The importance of Fiducial Reference Measurements (FRMs) for Satellite Earth Observation Characterisation

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Outline

- What are Fiducial Reference Measurements (FRM)?
- Why do we need them?
- Examples of FRMs
- Summary

Fiducial Reference Measurements (FRM)

- **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.]

- *What's wrong with "**in situ**" (in the satellite business)?*
  - It means everything to the uneducated
  - It's not tangible to a funding agency (*esp. in Europe*)
  - It is not closely related to satellite observations and difficult to argue to include in a validation programme

- Fiducial Reference Measurements (FRM):
  - Based on specific requirements (outlined in the MRD)
  - 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 groundbased measurements that provide the maximum Return On Investment (ROI) for a mission by **delivering the required confidence in the data products for users**, *as outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO)*

  - IF we have **no FRM** then we cannot really use 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"**

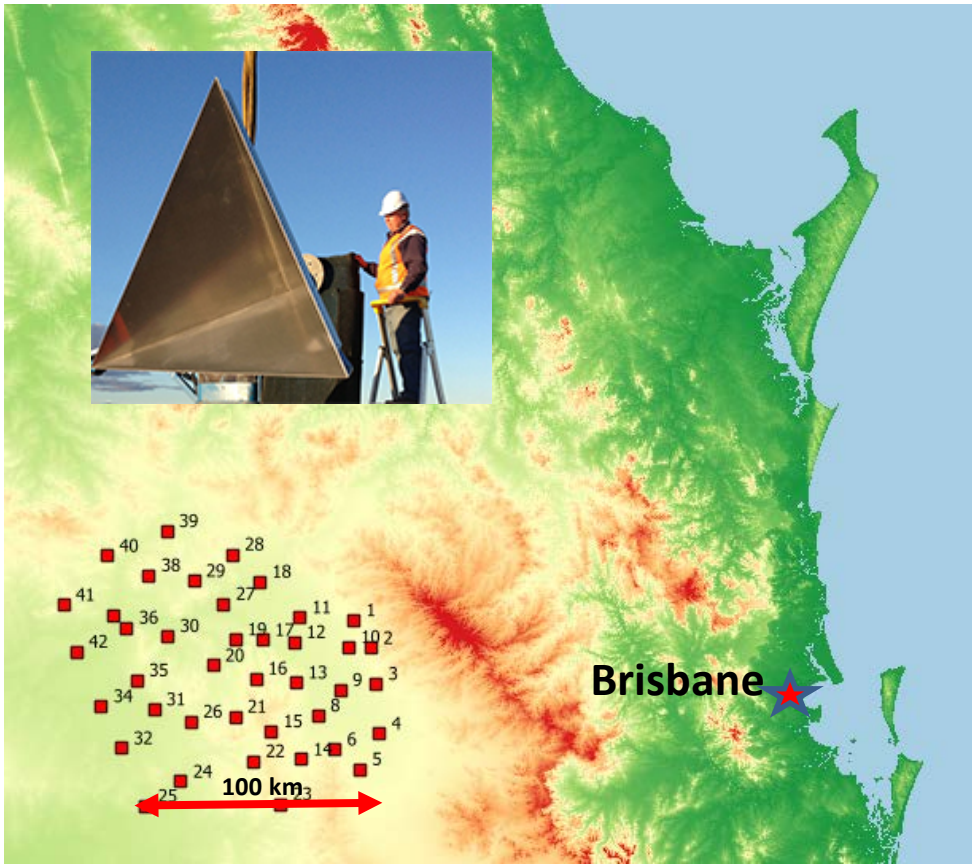
FRM for multi-mission SAR calibration

Surat basin (~300km west of Brisbane)

- Coal seam gas extraction study site with 40 corner reflectors to monitor terrain subsidence
- Routine SAR acquisitions (RADARSAT, RISAT and ALOS PALSAR, Sentinel-1)

