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OGC Best Practices for using Web Map Services (WMS) with Time-Dependent or Elevation-Dependent Data

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i. Abstract

This document proposes a set of Best Practices and some guidelines for implementing and using the OGC Web Map Service (WMS) to serve maps which are time-dependent or elevation-dependent. In particular, clarifications or restrictions on the use of WMS are defined to allow unambiguous and safe interoperability between clients and servers, both in the context of expert meteorological and oceanographic usage and in other communities using meteorological and oceanographic information in conjunction with their own domains' data. This Best Practice applies specifically to WMS version 1.3, but many concepts and recommendations herein will be applicable to other versions of WMS or to other OGC services, in particular the Web Coverage Service.

ii. Keywords

The following are keywords to be used by search engines and document catalogues:

meteorology oceanography time elevation wms 'web map service' 1.3 1.3.0 ogc 'best practice' ogcdoc

iii. Preface

This Best Practices document is the result of discussions within the Meteorology and Oceanography Domain Working Group (MetOcean DWG) of the Technical Committee (TC) of the Open Geospatial Consortium (OGC) regarding the use of the OGC Web Map Service (WMS) to produce map visualizations from the various types of data regularly produced, analyzed, and shared within those communities. The discussion considered the differences in the types of data and the issues, concerns, and responsibilities of data producers when sharing those data as maps with end users, including the general public, users with specific needs, and analysts within the meteorological and oceanographic communities. The limited scope of the requirements and recommendations in this document reflect the consensus reached by groups with vastly different types of data, limitations in the current design of WMS, compromises to ensure these services remain applicable to a mass market audience, and a reluctance to take too many decisions in this first version. Future work includes extending this Best Practice once the community gains experience with WMS and with implementing this document. This document does not require any changes to other OGC specifications but it is hoped that the WMS standard will evolve to address issues encountered in this work such as providing a mechanism to define exclusive dimensions and to define sparse combinations of dimensions.

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 when possible.

iv. Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium Inc.

DWD (Deutscher Wetterdienst)
ECMWF (European Centre for Medium-range Weather Forecasts)
Météo-France
Technische Universität Dresden

UK Met Office
US COMNAVMETOCCOM (Naval Meteorological and Oceanographic Command)
US NOAA (National Oceanic and Atmospheric Administration)

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1. Introduction

The meteorological and oceanographic communities have been exchanging information internationally for at least 150 years and well understand the importance for interoperability of geospatial standards defining data formats, interfaces and processes, shared conceptual models, and stable, sustainable, maintenance processes.

Because of the demanding nature of meteorological and oceanographic data processing, the communities have evolved domain specific solutions. As computers have become more powerful, it has become feasible to use general geospatial software for day-to-day operational purposes, and interoperability problems have arisen. There is also an increasing need to combine meteorological and oceanographic data with other forms of geospatial data from other domains, in ways convenient for those domains.

This document describes and justifies a set of Best Practices for offering and requesting data with temporal or elevational dependencies through Web Map Services (WMS) to meet the interoperability requirements of the meteorological and oceanographic communities and enable them to gain the economic benefits of using commercial, off the shelf (COTS) software implementations of WMS servers and clients.

1.1 Time

Complex geospatial data such as that in common use by the meteorological and oceanographic communities may be temporally independent or may have one or more temporal dependencies expressing the relation of the data to a time of applicability, to a time of collection, or to other significant times. The diversity of data and their temporal dependencies leads to confusion and means that temporally dependent data might be offered through a Web Map Service (WMS) in many different ways: as a huge number of different WMS Layers, as many layers with a temporal dimension, or as a single layer with many temporal dimensions for instance.

This document makes recommendations to promote interoperability of producers, distributors, and users of temporally dependent data. These recommendations may be useful for other domains but it have been defined originally for the use in the meteorological and oceanographic community by focusing on the most common temporal dependencies in the domain and developing both a consistent terminology for such data and an approach to structuring such data for distribution as layers in a WMS.

Data which have no temporal dependency can be treated simply by being offered as single WMS Layers without any associated temporal dimension. For example, topographic data or data for the climatological normal[1] may be offered as WMS Layers without any WMS dimensions, implicitly making the assumption that any temporal dependency is irrelevant over the time scale under consideration.

Data which have a single temporal association also can be treated simply by being offered as single WMS Layers with a single temporal dimension. For example, satellite imagery taken from the same platform for the same spatial extent at different moments in time can be offered as a single WMS layer with a single temporal dimension, where the temporal dimension represents a time used to

[1] WMO defines normals as “period averages computed for a uniform and relatively long period comprising at least three consecutive 10 year periods.

identify individual satellite products (conventionally it is usually the beginning or the end of the scan).

Data which have multiple temporal associations, such as numerical weather forecast calculation, series of alerts or data associated with trajectories of moving objects, do not have a single obvious representation as WMS Layers. The WMS standard only defines a single temporal dimension called `time`. Each user community has the flexibility of defining the use of that dimension, the possibility of defining other temporal dimensions for structuring this multi-temporal data, and the work of structuring common metadata using those temporal axes. This may result in splitting such data into many layers representing different temporal associations or the use of several temporal dimensions to reduce the number of WMS layers.

Several examples taken from the meteorological and oceanographic community illustrate different types of complex elevation-dependent data and some issues encountered when offering those data using WMS.

Forecast calculations present an example of data with multiple temporal associations.

For a certain forecast calculation, assume three separate calculations for air temperature, each containing 48 forecasts at successive 1 hour intervals, the available combinations of validity time and calculation nominal start time will be as shown in the table below. Columns sharing an "*" across rows indicate forecasts from different calculations that share the same validity time.

	Validity Time of Forecasts					
	2009-11-26		2009-11-27		2009-11-28	
Nominal Start Time	00-12	12-00	00-12	12-00	00-12	12-00
2009-11-26T00:00	*	*	*	*		
2009-11-26T12:00		*	*	*	*	
2009-11-27T00:00			*	*	*	*

Table 1: Example of Two Dimensional Time Axis for Numerical Model Forecast Data

These might be represented in a WMS as 48 separate layers or as a single layer with two time dimensions. The former approach will result in a larger, more complex capabilities document; the latter approach will permit the combinations to be expressed more compactly as a single layer.

Alert and warning data present another example.

Data associated with alerts or warnings often have multiple time axes. Warnings and alerts are a frequent category of meteorological data. A meteorological warning is a message about a meteorological event that will probably occur in the future at a geographic location. Typically, a warning becomes effective when it has been sent out. But, it will be also possible to specify an effective time explicitly. The validity period of a warning is the period between the expected beginning of the event in the warning and its expiry.

