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Surface Current Product Specification

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Surface Current Product Specification

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TABLE OF CONTENTS

1. OVERVIEW	1
1.1 INTRODUCTION	1
1.2 SCOPE	2
1.3 REFERENCES	3
1.3.1 Normative	3
1.3.2 Informative	3
1.4 TERMS, DEFINITIONS AND ABBREVIATIONS	4
1.4.1 Use of Language	4
1.4.2 Terms and Definitions	4
1.4.3 Abbreviations	7
1.5 GENERAL DATA PRODUCT DESCRIPTION	7
1.6 DATA PRODUCT SPECIFICATION METADATA AND MAINTENANCE	8
1.6.1 Product Specification Metadata	8
1.6.2 IHO Product Specification Maintenance	8
2. SPECIFICATION SCOPES	9
3. DATASET IDENTIFICATION	9
4. DATA CONTENT AND STRUCTURE	11
4.1 INTRODUCTION	11
4.2 APPLICATION SCHEMA	11
4.3 FEATURE CATALOGUE	11
4.3.1 Introduction	11
4.3.2 Feature Types	11
4.3.3 Feature Relationship	11
4.3.4 Information Types	12
4.3.5 Attributes	12
4.4 DATASET	14
4.4.1 Regular Grid	14
4.4.2 Irregular Grid	17
4.4.3 Point Set	17
5. COORDINATE REFERENCE SYSTEMS (CRS)	18
5.1 HORIZONTAL REFERENCE SYSTEM	18
5.2 VERTICAL REFERENCE SYSTEM	19
5.3 TEMPORAL REFERENCE SYSTEM	19
6. DATA QUALITY	19
6.1 INTRODUCTION	19
6.2 COMPLETENESS	19
7. DATA CAPTURE AND CLASSIFICATION	19
7.1 DATA SOURCES	20
7.2 THE PRODUCTION PROCESS	20
7.2.1 Metadata	20
7.2.2 Surface Current Data	21
7.2.3 Digital Tidal Atlas Data	21
8. MAINTENANCE	21
8.1 MAINTENANCE AND UPDATE FREQUENCY	21

8.2	DATA SOURCE	21
8.3	PRODUCTION PROCESS	22
9.	PORTRAYAL.....	22
9.1	INTRODUCTION	22
9.2	DISPLAY OF CURRENT AT A SINGLE POINT	22
9.2.1	Arrow Shape	23
9.2.2	Arrow Direction	24
9.2.3	Arrow Colour.....	24
9.2.4	Arrow Size	25
9.2.5	Numerical Values.....	25
9.2.6	Transparency.....	27
9.2.7	Scalable Vector Graphics	27
9.3	DISPLAY OF REGULARLY GRIDDED DATA.....	27
9.3.1	High Resolution	28
9.3.2	Low Resolution	29
9.4	TEMPORAL INTERPOLATION	31
9.5	PLACEMENT OF LEGEND.....	31
9.6	SAMPLE REPRESENTATION.....	31
10.	DATA PRODUCT FORMAT (encoding)	32
10.1	INTRODUCTION	32
10.2	PRODUCT STRUCTURE (NORMATIVE).....	33
10.3	METADATA	35
10.4	DIGITAL CERTIFICATION BLOCK	38
10.5	HDF5 ENCODING	38
11.	DATA PRODUCT DELIVERY.....	38
11.1	INTRODUCTION	38
11.2	EXCHANGE DATASETS	39
11.3	EXCHANGE CATALOGUE.....	39
11.4	DATA PRODUCT FILE NAMING.....	39
11.5	SUPPORT FILES.....	40
12.	METADATA.....	40
12.1	INTRODUCTION	40
12.2	ELEMENTS OF THE EXCHANGE SET.....	43
12.3	LANGUAGE	49
ANNEX A.	ADDITIONAL TERMS AND DEFINITIONS.....	50
ANNEX B.	APPLICATION SCHEMA.....	55
ANNEX C.	DATA CLASSIFICATION AND ENCODING GUIDE	59
C.1.	FEATURES.....	59
C.2.	FEATURE ATTRIBUTES.....	59
C.3.	METADATA	60
C.4.	METADATA ATTRIBUTES	60
ANNEX D.	TESTS OF COMPLETENESS (NORMATIVE).....	62
D.1	COVERAGE CONSISTENCY	62
D.1.1	Test case for coverage geometry	62
D.1.2	Test case for extra data.....	62
D.1.3	Test case for empty data.....	62
D.2	LOGICAL CONSISTENCY	62

D.2.1 Conceptual Consistency.....	63
D.2.2 Domain Consistency	63
D.2.3 Positional Accuracy	63
D.2.4 Temporal Accuracy	63
ANNEX E. PORTRAYAL CATALOGUE	64
ANNEX F. SURFACE CURRENT DATA.....	65
F.1. DATA SOURCES	65
F.2. DATA ORGANIZATION	65
F.2.1. Time Series Data	65
F.2.2. Gridded Data	67
F.3. DIGITAL TIDAL ATLAS DATA	69
F.4. LAGRANGIAN DRIFTER DATA.....	70
F.5 COMMON DATA PRODUCT FORMAT.....	70
F.6 ADDITIONAL FEATURES OF THE DATA	71
F.6.1 Vertical Reference Datum.....	71
F.6.2 Uncertainty	71
ANNEX G. HDF-5 ENCODING	73
G.1 INTRODUCTION	73
G.2 PRODUCT METADATA	74
G.3 DATASETS.....	74
G.4 SAMPLES OF TIME SERIES FILES.....	75
G.5 SAMPLES OF REGULARLY GRIDDED DATA FILES.....	78

1. OVERVIEW

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.

1.1 Introduction

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, conforms to S-100.

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 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. The framework identifies how the various elements of a coverage dataset fit together.

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 regular 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. Another coverage is a point set, which also contains metadata and attribute values, although the locations are not organized into a regular grid.

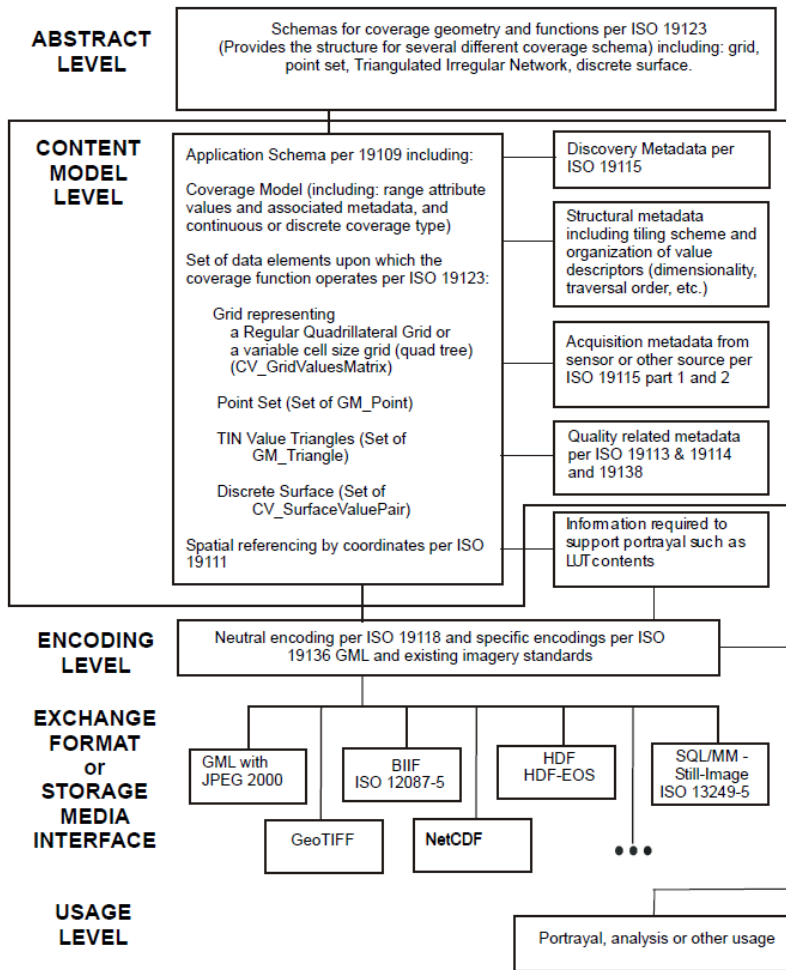


Figure 1.1 - Overall relationship between the elements of the framework (from S-100, Part 8).

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).

1.2 Scope

This document describes an S-100 compliant product specification for surface currents and it specifies the content, structure, and metadata needed for creating a fully compliant S-111 ENC and for its portrayal within an S-100 Surface Current product. This product specification includes the content model, the encoding, the feature catalogue, portrayal catalogue and metadata. The surface current product may be used alone or combined with an S-101 ENC or other S-100 compatible data.

1.3 References

1.3.1 Normative

- S-44.** *IHO Standards for Hydrographic Surveys*, 5th Edition February 2008.
- S-100.** *IHO Universal Hydrographic Data Model*, January 2015.
- S-101.** *IHO Electronic Navigational Chart Product Specification*, July 2014.
- S-102.** *IHO Bathymetric Surface Product Specification*, April 2012.
- ISO 8601. 2004.** *Data elements and interchange formats - 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

1.3.2 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]

1.4 Terms, Definitions and Abbreviations

1.4.1 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.

1.4.2 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 1.3, modifications were made when necessary. Additional terms have also been included (see ANNEX A). Terms that are defined in this clause or in 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**

NOTE: The S-111 data product consists of metadata and one or more sets of speed and direction values

[ISO 19131]

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

Domains are used to define the **domain** set and **range** set of **attributes**, operators, and **functions**

NOTE: *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 *colour* 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 a set of elements, or cells, whose vertices are nodes. See also **rectified grid**, **regular grid**, **irregular grid**, and **grid point**.

[ISO 19123]

NOTE 1: A uniform grid has constant spacing in the X-direction and constant spacing in the Y-direction, although the two spacing values are not necessarily equal

NOTE 2: A rectangular grid has axes perpendicular to each other

grid point

point located at the intersection of two or more **cells** in a **grid**. Also called a **node**.

[ISO 19123]

irregular grid

A **rectified grid** with non-uniform spacing of points. Grid elements are defined by their three, four, etc. surrounding nodes. Compare to **regular grid**.

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 metres (sea surface) to 10 metres.

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 1: If the **coordinate reference system** is related to the Earth by a **datum**, the **grid** is a **georectified grid**

[ISO 19123]

NOTE 2: 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]

regular grid

A **georectified grid** with geodetic coordinates, with the X-axis directed eastward, the Y-axis directed northward, and uniform spacing of points in each direction. Spacing units are degrees of arc. Compare to **irregular grid**.

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, but not astronomical tides, 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). **Depths** may extend from the **sea surface** down to 25 metres.

NOTE: IHO Hydrographic Dictionary: current: surface. A current that does not extend more than a few (2-3) metres below the surface.

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. For practical purposes, the **confidence** level is 95% and the **uncertainty** is defined herein as 1.96 times the standard deviation of the differences between observed and predicted values (cf. S-44. *IHO Standards for Hydrographic Surveys*, 5th Edition, February 2008).

1.4.3 Abbreviations

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

ECDIS	Electronic Chart Display Information System
ENC	Electronic Navigational Chart
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
SCWG	Surface Currents Working Group
UML	Unified Modelling Language
UTC	Coordinated Universal Time

1.5 General S-111 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.

1.6 Data Product Specification Metadata and Maintenance

1.6.1 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: 2.0.0

S-111 Version: 1.0.0

Date: 2016-03-15

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.

1.6.2 IHO Product Specification Maintenance

1.6.2.1 Introduction

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

1.6.2.2 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. All cumulative *revisions* and *clarifications* must be included with the release of approved New Editions.

1.6.2.3 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.

1.6.2.4 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.

1.6.2.5 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 national Hydrographic Office (HO), 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: 006 — series

Level name: Surface Current Dataset

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). The spatial resolution varies according to the model and the size of grid spacing, or on the number of observing locations adopted by the producer (Hydrographic Office).

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. 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 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

4.3.1 Introduction

The S-111 Feature Catalogue describes the feature types, information types, attributes, attribute values, associations and roles which may be used in a Surface Current Dataset.

The S-111 Feature Catalogue is available in an XML document which conforms to the S-100 XML Feature Catalogue Schema and can be downloaded from the IHO website. It is also available in a human readable version.

4.3.2 Feature Types

4.3.2.1 Geographic

Geographic (geo) feature types form the principle content of S-111 and are fully defined by their associated attributes and information types.

4.3.2.2 Meta

Meta features contain information about other features within a dataset. Information defined by meta features override the default metadata values defined by the dataset descriptive records. Meta attribution on individual features overrides attribution on meta features.

4.3.3 Feature Relationship

A feature relationship links instances of one feature type with instances of the same or a different feature type. In S-111, there are no feature relationships.

4.3.4 Information Types

Information types define identifiable pieces of information in a dataset that can be shared between other features. They have attributes but have no relationship to any geometry; information types may reference other information types.

4.3.4.1 Spatial Quality

Spatial quality attributes (Figure 4.1) are carried in an information class called **spatial quality**. Only points, multipoints and curves can be associated with spatial quality. Currently no use case for associating surfaces with spatial quality attributes is known, therefore this is prohibited. Vertical uncertainty is prohibited for curves as this dimension is not supported by curves.

Surface currents are usually defined at one or more individual locations, to spatial quality applies to these points.

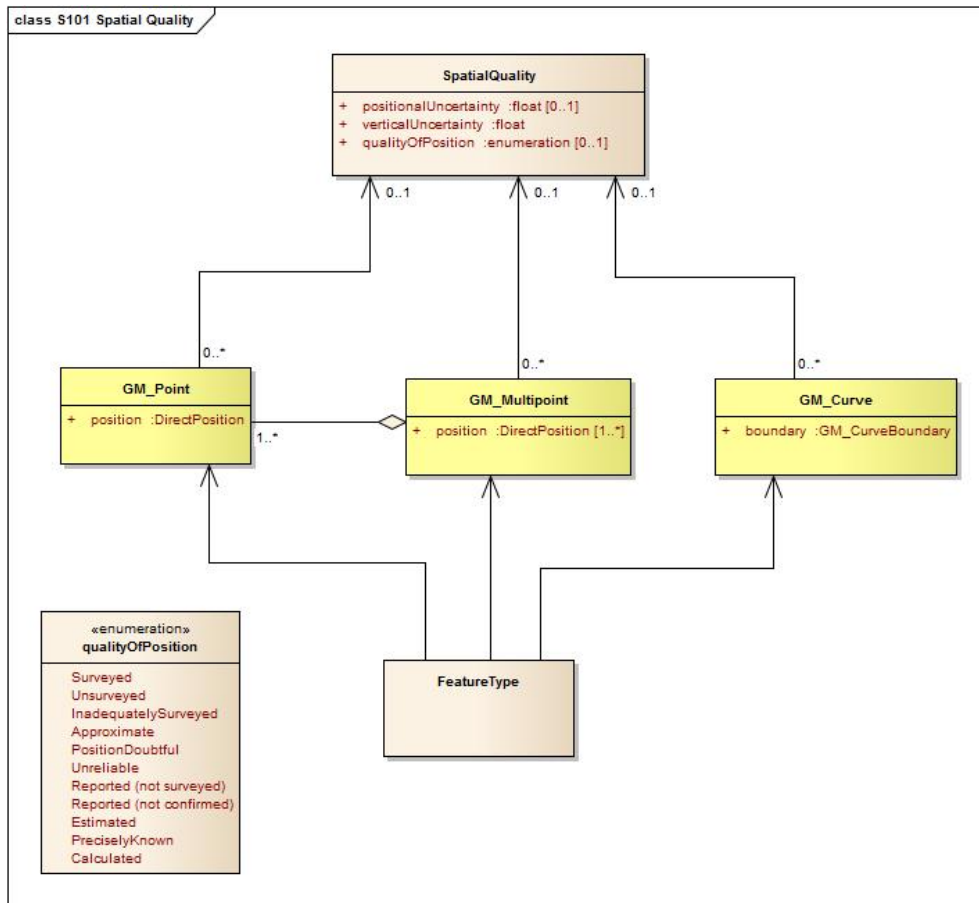


Figure 4.1 - Spatial Quality Information Type

4.3.5 Attributes

S-111 defines attributes as either simple or complex.

4.3.5.1 Simple Attributes

S-111 uses eight types of simple attributes; they are listed in Table 4.1.

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 in S-100, Clause 4a-5.6.4). See also ISO 8601:1988. EXAMPLE 19980918 (YYYYMMDD)
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 S-100, Clause 4a-5.6.4). See also ISO 8601:1988. EXAMPLE: 183059Z
Date and Time	A DateTime is a combination of a date and a time type. Character encoding of a DateTime shall follow S-100, Clause 4a-5.6.4). See also ISO 8601:1988. EXAMPLE: 19850412T101530Z

4.3.5.2 Complex Attributes

Complex attributes (Figure 4.2) are aggregations of other attributes that are either simple or complex. The aggregation is defined by means of attribute bindings.

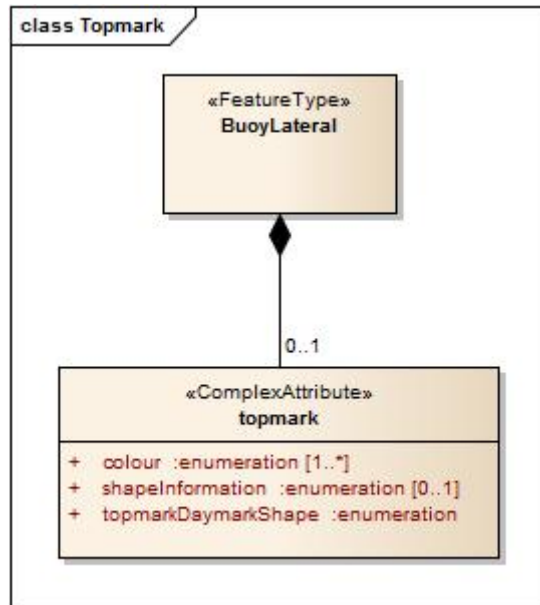


Figure 4.2 - Complex Attribute

EXAMPLE: In this example a **topmark** has three sub-attributes. The Buoy Lateral Feature may optionally include one instance of the complex attribute **topmark**.

4.4 Dataset

Surface current data are represented in three types of datasets: arrays of points contained in a regular grid, arrays of points in an irregular grid, or a set of ungridded points. Further details on the data product are given in clause 10 – DATA PRODUCT FORMAT. Additional information is included in ANNEX F – SURFACE CURRENT DATA.

4.4.1 Regular Grid

S-111 regular grid geometry is an implementation of S-100 Part 8-7.1.4 (S100_Grid Coverage Spatial Model). The spatial grids for the regular grid type are two dimensional, regular and geodetic (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 4.3. 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.

