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OGC® OWS 9 Data Quality and Web Mapping Engineering Report

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Abstract

This Engineering Report specifies conventions for conveying information about data quality through the OGC Web Map Service Standard (known hereafter as the "WMS-Q conventions"), OGC Web Map Tile Service Standard (known hereafter as the "WMTS-Q conventions"), OGC KML (known hereafter as the "KML-Q conventions") and OGC Augmented Reality Markup Language.

Keywords

ogcdoc, ogc document, data quality, wms, uncertml

What is OGC Web Services 9 (OWS-9)?

OWS-9 builds on the outcomes of prior OGC interoperability initiatives and is organized around the following threads:

- **Aviation**: Develop and demonstrate the use of the Aeronautical Information Exchange Model (AIXM) and the Weather Exchange Model (WXXM) in an OGC Web Services environment, focusing on support for several Single European Sky ATM Research (SESAR) project requirements as well as FAA (US Federal Aviation Administration) Aeronautical Information Management (AIM) and Aircraft Access to SWIM (System Wide Information Management) (AAtS) requirements.

- **Cross-Community Interoperability (CCI)**: Build on the CCI work accomplished in OWS–8 by increasing interoperability within communities sharing geospatial data, focusing on semantic mediation, query results delivery, data provenance and quality and Single Point of Entry Global Gazetteer.

- **Security and Services Interoperability (SSI)**: Investigate 5 main activities: Security Management, OGC Geography Markup Language (GML) Encoding Standard Application Schema UGAS (UML to GML Application Schema) Updates, Web Services Façade, Reference Architecture Profiling, and Bulk Data Transfer.

- **OWS Innovations**: Explore topics that represent either new areas of work for the Consortium (such as GPS and Mobile Applications), a desire for new approaches to existing technologies to solve new challenges (such as the OGC Web Coverage Service (WCS) work), or some combination of the two.

- **Compliance & Interoperability Testing & Evaluation (CITE)**: Develop a suite of compliance test scripts for testing and validation of products with interfaces implementing the following OGC standards: Web Map Service (WMS) 1.3 Interface Standard, Web Feature Service (WFS) 2.0 Interface Standard, Geography Markup Language (GML) 3.2.1 Encoding Standard, OWS Context 1.0 (candidate encoding standard), Sensor Web Enablement (SWE) standards, Web Coverage Service for Earth

Observation (WCS-EO) 1.0 Interface Standard, and TEAM (Test, Evaluation, And Measurement) Engine Capabilities.

The OWS-9 sponsors are: AGC (Army Geospatial Center, US Army Corps of Engineers), CREAF-GeoViQua-EC, EUROCONTROL, FAA (US Federal Aviation Administration), GeoConnections - Natural Resources Canada, Lockheed Martin Corporation, NASA (US National Aeronautics and Space Administration), NGA (US National Geospatial-Intelligence Agency), USGS (US Geological Survey), UK DSTL (UK MoD Defence Science and Technology Laboratory).

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OGC® OWS 9 Data Quality and Web Mapping Engineering Report

1 Introduction

This Engineering Report specifies conventions for conveying information about data quality through the OGC Web Map Service Standard, OGC Web Map Tile Service Standard, OGC KML and OGC Augmented Reality Markup Language. In general, it considers quality information to be of three types: "dataset-level" (pertaining to an entire dataset), "variable-level" (pertaining to a particular variable within the dataset) and "sample-level" (pertaining to an individual measurement). Our aim is for WMS-Q and WMTS-Q to be, as far as possible, a specialization of the WMS and WMTS specifications, to enable backward compatibility with existing clients. In the case of KML and ARML, only preliminary examples and approaches are discussed.

This work has been carried out within the context of the OWS-9 initiative, and within the FP7 ENV-265178 GeoViQua project (www.geoviqua.org).

1.1 Scope

The current version of this document specifies conventions for adding quality information in Map standards and in KML and ARML features, although some approaches could be applied to other OGC standards.

This document does not constitute a formal specification, but a collection of recommendations and points for future discussion.

1.2 Document contributor contact points

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

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1.3 Revision history

Date	Release	Editor	Primary clauses modified	Description
30/07/2012	1.0 draft	Jon Blower, Xiaoyu Yang	All	Initial draft for general review: based on WMS-Q conventions
03/01/2013	1.0	Jon Blower	All	First complete version for submission
18/01/2013	1.1	Simon Thum	8	Added KML-Q
21/02/2013	1.2	Joan Masó	All	Added WMTS-Q, ARML-Q and document restructure.

1.4 Future work

Future work will need to focus on styling mechanisms and the behavior of the GetFeatureInfo operation for WMS and WMTS. In addition, more work will be required on vector data in KML and ARML.

1.5 Forward

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.

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.

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3 Terms and definitions

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard [OGC 06-121r3] shall apply. In addition, the following terms and definitions apply.

3.1
Dataset level quality
Quality description information generally contained in metadata records that summaries the quality of a dataset.

3.2
Variable level quality
Quality description information generally contained in metadata records, which summaries the quality of a variable represented in a dataset.

