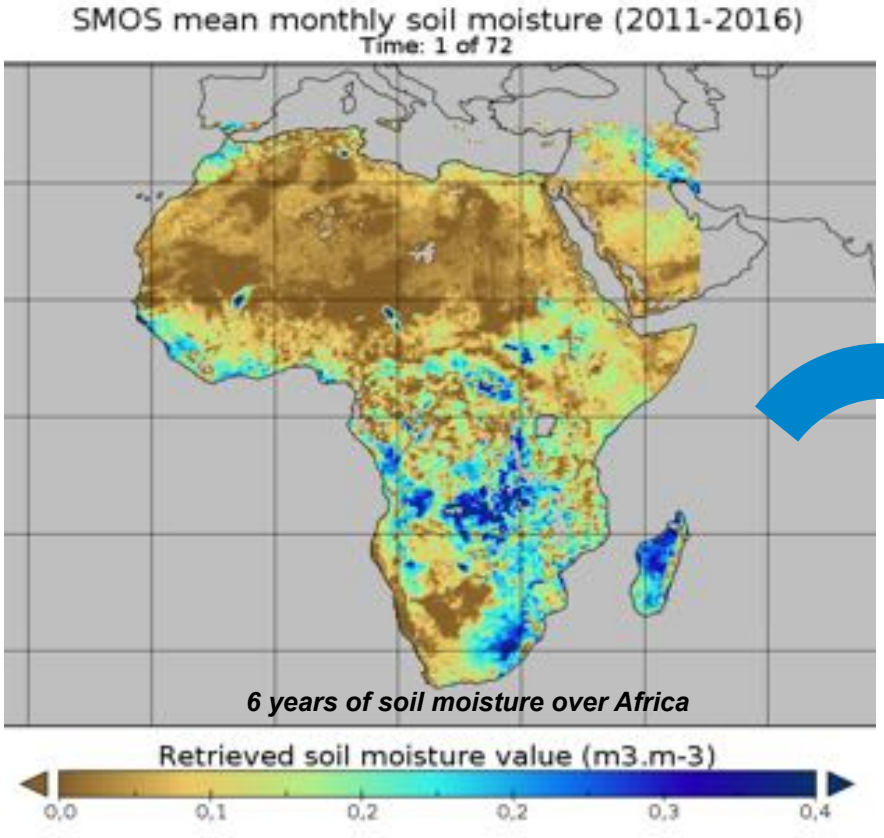
## The Netherlands

June 2017

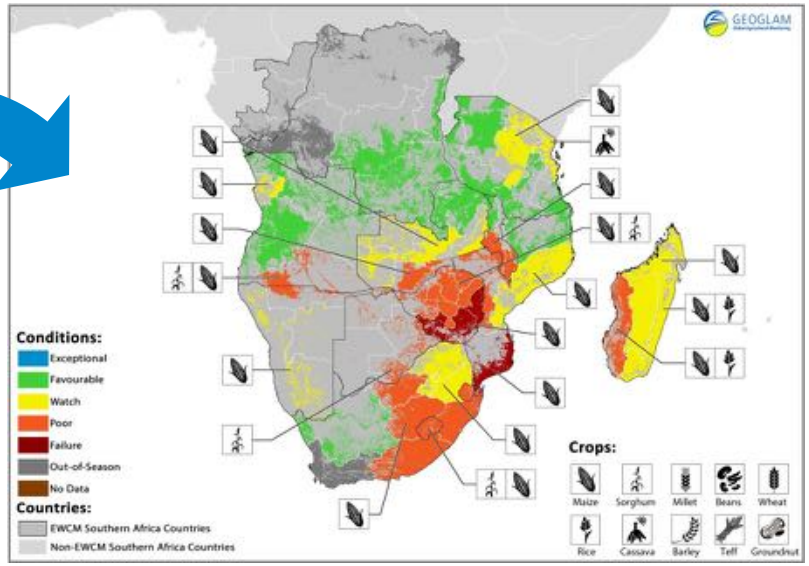
© VanderSat



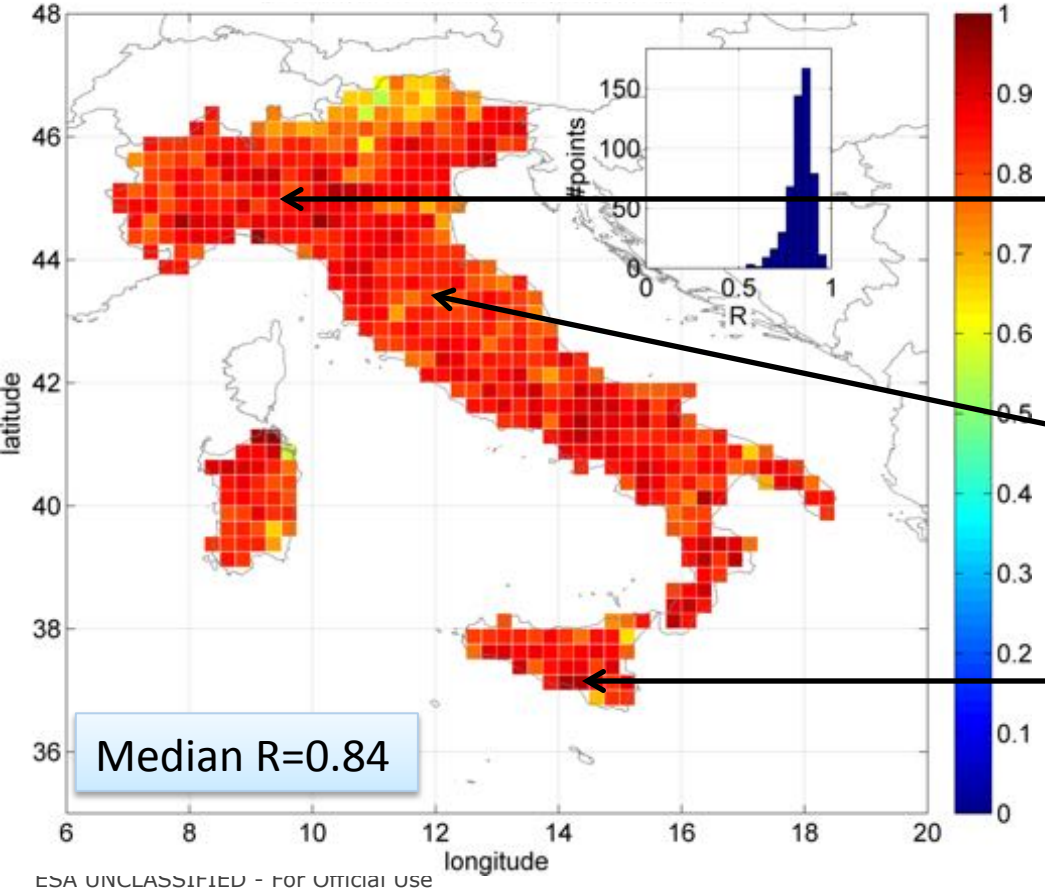
# Soil Moisture for Drought Monitoring



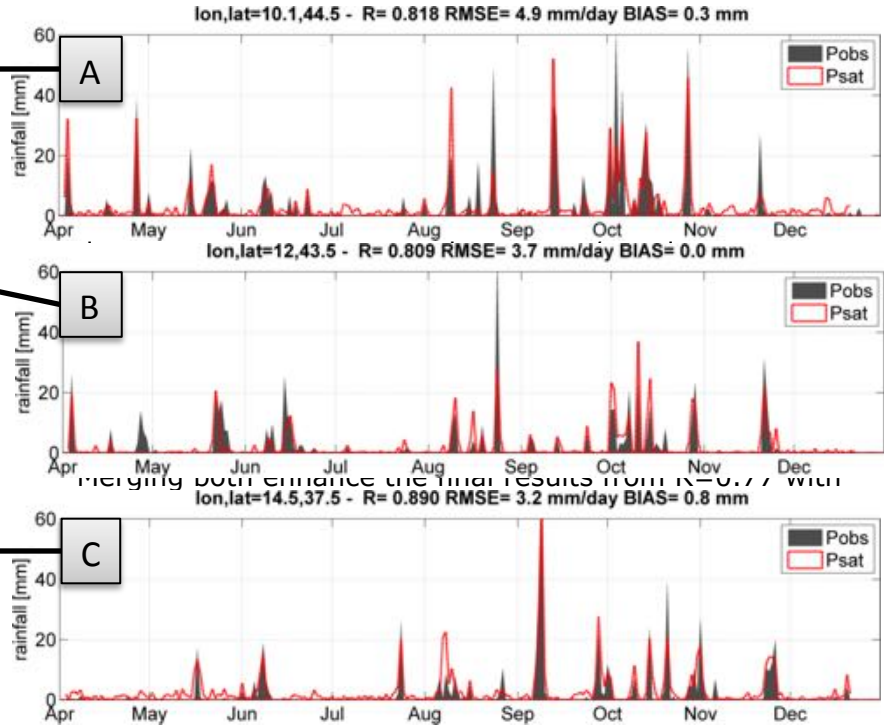

