Coordinating and monitoring quality information within the GMES Space Component Data Access System

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ABSTRACT

One of the key elements of GMES is its Space Component (GSC). Beyond the development of the Sentinel missions, the GSC also entails the coordination of assets made available by the data providers GCMs (i.e. GMES Contributing Missions) to realise a synergistic and complete operational system-of-systems in Europe for the provision of Earth Observation (EO) data. In the framework of GMES, ESA is therefore in charge of developing an efficient and harmonised system to facilitate access to relevant EO data and services by the GMES Service Projects (GSPs). This is achieved through the implementation of the GMES Space Component Data Access (GSCDA).

The Coordinated Quality Control (CQC) is the GSCDA component in charge of monitoring the quality of the EO DataSets and of coordinating the provision of data quality information to the users. Quality information is based upon GCM input specifications and quality parameters, that are made available to the users in a harmonized way. The CQC thus monitors that the data providers maintain the specified quality level and also monitors the related user satisfaction. More in details, the CQC gathers reference data specifications for each type of product or instrument, perform regular data quality checks to ensure that the delivered products are conform to the specifications, initiates and discusses harmonisation and standardization possibilities across data providers and provides helpdesk support to process data quality related issues.

The paper introduces the dynamics of the GSCDA and explains the role of the CQC with respect to data providers and data users. It then presents the activities that are performed by the CQC to achieve this objective within this system-of-systems. The concept of Quality Information Item is presented and detailed. Finally the future perspectives and guidelines concerning the benefits from the work of the CQC are presented.

Global Earth Observation System of Systems (GEOSS); Global Monitoring for Environment and Security (GMES); Quality For Earth Observation (Q4EO), Data Quality Control, Validation, Calibration

INTRODUCTION

The GMES Space Component Data Access (GSDA) infrastructure relies on the ground segment of various GMES Contributing Missions (GCMs) plus a set of coordinating functions in charge of ensuring internal coordination and control guaranteeing the GMES Service Projects (GSPs) with a harmonized access to GMES Space Components data. The two main elements of the GSDA are the Data Access Portfolio Management function (DAM) and the Coordinated Data Access System (CDS). The DAM ensures a management layer; by collecting GSP requirements, negotiating with GCMs and defining the operational baseline while the CDS is an operational entity in charge of coordinating data flow between the GSPs and the GCMs. A complex trade off which involves the GSP requirements, the mission capabilities, the GCM and the funding leads to the release of the Data Access Portfolio document (DAP). In brief, the DAP defined the Datasets, the related GMES Data requirements from GSP, and the quota per contributing mission for a qualified period. It is a key document in the GMES world and in particular for operational system such the CDS.

As shown in figure 1, the CDS itself is decomposed in various subsystems, the most relevant ones being responsible of the management of the infrastructure, the service coordination, the post processing, the analysis and reporting and the quality. The Coordinated Quality Control (CQC) is a relatively small sub-system compared to the totality. It has been plugged independently and is designed to ensure the quality monitoring of GMES Dataset and the provision of quality information.