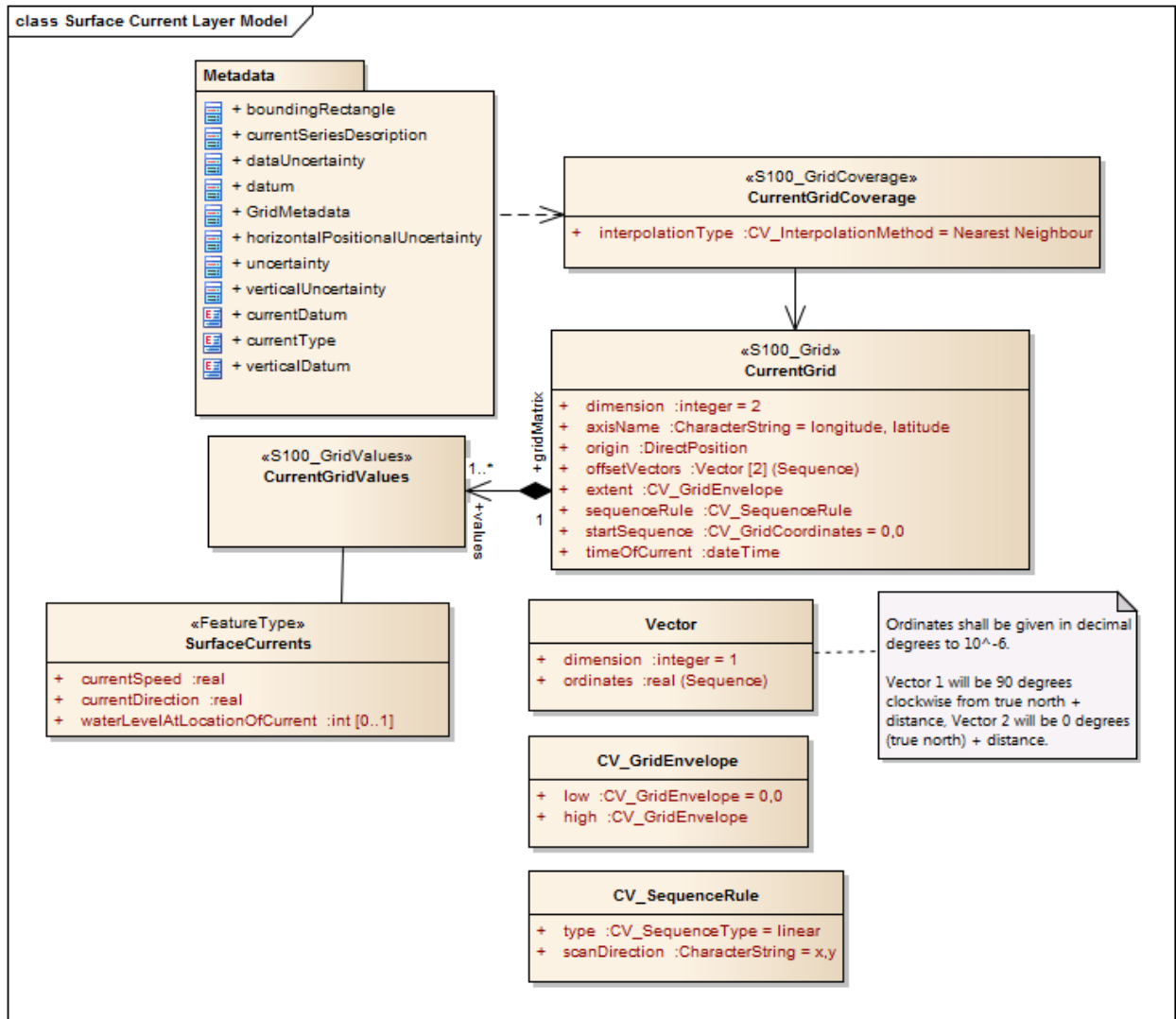


Figure 4.3 - UML schema for the Surface Current Layer (Fig. B.1).

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” and “Latitude”, respectively (Figure 4.4).

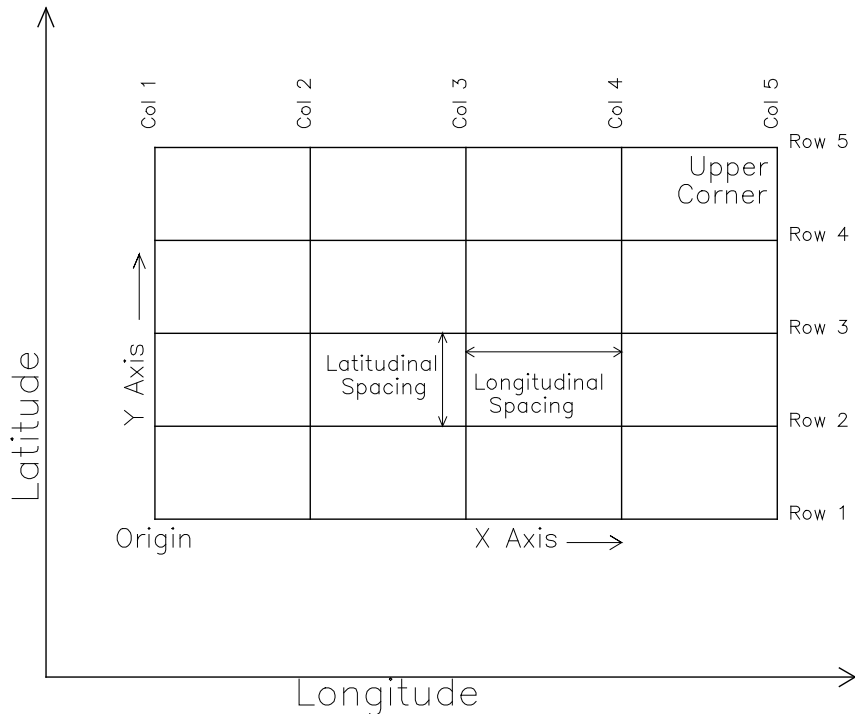


Figure 4.4 – Schematic of the regular grid and its attributes.

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. 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 4.4).

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).

S-111 grids allow for different spacing of points along the X axis and the Y axis. For rectangular grids the offset vector establishes the cell size. The attribute *offsetVectors* 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 clockwise from CRS north, and represents the distance between grid values on the X axis. The second vector is 0 degrees clockwise from CRS north, and represents the distance between the values on the Y axis (Figure 4.4). The distances are given in degrees.

The sequence rule for a regular cell size grid is straightforward. 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 subattributes; *type* and *scanDirection*. The sub attribute *type* carries the value “linear”, and the subattribute *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 position in the grid. In the figure, first all columns in row 1 are selected, then all columns in row 2, and so on.

4.4.2 Irregular Grid

For this type of grid coverage, the *axisNames* are the same as for the regular grid (Figure 4.5). However, the *origin* is arbitrary, and the extent (cf. the bounding rectangle) is defined by the minimum and maximum of the positions of the grid nodes. The total number of points, called nodes, is *numNodes*. Because the grid is not regular, attributes like spacing and scan direction have no meaning. The position of the nodes is carried in the one-dimensional arrays X and Y. For this grid, an attribute *timeOfCurrent* carries the date and time of the node values.

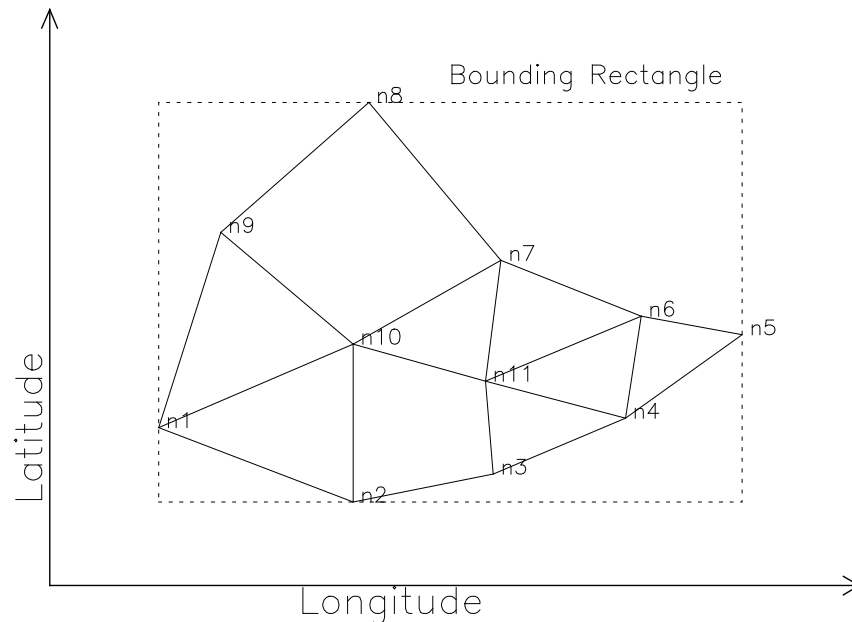


Figure 4.5 – Schematic of the irregular grid and some of its attributes. Nodes are numbered and appear as 'n1', etc.

4.4.3 Point Set

For this type of coverage, the *axisNames* are the same as for the regular grid (Figure 4.6). However, the *origin* is arbitrary, and the extent (cf. the bounding rectangle) is defined by the minimum and maximum of the positions of the stations. The total number of stations is *numStations*. Also, attributes like spacing and scan direction have no meaning. The position of the stations is carried in the one-dimensional arrays X and Y. For this dataset, the attribute

timeOfCurrent may carry the date and time of (a) all the stations in the set (for a number of fixed stations), or (b) each station individually (for a number of surface drifters).

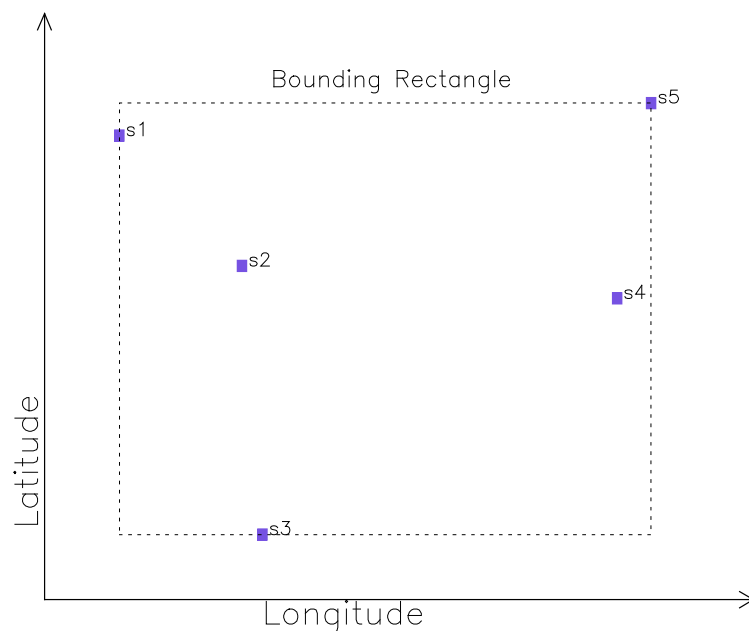


Figure 4.6 – Schematic of the point set and its attributes. Stations appear as filled-in rectangles, are labeled and have a format such as 's1'.

5. COORDINATE REFERENCE SYSTEMS (CRS)

The location of a feature in the S-100 standard is defined by means of coordinates, which relate a feature to a position. The S-111 CRS is a compound system, with a two-dimensional ellipsoidal horizontal component and a one-dimensional datum-related vertical component (cf. S-100, Part 6 – Coordinate Reference Systems).

5.1 Horizontal Reference System

For an ENC the horizontal CRS must be the ellipsoidal (geodetic) system EPSG: 4326 (WGS84). The full reference to EPSG: 4326 can be found at www.epsg-registry.org.

Horizontal coordinate reference system:	EPSG:4326 (WGS84)
Projection:	None
Coordinate reference system registry:	EPSG Geodetic Parameter Registry
Date type (according to ISO 19115):	002- publication
Responsible party:	International Organisation of Oil and Gas Producers (OGP)

5.2 Vertical Reference System

The vertical coordinate is directed upward (away from the Earth's center) from its origin, the vertical datum, and has units of metres. That is, a positive value for the level of the current relative to the vertical datum means that the level is above the vertical datum. This is consistent with the bathymetric CRS in S-102. The vertical datum is not an ellipsoid but is one of the following: (a) the sea surface (defined in Clause 1.4.2), (b) a standard tidal datum (MSL, LAT, etc.), or (c) the sea floor.

5.3 Temporal Reference System

The temporal reference system is the Gregorian calendar for date and UTC for time. Time is measured by reference to Calendar dates and Clock time in accordance with ISO 19108:2002, Temporal Schema clause 5.4.4. A date-time variable will have the following 16-character format: *yyyymmddThhmmssZ*.

6. DATA QUALITY

6.1 Introduction

Quality of surface current data for navigation consists of quality of the observed/predicted/forecast data, quality of the positional data, and quality of the time stamp. Quality of the observed data depends on the accuracy of the current meters and their processing techniques, and is normally available in field survey reports or QC analyses. Quality of predicted/forecast data depends on quality, timeliness, and spatial coverage of the input data as well as the mathematical techniques, and is normally described in technical reports describing the testing of the techniques. Temporal accuracy for observational data is normally available in field survey reports or QC analyses. Temporal accuracy for predicted/forecast data is normally described in technical reports.

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. See ANNEX D - TESTS FOR COMPLETENESS (NORMATIVE).

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 HO must be translated, sub-setted, reorganized, or otherwise processed to be made into a usable data format.

7.1 Data Sources

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

Observational surface current data comes initially from *in situ* sensors in the field (e.g., current meters) or from high-frequency radar, and such sensors are monitored by the HO. After reception, the data are quality-controlled and stored by the HO. Some of the observed data may be available for distribution within minutes of being collected and are thus described as being in real time.

Astronomical predictions are produced when a sufficiently long time series of observed currents has been obtained and the data has been harmonically analyzed by the HO 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 HO 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. Analyzed fields may be produced from sea-surface topography, data assimilation, or other means. These models and methods are developed, run, and monitored by the HO.

7.2 The Production Process

Nearly all available information on surface currents available from the HO 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 10.1) with the relevant data and (b) reorganizing the speed and direction data when using the encoding rules (discussed in ANNEX C and G).

7.2.1 Metadata

Metadata is derivable from the information available from the HO. 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 HO; otherwise they must be calculated

7.2.2 Surface Current Data

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

- Current level values are often available in the modeled data grid points, but for observational data such as for moored current meters they may be referenced to the bottom and therefore require re-referencing to a vertical datum.
- If a land mask array is included, the mask value is substituted into the gridded values as appropriate.
- Time stamps, if given in local time, must be converted to UTC.

7.2.3 Digital Tidal Atlas Data

Tidal atlas information 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, or current flood, at a reference tidal water level station (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. The conversion into a time series is the responsibility of the HO.

8. MAINTENANCE

8.1 Maintenance and Update Frequency

Surface currents change rapidly, so more-or-less continual revision or updating of the data is essential. For real-time observations, new values are periodically collected (on the order of once every 5 minutes). For a forecast, the entire field of currents is created one or more times per day. New issues of real-time observations or forecasts should be considered new editions.

Tidal atlas or harmonic constant data are updated much less often, typically on an annual basis. Table 8.1 summarizes this information.

Table 8.1 – Typical update/revision intervals and related information for S-111 products.

Data Types	Interval	Number Of Spatial Locations	Number Of Time Values Per Location
Tidal Predictions	1 year	100 to 1,000	8,760 (hourly data)
Model Forecasts	6 hr	100,000 to 1,000,000	1 to 24
Real-time Observations	0.1 hr	1 to 10	1 to 240
HF Radar Observations	0.1 hr	10,000 to 100,000	1 to 24

8.2 Data Source

Data is produced by the HO by collecting observational values, predicting astronomical tides, or running analysis/nowcast/forecast models. These data are typically quality-controlled and reformatted to conform to file size limitations and the S-111 standard encoding.

8.3 Production Process

S-111 data sets, including the metadata and the coverages for current speed and direction, are updated by replacement of the entire data product. HOs routinely collect observational data and maintain an analysis and/or forecast capability. When new data become available (often several times per day), the data is reformatted and made available for dissemination.

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 the second is gridded data, which would apply to analyses, coastal radar observations, and model-based forecasts. Current vector portrayal 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).

All recommended sizes are given assuming a minimum size ECDIS display of 270 by 270 mm or 1020 by 1020 pixels.

9.2 Display of Current at a Single Point

Portrayal of current using single point data should be used for instances where the data source is a current meter (e.g., a historical or real-time current measuring device) at a single geographic 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, and (c) a numerical value. The numerical value of speed as a number, in knots and hundredths of a knot, in black text with a white border and be available when the cursor 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 cursor is held over the data point.

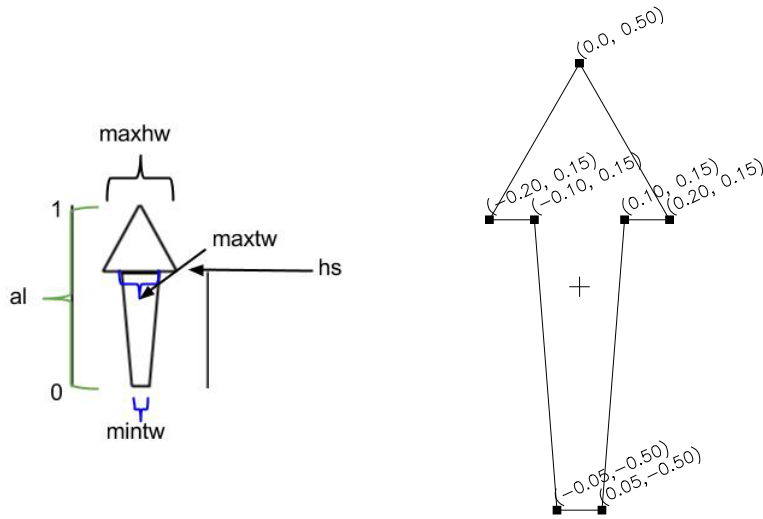
9.1.1 Arrow Shape

The generalized arrow shape (Figure 9.1) must 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 location on the arrow symbol which lies along the vertical centreline and is at a distance from the bottom equal to one-half the quantity 'al' is placed at the corresponding position (longitude and latitude) on the chart image. This location is called the arrow's 'pivot point'.

abbreviations

- al = arrow length
- mintw = min tail width
- maxtw = max tail width
- hs = head start
- maxhw = max head width
- minhw = 0
- *note: the head narrows to a point where minhw = 0

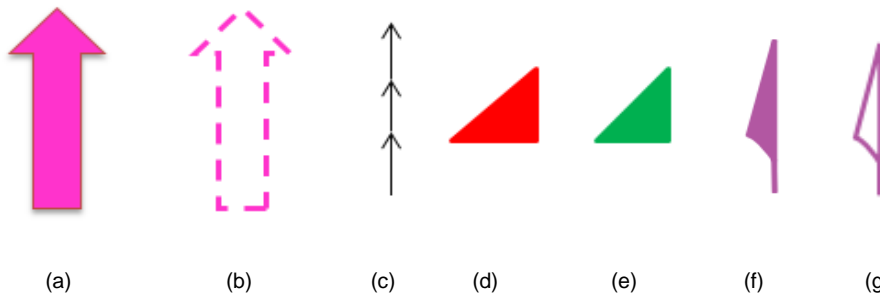
- al = 1 unit of measure
- mintw = al*.1
- maxtw = 2*mintw
- hs = al*.65
- maxhw = al*.4



(a)

(b)

Figure 9.1 – (a) Generalized arrow shape for use in representing surface currents.
(b) Arrow with vertex coordinates. The '+' is the pivot point at (0.0, 0.0).



