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Observation and Sampling of a Smiley Face

Observations, Measurements and Samples 101

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1. Introduction

This OGC document provides an overview of the OGC/ISO Observations, Measurements, and Samples (OMS) standard (ISO 19156:2023)[1][2]. The core example is abstracted from the currently described OMS use cases, often pertaining to measurements on specific media. To illustrate the applicability of OMS, the example of determining the color of a smiley face sticker is used. This is in order to avoid bias by focusing on a specific domain. The example covers all concepts defined within the OMS Standard, showing all options for both Observation and Sampling representation.

The same mechanisms utilized here to define the core example can be applied to a wide range of topics such as:

- Ozone concentration of the air at a point
- River flow at a given hydro station
- Nitrate concentration of a water sample
    - Various statistics on the concentration over time, e.g. mean, min, max, percentiles
- Consistency of a soil sample
- Temperature of a room
- State of a traffic light
- Population density in a NUTS region
- Gender distribution within the districts of a city

In the final section of this document, real-world examples of the implementation and use of the OMS Standard are provided.

2. Symbology

Within this document, a simplified representation of UML object diagrams is utilized. In order to avoid overloading the diagrams with text, a few conventions are defined.

- Classes are represented by rectangular forms, literals by ovals.

[1] https://www.ogc.org/standards/om/

[2] https://www.iso.org/standard/82463.html

- The specific class represented is indicated by color, as shown in the legends in Figure 1 - Figure 3 below.

- Representative text is displayed within the form.

While color coding can cause issues for the colorblind, the advantages for the color-sighted outweigh this issue. In order to enable the colorblind to follow, the legend includes the text used in the main diagrams.

The full UML of the OMS model[3] is available from the ISO cloud[4].

2.1 Classes and Objects

In the simplified UML object diagram representation, all objects are depicted as rectangles. The legend below shows the color scheme used to differentiate between the classes of the OMS model in all the Figures of this document. For example, medium blue rectangles represent instances (objects) of the OMS Observation class. The ObservationCharacteristics and ObservingCapabilities are rendered in darker shades of blue, as these concepts are very closely related to the Observation concept.

For the Observation part of the OMS model, the following legend applies.

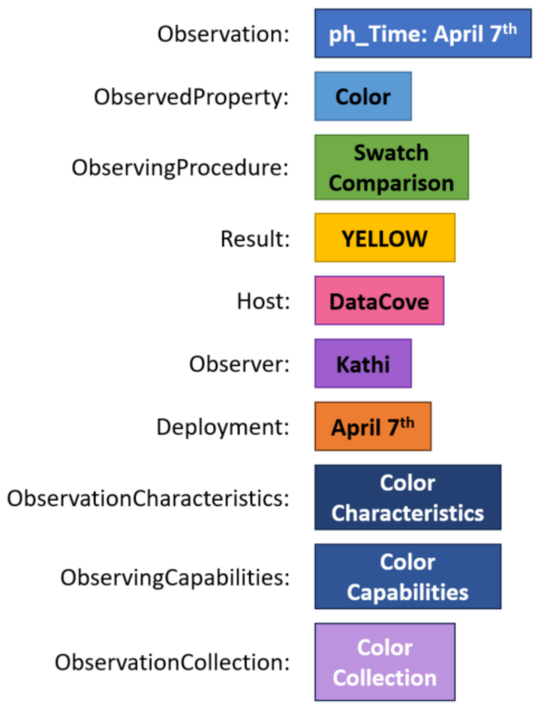

Figure 1: Legend Observation

[3] https://iso.sparxcloud.com/index.php?m=1&o=4542A7F6-7BC7-4218-8D91-4B799164C14A

[4] https://iso.sparxcloud.com/

For the Sampling part of the OMS model, the following legend applies.

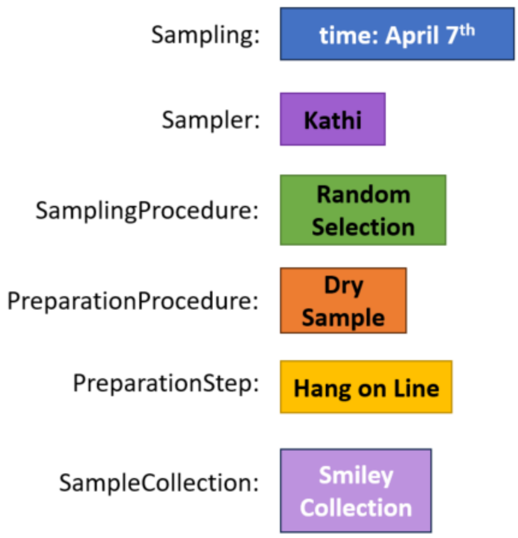

Figure 2: Legend Sampling

2.2 Literals

In our simplified UML object diagram representation, all literals (e.g. simple strings) are depicted as ovals, as shown in the figure below.

Figure 3: Legend Literals

3. Observation of a Smiley Face

3.1 Simplest form – class with attributes

The simplest form of an Observation is an attribute that carries information on an object (feature). As shown in both Figure 4 and Box 1, the color and expression of a smiley face sticker is being observed. In the simplest form, the object has the two attributes `Color` and `Expression`, with the values YELLOW and HAPPY respectively.

Figure 4: Smiley with simple attributes

```
{
      "color": "Yellow",
      "expression": "Happy"
}
```

Box 1: JSON representation of Smiley with simple attributes.

This example works well as long as no additional information needs to be provided together with the attribute. However, if additional qualifiers to the attribute, such as the `ObservingProcedure` used to ascertain the value, are required, this approach becomes difficult. We cannot provide this procedural information with the simple attribute approach. This leads to the `ObservingProcedure` information floating next to the attribute information, as shown in Figure 5.

Figure 5: Smiley with floating Procedure

3.2 Basic Observation

This is where the OMS `Observation` comes into play. The Observation class is designed to collect all relevant information on how an observation was performed. In the OMS model, the Procedure (OMS `ObservingProcedure` class) is linked to the observation class. This provides necessary context to the resulting value. Figure 6 shows how `Observation` can be used to bring the `ObservingProcedure` from above into context (in our example 'Swatch Comparison').

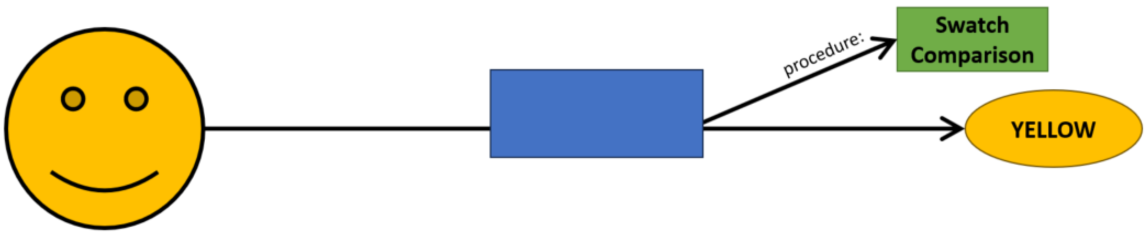

Figure 6: Basic Observation Take 1

However, now that `Observation` has been introduced, the information on what exactly the attribute represents, in this example 'Color', has been lost. Thus, an additional association `ObservedProperty` must be added to the `Observation` to convey this information, as shown in Figure 7.

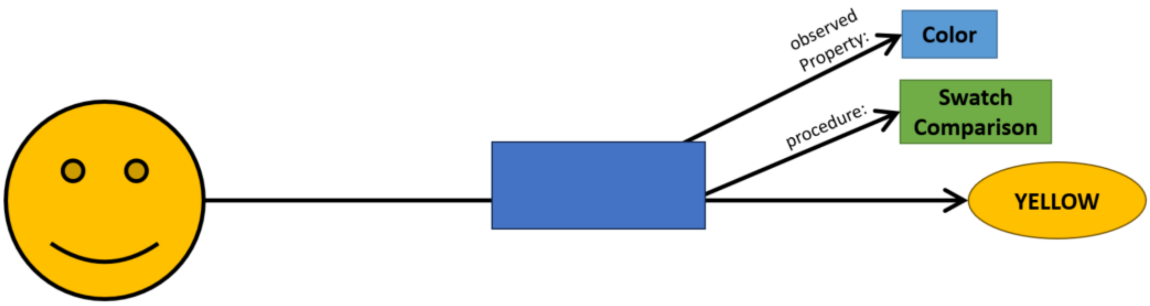

Figure 7: Basic Observation Take 2

In order to complete the picture of the basic `Observation`, some additional information is required. The association to the `Result`, in this case 'YELLOW', gets the association role `result`, while the association to the Smiley Face, the object of the Observation, gets the association role `featureOfInterest` to identify what feature the observation is actually about, as shown in Figure 8. This is in line with the Observation concept from O&M.

