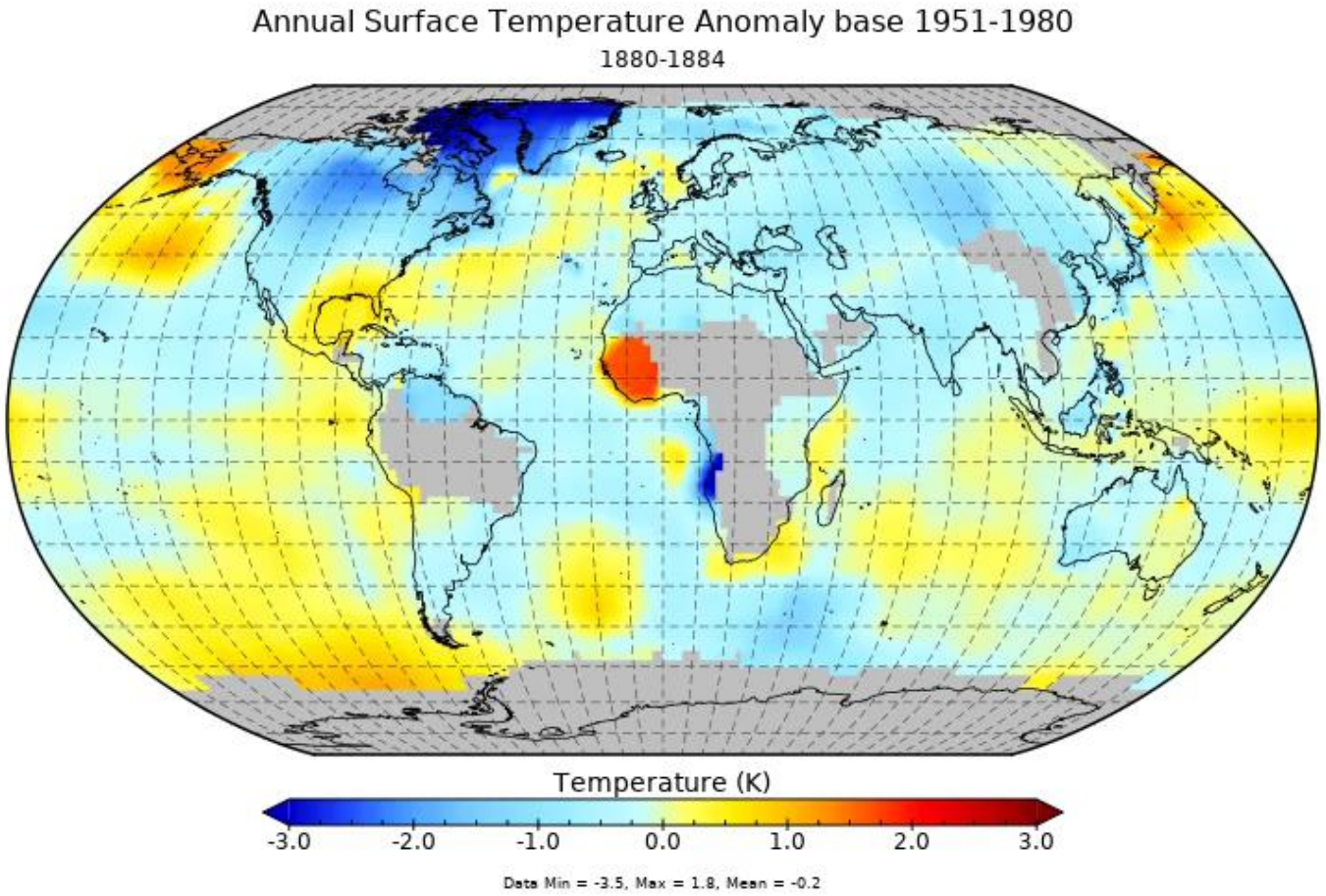
# The International SST FRM Radiometer Network

**Craig Donlon**
ESA/ESTEC, Noordwijk, The Netherlands

ISFRN Workshop, National Oceanography Centre Southampton, UK,
27-28 February 2019.

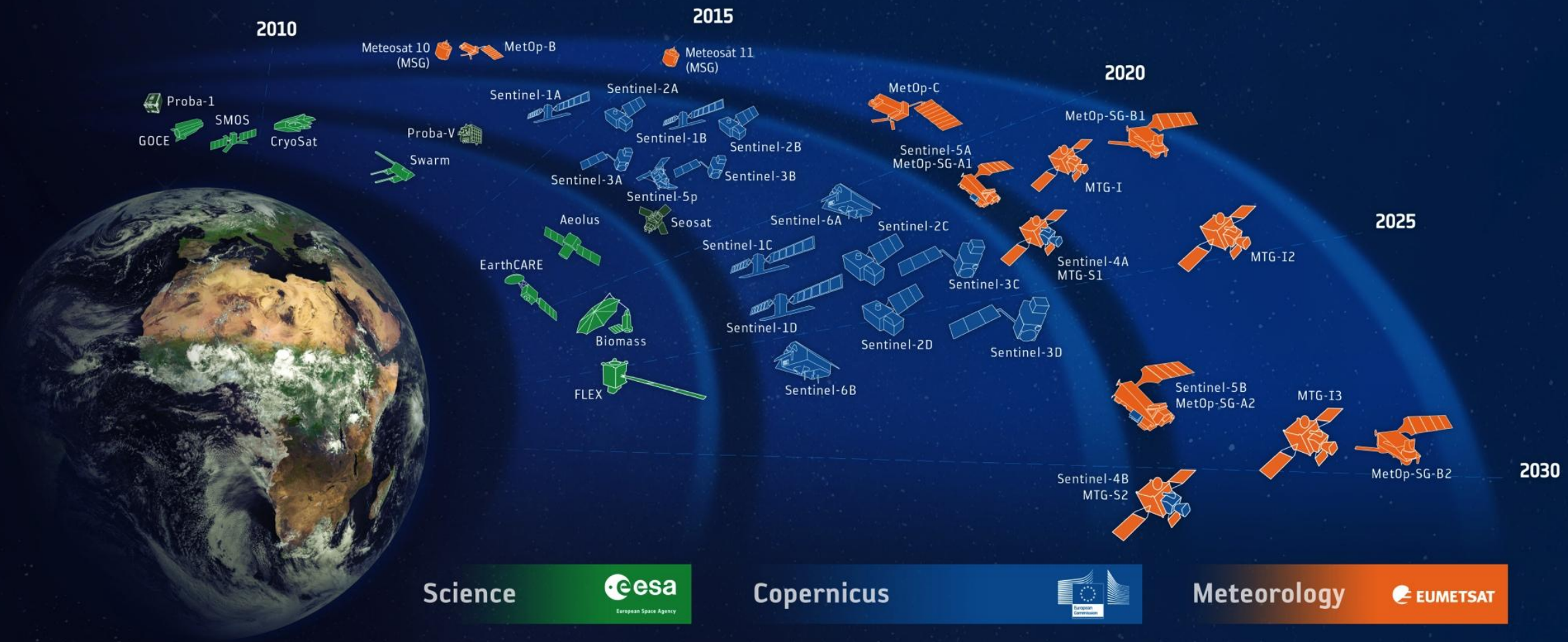
# Overview

- Why we need it
- Standards and uncertainty
- Developing capability
- Developing the network
- To the future
- Conclusions




GISS Surface Temperature Analysis (GISTEMP) estimate of global surface temperature change (Hansen et al. 2010).

