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Developments in Marine Standards

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Abstract

The Open Geospatial Consortium (OGC) is a member-based global organisation that promotes and provides governance for a range of specifications to support interoperability between systems processing geospatial data. There is a working relationship between OGC and ISO TC211 and CEN TC287 that are the *de jure* bodies for geospatial data standards international and in Europe respectively. Many organisations have reported efficiencies in adopting OGC specifications; indeed adoption of these specifications is recommend by the UK e-GIF and are forming the cornerstone of the proposed INSPIRE Directive of the EC. Despite this, there is still a lack of clarity as to how the oceanographic community can and should make use of these specifications. This paper presents the work of the national and international initiatives that are developing best practice on the use of geospatial data standards in the marine domain.

Keywords: Feature Types, ISO TC211, Open Geospatial Consortium, MarineXML, MOTIIVE, CSML

Introduction

There is a growing trend towards enabling interoperability of spatial data. This refers to the ability to find, understand, and employ information and tools independent of physical location and platform [1], and includes data exchange as a special case. Interoperable infrastructure supports a dynamic market for spatial data – avoiding vendor lock-in, facilitating consumer-driven products, and enhancing scope for value-added services. Interoperability of Geographic Information Systems (GIS) requires models for data and services, and allows data to be shared and used in a consistent manner ("semantic interoperability").

Interoperability can only be achieved by information communities agreeing on standards for data and services. The degree of support for the standards adopted defines the breadth of the interoperable community. The *de jure* standards body, ISO (International Organisation for Standardisation), is developing standards (the "19xxx" series) for spatial data interoperability through its Technical Committee (TC) 211 on Geographic Information and Geomatics. These standards are concerned with the full spectrum of geospatial data exploitation – from discovery to access and use.

With these emerging standards as enabling technology, political moves to improve utilisation of geospatial data are culminating in the establishment of national and supra-national 'spatial data infrastructures' (SDIs). Within the European Union, a proposed directive to establish an 'INfrastructure for SPatial InfoRmation in Europe' (INSPIRE, [2]) is under consideration by the European Commission.

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[1] ISO 19101: "Geographic information – Reference model"
[2] http://inspire.jrc.it

Traditionally, the marine communities (both research and operations) have remained somewhat closed, with 'stovepipe' solutions to data handling and exchange. However the political moves to establish SDIs – together with the requirements of the climate impacts and risk communities to access high-quality data products – are driving an investigation into standards-based mechanisms for improving interoperability of marine and meteorological data [3,4].

The key to semantic interoperability, encapsulated in the ISO standards framework, is the formalisation of shared knowledge in communities of practice through the definition and cataloguing of so-called 'feature types'. Features are abstractions of real world phenomena and are formalised through describing their attributes, relationships, and behaviour [5]. There is a direct relationship between this 'General Feature Model' and the meta-model underlying the object-modelling language, UML (Unified Modelling Language) [6]. Thus, feature-types may be regarded as object models for a universe of discourse. Establishing standards-based interoperability for marine data requires the definition of appropriate feature types. The ISO TC211 standards provide a wide range of conceptual models to draw from – including spatial and temporal referencing, geometry, topology, dictionary structures etc. Many of these are formalised in a canonical XML encoding through the Geography Markup Language (GML, [7]).

We consider in this paper some contributions to the development of these GIS standards for marine data interoperability. An approach to identifying a range of generic feature types for various oceanographic data types is being trialled by the UK based project, NERC DataGrid [8]. These have been further investigated by the MarineXML initiatives of the International Oceanogrpahic Commission of UNESCO [9]. The findings from the pre-standardisation phase of MarineXML are now being extended through the MOTIIVE project [10]. The aim of MOTIIVE is to provide some reference implementations for the deployment of OGC standards in the marine domain. The direction of this standardisation effort has been shared with the architectural teams of the Met Office UK and it has been established that the requirements for the operational oceanography domain are consistent with those in the operational meteorology domain [11].

