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Observations and Measurements

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i. Preface

This draft specification is one of five engineering specifications produced under OGC's Sensor Web Enablement (SWE) activity, which is being executed under OGC's Interoperability Program. This latest version was produced under the OGC Web Services (OWS) 1.2 Initiative, conducted June 2002 - January 2003.

ii. Submitting Organizations

This Interoperability Program Report, Engineering Specification, is being submitted to the OGC Interoperability Program by the following organizations:

CSIRO Australia

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iv. Revision history

Date	Release	Author	Paragraph modified	Description
2001-12-20	0.3	SJDC		
2001-12-24	0.4	SJDC	Clauses 6, 7 and Annex A	Big reorganisation – separated model from XML, more and better examples, simpleContent schemas included
2002-01-02	0.5	SJDC	Clauses 6, 7 and Annex A, B	Small changes in terminology; some parameters promoted (optionally) to collection containers; fixed the "redefine" structure in Y3observation.xsd; explicit "recommendation" clause
2002-01-04	0.6	SJDC, RL	Clauses 6, 7 and Annex A, B	Measurement promoted to be used for the measurement-event feature. Observed value used for an abstract typed value. Definitions inserted in clause 4.
2002-01-10	0.65	SJDC	Clauses 6, 7 and Annex A, B	Measurand changed to observable. Members parameter added to measurementArray. ValueBase moved into gml namespace. Placeholders for Galdos ObservableType dictionary inserted
2002-01-17	0.7	SJDC		Reintroduce simpleContent encoding of scalar values. Various fixes to arrays and collections – some impacting on content-model sequences. Make most element declarations global, attribute declarations local. Change namespace "swe" to "ows".
2002-01-30	0.76	SJDC		Introduce _ValueList form for homogeneous arrays.
2002-01-31	0.76.1	SJDC	Clause 7, Annex B	Corrected schemaLocation values
2002-04-04	0.8-0.85	SJDC		Replaced XML with "simpleContent" version Conforms with draft GML3 Emphasised weak typing approach Added more and more diverse instance examples to Annex B Added issues and future work clause Extensive rewriting
2002-04-19	02-027 (.86)	HAN	Various	Final OWS-1 review and edit; minor changes. Produced OGC 02-027.

2002-08-09	1.0.1	SJDC	Many	Amended Measurement model: measuredOn property, Target feature; New Observed Value encoding: map encoding, quality, observable name, composite observable, parameterised observable, observable grid; New schemas measurement.xsd, value.xsd, observedValue,xsds
2002-08-19	1.1.0	SJDC	Various	Add “observable” property to Measurement. Add “base” property to ParameterisedObservable, ObservableGrid Clean text
2002-09-04	1.2.0	SJDC	Many	Rename Measurement to “Observation” and associated changes throughout; clarify ParameterisedObservable structure.
2003-01-15	1.3.0	SJDC	All	Rename “Observable” to “Phenomenon”. Enhance Feature vs Coverage discussion. Add discussion of WCS requirements. Revise phenomenon model and description. GML3 harmonisation. Refactor schemas. Revise all examples.
18 Jan 2003	v0.9.0 (03-022)	Harry Niedzwiadek	Various	The final OWS 1.2 review and edit. Produced OGC 03-022. Version level fixed to be consistent with new OGC versioning scheme and incremented from v0.8.6 under OWS 1.1 to v0.9.0 to reflect successful implementation under OWS 1.2.
2003-01-23	V0.9.1	SJDC	Clause 8 – Guidelines Annex C.5	First complete version of guidelines. A few additional examples. General scrub.
2003-02-04	V 0.9.2	SJDC	Annex C.5	Additions to C.5 and cross references to this discussion added.

The issues in this specification are captured in the following format:

Issue Name: [Issue Name goes here. (Your Initials, Date)]

Issue Description: [Issue Description.]

Resolution: [Insert Resolution Details and History.] (Your Initials, Date)]

v. Changes to OpenGIS® Specifications

The OpenGIS© Specification requires changes to accommodate the technical contents of this document.

The following is a list of the required changes:

1. GML3 – in observation.xsd, the content model of the “resultOf” property should be changed to a choice of gml:_Object and gml:Null.

Foreword

Attention is drawn to the possibility that some of the elements of this document may be subject to patent rights claims. The Open GIS Consortium Inc. shall not be held responsible for identifying any or all such patent rights.

This report replaces the Observations and Measurements IPR prepared during OWS 1.1, and an earlier version was published by OGC as a Discussion Paper, specifically OGC document 02-027. The following changes have been made to the model presented in the first version:

1. The schemas are fully harmonised with GML version 3.00 (OGC document 02-023r4)
2. The feature type named “Measurement” in 02-027 is now named “RichObservation”
3. The RichObservation feature is now based on GML Observation. RichObservation now adds an observable property and supports some quality description.
4. Observation Collections have been simplified.
5. Geometry and Temporal Objects have been added to the set of datatypes available as Values.
6. The hierarchy of aggregate Values has been simplified.
7. The encoding of observable phenomena (aka measurand) has been significantly enhanced and now supports description of parameterised phenomena and composite phenomena. Note that the enhancements primarily concern the definition of derived phenomena types, for which the base or primitive values are defined elsewhere.
8. Observed Values and Rich Observations may now have one or more quality measures associated with them; for composite values, the quality indicators can be applied at any level of aggregation.

A revised set of XML schemas implementing the model is provided in Annex B.

This specification was developed under the OWS 1.2 initiative. It assumes the existence of a number of additional resources: descriptions of measurement procedures or sensors, normally using Sensor Model Language as defined in OGC 03-005r1; a source (e.g. a registry) for definitions of reference systems, such as units of measure and codelists, and coordinate reference systems; a source for definitions of observable types and related information. The measurement model described in this specification relates particularly to the Sensor Collection Service, as defined in OGC 03-023, and includes some discussion concerning the design of SCS, and also to measurement Coverages which might be delivered by a WCS as described in OGC 02-024.

Annex A (Conformance) and Annex B (XML Schemas) are normative.

Introduction

OGC's Sensor Web Enablement (SWE) activity, which is being executed through the OGC Web Services (OWS) initiatives (under the Interoperability Program), is establishing the interfaces and protocols that will enable a "Sensor Web" through which applications and services will be able to access sensors of all types over the Web. These initiatives have defined, prototyped and tested several foundational components needed for a Sensor Web, namely:

1. **Sensor Model Language (SensorML)** – The general models and XML encodings for sensors. SensorML originated under OWS 1.1, was significantly enhanced under OWS 1.2 and is now available as a public discussion paper.

2. **Observations & Measurements (O&M)** - The general models and XML encodings for sensor observations and measurements. O&M originated under OWS 1.1 and was significantly enhanced under OWS 1.2.

3. **Sensor Collection Service (SCS)** – A service by which a client can obtain observations from one or more sensors/platforms (can be of mixed sensor/platform types). Clients can also obtain information that describes the associated sensors and platforms. This service originated under OWS 1.1 and was significantly enhanced under OWS 1.2.

4. **Sensor Planning Service (SPS)** – A service by which a client can determine collection feasibility for a desired set of collection requests for one or more mobile sensors/platforms, or a client may submit collection requests directly to these sensors/platforms. This service was defined under OWS 1.2.

5. **Web Notification Service (WNS)** – A service by which a client may conduct asynchronous dialogues (message interchanges) with one or more other services. This service is useful when many collaborating services are required to satisfy a client request, and/or when significant delays are involved is satisfying the request. This service was defined under OWS 1.2 in support of SPS operations. WNS has broad applicability in many such multi-service applications.

This document specifies Observations and Measurements. The other components are specified under separate cover.

Herein we describe a framework and encoding for measurements and observations. This is required specifically for the Sensor Collection Service and related components of an OGC Sensor Web Enablement capability, and also for general support for OGC compliant systems dealing in technical measurements in science and engineering.

The aim is to define a number of terms used for measurements, and the relationships between them. This proposal discusses **Observation, Measurement, Value, Observed Value, Coverage, SensorInstance, Observable, Measurand, Phenomenon,** and related terms, presented using UML class diagrams and in equivalent GML conformant XML serialisations. The scope is restricted to measurements whose results are expressed as quantities, categories, temporal and geometry values, and composites and arrays of these.

A discussion regarding how the observation and measurement model is used in the context of SensorWeb Enablement is included. The discussion notes how different parts of the information model would be provided by different services. However, the details remain to be resolved and might depend on specific use-cases.

This report is a major revision of a report prepared during the first OGC Web Services 1.1 initiative.

This work was supported by OGC through the OWS-1.2 Interoperability project, and by the XMML project based at CSIRO Australia.

Observations and Measurements: A Draft Implementation Specification

1. Scope

We describe a conceptual model and encoding for observations and measurements.

We define an Observation to be an event with a result which is a value describing some phenomenon. This is modelled as a Feature within the context of the OGC Feature Model. An observation feature binds the result to the (spatiotemporal) location where it was made. An observation involves a procedure to determine the value, which may involve a sensor or observer, analytical procedure, simulation or other numerical process.

An observation results in an estimate of the Value of a property or phenomenon related to the target of the observation. Values are of various datatypes, including the primitive types category, quantity, count and boolean, time, location and geometry. The value normally requires a reference system to provide the context for its interpretation and valid operations on it. Common reference systems are the unit of measure for a quantity, a dictionary or "code space" for a category, a spatial reference system for location and geometry, and a temporal reference system for time values. A value may be constructed by aggregating primitive values, to build tuples, arrays and lists, and composite values such as vectors and tensors. An observed value may be semantically typed according to the phenomenon being observed or observable, sometimes called measurand. Observed values may have other properties, such as quality indicators.

We discuss how the observation and measurement model is used in the context of SensorWeb, noting that different parts of the information model may be provided by different services, though details remain to be resolved and might depend on specific use-cases.

Used, but not described in this report are:

- Sensor Model Language (SensorML) & Sensor Instance/Sensor Type registries,
- Reference System definitions (CRS, frames, units of measure, dictionaries & category lists),
- Semantic definition of observable types, observable registries, and
- Geometry and temporal objects.

2. Conformance

Conformance and Interoperability Testing for this specification may be checked using all the relevant tests specified in Annex A (normative). The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in ISO 19105: Geographic information — Conformance and Testing.

3. Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of this document are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

[Guidelines] Guidelines for Successful OGC Interface Specifications, OGC document 00-014r1

[Filter] Filter Encoding Implementation Specification. OGC Document 02-047 http://www.opengis.org/

[GML3] Geography Markup Language, version 3. OGC Document Number: 02-023r4 http://www.opengis.org/

[ISO1000] SI units and recommendations for the use of their multiples and of certain other units - ISO 1000. See also http://www.bipm.fr/en/3_SI

[ISO19103] ISO TC 211Geographic Information – Conceptual Schema Language ISO 19103 http://www.isotc211.org/pow.htm

[ISO19107] ISO TC 211Geographic Information – Spatial Schema ISO 19107 http://www.isotc211.org/pow.htm

[ISO19108] ISO TC 211Geographic Information – Temporal Schema ISO 19108 http://www.isotc211.org/pow.htm

[ISO19109] ISO TC 211Geographic Information – Rules for Application Schema ISO 19109 http://www.isotc211.org/pow.htm

[ISO19110] ISO TC 211Geographic Information – Feature cataloguing methodology ISO 19110 http://www.isotc211.org/pow.htm

[ISO19112] ISO TC 211Geographic Information – Spatial referencing by identifier ISO 19112 http://www.isotc211.org/pow.htm

[ISO19115] ISO TC 211Geographic Information – Metadata ISO 19115 http://www.isotc211.org/pow.htm

[ISO19123] ISO TC 211 Geographic Information – Schema for coverage geometry and functions ISO 19123 http://www.isotc211.org/pow.htm

[OGCAS0] The OpenGIS Abstract Specification. Topic 0: Overview, OGC document 99-100r1 http://www.opengis.org/public/abstract/99-100r1.pdf

[OGCAS2] The OpenGIS Abstract Specification. Topic 2: Spatial referencing by coordinates, OGC document 02-102 http://www.opengis.org/public/abstract/02-102.pdf

[OGCAS5] The OpenGIS Abstract Specification. Topic 5: Features. OGC Document 99-105r2. http://www.opengis.org/public/abstract/99-105r2.pdf

[OGCAS6] The OpenGIS Abstract Specification. Topic 6: The coverage type and its subtypes. OGC Document 00-106. http://www.opengis.org/public/abstract/00-106.pdf

[SCS] Sensor Collection Service IPR, OGC 03-023. http://member.opengis.org/tc/archive/arch03/03-023r1.pdf

[SensorML] Sensor Model Language IPR, OGC 03-005. http://member.opengis.org/tc/archive/arch03/03-005r2.pdf

[UOM2001] Units of Measure and Quantity Datatypes. OGC Project Document 01-044r3 http://feature.opengis.org/members/archive/arch01/01-044r3.pdf

[WCS] Web Coverage Service Implementation Specification. OGC Document 02-024 http://www.opengis.org/techno/discussions/02-024.pdf

[WFS] Web Feature Service Implementation Specification. OGC Document 02-058 http://www.opengis.org/techno/specs/02-058.pdf

[XPointer] XML Pointer Language (XPointer) Version 1.0. World Wide Web Consortium. 2001. http://www.w3.org/TR/xptr/

4. Terms and Definitions

The following terms and definitions apply.

4.1

Measurand

Is a member of the subset of observables, whose values are given as quantities [NRC1995].

4.2

Measurement (noun)

Is an observation using a single sensor or procedure, whose result is a quantity [FOW1998, VIM].

4.3
Observable
The particular phenomenon which is the subject of the observation and to which values are assigned, such as temperature, gravity, chemical concentration, orientation, number-of-individuals.

4.4
Observation (noun)
An instance of a procedure to assign numbers or other symbols to phenomena in such a way that relationships of the numbers or symbols reflect relationships of the attributes of the phenomena being observed [FOW1998, SAR1995]. An observation frequently involves an instrument or sensor. An observation feature effectively binds a value to a time, location, and to the instrument or procedure used.

4.5
Observed Value
An estimate of a value describing a natural phenomenon, which is characterised by its observable and may include other properties such as quality measures. The term is used regardless of whether the value is due to an instrumental observation, a theoretical model, subjective assignment or some other method of estimation or assignment. The value may be scalar or aggregate.

4.6
Scale
A particular way of assigning numbers or symbols to measure something is called a *scale* of measurement [SAR1995].

4.7
Value
A value is a member of the value-space of a datatype. It may use one of a variety of scales including nominal, ordinal, ratio and interval, spatial and temporal. Primitive datatypes may be combined to form aggregate datatypes with aggregate values, including vectors, tensors and images [ISO11404].

5. Conventions

5.1 Symbols (and abbreviated terms)

The following symbols and abbreviated terms are used in this document.

GML	OGC Geography Markup Language
ISO	International Organization for Standardization
OGC	Open GIS Consortium
OWS	OGC Web Services
O&M	Observations and Measurements

PSVI	Post schema-validated information set (for XML documents)
SCS	Sensor Collection Service
SensorML	Sensor Model Language
SWE	Sensor Web Enablement
UML	Unified Modeling Language
XML	eXtensible Markup Language
XSD	W3C XML Schema Definition Language
1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional

5.2 UML Notation

The diagrams that appear in this document are presented using the Unified Modeling Language (UML) static structure diagram. The UML notations used in this document are described in the diagram below.

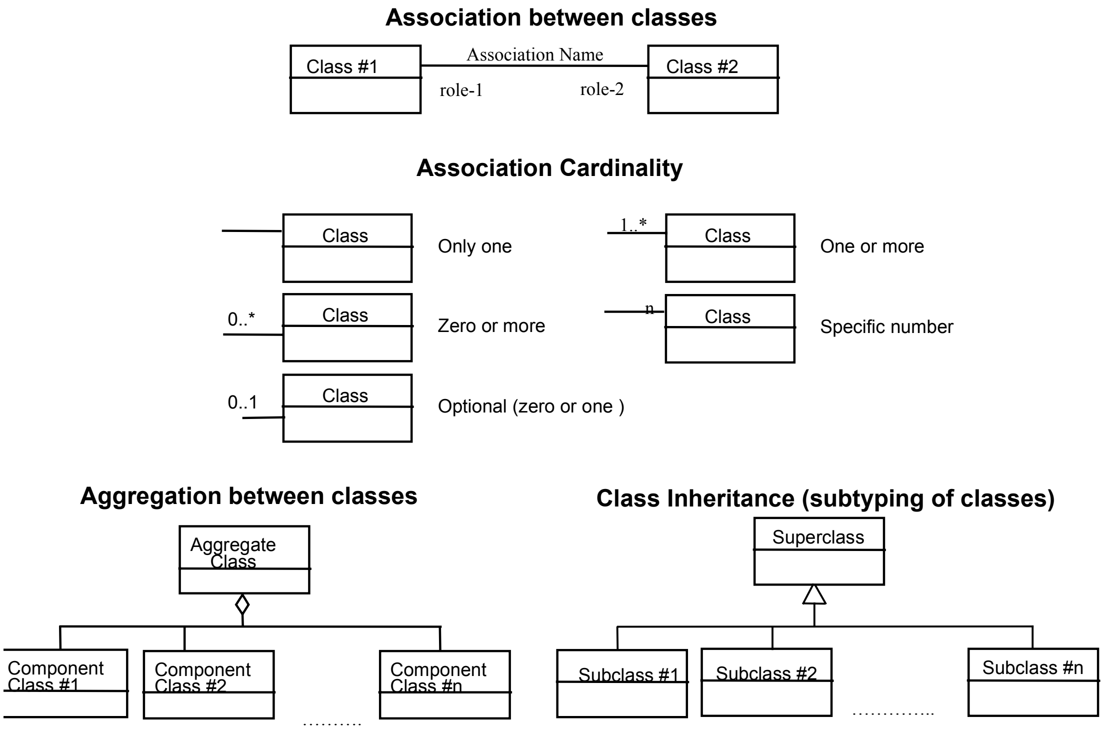


Figure 1. UML notation

In this document, the following stereotypes of UML classes are used:

a) <<Abstract>> class (or other classifier) that cannot be directly instantiated. UML notation for this to show the name in italics.

b) <<DataType>> A descriptor of a set of values that lack identity (independent existence and the possibility of side effects). A DataType is a class with no operations whose primary purpose is to hold the information.

c) <<Union>> describes a selection of one of the specified types. This is useful to specify a set of alternative classes/types that can be used, without the need to create a common super-type/class.

d) <<Enumeration>> data type whose instances form a list of named literal values. Both the enumeration name and its literal values are declared. Enumeration means a short list of well-understood potential values within a class.

6 A model for Observations and Measurements

In this Clause, we describe a model for observations and associated components. The analysis is presented as an information model using UML static class diagrams.

We start in Clause 6.1 with a summary of the "Feature" which is the basic item in the OGC model for geographic information. This is followed in Clause 6.2 with a brief discussion of a complementary view of geographic information based on the Coverage, focussing particularly on the shared information content between these views. Understanding this equivalence allows us to base the subsequent analysis on the Feature model with a clear understanding of how to transform the same information into a Coverage.

We follow in Clause 0 with descriptions of models for Observations and Observation Collections. The results of observations are held in Values which are described in Clause 6.4. In Clause 6.5 we describe some structures which may be used for descriptions of the Phenomena that are the topic of observations.

Finally, in Clause 6.6, we review the complete model, and introduce some associated components: sensors and reference systems. This supports a discussion of some operational factors of a Sensor Collection Service, particularly focussing on the supply of different information items by different services through various interfaces.

6.1 The Feature Model

The feature model underlies the ISO/OGC view of geographic information [OGCAS5, ISO19109]. The OGC abstract model defines a feature as "an abstraction of a real world phenomenon". The term **`Feature,`** as used here (Figure 2 – see also Figure 7.4-1 in GML3), is used for a software representation of an identifiable object located in geographic space. A Feature will have a number of **`properties`**, some of which may be geometric and spatial.

The latter is important. In traditional GIS an item of interest is usually defined as a single geometry – often a point, line or polygon – with attributes. In the Feature model the item of interest is a conceptually meaningful phenomenon within the domain of discourse – such as a Mine, Road or Land-Parcel – for which one or more properties may be geometric.

In a specific feature, the generic "_property" shown in the model would be replaced by several named properties, the values of which would be constrained to be of particular types. A specific Feature Type is defined in terms of this set of named properties that are associated with that type [ISO19110]. A Feature instance is thus the functional map of its property values.

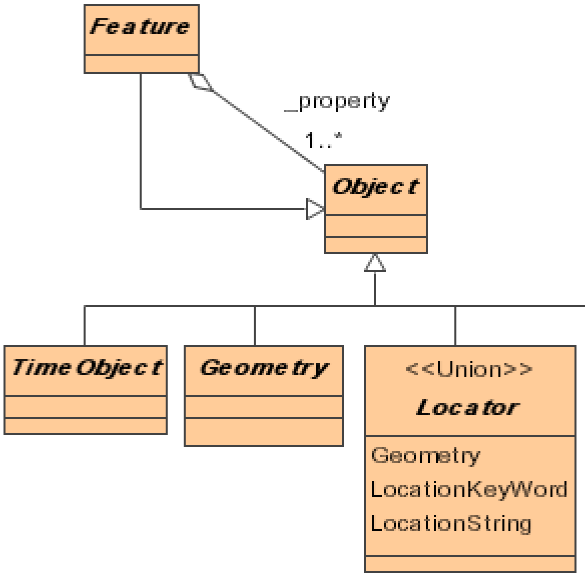


Figure 2. The Generic Feature Model

6.2 The Coverage model

6.2.1 Definition of coverage

Coverage is an important model of spatial data. A Coverage is "… a set of attribute values (its *range*) associated to position within a bounded space (its spatiotemporal *domain*) …" [ISO19123]. Coverage is thus a special case of a functional mapping, where the domain or index set is restricted to be spatiotemporal (Figure 3).

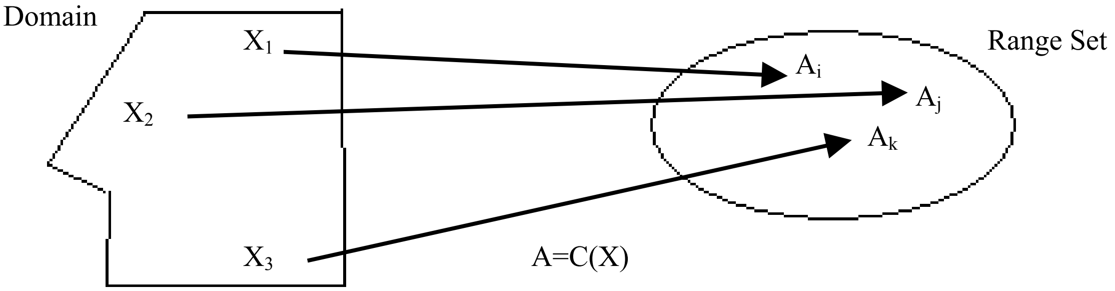


Figure 3. Coverage model

The attributes of a coverage (its range) are of homogeneous type throughout its domain. A coverage may be evaluated for any location in its domain, with the result being the set of attribute values of the coverage at that location. Nevertheless, in general the domain of a coverage does *not* have to be continuous, and a coverage may not have a value at every position within the envelope of the domain.

Imagery is a common way of collecting information associated with a coverage, by which the value of a continuous phenomenon is sampled at regular but discrete locations (pixels).

6.2.2 Representation of coverage

6.2.2.1 Discrete coverage

A discrete coverage may be represented:

i. as a set of homogeneous features, where for each feature its location is a member of the discrete geometry set composing the domain, and the other properties of the feature are the coverage attributes at that location. The "rule" that defines the mapping from the domain to the range is simply that the location and the other properties are properties of the same feature instance. Note that "location" is not necessarily a point. If the location of each member feature is extensive and the attributes scalar-valued, then value(s) of the coverage will be piecewise-constant; according to (for example) the polygon-patch collection that comprises the coverage domain;

ii. by collecting the description of the members of domain set (which may be implicit, such as a grid) and the values in the range separately, and providing a mapping between these so that each member of the domain is associated with a single (set of) value(s) from the range. The procedure or rule defining the functional mapping from the domain to the range is a required component of this representation.

The homogeneous feature collection and functional map representations of the information might be considered alternative views or interfaces to a discrete coverage. The conventional representation of large Coverages, such as imagery, describes the domain (e.g., a grid) separately from the range (i.e., the attribute values) and thus corresponds to a functional map. A "pixel collection" would be the feature collection equivalent of an image.

6.2.2.2 Continuous coverage

For a continuous coverage, the values at all arbitrary positions within the domain are not stored, but defined by an operation. Thus a continuous coverage may only be represented as a functional mapping.

The operation may be described using a regular or analytic function such as a polynomial. Or if the values in a coverage are related to a known governing phenomenon, a process simulation may be used to compute an estimate of the value at any location. Failing these, a statistical interpolation or a rule (e.g. "nearest neighbour") may be used. For most of these cases, constraints for the operation are provided by an associated discrete coverage, which samples a domain with the same footprint.

An auxiliary data structure, such as a spatial partitioning of the domain, may also be required. For example, a 2-D domain might be partitioned into polygonal patches, each sampled at one point and within each of which the values are known to behave in some regular manner (e.g. constant), with discontinuities between the patches. Evaluation of the coverage at any position then requires information about the patch within which the position falls, the values and positions of the constraining values from the associated discrete coverage, and a model for how the values vary.

6.2.3 Relationship between Feature and Coverage views

The OGC Abstract Specification Topic 6 [OGCAS6] discusses relationships between the feature and coverage representation of information in some detail in clause 1.2. Several relationships are possible.

6.2.3.1 A coverage is a feature

At the simplest level, a coverage may be modeled as a single gross feature, whose "location" attribute is the coverage domain, with another attribute holding the set of values in the range. The mapping from locations within the domain to values in the range (e.g., sequence rule, function) is an essential attribute of the coverage-feature.

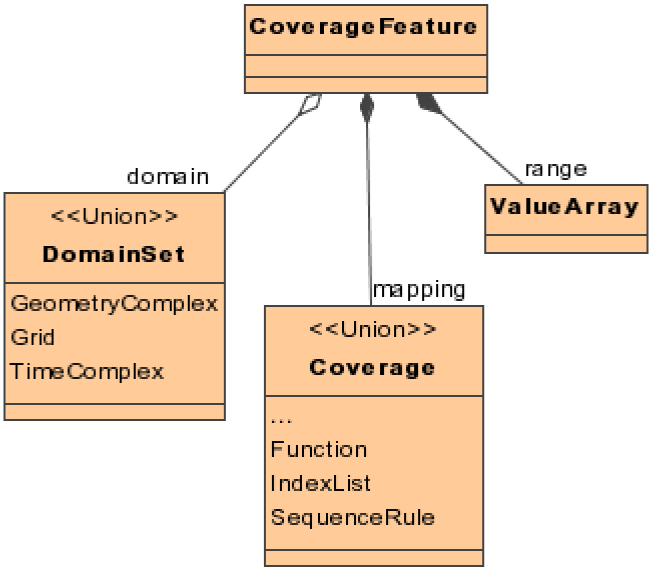
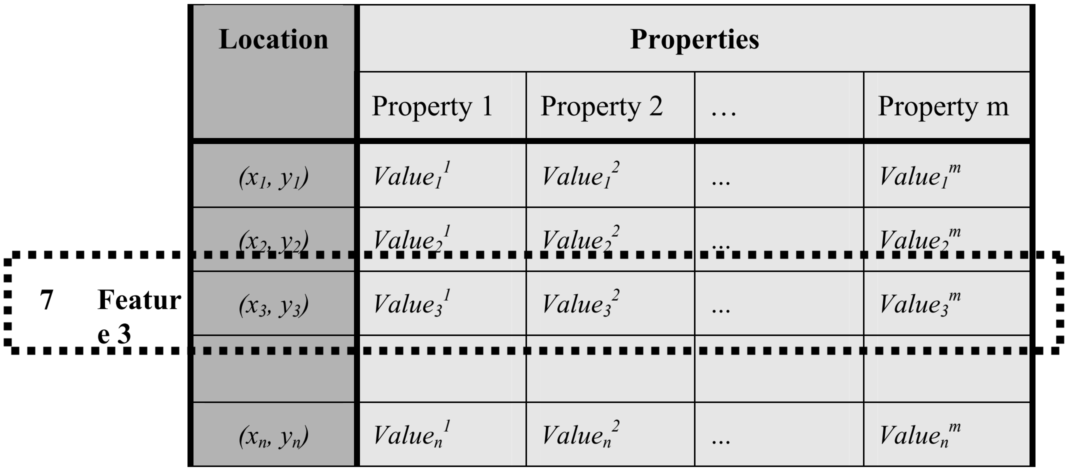


Figure 4. Coverage modelled as a Feature

This view is particularly appropriate for coverages such as images from frame cameras, where the values in the range are assigned through what is (apparently) a single homogeneous act. The image is then a feature, whose location corresponds with its footprint, and whose *array* of pixel values are the complex value of one attribute.

6.2.3.2 A coverage is a feature collection

The information associated with a discrete coverage may be represented in a table. In the example shown in Figure 5, the set of locations which enumerate the discrete domain of the coverage occur in one column (dark grey), and the other columns (light grey) contain the values of the range on each member of the domain set. The mapping from the domain to the range is given by the organisation of the rows of the table.



7 Feature 3

Location	Properties			
	Property 1	Property 2	…	Property m
(x_1, y_1)	$Value_1^1$	$Value_1^2$	...	$Value_1^m$
(x_2, y_2)	$Value_2^1$	$Value_2^2$	...	$Value_2^m$
(x_3, y_3)	$Value_3^1$	$Value_3^2$	...	$Value_3^m$
(x_n, y_n)	$Value_n^1$	$Value_n^2$	...	$Value_n^m$

Figure 5. Tabular representation of information associated with a discrete coverage.
(N.B. the locations may be a geometry such as a "cell" rather than a point position.)

Each row, therefore, holds information that describes a Feature from a corresponding feature collection. The feature type is implied by the set of properties {Property 1, Property 2, … Property m}. For example, the row outlined by the dotted box, gives the information related to Feature 3, whose location is (x_3, y_3), and value of Property 1 is $Value_3^{1,}$ Property 2 is $Value_3^2$, etc. The entire coverage is thus equivalent to a homogeneous feature collection. This view is appropriate when a coverage is compiled by aggregating values which may have been collected separately.

These views of a coverage are related through simple transposition. The feature-collection view focuses on gathering the information concerning a single location at a time, while the functional map view describes the column of locations as a group, and then the set of attribute values as a separate group or groups.

This feature-collection - coverage equivalence means that we can analyse and model both at the same time. A model for a particular feature type can be expressed in a map view by simply taking the non-location properties of a feature collection as the range of the coverage. Alternatively, a Feature is simply a coverage with only one member in the domain. This equivalence allows us to focus on the most appropriate or convenient view during analysis, knowing that conversion to the other view is straightforward.

This form of equivalence is discussed further in Clause 6.3.5.2 and illustrated in Figure 9. For the purposes of the discussion in this document, we assume a method for transforming any homogeneous Feature Collection into a discrete Coverage is available, and vice versa.

6.2.3.3 Using feature and coverage views

The Feature and Coverage representations of the information are both required. Typically they are important in different phases of the data-processing cycle:

- The feature view is important during data collection when an observation or measurement event causes values for all the properties of a single feature to be determined, and during data entry when the data-store is updated by inserting a new feature;

- The map view is often more important during analysis, when the requirement is to find patterns in the values of a property over a collection of features; at this stage it is necessary to have access to a complete "column" of values over all features at once.

OGC AS Topic 6 comments: "we should be comfortable moving back and forth between any of the [different representations of the same information] whenever it makes sense to do so".

6.2.4 Coverage types

It is common to define the type of a discrete coverage by the structure of its domain representation (e.g., "polygon coverage", "gridded coverage"). The domain structure may also constrain the interpolation method used to evaluate the coverage at general positions (e.g., point samples often lead to a "TIN coverage"; a "polygon coverage" is most often piecewise constant).

However, the natural type of a *continuous* coverage is in terms of the semantics of the attributes in the range (e.g., radiance, mineral grade, property ownership). This is related to the approach used for typing Features: based on their semantics and properties, rather than on their geometric realisation.

Following the equivalence relationship between features and coverages described above, we may apply a "semantic" typing to a discrete coverage that follows the type of features in the corresponding homogeneous feature collection. For example, a collection of classified roads that composes a "segmented-curve coverage" when considered in terms of the domain structure, is a "road-classification coverage" when considered in terms of its range; a collection of remotely sensed pixels composes a "gridded coverage" using structural typing, or a "radiance image" using semantic typing.

Typing coverages according to the structure of the representation is required for processing and portrayal, but typing coverages according to the attribute in the range is the key to comprehension and utility. The relationship between Representation and Meaning is discussed in relation to Observations in clause 6.3.3 below, and generally in clause 6.5.1.

Issue Name: [Moving towards a coherent, complete semantic framework for feature-related information. (SJDC, Dec 2002)]

Issue Description: [Additional discussion of the relationship between feature types and feature catalogues, and reference-systems or value-spaces for their properties is needed. Comprehension requires the ability to do comparison and ordering operations using the values of attributes. In turn, this requires not only that the features are typed in the same way, but also that the values of their properties are expressed on scales that can be related to each other.]

Resolution: [Insert Resolution Details and History.] (Your Initials, Date)]

6.3 Observation Model

6.3.1 Basic model

We follow Fowler [FOW1998] and consider an **observation** to be an act or event through which a number, term or other symbol is assigned to a phenomenon. An observation has a timestamp. The observation uses a procedure, which is often an instrument or sensor [NRC1995]. The phenomenon may be associated with an identifiable object, which is thus the target or subject of the observation, or may simply be sampled at some convenient location.

In conventional measurement theory [e.g. KRALST, SAR1995, VIM] the term "measurement" is used for the same concept. However, Fowler's distinction between measurement and category-observation has been adopted in more recent work [NIE2001, YOD] so the term "observation" is used here for the general concept, with "measurement" reserved for cases where the result is a scalar quantity.

