

## **Data Quality Guidelines for Satellite Sensor Observations Relevant to GEOSS<sup>1</sup>**

### *Calibration and Validation Issues*

Recommendations by CEOS/WGCV to the CEOS Task Force

#### **1. Introduction**

Currently, many countries and organizations are collaborating to develop a 10 year plan enabling comprehensive and sustained Earth observations. This Plan, called “The Global Earth Observations System of Systems (GEOSS)”, builds upon the existing Earth observation systems by coordinating their efforts. GEOSS addresses critical information gaps through the establishment of criteria for interoperability, sharing of information, reaching a common understanding of user requirements and improving delivery of information to users.

*GEO will establish, within 10 years, a system of systems to provide timely data and products for local, national, regional, and international policy makers. In the implementation of GEOSS, harmonization of observations, real- or near real-time monitoring, integration of information from in-situ, airborne and space-based observations through data assimilation and models, and early detection of significant and extreme events is advocated. Integration of in-situ, airborne and space-based observations within the various societal benefit areas will be encouraged, as will the establishment of global, efficient, and representative networks of in-situ observation to support process studies, satellite data validation, and algorithm and model development, as well as the detection, documentation and attribution of change.*

***The success of GEOSS will depend on data and information providers accepting and implementing a set of interoperability arrangements, including technical specifications for collecting, processing, storing, and disseminating shared data, metadata, and products. GEOSS interoperability will be based on non-proprietary standards, with preference to formal international standards.***

*Interoperability will be focused on interfaces, defining only how system components interface with each other and thereby minimizing any impact on affected systems other than where such affected systems have interfaces to the shared architecture (from the GEOSS 10 yr. Implementation plan).*

The harmonization of operational data products and the creation of higher level information products such as global maps and time series (from different sensor sources) are required to satisfy the operational service requirements of the societal benefit areas as outlined in the GEOSS implementation plan. The CEOS/WGCV concentrates on defining standards and procedures aimed at allowing for the inter-comparison and ultimate utilization of data from all Earth observing platforms, both current and future. WGCV strives to establish common approaches to validation, calibration and data exchange formats to ensure effective cooperative use of all CEOS member space assets in addressing important global scale problems.

#### **The WGCV Vision:**

Empower the climate, environmental and weather analyses and prediction community with sustained high quality observations and associated error characteristics, “*in order to improve monitoring of the state of the Earth, increase understanding of Earth processes and enhance prediction of the behavior of the Earth system*” (GEOSS 10 year Implementation Plan).

## **2. Data quality assurance strategy**

Operational services using data from different Earth Observing satellite sensors and the resulting synergistic data products require satellite measurements whose quality is well characterized and sufficient to produce a meaningful product. Accuracy assessment and reporting of measurement uncertainty is essential to assure product consistency and inter-operability (e.g. comparison/combination). This implies that the instrument calibration and product validation activities need to be continuously monitored and traceable to standards.

**In this context, CEOS/WGCV recommends, that all GEOSS partners participate in the establishment of the following common practices:**

- Document the methods used to derive and further process satellite measurements. Sensor signals are the starting point for all satellite derived information products. All current and planned Earth observing satellite sensors should be so documented, to enable product consistency and inter-operability (e.g. comparison/combination). Furthermore, standards for quality assurance of these products need to be defined.
- Create and maintain an internet-accessible information database containing, on an instrument or satellite basis, links to all instrument characteristics (including accuracy / precision / stability assessment) needed for ensuring inter-operability. CEOS-WGCV, in conjunction with CEOS-WGISS, will provide guidelines for the database content and format.
- Provide/publish reference methods in a readily accessible form. Calibration and validation material should address pre-flight characterization, vicarious calibration, geo-referencing, radiative transfer computation, data merging etc. The database should also include calibration and validation test-site characteristics and ancillary (meta-) data (see model case CEOS-WGISS-WGCV Test Facility).

Establishment of these practices should be phased in two steps as follows: 1) implementation period and 2) continuous maintenance and update (to accommodate new sensor information and data) throughout the GEOSS lifetime.

Participating countries and Agencies in GEOSS are asked to support these practices by providing adequate resources to produce and supply the appropriate information and data in a timely manner.

