The Earth Observation Programmes of ESA: Achievements, Evolutions, Challenges

Avionics, Data, Control and Software Systems (ADCSS)

Presented by P. Silvestrin (EOP-ΦM, EO Future Missions and Instruments Div.)

19-Oct-2017

Contents

ESA EO programmes: research missions (Earth Explorers), Copernicus (Sentinels), meteorological missions

- state-of-the-art, snapshots of results
- evolution with 2030 time horizon

Paradigm shifts (towards supporting commercial sector)

- complementing institutional missions

Challenges and needs:

- miniaturisation, higher integration, development time & cost reduction
- how can the avionics community help ?

ESA Earth Observation Missions

Colour Code:
Launched
To be launched

Living Planet

Earth Explorer
Research driven

Core Missions

GOCE
2009-2013


Aeolus
Jun 2018

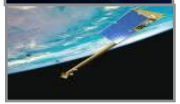

EarthCARE
2019


Biomass
(EE7) 2021

Opportunity

CryoSat-2
8 April 10


SMOS
2 Nov 09


Swarm
22 Nov 13

Fast Track

FLEX (EE8)
2022

Call EE9 –
Select. for Ph.A
(Nov-2017)

Earth Watch
Operational Service driven
In partnership

Meteorology

Meteosat


MSG - GEO
(1 s/c x 4)


MetOp
1 s/c x 3)


MTG - GEO
(2 s/c x 3)


MetOp SG
(2 s/c x 3)

Copernicus

Sentinel 1 a/b/c/d


Sentinel 2 a/b/c/d


Sentinel 3 a/b/c/d


Sentinel 4 (on MTG)


Sentinel 5 precursor


Sentinel 5 (on MetOp SG)


Sentinel 6 (Jason)

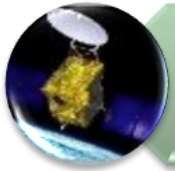
EO research missions: approved Earth Explorers (EE)

NB: research missions include also Missions of Opportunity (e.g. planned cooperation ESA-NASA for gravity monitoring)

Core Missions

GOCE (2009–13)
Earth's gravity field

ADM-Aeolus (2017)
global winds



EarthCARE (2018)
Earth's clouds, aerosols and radiation (ESA/JAXA)

Biomass (2021)
Earth's carbon cycle

Opportunity & Fast Track

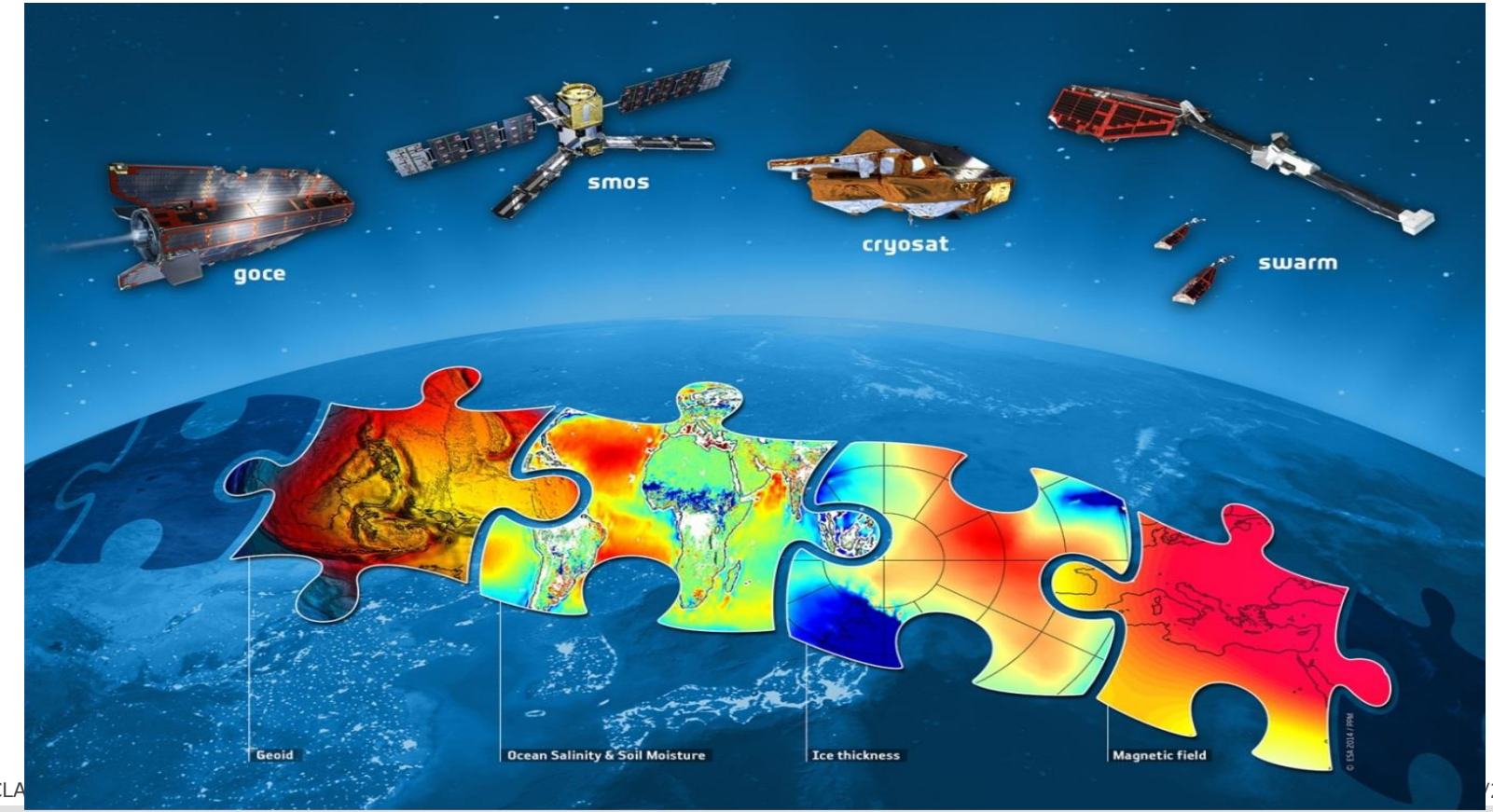
SMOS (2009–)
Earth's water cycle

CryoSat-2 (2010–)
polar ice elevation

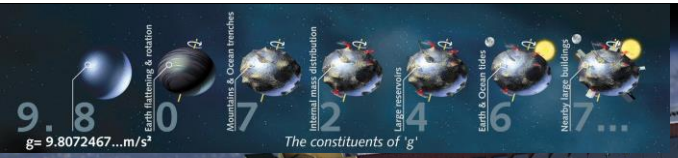
Swarm (2013–)
three satellites, Earth's magnetic field

FLEX (2022)
photosynthesis

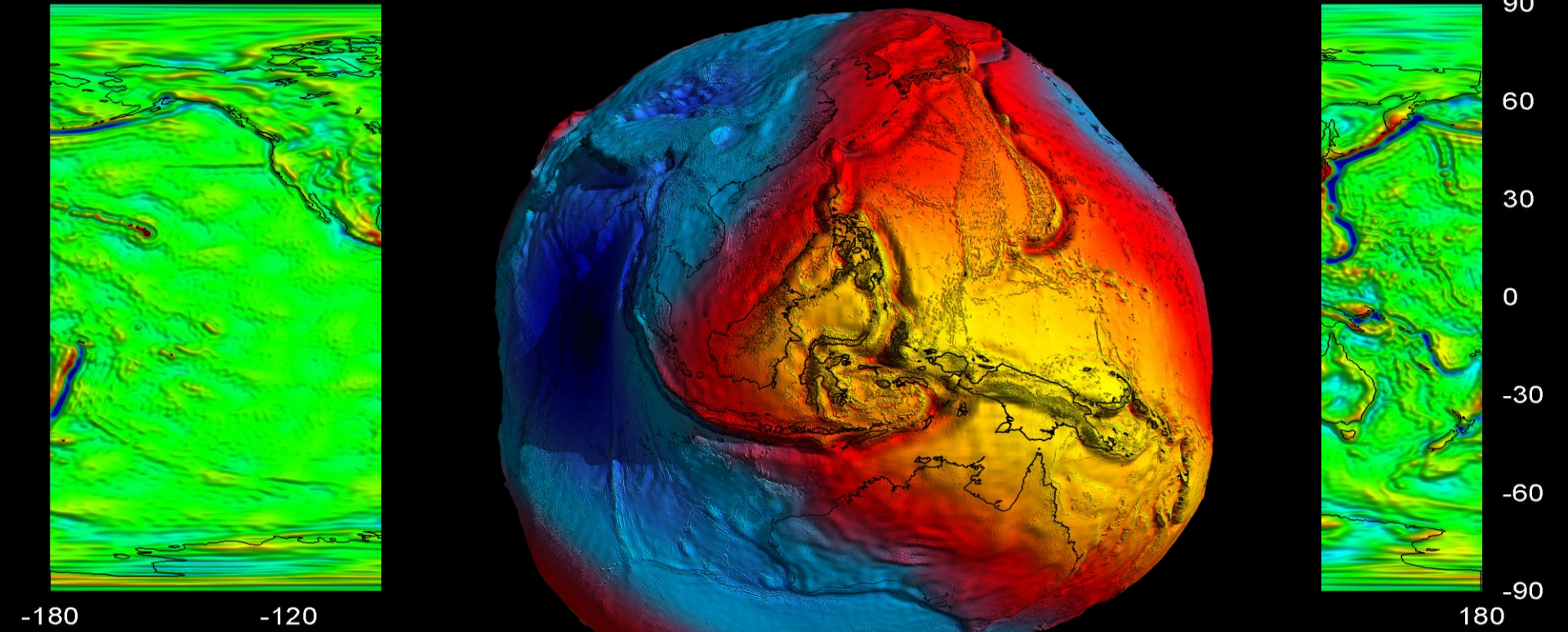
Earth Explorers launched so far



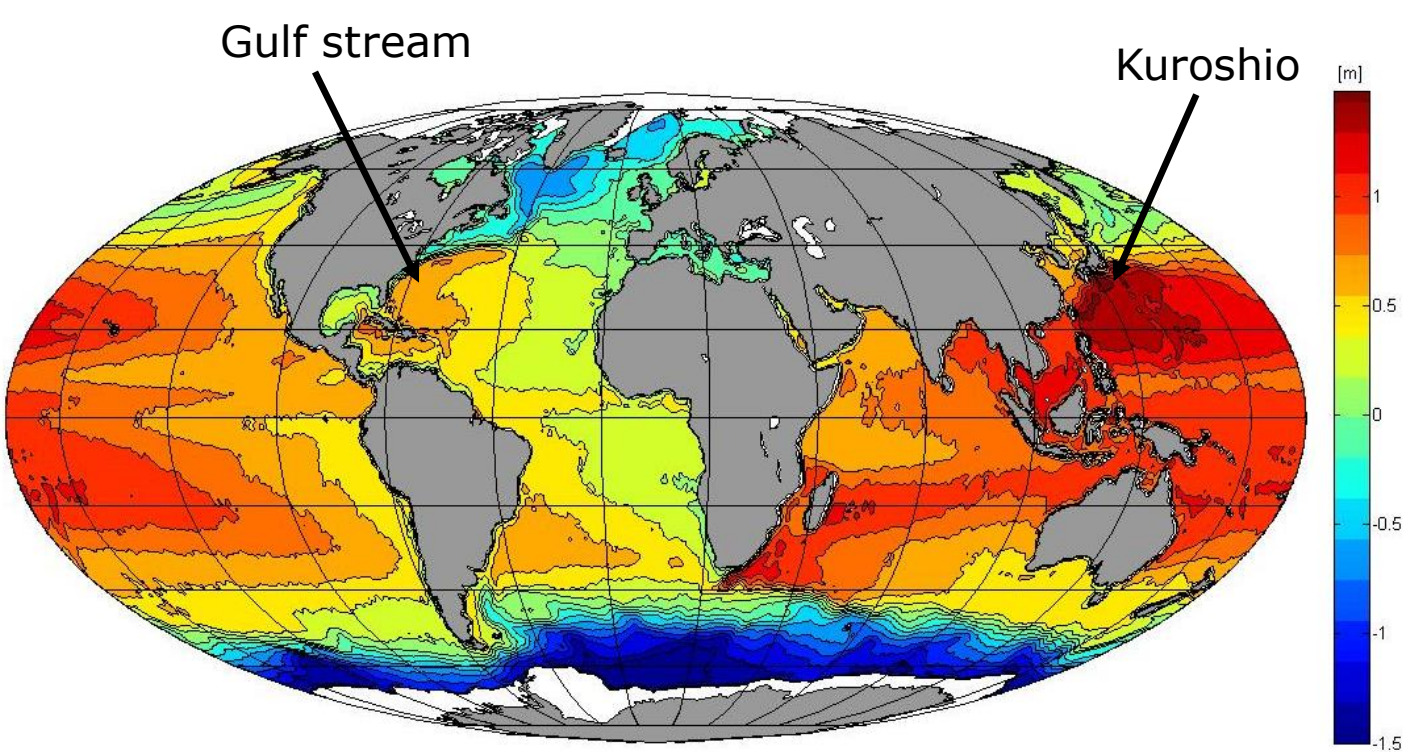
GOCE: Gravity field and steady-state Ocean Circulation Explorer



