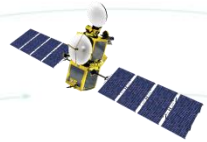
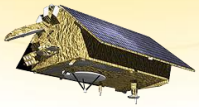
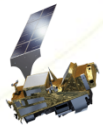


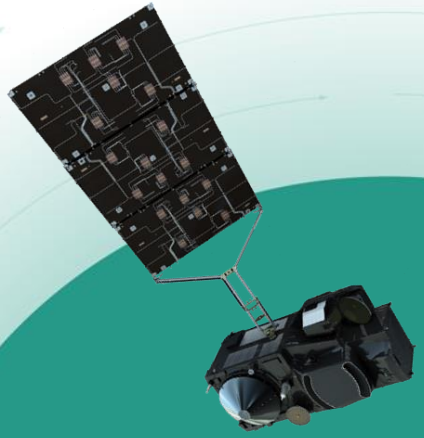


EUMETSAT Operational Use of In Situ Data

7th Copernicus Czech National User Forum

F. Montagner, EUMETSAT





EUMETSAT Operational Use of *In Situ* Data

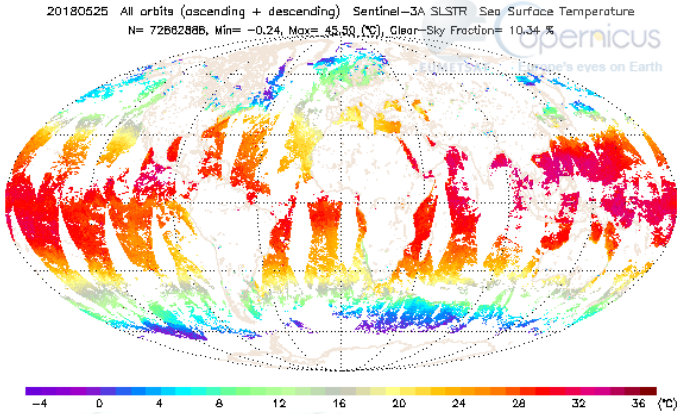
- EUMETSAT mission and satellite fleet
- Calibration and validation of satellite data
- Fiducial Reference Measurements

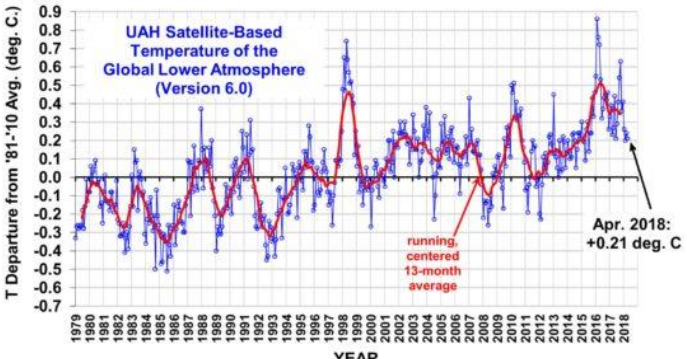
EUMETSAT's mission

- To **establish, maintain** and **exploit** European **operational** meteorological satellite systems, while considering the recommendations of **WMO** as much as possible

- By fulfilling these objectives, contribute to **environmental monitoring**, where **interactions** with the **ocean** and the **atmosphere** are involved

- A further objective is to contribute to **operational climate monitoring** and detection of **global climatic changes**





Space-based Global Observing System 2015 → 2022

- Operational GEO and LEO satellite systems supporting meteorology (following WMO data sharing)
- Meteorological satellites from EUMETSAT, CNES and EC (Europe), NOAA (USA), CMA (China), Roshydromet (Russia), JMA (Japan), IMD (India), KMA (S. Korea), Meteorological Society (Taiwan)
- Contributions from science missions such as from the A-Train (NASA/CNES)

The Current EUMETSAT satellite fleet

METOP -A and -B
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

Sentinel -3a, -3b
(LOW-EARTH, SUN-SYNCHRONOUS ORBIT)

Copernicus Global Marine and Land Environment Mission
Operated by EUMETSAT

JASON-2, -3
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION

METEOSAT SECOND GENERATION -9, -10, -11
(GEOSTATIONARY ORBIT)

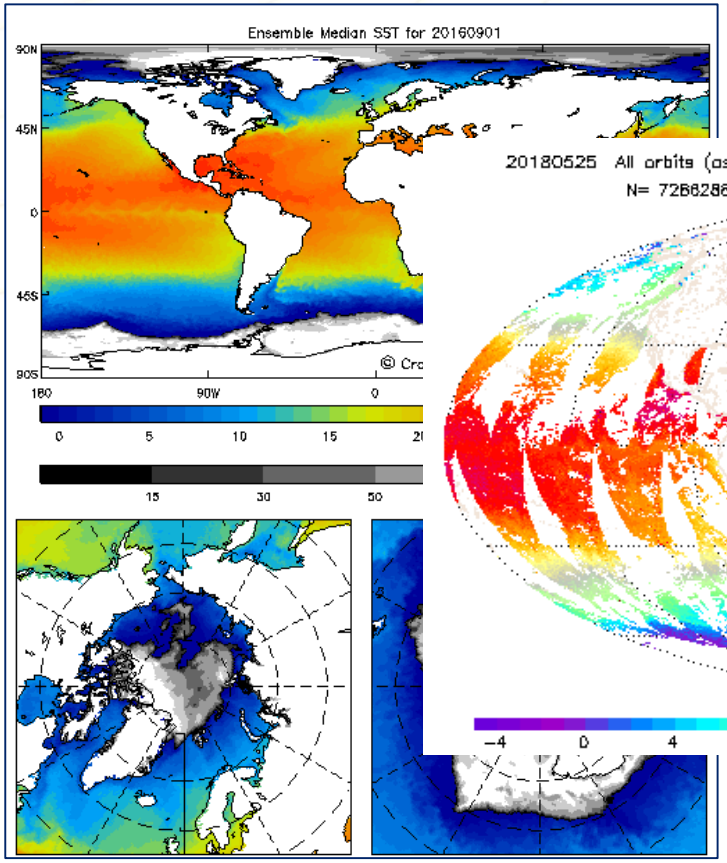
TWO-SATELLITE SYSTEM:
- METEOSAT-11: IN-ORBIT BACKUP
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)

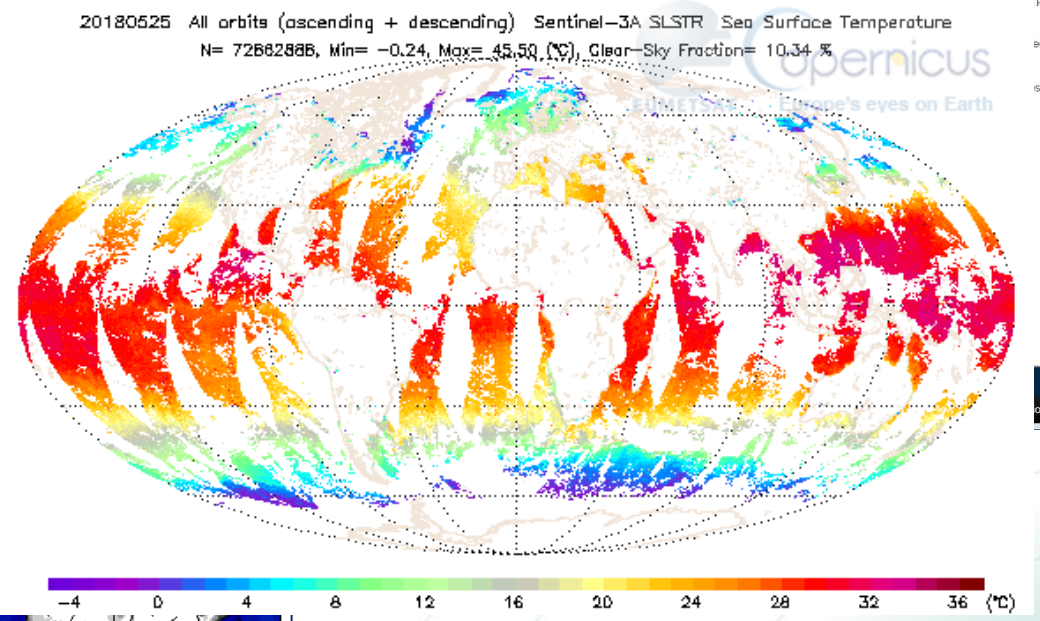
METEOSAT-8 (2nd GENERATION)
(GEOSTATIONARY ORBIT)

INDIAN OCEAN DATA COVERAGE MISSION
AT 40° E (TBD June 2016)