CLIMATE SCIENCE MODELLING LANGUAGE (CSML)

Standards and CSML

The UK-based project, NERC DataGrid (NDG), is trialling a feature-based approach for integrating a range of heterogeneous atmospheric and oceanographic data types across distributed data providers. The initial prototype provides uniform discovery and access to the holdings of the British Atmospheric Data Centre (BADC) and the British Oceanographic Data Centre (BODC). An important goal for NDG is compliance, where possible, with emerging standards (ISO and OGC) for geospatial data and services.

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[3] Millard, K., *et. al.* (2005): "Using XML Technology for Marine Data Exchange", Proc. 4th EuroGOOS Conference ,Brest.
[4] Woolf, A., *et. al.* (2005): "Standards-based data interoperability for the climate sciences", Met. Apps., **12**(1), 9-22.
[5] ISO 19109: "Geographic information – Rules for application schema"
[6] ISO I9103: "Geographic information – Conceptual schema language"
[7] ISO 19136: "Geographic information – Geography Markup Language"
[8] http://ndg.rl.ac.uk
[9] www.marineXML.net
[10] https://www.seegrid.csiro.au/twiki/bin/view/Marineweb/MOTIIVE
[11] To be published on line at www.metoffice.gov.uk – precise address not available at time of publication

The information architecture underlying the ISO TC211 series of standards is used in NDG for a wrapper/mediator approach to data integration (Figure 1). Semantic models of data (ISO 'feature types') are defined as the Climate Science Modelling Language (CSML). The underlying heterogeneous data stores of BADC and BODC (e.g. netCDF, GRIB files) are cast onto CSML and exposed as feature instances in logical datasets. Mediator services will be constructed to provide access to feature instances, e.g. through OGC web service interfaces.

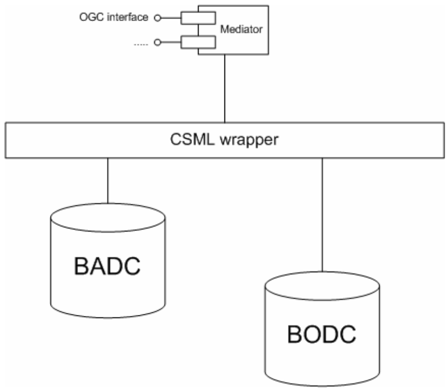

Figure 1: CSML provides a wrapper architecture for data integration in NDG.

CSML draws on conceptual schemas from a range of ISO TC211 standards for spatial and temporal referencing, geometry, etc. and is implemented as an application schema of the XML 'Geography Markup Language'. Various extensions to GML have been made (e.g. for non-rectified grids). In addition to defining the feature types above, it provides a mechanism for mapping legacy data onto feature instances and constructing logical datasets.

Future development will implement OGC web services as a layer over the CSML wrapper (e.g. feature instances exposed through the OGC Web Feature Service) and enable access to NDG data via GIS.

Defining Feature Types in CSML

In defining feature types for NDG, a range of typing granularity could be employed. For instance, an abstract feature type 'Measurement' might be defined for a very broad class of data. An oceanographic temperature reading would need to be qualified through additional feature attributes for measurement type (e.g. 'CDT') and measurand (e.g. 'temperature'). Alternatively, a more specialised feature type for 'CDT' could be defined, qualified only by the measured parameter ('temperature'). An even more specialised feature type could be defined for 'oceanographic temperature readings'. In practice, the degree of feature type specialisation depends on the management infrastructure (political and technical) available to support and maintain the definitions.

CSML has employed the following three principles in order to limit the number of feature types defined

- *Semantics offloaded to parameter type*. If two features are distinguished only by the measurand or physical parameter, they are regarded as the same feature type. For instance the same feature type is used for both a temperature and wind sounding, with a feature attribute defining the measurand.

