ImageIO MetaData for Multidimensional Coverages

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Preface

This document describes how metadata for Multidimensional Coverages[1] could be encoded inside a generic J2SE ImageIO Plugin[2] in order to have a standard way for all vendors to describe their

internal raster format structure and optimize the readers indexing capabilities. This document draws its essence from various OGC specifications, like as an instance OpenGIS Geography Markup Language (GML)[3] specification, GML in JPEG2000 for Geographic Imagery[4] specification and WCS 1.1.0[5] specification.
This document is the result of GeoSolutions's analysis for the Multidimensional Coverages and of all the work on rasters made with GeoTools[6] and ImageIO[2] libraries.

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Introduction

JAI ImageIO Tools[2] provides reader, writer, and stream plug-ins for the Java Image I/O Framework and Image I/O-based read and write operations for Java Advanced Imaging. Reader-writer plug-ins are supplied for the BMP, JPEG, JPEG 2000, PNG, PNM, Raw, TIFF, and WBMP image formats, but new plug-ins can be easily implemented by extending ImageIO core classes. Specifically the ImageIO package gives the opportunity to handle data sources metadata using XML through the *javax.imageio.metadata.IIOMetadata* and *javax.imageio.metadata.IIOMetadataFormat* [7] interfaces.
The aim of this document is to investigate and define a standard way to encode all the necessary metadata for a complete and exhaustive description of Multidimensional Coverages[1] with ImageIO plug-ins metadata[7].

ImageIO MetaData for Multidimensional Coverages

1. Scope

<TODO>

2. Normative 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.

IETF RFC 2396, Uniform Resource Identifiers (URI): Generic Syntax (1998)

ISO 19105:2000, Geographic information - Conformance and Testing

OGC 03-105r1, OpenGIS Geography Markup Language (GML) Encoding Specification V3.1.1 (February 2004)

OGC 05-010, URNs of Definitions in OGC Namespace (January 2005)

OGC 05-011, Recommended XML/GML 3.1.1 Encoding of Common CRS definitions

OGC 04-046r3, OGC Abstract Specification Topic 2, Spatial referencing by coordinates (a revision of ISO 19111)

XML 1.0 (October 2000), eXtensible Markup Language (XML) 1.0 (2nd edition), World Wide Web Consortium Recommendation, Bray, T., Paoli, J., Sperberg-McQueen, C.M., and Maler, E., eds., <http://www.w3.org/TR/2000/REC-xml>

3. Terms and Definitions

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

3.1 operation

specification of a transformation or query that an object may be called to execute

3.2 interface

named set of operations that characterize the behavior of an entity

3.3 service

distinct part of the functionality that is provided by an entity through interfaces

3.4 server

actual implementation of a service

3.5 client

software component that can invoke an operation from a server

3.6 request

invocation of an operation by a client

3.7 response

result of an operation returned from a server to a client

3.8 map

pictorial representation of geographic data.

3.9 capabilities

service-level metadata describing the operations and content available at a service instance.

3.10 process

model or calculation that is made available at a service instance.

3.11 input

data provided to a process.

3.12 output

result returned by a process.

4. Conventions

4.1 Abbreviated terms

EPSG	European Petroleum Survey Group
GML	Geography Markup Language
IETF	Internet Engineering Task Force
JPEG	Joint Photographic Experts Group
OGC	Open Geospatial Consortium
OWS	OGC Web Service
RFC	Request for Comments
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
XML	Extensible Markup Language

4.2 Document terms and definitions

The following specification terms and definitions are used in this document:

1. shall - verb form used to indicate a requirement to be strictly followed to conform to this specification, 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 specification.
4. can - verb form used for statements of possibility.
5. informative - a part of a document that is provided for explanation, but is not required.

6. normative - a part of a standards document that is required.
7. annex - an auxiliary part of a document, called an “appendix” in United States English.
8. clause - a major part of a document, called a “section” or “paragraph” in United States English.
9. subclause - a secondary part of a clause or annex, called a “subsection” in United States English.

5. ImageIO MetaData for Multidimensional Coverages overview

The Java ImageIO[2] package provides the capability to handle arbitrary raster metadata using XML through the javax.imageio.metadata.IIOMetadataFormat and javax.imageio.metadata.IIOMetadata [7] interfaces which together build a simplified XML API tuned for Image I/O needs.

The ImageIO package distinguishes between the concept of stream metadata, which is used to report information about the whole dataset we are referring to, and the concept of image metadata, which is used to report information about a single raster. A dataset can contain an arbitrary amount of rasters (however, note that not all image formats have this capability).

Figure 1 shows the structure of a Multidimensional Coverage composed up by 2D raster layers.

In Figure 2 two types of ImageIO readers are shown. The first one, labeled Direct, has no concept of time and space, it simply wraps 2D raster data as RenderedImages [2]. The second one, labeled Spatiotemporal while still able to produce RenderedImages, aims to provide a wide set of spatio-temporal information in the form of specific IIOMetadata which we will describe later in this document, in order to be able to create higher level structure which would collect together many RenderedImages, we would call this 5D Coverages.