Global Geoid f



From Global Mean Ocean Currents (from GOCE and Altimetry)…

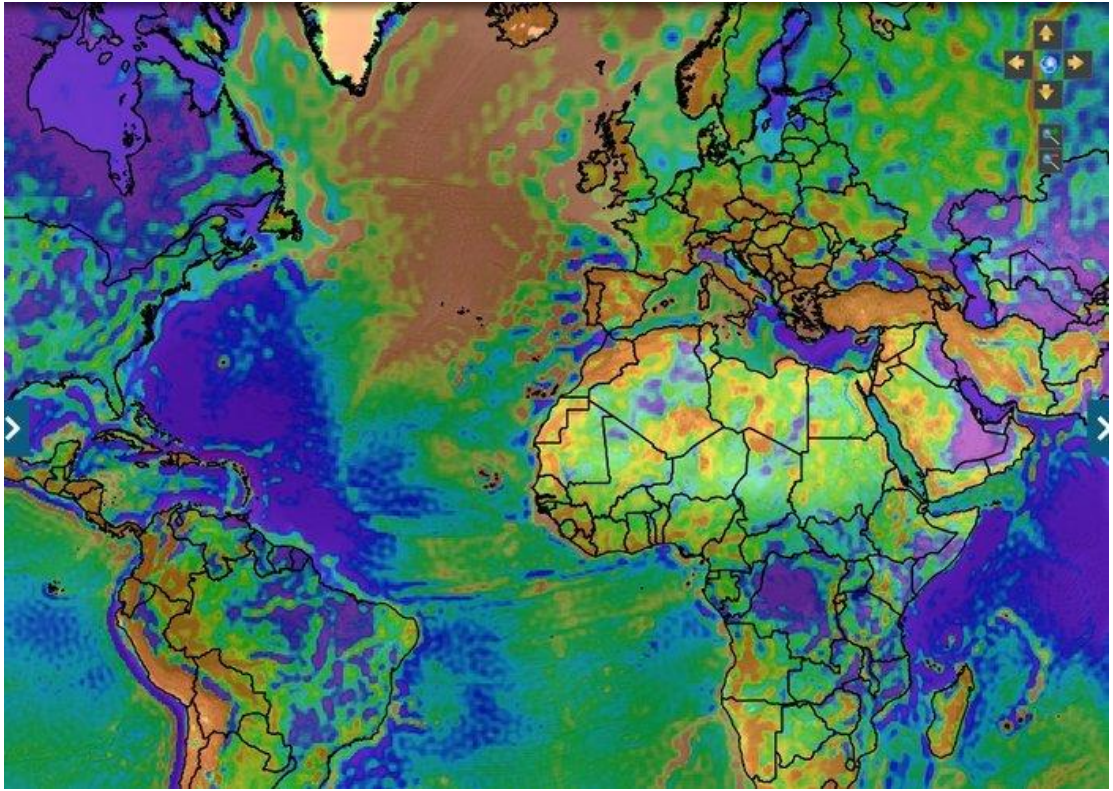


Altimetry derived mean sea surface when combined with geoid gives the "mean dynamic topography" (MDT)

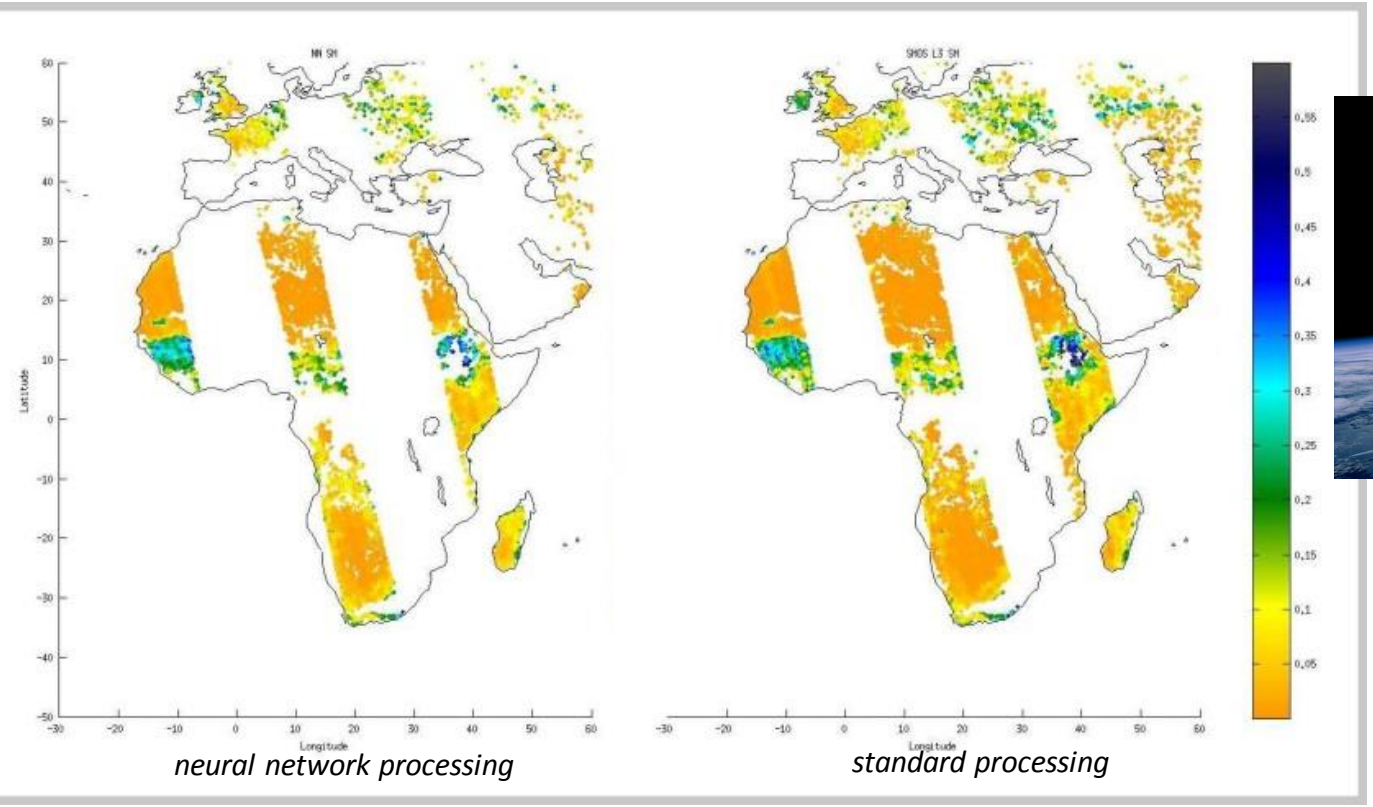
MDT = relief or shape of the ocean surface corresponding to mean ocean circulation

GOCE contributes to the fundamental understanding of role of global ocean circulation in distributing heat and freshwater/salt

