Testbed-12 Imagery Quality and Accuracy Engineering Report

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Abstract

The scenario of rapidly growing geodata catalogues requires tools focused on facilitating users the choice of products. Having populated quality fields in metadata allows the users to rank and then select the best fit-for-purpose products. For example, decision-makers would be able to find quality and uncertainty measures to take the best decisions as well as to perform dataset intercomparison. In addition, it allows other components (such as visualization, discovery, or comparison tools) to be quality-aware and interoperable.

This ER deals with completeness, logical consistency, positional accuracy, temporal accuracy and thematic accuracy issues to improve quality description in the metadata for imagery. Based on ISO 19157, UncertML and QualityML standardized measures, this ER describes how to encode quality measures in order to allow datasets comparison. Moreover, description of pixel-level quality measures is also included. Finally, alternatives to communicate tile level quality as well as mosaic products quality are proposed.

Business Value

This ER has the objective of facilitating the fit for purpose assessment of imagery based on quality measures. This will make the determination of the right data more agile. In addition, a machine readable quality reporting will make possible that processing tools such as WPS and WCPS can propagate quality indicators to the results.

Technology Value

This ER contributes to the Data Quality DWG activities by exploring quality documentation for imagery, that compliments other domain specifics previous works such as Data Quality for Citizen Science.

How this ER relates to the work of the Working Group

This ER is important for the Data Quality DWG because it represents a continuation of works initiated with the UncertML discussion paper.

Keywords

ogcdocs, testbed-12, Data quality, metadata, accuracy, uncertainty

Proposed OGC Working Group for Review and Approval

DataQuality DWG

Chapter 1. Introduction

1.1. Scope

This OGC® document proposes an encoding for data quality for imagery using metadata for dataset and pixel level quality. In addition it also deals with separating spatial resolution from spatial accuracy and uncertainty, as well as, temporal extent and the temporal accuracy

This OGC® document is applicable to ISO 19157 implementations and to data processing tools such as WPS, WCPS and WMTS.

1.2. Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Table 1. Contacts

Name	Organization
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1.3. Background

The research leading to the first version of QualityML was carried out in the GeoViQua project that has received funding from the European Union Seventh Framework Programme (FP7/2010-2013) under grant agreement no. 265178.

TestBed 12 has contributed to a considerable improvement of QualityML catalogue, in particular to quality measures concerning imagery.

1.4. Future Work

Implement and test the suggested "last time" parameter. Consider that, this may not be the best time parameter approach and other alternatives need to be explored (TIME=current.land) as described in WMTS Time Accuracy of this document.

The results of this work have been applied partially for time accuracy in a WMTS server. Extend the proposed service to the whole proposed A3C (Accuracy, Currency, Completeness and Consistency) framework and apply it to the WCS by means of a CIS quality extension.

QualityML vocabulary can be proposed as OGC discussion paper in the Data Quality DWG, in the same way that UncertML was proposed in the past.

1.5. Foreword

Attention is drawn to the possibility that some of the elements of this document may be the subject

of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

Chapter 2. References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

- ISO 19115-1:2014 — Geographic information — Metadata — Part 1: Fundamentals
- ISO 19115-2:2009 — Geographic information — Metadata — Part 2: Extensions for imagery and gridded data
- ISO 19157:2013 — Geographic information — Data quality
- ISO/TS 19115-3:2016 — Geographic information — Metadata — Part 3: XML schema implementation for fundamental concepts
- QualityML v1.0 Quality Indicators Dictionary and Markup Language
- UncertML v1.0 OGC 08-122r2 Uncertainty Markup Language
- WMTS v1.0.0 OGC 07-057r7 Web Map Tile Service Implementation Standard

Chapter 3. Terms and definitions

For the purposes of this report, the following terms and definitions apply.

3.1. accuracy

```
closeness of agreement between a test result or measurement result and the true value.
[SOURCE: ISO 3534-2:2006, 3.3.1]
```

3.2. conformance

```
fulfillment of specified requirements.
[SOURCE: ISO 19105:2000, 3.8]
```

3.3. data quality basic measure

```
generic data quality (4.21) measure used as a basis for the creation of specific data
quality measures.
[SOURCE: ISO 19157:2013, 4.7]
```

3.4. quality

```
degree to which a set of inherent characteristics fulfills requirements.
[SOURCE: ISO 9000:2005, 3.1.1]
```

3.5. tile

```
a rectangular pictorial representation of geographic data, often part of a set of such
elements, covering a spatially contiguous extent and sharing similar information
content and graphical styling, which can be uniquely defined by a pair of indices for
the column and row along with an identifier for the tile matrix.
[SOURCE: OGC 07-057r7, 4.11]
```

3.6. tile matrix

```
a collection of tiles for a fixed scale
[SOURCE: OGC 07-057r7, 4.12]
```

3.7. uncertainty

```
parameter, associated with the result of measurement, that characterizes the
dispersion of values that could reasonably be attributed to the measurand.
[SOURCE: JCGM 100:2008]
```

Chapter 4. Conventions

4.1. UML notation

Most diagrams that appear in this standard are presented using the Unified Modeling Language (UML) static structure diagram, as described in Subclause 5.2 of [OGC 06-121r9].

4.2. Data quality measures dictionary tables

The data quality measures dictionary is specified herein in a series of tables. The contents of the columns in these tables are described in the next Table.

ISO 19157 provides a long list of quality measures. To define these metrics in a formal way, we are using a data structure proposed in annex D of ISO 19157 with some modifications:

Table 2. Data Structure to define quality measures used in this section

Line	Component	Observation
1	Name	Name is the name of the measure.
2	Alias	Alias is another recognized name for the same data quality measure. It may be a different commonly used name, or an abbreviation or a short name. More than one alias may be provided.
3	Element name	Element name is the name of the data quality element to which a measure applies. More than one element name may be provided.
4	Basic measure	If a measure is based on one of the basic measures, it shall be described by its name, definition and value type. Basic measures are identified by their names. A variety of measures are based on counting of erroneous items. There are also several measures dealing with the uncertainty of numerical values. In order to avoid repetition, the most common methods of constructing count-related measures as well as general statistical measures for one- and two-dimensional random variables should be defined in terms of basic measures. The basic measures should also be used for creating new measures if applicable, for example to report non-closed surface patches or other application-dependent measures.
5	Definition	If the measure is derived from a basic measure, the definition is based on the basic measure definition and specialized for this measure.
6	Description	Description is the description of the measure including methods of calculation, with all formula and/or illustrations needed to establish the result of applying the measure. If the measure uses the concept of errors, it should be stated how an item is classified as incorrect. This is the case when the quality only can be reported as correct or incorrect.
7	Parameter	Parameter is an auxiliary variable used by the measure. It shall includes name, definition and value type, More than one measure parameter may be provided.
8	*Value type*	*Not used*

Line	Component	Observation
9	*Value structure*	*Not used*
10	Source reference	Source reference is the citation of the documentation of the measure. When a measure, for which additional information is provided in an external source, is added to the list of standardized measures, a reference to that source may be provided here.
11	Example	Example is an example of applying the measure or the result obtained for the measure. More than one example may be provided.
12	Identifier	Identifier is a value uniquely identifying a measure within a namespace.
13	Domain	Replaces *Value type* and *Value structure* in ISO 19157
14	Metrics	Replaces *Value type* and *Value structure* in ISO 19157

The contents of these data dictionary tables are normative, including any table footnotes and has been transposed to QualityML.

Chapter 5. Overview

The scenario of rapidly growing geodata catalogues requires tools focused on facilitating the choice of products to the users. Having populated quality fields in metadata allows the users to rank and then select the best fit-for-purpose products. For example, decision-makers would be able to find quality and uncertainty measures to take the best decisions as well as to perform dataset intercomparison. In addition, it allows other components (such as visualization, discovery, or comparison tools) to be quality-aware and interoperable.

This ER covers the following aspects of data quality: completeness, logical consistency, positional accuracy, temporal accuracy and thematic accuracy issues to improve quality description for imagery in the metadata.

In particular the ER address the following issues:

- Quality parameters offer a way to compare and determine the right data that fits for purpose. Standard vocabularies and taxonomies are paramount to describe data quality and allow comparison. In the 7th Framework Programme of the European Commission, the GeoViQua, a 3-year project, (UAB-CREAF were the coordinators) worked in different aspects of data quality and data visualization. One of the outcomes of the project was the QualityML vocabulary. This vocabulary is an extension of UncertML (the v1 of its community standard is a discussion paper in OGC). This vocabulary provides with a common solution for all quality indicators described in the former ISO 19138 which is the new ISO 19157. It also proposes a clear encoding in XML metadata documents (see http://www.QualityML.org/). QualityML has been reviewed and extended in this activity for imagery. The A3C (Accuracy, Currency, Completeness and Consistency) model quality framework is an instrument to compare imagery from multiple sources and determine which one fits better for the purpose that has also been integrated. These topics, and the relations among them, are discussed in A3C Framework, ISO Quality Framework, A3C mapped to ISO and QualityML vocabulary encoding.
- A list of quality measures for raw imagery and higher level raster derived data that follows the A3C model (and uses ISO 19157 and QualityML) is conceptually described in Quality Measures Raster.
- Traditionally, quality reports were associated to product specifications resulting in quality metrics common for all the elements of the dataset. XML encoding for quality metadata for dataset level, using QualityML to give semantics to quality measures, is discussed in Dataset Levels.
- Recently, per pixel or per object qualities are also being included (e.g MODIS and Sentinel quality bands). There are also intermediate levels that can be defined, including those that appear due to users visualize data at their preferred levels of resolution (scale denominator). An example of that is the tiling system where tiles can be considered a visualization units with an associated quality description. Therefore, a general way of expressing quality at levels below dataset is needed. These topics are discussed in Pixel Level and WMTS Time Accuracy.
- Data aggregation and data fusion are examples of simple processes where the resulting dataset needs an complex definition of quality as an integration of the quality indicators of each individual data source. This topic is discussed in Quality Big Mosaic.

5.1. A3C quality framework

The A3C (Accuracy, Currency, Completeness and Consistency) model quality framework is introduced by DigitalGlobe as an instrument to compare imagery from multiple sources and determine which one fits better for the purpose. This model was initially suggested in the *Request for Quotations*, Annex B of Testbed 12 and the original text is included in Appendix A3C for convenience.

The final aim is to generate an standard way to define quality measurements to allow image comparison based on these measures.

5.1.1. A3C description

The A3C defined the 4 quality classes (Accuracy, Currency, Completeness, and Consistency) as:

- Accuracy refers to spatial accuracy of a location derived from the pixel in X,Y dimensions and potentially in Z dimension.
- Currency refers to the temporal extent of the imagery and products used to cover the associated area, since multiple dates of collections are typically required to cover a large area.
- Completeness of imagery and products refers to quality metrics including cloud cover, sensor specs on collection geometry, temporal range of the data, other spectral bands if any, radiometric depth of the pixels, etc.
- Consistency metric describes the consistency of colors, relative accuracy over time and over different sensors, spectral and spatial error propagation from collection to production, etc.

A3C model is designed with the fit for purpose in mind and includes elements that are considered as data quality by ISO 19157 complemented by other aspects that can be found in other classes of the more general ISO 19115-1 metadata describing the datasets.

This ER links the A3C framework to ISO 19157 and QualityML vocabularies, and proposes encodings compatible with common metadata standards. In addition to this ER, implementations of this combined framework have been developed in Testbed 12 such as a WMTS server that implements the time accuracy part and a WCS that provides support to the complete framework.

5.1.2. Accuracy

Different sources of information come with different location *accuracy* (focusing in horizontal *accuracy*).

One of the common indications to define this *accuracy* is the CE90. It is defined in the ISO 19157 in Table D.46 — "Circular map accuracy standard".

Table 3. Circular map accuracy standard as defined by ISO 19157 and with QualityML identifiers

Line	Component	Description
1	Name	circular map accuracy
2	Alias	circular map accuracy standard (CMAS)[1]

Line	Component	Description
3	Element name	absolute or external accuracy
4	Basic measure	CE90[1]
5	Definition	radius describing a circle, in which the true point location lies with a certain probability
6	Description	image::includes\images\CE90.png[scaledwidth="30%"] The equation expresses CE90[1] measure that, for some particular probabilities, can be calculated depending on the standard deviations σ_x and σ_y.[2] The one dimensional standard deviation σ for each dimension (represented by a *Z*) can be estimated by: image::includes\images\LE68.3.png[scaledwidth="30%"]
7	Parameter	"level" for level of confidence
10	Source reference	ISO 19157 Id. 42 (39.4%), Id. 43 (50%), Id. 44 (90%), Id. 45 (95%), Id. 46 (99.8%), unified in QualityML
11	Example	20m
12	Identifier	http://www.qualityml.org/1.0/measure/CircularMapAccuracy
13	Domain	http://www.qualityml.org/1.0/domain/DifferentialErrors2D
14	Metrics	http://www.qualityml.org/1.0/metrics/Half-lengthConfidenceInterval

[1] only when confidence interval is 90%
[2] the precise definition was extracted form annex G.3.3 "Two-dimensional random variable X and Y"

For example, in the constellation of DigitalGlobe, the older satellites (Quickbird and Ikonos) have a positional accuracy of 20m CE90. In the new generation, they have a positional accuracy of 3m and in the future we could have 1m for satellites orbiting at 400 miles.

To be able to estimate this positional accuracy, several factors have to be taken into account giving us different approaches to determine positional accuracy.

- Sensor Accuracy: Some satellite use a push broom (that acts as a broom sweeping). In this case, we can have column errors coming from the stability of the DCA (detector chip array) and row errors derived from the stability of the satellite with sweeping the Earth (obtained through ephemerides and validation sites on Earth). Using this information a rough estimation of image positional accuracy can be done.
- Product accuracy (x,y,z): Processed pixel location accuracy on the ground. Another source of error are the ones introduced when the final product is elaborated. E.g. introduced by the orthorectifying process using a DEM (Digital Elevation Model) and GCP (Ground Control Points). The accuracy and resolution of the DEM can introduce more uncertainty in the *accuracy*.

It is important to clarify that the same quality measure would be used for any of these approaches, thus it is also important to provide information on the evaluation method of a particular metric.

5.1.3. Currency

The immediate aspect of *currency* is how recently the scene was taken. This can be found in the time stamp when the image was collected (initial and end time). If the image is being used as the "current" one, this introduces uncertainties in the features we are seeing in the images, if they are not recent enough (and some elements may have changed or moved).

A more elaborated use case with currency issues appears with temporal uncertainty related to a large image created by mosaicking multiple paths and scenes. For example, temporal accuracy can be provided as "90% of the mosaic is as current as 3 days or less". The temporal uncertainty can be bigger in mosaics over large territories (e.g. the African continent) . It can also be described as an overall measure (aggregation: "no pixel is older than a value *t*"). This can be provided at the pixel level as well.

This is in line with the WMTS service that is developed in this Testbed 12 and explained in WMTS Time Accuracy. In this case each, tiles can be tagged with a time accuracy estimation. For low scale tiles we will have time accuracy estimation for a small area. For higher scales we will have more aggregated values and in the extreme we will end in a scale where the whole extent fits in a tile and in this case the tagged quality will be the global time *accuracy* or the composed mosaic.

This is particularly important for the the disaster management use case, where currency is the most important factor.

5.1.4. Completeness

This is also related with mosaics of large areas (e.g. a mosaic of all African continent). For large extension it could not be possible to generate a completely cloud free image. In this case the percentage of the data tagged as NoData can be one of this metrics (e.g. 0.5 % of area is missing). We can go further defining the percentage of the mosaic covered by clouds. We could do the same for cloud shadows but this is much more difficult and the industry is not able to report this yet.

The presence of cloud information can also be exposed by a WMTS. We could try and use this information in the WMTS. Some times there are products that have a "cloud" raster layer. Some other times the clouds are stored as polygons in a database.

5.1.5. Consistency

Consistency in a GIS vector context is easily understandable and measured through a conformity test to the data model specification. In a remote sensing context there is no theoretical pattern to compare to, and only a reduced number field measures (e.g. field radiometry records) are usually available to correct image radiometry and make it consistent over time.

The weather and atmosphere status changes over time. Important factors that influence the image quality are the presence of aerosols and water vapor. This can be different even in areas of a single scene and changes the quality of portions the image.

There are different levels of radiometric corrections involved:

- Raw data is expressed in digital numbers (DN). In this case, the quality of the image is conditioned by the atmosphere but also by the reflectivity of the atmosphere due to the angle of

the sun.

- First level of correction is to get Top of the Atmospheric Reflectance (TOA) where we eliminate the reflectivity of the atmosphere due to the angle of the sun but the atmosphere effects are still there. This can be achieved by a calibrating the sensor (cal-val operations)
- A second level of correction is to calculate the Surface Reflectance (SR) using atmospheric models. In this case we need to know if the atmospheric data was captured at the scene level or at a coarse level (e.g Aerosol pixel image). The estimation of aerosols can be done at a 2 m resolution with modern techniques.
- In addition the Surface Reflectance can be obtained by introducing information about pseudo invariant areas (PIAs).

Consistency may be intended to be within a single image, the whole product series (all the historical archive of the instrument), the complete constellation (among Worldview satellites) or even within different constellations (e.g. Landsat 8 and Sentinel 2).

5.2. ISO quality framework

The ISO standards coming from TC 211 form a collection of standard documents dealing with different aspects of Geographic Information and Geomatics.

Current ISO standards dealing with data quality are:

- ISO 19157 *Data quality* unifies data quality in almost a single document: what is data quality, quantitative/conformance measures and metadata encoding
- ISO 19115-1 *Metadata* specifies only lineage/usage/purpose
- ISO 19115-2 *Metadata for imagery* specifies some extensions to 19115. In particular introduces the idea of a coverage to specify pixel level quality. ISO 19115-2 is in the revision period and contributions are welcome to improve it.
- ISO 19115-3 *XML schema implementation for Metadata* specifies XML encoding rules for ISO 19xxx standards

that replaces some previous well known standards:

- ISO 19113 *Data quality principles* specifies what is data quality and what is not
- ISO 19138 *Data quality measures* specifies a long list of quantitative/conformance measures for data quality.
- ISO 19115 *Metadata* specifies how to encode quantitative/conformance measures in ISO metadata.

Following subclauses introduce the main concepts relevant for data quality:

- Quality classes and structure of the quality measures
- Others quality related elements
- Others metadata elements indirectly related with quality

5.2.1. Quality classes and structure of the quality measures

According to ISO 19157 there are seven quality elements (or classes) describing certain aspects of the quality of a geographic dataset:

- completeness: presence and absence of features, their attributes and relationships;
- logical consistency: degree of adherence to logical rules of data structure, attribution and relationships (data structure can be conceptual, logical or physical);
- positional accuracy: accuracy of the position of features within a spatial reference system;
- thematic accuracy: accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships;
- temporal quality: accuracy of the temporal attributes and temporal relationships of features;
- usability: Usability is based on user requirements. All quality elements may be used to evaluate usability;
- metaquality: a set of quantitative and qualitative statements about a quality evaluation and its result. The knowledge about the quality and the suitability of the evaluation method, the measure applied and the given result may be of the same importance as the result itself.

These quality classes (or elements) can be elaborated in several quality indicators (or sub-elements).

Table 4. Data quality classes and subclasses

data quality element	**data quality subelement**	**definition**
completeness	commission	excess data present in a dataset
	omission	data absent from a dataset
logical consistency	conceptual consistency	adherence to rules of the conceptual schema
	domain consistency	adherence of values to the value domains
	format consistency	degree to which data is stored in accordance with the physical structure of the dataset
	topological consistency	correctness of the explicitly encoded topological characteristics of a dataset

data quality element	data quality subelement	definition
positional accuracy	absolute or external accuracy	closeness of reported coordinate values to values accepted as or being true
	relative or internal accuracy	closeness of the relative positions of features in a dataset to their respective relative positions accepted as or being true
	gridded data positional accuracy	closeness of gridded data position values to values accepted as or being true
thematic accuracy	classification correctness	comparison of the classes assigned to features or their attributes to a universe of discourse (e.g. ground truth or reference dataset)
	non-quantitative attribute correctness	correctness of non-quantitative attribute
	quantitative attribute accuracy	accuracy of quantitative attributes
temporal quality	accuracy of a time measurement	correctness of the temporal references of an item (reporting of error in time measurement)
	temporal consistency	correctness of ordered events or sequences, if reported
	temporal validity	validity of data with respect to time
usability	*all quality elements*	based on user requirements
metaquality	confidence	trustworthiness of a data quality result
	representativity	degree to which the sample used has produced a result which is representative of the data within the data quality scope
	homogeneity	expected or tested uniformity of the results obtained for a data quality evaluation

The definition of DQ_Element and its classes and sub-classes as described in ISO 19157 can be seen in next figure:

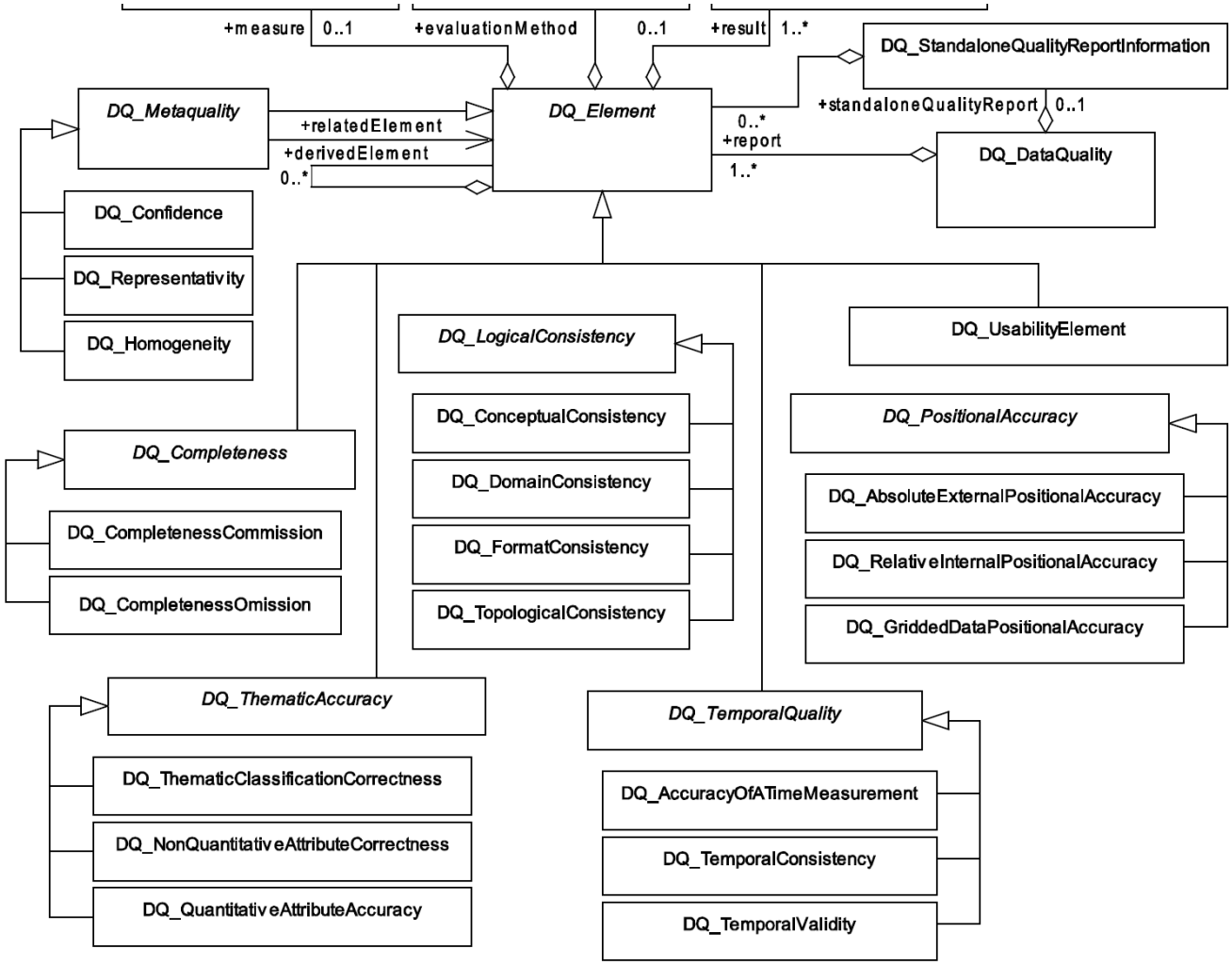

Figure 1. DQ_Element as defined in ISO 19157

When describing the quality of geographic data, different quality elements and different subsets of the data may be considered. In order to describe these, data quality units are used. A data quality unit is the combination of a scope and data quality elements.

The scope of the data quality unit(s) specifies the extent, spatial and/or temporal, and/or common characteristic(s) that identify the data on which data quality is to be evaluated. One data quality scope shall be specified for each data quality unit.

Moreover, an evaluation of a data quality element is described by the following:

- measure – the type of evaluation
- evaluation method – the procedure used to evaluate the measure
- result – the output of the evaluation (includes value type, unit and date)

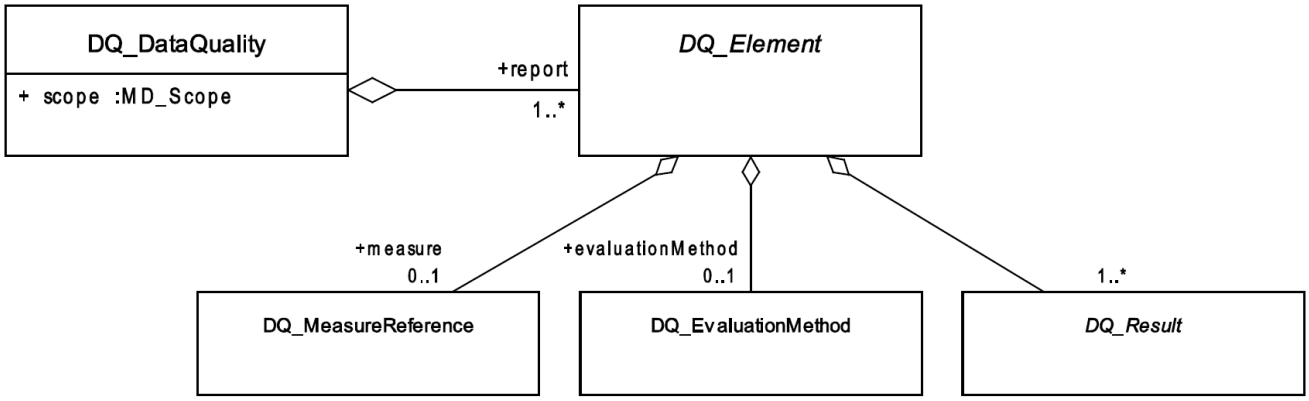

Figure 2. Data quality units and data quality element descriptors as defined in ISO 19157

Thus, to describe a quality subelement 7 items should be provided:

- data quality scope;
- data quality measure;
- data quality evaluation method;
- data quality result;
- data quality value type;
- data quality value unit;
- data quality date.

Results can be:

- Quantitative results (may be a single value or multiple values, depending on the values of attributes valueType and valueStructure defined in the description of the measure applied)
- Conformance results (in this case the "value" is a Boolean "yes" or "no")
- Descriptive results (in this case the "value" is a free text "statement")
- Coverage results (in this case the "value" is an image link)

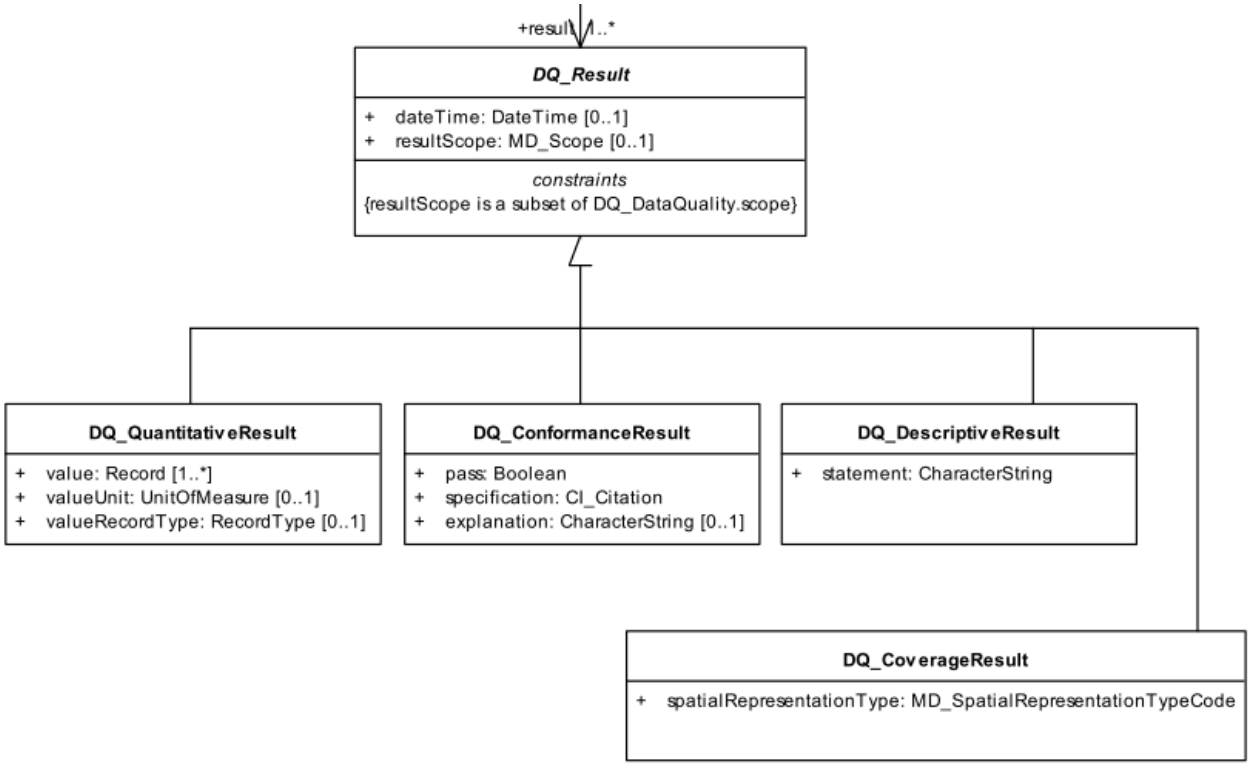

Figure 3. Alternatives for the DQ_Result

5.2.2. Others quality related elements

There are several non quantitative elements on the metadata that include information somehow related to data quality:

- purpose: describes the rationale for creating a dataset and contain information about its intended use.
- lineage: describes the history of a dataset and, in as much as is known, recount the life cycle of a dataset from collection and acquisition through compilation and derivation to its current form.
- usage: describes the application(s) for which a dataset has been used or uses of the dataset by the data producer or by other, distinct, data users.

In FP7 GeoViQua (http://www.geoviqua.org) the usage concept was extended to *geospatial user feedback* (GUF). GUF is a form of metadata derived from the experience that users gain by using the data. The GUF.SWG developed an standard in two separate documents:

- 15-097r1 Geospatial User Feedback Standard. Conceptual model
- 15-098r1 Geospatial User Feedback Standard. XML Encoding extension

Recently, the OGC TC approved these two documents as international standards. This work is probably out of scope in this ER but is worth to mention it for completeness.

5.2.3. Others metadata elements indirectly related with quality

There are some elements that can be used for "fit for purpose" assessment but are not considered parts of the data quality in ISO:

- spatial resolution: this information is commonly confused with the spatial accuracy. The spatial resolution is related to the pixel size chosen to encode the data in a raster/coverage format while the spatial accuracy refers to the deviance in the geographic position of the pixel from its real ground position. Many times both are related but are not the same. The encoding of this one escapes *data quality* and ISO 19115 explains how to do it.
- temporal extent: similar situation can be found with temporal extent and the temporal accuracy. The temporal extent indicates the interval of time (e.g. as a start time and an end time) of data in the image (e.g. in an remote sensing image is equal to the date the image was acquired; and in a photo-interpreted map is related to the acquisition date when the image had been taken, not the date when the photo-interpretation was carried out) while the temporal accuracy refers to the uncertainty in the individual time measurement. In ISO 19115 this is related to the extent of the data (in ISO 19115, *extent* is a multidimensional cube that gives information on BBOX, temporal extent and elevation interval).

5.3. Mapping the A3C model to ISO TC211 model

5.3.1. Accuracy

A3C accuracy can be expressed using DQ_PositionalAccuracy quality element from ISO 19157 (including AbsoluteExternalPositionalAccuracy, RelativeInternalPositionalAccuracy or GridedDataPositionalAccuracy). This is valid for X, Y. If the CRS is a 3D CRS, Z dimension can be also included. If Z is considered an attribute, ISO 19197 includes a DQ_QuantitativeAttributeAccuracy that could also be used the describe, for example, the elevation accuracy in a Digital Elevation Model (DEM).

In the original definition of the A3C model in the Annex B of the Request for Quotation, there is no mention of thematic accuracy. This could be an important component for vector data but also for imagery representing quantitative variables (e.g. temperatures) and categorical variables (e.g. Land cover classes).

So that, proposed measures will include thematic accuracy classes: i.e.: DQ_QuantitativeAttributeAccuracy, DQ_ThematicClassificationCorrecteness and DQ_NonQuantitativeAttributeCorrectness

5.3.2. Currency

Currency refers to the temporal extent of the imagery products used to cover the associated area, since multiple dates of images are typically required to cover a large area. This is covered by ISO 19115-1 in EX_Extent and the specialization EX_TemporalExtent.

In addition, other elements of the ISO 19115-1 model could be used to reflect the frequency in which the producer plans to update the dataset. This is not directly related with the currency of the data, but can be a proxy to it, in case the EX_TemporalExtent is not indicated. It is clear that if the producer intends to update the dataset every 15 days, the probability of having a current dataset is higher than if the maintenance is planned for each 10 years. Please note that the use of these elements to infer currency is not perfect: even if the dataset is updated frequently, the updated version could be another dataset and not the one at hand.

In the figure below, resourceMaintenance points to a MD_MaintenanceInformation with:

- maintenanceAndUpdateFrequency: frequency with which changes and additions are made to the resource after the initial resource is completed (e.g. daily, weekly, ...)
- userDefinedMaintenanceFrequency: Frequency maintenance period other than those defined in MD_MaintenanceAndUpdateFrequencyCode
- maintenanceDate: date information associated with maintenance of resource

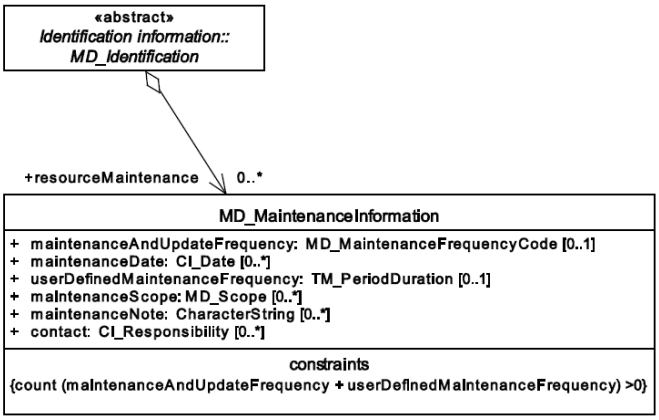

Figure 4. Maintenance information

Data quality classes can also be used in combination with EX_TemporalExtent. This is recorded using DQ_TemporalQuality. Temporal quality can represent different aspects concerning the temporal tags of the data, exemplified in the following use cases:

- To assess the quality of the temporal measurements one can use DQ_AccuracyOfATimeMeasurement.
- When combining data covering different EX_TemporalExtent's to produce a new product, the result can increase the time uncertainty and this can be recorded in DQ_AccuracyOfATimeMeasurement.
- When the time is uncertain, the sequence of events can be compromised (not being able to identify the most current image); this is reflected in DQ_TemporalConsistency (correctness of ordered events or sequences).
- DQ_TemporalValidity is defined as the validity of time measurements with respect to the expected time domain (expressed in EX_TemporalExtent), and can be used to describe a rate of items older than a specific date.