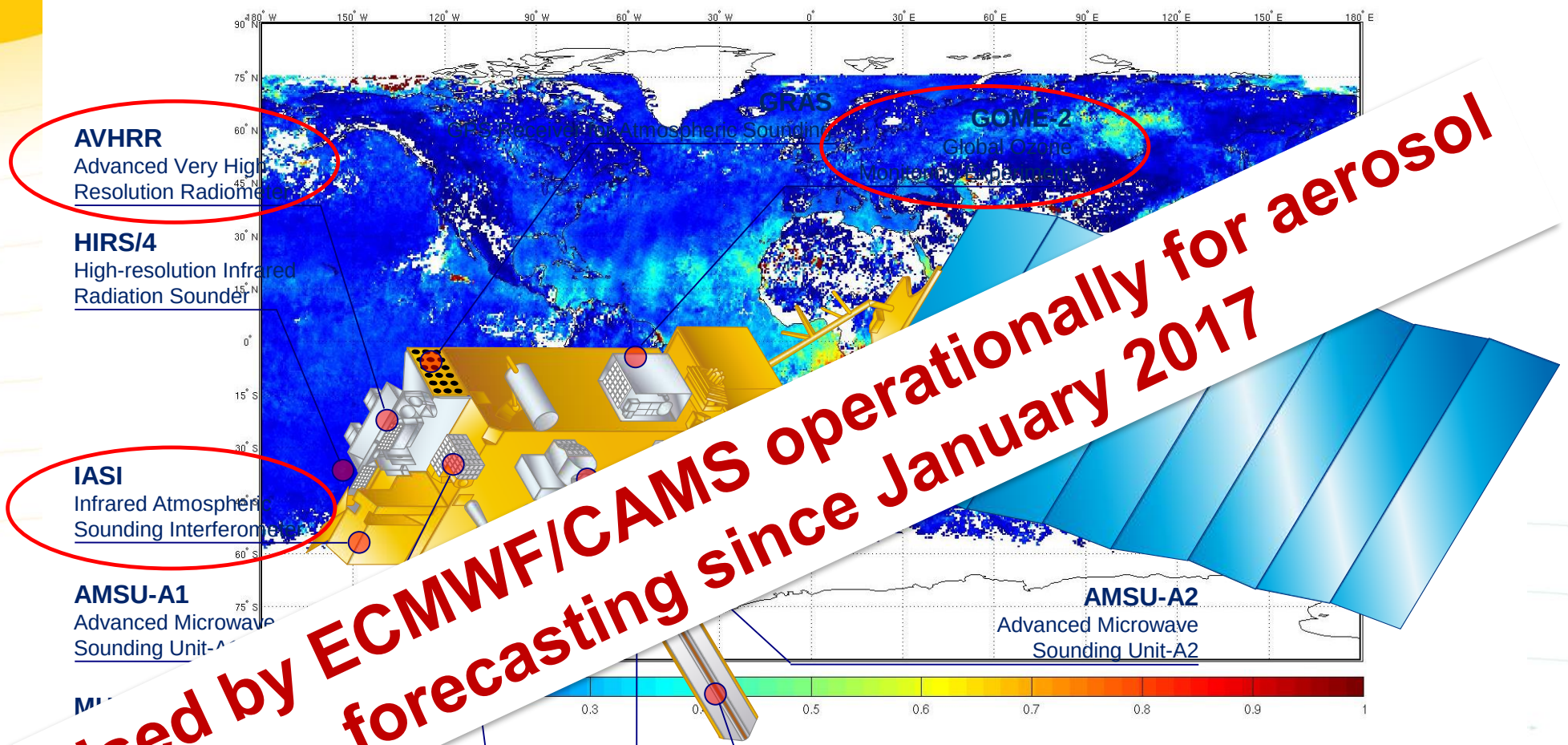
Support to Services: Sea Surface Temperature for CMEMS

- European services providing daily SST maps for users:
  - CMEMS (right)
  - OSTIA (MetOffice below)
  - METIS-SST (EUM for val. bottom-right)





Support to Services: Polar Multi-Sensor Aerosol Optical Properties (PMAp) for CAMS assimilation



Used by ECMWF/CAMS operationally for aerosol forecasting since January 2017

…on February 23, 2017:

1. **…d land surface albedo characterisation (using updated LER KNMI database)**
2. **…proved cloud/thick dust separation and screening**
3. **Improved characterisation of Rayleigh-scattering contribution (better elevation/pressure profile)**
4. **Addition of IASI volcanic ash/SO_2 detection scheme**
5. **Systematically validated using AERONET ground-based data**

Cal/Val of space-borne data

- Calibration /Validation (Cal/Val) is essential to **quantify the data quality**, for both scientific and operational missions, **through the lifetime of an EO mission**
- This involves specialised and direct investments in Cal/Val manpower and infrastructure, in ground-based/balloon/airborne/ships measurements, and coordination of both in-situ activities (calibration, protocols, collection) and data access
- Relies heavily on existing networks of in-situ data (for example WMO/GTS meteorological data, AERONET, etc.), and voluntary scientific efforts and contributions
- ESA, EUMETSAT, NASA and NOAA have similar budgets allocations for Cal/Val (*circa* 2012) :

  ~4M€/y for ESA Envisat; ~20M$/y for the NASA EOS missions;
  ~6M$/y for SNPP, …
- EO missions, and their data use, have been more successful because of well planned mission lifetime Cal/Val

How do you evaluate satellite products?

- Satellite data evaluation can be broken down into two distinct processes to meet products and services needs:

1. **Monitoring/(re)calibration of the fundamental measurement (*the "Cal" in Cal/Val*)**
   - Radiances, radar pulse timing, brightness temperatures, etc.
   - Using desert/ocean targets, transponders, radiometers, etc.

2. **Validation/inter-comparison of derived geophysical parameters (*the "Val" in Cal/Val*)**
   - Statistical inter-comparisons using large amounts of network data, for example total ozone measurements, buoys, etc.
   - Targeted process studies/measurements mimicking satellite sensors, for example BOUSSOLE, SST radiometers, AQ sun photometers or spectrometers, etc.

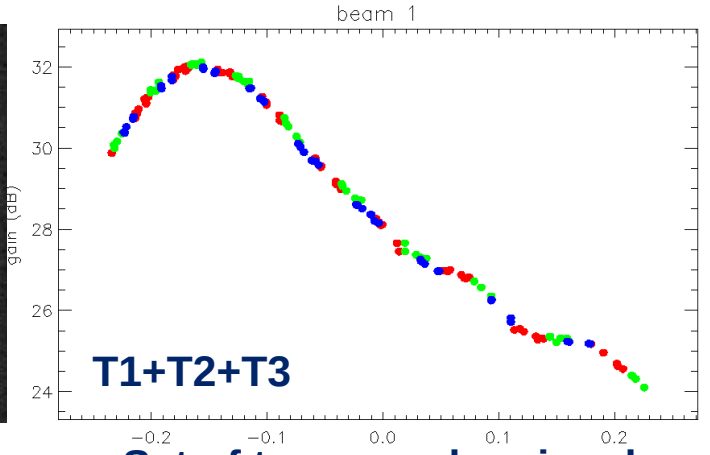
ASCAT calibration using transponders

- Objective is to monitor the in-orbit gain pattern of ASCAT using 3 transponders.
- Transponders transmit a signal of known strength.
- ASCAT measurements of the transponders depends on the transponder signal strength and the antenna gain, so we can use a ASCAT transponder measurement to calculate a gain value.
- Over a 29 day cycle the transponders appear at different places in the swath, so the set of gain values samples the gain pattern
- **Operational at EUMETSAT**