3.3
Sample level quality
Quality description information that describes individual samples (i.e. individual measurements) the user is typically most interested in quantifications of data uncertainty. It can be pixel level or feature level depending on the data model.

4 Conventions

4.1 Abbreviated terms

ARML	Augmented Reality Marked Language
GEOSS	Global Earth Observation System of Systems
GeoViQua	Quality aware Visualisation for Global Earth Observation System of Systems
ISO	International Standard Organization
WMS	Web Map Service
WMTS	Web Map Tile Service
UncertML	Uncertainty Markup Language
UML	Unified Modeling Language
URL	Uniform Resource Locator

5 Standardized quality overview

The notion of *data quality* has many aspects but we consider it here to mean “fitness for purpose”. Therefore different users have different notions of what is considered “high quality”. In order to assess fitness for purpose for a geospatial dataset, a user may look for many pieces of metadata, including completeness, consistency, positional, temporal and thematic accuracy, lineage and provenance information (see ISO19157). The GeoViQua project (http://www.geoviqua.org) has developed modifications to ISO19157 to encompass other measures of quality (e.g. user feedback). See Yang et al, 2012 for a high-level description of the GeoViQua data model.

This document is concerned mainly with displaying quality information related to *raster* data types, such as satellite images and output from numerical models. We consider only continuous (not categorical) quantities and focus on the problem of conveying thematic accuracy through uncertainties (Savoldi et al, 2010; David, 2004; Refsgaard et al., 2007). Different conventions may be required for vector data types and for categorical data. We aim to design a set of conventions for WMS version 1.3.0 and WMTS 1.0 that requires as few alterations to the original specification as possible. The mechanisms described in this clause are mostly specializations of the specification, not modifications or extensions to it. We name these conventions "WMS-Q" and "WMTS-Q" respectively.

5.1 Dataset-level quality metadata

Dataset level quality is a quality description information generally contained in metadata records that summaries the quality of a dataset. An example of dataset level quality is the DQ_element elements and with its quality measures that an ISO metadata record can contain. In WMS and WMTS quality metadata about dataset can be associated to corresponding layers in the server.

5.2 Variable-level quality information

Variable-level quality is a quality description information which summaries the quality of a variable represented in a dataset. Dataset level quality is also described in metadata records. In WMS and WMTS quality metadata about variables can also be associated to corresponding layers in the server.

5.3 Sample-level quality information

At the level of individual samples (i.e. individual measurements) the user is typically most interested in quantifications of data uncertainty, which may be further propagated through a data-processing workflow. Uncertainties may pertain to both *continuous* and *categorical* data, but in this document we consider only continuous data.

5.3.1 UncertML

The UncertML conceptual model (http://www.uncertml.org/) provides a taxonomy of means for quantifying and exchanging complex uncertainties in data. The types of information that can be exchanged using this model include:

- Samples: Uncertainties may be represented by explicitly providing each recorded sample from the population. Clearly this can often amount to a great deal of information.
- Statistics: Uncertainties may be represented by statistics summarizing the samples (e.g. mean, variance, confidence intervals, covariance matrices). These summary statistics do not convey information about the mathematical form of the probability density function.
- Distributions: Where the uncertainties are more clearly understood, they may be represented by specifying the mathematical form of the probability distribution (e.g. Gaussian, Exponential, Binomial etc).

5.3.2 NetCDF-U

The concepts of UncertML can be encoded using NetCDF by following the "NetCDF-U" conventions, currently published as an OGC Discussion Paper. NetCDF-U enables individual samples, statistics or parameters of a distribution to be recorded as individual NetCDF variables, which are grouped using a separate NetCDF variable that contains the required metadata but no data values. (This latter variable type is known as a "concept without values".) This structure is required because, in the NetCDF "classic" data model, variables cannot be hierarchical.

Figure 1 illustrates this: the "sea_surface_temperature" variable is the "concept without values", and defines that the uncertainties in the data form a normal distribution, whose mean and variance are recorded in the "sea_surface_temperature_mean" and "sea_surface_temperature_variance" variables respectively.

```
Variables:
  Double sea_surface_temperature (lat=163,lon=240 )
    :missing_value= -999.0;
    :ref= http://www.uncertml.org/distributions/normal   // netCDF-U extension
    :ancillary_variables = "sea_surface_temperature_mean Sea_surface_temperature_variance ";
  Double sea_surface_temperature_variance   (lat=163,lon=240 )
    :missing_value =  -999.0
    :ref= http://www.uncertml.org/distributions/normal  #variance    //netCDF-U extension
  Double sea_surface_temperature_mean (lat=163,lon=240 )
   :missing_value = -999.0
   :ref=http://www.uncertml.org/distributions/normal  #mean    //netCDF-U extension
```

Figure 1: A fragment of NetCDF-U, where ancillary_variables are used to associate variables and where ref is used to reference the UncertML term

6 Quality in WMS

The Web Map Service (WMS) specification (de la Beaujardiere 2006) describes how a client (e.g. a web browser or desktop application) may request a custom-generated, georeferenced image of a dataset from a server, together with associated metadata. Images from different Web Map Services can be precisely overlain in a Geographic Information System (GIS), permitting visualization and intercomparison (Zhao et al. 2012; Sun et al. 2012; Panagos et al. 2008). The use of WMS technology is partly driven by high-profile international interoperability initiatives such as GEOSS (http://www.earthobservations.org) and INSPIRE (http://inspire.jrc.ec.europa.eu/).