So, for warnings and alerts there are four different time attributes. The Common Alerting Protocol (CAP) Version 1.2, which is an OASIS standard format for exchanging all-hazard emergency alerts and public warnings over all kinds of networks, defines these four attributes as follows:

Element name	Definition	Optionality	Notes
sent	The time and date of the origination of the warning	required	
effective	The effective time of the information of the warning	optional	If the effective time is not explicitly defined, then this time shall be assumed to be the same as the sent time.
onset	The expected time of the beginning of the subject event of the warning	optional	
expires	The expiry time of the information of the warning	optional	If this value is not provided, each recipient is free to set its own policy as to when the warning is no longer in effect.

Table 2: Time related attributes in CAP Version 1.2

According to these definitions, the validity period of a warning is the period between the onset time and the expiry time, if the onset time is given. Otherwise, it is the period between the effective time and the expiry time.

A warning is valid at a particular time if it has not expired at that moment. A warning situation is a set of valid warnings at a particular time. A warning situation changes if a new warning is sent out or if an existing valid warning is withdrawn or modified. Typical modifications are the adjustment of the validity period or the change of the severity level. Figure 2 shows a warning situation on 12th August 2012 at 13:00 UTC. The diagram contains five warnings. But only three of them are part of the warning situation.

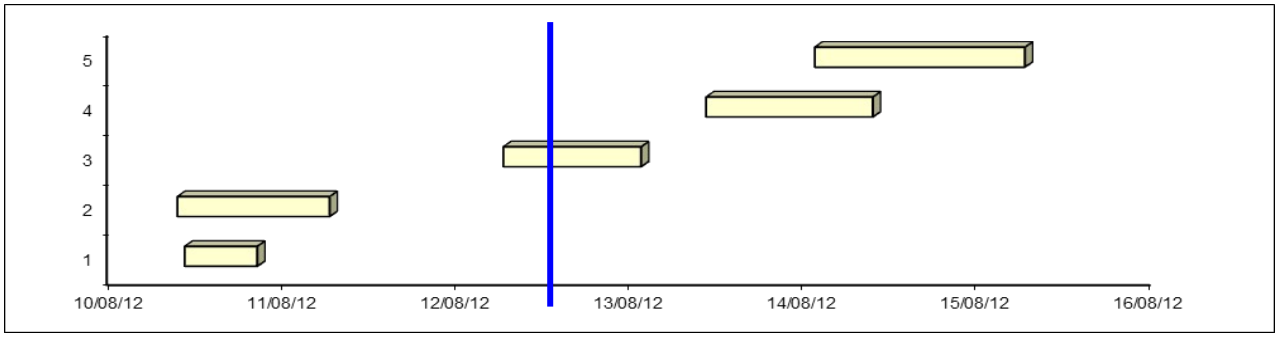

Figure 1: Example of a warning situation

There might be three ways to represent warnings in a WMS:

- Each warning could be registered as a separate layer. This approach seems not very practical because it will result in a large set of layers.
- Each warning situation could be registered as a separate layer with a time dimension. The values of this dimension are the validity periods of the warnings. The particular time (sent or effective time) that is associated with a warning situation might become part of the layer name.
- All warning situations could be represented as a single layer with two time dimensions. The values of the second dimension are the particular times of the warning situations. A warning situation can be stored in a CAP file. Some meteorological services produce those CAP files periodically (e.g. every 5 minutes). This results in a regular second time dimension for the "warning" layer.

The latter approach will permit maximum flexibility for the formulation of GetMap requests.

Trajectory data present a third example.

A trajectory is the path that a moving object follows through space as a function of time. In meteorology, trajectories are often observed or computed periodically. A data provider may then have a set of trajectories with different starting times. The trajectory data and map layers are distinguished by their "start times".

1.2 Elevation

Complex geospatial data such as that in common use by the meteorological and oceanographic communities may be independent of elevation or may have one or more vertical dependencies. The diversity of data and their elevational dependencies leads to confusion and means that such data can be offered through a WMS in many different ways: as a huge number of different WMS Layers, as many layers with a vertical dimension, or as a single layer with many vertical dimensions. Elevations can be specified using multiple measure types including nominal values such as 'earth surface,' 'tropopause,' or 'cloud top' or using numeric values specifying the distance above or below some vertical datum. Furthermore, data might have multiple elevational dependencies but these will be mutually exclusive; unfortunately the WMS standard does not specify any mechanism to declare two dimensions on a given layer but make them mutually exclusive to prevent clients asking for values in both dimension at once.

This document makes recommendations to promote interoperability of producers, distributors, and users of vertically dependent data. These recommendations may be useful for other domains but have been defined originally for the use in the meteorological and oceanographic community by focusing on the most common elevational dependencies in the domain and developing both a consistent terminology for such data and an approach to structuring such data for distribution as layers in a WMS.

Several examples taken from the meteorological and oceanographic community illustrate different types of elevation-dependent data.

A data set recording total cloud cover or bathymetry values may have no elevation dependency.

A data set recording air temperature at a given numeric height has an elevation dependency that can be specified by using a numeric value for the elevation and associating that value to a vertical coordinate reference system (CRS) specifying the vertical datum anchoring the height value.

A data set recording an environmental parameter on a computed surface, such as the tropopause, an isotherm, the base (or top) of contrail, a surface of constant potential vorticity, or a jet level, has an elevation dependency that can be specified using a nominal value identifying the surface. In

general, it is best if these nominal values are defined by some authority possibly through a controlled vocabulary.

A data set recording ocean salinity at multiple, fixed depths has an elevation dependency that can be specified by using multiple numeric values for the depths and associating those values to a vertical coordinate reference system specifying the vertical datum anchoring the depth value.

A data set recoding wind speed of one or more atmospheric 'layers', or 'non-zero vertical thickness surfaces,' between two isobaric levels (e.g. 1000-900 hPa) has an elevation dependency that can be specified, for each layer, through a pair of numeric elevation values specifying the top and the bottom of the layer along with a vertical CRS. The recorded values are related to the full thickness.