# ESA–DEVELOPED EARTH OBSERVATION MISSIONS



# Copernicus

- 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

# Copernicus Sentinel Satellite 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** 2021
- **B** 2027

## S-5P

Atmospheric Chemistry (LEO)

- **A** 13 Oct. 2017

## S-5

Atmospheric Chemistry (LEO)

- **A** 2021
- **B** 2027
- **C** > 2027

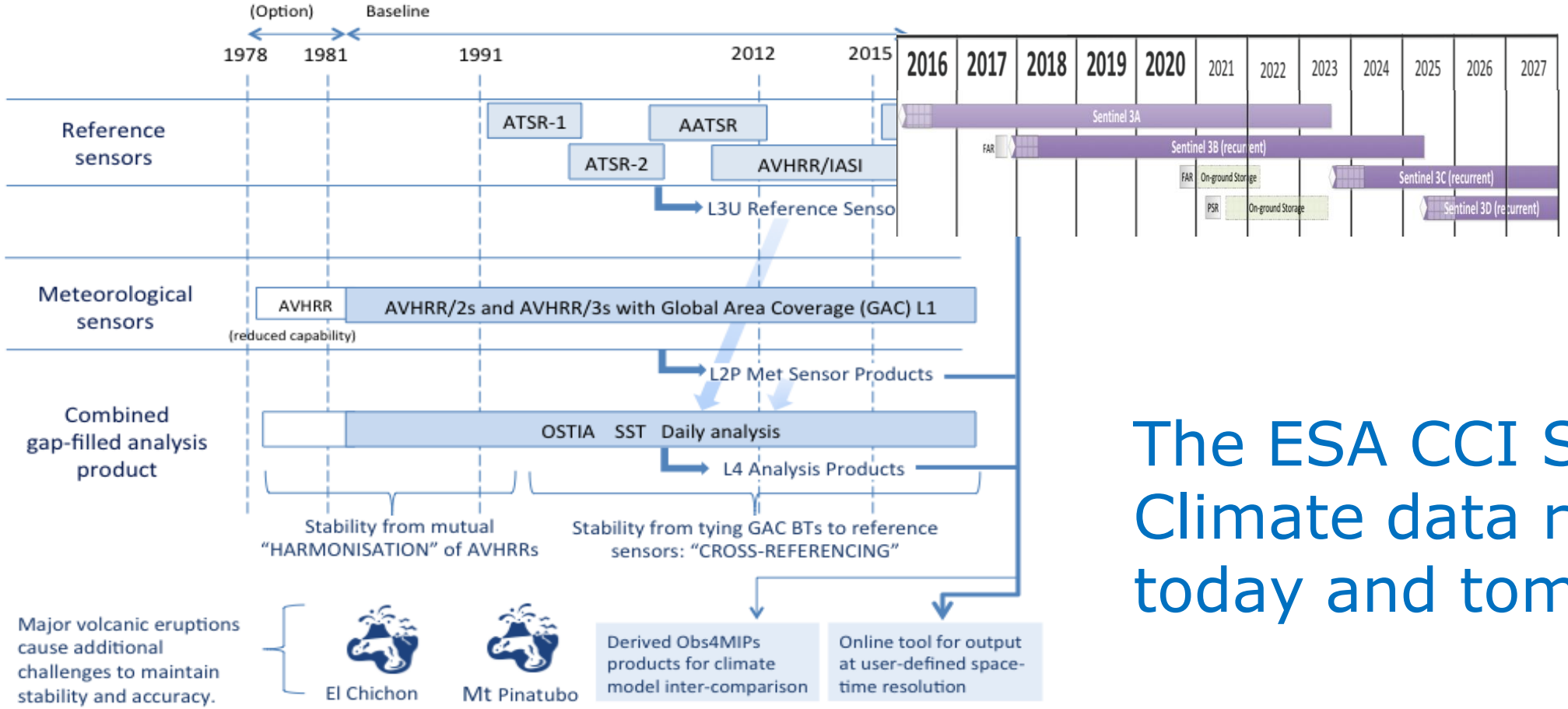
## S-6

Altimetry

- **A** 2020
- **B** 2025

opernicus
Europe's eyes on Earth

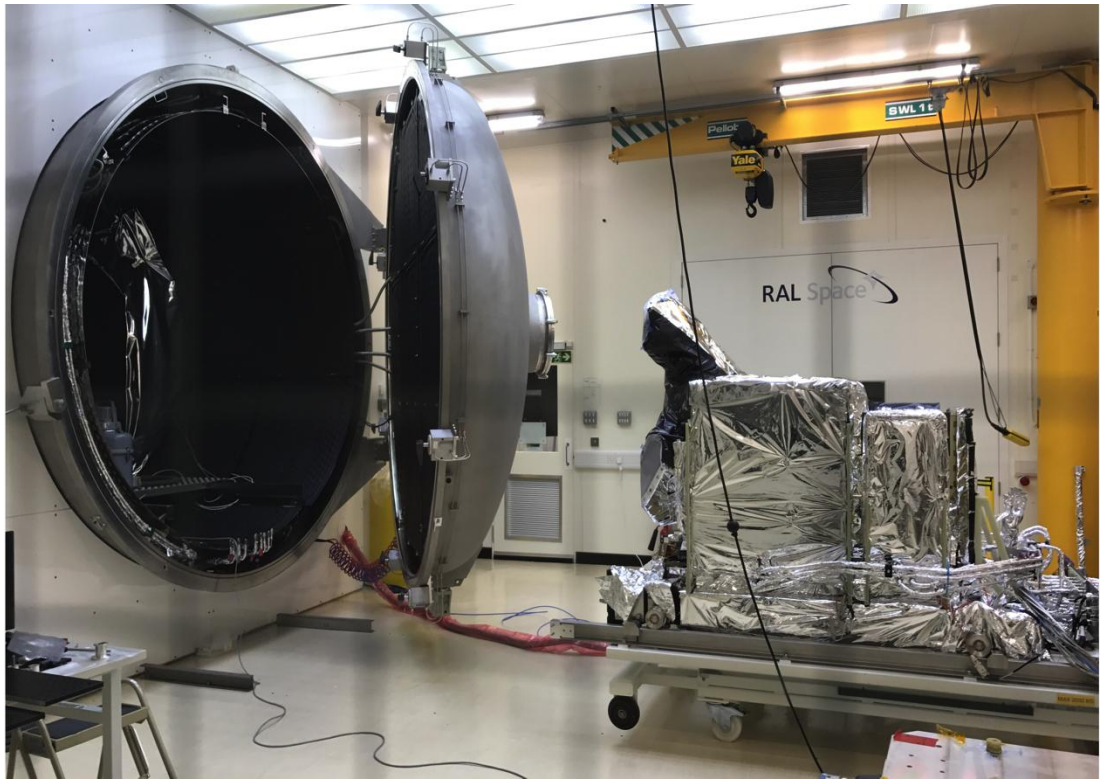
European Space Agency




# The ESA CCI SS Climate data record today and tomorrow.

climate change initiative

# Fiducial Reference Measurements




**SLSTR Pre-flight Calibration, STFC-RAL, UK, December 2016**

# SI traceability: LCE (June 2016)

## Necessary for all participants to assess biases to SI under Laboratory conditions


ITS-90

NPL BB

PTB BB

NPL Rad (AMBER)