In WMS, the essential unit of information is the *Layer*. Each Layer can be displayed in a number of *Styles*, each associated with a legend. Layers may be displayable or non-displayable and may be organized hierarchically, with the semantics of the parent-child relationship remaining unconstrained. Layers may therefore represent different data objects, but the following convention is typical in scientific WMS implementations (e.g. ncWMS, http://ncwms.sf.net):

1. The top-level Layer represents the service as a whole. This is non-displayable and contains metadata that applies to all data in the services (e.g. supported coordinate reference systems).
2. The Layers at the next level represent the Datasets offered by the server. These are also non-displayable.
3. The Layers at the lowest level of the hierarchy are displayable and represent the Variables. A single Layer may represent a composition of more than one Variable; e.g. a Layer may represent a vector quantity such as velocity, whose eastward and northward components are recorded in separate Variables (see Figure 1).

Three main operations can be performed by standard WMS clients: *GetCapabilities* requests an XML document containing metadata on available Layers and other service capabilities; *GetMap* requests a map image or animation according to the user's choice of Layer, Style, geographic extent and resolution; and *GetFeatureInfo* requests more information about a specific pixel in a map image. Other operations can be defined.

6.1 Dataset-level quality metadata inWMS

The WMS specification allows metadata to be attached to Layers within a WMS, using the "MetadataURL" element of the schema of the WMS Capabilities document. This URL points to an online resource that resolves to a separate document that provides metadata about the Layer. Layers may represent entire datasets or individual variables.

However, the limitation of WMS 1.3 is that the "Type" attribute of the "MetadataURL" element currently only supports "ISO19115" and "FGDC-STD-001-1998". This means that it is not possible to link to human-readable dataset description documents or to machine-readable documents in other formats. We therefore propose two extensions to the WMS specification:

1. Expand the range of values permitted by the "type" of the "MetadataURL" element to include other document types. These types may include "ISO19157", the GeoViQua quality models (see GeoViQua deliverable 6.1) or "unstructured" (i.e. human-readable) document types. At the present time, we have not enumerated the possible types, but suggest that this could be expanded as a CodeList that can be expanded by data providers to encompass many different metadata formats.

2. Add an optional "Description" fields to the definition of the "MetadataURL" element, which would provide a free-text, human-readable description of the format of the document to which the URL points. This would enable users to understand the target format better, if they are not familiar with it.

Figure 2 gives a sample fragment of a Capabilities document that follows these proposed extensions.

```
<Layer >
…
    <MetadataURL type="unstructured">
                <Description> This metadata will provide some background quality
        information about this layer </Description>
                <Format>applicaiton/pdf</Format>
                <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink"
                 xlink:type="simple"
                 xlink:href="http://localthost:8080/metadata/ backgroundInfo.pdf "/>
    </MetadataURL>
</Layer>
```

Figure 2: Sample fragment of a WMS Capabilities document that incorporates the modifications proposed in subclause 6.1.

6.2 Variable-level quality information in WMS

The same mechanism as in subclause 6.1 could be used to provide more information about a specific variable (such as a Layer representing the "temperature" field within a larger dataset), if there is a specific document for the variable's metadata that provides more information than the dataset-level document.

6.3 Sample-level quality information in WMS

In this WMS-Q convention, we use the concept of WMS Layer nesting to convey the semantic relationship between the variables that represent different components of the uncertainty information. This follows closely the approach taken in NetCDF-U, and therefore there is a fairly direct mapping between NetCDF-U and WMS-Q; however, the same WMS-Q structures could of course be mapped to other data formats.

6.3.1 ServiceMetadata document and layer conventions

The WMS-Q convention applies the following rules:

- An uncertain variable is modelled as a Layer nested within the Layer representing the parent Dataset. This acts as a container for other Layers that represent the components of the uncertainty information (hence is directly analogous to the "concept without values" in NetCDF-U).
- This Layer may or may not be displayable, depending on the service provider.
- If it is displayable it needs a Name, and a GetMap request on this name will display some representation of an uncertain variable in a single map image. (E.g. a raster field representing the mean, overlain by a contour field representing the variance, see Figure 5).
- This Layer has a Keyword that describes the type of the uncertainty information it represents. This Keyword is taken from the UncertML vocabulary. (Recall that in WMS, Keywords are taken from controlled vocabularies.)

- The children of this Layer are also Layers, and these represent the individual components of the uncertainty information (such as the mean of a normal distribution, or an individual Sample). Again these are tagged with Keywords (taken from UncertML) that define the type of the component.