**Anticipated crop failure can be used to predict & prevent famine**



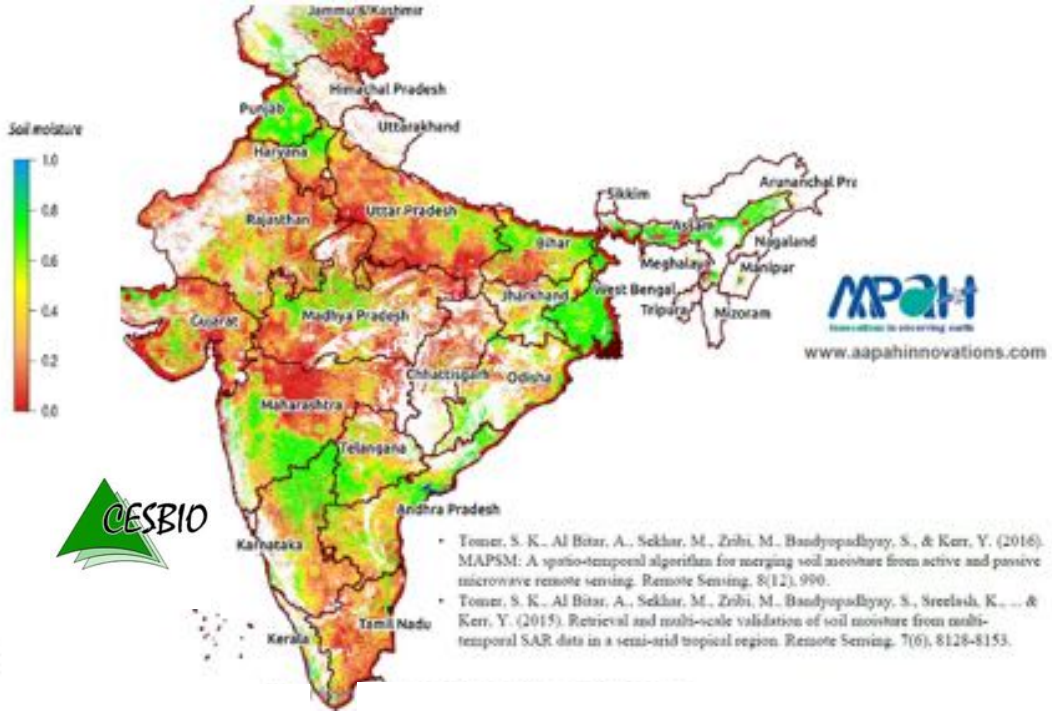
# Estimating Rainfall from Soil Moisture



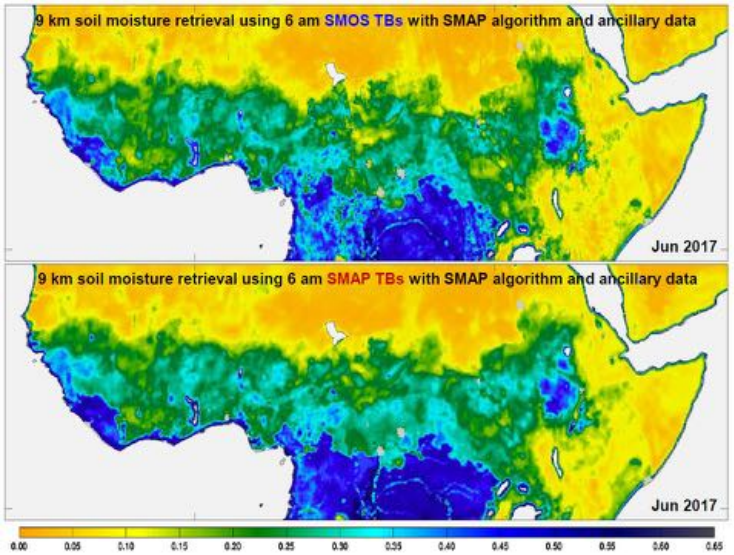

New methods to derive and improve traditional satellite rainfall products using soil moisture have been developed.