(a)

(b)

(c)

(d)

(e)

(f)

(g)

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, (d) and (e) for conical buoys, and (f) and (g) for magnetic variation and anomaly.

9.1.2 Arrow Direction

The direction of the arrow symbol must be the direction (relative to true north) toward which the current is flowing (Figure 9.3). 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.

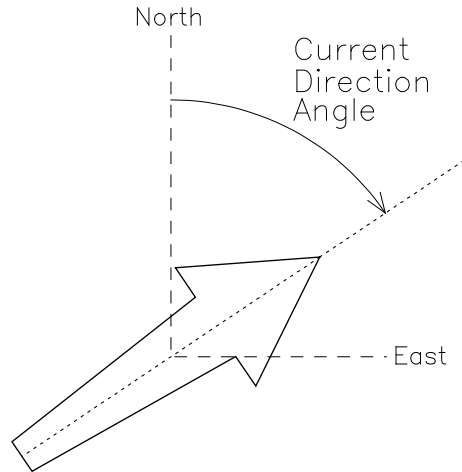


Figure 9.3 – Portrayal of the arrow’s direction, based on the current direction. The dashed line is the arrow’s centerline, and the origin of the East-North axis is at the arrow’s pivot point.

9.1.3 Arrow Colour

The colour of the arrow must be based on the speed value of the data, and must have 9 steps with colour values corresponding to the speed range (Table 9.1). (The monitor gamma values need to be taken into account – refer to IHO standards). A sample scale bar using the 9 colours in Table 9.1 is shown in Figure 9.4.

Table 9.1 – Speed ranges (knots) and RGB colour values for the 9-step display.

Step	Minimum Speed (kn)	Maximum Speed (kn)	Appx. Interval (kn)	Colour Scale Intensity			Displayed Colour
				Red	Green	Blue	
1	0.10	0.49	0.4	118	82	226	
2	0.50	0.99	0.5	72	152	211	
3	1.00	1.99	1	97	203	229	
4	2.00	2.99	1	109	188	69	
5	3.00	4.99	2	180	220	0	
6	5.00	6.99	2	205	193	0	
7	7.00	9.99	3	248	167	24	
8	10.00	12.99	3	247	162	157	
9	13.00	99.99	87	255	30	30	



Figure 9.4 – Surface current speed scale based on the colours and speed ranges in Table 9.1.

The range of speeds (Table 9.1) was selected to (a) keep the display uncluttered by not showing the very lowest speeds, (b) emphasize differences at low speeds (0.1 to 3 kn), and (c) be capable of displaying large currents (13 kn and above).

NOTE: The largest tidal currents may be those in the strait near Saltstrumen, Norway, which reach 22 kn.

9.1.4 Arrow Size

The arrow size must be a function of the speed the arrow represents. The speed scaling used shall be a linear interpolation between zero and a reference high value, S_{high} . The recommended value for S_{high} is the lower limit value in the highest group in Table 9.2, which is 13.0 kn. The value of S_{high} should be the same for all data sets from multiple sources so that the same speed in different data will be displayed with the same arrow length. Also, speeds below the lower limit of the first group in Table 9.2, S_{min} or 0.1 kn, will not be displayed.

A second parameter is the reference speed, S_{ref} , at which the arrow symbol has a length equal to the scaling length parameter, L_{ref} . Here S_{ref} is chosen to be 5 kn and L_{ref} is taken to be 10.0 mm.

Let S be the current speed to be displayed. If S exceeds S_{high} , then S_{high} is substituted for that speed, since areas of extremely high current speeds are rare and are likely to be avoided by navigators anyway. Therefore, a current with a speed of S will be displayed with a length, L mm, computed by:

$$L = L_{ref} \cdot \min(S, S_{high}) / S_{ref} \quad \text{for } S \geq S_{min}$$

9.1.5 Numerical Values

Current speed and direction, and additional data related to uncertainty and other metadata, should be visible when selected by placing the cursor within the solid area of the arrow shape. The data are invisible initially, and when the cursor is placed on the arrow, the data will be shown temporally. If the arrow is clicked, data will be shown continuously until another point is clicked. The information shown when the arrow is clicked will be displayed in black text inside a box with a white background and a black border with a 1 pixel line thickness. The box must have zero transparency.

There should be at least three levels of detail of information (Table 9.2). In the first level, speed (kn) and direction (arc-degrees clockwise from true north) shall be displayed. In the second

level, there are six additional items, each with appropriate units: data source/station name, latitude, longitude, date, time, and current depth or layer thickness. In the third level, there are at least five additional items: uncertainty in speed, direction, horizontal position, vertical position and time. A sample image showing a vector with the first level of information is shown in Figure 9.5. The additional levels are accessed by a cursor pick capability (cf. S-101. IHO Electronic Navigational Chart Product Specification).

Table 9.2 – Numerical information displayed at point of current vector in levels of priority.

Priority Level	Information Displayed
1	Speed Direction
2	Data source or station name Latitude Longitude Date-time Depth
3	Uncertainty in speed Uncertainty in direction Uncertainty in horizontal position Uncertainty in vertical position Uncertainty in time

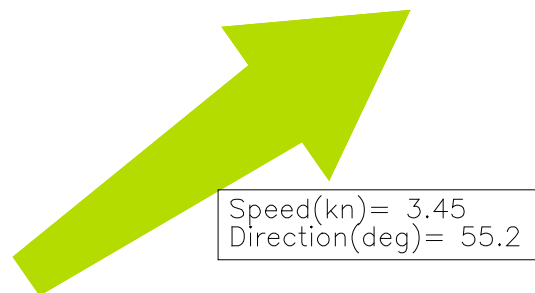


Figure 9.5 – Example of the display of the first level of numerical information available by cursor selection.

NOTE: The text box in Figure 9.5 requires the use of two additional colours: black for the text and box outline, and white for the interior of the box. Standard ISO colours are to be used. The interior of the box will have zero transparency.

9.1.6 Transparency

The symbol transparency must be adjusted according to the background chart/image used (Table 9.3). The value alpha represents the level of opaqueness (relative to the background image) of the arrow and the numerical values displayed. An alpha value of 1 denotes zero transparency and an alpha value of 0 denotes 100% transparency.

Table 9.3 - Alpha (opaqueness) values for various displays.
Transparency is 1.0 minus the alpha value.

Background	Alpha
Satellite image	1.0
Raster Nautical Chart	1.0
ENC Day	1.0
ENC Dusk	0.4
ENC Night	0.2

9.1.7 Scalable Vector Graphics

In ECDIS, the arrow symbol (e.g. Figure 9.5) is drawn using Scalable Vector Graphics (SVG) instructions. SVG allows a symbol of any given size, orientation, and colour to be displayed by only a few instructions. The coordinate system for the symbol is defined as follows. The overall width and height of the symbol are defined in mm. The viewBox covers the range of coordinates used for the symbol. The pivot point of the symbol is designed to be at the 0.0, 0.0 position. The default coordinate system used for S-100 SVG has the origin in the upper left corner with the x-axis pointing to the right and the y-axis pointing down.

For example, the using the image coordinates shown in Figure 9.1b, the SVG coordinate system, and L_{ref} of 10 mm, a 'path' command would contain

```
M -0.5, 5.0 L 0.5, 5.0 L 1.0 -1.5 L 2.0 -1.5 L 0.0, -5.0 L -2.0, -1.5 L -1.0,-1.5 L -0.5, 5.0
```

where M is the *moveto* instruction and L is the *lineto* instruction.

9.3 Display of Regularly Gridded Data

The display of gridded data depicts a surface current field of multiple arrows (Figure 9.6), with each individual current arrow having the qualities described in Clause 9.2. The acceptable arrowhead style for gridded arrows is the style defined in Figure 9.1. As with single-point data,

the speed and direction values at individual vectors must be available when the cursor is placed over a vector.

NOTE: current direction angles cannot be interpolated (in either space or time) directly, but must be derived using the X and Y components of current. That is, interpolation must be of the east/west and north/south components of current separately, with the interpolated components then used to calculate speed and direction.

9.1.8 High Resolution

A high-resolution display (i.e., zooming in) of regularly gridded data display produces a lower density of data (Figure 9.7). It is not recommended that linear spatial interpolation be used to fill in sparse data. Linear interpolation in space could be used to obtain data points from the model grid for generating additional grid points in the portrayal.

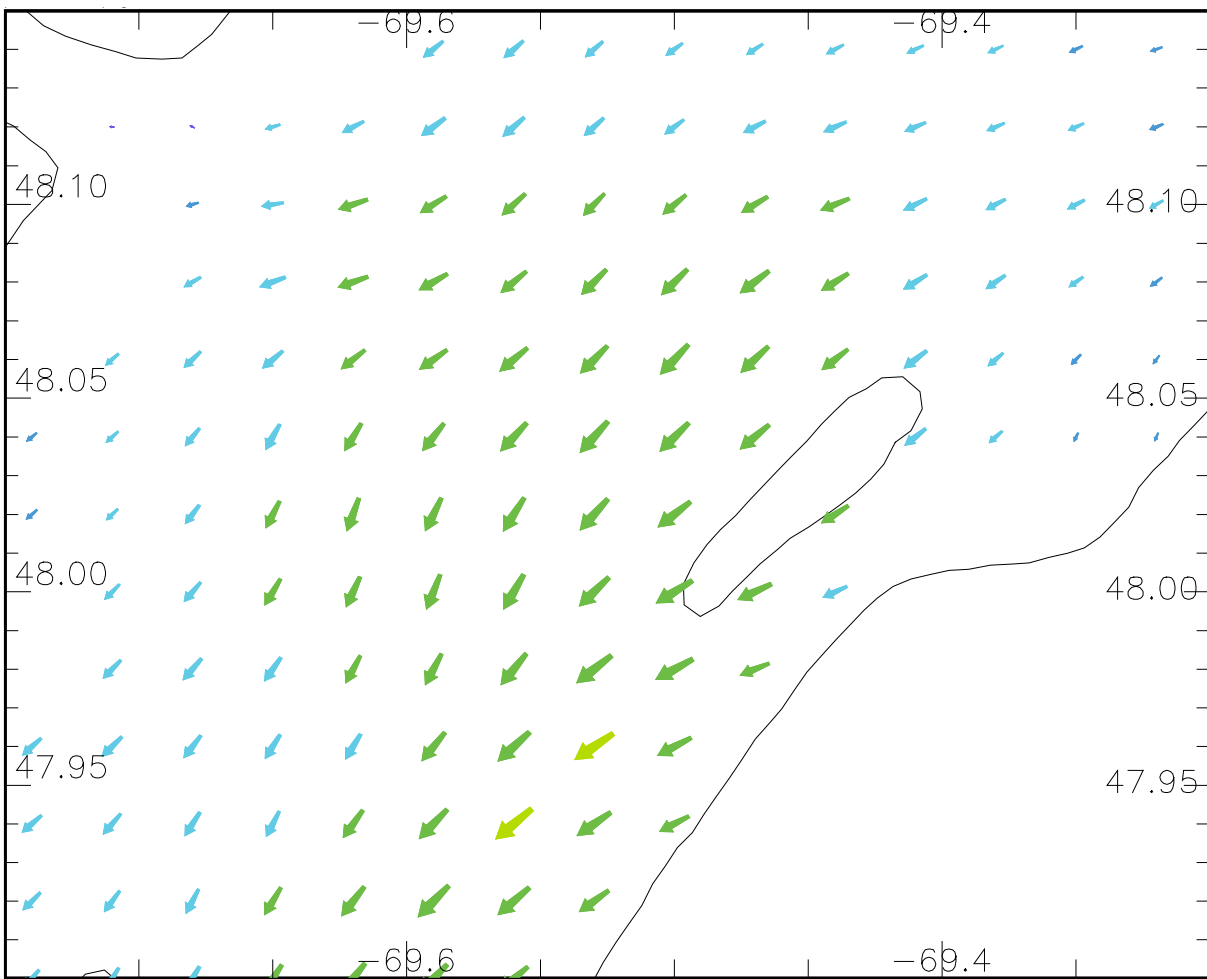


Figure 9.6 - Arrows representing gridded current data, with length increasing with speed, and S_{ref} is 5 kn, L_{ref} is 10 mm, and the maximum speed in the data is 3.15 kn. Coastline added for clarity. (data courtesy of St. Lawrence Global Observatory, Canada)

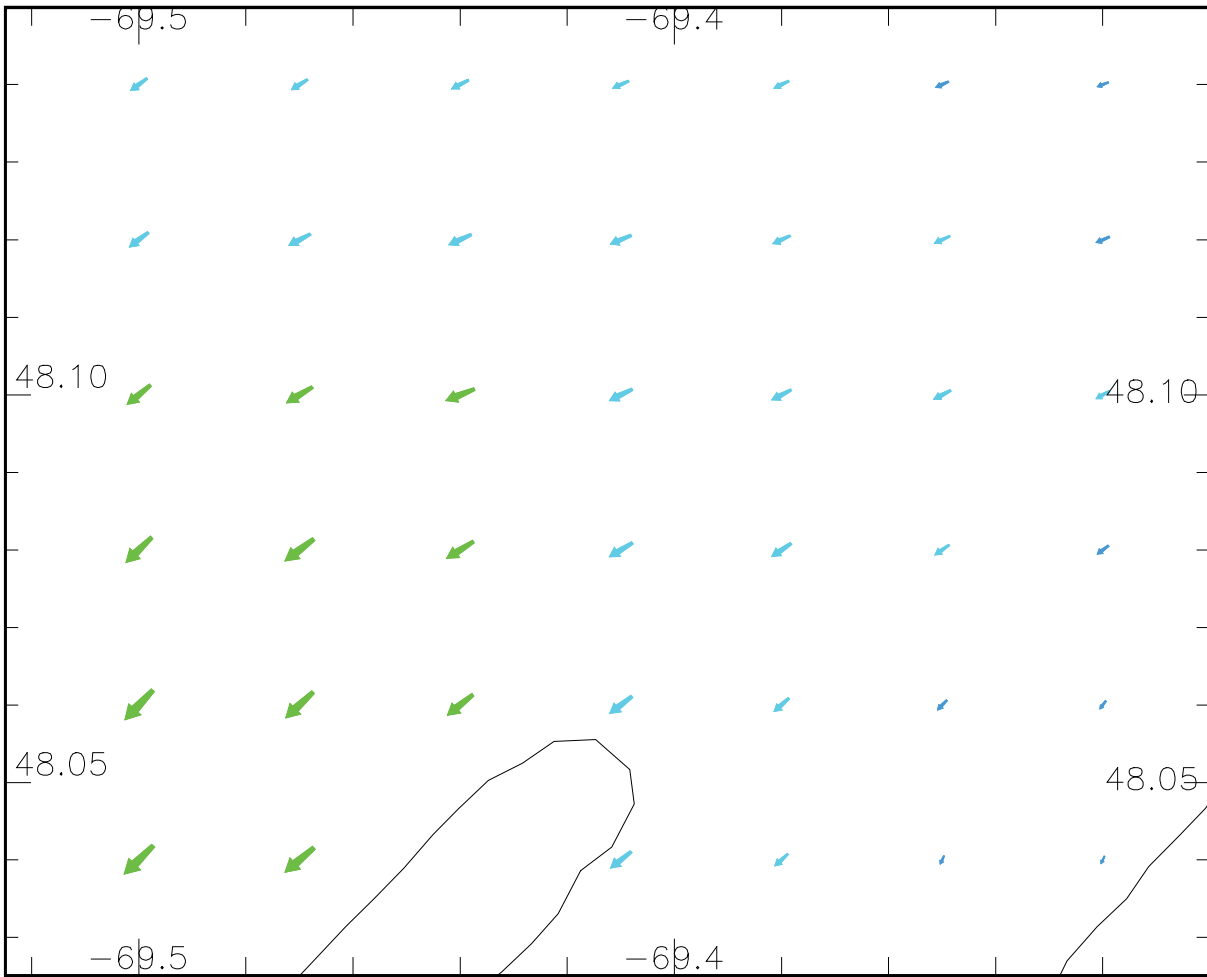


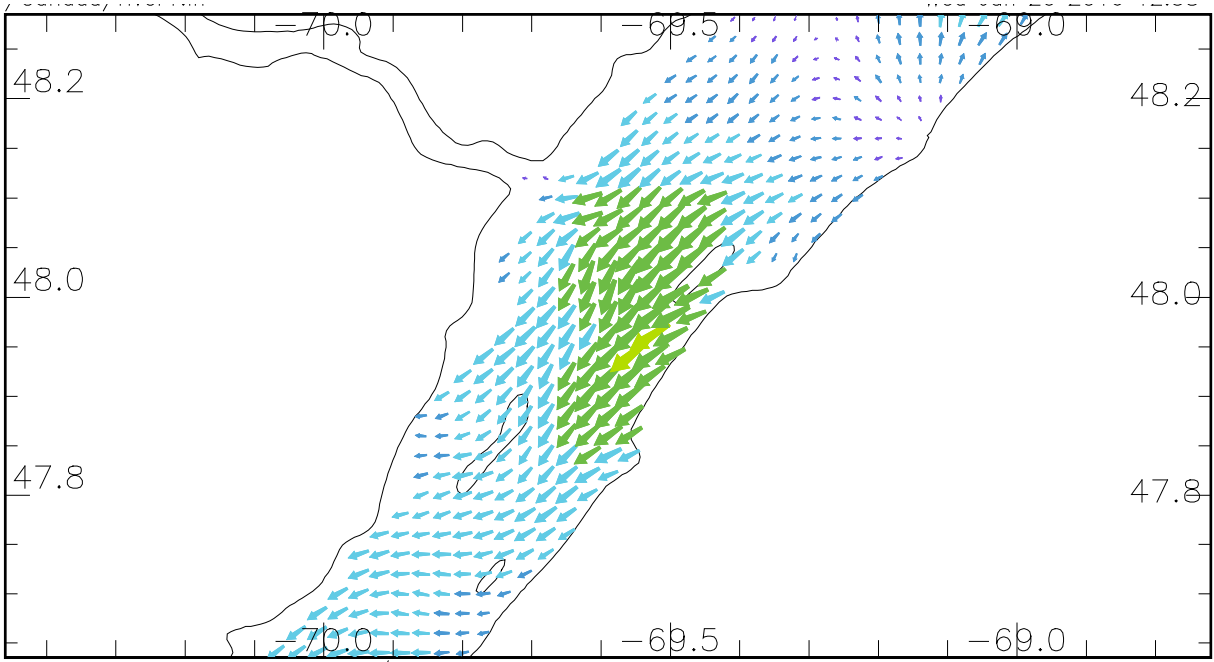
Figure 9.7 – Display of current data (see Figure 9.6) but at a higher resolution (data courtesy of St. Lawrence Global Observatory, Canada).