… to geothermal energy mapping



SMOS: Soil Moisture, processed in two ways

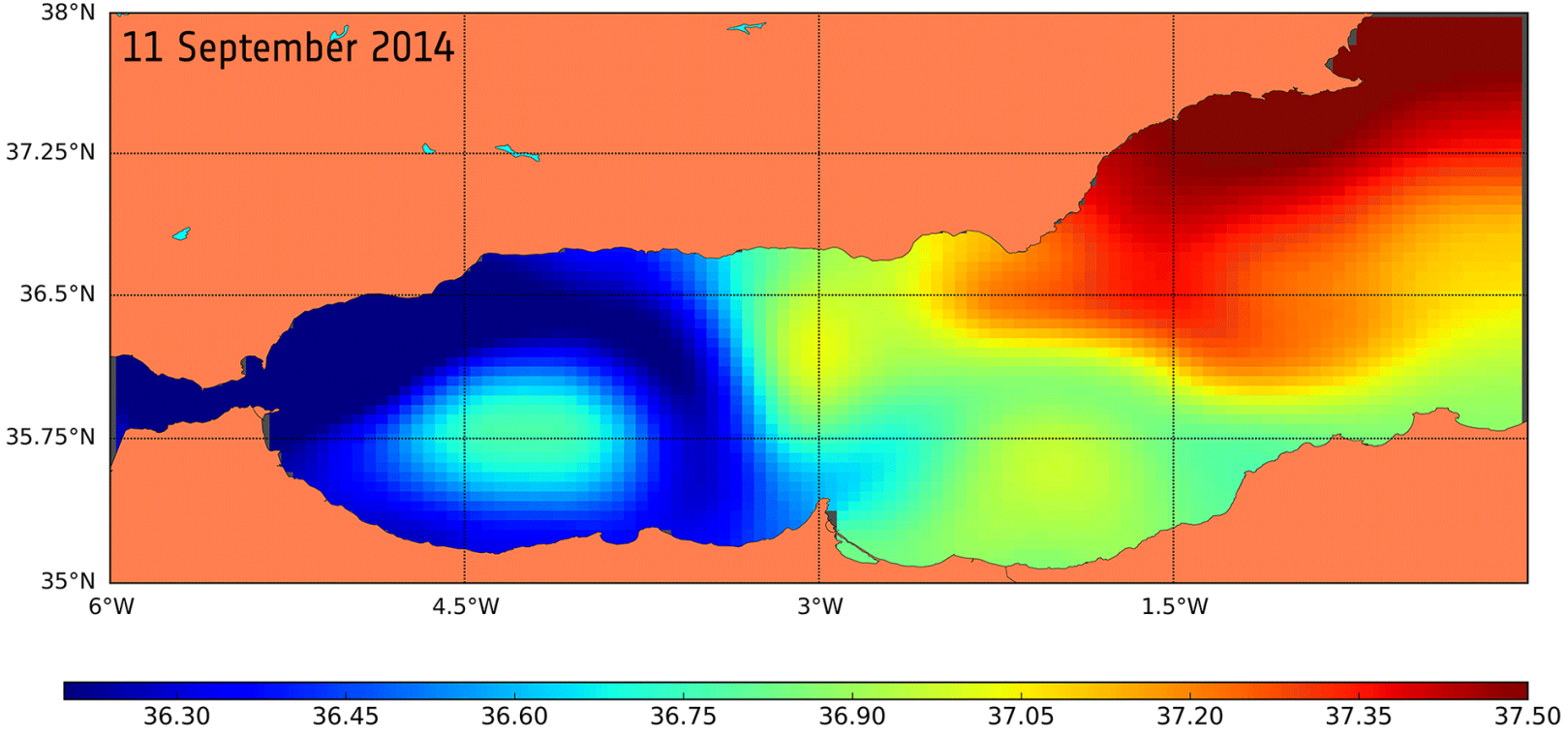


neural network processing

standard processing

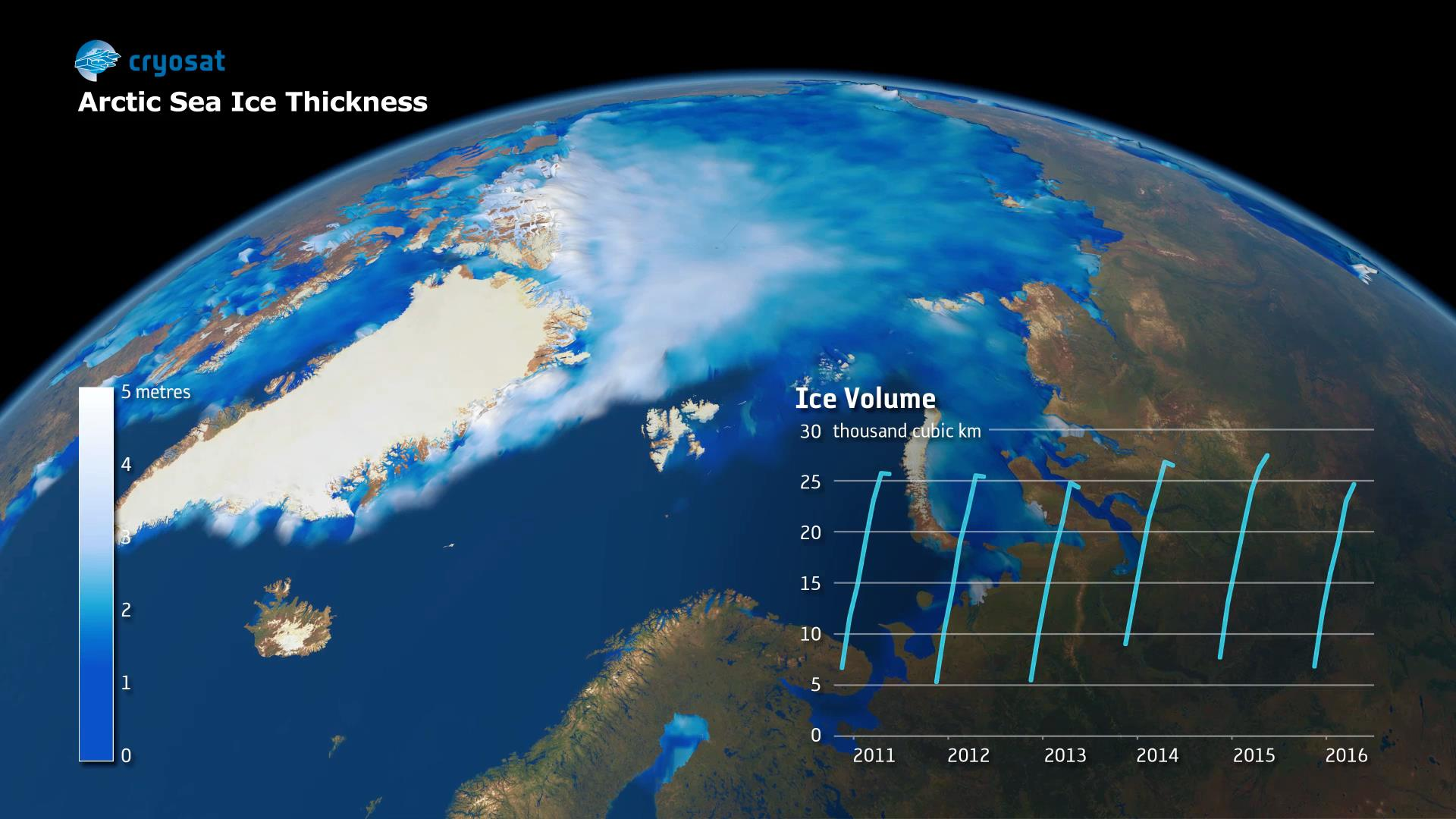
L-band passive microwave radiometry with synthetic aperture (interferometric radiometry)

