

Abstract

The concept of a Fiducial Reference Measurement (FRM) has been developed to highlight the need for precise and well-characterised measurements tailored to the post-launch calibration and validation (Cal/Val) of Earth Observation satellite missions. This need has been enhanced with the emergence of new commercial satellite operators to ensure that users have a transparent and fair means to judge the adequacy of data products to meet their needs.

The Committee on Earth Observation Satellites (CEOS) Working Group Cal/Val (WGCV) has put in place a framework to assess the maturity and compliance of a “Cal/Val reference measurement” in terms of a set of community-agreed criteria (CEOS-FRM quality). The assessment process is based on a Maturity Matrix that provides a visual assessment of the state of any FRM against each of a set of given criteria, making visible where it is mature and where evolution and effort are still needed.

FRMs Definition

Fiducial Reference Measurements (FRMs) are a suite of independent, fully characterised, and traceable (to a community agreed reference, ideally SI) measurements, tailored specifically to address the calibration and validation needs of a class of satellite borne sensor and that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO).



CEOS FRM Assessment Framework on Cal/Val Portal



CEOS FRMs Maturity Matrix

Grade	Self-Assessment						Independent Assessor
	Nature of FRM	FRM Instrumentation	Operations/ Sampling (single instrument)	Data	Metrology	Completeness, coverage and distribution	Verification
Not Assessed	Descriptor	Instrument documentation	Automation level	Data completeness	Uncertainty characterisation	Validation capacity	Guidelines adherence
Not Assessable	Location/ availability of FRM	Evidence of traceable calibration	Measurand sampling/ representativeness	Availability and Usability	Traceability documentation	Geographical coverage	Utilisation/ Feedback
Basic	Range of instruments	Maintenance plan	ATBDs on processing/ software	Data format	Comparison/ calibration of FRM	Temporal sampling	Metrology verification
Good						Centralized data, processing, quality assessment and adherence to community standards	
Excellent	Complementary observations	Operator expertise	Guidelines on transformation to satellite Pixel	Ancillary data	Adequacy for intended class of instrument/ measurand	Timeliness	Independent verification
Ideal							

Class A – Where the measurement fully meets all the criteria necessary to be considered an FRM for a particular class of instrument and measurand.
Class B – Where the measurement meets many of the key criteria and has a path towards meeting the Class A status in the near term.
Class C – Meets or has some clear path towards achieving the criteria needed to reach a higher class and provides some clear value to the validation of a class of satellite instruments/measurands.
Class D – Is a relatively basic adherence to the FRM criteria but there is a strategy and aspiration to progress towards a higher class. This can be considered an entry level class for those starting out on developing an FRM.

The mandatory defining characteristics for CEOS-FRMs are:

- Traceability**- FRMs should have documented evidence of their traceability to a community agreed reference, ideally tied to the International System of units, SI.
- Independence from satellite under test**- FRMs are independent from the satellite (under-comparison) geophysical retrieval process.
- Uncertainty budget**- A comprehensive uncertainty budget for all instruments used in deriving FRM of a particular measurand, including any transformation of the measurand to match that of the satellite product, is available and maintained.
- Documented protocols**- FRM protocols, procedures and community-wide quality management practices (measurement, processing, archive, documents, etc.) are defined, published and adhered to by FRM instrument deployments and usages.
- Accessibility**- FRM data, including metadata and documentation of processing, are accessible to other researchers allowing independent verification of processing systems. All data and information should be made available in a timely manner and in a form that is readily utilisable by a satellite operator.
- Representativeness**- FRM data allow the determination of the on-orbit uncertainty characteristics of satellite geophysical measurements via independent validation activities. It thus requires that the degree of representativeness of the FRM to that of the satellite observation and/or associated retrieval as well as the satellite to FRM comparison process needs to be documented and the uncertainty assessed.
- Adequacy of uncertainty**- The uncertainty of the FRM measurements, including the comparison process, must be commensurate with the requirements of the class of satellite/instrument/measurand they are specified to support.
- Utility (Return on Investment)**- FRM data are designed to apply to a class of satellite missions (several). They should not be mission-specific.

Maturity Matrix Tool

Pilots for CEOS FRMs Maturity Matrix Assessment:

- **PGN** (Pandonia Global Network) - Stefano Casadio (Serco)
- **RadCalNet** (Radiometric Calibration Network) - Marc Bouvet (ESA/ESTEC)
- **ICOS** (Integrated Carbon Observation System - Ecosystem Component) - Fabrizio Niro (Serco)
- **FRM4DOAS** (Ground-Based DOAS Air-Quality Observations) - Michel Van Roozendael and Jean-Christopher Lambert (BIRA)
- **BAQUNIN** (PREDE-POM LUNAR) - Stefano Casadio (Serco)
- **CSIRO (DION)** - Janet Anstee and Matt Garthwaite (CSIRO)
- **Brewer Spectrometer - NO2 Vertical Column Densities (VCDs) Measurements** - Henri Diémoz (ARPA Valle d'Aosta) - BAQUNIN project
- **FRM4GHG 2.0 project - COCCON** (EM27/SUN) XCO₂, XCH₄, and XCO data. - Mahesh Kumar Sha (BIRA) - FRM4GHG team.
- Tropical Centre for reactive trace gas remote sensing (**CREGARS**) in ACTRIS - Martine De Mazière (BIRA)