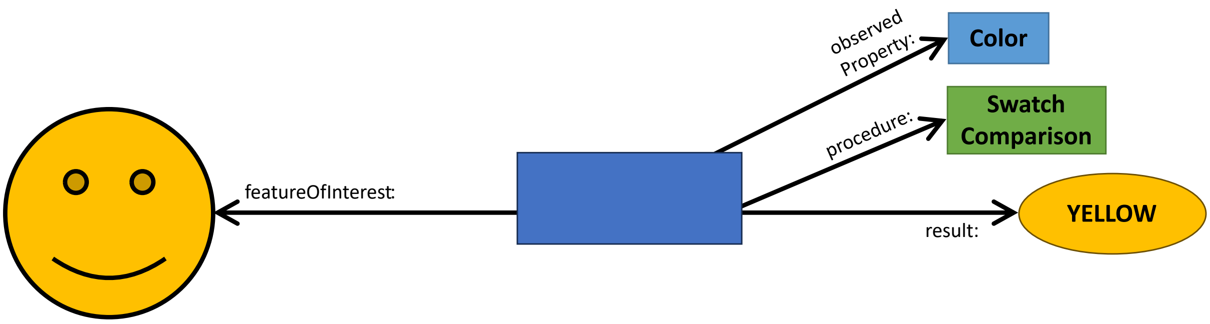

Figure 8: Complete basic Observation

3.3 Observer and Host

Within OMS, some additional concepts are introduced. The first is the `Observer`, the entity that made the `Observation`. This can be a sensor or alternatively a human being as shown in Figure 9.

The addition of the `Observer` solves the old question under O&M of what the Procedure describes: The process performed (e.g., the steps laid down by an ISO analysis standard) or the explicit device performing the measurement (e.g. a specific sensor). The `Observer` describes the explicit device performing the observation, while the `Procedure` describes the process performed to gain a result.

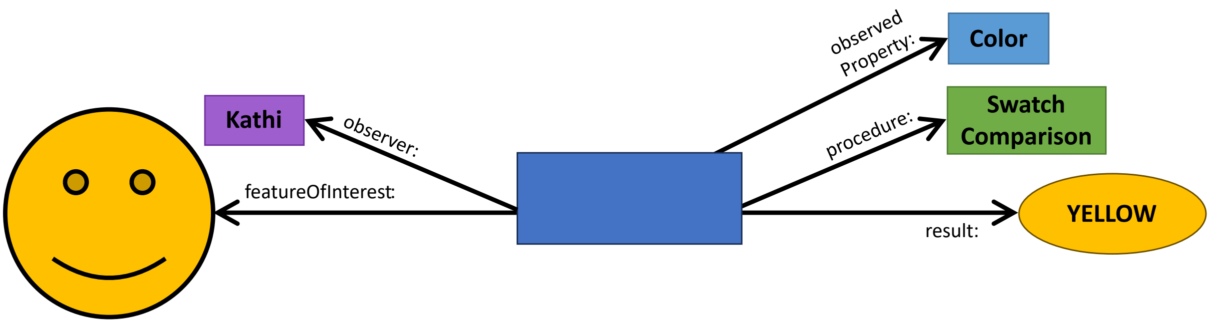

Figure 9: Observation with Observer

In many cases, there is some sort of facility hosting one or more sensors at a specific location. Similarly, when humans perform observations, this is often done in the context of a specific survey or regular monitoring. To provide information on such a facility or similar organizational grouping of `Observers`, the OMS concept of `Host` is introduced as shown in Figure 10.

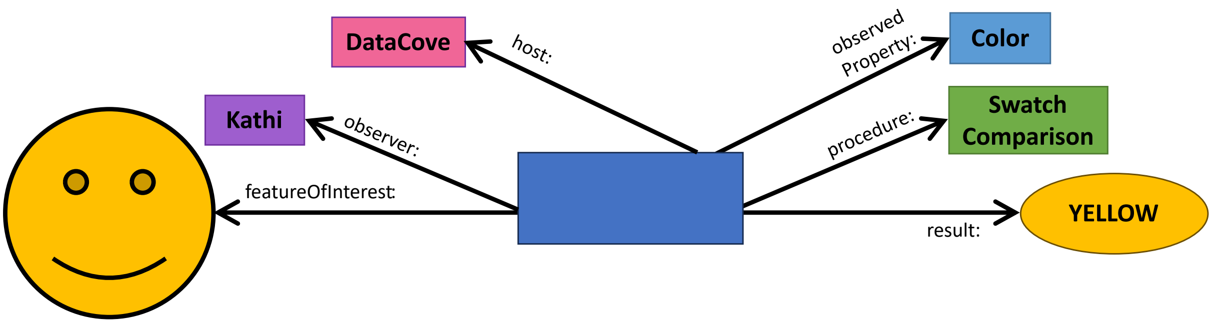

Figure 10: Observation with added Host

A further addition to the OMS Standard is the `Deployment` Class, providing information on when which `Observer` has been deployed at which `Host`, including information relevant to the deployment such as the date and time of deployment. In our example we describe how on April 7, 'Kathi', who is working at 'Datacove', has observed a yellow smiley sticker. The determination of the color is based on a swatch comparison, as shown in Figure 11.

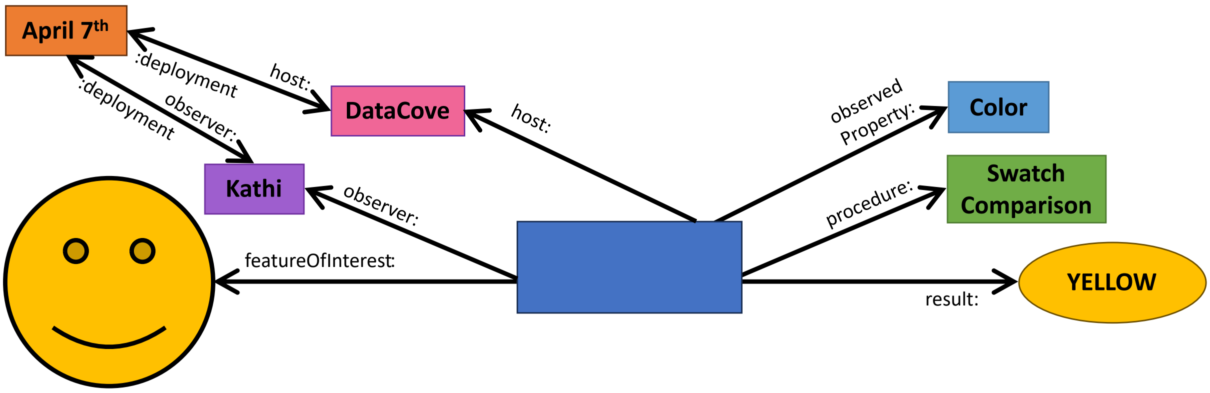

Figure 11: Observation with Deployment

3.4 Temporal aspects

As shown in Figure 12, a further essential qualification enabled by the OMS `Observation` pertains to timeFigure 12. The following times can be provided as attributes within an `Observation`.

- `phenomenonTime`: The time for which the `result` applies to the characteristic of the `FeatureOfInterest` being observed.
- `resultTime`: The instant of time when the result of the `Observation` became available.
- `validTime`: The time interval during which the `result` is assumed to be applicable for use.

All these temporal attributes can be time instants or time periods, as required by the nature of the Observation. Depending on the use case, the times can be very exact (e.g., at a specific second), alternatively more general (e.g. referring to a specific calendar day for daily values).

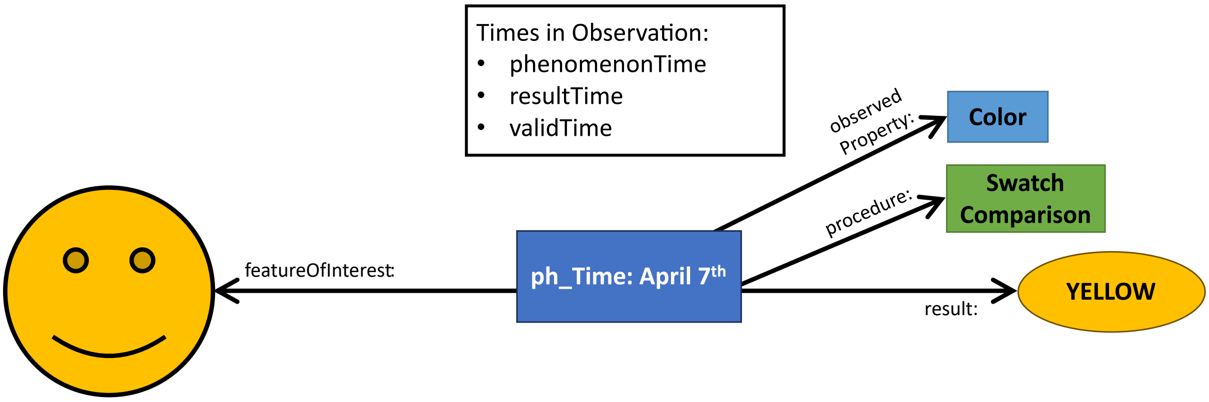

Figure 12: Observation with time

Note: `phenomenonTime` *has been shortened to "*`ph_Time`*" in the diagram for brevity*

Note: as times are attributes of `Observation`*, they are shown within the* `Observation` *box*

Note: `Sensor`*,* `Deployment` *and* `Observer` *have been removed in this diagram for simplicity*

3.5 Feature-of-Interest types

A final addition to the OMS `Observation` pertains to specializations of the `featureOfInterest`. This has been subtyped to:

- `proximateFeatureOfInterest`: The entity that is directly of interest in the act of observing; and
- `ultimateFeatureOfInterest`: The entity that is ultimately of interest in the act of observing.