SMOS: Alboran Sea Salinity Changes



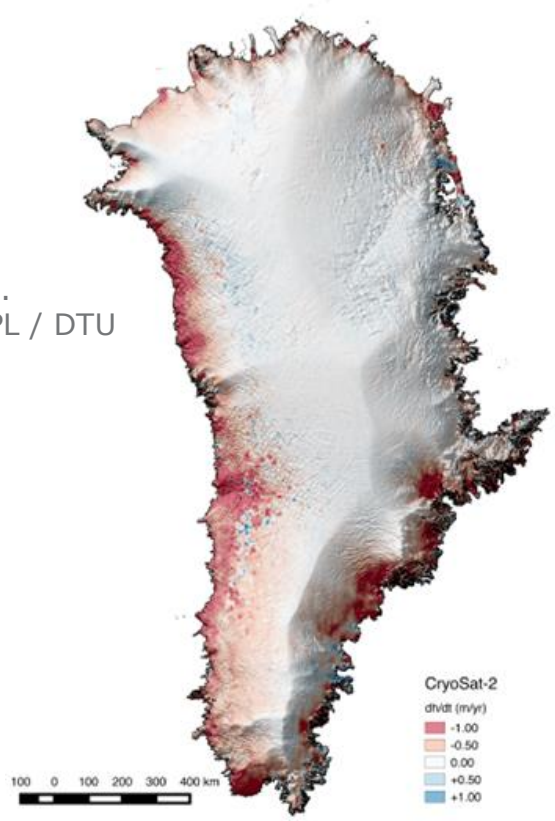
cryosat

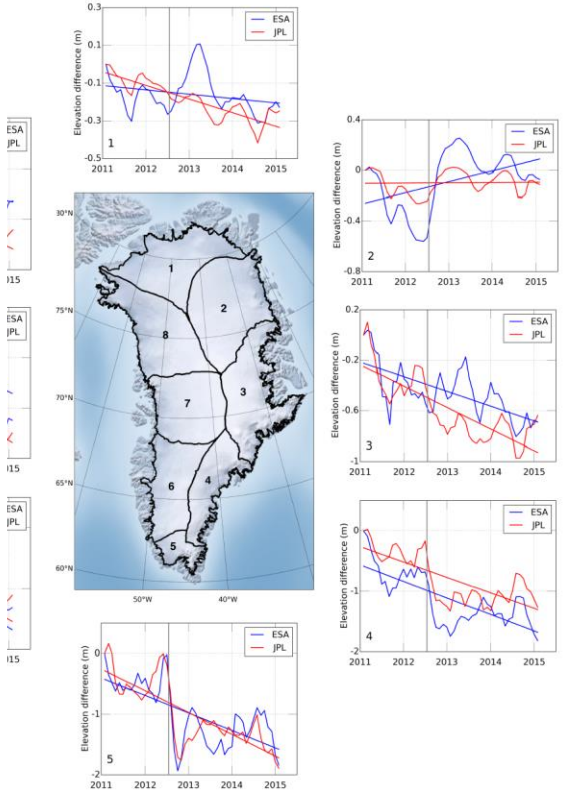
Arctic Sea Ice Thickness

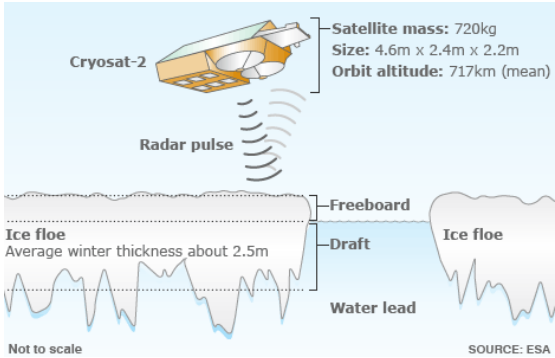


Greenland: Elevation Change and Regional Trends

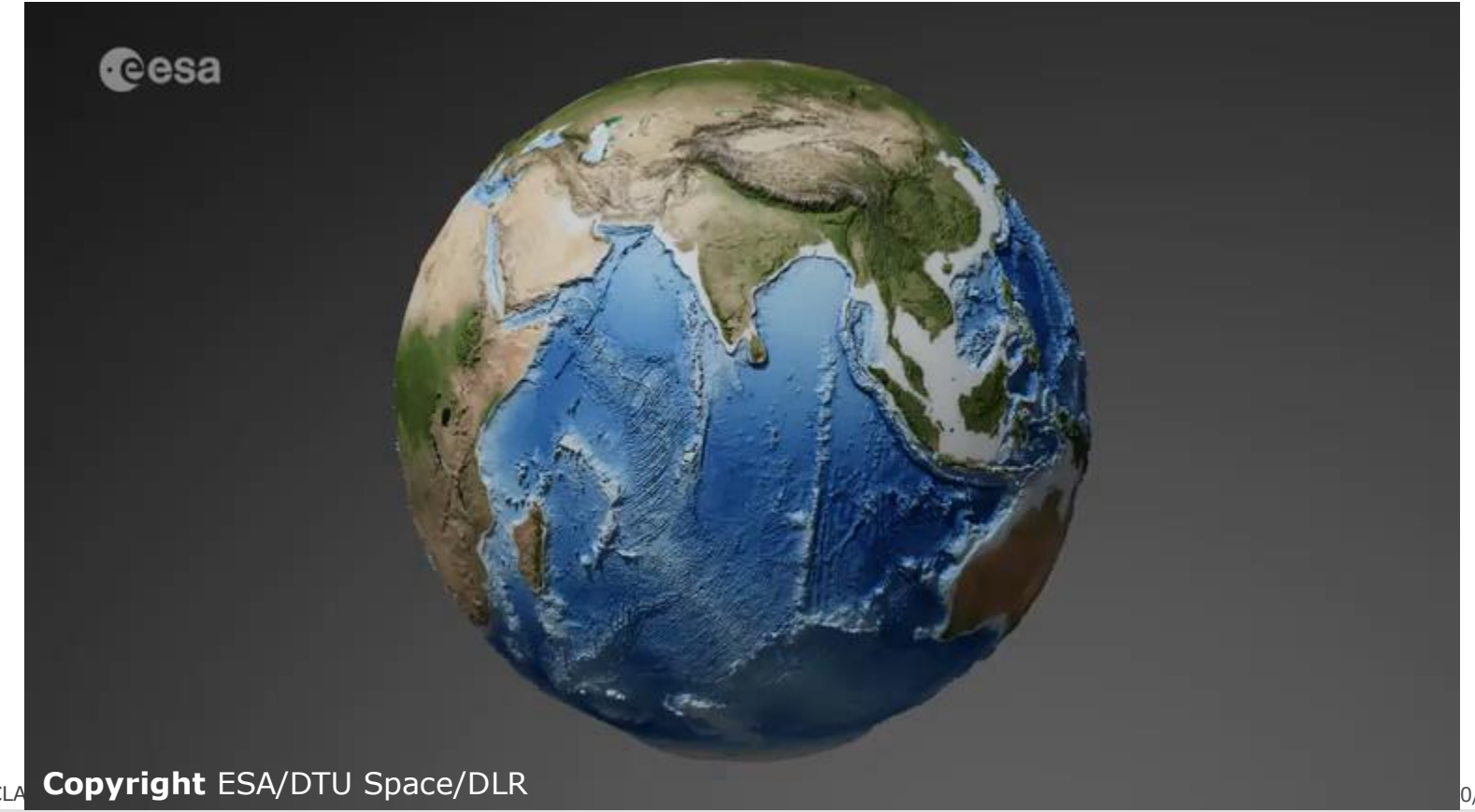
Courtesy J. Nilsson, JPL / DTU Space



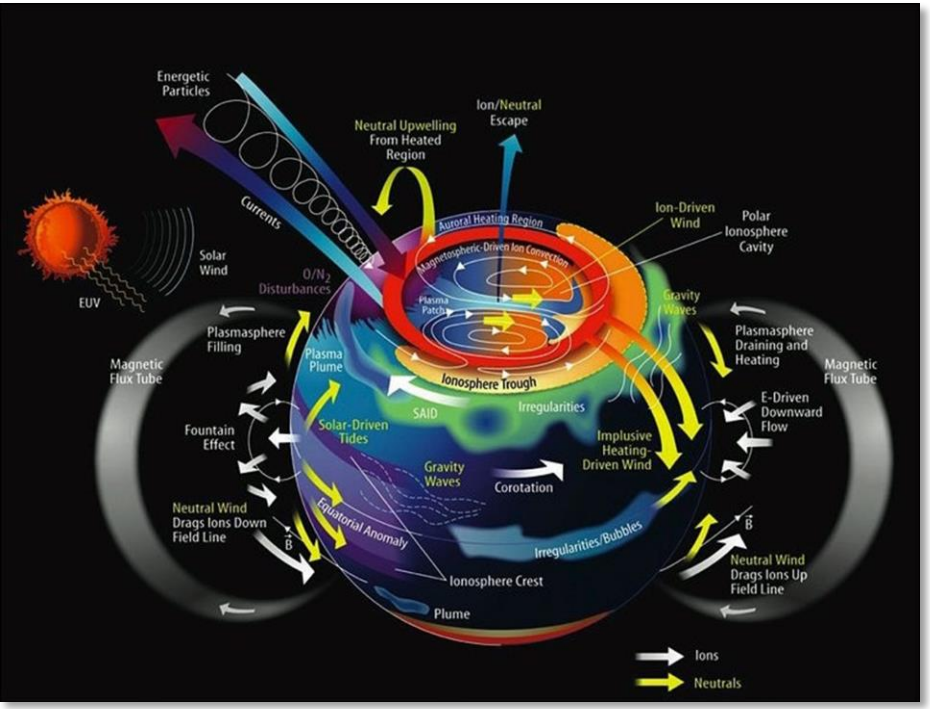


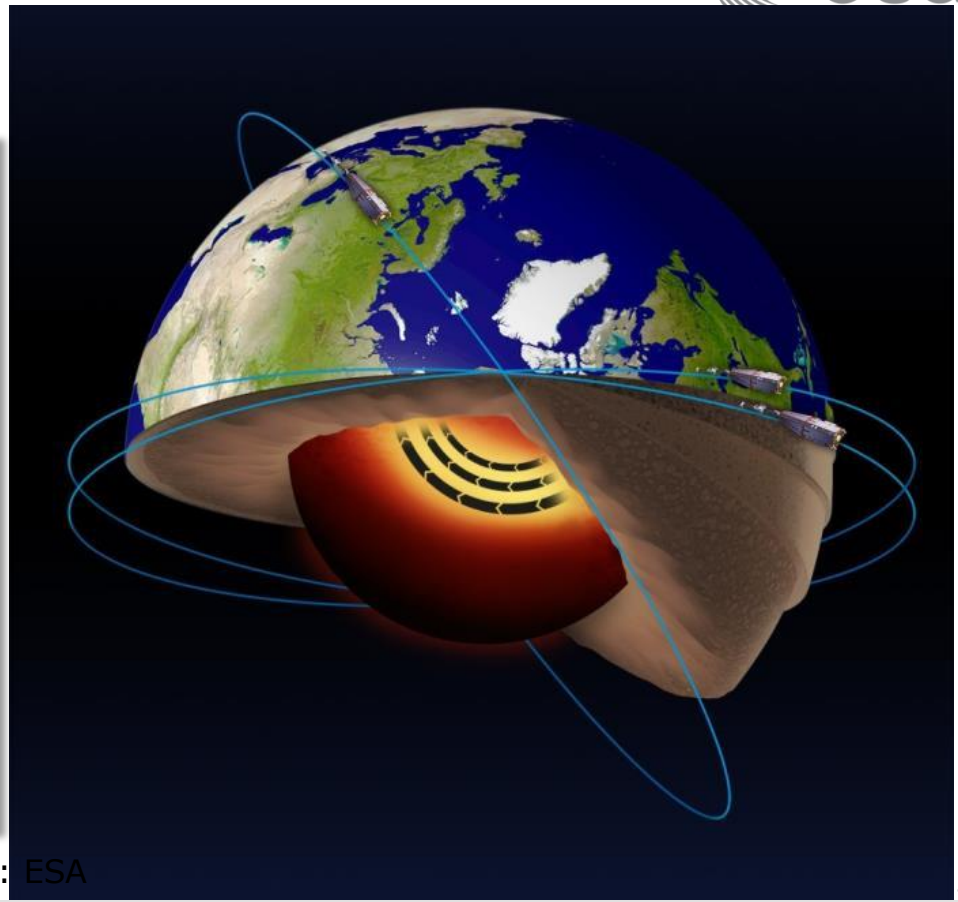


Swarm: Lithospheric Magnetic Field



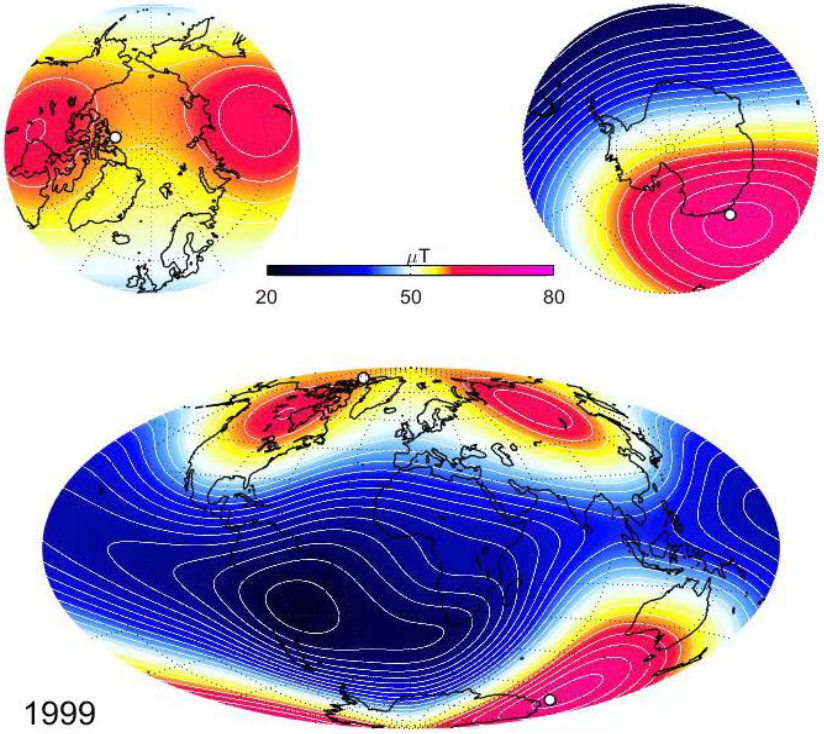
Swarm: Jet Stream in Earth's Core





Swarm: Geomagnetic Field Changes

- Field strength and location of poles are evolving on a decadal time scale
- Field strength concentrations at high latitude
- North America -3.5% in 17y; North Asia +2% in 17y
- South Atlantic Anomaly -2% in 17y and migrating westward
- Swarm also tracks rapid inter-annual accelerations



Courtesy: Finlay et al., EPS, 2016

Upcoming Earth Explorers

Aeolus

- Global observations of wind profiles for analysis of global 3D wind field
- First Doppler wind lidar in space
- Launch in 2018

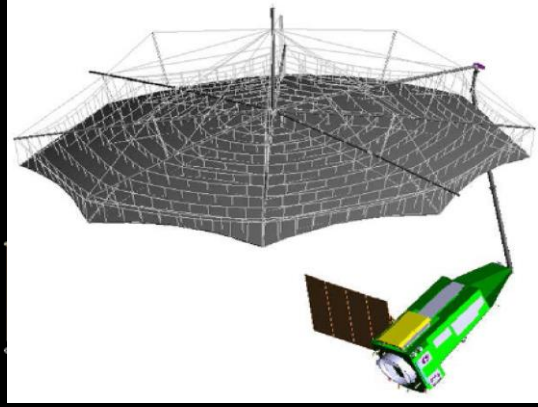
EarthCARE

- Global observations of clouds, aerosols and radiation
- Radar and optical (incl. lidar) observations
- Launch in 2019
- Cooperation with JAXA

Further Earth Explorer Missions

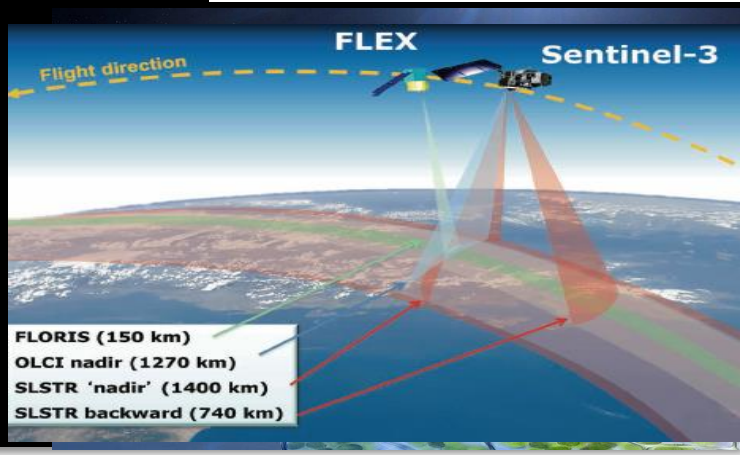
7th Earth Explorer: **Biomass**

- Forest biomass estimates based on global interferometric and polarimetric P-Band radar observations

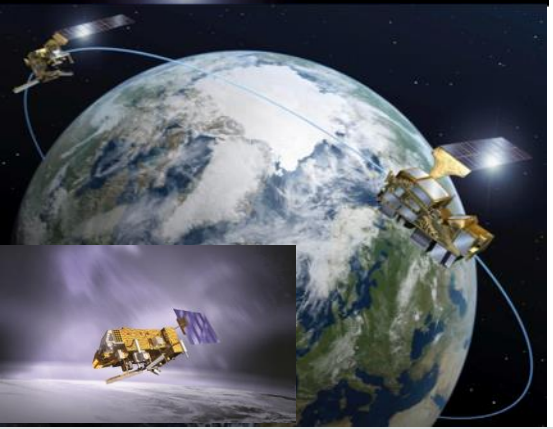


8th Earth Explorer: **FLEX**

- Global maps of vegetation fluorescence, which can be linked to photosynthetic activity
- Convoy between FLEX and Sentinel-3



Outlook on Earth Watch programmes: missions for / with EUMETSAT



Developed for, and in partnership with, EUMETSAT, also as Europe's contribution to the World Meteorological Organization (WMO)'s space-based Global Observing System (GSO):

Meteosat Second Generation (2002, 2005, 2012, 2015) – series of four satellites providing imagery in visible and infrared from geostationary orbit.

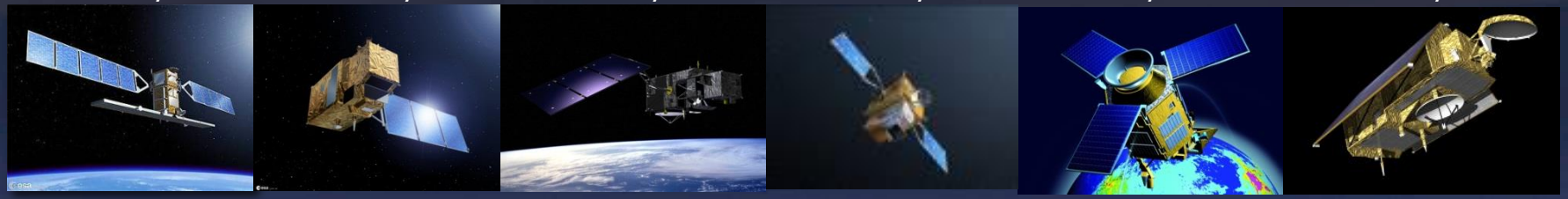
Meteosat Third Generation (2021–) – two series of geostationary satellites, providing imagery (four satellites) and atmospheric sounding (two satellites). MTG will embark the Sentinel-4 sensor of Copernicus

MetOp (2006, 2012, 2018) – series of three satellites providing operational meteorological observations from polar orbit.

