Open Geospatial Consortium

OGC® CF-netCDF 3.0 encoding using GML Coverage Application Schema

Warning

This document is an OGC Member approved international standard. This version is informative. The normative version is available at:

http://docs.opengeospatial.org/is/14-100r2/14-100r2.html

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Contents

i.   Abstract

The OGC CF-netCDF data model supports multi-dimensional gridded data and multi-dimensional multi-point data, representing space and time-varying phenomena. In particular, this extension standard is limited to multi-point, and regular and warped grids.

This standard specifies the CF-netCDF data model encoding using the OGC GML 3.2.1 coverage application schema, as well as CF-netCDF data exchange format and protocol encoding.

This standard specifies: (a) the CF-netCDF GML encoding to be used by OGC standards; (b) the CF-netCDF data format exchanged using OGC standards; (c) the Internet protocol characteristics to effectively exchange CF-netCDF data.

As per the GML 3.3. standard, GML 3.3 imports the 3.2 schema. The canonical location of the 3.2 all components schema document for 3.3 is
http://schemas.opengis.net/gml/3.2.1/gml.xsd

ii.   Keywords

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

ogcdoc, netcdf, cf-netcf, encoding extension, multi-dimensional, gml, data format.

iii. Preface

This standard describes an extension of the CF-netCDF 3.0 data model [OGC 11-165r02].

This extension is required to encode CF-netCDF 3.0 datasets using the "OGC Implementation Schema for Coverages" specification [OGC 09-146r2] and to exchange CF-netCDF datasets.

Suggested additions, changes, and comments on this draft standard are welcome and encouraged. Such suggestions may be submitted by email message or by making suggested changes in an edited copy of this document.

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iv.   Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

☐   The University Corporation for Atmospheric Research (UCAR);

☐   The Italian National Research Council, Institute of Atmospheric Pollution Research (CNR-IIA, Florence Dept.).

v.   Submitters

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1   Scope

This document specifies the CF-netCDF model encoding using the GML 3.2.1 Application Schema –Coverage entities. Besides, it specifies the data format and Internet protocol characteristics to serve CF-netCDF data in an effective and usable way.

GML 3.2.1 has not been deprecated. As per the GML 3.3. standard, GML 3.3 imports the 3.2 schema. The canonical location of the 3.2 all components schema document for 3.3 is http://schemas.opengis.net/gml/3.2.1/gml.xsd.

This CF-netCDF 3.0 extension allows discovery and access services to exchange CF-netCDF data –e.g. encoded in GML. In fact, this specification introduces a set of requirements which a WxS implementation must fulfil to describe and exchange CF-netCDF 3.0 datasets from server to client using the coverage extension of the GML 3.2.1 encoding format.

This standard specifies: (a) the CF-netCDF GML encoding to be used by OGC standards; (b) the CF-netCDF data format exchanged using OGC standards; (c) the Internet protocol characteristics to effectively exchange CF-netCDF data.

CF-netCDF encoding format is netCDF conforming to the Climate and Forecast (CF) conventions (CF-netCDF). It consists of either a binary, XML, or ASCII format which encodes the CF-netCDF data model.

CF-netCDF 3.0 has emerged as a well-supported data model and encoding for several different domains, including: atmospheric science, oceanography, climatology, meteorology, hydrology, etc.

This specification deals with multi-dimensional discrete coverage data and multi-dimensional multi-point data.

2 Conformance

Standardization target is the encoding of netCDF-CF datasets returned by any WxS implementation (currently: servers).

In particular, this standard defines three standardization targets: (a) CF-netCDF GML implementations (currently encodings); (b) CF-netCDF data format (currently encodings); (c) CF-netCDF data format (currently encodings) returned by multiple part messages.

This document establishes three requirements classes, one for each standardization target:

1. *CF-netCDF-1.6 GML encoding*, of http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding -for the standardization target (a);
2. *CF-netCDF-1.6 data format*, of   http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format -for the standardization target (b);
3. *CF-netCDF-1.6 multipart data encoding*, of http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Multipart-encoding -for the standardization target (c);

and three corresponding pertaining conformance class, *CF-netCDF-1.6*, with URIs:

1. http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding
2. http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format
3. http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Multipart-encoding

Requirements and conformance test URIs defined in this document are relative to http://www.opengis.net/spec/netCDF_data-model/.

Annex A lists the conformance tests which shall be exercised on any software artifact claiming to implement an CF-netCDF 3.0 extension for GML 3.2.1 encoding.

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.

OGC 10-090, *NetCDF Core version 1.0*
>   Conformance classes used:
>>   ☐   core

OGC 10-092, *NetCDF Binary Encoding Extension Standard: NetCDF Classic and 64-bit Offset Format version 1.0*
>   Conformance classes used:
>>   ☐   netCDF classic
>>
>>   ☐   netCDF 64-bit

OGC 11-165r2, *CF-netCDF Data Model extension specification*, version 2.0.1

>   Conformance classes used:
>>   ☐   CF-netCDF core
>>
>>   ☐   CF-netCDF Discrete Sampling
>>
>>   ☐   CF-netCDF Mapping onto ISO 19123

OGC 07-036, *Geography Markup Language (GML) Encoding Standard*, version 3.2.1

>   Conformance classes used:
>>   ☐   GML writing

OGC 09-146r1, *OGC® Implementation Schema for Coverages*, version 1.0
>   Conformance classes used:
>>   ☐   gml-coverage

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, the word "shall" (not "must") is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

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

4.1
Coverage
Feature that acts as a function to return values from its range for any direct position within its spatiotemporal domain [OGC 07-111]

4.2
Data Model
A description of the organization of data in a manner that reflects an information structure [ISO/IEC 11179-1 Specification and standardization of data elements – Part 1: Framework]

NOTE: netCDF literature reports the following definition for data model: a way of thinking about scientific data by applying a data model theory. It is an abstraction that describes how datasets are represented and used. In computer terms, a data model can be thought of as equivalent to an abstract object model in Object Oriented Programming in that an abstract data model describes data objects and what methods can be used on them.

4.3
Feature
abstraction of real world phenomena [5].
NOTE A feature may occur as a type or an instance.

4.4
GMLCOV
Note that OGC Coverage Implementation Schema 1.1 supersedes its predecessor version, GML 3.2.1 Application Schema – Coverages version 1.0.1, nicknamed GMLCOV, in a backwards compatible way. Instead of naming the new version GMLCOV 1.1, the standard has been renamed to Coverage Implementation Schema (CIS) 1.1 to remedy misunderstandings caused by the initial title, such as that only a GML encoding is defined here (whereas in fact a format-independent implementable coverage model is established).

For simplicity, the GMLCOV shorthand is used throughout this specification.

4.5
Grid
Network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in a algorithmic way [5]

NOTE: the curves partition a space into grid cells.

4.6
MIME
MIME (Multi-Purpose Internet Mail Extensions) is an extension of the original Internet e-mail protocol that lets people use the protocol to exchange different kinds of data files on the Internet: audio, video, images, application programs, and other kinds, as well as the ASCII text handled in the original protocol, the Simple Mail Transfer Protocol (SMTP).

4.7
Multipart messages

Through the use of the multipart type, MIME allows mail messages to have parts arranged in a tree structure where the leaf nodes are any non-multipart content type and the non-leaf nodes are any of a variety of multipart types.

4.8
Multi-point coverage

A discrete coverage which is characterized by a finite domain consisting of points. Generally, the domain is a set of irregularly distributed points.

A set of hydrographic soundings is an example of a discrete point coverage.

4.9
NetCDF

NetCDF is a standard for data on complex grids –curvilinear in XY; sigma and density-related in Z; climatological and artificial calendars in T; and heading towards "tile mosaics" and 5D forecast ensembles in the near future.

4.10
Web address

For purposes of this document, Web address is an HTTP URL that allows applications to access remote (optionally, time-aggregated collections of) netCDF-CF files (virtual datasets – often terabyte sized) through netCDF API –as if they were local netCDF files.

5   Conventions

5.1   Namespace prefix conventions

The following namespaces are used in this document. The prefix abbreviations used constitute conventions used here, but are **not** normative. The namespaces to which the prefixes refer are normative, however.

Namespace mappings

Prefix	Namespace URI	Description
GML	http://www.opengis.net/gml/3.2	GML 3.2.1
GMLCOV	http://www.opengis.net/gmlcov/1.0	GML Application Schema for Coverages 1.0
ncml	http://unidata.ucar.edu/ncml	ncML schema
xsd	http://www.w3.org/2001/XMLSchema	XML Schema

5.2 CF-netCDF data model

This document does not contain inline a formal specification of the CF-netCDF data model. In fact, it is available as an OGC specification [OGC 11-165r2]. This specification formalizes the CF-netCDF data model mapping onto the ISO 19123 coverage geometry model.

For reader's convenience, the CF-netCDF data model is shown in Figure 1, Figure 2, and Figure 3. An example of CF-netCDF dataset is reported in the Annex B.
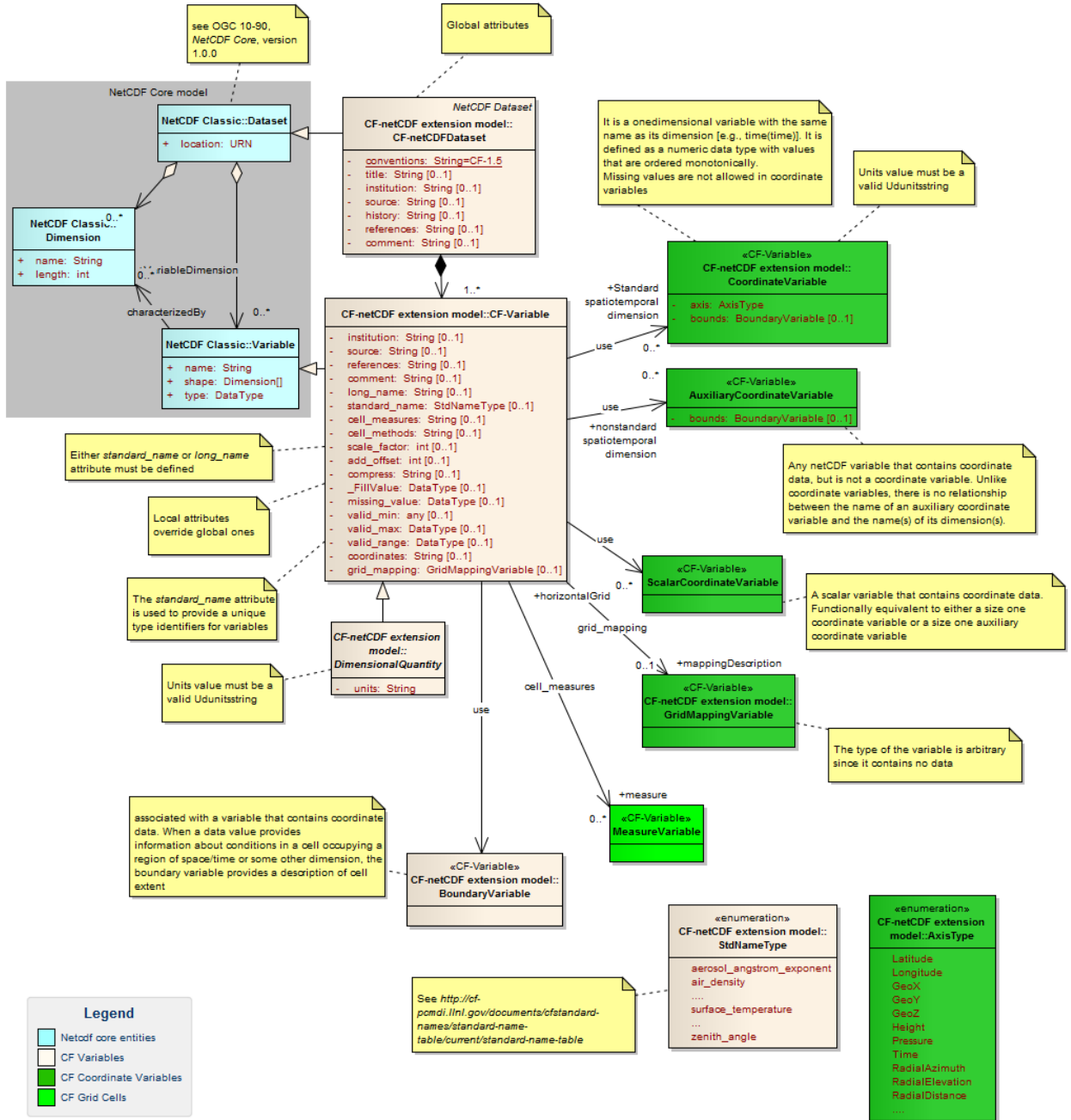
Figure 1 - CF-netCDF data model: Dataset and Variable elements [OGC 11-165r2]
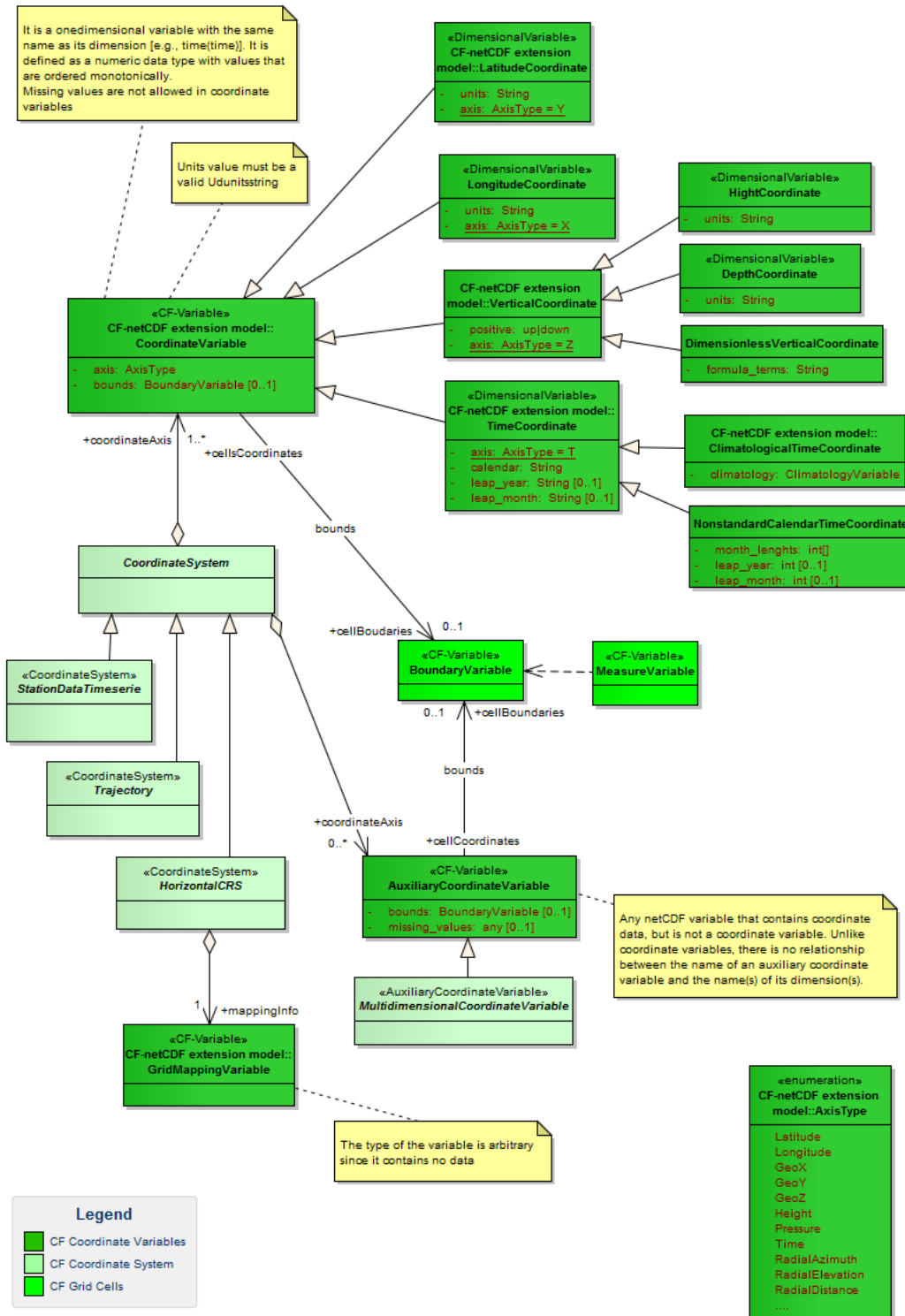
Figure 2 - CF-netCDF data model: Coordinate Variable and Coordinate System elements [OGC 11-165r2]