9.1.9 Low Resolution

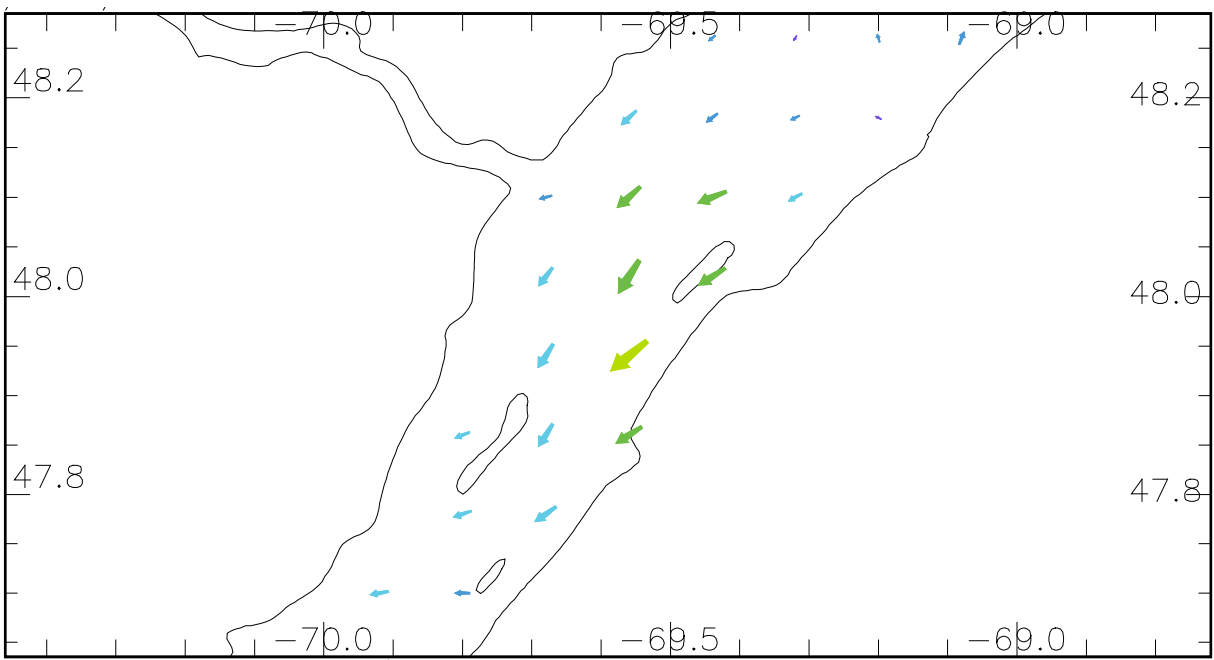
Displaying at a low resolution (i.e., zooming out) increases the density of symbols (Figure 9.8a). However, by applying a thinning algorithm, the number of vectors may be reduced (Figure 9.8b). In this case, every fourth vector was plotted.

Thinning for regularly gridded data is as follows. Suppose that the grid cell's diagonal as displayed has a distance of D mm and represents the grid spacing. Note that D is dependent on the specific geographic area and the size of the viewing monitor. If every n^{th} cell is displayed, the displayed spacing is nD . Next, suppose the length of the arrow representing the maximum speed in the displayed field is L_{smax} mm. Then the ratio of the maximum arrow length to the displayed grid spacing is constrained to be less than a prescribed maximum value, R_{max} , here taken to be 0.5. Thus

$$R = L_{\text{smax}}/nD \leq R_{\text{max}}$$



(a)



(b)

Figure 9.8 – (a) Current vectors (see Figure 9.6) displayed with identical parameters, but at low resolution. (b) Current vectors as in (a), but ‘thinned’ by plotting every fourth point. (data courtesy of St. Lawrence Global Observatory, Canada).

If the above inequality cannot be met with increment n equal to 1, then a new value for n is computed by the following formula:

$$n = 1 + \text{fix}(L_{\text{smax}}/DR_{\text{max}})$$

where $\text{fix}()$ is a function that returns the truncated integer value. For plotting, arrows at every n^{th} column and every n^{th} row are drawn, making sure that the row and column with the maximum vector is drawn (Figure 9.8b).

9.2 Temporal Interpolation

The time selected for realization (i.e., past, present, or future) of the display of the surface currents by the ENC system will typically not correspond exactly to the timestamp of the data. For real-time data, only the value closest to the (present) time and within a discrimination interval (e.g., 10 minutes) is displayed. For data at multiple times, whether single-point or gridded, the data must be temporally interpolated.

If the selected display time is later than the first timestamp and earlier than the last timestamp, then the closest two timestamps (i.e., one earlier and one later) in the data are found and the current values are linearly interpolated using the vector components (cf. clause 9.3.1).

9.3 Placement of Legend

The legend must consist of, at a minimum, the colour scale, with speed values, as shown in Figure 9.4. The precise position of the legend as it appears on the monitor will be determined so as to minimize the obscuring of other important navigational information.

9.4 Sample Representation

Surface currents vectors comprise a layer to be displayed on demand on top of other data and layers. Consideration must be made so as not to obscure critical navigational data nor create confusion by using symbols similar to those in other layers. Figure 9.9 shows a sample display.

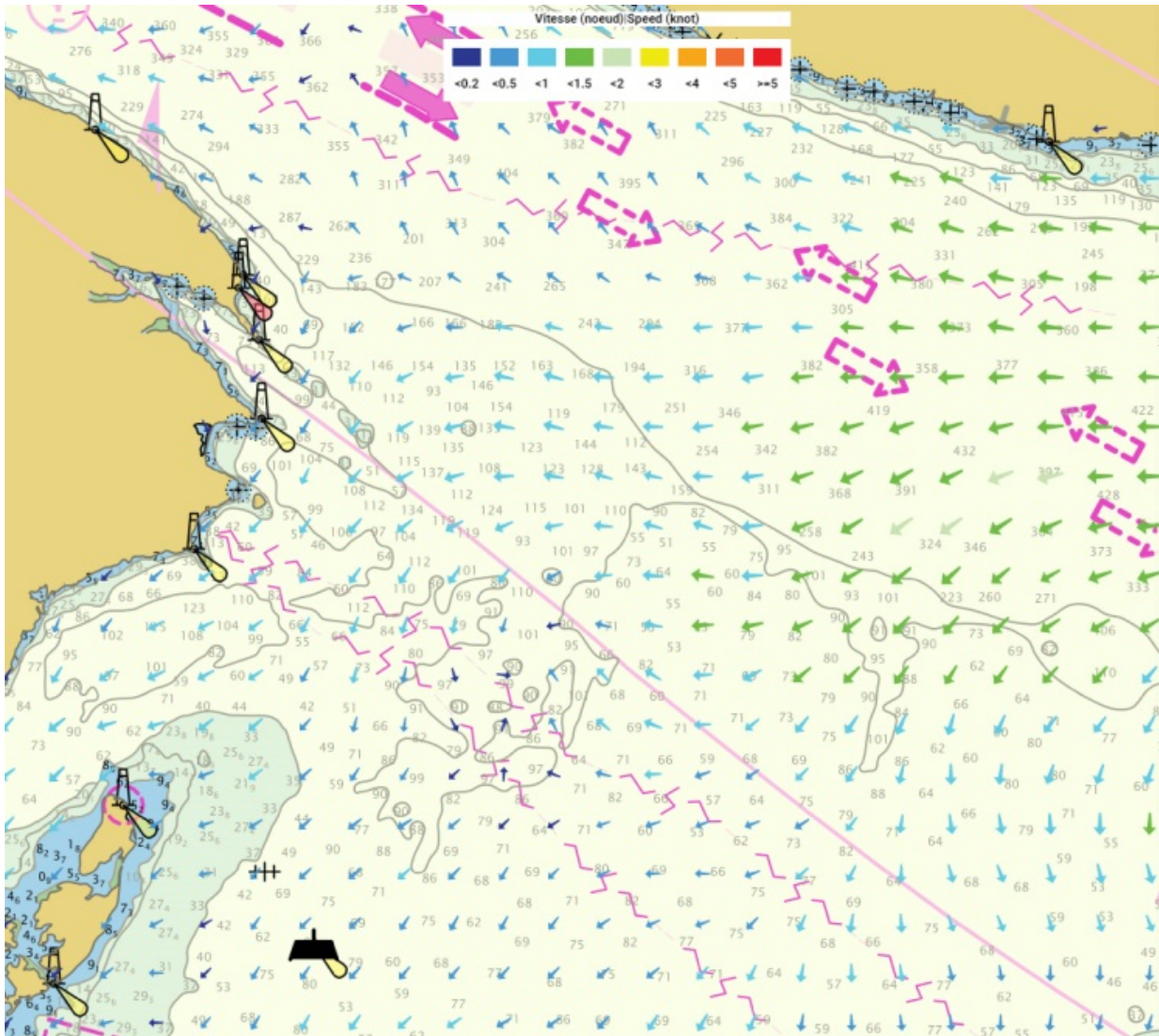


Figure 9.9 – Sample depiction of gridded surface current data in an electronic chart.
(Image courtesy of the University of New Hampshire, US)

10. DATA PRODUCT FORMAT (ENCODING)

10.1 Introduction

The Surface Current Data Product must be encoded using the Hierarchical Data Format standard, Version 5 (HDF5). The structure of the data product is discussed in the next section.

Format Name:	HDF-5
Character Set:	MD_CharacterSetCode (ISO 19115)
Specification:	S-100 profile of HDF-5

10.2 Product Structure

The key idea at the core of the structure is this: the organization of the information is substantially the same for each of the various types of data, but the information itself will be interpreted differently.

The product format is designed to be flexible enough to apply for (a) time series data for one or more individual, fixed stations, (b) regularly-gridded data for multiple times, (c) irregularly-gridded data for multiple times, and (d) Lagrangian drifter data with a constant time interval. This approach contains, for each type, data in a similar format but which is interpreted differently. Since each type of data will be interpreted differently, the type of data must be identified by the variable *dataCodingFormat*, as shown in Table 10.1.

Table 10.1 - Values of the variable *dataCodingFormat*.

dataCodingFormat	Type of Data
1	Time series data at one or more fixed stations
2	Regularly-gridded data at one or more times
3	Irregularly-gridded data at one or more times
4	Lagrangian drifter time series data with a constant time interval

For all data types, the product structure in HDF5 includes (a) a metadata block, which is followed by (b) one or more Groups which contain the actual surface current data. The speed and direction information are saved in arrays that hold either gridded data or a time series.

For regularly gridded data, the speed and direction arrays are two dimensional, with dimensions *numberPointsLong* and *numberPointsLat*. By knowing the grid origin and the grid spacings, the position of every point in the grid can be computed by simple formulae.

However, for time series data, irregularly gridded data, and Lagrangian drifter data (i.e., when *dataCodingFormat* is 1, 3 or 4), the location of each point must be specified individually. This is accomplished by the data in Group XY, which gives the individual longitude (X) and latitude (Y) for each location. For time series data, the X and Y values are the positions of the stations; the number of stations is *number*. For irregularly-gridded data, the X and Y values are the positions of each point in the grid; the number of grid points is *numberOfNodes*. For drifter data, X and Y values are the positions of the drifters at each time; the number of drifters is *numberOfStations*.

NOTE: If *dataCodingFormat* is 2, Group XY is not present.

The remaining Groups each contain a title, a date-time value, and the speed and direction arrays. The title can be used to identify each individual station with time-series data. For *dataCodingFormat* = 2 or 3, the date-time is for the entire grid. The speed and direction arrays are two dimensional, with a number of columns (*numCOL*) and rows (*numROW*). For a time series, the speed and direction values will be for each time in the series. For a grid, the speed and direction values will be for each point in the grid.

The Groups are numbered 1, 2, etc., up to the maximum number of Groups, *numGRP*. For fixed station data, the number of Groups is the number of stations. For regular and irregular grids, the number of Groups is the number of time records. For Lagrangian drifter data, aside from Group XY, there is only one Group, corresponding to a single drifter; additional drifters can be accommodated in additional data products.

To summarize, for non-regularly gridded data only, there is an initial Group with X and Y position, stored in one-dimensional arrays of size *numPOS*. Following that, there are data Groups containing the speed and direction data, which are stored in two-dimensional arrays of size *numROWS* by *numCOLS*. The total number of data Groups is *numGRPS*.

The four variables that determine the array sizes (*numROWS*, *numCOLS*, *numPOS*, and *numGRPS*) are different, depending upon which coding format is used. Their descriptions are given in Table 10.2.

Table 10.2 – The array dimensions used in the data product.

Data Type	Coding Format	numPOS	numCOL	numROW	numGRP
Time Series	1	numberOfStations	numberOfTimes	1	numberOfStations
Regular Grid	2	(not used)	numberPointsLong	numberPointsLat	numberOfTimes
Irregular Grid	3	numberOfNodes	numberOfNodes	1	numberOfTimes
Lagrangian Drifter	4	numberOfTimes	numberOfTimes	1	1

The overall structure of the surface current data product is created by assembling the data and metadata. The product structure is compliant with the HDF5 data architecture, which allows multi-dimensional arrays of data to be grouped with metadata. The format of the data product (cf. Figure F.5) described above is portrayed in Figure 10.1.

NOTE: The name of each Group is the 'Group n', where n is numbered from 1 to *numGRP*. The length of the name is six plus the number of digits in n.

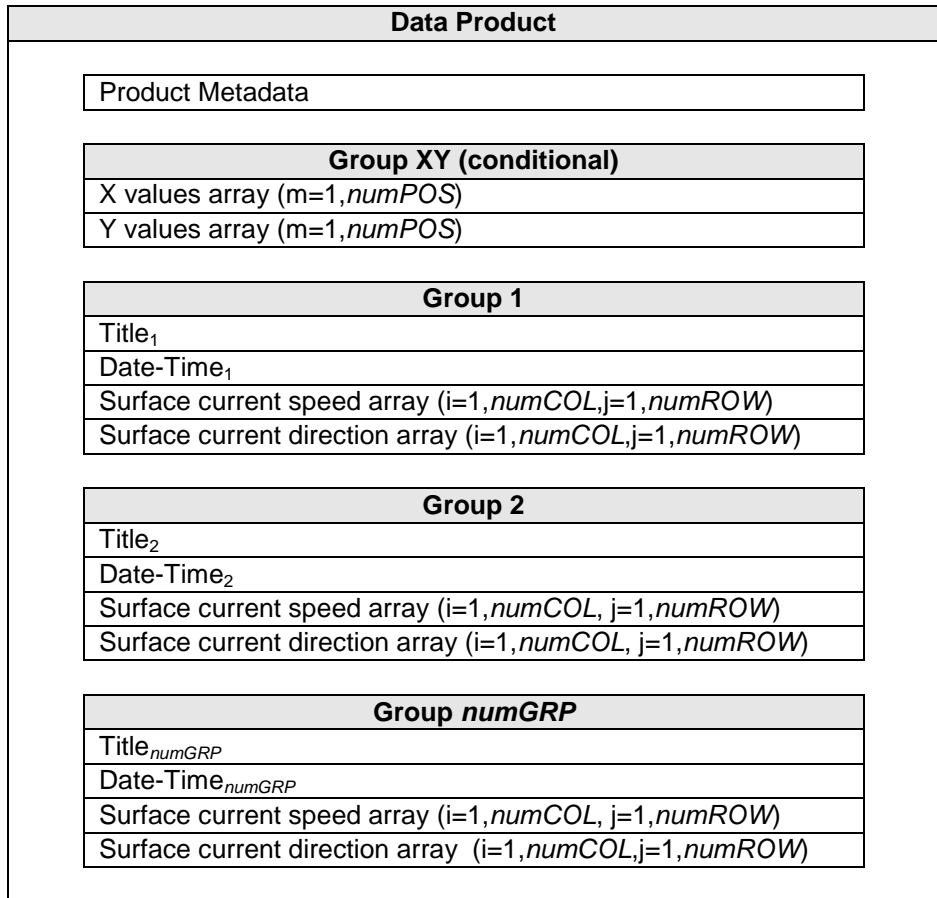


Figure 10.1 - Schematic of the S-111 data product structure. The parameters *numPOS*, *numCOL*, *numROW*, and *numGRP* are explained in Table 10.2.

10.3 Metadata

The Product Metadata is initial information (Table 10.3) that describes the surface current data. The content of the metadata is described in the table below (Table 10.3).

Table 10.3 - Metadata common to all surface current data products, grouped by general character. Data type refers to HDF 5. NOTE: multiplicity for all entries is 1.

