

Status of ESA EO Programmes

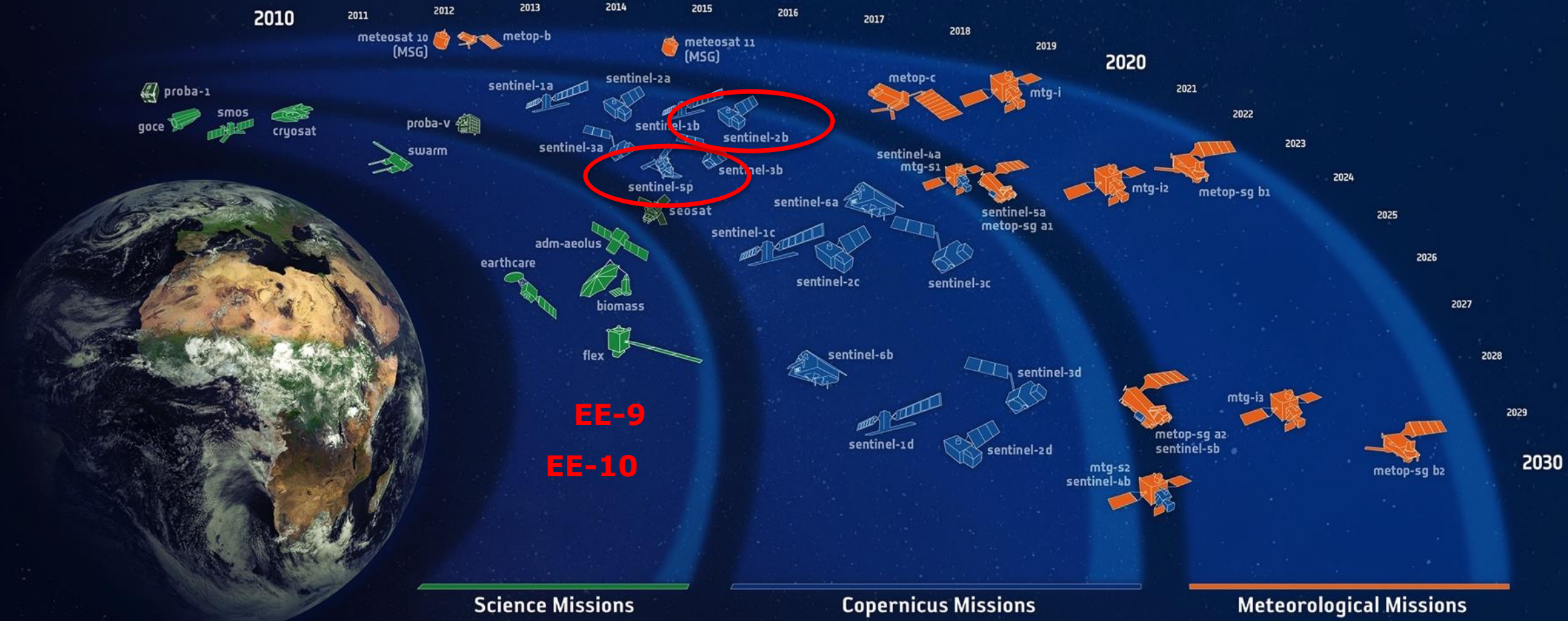
54th ESSC Plenary Meeting
24 November 2017

Maurice Borgeaud, ESA
Head of the ESA Earth Observation Science, Applications and
Climate Department

