CGMS

CGMS-XXXVII-ESA-WP-06
Prepared by ESA
Discussed in Plenary

A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION: OPERATIONAL GUIDELINES

The Earth Observation stakeholder community has now reached a level of maturity where it is critical that data derived products have an indicator of their quality associated to them, to enable users to assess their suitability for application i.e. their "fitness for purpose". This quality indicator needs to be unequivocal in its interpretation and derivation across the full range of EO activities which are coordinated through GEO. This guide provides an introduction to the Quality assurance framework of GEO (QA4EO) established to achieve this task.

1. INTRODUCTION

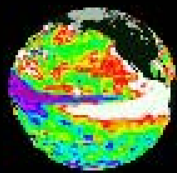
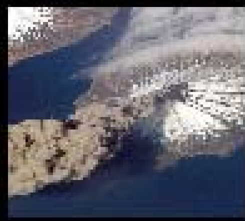
The Group on Earth Observations (GEO) Global Earth Observation System of Systems (GEOSS) must deliver comprehensive and timely "knowledge / information products" worldwide to meet the needs of its nine "societal benefit areas". This will be achieved through the synergistic use of data derived from a variety of sources (satellite, airborne and *in situ*) and the coordination of resources and efforts of the GEO members.

To accomplish this vision, starting from a system of disparate systems that were built for a multitude of applications, requires the establishment of an internationally coordinated operational framework to facilitate interoperability and harmonisation. The success of this framework, in terms of "data", is dependent upon the successful implementation of two key principles – **Accessibility / Availability** *and* **Suitability / Reliability**. Success also necessitates the means to efficiently communicate these attributes to all stakeholders.

To implement these principles in a harmonised manner, the Committee on Earth Observation Satellites (CEOS), the space arm of GEOSS, has through discussion with Cal/Val experts from around the world, established a quality assurance (QA) framework to facilitate interoperability of GEO systems. This Quality Assurance Framework for Earth Observation (QA4EO) is based on the adoption of some guiding principles which are implemented through a set of key operational guidelines derived from "best practices" for implementation by the GEO community. Although these guidelines were originally developed to meet the needs of the space community they have been written with the aid of national metrology institutes and where appropriate are based on best practises of the wider non-EO specific community. They should therefore be readily adoptable by all GEO stakeholder communities, as a top-level framework, which can subsequently be translated and implemented to serve the needs of their individual specialisms.

ANNEX I



QA4EO | A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

A Quality Assurance Framework for Earth Observation: Operational Guidelines

Version 3.0

01 July 2009

CONTENTS

ACRONYMS

ATM	QA4EO nomenclature label for documentation relating to the CEOS WGCV's Atmospheric Composition Subgroup
Cal/Val	Calibration and Validation
CE	QA4EO nomenclature label for documentation relating to Communication and Education
CEOS	Committee on Earth Observation Satellites
CIPM	Comité International des Poids et Mesures
DP	QA4EO nomenclature label for documentation relating to Data Product Policy
DQ	QA4EO nomenclature label for documentation relating to Data Product Quality
EO	Earth Observation
GEN	QA4EO nomenclature label for a generic guideline
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GPS	Global Positioning System
GUM	ISO Guide to the Expression of Uncertainty in Measurement
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organisation for Standardisation
IVO	QA4EO nomenclature label for documentation relating to the CEOS WGCV's Infrared, Visible & Optical Sensors Subgroup
KI	Knowledge Information
LPV	QA4EO nomenclature label for documentation relating to the CEOS WGCV's Land Product Validation Subgroup
MRA	Mutual Recognition Arrangement
MWS	QA4EO nomenclature label for documentation relating to the CEOS WGCV's Microwave Sensors Subgroup
NIST	National Institute for Standards and Technology
NMI	National Metrology Institute
NPL	National Physical Laboratory
QA	Quality Assurance
QA4EO	Quality Assurance Framework for Earth Observation
SBA	GEO's Societal Benefit Area
SAR	QA4EO nomenclature label for documentation relating to the CEOS WGCV's Synthetic Aperture Radar Subgroup
TMS	QA4EO nomenclature label for documentation relating to the CEOS WGCV's Terrain Mapping Subgroup
VIM	Vocabulary of International Metrology
WGCV	CEOS Working Group on Calibration and Validation
WMO	World Meteorological Organisation

1 Executive Summary

The Group on Earth Observations (GEO)'s Global Earth Observation System of Systems (GEOSS) must deliver comprehensive and timely "knowledge / information products" worldwide to meet the needs of its nine "societal benefit areas". This will be achieved through the synergistic use of data derived from a variety of sources (satellite, airborne and *in situ*) and the coordination of resources and efforts of the GEO members.

To accomplish this vision, starting from a system of disparate systems that were built for a multitude of applications, requires the establishment of an internationally coordinated operational framework to facilitate interoperability and harmonisation. The success of this framework, in terms of "data", is dependent upon the successful implementation of two key principles – **Accessibility / Availability** and **Suitability / Reliability**. Success also necessitates the means to efficiently communicate these attributes to all stakeholders.

