OGC (add title text)

Table of Contents

Open Geospatial Consortium

Submission Date: <yyyy-mm-dd>

Approval Date: <yyyy-mm-dd>

Publication Date: <yyyy-mm-dd>

External identifier of this OGC® document: http://www.opengis.net/doc/{doc-type}/{standard}/{m.n}

Internal reference number of this OGC® document: YY-nnnrx

Version: n.n

Category: OGC® <Implementation / Abstract Specification / Best Practice>

Editor: <Name(s) of Editor or Editors>

OGC (add title text)

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Document type:	OGC® <Standard/Abstract Specification/Best Practice>
Document subtype:	if applicable
Document stage:	Draft
Document language:	English

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i. Abstract

netCDF is a format for encoding array-oriented scientific data, particularly in many Earth & Space Science domains, and is an Open Geospatial Consortium (OGC) standard. While netCDF is strictly a self-describing format, a common practice to aid interoperability is to use the Climate and Forecasting (CF) convention and the Attribute Convention for Data Discovery (ACDD) convention. Several communities are defining additional netCDF conventions for describing the semantics relating of their different domains. As the concurrent use of multiple, and possibly clashing, netCDF conventions spreads the challenge of finding a common mechanism to validate and interpret metadata being embedded inside netCDF files grows.

Linked Data (LD) describes a method for encoding and publishing metadata to expose and connect data both within individual datasets and across multiple datasets. LD also allows dataset descriptions to become more useful through the ability to run semantically-enabled queries across datasets. Publishing netCDF file descriptions using LD methods presents the user community with an opportunity to address this exposure and connection and, further, to enhance data findability and re-use.

The netCDF Classic Linked Data standard (netCDF-Classic-LD) provides the encoding standard for encoding linked data semantics into netCDF Classic files and interpreting netCDF Classic files as RDF graphs.

ii. Keywords

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

ogcdoc, OGC document, netCDF, Linked Data

iii. Preface

NOTE	Insert Preface Text here. Give OGC specific commentary: describe the technical content, reason for document, history of the document and precursors, and plans for future work. > Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights. Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

iv. Submitting organizations

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

- UK Met Office
- CSIRO
- NOAA
- Marine Institute, Ireland

- HDF Group

v. Submitters

All questions regarding this submission should be directed to the editor or the submitters:

Name	Affiliation
Mark Hedley	UK Met Office
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James Biard	NOAA
Adam Leadbetter	Marine Institute, Ireland
Aleksander Jelenak	HDF Group

Chapter 1. Scope

NetCDF-LD is an approach for constructing Linked Data descriptions using the metadata and structures found in netCDF files. Linked Data is a set of practices to allow structured data to be published so that it can be interlinked on the web and support semantic queries. It uses the W3 Resource Description Framework (RDF) to express the information and relationships.

NetCDF-LD enhances netCDF metadata, enabling information found in netCDF files to be linked with published conventions and controlled vocabularies used to express the content.

The netCDF Classic Linked Data standard: netCDF-Classic-LD provides the encoding standard for encoding linked data semantics into netCDF Classic files and interpreting netCDF Classic files as RDF graphs.

NetCDF Classic files may use the HDF5 based netCDF-4 encoding, as long as it is limited to the netCDF classic data model, or the legacy netCDF-3 encoding.

Chapter 2. Conformance

This standard defines XXXX.

Requirements for N standardization target types are considered: * AAAA * BBBB

Conformance with this standard shall be checked using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site.

In order to conform to this OGC® interface standard, a software implementation shall choose to implement: * Any one of the conformance levels specified in Annex B (normative). * Any one of the Distributed Computing Platform profiles specified in Annexes TBD through TBD (normative).

All requirements-classes and conformance-classes described in this document are owned by the standard(s) identified.

Chapter 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.

Patrick J. Hayes, Peter F. Patel-Schneider. RDF 1.1 Semantics. W3C Recommendation, 25 February 2014. URL: http://www.w3.org/TR/2014/REC-rdf11-mt-20140225/. The latest edition is available at http://www.w3.org/TR/rdf11-mt/

Eric Prud'hommeaux, Gavin Carothers. RDF 1.1 Turtle: Terse RDF Triple Language. W3C Recommendation, 25 February 2014. URL: http://www.w3.org/TR/2014/REC-turtle-20140225/. The latest edition is available at http://www.w3.org/TR/turtle/

Miles, A., Bechhofer, S.: SKOS Simple Knowledge Organization System Reference. (2008).

