INSPIRE
Infrastructure for Spatial Information in Europe

D2.9 Guidelines for the use of Observations & Measurements and Sensor Web Enablement-related standards in INSPIRE Annex II and III data specification development

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O&M Guidelines – Executive Summary

While INSPIRE is foremost a Spatial Data Infrastructure, several of the Annex Themes have been specified so that their scope, in addition to the basic spatial information, includes measured, modelled or simulated data. The ISO 19156 standard on Observations and Measurements (O&M) was designed for this explicit purpose, and thus shall be used in INSPIRE to cover these requirements.

O&M is intended for cross-domain work and data exchange; it should mainly be used if provenance and quality of property values shall be provided with the data (e.g. to allow users to determine fitness-for-purpose). If this is not important to the user, or the provider does not want to provide it, do not use O&M. Before a decision is reached to use O&M, the requirements must be clearly analyzed to determine if an Observation-centric view is necessary or if a Result/Coverage-centric view will suffice. One key characteristics of O&M in this regard is the explicit relationships between the result and the feature of interest, sampling feature, procedure etc.

The following INSPIRE themes have identified O&M as integrally relevant to their thematic domain and are including elements of O&M into their data specifications:

- **Geology**
- **Oceanographic geographical features**
- **Atmospheric conditions and Meteorological geographical features**
- **Environmental monitoring facilities**
- **Soil**

In addition to these themes, several further INSPIRE themes have been identified to which observational information, while not at the core of the data specification, is relevant. These themes are:

- **Area management/restriction/regulation zones and reporting units**: Not mentioned but relevant for reporting on aggregated levels
- **Human Health and Safety**: provision of health determinants
- **Land cover**: Observations form the basis for land cover information
- **Natural risk zones**: Not in model, but use case states: "Monitoring data:
    - Type of monitoring instrumentation
    - Location of sampling measurements
    - Type and record of measurements"
- **Production and industrial facilities**: Relevant for provision of emissions data for E-PRTR
- **Statistical units & Population distribution, demography**: StatisticalDataValue looks a bit like OM_Observation, SU would also make sense
- **Utility and governmental services**: Currently stated that "Non-geographic data (e.g. information on flow in m^3/s) is also out of scope of this specification"
- **Habitats and biotopes & Species distribution**: Observation form the basis for these themes, link to primary observations

While the O&M standard provides a generic framework for the provision of measurement data, there are many ways of utilizing the core structures. In order to assure compatibility across thematic tailoring versions of the O&M standards, the X-TWG OM has provided guidelines as to how this standard is to be used within INSPIRE. These guidelines should be taken in to account in all INSPIRE themes integrating or referencing to the O&M standard.

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1 Scope

This document provides guidelines for the use of Observations & Measurements and Sensor Web Enablement-related standards in INSPIRE Annex II and III data specification development.

These guidelines provide the basis for the definition of INSPIRE Annex II and III data specifications if they are using the O&M schema.

2 Normative references

ISO 19115:2003, *Geographic information — Metadata*

ISO 19115:2003/Cor 1:2006, *Geographic information — Metadata — Corrigendum 1*

ISO 19123:2005, *Geographic information — Schema for coverage geometry and functions*

ISO 19136:2007, *Geographic information — Geography Markup Language*

ISO/FDIS 19156:2011(E) — *Geographic information — Observations and measurements*

ISO/IEC 19501:2005, *Information technology — Open Distributed Processing — Unified Modeling Language (UML) Version 1.4.*

3 Terms and abbreviations

3.1 Terms

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

3.1.1 application schema

conceptual schema for data required by one or more applications

[ISO 19101:2002, definition 4.2]

3.1.2 coverage

feature that acts as a function to return values from its range for any direct position within its spatial, temporal or spatiotemporal domain

[ISO 19123:2005, definition 4.17]

3.1.3 data type

specification of a value domain with operations allowed on values in this domain

[ISO/TS 19103:2005, definition 4.1.5]

EXAMPLE Integer, Real, Boolean, String, Date (conversion of a date into a series of codes).

NOTE Data types include primitive predefined types and user-definable types. All instances of a data type lack identity.

[ISO/FDIS 19156:2011(E)]

3.1.4 domain feature

feature of a type defined within a particular application domain

NOTE This may be contrasted with observations and sampling features, which are features of types defined for cross-domain purposes.

[ISO/FDIS 19156:2011(E)]

3.1.5 ex-situ

referring to the study, maintenance or conservation of a specimen or population away from its natural surroundings

NOTE Opposite of in-situ.

[ISO/FDIS 19156:2011(E)]

3.1.6 feature

abstraction of real-world phenomena

[ISO 19101:2002, definition 4.11]

NOTE A feature may occur as a type or an instance. In this document, feature instance is meant unless otherwise specified.

[ISO/FDIS 19156:2011(E)]

3.1.7 feature type

class of **features** having common characteristics

[ISO/FDIS 19156:2011(E)]

3.1.8 measure

value described using a numeric amount with a scale or using a scalar reference system

[ISO 19136:2007, definition 4.1.41]

3.1.9 measurement

set of operations having the object of determining the **value** of a quantity

[ISO/TS 19101-2:2008, definition 4.20]

3.1.10 observation

act of measuring or otherwise determining the **value** of a **property**

[ISO/FDIS 19156:2011(E)]

3.1.11 observation procedure

method, algorithm or instrument, or system of these, which may be used in making an **observation**

[ISO/FDIS 19156:2011(E)]

3.1.12 observation protocol

combination of a sampling strategy and an **observation procedure** used in making an **observation**

[ISO/FDIS 19156:2011(E)]

3.1.13 observation result

estimate of the **value** of a **property** determined through a known observation procedure

[ISO/FDIS 19156:2011(E)]

3.1.14 property

facet or attribute of an object referenced by a name

[ISO 19143:2010, definition 4.21]

EXAMPLE Abby's car has the colour red, where "colour red" is a property of the car instance

[ISO/FDIS 19156:2011(E)]

3.1.15 property type

characteristic of a **feature type**

EXAMPLE cars (a feature type) all have a characteristic colour, where "colour" is a property type

NOTE 1 The **value** for an instance of an observable property type can be estimated through an act of **observation**

NOTE 2 In chemistry-related applications, the term "determinand" or "analyte" is often used.

[Adapted from ISO 19109:2005]

3.1.16 sampling feature

feature which is involved in making **observations** concerning a **domain feature**

EXAMPLE station, transect, section or specimen.

NOTE A sampling feature is an artefact of the observational strategy, and has no significance independent of the observational campaign.

[ISO/FDIS 19156:2011(E)]

3.1.17 spatial sampling feature

a sampling feature with a spatial coverage. Used for observations where the result varies within the scope of the feature

EXAMPLE ShipsTrack, Profile, Swath.

NOTE A spatial sampling feature is an artefact of the observational strategy, and has no significance independent of the observational campaign.

3.1.18 specimen

a sampling feature that is a physical sample, obtained for ex-situ observations, usually analysed in a laboratory. A specimen may be archived for future reference after the observation has been performed

3.1.19 value

element of a type domain

[ISO/IEC 19501:2005]

NOTE 1 A value considers a possible state of an object within a class or type (domain).

NOTE 2 A data value is an instance of a **datatype**, a value without identity.

NOTE 3 A value can use one of a variety of scales including nominal, ordinal, ratio and interval, spatial and temporal. Primitive datatypes can be combined to form aggregate datatypes with aggregate values, including vectors, tensors and images.

[ISO/FDIS 19156:2011(E)]

3.2 Abbreviations

FoI	Feature of Interest
GFM	General Feature Model
GML	Geography Markup Language
O&M	Observations and Measurements
OGC	Open Geospatial Consortium
SensorML	Sensor Model Language
SOS	Sensor Observation Service
SWE	Sensor Web Enablement
UML	Unified Modeling Language
XML	Extensible Markup Language

4 General O&M Design Patterns

4.1 Short introduction to O&M

While INSPIRE is foremost a Spatial Data Infrastructure, several of the Annex Themes have been specified so that their scope, in addition to the basic spatial information, includes measured, modelled or simulated data. The ISO 19156 standard on Observations and Measurements (O&M) was designed for this explicit purpose, and thus shall be used in INSPIRE to cover these requirements.

This section serves to give the reader a simple overview of the main concepts of the O&M standard for better understanding of the INSPIRE specific design patterns proposed. For more detailed information on O&M, please refer either to ISO 19156 or the OGC Document: OGC 10-004r3 (Geographic Information: Observations and Measurements - OGC Abstract Specification Topic 20)

4.1.1 Observations

> An Observation is an action whose **result** is an estimate of the value of some **property** of the **feature-of-interest**, at a specific point in **time**, obtained using a specified **procedure**
>
> *After Cox 2008*

For the structuring of data pertaining to observations, the O&M standard has defined the OM_Observation type. The following diagram shows the basic OM_Observation type with all its attributes, associations and constraints.