Figure 3 shows an example of using these rules to encode the dataset from Figure 5 as a WMS Capabilities document.

```
<Layer>
 <Title>Some Dataset</Title>
 …
 <Layer queryable='1'>
   <! -- Parent layer, analogous to NetCDF-U "concept without values"-->
  <Title>Sea Surface Temperature</Title>
  <! -- The Name is only included if this parent layer is displayable -->
  <Name> sea_surface_temperature</Name>
  <KeywordList>
     <Keyword vocabulary='http://www.uncertml.org/distributions/'>
        normal
     </Keyword>
 <KeywordList>

  <!—Now the child layers represent the elements of the distribution -->
 <Layer queryable='1'>
   <Name>sea_surface_temperature_mean</Name>
   <Title>SST mean</Title>
   <KeywordList>
     <Keyword vocabulary='http://www.uncertml.org/distributions/'>
        normal#mean
     </Keyword>
   <KeywordList>
  </Layer>

 <Layer queryable='1'>
   <Name> sea_surface_temperature_variance</Name>
   <Title>SST variance</Title>
   <KeywordList>
     <Keyword vocabulary='http://www.uncertml.org/distributions/'>
        normal#variance
     </Keyword>
   <KeywordList>
  </Layer>
 </Layer>
</Layer>
```

Figure 3: A fragment from a WMS-Q Capabilities document, illustrating the use of Layer nesting and UncertML terms to convey the semantic relationship between Layers.

Figure 4 summarizes the WMS-Q conventions in the form of a UML diagram.

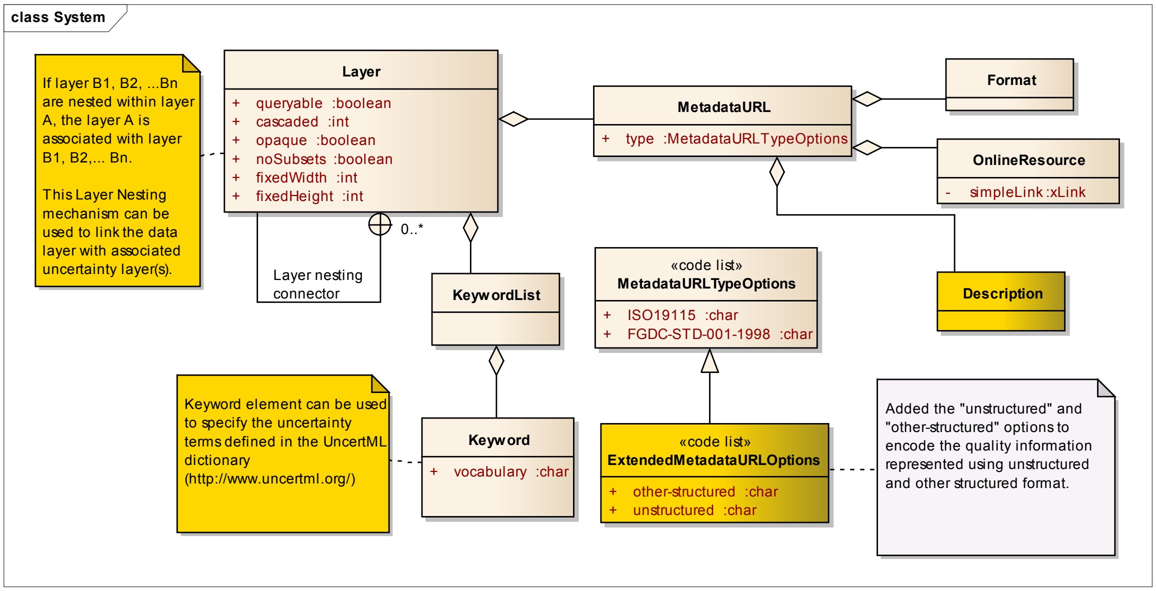

Figure 4: Summary of WMS-Q conventions in the form of a UML diagram. This diagram captures the conventions used to create the Capabilities document, but does not capture other features of WMS-Q such as the behavior of GetFeatureInfo.

6.3.2 Behaviour of GetMap

Child layers maps represent individual components of the uncertainty description of a pixel. Its values can be styled in several ways such as colors, contour lines, etc. Each available style has a name advertised in the capabilities document. Visualizing uncertainty is tricky and requires some specific visualization strategies and some user training. GetMap requests allow requesting individual layers (individual uncertainty components) with its style, while requesting more than one layer at the same time with its respective style names, this allows arbitrary combinations of uncertainty components from the same dataset (or even from different datasets), many of them resulting in improper visualization. Instead, this document recommends that clients request the parent layer that will already have style combinations, which are better for uncertainty visualization of this type of data.