Rew, R., Davis, G.: NetCDF: An interface for scientific data access. IEEE Comput. Graph. Appl. 10, 76–82 (1990).

Eaton, B., Gregory, J., Drach, B., Taylor, K., Hankin, S.: NetCDF Climate and Forecast (CF) Metadata Conventions, (2011).

Gregory, J.: The CF metadata standard. CLIVAR Exch. 8, 4 (2003).

OGC: NetCDF Core Encoding Standard version 1.0, http://portal.opengeospatial.org/files/?artifact_id=43732, (2011).

OGC: CF-netCDF Core and Extensions Primer, http://portal.opengeospatial.org/files/?artifact_id=43733, (2011).

ESIP: Attribute Convention for Data Discovery (ACDD) Version 1.3, http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery, (2015).

W3C: RDF 1.1 Turtle, https://www.w3.org/TR/turtle/, (2014).

W3C: RDF 1.1 XML Syntax, https://www.w3.org/TR/rdf-syntax-grammar/, (2014).

W3C: Notation3 (N3): A readable RDF syntax, https://www.w3.org/TeamSubmission/n3/, (2011)

W3C: SKOS Simple Knowledge Organization System Reference, (2009).

W3C: Resource Description Framework (RDF): Concepts and Abstract Syntax, (2004).

NOTE

Insert References here. If there are no references, state “There are no normative references”.

References are to follow the Springer LNCS style, with the exception that optional information may be appended to references: DOIs are added after the date and web resource references may include an access date at the end of the reference in parentheses. See examples from Springer and OGC below.

Smith, T.F., Waterman, M.S.: Identification of Common Molecular Subsequences. J. Mol. Biol. 147, 195–197 (1981)

May, P., Ehrlich, H.C., Steinke, T.: ZIB Structure Prediction Pipeline: Composing a Complex Biological Workflow through Web Services. In: Nagel, W.E., Walter, W.V., Lehner, W. (eds.) Euro-Par 2006. LNCS, vol. 4128, pp. 1148–1158. Springer, Heidelberg (2006)

Foster, I., Kesselman, C.: The Grid: Blueprint for a New Computing Infrastructure. Morgan Kaufmann, San Francisco (1999)

Czajkowski, K., Fitzgerald, S., Foster, I., Kesselman, C.: Grid Information Services for Distributed Resource Sharing. In: 10th IEEE International Symposium on High Performance Distributed Computing, pp. 181–184. IEEE Press, New York (2001)

Foster, I., Kesselman, C., Nick, J., Tuecke, S.: The Physiology of the Grid: an Open Grid Services Architecture for Distributed Systems Integration. Technical report, Global Grid Forum (2002)

National Center for Biotechnology Information, http://www.ncbi.nlm.nih.gov

ISO / TC 211: ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals (2014)

ISO / TC 211: ISO 19157:2013 Geographic information — Data quality (2013)

ISO / TC 211: ISO 19139:2007 Geographic information — Metadata — XML schema implementation (2007)

ISO / TC 211: ISO 19115-3: Geographic information — Metadata — Part 3: XML schemas (2016)

OGC: OGC 15-097 OGC Geospatial User Feedback Standard. Conceptual Model (2016)

OGC: OGC 12-019, OGC City Geography Markup Language (CityGML) Encoding Standard (2012)

OGC: OGC 14-005r3, OGC IndoorGML (2014)

Chapter 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. term name

text of the definition

Chapter 5. Conventions

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

5.1. Identifiers

The normative provisions in this specification are denoted by the URI

http://www.opengis.net/spec/{standard}/{m.n}

All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base.

5.2. UML model

UML diagrams are included in this standard to illustrate the conceptual model that underpins netCDF-classic-LD. The UML model is not normative. The UML profile used is specified in ISO 19103:2015.

Resources are modelled as UML interfaces.

