The role of FRM and reference measurements for performance certification and monitoring within the European EO Ecosystem

Splinter Session 3

12/022025

EO ECOSYSTEM 2040+ WORKSHOP

Objectives

- What should our European Earth Observation Ecosystem look like in 2040+?
- Which future operational or scientific users' needs will drive the definition of future system-of-systems?
- How do commercial Earth Observation data providers fit into the overall picture?
- How do we verify the performance of the system?

Consolidate the European Blueprint for Earth Observation.

Identify and prioritise actions to implement in order to sustain, operate, and evolve the performance and capacity of Earth Observation in Europe as the most advanced living systems-of-systems in the world in support of European citizens and policies.

Key Challenges

- The European EO Ecosystem in 2040+ - System-of-Systems view
- User expectations and requirements for synergies within the European EO ecosystem
- **The role of FRM and reference measurements for performance certification and monitoring within the European EO Ecosystem**
- The role of a constellation within the European EO ecosystem

EUROPEAN EO ECOSYSTEM BLUEPRINT - extracts

ESA UNCLASSIFIED – Releasable to the Public

esa

Executive Summary
The Netherlands, 31 October 2024

THE EUROPEAN EARTH OBSERVATION ECOSYSTEM – A SYSTEM-OF SYSTEMS BLUEPRINT REFERENCE ARCHITECTURE

1. The European Earth Observation Ecosystem - a system-of systems Blueprint Reference Architecture

"Wise men say, and not without reason, that whoever wishes to foresee the future must consult the past" (Niccolò Machiavelli, 1532)

Planet Earth is undergoing profound regime shifts driven by anthropogenic forcing of the dynamic equilibrium of the Earth system. Climate models predict a profoundly different Earth system, where new equilibria (after passing tipping points) are poorly known. Climate change is often thought about as a scientific problem with a technological solution when the fact is it is largely a social problem with a human solution. Human-induced pressures are rapidly undermining the resilience of Earth systems that have long remained stable, propelling the Earth system and its societal fabric past a stable and equilibrium state capable of sustaining the world as we know it today. This will impose significant challenges to the resilience, stability and security of global society. Europe must maintain approaches that observe the most interesting and relevant planet in the Universe, our home planet Earth, where humanity resides.

Within this context, European Earth Observation (EO) is a fundamental tool providing quasi-synoptic, regular repeat, global coverage, geophysical measurement evidence to assist policy makers, industry and application services to help manage the increasing pressures of the new global society and understanding its impact on long-term sustainability.

Some of the most radical discoveries emerge from curiosity-based research endeavours enabling Climate Action through better knowledge. Europe, led by ESA, has designed, implemented, and operates the most proficient and extensive Earth Observation system in the

"Key Characteristics and Baseline of the European EO ecosystem
(…)
7. **Standards:** It defines common standards, protocols, and interfaces to ensure consistency and interoperability across different components and implementations.
8. **Verification:** Certification that data are what they claim to be (i.e.. resilience against deep fake data).
9. **Performance:** Data are certified to a declared and traceable performance standard (e.g. to support enforcement of regulations and policy and therefore data need to be valid for legal arbitration).
(…) **"**

"The interconnected system –of systems requires an agile cross-mission ground segment empowering users with advanced multi-mission data processing capabilities, long-term preservation and transmission of data and knowledge. EO operations and data management activities now rely on an industrial service-based architecture paradigm that is essential to maintain competence in the highly dynamic world of Information Technology today.
As the EO ecosystem diversifies, it is both important and prudent to reflect on these aspects – particularly with respect to the proposed European EO Authentication and Measurement Performance Certification Services and their relevance to the commercial EO landscape"

Context

There are a growing number of new commercial and public providers of high resolution space-borne Earth Observation data. Key to using data from these new sources is a **good understanding of their characteristics**, how they are calibrated, and their quality and technical capabilities.