Fully defined vertical coordinate reference systems are critical for the proper expression of elevation using numeric values. Sources of predefined vertical CRS definitions include:

- the World Meteorological Organization (WMO) *Code Table 4.5* http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/LatestVERSION.html, and
- the EPSG Geodetic Parameter Registry http://www.epsg-registry.org/EPSG,

while new, custom vertical CRS definitions can be created using the data structures of the standard

- *ISO 19111: 2007 Geographic information -- Spatial referencing by coordinates*

and expressing those in data structures in any of several binary formats, notably in XML.

2. Scope

This version of this Best Practices document addresses only a limited number of issues related to the use of WMS for time-dependent and elevation-dependent data in order to produce an initial document as a basis for future expansion and for implementation experimentation. The document considers the issues with the most common temporally-dependent and elevation-dependent data. The document describes how to offer, as WMS layers, data with no temporal relation to 'validity time' (i.e. the Gregorian moment to which the map applies), data with a temporal relation to 'validity time', or data with a temporal relation both to 'validity time' and to some other moment of reference. The document describes how to offer, as WMS layers, data with no vertical dimension, data with a single vertical dimension expressed either as numeric or as nominal values and defining either a zero thickness surface or a non-zero thickness volume, and data with several vertical dimensions based on separate vertical coordinate reference systems (which must be split into layers with a single elevation dimension). The document specifies the use of the dimensions `time` and `elevation` defined in the WMS standard and also the use of a newly defined dimension `reference_time`. The document also specifies constraints on the behavior of WMS clients which have been created specifically to use WMS implementations which follow the requirements of this document. This document specifies a constrained, consistent interpretation of the WMS 1.3 standard that is applicable to government, academic, or commercial providers or users of time-dependent or elevation-dependent data offered as a WMS product.

This version of this Best Practices document has left many issues out of its scope. Design issues with WMS such as issues related to offering a large number of layers or to offering data which is updated frequently were not directly tackled. Issues in the workflow of users relying of a distributed spatial data infrastructure such as the discovery of services, or directly of layers, were not examined. Rules for the use of data covering climatological periods and ranges or of data using other non Gregorian calendars proved too complex for this version. No work was done aiming to address issues related to expressing the semantic content of particular layers. Developing a mechanism to obtain visualizations of non-horizontal data such as vertical slices was considered but rejected due to the need to modify the design of WMS itself. Related work on the internationalization of human visible text and on styling has been undertaken as separate efforts.

3. References

The following normative documents contain provisions that, through reference in this text, constitute provisions of 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.

CAP Common Alerting Protocol Version 1.2, OASIS Standard, 2010-07-01. http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html

ISO 8601:2004, Data elements and interchange formats — Information interchange — Representation of dates and times

ISO 19111:2007 Geographic information -- Spatial referencing by coordinates.

ISO 19156:2011, Geographic information -- Observations and measurements.

OpenGIS® Web Map Server Implementation Specification Version 1.3.0. 2006-03-15. http://portal.opengeospatial.org/files/?artifact_id=14416

The World Meteorological Organization (WMO) operational data formats. http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/LatestVERSION.html .

4. Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2: Rules for the structure and drafting of International Standards.

In particular:

1. **SHALL** – verb form used to indicate a requirement to be strictly followed to conform to this document, from which no deviation is permitted.
2. **SHOULD** – verb form used to indicate desirable ability or use, without mentioning or excluding other possibilities.

3. **MAY** – verb form used to indicate an action permissible within the limits of this document.

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

4.1
client
software component that can invoke an **operation** from a **server**

4.2
elevation
Vertical distance of a point or level expressed in a predefined Coordinate Reference System

4.3
geographic information
information concerning phenomena implicitly or explicitly associated with a location on Earth [ISO 19101]

4.4
interface
named set of **operations** that characterize the behaviour of an entity [ISO 19119]

4.5
layer
basic unit of **geographic information** that may be requested as a **map** from a **server**

4.6
map
portrayal of **geographic information** as a digital image file suitable for display on a computer screen

4.7
operation
specification of a transformation or query that an object may be called to execute [ISO 19119]

4.8
portrayal
presentation of information to humans [ISO 19117]

4.9
reference time
temporal parameter to be used to handle the second time axis (see 1.1)

4.10
request
invocation of an **operation** by a **client**

4.11
response
result of an **operation** returned from a **server** to a **client**

4.12
server
a particular instance of a **service**

4.13
service
distinct part of the functionality that is provided by an entity through interfaces [ISO 14252]

4.14
validity period
period of time for which data, a map or layer is valid to be used. Often used for warnings or forecasts. In [ISO 19156], the validity period has the semantics of validTime

4.15
validity time
An attribute value specified by an instant in or duration of universal chronological time that identifies when information is valid or applicable. In [ISO 19156], the validity time has the semantics of phenomenonTime.

5. Conventions

5.1 Abbreviated terms

CAP	Common Alerting Protocol
CRS	Coordinate Reference System
GIS	Geographic Information System
GRIB	Gridded Binary data format
IEC	International Electro-technical Commission
ISO	International Standards Organisation
OGC	Open GIS Consortium
Met Ocean	Meteorology and Oceanography
URL	Uniform Resource Locator
WMS	Web Map Service
XML	eXtensible Mark-up Language

5.2 Notational conventions

This clause provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

Any keywords from the WMS Standard are depicted in UPPER CASE, even if lower case is allowed by the Standard.

Any keywords specified by this Best Practice are depicted in lower case, non-italic.

Any example values for keywords from the WMS Standard or this Best Practice are depicted in *lower case italic.*

6. Requirements

This document defines injunctions for the use of OGC Web Map Service implementations for the distribution of map visualizations based on data with temporal or elevational dependencies. The injunctions constrain how such data offerings should be structured into WMS Layers, the way such layers should be described in the WMS Capabilities document, the way requests for such layers should be handled, and the way clients should issue requests for such layers. These injunctions do not necessitate modifications to the WMS standard but merely define rules for the use of that standard.

The injunctions of this document target two different kinds of implementations. “Conformant WMS servers” are WMS server implementations which follow the injunctions of this document to offer temporally dependent or elevation dependent data as WMS Layers structured in a manner useful both to users relying on general purpose clients and to advanced users leveraging clients purpose built for the needs of the community. “Conformant WMS clients” are these purpose built WMS clients which are expected to provide a user interface to select dimensional values; this document places certain restrictions on these clients to reduce the chance of confusion or error.