PTB Rad

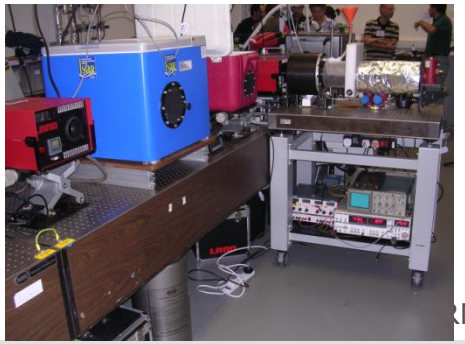
Rad 1 | Rad 2 | Rad 3 | Rad 4 | Rad n

BB1 | BB 2 | BB 3 | BB 4 | BB n

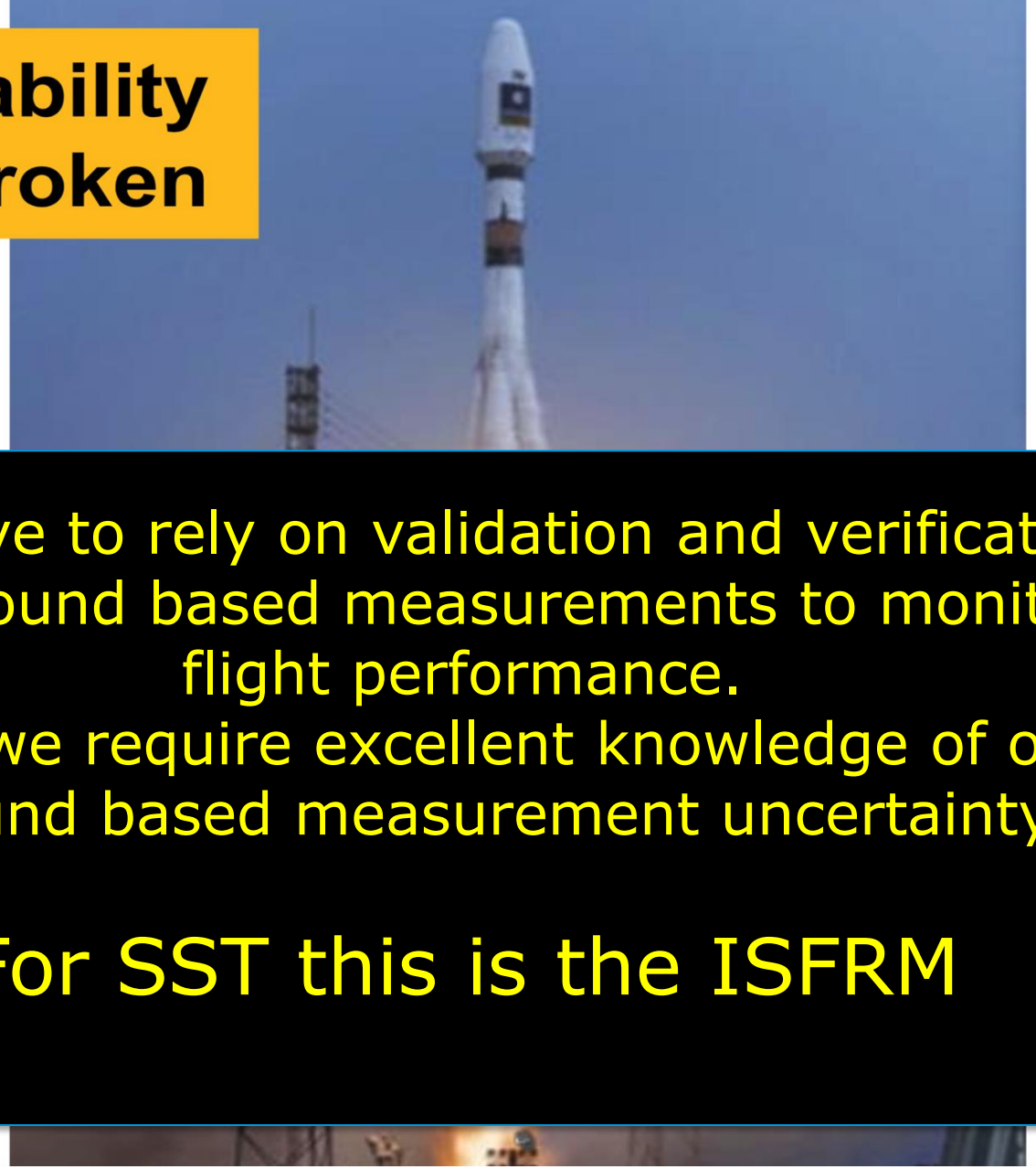
T= ~250 – 325 K

Non-vacuum

Room Environment with variable T



# The traceability chain is broken



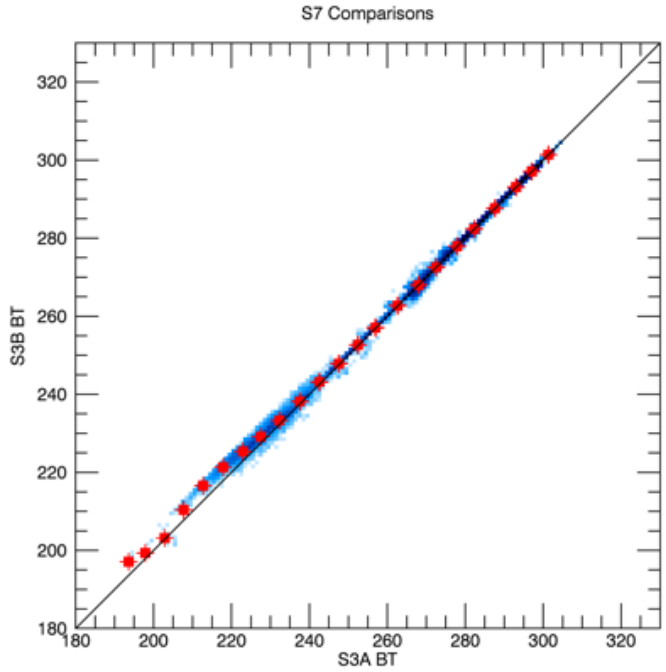
We have to rely on validation and verification using ground based measurements to monitor in flight performance.
Thus we require excellent knowledge of our ground based measurement uncertainty