6.3.2 Feature model for an observation

We define an **`Observation`** as a Feature type, in which one of its properties is **`resultOf`**, the value of which is a **`Value Object`** describing some phenomenon (Figure 6). **`Value Object`** is an abstract datatype, which is replaced in a data instance by a concrete type, such as quantity, category, count, etc, or by an aggregate of these primitives. The structure of various forms of value object is described in detail in clause 6.4. A **`Measurement`** is a specialisation of observation made using a sensor or instrument which results in a scalar quantitative value. This may be implemented as a subclass of Observation with a constraint to specify the result type. However, in the model and encoding presented in this report, we describe the general case which covers all result types.

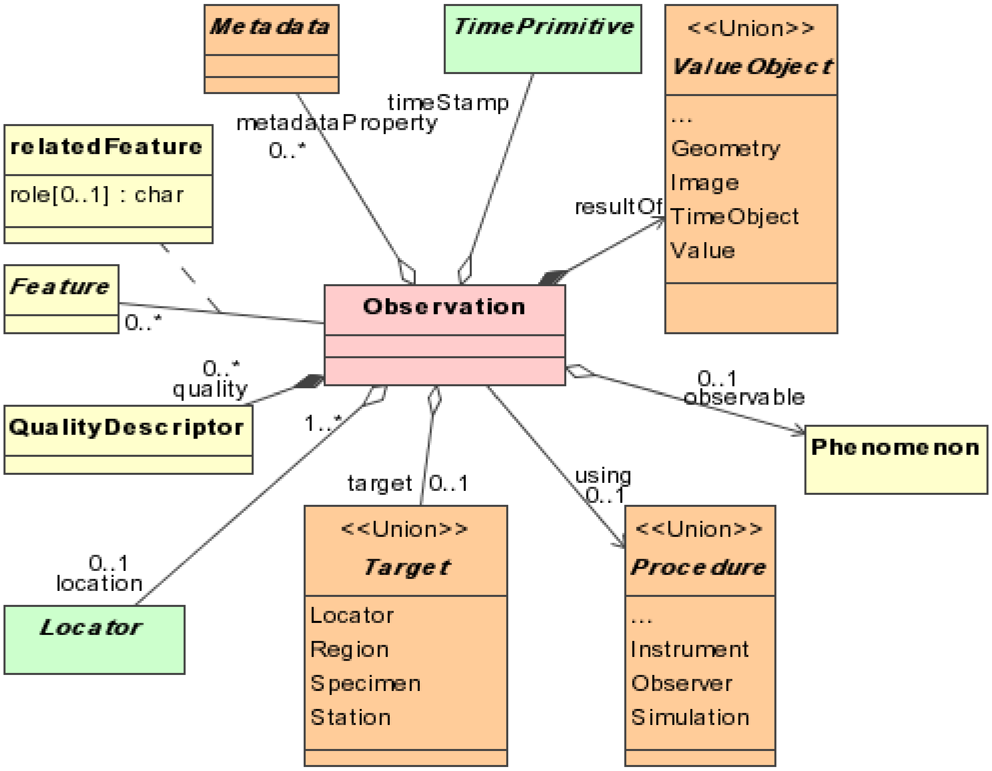


Figure 6. The Observation Feature

An observation has a **`timeStamp`**, since the Observation feature describes an act or "observation event". An observation has a **`using`** property, the value of which is a description of a procedure such as an instrument or observer. A model and encoding for the functional description of *sensors* is given in the OGC document describing Sensor Model Language [SensorML]. An observation may be semantically typed using an **`observable`** property, which identifies the **`Phenomenon`** being sampled.

An observation will frequently be related to other features, such as an observation collection, a survey tie-point, a previous observation from the same location, a previous observation which is the basis for a new observation (e.g., a *classification* may be based on an earlier set of measurements), etc. We model this general association with other Features using a **`relatedFeature`** association class, with a **`role`** attribute, allowing the association to be (weakly) typed. A common related feature is the subject of the observation, such as a Station or Specimen, so this is promoted to having a fixed role **`target`**. Finally, an observation may have several **`quality`** indicators associated with it.

An observation has a single procedure and observable, and a single result. The description of the procedure provides important metadata to support the interpretation of the result. If it is a sensor, then it may be a "sensor package" (such as a weather station, or multi-band radiance sensor) measuring an "aggregate observable" (weather, multi-band radiance), and producing a resulting "aggregate value" (the corresponding set of weather parameters, or a radiance spectrum). But when associated with an observation, the sensor, observable and result are each single logical entities.

It is through its association with an observation feature that a Value is bound to a feature of interest or a geospatial location, to a time instant or period, and to the `Sensor Instance` responsible for the observation.

Note that we indicate that the result of an observation may be an `Image`. In this case, the observation feature is essentially a vehicle that binds the image "metadata" to the image. The value of the `target` property will be the image extent and its structure. For images this is usually a grid so may be described using an implicit encoding.

In common with other features, Observation has a `location` property and a `metadataProperty`. However, some caution is required concerning location, especially when considering whether the procedure or instrument used and whether it operates in-situ or remote. For example:

1. if the sensor is a fixed in-situ instrument, or it is a mobile in-situ sensor for which the position at the time of the Observation is available, the sensor location is sufficient.
2. if the observation is on a specimen or station, and uses an in-situ instrument, the location of the specimen or station is sufficient.
3. if the observation is made using a remote sensor, the location of interest is described or computed separately.

In the context of GML, all features inherit the standard properties `id`, `metadataProperty`, `description`, `name`, `location`, and `boundedBy` from `gml:AbstractFeatureType`. The GML feature `Observation` adds `timeStamp`, `resultOf`, `using`, and `target`. The RichObservation feature introduced here adds `observable, quality` and `relatedFeature` properties.

6.3.3 Observation types

Observations may be classified or typed in several ways.

6.3.3.1 Typing according to the representation of the result

Fowler's classification of observations [FOW1998] focuses on the representation of the result. A "measurement" is distinguished from a "category-observation" depending on whether the result is a number or a term. Our interest here also extends to observations whose results are geometry, temporal, Boolean and frequency, so we specialise the observation model to generate the six sub-classes of observations shown in figure Figure 7, based on the representation of the result.

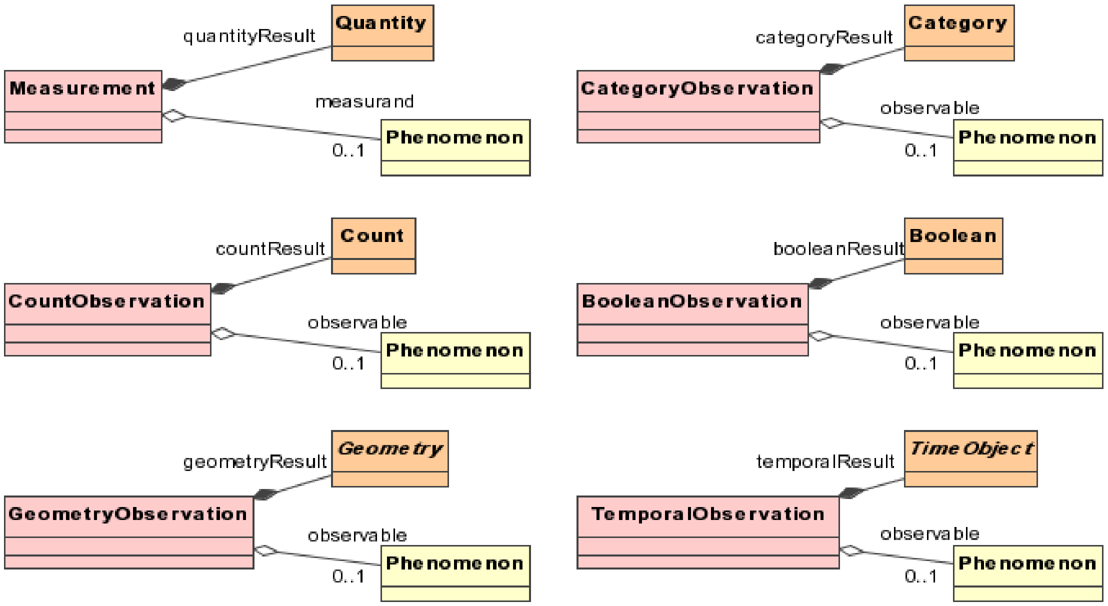


Figure 7. Specialised observation classes.

6.3.3.2 Semantic typing

Alternatively, the value of the observable, i.e., the phenomenon being sampled, may be used to classify an observation. This is the primary constraint on whether the results of observations may be compared. Thus we might be interested in discovering and compiling a set of "vegetation observations", regardless initially of whether the results are boolean (vegetated or not), quantitative (percentage vegetation cover) or categorical (vegetation type).

The second, practical requirement for comparison is that the results are available on the same scale, or that a conversion to a common scale is possible [SAR1995]. We discuss the relationship between representation and meaning below (clause 6.5.1)

If the result of the observation is an aggregate value, then the definition of the phenomenon should indicate the structure of the aggregate, in order that the components can be disambiguated. Furthermore, in most cases parameters are required to refine the definition of a phenomenon. Further discussion of models for the description of phenomena are given in Clause 6.5, and an XML encoding in Clause 7.2.2.

Note that classification of observations raises similar issues to the discussion of Coverage types above (clause 6.2.4).

6.3.4 Relationships within the observation model

Some further associations in the model for Observations are shown in Figure 8.

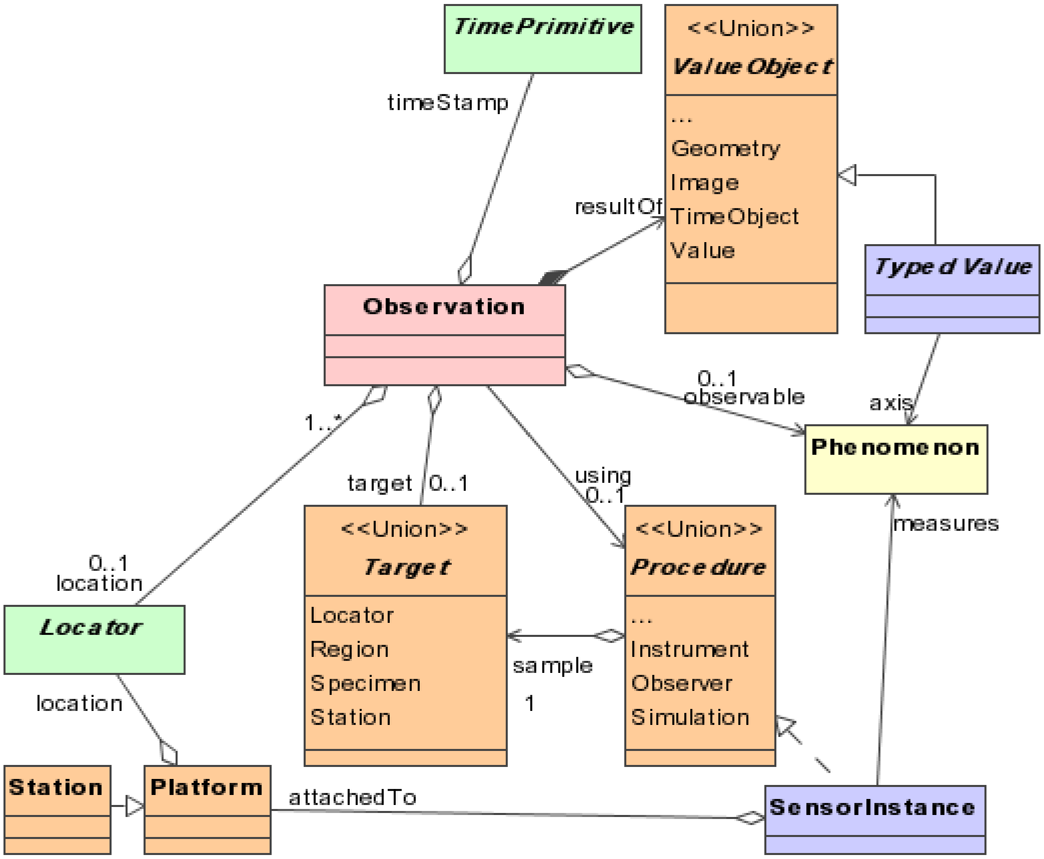


Figure 8. Observation Model showing additional associations and validation dependencies

The **`observable`** may be indicated in several positions in the information structure.

1. The definitive description of the observable is available through the description of the procedure responsible for the observation. If the procedure is a sensor, then the description will use the sensor model language SensorML [SensorML]. One of the properties of a sensor is **`measures`**, whose value is a detailed description of the **`Phenomenon`** also encompassing the sensitivity of the instrument. However, using this method, the mapping from the semantics of the observation to its value is quite indirect, as it requires traversal of two associations.

2. Alternatively, the observation may carry an **`observable`** property directly. This points to a definition of the **`Phenomenon`**, usually available from a dictionary or catalog. Using this method, the mapping from the semantics of the observation to its value is through them both being properties of the **`Observation`** feature.

3. Finally, in place of a **`Value`**, the **`resultOf`** property may contain a **`Typed Value`** which has an **`axis`** property to indicate the **`Phenomenon`**. Using this method, the mapping from the semantics to the value is bound within the **`Typed Value`**, the model for which is described in Clause 0.

If the phenomenon is indicated in more than one place, the processing system may check that it is consistent.

The **`location`** of the observation may be provided indirectly. The Procedure (which might be a SensorInstance) will normally indicate its sample. The subject of the Observation may be provided directly as the value of the **`target`** property, in which case its location defines the location relevant to the result. For *in-situ* sensors, the location of **`Platform`** or **`Station`** to which the **`Sensor Instance`** is attached defines the location of the observation. For remote sensors, the target **`Region`** will be at a different location to the **`Platform`**. Various opportunities for information normalisation exist.

Note that it may be useful for **`using`** to identify objects other than “sensors”. For example, a person may carry out a field survey. A commercial laboratory, using one of several procedures pre-defined according to standards applicable at the time the measurement is made, usually carries out an assay of a rock sample. Estimates of values of phenomena may be made by software such as a numerical simulation system or differential equation solvers, using finite elements, finite differences, etc. To cover each of these cases, it will be necessary to define additional descriptors for the procedures.

Note that the models from Fowler and Yoder et al. consider processing and validation, as well as the static information model. In the OGC context, this overlaps the interaction between the information and service models.

6.3.5 Observation Collections

6.3.5.1 Collections and arrays

Observations may be aggregated into a Collection (Figure 9). Using the composite pattern [PAT1995], an **`Observation Collection`** may itself be treated as an **`Observation`**.

Certain items may be common to all of the members of the collection. Thus we allow a general **`ObservationCollection`** to carry the **`relatedFeature`**, **`timeStamp`** and **`target`** properties.

An **`Observation Collection`** consisting of ordered, homogeneously typed Observations is an **`Observation Array`**. The array may carry an **`observable`** property, which is inherited by all of its members. In some cases, all the observations in an array may be **`using`** a single sensor, so this property may optionally be attached to the array and inherited by all of the members.

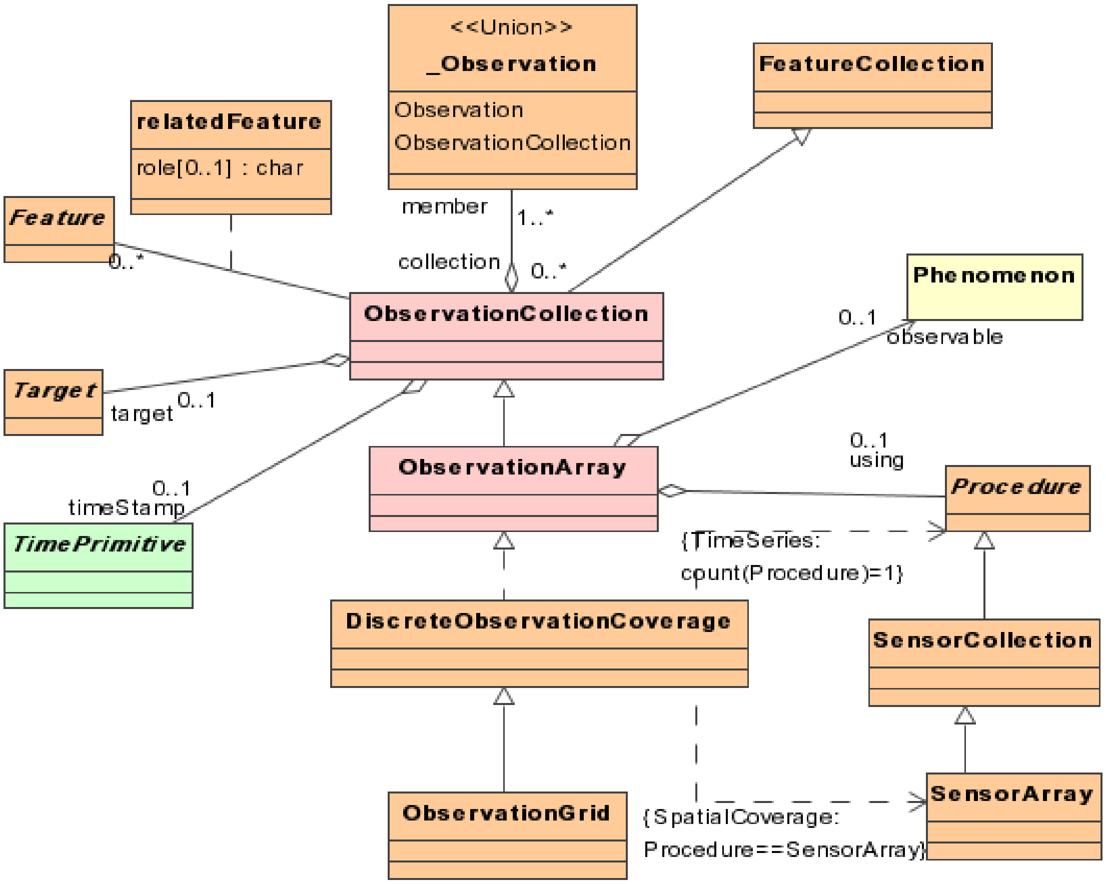


Figure 9. Observation Collection and Observation Coverage

6.3.5.2 Coverage view

Following the analysis presented in clause 6.2.3, an ObservationArray is a representation of a discrete observation coverage. The values of the set of `location` and `timeStamp` properties defines the domain set of the coverage. Any or all of the values of the other properties of the Observation features may comprise the range set, provided that the same properties are used from all the member Observations. The most common case would be where the range of the coverage is composed of the values of the `resultOf` properties from all the observations.

Alternatively, a single "Observation" may have an extensive location as its target, and the value of its resultOf property be composite. This view may be useful when the phenomenon is sampled instantaneously, such as when a frame-camera samples the light arriving from across a target region.

A temporal coverage or time-series is usually associated with observations made by a single sensor. A spatial coverage may be collected using a spatial array of similar sensors sampled at a single instant, or using a spatial array of similar sensors or a single sensor sampling a set of locations measuring a time-invariant phenomenon.

6.4 Value Model

6.4.1 Representation of the result

In engineering and natural sciences, “value” refers to the magnitude of a quantity expressed as a unit of measure multiplied by a number [VIM]. Measurement theory generalises this notion to include positions or ordinates on interval scales, and terms and other symbols, which may have nominal and ordinal scales [KRALST, SAR1995]. Here we also consider observations whose result may be related to positions within a frame, time instants within a particular calendar, and aggregate values. The components of aggregates may be primitive (scalar) values, or may themselves be aggregates. We refer to any of these as **`Value Objects`**.

Note that values are usually expressed using a small number of representations (numbers, character-strings, and composites of these), but the details of the measurement scale determine what **operations** are valid on the results [KRALST, SAR1995]. For example, values of mass and temperature may both be expressed as real numbers, but while both ratios and differences are meaningful for mass which is expressed on a ratio scale, only differences are valid for temperature which is expressed on an interval scale. Rank is often expressed as a number, but neither ratios nor differences are significant, only order. The valid operations are highly important when performing analysis.

Issue Name: [Valid operations summary. (SJDC, Dec 2002)]

Issue Description: [A summary (table?) of values/scales and valid operations should be prepared and provided as part of the abstract spec here. This may be based on material from SAR1995, KRALST, etc.]

Resolution: [Insert Resolution Details and History.] (Your Initials, Date)]

6.4.2 Scalar Values

Primitive or scalar values can occur on several scales, including nominal, ordinal, interval and ratio scales [KRALST]. We model these as a small number of generic DataTypes **`Category`**, **`Quantity`**, **`Count`** and **`Boolean`**, derived from an abstract superclass **`Scalar Value`** (Figure 10).

A similar pattern is used for each of the scalar value objects, comprising a numerator or value using the appropriate simple data type, and a denominator indicating the scale for the value. The model for **`Quantity`** is the same as **`Measure`** discussed in the OGC recommendation on Units of Measure [UOM2001] and ISO 19103 [19103].

6.4.3 Scalar Value Lists

In some contexts, we find an ordered set of values using the same scale, such as a set of radiance amplitudes, which are the value of multiband radiance or a spectrum. We model **`Category List`**, **`Quantity List`**, **`Count List`** and **`Boolean List`** following the equivalent scalar values by simply extending the cardinality of the value attribute to [1..*] (Figure 10). [Alternatively, the lists could be considered as the primitive type, with scalar values simply being lists of unity length.]

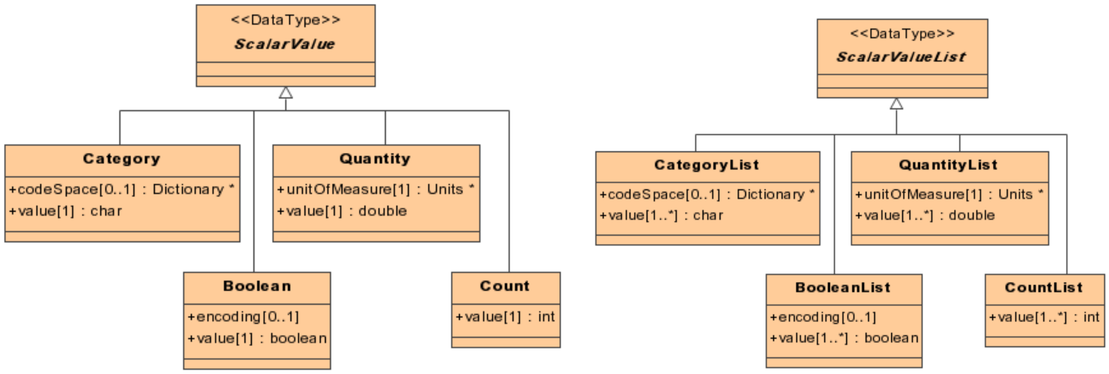


Figure 10. Generic scalar value model (left), and model for ordered lists of scalar values (right).

6.4.4 Scalar Value Objects

The results of certain observations are values of geometry or time. Spatial position and time instant are special forms of ordinates, which use an interval scale or *coordinate system*, and thus are similar to some of the scalar datatypes already described. However, these datatypes are conventionally managed using special components [ISO19107, ISO19108]. In order to accommodate the appearance of spatial and time objects within the same context as the scalar values, we group the components into a generalised class `Value` and a union class `Value Object` as shown in Figure 11.

Finally, in order to support a case that occurs frequently in practical situations where a value is expected but not present for some reason, a Null object may appear as a value object. The null object may carry some explanation for the absence of a valid value.

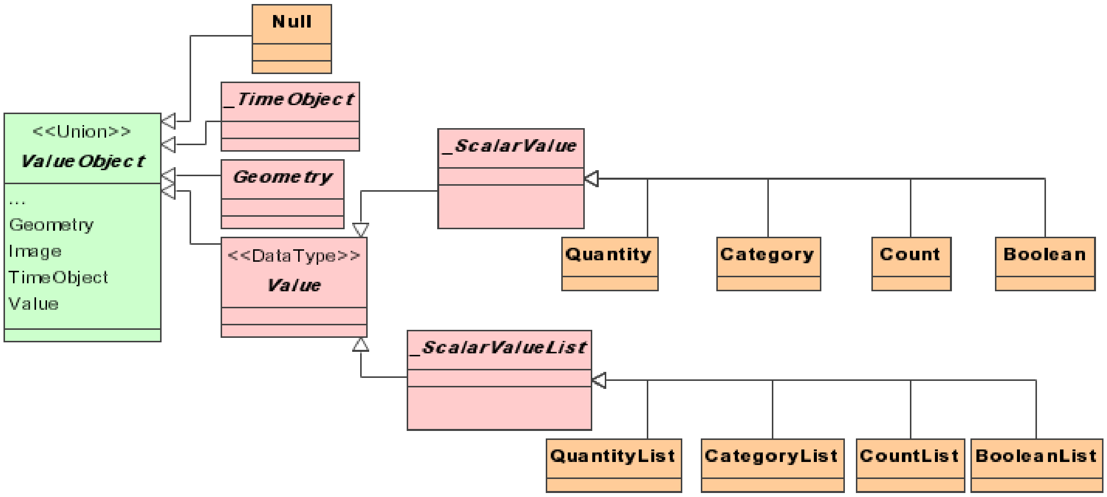


Figure 11. Class diagram showing scalar value substitutability

6.4.5 Aggregate Values

Some observations result in values with a more complex structure, in particular aggregate values composed of multiple components. The components of these aggregates may be strongly coupled, such as vectors and tensors where the values of the individual components are related and will be simultaneously changed by transformation of the reference system, or they may not be directly coupled. In general, the components may be scalar values or other aggregates [ISO11404]. Aggregate values correspond to the *record* datatype [ISO19103].

The composite pattern [PAT1995] provides a flexible method for constructing general aggregates by recursively attaching components. Here it is necessary to make a small adaptation to accommodate Geometry objects and Time Objects acting as primitives alongside the simple scalar values (clause 6.4.4). Thus, while a **`Composite Value`** may be composed of any of these, it is only substitutable for one member of the union class, i.e., **`Value`** (Figure 12). Note also that the components of a composite may be primitive values or aggregates. An aggregate value built in this way has a tree structure, which ultimately resolves to leaf nodes each bearing a **`Scalar Value`**, **`Scalar Value List`**, **`Geometry`** or **`Time Object`**, possibly at varying levels.

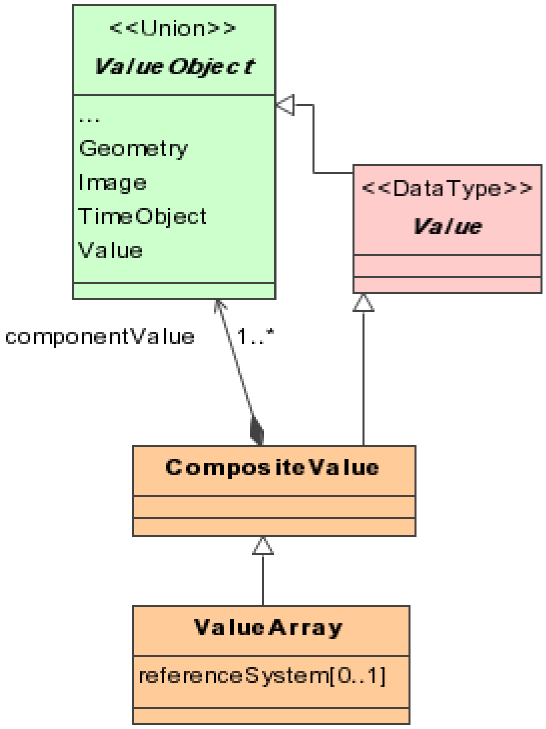


Figure 12. Composite model for aggregate value types

We define one special case of aggregate values. A **`Value Array`** is an ordered collection in which each member is of the same type. Arrays of **`Composite Values`** may form a **`Value Array`**, such as a series of vector values. Arrays themselves may be nested, so a set of values corresponding to time-series of the same **`Value`** from different locations can form an array of **`Value Arrays`**.

When the members of the array are **`Scalar Value`**s, the reference system may be indicated on the container. The optional attribute **`referenceSystem`** is abstract: this is substituted by **`codeSpace`** or **`unitOfMeasure`** as appropriate.

Note that an array whose members are scalars is more efficiently represented using a **`Scalar Value List`**.

6.4.6 Semantically typed values: Typed Values

As discussed in Clause 6.3.3, the meaning of the result of an observation is intrinsically determined by the procedure (sensor) used to make the observation, or the phenomenon may be indicated as a direct property of the observation. So when the result is provided in the context of the rest of the information associated with the observation the semantics of the result are available by inspecting the description of the sensor instance.

However, there are circumstances in which it may be convenient to indicate the meaning of a value directly. To accomplish this we add an attribute **`axis`** to the **`Scalar Value`**s, **`scalar value list`**s, **`Composite Value`**, and **`Value Array`** with an additional property, whose value indicates a Phenomenon. These are named Typed Values (figure Figure 13).

Typed Values act as a mapping from the semantic space (**`Phenomenon`**) to a **`Value`**. It is necessary that the Phenomenon and the Value class are consistent: for example it would be an error if a "Quantity" were associated with the observable "species Name".

The model is a generalisation of the DQ_QuantitativeResult datatype defined in ISO 19115 [ISO19115].

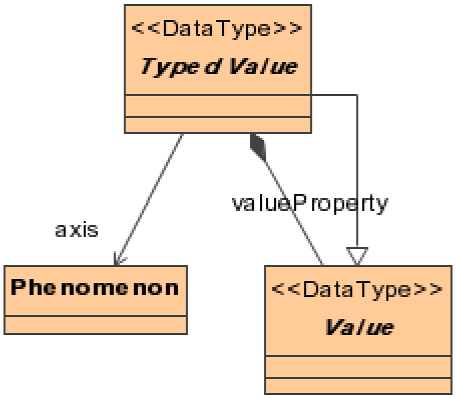


Figure 13. Model for a typed value

One further refinement is to associate one or more quality descriptions with an observed value. A provisional model for this is shown in Figure 14.

Various methods for encoding a quality description are available. Five specific methods ("Description" – a textual description; "Rank" – a value on an ordinal scale; "Error" – a single quantity; "Bounds" – a pair of quantities, "Errors" – a set of quantities) are described in the implementation in clause 7.2.3.

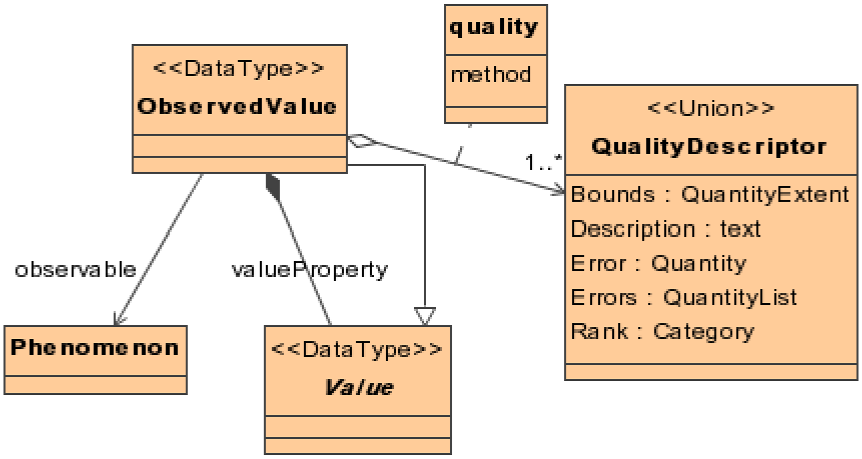


Figure 14. Model for an observed value

6.5 Model for observable phenomena and measurands

6.5.1 Representation vs meaning

The value of the observable indicates the phenomenon being sampled by an observation, and thus provides the conceptual type of the observation and its result. An observation may be typed at various levels of generalisation, which may support different operations. For example, measurements of *chloride ion concentration* in ground-water may be available within a small area, while over a broader area only *total dissolved solids* are recorded. Both of these might be useful within a study of *water quality* distribution, but direct quantitative comparison is not valid.

A single phenomenon may afford description on various scales: for example, *height* may be {short, medium, tall} or may be given using a quantitative measure of length such as metres. Furthermore, the same scale may be used for observations of different phenomena: for example, *metres* may be used to measure height, depth, wavelength, etc. Thus, although there is a strong assocation between the scale or reference system and the phenomenon such that only certain combinations are permitted, the correspondence is not one-to-one. Both must be available as part of a description of an observed value.

In general the phenomenon will be defined separately from scale or reference system, and needs a semantic definition which is ultimately grounded in natural language.

An important characterisation of a measurand (i.e., scalar observable type whose value is a quantity) is its dimensionality with respect to fundamental quantities, expressed in the form $L^aM^bT^c$, etc. This dimensionality must be reflected by the scale used for the result. A detailed classification of measurands using physical principles is presented in the report on sensor technology from US National Research Council [NRC1995]. However, the basis for classification of phenomena whose value is either non-quantitative or aggregate (e.g., Water Quality, Earthquake Parameters, Species) is not simple, and raises significant ontological and philosophical questions.

A system(s) of classification for phenomena/measurands is critical to allow comparison of and composition of the results of observations in analysis.

Issue Name: [Classification of observables/measurands/phenomena]

Issue Description: [The NRC classification, which deals with scalar phenomena that afford measurement using sensors is a useful start. Insert a table summarising the NRC classification.]

Resolution: [Insert Resolution Details and History.] (Your Initials, Date)]

6.5.2 Description of a phenomenon

There are many techniques available to represent aspects of the required semantics, including the XML languages XML Schema, RDF/XML, DAML-S. We make no recommendation about implementation of the fundamental definitions. For the purposes of the discussion here we will simply assume that an appropriate definition of each basic phenomenon is available, and may be referenced using a URI.

A simple phenomenon will in many cases be sufficient to characterise the type of the observation. However, for some observable types additional information is required. Combinations of phenomena are often required to define an observable. For example: in remote sensing *radiance* is usually characterised by *wavelength* band, as fixed by the wavelength dependent sensitivity of the sensor; *concentration* may be considered a basic observable, which needs to be combined with another classifier such as *substance*, *analyte* or *chemical species* to get a useful observable phenomenon.

Furthermore, in cases where the phenomenon has an aggregate value, each component of the value plays a role within the aggregate that may itself be classified with an phenomenon. For example, the horizontal component of *wind-speed* has two components: *speed* and *azimuth*, or two vector components such as *speed-north* and *speed-east*. A *spectrum* is a set of values of a homogeneous phenomenon, such as *reflectance*, distinguished by variation on a secondary axis, such as *frequency*. An aggregate result implies an aggregate observable.