The WMS 1.3.0 standard defines a system for declaring and requesting map layers with more dimensions than the two spatial dimensions represented in the map visualization. The standard defines a mechanism to assign dimensions to a map layer in the Capabilities document and then defines two specific dimensions, `time` and `elevation`. A WMS Layer is declared to be available at one or more values in a dimension by declaring an XML `<Dimension>` element either in the `<Layer>` element itself or in a parent layer, in which case the dimension will be inherited. For example, a Capabilities document might contain:

```
<Layer>
    ...
    <Dimension name=”time” units=”ISO8609” default=”1970-01-01”
               multipleValues=”0” nearestValue=”0” current=”0”
               >1900-01-01/2010-12-31/P1D</Dimension>
    <Layer>
        <Name>Surface_Irradiance</Name>
        ...
    </Layer>
    <Layer>
        <Name>Temperature</Name>
        ...
        <Dimension name=”elevation” units=”” unitSymbol=”” default=”surface”
                   multipleValues=”0” nearestValue=”0”
                   >surface,tropopause</Dimension>

    </Layer>
</Layer>
```

where the outer layer defines a temporal dimension which is inherited by both inner layers and the inner layer `Temperature` also declares that it is available at two heights. The time dimension is declared with a `<Dimension name=”time” ...>` element and the corresponding GetMap request may include the request parameter `&TIME=`*t* with an appropriate value. The elevation dimension is declared with a `<Dimension name=”elevation” ...>` element and the corresponding GetMap request may include the request parameter `&ELEVATION=`*z* with an appropriate value. Further dimensions can be declared with a `<Dimension name=”somename” ...>` element and the corresponding GetMap request may include the request parameter `&DIM_SOMENAME=`*v* with an appropriate value.

While the mechanism defined by WMS 1.3.0 is powerful, it unfortunately also has limitations. The mechanism does not provide any way to declare that dimensions are exclusive of one another so that elevation dependent data accessible using different vertical units, say meters and millibars, must be split into separate layers (otherwise GetMap requests with both values would cause problematic errors). The mechanism does not provide any way to declare what combinations of values in the different dimensions are available, making the discovery of available combinations a guessing game for the client.

This clause specifies requirements and recommendations for the use of the `time` dimension and the `elevation` dimension defined in the WMS standard, and for the use of a new dimension named `reference_time`. This specification considers only the OGC standard

OpenGIS® Web Map Server Implementation Specification, version 1.3.0 (OGC 06-042)

which is the only version of the standard which has not been deprecated at the time of writing of this best practices document.

6.1 Time-dependent data

Complex data sets can have temporal dependencies of many kinds. This best practice document focuses on two in particular.

The most pervasive temporal dependency comes from data values differing for different chronological times: observations may have been recorded at different moments, models may be predicting conditions for different days, alerts may refer to conditions expected at certain moments in the future. This document adopts the phrase 'validity time' in reference to this type of temporal dependency from the meteorological domain despite the potentially misleading natural language association of the root 'validity'. This concept is essentially identical to the concept of 'phenomenonTime' from the standard *ISO 19156:2011, Geographic information -- Observations and measurements*. This document reserves the dimension `time` for this type of temporal dependency.

Frequently, data are additionally temporally dependent relative to some reference moment: observations may have an accession time into a data repository, models may have a moment where the model was begun or where observational data stopped being updated, alerts may have a moment of expiration. The diversity of such references precludes defining a dimension type with explicit semantics but the need for a mechanism to distinguish data based on some temporal referent is widely shared. This document therefore defines a generic dimension called `reference_time` which may be used for any of these situations. If it is used however, the requirements specify that the semantics must be elucidated in the `<Abstract>` element of the Layer in which the dimension is defined.

In all cases, the dimension TIME must be used in accordance with the following guidelines:

Req. 1 Conformant WMS servers and clients SHALL use the dimension `time` and the request parameter TIME only to refer to 'validity time,' which refers to the applicability of the data to the chronological Gregorian calendar.

Req. 2 Conformant WMS servers SHALL offer any data which has a temporal dependency which can be referenced to 'validity time' as a WMS Layer with a TIME dimension. Conformant WMS servers SHALL aggregate multiple data sets differing only in 'validity time' values into a single WMS Layer with a TIME dimension.

Req. 3 Conformant WMS servers and clients SHALL use the dimension `time` and the request parameter TIME only with values specified according to the rules of *ISO 8601:2000 Data elements and interchange formats -- Information interchange -- Representation*

of dates and times and only using the format of each temporal instant loosely defined as:

```
datetimevalue = yyyy "-" mm "-" dd "T" hh ":" mm ":" ss "." sss "Z"
```

for example 1999-12-31 or 2013-01-22T15:08:45.336Z, specified to the desired level of precision meaning that only the yyyy value is required. Conformant WMS servers and clients SHALL specify all time values in Coordinated Universal Time (UTC) so that "Z" is the only time zone designator allowed.

Req. 4 Conformant WMS servers SHALL use the dimension TIME only with units declared using the units identifier `"ISO8601"` to indicate time values conformant with the standard ISO8601:2000.

Rec. Conformant WMS servers and clients MAY express multiple time instants as a comma separated list of instants or as a forward slash separated triplet, start/end/interval, as specified in the WMS 1.3.0 standard, Table C.2.

Req. 5 Conformant WMS servers SHALL include, for all `<Dimension ... />` elements declared in the Capabilities document with the name `time`, a `nearestValue` field with the value set to `0` (ASCII zero), indicating false.

Req. 6 Conformant WMS servers SHALL respond to requests for WMS Layers which have been declared in the Capabilities document as having a TIME dimension but which contain a TIME value which is not available on the server with an `InvalidDimensionValue` exception.

The following sub-clauses distinguish all WMS offerings based on their temporal dependency. For data with no temporal dependency, clause 6.1.2 applies. For data with a temporal dependency which can be mapped to validity time, clause 6.1.3 applies. For data with a temporal dependency which can be mapped to validity time and another temporal dependency which can be mapped to referential instant, clause 6.1.4 applies.

6.1.1 Atemporal data

WMS servers may wish to offer data which have no temporal dependency, in which case the following requirements apply:

Req. 7 Conformant WMS servers SHALL NOT declare in the Capabilities document a WMS Layer declaring or inheriting a TIME dimension for data with no temporal dependency mappable to 'validity time'.

Req. 8 Conformant WMS servers SHALL NOT declare in the Capabilities document a WMS Layer inheriting a TIME dimension for data with no temporal dependency mappable to 'validity time'.

Req. 9 Conformant WMS servers SHALL reject any GetMap request which includes a TIME request element with its value set if the request includes a WMS Layer which has not been defined as having a TIME dimension in the Capabilities document.