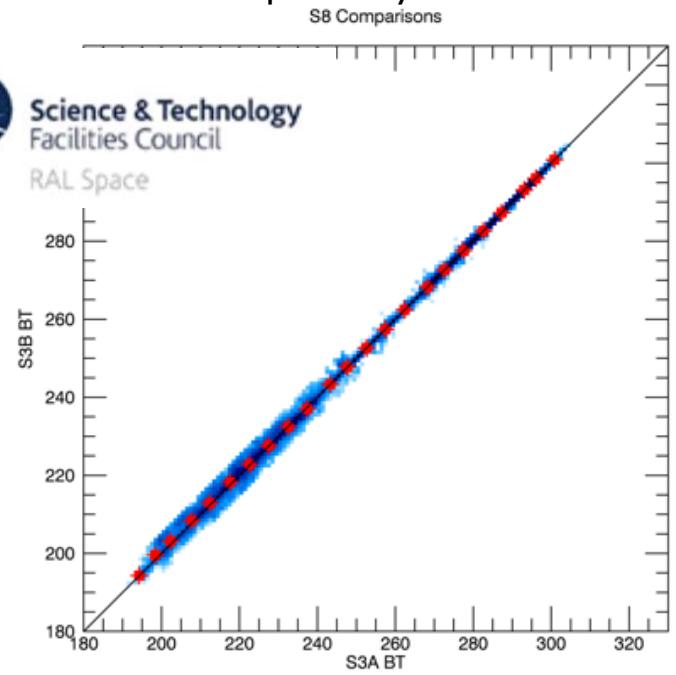
For SST this is the ISFRM

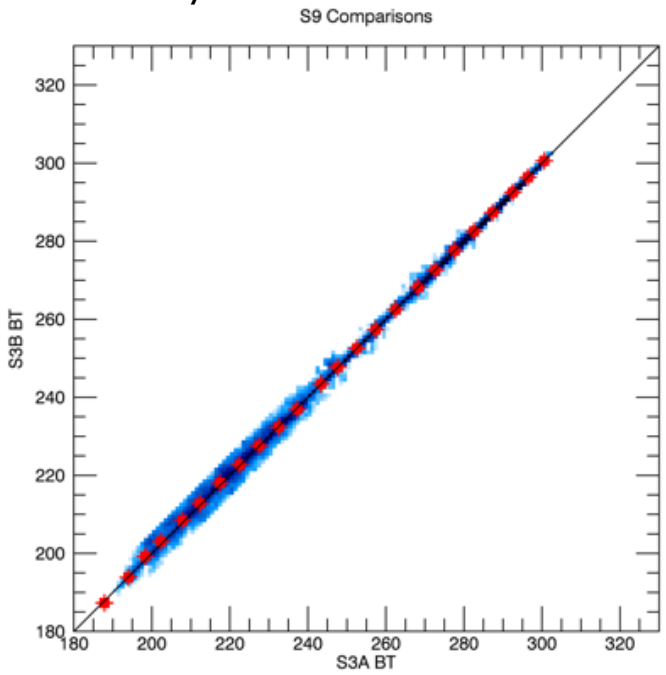
(E. Wooliams)

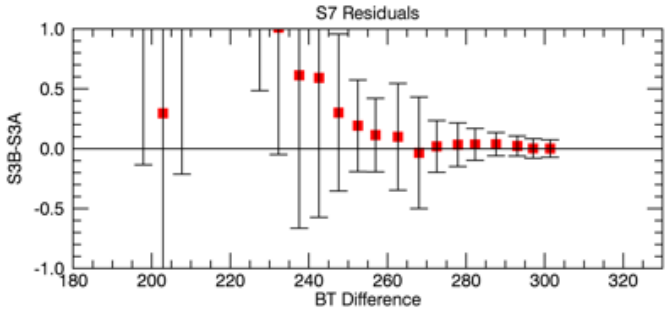
# S3B-S3A Tandem Comparisons – Nadir View

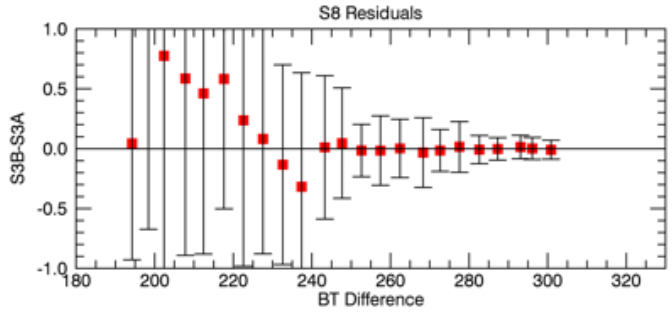
Low temperature differences possibly due to residual non-linearity