To implement these principles in a harmonised manner, the Committee on Earth Observation Satellites (CEOS), the space arm of GEOSS, has established a quality assurance (QA) strategy to facilitate interoperability of GEO systems. This strategy is based upon a set of key operational guidelines derived from "best practices" for implementation by the community. Although these guidelines have been developed to meet the needs of the space community, they have been written with the aid of national metrology institutes and experts knowledgeable in all aspects of remote sensing. Where appropriate, they are based on best practices from commercial and academic sectors, not just those of space or Earth Observation (EO) and are intended to be interpreted in a flexible manner that is commensurate with the needs of each application and its associated stakeholders, e.g. information derived from volunteers may be weighted differently than from a commercially contracted supplier as a consequence of less stringent (but QA4EO consistent) QA. They should therefore be readily adoptable by the wider GEO community as a basis for detailed implementation within each specific technical (application / community) domain.

These key guidelines have been structured into an operational framework based on interoperability requirements. As a result of agreement at two workshops held with calibration and validation (Cal/Val) experts from around the world, the guidelines have been collated into three theme areas – **Data Quality**, **Data Policy** and **Communication & Education**.

This Quality Assurance Framework for Earth Observation (QA4EO) has been completed and endorsed by CEOS in a direct response to GEO task DA-06-02 – GEOSS Quality Assurance Strategy [1] (now DA-09-01a [2]) – and is recommended for implementation and use throughout the whole GEO community.

2 Introduction

The Group on Earth Observations (GEO; http://earthobservations.org/) was founded in 2003 following calls for action from the World Summit on Sustainable Development and the G8 of leading industrialised countries. These high-level meetings recognised that international collaboration is essential to exploit the growing potential of Earth Observations to support decision making in an increasingly complex and environmentally stressed world.

GEO is a voluntary partnership of governments and international organisations which provides a framework for the coordination of effort and strategies to address common goals. In 2005 it launched a "ten-year implementation plan" to establish its visionary goal of a Global Earth Observation System of Systems (GEOSS [3]). The key objective of GEOSS is to deliver comprehensive and timely "knowledge information products" worldwide to meet the needs of its nine "societal benefit areas" (SBA). This will be achieved through the synergistic use of data. Data may be derived from a variety of sources (satellite, airborne and *in situ*) at all scales – global, regional and local – through the coordinated resources and efforts of the GEO members. As a voluntary process "adaptor plugs" must be developed to accept **all** (properly documented) data. GEOSS aims to allow the provision of, and the access to, *the Right Information, in the Right Format, at the Right Time, to the Right People, to Make the Right Decisions*.

To accomplish this vision, starting from a system of disparate systems that were built for a multitude of applications, requires 'data and information providers accepting and implementing a set of interoperability arrangements' [3]. Interoperability in terms of "data" is dependent upon the successful implementation of two key principles – **Accessibility / Availability** and **Suitability / Reliability**. Success also necessitates the means to efficiently communicate these attributes to all stakeholders. In particular, users and processors of data and derived products must be able to assess the data's suitability for their particular application and the **"fitness for purpose"** of the data on receipt, without the need for further evaluation. This, of course, places constraints and requirements on all aspects of the data processing chains – acquisition, processing, dissemination and archiving.

To address these issues, GEO identified the need 'to develop a GEO data quality assurance strategy, beginning with space-based observations and evaluating expansion to in situ observation, taking account of existing work in the area' (GEO task DA-06-02 [1], now DA-09-01). Calibration and validation (Cal/Val) is critical to data quality assurance (QA) and therefore data usability. The Committee on Earth Observation Satellites (CEOS)'s Working Group on Calibration and Validation (WGCV), in partnership with the Institute of Electrical and Electronics Engineers (IEEE), were therefore natural leads to carry out this task for space-based observations. By taking a generic approach and building on broad-based, non EO specific QA best practices that utilise, amongst others, the expertise of the national standards laboratories of the UK and USA, these organisations sought to encompass the needs of the wider GEO community in a single QA framework.

Initiated in 1984, CEOS WGCV pursues activities to coordinate, standardise and advance Cal/Val of Earth Observation (EO) missions and their data. In 2006, CEOS became the space arm of GEO and, in that capacity, CEOS is playing an active role in the establishment of GEOSS. CEOS recognised the pivotal importance of GEO task DA-06-02 (now DA-09-01), which is much more cross-cutting than many of the other GEO tasks, and has prioritised it within its implementation plan.

This document presents the conclusion of a community-derived process, led by CEOS WGCV, to establish an international QA framework to facilitate harmonisation and interoperability of EO data, derived products and the various tools and assets required to achieve them. The principles and operational details were debated with representatives of the EO Cal/Val community at the "GEO / CEOS workshop on quality assurance of calibration and validation processes: *Guiding principles*", held in Geneva in October 2007, and its subsequent workshop partner, "*Establishing an operational framework*", held in Gaithersburg in May 2008.