ESA Earth Observation Programmes



→ ESA-DEVELOPED EARTH OBSERVATION MISSIONS



Two Successful Sentinel Launches

Sentinel-2B
7 March 2017



Sentinel-5P
13 October 2017

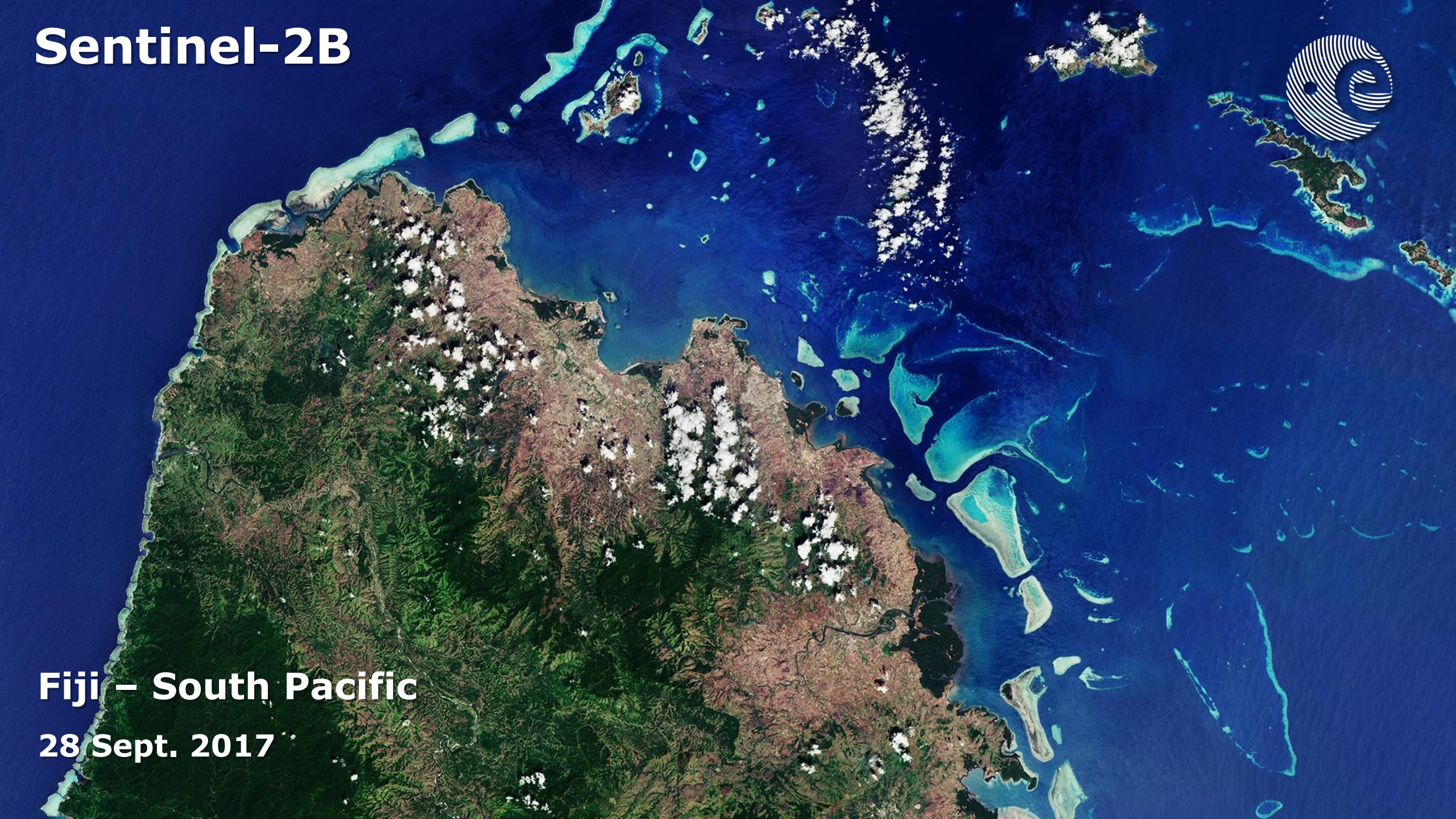


Sentinel-2B

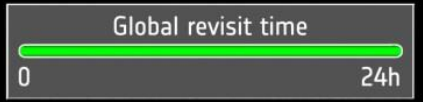


Fiji – South Pacific

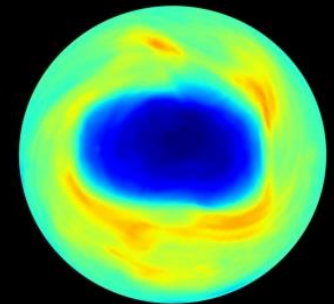
28 Sept. 2017



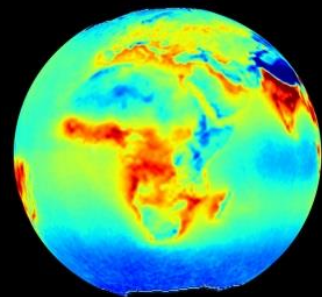
Sentinel-5P Air Quality Monitoring



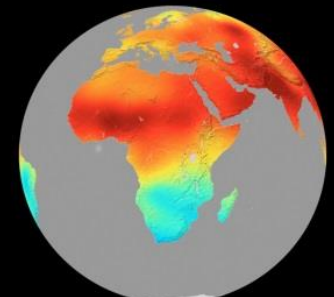
Nitrogen dioxide



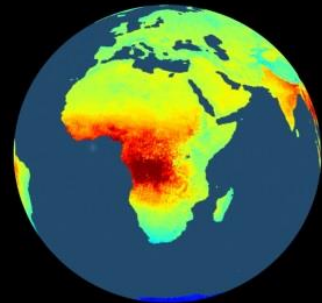
Ozone



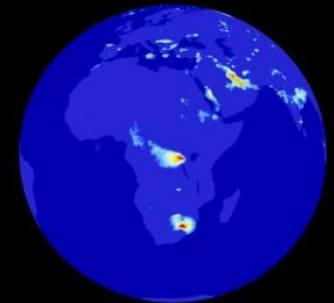
Formaldehyde



Methane



Carbon monoxide



Sulphur dioxide

Sentinel-5 Precursor

The ESA **Sentinel-5 Precursor (S-5P)** is the first atmospheric Sentinel mission focusing on global observations of the atmospheric composition for **air quality** and **climate**.

The TROPOspheric Monitoring Instrument (**TROPOMI**) is the payload of the S-5P mission and is jointly developed by **The Netherlands and ESA**.

S-5P will provide **enhanced radiometric sensitivity & spatial resolution** enabling sampling of small-scale variabilities specifically in the lower troposphere.

The planned launch date for S-5P is **13 October 2017**. **7 year** design lifetime.

TROPOMI: UV-VIS-NIR-SWIR nadir view grating spectrometer.

- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-1.1 nm
- Spatial Resolution: 7x3.5 km²
- Global daily coverage at 13:30 local solar time



Sentinel-5 Precursor Products

Product	Description
Level 1B	Calibrated, geo-located Earth radiance & solar irradiance spectra
Level 2	<p><i>Column Densities/Profiles for Sentinel-5 Precursor Primary Species:</i></p> <p><i>UVN Channel Products</i></p> <p>O₃ total & tropospheric columns, profiles NO₂ total & tropospheric columns SO₂, HCHO total columns aerosols aerosol index & aerosol layer height clouds cloud fraction, top height, optical thickness</p>
	<p><i>SWIR Channel Products</i></p> <p>CO, CH₄ total columns</p>

- Near Real Time delivery of unconsolidated L1B and all L2 products except CH₄, and Tropospheric Ozone
- Non Time Critical (NTC) delivery of L1B within 12 hours and L2 data within 5 days

Sentinel-5P LEOP all Green after 36 hrs



SEN5P SEN5P.ilv SG24 1 ASY_HK_30706 10663 2017.292.10.42.05.394

SENTINEL 5P - OVERVIEW

S/C Mode: **SAT_NOM** AOCs Mode: **NORMAL** NM Submode: **CAP** ASH Submode: **OFF** TC Mode: **OPEN** Nr. of Reconfl.: **0**

AOCs

SUN FLAG

AOCs Sel RIU IF: **A B**

CSS Function: **STARTED**

MAG Function: **STOPPED**

MTQ Function: **STARTED**

NAV Funct State: **STARTED**

NAV Funct Mode: **PROPAGA**

IAE Status: **STARTED**

CTRL Status: **STARTED**

RWL Function: **STARTED**

RWL Config: **NOMINAL**

RWL: **1 2 3 4**

STR: **1 2 3**

STR Funct State: **STARTED**

STR Mode: **AOM ATM**

STRE State: **ON OFF**

STRE Online: **A B**

GPS Function: **STARTED**

GPS Config: **NOMINAL**

GPS State: **ON OFF**

GPS Online: **GPS A**

Delta Time: **0.25**

EPS

PCDU State: **STARTED**

PCDU Selected: **A B**

PCDU Bat. Curr.: **6.182451 A**

PCDU Pwr Bus V.: **33.27 V**

Batteries

Power State: **STARTED**

Charge: **561931.66 C**

DoD: **-0.06**

EmF: **34.11 V**

Taper Mode: **TRUE**

EoC Voltage: **33.271999 V**

BAT 1: **7.95** BAT 2: **7.29** degC

TH MON4: **7.71** **7.41** degC

TH I Median: **10.21** **11.43** degC

TH E Median: **4.91** **5.75** degC

PCDU A Battery Relays:

Batt Relay 1: **RELAY ON**

Batt Relay 2: **RELAY ON**

Batt Relay 3: **RELAY ON**

Batt Relay 4: **RELAY ON**

POWER

SOLAR ARRBAYS

VBUS 1: **33.28** V TSA 1: **35.73** degC

VBUS 2: **33.28** V TSA 2: **32.70** degC

VBUS 3: **33.29** V TSA 3: **31.89** degC

ISA 1: **2.37** A ISA 4: **2.36** A

ISA 2: **2.33** A ISA 5: **2.32** A

ISA 3: **2.35** A ISA 6: **2.37** A

PCDU A DET1 Mode:

DET1 Mode (1): **NO SHUN**

DET1 Mode (2): **NO SHUN**

DET1 Mode (3): **NO SHUN**

DET1 Mode (4): **NO SHUN**

DET1 Mode (5): **NO SHUN**

DET1 Mode (6): **NO SHUN**

DET1 Mode (7): **NO SHUN**

THERMAL

Th. Ctr. State: **STARTED**

Th. Ctr. Mode: **TH OPER**

Configuration: **NOMINAL**

PDHU

PDHU State: **STARTED**

PDHU Mode: **STORAGE**

RECI_BOARD: **A B**

SPW Connection: **A B**

XDA Function: **STARTED**

XDA Online: **A B**

XDA A1 Position: **A B**

XDA B2 Position: **A B**

XDA EPC State: **ON OFF**

XDA Mod State: **ON OFF**

XDA TWT State: **OFF OFF**

PDHU Free Memory: **7320**

PDHU written/not read sectors: **752**

Time Correlation

Validity: **VALID**

Accuracy: **ACCURATE**

DHS

DWL 1 State: **TERMIN 1**

DWL 2 State: **TERMIN 3**

VC 5 Pending: **0**

SGM A Health: **GOOD**

SGM B Health: **GOOD**

RIU

RIU Func. State: **STARTED**

RIU Sel PROP: **A B**

RIU Sel TM/TC: **A B**

RIU Sel STDm: **A B**

DMS - MTL Status

Subsched 1: **ENABLED**

Subsched 2: **ENABLED**

Subsched 3: **ENABLED**

Subsched 4: **ENABLED**

Subsched 5: **ENABLED**

Subsched 6: **ENABLED**

MTL Avail. Entries: **7462**