C. Anderson, EUMETSAT

ASCAT transponder on site in Turkey

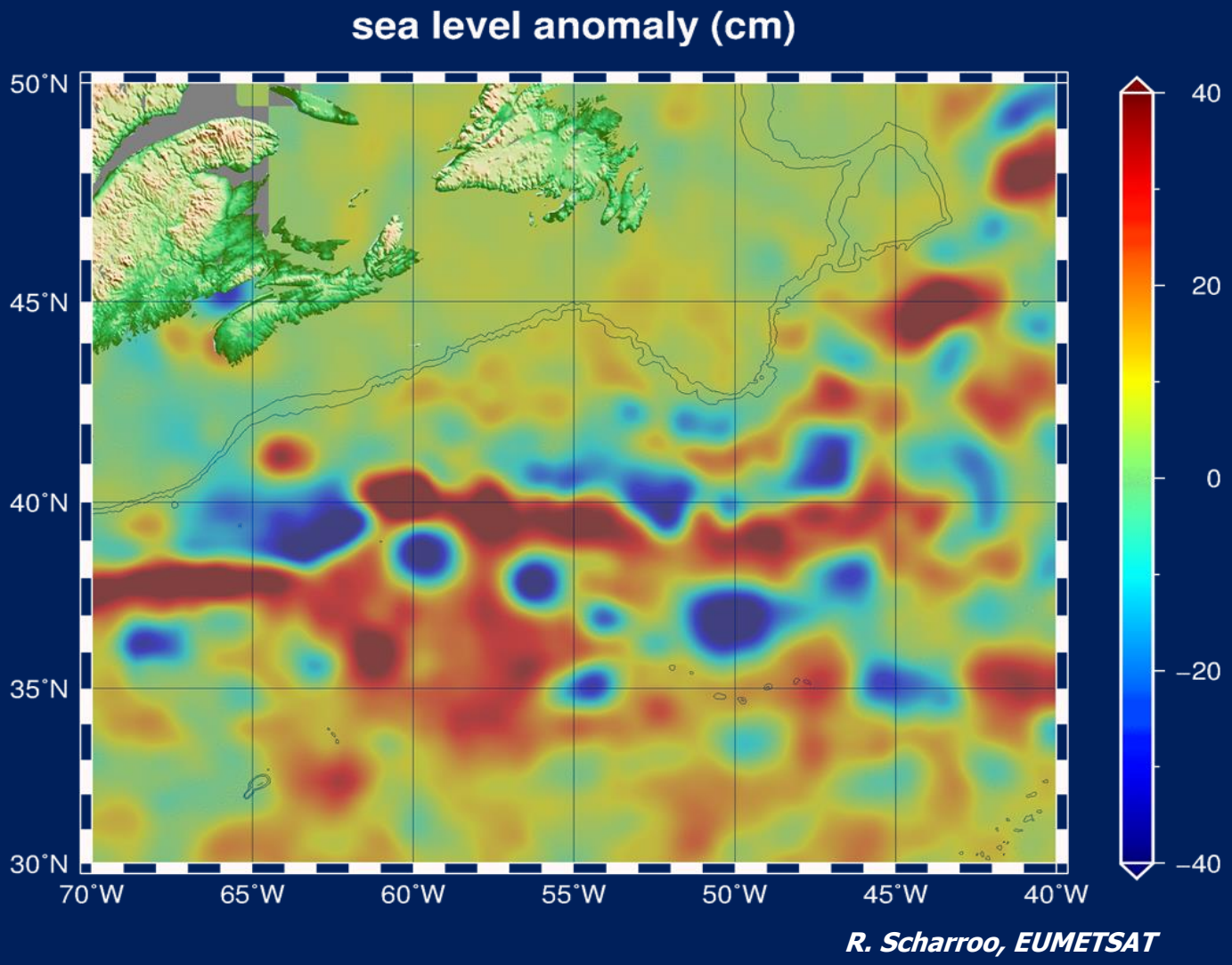
Raw transponder signal from ASCAT



Set of transponder signals converted to gain

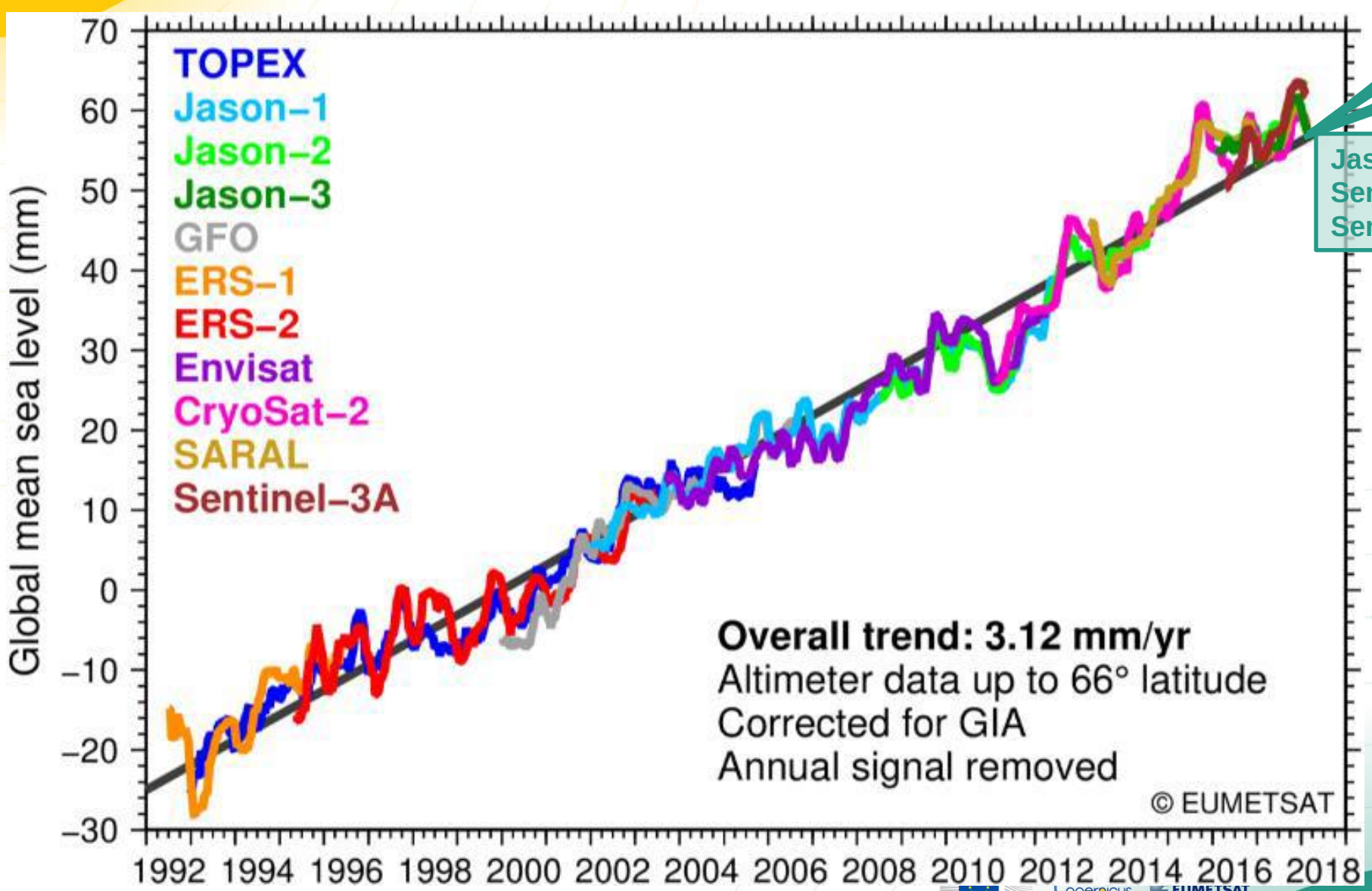
Similarly using transponders for altimeters: six mission are operational and interoperable

(*and by using the same QA tools*)



R. Scharroo, EUMETSAT

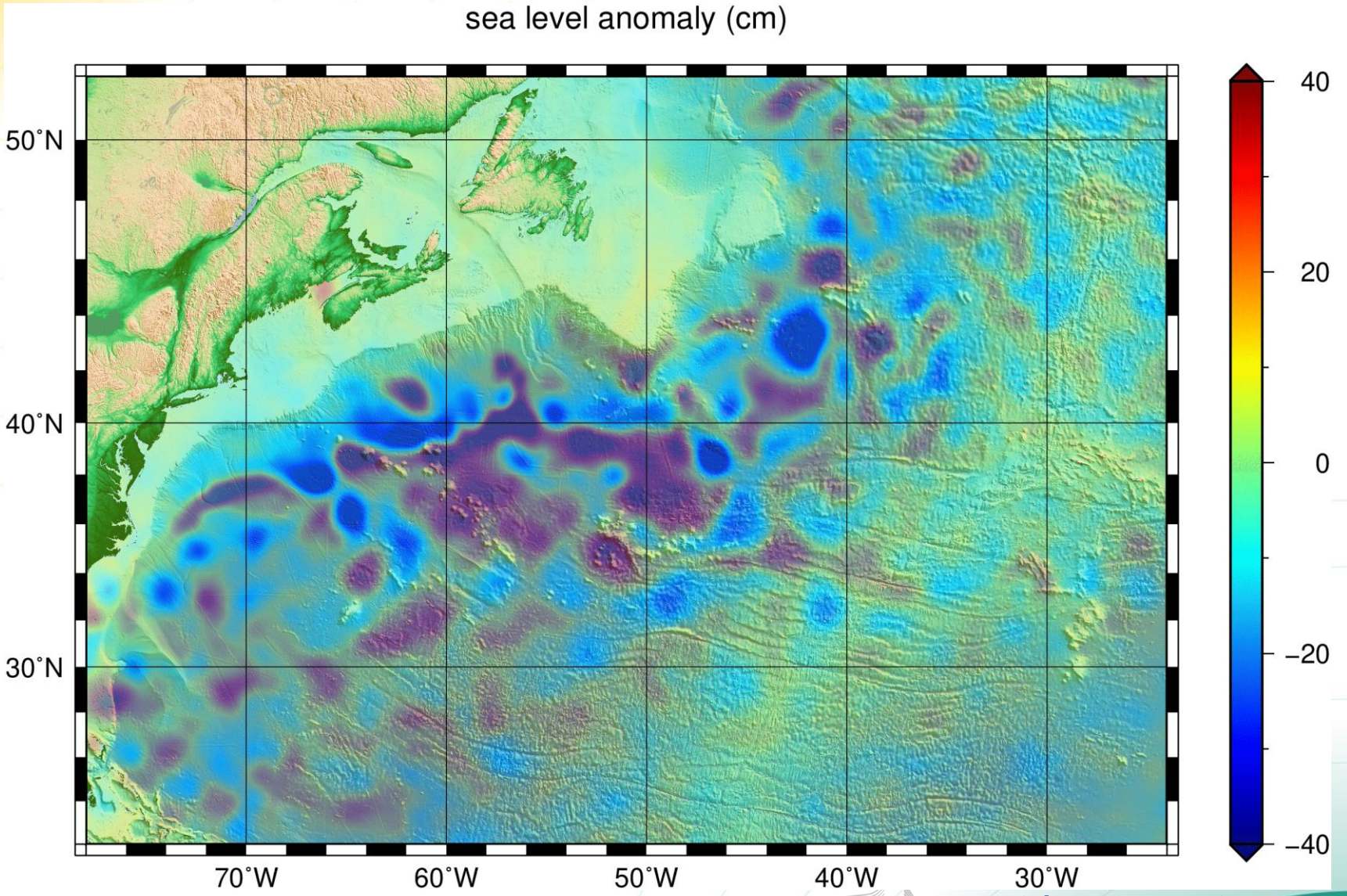
Allowing for a multi-satellite Sea Level Rise Estimate



?

Jason-3
Sentinel-3A/B
Sentinel-6

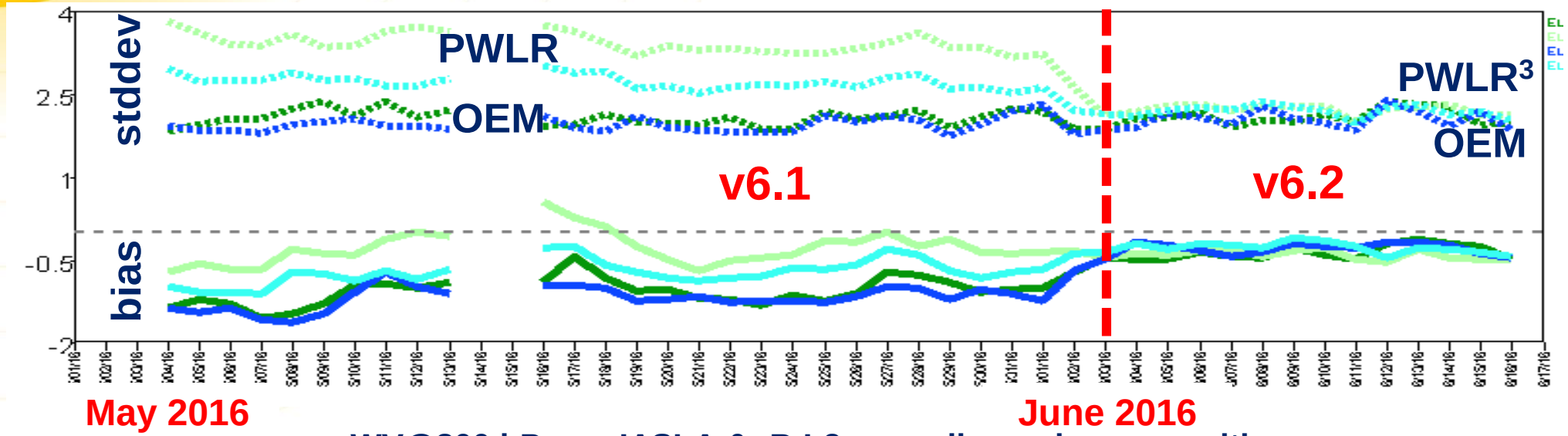
Sentinel-3B: first altimeter measurements
(8 May 2018, 2 weeks after launch)