A structure for this activity is suggested in Figure 1. The elements needed to implement this system are described below. It is recognized that this activity will take place over the 10 year GEOSS implementation plan and will rely on the best efforts and available resources by all participating countries and agencies.

### **System Element 1 – Instrument Characteristics**

System Element 1 contains the required information on the satellite sensor characteristics and performance, such as its spatial, radiometric, geometric/geo-referencing and spectral properties, as well as the spacecraft orbital characteristics.

Required information/activities include:

- Provision of instrument (system) characteristics and associated performance descriptions in common formats for all sensors and across all agencies,
- Use of common terminology (refer to CEOS/ISPRS Task Force Report) and methods to evaluate the sensor's characteristics,
- Instrument performance checks at regular intervals.

### **System Element 2 Sensor intercomparison Data**

System Element 2 contains satellite and *in-situ* data collected to facilitate sensor inter-comparison and vicarious calibrations over Diagnostic Sites. These data must be incorporated into a readily accessible database available to all GEOSS participants.

Successful achievement of the above is contingent on:

- Agreement on a common, fixed set of diagnostic sites for atmospheric, ocean and land observations by all participants,
- Systematic satellite data acquisition over these sites by all participants,
- Frequent *in-situ* data collection over these sites by all participants,
- Common *in-situ* measurement protocols and site characteristics description,
- Web based distribution of satellite and *in-situ* data in a common format by all participants (currently addressed by CEOS/WGISS-WGCV Test Facility).

### **System Element 3 – Reference Methods and Protocols**

System Element 3 contains the documentation describing procedures and methods to establish Data Quality Assurance criteria.

Required documentation includes:

- Guidelines for performing:
  - vicarious calibration,
  - sensor inter-comparison and,
  - product validation
- In-situ measurement protocols
- Data merging guidelines

### **System Element 4 – Compliance with Interoperability Requirements**

System Element 4 addresses the task of interoperability. Following the successful implementation of the first three basic system elements, System Element 4 will establish the requirements for interoperability of information from the different systems elements relevant to GEOSS. WGISS supports the metadata guidelines to ensure that all the ancillary data required for interoperability is ***supplied*** by the data providers. WGCV ensures that the data content of the various data sets can be made “integrable” by providing guidelines indicating which ancillary data needs to be ***acquired*** by the data provider. Thus WGISS sets interoperability guidelines and WGCV supplies harmonization and data/product integratability guidelines.

In this context it is required that:

- Satellite instrument-, diagnostic site- and methodology entries/data are available for the synergistic combination and merging of data from different optical sensors/sources.
- Differences in information products, due to the different observation techniques or system characteristics and different observing conditions (e.g. atmospheric influence), are understood and documented.

### **3. Detailed system element requirements to guarantee data quality**

To allow accurate retrieval of geophysical parameters that meet mission goals it is essential that a comprehensive calibration strategy be built into the system throughout the mission lifetime from initial concept to end-of-life. Ideally instruments must meet thresholds for spectral coverage and resolution, and radiometric performance (accuracy, precision and long-term stability). Instruments meeting these thresholds can be used to anchor instruments that do not meet them.

The building blocks for a calibration / validation system shall include:

- Extensive pre-launch calibration tests to properly characterize instruments and ensure calibration traceable to SI standards
- On-board calibration devices (e.g., black bodies, solar diffusers) where appropriate
- Sustained post launch activities including:
  - (a) In situ measurements of the state of the surface and atmosphere (e.g., the Cloud and Radiation Test-bed (CART) site, aircraft instruments with SI traceable calibrations)
  - (b) Intercomparison with other satellite observations across the range of spatial and spectral scales Radiative transfer models that enable comparison of calculated and observed radiances both for pre-launch and post-launch CAL/VAL activities
- Full end-to-end simulation methods and systems
- Data archive and documentation:
  - (a) Maintain long term open access to archives, accessible, possibly through ‘CAL/VAL portals’

#### **(1) Pre-launch activities:**

- (a) Full instrument cycle test (including instrument and environmental modeling) to ensure every element is traceable to SI standards where possible
- (b) All calibration data and procedures should be documented and kept

#### **(2) Onboard calibration devices:**

- (a) Should be concept proven and characterized
- (b) Should be traceable to SI units
- (c) The witness samples should be kept

#### **(3) Post launch requirements include:**

- (a) Vicarious calibration of ground sites with temporally and spatially stable surface characteristics and generally clear skies, and where possible, observations of the Sun, Moon, and stars, are useful for characterizing calibration drifts of VIS and NIR instruments. If appropriately calibrated from benchmark instruments in space these can be used as reference standards.