# SMOS Developments towards HR



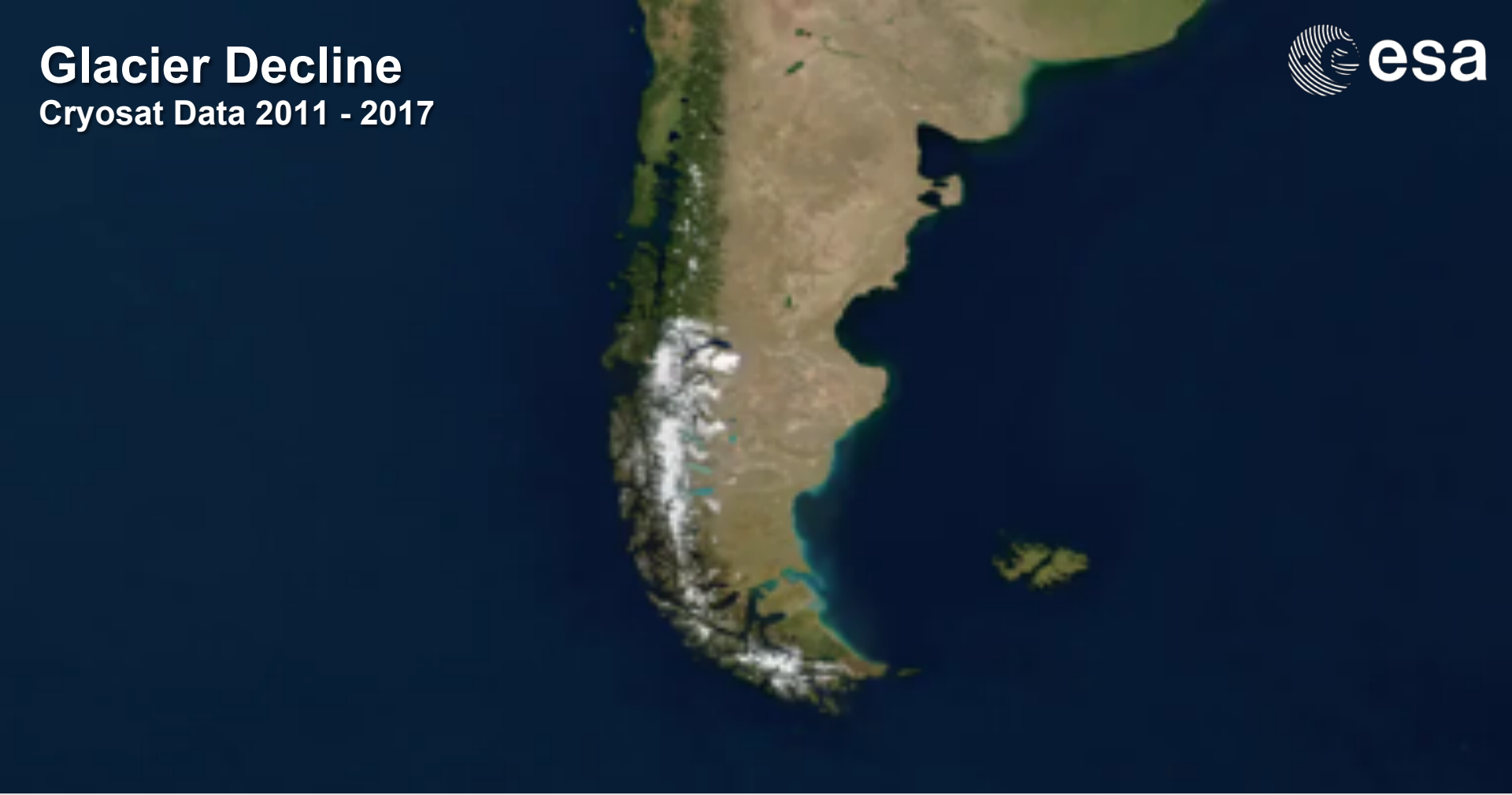

SMOS and S1 HR Soil Moisture 500m. Source: CESBIO




Consistent SMOS and SMAP TBs, algorithm, and ancillary data lead to a new consistent SMOS/SMAP soil moisture product. Source: CESBIO/NASA;

# Glacier Decline

## Cryosat Data 2011 - 2017



esa

The Cryosphere, 11, 451–467, 2017
www.the-cryosphere.net/11/451/2017/
doi:10.5194/tc-11-451-2017
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The Cryosphere | EGU

# Connected subglacial lake drainage beneath Thwaites Glacier, West Antarctica

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[3]IPGS UMR 7516, Université de Strasbourg, CNRS, Strasbourg, France
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Received: 16 July 2016 – Discussion started: 28 July 2016
Revised: 24 November 2016 – Accepted: 3 January 2017 – Published: 6 February 2017

**Abstract.** We present conventional and swath altimetry data from CryoSat-2, revealing a system of subglacial lakes that drained between June 2013 and January 2014 under the central part of Thwaites Glacier, West Antarctica (TWG). Much of the drainage happened in less than 6 months, with an apparent connection between three lakes spanning more than 130 km. Hydro-potential analysis of the glacier bed shows a large number of small closed basins that should trap water produced by subglacial melt, although the observed large-scale motion of water suggests that water can sometimes locally move against the apparent potential gradient, at least during lake-drainage events. This shows that there are important limitations in the ability of hydro-potential maps to predict subglacial water flow. An interpretation based on a map of the melt rate suggests that lake drainages of this type should take place every 20–40 years, depending on the connectivity of the water flow at the bed. Although we observed an acceleration in the downstream part of TWG immediately before the start of the lake drainage, there is no clear connection between the drainage and any speed change of the glacier.

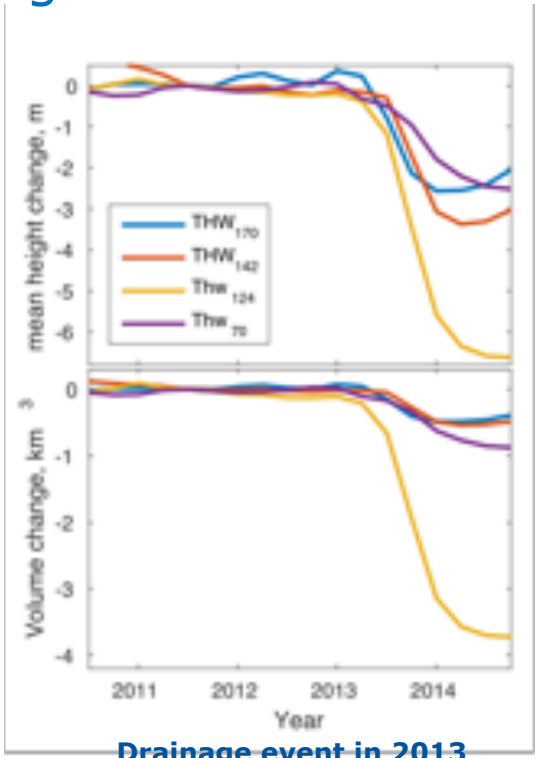
## 1 Background

The Amundsen Sea embayment is one of the fastest-changing part of Antarctica, with large changes since at least the 1990s (Rignot, 2008). Increased flow of Thwaites Glacier (TWG) is responsible for around half of the ice-sheet mass loss from this sector (Medley et al., 2014); in response to these large changes, NSF's AGASEA and NASA's Ice-Bridge programmes have flown extensive surveys measuring ice thickness and bed elevation in this area, with the twin goals of measuring mass-balance changes and enabling accurate ice-flow modelling for the region. As a result, the bed of TWG has been mapped in detail, allowing mapping of basal shear stress and potential subglacial water-flow paths. These reveal abundant basal meltwater production, estimated at about 3.5 $km^3 yr^{-1}$ and averaging ~ 19 mm $yr^{-1}$ (Joughin et al., 2009). Melt production is concentrated in the fast-flowing lower trunk of the glacier but is locally larger than 20 mm $yr^{-1}$ even in some regions within the slow-flowing catchment. Interpretation of radar-reflection properties has also led researchers (Schroeder et al., 2013, 2015) to identify an upstream region where water may drain through a persistent, distributed network of high-aspect-ratio canals and a downstream region drained by larger canals that concentrate water into a small area. The combination of radar observations and estimated melt rates led to a map of geothermal heat flux, based on the assumption that the basal water system was in equilibrium with steady-state melt rates (Schroeder et al., 2014). Further, the spatial correlation between relatively high driving stress in the lower trunk and the hypothesized channelized drainage system has led to speculation that the character of the basal water system plays a role in the stability of the glacier and that changes in this water system could lead to accelerated grounding-line retreat (Schroeder et al., 2013).

Active subglacial lakes (lakes that drain or fill over the course of a few years or less) have been identified throughout Antarctica (Smith et al., 2009). Well-documented lake sys-

Published by Copernicus Publications on behalf of the European Geosciences Union.