5.3.3. Completeness

ISO defines completeness as commission (DQ_CompletenessComission) and omission (DQ_CompletenessOmission).

In imagery products, cloud cover is usually documented as quality flags adding a quality band. A quality band can be added defining a quality band in MD_Band (new in ISO 19115-1) or by adding a quality measure with a QE_CoverageResult (ISO 19115-2) (alternatives are described in Pixel level Quality).

In some cases, the sensor specifications forces the collection of data with geometrical restrictions

that can leave gaps between scenes or paths that will create data omissions. For similar reasons, the revisiting time of some zones of the Earth in satellite imagery coming from near polar orbits is less frequent in the equator leaving gaps for some time periods. Other reasons for omissions are the lack of some bands due to sensor failure. In some situations measures can saturate the dynamic range of the sensor or the digital representation of them resulting in omission of information.

5.3.4. Consistency

On one hand, the description of the radiometric processing performed over the image should be documented on lineage (statement or processStep). This metadata element can help understanding the consistency that each image can have related to the whole time series.

Moreover, DQ_ConceptualConsistency and DQ_DomainConsistency can be used to record inconsistencies over time that can have its origin in lack of good calibration of the sensors and bias. This will generate inconsistency of colors and relative inaccuracy over time. Temporal series can be built combining old and new platforms and sensors resulting in non-homogeneous results. Spectral and spatial error propagation from collection to production can also influence in consistency (in particular if processing chains change over time).

5.4. QualityML quality vocabulary and encoding

In the 7th Framework Programme of the European Commission, the GeoViQua, a 3-year project, (UAB-CREAF were the coordinators) worked in different aspects of data quality and data visualization. One of the outcomes of the project was the Quality Mark-up Language (QualityML). QualityML is both a vocabulary and an encoding for data quality. QualityML is an extension of UncertML (the v1 of its community standard is a discussion paper in OGC). This vocabulary provides with a common solution for all quality indicators described in the former ISO 19138 which is the new ISO 19157. It also proposes a clear encoding of quality elements (using standardized quality measures) in XML metadata documents (see www.qualityML.org). QualityML has been reviewed and extended in this activity.

5.4.1. UncertML

In 2009, OGC announced the release of UncertML as a discussion paper (http://www.opengeospatial.org/pressroom/pressreleases/1002). "UncertML is a conceptual model and XML encoding designed for encapsulating probabilistic uncertainties and may be used to quantify and exchange complex uncertainties in data. Most data contains uncertainty arising from sources such as measurement error, observation operator error, processing/modeling errors, or corruption. Processing uncertain data propagates and often increases uncertainty. Thus there is a need for a standard way of characterizing uncertainty that is readily interpreted by software systems. UncertML is based on a number of ISO and OGC standards, such as ISO 19138 Data Quality Measures, and addresses the ISO/IEC guide to the expression of uncertainty in measurement (GUM). UncertML utilizes the OGC Geography Markup Language (GML) Standard and the OGC Sensor Web Enablement Common (SWE) Standard."

Later, UncertML was adopted by the UncertWeb project and a version 2.0 of it emerged as a well documented proposal maintained by a small community: http://www.uncertml.org.

5.4.2. Why QualityML

The problem with UncertML is that it only deals with one way of measuring the data quality: uncertainty. This works well with some measurements of accuracy but does not cover other quality measures like consistency, completeness etc. We needed a way to extend the UncertML approach to all other quality indicators and to harmonize them with the measurement definitions that ISO 19157 is providing and many more that are used in other domains.

5.4.3. How to understand QualityML

QualityML (http://www.qualityML.org) is a data model, a vocabulary and an encoding for data quality.

To report quantitative or conformance quality in QualityML, you need to combine the following concepts:

- quality class (called quality elements in ISO 19157): the *seven* elements described in ISO 19157 are considered
- quality indicator (called quality sub-elements in ISO 19157): the *eighteen* elements described in ISO 19157 are considered
- quality measure (called quality measures in ISO 19157 and described in its Annex D): the quality measure used to describe the quality element
- quality domain (or measurement field): the field where the metrics is going to be applied. Examples are: "deltas" between 1d expected and the real value, 3d "deltas", individual wrong measurements, predicted or actual values,...
- quality metric (which include a metric name, metric description, metric parameter, its values and units of measure): This is the mathematics expression applied to the "measurement field" and results in a value that can be a number count, a floating point average or a Boolean yes/no.

Table 5. Example of conceptual encoding using QualityML: an omission of 15% of the items in a dataset

Concept		**Value**	**Comments**
quality indicator		*DQ_CompletenessOmission*	
quality measure		*Missing items*	More information in QualityML definition
quality domain		*Non conformance*	More information in QualityML definition
domain parameters	Rule	*Forest*	needed if the omission of a single category is reported

Concept		Value	Comments
quality metric		*Items count*	Can be a choice of: * indicator (boolean) * count (int) * rate (real, attribute: max (real)) More information in QualityML definition
metric parameters	Rate	*66*	needed if *rate* is selected to describe *Items count*
metric parameters	Maximum	*100*	needed if *rate* is selected to describe *Items count*
metric units of measure		*none*	

5.4.4. From ISO 19157 to QualityML

The main idea behind QualityML is that it can be used to describe quality elements in metadata in a standardized way that it also includes semantics (as it also points to the included definitions), allowing easy comparison of products.

On one hand, the QualityML is a profile of the ISO geospatial metadata standards (e.g. ISO 19157) providing a set of rules for precisely documenting quality indicator parameters that is structured in 6 levels. On the other hand, QualityML includes semantics and vocabularies for the quality concepts.

Whenever possible, QualityML uses statistic expressions from the UncertML dictionary (http://www.uncertml.org) encoding. However it also extends UncertML to provide list of alternative metrics that are commonly used to quantify quality beyond the uncertainty concept, for example the ones used in ISO 19157.

Quality metrics are used to compute the result of each quality measure value, when applied to a certain domain. QualityML provide a matrix of the combinations of indicators, measurements, domains and metrics commonly used.

The main idea behind this structure is to **unlink** measures, domains and metrics description, in order to **maximize generalization** of descriptions and increase coherence among several measures using the same metrics (even with different domains), or several quality indicators using the same measures.

Unifying different ISO Quality Basic Measures into a single QualityML Quality Metrics (with parameters)

ISO 19157, in its Annex D, introduces the concept of data quality basic measure to avoid the repetitive definition of the same concept. There are data quality measures that have certain commonalities. Two principle categories of data quality basic measures are listed in the Annex. The uncertainty-related data quality basic measures are based on the concept of modeling the uncertainty of measurements with statistical methods. The measured quantity can be embedded in

different dimensions. Depending on the dimension of the measured quantity, different types of data quality basic measures are used to construct data quality measures. The counting-related data quality basic measures are based on the concept of counting errors or correct items.

Uncertainty-related data quality basic measures

Several uncertainty-related measures are described in ISO linked to a common Basic measure, for example:

Table 6. Measures and Basic measures in ISO 19157

Measure name	Element name	Basic measure	Identifier
linear error probable	absolute or external accuracy	LE50 or LE50(r)	33
time accuracy at 50% significance level	accuracy of a time measurement		55
attribute value uncertainty at 50% significance level	quantitative attribute accuracy		69

QualityML goes one step beyond this generalization effort and also group basic measures describing the same metrics with different parameters. For example, all the measures regarding "half length of the interval" are grouped in a single general metric called **Half-lengthConfidenceInterval**, that includes a parameter to describe the confidence level (or probability) of the true value being between the lower and the upper limit. Level has to be in the range [0,1]. This QualityML metric includes several ISO 19157 basic measures.

Table 7. ISO 19157 basic measures and QualityML metrics

Basic measure	Element name	Id.	Measure name	QualityML metric	Metric parameter
LE50	absolute or external accuracy	33	linear error probable	Half-length Confidence Interval (QualityML definition for more details)	level = 0.5
	accuracy of a time measurement	55	time accuracy at 50% significance level		
	quantitative attribute accuracy	69	attribute value uncertainty at 50% significance level		
LE68.3	absolute or external accuracy	34	standard linear error		level = 0.683
	accuracy of a time measurement	54	time accuracy at 68,3% significance level		
	quantitative attribute accuracy	68	attribute value uncertainty at 68,3% significance level		
LE90	absolute or external accuracy	35	linear map accuracy at 90% significance level		level = 0.90
	accuracy of a time measurement	56	time accuracy at 90 % significance level		
	quantitative attribute accuracy	70	attribute value uncertainty at 90% significance level		
LE95	absolute or external accuracy	36	linear map accuracy at 95% significance level		level = 0.95
	accuracy of a time measurement	57	time accuracy at 95 % significance level		
	quantitative attribute accuracy	71	attribute value uncertainty at 95% significance level		

Basic measure	Element name	Id.	Measure name	QualityML metric	Metric parameter
LE99	absolute or external accuracy	37	linear map accuracy at 99% significance level		level = 0.99
	accuracy of a time measurement	58	time accuracy at 99 % significance level		
	quantitative attribute accuracy	72	attribute value uncertainty at 99% significance level		
LE99.8	absolute or external accuracy	38	near certainty linear error		level = 0.998
	accuracy of a time measurement	59	time accuracy at 99,8% significance level		
	quantitative attribute accuracy	73	attribute value uncertainty at 99,8% significance level		

The advantage of this generalization is not only the increase of coherence on the quality measures and metrics description, but also the possibility of describe any other confidence level interval in a standardized way.

This is done in QualityML not only for one dimensional random variables (*Z*, using "Half-length Confidence Interval" metrics), but also for two dimensional variables, including in a single definition several ISO metrics (confidence ellipse and uncertainty ellipse). In fact, the ISO description of confidence ellipse is general in the same way, as it has a parameter to describe the confidence (or significance) level.

Counting-related data quality basic measures

The basic measures described in ISO 19157 related to counting are shown in the next table:

Table 8. Data quality basic measures for counting-related data quality measures as described in ISO 19157

Basic measure name	Basic measure definition	Example	Data quality value type
Error indicator	Indicator that an item is in error	False	Boolean (if the value is true the item is not correct)
Correctness indicator	Indicator that an item is correct	True	Boolean (if the value is true the item is correct)

Basic measure name	Basic measure definition	Example	Data quality value type
Error count	Total number of items that are subject to an error of a specified type	11	Integer
Correct items count	Total number of items that are free of errors of a specified type	571	Integer
Error rate	Number of the erroneous items with respect to the total number of items that should have been present	0.0189	Real
Correct items rate	Number of the correct items with respect to the total number of items that should have been present	0.9811	Real

A first grouping that QualityML defines beyond these ISO basic measures, is related to the concept of counting items. All the measures related to the same quality measure are grouped and used a metrics call **items** which result can be expresses as a boolean, count or rate.

In fact ISO 19157 slightly suggest several options, in this case for the rate elements, when recognizes that "*[Error rate / Correct items rate] can either be presented as* percentage *or as a* ratio. *The value unit in the quantitative result (see 7.5.4.2) can be used to specify that the result is presented in percentage or as a ratio.*" To standardize these options for the rate as well as to combine the other two options (boolean and count), QualityML describe the **Items** metrics as a choice among "indicator" (for boolean), "count" or "rate". For the last one a parameter is described in order to include the maximum value of the rate. Thus, a value of 100 in this attribute will be used to express that the value is a percentage. Default value for this attribute is 1, representing a *pure* ratio.

Moreover, usually measures based on errors and on correct items are described in ISO 19157. Both definitions are exactly the same, only with the difference about "which elements" the measure is counting. This, in QualityML is described by the Domain of the Quality measure, allowing then a higher agrupation schema, as shown in the table below (only for measures related to conceptual consistency):

Table 9. Data quality basic measures for counting-related data quality measures as described in ISO 19157 and as grouped in QualityML (describing **conceptual consistency***)*

Id.	Measure name	Basic measure	QualityML measure	QualityML metric	Metric choice (parameter)	QualityML domain
8	conceptual schema non-compliance	error indicator	Conceptual Schema (QualityML definition for more details)	Items (QualityML definition for more details)	indicator	Non-Conformance (QualityML definition for more details)
10	number of items not compliant with the rules of the conceptual schema	error count			count	
12	non-compliance rate with respect to the rules of the conceptual schema	error rate			rate (parameter *max*)	
9	conceptual schema compliance	correctness indicator			indicator	Conformance (QualityML definition for more details)
-	*not defined in ISO*	correct items count			count	
13	compliance rate with the rules of the conceptual schema	correct items rate			rate (parameter *max*)	

QualityML domain (with parameters)

QualityML describes several domains to which the quality measures can be applied. Sometimes restrictions on the domain used needs to be described, and thus some parameters are needed for the domain.

For example when describing domain conformance, the item metrics can be used to described the rate of elements no conformant with the domain. If a requirement is described then this should be encoded as a domain parameters. See the following table for an example.

Table 10. 'Temporal validity' element and 'Value domain' measure using several domains, with or without domain requirements

Quality measure	Domain	Metrics	Example	Elements to be encoded
Value domain	Non Conformance	items	30% of the items are not conformant with their value domain (e.g. invalid dates codified in a DBF table)	measure used: *measure/ValueDomain* result value type: *Items* result value record: - items/rate: *30* (max="100") - NonConformance/rule: *Invalid dates codified in a DBF table*
			30% of the pixels are older than a 24 month of the time intended for the data (i.e. older than 2014-05-01)	measure used: *measure/ValueDomain* result value type: *Items* result value record: - items/rate: *30* (max="100") - NonConformance/min: *2014-05-01* - NonConformance/rule: *Pixels are older than a 24 month of the time intended for the data (i.e. older than 2014-05-01)*
	Conformance		65%[1] of the items are conformant with their value domain (e.g. valid dates codified in a DBF table)	measure used: *measure/ValueDomain* result value type: *Items* result value record: - items/rate: *65* (max="100") - Conformance/rule: *Valid dates codified in a DBF table*
			65%[1] of the pixels are within the 24 months before the time intended for the data (i.e. after than 2014-05-01)	measure used: *measure/ValueDomain* result value type: *Items* result value record: - items/rate: *65* (max="100") - Conformance/min: *2014-05-01* - Conformance/rule: *Pixels are within the 24 month before the time intended for the data (i.e. after than 2014-05-01)*

[1] In this example we consider that 5% of the DBF records or of the pixels has an empty date, thus conformant and non conformant percetages does not sum up 100%.

More details about QualityML in http://www.QualityML.org.

5.5. Levels of granularity in quality measures

Quality evaluation is carried out at pixel or feature level, as those are the elements evaluated and compared with those accepted as or being true. This comparison is then statistically assessed resulting in a what is called the measure. Measures can be delivered as different levels of granularity, depending on statistical selected domain. This section enumerates the most commonly used levels of granularity.

5.5.1. Product level

Traditionally, quality reports are associated to product specifications resulting in quality metrics common for all scenes of the same product.

5.5.2. Dataset level

Each individual scene (associated here to the concept of dataset) can be validated against what is considered ground truth and can have quality metric reports e.g. about the geospatial accuracy of the positions of the individual pixels (a process that is commonly done applying GCP). This results in an statistical dataset quality.

5.5.3. Pixel level

Recently, per pixel or per object qualities are also being included (e.g MODIS and Sentinel). In this case, an uncertainty model is associated to an scene that allows to compute individual uncertainties for each pixel. These uncertainties can be of any kind but e.g a set go GCP can be used to model the uncertainty distribution of the scene or an illumination model can be used to model the radiometric uncertainty of each pixel. This error modeling is particularly interesting when there is a need to propagate uncertainty when the same scene is used to derive high level products.

Another source of per pixel uncertainty is introduced when several scenes are combined to create a mosaic product. In this case the pixels of the mosaic have different uncertainty depending on the source of the original data (depending on the original scene).

5.5.4. Tile level uncertainty

To improve performance of visualization portals, data is structured on map tiles that are served by a tile service (e.g. based on the OGC WMTS). Tile layer services are expected to be easy to use providing access to a product that is a spatial and temporal mosaic of a long time series. The quality of each tile depends on the quality of the source scenes. Potentially each tile can have a different quality information depending on the source scenes. More details are discussed in WMTS Time Accuracy.

Chapter 6. Quality Measures for Raster

ISO 19157 provides a long list of quality measures. This quality measures were mainly targeting vector data (features). This section proposes a list of quality measures at the conceptual level for raw imagery and higher level raster derived data that follows the A3C model (that has been mapped to the ISO 19157 structure in a previous section). In some cases, ISO 19157 measures can be used directly only requiring complementing the description with some imagery specific details in the description. In some other cases, a complete reformulation of the measures is needed. Some common imagery measurements have no match with ISO 19157 element and complete new measure proposals are enumerated.

To define these metrics in a formal way, we are using a data structure described in a table using the columns defined in the Conventions. If an existing measure is already available, only a link to its description (in QualityML and or ISO 10157) will be given.

These measures are also synchronized and stored in the QualityML vocabulary, and a general XML encoding proposal (giving semantics to quality measures) is given there. Moreover a detailed description of XML encoding is described in Dataset Level and Pixel Level.

6.1. Accuracy (positional)

Most of ISO 19157 quality measures can easily applied to imagery, and thus can describe the uncertainty of pixels positions. ISO 19157 describe three quality elements for positional accuracy (see the list in Data Quality Classes), and DQ_GriddedDataPositionalAccuracy is specially described for imagery.

The accuracy of gridded data may be described using the same data quality measures as for the horizontal positional uncertainty, so identifiers 42 to 51 (as specified in Annex D.4.1.3) of ISO 19157, as well as, of course, corresponding QualityML measures. All these measures are computed using 2D positions. Moreover, 1D position errors could also be used if positional uncertainties are expressed in each dimension separately (or even 3D if a Digital Elevation Model or a 3D raster data cube is described).

6.1.1. Sensor Accuracy: positional uncertainty of satellite position

Metadata of each image can describe the **positional uncertainty of satellite position** using: ISO 19157 D.29 — Mean value of positional uncertainties. This measure is a measure describing the whole **dataset series** for a certain amount of time (as the measure is using measures from validation stations during a certain amount of time), and thus this need to be specified using and specific EX_TemporalExtent on the scope of the quality measure.

In QualityML, this measure is called Mean Absolute Error (MAE) and the domain and metrics are different depending if a 1D, 2D or 3D approach is needed.

Table 11. Positional uncertainty of satellite position

Line	Component	Description
1	Name	Mean Absolute Error

Line	Component	Description
2	Alias	MAE
3	Element name	gridded data positional accuracy
4	Basic measure	—
5	Definition	Mean Absolute Error (MAE) of imagery related to satellite position within a certain time period using data coming from validation sites distributed around the world with precise GPS locations
6	Description	—
7	Parameter	—
10	Source reference	ISO 19157 Id. 28, Id. 29, unified in QualityML
11	Example	A positional uncertainty of 5 m is related to satellite position accuracy within a certain time period
12	Identifier	*http://www.qualityml.org/1.0/measure/MeanAbsoluteError*
13	Domain	MAE can be used over several differential errors domain. In this case the domain is: *http://www.qualityml.org/1.0/domain/DifferentialErrors2D*
14	Metrics	- metrics: *http://www.qualityml.org/1.0/metrics/MeanAbsolute2D* - value: *5* m

6.1.2. Ground location accuracy (x,y,z): Pixel location accuracy on the ground

Metadata of each imagery can describe the **ground location accuracy** using: ISO 19157 D.44 to D.49 — Circular error at different significance levels. This measure is a measure describing each **dataset**, and is usually computed according to satellite ephemerides.

A common measurement for positional accuracy is called the circular error. The circular error estimates probability for the true value to lie in an circular area assuming a two-dimensional density function of the normal distribution. The circular area is characterized by its radius. For the same set of values, the confidence radius can be returned at different probabilities.

Different probabilities are considered different measures in ISO 19157. As explained in QualityML quality vocabulary and encoding, some ISO measures are generalized in QualityML as single measure (with a parameter), called Circular Map Accuracy in this case (with a parameter "levels" to describe the confidence).

Table 12. Confidence level and quality measures for Circular Map Accuracy (source: ISO 19157, Table G.5)

Probability P (level of confidence)	Data quality basic measure	Name	ISO 19157 Identifier	QualityML measure
39.4 %	image::includes\images\CE39_4.png[scaledwidth="75%"]	CE39.4	42	Circular Map Accuracy
50 %	image::includes\images\CE50.png[scaledwidth="75%"]	CE50	43	
90 %	image::includes\images\CE90.png[scaledwidth="75%"]	CE90	44	
95 %	image::includes\images\CE95.png[scaledwidth="75%"]	CE95	45	
99.8 %	image::includes\images\CE99_8.png[scaledwidth="75%"]	CE99.8	46	

Thus, the description of **ground location accuracy** using QualityML would use:

Table 13. Pixel location accuracy on the ground

Line	Component	Description
1	Name	Circular Map Accuracy
2	Alias	—
3	Element name	gridded data positional accuracy
4	Basic measure	—
5	Definition	Radius describing a circle, in which the true point location lies with a certain probability, computed using satellite ephemerides
6	Description	—
7	Parameter	"level" value to indicate the confidence level (in the range [0,1])
10	Source reference	ISO 19157 Id. 42, Id.43, Id. 44, Id. 45, Id. 46, unified in QualityML
11	Example	3.2 m is the radius of the circle in which the true pixel location lies with a 95% probability
12	Identifier	*http://www.qualityml.org/1.0/measure/CircularMapAccuracy*
13	Domain	*http://www.qualityml.org/1.0/domain/DifferentialErrors2D*
14	Metrics	In this case the metrics and its parameters are: - metrics: *http://www.qualityml.org/1.0/metrics/CircularError* - level: *0.95* - value: *3.2* m

6.1.3. Product accuracy (x,y,z): Processed pixel location accuracy on the ground

Moreover, metadata of the imagery can describe the **product accuracy** meaning the positional accuraccy of the final product at a **dataset** level. Usually the evaluation of the positional accuracy for gridded data is carried out by the definition of ground control points (with known true, or accepted as true, positions).

In this case, most common measure for positional accuracy is root mean square error of planimetry RMSEP, that is equivalent to a bidimensional standard deviation (or σ)):

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[(x_{\mathrm{m}i} - x_{\mathrm{t}})^2 + (y_{\mathrm{m}i} - y_{\mathrm{t}})^2\right]}$$

(that, assuming a normal distribution of errors, describes a probability of 63.8%).

In QualityML, this measure is called Root Mean Square Error and, for planimetry, is applied to a 2D Differential Error Measure domain, and uses Root Mean Square Error 2D metrics.

Table 14. Processed pixel location accuracy on the ground

Line	Component	Description
1	Name	Root Mean Square
2	Alias	RMS
3	Element name	gridded data positional accuracy
4	Basic measure	—
5	Definition	Measure of the differences between 2D values predicted by a model or an estimator and the values actually observed in a set of ground control points
6	Description	—
7	Parameter	
10	Source reference	ISO 19157 Id. 39
11	Example	2.9 m
12	Identifier	*http://www.qualityml.org/1.0/measure/RootMeanSquare*
13	Domain	*http://www.qualityml.org/1.0/domain/DifferentialErrors2D*
14	Metrics	- metrics: *http://www.qualityml.org/1.0/metrics/RootMeanSquareError2D* - value: *2.9* m

6.2. Accuracy (thematic)

Thematic accuracy is an important issue for imagery for example to describe accuracy on the original digital numbers, on the radiances or on the reflectances. This is also really important for higher level products such as vegetation indexes, or biophysical parameters obtained from the imagery.

Most of ISO 19157 thematic accuracy measures can be easily applied to imagery, and thus can describe the uncertainty of pixels values (identifiers 60 to 63, as specified in Annex D.6.3; and in corresponding QualityML measures). ISO 19157 describe three quality elements for thematic accuracy (see the list in Data quality classes and subclasses) and all of them can be applied to imagery (depending if a raw image or a high-level product is described).

6.2.1. Thematic accuracy: DEM accuracy (dataset-level)

A Digital Elevation Model is a useful product and describing its accuracy on the height values is related to describing thematic accuracy. In this case a DQ_QuantitativeAttributeAccuracy quality element is the convenient, and the proposal is to use the UncertML Normal Distribution description to describe the mean and the variance of the uncertainty on this element:

Table 15. Thematic accuracy: DEM accuracy (dataset-level)

Line	Component	Description
1	Name	Mean Absolute Error
2	Alias	MAE
3	Element name	quantitative attribute accuracy
4	Basic measure	—
5	Definition	Mean Absolute Error (MAE) of DEM values and expressed as mean and variance
6	Description	—
7	Parameter	—
10	Source reference	QualityML proposal (based on UncertML)
11	Example	Mean absolute error for the DEM is 1.21 m with a variance of 3.06 m
12	Identifier	*http://www.qualityml.org/1.0/measure/MeanAbsoluteError*
13	Domain	MAE can be used over several differential errors domain. In this case the domain is: *http://www.qualityml.org/1.0/domain/DifferentialErrors1D*
14	Metrics	- metrics: *http://www.uncertml.org/distributions/normal* - value: mean: *1.21 m* - value: variance: *3.06 m*

6.2.2. Thematic accuracy: NDVI accuracy (pixel-level)

A Normalized Difference Vegetation Index (NDVI), for example, can be derived from imagery, and documenting its thematic accuracy is important for ulterior modeling based on this biophysical variable.

In this case a DQ_QuantitativeAttributeAccuracy quality element is the convenient, and measures such as Root Mean Square Error, Mean Absolute Error or Quantitative attribute correctness can be used.

Table 16. Thematic accuracy: NDVI accuracy (pixel-level)

Line	Component	Description
1	Name	Mean Absolute Error
2	Alias	MAE
3	Element name	quantitative attribute accuracy
4	Basic measure	—
5	Definition	Mean Absolute Error (MAE) of NDVI values computed using original bands uncertainty and error propagation
6	Description	—
7	Parameter	—
10	Source reference	QualityML proposal (based on ISO 19157 Id. 28, Id. 29 but applied to quantitative attribute accuracy)
11	Example	A coverage describing the mean absolute error for each pixel in an NDVI product
12	Identifier	*http://www.qualityml.org/1.0/measure/MeanAbsoluteError*
13	Domain	MAE can be used over several differential errors domain. In this case the domain is: *http://www.qualityml.org/1.0/domain/DifferentialErrors1D*
14	Metrics	- metrics: *http://www.qualityml.org/1.0/metrics/MeanAbsolute* - value: *pixel-level MAE result*

6.3. Currency

6.3.1. General purpose metadata: Image acquisition date

In generic terms, currency is defined by the distance between the date the data was captured and the current time. In the ISO 19115 and 19115-1 the acquisition date can be documented as the temporal extent of the resource.

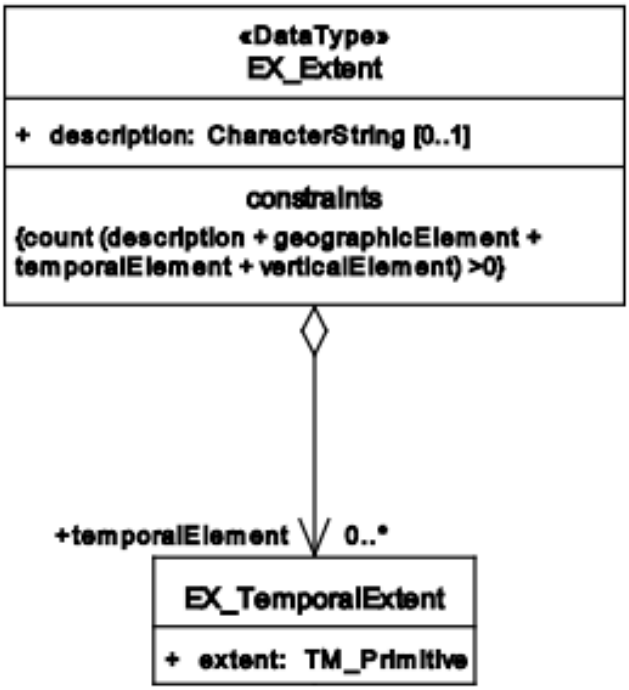

Figure 5. EX_TemporalExtent as a way to document the capture date

Then to calculate the currency, a difference between the temporal extent and the current date will give us a currency estimation.

Note that a temporal extent can be expressed not only by a single date but by a range. A range is useful for a single scene that is captured by a push-broom sensor. Sometimes a dataset is composed by juxtaposition/mosaic of scenes with a variety of acquisition time. In this case, the temporal extent of the result could be quite wide. Depending on the circumstances, it could diminish the quality of the data.

6.3.2. Currency: temporal validity with a domain requirement

If a currency requirement is described in a certain environment, or for a certain product specification, a *Temporal validity* indicator could be used to state the degree of agreement between image temporal extent and the requirement.

For example, if the product specifications has a requirement that considers pixels that are older than a limit (e.g. 24 months old) as not current enough, the temporal validity quality indicator can report this, describing the requirement as a parameter in the domain of the quality measure, as explained (with the same example) in QualityML domain (with parameters).

Table 17. Items that does not conform to a temporal validity requirement

Line	Component	Description
1	Name	Items
2	Alias	—
3	Element name	Temporal validity

Line	Component	Description
4	Basic measure	Value domain
5	Definition	Indication of if an item is conformant or not with a rule. The conformance or non-conformance can be expressed as a boolean, count or rate.
6	Description	—
7	Parameter	"max" for a maximum ratio if rate is used
10	Source reference	ISO 19157 Id. 14, Id.15 (boolean), Id.16 (count), Id.17 + Id.18 (rate), unified in QualityML
11	Example	30 % of the pixels are older than a 24 month of the time intended for the data (older than 2014-05-01)
12	Identifier	*http://www.qualityml.org/1.0/measure/ValueDomain*
13	Domain	Items metrics can be used with Conformance or Non-Conformance domains. In both cases the domain can describe a "range" ("min" and/or "max") and/or a "rule" parameters to define the requirement, as needed. In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - type: *range* - min: *2014-05-01* - rule: *Pixels are older than a 24 month of the time intended for the data (i.e. older than 2014-05-01)*
14	Metrics	In this case the metrics and its parameter are: - metrics: *http://www.qualityml.org/1.0/metrics/items* - type: *rate* - max: *100* - value: *30*

6.4. Completeness

In a dataset that has been produced by a classification of imagery (or a similar thecnique), some expected classes can be completely missing, but there is evidence that the class is present in the area.

Several quality measures to describe omission can be used are:

- Missing class
- Nodata values
- Flag areas

Table 18. Missing class

Line	Component	Description
1	Name	missing class

Line	Component	Description
2	Alias	missing category
3	Element name	omission
4	Basic measure	error indicator
5	Definition	indication showing that a specific class is missing in the data. It can be expressed as a boolean, count or rate.
6	Description	—
7	Parameter	—
10	Source reference	ISO 19157 Id. 5, Id. 6, Id. 7, unified in QualityML
11	Example	a class "boreal forest" is not present in the classified image. In situ data (ground truth) suggest that boreal forest is present in the scene extent.
12	Identifier	*http://www.qualityml.org/1.0/measure/MissingClass*
13	Domain	In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - rule: *Boreal class missing*
14	Metrics	*http://www.qualityml.org/1.0/metrics/items*

Table 19. Nodata values

Line	Component	Description
1	Name	Nodata areas
2	Alias	
3	Element name	omission
4	Basic measure	error indicator
5	Definition	This quality measure indicates if there is absence of data for some reason that made impossible to get data in this area. In the case that the measure is provided as a pixel level quality, the resulting parameters are presented in the form of a data mask
6	Description	Typically used in imagery to mark pixels that has a value that does not represent a correct measurement. Can be reported as a boolean per pixel or a percentage of "nodata" pixels in an scene. This metrics is particularly relevant when building big mosaics of several scenes where, despite the efforts of the producer, some parts of the mosaic area are covered by any of the scenes and result in nodata values.
7	Parameter	—

Line	Component	Description
10	Source reference	—
11	Example	
12	Identifier	*http://www.qualityml.org/1.0/measure/NodataAreas*
13	Domain	In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - rule: *Nodata areas*
14	Metrics	*http://www.qualityml.org/1.0/metrics/items*

Table 20. Flag values

Line	Component	Description
1	Name	Flag areas
2	Alias	
3	Element name	omission
4	Basic measure	error indicator
5	Definition	This quality measure indicates if a data has the presence of some detected as anomalous such as snow or cloud. In the case that the measure is provided as a pixel level quality, the resulting parameters are presented in the form of a data mask.
6	Description	Typically used in imagery to mark pixels that show snow instead of "land" behind, covered by clouds, in the shadow of a cloud, etc. It can be reported as a boolean per pixel or a percentage of "flagged" pixels in an scene. This metrics is particularly relevant when building big mosaics of several scenes where, despite the efforts of the producer, some parts of the mosaic area cannot be covered with better scenes and still contain snow, cloud, shadows or other artifacts.
7	Parameter	—
10	Source reference	—
11	Example	
12	Identifier	*http://www.qualityml.org/1.0/measure/FlagAreas*
13	Domain	In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - rule: *Cloud areas*
14	Metrics	*http://www.qualityml.org/1.0/metrics/items*

Related to cloud cover, if a single value for the whole image is described, then there are two

options:

- general purpose metadata: *cloudCoverPercentage* in MD_ContentInformation | MD_ImageDescription can be used if a single percentage is used. This is a general metadata element is described in ISO 19115
- quality measure FlagAreas (QualityML) using the domain as "cloud areas" can be used. This is mandatory if a coverage indicating whether each pixel is a cloud or not is used, but it is optional if a single percentage for the whole images is given

6.4.1. Completeness: cloud cover (percentage result) and snow cover (pixel-level result)

Note, that metrics/items allow for both a boolean indicator, the number of pixels or a percentage. Thus, usually when a pixel-value result is used, the items is used as a boolean to indicate (for each pixel) if a certain characteristic is present (e.g. is this pixel covered by snow). When the result is given as a quantitative result, usually rates (or number of pixels) are used (e.g. 26% of the image is covered by clouds).

In the next sections QualityML Flag areas measure is used to describe snow cover, including pixel-level encoding examples. On the other hand, cloud cover is provided using the general purpose metadata *cloudCoverPercentage*:

Table 21. 'Flag areas' element and 'Items' metrics for snow cover pixel-level indicator

Quality measure	Domain	Metrics	Example	Elements to be encoded
Flag areas	Non Conformance	items	Flag areas indicate in this report the snow cover of the image	*measure/FlagAreas* result value type: *Items* result value record: - items/rate: *pixel-level boolean indicator* - NonConformance/rule: *a coverage result is used including for each pixel a boolean indication whether the pixel is covered by snow*

6.5. Consistency

Consistencies in imagery is mainly related to homogeneity among servers images and even among sensors in order to have common measures along time two produce radiometric-consistent time series.

One way to document part of this information is using general purpose metadata to describe the processing level of the image. Satellite optical imagery is commonly classified in raw data (where the content of the data is related with the quantity of light measured) and high level products (where the content of the data is related to a biophysical or biochemical variable of the terrain; quantitative or categorical). But not all raw data is equivalent and there are several levels of processing to remove atmospheric and topographical effects. In general this is characterized by a

level number, but agencies are not completely consistent with the numbering of the levels.

In the ISO 19115-1 introduces a new element in *MD_CoverageDescription* called *processingLevelCode* that is an *MD_Identifier*.

