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systems**

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practice report***

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## 1. Introduction

This document describes mechanisms for integrating information about data quality with a number of Open Geospatial Consortium technologies and standards relevant to visualization. In the current draft, the major focus is on the OGC Web Map Service specification (WMS, section 2), and information is currently being gathered regarding the Web Map Tile Service (WMTS, section 3), KML (section 4) and Augmented Reality Markup Language (section 5).

In general, we consider 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). We acknowledge that in reality, other levels of quality information may be required.

## 2. Integration of quality information with Web Map Services (WMS)

*(The information in this section is being prepared as an OGC Engineering Report as part of the OWS-9 initiative.)*

### 2.1 Introduction

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.

## 2.2 Aims and scope

This section is concerned mainly with attaching quality information to raster data types, such as satellite images and output from numerical models. Different conventions may be required for vector data types.

We aim to design a profile of WMS version 1.3.0 that requires as few alterations to the original specification as possible. The mechanisms described in this section are mostly specializations of the specification, not modifications or extensions to it. We name this new profile "WMS-Q".

## 2.3 Dataset-level quality metadata

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 (see section 2.1 por encima de).

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 1 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://localhost:8080/metadata/ backgroundInfo.pdf "/>
  </MetadataURL>
</Layer>
```

**Figure 1: Sample fragment of a WMS Capabilities document that incorporates the modifications proposed in section 2.3.**

## 2.4 Variable-level quality information

The same mechanism as in section 2.3 por encima de 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.

## 2.5 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. The application of uncertainties to categorical data is an active area of research with the GeoViQua project.

### 2.5.1 Background: 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).

### 2.5.2 Background: 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 2 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 2: A fragment of NetCDF-U, where ancillary\_variables is used to associate variables and ref is used to reference the UncertML term**

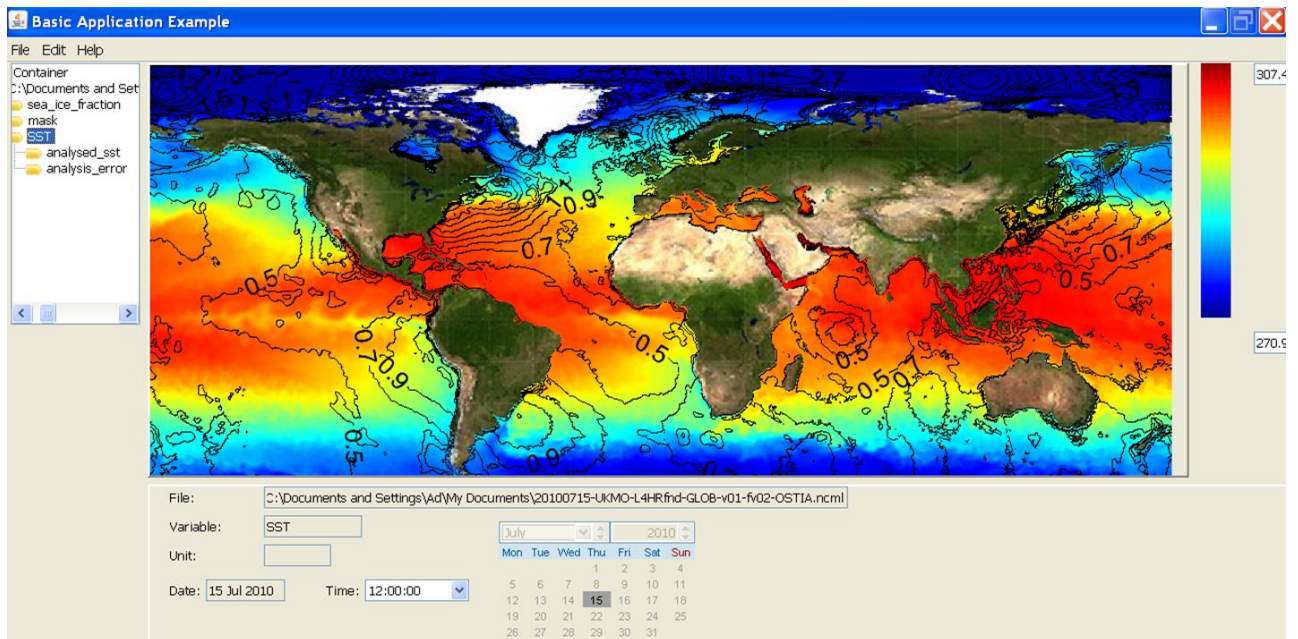