In the example, the `ProximateFeatureOfInterest` is the Smiley Face Sticker. The `UltimateFeatureOfInterest` could be a wider population of Smiley Face Stickers. The specific Smiley Face Sticker actually being observed could have been selected via some random (or statistical) sampling approach as shown in Figure 13. More details on the actual sampling approach selected is described in chapter 4 Sampling.

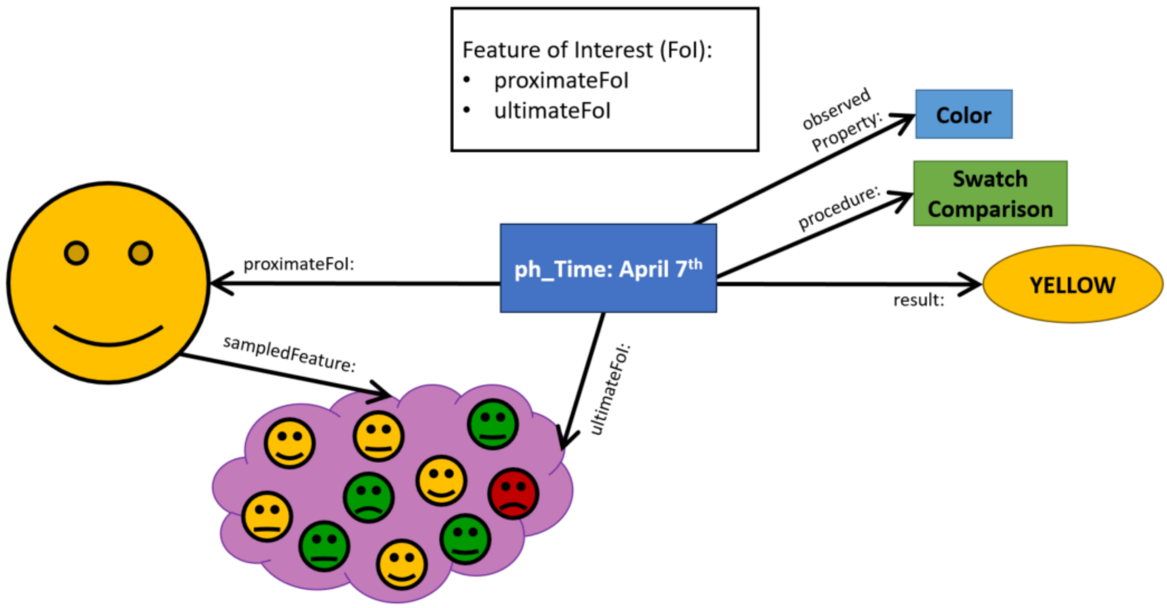

Figure 13: Observation with proximate- and ultimateFeatureOfInterest

3.6 Observation Characteristics

There are many cases where it is useful to have a class with all the characteristics of an observation, but without any of the constraints. For this purpose, OMS introduced the `ObservationCharacteristics` class (Figure 14). The information provided by the `ObservationCharacteristics` is the same information as used in our example describing `Observations`.

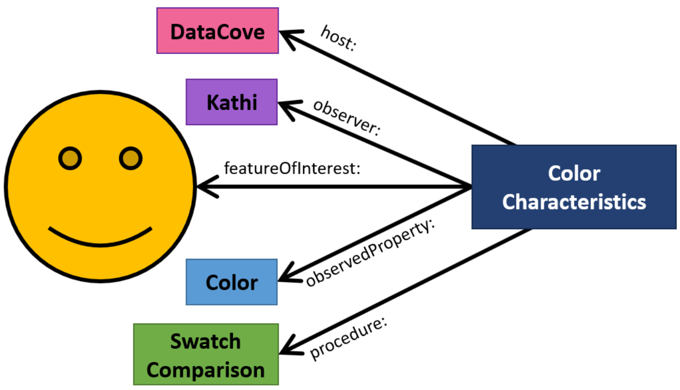

Figure 14: Observation Characteristics

This class is utilized in various contexts within OMS, as shown in the following sections.

3.7 Observation Collection

As it is often useful to be able to group observational data into collections, OMS provides the `ObservationCollection` class. In its simplest form, the `ObservationCollection` is a simple grab-bag collection, containing whatever `Observation`(s) it makes sense to collect. (Figure 15).

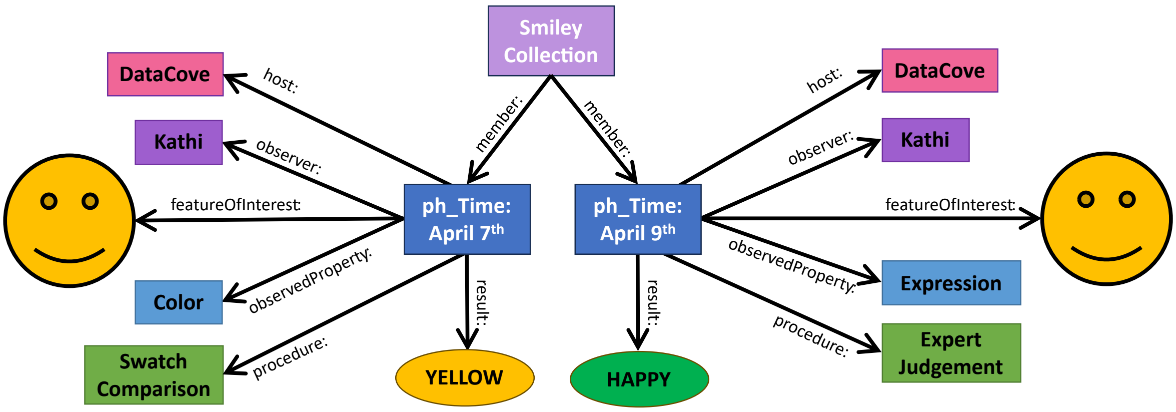

Figure 15: Simple Observation Collection

However, in many cases, the `Observation`(s) contained within an `ObservationCollection` have certain commonalities, such as all `Observation`(s) pertain to a specific `FeatureOfInterest`, are performed by the same `Observer` at the same `Host`. This is where the `ObservationCharacteristics` comes into play. Each `ObservationCollection` can link to one `ObservationCharacteristics` via the `memberCharacteristics` association. In Figure 16 we see a collection where all `Observations` contained have our Smiley Face Sticker as `FeatureOfInterest`, 'DataCove' as the `Host` and 'Kathi' as the `Observer`, described by the `ObservationCharacteristics` Smiley Characteristics. For characteristics not provided within the `ObservationCharacteristics` of the `ObservationCollection`, the member `Observations` can specify any values. In our example, one `Observation` has the `ObservedProperty` 'Color', the other has the `ObservedProperty` 'Expression'.