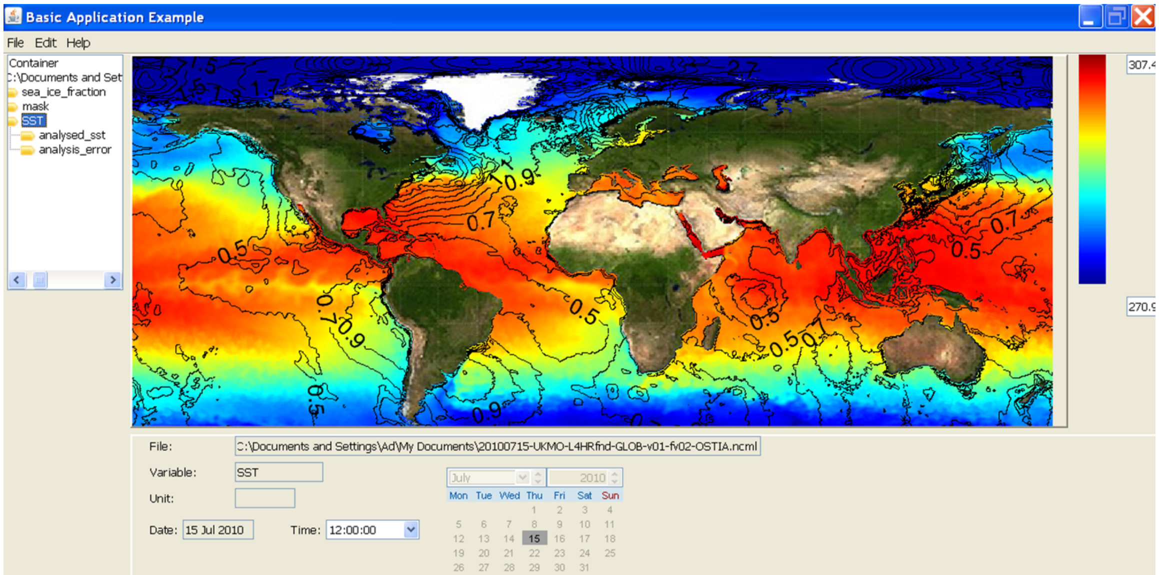

Figure 5: A screenshot of visualizing uncertainty information using contouring approach (produced by desktop WMS-Q Viewer)

6.3.2.1 Map image styling considerations

A standard WMS enumerates a finite number of Styles in which images can be generated from Layers. These cannot be configured by the end user. Scientific users usually require more flexibility, for example to control how data values map to palette colours, to control the contour spacing or to control the size and appearance of glyphs (e.g. arrows representing a velocity field).

Such advanced requirements can be achieved at least partially through the OGC Styled Layer Descriptor and Symbology Encoding (SLD/SE) specifications. However this mechanism is poorly supported in current clients and further work is required to ascertain whether SLD/SE is capable of encoding with a sufficient degree of flexibility all the styles that may be required by users of a WMS-Q.

6.3.3 Behaviour of GetFeatureInfo

The GetFeatureInfo operation of WMS requests more information about a specific pixel on a map. This operation is relevant to:

- Layers that represent the total uncertainty distribution (i.e. the NetCDF-U "concept without values"). GetFeatureInfo may only be performed on displayable Layers.
- Layers that represent a single component within the uncertainty distribution (i.e. individual scalar fields).

The behaviour of GetFeatureInfo must be defined in each case, but the format of the returned information is unconstrained by the WMS 1.3.0 specification. For WMS-Q, these formats should include:

- Machine-readable XML documents describing the particular Feature represented by the data value, using UncertML to encode uncertainty information.
- Images representing the probability distribution function of the value at the pixel in question (see Figure 6).
- Human-readable HTML documents describing the Feature (as recommended by the INSPIRE conventions).

More work is required to define the behaviour of GetFeatureInfo in WMS-Q further.

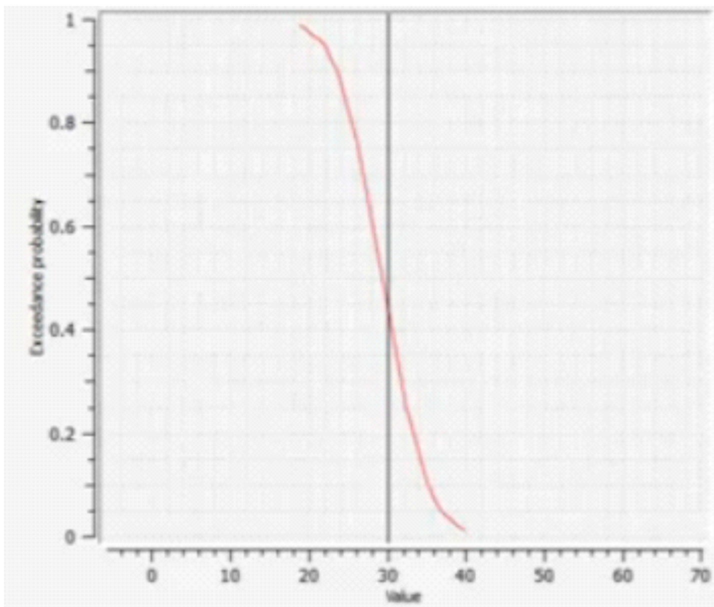

Figure 6: Sample image representing a probability distribution. This could be returned from a GetFeatureInfo request

7 Quality in WMTS

The Web Map Tile Service (WMTS) specification (OGC 07-057r7) describes how a client (e.g. a web browser or desktop application) may request a custom-generated, georeferenced tile of a dataset from a server, together with associated metadata.