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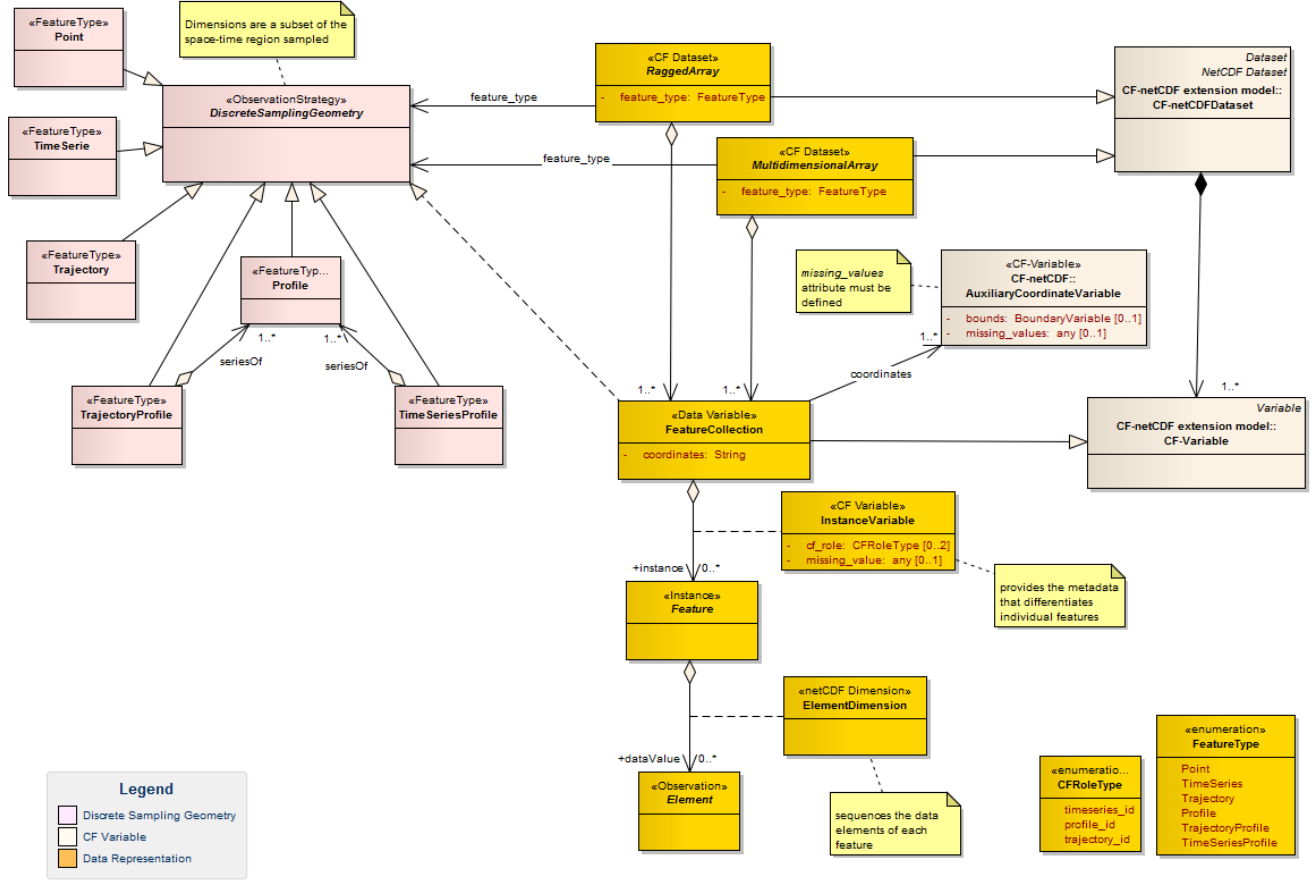
Figure 3 - CF-netCDF data model: Discrete Sampling Geometry elements [OGC 11-165r2]

5.3 Web address

For the scope of this document, a Web address is a transparent mechanism by which an application can use netCDF API calls on a remote file. Thus, for any netCDF subset that may be derived from a WxS server, there may be a Web URL that is an indirect reference to that same subset.

Essentially, the netCDF file is just a de-referencing of this URL. Any application program that can utilize a netCDF file can (in principal) utilize the URL equivalently.

NetCDF Community applications commonly make use of Web addresses (i.e. HTTP URLs) to access remote (optionally, time-aggregated collections of) netCDF-CF files (virtual datasets – often terabyte sized) through netCDF API –as if they were local netCDF files.

6 CF-NetCDF dataset encoding with GML 3.2.1 – application schema – Coverages

GML 3.2.1 Application Schema -Coverage data model [OGC 09-146r1] introduces the concept of Coverage (i.e. `GMLCOV:Coverage`). For the reader's convenience the data model is depicted in Figure 4 and Figure 5.

The related `GML:DomainSet` and `GML:RangeSet` entities are defined in [7]; while, `SWE Common:DataRecord` is defined in [8].
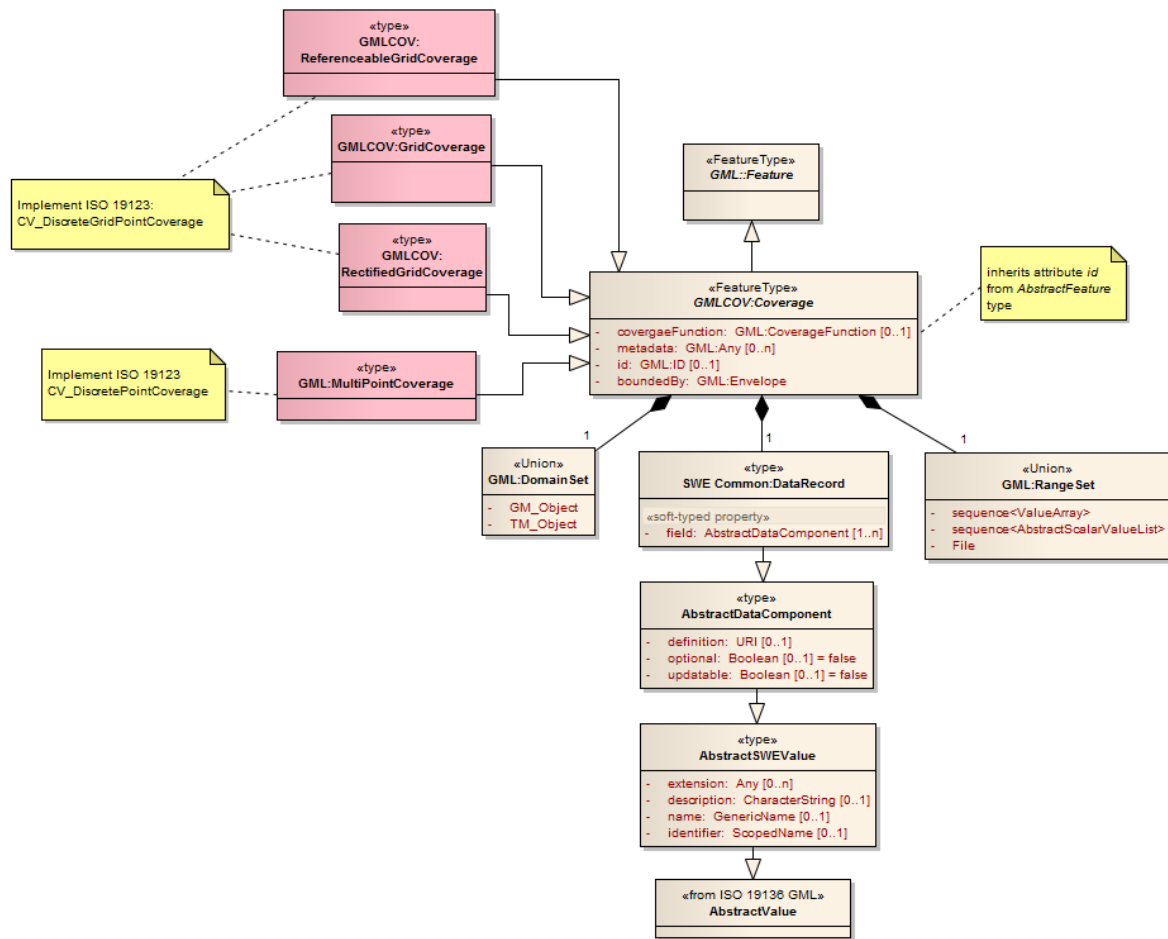
Figure 4. GML 3.2.1 `Coverage` structure [OGC 09-146r1]
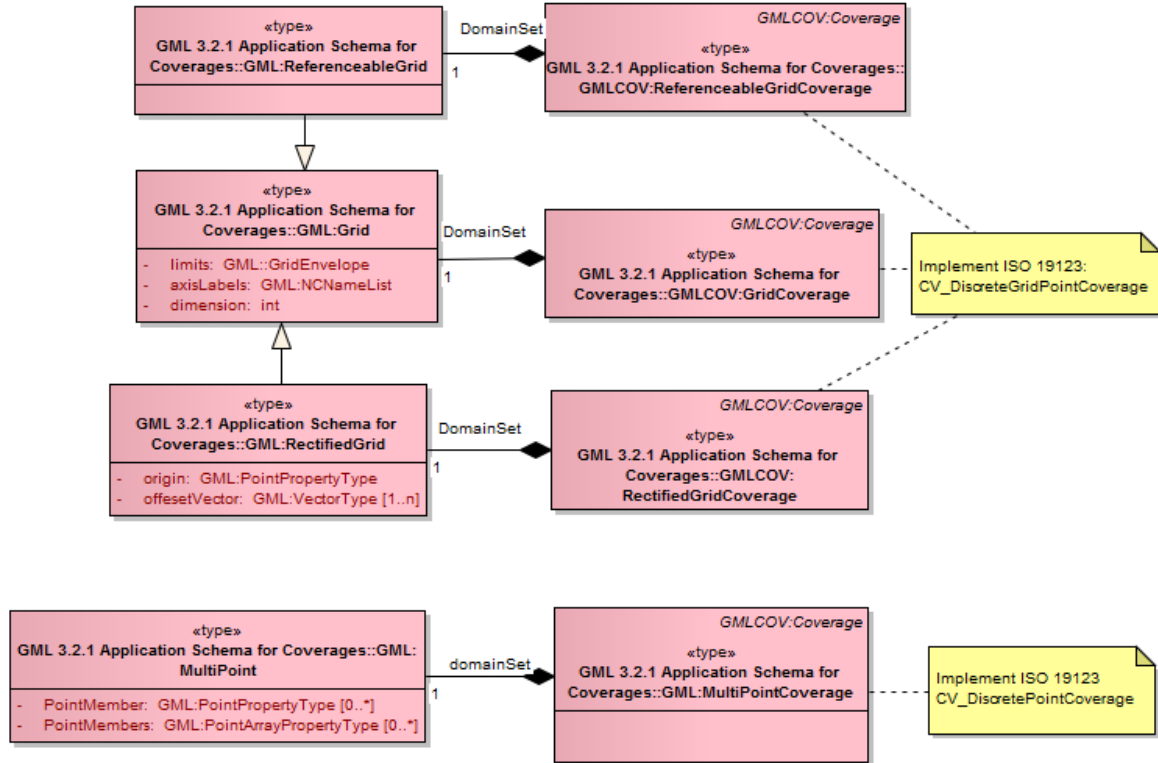
Figure 5. `GML:DomainSet` implementations [OGC 09-146r1]

6.1   GML 3.2.1 Coverage types

Since CF-netCDF dataset realizes the ISO19123:CV_DiscreteCoverage type [4], the following GML 3.2.1 coverage types are considered for the mapping (see Figure 4): `GMLCOV:GridCoverage` type, `GMLCOV:RectifiedGridCoverage` type, `GMLCOV:ReferenceableGridCoverage` type, or `GMLCOV:MultiPointCoverage` –i.e. ISO `19123:CV_DiscretePointCoverage`.

6.2   Encoding rules for CF-netCDF dataset

Considering the mapping between the `GMLCOV:Coverage` object and property names to the corresponding class names and their attributes in ISO 19123 (see Table D.8 of [7] and the constraints introduced by [OGC 09-146r1]), and the mapping between the CF-netCDF dataset object and property names to the corresponding class names and their attributes in ISO 19123 (see OGC 11-165r2 [4]), Table 1 defines the mapping between the CF-netCDF dataset object and property names to the corresponding `GMLCOV:Coverage` object and property names. Figure 6 and Figure 7 depict these mapping rules.

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Table 1. Encoding rules for CF-netCDF dataset

CF-netCDF entity	ISO Grid Coverage entity	Encoding Cardinality	`GMLCOV:Coverage` entity	Rule #
CF_Dataset and sub-types (e.g. *MultidimensionalArray* and *RaggedArray* entities)	`CV_DiscreteCoverage` `(CV_DiscreteGridPointCoverage` `or` `CV_DiscretePointCoverage )`	1 to 0..n	`GML:Coverage` implemented as: `GMLCOV:GridCoverage	` `GMLCOV:RectifiedGridCoverage	` `GMLCOV:ReferenceableGridCoverage	GMLCOV:MultiPointCoverage`	1
CF_Variable(s) and sub-types related to a *CoordinateSystem*	`CV_CoverageFunction`	1 to 0..1	`coverageFunction, domainSet, rangeType, rangeSet` implemented as, respectively: `GML:CoverageFunction` `GML:Grid	GML:RectifiedGrid	GML:ReferenceableGrid	GML:MultiPoint`  `SWE:DataRecord`  `GML:RangeSet` (see Table 2)	--
CoordinateSystem	`CS_CRS`	1 to 1	`boundedBy` implemented as `GML:Envelope` or the subtype `GML:EnvelopeWithTimePeriod` (`GML:Envelope` attributes: `srsName` and `axisLabels` must be instantiated) (see Table 3)	--
FeatureCollection	`CV_CoverageFunction`	1 to 0..1	`coverageFunction, domainSet, rangeType, rangeSet` implemented as, respectively: `GML:CoverageFunction` `GML:Grid	GML:RectifiedGrid	GML:ReferenceableGrid	GML:MultiPoint`  `SWE:DataRecord`  `GML:RangeSet` (see Table 4)	--

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Requirement 1 **/req/CF-netCDF-1.6-GML-encoding/CF-dataset**: CF-netCDF datasets, its subtypes and its realizations CF-netCDF RaggedArray and CF-netCDF MultidimensionalArray **shall** realize one of the following GMLCOV:Coverage subtypes: GMLCOV:GridCoverage, GMLCOV:RectifiedGridCoverage, GMLCOV:ReferenceableGridCoverage, GMLCOV:MultiPointCoverage.