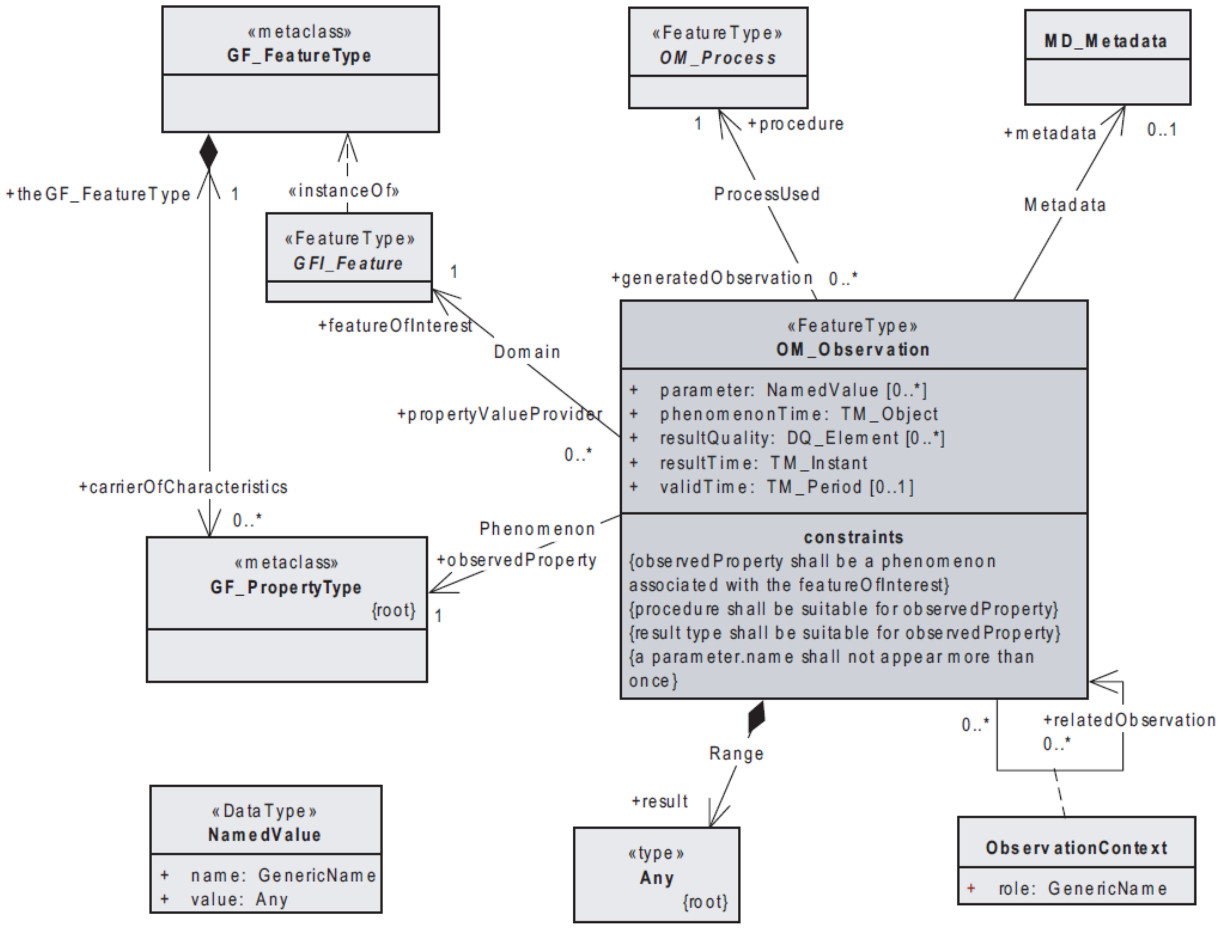


Figure 1: The basic Observation type

4.1.1.1. Observation Associations

The following associations link classes to the observation that serve to explicitly describe all aspects of the observation performed,

4.1.1.1.1. Property

Association: Phenomenon

Role: observedProperty

The association Phenomenon links to the GF_PropertyType describing the property of the feature-of-interest that is being estimated in this observation.

The following terms are used to refer to the property in other domains:

Earth Observations:	parameter, variable
Metrology:	measurand
Earth science simulations:	Variable, parameter
Assay/Chemistry:	Analyte
Geology field observations:	Strike and dip, lithology, alteration state, etc

4.1.1.1.2. Procedure

Association: ProcessUsed

Role: procedure

Inverse Role: generatedObservation

The association ProcessUsed links to the OM_Process describing the process or methodology usedin the estimation of the result in this observation.

The following terms are used to refer to the procedure in other domains:

Earth Observations: method, sensor

Metrology: instrument

Earth science simulations: Earth process simulator

Assay/Chemistry: Instrument, analytical process

Geology field observations:

4.1.1.1.3. Feature-Of-Interest

Association: Domain

Role: featureOfInterest

Inverse Role: propertyValueProvider

The association Domain links to the GFI_Feature that is the subject of the observation. This is a representation of the real world object the property is being estimated on.

The following terms are used to refer to the Feature-Of-Interest in other domains:

Earth Observations: 2-D swath or scene; 3-D sampling space

Earth science simulations: Section, swath, volume, grid

Assay/Chemistry: Sample

Geology field observations: Location of structure observation; Rock sample

4.1.1.1.4. Result

Association: Range

Role: result

The association Range links to the estimate of the property on the feature-of-interest generated by the procedure.

The following terms are used to refer to the Result in other domains:

Earth Observations: observation value, measurement value, observation

Metrology: value

Earth science simulations: model

Assay/Chemistry: Analysis

Geology field observations:

4.1.1.2. Observation Attributes

The following attributes provide further detail on the observation performed,

4.1.1.2.1. Parameter

Datatype: NamedValue

The attributes provided under parameter describe any event-specific parameter of relevance to interpreting the observation. These will typically complement the re-usable (event-neutral) description of the observation procedure. The datatype NamedValue allows for the provision of key/value pairs for the parameter.

Within O&M, any GenericName may be provided as the name, and any data type may be provided for the value. In INSPIRE, this has been further constrained; for more information, see section “5.4.1 Process Parameters”.

4.1.1.2.2. PhenomenonTime

Datatype: TM_Object

The attribute phenomenonTime shall describe the time that the result applies to the property of the feature-of-interest. This may be the time when a specimen was collected or the observation procedure was performed on a real-world feature, but may be in the future in the case of forecasts, or in the deep past for archeological or geological observations. The type ‘TM_Object’ allows for time instants, time periods (where the result is extensive in time such as a temporal coverage), or temporal topologies if this is the most appropriate representation..

4.1.1.2.3. ResultQuality

Datatype: DQ_Element

When the Observation result consists of a single value, or a set of values that are all of the same quality, the quality of the result is to be provided here. However, in the case of complex results (spatial or temporal coverages), the quality may vary across the result values; in this case, the quality must be provided for each value within the result.

4.1.1.2.4. ResultTime

Datatype: TM_Instant

The attribute resultTime describes the time when the result became available, typically when the procedure associated with the observation was completed For some observations this is identical to the phenomenonTime. However, there are important cases where they differ; an example of this is a specimen analyzed in a laboratory, where the PhenomenonTime should correspond to the time the specimen was taken, while the ResultTime is the time when the laboratory analysis was completed.

4.1.1.2.5. ValidTime

Datatype: TM_Period

If present, the attribute validTime describes the time period during which the result is intended to be used. This attribute is commonly required in forecasting applications.

4.1.2 Sampling

In order to understand the meaning of an observation, one must also understand the exact domain of the observation, the feature-of-interest. In some cases, this feature-of-interest can be be analysed in its entirety. Some examples for this are:

- The weight of a specific animal
- The type of crop planted on a specific field

In this case, this feature-of-interest should be directly used. In other cases, it is difficult to estimate a property on the entirety of a feature; thus, one usually samples one representative part of this larger feature for analysis purposes. In this case, the feature-of-interest is this sample, which refers to the feature it has been taken as a representative of as it's sampledFeature. Some examples of this are:

- A rock sample taken as a representative for an outcrop.
- A sample of river water taken as a representative for the river segment sampled from.

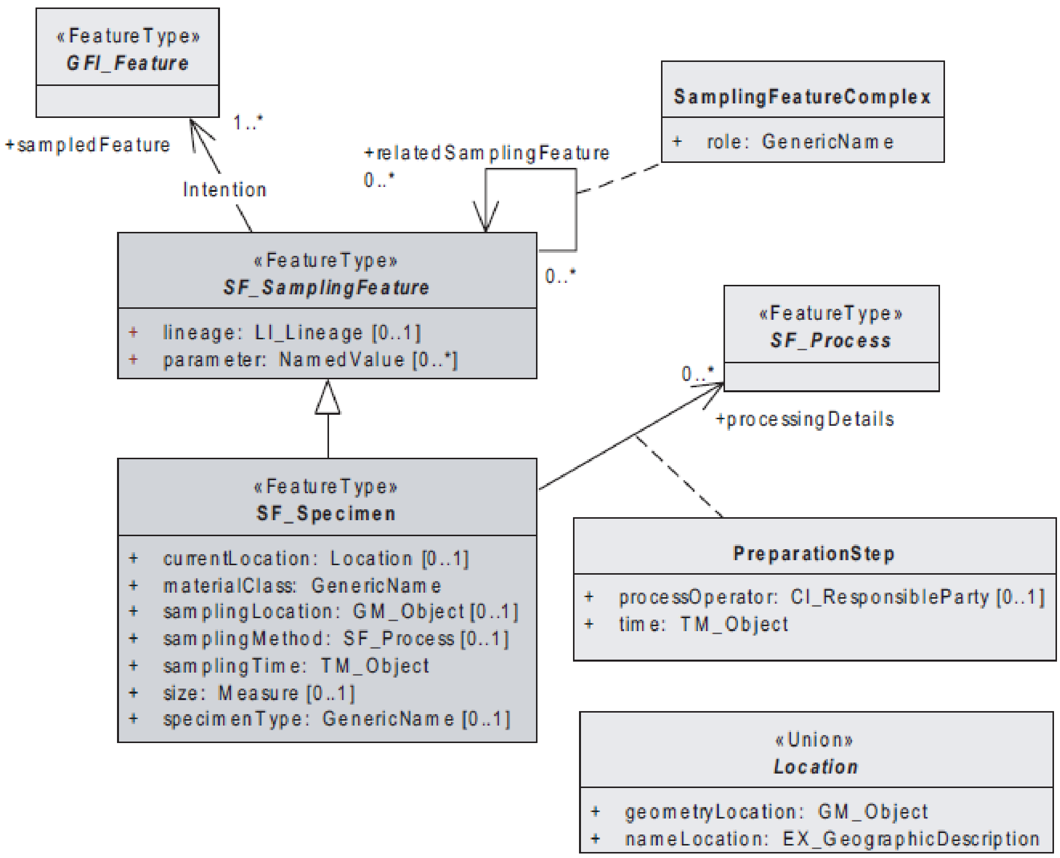


Figure 2: Basic Sampling Types

4.1.2.1. SamplingFeature

A samplingFeature is an intermediate feature involved in an observation which allows an estimate of a property value for the ultimate feature of interest to be made In the case of a spatial sampling feature, which is derived from the SF_SamplingFeature, the SpatialSamplingFeature is a point, line, surface or volume which may be co-located with the ultimate FOI. e.g. a point in a river. The result values will vary across the SpatialSamplingFeature.