6.1.2 TIME axis

WMS servers may wish to offer data which have a temporal dependency which can be mapped to 'validity time' and therefore whose values differ by Gregorian calendar time, in which case the following requirements apply:

Req. 10 Conformant WMS servers SHALL only offer data which has a temporal dependency mappable to 'validity time' as a WMS layer for which a dimension named `time` is declared or inherited in the Capabilities document.

Req. 11 Conformant WMS servers SHALL declare in the Capabilities document the times available for the TIME dimension either as a list (T_0, T_1, ... T_N) and/or range ($T_0/T_1/\Delta T$) in accordance with WMS 1.3, Table C.2.

Req. 12 Conformant WMS servers SHALL declare in each TIME dimension of the Capabilities document the attribute *current* and assign it the appropriate boolean value, either `0` (ASCII zero) or `1` (ASCII one) meaning *false* and *true* respectively, as specified in Annex C.2 of the WMS 1.3.0 standard. Conformant WMS servers SHALL set the *current* attribute value to `1` (ASCII one) meaning *true* for any Layer produced from data which are continually updated.

Req. 13 Conformant WMS servers SHALL declare in each TIME dimension of the Capabilities document the attribute *default* and assign it the time value returned for requests which do not specify a TIME value as specified in Annex C.2 of the WMS 1.3.0 standard.

Rec. Conformant WMS servers SHOULD declare, for any Layer which declares a TIME dimension in the Capabilities document, an Abstract property for the same Layer, as defined in clause 7.2.4.6 of the WMS 1.3.0 standard, which explains the policy used to choose the default value for the TIME dimension.

Rec. Conformant WMS servers MAY declare in a TIME dimension of the Capabilities document the attribute *multipleValues* and assign it the appropriate boolean value as specified in Annex C.2 of the WMS 1.3.0 standard.

Req. 14 Conformant WMS servers which support animations or mash-ups of multiple layers SHALL declare this support by setting the attribute *multipleValues* to *true.*

Req. 15 Conformant WMS servers SHALL respond to GetMap requests which do not have the TIME request element set to a valid value using, for any Layer specified in the request which specifies a TIME dimension, the time value declared as the default.

Req. 16 Conformant WMS servers SHALL respond with an `InvalidDimensionValue` exception to any GetMap request which has a TIME request element set to a valid value but that value is not declared as available for any of the layers specified in the

request.

Rec. Conformant WMS clients SHOULD specify a TIME value in any GetMap request including a WMS Layer for which a TIME dimension has been defined in the Capabilities document.

Note that the recommendation that conformant clients build specifically for users in the community include the TIME parameter in every GetMap request rather than relying on the default value is intended to increase precision in the community. The use of a DEFAULT value for TIME is intended for mass market clients.

Conformant WMS servers can handle GetMap Requests according to the following decision tree.

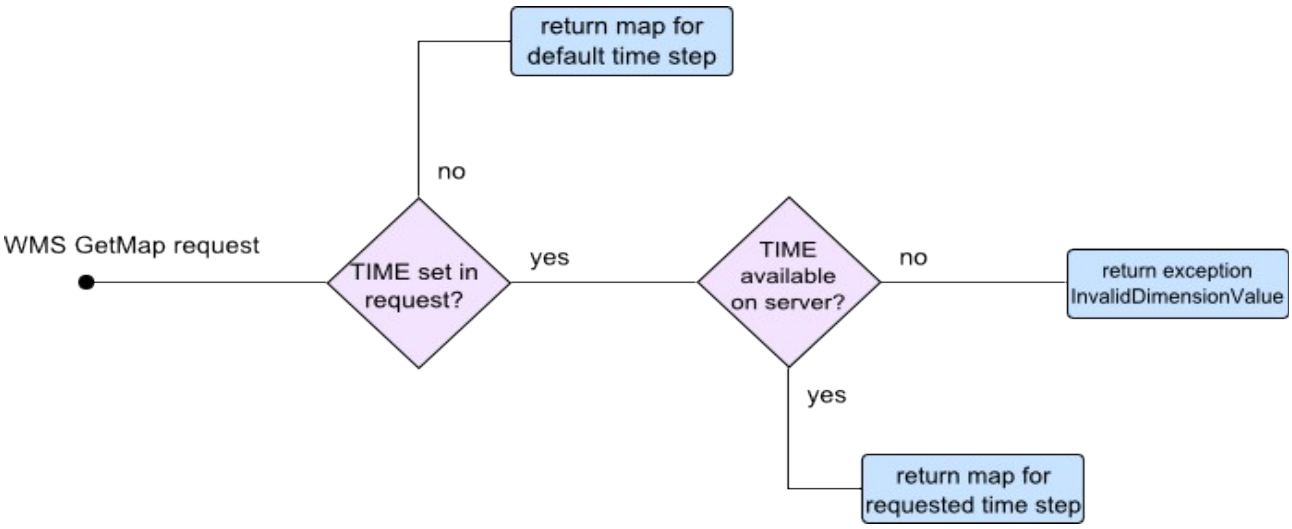

Figure 2: Decision Tree for Time in GetMap request.

Note that the TIME value is considered 'set' only if it is assigned a value in the request, not merely due to the presence of a TIME element in the request.

6.1.3 REFERENCE_TIME axis

WMS servers may wish to offer data which both have a temporal dependency which can be mapped to 'validity time' and therefore whose values differ by Gregorian calendar time and also have a second temporal dependency to some temporal moment of reference. The semantic meaning of this time of reference differs for different types of data, as was presented in the examples of clause 1.1, but the usage pattern of this second time axis applies broadly. This best practice allows the use of a WMS dimension called REFERENCE_TIME for these temporal dependencies towards moments of reference. Values for this dimension can be specified in client requests using the DIM_REFERENCE_TIME element.

The general rules for the use of REFERENCE_TIME are:

Req. 17 Conformant WMS servers and clients SHALL use the dimension REFERENCE_TIME only for data which has a temporal dependency to some moment of reference, such as the beginning of an analysis, a time of data collection, or a time of issuance, and only when that data also has a temporal dependency to 'validity_time' (and therefore has declared a TIME dimension in the Layer definition of the

Capabilities document).