Additionally, the GML:DomainSet is implemented as one of the following subtypes: GML:Grid, GML:RectifiedGrid, GML:ReferenceableGrid, GML:MultiPoint (see Figure 5).

6.3   Encoding rules for CF-Variables

Table 2. Encoding rules for CF_Variable.

CF-netCDF entity	ISO Coverage entity	Encoding Cardinality	GMLCOV entity	GML 3.2.1 entity	rule #
CF_CoordinateVariable [a] (Valid subtypes are: LatitudeCoordinateLongitudeCoordinate, VerticalCoordinate, TimeCoordinate) or Spatial/ temporal *CF_AuxiliaryCoordinateVariable* [b]	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValueMatrix.CV_GridPoint.gridCoord`	1 to 1	`GMLCOV:GridCoverage.domainSet` | `GMLCOV:RectifiedGridCoverage.domainSet` | `GMLCOV:ReferenceableGridCoverage.domainSet`	`GML:DomainSet` realized as: `GML:Grid` or its subtypes: `GML:RectifiedGrid` | `GML:ReferenceableGrid`	2, 3
	`ISO19123:CV_DiscretePointCoverage.CV_PointValuePair.geometry.GM_Point`	1 to 1	`GMLCOV:MultiPointCoverage.domainSet`	`GML:DomainSet` realized as: `GML:MultiPoint`	2, 3
	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValueMatrix.sequencingRule`	1 to 0..1	`GMLCOV:Coverage.coverageFunction`	`GML:CoverageFunction.GridFunction`	4, 5
	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValueMatrix.startSequence`				
	`ISO19123:CV_DiscretePointCoverage.CoverageFunction` [e]	1 to 0..1	`GMLCOV:Coverage.coverageFunction`	`GML:CoverageFunction.CoverageMappingRule`	4, 5
data *CF_Variable* [c] or non Spatial/temporal *CF_AuxiliaryCoordinateVariable* [e]	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValuesMatrix.values`	1 to 1	`GMLCOV:Coverage.rangeSet`	`GML:RangeSet`	6, 8
	`ISO19123:CV_DiscretePointCoverage.CV_PointValuePair.value` [f]	1 to 1	`GMLCOV:Coverage.rangeSet`	`GML:RangeSet`	6, 8
data *CF_Variable* [d] or non spatial/temporal *CF_AuxiliaryCoordinateVariable* [e]	`ISO19123:CV_DiscreteGridPointCoverage.RangeType.AttributesType entry (i.e. AttributeName, TypeName)`	1 to 1	`GMLCOV:Coverage.rangeType`	`SWE:DataRecord`	7, 9
	`CV_DiscretePointCoverage.RangeType.AttributesType entry (i.e. AttributeName, TypeName)`	1 to 1	`GMLCOV:Coverage.rangeType`	`SWE:DataRecord`	7, 9

The set of spatial/temporal coordinate variables (shared by a group of CF_Variables) maps to the coverage domain, whose geometry is represented by a single grid (`ISO19123:CV_Grid`) or point value pairs (`ISO19123:CV_PointValuePair`).

The set of spatial/temporal auxiliary coordinate variables (shared by a group of CF_Variables) maps to the coverage domain, whose geometry is represented by a single grid (`ISO19123:CV_Grid`) or point value pairs (`ISO19123:CV_PointValuePair`). The CF_Variables must define a `coordinates` attribute identifying the auxiliary coordinate variables. This is the case implemented by `CF_FeatureCollection` variables.

The set of CF_Variables comprising the group that shares a common Coordinate System (i.e. set of spatial/temporal CF_CoordinateVariables or CF_AuxiliaryCoordinateVariables). The CF_Variable data values generate the grid value matrix record values: `CV_GridValueMatrix.values.record` entry (i.e. `AttributeName, Any`).
The *range* of each `CV_DiscreteGridPointCoverage` is a list of records with an attribute for every related CF-netCDF variable and for every CF_CoordinateVariable –of the shared CoordinateSystem- that is not allowed in a coverage CRS (i.e. parametric dimension axes). Thus, the CF_Variable properties (i.e. *name* and *type*) realize the
`CV_DiscreteGridPointCoverage.RangeType.AttributesType` entry (i.e. `AttributeName, TypeName`).

The *range* of each `CV_DiscreteGridPointCoverage` is a list of records with an attribute for every related CF-netCDF variable and for every CF_AuxiliaryCoordinateVariable that is not allowed in a coverage domain/CRS (i.e. parametric dimension axes).

Parametric dimensions; examples are: *pressure*, *salinity*, *density*.
These coordinate variables do not behave like a discrete coverage *domain* axis; on the contrary, they behave like a discrete coverage *range* axis.

In a `gml:MultiPointCoverage` the mapping from the domain to the range is straightforward.

- For `gml:DataBlock` encodings, the points of the `gml:MultiPoint` are mapped in document order to the tuples of the data block.
- For `gml:CompositeValue` encodings, the points of the `gml:MultiPoint` are mapped to the members of the composite value in document order.
- For `gml:File` encodings, the points of the `gml:MultiPoint` are mapped to the records of the file in sequential order.

CF_RaggedArray representations of a CF_Dataset should use such encodings

Requirement 2 **/req/CF-netCDF-1.6-GML-encoding/Dataset.domainSet#1**: The set of spatial/temporal CF_CoordinateVariable (comprised of a common coordinate system) that characterize a CF-netCDF dataset, **shall** realize a `GML:Coverage.domainSet` property, implemented as: `GML:MultiPoint, GML:Grid` object or its subtypes: `GML:RectifiedGrid, GML:ReferenceableGrid`.

Requirement 3 **/req/CF-netCDF-1.6-GML-encoding/Dataset.domainSet#2**: if the spatial/temporal domain is defined by auxiliary variables, the set of spatial/temporal CF_AuxiliaryCoordinateVariable that characterizes a CF-netCDF Variable, **shall** realize a `GML:Coverage.domainSet` property, implemented as: `GML:MultiPoint, GML:Grid` object or its subtypes: `GML:RectifiedGrid, GML:ReferenceableGrid`.

Requirement 4 **/req/CF-netCDF-1.6-GML-encoding/Dataset.coverageFunction#1**: if the mapping from the domain to the range of the coverage is not characterized by the default values for `GML:Coverage` (see [7]), the set of spatial/temporal CF_CoordinateVariable (comprised of a common coordinate system) that characterizes a CF-

netCDF dataset **shall** realize a `GML:Coverage.coverageFunction` property, implemented as either a `GML:CoverageFunction.GridFunction` or a `GML:CoverageFunction.CoverageMappingRule` object.

Requirement 5   **/req/CF-netCDF-1.6-GML-encoding/Dataset.coverageFunction#2:** if the spatial/temporal domain is defined by auxiliary variables, the set of spatial/temporal CF_AuxiliaryCoordinateVariable that characterizes one or more CF-netCDF Variables **shall** realize a `GML:Coverage.coverageFunction` property, implemented as either a `GML:CoverageFunction.GridFunction` or a `GML:CoverageFunction.CoverageMappingRule` object.

Requirement 6   **/req/CF-netCDF-1.6-GML-encoding/Dataset.rangeSet**: The set of CF-netCDF CF_Variable that shares a common spatial/temporal coordinate system, **shall** realize a `GML:Coverage.rangeSet` property, implemented as a `GML:RangeSet` object.

Requirement 7   **/req/CF-netCDF-1.6-GML-encoding/Dataset.rangeType**: The set of CF-netCDF CF_Variable that shares a common spatial/temporal coordinate system, **shall** realize a `GML:Coverage.rangeType` property, implemented as a `SWE:DataRecord` object.

Requirement 8   **/req/CF-netCDF-1.6-GML-encoding/Dataset.parametric-rangeSet**: The set of CF_AuxiliaryCoordinateVariable, which are not space or time dimension, **shall** contribute to realize a `GML:Coverage.rangeSet` property, implemented as a `GML:RangeSet` object.

Requirement 9   **/req/CF-netCDF-1.6-GML-encoding/Dataset.parametric-rangeType**: the set of CF_AuxiliaryCoordinateVariable, which are not space or time dimension, **shall** contribute to realize a `GML:Coverage.rangeType` property, implemented as a `SWE:DataRecord` object.

6.4   Encoding rules for CF-netCDF CoordinateSystem

Table 3. Encoding rules for CF-netCDF CoordinateSystem

CF-netCDF entity	ISO Coverage entity	Encoding Cardinality	`GML 3.2.1` entity	Rule #
Spatial/temporal *Coordinate System* [a]	`CV_DiscreteGridPointCoverage.SC_CRS.SC_CoordinateSystem | CV_DiscretePointCoverage.SC_CRS.SC_CoordinateSystem`	1 to 1	`GML:Envelope` or the subtype `GML:EnvelopeWithTimePeriod`	10

CF_CoordinateVariable [b]
 	
or
 	
spatial/temporal
 	
CF_AuxiliaryCoordinateVariable [d]
	`CV_DiscreteGridPointCoverage.SC_CRS.SC_CoordinateSystem.SC_CoordinateSystemAxis`	1 to 1	`GML:Envelope.axisLabels`
			
			or
			
			`GML:EnvelopeWithTimePeriod.axisLabels`
				11, 12

	`CV_DiscretePointCoverage.SC_CRS.SC_CoordinateSystem.SC_CoordinateSystemAxis`	1 to 1		

GridMappingVariable	`CV_DiscreteGridPointCoverage.SC_CRS.SC_CoordinateSystem.type |`
	
	`CV_DiscretePointCoverage.SC_CRS.SC_CoordinateSystem.type`
		1 to 0..1	the subtype of `GML_AbstractCRS` pointed by the `GML:Envelope.srsName` attribute[c]	13

[a] Parametric coordinate systems are allowed in CF-netCDF but not in CRS[1]. A coordinate system is of type parametric if a physical or material property is used as a dimension [21]; valuable examples are pressure in meteorology and density in oceanography. It is possible that a CoordinateSystem entity does not contain any axes allowed in coverage CRS (i.e. only parametric dimension axes).
Only spatial and temporal coordinates in a CF-netCDF CoordinateSystem become part of a coverage CRS, whereas parametric dimension axes are mapped to compound range set components.

[b] A CF-netCDF spatial/temporal CoordinateVariable shared by a group of CF-Variables. Valid subtypes are: LatitudeCoordinate LongitudeCoordinate, VerticalCoordinate, TimeCoordinate, CoordinateSystem.CoordinateAxis (with axis type attribute equal to: *Lat*, *Lon*, *Height*, *GeoX*, *GeoY*, *GeoZ*, *RadialAzimuth*, *RadialElevation*, *RadialDistance, time)*.

[c] Wherever a GML object is associated with a Coordinate Reference System, this is implemented by an attribute (`srsName`) pointing to a `GML:AbstractCRS` element [7].

[d] The set of spatial/temporal auxiliary coordinate variables (shared by a group of CF_Variables) maps to the coverage domain, whose geometry is represented by a single grid (`ISO19123:CV_Grid`) or point value pairs (`ISO19123:CV_PointValuePair`).

---

[1] Future extension to ISO 19111 (see ISO/CD19111-2) may permit parametric CRS, that would accommodate the pressure axis.

Requirement 10   **/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy**: The spatial/temporal CoordinateSystem, which is comprised of either spatial and temporal CF_CoordinateVariable objects or spatial and temporal CF_AuxiliaryCoordinateVariable objects, **shall** realize a `GML:Coverage.boundedBy` property, implemented as a `GML:Envelope` object or its subtype `GML:EnvelopeWithTimePeriod`.

Additionally, the attribute `GML:Envelope.srsName` **shall** have a value.

Requirement 11   **/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.axisLabels#1**: The set of spatial/temporal CF_CoordinateVariable comprised of a CoordinateSystem object, **shall** realize a `GML:Envelope.axisLabels` object or its subtype `GML:EnvelopeWithTimePeriod.axisLabels`.

Requirement 12   **/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.axisLabels#2**: The set of spatial/temporal CF_Auxiliary CoordinateVariable, comprised of a CoordinateSystem object related to CF_Variables, **shall** realize a `GML:Envelope.axisLabels` object or its subtype `GML:EnvelopeWithTimePeriod.axisLabels`.

Requirement 13   **/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.CRS**: The CF-netCDF GridMappingVariable, **shall** determine the subype of `GML_AbstractCRS` pointed by the `GML:Envelope.srsName` attribute.

6.5   Encoding rules for CF-netCDF DiscreteSamplingGeometry

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Table 4 - Encoding rules for CF-netCDF DiscreteSamplingGeometry

CF-netCDF entity	ISO Coverage entity	Encoding. Cardinality	GMLCOV entity	GML 3.2.1 entity	Rule #

Spatial/temporal *CF_InstanceVariable[a]*	`CV_DiscreteGridPointCoverage.SC_CRS.SC_CoordinateSystem.SC_CoordinateSystemAxis`
	
	 or
	
	 `CV_DiscretePointCoverage.SC_CRS.SC_CoordinateSystem.SC_CoordinateSystemAxis`
		1 to 1	`--`	`GML:Envelope.axisLabels`
				
				 or
				
				 `GML:EnvelopeWithTimePeriod.axisLabels`
					14 (12)

	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValueMatrix.CV_GridPoint.gridCoord`	1 to 1	`GMLCOV:GridCoverage.domainSet | GMLCOV:RectifiedGridCoverage.domainSet | GMLCOV:ReferenceableGridCoverage.domainSet`	`GML:DomainSet` realized as: `GML:Grid` or its subtypes: `GML:RectifiedGrid | GML:ReferenceableGrid`	14 (3)
	`ISO19123:CV_DiscretePointCoverage.CV_PointValuePair.geometry.GM_Point`	1 to 1	`GMLCOV:MultiPointCoverage.domainSet`	`GML:DomainSet` realized as: `GML:MultiPoint`	14 (3)
	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValueMatrix.sequencingRule`	1 to 0..1	`GMLCOV:Coverage.coverageFunction`	`GML:CoverageFunction.GridFunction`	14 (5)
	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValueMatrix.startSequence`	1 to 0..1		`GML:CoverageFunction.CoverageMappingRule`	14 (5)
	`ISO19123:CV_DiscretePointCoverage.CoverageFunction` [e]				
CF_Multidimensional Array.InstanceDimens	`ISO19123:CV_DiscreteGridPointCoverage.CV_GridValuesMat`	1 to 0..1	`GMLCOV:Coverage.r`	`GML:RangeSet`	15