# ub-glacial lakes



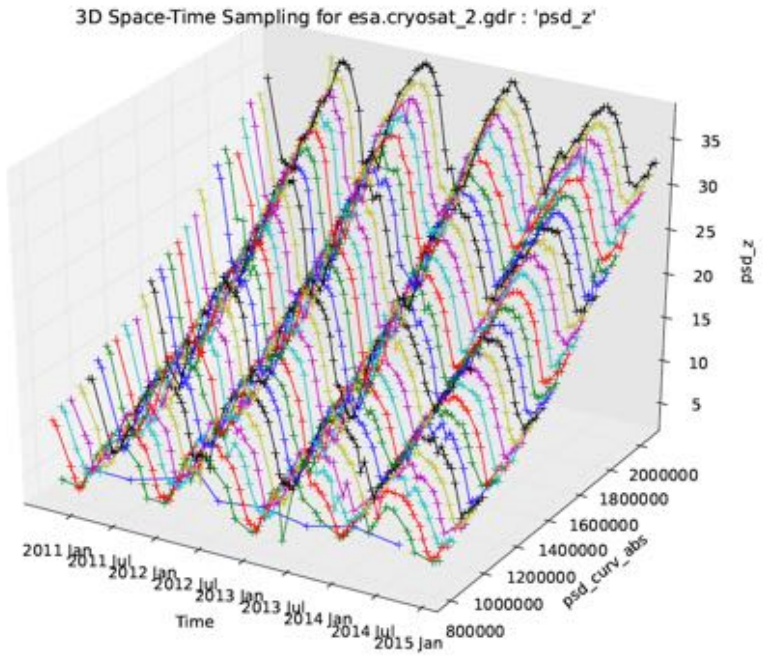

**Drainage event in 2013**
The centres of the features are approximately 70, 124, 142, and 170 km upstream of the grounding line

Peak discharge of 240 $m^3$ per second

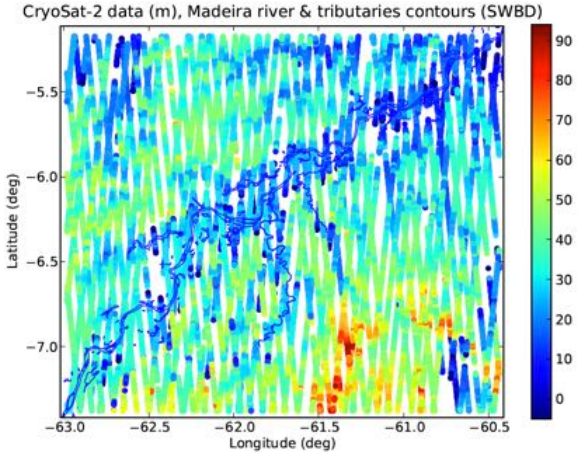
Much of the drainage happened in less than 6 months, with an apparent connection between three lakes spanning more than 130 km.

# River Level from CryoSat

## Space & time 3D




## Map of CryoSat-2 measurements




Madeira River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# Antarctica Ice Melting Impact

## Ice Loss (billion tonnes per year)

| | 1990s | | 2010s |
|---|---|---|---|
| West-Antarctic | $53_{\pm 29}$ | ➡ | $159_{\pm 26}$ |
| Antarctic Peninsula | $7_{\pm 13}$ | ➡ | $33_{\pm 16}$ |

© Nature
June 2018

# EarthCARE Contribution to the Water Cycle

Mission Objective:

Impact of Clouds and Aerosols on Radiation

Observations:

Cloud profiles, cloud coverage, precipitation,

aerosol profiles, broad-band solar & thermal radiation

Satellite:

- Sun-sync. orbit at 393 km, 14:00 hours desc.node
- UV Lidar with high spectral resolution receiver
- W-band Cloud Radar with Doppler (contribution JAXA)
- Imager and Broad-Band Radiometer

# EarthCARE Contribution to the Water Cycle

Data Products:

Clouds:

- Vertically resolved profiles of ice water content and liquid water content
- particle fall speed, melting layer

Precipitation:

- Rain (notably, also light rain)
- Snow (notably, also over high & polar latitudes)

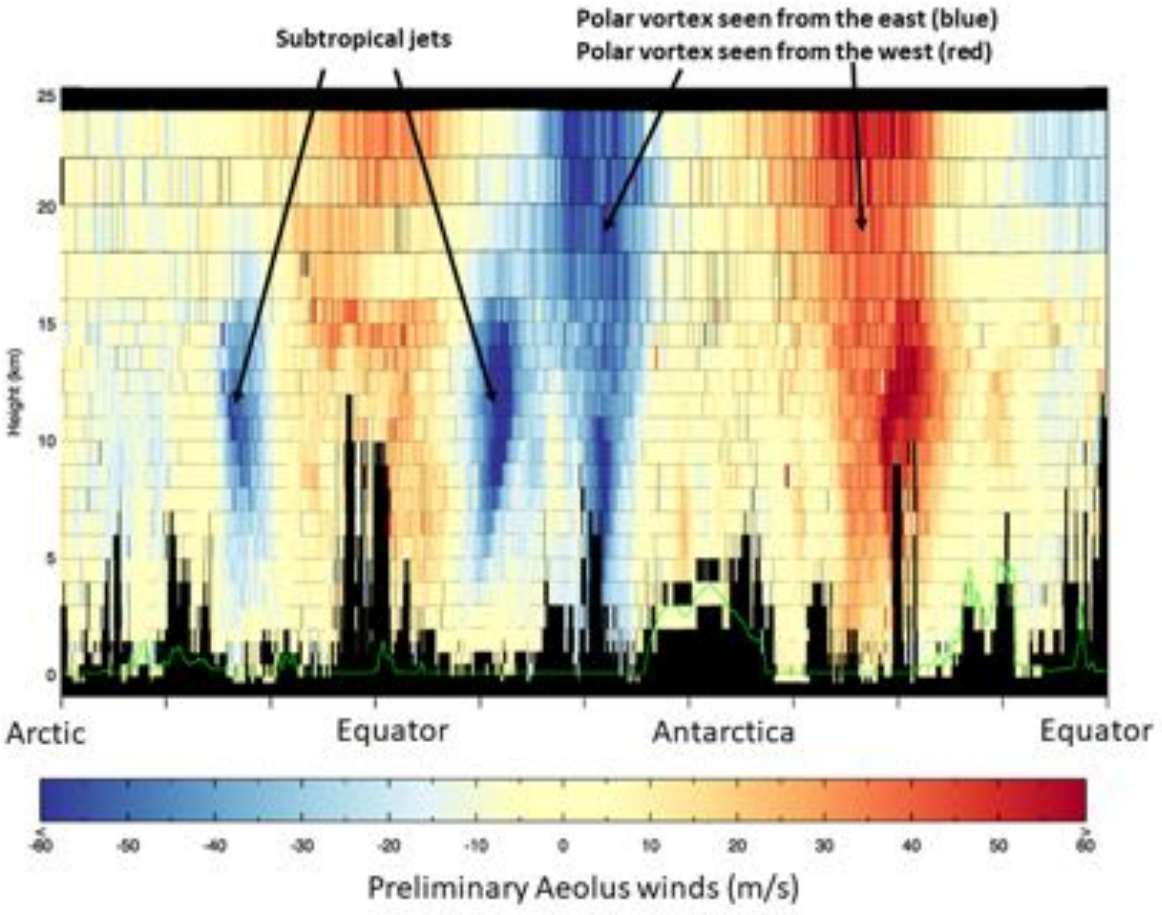
Aerosol Profiles …

Radiation Products …

Mission Status

- Presently in Phase D
- Acceptance Review 2022

# Aeolus




12 September 2018

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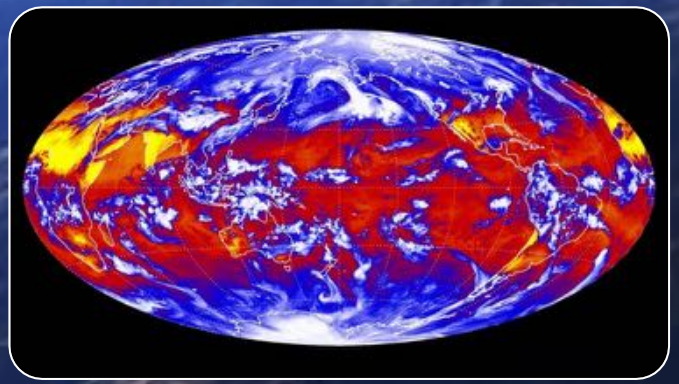
# Earth Explorer 9 – Two Candidates