Avail. TC Pool 1: **10180**

Avail. TC Pool 2: **1250**

PROPULSION

Thr State: **STOPPED**

LV A Status: **LV OPEN**

LV B Status: **LV OPEN**

S5P

TC Mode: **OPEN**

Err. Sgm. Disc: **0**

OBC

OBCReg RUA: **ENABLED**

OBCReg RUB: **ENABLED**

MMA State: **USED**

MMB State: **USED**

DMS RU on control: **A B**

DMS Master PM: **A B**

Xstrap State/Err.: **USED 0**

TROPOMI

ICU State: **STARTED**

ICU PM Board: **A B**

ICU Mode: **MEASURE**

MDL Status: **ACTIVE**

Ancillary Data: **TRUE**

PS Filling

PS 1 State: **CIRCULAR**

1: **1** %

2: **0** %

3: **21** %

4: **0** %

5: **0** %

TX A/B

Status B/R: **A ON HIGH** **B OFF LOW**

Coherency: **COHERENT**

Rng: **ON**

RX A/B

RF LOCK: **RF LOCK**

BIT LOCK: **BIT LOCK**

-VCI: **-VCI**

TC Decoder A/B

Lockout: **INACTIVE**

Wait: **INACTIVE**

Retrans: **INACTIVE**

TM/TC Config

SBT Selected: **A B**

SBT Nom Conf: **A B**





Sentinel Launch Overview



S-1



Radar

A 
3 Apr. 2014

B 
25 Apr. 2016

S-2



High Resolution Optical

A 
23 Jun. 2015

B 
6 Mar. 2017

S-3



Medium Resolution Optical & Altimetry

A 
16 Feb. 2016

B
2018

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

S-6

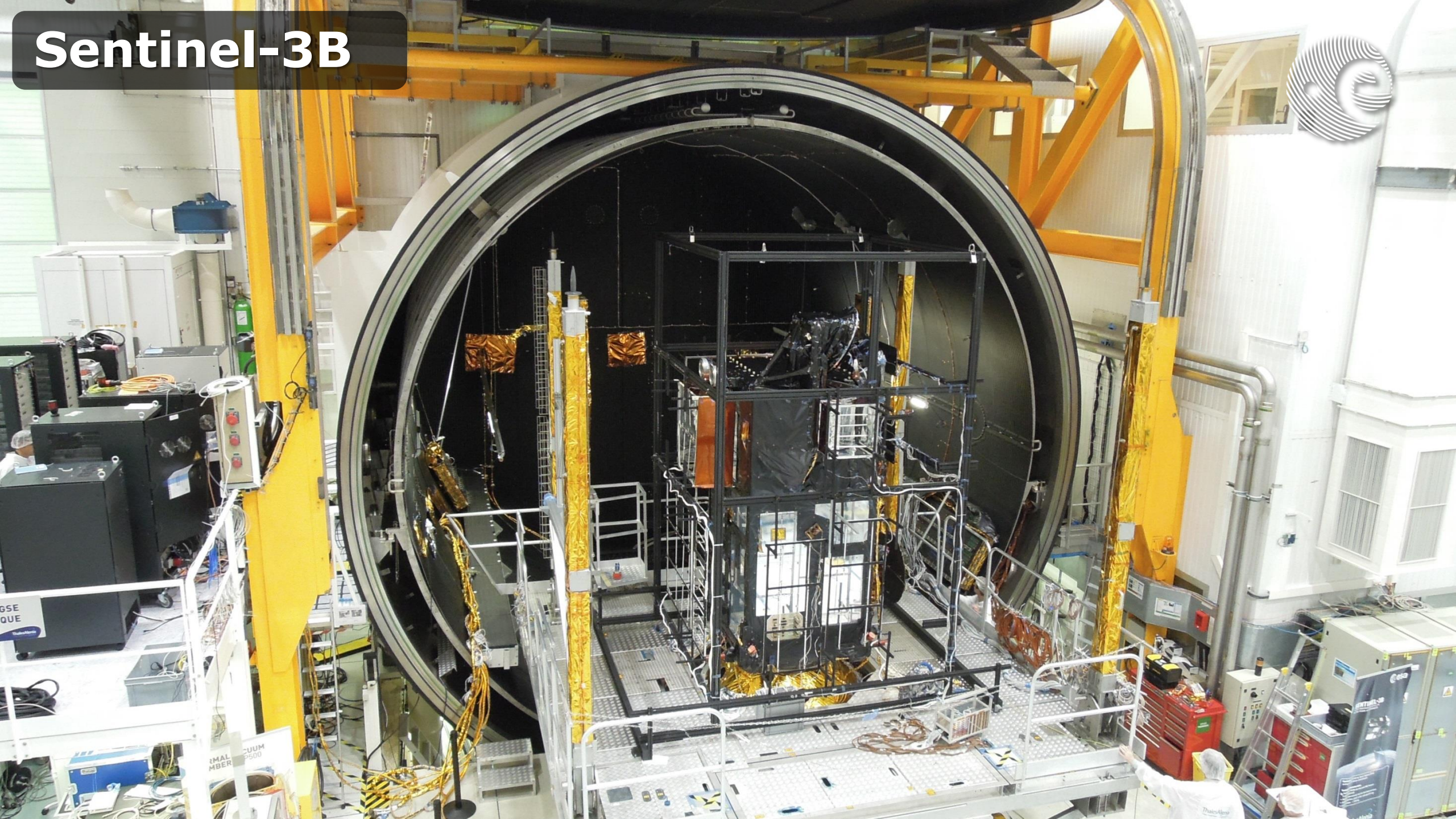


Altimetry

A
2020

B
2025

Sentinel-3B

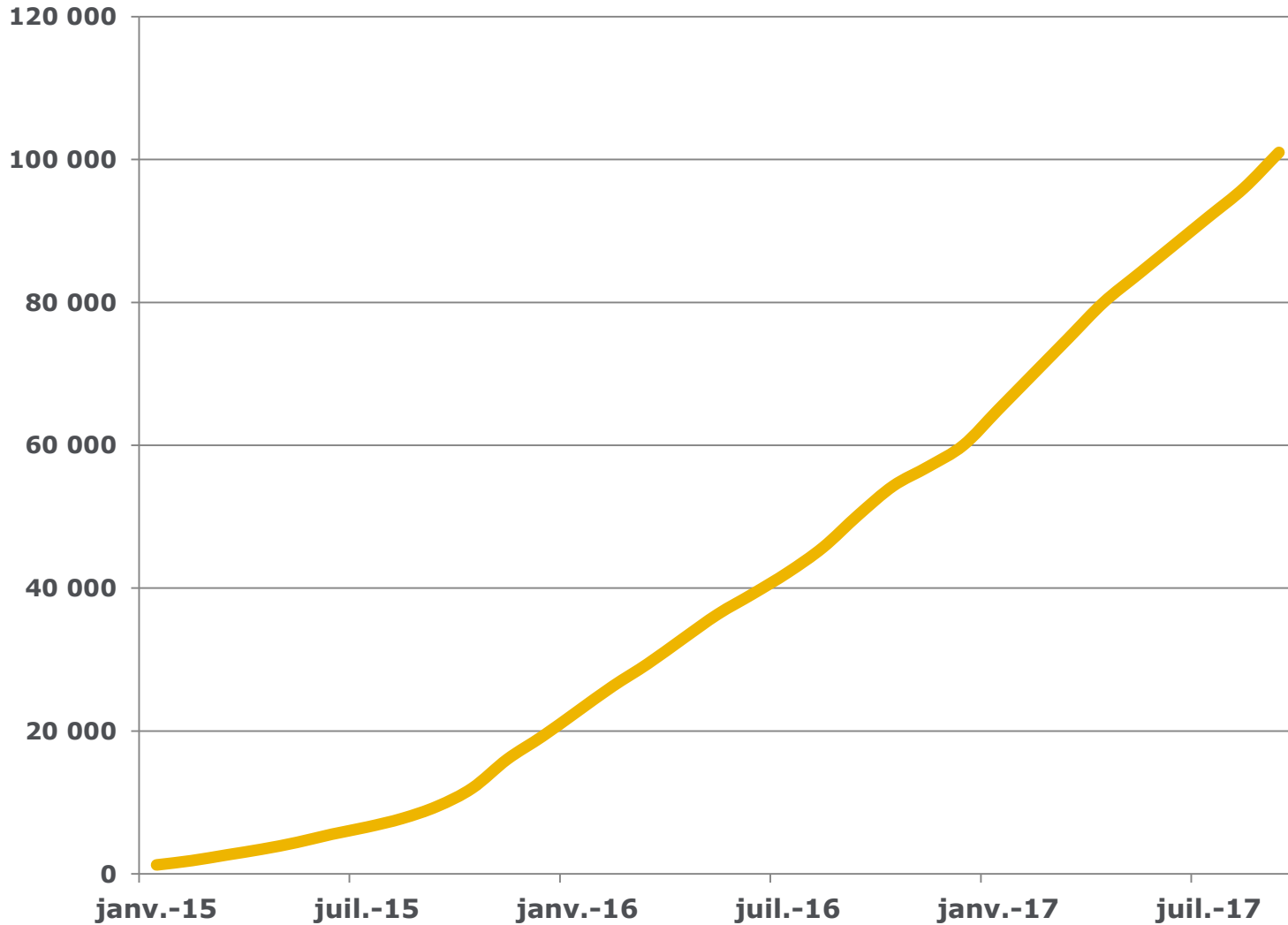


GE
QUE

SMAL
MBER
CUUM
P500



Copernicus User Uptake



Sentinel Registered Users

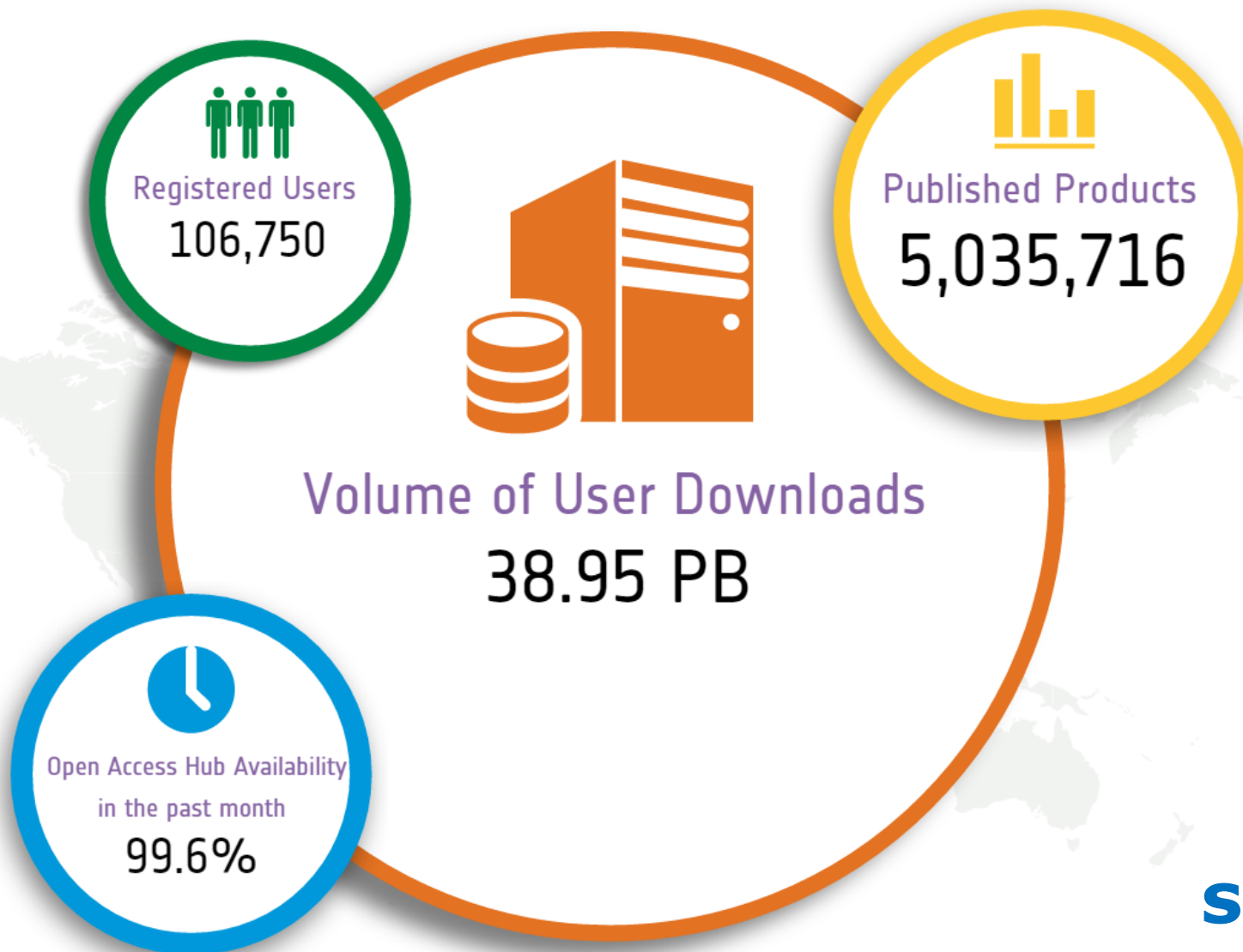
Real number of users is much higher but unknown due to the "open" data policy.