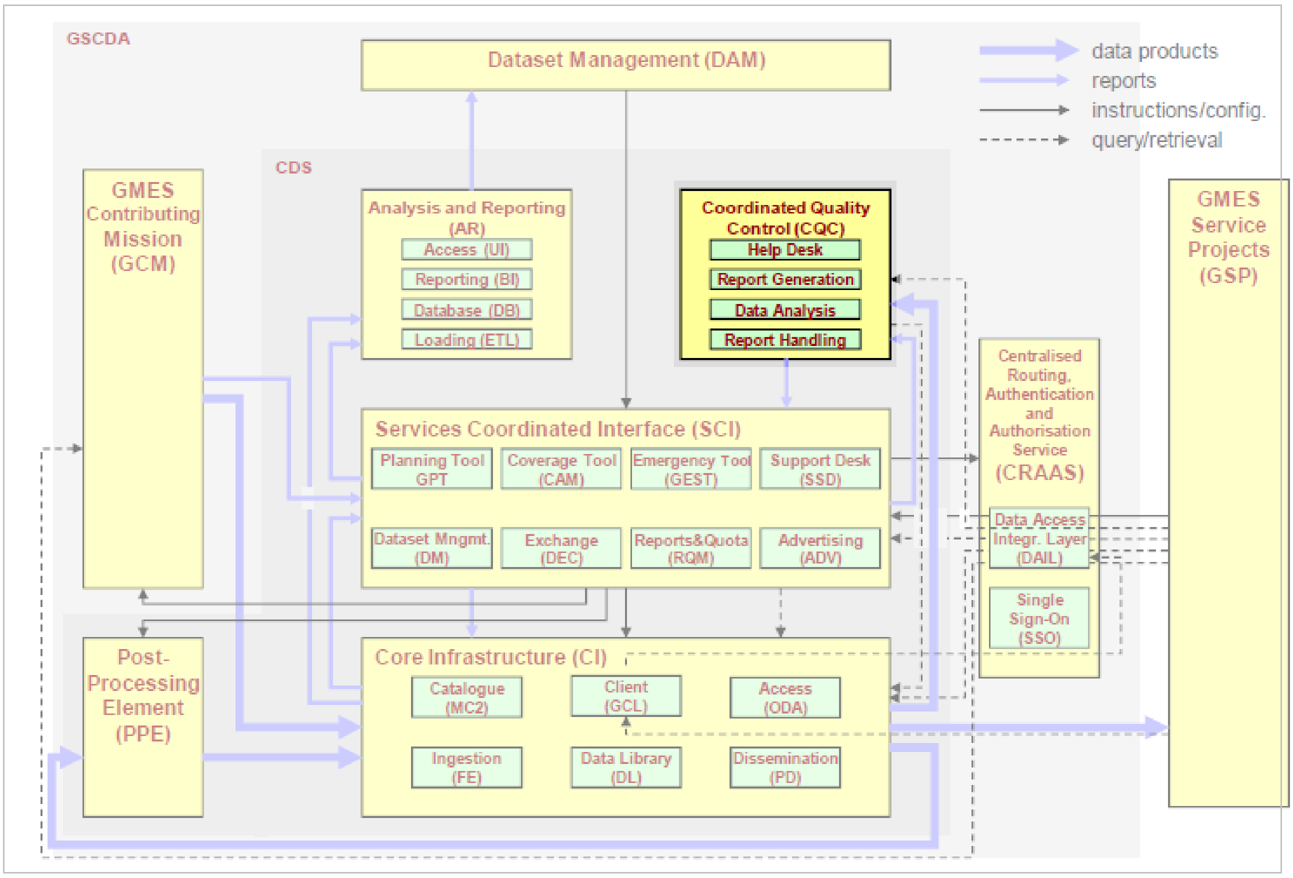


Figure 1: CQC in the context of GSDA subsystems.

A relevant data flow between the provider (GCM) and the user (GSP) is not broadcast without associating quality information.

The CQC service has been build up and is operated with the aim to implement a data quality assurance policy in following Quality Assurance for Earth Observation (Q4EO) principles [1]. Thereby the CQC role is fundamental to apply these principles from the GCM to the GSP, in controlling all the data flow. As shown in the figure 2, the CQC concentrate, maintain the quality information items coming from the GCMs and remains in communication with the GSPs.

The GCM generates the quality information, summarizing the mission and sensor performance, and data quality aspects. The CQC ensures full traceability of the quality information issued by the GCM. And the GCPs utilize the quality information for correct data exploitation concerns.

Therefore, the functions of the CQC span from quality information management to EO data analysis. One may understand that the system is complex; a large panel of software developer, architect, EO experts has been team up together to develop the associated software components and procedures for the service support. The GMES dataset analysis is an important part of the work. Keeping in mind that data products are originated from a broad category of missions embedding optical, SAR, Radar Altimeter, Atmospheric sensors. The service has also the duty to organize and manage a pool of experts for handling request requiring deeper knowledge.