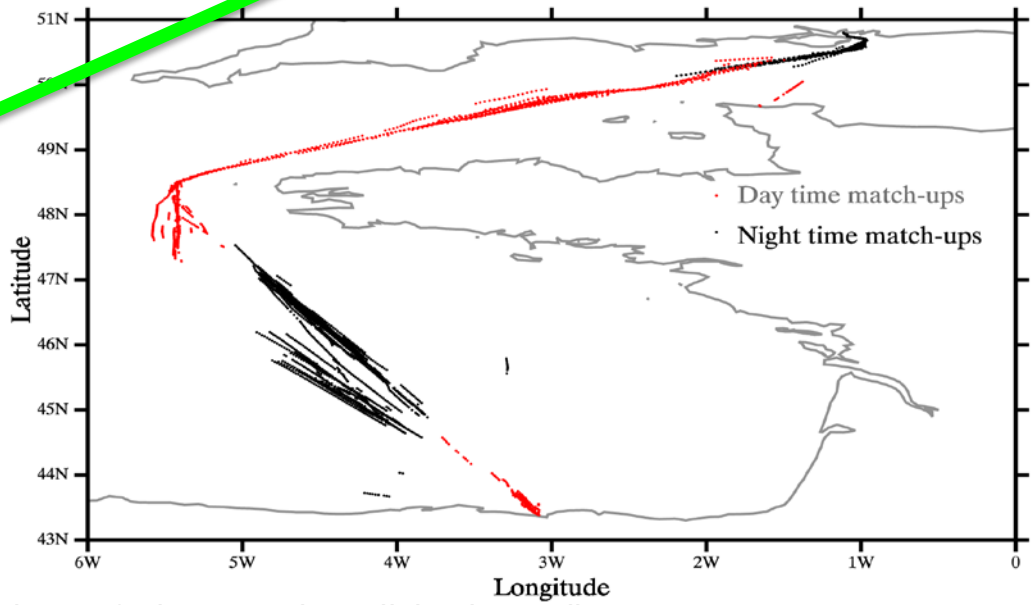
ESA's FRM activity, in cooperation with Geosciences Australia (GA), is:

- Initiated a joint project in late 2015 to document the survey approach and to support the GA's Geodesy group during their survey campaigns
- Also deploying a set of 4 additional corner reflectors (2 ascending, 2 descending) similar to what was done in Switzerland in the past for ERS/Envisat *(but in a more stable geological location)*



For Envisat/AATSR SST validation using high-quality radiometer FRMs

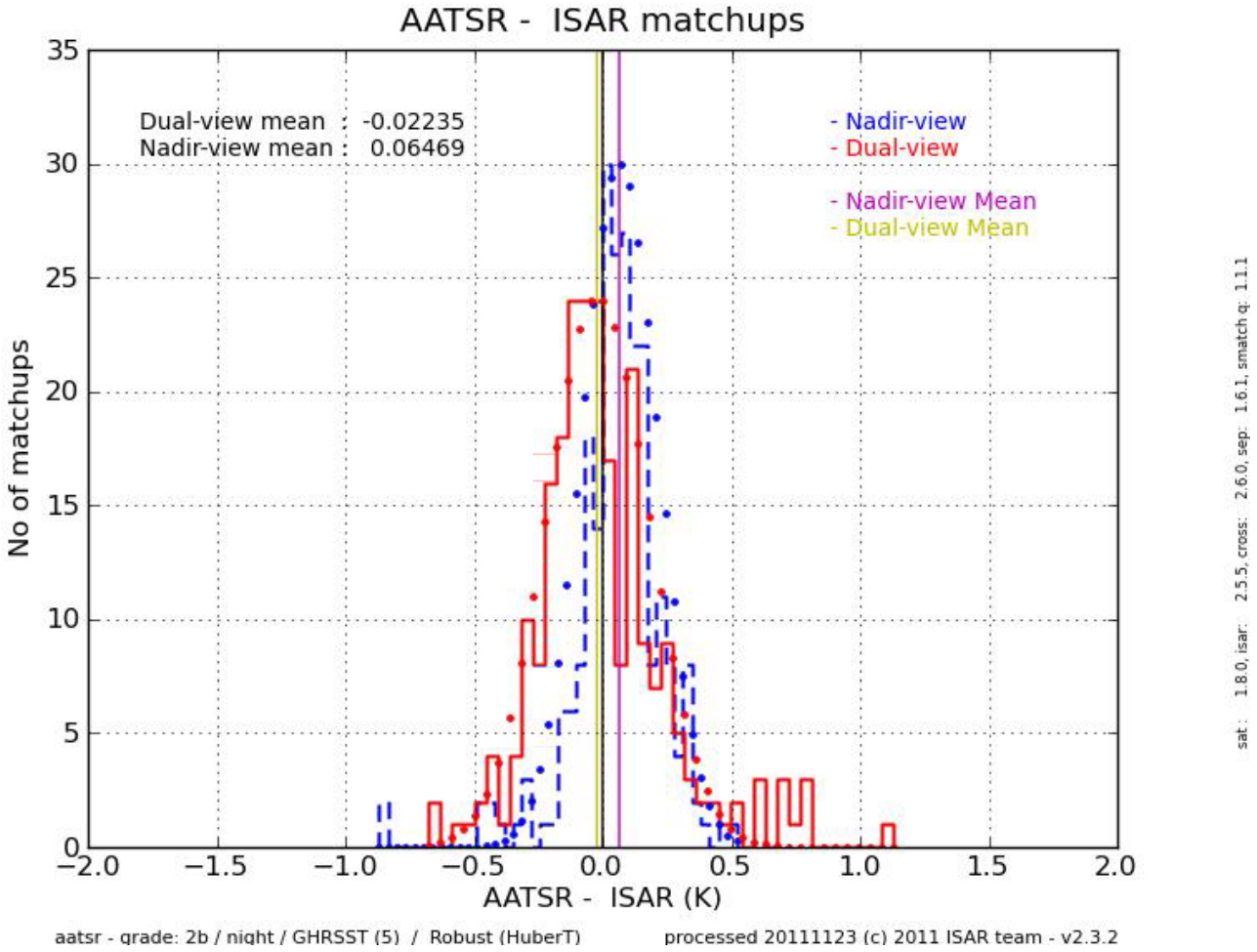
- High quality, calibrated, cheap, radiometer mimicking satellite measurements (http://www.isar.org.uk)
- Follows well defined calibration and measurement protocols traceable to **National Metrology Institutes** (NMIs)
- Deployed as self-contained packages on ferries