Chapter 6. Clauses not Containing Normative Material

6.1. Design principles and Rationale

netCDF-Classic-LD allows existing netCDF files to be interpreted as Linked Data with minimal changes. netCDF-Classic-LD encoding rules and mechanisms allow users to leverage Linked Data in programming environments using netCDF and to improve interoperability for netCDF files using different combinations of metadata conventions.

A design principle of netCDF-Classic-LD is that it works with existing netCDF classic encoded files. This means existing netCDF libraries can be used to parse files encoded as netCDF-Classic-LD. This also ensures that netCDF-Classic-LD files can be used as simply as netCDF, with no knowledge of RDF.

A key aspect of netCDF-Classic-LD is the introduction of rules for mapping identifiers for netCDF global and variable attributes and variables to IRIs via prefixes and aliases mechanisms. Using these mechanisms, netCDF-Classic-LD provides a way to disambiguate attribute names and values shared among different netCDF files. Identifiers are the building blocks for defining unambiguous semantics via concept definitions and relationships between concepts.

netCDF-Classic-LD aims to enable any netCDF file to be represented as RDF, if desired, for use with other Linked Data technologies like SPARQL. People intending to use netCDF-LD with RDF tools will find it can be used as another RDF syntax, like Turtle (Prud'hommeaux and Carothers 2014).

6.2. Resource Description Framework

The *Resource Description Framework (RDF)* is a W3 standard (Hayes and Patel-Schneider 2014). Information elements are statements which have three parts: *Subject*, *Predicate*, and *Object*.

Subjects and *Predicates* are *Universal Resource Identifiers (URIs)* whilst Objects may be URIs or Literals. Where an *Object* is a *URI*, this may also be a subject for another statement.

Statements are collected together within an *RDF Graph*.

This standard maps the netCDF Classic data model encoding onto the RDF information model.

6.3. Metadata RDF Graph

An *RDF graph* representing the metadata of multiple files provides a valuable resource for summarising the file collection.

The numerical data within the file is not encoded within the graph, only the metadata. In general this means that the graph is orders of magnitude smaller than the data file it summarises.

Having an *RDF graph* of metadata across a file collection enables the use of Semantic Web technologies to explore, interrogate and visualise the metadata in a variety of ways.

The following sections of this standard define how to interpret a netCDF file as an RDF metadata graph.

Multiple graphs may be combined into a single multi-file metadata graph as long as individual file identity is unique across the multiple graph.

6.3.1. Universal Resource Identifiers within netCDF files

At the core of this standard is the mechanism for encoding and interpreting Universal Resource Identifiers (URIs) within netCDF files.

These URIs may be declared explicitly within the files, or interpreted from file metadata and external information sources.

6.3.2. Identity

A *netCDF file* has an identity. This identity provides the mechanism to obtain the file. As such it is mutable, it is dependent on how the file is provided. Two systems may provide an identical file, but in different ways, and hence use different identities.

An explicit identity may be provided during file interpretation. If no identity is provided, a default identity, a local file URI, will be used.

Each variable within that file has its own identity, defined relative to the file identity. This is defined using the variable name appended to the file identity and separated by a `/`.

6.3.3. Prefix Definition

The prefix is the most straightforward and the most powerful way to encode explicit URIs in this standard. It has two parts: the first part is the declaration of a prefix, the second part is the use of the prefix.

Prefixes are in wide use in a number of domains, including XML and RDF. They allow a URI to be expressed in a compact fashion that saves space, enhances human readability and can mitigate issues with reserved characters.

A prefix is declared using a name : value pair that associates a short name (e.g. `cf, bald`), with a URI. A single prefix declaration is an attribute and a value: the attribute name is the prefix name and the attribute value is the full URI for that prefix.

The 'double underscore' character pair: `__` is used as an identifier and suffix for the prefix, the double underscore is part of the prefix.

The double underscore is interpreted as a special character by this standard: all uses of the double underscore shall be interpreted as prefixed entities and will be unpacked into full URIs by aware software if a full URI is defined.

Prefixes are applied across the file they are declared within. A single dedicated variable shall be used to contain all of the prefixes applied to that file by that file.

The prefix variable is optional.

If included the prefixes variable shall be identified within the file by a single global attribute, using the attribute name `bald__isPrefixedBy`.