Interoperability between satellites/products will allow to extend dramatically the opportunities for applications (agriculture, water use, forest and vegetation monitoring, pollution monitoring…etc…and also climate applications).

The data can be used together only if **we can trust their accuracy and characterisation.**

Harmonisation in Calibration and Validation approaches are fundamental.

Improving the confidence in new EO products

Toward Product Certification

Establish standards for quality

Development and operations of the quality assessment framework

Toward certification, but certification of what ?

In EO context, Product Certification can be defined at 3 levels:

- ✓ **Certification of a Company**

  *Control the production process wrt quality standard. QMS certification is a **pre-requisite** to obtaining certification. It could be **supplementary** to ISO9001 certification: process should be streamlined for ISO9001 holders. It must be lighter than ISO9001; training & guidance for applicants should be clear and easily available.*

- ✓ **EO Products (or Dataset) Certification**

  Control the quality of a Level 1 or Level 2 product or dataset (collection). Mission success is dependent upon quality assurance. Evidencing data quality adds significantly to the value of datasets. It gives potential customers the confidence data is fit for their purpose. Many aspects of data quality are aimed at facilitating communication to users → required for e.g. interoperability. The assessment framework aims at verifying claimed mission performance and adheres, where applicable, to community best practices to an extent that is "fit for purpose".
  Assessment can be divided into two parts: 1- Review of mission quality as evidenced by its documentation, 2- Validation analysis performed by mission quality assessor.

- ✓ **Certification of value adding service**

  Control the quality of a data-value adding service. The Certification of Service requires close co-operation with individual thematic communities.

EO Product Certification / Qualification

EO Product Certification or Qualification has three main domains:

- ✓ **Data Authenticity**

  that should guarantee the authenticity of the product, avoiding any manipulation that can lead to wrong interpretation and misuse of the information.

- ✓ **Data content and performance measurement**

  that should guarantee that the measurement is accurate, providing uncertainties that are documented, traceable ideally to SI standards or community agreed best practises.

- ✓ **Fitness for purpose**

  that should demonstrate that the data from which one we know the provenance (authenticity) and the quality (performance measurement) is fit for purpose or for a specific application.

A levelled approach to certification is recommended, which will:

- improve accessibility to the scheme whilst retaining scheme rigour,
- retain differentiation between products with different quality specifications,
- improve the quality of data products over time.

Level	Description	Purpose
1	Meets essential criteria	R&D / pre-operational products
2	Meets all but the most demanding products rigorous requirements	Operational products
3	Meets all requirements	Most demanding applications – e.g., climate, litigation

EO Product Certification / Qualification : initial approach

ESA Earthnet ⟷ NASA Commercial Smallsat Data Acquisition (CSDA) Program

In the context of the ESA/NASA JPPG, both institutions are working toward a comprehensive **ESA-NASA Evaluation Framework**.

EDAP – Earthnet Data Assessment Project - is intended to perform quality assessment for various EO missions, including New Space missions.

EDAP approach aims to define a mission quality **Cal/Val Maturity Matrix**

This framework is something data producers can refer to as they define products and evidence themselves.

Common framework between ESA and NASA simplifies process for vendors, and makes results more comparable.

Assessment process is an interactive activity between assessors and missions.

Data Provider Documentation Review			Validation Summary
Product Information	Metrology	Product Generation	
Product Details	Radiometric Calibration & Characterisation	Radiometric Calibration Algorithm	Radiometric Validation Method
Availability & Accessibility	Geometric Calibration & Characterisation	Geometric Processing	Radiometric Validation Results Compliance
Product Format, Flags & Metadata	Metrological Traceability Documentation	Retrieval Algorithm	Geometric Validation Method
User Documentation	Uncertainty Characterisation	Mission-Specific Processing	Geometric Validation Results Compliance
	Ancillary Data		

Key
Not Assessed
Not Assessable
Basic
Good
Excellent
Ideal
Not Public

→ *Need to further develop the "fitness for purpose maturity matrix"*

EO Product Certification: link with cal/val reference

EO product certification requires the use of cal/val reference, i.e.