The following terms describe specific SamplingFeatures in various domains:

Earth Observations:	2-D swath or scene; 3-D sampling space
Earth science simulations:	Section, swath, volume, grid
Assay/Chemistry:	Polished section, probe spot, pulp
Geology field observations:	Outcrop; Location of structure observation

4.1.2.2. Sampled Feature

The sampledFeature is the feature the SamplingFeature was sampled from, providing the ultimate context for the observation. An example of sampledFeature would be the river segment a specimen was taken from

The following terms are used to refer to the sampledFeature in other domains:

Earth Observations:	Earth surface; media (air, water, …), Global Change Master Directory "Topic"
Earth science simulations:	Atmosphere, ocean, solid earth
Geology field observations:	Ore body, Geologic Unit

4.1.2.3. Specimen

A specimen is a feature sampled from a feature of interest to enable ex-situ observation, such as in a laboratory. Information on how the specimen was acquired, where it is presently stored, and its preparation procedure are provided.

The following terms are used to refer to the Specimen in other domains:

Assay/Chemistry:	Sample; Pulp, separation
Geology field observations:	Rock sample

4.2 Short introduction to SOS & SensorML

In addition to the use of the Observations and Measurements standard, further elements of the OGC Sensor Web Enablement Suite (SWE) have been identified as useful for the encoding and provision of observational data. While further SWE elements may be nominated for use in INSPIRE, at the present we have identified the following:

- Sensor Observation Service (SOS): service created for the provision of observational data
- SensorML: Standard for the provision of procedural information

4.2.1 SOS Overview

The OGC SOS specification has been designed similar to the other OGC service interfaces, thus, it has a similar structure of service requests. In the case of SOS, the operation signature is constrained by the observation schema, as it defines the response model. The followingSOS requests have been identified as relevant to INSPIRE, and will be simply described in the sections below:

- getCapabilities
- getObservation
- describeSensor
- getFeatureOfInterest

At present, SOS is only available in the version 1.0. Work on the 2.0 version is ongoing, and results shall soon be available. For more detailed information on SOS, please refer to the OGC Document: OGC 06-009r6 (Sensor Observation Service)

4.2.1.1. getCapabilities

This operation allows clients to retrieve service metadata about a specific service instance, including metadata about the tightly-coupled data served. In addition to more generic capabilities response elements such as filter options, the SOS getCapabilities returns a list of so called Offerings, that provide a list of available observations described by their Feature of Interest, Procedure, Observed property, temporal coverage and the like. This allows the user application to clearly identify the types and quality of data that can be requested from this service.

4.2.1.2. getObservation

The GetObservation operation is designed to query a service to retrieve observation data structured according to the Observation and Measurement specification. Within the getObservation request, the user can provide a filter, including the desired observedProperty, Feature-of-Interest and time interval, which determines which observations are to be returned. The response to the getObservation request is one or more observations encoded as an OM_Observation

4.2.1.3. describeSensor

DescribeSensor is designed to request detailed sensor metadata, the response provides this procedural metadata, encoded using either the Sensor Model Language (SensorML) and Transducer Markup Language (TML). This provides all information required on how the observation or measurement was obtained. This information should be sufficient to determine if the data from the observations meets ones further processing requirements.

4.2.1.4. getFeatureOfInterest

GetFeatureOfInterest returns a featureOfInterest that was advertised in one of the observation offerings of the SOS capabilities document.

4.2.2 SensorML Overview

Sensor Model Language (SensorML) was created by the sensor community for structuring of information pertaining to sensors. This covers all procedural information as required within O&M, and is often the default procedure expected by SOS implementations. Of primary interest to these guidelines is the SensorML component class – this class was created for the description of measurement components (i.e. individual sensors).

While SensorML was primarily designed by the sensor community, due to its abstract structure it can also be used for data survey process descriptions not using sensors, or very abstract concepts of sensors such as human sensors performing a biodiversity survey.

At present, SensorML is only available in the version 1.0. Work on the 2.0 version is ongoing, but it is at present not clear how this will differ from the 1.0 version or when it will be made available. For more detailed information on SensorML, please refer to the OGC Document: OGC® 07-000 (OpenGIS® Sensor Model Language (SensorML) Implementation Specification)

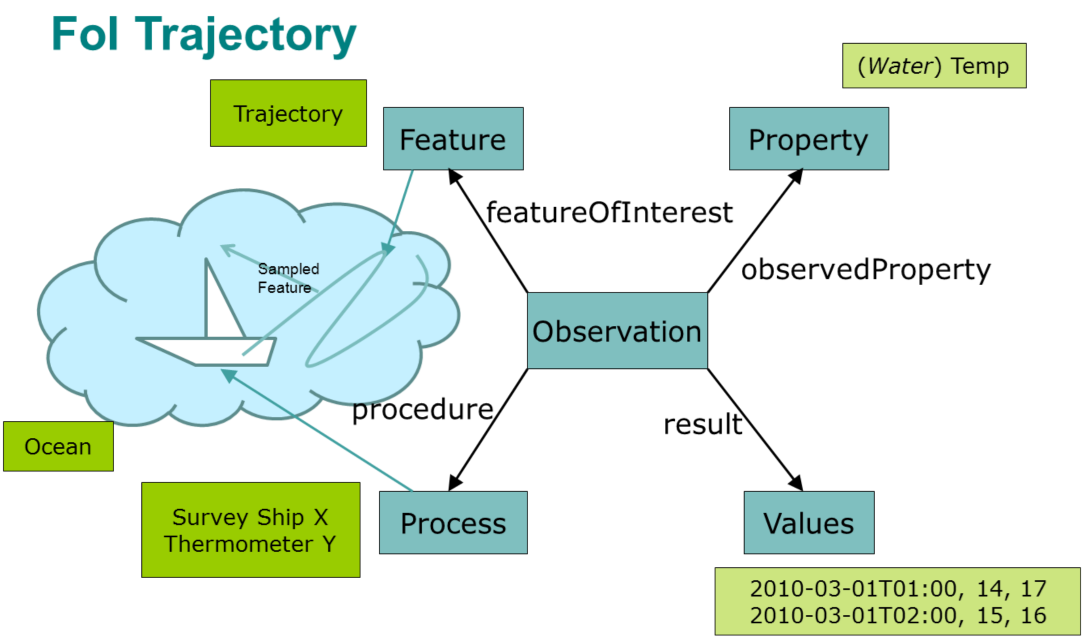
4.3 O&M Design Patterns by Feature of Interest

Different Design Patterns for the use of O&M have been identified, in this case following different types of FoI. The five following patterns were presented as illustrative of the type of observations we might encounter in INSPIRE and discussed:

- Feature of Interest Trajectory (sampling curve)
- Feature of Interest Station/Location (sampling point)
- Feature of Interest Sample/Specimen
- Feature of Interest Extensive Feature (sampling surface)
- Feature of Interest Media

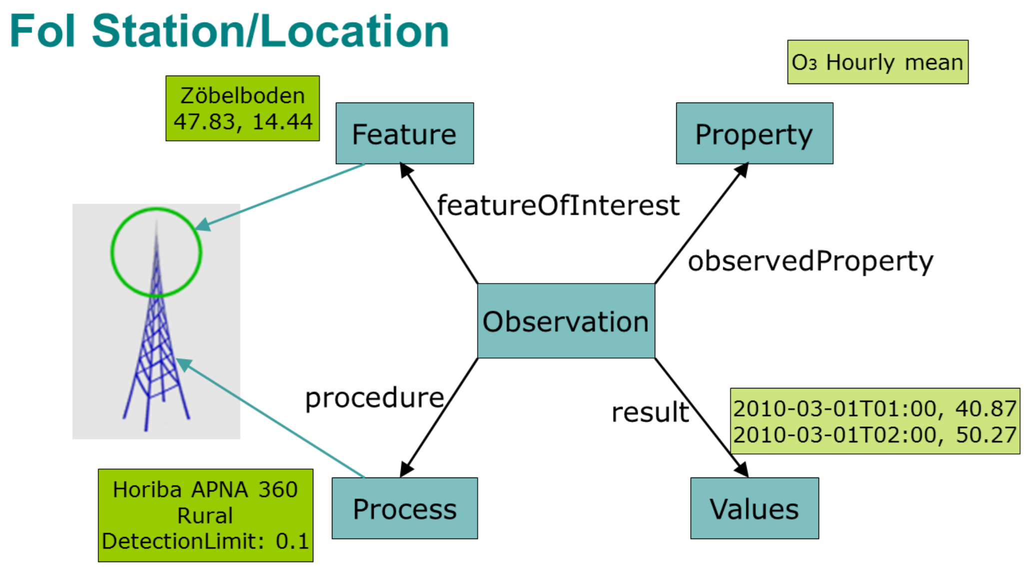
4.3.1 *FoI Trajectory (sampling curve)*

In this design pattern the FoI represents the trajectory of a moving facility, for example a moving ship making sea surface temperature measurements. The trajectory is modeled as a samplingFeature, with the spatial sampling feature (e.g. a SF_SamplingCurve in O&M)being the media referred to, in this case, the ocean (or a further chain of samplingFeatures finally referring to the media). The actual location of individual measurements along the trajectory to are provided with the results. All measurement locations should be located within the trajectory described by the FoI; depending on the encoding of the result the actual location within the FoI as well as phenomenonTime and resultTime may be provided as a relative (i.e. 5m from start of trajectory) or absolute (i.e. coordinates) position.