Launch around 2025

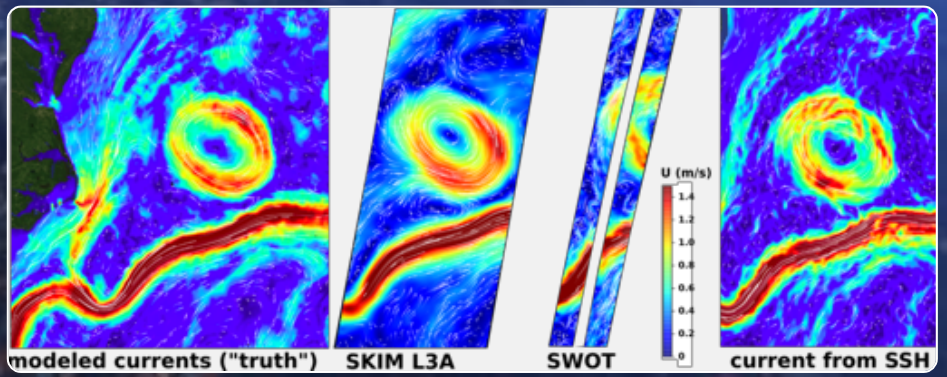
## FORUM

Greenhouse Effect / Climate Change



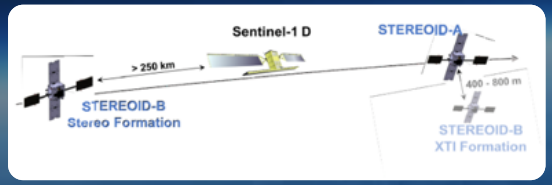
## SKIM

Ocean Surface Currents



# Earth Explorer 10 – Three Candidates

## STEREOID

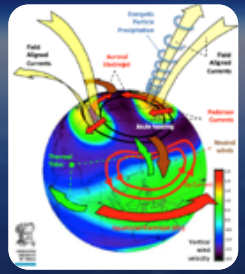



Bistatic SAR as passive followers of Sentinel-1
Two <500kg spacecraft

**Applications**

- Cryosphere
- Oceanography
- Geosphere

## Daedalus



Explore mesosphere, lower thermosphere & Ionosphere

Four cubesats at 120 km altitude

Focus on temperature, heating processes & composition structure

## G-CLASS: $H_2O$

Science on daily water cycle

Geostationary C-band SAR

Benefits for weather forecasting, hydrology, mountain cryosphere

# Copernicus Sentinel Status

## 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 | 2022 |
| 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 |

