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FOR HYDROGRAPHIC DATA

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Surface Current Product Specification

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Surface Current Product Specification

Revision History

Version Number	Date	Author/Editor	Purpose
Draft 1.0	December 2012	D. O'Brien, Auth.	Demonstration Version
Draft 1.1	April 2014	L. Maltais, Ed.	Revision for currents
Draft 1.2	August 2014	L. Maltais, Ed	Additional revision of previous version
Draft 1.3	December 2014	L. Maltais, Ed	Additional revision of previous version
Draft 1.4	March 2015	L. Maltais, Ed	Additional revision of previous version
Draft 1.5	April 2015	K. Hess, B. Sullivan, C. Kammerer, E. Mong, Eds.	Put into template format, numerous changes

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1 OVERVIEW

A data product specification is a precise technical description that defines the requirements for a geospatial data product and forms the basis for producing or acquiring data. This product specification, S-111, is compliant with S-100 Part 11. S-111 defines the requirements for a surface current data product which could be a Gridded Coverage compliant with S-100 Part 8.

S-111 describes all the features, attributes and relationships of surface currents and their mapping to a dataset. It includes general information for data identification as well as information for data content and structure, reference system, data quality aspects, data capture, maintenance, encoding, delivery, metadata and portrayal. The framework, i.e., the relationships between these elements, is depicted in Figure 1.1 (ISO 19129). The framework identifies how the various elements of a coverage dataset fit together.

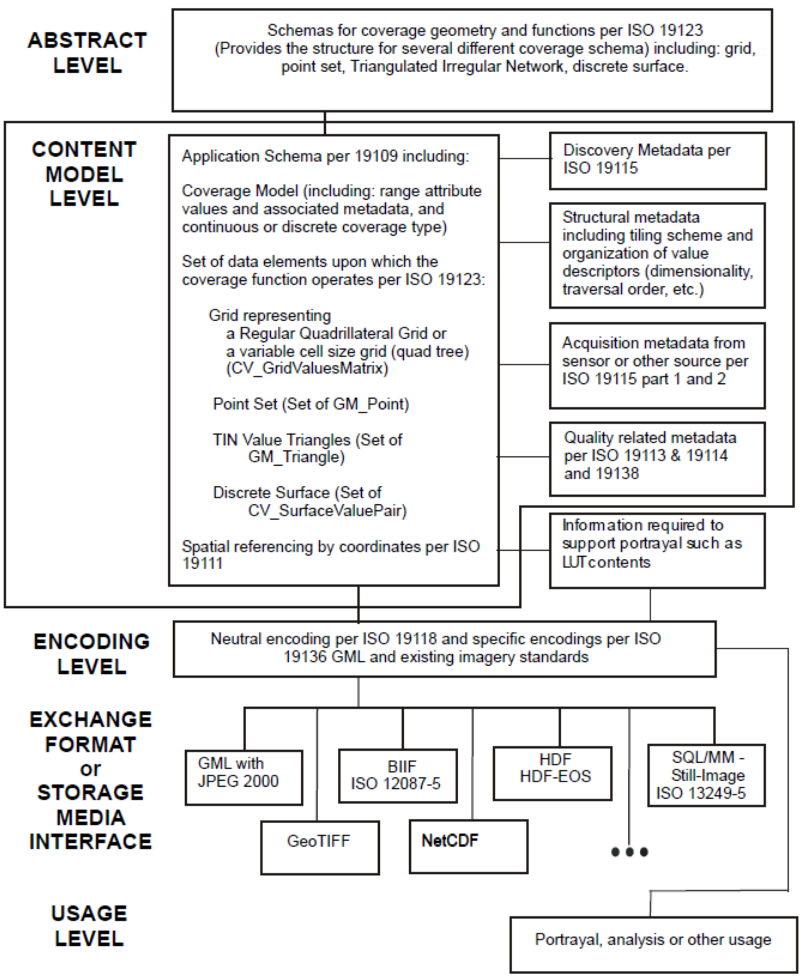


Figure 1.1 - Overall relationship between the elements of the framework

The Hierarchical Data Format version 5 (HDF5) promotes compatible data exchange due to its common neutral encoding format, and is the format used for this data product. HDF5 is object oriented and suitable for all types of coverage data and forms the basis of NetCDF (a popular format used for scientific data).

1.1 Introduction

From ancient times of exploration to modern day shipping, surface currents have played an important role in navigation. With the advent of electronic navigation, surface current data and updates are more accessible and easier to integrate into navigation displays. This integration of the chart with other supplemental data improves decision making and results in more efficient navigation.

The surface current products may be used alone or combined with ENC or other S-100 compatible data.

A dataset that describes a set of attribute values distributed over an area is called a coverage. There are many different types of coverages, but the most common structure is a grid. Gridded data is fundamentally simple. It consists of a set of attribute values organized in a grid together with metadata to describe the meaning of the attribute values and spatial referencing information to position the data.

1.2 References

1.2.1 Normative

S-100. *IHO Universal Hydrographic Data Model.* January 2015
ISO 8601. 2004. *Data elements and interchange formates - Information interchange - Representation of dates and times.* 2004.
ISO 3166-1. 1997. *Country Codes.* 1997.
ISO/TS 19103. 2005. *Geographic information - Conceptual schema language.* 2005.
ISO 19111. 2003. *Geographic information - Spatial referencing by coordinates.* 2003.
ISO 19115. 2003. *Geographic information - Metadata.* 2003.
ISO 19115-2. 2009. *Geographic information - Metadata - Part 2: Extension for imagery and gridded data.* 2009.
ISO/TS 19123. 2005. *Geographic information - Schema for coverage geometry and functions.* 2005.
ISO 19129. 2009. *Geographic information - Imagery, gridded and coverage data framework.* 2009.
ISO 19131. 2007. *Geographic information - Data product specifications.* 2007.
ISO/IEC 19501. 2005. *Information technology - Unified Modeling Language (UML) Version 1.4.2.* 2005.
netCDF – *Network Common Data Form: Unidata* – www.unidata.ucar.edu/software/netcdf
HDF5 – *Hierarchical Data Format version 5* – www.hdfgroup.org

1.2.2 Informative

ISO 19101. 2002. *Geographic information - Reference model.* 2002.
ISO 19103-2. 2005. *Geographic information - Conceptual schema language - Part 2.* 2005.
ISO 19105. 2000. *Geographic information - Conformance and testing.* 2000.
ISO 19107. 2003. *Geographic information - Spatial schema.* 2003.
ISO 19108. 2002. *Geographic information - Temporal schema.* 2002.
ISO 19109. 2005. *Geographic information - Rules for application schema.* 2005.

ISO 19110. 2005. *Geographic information - Methodology for feature cataloguing.* 2005.
ISO 19113. 2002. *Geographic information - Quality principles.* 2002.
ISO 19116. 2004. *Geographic information - Positioning services.* 2004.
ISO 19117. 2005. *Geographic information - Portrayal.* 2005.
ISO 19118. 2005. *Geographic information - Encoding.* 2005.
ISO 19128. 2005. *Geographic information - Web Map Server interface.* 2005.
ISO/TS 19130. 2010. *Geographic information - Imagery sensor models for geopositioning.* 2010.
ISO/TS 19130-2. 2010. *Geographic information - Imagery sensor models for geopositioning - Part 2.* 2010.
ISO 19132. 2007. *Geographic information - Location-based services – Reference model.* 2007.
ISO 19133. 2005. *Geographic Information - Location-based services - Tracking and navigation.* 2005.
ISO 19136. 2007. *Geographic information - Geography Markup Language (GML).* 2007.
ISO/TS 19138. 2006. *Geographic information - Data quality measures.* 2006.
ISO 19142. 2010. *Geographic information - Web Feature Service.* 2010.
ISO 19144-1. 2009. *Geographic information - Classification systems – Part 1: Classification system structure.* 2009.
ISO 19145. 2010. *Geographic information - Registry of representations of geographic point location.* 2010.
ISO 19153. 2010. *Geographic information - Geospatial Digital Rights Management Reference Model (GeoDRM RM) 1).* 2010.
ISO 19156. 2010. *Geographic information - Observations and measurements.* 2010.
ISO 19157. 2010. *Geographic information - Data quality.* 2010.
ISO 19158. 2010. *Geographic Information - Quality assurance of data supply.* 2010.
2012. *Springer Handbook of Geographic Information.* 2012.
CO-OPS – Tide and Current Glossary 2000
Wikipedia. *Wikipedia.* [Online]

1.3 Terms, Definitions and Abbreviations

1.3.1 Use of Language

Within this document:

- “Must” indicates a mandatory requirement.
- “Should” indicates an optional requirement, that is the recommended process to be followed, but is not mandatory.
- “May” means “allowed to” or “could possibly”, and is not mandatory.

1.3.2 Terms and Definitions

The S-100 framework is based on the ISO 19100 series of geographic standards. The terms and definitions provided here are used to standardize the nomenclature found within that framework, whenever possible. They are taken from the references cited in clause 1.2, modifications were made when necessary. Additional terms have also been included (see ANNEX A). Terms that are defined in this clause and ANNEX A are highlighted in **bold**.

coordinate
one of a sequence of n numbers designating the position of a point in n-dimensional space

> **NOTE** In a **coordinate reference system**, the **coordinate** numbers are qualified by units [ISO 19107, ISO 19111]

coordinate reference system

coordinate system that is related to an **object** by a **datum**

NOTE For geodetic and **vertical datums**, the **object** will be the Earth
[ISO 19111]

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

EXAMPLE Examples include a raster **image**, polygon overlay, or digital elevation matrix
NOTE In other words, a **coverage** is a **feature** that has multiple values for each **attribute** type, where each **direct position** within the geometric representation of the **feature** has a single value for each **attribute** type
[ISO 19123]

coverage geometry
configuration of the **domain** of a **coverage** described in terms of **coordinates**
[ISO 19123]

data product
dataset or **dataset series** that conforms to a **data product specification**
[ISO 19131]

layer-averaged surface current
The water current averaged over the vertical, from the surface to a specified **depth** below the sea surface.

EXAMPLE from 0 meters (sea surface) to 10 meters.

depth-specific current
The water current at a specified **depth** below the **sea surface**

direct position
position described by a single set of **coordinates** within a **coordinate reference system**
[ISO 19107]

domain
well-defined set

NOTE 1 **Domains** are used to define the **domain** set and **range** set of **attributes**, operators, and **functions**
NOTE 2 *Well-defined* means that the definition is both necessary and sufficient, as everything that satisfies the definition is in the set and everything that does not satisfy the definition is necessarily outside the set
[ISO/TS 19103, ISO 19107, ISO 19109]

feature
abstraction of real-world phenomena

EXAMPLE The phenomenon named *Eiffel Tower* may be classified with other similar phenomena into a **feature type** named *tower*
NOTE 1 A **feature** may occur as a **type** or an **instance**. **Feature type** or feature instance shall be used when only one is meant
NOTE 2 In UML 2, a **feature** is a property, such as an operation or **attribute**, which is encapsulated as part of a list within a classifier, such as an interface, **class**, or **data type**

[ISO 19101, ISO/TS 19103, ISO 19110]

feature attribute
characteristic of a **feature**

EXAMPLE 1 A **feature attribute** named *color* may have an **attribute** value *green* which belongs to the **data type** *text*

EXAMPLE 2 A **feature attribute** named *length* may have an **attribute** value *82.4* which belongs to the **data type** *real*

NOTE 1 A **feature attribute** may occur as a **type** or an **instance**. **Feature attribute** type or **feature attribute** instance is used when only one is meant

NOTE 2 A **feature attribute** type has a name, a **data type**, and a **domain** associated to it. A **feature attribute** instance has an **attribute** value taken from the **domain** of the **feature attribute** type

NOTE 3 In a **feature catalog**, a **feature attribute** may include a value **domain** but does not specify **attribute** values for **feature** instances

[ISO 19101, ISO 19109, ISO 19110, ISO 19117]

function
rule that associates each element from a **domain** (source, or **domain** of the **function**) to a unique element in another **domain** (target, codomain, or **range**)

[ISO 19107]

geometric object
spatial **object** representing a geometric set

NOTE A **geometric object** consists of a **geometric primitive**, a collection of **geometric primitives**, or a **geometric complex** treated as a single entity. A **geometric object** may be the spatial representation of an **object** such as a ***feature*** or a significant part of a ***feature***

[ISO 19107]

grid
network composed of two or more sets of **curves** in which the members of each set intersect the members of the other sets in an algorithmic way

NOTE The **curves** partition a space into **grid** cells

[ISO 19123]

grid point
point located at the intersection of two or more **curves** in a **grid**

[ISO 19123]

range <coverage>
set of **feature attribute** values associated by a **function** with the elements of the **domain** of a **coverage**

[ISO 19123]

record
finite, named collection of related items (**objects** or values)

NOTE Logically, a **record** is a set of pairs <name, item>

[ISO 19107]

rectified grid

grid for which there is an affine transformation between the **grid coordinates** and the **coordinates** of an external **coordinate reference system**

> **NOTE** If the **coordinate reference system** is related to the Earth by a **datum**, the **grid** is a **georectified grid**
> [ISO 19123]
> **NOTE** an affine transformation has six parameters: two translations (*x, y*), two rotations (one for each axis), and two scales (one for each axis).
> [Springer 2012]

sea surface

A two-dimensional (in the horizontal plane) field representing the air-sea interface, with high-frequency fluctuations such as wind waves and swell filtered out.

> **EXAMPLE** sea surface, river surface, and lake surface
> **NOTE** This implies marine water, lakes, waterways, navigable rivers, etc.

surface current

The horizontal motion of water at a navigationally significant **depth** represented as a velocity **vector** (i.e., speed and direction).

surface current direction

The direction toward which the current flows,

> [CO-OPS 2000]
> **NOTE**: measured clockwise from true north. AKA set

uncertainty

The interval about a given value that will contain the true value at a given **confidence** level

> **NOTE** **uncertainty** is the estimate of the **error** in any measurement or value; since the **error** (difference between true and observed value) depends on true value, which can never be measured, it cannot be determined. **Uncertainty** is the next best thing. For our purposes the **confidence** level is 95%.

1.3.3 Abbreviations

This product specification adopts the following convention for symbols and abbreviated terms:

API	Application Programming Interface
DS	Digital Signature
DSS	Digital Signature Scheme
ECDIS	Electronic Chart Display Information System
ECS	Electronic Chart System
ENC	Electronic Navigational Chart
GML	Geography Markup Language
HDF	Hierarchical Data Format (HDF5 is the fifth release)
IEEE	Institute of Electrical and Electronics Engineers
IHO	International Hydrographic Organization
ISO	International Organization for Standardization
NetCDF	Network Common Data Form
ONA	Official National Authority

PK	Public Key
SA	Signature Authority
SK	Secret Key
UML	Unified Modelling Language

1.3.4 UML Notations

In this document conceptual schemas are presented in the Unified Modelling Language (UML). Several model elements used in this schema are defined in ISO standards developed by ISO/TC211, or in IHO S-100. In order to ensure that class names in the model are unique ISO/TC211 has adopted a convention of establishing a prefix to the names of classes that define the TC211 defined UML package in which the UML class is defined (Table 1.1). Since the IHO standards and this product specification make use of classes derived directly from the ISO standards this convention is also followed here.