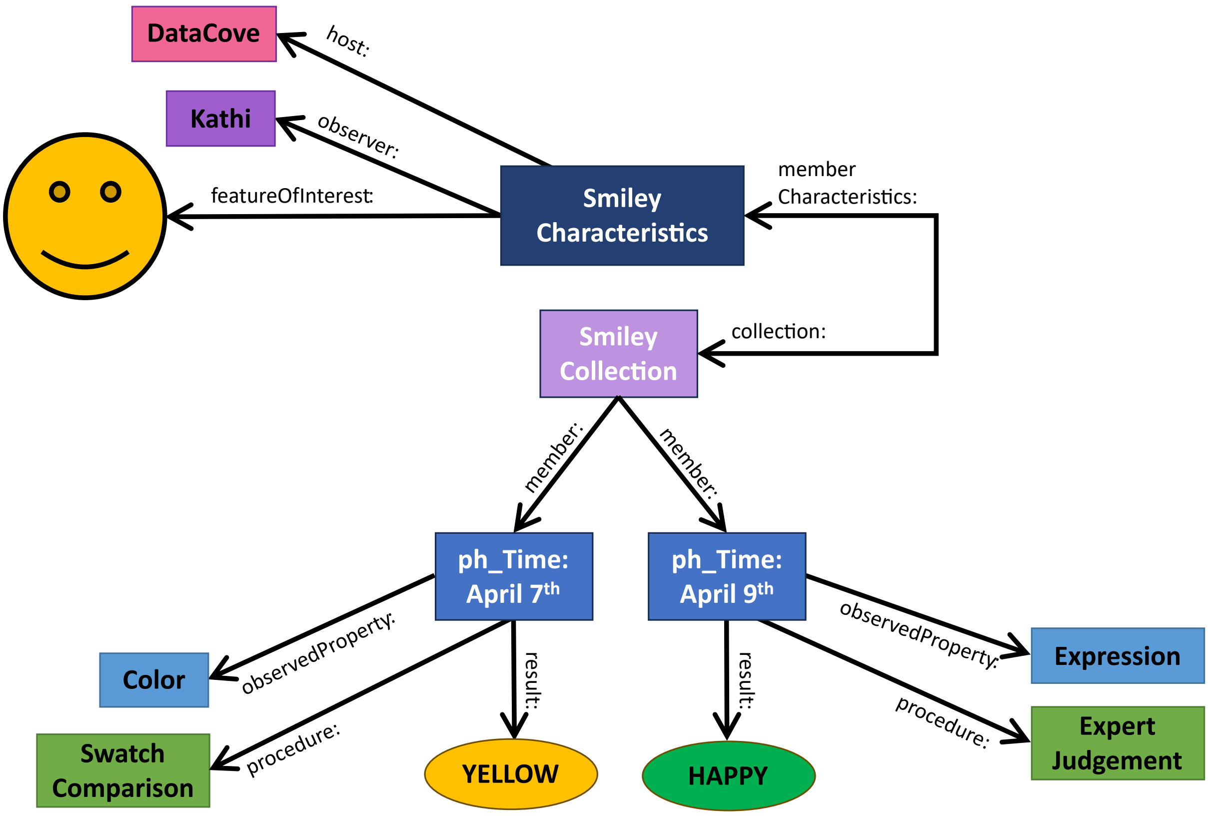

Figure 16: Observation Collection with Characteristics

In some cases, all `Observation`(s) within a collection share all `ObservationCharacteristics`. All `Observation`(s) shown in Figure 16 pertain not just to the same `FeatureOfInterest`, `Observer` and `Host`, but also share `ObservedProperty` and `ObservingProcedure`. This information is conveyed by the `ObservationCharacteristics` (renamed `Color Characteristics` as it indicates that all `Observations` contained have the `ObservedProperty` 'Color'). Therefore, individual `Observation`(s) do not need to provide this information.

In such cases, the `Observation`(s) can be reduced to a simple time and value. This is similar to our initial approach at the start of this example, but complemented with the relevant information at the `ObservationCollection` level. This is a valuable approach for the provision of time-series, as done in the OGC TimeseriesML 2.0 standard.

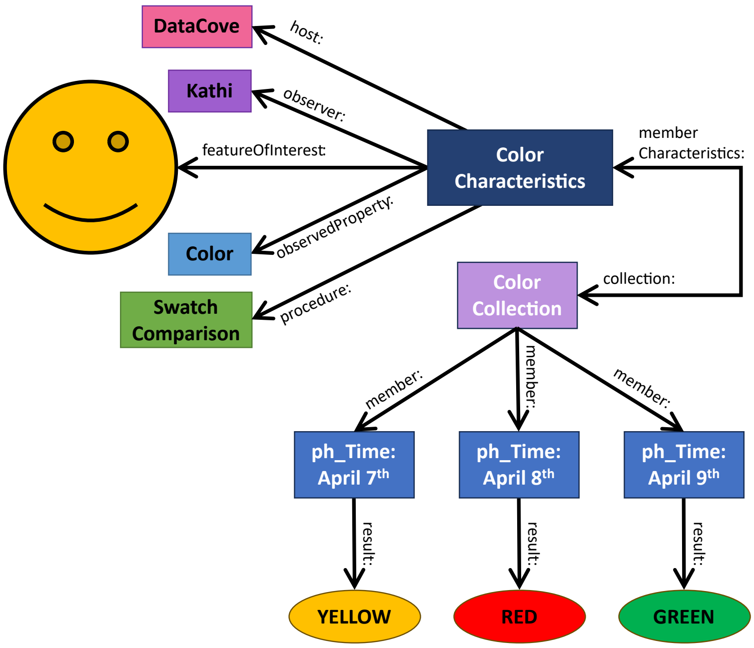

Figure 17: Observation Collection with homogeneous Characteristics

Please note that OMS is a conceptual model, implementations may vary in their interpretation. For example, OGC SensorThings API merges the OMS `ObservationCollection` and `ObservationCharacteristics` concepts to the `Datastream` class.

3.8 Observing Capability

The OMS `ObservationCharacteristics` are reused in a second context, the `ObservingCapabilities` class. This class can be used to indicate potential `Observation`(s) that could be performed at a specific `Host`. This class is often required in reporting contexts, where countries must indicate which environmental factors they monitor at what location with what methodology, without being obliged to provide the actual data collected. Figure 18 shows that the `Host` 'DataCove' has been set up with the necessary instrumentation (`Observer`) to determine the color (`ObservedProperty`) of the Smiley Face Sticker, using 'Swatch Comparison' (`Procedure`).

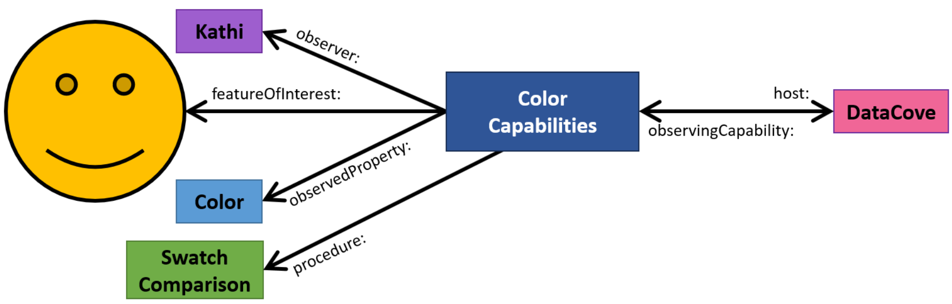

Figure 18: Host with ObservingCapability

4. Sampling

4.1 Sampled Feature

Understanding how the object serving as the feature of interest of an Observation has been selected is often essential to understanding the quality and robustness of data. The OMS Sample model is designed to represent all relevant aspects of both sample selection as well as preparation steps performed on the sample. This model is similar to the Observation model described in the previous section, relying on similar concepts such as the 'feature of interest'. The sampling act takes the central role under Sampling, similar to the act of observation being the core of Observation.

Continuing with the example, the next step is to investigate how the Smiley Face Sticker under consideration has been selected from the wider population of Smiley Face Stickers, as well as preparation steps taken on this Smiley Face Sticker before performing the Observation as described above. The Smiley Face Sticker and population of Smiley Face Stickers are associated with the `sampledFeature` relationship as shown in Figure 19.

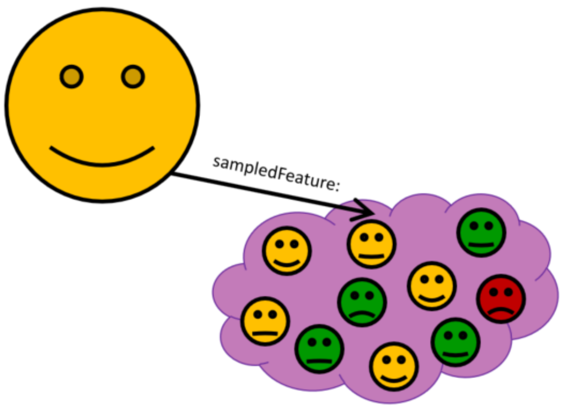

Figure 19: Sample with Sampled Feature

4.2 Sampling

In order to provide more explicit information on the sampling act, a `Sampling` object is added as shown in Figure 20. `Sampling` provides information on the time of the sampling act, as well as links to the `Sample`(s) created by this sampling act (via the `sample` association) and the source of the `Sample`(s) (indicated as `featureOfInterest`). The `sampledFeature` association can be seen as a shorthand notation of the more complex `Sampling` approach.

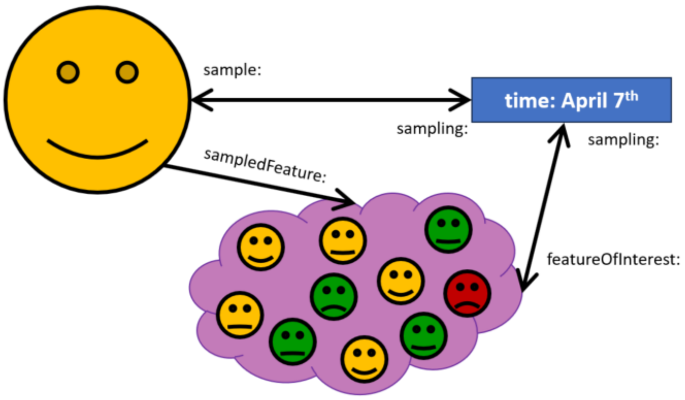

Figure 20: Sample with added Sampling

The `Sampling` provides information on both the `SamplingProcedure` utilized in the sampling act as well as the `Sampler`. The `Sampler` is the device or entity (including humans) that is used by or implements said `SamplingProcedure` to create or transform one or more `Sample`(s).

In the example the `SamplingProcedure` ‘random selection’ is utilized by our `Sampler` ‘Kathi’ as shown in Figure 21.