3 Quality Assurance Framework for Earth Observation (QA4EO)

3.1 Overview

The GEO / CEOS workshops on quality assurance of calibration and validation processes held in 2007 and 2008 concluded that, in order to achieve harmonisation and facilitate interoperability between data type and sources, as required by GEOSS, two key elements need to be considered:

- A communication / data policy *and*
- A means to ascribe a Quality Indicator (QI) to a Knowledge Information (KI) product. The QI is based on a quantifiable metrological / statistical based measure).

To address these issues, a set of guiding principles was established, supported by a suite of "key guidelines" based on the adoption / adaptation of existing "best practises". Together, these ten key guidelines define the generic processes and activities needed to establish and underpin an operational Quality Assurance Framework for Earth Observation (QA4EO). This strategy and the key guidelines were endorsed by the 22nd CEOS plenary in 2008 and will be presented to the GEO ministerial in 2009. Implementation by individual agencies / organisations and GEO communities can therefore begin in anticipation of a more formalised structure.

Implementation will lead to a population of QA4EO with more detailed technical procedures and activities at all stakeholder levels i.e. individual data providers, sensor builders and algorithm developers through to community agreed processes recommended for wide adoption to facilitate international harmonisation. The procedures and activities will be established by appropriate technical experts within the research and operational EO community. Many activities or procedures in common use will already be fully consistent with the QA4EO key guidelines, others may need small additions before they can be fully endorsed within the system. It is anticipated that future procedures and activities will be documented and carried out following the guidance contained within the key guidelines.

The key guidelines are intended to facilitate the establishment and presentation of the documentary evidence needed to support a QI in a common and consistent manner. Individual organisations responsible for delivery of data, product or associated process are responsible for using the guidelines to enable them to establish and demonstrate a QI to their customer and/or the user. The user is responsible for assessing, based on the QI and associated evidence, that the delivered "product" is suitable for their application. The user (or its proxy, e.g. centralised governmental funding agencies) are thus responsible for the detailed "day to day" governance. This includes specifying the requirement to be compliant with both generic key guidelines of QA4EO and also any community or specific organisational detailed procedures that they consider necessary.

Some of the activities and processes may themselves be submitted, considered and endorsed by broader EO representative communities as current "best practice" but would always be seen as living documents or processes that could, with time, be improved upon. These are likely to be related to relatively generic activities that span a wide range of organisations, especially where there is a need to establish international harmonisation and interoperability. They are, in general, intended to be suggested (not required) practices that provide baseline reference material and good guidance to newcomers and to established institutions and professionals alike. It is hoped that the endorsement and encouragement of use of such "practices" will lead to improved coordination between agencies and a common set of well-established procedures. These procedures could ultimately result in a reduction of overall costs and bring the prospect of a fully integrated, interoperable GEOSS closer to a reality.

An operational QA4EO will include coordinated comparisons and the establishment of "common community reference standards" to facilitate "bias evaluation". This, together with the encouragement of openness and access to results of Cal/Val and performance evaluation, will provide the necessary evidence to support assigned QIs. A QA4EO secretariat and management board, composed of representatives from appropriate international bodies representing key GEO technical communities, will provide the technical administration and governance under the overall direction of GEO and the GEO membership. Implementation will be through the EO community, individual organisations and agencies, and their representative bodies (e.g. CEOS in the case of space, the World Meteorological Organisation (WMO) for meteorology, etc.) upon which it will also depend for detailed practical support, particularly in terms of infrastructure.

3.2 Architecture

For convenience, the key guidelines of QA4EO have been collated into three themes corresponding to broadly similar activities and concepts that benefit from harmonisation. These "interoperability themes" are:

- **Data Quality (DQ),**
- **Data Policy (DP)**, *and*
- **Communication and Education (CE).**

Each theme has a guiding principle, which must be met to achieve interoperability, and a set of key (generic) guidelines to support this operationally. The key guidelines detailed within each theme are labelled according to that theme (DQ, DP or CE) and their generic nature (GEN; see QA4EO-QAEO-GEN-CEK-001). There are seven key guidelines that sit under the Data Quality theme (QA4EO-QAEO-GEN-DQK-001 to -007), two under the Data Policy theme (QA4EO-QAEO-GEN-DPK-001 and -002) and one under the

Education and Communication theme (QA4EO-QAEO-GEN-CEK-001). All ten key guidelines are written as self-contained documents and only a summary abstract is presented here. Although each is self-contained most rely on the content of others to provide specific detailed guidance on particular aspects and so all ten guidelines should be viewed as a linked set. For example, in the Data Quality Theme, guideline QA4EO-QAEO-GEN-DQK-002 provides the core template that details the content and evidence needed to demonstrate compliance. However, it relies on guidelines QA4EO-QAEO-GEN-DQK-003 to -007 to provide the detailed guidance needed for many of its specific inputs.