In the IHO standards the class names are identified by the name of the standard, such as "S100" as the prefix optionally followed by the bialpha prefix derived from ISO. For the classes defined in this product specification the prefix is "S111". In order to avoid having multiple classes instantiating the same root classes, the ISO classes and S-100 classes have been used where possible; however, a new instantiated class is required if there is a need to alter a class or relationship to prevent a reverse coupling between the model elements introduced in this document and those defined in S-100 or the ISO model.

Table 1.1 - Sources of externally defined UML classes.

Prefix	Standard	Package
CI	ISO 19115	Citation and Responsible Party
CV	ISO 19123	Coverage Core & Discrete Coverages
DQ	ISO 19115	Data Quality Information
DS	ISO 19115	Metadata Application Information
EX	ISO 19115	Metadata Extent information
IF	ISO 19129	Imagery Gridded and Coverage Data Framework
LI	ISO 19115	Linage Information
MD	ISO 19115	Metadata entity set information
MI	ISO 19115-2	Metadata entity set imagery
S100	IHO S-100	IHO Standard for Hydrographic Data
SC	ISO 19111	Spatial Referencing by Coordinates
SD	ISO 19130	Sensor Data

1.4 General Data Product Description

This clause provides general information regarding the data product.

Title: Surface Current Information
Abstract: Encodes information and parameters for use with surface current data
Content: A conformant dataset may contain features associated with surface currents. The specific content is defined by the Feature Catalogue and the Application Schema.
Spatial Extent:
- **Description:** Global, marine areas only
- **East Bounding Longitude:** 180
- **West Bounding Longitude: -**180
- **North Bounding Latitude:** 90

South Bounding Latitude: -90

Purpose: The data shall be collected/produced for the purposes related to surface current use.

1.5 Data Product Specification Metadata and Maintenance

1.5.1 Product Specification Metadata

This information uniquely identifies this Product Specification and provides information about its creation and maintenance. For further information on dataset metadata see the metadata clause.

Title: S-111 Surface Current Product Specification
S-100 Version: 1.0.0
S-111 Version: 1.0
Date: 2015-01-15
Language: English
Classification: Unclassified
Contact:

International Hydrographic Bureau,
4 quai Antoine 1er,
B.P. 445
MC 98011 MONACO CEDEX
Telephone: +377 93 10 81 00
Telefax: + 377 93 10 81 40
Role: Owner

URL: http://www.iho.int/mtg_docs/com_wg/SCWG/SCWG_Misc/S-111.pdf
Identifier: S111
Maintenance: For reporting issues which need correction, use the contact information.

1.5.2 IHO Product Specification Maintenance

1.5.2.1 Introduction

Changes to S-111 will be released by the IHO as a new edition, revision, or clarification.

1.5.2.2 New Edition

New Editions of S-111 introduce significant changes. New Editions enable new concepts, such as the ability to support new functions or applications, or the introduction of new constructs or data types. New Editions are likely to have a significant impact on either existing users or future users of S-111.

1.5.2.3 Revisions

Revisions are defined as substantive semantic changes to S-111. Typically, revisions will change S-111 to correct factual errors; introduce necessary changes that have become evident as a result of practical experience or changing circumstances. A revision must not be classified as a clarification. Revisions could have an impact on either existing users or future users of S-111. All cumulative clarifications must be included with the release of approved corrections revisions.

Changes in a revision are minor and ensure backward compatibility with the previous versions within the same Edition. Newer revisions, for example, introduce new features and attributes. Within the same Edition, a dataset of one version could always be processed with a later version of the feature and portrayal catalogues. In most cases a new feature or portrayal catalogue will result in a revision of S-111.

1.5.2.4 Clarification

Clarifications are non-substantive changes to S-111. Typically, clarifications: remove ambiguity; correct grammatical and spelling errors; amend or update cross references; insert improved graphics in spelling, punctuation and grammar. A clarification must not cause any substantive semantic change to S-111.

Changes in a clarification are minor and ensure backward compatibility with the previous versions within the same Edition. Within the same Edition, a dataset of one clarification version could always be processed with a later version of the feature and portrayal catalogues, and a portrayal catalogue can always rely on earlier versions of the feature catalogues.
Changes in a clarification are minor and ensure backward compatibility with the previous versions.

1.5.2.5 Version Numbers

The associated version control numbering to identify changes (n) to S-111 must be as follows:

New Editions denoted as **n**.0.0

Revisions denoted as n.**n**.0

Clarifications denoted as n.n.**n**

2 SPECIFICATION SCOPES

This product specification outlines the flow of data from inception, through the official national authority (ONA), to the end user. The data may be observed or modelled. Requirements for data and metadata are provided. This document does not include product delivery mechanisms.

Scope ID: Global
Level: General Scope
Level name: General Scope

Note: "Global" means that this scope refers to all parts of this data product specifications

3 DATASET IDENTIFICATION

A surface current dataset that conforms to this Product Specification uses the following general information for distinction:

Title: Surface Current Data Product
Alternate Title: None

Abstract: The data product is a file containing surface water current data for a particular geographic region and set of times, along with the accompanying metadata describing the content, variables, applicable times and locations, and structure of the data product. Surface current data includes speed and direction of the current, and may represent observed or mathematically-predicted values. The data may consist of currents at a small set of points where observations and/or predictions are available, or may consist of numerous points organized in a grid as from a hydrodynamic model forecast.
Topic Category: Transportation (ISO 19115 Domain Code 018).
Geographic Description: Areas specific to marine navigation.
Spatial resolution: Varies (e.g., 0.1 km to 1000 km)
Purpose: Surface current data are intended to be used as stand-alone data or as a layer in an ENC.
Language: English (mandatory).
Classification: Data may be classified as one of the following:
Unclassified
Restricted
Confidential
Secret
Top Secret
Spatial Representation Types: Coverage
Point of Contact: Producing agency.
Use Limitation: Invalid over land.

4 DATA CONTENT AND STRUCTURE

4.1 Introduction

This Section discusses the application schema, which is described in UML; the feature catalogue; dataset types, in which there is an extensive discussion of the current data; dataset loading and unloading; and geometry.

Surface current data consist of the current speed and direction near the sea surface. Optional variables may be the water level, uncertainty in speed, and uncertainty in direction. The data may either be depth-specific current or layer-averaged surface current. Current data usually are represented as a time series of values for either a single point (i.e., one geographic location) or for an array of points contained in a regular grid. Additional information is included in ANNEX F – SURFACE CURRENT DATA.

4.2 Application Schema

This application schema shall be expressed in UML. The details of the Application Schema are given in ANNEX B – APPLICATION SCHEMA.

4.3 Feature Catalogue

Surface current data has one feature with five attributes that are summarized in ANNEX C – DATA CLASSIFICATION AND ENCODING GUIDE.

Table 4.1 describes the information for each type of attribute allowed.

Table 4.1 - Simple feature attributes.

Type	Definition
Enumeration	A fixed list of valid identifiers of named literal values
Boolean	A value representing binary logic. The value can be either True or False. The default state for Boolean type attributes (i.e. where the attribute is not populated for the feature) is False.
Real	A signed Real (floating point) number consisting of a mantissa and an exponent
Integer	A signed integer number. The representation of an integer is encapsulation and usage dependent.
CharacterString	An arbitrary-length sequence of characters including accents and special characters from a repertoire of one of the adopted character sets
Date	A date provides values for year, month and day according to the Gregorian Calendar. Character encoding of a date is a string which must follow the calendar date format (complete representation, basic format) for date specified by ISO 8601:1988. EXAMPLE 19980918 (YYYY-MM-DD)
Time	A time is given by an hour, minute and second. Character encoding of a time is a string that follows the local time (complete representation, basic format) format defined in ISO 8601:1988. EXAMPLE 183059 or 183059+0100 or 183059Z
Date and Time	A DateTime is a combination of a date and a time type. Character encoding of a DateTime shall follow ISO 8601:1988 EXAMPLE 19850412T101530

4.4 Dataset Types

Surface current data are represented in one type of dataset: a set of arrays of points contained in a regular grid. Data for a single station will be assumed to be on a grid consisting of a single point. Additional information is included in ANNEX F – SURFACE CURRENT DATA. Further details on the data product are given in clause 10 – DATA PRODUCT FORMAT (encoding).

NOTE: The potential inclusion of data from irregular (i.e., unstructured) grids and tidal atlases is postponed until a later version of this Product Specification.

4.5 Dataset Loading and Unloading

The data will be supplied at the highest resolution so there will be no need for loading and unloading the data.

4.6 Geometry

S-111 geometry is an implementation of S-100 Part 8-7.1.4 (S100_Grid Coverage Spatial Model). The spatial grids containing the surface current data must be two dimensional, regular and Cartesian (with the X-axis directed toward the east), and are defined by several attributes depicted in the S100_Grid/CurrentGrid block of the Surface Current Layer Model in Figure 4.1. These parameters are explained in more detail below. To simplify the geometry model for cases where only one instance in time is needed, the time dimension is encoded as an attribute in each instance of the grid.

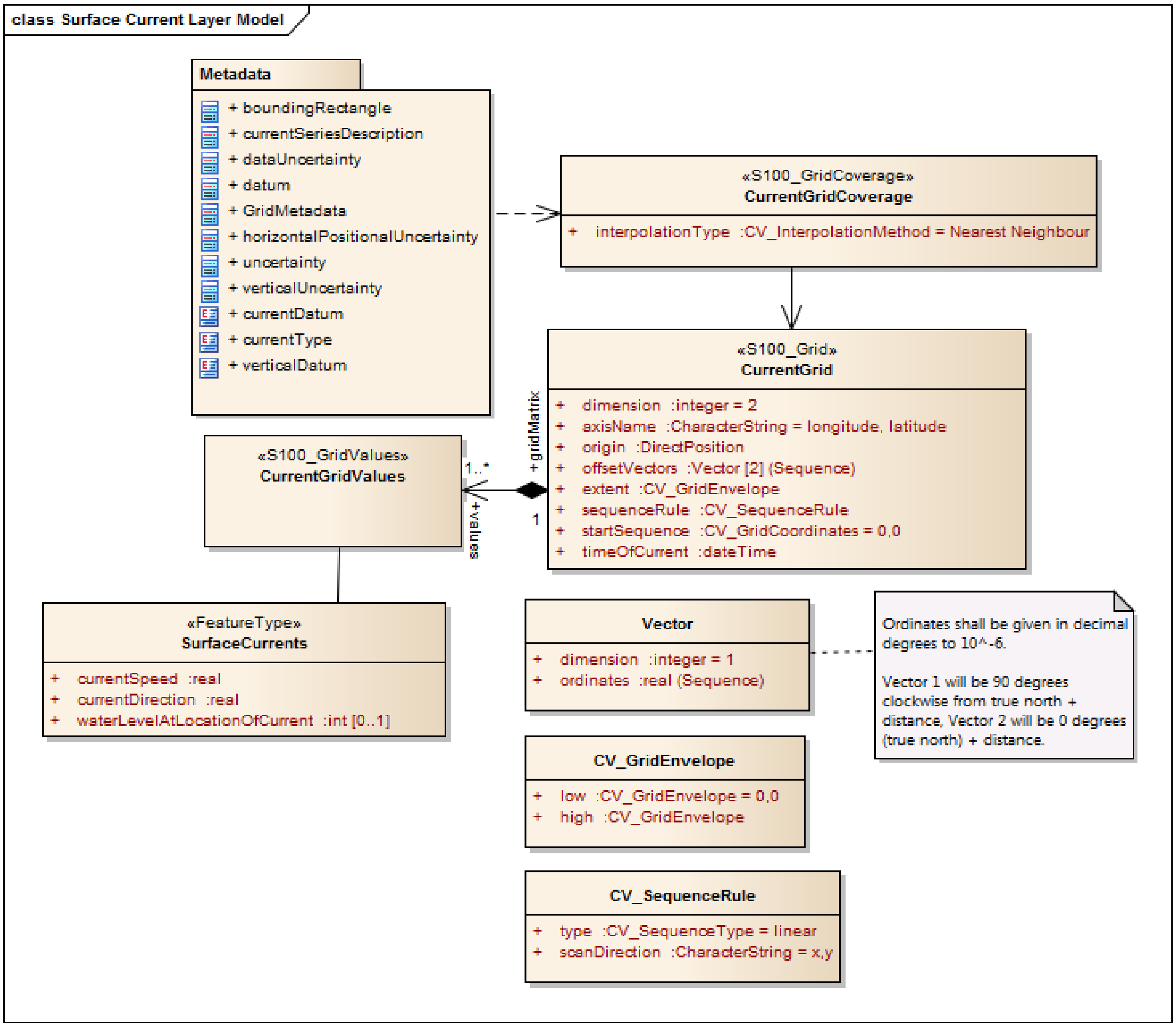


Figure 4.1 - UML schema for the Surface Current Layer.

4.6.1 Grid Axis Names

The name of the axis in the S-111 grid is longitude for the X-axis and latitude for the Y-axis. The attribute *axisName* carry the names “longitude, latitude” – respectively **(**Figure 4.2).

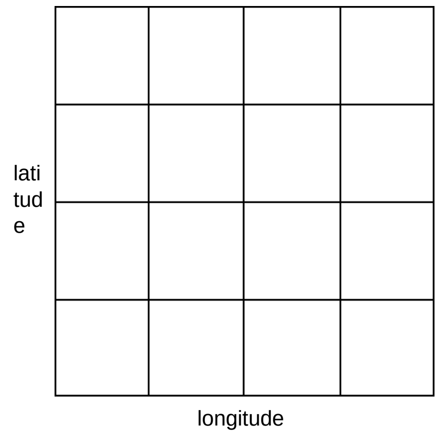


Figure 4.2 – The grid axis names

4.6.2 Grid Extent

The extent of an S-111 grid is captured in the attribute extent. The attribute *extent* effectively defines a bounding rectangle describing where data is provided. For simple grids with equal cell sizes, if data is not available for the whole area within this rectangle, then padding with null values shall be used to represent areas where no data is available. The attribute extent carries two sub attributes; *low* and *high*. The sub attribute *low*, carries the value "0,0" to indicate the start of the extent is the lower left corner of the grid. The sub attribute *high*, carries the value of the highest position along the X-axis and the highest position along the Y-axis. Together they form the grid coordinate of the upper right corner (Figure 4.3).