In WMTS, the essential unit of information is the *Layer*. Each Layer can be displayed in a number of *Styles*, each associated with a legend. A difference between WMTS and WMS is that WMTS layers cannot be organized hierarchically. Instead, in WMTS layers are represented as a linear list without hierarchy, and a hierarchy of *themes* is specified separately. The optional *Themes* section of a WMTS service metadata document contains metadata about how layers are organized thematically. This separates both concepts allows servers to offer more than one layer organization (in more than one theme section). This mechanism will be used here to represent pixel level quality.

Three main operations can be performed by the WMS client standard : *GetCapabilities* requests an XML document containing metadata on available layers and other service capabilities; *GetTile* requests a map tile according to the user's choice of layer, style, tile column, tile row, TileMatrixSet and resolution; and *GetFeatureInfo* requests more information about a specific pixel from a map tile. Other operations can be defined by extensions.

7.1 Dataset-level quality metadata: ServiceMetadata

The WMTS specification allows metadata to be attached to Layers within a WMTS, using the "ows:Metadata" element of the schema of the WMS Capabilities document. This URL points to an online resource that is a separate document that provides the Layer's metadata. Layers may represent entire datasets or individual variables. In WMTS there is no restrictions on the type of metadata you can link so it is possible to use the same ones that are used in WMS ("ISO19115" and "FGDC-STD-001-1998") and others such as "ISO19157", the GeoViQua quality models (see GeoViQua deliverable 6.1) or "unstructured" metadata (i.e. human-readable) document types. Metadata documents are linked using an xlink:href. Ows:Metadata also has several attributes such as "xlink:title" and "xlink:role", and "about" that can be used to provide a free-text, human-readable description, of the format and content of the document to which the URL points to. This would enable users to better understand the target format, in those cases where they are not familiar with it. See Table 35 in OGC 06-121r9 for more details on ows:Metadata.

Figure 7 gives a sample fragment of a Capabilities document that follows these proposed extensions.

```
<layer>
...
    <ows:Metadata xlink:role="unstructured"
        xlink:title="This metadata will provide some background quality
information about this layer"
        xlink:href="http://www.server.bob/metadata/backgroundInfo.pdf"/>
</layer>
```

Figure 7: Sample fragment of a WMTS Capabilities document.

7.2 Variable-level quality information

The same mechanism used in subclause 7.1could be used to provide more information about a specific variable (such as a Layer representing the "temperature" field within a larger dataset), when there is a specific document for the variable's metadata that provides more information than the dataset-level document.

7.3 Sample-level quality information in WMS

In this WMTS-Q convention, we use the concept of WMTS Themes to convey the semantic relationship between the variables that represent different components of the uncertainty information. This closely follows the approach taken in NetCDF-U, and therefore there is a fairly direct mapping between NetCDF-U and WMTS-Q; however, the same WMTS-Q structures could, of course, be mapped to other data formats.

7.3.1 ServiceMetadata document and layer conventions

The WMTS-Q convention applies the following rules:

- The server will define a layer for each individual component of the uncertainty information (such as the mean of a normal distribution, or an individual Sample).

These are tagged with Keywords that define the type of the component. The Keywords are taken from the UncertML vocabulary.

- Optionally, depending on the service provider, the server will define a composed layer that will display some representation of an uncertain variable in a single map image. (E.g. a raster field representing the mean, overlain by a contour field representing the variance). This is tagged with a keyword that describes the type of the uncertainty information it represents (taken from UncertML).
- For each dataset, there will be a Theme representing the parent Dataset, which will contain another theme that acts as a container for other Layers. These represent the parameters of the uncertainty information (hence is directly analogous to the "concept without values" in NetCDF-U). If a Layer representing the dataset exists, then it will be referenced by the parent theme.