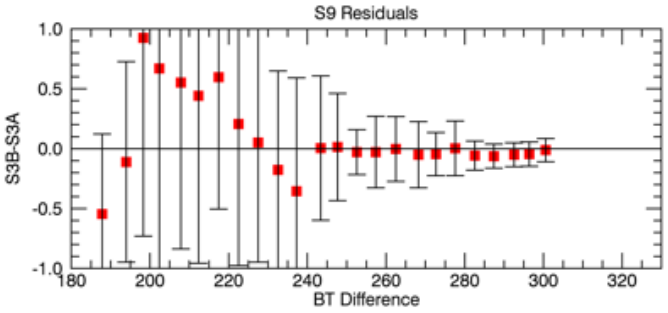


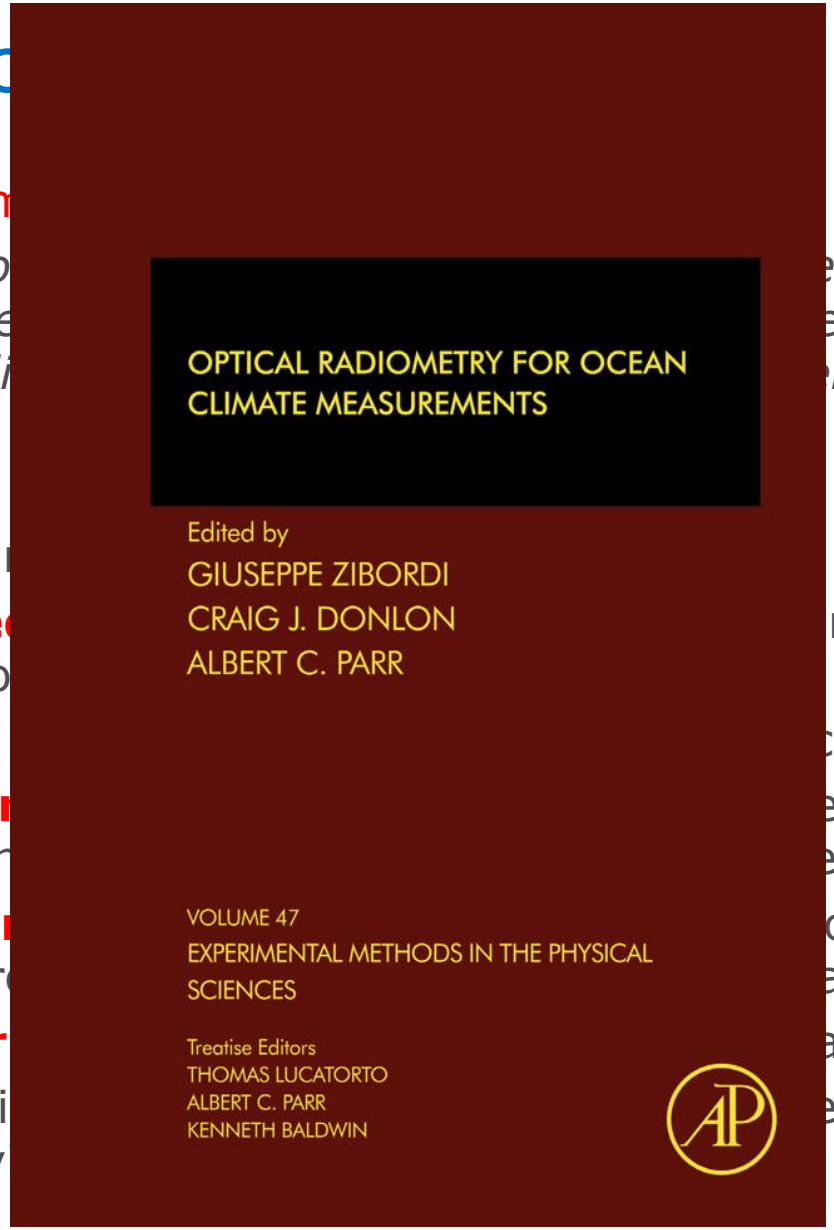



# Fiducial Referenc

## Fiducial Reference Measurem

*the suite of independent gro* *e maximum Scientific Utility and Return On Investment for a satellite* *e required confidence in data products, in the form of independent vali* *ement uncertainty estimation, over the duration of the mission.*




The defining mandatory cha

- Have **documente** nter-comparison of instruments under operational-like co
- Are **independent** cess.
- **Include an uncer** ents and derived measurements is available and mai to SI ideally directly through an NMI
- Are **collected usi** ommunity-wide management practices (measurement, pr are defined and adhered to.

FRM are as close **to the "Tr** an get!

FRM are required to determi eristics of satellite measurements via independent validation activ

# Strategies for the Laboratory and Field Deployment of Ship-Borne Fiducial Reference Thermal Infrared Radiometers in Support of Satellite-Derived Sea Surface Temperature Climate Data Records

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fiducial reference temperature measurements

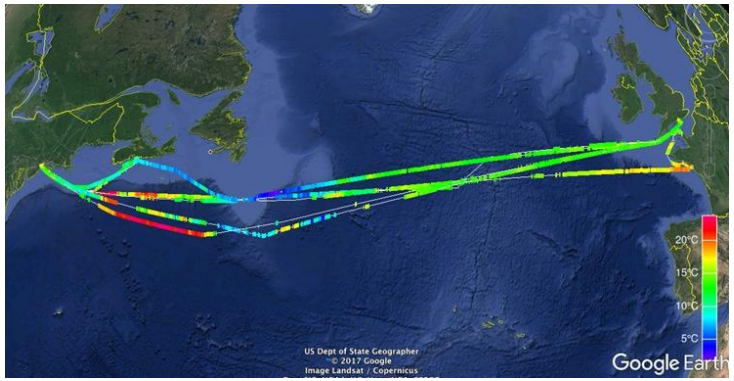
amt4sentinelfrm

fiducial reference measurements for satellite ocean colour

ships4sst

# (13 participants / 4 Continents)

1. Miami University (USA)
2. ONERA (France)
3. University of Valencia (Spain)
4. University of Southampton (UK)
5. Qing Dao (China) -1
6. Qing Dao (China) -2
7. RAL (UK)
8. CSIRO (Australia)
9. KIT (Germany)
10. DMI (Denmark)
11. GOTA (Canary Islands
12. JPL NASA (USA)
13. Ian Barton (Australia)



# ISAR uncertainty model (Dr. W. Wimmer)

- *ISAR uncertainty*
  - *Uncertainty value for each SST measurement*
  - *Analysis of the uncertainties of the individual instrument components*
  - *Propagation of uncertainties through the SST processor to the final value.*