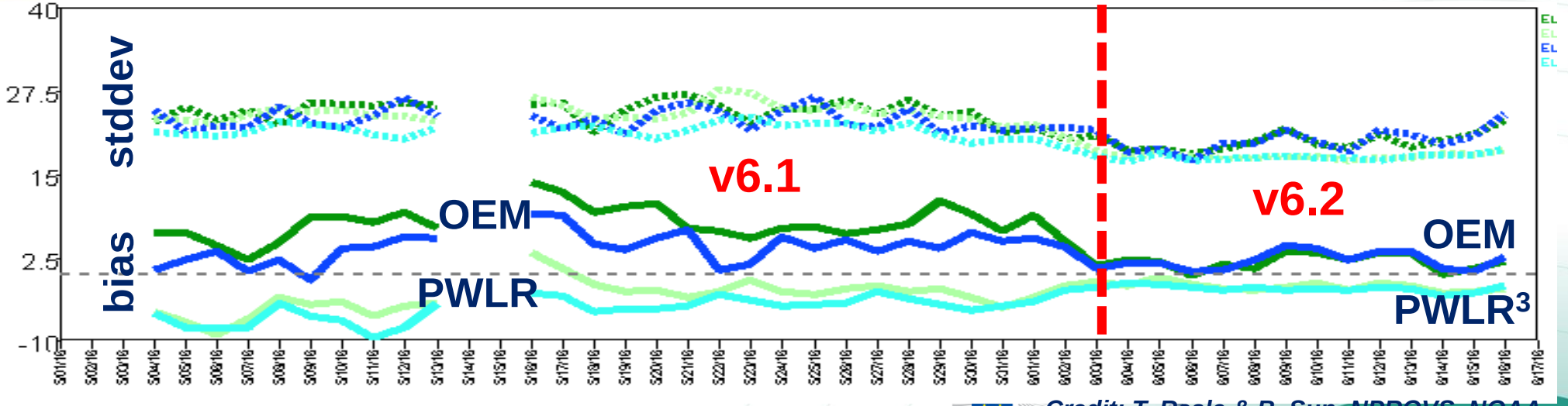
R. Scharroo, EUMETSAT

IASI L2 v6 performances - *monitoring with in-situ data*

T@940 hPa :: IASI-A & -B L2 vs. radiosondes :: maritime



WV@800 hPa :: IASI-A & -B L2 vs. radiosondes :: maritime

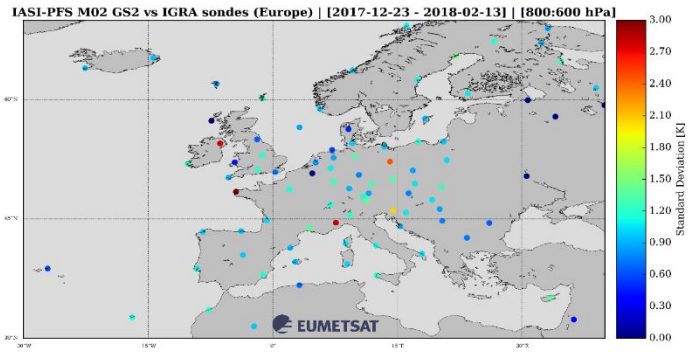


Credit: T. Reale & B. Sun, NPROVS, NOAA

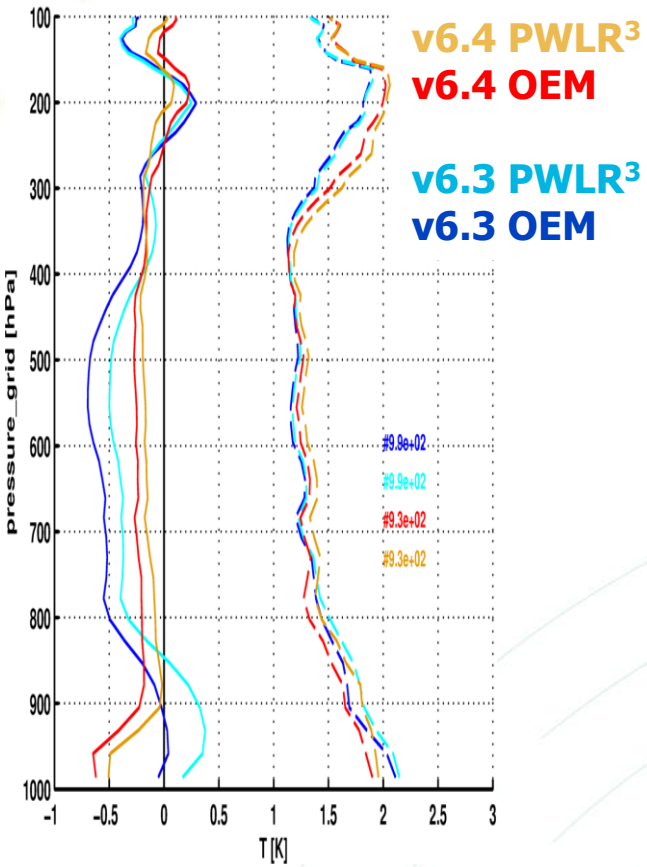
IASI L2 v6.4: update statistical PWLR^3 and OEM retrievals

Comparisons to sondes (IGRA) over Europe

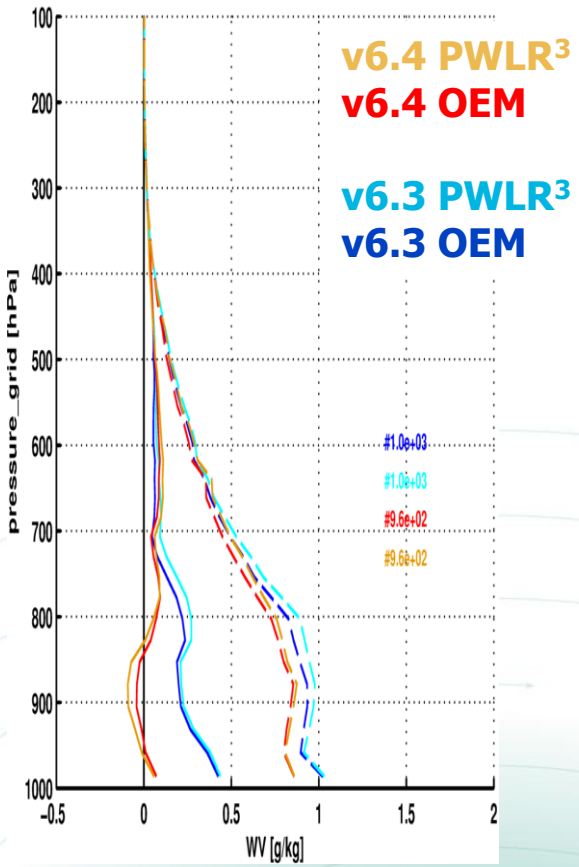
23/12/2017 → 13/02/2018



Temperature



Humidity



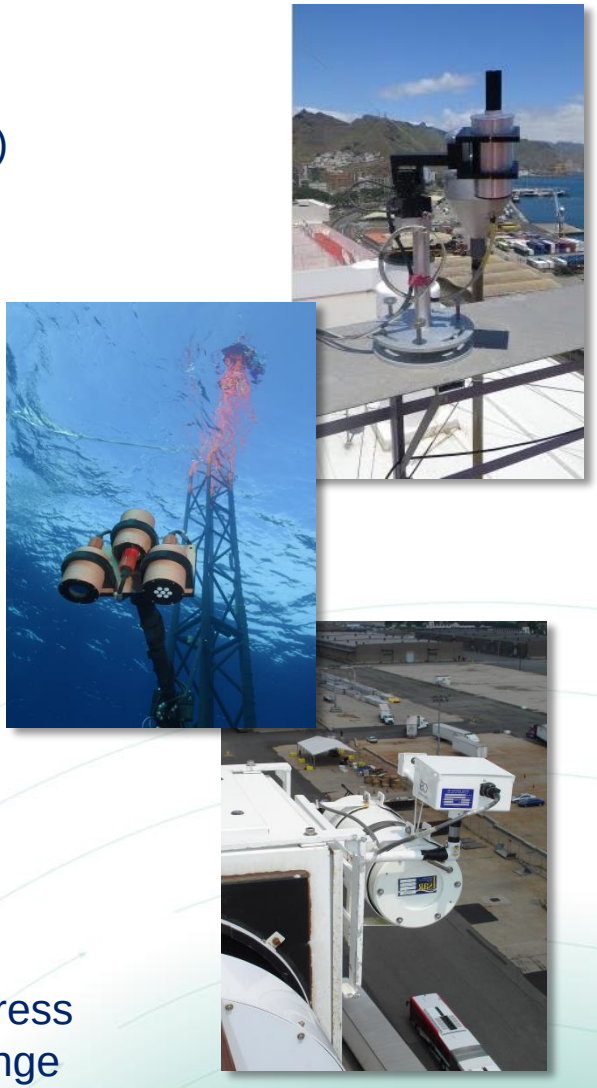
T. August, EUMETSAT

Fiducial Reference Measurements (FRM)

- *What's wrong with "**in situ**" (in the satellite business)?*
  - It means everything to everybody (→ *confusion*)
  - It's not tangible to a space agency (→ *does it not exist already!?*)
  - It is not necessarily directly related to satellite observations and difficult to argue to include in a validation programme

- **fi·du·cial** *(adj) Regarded or employed as a standard of reference, as in surveying*
  - [Late Latin fiducialis, equivalent to fidi(a) trust, from fidere, to trust.]