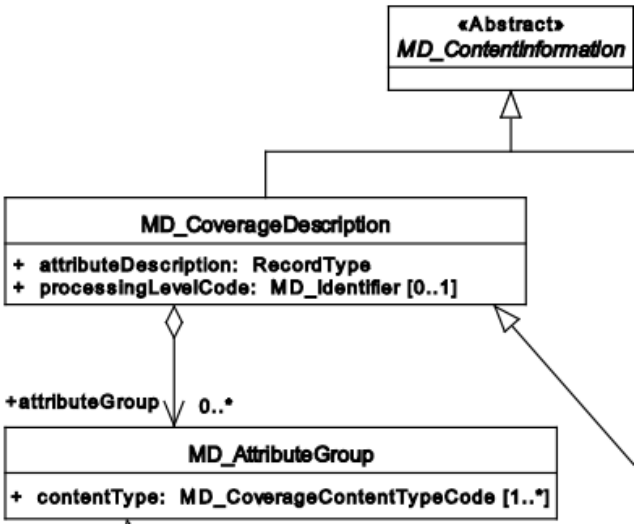

Figure 6. MD_CoverageDescription showing the processingLevelCode

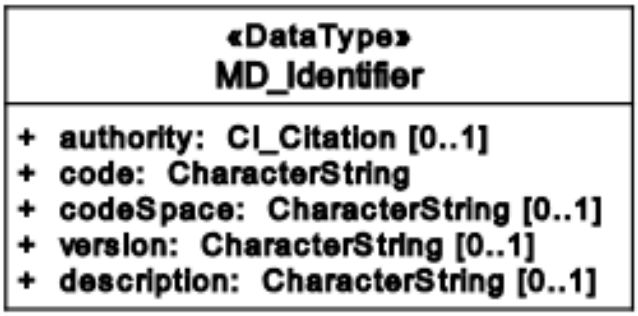

Figure 7. MD_Identifier that is used as processingLevelCode data type

This data type allows for the different agencies to define their own identifiers and reference them here.

Our proposal is to define the levels, not as a sequential numbers but as codes that can be better understood by users.

This are the proposed MD_Identifiers that can also be maintained in the QualityML vocabulary:

Table 22. processingLevel identifiers defined in QualityML

code	codeSpace	version	description
DigitalNumbers	http://www.qualityml.org/processLevel	1.0	Digital Numbers
TopOfAtmosphereReflectance	http://www.qualityml.org/processLevel	1.0	Top of the Atmosphere Reflectance
SurfaceReflectanceAtmosphericModel	http://www.qualityml.org/processLevel	1.0	Surface Reflectance based on atmospheric modeling

code	codeSpace	version	description
SurfaceReflectancePseudoInvariantAreas	http://www.qualityml.org/processLevel	1.0	Surface Reflectance based on pseudo invariant areas

Moreover, quality measures related to consistency can be provided such as:

- logical consistency - domain consistency - value domain: it can be used to describe domain inconsistencies on the image values (e.g. reflectances or normalized vegetation index values outside theoretical range)
- logical consistency - format consistency - physical structure conflicts: problems sue to format consistency (e.g. incorrect file format or value type selection or encoding)

6.5.1. Consistency: surface reflectance and rate of domain inconsistencies

Next sections will show and example of image processing level documentation to describe the values of the image according to a general codeSpace (liked to a QualityML dictionary), as well as to include a quality measure to describe the rate on pixel values that are not conformant to its value domain, because they have reflectance values higher that the maximum (e.g. due to sensor saturation).

Table 23. Items that does not conform to a the value domain

Line	Component	Description
1	Name	Items
2	Alias	—
3	Element name	Domain consistency
4	Basic measure	Value domain
5	Definition	Pixel values that are not conformant to its value domain, because they have reflectance values higher that the maximum (e.g. due to sensor saturation)
6	Description	—
7	Parameter	"max" for a maximum ratio if rate is used
10	Source reference	ISO 19157 Id. 14, Id.15 (boolean), Id.16 (count), Id.17 + Id.18 (rate), unified in QualityML
11	Example	5% of the pixels have reflectances values higher than its theoretical maximum, due to sensor saturation
12	Identifier	*http://www.qualityml.org/1.0/measure/ValueDomain*

Line	Component	Description
13	Domain	Items metrics can be used with Conformance or Non-Conformance domains. In both cases the domain can describe a "range" ("min" and/or "max") and/or a "rule" parameters to define the requirement, as needed. In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - rule: *Pixel reflectances with values higher than its theoretical maximum, due to sensor saturation*
14	Metrics	In this case the metrics and its parameter are: - metrics: *http://www.qualityml.org/1.0/metrics/items* - type: *rate* - max: *100* - value: *5*

Chapter 7. Dataset level quality

This ER assumes that dataset level quality and pixel level quality will be documented in and ISO 19115-1/19157 metadata document following ISO 19115-3 XML encoding. In this chapter we discuss the different encoding for dataset level quality.

Since ISO 19115-1 was initially designed for dataset level metadata, it is logical to assume that dataset level quality will be more direct to do. This is true in simple cases but it can also be more complex than initially expected, in particular, if the dataset is a composite of several layers and each layer can have quality indicators that requires more that one parameter to be described.

NOTE

ISO 19115 and 19115-1 schemas are not identical as:
- new elements are added to ISO 19115-1 (e.g codeSpace for MD_Identifier, DQ_CoverageResult for DQ_Result,...)
- namespaces have dramatically changed on ISO 19115-1.

In this ER, ISO 19115 encoding will only be described if differences between both encoding differ only in the namespaces notation. On the other hand, if other differences arise between the two schemas, then both encodings will be provided.

7.1. Basic encoding

ISO 19157 describes the DQ_DataQuality package, used in ISO 19115-1 to describe the overall assessment of quality of a resource (trough the "dataQualityInfo" association). As described in previous clauses, to describe a quality elements several aspects should be described.

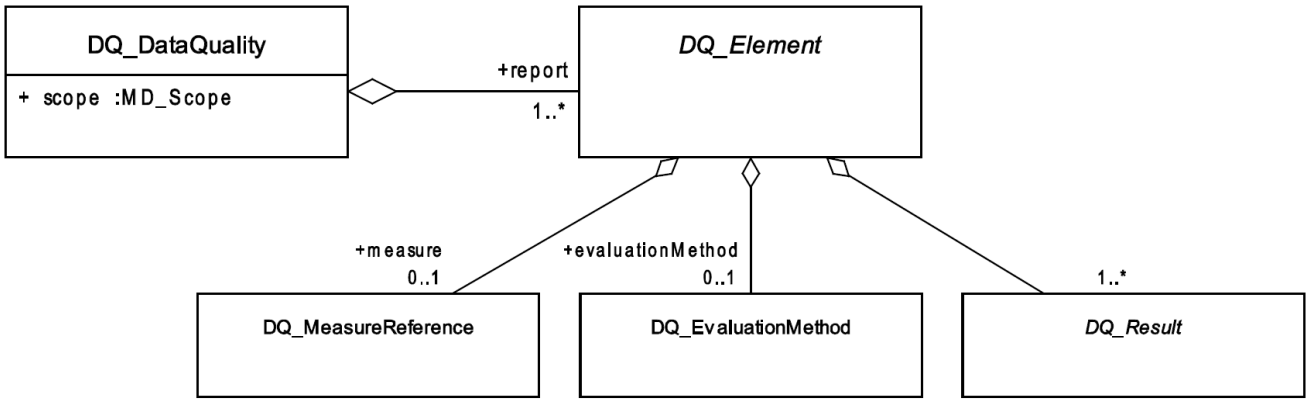

Figure 8. Data quality units and data quality element descriptors as defined in ISO 19157

See also Data Quality Classes and DQ Element as 19157 for a list and description of the data quality elements, that are components describing a certain aspect of the quality of geographic data an have been organized into different categories.

7.2. Scope encoding

When describing the quality of geographic data, different quality elements and different subsets of the data may be considered. In order to describe these, data quality units are used. A data quality

unit is the combination of a scope and data quality elements. The scope of the data quality unit(s) specifies the extent, spatial and/or temporal, and/or common characteristic(s) that identify the data on which data quality is to be evaluated.

The following are examples of what defines a data quality scope (see also MD_Scope in ISO 19115-1):

- a dataset series;
- a dataset;
- a subset of data defined by one or more of the following characteristics:
  - types of items (sets of feature types, feature attributes, feature operations or feature relationships);
  - specific items (sets of feature instances, attribute values or instances of feature relationships);
  - geographic extent;
  - temporal extent (the time frame of reference and accuracy of the time frame).

On of the most typical scopes for a data quality unit is the dataset, but sometimes other are used. Moreover, sometimes the scope may include a specific extent (spatial, temporal or both) to describe more information.

This is the case of the quality measure conceptually described in QM_1 Accuracy Satellite Position QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_1 Accuracy Satellite Position old 19115 XML and QM_1 Accuracy Satellite Position 19115_1 XML.

The encoding of a temporal extent for the dataset series scope following ISO 19115 is described here for convenience:

```
    <gmd:scope>
        <gmd:DQ_Scope>
            <gmd:level>
                <gmd:MD_ScopeCode codeListValue="series" codeList="MD_ScopeCode"/>
            </gmd:level>
            <gmd:extent>
                <gmd:EX_Extent>
                    <gmd:temporalElement>
                        <gmd:EX_TemporalExtent>
                            <!-- temporal extent used to compute "positional
uncertainty of satellite position" should be stated here  -->
                            <gmd:extent>
                                <gml:TimePeriod gml:id="SensorAccuracy_Scope_TempExt">
                                    <gml:beginPosition>2016-01-
01T00:00:00.000+01:00</gml:beginPosition>
                                    <gml:endPosition>2016-06-
30T00:00:00.000+01:00</gml:endPosition>
                                </gml:TimePeriod>
                            </gmd:extent>
                        </gmd:EX_TemporalExtent>
                    </gmd:temporalElement>
                </gmd:EX_Extent>
            </gmd:extent>
        </gmd:DQ_Scope>
    </gmd:scope>
```

7.3. Give semantics to Quality Measures

According to ISO 19157, a data quality element should refer to one measure only, by means of a measure reference, providing an identifier of a measure fully described elsewhere and/or providing the name and a short description of the measure.

To facilitate dataset comparisons, it is necessary that the results in the data quality reports are expressed in a comparable way and that there is a common understanding of the data quality measures that have been used. In order to make evaluations and data quality reports (metadata or a standalone quality report) from different sources comparable, standardized data quality measures described in ISO 19157, Annex D, shall be used when possible.

This ER in its Quality Measures Raster chapter describes quality measures, sometimes directly coming from the standard, or sometimes described in QualityML.

Encoding of quality measures in the metadata shall directly link to catalogues of data quality measures to fully describe the measures referenced in the data quality report of the data evaluated. Our proposal is to link to QualityML that includes ISO 19157 measures and extend it with new definitions.

7.3.1. ISO 19157 XML encoding of 'Measure reference'

ISO 19157 gives examples of how DQ_MeasureReference should be described in metadata (e.g. in section E.4.1.2 Reporting commission, table E.12):

- nameOfMeasure/CharacterString: *Number of excess item*
- measureIdentification/MD_Identifier/code/CharacterString: *2*
- measureDescription/CharacterString: *number of items within the dataset that should not have been in the dataset*

In this example, the namespace (in the 'codeSpace' element of the MD_Identifier) is not defined. Moreover, the identifier is not directly linked to a catalogue defining the measure.

Encoded in XML following ISO 19115 this example looks like:

```
     <gmd:nameOfMeasure>
          <gco:CharacterString>Number of excess item</gco:CharacterString>
     </gmd:nameOfMeasure>
     <gmd:measureIdentification>
          <gmd:MD_Identifier>
               <gmd:code>2</gmd:code>
          </gmd:MD_Identifier>
     </gmd:measureIdentification>
     <gmd:measureDescription>
          <gco:CharacterString>Number of items within the dataset that should not have
been in the dataset</gco:CharacterString>
     </gmd:measureDescription>
```

7.3.2. ISO 19139 XML encoding of a link (*Anchor* element) instead of CharacterString

According to ISO 19139, Anchor is substitutable of CharacterString, so this ability can be used when instantiating the web environment extensions for properties having CharacterString type in ISO 19115-1. The main advantage of using 'Anchor' element is that it allows to define an "xlink:href" attribute to include a link to the catalogue definition of the code or the codeSpace when describing a measure.

7.3.3. Encoding proposal including semantics

Our general proposal to give semantics to a Measure reference (by means of directly link it to a catalogue) is the use of **Anchor** element in:

- MD_Identifier/code (ISO 19115 and ISO 19115-1 schemas)
- MD_Identifier/codeSpace (only in ISO 19115-1 schemas)

to include direct links to QualityML measures as a recommended option (but any other dictionary that a user would like to use is also possible).

Next examples are covering the quality measure conceptually described in QM_3 Accuracy Processed pixel location QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_3 Accuracy Processed pixel location old 19115 XML and QM_3 Accuracy Processed pixel location 19115_1 XML.

The encodings of a nameOfMeasure, measureIdentification and measureDescription for this quality measure are described here for convenience (as an exemplification of the Anchor element usage):

First option: 19115 schema

```
    <gmd:DQ_GriddedDataPositionalAccuracy>
        <gmd:nameOfMeasure>
            <gco:CharacterString>Root Mean Square (RMS)</gco:CharacterString>
        </gmd:nameOfMeasure>
        <gmd:measureIdentification>
            <gmd:MD_Identifier>
                <gmd:code>
                    <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/RootMeanSquare">RootMeanSquare</gmx:A
nchor>
                </gmd:code>
            </gmd:MD_Identifier>
        </gmd:measureIdentification>
        <gmd:measureDescription>
            <gco:CharacterString>Measure of the differences between 2D values
predicted by a model or an estimator and the values actually observed in a set of
ground control points.</gco:CharacterString>
        </gmd:measureDescription>
        <gmd:result>
            [...]
        </gmd:result>
    </gmd:DQ_GriddedDataPositionalAccuracy>
```

Second option: 19115-1 schema

```
    <mdq:DQ_GriddedDataPositionalAccuracy>
        <mdq:measure>
            <mdq:DQ_MeasureReference>
                <mdq:measureIdentification>
                    <mcc:MD_Identifier>
                        <mcc:code>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/RootMeanSquare">RootMeanSquare</gcx:A
nchor>
                        </mcc:code>
                        <mcc:codeSpace>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                        </mcc:codeSpace>
                        <mcc:version>
                            <gco:CharacterString>1.0</gco:CharacterString>
                        </mcc:version>
                    </mcc:MD_Identifier>
                </mdq:measureIdentification>
                <mdq:nameOfMeasure>
                    <gco:CharacterString>Root Mean Square (RMS)</gco:CharacterString>
                </mdq:nameOfMeasure>
                <mdq:measureDescription>
                    <gco:CharacterString>Measure of the differences between 2D values
predicted by a model or an estimator and the values actually observed in a set of
ground control points.</gco:CharacterString>
                </mdq:measureDescription>
            </mdq:DQ_MeasureReference>
        </mdq:measure>
        <mdq:result>
            [...]
        </mdq:result>
    </mdq:DQ_GriddedDataPositionalAccuracy>
```

7.4. Give semantics to Quality Metrics

7.4.1. Basic encoding

Quality Metrics are described in QualityML as the elements used to describe the result for a certain Quality Measure. A single quality measure can be expressed by different metrics, and this is the reason for the split between the two concepts. More details can be found in QualityML quality vocabulary and encoding or in QualityML.

Quantitative result may be a single value or multiple values, depending on the values of attributes valueType and valueStructure defined in the description of the measure applied. The attribute valueRecordType is used to describe how the valueType and valueStructure defined in the measure are implemented to provide the value of the quantitative result.

QualityML metrics schema (available at http://qualityml.geoviqua.org/schemas/qualityml/1.0/qualityml.xsd) describes the metrics defined in QualityML that can be used in an XML encoding within the gmd:value/gco:Record.

When describing a quantitative result, the recommendation to give semantics is to:

- DQ_QuantitativeResult/valueType/RecordType: include an xlink:href attribute to QualityML description of the metrics used
- DQ_QuantitativeResult/value/Record: include the QualityML element for the selected RecordType.
- DQ_QuantitativeResult/valueUnit: include an xlink:href attribute to a units dictionary

Next examples are still covering the quality measure conceptually described in Product accuracy (x,y,z): Processed pixel location accuracy on the ground. The full XML encoding for this quality measure can be found in XML examples of encoding for Quality Measures for Raster, in ISO 19115 encoding and ISO 19115-1 encoding.

The encodings of a RecordType, Record and valueUnit for this quality measure result are described here for convenience (as an exemplification of the QualityML metrics elements usage):

First option: 19115 schema

```
    <gmd:DQ_GriddedDataPositionalAccuracy>
        [...]
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/RootMeanSquareError2D">Root mean
square error 2D</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                <gmd:value>
                    <gco:Record>
                        <qml:RootMeanSquare>
                            <qml:values>2.9</qml:values>
                        </qml:RootMeanSquare>
                    </gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
    </gmd:DQ_GriddedDataPositionalAccuracy>
```

Second option: 19115-1 schema

```
    <mdq:DQ_GriddedDataPositionalAccuracy>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq:DQ_QuantitativeResult>
                <mdq:value>
                    <gco:Record>
                        <qml:RootMeanSquare>
                            <qml:values>2.9</qml:values>
                        </qml:RootMeanSquare>
                    </gco:Record>
                </mdq:value>
                <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                <mdq:valueRecordType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/RootMeanSquareError2D">Root mean
square error 2D</gco:RecordType>
                </mdq:valueRecordType>
            </mdq:DQ_QuantitativeResult>
        </mdq:result>
    </mdq:DQ_GriddedDataPositionalAccuracy>
```

7.4.2. Parameter encoding

Some metrics, or some metrics options need the description of some parameters to be fully described. A first example of this is the description of the parameter "max" when an Items/rate metrics is used, or the parameter "level" when the CircularError metrics is used. More details can be found in QualityML quality vocabulary and encoding or in QualityML.

Next examples are covering the quality measure conceptually described in QM_2 Accuracy Pixel location QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_2 Accuracy Pixel location old 19115 XML and QM_2 Accuracy Pixel location 19115_1 XML.

The encodings of a RecordType, Record and valueUnit for this quality measure result are described here for convenience (as an exemplification of the QualityML metrics elements, and its parameters, usage):

First option: 19115 schema

```
    <gmd:DQ_GriddedDataPositionalAccuracy>
        [...]
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/CircularError">Circular
Error</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                <gmd:value>
                    <gco:Record>
                        <qml:CircularError level="0.95">
                            <qml:values>3.2</qml:values>
                        </qml:CircularError>
                    </gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
    </gmd:DQ_GriddedDataPositionalAccuracy>
```

Second option: 19115-1 schema

```
    <mdq:DQ_GriddedDataPositionalAccuracy>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq:DQ_QuantitativeResult>
                <mdq:value>
                    <gco:Record>
                        <qml:CircularError level="0.95">
                            <qml:values>3.2</qml:values>
                        </qml:CircularError>
                    </gco:Record>
                </mdq:value>
                <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                <mdq:valueRecordType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/CircularError">Circular
Error</gco:RecordType>
                </mdq:valueRecordType>
            </mdq:DQ_QuantitativeResult>
        </mdq:result>
    </mdq:DQ_GriddedDataPositionalAccuracy>
```

7.5. Give semantics to Quality Domain

7.5.1. Basic encoding

Some metrics, or some metrics options need the description of some parameters to be fully described. A firs example of this is the description of the parameter "max" when an Items/rate metrics is used, or the parameter "level" when the CircularError metrics is used. Quality Metrics are described in QualityML as the elements used to describe the result for a certain Quality Measure. A single quality measure can be expressed by different metrics, and this is the reason for the split between the two concepts. More details can be found in QualityML quality vocabulary and encoding or in QualityML.

The use of the Domain of the Quality measure, un QualityML has been described in QualityML vocabulary encoding, allowing then a higher agrupation schema. QualityML describes several domains to which the quality measures can be applied.

Next examples are covering the quality measure conceptually described in QM_7 Consistency SurfRefl value domain QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_7 Consistency SurfRefl value domain old 19115 XML and QM_7 Consistency SurfRefl value domain 19115_1 XML.

The encodings of a RecordType, Record and valueUnit for this quality measure result are described here for convenience, as an exemplification of the QualityML metrics elements, its parameters, and a general "rule" for the quality metric domain:

First option: 19115 schema

```
    <gmd:DQ_DomainConsistency>
        [...]
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                <gmd:value>
                    <gco:Record>
                        <qml:Items>
                            <qml:rate max="100">5</qml:rate>
                        </qml:Items>
                        <qmld:NonConformance>
                            <qmld:rule>Pixel reflectances with values higher than its
theoretical maximum, due to sensor saturation</qmld:rule>
                        </qmld:NonConformance>
                    </gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
    </gmd:DQ_DomainConsistency>
```

Second option: 19115-1 schema

```
    <mdq:DQ_DomainConsistency>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq:DQ_QuantitativeResult>
                <mdq:value>
                    <gco:Record>
                        <qml:Items>
                            <qml:rate max="100">5</qml:rate>
                        </qml:Items>
                        <qmld:NonConformance>
                            <qmld:rule>Pixel reflectances with values higher than its
theoretical maximum, due to sensor saturation</qmld:rule>
                        </qmld:NonConformance>
                    </gco:Record>
                </mdq:value>
                <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                <mdq:valueRecordType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                </mdq:valueRecordType>
            </mdq:DQ_QuantitativeResult>
        </mdq:result>
    </mdq:DQ_DomainConsistency>
```

7.5.2. Parameters encoding

Sometimes restrictions on the domain used needs to be described, and thus some parameters are needed for the domain.

Next examples are covering the quality measure conceptually described in QM_5 Currency TemporalValidity QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_5 Currency TemporalValidity old 19115 XML and QM_5 Currency TemporalValidity 19115_1 XML.

The encodings of a RecordType, Record and valueUnit for this quality measure result are described here for convenience, as an exemplification of the QualityML metrics elements, its parameters, and also a domain and its parameters:

First option: 19115 schema

```
    <gmd:DQ_TemporalValidity>
        [...]
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                <gmd:value>
                    <gco:Record>
                        <qml:Items>
                            <qml:rate max="100">30</qml:rate>
                        </qml:Items>
                        <qmld:NonConformance>
                            <qmld:range>
                                <qmld:min>
                                    <qmld:date>2014-05-01</qmld:date>
                                </qmld:min>
                            </qmld:range>
                            <qmld:rule>Pixels are older than a 24 month of the time
intended for the data (i.e. older than 2014-05-01)</qmld:rule>
                        </qmld:NonConformance>
                    </gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
    </gmd:DQ_TemporalValidity>
```

Second option: 19115-1 schema

```
    <mdq:DQ_TemporalValidity>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq:DQ_QuantitativeResult>
                <mdq:value>
                    <gco:Record>
                        <qml:Items>
                            <qml:rate max="100">30</qml:rate>
                        </qml:Items>
                        <qmld:NonConformance>
                            <qmld:range>
                                <qmld:min>
                                    <qmld:date>2014-05-01</qmld:date>
                                </qmld:min>
                            </qmld:range>
                            <qmld:rule>Pixels are older than a 24 month of the time
intended for the data (i.e. older than 2014-05-01)</qmld:rule>
                        </qmld:NonConformance>
                    </gco:Record>
                </mdq:value>
                <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                <mdq:valueRecordType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                </mdq:valueRecordType>
            </mdq:DQ_QuantitativeResult>
        </mdq:result>
    </mdq:DQ_TemporalValidity>
```

7.6. Other general metadata elements related with quality

7.6.1. Temporal extent

Related to temporal quality element, the TemporalExtent general metadata element is usually documented, sometimes giving information needed to better understand the quality measure.

Next examples are covering the description of temporal extent that is related to the quality measure conceptually described in QM_5 Currency TemporalValidity QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_5 Currency TemporalValidity old 19115 XML and QM_5 Currency TemporalValidity 19115_1 XML.

The encodings of temporalExtent (following ISO 19115) is described here for convenience (other sections of the same example have been shown previously and the full XML is also referenced above):

```
<gmd:EX_Extent>
    <gmd:temporalElement>
        <gmd:EX_TemporalExtent>
            <gmd:extent>
                <gml:TimePeriod gml:id="TE_1">
                    <gml:beginPosition>2012-07-15</gml:beginPosition>
                    <gml:endPosition>2016-05-01</gml:endPosition>
                </gml:TimePeriod>
            </gmd:extent>
        </gmd:EX_TemporalExtent>
    </gmd:temporalElement>
</gmd:EX_Extent>
```

7.6.2. Cloud coverage percentage

Related to Completeness quality element, the cloudCoverPercentage general metadata element is usually documented (in MD_ContentInformation | MD_ImageDescription) if only a dataset-level value is available. If a clouds flag mask (pixel-level) is available, it can be described in metadata as explained in Pixel level Quality can be used if a single percentage is used.

Next examples are covering the description of cloudCoverPercentage that is related to the quality measure conceptually described in QM_6 Completeness FlagAreas QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_6 Completeness FlagAreas old 19115_XML and QM_6 Completeness FlagAreas 19115_1 XML.

The encodings of temporalExtent (following ISO 19115) is described here for convenience (other sections of the same example will be discussed in Pixel Level):

First option: 19115 schema

```
    <gmd:contentInfo>
        <gmd:MD_ImageDescription>
            <gmd:attributeDescription>
                <gco:RecordType>Imagery bands</gco:RecordType>
            </gmd:attributeDescription>
            <gmd:contentType>
                <gmd:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
                codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
            </gmd:contentType>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="Imagery_R">
                    <gmd:descriptor>
                        <gco:CharacterString>Red imagery band</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="Imagery_G">
                    <gmd:descriptor>
                        <gco:CharacterString>Green imagery band</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="Imagery_B">
                    <gmd:descriptor>
                        <gco:CharacterString>Blue imagery band</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:cloudCoverPercentage>
                <gco:Real>26</gco:Real>
            </gmd:cloudCoverPercentage>
        </gmd:MD_ImageDescription>
    </gmd:contentInfo>
```

Second option: 19115-1 schema

```
    <mdb:contentInfo>
        <mrc:MI_ImageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>Imagery and quality flag bands</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="Imagery">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"
```

```
codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Red imagery
band</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Green imagery
band</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Blue imagery
band</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="SnowCover_Quality_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        [...]
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:cloudCoverPercentage>
                <gco:Real>26</gco:Real>
            </mrc:cloudCoverPercentage>
        </mrc:MI_ImageDescription>
    </mdb:contentInfo>
```

7.6.3. Image processing level

One way to document part of this information is using general purpose metadata to describe the

processing level of the image. In the ISO 19115-1 introduces a new element in *MD_CoverageDescription* called *processingLevelCode* that is an *MD_Identifier* and thus the proposal is to link to a code described in the QualityML vocabulary, using the Anchor element (as explained in other examples above).

Next examples are covering the description of image processing level general metadata, that is related to the quality measure conceptually described in QM_7 Consistency SurfRefl value domain QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_7 Consistency SurfRefl value domain old 19115 XML and QM_7 Consistency SurfRefl value domain 19115_1 XML.

The encoding of processingLevel (following ISO 19115) is described here for convenience (other sections of the same example have been shown previously and the full XML is also referenced above):

First option: 19115 schema

```
    <gmd:contentInfo>
        <gmd:MD_ImageDescription>
            <gmd:attributeDescription>
                <gco:RecordType>Surface reflectance</gco:RecordType>
            </gmd:attributeDescription>
            <gmd:contentType>
                <gmd:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
                codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
            </gmd:contentType>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="SurfRefl_AttributeGroup">
                    <gmd:descriptor>
                        <gco:CharacterString>Surface Reflectance</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:processingLevelCode>
                <gmd:MD_Identifier>
                    <gmd:code>
                        <gmx:Anchor
xlink:href="http://www.qualityml.org/processLevel">SurfaceReflectancePseudoInvariantAr
eas</gmx:Anchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:processingLevelCode>
        </gmd:MD_ImageDescription>
    </gmd:contentInfo>
```

Second option: 19115-1 schema

```
    <mdb:contentInfo>
        <mrc:MI_ImageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>Surface reflectance</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:processingLevelCode>
                <mcc:MD_Identifier>
                    <mcc:code>
                        <gcx:Anchor
xlink:href="http://www.qualityml.org/processLevel">SurfaceReflectancePseudoInvariantAr
eas</gcx:Anchor>
                    </mcc:code>
                    <mcc:codeSpace>
                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                    </mcc:codeSpace>
                    <mcc:version>
                        <gco:CharacterString>1.0</gco:CharacterString>
                    </mcc:version>
                </mcc:MD_Identifier>
            </mrc:processingLevelCode>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="SurfRefl_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Surface
Reflectance</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
        </mrc:MI_ImageDescription>
    </mdb:contentInfo>
```

7.7. A multicomponent quality attribute

Sometimes for describing a quality parameter, not only one but two values are needed. This is easily solved using quality measures described in QualityML as the schema for each metric can include several child elements if needed.

Next examples are covering the description the quality measure conceptually described in QM_3b

Accuracy DEM accuracy QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_3b Accuracy DEM accuracy old_19115 XML and QM_3b Accuracy DEM accuracy 19115_1 XML.

The encoding of DQ_QuantitativeResult (following ISO 19115) is described here for convenience (the full XML is referenced above):

```
    <gmd:DQ_QuantitativeResult>
        <gmd:valueType>
            <gco:RecordType
xlink:href="http://www.uncertml.org/distributions/normal">Normal
Distribution</gco:RecordType>
        </gmd:valueType>
        <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
        <gmd:value>
            <gco:Record>
                <un:NormalDistribution>
                    <un:mean>1.21</un:mean>
                    <un:variance>3.06</un:variance>
                </un:NormalDistribution>
            </gco:Record>
        </gmd:value>
    </gmd:DQ_QuantitativeResult>
```

Chapter 8. Pixel level Quality

This ER assumes that dataset level quality and pixel level quality will be documented in an ISO 19115-1 metadata document. In this chapter we discuss the different possible encoding for pixel level quality, reviewing the alternatives and defining a recommended proposal. Moreover, some examples of quality measures described in Quality Measures Raster will be included.

8.1. Encoding alternatives

ISO 19115-1 was initially designed for dataset level metadata, but there are still some ways of convey *per pixel level* quality (one of them included in the ISO 19115-2). Again, it is not complicated to do it in simple cases but it can also be more complex than initially expected, in particular, if the dataset is a composite of several layers (or bands) and each layer can have quality indicators that requires more that one parameter to be described.

The current approach for CoverageResult supposes that the “coverage” that defines the quality is NOT part of the dataset but part of the metadata. This way adds a link to an “external file” as a MX_DataFile. This has 2 problems:

- Since this file is not part of the dataset it has no “distribution” so it is probable that it is never distributed. People will forget about the link or will not be able to support it due to that current metadata systems assume the metadata record is a “monolithic” self-contained XML.
- In remote sensing, data “bands” and quality “bands” are usually integrated in a single package and they are distributed together. E.g. you can have an IR band, 3 visible bands + a cloud flag band, a nodata flag band, and even an uncertainty band. All bands should be described in the contentInfo.

This is why two approaches will be considered:

- Quality bands included in the product (and thus explained in the same metadata file) *e.g.* for MODIS or Landsat-8 quality masks.
- Quality bands included in other files or even obtained through web services

This two approaches are more inline with common practice in the remote sensing domain.

8.1.1. Alternative 1: Quality coverage

ISO 19115-2 adds a new subclass to DQ_Element specifically designed to include a coverage that contains a raster file that has values indicating the error or the uncertainty for each pixel.

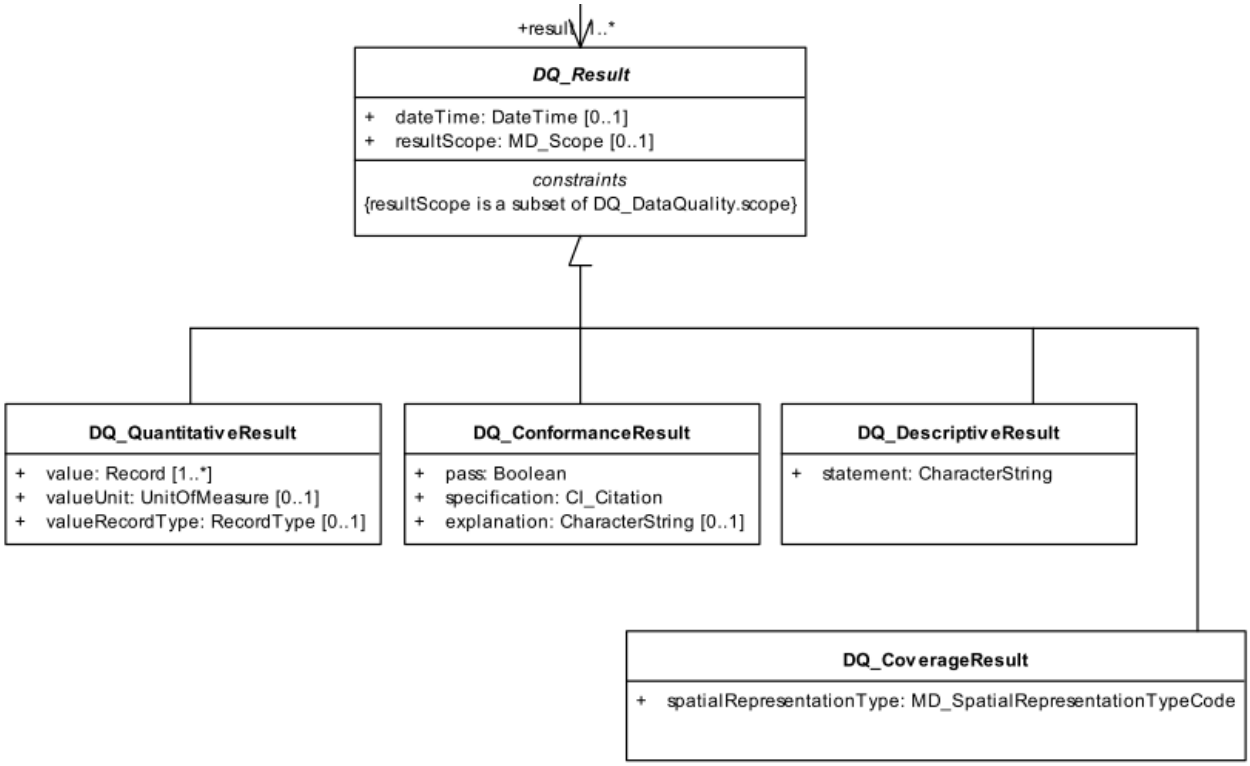

Figure 9. DQ_CoverageResult as an alternative to DQ_QuantitativeResult

The coverage result has several additional attributes of type MD_SpatialRepresentation (to describe the grid; its dimension etc), MD_CoverageDescription (to describe the semantics of the coverage and a description of several bands grouped in attribute groups), MD_Format (describes de format of the data) and MX_DataFile (that allow for the inclusion of the file itself).