Free, full & open data policy

Sentinels: Data Access Stats

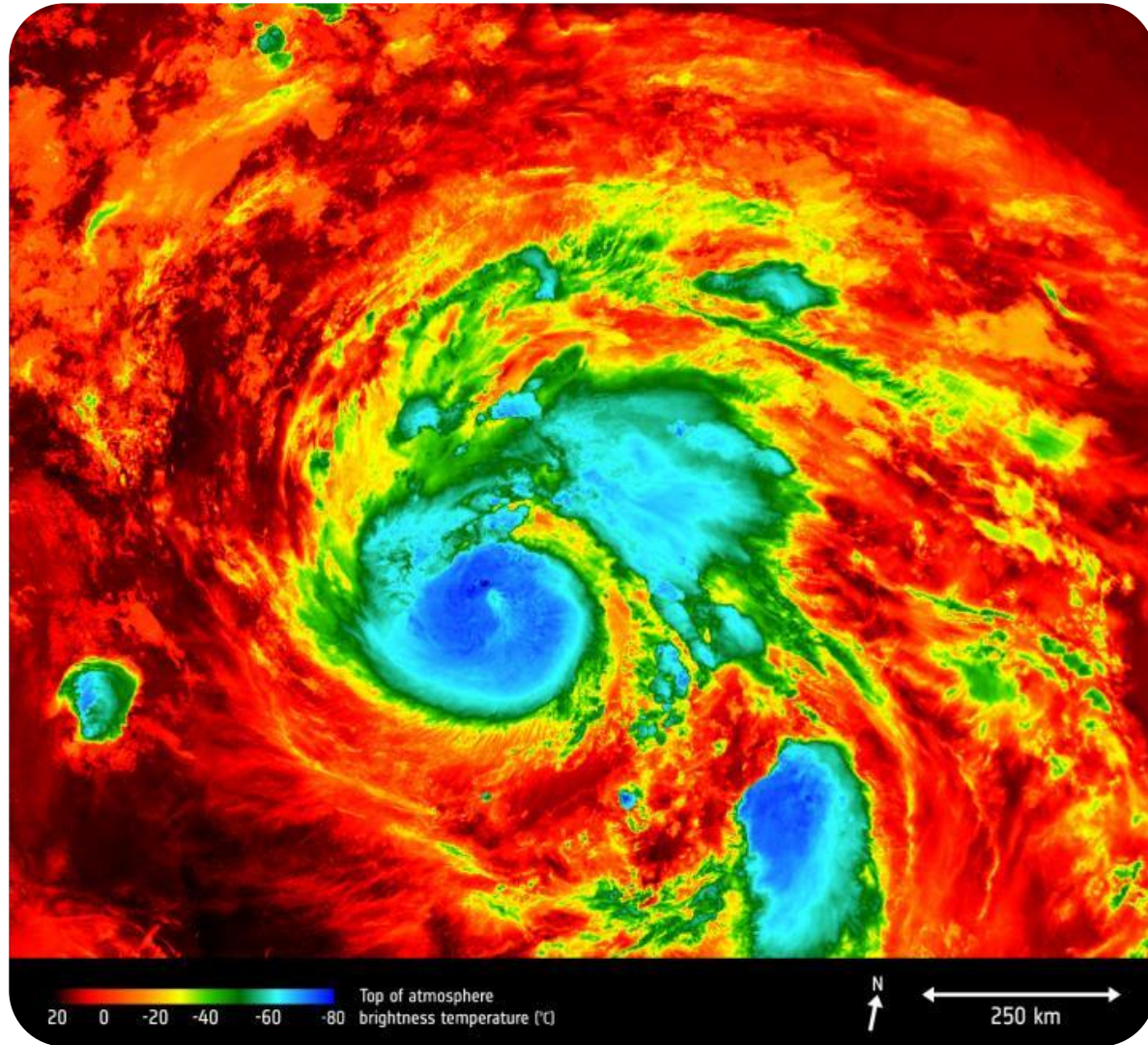
16 Nov. 2017

Source: Open Access Data Hub



scihub.copernicus.eu

Hurricane Harvey



< Temperature at the top of the storm as it approaches Texas

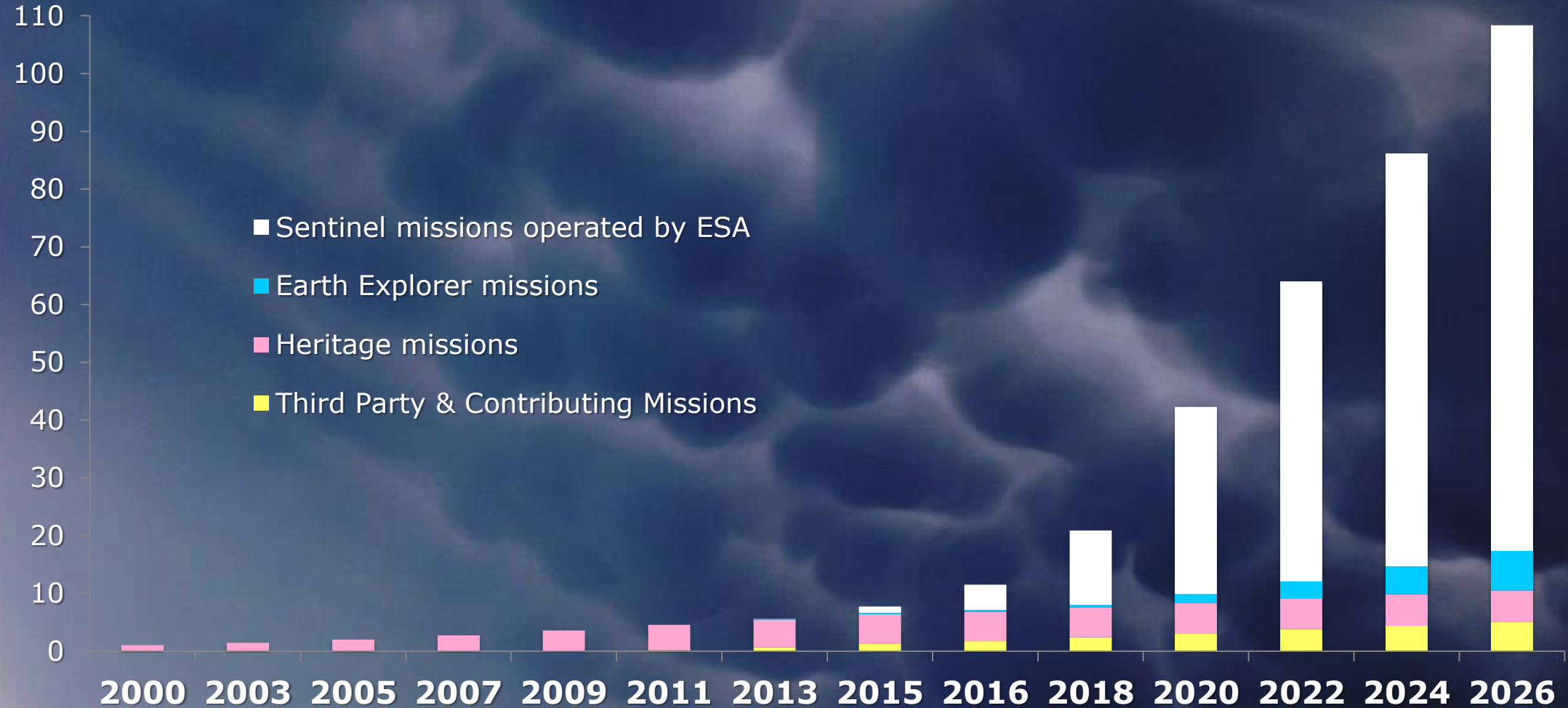
25 August 2017
Based on Sentinel-3A data



Big Data Revolution



ESA EO Data Archive, in Petabyte



Expansion Copernicus (Sentinel 7, 8, 9, ...)



Envisaged Candidates

Anthropogenic CO₂

Agriculture/Urban

Agriculture/Mining

Agriculture/Polar

Polar Ice & Snow

Polar Floating Sea Ice

Copernicus Space Component Evolution



2014



Next-Gen. missions will replace current & expansion missions