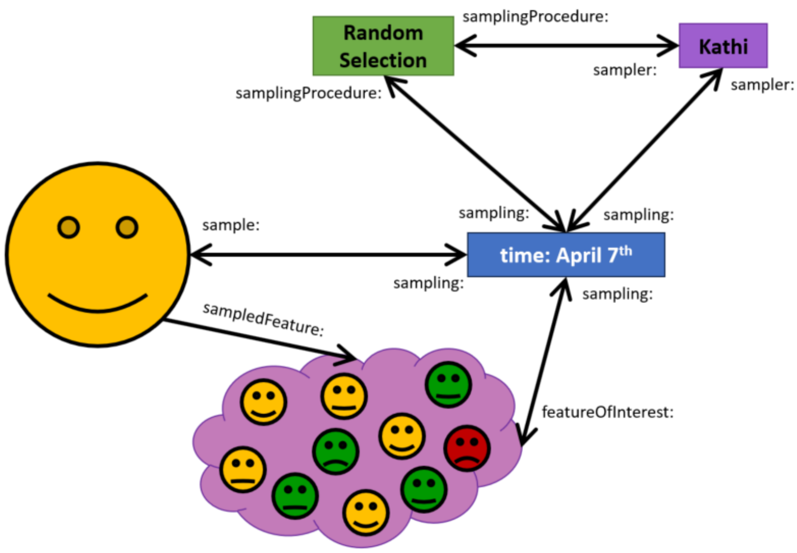

Figure 21: Sampling with added SamplingProcedure and Sampling

4.3 Sample Preparation

In many cases, some preparatory steps must be performed before an `Observation` can be performed on a `Sample`. In the example, it is important that the Smiley Face Sticker is dry before the color is determined, as a wet sticker may have a different color.

OMS provides the `PreparationStep` class to describe individual treatments to the `Sample` , whereby each `PreparationStep` can reference multiple `PreparationProcedure` that detail the procedures used in this step. In the example, the `PreparationStep` 'Dry Sample' implements the `PreparationProcedure` 'Hang on Line' (Figure 22).

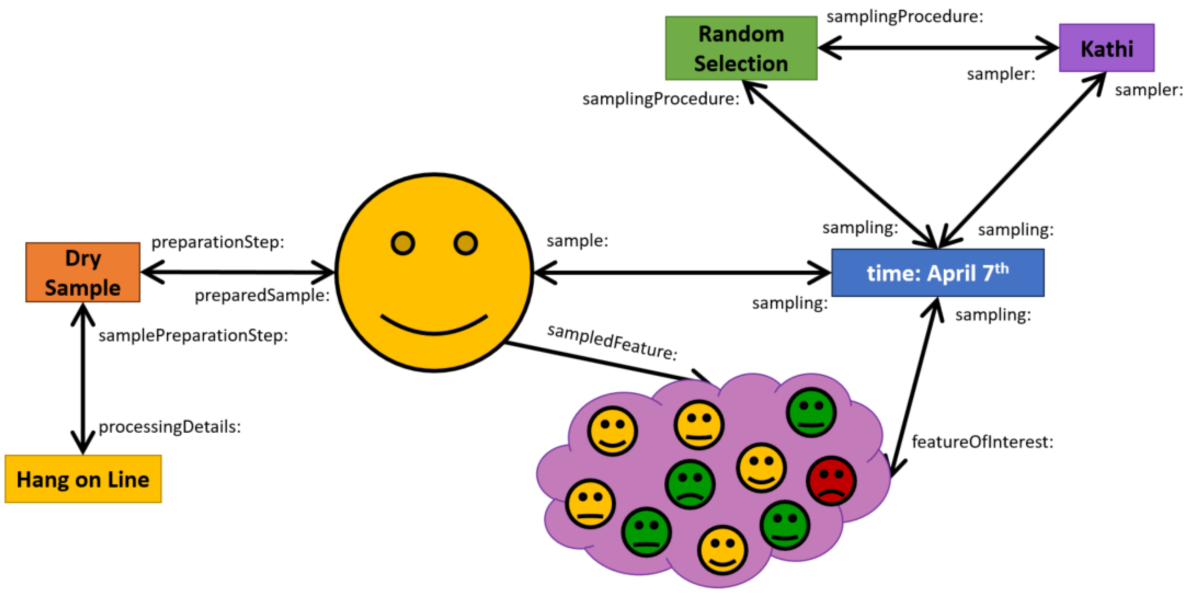

Figure 22: Sample with PreparationStep and PreparationProcedure

4.4 Sample Collection

Similar to the `ObservationCollection`, OMS also provides a `SampleCollection` class (Figure 23). As no further indication on the nature of the contained `Sample`(s) is provided, this class is far simpler than `ObservationCollection`.

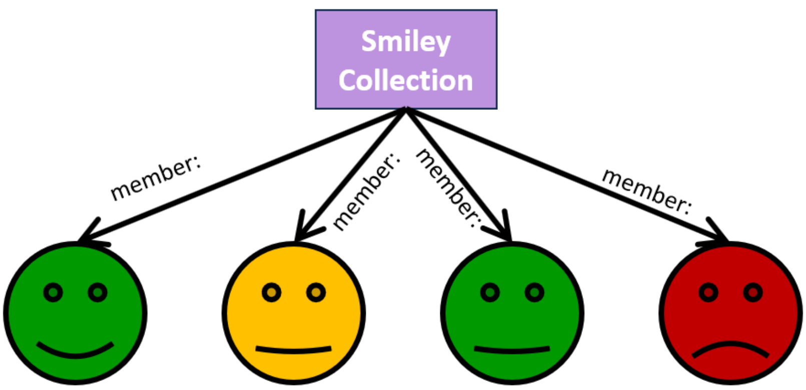

Figure 23: Sample Collection

5. Observations and Sampling applied to Environmental Media

5.1 Air Quality Observation Examples

5.1.1 Observation of Ozone Concentration at an Air Quality Station

Figure 24: Observation of Ozone Concentration at an Air Quality Station shows how the `ObservedProperty` 'Ozone Concentration' is determined at the air quality station 'STA.09.LIES' (the `Host`). As the exact location of the air intake is relevant to understanding the data provided, the `featureOfInterest` is modelled as the air bubble around the intake. It also indicates that this observation was performed by a sensor of type 'Horiba APNA 360' (the `Observer`), that was deployed at the air quality station from March 1st 1996 through March 1st 2019, and utilizes the `ObservingProcedure` 'Chemiluminescense'.

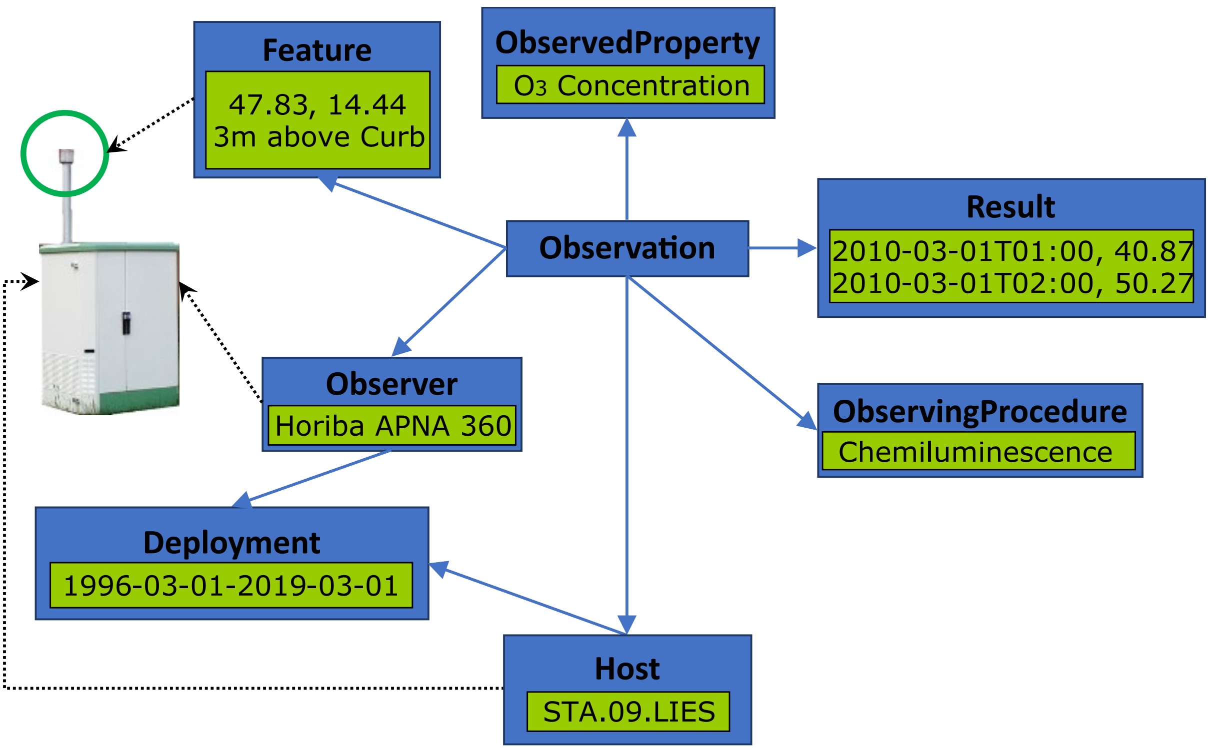

Figure 24: Observation of Ozone Concentration at an Air Quality Station

5.2 Biodiversity Observation Examples

5.2.1 Breast Height Diameter of a Tree

Figure 25: Breast Height Diameter of a Tree shows how the `ObservedProperty` 'Diameter at breast height' is determined on a specific Tree (the `featureOfInterest`), using the `ObservingProcedure` 'Measurement w/ DBH Clip', and utilizing a specific clip 'DBH Clip #23' as the `Observer`.