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ion [b]	`rix.values`		`angeSet`		
	`ISO19123:CV_Discre tePointCoverage. CV_PointValuePair. value` [f]	1 to 0..1			
	`ISO19123:CV_Discre teGridPointCoverag e.RangeType.Attrib utesType entry (i.e. AttributeName, TypeName)`	1 to 0..1	`GMLCOV: Coverage.r angeType`	`SWE:DataRecord`	16
	`CV_DiscretePointCo verage.RangeType.A ttributesType entry (i.e. AttributeName, TypeName)`	1 to 0..1			
CF_RaggedArray.Sam pleDimension and *CF_IndexVariable* [c] or *CF_CountVariable* [c]	`ISO19123:CV_Discre teGridPointCoverag e.CV_GridValuesMat rix.values`	1 to 0..1	`GMLCOV: Coverage.r angeSet`	`GML:RangeSet`	17
	`ISO19123:CV_Discre tePointCoverage. CV_PointValuePair. value` [f]	1 to 0..1			
	`ISO19123:CV_Discre teGridPointCoverag e.RangeType.Attrib utesType entry (i.e. AttributeName, TypeName)`	1 to 0..1	`GMLCOV: Coverage.r angeType`	`SWE:DataRecord`	18
	`CV_DiscretePointCo verage.RangeType.A ttributesType entry (i.e. AttributeName, TypeName)`	1 to 0..1			
CF_Point FeatureCollection domain [d]	`ISO19123:CV_Discre teCoverage.domainE xtent` and `CV_DiscreteCoverag e.SC_CRS.SC_Coordi nateSystem.SC_Coor`	1 to 1	`GMLCOV: Coverage.d omainSet`	`GML:EnvelopeWithTimePeri od.axisLabels="x y t" | "lat lon t" | "lon lat t"`	19

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	dinateSystemAxis				
CF_TimeSerie FeatureCollection domain [e]	`ISO19123:CV_Discre teCoverage.domainE xtent`	1 to 1	`GMLCOV: Coverage.d omainSet`	`GML:EnvelopeWithTimePeri od.axisLabels = "x y t"` | `"lat lon t"` | `"lon lat t"`	20
CF_Trajectory FeatureCollection domain [f]	`ISO19123:CV_Discre teCoverage.domainE xtent`	1 to 1	`GMLCOV: Coverage.d omainSet`	`GML:EnvelopeWithTimePeri od.axisLabels = "x y t"` | `"lat lon t"` | `"lon lat t"`	21
CF_Profile FeatureCollection domain [g]	`ISO19123:CV_Discre teCoverage.domainE xtent`	1 to 1	`GMLCOV: Coverage.d omainSet`	`GML:EnvelopeWithTimePeri od.axisLabels = "x y z t"` | `"lat lon z t"` | `"lon lat z t"`	22
CF_TimeSeriesProfile FeatureCollection domain [h]	`ISO19123:CV_Discre teCoverage.domainE xtent`	1 to 1	`GMLCOV: Coverage.d omainSet`	`GML:EnvelopeWithTimePeri od.axisLabels = "x y z t"` | `"lat lon z t"` | `"lon lat z t"`	23
CF_TrajectoryProfile FeatureCollection domain [i]	`ISO19123:CV_Discre teCoverage.domainE xtent`	1 to 1	`GMLCOV: Coverage.d omainSet`	`GML:EnvelopeWithTimePeri od.axisLabels = "x y z t"` | `"lat lon z t"` | `"lon lat z t"`	24

[a] spatial/temporal CF_AuxiliaryCooridnateVariable which has as only dimension the "instance" dimension; it is used to differentiate the Feature instances comprised of a Feature Collection -e.g. X(station), lat(profile), etc.
This mapping was already formalized by Requirement 3, Requirement 5, Requirement 8and Requirement 12.

[b] CF_MultidimensionalArray instance dimension(s) may be used to generate an instance dimensionality for the coverage range-set.

[c] CF_RaggedArray sample dimension(s) and variables used to index the observation elements (i.e. either CF_IndexVariable or CF_CountVariable) may be used to generate an instance dimensionality for the coverage range-set.

[d] Point Feature Collection has the following mandatory space-time coordinates x(i) y(i) t(i); i=collection instance.

[e] TimeSerie Feature Collection has the following mandatory space-time coordinates x(i) y(i) t(i,o); i=collection instance; o=observation.

[f] Trajectory Feature Collection has the following mandatory space-time coordinates x(i,o) y(i,o) t(i,o); i=collection instance; o=observation.

[g] Profile Feature Collection has the following mandatory space-time coordinates x(i) y(i) z(i,o) t(i); i=collection instance; o=observation.

[h] TimeSerieProfile Feature Collection has the following mandatory space-time coordinates x(i) y(i) z(i,p,o) t(i,p); i=collection instance; p=profile; o=observation.

[i] TrajectoryProfile Feature Collection has the following mandatory space-time coordinates x(i,p) y(i,p) z(i,p,o) t(i,p); i=collection instance; p=profile; o=observation.

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Requirement 14 **/req/CF-netCDF-1.6-GML-encoding/InstanceVariable**: each CF_InstanceVariable object **shall** be encoded as a spatial/temporal CF_AuxiliaryCooridnateVariable which has as only dimension the "instance" dimension.

Requirement 15 **/req/CF-netCDF-1.6-GML-encoding/ RangeInstanceDimension#1**: each CF_MultidimensionalArray.InstanceDimension object **shall** contribute to realize a `GML:Coverage.rangeSet` property, implemented as a `GML:RangeSet` object.

Requirement 16 **/req/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#2**: each CF_MultidimensionalArray.InstanceDimension object **shall** contribute to realize a `GML:Coverage.rangeType` property, implemented as a `SWE:DataRecord` object.

Requirement 17 **/req/CF-netCDF-1.6-GML-encoding/ RangeInstanceDimension#3**: each CF_RaggedArray.SampleDimension object along with associated CF_IndexVariable or CF_CountVariable **shall** contribute to realize a `GML:Coverage.rangeSet` property, implemented as a `GML:RangeSet` object.

Requirement 18 **/req/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#4**: each CF_RaggedArray.SampleDimension object along with associated CF_IndexVariable or CF_CountVariable **shall** contribute to realize a `GML:Coverage.rangeType` property, implemented as a `SWE:DataRecord` object.

Requirement 19 **/req/CF-netCDF-1.6-GML-encoding/PointFeatureCollection.axisLabels**: each CF_Point FeatureCollection **shall** realize a `GML:EnvelopeWithTimePeriod.axisLabels` with value equal to `"x y t"` | `"lat lon t"` | `"lon lat t"`.

Requirement 20 **/req/CF-netCDF-1.6-GML-encoding/TimeSerieFeatureCollection.axisLabels**: each CF_TimeSerie FeatureCollection **shall** realize a `GML:EnvelopeWithTimePeriod.axisLabels` with value equal to `"x y t"` | `"lat lon t"` | `"lon lat t"`.

Requirement 21   **/req/CF-netCDF-1.6-GML-encoding/TrajectoryFeatureCollection.axisLabels**: each CF_Trajectory FeatureCollection **shall** realize a `GML:EnvelopeWithTimePeriod.axisLabels` with value equal to `"x y t" | "lat lon t" | "lon lat t"`.

Requirement 22   **/req/CF-netCDF-1.6-GML-encoding/ProfileFeatureCollection.axisLabels**: each CF_Profile FeatureCollection **shall** realize a `GML:EnvelopeWithTimePeriod.axisLabels` with value equal to `"x y z t" | "lat lon z t" | "lon lat z t"`.

Requirement 23   **/req/CF-netCDF-1.6-GML-encoding/TimeSeriesProfileFeatureCollection.axisLabels**: each CF_TimeSeriesProfile FeatureCollection **shall** realize a `GML:EnvelopeWithTimePeriod.axisLabels` with value equal to `"x y z t" | "lat lon z t" | "lon lat z t"`.

Requirement 24   **/req/CF-netCDF-1.6-GML-encoding/TrajectoryProfileFeatureCollection.axisLabels**: each CF_TrajectoryProfile FeatureCollection **shall** realize a `GML:EnvelopeWithTimePeriod.axisLabels` with value equal to `"x y z t" | "lat lon z t" | "lon lat z t"`.
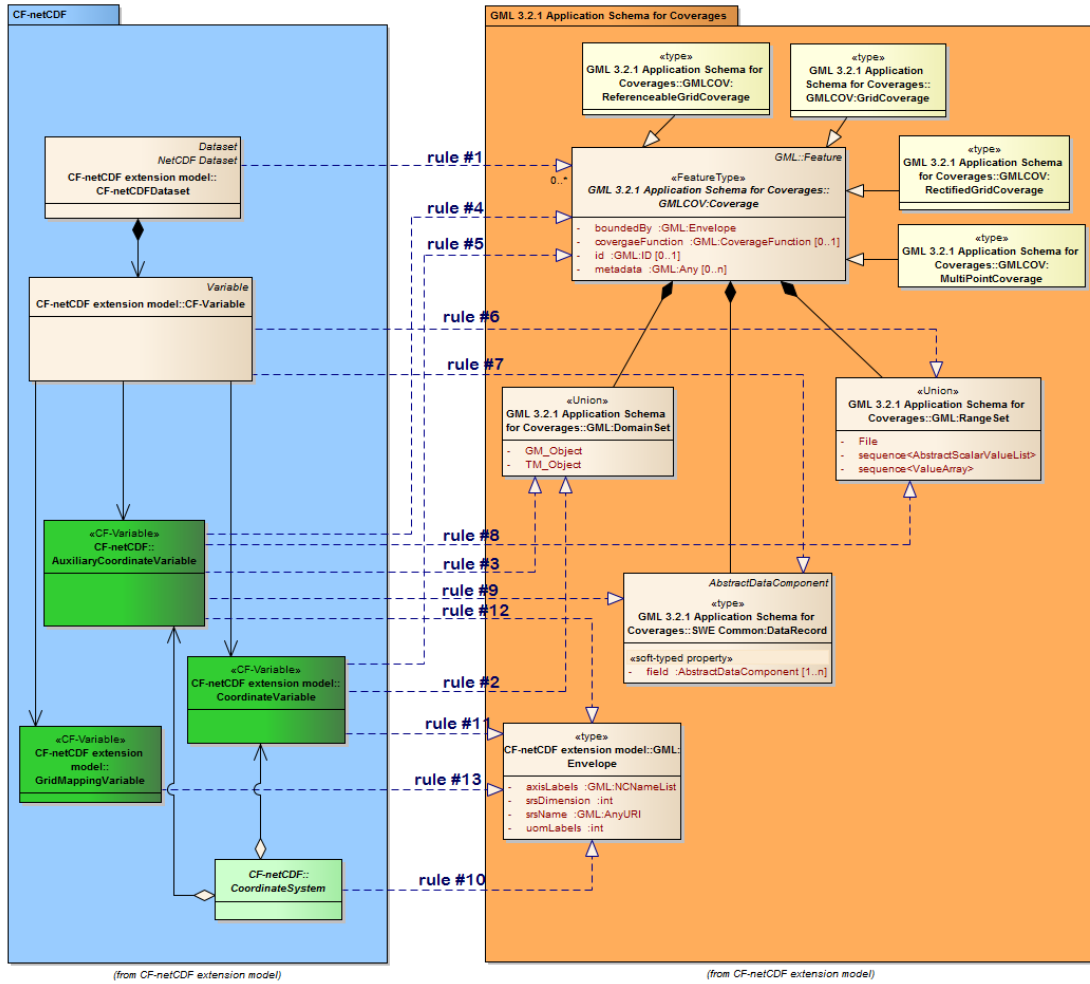
Figure 6. CF-netCDF dataset mapping to GMLCOV data model
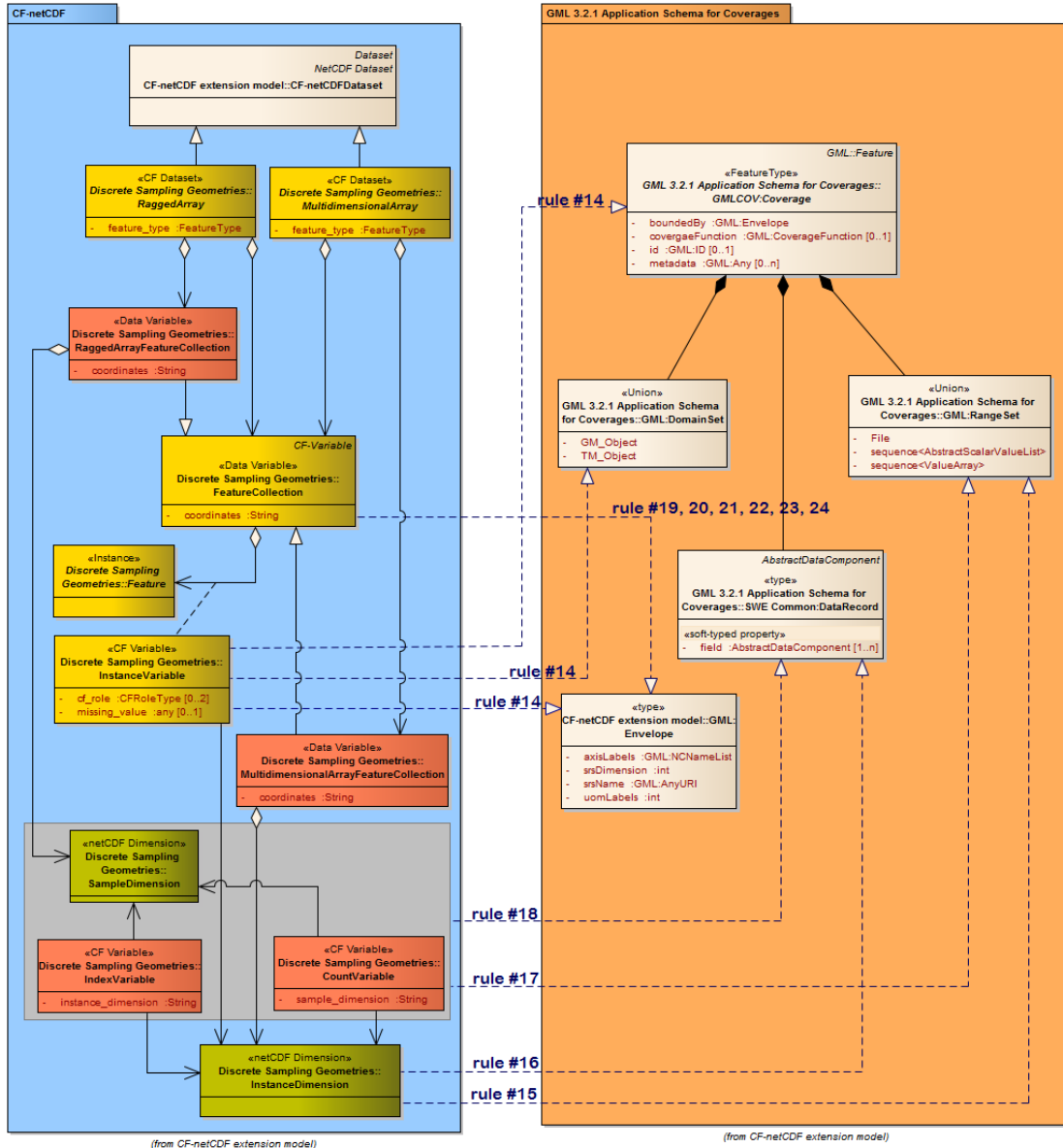
Figure 7. CF-netCDF discrete sampling geometries mapping to GMLCOV data model

7 Service operation response returning a CF-netCDF dataset

7.1 Concrete coverage types

For WxS, the GML encoding is generally used for the purpose of defining response semantics. A server may deliver a result dataset in some other format –e.g. CF-netCDF. However, it is required that result datasets, regardless of what the encoding chosen is, have a content which is consistent with the GML specification [OGC 09-146r1].