Pride of Bilbao (Bay of Biscay and English Channel)

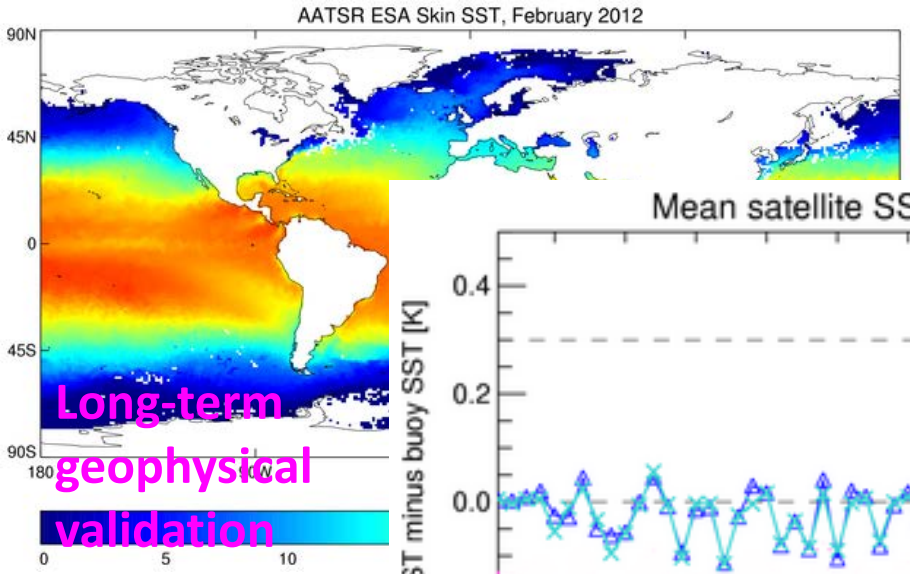
ISAR-AATSR intercomparisons

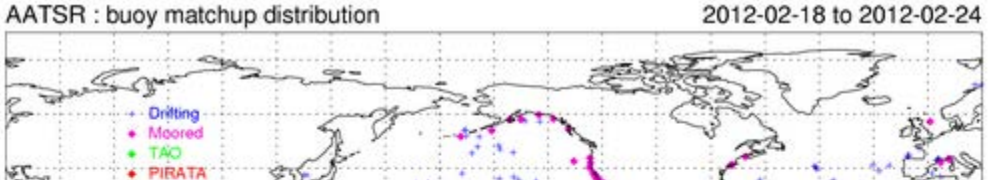
(1 week of match-up data, Nov. 2011)