The primitive phenomena may be refined or combined in systematic ways to generate an unlimited number of derived phenomena. Figure 15 shows a basic model for constructing parameterised and composite phenomena, starting from the assumption that definitions of scalar or primitive phenomena are available and sufficient.

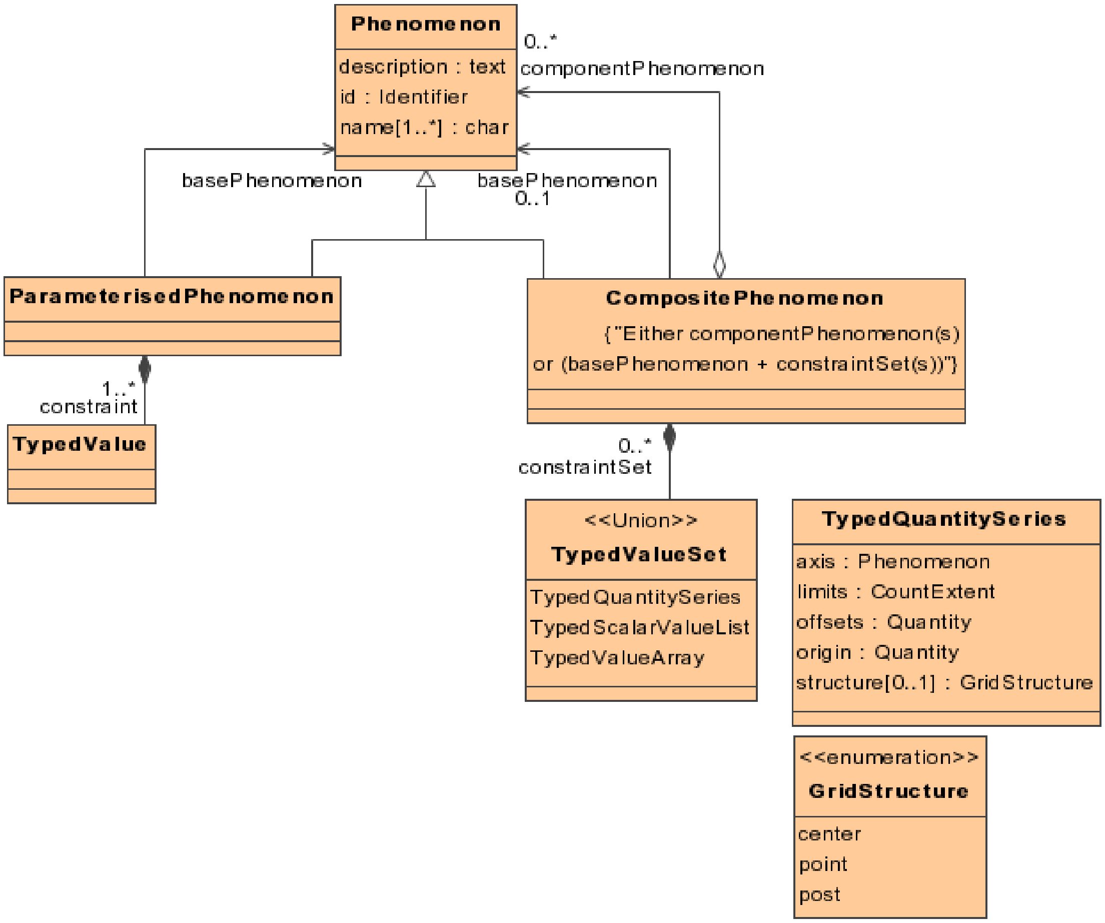


Figure 15. Structure of derived phenomena

6.5.3 Phenomenon

A basic definition of a phenomenon may be provided as a text description or using some knowledge representation language.

6.5.4 Parameterised Phenomenon

A **Parameterised Phenomenon** takes a **base Phenomenon** and applies one or more **constraints**, the content of each of which is a **Typed Value**, and thus defines an **axis** and a **value**. This is interpreted as specifying a restriction of the base observable on a set of orthogonal axes. For example, the base may be *radiance* with the constraints *wavelength* and *polarisation direction*.

The resulting parameterised phenomenon is derived from a set of more primitive phenomena: one identified as the base Phenomenon, and one indicated by the value of the axis on each of the constraints.

6.5.5 Composite Phenomenon

A **`Composite Phenomenon`** may be constructed from **`component Phenomena`** using the composite pattern. For example, *Earthquake parameters* may have the components *Origin Time*, *Epicentre* (a 2D location), *depth*, and *moment tensor* (the size of the event), the latter being another composite.

Alternatively, a **`Composite Phenomenon`** may be constructed by taking a **`base Phenomenon`** and applying one or more **`constraintSets`**, each comprising an (equal length) array or series of typed values. For example, a *Radiance Spectrum* may have a base of *Radiance* and a constraint set of typed quantity extents describing the *wavelengths*. This set might be expressed explicitly as a **`TypedValueArray`**, or implicitly as a **`TypedQuantitySeries`**.

The **`TypedValueArray`** follows the ValueArray pattern described in clause 6.4.5, extended with a typing axis as described in clause 0. The TypedQuantitySeries is an implicitly defined array of quantities described using the parameters

> **`axis`** indicates the phenomenon being varied,
>
> **`limits`** gives the integer index of the low and high positions in the grid,
>
> **`origin`** gives the absolute location of the grid position with zero index, and
>
> **`offsets`** gives the separation between adjacent positions in the grid.
>
> **`structure`** indicates how the positions in the grid should be used to construct the members of the grid, with the values:
>
> > **`point`** if the members have zero width, with the grid positions used directly, giving a total count of (high-low+1),
> >
> > **`post`** if the members have a width equal to the offset, and grid positions delimit cells, with a total count of (high-low), or
> >
> > **`center`** if the members have a width equal to the offset, and grid cells are centered on the grid positions, with a total count of (high-low+1).

Note that a Composite Phenomenon corresponds with the ISO 19103 RecordType.

When considering aggregate values, the mapping from the components of the composite phenomenon to the components of the aggregate value must be clear (e.g. see example in C.5.2).

6.6 Sensor Web and the Information Model

6.6.1 Using observations

Observations are frequently used in signal or feature detection, which involves comparison of values between one place or time and another. Thus a requirement for most observations is that they may be assembled into an observation coverage.

The homogeneity requirement might be satisfied to various levels of rigour. For example, perfect homogeneity amongst the values strictly requires that the same measuring device or sensor, with the same calibrations, be used for all observations. If the sensor does not vary, then its description (or the method used to estimate the value) is a property of (or metadata for) the whole coverage.

In practice, a useful coverage can be built from the results of observations providing the values sample the same phenomenon, and that the results may be converted into a common scale. This requires that the phenomenon is identified or described in a way that supports comparison at a semantic level. Evaluation of suitability may involve tests of the phenomena from which the derived phenomenon is composed (i.e., the values of the basePhenomenon and axis properties). If the sensor varies, then the sensor identity or description comprises a separate component of the coverage, or may be represented separately as a "sensor coverage" complementing the "observed value coverage".

6.6.2 Measurements from a Sensor Collection Service

Measurement results may be encapsulated within Observation Features, Observation Collections and Observation Arrays, and within Discrete Observation Coverages. Since Observations and Coverages are Features, then these can be delivered through the general OGC service interfaces Web Feature Service [WFS], and Web Coverage Service [WCS]. However, the Sensor Collection Service [SCS] interface is optimised for access to observations and associated information.

Valid XML documents may also be constructed which contain only "disembodied" or context-free Values, Composite Values and Typed Values – i.e., a Value or Typed Value element can occur as the root element of a document which is valid according to the value.xsd or observedValue.xsd schema. Since Values and Observed Values are not Features, then such XML documents cannot be delivered by a WFS. Nevertheless, there may still be some utility in such a service: provided the client which invokes the service stores the parameters of the request (the sensor identity, the time of interest, etc.), then a "disembodied value" could be used to complete an observation feature, the other properties of which are predefined. Provision of "disembodied values" might be a very lightweight service, which may be suitable for fast streaming data, or over a low-bandwidth connection. It is not yet clear if a SCS should return Values not contained within Observation Features, as discussed here.

6.6.3 Reference systems or scales for Values

The scale for each value is indicated by the value of the relevant attribute of the value object – i.e., the **`unit of measure`**, **`code space`**, **`spatial reference system`**, **`frame`**. In a serialisation, the scale is included through an association with a value instance; its complete description will usually be held elsewhere. Thus, the model is not strongly dependent on the mechanisms used to describe reference systems for values.

A number of models and encodings for reference systems are available.

The description of the International System of Units [ISO1000] establishes a convenient terminology that can be used to define a unit-of-measure for a quantity. This includes the concepts of Base Units, Derived Units, quantity types, symbols, etc (see also Figure 6 in YOD). The XML schema **`units.xsd`** described in the GML3 specification [GML3] describes a convenient serialization of this, also adding Conventional Units, which are related to other units through scaling and offset. A sample dictionary of units encoded using this model is included in Annex D.

ISO 19108 [ISO19108] describes a model for certain types of temporal reference systems. A subset of these is implemented in the XML schema `temporal.xsd` described in the GML3 specification [GML3].

OGC Abstract Specification Topic 2 [OGCAS2] describes a set of models covering coordinate reference systems and transformations. These are implemented as a set of XML schemas in GML3 [GML3]. These provide a reasonably a comprehensive solution in the area of spatial reference systems.

We have not yet explored or implemented general solutions proposed for the other classes of "reference systems" required for generalised observed-values. These are:

- Nominal scale or dictionary ("code space"), which may need to be cross-referenced through a thesaurus. Note that a gazetteer is a specialised dictionary that binds a code to a location.
- Ordinal scale or ordered dictionary ("code frame") which is very complex when considering all the ways in which things can be ordered (relative, numerical, fuzzy/partial) and also the relationships between code-frames which purport to cover the same space.

A number of resources address the issue of terms and identifiers. Within GML3 a generic Definition and Dictionary is provided, which supports the binding of a description to a name, with a handle that may be used to construct a URI that identifies the definition. ISO standards 2788 and 5694 describe guidelines for monolingual and multilingual thesauri. ISO 19112 [ISO19112] describes spatial referencing by identifier (gazetteer) which is essentially a special case of a term list, and OGC document 02-076r2 describes an implementation of this as a profile of WFS.

The Reference System must be consistent with the Phenomenon: e.g., Temperature should use Celsius, Fahrenheit or Kelvin; Speed should use Metres per second or Miles per Hour, etc. This is managed within the definition of the units-of-measure through the `quantityType` parameter. Validation will be supported providing the `quantityType` used in the units directory relates to the definitions used for the `Phenomenon`, with suitable allowance for generalisation. For example, an observation with the observable “Water Temperature” for which the `basePhenomenon` is “Temperature”, is valid using units of measure whose `quantityType` is simply “Temperature”.

Note that we do not expect that this condition can or will be checked through XML Schema validation, so it is the responsibility of application processes to ensure validity using other methods. Beyond these general model implications, the definition or syntax used for Reference Systems is outside scope here.

In the rest of the report we assume that an appropriate definition is available, and may be referenced using a URI.

6.6.4 Sensor Instances and Other Descriptions of Observation Methodology

Information about the Sensor Instance, encoded using SensorML, would usually be available from a Sensor Instance registry, which would acquire this data when a related Sensor Web service is published. The client would probably access this information prior to acquiring observations or measurements from a specific Sensor Web service.

The Sensor Instance description might also be available directly in response to a DescribeSensor request. The description will include information about the sensor calibration and accuracy, the sensor frame, mount and platform. Thus, the description of the sensor should allow an estimate of the error on the observation to be made. The definition of SensorML, the model and language used to describe sensors, is the subject of another IPR [SensorML], so is not described further here.

The Sensor Instance description should also include a description of the structure of results delivered by the sensor. This will probably use the encoding for Phenomena discussed in this report.

7 XML Encoding of the Observation and Measurement Models

In this Clause we describe the implementation of the model for Observations, Values and Phenomena in XML. The analysis is presented through reference to the XML Schema documents shown in Annex B, with example instances given embedded within the description and also in Annex C.

We start in Clause 7.1 with a brief description of the XML idiom used to serialise the models presented in Clause 6. Since the components for Values are required by the other components, these are described first in clause 7.2. The encoding for definitions of Phenomena are described next in clause 7.2.2. Clause 7.4 describes the encoding of observation features. The examples focus particularly on Observation Collections and Value Collections, which will be important in building Coverages. In Clause 7.5 we briefly describe a method for deriving strongly typed values, though this work is incomplete.

The descriptions are primarily accomplished by showing examples of *instance documents* representing how data streams from sensor services and encoded as XML documents might appear. These examples show a useful variety of instances, but the normative capabilities are the XML schemas for these components, given in Annex B.

The Observations and Measurements schemas have been developed to be consistent with GML3, and re-use many GML components, which can be identified by their namespace prefix `gml:`. The new components developed for Observations and Measurements are assigned to a namespace with the identifier http://www.opengis.net/om, for which the prefix `om:` is used in the examples shown here.

XML Schema 1.0 is used in this document to define the syntax and vocabulary of XML documents. It is not assumed that XML documents will be fully validated against their respective schemas for normal service invocation. It is assumed, however, that XML parsing and validation will follow normal XML syntax rules, for example regarding XML Namespaces and their definition within XML documents. Specific namespace URI's are suggested and their standardization is encouraged. Specific namespace prefixes area used, but their standardization is not suggested in order to maintain maximum flexibility in aggregating XML from different namespaces.

7.1 GML Mapping of Model Components into XML

OGC's Geography Markup Language [GML3] defines a consistent XML serialisation for information modelled in UML. The style used results in very explicit XML instance documents: UML attribute names and association rolenames are used for the names of XML elements representing properties. UML class names are used for the names of XML elements representing objects which may have identity.

Consider a simple Feature modeled according to Figure 16.

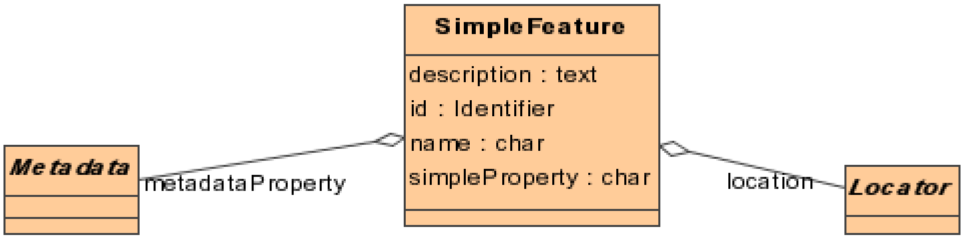


Figure 16. Simple feature model

Following the GML encoding rules, this appears:

Code sample (i)

```
<Feature id="ACB123">
  <metadataProperty><Metadata>Some structured metadata </Metadata></metadataProperty>
  <description>A basic located feature for illustration</description>
  <name>Fred</name>
  <location xlink:href="http://your.domain.org/locations#point3"/>
  <simpleProperty>Some property value</simpleProperty>
</Feature>
```

The components “id”, “metadataProperty”, “description”, “name”, “location”, and “simpleProperty” are all properties of this feature. In this example, three properties have a value that is encoded as a text-string, `id` is an XML ID and is carried as an XML attribute, `metadataProperty` contains an element which would contain some structured metadata, and `location` uses `href` to make an association with the description of a Point or other locator available elsewhere.

The encoding used in this recommendation generally follows the GML idiom, so the default mapping is that *properties* are encoded as *elements* in content models. Thus “location”, “target”, “using” and “resultOf”, etc., are XML elements. Exceptions are made:

(i) for components used for identity and in building links and relations (whose values have XSD type ID, anyURI, etc),

(ii) for a few parameters that indicate *refined semantics* of element types without affecting the content model. These are encoded as XML attributes on the parent element.

(iii) in the context of UML classes with the stereotype `<<DataType>>`, instances of which are not identifiable objects, and are represented using customised encodings which may take advantage of specific XML capabilities.

For other details of GML, consult the GML3 specification [GML3].

7.2 XML for Values

7.2.1 Basic value objects

The Value model presented in Clause 6.3.3 is the basis for the GML Schema **`valueObjects.xsd`**. This contributes components to the GML namespace. The normative description of the schema document valueObjects.xsd is provided in clause 7.10.4 of the GML3 specification [GML3].

Note that in our use of reference systems, we have followed the OGC Units of Measure recommendation [UOM2001] so the scale is bound directly to each value.

The model described in clause 6.4 above makes two enhancements to the basic value model. These are implemented in two new schema documents **typedValue.xsd** described in clause 7.2.2, and **observedValue.xsd** described in clause Code sample (viii).

7.2.2 Typed values

The schema document typedValue.xsd is presented in Annex B. The components in this document essentially reproduce the components defined in the GML schema valueObjects.xsd, but add an additional XML attribute **`axis`**, whose value is a URI. The intention is that **`axis`** will identify a phenomenon, from a phenomenon dictionary or service (see clause 7.3 for a proposed encoding).

This use of an XML attribute **`axis`** to sub-type the value is an example of "soft-typing" applied at a datatype level.

The following shows a series of examples of typed values using the soft-typing approach. The first three are straightforward extensions of the corresponding value objects:

Code sample (ii)

```
<om:TypedCategory
axis="http://my.big.org/phenomena #animalSpecies"
codeSpace="http://my.zoo.org/referenceSystems/classifications/marsupials">Quokka</om:TypedCategory>
```

Code sample (iii)

```
<om:TypedQuantity
axis="http://my.big.org/phenomena#waterTemperature"
uom="http://my.big.org/referenceSystems/units#Celsius">21.2</om:TypedQuantity>
```

Code sample (iv)

```
<om:TypedQuantityExtent
uom="http://my.big.org/referenceSystems/units#um"
axis="http://my.big.org/phenomena#wavelength">0.45 0.52</om:TypedQuantityExtent >
```

Note that the order of XML attributes is not significant.

In the next example, values from an ordinal scale are used to describe values from a phenomenon which is often described using numeric values:

Code sample (v)

```
<om:TypedCategoryList
codeSpace="http://my.big.org/referenceSystems/classifications/weight"
axis="http://my.big.org/phenomena#weight">heavy light withheld medium</om:TypedCategoryList>
```

Note that one of the values in the list is absent. Its place is marked by the GML null value "withheld".

The final pair of examples give values for the composite phenomenon *Moment Tensor* from earthquake seismology. In the first example, the components are disambiguated through additional axis attributes.

Code sample (vi)

```
<om:TypedCompositeValue axis="http://my.big.org/phenomena#MomentTensor">
  <gml:valueComponents>
    <om:TypedQuantity axis="http://my.big.org/phenomena#Mrr" uom="#Nm_19">-1.00</om:TypedQuantity>
    <om:TypedQuantity axis="http://my.big.org/phenomena#Mtt" uom="#Nm_19">0.92</om:TypedQuantity>
    <om:TypedQuantity axis="http://my.big.org/phenomena#Mff" uom="#Nm_19">0.09</om:TypedQuantity>
    <om:TypedQuantity axis="http://my.big.org/phenomena#Mrt" uom="#Nm_19">-1.69</om:TypedQuantity>
    <om:TypedQuantity axis="http://my.big.org/phenomena#Mrf" uom="#Nm_19">-0.09</om:TypedQuantity>
    <om:TypedQuantity axis="http://my.big.org/phenomena#Mtf" uom="#Nm_19">-0.37</om:TypedQuantity>
  </gml:valueComponents>
</om:TypedCompositeValue>
```

In the second example, a scalar value list is used, so there is an implied mapping between the sequence of components described in the definition of the composite phenomenon *Moment Tensor* (see clause 7.3.3), and the values in the QuantityList.

Code sample (vii)

```
<om:TypedQuantityList axis="http://my.big.org/phenomena#MomentTensor" uom="#Nm_19">-1.00 0.92
0.09 -1.69 -0.09 -0.37</om:TypedQuantityList>
```

The method of carrying the type information as the value of the `axis` attribute is designed to support applications where it is desired to reserve typing until run-time. It is also used as part of the derived phenomena descriptions, where it is useful to have the axis explicit within the instance.

As an alternative to soft-typing, for applications that deal with a limited number of value types, it may be more desirable to create a local application schema, and declare a named element whose name indicates the phenomenon. Given the necessary schema declarations, the following might represent equivalent information:

Code sample (viii)

```
<om:TypedQuantity axis="phenomena.xml#Temperature”
uom="units.xml#degC">35.5</om:TypedQuantity>

<my:Temperature uom="units.xml#degC">35.5</my:Temperature>
```

7.2.3 Observed values

The schema document `observedValue.xsd` is presented in Annex B. This schema is experimental and is provided for information only and will not be discussed further at this time.

7.3 XML for phenomenon descriptions

The Phenomenon model presented in Clause 6.5 is used as the basis for a GML conformant XML Schema **`phenomenon.xsd`** (Annex B.2.4). This schema document <**`include`**>s **`typedValue.xsd`** (Annex B.2.5).

7.3.1 Basic phenomena

The element **`om:Phenomenon`** uses **`gml:DefinitionType`**, which supports a generic definition consisting of a name (and aliases) and a description. Thus basic phenomena can be defined as shown in the following examples.

Code sample (ix)

```
  <om:Phenomenon gml:id="Age">
    <gml:description>Time duration since creation</gml:description>
    <gml:name>Age</gml:name>
  </om:Phenomenon>
```

Code sample (x)

```
  <om:Phenomenon gml:id="AtmosphericPressure">
    <gml:description>fluid pressure exerted due to the gravitational effect on the column of atmosphere
above the position of interest</gml:description>
    <gml:name>Atmospheric Pressure</gml:name>
  </om:Phenomenon>
```

If a definitive definition is available from a source that can be identified using a URI, then this can be indicated using a link on the description element, instead of having the description of the term inline:

Code sample (xi)

```
  <om:Phenomenon gml:id="Mrr">
    <gml:description xlink:href="http://big.geophysics.org/parameters/earthquakes/moment/Mrr"/>
    <gml:name>Earthquake Moment Tensor component Mrr</gml:name>
  </om:Phenomenon>
```

7.3.2 Parameterised phenomena for scalar values

A value of radiance measured in one band from Landsat's Thematic Mapper can be expressed using a **`ParameterisedPhenomenon`** element, which applies a **`constraint`** to a **`basePhenomenon`**:

Code sample (xii)

```
    <om:ParameterisedPhenomenon gml:id="TMBand1">
      <gml:name>Landsat TM band 1</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.45
0.52</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
```

This description assumes the existence of definitions of the phenomena *Radiation* and *Wavelength* elsewhere in the context, and dictionary of units-of-measure.

A **`ParameterisedPhenomenon`** can have an arbitrary length sequence of **`constraint`** properties. For example, the phenomenon associated with a channel on a radar scanner might be characterized as:

Code sample (xiii)

```
  <om:ParameterisedPhenomenon gml:id="_19V">
    <gml:description>19 GHz radiation Vertical Polarisation</gml:description>
    <gml:name>19V</gml:name>
    <om:basePhenomenon xlink:href="#Radiation"/>
    <om:constraint>
      <om:TypedQuantity axis="#PeakWavelength" uom="./units.xml#GHz">19.35</om:TypedQuantity>
    </om:constraint>
    <om:constraint>
      <om:TypedCategory axis="http://www.opengis.net/componentPhenomenonType#PolarisationDirection"
codeSpace="http://www.opengis.net/sensorGlossary">V</om:TypedCategory>
    </om:constraint>
  </om:ParameterisedPhenomenon>
```

Alternatively, any previously defined **`Phenomenon`** can be subject to additional **`constraints`**. These might be applied consecutively as follows:

Code sample (xiv)

```
  <om:ParameterisedPhenomenon gml:id="WaterTemperature">
    <gml:name>Water Temperature</gml:name>
    <om:basePhenomenon xlink:href="#Temperature"/>
    <om:constraint>
      <om:TypedCategory axis="#Medium"
codeSpace="http://www.opengis.net/ows/media">water</om:TypedCategory>
    </om:constraint>
  </om:ParameterisedPhenomenon>

  <om:ParameterisedPhenomenon gml:id="SurfaceWaterTemperature">
    <gml:name>Surface Water Temperature</gml:name>
    <om:basePhenomenon xlink:href="#WaterTemperature"/>
    <om:constraint>
      <om:TypedQuantityExtent axis="#Depth" uom="./units.xml#m">0.0 0.5</om:TypedQuantityExtent>
    </om:constraint>
  </om:ParameterisedPhenomenon>
```

7.3.3 Composite Phenomena for aggregate values

Composite Phenomena may be defined according to two patterns.

7.3.3.1 Explicit Composite pattern

The composite pattern may be used to describe a composite in which the components are explicitly enumerated. For example, the NEIC site (http://neic.usgs.gov/neis/FM/) reports descriptions of earthquakes through a set of parameters that could be described (in part) as follows:

Code sample (xv)

```
<om:CompositePhenomenon gml:id="EarthquakeParameters">
  <gml:name>Earthquake Parameters</gml:name>
  <om:componentPhenomenon>
    <om:CompositePhenomenon gml:id="EarthquakeLocation">
      <gml:name>Earthquake Location</gml:name>
      <om:componentPhenomenon xlink:href="#Epicentre"/>
      <om:componentPhenomenon xlink:href="#Depth"/>
      <om:componentPhenomenon xlink:href="#OriginTime"/>
    </om:CompositePhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:CompositePhenomenon gml:id="MomentTensor">
      <gml:name>Earthquake Moment Tensor</gml:name>
      <om:componentPhenomenon xlink:href="#Mrr"/>
      <om:componentPhenomenon xlink:href="#Mtt"/>
      <om:componentPhenomenon xlink:href="#Mff"/>
      <om:componentPhenomenon xlink:href="#Mrt"/>
      <om:componentPhenomenon xlink:href="#Mrf"/>
      <om:componentPhenomenon xlink:href="#Mtf"/>
    </om:CompositePhenomenon>
  </om:componentPhenomenon>
</om:CompositePhenomenon>
```

This example illustrates nesting of composite phenenomena. *Earthquake Parameters* are comprised of *Earthquake Location* and *Moment Tensor*, each of which has further structure. In this definition, the phenomena *Epicentre*, *Depth*, *OriginTime* and the components of the *Moment Tensor* are treated as the base values, defined elsewhere.

Following the definition of a LandsatTM band above, the complete *LandsatTM spectrum* can be described explicitly as a `CompositePhenomenon` as follows:

Code sample (xvi)

```
<om:CompositePhenomenon gml:id="DiscreteSpectrumTM">
  <gml:name>Landsat Thematic Mapper spectrum</gml:name>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand1">
      <gml:name>Landsat TM band 1</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.45 0.52</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand2">
      <gml:name>Landsat TM band 2</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.52 0.60</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand3">
      <gml:name>Landsat TM band 3</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.63 0.69</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand4">
      <gml:name>Landsat TM band 4</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.76 0.90</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand5">
      <gml:name>Landsat TM band 5</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">1.55 1.75</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand6">
      <gml:name>Landsat TM band 6</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">10.4 12.5</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
  <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand7">
      <gml:name>Landsat TM band 7</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">2.08 2.35</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:componentPhenomenon>
</om:CompositePhenomenon>
```

7.3.3.2 Using a ConstraintSet

For composites where the `basePhenomenon` is uniform, and the `constraints` applied on one or more uniform `axes`, it is more efficient to use another pattern to build a description of the composite phenomena. This uses a variation of the method used for `ParameterisedPhenomenon`, with one or more uniform length `constraintSets`. For example, the Landsat spectrum can be described:

Code sample (xvii)

```
<om:CompositePhenomenon gml:id="TM">
  <gml:description>Landsat Thematic Mapper all bands</gml:description>
  <gml:name>Landsat TM</gml:name>
  <om:basePhenomenon xlink:href="#Radiation"/>
  <om:constraintSet>
    <om:TypedValueArray axis="#Wavelength">
      <gml:valueComponents>
        <gml:QuantityExtent uom="#um">0.45 0.52</gml:QuantityExtent>
        <gml:QuantityExtent uom="#um">0.52 0.60</gml:QuantityExtent>
        <gml:QuantityExtent uom="#um">0.63 0.69</gml:QuantityExtent>
        <gml:QuantityExtent uom="#um">0.76 0.90</gml:QuantityExtent>
        <gml:QuantityExtent uom="#um">1.55 1.75</gml:QuantityExtent>
        <gml:QuantityExtent uom="#um">10.4 12.5</gml:QuantityExtent>
        <gml:QuantityExtent uom="#um">2.08 2.35</gml:QuantityExtent>
      </gml:valueComponents>
    </om:TypedValueArray>
  </om:constraintSet>
</om:CompositePhenomenon>
```

If the components also vary according to another **`axis`**, for example *polarization*, then the values on the additional axes should be listed in the same sequence in additional **`constraintSets`**.

Finally, if the values of a **`constraintSet`** form a uniform series, this may be described using the implicit notation afforded by a **`TypedQuantitySeries`**. For example, a 512 channel spectrum with 4 nm wavelength channels might be described as follom:

Code sample (xviii)

```
<om:CompositePhenomenon gml:id="uSpectrum">
  <gml:description>Simple spectrum with uniform spacing of bands</gml:description>
  <gml:name>UniformSpectrum</gml:name>
  <om:basePhenomenon xlink:href="#Radiation"/>
  <om:constraintSet>
    <om:TypedQuantitySeries>
      <om:limits>0 512</om:limits>
      <om:axis>http://www.opengis.net/componentPhenomena#Wavelength</om:axis>
      <om:origin uom="#um">0.30</om:origin>
      <om:offset uom="#um">0.004</om:offset>
      <om:structure>post</om:structure>
    </om:TypedQuantitySeries>
  </om:constraintSet>
</om:CompositePhenomenon>
```

7.3.3.3 Mapping values to meaning - applying CompositePhenomenon

A **`CompositePhenomenon`** can be used by a **`TypedCompositeValue`**. In the first example, the component phenomena from the explicit form of the composite are shown on all the components of the typed value:

Code sample (xix)

```
<om:TypedCompositeValue axis="phenomena.xml#EarthquakeParameters">
 <gml:valueComponents>
  <om:TypedCompositeValue axis="phenomena.xml#EarthquakeLocation">
   <gml:valueComponents>
    <om:TypedValue axis="phenomena.xml#Epicentre">
     <gml:valueProperty>
      <gml:Point srsName="epsg:4326">
       <gml:pos>-67.563 -13.834</gml:pos>
      </gml:Point>
     </gml:valueProperty>
    </om:TypedValue>
    <om:TypedQuantity axis="phenomena.xml#Depth" uom="#km">632.</om:TypedQuantity>
    <om:TypedValue axis="phenomena.xml#OriginTime">
     <gml:valueProperty>
      <gml:TimeInstant frame="#ISO-8601">
       <gml:timePosition>1994-06-09T00:33:16.4</gml:timePosition>
      </gml:TimeInstant>
     </gml:valueProperty>
    </om:TypedValue>
   </gml:valueComponents>
  </om:TypedCompositeValue>
```

```
    <om:TypedCompositeValue axis="phenomena.xml#MomentTensor">
      <gml:valueComponents>
        <om:TypedQuantity axis="phenomena.xml#Mrr" uom="Nm_21">-1.00</om:TypedQuantity>
        <om:TypedQuantity axis="phenomena.xml#Mtt" uom="Nm_21">0.92</om:TypedQuantity>
        <om:TypedQuantity axis="phenomena.xml#Mff" uom="Nm_21">0.09</om:TypedQuantity>
        <om:TypedQuantity axis="phenomena.xml#Mrt" uom="Nm_21">-1.69</om:TypedQuantity>
        <om:TypedQuantity axis="phenomena.xml#Mrf" uom="Nm_21">-0.09</om:TypedQuantity>
        <om:TypedQuantity axis="phenomena.xml#Mtf" uom="Nm_21">-0.37</om:TypedQuantity>
      </gml:valueComponents>
    </om:TypedCompositeValue>
  </gml:valueComponents>
</om:TypedCompositeValue>
```

The composite value and the composite phenomenon have exactly the same structure.

Alternatively, the **`axis`** might only be indicated on the container element, and the value can be expressed using a simple list of components where the sequence of components of the **`CompositePhenomenon`** and in the **`CompositeValue`** are mapped to each other. For example, the information from the previous example could be expressed:

Code sample (xx)

```
    <om:TypedCompositeValue axis="phenomena.xml#EarthquakeParameters">
      <gml:valueComponents>
        <gml:Point srsName="epsg:4326">
          <gml:pos>-67.563 -13.834</gml:pos>
        </gml:Point>
        <gml:Quantity uom="#km">632.</gml:Quantity>
        <gml:TimeInstant frame="#ISO-8601"><gml:timePosition>1994-06-
09T00:33:16.4</gml:timePosition></gml:TimeInstant>
        <gml:Quantity uom="Nm_21">-1.00</gml:Quantity>
        <gml:Quantity uom="Nm_21">0.92</gml:Quantity>
        <gml:Quantity uom="Nm_21">0.09</gml:Quantity>
        <gml:Quantity uom="Nm_21">-1.69</gml:Quantity>
        <gml:Quantity uom="Nm_21">-0.09</gml:Quantity>
        <gml:Quantity uom="Nm_21">-0.37</gml:Quantity>
      </gml:valueComponents>
    </om:TypedCompositeValue>
```

This implements a *mapping* from the semantic domain to the value at the level of the composite, rather than the component, and results in a more compact encoding. However, it imposes an additional burden on processing software, which must resolve and then analyse the definition of the Phenomenon.

7.3.4 Phenomenon dictionary

The elements **`om:ParameterisedPhenomenon`** and **`om:CompositePhenomenon`** are in a substitution group headed by **`om:Phenomenon`**, which in turn is in the substitution group **`gml:Definition`**. Thus a list of descriptions of observable phenomena may be assembled in a **`gml:Dictionary`**. An example of such a dictionary is included in Annex D.

7.4 XML for Observations

A basic observation model has been implemented in GML3 in the schema document **`observation.xsd`**.