Subsequent operational guidelines, procedures and activities written by the community following the guidance contained within the key guidelines will be organised and categorised according to their principal technical domain of interest. For example, those defined by the CEOS WGCV subgroup structure for space sensors will be categorised as,

- Atmospheric Composition (ATM),
- Infrared Visible and Optical Sensors (IVO),
- Land Product Validation (LPV),
- Terrain Mapping (TMS),
- Microwave Sensors (MWS), *and*
- Synthetic Aperture Radar (SAR).

This organisational structure is, of course, shown as an example and each GEO community will make use of its own structures to establish and approve technical and detailed procedures following the generic guidance of the key guidelines. The QA4EO management board, established by GEO to oversee the process, will be responsible for coordination between GEO communities and for ensuring that the key guidelines evolve to take account of all stakeholder needs.,

QA4EO and its "raison d'être" can be summarised in conceptual form through figure 1. Figure 1 starts with the GEOSS requirement and illustrates the key activities, in terms of data quality, that need to be carried out to deliver the strategy, i.e., documented procedures and evidence of traceability and performance. This can be achieved through comparison exercises, facilitated by internationally agreed reference standards, which, in this example, may take the form of internationally designated "test sites". They may equally be "test data sets", a manmade artefact, a standard reference chemical sample etc. They may also be a standardised documentary procedure containing specific test or sampling criteria. This latter type of approach will be particularly common where teams of volunteers may be utilised for bio-diversity type applications where there is little opportunity for significant rigour other than "random sampling" or "sanity checks".

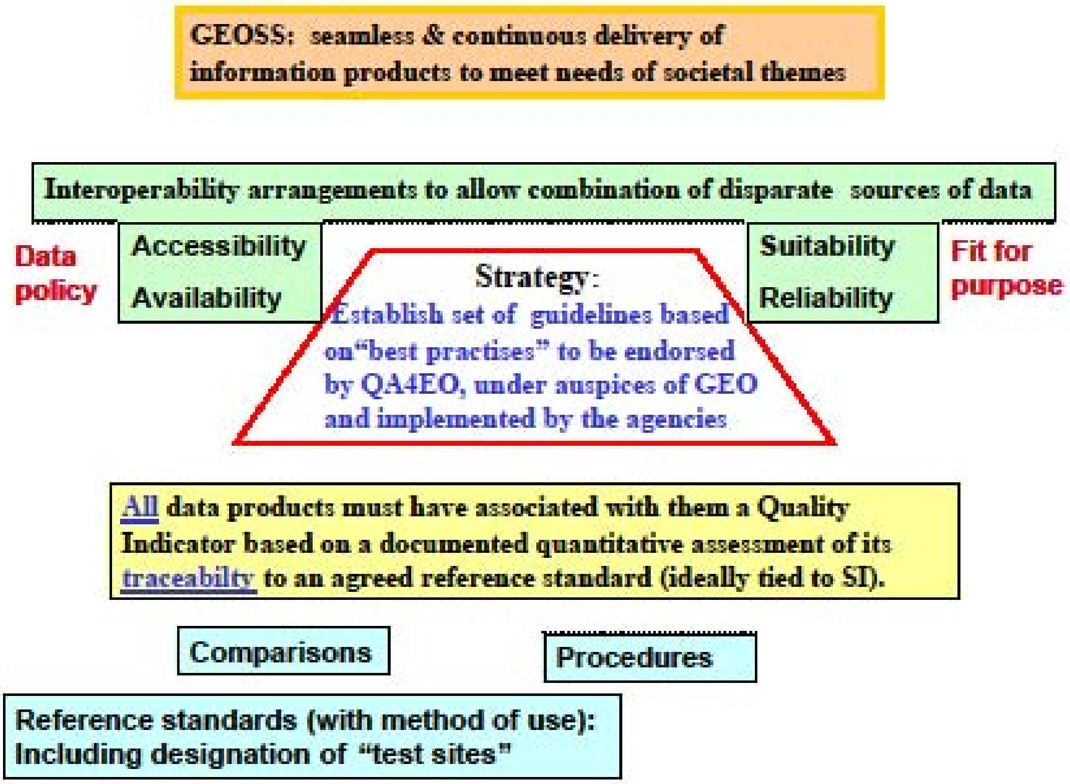


Figure 1: Structure of QA4EO and key guiding principle in conceptual form

3.2.1 Data Quality

Data quality can be considered the key to interoperability. Without at least a means to assess data quality, it would be impossible to combine or use data from different sources in any meaningful way.

The guiding principle for this theme is that:

> *All data and derived products must have associated with them a Quality Indicator (QI) based on documented quantitative assessment of its traceability to community agreed reference standards.*

All steps in the data product delivery chain (collection, processing and dissemination) must be documented with evidence of their traceability and the resulting quality information propagated through from end to end. This can be achieved by following the guidance document QA4EO-QAEO-GEN-DQK-002.