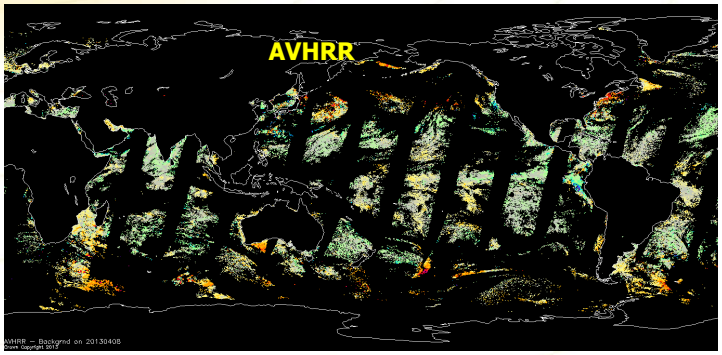
- **Fiducial Reference Measurements (FRM):**
  - Based on specific requirements (outlined in the EURD)
  - Linked to a mission's Cal/Val plan activities
  - Building on the existing capabilities
  - Forward thinking and long-term vision
  - Inclusive: FRM are not necessarily mission specific and can address multi-mission needs (e.g. all altimeters need transponders for range calibration – and Sigma0…)

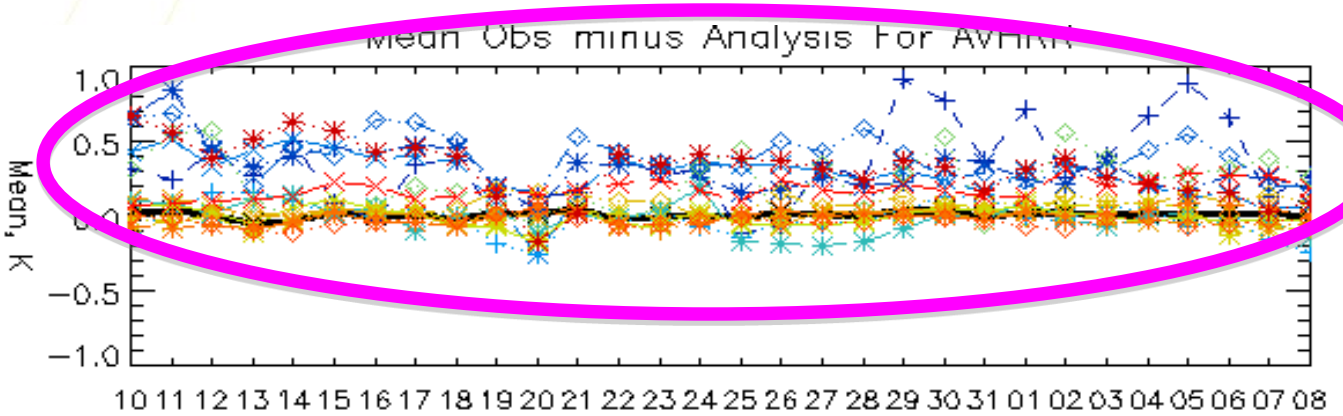


Why do Space Agencies need FRM?

- FRM is the suite of ground-based measurements that provide the maximum Return On Investment (ROI) for a mission by **delivering the required confidence in the data products for users**
    - *IF we have **no FRM** then we cannot fully exploit the mission as we have no idea how accurate data products really are*
    - *IF we have **many FRM** this is great scientifically (statistical significance, geographic coverage, robust network…) but incurs additional costs with reducing ROI*
- **There is a balance between these two extremes to deliver a satellite mission with a KNOWN product quality that is "fit for purpose"**

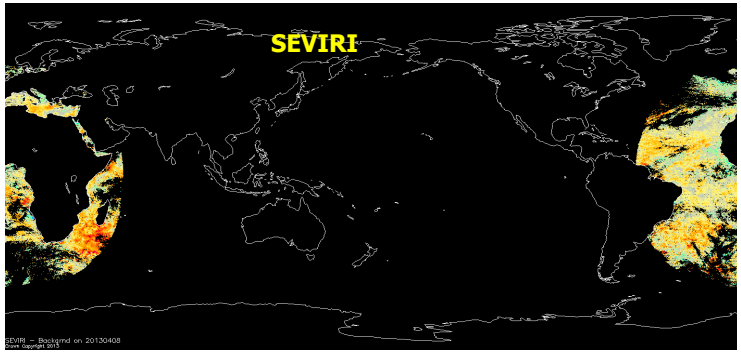
Example: how do the different satellite SST fare?

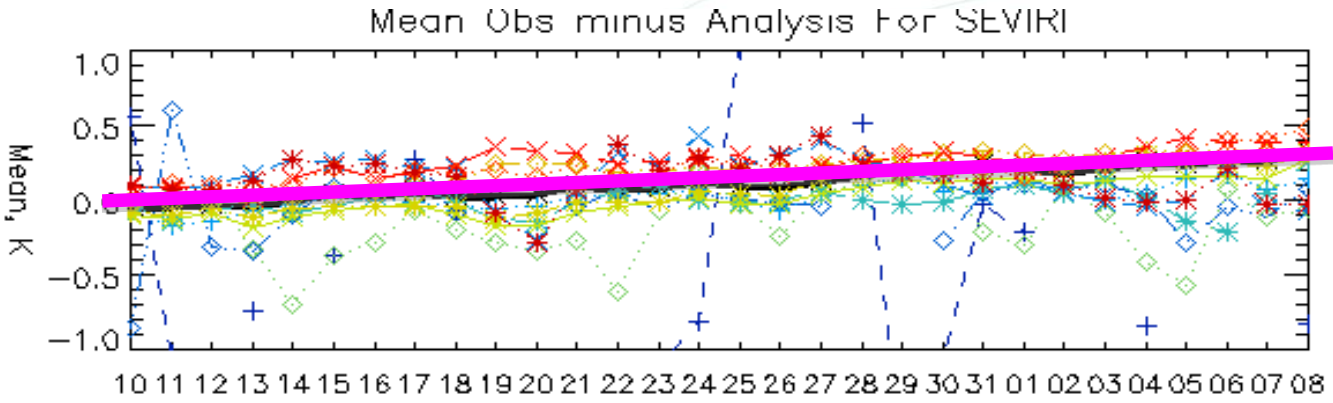




AVHRR and SEVIRI performance during the last calendar month

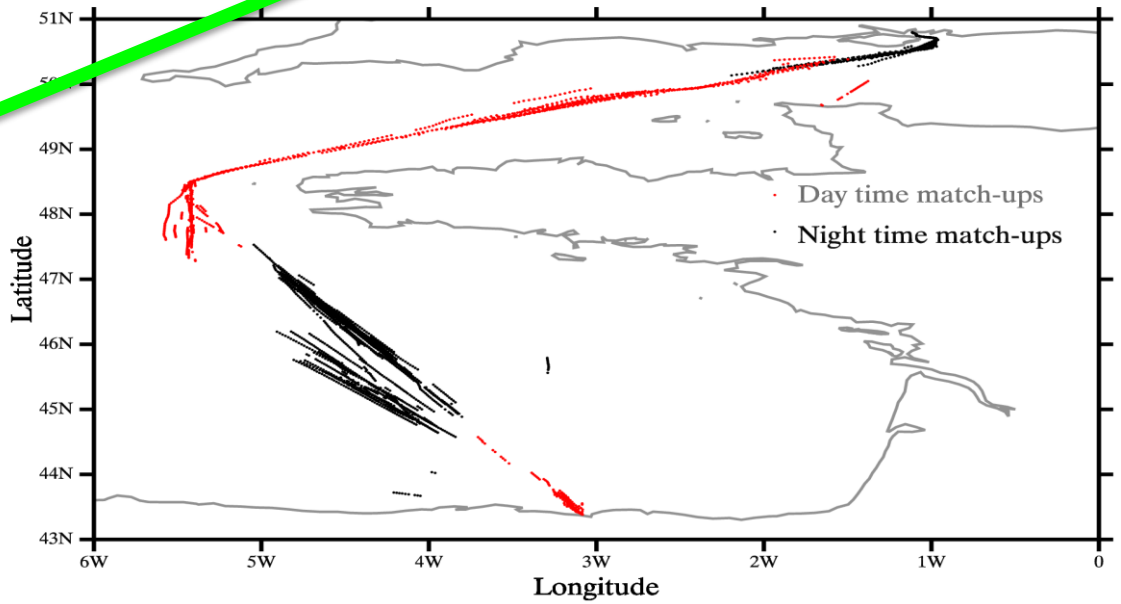
(ref. MetOffice OSTIA monitoring, GHRSST project)