N	Name	Camel Case	Data Type	Remarks and/or Units
Administrative Information				
1	Country of Origin	nationalOriginator	Character	Country code for producer (ISO 3166-1)
2	Producing agency	producingAgency	Character	Agency responsible for producing the data.
3	Product Spec and version	productSpecification	Character	This must be encoded as 'S-111.X.X.X', with Xs representing the version number
4	Date of edition issue	dateOfIssue	Character	Date
5	Number of this edition	editionNumber	Integer	Edition for the date of issue
6	Date of update	updateApplicationDate	Character	Date
7	Update number of this product	updateNumber	Integer	Update number is assigned to each new dataset
8	Name of Data Product file	fileName	Character	File name. e.g.: CAxxxxxxxxxxxxxxxx.hdf5
9	Data file format	dataType	Character	ISO HDF5
10	Name of geographic region	nameRegion	Character	
11	Name of geographic sub-region	nameSubregion	Character	
12	Horizontal datum	horizontalDatumReference	Character	EPSG
13	Horizontal datum number	horizontalDatumValue	Integer	4326 (for WGS84)
Area and Time Coverage Information				
14	Westmost longitude	westBoundLongitude	Float	Arc Degrees
15	Eastmost longitude	eastBoundLongitude	Float	Arc Degrees
16	Southmost latitude	southBoundLatitude	Float	Arc Degrees
17	Northmost latitude	northBoundLatitude	Float	Arc Degrees
18	Valid Time of Earliest Value	dateTimeOfFirstRecord	Character	Date-time
19	Valid Time of Latest Value	dateTimeOfLastRecord	Character	Date-time
20	Time interval	timeRecordInterval	Integer	Seconds
21	Number of time records	numberOfTimes	Integer	
Surface Current Information				
22	Type of current data	typeOfCurrentData	Enumeration	1: Historical observation 2: Real-time observation 3: Astronomical prediction 4: Analysis 5: Model-based hindcast 6: Model-based forecast
23	Data organization index	dataCodingFormat	Enumeration	1: Time series at one or more fixed stations with same starting date-time, ending date-time, and number of points 2: Regularly-gridded arrays 3: Irregularly-gridded arrays 4: Lagrangian drifters
24	Number of stations with time series data	numberOfStations	Integer	Used only if dataCodingFormat = 1 or 4
25	Methodology, instrument, or model	methodOrSource	Character	Instrument or model type
26	Vertical reference	depthTypeIndex	Enumeration	1: Layer average 2: Sea surface 3: Vertical datum (see verticalDatum) 4: Sea bottom
27	Depth value	surfaceCurrentDepth	Float	Layer thickness (depthTypeIndex=1), or height (depthTypeIndex=2, 3, 4) (m)

28	Vertical datum reference	verticalDatum	Enumeration	1 : Mean low water springs 2 : Mean lower low water springs 3 : Mean sea level 4 : Lowest low water 5 : Mean low water 6 : Lowest low water springs 7 : Approximate mean low water springs 8 : Indian spring low water 9 : Low water springs 10 : Approximate lowest astronomical tide 11 : Nearly lowest low water 12 : Mean lower low water 13 : Low water 14 : Approximate mean low water 15 : Approximate mean lower low water 16 : Mean high water 17 : Mean high water springs 18 : High water 19 : Approximate mean sea level 20 : High water springs 21 : Mean higher high water 22 : Equinoctial spring low water 23 : Lowest astronomical tide 24 : Local datum 25 : International Great Lakes Datum 1985 26 : Mean water level 27 : Lower low water large tide 28 : Higher high water large tide 29 : Nearly highest high water 30 : Highest astronomical tide (HAT)
Grid Information				
29	Longitude of grid origin	gridOriginLongitude	Float	Arc Degrees (if dataCodingFormat=2)
30	Latitude of grid origin	gridOriginLatitude	Float	Arc Degrees (if dataCodingFormat=2)
31	Grid spacing, long.	gridSpacingLongitudinal	Float	Arc Degrees (if dataCodingFormat=2)
32	Grid spacing, lat.	gridSpacingLatitudinal	Float	Arc Degrees (if dataCodingFormat=2)
33	Number of points, long.	numberPointsLong	Integer	iMax (if dataCodingFormat=2)
34	Number of points, lat.	numberPointsLat	Integer	jMax (if dataCodingFormat=2)
35	First grid point num., long.	minimumGridPointLongitudinal	Integer	0 (if dataCodingFormat=2)
36	First grid point num., lat.	minimumGridPointLatitudinal	Integer	0 (if dataCodingFormat=2)
37	Nodes in irregular grid	numberOfNodes	Integer	Used if dataCodingFormat=3
38	Land mask	gridLandMaskValue	Float	Negative value (e.g. -1.0 or -99.999). Also denotes a missing value.
Uncertainty Information				
39	Speed uncertainty	uncertaintyOfSpeed	Float	kn. Negative value indicates unknown
40	Direction uncertainty	uncertaintyOfDirection	Float	Arc Deg. Negative value indicates unknown
41	Horizontal position uncertainty	uncertaintyOfHorizontalPosition	Float	m. Negative value indicates unknown
42	Vertical position uncertainty	uncertaintyOfVerticalPosition	Float	m. Negative value indicates unknown
43	Time uncertainty	uncertaintyOfTime	Float	s. Negative value indicates unknown

A few of the parameters require further explanation.

Parameters No. 14 – 17: The area coverage limits (*minimumLongitude*, *maximumLongitude*, *minimumLatitude*, and *maximumLatitude*) are determined as shown in Table 10.4.

Table 10.4 – Metadata variables No 14 through 17 (Table 10.3) for different data coding formats.

Variable	dataCodingFormat			
	1	2	3	4
<i>minimumLongitude</i>	Minimum of all station longitudes	Grid origin longitude	Minimum of all node longitudes	Minimum of all position longitudes
<i>maximumLongitude</i>	Maximum of all station longitudes	Grid origin latitude	Maximum of all node longitudes	Maximum of all position longitudes
<i>minimumLatitude</i>	Minimum of all station latitudes	Upper grid boundary	Minimum of all node latitudes	Minimum of all position latitudes
<i>maximumLatitude</i>	Maximum of all station latitudes	Upper grid boundary	Maximum of all node latitudes	Maximum of all position latitudes

Parameters No. 39 – 43: Uncertainty fields are optional, and there is a provision to specify uncertainty as unknown (by a negative value) or as spatially-constant value.

10.4 Digital Certification Block

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

10.5 HDF5 Encoding

The HDF-5 encoding of the data set and its metadata is discussed in Annex G.

11. DATA PRODUCT DELIVERY

11.1 Introduction

This section describes how the Surface Current Data Product is to be delivered from the HO to the end user (i.e., navigation officer, route planner, etc.). HDF5 is the standard format for surface current data exchange.

Due to the cost of transmitting data via Internet, it is desirable to limit file size and updating frequency whenever possible. The file size, before compression, is limited to 10 MB. **<is 10 MB too large?>**

Updating of files typically means issuing a new forecast, or disseminating the latest observed current for a specific geographic region. Therefore, all updates are considered to be new editions. Each new edition will be defined by (a) the date of issue of the edition, and (b) the version issued in that date. For example, the first forecast of the day with a 24-hr projection time will be edition number 1. The next forecast, issued 6 hr later, will be edition number 2. Similarly, the first real-time observation of the day will be edition number 1. The next update, say 5 min later, will be edition number 2.

11.2 Exchange Datasets

Datasets, or data products, produced by the HO consist of files containing both the exchange catalogue and one or more data products (of possibly different S-100 types), with each product covering a specific geographic region and specific period of time (Figure 11.1). The Exchange Catalogue lists the products and contains the discovery metadata.

The name of the exchange dataset will have the character string 'S-111' somewhere in it (e.g., 'S-111_ExchangeDataset'), and this will identify the data as containing surface currents. <full names are still to be decided on>

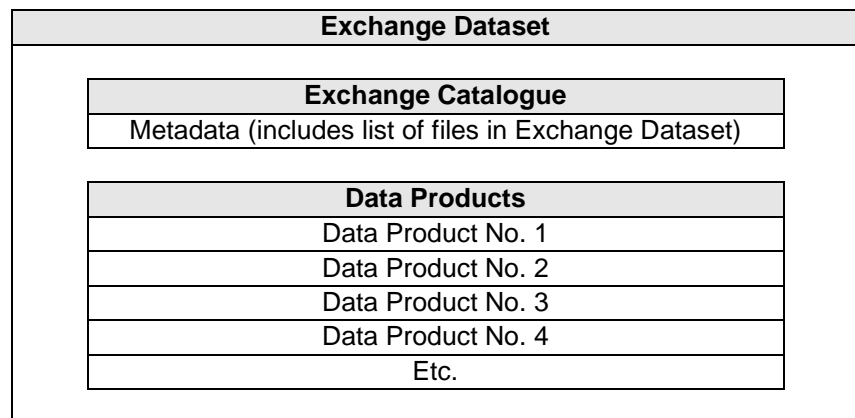


Figure 11.1 – Schematic diagram of the Exchange Dataset.

The dataset size is limited to 10 Mbytes. 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 Mbytes. Exchange files may be compressed using zip methodology. Doing so can reduce file size by 80% or more.

11.3 Exchange Catalogue

The exchange catalogue (normally in XML format) acts as the table of contents for the exchange set. The catalogue file of the exchange set must be named S111ed1.CAT; no other file in the exchange set may have the same name. The contents of the exchange catalogue are described in Clause 12.

11.4 Data Product File Naming

The data product file contains both a metadata block and one or more sets of speed and direction arrays. The file naming convention described here must be used for all surface current files from all sources. The file naming convention consists of from 20 to 22 characters. The characters are used to identify the following: the country code (two characters), followed by HO

specific characters to uniquely define the dataset (15 characters). The filename extension (e.g., .hdf5) denotes the file format. Characters may be lower or upper case. This is summarized in Table 11.1.

Table 11.1 - Characters used in the file naming convention.

N	DESCRIPTION	LENGTH	EXAMPLE
1	Country Code	2	CA
2	Unrestricted	15	Gulf20141106ABC
3	Extension	3 to 5	.h5, .hdf5

Total = 20-22

The unrestricted characters may be used to denote geographical region, valid time, source of the data, version numbers, and/or any other relevant information.

11.5 Support Files

This Data Product requires no support files.

12. METADATA

12.1 Introduction

For information exchange, there are several categories of metadata required: metadata about the overall exchange catalogue, metadata about each of the datasets contained in the catalogue, and metadata about the support files that make up the package. The discovery metadata classes have numerous attributes which enable important information about the datasets and accompanying support files to be examined without the need to process the data, e.g. decrypt, decompress, load etc. Other catalogues can be included in the exchange set in support of the datasets such as feature, portrayal, coordinate reference systems, codelists etc. The attribute “purpose” of the support file metadata provides a mechanism to update support files more easily.

This clause defines the mandatory and optional metadata needed for S-111. For information exchange, there are several categories of metadata required: metadata about the overall exchange catalogue, metadata about each of the datasets contained in the catalogue, and metadata about the support files, if any, that make up the package. In some cases the metadata may be repeated in a national language.

An outline the overall concept of an S-111 exchange set for the interchange of geospatial data and its relevant metadata is explained in the following figures. Figure 12.1 depicts the realization of the ISO 19139 classes which form the foundation of the exchange set. The overall structure of S-111 metadata for exchange sets is modelled in Figures 12.2 and 12.3. More detailed information about the various classes is shown in Figure 12.4 and a textual description in the tables at Clause 12.3. The major components of the exchange set are shown in Figure 11.1.

The discovery metadata classes have numerous attributes which enable important information about the datasets and accompanying support files to be examined without the need to process the data, e.g. decrypt, decompress, load etc. Other catalogues can be included in the exchange set in support of the datasets such as feature and portrayal. The attribute “purpose” of the support file metadata provides a mechanism to update support files more easily.

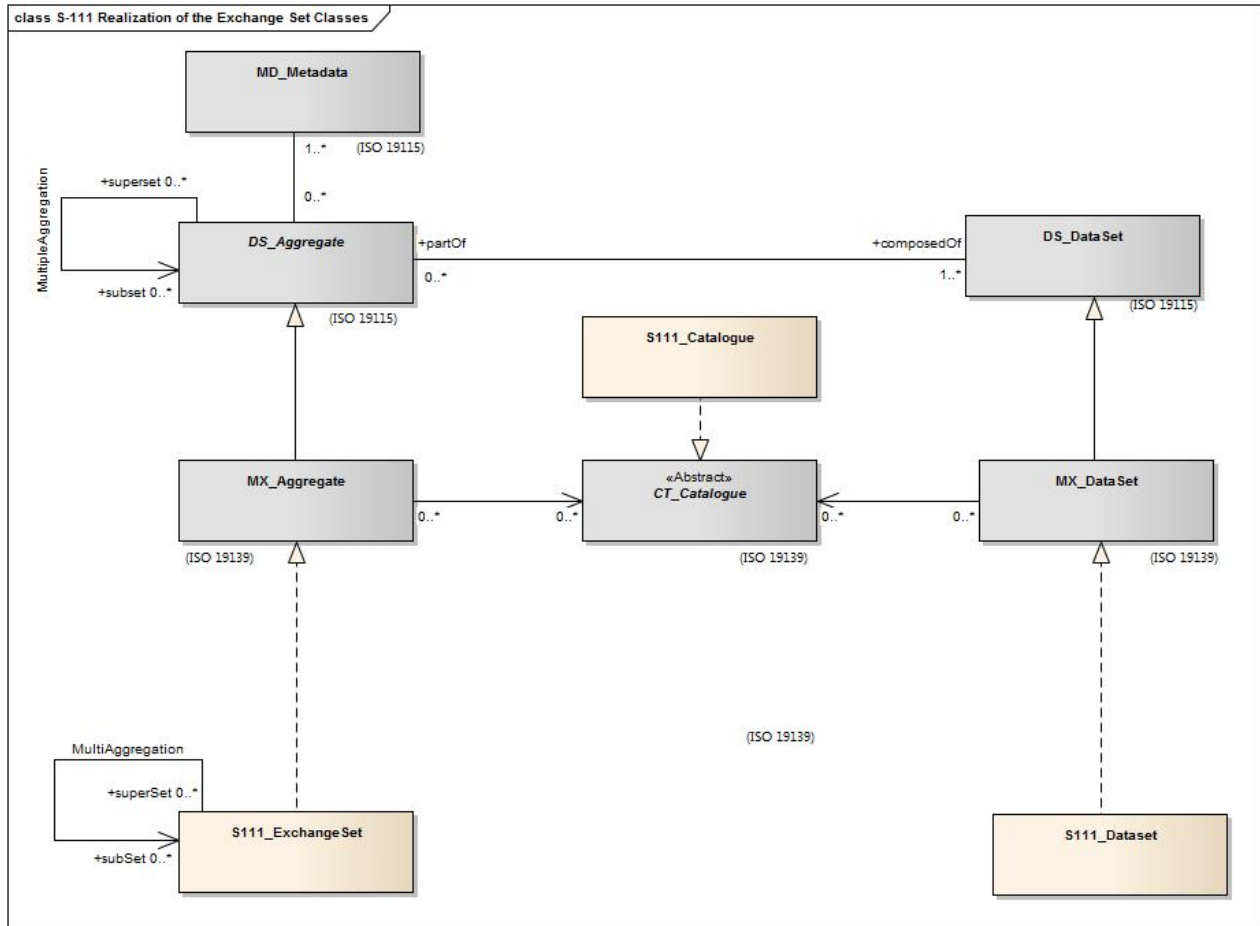


Figure 12.1 - Realization of the exchange set classes.

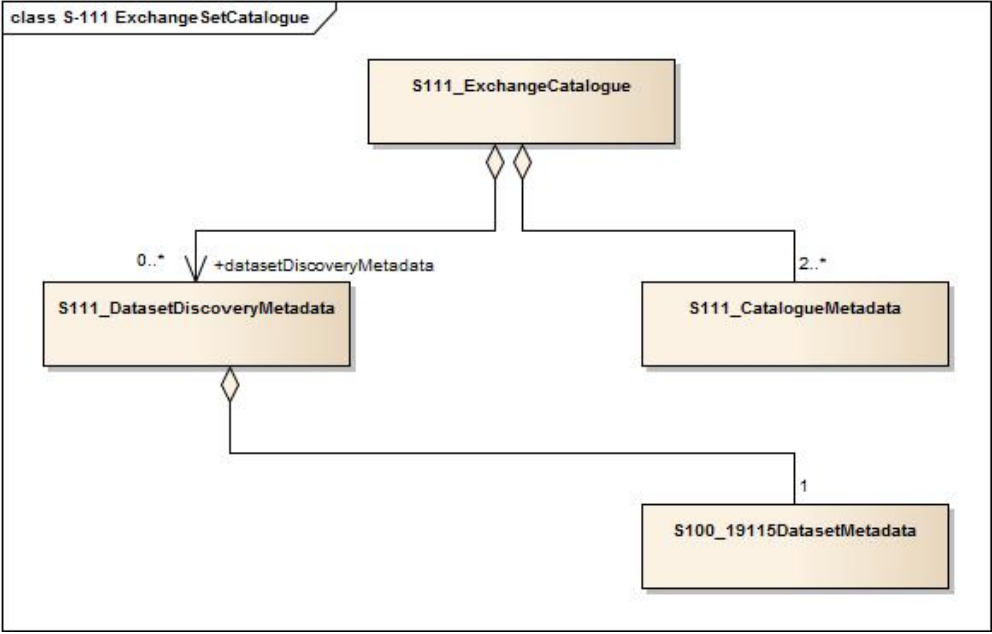


Figure 12.2 - S-111 ExchangeSet Catalogue

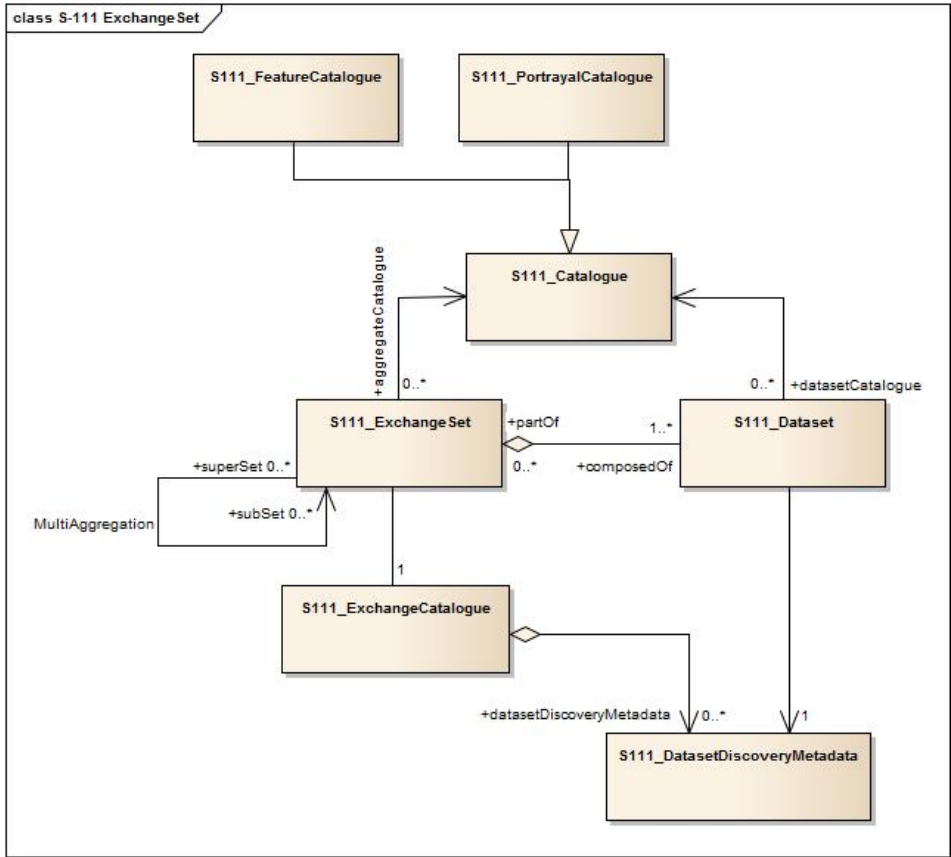


Figure 12.3 – S-111 ExchangeSet.