To achieve the "guiding principle" above requires a range of generic (non-sensor specific) processes or activities. Key guidelines have been written to support their implementation:

- Establish a QI for a sensor delivered data product (QA4EO-QAEO-GEN-DQK-001),
- Content of a documentary procedure to meet the QA requirements of QA4EO (QA4EO-QAEO-GEN-DQK-002),
- Establishing reference standards (QA4EO-QAEO-GEN-DQK-003),
- Organisation and analysis of "comparison of measurements" (QA4EO-QAEO-GEN-DQK-004),
- Writing and validating models, algorithms & software (QA4EO-QAEO-GEN-DQK-005),
- Evaluating uncertainty of measurement (QA4EO-QAEO-GEN-DQK-006), *and*
- Establishing and assessing "quantitative evidence of traceability" (QA4EO-QAEO-GEN-DQK-007).

Figure 2, illustrates how the guidelines interact together.

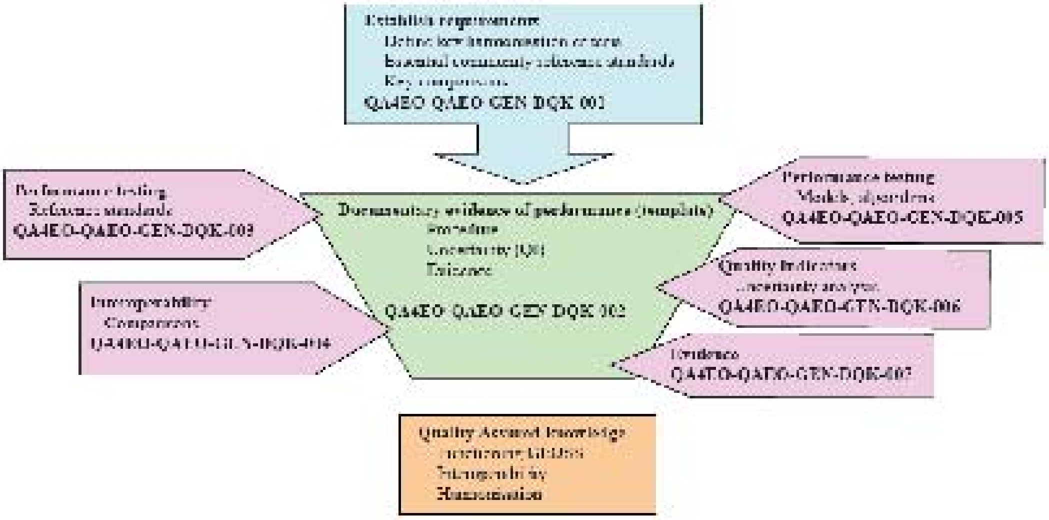


Figure 2: Schematic of the Data Quality Aspects of the QA4EO Process

The key guideline QA4EO-QAEO-GEN-DQK-001 can be considered as the "process driver" that translates the guiding principle into its top-level requirements. The guideline has been specifically written using satellite sensors as an example to aid those translating the guiding principle into other EO specific domains. This key guideline (example) is illustrated in figure 3. This figure also provides further examples of how this top-level set of requirements can subsequently be translated into more detailed sensor-specific requirements, which themselves would be the subject of specific guidelines, procedures and reference standards. The example chosen is for post-launch Cal/Val of radiometric gain to meet the needs of the CEOS Land Surface Imaging satellite virtual constellation. In this example, a number of methods are available to evaluate radiometric gain at the individual sensor level and each either has, or will require, a specific procedure.

Similarly, there are a number of methods for bias evaluation and stability monitoring. In all these cases, the procedure to carry out the task and the choice of reference standard can and should be harmonised.