Fiducial Reference Measurement (FRM)

FRM is of particular importance because it gives a reference properly characterised and traceable to standards and/or community best practises on which the Cal/Val results can be anchored → increase trust in data

FRM Example:
RADCalnet, SARCalnet, TIRCalnet, PGN

FRM definition :
*"The suite of independent **tailored and fully characterised** measurements that 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."*

The defining **mandatory characteristics for FRM** are:

- FRM measurements should ideally have ***documented SI traceability*** (e.g. via round-robin characterisation and regular pre-and post deployment calibration of instruments) 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 on-orbit uncertainty characteristics of satellite geophysical measurements via independent validation activities.

EO Product Certification: example of cal/val reference CAL/VAL PARK

Establishment of a **Cal/Val Park** in Italy:

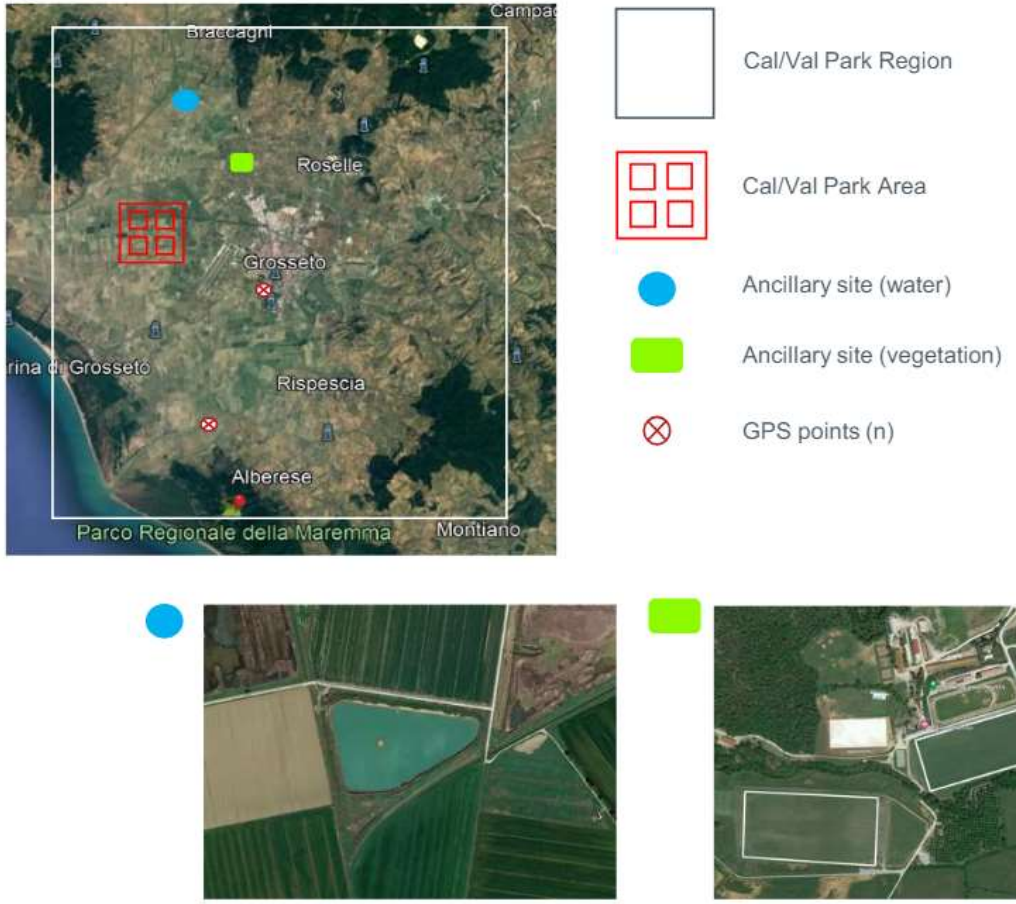
→ reference for High Resolution commercial and public missions