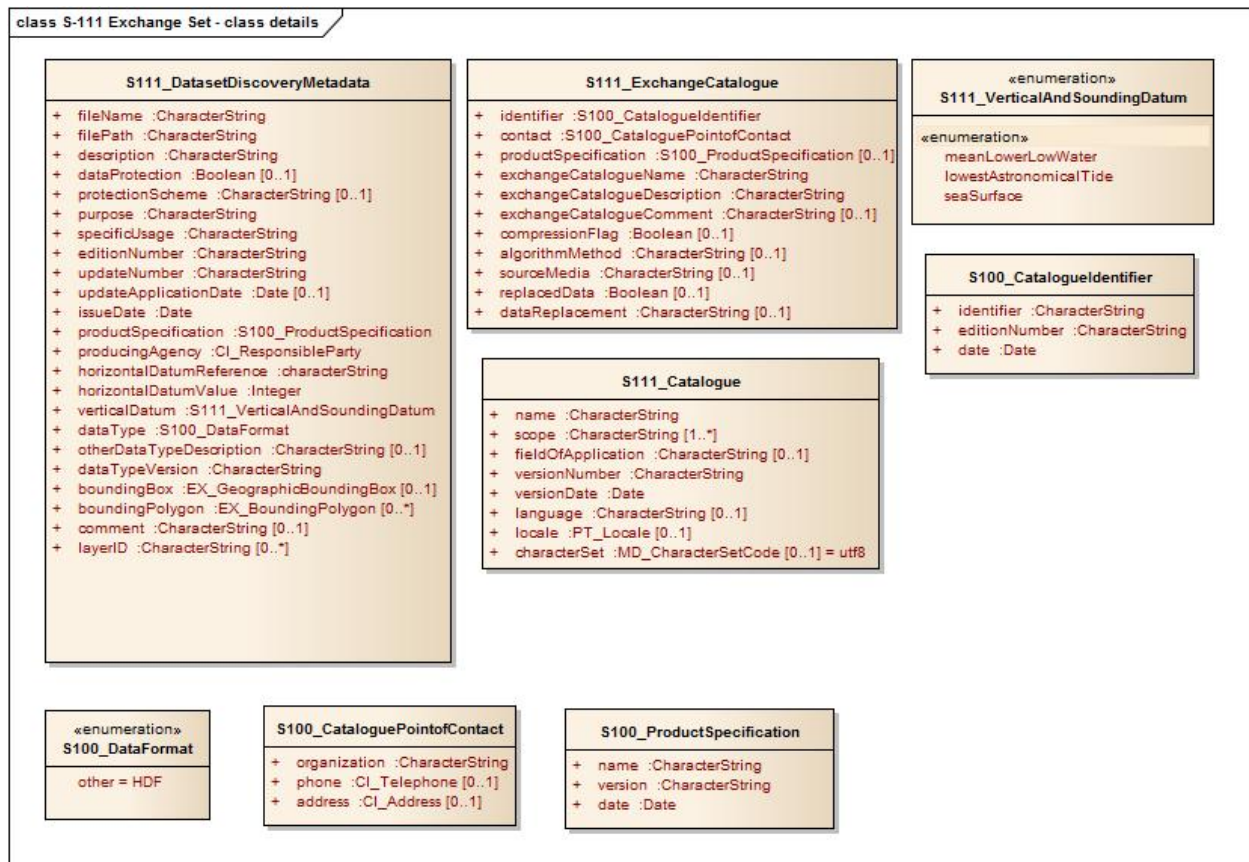


Figure 12.4 - S-111 Exchange Set: Class details.

12.2 Elements of the Exchange Set

S111_ExchangeSet

An S-111 Exchange Set is an aggregation of all the various elements required to support the interchange of geospatial data and metadata. The MultiAggregation association introduces the concept of using subsets which could be domain oriented e.g. packaged by scale, producer, region etc.

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_ExchangeSet	Aggregation of the elements comprising an exchange set for the transfer of data	-	-	-
Role	aggregateFile	Collection of support files in the exchange set	0..*	-	
Role	partOf	Collection of datasets which are part of the exchange set	0..*	-	
Role	aggregateCatalogue	Collection of catalogues	0..*	-	
Role	superSet	The master container exchange set which can contain a subSet of exchange sets			
Role	subSet	Exchange set which is part of the superSet			

S111_ExchangeCatalogue

Each exchange set has a single S111_ExchangeCatalogue which contains meta information for the data and support files in the exchange set.

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_ExchangeCatalogue	An exchange catalogue contains the discovery metadata about the exchange datasets and support files	-	-	-
Attribute	Identifier	Uniquely identifies this exchange catalogue	1	S111_CatalogueIdentifier	
Attribute	Contact	Details about the issuer of this exchange catalogue	1	S111_CataloguePointOfContact	
Attribute	productSpecification	Details about the product specifications used for the datasets contained in the exchange catalogue	0..1	S111_ProductSpecification	Conditional on all the datasets using the same product specification
Attribute	exchangeCatalogueName	Catalogue filename	1	CharacterString	In S-101 it would be CATLOG.101
Attribute	exchangeCatalogueDescription	Description of what the exchange catalogue contains	1	CharacterString	
Attribute	exchangeCatalogueComment	Any additional information	0..1	CharacterString	
Attribute	compressionFlag	Is the data compressed	0..1	Boolean	Yes or No
Attribute	algorithmMethod	Type of compression algorithm	0..1	CharacterString	Eg. RAR or ZIP
Attribute	sourceMedia	Distribution media	0..1	CharacterString	
Attribute	replacedData	If a data file is cancelled is it replaced by another data file	0..1	Boolean	
Attribute	dataReplacement	Cell name	0..1	CharacterString	

S111_CatalogueIdentifier

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_CatalogueIdentifier	An exchange catalogue contains the discovery metadata about the exchange datasets and support files	-	-	-
Attribute	identifier	Uniquely identifies this exchange catalogue	1	CharacterString	
Attribute	editionNumber	The edition number of this exchange catalogue	1	CharacterString	
Attribute	date	Creation date of the exchange catalogue	1	Date	

S111_CataloguePointofContact

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_CataloguePointOfContact	Contact details of the issuer of this exchange catalogue	-	-	-
Attribute	organization	The organization distributing this exchange catalogue	1	CharacterString	This could be an individual producer, value added reseller, etc.
Attribute	phone	The phone number of the organization	0..1	CI_Telephone	
Attribute	address	The address of the organization	0..1	CI_Address	

S111_Dataset

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_Dataset		-	-	-
Role	composedOf	An exchange set is composed of 0 or more datasets	0..*	-	
Role	datasetCatalogue	Catalogue which is related to this dataset	0..*	-	

S111_DatasetDiscoveryMetaData

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_DatasetDiscoveryMetadata	Metadata about the individual datasets in the exchange catalogue	-	-	-
Attribute	fileName	Dataset file name	1	CharacterString	
Attribute	filePath	Full path from the exchange set root directory	1	CharacterString	Path relative to the root directory of the exchange set. The location of the file after the exchange set is unpacked into directory <EXCH_ROOT> will be <EXCH_ROOT>/<filePath>/<filename>
Attribute	description	Short description giving the area or location covered by the dataset	1	CharacterString	E.g. a harbour or port name, between two named locations etc.
Attribute	dataProtection	Indicates if the data is encrypted	0..1	Boolean	0 indicates an unencrypted dataset 1 indicates an encrypted dataset
Attribute	protectionScheme	specification or method used for data protection	0..1	CharacterString	Eg S-63

Role Name	Name	Description	Mult	Type	Remarks
Attribute	purpose	The purpose for which the dataset has been issued	1	MD_Identifier>purpose CharacterString	E.g. new, re-issue, new edition, update etc.
Attribute	specificUsage	The use for which the dataset is intended	1	CharacterString	E.g. in the case of ENCs this would be a navigation purpose classification.
Attribute	editionNumber	The edition number of the dataset	1	CharacterString	when a data set is initially created, the edition number 1 is assigned to it. The edition number is increased by 1 at each new edition. Edition number remains the same for a re-issue.
Attribute	updateNumber	Update number assigned to the dataset and increased by one for each subsequent update	1	CharacterString	Update number 0 is assigned to a new dataset.
Attribute	updateApplicationDate	this date is only used for the base cell files (i.e. new data sets, re-issue and new edition), not update cell files. All updates dated on or before this date must have been applied by the producer	0..1	Date	
Attribute	issueDate	date on which the data was made available by the data producer	1	Date	
Attribute	productSpecification	The product specification used to create this dataset	1	S111_ProductSpecification	
Attribute	producingAgency	Agency responsible for producing the data	1	CI_ResponsibleParty	
Attribute	horizontalDatumReference	Reference to the register from which the horizontal datum value is taken	1	characterString	EPSG
Attribute	horizontalDatumValue	Horizontal Datum of the entire dataset	1	Integer	4326
Attribute	verticalDatum	Vertical Datum of the entire dataset	1	S111_VerticalAndSoundingDatum	
Attribute	dataType	The encoding format of the dataset	1	S100_DataFormat	
Attribute	otherDataTypeDescription	Encoding format other than those listed.	0..1	CharacterString	
Attribute	dataTypeVersion	The version number of the dataType.	1	CharacterString	
Attribute	boundingBox	The extent of the cell limits	0..1	EX_GeographicBoundingBox	
Attribute	boundingPolygon	A polygon which defines the actual data limit	0..*	EX_BoundingPolygon	
Attribute	comment	any additional information	0..1	CharacterString	
Attribute	layerID	Identifies the relationship to other layers that are required to view the complete data set.	0..*	CharacterString	Eg – Scale Independent or Dependents

S111_DataCoverage

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_DataCoverage		-	-	-
Attribute	ID	Uniquely identifies the coverage	1	Integer	-
Attribute	boundingBox	The extent of the dataset limits	1	EX_GeographicBoundingBox	-
Attribute	boundingPolygon	A polygon which defines the actual data limit	1..*	EX_BoundingPolygon	-
Attribute	optimumDisplayScale	The scale with which the data is optimally displayed	0..1	Integer	Example: A scale of 1:25000 is encoded as 25000
Attribute	maximumDisplayScale	The maximum scale with which the data is displayed	0..1	Integer	
Attribute	minimumDisplayScale	The minimum scale with which the data is displayed	0..1	Integer	

S111_DataFormat

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_DataFormat	Encoding format	-	-	
Value	HFD5				

S111_ProductSpecification

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_ProductSpecification	The Product Specification contains the information needed to build the specified product	-	-	-
Attribute	name	The name of the product specification used to create the datasets	1	CharacterString	
Attribute	version	The version number of the product specification	1	CharacterString	
Attribute	date	The version date of the product specification	1	Date	

S111_VerticalAndSoundingDatum

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_VerticalAndSoundingDatum	Allowable vertical and sounding datums	-	-	-
Value	meanLowWaterSprings		-	-	-
Value	meanSeaLevel		-	-	-
Value	meanLowerLowWaterSprings		-	-	-
Value	lowestLowWater		-	-	-
Value	meanLowWater		-	-	-
Value	lowestLowWaterSprings		-	-	-
Value	approximateMeanLowWaterSprings		-	-	-
Value	indianSpringLowWater		-	-	-
Value	lowWaterSprings		-	-	-
Value	approximateLowestAstronomicalTide		-	-	-
Value	nearlyLowestLowWater		-	-	-
Value	meanLowerLowWater		-	-	-
Value	lowWater		-	-	-
Value	approximateMeanLowWater		-	-	-
Value	approximateMeanLowerLowWater		-	-	-
Value	meanHighWater		-	-	-
Value	meanHighWaterSprings		-	-	-
Value	highWater		-	-	-
Value	approximateMeanSeaLevel		-	-	-
Value	highWaterSprings		-	-	-
Value	meanHigherHighWater		-	-	-
Value	equinoctialSpringLowWater		-	-	-
Value	lowestAstronomicalTide		-	-	-
Value	localDatum		-	-	-
Value	internationalGreatLakesDatum1985		-	-	-
Value	meanWaterLevel		-	-	-
Value	lowerLowWaterLargeTide		-	-	-
Value	higherHighWaterLargeTide		-	-	-
Value	nearlyHighestHighWater		-	-	-
Value	highestAstronomicalTide		-	-	(HAT)

S111_DataFormat

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_DataFormat	Encoding format	-	-	
Value	HFD5				

S111_ProductSpecification

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_ProductSpecification	The Product Specification contains the information needed to build the specified product	-	-	-
Attribute	name	The name of the product specification used to create the datasets	1	CharacterString	
Attribute	version	The version number of the product specification	1	CharacterString	
Attribute	date	The version date of the product specification	1	Date	

S111_CatalogueMetadata

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_CatalogueMetadata		-	-	-
Attribute	filename	The name for the catalogue	1..*	CharacterString	
Attribute	fileLocation	Full location from the exchange set root director	1..*	CharacterString	Path relative to the root directory of the exchange set. The location of the file after the exchange set is unpacked into directory <EXCH_ROOT> will be <EXCH_ROOT>/<file Path>/<filename>
Attribute	scope	Subject domain of the catalogue	1..*	S111_CatalogueScope	
Attribute	versionNumber	The version number of the product specification	1..*	CharacterString	
Attribute	issueDate	The version date of the product specification	1..*	Date	
Attribute	productSpecification	The product specification used to create this file	1..*	S111_ProductSpecification	
Attribute	digitalSignatureReference	Digital Signature of the file	1	CharacterString	Reference to the appropriate digital signature algorithm
Attribute	digitalSignatureValue	Value derived from the digital signature	1	CharacterString	

S111_CatalogueScope

Role Name	Name	Description	Mult	Type	Remarks
Class	S111_CatalogueScope		-	-	-
Value	featureCatalogue				
Value	portrayalCatalogue				

12.3 Language

The language used for the metadata is English.

ANNEX A. ADDITIONAL TERMS AND DEFINITIONS

Terms that are defined in this Annex or in Clause 1.4.2 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: 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 1: **Data types** include primitive predefined **types** and user-definable **types**
NOTE 2: 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: 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: 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 primitives** 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 non-decomposed **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

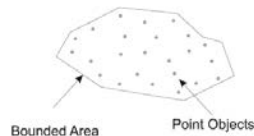
coverage that has a **domain** composed of **points**

[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 position.

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.

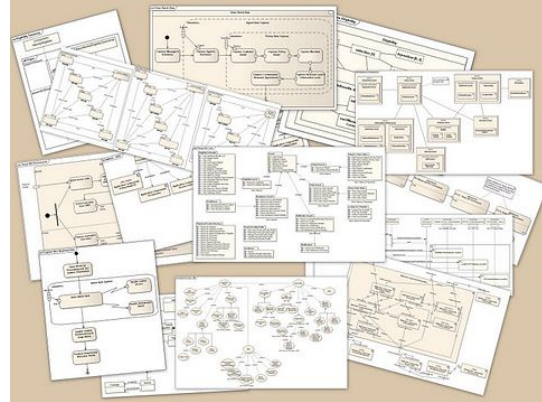


image courtesy of [Kishorekumar 62](#)

[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 B.1.

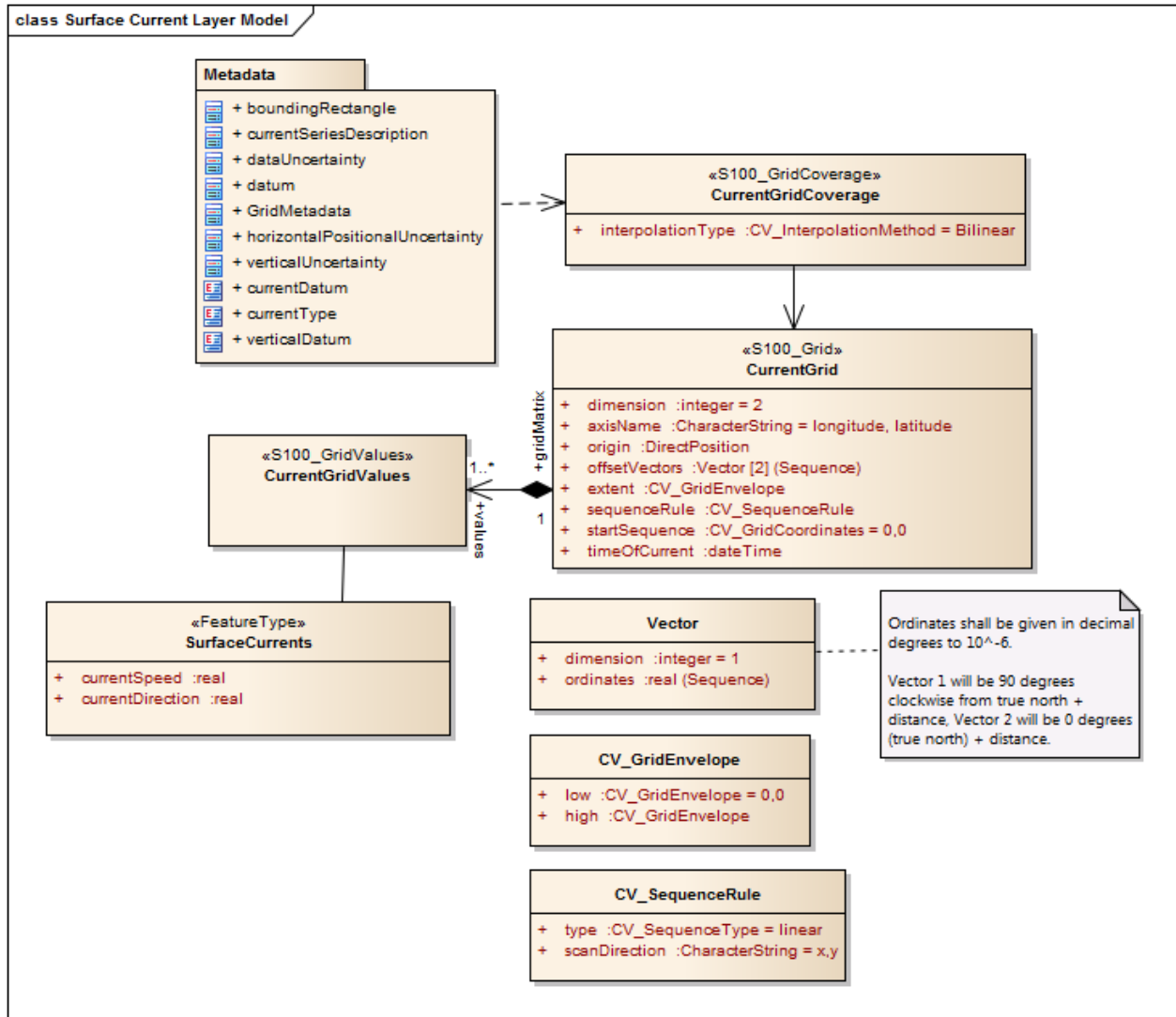


Figure B.1 – Surface Current Model.

The Surface current feature class has two mandatory attributes; *currentSpeed* and *currentDirection* used to capture the speed of current over ground and the general direction of the current at the grid point. 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.

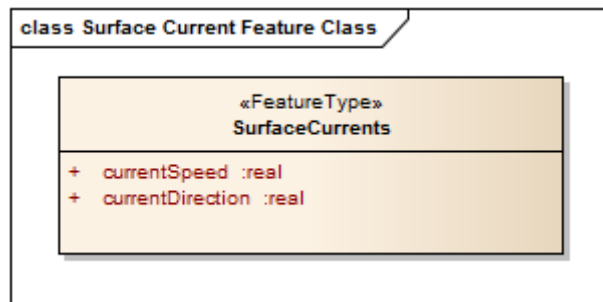


Figure B.2 – Surface Current Feature Class.