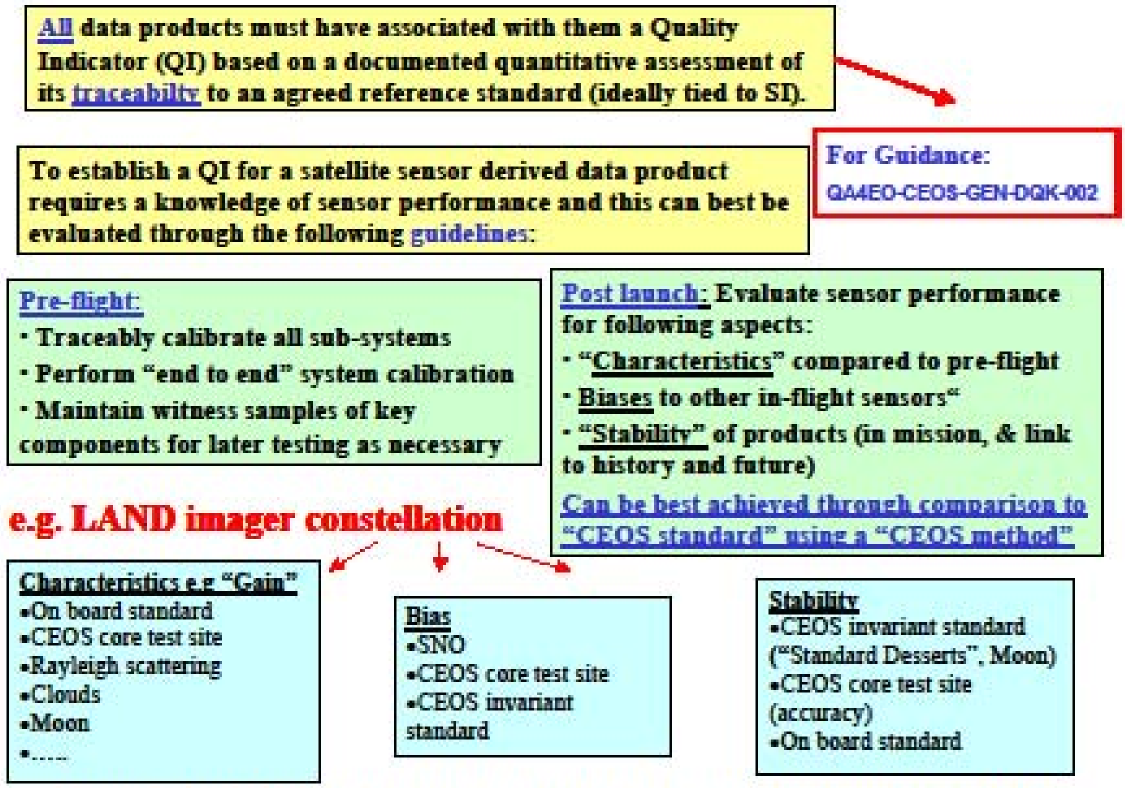


Figure 3: Translation of guiding principle on data quality into key guideline QA4EO-QAEO-GEN-DQK-001 and an example of its subsequent detailed interpretation at CEOS WGCV subgroup level for the CEOS Land Surface Imaging constellation

A similar set of procedures and associated reference standards can be identified for other sensor characteristics and other sensor types and products. For example, a characterised vegetated site can be used for land products, or a Global Positioning System (GPS) for mapping a commercial building complex for geometry and image quality. For other GEO disciplines a similar set of requirements, procedures and standards can be defined by the relevant community's representative bodies.

QA4EO-QAEO-GEN-DQK-002 provides guidance on how to document an activity, providing through its template a "checklist". This key guideline can be considered the translation of a "requirement", such as those highlighted in QA4EO-QAEO-GEN-DQK-001 and subsequent detailed specifications, into a task or set of tasks and how to describe them. QA4EO-QAEO-GEN-DQK-003 to -007 are the tools to aid the completion of the documents, resulting from implementation of QA4EO-QAEO-GEN-DQK-002, and consequently to meet the requirements identified in QA4EO-QAEO-GEN-DQK-001.

3.2.1.1 QA4EO-QAEO-GEN-DQK-001

A guide to establishing a Quality Indicator on a satellite sensor derived data product

Although this guideline is specifically written to address the needs of satellite-based sensors, it provides an example, at high level, of the application of the underpinning principles of the GEO QA4EO to a full product lifecycle, which can be translated to other disciplines within the GEO community. This guideline provides a generic "top level" set of activities or requirements that should be performed with all satellite-based EO sensors to enable a reliable QI to be established and maintained for its delivered data products. These data products are the principle starting point for many EO knowledge information products. Their reliability is thus a key issue, not only within the confines of a specific mission's goals but also as a component of an international partnership as envisaged by GEOSS. To ensure maximum benefit from the relatively high cost of developing and operating space assets such as these, it is essential that all reasonable steps are taken to reduce the risk of instrument / mission failure. However, as part of this process, it is crucial that we also establish an appropriate coordinated programme of calibration and validation throughout all stages of the mission from sensor build to end-of-life. Where possible, this should anticipate sensor degradation and the likelihood of unforeseen issues and/or modifications as a result of new knowledge at some future point during or after the mission's life.

3.2.1.2 QA4EO-QAEO-GEN-DQK-002

A guide to content of a documentary procedure to meet the Quality Assurance requirements of GEO

This document provides guidance on the recommended content, together with an example structure, for a written "procedure", which will facilitate the demonstration of compliance with the data quality aspects of GEO's QA4EO. The requirement driving QA4EO is the need to assign to all data / information products a QI, which will allow all stakeholders to unequivocally evaluate the products' suitability for a particular application. This requires that the basis for such a QI must be transparent, internationally consistent and independent of sensor or application domain. The QI and evidence to support its "value" must also be fully traceable back through the processing chain to the original source data / measurement. This processing chain can be considered as a set of linked activities or processes (e.g. data collection, correction / conversion algorithm, dissemination, etc.), some operating in a direct linear path, others providing ancillary information to aid the next processing step. The purpose of this "key guideline" is to provide an example template (referencing other appropriate key guidelines) to aid its user in establishing and documenting the evidence needed to assign a QI to each step of the processing chain. This covers both the written procedure to develop and carry out any particular activity or process and the written evidence and its derivation to support the value of any assigned

QI. This guideline can be considered the core of QA4EO and the user / reader can have confidence in any output resulting from processes carried out that are fully compliant with its content. This key guideline is written and structured in the style of the document it is providing guidance on, so in places it may appear repetitive.