# Copernicus – global leadership in EO

**> 200.000**
registered users
= tip of the iceberg

## 6 operational services

Land | Atmosphere | Ocean | Climate | Disaster | Security

**150 TB** satellite data distributed per day

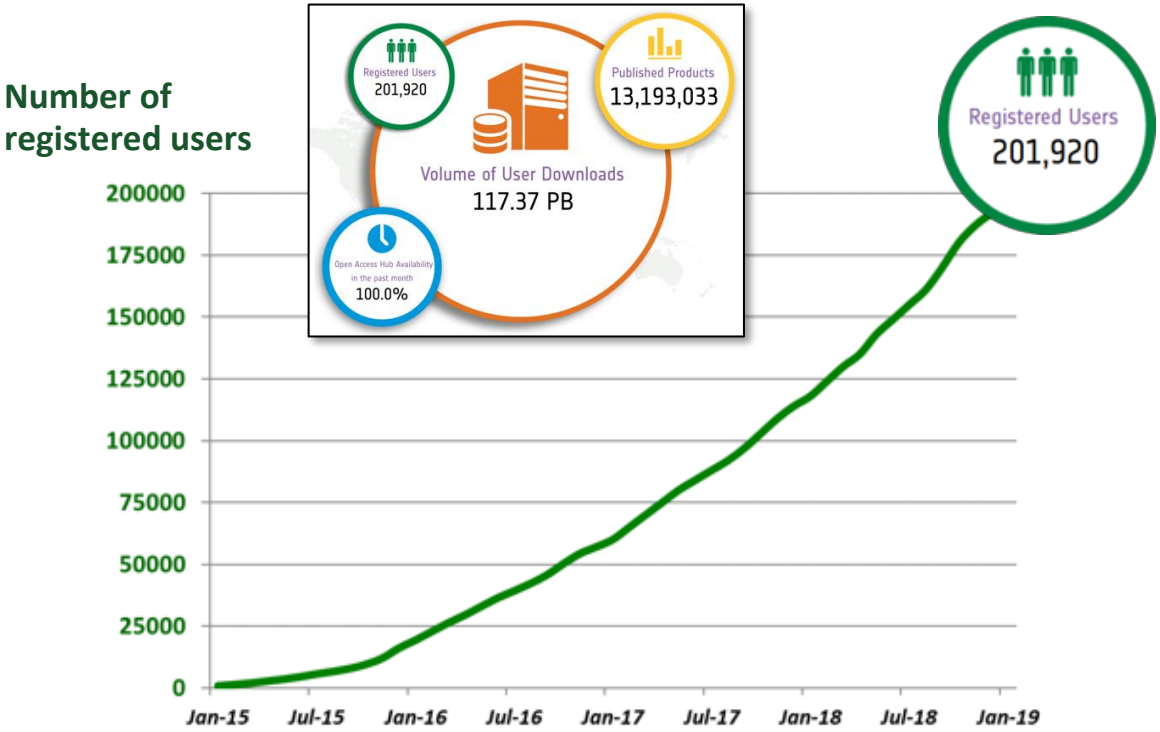
**full, free & open** data policy

## 7 satellites flying

S1 | S2 | S3 | S4 | S5P | S5 | S6

## preparing Copernicus 2.0

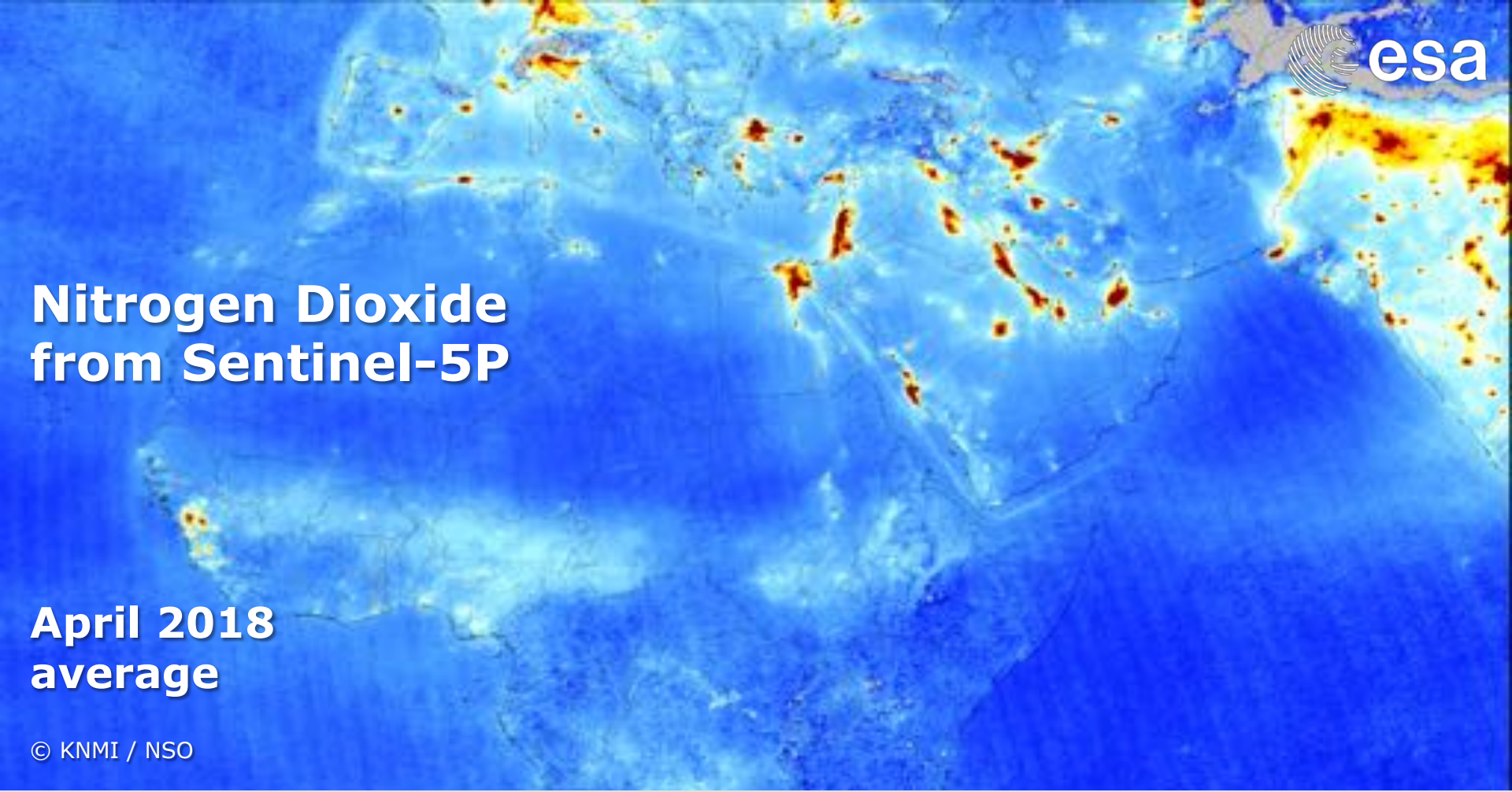
# Evolution of registered users on Sentinel Open Access Hub

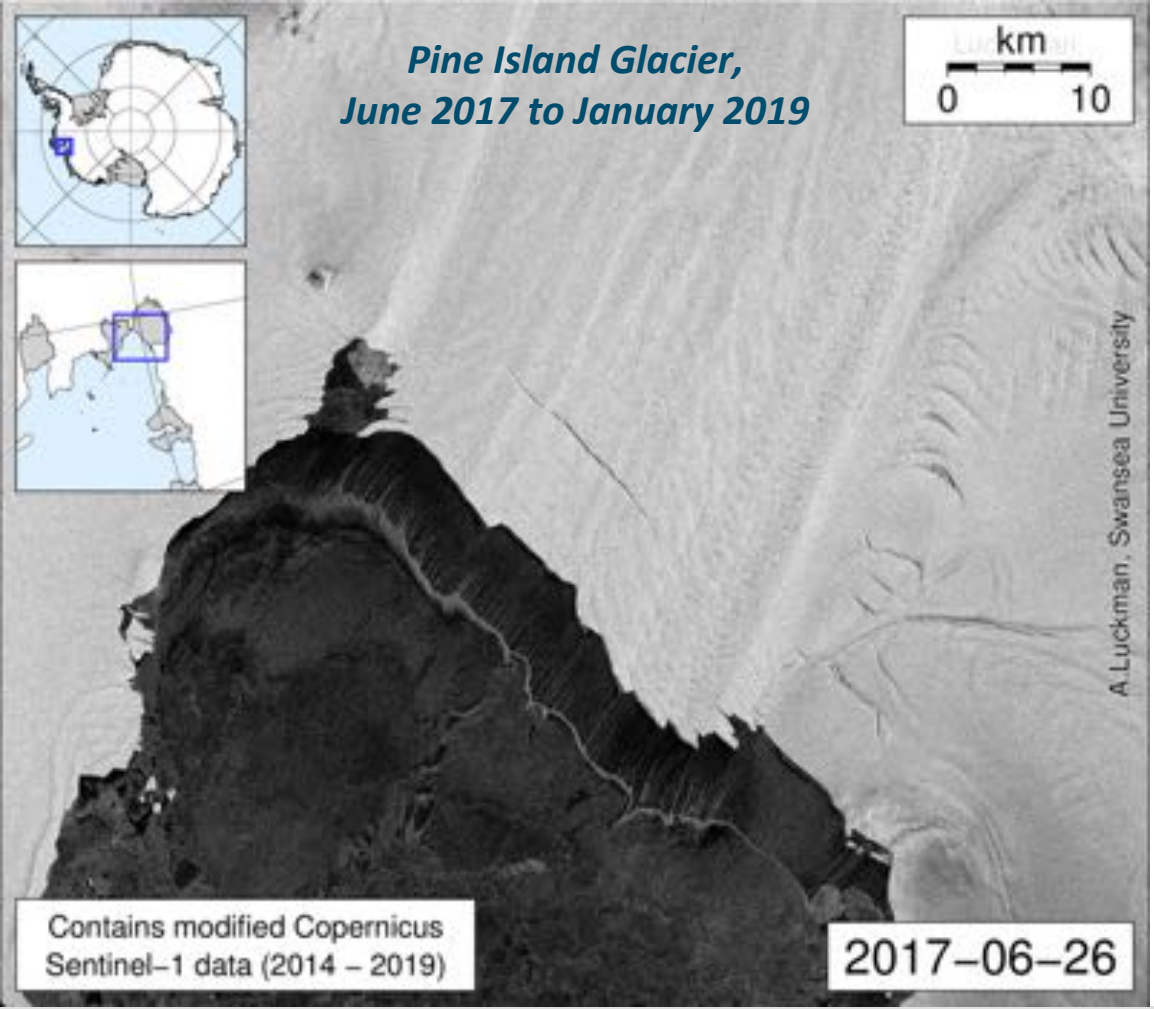



*Statistics at beginning February 2019*

*Now access to data of first 7 Sentinel satellites*

- sentinel-1a
- sentinel-1b
- sentinel-2a
- sentinel-2b
- sentinel-3a
- sentinel-3b
- sentinel-5p


esa
Nitrogen Dioxide
from Sentinel-5P
April 2018
average
© KNMI / NSO




# Sentinel-1 mission status

- Sentinel-1A and Sentinel-1B mission operations → **nominal**
- Sentinel-1 **contribution to emergency activations**, in particular from the Copernicus Emergency Management Service, continues to be very high