http://www.isar.org.uk

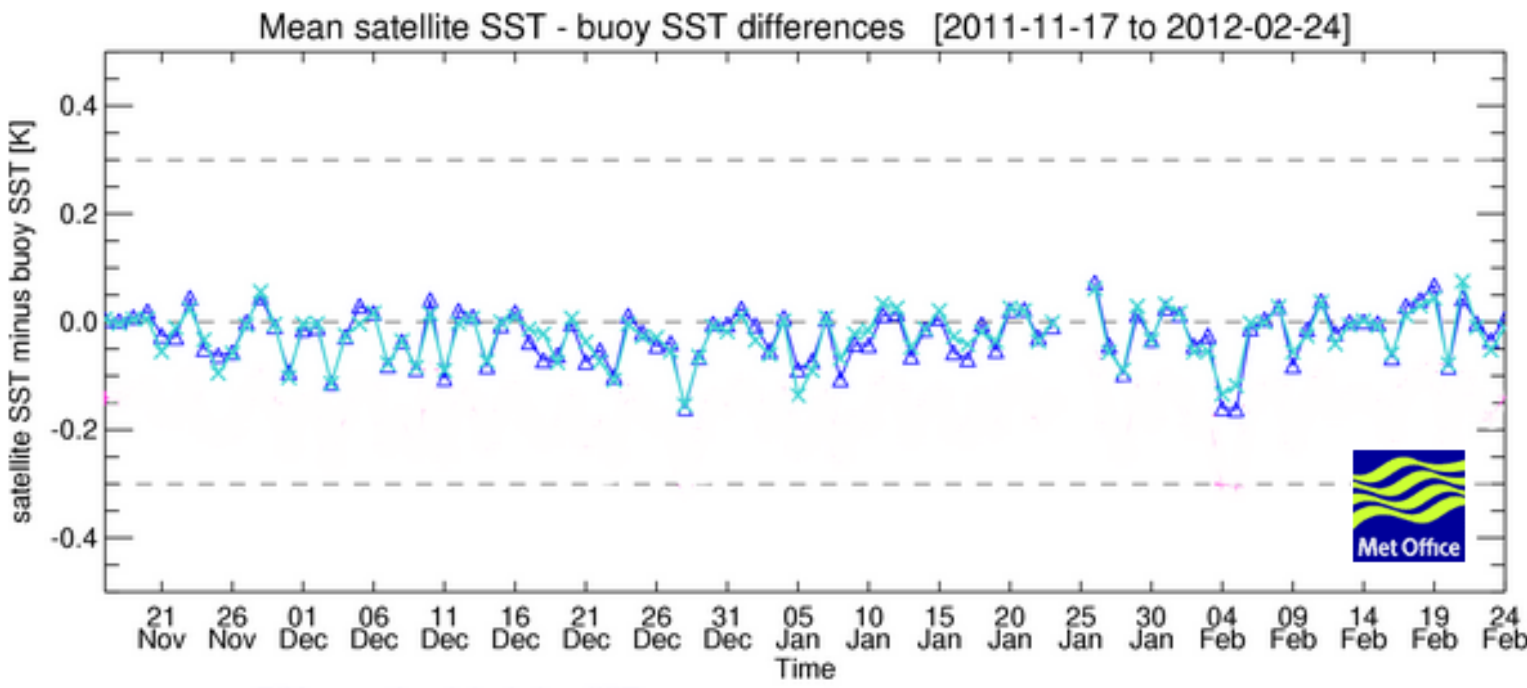
so when comparing AATSR SST globally…





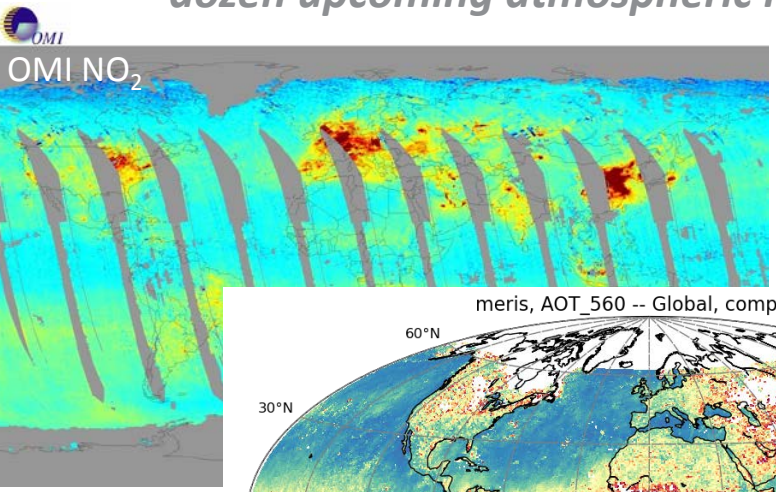
Long-term geophysical validation

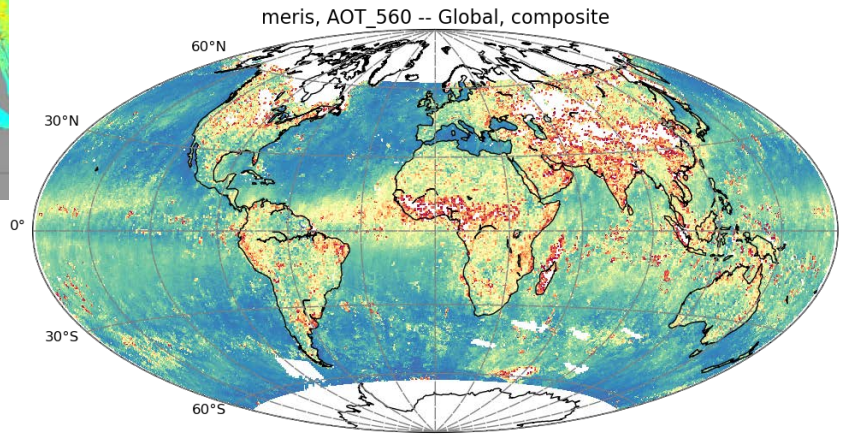
→ essential for data credibility and reliability