- *Semantics offloaded to underlying coordinate reference system*. If two feature types are distinguished only by the underlying coordinate system, they are regarded as the same feature type. For instance, both a scanning radar and vertical sounding radar consist of a time-series of backscatter measurements along some look direction. In one case the direction remains vertical, in the other it rotates in azimuth. These are regarded as the same feature type, distinguished through the underlying coordinate reference system.
- *'Sensible plotting' as discriminant*. To ensure a workable minimum granularity, there must be sufficient specialisation of feature types to enable data to be rendered with conventional styling. Thus, while a sonde and scanning radar may both measure moisture, the first is typically plotted as a line graph of humidity against height, whereas the second uses shading and a colour scale to present a two-dimensional 'map' of moisture content

Using these principles, a set of seven basic feature types have been defined in CSML to represent semantically a significant portion of the data curated by BODC and BADC. These feature types are listed in Table 1 and shown architecturally in Figure 2 below.

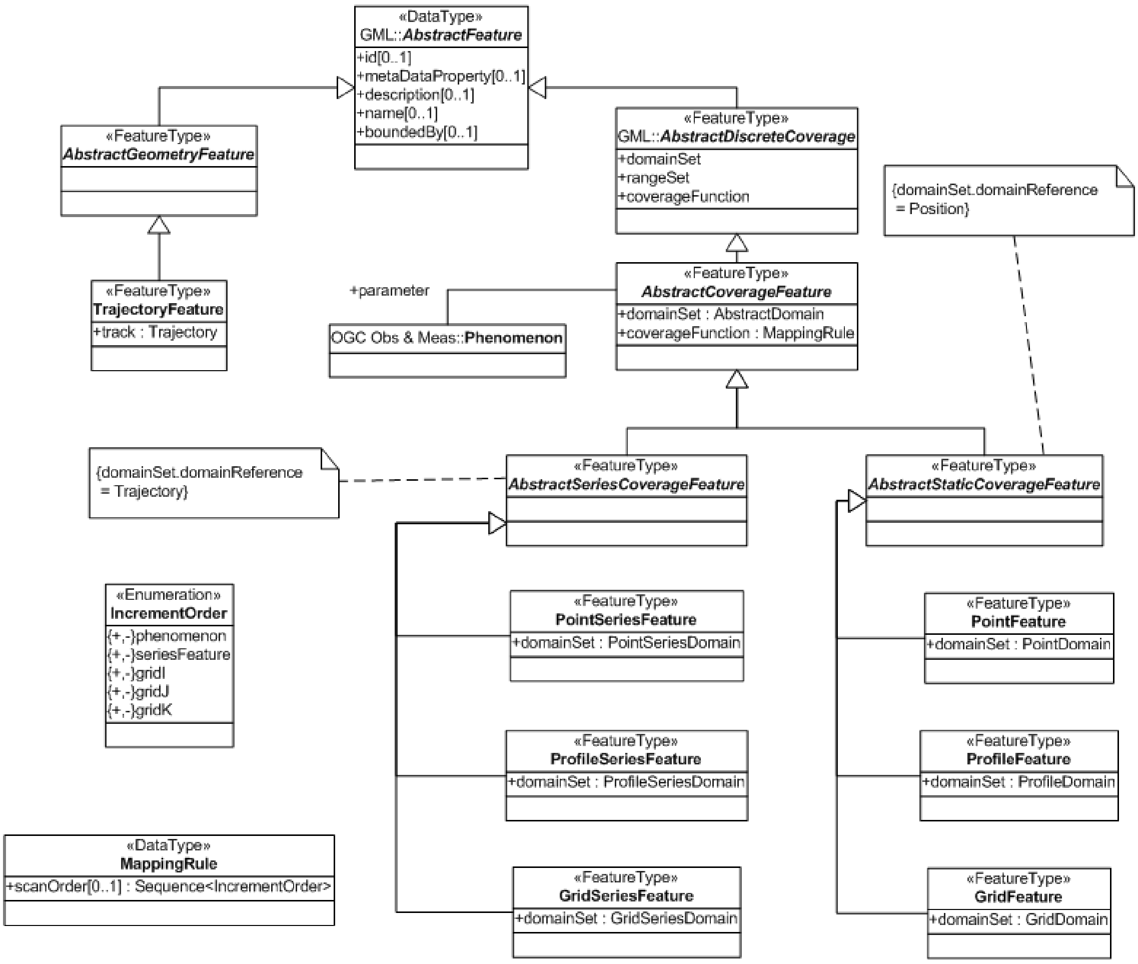

Figure 2 Conceptual Model of CSML Feature Types

Table 1: CSML feature types

CSML feature type	Description	Examples
TrajectoryFeature	Discrete path in time and space of a platform or instrument.	ship's cruise track, aircraft's flight path
PointFeature	Single point measurement.	raingauge measurement
ProfileFeature	Single 'profile' of some parameter along a directed line in space.	wind sounding, XBT, CTD, radiosonde
GridFeature	Single time-snapshot of a gridded field.	gridded analysis field
PointSeriesFeature	Series of single datum measurements.	tidegauge, rainfall timeseries
ProfileSeriesFeature	Series of profile-type measurements.	vertical or scanning radar, shipborne ADCP, thermistor chain timeseries
GridSeriesFeature	Timeseries of gridded parameter fields.	numerical weather prediction model, ocean general circulation model

MARINEXML

Provenance of MarineXML

MarineXML is an initiative under the governance of the IOC/IODE of UNESCO to improve marine data exchange within the marine community. The European Commission has provided a funding contribution to this initiative as part of its 5th Framework Programme to undertake a 'pre-standardisation' task of identifying the approaches the marine community should adopt regarding XML technology to achieve improved data exchange. This project (MarineXML EC) ran from February 2003 to January 2005. Other projects have contributed to MarineXML in this timeframe including the Study Group on XML (SGXML) of ICES/IOC, the UK NERC Data Grid Project (mentioned in the previous section) and the UKHO S-57 GML project [[12]]. All these projects worked closely together to reach consensus on using XML for marine data exchange.

Principles for Developing Standards

From the research and analysis conducted as part of MarineXML, several principles for an XML-based framework for marine data exchange were established, as presented below:

- *Marine Data exchange based on ISO 19136.* The alignment between ISO and OGC on ISO 19136 makes GML the clear (only) choice for developing an XML-based framework for marine data exchange. The adoption of this approach by significant organisations in the marine community such as IHO and WMO also reinforce this.
- *There is no single 'Marine Feature Type'.* It is not possible to have a single 'Marine Feature Type'. Given the diversity of the marine community, what is needed is a mechanism to represent what needs to be exchanged. This was a challenge to early views held by the project on how an XML-based exchange framework could work. Whilst it was accepted that some degree of modularity was required, it was perhaps not conceived how broad this modularity had to be to represent the whole of the marine community.

[12] www.ukho.gov.uk/b2b_gml_home.asp

- *Different sub-communities take responsibility for their feature types.* The breadth of the marine community means that it becomes wholly impractical for any single organisation, such as IOC, to manage and maintain all the Feature Types that the marine community could require. Different parts and operations of the marine community need to subscribe to their own data standards as these are integral to their operations. These standards are often highly specialised to meet the requirements of particular services. For example, the highly specialised feature types for universal exchange of meteorological observations (SYNOPs, METARs etc.). The definition of such specialised feature types is rightly the domain of international organisations such as the WMO.
- *MarineXML Feature Type responsibilities*. Through its MarineXML initiative, IOC/IODE should act as the authority (registry owner) for the specialist feature types that are central to the marine community and the general purpose feature types for exchange within the marine community (e.g. to enable 'cruise' and 'met observations' to be effectively combined). These general-purpose feature types should be developed in liaison with key organisations in the marine community such as IHO and WMO, not least to combine resources for standards maintenance and update.
- *Wrapper for Legacy Data*. The XML based framework should not only encode text-based data as XML, it is also required to provide a wrapper to data that exists or is best delivered by binary encoded files.

Test Bed Deployment

Taking account of the above principles, MarineXML looked to develop and test some general purpose Feature Types for data exchange within the marine community. To undertake this activity MarineXML collaborated with the NERC Data Grid Project on the development of CSML. Specifically a testbed was established to appraise at a practical level how the CSML Feature Types functioned to provide data exchange in the marine community. The test bed was based around the tools and standards used by the navigation community. This includes the S-57 standard for exchange of hydrographic data and a viewer for these electronic navigation charts conforming to this standard called SeeMyDENC [[13]]. A key aim was to demonstrate how this display tool for navigation data could also display other data, in a seamless manner that did not conform to the S-57 standard [[14]].

Source data was provided for domains covering marine biology [[15]], marine remote sensing, measured hydrodynamics and modelled hydrodynamics. These communities have their own, often ad-hoc vocabularies for expressing the content of their datasets. This data was translated to XML conforming to general-purpose Feature Types described by CSML. The software in SeeMyDENC was extended to parse these CSML Feature Types and display them accordingly. This is shown in Figure 2 below.

In most cases CSML proved a robust recipient for the data from each community. It produced economical files with few redundant elements, striking about the right balance between weak and strong typing. As CSML is based on geometric and topologic structures, the mappings worked less efficiently for data structured around

[[13]] See http://www.sevencs.com for more information on SeeMyDENC.
[[14]] Pillich, D., *et. al.* (2005): "Working Test Bed Final Prototype", Deliverable D10 of the MarineXML project, http://ioc3.unesco.org/marinexml/files/MarineXML_D10_Draft8.pdf
[[15]] Biological data was collected by the North Sea Benthos Project of ICES. The data has several abiotic parameters that can not by described in the Darwin schema used by OBIS.

groupings of phenomena. Such mappings were possible but resulted in more unwieldy results. In implementing the test-bed, most discussion was not on the Feature Types themselves, but on ensuring equivalent naming of the equivalent phenomena. For the test bed a translation of the CF Standard Names Table [[16]] into GML dictionary format [[17]] was used for physical phenomena. For biological data, phenomena were taken from OBIS [[18]] with a webservice established to the OBIS taxonomic database to provide definitions.