Figure 8 shows an example of using these rules to encode the dataset from as a WMTS Capabilities document.

```
<Capabilities>
   ...
   <Contents>
      <Layer>
         <ows:Title>See Surface Temperature</ows:Title>
         <ows:Keywords>
            <ows:Keyword>normal</ows:Keyword>
            <ows:Type
codeSpace="http://www.uncertml.org">distributions</ows:Type>
         </ows:Keywords>
         <ows:Identifier>see_surface_temperature</ows:Identifier>
         <Style>
            <ows:Title>Mean as colors and variance as contour lines</ows:Title>
            <ows:Identifier>default</ows:Identifier>
         </Style>
         ...
      </Layer>
      <Layer>
         <ows:Title>SST mean</ows:Title>
         <ows:Keywords>
            <ows:Keyword>normal#mean</ows:Keyword>
            <ows:Type
codeSpace="http://www.uncertml.org">distributions</ows:Type>
         </ows:Keywords>
         <ows:Identifier>see_surface_temperature_mean</ows:Identifier>
         ...
      </Layer>
      <Layer>
         <ows:Title>SST variance</ows:Title>
```

```
                <ows:Keywords>
                    <ows:Keyword>normal#variance</ows:Keyword>
                    <ows:Type
codeSpace="http://www.uncertml.org">distributions</ows:Type>
                </ows:Keywords>
                <ows:Identifier>see_surface_temperature_variance</ows:Identifier>
                ...
            </Layer>
            <TileMatrixSet>
                ...
            </TileMatrixSet>
        </Contents>
        <Themes>
            <Theme>
                <ows:Title>See SurfaceTemperature</ows:Title>
                <ows:Identifier>SST</ows:Identifier>
                <Theme>
                    <ows:Title>See SurfaceTemperature Parameters</ows:Title>
                    <ows:Identifier>SST Param</ows:Identifier>
                    <LayerRef>see_surface_temperature_mean</LayerRef>
                    <LayerRef>see_surface_temperature_variance</LayerRef>
                </Theme>
                <LayerRef>see_surface_temperature</LayerRef>
            </Theme>
        </Themes>
</Capabilities>
```

Figure 8: A fragment from a WMTS-Q Capabilities document, illustrating the use of Themes to express Layer nesting and UncertML terms to convey the semantic relationship between Layers.

7.3.2 Behaviour of GetTile

The same considerations done for GetMap WMS-Q apply here. In fact, WMTS only allows requesting one layer at a time, so the only way to get a combined uncertainty visualization map is that the server provider has already included a parent layer with a combined style name.

7.3.3 Behaviour of GetFeatureInfo

The same considerations done for GetFeatureInfo WMS-Q apply here.

8 Quality in KML

The OGC KML specification (OGC 07-147r2) describes an XML grammar used to encode and transport representations of geographic data for display in an Earth browser.

It encodes geospatial information and the way this information has to be presented in the browser.

The clause exposes our first ideas on how to extend KML to include data quality information and describes how to associate the quality information to contained and referenced geometries and data. It also describes how to visualize the quality information along the data it characterizes. The extension described receives the abbreviated name of KML-Q.

We design KML-Q in a way that a KML document stays valid and ideally allow a reasonable implementation which does not support this extension to show the actual data without quality information.

KML offers a finely grained set of extension mechanisms inside its own schema. These have the upside of being interpreted by established KML 2.2 clients, e.g. by showing values in pop-up tables. Extension using a separate XML name-spacing has the benefit of not interfering with other KML elements.

This roughly corresponds to the two major use cases KML-Q will first be tested in; as input to a visualization service and as output thereof. Detail will be given in the clause on use cases.

8.1 Integration of quality information in KML

This proposal:

- Embeds the quality information wherever sensible.
- Explicitly models the scope of quality information to separate the scope from the embedding in KML.
- Minimizes the use o a specific XML schema

Some things are left open for a prototype to clarify.

A KML-Q instance might (optionally) contain a leading declaration of KML-Q document properties. Leading means before (in text) any `kml:AbstractGeometryGroup`. The KML-Q document properties may be used to declare how quality information embedded in the KML relates to other data for the benefit of interoperability.

Further, a KML-Q instance may embed scoped quality information in `kml:Extended-Data` elements. In cases where the scope encoded in the PQM cannot be applied to KML unambiguously the `kml:ExtendedData` could be equipped with a scope disambiguator. Ideally this would be the only KML-Q-specific element in `kml:ExtendedData`.

8.1.1 Dataset level quality metadata in KML

These use cases encode quality information in KML primarily as a machine-to-machine vehicle. Because the recipient is a potential specialized KML-Q implementation, there is no need to confine the XML to the KML namespace.

This approach is tested in the KML-Q visualization service prototype, to which such an encoding would be input, together with hints detailing how to visualize the KML-Q.

```
<kml xmlns="http://www.opengis.net/kml/2.2">
    <Document>
        <name>Embedding of UQM data for machine-to-machine
scenarios</name>

        <!-- Apply data to referenced dataset -->
        <NetworkLink>
            <ExtendedData
xmlns:qim="http://www.geoviqua.org/QualityInformationModel/3.1">
                <qim:GVQ_UsageReport_Type>
                    <qim:usageDescription>Tried to use it for refining
                 near-ground wind speeds
                      in a weather forecasting setting.
                    </qim:usageDescription>
                </qim:GVQ_UsageReport_Type>
                <qim:discoveredIssue>
                    Many buildings were all flat so it as not useable.
                </qim:discoveredIssue>
            </ExtendedData>
            <Link>
                <href>
                    http://somedata.set/34542352.kml
                </href>
            </Link>
        </NetworkLink>
    </Document>
</kml>
```

8.1.2 Sample level quality information in KML

There is not fundamental difference in how this would work, except that we have to account for potential sample level quality information which needs to be represented. This scenario needs to be evaluated further.

8.2 Portrayal quality information encoded in KML

In this case the encoding of quality information would be more implicit, not in a fashion suitable for semantic interoperability but easy to consume for existing client implementations.