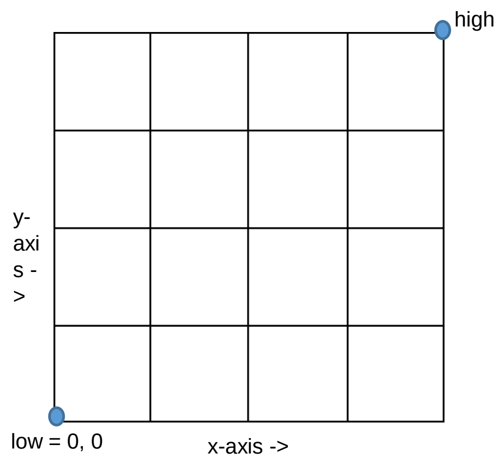


Figure 4.3 – The grid extent

4.6.3 Grid Origin

The attribute *origin* specifies the coordinates of the grid origin with respect to an external coordinate system. The grid origin is captured in the attribute origin, which contains the latitude and longitude as a *DirectPosition* containing a two-dimensional coordinate tuple (longitude, latitude). The grid origin is located at the lower extent of the grid (Figure 4.4)

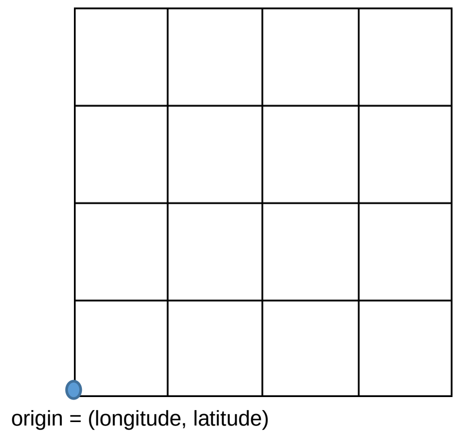


Figure 4.4 - The grid origin

4.6.4 Grid Spacing and Offset Vector

S-111 grids allow for different spacing in the X-axis and the Y-axis. For simple grids with equal cell sizes the offset vector establishes the cell size. The attribute *offsetVector* carries the two vectors for grid spacing. The attribute *offsetVectors* specifies the spacing between grid points and the orientation of the grid axis with respect to the external coordinate reference system (CRS) identified through the attribute *origin*. The first vector is 90 degrees to ~~Coordinate Reference System~~ (CRS) north, and the distance between grid values on the X-axis. The second vector is 0 degrees to CRS north, and the distance between the values on the Y-axis (Figure 4.5). The distances are given in whole minutes.

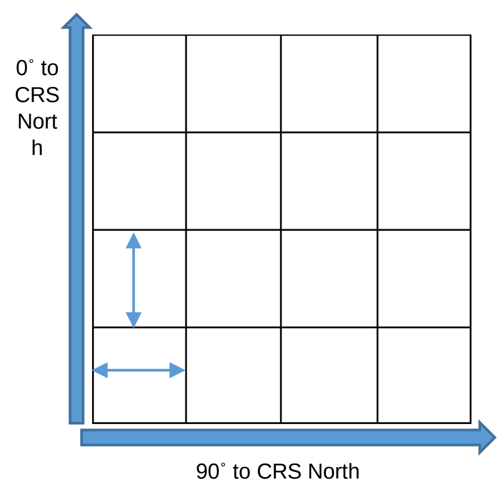


Figure 4.5 – Distance between grid values on X and Y axis.

4.6.5 Sequence Rule and Start Sequence

The sequence rule for a regular cell size grid is straight-forward. When the cells are all of the same size, the cell index can be derived from the position of the Record within the sequence of Records. The attribute *sequenceRule* has two sub attributes; *type* and *scanDirection*. The sub attribute *type* carries the value "linear", and the sub attribute *scanDirection* carries the value "x,y". Together with the value "0,0" stored in the attribute *startSequence*, they indicate that for S-111 the grid values along the X-axis at the lowest Y-axis position are stored first, starting with the left most value going right, followed by the values along the X-axis at the next increment upward along the Y-axis, and so on till the top of the Y-axis. The last value in the value sequence of the grid will be at the top rightmost positon in the grid (Figure 4.6).

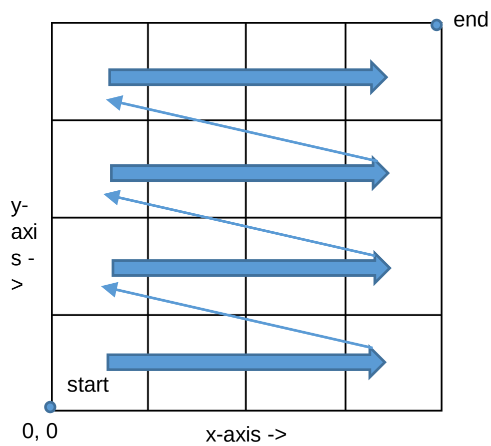


Figure 4.6 – Linear scan direction

4.6.6 Time of Current Grid

The attribute *timeOfCurrent* carries the date and time of the grid values.

5 COORDINATE REFERENCE SYSTEMS (CRS)

The location of an object in the S-100 standard is defined by means of coordinates. Those coordinates relate a feature to a position.

5.1 Horizontal reference system

Positional data is expressed in latitude and longitude geographic coordinates to one of the reference horizontal reference systems defined in the HORDAT attribute associated with coverage and with the metadata of the data set.

5.2 Projection

Surface Current data is unprojected.

5.3 Vertical coordinate reference system

Surface Current data is two dimensional data. There is no vertical component.

NOTE: The top 25 meters for which the Surface Current Product Specification applies relates to the surface of the water (a real world object) that is not related to a vertical reference as part of the surface current product specification. The surface of the water may be related to a vertical datum in another S-100 product specification such as S-101, but such a reference to a vertical datum is not necessary in this product specification.

5.4 Temporal reference system

Time is measured by reference to Calendar dates and Clock time in accordance with ISO 19108:2002 Temporal Schema clause 5.4.4.

6 DATA QUALITY

6.1 Introduction

< The data quality overview element should include at least the intended purpose and statement of quality or lineage. Other data quality elements cover: completeness, logical consistency, positional accuracy, temporal accuracy, thematic accuracy, and anything specifically required for the product being specified.>

6.2 Completeness

A Surface Current coverage data set is complete when the grid coverage value matrix contains direction and speed values or the null value for every vertex point defined in the grid, and when all of the mandatory associated metadata is provided.

6.2.1 Test case for coverage geometry

Test purpose:	Verify that the coverage geometry corresponds to one of two conformance classes
Conformance class 1	Gridded coverage;
Conformance class 2	**???**
Test method:	Check that the coverage geometry type complies with one of the two coverage types defined in the Application Schema defined in Appendix B
Test type:	Basic

6.2.2 Test case for extra data

Test purpose:	Verify that a Surface Current coverage data set is complete by testing that the grid coverage value matrix contains direction and speed values for every vertex point defined in the grid, and when all of the mandatory associated metadata is provided

Test method: Check that for each feature, all of the mandatory metadata is provided and that all of the vertex points required to define either the grid coverage (all the rows and columns exist).

Test type: Basic

6.2.3 Test case for empty data

Test purpose: Verify that data is not missing

Test method: Check that all mandatory metadata is provided, and test that all grid matrix values for the grid established in the metadata are provided

Test type: Basic

6.3 Logical Consistency

6.4 Conceptual Consistency

The implementation of the Surface Current Product is required to align with one of the two conformance classes defined in (the appendix with the Abstract Test Suite and Conformance Classes).

6.5 Domain Consistency

The attributive values are validated to ensure they are within defined range.

6.5.1 Test case for range

Test purpose: Verify that attribute values are within specified ranges

Test method: Check that the orientation value attribute is within the range 0 to 360 degrees or are a Null (NAN) value and that other values are within the range specified or are a Null (NAN) value for the particular product specification defined by a producer, ONA. This would be validated by means of test software

Test type: Basic

6.6 Format Consistency

The structure of this product specification is independent from the data format. The data format encoding may be in accordance with different encoding specification. Conformance rules for each particular encoding are different and dependent on the particular encoding.

6.6.1 Test case for format

Test purpose: Verify that format is compliant with the formats allowed for encoding coverage data

Test method: The format consistency test is done by encoding test software

Test type: Basic

6.7 Positional Accuracy

For a gridded coverage the positional accuracy for the grid reference point and the length of the offset vectors defining the size of each grid cell, when specified, are defined in the metadata.

6.7.1 Test case for positional accuracy

Test purpose: Verify that the grid reference point and offset vector (defining a cell) in a grid coverage are defined and in accordance with the accuracy established for the data set by the producer, ONA

Test method: Verify that the positional accuracy of the defining points of the coverage are within the accuracy established for the data set by the producer, in particular Hydrographic Office by the use of test software

Test type: Basic

6.8 Temporal Accuracy

For a gridded coverage the temporal reference time for the data at all grid points is the same. Temporal accuracy is not defined.

6.9 Thematic Accuracy

6.9.1 Thematic Classification Correctness

The measurement accuracy for each of the parameters of the current direction and speed may be specified in a separate uncertainty coverage. This optional second coverage may be combined with the base surface current coverage as additional values in each value record in the coverage. This is described in the Application Schema in Appendix B.

6.9.2 Non Quantitative Attribute Accuracy

The method used for evaluating the accuracy of the non-quantitative attribute values may be expressed in the metadata.

6.9.3 Quantitative Attribute Accuracy

The method used for evaluating the accuracy of the quantitative attribute values with respect to reality is determined by the method of acquisition, and may be expressed in the metadata.

<S-100 Part 11-8>
The data product specification shall identify the data quality requirements for each scope within the data product in accordance with S-100 Part 3. For every data quality scope it is necessary to list all the data quality elements and data quality sub-elements defined in S-100 Part 3, even if

only to state that a specific data quality element or data quality sub-element is not applicable for this data quality scope.

Each product specification shall describe the data quality requirements. One aspect is the "data quality overview element" which should allow a user to decide whether this dataset is the one they want. The other aspect is the metadata allowed for specific feature collections, features and attributes within the dataset.

The data quality overview element should include at least the intended purpose and statement of quality or lineage. Other data quality elements cover: completeness, logical consistency, positional accuracy, temporal accuracy, thematic accuracy, and anything specifically required for the product being specified.

The product specification should comment on which of these are to be used and how, including a description of (or reference to) conformance tests. For example, should data only be published if it passes a particular test, or is it allowable to publish the data with a quality statement which indicates non-conformance? The product specification shall describe how each quality element is to be populated, for example, stating the mechanism to reference the quality evaluation procedure, and allowable values for the quality results.

The application schema shall indicate how the data quality elements will be related to the data items, for example whether a particular dataset should have homogeneous quality, or whether quality elements can be related to feature collections, individual feature objects or attributes.

6.9.3.1 Test case for uncertainty coverage

Test purpose:	Optionally verify that a second uncertainty coverage is available to describe the uncertainty of the elements of the coverage and that other aspects of accuracy are described in the metadata
Test method:	Verify that the uncertainty coverage exists and is coincident with the surface current coverage (i.e. the additional value record elements are present)
Test type:	Basic

7 DATA CAPTURE AND CLASSIFICATION

The Surface Current product contains data processed from sensors or derived from the output from mathematical models. In most cases, the data collected by the ONA must be translated, subsetted, reorganized, or otherwise processed to be made into a usable data format.

7.1 Data Sources

Surface current data comes from three specific sources: observations, astronomical predictions, and computational models. When such data are produced and quality-controlled by an ONA, they are suitable for the Surface Current data product.

Observational surface current data comes initially from *in situ* sensors in the field, and such sensors are monitored by the ONA. After reception, the data are quality-controlled and stored by the ONA. Some of the observed data may be available for distribution within minutes of being collected and are thus described as being in real time.

When a sufficiently long time series of observed currents has been obtained, the data may be harmonically analyzed by the ONA to produce a set of amplitude and phase constants. The harmonic values can then be used to predict the astronomical component of the current as a time series covering any desired time interval. In addition, the harmonic constants may be used to estimate tidal currents for a generic tidal cycle, with the specific amplitude and direction of the current based on the tide range at a specified nearby tide station, and the specific phase of the current based on the time of high water at the same nearby tide station. Data such as these may be available for single stations or if the stations are numerous they may be arranged by the ONA into a tidal atlas.

Hydrodynamic forecast models rely on observational data, including water levels and winds, to supply boundary conditions. Such models are often run several times per day, and in each run a forecast is made for many hours into the future. The results are saved for a limited number of times, and are stored as arrays that derive from the model's grid. These models are developed, run, and monitored by the ONA.

7.2 The Production Process

Nearly all available information on surface currents available from the ONA must be reformatted to meet the standards of this Product Specification (Figure 10.1 – the S-111 format). This means (a) populating the metadata block (Table 10.2) with the relevant data and (b) reorganizing the speed and direction data when using the encoding rules (discussed in section 10.4 – Data Referencing System and in ANNEX C - DATA CLASSIFICATION AND ENCODING GUIDE).

7.2.1 Metadata

Metadata is derivable from the information available from the ONA. The following variables will require additional processing:

- The bounding rectangle is computable from the grid origin, grid point spacing, and the number of points in each direction
- Grid position uncertainties may be available from the ONA's metadata; otherwise they must be calculated.
- Speed and direction uncertainties, if specified as a single value for the grid, may be available from the ONA; otherwise they must be calculated.

7.2.2 Surface Current Data

Observational currents and astronomical tidal predictions at a single location and gridded forecast data will have the same S-111 format. The following may require additional processing:

- Surface elevation values are often available in the modeled data grid points, but for observational data they may not be available
- If a land mask array is included, the mask value is substituted into the gridded values as appropriate

7.2.3 Digital Tidal Atlas Data

Tidal atlas information (Clause F.3) may require additional processing to produce a time series. A tidal atlas typically contains speed and direction information for a number of locations, the valid time of which is expressed as a whole number of hours before and after time of high water at a reference tidal water level station (**Error! Reference source not found.**). The speed and direction for any time are computed as a function of the daily predicted tides at the reference station.

For currents based on tide range, the range at the reference station for the day in question first has to be determined. Second, if the amplitude is based on the neap and spring ranges, a factor is computed; otherwise the factor is 1.

The factor (F) is computed as $F = (R - R_{neap})/(R_{spring} – R_{neap})$.
Where:

R = the range for that tidal cycle
R_{spring} = the spring tide range
R_{neap} = the tide range at neap

Third, F is applied to the atlas value to determine the current speed and direction at each hour before and after high water at the reference station.

For example, speed is computed as: $S = S_{neap} + F(S_{spring} – S_{neap})$.

Finally, the time of the current, whether before or after high water, is converted to time and date.

For currents based on tidal current stage, the process is similar except that the time and factor are related to a specific current stage (e.g., flood) at the reference station.

8 MAINTENANCE

<This clause is in the template>

Maintenance and Update Frequency:

Data Source:

Production Process:

<S-100 Part 11 Product Specification 11-10 Data maintenance>

The data product specification shall provide information on how the data is maintained. It should describe the principles and criteria applied in maintenance decisions, as well as the expected frequency of updates. The product specification shall include this information for each identified scope.

Maintenance information shall also provide procedures regarding how known errors in the data shall be handled. Any organisation performing data maintenance for the data product defined by the data product specification shall provide a reference to the detailed maintenance guide used for the maintenance process. (See also Metadata / Maintenance Information). Information about maintaining the data product specification itself is included in the Overview.