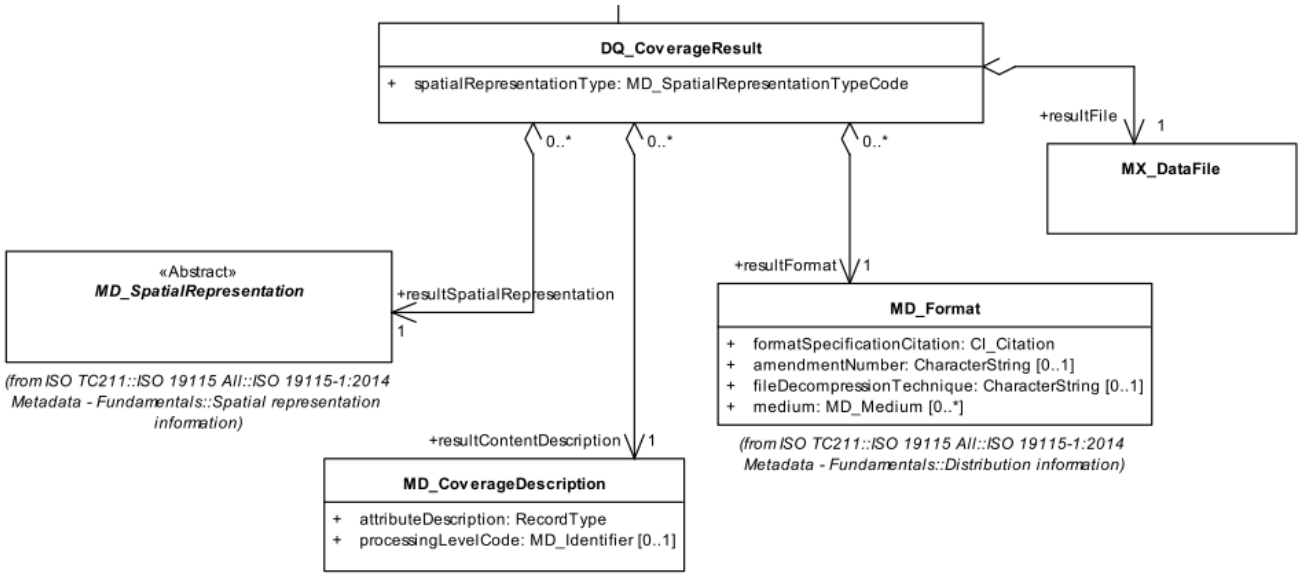

Figure 10. DQ_CoverageResult details

Example:

XML code fragment for a DQ_DataQuality element that has QE_CoverageResult as a result.

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:gml="http://www.opengis.net/gml/3.2"
```

```
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mrd="http://standards.iso.org/iso/19115/-3/mrd/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0 ../19115/-
3/gco/1.0/gco.xsd http://www.opengis.net/gml/3.2 ../19136/gml.xsd
http://standards.iso.org/iso/19115/-3/cit/1.0 ../19115/-3/cit/1.0/cit.xsd
http://standards.iso.org/iso/19115/-3/gcx/1.0 ../19115/-3/gcx/1.0/gcx.xsd
http://standards.iso.org/iso/19115/-3/mcc/1.0 ../19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../19157/-2/mdq/1.0/mdq.xsd
http://standards.iso.org/iso/19115/-3/mrd/1.0 ../19115/-3/mrd/1.0/mrd.xsd
http://standards.iso.org/iso/19115/-3/mrc/1.0 ../19115/-3/mrc/1.0/mrc.xsd
http://standards.iso.org/iso/19115/-3/msr/1.0 ../19115/-3/msr/1.0/msr.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_QuantitativeAttributeAccuracy>
            <mdq:result>
                <mdq:QE_CoverageResult>
                    <mdq:spatialRepresentationType>
                        <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                        codeList="MD_SpatialRepresentationTypeCode"/>
                    </mdq:spatialRepresentationType>
                    <mdq:resultFile>
                        <mdq:QualityResultFile>
                            <mdq:fileName>
                                <gcx:FileName>UncertaintyCoverage.tiff</gcx:FileName>
                            </mdq:fileName>
                            <mdq:fileType>
                                <gcx:MimeFileType type="image/tiff"/>
                            </mdq:fileType>
                            <mdq:fileDescription>
                                <gco:CharacterString>Uncertainty Coverage
Description</gco:CharacterString>
                            </mdq:fileDescription>
                            <mdq:fileFormat xlink:href="#TIFF_File_format"/>
                        </mdq:QualityResultFile>
                    </mdq:resultFile>
                    <mdq:resultSpatialRepresentation>
                        <msr:MD_Georectified>
                            <msr:numberOfDimensions>
```

```
                                <gco:Integer>2</gco:Integer>
                            </msr:numberOfDimensions>
                            <msr:cellGeometry>
                                <msr:MD_CellGeometryCode codeListValue="point"
codeList="MD_CellGeometryCode"/>
                            </msr:cellGeometry>
                            <msr:transformationParameterAvailability>
                                <gco:Boolean>false</gco:Boolean>
                            </msr:transformationParameterAvailability>
                            <msr:checkPointAvailability>
                                <gco:Boolean>false</gco:Boolean>
                            </msr:checkPointAvailability>
                            <msr:cornerPoints>
                                <gml:Point gml:id="ID_1">
                                    <gml:pos>123.0 45.0</gml:pos>
                                </gml:Point>
                            </msr:cornerPoints>
                            <msr:cornerPoints>
                                <gml:Point gml:id="ID_2">
                                    <gml:pos>123.1 45.1</gml:pos>
                                </gml:Point>
                            </msr:cornerPoints>
                            <msr:pointInPixel>

<msr:MD_PixelOrientationCode>upperRight</msr:MD_PixelOrientationCode>
                            </msr:pointInPixel>
                        </msr:MD_Georectified>
                    </mdq:resultSpatialRepresentation>
                    <mdq:resultContentDescription>
                        <mrc:MD_ImageDescription>
                            <mrc:attributeDescription>
                                <gco:RecordType>uncertainty</gco:RecordType>
                            </mrc:attributeDescription>
                        </mrc:MD_ImageDescription>
                    </mdq:resultContentDescription>
                    <mdq:resultFormat>
                        <mrd:MD_Format id="TIFF_File_format">
                            <mrd:formatSpecificationCitation>
                                <cit:CI_Citation>
                                    <cit:title>
                                        <gco:CharacterString>TIFF
format</gco:CharacterString>
                                    </cit:title>
                                </cit:CI_Citation>
                            </mrd:formatSpecificationCitation>
                        </mrd:MD_Format>
                    </mdq:resultFormat>
                </mdq:QE_CoverageResult>
            </mdq:result>
        </mdq:DQ_QuantitativeAttributeAccuracy>
    </mdq:report>
```

```
</mdq:DQ_DataQuality>
```

Limitations:

- A single MX_File can be added per DQ_element. A Quality Indicator with more that one component should be described using a multiband file. Semantics of what is each band may be included in resultContentDescription or in the same MX_File if the format allow it (*e.g.* netCDF file, MMZ file,...)
- Difficulties to add semantics. The only possible way is attributeDescription (RecordType).
- Coverage data is described as a file that has a path. A more service oriented approach is sometimes convenient.
- The coverage of quality is sometimes one of the "bands" offered in the band collection, and this needs to be properly described.

8.1.2. Alternative 2: Quality band

ISO 19115-1 adds a new MD_CoverageContentTypeCode called "qualityInformation" specifically designed to include a "band" that contains a raster file that has values indicating the error or the uncertainty for each pixel.

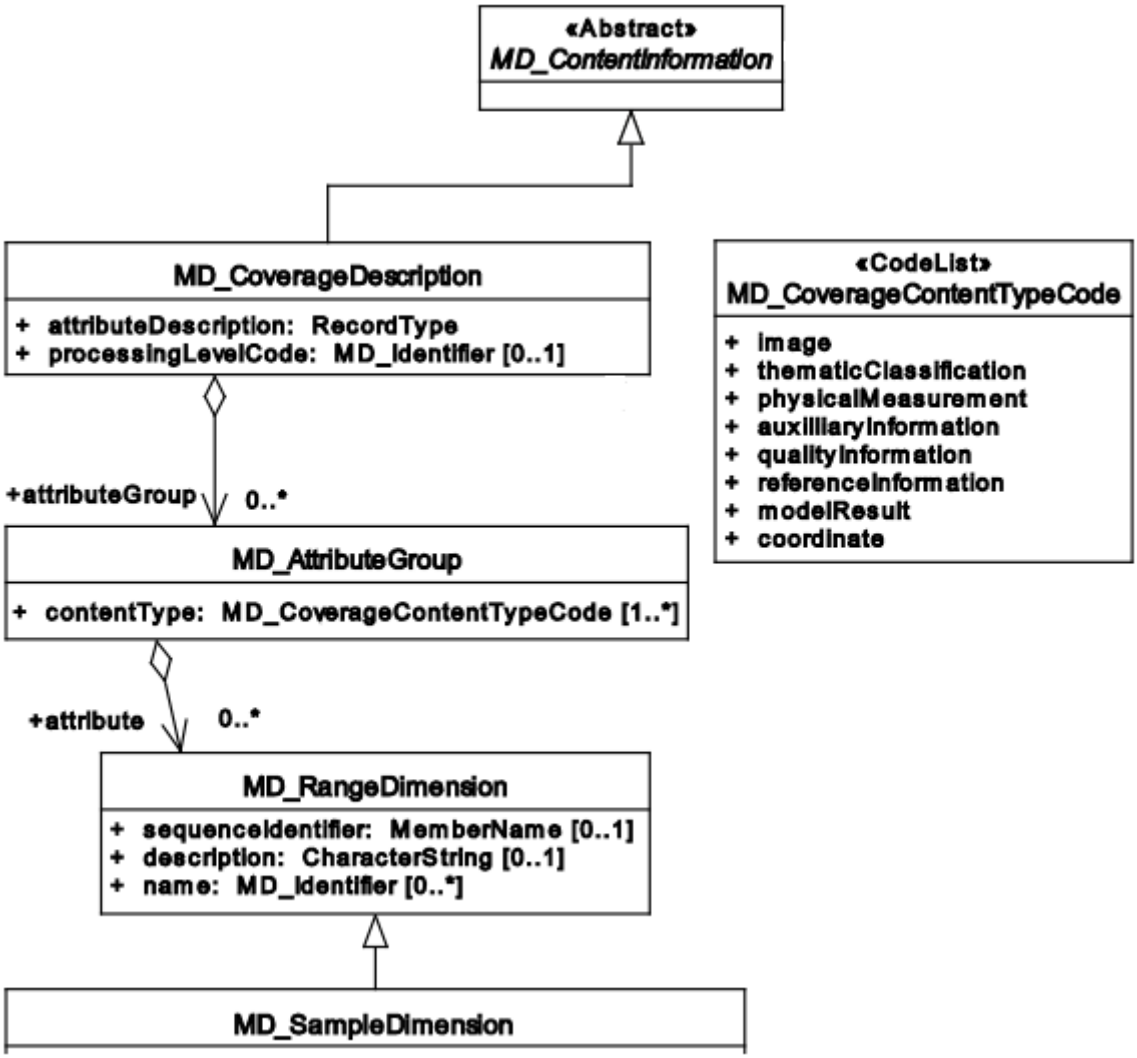

Figure 11. MD_CoverageContentTypeCode quality band

Example:

XML code fragment for a MD_CoverageDescription element that has MD_CoverageContentTypeCode value "qualityInformation".

```
<?xml version="1.0" encoding="UTF-8"?>
<mrc:MD_CoverageDescription xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0 ../19115/-
3/gco/1.0/gco.xsd http://standards.iso.org/iso/19115/-3/mcc/1.0 ../19115/-
3/mcc/1.0/mcc.xsd http://standards.iso.org/iso/19115/-3/mrc/1.0 ../19115/-
3/mrc/1.0/mrc.xsd">
    <mrc:attributeDescription>
        <gco:RecordType/>
    </mrc:attributeDescription>
    <mrc:attributeGroup>
        <mrc:MD_AttributeGroup>
            <mrc:contentType>
                <mrc:MD_CoverageContentTypeCode codeListValue="Image"
codeList="MD_CoverageContentTypeCode"/>
            </mrc:contentType>
            <mrc:attribute>
                <mrc:MD_SampleDimension>
                    <mrc:name>
                        <mcc:MD_Identifier>
                            <mcc:code>
                                <gco:CharacterString>image12345</gco:CharacterString>
                            </mcc:code>
                            <mcc:codeSpace>

<gco:CharacterString>www.opengis.net/testbed12</gco:CharacterString>
                            </mcc:codeSpace>
                        </mcc:MD_Identifier>
                    </mrc:name>
                </mrc:MD_SampleDimension>
            </mrc:attribute>
        </mrc:MD_AttributeGroup>
    </mrc:attributeGroup>
    <mrc:attributeGroup>
        <mrc:MD_AttributeGroup>
            <mrc:contentType>
                <mrc:MD_CoverageContentTypeCode codeListValue="qualityInformation"
                codeList="MD_CoverageContentTypeCode"/>
            </mrc:contentType>
            <mrc:attribute>
                <mrc:MD_SampleDimension>
                    <mrc:description>
                        <gco:CharacterString>Quality layer for the
image12345</gco:CharacterString>
```

```
                    </mrc:description>
                    <mrc:name>
                        <mcc:MD_Identifier>
                            <mcc:code>

<gco:CharacterString>quality12345</gco:CharacterString>
                            </mcc:code>
                            <mcc:codeSpace>

<gco:CharacterString>www.opengis.net/testbed12</gco:CharacterString>
                            </mcc:codeSpace>
                        </mcc:MD_Identifier>
                    </mrc:name>
                    <mrc:otherProperty>
                        <gco:Record>$$</gco:Record>
                    </mrc:otherProperty>
                </mrc:MD_SampleDimension>
            </mrc:attribute>
        </mrc:MD_AttributeGroup>
    </mrc:attributeGroup>
</mrc:MD_CoverageDescription>
```

Limitations:

- No direct link to the quality layer from the DQ_Result. It is supposed to be part of the dataset an included in the dataset distribution somehow.
- Difficulties to add semantics. The only possible way is otherPropertyType (RecordType).
- No way of saying "this layer is the quality layer of this other layer". It could be done with otherProperty (Record).

8.1.3. Alternative 3: Direct link from DQ_QuantitativeResult

The *value* is a Result that is a free type that allows for including a link to a external or an internal coverage. See DQ_CoverageResult as an alternative to DQ_QuantitativeResult.

XML code fragment for a MD_CoverageDescription element that has MD_CoverageContentTypeCode value "qualityInformation".

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mrd="http://standards.iso.org/iso/19115/-3/mrd/1.0"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0 ../19115/-
3/gco/1.0/gco.xsd http://standards.iso.org/iso/19115/-3/gcx/1.0 ../19115/-
```

```
3/gcx/1.0/gcx.xsd http://standards.iso.org/iso/19115/-3/mcc/1.0 ../19115/-
3/mcc/1.0/mcc.xsd http://standards.iso.org/iso/19157/-2/mdq/1.0 ../19157/-
2/mdq/1.0/mdq.xsd  http://standards.iso.org/iso/19115/-3/mrd/1.0 ../19115/-
3/mrd/1.0/mrd.xsd http://standards.iso.org/iso/19115/-3/cit/1.0 ../19115/-
3/cit/1.0/cit.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_QuantitativeAttributeAccuracy>
            <mdq:result>
                <mdq:DQ_QuantitativeResult>
                    <mdq:value>
                        <gco:Record>
                            <mdq:QualityResultFile>
                                <mdq:fileName>

<gcx:FileName>UncertaintyCoverage.tiff</gcx:FileName>
                                </mdq:fileName>
                                <mdq:fileType>
                                    <gcx:MimeFileType type="image/tiff"/>
                                </mdq:fileType>
                                <mdq:fileDescription>
                                    <gco:CharacterString>Uncertainty Coverage
Description</gco:CharacterString>
                                </mdq:fileDescription>
                                <mdq:fileFormat>
                                    <mrd:MD_Format id="TIFF_File_format">
                                        <mrd:formatSpecificationCitation>
                                            <cit:CI_Citation>
                                                <cit:title>
                                                    <gco:CharacterString>TIFF
format</gco:CharacterString>
                                                </cit:title>
                                            </cit:CI_Citation>
                                        </mrd:formatSpecificationCitation>
                                    </mrd:MD_Format>
                                </mdq:fileFormat>
                            </mdq:QualityResultFile>
                            <mdq:QualityResultFile>
                                <mdq:fileName>

<gcx:FileName>Uncertainty2Coverage.tiff</gcx:FileName>
                                </mdq:fileName>
                                <mdq:fileType>
                                    <gcx:MimeFileType type="image/tiff"/>
                                </mdq:fileType>
```

```
                                <mdq:fileDescription>
                                    <gco:CharacterString>Uncertainty2 Coverage
Description</gco:CharacterString>
                                </mdq:fileDescription>
                                <mdq:fileFormat xlink:href="#TIFF_File_format"/>
                            </mdq:QualityResultFile>
                        </gco:Record>
                    </mdq:value>
                    <mdq:valueUnit/>
                    <mdq:valueRecordType>
                        <gco:RecordType>Uncertainty</gco:RecordType>
                    </mdq:valueRecordType>
                </mdq:DQ_QuantitativeResult>
            </mdq:result>
        </mdq:DQ_QuantitativeAttributeAccuracy>
    </mdq:report>
</mdq:DQ_DataQuality>
```

Limitations:

- Difficulties to add semantics: a possible way is valueType (RecordType).
- Non standardized method: a Record can contain anything.

8.1.4. Alternative 3.1: Direct link from DQ_QuantitativeResult to a Quality distribution

The link can be done internally into a Distribution information to have a better description of how to get the quality dataset.

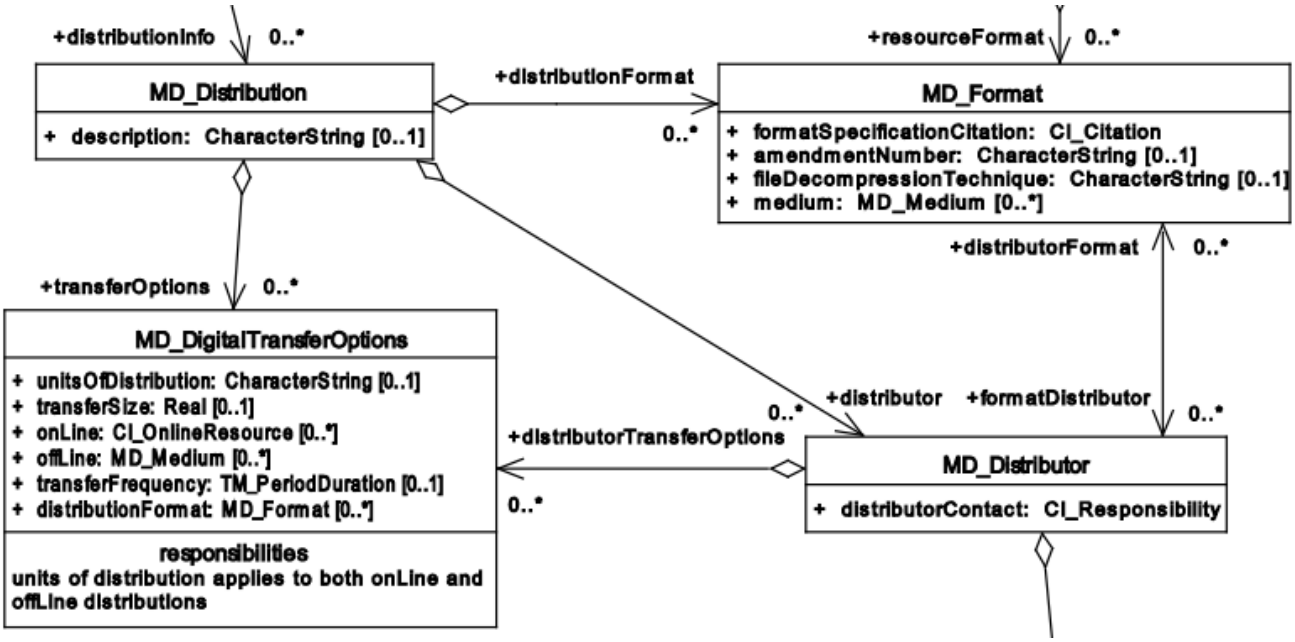

Figure 12. MD_Distribution

8.1.5. Alternative 4: Coverage Implementation Schema (CIS).

It could be possible to define a coverage using the CIS description. This is a very flexible data structure.

- The RangeType allows for describing the semantics of a quality band.
- Recently introduced PartitionSet allow for delivering several DomainSets and RangeSets allowing for organizing the data into several layers stored in different files or in the same file.

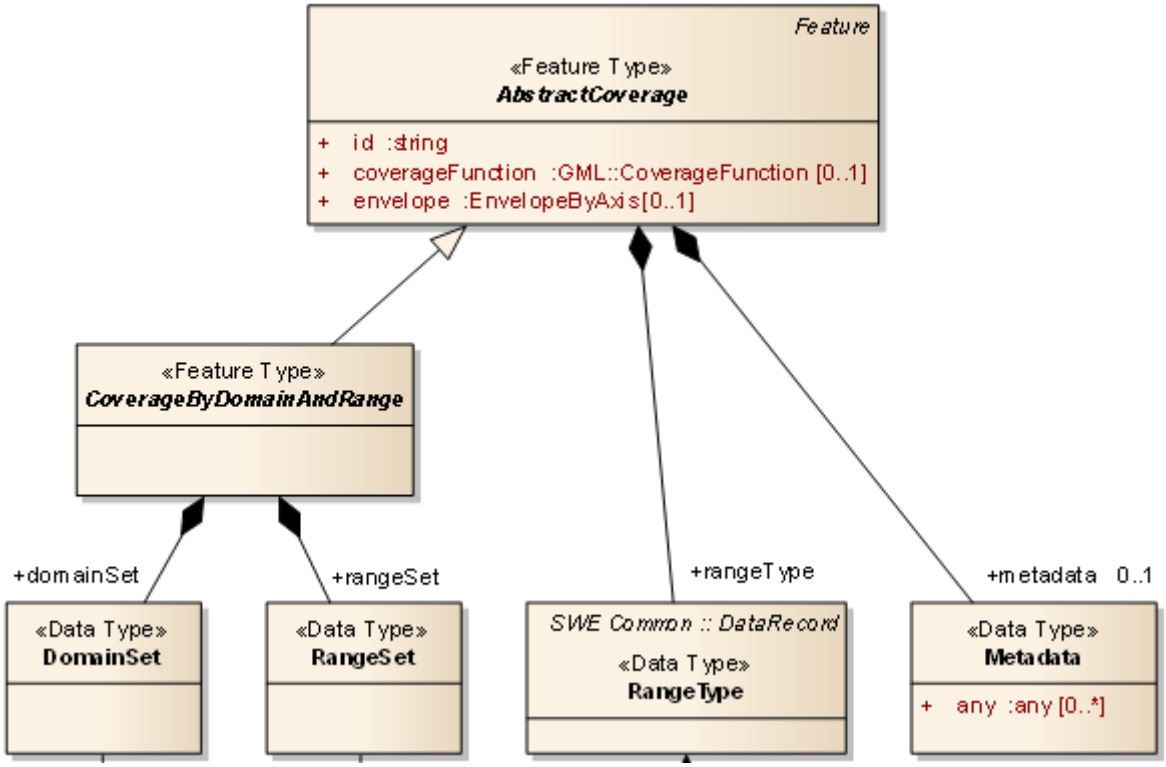

Figure 13. Coverage Implementation Schema basic UML class model

Limitations:

- There is no direct mechanism to link two bands together (band A is quality of band B).

8.1.6. Final proposal: Combined alternative

Final proposal includes a combination of alternative 1, 2 and 3.1 to avoid the maximum number of limitations. Even though, the proposal based on current ISO 19115-1 still has a minor drawback, and thus a suggestion to the amendment to ISO 19157 that includes DQ_CoverageResult modification is described.

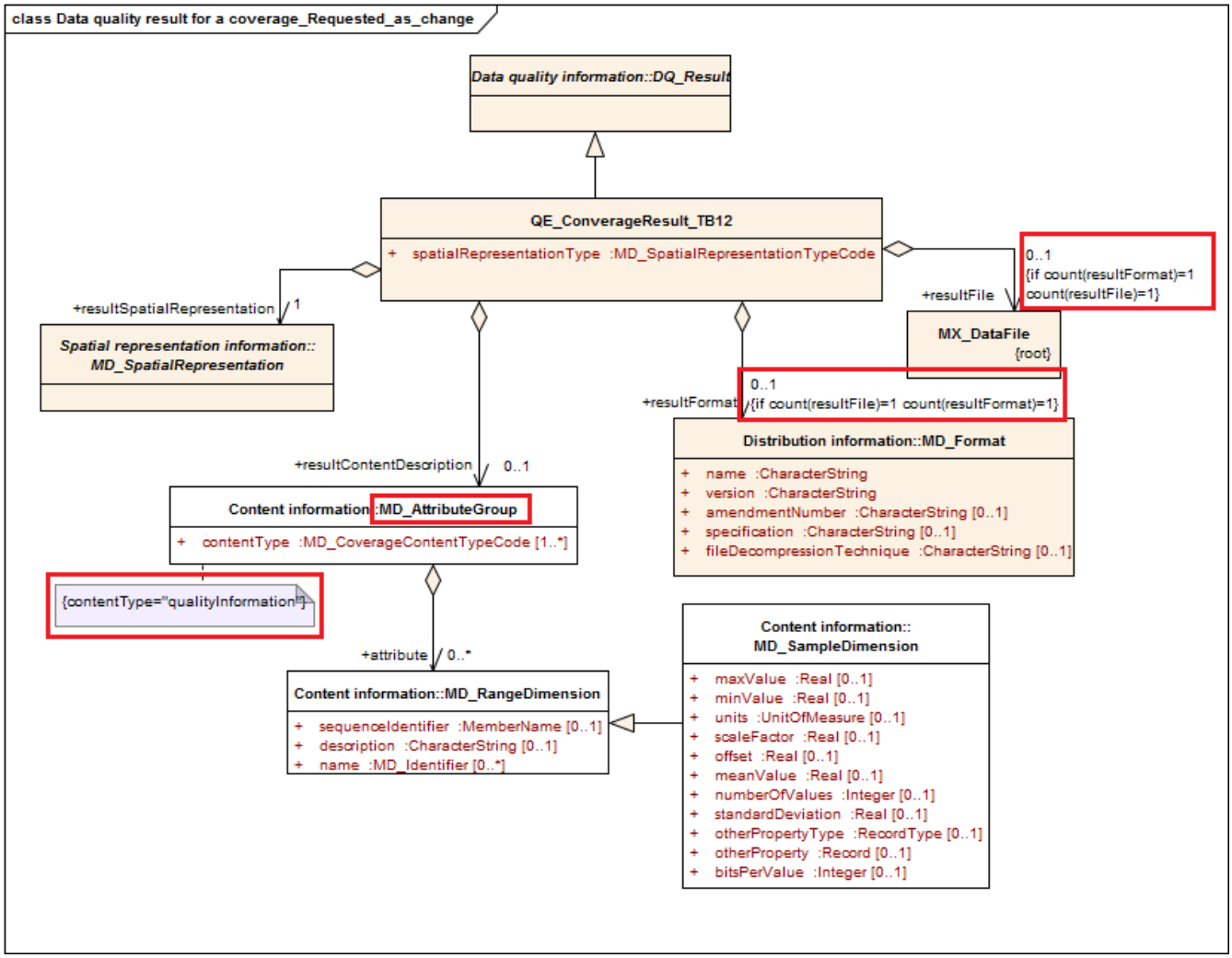

Figure 14. DQ_CoverageResult modification

Changes from current DQ_CoverageResult are red-box market in the figure above. Explanations on each of these changes are included in the next section.

First approach: quality bands distributed within the product

To solve initial as well as different alternatives' issues, this approach combines the use of QE_CoverageResult (in DQ_DataQuality), MD_CoverageDescription and likely MD_Distribution and MD_SpatialRepresentation:

- **MD_CoverageDescription** (*i.e.* content information) describes all bands of the product: both the regular ones (image, thematic classification, etc) as well as and those including quality information. Last ones should be grouped under a attributeGroup marked as contentType=qualityInformation (already possible in the current ISO 19115-1). If needed, several groups attributeGroup marked as contentType=qualityInformation can be used if more than one quality reports are given. Moreover, if one quality report needs two components, this is easily codified using one attributeGroup with several elements. An example is shown in the first XML code fragment below.
- **DQ_CoverageResult** is used in the DQ_Result where a per pixel quality value is used. The recommended values for the elements are (an example is shown in the second XML code fragment below):
  - *resultFile and resultFormat* are not described in this approach, as the bands are already

described (and probably distributed) with the described dataset. As they are not needed in this case, the first two proposed changes on the current QE_CoverageResult is to define that they are not mandatory.

- *resultContentDescription* is not defined in-line but links to a MD_AttributeGroup where the semantic description of a group of quality bands (contentType of this MD_AttributeGroup should be "qualityInformation"). This is mandatory in this approach as this is half the way (a part from the general information on the quality section) to include semantics to the quality elements. This is also the third change to the current QE_CoverageResult and is needed as the information on the result content should be defined by a single attribute group defining quality (there is no need to relate the result with the description of the images, thematic classifications, but only to qualityInformation coverages).
- *resultSpatialRepresentation* is not defined in-line but links to a MD_SpatialRepresentation section on the metadata where the spatial representations for quality bands (or for some of them if needed). This is optional as is not needed to better describe semantics of quality bans, but is highly recommended to increase metadata coherence.

- **MD_Distribution**: *distributionInfo* will describe how to get the data including the quality bands (nothing new) making sure they are distributed with the data and not lost. Distribution information can describe a service as the access point to the data and the quality coverages as well.
- **MD_SpatialRepresentation**: *spatialRepresentation* will describe the spatial representation of the data and the quality bands. If the representation is not exactly the same (quality coverages may have, for example, a lower spatial resolution), two spatialRepresentations can be described and the one for the quality layers is the one linked from *resultSpatialRepresentation*. An example is shown in the third XML code fragment below.

1/ XML code **fragment for a MD_CoverageDescription** *with two MD_AttributeGroup: NDVI and NDVI_Quality*

```
    <mdb:contentInfo>
        <mrc:MD_CoverageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>NDVI and NDVI Quality</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="NDVI_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>NDVI</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="NDVI_Quality_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Quality of
NDVI</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
        </mrc:MD_CoverageDescription>
    </mdb:contentInfo>
```

2/ XML code **fragment for a DQ_DataQuality** *with a QE_CoverageResult_TB12 result*

Please note that the xlink:href with value "NDVI_Quality_AttributeGroup" links the "mrc:MD_AttributeGroup" with the same id that is described in the previous XML fragment.

```
    <mdb:dataQualityInfo>
        <mdq:DQ_DataQuality>
            <mdq:scope>
                <mcc:MD_Scope>
                    <mcc:level>
                        <mcc:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </mcc:level>
                </mcc:MD_Scope>
            </mdq:scope>
            <mdq:report>
                <mdq:DQ_QuantitativeAttributeAccuracy>
                    <mdq:result>
                        <mdq_TB12:QE_CoverageResult_TB12>
                            <mdq_TB12:spatialRepresentationType>
                                <mcc:MD_SpatialRepresentationTypeCode
codeListValue="grid"
                                codeList="MD_SpatialRepresentationTypeCode"/>
                            </mdq_TB12:spatialRepresentationType>
                            <mdq_TB12:resultSpatialRepresentation
xlink:href="#NDVI_Quality_SpatialRepresentation"/>
                            <mdq_TB12:resultContentDescription
xlink:href="#NDVI_Quality_AttributeGroup"/>
                        </mdq_TB12:QE_CoverageResult_TB12>
                    </mdq:result>
                </mdq:DQ_QuantitativeAttributeAccuracy>
            </mdq:report>
        </mdq:DQ_DataQuality>
    </mdb:dataQualityInfo>
```

3/ XML code **fragment for two MD_SpatialRepresentation** *describing NDVI and NDVI_Quality*

```
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="NDVI_SpatialRepresentation">
            <!-- inventend documentation for example purposes -->
            <msr:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </msr:numberOfDimensions>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>1600</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
```

```
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:cellGeometry>
                <msr:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </msr:cellGeometry>
            <msr:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </msr:transformationParameterAvailability>
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="NDVI_Quality_SpatialRepresentation">
            <!-- inventend documentation for example purposes, with a different
resolution for quality bands -->
            <msr:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </msr:numberOfDimensions>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">60</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
```

```
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>400</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">60</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:cellGeometry>
                <msr:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </msr:cellGeometry>
            <msr:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </msr:transformationParameterAvailability>
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
```

Second approach: quality bands distributed apart from the product

In case that the quality bands are not distributed with the product, then we only need to use **DQ_CoverageResult** in the following way:

- *resultFile and resultFormat* are used to describe the file including quality. If the quality parameter needs more than one coverage (*e.g.* minimum and maximum value for a confidence interval), a file that includes some semantics needs to be used, at least to identify which band represents which quality coverage (described in resultContentDescription as explained below).
- *resultContentDescription* is defined in-line describing quality coverages (contentType of this MD_AttributeGroup should be "quality").
- *resultSpatialRepresentation* is defined in-line describing quality coverages.

In this approach, **MD_CoverageDescription**, **MD_Distribution** and **MD_SpatialRepresentation** are not use to describe quality coverages as they are not directly part of the described dataset.