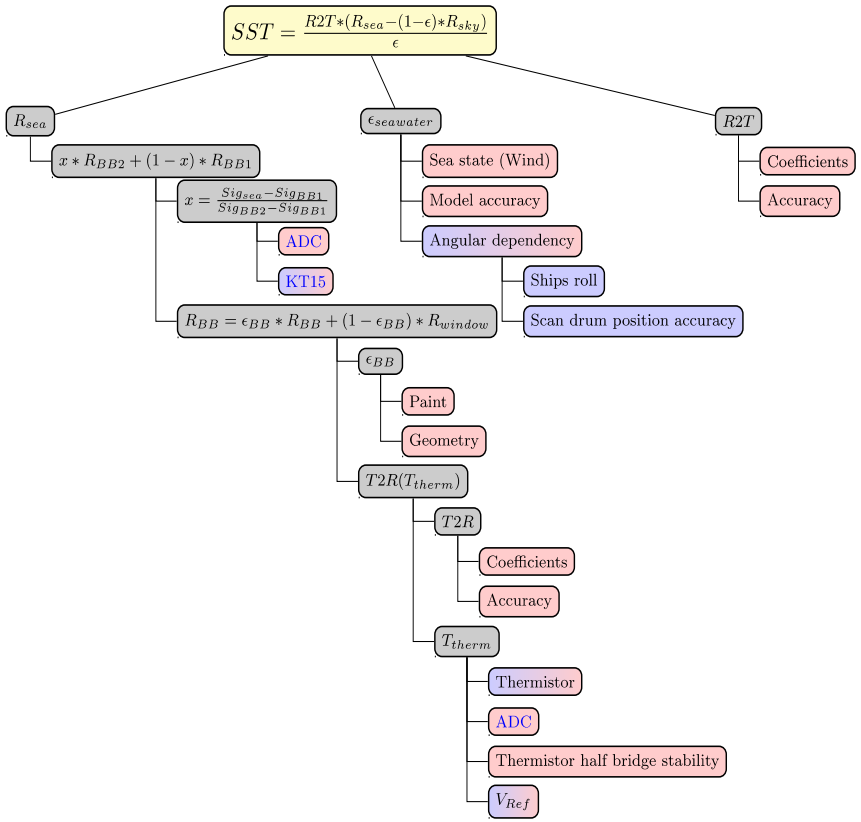
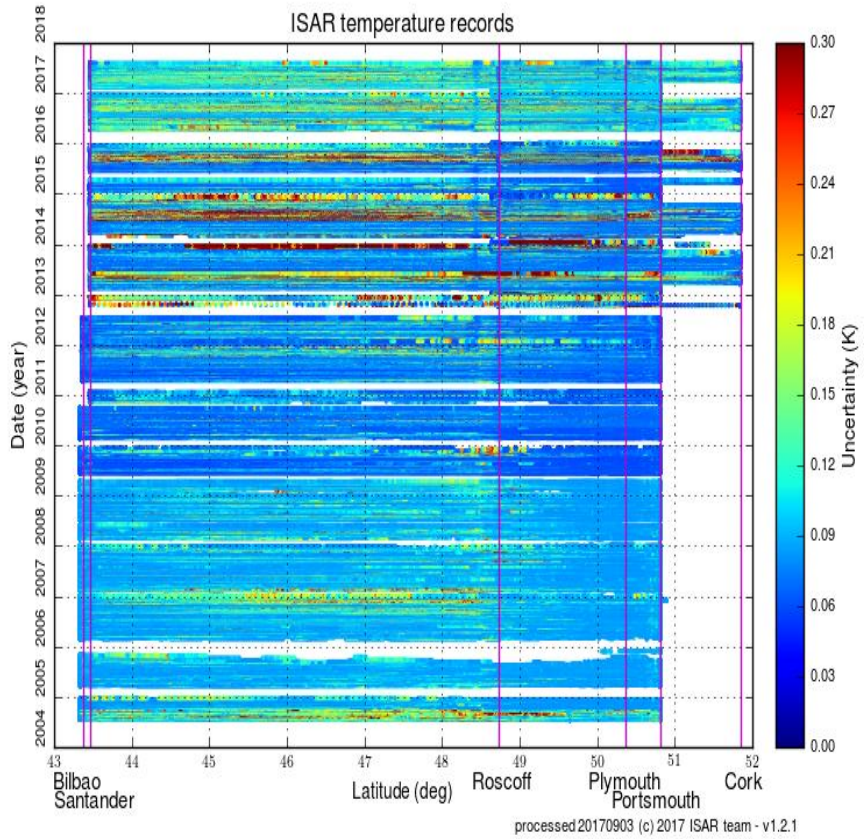
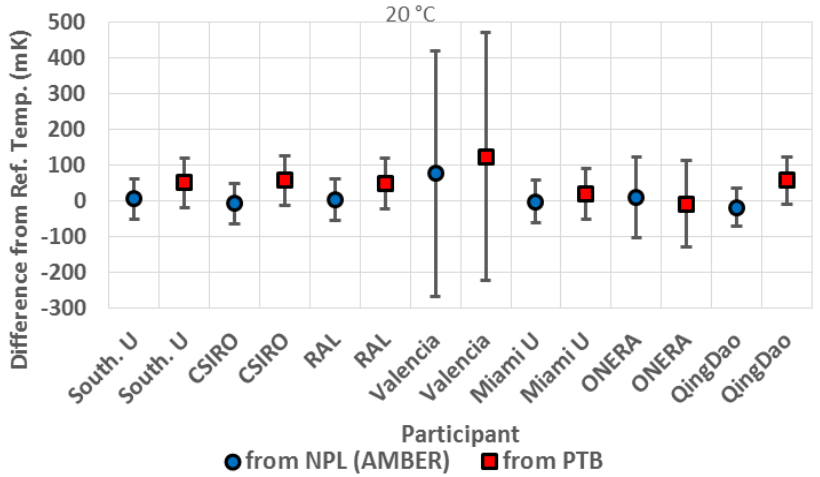



FIGURE 1.1: Flow chart of the ISAR *SST* processor. $R_{sky}$ follows the same path as $R_{sea}$. Boxes coloured in blue show Type A uncertainties, boxes coloured in red show Type B uncertainties and boxes in red and blue show that the particular box has both Type A and Type B uncertainties.