Climate Change Initiative Extension (CCI+)



Four Lines of Activity

- R&D on existing ECV
- New ECV
- Knowledge Exchange
- Cross-ECV Scientific Exploitation



Earth Explorers: EO Science Missions



GOCE	2009 - 2013
SMOS	2009 - Present
Cryosat	2010 - Present
SWARM	2013 - Present
ADM - Aeolus	2018
EarthCARE	2019
Biomass	2021

Upcoming Earth Explorers



5

Aeolus

- Global observations of wind profiles for analysis of global 3D wind field
- Launch planned for 2018



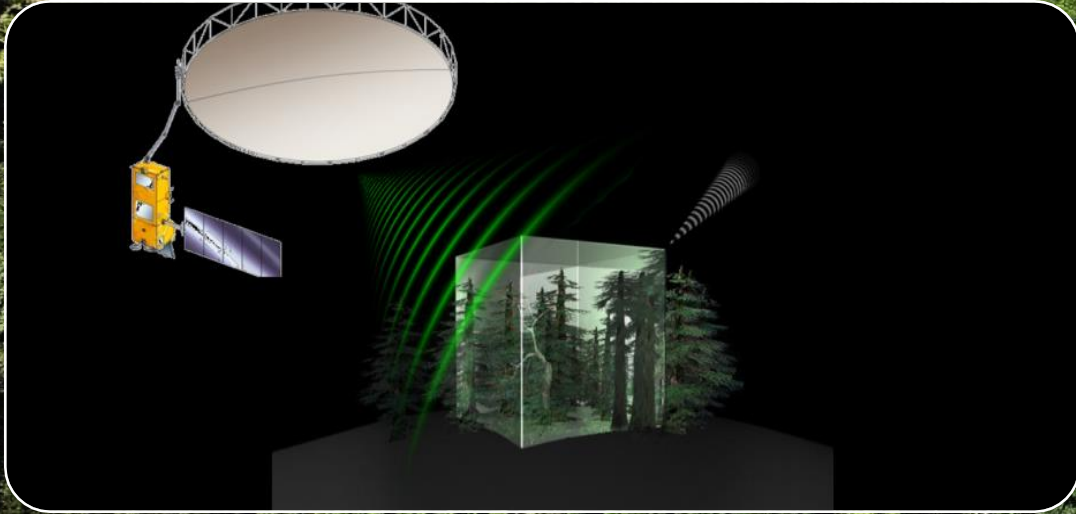
6

EarthCARE

- Global observations of clouds, aerosols & radiation
- Cooperation with JAXA
- Launch planned for 2019