The model described in clause 6.3 extends this with the additional properties **`observable`**, **`quality`** and **`relatedFeature`**, and also introduces a structure for aggregate observations. This model is implemented in the GML conformant XML Schema **`richObservation.xsd`** (Annex B.2.2). This schema **`<import>`**s components from GML via the **`observationAndValue.xsd`**, which in turn <**`include`**>s the **`observation.xsd`** and **`valueObjects.xsd`** schema documents. The richObservation schema **`<include>`**s the components from the **`observedValue.xsd`** schema document directly.

In the schema presented here, the property **`gml:using`** is replaced in **`om:RichObservation`** (and in all observation types derived from it) by **`om:using`**. The property **`om:using`** has a more restricted content model, consisting of a **`om:Procedure`** rather than just a **`gml:Feature`**. The element **`om:Procedure`** is implemented merely as a concrete feature without any additional properties, but is intended to act as the head of a substitution group which will contain various procedure types, including sensors and instruments. This restriction may have consequences for the SensorML schema. Note, however, that when the "by-reference" form of the property is used, there is no restriction on the type of the associated object.

7.4.1 Simple Observation – Single Value

To illustrate some alternative uses of the encoding, consider an observation of Dissolved Solids made at a particular sampling station. Using the element **`gml:Observation`** from GML3 directly we can encode the following:

Code sample (xxi)

```
<gml:Observation gml:id="OD653">
  <gml:timeStamp>
    <gml:TimeInstant><gml:timePosition>2001-12-12</gml:timePosition></gml:TimeInstant>
  </gml:timeStamp>
  <gml:using xlink:href="sensors.xml#TDS"/>
  <gml:target xlink:href="stations.xml#s432"/>
  <gml:resultOf>
    <gml:Quantity uom="units.xml#gpL">72.1</gml:Quantity>
  </gml:resultOf>
</gml:Observation>
```

In this description of the Observation, the description of the sensor that the observation is **`using`** will indicate the phenomenon that is being observed, and a station is identified as the **`target`** of the Observation.

Using the enhanced form **`om:RichObservation`**, which is declared in the schema document richObservation.xsd (Annex B.4.2) we can indicate the **`observable`** directly, record some **`quality`** information, and also the fact that there is a previous observation available as a **`relatedFeature`**:

Code sample (xxii)

```
<om:RichObservation gml:id="OD654">
  <gml:timeStamp>
    <gml:TimeInstant><gml:timePosition>2001-12-12</gml:timePosition></gml:TimeInstant>
  </gml:timeStamp>
  <om:using xlink:href="sensors.xml#TDS"/>
  <gml:target xlink:href="stations.xml#s432"/>
  <gml:resultOf>
    <gml:Quantity uom="units.xml#gpL">72.1</gml:Quantity>
  </gml:resultOf>
  <om:observable xlink:href="phenomena.xml#DissolvedSolids"/>
  <om:quality method="quality.xml#confidence95percent">
    <om:Bounds uom="units.xml#gpL">65.2 75.2</om:Bounds>
  </om:quality>
  <om:relatedFeature xlink:role="previous observation" xlink:href="archive/observations.xml#OD321"/>
</om:RichObservation>
```

Note that the value of the `observable` and the value of the measures property of the sensor description should match. This should be the same as the observable property of the observation.

There are several alternative ways to store certain components of the information. In the next example, the phenomenon is indicated on a typed value, and the `location` is recorded directly (though here we use an XPointer to make it clear that the location is that of the station):

Code sample (xxiii)

```
<gml:Observation gml:id="OD655">
  <gml:location xlink:href="locations.xml#xpointer(id('s432')/location)"/>
  <gml:timeStamp>
    <gml:TimeInstant><gml:timePosition>2001-12-12</gml:timePosition></gml:TimeInstant>
  </gml:timeStamp>
  <gml:using xlink:href="sensors.xml#TDS"/>
  <gml:resultOf>
    <om:TypedQuantity axis="phenomena.xml#DissolvedSolids"
uom="units.xml#gpL">72.1</om:TypedQuantity>
  </gml:resultOf>
</gml:Observation>
```

Note that `om:TypedQuantity` may be substituted anywhere that a `gml:Quantity` is valid.

Finally, we may use the strongly typed `om:Measurement`, which is declared in the schema document fowler.xsd (Annex B.4.3):

Code sample (xxiv)

```
<om:Measurement gml:id="OD654f">
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2001-12-12</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <om:using xlink:href="sensors.xml#TDS"/>
  <gml:target xlink:href="stations.xml#s432"/>
  <om:quantityResult>
    <gml:Quantity uom="units.xml#gpL">72.1</gml:Quantity>
  </om:quantityResult>
  <om:measurand xlink:href="phenomena.xml#DissolvedSolids"/>
  <om:quality method="quality.xml#confidence95percent">
    <om:Bounds uom="units.xml#gpL">65.2 75.2</om:Bounds>
  </om:quality>
  <om:relatedFeature xlink:role="previous observation" xlink:href="archive/observations.xml#OD321"/>
</om:Measurement>
```

This form signals to the consuming application that the result will be a `gml:Quantity`.

7.4.2 Observation Collection – Heterogeneous Observed Values

Three **`Observations`** of different Phenomena, may be recorded in an **`om:ObservationCollection`**:

Code sample (xxv)

```
  <om:ObservationCollection gml:id="c234">
    <gml:boundedBy>
      <gml:Null>unknown</gml:Null>
    </gml:boundedBy>
    <om:observationMember>
      <gml:Observation gml:id="OD656">
        <gml:location xlink:href="locations.xml#p432"/>
        <gml:timeStamp>
          <gml:TimeInstant><gml:timePosition>2001-12-12</gml:timePosition></gml:TimeInstant>
        </gml:timeStamp>
        <om:using xlink:href="sensors.xml#TDS"/>
        <gml:resultOf>
          <om:TypedQuantity axis="phenomena.xml#DissolvedSolids"
uom="units.xml#gpL">72.1</om:TypedQuantity>
        </gml:resultOf>
      </gml:Observation>
    </om:observationMember>
    <om:observationMember>
      <gml:Observation gml:id="OD657">
        <gml:timeStamp>
          <gml:TimeInstant><gml:timePosition>2001-12-12</gml:timePosition></gml:TimeInstant>
        </gml:timeStamp>
        <om:using xlink:href="sensors.xml#WVL"/>
        <gml:resultOf>
          <om:TypedCompositeValue axis="phenomena.xml#windVelocity">
            <gml:valueComponent>
              <gml:Quantity uom="units.xml#m_s">14.7</gml:Quantity>
            </gml:valueComponent>
            <gml:valueComponent>
              <gml:Quantity uom="frames.xml#degreesEast">315.</gml:Quantity>
            </gml:valueComponent>
          </om:TypedCompositeValue>
        </gml:resultOf>
      </gml:Observation>
    </om:observationMember>
    <om:observationMember>
      <gml:Observation gml:id="OD658">
        <gml:timeStamp>
          <gml:TimeInstant><gml:timePosition>2001-12-12</gml:timePosition></gml:TimeInstant>
        </gml:timeStamp>
        <om:using xlink:href="sensors.xml#TEMPC"/>
        <gml:resultOf>
          <om:TypedQuantity axis="phenomena.xml#waterTemperature"
uom="units.xml#Celsius">21.2</om:TypedQuantity>
        </gml:resultOf>
      </gml:Observation>
    </om:observationMember>
    <gml:target xlink:href="stations.xml#s432"/>
  </om:ObservationCollection>
```

Note that since the observations were all made on the same station, the **`gml:target`** property is promoted to the **`ObservationCollection`**.

7.4.3 Observation Array – Time Series

A set of observations of a single phenomenon, made on a single station using the same sensor, comprising a time-series, may be recorded in an **`om:ObservationArray`**:

Code sample (xxvi)

```
<om:ObservationArray gml:id="a567">
  <gml:boundedBy>
    <gml:EnvelopeWithTimePeriod srsName="http://opengis.org/epsg#4326">
      <gml:pos>-92.0 33.0</gml:pos>
      <gml:pos>-91.0 34.0</gml:pos>
      <gml:timePosition>2001-12-03</gml:timePosition>
      <gml:timePosition>2001-12-05</gml:timePosition>
    </gml:EnvelopeWithTimePeriod>
  </gml:boundedBy>
  <om:observationMembers>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant><gml:timePosition>2001-12-03</gml:timePosition></gml:TimeInstant>
      </gml:timeStamp>
      <gml:resultOf>
        <gml:Quantity uom="units.xml#degC">16.5</gml:Quantity>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant><gml:timePosition>2001-12-04</gml:timePosition></gml:TimeInstant>
      </gml:timeStamp>
      <gml:resultOf>
        <gml:Quantity uom="units.xml#degC">17.2</gml:Quantity>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant><gml:timePosition>2001-12-05</gml:timePosition></gml:TimeInstant>
      </gml:timeStamp>
      <gml:resultOf>
        <gml:Quantity uom="units.xml#degC">18.3</gml:Quantity>
      </gml:resultOf>
    </gml:Observation>
  </om:observationMembers>
  <gml:target xlink:href="stations.xml#s432"/>
  <om:using xlink:href="sensors.xml#TEMPCb6"/>
  <om:observable>
    <om:ParameterisedPhenomenon gml:id="WaterTemperature">
      <gml:name>Water Temperature</gml:name>
      <om:basePhenomenon xlink:href="phenomena.xml#Temperature"/>
      <om:constraint>
        <om:TypedCategory axis="phenomena.xml#Medium"
codeSpace="http://www.opengis.net/ows/media">water</om:TypedCategory>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </om:observable>
</om:ObservationArray>
```

Since this is a time series of measurements at the same location using the same sensor, the values of the **`target, using`**, and **`observable`** properties are promoted to the container, but each member **`Observation`** has a specific **`timeStamp`**. Note that, in this example, we exploit the GML “property” pattern [GML3], and record the description of the **`ParameterisedPhenomenon`** inline, rather than by reference.

7.4.4 Observation Array – Spatial Sampling

A spatial array of **`Observations`** of the same **`Phenomenon`** (O_2 concentration in water samples) can be recorded in an **`om:ObservationArray`**:

Code sample (xxvii)

```
<om:ObservationArray gml:id="a568">
  <gml:boundedBy>
    <gml:Envelope srsName="http://opengis.org/epsg#4326">
      <gml:pos>-92.0 33.0</gml:pos>
      <gml:pos>-91.0 34.0</gml:pos>
    </gml:Envelope>
  </gml:boundedBy>
  <om:observationMembers>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2001-12-03</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href="samples.xml#s432"/>
      <gml:resultOf>
        <gml:Quantity uom="units.xml#percent">0.05</gml:Quantity>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2001-12-03</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href=" samples.xml#s434"/>
      <gml:resultOf>
        <gml:Quantity uom="units.xml#percent">0.17</gml:Quantity>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2001-12-03</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href=" samples.xml#s532"/>
      <gml:resultOf>
        <gml:Quantity uom="units.xml#percent">0.075</gml:Quantity>
      </gml:resultOf>
    </gml:Observation>
  </om:observationMembers>
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2001-12-03</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <om:using xlink:href="http://www.opengis.net/ows/sensors#DOXP"/>
  <om:observable xlink:href="phenomena.xml#DOX"/>
```

```
</om:ObservationArray>
```

In this example, since the stations for the measurements are all different, the **`target`** element is on each of the member **`Observations`**. The **`timestamp`**, **`using`** and **`observable`** properties are promoted to the container, though since the **`timeStamp`** property is required on an **`Observation`**, it also appears on each member even though it does not vary

7.4.5 Extended Examples

In Annex C we present some additional examples. These show the flexibility of the Observation and Value schemas, and illustrate some patterns for applying them to specific examples. The examples include:

C.1 Observations of several weather parameters made at an array of stations

C.2 Time series of observations of air quality made at an array of stations

C.3 Spatial survey of gravity observations

C.4 Set of multi-element assays on samples from an exploration drillhole

C.5 A multi-species ecological survey.

Note that in C.5 we show two alternative encodings of a uniform set of observations over a set of targets:

- as an array, which highlights the separate observations on each target region; and
- as a single complex observation, which highlights the fact that the results describe a phenomenon distributed over a complex target.

7.5 Typed Observations and Observed Values

7.5.1 Methods for strong-typing

It is possible to derive more strongly typed observations and observed values from the generic components. Standard XML Schema methods may be used in order to:

- declare elements with useful names in new namespace(s), that use the XML Schema types defined here: e.g.

```
<xs:element name="Temperature" type="gml:MeasureType" substitutionGroup="gml:Quantity"/>

<xs:element name="GravityMeasurement" type="om:MeasurementType"
substitutionGroup="gml:Observation"/>

<xs:element name="EcoSurvey" type="om:ObservationArrayType"
substitutionGroup="om:ObservationArray"/>
```

- restrict or extend the content models relative to what has been defined in the schemas provided here, then use these in the declaration of new elements (e.g. see the method used to restrict om:RichObservation to om:GeometryObservation in the schema document fowler.xsd).

If the new components are required to be substitutable for elements in the gml or om namespaces, then the necessary XML Schema type derivation and element substitution group rules must be followed;

Several of the components in the `om` namespace that have a "soft-typing" mechanism (e.g. using the `axis` attribute or `observable` property). These may be used in type derivation by restriction where the parameter is given a "fixed" value in a schema. This means that an element using the new type has the value of the typing parameter fixed in a schema-validated instance, even if (as in the case of "observable") the component is optional and does not appear in the instance.

7.5.2 Typing strategies

A service provider might define an exquisitely specific model and deliver XML data in which every element is very specifically typed. A data instance encoded in a strongly typed language will often be more compact and apparently descriptive. However, the desirability of strong typing must be assessed carefully. In a service deployment, the primary issues are

- which models and schemas are known in advance by a client, and
- whether it is reasonable, or even possible, to expect a client to be configurable in real-time when supplied with a new schema, even if that schema mostly uses components that are already known by the client.

The usefulness of information items depends on whether the client can classify the items sensibly. This means that either there is an agreement about the meaning of the specific terms in advance (a strategy which may be available only within small or very well-organised communities), or that the links from the data instance to the necessary definitions are provided in a form that allows them to be analysed to enable semantic comparison.

The connection from the data instance to its explanation is accomplished using a couple of basic strategies:

- through reference to its schema, where all the components used are described using the schema language – this method is required if the elements are strongly-typed;
- using links from certain components to an explanation or gloss provided by another service – this method is used for soft-typing.

In the examples in this report we use strong typing to define generalised observation and measurement features and arrays, and basic value structures. Following the approach of the standard feature-definition model [ISO19110], the semantics of these features are implied by their structure, rather than explicitly described using some KR language. The assumption is that the community interested in "sensor-webs" will agree that the general model for observations and measurements presented here is suitably expressive, and they will configure their software to process the named components sensibly.

However, we use soft-typing to further refine observation types and their results. The main reason for our use of soft-typing is that, given the huge variety of phenomena that might be the topic of observations, of reference systems that can be used to characterise the results, and procedures that are used in accomplishing the task, in a general sensor-web there is almost unlimited scope for new types of values and observation. Interoperability amongst a general community requires that they use common components, and reserve additional typing to secondary mechanisms that do not impede the processing of basic data streams using generic (sensor-web) software.

In the model described in this report, we identify a small set of key places where typing parameters may be attached: namely **reference-systems**, **observables**, **procedures**. While there is not a one-to-one correspondence between each specific scale, phenomenon, and procedure, these must be consistent with each other within a single service or analysis. Thus, methods of classification are required so that comparisons may be made. In some cases these comparisons must be made at run time. We discussed approaches to populating these slots. While many of the issues have now been discovered, the classifications are not yet mature, and further work is needed to address the classification problem.

Note, however, that the XML mechansism used to associate these classifiers with objects (i.e. they may be included inline, but more often will be indicated through links and URI's) allows us to defer resolution of the details of the problem, while providing a solution that is consistent with the general XML and web service model, and that can be used in a limited way now.

8 Guidelines for using the observations and measurements model and encoding

The model for Observations presented here is very general. The examples in the body and Annex C provide an illustration of many common cases. Most users will find an example similar to their specific case so may use one of these as a pattern. However, there are some general principles that apply, which determine some of the choices.

In this Clause we first describe some considerations to guide the selection of the particular encoding which applies in a specific observation situation. We follow this with a sketch of the procedures to followed to define the reference system(s) used to scope the resulting values, and the Phenomenon(s) which are the topic of the observation.

8.1 Observations, Observation collections, Observation arrays

A single observation is defined as a single act to sample a single phenomenon using a single procedure regarding a single target. However, in many practical cases we are interested in information contained in an aggregation of results. The model and encoding described here allows an aggregation to be formed in a number of ways: as a **collection** or **array** of observations, or as a single observation with a **composite value** as its result.

8.1.1 Constraints on the formation of various tpes of aggregation

The option of which representation to use in a particular situation is constrained by the actual information content and various opportunities for normalization of components within this. Specifically:

- if it is required to form an **arbitrary set** of Observations, ObservationArrays or ObservationCollections, or a mixture of these, then you must use an **ObservationCollection**. A collection is merely a convenient bag for a set of items whose descriptions are largely independent of each other;

- if it is required to form a set whose members observe **different phenomena**, then you must use an **ObservationCollection**. However, if all the member observations are regarding a common **target**, then this may be promoted to be a property of the ObservationCollection. An ObservationCollection may carry a **timestamp** that applies to whole collection, but a timestamp is required on each member as well;

- if it is required to form a set whose members are **homogeneously typed**, an **ObservationArray** may be used. Homogeneity is defined such that the value of the **observable** property on the members is constant. The value of the observable property may then be promoted to the ObservationArray. In most cases a common observable is associated with a common procedure, so the **using** property may also be promoted to the ObservationArray. If all the member observations are regarding a common **target**, then this may be promoted to be a property of the ObservationArray. An ObservationArray may carry a **timestamp** that applies to whole array, but a timestamp is required on each member as well;

- if a set of results are components of a value which describes a **single conceptual phenomenon**, and furthermore were collected in a single act, they may be described with a single **Observation**. The "single observation" option is available because of the way that we allow extensive or composite objects to act as values of some of the properties of an observation. For example:

    - if the phenomenon of interest are essentially invariant over a time period, the **TimeObject**, which is the value of the timeStamp that describes of the time of the act, may be extensive (a day or a week or a year, etc);

    - a single **Phenomenon** may be a vector (e.g. wind velocity) or tensor (e.g. stress in the solid earth), or another composite which carries a single name (e.g. "vegetation" which is composed of densities of a set of species). This requires more than one scalar value in the result, and more then one element in the sensor or procedure;

    - the **target** might describe a region or collection of geospatial objects (e.g. a swath, consisting of millions of pixels; a survey domain consisting of many paddocks).

8.1.2 A generalised example, showing many possibilities

To illustrate the possibilities, consider the following scenario. An operator involved in a field survey may during the course of one day visit several sites and make a uniform set of observations at each one. Let us denote each Observation as a set of properties **(t,T,u,o,r)** representing the timeStamp, target, using, observable, result, each of which may have components (a_1,a_2, … a_i, … a_n). We use brackets **[]** to indicate iteration or summation over the members of a set.

The results from a *single site* might be considered in

i. an ObservationCollection, with member Observations for each independent component – **(T,[t,u,o,r])**;

ii. a single Observation with a CompositeValue as its result, if the results are related to each other such that they all describe components of a phenomenon that can be given a single name – **(t,T,u,o,[r])**.

The results from the *whole day* might be considered in

iii. an ObservationArray over the set of target sites, whose members are ObservationCollections, each containing a set of Observations corresponding to the components of the result for a single site, as described in i. above. There is very little opportunity for normalization of common metadata, such as observable, procedure, etc since these are fully disaggregated and interleaved amongst the properties of the member Observations – **([T,[t,u,o,r]])**;

iv. an ObservationArray over the set of target sites, whose members are a set of Observations each of which has a CompositeValue in its result, as described in ii above. The observable and procedure may be carried on the array and inherited by the members, but each member observation will carry its own target and timestamp – **(u,o,[t,T,[r]])**;

v. a single Observation whose target is a composite object corresponding to the set of sites, whose timestamp is the whole day, and whose result will be described in a set of arrays or lists. Both target and observable are single elements but contain composite objects, whose members are convolved with the values in the result. This representation is only valid if the phenomenon is invariant over the day, so that the survey may be considered to be a single event using a single procedure – **(t,[T],[u],[o],[[r]])**;

vi. an ObservationCollection, whose members are a set of ObservationArrays, each containing a set of Observations corresponding to one component of the phenomenon sampled over the set of sites. The observable of each array is a single component of the phenomenon, but the target sites are interleaved amongst the member observations – **([u,o,[t,T,r]])**;

vii. an ObservationCollection, whose members are a set of Observations, the result of each of which is a list of values describing a single component of the phenomenon as sampled over the set of sites. The observable of each Observation is a single component of the phenomenon, and its target is a composite which is convolved with the value – **([t,u,o,[T],[r]])**.

Note that this set of permutations is *not* exhaustive.

8.1.3 Reasons to select a particular aggregation type

We see that several alternatives are valid and each contains the complete information, transformed or transposed in some way with respect to the other representations. The choice of which one to use should be based on analyzing the context or purpose to which the information will be put. This will often relate to the stage within a data processing sequence, as described briefly in clause 6.2.3.3.

For example, in the scenario sketched here:

- During data collection, and the primary interaction with a information service will be insertion into a data-store. To reduce risk of data loss, the information should be managed so that it tracks the operational sequence, which is on a site by site basis.
    - If all the data is being collected for a single purpose, then the results should probably be treated as in (ii). above - single observations from each site, with a composite value as a result (see the example in Annex C 5.1).
    - If the results are being collected for different purposes, and inserted into different data-stores, then it will probably be more convenient to encode each result in a separate observation, as in (i) above;
- During an analysis phase, it is likely that the information about the observed phenomenon will be examined as it varies across the set of sites, in order to discern patterns or anomalies within a phenomenon. In this case it will be most convenient if a report from the data-store is organized to support this.
    - If the phenomena are coupled, so that an analysis must access the value of more than one for each site at once, then a representation that collects the values in this form, such as (iv) or (v) should be used (see the examples in Annex C 5.2, C 5.3, C 5.5.2).
    - If interest is in the variation of a single phenomenon, then a representation that collects the values of a single component over all sites is appropriate, such as (vi) or (vii) above (see the example in Annex C 5.4, C 5.5.1).
- Finally, if the analysis is focusing on details of the procedure used, such as in a quality control exercise, then it might be necessary to disaggregate the components completely such as in representation (iii).

This example assumes a time-invariant phenomenon. If time variation is of interest, then arrays and composites that reflect this variation must be constructed.

8.2 Reference system/units

For each component of the result:

What is the representation of the result? Is it a number or a term, or something else?

If it is a number, then do we know the units of scale? Is a description of the scale available at a location that can be identified using a URI[1]? If so, note this URI – it will be used as the value of

---

[1] e.g. a member of the units dictionary shown in Annex D.1 and posted at http://www.opengis.net/dictionaries/units.xml.

the **`uom`** attribute of a **`Quantity`** or **`QuantityList`**. If not, create a new definition as a **`UnitDefinition`**, **`BaseUnit`**, **`DerivedUnit`** or **`ConventionalUnit`** using components from the GML schema units.xsd, and put it in a place that can be addressed using a URI, which will be used as the value of the **`uom`** attribute of a **`Quantity`** or **`QuantityList`**.

If it is a term, then do we know the vocabulary from which it is drawn? Is a description of the vocabulary available at a location that can be identified using a URI? If so, note this URI – it may be used as the value of the **`codeSpace`** attribute of a **`Category`** or **`CategoryList`**.

If it is a geometry, then do we know its spatial reference system? Is a description of the SRS available at a location that can be identified using a URI? If so, note this URI – it may be used as the value of the **`srsName`** attribute of a **`Geometry`**.

If it is a temporal quantity, then do we know its frame of reference? Is a description of the frame available at a location that can be identified using a URI? If so, note this URI – it may be used as the value of the **`frame`** attribute of a **`TimeObject`**.

8.3 Observable phenomenon/Measurand

What is the phenomenon being sampled by this observation? Is a description of the phenomenon available from a source that allows it to be addressed using a URI[2]? If so, note this URI – it will be used as the value of the **`xlink:href`** attribute of a **`observable`** element, or as the value of an **`axis`** attribute.

If not, then is the result of an observation a scalar value or a composite?

If a scalar, then is this a primitive phenomenon that requires a new description? Create a new phenomenon description using the **`Phenomenon`** element from the OM schema phenomena.xsd. This **`Phenomenon`** element will used as the content of an **`observable`** element, or it should be put in a place that can be addressed using a URI, in which case the URI will be used as the value of the **`xlink:href`** attribute of a **`observable`** element, or as the value of an **`axis`** attribute.

Or is the phenomenon related to a phenomena whose description can be addressed through a URI? Can a description of the phenomenon take the form of a **`ParameterisedPhenomenon`**? Create a new phenomenon description. This **`ParameterisedPhenomenon`** element will be used as the content of an **`observable`** element, or it should be put in a place that can be addressed using a URI, in which case the URI will be used as the value of the **`xlink:href`** attribute of a **`observable`** element, or as the value of an **`axis`** attribute.

If it is a composite, then is the phenomenon a simple composite of phenomena? If any of the components are not available using a URI, then create entries for these as described above. When all the components are described, then create a new CompositePhenomenon using a componentPhenomenon element for each component. This CompositePhenomenon element will be used as the content of an **`observable`** element, or it should be put in a place that can be

---

[2] e.g. a member of the dictionary of phenomena shown in Annex D.2 and posted at http://www.opengis.net/dictionaries/phenomena.xml.

addressed using a URI, in which case the URI will be used as the value of the **`xlink:href`** attribute of a **`observable`** element, or as the value of an **`axis`** attribute.

Else is the composite phenomenon related to another phenomenon through a set of constraints? Can these constraints be expressed as a series? If so, then create a new CompositePhenomenon with one or more constraints parameters containing a TypedQuantitySeries. If not, create a new CompositePhenomenon with one or more constraints parameters containing a TypedValueArray. This CompositePhenomenon element will be used as the content of an **`observable`** element, or it should be put in a place that can be addressed using a URI, in which case the URI will be used as the value of the **`xlink:href`** attribute of a **`observable`** element, or as the value of an **`axis`** attribute.

9 Harmonisation with WCS, SensorML

In both WCS and SensorML there is a requirement to describe measurement "channels", each of which combines a description of the *meaning* of the value (the phenomenon) and its *representation* (number, text, etc, with a reference system). This information is often found in the "column headings" of data represented as a table, and may be considered as essential "metadata" for individual values. The example given in Annex C.5 illustrates this. In this case a single representation is used for many channels, but in general there will be a unique phenomenon and a unique representation for each channel.

In the proposed WCS interface [WCS] these are given within the **`RangeComponentDescription`** so that **`Observable`** has two sub-elements **`docURL`** which points to a primitive (scalar?) observable definition, and **`referenceSystem`** which binds a scale to the observable. One possible encoding for compound observables is provided, using a set of **`RangeAxis`** elements each of which allows the specification of a **`RangeExtent`**, being either a **`SingleValue`** or an **`Interval`**. The other alternative for supporting compound values is provided through the fact that multiple **`RangeComponentDescription`**'s can be specified.

The WCS approach is consistent with the models described in this report, in that the ultimate definition of an phenomenon or measurand is provided elsewhere, and is attached to a description by-reference (a URI). This allows the full definition of the observable type to made using some appropriate semantic language, which may be prose. Furthermore, there is a common requirement for an XML description of derived phenomena in a form that can effectively act as a descriptor for a (possibly compound) value.

The approach in WCS diverges from O&M in two ways:

(i) the method for describing parameterized and compound observables using the primitive base observables does not follow a consistent model;

(ii) the reference system is bound to the observable rather than to the result.

Resolving the former is relatively straightforward – in clause 6.5 here we have made significant progress towards a more general and consistent model.

Regarding the latter, in the XML representation of the results of observations as "features" there is no need to separate the scale from the value. However, in a coverage description the representation of the value and its scale is part of the metadata, it is necessarily stored separately, as a descriptor rather than as part of a direct representation.

It is necessary for us to explore the development of a generalised way to combine descriptors or classifiers, such that the full description of a single data item is through a product of components stored in some convenient set. Conversely, in some of the examples in this report we do extensive normalisation of the data, pulling out common components such as observable, target, etc where it applies uniformly to a collection. We should examine whether this approach might also be applied to additional descriptors such as scale.

10 Issues Outstanding and Future Work

The model and schemas that have been developed are suitable for deployment as is. However, they do not cover the full range of requirements, and a number of associated components are outstanding. Briefly some of these are as follows:

1. Full **harmonisation** of O&M with SensorML and WCS is an urgent requirement. These specifications describe complementary aspects of the information and service model, so it is necessary that they use a consistent terminology and encoding.

2. The definition and encoding for reference systems and key concepts and terms is very limited. Some reference systems (classifications, non-spatial frames) are not yet covered. Some have proposed standard, online glossaries, dictionaries, schema repositories for this purpose. The present thinking is to use the registry framework for this function.

3. A consistent approach to the **classification** of **reference systems** and **phenomena** is required, to support validation, discovery and selection. The method must be consistent with or implementable within the registry framework.

4. Methods to describe **observation methodologies** other than instruments and sensors are needed. Estimates of values may be generated by instruments, computational simulators or numerical process modeling system, and by human observers. All of these may be combined in an analysis. These non-sensor systems may require a different parameterisation than sensors, but the basis for this is not well understood.

5. In many situations we are using **high-dimensional** data, which is traditionally represented in tables with column and row descriptors. However, the XML data model is a tree, and its representation is serial. It is usually convenient to normalise aspects of the data and represent it in lists and arrays (e.g. a set of phenomena and units, a set of locations, a set of time instants or periods), which are mapped onto one another and onto the data in "dot" and "cross" products to generate the complete description. Within the data stream, XML list structures can be used for both tuples (rows) and channels (columns). Indexing and sequence methods need to be established (see examples and further discussion in Annex C.5).

6. The mechanisms introduced to allow recording of **quality** indicators and measures are very rudimentary and need to be developed further.

7. A more explicit description of relationships between "observations" that are intermediate stages in a **processing chain** needs to be developed. For example, many category

observations are based on applying a procedure to a more primitive (set of) numerical data, the result of an earlier “observation”. Keeping track of the audit-trail is highly important.

Annex A: Conformance
(normative)

Not needed for DIPR, IPR or Discussion Paper.

Annex B: XML Schemas for Observations
(normative)

B.1 Utility Schemas

The utility schema **`observationAndValue.xsd`** includes two component schema documents from GML. It is used to import the required components from the GML namespace into derived schemas such as **`richObservation.xsd`**.