Req. 18 Conformant WMS servers and clients SHALL use the dimension REFERENCE_TIME only with values specified according to the rules of *ISO 8601:2000 Data elements and interchange formats -- Information interchange -- Representation of dates and times* and only using the format of each temporal instant loosely defined as:

```
datetimevalue = yyyy "-" mm "-" dd "T" hh ":" mm ":" ss "." sss "Z"
```

for example 1999-12-31 or 2013-01-22T15:08:45.336Z, specified to the desired level of precision meaning that only the yyyy value is required. Conformant WMS servers and clients SHALL specify all time values in Coordinated Universal Time (UTC) so that "Z" is the only time zone designator allowed.

Req. 19 Conformant WMS servers SHALL use the dimension REFERENCE_TIME only with units declared using the units identifier `"ISO8601"` to indicate time values conformant with the standard ISO8601:2000.

For such data, the following requirements apply:

Rec. Conformant WMS servers MAY declare in the Capabilities document a WMS Layer with a REFERENCE_TIME dimension if both the layer declares a TIME dimension because the data generating the layer have an association to 'validity_time' and the data generating the layer have an association to several different temporal moments of reference.

Req. 20 Conformant WMS servers SHALL declare, for any Layer which declares a REFERENCE_TIME dimension in the Capabilities document, an Abstract property for the same Layer, as defined in clause 7.2.4.6 of the WMS 1.3.0 standard, which explains the semantic nature of the REFERENCE_TIME dimension.

Req. 21 Conformant WMS servers SHALL declare, in each REFERENCE_TIME dimension declaration in the Capabilities document, the attribute `default` and assign it the value of REFERENCE_TIME that will be used if a request specifies that layer but does not contain a REFERENCE_TIME request element.

Req. 22

Rec. Conformant WMS servers SHOULD declare, for any Layer which declares a REFERENCE_TIME dimension in the Capabilities document, an Abstract property for the same Layer, as defined in clause 7.2.4.6 of the WMS 1.3.0 standard, which explains the policy used to choose the default value for the REFERENCE_TIME dimension.

Req. 23

Req. 24 Conformant WMS servers SHALL respond with an `InvalidDimensionValue`

exception to any GetMap request which has a DIM_REFERENCE_TIME request element set to a valid value but that value is not declared in the Capabilities document as available for any of the Layers specified in the request.

Rec. Conformant WMS clients SHOULD specify in the GetMap request the value of the DIM_REFERENCE_TIME if any Layer in the request declares a REFERENCE_TIME dimension in the Layer declaration of the Capabilities document.

The use of a DEFAULT value for REFERENCE_TIME is intended for mass market clients.

Conformant WMS servers can handle GetMap Requests according to the following decision tree.

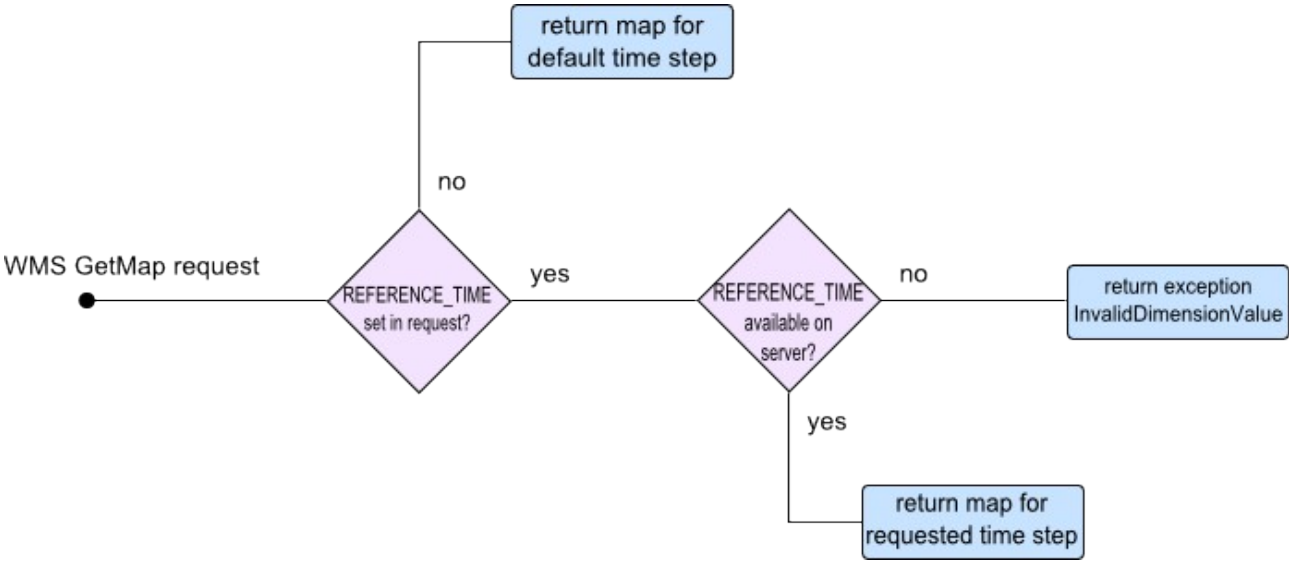

Figure 3: Decision Tree for Reference_Time in GetMap request.

Note that the REFERENCE_TIME value is considered 'set' only if it is assigned a value in the request, not merely due to the presence of the REFERENCE_TIME element in the request.

6.2 Elevation-dependent data

Complex data sets can have elevation dependencies of many kinds. Data might be referenced to the distance above mean sea level, distance below the surface of the sea, depth below the earth surface, distance from the calculated center of the earth, or height in the atmosphere possibly metric, barometric, or a named surface.

Data sets defining data available along several different elevation axes, differing either in their units, their vertical datums, or their measure type, *must be offered as separate WMS Layers*. This is due to the lack of any mechanism in the WMS standard to specify that certain dimensions are exclusive of one another (to prevent a request specifying two different of elevation values at once).

Data sets being offered as elevation dependent WMS Layers must define that dependency according to the type of elevation values present. Data without any elevation dependency must not declare or inherit any elevation dimension. Data sets which are only available at one vertical elevation are expected nonetheless to declare an elevation dimension having only that one value available. Data sets which are available at elevations specified by numeric values must follow the injunctions of clause 6.2.2. Data sets which are available at elevations specified by named values must follow the injunctions of clause 6.2.3. Some data sets may be available not at point elevations but rather as an aggregate value over an elevational range; such non-zero thickness layers, despite often being defined through a numeric upper and lower limit, are considered by this standard to be named ranges as specified in clause 6.2.4.

In all cases, the dimension ELEVATION must be used in accordance with the following guidelines:

Req. ? Conformant WMS servers SHALL offer elevation dependent data only as WMS Layers with a single vertical dimension and SHALL use the dimension ELEVATION for that vertical dimension.