XML code for the final proposal if quality bands are given apart from the product

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mdq_TB12="http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0"
xmlns:mdt="http://standards.iso.org/iso/19115/-3/mdt/1.0"
```

```
xmlns:mil="http://standards.iso.org/iso/19115/-3/mil/1.0"
xmlns:mrd="http://standards.iso.org/iso/19115/-3/mrd/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/mdb/1.0 ../19115/-
3/mdb/1.0/mdb.xsd http://standards.iso.org/iso/19115/-3/gco/1.0 ../19115/-
3/gco/1.0/gco.xsd http://standards.iso.org/iso/19115/-3/cit/1.0 ../19115/-
3/cit/1.0/cit.xsd http://standards.iso.org/iso/19115/-3/gcx/1.0 ../19115/-
3/gcx/1.0/gcx.xsd http://standards.iso.org/iso/19115/-3/mcc/1.0 ../19115/-
3/mcc/1.0/mcc.xsd http://standards.iso.org/iso/19157/-2/mdq/1.0 ../19157/-
2/mdq/1.0/mdq.xsd http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0 ../19157/-
2/mdq/1.0/mdq_TB12.xsd http://standards.iso.org/iso/19115/-3/mdt/1.0 ../19115/-
3/mdt/1.0/mdt.xsd http://standards.iso.org/iso/19115/-3/mrd/1.0 ../19115/-
3/mrd/1.0/mrd.xsd http://standards.iso.org/iso/19115/-3/mrc/1.0 ../19115/-
3/mrc/1.0/mrc.xsd http://standards.iso.org/iso/19115/-3/mri/1.0 ../19115/-
3/mri/1.0/mri.xsd http://standards.iso.org/iso/19115/-3/msr/1.0 ../19115/-
3/msr/1.0/msr.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_QuantitativeAttributeAccuracy>
            <mdq:result>
                <mdq_TB12:QE_CoverageResult_TB12>
                    <mdq_TB12:spatialRepresentationType>
                        <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                        codeList="MD_SpatialRepresentationTypeCode"/>
                    </mdq_TB12:spatialRepresentationType>
                    <mdq_TB12:resultFile>
                        <mdq:QualityResultFile>
                            <mdq:fileName>
                                <gcx:FileName>UncertaintyCoverage.tiff</gcx:FileName>
                            </mdq:fileName>
                            <mdq:fileType>
                                <gcx:MimeFileType type="image/tiff"/>
                            </mdq:fileType>
                            <mdq:fileDescription>
                                <gco:CharacterString>Uncertaty Coverage
Description</gco:CharacterString>
                            </mdq:fileDescription>
                            <mdq:fileFormat
xlink:href="#TIFF_File_format"></mdq:fileFormat>
                        </mdq:QualityResultFile>
```

```
                    </mdq_TB12:resultFile>
                    <mdq_TB12:resultSpatialRepresentation>
                        <msr:MD_GridSpatialRepresentation
id="NDVI_Quality_SpatialRepresentation">
                            <!-- inventend documentation for example purposes, with a
different resolution for quality bands -->
                            <msr:numberOfDimensions>
                                <gco:Integer>2</gco:Integer>
                            </msr:numberOfDimensions>
                            <msr:axisDimensionProperties>
                                <msr:MD_Dimension>
                                    <msr:dimensionName>
                                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                                        codeList="MD_DimensionNameTypeCode"/>
                                    </msr:dimensionName>
                                    <msr:dimensionSize>
                                        <gco:Integer>800</gco:Integer>
                                    </msr:dimensionSize>
                                    <msr:resolution>
                                        <gco:Length uom="m">60</gco:Length>
                                    </msr:resolution>
                                </msr:MD_Dimension>
                            </msr:axisDimensionProperties>
                            <msr:axisDimensionProperties>
                                <msr:MD_Dimension>
                                    <msr:dimensionName>
                                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                                        codeList="MD_DimensionNameTypeCode"/>
                                    </msr:dimensionName>
                                    <msr:dimensionSize>
                                        <gco:Integer>400</gco:Integer>
                                    </msr:dimensionSize>
                                    <msr:resolution>
                                        <gco:Length uom="m">60</gco:Length>
                                    </msr:resolution>
                                </msr:MD_Dimension>
                            </msr:axisDimensionProperties>
                            <msr:cellGeometry>
                                <msr:MD_CellGeometryCode
codeListValue="MD_CellGeometryCode_area"
                                codeList="MD_CellGeometryCode"/>
                            </msr:cellGeometry>
                            <msr:transformationParameterAvailability>
                                <gco:Boolean>false</gco:Boolean>
                            </msr:transformationParameterAvailability>
                        </msr:MD_GridSpatialRepresentation>
                    </mdq_TB12:resultSpatialRepresentation>
                    <mdq_TB12:resultContentDescription>
                        <mrc:MD_AttributeGroup id="NDVI_Quality_AttributeGroup">
```

```
                            <mrc:contentType>
                                <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                            </mrc:contentType>
                            <mrc:attribute>
                                <mrc:MD_RangeDimension>
                                    <mrc:description>
                                        <gco:CharacterString>Quality of
NDVI</gco:CharacterString>
                                    </mrc:description>
                                </mrc:MD_RangeDimension>
                            </mrc:attribute>
                        </mrc:MD_AttributeGroup>
                    </mdq_TB12:resultContentDescription>
                    <mdq_TB12:resultFormat>
                        <mrd:MD_Format id="TIFF_File_format">
                            <mrd:formatSpecificationCitation>
                                <cit:CI_Citation>
                                    <cit:title>
                                        <gco:CharacterString>TIFF
format</gco:CharacterString>
                                    </cit:title>
                                </cit:CI_Citation>
                            </mrd:formatSpecificationCitation>
                        </mrd:MD_Format>
                    </mdq_TB12:resultFormat>
                </mdq_TB12:QE_CoverageResult_TB12>
            </mdq:result>
        </mdq:DQ_QuantitativeAttributeAccuracy>
    </mdq:report>
</mdq:DQ_DataQuality>
```

8.2. Examples of Pixel-level Quality Measures for Raster

In this sections two pixel-level quality measures previously described in Quality Measures Raster will be encoded and linked to QualityML to include semantics on them. In both examples we assume that the quality bands are distributed within the product.

8.2.1. Thematic accuracy: NDVI accuracy

This example is covering the quality measure conceptually described in QM_4 Accuracy NDVI accuracy QMR. The full XML encoding for this quality measure can be found in Appendix QM Raster, in QM_4 Accuracy NDVI accuracy old 19115 XML and QM_4 Accuracy NDVI accuracy 19115_1 XML.

XML section describing the scope and measure (nameOfMeasure, measureIdentification and

measureDescription, and its links to QualityML) are the same than in dataset-level quality measures (explained in DataSetLevel) and thus will not be described here (link to the full XML encoding has been also provided above).

As explained before, the recommended option when encoding the QE_CoverageResult (in fact QE_CoverageResult_TB12) is to link to spatialRepresentation and contentDescription described in the metadata, like this:

XML code for the QE_CoverageResult

```
    <mdq:DQ_QuantitativeAttributeAccuracy>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq_TB12:QE_CoverageResult_TB12>
                <mdq_TB12:spatialRepresentationType>
                    <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                    codeList="MD_SpatialRepresentationTypeCode"/>
                </mdq_TB12:spatialRepresentationType>
                <mdq_TB12:resultSpatialRepresentation
xlink:href="#NDVI_Quality_SpatialRepresentation"/>
                <mdq_TB12:resultContentDescription
xlink:href="#NDVI_Quality_AttributeGroup"/>
            </mdq_TB12:QE_CoverageResult_TB12>
        </mdq:result>
    </mdq:DQ_QuantitativeAttributeAccuracy>
```

In this example, we lack the link to QualityML to give semantics to the metrics used as this is not included in the *result* description.

Other metadata sections describing *NDVI_Quality_SpatialRepresentation* (that may differ from *NDVI_SpatialRepresentation*) and *NDVI_Quality_AttributeGroup* are provided within the same XML document (only main structure is included here for convenience). Please note that MD_CoverageContentTypeCode for quality bands is set to **qualityInformation**:

XML code for the spatialRepresentationInfo and ContentDescription

```
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="NDVI_SpatialRepresentation">
            [...]
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="NDVI_Quality_SpatialRepresentation">
            [...]
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    [...]
    <mdb:contentInfo>
        <mrc:MD_CoverageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>NDVI and NDVI Quality</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="NDVI_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        [...]
                     </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="NDVI_Quality_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                    </mrc:contentType>
                    <mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
        </mrc:MD_CoverageDescription>
    </mdb:contentInfo>
```

And looking to the full description of the NDVI_Quality_AttributeGroup is where link to quality metrics can be included:

XML code for the NDVI_Quality_AttributeGroup, including link to metrics description in MD_Identifier

```
    <mrc:MD_AttributeGroup id="NDVI_Quality_AttributeGroup">
        <mrc:contentType>
            <mrc:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
            codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
        </mrc:contentType>
        <mrc:attribute>
            <mrc:MD_RangeDimension>
                <mrc:description>
                    <gco:CharacterString>NDVI error</gco:CharacterString>
                </mrc:description>
                <mrc:name>
                    <mcc:MD_Identifier>
                        <mcc:code>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/metrics/MeanAbsolute">Mean
Absolute</gcx:Anchor>
                        </mcc:code>
                        <mcc:codeSpace>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                        </mcc:codeSpace>
                        <mcc:version>
                            <gco:CharacterString>1.0</gco:CharacterString>
                        </mcc:version>
                    </mcc:MD_Identifier>
                </mrc:name>
            </mrc:MD_RangeDimension>
        </mrc:attribute>
    </mrc:MD_AttributeGroup>
```

8.2.2. Completeness: snow cover

This example is covering the quality measure conceptually described in QM_6_Completeness_FlagAreas_QMR. The full XML encoding for this quality measure can be found in Appendix-QM-Raster, in QM_6_Completeness_FlagAreas_19115_XML and QM_6_Completeness_FlagAreas_19115_1_XML.

The encodings of metadata elements follow the same structure as the previous example. Several XML sections are described here for convenience:

XML code for the QE_CoverageResult

```
    <mdq:DQ_QuantitativeAttributeAccuracy>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq_TB12:QE_CoverageResult_TB12>
                <mdq_TB12:spatialRepresentationType>
                    <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                    codeList="MD_SpatialRepresentationTypeCode"/>
                </mdq_TB12:spatialRepresentationType>
                <mdq_TB12:resultSpatialRepresentation
xlink:href="#Imagery_SpatialRepresentation"/>
                <mdq_TB12:resultContentDescription
xlink:href="#SnowCover_Quality_AttributeGroup"/>
            </mdq_TB12:QE_CoverageResult_TB12>
        </mdq:result>
    </mdq:DQ_QuantitativeAttributeAccuracy>
```

Please note that in this example a single spatialRepresentationInfo is described for imagery and quality bands, and also note that cloudCoverPercentage general metadata is documented (using MI_ImageDescription instead of MD_CoverageDescription).

XML code for the spatialRepresentationInfo and ContentDescription

```
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="Imagery_SpatialRepresentation">
            [...]
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    [...]
    <mdb:contentInfo>
        <mrc:MI_ImageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>Imagery and quality flag bands</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="Imagery">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        [...]
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="SnowCover_Quality_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        [...]
                    <mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:cloudCoverPercentage>
                <gco:Real>26</gco:Real>
            </mrc:cloudCoverPercentage>
        </mrc:MI_ImageDescription>
    </mdb:contentInfo>
```

XML code for the SnowCover_Quality_AttributeGroup, including link to metrics description in MD_Identifier

```
    <mrc:MD_AttributeGroup id="SnowCover_Quality_AttributeGroup">
        <mrc:contentType>
            <mrc:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
            codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
        </mrc:contentType>
        <mrc:attribute>
            <mrc:MD_RangeDimension>
                <mrc:description>
                    <gco:CharacterString>Snow Cover flag band: boolean indication
whether the pixel is covered by snow</gco:CharacterString>
                </mrc:description>
                <mrc:name>
                    <mcc:MD_Identifier>
                        <mcc:code>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/metrics/Items">Items</gcx:Anchor>
                        </mcc:code>
                        <mcc:codeSpace>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                        </mcc:codeSpace>
                        <mcc:version>
                            <gco:CharacterString>1.0</gco:CharacterString>
                        </mcc:version>
                    </mcc:MD_Identifier>
                </mrc:name>
            </mrc:MD_RangeDimension>
        </mrc:attribute>
    </mrc:MD_AttributeGroup>
```

Chapter 9. WMTS with time accuracy

9.1. Introduction to time in WMTS

The WMTS specification does NOT describe a TIME parameter as the predecessor WMS did in an specific annex. Instead, WMTS provides a generic mechanism to define and use extra dimensions. This opens the door to server instances to define a temporal dimensions with "TIME" as a name, or with any other name too.

In essence a temporal dimension is defined by a sequence of valid time-date values in the ServiceMetadata. In fact, the need to enumerate all supported time-date values in the ServiceMetadata has been criticized as an inefficient strategy when many times are available. In the definition of the dimension values, the words 'default' and 'current' are reserved. In addition, the service support for 'current' as a value for a temporal dimension can be declared in the ServiceMetadata document in a boolean flag.

Nevertheless, when a client sends a query containing a tile-date value and it receives a tile image back, there is no additional information that allows the client to know the actual time of the data so there is an unknown temporal uncertainty in the data received and the client needs to trust the server and assume that the time requested is actually the time received. In other words, there is no mechanism in the WMTS standard for the server to communicate to the client the actual decision taken by the server and the actual date-time of the tile resource received.

NOTE	The Testbed 12 ER OGC 16-042 proposes a more complete definition of the TIME parameter to extend its semantics series, intervals and animations.

9.2. Time negotiation between client and service.

WMTS instances expose the possible times available for a temporal parameter as a list of values in the ServiceMetadata document. The client is supposed to request from one of the values of the list. The behavior of the service when a value that is not on the list of values in the service metadata is not completely defined (This situation could simply happen because the client considers the time as a continuum and it uses a time that is off by only a fraction of second). Essentially, there are 2 possibilities on how the service would react:

- The server considers the request is erroneous and issues an exception indicating InvalidParameterValue as a reason.
- The server tries to approximate the requested value to one it is able to respond.

Actually the second possibility is the only possible alternative when the client requests the 'current' time. As we said, there is no specification for the server on how to inform the client about the time actually returned so the client will only be able to guess the server behavior using the server values list as a clue. There is a need for the server to provide additional metadata to the client with the actual tile image.

If the data behind the WMTS service layer is a mosaic of different satellite scenes, the time uncertainty can increase since a satellite scene is many times acquired using a push-broom sensor

where each scanned line has a different time and in some situations a tile can be built as a result of two scenes tracks side-by-side. In these situations the time of the image is more uncertain.

9.2.1. The "best time" concept in a temporal quality aware service

Let's consider a situation where a region of the Earth is covered several times with the same satellite at different revisiting days with an optical sensor with the purpose of analyzing the status of the landscape and the human build infrastructures in it. In this situation, the parameter TIME='current' will result in the last available image. The problem occurs when the last available image is of poor quality due to cloud cover, snow cover or instrument malfunction. In this case, the most current image could not be the best available one. If the server is aware of the temporal quality and each tile has associated an internal quality metadata, then it could be possible to issue a request TIME='current.land' (we are using a '.' as a separator to mimic the Testbed 12 ER OGC 16-042) to request the *best* currently available image and the server will be able to react. We could combine this with other time values such as '2015-12-31.land' to indicate to the server that if 2015-12-31 is not good enough to recognize the land, then a previous is preferred.

Internally, the server will need to have an "algorithm" to determine what *better-for-the-user* means, based on the metadata (data quality information) available. Sensor quality, cloud cover percentage, inaccuracies in the position etc, could be used to determine the *fit-for-purpose* time value.

In a situation like the one described above, it is no longer possible for the client to guess the time of the individual tile and a mechanism to communicate the time and its temporal uncertainty is required.

9.3. Communicating tile level quality in the WMTS tile operation.

9.3.1. Introduction

This ER describes some approaches for a quality enabled WMTS that has been analyzed and considered. This section focuses on tile level quality and introduces practical ways to retrieve quality at the tile level. It also describes the finally implemented one and the lessons learned. The approach is designed based on a general WMTS 1.0 using KVP and REST requests with minimum changes or additions to the base standard.

In the testbed 12 a WMTS service with support for temporal accuracy information has been implemented and tested. The implementation was designed to convey quality information about "currency" and *time accuracy* in general but the approach is completely extendable and can be applied to other quality indicators (e.g. percentage of **clouds** per tile).

9.3.2. Tile layer quality

Tile layer services are expected to be easy to use, providing access to a product that is a spatial and temporal mosaic of a long time series. The quality of each tile depends on the quality of the source scenes. Potentially each tile can have a different quality information depending on the source scenes.

9.3.3. Implication of tile quality at different scale.

Different scale denominator tiles have different extends. Quality for big pixel sizes (big scale denominators) are closer to the overall quality and have a less space distribute significance. The quality for a small pixel sizes (small scale denominators) is more local and better expresses the geospatial distribution of the data quality. From our point of view, quality accuracy at small pixel size tiles will be more useful and makes more sense. However, quality for big pixel sizes can be generated for smaller pixel size tiles by aggregating the uncertainties.

9.3.4. Overall layer/dataset quality level

The use of WMTS Service Metadata document to specify the overall quality of the whole product by linking each layer to a global metadata file

9.3.5. Alternatives for communicating tile quality level quality

Alternative A: RESTful approach based on simple HTTP headers

The most simple approach to this use case is to use and HTTP header to record the time and its accuracy.

Currently, HTTP headers already includes a tag that is relevant to this discussion:

```
Last-Modified: Sun, 06 Nov 1994 08:49:37 GMT
```

The format of this tag is defined in the HTTP-Date part of the following document https://tools.ietf.org/html/rfc5988.

This is referring to the date when the data was prepared and the presence of this header field could condition the caching mechanism in Internet. If the same data is found wrong and is prepared again, the Last-Modified date is expecting to change even if the source date is the same and its date has not changed.

For the real content date we are proposing a new header field called:

```
X-Content-Date: Sun, 06 Nov 1994 08:49:37 GMT
```

The concept "content date" comes from the FGDC metadata. We could use alternative name more closed to the ISO 19115

```
X-Temporal-Extent: Sun, 06 Nov 1994 08:49:37 GMT
```

There could be the need to enrich the possibilities of the parameter by allowing for specification of more than one time instant or the addition of time internals. Time instants will be separated by '/' and intervals by square brackets [].

```
X-Temporal-Extent: [Sun, 06 Nov 1994 08:49:37 GMT-Mon, 07 Nov 1994 18:30:00 GMT]/Tue,
07 Nov 1995 08:00:00 GMT
```

This can be used by a WMTS the server to report the date of the content (the date of the imagery) rendered in the tile. The server only has to include this text into the http headers while serving the tile itself (while responding the unmodified GetTile operation in WMTS 1.0).

The way it is defined in the RFC5988, it does not contain the uncertainty on the time (or the time accuracy). We need to extend the syntax to allow this.

Our proposal is to add a another parameter that contains the a list of parameters that can completely express the quality measure and value of it. The parameters concepts comes from QualityML http://www.qualityml.org.

```
X-Temporal-Extent: Sun, 06 Nov 1994 08:49:37 GMT
X-Temporal-Extent-Quality: 3600;  units="seconds"; measure="qml:TimeAccuracy";
domain="qml:DifferentialErrors1D; metrics="qml:HalfLengthConfidenceInterval"; param-
level="0.683"
```

Alternative B: RESTful approach for linking to a metadata file

The problem with the HTTP headers approach is that there is limitation in what is possible to encode in a couple of lines of text. In addition the total length of the headers string has also a limitation. In practice this approach is limited a few basic informations (including time accuracy) and it is to possible to generalize it to embed a full ISO 19115 metadata record.

To allow a more comprehensive quality report, we could link to a complete XML metadata file that quantifies the temporal accuracy of the data and any other quality parameter or even a full ISO metadata document.

The RFC5988 (https://tools.ietf.org/html/rfc5988) suggests a simple mechanism to link a http resource to other http resources using a link header field. The mechanism is very simple: The Link attribute provides a URL for a linked document, a reason for the link (rel) and eventually a title. In the case you need to link to metadata, the rel attribute has the "describedby" value.

```
Link: <http://example.com/imagery/sentinel/metadata.xml>; rel="describedby";
title="Quality metadata about this image tile"
```

A request to a GetTile can return the tile with this information linked to the header.

Note that recently a more complicated linking mechanism has been suggested by M Nottingham (http://tools.ietf.org/html/draft-nottingham-link-hint-00) but we believe this is not necessary in this case.

9.3.6. RESTful URL template for Metadata

The current WMTS standard OGC 07-057r7 provides a mechanism to link a metadata file to each layer in the ServiceMetadata. In fact, this mechanism is inherited from OWS Common DatasetDescripton summary element, and has the following xpath.

```
/Capabilities/Contents/Layer[]/ows:metadata/@link
```

In principle it was initially designed to provide a URL for a *layer* (dataset) level metadata.

We could use this mechanism to provide a URL template to metadata at the tile level. This URL template could follow the same rules as the tile URL template explained in OGC 07-057r7 section 10.2.1. Obviously, the extension present in the template will be one commonly used in metadata files (e.g. .xml).

```
http://www.maps.bob/etopo2/default/{TileMatrixSet}/{TileMatrix}/{TileRow}/{TileCol}.xm
l
```

The WMTS client will need to identify this URL template and use the same mechanism to retrieve tiles in the ROA approach. Nevertheless, nothing precludes to use the same mechanisms in a pure SOA WMTS (even if tiles are retrieved using KVP, metadata can still be retrieved using the URL template.

9.3.7. Accessing the headers of a tile in a web browser.

WMTS standard was specifically designed to provide an optimum solution for web browser based clients (even if it can be supported in other platform that can access HTTP). It is reasonable that we consider if it is possible to get the HTTP headers from a HTML client written in JavaScript.

In JavaScript, the typical way of retrieving a tile is using the <img src⇒ tag where the src is manipulated into containing a WMTS KVP request that changes when the user moves the view area. In this approach getting the headers back is not possible. The only alternative seems to generate an asynchronous call for the WMTS KVP. In the asynchronous mechanisms headers can be retrieved using the getAllResponseHeaders() as explained in http://stackoverflow.com/questions/220231/accessing-the-web-pages-http-headers-in-javascript.

```
var req = new XMLHttpRequest();
req.open('GET', document.location, false);
req.send(null);
var headers = req.getAllResponseHeaders()
```

Unfortunately, there is a drawback to this strategy: the data that you can get from this request cannot be easily used in a <img src=""> because you are not suppose to inject data in an img but only change the URL. Modern browsers can accept *data-as-a-url* in this format: <img src="..."> but this requires to request the data in base64 (or in ascii UTF8) to the server in the first place, and most servers will not be prepared to do that except if they

implement the SOAP approach described in the WMTS 1.0 standard.

The immediate solution to that is request the data twice; one in a <img src="">, to represent it on the screen; and another, in an asynchronous way, to get the headers. This will work fine when we can assume that the data and the metadata is not going to change for a few seconds.

This problem specifically affect web browsers. Most of the developer platforms are able to access both headers and data with no restrictions.

9.3.8. Alternative C: New operation GetTileMetadata to know more info about a tile.

As described before, in certain circumstances, obtaining the information in the headers of a HTTP GET request could be difficult, or the information is too long to be embedded. In this case a another approach to this problem is introduced: A new operation for getting more information (metadata) about a tile.

Lets imagine that we have a tile that can be retrieved in KVP using the following URL:

```
http://www.maps.bob/maps.cgi?service=WMTS&  request=GetTile&version=1.0.0&layer=etopo2
&style=default&format=image/png&TileMatrixSet=WholeWorld_CRS_84&TileMatrix=10m&  TileR
ow=1&  TileCol=3
```

We can define a new operation called GetTileMetadata that, instead of retrieving the imagery, it will retrieve the metadata about the imagery. This is the example of how this URL could look:

```
http://www.maps.bob/maps.cgi?service=WMTS&  request=GetTileMetadata&version=1.0.0&laye
r=etopo2&style=default&outputFormat=application/xml&TileMatrixSet=WholeWorld_CRS_84&Ti
leMatrix=10m&  TileRow=1&  TileCol=3
```

Since the objective is to get metadata, we are borrowing the outputformat and outputschema from the CSW standard. This way we are able to differentiate different dialects of XML that share the same MIME type. Common accepted MIME types will be text/html, text/plain and text/xml.

In the RESTful encoding a tile that can be retrieved in KVP using the following URL:

```
http://www.maps.bob/etopo2/default/WholeWorld_CRS_84/10m/1/3.png
```

It can retrieve the metadata information by adding the word "metadata" and the relevant extension (e.g. .xml)

```
http://www.maps.bob/etopo2/default/WholeWorld_CRS_84/10m/1/3/metadata.xml
```

The result of this request will be a metadata file containing the metadata about the tile (que can include quality information about the original dataset and, in particular, time accuracy).

Changes required in the GetCapabilities

Obviously new operations shall be advertised in the GetCapabilities document. The option in KVP will be advertised in the Operations metadata section, while the RESTful option will be advertised in the ResourceURL of each layer.

The following XML fragment shows how the new KVP and SOAP operation description will look like in the capabilities document:

```
<ows:Operation name="GetTileMetadata">
    <ows:DCP>
        <ows:HTTP>
            <ows:Get xlink:href="http://www.bob.com/wms">
                <ows:Constraint name="GetEncoding">
                    <ows:AllowedValues>
                        <ows:Value>KVP</ows:Value>
                    </ows:AllowedValues>
                </ows:Constraint>
            </ows:Get>
            <ows:Post xlink:href=\"%s\">"
                <ows:Constraint name="PostEncoding">
                    <ows:AllowedValues>
                        <ows:Value>SOAP</ows:Value>
                    </ows:AllowedValues>
                </ows:Constraint>
            </ows:Post>
        </ows:HTTP>"
    </ows:DCP>"
    <ows:Parameter name="outputformat">
        <ows:AllowedValues>
            <ows:Value>text/xml</ows:Value>
            <ows:Value>text/html</ows:Value>
            <ows:Value>text/plain</ows:Value>
        </ows:AllowedValues>
        <ows:DefaultValue>text/xml</ows:DefaultValue>
    </ows:Parameter>
    <ows:Parameter name="outputschema">
        <ows:AllowedValues>
            <ows:Value>http://www.fgdc.gov/metadata/csdgm</ows:Value>
            <ows:Value>http://www.isotc211.org/2005/gmd</ows:Value>
        </ows:AllowedValues>
        <ows:DefaultValue>http://www.isotc211.org/2005/gmd</ows:DefaultValue>
    </ows:Parameter>
</ows:Operation>
```

To declare access to the metadata using the REST approach, we can use the ResourceURL tag but we need to include the possibility for resourceType and add "metadataTile" to its codelist.

```
<ResourceURL format="text/xml" resourceType="metadataTile"
template="http://www.maps.bob/etopo2/{style}/{TileMatrixSet}/{TileMatrix}/{TileRow}/{T
ileCol}/metadata.xml"/>
```

The file extension will be associated with the outputFormat. If needed, more that one template can be defined for the different outputSchema supported.

```
<ResourceURL format="text/xml" resourceType="metadataTile"
template="http://www.maps.bob/etopo2/{style}/{TileMatrixSet}/{TileMatrix}/{TileRow}/{T
ileCol}/fgdc/metadata.xml"/>
<ResourceURL format="text/xml" resourceType="metadataTile"
template="http://www.maps.bob/etopo2/{style}/{TileMatrixSet}/{TileMatrix}/{TileRow}/{T
ileCol}/iso/metadata.xml"/>
```

Alternative D: Multipart tile

To avoid the need for a new operation, the multipart response idea is introduced. This allows for adding metadata to individual tiles by requesting a file format (a MIME type) which is able to contain them, such XML or JSON and the image at the same time. The approach was described for WMS in the section 10.2.2 JSON for WMS GetMap response of the OGC 15-053 Testbed-11 Implementing JSON/GeoJSON in an OGC Standard Engineering Report. Essentially, the approach consists in a multipart file that is a container for the needed XML metadata or a JSON encoded metadata fragments and for the images (that could be embedded in the same document as a MIME64 character string, or could be a link to another WMTS GetTile request with an image format). The metadata fragments can describe the temporal extent and temporal accuracy or contain a full metadata document.

The request could look like:

```
http://www.maps.bob/etopo2/default/WholeWorld_CRS_84/10m/1/3.json
```

The response can have the tile embedded or linked externally. The following example returns the image code embedded in the JSON as base64 encoding, requiring to decode the image to present it.

```
{
    "id": 15,
    "box": [-180,-90,180,90],
    "title": "Example data fragment",
    "author": "ACME Corp.",
    "contentDate": "Sun, 06 Nov 1994 08:49:37 GMT",
    "quality": {
        "measure": "qml:TimeAccuracy",
        "field": "qml:DifferentialErrors1D",
        "metrics": "qml:HalfLengthConfidenceInterval",
        "value": "3600",
        "units": "seconds",
        "level": "0.683"
    },
    "img":{
        "format": "image/png",
        "data": "iVBORw...kJggg=="
    }
}
```

The following example return a link to the image requiring a second request

```
{
    "id": 16,
    "title": "Example data fragment",
    "author": "ACME Corp.",
    "contentDate": "Sun, 06 Nov 1994 08:49:37 GMT",
    "quality": {
        "measure": "qml:TimeAccuracy",
        "field": "qml:DifferentialErrors1D",
        "metrics": "qml:HalfLengthConfidenceInterval",
        "value": "3600",
        "units": "seconds",
        "level": "0.683"
    },
    "img": {
        "href": "http://www.maps.bob/etopo2/default/WholeWorld_CRS_84/10m/1/3.png"
    }
}
```

This JSON encoding fragments reproduce some suggestions coming from: http://json-schema.org/latest/json-schema-hypermedia.html

As an alternative, the MIME multipart encoding could be used (IETF RFC 2392), as suggested by the OGC 09-146r2 GML Application schema — Coverages.

```
Content-Type: Multipart/Related; boundary=wmts;
        start="Metadata-Part"
        type="text/xml"
--wmts
Content-type: text/xml
Content-ID: Metadata-Part
<?xml version="1.0" ⋯>
<mdq:DQ_DataQuality xmlns:gco="http://www.isotc211.org/2005/gco"
...
    <mdq:report>
        <mdq:DQ_AccuracyOfATimeMeasurement>
            <mdq:result>
...
            </mdq:result>
        </mdq:DQ_AccuracyOfATimeMeasurement>
    </mdq:report>
</mdq:DQ_DataQuality>

--wmts
Content-Type: image/png
Content-Description: tile data
Content-Transfer-Encoding: binary
Content-ID: tile.png
Content-Disposition: INLINE
...binary PNG data...
--wmts--
```

Alternative E: Coupled layer with GetFeatureInfo enabled operation

The GetFeatureInfo operation could be used to convey pixel level metadata (and particularly) data quality that is associated to each pixel of a tile. In the cases where the quality of the tile depends on the quality of the individual scenes used to create the layer mosaic, having an additional layer that represents the rectangles of the individual scenes can be useful. This additional layer can represent the rectangles associated to the individual scenes. Each rectangle can be connected to a database record where there is information about this rectangle including data quality information. This information could be retrieved by a GetFeatureInfo operation that will show quality information about the *associated-with* layer.

9.4. Data quality XML encoding for temporal accuracy

In this ER we recommend QualityML to encode the data quality. This way we are able to convey not only the quality value but also the semantics of it. QualityML can be used to encode quality measures in XML ISO metadata document.

This is the way temporal accuracy quality has to be encoded in an XML document.

XML fragment of the ISO 19115-1 metadata for time accuracy that uses QualityML

```
<?xml version="1.0" encoding="UTF-8"?>
```

```
<mdq:DQ_DataQuality xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:gss="http://www.isotc211.org/2005/gss"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:qml="http://qualityml.geoviqua.org/1.0" xmlns:un="http://www.uncertml.org/2.0"
xmlns:cit="http://www.isotc211.org/2005/cit/1.0/2013-06-24"
xmlns:gcx="http://www.isotc211.org/2005/gcx/1.0/2013-06-24"
xmlns:mcc="http://www.isotc211.org/2005/mcc/1.0/2013-06-24"
xmlns:mdq="http://www.isotc211.org/2005/mdq/1.0/2013-06-24"
xmlns:mdt="http://www.isotc211.org/2005/mdt/1.0/2013-06-24"
xmlns:mil="http://www.isotc211.org/2005/mil/1.0/2013-06-24"
xmlns:mrd="http://www.isotc211.org/2005/mrd/1.0/2013-06-24"
xmlns:mrc="http://www.isotc211.org/2005/mrc/1.0/2013-06-24"
xmlns:mri="http://www.isotc211.org/2005/mri/1.0/2013-06-24"
xmlns:msr="http://www.isotc211.org/2005/msr/1.0/2013-06-24"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.isotc211.org/2005/gco
../../ISO_19139_Schemas/gco/gco.xsd http://www.opengis.net/gml/3.2
../../ISO_19136_Schemas/gml.xsd http://www.isotc211.org/2005/gss
../../ISO_19139_Schemas/gss/gss.xsd http://www.w3.org/1999/xlink
../../W3C_xlink_Schemas/xlink.xsd http://qualityml.geoviqua.org/1.0
../../qualityml/1.0/qualityml.xsd http://www.uncertml.org/2.0
../../uncertml/2.0/uncertml.xsd http://www.isotc211.org/2005/cit/1.0/2013-06-24
../../xsd20130624/ISO19115-3/cit/1.0/cit.xsd
http://www.isotc211.org/2005/gcx/1.0/2013-06-24 ../../xsd20130624/ISO19115-
3/gcx/1.0/gcx.xsd http://www.isotc211.org/2005/mcc/1.0/2013-06-24
../../xsd20130624/ISO19115-3/mcc/1.0/mcc.xsd
http://www.isotc211.org/2005/mdq/1.0/2013-06-24 ../../xsd20130624/ISO19157-
2/mdq/1.0/mdq.xsd http://www.isotc211.org/2005/mdt/1.0/2013-06-24
../../xsd20130624/ISO19115-3/mdt/1.0/mdt.xsd
http://www.isotc211.org/2005/mil/1.0/2013-06-24 ../../xsd20130624/ISO19115-
4/mil/1.0/mil.xsd http://www.isotc211.org/2005/mrd/1.0/2013-06-24
../../xsd20130624/ISO19115-3/mrd/1.0/mrd.xsd
http://www.isotc211.org/2005/mrc/1.0/2013-06-24 ../../xsd20130624/ISO19115-
3/mrc/1.0/mrc.xsd http://www.isotc211.org/2005/mri/1.0/2013-06-24
../../xsd20130624/ISO19115-3/mri/1.0/mri.xsd
http://www.isotc211.org/2005/msr/1.0/2013-06-24 ../../xsd20130624/ISO19115-
3/msr/1.0/msr.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level><mcc:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"></mcc:MD_ScopeCode></mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_AccuracyOfATimeMeasurement>
            <mdq:measure>
                <mdq:DQ_MeasureReference>
                    <mdq:measureIdentification><mcc:MD_Identifier>