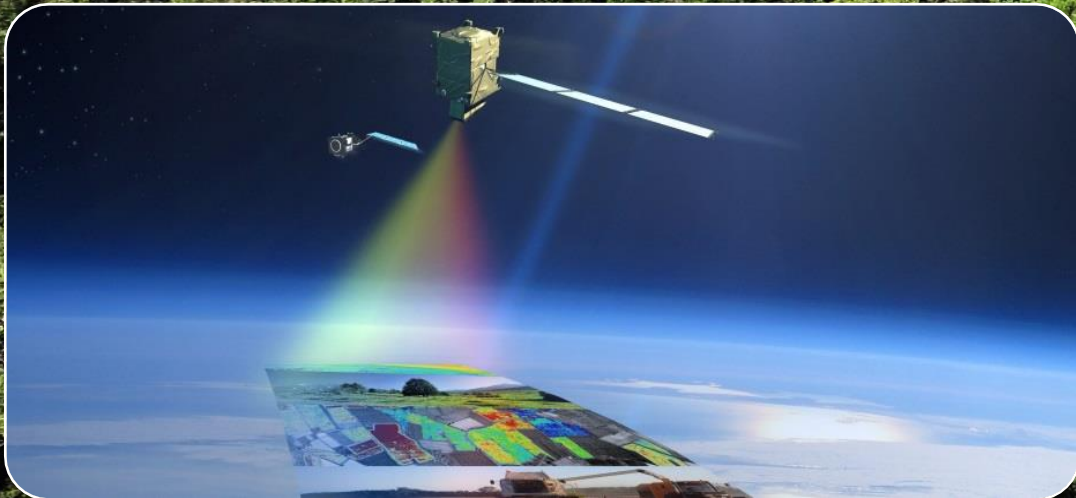
Further Earth Explorers



7

Biomass

- Biomass estimates based on global radar observations
- Launch planned for 2021



8

FLEX

- Global maps of vegetation fluorescence, an indicator of photosynthetic activity
- Launch planned for 2022

Earth Explorers 9 & 10



9

2 Candidates

- **FORUM**
- **SKIM**

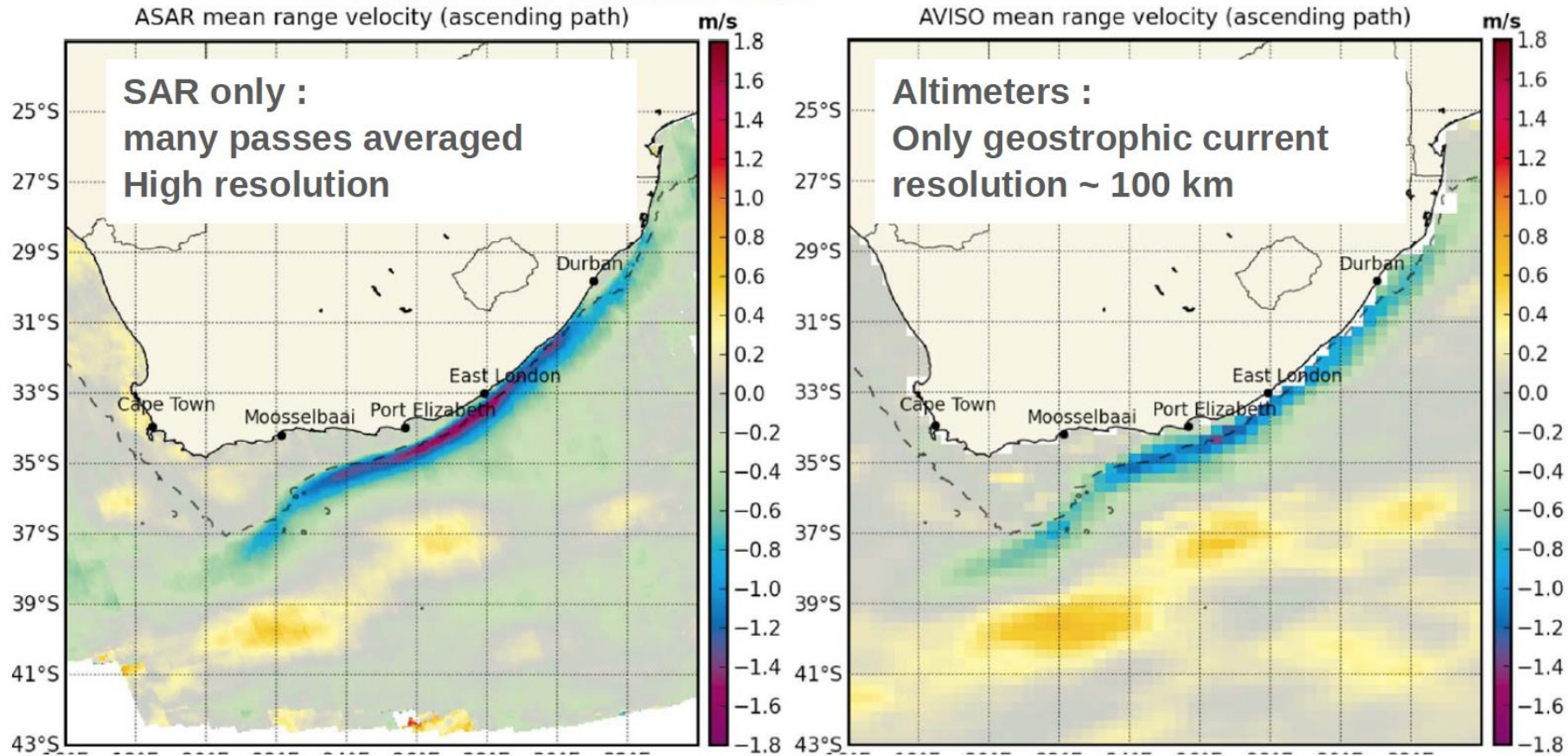
Launch around 2025

10

- Call for Ideas Phase
- Letters of intent due in Dec. 2017
- Mission idea proposals by Mar. 2018
- Launch around 2027/28



SKIM will give **total surface current** on **each pass** at **high resolution**
 Accuracy ~ **0.3 m/s** on 6 km footprint (~ 0.7 m/s with Envisat, ?? with S1)
 ~ **0.15 m/s** in ice-covered ocean