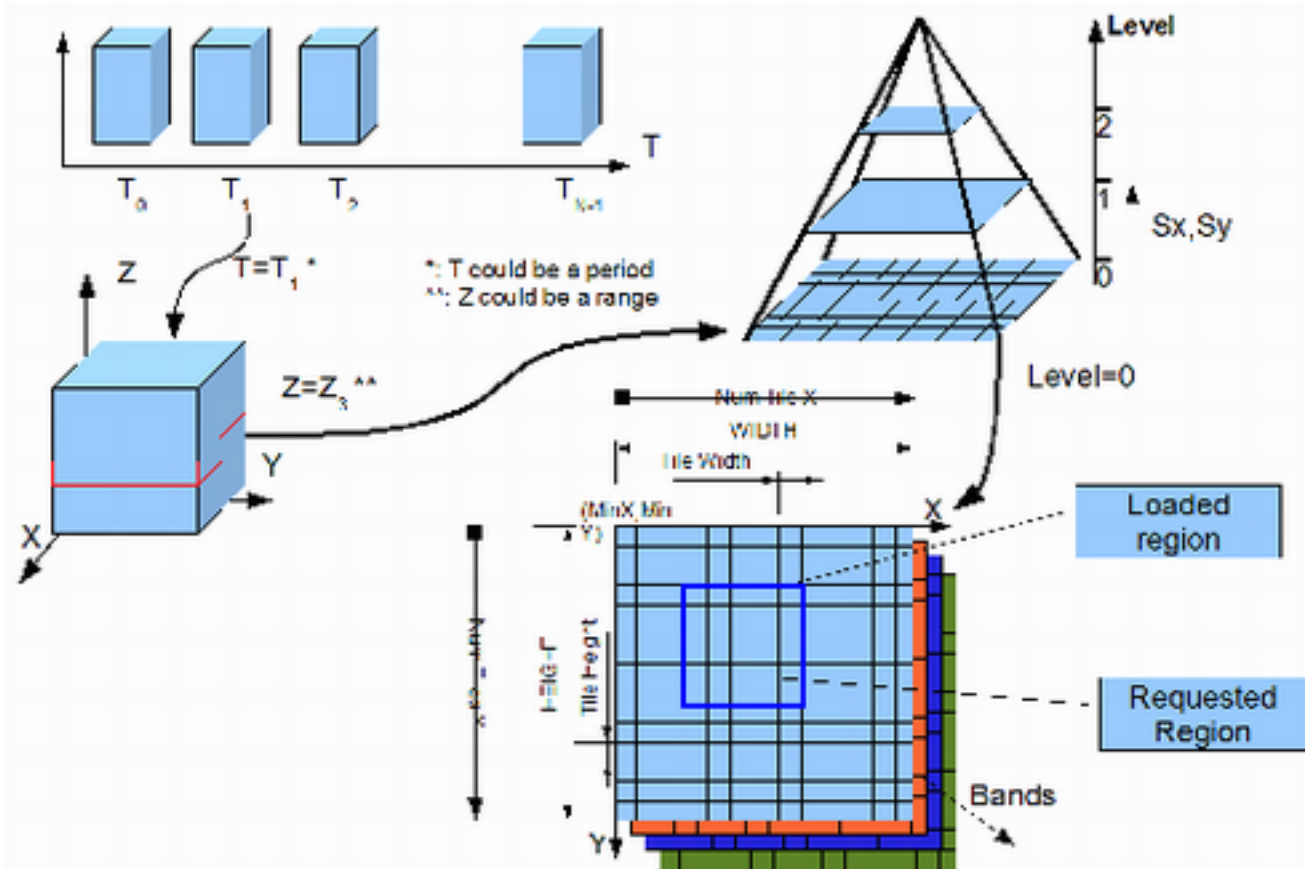

Figure 1: Multidimensional Coverage

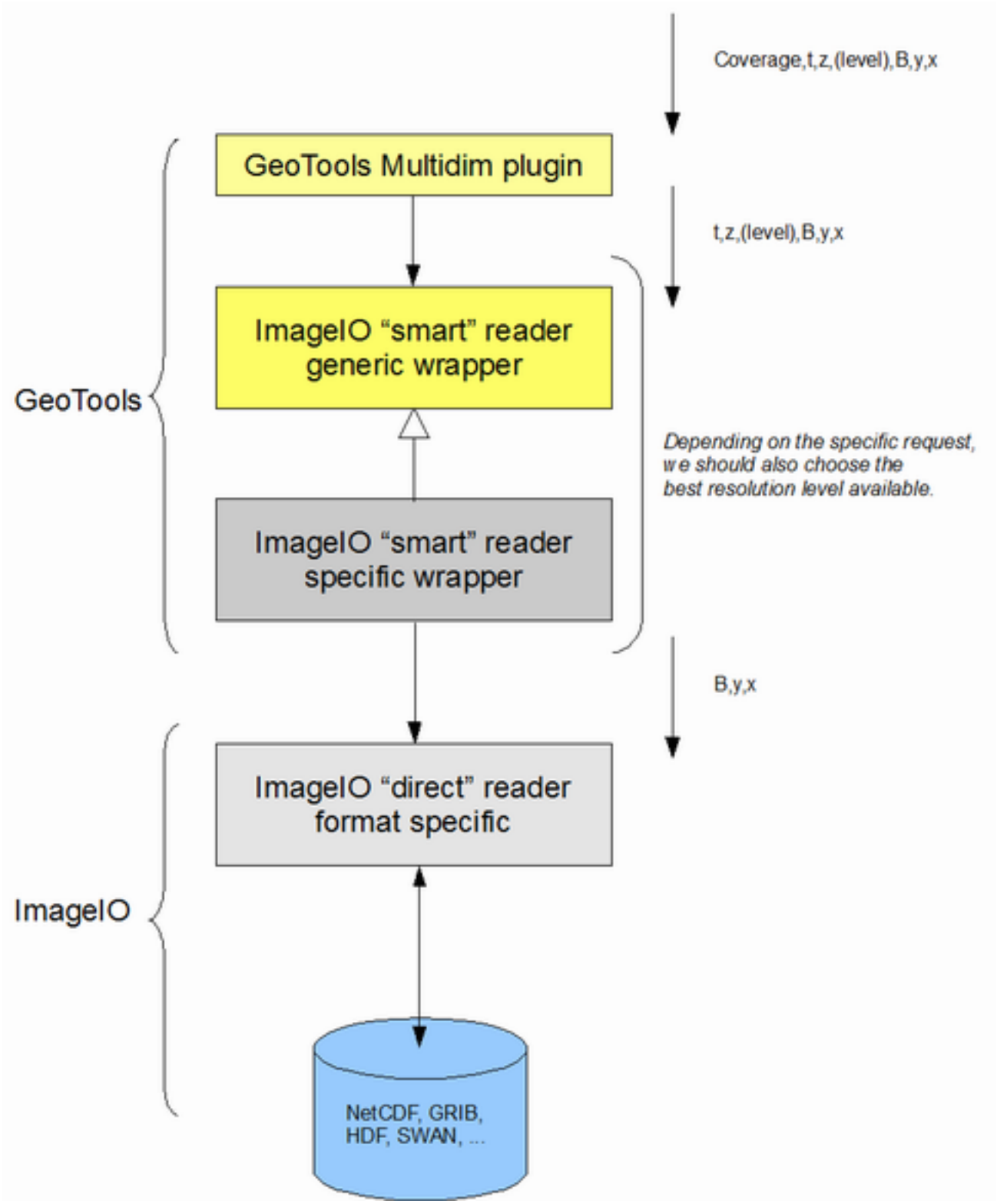

Figure 2: Multidimensional Plugin Requests

At the GeoTools coverage plug-in level an user may ask for one or more coverages, specifying a certain number of desired bands, time positions and/or time intervals, elevations, a two dimensional bounding box and an optional extent in pixels as well as an optional desired resolution level. For each

requested coverage, the GeoTools plug-in handles the parameters (Time,Z, (Level), Band,Y,X) in order to find the proper set of image indexes to be used by the underlying ImageIO levels to perform the necessary image read operations. Note that spatio-temporal metadata allow to retrieve the proper image index since each metadata instance describes the spatio-temporal domain of a 2D raster.
The ImageIO "spatio-temporal" reader allows to build the spatio-temporal metadata for each raster contained in the source.