Table 8.1 - Maintenance and Update Frequency

Item Name	**Description**	**Multiplicity**	**Type**
maintenanceAndUpdateFrequency	Frequency with which changes and additions are made to the data product (per update scope)	1..*	MD_MaintenanceInformation (ISO 19115)
dataSource	Identification of the kinds of data sources usable to produce datasets	1..*	LI_Source (ISO 19115)
productionProcess	Textual description of the production process applicable to the datasets (per scope or data source)	1..*	LI_ProcessStep (ISO 19115)

9 PORTRAYAL

9.1 Introduction

This section describes means of displaying surface current vectors to support route planning and route monitoring. Two types of data are discussed in depth. The first is point data, which would apply to historical data, astronomical predictions, and real-time data, and gridded data, which would apply to model-based forecasts. Current vector characteristics used for single-point data can be adapted to displaying gridded data.

For example, a point portrayal may be provided to display currents at significant locations such as turning points or where real-time observations are available. A gridded portrayal may be provided for voyage planning where a mariner's selection of routes may be influenced by an overview of the currents. Note that not all portrayal categories (point and gridded) may be available for all types of currents data (historical observations, real-time observations, astronomical predictions, and forecast total currents).

Some additional topics are raised but will be discussed only briefly. These include one-dimensional display (e.g., currents along a transit path) and portrayal of surface current data along streamlines.

All recommended sizes are given assuming a minimum size ECDIS display of 270x270 mm or 1020x1020 pixels. In the case of larger, smaller or higher resolution display, appropriate adjustments should be made. For example with a high resolution small display, spacing should be higher, and with a large screen wall size display they should be lower. Here we assume a display of width w mm and height h mm.

Also, we use functions to convert data longitude (X) and latitude (Y) into screen coordinates x and y. Therefore,

$x = f(X,Y), \quad 0 \leq x \leq w$
$y = g(X,Y), \quad 0 \leq y \leq h.$

9.2 Point Data

Portrayal of current using single point data should be used for instances where the data source is a single current meter (e.g., a historical or real-time current measuring device) or a tide prediction at a single location. The single-point current is represented by an image of an arrow placed at the position of the originating data. The direction of the current is represented by the orientation of the arrow. Current speed is represented by (a) the size of the arrow, (b) the colour, or (c) a numerical value. The numerical value of speed as a number, in knots and tenths of a knot, in black text with a white border and be available when the mouse is held over the data point. Similarly, the numerical value of direction as a number, in degrees and tenths of a degree, in black text with a white border and be available when the mouse is held over the data point.

Arrow Shape

The generalized arrow shape (Figure 9.1) shall be created and scaled to any size using the input parameters shown. This shape is unique and so does not conflict with existing arrow and arrow-like shapes previously approved for use in ECDIS (Figure 9.2). The point on the arrow symbol along the vertical centreline at a height equal to one-half the quantity ‘al’ is placed at the corresponding position (longitude and latitude) on the chart image.

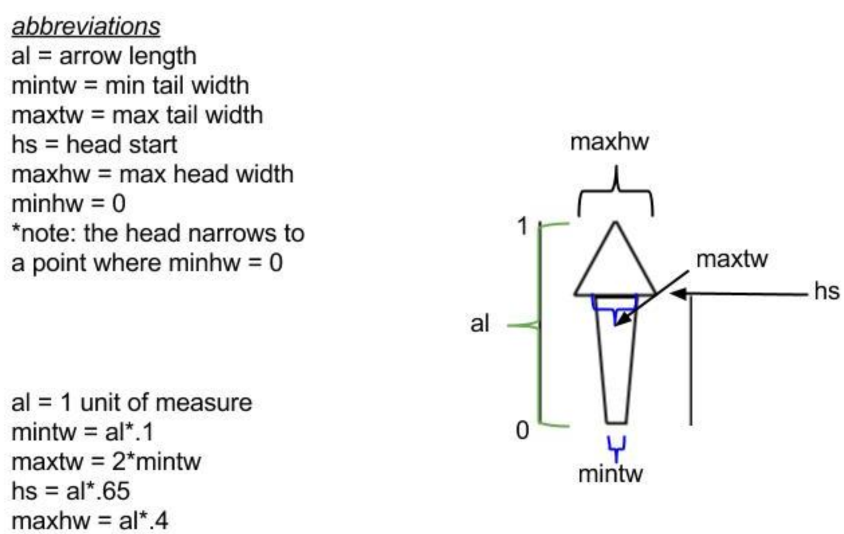


Figure 9.1 - Generalized arrow shape for use in representing surface currents. (need to show the position on the arrow of ½ the height) (Also, symbol should one shape, not two shapes)

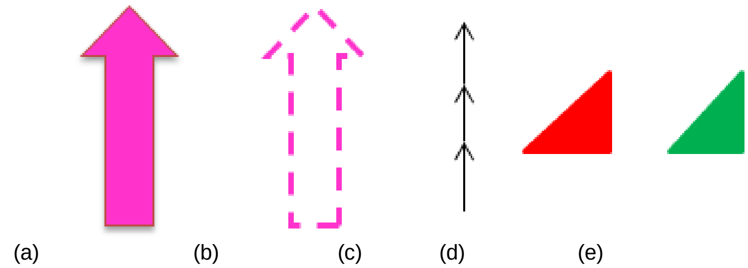


Figure 9.2 – Existing arrow types and approximate colours approved for use in ECDIS: (a) and (b) for traffic separation schemes, (c) for recommended (one-way) tracks, and (d) and (e) for conical buoys.

Arrow Size

The arrow size should be a function of the speed the arrow represents. The speed scaling used shall be a linear interpolation between zero and the highest values in the appropriate dataset. Let S_{max} be the highest speed in the dataset. Then let S'_{max} be the highest value, based on N intervals and rounding upward to give 0.1 kt precision. Let the highest speed be equivalent to 5 % of the screen width, or 0.05w. Then speed is then scaled by:

$$cS'_{max} = 0.05w,$$

so that the scaling factor is

$$c = 0.05w/S'_{max}$$

Note that the use of a constant factor precludes the zooming capability.

Arrow Direction

The direction of the arrow symbol is the same as the direction toward which the current is flowing. If the map projection is Mercator, angles are preserved, so current direction is identical to direction on the screen. For other map projections, the portrayed direction must be computed.

Colour

The colour of the arrow will be based on the speed value of the data, and will have a fixed number of colour values corresponding to a speed range. Assume that the number of values, N, is 9 (Table 9.1). (The monitor gamma values need to be taken into account – refer to IHO standards). A sample scale is shown in Figure 9.4.

Table 9.1 – Sample color values for a 9-interval display.

Step	Red	Green	Blue	Step	Red	Green	Blue
1	118	82	226	6	205	193	0
2	72	152	211	7	248	167	24
3	97	203	229	8	247	162	157
4	109	188	69	9	255	30	30
5	180	220	0				

Figure 9.4 Sample colour scale. (should it be based on equal speed intervals?)

Numerical Values

The current speed and direction values for the generalized arrow should be located in the center of the base of the triangle (Figure 9.3). Also, the optional data (water level, speed uncertainty, and direction uncertainty) are portrayed here.

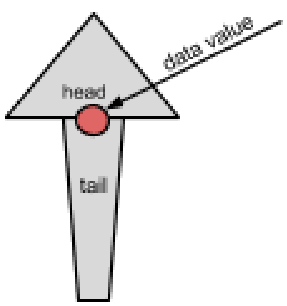


Figure 9.3 - Location of the data value in the generalized arrow.

(need a figure which shows speed and direction numerical values)

Transparency

The transparency will be adjusted according to the background chart/image used (Table 9.2). The value alpha represents the level of opaqueness of the arrow and numerical value of speed relative to the background image. (What are the rules for selecting alpha?)

Background	Alpha
Satellite	1.0
RNC	1.0
ENC Day	1.0
ENC Dusk	.4
ENC Night	.2

Table 9.2 - Alpha (transparency) values.

9.3 Gridded Data

A gridded coverage will use multiple arrows to depict the current (Figure 9.4), with each individual current arrow having the qualities described in Section 9.2. The acceptable arrowhead style for gridded arrows will be the generalized style defined in Figure 9.1.

Linear interpolation in space should be used to obtain data points from the model grid for generating additional grid points in the portrayal. Interpolation should be of the horizontal and vertical components of current, and the interpolated components are then used to calculate speed and direction.

The number of interpolated points is based on (a) the number of original grid points that can be displayed in the screen window, and the desired number of points to be displayed. For example, of there only two points in the horizontal, and it is desired to show 10 points, the interpolation should yield 10/2 or 5 computed points between the original points. (need more explanation here)

The speed and direction values of the dataset could be available when the mouse is over a data point as well as encoded into a color scheme for the arrows. Methods of portraying uncertainty, other than by displaying the numerical value, have not yet been established.

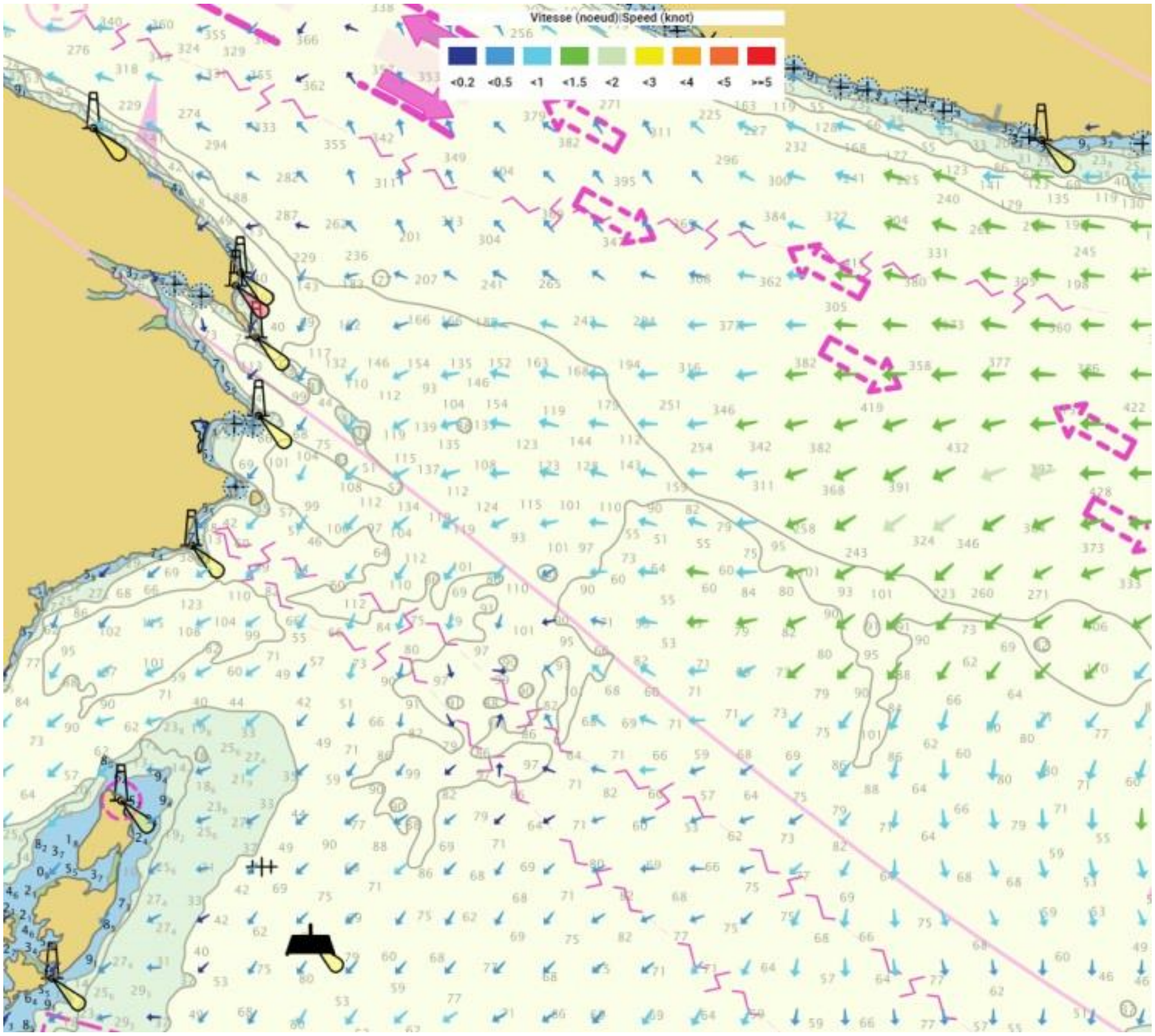


Figure 9.4 – Sample depiction of gridded surface current data in an electronic chart.

For gridded arrows, the arrow scaling shall be defined as the minimum and maximum sizes in mm of the corresponding speed/intensity values from the data set. The spacing will be dependent upon the resolution of the original grid and zooming capability.

9.4 Zooming Capability

It is important to note that for each defined feature below (arrow spacing on the line/in the grid, arrow size, streamline spacing), when a user zooms out the size of the feature should stay constant in screen coordinates (but change in map coordinates). It is important to stop adding more detail beyond model resolution. When zoomed in beyond the highest data density, the spacing should be approximately the same as the flow model resolution so as not to give a false impression of model resolution (Figure 9.5).

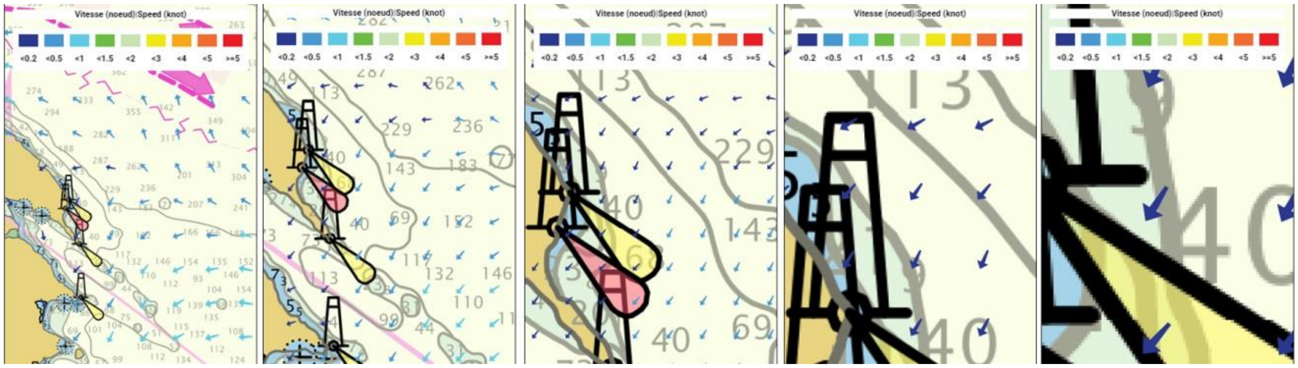


Figure 9.5 - Example of multiple zoom levels with gridded representation.