MetOp Second Generation (2021–) - two series of polar-orbiters, three satellites in each series, continuing and enhancing meteorological, oceanographic and climate monitoring observations from the first MetOp series. They will embark the Sentinel-5 sensor of Copernicus

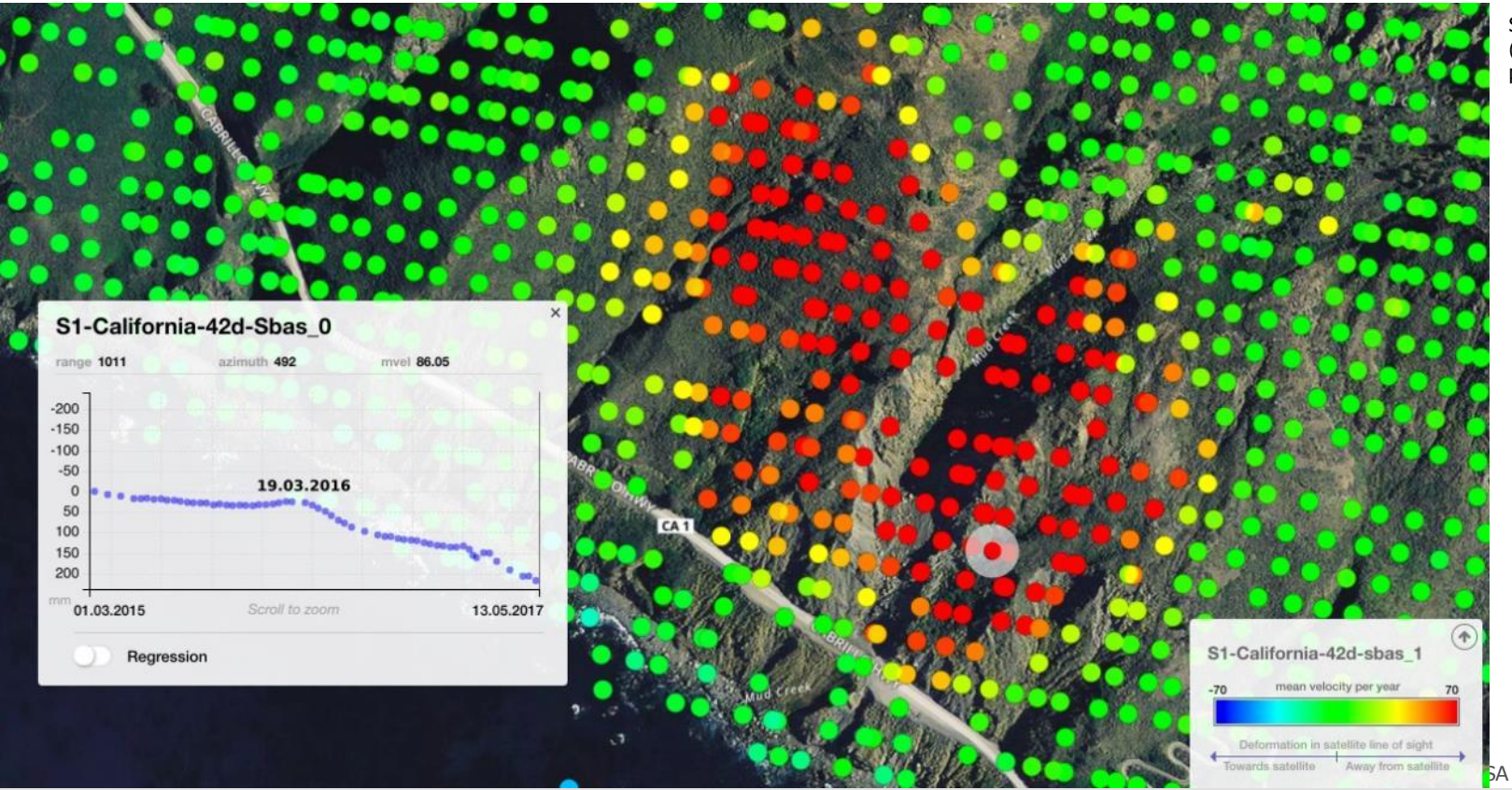
Copernicus: A New Generation of Earth Data Sources

Sent-1A/B | Sent-2A/B | Sent-3A/B | Sent-4A/B | Sent-5/5P | Sent-6A/B



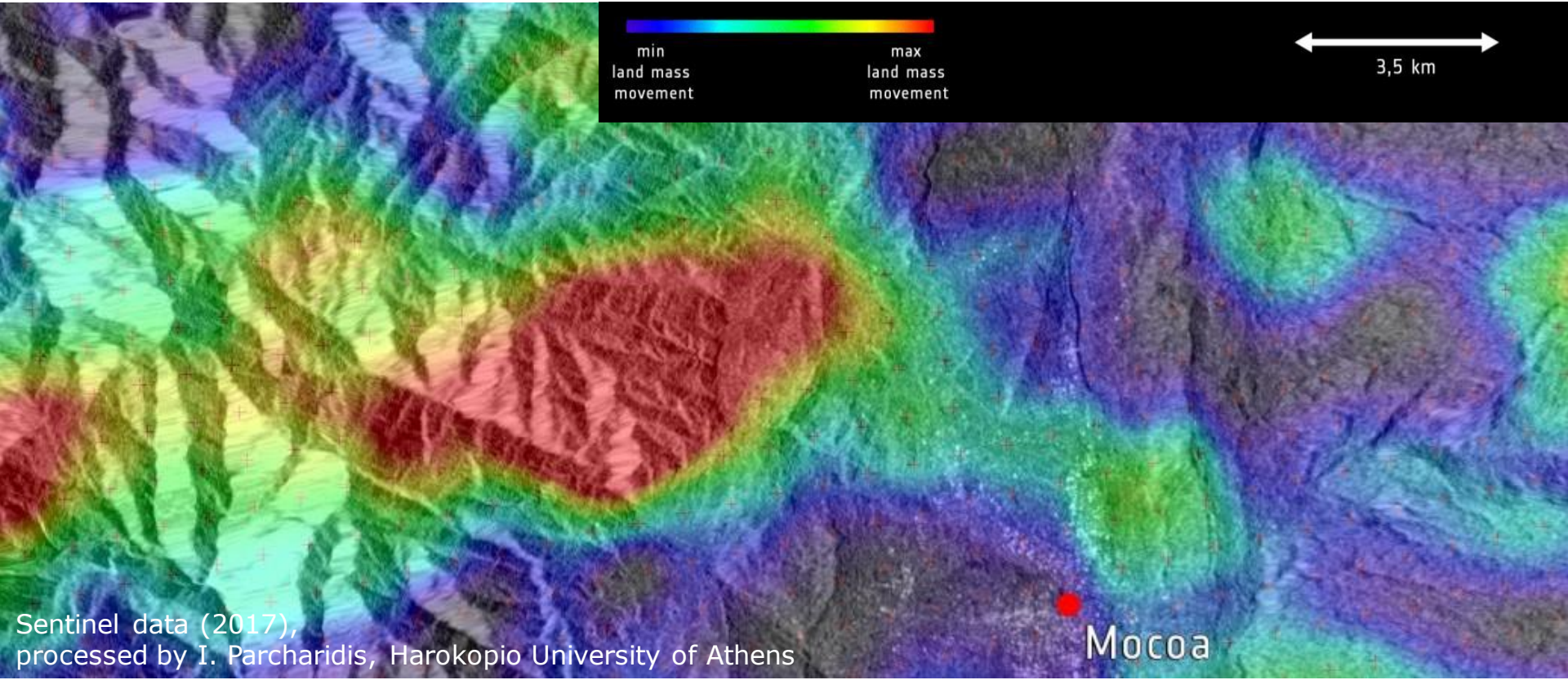
- European space flagship programme, led by the EU, for global monitoring of environment
- Missions include Sentinels and contributing missions (from national Agencies and companies)
- ESA is responsible for the space component, operation of some Sentinels, data buy from other partners, system evolution
- Free and open data policy
- Perennity of data streams through enhanced continuity of missions

Sentinel-1: Landslide on Highway 1



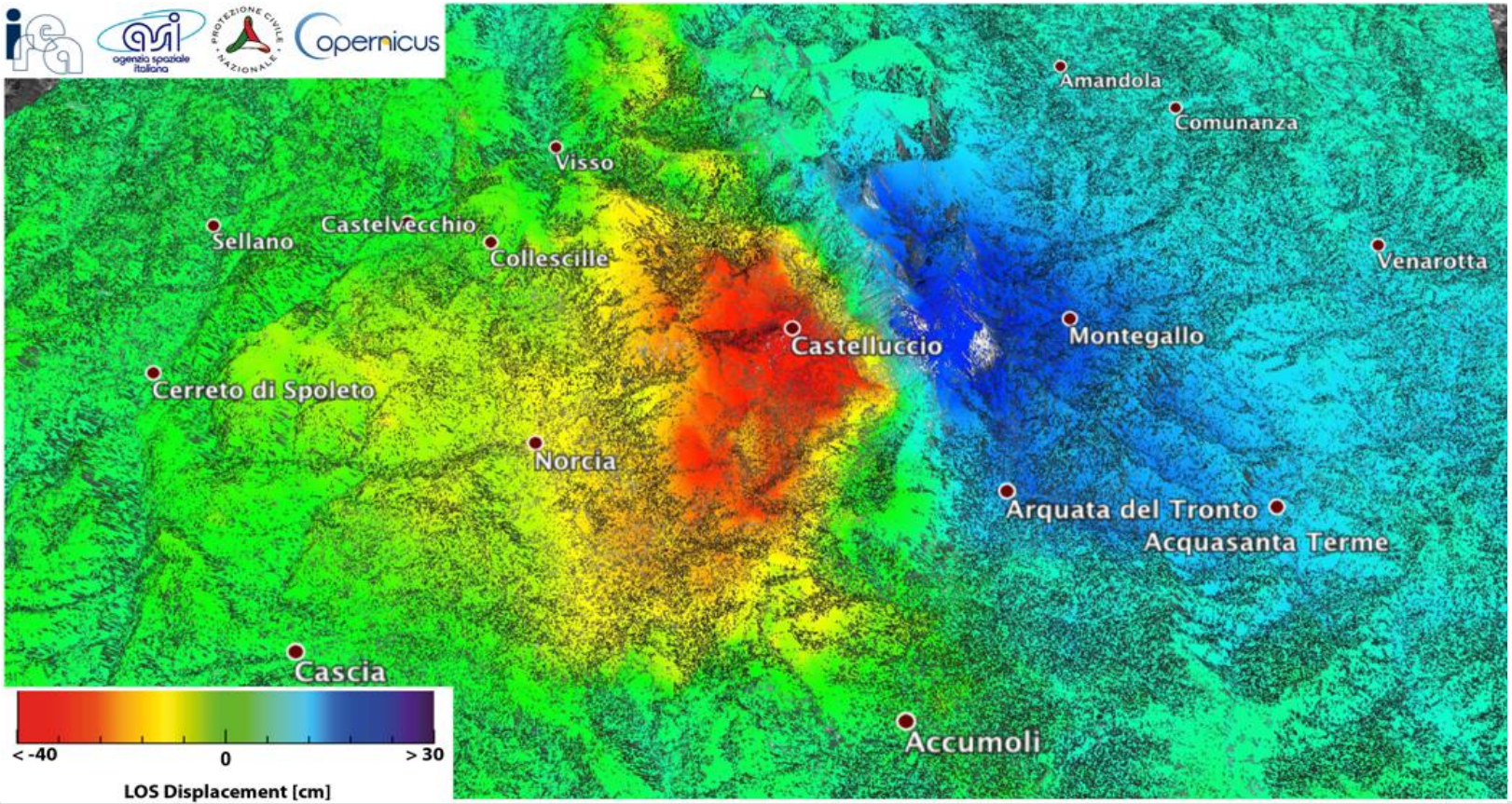
Sentinel data (2015–17), processed by Norut