6. ImageIO MetaData Schema

In this section we will define the XML schema to be used when creating new ImageIO plug-ins *SpatioTemporalMetadata.* We will provide also a description of the single metadata elements along with their meanings.

6.1 ImageIO MetaData constraints

There are some rules to respect when designing the ImageIO metadata structure which are a restriction of the ones present in DTD and XML schema.
These rules are as follows:

- Metadata elements may not contain text or mix text with embedded tags (i.e. Java objects are allowed, but not mandatory).
- The children of a metadata element must conform to one of a few simple patterns, described in the documentation for the CHILD_* constants:
    - **CHILD_POLICY_ALL** A constant returned by getChildPolicy to indicate that an element must have a single instance of each of its legal child elements, in order.
    - **CHILD_POLICY_CHOICE** A constant returned by getChildPolicy to indicate that an element must have zero or one children, selected from among its legal child elements.
    - **CHILD_POLICY_EMPTY** A constant returned by getChildPolicy to indicate that an element may not have any children.
    - **CHILD_POLICY_REPEAT** A constant returned by getChildPolicy to indicate that an element must have zero or more instances of its unique legal child element.
    - **CHILD_POLICY_SEQUENCE** A constant returned by getChildPolicy to indicate that an element must have a sequence of instances of any of its legal child elements.
    - **CHILD_POLICY_SOME** A constant returned by getChildPolicy to indicate that an element must have zero or one instance of each of its legal child elements, in order.
- The in-memory representation of an elements may contain a reference to an Object. There is no provision for representing such objects textually.
- Namespaces are not supported (big limitation).

For our purposes we will try to respect as much as possible these rules, but we might need to violate some of them to produce a useful metadata structure. It is worth to point out that ImageIO would not complain about violating the latter rules.
We need to introduce these few rules to respect our specific needs:

- We will drop "gml" prefix in order to respect the *IIOMetadataNode* constraint for namespaces.
- We will always group repeated elements together under a single node as for *IIOMetadataFormat* requirements.
- We will try to simplify the XML three as much as possible in order to have a simpler document structure, even if sometimes this may introduce a discrepancy with the OGC standards.

6.2 SpatioTemporalMetadata

This metadata set will provide information about the spatio-temporal domain as well as the codomain of a 2D raster which can be therefore used at an higher level to build multidimensional coverage. It provides information about raster geometry as well as the raster spatio-temporal positioning. Band descriptions will contain useful information about the raster bands, such as no-data values,

range of validity, categories (if present) by which the values are grouped by, as well as other useful information like, as an instance, statistical information.
NOTE: several nodes contain a set of 4 common attributes: *name*, *remark*, *alias* and *identifier* referring to a specific element node. Anyway, in the next TAG table, a description will be provided only for the CoordinateReferenceSystem element in order to avoid redundancy. The **optional/mandatory** rules for these attributes are the same for each element having those attributes. Finally, it is worth to point out that *alias* and *identifier* attributes may contain multiple space-separated values.
Figure 3 represents the schema
structure.