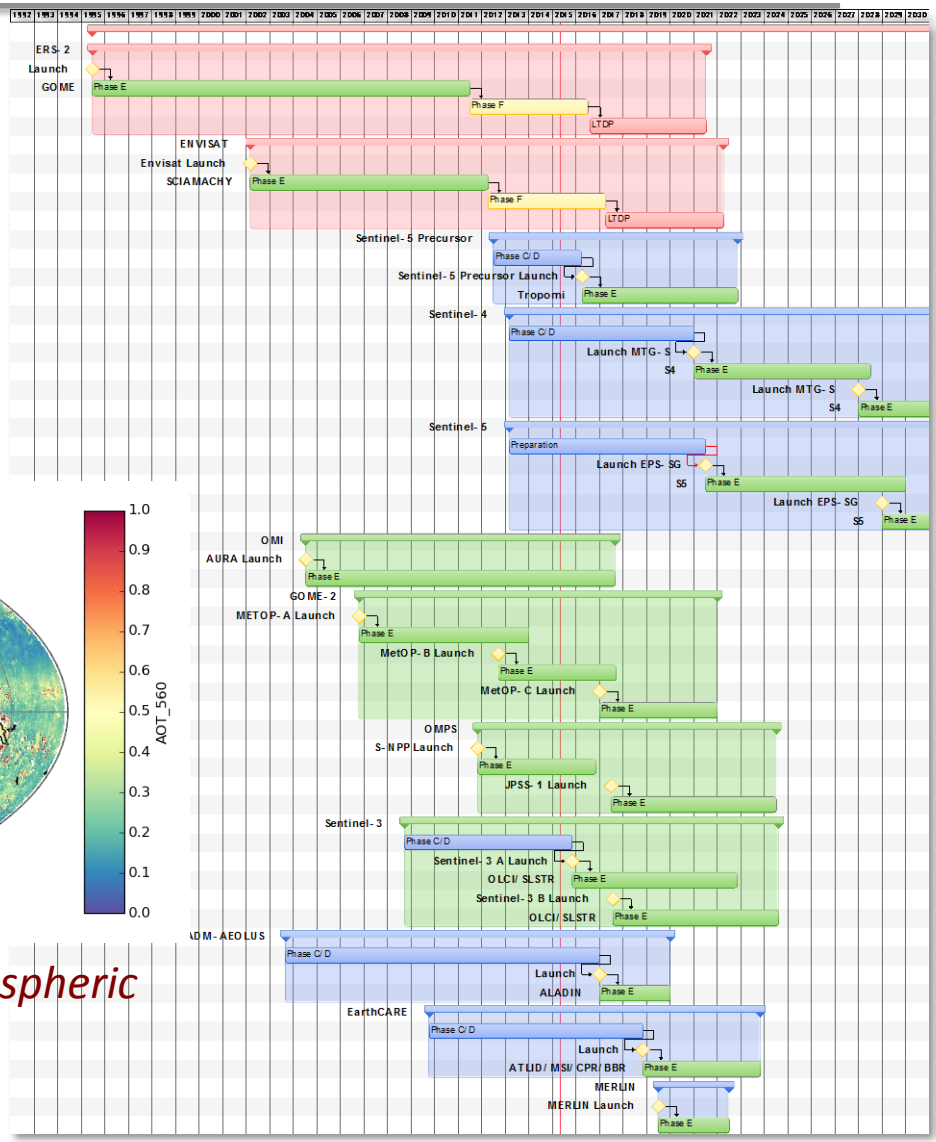


A network of Atmospheric Composition FRMs

- Need of automatic, high-quality, tailored groundbased AC FRMs, ***to be used for a dozen upcoming atmospheric missions***







- ***Note the dual use*** ➜ *validation and atmospheric characterisation for surface products*

A network of Atmospheric Composition FRMs (ii)

Cardinal requirements:

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*

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

QA4EO A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

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
   - *IPR (spectra) remains with PIs, allowing for research products*

Example: *the ESA Pandonia network*

- Support the further development of the Pandora systems by
  - Extending to profile measurements, water vapour, and 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), PMOD/WRC (CH) and NPL (UK):
  - 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
  - To develop a field calibration capability traceable to SI by 2017

pandonia-frm

- Network to incorporate existing instruments (E, FIN, CND, selected sites in North America) and will have ~30 operational instruments by the end of 2017 to meet the varied geophysical environment requirements for validation

ESA support to FRMs

- **FRM4DOAS** (PI. M. van Roozendael, BIRA/IASB)
  - MaxDOAS algorithm development and preparation of the CINDI-2 air quality intercomparison campaign (Cabauw, NL)
  - Key: NDACC UV-Vis WG
  - KO: March 2016

- **FRM4GHG** (PI J. Nothold, IUP)
  - IR instrument intercomparisons and best practice development for GHG measurements
  - Key: TCCON and NDACC IR WG
  - KO: March 2016, Campaign in Spring