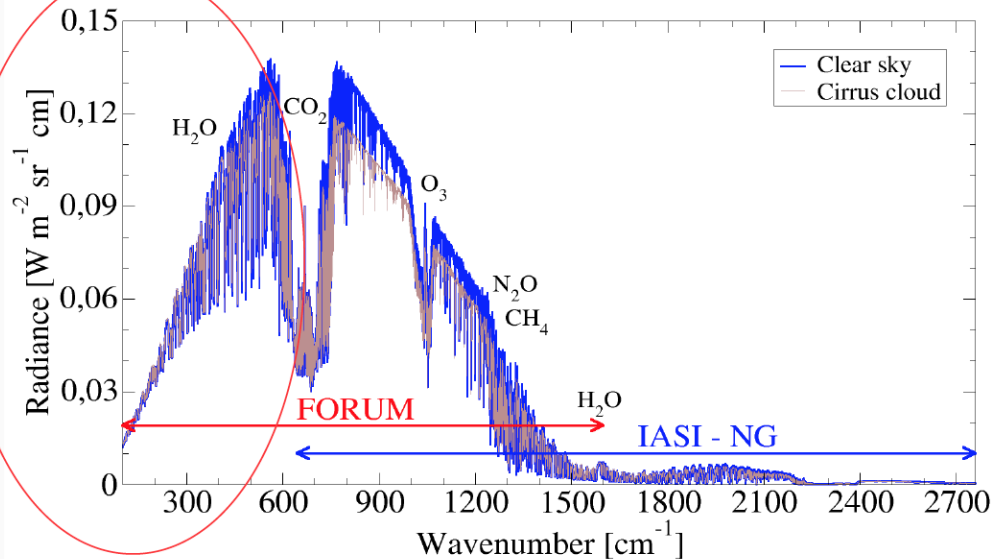


Rouault et al. (J. Geophys. Res. 2010)



INO-CNR
NATIONAL
INSTITUTE OF
OPTICS

Far-infrared-Outgoing-Radiation Understanding and Monitoring



Lead Investigator
Luca Palchetti (INO-CNR)

Partners from 8 ESA
countries international
partnership (USA)

- 1) Provide the first global **spectrally resolved observations of the OLR** from 100 to 1600 cm^{-1} (100-6.25 μm) with a resolution of 0.3 cm^{-1}
- 2) Fills the observational gap across the **far-infrared** (FIR: 100-667 cm^{-1}) region, never before sounded spectrally, in its entirety from space
- 3) By flying FORUM in tandem with Metop-SG it will be possible, for the first time, to observe the entire outgoing infra-red spectrum at high spectral resolution and accuracy
- 4) Provides a multi-year dataset benchmarked against international standards with an **absolute accuracy of at least 0.1 K** in TOA brightness temperature.

ESA Roadmap for the Arctic



Axis 1: Large satellite missions and experiments

Axis 2: Small/medium satellite missions including micro-launchers to bring these missions into orbit

Axis 3: Exploitation, applications, services, Business Incubators (BIC)

Draft Workplan for Arctic Activities 2018-19

- Based on existing activities approved, particular at CMIN-16, in programmes directorates (EOP, TIA, NAV, TEC, OPS, LAU)
- Workplan based on the ESA Arctic Roadmap
- Take note on MS, scientific, environmental, operational, and commercial needs/requirements
- Include both activities funded by existing ESA programmes and additional new actions to be financed in the frame of the Arctic Task Force
- Workplan under consolidation and to be presented at ESA December 2017 Council for approval

About Cal/Val (1) ...

ESA has its own mechanisms for cal/val issues for its own missions

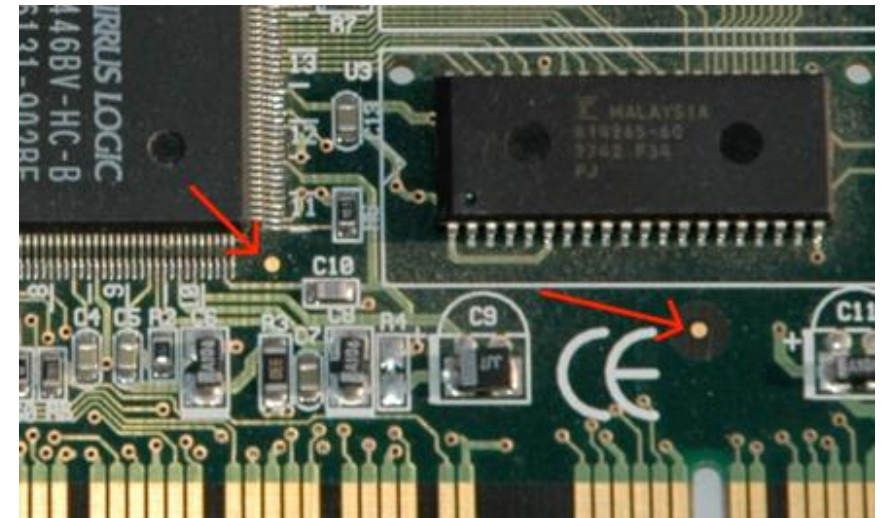
- Huge efforts in the past (developed transponders for ERS, ENVISAT, Flevoland test site)
- Cal/Val of L0 and L1 products (radiance, backscattering coefficient as L1b product)
- Also activities to cal/val L2 (geophysical product, e.g. soil moisture)
- Includes also reprocessing of the data (e.g. for CCI)
- Part of the EOEP (EO Envelope Programme), but underfunded at CM-16
- ESA involved in CEOS Quality Assurance Framework for Earth Observation (QA4EO; <http://QA4EO.org/>)



About Cal/Val (2) ...

For Sentinel and Copernicus data

- Copernicus developed by the EC as an operational system to answer the needs of the six Copernicus services (not for science purposes, hence different requirements for cal/val)
- Cal/Val are funded through the MPC (Mission Performance Centers)
- Issues in funding in-situ data (FRM: Fiducial Reference Measurement)
- ESA launched in 2016 a 500 K€ activity (FRM4SOC: FRM for satellite ocean color)



About Cal/Val (3) ...

- ESA+EUM are raising the awareness of the EC to the cal/val issue.
 - To develop a vicarious calibration infrastructure for Sentinel-3 to be proposed for funding to the EC as part of the Copernicus programme.
- International collaboration has been already triggered.
 - S2a and Landsat-8 optical systems have been measured and inter-calibrated before launch
 - Discussions with NASA, JAXA, China for inter-calibration between OCO-2 and TanSAT, and GOSAT

Cal/Val is difficult and expensive. Cost was and is still a driver !

Thank you for your attention!

www.esa.int