<mcc:code><gco:CharacterString>TimeAccuracy</gco:CharacterString></mcc:code>
```

```
<mcc:codeSpace><gco:CharacterString>http://qualityml.geoviqua.org/1.0/measures</gco:Ch
aracterString></mcc:codeSpace>
                    </mcc:MD_Identifier></mdq:measureIdentification>
                </mdq:DQ_MeasureReference>
            </mdq:measure>
            <mdq:result>
                <mdq:DQ_QuantitativeResult>
                    <mdq:value>
                        <gco:Record>
                            <qml:HalfLengthConfidenceInterval level="0.683">
                                <un:values>3600</un:values>
                            </qml:HalfLengthConfidenceInterval>
                        </gco:Record>
                    </mdq:value>
                    <mdq:valueUnit>
                        <gml:BaseUnit gml:id="s">
                            <gml:identifier
codeSpace="http://www.bipm.org/en/si/base_units/l">second</gml:identifier>
                            <gml:name
codeSpace="http://www.bipm.org/en/si/base_units/l">second</gml:name>
                            <gml:quantityType>time</gml:quantityType>
                            <gml:catalogSymbol
codeSpace="http://www.bipm.org/en/si/base_units/">s</gml:catalogSymbol>
                            <gml:unitsSystem xlink:href="http://www.bipm.fr/en/si"/>
                        </gml:BaseUnit>
                    </mdq:valueUnit>
                    <mdq:valueType>
                        <gco:RecordType
xlink:href="http://qualityml.geoviqua.org/1.0/metrics/Half-
lengthConfidenceInterval">The probability of a measurement to lie inside a confidence
interval expressed in the half-length distance</gco:RecordType>
                    </mdq:valueType>
                </mdq:DQ_QuantitativeResult>
            </mdq:result>
        </mdq:DQ_AccuracyOfATimeMeasurement>
    </mdq:report>
</mdq:DQ_DataQuality>
```

9.5. Details of the WMTS server implementation

The implemented service uses the MiraMon RS-GIS approach that requires pre-rendering tiles at the different scales. The pre-rendering is done as a batch process. The tiles can be accessed directly from a web server as files (the REST approach) or can be requested using a MiraMon.cgi application that interprets KVP requests and is able to find the pre-render tile and deliver it.

The pre-rendering process will be extended to implement a file that contains metadata in an XML encoding about a quality aspect (in particular time extent and time accuracy) and a link to the actual tile image. In addition to that, a multipart file can be generated if needed.

9.6. Details of the WMTS client implementation

The WMTS client can access the service in two ways:

- The client asks for the image tile first and shows it. Later, the client issues a second request for the XML file, extracts the metadata and shows it only if the user requests it.
- The client asks for the multipart file, and shows the metadata to the user and immediately after that uses the image URL to request the tile and show it in the right position on the screen.

Chapter 10. Quality levels in a big mosaic

10.1. Introduction

One interesting example about spatialized currency metadata (as well as temporal quality parameters) is the production of an image mosaic over large area, using the most current image possible.

The actual date of each pixel is different depending on which is the coverage of the original images. This can be documented using several EX_SpatialTemporalExtent elements on the general metadata regarding Extent. Moreover, several quality parameters can be used to describe:

- Currency: temporal validity with a domain requirement: percentage of pixels are older than a 6 month of the time intended for the data (i.e. older than 2016-03-15 if intended date is 2016-09-15). Scope of the quality measure is the dataset.
- Currency: temporal validity with a domain requirement: pixel-based quality measure containing a flag value if the pixel is compliant to the currency requirement. Scope of the quality measure is the dataset.
- Temporal quality: describe several quality measures regarding temporal accuracy in different quality measures with a different MD_Scope (including a extent description) each.

10.2. Example dataset

Next image shows an example of a composite over San Francisco Bay area, combining three images of the Currency Data Set obtained from the DigitalGlobe FTP during the OGC TestBed 12 development. The datasets capture the temporal resolution of satellites a.k.a, the frequency at which a location on the earth can be captured by satellite constellation. A constellation of satellites can come back to the same spot on the earth any given day. Satellites in sun synchronous orbits come back to it at the same local time. This dataset is a compilation of 8 temporal datasets over a span of 3-4 years over San Francisco downtown area. The images capture a wide range of seasons as well as off-nadir angles of collection of imagery and is ideal to highlight image quality effects over a time period.

As an example, only images captured in 2016 are considered as an example:

Table 24. Acquisition date of the images used to create a mosaic

Sensor	Feature ID	Cat ID	Acquisition date
WV02	e8bdab7660962c601f6042d15e6fa4af	103001005553CF00	2016/04/02
WV02	16284834df1d88d59e9a0f74d4c471f2	10300100545AEF00	2016/03/25
WV02	2b5f8529f780727d6c15f9daa7e94f14	1030010052208D00	2016/02/21

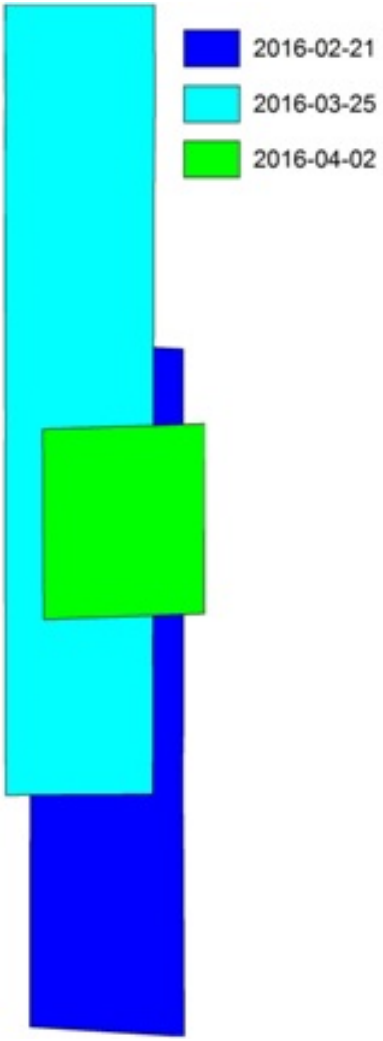

Figure 15. Spatial coverage of the images used to create a mosaic

10.3. Example metadata documentation

Several temporalElement can be defined in the general purpose metadata of the mosaic imagery, in order to properly define the date of different areas on the mosaic.

In this case, three spatio-temporal extent elements are used, each of them defining the bounding polygon of each scene (with more than one patch if needed) with its date:

Table 25. Spatio-temporal elements defined in the mosaic metadata

Temp. Id	TimeInstant	Num. Coord	Coord. list	Patch Id	Spat. Id
TE_1	2016-02-21 T19:10:06.425678Z	14	-122.3918563 38.01302909 -122.391898 37.99734093 … -122.3918563 38.01302909	SE_1_PP_1	SE_1
		33	-122.3521546 37.65337115 -122.3521546 37.6533711 … -122.3521546 37.65337115	SE_1_PP_2	
TE_2	2016-03-25 T18:53:18.223040Z	72	-122.3920894 37.91034941 -122.3920864 37.91157935 … -122.3920894 37.91034941	SE_2_LS_1	SE_2
TE_3	2016-04-02 T18:59:27.034854Z	35	-122.5388838 37.80215124 -122.5388175 37.79186755 … -122.5388838 37.80215124	SE_3_LS_1	SE_3

The XML encoding of these elements is show below. Please note the use of "gml:id" to identify each element (the same Id. are used in the table above).

XML encoding of the spatio-temporal elements defined in the mosaic metadata

```
    <mdb:identificationInfo>
        <mri:MD_DataIdentification>
            [...]
            <mri:extent>
                <gex:EX_Extent>
                    <gex:temporalElement>
                        <gex:EX_SpatialTemporalExtent id="STE_1">
                            <gex:extent>
                                <gml:TimeInstant gml:id="TE_1">
                                    <gml:timePosition>2016-02-
21T19:10:06.425678Z</gml:timePosition>
                                </gml:TimeInstant>
                            </gex:extent>
                            <gex:spatialExtent>
                                <gex:EX_BoundingPolygon>
                                    <gex:polygon>
                                        <gml:Surface gml:id="SE_1">
```

```
                                        <gml:polygonPatches>
                                            <gml:PolygonPatch>
                                                <gml:exterior>
                                                    <gml:Ring>
                                                        <gml:curveMember>
                                                            <gml:LineString
gml:id="SE_1_LS_1">
                                                                <gml:pos>-
122.3918563034 38.0130290916</gml:pos>
                                                                <gml:pos>-
122.391898 37.99734093</gml:pos>
                                                                [...]
                                                                <gml:pos>-
122.3918563034 38.0130290916</gml:pos>
                                                            </gml:LineString>
                                                        </gml:curveMember>
                                                    </gml:Ring>
                                                </gml:exterior>
                                            </gml:PolygonPatch>
                                            <gml:PolygonPatch>
                                                <gml:exterior>
                                                    <gml:Ring>
                                                        <gml:curveMember>
                                                            <gml:LineString
gml:id="SE_1_LS_2">
                                                                <gml:pos>-
122.3521545885 37.6533711537</gml:pos>
                                                                <gml:pos>-
122.3521581296 37.6579408719</gml:pos>
                                                                [...]
                                                                <gml:pos>-
122.3521545885 37.6533711537</gml:pos>
                                                            </gml:LineString>
                                                        </gml:curveMember>
                                                    </gml:Ring>
                                                </gml:exterior>
                                            </gml:PolygonPatch>
                                        </gml:polygonPatches>
                                    </gml:Surface>
                                </gex:polygon>
                            </gex:EX_BoundingPolygon>
                        </gex:spatialExtent>
                    </gex:EX_SpatialTemporalExtent>
                </gex:temporalElement>
                <gex:temporalElement>
                    <gex:EX_SpatialTemporalExtent id="STE_2">
                        <gex:extent>
                            <gml:TimeInstant gml:id="TE_2">
                                <gml:timePosition>2016-03-
25T18:53:18.223040Z</gml:timePosition>
                            </gml:TimeInstant>
```

```
                            </gex:extent>
                            <gex:spatialExtent>
                                <gex:EX_BoundingPolygon>
                                    <gex:polygon>
                                        <gml:Polygon gml:id="SE_2">
                                            <gml:exterior>
                                                <gml:Ring>
                                                    <gml:curveMember>
                                                        <gml:LineString
gml:id="SE_2_LS_1">
                                                            <gml:pos>-122.3920893812
37.9103494132</gml:pos>
                                                            <gml:pos>-122.3920864
37.91157935</gml:pos>
                                                            [...]
                                                            <gml:pos>-122.3920893812
37.9103494132</gml:pos>
                                                        </gml:LineString>
                                                    </gml:curveMember>
                                                </gml:Ring>
                                            </gml:exterior>
                                        </gml:Polygon>
                                    </gex:polygon>
                                </gex:EX_BoundingPolygon>
                            </gex:spatialExtent>
                        </gex:EX_SpatialTemporalExtent>
                    </gex:temporalElement>
                    <gex:temporalElement>
                        <gex:EX_SpatialTemporalExtent id="STE_3">
                            <gex:extent>
                                <gml:TimeInstant gml:id="TE_3">
                                    <gml:timePosition>2016-04-
02T18:59:27.034854Z</gml:timePosition>
                                </gml:TimeInstant>
                            </gex:extent>
                            <gex:spatialExtent>
                                <gex:EX_BoundingPolygon>
                                    <gex:polygon>
                                        <gml:Polygon gml:id="SE_3">
                                            <gml:exterior>
                                                <gml:Ring>
                                                    <gml:curveMember>
                                                        <gml:LineString
gml:id="SE_3_LS_1">
                                                            <gml:pos>-122.53888384
37.8021512436</gml:pos>
                                                            <gml:pos>-122.5388175
37.79186755</gml:pos>
                                                            [...]
                                                            <gml:pos>-122.53888384
37.8021512436</gml:pos>
```

```
                                                        </gml:LineString>
                                                    </gml:curveMember>
                                                </gml:Ring>
                                            </gml:exterior>
                                        </gml:Polygon>
                                    </gex:polygon>
                                </gex:EX_BoundingPolygon>
                            </gex:spatialExtent>
                        </gex:EX_SpatialTemporalExtent>
                    </gex:temporalElement>
                </gex:EX_Extent>
            </mri:extent>
        </mri:MD_DataIdentification>
    </mdb:identificationInfo>
```

The full XML encoding for this example can be found in appendix-QM-Raster, in QM_8_Currency_Mosaic_19115_1_XML.

10.4. Example quality measures

10.4.1. Currency: temporal validity with a domain requirement (dataset-level)

The percentage of pixels are older than a 6 month from the time intended for the data (i.e. older than 2016-03-15 if intended date is 2016-09-15) can be given as a first quality measure regarding currency as similarly as done in QM_5_Currency_TemporalValidity_QMR. The encoding has been explained in section "Domain parameters encoding" in DataSetLevel.

Conceptually, the quality measure used is:

Table 26. Items that do not conform to a temporal validity requirement

Line	Component	Description
1	Name	Items
2	Alias	—
3	Element name	Temporal validity
4	Basic measure	Value domain
5	Definition	Indication of if an item is conformant or not with a rule. The conformance or non-conformance can be expressed as a boolean, count or rate.
6	Description	—
7	Parameter	"max" for a maximum ratio if rate is used
10	Source reference	ISO 19157 Id. 14, Id.15 (boolean), Id.16 (count), Id.17 + Id.18 (rate), unified in QualityML

Line	Component	Description
11	Example	30 % of the pixels are older than a 24 month of the time intended for the data (older than 2014-05-01)
12	Identifier	*http://www.qualityml.org/1.0/measure/ValueDomain*
13	Domain	Items metrics can be used with Conformance or Non-Conformance domains. In both cases the domain can describe a "range" ("min" and/or "max") and/or a "rule" parameters to define the requirement, as needed. In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - type: *range* - min: *2016-03-15* - rule: *Pixels are older than 6 months of the time intended for the data (i.e. older than 2016-03-15)*
14	Metrics	In this case the metrics and its parameter are: - metrics: *http://www.qualityml.org/1.0/metrics/items* - type: *rate* - max: *100* - value: *25.88*

And the XML encoding (following 19115-1 schema) is:

```
    <mdq:DQ_TemporalValidity>
        <mdq:measure>
            <mdq:DQ_MeasureReference>
                <mdq:measureIdentification>
                    <mcc:MD_Identifier>
                        <mcc:code>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/ValueDomain">ValueDomain</gcx:Anchor>
                        </mcc:code>
                        <mcc:codeSpace>
                            <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                        </mcc:codeSpace>
                        <mcc:version>
                            <gco:CharacterString>1.0</gco:CharacterString>
                        </mcc:version>
                    </mcc:MD_Identifier>
                </mdq:measureIdentification>
                <mdq:nameOfMeasure>
                    <gco:CharacterString>Value domain</gco:CharacterString>
                </mdq:nameOfMeasure>
                <mdq:measureDescription>
                    <gco:CharacterString>Indication of if an item is conformant or not
with a rule. The conformance or non-conformance can be expressed as a boolean, count
or rate.</gco:CharacterString>
                </mdq:measureDescription>
            </mdq:DQ_MeasureReference>
```

```
        </mdq:measure>
        <mdq:result>
            <mdq:DQ_QuantitativeResult>
                <mdq:value>
                    <gco:Record>
                        <qml:Items>
                            <qml:rate max="100">25.88</qml:rate>
                        </qml:Items>
                        <qmld:NonConformance>
                            <qmld:range>
                                <qmld:min>
                                    <qmld:date>2016-03-15</qmld:date>
                                </qmld:min>
                            </qmld:range>
                            <qmld:rule>Pixels are older than 6 months of the time
intended for the data (i.e. older than 2016-03-15)</qmld:rule>
                        </qmld:NonConformance>
                    </gco:Record>
                </mdq:value>
                <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                <mdq:valueRecordType>
                    <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                </mdq:valueRecordType>
            </mdq:DQ_QuantitativeResult>
        </mdq:result>
    </mdq:DQ_TemporalValidity>
```

The full XML encoding for this example can be found in appendix-QM-Raster, in QM_8_Currency_Mosaic_19115_1_XML.

10.4.2. Currency: temporal validity with a domain requirement (pixel-level)

Moreover, also a quality band describing if each pixel describing is compliant with the temporal requirement can be produced and given as a second result of the same quality measure. The main structure of this metadata record is similar to QM_6_Completeness_FlagAreas_QMR (but with another quality measure described, as temporal validity instead of completeness omission is intended).

Conceptually, the quality measure used is:

Table 27. Items that do not conform to a temporal validity requirement

Line	Component	Description
1	Name	Items
2	Alias	—
3	Element name	Temporal validity

Line	Component	Description
4	Basic measure	Value domain
5	Definition	Indication of if an item is conformant or not with a rule. The conformance or non-conformance can be expressed as a boolean, count or rate.
6	Description	—
7	Parameter	"max" for a maximum ratio if rate is used
10	Source reference	ISO 19157 Id. 14, Id.15 (boolean), Id.16 (count), Id.17 + Id.18 (rate), unified in QualityML
11	Example	30 % of the pixels are older than a 24 month of the time intended for the data (older than 2016-03-15)
12	Identifier	*http://www.qualityml.org/1.0/measure/ValueDomain*
13	Domain	Items metrics can be used with Conformance or Non-Conformance domains. In both cases the domain can describe a "range" ("min" and/or "max") and/or a "rule" parameters to define the requirement, as needed. In this case the domain is: - domain: *http://www.qualityml.org/1.0/domain/NonConformance* - type: *range* - min: *2016-03-15* - rule: *Pixels are older than 6 months of the time intended for the data (i.e. older than 2016-03-15)*
14	Metrics	In this case the metrics and its parameter are: - metrics: *http://www.qualityml.org/1.0/metrics/items* - type: *indicator* - value: *pixel-level boolean indicator* - NonConformance/rule: *a coverage result is used including for each pixel a boolean indication whether the pixel is older than 2016-03-15*

As another result for the same measure is given, the XML encoding including both results (following 19115-1 schema) is:

```
    <mdq:DQ_TemporalValidity>
        <mdq:measure>
            [...]
        </mdq:measure>
        <mdq:result>
            <mdq:DQ_QuantitativeResult>
                [...]
            </mdq:DQ_QuantitativeResult>
        </mdq:result>
        <mdq:result>
            <mdq_TB12:QE_CoverageResult_TB12>
                <mdq_TB12:spatialRepresentationType>
                    <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                    codeList="MD_SpatialRepresentationTypeCode"/>
                </mdq_TB12:spatialRepresentationType>
                <mdq_TB12:resultSpatialRepresentation
xlink:href="#Imagery_Mosaic_SpatialRepresentation"/>
                <mdq_TB12:resultContentDescription
xlink:href="#Currency_Quality_AttributeGroup"/>
            </mdq_TB12:QE_CoverageResult_TB12>
        </mdq:result>
    </mdq:DQ_TemporalValidity>
```

The full XML encoding for this example can be found in XML examples of encoding for Quality Measures for Raster, in Quality levels in a big mosaic.

10.5. Final considerations

If clouds are masked with nodata, mosaics can be executed using cover functions, creating a spatial distribution of dates much more complicated than the one show in the previous example. Nevertheless, no matter the complex situation that arises, it can be always described using several EX_SpatialTemporalExtent elements (some of them maybe using "interior" boundaries to describe "holes" on it).

Appendix A: Geospatial Imagery Quality Framework

Background

The last decade has seen proliferation of sensors on various platforms (satellites, aerial, UAV's) that collect imagery at multiple scales/resolutions. It is estimated that several hundred small satellites and UAV's will be added to this asset base in the next 5-10 years. Currently there is no consistent quality framework that will allow end users to compare imagery from multiple sources across the different quality attributes in order to have a holistic view of imagery value as it may apply to particular set of requirements.

Testbed-12 shall develop a quality framework called "A3C" (Accuracy, Currency, Completeness, and Consistency) that can be used to compare imagery from multiple sources. Accuracy refers to spatial accuracy of a location derived from the pixel in X,Y dimensions and potentially in Z dimension. Currency refers to the temporal extent of the imagery products used to cover the associated area, since multiple dates of collects are typically required to cover a large area. Completeness of imagery products refers to quality metrics including cloud cover, sensor specs on collection geometry, temporal range of the data, other spectral bands if any, radiometric depth of the pixels, etc. Finally, the Consistency metric describes the consistency of colors, relative accuracy over time and over different sensors, spectral and spatial error propagation from collection to production, etc.

Requirements and Work Items

The following figure illustrates all work items that shall be addressed in this work package. They are described in further detail in figure 5.1. All funded work items are shaded in green, unfunded in blue. Each work item may implement several requirements, i.e. components need to fulfill various requirements, or engineering reports need to address and summarize the results from various requirements.

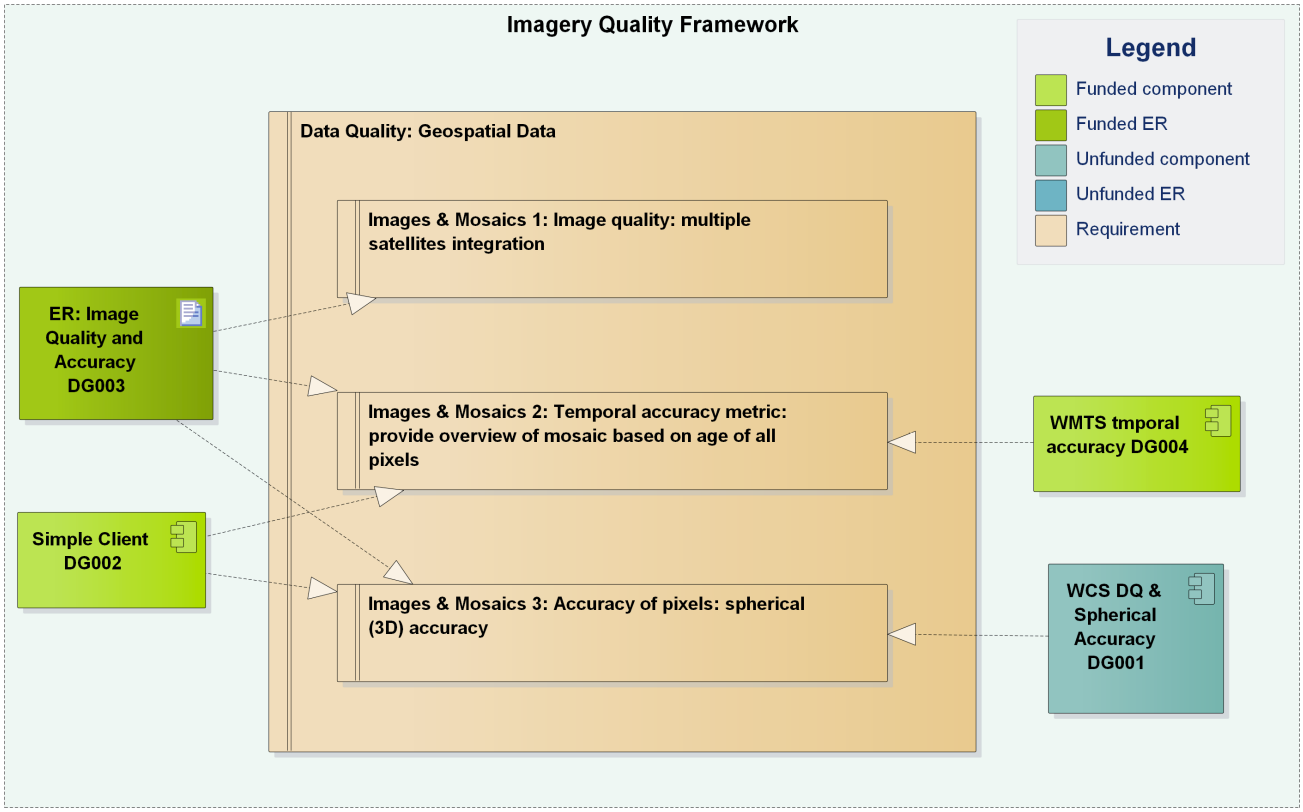

Figure 16. Geospatial Data Quality work package: Requirements and work items

Accuracy, Currency, Completeness, Consistency

The detailed image quality framework to be developed in Testbed-12 shall support comparing multiple sources of imagery. A framework of this nature, vetted by the OGC experts, improves interoperability of multiple imagery sources and provides users a much more consistent mechanism to assess imagery products.

Desired Output

The goal of this work package is to develop the image quality framework that addresses all aspects mentioned below. Its functionality shall be demonstrated using at least a WMTS implementation that supports temporal accuracy information. If funding allows, a WCS shall be implemented that supports all A3C data. Independent of the available services to demonstrate its functionality, the image quality framework shall be documented with all detail in the Image Quality and Accuracy Engineering Report. The report shall support at least the following aspects:

Creation of use cases to show how different missions could use A3C metrics to assess the applicability of imagery to their goals

- Analysis of use cases to derive the set of metrics that can best support A3C goals of the use cases
- Definition of a data model which allows a source system to capture A3C metrics
- Specifications of data elements within the model to insure consistent, appropriate interpretation across a variety of sensors based on spatial resolution, spectral resolution, radiometric resolution and temporal resolution.
- Demonstration of use of the model to show how A3C metrics can distinguish value across several different use cases (can be same missions as defined above), for example:
  - Mapping Mission
  - Disaster Response
  - Monitoring Mission
- Proposed A3C Specification

Example Use Cases

As an example of the need for A3C metrics, consider two use cases: A Land Use analysis and a Mapping mission. In both cases the users may desire mosaic imagery, but there will be differences in the metrics for the intended purpose:

The Land Use analysis requires:

- Similar currency of the imagery, consistency across the mosaic
- Atmospherically corrected, consistent known color balancing
- Any color enhancements

The Mapping Mission is more concerned with:

- Horizontal accuracy
- Extent of collection dates
- DEMs and GCPs used
- Any seam line alteration

Proposed Example Metrics

- Accuracy
  - Accuracy of products:
    - Horizontal Accuracy CE90
    - Vertical Accuracy LE90
  - Accuracy of Raw Satellite Imagery (basically reflects satellite pointing accuracy)
    - Horizontal Accuracy CE90 based on observed locations on ground
- Currency of products
  - Raw imagery
    - Times of collection, seasonality, leaf-on or leaf-off
  - Finished products
    - Earliest collection date, Latest collection date, Average age, seasonality, leaf-on or leaf-off
- Completeness
  - Single scene/strip imagery
    - Metadata on sensor, orbit, spatial resolution, spectral resolution, radiometric resolution, collection geometry, resampling technique, data compression, DEM used, GCP's used, geometric alteration (e.g. photoshop), color enhancements, image enhancements (e.g.sharpening)
  - Finished Products
    - Metadata on sensors, orbits, spatial resolution(s), spectral resolution(s), radiometric resolution(s), collection geometries, resampling technique, data compression, DEM used, GCP's used, Seamlines, geometric alteration (e.g. photoshop), color enhancements, image enhancements
- Consistency
  - Atmospherically corrected or not
  - Atmospheric correction based on in scene data or ancillary data
  - Cross sensor calibration (constellation sensors)

- Ground based spectral calibration
- Color balancing technique (local color balancing or global color balancing)
- NIIRS for imagery quality from sensor
- Standard deviation of collection dates

Appendix B: XML examples of encoding for Quality Measures for Raster

Accuracy (positional)

Sensor Accuracy: positional uncertainty of satellite position

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:DQ_DataQuality xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd
http://www.opengis.net/gml ../old_ISO_19115/gml/gml.xsd">
    <gmd:scope>
        <gmd:DQ_Scope>
            <gmd:level>
                <gmd:MD_ScopeCode codeListValue="series" codeList="MD_ScopeCode"/>
            </gmd:level>
            <gmd:extent>
                <gmd:EX_Extent>
                    <gmd:temporalElement>
                        <gmd:EX_TemporalExtent>
                            <!-- temporal extent used to compute "positional
uncertainty of satellite position" should be stated here  -->
                            <gmd:extent>
                                <gml:TimePeriod gml:id="SensorAccuracy_Scope_TempExt">
                                    <gml:beginPosition>2016-01-
01T00:00:00.000+01:00</gml:beginPosition>
                                    <gml:endPosition>2016-06-
30T00:00:00.000+01:00</gml:endPosition>
                                </gml:TimePeriod>
                            </gmd:extent>
                        </gmd:EX_TemporalExtent>
                    </gmd:temporalElement>
                </gmd:EX_Extent>
            </gmd:extent>
        </gmd:DQ_Scope>
    </gmd:scope>
    <gmd:report>
        <gmd:DQ_GriddedDataPositionalAccuracy>
            <gmd:nameOfMeasure>
                <gco:CharacterString>Mean Absolute Error (MAE)</gco:CharacterString>
```

```
            </gmd:nameOfMeasure>
            <gmd:measureIdentification>
                <gmd:MD_Identifier>
                    <gmd:code>
                        <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/MeanAbsoluteError">MeanAbsoluteError<
/gmx:Anchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:measureIdentification>
            <gmd:measureDescription>
                <gco:CharacterString>Mean Absolute Error (MAE) of imagery related to
satellite position within a certain time period using data coming from validation
sites distributed around the world with precise GPS locations.</gco:CharacterString>
            </gmd:measureDescription>
            <gmd:result>
                <gmd:DQ_QuantitativeResult>
                    <gmd:valueType>
                        <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/meanAbsolute2D">Mean Absolut
2D</gco:RecordType>
                    </gmd:valueType>
                    <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <gmd:value>
                        <gco:Record>
                            <qml:MeanAbsolute2D>
                                <qml:values>5</qml:values>
                            </qml:MeanAbsolute2D>
                        </gco:Record>
                    </gmd:value>
                </gmd:DQ_QuantitativeResult>
            </gmd:result>
        </gmd:DQ_GriddedDataPositionalAccuracy>
    </gmd:report>
</gmd:DQ_DataQuality>
```

ISO 19115-1 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:gex="http://standards.iso.org/iso/19115/-3/gex/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0
../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd http://www.opengis.net/gml/3.2
```

```
../new_ISO_19115_1/19136/gml.xsd http://standards.iso.org/iso/19115/-3/mcc/1.0
../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd http://standards.iso.org/iso/19157/-
2/mdq/1.0 ../new_ISO_19115_1/19157/-2/mdq/1.0/mdq.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="series" codeList="MD_ScopeCode"/>
            </mcc:level>
            <mcc:extent>
                <gex:EX_Extent>
                    <gex:temporalElement>
                        <gex:EX_TemporalExtent>
                            <!-- temporal extent used to compute "positional
uncertainty of satellite position" should be stated here -->
                            <gex:extent>
                                <gml:TimePeriod gml:id="SensorAccuracy_Scope_TempExt">
                                    <gml:beginPosition>2016-01-
01T00:00:00.000+01:00</gml:beginPosition>
                                    <gml:endPosition>2016-06-
30T00:00:00.000+01:00</gml:endPosition>
                                </gml:TimePeriod>
                            </gex:extent>
                        </gex:EX_TemporalExtent>
                    </gex:temporalElement>
                </gex:EX_Extent>
            </mcc:extent>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_GriddedDataPositionalAccuracy>
            <mdq:measure>
                <mdq:DQ_MeasureReference>
                    <mdq:measureIdentification>
                        <mcc:MD_Identifier>
                            <mcc:code>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/MeanAbsoluteError">MeanAbsoluteError<
/gcx:Anchor>
                            </mcc:code>
                            <mcc:codeSpace>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                            </mcc:codeSpace>
                            <mcc:version>
                                <gco:CharacterString>1.0</gco:CharacterString>
                            </mcc:version>
                        </mcc:MD_Identifier>
                    </mdq:measureIdentification>
                    <mdq:nameOfMeasure>
                        <gco:CharacterString>Mean Absolute Error
```

```
(MAE)</gco:CharacterString>
                    </mdq:nameOfMeasure>
                    <mdq:measureDescription>
                        <gco:CharacterString>Mean Absolute Error (MAE) of imagery
related to satellite position within a certain time period using data coming from
validation sites distributed around the world with precise GPS
locations.</gco:CharacterString>
                    </mdq:measureDescription>
                </mdq:DQ_MeasureReference>
            </mdq:measure>
            <mdq:result>
                <mdq:DQ_QuantitativeResult>
                    <mdq:value>
                        <gco:Record>
                            <qml:MeanAbsolute2D>
                                <qml:values>5</qml:values>
                            </qml:MeanAbsolute2D>
                        </gco:Record>
                    </mdq:value>
                    <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <mdq:valueRecordType>
                        <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/meanAbsolute2D">Mean Absolut
2D</gco:RecordType>
                    </mdq:valueRecordType>
                </mdq:DQ_QuantitativeResult>
            </mdq:result>
        </mdq:DQ_GriddedDataPositionalAccuracy>
    </mdq:report>
</mdq:DQ_DataQuality>
```

Ground location accuracy (x,y,z): Pixel location accuracy on the ground

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:DQ_DataQuality xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd">
    <gmd:scope>
        <gmd:DQ_Scope>
```

```
            <gmd:level>
                <gmd:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </gmd:level>
        </gmd:DQ_Scope>
    </gmd:scope>
    <gmd:report>
        <gmd:DQ_GriddedDataPositionalAccuracy>
            <gmd:nameOfMeasure>
                <gco:CharacterString>Circular Map Accuracy</gco:CharacterString>
            </gmd:nameOfMeasure>
            <gmd:measureIdentification>
                <gmd:MD_Identifier>
                    <gmd:code>
                        <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/CircularMapAccuracy">CircularMapAccur
acy</gmx:Anchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:measureIdentification>
            <gmd:measureDescription>
                <gco:CharacterString>Radius describing a circle, in which the true
point location lies with a certain probability, computed using satellite
ephemerides.</gco:CharacterString>
            </gmd:measureDescription>
            <gmd:result>
                <gmd:DQ_QuantitativeResult>
                    <gmd:valueType>
                        <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/CircularError">Circular
Error</gco:RecordType>
                    </gmd:valueType>
                    <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <gmd:value>
                        <gco:Record>
                            <qml:CircularError level="0.95">
                                <qml:values>3.2</qml:values>
                            </qml:CircularError>
                        </gco:Record>
                    </gmd:value>
                </gmd:DQ_QuantitativeResult>
            </gmd:result>
        </gmd:DQ_GriddedDataPositionalAccuracy>
    </gmd:report>
</gmd:DQ_DataQuality>
```

ISO 19115-1 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
```

```
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0
../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd http://standards.iso.org/iso/19115/-
3/mcc/1.0 ../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../new_ISO_19115_1/19157/-
2/mdq/1.0/mdq.xsd http://www.qualityml.org/1.0/metrics
../qualityml/1.0/qualityml.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_GriddedDataPositionalAccuracy>
            <mdq:measure>
                <mdq:DQ_MeasureReference>
                    <mdq:measureIdentification>
                        <mcc:MD_Identifier>
                            <mcc:code>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/CircularMapAccuracy">CircularMapAccur
acy</gcx:Anchor>
                            </mcc:code>
                            <mcc:codeSpace>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                            </mcc:codeSpace>
                            <mcc:version>
                                <gco:CharacterString>1.0</gco:CharacterString>
                            </mcc:version>
                        </mcc:MD_Identifier>
                    </mdq:measureIdentification>
                    <mdq:nameOfMeasure>
                        <gco:CharacterString>Circular Map
Accuracy</gco:CharacterString>
                    </mdq:nameOfMeasure>
                    <mdq:measureDescription>
                        <gco:CharacterString>Radius describing a circle, in which the
true point location lies with a certain probability, computed using satellite
ephemerides.</gco:CharacterString>
                    </mdq:measureDescription>
                </mdq:DQ_MeasureReference>
            </mdq:measure>
            <mdq:result>
                <mdq:DQ_QuantitativeResult>
```

```
                    <mdq:value>
                        <gco:Record>
                            <qml:CircularError level="0.95">
                                <qml:values>3.2</qml:values>
                            </qml:CircularError>
                        </gco:Record>
                    </mdq:value>
                    <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <mdq:valueRecordType>
                        <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/CircularError">Circular
Error</gco:RecordType>
                    </mdq:valueRecordType>
                </mdq:DQ_QuantitativeResult>
            </mdq:result>
        </mdq:DQ_GriddedDataPositionalAccuracy>
    </mdq:report>
</mdq:DQ_DataQuality>
```

Product accuracy (x,y,z): Processed pixel location accuracy on the ground

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:DQ_DataQuality xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd">
    <gmd:scope>
        <gmd:DQ_Scope>
            <gmd:level>
                <gmd:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </gmd:level>
        </gmd:DQ_Scope>
    </gmd:scope>
    <gmd:report>
        <gmd:DQ_GriddedDataPositionalAccuracy>
            <gmd:nameOfMeasure>
                <gco:CharacterString>Root Mean Square (RMS)</gco:CharacterString>
            </gmd:nameOfMeasure>
            <gmd:measureIdentification>
                <gmd:MD_Identifier>
```

```
                    <gmd:code>
                        <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/RootMeanSquare">RootMeanSquare</gmx:A
nchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:measureIdentification>
            <gmd:measureDescription>
                <gco:CharacterString>Measure of the differences between 2D values
predicted by a model or an estimator and the values actually observed in a set of
ground control points.</gco:CharacterString>
            </gmd:measureDescription>
            <gmd:result>
                <gmd:DQ_QuantitativeResult>
                    <gmd:valueType>
                        <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/RootMeanSquareError2D">Root mean
square error 2D</gco:RecordType>
                    </gmd:valueType>
                    <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <gmd:value>
                        <gco:Record>
                            <qml:RootMeanSquare>
                                <qml:values>2.9</qml:values>
                            </qml:RootMeanSquare>
                        </gco:Record>
                    </gmd:value>
                </gmd:DQ_QuantitativeResult>
            </gmd:result>
        </gmd:DQ_GriddedDataPositionalAccuracy>
    </gmd:report>
</gmd:DQ_DataQuality>
```

ISO 19115-1 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0
../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd http://standards.iso.org/iso/19115/-
3/mcc/1.0 ../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../new_ISO_19115_1/19157/-
2/mdq/1.0/mdq.xsd http://www.qualityml.org/1.0/metrics
../qualityml/1.0/qualityml.xsd">
    <mdq:scope>
```

```
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_GriddedDataPositionalAccuracy>
            <mdq:measure>
                <mdq:DQ_MeasureReference>
                    <mdq:measureIdentification>
                        <mcc:MD_Identifier>
                            <mcc:code>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/RootMeanSquare">RootMeanSquare</gcx:A
nchor>
                            </mcc:code>
                            <mcc:codeSpace>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                            </mcc:codeSpace>
                            <mcc:version>
                                <gco:CharacterString>1.0</gco:CharacterString>
                            </mcc:version>
                        </mcc:MD_Identifier>
                    </mdq:measureIdentification>
                    <mdq:nameOfMeasure>
                        <gco:CharacterString>Root Mean Square
(RMS)</gco:CharacterString>
                    </mdq:nameOfMeasure>
                    <mdq:measureDescription>
                        <gco:CharacterString>Measure of the differences between 2D
values predicted by a model or an estimator and the values actually observed in a set
of ground control points.</gco:CharacterString>
                    </mdq:measureDescription>
                </mdq:DQ_MeasureReference>
            </mdq:measure>
            <mdq:result>
                <mdq:DQ_QuantitativeResult>
                    <mdq:value>
                        <gco:Record>
                            <qml:RootMeanSquare>
                                <qml:values>2.9</qml:values>
                            </qml:RootMeanSquare>
                        </gco:Record>
                    </mdq:value>
                    <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <mdq:valueRecordType>
                        <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/RootMeanSquareError2D">Root mean
square error 2D</gco:RecordType>
```