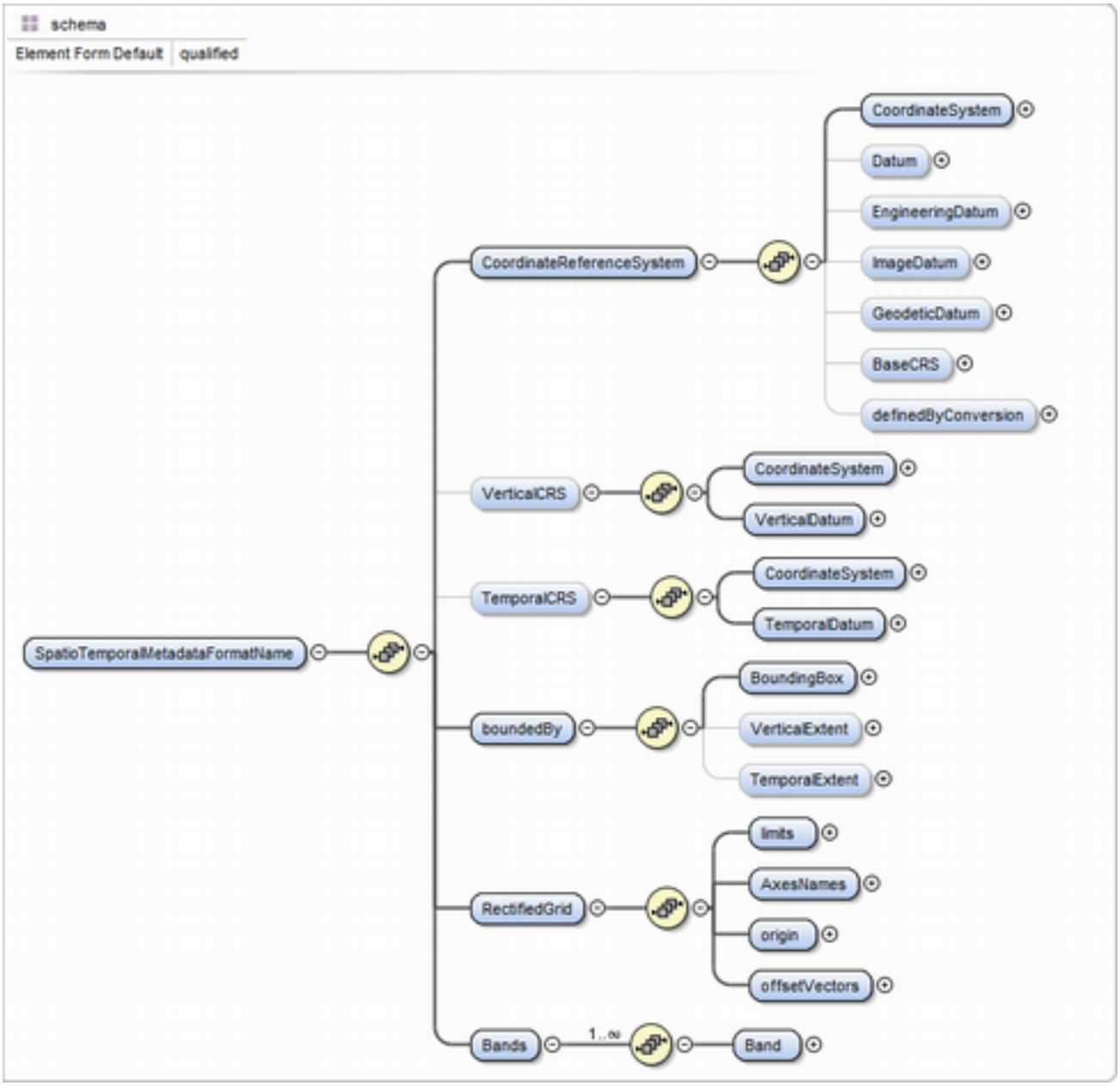

Figure 3: SpatioTemporalMetadata Schema

Tag Name	Tag Description
SpatioTemporalMetadataFormatName	Root node of the spatiotemporal metadata set.
CoordinateReferenceSystem	The CRS describes the 2Dspatial/Geographic3D Coordinate Reference System of the slice. It can be represented as a set of metadata compliant with ISO 19111[8]. (see details on Figure 4). It has an optional *WKT* attribute containing CRS definition expressed in WKT plus 4 main attributes:
name	Mandatory attribute describing the CRS name
alias	Optional attribute with unbounded multiplicity describing CRS aliases
identifier	Optional element with unbounded multiplicity describing CRS identifiers
remarks	Optional element reporting eventually notes or remarks
CoordinateSystem	Mandatory complex element describing the CRS Coordinate System; similarly to the CRS node, the CS is identified by a set of 4 attributes: *name, alias, identifier* and *remarks.* Moreover it contains a set of Axes, each one with its own range, unit of measure and direction and additional attributes. (see details on Figure 4)
*Datum	An optional element describing the CRS **Datum**; depending on CRS type we can have different kind of Datums (the "*" specifies the datum prefix). All Datums are identified by a set of 4 attributes: *name, alias, identifier* and *remarks*, plus several mandatory attributes related to the specific type of Datum. Usually the mandatory attribute *anchorPoint* specifies the Datum origin. Please note that the **Geodetic Datum** needs at least an **Ellipsoid** and the **Prime Meridian** description in order to be fully described. (see details about GeodeticDatum and its attributes, on Figure 5).
BaseCRS	This optional elements should be defined when the CoordinateReferenceSystem is a DerivedCRS/ProjectedCRS which is a CRS defined by a standard simple CRS used as Base plus a set of operations and parameters needed to defined the conversion. (see details on Figure 6). It needs to specify the *Datum on which this BaseCRS is referred. (As an instance, a GeodeticDatum).

definedByConversion	As stated in the previous table row, this optional node should be defined when the CoordinateReferenceSystem is a DerivedCRS/ProjectedCRS in order to define the operation properties/information to handle the derived/projected CRS. It contains the usual attributes *name*, *identifier*, *remarks*, *alias* plus several specific attributes as defined in [8]: *formula* (optional) defining the formula to be used with the provided parameters. *sourceDimensions* (optional) defining the number of dimensions in the source CRS of this operation method. *targetDimensons* (optional) defining the number of dimensions in the target CRS of this operation method.
parameters	A simple node to contain several parameters involved in the operation.
parameter	A node defining a parameter. It contains the usual attributes: *name*, *identifier*, *remarks*, *alias* plus the *value* attribute storing the parameter value.
VerticalCRS	A node to give easy access to the eventually Vertical CRS definition. In the case of the Vertical CRS, a Vertical Datum need to be defined in the metadata set.
TemporalCRS	A node to give easy access to the eventually Temporal CRS definition. In the case of the Temporal CRS, a Temporal Datum need to be defined in the metadata set. It is worth pointing out out that the **Temporal Datum** substitutes the *anchorPoint* attribute with *origin*, representing its base time position.
boundedBy	A node identifying the extent of the related 2D slice into a spatial/temporal context. (see details on Figure 7).
BoundingBox	The 2D envelope of the underlying 2D slice. It has 2 attributes, *lowerCorner* and *upperCorner*
VerticalExtent	The vertical extent validity of the underlying 2D slice referred to the previously specified VerticalCRS. It may be defined by one of **singleValue** / **verticalRange** nodes.
singleValue	A single vertical position specified by the *value* attribute which could be a symbolic value (such as "*sea surface level*") as well as a numeric value.
verticalRange	An extended vertical range identified by the *minimum* and *maximum* attributes.
TemporalExtent	The temporal extent validity of the underlying 2D slice. It may be specified as a time period or a single time instant as defined by one of **timePosition** / **timePeriod** nodes.
timePosition	A single time position specified by the *value* attribute.
timePeriod	An extended time period identified by the *beginPosition* and *endPosition* attributes.
RectifiedGrid	A node describing the RectifiedGrid. The attribute *dimension* defines the dimension of the grid. See details on Figure 8.
limits	The main node to define the extent of the RectifiedGrid.

RasterLayout	The RasterLayout extent specified by attributes *low* and *high.*
origin	The main node to define the origin of the RectifiedGrid as specified in [4].
Point	A node identifying the Grid origin point.
coordinates	The element containing the coordinates of the grid origin. Its *value* attribute contains space delimited coordinates values.
AxesNames	Although this name is not part of [4], this node has been introduced only to group repeated **axisName** nodes together under a single node.
axisName	A single node containing the name of the related Axis, specified by the attribute *value*
OffsetVectors	A node grouping the offset vectors identified by an **offsetVector** node.
Bands	A node collecting band information. See Figure 7 for further details.
Band	A node describing a band. The *name* attribute simply contains the name of this band. The *validRange* contains the min and max (space separated) values of the band. The *noDataValues* attribute contains a space separated list of values identifying noData. *scale* and *offset* attributes contains factors for data encoding. Finally, the optional *uom* attribute contains the unit of measure.
categories	An optional node containing categories definition for this sample dimension. Each category is defined by a **category** child node.
category	A single category defined by means of its attributes: *name*, *description* and *range*.
Statistics	An optional node containing statistical information such as mean, mode and standard deviation, which values are contained in the related attributes (*name*, *mode*, *standardDeviation*). Statistical information also contains Histogram info by means of the **Histogram** node.
Histogram	A node containing histogram statistics. The *bins* attribute contains the number of histogram bins, while the *values* attribute contains the space separated list of histogram bins.