10 DATA PRODUCT FORMAT (encoding)

10.1 Introduction

<S-100 section 11-12:Data Product format (encoding)>

This section includes a description of file structures and format. The file structure (encoding) could be specified completely here, or by reference to a separate profile or standard. For example, S-100 gives guidance on GML (ISO 19136) encoding; a given product would have a specific GML application schema, expressed in one or more XML Schema Definition Language files. Specialized products may use other encodings, for example S-100 contains a profile of ISO 8211 binary encoding.

Table 10.1 - Data format information

Item Name	**Description**	**Multiplicity**	**type**
formatName	Name of the data format	1..*	CharacterString
version	Version of the format (date, number, etc.)	0..1	CharacterString
characterSet	Character coding standard used for the dataset (western European requirement, Greek, Turkish, Cyrillic)	1	MD_CharacterSetCode (ISO 19115)
specification	Name of a subset, profile, or product specification of the format	0..1	CharacterString
fileStructure	Structure of delivery file	0..1	CharacterString

Surface current data is packaged and transmitted to a ship-board ENS in a small number of structured datasets. Here we define structures for time-series data and for gridded data. An explanation of the required metadata is also included.

10.2 Product Structure

Here we describe the single product format, one developed for both time series data (at a single station) or for gridded data. That format is portrayed in Figure 10.1. The metadata block will describe both time series data and gridded data, and following that there will be the sets of the actual surface current data, one set for each time period.

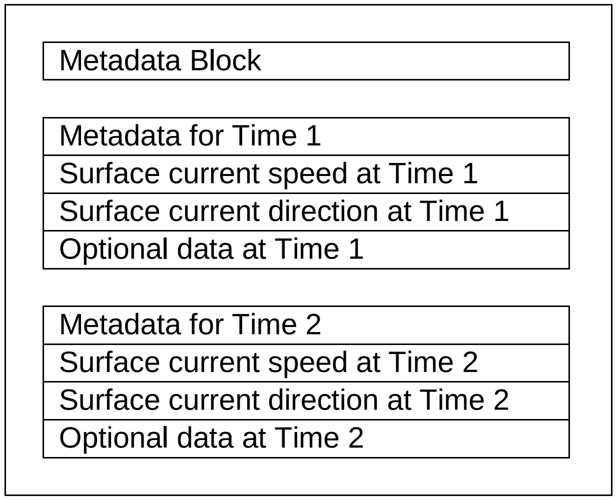


Figure 10.1 - Schematic of the S-111 data product format.

10.3 Metadata

There will be an initial group of product metadata (the Metadata Block in Figure 10.1) containing information that is common to all types of current data. The format of the metadata is described in the table below (Table 10.2). Most of the variables are self-explanatory. However, the following definitions and assumptions apply:

- Country of origin and subdivisions (Nos. 1, 2) are given in ISO 3166-1.
- The number of grid points in each direction must be computed from the minimum and maximum longitudes and latitudes (Nos. 6 through 9) and the grid spacing (Nos. 19, 20) (see Clause 10.4).
- The land mask (No. 21) is coded by the null value, which must be negative.
- The coding for missing data is the same as the land mask (No. 21).
- If the current is described as a layer average (No. 22), the depth value (No. 23) is the layer thickness. If the current is described as having a depth, the actual depth below the surface is given in No. 23.
- Since speed and direction uncertainty fields are optional (No. 29), there is a provision to specify uncertainty as unknown, provide spatially-constant values, or to provide an array.

The overall structure of the surface current data product may be created by assembling the data and metadata, each of which were described above. Sets of arrays for speed, direction, etc. for any one specific time are shown as grouped together in a block of data. The organization of the data product for time series differs slightly from that for the gridded data, so they are treated separately. Both product structures are compliant with the HDF5 and NetCDF data architectures, which allow multidimensional arrays of data to be grouped with metadata.

Table 10.2 - Primary metadata common to all surface currents data. Variables are grouped by: administration, geography, time information, data format, depth, and uncertainty information.

N	DESCRIPTION	UNITS	DATA TYPE	PROPOSED VARIABLE NAME
1	Country of Origin	NA	CodeList	Country
2	Primary Producing Agency Information	NA	CodeList	Producing_Agency
3	Secondary Producing Agency Information	NA	Text	Secondary_Agency
4	Name of Geographic Region	NA	Text	Geographic_Region
5	Name of Geographic Subregion	NA	Text	Geographic_Subregion
6	Minimum Longitude of Area	Arc Degrees	Real	West_Bound_Long
7	Maximum Longitude of Area	Arc Degrees	Real	East_Bound_Long
8	Minimum Latitude of Area	Arc Degrees	Real	South_Bound_Lat
9	Maximum Latitude of Area	Arc Degrees	Real	North_Bound_Lat
10	Time of Data Product Production	Y,M,D,H,M,S	Date-Time	T_product
11	Valid Time of First Value	Y,M,D,H,M,S	Date-Time	T_valid1
12	Valid Time of Last Value	Y,M,D,H,M,S	Date-Time	T_valid2
13	Number of Individual Time Values	None	Integer	K_Sets
14	Data Type (1=historical obs, 2=real-time observation, 3=astronomical prediction, 4=analysis, 5=hindcast, 6=forecast)	None	Enumeration	Index_Data_Type
15	Name of Station or Grid	NA	Text	-
16	Methodology: instrument or model	NA	Text	-
17	Grid Origin Longitude	Arc Degrees	Real	Origin_Longitude
18	Grid Origin Latitude	Arc Degrees	Real	Origin_Latitude
19	Grid Spacing Longitudinal	Arc Degrees	Real	Delta_Longitude
20	Grid Spacing Latitudinal	Arc Degrees	Real	Delta_Latitude
21	Land Mask/Missing Data Value (e.g., -1.0)	(Varies)	Real	Land_Mask_Value
22	Index for Layer Averaging or Depth of Current (1=layer, 2=depth below surf, 3=depth below fixed datum)	None	Enumeration	Index_Depth_Ref
23	Layer Thickness (if above index=1) or Depth of Current Below Datum (if above index=2,3)	Meters	Real	Surcur_Depth
24	Datum for Surface Elevation (if above index=3, then 0=unk, 1=LAT, 2=MLLW, 3=bottom, etc.)	None	Enumeration	Index_SurfDatum
25	Index for Surface Elevation (0=no,1=array)	None	Enumeration	Index_Surface_Elev
26	Datum for Surface Elevation (if above index=1, then 0=unk, 1=LAT, 2=MLLW, 3=bottom, etc.)	None	Enumeration	Index_ElevDatum
27	Horizontal Position Uncertainty	Meters	Real	Unc_Horizpos
28	Vertical Position Uncertainty	Meters	Real	Unc_Vertpos
29	Data Uncertainty Index (0=unk,1=const, 2=array)	None	Enumeration	Index_Data_Uncert
30	Speed Uncertainty Constant Value (Optional)	Meters	Real	Unc_Speed
31	Direction Uncertainty Constant Value (Optional)	Arc Degrees	Real	Unc_Direction

10.4 Data Referencing System

The time series data in the surface current product consists of sets of arrays, with one set per time (T_1, T_2, etc.) (Figure 10.1). There will be from two to five variables for each set of data for a station, one for each variable. The variables include, in order, the speed and direction, and optionally (if *Index_Surf_Elev* = 1) the sea surface elevation, and (optionally, depending on the value of *Index_Data_Uncert*) the uncertainty in speed and uncertainty in direction. We represent each array as A^m, where *m* is the variable type. Thus A^1 = speed, A^2 = direction, A^3 = water level, A^4 = speed uncertainty, *and* A^5 = direction uncertainty.

As an example, consider the time series of speed values shown in Figure F.4.

speed = 0, 0, 0, 0.5191959, 0.5159838, 0.5159435, 0.5186388, 0.5209069, 0.5167338,..

For shorthand, we represent this series as A1i,j,k , where i is the longitudinal index, j is the latitudinal index, and k is the time index. Each array will be dimensioned as A(I_Max,J_Max, N_Values), where I_Max is the maximum number of points in the longitudinal direction, J_Max is the maximum number of points in the latitudinal direction, and K_Sets is the number of the time series. Null values are used to represent missing values.

NOTE: I_Max = (East_Bound_Long – West_Bound_Long)/Delta_Longitude + 1
and J_Max = (North_Bound_Lat – South_Bound_Lat)/Delta_Latitude + 1.

For the spatial index pair (i,j), where i varies from 1 to I_Max and j varies from 1 to J_Max, the geographic location can be calculated as

Longitude of point (i,j) = Xij = Origin_longitude + (i – 1)*Delta_Longitude

Latitude of point (i,j) = Y ij = Origin_latitude + (j – 1)*Delta_Latitude

The time for which tha data are valid is given in the block metadata.

For any one time, the data are arranged spatially as follows. The first I_Max values are for row 1 (i.e., j = 1), the next I_Max values are for row 2 (i.e., j = 2), etc. The first set will consist of the following coverage data for the first valid time, and the set for the second valid time (if any) will follow.

10.5 Digital Certification Block

Information here is used to certify the validity or integrity of the data.

11 DATA PRODUCT DELIVERY

11.1 Introduction

Shouldn't there be a different term used to distinguish encoding from the Data Producers to the NetCDF/HDF5 format for this product description and the encoding that goes from the 3rd party to the end user?

The Product Specification only addresses the information content of the product. Multiple encodings and product delivery mechanisms for the data are permitted.

Should we be consistent and say "Multiple exchange formats" as to not confuse with the original "encoding" from the data producer to this specification?

In order to support the certification of surface current data as an aid to navigation a Digital Certification Block may be included with the surface current data. That is, if the Digital Certification Block is included then the certification of the data set can be verified. Otherwise the data set is unverified.

Table 11.1 – Elements of Data Product Delivery.

Item Name	Description	Multiplicity	Type
unitsOfDelivery	Description of the units of delivery (e.g. tiles, geographic areas)	0..1	CharacterString
transferSize	Estimated size of a unit in the specified format, expressed in Mbytes	1	>0
mediumName	Name of the data medium	1	Free text
otherDeliveryInformation	Other information about the delivery	1	Free text

11.2 Dataset

Datasets include both New Editions and Updates.

Dataset size is limited to 10 MB. The size of each file can vary widely, depending on the data. Using the sample HDF5 file (see Figure F.3), a file containing, along with metadata, a single speed array and a single direction array, each with 100,000 grid points would have a size of approximately 0.21 mb.

11.3 Dataset File Naming

The file naming convention described here is to be used for all surface current files from all sources.The proposed file naming convention consists of 21 characters. The characters are used to identify the following: the country code (two characters);; ONA specified geographic designator for the region of coverage (four characters); date (year, month, day) of first valid time (8 characters); current source (Observation [including real-time], Prediction, or Forecast) (one character); and version designation for that day (two characters). The version designation allows for up to 260 versions per day. The filename extension (sfc) denotes the surface current data product. This is summarized in the table below (Table 11.1).

Table 11.1 - Characters used in the file naming convention.

N	DESCRIPTION	LENGTH	EXAMPLE
1	Country Code	2	CA
2	Geographic Designator	4	GSTL
3	First Valid Time (YYYYMMDD)	8	20140611
4	Data Source (O=Obs, F=Fcst, P=Pred)	1	F
5	Version (first=a1,second=a2, etc, up to z9)	2	a3
6	Extension	4	.sfc
	Total =	21	

For example, the file named

20140611145146-currents-MOGSL-20140611180000.hdf5

was downloaded from Canada's St. Lawrence Global Observatory English-language server (http://slgo.ca/ocean/index.jsp?lg=en), and contains a surface current prediction for the Gulf of St. Lawrence on June 11, 2014. The file was downloaded at 2:51 PM EST (or 14:51:46 on a 24-hr clock) and valid for 18:00:00 EST that day. The corresponding standard file name (presuming that there are forecasts for the hours 00, 06, 12, and 18) would be:

CAGSTL20140611Fa3.sfc

Similarly, a file for the U.S.'s Tampa Bay operational forecast system,

nos.tbofs.fields.f048.2014111430.t12z.nc

was originally created on November 30, 2014 at 12:00 UCT (or 7:00 AM EST) and is valid for a time 48 hours after the 12:00 UTC origination time. The file was downloaded from (http://opendap.co-ops.nos.noaa.gov/thredds/catalog/NOAA/TBOFS/MODELS/201411/catalog.html), the CO-OPS server web portal. The corresponding standard file name (presuming that there are forecasts for the hours 00, 06, 12, and 18 that day) would be:

USTAMP20141202Fa2.sfc

11.4 Support Files

<Specify if the product will utilize support files>

Support file Naming
<Specify if naming convention for support files>

11.5 Exchange Catalogue

<Specify if the datasets will be part of an exchange catalogue>

11.6 Transmission of the Data

Surface current data must be delivered to the vessel on a timely basis. Real-time observations require the most frequent updating, typically have only a small amount of data, and are only valid for a short time (i.e., a few minutes). Therefore, radio and/or internet-based transmission are the most logical. Model-based forecasts are typically updated only a few times per day, but often involve a large number of grid points and valid times. This internet-based transmission seems the most logical. Tidal prediction time series, while often involving numerous stations and valid times, can be prepared far ahead of time. There, solid-state media (e.g., flash drive) would be suitable for transmission. Table 7.2 summarizes these options.

Table 7.2 – Surface current data types and preferred modes of transmission.

Data Type	Update period	Transmission Mode
Real-Time Observation	0.1 hr	Radio, Internet
Model-based Forecast	6 hr	Internet
Astronomical Tidal Prediction	1 yr	Media

12 METADATA

12.1 Introduction

This section is for exchange metadata

Metadata is described as part of the Application Schema (ANNEX B).

12.2 Language

English

ANNEX A ADDITIONAL TERMS AND DEFINITIONS

Terms that are defined in this annex and clause 1.3.2 are highlighted in **bold**.