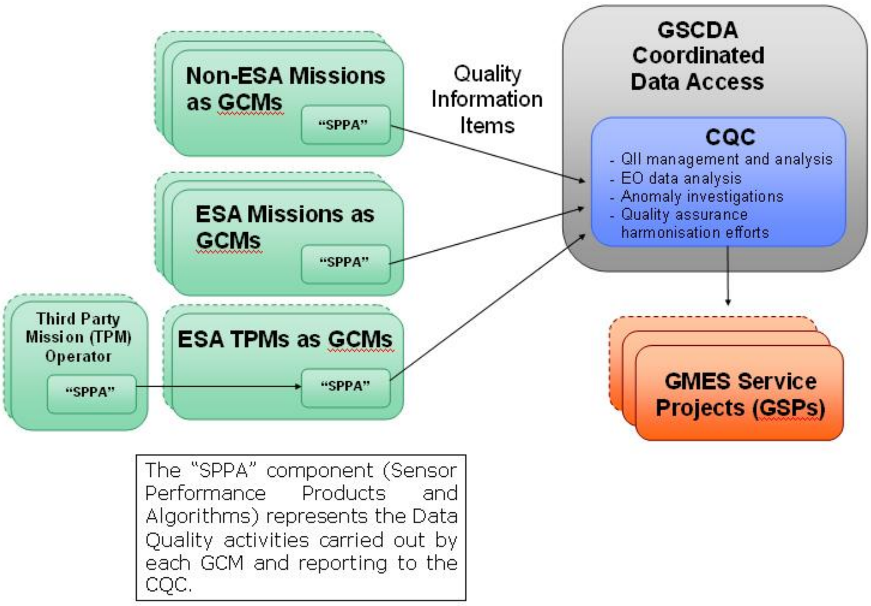


Figure 2: CQC System between GCM and GSP.

The CQC service is now in operation with its full support for the traceability of the quality information. The concept of quality information has been translated in term of Quality Information Item (QII). A QII is any of the following:

- Instrument Product Specification (IPS): this document defines the reference characteristics against which the quality of data delivered during operations will be assessed. It contains information on mission, geometric, radiometric, spectral, orbit, coverage and temporal characteristics.
- Background Documentation (BGD): in support of the IPS and other QIIs, these include documents such as the commissioning phase report, cal/val reports, details of the data processing algorithms and scientific papers supporting data quality along with any relevant documentation that describes the data content of the products.
- Mission Performance Report (MPR): these are delivered regularly (e.g. by cycle or month) and summarize any variation (or confirm the absence of such) in the mission and sensor performance. It may include information such as changes in processing algorithms, degradation of instrument performance, etc.
- Product Quality Report (PQR): these are provided for each delivered product or unit of delivery, providing information on the product quality. This covers, for example, direct product QC information, spacecraft activities, anomalies, sensor performance etc.
- A-posteriori Report (APR): these report on specific data quality issues, e.g. in response to a user query or a data anomaly.

- Synthesis Report (SYR), these report on the product quality monitoring and the overall GMES dataset quality.

For full traceability purposes, the QIIs are received, catalogued, managed, searched, distributed and preserved by the CQC. The CQC is responsible for the production of the SYR and the APR while the other ones are provided by the GCMs. Before transferring QIIs several actions shall be carried out; QII preparation, generation of a metadata description.

CQC FUNCTIONS

Overview

The CQC identifies six responsibilities or service:

- To ensure full traceability of the quality information for all delivered data products. GMES Service Project that can access the quality information related to their received Earth Observation (EO) products.
- To monitor the overall Dataset quality.
- To coordinate investigations of anomalies related to delivered products, providing feedback to various components of the CDS on the GCM data quality and service performance.
- To provide support to GCM integration: the content and structure of predefined documentation shall be verified by the CQC
- To report on the global quality of dataset through the generation of synthesis report
- To animate and launch harmonization activities within the GCM community.