SST validation using high-quality radiometer FRM

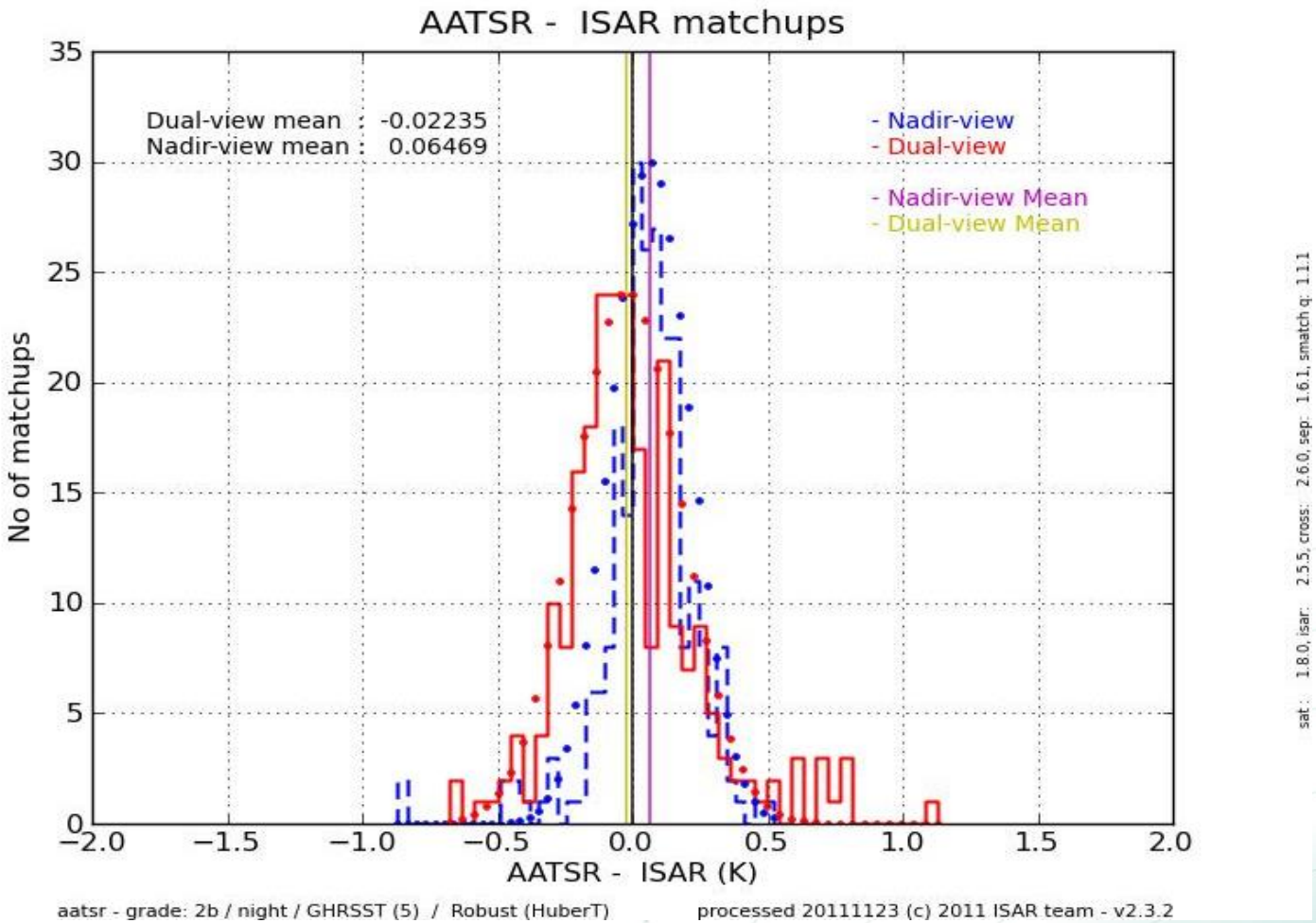
- High quality, calibrated, cheap, radiometer mimicking satellite measurements (http://www.isar.org.uk)
- Follows well defined calibration and measurement protocols traceable to **National Metrology Institutes** (NMIs)
- Deployed as self-contained packages on ferries



Pride of Bilbao (Bay of Biscay and English Channel)

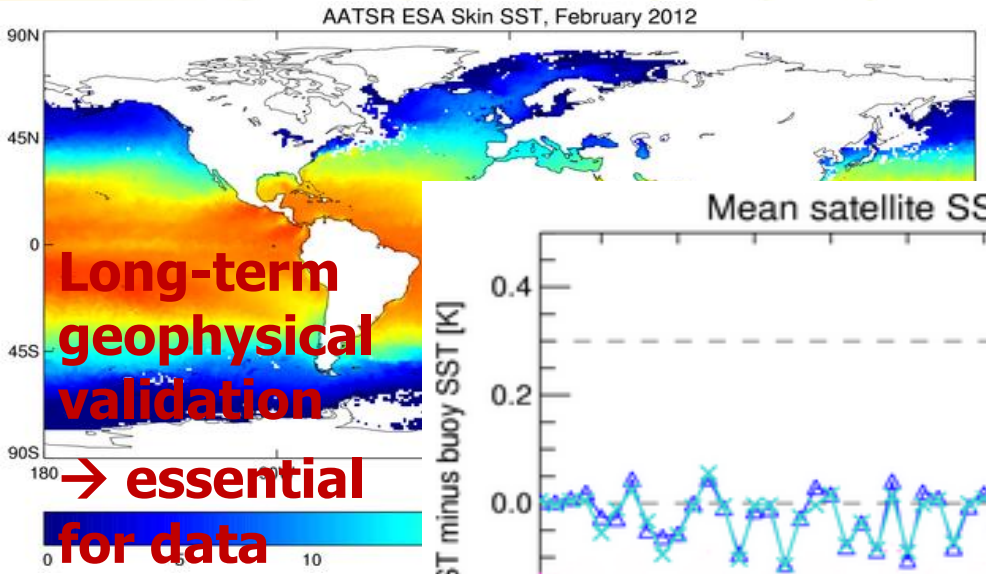
ISAR-AATSR intercomparisons

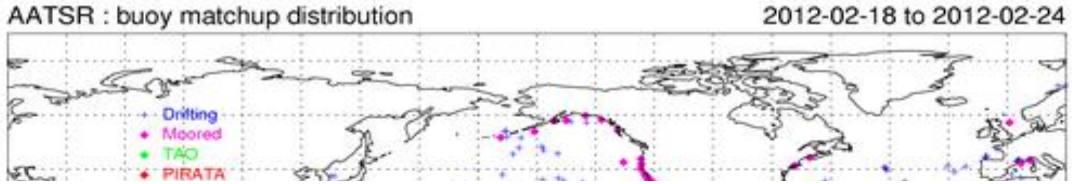
(1 week of match-up data, Nov. 2011)



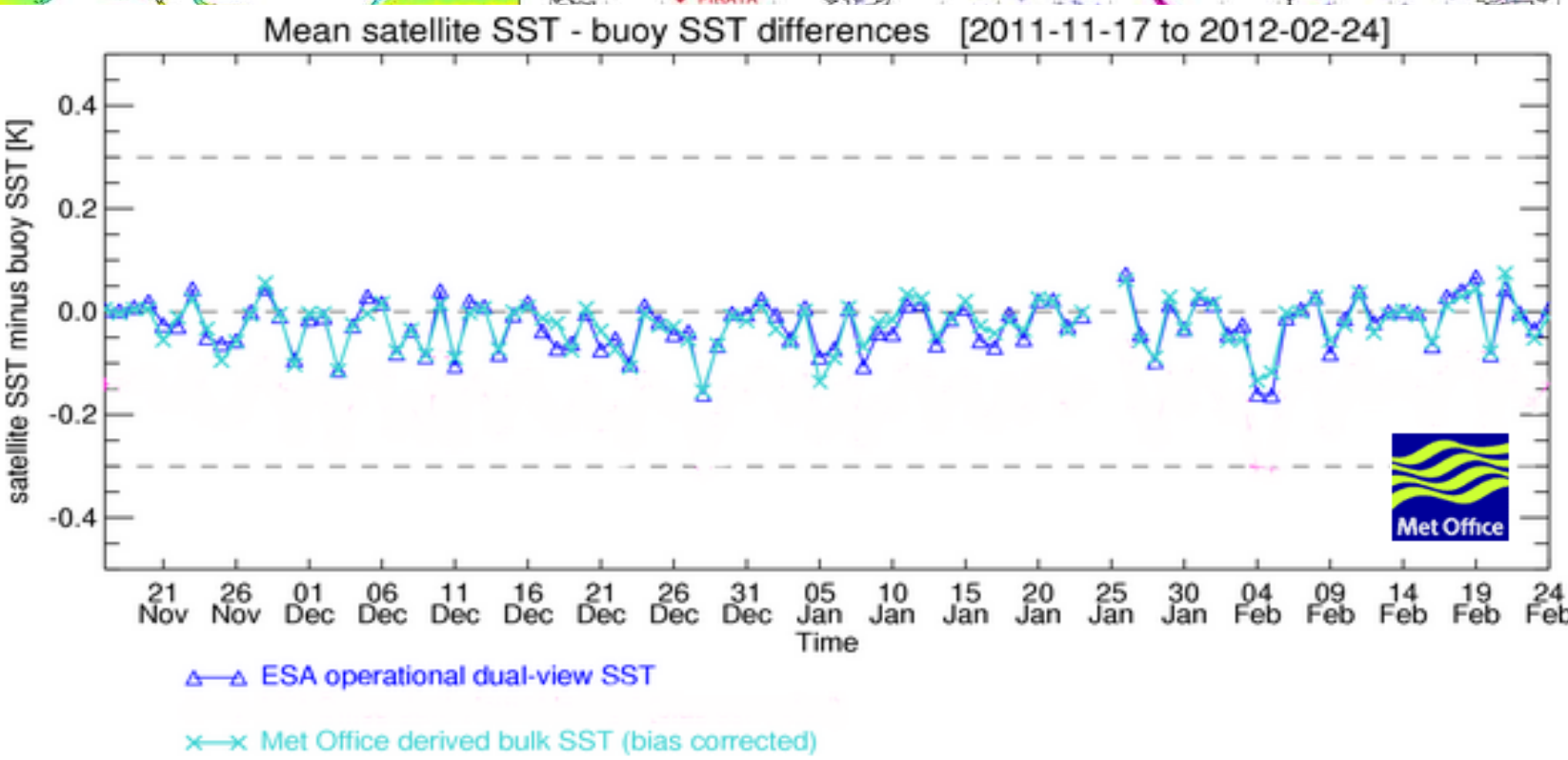
http://www.isar.org.uk

so when comparing AATSR SST globally…





Long-term geophysical validation → essential for data credibility and reliability



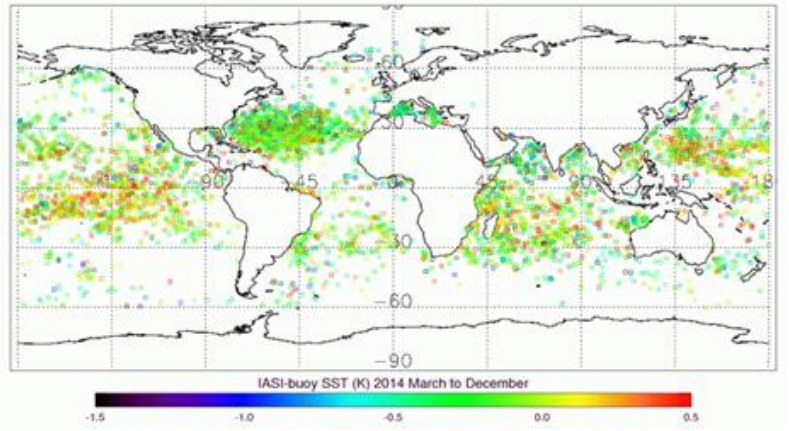
EUMETSAT contribution to SST: Improve drifting buoy for satellite validation