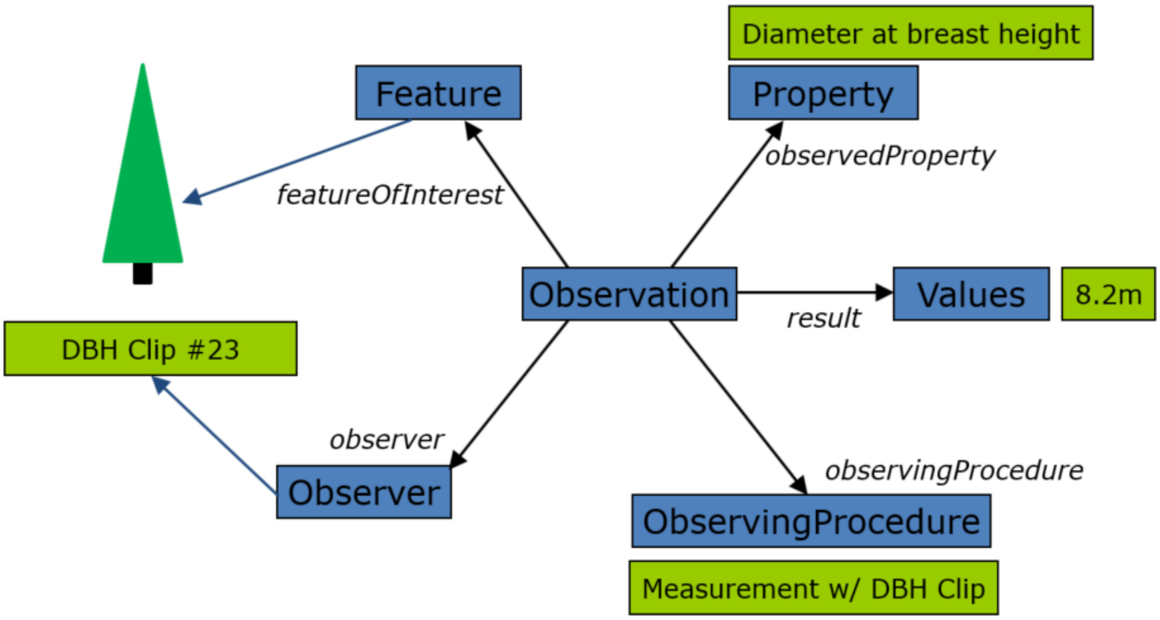

Figure 25: Breast Height Diameter of a Tree

5.3 Water Quality Observation Examples

In the water quality examples described in this section, we indicate which of the used classes were available under O&M, the previous version of the standard, and which classes were introduced under OMS.

5.3.1 Surface water *in situ* Temperature

In the example shown in Figure 26: Surface water in situ Temperature, additional information is provided, utilizing classes introduced under OMS. The `Host` is indicated, as well as the time during which the specified `Observer` was deployed (`Deployment`) at that `Host`. In addition, the `featureOfInterest` concept has been differentiated into `proximateFeatureOfInterest` and `ultimateFeatureOfInterest`, providing the sampling location and sampled stream respectively.

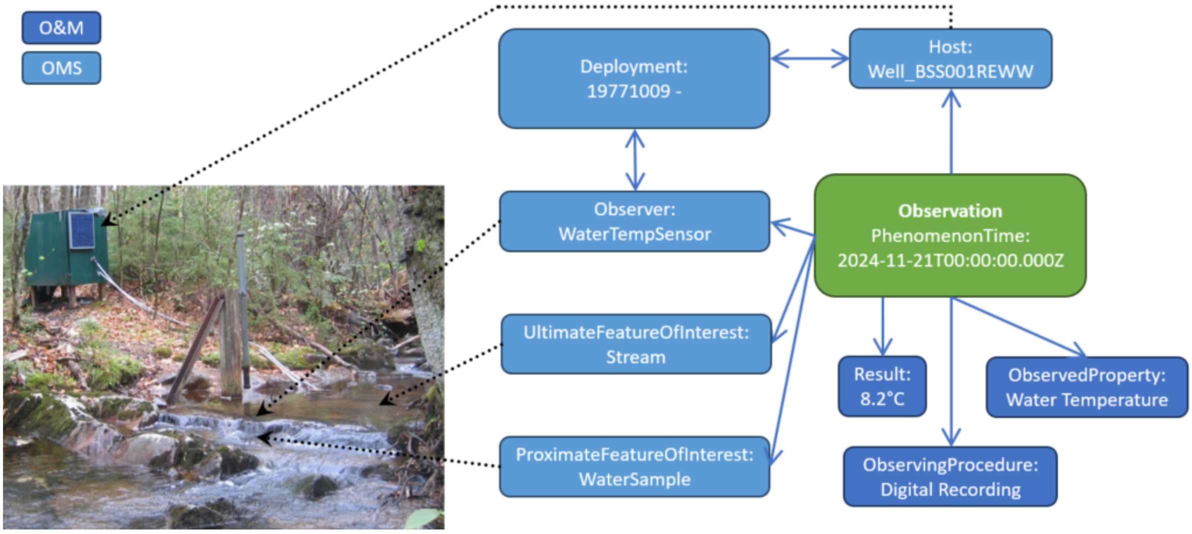

Figure 26: Surface water in situ Temperature

5.3.2 Ground Water ex situ Arsenic

In the example shown in Figure 27: Ground Water ex situ Arsenic - Observation, aspects of OMS Samples are integrated. The water `Sample` must be prepared before the Sample can be sent to a laboratory. The example shows a `PreparationStep` performing the 'Acid Stabilization' `PreparationProcedure` on the `Sample`.

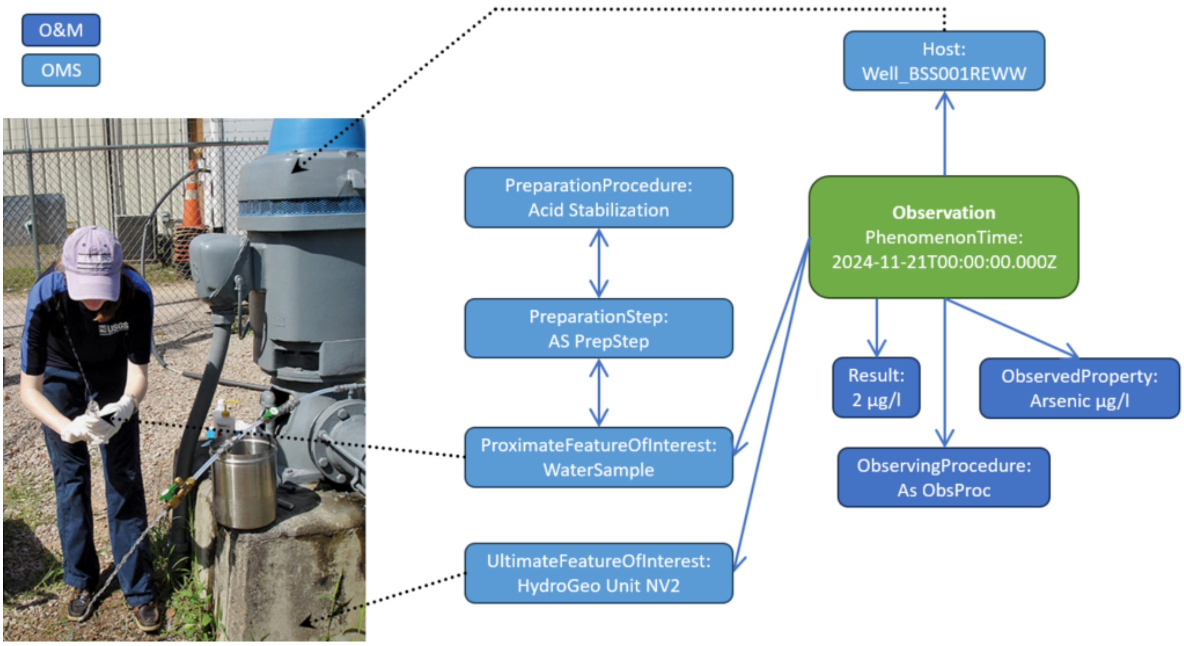

Figure 27: Ground Water ex situ Arsenic - Observation

In Figure 28: Ground Water ex situ Arsenic - Sampling, further sampling related aspects of this example are shown. In this example, two `Sampling` acts are documented. An initial

`Sample` is taken from the `featureOfInterest` 'Well_BSS001REWW' in a first `Sampling`, creating a raw `MaterialSample`. In a second `Sampling` act, this `Sample` is subsampled to create the specific `Sample` 'Arsenic Sample" and then prepared as described above.