The QII traceability function is fundamental, its interest is threefold. First of all, the GSP interest in accessing quality information (i.e relevant QIIs) related to their received Earth Observation products and quality information related to the processing chain through which products have been generated. Then the GCM interest, the CQC provides quality to demonstrate that the GCMs fulfill the agreed requirements (as specified in the DAP document). And finally, the GSDA, the CQC ensures completeness, traceability and availability of QIIs against catalogued data.
Over these six responsibilities, functional requirements have been derived in order to design the system. The functions of the CQC system are fulfilled through a number of automatic process and manual process undertaken on the flow by the CQC operator.

The overall system is complex for at least one reason; the design complies with a strong security policy. The architecture accounts for security issue and
Herein is detailed how the system fulfill the needs in term of QIIs management/monitoring and QIIs analysis and more particularly Dataset analysis.

QIIs management and monitoring

The CQC components have been implemented to ensure the full traceability of the QIIs. The CQC operator interacts with an interface for QIIs management and monitoring support with lot of automatic process aiming to control the data flow. These interactions are well defined through so called operational scenarios.

The data flow is controlled at the GCM level to the unitary product/instrument specification level. For instance, the CQC system gets its own catalog that is a sub view of the ESA master catalog. The catalog is routinely updated, if some product/dataset is unknown in the CQC database, the process tries to retrieve them on the fly from the master catalogue. Thereby, depending on the agreement between the GCM and ESA, automatic process are responsible to check that for any products proposed to the user a product quality report is associated.

The situation can be more complicated. Indeed, for some QII types only one version of QII is expected (PQR) while for other QII types there are various versions (IPS).

Aside the completeness and correctness of each QII, the QIIs set should be consistent all together; quality information of the PQR does agree with the quality information provided with the IPS or the quality of the dataset itself.

Therefore it is important to monitor selected QIIs and related products against the DAP requirement and against IPS/BGD documents. This is guarantee through a discipline approach for QII analysis purposes and it is supported by the CQC components.

QIIs analysis

The CQC service performs assessment and monitoring of QIIs at various GSCDA operational phases in order to verify that the EO products delivered by the GCMs in the context of the GSCDA fit to the GSP requirements.

The QIIs are assessed at the kick-off of GCMs (integration into the GSCDA), and also during nominal operation of GSCDA. The CQC team checks and validates the content of the delivery IPS, BGD and Sample Datasets. Some comments are prepared and actions proposed. The message is relayed to the correct interface for discussion / negotiations purposes with the GCM. Feedbacks, improvements can be undertaken. Thereby, a loop is implemented to improve the overall quality of the information in following standardization philosophy.

The Sample Datasets are also considered as QII. These are sample products over specified test sites (defined in the DAP-R), for intercomparison with other sensors, use in setup and testing of GCM integration and can be used to establish independent checks on data quality from the GCMs.

The data quality analysis is also played while a GMES Dataset is considered as close. The full dataset is investigated as a fit for purposes check and a synthesis report is issued. This activity is undertaken in using an Automatic Analysis Infrastructure (AAI). The AAI includes several workflows build up based on external tools, if possible freely available, such ESA and CNES Tools ([2], [3], [4], [5]) or belonging to Magellium (GEOLOC INGRID) with the objective to capitalize the knowledge and share process for cross comparison purposes.

The term infrastructure refers to the availability of methodologies, tool / process and reference data in order to perform the quality evaluation of the dataset.

Any missions / instruments of GMES are supported by the AAI. The processing chains have been set up in following standardized approach for data quality validation. Thereby, our approach implements the recommendations of the subgroup on Calibration and Validation of the Committee on Earth Observing System (CEOS), [6], and the AAI has integrated method and data promoted by the CEOS cal/val Portal [7].

As shown in Figure 3, the optical data workflow includes three subsequent stages; the visual inspection, the check of the format, the radiometric and the geometric evaluations. A part of these evaluation leads to performance indicators that are compared against the IPS quality information.

At higher level, a strategy has been set up to analyze all the GMES dataset to provide statistics and undertake comparison against the DAP specifications. The data volume is huge, however some specification such temporal granularity / spatial coverage and cloud content, are checked. In this case, the Google Earth is a convenient tool, as shown in Figure 4.