```
                    </mdq:valueRecordType>
                </mdq:DQ_QuantitativeResult>
            </mdq:result>
        </mdq:DQ_GriddedDataPositionalAccuracy>
    </mdq:report>
</mdq:DQ_DataQuality>
```

Accuracy (thematic)

Thematic accuracy: DEM accuracy (dataset-level)

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:DQ_DataQuality xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx" xmlns:un="http://www.uncertml.org/2.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.uncertml.org/2.0 ../uncertml/2.0/uncertml.xsd">
    <gmd:scope>
        <gmd:DQ_Scope>
            <gmd:level>
                <gmd:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </gmd:level>
        </gmd:DQ_Scope>
    </gmd:scope>
    <gmd:report>
        <gmd:DQ_QuantitativeAttributeAccuracy>
            <gmd:nameOfMeasure>
                <gco:CharacterString>Mean Absolute Error (MAE)</gco:CharacterString>
            </gmd:nameOfMeasure>
            <gmd:measureIdentification>
                <gmd:MD_Identifier>
                    <gmd:code>
                        <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/MeanAbsoluteError">MeanAbsoluteError<
/gmx:Anchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:measureIdentification>
            <gmd:measureDescription>
                <gco:CharacterString>Mean Absolute Error (MAE) of DEM values and
expressed as mean and variance.</gco:CharacterString>
            </gmd:measureDescription>
            <gmd:result>
                <gmd:DQ_QuantitativeResult>
                    <gmd:valueType>
                        <gco:RecordType
xlink:href="http://www.uncertml.org/distributions/normal">Normal
Distribution</gco:RecordType>
                    </gmd:valueType>
                    <gmd:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <gmd:value>
```

```
                        <gco:Record>
                            <un:NormalDistribution>
                                <un:mean>1.21</un:mean>
                                <un:variance>3.06</un:variance>
                            </un:NormalDistribution>
                        </gco:Record>
                    </gmd:value>
                </gmd:DQ_QuantitativeResult>
            </gmd:result>
        </gmd:DQ_QuantitativeAttributeAccuracy>
    </gmd:report>
</gmd:DQ_DataQuality>
```

ISO 19115-1 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<mdq:DQ_DataQuality xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:un="http://www.uncertml.org/2.0" xmlns:mcc="http://standards.iso.org/iso/19115/-
3/mcc/1.0" xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/gco/1.0
../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd http://standards.iso.org/iso/19115/-
3/mcc/1.0 ../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../new_ISO_19115_1/19157/-
2/mdq/1.0/mdq.xsd http://www.uncertml.org/2.0 ../uncertml/2.0/uncertml.xsd">
    <mdq:scope>
        <mcc:MD_Scope>
            <mcc:level>
                <mcc:MD_ScopeCode codeListValue="dataset" codeList="MD_ScopeCode"/>
            </mcc:level>
        </mcc:MD_Scope>
    </mdq:scope>
    <mdq:report>
        <mdq:DQ_QuantitativeAttributeAccuracy>
            <mdq:measure>
                <mdq:DQ_MeasureReference>
                    <mdq:measureIdentification>
                        <mcc:MD_Identifier>
                            <mcc:code>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/MeanAbsoluteError">MeanAbsoluteError<
/gcx:Anchor>
                            </mcc:code>
                            <mcc:codeSpace>
                                <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                            </mcc:codeSpace>
                            <mcc:version>
```

```
                                <gco:CharacterString>1.0</gco:CharacterString>
                            </mcc:version>
                        </mcc:MD_Identifier>
                    </mdq:measureIdentification>
                    <mdq:nameOfMeasure>
                        <gco:CharacterString>Mean Absolute Error
(MAE)</gco:CharacterString>
                    </mdq:nameOfMeasure>
                    <mdq:measureDescription>
                        <gco:CharacterString>Mean Absolute Error (MAE) of DEM values
and expressed as mean and variance.</gco:CharacterString>
                    </mdq:measureDescription>
                </mdq:DQ_MeasureReference>
            </mdq:measure>
            <mdq:result>
                <mdq:DQ_QuantitativeResult>
                    <mdq:value>
                        <gco:Record>
                            <un:NormalDistribution>
                                <un:mean>1.21</un:mean>
                                <un:variance>3.06</un:variance>
                            </un:NormalDistribution>
                        </gco:Record>
                    </mdq:value>
                    <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:metre"/>
                    <mdq:valueRecordType>
                        <gco:RecordType
xlink:href="http://www.uncertml.org/distributions/normal">Normal
Distribution</gco:RecordType>
                    </mdq:valueRecordType>
                </mdq:DQ_QuantitativeResult>
            </mdq:result>
        </mdq:DQ_QuantitativeAttributeAccuracy>
    </mdq:report>
</mdq:DQ_DataQuality>
```

Thematic accuracy: NDVI accuracy (pixel-level)

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:MD_Metadata xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd">
    <gmd:fileIdentifier>
```

```
<gco:CharacterString>QM_4_Accuracy_NDVI_accuracy_old_19115</gco:CharacterString>
    </gmd:fileIdentifier>
    <gmd:contact>
        <gmd:CI_ResponsibleParty>
            <gmd:individualName>
                <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
            </gmd:individualName>
            <gmd:contactInfo>
                <gmd:CI_Contact>
                    <gmd:address>
                        <gmd:CI_Address>
                            <gmd:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                            </gmd:electronicMailAddress>
                        </gmd:CI_Address>
                    </gmd:address>
                </gmd:CI_Contact>
            </gmd:contactInfo>
            <gmd:role>
                <gmd:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </gmd:role>
        </gmd:CI_ResponsibleParty>
    </gmd:contact>
    <gmd:dateStamp>
        <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
    </gmd:dateStamp>
    <gmd:spatialRepresentationInfo>
        <gmd:MD_GridSpatialRepresentation id="NDVI_SpatialRepresentation">
            <!-- Documentation created for example purposes only -->
            <gmd:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </gmd:numberOfDimensions>
            <gmd:axisDimensionProperties>
                <gmd:MD_Dimension>
                    <gmd:dimensionName>
                        <gmd:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </gmd:dimensionName>
                    <gmd:dimensionSize>
                        <gco:Integer>1600</gco:Integer>
                    </gmd:dimensionSize>
                    <gmd:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </gmd:resolution>
                </gmd:MD_Dimension>
            </gmd:axisDimensionProperties>
            <gmd:axisDimensionProperties>
```

```
                <gmd:MD_Dimension>
                    <gmd:dimensionName>
                        <gmd:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </gmd:dimensionName>
                    <gmd:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </gmd:dimensionSize>
                    <gmd:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </gmd:resolution>
                </gmd:MD_Dimension>
            </gmd:axisDimensionProperties>
            <gmd:cellGeometry>
                <gmd:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </gmd:cellGeometry>
            <gmd:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </gmd:transformationParameterAvailability>
        </gmd:MD_GridSpatialRepresentation>
    </gmd:spatialRepresentationInfo>
    <gmd:spatialRepresentationInfo>
        <gmd:MD_GridSpatialRepresentation id="NDVI_Quality_SpatialRepresentation">
            <!-- Documentation created for example purposes only, with a different
resolution for quality bands -->
            <gmd:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </gmd:numberOfDimensions>
            <gmd:axisDimensionProperties>
                <gmd:MD_Dimension>
                    <gmd:dimensionName>
                        <gmd:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </gmd:dimensionName>
                    <gmd:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </gmd:dimensionSize>
                    <gmd:resolution>
                        <gco:Length uom="m">60</gco:Length>
                    </gmd:resolution>
                </gmd:MD_Dimension>
            </gmd:axisDimensionProperties>
            <gmd:axisDimensionProperties>
                <gmd:MD_Dimension>
                    <gmd:dimensionName>
                        <gmd:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
```

```
                    </gmd:dimensionName>
                    <gmd:dimensionSize>
                        <gco:Integer>400</gco:Integer>
                    </gmd:dimensionSize>
                    <gmd:resolution>
                        <gco:Length uom="m">60</gco:Length>
                    </gmd:resolution>
                </gmd:MD_Dimension>
            </gmd:axisDimensionProperties>
            <gmd:cellGeometry>
                <gmd:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </gmd:cellGeometry>
            <gmd:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </gmd:transformationParameterAvailability>
        </gmd:MD_GridSpatialRepresentation>
    </gmd:spatialRepresentationInfo>
    <gmd:identificationInfo>
        <gmd:MD_DataIdentification>
            <gmd:citation>
                <gmd:CI_Citation>
                    <gmd:title>
                        <gco:CharacterString>Thematic accuracy: NDVI accuracy
dataset</gco:CharacterString>
                    </gmd:title>
                    <gmd:date>
                        <gmd:CI_Date>
                            <gmd:date>
                                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
                            </gmd:date>
                            <gmd:dateType>
                                <gmd:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
                            </gmd:dateType>
                        </gmd:CI_Date>
                    </gmd:date>
                </gmd:CI_Citation>
            </gmd:citation>
            <gmd:abstract>
                <gco:CharacterString>NDVI accuracy dataset for demostration purposes
only</gco:CharacterString>
            </gmd:abstract>
            <gmd:spatialRepresentationType>
                <gmd:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </gmd:spatialRepresentationType>
            <gmd:language>
                <gco:CharacterString>English</gco:CharacterString>
            </gmd:language>
        </gmd:MD_DataIdentification>
```

```
    </gmd:identificationInfo>
    <gmd:contentInfo>
        <gmd:MD_CoverageDescription>
            <gmd:attributeDescription>
                <gco:RecordType>NDVI and NDVI Quality</gco:RecordType>
            </gmd:attributeDescription>
            <gmd:contentType>
                <gmd:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
                codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
            </gmd:contentType>
            <gmd:dimension>
            <gmd:MD_RangeDimension id="NDVI_AttributeGroup">
                <gmd:descriptor>
                    <gco:CharacterString>NDVI</gco:CharacterString>
                </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="NDVI_Quality_AttributeGroup">
                    <gmd:descriptor>
                        <gco:CharacterString>NDVI error</gco:CharacterString>
                    </gmd:descriptor>
                    <!-- ISO 19115 does no allow describing gmd:name ->
gmd:MD_Identifier, so direct link to QualityML metrics is not possible
                    <gmd:name>
                        <gmd:MD_Identifier>
                            <gmd:code>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/metrics/MeanAbsoluter">Mean
Absolute</gmx:Anchor>
                            </gmd:code>
                            <gmd:codeSpace>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gmx:Anchor>
                            </gmd:codeSpace>
                            <gmd:version>
                                <gco:CharacterString>1.0</gco:CharacterString>
                            </gmd:version>
                        </gmd:MD_Identifier>
                    </gmd:name -->
                </gmd:MD_RangeDimension>
            </gmd:dimension>
        </gmd:MD_CoverageDescription>
    </gmd:contentInfo>
    <gmd:dataQualityInfo>
        <gmd:DQ_DataQuality>
            <gmd:scope>
                <gmd:DQ_Scope>
                    <gmd:level>
                        <gmd:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
```

```
                    </gmd:level>
                </gmd:DQ_Scope>
            </gmd:scope>
            <gmd:report>
                <gmd:DQ_QuantitativeAttributeAccuracy>
                    <gmd:nameOfMeasure>
                        <gco:CharacterString>Mean Absolute Error
(MAE)</gco:CharacterString>
                    </gmd:nameOfMeasure>
                    <gmd:measureIdentification>
                        <gmd:MD_Identifier>
                            <gmd:code>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/meanAbsolute">MeanAbsoluteError</gmx:
Anchor>
                            </gmd:code>
                        </gmd:MD_Identifier>
                    </gmd:measureIdentification>
                    <gmd:measureDescription>
                        <gco:CharacterString>Mean Absolute Error (MAE) of NDVI values
computed using original bands uncertainty and error propagation.</gco:CharacterString>
                    </gmd:measureDescription>
                    <gmd:result>
                        <!-- Coverage result is not included in ISO 19115, so no
result is provided in this example. If a dataset-level result wants to be documented,
other XML examples can be followed -->
                        <!--gmd_TB12:QE_CoverageResult_TB12>
                            <gmd_TB12:spatialRepresentationType>
                                <gmd:MD_SpatialRepresentationTypeCode
codeListValue="grid"
                                    codeList="MD_SpatialRepresentationTypeCode"/>
                            </gmd_TB12:spatialRepresentationType>
                            <gmd_TB12:resultSpatialRepresentation
xlink:href="#NDVI_Quality_SpatialRepresentation"/>
                            <gmd_TB12:resultContentDescription
xlink:href="#NDVI_Quality_AttributeGroup"/>
                        </gmd_TB12:QE_CoverageResult_TB12-->
                    </gmd:result>
                </gmd:DQ_QuantitativeAttributeAccuracy>
            </gmd:report>
        </gmd:DQ_DataQuality>
    </gmd:dataQualityInfo>
</gmd:MD_Metadata>
```

ISO 19115-1 encoding (including modifications in QE_CoverageResult_TB12)

```
<?xml version="1.0" encoding="UTF-8"?>
<mdb:MD_Metadata xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
```

```
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mdq_TB12="http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/mdb/1.0
../new_ISO_19115_1/19115/-3/mdb/1.0/mdb.xsd http://standards.iso.org/iso/19115/-
3/gco/1.0 ../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd
http://standards.iso.org/iso/19115/-3/cit/1.0 ../new_ISO_19115_1/19115/-
3/cit/1.0/cit.xsd http://standards.iso.org/iso/19115/-3/gcx/1.0
../new_ISO_19115_1/19115/-3/gcx/1.0/gcx.xsd http://standards.iso.org/iso/19115/-
3/mcc/1.0 ../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../new_ISO_19115_1/19157/-
2/mdq/1.0/mdq.xsd http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0
../new_ISO_19115_1/19157/-2/mdq/1.0/mdq_TB12.xsd http://standards.iso.org/iso/19115/-
3/mrc/1.0 ../new_ISO_19115_1/19115/-3/mrc/1.0/mrc.xsd
http://standards.iso.org/iso/19115/-3/mri/1.0 ../new_ISO_19115_1/19115/-
3/mri/1.0/mri.xsd http://standards.iso.org/iso/19115/-3/msr/1.0
../new_ISO_19115_1/19115/-3/msr/1.0/msr.xsd">
    <mdb:metadataIdentifier>
        <mcc:MD_Identifier>
            <mcc:code>

<gco:CharacterString>QM_4_Accuracy_NDVI_accuracy_19115_1</gco:CharacterString>
            </mcc:code>
            <mcc:codeSpace>

<gco:CharacterString>http://www.creaf.uab.es/TestBed12</gco:CharacterString>
            </mcc:codeSpace>
        </mcc:MD_Identifier>
    </mdb:metadataIdentifier>
    <mdb:contact>
        <cit:CI_Responsibility>
            <cit:role>
                <cit:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </cit:role>
            <cit:party>
                <cit:CI_Individual>
                    <cit:name>
                        <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
                    </cit:name>
                    <cit:contactInfo>
                        <cit:CI_Contact>
                            <cit:address>
                                <cit:CI_Address>
                                    <cit:electronicMailAddress>
```

```
<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                                    </cit:electronicMailAddress>
                                </cit:CI_Address>
                            </cit:address>
                        </cit:CI_Contact>
                    </cit:contactInfo>
                </cit:CI_Individual>
            </cit:party>
        </cit:CI_Responsibility>
    </mdb:contact>
    <mdb:dateInfo>
        <cit:CI_Date>
            <cit:date>
                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
            </cit:date>
            <cit:dateType>
                <cit:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
            </cit:dateType>
        </cit:CI_Date>
    </mdb:dateInfo>
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="NDVI_SpatialRepresentation">
            <!-- Documentation created for example purposes only -->
            <msr:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </msr:numberOfDimensions>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>1600</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
```

```
                        <gco:Integer>800</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:cellGeometry>
                <msr:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </msr:cellGeometry>
            <msr:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </msr:transformationParameterAvailability>
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="NDVI_Quality_SpatialRepresentation">
            <!-- Documentation created for example purposes only, with a different
resolution for quality bands -->
            <msr:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </msr:numberOfDimensions>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">60</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>400</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">60</gco:Length>
                    </msr:resolution>
```

```
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:cellGeometry>
                <msr:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </msr:cellGeometry>
            <msr:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </msr:transformationParameterAvailability>
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    <mdb:identificationInfo>
        <mri:MD_DataIdentification>
            <mri:citation>
                <cit:CI_Citation>
                    <cit:title>
                        <gco:CharacterString>Thematic accuracy: NDVI accuracy
dataset</gco:CharacterString>
                    </cit:title>
                </cit:CI_Citation>
            </mri:citation>
            <mri:abstract>
                <gco:CharacterString>NDVI accuracy dataset for demonstration purposes
only</gco:CharacterString>
            </mri:abstract>
            <mri:spatialRepresentationType>
                <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </mri:spatialRepresentationType>
        </mri:MD_DataIdentification>
    </mdb:identificationInfo>
    <mdb:contentInfo>
        <mrc:MD_CoverageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>NDVI and NDVI Quality</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="NDVI_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>NDVI</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
```

```
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="NDVI_Quality_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>NDVI error</gco:CharacterString>
                            </mrc:description>
                            <mrc:name>
                                <mcc:MD_Identifier>
                                    <mcc:code>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/metrics/MeanAbsolute">Mean
Absolute</gcx:Anchor>
                                    </mcc:code>
                                    <mcc:codeSpace>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                                    </mcc:codeSpace>
                                    <mcc:version>
                                        <gco:CharacterString>1.0</gco:CharacterString>
                                    </mcc:version>
                                </mcc:MD_Identifier>
                            </mrc:name>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
        </mrc:MD_CoverageDescription>
    </mdb:contentInfo>
    <mdb:dataQualityInfo>
        <mdq:DQ_DataQuality>
            <mdq:scope>
                <mcc:MD_Scope>
                    <mcc:level>
                        <mcc:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </mcc:level>
                </mcc:MD_Scope>
            </mdq:scope>
            <mdq:report>
                <mdq:DQ_QuantitativeAttributeAccuracy>
                    <mdq:measure>
                        <mdq:DQ_MeasureReference>
```

```
                            <mdq:measureIdentification>
                                <mcc:MD_Identifier>
                                    <mcc:code>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/MeanAbsoluteError">MeanAbsoluteError<
/gcx:Anchor>
                                    </mcc:code>
                                    <mcc:codeSpace>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                                    </mcc:codeSpace>
                                    <mcc:version>
                                        <gco:CharacterString>1.0</gco:CharacterString>
                                    </mcc:version>
                                </mcc:MD_Identifier>
                            </mdq:measureIdentification>
                            <mdq:nameOfMeasure>
                                <gco:CharacterString>Mean Absolute Error
(MAE)</gco:CharacterString>
                            </mdq:nameOfMeasure>
                            <mdq:measureDescription>
                                <gco:CharacterString>Mean Absolute Error (MAE) of NDVI
values computed using original bands uncertainty and error
propagation.</gco:CharacterString>
                            </mdq:measureDescription>
                        </mdq:DQ_MeasureReference>
                    </mdq:measure>
                    <mdq:result>
                        <mdq_TB12:QE_CoverageResult_TB12>
                            <mdq_TB12:spatialRepresentationType>
                                <mcc:MD_SpatialRepresentationTypeCode
codeListValue="grid"
                                    codeList="MD_SpatialRepresentationTypeCode"/>
                            </mdq_TB12:spatialRepresentationType>
                            <mdq_TB12:resultSpatialRepresentation
xlink:href="#NDVI_Quality_SpatialRepresentation"/>
                            <mdq_TB12:resultContentDescription
xlink:href="#NDVI_Quality_AttributeGroup"/>
                        </mdq_TB12:QE_CoverageResult_TB12>
                    </mdq:result>
                </mdq:DQ_QuantitativeAttributeAccuracy>
            </mdq:report>
        </mdq:DQ_DataQuality>
    </mdb:dataQualityInfo>
</mdb:MD_Metadata>
```

Currency

Currency: temporal extent and validity with a domain requirement

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:MD_Metadata xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd
http://www.opengis.net/gml ../old_ISO_19115/gml/gml.xsd">
    <gmd:fileIdentifier>

<gco:CharacterString>QM_5_Currency_TemporalValidity_old_19115</gco:CharacterString>
    </gmd:fileIdentifier>
    <gmd:contact>
        <gmd:CI_ResponsibleParty>
            <gmd:individualName>
                <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
            </gmd:individualName>
            <gmd:contactInfo>
                <gmd:CI_Contact>
                    <gmd:address>
                        <gmd:CI_Address>
                            <gmd:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                            </gmd:electronicMailAddress>
                        </gmd:CI_Address>
                    </gmd:address>
                </gmd:CI_Contact>
            </gmd:contactInfo>
            <gmd:role>
                <gmd:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </gmd:role>
        </gmd:CI_ResponsibleParty>
    </gmd:contact>
    <gmd:dateStamp>
```

```
        <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
    </gmd:dateStamp>
    <gmd:identificationInfo>
        <gmd:MD_DataIdentification>
            <gmd:citation>
                <gmd:CI_Citation>
                    <gmd:title>
                        <gco:CharacterString>Currency: temporal validity with a domain
requirement</gco:CharacterString>
                    </gmd:title>
                    <gmd:date>
                        <gmd:CI_Date>
                            <gmd:date>
                                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
                            </gmd:date>
                            <gmd:dateType>
                                <gmd:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
                            </gmd:dateType>
                        </gmd:CI_Date>
                    </gmd:date>
                </gmd:CI_Citation>
            </gmd:citation>
            <gmd:abstract>
                <gco:CharacterString>Currency and temporal validity for demonstration
purposes only</gco:CharacterString>
            </gmd:abstract>
            <gmd:spatialRepresentationType>
                <gmd:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </gmd:spatialRepresentationType>
            <gmd:language>
                <gco:CharacterString>English</gco:CharacterString>
            </gmd:language>
            <gmd:extent>
                <gmd:EX_Extent>
                    <gmd:temporalElement>
                        <gmd:EX_TemporalExtent>
                            <gmd:extent>
                                <gml:TimeInstant gml:id="TE_1">
                                    <gml:timePosition>2016-05-01</gml:timePosition>
                                </gml:TimeInstant>
                            </gmd:extent>
                        </gmd:EX_TemporalExtent>
                    </gmd:temporalElement>
                </gmd:EX_Extent>
            </gmd:extent>
        </gmd:MD_DataIdentification>
    </gmd:identificationInfo>
    <gmd:dataQualityInfo>
        <gmd:DQ_DataQuality>
```

```
            <gmd:scope>
                <gmd:DQ_Scope>
                    <gmd:level>
                        <gmd:MD_ScopeCode codeList="MD_ScopeCode"
codeListValue="dataset"/>
                    </gmd:level>
                </gmd:DQ_Scope>
            </gmd:scope>
            <gmd:report>
                <gmd:DQ_TemporalValidity>
                    <gmd:nameOfMeasure>
                        <gco:CharacterString>Value domain</gco:CharacterString>
                    </gmd:nameOfMeasure>
                    <gmd:measureIdentification>
                        <gmd:MD_Identifier>
                            <gmd:code>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/ValueDomain">ValueDomain</gmx:Anchor>
                            </gmd:code>
                        </gmd:MD_Identifier>
                    </gmd:measureIdentification>
                    <gmd:measureDescription>
                        <gco:CharacterString>Indication of if an item is conformant or
not with a rule. The conformance or non-conformance can be expressed as a boolean,
count or rate.</gco:CharacterString>
                    </gmd:measureDescription>
                    <gmd:result>
                        <gmd:DQ_QuantitativeResult>
                            <gmd:valueType>
                                <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                            </gmd:valueType>
                            <gmd:valueUnit
xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                            <gmd:value>
                                <gco:Record>
                                    <qml:Items>
                                        <!--qml:indicator>true</qml:indicator-->
                                        <!--qml:count>33</qml:count-->
                                        <!--qml:rate max="1">0.3</qml:rate-->
                                        <qml:rate max="100">30</qml:rate>
                                    </qml:Items>
                                    <qmld:NonConformance>
                                        <qmld:range>
                                            <qmld:min>
                                                <qmld:date>2014-05-01</qmld:date>
                                            </qmld:min>
                                        </qmld:range>
                                        <qmld:rule>Pixels are older than a 24 month of
the time intended for the data (i.e. older than 2014-05-01)</qmld:rule>
                                    </qmld:NonConformance>
```

```
                                </gco:Record>
                            </gmd:value>
                        </gmd:DQ_QuantitativeResult>
                    </gmd:result>
                </gmd:DQ_TemporalValidity>
            </gmd:report>
        </gmd:DQ_DataQuality>
    </gmd:dataQualityInfo>
</gmd:MD_Metadata>
```

ISO 19115-1 encoding (including modifications in QE_CoverageResult_TB12)

```
<?xml version="1.0" encoding="UTF-8"?>
<mdb:MD_Metadata xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:gex="http://standards.iso.org/iso/19115/-3/gex/1.0"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/mdb/1.0
../new_ISO_19115_1/19115/-3/mdb/1.0/mdb.xsd http://standards.iso.org/iso/19115/-
3/gco/1.0 ../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd http://www.opengis.net/gml/3.2
../new_ISO_19115_1/19136/gml.xsd http://standards.iso.org/iso/19115/-3/cit/1.0
../new_ISO_19115_1/19115/-3/cit/1.0/cit.xsd http://standards.iso.org/iso/19115/-
3/gcx/1.0 ../new_ISO_19115_1/19115/-3/gcx/1.0/gcx.xsd
http://standards.iso.org/iso/19115/-3/mcc/1.0 ../new_ISO_19115_1/19115/-
3/mcc/1.0/mcc.xsd http://standards.iso.org/iso/19157/-2/mdq/1.0
../new_ISO_19115_1/19157/-2/mdq/1.0/mdq.xsd http://standards.iso.org/iso/19115/-
3/mri/1.0 ../new_ISO_19115_1/19115/-3/mri/1.0/mri.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd">
    <mdb:metadataIdentifier>
        <mcc:MD_Identifier>
            <mcc:code>

<gco:CharacterString>QM_5_Currency_TemporalValidity_19115_1</gco:CharacterString>
            </mcc:code>
            <mcc:codeSpace>

<gco:CharacterString>http://www.creaf.uab.es/TestBed12</gco:CharacterString>
            </mcc:codeSpace>
        </mcc:MD_Identifier>
    </mdb:metadataIdentifier>
```

```
    <mdb:contact>
        <cit:CI_Responsibility>
            <cit:role>
                <cit:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </cit:role>
            <cit:party>
                <cit:CI_Individual>
                    <cit:name>
                        <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
                    </cit:name>
                    <cit:contactInfo>
                        <cit:CI_Contact>
                            <cit:address>
                                <cit:CI_Address>
                                    <cit:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                                    </cit:electronicMailAddress>
                                </cit:CI_Address>
                            </cit:address>
                        </cit:CI_Contact>
                    </cit:contactInfo>
                </cit:CI_Individual>
            </cit:party>
        </cit:CI_Responsibility>
    </mdb:contact>
    <mdb:dateInfo>
        <cit:CI_Date>
            <cit:date>
                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
            </cit:date>
            <cit:dateType>
                <cit:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
            </cit:dateType>
        </cit:CI_Date>
    </mdb:dateInfo>
    <mdb:identificationInfo>
        <mri:MD_DataIdentification>
            <mri:citation>
                <cit:CI_Citation>
                    <cit:title>
                        <gco:CharacterString>Currency: temporal validity with a domain
requirement</gco:CharacterString>
                    </cit:title>
                </cit:CI_Citation>
            </mri:citation>
            <mri:abstract>
                <gco:CharacterString>Currency and temporal validity for demonstration
purposes only</gco:CharacterString>
```

```
            </mri:abstract>
            <mri:extent>
                <gex:EX_Extent>
                    <gex:temporalElement>
                        <gex:EX_TemporalExtent>
                            <gex:extent>
                                <gml:TimeInstant gml:id="TE_1">
                                    <gml:timePosition>2016-05-01</gml:timePosition>
                                </gml:TimeInstant>
                            </gex:extent>
                        </gex:EX_TemporalExtent>
                    </gex:temporalElement>
                </gex:EX_Extent>
            </mri:extent>
        </mri:MD_DataIdentification>
    </mdb:identificationInfo>
    <mdb:dataQualityInfo>
        <mdq:DQ_DataQuality>
            <mdq:scope>
                <mcc:MD_Scope>
                    <mcc:level>
                        <mcc:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </mcc:level>
                </mcc:MD_Scope>
            </mdq:scope>
            <mdq:report>
                <mdq:DQ_TemporalValidity>
                    <mdq:measure>
                        <mdq:DQ_MeasureReference>
                            <mdq:measureIdentification>
                                <mcc:MD_Identifier>
                                    <mcc:code>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/ValueDomain">ValueDomain</gcx:Anchor>
                                    </mcc:code>
                                    <mcc:codeSpace>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                                    </mcc:codeSpace>
                                    <mcc:version>
                                        <gco:CharacterString>1.0</gco:CharacterString>
                                    </mcc:version>
                                </mcc:MD_Identifier>
                            </mdq:measureIdentification>
                            <mdq:nameOfMeasure>
                                <gco:CharacterString>Value
domain</gco:CharacterString>
                            </mdq:nameOfMeasure>
                            <mdq:measureDescription>
                                <gco:CharacterString>Indication of if an item is
```

```
conformant or not with a rule. The conformance or non-conformance can be expressed as
a boolean, count or rate.</gco:CharacterString>
                            </mdq:measureDescription>
                        </mdq:DQ_MeasureReference>
                    </mdq:measure>
                    <mdq:result>
                    <mdq:DQ_QuantitativeResult>
                        <mdq:value>
                            <gco:Record>
                                    <qml:Items>
                                        <!--qml:indicator>true</qml:indicator-->
                                        <!--qml:count>33</qml:count-->
                                        <!--qml:rate max="1">0.3</qml:rate-->
                                        <qml:rate max="100">30</qml:rate>
                                    </qml:Items>
                                    <qmld:NonConformance>
                                        <qmld:range>
                                            <qmld:min>
                                                <qmld:date>2014-05-01</qmld:date>
                                            </qmld:min>
                                        </qmld:range>
                                        <qmld:rule>Pixels are older than a 24 month of
the time intended for the data (i.e. older than 2014-05-01)</qmld:rule>
                                    </qmld:NonConformance>
                            </gco:Record>
                        </mdq:value>
                        <mdq:valueUnit xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                        <mdq:valueRecordType>
                            <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                        </mdq:valueRecordType>
                    </mdq:DQ_QuantitativeResult>
                    </mdq:result>
                </mdq:DQ_TemporalValidity>
            </mdq:report>
        </mdq:DQ_DataQuality>
    </mdb:dataQualityInfo>
</mdb:MD_Metadata>
```

Completeness

Completeness: cloud cover (percentage result) and snow cover (per pixel result)

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:MD_Metadata xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd">
    <gmd:fileIdentifier>
        <gco:CharacterString>QM_6_Completeness_FlagAreas_19115_1</gco:CharacterString>
    </gmd:fileIdentifier>
    <gmd:contact>
        <gmd:CI_ResponsibleParty>
            <gmd:individualName>
                <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
            </gmd:individualName>
            <gmd:contactInfo>
                <gmd:CI_Contact>
                    <gmd:address>
                        <gmd:CI_Address>
                            <gmd:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                            </gmd:electronicMailAddress>
                        </gmd:CI_Address>
                    </gmd:address>
                </gmd:CI_Contact>
            </gmd:contactInfo>
            <gmd:role>
                <gmd:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </gmd:role>
        </gmd:CI_ResponsibleParty>
    </gmd:contact>
    <gmd:dateStamp>
        <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
    </gmd:dateStamp>
    <gmd:spatialRepresentationInfo>
        <gmd:MD_GridSpatialRepresentation id="Imagery_SpatialRepresentation">
```

```
            <!-- Documentation created for example purposes only -->
            <gmd:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </gmd:numberOfDimensions>
            <gmd:axisDimensionProperties>
                <gmd:MD_Dimension>
                    <gmd:dimensionName>
                        <gmd:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </gmd:dimensionName>
                    <gmd:dimensionSize>
                        <gco:Integer>1600</gco:Integer>
                    </gmd:dimensionSize>
                    <gmd:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </gmd:resolution>
                </gmd:MD_Dimension>
            </gmd:axisDimensionProperties>
            <gmd:axisDimensionProperties>
                <gmd:MD_Dimension>
                    <gmd:dimensionName>
                        <gmd:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </gmd:dimensionName>
                    <gmd:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </gmd:dimensionSize>
                    <gmd:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </gmd:resolution>
                </gmd:MD_Dimension>
            </gmd:axisDimensionProperties>
            <gmd:cellGeometry>
                <gmd:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </gmd:cellGeometry>
            <gmd:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </gmd:transformationParameterAvailability>
        </gmd:MD_GridSpatialRepresentation>
    </gmd:spatialRepresentationInfo>
    <gmd:identificationInfo>
        <gmd:MD_DataIdentification>
            <gmd:citation>
                <gmd:CI_Citation>
                    <gmd:title>
                        <gco:CharacterString>Currency: Flag areas
dataset</gco:CharacterString>
                    </gmd:title>
```

```
                    <gmd:date>
                        <gmd:CI_Date>
                            <gmd:date>
                                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
                            </gmd:date>
                            <gmd:dateType>
                                <gmd:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
                            </gmd:dateType>
                        </gmd:CI_Date>
                    </gmd:date>
                </gmd:CI_Citation>
            </gmd:citation>
            <gmd:abstract>
                <gco:CharacterString>Imagery with a quality band describing snow
flags</gco:CharacterString>
            </gmd:abstract>
            <gmd:spatialRepresentationType>
                <gmd:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </gmd:spatialRepresentationType>
            <gmd:language>
                <gco:CharacterString>English</gco:CharacterString>
            </gmd:language>
        </gmd:MD_DataIdentification>
    </gmd:identificationInfo>
    <gmd:contentInfo>
        <gmd:MD_ImageDescription>
            <gmd:attributeDescription>
                <gco:RecordType>Imagery bands</gco:RecordType>
            </gmd:attributeDescription>
            <gmd:contentType>
                <gmd:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
                codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
            </gmd:contentType>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="Imagery_R">
                    <gmd:descriptor>
                        <gco:CharacterString>Red imagery band</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="Imagery_G">
                    <gmd:descriptor>
                        <gco:CharacterString>Green imagery band</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="Imagery_B">
```

```
                    <gmd:descriptor>
                        <gco:CharacterString>Blue imagery band</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
            </gmd:dimension>
            <gmd:cloudCoverPercentage>
                <gco:Real>26</gco:Real>
            </gmd:cloudCoverPercentage>
        </gmd:MD_ImageDescription>
    </gmd:contentInfo>
    <gmd:contentInfo>
        <gmd:MD_CoverageDescription>
            <gmd:attributeDescription>
                <gco:RecordType>Quality flag bands</gco:RecordType>
            </gmd:attributeDescription>
            <gmd:contentType>
                <gmd:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
                codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
            </gmd:contentType>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="SnowCover_Quality_AttributeGroup">
                    <gmd:descriptor>
                        <gco:CharacterString>Snow Cover flag band: boolean indication
whether the pixel is covered by snow</gco:CharacterString>
                    </gmd:descriptor>
                    <!-- ISO 19115 does no allow describing gmd:name ->
gmd:MD_Identifier, so direct link to QualityML metrics is not possible
                    <gmd:name>
                        <gmd:MD_Identifier>
                            <gmd:code>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/metrics/Items">Items</gmx:Anchor>
                            </gmd:code>
                            <gmd:codeSpace>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gmx:Anchor>
                            </gmd:codeSpace>
                            <gmd:version>
                                <gco:CharacterString>1.0</gco:CharacterString>
                            </gmd:version>
                        </gmd:MD_Identifier>
                    </gmd:name-->
                </gmd:MD_RangeDimension>
            </gmd:dimension>
        </gmd:MD_CoverageDescription>
    </gmd:contentInfo>
    <gmd:dataQualityInfo>
        <gmd:DQ_DataQuality>
            <gmd:scope>
                <gmd:DQ_Scope>
                    <gmd:level>
```

```
                        <gmd:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </gmd:level>
                </gmd:DQ_Scope>
            </gmd:scope>
            <gmd:report>
                <gmd:DQ_CompletenessOmission>
                    <gmd:nameOfMeasure>
                        <gco:CharacterString>Flag Areas</gco:CharacterString>
                    </gmd:nameOfMeasure>
                    <gmd:measureIdentification>
                        <gmd:MD_Identifier>
                            <gmd:code>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/FlagAreas">FlagAreas</gmx:Anchor>
                            </gmd:code>
                        </gmd:MD_Identifier>
                    </gmd:measureIdentification>
                    <gmd:measureDescription>
                        <gco:CharacterString>Flag areas indicate in this report the
snow cover of the image</gco:CharacterString>
                    </gmd:measureDescription>
                    <gmd:result>
                        <!-- Coverage result is not included in ISO 19115, so no
result is provided in this example. If a dataset-level result wants to be documented,
other XML examples can be followed
                        <gmd_TB12:QE_CoverageResult_TB12>
                            <gmd_TB12:spatialRepresentationType>
                                <gmd:MD_SpatialRepresentationTypeCode
codeListValue="grid" codeList="MD_SpatialRepresentationTypeCode"/>
                            </gmd_TB12:spatialRepresentationType>
                            <gmd_TB12:resultSpatialRepresentation
xlink:href="#Imagery_SpatialRepresentation"/>
                            <gmd_TB12:resultContentDescription
xlink:href="#SnowCover_Quality_AttributeGroup"/>
                        </gmd_TB12:QE_CoverageResult_TB12-->
                    </gmd:result>
                </gmd:DQ_CompletenessOmission>
            </gmd:report>
        </gmd:DQ_DataQuality>
    </gmd:dataQualityInfo>
</gmd:MD_Metadata>
```