Sentinel-1: Mocoa (Colombia) Landslide 1 April 2017

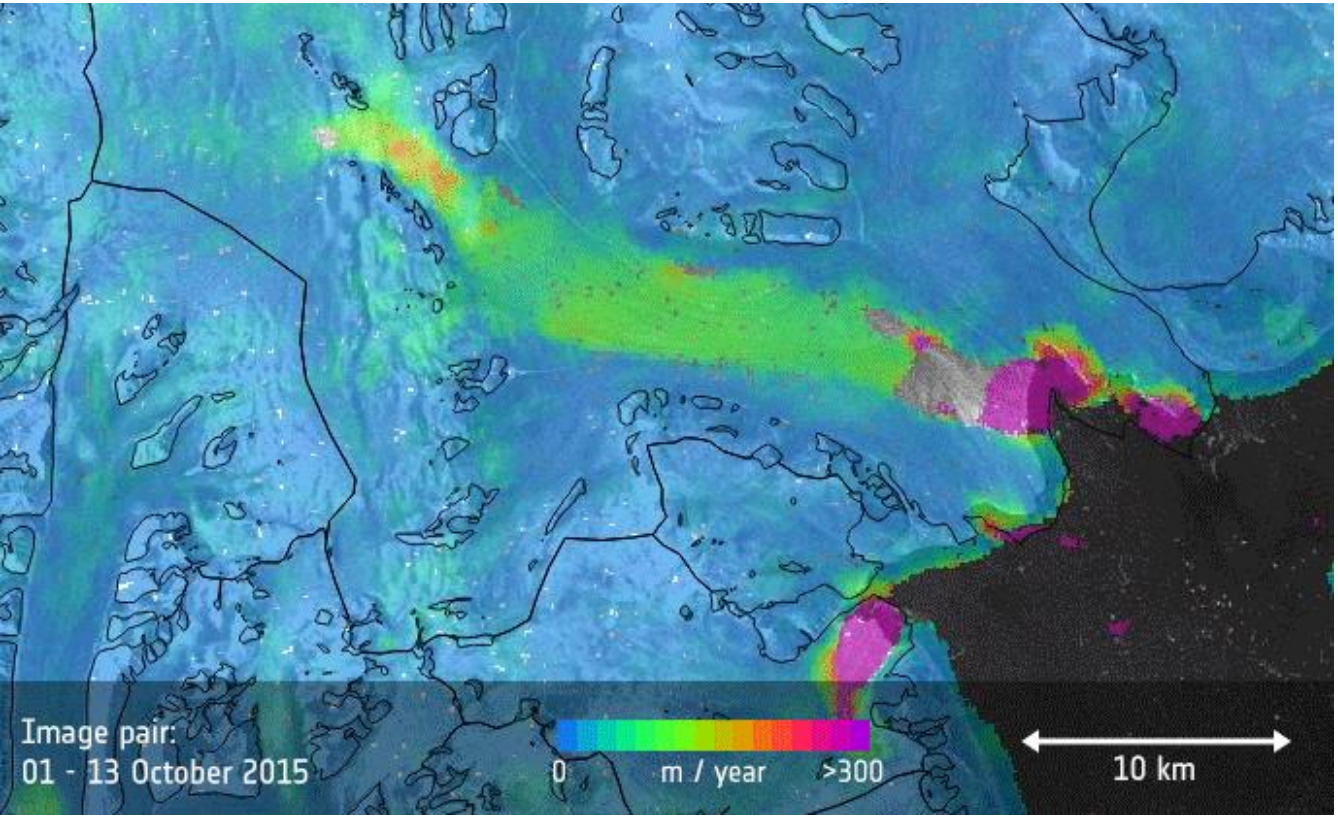


Sentinel data (2017),
processed by I. Parcharidis, Harokopio University of Athens

Sentinel-1: earthquake Italy 30 Oct 2016

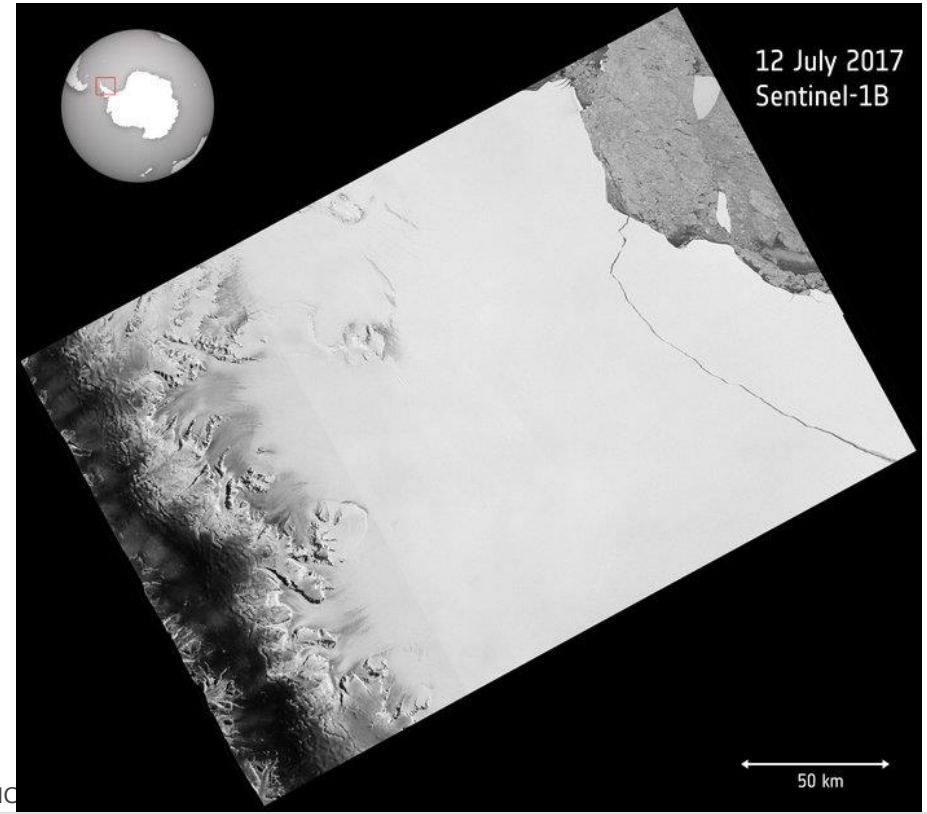


Sentinel-1: Negribreen Glacier (Norway)



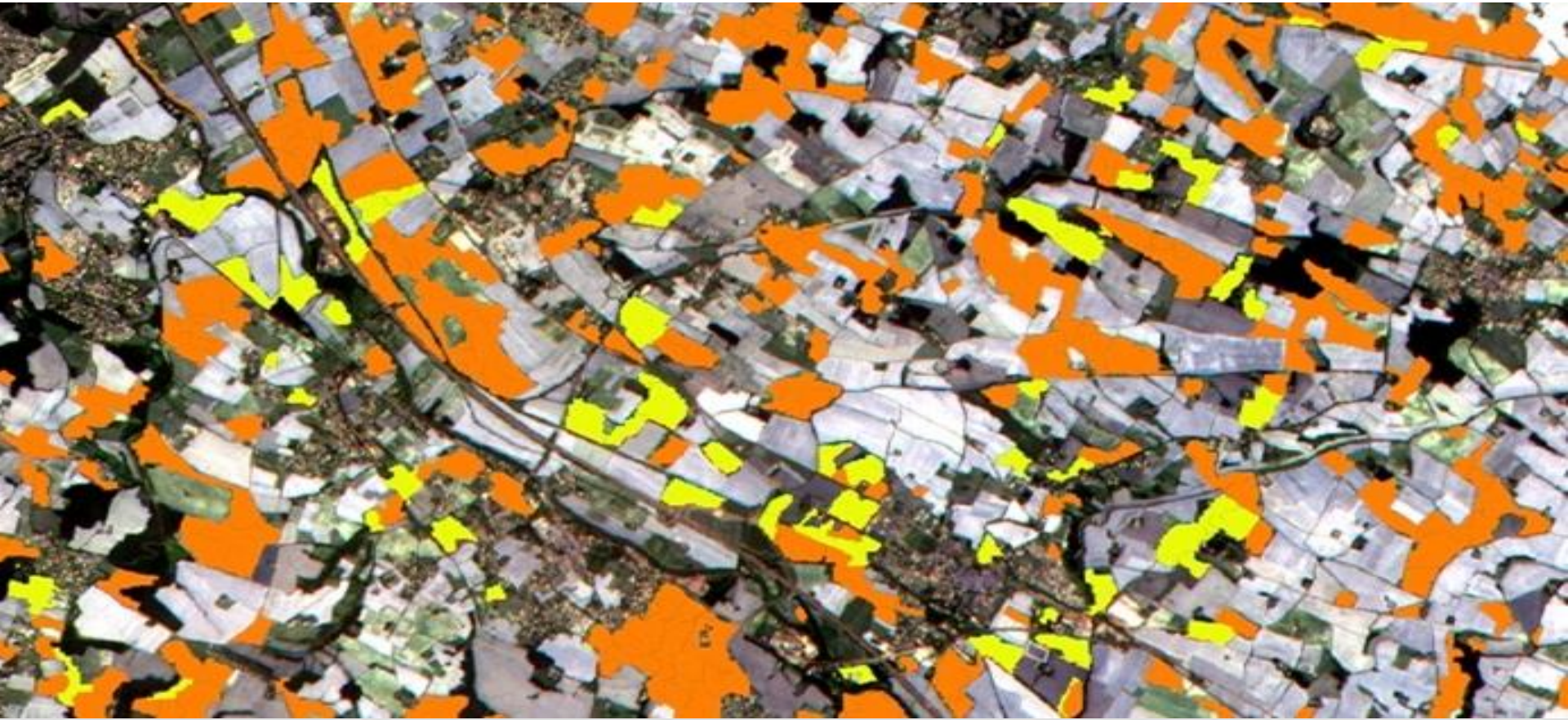
Sentinel data (2016/17), processed by
T. Strozzi