The target namespace for components from this schema is the GML namespace, identified **`http://www.opengis.net/gml`**.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://www.opengis.net/gml" xmlns:gml="http://www.opengis.net/gml"
xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
    observatioAndValue.xsd
    Utility schema which simply includes both observation and valueObjects</xs:documentation>
  </xs:annotation>
  <!-- ============================================================
      includes and imports
     ============================================================== -->
  <xs:include schemaLocation="../gml/base/observation.xsd"/>
  <xs:include schemaLocation="../gml/base/valueObjects.xsd"/>
</xs:schema>
```

B.2 Value Schemas

B.2.1 valueObjects

The GML schema **`valueObjects.xsd`** defines XML components for generic value objects and composites used in observations and measurements. Elements declared in this schema may be used as components of Observations, or in other data instances. Note that the definitions of several primitive simpleContent types used in valueObjects, such as **`MeasureType`**, are found in the GML 3 schema **`basicTypes.xsd`**. For more documentation, refer to the GML3 specification [GML3].

The target namespace for components from this schema is the GML namespace, identified **`http://www.opengis.net/gml`**.

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml" xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:sch="http://www.ascc.net/xml/schematron" xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink" elementFormDefault="qualified"
attributeFormDefault="unqualified" version="3.00">
  <annotation>
    <appinfo source="urn:opengis:specification:gml:schema-
xsd:valueObjects:v3.00">valueObjects.xsd</appinfo>
```

```
  <documentation>     Copyright (c) 2002 OGC, All Rights Reserved.  GML conformant schema for Values
in which the  * scalar Value types and lists have their values recorded in simpleContent elements * complex
Value types are built recursively
  </documentation>
 </annotation>
 <!-- ====================================================================== -->
 <!-- geometry and temporal included so that _Geometry and _TimeObject can be added to Value choice
group -->
 <include schemaLocation="geometryBasic0d1d.xsd"/>
 <include schemaLocation="temporal.xsd"/>
 <!-- ====================================================================== -->
 <group name="Value">
  <choice>
   <element ref="gml:_Value"/>
   <element ref="gml:_Geometry"/>
   <element ref="gml:_TimeObject"/>
   <element ref="gml:Null"/>
   <element ref="gml:measure"/>
  </choice>
  <!--    <xs:documentation>       <xs:annotation>Utility choice group which unifies generic Values defined in
this schema document with Geometry and Temporal objects and the Measures described above, so that any
of these may be used within aggregate Values.     </xs:annotation>     </xs:documentation> -->
 </group>
 <!-- ====================================================================== -->
 <element name="_Value" abstract="true" substitutionGroup="gml:_Object">
  <annotation>
   <documentation>Abstract element which acts as the head of a substitution group which contains
_ScalarValue, _ScalarValueList and CompositeValue and (transitively) the elements in their substitution
groups.  This element may be used in an application schema as a variable, so that in an XML instance
document any member of its substitution group may occur.  </documentation>
  </annotation>
 </element>
 <!-- ====================================================================== -->
 <!-- ================== Scalar Values ========================= -->
 <element name="_ScalarValue" abstract="true" substitutionGroup="gml:_Value">
  <annotation>
   <documentation>Abstract element which acts as the head of a substitution group which contains
Boolean, Category, Count and Quantity, and (transitively) the elements in their substitution groups.  This
element may be used in an application schema as a variable, so that in an XML instance document any
member of its substitution group may occur.  </documentation>
  </annotation>
 </element>
 <!-- ====================================================================== -->
 <element name="_ScalarValueList" abstract="true" substitutionGroup="gml:_Value">
  <annotation>
   <documentation>Abstract element which acts as the head of a substitution group which contains the
compact encodings BooleanList, CategoryList, CountList and QuantityList, and (transitively) the elements in
their substitution groups.  This element may be used in an application schema as a variable, so that in an
XML instance document any member of its substitution group may occur.  </documentation>
  </annotation>
 </element>
 <!-- ====================================================================== -->
 <!-- ======================= Boolean ======================= -->
 <element name="Boolean" type="boolean" substitutionGroup="gml:_ScalarValue">
  <annotation>
   <documentation>A value from two-valued logic, using the XML Schema boolean type.  An instance may
take the values {true, false, 1, 0}.  </documentation>
  </annotation>
 </element>
 <element name="BooleanList" type="gml:booleanOrNullList" substitutionGroup="gml:_ScalarValueList">
  <annotation>
```

```
     <documentation>XML List based on XML Schema boolean type.  An element of this type contains a
space-separated list of boolean values {0,1,true,false}</documentation>
    </annotation>
  </element>
  <!-- ========================================================================= -->
  <!-- ======================== Category =========================== -->
  <element name="Category" type="gml:CodeType" substitutionGroup="gml:_ScalarValue">
    <annotation>
      <documentation>A term representing a classification.  It has an optional XML attribute codeSpace,
whose value is a URI which identifies a dictionary, codelist or authority for the term.  </documentation>
    </annotation>
  </element>
  <element name="CategoryList" type="gml:CodeOrNullListType"
substitutionGroup="gml:_ScalarValueList">
    <annotation>
      <documentation>A space-separated list of terms or nulls.  A single XML attribute codeSpace may be
provided, which authorises all the terms in the list.    </documentation>
    </annotation>
  </element>
  <!-- ========================================================================= -->
  <!-- ============================ Quantity ============================= -->
  <element name="Quantity" type="gml:MeasureType" substitutionGroup="gml:_ScalarValue">
    <annotation>
      <documentation>A numeric value with a scale.  The content of the element is an amount using the XML
Schema type double which permits decimal or scientific notation.  An XML attribute uom (“unit of measure”)
is required, whose value is a URI which identifies the definition of the scale or units by which the numeric
value must be multiplied.  </documentation>
    </annotation>
  </element>
  <element name="QuantityList" type="gml:MeasureOrNullListType"
substitutionGroup="gml:_ScalarValueList">
    <annotation>
      <documentation>A space separated list of amounts or nulls.  The amounts use the XML Schema type
double.  A single XML attribute uom (“unit of measure”) is required, whose value is a URI which identifies the
definition of the scale or units by which all the amounts in the list must be multiplied.  </documentation>
    </annotation>
  </element>
  <!-- ========================================================================= -->
  <!-- =========================== Count =========================== -->
  <element name="Count" type="integer" substitutionGroup="gml:_ScalarValue">
    <annotation>
      <documentation>An integer representing a frequency of occurrence. </documentation>
    </annotation>
  </element>
  <element name="CountList" type="gml:integerOrNullList" substitutionGroup="gml:_ScalarValueList">
    <annotation>
      <documentation>A space-separated list of integers or nulls.  </documentation>
    </annotation>
  </element>
  <!-- ========================================================================= -->
  <!--                    aggregate Value types                       -->
  <!-- ========================================================================= -->
  <!-- ====================== ValueCollection =========================== -->
  <complexType name="CompositeValueType">
    <annotation>
      <documentation>Aggregate value built from other Values using the Composite pattern. It contains zero
or an arbitrary number of valueComponent elements, and zero or one valueComponents elements.  It may
be used for strongly coupled aggregates (vectors, tensors) or for arbitrary collections of
values.</documentation>
    </annotation>
    <complexContent>
```

```
   <extension base="gml:AbstractGMLType">
    <sequence>
     <element ref="gml:valueComponent" minOccurs="0" maxOccurs="unbounded"/>
     <element ref="gml:valueComponents" minOccurs="0"/>
    </sequence>
   </extension>
  </complexContent>
 </complexType>
 <element name="CompositeValue" type="gml:CompositeValueType" substitutionGroup="gml:_Value">
  <annotation>
   <documentation>Aggregate value built using the Composite pattern.  </documentation>
  </annotation>
 </element>
 <!-- ====================================================================== -->
 <!-- ========================= ValueArray ========================== -->
 <complexType name="ValueArrayType">
  <annotation>
   <documentation>A Value Array is used for homogeneous arrays of primitive and aggregate values.  The
member values may be scalars, composites, arrays or lists.  ValueArray has the same content model as
CompositeValue, but the member values must be homogeneous.  The element declaration contains a
Schematron constraint which expresses this restriction precisely.        Since the members are
homogeneous, the referenceSystem (uom, codeSpace) may be specified on the ValueArray itself and
implicitly inherited by all the members if desired.    Note that a_ScalarValueList is preferred for arrays of
Scalar Values since this is a more efficient encoding.  </documentation>
  </annotation>
  <complexContent>
   <extension base="gml:CompositeValueType">
    <attributeGroup ref="gml:referenceSystem"/>
   </extension>
  </complexContent>
 </complexType>
 <element name="ValueArray" type="gml:ValueArrayType" substitutionGroup="gml:CompositeValue">
  <annotation>
   <appinfo>
    <sch:pattern name="Check either codeSpace or uom not both">
     <sch:rule context="gml:ValueArray">
      <sch:report test="@codeSpace and @uom">ValueArray may not carry both a reference to a
codeSpace and a uom</sch:report>
     </sch:rule>
    </sch:pattern>
    <sch:pattern name="Check components are homogeneous">
     <sch:rule context="gml:ValueArray">
      <sch:assert test="count(gml:valueComponent/*) = count(gml:valueComponent/*[name() =
name(../../gml:valueComponent[1]/*[1])])">All components of <sch:name/> must be of the same
type</sch:assert>
      <sch:assert test="count(gml:valueComponents/*) = count(gml:valueComponents/*[name() =
name(../*[1])])">All components of <sch:name/> must be of the same type</sch:assert>
     </sch:rule>
    </sch:pattern>
   </appinfo>
   <documentation>A Value Array is used for homogeneous arrays of primitive and aggregate values.
_ScalarValueList is preferred for arrays of Scalar Values since this is more efficient.  Since "choice" is not
available for attribute groups, an external constraint (e.g. Schematron) would be required to enforce the
selection of only one of these through schema validation </documentation>
  </annotation>
 </element>
 <!-- attribute group required for ValueArray -->
 <attributeGroup name="referenceSystem">
  <attribute name="codeSpace" type="anyURI" use="optional"/>
  <attribute name="uom" type="anyURI" use="optional"/>
 </attributeGroup>
```

```
  <!-- ==================================================================== -->
  <!-- ===================== Typed ValueExtents =========================== -->
  <element name="QuantityExtent" type="gml:QuantityExtentType" substitutionGroup="gml:_Value">
    <annotation>
      <documentation>Utility element to store a 2-point range of numeric values. If one member is a null, then
this is a single ended interval. </documentation>
    </annotation>
  </element>
  <!-- -->
  <complexType name="QuantityExtentType">
    <annotation>
      <documentation>Restriction of list type to store a 2-point range of numeric values. If one member is a
null, then this is a single ended interval. </documentation>
    </annotation>
    <simpleContent>
      <restriction base="gml:MeasureOrNullListType">
        <length value="2"/>
      </restriction>
    </simpleContent>
  </complexType>
  <!-- ==================================================================== -->
  <element name="CategoryExtent" type="gml:CategoryExtentType" substitutionGroup="gml:_Value">
    <annotation>
      <documentation>Utility element to store a 2-point range of ordinal values. If one member is a null, then
this is a single ended interval. </documentation>
    </annotation>
  </element>
  <!-- -->
  <complexType name="CategoryExtentType">
    <annotation>
      <documentation>Restriction of list type to store a 2-point range of ordinal values. If one member is a null,
then this is a single ended interval. </documentation>
    </annotation>
    <simpleContent>
      <restriction base="gml:CodeOrNullListType">
        <length value="2"/>
      </restriction>
    </simpleContent>
  </complexType>
  <!-- ==================================================================== -->
  <element name="CountExtent" type="gml:CountExtentType" substitutionGroup="gml:_Value">
    <annotation>
      <documentation>Utility element to store a 2-point range of frequency values. If one member is a null,
then this is a single ended interval. </documentation>
    </annotation>
  </element>
  <!-- -->
  <simpleType name="CountExtentType">
    <annotation>
      <documentation>Restriction of list type to store a 2-point range of frequency values. If one member is a
null, then this is a single ended interval. </documentation>
    </annotation>
    <restriction base="gml:integerOrNullList">
      <length value="2"/>
    </restriction>
  </simpleType>
  <!-- ==================================================================== -->
  <!-- ==================== pieces needed for compositing =================== -->
  <element name="valueProperty" type="gml:ValuePropertyType">
    <annotation>
      <documentation>Element which refers to, or contains, a Value</documentation>
    </annotation>
  </element>
  <!-- ============================================================================ -->
  <element name="valueComponent" type="gml:ValuePropertyType">
    <annotation>
      <documentation>Element which refers to, or contains, a Value.  This version is used in
CompositeValues.  </documentation>
    </annotation>
  </element>
  <!-- ============================================================================ -->
  <complexType name="ValuePropertyType">
    <annotation>
      <documentation>GML property which refers to, or contains, a Value</documentation>
    </annotation>
    <sequence>
      <group ref="gml:Value" minOccurs="0"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
  </complexType>
  <!-- ============================================================================ -->
  <!-- ============================================================================ -->
  <element name="valueComponents" type="gml:ValueArrayPropertyType">
    <annotation>
      <documentation>Element which refers to, or contains, a set of homogeneously typed Values.
</documentation>
    </annotation>
  </element>
  <!-- ============================================================================ -->
  <complexType name="ValueArrayPropertyType">
    <annotation>
      <documentation>GML property which refers to, or contains, a set of homogeneously typed Values.
</documentation>
    </annotation>
    <sequence>
      <group ref="gml:Value" maxOccurs="unbounded"/>
    </sequence>
  </complexType>
  <!-- ======================== utility typed valueProperty types ====================  -->
  <complexType name="BooleanPropertyType">
    <annotation>
      <documentation>Property whose content is a Boolean value.</documentation>
    </annotation>
    <complexContent>
      <restriction base="gml:ValuePropertyType">
        <sequence>
          <element ref="gml:Boolean" minOccurs="0"/>
        </sequence>
      </restriction>
    </complexContent>
  </complexType>
  <complexType name="CategoryPropertyType">
    <annotation>
      <documentation>Property whose content is a Category.</documentation>
    </annotation>
    <complexContent>
      <restriction base="gml:ValuePropertyType">
        <sequence>
          <element ref="gml:Category" minOccurs="0"/>
        </sequence>
      </restriction>
    </complexContent>
  </complexType>
  <complexType name="QuantityPropertyType">
    <annotation>
      <documentation>Property whose content is a Quantity.</documentation>
    </annotation>
    <complexContent>
      <restriction base="gml:ValuePropertyType">
        <sequence>
          <element ref="gml:Quantity" minOccurs="0"/>
        </sequence>
      </restriction>
    </complexContent>
  </complexType>
  <complexType name="CountPropertyType">
    <annotation>
      <documentation>Property whose content is a Count.</documentation>
    </annotation>
    <complexContent>
      <restriction base="gml:ValuePropertyType">
        <sequence>
          <element ref="gml:Count" minOccurs="0"/>
        </sequence>
      </restriction>
    </complexContent>
  </complexType>
  <!-- ====================================================================== -->
</schema>
```

B.2.2 typedValue

The schema **`typedValue.xsd`** defines XML components for augmenting values with properties for semantic typing indicators. The value type is indicated using an XML attribute “axis”.

Elements declared in this schema are generally substitutable for valueObjects and thus may be used in the results of of Observations. Typed values are also an important component of phenomenon descriptions as described in the phenomenon schema.

The target namespace for components from this schema is identified **`http://www.opengis.net/om`**.

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/om" xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml" xmlns:om="http://www.opengis.net/om"
xmlns:xlink="http://www.w3.org/1999/xlink" elementFormDefault="qualified"
attributeFormDefault="unqualified" version="0.4">
  <annotation>
    <appinfo>TypedValue.xsd</appinfo>
    <documentation>
GML conformant schema for Typed Values
Compact form for scalar values, adds an "axis" attribute for soft-typing.

The value of the axis attribute should point to a description of the phenomenon which this value describes

SJDC  2003-01-13
</documentation>
  </annotation>
  <!-- ====================================================================== -->
```

```
 <import namespace="http://www.opengis.net/gml" schemaLocation="../gml/base/valueObjects.xsd"/>
 <!-- ====================================================================== -->
 <element name="_TypedValue" substitutionGroup="gml:_Value">
  <annotation>
   <documentation>Typed values have a semantic indicator "axis" added to the value.
   The abstract element TypedValue is added to the gml:_Value substitution group in order that it may be
used in place of the standard values.
</documentation>
  </annotation>
 </element>
 <!-- ====================================================================== -->
 <element name="TypedValue" type="om:TypedValueType" substitutionGroup="gml:_Value"/>
 <complexType name="TypedValueType">
  <annotation>
   <documentation>Typed values have a semantic indicator "axis" added to the value.
   The abstract element TypedValue is added to the gml:_Value substitution group in order that it may be
used in place of the standard values.
</documentation>
  </annotation>
  <sequence>
   <element ref="gml:valueProperty"/>
  </sequence>
  <attribute name="axis" type="anyURI" use="required"/>
 </complexType>
 <!-- ====================================================================== -->
 <!-- ====================================================================== -->
 <element name="_TypedScalarValue" substitutionGroup="gml:_ScalarValue"/>
 <!-- ====================================================================== -->
 <element name="TypedBoolean" type="om:TypedBooleanType"
substitutionGroup="om:_TypedScalarValue"/>
 <complexType name="TypedBooleanType">
  <simpleContent>
   <extension base="boolean">
    <attribute name="axis" type="anyURI" use="required"/>
   </extension>
  </simpleContent>
 </complexType>
 <!-- ====================================================================== -->
 <element name="TypedCategory" type="om:TypedCategoryType"
substitutionGroup="om:_TypedScalarValue"/>
 <complexType name="TypedCategoryType">
  <simpleContent>
   <extension base="gml:CodeType">
    <attribute name="axis" type="anyURI" use="required"/>
   </extension>
  </simpleContent>
 </complexType>
 <!-- ====================================================================== -->
 <element name="TypedCount" type="om:TypedCountType" substitutionGroup="om:_TypedScalarValue"/>
 <complexType name="TypedCountType">
  <simpleContent>
   <extension base="integer">
    <attribute name="axis" type="anyURI" use="required"/>
   </extension>
  </simpleContent>
 </complexType>
 <!-- ====================================================================== -->
 <element name="TypedQuantity" type="om:TypedQuantityType"
substitutionGroup="om:_TypedScalarValue"/>
 <complexType name="TypedQuantityType">
  <simpleContent>
```

```
      <extension base="gml:MeasureType">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </simpleContent>
  </complexType>
  <!-- ======================================================================== -->
  <element name="_TypedScalarValueList" substitutionGroup="gml:_ScalarValueList"/>
  <!-- ======================================================================== -->
  <element name="TypedBooleanList" type="om:TypedBooleanListType"
substitutionGroup="om:_TypedScalarValueList"/>
  <complexType name="TypedBooleanListType">
    <simpleContent>
      <extension base="gml:booleanOrNullList">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </simpleContent>
  </complexType>
  <!-- ======================================================================== -->
  <element name="TypedCategoryList" type="om:TypedCategoryListType"
substitutionGroup="om:_TypedScalarValueList"/>
  <complexType name="TypedCategoryListType">
    <simpleContent>
      <extension base="gml:CodeOrNullListType">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </simpleContent>
  </complexType>
  <!-- ======================================================================== -->
  <element name="TypedCountList" type="om:TypedCountListType"
substitutionGroup="om:_TypedScalarValueList"/>
  <complexType name="TypedCountListType">
    <simpleContent>
      <extension base="gml:integerOrNullList">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </simpleContent>
  </complexType>
  <!-- ======================================================================== -->
  <element name="TypedQuantityList" type="om:TypedQuantityListType"
substitutionGroup="om:_TypedScalarValueList"/>
  <complexType name="TypedQuantityListType">
    <simpleContent>
      <extension base="gml:MeasureOrNullListType">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </simpleContent>
  </complexType>
  <!-- ========================================================================  -->
  <element name="_TypedScalarValueExtent" substitutionGroup="om:_TypedValue"/>
  <!-- ======================================================================== -->
  <element name="TypedCategoryExtent" type="om:TypedCategoryExtentType"
substitutionGroup="om:_TypedScalarValueExtent"/>
  <complexType name="TypedCategoryExtentType">
    <simpleContent>
      <restriction base="om:TypedCategoryListType">
        <length value="2"/>
      </restriction>
    </simpleContent>
  </complexType>
  <!-- ======================================================================== -->
  <element name="TypedCountExtent" type="om:TypedCountExtentType"
substitutionGroup="om:_TypedScalarValueExtent"/>
  <complexType name="TypedCountExtentType">
    <simpleContent>
      <restriction base="om:TypedCountListType">
        <length value="2"/>
      </restriction>
    </simpleContent>
  </complexType>
  <!-- ====================================================================== -->
  <element name="TypedQuantityExtent" type="om:TypedQuantityExtentType"
substitutionGroup="om:_TypedScalarValueExtent"/>
  <complexType name="TypedQuantityExtentType">
    <simpleContent>
      <restriction base="om:TypedQuantityListType">
        <length value="2"/>
      </restriction>
    </simpleContent>
  </complexType>
  <!-- ====================================================================== -->
  <!-- ====================================================================== -->
  <element name="TypedCompositeValue" type="om:TypedCompositeValueType"
substitutionGroup="gml:CompositeValue"/>
  <complexType name="TypedCompositeValueType">
    <complexContent>
      <extension base="gml:CompositeValueType">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </complexContent>
  </complexType>
  <!-- ====================================================================== -->
  <element name="TypedValueArray" type="om:TypedValueArrayType"
substitutionGroup="gml:ValueArray"/>
  <complexType name="TypedValueArrayType">
    <complexContent>
      <extension base="gml:ValueArrayType">
        <attribute name="axis" type="anyURI" use="required"/>
      </extension>
    </complexContent>
  </complexType>
  <!-- ====================================================================== -->
</schema>
```

B.2.3 observedValue

The schema **`observedValue.xsd`** defines XML components for augmenting values with properties for semantic typing (observable) and quality indicators. The value type is indicated using an XML element “observable”. Quality is indicated using one or more XML elements “quality”.

Elements declared in this schema are generally substitutable for valueObjects.

The target namespace for components from this schema is identified **`http://www.opengis.net/om`**.

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

```
<schema targetNamespace="http://www.opengis.net/om" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:om="http://www.opengis.net/om" xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified" version="0.5">
  <annotation>
    <appinfo>ObservedValue.xsd</appinfo>
    <documentation>
GML conformant schema for Observed Values
Adds "quality" and “observable” to a Value.

SJDC  2002-12-24
</documentation>
  </annotation>
  <!-- ====================================================================== -->
  <include schemaLocation="./phenomenon.xsd"/>
  <!-- ====================================================================== -->
  <element name="observable" type="om:PhenomenonPropertyType" substitutionGroup="om:axis"/>
  <!-- ====================================================================== -->
  <element name="ObservedValue" type="om:ObservedValueType"
substitutionGroup="gml:CompositeValue">
    <annotation>
      <documentation>Observed value has optional semantic and quality indicators.
      The concrete element ObservedValue is added to the gml:_Value substitution group in order that it may
be used in place of the standard value types.
The semantic property "axis" or "observable" may be useful in disaggregating the members of a
valueCollection. </documentation>
    </annotation>
  </element>
  <!-- -->
  <complexType name="ObservedValueType">
    <annotation>
      <documentation>Observed value has optional semantic and quality indicators.
Observed Value is a "mapping" from the semantic domain (axis) to the sample range (value) plus some
metadata (quality).  </documentation>
    </annotation>
    <sequence>
      <element ref="gml:valueProperty"/>
      <element ref="om:observable"/>
      <element ref="om:quality" maxOccurs="unbounded">
        <annotation>
          <documentation>Observed value has optional quality indicators.
            Using this component, the components of an aggregate value may have independent quality
indicators.</documentation>
        </annotation>
      </element>
    </sequence>
  </complexType>
  <!-- ====================================================================== -->
  <element name="quality">
    <annotation>
      <documentation>
    Intended to store information concerning the quality of the value.
    An attribute "method" allows the user to indicate what kind of quality indicator this is: absolute limits, SD,
95% confidence, qualitative code, etc.  </documentation>
    </annotation>
    <complexType>
      <choice>
        <element name="Description" type="gml:StringOrRefType">
          <annotation>
            <documentation>Descriptive assessment of data quality</documentation>
          </annotation>
        </element>
        <element name="Rank" type="gml:CodeType">
          <annotation>
            <documentation>Qualitative assessment of data quality</documentation>
          </annotation>
        </element>
        <element name="Error" type="gml:MeasureType">
          <annotation>
            <documentation>Used for error measurements requiring one quantity</documentation>
          </annotation>
        </element>
        <element name="Bounds" type="gml:QuantityExtentType">
          <annotation>
            <documentation>Used for error measurements requiring two quantities on the same
scale</documentation>
          </annotation>
        </element>
        <element name="Errors" type="gml:MeasureListType">
          <annotation>
            <documentation>Used for error measurements requiring multiple quantities on the same
scale</documentation>
          </annotation>
        </element>
      </choice>
      <attribute name="method" type="anyURI" use="required"/>
    </complexType>
  </element>
  <!-- ====================================================================== -->
</schema>
```

B.3 Phenomenon Schemas

B.3.1 phenomenon

The schema `phenomenon.xsd` defines XML components for constructing descriptions of phenomena. The structures defined in phenomena.xsd are primarily concerned with descriptions derived from primitive types defined using some descriptive technology.

Elements declared in this schema can be used directly in data instances, or may be used as components of Observed Values, of Observations, and in descriptions of sensors using SensorML.

The target namespace for components from this schema is identified `http://www.opengis.net/om`.

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/om" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:om="http://www.opengis.net/om" xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified" version="0.5">
  <annotation>
    <appinfo>observable.xsd</appinfo>
    <documentation>
GML conformant schema for defininng Phenomenon Types.
A phenomenon may be derived from other phenomena through constraints.
```

```xml
A composite phenomenon may be derived by simple composition or by applying constraint set(s).

SJDC  2002-12-24
</documentation>
 </annotation>
 <!-- =========================================================================== -->
 <import namespace="http://www.opengis.net/gml" schemaLocation="../gml/base/dictionary.xsd"/>
 <include schemaLocation="./typedValue.xsd"/>
 <!-- =========================================================================== -->
 <complexType name="PhenomenonPropertyType">
  <sequence minOccurs="0">
   <element ref="om:Phenomenon"/>
  </sequence>
  <attributeGroup ref="gml:AssociationAttributeGroup"/>
 </complexType>
 <!-- =========================================================================== -->
 <element name="axis" type="om:PhenomenonPropertyType">
  <annotation>
   <documentation>Property containing a description of, or reference to, an Phenomenon
Type.</documentation>
  </annotation>
 </element>
 <!-- =========================================================================== -->
 <element name="componentPhenomenon" type="om:PhenomenonPropertyType"
substitutionGroup="om:axis">
  <annotation>
   <documentation>Property containing a description of, or reference to, an Phenomenon Type.
   Alternative name for axis. </documentation>
  </annotation>
 </element>
 <!-- =========================================================================== -->
 <element name="basePhenomenon" type="om:PhenomenonPropertyType">
  <annotation>
   <documentation>Property containing a description of, or reference to, an Phenomenon Type.
</documentation>
  </annotation>
 </element>
 <!-- =========================================================================== -->
 <complexType name="PhenomenonReferenceType">
  <complexContent>
   <restriction base="om:PhenomenonPropertyType">
    <sequence/>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
   </restriction>
  </complexContent>
 </complexType>
 <element name="phenomenonRef" type="om:PhenomenonReferenceType" substitutionGroup="om:axis">
  <annotation>
   <documentation>Property carrying a reference to an Phenomenon Type definition. No
content.</documentation>
  </annotation>
 </element>
 <!-- =========================================================================== -->
 <element name="Phenomenon" type="gml:DefinitionType" substitutionGroup="gml:Definition"/>
 <!-- =========================================================================== -->
 <element name="ParameterisedPhenomenon" type="om:ParameterisedPhenomenonType"
substitutionGroup="om:Phenomenon">
  <annotation>
   <documentation>single component phenomenon - either
   1.  simple definition
   2.  reference to a definition available elsewhere
   3.  parameterised by a single value on one or more auxilliary axes to be applied simultaneously
   </documentation>
  </annotation>
 </element>
 <!-- ====================================================================== -->
 <complexType name="ParameterisedPhenomenonType">
  <complexContent>
   <extension base="gml:DefinitionType">
    <sequence>
     <element ref="om:basePhenomenon"/>
     <element name="constraint" maxOccurs="unbounded">
      <complexType>
       <choice>
        <element ref="om:_TypedScalarValue"/>
        <element ref="om:_TypedScalarValueExtent"/>
       </choice>
      </complexType>
     </element>
    </sequence>
   </extension>
  </complexContent>
 </complexType>
 <!-- ======================================================================   -->
 <element name="CompositePhenomenon" type="om:CompositePhenomenonType"
substitutionGroup="om:Phenomenon">
  <annotation>
   <documentation>phenomenon composed of several components
   3.  composite of discrete non-homogeneous component phenomena
   4.  parameterised by an explicit set of values on each of one or more axes to be applied simultaneously
to generate a set of component phenomena
   5.  parameterised by an implicit set of values on each of one or more axes to be applied simultaneously
to generate a set of component phenomena
   </documentation>
  </annotation>
 </element>
 <!-- ======================================================================   -->
 <complexType name="CompositePhenomenonType">
  <complexContent>
   <extension base="gml:DefinitionType">
    <choice minOccurs="0">
     <element ref="om:componentPhenomenon" maxOccurs="unbounded"/>
     <sequence>
      <element ref="om:basePhenomenon"/>
      <element name="constraintSet" maxOccurs="unbounded">
       <complexType>
        <choice>
         <element ref="om:TypedValueArray"/>
         <element ref="om:_TypedScalarValueList"/>
         <element ref="om:TypedQuantitySeries"/>
        </choice>
       </complexType>
      </element>
     </sequence>
    </choice>
   </extension>
  </complexContent>
 </complexType>
 <!-- ======================================================================   -->
 <element name="TypedQuantitySeries" type="om:TypedQuantitySeriesType"/>
 <complexType name="TypedQuantitySeriesType">
  <annotation>
```

```
      <documentation>A series of equally spaced quantities described using an implicit form.
      limits - gives the low and high indices of the segment of the series
      axis - indicates the phenomenon which this series of values describes
      origin - gives the base position corresponding to the value with index=0
      offset - gives the span increment used to generate the other values
      structure - indicates whether the positions in the series relate to point values or intervals
</documentation>
    </annotation>
    <sequence>
      <element name="limits" type="gml:CountExtentType"/>
      <element name="axis" type="anyURI"/>
      <element name="origin" type="gml:MeasureType"/>
      <element name="offset" type="gml:MeasureType"/>
      <element name="structure" type="om:GridStructureType" default="point" minOccurs="0"/>
    </sequence>
  </complexType>
  <simpleType name="integerPair">
    <restriction base="gml:integerList">
      <length value="2"/>
    </restriction>
  </simpleType>
  <simpleType name="GridStructureType">
    <annotation>
      <documentation>structure indicates how the positions in the grid should be used to construct the
members of the grid, with the values:
    point if the members have zero width, with the grid positions used directly, giving a total count of (high-
low+1)
post if the members have a width equal to the offset, and grid positions delimit cells, with a total count of
(high-low)
center if the members have a width equal to the offset, and grid cells are centered on the grid positions, with
a total count of (high-low+1).
    </documentation>
    </annotation>
    <restriction base="string">
      <enumeration value="point"/>
      <enumeration value="post"/>
      <enumeration value="center"/>
    </restriction>
  </simpleType>
  <!-- ======================================================================   -->
</schema>
```

B.4 Observation Schemas

B.4.1 observation

The GML schema **`observation.xsd`** defines XML components for simple observations. For more documentation, refer to the GML3 specification [GML3].

The target namespace for components from this schema is the GML namespace, identified **`http://www.opengis.net/gml`**.

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml" xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified" version="3.00">
  <annotation>
   <appinfo source="urn:opengis:specification:gml:schema-
xsd:observation:v3.00">observation.xsd</appinfo>
   <documentation>Observation schema for GML 3.0
   </documentation>
  </annotation>
  <!-- ====================================================================== -->
  <!-- ===     includes and imports ============================================== -->
  <include schemaLocation="feature.xsd"/>
  <include schemaLocation="direction.xsd"/>
  <!-- ====================================================================== -->
  <!-- =================== properties ==================================== -->
  <element name="using" type="gml:FeaturePropertyType">
   <annotation>
    <documentation>This element contains or points to a description of a sensor, instrument or procedure
used for the observation</documentation>
   </annotation>
  </element>
  <!-- ====================================================================== -->
  <element name="target" type="gml:TargetPropertyType">
   <annotation>
    <documentation>This element contains or points to the specimen, region or station which is the object of
the observation</documentation>
   </annotation>
  </element>
  <!-- ====================================================================== -->
  <element name="subject" type="gml:TargetPropertyType" substitutionGroup="gml:target">
   <annotation>
    <documentation>Synonym for target - common word used for photographs</documentation>
   </annotation>
  </element>
  <!-- ====================================================================== -->
  <complexType name="TargetPropertyType">
   <annotation>
    <documentation>Container for an object representing the target or subject of an
observation.</documentation>
   </annotation>
   <choice minOccurs="0">
    <element ref="gml:_Feature"/>
    <element ref="gml:_Geometry"/>
   </choice>
   <attributeGroup ref="gml:AssociationAttributeGroup"/>
  </complexType>
  <!-- ====================================================================== -->
  <element name="resultOf" type="gml:AssociationType">
   <annotation>
    <documentation>The result of the observation: an image, external object, etc</documentation>
   </annotation>
  </element>
  <!-- ====================================================================== -->
  <!-- ====================== Features ============================ -->
  <element name="Observation" type="gml:ObservationType" substitutionGroup="gml:_Feature"/>
  <!-- ============================================================= -->
  <complexType name="ObservationType">
   <complexContent>
    <extension base="gml:AbstractFeatureType">
     <sequence>
      <element ref="gml:timeStamp"/>
      <element ref="gml:using" minOccurs="0"/>
      <element ref="gml:target" minOccurs="0"/>
      <element ref="gml:resultOf"/>
     </sequence>
    </extension>
   </complexContent>
  </complexType>
  <!-- ============================================================ -->
  <element name="DirectedObservation" type="gml:DirectedObservationType"
substitutionGroup="gml:_Feature"/>
  <!-- ============================================================ -->
  <complexType name="DirectedObservationType">
   <complexContent>
    <extension base="gml:ObservationType">
     <sequence>
      <element ref="gml:direction"/>
     </sequence>
    </extension>
   </complexContent>
  </complexType>
  <!-- ============================================================ -->
</schema>
```

B.4.2 richObservation

The schema **`richObservation.xsd`** enhances the GML observation schema in two areas:

1. the feature type **`RichObservation`** has additional properties to allow typing of the observation, some indication of quality, and links to related features;
2. components for **`ObservationCollection`** and **`ObservationArray`** are defined.

The main elements declared in this schema are generally substitutable for **`gml:Observation`** and **`gml:FeatureCollection`**.

Also included in this schema are a set of convenience features

- **`Station`**, **`Specimen`** and **`Region`**, may be used to provide brief descriptions of the targets of observations;
- **`Procedure`**, does the same for sensors and procedures.

These elements may be considered placeholders for more elaborate feature types that may be defined elsewhere.

Also, the element **`om:using`** is substituted for **`gml:using`**. **`om:using`** has a content model restricted relative such that it must contain a **`Procedure`**, rather than an arbitrary Feature.

The target namespace for components from this schema is identified **`http://www.opengis.net/om`**.

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/om" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:om="http://www.opengis.net/om" xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified" version="1.25">
  <annotation>
   <documentation>
```

```
SWEobservation.xsd

A GML conformant schema for rich Observations and Measurements

SJDC  2003-01-30
</documentation>
  </annotation>
  <!-- ======================================================================== -->
  <!-- bring in other schemas -->
  <import namespace="http://www.opengis.net/gml" schemaLocation="./observationAndValue.xsd"/>
  <include schemaLocation="./observedValue.xsd"/>
  <!-- ======================================================================== -->
  <!-- Observation -->
  <element name="RichObservation" type="om:RichObservationType"
substitutionGroup="gml:Observation"/>
  <!-- -->
  <complexType name="RichObservationBaseType">
    <annotation>
      <documentation>   base gml:Observation
            restricts
            using - must contain or point to a Procedure or Sensor
</documentation>
    </annotation>
    <complexContent>
      <restriction base="gml:ObservationType">
        <sequence>
          <element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
          <element ref="gml:description" minOccurs="0"/>
          <element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
          <element ref="gml:boundedBy" minOccurs="0"/>
          <element ref="gml:location" minOccurs="0"/>
          <element ref="gml:timeStamp"/>
          <element ref="om:using" minOccurs="0"/>
          <element ref="gml:target" minOccurs="0"/>
          <element ref="gml:resultOf"/>
        </sequence>
      </restriction>
    </complexContent>
  </complexType>
  <complexType name="RichObservationType">
    <annotation>
      <documentation>
            add
            observable - identifes the phenomenon being sampled
            quality - some basic quality indications on the result
            relatedFeature - is a pointer to any other arbitrary feature
</documentation>
    </annotation>
    <complexContent>
      <extension base="om:RichObservationBaseType">
        <sequence>
          <element ref="om:observable" minOccurs="0"/>
          <element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
          <element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <!-- ======================================================================== -->
  <!-- Observation Collections -->
  <element name="ObservationCollection" type="om:ObservationCollectionType"
substitutionGroup="gml:FeatureCollection"/>
  <!-- -->
  <complexType name="ObservationCollectionBaseType">
    <annotation>
      <documentation>restrict member types</documentation>
    </annotation>
    <complexContent>
      <restriction base="gml:FeatureCollectionType">
        <sequence>
          <element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
          <element ref="gml:description" minOccurs="0"/>
          <element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
          <element ref="gml:boundedBy"/>
          <element ref="gml:location" minOccurs="0">
            <annotation>
              <documentation>use the location property on a collection if all the members have the same
location</documentation>
            </annotation>
          </element>
          <element ref="om:observationMember" minOccurs="0" maxOccurs="unbounded"/>
          <element ref="om:observationMembers" minOccurs="0"/>
        </sequence>
      </restriction>
    </complexContent>
  </complexType>
  <!-- -->
  <complexType name="ObservationCollectionType">
    <annotation>
      <documentation>add timeStamp, target and relatedFeature</documentation>
    </annotation>
    <complexContent>
      <extension base="om:ObservationCollectionBaseType">
        <sequence>
          <element ref="gml:timeStamp" minOccurs="0">
            <annotation>
              <documentation>use the timeStamp property on a collection if all the member observations have
the same timeStamp</documentation>
            </annotation>
          </element>
          <element ref="gml:target" minOccurs="0">
            <annotation>
              <documentation>use single target property on a collection if all the member observations have the
same target</documentation>
            </annotation>
          </element>
          <element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <!-- ====================================================================== -->
  <element name="ObservationArray" type="om:ObservationArrayType"
substitutionGroup="om:ObservationCollection"/>
  <!-- -->
  <complexType name="ObservationArrayType">
    <annotation>
      <documentation>
      As observationCollection, except has homogeneous member observations
      Thus the array may carry the observable and using .
      </documentation>
    </annotation>
    <complexContent>
      <extension base="om:ObservationCollectionType">
        <sequence>
          <element ref="om:using" minOccurs="0">
            <annotation>
              <documentation>use the using property on an array if all the member observations use the same
procedure</documentation>
            </annotation>
          </element>
          <element ref="om:observable" minOccurs="0">
            <annotation>
              <documentation>use the observable property on an array to indicate the phenomenon of
interest</documentation>
            </annotation>
          </element>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <!-- =========================================================================== -->
  <element name="observationProperty" type="om:ObservationPropertyType"
substitutionGroup="gml:featureProperty"/>
  <!-- -->
  <complexType name="ObservationPropertyType">
    <complexContent>
      <restriction base="gml:FeaturePropertyType">
        <choice minOccurs="0">
          <element ref="gml:Observation"/>
          <element ref="om:ObservationCollection"/>
        </choice>
        <attributeGroup ref="gml:AssociationAttributeGroup"/>
      </restriction>
    </complexContent>
  </complexType>
  <!-- components of observation Collections -->
  <element name="observationMember" type="om:ObservationPropertyType"
substitutionGroup="gml:featureMember"/>
  <!-- =========================================================================== -->
  <element name="observationMembers" type="om:ObservationArrayPropertyType"
substitutionGroup="gml:featureMembers"/>
  <!-- -->
  <complexType name="ObservationArrayPropertyType">
    <complexContent>
      <restriction base="gml:FeatureArrayPropertyType">
        <choice minOccurs="0" maxOccurs="unbounded">
          <element ref="gml:Observation"/>
          <element ref="om:ObservationCollection"/>
        </choice>
      </restriction>
    </complexContent>
  </complexType>
  <!-- =========================================================================== -->
  <!-- Related Features -->
  <element name="relatedFeature" type="gml:FeaturePropertyType"/>
  <!-- -->
  <element name="relatedObservation" type="om:ObservationPropertyType"
substitutionGroup="om:relatedFeature"/>
  <!-- ========================================================================== -->
  <complexType name="TargetObjectType">
    <annotation>
```

```
      <documentation>Concrete feature type.</documentation>
    </annotation>
    <complexContent>
      <extension base="gml:AbstractFeatureType"/>
    </complexContent>
  </complexType>
  <element name="Station" type="om:TargetObjectType" substitutionGroup="gml:_Feature"/>
  <element name="Region" type="om:TargetObjectType" substitutionGroup="gml:_Feature"/>
  <element name="Specimen" type="om:TargetObjectType" substitutionGroup="gml:_Feature"/>
  <!-- ====================================================================== -->
  <complexType name="ProcedureType">
    <annotation>
      <documentation>Concrete feature type.</documentation>
    </annotation>
    <complexContent>
      <extension base="gml:AbstractFeatureType"/>
    </complexContent>
  </complexType>
  <element name="Procedure" type="om:ProcedureType" substitutionGroup="gml:_Feature"/>
  <!-- ====================================================================== -->
  <element name="using" type="om:ProcedurePropertyType" substitutionGroup="gml:using">
    <annotation>
      <documentation>This element contains or points to a description of a sensor, instrument or procedure
used for the observation</documentation>
    </annotation>
  </element>
  <complexType name="ProcedurePropertyType">
    <complexContent>
      <restriction base="gml:FeaturePropertyType">
        <sequence>
          <element ref="om:Procedure" minOccurs="0"/>
        </sequence>
        <attributeGroup ref="gml:AssociationAttributeGroup"/>
      </restriction>
    </complexContent>
  </complexType>
  <!-- ====================================================================== -->
</schema>
```