3.2.1.3 QA4EO-QAEO-GEN-DQK-003
A guide to "reference standards" in support of Quality Assurance requirements of QA4EO

This key guideline summarises the processes that should be followed to identify, establish and use a "reference standard" as a means of evaluating performance or compliance for a particular activity as part of an internationally harmonised QA procedure. Such "reference standards" can take many forms including natural or manmade artefacts or targets and datasets, as dictated by the application.

The guideline provides advice to those seeking to find a "reference standard" for a particular application as well as the establishment of new ones. It also provides a template to aid those documenting the characteristics of a "reference standard" and serves as a checklist for those seeking to find one.

The guideline also sets out the steps needed to register and/or obtain formal endorsement of a "reference standard" where this may be appropriate to educate others and facilitate international harmonisation in support of GEOSS.

3.2.1.4 QA4EO-QAEO-GEN-DQK-004
A guide to comparisons – organisation, operation and analysis to establish measurement equivalence to underpin the Quality Assurance requirements of QA4EO

This document provides guidance on how best to organise, operate and analyse the results of a comparison to evaluate the equivalence of different techniques, instruments and/or teams when used to measure or nominally process the same information. Comparisons are an essential tool within any QA strategy as they provide a source of unequivocal information on differences and biases associated with similar activities. In general, comparisons are not a test of "right or wrong" but a means to identify and sometimes understand differences.

The guide is written based on best practise guidance established by the Comité International des Poids et Mesures (CIPM), and its associated technical committees, for performing comparisons of key quantities between National Metrology Institutes (NMI) to underpin the Mutual Recognition Arrangement (MRA of the metre convention; http://www.BIPM.org/). Comparisons need to be fair and unbiased but should also provide unequivocal evidence of performance to underpin QA statements. It is therefore essential that they are organised, and all results analysed, in a transparent and consistent manner.

3.2.1.5 QA4EO-QAEO-GEN-DQK-005
A guide to establishing validated software, algorithms and models to underpin the Quality Assurance requirements of QA4EO

This document provides the link to existing generic "best practice" guidelines for testing and validating models or algorithms and derived software used for measurement systems. These guidelines are recommended for use within the processing chain of Earth Observation data products. Many guidance documents exist to aid in the writing and development of software, some have the status of international standards and others are in-house procedures, but all in concept are broadly similar to each other. However, few of these provide detailed guidance on appropriate techniques for validation and assessment of its "fitness for purpose" and the means to assign a "quality indicator". The guidelines linked from this document provide this guidance for both the developed software and the models or algorithms upon which it is based.

3.2.1.6 QA4EO-QAEO-GEN-DQK-006
A guide to expression of uncertainty of measurements

This key guideline provides an introduction to the ISO *Guide to the Expression of Uncertainty in Measurement* (GUM). Confidence in a measured value requires a quantitative statement of its quality, which in turn necessitates the evaluation of the uncertainty associated with the value. The basis for the value and the associated uncertainty is "traceability" involving the relationship of relevant quantities to national or international (community agreed) standards through an unbroken chain of comparisons. Each comparison involves calibration of a standard at one level in the chain using a standard at a higher level. The concept must involve all relevant processes and be fully transparent. This principle is common to all scientific activities and EO is no exception. QA4EO is built on this principle with uncertainty at its core. The evaluation of uncertainty of measurement is founded on the use of models of measurement for each stage of the chain, which are detailed in the GUM. This document provides a brief introduction to the GUM and is itself based on other more generic published texts.

3.2.1.7 QA4EO-QAEO-GEN-DQK-007

A guide to establishing quantitative evidence of traceability to underpin the Quality Assurance requirements of QA4EO

The key guidelines within the data quality theme of GEO's QA4EO provide guidance on the generic requirements and the means to achieve and document the information necessary to establish a QI for Earth observation data products in a harmonised way. In principle, if followed, these guidelines provide the evidence needed to support any derived QI. This key guideline summarises the type of evidence needed, the means to achieve it and guidance to any "approving authority" on how to assess its adequacy.

3.2.2 Data Policy

The guiding principle for this theme is that:

> ***The data product must be freely and readily available / accessible / useable in an unencumbered manner for the good of the GEOSS community, for both current and future users. This necessitates that all Cal/Val data and associated support information (metadata, processing methodologies, QA, etc.) is associated with the means to effectively implement a quality indicator. In return, the provider must be consistently acknowledged.***

To facilitate the above, two guidelines on Data Policy are required to address the following issues:

- Code of use / practise / access (QA4EO-QAEO-GEN-DPK-001), *and*
- Common formats (QA4EO-QAEO-GEN-DPK-002).

