

# Fiducial Reference Measurement Concept

2<sup>nd</sup> EarthCARE Cal/Val Workshop  
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**fi·du·cial (adj)** *Regarded or employed as a standard of reference, as in surveying.*

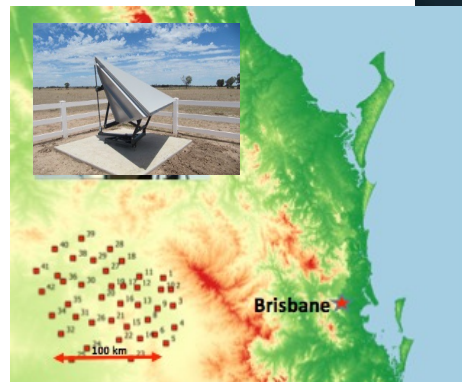
[Late Latin *fdcilis*, from Latin *fdcia*, *trust*, from *fdere*, *to trust*; *seebheidh-* in Indo-European roots.]

- Cal/Val activities are a key component of a satellite mission, giving credibility to the mission data. For ESA's EO mission they usually are a complementary effort of:
  - ESA and ESL/DISC/MPC expert teams
  - Independent validation teams and ESA campaigns
  - **FRMs (Fiducial Reference Measurements)**
- Maintaining quality is all about a regular stream of verification and validation data that can be used to check mission and product performance. Optimally:
  - Validate satellites with standard data that we can be trusted → **FIDUCIAL**
  - fundamental **traceability and uncertainty budgets** for ground measurements used

## Fiducial Reference Measurements (FRM)

*"Fiducial Reference Measurements (FRM) are a suite of independent, fully characterized, and traceable ground measurements that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO). These FRM provide the maximum Return On Investment (ROI) for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission.."*

->In short: FRMs are tailored and fully characterized measurements in support of satellite Cal/Val, directly mimicking the satellite sensor measurements when possible.  
«FRM4» projects : preparatory R&D activities



# Fiducial Reference Measurements (FRM)

The defining **characteristics for FRM** are:

- FRM measurements should ideally have **documented SI traceability** using metrology standards and/or community recognised best practices;
- FRM measurements are **independent** from the satellite geophysical retrieval process;
- An **uncertainty budget** for all FRM instruments, and derived measurements, is available and maintained;
- FRM measurement **protocols, procedures** and community-wide management practices (measurement, processing, archive, documents, etc.) are defined, published and adhered to by FRM instrument deployments;
- FRM are **accessible** to other researchers allowing independent verification of processing systems;
- FRM are **required** to determine the in-orbit uncertainty characteristics of satellite geophysical measurements via independent validation activities.

# Selection of FRM4 and FRM Projects run by the ESA SPPA team:

<a href="http://frm4ghg.aeronomie.be/">http://frm4ghg.aeronomie.be/</a>	The focus of the "FRM Ground-Based FTIR Greenhouse Gas Observations" (FRM4GHG) project is the intercomparison of instruments and harmonization of products and retrievals from ground based FTIR systems → Greenhouse Gas. New project starting 2021, 4 years duration.
<a href="http://frm4doas.aeronomie.be/">http://frm4doas.aeronomie.be/</a>	The "FRM for Ground-Based DOAS Air-Quality Observations" project aims at the harmonization of the retrievals from UV-Visible ground based spectrometers (MAXDOAS or Pandora) -> the standards of FRMs for NO2 and ozone. New project starting 2021, 4 years duration.
FRM4SAR	Best practice for deploying an a site (and analysis) for accurate geometric calibration.
FRM4RADAR -> see following presentation	Mini observation network for validation/ verification of cloud profile measurements from space (EarthCARE CPR L2A etc) integrated and fully compatible with ACTRIS-Cloudnet
<a href="https://www.pandonia-global-network.org/">https://www.pandonia-global-network.org/</a>	PGN is a joint ESA-NASA ground-based remote sensing network for trace gases and atm composition. The main instrument of Pandonia is the Pandora-1S/2S system.
FRM4VEG <a href="https://frm4veg.org/">https://frm4veg.org/</a>	Protocols for traceable in-situ measurements of vegetation-related parameters, to support the validation of Copernicus products from Sentinel-2, -3, and PROBA-V and optical Sensor TPMs. Characterisation of Sites.