- **DIVA** - **D**emonstration of an **I**ntegrated approach for the **V**alidation and exploitation of **A**tmospheric missions (PI. D. Nicolae, INOE 2000)
  - Preparation of aerosol FRM infrastructure/calibrations, and algorithm consolidation
  - Key: PHOTONS/RIMA/AERONET, EARLINET, Pandonia , ACTRIS-2
  - KO: mid-2016

ESA support to FRMs (ii)

- **FRM4RADAR**
  - Preparation of cloud radar validation
  - Key: ACTRIS-2 cloud community
  - KO: Q4 2016

- **Infrastructure support** to stations/laboratories:
  - Support annual European Brewer calibration campaigns (AEMet, Izaña)
  - Calibration laboratory upgrades: PMOD/WRC, PHOTON/RIMA (AERONET)
  - Direct station support to Thule station for 2016-2018 (through DMI, DK)
  - Support of Neural network Aerosol Typing Algorithm based on LIdar data - **NATALI** (INOE, RO)

- Continued support to the EVDC ("NILU database")
  - Easy access to groundbased data and ECMWF analyses/forecasts; Sub-setting of all ESA and ESA TPM datasets
  - Contract renewed for 3 years

Summary

- A requirements-based (justified) and prioritized (cost-benefit ROI) suite of measurements is required to demonstrate that mission products are “fit for purpose” *(and to meet traceability requirements as outlined by QA4EO)*

- Special fully characterised FRMs, operating throughout the lifetime of the mission, mimicking the satellite sensor measurements are needed - *but care is needed to define FRMs appropriately*

- Easy and timely access to the FRM data to validate the product performance in time, under different weather conditions and varying geophysical areas - *and to bridge missions*

Thank you - any questions?

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