Table 1: SpatioTemporalMetadata structure

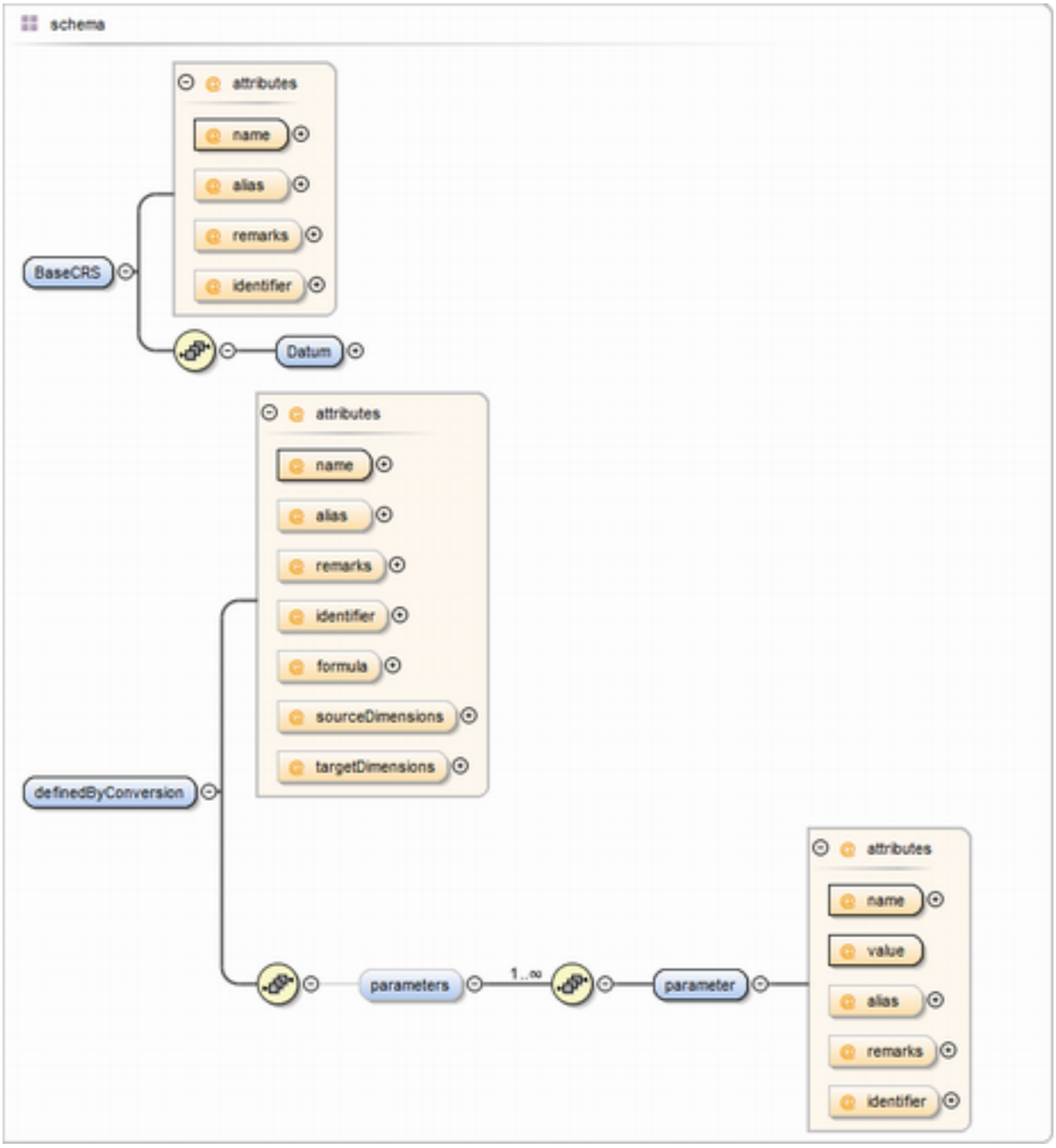

Figure 4: BaseCRS + definedByConversion details

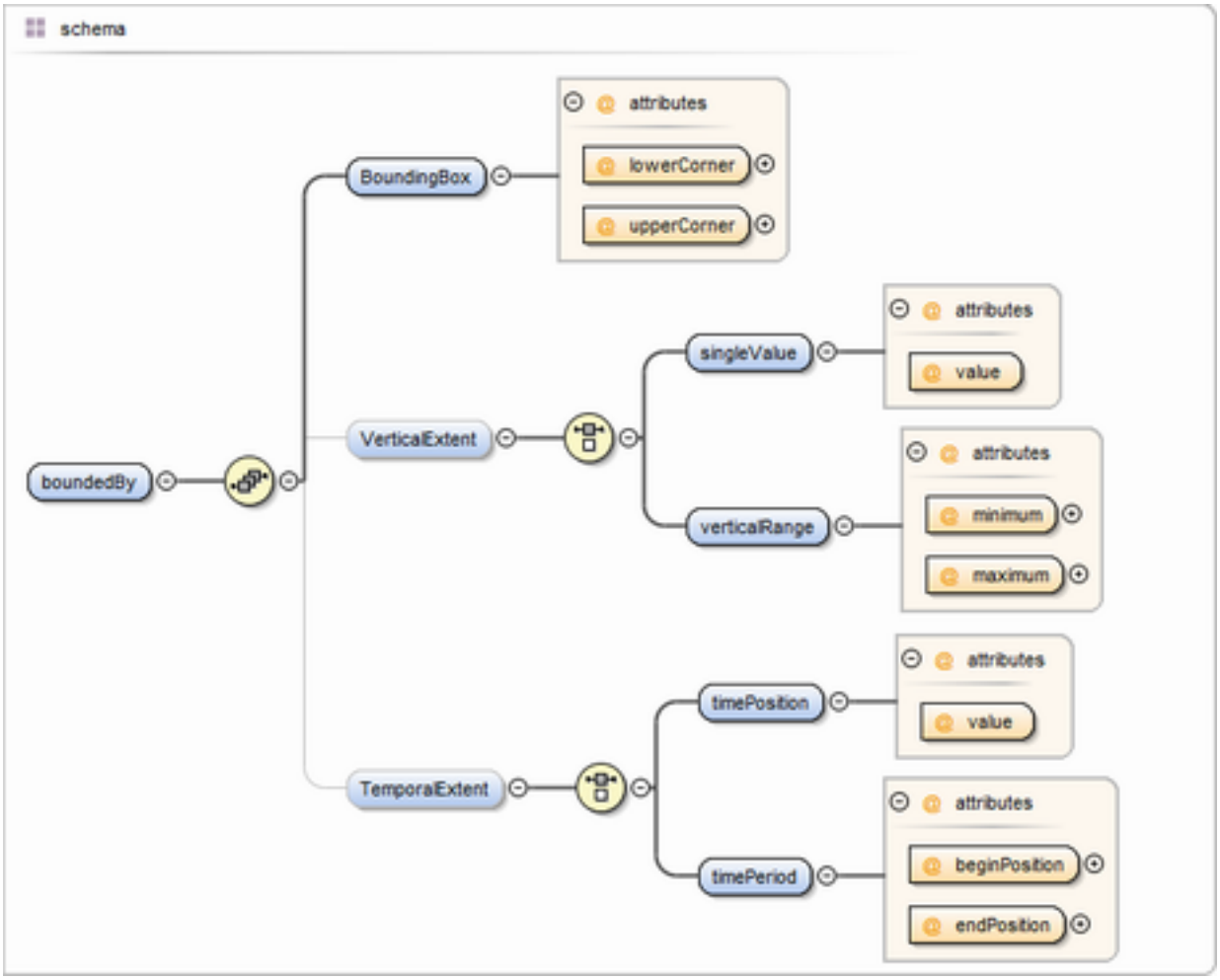

Figure 5: boundedBy details

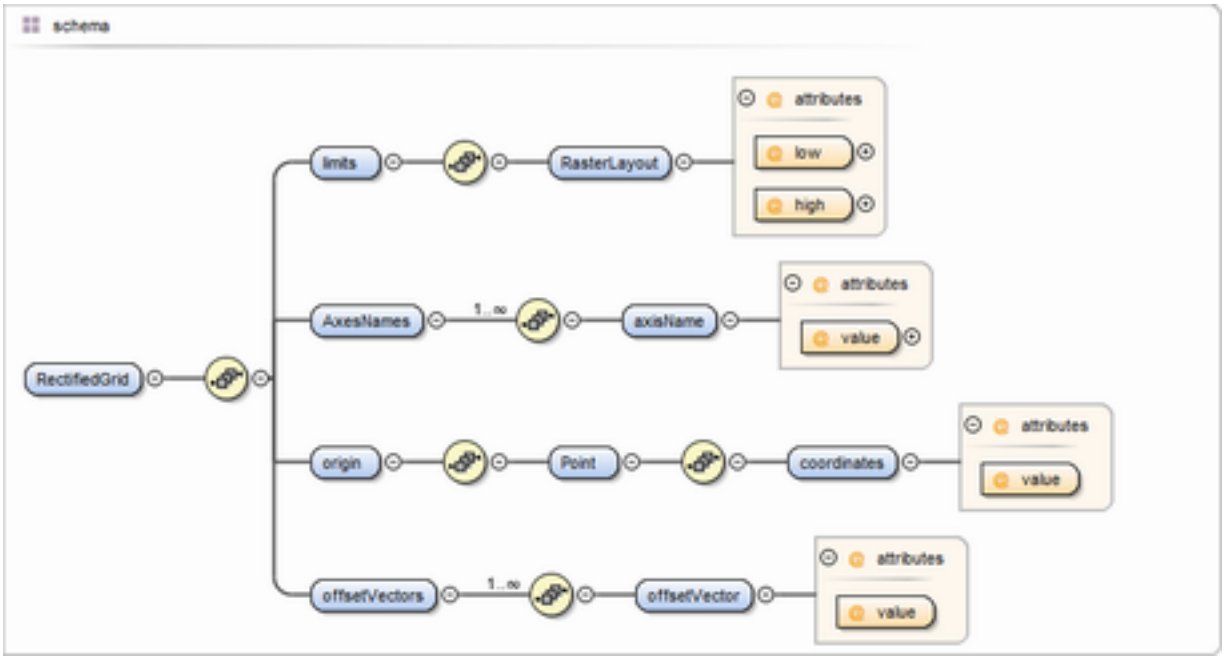

Figure 6: RectifiedGrid details

