PAN-EUROPEAN INFRASTRUCTURE FOR OCEAN & MARINE DATA MANAGEMENT

SensorML profiles and O&M data models adapted to specific marine observation data.

SensorML and O&M expressions for Research Vessels and Fixed Stations.

Deliverables 8.2 and 8.3 combined

Project Acronym : SeaDataNet II

Project Full Title : SeaDataNet II: Pan-European infrastructure for ocean and marine data management

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Long title
SensorML profiles and O&M data models adapted to specific marine observations data. SensorML and O&M expressions for Research Vessels and Fixed Stations

Short description
SeaDataNet II wants to adopt the OGC standards for Sensor Web Enablement (SWE). This document formulates specific SeaDataNet profiles for the SensorML and Observations & Measurements models that can be applied by operators of operational observation systems to describe in more detail their observations and to provide standardised access to these observations using the SOS service protocol. In practice, the SensorML and O&M metadata will be attached to the core CDI discovery format as extensions, giving users of the SeaDataNet portal more usage information on specific observations and a way for direct access to the related data streams from operational sensor systems, such as real-time Metocean networks and underway data from systems onboard research vessels.

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1. Introduction

The main objective of this document is to establish the basis for the creation of SensorML profiles (specific rules and restrictions to the general SensorML schema) to be used to describe research vessels with their commonly used on-board instrumentation, and fixed stations used in long term data acquisition series. It also outlines Observation & Measurements (O&M) profiles associated to these sensors.

Together SensorML and O&M profiles will constitute the base of the technology that will complement the already existing SeaDataNet2 infrastructure enhancing the instrument descriptions, today only supported by dictionary entries, and integrating the data flow from instruments to end users in real time.

The “paths” that the data should follow from instrument to end users or end data services are outlined in Figure 1.

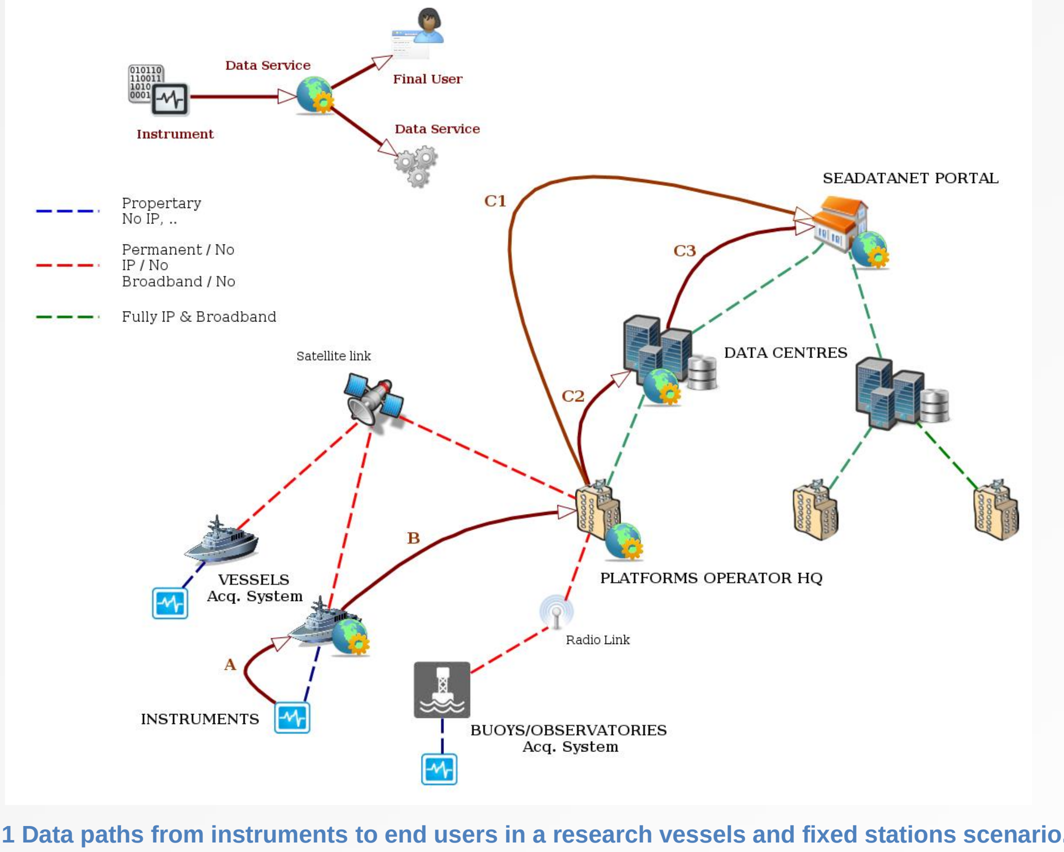


Figure 1 Data paths from instruments to end users in a research vessels and fixed stations scenario. The places where Real Time Data Services using OGC Sensor Web Enablement technologies are also outlined.

O&M has a focus on standardization of the data flow directly out of the sensors or observation systems at sea enhancing also the meta-information related with the data itself (format, units of measure, associated phenomenon etc.). SensorML will provide very precise information about the instrumentation and processes involved in data acquisition. Such information will help end users to understand better their requested data as it should contain information about data acquisition parameters, calibrations, and also the operational history of the instrumentation involved.

This document provides a first version of the O&M and SensorML profiles for a number of specific sensors. Further refinement will take place in the coming months in dialogue with the SeaDataNet Technical Task Group (TTG), as part of the cooperation with related ongoing projects such as ODIP, Eurofleets2 and JERICO, and through the implementation activities.

1.1. Scope of work: A reference to the DoW.

As described in the SeaDataNet II DOW, it is planned to adopt the new set of OGC standards, the Sensor Web Enablement (SWE) family, to enable the discovery and exchange of sensor observations and improve the descriptions of complex instrumentation and data structures.

This adoption implies the specific definition of SensorML and Observations & Measurements (O&M) profiles that then can be applied by operators of operational observation systems to describe in more detail their observations and to provide standardised access to these observations using the SOS service protocol. In practice, the SensorML and O&M metadata will be attached to the core CDI discovery format as extensions, giving users of the SeaDataNet portal more usage information on specific observations and a way for direct access to the related data streams from operational sensor systems, such as real-time metocean networks and underway data from systems onboard research vessels. Definition activities will include:

- Define SensorML profiles to describe instrument and sensors used in the field of marine observation, both for automatic systems such as floats, buoys, sea-floor and coastal observatories, vessel mounted devices and for manual observations. These definitions will be conducted via strong relationships with other groups and projects, active in marine observation, and with sensor manufacturers when useful such as ESONET/EMSO, EuroArgo, FerryBox, MyOcean, Geo-Seas, etc, in order to reach a very large agreement which can be proposed and considered as a real reference in the marine community via the IOC-IODE. These sensor descriptions will be implemented in the SeaDataNet CDI discovery service as extensions and applied where appropriate and feasible (i.e. for recent observations). The SensorML part may be queried using SOS requests.
- Define O&M data models adapted to the marine observation data such as water column vertical profiles, time series, and vessel underway data. Specifications of these models will be studied according to the work already conducted by other groups in related domains such as fresh water, atmosphere, terrestrial and marine geology, to be based on the same core principles and to be proposed as a common specification for the marine community through IOC-IODE. Implementation of these models will be conducted both for the OGC SOS protocol and for OpeNDAP (Open-source Project for a Network Data Access Protocol) which is already widely used in the Ocean/Atmosphere community (Operational Oceanography). For opendap in-situ observation, IFREMER develops « oceanotron »: http://www.ifremer.fr/oceanotron/OPENDAP/
- The 3 SOS mandatory ‘core’ operations: GetObservation, DescribeSensor, and GetCapabilities will be implemented. The CDI service will be used as a service registry to access these SOS services. The GetObservation operation will provide a convenient access to the real-time data that are managed at the distributed data centres and monitoring agencies (EuroGOOS members and others), also for machine to machine communications. This implies that related data centres / operators have to install and configure SOS services locally. The SOS GetObservation can also be used to provide advanced services to human users such as data visualisation, whereby visualisation types must be adapted to the different O&M defined models.
- An alternative for operators of monitoring systems might be to install and configure OpeNDAP and/or Oceanotron services locally with observations in NetCDF (CF) data files, queried via THREDDS from the CDI portal services to provide access and delivery to their real-time and near-real-time data sets.

These topics are to be developed by means of WP8.2 and WP8.6 (new web services) resulting in Deliverables D8.2 and D8.3 and a consecutive SOS service implementation via WP9 (Deliverable D9.4).

A key issue of this family standards adoption is how the connection between existing SeaDataNet metadata products and data services is planned. Far from to play a substitute role, SensorML, O&M and SOS will be complementary to CDI registers and Request Status Manager. SWE standards will be especially useful for those Data that need a specific consideration (like Seismic Data), and therefore specific CDI extensions. In particular SensorML adoption will provide all the specific information about the instrumentation used to acquire data sets that is complementary to the metadata as included in the CDI schema and which is relevant to better understand the data itself as calibration values, operation parameters or the instrument operation history. A description on how the links between the CDI structure and SWE components could be established will be given in chapter 2.

1.2. Agreed road map for SWE implementation plan

The Sensor Web Enablement potential for real time data was introduced during the 2nd meeting of the Technical Task Group (TTG) of SeaDataNet II (March 29 and 30th 2012). Also a roadmap was discussed considering possible cooperation and synergy between SeaDataNet, and other ongoing projects such as Eurofleets2, JERICO, and EMSO, and also learning from the recently finished Geo-Seas project:

- Eurofleets2: logging and streamlining the flow of metadata and data from instruments at research vessels to the data centres and to RT users, and Charly development
- JERICO: formulating best practices for streamlining metadata and data from instruments on oceanographic monitoring platforms to the data centres and RT users
- EMSO: bottom mounted deep ocean platforms with data flow and Sensor Registry
- Geo-Seas: seismic example of O&M and SensorML

Each of these projects is analysing specific components and has agreed in principle to adopt SeaDataNet standards. Therefore a working model was proposed whereby SeaDataNet will lead the standard setting forum which interacts with the other projects for formulating best practice and testing these. The exchange and synergy should lead to adapted SeaDataNet standards that are implemented and evaluated in the SeaDataNet, JERICO, EMSO and Eurofleets2 testbeds, before distributed and implemented on a wider scale.

The proposed approach for implementation of OGC SWE technologies in SeaDataNet is setting up a Real-Time data service as part of the SeaDataNet infrastructure using SWE. This will involve three phases of work with the following milestones to achieve:

- The first phase concerns deciding on the precise scope of services, the definition of the targets (instruments and data types) and their generic description independently of the underlying technology used
- The second phase starts with codification of such descriptions using SensorML and O&M schemas and the definition of profiles or restrictions to these general schemas. The profile definitions can be formalized as new schemas using “schematron” and handled for data providers by adapting the existing SeaDataNet XML editing tool 'Mikado'. The second phase should end with testing of different cases and examples
- The third and last phase is the service implementation, starting with the definition of the architecture of services, and analysing and considering how to integrate these in the overall SeaDataNet infrastructure. This phase should result in the final integration with the SeaDataNet existing services.

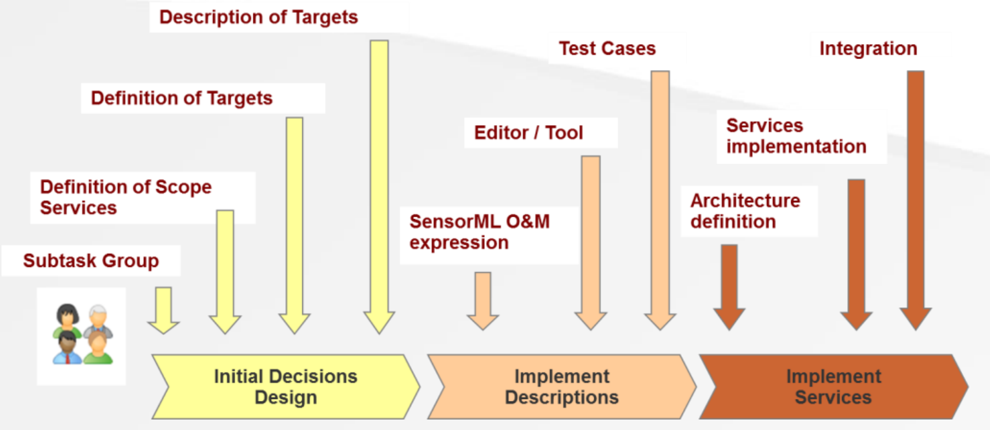


Figure 2 Planned Road Map for SeaDataNet2 SWE infrastructure implementation

1.2.1. Current status of the planned work

This document describes the work done until now, which has progressed up to the formulation of SensorML and O&M expressions. As defined in the SeaDataNet II DoW, the focus concerning instrument and system descriptions has been directed towards Research Vessels including the underway (commonly and always used) on-board instrumentation, and towards Fixed Measurement Stations like buoys, stations or observatories related to mid-long term data series activities.

The scope has been defined as considering both real time and historical data series. The targets have been defined as vessels, underway instrumentation and fixed stations. For the targets the minimum and recommended information blocs necessary to define them have been decribed. SensorML and O&M files have been produced over an extended set of examples representative of these targets. This last step has involved the use of existing SeaDataNet technologies such as the vocabularies. These have been used not only in common concepts for all descriptions but also for referrer specific terms in each example coded in SensorML and O&M.

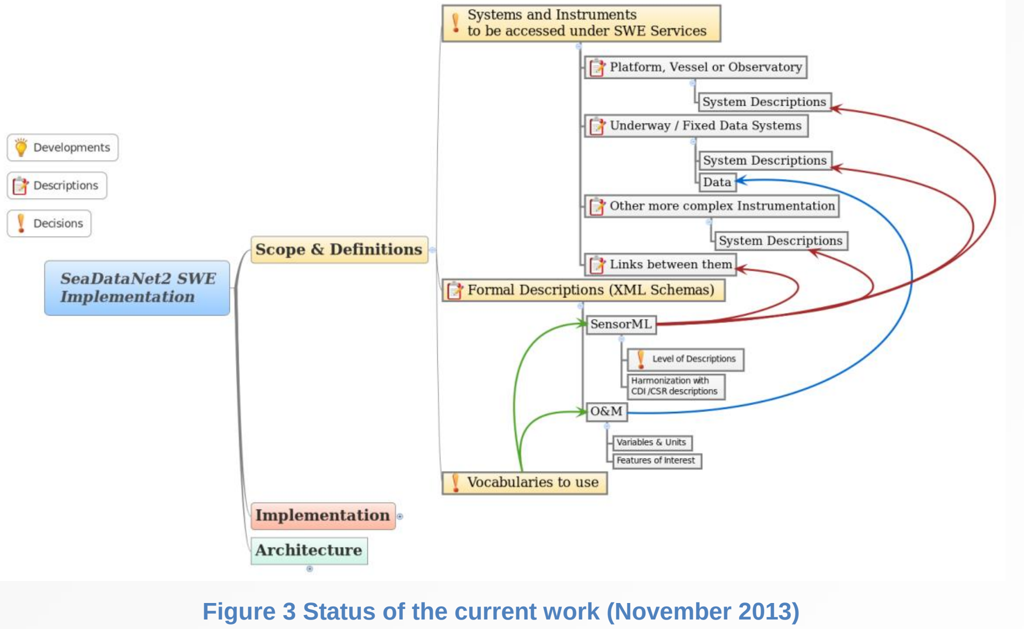


Figure 3 Status of the current work (November 2013)

These results will be described in detail below.

1.3. Synergies, cooperation and follow ups

The SensorML and O&M profiles presented in this document are a first draft, based upon SeaDataNet - Eurofleets - MyOcean analysis activities, including individual experiences of several partners (CSIC, IFREMER, OGS, ..). Further refinement will take place in the coming months in dialogue with the SeaDataNet Technical Task Group (TTG), as part of the cooperation with related ongoing projects such as ODIP, JERICO, and EMSO. Further fine-tuning will also take place as part of the SeaDataNet WP9 activities for implementing prototype SOS services in connection with the CDI Service and EDIOS Service and as part of Eurofleets2 for further upgrading and deployment of the EARS on board of research vessels.

1.3.1. Manufacturers and Software companies

A weak point so far has been the cooperation with manufacturers of instruments. On the software front it is considered to bring in the SWE expert company 52North (DE) who has developed the 52 North Server SOS. It is also planned in the DoW to undertake an OGC Interoperability Experiment. This will be worked out as part of the process of cooperation with other projects. Recently the ODIP project has gained the interest of 52North which has configured a number of SOS services in the USA for NOAA (USA), partner in ODIP. Moreover talks are ongoing with OGC about how to organise an OGC Interoperability Experiment as part of ODIP.