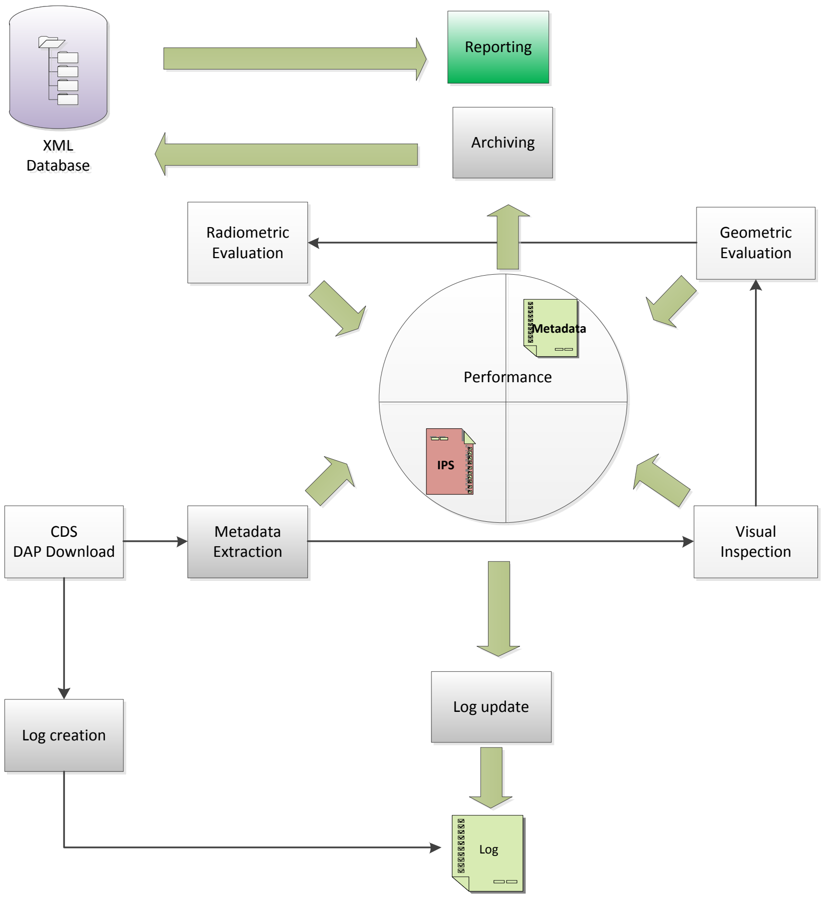


Figure 3: Diagram flow of the AAI for optical data processing.