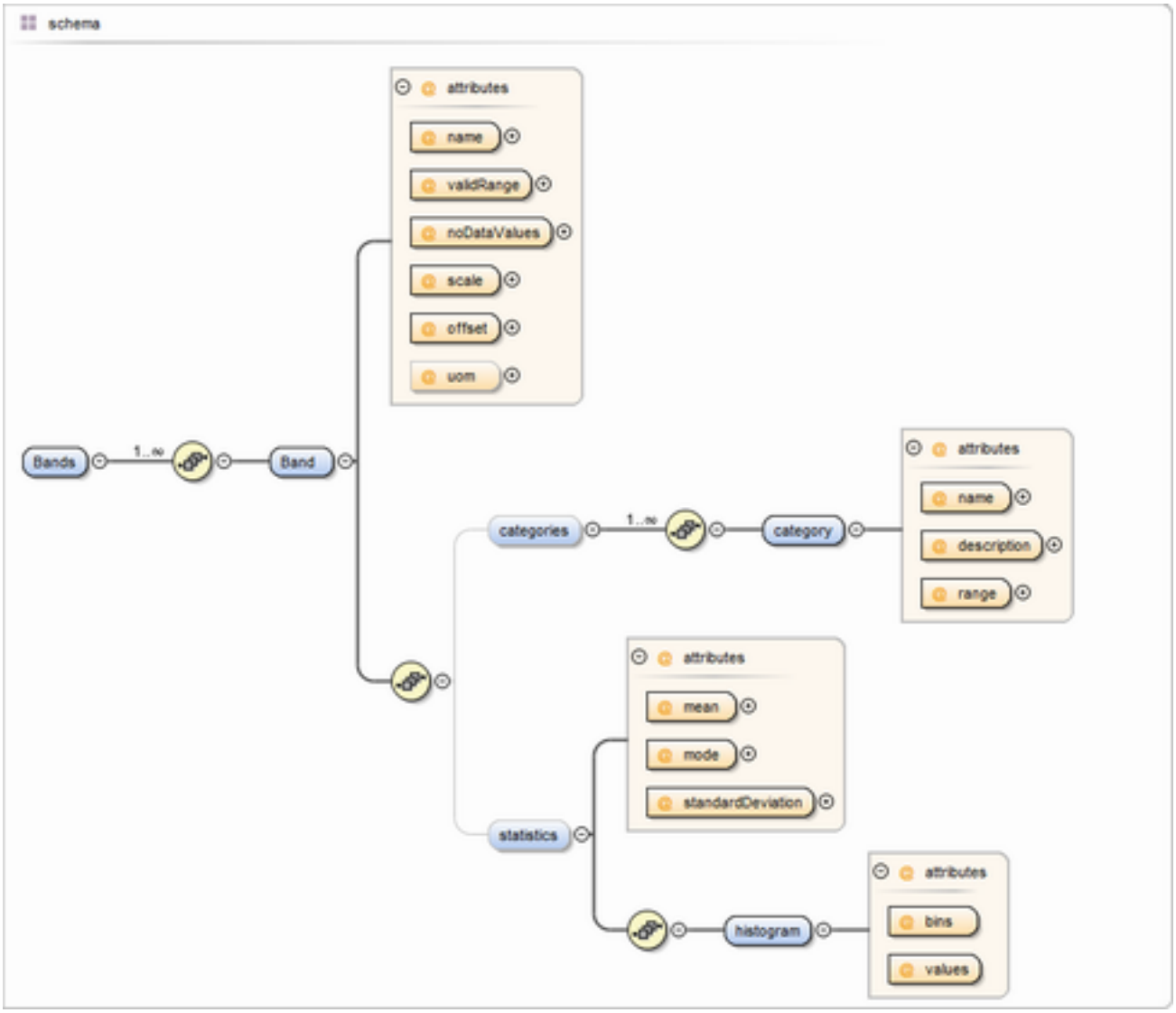

Figure 7: Bands details

Future Improvement

Future version of metadata could contain a single CoordinateReferenceSystem element in the form of a CompoundCRS in order to collect TemporalCRS/VerticalCRS/ GeographicCRS(ProjectedCRS) within a single entity.