B.4.3 fowler

The schema **`fowler.xsd`** defines certain specialised observations **`Measurement`**, **`CategoryObservation`**, **`CountObservation`**, **`BooleanObservation`**, **`GeometryObservation`** and **`TemporalObservation`**, whose results are constrained to be either quantity, category, boolean, count, geometry, or time objects. The classification is inspired by Fowlers analysis [FOW1998].

These special observations are all substitutable for gml:Observation.

The target namespace for components from this schema is identified **`http://www.opengis.net/om`**.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://www.opengis.net/om"
xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns:gml="http://www.opengis.net/gml"
xmlns:om="http://www.opengis.net/om" xmlns:xlink="http://www.w3.org/1999/xlink"
elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.3">
  <xs:annotation>
    <xs:documentation>
```

```
fowler.xsd

Typed observations, using Fowler's [1998] Analysis Patterns terminology

2003-01-30

</xs:documentation>
  </xs:annotation>
  <!-- ====================================================================== -->
  <!-- bring in other schemas -->
  <xs:include schemaLocation="./richObservation.xsd"/>
  <!-- ====================================================================== -->
  <!-- Measurement -->
  <xs:element name="Measurement" type="om:MeasurementType" substitutionGroup="gml:Observation"/>
  <!-- -->
  <xs:complexType name="MeasurementType">
    <xs:annotation>
      <xs:documentation> Restrict resultOf to be quantityResult, observable to be measurand
</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:restriction base="om:RichObservationType">
        <xs:sequence>
          <xs:element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="gml:description" minOccurs="0"/>
          <xs:element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="gml:boundedBy" minOccurs="0"/>
          <xs:element ref="gml:location" minOccurs="0"/>
          <xs:element ref="gml:timeStamp"/>
          <xs:element ref="om:using" minOccurs="0"/>
          <xs:element ref="gml:target" minOccurs="0"/>
          <xs:element ref="om:quantityResult"/>
          <xs:element ref="om:measurand" minOccurs="0"/>
          <xs:element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:restriction>
    </xs:complexContent>
  </xs:complexType>
  <!-- -->
  <xs:element name="measurand" type="om:PhenomenonPropertyType"
substitutionGroup="om:observable">
    <xs:annotation>
      <xs:documentation>Substitute measurand for observable if the result is a quantity and the observation is
made using a sensor with a single element.</xs:documentation>
    </xs:annotation>
  </xs:element>
  <!-- -->
  <xs:element name="quantityResult" type="gml:QuantityPropertyType" substitutionGroup="gml:resultOf"/>
  <!-- ====================================================================== -->
  <!-- CategoryObservation -->
  <xs:element name="CategoryObservation" type="om:CategoryObservationType"
substitutionGroup="gml:Observation"/>
  <!-- -->
  <xs:complexType name="CategoryObservationType">
    <xs:annotation>
      <xs:documentation> Restrict resultOf to be categoryResult
</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:restriction base="om:RichObservationType">
        <xs:sequence>
          <xs:element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="gml:description" minOccurs="0"/>
          <xs:element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="gml:boundedBy" minOccurs="0"/>
          <xs:element ref="gml:location" minOccurs="0"/>
          <xs:element ref="gml:timeStamp"/>
          <xs:element ref="om:using" minOccurs="0"/>
          <xs:element ref="gml:target" minOccurs="0"/>
          <xs:element ref="om:categoryResult"/>
          <xs:element ref="om:observable" minOccurs="0"/>
          <xs:element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:restriction>
    </xs:complexContent>
  </xs:complexType>
  <!-- -->
  <xs:element name="categoryResult" type="gml:CategoryPropertyType" substitutionGroup="gml:resultOf"/>
  <!-- ====================================================================== -->
  <!-- CountObservation -->
  <xs:element name="CountObservation" type="om:CountObservationType"
substitutionGroup="gml:Observation"/>
  <!-- -->
  <xs:complexType name="CountObservationType">
    <xs:annotation>
      <xs:documentation> Restrict resultOf to be countResult
</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:restriction base="om:RichObservationType">
        <xs:sequence>
          <xs:element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="gml:description" minOccurs="0"/>
          <xs:element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="gml:boundedBy" minOccurs="0"/>
          <xs:element ref="gml:location" minOccurs="0"/>
          <xs:element ref="gml:timeStamp"/>
          <xs:element ref="om:using" minOccurs="0"/>
          <xs:element ref="gml:target" minOccurs="0"/>
          <xs:element ref="om:countResult"/>
          <xs:element ref="om:observable" minOccurs="0"/>
          <xs:element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:restriction>
    </xs:complexContent>
  </xs:complexType>
  <!-- -->
  <xs:element name="countResult" type="gml:CountPropertyType" substitutionGroup="gml:resultOf"/>
  <!-- ====================================================================== -->
  <!-- BooleanObservation -->
  <xs:element name="BooleanObservation" type="om:BooleanObservationType"
substitutionGroup="gml:Observation"/>
  <!-- -->
  <xs:complexType name="BooleanObservationType">
    <xs:annotation>
      <xs:documentation> Restrict resultOf to be booleanResult
</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
```

```
   <xs:restriction base="om:RichObservationType">
    <xs:sequence>
     <xs:element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="gml:description" minOccurs="0"/>
     <xs:element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="gml:boundedBy" minOccurs="0"/>
     <xs:element ref="gml:location" minOccurs="0"/>
     <xs:element ref="gml:timeStamp"/>
     <xs:element ref="om:using" minOccurs="0"/>
     <xs:element ref="gml:target" minOccurs="0"/>
     <xs:element ref="om:booleanResult"/>
     <xs:element ref="om:observable" minOccurs="0"/>
     <xs:element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
   </xs:restriction>
  </xs:complexContent>
 </xs:complexType>
 <!-- -->
 <xs:element name="booleanResult" type="gml:BooleanPropertyType" substitutionGroup="gml:resultOf"/>
 <!-- =================================================================== -->
 <!-- GeometryObservation -->
 <xs:element name="GeometryObservation" type="om:GeometryObservationType"
substitutionGroup="gml:Observation"/>
 <!-- -->
 <xs:complexType name="GeometryObservationType">
  <xs:annotation>
   <xs:documentation> Restrict resultOf to be geometryResult
</xs:documentation>
  </xs:annotation>
  <xs:complexContent>
   <xs:restriction base="om:RichObservationType">
    <xs:sequence>
     <xs:element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="gml:description" minOccurs="0"/>
     <xs:element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="gml:boundedBy" minOccurs="0"/>
     <xs:element ref="gml:location" minOccurs="0"/>
     <xs:element ref="gml:timeStamp"/>
     <xs:element ref="om:using" minOccurs="0"/>
     <xs:element ref="gml:target" minOccurs="0"/>
     <xs:element ref="om:geometryResult"/>
     <xs:element ref="om:observable" minOccurs="0"/>
     <xs:element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
   </xs:restriction>
  </xs:complexContent>
 </xs:complexType>
 <!-- -->
 <xs:element name="geometryResult" type="gml:GeometryPropertyType"
substitutionGroup="gml:resultOf"/>
 <!-- =================================================================== -->
 <!-- TemporalObservation -->
 <xs:element name="TemporalObservation" type="om:TemporalObservationType"
substitutionGroup="gml:Observation"/>
 <!-- -->
 <xs:complexType name="TemporalObservationType">
  <xs:annotation>
   <xs:documentation> Restrict resultOf to be temporalResult
</xs:documentation>
```

```
  </xs:annotation>
  <xs:complexContent>
   <xs:restriction base="om:RichObservationType">
    <xs:sequence>
     <xs:element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="gml:description" minOccurs="0"/>
     <xs:element ref="gml:name" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="gml:boundedBy" minOccurs="0"/>
     <xs:element ref="gml:location" minOccurs="0"/>
     <xs:element ref="gml:timeStamp"/>
     <xs:element ref="om:using" minOccurs="0"/>
     <xs:element ref="gml:target" minOccurs="0"/>
     <xs:element ref="om:temporalResult"/>
     <xs:element ref="om:observable" minOccurs="0"/>
     <xs:element ref="om:quality" minOccurs="0" maxOccurs="unbounded"/>
     <xs:element ref="om:relatedFeature" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
   </xs:restriction>
  </xs:complexContent>
 </xs:complexType>
 <!-- -->
 <xs:element name="temporalResult" type="gml:TimePrimitivePropertyType"
substitutionGroup="gml:resultOf"/>
 <!-- ====================================================================== -->
</xs:schema>
```

Annex C: Extended examples
(informative)

C.1 SAIC Weather Station Observations

This example is an `ObservationArray`, containing a set of member `Observations` made at weather stations. The result of each of each of these is a `CompositeValue`. The structure of the composite value is described by the `CompositePhenomenon` that is the value of the `observable` property on the array. The `Stations` are listed in a `FeatureCollection` in a `relatedFeature`, and then indicated by reference on the individual Observations. In this example the sensor is not identified.

```
<om:ObservationArray gml:id="SAICw1">
  <gml:name>SAIC Weather Monitoring System</gml:name>
  <gml:boundedBy>
    <gml:Envelope>
      <gml:pos>-116.96666666666667 32.626111111111108</gml:pos>
      <gml:pos>-116.46833333333333 32.833333333333336</gml:pos>
    </gml:Envelope>
  </gml:boundedBy>
  <om:observationMembers>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2002-01-18T20:47:00.000</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href="#KSEE"/>
      <gml:resultOf>
        <gml:CompositeValue>
          <gml:valueComponents>
            <gml:Category codeSpace="terms.xml#cloudcovercode">BKN</gml:Category>
            <gml:Quantity uom="units.xml#Celsius">21.0</gml:Quantity>
            <gml:Quantity uom="units.xml#RHpercent">23</gml:Quantity>
            <gml:Null>missing</gml:Null>
            <gml:Quantity uom="units.xml#eastOfNorth">270</gml:Quantity>
            <gml:Quantity uom="units.xml#mps">6.0</gml:Quantity>
          </gml:valueComponents>
        </gml:CompositeValue>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation>
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2002-01-18T20:52:00.000</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href="#KCZZ"/>
      <gml:resultOf>
        <gml:CompositeValue>
          <gml:valueComponents>
            <gml:Null>missing</gml:Null>
            <gml:Quantity uom="units.xml#Celsius">13.0</gml:Quantity>
            <gml:Quantity uom="units.xml#RHpercent">23</gml:Quantity>
            <gml:Quantity uom="units.xml#hPa">1018.0</gml:Quantity>
            <gml:Quantity uom="units.xml#eastOfNorth">70</gml:Quantity>
            <gml:Quantity uom="units.xml#mps">18.0</gml:Quantity>
          </gml:valueComponents>
        </gml:CompositeValue>
      </gml:resultOf>
    </gml:Observation>
  </om:observationMembers>
  <om:relatedFeature xlink:role="stations">
    <gml:FeatureCollection gml:id="SAICSamplingStations">
      <gml:description>List of stations used</gml:description>
      <gml:boundedBy>
        <gml:Envelope>
          <gml:pos>-116.96666666666667 32.626111111111108</gml:pos>
          <gml:pos>-116.46833333333333 32.833333333333336</gml:pos>
        </gml:Envelope>
      </gml:boundedBy>
      <gml:featureMembers>
        <om:Station gml:id="KSEE">
          <gml:name>San Diego / Gillespie, United States</gml:name>
          <gml:location>
            <gml:Point>
              <gml:pos>-116.96666666666667 32.833333333333336</gml:pos>
            </gml:Point>
          </gml:location>
        </om:Station>
        <om:Station gml:id="KCZZ">
          <gml:name>Campo, United States</gml:name>
          <gml:location>
            <gml:Point>
              <gml:pos>-116.46833333333333 32.626111111111108</gml:pos>
            </gml:Point>
          </gml:location>
        </om:Station>
      </gml:featureMembers>
    </gml:FeatureCollection>
  </om:relatedFeature>
  <om:observable>
    <om:CompositePhenomenon gml:id="weather">
      <gml:name>Weather</gml:name>
      <om:componentPhenomenon xlink:href="phenomena.xml#cloudcover"/>
      <om:componentPhenomenon xlink:href="phenomena.xml#temperature"/>
      <om:componentPhenomenon xlink:href="phenomena.xml#humidity"/>
      <om:componentPhenomenon xlink:href="phenomena.xml#pressure"/>
      <om:componentPhenomenon xlink:href="phenomena.xml#windDirection"/>
      <om:componentPhenomenon xlink:href="phenomena.xml#windSpeed"/>
    </om:CompositePhenomenon>
  </om:observable>
</om:ObservationArray>
```

C.2 Polexis Air Monitoring System

This example is an **`ObservationCollection`**, containing several member **`ObservationCollections`**, in turn containing a different set of **`ObservationArrays`** of time-series of **`Observations`** of several air quality parameters. The station descriptions are collected in a **`FeatureCollection`** in a **`relatedFeature`**.

```
<om:ObservationCollection gml:id="NYSair1">
 <gml:name>New York State Ambient Air Monitoring System</gml:name>
 <gml:boundedBy>
  <gml:Null>unknown</gml:Null>
 </gml:boundedBy>
 <om:observationMember>
  <om:ObservationCollection>
   <gml:boundedBy>
    <gml:Null>unknown</gml:Null>
   </gml:boundedBy>
   <om:observationMember>
    <om:ObservationArray>
     <gml:boundedBy>
      <gml:Null>unknown</gml:Null>
     </gml:boundedBy>
     <om:observationMembers>
      <gml:Observation>
       <gml:timeStamp>
        <gml:TimeInstant>
         <gml:timePosition>2002-01-14T12:00:00Z</gml:timePosition>
        </gml:TimeInstant>
       </gml:timeStamp>
       <gml:resultOf>
        <gml:Quantity uom="#ppm">0.016</gml:Quantity>
       </gml:resultOf>
      </gml:Observation>
      <gml:Observation>
       <gml:timeStamp>
        <gml:TimeInstant>
         <gml:timePosition>2002-01-14T13:00:00Z</gml:timePosition>
        </gml:TimeInstant>
       </gml:timeStamp>
       <gml:resultOf>
        <gml:Quantity uom="#ppm">0.016</gml:Quantity>
       </gml:resultOf>
      </gml:Observation>
      <gml:Observation>
       <gml:timeStamp>
        <gml:TimeInstant>
         <gml:timePosition>2002-01-14T14:00:00Z</gml:timePosition>
        </gml:TimeInstant>
       </gml:timeStamp>
       <gml:resultOf>
        <gml:Quantity uom="#ppm">0.014</gml:Quantity>
       </gml:resultOf>
      </gml:Observation>
     </om:observationMembers>
     <om:observable xlink:href="http://www.opengis.net/ows/observableTypes#SO2"/>
    </om:ObservationArray>
   </om:observationMember>
   <om:observationMember>
    <om:ObservationArray>
     <gml:boundedBy>
      <gml:Null>unknown</gml:Null>
     </gml:boundedBy>
     <om:observationMembers>
      <gml:Observation>
```

```
            <gml:timeStamp>
              <gml:TimeInstant>
                <gml:timePosition>2002-01-14T23:00:00Z</gml:timePosition>
              </gml:TimeInstant>
            </gml:timeStamp>
            <gml:resultOf>
              <gml:Quantity uom="#ppm">0.015</gml:Quantity>
            </gml:resultOf>
          </gml:Observation>
          <gml:Observation>
            <gml:timeStamp>
              <gml:TimeInstant>
                <gml:timePosition>2002-01-15T00:00:00Z</gml:timePosition>
              </gml:TimeInstant>
            </gml:timeStamp>
            <gml:resultOf>
              <gml:Quantity uom="#ppm">0.015</gml:Quantity>
            </gml:resultOf>
          </gml:Observation>
          <gml:Observation>
            <gml:timeStamp>
              <gml:TimeInstant>
                <gml:timePosition>2002-01-15T01:00:00Z</gml:timePosition>
              </gml:TimeInstant>
            </gml:timeStamp>
            <gml:resultOf>
              <gml:Quantity uom="#ppm">0.015</gml:Quantity>
            </gml:resultOf>
          </gml:Observation>
        </om:observationMembers>
        <om:observable xlink:href="http://www.opengis.net/ows/observableTypes#24HrSO2"/>
      </om:ObservationArray>
    </om:observationMember>
    <gml:target xlink:href="#_709310"/>
  </om:ObservationCollection>
</om:observationMember>
<om:observationMember>
  <om:ObservationCollection>
    <gml:boundedBy>
      <gml:Null>unknown</gml:Null>
    </gml:boundedBy>
    <om:observationMember>
      <om:ObservationArray>
        <gml:boundedBy>
          <gml:Null>unknown</gml:Null>
        </gml:boundedBy>
        <om:observationMembers>
          <gml:Observation>
            <gml:timeStamp>
              <gml:TimeInstant>
                <gml:timePosition>2002-01-14T12:00:00Z</gml:timePosition>
              </gml:TimeInstant>
            </gml:timeStamp>
            <gml:resultOf>
              <gml:Quantity uom="#ugperm3">17.62</gml:Quantity>
            </gml:resultOf>
          </gml:Observation>
          <gml:Observation>
            <gml:timeStamp>
              <gml:TimeInstant>
                <gml:timePosition>2002-01-14T13:00:00Z</gml:timePosition>
              </gml:TimeInstant>
            </gml:timeStamp>
            <gml:resultOf>
              <gml:Quantity uom="#ugperm3">13.9</gml:Quantity>
            </gml:resultOf>
          </gml:Observation>
          <gml:Observation>
            <gml:timeStamp>
```

```
                <gml:TimeInstant>
                  <gml:timePosition>2002-01-14T14:00:00Z</gml:timePosition>
                </gml:TimeInstant>
              </gml:timeStamp>
              <gml:resultOf>
                <gml:Quantity uom="#ugperm3">18.37</gml:Quantity>
              </gml:resultOf>
            </gml:Observation>
          </om:observationMembers>
          <om:observable xlink:href="http://www.opengis.net/ows/observableTypes#PM2.5"/>
        </om:ObservationArray>
      </om:observationMember>
      <om:observationMember xlink:href="anotherArraySomewhere"/>
      <gml:target xlink:href="#_709315"/>
    </om:ObservationCollection>
  </om:observationMember>
  <om:relatedFeature xlink:role="stations">
    <gml:FeatureCollection gml:id="NYSairSamplingStations">
      <gml:description>List of stations used</gml:description>
      <gml:boundedBy>
        <gml:Envelope>
          <gml:pos>-73.96708 40.75982</gml:pos>
          <gml:pos>-73.93094 40.84886</gml:pos>
        </gml:Envelope>
      </gml:boundedBy>
      <gml:featureMembers>
        <om:Station gml:id="_709310">
          <gml:description xlink:href="http://www.dec.state.ny.us/website/dar/bts/airmon/709310site.htm"/>
          <gml:name>P.S. 59</gml:name>
          <gml:location>
            <gml:Point srsName="epsg:4256">
              <gml:pos>-73.96708 40.75982</gml:pos>
            </gml:Point>
          </gml:location>
        </om:Station>
        <om:Station gml:id="_709315">
          <gml:description xlink:href="http//www.dec.state.ny.us/website/dar/bts/airmon/709315site.htm"/>
          <gml:name>IS 143</gml:name>
          <gml:location>
            <gml:Point srsName="epsg:4256">
              <gml:pos>-73.93094 40.84886</gml:pos>
            </gml:Point>
          </gml:location>
        </om:Station>
      </gml:featureMembers>
    </gml:FeatureCollection>
  </om:relatedFeature>
</om:ObservationCollection>
```

C.3 Gravity Survey

A Gravity Survey is packaged as an **`observationArray`**, whose members are **`Observations`** of gravity at different locations. In this case it is a requirement to record the error for each measurement separately, so the **`RichObservation`** is used. The locations are defined through **`Stations`**, a collection of which is collected in a **`relatedFeature`** of the survey. All measurement used the same instrument, so the **`using`** (and **`observable`**) property is on the array. A reference station is recorded in another **`relatedFeature`**.

```
  <om:ObservationArray gml:id="GravitySurvey2001">
    <gml:description>Small Gravity Survey</gml:description>
    <gml:name>2001 Survey 1</gml:name>
    <gml:boundedBy>
      <gml:EnvelopeWithTimePeriod>
        <gml:pos>115.88 -32.20 23.</gml:pos>
        <gml:pos>115.95 -31.95 40.</gml:pos>
        <gml:timePosition>2001-09-22</gml:timePosition>
        <gml:timePosition>2001-09-22</gml:timePosition>
      </gml:EnvelopeWithTimePeriod>
    </gml:boundedBy>
    <om:observationMembers>
      <om:RichObservation gml:id="OG1">
        <gml:description> ... comments - information on processing history, etc ... </gml:description>
        <gml:timeStamp>
          <gml:TimeInstant>
            <gml:timePosition>2001-09-22</gml:timePosition>
          </gml:TimeInstant>
        </gml:timeStamp>
        <gml:target xlink:href="#GravityStation1"/>
        <gml:resultOf>
          <gml:Quantity uom="units.xml#m_s2">9.87001</gml:Quantity>
        </gml:resultOf>
        <om:quality method="methods.xml#gravError">
          <om:Error uom="units.xml#m_s2">0.00002</om:Error>
        </om:quality>
        <om:relatedFeature xlink:role="previous observation"
xlink:href="http://www.ned.dem.csiro.au/XMML/gravity/surveys/99#OG32"/>
        <om:relatedFeature xlink:role="Parent Survey" xlink:href="#GravitySurvey2001"/>
      </om:RichObservation>
      <om:RichObservation gml:id="OG2">
        <gml:description> ... comments - information on processing history, etc ... </gml:description>
        <gml:timeStamp>
          <gml:TimeInstant>
            <gml:timePosition>2001-09-22</gml:timePosition>
          </gml:TimeInstant>
        </gml:timeStamp>
        <gml:target xlink:href="#GravityStation2"/>
        <gml:resultOf>
          <gml:Quantity uom="units.xml#m_s2">9.86678</gml:Quantity>
        </gml:resultOf>
        <om:quality method="methods.xml#gravError">
          <om:Error uom="units.xml#m_s2">0.000022</om:Error>
        </om:quality>
        <om:relatedFeature xlink:role="Parent Survey" xlink:href="#GravitySurvey2001"/>
      </om:RichObservation>
    </om:observationMembers>
    <om:relatedFeature xlink:role="locations">
      <gml:FeatureCollection gml:id="GravityStations2001">
        <gml:description>List of stations occupied in this survey</gml:description>
        <gml:boundedBy>
          <gml:Envelope>
            <gml:pos>115.88 -32.20 23.</gml:pos>
            <gml:pos>115.95 -31.95 40.</gml:pos>
          </gml:Envelope>
        </gml:boundedBy>
        <gml:featureMember>
          <om:Station gml:id="GravityStation1">
            <gml:description>road junction</gml:description>
            <gml:location>
              <gml:Point srsName="SRS1" gml:id="point1">
                <gml:pos>115.88 -31.95 23.</gml:pos>
              </gml:Point>
            </gml:location>
          </om:Station>
        </gml:featureMember>
        <gml:featureMember>
          <om:Station gml:id="GravityStation2">
            <gml:description>benchmark outside Post Office</gml:description>
            <gml:location>
              <gml:Point srsName="SRS1" gml:id="point2">
                <gml:pos>115.95 -32.20 40.</gml:pos>
              </gml:Point>
            </gml:location>
          </om:Station>
        </gml:featureMember>
      </gml:FeatureCollection>
    </om:relatedFeature>
    <om:relatedFeature xlink:role="Reference Station" xlink:href="http://www.agso.gov.au/gravity/stations#ref045"/>
    <om:using xlink:href="sensors.xml#gm1"/>
    <om:observable xlink:href="phenomena.xml#gravity"/>
  </om:ObservationArray>
```

C.4 Assay Samples from a Drillhole

A set of multi-element assays, made on samples taken from a drillhole. The results were `using` a particular laboratory using a specified procedure. Each result is a `CompositeValue`, whose structure is defined by a `CompositePhenomenon`, each of whose members is a `ParameterisedPhenomenon` defining the concentration of the chemical species of interest. The list of `Specimens` is collected in a `relatedFeature`. The location of each `Specimen` is given as an interval within the spatial reference system represented by the drillhole survey.

```
<om:ObservationArray gml:id="ANA-67403">
  <gml:description>Composite assays for a set of samples</gml:description>
  <gml:boundedBy>
    <gml:Envelope srsName="http://www.ned.dem.csiro.au/drillholes/surveys#d722">
      <gml:pos>35.2</gml:pos>
      <gml:pos>36.7</gml:pos>
    </gml:Envelope>
  </gml:boundedBy>
  <om:observationMembers>
    <gml:Observation gml:id="SR722410">
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2001-10-12</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href="#DR722410"/>
      <gml:resultOf>
        <gml:CompositeValue>
          <gml:valueComponents>
            <gml:Quantity uom="#ppm">185</gml:Quantity>
            <gml:Quantity uom="#percent">0.86</gml:Quantity>
            <gml:Quantity uom="#ppm">159</gml:Quantity>
          </gml:valueComponents>
        </gml:CompositeValue>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation gml:id="SR722411">
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2001-10-12</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href="#DR722411"/>
      <gml:resultOf>
        <gml:CompositeValue>
          <gml:valueComponents>
            <gml:Quantity uom="#ppm">190</gml:Quantity>
            <gml:Quantity uom="#percent">0.86</gml:Quantity>
            <gml:Quantity uom="#ppm">159</gml:Quantity>
          </gml:valueComponents>
        </gml:CompositeValue>
      </gml:resultOf>
    </gml:Observation>
    <gml:Observation gml:id="SR722412">
      <gml:timeStamp>
        <gml:TimeInstant>
          <gml:timePosition>2001-10-13</gml:timePosition>
        </gml:TimeInstant>
      </gml:timeStamp>
      <gml:target xlink:href="#DR722412"/>
      <gml:resultOf>
        <gml:CompositeValue>
          <gml:valueComponents>
            <gml:Quantity uom="#ppm">17</gml:Quantity>
            <gml:Null>missing</gml:Null>
```

```
       <gml:Quantity uom="#ppm">5</gml:Quantity>
      </gml:valueComponents>
     </gml:CompositeValue>
    </gml:resultOf>
   </gml:Observation>
  </om:observationMembers>
  <om:relatedFeature xlink:role="Specimens">
   <gml:FeatureCollection gml:id="SpecimenCollectionA">
    <gml:boundedBy>
     <gml:Envelope srsName="http://www.ned.dem.csiro.au/drillholes/surveys#d722">
      <gml:pos>35.2</gml:pos>
      <gml:pos>36.7</gml:pos>
     </gml:Envelope>
    </gml:boundedBy>
    <gml:featureMembers>
     <om:Specimen gml:id="DR722410">
      <gml:location>
       <gml:Envelope srsName="http://www.ned.dem.csiro.au/drillholes/surveys#d722">
        <gml:pos>35.2</gml:pos>
        <gml:pos>35.7</gml:pos>
       </gml:Envelope>
      </gml:location>
     </om:Specimen>
     <om:Specimen gml:id="DR722411">
      <gml:location>
       <gml:Envelope srsName="http://www.ned.dem.csiro.au/drillholes/surveys#d722">
        <gml:pos>35.7</gml:pos>
        <gml:pos>36.2</gml:pos>
       </gml:Envelope>
      </gml:location>
     </om:Specimen>
     <om:Specimen gml:id="DR722412">
      <gml:location>
       <gml:Envelope srsName="http://www.ned.dem.csiro.au/drillholes/surveys#d722">
        <gml:pos>36.2</gml:pos>
        <gml:pos>36.7</gml:pos>
       </gml:Envelope>
      </gml:location>
     </om:Specimen>
    </gml:featureMembers>
   </gml:FeatureCollection>
  </om:relatedFeature>
  <om:using xlink:href="http://my.analytical.lab.com#procedure54"/>
  <om:observable>
   <om:CompositePhenomenon gml:id="assaySuite54">
    <gml:name>Assay Suite number 54</gml:name>
    <om:componentPhenomenon>
     <om:ParameterisedPhenomenon gml:id="AsConcentration">
      <gml:name>Arsenic concentration</gml:name>
      <om:basePhenomenon xlink:href="#ChemicalConcentration"/>
      <om:constraint>
       <om:TypedCategory axis="phenomena.xml#chemicalSpecies">As</om:TypedCategory>
      </om:constraint>
     </om:ParameterisedPhenomenon>
    </om:componentPhenomenon>
    <om:componentPhenomenon>
     <om:ParameterisedPhenomenon gml:id="CuConcentration">
      <gml:name>Copper concentration</gml:name>
      <om:basePhenomenon xlink:href="#ChemicalConcentration"/>
      <om:constraint>
       <om:TypedCategory axis="phenomena.xml#chemicalSpecies">Cu</om:TypedCategory>
      </om:constraint>
     </om:ParameterisedPhenomenon>
    </om:componentPhenomenon>
    <om:componentPhenomenon>
     <om:ParameterisedPhenomenon gml:id="NiConcentration">
      <gml:name>Nickel concentration</gml:name>
      <om:basePhenomenon xlink:href="#ChemicalConcentration"/>
      <om:constraint>
```

```
          <om:TypedCategory axis="phenomena.xml#chemicalSpecies">Ni</om:TypedCategory>
        </om:constraint>
      </om:ParameterisedPhenomenon>
    </om:componentPhenomenon>
  </om:CompositePhenomenon>
</om:observable>
</om:ObservationArray>
```

C.5 Ecological Survey

A survey of percent cover of certain species in a grassland community. Several alternative encodings are given, which conveniently illustrate several of the options discussed in clause 8.1.2, and expose some outstanding issues particularly concerning the encoding of multi-component results.

The dataset is summarised in the following table, supplied by Phillip Dibner (Ecosystem Associates).

Grassland Species Composition of a Coastal Terrace Prairie (as defined by Holland, 1986)

as %cover by species (totals > 100% are allowed)

	Quadrat #:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average % Cover by Species**
Scientific name	**Common name**											
Danthonia californica	California oat grass	75	60	60	75	40	5	5	10	10	15	35.5
Nassella pulchra	Purple needle grass	25	25	25	10	20	25	5	5	10	10	16
Camissonia ovata	Suncups	0	2	0	5	0	2	0	0	0	0	0.9
Solidago canadensis ssp. *elongata*	Canada goldenrod	0	10	15	5	0	0	0	0	0	0	3
Avena barbata	Slender oats	0	0	0	5	25	30	50	60	40	40	25
Vulpia bromoides	Six-weeks fescue	5	10	5	5	10	40	35	25	25	40	20
Plantago lanceolata	English plantain	0	0	0	0	2	5	10	10	15	10	5.2

C.5.1 ObservationArray

The first form considers the observation on each component of the sampling domain separately and uses an **`ObservationArray`** to aggregate them. The **`target`** of each observation is a **`Region`** (known in this user-community as a *Quadrat)*. The result of each **`Observation`** is a list of percentages of each species. A brief description of the uniform method used is provided in the **`description`** of a generic **`Procedure`** which is attached to the array (though it could have been attached to each observation independently). The list of species is recorded in a **`CompositePhenemenon`**, described as the **`observable`** for the entire array (though again it could have been attached to each observation independently).

This representation emphasizes the properties of each element of the sampling domain or quadrat. In each **`QuantityList`** the list members scan across the set of species. Note that it is only possible to use a QuantityList because the datatype of the results is homogeneous across the elements of the composite phenomenon (i.e. a quantity, measured in percent). In the general case the components may not be represented by a homogeneous datatype, so the compact representation of the result-tuple may not be available.