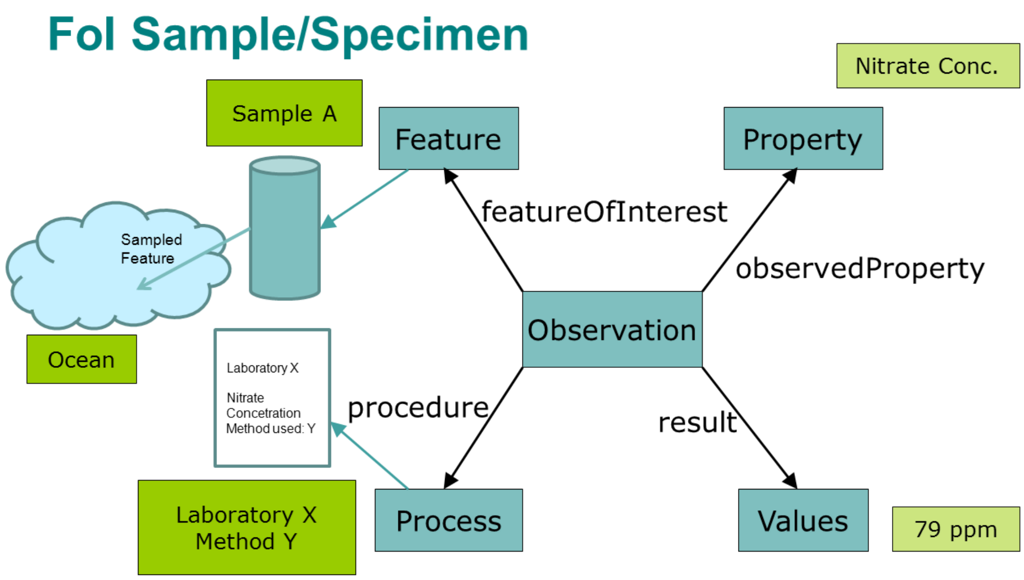
4.3.2 FoI Station/Location (sampling point)

In this design pattern the FoI represents the direct surrounds of a facility (i.e. the air bubble at the location of the facility, to be modeled as a sampling point (SF_SamplingPoint)) and is modeled as a samplingFeature. The location for the measurements is provided through the FoI. Administrative information relevant to the facility is stored in the FoI. As this design patters usually provides a time series (temporal coverage) result, the phenomenonTime and/or resultTime will often be provided together with the result values.



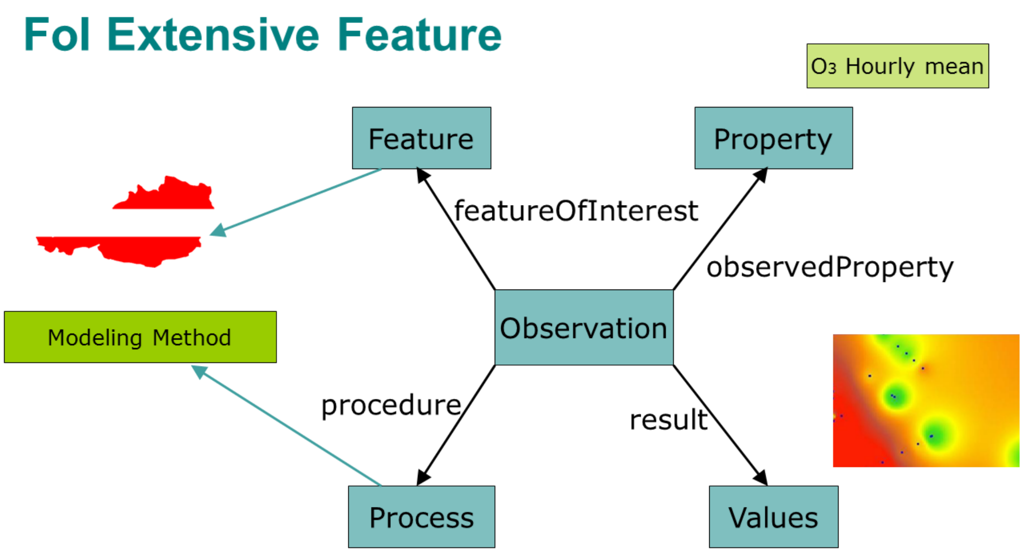
4.3.3 FoI Sample/Specimen

In this design pattern the FoI represents a sample or specimen taken from the sampled feature and analyzed *ex situ* in an external laboratory. The FoI is modeled as a SF_Specimen; the location pertaining to the measurement is provided by the attribute samplingLocation, the current location of the specimen is provided by the attribute currentLocation. Procedural information is provided through a laboratory report, the location of the laboratory is not relevant. In this design pattern, phenomenonTime and resultTime will both be required, as phenomenonTime provides the time the sample was taken whereas resultTime provides the time the results of the laboratory analysis were made available.



4.3.4 FoI Extensive Feature (sampling surface)

While the previously mentioned design patterns are all focused on providing point based results, often compiled into spatial or temporal coverages, this design pattern takes the spatial coverage of the result into account when defining the FoI. A further difference to the FoI Station/Location design pattern is the dislocation of facility and FoI.



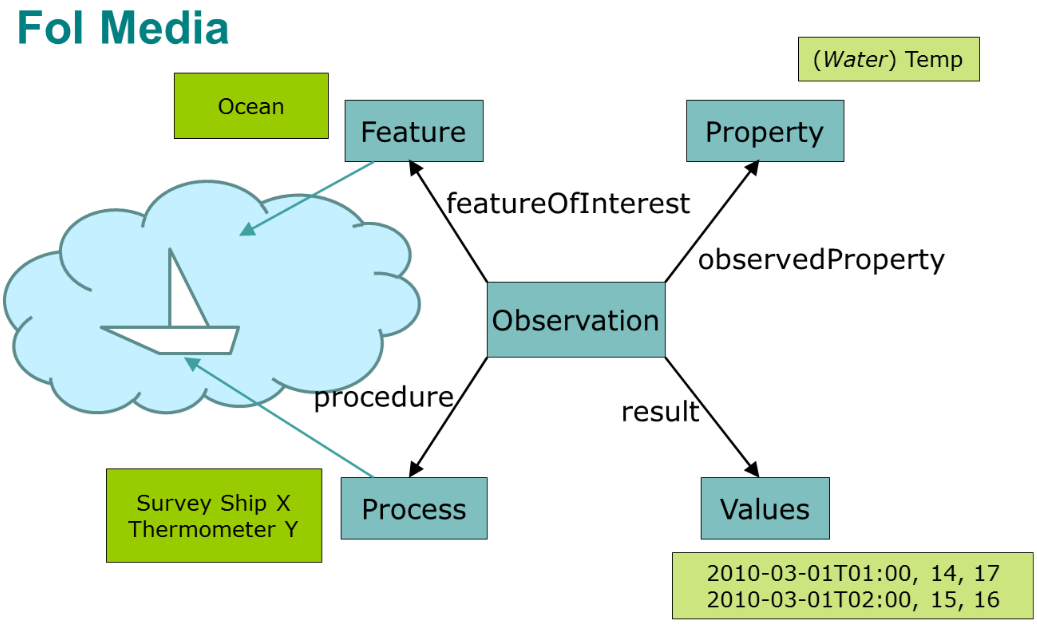
This design pattern is also relevant for remote sampling. In this version, the FoI is the swath covered by a satellite, while the process information is linked to the satellite.

The difference between FoI Extensive Feature and FoI Media is that in FoI Extensive Feature, there is a clear geometric FoI, in FoI Media, there isn't (actually Atlantic would already be (VERY) extensive feature. Ocean or Atmosphere does not have a geometry in itself

4.3.5 FoI Media

In this design pattern the FoI is kept very vague, just referring to the media being sampled, but not defining an explicit samplingFeature. The actual location of a measurement within the media referred to is provided with the results.

This design pattern was considered too vague for INSPIRE purposes.



4.4 O&M Design Patterns by Result

A further possibility for identifying O&M design patterns is through analysis of the result nature. In certain cases, often pertaining to coverage results, the result is of primary interest while the methodology used in attaining this result is secondary. In other cases, while the result is still of importance, a good understanding of the process that was utilized in generating these results is of utmost importance in proper further utilization of the result data. Differentiation in a Result/Coverage-centric - vs. an Observation-centric view helps us to refine the requirements for these 2 design patterns

4.4.1 Result/Coverage-centric view

In the Result/Coverage-centric view, the result (generally a coverage in this case) is the primary object of interest while the description of the observation process is just metadata of the result; coverages are “first class citizens” and observation is metadata about the coverage.

In this context, it is possible to envision design patterns that forgo provision of procedural metadata entirely as this in not of further relevance for the interpretation of the result. However, there are also cases where the procedural metadata can be of relevance to the further processing chain. In such cases, the coverage metadata can be used to supply such information

4.4.2 Observation-centric view

In the Observation-centric view, observations are first-class citizens, and the result could almost be seen as “metadata”; full knowledge of the result acquisition process is necessary and must be provided. In this context, design patterns fully embracing the richness of O&M are recommended, as these are far richer in properties and description of the observation process.