In compliance with this assumption, the boundedBy node could be refactored in order to contain a single ND "Envelope" node storing the spatio/temporal domain all in one.

In such a context, note that WCS and WMS handle time using ISO8601 Formatted Strings hence a method to convert numeric times to ISO8601 values should be provided. Moreover WMS 1.1.1 handle elevation as a dimension relying on a VerticalCRS by exposing in the getCapabilities XML response a Vertical_datum value identifying the EPSG code of the adopted vertical_datum. Working on an implicit Geographic3D CRS would requires to convert it into a Geographic2D + Vertical. See more details in the Summary Annex.

Finally, SampleDimension could be handled within the GML RangeSet element.

Annex A – Summary on specifications involving multidimensional data.

WMS 1.1.1 – (OGC 01-068r3)

This specification, relying on Web Map Services, allows elevation management by defining, inside a capabilities XML response, a Dimension element having attribute “name” equal to “elevation” and an EPSG:Vertical_datum (referring to a EPSG code for vertical datums) as value of the “units” attribute of the Dimension. Moreover, the capabilities XML response uses Extent elements to specify the bounds of a geodata object defining the “value” attribute in the form of one of:

- single value
- comma separated multiple values
- slash separated elements defining an interval described by lowerbound/upperbound/resolution.

When defining the Extent element, its attribute “name” shall match the Dimension's name previously introduced.
When querying for a map using GetMap requests, it is possible to specify an ELEVATION=value parameter, where the value should be specified following the same rules defining the Extent's “value” attribute (single value Or multiple values Or interval).

Additionally, in case of multiple times availability, the capabilities XML response needs to specify a “Time” Dimension in the layer. This occurs by specifying a Dimension having “name” = “time” and “units”=ISO8601 followed by an Extent element having the same name of the dimension, containing the values of the time extent in the form of a single value, a comma separated list of values or a beginTime/endTime/resolution in ISO8601 format, as expressed in Annex B.
The capabilities XML response should contain a Default value for the Time dimension.
Finally, when querying for a map using GetMap requests, it is possible to specify a TIME=value parameter following the same rules adopted to define the extent element.
Optionally, “time” extent may contain a boolean “current” attribute which indicates that temporal data are normally kept current and that the request parameter TIME may include the keyword 'current'.

WMS 1.3.0 – (OGC 06-042)

This specification states that when geographic information are available at multiple elevations, the WMS may announce them in its service metadata. A single elevation or depth value is a number whose units, and the direction in which ordinates increment, are declared through a vertical CRS.
In order to support multidimensional data, WMS 1.3 service metadata and operation requests use the Dimension element. For elevations management, a predefined Dimension with name “elevation” is available having a “units” attribute containing a “verticalCRSid” referring to a verticalCRS. Two type of VerticalCRS identifiers are permitted: “label” and “URI”.

- **Label** includes a namespace prefix, a colon and a numeric string or code. If the namespace prefix is “EPSG”, then the vertical CRS is one of those defined in the EPSG database.

- **URL** is a fully qualified URL that references a publicly-accessible file containing a definition of the CRS that is compliant with ISO 19111.

Note that in case the height is the vertical component of a 3D CRS, the vertical CRS identifier shall be the one of the 3D Dimensional CRS.

A GetMap request may specify an optional parameter to request a specific elevation. Note that a request for a map at a specific elevation includes an "elevation" value but does not include the VerticalCRS identifier. In such a context, querying for a map using the GetMap follows the same rules defined before in WMS 1.1.1 section.

In case of geographic information available at multiple times the WMS may announce available times in its service metadata, and the GetMap operation includes a parameter for requesting a particular time. This is handled by a predefined Dimension element with name "time" and "units" attribute as "ISO8601"
Finally, time may be requested using the "time" parameter containing a single value, a comma-separated list, or an interval of the form start/end without a resolution expressed in the form of ISO8601 format (See Annex D). Note that an interval in a request value is a request for all the data from the start value up to and including the end value.
This specification handles the "current" attribute (see C.3.2).

WCS 1.0 – (OGC 03-065r6)

This specification doesn't provide any specific information about how to handle ND data involving elevations settings. When interfacing with a WCS, a client may issue a DescribeCoverage request in order to get information about a specific coverage. After that request, a WCS should return a CoverageDescription containing CoverageOffering elements (one for each coverage to be described). CoverageOffering extends a CoverageOfferingBrief element which contains a lotLanEnvelope element defining a bounding box that encloses all of the data available through the coverage offering, expressed as the corners of the BB by means of a pair of GML "pos" elements, in the WGS 84 geographic CRS with longitude preceding latitude and both using decimal degrees only. If included, height values are a third GML pos using metre units. Moreover a CoverageOffering element contains a domainSet element specifying the domain of the coverage offering in terms of locations in the space for which measure of coverage are available. Mainly the domainSet element contains a spatialDomain object specifying the spatial extent of the coverage by means of one or more gml Envelope elements (each one describing a bounding box element via 2 gml Pos elements). Moreover, a spatialDomain object may contain a Grid or a GeorectifiedGrid element to describe the internal grid structure of a coverage offering. The gml EnvelopeWithTimePeriod may be used to add the time bounds of the coverage offering.
Finally the domainSet may contain a temporalDomain element which describes the valid time constraints for the GetCoverage requests. It is composed of a set of GML TimePosition elements or a TimePeriod element composed of 2 GML TimePosition elements, identifying the beginPosition/ endPosition, plus an optional timeResolution element.

When requesting a coverage, a GetCoverage requests may specify a 3D spatial constraint expressed as a parallelepiped (using a BBOX parameter) aligned with the axes of the coordinate reference system given in the CRS parameter. Moreover the GetCoverage may request coverage replies with a custom grid size specified using parameters WIDTH, HEIGHT, DEPTH (integer values) or a grid resolution using RESX, RESY, RESZ (double values). The third parameter of these 2 sets allows to

specify the requested values along the third axis in case the response CRS is a 3D CRS. Note that the value related to the 3rd dimension should be only specified as a number (integer for grid size, double for grid resolution).

Finally, a TIME parameter in the GetCoverage request allows to specify a subset corresponding to the specified time instants (comma separated values) or intervals (min/max/resolution), expressed in an extended ISO 8601 syntax (See Annex D of [OGC 06-042]).