```xml
  <om:ObservationArray gml:id="Grassland56">
   <gml:description>Grassland Species Composition of a Coastal Terrace Prairie (supplied by Phillip Dibner)</gml:description>
   <gml:name>Grassland survey</gml:name>
   <gml:boundedBy>
    <gml:Null>unknown</gml:Null>
   </gml:boundedBy>
   <om:observationMembers>
    <gml:Observation gml:id="GO1">
     <gml:timeStamp>
      <gml:TimeInstant>
       <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
     </gml:timeStamp>
     <gml:target>
      <om:Region gml:id="Q1">
       <gml:name>Quadrat 1</gml:name>
       <gml:location xlink:href="regions.xml#l1"/>
      </om:Region>
     </gml:target>
     <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">75 25 0 0 0 5 0</gml:QuantityList>
     </gml:resultOf>
    </gml:Observation>
    <gml:Observation gml:id="GO2">
     <gml:timeStamp>
      <gml:TimeInstant>
       <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
     </gml:timeStamp>
     <gml:target>
      <om:Region gml:id="Q2">
       <gml:name>Quadrat 2</gml:name>
       <gml:location xlink:href="regions.xml#l2"/>
      </om:Region>
     </gml:target>
     <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">60 25 2 10 0 10 0</gml:QuantityList>
     </gml:resultOf>
    </gml:Observation>
    <gml:Observation gml:id="GO3">
     <gml:timeStamp>
      <gml:TimeInstant>
       <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
     </gml:timeStamp>
     <gml:target>
      <om:Region gml:id="Q3">
       <gml:name>Quadrat 3</gml:name>
       <gml:location xlink:href="regions.xml#l3"/>
      </om:Region>
     </gml:target>
  <gml:resultOf>
    <gml:QuantityList uom="units.xml#percent">60 25 0 15 0 5 0</gml:QuantityList>
  </gml:resultOf>
</gml:Observation>
<gml:Observation gml:id="GO4">
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2002-12</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <gml:target>
    <om:Region gml:id="Q4">
      <gml:name>Quadrat 4</gml:name>
      <gml:location xlink:href="regions.xml#l4"/>
    </om:Region>
  </gml:target>
  <gml:resultOf>
    <gml:QuantityList uom="units.xml#percent">75 10 5 5 5 5 0 </gml:QuantityList>
  </gml:resultOf>
</gml:Observation>
<gml:Observation gml:id="GO5">
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2002-12</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <gml:target>
    <om:Region gml:id="Q5">
      <gml:name>Quadrat 5</gml:name>
      <gml:location xlink:href="regions.xml#l5"/>
    </om:Region>
  </gml:target>
  <gml:resultOf>
    <gml:QuantityList uom="units.xml#percent">40 20 0 0 25 10 2 </gml:QuantityList>
  </gml:resultOf>
</gml:Observation>
<gml:Observation gml:id="GO6">
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2002-12</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <gml:target>
    <om:Region gml:id="Q6">
      <gml:name>Quadrat 6</gml:name>
      <gml:location xlink:href="regions.xml#l6"/>
    </om:Region>
  </gml:target>
  <gml:resultOf>
    <gml:QuantityList uom="units.xml#percent">5 25 2 0 30 40 5 </gml:QuantityList>
  </gml:resultOf>
</gml:Observation>
<gml:Observation gml:id="GO7">
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2002-12</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <gml:target>
    <om:Region gml:id="Q7">
      <gml:name>Quadrat 7</gml:name>
```

```
        <gml:location xlink:href="regions.xml#l7"/>
      </om:Region>
    </gml:target>
    <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">5 5 0 0 50 35 10 </gml:QuantityList>
    </gml:resultOf>
  </gml:Observation>
  <gml:Observation gml:id="GO8">
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <gml:target>
      <om:Region gml:id="Q8">
        <gml:name>Quadrat 8</gml:name>
        <gml:location xlink:href="regions.xml#l8"/>
      </om:Region>
    </gml:target>
    <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">10 5 0 0 60 25 10 </gml:QuantityList>
    </gml:resultOf>
  </gml:Observation>
  <gml:Observation gml:id="GO9">
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <gml:target>
      <om:Region gml:id="Q9">
        <gml:name>Quadrat 9</gml:name>
        <gml:location xlink:href="regions.xml#l9"/>
      </om:Region>
    </gml:target>
    <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">10 10 0 0 40 25 15 </gml:QuantityList>
    </gml:resultOf>
  </gml:Observation>
  <gml:Observation gml:id="GO10">
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <gml:target>
      <om:Region gml:id="Q10">
        <gml:name>Quadrat 10</gml:name>
        <gml:location xlink:href="regions.xml#l10"/>
      </om:Region>
    </gml:target>
    <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">15 10 0 0 40 40 10 </gml:QuantityList>
    </gml:resultOf>
  </gml:Observation>
</om:observationMembers>
<om:using>
  <om:Procedure gml:id="p1">
    <gml:description>as %cover by species (totals > 100% are allowed)</gml:description>
  </om:Procedure>
</om:using>
```

```
   <om:observable>
    <om:CompositePhenomenon gml:id="gs1">
     <gml:description>A suite of grassland species, as defined by Holland, 1986</gml:description>
     <gml:name>Grassland Species</gml:name>
     <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
     <om:constraintSet>
      <om:TypedValueArray axis="species">
       <gml:valueComponents>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Danthonia californica</gml:Category>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Nassella pulchra</gml:Category>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Camissonia ovata</gml:Category>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Solidago canadensis ssp.
elongata</gml:Category>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Avena barbata</gml:Category>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Vulpia bromoides</gml:Category>
        <gml:Category codeSpace="taxonomy.xml#holland1986">Plantago lanceolata</gml:Category>
       </gml:valueComponents>
      </om:TypedValueArray>
     </om:constraintSet>
    </om:CompositePhenomenon>
   </om:observable>
  </om:ObservationArray>
```

C.5.2 Single observation with complex target (a.k.a. Coverage)

In the second form, this is encoded more compactly as a single **`RichObservation`**. A brief description of the method used is provided in the **`description`** of a generic **`procedure`**. The field of the observation (its **`target`**) is a **`FeatureCollection`** which describes a set of **`Regions`** termed *Quadrats*. The result is a **`ValueArray`**, composed of a set of lists of percentages of each species. The list of species is recorded in a **`CompositePhenemenon`**, described as the **`observable`** for the entire array. Thus, the interpretation of the results requires that the values be convolved with (i) the list of target regions; (ii) the components of the composite phenomenon.

This representation more clearly shows the relationship with a discrete coverage, whose domain is the set of locations of the Quadrats, and whose range is the set of results with a range description of the composite phenomenon.

This representation emphasizes the variation of species within each single element of the sampling domain (quadrat). As in the previous example, each **`QuantityList`** applies to a single quadrat, while its list members scan across the set of species.

```
  <om:RichObservation gml:id="Grassland57">
   <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
   <gml:name>Grassland survey</gml:name>
   <gml:timeStamp>
    <gml:TimeInstant>
     <gml:timePosition>2002-12</gml:timePosition>
    </gml:TimeInstant>
   </gml:timeStamp>
   <om:using>
    <om:Procedure gml:id="p1">
     <gml:description>as %cover by species (totals > 100% are allowed)</gml:description>
    </om:Procedure>
   </om:using>
   <gml:target>
```

```
 <gml:FeatureCollection gml:id="quadrats56">
  <gml:description>Quadrats used in grassland survey</gml:description>
  <gml:boundedBy>
   <gml:Null>unknown</gml:Null>
  </gml:boundedBy>
  <gml:featureMembers>
   <om:Region gml:id="Q1">
    <gml:name>Quadrat 1</gml:name>
    <gml:location xlink:href="regions.xml#l1"/>
   </om:Region>
   <om:Region gml:id="Q2">
    <gml:name>Quadrat 2</gml:name>
    <gml:location xlink:href="regions.xml#l2"/>
   </om:Region>
   <om:Region gml:id="Q3">
    <gml:name>Quadrat 3</gml:name>
    <gml:location xlink:href="regions.xml#l3"/>
   </om:Region>
   <om:Region gml:id="Q4">
    <gml:name>Quadrat 4</gml:name>
    <gml:location xlink:href="regions.xml#l4"/>
   </om:Region>
   <om:Region gml:id="Q5">
    <gml:name>Quadrat 5</gml:name>
    <gml:location xlink:href="regions.xml#l5"/>
   </om:Region>
   <om:Region gml:id="Q6">
    <gml:name>Quadrat 6</gml:name>
    <gml:location xlink:href="regions.xml#l6"/>
   </om:Region>
   <om:Region gml:id="Q7">
    <gml:name>Quadrat 7</gml:name>
    <gml:location xlink:href="regions.xml#l7"/>
   </om:Region>
   <om:Region gml:id="Q8">
    <gml:name>Quadrat 8</gml:name>
    <gml:location xlink:href="regions.xml#l8"/>
   </om:Region>
   <om:Region gml:id="Q9">
    <gml:name>Quadrat 9</gml:name>
    <gml:location xlink:href="regions.xml#l9"/>
   </om:Region>
   <om:Region gml:id="Q10">
    <gml:name>Quadrat 10</gml:name>
    <gml:location xlink:href="regions.xml#l10"/>
   </om:Region>
  </gml:featureMembers>
 </gml:FeatureCollection>
</gml:target>
<gml:resultOf>
 <gml:ValueArray>
  <gml:valueComponents>
   <gml:QuantityList uom="units.xml#percent">75 25 0 0 0 5 0</gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">60 25 2 10 0 10 0</gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">60 25 0 15 0 5 0</gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">75 10 5 5 5 5 0 </gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">40 20 0 0 25 10 2 </gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">5 25 2 0 30 40 5 </gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">5 5 0 0 50 35 10 </gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">10 5 0 0 60 25 10 </gml:QuantityList>
   <gml:QuantityList uom="units.xml#percent">10 10 0 0 40 25 15 </gml:QuantityList>
```

```
        <gml:QuantityList uom="units.xml#percent">15 10 0 0 40 40 10 </gml:QuantityList>
      </gml:valueComponents>
    </gml:ValueArray>
  </gml:resultOf>
  <om:observable>
    <om:CompositePhenomenon gml:id="gs1">
      <gml:description>A suite of grassland species, as defined by Holland, 1986</gml:description>
      <gml:name>Grassland Species</gml:name>
      <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
      <om:constraintSet>
        <om:TypedValueArray axis="species">
          <gml:valueComponents>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Danthonia californica</gml:Category>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Nassella pulchra</gml:Category>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Camissonia ovata</gml:Category>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Solidago canadensis ssp.
elongata</gml:Category>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Avena barbata</gml:Category>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Vulpia bromoides</gml:Category>
            <gml:Category codeSpace="taxonomy.xml#holland1986">Plantago lanceolata</gml:Category>
          </gml:valueComponents>
        </om:TypedValueArray>
      </om:constraintSet>
    </om:CompositePhenomenon>
  </om:observable>
</om:RichObservation>
```

C.5.3 Single observation with remote metadata components

If the description of the Procedure used, the target Region, and observable Phenomenon are recorded elsewhere, then the observation may be recorded more compactly still by indicating these "metadata" items by reference. The following example is identical to the previous one, except that the explicit description of the procedure, and enumeration of the target and composite phenomenon is replaced by **`xlink:href`** associations on the **`om:using`**, **`gml:target`** and **`om:observable`** properties, respectively.

As in the previous example, this representation emphasizes the variation of species within each single element of the sampling domain (quadrat).

```
<om:RichObservation gml:id="Grassland58">
  <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
  <gml:name>Grassland survey</gml:name>
  <gml:timeStamp>
    <gml:TimeInstant>
      <gml:timePosition>2002-12</gml:timePosition>
    </gml:TimeInstant>
  </gml:timeStamp>
  <om:using xlink:href="#p1"/>
  <gml:target xlink:href="#quadrats56"/>
  <gml:resultOf>
    <gml:ValueArray>
      <gml:valueComponents>
        <gml:QuantityList uom="units.xml#percent">75 25 0 0 0 5 0</gml:QuantityList>
        <gml:QuantityList uom="units.xml#percent">60 25 2 10 0 10 0</gml:QuantityList>
        <gml:QuantityList uom="units.xml#percent">60 25 0 15 0 5 0</gml:QuantityList>
        <gml:QuantityList uom="units.xml#percent">75 10 5 5 5 5 0 </gml:QuantityList>
        <gml:QuantityList uom="units.xml#percent">40 20 0 0 25 10 2 </gml:QuantityList>
```

```
          <gml:QuantityList uom="units.xml#percent">5 25 2 0 30 40 5 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">5 5 0 0 50 35 10 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">10 5 0 0 60 25 10 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">10 10 0 0 40 25 15 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">15 10 0 0 40 40 10 </gml:QuantityList>
        </gml:valueComponents>
      </gml:ValueArray>
    </gml:resultOf>
    <om:observable xlink:href="#gs1"/>
  </om:RichObservation>
```

Since the components of the result have homogeneous type and uom, the array of lists may be consolidated into a single QuantityList, as follows:

```
  <om:RichObservation gml:id="Grassland58">
    <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
    <gml:name>Grassland survey</gml:name>
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <om:using xlink:href="#p1"/>
    <gml:target xlink:href="#quadrats56"/>
    <gml:resultOf>
      <gml:QuantityList uom="units.xml#percent">75 25 0 0 0 5 0 60 25 2 10 0 10 0 60 25 0 15 0 5 0 75 10 5
5 5 5 0 40 20 0 0 25 10 2 5 25 2 0 30 40 5  5 5 0 0 50 35 10 10 5 0 0 60 25 10 10 10 0 0 40 25 15 15 10 0 0
40 40 10 </gml:QuantityList>
    </gml:resultOf>
    <om:observable xlink:href="#gs1"/>
  </om:RichObservation>
```

C.5.4 Transposed results

The result may also be expressed with the results transposed, so the lists each represent the result of one component of the phenomenon. This representation emphasizes the variation across the sampling domain of each species. Each `QuantityList` applies to a single species, while the list members scan across the set of quadrats. Note that it is *always* possible to use a QuantityList in this way because each list describes a single component of the phenomenon.

```
  <om:RichObservation gml:id="Grassland58">
    <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
    <gml:name>Grassland survey</gml:name>
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <om:using xlink:href="#p1"/>
    <gml:target xlink:href="#quadrats56"/>
    <gml:resultOf>
      <gml:ValueArray>
        <gml:valueComponents>
          <gml:QuantityList uom="units.xml#percent">75 60 60 75 40 5 5 10 10 15</gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">25 25 25 10 20 25 5 5 10 10</gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">0 2 0 5 0 2 0 0 0 0</gml:QuantityList>
    <gml:QuantityList uom="units.xml#percent">0 10 15 5 0 0 0 0 0 0</gml:QuantityList>
    <gml:QuantityList uom="units.xml#percent">0 0 0 5 25 30 50 60 40 40</gml:QuantityList>
    <gml:QuantityList uom="units.xml#percent">5 10 5 5 10 40 35 25 25 40</gml:QuantityList>
    <gml:QuantityList uom="units.xml#percent">0 0 0 0 2 5 10 10 15 10</gml:QuantityList>
   </gml:valueComponents>
  </gml:ValueArray>
 </gml:resultOf>
 <om:observable xlink:href="#gs1"/>
</om:RichObservation>
```

As in the previous example, a single QuantityList may be used for the result:

```
<om:RichObservation gml:id="Grassland58">
 <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
 <gml:name>Grassland survey</gml:name>
 <gml:timeStamp>
  <gml:TimeInstant>
   <gml:timePosition>2002-12</gml:timePosition>
  </gml:TimeInstant>
 </gml:timeStamp>
 <om:using xlink:href="#p1"/>
 <gml:target xlink:href="#quadrats56"/>
 <gml:resultOf>
  <gml:QuantityList uom="units.xml#percent">75 60 60 75 40 5 5 10 10 15 25 25 25 10 20 25 5 5 10 10
0 2 0 5 0 2 0 0 0 0 0 10 15 5 0 0 0 0 0 0 0 0 0 5 25 30 50 60 40 40 5 10 5 5 10 40 35 25 25 40 0 0 0 0 2 5 10
10 15 10</gml:QuantityList>
 </gml:resultOf>
 <om:observable xlink:href="#gs1"/>
</om:RichObservation>
```

C 5.5 Indexing the components of the result

The results in the previous three examples are composed of one or a set of **`QuantityLists`**. The result set here has two dimensions, but the mapping from the components of the result to the components of the **`target`** and the components of the **`observable`** is not explicit. When arrays of lists are used, and since the number of components of the target and observable are not equal, the dimensions of the result set implies the appropriate mapping. However, this is not really satisfactory, and of course would fail if the lengths of the two sets happened to be equal.

A number of strategies may be used to describe an explicit mapping. A few of these are discussed below.

C 5.5.1 Use component phenomena as “column headings”

The **`CompositePhenomenon`** described above using a **`constraintSet`** may be described more explicitly with a set of **`componentPhenomenon`** elements. This allows each component to have its own handle.

```
<om:CompositePhenomenon gml:id="gs1">
 <gml:description>A suite of grassland species, as defined by Holland, 1986</gml:description>
 <gml:name>Grassland Species</gml:name>
 <om:componentPhenomenon>
  <om:ParameterisedPhenomenon gml:id="gs1D">
   <gml:name>California oat grass</gml:name>
```

```
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
              <om:constraint>
                <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Danthonia
californica</om:TypedCategory>
              </om:constraint>
            </om:ParameterisedPhenomenon>
          </om:componentPhenomenon>
          <om:componentPhenomenon>
            <om:ParameterisedPhenomenon gml:id="gs1N">
              <gml:name>Purple needle grass</gml:name>
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
              <om:constraint>
                <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Nassella
pulchra</om:TypedCategory>
              </om:constraint>
            </om:ParameterisedPhenomenon>
          </om:componentPhenomenon>
          <om:componentPhenomenon>
            <om:ParameterisedPhenomenon gml:id="gs1C">
              <gml:name>Suncups</gml:name>
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
              <om:constraint>
                <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Camissonia
ovata</om:TypedCategory>
              </om:constraint>
            </om:ParameterisedPhenomenon>
          </om:componentPhenomenon>
          <om:componentPhenomenon>
            <om:ParameterisedPhenomenon gml:id="gs1S">
              <gml:name>Canada goldenrod</gml:name>
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
              <om:constraint>
                <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Solidago
canadensis ssp. elongata</om:TypedCategory>
              </om:constraint>
            </om:ParameterisedPhenomenon>
          </om:componentPhenomenon>
          <om:componentPhenomenon>
            <om:ParameterisedPhenomenon gml:id="gs1A">
              <gml:name>Slender oats</gml:name>
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
              <om:constraint>
                <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Avena
barbata</om:TypedCategory>
              </om:constraint>
            </om:ParameterisedPhenomenon>
          </om:componentPhenomenon>
          <om:componentPhenomenon>
            <om:ParameterisedPhenomenon gml:id="gs1V">
              <gml:name>Six-weeks fescue</gml:name>
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
              <om:constraint>
                <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Vulpia
bromoides</om:TypedCategory>
              </om:constraint>
            </om:ParameterisedPhenomenon>
          </om:componentPhenomenon>
          <om:componentPhenomenon>
            <om:ParameterisedPhenomenon gml:id="gs1P">
              <gml:name>English plantain</gml:name>
              <om:basePhenomenon xlink:href="phenomena.xml#organismFrequency"/>
```

```
       <om:constraint>
        <om:TypedCategory axis="species" codeSpace="taxonomy.xml#holland1986">Plantago
lanceolata</om:TypedCategory>
       </om:constraint>
      </om:ParameterisedPhenomenon>
     </om:componentPhenomenon>
    </om:CompositePhenomenon>
```

Given handles for the components of the observable phenomenon, the **`QuantityLists`** from example C.5.4 may be replaced by **`TypedQuantityLists`** which are labelled with these components. The fact that each list iterates over the members of the target remains implicit.

```
<om:RichObservation gml:id="Grassland59">
 <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
 <gml:name>Grassland survey</gml:name>
 <gml:timeStamp>
  <gml:TimeInstant>
   <gml:timePosition>2002-12</gml:timePosition>
  </gml:TimeInstant>
 </gml:timeStamp>
 <om:using xlink:href="#p1"/>
 <gml:target xlink:href="#quadrats56"/>
 <gml:resultOf>
  <om:TypedValueArray axis="#gs1">
   <gml:valueComponents>
    <om:TypedQuantityList axis="#gs1D" uom="units.xml#percent">75 60 60 75 40 5 5 10 10
15</om:TypedQuantityList >
    <om:TypedQuantityList axis="#gs1N" uom="units.xml#percent">25 25 25 10 20 25 5 5 10
10</om:TypedQuantityList >
    <om:TypedQuantityList axis="#gs1C" uom="units.xml#percent">0 2 0 5 0 2 0 0 0
0</om:TypedQuantityList >
    <om:TypedQuantityList axis="#gs1S" uom="units.xml#percent">0 10 15 5 0 0 0 0 0
0</om:TypedQuantityList >
    <om:TypedQuantityList axis="#gs1A" uom="units.xml#percent">0 0 0 5 25 30 50 60 40
40</om:TypedQuantityList >
    <om:TypedQuantityList axis="#gs1V" uom="units.xml#percent">5 10 5 5 10 40 35 25 25
40</om:TypedQuantityList >
    <om:TypedQuantityList axis="#gs1P" uom="units.xml#percent">0 0 0 0 2 5 10 10 15
10</om:TypedQuantityList >
   </gml:valueComponents>
  </om:TypedValueArray>
 </gml:resultOf>
</om:RichObservation>
```

This method is robust and does not require any extension to the current model and schemas. It relies on segregating the set of results relating to each component of the observable phenomenon in a separate list element. **At present this is the recommended encoding for a multi-dimensional result-set relating to observations over a multi-component target.**

C 5.5.2 Explicit iterators

A more general solution might be to explicitly indicate the set over which the iteration is made at each level. For example, we might add “**`for`**” attributes to the array containers, and use Xpath (or Xpointer) expressions to indicate the components. The data in C.5.3 might appear:

```xml
  <om:RichObservation gml:id="Grassland58">
    <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
    <gml:name>Grassland survey</gml:name>
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <om:using xlink:href="#p1"/>
    <gml:target xlink:href="#quadrats56"/>
    <gml:resultOf>
      <gml:ValueArray>
        <gml:valueComponents for="../../../gml:target/gml:FeatureCollection/gml:featureMembers">
          <gml:QuantityList uom="units.xml#percent"
for="../../../../om:observable/om:CompositePhenomenon/om:constraintSet/om:TypedValueArray/gml:valueCo
mponents">75 25 0 0 0 5 0</gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">60 25 2 10 0 10 0</gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">60 25 0 15 0 5 0</gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">75 10 5 5 5 5 0 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">40 20 0 0 25 10 2 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">5 25 2 0 30 40 5 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">5 5 0 0 50 35 10 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">10 5 0 0 60 25 10 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">10 10 0 0 40 25 15 </gml:QuantityList>
          <gml:QuantityList uom="units.xml#percent">15 10 0 0 40 40 10 </gml:QuantityList>
        </gml:valueComponents>
      </gml:ValueArray>
    </gml:resultOf>
    <om:observable xlink:href="#gs1"/>
  </om:RichObservation>
```

For convenience, or perhaps by convention, the iterator "`for`" is only shown on the first of the QuantityLists.

If the results are in a singleQuantityList, then iterators must be applied to the same element in sequence. In order to support an arbitrary number of dimensions, this suggests a solution using XML elements, rather than XML attributes. For example

```xml
  <om:RichObservation gml:id="Grassland58">
    <gml:description>Grassland Species Composition of a Coastal Terrace Prairie</gml:description>
    <gml:name>Grassland survey</gml:name>
    <gml:timeStamp>
      <gml:TimeInstant>
        <gml:timePosition>2002-12</gml:timePosition>
      </gml:TimeInstant>
    </gml:timeStamp>
    <om:using xlink:href="#p1"/>
    <gml:target xlink:href="#quadrats56"/>
    <gml:resultOf>
      <om:iterate over="../../../gml:target/gml:FeatureCollection/gml:featureMembers"/>
      <om:iterate
over="../../../../om:observable/om:CompositePhenomenon/om:constraintSet/om:TypedValueArray/gml:value
Components"/>
      <gml:QuantityList uom="units.xml#percent">75 25 0 0 0 5 0 60 25 2 10 0 10 0 60 25 0 15 0 5 0 75 10 5
5 5 5 0 40 20 0 0 25 10 2 5 25 2 0 30 40 5  5 5 0 0 50 35 10 10 5 0 0 60 25 10 10 10 0 0 40 25 15 15 10 0 0
40 40 10 </gml:QuantityList>
    </gml:resultOf>
    <om:observable xlink:href="#gs1"/>
```

```
</om:RichObservation>
```

Note that the attribute “**`for`**” and element **`om:iterate`** shown in these examples are introduced for discussion only and have not been implemented in the schemas given in Annex B.

This issue – of developing a convention for convolving descriptions of axes with a multidimensional array of results in XML – is an important area for future work.

Annex D: Useful definitions and dictionaries
(informative)

D.1 units.xsd

This XML document encodes a set of units of measure using the encoding defined GML3.

```
<?xml version="1.0" encoding="UTF-8"?>
<gml:Dictionary xmlns:gml="http://www.opengis.net/gml" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.opengis.net/gml
../gml/base/units.xsd" gml:id="unitsDictionary">
  <gml:description>A dictionary of units of measure</gml:description>
  <gml:name>OWS-1.2 Units</gml:name>
  <gml:dictionaryEntry>
    <gml:DefinitionCollection gml:id="SIBaseUnits">
      <gml:description xlink:href="http://www.bipm.fr/en/3_SI/base_units.html">The Base Units from the SI
units system.</gml:description>
      <gml:name>SI Base Units</gml:name>
      <gml:dictionaryEntry>
        <gml:BaseUnit gml:id="m">
          <gml:description>The metre is the length of the path travelled by light in vacuum during a time interval
of 1/299 792 458 of a second.</gml:description>
          <gml:name>metre</gml:name>
          <gml:name>meter</gml:name>
          <gml:quantityType>length</gml:quantityType>
          <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">m</gml:catalogSymbol>
          <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
        </gml:BaseUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:BaseUnit gml:id="kg">
          <gml:description>The kilogram is the unit of mass; it is equal to the mass of the international prototype
of the kilogram. </gml:description>
          <gml:name>kilogram</gml:name>
          <gml:quantityType>Mass</gml:quantityType>
          <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">kg</gml:catalogSymbol>
          <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
        </gml:BaseUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:BaseUnit gml:id="s">
          <gml:description>The second is the duration of 9 192 631 770 periods of the radiation corresponding
to the transition between the two hyperfine levels of the ground state of the caesium 133
atom.</gml:description>
          <gml:name>second</gml:name>
          <gml:quantityType>Time</gml:quantityType>
          <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">s</gml:catalogSymbol>
          <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
        </gml:BaseUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:BaseUnit gml:id="A">
          <gml:description>The ampere is that constant current which, if maintained in two straight parallel
conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would
produce between these conductors a force equal to 2 × 10-7 newton per metre of length.
```

```
</gml:description>
     <gml:name>Ampere</gml:name>
     <gml:quantityType>Electric current</gml:quantityType>
     <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">A</gml:catalogSymbol>
     <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
    </gml:BaseUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:BaseUnit gml:id="K">
     <gml:description>The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the
thermodynamic temperature of the triple point of water.</gml:description>
     <gml:name>kelvin</gml:name>
     <gml:quantityType>Thermodynamic temperature</gml:quantityType>
     <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">K</gml:catalogSymbol>
     <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
    </gml:BaseUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:BaseUnit gml:id="mol">
     <gml:description>1. The mole is the amount of substance of a system which contains as many
elementary entities as there are atoms in 0.012 kilogram of carbon 12.
2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions,
electrons, other particles, or specified groups of such particles. </gml:description>
     <gml:name>mole</gml:name>
     <gml:quantityType>Amount of substance</gml:quantityType>
     <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">mol</gml:catalogSymbol>
     <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
    </gml:BaseUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:BaseUnit gml:id="cd">
     <gml:description> The candela is the luminous intensity, in a given direction, of a source that emits
monochromatic radiation of frequency 540 × 1012 hertz and that has a radiant intensity in that direction of
1/683 watt per steradian.</gml:description>
     <gml:name>candela</gml:name>
     <gml:quantityType>Luminous intensity</gml:quantityType>
     <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">cd</gml:catalogSymbol>
     <gml:unitsSystem xlink:href="http://www.bipm.fr/en/3_SI"/>
    </gml:BaseUnit>
   </gml:dictionaryEntry>
  </gml:DefinitionCollection>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <gml:DefinitionCollection gml:id="SIDerivedUnits">
   <gml:description xlink:href="http://www.bipm.fr/enus/3_SI/si-derived.html">The Derived Units from the SI
units system.  These are all derived as a product of SI Base Units, except degrees Celsius in which the
conversion formaula to the SI Base Unit (kelvin) involves an offset.  </gml:description>
   <gml:name>SI Derived Units</gml:name>
   <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="rad">
     <gml:name>radian</gml:name>
     <gml:quantityType>plane angle</gml:quantityType>
     <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">rad</gml:catalogSymbol>
     <gml:unitDerivation>
      <gml:unitTerm uom="#m" exponent="1"/>
      <gml:unitTerm uom="#m" exponent="-1"/>
     </gml:unitDerivation>
    </gml:DerivedUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="sr">
```

```
        <gml:name>steradian</gml:name>
        <gml:quantityType>solid angle</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">sr</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#m" exponent="2"/>
          <gml:unitTerm uom="#m" exponent="-2"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="Hz">
        <gml:name>hertz</gml:name>
        <gml:quantityType>frequency</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Hz</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#s" exponent="-1"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="N">
        <gml:name>newton</gml:name>
        <gml:quantityType>force</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">N</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#m" exponent="1"/>
          <gml:unitTerm uom="#kg" exponent="1"/>
          <gml:unitTerm uom="#s" exponent="-2"/>
        </gml:unitDerivation>
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    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="Pa">
        <gml:name>pascal</gml:name>
        <gml:quantityType>pressure, stress</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Pa</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#N" exponent="1"/>
          <gml:unitTerm uom="#m" exponent="-2"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="J">
        <gml:name>joule</gml:name>
        <gml:quantityType>energy, work, quantity of heat</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">J</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#N" exponent="1"/>
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      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="W">
        <gml:name>watt</gml:name>
        <gml:quantityType>power, radiant flux</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">W</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#J" exponent="1"/>
          <gml:unitTerm uom="#s" exponent="-1"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="C">
        <gml:name>coulomb</gml:name>
        <gml:quantityType>electric charge, quantity of electricity</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">C</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#s" exponent="1"/>
          <gml:unitTerm uom="#A" exponent="1"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="V">
        <gml:name>volt</gml:name>
        <gml:quantityType>electric potential difference, electromotive force</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">V</gml:catalogSymbol>
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        </gml:unitDerivation>
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    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="F">
        <gml:name>farad</gml:name>
        <gml:quantityType>capacitance</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">F</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#C" exponent="1"/>
          <gml:unitTerm uom="#V" exponent="-1"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="ohm">
        <gml:name>ohm</gml:name>
        <gml:quantityType>electric resistance</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Ω</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#V" exponent="1"/>
          <gml:unitTerm uom="#A" exponent="-1"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="S">
        <gml:name>siemens</gml:name>
        <gml:quantityType>electric conductance</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">S</gml:catalogSymbol>
        <gml:unitDerivation>
          <gml:unitTerm uom="#A" exponent="1"/>
          <gml:unitTerm uom="#V" exponent="-1"/>
        </gml:unitDerivation>
      </gml:DerivedUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
      <gml:DerivedUnit gml:id="Wb">
        <gml:name>weber</gml:name>
        <gml:quantityType>magnetic flux</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Wb</gml:catalogSymbol>
        <gml:unitDerivation>
         <gml:unitTerm uom="#V" exponent="1"/>
         <gml:unitTerm uom="#s" exponent="1"/>
        </gml:unitDerivation>
       </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
       <gml:DerivedUnit gml:id="T">
        <gml:name>tesla</gml:name>
        <gml:quantityType>magnetic flux density</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">T</gml:catalogSymbol>
        <gml:unitDerivation>
         <gml:unitTerm uom="#Wb" exponent="1"/>
         <gml:unitTerm uom="#m" exponent="-2"/>
        </gml:unitDerivation>
       </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
       <gml:DerivedUnit gml:id="H">
        <gml:name>henry</gml:name>
        <gml:quantityType>inductance</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">H</gml:catalogSymbol>
        <gml:unitDerivation>
         <gml:unitTerm uom="#Wb" exponent="1"/>
         <gml:unitTerm uom="#A" exponent="-1"/>
        </gml:unitDerivation>
       </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
       <gml:ConventionalUnit gml:id="degC">
        <gml:name>degree Celsius</gml:name>
        <gml:quantityType>Celsius temperature</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">°C</gml:catalogSymbol>
        <gml:conversionToPreferredUnit uom="#K">
         <gml:formula>
          <gml:a>273.16</gml:a>
          <gml:b>1</gml:b>
          <gml:c>1</gml:c>
         </gml:formula>
        </gml:conversionToPreferredUnit>
       </gml:ConventionalUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
       <gml:DerivedUnit gml:id="lm">
        <gml:name>lumen</gml:name>
        <gml:quantityType>luminous flux</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">lm</gml:catalogSymbol>
        <gml:unitDerivation>
         <gml:unitTerm uom="#cd" exponent="1"/>
         <gml:unitTerm uom="#sr" exponent="1"/>
        </gml:unitDerivation>
       </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
       <gml:DerivedUnit gml:id="lx">
        <gml:name>lux</gml:name>
        <gml:quantityType>illuminance</gml:quantityType>
        <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">lx</gml:catalogSymbol>
        <gml:unitDerivation>
```