The metadata model for a specific grid is shown in Figure B.3.

There are four mandatory simple attributes for the metadata. The first one is a name of the station or grid. The second is *countryOfOrigin* using a code according to ISO3166, the third is *dataSourceAgency* using a code according to S-62, and the last is a description of the methodology used to create the data, usually from an instrument or calculations from a model.

The complex attribute *currentSeriesDescription* is used to describe type of current, and time series attributes with any known time uncertainty. The complex attribute datum gives the current depth origin. The attribute *depthOfCurrent* can be used to capture how deep the current is referenced to chart datum, alternatively the attribute *layerThickness* can be used to encode the thickness of the current zone. Only one of *depthOfCurrent* or *layerThickness* can be encoded for an instance of GridMetadata. The optional attribute *timeBetweenDataValues* is an integer that captures whole minutes between the data values in a series.

The optional complex attributes *verticalUncertainty*, *horizontalPositionUncertainty* and *dataUncertainty* can be used to capture uncertainties for the various aspects of the data.

The mandatory complex attribute *boundingRectangle* carries the sides of a bounding rectangle indicating the general area where the current information is located.

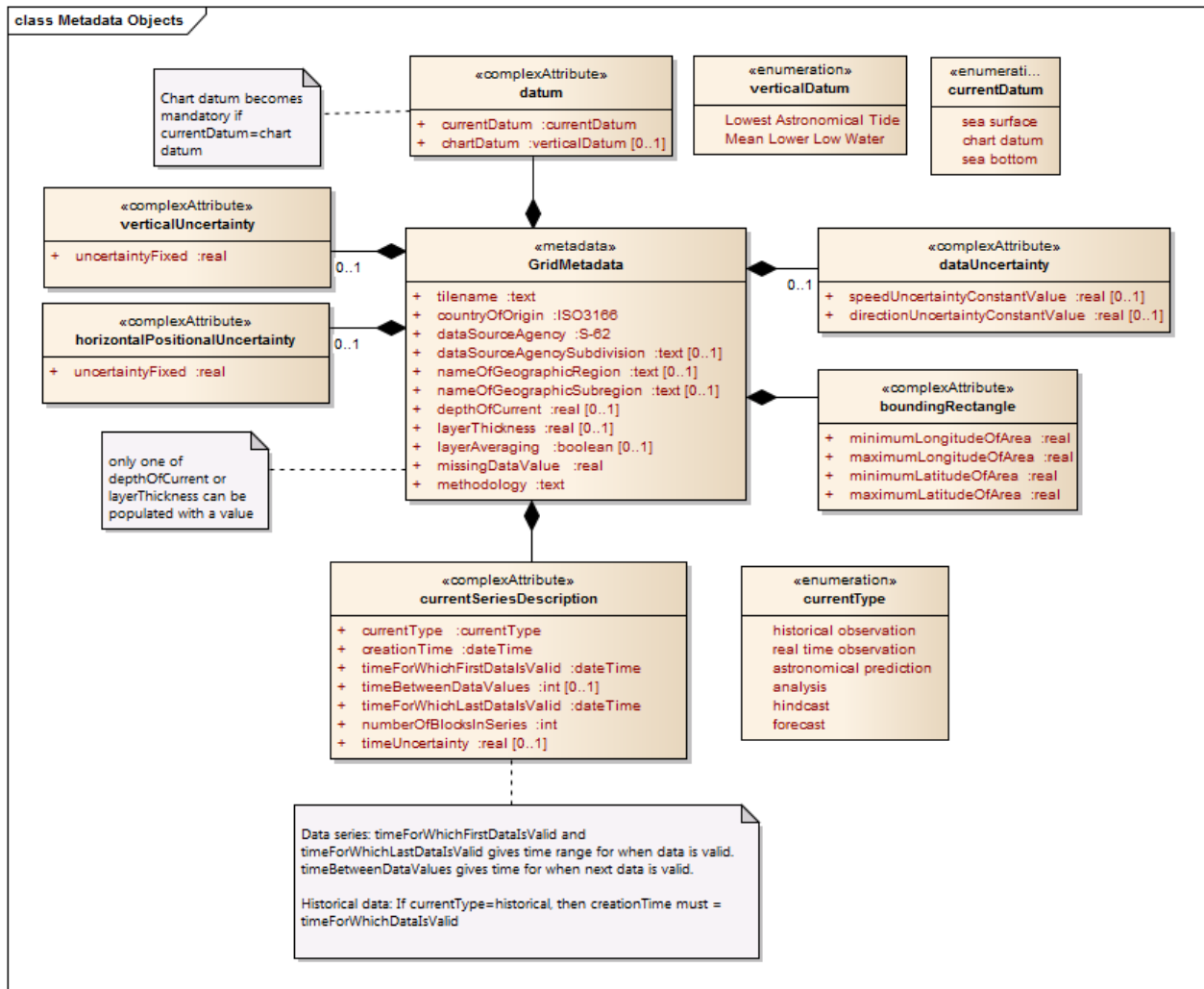


Figure B.3 – Surface Current Metadata.

The exchange set structure of Surface Current data is described in Figure B.4.

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

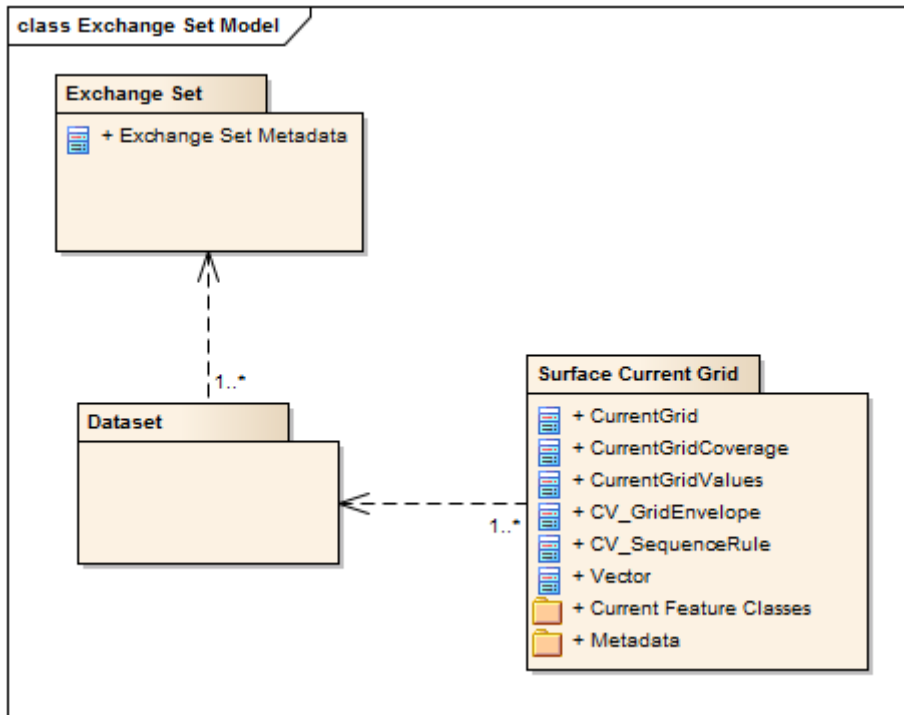


Figure B.4 – Surface Current Exchange Set Model.

ANNEX C. DATA CLASSIFICATION AND ENCODING GUIDE

C.1. Features

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-100_PointSet			
S-111 Attribute	Allowable Encoding Value	Type	Multiplicity
Surface Current Speed	must be in decimal Knots, max resolution 0.01 knot	RE	1
Surface Current Direction	must be in decimal degrees, max resolution 0.1 degree	RE	1

C.2. Feature Attributes

1. Surface Current Speed (*surfaceCurrentSpeed*)

Surface Current Speed: IHO Definition: SPEED. Rate of motion. The terms speed and VELOCITY are often used interchangeably, but speed is a scalar, having magnitude only, while VELOCITY is a vector quantity, having both magnitude and direction. Speed may either be the ship's speed through water, or the SPEED MADE GOOD over ground.
Unit: knot (kn)
Resolution: 0.01 kn
Format: xxx.xx
Examples: 2.54
Remarks:

- Valid speed always non-negative
- Negative number denotes land mask
- 0.01 kn equals 0.5144 cm/s

2. Surface Current Direction (*surfaceCurrentDirection*)

Surface Current Direction: IHO Definition: DIRECTION OF CURRENT. The direction toward which a CURRENT is flowing, called the SET of the CURRENT. Also called current direction
Unit: degree (of arc) (°)
Resolution: 0.1 °
Format: xxx.x
Examples: 298.3
Remarks:

- direction clockwise from true north
- Valid direction always non-negative
- Negative number denotes land mask

C.3.Metadata

IHO Definition: METADATA **QUALITY OF SURFACE CURRENT DATA.** An area within which a uniform assessment of the quality of the surface current data exists.

S-111 Metadata Feature: Quality of Surface Current Data

Primitives: Surface

S-111 Attribute	S-57 Acronym	Allowable Encoding	Type	Multiplicity
Surface current speed uncertainty			RE	0,1
Surface current direction uncertainty			RE	0,1
Horizontal positional uncertainty	(POSACC)		RE	1,1
Vertical positional uncertainty	(VERACC)		RE	0,1
Time uncertainty		ISO 8601:2004	T	0,1

C.4.Metadata Attributes

1.Surface Current Speed Uncertainty (*dataUncertainty*)

Surface Current Speed Uncertainty: IHO Definition:

Unit: knot (kn)

Resolution: 0.01 kn

Format: xx.xx

Examples: 0.05

Remarks:

- Uncertainty interval is always positive

2.Surface Current Direction Uncertainty (*dataUncertainty*)

Surface Current Direction Uncertainty: IHO Definition:

Unit: degree (of arc) (°)

Resolution: 0.1 °

Format: xxx.x

Examples: 9.5

Remarks:

- Uncertainty interval is always positive

3.Horizontal Positional Uncertainty (*horizontalPositionalUncertainty*)

Horizontal Positional Uncertainty

Unit: metre

Resolution: 0.1 m

Format: xxxxx.x

Example: 120.2

Remarks:

4. Vertical Positional Uncertainty (*verticalUncertainty*)

Vertical Positional Uncertainty

Unit: metre

Resolution: 0.1

Format: xxx.x

Example: 1.2

5. Time Uncertainty

Time Uncertainty

Unit: minute

Resolution: 0.1

Format: xxx.x

Example: 1.0

Remarks:

ANNEX D. TESTS OF COMPLETENESS (NORMATIVE)

D.1 Coverage Consistency

D.1.1 Test case for coverage geometry

Test purpose: Verify that the coverage geometry corresponds to the conformance class

Conformance class Gridded coverage

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

D.1.2 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, or null 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 the grid coverage (all the rows and columns) is provided.

Test type: Basic

D.1.3 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

D.2 Logical Consistency

Check that grid extent defined in the metadata is consistent with grid spacing and number of points. Check that the number of null values in the speed grid equals the number in the direction grid.

D.2.1 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).

D.2.2 Domain Consistency

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

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 . This would be validated by means of test software

Test type: Basic

D.2.3 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.

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

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

D.2.4 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.

ANNEX E. PORTRAYAL CATALOGUE

<XML code>

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, surface current data categorized as one of three types, depending on the source of production. These are:

- Historical and real-time observation,
- Astronomical prediction, and
- Model-based forecast or 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 fixed point (current meter), a moving point (Lagrangian drifter), along a vertical or horizontal line (Doppler profiler), or an area (coastal radar). A real-time (or near-real-time) observation is actually a historical observation but for the very 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 forecasts or 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 by the HO producer 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. Time Series 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 containing surface current observations at 6-minute intervals. The native format is ASCII text (other options were available). Data courtesy of the Center for Operational Oceanographic Products and Services, US.

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.2a).

```
[Metadata 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
```

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

The data in Figure F.2a can be rearranged so that all the speeds and all the directions appear in a sequence, as in Figure F2b.

```
[Metadata block for station # 1]
Value of Time 1: 2014-12-01 00:00:00
Speed = 1.08, 1.00, 0.83
Direction = 215, 225, 226
```

Figure F.2b - Reformatted time series 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.

Many spatial grids are regular (i.e., having uniform spacing in each direction) and geodetic (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 the product specification uses a land mask value (e.g., -99.999), which is substituted for a gridded value which is on land, 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': '51.9799985516071 '
  '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 metadata).

Current data produced on irregular grids or on unstructured grids, or for surface drifters, 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 either time of high water at a reference tidal water level station or time of maximum flood current at a reference station. Often the speed and direction are given for both neap and spring tide conditions (Table F.1).

Data in the atlas format, when used with daily predictions of tidal water levels or currents at a reference station, can be converted into time series data (see Figure F.2b), and thus into the S-111 format. This conversion is to the responsibility of the HO.

Table F.1 – Example of digital tidal data for a station off the French coast. Speed and direction vary by hour relative to high water at a reference station, and by tide range. Data courtesy of Service Hydrographique et Océanographique de la Marine, France.

Hour	Speed (ms ⁻¹)		Direction (deg)	
	Neap	Spring	Neap	Spring
-6	0.924	0.991	234.0	232.8
-5	0.991	1.047	235.4	233.5
-4	1.015	1.104	233.1	234.8
-3	0.939	1.132	233.4	233.0
-2	0.447	0.947	233.7	233.3
-1	0.302	0.061	232.8	200.1
0	0.444	0.292	232.5	56.0
1	0.562	0.044	232.5	68.2
2	0.596	0.469	232.4	231.2
3	0.620	0.662	232.5	231.3
4	0.705	0.779	232.7	231.6
5	0.797	0.886	233.0	232.1
6	0.876	0.967	233.5	232.6

F.4. Lagrangian Drifter Data

Lagrangian drifters float along with the currents and represent the motion at some depth depending on the specific design. The data are often available, in the raw form, as a list with locations and (usually non-equally-spaced) times (Figure F.5). The data are often telemetered from the drifter to a collection station.

```
OBJECTID,ARID,YR,MON,DD,HH,MM,SS,LAT,LON,ACC
127134,52299,2005,9,25,7,18,16,15.57400000000,142.82200000000,2
127135,52299,2005,9,25,8,58,0,15.57400000000,142.80000000000,2
127136,52299,2005,9,25,18,47,37,15.54300000000,142.72100000000,2
127137,52299,2005,9,25,19,47,45,15.54100000000,142.71100000000,2
127138,52299,2005,9,25,21,27,29,15.53300000000,142.69200000000,2
127139,52299,2005,9,26,6,55,6,15.49900000000,142.65500000000,1
127140,52299,2005,9,26,8,34,6,15.48600000000,142.64400000000,2
127141,52299,2005,9,26,18,35,27,15.43800000000,142.59300000000,1
127142,52299,2005,9,26,19,23,51,15.43300000000,142.59000000000,2
```

Figure F.5 - Portion of an Argos System CLS file describing the positions and times of a specific Lagrangian drifter.

In the raw form, the data must be converted into speed and directions. This can be accomplished by cubic spline interpolation of the longitudes and latitudes separately, then dividing the difference in position by the differences in time. The data can be converted into time series data (see Figure F.2b), and thus into the S-111 format.

F.5 Common Data Product Format

The two forms (Figures F.2b and F.4) are similar, the main difference being that the multiple values for each variable in Figure F.4 correspond to multiple grid points, rather than the multiple times in Figure F.2b (at a single station). Thus the two forms can be combined into a single form (Figure F.6, although the data are interpreted differently).

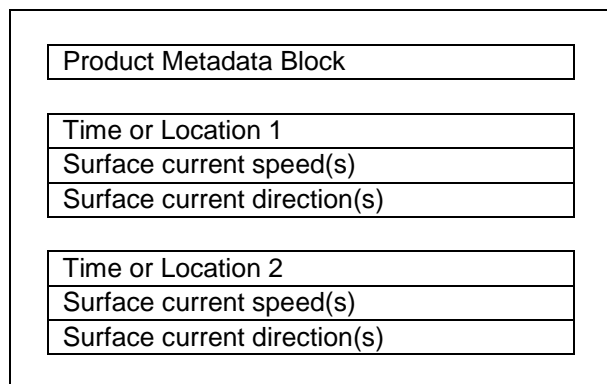


Figure F.6 – Schematic of the product data set. The product can represent either a time series at a number of stations or gridded data.

F.6 Additional Features of the Data

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

F.6.1 Vertical Reference Datums

The vertical location of the current in the water column is normally referenced to some vertical datum. In this Product Specification, the datum is selectable: it can be the sea surface, the sea bottom, or any of 30 standard tidal datums. The coordinate system axis is directed upward, so if the level of the current is below the datum, the depth will have a negative value. Levels referenced above the sea bottom will have a positive value. For a layer average, the thickness of the layer is specified as a positive value. <or possibly at mid-depth, as a negative value>

In principle, it is possible to transform elevations between the different datums. The separation between a standard tidal datum and the sea surface varies with time, and can be obtained by a prediction of the water level at the location of the current. In the case of a hydrodynamic model for currents, the model itself usually includes a water level prediction. The separation between the sea bottom and the standard tidal datum is often contained automatically in bathymetric data that is reference to a chart datum. If chart datum and the selected currents datum are different, an estimation of the difference in elevation is required.

F.6.2 Uncertainty

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. For practical purposes, the confidence level is 95% and the uncertainty is defined herein as 1.96 times the standard deviation of the differences between observed and predicted values (cf. S-44. *IHO Standards for Hydrographic Surveys*, 5th Edition February 2008). For multiple sources of uncertainty, the total propagated uncertainty is the relevant value.

For example, the comparison between a predicted speed and the observed speed is normally based on an analysis using the time series for each. The standard deviation of the speed differences at each point in the series can be computed by the common formula. The calculation is similar for direction. It should be noted that for model-based predictions, uncertainty usually increases with the projection into the future.

Uncertainty for location is somewhat different. Horizontal locations of fixed or drifting observing stations are determined by surveying or GPS. The inherent uncertainties in these types of measurements are normally documented. For gridded hydrodynamic model data, uncertainties are based on the precision of the grid parameters (origin and spacing) and, if used, on any transformation from Cartesian (flat plane) position to geographic location. For coastal radar, uncertainty in position may be estimated by the local geometry and radar's accuracy in computing distances and angles.

Vertical locations of fixed or drifting observing stations are determined by surveying or GPS, and by configuration geometry. For gridded hydrodynamic model data, uncertainties are determined

in a manner similar to the horizontal positions, but with consideration for uncertainties in instantaneous sea surface height, actual water depth, and vertical (if used).

Uncertainties in time are based on instrumentation and GPS parameters, record keeping, and computer/processing accuracy.