Req. 25 Conformant WMS servers and clients SHALL use the dimension ELEVATION only to refer to a vertical axis having metric values or named values.

Req. 26 Conformant WMS servers SHALL offer any data which has a vertical dependency which can be referenced to metric or named values as a WMS Layer with an ELEVATION dimension. Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute `nearestValue` and assign it the boolean value `0` (ASCII zero) indicating *false* as specified in Annex C.2 of the WMS 1.3.0 standard.

Req. 27 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute *multipleValues* and SHALL assign it the boolean value `0` (ASCII zero) indicating *false* as specified in Annex C.2 of the WMS 1.3.0 standard.

Req. 28

Req. 29 Conformant WMS servers SHALL respond to requests for WMS Layers which have been declared in the Capabilities document as having an ELEVATION dimension but which contain an ELEVATION value which is not available on the server with an `InvalidDimensionValue` exception.

The following sub-clauses distinguish all WMS offerings based on their vertical dependency. For data with no vertical dependency, clause 7.2.1 applies. For data with a vertical dependency referenced to metric values, clause 7.2.2 applies. For data with a vertical dependency referenced to named values, clause 7.2.3 applies.

6.2.1 No vertical dependency

WMS servers may wish to offer data which have no vertical dependency, in which case the following requirements apply:

Req. 30 Conformant WMS servers SHALL NOT declare in the Capabilities document a WMS Layer declaring or inheriting an ELEVATION dimension for data that does not have a vertical dependency.

Req. 31 Conformant WMS servers SHALL NOT declare in the Capabilities document a WMS Layer inheriting an ELEVATION dimension for data that does not have a vertical dependency.

Req. 32 Conformant WMS servers SHALL reject any GetMap request which includes an ELEVATION request element with its value set if the request includes a WMS Layer which has not been defined as having an ELEVATION dimension in the Capabilities document.

6.2.2 ELEVATION axis using numeric values

WMS servers may wish to offer data which have a vertical dependency which can be referenced to metric values, in which case the following requirements apply:

Req. 33 Conformant WMS servers SHALL aggregate multiple data sets differing only in metric values into a single WMS Layer with an ELEVATION dimension. This will avoid multiple independent layers related by a common coordinate reference system (CRS).

Req. 34 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute UNITS and assign it a CRS identifier specifying the vertical CRS. Elevation metric values SHALL be expressed in units of the CRS.

Req. 35 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute UNITSYMBOL and SHALL assign it the string representation of the symbol for the units.

Req. 36 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document at least one metric value for elevation.

Req. 37 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document metric values {Zi} of zero vertical thickness either as a list (Z0, Z1,… , ZN) and/or range (Z0/Z1/ΔZ) in accordance with WMS 1.3, Table C.2.

Req. 38 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute DEFAULT and SHALL assign it the metric value that will be sent if the GetMap request does not specify an elevation.

Rec. Conformant WMS servers offering any data which has a vertical dependency which can be referenced to metric values SHOULD sort lists of elevation metric values in order from nearest the surface of the Earth (or ocean) to farthest from the surface. In other words, lower elevations should come before higher elevations, and shallower depths should come before deeper depths.

Rec. Conformant WMS clients SHOULD issue GetMap requests specifying a WMS Layer which has been declared in the Capabilities document as having an ELEVATION dimension only with the request including a metric value declared in the Capabilities document. Where the metric value declared in the Capabilities document represents a layer of non-zero vertical thickness, the GetMap requests SHOULD specify ELEVATION using the pairs of values exactly as stated in the list of available elevations.

6.2.3 ELEVATION axis using named values

WMS servers may wish to offer data which have a vertical dependency which can be referenced to named values, in which case the following requirements apply:

Req. 39 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document specifying ELEVATION values using named values the attribute `verticalCRSid` and SHALL assign it the value `computed_surface`.

Rec.

Req. 40 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute UNITS and SHALL assign the value of the null string, `UNITS=""`.

Req. 41 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute and SHALL assign the value of the null string, `UNITSYMBOL=""`.

Req. 42 Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute `DEFAULT` and SHALL assign it the named value that will be sent if the GetMap request does not specify an elevation.

6.2.4 ELEVATION axis using named ranges

WMS servers may wish to offer data which have a vertical dependency related to a vertical range, that is that have a non-zero vertical thickness vertical dependency, in which case the following requirements apply:

Req. 43 Conformant WMS servers SHALL offer data with a vertical dependence based on a non-zero vertical thickness using an ELEVATION dimension specified using named values, where the values are constructed from the numeric values of the upper and lower surface of the elevation thickness in the vertical CRS specified in the `units` attribute of the `Dimension` element of the Layer.

Conformant WMS servers SHALL construct the name of each non-zero thickness ELEVATION value by concatenating a pair of values $\{Z_i,Z_j\}$, which specify the lower and upper numeric values of the non-zero thickness elevation in the vertical CRS specified in the `units` attribute of the dimension, with the fixed separator - (ASCII hyhen-minus), that is Z_i-Z_j.

Conformant WMS servers SHALL declare the list of available ELEVATION values for a non-zero vertical thickness elevation as a comma separated list of names, that is Z_0-Z_1,Z_2-Z_3,Z_4-Z_5,Z_6-Z_7,Z_8-Z_9,Z_{10}-Z_{11}.

Req. ? Conformant WMS servers SHALL declare in each ELEVATION dimension of the Capabilities document the attribute UNITS and assign it a CRS identifier specifying the vertical CRS. Elevation metric values SHALL be expressed in units of the CRS.

6.2.5 Metric and Named Values

WMS servers may wish to offer data which have vertical dependencies that can be referenced to metric and named values, in which case the following requirements apply:

Req. 44 Conformant WMS servers SHALL NOT declare in the Capabilities document a WMS Layer with an ELEVATION dimension that includes both metric and named values.