- (b) Space-based benchmark observations, with the required accuracy, spectral coverage and resolution and traceable to international standards as “gold” standards for validation and inter-calibration of other satellite sensors.
- (c) Permanent reference sites and dedicated campaigns to collect in situ measurements of the state of the surface and atmosphere. All instruments used for in-situ measurements should be calibrated and traceable to SI standards.
- (d ) Satellite inter-calibration from simultaneous and collocated observations:
  - Simultaneous observations from collocations between a LEO and all GEO sensors have also been demonstrated and can be used as a means to inter-calibrate GEO satellites. Conversely, an instrument with high accuracy, precision and stability in GEO orbit can be used as a means to inter-calibrate all LEO sensors;
  - Collocated high spectral resolutions observations are important for validating and vicariously calibrating broader band radiometers.

(4) Benchmark Radiative Transfer Models, as well as full end-to-end system simulation tools for all sensors must be documented, maintained and openly available.

(5) Data archive and documentation:

- All pre-launch instrument data must be archived with metadata and be freely and openly exchanged–Consistent common file format and projection information or tools to perform related processing;
- All collocated observations for satellite inter-calibration must be archived with metadata and should be freely and openly exchanged;
- Special cal/val campaigns using aircraft and ground-based measurements are encouraged and resulting data must be archived with metadata and be readily accessible.
- Space Agencies should share responsibility in providing required sub-samples of satellite observations needed for inter-calibration. These data needs to be easily accessible and free.

All the information provided should be end-user oriented. All delivered products should have associated with them a statement of uncertainty and its level of confidence.

#### **4. Current CEOS/WGCV activities for the generation and validation of data products**

**WGCV data product validation can benefit GEOSS in the following ways:**

- promote quantitative validation of higher level products derived from remote sensing data and relay results so they are relevant to users;
- identify missing cal/val elements in preflight characterization, on orbit operations, and product generation;
- increase the quality, consistency and efficiency of satellite product validation *via* developing and promoting international standards and protocols for remote-and/or in situ sampling, scaling, error budgeting, data exchange for product validation;

- provide templates for mission-long validation and intercomparison programs for current and future earth observing satellites.