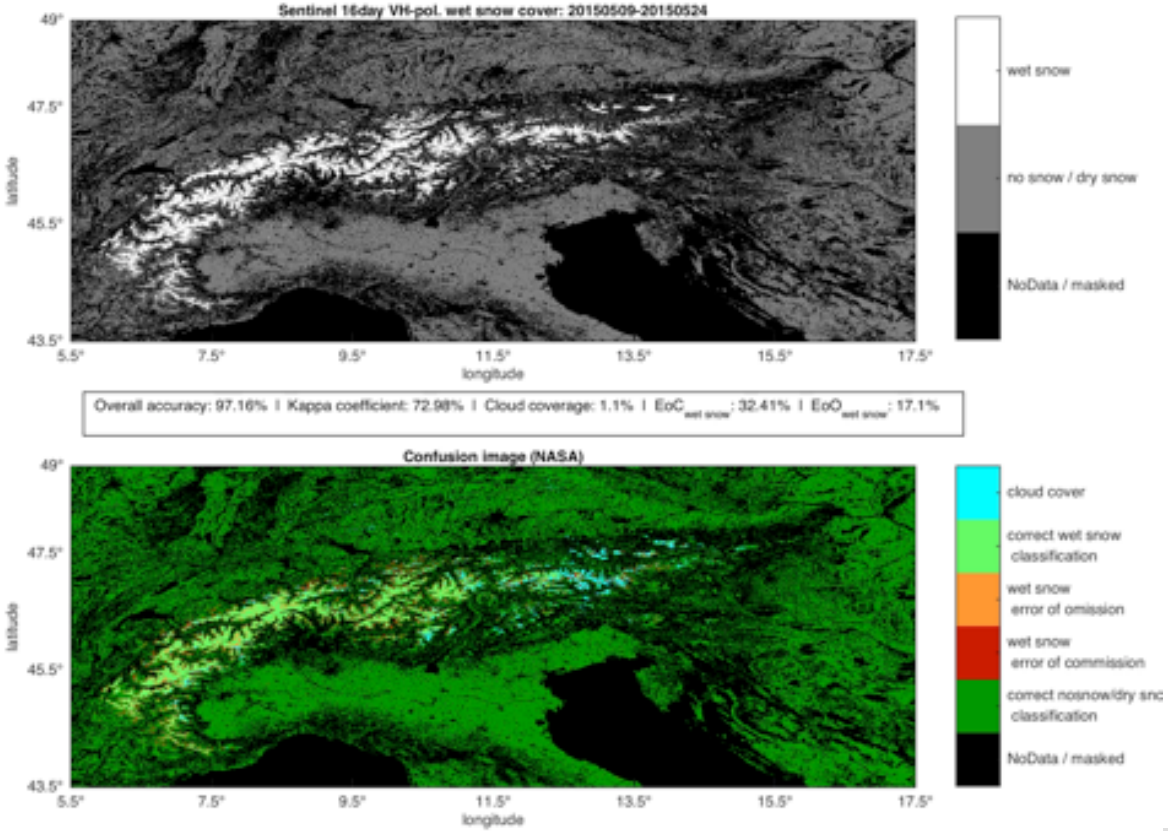
*Pine Island Glacier:*
*18 months of flow and calving*
*https://adrianluckman.wordpress.com*

# S1A Alps Wet Snow Maps

Contains modified Copernicus Sentinel data (2015)

S1A IW 2015
VH & VV-pol.

S1-based wet snow classifications compared with 16 day NASA MODIS snow product (MOD10A2)