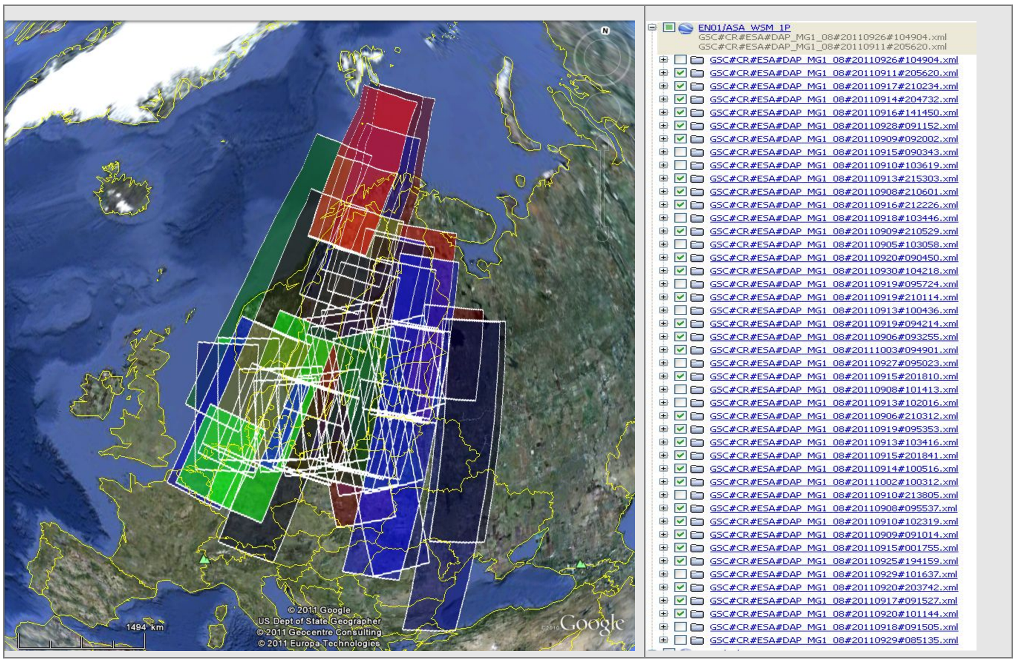


Figure 4: The left panel is all the product footprints of the DAP MG1_08 (SAR) and on the right panel the meta information used to compute statisitics are listed.

RESULTS

The standard approach for GMES Dataset analysis addresses a large panel of quality performance indicators. Herein, some results have been selected, these are focused on:

- Cloud coverage assessment,
- Multi temportal registration,
- Radiometric stability.

Cloud coverage assessment

The Figure 5 shows an image mosaic over a DAP MG 10 area of interest (AOI), Bamako. Data observed more than ten AOIs like this one is proposed within this dataset. The boundaries of each scene overlaid the related mosaic. The mosaic is built at the full spatial resolution; it is a convenient way to undertake visual inspection activities and check the cloud coverage content against information written into the metadata. For specific cases, it is observed that the cloud coverage quality parameter is not accurate. Sometimes high while there is no cloud and conversely extremely low while cloud contaminated the data.

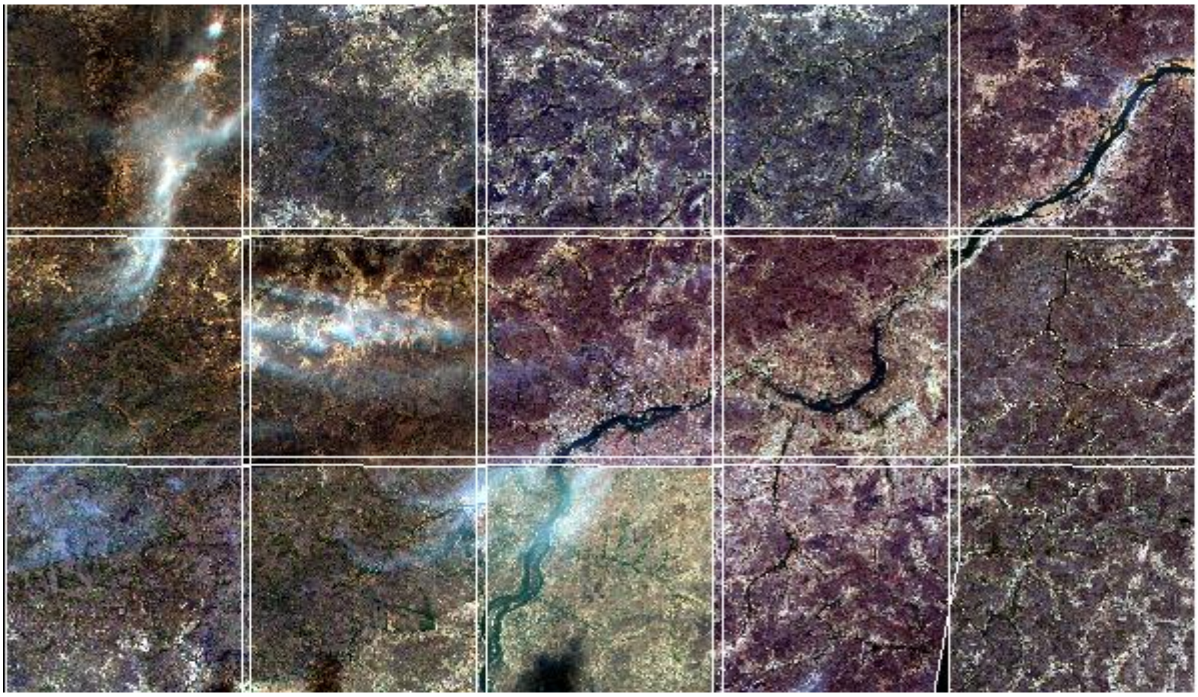


Figure 5 - Bamako image mosaic, DAP MG2 10.