5 INSPIRE O&M Design Patterns

5.1 General

O&M is intended for cross-domain work and data exchange; it should mainly be used if provenance and quality of property values shall be provided with the data (e.g. to allow users to determine fitness-for-purpose). It is also useful for data discovery using the primary slots in the model (feature of interest, observed property, procedure) and can assist in data fusion across discipline boundaries. For intra-domain purposes, if the observation metadata is not important to the user, or the provider does not want to provide it, do not use O&M. Before a decision is reached to use O&M, the requirements must be clearly analyzed to determine if an Observation-centric view is necessary or if a Result/Coverage-centric view will suffice. One key characteristics of O&M in this regard is the explicit relationships between the result and the feature of interest, sampling feature, procedure etc.

Application of O&M within a technical community requires that the community agree on standard content for the key slots in the model. In particular, it is necessary to havbe standard vocabularies for the following:

i. The feature-types that may serve as the **feature-of-interest** (for direct observations) or for the **sampled-feature** (where a sampling feature is involved and described)

  a. In the context of INSPIRE these feature types will usually be drawn from the feature-concept-dictionary and associated feature-type-catalogue.

ii. The property definitions that may serve as the **observed property**, These should be assigned persistent identifiers (URIs) to allow them to be referenced in observation instances

iii. The observation **procedures** used in the community. These may be expressed using SensorML or any suitable alternative formulation, and should be assigned persistent identifiers (URIs) to allow them to be referenced in observation instances

5.2 Observation

In order to maintain compatibility with the various domain specific standards based on O&M such as CSML or WaterML 2.0, we have decided not to specialize OM_Observation within INSPIRE. At the same time, we do see a requirement to provide further information on the observational process within the observation itself. For example, it would often be valuable to store a limited amount of calibration info information linked to the observation instance and not the procedure.

For this purpose, we propose the use of the observation "parameter" attribute. This attribute allows for provision of diverse types of data as key-value pairs. As most of the additional observation-relevant information identified is clearly linked to the procedure defined in the process, to describe process runtime parameters. These should be clearly documented in the process description, so that the user of the data is informed as to what types of information are to be expected here. More information on these process parameters can be found in section 5.4.

In certain cases, a direct link from an observation to a facility or other feature type is required. This information should also be stored in the observation attribute parameter; the reference type EnvironmentalFeatureReference shall be used as the value of the parameter, which references the relevant facility feature. As this type refers to the AbstractMonitoringFeature Class, it can be used to link an observation to either an EnvironmentalMonitoringFacility or to an EnvironmentalMonitoringNetwork.

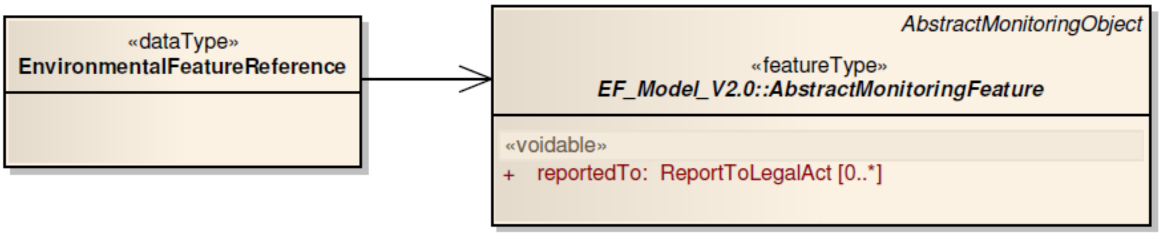


Figure 3: EnvironmentalFeatureReference Class

In certain usage areas such as Atmospheric Conditions or Oceanographic Features, there is a requirement for a semantic observation collection. While O&M V1.0 contained an observation collection class, this has been dropped in the O&M V2.0 specification. A semantic observation collection class shall be reintroduced for this purpose.

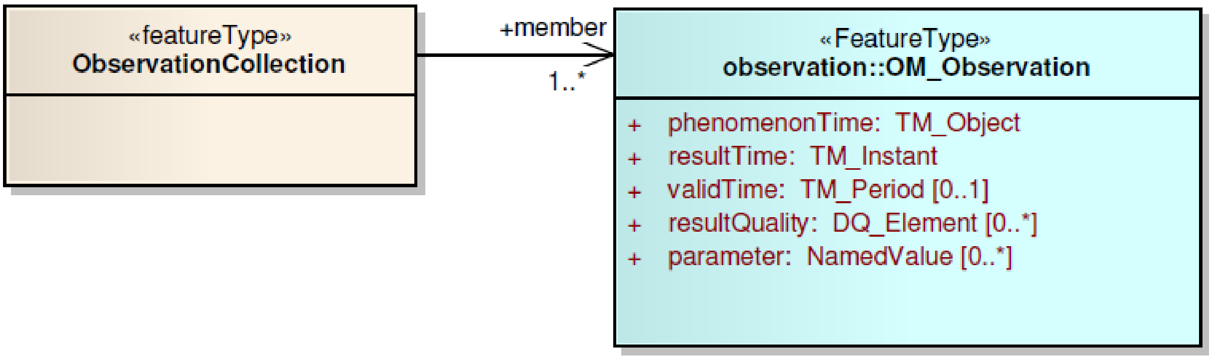


Figure 4: ObservationCollection Class

5.3 FoI

Sampling feature:

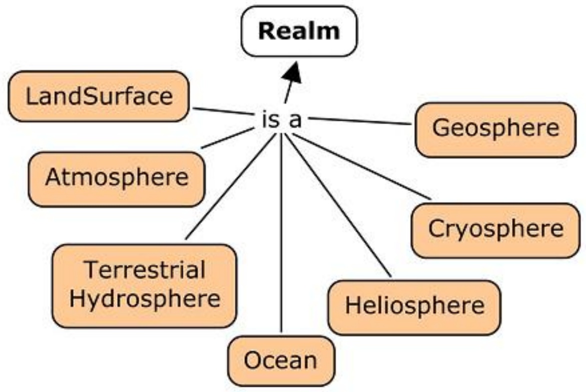
- Is a thing from which the actual measurement is taken
- Only exists because we have an Observation; i.e. it is only defined in order to perform an observation of the real world
- We don't have temporal SF_SamplingFeature because, for the time being, we cannot revisit time (contrary to space)
- It is not a device, but the actually focus of the observation
- example: scene is a proxy for the land cover
- example Biodiv : a citizen realizing an observation - the trajectory or exact location of the citizen making out the observation is the SamplingFeature -> not the citizen by itself

Constraint: if we have a coverage as result, the domain of coverage has to be inside the geometry of the SamplingFeature. This is only true for coverageObservations. If processing chains are merged, linking the results of a sequence of observations and processing steps, this constraint cannot be fulfilled, and coverageObservation should not be used.

In many cases, only a FoI is provided in the form of a samplingFeature; however, this is often missing a sampled feature. The provision of standardized high-level sampled features referring to the media or realm covered would be useful in gaining a better understanding of the context of the FoI. Examples for high-level sampledFeatures are:

- Atlantic
- Atmosphere
- Danube River

While some of these high-level sampledFeatures may be INSPIRE feature types in their own right. E.g. Atlantic is a Sea (from SR). Danube is presumably a SurfaceWater feature (Hydro-Physical waters), it was not possible to identify an existing vocabulary that covers this type of concept across domains. The closest candidate identified is the Sweet Realms Ontology engineered by NASA (*http://sweet.jpl.nasa.gov/2.1/*). The following diagram shows the first level of classes in the Sweet Realms Ontology:



While this ontology covers most areas required, the internal structure is not always satisfactory to domain experts. If it suffices for a specific domain, we recommend its use; if it is not sufficient, we recommend the definition of an application specific sampled feature for this purpose.

In addition to these very abstract sampledFeatures, we recommend the use of more direct sampledFeatures of direct relevance to the samplingFeature. As multiple features may be cascaded via the sampledFeature relation, a sampledFeature can in turn be a samplingFeature of a higher level sampledFeature.

Examples:

- Water SamplingFeature points to a specific River as Sampled Feature; the River can in turn be sampled from the Terrestrial Hydrophere
- Air Quality SamplingFeature points to RepresentativeGeometry describing the area directly affected by a pollutant as Sampled Feature, which can in turn be sampled from the atmosphere over the country

5.4 Procedure

Within O&M, the base definition of OM_Process is an empty class. For use within INSPIRE, the following 2 options have been determined:

- SensorML: Using SensorML has the advantage of maintaining compliance with the wider SWE scope. To bring this closer to INSPIRE, we propose a standardized mapping of agreed upon attributes to the SensorML model. It is important to keep in mind that SensorML was developed by a team whose main experience was remote sensing, so it may not be suitable for all domains. Much will depend on how SensorML V2.0 evolves.
- OM_INSPIRE_Process: defining a specific OM_INSPIRE_Process would allow for the lightweight provision of procedural information. The disadvantage is that it goes away from the base standard and thus must be optional to allow for re-use of domain standards

The following attributes have been proposed as the minimum specialization of OM_Process for use in INSPIRE:

- inspireId: Identifier
- documentation: reference [0..*]
- processParameter: reference [0..*]

The INSPIRE_OM_Process has been created for this purpose:

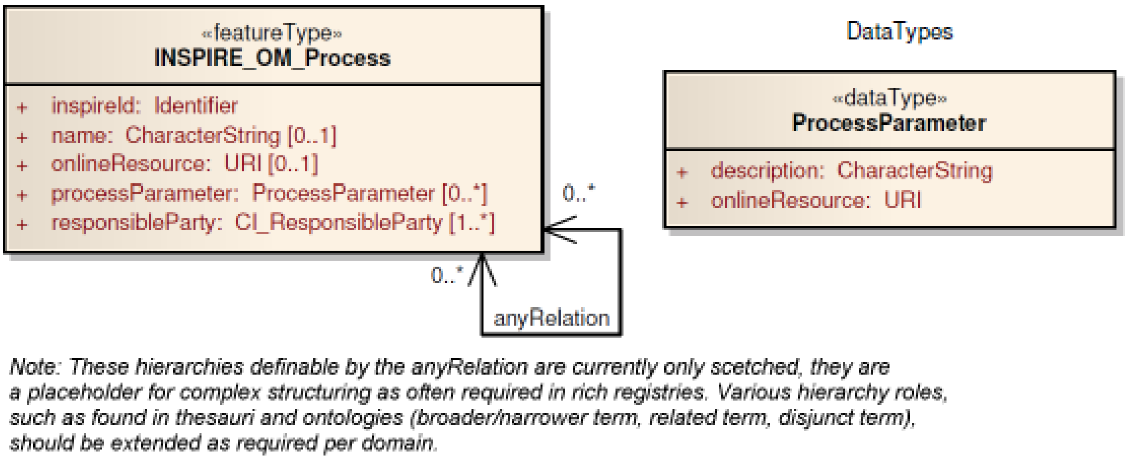


Figure 5: INSPIRE_OM_ Process Class

In addition, the following attribute has been proposed:

- responsibleParty: CI_ResponsibleParty [1..*]

5.4.1 Process Parameters

The Process Parameters define either instrumentation settings for a specific measurement or measurement series, or other information, sometimes stemming from other observations or measurements, that are of relevance to interpreting this observation. The Process Parameters show which types of additional information are to be expected within the observation, the actual values detailing this information are then stored in the parameter attribute of the observation. This parameter attribute should use the value defined in the Process Parameters as the key, the value can be a single field, but also a complex structure (question how to constrain the type of structure allowed). This allows for the definition of a re-usable process that can be further configured through the Process Parameters.

5.4.1.1. Types of Process Parameters expected

Very different types of information will be supplied via the Process Parameters. At present, we have identified the following categories:

- Results of related "observations": not necessarily available in the form of an observation, the information provided are the results of related observations relevant to the current observation. Examples of this are:
  - the water hardness of the river being sampled from
  - the width of the river at the measurement point
- Temporal information not currently covered by the OM_Observation. This is often necessary in forecasts and modeling. Examples of this are:
  - Analysis Time
  - Forecast period
- Instrument settings can be stored via process parameters to allow for the reuse of this process instance in various settings. Examples of this are:
  - sampling rate
  - minimum & maximum offset
- EnsembleMember can be specified as an easy way of providing data from aggregate sensors. In this case, the Process Parameters provide information in which exact sensor was used.

5.4.1.2. Referencing Process Parameters

For true interoperability, the re-use of Process Parameters stemming from an external source (vocabulary) would be necessary. Otherwise, it will often not be clear what type of information is to be stored here. Unfortunately, this will not always be possible as in most cases these vocabularies do not yet exist, and where they do, we cannot be sure that they will encompass all requirements.

The following example shows how the Process Parameters stored under the referenced procedure link to the observation parameters.

Note: The URIs have been shortened for readability, "inspire.jrc.ec.europa.eu" has been reduced to “inspire”

Inspire_OM_Process

- identifier: ukmo_global_model
- documentation: http://www.metoffice.gov.uk/research/modelling-systems/unified-model/weather-forecasting
- processParameter: http://inspire/processParameterValue.html#AnalysisTime
- processParameter: http://inspire/processParameterValue.html#AssimilationWindow

OM_Observation

- phenomenonTime: 00z 15/05/2011 - 00z 21/05/2011
- resultTime: 0420z 15/05/2011
- parameter: Name: http://inspire/processParameterValue.html#AnalysisTime, Value: 00z 15/05/2011
- parameter: Name: http://inspire/processParameterValue.html#AssimilationWindow , Value: 20z 14/05/2011 - 02z 15/05/2011

5.4.1.3. Constraints for Process Parameters

In order to assure consistency between the Process Parameters in the procedure and the parameters within the observation, constraints should be applied. At the same time, we do not wish to specialize the OM_Observation to maintain compatibility with thematic O&M based standards. Thus, we will not formally provide constraints within the OM_Observation, but recommend the provision of Schematron rules together with the schema in order to assure that all keys used in the observation parameters must also be listed under the process parameters

5.5 Observed Property

In the pure O&M model, the Phenomenon to be stored as the Observed Property is a simple phenomenon such as temperature or concentration; any further information detailing this phenomenon, such as the fact that the actual result is the daily mean temperature is considered part of the process. However, this greatly diverges from what domain users are expecting to find, and thus what they will be looking for. In order to bring the O&M Phenomenon model closer to what domain users expect, complex properties have been proposed.

While from an abstract modeling perspective observed properties should be as “pure” as possible, this often causes confusion in interaction with domain experts accustomed to thinking in their common terms such as

- Precipitation where type =”rain” vs. Precipitation where type =”snow”
- Hourly mean temperature vs. Daily mean temperature
- Radiance wavelength = 1000-2000 nm vs Radiance wavelength = 1050-2050 nm
- Abundance grasses vs. Abundance herbs

The following design pattern for the modeling of complex properties was presented:

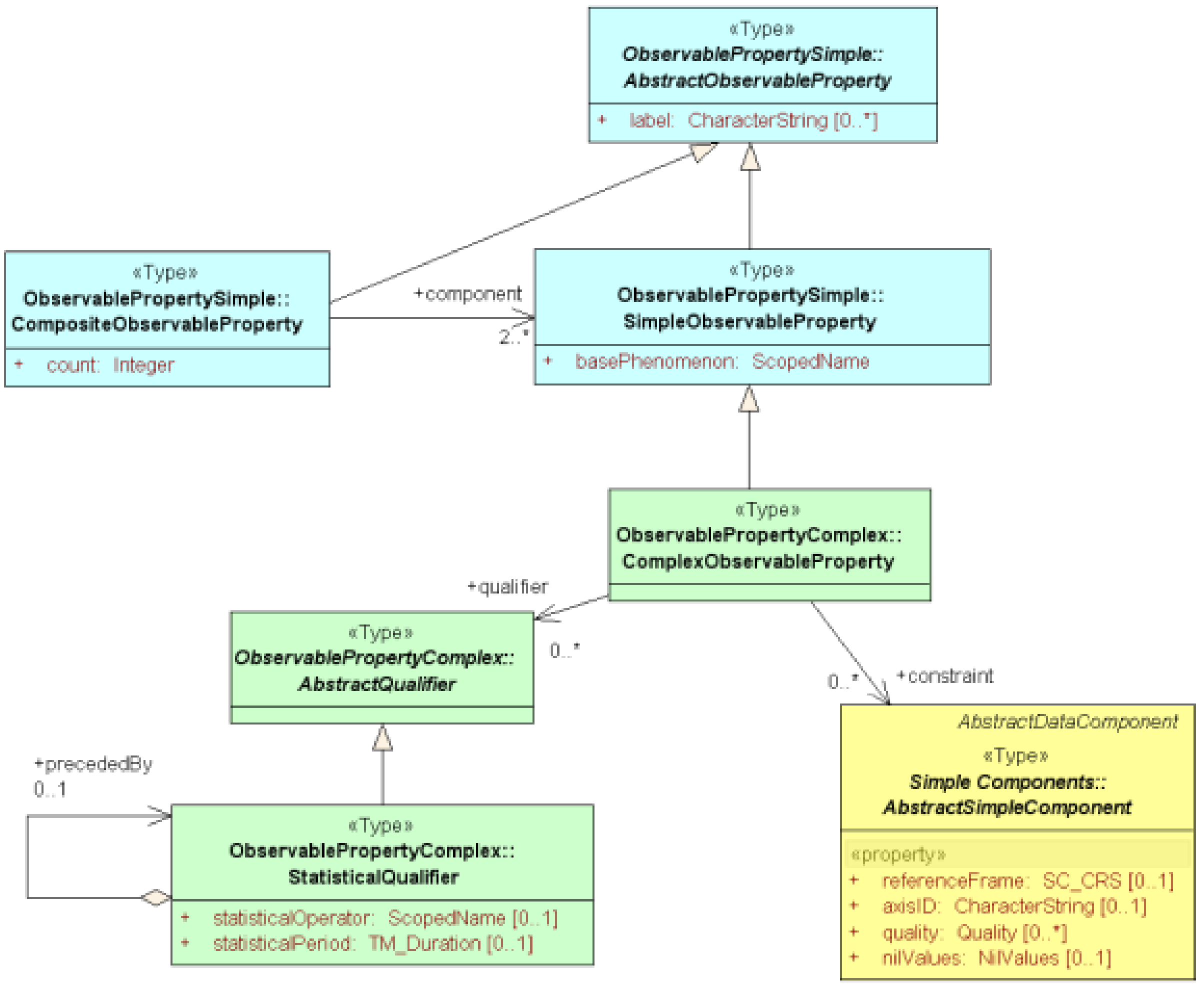


Figure 6: Complex Properties Model

The following examples serve to illustrate this model:

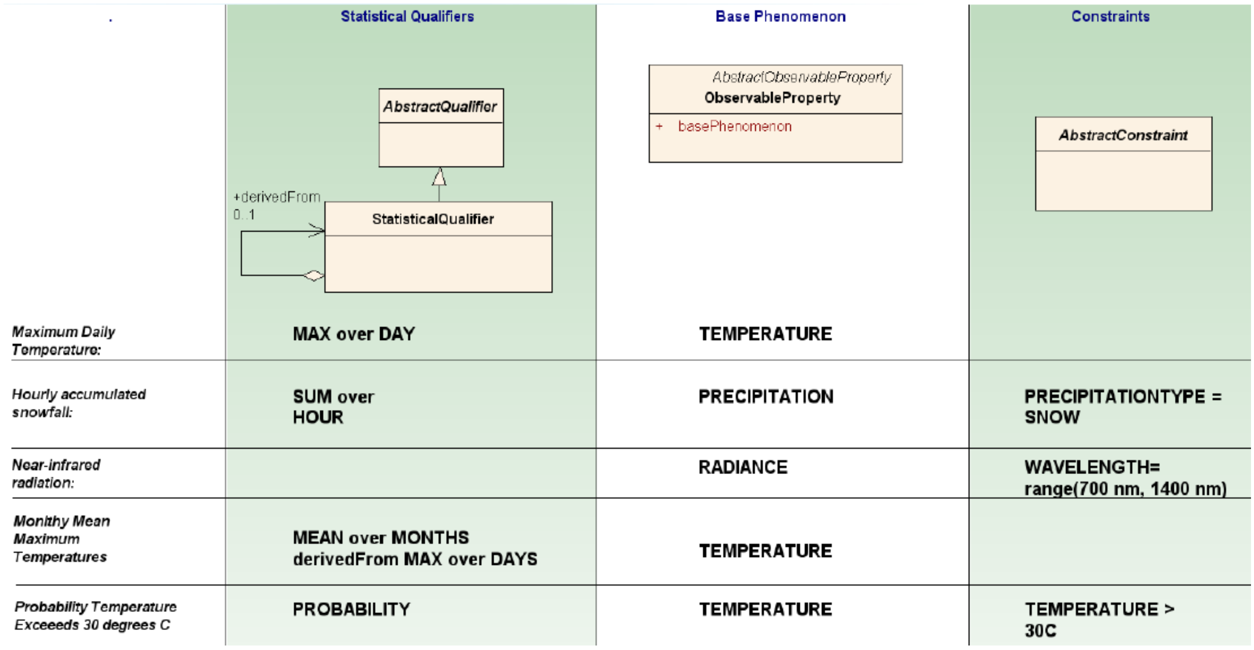


Figure 7: Examples of Complex Properties Model

5.6 Result

In many cases, it will be possible to provide the result data using either GML coverages or the result types provided in SWE Common. These allow for the standardized encoding of a wide range of simple and complex result types including spatial and temporal coverages.

The following examples from ISO/DIS 19156 illustrate different types of observations with various types of spatial sampling features. They are listed in order to provide help in understanding the different types of results that would be consistent with the spatial sampling feature type in these observations:

Observation class	Example	Spatial sampling feature	Coverage result
Profile	Expendable bathythermograph observation of seawater temperature	SF_SamplingCurve	• one-dimensional grid at fixed (x,y,t) within four-dimensional (x-y-z-t) CRS • grid axis aligned with CRS z-axis
ProfileTimeSeries	Radar wind profiler measurement	SF_SamplingCurve	• two-dimensional grid at fixed (x,y) within four-dimensional (x,y,z,t) CRS • grid axes aligned with CRS z- and t-axes
Trajectory	Pollutant concentration from mobile air quality sensor	SF_SamplingCurve	• one-dimensional grid within four-dimensional (x-y-z-t) CRS
Section	Vertical profiles of water current measurements taken by an acoustic doppler current profiler towed along a ship's track	SF_SamplingSurface	• two-dimensional grid within four-dimensional (x-y-z-t) CRS • one grid axis aligned with CRS z-axis
GridTimeSeries	Time-series of 3-D velocity field from a finite-difference seismic model	SF_SamplingSolid	• four-dimensional grid within four-dimensional (x-y-z-t) CRS

The result should contain validation information, either on general result level or in coverages this could also be on specific element level

5.6.1 Result Encoding

As to the encoding, various INSPIRE themes (GE, AC, …) have mentioned the requirement for the use of industry standards for result encoding (i.e. NetCDF, SEG-Y, LAS, WITSML). While it would be possible to directly reference resources encoded in these industry standards directly from the observation, it does not provide the user with the information required to determine if results of this type can be further processed on the available systems.

A type for referencing external coverage results shall be defined, based on the pattern provided within CSML. So in pseudo-xml you could encode the result as:

```
<Coverage>
    <domain>.. .encode domain inline e.g. x, y, z, t axes .. </domain>
    <rangeType> ... encode inline using swe:DataRecord </rangeType>
    <rangeSet> ... xlink to the file containing the values.. </rangeSet>
</Coverage>
```

5.6.2 Coverages as Results

In the Result/Coverage-centric view, the result (generally a coverage in this case) is the primary object of interest while the description of the observation process is just metadata of the result; coverages are "first class citizens" and observation is metadata about the coverage.

In this context, it is possible to envision design patterns that forgo provision of procedural metadata entirely as this in not of further relevance for the interpretation of the result. However, there are also cases where the procedural metadata can be of relevance to the further processing chain. In such cases, the coverage metadata attribute can be used to supply such information.

The following datatypes have been identified as suitable for the provision of observational metadata to coverages:

- MI_Metadata: acquisition source
- OM_Observation
- ObservingCapability

5.7 Referencing Observations from INSPIRE Features

The core of this document addresses those working in INSPIRE themes directly integrating O&M into their data specifications. However, there are also cases where, while observational data is not the main focus of this theme, the final resulting data provided under INSPIRE is based on observational data. In such cases, it would be valuable to reference the source observations used in the generation of the results provided. For such purposes, the following two design patterns for referencing external observation from INSPIRE features have been proposed and included in the GCM:

- Direct association
- Property contains association

Figure 8: Direct association of Observation

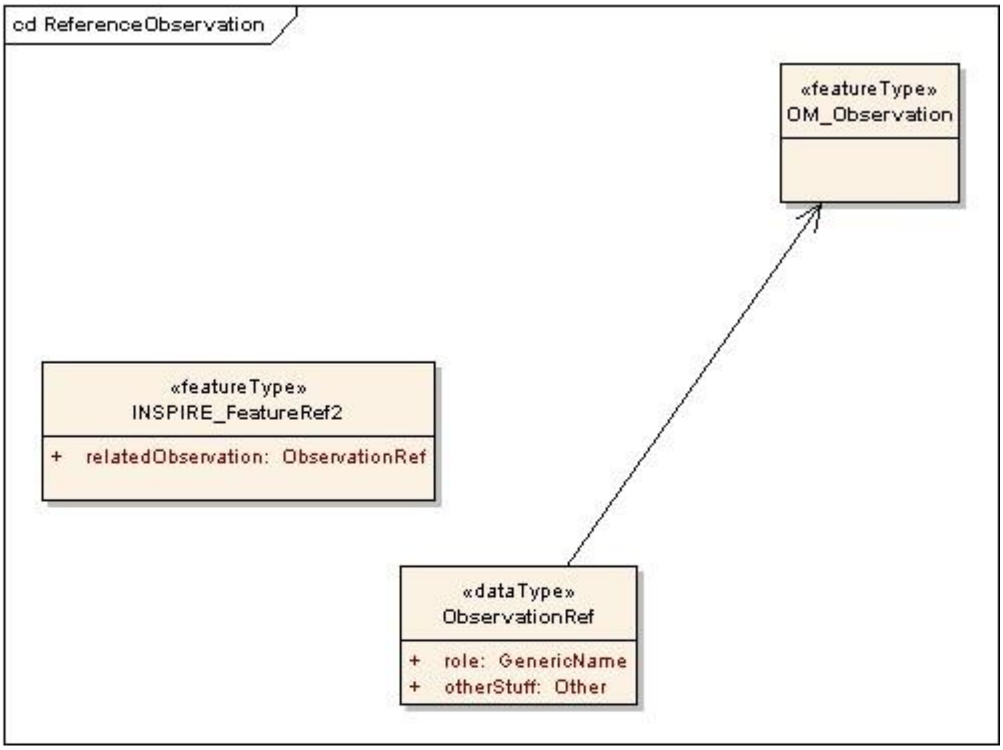


Figure 9: Reference Observation via Property

5.8 Facility

While there is no formal facility or station concept within the O&M standard, there is often a requirement to provide information on specialized locations used for the provision of multiple observations. While the O&M standard suggests the modelling of stations, which could be seen as facilities, as a form of SamplingPoint, this causes difficulties when one wishes to include remote sensing within the facility concept. It also doesn't provide support for mobile facilities, and thus cannot be used within the INSPIRE context.

Within INSPIRE, Environmental Monitoring Facilities are their own theme across thematic domains. At the same time, other INSPIRE Themes provide either primary data from Environmental Monitoring Facilities, or processes results based on this primary data. Thus, a facility concept is being defined to cover the requirements stemming from all these themes.

This wide range of facility concepts requires a model that allows for reuse of the facility concept in various concepts, supporting various requirements. These requirements range from very simple information on where the facility is located and what media is being assayed over more detailed information on exactly what phenomena are being monitored at this facility at which locations using which localities to cases where the full set of observational data obtained from the facility must be provided.

INSPIRE Environmental Monitoring Facilities can also be grouped together into Networks. As derived coverage results are often calculated from primary measurements stemming from an entire network, this type of observation should be linked to the Network class.

5.8.1 Observing Capabilitiy of a Facility

Within TWG EF, the facility type has been modeled with a cascadable relationship allowing for multiple facility parts to be nested under a higher level facility. This has been modeled in this manner as a station can have various parts or platforms, in turn containing further parts, which at the end contain an array of sensors or other measurement devices. At whatever level of this cascade, it must be possible to attach measurement data as well as a clear description of the measurement regime, which includes:

- Result Location (Where)
- Observed Property (What)
- Method (How)

A difficulty arises because there are cases where the measurement regime must be provided while the actual measurements will not be provided. For this purpose, we have defined the ObservingCapability Class, that serves to link the measurement regime to the facility class.