### 2.5.3 Applying UncertML within WMS

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.

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 3).
- 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: A screenshot of visualizing uncertainty information using contouring approach (produced by desktop WMS-Q Viewer)**

Figure 4 shows an example of using these rules to encode the dataset from Figure 2 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 4: A fragment from a WMS-Q Capabilities document, illustrating the use of Layer nesting and UncertML terms to convey the semantic relationship between Layers.**

## 2.6 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 5).
- 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.

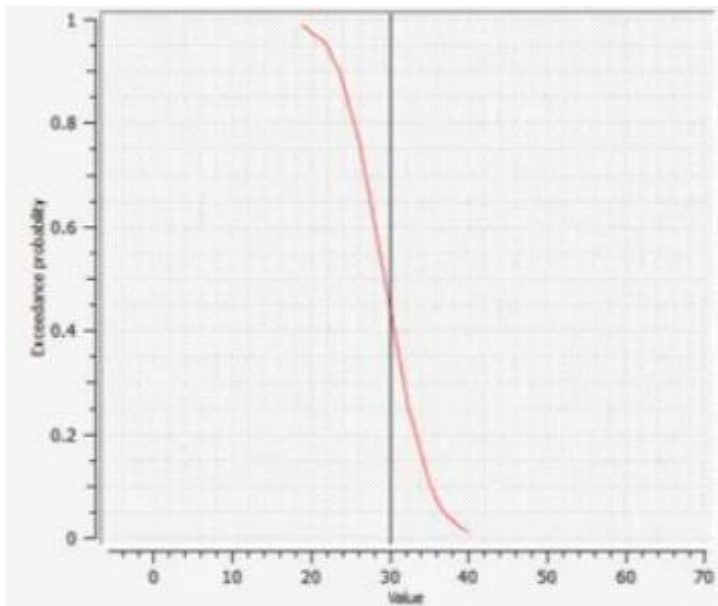


Figure 5: Sample image representing a probability distribution. This could be returned from a GetFeatureInfo request

## 2.7 Map image styling

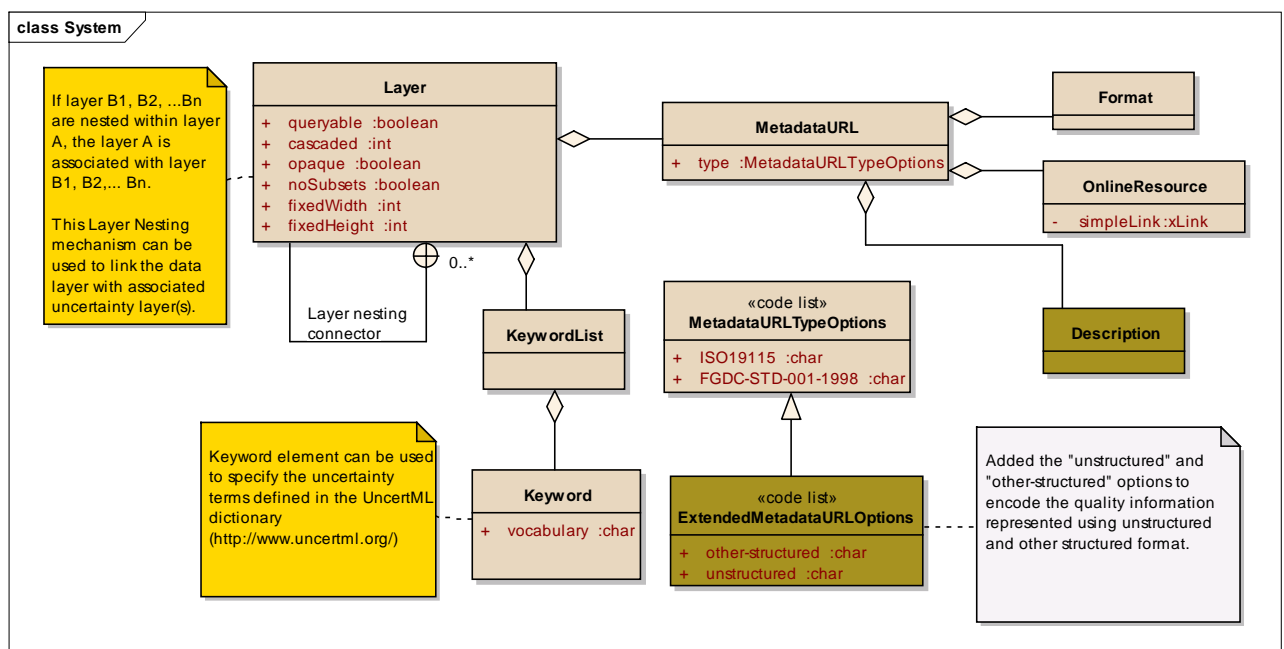
A standard WMS enumerates a finite number of Styles in which images can be generated from Layers. These cannot be configured by the end user. Scientific users usually require more flexibility, for example to control how data values map to palette colours, to control the contour spacing or to control 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.

## 2.8 Summary

This section describes the “WMS-Q” conventions for encoding quality information in a Web Map Service. 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. Figure 6 summarizes the WMS-Q conventions in the form of a UML diagram.



**Figure 6: 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 behaviour of GetFeatureInfo.**

At the time of writing, two particular areas require further investigation: the behaviour of the GetFeatureInfo operation and the mechanism for map styling. These are active areas of research within the GeoViQua project and this document will be updated as results are produced.

## 3. Integration of quality information with Web Map Tile Services (WMTS)

TODO (CREAF) It will be included in the final version

#### **4. Integration of quality information with KML**

TODO (FRAUN, 52N) It will be included in the final version

#### **5. Integration of quality information with Augmented Reality Markup Language (ARML)**

TODO (CREAF, 52N) It will be included in the final version