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7.2 Concrete CF-netCDF data format

The schema depicted in Figure 8 introduces the concrete CF-netCDF data format used to return requested datasets.

7.3 GridCoverageFile class

The response to a successful *operation* requesting a CF-netCDF dataset is a concrete sub-type of `GMLCOV:Coverage` which is encoded as a *GridCoverageFile*, an abstract entity which has three valuation subclasses: *BinaryFile*, *XMLDocument*, and *Web address*.

NOTE: a CF-netCDF *BinaryFile* may be accessed directly or can be referenced by: (a) an *XMLDocument* object (e.g. an ncML dataset); (b) an *Web address* object.

7.4 BinaryFile class

BinaryFile class has two concrete sub-types: *CF-netCDF-File* and *CF-netCDF-64bit-File*. They represent a netCDF ver. 3.0 binary file, complying with the CF ver. 1.1 conventions. These binary encodings are based on the "OGC NetCDF Binary Encoding Extension Standard: NetCDF Classic and 64-bit Offset Format" [9].

MIME type string used to refer to CF-netCDF binary encoding is:

application/CF-netCDF

Note: the only MIME type in use presently is "application/x-netcdf" and it is not officially registered. Thus, the MIME types discussed below are new and application for registration will be made to IANA.
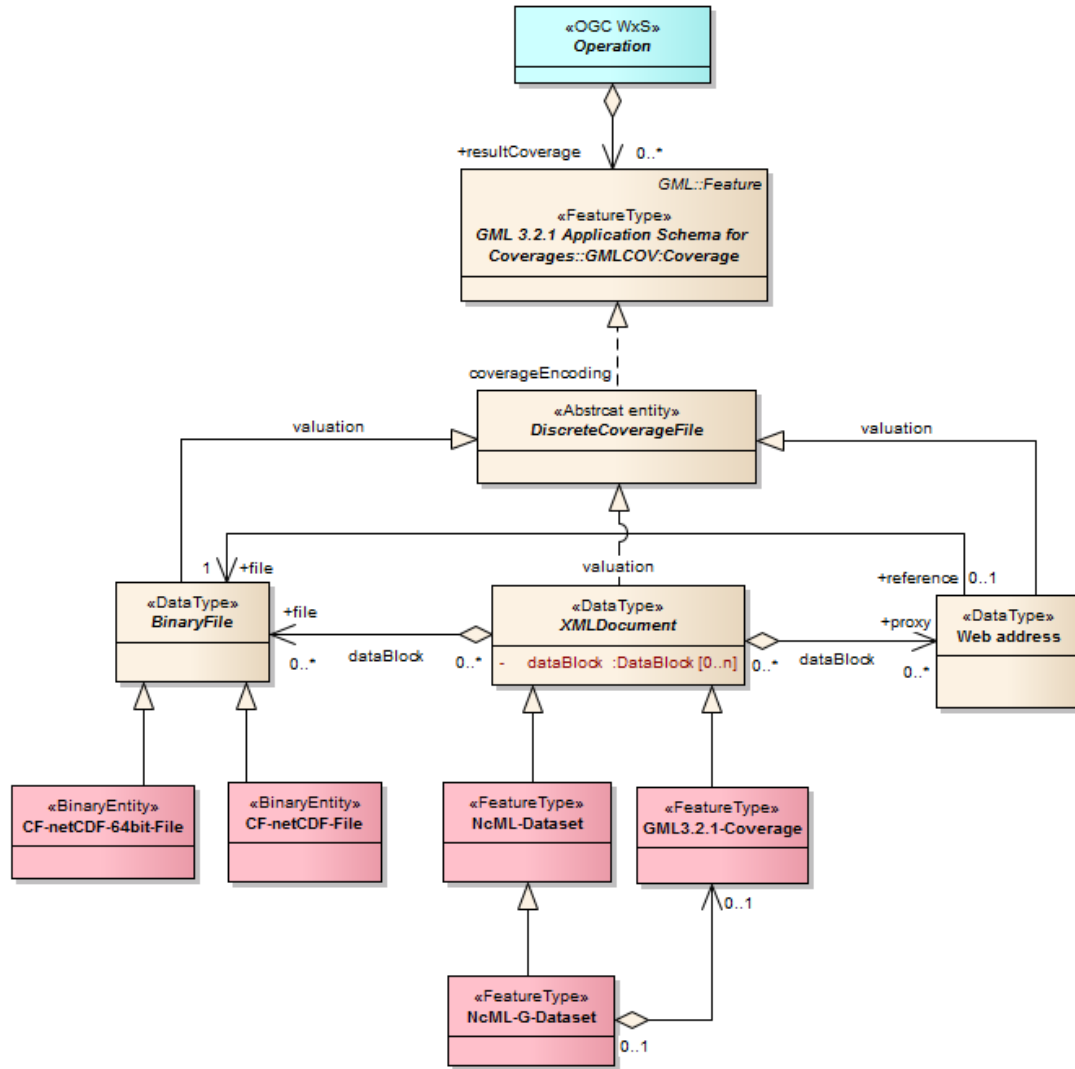
Figure 8. Supported CF-netCDF Coverage encodings

7.5   XMLDataset class

XMLDataset class has three concrete sub-types: *NcML-Dataset*, *GML-3.2.1-Coverage*, and *NcML-G-Dataset*.

7.5.1   NcML-Dataset

NcML-Dataset represents a ncML ver. 1.0 document [10]. A ncML document provides the XML encoding of one or more CF-netCDF files. For performances sake, a ncML document generally encodes only the CF-netCDF coverage metadata leaving the data values in the binary format and providing pointers (i.e. references) to those.

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A ncML document may point to data values: (a) directly –i.e. referencing a CF-netCDF binary file; (b) including an Web address (i.e. HTTP URL)–which in turn reference a CF-netCDF file.

MIME type string used to refer to ncML-G dataset encoding is:

application/ncML+xml

This xml media type is still unregistered.

7.5.2   *GML-3.2.1-Coverage*

GML-3.2.1-Coverage represents the GML-based coverage encoding as specified by [OGC 09-146r1]. Such a document is generated applying the requirements contained in clause 6 and summarized in Table 1, Table 2, and Table 3.

MIME type string used to refer to GML coverage encoding is [OGC 09-144r1]:

application/gml+xml

7.5.3   *NCML-G-Dataset*

NcML-G-Dataset represents a ncML-G ver. 1.0 document [10]. A ncML-G document extends a ncML-Dataset by including a GML Coverage element generated from the ncML dataset itself. In fact, this language was conceived to explicitly encode the two data models mapping. This may be very useful to fully support both GIS and netCDF applications.

MIME type string used to refer to ncML-G dataset encoding is:

application/ncML+xml

This xml media type is still unregistered.

7.6   Web address class

This class realizes a well-adopted online reference to a CF-netCDF file. In fact, Web address is a relatively simple approach (i.e. an HTTP URL) that allows applications to access remote (optionally, time-aggregated collections of) netCDF-CF files (virtual datasets –often terabyte sized) through netCDF API –as if they were local netCDF files.

A Web address may also be contained by any concrete *XMLDataset* object to reference a CF-netCDF binary file.

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Web address may be encoded using one of the following options: i) a specific MIME type for a well-known address syntax; ii) an HTML document containing a HTTP URL; iii) a simple text –semantically, this is a very dull solution, and is deprecated.

NOTE: Result coverages, regardless of what the encoding chosen is, have a contents which is consistent with the `GMLCOV:Coverage` specification –see clause 6 and Table 1, Table 2, and Table 3.

Requirement 27   /req/CF-netCDF-1.6-Data-format/coverages-format:
For a WxS service implementing this extension, the contents of the response to a successful *GetCoverage* request **shall** be encoded in one of the following coverage encoding formats: *CF-netCDF-File, CF-netCDF-64bit-File, ncML-Dataset, GML-3.2.1-Coverage, ncML-G-Dataset, Web-address.*

Requirement 28   /req/CF-netCDF-1.6-Data-format/binaryFile-MIME-type:
WxS server implementing this specification **shall** use the following MIME type string to refer to CF-netCDF binary encoding: "*application/CF-netCDF*".

Requirement 29   /req/CF-netCDF-1.6-Data-format/ncML-Dataset-MIME-type:
WxS server implementing this specification **shall** use the following MIME type string to refer to ncML-Dataset encoding: "*application/ncML+xml*".

Requirement 30   /req/CF-netCDF-1.6-Data-format/Web-address-reference:
WxS server implementing this specification **shall** use a MIME type string to refer to a well-known Web address syntax*"*

Requirement 31   /req/CF-netCDF-1.6-Data-format/Web-address-encoding:
In a service operation successful response, a coverage returned as a generic Web address **shall** be encoded as an HTML document containing the HTTP URL.

7.7   WxS operation response: *ncML-Dataset* document structure

The netCDF community makes use of ncML to encode complex netCDF data structures. In fact, it is possible to use ncML elements to define a virtual netCDF dataset which consists of one or more netCDF data files.

In a service operation response returning a ncML document, the discrete coverage values are encoded and returned according to one or more of the following options:

(i)   XML encoded values conforming to the ncML schema: this ncML section encodes the content of a CF-netCDF binary file.
(ii) CF-NetCDF binary files (i.e. *BinaryFile* objects) attached to an ncML document.
(iii) Web address encoded in the ncML schema: actually, this ncML section references the content of a CF-netCDF binary file.

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In any case, the coverage metadata section is encoded in the ncML document as elements conforming to the ncML schema.

For instance, Figure 9 depicts a complex *ncML-Dataset* (and optionally *ncML-G-Dataset*) structure transferred as a successful WxS operation response.
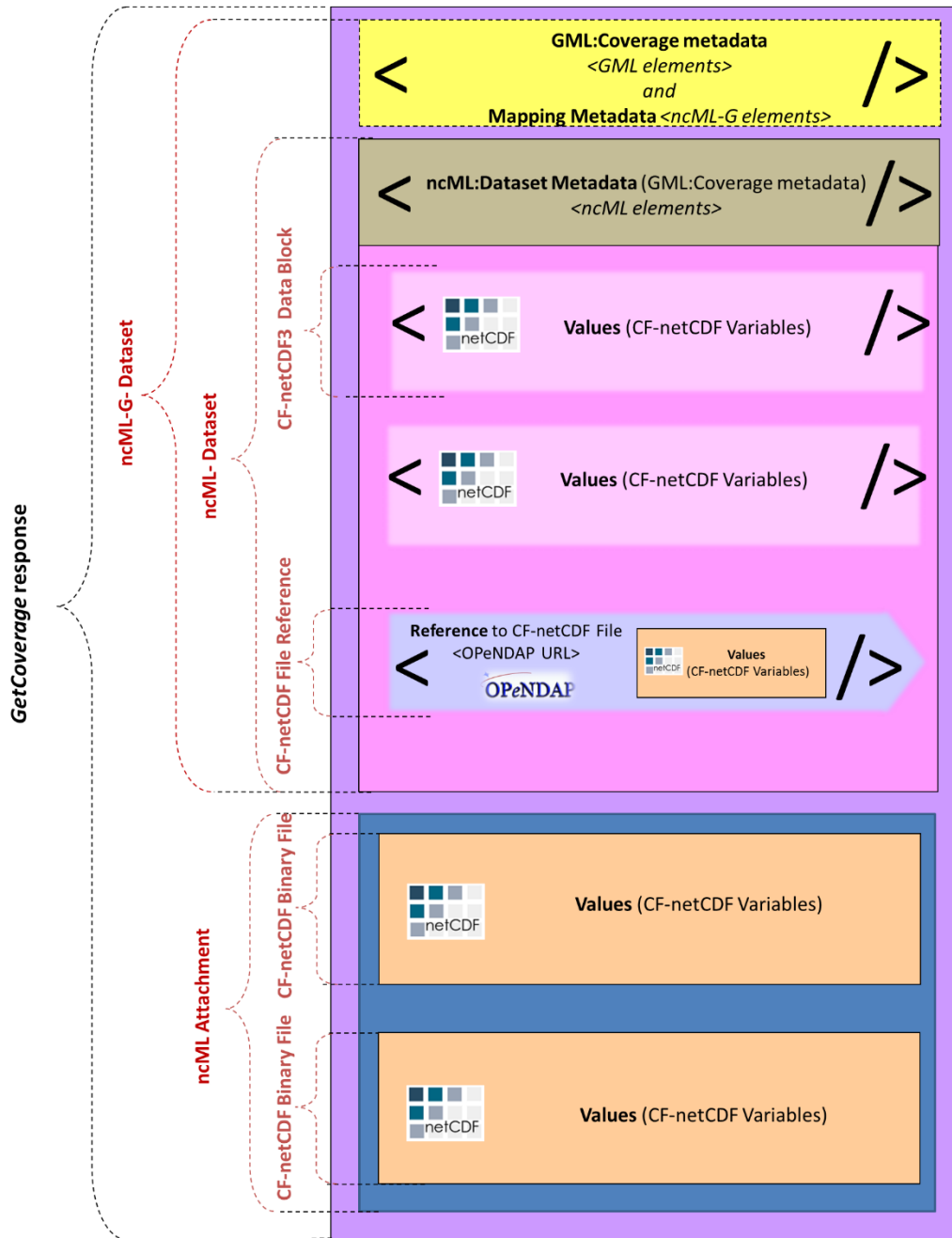
Figure 9. An example of service operation response returning a complex *ncML-Dataset*

This type of encoding allows to return very complex data packages. As to the considered example, the returned coverage (i.e. dataset) values are encoded as: (a) two ncML *DataBlocks* elements (encoding values defined in a couple of CF-netCDF binary files); (b) a Web address pointing to the values defined in a third CF-netCDF file; (c) binary attachments –i.e. the data values defined in a fourth and fifth CF-netCDF binary file enclosed as ncML binary attachments.

For *ncML-Dataset*, coverage metadata are encoded as ncML elements. Besides, the *ncML-G-Dataset* extension adds a related grid coverage description using the GML elements (see Figure 9); thus, the metadata elements mapping is explicitly reported.

8   WxS operation response message: Multipart data encoding

Multipart data encoding is a technique for transferring multiple contents inside a single HTTP (or HTTPS) Response. In the context of WxS *operation* response it can be adopted whenever a binary content must be transferred.

Different strategies should be adopted for the different possible protocol bindings and encoding formats. Table 5 shows the two possibilities:

Table 5. *Multipart possible strategies*

Case	Request	Target	Possible Responses	Specification
#1	SOAP	ncML-Dataset	SOAP with ncML Attachment	SOAP Messages with Attachments 1.2 / MTOM-XOP
#2	HTTP (GET or POST)	ncML-Dataset	MIME Multipart with ncML parts	MIME multipart/related

The WxS *operation* response can be encoded in a Multipart message. The encoding strategy is different depending on the use of SOAP or HTTP binding.

For multipart encoding of ncML-Dataset in SOAP responses, the MTOM-XOP specification is adopted according to the OGC "Web Services Common Standard" (OGC 06-121r9).

For multipart encoding of ncML-Dataset in HTTP responses the MIME Multipart/related standard is adopted.

Requirement 32   /req/CF-netCDF-1.6-Data-format/HTTP-multipart-encoding:
In a service operation successful response, a coverage returned in a HTTP (or HTTPS) multipart message **shall** be encoded as MIME Multipart/Related (RFC 2045, RFC 2046)

8.1 Case #1and #2: SOAP or HTTP Response returning ncML data

In case of ncML data the response can refer to a local or remote document. Local resources are always attached to the message, while remote resources can be attached as a copy to avoid multiple access. The HTTP or SOAP response must be encoded along with its attachments in a MIME Multipart/Related message using the rules described in Table 5. At least one multipart section will contain XML data instead of binary data.