ISO 19115-1 encoding (including modifications in QE_CoverageResult_TB12)

```
<?xml version="1.0" encoding="UTF-8"?>
<mdb:MD_Metadata xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
```

```
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mdq_TB12="http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/mdb/1.0
../new_ISO_19115_1/19115/-3/mdb/1.0/mdb.xsd http://standards.iso.org/iso/19115/-
3/gco/1.0 ../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd
http://standards.iso.org/iso/19115/-3/cit/1.0 ../new_ISO_19115_1/19115/-
3/cit/1.0/cit.xsd http://standards.iso.org/iso/19115/-3/gcx/1.0
../new_ISO_19115_1/19115/-3/gcx/1.0/gcx.xsd http://standards.iso.org/iso/19115/-
3/mcc/1.0 ../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../new_ISO_19115_1/19157/-
2/mdq/1.0/mdq.xsd http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0
../new_ISO_19115_1/19157/-2/mdq/1.0/mdq_TB12.xsd http://standards.iso.org/iso/19115/-
3/mrc/1.0 ../new_ISO_19115_1/19115/-3/mrc/1.0/mrc.xsd
http://standards.iso.org/iso/19115/-3/mri/1.0 ../new_ISO_19115_1/19115/-
3/mri/1.0/mri.xsd http://standards.iso.org/iso/19115/-3/msr/1.0
../new_ISO_19115_1/19115/-3/msr/1.0/msr.xsd
 http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd">
    <mdb:metadataIdentifier>
        <mcc:MD_Identifier>
            <mcc:code>

<gco:CharacterString>QM_6_Completeness_FlagAreas_19115_1</gco:CharacterString>
            </mcc:code>
            <mcc:codeSpace>

<gco:CharacterString>http://www.creaf.uab.es/TestBed12</gco:CharacterString>
            </mcc:codeSpace>
        </mcc:MD_Identifier>
    </mdb:metadataIdentifier>
    <mdb:contact>
        <cit:CI_Responsibility>
            <cit:role>
                <cit:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </cit:role>
            <cit:party>
                <cit:CI_Individual>
                    <cit:name>
                        <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
                    </cit:name>
                    <cit:contactInfo>
                        <cit:CI_Contact>
                            <cit:address>
                                <cit:CI_Address>
```

```
                                    <cit:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                                    </cit:electronicMailAddress>
                                </cit:CI_Address>
                            </cit:address>
                        </cit:CI_Contact>
                    </cit:contactInfo>
                </cit:CI_Individual>
            </cit:party>
        </cit:CI_Responsibility>
    </mdb:contact>
    <mdb:dateInfo>
        <cit:CI_Date>
            <cit:date>
                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
            </cit:date>
            <cit:dateType>
                <cit:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
            </cit:dateType>
        </cit:CI_Date>
    </mdb:dateInfo>
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="Imagery_SpatialRepresentation">
            <!-- Documentation created for example purposes only -->
            <msr:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </msr:numberOfDimensions>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>1600</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
```

```
                    <msr:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:cellGeometry>
                <msr:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </msr:cellGeometry>
            <msr:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </msr:transformationParameterAvailability>
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    <mdb:identificationInfo>
        <mri:MD_DataIdentification>
            <mri:citation>
                <cit:CI_Citation>
                    <cit:title>
                        <gco:CharacterString>Currency: Flag areas
dataset</gco:CharacterString>
                    </cit:title>
                </cit:CI_Citation>
            </mri:citation>
            <mri:abstract>
                <gco:CharacterString>Imagery with a quality band describing snow
flags</gco:CharacterString>
            </mri:abstract>
            <mri:spatialRepresentationType>
                <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </mri:spatialRepresentationType>
        </mri:MD_DataIdentification>
    </mdb:identificationInfo>
    <mdb:contentInfo>
        <mrc:MI_ImageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>Imagery and quality flag bands</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="Imagery">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
```

```
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Red imagery
band</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Green imagery
band</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Blue imagery
band</gco:CharacterString>
                            </mrc:description>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="SnowCover_Quality_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_qualityInformation"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Snow Cover flag band: boolean
indication whether the pixel is covered by snow</gco:CharacterString>
                            </mrc:description>
                            <mrc:name>
                                <mcc:MD_Identifier>
                                    <mcc:code>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/metrics/Items">Items</gcx:Anchor>
                                    </mcc:code>
                                    <mcc:codeSpace>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                                    </mcc:codeSpace>
                                    <mcc:version>
                                        <gco:CharacterString>1.0</gco:CharacterString>
```

```
                                    </mcc:version>
                                </mcc:MD_Identifier>
                            </mrc:name>
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
            <mrc:cloudCoverPercentage>
                <gco:Real>26</gco:Real>
            </mrc:cloudCoverPercentage>
        </mrc:MI_ImageDescription>
    </mdb:contentInfo>
    <mdb:dataQualityInfo>
        <mdq:DQ_DataQuality>
            <mdq:scope>
                <mcc:MD_Scope>
                    <mcc:level>
                        <mcc:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </mcc:level>
                </mcc:MD_Scope>
            </mdq:scope>
            <mdq:report>
                <mdq:DQ_CompletenessOmission>
                    <mdq:measure>
                        <mdq:DQ_MeasureReference>
                            <mdq:measureIdentification>
                                <mcc:MD_Identifier>
                                    <mcc:code>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/FlagAreas">FlagAreas</gcx:Anchor>
                                    </mcc:code>
                                    <mcc:codeSpace>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                                    </mcc:codeSpace>
                                    <mcc:version>
                                        <gco:CharacterString>1.0</gco:CharacterString>
                                    </mcc:version>
                                </mcc:MD_Identifier>
                            </mdq:measureIdentification>
                            <mdq:nameOfMeasure>
                                <gco:CharacterString>Flag areas</gco:CharacterString>
                            </mdq:nameOfMeasure>
                            <mdq:measureDescription>
                                <gco:CharacterString>Flag areas indicate in this
report the snow cover of the image</gco:CharacterString>
                            </mdq:measureDescription>
                        </mdq:DQ_MeasureReference>
                    </mdq:measure>
                    <mdq:result>
```

```
                        <mdq_TB12:QE_CoverageResult_TB12>
                            <mdq_TB12:spatialRepresentationType>
                                <mcc:MD_SpatialRepresentationTypeCode
codeListValue="grid" codeList="MD_SpatialRepresentationTypeCode"/>
                            </mdq_TB12:spatialRepresentationType>
                            <mdq_TB12:resultSpatialRepresentation
xlink:href="#Imagery_SpatialRepresentation"/>
                            <mdq_TB12:resultContentDescription
xlink:href="#SnowCover_Quality_AttributeGroup"/>
                        </mdq_TB12:QE_CoverageResult_TB12>
                    </mdq:result>
                </mdq:DQ_CompletenessOmission>
            </mdq:report>
        </mdq:DQ_DataQuality>
    </mdb:dataQualityInfo>
</mdb:MD_Metadata>
```

Consistency

Consistency: surface reflectance and rate of domain inconsistencies

ISO 19115 encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:MD_Metadata xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco"
xmlns:gmx="http://www.isotc211.org/2005/gmx"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.isotc211.org/2005/gmd ../old_ISO_19115/gmd/gmd.xsd
http://www.isotc211.org/2005/gmx  ../old_ISO_19115/gmx/extendedTypes.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd">
    <gmd:fileIdentifier>

<gco:CharacterString>QM_7_Consistency_SurfRefl_value_domain_old_19115</gco:CharacterSt
ring>
    </gmd:fileIdentifier>
    <gmd:contact>
        <gmd:CI_ResponsibleParty>
            <gmd:individualName>
                <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
            </gmd:individualName>
            <gmd:contactInfo>
                <gmd:CI_Contact>
                    <gmd:address>
                        <gmd:CI_Address>
                            <gmd:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                            </gmd:electronicMailAddress>
                        </gmd:CI_Address>
                    </gmd:address>
                </gmd:CI_Contact>
            </gmd:contactInfo>
            <gmd:role>
                <gmd:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </gmd:role>
        </gmd:CI_ResponsibleParty>
    </gmd:contact>
    <gmd:dateStamp>
```

```
        <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
    </gmd:dateStamp>
    <gmd:identificationInfo>
        <gmd:MD_DataIdentification>
            <gmd:citation>
                <gmd:CI_Citation>
                    <gmd:title>
                        <gco:CharacterString>Consistency: surface reflectance and rate
of domain inconsistencies</gco:CharacterString>
                    </gmd:title>
                    <gmd:date>
                        <gmd:CI_Date>
                            <gmd:date>
                                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
                            </gmd:date>
                            <gmd:dateType>
                                <gmd:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
                            </gmd:dateType>
                        </gmd:CI_Date>
                    </gmd:date>
                </gmd:CI_Citation>
            </gmd:citation>
            <gmd:abstract>
                <gco:CharacterString>Surface reflectance dataset for demostration
purposes only</gco:CharacterString>
            </gmd:abstract>
            <gmd:spatialRepresentationType>
                <gmd:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </gmd:spatialRepresentationType>
            <gmd:language>
                <gco:CharacterString>English</gco:CharacterString>
            </gmd:language>
        </gmd:MD_DataIdentification>
    </gmd:identificationInfo>
    <gmd:contentInfo>
        <gmd:MD_ImageDescription>
            <gmd:attributeDescription>
                <gco:RecordType>Surface reflectance</gco:RecordType>
            </gmd:attributeDescription>
            <gmd:contentType>
                <gmd:MD_CoverageContentTypeCode codeList="MD_CoverageContentTypeCode"
codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
            </gmd:contentType>
            <gmd:dimension>
                <gmd:MD_RangeDimension id="SurfRefl_AttributeGroup">
                    <gmd:descriptor>
                        <gco:CharacterString>Surface Reflectance</gco:CharacterString>
                    </gmd:descriptor>
                </gmd:MD_RangeDimension>
```

```
            </gmd:dimension>
            <gmd:processingLevelCode>
                <gmd:MD_Identifier>
                    <gmd:code>
                        <gmx:Anchor
xlink:href="http://www.qualityml.org/processLevel">SurfaceReflectancePseudoInvariantAr
eas</gmx:Anchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:processingLevelCode>
        </gmd:MD_ImageDescription>
    </gmd:contentInfo>
    <gmd:dataQualityInfo>
        <gmd:DQ_DataQuality>
            <gmd:scope>
                <gmd:DQ_Scope>
                    <gmd:level>
                        <gmd:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </gmd:level>
                </gmd:DQ_Scope>
            </gmd:scope>
            <gmd:report>
                <gmd:DQ_DomainConsistency>
                    <gmd:nameOfMeasure>
                        <gco:CharacterString>Value domain</gco:CharacterString>
                    </gmd:nameOfMeasure>
                    <gmd:measureIdentification>
                        <gmd:MD_Identifier>
                            <gmd:code>
                                <gmx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/ValueDomain">ValueDomain</gmx:Anchor>
                            </gmd:code>
                        </gmd:MD_Identifier>
                    </gmd:measureIdentification>
                    <gmd:measureDescription>
                        <gco:CharacterString>Pixel values that are not conformant to
its value domain, because they have reflectance values higher that the maximum (e.g.
due to sensor saturation).</gco:CharacterString>
                    </gmd:measureDescription>
                    <gmd:result>
                        <gmd:DQ_QuantitativeResult>
                            <gmd:valueType>
                                <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                            </gmd:valueType>
                            <gmd:valueUnit
xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                            <gmd:value>
                                <gco:Record>
                                    <qml:Items>
```

```
                                        <qml:rate max="100">5</qml:rate>
                                    </qml:Items>
                                    <qmld:NonConformance>
                                        <qmld:rule>Pixel reflectances with values
higher than its theoretical maximum, due to sensor saturation</qmld:rule>
                                    </qmld:NonConformance>
                                </gco:Record>
                            </gmd:value>
                        </gmd:DQ_QuantitativeResult>
                    </gmd:result>
                </gmd:DQ_DomainConsistency>
            </gmd:report>
        </gmd:DQ_DataQuality>
    </gmd:dataQualityInfo>
</gmd:MD_Metadata>
```

ISO 19115-1 encoding (including modifications in QE_CoverageResult_TB12)

```
<?xml version="1.0" encoding="UTF-8"?>
<mdb:MD_Metadata xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/mdb/1.0
../new_ISO_19115_1/19115/-3/mdb/1.0/mdb.xsd http://standards.iso.org/iso/19115/-
3/gco/1.0 ../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd
http://standards.iso.org/iso/19115/-3/cit/1.0 ../new_ISO_19115_1/19115/-
3/cit/1.0/cit.xsd http://standards.iso.org/iso/19115/-3/gcx/1.0
../new_ISO_19115_1/19115/-3/gcx/1.0/gcx.xsd http://standards.iso.org/iso/19115/-
3/mcc/1.0 ../new_ISO_19115_1/19115/-3/mcc/1.0/mcc.xsd
http://standards.iso.org/iso/19157/-2/mdq/1.0 ../new_ISO_19115_1/19157/-
2/mdq/1.0/mdq.xsd http://standards.iso.org/iso/19115/-3/mrc/1.0
../new_ISO_19115_1/19115/-3/mrc/1.0/mrc.xsd http://standards.iso.org/iso/19115/-
3/mri/1.0 ../new_ISO_19115_1/19115/-3/mri/1.0/mri.xsd
http://standards.iso.org/iso/19115/-3/msr/1.0 ../new_ISO_19115_1/19115/-
3/msr/1.0/msr.xsd http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd">
    <mdb:metadataIdentifier>
        <mcc:MD_Identifier>
            <mcc:code>
```

```
<gco:CharacterString>QM_7_Consistency_SurfRefl_value_domain_19115_1</gco:CharacterStri
ng>
            </mcc:code>
            <mcc:codeSpace>

<gco:CharacterString>http://www.creaf.uab.es/TestBed12</gco:CharacterString>
            </mcc:codeSpace>
        </mcc:MD_Identifier>
    </mdb:metadataIdentifier>
    <mdb:contact>
        <cit:CI_Responsibility>
            <cit:role>
                <cit:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </cit:role>
            <cit:party>
                <cit:CI_Individual>
                    <cit:name>
                        <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
                    </cit:name>
                    <cit:contactInfo>
                        <cit:CI_Contact>
                            <cit:address>
                                <cit:CI_Address>
                                    <cit:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                                    </cit:electronicMailAddress>
                                </cit:CI_Address>
                            </cit:address>
                        </cit:CI_Contact>
                    </cit:contactInfo>
                </cit:CI_Individual>
            </cit:party>
        </cit:CI_Responsibility>
    </mdb:contact>
    <mdb:dateInfo>
        <cit:CI_Date>
            <cit:date>
                <gco:DateTime>2016-07-12T09:00:00.0Z</gco:DateTime>
            </cit:date>
            <cit:dateType>
                <cit:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
            </cit:dateType>
        </cit:CI_Date>
    </mdb:dateInfo>
    <mdb:identificationInfo>
        <mri:MD_DataIdentification>
            <mri:citation>
                <cit:CI_Citation>
```

```
                    <cit:title>
                        <gco:CharacterString>Consistency: surface reflectance and rate
of domain inconsistencies</gco:CharacterString>
                    </cit:title>
                </cit:CI_Citation>
            </mri:citation>
            <mri:abstract>
                <gco:CharacterString>Surface reflectance dataset for demonstration
purposes only</gco:CharacterString>
            </mri:abstract>
            <mri:spatialRepresentationType>
                <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </mri:spatialRepresentationType>
        </mri:MD_DataIdentification>
    </mdb:identificationInfo>
    <mdb:contentInfo>
        <mrc:MI_ImageDescription>
            <mrc:attributeDescription>
                <gco:RecordType>Surface reflectance</gco:RecordType>
            </mrc:attributeDescription>
            <mrc:processingLevelCode>
                <mcc:MD_Identifier>
                    <mcc:code>
                        <gcx:Anchor
xlink:href="http://www.qualityml.org/processLevel">SurfaceReflectancePseudoInvariantAr
eas</gcx:Anchor>
                    </mcc:code>
                    <mcc:codeSpace>
                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                    </mcc:codeSpace>
                    <mcc:version>
                        <gco:CharacterString>1.0</gco:CharacterString>
                    </mcc:version>
                </mcc:MD_Identifier>
            </mrc:processingLevelCode>
            <mrc:attributeGroup>
                <mrc:MD_AttributeGroup id="SurfRefl_AttributeGroup">
                    <mrc:contentType>
                        <mrc:MD_CoverageContentTypeCode
codeList="MD_CoverageContentTypeCode"

codeListValue="MD_CoverageContentTypeCode_physicalMeasurement"/>
                    </mrc:contentType>
                    <mrc:attribute>
                        <mrc:MD_RangeDimension>
                            <mrc:description>
                                <gco:CharacterString>Surface
Reflectance</gco:CharacterString>
                            </mrc:description>
```

```
                        </mrc:MD_RangeDimension>
                    </mrc:attribute>
                </mrc:MD_AttributeGroup>
            </mrc:attributeGroup>
        </mrc:MI_ImageDescription>
    </mdb:contentInfo>
    <mdb:dataQualityInfo>
        <mdq:DQ_DataQuality>
            <mdq:scope>
                <mcc:MD_Scope>
                    <mcc:level>
                        <mcc:MD_ScopeCode codeListValue="dataset"
codeList="MD_ScopeCode"/>
                    </mcc:level>
                </mcc:MD_Scope>
            </mdq:scope>
            <mdq:report>
                <mdq:DQ_DomainConsistency>
                    <mdq:measure>
                        <mdq:DQ_MeasureReference>
                            <mdq:measureIdentification>
                                <mcc:MD_Identifier>
                                    <mcc:code>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org/1.0/measure/ValueDomain">ValueDomain</gcx:Anchor>
                                    </mcc:code>
                                    <mcc:codeSpace>
                                        <gcx:Anchor
xlink:href="http://www.qualityml.org">QualityML</gcx:Anchor>
                                    </mcc:codeSpace>
                                    <mcc:version>
                                        <gco:CharacterString>1.0</gco:CharacterString>
                                    </mcc:version>
                                </mcc:MD_Identifier>
                            </mdq:measureIdentification>
                            <mdq:nameOfMeasure>
                                <gco:CharacterString>Value
domain</gco:CharacterString>
                            </mdq:nameOfMeasure>
                            <mdq:measureDescription>
                                <gco:CharacterString>Pixel values that are not
conformant to its value domain, because they have reflectance values higher that the
maximum (e.g. due to sensor saturation).</gco:CharacterString>
                            </mdq:measureDescription>
                        </mdq:DQ_MeasureReference>
                    </mdq:measure>
                    <mdq:result>
                        <mdq:DQ_QuantitativeResult>
                            <mdq:value>
                                <gco:Record>
                                    <qml:Items>
```

```
                                        <qml:rate max="100">5</qml:rate>
                                    </qml:Items>
                                    <qmld:NonConformance>
                                        <qmld:rule>Pixel reflectances with values
higher than its theoretical maximum, due to sensor saturation</qmld:rule>
                                    </qmld:NonConformance>
                                </gco:Record>
                            </mdq:value>
                            <mdq:valueUnit
xlink:href="urn:ogc:def:uom:OGC:1.0:percent"/>
                            <mdq:valueRecordType>
                                <gco:RecordType
xlink:href="http://www.qualityml.org/1.0/metrics/items">Items</gco:RecordType>
                            </mdq:valueRecordType>
                        </mdq:DQ_QuantitativeResult>
                    </mdq:result>
                </mdq:DQ_DomainConsistency>
            </mdq:report>
        </mdq:DQ_DataQuality>
    </mdb:dataQualityInfo>
</mdb:MD_Metadata>
```

Quality levels in a big mosaic

```
<?xml version="1.0" encoding="UTF-8"?>
<mdb:MD_Metadata xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mdq_TB12="http://standards.iso.org/iso/19157/-2/mdq_TB12/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:gex="http://standards.iso.org/iso/19115/-3/gex/1.0"
xmlns:qml="http://www.qualityml.org/1.0/metrics"
xmlns:qmld="http://www.qualityml.org/1.0/domain"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://standards.iso.org/iso/19115/-3/mdb/1.0
../new_ISO_19115_1/19115/-3/mdb/1.0/mdb.xsd http://standards.iso.org/iso/19115/-
3/gco/1.0 ../new_ISO_19115_1/19115/-3/gco/1.0/gco.xsd http://www.opengis.net/gml/3.2
../new_ISO_19115_1/19136/gml.xsd http://standards.iso.org/iso/19115/-3/cit/1.0
../new_ISO_19115_1/19115/-3/cit/1.0/cit.xsd http://standards.iso.org/iso/19115/-
3/gcx/1.0 ../new_ISO_19115_1/19115/-3/gcx/1.0/gcx.xsd
http://standards.iso.org/iso/19115/-3/mcc/1.0 ../new_ISO_19115_1/19115/-
3/mcc/1.0/mcc.xsd http://standards.iso.org/iso/19157/-2/mdq/1.0
../new_ISO_19115_1/19157/-2/mdq/1.0/mdq.xsd http://standards.iso.org/iso/19157/-
2/mdq_TB12/1.0 ../new_ISO_19115_1/19157/-2/mdq/1.0/mdq_TB12.xsd
http://standards.iso.org/iso/19115/-3/mrc/1.0 ../new_ISO_19115_1/19115/-
3/mrc/1.0/mrc.xsd http://standards.iso.org/iso/19115/-3/mri/1.0
../new_ISO_19115_1/19115/-3/mri/1.0/mri.xsd http://standards.iso.org/iso/19115/-
3/msr/1.0 ../new_ISO_19115_1/19115/-3/msr/1.0/msr.xsd
http://www.qualityml.org/1.0/metrics ../qualityml/1.0/qualityml.xsd
http://www.qualityml.org/1.0/domain ../qualityml/1.0/qualityml-domain.xsd">
    <mdb:metadataIdentifier>
        <mcc:MD_Identifier>
            <mcc:code>

<gco:CharacterString>QM_8_Currency_Mosaic_19115_1</gco:CharacterString>
            </mcc:code>
            <mcc:codeSpace>

<gco:CharacterString>http://www.creaf.uab.es/TestBed12</gco:CharacterString>
            </mcc:codeSpace>
        </mcc:MD_Identifier>
    </mdb:metadataIdentifier>
    <mdb:contact>
        <cit:CI_Responsibility>
```

```
            <cit:role>
                <cit:CI_RoleCode codeList="CI_RoleCode"
codeListValue="CI_RoleCode_author"/>
            </cit:role>
            <cit:party>
                <cit:CI_Individual>
                    <cit:name>
                        <gco:CharacterString>Alaitz Zabala</gco:CharacterString>
                    </cit:name>
                    <cit:contactInfo>
                        <cit:CI_Contact>
                            <cit:address>
                                <cit:CI_Address>
                                    <cit:electronicMailAddress>

<gco:CharacterString>alaitz.zabala@uab.cat</gco:CharacterString>
                                    </cit:electronicMailAddress>
                                </cit:CI_Address>
                            </cit:address>
                        </cit:CI_Contact>
                    </cit:contactInfo>
                </cit:CI_Individual>
            </cit:party>
        </cit:CI_Responsibility>
    </mdb:contact>
    <mdb:dateInfo>
        <cit:CI_Date>
            <cit:date>
                <gco:DateTime>2016-09-15T09:00:00.0Z</gco:DateTime>
            </cit:date>
            <cit:dateType>
                <cit:CI_DateTypeCode codeList="CI_DateTypeCode"
codeListValue="CI_DateTypeCode_creation"/>
            </cit:dateType>
        </cit:CI_Date>
    </mdb:dateInfo>
    <mdb:spatialRepresentationInfo>
        <msr:MD_GridSpatialRepresentation id="Imagery_Mosaic_SpatialRepresentation">
            <!-- Documentation created for example purposes only, data is not the
actual for the currency dataset of the Test Bed 12 DigitalGlobe FTP -->
            <msr:numberOfDimensions>
                <gco:Integer>2</gco:Integer>
            </msr:numberOfDimensions>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_row"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
```

```
                        <gco:Integer>1600</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:axisDimensionProperties>
                <msr:MD_Dimension>
                    <msr:dimensionName>
                        <msr:MD_DimensionNameTypeCode
codeListValue="MD_DimensionNameTypeCode_column"
                        codeList="MD_DimensionNameTypeCode"/>
                    </msr:dimensionName>
                    <msr:dimensionSize>
                        <gco:Integer>800</gco:Integer>
                    </msr:dimensionSize>
                    <msr:resolution>
                        <gco:Length uom="m">30</gco:Length>
                    </msr:resolution>
                </msr:MD_Dimension>
            </msr:axisDimensionProperties>
            <msr:cellGeometry>
                <msr:MD_CellGeometryCode codeListValue="MD_CellGeometryCode_area"
                codeList="MD_CellGeometryCode"/>
            </msr:cellGeometry>
            <msr:transformationParameterAvailability>
                <gco:Boolean>false</gco:Boolean>
            </msr:transformationParameterAvailability>
        </msr:MD_GridSpatialRepresentation>
    </mdb:spatialRepresentationInfo>
    <mdb:identificationInfo>
        <mri:MD_DataIdentification>
            <mri:citation>
                <cit:CI_Citation>
                    <cit:title>
                        <gco:CharacterString>Currency: mosaic
example</gco:CharacterString>
                    </cit:title>
                </cit:CI_Citation>
            </mri:citation>
            <mri:abstract>
                <gco:CharacterString>Imagery mosaic example for demonstration purposes
only</gco:CharacterString>
            </mri:abstract>
            <mri:spatialRepresentationType>
                <mcc:MD_SpatialRepresentationTypeCode codeListValue="grid"
                codeList="MD_SpatialRepresentationTypeCode"/>
            </mri:spatialRepresentationType>
            <mri:extent>
                <gex:EX_Extent id="Imagery_Mosaic_SpatioTemporalExtent">
```

```
                    <gex:temporalElement>
                        <gex:EX_SpatialTemporalExtent id="STE_1">
                            <gex:extent>
                                <gml:TimeInstant gml:id="TE_1">
                                    <gml:timePosition>2016-02-
21T19:10:06.425678Z</gml:timePosition>
                                </gml:TimeInstant>
                            </gex:extent>
                            <gex:spatialExtent>
                                <gex:EX_BoundingPolygon>
                                    <gex:polygon>
                                        <gml:Surface gml:id="SE_1">
                                            <gml:polygonPatches>
                                                <gml:PolygonPatch>
                                                    <gml:exterior>
                                                        <gml:Ring>
                                                            <gml:curveMember>
                                                                <gml:LineString
gml:id="SE_1_LS_1">
                                                                    <gml:pos>-
122.3918563034 38.0130290916</gml:pos>
                                                                    <gml:pos>-
122.391898 37.99734093</gml:pos>
                                                                    <gml:pos>-
122.3919856 37.95445502</gml:pos>
                                                                    <gml:pos>-
122.3920646691 37.9208226757</gml:pos>
                                                                    <gml:pos>-
122.3920864 37.91157935</gml:pos>
                                                                    <gml:pos>-
122.3920893812 37.9103494132</gml:pos>
                                                                    <gml:pos>-
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Appendix C: Use Cases

Introduction

During initial phases of the TestBed 12, these use cases where drafted in order to guide the elaboration of this ER. They were inspirational during the writing process and, in fact, many of the different ideas covered here had been used. They have not been further developed at the end, as another structure (based on a point-by-point revision of A3C) has been the central line of the ER.

Land Cover Monitoring Mission

Objective

To produce a Land cover map by automatic classification of satellite imagery

Procedure to derive a Land Cover map

- Geometric correction. Needs to be done before the mosaic or mosaic is impossible. We will assume that this was done with enough precision with orbital parameters by the imagery provider (Commonly known as Level 1b data).
  - Metadata of the image provider will inform us. Combination of "compatible" missions is allows and in particular Landsat 8 and Sentinel 2.
- Radiometric correction. This depends on each individual scene so need to be done before the mosaic.
  - DEM + solar position is used to detect shadows and orientations
  - Need of pseudo-invariant surfaces to make the temporal series completely homogeneous
- Ensure the maximum number of images all over the year (for all seasons)
  - Cloud masks to remove the areas covered by them
  - Use maximum number of images of the same year.
  - Use adjacent years to cover the areas where clouds made the scene of the desired year unusable.
- Adoption of an external (imposed) classification schema (legend)
- Training areas collected from reference data that is considered the truth (probably for *in-situ* campaigns). This data was captured for one year and is applied to several years with some "caution" of possible changes in time. The more temporal distance between training areas and data the more temporal uncertainty.
- Classification with the algorithm (parametrization)
- Testing areas will be compared to the classification and confusion matrices created.
- Mosaic. Integration of errors estimations for each scene and how to express the "mean" and the deviations in the errors for each scene.

Analysis

- First focus on radiometric correction and homogeneous temporal series generation
- Second focus on thematic accuracy (training and test areas generation, overall and per category accuracies) and on summary of thematic accuracies after mosaic
- Temporal extent proper description
- Semantic precise definition of the classes, referring to international standards for land cover

- Effects of classification parameters on generated land cover map: classification of all pixels (no matter the uncertainty) vs limiting the uncertainty and thus obtaining non-classified (nodata) pixels

Quality parameters

- When selecting raw imagery (to mosaic) we will be interested in:
  - Similar currency of the imagery, consistency across the mosaic
  - Times of collection, seasonality, leaf-on or leaf-off (phenology consistency)
  - Atmospherically corrected, consistent known color balancing
  - No color enhancements
- When processing the data and delivering the metadata
  - Homogeneous procedures (consistency)
  - Temporal extent that represents the data and temporal uncertainty.

Mapping Mission

Objective

To produce an updated map from satellite imagery and a DEM

Procedure to derive a the Map

- Geometric correction. We do require a precise description of the infrastructures that can be seen from the satellite imagery. This will be done by identifying GPC in a topographic map and using a DEM to correct the relief deformations on the image.
- A local color enhancement can be done to increase the "contrast" of the imagery. Radiometric correction will NOT be necessary in this case.
- Mosaic
- Then some feature extraction can be done. In this case we consider that a manual photointerpretation with 3D extraction.

Analysis

- Focus on positional (3D) accuracy. Deeply related with seamless objects (no interrupted lines). In theory if the geometric correction uncertainty is within the image resolution this seamless effect will be minimal but not inexistent.
- Minimal temporal extensions desirable
- Spatial distribution of geometric correction errors
- 3D positional precision is conditioned by DEM thematic accuracy

Quality parameters

- Mosaic of imagery
- Horizontal accuracy
  - Position accuracy
    - Accuracy of products:
      - Horizontal Accuracy CE90
      - Vertical Accuracy LE90
    - Accuracy of Raw Satellite Imagery (basically reflects satellite pointing accuracy)
    - Horizontal Accuracy CE90 based on observed locations on ground
- Extent of collection dates
- DEMs and GCPs used

- Any seam line alteration
- Local color enhancement.

Disaster Response

Objective

To produce a fast map from satellite imagery to immediate reaction.

Procedure to derive a the Map

- The most current satellite product is searched (after the event) and a past image closed to the event time (before the event)
- Geometric correction. We assume that a raw image is delivered as fast as possible and a polynomic correction is done with a limited number of GCP.
- A global color enhancement can be done to increase the "contrast" of the imagery globally. Radiometric correction will NOT be necessary in this case.
- Comparison of both images side-by-side.
- Annotations and "affected" feature recognition is done: Estimation of damaged area, damaged critical infrastructures, displacement fields candidates.

Analysis

- Focus on imagery producer name and mission and platform quality parameters in the specifications
- Need of the past cartography to extract GPC well parameterized. Global estimation of the quality of the corrected product.
- Focus on time and currency
- No possible in-field validation

Quality parameters

- Up to date
- Fast production

Appendix D: Revision History

Table 28. Revision History

Date	Editor	Release	Primary clauses modified	Descriptions
June 22, 2016	J. Masó	0.1	all	Initial version
July 12, 2016	A. Zabala	0.2	various	Pixel level quality improved
August 22, 2016	J. Masó	0.3	various	Quality measures section started. WMTS time completed
September 11, 2016	J. Masó	0.4	various	Added details about WMTS image quality implementation
September 18, 2016	J. Masó	0.5	various	Quality measures updated
September 27, 2016	A. Zabala	0.6	various	Quality documentation in a big mosaic
November 25, 2016	A. Zabala	0.7	various	QualityML better description, quality measures and dataset-level improved
November 30, 2016	A. Zabala	1.0	various	Preparation for publication

Appendix E: Bibliography

- ISO 19115:2003 — Geographic information — Metadata (*deprecated*)
- ISO/TS 19138:2006 — Geographic information — Data quality measures (*deprecated*)
- ISO/TS 19139:2007 — Geographic information — Metadata — XML schema implementation (*deprecated*)
- ISO/TC 211 Standards Guide
- NGA.STND.0012-2_1.1 National System for Geospatial Intelligence. Metadata Foundation (NMF) — Part 2: Quality Metadata v1.1 NGA Standardization document
- WPS 2.0 OGC 14-065 OGC® WPS 2.0 Interface Standard
- GUM JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement
- OWS Common v2.0.0 OGC 06-121r9 Web Service Common Implementation Specification
- NGA Quality Measures Register
- Argo Parameters and quality control code lists