.

accuracy
closeness of agreement between an observed value and the true value or a reference value accepted as true
NOTE 1 A test result can be observations or measurements
NOTE 2 For positioning services, the test result is a measured value or set of values
NOTE 3 For observations and measurements, true values are not obtainable. In their place reference values which are accepted as true values are used
[ISO 19157, ISO 19116]

application
manipulation and processing of **data** in support of user requirements
[ISO 19101]

application schema
conceptual **schema** for **data** required by one or more **applications**
[ISO 19101]

attribute
a named element within a classifier that describes a **range** of values that **instances** of the classifier may hold
NOTE An **attribute** is semantically equivalent to a composition association; however, the intent and usage are normally different
[ISO/TS 19103]
named property of an entity
NOTE 1 Describes a geometrical, topological, thematic, or other **characteristic** of an entity
[ISO/TS 19130]

attribute <**UML**>
feature within a classifier that describes a **range** of values that **instances** of the classifier may hold
[ISO/TS 19103]

characteristic
abstraction of a property of an **object** or of a set of **objects**
NOTE Characteristics are used for describing concepts
[ISO 1087-1, ISO 19146]
distinguishing **feature**
NOTE 1 A **characteristic** can be inherent or assigned
NOTE 2 A **characteristic** can be qualitative or Quantitative
NOTE 3 There are various classes of **characteristics**, such as the following: physical (e.g., mechanical, electrical, chemical, or biological), sensory (e.g., related to smell, touch, taste, sight, or hearing), behavioral (e.g., courtesy, honesty, or veracity), temporal (e.g., punctuality, reliability, or availability), ergonomic (e.g., physiological, or related to human safety), and functional (e.g., maximum speed of an aircraft)
[ISO 19113]

class <**UML**>
description of a set of **objects** that share the same **attributes**, operations, methods, relationships, and semantics
NOTE A **class** may use a set of interfaces to specify collections of operations it provides to its environment. See: interface
[ISO/TS 19103-2]

classification
abstract representation of real-world phenomena using **classifiers**
[ISO 19144-1]

classifier
a **model** element that describes behavioral and structural features
[ISO/TS 19103]
definition used to assign **objects** to legend **classes**
NOTE Classifiers can be defined algorithmically or according to a set of classification system-specific rules
[ISO 19144-1]

classifier <**UML**>
mechanism that describes behavioral and structural features
NOTE Classifiers include interfaces, classes, data types, and components
[ISO/TS 19103-2]

conceptual model
model that defines concepts of a universe of discourse
[ISO 19101]

confidence
accuracy of a **data** quality result
[ISO 19157]

conformance
fulfilment of specified requirements
[ISO 19105]

constraint
condition or restriction expressed in natural-language text or in a machine-readable language for the purpose of declaring some of the semantics of an element
[ISO/TS 19103]
restriction on how a link or turn may be traversed by a vehicle, such as a vehicle **classification**, or physical or temporal **constraint**
[ISO 19133]

constraint <**UML**>
condition or restriction expressed in natural-language text or in a machine-readable language for the purpose of declaring some of the semantics of an element
[ISO/TS 19103]
NOTE Certain **constraints** are predefined in the UML; others may be user defined. **Constraints** are one of three extensibility mechanisms in UML. See: tagged value, stereotype
[retired version of ISO/TS 19103]

content model
information view of an **application schema**
NOTE The term “information view” comes from the ISO Reference **model** for Open distributed processing (RM-ODP) as specified in ISO 19101-2
[ISO/TS 19129]

continuous coverage
coverage that returns different values for the same **feature attribute** at different **direct positions** within a single spatial **object**, temporal **object**, or spatiotemporal **object** in its **domain**
NOTE Although the **domain** of a **continuous coverage** is ordinarily bounded in terms of its spatial and/or temporal extent, it can be subdivided into an infinite number of **direct positions**
[ISO 19123]

coverage domain
Consists of a collection of **direct positions** in a coordinate space that may be defined in terms of up to three spatial dimensions as well as a temporal dimension.

[Springer 2012]

curve
one-dimensional **geometric primitive**, representing the continuous **image** of a line

NOTE The boundary of a **curve** is the set of **points** at either end of the **curve**. If the **curve** is a cycle, the two ends are identical, and the **curve** (if topologically closed) is considered to not have a boundary. The first **point** is called the start **point**, and the last is the end **point**. Connectivity of the **curve** is guaranteed by the *continuous **image** of a line* clause. A topological theorem states that a continuous **image** of a connected set is connected

[ISO 19107]

data
reinterpretable representation of **information** in a formalized manner suitable for communication, interpretation, or processing

[ISO 19115]

data product specification
detailed description of a **dataset** or **dataset series** together with additional **information** that will enable it to be created, and supplied to and used by another party

NOTE A **data product specification** provides a description of the universe of discourse and a specification for mapping the universe of discourse to a **dataset**. It may be used for production, sales, end-use, or other purpose

[ISO 19131]

data type
a descriptor of a set of values that lack identity (independent existence and the possibility of side-effects)

EXAMPLE Integer, Real, Boolean, String, and Date

NOTE **Data types** include primitive predefined **types** and user-definable **types**

[ISO/TS 19103]

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

EXAMPLE Integer, Real, Boolean, String, and Date

NOTE **Data types** include primitive predefined ***types*** and user-definable **types**

NOTE A **data type** is identified by a term, e.g., Integer. Values of the **data types** are of the specified value **domain**, e.g., all integer numbers between −65 537 and 65 536. The set of operations can be +, -, *, and /, and is semantically well defined. A **data type** can be simple or complex. A simple **data type** defines a value **domain** where values are considered atomic in a certain context, e.g., Integer. A complex **data type** is a collection of **data types** which are grouped together. A complex **data type** may represent an **object** and can thus have identity

[ISO 19118]

data value
an **instance** of a **data type**; a value without identity

NOTE A value may describe a possible state of an **object** within a **class** or **type** (**domain**)

[ISO/TS 19103]

dataset
identifiable collection of **data**

NOTE 1 A **dataset** may be a smaller grouping of **data** which, though limited by some **constraint** such as spatial extent or **feature type**, is located physically within a larger **dataset**. Theoretically, a **dataset** may be as small as a single **feature** or **feature attribute** contained within a larger **dataset**. A hard-copy map or chart may be considered a **dataset**

NOTE 2 The principles which apply to **datasets** may also be applied to **dataset series** and reporting groups

[ISO 19101, ISO 19115, ISO 19117]

dataset series
collection of **datasets** sharing the same **product specification**

[ISO 19115]

datum
parameter or set of parameters that define the **position** of the origin, the scale, and the orientation of a **coordinate** system

NOTE 1 A **datum** defines the **position** of the origin, the scale, and the orientation of the axes of a **coordinate** system

NOTE 2 A **datum** may be a geodetic **datum**, a **vertical datum**, an engineering **datum**, an **image datum**, or a temporal **datum**

[ISO 19111, ISO 19116]

depth
distance of a **point** from a chosen reference surface measured downward along a line perpendicular to that surface

NOTE A **depth** above the reference surface will have a negative value

[ISO 19111]

element <**XML**>
basic **information** item of an XML document containing child **elements**, **attributes**, and character **data**

NOTE From the XML **information** set: “Each XML document contains one or more **elements**, the boundaries of which are either delimited by start-tags and end-tags, or, for empty **elements**, by an empty-element tag. Each **element** has a **type**, identified by name, sometimes called its *generic identifier* (GI), and may have a set of **attribute** specifications. Each **attribute** specification has a name and a value.”

[ISO 19136]

elevation
the altitude of the ground level of an object, measured from a specified vertical datum.

[IHO:S100 GFM]

encoding
conversion of **data** into a series of codes

[ISO 19118]

error
discrepancy with the universe of discourse

[ISO 19138]

feature catalog
catalog containing definitions and descriptions of the **feature types**, **feature attributes**, and feature relationships occurring in one or more sets of geographic **data**, together with any **feature** operations that may be applied

[ISO 19101, ISO 19110]

feature type
classifier for **features**, defined by the set of **characteristic** properties that all **features** of this type carry

[ISO 19109]

class of **features** having common **characteristics**

[ISO 19156]

format
a language construct that specifies the representation, in character form, of **data objects** in a record, file, message, storage device, or transmission channel

[ISO 19145]

framework
relationship between the elements of the **content model** and the separate **encoding** and **portrayal** mechanisms

[ISO/TS 19129]

geographic location
longitude, latitude, and **elevation** of a ground or elevated **point**

[ISO/TS 19130-2]

NOTE For the purpose of this document elevated **point** will be a **depth** based on a specified **datum**.
[CARL 2015]

geometric complex
set of disjoint **geometric primitive**s where the boundary of each **geometric primitive** can be represented as the union of other **geometric primitives** of smaller dimension within the same set
NOTE The **geometric primitives** in the set are disjoint in the sense that no **direct position** is interior to more than one **geometric primitive**. The set is closed under boundary operations, meaning that, for each element in the **geometric complex**, there is a collection (also a **geometric complex**) of **geometric primitives** that represents the boundary of that element. Recall that the boundary of a **point** (the only 0-D primitive **object** type in geometry) is empty. Thus, if the largest dimension **geometric primitive** is a solid (3-D), the composition of the boundary operator in this definition terminates after at most three steps. It is also the case that the boundary of any **object** is a cycle
[ISO 19107]

geometric object
spatial **object** representing a geometric set
NOTE A **geometric object** consists of a **geometric primitive**, a collection of **geometric primitives**, or a **geometric complex** treated as a single entity. A **geometric object** may be the spatial representation of an **object** such as a ***feature*** or a significant part of a ***feature***
[ISO 19107]

geometric primitive
geometric object representing a single, connected, homogeneous element of space
NOTE **Geometric primitives** are nondecomposed **objects** that present **information** about geometric configuration. They include **points**, **curves**, surfaces, and solids
[ISO 19107]

georectified
corrected for positional displacement with respect to the surface of the Earth
[ISO 19115-2]

gridded data
data whose **attribute** values are associated with **positions** on a **grid coordinate** system
[ISO 19115-2]

image
gridded **coverage** whose **attribute** values are a numerical representation of a physical parameter
NOTE The physical parameters are the result of measurement by a sensor or a prediction from a **model**
[ISO 19115-2]

implementation
realization of a specification
NOTE In the context of the ISO geographic **information** standards, this includes specifications of geographic **information** services and **datasets**
[ISO 19105]

information
knowledge concerning objects, such as facts, events, things, processes, or ideas, including concepts, that within a certain context has a particular meaning
[ISO 19118]

instance
individual entity having its own identity and value
NOTE A classifier specifies the form and behavior of a set of **instances** with similar properties
[ISO/TS 19103]
object that realizes a **class**
[ISO 19107]

layer
basic unit of geographic **information** that may be requested as a map from a server
[ISO 19128]

lineage
chain of legal ownership of content; history of ownership
[ISO 19153]

metadata
data about **data**
[ISO 19115]

metamodel <**UML**>
model that defines the language for expressing other models
NOTE A **metamodel** is an instance of a meta-metamodel
[ISO/TS 19103]

model
abstraction of some aspects of reality
[ISO 19109]

navigation
combination of routing, route transversal, and tracking
NOTE This is essentially the common term **navigation**, but the definition decomposes the process in terms used in the packages defined in this international standard
[ISO 19133]

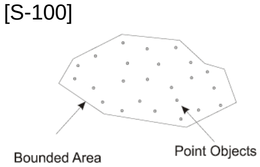
object
entity with a well-defined boundary and identity that encapsulates state and behavior
NOTE 1 An **object** is an **instance** of a **class**
NOTE 2 This term was first used in this way in the general theory of object-oriented programming, and later adopted for use in this same sense in UML. **Attributes** and relationships represent state. Operations, methods, and state machines represent behavior
NOTE 3 A GML **object** is an XML **element** of a **type** derived from AbstractGMLType
[ISO 19107]

object <**UML**>
a discrete entity with a well-defined boundary and identity that encapsulates state and behavior; an **instance** of a **class**
[ISO/TS 19103]

point
zero-dimensional **geometric primitive**, representing a **position**
NOTE The boundary of a **point** is the empty set
[ISO 19107]

point coverage
coverage that has a **domain** composed of **points**
[ISO 19123]

point set
set of 2, 3 or n dimensional points in space.
[S-100]



point set coverage
coverage function associated with point value pairs in 2 dimensions.
[S-100]
NOTE a coverage function is driven by a set of points (with X, Y position) together with a record of one or more values at that postion.

portrayal
presentation of **information** to humans

[ISO 19109, ISO 19117]

portrayal catalogue

collection of defined **portrayals** for a feature catalogue

NOTE: Content of a portrayal catalogue includes **portrayal functions**, **symbols**, and **portrayal context.**

[ISO 19117]

portrayal context

circumstances, imposed by factors extrinsic to a geographic dataset, that affect the **portrayal** of that dataset.

EXAMPLE Factors contributing to portrayal context may include the proposed display or map scale, the viewing conditions (day/night/dusk), and the display orientation requirements (north not necessarily at the top of the screen or page), among others

NOTE Portrayal context may influence the selection of portrayal functions and construction of symbols

[ISO 19117]

portrayal function

function that maps geographic features to symbols

NOTE Portrayal functions can also include parameters and other computations that are not dependent on geographic feature properties

[ISO 19117]

portrayal function set

function that maps a feature catalog to a symbol set

[ISO 19117]

portrayal rule

specific kind of portrayal function expressed in a declarative language

NOTE A declarative language is rule based and includes decision and branching statements

[ISO 19117]

portrayal service

generic interface used to portray features

[ISO 19117]

portrayal specification

collection of operations applied to the feature instance to portray it

[ISO 19117]

position

data type that describes a **point** or geometry potentially occupied by an **object** or person

NOTE A **direct position** is a semantic subtype of **position**. **Direct positions** as described can only define a **point**, and therefore not all **positions** can be represented by a **direct position**. That is consistent with the *is type of* relation. An ISO 19107 geometry is also a **position**, but not a **direct position**

[ISO 19132]

positional accuracy

closeness of **coordinate** value to the true or accepted value in a specified reference system

NOTE The term *absolute accuracy* is sometimes used for this concept to distinguish it from relative **positional accuracy**. Where the true **coordinate** value may not be perfectly known, **accuracy** is normally tested by comparison with available values that can best be accepted as true

[ISO 19116]

product

result of a process

[ISO 19158]

product specification

description of the universe of discourse and a **specification** for mapping the universe of discourse to a **dataset**

[ISO 19158]

profile

set of one or more base standards or subsets of base standards, and, where applicable, the identification of chosen clauses, classes, options, and parameters of those base standards, that are necessary for accomplishing a particular **function**

NOTE A **profile** is derived from base standards so that, by definition, **conformance** to a **profile** is **conformance** to the base standards from which it is derived

[ISO 19101, ISO 19106]

profile <**UML**>

definition of a limited extension to a reference **metamodel** with the purpose of adapting the **metamodel** to a specific platform or **domain**

[ISO/TS 19103]

quadrilateral grid coverage

may be a **rectified grid** or a **referenceable grid**.

[Springer 2012]

quality

totality of **characteristics** of a **product** that bear on its ability to satisfy stated and implied needs

[ISO 19101, ISO 19109]

Degree to which a set of inherent **characteristics** fulfills requirements

NOTE 1 The term ***quality*** can be used with adjectives such as poor, good or excellent

NOTE 2 *Inherent*, as opposed to *assigned*, means existing in something, especially as a permanent **characteristic**

[ISO 19157]

NOTE 3 For the purposes of this technical specification the quality **characteristics** of **product** include:

– **Data** quality (the elements of which are described by ISO 19113)

– Volume of delivery

– Schedule of delivery

– Cost of production and/or update

[ISO 19158]

range

set of all values a **function** *f* can take as its arguments vary over its **domain**

[ISO 19136]

referenceable grid

requires a formula of higher order that transforms into a coordinate reference system.

EXAMPLE the perspective transformation with eight parameters.