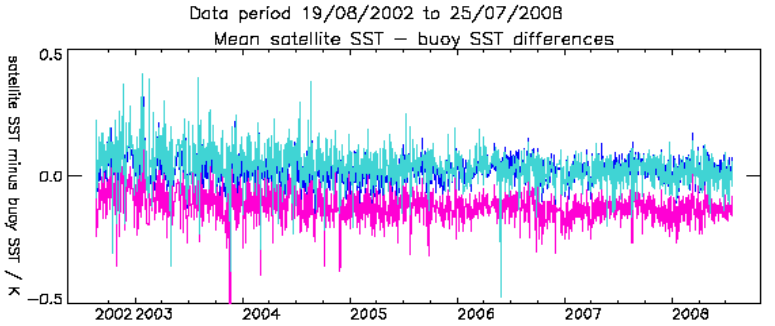
Fact: Currently drifting buoys in the WMO GTS are not calibrated to traceable standards

The objective of this EUMETSAT activity is to Improve the Drifting Buoy Sea Surface Temperature measurements for Copernicus Satellite Validation:

- Improving the drifting buoys capability: accuracies better than ±0.05K, **traceable to SI**
- Inclusion of near surface water pressure sensor as auxiliary information to understand depth and passage of drifter in water
- **Coordinate with the WMO Data Buoys Coordination Body (DBCP), EUMETNET, and manufacturers**
- Coordinate with ESA QA4EO FRM4STS the **development of new best-practice guidelines** for drifting buoys calibration
- Assess the performance of Sentinel-3 with the OSI SAF SST Cal/Val activities in quasi-NRT

and ultimately, establish drifting buoys as FRM for SST

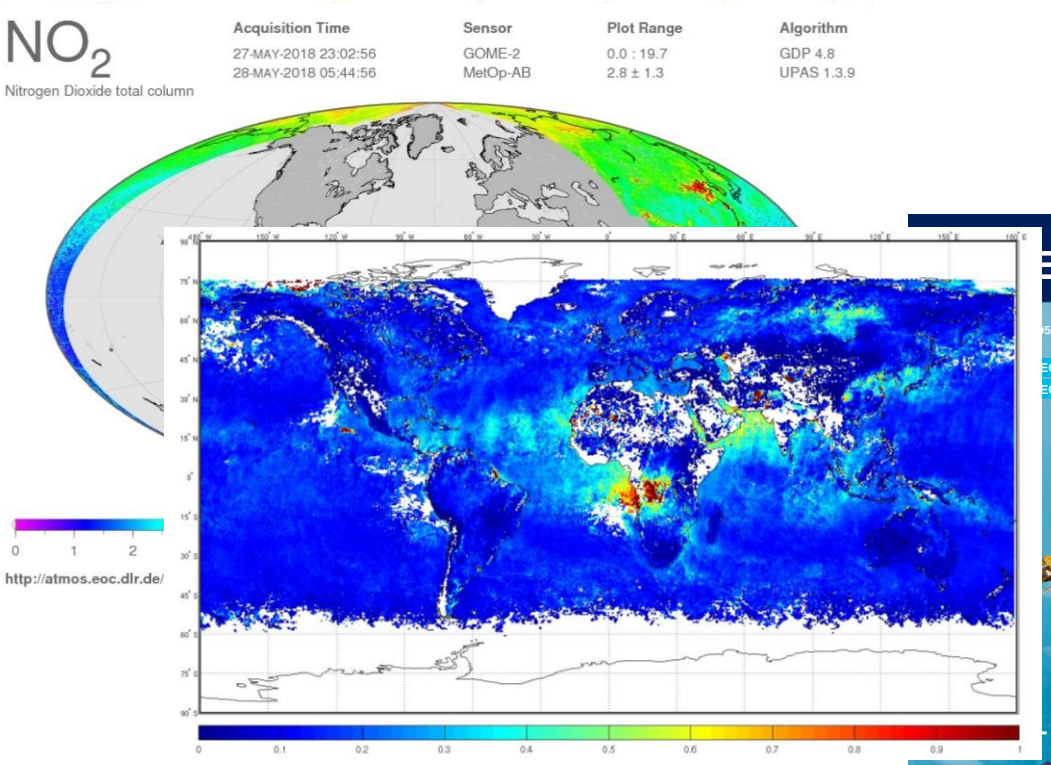


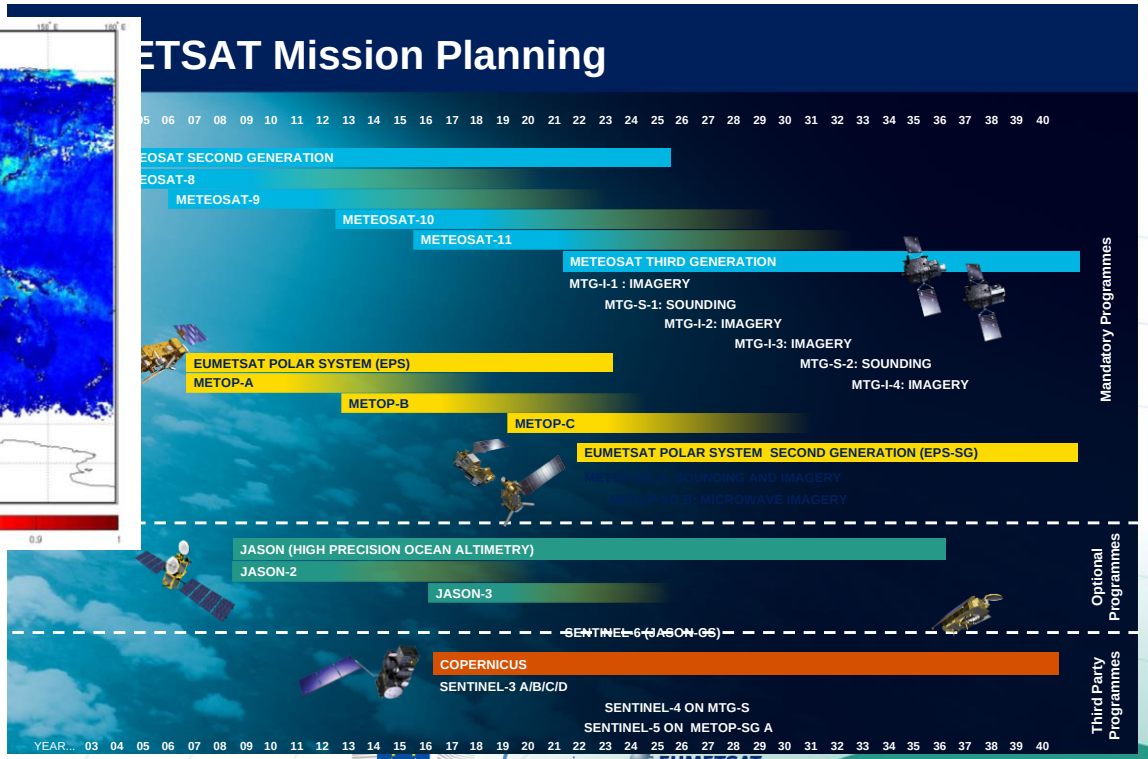


A. O'Carroll, EUMETSAT

A network of Atmospheric Composition FRMs

- EUMETSAT's/Copernicus' need for automatic, high-quality, tailored groundbased AC FRMs, ***to be used for a dozen upcoming atmospheric missions…***





Note the dual use ➔ *validation and atmospheric characterization for surface products*

A network of Atmospheric Composition FRMs (ii)

Based on the 30+ years ozone validation experiences, the cardinal requirements for the Air Quality FRM are:

1. High quality and fully characterised atmospheric composition measurements
   - *O_3, NO_2, SO_2, AOD, profiles*

2. Fully traceable and documented data products
   - *driven by community oversight/consensus/Standard Operational Procedures*
   - *e.g. WMO/GAW, AERONET, TCCON*

3. Annual absolute instrument calibration
   - *laboratory and/or field calibrations*

4. Long-term (addressing multi-mission), hi-frequency and satellite specific (matchups) measurements

5. Daily dataset reporting and central processing of *standard* products for Cal/Val

6. Cooperative nature with station PIs
   - *Intellectual Property Rights (spectra) remains with Principal Investigators, allowing for research products*