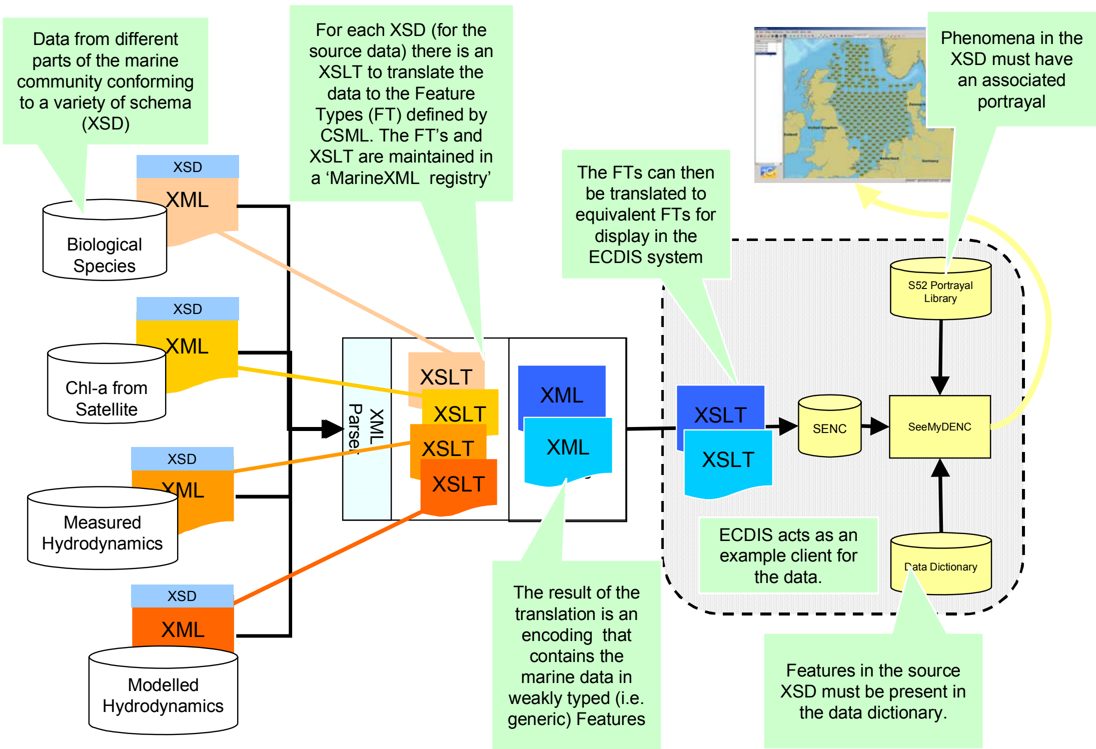

Figure 3: MarineXML Test Bed Conceptual Diagram

Standard dictionaries of both phenomena (what was observed) and units in which the phenomena have been measured are required if automated parameter interoperability is to be realised. Whilst the test-bed proved the concept of using a GML encoding of CF standard names, this is not an extensible option. The final report of SGXML [[19]] recommended that the oceanographic phenomena dictionary developed by BODC [[20]] be adopted as the marine oceanographic community standard.

The test bed worked from a functional perspective, but it should be remembered that it was established to prove the concept that data providers and data services can make use of one another by subscribing to common data vocabularies. These data vocabularies can be expressed as a large number of strongly typed features or a small number of weakly typed features. What the test bed has shown is that the seven feature types represented by CSML can provide a good basis for the exchange of marine data.

[[16]] http://www.cgd.ucar.edu/cms/eaton/cf-metadata/standard_name.html
[[17]] http://ndg.nerc.ac.uk/csml/CFStandardNames.xml
[[18]]http://www.iobis.org
[[19]] Isenor, A., and R. Lowry (2005): Final Report of the ICES/IOC Study Group on the Development of Marine Data Exchange using XML. Defence R&D Canada – Atlantic Technical Report TR2005-005.
[[20]] http://www.bodc.ac.uk/data/codes_and_formats/parameter_codes

MOTIIVE

'INSPIRING GMES'

MOTIIVE (Marine Overlays on Topography for Annex II Valuation and Exploitation) extends the pre-standardisation work of MarineXML. It is a 2-year project funded by the European Commission 6th Framework RTD Programme in relation to the joint EC and European Space Agency (ESA) programme GMES – Global Monitoring for Environment and Security[21]. MOTIIVE addresses the current disconnect between the standards available to promote interoperability and the lack of coherent best-practice that organisations should follow when looking to establish services.

Specifically, the objective of MOTIIVE is to examine the cost benefit of using non-proprietary data standards to address the data harmonisation requirements between the INSPIRE data component "elevation" (terrestrial, bathymetric and coastal) and INSPIRE marine thematic data for "sea regions", "oceanic spatial features" and "coastal zone management areas". The project stresses analysis of the cost-benefit implied by strong harmonisation between "core" and "thematic" INSPIRE data, while supporting the infrastructure requirements of the GMES "Ocean and Marine Applications" theme, now being implemented by GMES Service Element (GSE) Phase 2 projects such as MARCOAST [[22]].

The aims of MOTIIVE are to produce application instances of a series of OpenGIS specifications and use these to examine the potential need for a formal OGC Working Group (WG) for Marine Data, while actively participating in existing OGC Working Groups within which marine data is an important component of thematic data coverage, e.g. remote sensing, environmental data, etc. Determining such need requires, as per OGC rules, development of a qualified business case for creating such a WG, which must be accepted by the OGC Technical and Management Committees.