Requirements for site selection:

- Suitability criteria: size, atmosphere, clouds, topography, land-use, adjacency effects
- Practical criteria: availability, logistics, long-term accessibility (>10 years)

Status and current approach:

- Site will be in Tuscany (Italy): low cloudiness, extensively used for past Cal/Val campaigns, support from local authorities



EO Product Certification:

With the arrival of **many new data providers**, there is a need to increase the confidence in the EO product/ information

→ There is a consensus to go toward **product certification** (including authenticity)

→ Wording “certification” is still causing debate → from qualification of product to litigation ready data

→ As first principle certification is understood as: Demonstrating you are doing what you say. Providing evidence of what you are claiming

Design, develop, implement, and operate a European EO Authentication and Measurement Performance Certification System (AMPCS) that can guarantee certification of EO measurement performance uncertainty with well documented traceability to SI standards to be recognised as authentic measurements ***(see Inter-departmental 2024 strategic WGs on 1- EO Reference Architecture (Blueprint) and on 2- EO role in support of commercialisation activities beyond traditional elements/ dimensions*****).**

→ ESA/Europe **sets and assess standards and quality level** of newspace / commercial space in the field of EO worldwide

- There is question on who should certify, but there is a consensus that it should done in International framework or agreement → role of CEOS ?
- Element of this Certification framework are put in place – FRM. Europe is taking the lead in International cooperation (ESA/NASA for EDAP).
- All stakeholders should be involved in the process.

FRM from Space

- FRM in space, moving towards SITSats concept.

- TRUTHS is a good model - We should develop similar concept for other observables
  - altimetry,
  - thermal,
  - atmospheric domains
  - MWR
  - Others

Need international collaboration (CEOS SITSat Task group is an example)

AI for Cal/Val

Role / Potential from AI in Cal/Val and FRM. → There is a consensus on the role AI in Cal/Val and FRM in particular

→ Optimise the FRM characterisation/ representativeness, link to physical model. Hybrid approach is needed.

→ Use of AI for FRM generation (ex GCP at VHR)

→ Issue of traceability → XAI

Filling the GAP in FRM

- **Reference for Very High Resolution (VHR) →**
  - **GCP,**
  - **grid reference image**
  - **DEM at VHR**

For example, → FRM in methane emission plumes for high resolution mission (GHGSat)

→ GAP ANALYSIS SHOULD BE CONDUCTED

It is important that FRMs are planned and integrated in a satellite programme from the very beginning of the development phase (Phase 0/A/B/C/D). Operated and maintained in Phase E.

OPEN SCIENCE

-

- **Reproducibility (open source, traceability, documents…)**
- **Open Science issue → Intellectual property concerns / export control**
- **Minimum documentation must be available**
- **Need to built Supersite Data Cube covering multi resolution and multiple domain in order to explore synergy. Role for AI → Reference Supersite**

International Network

International Network (toward FRM) sustainability / Low cost / portable sensors (FRM?) / DRONE / Citizen science

Internation network are fundamental for Cal/Val

- **Going toward FRM for internation network (SST…etc…)**

  → Tier approach (starting from very well characterised golden site (few site –Class A) and the other sites can be anchored (improving geographical representation)

  → Need to go low cost / portable → toward FRM

→Sustainability is the issue

- **→ Need to local expertise**
- **→ Need/engage to local stakeholder**
- **→ Sustainability of network → attract new player (with improvement/innovation) → FRM business model**

Conclusion

We go towards European EO Verification and Measurement Performance Certification System (VMPCS) – We need a framework for quality.

All the elements are in place

How we can leverage existing community standards and best practices (e.g., FRM, Networks, Maturity Matrices, FAIR principles) to build a consistent quality framework

FRM is enabling the certification.

Need to follow up :

- Word certification – clear definition is needed
- international engagement (CEOS)