3.2.2.1 QA4EO-QAEO-GEN-DPK-001

A guide to calibration / validation data sharing principles and data exchange

The purpose of this key guideline is to establish policy and protocol for data sharing and data exchange. To promote a "system of systems" concept where data is used interoperably to address integrated science needs, the data must be well understood, calibrated, validated, available and easily assessable. To achieve this goal, the calibration / validation (Cal/Val) data must be freely and readily available, accessible and useable in an unencumbered manner for the good of the GEOSS community, including current and future users. This necessitates that all data and associated support information have the means to effectively implement a quality indicator. To promote data that is well understood for use by the community, data sharing and data exchange principles and processes must be defined and promoted to the community. This guide provides recommended policy, processes and procedures for data sharing and data exchange.

3.2.2.2 QA4EO-QAEO-GEN-DPK-002

A guide to the provision of calibration and validation data: content and metadata

The means for providing Cal/Val data that are useable by the Cal/Val community depends on whether the data can be understood and characterised for valid scientific use. The data must be documented so that the validity of the data can be assessed. Depending on the use of the data, various levels of content may be appropriate and "fit for purpose". Therefore, all data must be reviewed and documented within this context.

The data must be easily usable from a processing perspective so that the user can read and understand the data either by manual or automated electronic processes. In addition to understanding the data content, the metadata associated with the data content must be complete. Therefore, data format standards that allow understandable and useable data content and metadata are critical to ensuring that the Cal/Val user community can use the data. Policies and procedures are needed to control and manage data format, content, and associated metadata.

3.2.3 Communication and Education

The guiding principle for this theme is that

> ***Sound and effective communication and education activities are needed to facilitate and enhance interoperability and achieve the objectives of harmonisation and traceability of quality information. All stakeholders must have a clear understanding of the adequacy of the information that they are accessing and using for their specific application. The evidence for this clarity should be accessible through a single portal and should be fully traceable to its origins. The traceability and interoperability process must be understandable by any appropriately trained individual within GEOSS and efforts must be made to encourage the wider usage of information and facilitate the training of GEOSS users.***

To facilitate this requires:

- The use of common terminology,
- A single access portal as a gateway to relevant data quality information (addressed within QA4EO-QAEO-GEN-DPK-001),
- A document management system (QA4EO-QAEO-GEN-CEK-001), *and*

- The support and facilitation of education and capacity building activities to promote the QA4EO and encourage its adoption.

The development, use and encouragement of the use of internationally agreed terminology for all EO-related fields of expertise is recommended. This activity should avoid duplication of documents by harmonising and adopting already existing internationally agreed or endorsed dictionaries. New documents should be developed to cover all EO aspects, providing a clear and unambiguous definition for all relevant terms and parameters. The various dictionaries can independently be stored in different locations but must all be linked to, and accessible from, a common portal. Some examples of existing dictionaries are:

- NIST dictionary, ISO guide 99:2007 to Vocabulary of International Metrology (VIM; http://www.iso.org/iso/catalogue_detail?csnumber=45324)
- GEO/CEOS Cal /Val portal Terms and Definitions (http://calvalportal.ceos.org/CalValPortal/docs/information/TermsAndDefinitions.pdf)

A centralised web portal can act as a gateway to all relevant data and information. This portal should link to other websites that store additional quality information. The QA4EO website (http://QA4EO.org/) will serve to provide a link to community specific portals. For example, the GEO / CEOS Cal/Val portal is currently the space community's portal for all Cal/Val data (http://calvalportal.ceos.org/). The means to access and populate the portal in a manner that is unambiguous, unencumbered but also robust is addressed further in QA4EO-QAEO-GEN-DPK-001.

For QA4EO to become a globally effective framework for the Quality Assurance of Earth Observation data, it will be important to seek to encourage the uptake of its "best practice" methods. It will also be important to facilitate rapid entry and contribution of new groups to support global Cal/Val needs when developing or carrying out Cal/Val related activities.

3.2.3.1 QA4EO-QAEO-GEN-CEK-001 A guide to facilitate Review and Management of Documents

The peer review and effective management of documents within QA4EO are critical tasks to ensure that appropriate and correct information is identifiable and retrievable when needed. Therefore, guidelines are needed to identify, control and manage document preparation, review, approval, authorisation, issue and change.

4 Summary

This document provides an introduction to a framework for establishing and demonstrating Quality Assurance for Earth Observation data and derived products. This QA4EO is based on the need to coordinate and harmonise processes and activities to enable interoperability. It is structured around a set of internationally agreed "guiding principles" that can be achieved through following the guidance contained within a suite of ten key generic guidelines.

QA4EO under the auspices of GEO, will be responsible for the operation and strategic development of the process, but it will be implemented and operated at a detailed level by individual organisations and communities. It is anticipated that there will be some coordination and sharing of resource, infrastructure and knowledge between members of "communities" to ensure that implementation can progress rapidly and in a relatively uniform manner across the globe.

As the system develops and matures, the coordination and cooperation between individual organisations and GEO communities is likely to become more structured and formalised to ensure the continued maintenance and evolution of QA4EO.

5 References

[1] GEO, 2008, v6, GEO 2007-2009 Work Plan: Toward Convergence

[2] GEO, November 2008, 2009-2011 Work Plan, Document 12

[3] GEO, adopted 16 February 2005, The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan