Applying Open Geospatial Consortium's Sensor Web Enablement to Address Real-Time Oceanographic Data Quality, Secondary Data Use, and Long-Term Preservation

Julie Bosch
NOAA National Coastal Data Development Center
Stennis Space Center, MS 39529 USA

Janet Fredericks
Woods Hole Oceanographic Institution
Woods Hole, MA 02540 USA

Mike Botts, Tony Cook
University of Alabama in Huntsville
National Space Science and Technology Center
Huntsville, AL 35805 USA

Sara Haines
University of North Carolina
Department of Marine Sciences
Chapel Hill, NC 27599-3300 USA

Philip Bogden, Eric Bridger
Gulf of Maine Ocean Observing System
Portland, ME 04101 USA

***Abstract* – Key to the appropriate use of data is the knowledge of data quality. This knowledge is critical for products and decision-support tools that utilize real-time data, and it is also essential for the longer term application of data as well. Guidance by the National Archives and Records Administration (NARA) for appraising observational data for archive states that factors favoring long-term or permanent retention include the uniqueness, completeness, and quality of observational data and the quality and completeness of metadata [1]. The National Oceanographic Data Center (NODC), the designated archive center for oceanographic data in the U.S., requires that data submitted be documented to enable secondary use and ensure data posterity. Such metadata should include not only geospatial characteristics and time periods of observations, but also the collection methods, instrumentation used, units of measure, acceptable values, error tolerance, processing history, quality assessments and explanations of quality flags, data aggregation methods, and other pertinent information [2]. Providing this information in a consistent manner can be a challenge. However, an approach to capturing and conveying this metadata using community-developed practices for ocean observing system data and metadata is well underway.**

This paper presents methods of capturing data and provenance of data quality using the Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) framework. It describes the types of metadata content captured and demonstrates the utility and significance of defining and registering terms to enable semantic, as well as syntactic, interoperability. The SWE framework provides an avenue for conveying quality flags and methods used to make assurances about the integrity of oceanographic data for real-time consumption and for potential submittal to permanent archives such as NODC.

I. Introduction

A “grassroots” activity, called QARTOD (Quality Assurance of Real-Time Oceanographic Data), funded primarily by the National Oceanic and Atmospheric Administration (NOAA), has brought together data managers, scientists and sensor manufacturers from government and private industry to determine minimum requirements in quality assurance and quality control (QA/QC) for real-time oceanographic data. To date, four QARTOD workshops have focused on waves, *in situ* currents, conductivity/ temperature/depth (CTD), and dissolved oxygen (DO) data.

The OGC is a standards organization that is leading the development of publicly available, consensus-based standards

This work was funded under NOAA’s Cooperative Agreement FY 2007 Regional Integrated Ocean Observing System Development (NOS-CSC-2007-2000875).

Report Documentation Page			*Form Approved* *OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.			
1. REPORT DATE **JUN 2010**	2. REPORT TYPE **N/A**		3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Applying Open Geospatial Consortium's Sensor Web Enablement to Address Real-Time Oceanographic Data Quality, Secondary Data Use, and Long-Term Preservation**			5a. CONTRACT NUMBER
			5b. GRANT NUMBER
			5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)			5d. PROJECT NUMBER
			5e. TASK NUMBER
			5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **NOAA National Coastal Data Development Center Stennis Space Center, MS 39529 USA**			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**			
13. SUPPLEMENTARY NOTES **See also ADM202806. Proceedings of the Oceans 2009 MTS/IEEE Conference held in Biloxi, Mississippi on 26-29 October 2009. U.S. Government or Federal Purpose Rights License, The original document contains color images.**			

14. ABSTRACT

Key to the appropriate use of data is the knowledge of data quality. This knowledge is critical for products and decisionsupport tools that utilize real-time data, and it is also essential for the longer term application of data as well. Guidance by the National Archives and Records Administration (NARA) for appraising observational data for archive states that factors favoring long-term or permanent retention include the uniqueness, completeness, and quality of observational data and the quality and completeness of metadata [1]. The National Oceanographic Data Center (NODC), the designated archive center for oceanographic data in the U.S., requires that data submitted be documented to enable secondary use and ensure data posterity. Such metadata should include not only geospatial characteristics and time periods of observations, but also the collection methods, instrumentation used, units of measure, acceptable values, error tolerance, processing history, quality assessments and explanations of quality flags, data aggregation methods, and other pertinent information [2]. Providing this information in a consistent manner can be a challenge. However, an approach to capturing and conveying this metadata using community-developed practices for ocean observing system data and metadata is well underway. This paper presents methods of capturing data and provenance of data quality using the Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) framework. It describes the types of metadata content captured and demonstrates the utility and significance of defining and registering terms to enable semantic, as well as syntactic, interoperability.1The SWE framework provides an avenue for conveying quality flags and methods used to make assurances about the integrity of oceanographic data for real-time consumption and for potential submittal to permanent archives such as NODC.

<table>
<tr><td colspan="6">15. SUBJECT TERMS</td></tr>
<tr><td colspan="3">16. SECURITY CLASSIFICATION OF:</td><td rowspan="2">17. LIMITATION OF ABSTRACT
SAR</td><td rowspan="2">18. NUMBER OF PAGES
6</td><td rowspan="2">19a. NAME OF RESPONSIBLE PERSON</td></tr>
<tr><td>a. REPORT
unclassified</td><td>b. ABSTRACT
unclassified</td><td>c. THIS PAGE
unclassified</td></tr>
</table>

to "geo-enable the Web." The suite of OGC standards that comprise the SWE framework, specifically, the Sensor Observation Service (SOS), which enables retrieval of data and metadata from sensors and sensor systems, and Sensor Modeling Language (SensorML), which is specifically designed to describe how observable properties (such as pressure) are transformed into an observation (such as wave height), seemed a perfect match for oceanographic sensor networks.

Q2O, short for QARTOD to OGC, is a project funded by NOAA to implement QA/QC standards for *in situ* ocean sensors using the OGC SWE framework. This project brings the OGC SWE developers and information technology (IT) specialists together with oceanographers and data managers to develop specifications, data dictionaries, and SWE profiles for the application of QARTOD-identified, QC tests, and the capture of QA information.

As data are moved along the path from the sensor (point of origin) to the data provider and on to aggregation centers, data archives or consumers, knowledge of data provenance, characteristics of the data source, system configurations, and corrections to the data itself must be maintained. Use of the OGC standards provides the ability to track such information in a manner that not only accompanies the real-time data but also can provide persistent reference for the long-term. Applying a common framework to communicate the history of a sensor, data processing and results can create a shared understanding of the data and aid in enabling the machine-to-machine integration of these data.

II. QA/QC and Metadata Considerations

The series of QARTOD workshops addressed determining standards for QA/QC and metadata for real-time ocean data. Taking the community approach to this work helps ensure that the practices identified are those accepted by and applied by the data collectors. Each QARTOD group (waves, *in situ* currents, CTD, and DO) is at a different stage of completion. The waves and *in situ* currents groups are farthest along, having identified QC tests and QA and metadata needed to support the real-time observations. Tables 1 and 2, provide a sampling of the QARTOD-recommended QC tests for waves and *in situ* currents, respectively. These examples provide not only the test, but also a recommended action or flagging to be used based on the test results for given criteria.

In addition to the QC tests, each group identified QA best practices and related information. With the understanding that the most appropriate procedures for a given technology be applied, documenting or logging instrument pre-release, deployment and post-recovery activities was emphasized by all groups. Also important is recording events, such as instrument servicing (changing batteries, cleaning faces, replacing membranes, etc.) or notable environmental factors (e.g., biofouling, meteorological events). Maintenance and storage of sensors, when not deployed, also contribute to the sensor histories and can play a role in evaluating sensor performance.

QA/QC and sensor selection discussions included reference of manufacturer specification and recommended operational environments. Many of these sensor characteristics also contributed to the metadata content recommendations. Such sensor information as sampling rates and durations; firmware versions; and calibration dates, methods, and coefficients were combined with station, platform and deployment characteristics to make up an extensive list of potential metadata [4]. Although no final requirements were laid out for metadata content, commonalities were identified among the QARTOD groups on the types of metadata necessary. Both the minimum information that needs to be transmitted with the data and the complete record containing all information to document and enable users to understand the quality and appropriateness of the data still need to be refined by the community.

TABLE 1
EXAMPLE OF QARTOD-RECOMMENDED TESTS FOR WAVES [3]

SPECTRAL VALUES				
Category	**Criteria**	**Order**	**Flag**	**Action**
NON-DIRECTIONAL:				
Operational frequency range test	'defined by the environment and instrument	1	1. Soft 2. Hard	1. Max/min user defined. 2. Instrument spec exceeded, reject.
DIRECTIONAL:				
Incident low frequency energy direction	Location defined	1	Soft	User defined
Check factors, ratio	Should be approximately = 1, check over time. Location dependent	1	Soft	User defined
PARAMETER VALUES				
Category	**Criteria**	**Order**	**Flag**	**Action**
Wave parameters max/min /acceptable range (Height, Period, Direction, Directional Spread)	Location dependent	1	1. Soft 2. Hard	User defined 1. flag values outside expected limits 2. reject entire record if H exceeds gross limit otherwise reject individual parameter.
Time continuity	Short range history (applied to H)	2	Soft	User defined

TABLE 2
EXAMPLE OF QARTOD-RECOMMENDED TESTS FOR *IN SITU* CURRENTS USING TELEDYNE RD INSTRUMENTS ADCP [4]

Test	Pass	Suspect	Fail
BIT status (Built In Test) - diagnostics	BIT result is zero	BIT result is non-zero	BIT result is NA
Echo amplitude/intensity	value between 70 and 220 counts	values between 60 and 70 counts	values greater than 220 counts; values less than 60 counts
Pitch/Roll (absolute value)	0-15 deg	15-20 deg	>20deg
UV - Horizontal velocity	The velocity magnitude is less than or equal to 220 cm/s for OO 38 (BB and NB), OS 38, 75 and 150 (BB and NB), WH Long Ranger 75 (BB and NB) and WH QuarterMaster 150 (BB and NB), WH 300, 600 and 1200 kHz (BB and NB)	The velocity magnitude is greater than 220 cm/s and less than or equal to 300 cm/s for OO 38 (BB and NB), OS 38, 75 and 150 (BB and NB), WH Long Ranger 75 (BB and NB) and WH QuarterMaster 150 (BB and NB), WH 300, 600 and 1200 kHz (BB and NB)	The velocity magnitude is greater than 300 cm/s for OO 38 (BB and NB), OS 38, 75 and 150 (BB and NB), WH Long Ranger 75 (BB and NB) and WH QuarterMaster 150 (BB and NB), WH 300, 600 and 1200 kHz (BB and NB)

III. Applying Sensor Web Enablement

A. Describing the System

The Martha's Vineyard Coastal Observatory (MVCO; http://www.whoi.edu/mvco), owned and operated by the Woods Hole Oceanographic Institution (WHOI), provided the testbed for the demonstration of the first part of the project. The MVCO is comprised of a shore station, a meteorological mast, a 12-m node, and an air-sea interaction tower (Fig. 1). Each of these components can include a number of instruments and sensors. In describing the waves measurements from MVCO, the system's components are characterized using a number of SensorML files. SensorML was selected because it is specifically designed to describe systems and configurations of systems, as well as the processes by which measured properties are transformed into observations.

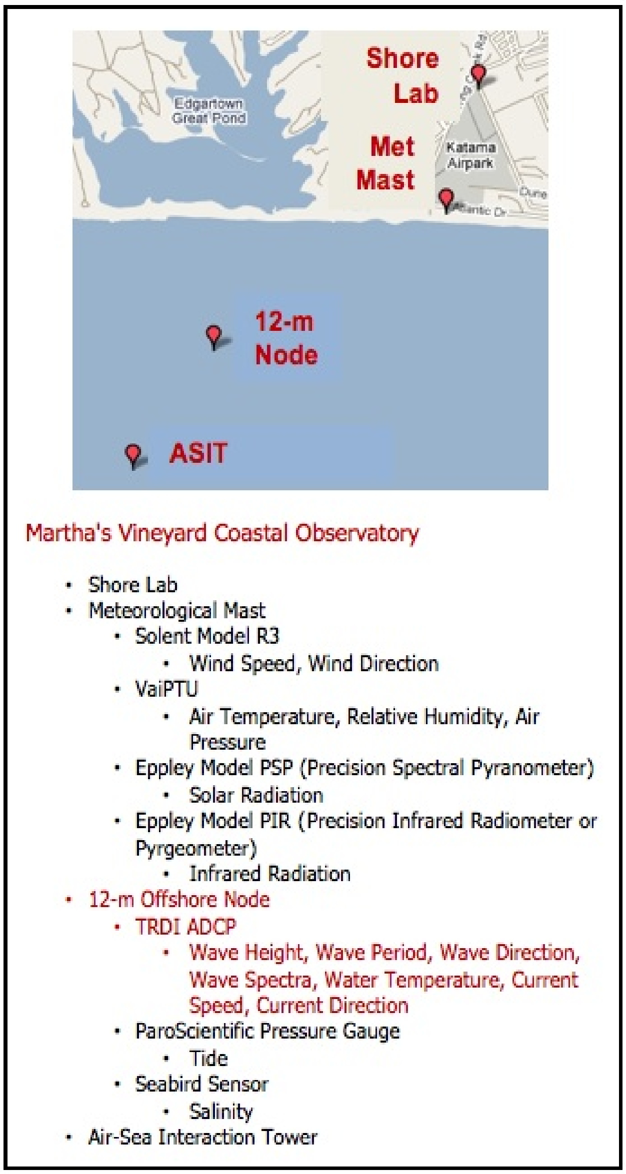

Figure 1. MVCO Components

The modular approach used in describing the MVCO allows for independent descriptions of the components that can be linked and reused by various configurations. For the Acoustic Doppler Current Profiler (ADCP) waves measurements, SensorML files are developed for the observatory, the 12-m node, and the ADCP sensor, which includes both a manufacturer/model-level file and an instance/serial number-level file. These files are listed below with a brief description of some of the key contents.

- MVCO: Owner and operator contact information. List of and links to four major components of the observatory.
- 12_m_node: Position information and coordinate reference system. List of and links to instrumentation associated with 12-m node.
- RDI_Workhorse_1200: A general SensorML description of the Teledyne RDI Workhorse Model 1200. Technical specifications and system characteristics for this model. Manufacturer and technical point of contact information. Note (1): This points to references from the manufacturer and can be used by anyone who is using a Teledyne RDI_Workhorse 1200. Note (2): Work on the development of the Workhorse 1200 SensorML is still ongoing.
- MVCO_Workhorse_1200: A SensorML description entailing details about the specific MVCO instance of a Teledyne RDI Workhorse Model 1200 and the ProcessModels that operate on individual data points. It describes the setup at the MVCO and specifies particulars, such as sampling frequency, reporting frequency, and burst length. It also refers to operational points of contact and time-stamped service events that occur which may affect the quality of the observation (e.g., a failed pressure port and its replacement, a cleaned ADCP face).

B. *Describing the Data Processing*

Tracking the quality of the data is aided by the ability to describe the workflow processes for the measurements and the QC procedures applied by the different data providers. To facilitate this capability, SensorML was employed. In SensorML, all components are modeled as processes. The building blocks of the SensorML descriptions are ProcessChain, ProcessModel, System and Component. ProcessChain and ProcessModel refer to nonphysical composite and atomic processes, respectively. Component refers to an atomic sensor while System refers to a collection of Components such as a system of sensors (e.g., a CTD).

The SensorML files are used for describing the data processing and include ProcessChains that string together the individual components and ProcessModels. For the MVCO, that top-level SensorML file links sensor and lineage descriptions, the process components, and the input and output of each process step. Fig. 2 depicts a flow diagram of the ADCP_System and shows how the QC tests are incorporated into this data model and description within SensorML. Each part is represented by its own SensorML file. The following material lists the SensorML documents used to describe the MVCO ADCP System, including the processes and general QC tests.

- ADCP_System - Main SensorML description that pulls together processes, tests, and the system components, RDI_Workhorse_1200 and MVCO_Workhorse_1200.

Process modules include:

- Pressure_QC_Chain - General ProcessChain for Pressure time series data.
- Velocity_QC_Chain - General ProcessChain for Velocity time series data.
- Pressure_QC_Chain Values - ProcessChain for Pressure time series data with parameters configured for MVCO setup.
- Velocity_QC_Chain_Values - ProcessChain for Velocity time series data with parameters configured for MVCO setup.
- Pressure_Obs_Process - Chain that generates a number of observable properties, such as wave height and period, from the cleaned, interpolated time series that is output from Pressure_QC_Chain.
- Velocity_Obs_Process - Chain that generates a number of observable directional wave properties from the cleaned, interpolated time series that is output from Velocity_QC_Chain.
- TimeSeriesChain - ProcessChain composed of several individual processes that perform time-related QC checks on the Pressure and Velocity Series data.

QC test modules include:

- DataGapTest - ProcessChain composed of several individual processes that perform time-related QC checks on the Pressure and Velocity Series data.

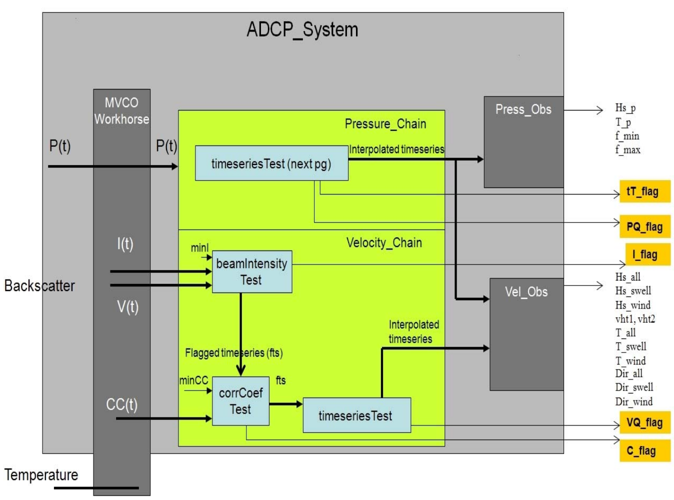

Figure 2. Each ProcessChain documents input into the system, a description of the ProcessModels, including QC tests and Components, and its output. [5]

- RangeSeriesTest - Test to determine if a data point lies between an upper and lower bound. Operates on a data series.
- RangeTest - The atomic Process for Range checking a single point. This is used in several places in the ADCP Q2O framework.
- MinThresholdSeriesTest - Like RangeTest, but only operates on a lower bound. Operates on a data series.
- MinThresholdTest - The atomic Process for testing if a data value exceeds a lower bound.
- SpikeTest - ProcessChain for SpikeTest.

Each ProcessChain encapsulates one or more elements which can be either tests or other chains. The ProcessChain describes the data flow via inputs, outputs, and parameters. A series of connections serves to describe the linkage between these elements. Several of the tests and processes use specific parameters. These criteria for evaluating the data, such as a maximum value for wave height, can be included inline or declared externally and coupled to the appropriate process by SensorML-aware software. The MVCO SOS serves these parameters as another SOS offering, so that the parameter values used for any time in the archive can be retrieved at a later date.

The flexibility of the SWE Framework, as seen in the MVCO ADCP System, can support all the elements of how the data were collected and what was done to it as well as the complexity and provenance of tests applied. While this framework is excellent for the real-time data use, it also provides information required for its secondary use or reuse, as well as the submission to archives.

C. *Developing Vocabularies*

Terms referred to in the SensorML, from the input observables to the resulting test flags, should reference a meaningful, resolvable definition. Wherever possible, existing vocabularies can be referenced; however, for this work with the QARTOD quality tests and processes, registered vocabularies did not exist. During a Q2O workshop in June 2008, discussions on vocabulary development resulted in an approach for content requirements summarized in Table 3.

In developing the Q2O and MVCO vocabularies, an attempt was made for each term to include the same components. The Q2O team compiled vocabulary terms for the QARTOD recommended tests, input parameters, QC flags and bibliographic references. The MVCO vocabulary required additional categories to capture the processing (process chains) applied to data, as well as the outputs and measurement properties. The resulting vocabularies compiled for Q2O and MVCO are registered in the Marine Metadata Interoperability (MMI) Project's Ontology Registry and Repository (http://mmisw.org/or). This registry provides a unique, resolvable Uniform Resource Locator (URL) for each term, and the categories of the terms are carried as part of this URL. In addition, vocabulary terms registered with MMI can be mapped and related to other vocabularies and knowledge domains, further enabling semantic interoperability.

TABLE 3.
Q2O VOCABULARY GUIDANCE

Name	Definition	Example
Identifier *	unique expression	rangeTest (http://mmisw.org/ont/q2o/test/rangeTest)
Long name *	official name; human readable label; not necessarily the common name	Range Test
Short Name	descriptive or commonly referred to name or label; can be the same as long name	Range Test
Definition *	the formal statement of the meaning or significance of a term; note: multiple definitions must not be conflicting	The check to ensure that all measurements or values fall within established upper and lower limits.
Symbol	sign used to represent an element, quantity, quality, operation or relation (e.g.,"Hs, Td")	n/a
Reference	source report, publication, document or other record; creating a reference list as part of the vocabulary allows for a resolvable link to a citation	Fourth Workshop on the Quality Assurance of Real-time Data, Final Report, QARTOD-IV Woods Hole Oceanographic Institute, Woods Hole, MA, June 21-23, 2006. (http://mmisw.org/ont/q2o/reference/q4)
Figure	a graphical representation or image that help explain or is referenced in the definition; should be included as a persistent url if possible	n/a
Category	a grouping or classification of the terms; for Q2O this is a distinction among a test, a parameter, a flag or a reference.	Test (http://mmisw.org/ont/q2o/test/rangeTest)
Relationship	terms associated with the identified term (e.g., parameters that are inputs to tests or resultant flags that are outputs from tests); ontological links to other objects	http://mmisw.org/ont/q2o/parameter/minimum http://mmisw.org/ont/q2o/parameter/maximum http://mmisw.org/ont/q2o/parameter/flag
Equation	A symbolic representation showing the kind and/or amount of the starting inputs and products (outputs) of a process; could be included as a persistent url link to a document or image or a urn to a MathML file (e.g., xmlns="http://www.w3.org/1998/Math/MathML")	min > x and x < max
Note	explanatory comment or brief record	A more general name for all types of specific range checks.

* determined to be a required element for a vocabulary

For Q20, we tried to limit the vocabulary development to those terms that are unique or have distinct definitions related to the QARTOD tests. Rather than defining characteristics of the sensors or instruments, we have encouraged manufacturers to register the terms that describe their products and processing. This will allow operators to point to a common, authoritative vocabulary for an instrument and not unnecessarily redefine the terms.

Determining whether or not an existing vocabulary is appropriate for use must be done with the awareness of the full meaning of the terms as they are defined. Misunderstanding and data integration problems can occur if similar terms have seemingly minor but distinct detail variations. For example, the registered Climate Forecast (CF) definition of water pressure includes a definition in decibels, while the output of the MVCO system is in cm, so an MVCO use of that CF term could lead to uncertainty about a value's unit of measure.

IV. ACCESSING THE DATA AND METADATA

One piece of the SWE framework is the SOS. Through this web service, data can be retrieved from sensors and/or sensor systems. The SOS acts as an intermediary between a near-real time sensor channel or observation repository and a client. Along with the data, clients can use SOS to obtain metadata that describes the sensors, platforms, and processing applied to the data.

A. SOS Core Operations

Three core operations are mandatory with SOS: GetCapabilities, DescribeSensor and GetObservation. Access to the SOS service metadata containing information about the observation offerings (the data being served) is through the GetCapabilities operation. The DescribeSensor operation retrieves detailed information about the sensors and processes generating the measurements or observations. The GetObservation operation provides access to the sensor observation and measurement data itself. The combination of these three operations provides a comprehensive characterization of a data set.

B. MVCO Implementation

The initial Q2O implementation of SOS returns responses for real-time and archived wave data from the MVCO. The DescribeSensor operation for the MVCO includes the observatory, the 12-m node and the ADCP characteristics, provenance and lineage including linked SensorML files with QC tests and parameters used in processing. The GetCapabilities operation provides MVCO ADCP system metadata and notifications for the six possible observation offerings from one data stream. These offerings include options for only the data that has passed QC testing or all data with the associated QC flags. The flags indicate which tests the data either passed or failed. Access to these data offerings is through the Get-Observation operation.

C. Resulting Information Returned

Results returned from the SOS operations are Extensible Markup Language (XML) documents. These results are generally intended for machine interpretation; however, some of this information also needs to be "human readable." SWE experts from the University of Alabama Huntsville developed a basic web application for displaying SensorML files in a tabular form, called PrettyView. This application is in a beta state (http://vast.uah.edu/SensorMLforms/upload.jsp), but supports most SensorML constructs in its present form. Using the PrettyView application with the results from the MVCO SOS operations lets the user quickly navigate the content of the XML documents and link QC test results to the processes and parameters (test criteria) applied to the data.

The data returned are created as comma separated value (CSV) text wrapped in the content-rich SensorML files as part of the GetObservations operation. Carrying the supporting metadata with the data extends the value of long-term data sets by enabling providers to serve well documented sensor and processing history with their offerings.

V. Next Steps

Continued refinement of profiles for the different types of observations and the development of guidance for implementers continues. Integration of these capabilities into the cookbooks of the OOSTethys/OpenIOOS project (http://www.oostethys.org) is planned.

Including additional metadata content in SensorML, expanding methods that can transform this information into other required metadata standards, and providing clients that can leverage the capabilities of the Sensor Web are all potential areas for development.

The Q2O work has focused on demonstrating the use of SWE to enable the QARTOD QA/QC recommendations. The content captured in these SensorML files is only a basic step in the use of the SWE standards. Richer applications of SWE for the sensors and measurements discussed by QARTOD can be developed which further relate sensors to co-located or duplicate sensors, sensors within instrument packages, instruments with respect to other instruments onboard platforms, or platforms as part of ocean observatories.

From the data archive perspective, getting the information (metadata) into a usable form from the SensorML is something that needs to be considered. Automating the requests for data through an SOS and transforming the metadata content into a standard usable by both an archive center and human-searchable, data-discovery systems would be beneficial. Any automation of such requests can be incorporated into submission agreements between data providers and archive centers.

VI. Conclusions

Ocean data climatologies that advise mariners of typical conditions, offer engineers the probabilities of extreme environmental conditions for designs or are used by scientists to examine trends and impacts on ecosystem health are built from the long-term compilation of that once real-time data. Reuse or secondary use of data for climatology purposes or for applications that extend well beyond the initial data collection considerations require an understanding of the data. This means that the lineage of the data, its collection and processing method, post-processing corrections, and other history must be readily available. Capturing this information from the start of the collection activities is key to the data's potential use, secondary-use and long-term preservation. Using standards that are specifically designed for sensor systems, observations and measurements such as those components of OGC SWE provides a means to both capture and access the data and metadata. Combining these standards with community-accepted data quality and information management practices helps ensure data posterity.

Acknowledgments

The authors wish to thank the NOAA's Integrated Ocean Observing System Program Office and the National Coastal Data Development Center for continued support of the Q2O effort. Valuable and greatly appreciated feedback on ongoing development and test implementations has been received from Vembu Subramanian (USF COMPS), Grace Cartwright (VIMS) and Brenda Babin (LUMCON). Also, we wish to thank John Graybeal and Carlos Rueda, from the Marine Metadata Interoperability (MMI) Project, for assistance with vocabularies and modifications made to MMI's Ontology Registry and Repository.

References

[1] National Archives and Records Administration, "Strategic Directions: Appraisal Policy," NARA Directive 1441, September 20, 2007, http://www.archives.gov/records-mgmt/initiatives/appraisal.html.

[2] National Oceanographic Data Center, "Data Submission Guidelines," http://www.nodc.noaa.gov/General/NODC-Submit/submit-guide.html.

[3] Coastal Data Information Program website: http://cdip.ucsd.edu/ documents/index/product_docs/qc_summaries/waves/ waves_table.php.

[4] W. Burnett, M. Bushnell, J. Bosch, R. Bouchard, J. Boyd, C. Chandler, K. Cohen, J. Fredericks, T. Koles, J. Thomas, and P. White, "QARTOD IV–Final Report: Fourth Workshop on the QC/QA of Real-Time Data," 2006, unpublished.

[5] J. Fredericks, M. Botts, L. Bermudez, J. Bosch, P. Bogden, E. Bridger, T. Cook, J. Graybeal, S. Haines, C. Rueda, and C. Waldmann, "Integrating QA/QC into Open Geospatial Consortium Sensor Web Enablement," OceanObs'09, Community White Paper, accepted.