Measurable objectives of MOTIIVE

The specific aims of MOTIIVE are:

- ☐ Provide a documented methodology for implementing and monitoring data harmonisation activities between INSPIRE 'Annex I' (core - elevation) and 'Annex II' (thematic - marine/coastal) datasets. This follows the steps required in the OGC Reference Model for interoperability, application of the CEN/TC 287 standards profiles for ISO 19xxx, with associated Feature Type Catalogues.
- ☐ Using the open standards and tools developed in early stages of the project, demonstrate this methodology applied to the data integration requirements of those GMES (Global Monitoring for Environment and Security) Service Element (GSE) pilot projects.
- ☐ Provide a cost-benefit assessment for using OGC interoperability specifications to harmonise INSPIRE Annex I (elevation) and Annex II (marine, coastal management) spatial data systems.
- ☐ Building on the pre-standardisation work of MarineXML[[23]], establish a marine data standards registry under the auspices of the Intergovernmental

[[21]] www,gmes.info
[[22]] http://www.marcoast.info/
[[23]] Millard et al, 2005, Using XML Technology for Marine Data Exchange. A Position Paper of the MarineXML Initiative. Download from www.marineXML.net

Oceanographic Commission (IOC and International Hydrographic Organization (IHO).

In undertaking this work MOTIIVE is aligned with its sister project RISE [[24]] that examines land based harmonisation issues. The result will be a consistent set of guidelines for the use and adoption of OGC standards, prepared from the findings of both projects.

Met Office Workshop

In February 2006, the UK Met Office convened a workshop to examine the application of OGC Web Services and GML modelling to Operational Meteorology. This workshop provided the opportunity to discuss the objectives of MOTIIVE in the context of the requirements of the UK Met Office and other initiatives also working in the same problem space, notably other members of the SEEGRID community, the NERC DG Community and the UK Hydrographic Office. The following sections highlight some of the points discussed and the conclusions reached.

FeatureType definitions and the utility of facets

ISO 19101 states that a 'feature type' is "an abstraction of a real-world phenomenon"; this is not an entirely helpful description in the context of practical oceanographic activities such as data collection, data processing, surveying and construction. To clarify this definition the rule of thumb can be applied that "if something has a specific name (or classifier) in your domain of interest, it's probably a candidate feature type". However, even within these guidelines, there is significant scope for variation in how the feature is defined. Evidence suggests that feature types are developed to meet specific local needs. As these needs change, the feature type is redefined to suit. However, all of these feature types lack coherence & consistency with each other as they have been developed independently. The assertion is that:

- A feature type is an *incomplete* view (or 'facet') of some 'conceptual model' of the real world
- The conceptual model may not necessarily be implementable
- A feature type is an implementable 'facet' (or representation) of the conceptual model, and may be based on: geometry / topology, semantics / governing equations, governance, 'processing affordance' (what you can do with the feature), sampling regime etc.
- The format in which the information is stored is simply another representation (facet) of the conceptual model

This results in feature types that can be defined in response to a specific requirement (use case) enabling clear separation of concerns, improved governance and reduced risk of any one Feature Type becoming obsolete.

Application schemas for Metocean systems

The workshop considered which application schema should/could be used for metocean operations. In particular "Do we base our feature types on CSML or on the Observations and Measurements (O&M) model from SEEGrid / XMML[[25]]?" The answer was 'both' and to pick and choose parts of each as required: observations and

[[24]]http://www.eurogeographics.org/eng/documents/RISE_Summary_10Oct2005.pdf
[[25]] https://www.seegrid.csiro.au/twiki/bin/view/Xmml/ObservationsAndMeasurements, latest OGC documentation ref: OGC 05-087r2, Simon Cox (pending open publication)

sampling naturally fitting the O&M model, whilst most numerical simulation 'coverages' were well described by CSML.

The only variation between coverage features was the phenomenon (e.g. temperature, humidity), a useful guideline suggests that it is most appropriate to soft-type the generic coverage feature rather than create one feature type for each different phenomena.