**fiducial reference  
temperature  
measurements**



Towards a global land surface climate fiducial reference measurement network  
 PW Thorne, HJ Diamond, B Goodison... - International Journal... 2018 - Wiley  
 There is overwhelming evidence that the climate system has warmed since the instrumental meteorological observations. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change concluded that the evidence for warming is unequivocal.  
 ☆ 92 Zibert von: 15 Ähnliche Artikel Alle 12 Versionen

A review of protocols for fiducial reference measurements of irradiance for the validation of satellite remote sensing data over water  
 KG Ruddick, K Voss, AC Banks, E Boss, A Castagna... - Remote Sensing, 2019  
 This paper reviews the state of the art of protocols for the measurement of downwelling irradiance in the context of Fiducial Reference Measurements (FRM) of water-leaving radiance. The measurement of water reflectance requires the measurement of irradiance.  
 ☆ 92 Zibert von: 16 Ähnliche Artikel Alle 17 Versionen 90

A review of protocols for fiducial reference measurements of radiance for validation of satellite remote-sensing data over water  
 KG Ruddick, K Voss, E Boss, A Castagna, R Erouin... - Remote Sensing, 2019  
 This paper reviews the state of the art of protocols for the measurement of downwelling irradiance in the context of fiducial reference measurements (FRM) of water-leaving radiance. Measurement of water reflectance requires the measurement of irradiance.  
 ☆ 92 Zibert von: 26 Ähnliche Artikel Alle 15 Versionen 90

Fiducial Reference Measurements for Satellite Ocean Colour  
 AC Banks, R Verrill, K Alkaskas, A Bialek, J Kuusk... - Remote Sensing, 2020 - mdpi  
 Earth observation data can help us understand and address some of the grand challenges facing us today as a species and as a planet, for example climate change impacts and sustainable use of the Earth's resources. However, in order to have confidence in the data, we need to know how well the instruments are working.  
 ☆ 92 Zibert von: 7 Ähnliche Artikel Alle 8 Versionen 90

An action plan towards fiducial reference measurements for Earth observation  
 SP Merikas, C Donlon, P Vuilleumier, R Cullen... - Remote Sensing, 2019 - mdpi  
 Satellite altimeters have been producing, as of 1992, an amazing and historic record of sea level changes. As Europe moves into full operational altimetry, it has become more important to ensure the quality of these monitoring signals with their uncertainties should be controlled.  
 ☆ 92 Zibert von: 7 Ähnliche Artikel Alle 3 Versionen 90

Fiducial Reference Measurements for Validation of Sentinel-2 Surface Reflectance Products  
 N Origo, J Gornoffo, J Rydler, J Nightingale... - Remote Sensing, 2020 - Elsevier  
 Abstract Many derived Earth Observation products share surface reflectance as a common level in their processing chains. This makes the maintenance and improvement of the reference product quality of fundamental importance to ensure information derived from these products is reliable.  
 ☆ 92 Zibert von: 1 Ähnliche Artikel Alle 6 Versionen

Fiducial Reference Measurements for Satellite Altimetry Calibration  
 SP Merikas, C Donlon, P Faméras, R Cullen... - Fiducial Reference Measurements, 2019 - Wiley  
 This work defines the concept of Fiducial Reference Measurements (FRM) for altimetry calibration. It has emerged out of the requirement for reliable, consistent, standardised Earth observation records. FRM observations are to become compulsory for altimetry.  
 ☆ 92 Zibert von: 6 Ähnliche Artikel Alle 3 Versionen

Fiducial reference systems for time and coordinates in space  
 SP Merikas, C Donlon, D Maltsev... - Advances in Space Research, 2020 - Elsevier  
 Fiducial reference measurements for altimetry (FRM4ALT) rhymes along the path to reach uniform and absolute... Time is the absolute reference yardstick for altimetry... in the sequel could be tied to either an inertial or a terrestrial reference frame.  
 ☆ 92 Zibert von: 1 Ähnliche Artikel Alle 2 Versionen

Scientific and Operational Roadmap for Fiducial Reference Measurements for Satellite Altimetry Calibration & Validation  
 SP Merikas, C Donlon, R Cullen... - Reference Measurements, 2019 - Wiley  
 This work defines the essential elements for a scientific and operational roadmap for altimetry calibration. It has emerged out of the requirement for reliable, consistent, standardised Earth observation records. FRM observations are to become compulsory for altimetry.  
 ☆ 92 Zibert von: 4 Ähnliche Artikel Alle 3 Versionen

An in situ optical dataset for working towards fiducial reference based satellite ocean colour validation in the Eastern Mediterranean  
 AC Banks, PG Dritsakopoulos, S Chalkias... - Remote Sensing, 2020 - mdpi  
 The societal benefits of satellite ocean colour include aiding the management of marine ecosystems, helping understand the role of the ocean ecosystem in climate change, aquaculture, fisheries, coastal zone water quality, and the mapping and monitoring of marine resources.  
 ☆ 92 Zibert von: 1 Ähnliche Artikel Alle 4 Versionen



- Fiducial Reference Measurements (FRM) are tailored and fully characterized measurements in support for satellite Cal/Val, and may be considered a sub-set of 'in-situ' measurements.
- They are a prioritized suite of measurements to demonstrate that mission products meet the mission's requirements.
- The FRM are essential for the validation of satellite measured parameters, in particular for missions aiming to respond to long-term public needs (e.g. Sentinel missions, meteorological missions).
- The FRM shall meet specific mission requirements in terms of accuracy and traceability