```
            <gml:unitTerm uom="#lm" exponent="1"/>
            <gml:unitTerm uom="#m" exponent="-2"/>
          </gml:unitDerivation>
        </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:DerivedUnit gml:id="Bq">
          <gml:name>becquerel</gml:name>
          <gml:quantityType>activity (referred to a radionuclide)</gml:quantityType>
          <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Bq</gml:catalogSymbol>
          <gml:unitDerivation>
            <gml:unitTerm uom="#s" exponent="-1"/>
          </gml:unitDerivation>
        </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:DerivedUnit gml:id="Gy">
          <gml:name>gray</gml:name>
          <gml:quantityType>absorbed dose, specific energy (imparted), kerma</gml:quantityType>
          <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Gy</gml:catalogSymbol>
          <gml:unitDerivation>
            <gml:unitTerm uom="#J" exponent="1"/>
            <gml:unitTerm uom="#kg" exponent="-1"/>
          </gml:unitDerivation>
        </gml:DerivedUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:DerivedUnit gml:id="Sv">
          <gml:name>sievert</gml:name>
          <gml:quantityType>dose equivalent, ambient dose equivalent, directional dose equivalent, personal
dose equivalent, organ equivalent dose</gml:quantityType>
          <gml:catalogSymbol codeSpace="http://www.bipm.fr/en/3_SI">Sv</gml:catalogSymbol>
          <gml:unitDerivation>
            <gml:unitTerm uom="#J" exponent="1"/>
            <gml:unitTerm uom="#kg" exponent="-1"/>
          </gml:unitDerivation>
        </gml:DerivedUnit>
      </gml:dictionaryEntry>
    </gml:DefinitionCollection>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:DefinitionCollection gml:id="ConventionalUnitsDictionary">
      <gml:description>A collection of Conventional Units.  These are units of measure which are either widely
used or important within a specific community.  For most of these there is
1. a known derivation from more primitive units, which may or may not be SI Base Units, or
2. a known conversion to a preferred unit, which may or may not be an SI Base or Derived unit, through
rescaling and offset,
or both.  </gml:description>
      <gml:name>Conventional units.</gml:name>
      <gml:dictionaryEntry>
        <gml:ConventionalUnit gml:id="deg">
          <gml:name>degree</gml:name>
          <gml:quantityType>plane angle</gml:quantityType>
          <gml:conversionToPreferredUnit uom="#rad">
            <gml:factor>0.0174533</gml:factor>
          </gml:conversionToPreferredUnit>
        </gml:ConventionalUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:DerivedUnit gml:id="m2">
          <gml:name>metre squared</gml:name>
```

```xml
     <gml:quantityType>area</gml:quantityType>
     <gml:unitDerivation>
      <gml:unitTerm uom="m" exponent="2"/>
     </gml:unitDerivation>
    </gml:DerivedUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="acre">
     <gml:name>acre</gml:name>
     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>4046.86</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="hare">
     <gml:name>hare</gml:name>
     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>0.000610609</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="ft2">
     <gml:name>square foot</gml:name>
     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>0.092903</gml:factor>
     </gml:conversionToPreferredUnit>
     <gml:unitDerivation>
      <gml:unitTerm uom="#ft" exponent="2"/>
     </gml:unitDerivation>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
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     <gml:name>hectare</gml:name>
     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>10000</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
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     <gml:name>square yard</gml:name>
     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>0.836127</gml:factor>
     </gml:conversionToPreferredUnit>
     <gml:unitDerivation>
      <gml:unitTerm uom="#yd" exponent="2"/>
     </gml:unitDerivation>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
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     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>0.00064516</gml:factor>
     </gml:conversionToPreferredUnit>
     <gml:unitDerivation>
      <gml:unitTerm uom="#in" exponent="2"/>
     </gml:unitDerivation>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
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     <gml:name>square centimetre</gml:name>
     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>0.0001</gml:factor>
     </gml:conversionToPreferredUnit>
     <gml:unitDerivation>
      <gml:unitTerm uom="#cm" exponent="2"/>
     </gml:unitDerivation>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
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     <gml:quantityType>area</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m2">
      <gml:factor>1.e-6</gml:factor>
     </gml:conversionToPreferredUnit>
     <gml:unitDerivation>
      <gml:unitTerm uom="#mm" exponent="2"/>
     </gml:unitDerivation>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="km">
     <gml:name>kilometre</gml:name>
     <gml:quantityType>length</gml:quantityType>
     <gml:catalogSymbol>km</gml:catalogSymbol>
     <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>1.e3</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="cm">
     <gml:name>centimetre</gml:name>
     <gml:quantityType>length</gml:quantityType>
     <gml:catalogSymbol>cm</gml:catalogSymbol>
     <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>1.e-2</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
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     <gml:quantityType>length</gml:quantityType>
     <gml:catalogSymbol>mm</gml:catalogSymbol>
     <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>1.e-3</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
```

```xml
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="um">
    <gml:name>micrometre</gml:name>
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    <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>1.e-6</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="nm">
    <gml:name>nanometre</gml:name>
    <gml:quantityType>length</gml:quantityType>
    <gml:catalogSymbol>nm</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>1.e-9</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="pm">
    <gml:name>picometre</gml:name>
    <gml:quantityType>length</gml:quantityType>
    <gml:catalogSymbol>pm</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>1.e-12</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="yd">
    <gml:name>yard</gml:name>
    <gml:quantityType>length</gml:quantityType>
    <gml:catalogSymbol>yd</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#m">
      <gml:factor>0.9144</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="ft">
    <gml:name>foot</gml:name>
    <gml:quantityType>length</gml:quantityType>
    <gml:catalogSymbol>'</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#m">
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    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
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    <gml:name>inch</gml:name>
    <gml:quantityType>length</gml:quantityType>
    <gml:catalogSymbol>"</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#m">
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    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
```

```
     <gml:ConventionalUnit gml:id="mile">
      <gml:name>mile</gml:name>
      <gml:quantityType>length</gml:quantityType>
      <gml:catalogSymbol>mi</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#m">
       <gml:factor>1609.34</gml:factor>
      </gml:conversionToPreferredUnit>
     </gml:ConventionalUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
     <gml:ConventionalUnit gml:id="Tonne">
      <gml:name>tonne</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>T</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
       <gml:factor>1.e3</gml:factor>
      </gml:conversionToPreferredUnit>
     </gml:ConventionalUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
     <gml:ConventionalUnit gml:id="g">
      <gml:name>gram</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:conversionToPreferredUnit uom="#kg">
       <gml:factor>1.e-3</gml:factor>
      </gml:conversionToPreferredUnit>
     </gml:ConventionalUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
     <gml:ConventionalUnit gml:id="mg">
      <gml:name>milligram</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>mg</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
       <gml:factor>1.e-6</gml:factor>
      </gml:conversionToPreferredUnit>
     </gml:ConventionalUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
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      <gml:name>microgram</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:conversionToPreferredUnit uom="#kg">
       <gml:factor>1.e-9</gml:factor>
      </gml:conversionToPreferredUnit>
     </gml:ConventionalUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
     <gml:ConventionalUnit gml:id="lb">
      <gml:name>pound</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>lb</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
       <gml:factor>0.453592</gml:factor>
      </gml:conversionToPreferredUnit>
     </gml:ConventionalUnit>
    </gml:dictionaryEntry>
    <gml:dictionaryEntry>
     <gml:ConventionalUnit gml:id="oz">
      <gml:name>ounce</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>oz</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
        <gml:factor>0.0283495</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="sack">
      <gml:name>sack</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>sack</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
        <gml:factor>45.3592</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="sk94">
      <gml:name>sk94</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>sk94</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
        <gml:factor>42.6377</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="USton">
      <gml:name>US ton</gml:name>
      <gml:quantityType>mass</gml:quantityType>
      <gml:catalogSymbol>ton</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#kg">
        <gml:factor>907.185</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="Ma">
      <gml:name>million year</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>Ma</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>3.15569e13</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="yr">
      <gml:name>year</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>yr</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>3.15569e7</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="wk">
      <gml:name>week</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>wk</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>604800</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="day">
      <gml:name>day</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>d</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>86400</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="hr">
      <gml:name>hour</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>hr</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>3600</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="min">
      <gml:name>minute</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>min</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>60</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="ms">
      <gml:name>millsecond</gml:name>
      <gml:quantityType>Time</gml:quantityType>
      <gml:catalogSymbol>ms</gml:catalogSymbol>
      <gml:conversionToPreferredUnit uom="#s">
        <gml:factor>0.001</gml:factor>
      </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="m_s">
      <gml:name>metres per second</gml:name>
      <gml:quantityType>velocity</gml:quantityType>
      <gml:catalogSymbol>m/s</gml:catalogSymbol>
      <gml:unitDerivation>
        <gml:unitTerm uom="#m" exponent="1"/>
        <gml:unitTerm uom="#s" exponent="-1"/>
      </gml:unitDerivation>
    </gml:DerivedUnit>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="m_s2">
      <gml:name>metres per second per second</gml:name>
      <gml:quantityType>acceleration</gml:quantityType>
      <gml:catalogSymbol>m/m2</gml:catalogSymbol>
    <gml:unitDerivation>
      <gml:unitTerm uom="#m" exponent="1"/>
      <gml:unitTerm uom="#s" exponent="-2"/>
    </gml:unitDerivation>
  </gml:DerivedUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="gu">
    <gml:name>Gravity units</gml:name>
    <gml:quantityType>acceleration</gml:quantityType>
    <gml:conversionToPreferredUnit uom="#m_s2">
      <gml:factor>1.e-6</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="hPa">
    <gml:name>hectoPascal</gml:name>
    <gml:quantityType>pressure</gml:quantityType>
    <gml:catalogSymbol>hPa</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#Pa">
      <gml:factor>1.e-2</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="bar">
    <gml:name>bar</gml:name>
    <gml:quantityType>pressure</gml:quantityType>
    <gml:catalogSymbol>bar</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#Pa">
      <gml:factor>1.e5</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="mbar">
    <gml:name>milliBar</gml:name>
    <gml:quantityType>pressure</gml:quantityType>
    <gml:catalogSymbol>mbar</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#Pa">
      <gml:factor>1.e-1</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="atm">
    <gml:name>Atmosphere</gml:name>
    <gml:quantityType>pressure</gml:quantityType>
    <gml:catalogSymbol>atm</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#Pa">
      <gml:factor>101325</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="psi">
    <gml:name>Pound per square inch</gml:name>
    <gml:quantityType>pressure</gml:quantityType>
    <gml:catalogSymbol>psi</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#Pa">
```

```
      <gml:factor>6894.76</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="hp">
    <gml:name>horsepower</gml:name>
    <gml:quantityType>power</gml:quantityType>
    <gml:catalogSymbol>hp</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#W">
      <gml:factor>746</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="GHz">
    <gml:name>GigaHertz</gml:name>
    <gml:quantityType>frequency</gml:quantityType>
    <gml:catalogSymbol>GHz</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#Hz">
      <gml:factor>1.e9</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="cal">
    <gml:name>Calorie</gml:name>
    <gml:quantityType>energy</gml:quantityType>
    <gml:catalogSymbol>cal</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#J">
      <gml:factor>4.1868</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="kJ">
    <gml:name>kiloJoule</gml:name>
    <gml:quantityType>energy</gml:quantityType>
    <gml:catalogSymbol>kJ</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="#J">
      <gml:factor>1.e3</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:DerivedUnit gml:id="kJ_Nm3">
    <gml:name>kilojoules per Newton metre</gml:name>
    <gml:quantityType>Point of evaporation</gml:quantityType>
    <gml:unitDerivation>
      <gml:unitTerm uom="#kJ" exponent="1"/>
      <gml:unitTerm uom="#N" exponent="-1"/>
      <gml:unitTerm uom="#m" exponent="-3"/>
    </gml:unitDerivation>
  </gml:DerivedUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="g_l">
    <gml:name>grams per litre</gml:name>
    <gml:quantityType>w/v concentration</gml:quantityType>
    <gml:conversionToPreferredUnit uom="#kg_m3">
      <gml:factor>1.</gml:factor>
    </gml:conversionToPreferredUnit>
    <gml:unitDerivation>
      <gml:unitTerm uom="#g" exponent="1"/>
      <gml:unitTerm uom="#l" exponent="-1"/>
    </gml:unitDerivation>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="ug_m3">
    <gml:name>micrograms per cubic metre</gml:name>
    <gml:quantityType>w/v concentration</gml:quantityType>
    <gml:conversionToPreferredUnit uom="#kg_m3">
      <gml:factor>1.e-9</gml:factor>
    </gml:conversionToPreferredUnit>
    <gml:unitDerivation>
      <gml:unitTerm uom="#ug" exponent="1"/>
      <gml:unitTerm uom="#m" exponent="-3"/>
    </gml:unitDerivation>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:DerivedUnit gml:id="kg_m3">
    <gml:name>kilograms per cubic metre</gml:name>
    <gml:quantityType>Density</gml:quantityType>
    <gml:unitDerivation>
      <gml:unitTerm uom="#kg" exponent="1"/>
      <gml:unitTerm uom="#m" exponent="-3"/>
    </gml:unitDerivation>
  </gml:DerivedUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="T_m3">
    <gml:name>Tonnes per cubic metre</gml:name>
    <gml:quantityType>Density</gml:quantityType>
    <gml:conversionToPreferredUnit uom="#kg_m3">
      <gml:factor>1000.</gml:factor>
    </gml:conversionToPreferredUnit>
    <gml:unitDerivation>
      <gml:unitTerm uom="#T" exponent="1"/>
      <gml:unitTerm uom="#m" exponent="-3"/>
    </gml:unitDerivation>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:UnitDefinition gml:id="ratio">
    <gml:name>Ratio</gml:name>
    <gml:quantityType>fraction</gml:quantityType>
  </gml:UnitDefinition>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="percent">
    <gml:name>percent</gml:name>
    <gml:quantityType>fraction</gml:quantityType>
    <gml:catalogSymbol>%</gml:catalogSymbol>
    <gml:conversionToPreferredUnit uom="ratio">
      <gml:factor>0.01</gml:factor>
    </gml:conversionToPreferredUnit>
  </gml:ConventionalUnit>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <gml:ConventionalUnit gml:id="ppm">
```

```
     <gml:name>parts per million</gml:name>
     <gml:quantityType>fraction</gml:quantityType>
     <gml:catalogSymbol>ppm</gml:catalogSymbol>
     <gml:conversionToPreferredUnit uom="ratio">
      <gml:factor>1.e-6</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="ppb">
     <gml:name>parts per billiion</gml:name>
     <gml:quantityType>fraction</gml:quantityType>
     <gml:catalogSymbol>ppb</gml:catalogSymbol>
     <gml:conversionToPreferredUnit uom="ratio">
      <gml:factor>1.e-9</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="m3">
     <gml:name>cubic metre</gml:name>
     <gml:quantityType>Volume</gml:quantityType>
     <gml:unitDerivation>
      <gml:unitTerm uom="#m" exponent="3"/>
     </gml:unitDerivation>
    </gml:DerivedUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="l">
     <gml:name>litre</gml:name>
     <gml:quantityType>Volume</gml:quantityType>
     <gml:conversionToPreferredUnit uom="#m3">
      <gml:factor>0.001</gml:factor>
     </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="kappa">
     <gml:name>kappa</gml:name>
     <gml:quantityType>kinematic viscosity </gml:quantityType>
     <gml:catalogSymbol>k</gml:catalogSymbol>
     <gml:unitDerivation>
      <gml:unitTerm uom="#Pa" exponent="1"/>
      <gml:unitTerm uom="#m" exponent="-3"/>
     </gml:unitDerivation>
    </gml:DerivedUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:DerivedUnit gml:id="Pas">
     <gml:name>poiseuille</gml:name>
     <gml:quantityType>dynamic viscosity</gml:quantityType>
     <gml:catalogSymbol> Pa.s</gml:catalogSymbol>
     <gml:unitDerivation>
      <gml:unitTerm uom="#Pa" exponent="1"/>
      <gml:unitTerm uom="#s" exponent="1"/>
     </gml:unitDerivation>
    </gml:DerivedUnit>
   </gml:dictionaryEntry>
   <gml:dictionaryEntry>
    <gml:ConventionalUnit gml:id="poise">
     <gml:name>poise</gml:name>
```

```
          <gml:quantityType>dynamic viscosity</gml:quantityType>
          <gml:catalogSymbol>po</gml:catalogSymbol>
          <gml:conversionToPreferredUnit uom="#Pa.s">
            <gml:factor>0.1</gml:factor>
          </gml:conversionToPreferredUnit>
          <gml:unitDerivation>
            <gml:unitTerm uom="#cm" exponent="-1"/>
            <gml:unitTerm uom="#g" exponent="1"/>
            <gml:unitTerm uom="#s" exponent="1"/>
          </gml:unitDerivation>
        </gml:ConventionalUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:ConventionalUnit gml:id="slug_fts">
          <gml:name>slugs/foot-second</gml:name>
          <gml:quantityType>dynamic viscosity</gml:quantityType>
          <gml:catalogSymbol>slug/fts</gml:catalogSymbol>
          <gml:conversionToPreferredUnit uom="#Pa.s">
            <gml:factor>47.9</gml:factor>
          </gml:conversionToPreferredUnit>
          <gml:unitDerivation>
            <gml:unitTerm uom="#slug" exponent="1"/>
            <gml:unitTerm uom="#ft" exponent="-1"/>
            <gml:unitTerm uom="#s" exponent="-1"/>
          </gml:unitDerivation>
        </gml:ConventionalUnit>
      </gml:dictionaryEntry>
      <gml:dictionaryEntry>
        <gml:ConventionalUnit gml:id="slug">
          <gml:name>slug</gml:name>
          <gml:quantityType>mass</gml:quantityType>
          <gml:catalogSymbol>slug</gml:catalogSymbol>
          <gml:conversionToPreferredUnit uom="#kg">
            <gml:factor>14.593903</gml:factor>
          </gml:conversionToPreferredUnit>
        </gml:ConventionalUnit>
      </gml:dictionaryEntry>
    </gml:DefinitionCollection>
  </gml:dictionaryEntry>
</gml:Dictionary>
```

D.2 phenomena.xsd

This XML document encodes a set of observable phenomena using the encoding defined in clause 7.3.

```
<?xml version="1.0" encoding="UTF-8"?>
<gml:Dictionary xmlns:gml="http://www.opengis.net/gml" xmlns:om="http://www.opengis.net/om"
xmlns:sch="http://www.ascc.net/xml/schematron" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.opengis.net/om
../OM/phenomenon.xsd" gml:id="phenomena">
  <gml:description>A dictionary of phenomena, thrown together for illustation.
SJDC 2002-12-24</gml:description>
  <gml:name>OWS Phenomena</gml:name>
  <gml:dictionaryEntry>
    <om:ParameterisedPhenomenon gml:id="_19V">
      <gml:description>19 GHz radiation Vertical Polarisation</gml:description>
      <gml:name>19V</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
```

```
   <om:constraint>
    <om:TypedQuantity axis="#PeakWavelength" uom="./units.xml#GHz">19.35</om:TypedQuantity>
   </om:constraint>
   <om:constraint>
    <om:TypedCategory axis="http://www.opengis.net/componentPhenomenonType#PolarisationDirection"
codeSpace="http://www.opengis.net/sensorGlossary">V</om:TypedCategory>
   </om:constraint>
  </om:ParameterisedPhenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:ParameterisedPhenomenon gml:id="_19H">
   <gml:description>19 GHz radiation Horizontal Polarisation</gml:description>
   <gml:name>19H</gml:name>
   <om:basePhenomenon xlink:href="#Radiation"/>
   <om:constraint>
    <om:TypedQuantity axis="http://www.opengis.net/componentPhenomenonType#peakWavelength"
uom="#GHz">19.35</om:TypedQuantity>
   </om:constraint>
   <om:constraint>
    <om:TypedCategory axis="http://www.opengis.net/componentPhenomenonType#PolarisationDirection"
codeSpace="http://www.opengis.net/sensorGlossary">H</om:TypedCategory>
   </om:constraint>
  </om:ParameterisedPhenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Age">
   <gml:description>Time duration since creation</gml:description>
   <gml:name>Age</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="AtmosphericPressure">
   <gml:description>fluid pressure exerted due to the gravitational effect on the column of atmosphere
above the position of interest</gml:description>
   <gml:name>Atmospheric Pressure</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="CloudCover">
   <gml:description>fraction of sky occupied by visible cloud</gml:description>
   <gml:name>Cloud Cover</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Density">
   <gml:description/>
   <gml:name>Density</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Depth">
   <gml:description>Linear distance measured vertically downwards from a reference
surface</gml:description>
   <gml:name>Depth</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Direction">
   <gml:description>Orientation of a vector relative to a reference frame.</gml:description>
   <gml:name>Direction</gml:name>
  </om:Phenomenon>
```

```xml
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="DissolvedSolids">
   <gml:description>Amount of solids remaining after evaporation</gml:description>
   <gml:name>Dissolved Solids</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="DOX">
   <gml:name>Dissolved Oxygen</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:CompositePhenomenon gml:id="EarthquakeParameters">
   <gml:name>Earthquake Parameters</gml:name>
   <om:componentPhenomenon>
    <om:CompositePhenomenon gml:id="EarthquakeLocation">
     <gml:name>Earthquake Location</gml:name>
     <om:componentPhenomenon xlink:href="#Epicentre"/>
     <om:componentPhenomenon xlink:href="#Depth"/>
     <om:componentPhenomenon xlink:href="#OriginTime"/>
    </om:CompositePhenomenon>
   </om:componentPhenomenon>
   <om:componentPhenomenon>
    <om:CompositePhenomenon gml:id="MomentTensor">
     <gml:name>Earthquake Moment Tensor</gml:name>
     <om:componentPhenomenon xlink:href="#Mrr"/>
     <om:componentPhenomenon xlink:href="#Mtt"/>
     <om:componentPhenomenon xlink:href="#Mff"/>
     <om:componentPhenomenon xlink:href="#Mrt"/>
     <om:componentPhenomenon xlink:href="#Mrf"/>
     <om:componentPhenomenon xlink:href="#Mtf"/>
    </om:CompositePhenomenon>
   </om:componentPhenomenon>
  </om:CompositePhenomenon>
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  <om:Phenomenon gml:id="Elevation">
   <gml:description>Linear distance measured vertically upwards from a reference
surface</gml:description>
   <gml:name>Elevation</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
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  <om:Phenomenon gml:id="Epicentre">
   <gml:description>The location on the surface of the earth directly above the position of the origin of an
earthquake</gml:description>
   <gml:name>Epicentre</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Medium">
   <gml:description>Material of which an object is constructed or within which a phenomenon
occurs</gml:description>
   <gml:name>Medium</gml:name>
  </om:Phenomenon>
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 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Mrr">
   <gml:description xlink:href="http://biggeophysicsdictionary.org/parameters/earthquakes/moment/Mrr"/>
   <gml:name>Earthquake Moment Tensor component Mrr</gml:name>
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<gml:dictionaryEntry>
  <om:Phenomenon gml:id="Mtt">
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    <gml:name>Earthquake Moment Tensor component Mtt</gml:name>
  </om:Phenomenon>
</gml:dictionaryEntry>
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  <om:Phenomenon gml:id="Mff">
    <gml:description xlink:href="http://biggeophysicsdictionary.org/parameters/earthquakes/moment/Mff"/>
    <gml:name>Earthquake Moment Tensor component Mff</gml:name>
  </om:Phenomenon>
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  <om:Phenomenon gml:id="Mrt">
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    <gml:name>Earthquake Moment Tensor component Mrt</gml:name>
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<gml:dictionaryEntry>
  <om:Phenomenon gml:id="Mrf">
    <gml:description xlink:href="http://biggeophysicsdictionary.org/parameters/earthquakes/moment/Mrf"/>
    <gml:name>Earthquake Moment Tensor component Mrf</gml:name>
  </om:Phenomenon>
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    <gml:description xlink:href="http://biggeophysicsdictionary.org/parameters/earthquakes/moment/Mtf"/>
    <gml:name>Earthquake Moment Tensor component Mtf</gml:name>
  </om:Phenomenon>
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    <gml:name>Molecular weight</gml:name>
  </om:Phenomenon>
</gml:dictionaryEntry>
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  <om:Phenomenon gml:id="MolVol">
    <gml:description/>
    <gml:name>Molecular volume</gml:name>
  </om:Phenomenon>
</gml:dictionaryEntry>
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  <om:Phenomenon gml:id="OrganismCount">
    <gml:description>Number of organisms</gml:description>
    <gml:name>Organism count</gml:name>
  </om:Phenomenon>
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  <om:Phenomenon gml:id="OriginTime">
    <gml:description>The time instant corresponding to the initiation of the event.</gml:description>
    <gml:name>Origin Time</gml:name>
  </om:Phenomenon>
</gml:dictionaryEntry>
<gml:dictionaryEntry>
  <om:Phenomenon gml:id="PeakWavelength">
    <gml:description>Centre of wavelength sensitivity band</gml:description>
    <gml:name>Peak Wavelength</gml:name>
  </om:Phenomenon>
```

```xml
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Radiation">
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 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="RelativeHumidity">
   <gml:description>Amount of water vapour in a gas measured as a fraction of full
saturation</gml:description>
   <gml:name>Relative Humidity</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Species">
   <gml:name>Species</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:Phenomenon gml:id="Speed">
   <gml:description>Scalar rate of movement</gml:description>
   <gml:name>Speed</gml:name>
  </om:Phenomenon>
 </gml:dictionaryEntry>
 <gml:dictionaryEntry>
  <om:CompositePhenomenon gml:id="DiscreteSpectrumTM">
   <gml:name>Landsat Thematic Mapper spectrum</gml:name>
   <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand1">
     <gml:name>Landsat TM band 1</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.45
0.52</om:TypedQuantityExtent>
     </om:constraint>
    </om:ParameterisedPhenomenon>
   </om:componentPhenomenon>
   <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand2">
     <gml:name>Landsat TM band 2</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.52
0.60</om:TypedQuantityExtent>
     </om:constraint>
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   </om:componentPhenomenon>
   <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand3">
     <gml:name>Landsat TM band 3</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.63
0.69</om:TypedQuantityExtent>
     </om:constraint>
    </om:ParameterisedPhenomenon>
   </om:componentPhenomenon>
   <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand4">
     <gml:name>Landsat TM band 4</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">0.76
0.90</om:TypedQuantityExtent>
     </om:constraint>
    </om:ParameterisedPhenomenon>
   </om:componentPhenomenon>
   <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand5">
     <gml:name>Landsat TM band 5</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">1.55
1.75</om:TypedQuantityExtent>
     </om:constraint>
    </om:ParameterisedPhenomenon>
   </om:componentPhenomenon>
   <om:componentPhenomenon>
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     <gml:name>Landsat TM band 6</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">10.4
12.5</om:TypedQuantityExtent>
     </om:constraint>
    </om:ParameterisedPhenomenon>
   </om:componentPhenomenon>
   <om:componentPhenomenon>
    <om:ParameterisedPhenomenon gml:id="TMBand7">
     <gml:name>Landsat TM band 7</gml:name>
     <om:basePhenomenon xlink:href="#Radiation"/>
     <om:constraint>
      <om:TypedQuantityExtent axis="#Wavelength" uom="./units.xml#um">2.08
2.35</om:TypedQuantityExtent>
     </om:constraint>
    </om:ParameterisedPhenomenon>
   </om:componentPhenomenon>
  </om:CompositePhenomenon>
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  <om:CompositePhenomenon gml:id="TM">
   <gml:description>Landsat Thematic Mapper all bands</gml:description>
   <gml:name codeSpace="#OWS1">Landsat TM</gml:name>
   <om:basePhenomenon xlink:href="http://www.opengis.net/componentPhenomena#Radiation"/>
   <om:constraintSet>
    <om:TypedValueArray axis="http://www.opengis.net/componentPhenomena#Wavelength">
     <gml:valueComponents>
      <gml:QuantityExtent uom="#um">0.45 0.52</gml:QuantityExtent>
      <gml:QuantityExtent uom="#um">0.52 0.60</gml:QuantityExtent>
      <gml:QuantityExtent uom="#um">0.63 0.69</gml:QuantityExtent>
      <gml:QuantityExtent uom="#um">0.76 0.90</gml:QuantityExtent>
      <gml:QuantityExtent uom="#um">1.55 1.75</gml:QuantityExtent>
      <gml:QuantityExtent uom="#um">10.4 12.5</gml:QuantityExtent>
      <gml:QuantityExtent uom="#um">2.08 2.35</gml:QuantityExtent>
     </gml:valueComponents>
    </om:TypedValueArray>
   </om:constraintSet>
  </om:CompositePhenomenon>
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  <om:ParameterisedPhenomenon gml:id="SurfaceWaterTemperature2">
   <gml:name>Surface Water Temperature 2</gml:name>
```

```
      <om:basePhenomenon xlink:href="#Temperature"/>
      <om:constraint>
        <om:TypedCategory axis="#Medium"
codeSpace="http://www.opengis.net/ows/media">water</om:TypedCategory>
      </om:constraint>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Depth" uom="./units.xml#m">0.0 1.5</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <om:ParameterisedPhenomenon gml:id="SurfaceWaterTemperature">
      <gml:name>Surface Water Temperature</gml:name>
      <om:basePhenomenon xlink:href="#WaterTemperature"/>
      <om:constraint>
        <om:TypedQuantityExtent axis="#Depth" uom="./units.xml#m">0.0 1.5</om:TypedQuantityExtent>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <om:Phenomenon gml:id="Temperature">
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      <gml:name>Temperature</gml:name>
    </om:Phenomenon>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <om:CompositePhenomenon gml:id="uSpectrum">
      <gml:description>Simple spectrum with uniform spacing of bands</gml:description>
      <gml:name>UniformSpectrum</gml:name>
      <om:basePhenomenon xlink:href="#Radiation"/>
      <om:constraintSet>
        <om:TypedQuantitySeries>
          <om:limits>0 512</om:limits>
          <om:axis>http://www.opengis.net/componentPhenomena#Wavelength</om:axis>
          <om:origin uom="#um">0.30</om:origin>
          <om:offset uom="#um">0.004</om:offset>
          <om:structure>post</om:structure>
        </om:TypedQuantitySeries>
      </om:constraintSet>
    </om:CompositePhenomenon>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <om:CompositePhenomenon gml:id="Velocity">
      <gml:description>Vector rate of movement relative to a reference frame</gml:description>
      <gml:name>Velocity</gml:name>
      <om:componentPhenomenon xlink:href="#Speed"/>
      <om:componentPhenomenon xlink:href="#Direction"/>
    </om:CompositePhenomenon>
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    <om:ParameterisedPhenomenon gml:id="WaterTemperature">
      <gml:name>Water Temperature</gml:name>
      <om:basePhenomenon xlink:href="#Temperature"/>
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        <om:TypedCategory axis="#Medium"
codeSpace="http://www.opengis.net/ows/media">water</om:TypedCategory>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </gml:dictionaryEntry>
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    <om:Phenomenon gml:id="Wavelength">
```

```
      <gml:description>Distance between peak values of a wave</gml:description>
      <gml:name>Wavelength</gml:name>
    </om:Phenomenon>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <om:ParameterisedPhenomenon gml:id="WindDirection">
      <gml:name>Wind Direction</gml:name>
      <om:basePhenomenon xlink:href="#Direction"/>
      <om:constraint>
        <om:TypedCategory axis="#Medium">Wind</om:TypedCategory>
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    </om:ParameterisedPhenomenon>
  </gml:dictionaryEntry>
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    <om:ParameterisedPhenomenon gml:id="WindSpeed">
      <gml:name>Wind Speed</gml:name>
      <om:basePhenomenon xlink:href="#Speed"/>
      <om:constraint>
        <om:TypedCategory axis="#Medium">Wind</om:TypedCategory>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </gml:dictionaryEntry>
  <gml:dictionaryEntry>
    <om:ParameterisedPhenomenon gml:id="WindVelocity">
      <gml:name>Wind Velocity</gml:name>
      <om:basePhenomenon xlink:href="#Velocity"/>
      <om:constraint>
        <om:TypedCategory axis="#Medium">Wind</om:TypedCategory>
      </om:constraint>
    </om:ParameterisedPhenomenon>
  </gml:dictionaryEntry>
</gml:Dictionary>
```

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