# FRM Metrology embedded in the ISFRM community

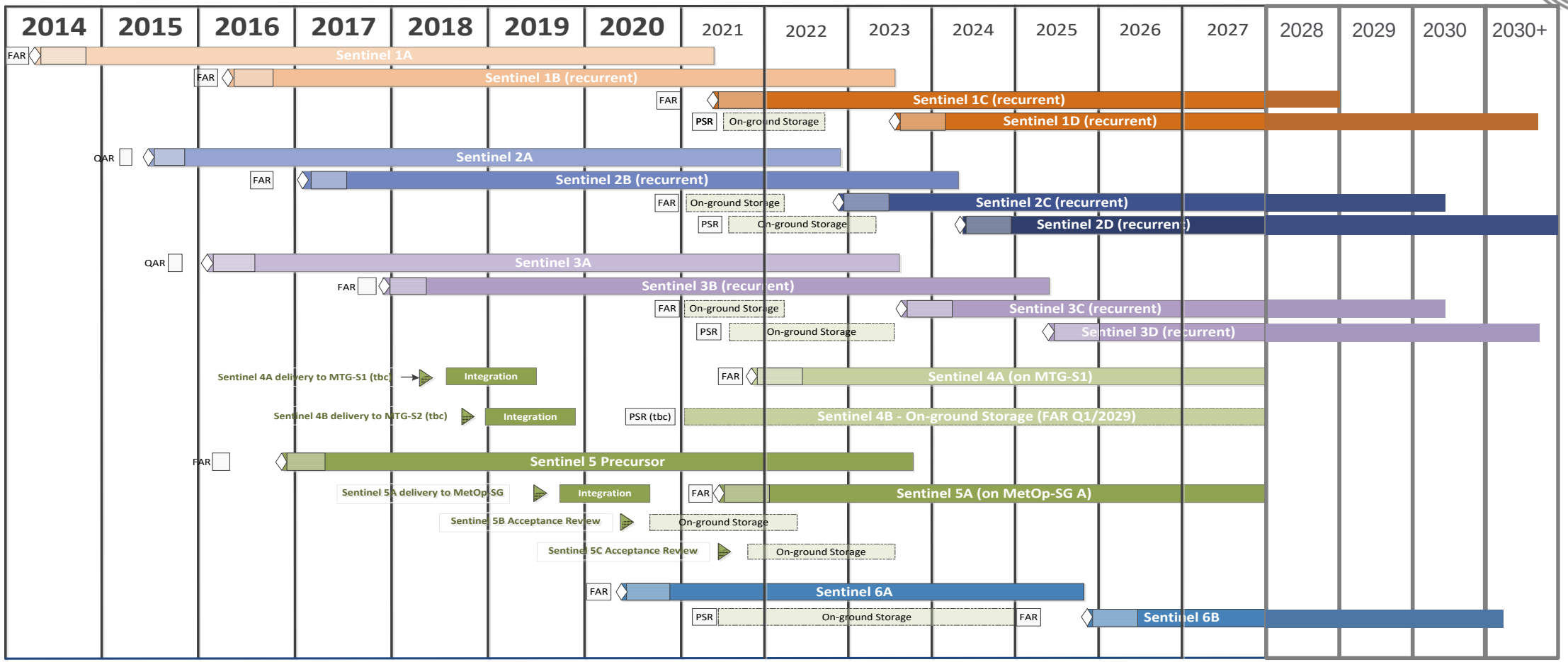

| | mean difference from mean (°C) | | |
|---|---|---|---|
| Radiometer | All radiometers Included | SST-Measuring Radiometers Only | SST-Measuring Radiometers excl. CSIRO |
| | °C | °C | °C |
| RAL | 0.123 | 0.084 | 0.037 |
| KIT | -0.159 | | |
| CSIRO | -0.189 | -0.228 | |
| DMI | -0.020 | -0.053 | -0.106 |
| UoV | 0.117 | | |
| UoS | 0.125 | 0.090 | 0.044 |
| OUCFIRST | 0.033 | -0.002 | -0.054 |
| OUC-ISAR | 0.206 | 0.174 | 0.119 |
| GOTA | 0.593 | | |
| JPL | -0.109 | | |

# The current ISFRN http://www.shipborne-radiometer.org/


- **International partnership** (UK, USA, DK, AUS, CN, KO)
- **A common data format** used by most if not all radiometer operators
- **A central archive**, again used by all - a truly international archive
- **Web presence** with protocols, data format access to archive
- **Software tools**
- Validation analysis

- A real credit to the people involved!

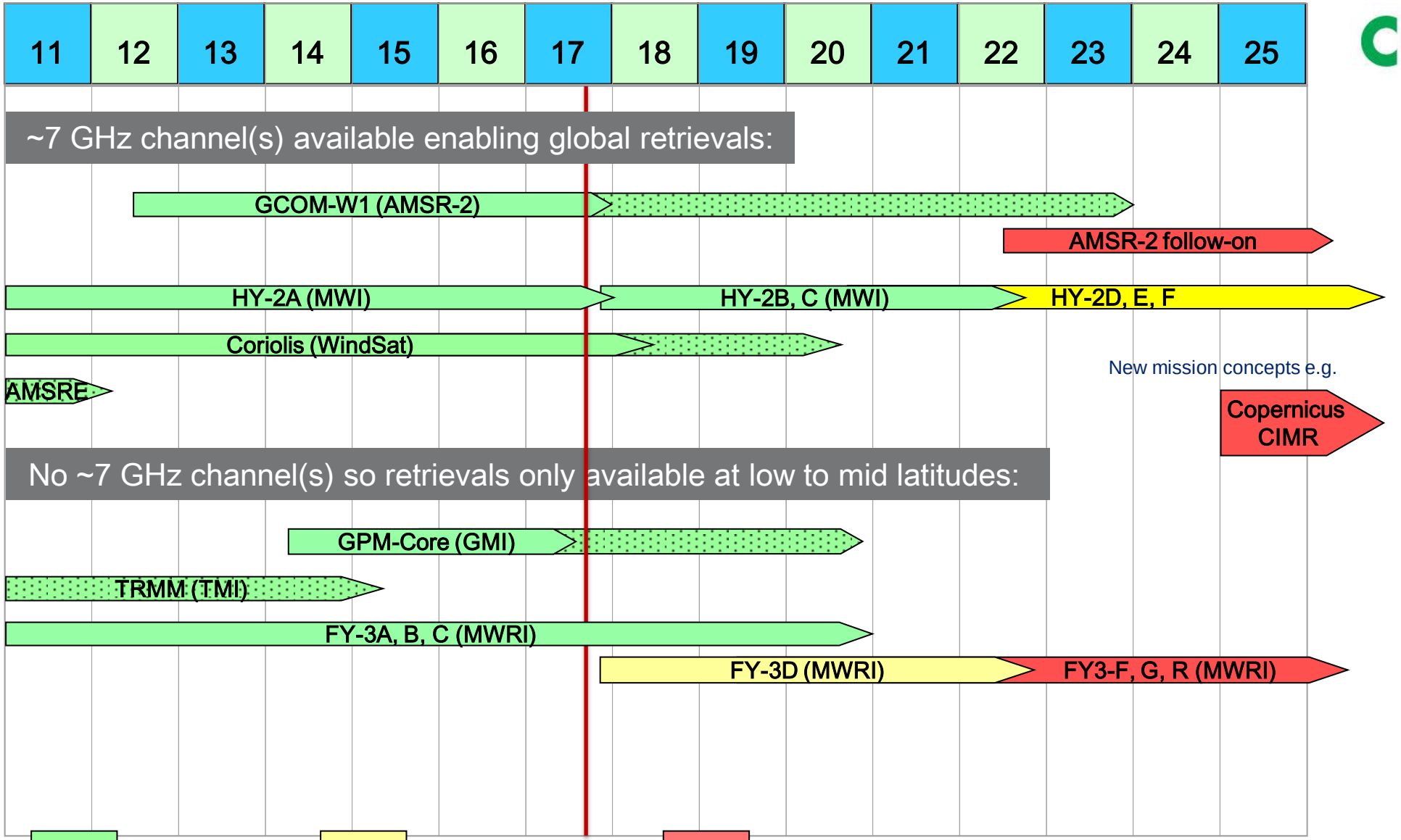
# CSC Segment-4 (2020-2029)




**Copernicus Extension: Copernicus-NG**

**Copernicus Expansion: High Priority Candidate Missions**

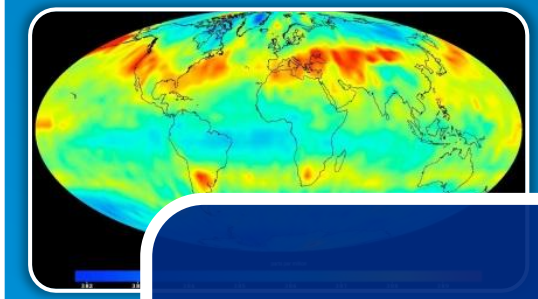
# Polar Orbiting Microwave Radiometers



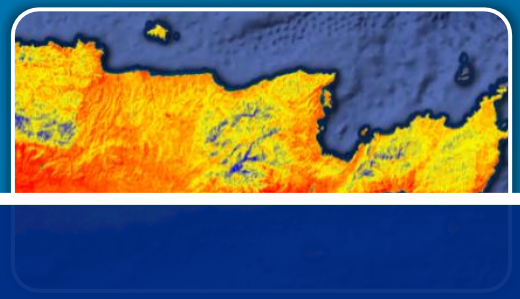

In orbit | Approved | Planned/Pending approval | (in extended mission phase)