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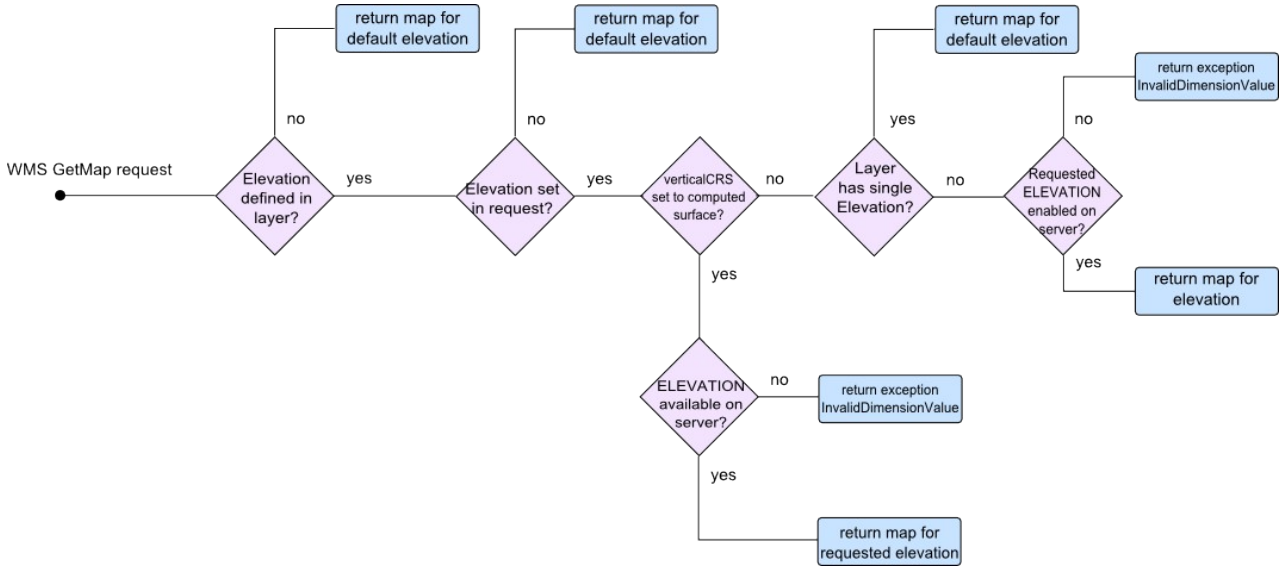

Figure 4: Decision Tree for Elevation in GetMap request.

Annex A: Revision history

Date	Release	Author	Paragraph modified	Description
2012-07-10	0.1.0	CTL	All	First introductory text
2012-07-11	0.2.0	CTL	Annexes added	Added agreed content from presentations
2012-07-25	0.2.1	JdLB		
2012-07-25	0.3.0	SS		
2012-07-26	0.3.1	RL		
2012-07-27	0.3.2	JS		
2012-07-30	0.3.3	CTL	All	Editorial changes agreed by telecon
2012-07-31	0.3.4	CTL, MM	All and Clause 7	Accepted changes: should to must
2012-07-31	0.3.4.1	RL	1, 1.1.x, 7.1.x	Clause 1 – grammatical edits; corrected numbering in 1.1.x; clause 7 edits in accord with clause 6 conventions; added content to 7.1.2 per July 2 telecon discussion.
2012-08-06	0.3.4.2	RL	1.x-7.1.x, 7.2.1	1.x-7.1.x – accepted changes and provided edits based on 6 August telecon, added validity time. 7.2.1 – rephrased last sentence.
2012-08-13	0.3.4.3	CTL	1, 3, 4,	Accept changes, deleted some comments inserted text as discussed
2012-08-14	0.3.4.3	RL	7.1.2, 7.1.3, 7.2.4, 1.2.4	Inserted text and flow charts as discussed.
2012-8-27	0.3.4.4	RL	7.1.2, 7.1.3, 7.2.1, 7.2.5	Edits per today's telecon.
2012-9-4	0.3.5	RL	Various	Edits per today's telecon.
2012-9-11	0.3.5.1	RL	Various	Edits per today's telecon.
2012-9-19	0.3.5.2	JdLB, RL, CL		Edits per today's telecon. Final OGC format/terminology
2012-9-19	0.4.0	CL	Title	Final draft, pages numbers, headers, footers, etc
2013-01-22	0.5.0	AVC	All except preamble, 2, 3, and 7.2	Editorial revision and integration of all the Change Requests in the *Synthesis...* document related to temporality.
2013-02-18	0.6.0	RL MFV	7.2 and followings	Editorial revision to enhance servers and clients behaviour in a way consistent with previous editorial changes made for time Cleaning up of changes and comments, tracking of the changes, consistency review
	0.7.0	AVC	All Document Properties All	Formalize and number Requirements Edit title, keywords Extensive explanatory text.

TEMPORARY: Injunction Review (*to be completed*)

This represents an effort to develop the requirements systematically. Requirements fall into four categories, specifying:

- how data must be mapped into WMS Layers
- how the WMS Layers must be declared in the Caps doc, <dimension> and <abstract>
- how GetMap requests must be handled
- how domain clients must issue GetMap Requests

Requirements that target how data must be mapped into WMS Layers

temporal			**elevation**		
Atemporal	**to 'validity time'**	**to reference moment**	**numeric**	**named value**	**named range**
	must use '`time`'	require the split of data with multiple referents into separate layers?	must use '`elevation`'		

Requirements that target WMS Layer declaration (i.e. `<Dimension>` or `<Abstract>` properties).

	time	**reference_time**	**elevation**		
Dimension			**numeric**	**named value**	**named range**
`name=`	`time` (Req 10)	implicit?	`elevation` (Req 26)		
`units=`	`ISO8609` (Req 4)	`ISO8609` (Req 19)	VertCRS (Req 34)	`""` (Req 40)	
`unitSymbol=`			`""` (Req 35)	`""` (Req41)	
`default=`	required (Req 13)	required (Req 21)	required (Req 37)		
`multipleValues=`	allowed (Rec before req 14)		`false` (Req 27)		
`nearestValue=`	`false` (Req 5)		`false` (Req 26)		
`current=`	required (Req 12)				
Values	list **or** range(Rec after req 4)		at lest one (Req 36) list and/or range (Req 37)		
Abstract		explain meaning of ref_t (Req 20)			

	explain default (Rec after 13)	explain default (Rec before req 23)			

Requirements that target the handling of requests.

They must consider requests with or without the parameter requesting either single layers with or without an equivalent dimension and with or without the requested value or multiple layers of the different combinations.

Requirements that enjoin the way domain specific clients issue GetMap requests.

Should they be required to offer some user interface showing the temporal or elevation steps available for each layer?

Should they be required to warn when users make a request mixing dimensions illegally (either before or when the server rejects, i.e. showing the exception)?

Requests with the TIME element

Requests with REFERENCE_TIME element

Requests with the ELEVATION element