1.3.2. JERICO

JERICO is an FP7 project. It proposes a Pan European approach for a European coastal marine observatory network, integrating infrastructure and technologies such as moorings, drifters, ferrybox and gliders. Its networking activities aim at definitions of best practices for design, implementation, maintenance and distribution of data of coastal observing systems, as well as the definition of a quality standard. New joint research is conducted in order to identify new and strategic technologies to be implemented in the next generation European coastal observatories.

Cooperation with JERICO can provide an excellent opportunity for testing and making the new SeaDataNet SWE standards fit for purpose for supporting operational oceanography and for implementing these in operational services. Such a test will focus on implementing the 3 SOS mandatory 'core' operations: GetObservation, DescribeSensor, and GetCapabilities. The CDI service can then be used as a service registry to access these SOS services. The GetObservation operation will provide a convenient access to the real-time data that are managed at distributed data centres and monitoring agencies (such as EuroGOOS members and others), also for machine to machine communications. This implies that data centres / operators involved in the test have to install and configure SOS services locally. This will then give structured access to both archived data sets (SeaDataNet CDI service) and real-time data (SOS service).

The SOS GetObservation can also be used to provide advanced services such as data visualisation, whereby visualisation types must be adapted to the different O&M defined models. These extensions and SOS services can also be used to provide improved functionality for the EDIOS services to lead users directly to real-time data services.

1.3.3. Eurofleets2 and Eurofleets1

Eurofleets2

Eurofleets2 is an ongoing FP7 project and successor of Eurofleets1. In Eurofleets2 it is an ultimate goal to establish a common system for giving e-access to underway and operational information and data from sailing research vessels. This is foreseen as:

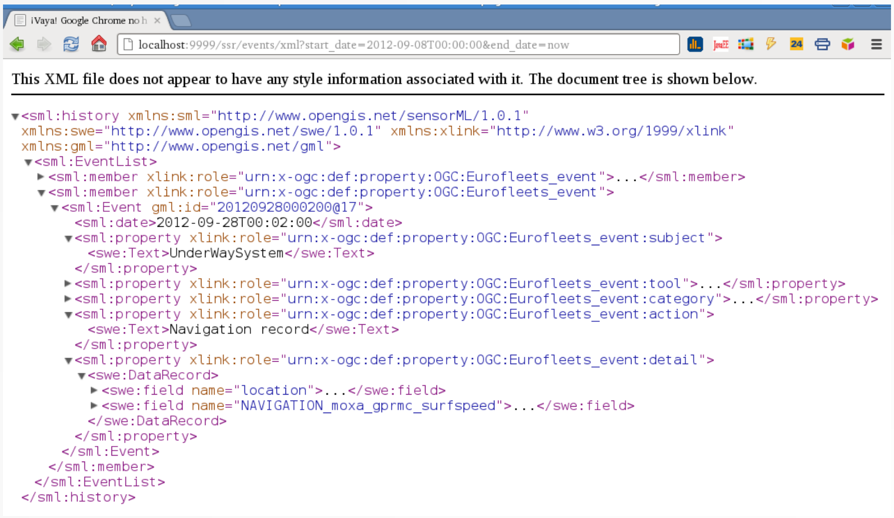
- A generic RV boardsystem, to be installed and configured at research vessels, capable of recording any possible event, ranging from a sample taken or an observation done to any malfunction occurring;
- An en-route Ship Summary Reporting (SSR) system integrated into the RV boardsystem of which the output can be made available on the Eurofleets EVIOR portal, giving the cruise track and position of each RV, outfitted with the system, while sailing, an overview of events, and a first level inventory of oceanographic measurements made and samples taken during the cruises;
- A linkage between the shipboard metadata and data systems to the EVIOR portal for giving users opportunities for direct access to operational data for selected situations.

As part of the Eurofleets2 project a first step has been undertaken in analysing and exploring the options whereby UTM-CSIC has developed and set-up a prototype system for its Research Vessels (RVs) Hesperides and Sarmiento de Gamboa for on-line reporting of the geographic position, speed, bearing and logged events for the onboard fixed instruments from the RVs to the UTM-CSIC data centre. The underway instruments are described as SensorML files.

Eurofleets1 - EARS

As part of Eurofleets 1 a first release took place of the Eurofleets Automatic Reporting System (EARS) capable of recording any possible event, ranging from a sample taken or an observation done to any malfunction occurring. As part of Eurofleets2, EARS will be made more robust and fit for various RV configurations. Further it is planned to develop a routine for producing en-route Cruise Summary Reports based on the EARS logged event information, by combining cruise data, events data and automatically acquired data.

For EARS a SensorML expression was adopted to code the 24h Event registry. The root element is a sml:history tag, while each Event is coded using individual sml:Event elements of a sml:EventList container element. Every individual component of each event (subject, actor, tool, action, details) is coded inside the sml:Event using sml:property tags where a specific role attribute is used to distinguish one from each other’s.



```
¡Vaya! Google Chrome no h
localhost:9999/ssr/events/xml?start_date=2012-09-08T00:00:00&end_date=now

This XML file does not appear to have any style information associated with it. The document tree is shown below.

▼<sml:history xmlns:sml="http://www.opengis.net/sensorML/1.0.1"
 xmlns:swe="http://www.opengis.net/swe/1.0.1" xmlns:xlink="http://www.w3.org/1999/xlink"
 xmlns:gml="http://www.opengis.net/gml">
  ▼<sml:EventList>
    ►<sml:member xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event">...</sml:member>
    ▼<sml:member xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event">
      ▼<sml:Event gml:id="20120928000200@17">
          <sml:date>2012-09-28T00:02:00</sml:date>
        ▼<sml:property xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event:subject">
            <swe:Text>UnderWaySystem</swe:Text>
          </sml:property>
        ►<sml:property xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event:tool">...</sml:property>
        ►<sml:property xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event:category">...</sml:property>
        ▼<sml:property xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event:action">
            <swe:Text>Navigation record</swe:Text>
          </sml:property>
        ▼<sml:property xlink:role="urn:x-ogc:def:property:OGC:Eurofleets_event:detail">
          ▼<swe:DataRecord>
            ►<swe:field name="location">...</swe:field>
            ►<swe:field name="NAVIGATION_moxa_gprmc_surfspeed">...</swe:field>
            </swe:DataRecord>
          </sml:property>
        </sml:Event>
      </sml:member>
    </sml:EventList>
  </sml:history>
```

Figure 4 24 hours event registry obtained from EARS system

Eurofleets1 - Calibration

Another activity in Eurofleets1 has been the development of software/calibration tools. This aimed at offering and providing the scientific community with basic tools to calibrate sensors, mainly used in multi- parametric probes. This information is important not only for data logging but also for the delivery of raw data to the scientific community. Moreover, suitable and regular sensor calibration together with maintenance of calibration history for each sensor are essential requirements to assure a high data quality. Calibration history is another important part for the assessment of data quality. In general, sensors should be calibrated before and after each cruise.

Due to its potentiality, an OGC Sensor Web Enablement SensorML [1] approach has been chosen as a standard to describe instruments and sensors and to maintain their calibration history. This is described in more detail below.

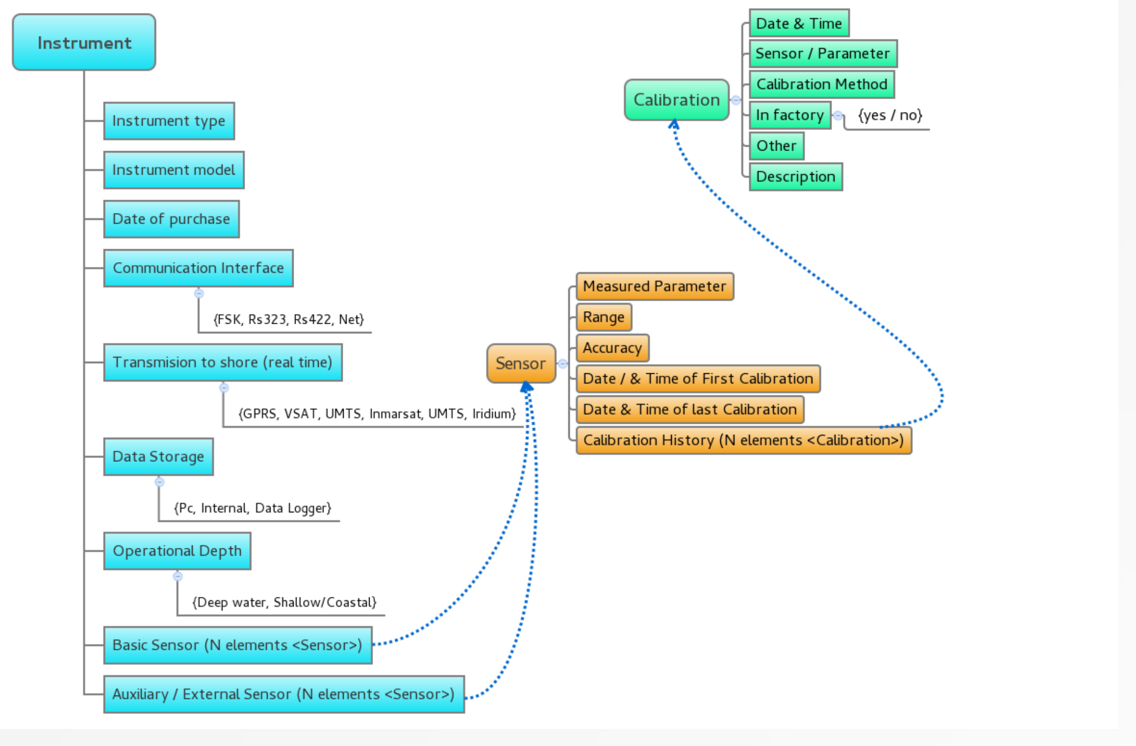


Figure 5 Information blocks necessary to describe an instrument (CTD like) with its calibration information

Figure 5 identifies the mandatory elements needed to describe an instrument with its sensors and the calibrations related with every sensor. Every instrument can contain a number of sensors (N) and each sensor has a number of calibrations (N) that constitute the calibration history.

The description of the instrument is composed by the following elements:Instrument type

- Instrument model
- Date of purchase
- Operational range (depth)
- Storage capabilities
- Communication interfaces
- The description of the sensors present in the instrument is composed by the following elements:Measured parameters
- Range of measurement
- Accuracy
- The description of the calibrations corresponding to every sensor is composed by the following elements:Date of calibration
- Calibration method
- Calibration description
- In-factory tag

In order to accommodate the information needed to describe an instrument, and its calibration history, Eurofleets1 has defined SensorML files as given in the schema below.

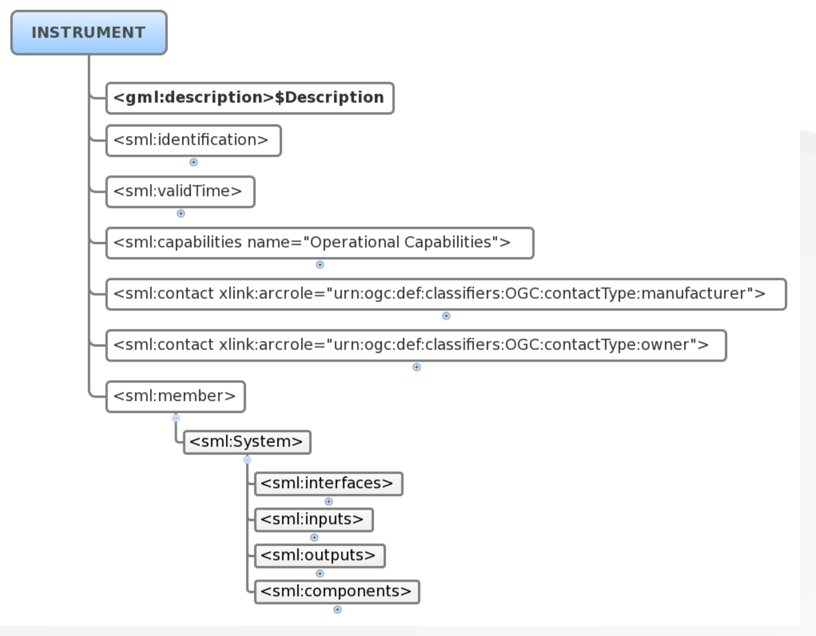


Figure 6 SensorML tags used to describe EuroFleets WP10.2 calibrated instrument

The history property records all the events related to the live and operation of a detector. Such events can include deployment, calibration, repairs, algorithm corrections, and decommissioning episodes. The roles that specify the events type can be specified using any xlink:arcrole attribute at the history or member properties. It is anticipated but not required that history will typically be maintained online in an external document and referenced from within the process description.

All of the “events” can be coded as a collection of sml:event elements.

Following the calibration approach and the schema definition of the sml:event, each “event” should contain the following elements:

- A name and a role that defines the type of the event. In the case of a calibration event it is possible to use a role defined using the urn “ogc:def:property:OGC:calibration”.
- A unique identifier for each event.
- A date, i.e. the timestamp of the event. It can be expressed easily as an interval using ISO-8601 notation.
- The operator's details. In case of calibration events this should reference to the person who has been responsible of the calibration operation.

The calibration report is the documentation that describes extensively the calibration episode or any additional information necessary to understand the recorded event. This can be coded easily in SensorML using a ***sml:documentation*** element that allow to place this information outside of the SensorML file by using a ***sml:onlineResource*** tag. The onlineReosurce can point to any document in any format accessible by means of an URL.In factory. This is a specific element that indicates whether a calibration episode has been carried out at the sensor manufacturer site. In order to accommodate such so specific information elements, the ***sml:Event*** schema provides a quite flexible object to use it in this occasions. The ***sml:property*** is an object of type ***swe:DataComponentPropertyType***, a complex type for all properties taking the swe:AnyData Group. This means that with ***sml:property*** we can represent any kind of information of complex nature using primitive data types for any scalar or data range. As “in factory” can be a boolean expression it is easy to express it using a ***swe:boolean*** value inside an ***sml:property*** tag.

The Calibration method is another element and is the formal textual description of the calibration method used in the referenced calibration event. Again is it quite straight to code using a ***sml:property*** tag with a ***swe:Text*** object inside.

Although the calibration history of a detector can be very well represented using the above-mentioned schema, it is also possible to include on it the numerical expression of a calibration curve when it is available. The calibration curves can be included in the above schema by use of ***sml:Document*** element that provides us a link to a external resources, but the ***sml:property*** of an ***sml:event*** allow the inclusion of any kind of data with a complex structure and also the numerical expression of calibration curves.

The ***swe:Curve*** element is derived from ***swe:AbstractArrayType*** and is part of the ***swe:AnyData*** group. It allows one to define one or more axes (or fields) for a curve (taking AnyScalar for each field value) and to provide a series of coordinate values using the values properties. An example of a calibration curve mapping temperature to resistance is given below. In the example the definition property defines two Quantity axes (i.e., temperature and resistance). The values property allows one to provide an array of the coordinate values using an efficient data block. Within the values block, are 21 pairs of temperature and resistance values, with white space separating tuples (i.e., the value pair in this case) and commas separating the tokens within a tuple.

1.3.4. ODIP

The EU FP7 ODIP project is operating an Ocean Data Interoperability Platform. ODIP aims to establish an EU / USA / Australia/ IOC-IODE coordination platform, the objective of which is achieving the interoperability of ocean and marine data management infrastructures, and to demonstrate this coordination through several joint EU-USA-Australia-IOC/IODE prototypes that would ensure persistent availability and effective sharing of data across scientific domains, organisations and national boundaries. ODIP is undertaken by representatives of the leading marine data management infrastructures in Europe (such as SeaDataNet, Geo-Seas, MyOcean), USA (such as US NODC, IOOS, R2R) and Australia (such as IMOS) and IOC-IODE (ODP).

The ODIP platform organises international workshops to foster the development of common standards and develop prototypes to evaluate and test selected potential standards and interoperability solutions. The ODIP partnership also provides a forum to harmonise the diverse regional systems, while advancing the European contribution to the global system.

The 1st ODIP Workshop took place at the IODE project office in Ostende, Belgium, on 25-28 February 2013 with 46 participants, representing well the various EU, USA, Australian regional infrastructure projects and initiatives that are stakeholders of the ODIP project. The brainstorming and discussions resulted in a long list of possible actions. Their implementation is planned by means of a limited number of ODIP Prototype projects. Each of these projects will bring together a number of the identified actions (with possibe overlap). The actual developments for implementing the Prototypes is foreseen as a joint activity of ODIP participants in synergy with and harvesting from activities underway in regional projects and initiatives, such as SeaDataNet (EU), IMOS (Australia), R2R (USA), and ODIP. ODIP will provide a communication and exchange platform where partners can meet, discuss and tune their development activities and ensure that results are made fit for building the ODIP Prototypes.