Copernicus: Antarctica's Larsen-C Crack



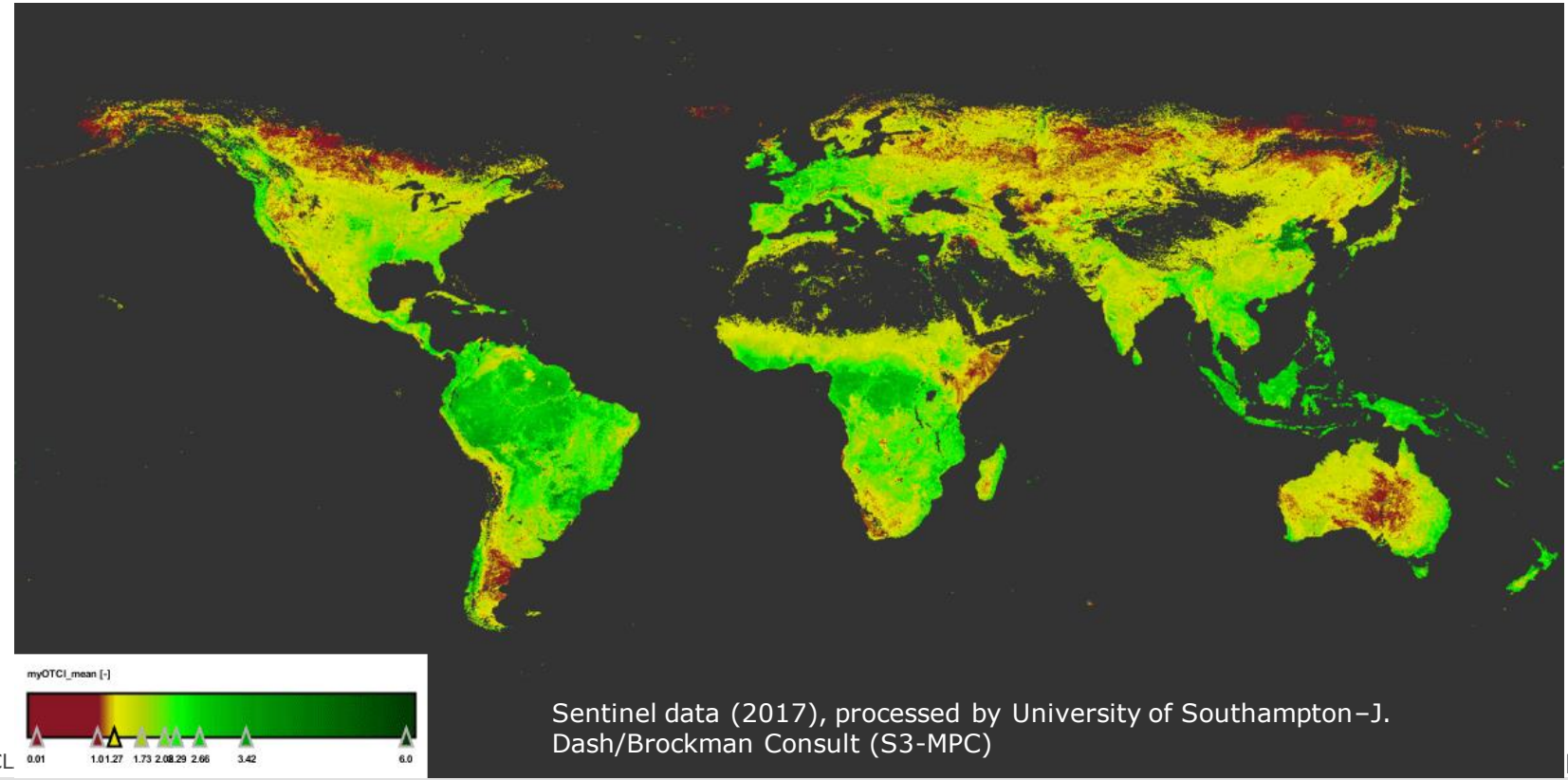
Sentinel data (2017), processed by ESA, CC BY-SA 3.0 IGO

Sentinel-2: Agricultural Monitoring



Sentinel-2: Mapping Water Bodies

Sentinel-3: The Effects of Spring

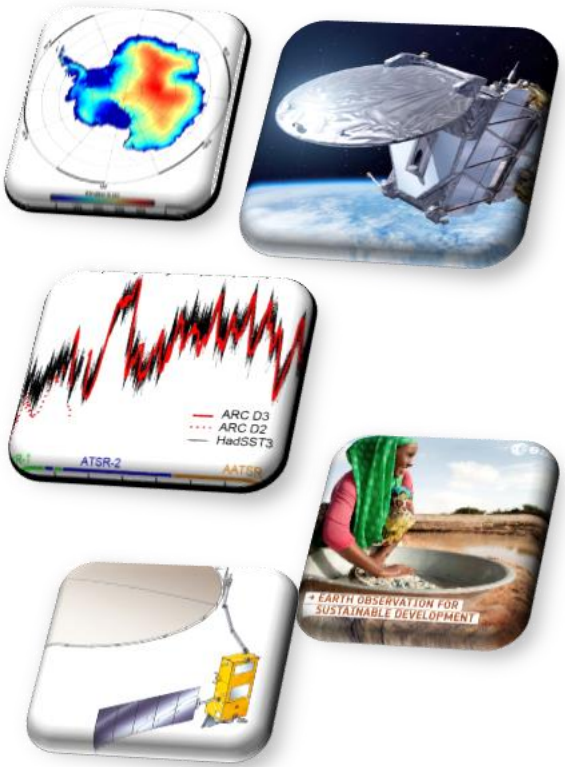


Sentinel data (2017), processed by University of Southampton–J. Dash/Brockman Consult (S3-MPC)

Preparing for the future: EOEP-5 (2017-2021)

Earth Observation Envelope Programme:
EO backbone programme of ESA

- Science but also societal challenges (climate, water, food, SDG, etc.)
- Develops Earth Explorer missions
- Prepares all future missions and key technologies
- From pre-development to exploitation
- Drives scientific excellence and innovation
- Brings EO to all levels of society

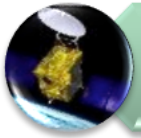


Earth Explorers (EE): EE9 (Fast-Track) and EE10 (Core)

Core Missions

GOCE (2009–13)
Earth's gravity field

ADM-Aeolus (2017)
studying global winds



EarthCARE (2018) studying Earth's clouds, aerosols and radiation (ESA/JAXA)

Biomass (2021)
Earth's carbon cycle

EE 10 Call released in Oct 2017, selection in 3Q-2018, launch 2027/28

Opportunity/Fast Track

SMOS (2009–)
Earth's water cycle

CryoSat-2 (2010–)
polar ice elevation

Swarm (2013–) three satellites, Earth's magnetic field

FLEX (2022)
photosynthesis

EE 9 proposals selected, approval by PB-EO of Nov. '17, launch 2025

Copernicus Evolution up to ~2030: New Mission Concepts & Thematic Areas

- CO_2 anthropogenic emissions monitoring

climate change

- Polar ice/ocean (Arctic) observations:
  - sea ice concentration
  - ice elevation

marine & polar envir. monitoring

- High-resolution land thermal imaging
- Hyperspectral land imaging
- L-band radar imaging

- land monitoring *(agriculture, food security,..)*
- emergency management *(e.g. geohazards)*
- marine envir. monitoring

➔ ***six new Sentinel missions enter Phase A in 2018, plus Next-Generation Sentinels (S3NG-topography, S1NG-CSAR, S3NG-optical, S2NG,...) in Phase 0; system of systems, e.g. CO_2 constellation***

Paradigm shift (finally!): constellations and smallsats

Cubesat (#U)
megaconstellation
megaformation (swarm)

Swarm + e-POP
Sent-1,2,3+6,4+5
MTG (I+S)
EPS-SG (a+b)
GPM
Kompsat
COSMO
SPOT/Pleiades, CSO
Cosmic-2/FS-2,
CYGNSS,
TROPICS
[RCM, APM, ACE+,..
int. gravity const.
..]

Swarm (2/3)
Tandem-X
GRACE
[Tandem-L
NGGM
SAR CSs
..]

formations

convoys

A-train
FLEX w. S3
S5p w. JPSS
OptiSAR
Tandem-X
[SAR CSs
..]

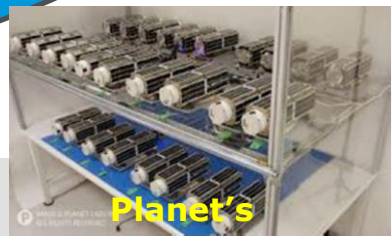
1HOPSat (Hera)
BlackSky Globals
Capella Space
CERES (Planetary Res.)
CICERO, DMC-3
NorthStar
Pathfinder (BlackSky)
Planet Labs (Rapid-Eye..)
SkySat (Terra Bella)
PlanetiQ, SPIRE, URSA
VHR2020, Urthedaily,
Satellogic, Iceye,
ORORO, WorldSAR,
WorldView (DigitalGlobe)
XpressSAR
..

institutional

commercial
(a gold rush ?)

constellations

Use



Reflection: What do current ESA EO missions share wrt technology?

	Earth Explorers	Copernicus & Meteorological
Lifetime	3+ years (but typ. much extended)	7+ years
Science & Observation Technique	Innovation driven	Proven (not necessarily by ESA)
Continuity	One-off, but with potential for operational follow-on	Yes (series of satellites, enhanced continuity)
Data quality (calibration, SNR,..)	Excellent (payload, other missions support)	Excellent (payload)
Cost	Medium to (very) high	Medium to high

Trends :

Mission requirements and technology innovations are – with few exceptions - driven by payload (not avionics), but:

- Technology evolutions enable:
  - increased return/performance, e.g. use of GaN for communication links (at K-band, for instance)
  - miniaturisation: more compact platforms ➔ larger payload ➔ better mission return
- Cost reductions per satellite expected from:
  - use of (more) standardised platforms (avionics)
  - higher integration (e.g. navigation function in OBC)
- Lifetime: typ. longer (e.g. 10+ years), but trend to use COTS in commercial missions creates pressure ➔ different architectures and approaches might enable wider use of COTS (with better screening, mitigation,..)

Paradigm shift: Space 4.0 & NewSpace

	Standard	NewSpace
Data quality (calibration, SNR,..)	High effort	Low, more reliance on aux. missions, new data processing
Size	Mid- to large	From CubeSat to mini-sat
Lifetime	Long (rad-hard, redundant sub-systems)	Shorter (?) (COTS, lower redundancy)
Cost	Mid to high	Low to very low (launch?)
Revisit time	Not driving (one-three satellites)	Higher (constellations)

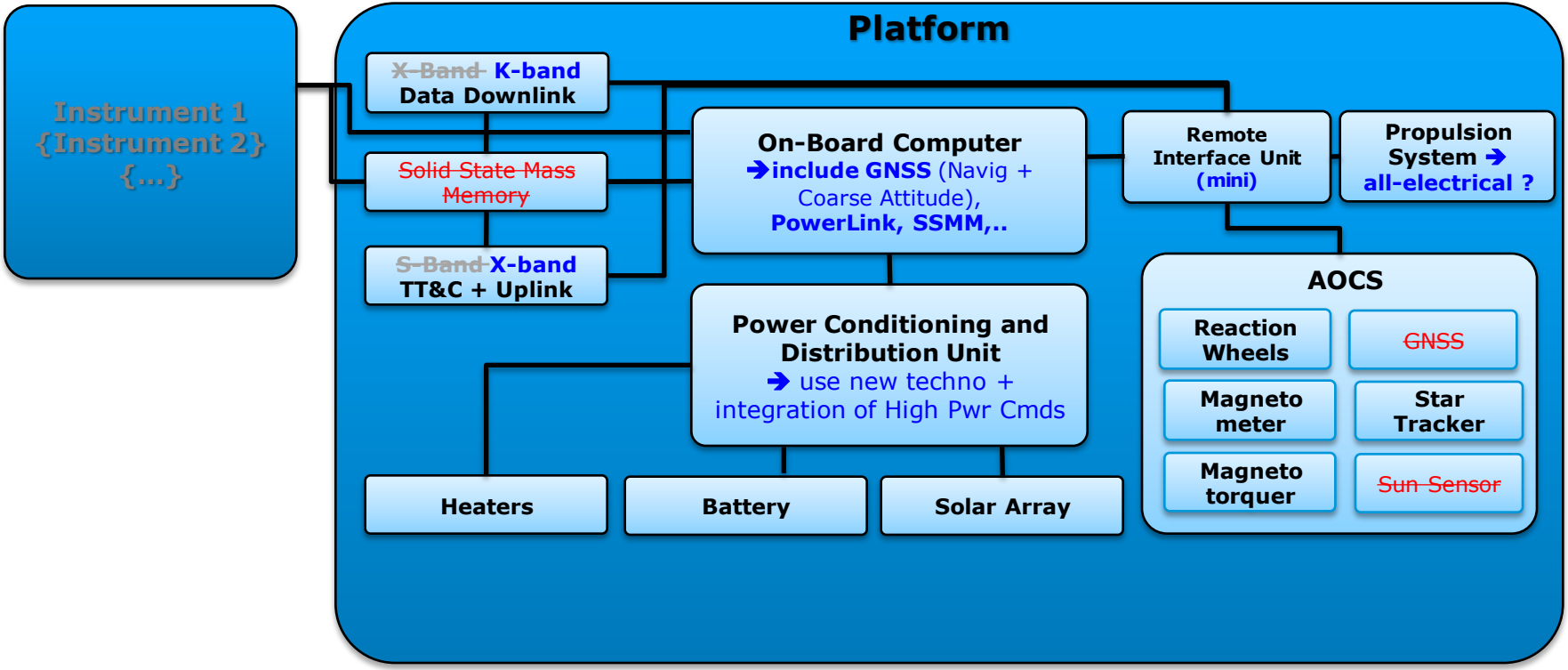
Common trends:

- Miniaturisation of electronics, thus also of avionics (higher integration of functions, enhanced performance)
- Standardisation:
  - CubeSat: key to reach very compact avionics
  - applicable to other smallsats (e.g. to derive std I/Fs Platform-Payload from mega-constellation sats.)