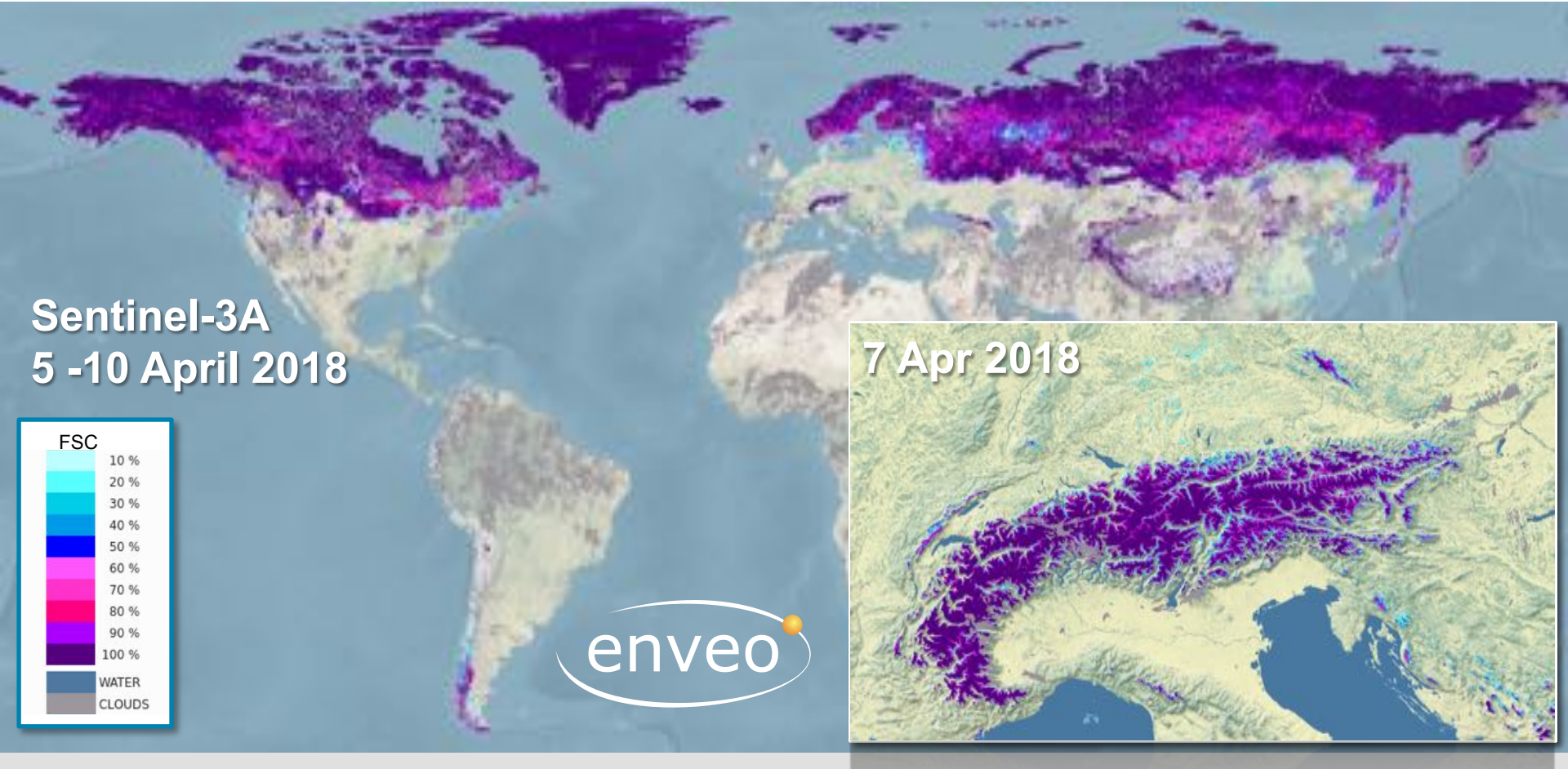



M.Sc.
D. Jäger, 2016,
Univ. Zürich

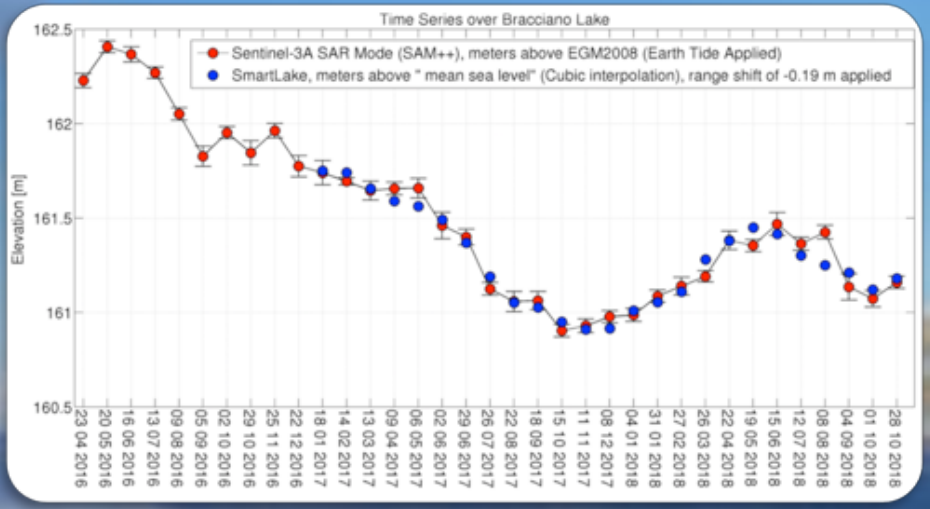


European Space Agency

# Snow Extent


Sentinel-3A
5 -10 April 2018
FSC
10 %
20 %
30 %
40 %
50 %
60 %
70 %
80 %
90 %
100 %
WATER
CLOUDS
enveo
7 Apr 2018

# Water Level Changes


## Lake Bracciano, Italy
## Summer 2017 Drought

Based upon Copernicus Sentinel-2 and Sentinel-3

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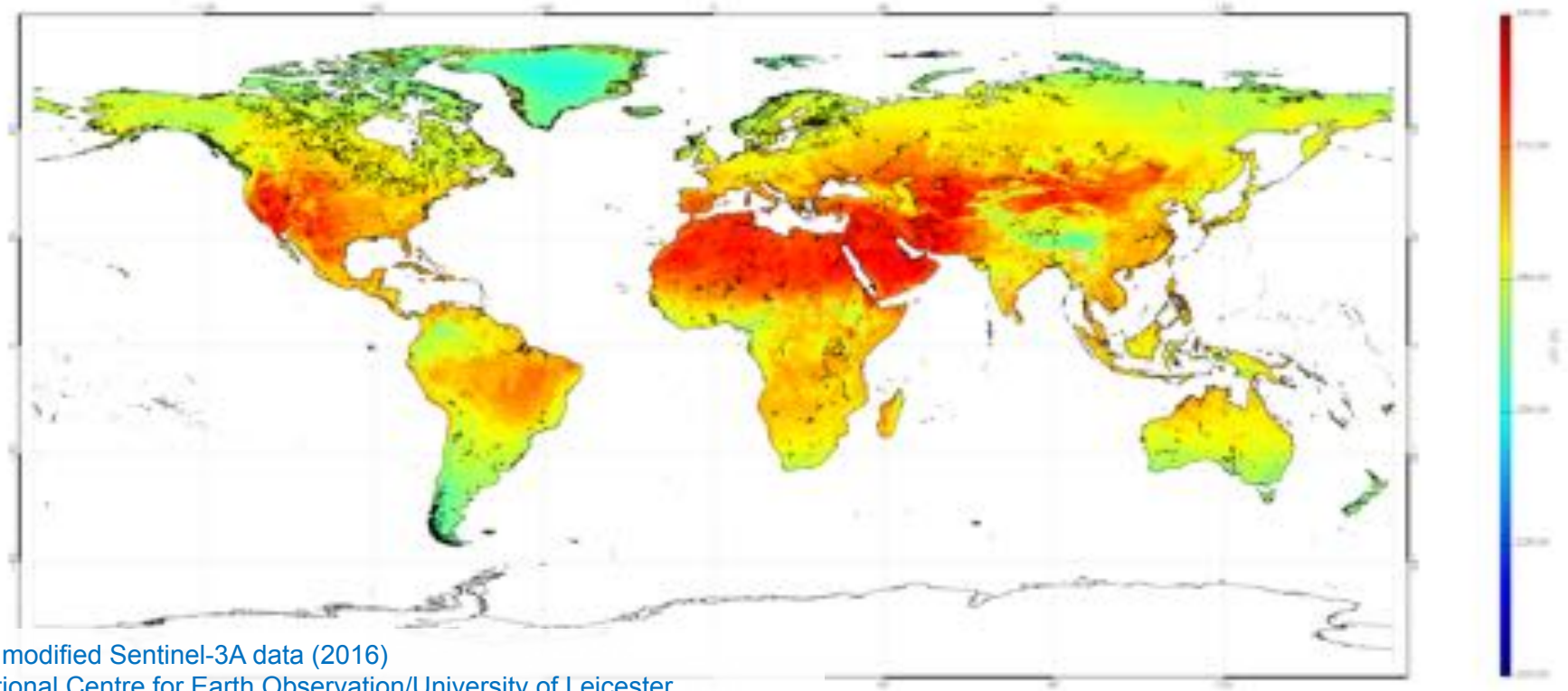
# Sentinel-2A: Mapping Water Bodies

# Land Surface Temperature



Contains modified Sentinel-3A data (2016)
© UK National Centre for Earth Observation/University of Leicester

# Copernicus 2.0 – New Monitoring Missions

## Six High Priority Candidate Missions
### Progress Status

- Preliminary Requirements Review concluded successfully for all 12 Phase A/B1 studies
- Consolidation of inputs for preparation of ESA ITTs for Phase B2/C/D/E1 contracts

cci

esa


sea ice cci


glaciers cci


antarctic ice sheet cci


greenland ice sheet cci


land cover cci


fire cci


soil moisture cci


aerosol cci


cloud cci


ghg cci


ozone cci


sea level cci


ocean colour cci


sst cci


biomass cci


high resolution land cover cci


lakes cci


land surface temperature cci


permafrost cci


salinity cci


sea state cci


snow cci


water vapour cci

# EO in a World of Disruption – 3 Megatrends

## Our Changing Planet

**New & Increased EO Monitoring Needs & Requirements**

## Tech & EO Revolution

**Need for end-to-end EO system architecture approach**

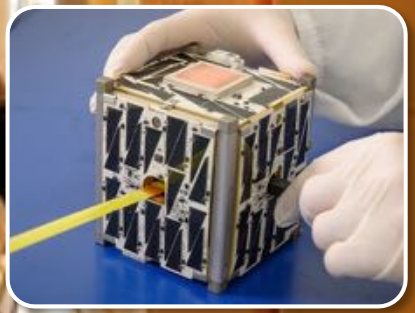
## Data-Driven Economy

**Demand for user-driven EO Services & Applications**

# Φ-lab as Catalyst

"Introducing disruptive innovation into European EO"

HAPS



NanoSats

Mega-constellations

AI for EO

# Engaging the International Science Community

# Thank you for your attention!

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