If included, the prefixes variable shall include the prefix declaration

```
bald__ = http://binary-array-ld.net/latest/
```

A prefix is used with netCDF file elements as:

```
<prefix><name>
```

Prefixes shall end in a URI separator, either a `/` or a `#`.

The following example CDL uses the binary-array-ld.net and the `w3.org rdf-syntax-ns` vocabularies to describe a reference relationship between two variables.

```
netcdf tmpMwXy8U {
dimensions:
    pdim0 = 11 ;
    pdim1 = 17 ;
variables:
    int a_variable(pdim0, pdim1) ;
        parent_variable:rdf__type = "bald__Array" ;
        parent_variable:bald__references = "b_variable" ;
    int b_variable(pdim0, pdim1) ;
        child_variable:rdf__type = "bald__Reference" ;
        child_variable:bald__array = "b_variable" ;
    int prefix_list ;
        prefix_list:bald__ = "http://binary-array-ld.net/latest/" ;
        prefix_list:rdf__ = "http://www.w3.org/1999/02/22-rdf-syntax-ns#" ;

// global attributes:
        :bald__isPrefixedBy = "prefix_list" ;
}
```

In this example:

- `rdf__type` is interpreted as http://www.w3.org/1999/02/22-rdf-syntax-ns#type
- `bald__array` is interpreted as http://binary-array-ld.net/latest/array

6.3.4. Alias Definition

Alongside the definition of prefixes, explicit aliases may be defined within the file, or as a scope for a file during parsing. Aliases enable controlled attribute names to be interpreted as URIs.

The aliases mechanism is less flexible than the prefixes mechanism. It does enable interpretation of atribute names directly, making it useful for existing standards and existing files.

Aliases are applied across the file they are declared for.

Aliases are declared as a set of RDF graphs. These RDF graphs are commonly provided as URIs, to be obtained during parsing and file metadata interpretation.

The RDF graphs shall be combined and treated as a single alias scope for the file.

6.3.5. Attribute Names

In order to map netCDF metadata to RDF, all global and variable attributes are interpreted as RDF statements. This requires that all attribute names are interpreted as URIs.

A parsing process shall map attribute names to URIs using prefix definitions first, then map attribute names to URIs aliases.

An attribute name shall be mapped to an alias URI if and only if there is an exact match for the full attribute name as a dct:notation (expand to full uri) for an entity within the alias graph where that entity declares a statement <entity> <rdf:type> <rdfs:ObjectProperty> (full URIs).

If multiple aliases match an attribute name, this is an error condition, the declared alias scope cannot be uniquely applied to the file.

All remaining attribute names shall be mapped to local identifiers, using the file identity and variable identity (ref{}) to form a locally applicable URI.

The value of an attribute may be a reference to another variable, or multiple variables, within the file. The process of establishing identity for each variable within the file enables this reference to be interpreted as a URI. In this way, the RDF approach to having objects that are links to subjects, chaining statements into graphs, is implemented.

References to variables are implemented in netCDF files by defining the value of an attribute as the name of a variable, or as a space separated set of names of variables, or as a parenthesis bound space separated list of names of variables.

A set of references is explicitly unordered whilst a list of references is explicitly ordered.

CDL defining a set of references:

```
    int set_collection ;
        set_collection:bald__references = "data_variable1 data_variable2" ;
```

will be interpreted into RDF(turtle) as:

```
    ns1:set_collection a bald:Subject ;
        bald:references ns1:data_variable1_pdim0_ref,
                        ns1:data_variable2_pdim0_ref .
```

CDL defining a list of references:

```
    int list_collection ;
        list_collection:bald__references = "( data_variable1 data_variable2 )" ;
```

will be interpreted into RDF(turtle) as:

```
    ns1:list_collection a bald:Subject ;
        bald:references ( ns1:data_variable1_pdim0_ref ns1:data_variable2_pdim0_ref )
.
```

All variable names shall be within the file, or no references shall be interpreted. There shall be no partial matching.

Exemption

An attribute name may be exempted from the process of inferring references. In order for an attribute name to be exempted, the attribute shall provide a downloadable resource from its URI and that resource shall declare an `rdfs:range` of either `rdfs:Literal` or `skos:Concept`.