For this dataset, it has been concluded that the cloud coverage was in conformance with the DAP specification. However, regarding products for which anomaly were observed, some exchange with the GCM has been undertaken in order to clarify and if necessary remove the contaminated products from the DAP.

MultiTemporal registration

For certain thematic, an accurate multitemporal registration should be achieved. For instance, some GEOLAND-2 service projects analyses the burn scared areas. In this case, the spatial extent of a fire signature can be within one pixel. Any geo location shift may cause significant errors in the final results. Therefore, the relative location of any products (from one Dataset) is assessed. If an absolute geometric reference is available, the planimetric accuracy of the terrain corrected products is checked, as well.

The figure 6 shows disparity analysis results where the correlation is applied for a couple of multi temporal RapidEye 1 (RE1) imagery (DAP MG 10). The line displacement image exhibits linear deformation from -2 pixels (upper left) up to 0.4 pixels (lower right). While dynamic errors, more likely due to the relief, are observed when looking at the pixel displacement image.

These illustrate a limitation of use for certain thematic that has been documented and disseminated to the GSP. Simultaneously, some discussions have been undertaken with the GCM to investigate the root causes of this anomaly.

Line displacements	Pixel displacements

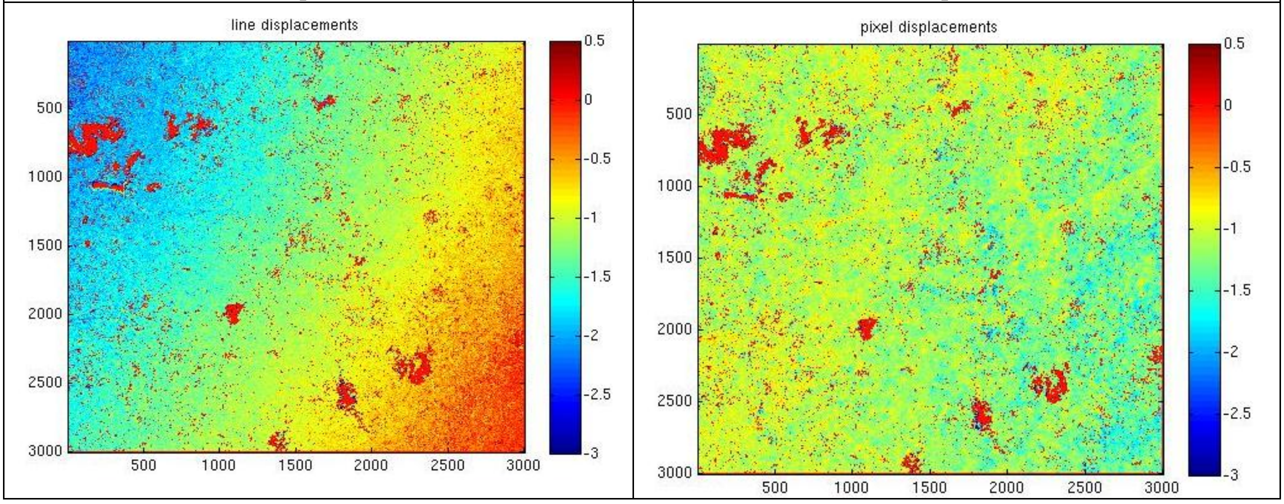


Figure 6 - Disparity analysis between two ortho products.

Radiometric stability

In theory, the DMC satellites should have the same relative and absolute calibration. The DAP MG2 13 dataset contains products from UK-DMC2 and DEIMOS-1. The objective of this investigation is the analysis of the radiometric matching between couple of observations.

The radiometric stability of the dataset can be studied from a thematic point of view, in computing the normalized difference vegetative index (NDVI).