Additionally, CSML describes two concepts which may benefit from separation. First, there are semantics associated with environmental science. Second, there are packaging strategies for multi-dimensional datasets (extending GML's geometry packing). Whilst the former is unique to the environmental science community, the latter could be used anywhere that multi-dimensional datasets occur.

Operational interfaces for feature types

The General Feature Model (as specified in ISO 19109) supports the concept of 'operations'. However, implementation of features using W3C XML Schema only allows definition of a static XML document; defining only the structure and properties. There is no mechanism allowing the description of operations that a feature can invoke / be invoked on it. The concept of 'processing affordance' is proposed to enable description of operational interfaces.

The semantics of processing affordance are equivalent to those of an interface in Object Oriented programming, or 'mix-ins' in Aspect Oriented programming. The 'interface' defines a declaration of intent, describing a series of operations that can be invoked. Where a feature supports the 'interface', it implies that that feature is able to provide sufficient information to execute the operation described in the interface. Or in mathematical parlance: 'this feature has attributes p,q,r to support f(p,q,r)'. Furthermore, a feature could support multiple interfaces, thus enabling polymorphism.

While the properties of features can be defined in W3C XML schema, definition of the relationships between features (and other objects) is a capability provided by the registry / catalogue. A method to capture the association between the feature and the processing affordance (interface) is to define the processing affordance as an object in the registry (with appropriate governance) and associate it with feature instances or feature types. However, this hypothesis clearly needs to be tested and the impact of this proposal is a change to the UML idiom.

Registries & Repositories

The ebXML Registry Information Model v3.0 (developed by Sun MicroSystems *et al* under the banner of Oasis [[26]]) is the only standards-based registry object that provides sufficient functionality to deliver services to the metocean community. A number of 'use case' services have been established by the MOTIIVE project. These use cases have been established to represent the general needs of the operational metocean community.

MOTIIVE are planning to deliver an ebRIM registry / repository implementation in association with software developer Cubewerx [[27]]. The implementation will focus on

[[26]] [http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=regrep, also see the SEEGrid twiki for a useful introduction to ebRIM [https://www.seegrid.csiro.au/twiki/bin/view/Compsrvices/EbXMLRim].

[[27]] www.cubewerx.com

delivering a feature type catalogue, additionally exposing service bindings and query models within the registry.

The Met Office has proposed to initiate a parallel implementation track to develop a second reference implementation based on the OGC Catalogue Services for Web (CSW) for (at least) the same set of use cases. Additionally, deployment of phenomenon dictionaries may also be investigated. This activity is seen as a key strand for the Met Office's geospatial interoperability programme and of great importance within the wider meteorological community and WMO.

Conclusions

There are a number of national and international initiatives that are coherently working together to advance and improve interoperability in the marine domain through the adoption of open standards. There is a major UK contribution to this process. The current impetus is on best practice deployment for ISO TC211 standards for Geographic Information and Geomatics. The purpose for this is to support the establishment of spatial data infrastructures (SDI) in the marine domain.

The introduction to this paper highlighted that ISO TC211 standards provide a wide range of conceptual models to draw from and that many of these are formalised in a canonical XML encoding through the Geography Markup Language (GML). As such GML can be used as tool kit from which feature types can be realised as application schema. Application Schemas provide a mechanism to realise Feature Types as objects that can be used within software.

Interoperability cannot be achieved by definition of an application schema alone. A set of well-defined service interfaces are vital to ensure that data can be accessed in an 'implementation agnostic' fashion. However, the kingpin of interoperability is the registry. The registry provides the capability to publish (and govern) application schemas, phenomena dictionaries, controlled vocabularies, service bindings etc. for all to see and use. Furthermore, it is the registry that enables associations between objects to be expressed. This leads to true interoperability; for example, allowing a user to discover an object of interest, browse by navigating associations & execute a chain of processes on some dataset to derive added value.

As a result of the coherence between standards projects in the metocean domain, a number of interoperability tests across registries prototype deployments could be scheduled for late 2006, perhaps forming the basis of an OGC interoperability experiment.

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Fluid thinking...smart solutions

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