[Springer 2012]

render

conversion of digital graphics data into visual form

EXAMPLE Generation of an image on a video display

[ISO 19117]

schema

formal description of a **model**

NOTE In general, a **schema** is an abstract representation of an **object**'s **characteristics** and relationship to other **objects**. An XML **schema** represents the relationship between the **attributes** and **elements** of an XML **object** (for example, a document or a portion of a document)

[ISO 19101]

sequence

finite, ordered collection of related items (**objects** or values) that may be repeated

NOTE Logically, a **sequence** is a set of pairs <item, offset>. LISP syntax, which delimits **sequences** with

parentheses and separates elements in the **sequence** with commas, is used in this international standard
[ISO 19107]

set
unordered collection of related items (**objects** or values) with no repetition
[ISO 19107]

specification
declarative description of what something is or does
NOTE Contrast: **implementation**
[retired version of ISO/TS 19103]**timestamp**
value of time at which an **object**'s state is measured and recorded
[ISO 19132]

symbol
portrayal primitive that can be graphic, audible, or tactile in nature, or a combination of these
[ISO 19117]

tuple
ordered list of values
NOTE 1 The number of values in a tuple is immutable
NOTE 2 the ordered list will generally be a finite **sequence** of **features,** each of a specific **feature type**
[ISO 19136, ISO 19142]

type
a specification of the general structure and behavior of a **domain** of **objects** without providing a physical **implementation**
NOTE A **type** may have **attributes** and associations
[ISO/TS 19103]

UML
The Unified Modeling Language (**UML**) is a general-purpose modeling language in the field of software engineering, which is designed to provide a standard way to visualize the design of a system.

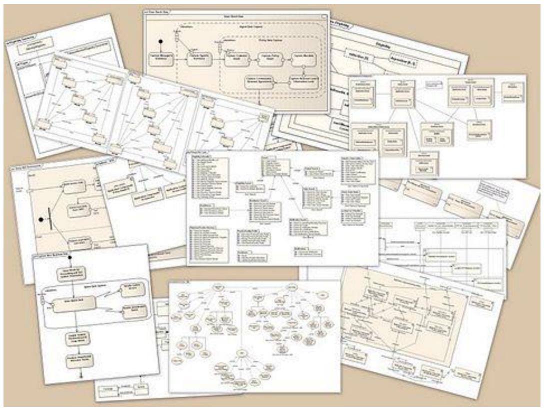


Figure 12.1. image courtesy of Kishorekumar 62

[Wikipedia 2015]

UML application schema
application schema written in UML in accordance with ISO 19109
[ISO 19136]**valid time**
time when a fact is true in the abstracted reality
[ISO 19108]

vector
quantity having direction as well as magnitude
NOTE A directed line segment represents a **vector** if the length and direction of the line segment are equal to the magnitude and direction of the **vector**. The term *vector data* refers to **data** that represents the spatial configuration of **features** as a set of directed line segments
[ISO 19123]

vertical coordinate system
one-dimensional **coordinate** system used for gravity-related height or **depth** measurements
[ISO 19111]

vertical datum
datum describing the relation of gravity-related heights or **depths** to the Earth
NOTE In most cases the **vertical datum** will be related to mean sea level. Ellipsoidal heights are treated as related to a three-dimensional ellipsoidal **coordinate** system referenced to a geodetic **datum**. **Vertical datums** include sounding **datums** (used for hydrographic purposes), in which case the heights may be negative heights or **depths**
[ISO 19111]

ANNEX B APPLICATION SCHEMA

Surface Currents are described using a regularly spaced grid over the areas of interest. The Surface Current Model (SCM) has been broken into parts for easier reading. The core of SCM is described in Figure B1.

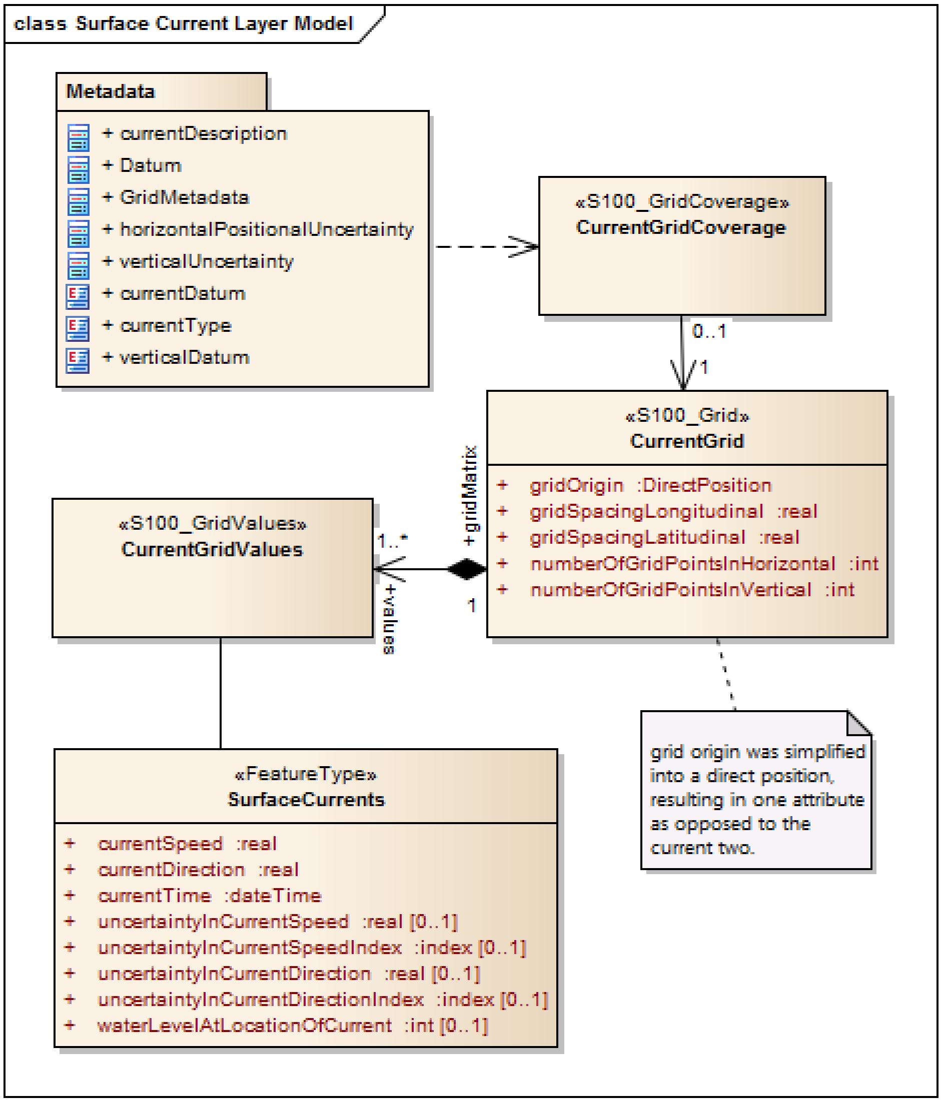


Figure B1 – Surface Current Model.

The Surface current feature class has three mandatory attributes; currentSpeed, currentDirection and currentTime. The remaining attributes are all optional and describe uncertainty regarding the two mandatory attributes and the water level of the specific instance of current. Each instance of surface current is only valid for a specific moment in time and may be part of a time series, as described in the grid metadata.

TBD – clarify the uncertainty attributes; are they the same for a whole grid, or are they individual to the specific grid point.

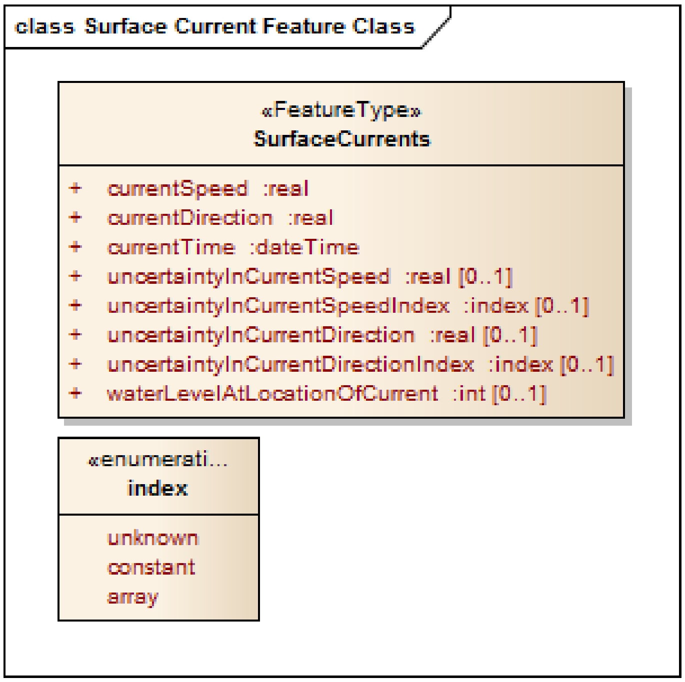


Figure B2 – Surface Current Feature Class.

The metadata model for a specific grid is described in figure B3. The complex attribute currentDescription is used to describe type of current and time series. The complex attribute datum gives the current depth origin. Only one of depthOfCurrent or layerThickness can be encoded for an instance of GridMetadata. The optional attribute timeBetweenDataValues is an integer that captures whole hours between the data values in a series.

TBD – depthOfCurrent is an integer, which means it can only capture whole meters, feet, fathoms, etc. Is that sufficient?

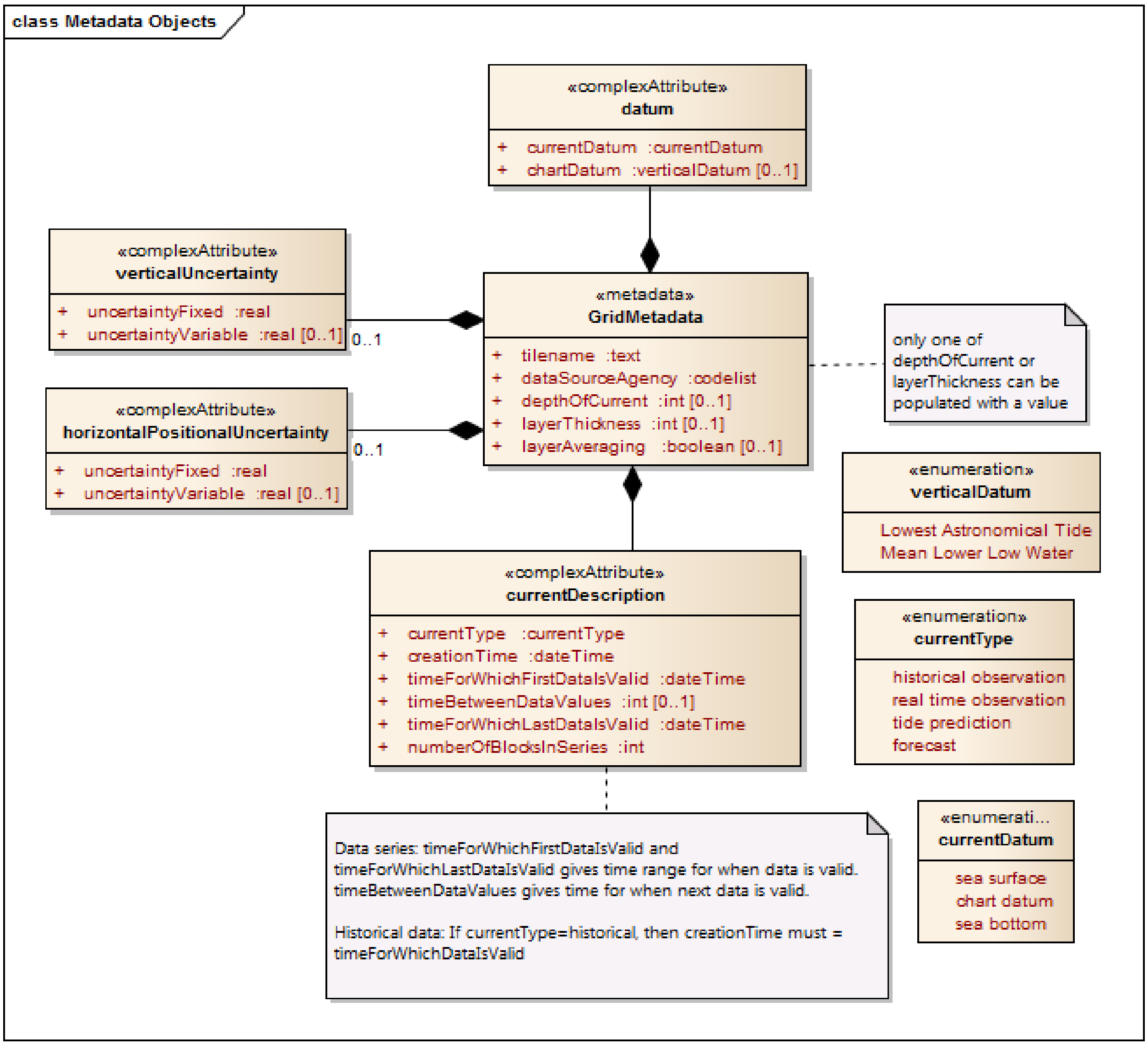


Figure B3 – Surface Current Metadata.

The exchange set structure of Surface Current data is described in figure B4.

TBD – Discovery metadata for surface current datasets/exchange sets and checking for S-100 core metadata compliancy.

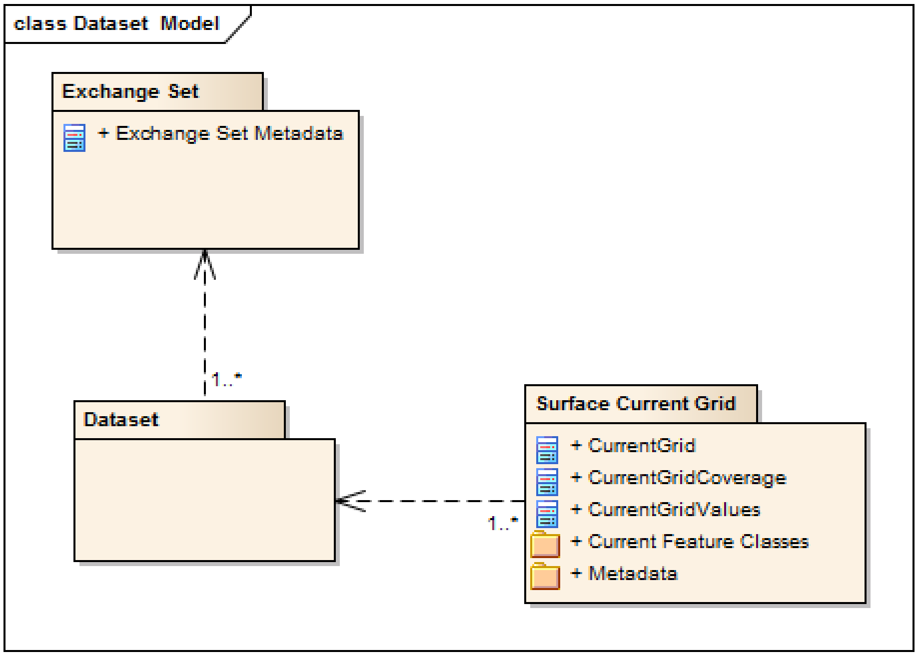


Figure B4 – Surface Current Exchange Set Model.