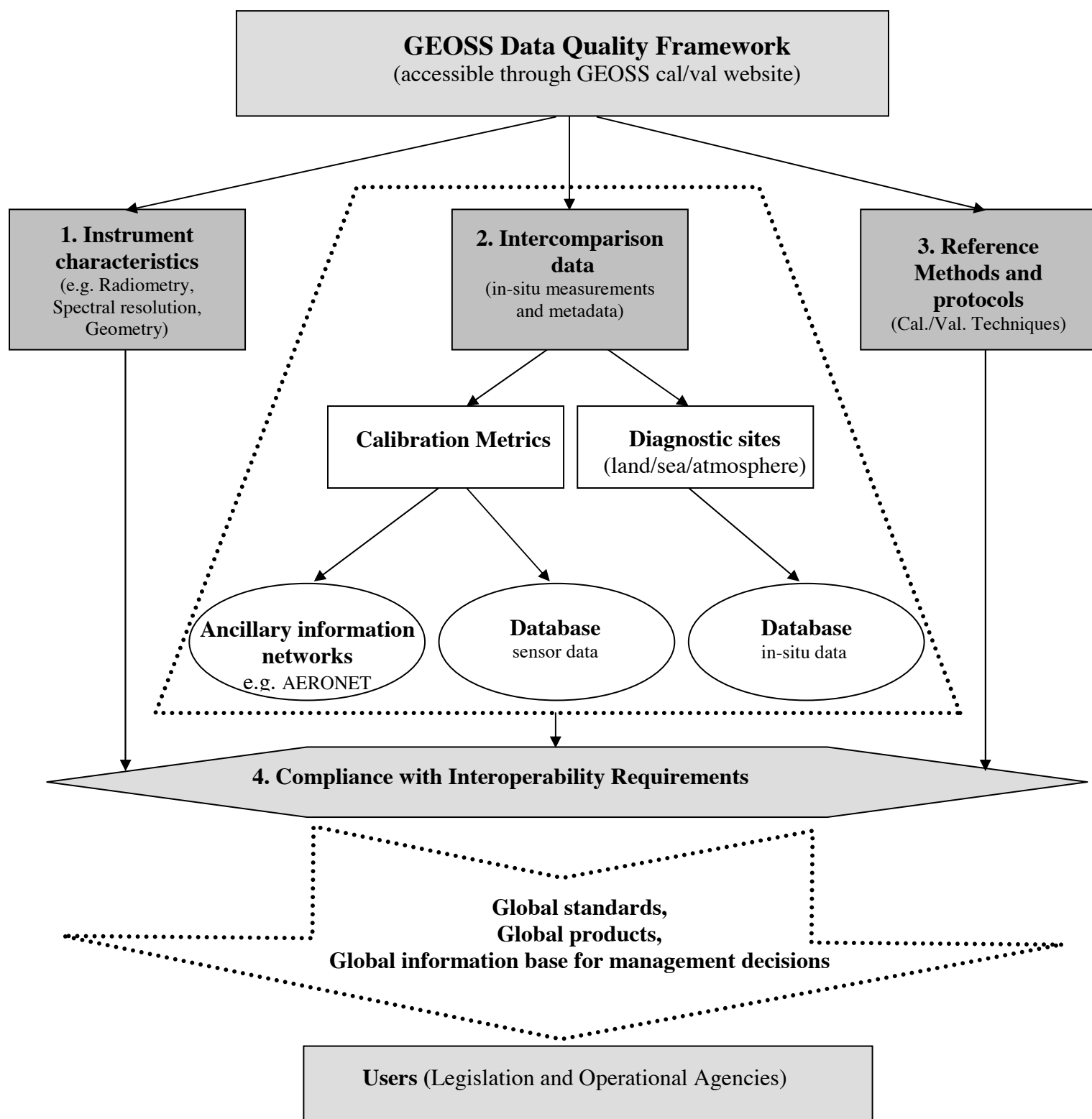
**CEOS/WGCV specifically recommends that GEOSS use CEOS as follows:**

- GEOSS task CEOS/WGCV to serve as a clearinghouse for accuracy statements on CEOS member global satellite-derived products (via enhancements to the existing CEOS/WMO database).
- WGCV will participate in interactive forums, with GEOSS participants, to help determine the practical impact of uncertainty in the satellite-derived products used to support all application areas.

These recommendations will help CEOS WGCV quantify the accuracy of those products critical to the GEOSS focus areas and relay these accuracy figures to GEOSS participants. This, in turn, will set a context for proper use of these products and highlight the strengths and weaknesses of the existing suite of satellite-derived products used to support the focus areas. GEOSS can then advocate both the continued use of the strong components and further development of the weaker components.

## **5. Conclusion**

The approach outlined above ensures the quality assessment of space-borne optical instrument data in the context of a service driven global operational Earth observation remote sensing system. It exploits ongoing work and available expertise among the CEOS working group members, and provides a mechanism for further development over the 10-year timescale of the GEOSS implementation plan.

**Figure 1.** GEOSS cal/val and data quality assessment framework system elements are highlighted

## APPENDIX

### Acronyms

AERONET - Aerosol Robotic Network

CEOS - Committee on Earth Observation Satellites

CEOS/WMO database - World Meteorological Organization

E.O. satellites – Earth Observing satellites

GEOSS - The Global Earth Observations System of Systems

GEO - Group on Earth Observations

ISPRS - [International Society for Photogrammetry and Remote Sensing](#)

Nilu (Norsk institutt for luftforskning) – Database of the Norwegian Institute for Air Research

Sade – Database for sensor inter-comparison for the Saharian Desert (ESA/CNES)

SIMBIOS - Sensor Intercomparison for Marine Biological and Interdisciplinary Ocean Studies

WGCV - Working Group on Calibration and Validation within CEOS

WTF – CEOS / WGISS-WGCV Test Facility