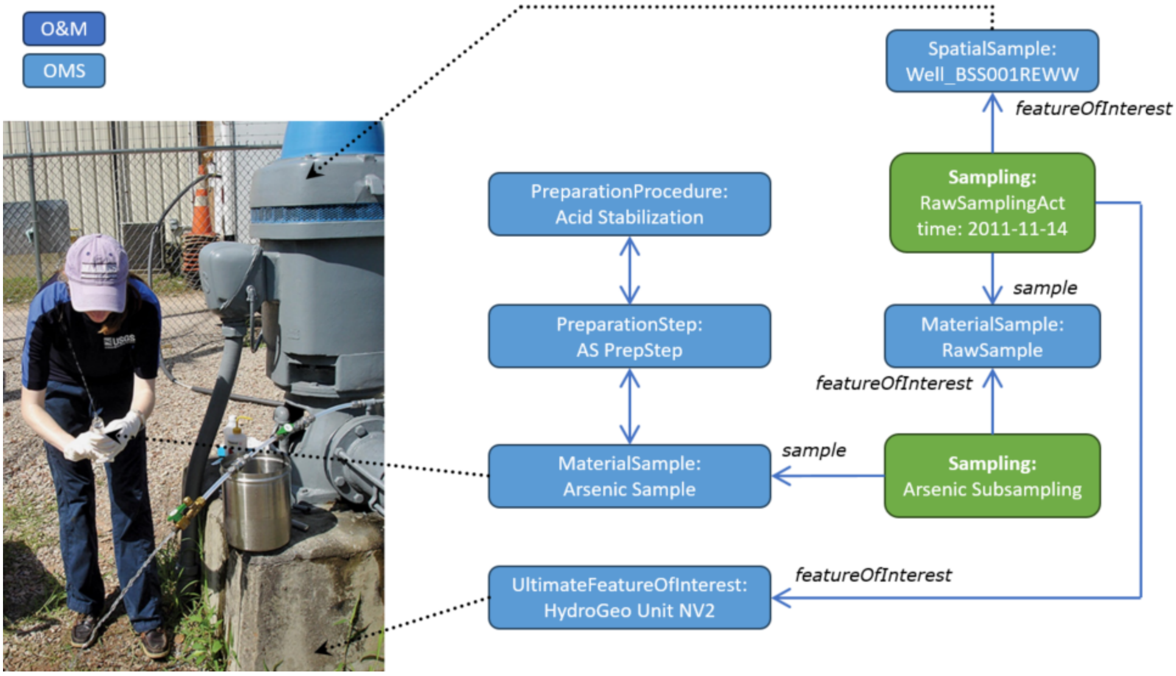

Figure 28: Ground Water ex situ Arsenic - Sampling

5.4 Soil Observation Examples

5.4.1 Observation of average precipitation on a Soil Plot

Figure 29: Observation of average precipitation on a Soil Plot shows how information on average precipitation can be provided for a Soil Plot. The featureOfInterest associates the Observation with a specific Soil Plot. The observedProperty references a codelist indicating that the Observation will provide information on average precipitation. The procedure indicates that a rain gauge has been used to determine the precipitation. The result shows that the average precipitation on the plot under investigation in the given year was 1434 mm.

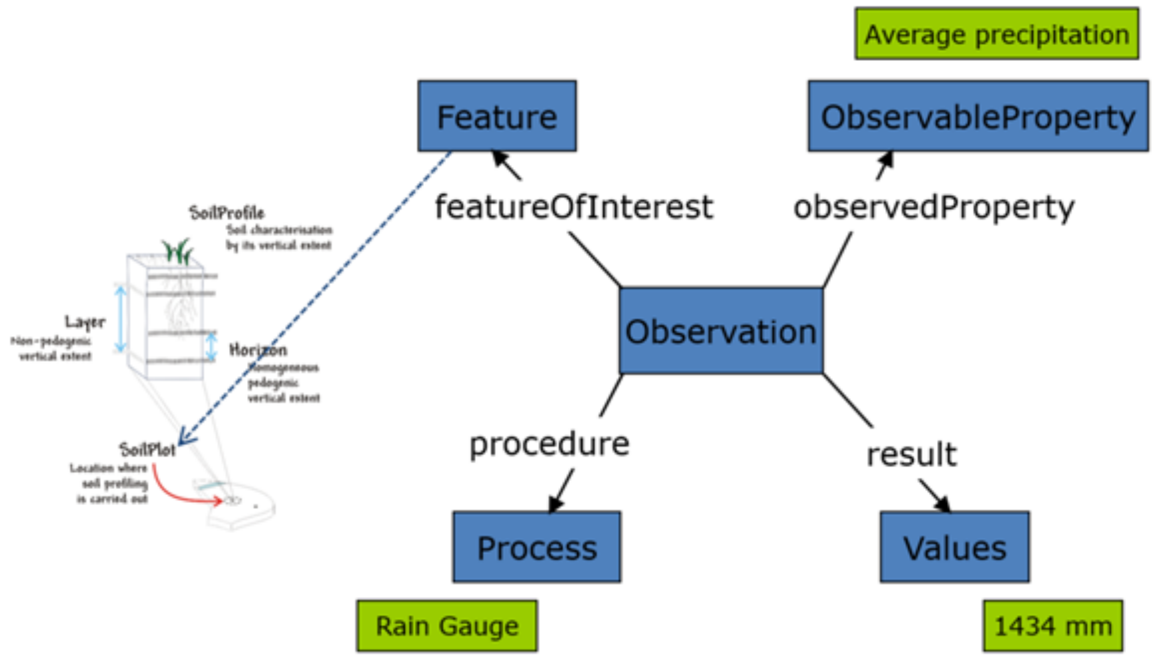

Figure 29: Observation of average precipitation on a Soil Plot

5.4.2 Observation of the effective soil depth on a Soil Profile

Figure 30: Observation of the effective soil depth on a Soil Profile shows how information on the effective soil depth can be provided for a Soil Profile. The featureOfInterest associates the Observation with a specific Soil Profile. The observedProperty references a codelist indicating that the Observation will provide information on the effective soil depth. The procedure indicates that this value has been determined in line with the requirements from ICP Forest. The result shows that the effective soil depth on the profile under investigation in the given year was 314 cm.

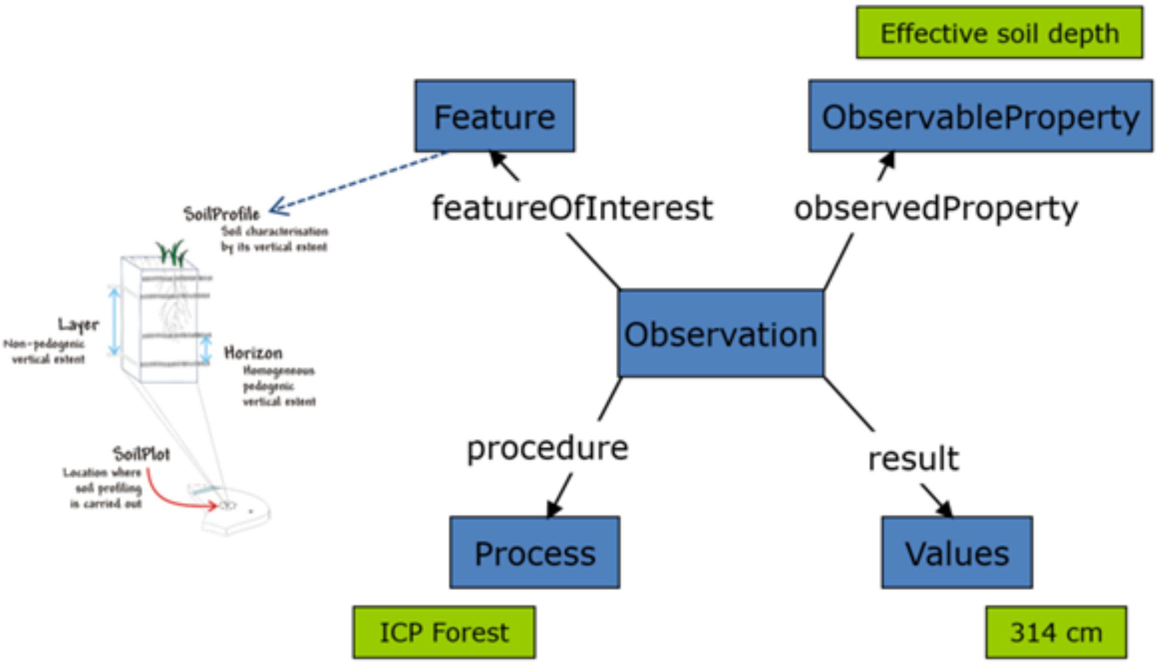

Figure 30: Observation of the effective soil depth on a Soil Profile

5.4.3 Observation of the percentage of clay in a Soil Horizon

Figure 31: Observation of the percentage of clay in a Soil Horizon shows how information on the percentage of clay can be provided for a Soil Horizon. The featureOfInterest associates the Observation with a specific Soil Horizon. The observedProperty references a codelist indicating that the Observation will provide information on the percentage of clay. The procedure indicates that this value has been determined by expert judgement. The result shows that the percentage of clay on the horizon under investigation in the given year was 30%.