The following example details how KML to portray an average rating for some data might look. It is likely that additional elements or logic will be required to associate the data at the right granularity.

```
<kml xmlns="http://www.opengis.net/kml/2.2">
    <Document>
        <name>Portrayal of User Quailty Model data</name>

        <!-- Declare KML schema for user rating summary -->
```

```
        <Schema name="RatingSummary"
id="UserRatingSummaryTypeId">
            <SimpleField type="string" name="UserDomain">

<displayName><![CDATA[<b>Domain</b>]]></displayName>
            </SimpleField>
            <SimpleField type="double" name="AverageRating">
                <displayName><![CDATA[<b>average
Rating</b>]]></displayName>
            </SimpleField>
            <SimpleField type="int" name="NumberOfVotes">
                <displayName>No. of votes included in the
average</displayName>
            </SimpleField>
        </Schema>

        <!-- Apply data to referenced dataset -->
        <NetworkLink>
            <ExtendedData>
                <SchemaData schemaUrl="#UserRatingSummaryTypeId">
                    <SimpleData
name="UserDomain">Geodesy</SimpleData>
                    <SimpleData
name="AverageRating">3.1</SimpleData>
                    <SimpleData
name="NumberOfVotes">8</SimpleData>
                </SchemaData>
                <SchemaData schemaUrl="#UserRatingSummaryTypeId">
                    <SimpleData
name="UserDomain">Bathymetry</SimpleData>
                    <SimpleData
name="AverageRating">1.3</SimpleData>
                    <SimpleData
name="NumberOfVotes">2</SimpleData>
                </SchemaData>
            </ExtendedData>
            <Link><href>
                http://somedata.set/34542352.kml
            </href></Link>
         </NetworkLink>
    </Document>
</kml>
```

In this example a hypothetic data set will be colored according to quality information that was available when the KML was generated, but is not lost except for its visual correlates.

```xml
<kml xmlns="http://www.opengis.net/kml/2.2">
    <Document>
        <name>Portrayal of Quality data</name>

        <!-- These would be autogenerated or selected from a
well-known scale -->
        <Style id="veryBadQuality">
            <LabelStyle>
                <color>ff0000ff</color>
            </LabelStyle>
        </Style>
        <Style id="reasonableQuality">
            <LabelStyle>
                <color>00ffffff</color>
            </LabelStyle>
        </Style>
        <Style id="veryGoodQuality">
            <LabelStyle>
                <color>00ff00ff</color>
            </LabelStyle>
        </Style>
        <!-- Apply data to referenced dataset -->
        <NetworkLink>
            <styleUrl>#veryGoodQuality</styleUrl>
            <Link>
                <href>
                    http://somedata.set/34542352.kml
                </href>
            </Link>
         </NetworkLink>
    </Document>
</kml>
```

9 Quality in ARML

Augmented Reality Marked Language version 2.0 candidate standard was open for comments during OWS-9 period (http://www.opengeospatial.org/standards/requests/94). This clause captures our first impressions and a CR that we submitted to the standards working group.

Essentially, the specification provides a way to encode geospatial features that you want to “mark” or “augment” in your “view of the reality. It provides a way to generate screen coordinates features (to have a fix window in your screen, e.g. to see messages of text), and real world coordinate features that will be overlapped to the “reality” with some hardware visualization system. We envisage a system that allows overlapping features in the reality, which informs about sample quality information in a way that allows us to walk thought the data and explore its quality.

Unfortunately, the initial evaluated version was poor in metadata (features just had names and titles). Particularly, there was no placeholder for metadata regarding features, and therefore features could not include sample/feature level quality, uncertainty or provenance. Features had no semantics (not even keywords) so it is possible to say that this feature is a label that represent a quality label for a particular object.

We submitted a CR asking to include "keywords" in order to tag the features with controlled vocabularies and also to add a “gml:metadataDataProperty” to include some metadata features.

As a result, a new metadata-element in feature has been included, which allows any XML to be wrapped (with processContents set to lax, so custom schemas can be added optionally) in this element. This fulfills our requirements and opens the door to explore how quality indicators and measures can be visualized in ARML compatible augmented reality systems.

10 Future Work

This document describes the WMS-Q and WMTS-Q conventions for encoding quality information in a Web Map Service and Web Map Tile Service respectively. The only extension to the WMS 1.3.0 specification is minor (the modification to the MetadataURL element); all other rules define special interpretations of the specification without extension. No extension is required in WMTS.

At the time of writing, two particular areas require further investigation: the behavior of the GetFeatureInfo operation and the mechanism for map styling and the way SLD can be used to improve user control on the resulting uncertainty visualization. These are active areas of research within the GeoViQua project and this document will be updated as results are produced.

Additionally, the document also explores how to apply quality information to features encoded in KML and in ARML. In both cases, only preliminary examples and approaches have been discussed broadening the number of ways sample/feature level quality information could be integrated with geospatial data, and visualized in virtual globes and augmented reality systems. More work needs to be done to generate detailed best practice documents on both standards.