ANNEX C DATA CLASSIFICATION AND ENCODING GUIDE

IHO Definition: FEATURE: **CURRENT (Water Current):** a set of value items required to define a coverage dataset representing direction and speed of the current.			
S-111 Geo Feature: Surface Currents			
Primitives: S-100_Grid Coverage			
S-111 Attribute	**Allowable Encoding Value**	**Type**	**Multiplicity**
Current Speed	must be in decimal Knots, max resolution 0.01 knot	RE	1
Current Direction	must be in decimal degrees, max resolution 0.1 degree	RE	1
Current Speed Uncertainty (Optional)	must be in decimal Knots, max resolution 0.01 knot	RE	0..1
Direction Uncertainty (Optional)	must be in decimal degrees, max resolution 0.1 degree	RE	0..1
Water level at location of current (Optional)	must be in meters, max resolution 0.001 meters, positive upward	RE	0..1

Feature Attributes

1. Surface Current Speed (surCurSpeed)

Surface Current Speed: IHO Definition:
Unit: knot (kn)
Resolution: 0.01 kn
Format: xx.xx
Examples: 2.54
Remarks:
- Speed always positive
- 0.01 kn equals 0.5144 cm/s

2. Surface Current Direction (surCurDir)

Surface Current Direction: IHO Definition:
Unit: degree (of arc) (˚)
Resolution: 0.1 ˚
Format: xxx.x
Examples: 298.3
Remarks:
- Direction clockwise from true north
- Direction always positive

3. Water Elevation at Surface Current (surCurWatElev)

Water Elevation at Surface Current: IHO Definition:
Unit: metre (m)
Resolution: 0.001 m
Format: xxx.xxx
Examples: -0.514
Remarks:
- Referenced to a vertical datum

4. Surface Current Speed Uncertainty (surCurSpeedUnc)

Surface Current Speed Uncertainty: IHO Definition: Unit: knot (kn) Resolution: 0.01 kn Format: xx.xx Examples: 0.05 Remarks: • Uncertainty interval always positive

5. Direction Uncertainty (surCurDirUnc)

Surface Current Direction Uncertainty: IHO Definition: Unit: degree (of arc) (˚) Resolution: 0.1 ˚ Format: xxx.x Examples: 9.5 Remarks: • Uncertainty interval always positive

ANNEX D NORMATIVE IMPLEMENTATION GUIDANCE

ANNEX E PORTRAYAL CATALOGUE

ANNEX F SURFACE CURRENT DATA

This Annex describes the sources of data, methods of organizing surface current data(the time series and the grid), how the data product format is derived. In the last section we discuss additional features of current data.

F.1. **Data Sources**

For the purposes of this Product Specification, we categorize surface current data into four types, depending on the source. These are:

- Historical observation,
- Real-time observation,
- Astronomical prediction, and
- Model-based prediction.

An historical observation consists of a time series of values at a specific location or area, often at a specific elevation above the bottom or below the surface. Observations can be for a single point (current meter), along a line (Doppler profiler), or an area (coastal radar).

A real-time observation is actually a historical observation but for the recent past. The astronomical tidal current prediction is often a time series computed by a mathematical formula using harmonic constants. This prediction applies to a specific location and depth, and is often produced many months ahead of time.

The astronomical predictions for multiple stations are often combined into a digital tidal atlas, and the individual predicted currents are usually keyed to the time and amplitude of tidal water levels at a nearby station.

Finally, model-based predictions are usually produced by a two- or three-dimensional numerical hydrodynamic model, and include astronomical tide, meteorological forcing, river inflow, spatially varying water density, and open ocean boundary inputs. A model-based hindcast, including an analysis, is based on historically-observed conditions. A forecast is usually produced to predict conditions a few hours or days ahead into the future.

F.2. **Data Organization**

Data are usually organized into either (a) a time series of values, such as for historical and real-time observations, at a single point, or (b) a gridded set of values, such as from a model-based forecast or sea-surface analysis.

F.2.1. **Historical Time Series and Real-Time Data**

An historical observation consists of a time series of values at a specific location or area, often at a specific elevation above the bottom or below the surface. Observations can be for a single point (current meter), along a line (Doppler profiler), or an area (coastal radar).

The data for individual current meter stations are most conveniently organized in a time series. For example, for historical observations and astronomical predictions, each record in the series consists of a time for which the data are valid and the water current data itself: speed and direction. Descriptive data may be contained in a metadata block at the beginning of the file.

Real-time data is similar to historical data in that, in addition to dataset metadata, they include either a single near-real-time value or a time series of values for speed and direction, with the most recent being the near-real-time value. A sample file containing observations is shown in Figure F.1.

```
# Station ID:         cb1101
# # Orientation:        Down (Buoy-Mounted)
# # Time Zone:          UTC
# # Approx. Depth:      Near Surface
# # Blank rows indicate missing data. See our data
# # disclaimer online.
# #
# # Date      Time        Speed (knots) Dir (true)
# 2014-12-01 00:00:00      1.08         215
# 2014-12-01 00:06:00      1.00         225
# 2014-12-01 00:12:00      0.83         226
# 2014-12-01 00:18:00      0.73         230
# 2014-12-01 00:24:00      0.80         223
# 2014-12-01 00:30:00      0.77         236
# 2014-12-01 00:36:00      0.73         229
# 2014-12-01 00:42:00      0.61         224
# 2014-12-01 00:48:00      0.71         224
# 2014-12-01 00:54:00      0.71         220
# 2014-12-01 01:00:00      0.67         230
```

Figure F.1 – Portion of an actual text file produced by US/NOAA containing surface current observations at 6-minute intervals. The native format is ASCII text (other options were available).

The sample file contains (a) a metadata block, with information on the station, location, instrument type, and depth, and (b) a header line followed by multiple lines of values which include the date and time, the current speed, and the current direction.

The file shown in Figure F.1 can be reformatted so that the metadata appears at the beginning of the file, and the speed at direction data is group for each time (Figure F.2).

```
[data block for station # 1]

Value of Time 1: 2014-12-01 00:00:00
Speed at Time 1 =       1.08
Direction at Time 1 = 215

Value of Time 2: 2014-12-01 00:06:00
Speed at Time 2 =       1.00
Direction at Time 2 = 225

Value of Time 3: 2014-12-01 00:12:00
Speed at Time 3 =       0.83
Direction at Time 3 =  226
Etc.
```

Figure F.2 - Reformatted time series or real-time data.

F.2.2. **Gridded Data**

For certain data products that cover a specific geographic area, the data are most likely to be gridded. Examples are nowcasts and forecasts produced by a hydrodynamic model, currents derived from the analysis of sea-surface topography, and currents derived from high-frequency coastal radar observations.

We confine our discussions to spatial grids that are regular (i.e., having uniform spacing in each direction) and Cartesian (with the X-axis directed toward the east and Y-axis directed toward the north). Such grids are defined by several parameters: the origin (longitude and latitude of a geographic point), the grid spacing along each axis (degrees), and the number of points along each axis. Given an uncertainty in the location of the origin and in the spacing, there will be an uncertainty on the precise position of the grid points. A portion of the metadata and the current speed data from a forecast model is shown in Figure F.3. There are similar data for the current direction grid.

NOTE: some datasets contain a land mask array, for the purpose of determining whether a grid point represents land or water. Herein we use a land mask value (e.g., -99.999) to represent land, thus reducing the number of arrays required.

```
      Dataset 'speed(knots)'
         Size:  500x325
         MaxSize:  500x325
         Datatype:   H5T_IEEE_F32LE (single)
         ChunkSize:  1x325
         Filters:  deflate(9)
         FillValue:  0.000000
         Attributes:
            'organization':  'Center Canadian Meteorological Service - Montreal (RSMC) (54) '
            'Delta_Longitude':  '0.02993999933078885 '
            'Delta_Latitude':  '0.019938461092802194 '
            'forecastDateTime':  '20140611_180000 '
            'Product':  'Type: Forecast products Status: Operational products '
            'Minimum_Latitude':  '45.5 '
            'Maximum_Latitude':  '51.97999985516071 '
            'Maximum_Longitude':  '-56.030000334605575 '
            'Number_Of_Cells_South_North':  '325 '
            'Minimum_Longitude':  '-71.0 '
            'Number_Of_Cells_West_East':  '500 '
            'generatedDateTime':  '20140611_000000 '
            'units':  'mm/s '
   speed(knots) =
      0, 0, 0, 0.5191959, 0.5159838, 0.5159435, 0.5186388,
      0.5209069, 0.5167338, 0.5114825, 0.4738558, 0.378551, 0.2911682,
      0.204335, 0.1294665, …
```

Figure F.3 - A portion of the actual metadata and the gridded current speed data produced by the Canadian Meteorological Service from a model-based forecast. The native format is HDF5.

Note that the data for current speed in Figure F.3 is organized similarly to that for time series: (a) metadata followed by (b) a header record and then the data. However, unlike the time series, the data are valid for a single time (the value of which appears elsewhere in the grid metadata).

NOTE: In the future, current data produced on irregular grids or on unstructured grids may be incorporated by spatially referencing each individual velocity location by explicitly giving its latitude and longitude in the metadata.

For gridded data in general, the metadata for both speed and direction will be the same, so only one metadata block is required to describe both the speed and direction data (Figure F.4). The data for speed in Figure F.3 is a series of values at grid points, starting from the lower left corner of the grid and proceeding along the first row until the end, then starting with the first point in the second row, and so on. Note that for the two fields (speed and direction) in this example, the memory required is 0.325 mb.

```
[Metadata block for gridded  fields]
Value of Time 1
Speed at T1 =  0, 0, 0, 0.5191959, 0.5159838, 0.5159435, 0.5186388, 0.5209069,  0.5167338,
0.5114825, 0.4738558, 0.378551, 0.2911682, 0.204335, 0.1294665, …
 Direction at T1 = 0, 0, 0, 32.7725, 30.33029, 27.84417, 26.28601, 26.46908, 26.46744, 26.56505,
25.9423, 24.28312, 23.54004, 24.69553, 28.52312, …
```

Figure F.4 - A portion of a generalized file with the metadata and the gridded current speed and direction data at one specific time from a model-based forecast shown in Figure F.3.

F.3 Digital Tidal Atlas Data

A digital tidal atlas typically contains speed and direction information for a number of locations, the valid time of which is expressed as a whole number of hours before and/or after time of high water at a reference tidal water level station. Often the speed and direction are given for both neap and spring tide conditions (Table F.1).

The speed and direction for any time are computed as a function of the daily predicted tides or currents at the reference station. For currents based on tide range, the range at the reference station for the day in question first has to be determined. Second, if the amplitude is based on the neap and spring ranges, a factor is computed; otherwise the factor is 1.

Table F.1 – Example of digital tidal data for a station off the French coast.

HOUR	SPEED (ms^{-1})		DIRECTION	
	NEAP	SPRING	NEAP	SPRING
1	0.924	0.991	234.0	232.8
2	0.991	1.047	235.4	233.5
3	1.015	1.104	233.1	234.8
4	0.939	1.132	233.4	233.0
5	0.447	0.947	233.7	233.3
6	0.302	0.061	232.8	200.1
7	0.444	0.292	232.5	56.0
8	0.562	0.044	232.5	68.2
9	0.596	0.469	232.4	231.2
10	0.620	0.662	232.5	231.3
11	0.705	0.779	232.7	231.6
12	0.797	0.886	233.0	232.1
13	0.876	0.967	233.5	232.6

The factor (F) is computed as

$$F = (R - R_{neap})/(R_{spring} – R_{neap}).$$

where:

R = the range for that tidal cycle
R_{spring} = the spring tide range
R_{neap} = the neap tide range

Third, F is applied to the atlas value to determine the current speed and direction at each hour before and after high water at the reference station. For example, speed is computed as:

$$S = S_{neap} + F(S_{spring} – S_{neap}).$$

Finally, the time of the current, whether before or after high water, is converted to time and date.

For atlas currents based on tidal current stage, the process is similar except that the time and factor are related to a specific current stage (e.g., flood) at the reference station.

F.3 Common Data Product Format

The two forms (Figures F.2 and F.4) are similar, the main difference being that there are multiple values for each variable in Figure F.4 (corresponding to multiple grid points), rather than the single value in Figure F.2 (corresponding to a single station). Thus the two forms can be combined into a single form (Figure F.5), where we consider a single station to be described as a 1 x 1 grid.

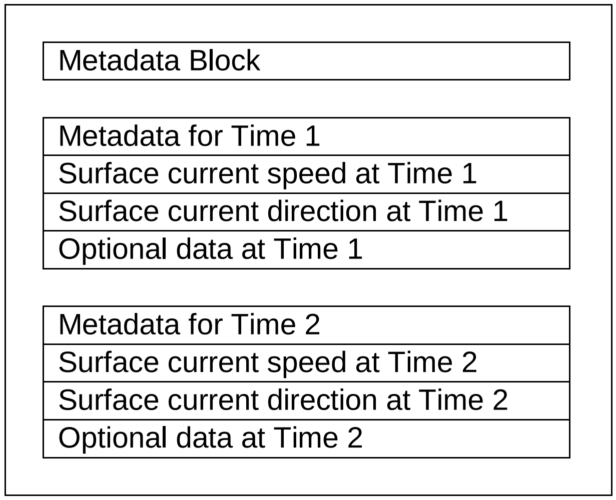


Figure F.5 – Schematic of the product data set. The product can be either a time series at a single station and gridded data.

F.4 Additional Features of the Data

The following sections described additional features of current data and types.

F.4.1 Vertical Reference Datum

The vertical location of the current in the water column is normally referenced to some vertical datum. In this Product Specification, the datum is the sea surface, so the depth of the current below the surface is specified. For a layer average, the thickness of the layer is specified.
A more difficult situation is that some currents are referenced to the sea bottom. Both astronomical predictions and current observations (historical and real time) from stationary platforms are usually defined by an elevation above the bottom. Hydrodynamic forecast models have a variety of vertical datums, but the most common is a terrain-following vertical coordinate system. In this coordinate system, the current elevation is referenced to either the sea surface or the bottom.

It may be possible to re-reference these above-bottom currents to the sea surface. If the sea surface relative to sounding datum is supplied in this product, and if water depth relative to sounding datum (from bathymetry data supplied elsewhere in the ENC) is known, transformation between datums might be accomplished.

F.4.2 Uncertainty

IHO specs S-44 (standards for the quality requirements) for tidal streams and current observations.

The interval about a given value that will contain the true value at a given confidence level (95%)

expand upon how the uncertainty is derived. Constant value…how to get it? Where to get it? Forecast model there is some indication.