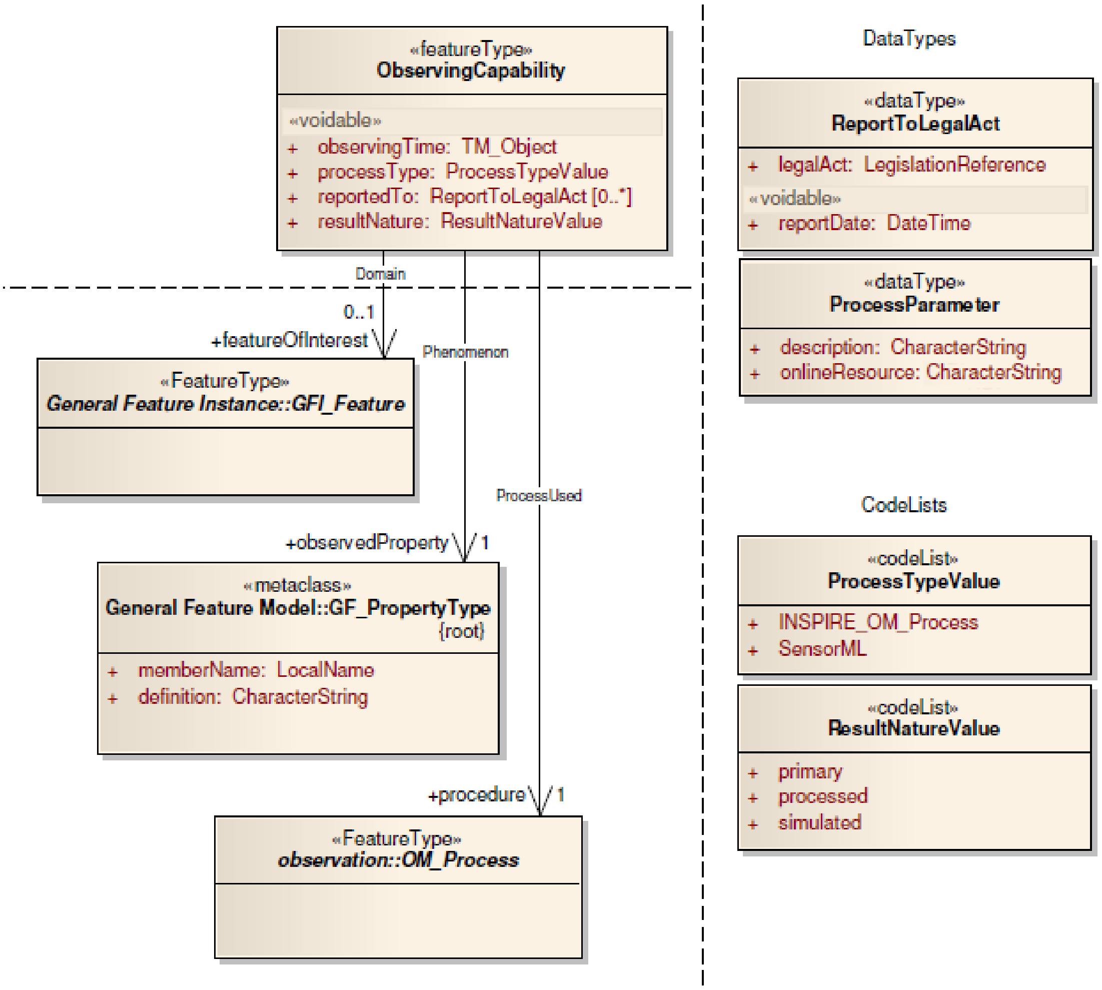


Figure 10: Observing Capability Class

ObservingCapability Class has been defined with the following attributes:

- observingTime: TM_Object – the time that this measurement regime is operational. This may be only the starting date for facilities that are still in operation, or a time interval for facilities that only provided data for a specific interval in time.
- processType: ProcessTypeValue – as we allow for encoding of the OM_Process either as an INSPIRE_OM_Process or via SensorML, this attribute shows the user what data type is to be expected under the process relation. Should other forms of process encoding be used, this should be added to the codelist.
- reportedTo: ReportToLegalAct [0..*] – in many cases, the reason that a station contains a certain measurement configuration is due to a legal obligation. In such cases, the legal act leading to the installation of this measurement configuration should be provided here.

In addition to these attributes, the ObservingCapability Class has the following associations:

- ProcessUsed
- Phenomenon
- Domain

The definition of these relations are the same as the corresponding ones from the OM_Observation.

The Facility and Network types defined for the Environmental Monitoring Facilities Theme provide the constraints to assure that observations may only be linked to a facility that has an ObservingCapability Class referencing the same Procedure, ObservedProperty and Feature-of-Interest as those referenced in the Observation itself.

We have yet to determine if we could use the Offering Class from SOS as a base class for the ObservingCapability.

5.8.2 Further Observation Related Facility Attributes

Pertaining to the question: 'what is the location of the Facility?' - 'what is the location of the Observation?' - 'what is the location of the ultimate FoI?', this can be decompose into the following three options for the result acquisition source:

- **in situ**: the the sampling_feature is co-located with the ultimate FOI (i.e. the sampledFeature). the measurement process is performed at this location
- **ex situ**: the sampling_feature is a specimen taken from the ultimate FOI (i.e. the sampledFeature), the measurement process is performed at a different location
- **remote**: the samping_feature is often the ultimate FOI (i.e. the sampledFeature), the measurement process is performed at a different location (but no sample taken). This also be used for simulations.

A further question that comes up is the nature of the result. While classical observational data tends to be primary measurement or observational data, O&M is also well suited to the provision of a highly processed or aggregated nature; this leads to a differentiation of the result nature into the following three categories:

- **Primary:** The result provided with the observation is the direct result of an estimate of a property on the feature-of-interest. No further processing has been performed. Processing may have taken place, but only in the sense of the measurement methodology itself, i.e. converting the millivolt returned from the sensor to the concentration of a substance.
- **Processed:** The result provided, while usually based on primary measurements, has been substantially processed. This processing can be of diverse natures, in some situations complex aggregates are provided, in other situations, the existing values are interpolated to a continuum.
- **Simulated:** The result provided, while usually based on primary measurements, is based on an interpretation model, and provides a simulation of past or future states of the media being analyzed. In this case, the existing values are usually extrapolated into the past or future.

The constellation of objects related to an observation, and the ensuing possible design patterns, can also be influenced by the fact that the facility performing the measurement is fixed or mobile. In a fixed facility, there is a strong coupling between the facility and the FoI; with a moving facility, while the FoI is often co-located with the current location of the facility, the locational information cannot be directly linked to the location of the facility. Thus, differentiation into fixed and mobile facilities must be made. It must also be possible to mark Facilities as fixed or mobile, as mobile facilities will not have a fixed location while fixed facilities can be expected to contain this.

5.9 Reuse of Constraints

In lieu of multiple derivation in INSPIRE, it would be valuable if it were possible to create packages of constraints and reuse these across themes. However, we have not been able to identify a model allowing us to do this. Thus, at present, try and reuse them as cleanly as possible. If further solutions are required, we will look for them in the future.

6 Metadata

Various elements describing the observation would be valuable for discovery purposes, and thus should be added to the Metadata requirements. This is a highly domain oriented question, closely related to architecture issues (see OGC Water Information Services Concept Development Study Report; CSW ebRIM to harvest SOS service) Concepts that could be included in the metadata are:

- overarching EF info (Facility, Network, MonitoringProgram),
- Observed property,
- Specific measurement method,
- dateTime info,
- …

Which concepts to finally include as well as where should these be mapped to within MD_Metadata shall be determined after the Version 2 Testing phase.

7 Provision of O&M encoded data

7.1 Services for the Provision of O&M Encoded Data

While it is possible to serve the various O&M related classes via a WFS or WCS, this is not the most comfortable method of accessing this data. We recommend the inclusion of the Sensor Observation Service (SOS 2.0) into the Network Services to be used for download services.

7.2 Registers/Registries

The requirement for various types of Registers/Registries/Codelists is very strong in the O&M area. These registers will usually need to be extendible. An additional challenge is the requirement for various types of structured registers, i.e. hierarchies and cross links such as found in thesauri or taxonomies. While we are aware of the fact that Registers/Registries/Codelists will also be required within other areas of INSPIRE, we wish to stress the fact that this is a very strong requirement for the clear provision of re-usable observational data.

Annex A - Mapping to O&M Classes

For the mapping of standardised concepts to existing classes, there are no provisions within UML. We have found it most effective to provide this information in the form of a mapping table listing the individual concepts along with their mapping to an attribute within the existing classes. The following template is recommended for this purpose:

Name of element	
Meaning of element	
Comments	
Proposed position within SWE data model	
X-Path within SWE data model	
XML example	

The following shows an example of this table filled out for the Network Name within Air Quality Monitoring:

Name of AQ element	name
Meaning of AQ element	Name of network
Comments	The full official name of the Air Quality Monitoring Network should be provided here
Proposed position within SWE data model	Should mapped to Procedure (system type)
X-Path within SWE data model	/sml:SensorML/sml:member/sml:System/sml:contact/sml:ContactList/sml:member/sml:ResponsibleParty/sml:organizationName
XML example	<sml:ResponsibleParty> <sml:organizationName>organizationName</sml:organizationName> <sml:contactInfo> <sml:address> <sml:country>countryCode</sml:country> <sml:electronicMailAddress>contact</sml:electronicMailAddress> </sml:address> <sml:onlineResource xlink:href="onlineResource"/> </sml:contactInfo> </sml:ResponsibleParty>