- Common interfaces, e.g. SpW, but also digitisation of discrete interfaces for hardness reduction
- Increased functionality: e.g. FDIR, CFDP (file data transfer), …

➔ need for increased cooperation Primes-Suppliers to reap benefits

Functional Architecture: some possible areas for evolution



Examples of relevant developments (co-)funded by EOP

PowerLink: digitisation and reduction of harness for Discrete Interfaces

Integration of GNSS and SSMM in OBC

- Definition of a Complete SMU and Critical BreadBoarding

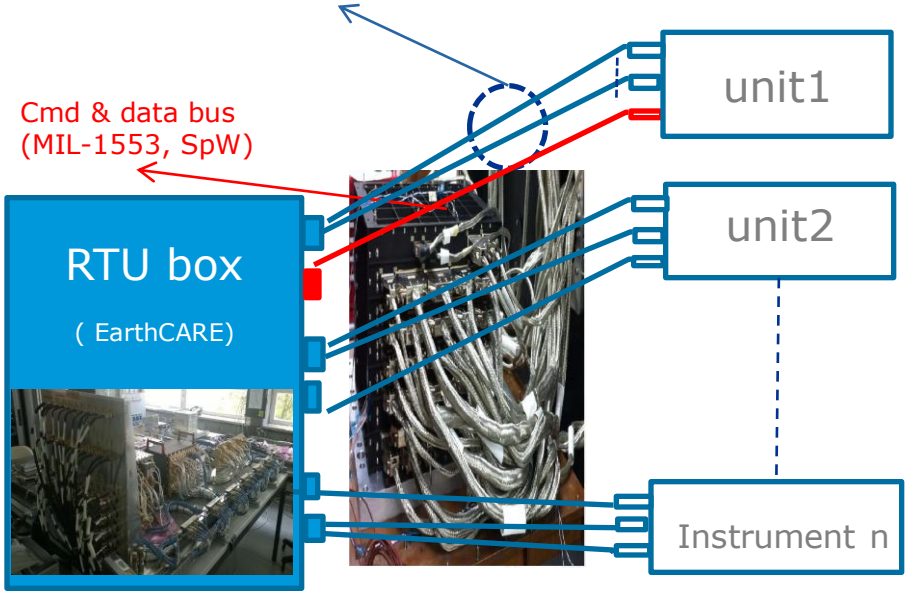
Data Downlink & TT&C Uplink

- Multiple activities for K-band downlink ➔ 26 GHz band adopted for MetOp-SG,…
  - Data rates up to 10 Gb/s for LEO
- X-band TT&C
  - uplink up to 2 Mb/s
  - pre-developments planned

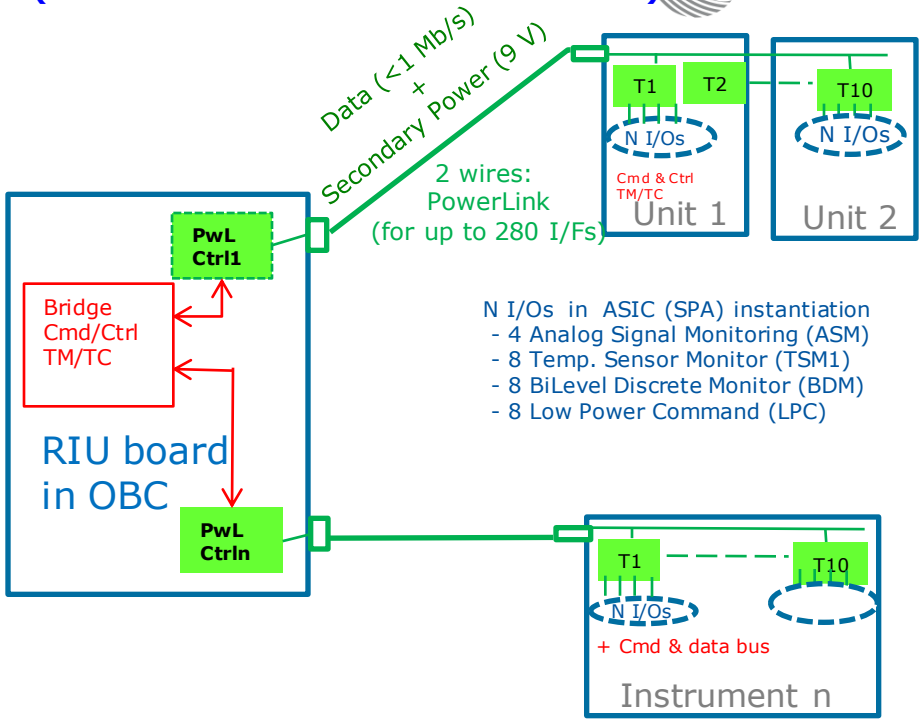
Building blocks for more performant miniaturised equipment & subsystems, e.g. satellite navigation ASICs (AGGA, RF/ADC ASICs), micro/milliNewton electrical thrusters (IOD on Iceye),..

PowerLink: digitisation of discrete interfaces
➔ reduction of RIU **(Presentation Wedn. 14-Oct at 14:45)**

N Input/Output terfaces
(ECSS-E-ST-50-14C: ASM,TSM,BDM,
BSM,ISD,OSD,BSD,SDI : up to 8 ≠ types of sensor/actuator interfaces)



Present Status: centralised architecture with **bulky and heavy harness**

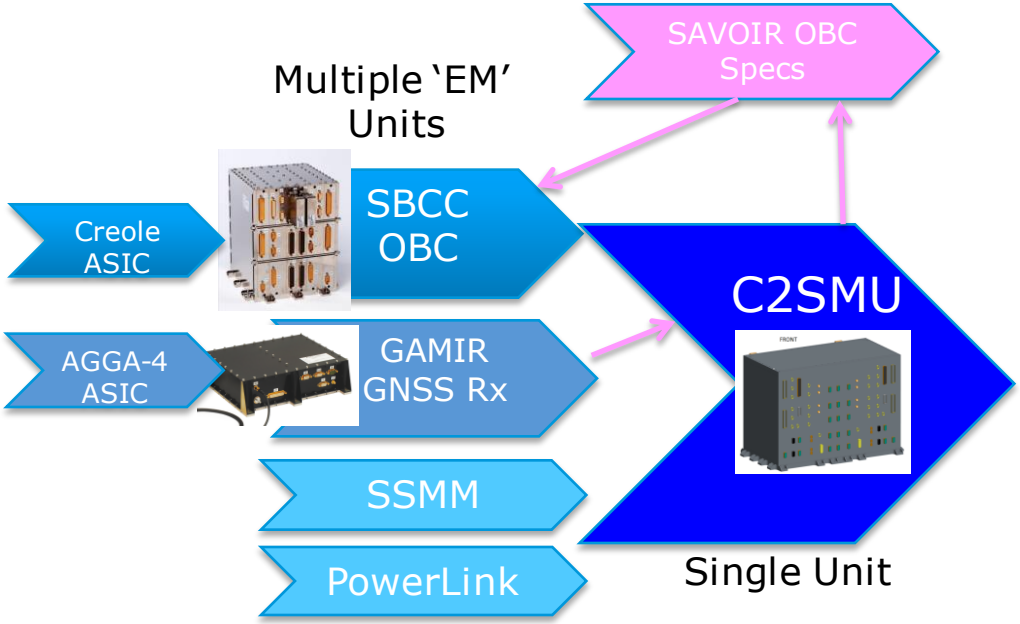


Future: Decentralised Architecture with
light two-wire PowerLink harness

Study Definition of C2SMU

Complex & Complete SMU and Critical BreadBoarding

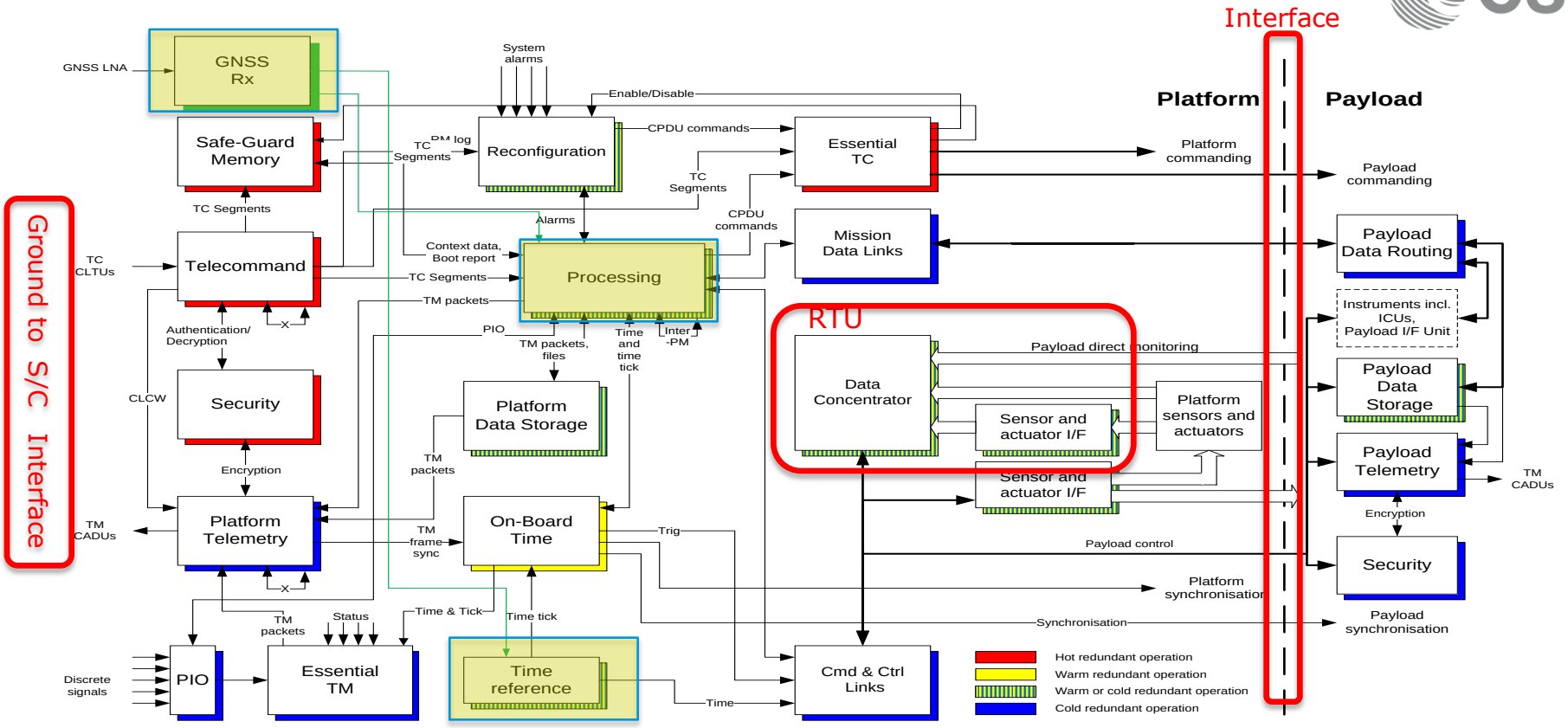
(Presentation this afternoon at 14:00)



C2SMU Feasibility Study
- Requir. + Architectural Design
- Integration + Analysis/Testing key modules
- Development Plan

Development in follow-up study

SAVOIR Ref. Architecture – good starting point → need to evolve



Thank you for the attention!

Have a great 11th ADCSS Workshop!

(Avionics, Data, Control and Software Systems)