ANNEX G. HDF-5 ENCODING

G.1 Introduction

The Hierarchical Data Format 5 (HDF5) has been developed by the HDF Group as a file format for the transfer of data that is used for imagery and gridded data. This Annex specifies an interchange format to facilitate the moving of files containing data records between computer systems. It defines a specific structure which can be used to transmit files containing data type and data structures specific to S-100.

For S-111 purposes, an HDF5 file is structured to consist of Groups and sub-Groups, each of which may consist of Attributes and Datasets. Datasets are designed to hold large amounts of numerical data and may be used to hold the speed and direction data. Attributes are designed to hold single-valued information which apply to Groups and may be used to hold the metadata, although Datasets could also be used to hold the metadata.

It should be noted that not all S-100 data formats are readily available in HDF5. Predefined HDF5 formats include Integer, Float (cf. Real in S-100), Character (cf. CharacterString in S-100), and Enumeration but not Boolean, Date, Time, or DateTime formats. In S-111, Integer shall be used for Boolean variables, and Character shall be used for the date and time variables.

The general structure of the data product (Figure 10.1) may be expressed as an organized HDF5 file as shown in Table G.1. The root directory contains the metadata as Attributes, and each Group contains the speed and direction of the currents.

Table G.1 - HDF5 encoding scheme for Surface Currents. The total number of groups with speed and direction data is *numGRP*. Group XY appears only when *dataCodingFormat* is 1, 3 or 4.

Group	HDF5 Category	Data Type	Data Space
'/' (root)	Attributes. See Table 10.3	Integer, Float, Enumeration, or Character	-
'/Group XY'	Dataset: X	Float	Vector (1-d): n=1, <i>numPOS</i>
	Dataset: Y	Float	Vector (1-d): n=1, <i>numPOS</i>
'/Group 1'	Attribute: Title	Character	
	Attribute: Date-Time	Character	
	Dataset: Speed	Float	Vector (2-d): i=1, <i>numCOL</i> , j=1, <i>numROW</i>
	Dataset: Direction	Float	Vector (2-d): i=1, <i>numCOL</i> , j=1, <i>numROW</i>
'/Group 2'	Attribute: Title	Character	
	Attribute: Date-Time	Character	
	Dataset: Speed	Float	Vector (2-d): i=1, <i>numCOL</i> , j=1, <i>numROW</i>
	Dataset: Direction	Float	Vector (2-d): i=1, <i>numCOL</i> , j=1, <i>numROW</i>
'/Group <i>numGRP</i> '	Attribute: Title	Character	
	Attribute: Date-Time	Character	
	Dataset: Speed	Float	Vector (2-d): i=1, <i>numCOL</i> , j=1, <i>numROW</i>
	Dataset: Direction	Float	Vector (2-d): i=1, <i>numCOL</i> , j=1, <i>numROW</i>

G.2 Product Metadata

The metadata is contained in the root directory in Table G.1. Data are based on Table 10.3, but may have been modified to conform to HDF5 coding.

G.3 Datasets

Depending on the data format, there can be an initial group of longitudes and latitudes, Group XY. This group contains two datasets, X (longitude) and Y (latitude). The number of values is *numPOS*. This group appears for values of *dataCodingFormat* of 1, 3, and 4.

For each individual Group, there are two datasets: a set of speed values and a set of direction values. The number of individual values in the speed and direction arrays is given by the parameter *numVAL*. The number of individual Groups is given by the metadata variable, *numGRP*. The time interval between individual times is given by the metadata variable *timeRecordInterval*.

Values which represent different times are stored sequentially, from oldest to newest. The initial date value is contained in the Character format mimicking the DT format: *yyyymmddThhmmssZ*. By knowing the time interval (seconds) between each record, the time applicable to each value can be computed. In addition, the Groups, if they represent different times, are also arranged sequentially, from oldest to newest.

The speed values are contained in a Float array of length equal to *numVAL*. Each number representing speed (knots) has two digits to the right of the decimal point, and to the left of the decimal point, either a one- or two-digit number representing a valid speed, or a negative one denoting a null value or land location. Table G.2 shows a sample dataset.

Table G.2 – Sample speed dataset, where a negative one ('-1.00') denotes a null value or land location.

-1.00	-1.00	2.34	5.67	8.99	12.34	9.87
-------	-------	------	------	------	-------	------

The direction values are contained in a Float array of length equal to *numVAL*. Each number representing direction (degrees, clockwise from true north) has one digit to the right of the decimal point, and to the left of the decimal point, either a one-, two-, or three-digit number representing a valid direction, or a negative one ('-1') denoting a null value or land location. Table G.3 shows a sample dataset.

Table G.3 – Sample direction dataset where a negative one ('-1.0') denotes a null value or land location.

-1.0	-1.0	345.1	356.2	4.3	8.9	12.3
------	------	-------	-------	-----	-----	------

G.4 Samples of Time Series Files

The following are examples of HDF5 files data from four current stations (*dataCodingFormat* = 1).. Files were produced by Matlab®.

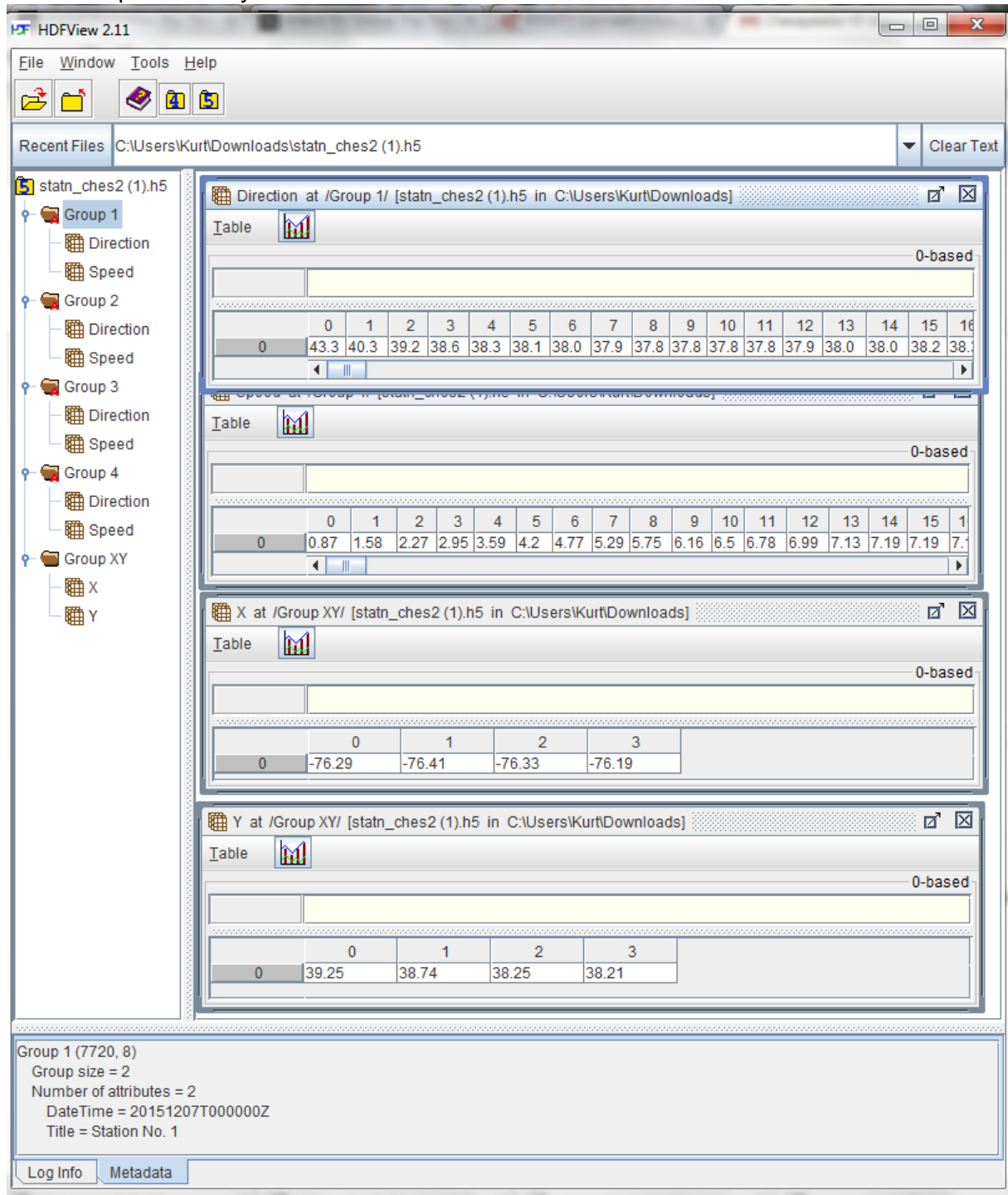


Figure G.1 – Display of a sample file (using HDFView) containing speed and direction data at four stations, along with the longitudes and latitudes of the stations (*dataCodingFormat* = 1).

Group '/'

Attributes:

'nationalOriginator': 'US'
'producingAgency': 'CO-OPS_harmonics'
'productSpecification': 'S-111_version_1.0.0'
'dateOfIssue': '20160119'
'editionNumber': 1
'updateApplicationDate': '20160119'
'updateNumber': 1
'fileName': 'USastroTS20150903.h5'
'dataType': 'IHO_HDF5'
'nameRegion': 'US_east_coast'
'nameSubregion': 'Chesapeake_Bay'
'horizDatumRef': 'ESPG'
'horizDatumValue': 4326
'westBoundLongitude': -76.410000
'eastBoundLongitude': -76.190000
'southBoundLatitude': 38.210000
'northBoundLatitude': 39.250000
'dateOfFirstRecord': '20160120T000000Z'
'dateOfLastRecord': '20160121T000000Z'
'timeRecordInterval': 720
'numberOfTimes': 121
'typeOfCurrentData': 3
'dataCodingFormat': 1
'numberOfStations': 4
'methodOrSource': 'harmonic_constant_pred'
'depthTypeIndex': 2
'surfaceCurrentDepth': 0.000000
'verticalDatum': 0
'gridOriginLongitude': -76.410000
'gridOriginLatitude': 38.210000
'gridSpacingLongitudinal': 0.000000
'gridSpacingLatitudinal': 0.000000
'numGridPointsLongitudinal': 1
'numGridPointsLatitudinal': 1
'minimumGridPointLongitudinal': 1
'minimumGridPointLatitudinal': 1
'numberOfNodes': 0
'gridLandMaskValue': -1.000000
'uncertaintyOfSpeed': -1.000000
'uncertaintyOfDirection': -1.000000
'uncertaintyOfHorizPosition': -1.000000
'uncertaintyOfVertPosition': -1.000000
'uncertaintyOfTime': -1.000000

Group '/Group 1'

Attributes:

'Title': 'Station No. 1'
'DateTime': '20160120T000000Z'

Dataset 'Direction'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Dataset 'Speed'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []

Filters: none
FillValue: 0.000000

Group '/Group 2'

Attributes:

'Title': 'Station No. 2'
'DateTime': '20160120T000000Z'

Dataset 'Direction'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Dataset 'Speed'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Group '/Group 3'

Attributes:

'Title': 'Station No. 3'
'DateTime': '20160120T000000Z'

Dataset 'Direction'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Dataset 'Speed'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Group '/Group 4'

Attributes:

'Title': 'Station No. 4'
'DateTime': '20160120T000000Z'

Dataset 'Direction'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Dataset 'Speed'

Size: 121x1
MaxSize: 121x1
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Group '/Group XY'

Dataset 'X'

Size: 4x1
MaxSize: 4x1
Datatype: H5T_IEEE_F64LE (double)

```
ChunkSize: []  
Filters: none  
FillValue: 0.00000  
Dataset 'Y'  
Size: 4x1  
MaxSize: 4x1  
Datatype: H5T_IEEE_F64LE (double)  
ChunkSize: []  
Filters: none  
FillValue: 0.000000
```

Figure G.2 - Sample output for a regularly-gridded data set,
created using the software package Matlab®.

G.5 Samples of Regularly Gridded Data Files

The following shows examples of HDF5 files for regularly-gridded data from a forecast model (*dataCodingFormat* = 2). Files were produced by Matlab®. Data courtesy of Center for Operational Oceanographic Products and Services, US.

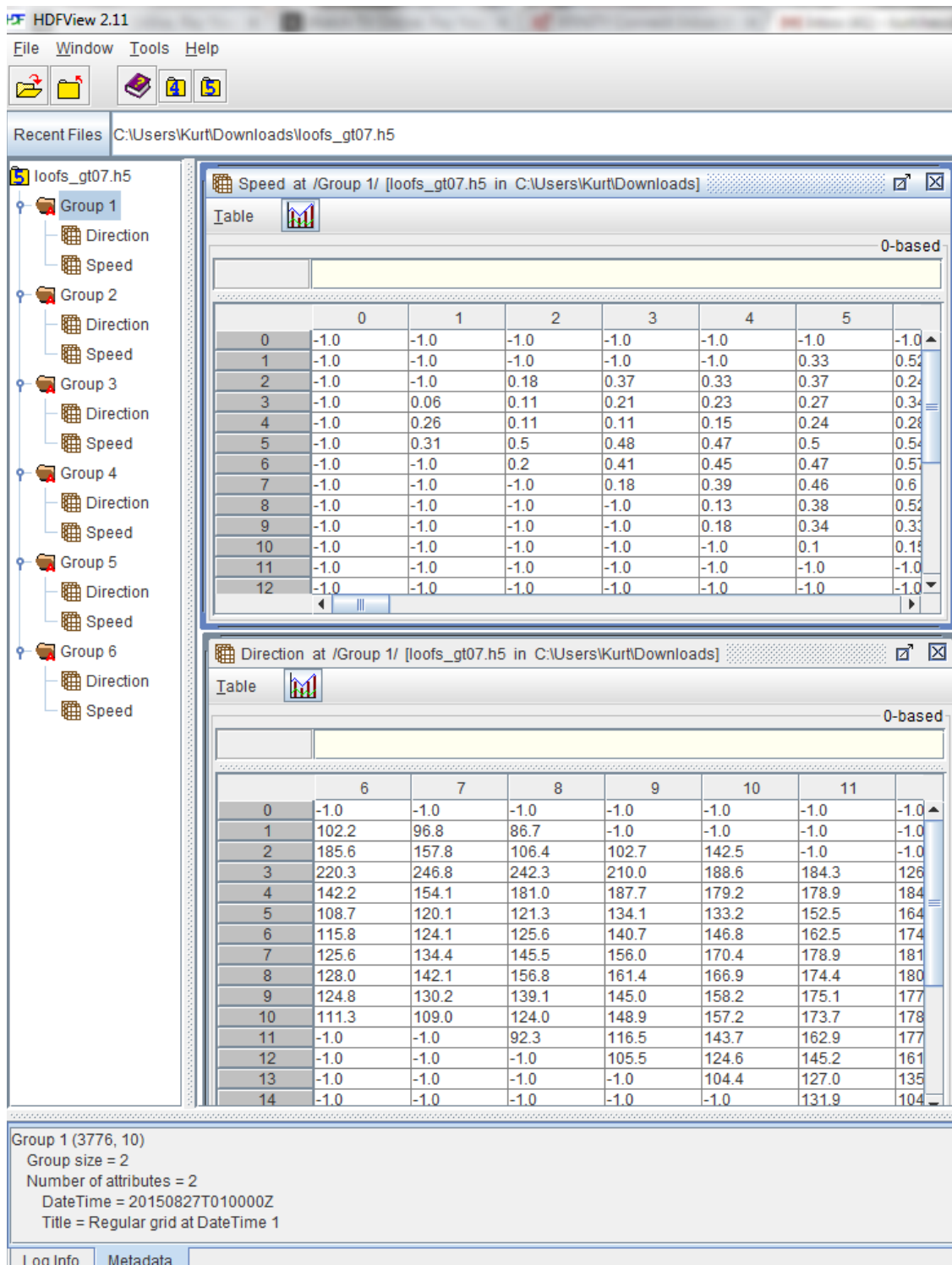


Figure G.3 – HDFView display of the overall file structure for gridded data (*dataCodingFormat* = 2).

Group '/'

Attributes:

'nationalOriginator': 'US'
'producingAgency': 'CO-OPS_Great_Lakes_FCST'
'productSpecification': 'S-111_version_1.0.0'
'dateOfIssue': '20160114'
'editionNumber': 1
'updateApplicationDate': '20160114'
'updateNumber': 1
'fileName': 'USloofsGR20150903.h5'
'dataType': 'IHO_HDF5'
'nameRegion': 'Great_Lakes'
'nameSubregion': 'Ontario'
'horizDatumReference': 'ESPG'
'horizDatumValue': 4326
'westBoundLongitude': -79.788500
'eastBoundLongitude': -76.066500
'southBoundLatitude': 43.143540
'northBoundLatitude': 44.221340
'dateTimeOfFirstRecord': '20150827T010000Z'
'dateTimeOfLastRecord': '20150827T060000Z'
'timeRecordInterval': 3600
'numberOfTimes': 6
'typeOfCurrentData': 6
'dataCodingFormat': 2
'numberOfStations': 0
'methodOrSource': 'lakes_forecast_model'
'depthTypeIndex': 2
'surfaceCurrentDepth': 0.000000
'verticalDatum': 0
'gridOriginLongitude': -79.788500
'gridOriginLatitude': 43.143540
'gridSpacingLongitudinal': 0.061400
'gridSpacingLatitudinal': 0.044990
'numPointsLongitudinal': 61
'numPointsLatitudinal': 25
'minimumGridPointLongitudinal': 1
'minimumGridPointLatitudinal': 1
'numberOfNodes': 0
'gridLandMaskValue': -1.000000
'uncertaintyOfSpeed': -1.000000
'uncertaintyOfDirection': -1.000000
'uncertaintyOfHorizontalPosition': -1.000000
'uncertaintyOfVerticalPosition': -1.000000
'uncertaintyOfTime': -1.000000

Group '/Group 1'

Attributes:

'Title': 'Regular grid at DateTime 1'
'DateTime': '20150827T010000Z'

Dataset 'Direction'

Size: 61x25
MaxSize: 61x25
Datatype: H5T_IEEE_F32LE (single)
ChunkSize: []
Filters: none
FillValue: 0.000000

Dataset 'Speed'

Size: 61x25
MaxSize: 61x25
Datatype: H5T_IEEE_F32LE (single)

```
ChunkSize: []
Filters: none
FillValue: 0.000000

Group '/Group 2'
Attributes:
  'Title': 'Regular grid at DateTime 2'
  'DateTime': '20150827T020000Z'
Dataset 'Direction'
  Size: 61x25
  MaxSize: 61x25
  Datatype: H5T_IEEE_F32LE (single)
  ChunkSize: []
  Filters: none
  FillValue: 0.000000
Dataset 'Speed'
  Size: 61x25
  MaxSize: 61x25
  Datatype: H5T_IEEE_F32LE (single)
  ChunkSize: []
  Filters: none
  FillValue: 0.000000
```

Figure G.4 – Sample output for a regularly-gridded data set, made using the software package Matlab®.