Requirement 33 **/req/CF-netCDF-1.6-Data-format/SOAP-ncMLdata-multipart-encoding:**
In a service operation successful response, a coverage returned as ncML data in a SOAP multipart message **shall** be encoded with the SOAP Envelope section in the root part of the multipart message.

Requirement 34 **/req/CF-netCDF-1.6-Data-format/HTTP-ncMLdata-multipart-encoding:**
In a service operation successful response, a coverage returned as ncML data in a HTTP (or HTTPS) multipart message **shall** be encoded with the ncML metadata section in the root part of the multipart message.

An ncML dataset include either coverage data values or a pointer to them –i.e. a pointer to one or more netCDF binary files.

Therefore, returned ncML documents may directly encode coverage data values or point to one or more netCDF binary files. Example B.3.3 shows a response returning an ncML document which points to a netCDF binary file, which is included in the MIME Multipart/Related message. Both ncML and netCDF binary are remote resources referred by the SOAP document.

Examples B.3.1 and B.3.2 describe responses returning ncML documents which encode coverage data values.

Example B.3.3: SOAP Response returning an ncML document referring a netCDF binary file included in the message.

```
MIME-Version: 1.0

Content-Type: multipart/related; boundary="----=_NextPart_000_0000_93251752.3C5526C0"


------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/xml; charset="UTF-8"
```

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

<soap:Envelope xmlns:soap="http://www.w3.org/2001/12/soap-envelope">

 <soap:Header/>

 <soap:Body>

   <Coverages xmlns="http://www.opengis.net/wcs/1.1/ows" xmlns:ows="http://www.opengis.net/ows"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:schemaLocation="http://www.opengis.net/wcs/1.1/ows ../owsCoverages.xsd
http://www.opengis.net/ows ../../../ows/1.0.0/ows19115subset.xsd">

    <Coverage>

     <ows:Title>Example</ows:Title>

     <ows:Abstract>Example of coverage</ows:Abstract>

     <Identifier>Example</Identifier>

     <Reference href="cid:bfa8e8ac@example.net" />

     <Reference href="http://example.net/data/CoverageDataValues.nc" />

     <Reference href="http://example.net/data/Dataset.ncml" />

    </Coverage>

   </Coverages>

 </soap:Body>

</soap:Envelope>
```

------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/xml

Content-ID: <bfa8e8ac@example.net>

...(metadata content)...

------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/CF-netCDF

Content-Transfer-Encoding: base64

Content-ID: <c3499c27@example.net>

```
Content-Location: http://example.net/data/CoverageDataValues.nc……

...(netCDF binary data content, pointed by the ncML dataset)...

------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/ncML+xml

Content-Transfer-Encoding: base64

Content-ID: <1324bc12@example.net>

Content-Location: http://example.net/data/Dataset.ncml

…..

...( ncML dataset content)...

------=_NextPart_000_0000_93251752.3C5526C0--
```

NcML documents may contain coverage data values encoded as binary sections in base64 encoding. They can be left enclosed in the ncML document or, for efficiency purposes, they can be extracted and encoded in a format other than base64. Such improvement can be obtained serializing the ncML values element using nested multipart messages according to the MTOM/XOP specifications.

The following two encoding examples report multipart sections for ncML with binary data included and extracted using XOP, respectively.

Requirement 35   /req/CF-netCDF-1.6-Data-format/ncMLdata-binary-multipart-encoding:
In a service operation successful response, a coverage returned as ncML data in a multipart message **shall** encode binary values either as XML MIME inline content or as XOP section.

8.1.1   Binary data included

Example 8.1.1: Response excerpt showing a ncML dataset containing coverage data values encoded as a binary section in base64 encoding.

multipart section containing a ncML dataset with binary data included (section outlined by a pale blue background)

```
------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/CF-netCDF

Content-ID: <1324bc12@example.net>
```

Content-Location: http://example.net/data/data2.ncml

```xml
<?xml version="1.0" encoding="UTF-8"?>
<netcdf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">
  <dimension name="longitude" length="96"/>
  <dimension name="bounds_axis" length="2"/>
  <dimension name="latitude" length="73"/>
  <dimension name="air_pressure" length="15"/>
  <dimension name="time" length="140"/>
  <attribute name="Conventions" type="string" value="CF-1.1"/>
  <attribute name="source" type="string" value="Data from model run ABC123"/>
  <variable name="longitude" shape="longitude" type="double">
    <attribute name="standard_name" type="string" value="longitude"/>
    <attribute name="units" type="string" value="degrees_east"/>
    <attribute name="bounds" type="string" value="bound_longitude"/>
    <attribute name="axis" type="string" value="X"/>
    <values increment="3.75" npts="96" start="0.0"/>
  </variable>
  <variable name="bound_longitude" shape="longitude bounds_axis" type="double"> </variable>
  <variable name="latitude" shape="latitude" type="double">
    <attribute name="standard_name" type="string" value="latitude"/>
    <attribute name="units" type="string" value="degrees_north"/>
    <attribute name="bounds" type="string" value="bound_latitude"/>
    <attribute name="axis" type="string" value="Y"/>
    <values increment="-2.5" npts="73" start="90.0"/>
  </variable>
```

```xml
  <variable name="bound_latitude" shape="latitude bounds_axis" type="double"> </variable>

  <variable name="air_pressure" shape="air_pressure" type="float">

    <attribute name="standard_name" type="string" value="air_pressure"/>

    <attribute name="units" type="string" value="hPa"/>

    <attribute name="axis" type="string" value="Z"/>

    <attribute name="positive" type="string" value="down"/>

    <values increment="70.71429" npts="15" start="10.0"/>

  </variable>

  <variable name="time" shape="time" type="double">

    <attribute name="calendar" type="string" value="360_day"/>

    <attribute name="standard_name" type="string" value="time"/>

    <attribute name="units" type="string" value="days since 2289-1-1"/>

    <attribute name="bounds" type="string" value="bound_time"/>

    <attribute name="axis" type="string" value="T"/>

    <values increment="360.0" npts="140" start="510.0"/>

  </variable>

  <variable name="bound_time" shape="time bounds_axis" type="double"> </variable>

  <variable name="air_temperature" shape="time air_pressure latitude longitude" type="float">

    <attribute name="standard_name" type="string" value="air_temperature"/>

    <attribute name="units" type="string" value="Kir_temperature"/>

    <attribute name="long_name" type="string" value="temperature on pressure level"/>

    <attribute name="cell_methods" type="string" value="longitude: latitude: mean time: mean (interval: 4 h)"/>

    <attribute name="_FillValue" type="float" value="-1.073742e+09"/>
```
```xml
    <values xm:xmlmime="binary/octet-stream">Li4uKGJhc2U2NCBlbmNvZGVkIGRhdGEpLi4u...(base64 encoded data)...BlbmNvZGVkIGRhdGEpLi4u==</values>
```
```xml
  </variable>

</netcdf>
```

------=_NextPart_000_0000_93251752.3C5526C0--

8.1.2   Binary extracted using XOP

Example 8.1.2: HTTP Multipart/Related response showing a ncML dataset containing coverage data values extracted and encoded in a format other than base64 by serializing the <values> element using nested multipart messages according to the MTOM/XOP specifications.

multipart section containing a ncML dataset with binary data extracted using XOP (section outlined by a pale blue background)

------=_NextPart_000_0000_93251752.3C5526C0

MIME-Version: 1.0

Content-Type: Multipart/Related;boundary=MIME_boundary; type="application/xop+xml";

   start="<12dea45c@example.net >";

   startinfo="application/ncML+xml";

--MIME_boundary

Content-Type: application/xop+xml; charset=UTF-8;

   type="application/ncML+xml; action=\"ProcessData\""

Content-ID: <12dea45c@example.net>

Content-Location: http://example.net/data/data2.ncml

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

<netcdf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

   xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">

   <dimension name="longitude" length="96"/>

   <dimension name="bounds_axis" length="2"/>

   <dimension name="latitude" length="73"/>

   <dimension name="air_pressure" length="15"/>

```xml
<dimension name="time" length="140"/>

<attribute name="Conventions" type="string" value="CF-1.1"/>

<attribute name="source" type="string" value="Data from model run ABC123"/>

<variable name="longitude" shape="longitude" type="double">

  <attribute name="standard_name" type="string" value="longitude"/>

  <attribute name="units" type="string" value="degrees_east"/>

  <attribute name="bounds" type="string" value="bound_longitude"/>

  <attribute name="axis" type="string" value="X"/>

  <values increment="3.75" npts="96" start="0.0"/>

</variable>

<variable name="bound_longitude" shape="longitude bounds_axis" type="double"> </variable>

<variable name="latitude" shape="latitude" type="double">

  <attribute name="standard_name" type="string" value="latitude"/>

  <attribute name="units" type="string" value="degrees_north"/>

  <attribute name="bounds" type="string" value="bound_latitude"/>

  <attribute name="axis" type="string" value="Y"/>

  <values increment="-2.5" npts="73" start="90.0"/>

</variable>

<variable name="bound_latitude" shape="latitude bounds_axis" type="double"> </variable>

<variable name="air_pressure" shape="air_pressure" type="float">

  <attribute name="standard_name" type="string" value="air_pressure"/>

  <attribute name="units" type="string" value="hPa"/>

  <attribute name="axis" type="string" value="Z"/>

  <attribute name="positive" type="string" value="down"/>

  <values increment="70.71429" npts="15" start="10.0"/>

</variable>

<variable name="time" shape="time" type="double">
```

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```
                <attribute name="calendar" type="string" value="360_day"/>

                <attribute name="standard_name" type="string" value="time"/>

                <attribute name="units" type="string" value="days since 2289-1-1"/>

                <attribute name="bounds" type="string" value="bound_time"/>

                <attribute name="axis" type="string" value="T"/>

                <values increment="360.0" npts="140" start="510.0"/>

        </variable>

        <variable name="bound_time" shape="time bounds_axis" type="double"> </variable>

        <variable name="air_temperature" shape="time air_pressure latitude longitude" type="float">

                <attribute name="standard_name" type="string" value="air_temperature"/>

                <attribute name="units" type="string" value="Kir_temperature"/>

                <attribute name="long_name" type="string" value="temperature on pressure level"/>

                <attribute name="cell_methods" type="string" value="longitude: latitude: mean time: mean (interval:
4 h)"/>

                <attribute name="_FillValue" type="float" value="-1.073742e+09"/>

                <values xm:xmlmime="binary/octet-stream"><xop:Include

        xmlns:xop='http://www.w3.org/2004/08/xop/include'

        href='cid:bd43gh2y@example.net'/>

                </values>

        </variable>

</netcdf>

--MIME_boundary

Content-Type: application/octet-stream

Content-Transfer-Encoding: binary

Content-ID: <bd43gh2y@example.net>

….

...(binary encoded data)...

--MIME_boundary--
```

```
------=_NextPart_000_0000_93251752.3C5526C0--
```

8.2 Content-ID generation

The RFC 2045 and RFC 2046 describe the use of the Content-ID header to identify the different sections of a multipart message. It allows cross-reference of sections, but since it is not required for all the usages, it is specified as optional. In some cases the Content-Location header can be used for the same objective. For netCDF datasets the cross-reference between sections (e.g. between metadata and binary section) is required, therefore the presence of the Content-ID is considered mandatory.

Requirement 36   **/req/CF-netCDF-1.6-Data-format/netCDF-multipart-encoding-id:** In a service operation successful response, a coverage returned as multipart message **shall** identify each multipart section with a valid "Content-ID" header.

According to [RFC 2045] "Content-ID values must be generated to be world-unique". In WxS operation responses it is suggested that Content-ID has the following format:

Content-ID : = Local "@" Domain

where Local is a locally unique identifier and Domain is an Internet domain administered by the coverages provider. The domain names assignment process assures the unicity. The locally unique identifier is opaque, meaning that no semantics is associated to the local name. For example it could be generated with a hashing function from coverages metadata.

8.3 OWS Common Manifest

According to the OGC "Web Services Common Standard" (OGC 06-121r9), if the coverage dataset is provided with a Manifest the message can be encoded as Multipart/Related. In such case the manifest is in the root part, while the netCDF coverage is encoded in other sections. Exploiting the recursive structure of multipart messages, the netCDF sections can be structured as explained above in SOAP or HTTP multipart sub-messages.

Annex A: Conformance Class Abstract Test Suite (Normative)

A CF-netCDF 3.0 encoding using GML 3.2.1 Coverage application schema must satisfy the following system characteristics to be conformant with this specification.

A.1 Conformance Test Classes: CF-netCDF-1.6

This document establishes three conformance classes *CF-netCDF ver 1.6 GML encoding instance*, with URIs:

1. http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding
2. http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format
3. http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Multipart-encoding

A.2 CF-netCDF-1.6-GML-encoding conformance class

This is the *GML encoding* conformance class for this standard.

There is a dependency on: *CF-netCDF Data Model extension specification* (OGC 11-165r2), *Geography Markup Language (GML) Encoding Standard*, version 3.2.1 (OGC 07-036), and *OGC® GML Application Schema for Coverages* (OGC 09-146r1)

The following clauses relate to the conformance class identified with the URI: http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding

Conformance Class	
http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding	
Requirements	**http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding**
Dependency	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-ISOMapping *Geography Markup Language (GML) Encoding Standard, version 3.2.1 (OGC 07-036)* *OGC® GML Application Schema for Coverages (OGC 09-146r1)*
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/CF-dataset

	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/CF-dataset
	Test purpose	CF-netCDF datasets, its subtypes and its realizations CF-netCDF RaggedArray and CF-netCDF MultidimensionalArray shall realize one of the following GMLCOV:Coverage subtypes: GMLCOV:GridCoverage, GMLCOV:RectifiedGridCoverage, GMLCOV:ReferenceableGridCoverage, GMLCOV:MultiPointCoverage.
	Test method	verify that the CF-netCDF datasets, its subtypes and its realizations (i.e. CF-netCDF RaggedArray and CF-netCDF MultidimensionalArray) realize one of the following GMLCOV:Coverage subtypes: GMLCOV:GridCoverage, GMLCOV:RectifiedGridCoverage, GMLCOV:ReferenceableGridCoverage, GMLCOV:MultiPointCoverage.
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.domainSet#1
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.domainSet#1
	Test purpose	The set of spatial/temporal CF_CoordinateVariable (comprised of a common coordinate system) that characterize a CF-netCDF dataset, shall realize a GML:Coverage.domainSet property, implemented as: GML:MultiPoint, GML:Grid object or its subtypes: GML:RectifiedGrid, GML:ReferenceableGrid.
	Test method	Verify that the set of spatial/temporal CF_CoordinateVariable (comprised of a common coordinate system) that characterize a CF-netCDF dataset, realize a GML:Coverage.domainSet property, implemented as: GML:MultiPoint, GML:Grid object or its subtypes: GML:RectifiedGrid, GML:ReferenceableGrid
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.domainSet#2
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.domainSet#2
	Test purpose	If the spatial/temporal domain is defined by auxiliary variables, the set of spatial/temporal CF_AuxiliaryCoordinateVariable that characterizes a CF-netCDF Variable, shall realize a GML:Coverage.domainSet property, implemented as: GML:MultiPoint, GML:Grid object or its subtypes: GML:RectifiedGrid, GML:ReferenceableGrid.