Example: *the Pandonia network*

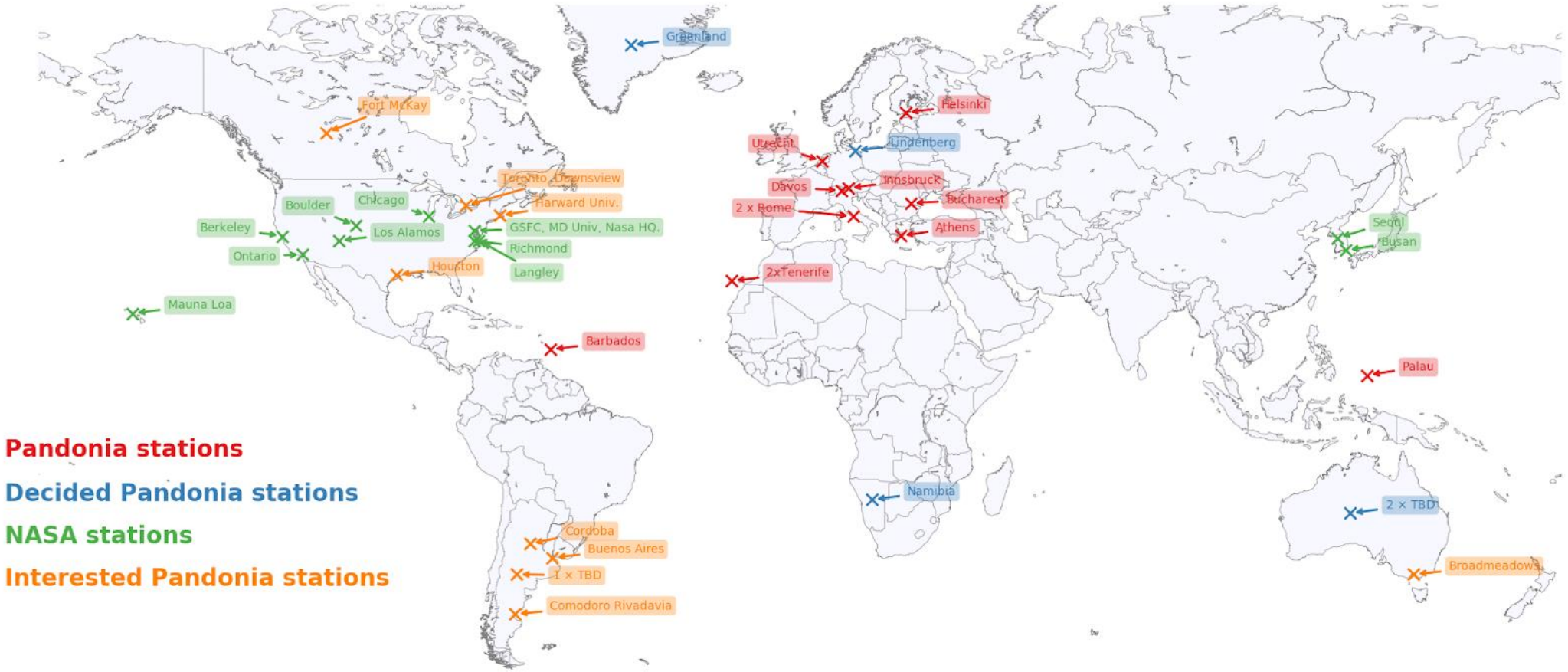
- International effort (ESA, FUB, NASA/NOAA, WMO/GAW) to enhance Pandora direct-sun mini-spectrometers
  - Extending to profile measurements, water vapour, and spectral aerosols with the Pandora 2S (new system, new tracker)
  - Formalising SOPs (best practices) for calibration and measurements
  - Automating the network with central data processing and near-real time data processing every 10min

- Calibration in cooperation with U. Innsbruck (Austria), AEMet (SP), and PMOD/WRC (CH) :
  - To establish by 2017 a Pandonia triad at Izaña (and traceability for total ozone with AEMet Brewer triad)
  - Established a central calibration lab at the Uni. Innsbruck in 2014 and Davos (PMOD/WRC) in 2015
  - Developed a field calibration capability traceable to SI

- Network to incorporate existing instruments (E, FIN, CND, selected sites in North America) and will have ~30 operational instruments by the end of 2018 to meet the varied geophysical environment requirements for validation

- *see http://pandonia.net/ for more information*

Pandora stations globally (May 2018)



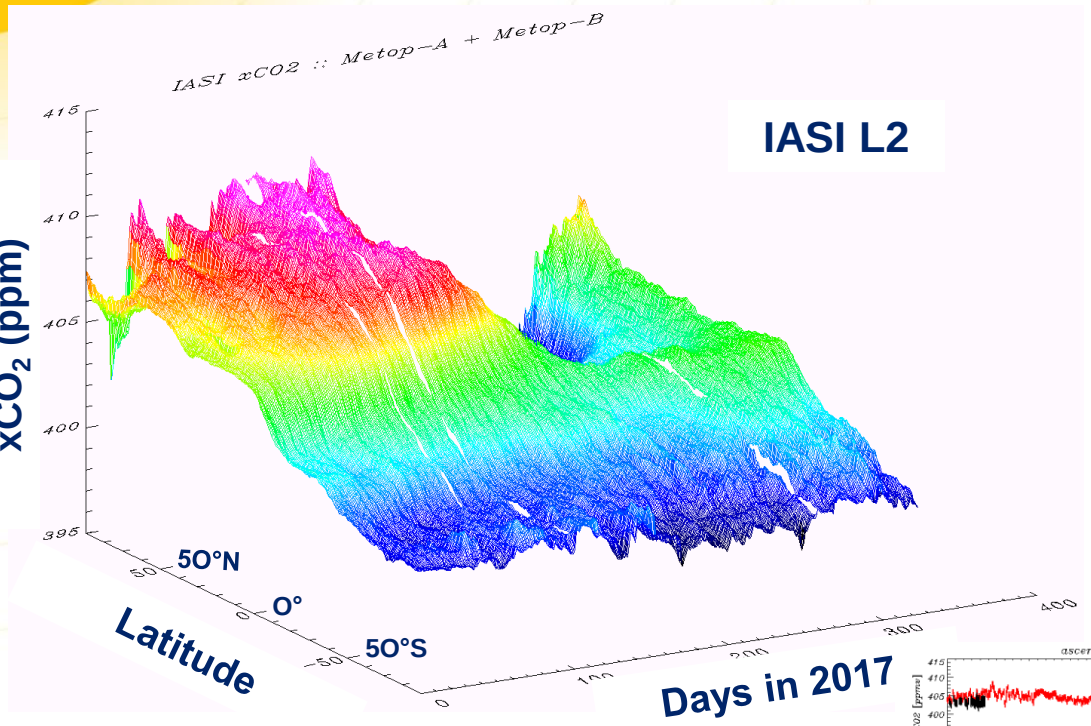
Summary

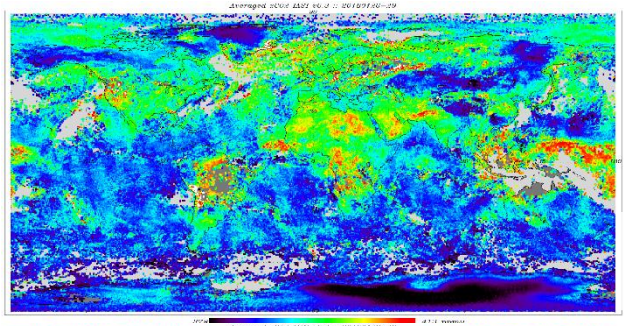
- A requirements-based (*justified*) and prioritized (*cost-benefit ROI*) suite of Cal/Val processes and measurements is required to demonstrate that mission products are “fit for purpose” *and meet traceability requirements of the data quality* throughout the mission lifetime *and beyond*
- Confidence in the products, through robust/traceable Cal/Val processes, allow to readily support end-user services, for the testing of new concepts, for the preparations of future missions, and for climate applications
- Special fully characterised FRMs, operating throughout the lifetime of the mission, mimicking the satellite sensor measurements are needed - *but care is needed to define these FRM appropriately*
- Easy and timely access to data to validate the product performance in time, under different weather conditions and varying geophysical areas - *and to bridge missions*

Conclusion

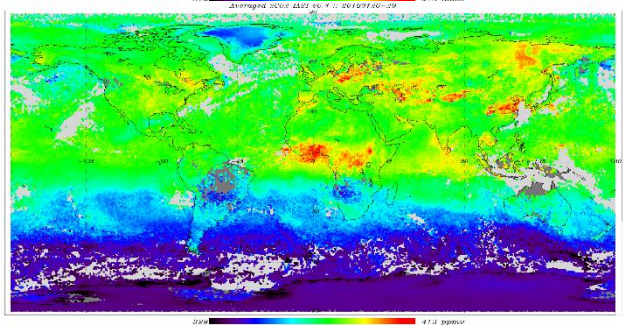
To meet the quality goals of EUMETSAT (and Copernicus missions) over the next decades, a close cooperation between Space Agencies and expert communities (ground-based, through NMIs, through international bodies) is needed to coordinate infrastructure, calibration facilities and procedures/"best practices", measurement Standard Operational Procedures (SOPs), ground-based/space data accessibility.

Thank you for your attention!

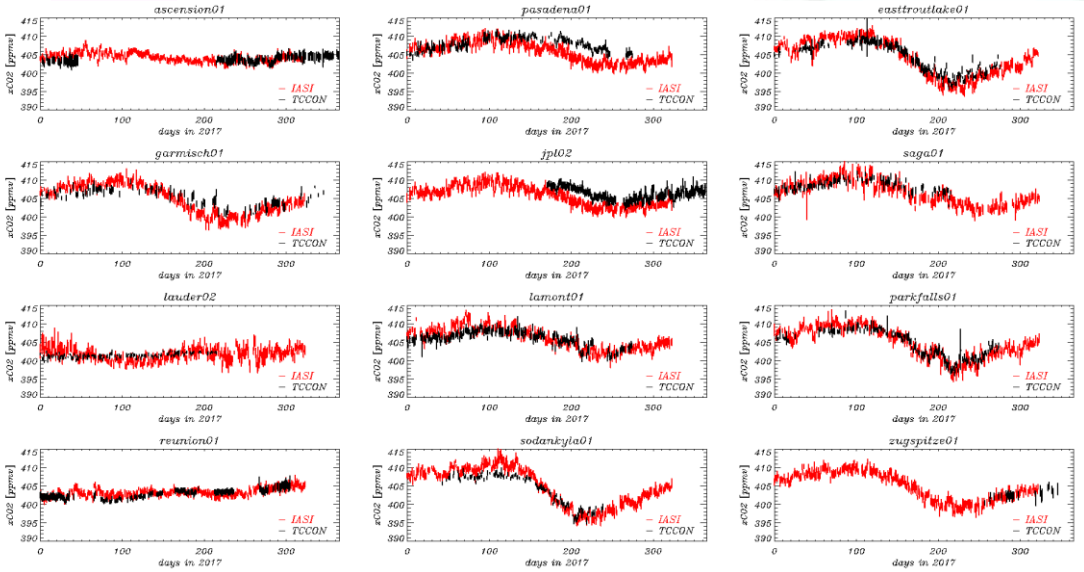




v6.3
26-29/01/2018



v6.4
26-29/01/2018



Caveats:

- ***xCO_2 is auxiliary data for T & Q retrievals;***
- ***These are prototype results compared to TCCON;***
- ***A full & systematic validation is required;***
- ***Includes some cloudy pixels.***