For concomitant observations such as ‘Uk1’ and ‘De2’, where the time difference between observations does not exceed 5 days, the NDVI is expected to be stable.

From a methodology point of view, the couple ‘De1’ and ‘De2’, where the time difference is about 2 months, is considered. These results are used for the validation of the method and comparison purposes.

Table 1 is a summary of the results. Whereas the couple of observations originated from the same sensor are agreeing together (‘De1 / De2’), a more significant deviation is observed for the first couple ‘Uk1’/’De2’.

In applying a least square fitting for each couple, a linear transformation is deduced with a confidence above 95%. Table 14 gives also the coefficients of this linear transformation (Intercept on Y axis and Slope).

Couple (c1/c2)	**Mean of C1**	**Mean of C2**	**Overall Percent difference**	**Intercept**	**Slope**
‘Uk1’/’De2’	0.5033	0.4829	4%	0.0831	0.8701
‘De1’/’De2’	0.47407	0.4849	-2%	0.0202	0.9803

Table 1: NDVI and match up results.

This study demonstrated that radiometric calibration of SLIM-6-22 instrument on board DMC UK 2 slightly differs from the DEIMOS one. The radiometric stability of the NDVI can however be considered as nominal and suitable for the dataset applications.

It has been concluded that the radiometric calibration was stable and the related Dataset was fit for purpose from this perspective.

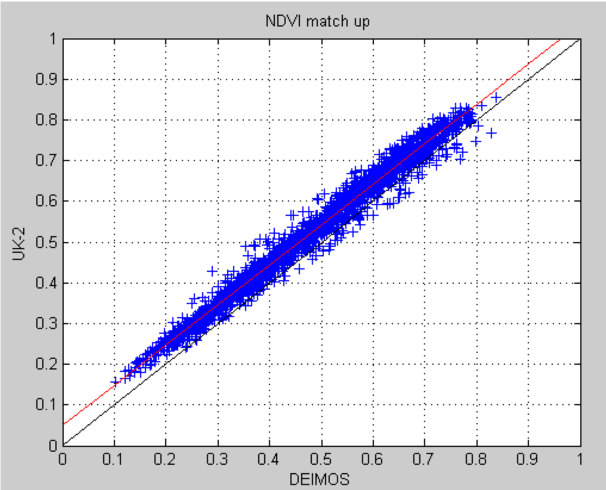
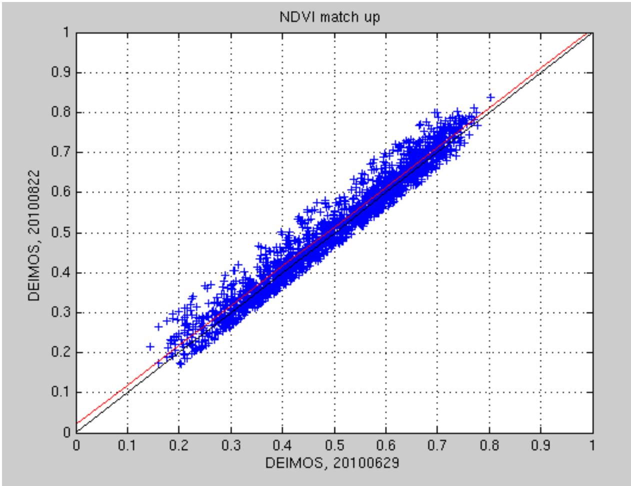
‘UK-2 / Deimos’ couple.	‘Deimos’ couple.
	

Figure 7 – NDVI Match up.

CONCLUSIONS

This paper demonstrates that the CQC system is fundamental to implement the quality assurance strategy. The GSCDA provides the GSP with an increased number of multi-source data included in a Dataset. Conversely, for their optimal use, the GCM should ensure that data products are fit for purpose over broad categories of thematic. One key challenge of the CQC system is the harmonization and standardization across the GCM at the Dataset level.

This paper shows that the overall system CQC system gets the capabilities to achieve this objective. In the early age of the service, the first results are promising.

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