# Copernicus 2.0: Expansion

## 6 High Priority Candidate Missions



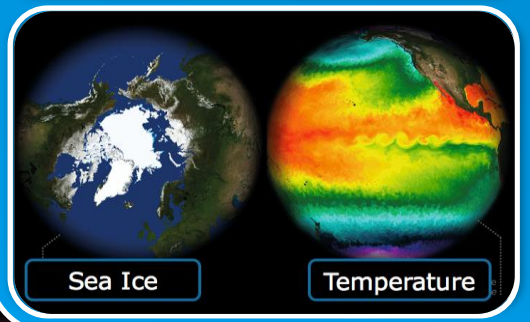
Anthropogenic $CO_2$ Emissions



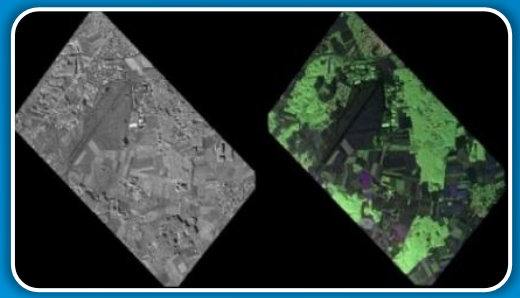
High Resolution Imaging

Polar Ice & Snow Topography

Hyperspectral Imaging




Sea Ice & SST (Arctic situational awareness)



L-band SAR

Monitor causes of Climate Change

Imaging Microwave Radiometer

Agriculture & Water

Surface Temp

Phase A/B1 HPCM Studies are ongoing

volume)

Biodiversity

Soil Moisture, Vegetation & Ground Motion

European Space Agency

# Copernicus Imaging Microwave Radiometer (CIMR)

**Mission Objective**

Respond's directly to the ***Integrated EU Arctic Policy***

- Climate Change and Safeguarding the Arctic
- Environment Sustainable Development in and around the Arctic
- International Cooperation on Arctic Issues
- Operational Sea Ice Services and Global SST capability

**Characteristics**

- **Conically scanning multi-frequency microwave radiometer**
- **Single satellite**, Observation Zenith angle 55±1.5°
  **Coordinated flight with MetOp-SG(B)** <360s separation
- **~95% global coverage every day, mean 6 hourly-revisit in Arctic Areas**
- In Phase A/B1, Launch: 2025

| | | | | | |
|---|---|---|---|---|---|
| Channels (GHz, Full Stokes): | **1.4** | **6.9** | **10.65** | **18.7** | **36.5** |
| Resolution (km): | **<60** | **≤15** | **≤15** | **≤5** | **≤5** (g:4km) |
| NEΔT (K @150K): | **≤0.3** | **≤0.2** | **≤0.3** | **≤0.4** | **≤0.8** |

**L2 Products (Performance, P=Primary, S=Secondary)**

***P1: Sea Ice Concentration (≤5 km, 5%)***

***P2: Sea Surface Temperature (5 km km, ~0.2 K)***

*S: Sea Ice Drift (≤25 km, 3 cm/s)*

*S: Thin Sea Ice Thickness (~40 km, 10%)*

*S: Terrestrial Snow extent*

*S: Snow Water Equivalent*

*S: Sea Surface Salinity (~40 km)*

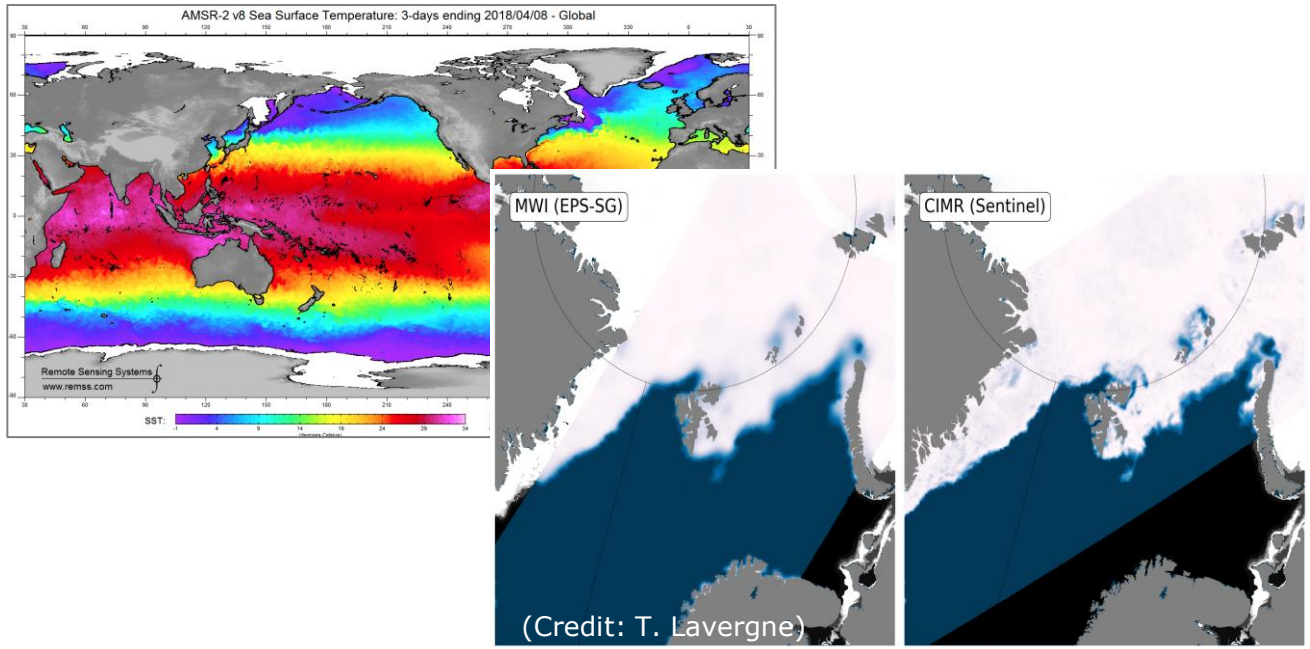
*S: Ice Type (≤5 km)*

*S: Extreme Wind*

Additional tertiary products (eg. global soil moisture, water vapour, precipitation rate…)

Driving requirements:

- Low frequency L, C, X, Ku, Ka) Polarized channels
- Ka and C band essential
- High spatial resolution
- Radiometric performance (NEΔT 0.3K), proximity to radiometric boundaries
- Wide Swath (no hole at pole)
- RFI mitigation



# living planet symposium

MILAN
13–17 May
2019

## UNDERSTANDING THE EARTH SYSTEM

## SPACE 4.0 AND EARTH OBSERVATION

## BENEFITS FOR A RESILIENT SOCIETY

## PUBLIC AND PRIVATE SECTOR INTERACTIONS

**Deadlines**

| Session Proposals | Abstracts | Registration | |
|---|---|---|---|
| 17 June 2018 | 11 November 2018 | April 2019 | lps19.esa.int |

European Space Agency


opernicus
Europe's eyes on Earth


European
Commission


esa
European Space Agency