A proposal about possible ODIP Prototype projects and the way forward has been drafted in July 2013 and accepted in September 2013. It has been decided to develop 3 ODIP Prototype projects. ODIP Prototype project 3 is about establishing a prototype for a Sensor Observation Service (SOS) and common SensorML and O&M profiles for selected sensors (SWE) and installed on vessels and in real-time monitoring systems. The lead of ODIP 3 is given to Australia (IMOS) while the project should be developed by partners from Europe, USA and Australia.

The contributions from Europe are coordinated via SeaDataNet and their present status is described in the underlying document.

The ODIP Prototype project facilitates to learn and discuss best practices also from the USA and Australia, which should lead to the formulation of more common profiles and practices.

In the USA SOS services have been central to US-IOOS work for the last few years. The figure below shows some of the elements of the sensor data distribution framework. IOOS is leveraging both 52North and the THREDDS data server and have written or are writing software to ease the integration of both elements into a framework. For THREDDS, data utilizing the CF v1.6 conventions and implementing the discrete sampling 4 geometries, ncSOS provides an SOS interface to this data. The standards they are currently using are SOS 1.0, SWE 1.0, O&M 1.0, and SensorML 1.0, but they plan to migrate to the 2.0 family in the next year. In parallel with the THREDDS/ncSOS option IOOS has been profiling the 52North code base to deliver sensor data using the same standards. IOOS has been creating specific templates of the SWE/O&M standards for ocean observations. The IOOS ncSOS package and the IOOS fork of the 52North code base both provide these templates as web service responses. These templates are different to the standard 52North implementation and were created to address some of the feature types that were not included in the 52North trunk (trajectories, hierarchical relationships between sensors, platforms, and networks just to name a couple). The feature types that IOOS implement in SOS conceptually map to the CF 1.6 discrete sampling geometries so there is a built in connection between these two prevalent standards for ocean/atmosphere observations. IOOS has a solid relationship developing between with the 52North team - one of the IOOS developers has been admitted onto the 52North development team. Through this relationship IOOS is ensuring that the 52North trunk developments and the IOOS fork developments are kept in line with each other architecturally.

In Australia BOM has been implementing a 52 North SOS service as a component of the National Environmental Information Infrastructure. This has been in association with 52 North and has resulted in a set of improvements for the 52N SOS 2 server. These reduce memory footprint and improve SOS-T (in-situ observations), overcoming some of the earlier limitations. AIMS has implemented a 52 North SOS 2 instance delivering data from IMOS sensors on the Great Barrier Reef. This is the main AODN development and involves IMOS. The main interest is what to put in the sensorML and O&M documents and how these links into the metadata. Producing standard templates for these and then using them to discover data is the real work.

The 2nd ODIP Workshop will take place in December in San Diego, USA. Discussion on the state of the art and the activities needed for developing the ODIP Prototype project 3 will be one of the agenda items. CSIC will present the underlying SeaDataNet - Eurofleets work. It is envisaged that this ODIP cooperation will lead to further insights and fine-tuning of the SensorML and O&M profiles as defined at present.

1.3.5. OGS initiative

SeaDataNet partner OGS is testing a SOS service linked to the meteo-oceanographic Mambo buoy. This buoy is equipped with a set of sensors (meteorological station, CTD, current meter, with several probes) which are described with SensorML. OGS uses a SOS developed by IREA within the Italian project RITMARE. The same SOS is already in use by CNR/ISMAR for two buoys in front of Venice. OGS aims to adopt the SeaDataNet Vocabularies and to establish interoperability with the SeaDataNet CDI and EDIOS services. Therefore OGS will provide its experience as further input for the SeaDataNet and ODIP SWE formulation and implementation processes and will give feedback on the draft SeaDataNet profiles via its participation in the SeaDataNet TTG.

2. Basic principles of SWE, SensorML, O&M and SOS

In much the same way that HTML and HTTP standards enabled the exchange of any type of information on the World Wide Web, the OGC Sensor Web Enablement (SWE) standards family is focused to enable the discovery and exchange of sensor observations, as well as the tasking of sensor systems. It is concerned with establishing interfaces and protocols that will enable a “Sensor Web” through which applications and services will be able to access sensors of all types, and observations generated by them, over the Web. SWE has defined, prototyped and tested several components needed for a Sensor Web, namely:

- Sensor Model Language (SensorML).
- Observations & Measurements (O&M)

- Sensor Observation Service (SOS).
- Sensor Planning Service (SPS).

The functionality that has been targeted in SWE includes:

1. Discovery of sensors and sensor observations that meet our needs
2. Determination of a sensor's capabilities and quality of measurements
3. Access to sensor parameters and processes that automatically allow software to process and geolocate observations
4. Retrieval of real-time or time-series observations and coverage in standard encodings
5. Tasking of sensors to acquire observations of interest
6. Subscription to and publishing of alerts to be issued by sensors or sensor services based upon certain criteria

SensorML is the key component (conceptual schema and XML encoding) for the descriptive part of instruments and information processes (sensor's capabilities, location, and task-ability) while Sensor Observation Service is the application layer to interact with the information contained in SensorML and/or the gateway to the live data.

The OGC Observations and Measurements (O&M) standard provides a standard conceptual model for representing and exchanging observation results. It provides standard constructs for accessing and exchanging observations, alleviating the need to support a wide range of sensor-specific and community-specific data formats. O&M establishes a high-level framework for representing observations, measurements, procedures and metadata of sensor systems and is required by the Sensor Observation Service Implementation Standard, for implementation of SWE-enabled architectures, and for general support for OGC standards compliant systems dealing in technical measurements in science and engineering.

As defined within the O&M standard, an Observation is an event with a result that has a value describing some phenomenon. The observation is modeled as a Feature within the context of the ISO/OGC General Feature Model. An observation feature binds the result to the feature of interest, upon which it was made. An observation uses a procedure to determine the value, which may involve a sensor or observer, analytical procedure, simulation or other numerical processes.

This OMXML standard specifies an XML implementation for the O&M conceptual model, including a schema for Sampling Features. This encoding is an essential dependency for the SOS Interface Standard. More specifically, this standard defines XML schemas for observations, and for features involved in sampling when making observations. These provide document models for the exchange of information describing observation acts and their results, both within and between different scientific and technical communities.

SOS provides an Application Programming Interface for managing deployed sensors and retrieving sensor data and specifically “observation” data. Observations and Measurements (O&M) is the SWE family component (conceptual schema and XML encoding) used to describe “observations” and provide the final link to the data itself.

Any SOS instance should organize collections of related sensor systems and observations into Observation Offerings. The concept of an Observation Offering is often equivalent to that of a sensor constellation and is analogous to a “layer” in Web Map Service in the sense that each offering is typically a non- overlapping group of related observations.

Sensor descriptions can be retrieved for any sensor that is advertised in an observation offering using the SOS *DescribeSensor* interface. This will return a SensorML document with detailed information about the sensor. This might be used to filter out observations produced by sensors. The SOS *GetObservation* operation is designed to retrieve such observation data structured according to the Observation and Measurement specification. The available sensors are identified in the *GetCapabilities* response, so may also be harvested by a registry that is indexing the service.

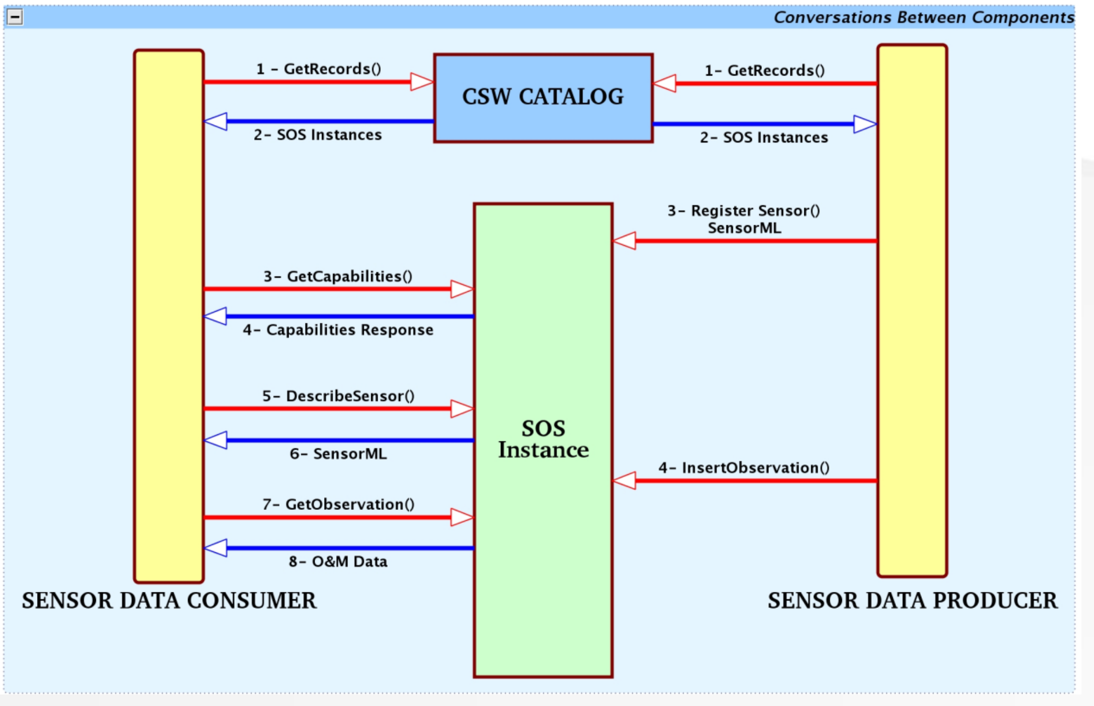


Figure 7 Message exchange between Data Producers and Data Consumers with a Sensor Observation Service instance

During the preparation of the second major version of the Sensor Planning Service (SPS) and Sensor Observation Service (SOS), the OGC Members recognized that certain interfaces and data types are common across SWE services. The ***DescribeSensor*** operation is the most prominent example for such an interface and according data types. Common sense was that these types should be specified in a separate document that could then be referenced by all standards that reuse the defined types.

The OGC® SWE Service Model document specifies data types and interfaces common to Sensor Web services. It therefore serves as a baseline for the development of such services.

Specifically the SWE Service Model:

- Is applicable to all services that provide information from or about sensors;
- Is applicable for uses cases in which sensors need to be managed through service interfaces.
- Specifies how sensor descriptions can be accessed and managed;
- Specifies how historical sensor descriptions can be accessed and managed;
- Establishes the means for inserting and deleting sensors through a common service interface.
- Specifies publish/subscribe functionality for Sensor Web services – through definition of recognizable event types, their encodings and association to notification topics.
- Gives guidelines for use of identifiers;
- Provides guidelines on creating an automatic mapping of the data types relevant in a service model from their UML representation to their XML Schema encoding;
- Defines the information required in a SOAP binding to realize the specified service functionality. The SOAP binding specifies WS-Notification to realize Publish/Subscribe service functionality

2.1. SensorML 2.0 vs. SensorML1.0

At the present moment Version 2.0 of SensorML schema is in vote for final approval. For a while, ~~At the present moment V~~version 1.0 of SensorML schema is the approved and official OGC schema. ~~.~~It was approved as an OGC Technical Specification on June 23, 2007. In Version 1.0, SWE Common and SensorML were combined in the same specification. SWE Common defines the common data types and data aggregates used throughout all SWE specifications (excluding TML). The latest official document related to the schema is OpenGIS® SensorML Encoding Standard, version 1.0 Schema - Corrigendum 1 (OGC 07-122r2) . This corrigendum change notes for SensorML version 1.0 and as a result of the Corrigendum process, there were edits and enhancements made to this standard to correct typographic errors, schema errors, or some deficiency that prevented proper use of this standard. This document provides the details of those edits, deficiency corrections, and other corrects. It also documents those items that have been deprecated.

On September 2013 the voting members of the SensorML 2.0 SWG approved the final version of the standard for release to the OAB and then the general membership.

The main changes from SensorML 1.0.1(OGC 07-122r2) and SensorML 2.0 are:

- The separation of SWE Common Data into a separate specification (OGC 07-094r1)
- Improved derivation and association of SensorML from GML 3.2 and ISO 19115
- More explicit definition of the standard and its requirements
- Separation of SensorML into several conformance classes to allow software to support only the part of SensorML that is relevant to the application (e.g. non-physical processes only)
- Improved support for inheritance, configuration, and modes (e.g. for describing a particular model of a sensor and then an instance of that sensor with particular configuration)
- Improved explicit support for data streaming (associated with inputs, outputs, and parameters)
- Addition of Feature of Interest for support of discovery
- Addition of extension points for domain or community-specific schema
- Improved support for defining position of both static and dynamic components and systems
- Inclusion of DataInterface and DataStream as a possible input, output, or parameter value

Additionally, much additional and improved functionality of SensorML has been gained through additions and improvements of the SWE Common Data Model specification.

SensorML 2.0 supports the descriptions of things within the Internet of Things (IoT) and Web of Things (WoT) by providing a common standard for sensors ("things the measure"), actuators ("things that act"), and processors ("things that calculate"). Efforts are also underway to take advantage of the complementary role that SensorML 2.0 can play with the OGC City Geography Markup Language (CityGML) Encoding Standard and the candidate OGC standard IndoorGML.

2.2. SWE Common

The primary focus of the SWE Common Data Model is to define and package sensor related data in a self-describing and semantically enabled way. The main objective is to achieve interoperability, first at the syntactic level, and later at the semantic level (by using ontologies and probably semantic mediation) so that sensor data can be better understood by machines, processed automatically in complex workflows and easily shared between intelligent sensor web nodes.

This standard is one of several implementation standards produced under OGC’s Sensor Web Enablement (SWE) activity.

The OGC® SWE Common Data Model Encoding Standard document (OGC 08-094r1 2011-01-04), is a revision of the schema that was previously integrated to the SensorML standard (OGC 07-000) and a definition of the common data models.

This document deprecates and replaces clauses 8 “SWE Common Conceptual Models” and 9 “SWE Common XML Encoding and Examples” of the first edition of OGC® Sensor Model Language Specification (OGC 07-000) from which they were extracted.

Additionally these clauses have been technically revised and explanations have been improved. These clauses will be removed from version 2.0 of the SensorML standard.

The main changes from version 1.0 (part of SensorML 1.0) are additions of new features such as:

- The DataChoice component providing support for variant (disjoint union) data type
- The DataStream object improving support for real-time (never-ending) streams

- The XMLBlock encoding providing support for simple XML encoded data
- Support for definition of NIL values and associated reasons
- The CategoryRange class to define ranges of ordered categorical quantities

Additionally, some elements of the language have been removed and replaced by soft-typed equivalent defined using RelaxNG and/or Schematron. The list is given below:

- Position, SquareMatrix
- SimpleDataRecord, ObservableProperty
- ConditionalData, ConditionalValue
- Curve, NormalizedCurve

2.3. O&M 2.0

O&M 2.0 was approved by the OGC Members as a standard in late 2010. In early 2010, the document was also approved by the ISO TC211 Members as an ISO Standard.

The Observations and Measurements XML Implementation standard is part of the revision and refactoring of O&M for its publication in two parts

1. The conceptual model (in UML) is being published as ISO 19156 through ISO/TC 211, and jointly by OGC as a Topic 20 of the Abstract Specification.
2. The XML implementation is being published by OGC as an independent document

In recognition of the fact that XML is only one of all the possible implementations for O&M, to decouple maintenance of the implementation from revision of the abstract model, and to better reflect the scope of activities and publications appropriate to ISO and OGC.

The official latest standard version is 2.0. This standard specifies an XML implementation for the OGC and ISO Observations and Measurements (O&M) conceptual model (OGC Observations and Measurements v2.0 also published as ISO/DIS 19156), including a schema for Sampling Features. This encoding is an essential dependency for the OGC Sensor Observation Service (SOS) Interface Standard. More specifically, this standard defines XML schemas for observations, and for features involved in sampling when making observations. At present time, the official document is “Observations and Measurements - XML Implementation OGC 10-025r1 2011-03-22 “.

Official Schemas are located at:

http://schemas.opengis.net/om/2.0/

http://schemas.opengis.net/sampling/2.0/

http://schemas.opengis.net/samplingSpatial/2.0/

3. How SWE standards should be integrated into SeaDataNet2 existing infrastructure

As a basis for the SeaDataNet services, common standards have been defined for metadata and data formats, common vocabularies, quality flags, and quality control methods, based on international standards, such as ISO 19115 - 19139, NetCDF (CF), ODV, and best practices from IOC and ICES.

The Common Data Index (CDI) was initiated in the Sea-Search project. As part of SeaDataNet it has been further developed and extended in data coverage to all SeaDataNet data centres, and as part of SeaDataNet II it recently has been upgraded to using the ISO 19139 Schema and achieving INSPIRE compliance. Its primary objective is to give users a highly detailed insight in the availability and geographical spreading of marine data across the different data centres and institutes across Europe. The CDI provides an index (metadatabase) to individual data sets. Moreover it provides online access to the distributed data resources by means of downloads and server side visualization. At present more than 90 marine data centres are connected to the SeaDataNet CDI infrastructure, giving standard metadata and access to more than 1.35 million data sets on a wide range of marine disciplines. .

The use of a common vocabulary in all metadatabase and data formats is an important prerequisite towards consistency and interoperability. The SeadataNet vocabulary is based upon the NERC dataGrid (NDG) vocabulary Web service. The present release is NVS 2.0. .

It is very important to preserve the CDI from becoming a speciated metadata model, since it should continue to act as a tool that could be used to discover all the data types considered within SeaDataNet. However it is important, for specific knowledge areas, to extend the amount of information that the CDI schema could provide in order to understand better how data has been acquired or to achieve a finer level of data selection upon domain specific parameters. The use of SensorML and O&M expressions can help to achieve this without disturbing the original data discovery and access based on CDI infrastructure.

In the Geo-Seas project an interesting solution for coupling CDI with SensorMl and O&M has been proposed and put in practice for Seismic data. This approach highlights that “discovery” is to be intended in a strict ISO 19115 sense as a tool that spans multiple data types (CDI realm) while data selection upon domain specific parameters can be referred to as “browsing” (SensorML realm). Browsing is intended to help user select on finer grain criteria the data they are interested in, through specific fields included in detailed instrument descriptions. Separating discovery and browsing can be achieved using the CDI, service binding capabilities. For the implementation of service bindings the ISO 19139 profile for CDI has been followed under gmd:MD_Metadata /gmd:distributionInfo/gmd:MD_Distribution/gmd:transferOptions.

The use of O&M can be seen as a bridge between CDI and SensorML. O&M files can provide good fine grained data descriptions of the data referred by CDI files, a mechanism for achieving data segmentation issues like those related with seismic lines, precise descriptions about the geographic geometry of the sampling features and, finally a straight connection to the description of the procedure or instrument used to acquired data through the **<om:procedure>** element.

Figure 8 shows the framework which has been developed in the frame of Geo-Seas and which is now operationally supported in SeaDataNet for Seismic data handling. Discovery is granted by the CDI, Data access is handled by the O&M part while Browsing is handled by SensorML

In this framework it is defined that one CDI record can have one O&M document. This O&M document can relate to multiple SensorML documents.

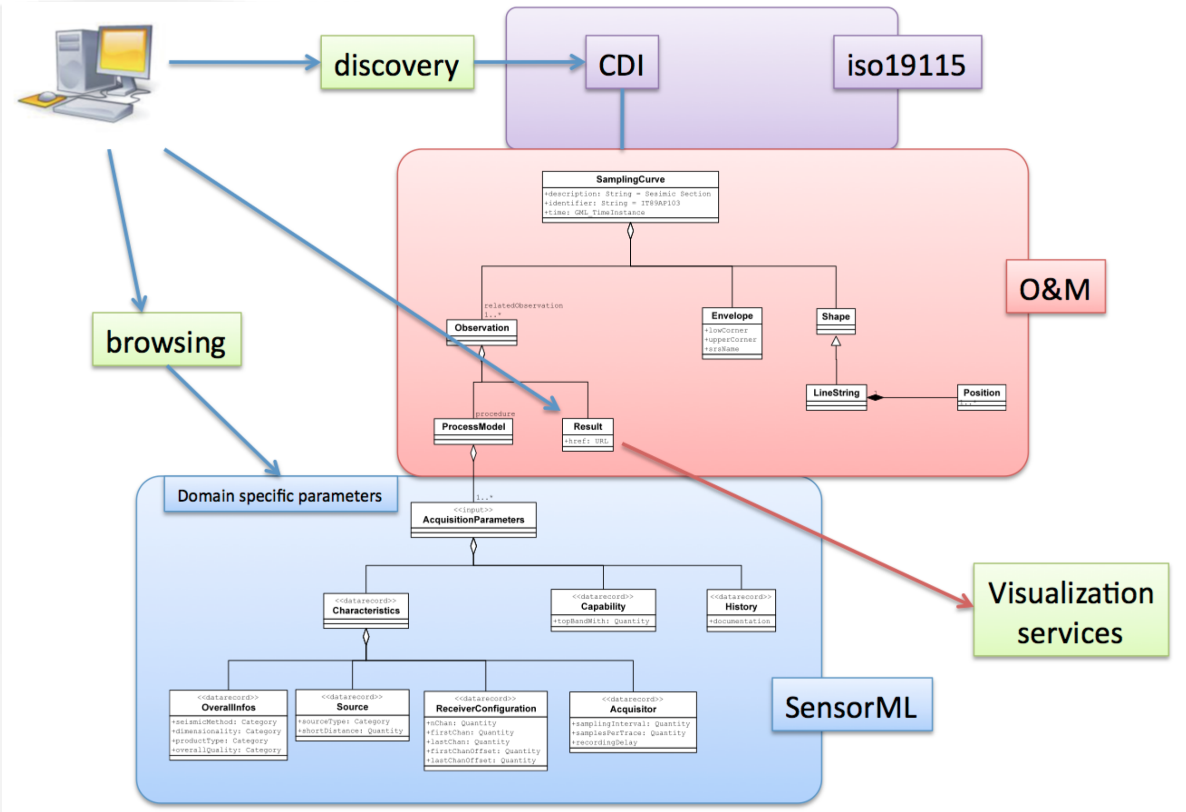


Figure 8 The framework to be used in Seismic data handling is based on a three layer approach. (Diviacco, P. et al. 2011 Marine Seismic Metadata for an Integrated European Scale Data Infrastructure. The Fp7 Geo-Seas Project, BGTA, DOI: 10.4430/bgta0051)

This approach used for seismic data handling as adopted in Geo-Seas and SeaDataNet can be adapted also in a broader scenario presented by the Research Vessels and Fixed Stations (Figure 9).

In both research platforms the precise description of the instrumentation used during a specific time interval (survey or project) has an absolute relevance to better understand not only how the data has been acquired but also to have an exact idea about the quality of the data. The knowledge about the history of the events related with the instrumentation or with the platform (vessel or station) is also valuable to contextualize the data and its quality. Such descriptions are perfectly addressable by the use of SensorML files.

In this scenario O&M will provide not only the existing link between the CDI registries and SensorML expressions, using the <***om:procedure***> tag, but also the link to real time data services with the latest values from the instrumentation installed on-board a research vessel or a fixed station. These real time data values can formally described, and embedded inside O&M bodies using ASCII or binary expressions , or referred to any external by the use of xlink attribute, in <***om:result***> element tag.

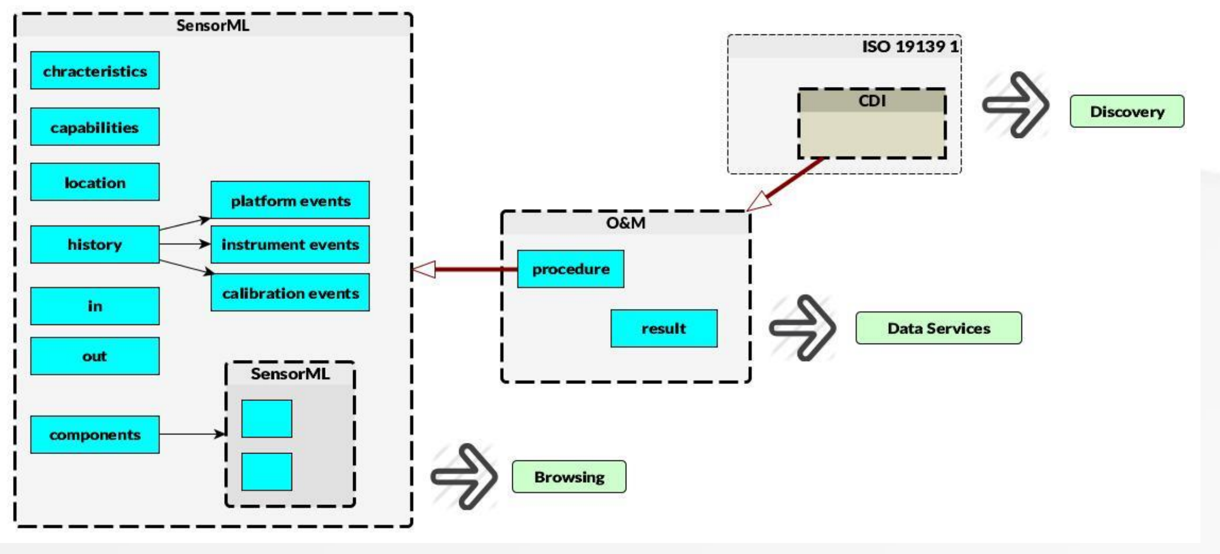


Figure 9 Framework to be used in research vessels and fixed stations data handling scenario based on a three layer approach (Discovery, Data Service and Browsing) following GeoSeas /SeaDataNet2 approach.

4. SensorML and O&M profile for Research Vessels

Research vessels are complex data acquisition systems, consisting of a large number of instruments and sensors producing complex observations for many different disciplines. The data and general metadata produced, is commonly disseminated using well established standards by the data centres. However, the on-board instruments and systems are not always well described, important information can be missed, for example the date when a new instrument was brought on board. The data flux from the vessels to the data centres is still a "road with interruptions". Important information like instrument calibration or operational data often does not reach the data centres. The OGC Sensor Web Enablement standards thus can provide solutions to serve complex data along with detailed description of the process used to obtain them.

Based on Sensor Web Enablement standards and rich semantics it is possible to describe and serve information related to the research vessels, the data acquisition systems used on-board, and the data sets resulting from the on-board work. This approach is designed to be used at sea but also at the Data Centres in order to avoid the loss of information in between. For this reason the proposed solution (I) must deal with the inherent difficulty to describe a multidisciplinary and complex mobile sensor system, (II) be easily integrated with the on-board data acquisition systems, (III) use the complex but incomplete most used vocabularies in marine disciplines, (IV) provide points of contact with the data and metadata services at the Data Centres, and (V) manage the changes in instrument set-up over the time.

Most part of the existing acquired data sets from research vessels have being acquired through proprietary software or by commercial packages. In contrast, the metadata, descriptions of data and instruments, are not well acquired and generated at sea. The production of metadata should be produced as close as possible in space and in time to the acquisition moment

One of the most significant characteristics of oceanographic ships is its dynamic character in terms of location and instruments composition. The vessel`s dynamic location impacts the description of the physical setting where the observations have been made. In SWE terminology, it is refer as the "feature of interest".

The vessel`s dynamic composition impacts the description of the ship allowing the continue reconfiguration of its components, while recording the history of changes. Appropriately capturing the dynamic composition of the vessel is a key to help in the data interpretation. For example, if an instrument was redeployed and the data changed significantly due to calibration errors. It is also important that the description of the vessel allows to record every success or "event" occurred on-board during a data acquisition episode. This last aspect is being elaborated in the development of the EARS system within the FP7 Eurofleets2 project.

4.1. Definition of the information blocks and their codification using SensorML and O&M

A research vessel can be considered as a platform, or as a system of systems, where there are installed a fixed number of "always on" instruments that run normally without human interaction, (called from now underway system), and where -depending the research discipline- a different group of instruments can be installed and putted in operation.

The output of the underway instruments are commonly called "underway data" and, from the survey point of view, in general, can be considered as general purpose data. The Navigation System, the Weather Station, the Thermosalinometer and the Gravimeter are commonly considered as underway instruments.

All other instruments that can be fixed or removable but only operated during specific research cruises should be considered apart and referenced through the vessel description in a different way.

In order to simplify the formal representation of this concept it is advised to place the different information parts which describe the whole in separated files related each other using different conceptual links.

Following this approach (Figure 10) individual files are considered for:

1. ***Vessel as platform***: With the necessary information to identify the ship, to precise its dimensions and capabilities, to locate it as a moving object and as a same time to define the axis of reference to locate the on-board instruments, to link to the underway instruments and to include at least links to the instrumental composition history and to the vessel events history.
2. ***Underway instruments***: Individually coded in separated files, with the necessary information to uniquely identify them (serial number, model and trade mark …), to describe the input signals and output values, to precise their operational parameters and its own calibration sheets history. Those instruments can be viewed also as complex systems occasionally when they combine individual instruments and sensors cooperating to provide conceptually grouped data. This last is the case of the Navigation System, composed by GPS, gyros, motion reference units and single beam ~~echosounders~~echo sounders that acting as a "virtual" individual instrument provides general purpose navigation information.
3. ***Survey instruments***: Those required only in specific surveys depending on the research discipline. Can be maintained apart and referenced to the vessel using the "instrumental composition history" record.
4. ***Observations***: Contain precise descriptions of the data provided by the underway instruments, embedding the values itself or linking to a source of information or data service.
5. ***Instrument composition history***: Is the relation of those instruments installed on-board and used during a specific time interval. It allows the reconstruction of instrumentation present on-board during a specific survey helping users to search for complementary data and to know precisely the instrumental composition of the whole system.
6. ***Event history***: Contains the list of events or facts related to the operation of the vessel during surveys. It helps users to track all of the works done on-board and also view all of the instrumental incidences during the survey. This last of special relevance for data quality assessment.
7. ***Calibration history***: It keeps the record of instrument calibrations and also sensor replacements and/or technical interventions.

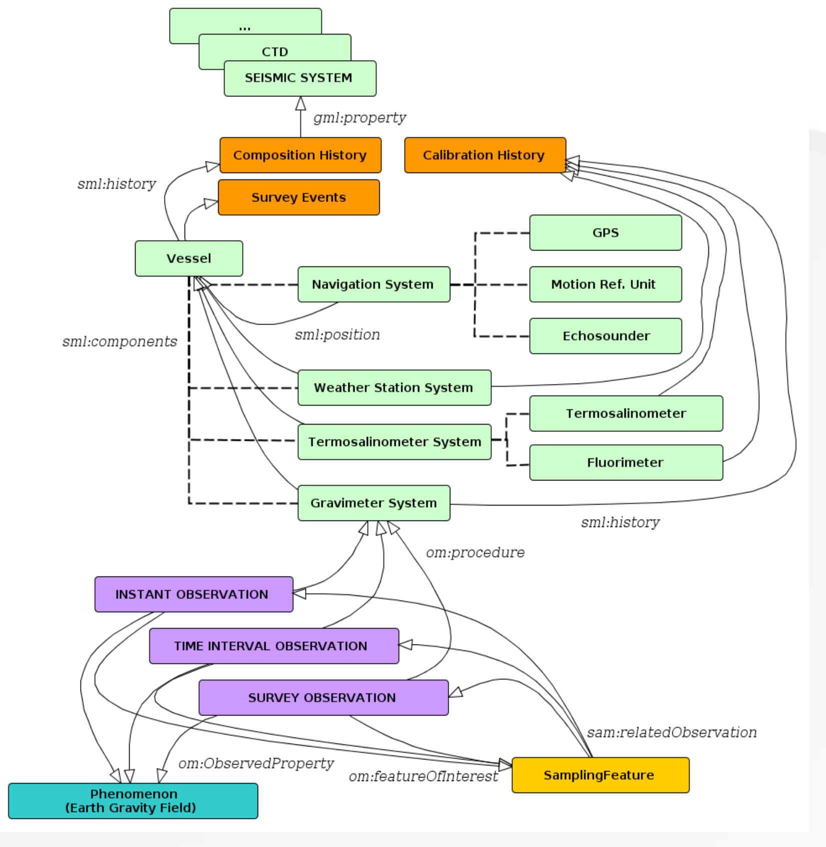


Figure 10- SensorML and O&M files used in the SWE implementation for research vessels. In green sml:SensorML elements, in purple om:OM_Measurements, and in orange sml:EventList components.

As a starting point, the underway instruments under consideration will be:

- Navigation System
- Weather Station System
- Thermosalinometer System
- Gravimeter System.

This list is not restrictive and should not be strictly reflected at the formal definition of the SensorML profile (schematron, SensorML2.0 “typeOf” tagging …)

Except observations, all of the above described pieces of information can be coded using SensorML schemas. Although all the working examples have been tested and validated using SensorML 1.01, an exercise over the new SensorML 2,0 schema has been done and all the comments and references to SensorML tags of this chapter and Annex examples have been referred to 2.0.

As stated in chapter 2.1 the new SensorML 2.0 schema offers several advantages over its precursor. Although it is not yet officially accepted by the OGC community its degree of maturity is enough to consider as the candidate to code SeaDataNet files.

As a test of validation, all the examples from the Annex, have been validated against the official schemas 1.0.1 and 2.0 and also a tentative action to register them in a SOS 2.0 instance from 52North has been made. Both versions SensorML1.0.1 and SensorML 2.0 have been validated using the schemas with no errors, while the registry at SOS (registerSensor using SOAP petitions) has been only successful for 1.0.1 files with minor changes. Results are shown in next table:

SensorML files	SensorML v1 SOS 2 52N server
Sarmiento_Gravimeter_System	Minor modification Change of x,y, z notation of the reference frame to: easting, northing, altitude
Sarmiento_Navigation_System	OK
Sarmiento_System	OK
Sarmiento_TermosalinometerFluorometer_System	Minor modification Change of x,y, z notation of the reference frame to: easting, northing, altitude
Sarmiento_WeatherStation_System	OK

Coding the vessel

The central part of the description element, used to characterize the vessel, is coded using SensorML Version 2.0.

This is modeled as a ***sml:PhysicalSystem*** normally used at the schema for composed systems. The minimum information blocks needed to describe a research vessel are (Figure 11):

1. ***gml:description:*** General description of the research vessel.
2. ***sml:identification:*** It contains the unique identifiers of the vessel to distinguish it from other ships. Contains the long name of the ship and the SeaDatNet code of the vessel
3. ***sml:validTime:*** Validity of the description. Useful when vessel has been changed any of its main characteristics or capabilities.
4. ***sml:characteristics:*** Used to capture the main physical features of the vessel, like length, breadth, draft, and gross tonnage.
5. ***sml:capabilities:*** Used to capture its operational characteristics like maximum working speed or the maximum days at sea.
6. ***sml:contact:*** Used to specify the vessel operator.
7. ***sml:documentation:*** Provides a link to an external source of information about the vessel as brochure or spec document. Addressable by using a specific url
8. ***sml:spatialReferenceFrame:*** This element is used to define the coordinate reference system and datum of the vessel, named VESSEL_FRAME used to reference the position of the different instruments on board relevant to the vessel system axis coordinates by the sml:position element.. By following this approach, all the observations made by the different instruments can be corrected to the same origin.
9. ***sml:position:*** It is used to locate the vessel as a dynamic platform. In order to maintain the SensorML file as much immutable as possible a link to the output definition is placed.
10. ***sml:outputs:*** Although the vessel can be seen as a simple platform that doesn't provide any data by itself an output to provide vessel location information can be considered. This provides the information referred by for sml:position needed to georeference properly any of the onboarded instruments at any time. To maintain the immutability of the file a xref link to any

real time protocol that provides vessel position can be referred instead of hardcoding the position values.

11. ***sml:components:*** This tag is used to reference by xlink the SensorML files that are used to describe the different underway instruments present any time on-board.
12. ***sml:history (1):*** The first sml:history element is used to record the history of all system "onboardings". This mimics a registry of all the systems that have been placed used onboard for a specific research cruise. By placing such sml:history in a separated file, and referred by xlink:href attribute, it is possible to maintain a single and immutable copy of the vessel SensorML file. The onboarding history is quite simple, coded using **sml:EventList** as root element it contains one **sml:event** entry for each complete period where an specific instrument is placed in operation for a survey (Figure 12). Each onboarding event contains an xlink to the specific definition of the instrument.
13. ***sml:history (2):*** The second sml:history element is used to record the history of events or facts related by vessel and instrument operations and incidences during surveys. This conforms the "log book" of the vessel and it provides valuable information to contextualize the acquired data during a survey. This has been developed on the basis of "Eurofleets Events" reports which concern with any fact or circumstance related with a research survey or navigation. This history is also represented as a separated file and referenced through xlink attribute (Figure 13).

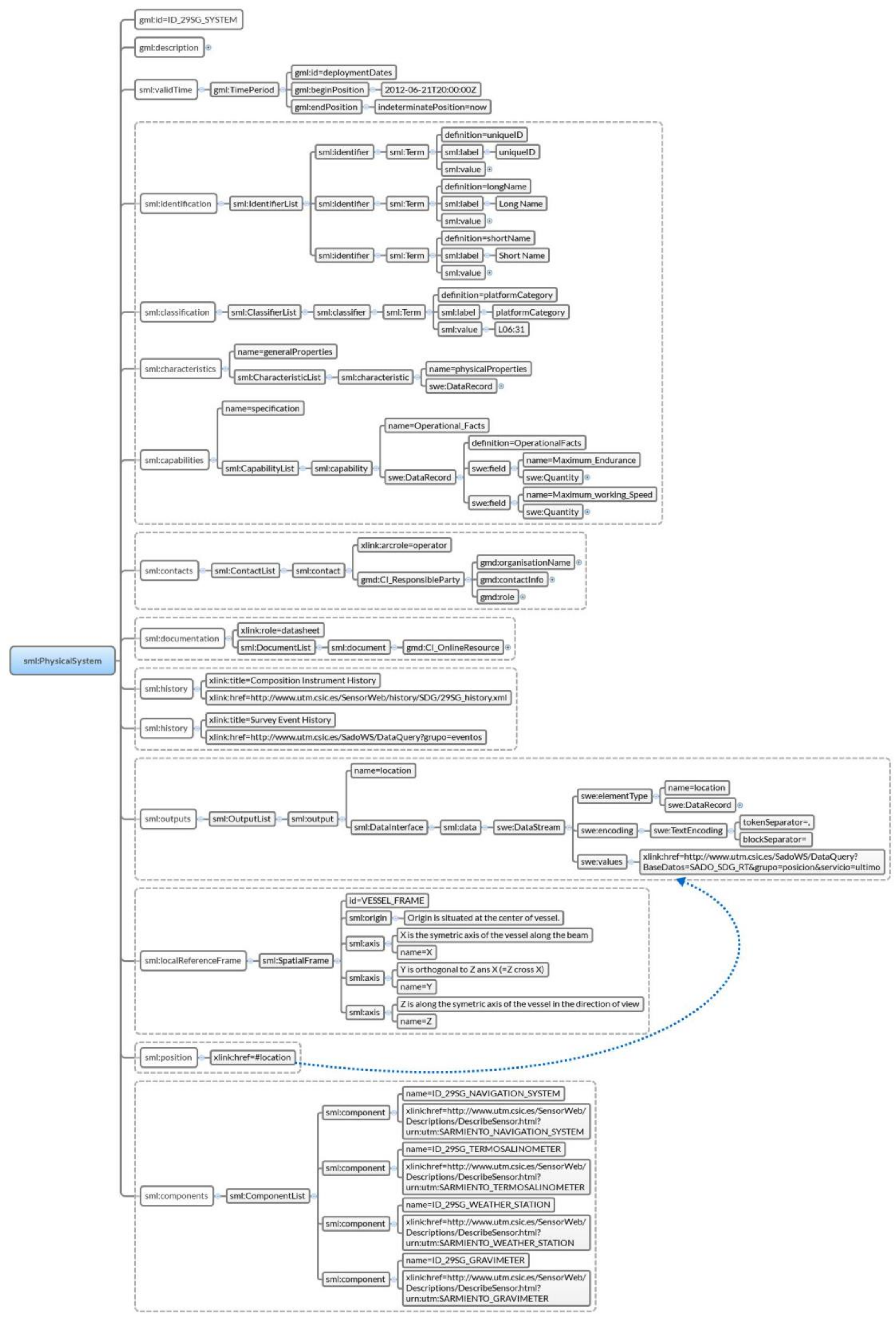


Figure 11 SensorML 2.0 expression for Research vessel system

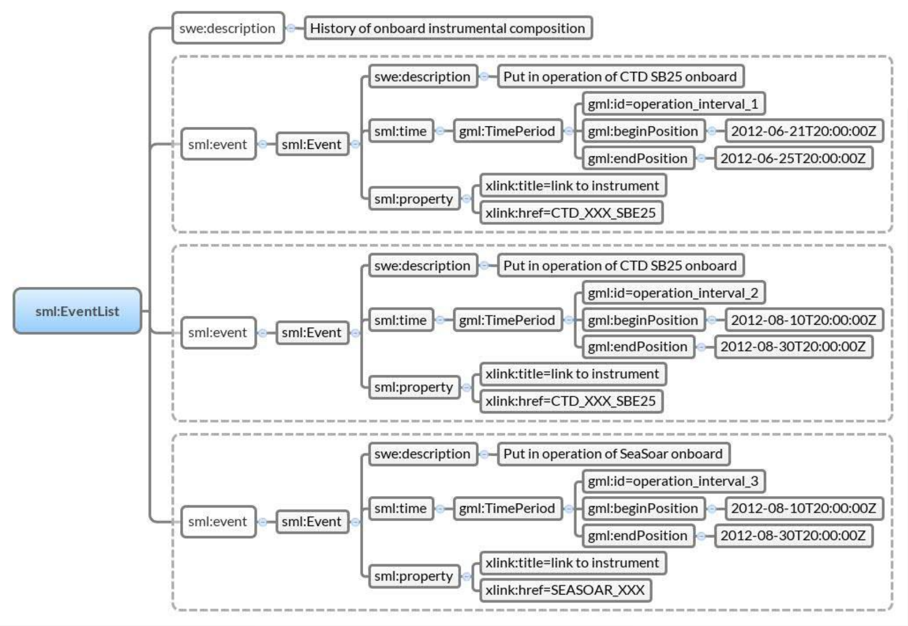


Figure 12 SensorML codification of on-boarded instrument history

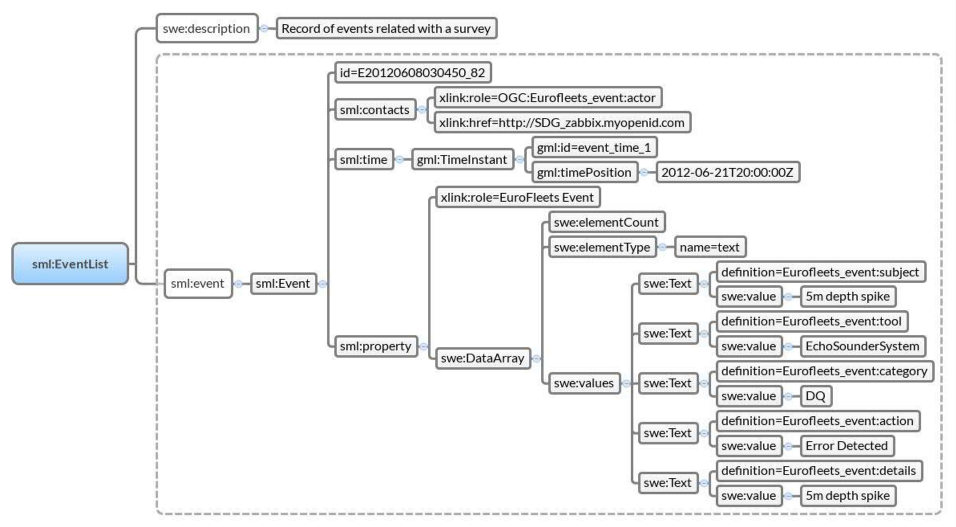


Figure 13 SensorML expression for survey events history as is coded in Eurofleets EARS

A set of general purpose pieces of information could be directly associated to the vessel system. They can be seen as a part of the metadata associated to the vessel and therefore should be included in the SensorML body but also, considering their dynamic behaviour (change their values by time), can be seen as data itself. For this last consideration an O&M file has been designed to provide information about the general facts of the research surveys like cruise id, cruise name and knowledge area or scientific discipline (Figure 14). The O&M file contains:

- Reference to the vessel SensorML description by using ***<om:procedure>*** tag
- The definition of the "observed propriety" that in this case is the definition of the "Survey Information" concept, by using ***<om:observedProperty>*** tag. This should point to a vocabulary entry where this concept is defined.
- For data search and classification purpose the definition of the feature of interest by using ***<om:featureOfInterest>*** tag. The feature of interest can be seen as the current vessel site as the shape of the observation (a 3D box) in a specific time. It should correspond to the current vessel location and as the vessel is a moving object a Dynamic Feature has been chosen to

describe it. The location values are coded using an internal xlink to one of the results of the observation that should provide the last positioning data

- For the data itself a ***<swe:DataRecord>*** element is used inside the ***<om:result>*** tag. This element provides all the general purpose information elements referred above. Most part of data coded in it will be text values.

This codification provides a good response to all the dynamic information, apart from survey events, contained in ***Eurofleets Ship Summary Report*** (SSR) structure. So in the near future the SSR should be constructed on the basis of the SensorML that describes the vessel plus the O&M file that provides last data related to the current survey.

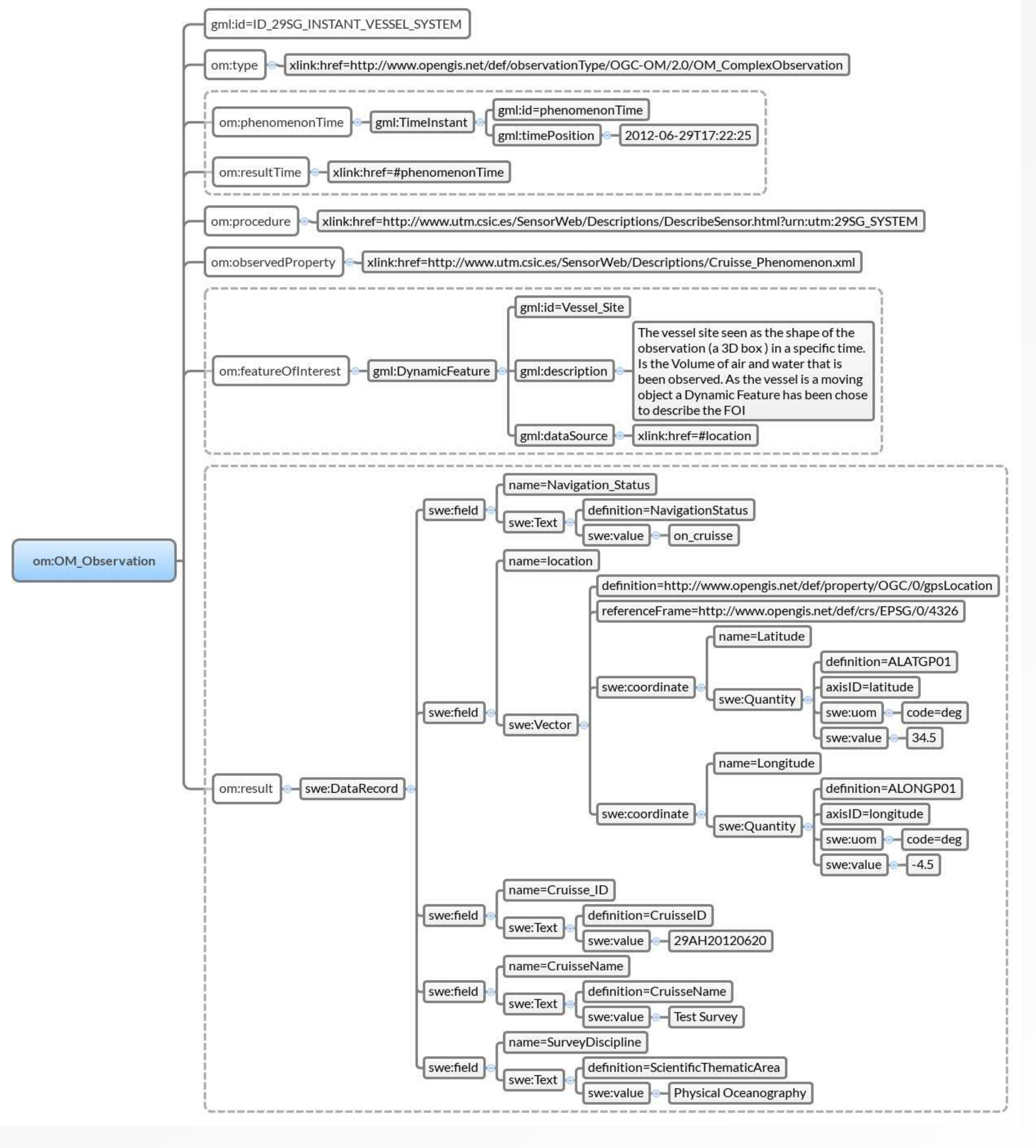


Figure 14 O&M expression for general purpose data associated to the vessel.

Coding the underway systems

Each one of the instruments corresponding to the underway category (always on and fixed to the vessel) should be coded in independent SensorML files using again the ***<sml:PhysicalSystem>*** root element. They are referenced from vessel description by use of xlink:href attribute inside ***<sml:component>*** tag.

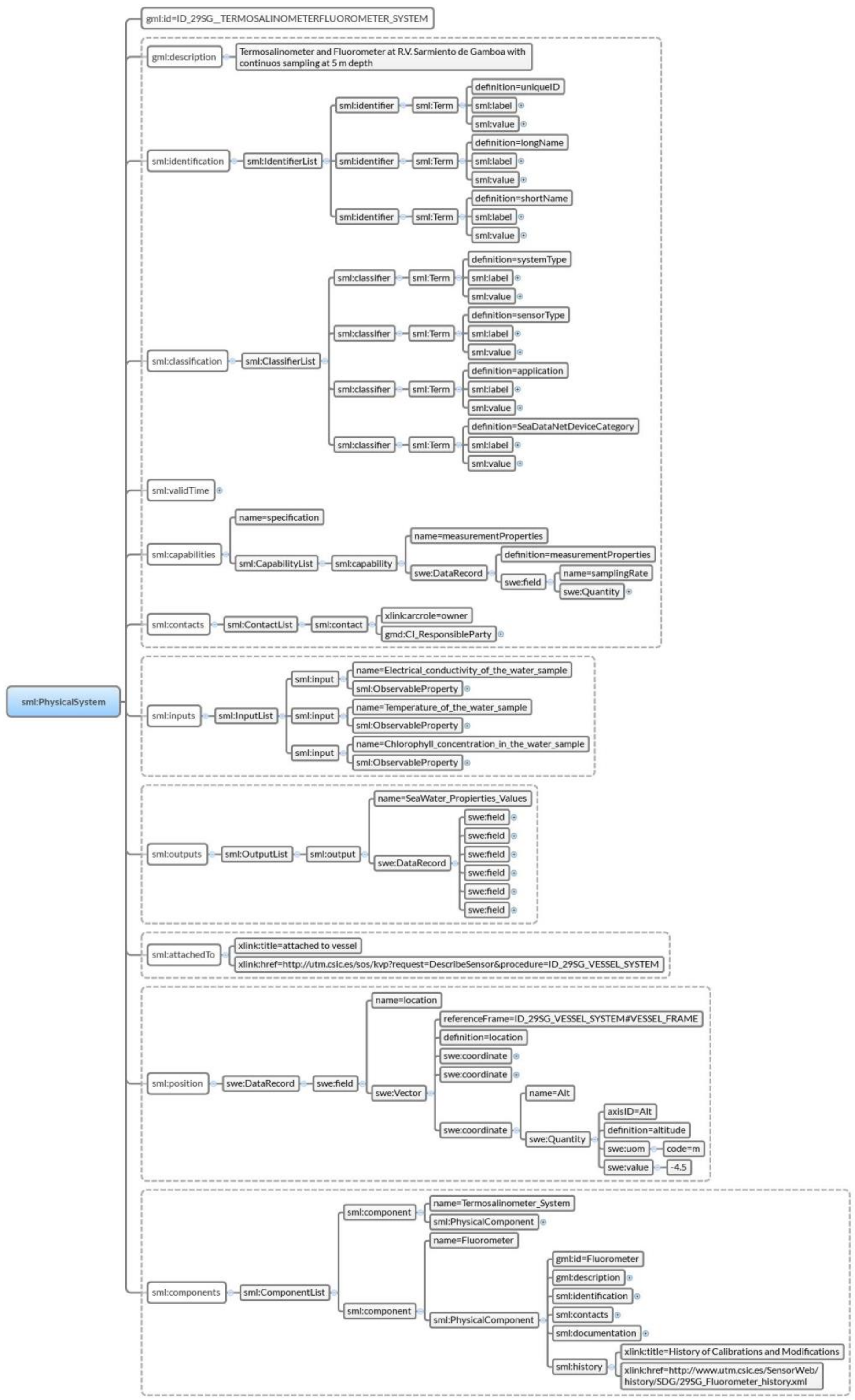


Figure 15 SensorML expression for an underway instrument (Thermosalinometer)

Depending on the instrument complexity more or less SensorMl elements could be added to the description, nevertheless these could be the minimum pieces of information that always should be taken in consideration (Figure 15):

- A group of tags for general instrument description, unique identification, classification to have a fast idea about the capabilities and purpose of the instrument.
- A list of inputs, using the tag ***<sml:inputs>,*** to identify which variables are directly measured by the instrument
- A list of outputs, using the tag ***<sml:outputs>,*** to identify which values are provided by the instrument. Some of them are correlated directly with the inputs or calculated using any internal logical process, as is the case of salinity that is calculated from the measured values of temperature and conductivity.
- An element to refer the vessel where is attached using the tag ***<sml:attachedTo>*** and a xlink attribute that points where the vessel SensorML description is.
- A list of components in case of the instrument can be physically divided and/or interesting to record individual information for each sensor or component as is the case of the calibration values and history.
- In case of the instrument has no individual components a reference to an ***<sml:history>*** should be maintained to store the occasional calibration facts or any other operational information (technical interventions, failures, etc.). The history element should point to an external individual file to maintain as much as possible the immutability of the sensorML file (Figure .16).
- A description of the location of the instrument with a reference to the vessel axis frame using ***<sml:position>*** tag. With this information is possible to locate precisely all the measurements obtained. This is relevant when corrections derived from the vessel navigation vector should be applied as is the case of wind and gravity field data.

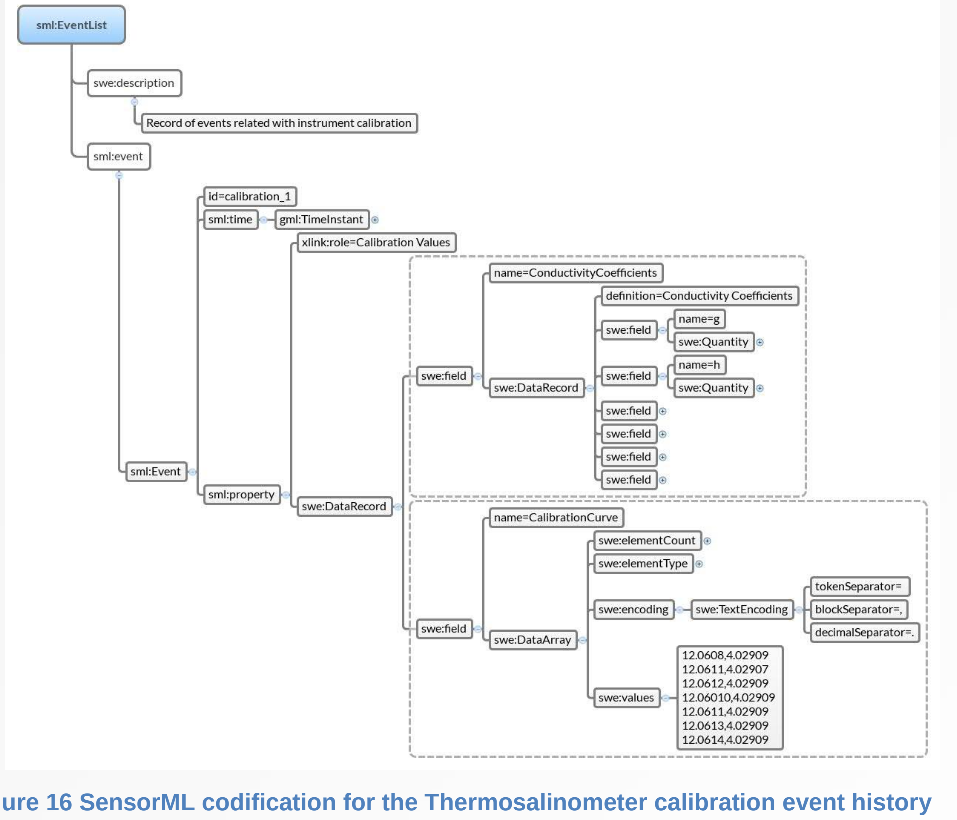


Figure 16 SensorML codification for the Thermosalinometer calibration event history

O&M expression should be used to code the observations produced by every "underway" instruments where the final objective is to reach the underway data by the use of SOS interfaces like ***getObservation***. As is mentioned for the underway instruments descriptions the level of detail in O&M files could be different for the different type of data but at least these are the information elements to be maintained as a mandatory (Figure 16):

- Reference to the underway instrument SensorML description by using ***<om:procedure>*** tag

- The definition of the "observed propriety" different for each underway observations, by using ***<om:observedProperty>*** tag. This should point to a vocabulary entry where this concept is defined.
- For data search and classification purpose the definition of the feature of interest by using ***<om:featureOfInterest>*** tag. The feature of interest can be seen as the current vessel site as the shape of the observation (a 3D box) in a specific time. It should correspond to the current vessel location and as the vessel is a moving object a Dynamic Feature has been chose to describe it. The position values are coded using an xlink to the vessel #location element.
- To code the observation data ***<swe:DataRecord>*** or ***<swe:DataArray>*** elements are used inside the ***<om:result>*** tag. They provide the necessary information to understand the data and also the values themselves that can of any type. The codification of the values can be hardcoded embedding them into the O&M file or can be referenced to and external data service that provides finally the data accordingly to the format reported in this tag. This last is specially is useful to reference big datasets corresponding large time intervals but also is valuable when is planned to maintain or integrate existing data services.

Three types of observations for the underway data can be considered depending on the time interval requested:

- An observation for a defined time interval.
- An observation for a specific instant (Figure 17).
- An observation for a specific cruise or survey (Figure 18).

The last two are refinements of the first one but they have been considered separately because they have a special functional meaning in the context of a research vessel. The data of a specific instant is intensively used by the onboard "last value data consumers" (like graphical data visual interfaces), while the data related with a cruise is normally referred by the name of the cruise not by the start and end dates of the survey. However, they all should match with O&M pre-defined sampling features: trajectory, swath, point, profile, etc.

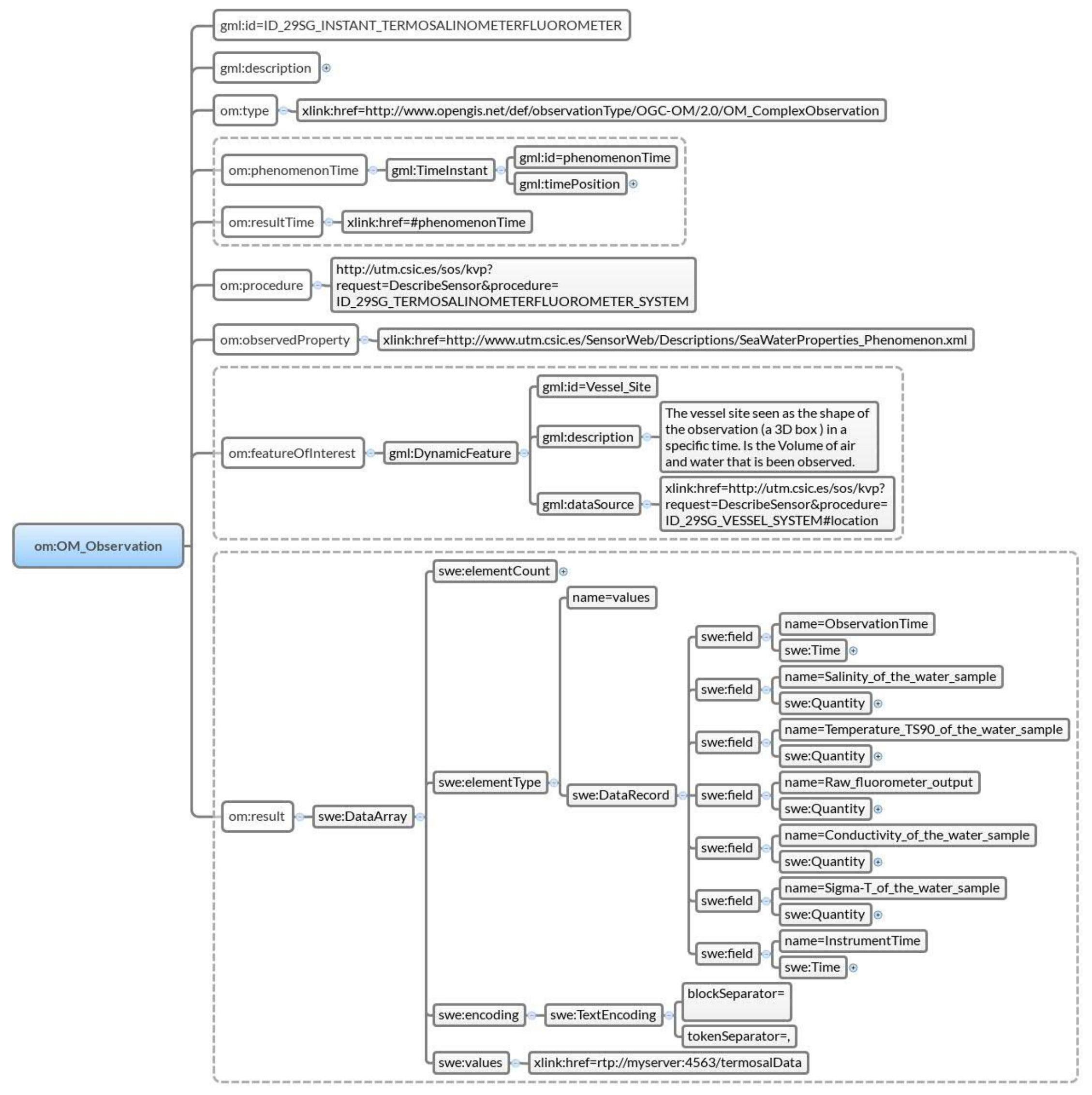


Figure 17 O&M expression for real time data provided by a Termosalinometer.

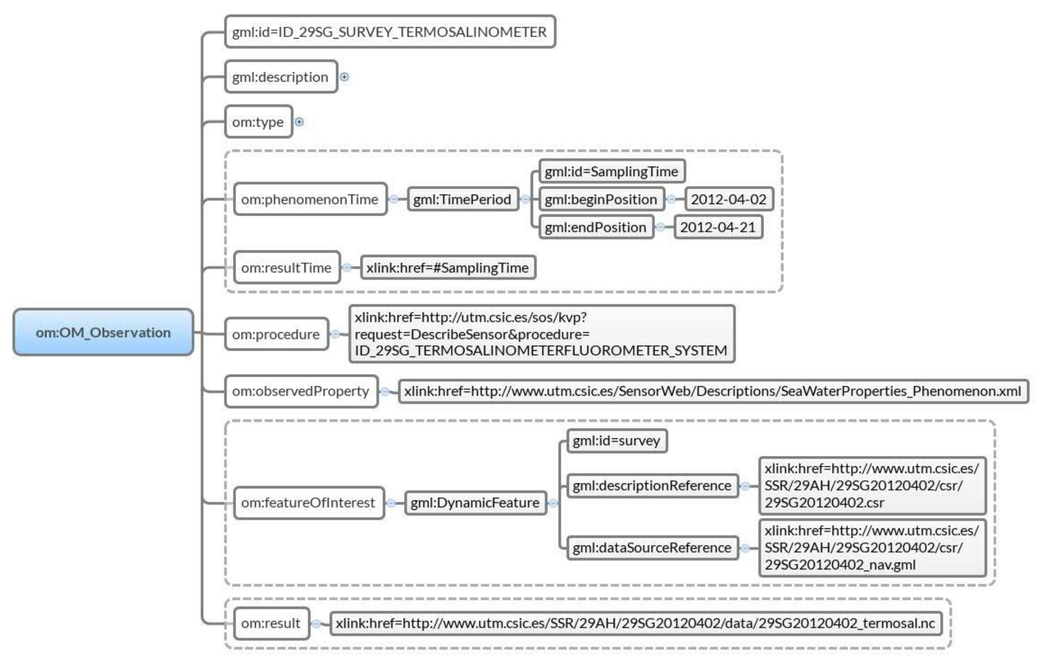


Figure 18 O&M expression for survey data provided by a Termosalinometer

4.2. Examples of implementation

Both SensorML and O&M approaches for research vessels has been tested using real information from two Spanish research vessels, B/O Sarmiento de Gamboa and BIO Hesperides and their underway instrumentation composed by: Navigation system, Weather Station, Termosalinometer with Fluorimeter and a Gravimeter. All the files generated are included as annex only considering one of the vessels for simplicity.

SensorML and O&M files are online accessible at the following url :

http://www.utm.csic.es/SensorWeb/Descriptions.

Two root folders, 1.0 and 2.0 has been made to place the descriptions in SensorML 1.0.1 schema and in SensorML 2.0 schema.

5. SensorML and O&M profiles for Fixed Stations

The inspiration for constructing the SensorML and O&M profiles for Fixed stations (fixed buoys, land station, submarine observatories, etc.) arises from the European Directory of the initial Ocean-observing Systems (EDIOS) concepts.

EDIOS is an initiative of EuroGOOS and is maintained and operated by SeaDataNet. It gives an overview of the ocean measuring and monitoring systems operated by European countries. The directory is a prerequisite for the full implementation of EuroGOOS providing an inventory of the continuously available data for operational models. This information provides the basis for optimal deployment of new instruments, and the design of sampling strategies. This directory includes discovery information on location, measured parameters, data availability, responsible institutes and links to data-holding agencies plus some more technical information on instruments such as sampling frequency.

The EDIOS metadata service provides a tool for searching for information on oceanographic measurements made repeatedly, regularly and routinely in European waters. EDIOS is an information system for marine observing and monitoring programmes, stations and platforms (including moored buoys, coastal installations, seabed stations, drifting buoys, repeated sections and sampling stations, airborne repeated tracks, etc) where there are routine, repeated, and consistent long-term observations of the marine environmental conditions, and where the data are made available for use in real-time, or near real-time. This directory includes discovery information on location, measured parameters, data availability, responsible institutes and links to data-holding agencies.

5.1. Definition of the information blocks and their codification using SensorML and O&M

The first step to build SensorML and O&M profiles for fixed stations is to identify the minimum and necessary information pieces necessary to describe such systems. This has been accomplished looking at the elements that conforms the EDIOS metadata entries and more precisely the EDIOS Platforms and the EDIOS Series for the physical systems and for the data respectively. The resulting entities and information block are outlined in Figure 19.

The idea is to maintain separate files for platforms, instruments, calibrations, operational events and measurements in order to gain flexibility and maintain the files as much immutable as possible putting all the dynamic elements in external links or references.

The independent but linked files are:

- Platform
- Instrument
- Operational events
- Calibration events
- Data sets

Platforms are representative of the same concept used in research vessels; they are the container part and are modelled as a system of systems and jointly with ***instruments*** constitute the core of the information present in ***EDIOS Platforms***.

Operational events provide information about all the operational facts and episodes related with the operation of the fixed stations and instruments, as failures, start-ups, commissioning, and technical interventions.

Calibration events records any calibration episode with parameters, calibration curves and algorithms used.

Data sets are designed to hold the description of the data recorded by instruments at platforms and to provide links to values of them. Constitute the core of the information present in ***EDIOS Series***.

Coding Platforms, Operational and Calibration Events

Platforms should contain the following information pieces:

- ***Identification***: Including a unique id, a short name and the definition of the platform class accordingly to SeaDataNet vocabularies.
- ***Who***: It is used to identify the owner of the platform, the operator, and to which country it belongs
- ***Location***: Although stations and their instruments have a fixed position in this scenario, characterization of their position is relevant to contextualize data regionally, and to allow geo searching.
- ***How:*** It is used to specify the platform instrumental composition.
- ***History***: used to handle the logbook of operational events.

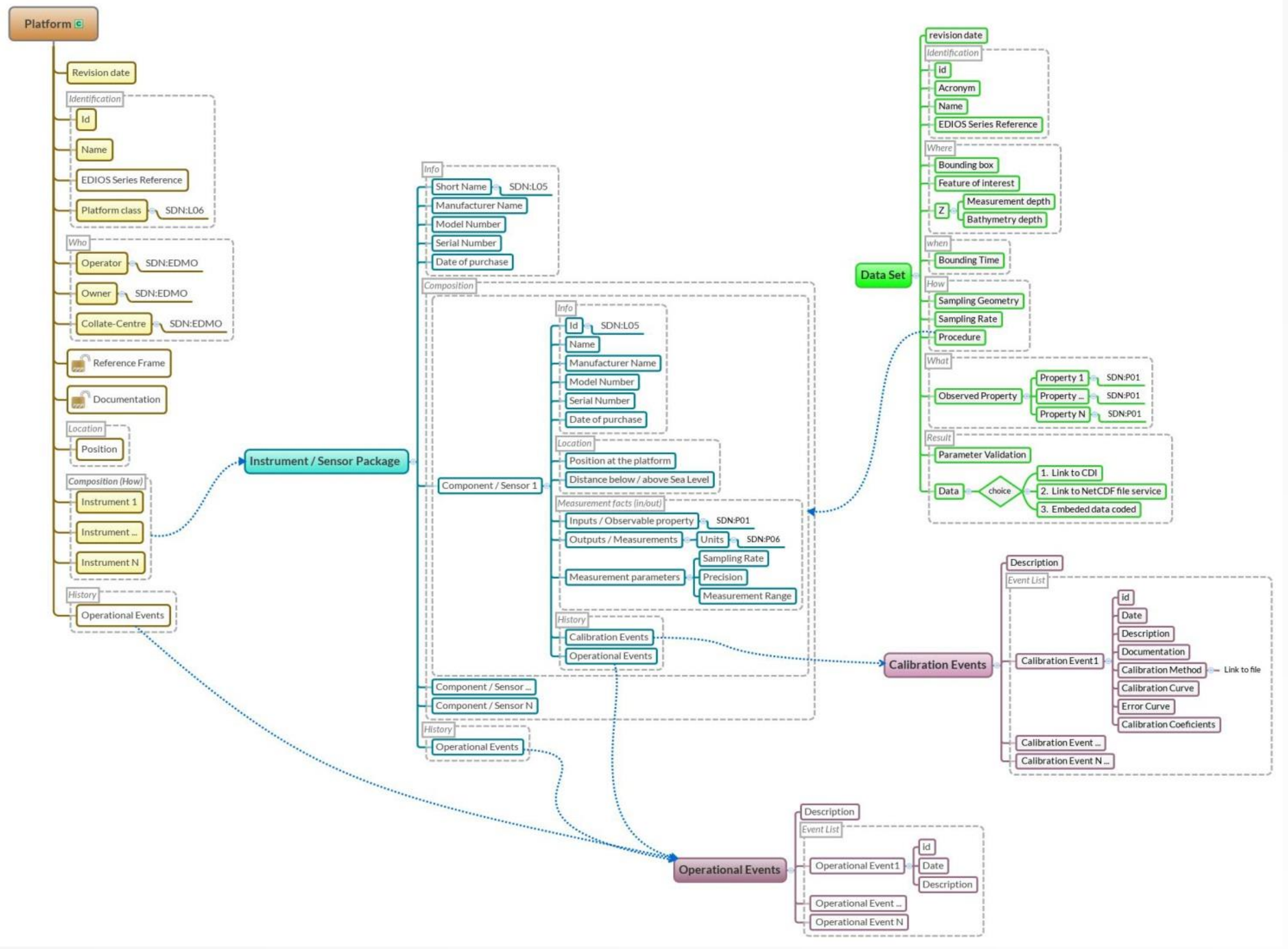


Figure 19 Information blocks needed to describe fixed buoys and stations and their data series.

These pieces of information can be coded using SensorML 2.0 as follows (Figure 20):

- For general description, classification and capabilities using ***<gml:description>***, ***<sml:identification>*** with identifier containing EDIOS platform reference code, ***<sml:classification>, <sml:contacts>*** and ***<sml:capabilities>***
- For additional information a ***<sml:documentation>*** that is able to link with online external brochures and also to the EDIOS portal or EDIOS program where the fixed station is referenced
- For tracking the instrumental composition of the station a ***<sml:history>*** tag. In the same way as used for research vessels an external file containing a ***<sml:EventList>*** root element will record all of changes in the station instrumentation maintaining the sensorML file immutable as much as possible. This composition history is designed specifically to track the installation of occasional instruments while the ***<sml:composition>*** element (mentioned below) will

record the fixed ones. The EventList file can be also used to record all the maintenance operations and operational facts related to the structure of the station.

- For referencing the location of the station but also for the definition of the axis of coordinates to where all the mounting instruments should be referenced, a pair of ***<sml:LocalRefrenceFrame>*** and ***<sml:position>*** tags.
- For referencing all the instrumentation installed on the station a ***<sml:composition>*** tag. In the same way as stated in research vessels, any ***<sml.component>*** will contain a xlink to an external SensorML file describing precisely the current instrumental composition attending to those instruments that are always present at the station.

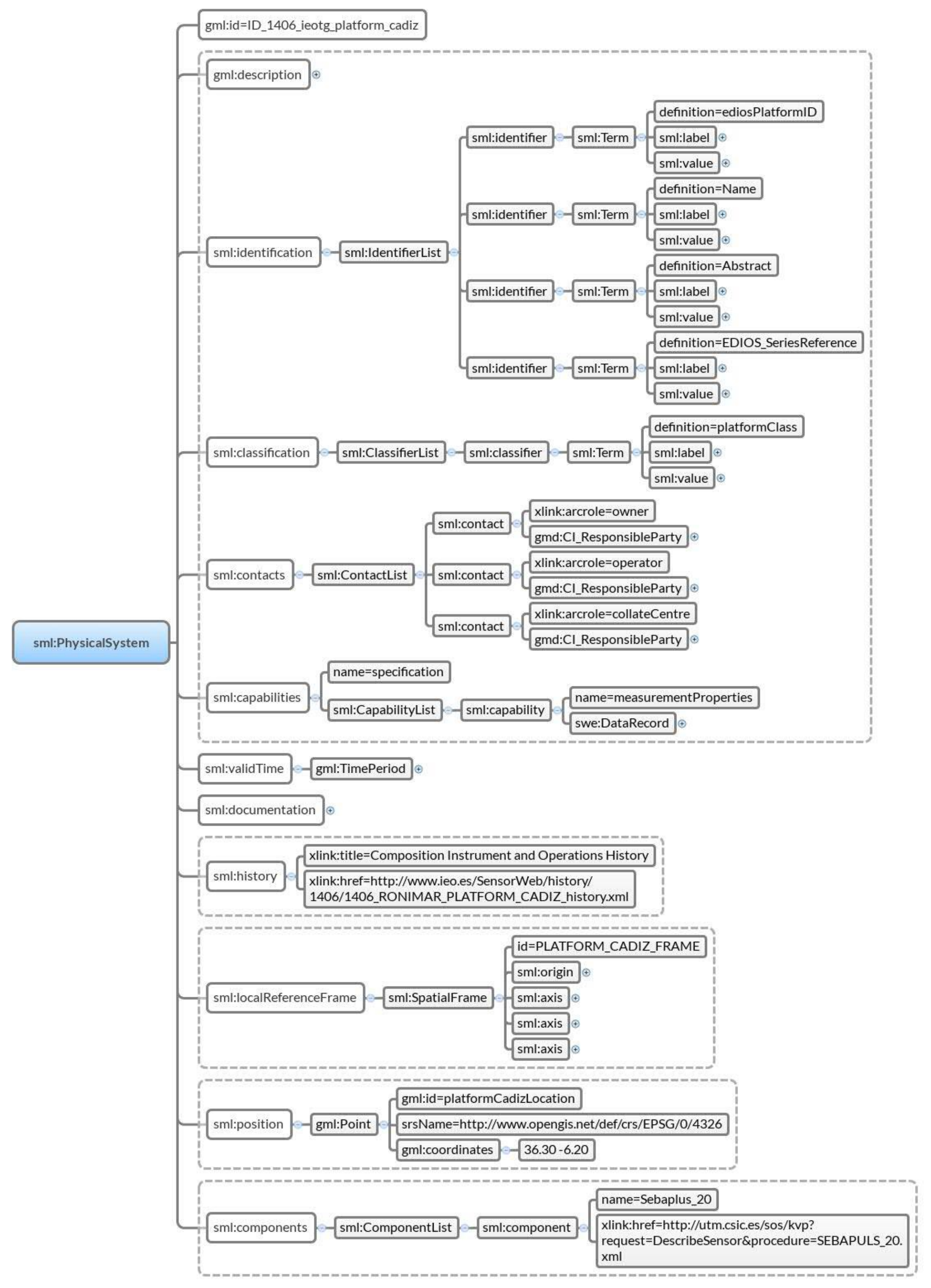


Figure 20 SensorML expression for an EDIOS platform

The specific description of the instrumentation installed on a fixed station can follow the same minimal profile that is formerly described for underway instruments.

Depending on the instrument complexity more or less SensorMl elements could be added to the description, nevertheless these could be the minimum pieces of information that always should be taken in consideration (same approach as in Figure 15):

- A group of tags for general instrument description, unique identification, classification to have a fast idea about the capabilities and purpose of the instrument.
- A list of inputs, using the tag ***<sml:inputs>,*** to identify which variables are directly measured by the instrument
- A list of outputs, using the tag ***<sml:outputs>,*** to identify which values are provided by the instrument. Some of them are correlated directly with the inputs or calculated using any internal logical process, as is the case of salinity that is calculated from the measured values of temperature and conductivity.
- An element to refer the vessel where is attached using the tag ***<sml:attachedTo>*** and a xlink attribute that points where the fixed station SensorML description is.
- A list of components in case of the instrument can be physically divided and/or interesting to record individual information for each sensor or component as is the case of the calibration values and history.
- In case of the instrument has no individual components a reference to an ***<sml:history>*** should be maintained to store the occasional calibration facts or any other operational information (technical interventions, failures, etc.). The history element should point to an external individual file to maintain as much as possible the immutability of the sensorML file (same approach than in Figure .16).
- A description of the location of the instrument with a reference to the fixed station axis frame using ***<sml:position>*** tag. With this information is possible to locate precisely all the measurements obtained.

Coding Data Series

The definition of the necessary information elements needed to describe the data series related to a fixed station has been made on basis of the EDIOS Series metadata entries. The included information blocks are:

- An "***Identification"*** group to reference de data series containing id, name, acronym and EDIOS Series Reference id
- A "***Where"*** group to reference the geographic bounding box, locate the measurements in depth and respect to bathymetry and characterize the feature of interest
- A "***When"*** group to reference temporally the data
- A "***What"*** group to describe the observed properties related to the "observation". These are straight forward to P01 vocabulary definitions.
- A "***Result***" group containing the link to the data values. This can be a link to a EDIOS data series provided by SeaDataNet currently used data services or embed/link the last data values corresponding a Real Time scenario.

These information blocks can be coded using O&M 2.0 schema as follows (Figure 21):

- Reference to the instrument SensorML description by using ***<om:procedure>*** tag
- Define the "observed propriety" by using ***<om:observedProperty>*** tag. This should point to a vocabulary entry where this concept is defined like P02.
- For data search and classification purpose the definition of the feature of interest by using ***<om:featureOfInterest>*** tag. The feature of interest can be seen as the geographic region where the station is placed so can be referenced using a gazetteer entry.
- To code the observation data ***<swe:DataRecord>*** or ***<swe:DataArray>*** elements are used inside the ***<om:result>*** tag. They provide the necessary information to understand the data and also the values themselves that can be of any type. The codification of the values can be hardcoded embedding them into the O&M file or can be referenced to and external data service that provides finally the data accordingly to the format reported in this tag. This last is specially useful to reference big datasets corresponding to large time intervals but also is valuable when it is planned to maintain or integrate existing data services.

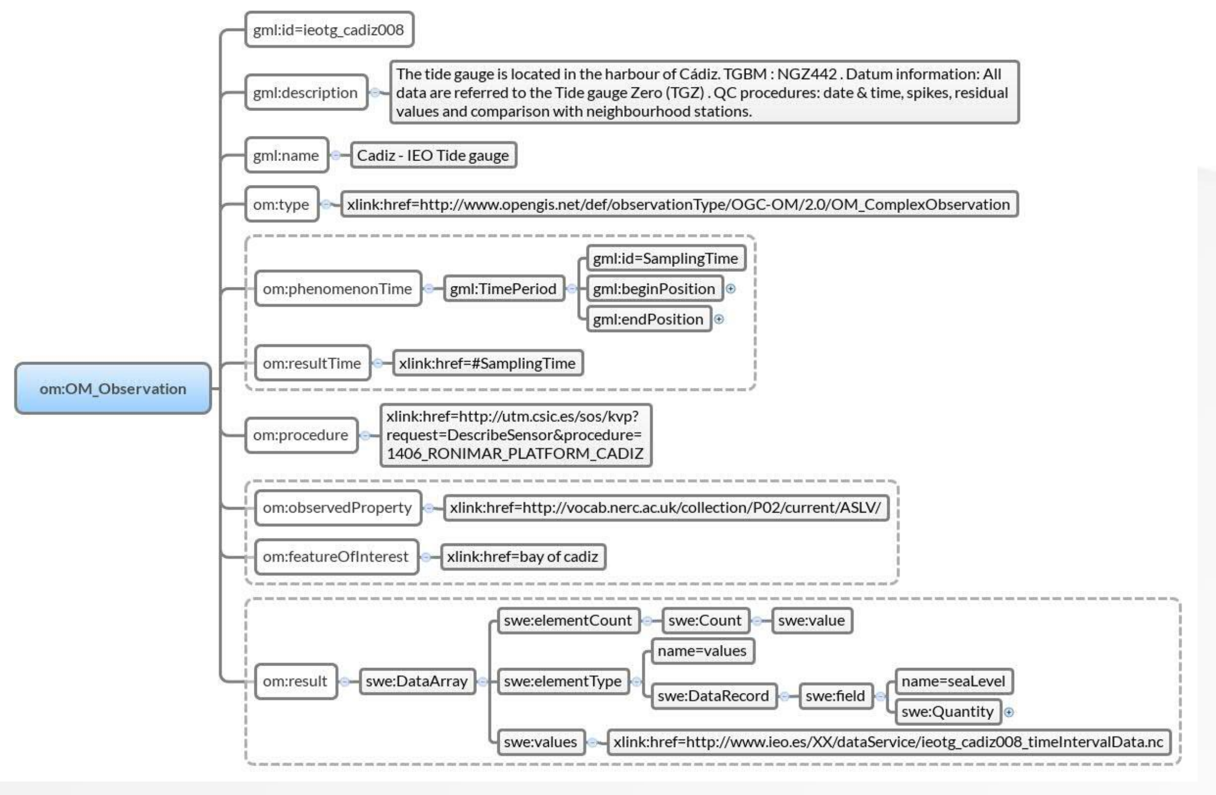


Figure 21 O&M expression for a EDIOS data series related to a specific EDIOS platform (referenced by a procedure SensorML file)

5.2. Examples of implementation

The SensorML and O&M approach for fixed stations has been tested against real examples coming from Instituto Español de Oceanografia (IEO) Edios entries. For simplicity it has been included in the annex. It concerns a RONIMAR program station located in Cadiz with a tide gauge.

SensorML and O&M files are online accessible at the following url :

http://www.utm.csic.es/SensorWeb/Descriptions.

To describe these fixed stations it has been used only the SensorML 2.0 schema.

6. Relax NG profiles

6.1. Why use Relax NG?

RelaxNG is a schema language for XML that specifies a pattern for the structure and content of an XML document.

In fact, RelaxNG is itself XML document, but it also offers a popular compact non-XML syntax. Compared to other XML schema languages, it is very simple, the syntax is intuitive and it is easy to learn, is an evolution and generalization of XML DTD's. Its major goal is that it be easy to learn and easy to use. This schema makes sure that all the required elements and attributes are present, and that some of these have the correct datatype.

Only one Relax NG file is needed to validate all instruments.

6.2. Schematron + RelaxNG

Schematron is a language for making assertions about the presence or absence of patterns in XML documents.

Its possible to add some Schematron rules in RelaxNG profile. Using both rules, we will apply ISO/IEC 19757.

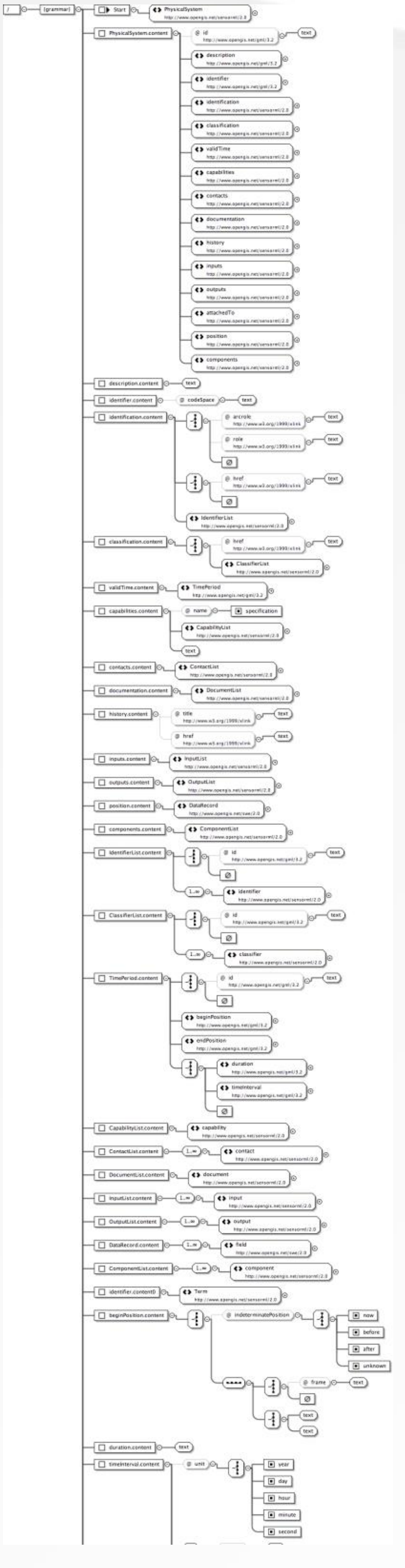
Embedding Schematron rules in Relax NG is very simple because a Relax NG validator ignores all elements not in Relax NG namespace. This means that Schematron rules can be embedded in any element and on any level in Relax NG Schema.

The RelaxNG schema makes sure that all the required elements and attributes are present, and that some of these have the correct datatype. For example, all degrees values must have an integer value; the id of an item must be three digits, followed by a hyphen, followed by two uppercase letters…

On the other hand, Schematron rules specify its context as all items with a parent and his grandparents.

Thus, Schematron and Relax NG make the perfect combination to work.

6.3. Profile map example



7. Relevant issues found during examples codification

During testing of the formulated SensorML and O&M profiles by use of real examples, several relevant issues have been found basically related with the definition of identifiers, use of vocabularies and use of external links to refer connected SensorML and O&M pieces.

Unique ID

On the SeaDataNet global scenario where it is intended to describe multiples platforms and instruments from different countries and institutions a key for the success or at least for reducing complexity should be the establishment of a common way to define object identifiers. Any SensorML or O&M should have a <***gml:id***> object to be used in the future as an entry point for SOS requests or used by any other search services.

Apart from some restrictions imposed by the gml schema (Ids can't start by numeric values or have some characters like spaces) there is not a general rule on how construct them. To have a common rule in SeaDataNet II to construct them will help later in the implementation phase.

Vocabularies

There are a lot of elements in SensorML and O&M that need a reference to a vocabulary entry, most of them related to the variables measured by the instrumentation but also to the general descriptions.

Unfortunately not all of them are present (yet) in the SeaDataNet vocabularies library, and a considerable amount of these terms are not referred also in any well-known vocabulary database.

The other issue related with the use of vocabularies is the convenience to use URL or URN and the establishment of the necessary mechanism to ensure stability of references along time (especially when using URL).

The next table is a relation of the terms used in the examples and the URL links providing the correspondent definitions.

Term	URL to an existing and known vocabulary entry	Use
uniqueID	http://mmisw.org/ont/ioos/definition/sensorID.html	SML:Identification GML:Identification
longName	http://mmisw.org/ont/ioos/definition/longName	SML: Identification
shortName	http://mmisw.org/ont/ioos/definition/shortName	SML: Identification
manufacturerName	http://mmisw.org/ont/ioos/active_acoustic_metadata/instrument_transducer_manufacturer.html	SML: Identification
modelNumber		SML: Identification
systemType	http://www.opengis.net/def/property/OGC/0/PlatformType SDN:L06	SML:Classification – Classifier
sensorType	http://vocab.nerc.ac.uk/collection/L05/current/accepted http://www.opengis.net/def/property/OGC/0/SensorType	SML:Classification – Classifier
sensorApplication		SML:Classification – Classifier
SeaDatanetDeviceCategory	SDN:L05:20:102	SML:Classification – Classifier
measurementProperties		SML:Capabilities
samplingRate	http://mmisw.org/ont/noaa/noaa-waves/Sample_Rate.html	SML:Capabilities
owner (rol)		SML:Contacts
manufacturer (rol)		SML:Contacts
Location (sensor)	http://www.opengis.net/def/property/OGC/0/SensorLocation	OM:featureOfInterest SML:position SML:outputs SML:inputs
gravity field of the earth	http://vocab.nerc.ac.uk/collection/P01/current/GRAVFLDX	SML:outputs SML:inputs
Accuracy	http://mmisw.org/ont/ioos/parameter/sensor_accuracy.html	SML:outputs
Measurement Range		SML:outputs

drift	http://seadatanet.maris2.nl/v_bodc_vocab_v2/browse.asp?order=conceptid&formname=search&screen=0&lib=p01&v0_0=drift&v1_0=conceptid%2Cpreflabel%2Caltlabel%2Cdefinition%2Cmodified&v2_0=0&v0_4=&v1_4=modified&v2_4=9&v0_5=&v1_5=modified&v2_5=10&x=61&y=15&v1_6=&v2_6=&v1_7=&v2_7=	SML:output - quality
spring tension		SML: output
Latitude	http://sensorml.com/ont/swe/property/Latitude.html	SML: position, SML:output
Longitude	http://sensorml.com/ont/swe/property/Longitude.html	SML: position, SML:output
Altitude	http://sensorml.com/ont/swe/property/Altitude.html	SML: position, SML:output
Position	http://sensorml.com/ont/csm/property/PLATFORM_GEOLOC	SML:output
Attitude	http://sensorml.com/ont/swe/property/Orientation.html	SML:output
Depth (seaFloor Depth)	http://www.opengis.net/def/verticalDatumType/OGC/1.0/depth http://mmisw.org/ont/cdip/term/DEPTH.html	SML: position, SML:output
True heading	http://mmisw.org/ont/ioos/parameter/heading.html	SML:output
Pitch	http://mmisw.org/ont/ioos/parameter/pitch.html	SML:output
Roll	http://mmisw.org/ont/ioos/parameter/roll.html	SML:output
vessel speed		SML: position, SML:output
user manual		SML: documentation
Satellite positioning system	http://mmisw.org/ont/cdip/term/GLOBAL_POSITIONING_SYSTEM_GPS.html	SML:component
Platform attitude sensor	http://vocab.nerc.ac.uk/collection/L05/current/385/	SML:component
Platform category		SML: classification
Length	http://www.opengis.net/def/dataType/OGC/1.1/length	SML: characteristics
max breadth		SML: characteristics
design draft		SML: characteristics
gross tonnage		SML: characteristics
operational facts		SML: capabilities
maximum endurance		SML: capabilities
maximum working speed		SML: capabilities
course	http://vocab.nerc.ac.uk/collection/P01/current/APDAGP01/	SML:output
cog	http://vocab.nerc.ac.uk/collection/P01/current/APDAGP01/	SML:output
sog	http://vocab.nerc.ac.uk/collection/P01/current/APSAGP01/	SML:output
timestamp	http://www.opengis.net/def/property/OGC/0/SamplingTime http://www.opengis.net/def/property/OGC/0/PhenomenonTime http://www.opengis.net/def/property/OGC-EO/0/TimeSeries	OM: result
Electrical conductivity of the water sample	http://vocab.nerc.ac.uk/collection/P02/current/CNDC/ http://vocab.nerc.ac.uk/collection/P01/current/CNDCMV01/	SML:output
Temperature of the water sample	http://vocab.nerc.ac.uk/collection/P02/current/TEMP/	SML:output
Chlorophyll concentration in the water sample	http://vocab.nerc.ac.uk/collection/P02/current/CPWC/	SML:output
Sigma-T of the water sample	http://vocab.nerc.ac.uk/collection/P01/current/SIGTEQST/	SML:output
Salinity of the water body	http://vocab.nerc.ac.uk/collection/P01/current/PSLTZZ01/	SML:output
Raw fluorometer output		SML:output
ObservationTime		OM:result, SML:output
Temperature Detector		SML:component
Conductivity Detector		SML:component
Pressure Detector		SML:component

Salinity	http://vocab.nerc.ac.uk/collection/P01/current/PSLTZZ01/	SML:output, SML:simpleProcess
Wind speed Gust	http://vocab.nerc.ac.uk/collection/P01/current/EGTSS15S/	SML:output
Wind from direction Gust	http://vocab.nerc.ac.uk/collection/P01/current/EGTDSS01/	SML:output
Air temperature	http://vocab.nerc.ac.uk/collection/P02/current/CDTA/ http://vocab.nerc.ac.uk/collection/P01/current/CDTAZZ01/	SML:output
Atmospheric humidity	http://vocab.nerc.ac.uk/collection/P02/current/CHUM/	SML:output
Solar Radiation	http://vocab.nerc.ac.uk/collection/P02/current/CSLR/	SML:output
Air pressure	http://vocab.nerc.ac.uk/collection/P02/current/CAPH/ http://vocab.nerc.ac.uk/collection/P01/current/CAPASS01 http://vocab.nerc.ac.uk/collection/P01/current/APRESSTN	SML:output
Temperature of the water column	http://vocab.nerc.ac.uk/collection/P01/current/TEMPPR01/	SML:output
Navigation system		SML:input
wind speed	http://vocab.nerc.ac.uk/collection/P01/current/EWSBZZ01/	SML:output
wind speed gust	http://vocab.nerc.ac.uk/collection/P01/current/EGTSS15S/	SML:output
ObservationTime	http://mmisw.org/ont/ioos/swe_element_type/observationTimeRange http://mmisw.org/ont/ioos/swe_element_type/observationTimeRange.html	SML:output
srsName, referenceFrame	http://www.opengis.net/def/crs/EPSG/0/4326	SML: position (reference frame)

Links and references

During the profiles design phase and the implementations of the examples the necessity to use links between different SensorML descriptions has been revealed as necessary to ensure the immutability of most “static” descriptions. This way one can use links in the ***<sml:component>*** and ***<om:procedure>*** tags that are supposed to address to the referenced SensorML descriptions.

There are several possibilities to encapsulate these links:

- A simple URL to this SensorML file located in an http server
- A directly call to the SOS service that stores these descriptions.
- An simple URL that hides the complexity of the SOS call

First one is simpler but is lacks the standardization procedure to get the file (so a consensus should be reached on how to build the url to provide a common approach).

The use of SOS to access SensorML files will allow to use a standardized notation to get them.

There are several ways to use the SOS DescribeSensor interface. For example, with 52North SOS 4.0 implementation is it's possible to retrieve SensorML files by use of three different methods:

1. KPV (HTTP GET petition):
2. SOAP (HTTP POST petition):
3. POX (HTTP POST petition

The most compact and suitable to use inside a xlink:ref attribute is KPV, but it is still complex. This is an example of a “DescribeSensor” petition using KPV

http://ortelius.cmima.csic.es:9090/52n-sos-webapp/sos/kvp?service=SOS&version=2.0.0&request=DescribeSensor&procedure=ID_29SG_VESSEL&procedureDescriptionFormat=http%3A%2F%2Fwww.opengis.net%2FsensorML%2F1.0.1

As is it written in the above example any change in the SOS implementation (ex. Version, server port, etc ..) could break the link.

Alternative solutions can be:

1. Use of reverse proxies to encapsulate the part of the URL corresponding to the address, server port and root element like:

http://seadatanet.org/SOS/UTMSOS/kvp?service=SOS&version=2.0.0&request=DescribeSensor&procedure=ID_29SG_VESSEL&procedureDescriptionFormat=http%3A%2F%2Fwww.opengis.net%2FsensorML%2F1.0.1

Use of scripts (ex. javascript) that encapsulate the complexity of the SOS call.

http://seadatanet.org/SOS/UTMSOS/DescribeSensor.html?ID= ID_29SG_VESSEL

In any case it is advisable to get a consensus and to have a common policy on how build the url used to get SensorML descriptions by the use of xlink:ref attributes.

8. Annexes

Due to the extension of the XML files included as annexes, these has been included in a separated document, corresponding the same deliverable, named “Annexes to SensorML and O&M expressions for Research Vessels and Fixed Stations”.