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	Test method	If the spatial/temporal domain is defined by auxiliary variables, verify that the set of spatial/temporal CF_AuxiliaryCoordinateVariable that characterizes a CF-netCDF Variable, realizes a GML:Coverage.domainSet property, implemented as: GML:MultiPoint, GML:Grid object or its subtypes: GML:RectifiedGrid, GML:ReferenceableGrid.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.coverageFunction#1	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.coverageFunction#1
	Test purpose	If the mapping from the domain to the range of the coverage is not characterized by the default values for GML:Coverage (see [7]), the set of spatial/temporal CF_CoordinateVariable (comprised of a common coordinate system) that characterizes a CF-netCDF dataset shall realize a GML:Coverage.coverageFunction property, implemented as either a GML:CoverageFunction.GridFunction or a GML:CoverageFunction.CoverageMappingRule object.
	Test method	If the mapping from the domain to the range of the coverage is not characterized by the default values for GML:Coverage (see [7]), verify that the set of spatial/temporal CF_CoordinateVariable (comprised of a common coordinate system) that characterizes a CF-netCDF dataset realizes a GML:Coverage.coverageFunction property, implemented as either a GML:CoverageFunction.GridFunction or a GML:CoverageFunction.CoverageMappingRule object.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.coverageFunction#2	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.coverageFunction#2
	Test purpose	If the spatial/temporal domain is defined by auxiliary variables, the set of spatial/temporal CF_AuxiliaryCoordinateVariable that characterizes one or more CF-netCDF Variables shall realize a GML:Coverage.coverageFunction property, implemented as either a GML:CoverageFunction.GridFunction or a GML:CoverageFunction.CoverageMappingRule object.
	Test method	If the spatial/temporal domain is defined by auxiliary variables, verify that the set of spatial/temporal CF_AuxiliaryCoordinateVariable that characterizes one or more CF-netCDF Variables realizes a GML:Coverage.coverageFunction property, implemented as either a GML:CoverageFunction.GridFunction or a

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		GML:CoverageFunction.CoverageMappingRule object.
Test	__	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.rangeSet
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.rangeSet
	Test purpose	The set of CF-netCDF CF_Variable that share a common spatial/temporal coordinate system, shall realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
	Test method	Verify that the set of CF-netCDF CF_Variable that shares a common spatial/temporal coordinate system, realizes a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
Test	__	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.rangeType
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.rangeType
	Test purpose	The set of CF-netCDF CF_Variable that share a common spatial/temporal coordinate system, shall realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
	Test method	Verify that the set of CF-netCDF CF_Variable that shares a common spatial/temporal coordinate system, realizes a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
Test	__	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.parametric-rangeSet
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.parametric-rangeSet
	Test purpose	The set of CF_AuxiliaryCoordinateVariable, which are not space or time dimension, shall contribute to realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
	Test method	Verify that the set of CF_AuxiliaryCoordinateVariable, which are not space or time dimension, contribute to realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
Test	__	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.parametric-rangeType

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	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.parametric-rangeType
	Test purpose	The set of CF_AuxiliaryCoordinateVariable, which are not space or time dimension, shall contribute to realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
	Test method	Verify that the set of CF_AuxiliaryCoordinateVariable, which are not space or time dimension, contribute to realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy
	Test purpose	The spatial/temporal CoordinateSystem, which is comprised of either spatial and temporal CF_CoordinateVariable objects or spatial and temporal CF_AuxiliaryCoordinateVariable objects, shall realize a GML:Coverage.boundedBy property, implemented as a GML:Envelope object or its subtype GML:EnvelopeWithTimePeriod. Additionally, the attribute GML:Envelope.srsName shall have a value.
	Test method	Verify that the spatial/temporal CoordinateSystem, which is comprised of either spatial and temporal CF_CoordinateVariable objects or spatial and temporal CF_AuxiliaryCoordinateVariable objects, realizes a GML:Coverage.boundedBy property, implemented as a GML:Envelope object or its subtype GML:EnvelopeWithTimePeriod. Additionally, verify that the attribute GML:Envelope.srsName has a value.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.axisLabels#1	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.axisLabels#1

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	Test purpose	The set of spatial/temporal CF_CoordinateVariable comprised of a CoordinateSystem object, shall realize a GML:Envelope.axisLabels object or its subtype GML:EnvelopeWithTimePeriod.axisLabels.
	Test method	Verify that the set of spatial/temporal CF_CoordinateVariable comprised of a CoordinateSystem object, realizes a GML:Envelope.axisLabels object or its subtype GML:EnvelopeWithTimePeriod.axisLabels.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.axisLabels#2	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.axisLabels#2
	Test purpose	The set of spatial/temporal CF_Auxiliary CoordinateVariable, comprised of a CoordinateSystem object related to CF_Variables, shall realize a GML:Envelope.axisLabels object or its subtype GML:EnvelopeWithTimePeriod.axisLabels.
	Test method	Verify that the set of spatial/temporal CF_Auxiliary CoordinateVariable, comprised of a CoordinateSystem object related to CF_Variables, realizes a GML:Envelope.axisLabels object or its subtype GML:EnvelopeWithTimePeriod.axisLabels.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.CRS	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/Dataset.boundedBy.CRS
	Test purpose	The CF-netCDF GridMappingVariable shall determine the subype of GML_AbstractCRS pointed by the GML:Envelope.srsName attribute.
	Test method	Verify that the CF-netCDF GridMappingVariable determines the subype of GML_AbstractCRS pointed by the GML:Envelope.srsName attribute.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/InstanceVariable	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/InstanceVariable
	Test purpose	Each CF_InstanceVariable object shall be encoded as a spatial/temporal CF_AuxiliaryCooridnateVariable which has as only dimension the "instance" dimension.

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	Test method	Verify that each CF_InstanceVariable object is encoded as a spatial/temporal CF_AuxiliaryCooridnateVariable which has as only dimension the "instance" dimension.
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#1
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#1
	Test purpose	Each CF_MultidimensionalArray.InstanceDimension object shall contribute to realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
	Test method	Verify that each CF_MultidimensionalArray.InstanceDimension object contributes to realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#2
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#2
	Test purpose	Each CF_MultidimensionalArray.InstanceDimension object shall contribute to realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
	Test method	Verify that each CF_MultidimensionalArray.InstanceDimension object contributes to realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/ RangeInstanceDimension#3
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/ RangeInstanceDimension#3
	Test purpose	Each CF_RaggedArray.SampleDimension object along with associated CF_IndexVariable or CF_CountVariable shall contribute to realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
	Test method	Verify that each CF_RaggedArray.SampleDimension object along with associated CF_IndexVariable or CF_CountVariable contributes to realize a GML:Coverage.rangeSet property, implemented as a GML:RangeSet object.
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-

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		encoding/RangeInstanceDimension#4
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/RangeInstanceDimension#4
	Test purpose	Each CF_RaggedArray.SampleDimension object along with associated CF_IndexVariable or CF_CountVariable shall contribute to realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
	Test method	Verify that each CF_RaggedArray.SampleDimension object along with associated CF_IndexVariable or CF_CountVariable contributes to realize a GML:Coverage.rangeType property, implemented as a SWE:DataRecord object.
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/PointFeatureCollection.axisLabels
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/PointFeatureCollection.axisLabels
	Test purpose	Each CF_Point FeatureCollection shall realize a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y t"	"lat lon t"	"lon lat t".
	Test method	Verify that each CF_Point FeatureCollection realizes a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y t"	"lat lon t"	"lon lat t".
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/TimeSerieFeatureCollection.axisLabels
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/TimeSerieFeatureCollection.axisLabels
	Test purpose	Each CF_TimeSerie FeatureCollection shall realize a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y t"	"lat lon t"	"lon lat t".
	Test method	Verify that each CF_TimeSerie FeatureCollection realizes a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y t"	"lat lon t"	"lon lat t".
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/TrajectoryFeatureCollection.axisLabels
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/TrajectoryFeatureCollection.axisLabels

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	Test purpose	Each CF_Trajectory FeatureCollection shall realize a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y t" | "lat lon t" | "lon lat t".
	Test method	Verify that each CF_Trajectory FeatureCollection realizes a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y t" | "lat lon t" | "lon lat t".
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/ProfileFeatureCollection.axisLabels
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/ProfileFeatureCollection.axisLabels
	Test purpose	Each CF_Profile FeatureCollection shall realize a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y z t" | "lat lon z t" | "lon lat z t".
	Test method	Verify that each CF_Profile FeatureCollection realizes a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y z t" | "lat lon z t" | "lon lat z t".
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/TimeSeriesProfileFeatureCollection.axisLabels
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/TimeSeriesProfileFeatureCollection.axisLabels
	Test purpose	Each CF_TimeSeriesProfile FeatureCollection shall realize a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y z t" | "lat lon z t" | "lon lat z t".
	Test method	Verify that each CF_TimeSeriesProfile FeatureCollection realizes a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y z t" | "lat lon z t" | "lon lat z t".
Test		http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding/TrajectoryProfileFeatureCollection.axisLabels
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-GML-encoding/TrajectoryProfileFeatureCollection.axisLabels
	Test purpose	Each CF_TrajectoryProfile FeatureCollection shall realize a GML:EnvelopeWithTimePeriod.axisLabels with value equal to "x y z t" | "lat lon z t" | "lon lat z t".
	Test method	Verify that each CF_TrajectoryProfile FeatureCollection realizes a GML:EnvelopeWithTimePeriod.axisLabels with

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		value equal to "x y z t" | "lat lon z t" | "lon lat z t".

A.3   CF-netCDF-1.6-Data-format conformance class

This is the *data format* conformance class for this standard.

There is a dependency on the *GML encoding* conformance class of this standard (see A.2).

The following clauses relate to the conformance class identified with the URI: http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format

Conformance Class		
http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format		
Requirements	**http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format**	
Dependency	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-GML-encoding	
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/ServiceOperationResponse	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/ServiceOperationResponse
	Test purpose	Any service operation response returning successfully a CF-netCDF dataset, shall return a concrete sub-type of the GMLCOV:Coverage class, as showed in Figure 4.
	Test method	Verify that any service operation response returning successfully a CF-netCDF dataset, returns a concrete sub-type of the GMLCOV:Coverage class, as showed in Figure 4.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/coverageFormat-structure	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/coverageFormat-structure
	Test purpose	The CF-netCDF data format used to return requested GMLCOV:Coverages shall adhere to Figure 8.

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	Test method	Verify that the CF-netCDF data format used to return requested GMLCOV:Coverages adheres to Figure 8.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/coverages-format	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/coverages-format
	Test purpose	For a WxS service implementing this extension, the contents of the response to a successful GetCoverage request shall be encoded in one of the following coverage encoding formats: CF-netCDF-File, CF-netCDF-64bit-File, ncML-Dataset, GML-3.2.1-Coverage, ncML-G-Dataset, Web-address.
	Test method	Verify that for any WxS service implementing this extension, the content of the response to a successful GetCoverage request is encoded in one of the following coverage encoding formats: CF-netCDF-File, CF-netCDF-64bit-File, ncML-Dataset, GML-3.2.1-Coverage, ncML-G-Dataset, Web-address.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/binaryFile-MIME-type	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/binaryFile-MIME-type
	Test purpose	WxS server implementing this specification shall use the following MIME type string to refer to CF-netCDF binary encoding: "application/CF-netCDF".
	Test method	Verify that any WxS server implementing this specification uses the following MIME type string to refer to CF-netCDF binary encoding: "application/CF-netCDF".
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/ncML-Dataset-MIME-type	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/ncML-Dataset-MIME-type
	Test purpose	WxS server implementing this specification shall use the following MIME type string to refer to ncML-Dataset encoding: "application/ncML+xml".
	Test method	Verify that any WxS server implementing this specification uses the following MIME type string to refer to ncML-Dataset encoding: "application/ncML+xml".
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-	

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	format/Web-address-reference	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/Web-address-reference
	Test purpose	WxS server implementing this specification shall use a MIME type string to refer to a well-known Web address syntax".
	Test method	Verify that any WxS server implementing this specification uses a MIME type string to refer to a well-known Web address syntax".
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/Web-address-encoding	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/Web-address-encoding
	Test purpose	In a service operation successful response, a coverage returned as a generic Web address shall be encoded as an HTML document containing the HTTP URL.
	Test method	Verify that in a service operation successful response, a coverage returned as a generic Web address is encoded as an HTML document containing the HTTP URL.

A.4 CF-netCDF-1.6-Multipart-encoding conformance class

This is the *multipart data encoding* conformance class for this standard.

There is a dependency on the *data format* conformance class of this standard (see A.3).

The following clauses relate to the conformance class identified with the URI:
http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Multipart-encoding

Conformance Class	
http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Multipart-encoding	
Requirements	**http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Multipart-encoding**
Dependency	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-

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	format	
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/HTTP-multipart-encoding	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/HTTP-multipart-encoding
	Test purpose	In a service operation successful response, a coverage returned in a HTTP (or HTTPS) multipart message shall be encoded as MIME Multipart/Related (RFC 2045, RFC 2046).
	Test method	Verify that in a service operation successful response, a coverage returned in a HTTP (or HTTPS) multipart message is encoded as MIME Multipart/Related (RFC 2045, RFC 2046).
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/SOAP-ncMLdata-multipart-encoding	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/SOAP-ncMLdata-multipart-encoding
	Test purpose	In a service operation successful response, a coverage returned as ncML data in a SOAP multipart message shall be encoded with the SOAP Envelope section in the root part of the multipart message.
	Test method	Verify that in a service operation successful response, a coverage returned as ncML data in a SOAP multipart message is encoded with the SOAP Envelope section in the root part of the multipart message.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/HTTP-ncMLdata-multipart-encoding	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/HTTP-ncMLdata-multipart-encoding
	Test purpose	In a service operation successful response, a coverage returned as ncML data in a HTTP multipart message shall be encoded with the ncML metadata section in the root part of the multipart message.
	Test method	Verify that in a service operation successful response, a coverage returned as ncML data in a HTTP (or HTTPS) multipart message is encoded with the ncML metadata section in the root part of the multipart message.

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Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/ncMLdata-binary-multipart-encoding	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/ncMLdata-binary-multipart-encoding
	Test purpose	In a service operation successful response, a coverage returned as ncML data in a multipart message shall encode binary values either as XML MIME inline content or as XOP section.
	Test method	Verify that in a service operation successful response, a coverage returned as ncML data in a multipart message encodes binary values either as XML MIME inline content or as XOP section.
Test	http://www.opengis.net/spec/netCDF_data-model/conf/CF-netCDF-1.6-Data-format/netCDF-multipart-encoding-id	
	Requirement	http://www.opengis.net/spec/netCDF_data-model/req/CF-netCDF-1.6-Data-format/netCDF-multipart-encoding-id
	Test purpose	In a service operation successful response, a coverage returned as multipart message shall identify each multipart section with a valid "Content-ID" header.
	Test method	Verify that in a service operation successful response, a coverage returned as multipart message identifies each multipart section with a valid "Content-ID" header.

Annex B: Examples

The following paragraphs collect the examples used and explained throughout the document.