WCS 1.1.1 – (OGC 07-067r2)

Similarly to WCS 1.0, a CoverageDescription element returned by a DescribeCoverage request, should specify the spatial domain of the coverage offering, by setting a proper mandatory SpatialDomain object within a Domain element of the returned CoverageDescription. The main element of a SpatialDomain object is BoundingBox specifying the lower and the upper corners of the spatial extent of this coverage. Moreover, in case the coverage is georectified, the SpatialDomain element may also contain a GridCRS element described in Annex G of this specification.
Domain element contains also Time definition specified by means of a TemporalDomain element composed of a TimeSequence identifying one or more TimePositionOrInterval identifying an ordered sequence of time position or intervals defined by a TM_Position element or a TimePeriod element. TM_Position is defined in ISO19108 while a TimePeriod is defined by a beginTime/endTime couple (instances of TM_Position) plus an optional TM_PeriodDuration identifying the time resolution as the spacing between valid times within the period. Finally an optional frame element represents an URI identifying a TemporalReferenceSystem (by Default: #ISO-8601).

When requesting for a coverage via GetCoverage, the user needs to define a DomainSubset elements mainly specifying a spatial subset of the desired coverage using a BoundingBox element as well as an optional GridCRS element and an optional timeSequence element identifying the temporalSubset expressed as a comma separated value list of times expressed in the extended ISO 8601 format.

WCS operation requests and responses include references to a specific CRS where each referenced CRS shall be defined somewhere. GML 3.1.1 common CRSs profiles is a document containing XML encoding which may be used in WCS to cover GeographicCRS, ProjectedCRS, VerticalCRS and CompoundCRS definitions (But not TemporalCRS).

GML 3.1.1 Common CRSs profiles – (OGC 05-095r1)

This specification provides the definition for a VerticalCRS XML element needed to encode Vertical Coordinate Reference Systems. The skeleton of the related XML document is:

```
<VerticalCRS>
    <usesVerticalCS>
         <VerticalCS>
             <usesAxis>
                 <CoordinateSystemAxis></CoordinateSystemAxis>
             </usesAxis>
         </VerticalCS>
     </usesVerticalCS>
     <usesVerticalDatum>
     <VerticalDatum></VerticalDatum>
     </usesVerticalDatum>
```

```
</VerticalCRS>
```

Moreover, the specification provides the definition for a CompoundCRS XML element needed to encode compound Coordinate Reference Systems. The skeleton of the related XML document is:

```
<CompoundCRS>
     <includesCRS>
         <ProjectedCRS></ProjectedCRS> or <GeographicCRS></GeographicCRS>
     </includesCRS>
     <includesCRS>
         <VerticalCRS></VerticalCRS>
     </includesCRS>
</CompoundCRS
```

Definitions of the CRS elements represented by the XML components of these skeletons are available in ISO 19111 which is briefly introduced in the next chapter.

ISO 19111 – (OGC 04-046r3)

This specification relies on Coordinate Reference Systems. In the context of this analysis we report some concepts and definitions related to Vertical CRSs which are used for recording of heights or depths. In ISO19111 a Vertical CRS is defined through a SC_VerticalCRS class which is associated to a CS_VerticalCS (coordinate system) and a CD_VerticalDatum.
CS_VerticalCS defines a one-dimensional coordinate system used to record the heights or depths of points. Such a class is associated to a CS_CoordinateSystemAxis which needs to specify the axisAbbreviation, the axisDirection as well as the axisUnitID.
On the other side, a CD_VerticalDatum provides a textual description and/or a set of parameters identifying a particular reference level surface used as a zero-height or zero-depth surface. It contains a mandatory "vertDatumType" attribute of type CD_VerticalDatumType defining the vertical datum type. It is worth to point out that the vertical datum type allows to use an "otherSurface" value which may be used to identify special vertical CRS having datums which aren't geoidal, depth related or barometric related.

ISO 19123 – (ISO/FDIS 19123:2004(E))

This specification doesn't contain any explicit reference to Vertical or 3D CRSs. It simply defines a domainExtent attribute identifying the extent of the domain of a coverage in terms of EX_Extent element defined in ISO 19115 as will be introduced in the next section.

ISO 19115 + corrigendum

This specification covers Metadata related to geographic information. In the context of our analysis, it provides an "Extent information" package to describe the spatial and the temporal extent of the entities referred by the metadata by means of an EX_Extent metadata element. This element allows to specify information about the geographic, temporal and vertical extent of the referred entity by means of EX_GeographicExtent, EX_TemporalExtent and EX_VerticalExtent respectively.
EX_GeographicBoundingBox is the typical subclass of EX_GeographicExtent which needs to be used to specify the geographic bounding box. Its attributes are westBoundLongitude, eastBoundLongitude, southBoundLatitude and northBoundLatitude. As you may immediately

notice, the EX_GeographicBoundingBox doesn't hold any “Vertical”/”Elevation” information since this type of info needs to be provided using the EX_VerticalExtent element which is defined by minimumValue, maximumValue and unitOfMeasure attributes. For this reason, to handle a 3D CRS with this specification we needs to split the 3 components into a 2D GeographicBoundingBox plus an additional VerticalExtent. Moreover, as expressed in the 19115 Corrigendum, a VerticalExtent should be associated to a VerticalCRS wherein the 3rd component lives.

Additional information and API availability

The GeoTools project actually provides a Referencing3D module able to do the following vertical height transformation:

Geoidal height (WGS84) <----> Ellipsoidal height (WGS84)
Geoidal height (WGS80) <----> Ellipsoidal height (WGS80)

It is also worth to point out that the available GeoAPI allows to define an Ellipsoidal verticalDatumType although ISO19111 explicitly states that Ellipsoidal height shouldn't be captured within a VerticalCRS being inseparable part of the 3D components of a 3D GeographicCRS.

- 3D CRSs and Vertical Levels

Based on the analysis of the available specifications, we could transform (when it is possible) the 3rd component of a GeographicCRS to a VerticalCRS and extend the VerticalExtent interface provided in GeoAPI by adding a method getOriginalCRS linking to the original GeographicCRS from which the VerticalCRS has been obtained with the transfomation.

- Elevations involving symbolic levels (No standard VerticalCRS could be used)

When leveraging on data having a vertical level defined by a symbolic value (like, as an instance, “Base cloud level”), we may define a special VerticalCRS having a VerticalDatum with type “OtherSurface” with custom AxisAbbreviation/Direction/UnitID as well as custom UoM. Moreover, a default integer value could be related to a similar symbolic value in order to be queried through WCS by means of the Depth parameter. The underlying framework will hold such a relation “number to symbol”.

- Time management

Both WMS and WCS specification handle times using ISO8601 format.

References

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