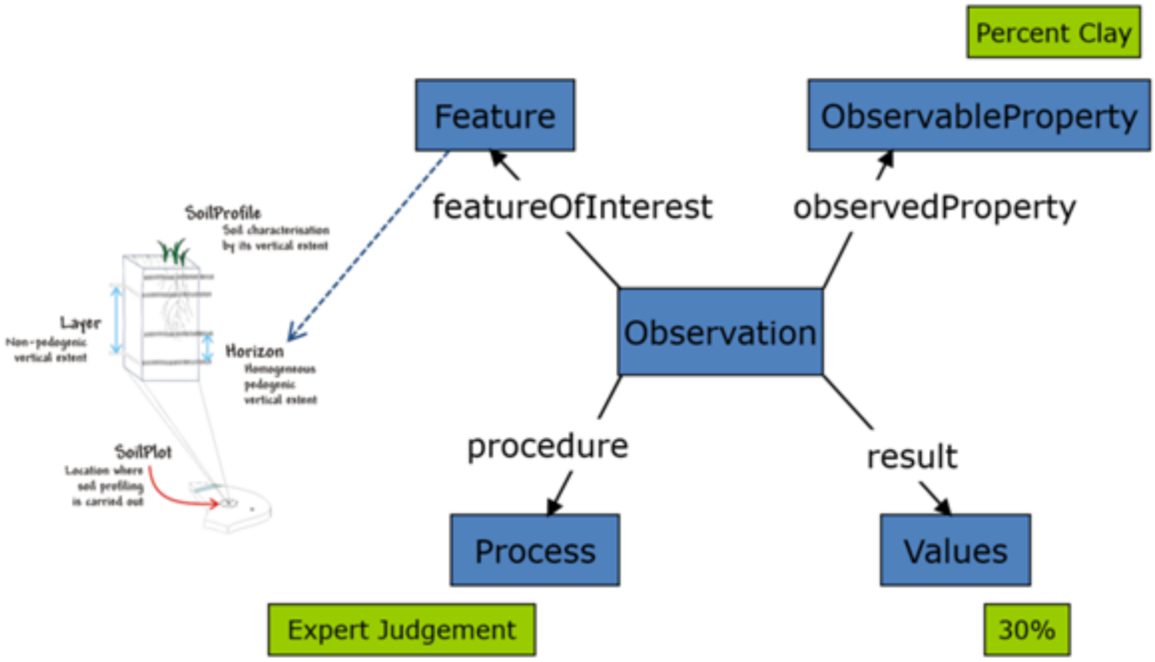

Figure 31: Observation of the percentage of clay in a Soil Horizon

5.4.4 Observation of the textural class of a Soil Layer

Figure 32: Observation of the textural class of a Soil Layer shows how information on the textural class can be provided for a Soil Layer. The featureOfInterest associates the Observation with a specific Soil Layer. The observedProperty references a codelist indicating that the Observation will provide information on the textural class. The procedure indicates that this value has been determined by expert judgement. The result shows that the textural class on the layer under investigation in the given year was 30%.

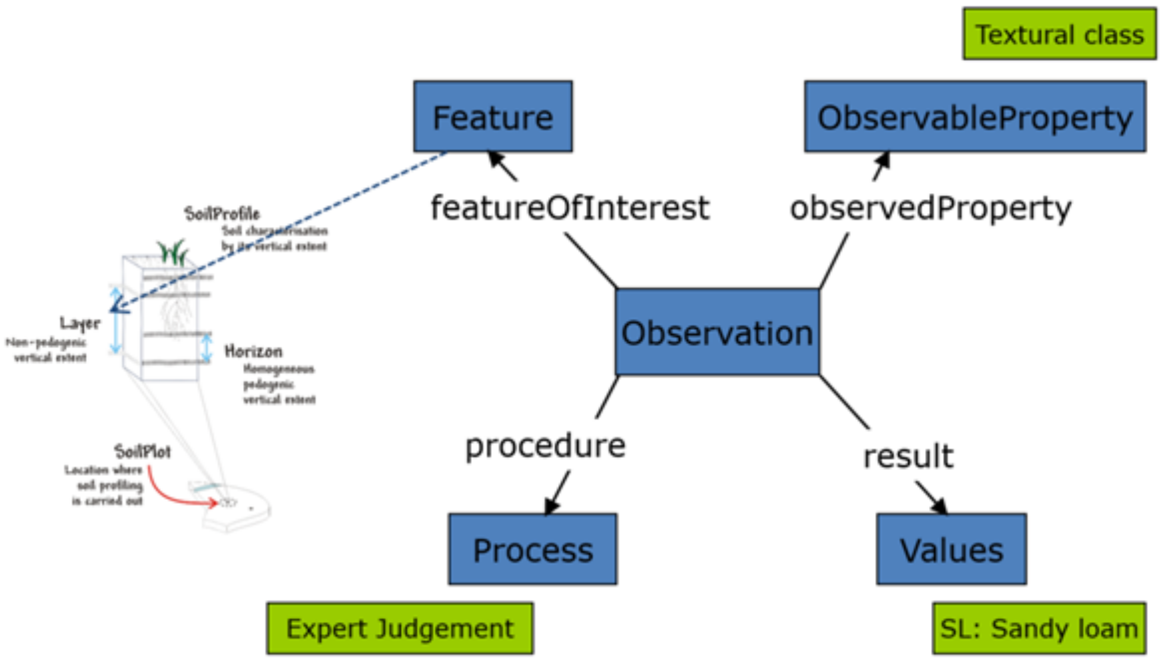

Figure 32: Observation of the textural class of a Soil Layer

5.4.5 Observation of the pH of a Soil Layer

Figure 33: Observation of the pH of a Soil Layer shows how information on the pH can be provided for a Soil Layer. The featureOfInterest associates the Observation with a specific Soil Layer. The observedProperty references a codelist indicating that the Observation will provide information on the pH. The procedure indicates that this value has been determined in accordance with ISO 10390:2005. The result shows that the textural class on the layer under investigation in the given year was 6.4.

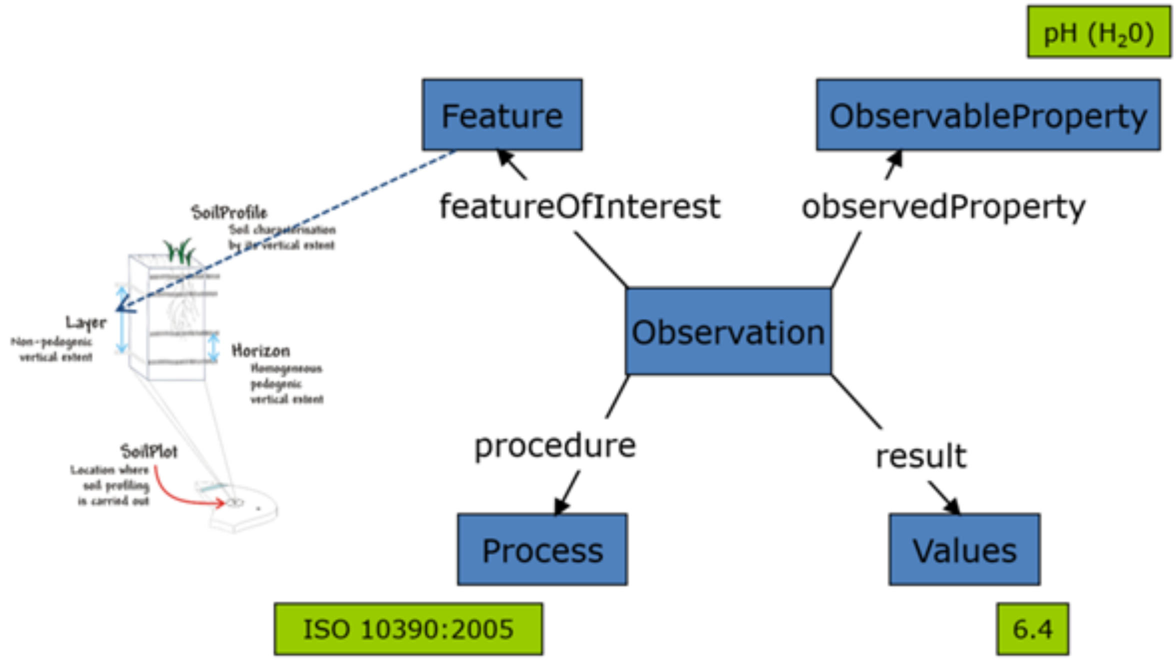

Figure 33: Observation of the pH of a Soil Layer