B.1. Example: netCDF ver. 3 with CF1.1 convention dataset

```
netcdf air_temperature {

dimensions:

        longitude = 96 ;

        bounds_axis = 2 ;

        latitude = 73 ;

        air_pressure = 15 ;

        time = 140 ;

variables:

        double longitude(longitude) ;

                longitude:standard_name = "longitude" ;

                longitude:units = "degrees_east" ;

                longitude:bounds = "bound_longitude" ;

                longitude:axis = "X" ;

                double bound_longitude(longitude, bounds_axis) ;

        double latitude(latitude) ;

                latitude:standard_name = "latitude" ;

                latitude:units = "degrees_north" ;

                latitude:bounds = "bound_latitude" ;

                latitude:axis = "Y" ;

                double bound_latitude(latitude, bounds_axis) ;

        float air_pressure(air_pressure) ;

                air_pressure:standard_name = "air_pressure" ;

                air_pressure:units = "hPa" ;

                air_pressure:axis = "Z" ;
```

```
                    air_pressure:positive = "down" ;

        double time(time) ;

                time:calendar = "360_day" ;

                time:standard_name = "time" ;

                time:units = "days since 2289-1-1" ;

                time:bounds = "bound_time" ;

                time:axis = "T" ;

                double bound_time(time, bounds_axis) ;

        float air_temperature(time, air_pressure, latitude, longitude) ;

                air_temperature:standard_name = "air_temperature" ;

                air_temperature:units = "K" ;

                air_temperature:long_name = "temperature on pressure levels" ;

                air_temperature:cell_methods = "longitude: latitude: mean time: mean (interval: 4 h)" ;

                air_temperature:_FillValue = -1.073742e+09f ;


// global attributes:

                :Conventions = "CF-1.1" ;

                :source = "Data from model run ABC123" ;

data:


 longitude = 0, 3.75, 7.5, 11.25, 15, 18.75, 22.5, 26.25, 30, 33.75, 37.5,

   41.25, 45, 48.75, 52.5, 56.25, 60, 63.75, 67.5, 71.25, 75, 78.75, 82.5,

   86.25, 90, 93.75, 97.5, 101.25, 105, 108.75, 112.5, 116.25, 120, 123.75,

   127.5, 131.25, 135, 138.75, 142.5, 146.25, 150, 153.75, 157.5, 161.25,

   165, 168.75, 172.5, 176.25, 180, 183.75, 187.5, 191.25, 195, 198.75,

   202.5, 206.25, 210, 213.75, 217.5, 221.25, 225, 228.75, 232.5, 236.25,

   240, 243.75, 247.5, 251.25, 255, 258.75, 262.5, 266.25, 270, 273.75,

   277.5, 281.25, 285, 288.75, 292.5, 296.25, 300, 303.75, 307.5, 311.25,
```

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```
315, 318.75, 322.5, 326.25, 330, 333.75, 337.5, 341.25, 345, 348.75,

352.5, 356.25 ;
```

B.2.   Example for an ncML dataset

```xml
<?xml version="1.0" encoding="UTF-8"?>
<netcdf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">
  <dimension name="longitude" length="96"/>
  <dimension name="bounds_axis" length="2"/>
  <dimension name="latitude" length="73"/>
  <dimension name="air_pressure" length="15"/>
  <dimension name="time" length="140"/>
  <attribute name="Conventions" type="string" value="CF-1.1"/>
  <attribute name="source" type="string" value="Data from model run ABC123"/>
  <variable name="longitude" shape="longitude" type="double">
    <attribute name="standard_name" type="string" value="longitude"/>
    <attribute name="units" type="string" value="degrees_east"/>
    <attribute name="bounds" type="string" value="bound_longitude"/>
    <attribute name="axis" type="string" value="X"/>
    <values increment="3.75" npts="96" start="0.0"/>
  </variable>
  <variable name="bound_longitude" shape="longitude bounds_axis" type="double"> </variable>
  <variable name="latitude" shape="latitude" type="double">
    <attribute name="standard_name" type="string" value="latitude"/>
    <attribute name="units" type="string" value="degrees_north"/>
    <attribute name="bounds" type="string" value="bound_latitude"/>
    <attribute name="axis" type="string" value="Y"/>
    <values increment="-2.5" npts="73" start="90.0"/>
  </variable>
  <variable name="bound_latitude" shape="latitude bounds_axis" type="double"> </variable>
  <variable name="air_pressure" shape="air_pressure" type="float">
    <attribute name="standard_name" type="string" value="air_pressure"/>
    <attribute name="units" type="string" value="hPa"/>
    <attribute name="axis" type="string" value="Z"/>
    <attribute name="positive" type="string" value="down"/>
    <values increment="70.71429" npts="15" start="10.0"/>
  </variable>
  <variable name="time" shape="time" type="double">
    <attribute name="calendar" type="string" value="360_day"/>
    <attribute name="standard_name" type="string" value="time"/>
    <attribute name="units" type="string" value="days since 2289-1-1"/>
    <attribute name="bounds" type="string" value="bound_time"/>
    <attribute name="axis" type="string" value="T"/>
    <values increment="360.0" npts="140" start="510.0"/>
  </variable>
  <variable name="bound_time" shape="time bounds_axis" type="double"> </variable>
  <variable name="air_temperature" shape="time air_pressure latitude longitude" type="float">
    <attribute name="standard_name" type="string" value="air_temperature"/>
    <attribute name="units" type="string" value="Kir_temperature"/>
    <attribute name="long_name" type="string" value="temperature on pressure level"/>
```

```
    <attribute name="cell_methods" type="string" value="longitude: latitude: mean time: mean (interval:
4 h)"/>
    <attribute name="_FillValue" type="float" value="-1.073742e+09"/>
  </variable>
</netcdf>
```

B.3.   GetCoverage response encoding examples

This section details examples of GetCoverage response encodings based on SOAP and Multipart-related technology. -

B.3.1.   SOAP Response returning an ncML document referring a netCDF binary file included in the message

```
MIME-Version: 1.0

Content-Type: multipart/related; boundary="----=_NextPart_000_0000_93251752.3C5526C0"



------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/xml; charset="UTF-8"



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

<soap:Envelope xmlns:soap="http://www.w3.org/2001/12/soap-envelope">

 <soap:Header/>

 <soap:Body>

   <Coverages xmlns="http://www.opengis.net/wcs/1.1/ows" xmlns:ows="http://www.opengis.net/ows"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:schemaLocation="http://www.opengis.net/wcs/1.1/ows ../owsCoverages.xsd
http://www.opengis.net/ows ../../../ows/1.0.0/ows19115subset.xsd">

    <Coverage>

     <ows:Title>Example</ows:Title>

     <ows:Abstract>Example of coverage</ows:Abstract>

     <Identifier>Example</Identifier>

     <Reference href="cid:bfa8e8ac@example.net" />
```

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```
    <Reference href="http://example.net/data/CoverageDataValues.nc" />

    <Reference href="http://example.net/data/Dataset.ncml" />

  </Coverage>

 </Coverages>

 </soap:Body>

</soap:Envelope>

------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/xml

Content-ID: <bfa8e8ac@example.net>


...(metadata content)...

------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/CF-netCDF

Content-Transfer-Encoding: base64

Content-ID: <c3499c27@example.net>

Content-Location: http://example.net/data/CoverageDataValues.nc……

...(netCDF binary data content, pointed by the ncML dataset)...

------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/ ncML+xml

Content-Transfer-Encoding: base64

Content-ID: <1324bc12@example.net>

Content-Location: http://example.net/data/Dataset.ncml

…..

...( ncML dataset content)...

------=_NextPart_000_0000_93251752.3C5526C0--
```

C.3.4 Multipart section containing ncML with binary data included

```
------=_NextPart_000_0000_93251752.3C5526C0

Content-Type: application/CF-netCDF

Content-Transfer-Encoding: base64

Content-ID: <1324bc12@example.net>

Content-Location: http://example.net/data/data2.ncml


<?xml version="1.0" encoding="UTF-8"?>
<netcdf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

  xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">

  <dimension name="longitude" length="96"/>

  <dimension name="bounds_axis" length="2"/>

  <dimension name="latitude" length="73"/>

  <dimension name="air_pressure" length="15"/>

  <dimension name="time" length="140"/>

  <attribute name="Conventions" type="string" value="CF-1.1"/>

  <attribute name="source" type="string" value="Data from model run ABC123"/>

  <variable name="longitude" shape="longitude" type="double">

    <attribute name="standard_name" type="string" value="longitude"/>

    <attribute name="units" type="string" value="degrees_east"/>

    <attribute name="bounds" type="string" value="bound_longitude"/>

    <attribute name="axis" type="string" value="X"/>

    <values increment="3.75" npts="96" start="0.0"/>

  </variable>

  <variable name="bound_longitude" shape="longitude bounds_axis" type="double"> </variable>

  <variable name="latitude" shape="latitude" type="double">

    <attribute name="standard_name" type="string" value="latitude"/>
```

```xml
    <attribute name="units" type="string" value="degrees_north"/>

    <attribute name="bounds" type="string" value="bound_latitude"/>

    <attribute name="axis" type="string" value="Y"/>

    <values increment="-2.5" npts="73" start="90.0"/>

  </variable>

  <variable name="bound_latitude" shape="latitude bounds_axis" type="double"> </variable>

  <variable name="air_pressure" shape="air_pressure" type="float">

    <attribute name="standard_name" type="string" value="air_pressure"/>

    <attribute name="units" type="string" value="hPa"/>

    <attribute name="axis" type="string" value="Z"/>

    <attribute name="positive" type="string" value="down"/>

    <values increment="70.71429" npts="15" start="10.0"/>

  </variable>

  <variable name="time" shape="time" type="double">

    <attribute name="calendar" type="string" value="360_day"/>

    <attribute name="standard_name" type="string" value="time"/>

    <attribute name="units" type="string" value="days since 2289-1-1"/>

    <attribute name="bounds" type="string" value="bound_time"/>

    <attribute name="axis" type="string" value="T"/>

    <values increment="360.0" npts="140" start="510.0"/>

  </variable>

  <variable name="bound_time" shape="time bounds_axis" type="double"> </variable>

  <variable name="air_temperature" shape="time air_pressure latitude longitude" type="float">

    <attribute name="standard_name" type="string" value="air_temperature"/>

    <attribute name="units" type="string" value="Kir_temperature"/>

    <attribute name="long_name" type="string" value="temperature on pressure level"/>

    <attribute name="cell_methods" type="string" value="longitude: latitude: mean time: mean (interval:
4 h)"/>
```

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```
     <attribute name="_FillValue" type="float" value="-1.073742e+09"/>

     <values xm:xmlmime="binary/octet-
stream">Li4uKGJhc2U2NCBlbmNvZGVkIGRhdGEpLi4u...(base64 encoded
data)...BlbmNvZGVkIGRhdGEpLi4u==</values>

   </variable>

</netcdf>

------=_NextPart_000_0000_93251752.3C5526C0--
```

B.3.3.   C.3.5 Multipart section containing ncML with binary data extracted using XOP

```
------=_NextPart_000_0000_93251752.3C5526C0

MIME-Version: 1.0

Content-Type: Multipart/Related;boundary=MIME_boundary;  type="application/xop+xml";

   start="<12dea45c@example.net >";

   startinfo="application/ncML+xml";


--MIME_boundary

Content-Type: application/xop+xml; charset=UTF-8;

   type="application/ncML+xml; action=\"ProcessData\""

Content-ID: <12dea45c@example.net>

Content-Location: http://example.net/data/data2.ncml


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

<netcdf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

   xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">

   <dimension name="longitude" length="96"/>

   <dimension name="bounds_axis" length="2"/>

   <dimension name="latitude" length="73"/>

   <dimension name="air_pressure" length="15"/>
```

```xml
<dimension name="time" length="140"/>

<attribute name="Conventions" type="string" value="CF-1.1"/>

<attribute name="source" type="string" value="Data from model run ABC123"/>

<variable name="longitude" shape="longitude" type="double">

  <attribute name="standard_name" type="string" value="longitude"/>

  <attribute name="units" type="string" value="degrees_east"/>

  <attribute name="bounds" type="string" value="bound_longitude"/>

  <attribute name="axis" type="string" value="X"/>

  <values increment="3.75" npts="96" start="0.0"/>

</variable>

<variable name="bound_longitude" shape="longitude bounds_axis" type="double"> </variable>

<variable name="latitude" shape="latitude" type="double">

  <attribute name="standard_name" type="string" value="latitude"/>

  <attribute name="units" type="string" value="degrees_north"/>

  <attribute name="bounds" type="string" value="bound_latitude"/>

  <attribute name="axis" type="string" value="Y"/>

  <values increment="-2.5" npts="73" start="90.0"/>

</variable>

<variable name="bound_latitude" shape="latitude bounds_axis" type="double"> </variable>

<variable name="air_pressure" shape="air_pressure" type="float">

  <attribute name="standard_name" type="string" value="air_pressure"/>

  <attribute name="units" type="string" value="hPa"/>

  <attribute name="axis" type="string" value="Z"/>

  <attribute name="positive" type="string" value="down"/>

  <values increment="70.71429" npts="15" start="10.0"/>

</variable>

<variable name="time" shape="time" type="double">
```

```
        <attribute name="calendar" type="string" value="360_day"/>

        <attribute name="standard_name" type="string" value="time"/>

        <attribute name="units" type="string" value="days since 2289-1-1"/>

        <attribute name="bounds" type="string" value="bound_time"/>

        <attribute name="axis" type="string" value="T"/>

        <values increment="360.0" npts="140" start="510.0"/>

    </variable>

    <variable name="bound_time" shape="time bounds_axis" type="double"> </variable>

    <variable name="air_temperature" shape="time air_pressure latitude longitude" type="float">

        <attribute name="standard_name" type="string" value="air_temperature"/>

        <attribute name="units" type="string" value="Kir_temperature"/>

        <attribute name="long_name" type="string" value="temperature on pressure level"/>

        <attribute name="cell_methods" type="string" value="longitude: latitude: mean time: mean (interval:
4 h)"/>

        <attribute name="_FillValue" type="float" value="-1.073742e+09"/>

        <values xm:xmlmime="binary/octet-stream"><xop:Include

    xmlns:xop='http://www.w3.org/2004/08/xop/include'

    href='cid:bd43gh2y@example.net'/>

        </values>

    </variable>

</netcdf>

--MIME_boundary

Content-Type: application/octet-stream

Content-Transfer-Encoding: binary

Content-ID: <bd43gh2y@example.net>


...(binary encoded data)...

--MIME_boundary--
```

------=_NextPart_000_0000_93251752.3C5526C0--

Annex C: Revision history

Date	Release	Author	Paragraph modified	Description
2010-08-09	0.1.0	Stefano Nativi	All	Created
2010-09-12	0.1.1	Ben Domenico	Comments	Updated
2011-02-19	1.0.0	Stefano Nativi	All –added Multi-pointCoverage data	Updated
2011-08-27	1.0.0	Stefano Nativi	CF ver. 1.6	Updated
2013-02-06	1.1.0	Stefano Nativi	Recommendations from WCS 2.0 SWG	Document split up into three parts
2013-21-27	0.3	Stefano Nativi	New specification document extending CF-netCDF1.6 data model	Created
2014-01-03	0.3.1	Paolo Mazzetti	Requirements on Multipart	Updated
2014-10-19	1.0	Stefano Nativi	Removal of OPeNDAP and introduction of Web address. From discussion paper to International Standard	Created the IS draft
2015-04-13	2.0	Stefano Nativi	Addressed recommendations from OAB Creation of the Abstract test suite	Updated
2015-14-15	2.0	Scott Simmons	Updated format to latest Standards template and minor corrections throughout document.	Updated

Annex D: Bibliography

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