6.3.6. Attribute Values

In RDF, objects may be Literals or URIs, therefore attribute values are conditionally interpreted as Literals or as URIs.

A parsing process shall map attribute values to URIs using identified prefixes first.

Attribute Variable References

The value of a variable attribute may be an internal reference to another variable within the file.

For a variable reference to be declared, three conditions shall be met.

Condition one: the value is a string which exactly matches the name of a variable within the file.

Condition two: the attribute name is already interpreted as a URI, defining an entity, external to the file.

Condition three: the attribute name entity declares and <rdfs:range> of <bald:subject>.

An identified attribute reference shall map the attribute value to the identify of the matched variable within the file.

This identification takes place after prefixes are identified and mapped.

Attribute Value Aliases

After prefix and reference interpretation, remaining attribute values are mapped to URIs using the alias graph.

An attribute value shall be mapped to an alias URI if and only if there is an exact match for the full attribute value as a dct:notation (expand to full uri) for an entity within the alias graph.

If multiple aliases match an attribute name, this is an error condition, the declared alias scope cannot be uniquely applied to the file.

Attribute Value Literals

All remaining attribute values shall be left unchanged and declared as instances of <rdf:Literal>.

6.4. NetCDF Dimensions

Chapter 7. Clause containing normative material

Paragraph

7.1. Requirement Class A or Requirement A Example

Paragraph – intro text for the requirement class.

Use the following table for Requirements Classes.

Requirements Class	
http://www.opengis.net/spec/ABCD/m.n/req/req-class-a	
Target type	Token
Dependency	http://www.example.org/req/blah
Dependency	urn:iso:ts:iso:19139:clause:6
Requirement 1	http://www.opengis.net/spec/ABCD/m.n/req/req-class-a/req-name-1 requirement description
Requirement 2	http://www.opengis.net/spec/ABCD/m.n/req/req-class-a/req-name-2 requirement description
Requirement 3	http://www.opengis.net/spec/ABCD/m.n/req/req-class-a/req-name-3 requirement description

7.1.1. Requirement 1

Paragraph - intro text for the requirement.

Use the following table for Requirements, number sequentially.

Requirement 1	/req/req-class-a/req-name-1 Requirement 'shall' statement

Dictionary tables for requirements can be added as necessary. Modify the following example as needed.

Names	Definition	Data types and values	Multiplicity and use
name 1	definition of name 1	float	One or more (mandatory)
name 2	definition of name 2	character string type, not empty	Zero or one (optional)

Names	Definition	Data types and values	Multiplicity and use
name 3	definition of name 3	GML:: Point PropertyType	One (mandatory)

Chapter 8. Media Types for any data encoding(s)

A section describing the MIME-types to be used is mandatory for any standard involving data encodings. If no suitable MIME type exists in http://www.iana.org/assignments/media-types/index.html then this section may be used to define a new MIME type for registration with IANA.

Annex A: Conformance Class Abstract Test Suite (Normative)

NOTE	Ensure that there is a conformance class for each requirements class and a test for each requirement (identified by requirement name and number)

A.1. Conformance Class A

A.1.1. Requirement 1

Test id:	/conf/conf-class-a/req-name-1
Requirement:	/req/req-class-a/req-name-1
Test purpose:	Verify that…
Test method:	Inspect…

A.1.2. Requirement 2

Annex B: Title ({Normative/Informative})

NOTE	Place other Annex material in sequential annexes beginning with "B" and leave final two annexes for the Revision History and Bibliography

Annex C: Revision History

Date	Release	Editor	Primary clauses modified	Description
2016-04-28	0.1	G. Editor	all	initial version

Annex D: Bibliography

NOTE

Example Bibliography (Delete this note).

The TC has approved Springer LNCS as the official document citation type.

Springer LNCS is widely used in technical and computer science journals and other publications

- For citations in the text please use square brackets and consecutive numbers: [1], [2], [3]

– Actual References:

[n] Journal: Author Surname, A.: Title. Publication Title. Volume number, Issue number, Pages Used (Year Published)

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[1] OGC: OGC Testbed 12 Annex B: Architecture. (2015).