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FOR HYDROGRAPHIC DATA

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Surface Current Product Specification

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Surface Current Product Specification
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</tr>
</tbody>
</table>
### 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 .................................................................................................................. 8
   1.5 GENERAL S-111 DATA PRODUCT DESCRIPTION ............................................................... 8
   1.6 DATA PRODUCT SPECIFICATION METADATA AND MAINTENANCE ................... 8
      1.6.1 Product Specification Metadata ...................................................................................... 8
      1.6.2 HO Product Specification Maintenance ......................................................................... 9

2. SPECIFICATION SCOPES ........................................................................................................... 10
3. DATASET IDENTIFICATION ........................................................................................................ 10
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 .................................................................................................................. 12
      4.3.3 Feature Relationship ....................................................................................................... 12
      4.3.4 Information Types ........................................................................................................... 12
      4.3.5 Spatial Quality ................................................................................................................. 12
      4.3.6 Attributes ....................................................................................................................... 13
   4.4 SPATIAL SCHEMA .................................................................................................................. 13
      4.4.1 Regular Grids .................................................................................................................... 14
      4.4.2 Points ............................................................................................................................... 16
      4.4.3 Summary .......................................................................................................................... 16

5. COORDINATE REFERENCE SYSTEMS (CRS) ........................................................................ 17
   5.1 HORIZONTAL REFERENCE SYSTEM .................................................................................. 17
   5.2 VERTICAL REFERENCE SYSTEM ....................................................................................... 18
   5.3 TEMPORAL REFERENCE SYSTEM ....................................................................................... 18

6. DATA QUALITY ........................................................................................................................... 18
   6.1 ASSESSMENT OF DATA ......................................................................................................... 18
   6.2 ADDITIONAL COMPONENTS ............................................................................................... 19

7. DATA CAPTURE AND CLASSIFICATION ............................................................................... 20
   7.1 DATA SOURCES .................................................................................................................... 20
   7.2 THE PRODUCTION PROCESS .............................................................................................. 20
      7.2.1 Metadata ........................................................................................................................ 21
      7.2.2 Surface Current Data ....................................................................................................... 22
      7.2.3 Digital Tidal Atlas Data .................................................................................................. 22

8. MAINTENANCE ........................................................................................................................... 22
   8.1 MAINTENANCE AND UPDATE FREQUENCY ..................................................................... 22
   8.2 DATA SOURCE ....................................................................................................................... 23
   8.3 PRODUCTION PROCESS ........................................................................................................ 23

9. PORTRAYAL .................................................................................................................................. 23
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 (PS) is a precise technical description that defines the requirements for a geospatial data product and forms the basis for producing or acquiring data. This PS, S-111, conforms to S-100.

The S-111 PS describes the feature Surface Current and its two attributes Surface Current Speed and Surface Current Direction (ANNEX A - DATA CLASSIFICATION AND ENCODING GUIDE), and the relationships of surface currents and their mapping to a dataset. The Surface Current represents the water velocity at one or more geographic locations at either (a) a given depth relative to a named vertical datum, or (b) an average from the surface down to a given depth. The current values are obtained through in situ or remote measurement or by analytic methods or hydrodynamic modeling. The PS 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 containing Surface Current data describes a set of values distributed over an area. The structure containing the values is either a Grid Coverage or a Point Coverage.

- Gridded data 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. An essential characteristic of a regular grid is that the geographic position of any node can be computed from the values of the origin and point spacing. A coverage includes a function which provides values at geographic locations within the extent of the grid. A continuous function provides values at all locations, while a discrete function, which is used for Surface Currents, provides values at only specific points (e.g., grid nodes).

- Another type of structure is a Point Coverage, which also contains metadata and attribute values, although the locations of the points are not organized into a regular grid. The location of all points must be explicitly specified. There is no coverage function.
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 many types of data and forms the basis of the Network Common Data Form (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 product and for its portrayal within an S-100 electronic charting environment. This product specification includes the content model, the encoding, the feature catalogue and metadata. The surface current product may be used either alone or combined with other S-100 compatible data.
1.3 References

1.3.1 Normative

S-100. IHO Universal Hydrographic Data Model, ver. 4.0.0. (September 2018).
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

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 B). Terms that are defined in this clause or in ANNEX B 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]

data quality

a set of elements describing aspects of quality, including a measure of quality, an evaluation procedure, a quality result, and a scope

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]

georeferenced grid
grid for which cells can be located geographically by the use of specific algorithms or additional data.

grid
network composed of a set of elements, or cells, whose vertices, or nodes, have defined positions within a coordinate system. See also georeferenced grid, regular grid, rectangular grid, ungeorectified grid, node, and grid point.
[ISO 19123]

grid cell
element of a grid defined by its vertices, or nodes

grid point
point located at the intersection of two or more grid cells in a grid. Also called a node.
[ISO 19123]

layer-averaged surface current
the water current averaged over the vertical, from the surface to a specified depth below the sea surface.
EXAMPLE: the current averaged from 0 metres (sea surface) down to 10 metres.

node
a point located at the vertex of a grid cell. Also called a grid point.

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]

rectangular grid
an orthogonal grid whose cells are rectangles.
regular grid
a georeferenced rectangular 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.

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, or the vertical average over a 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 surface current flows. Units are arc-degrees.
   [CO-OPS 2000]
   NOTE: measured clockwise from true north. AKA set.

surface current speed
the speed (rate of change of position over time) of a surface current. Units are knots.

tessellation
partitioning of a space into a set of conterminous geometric objects having the same dimension as the space being partitioned [ISO 19123] NOTE A tessellation composed of congruent regular polygons or polyhedra is a regular tessellation; One composed of regular, but non-congruent polygons or polyhedra is semi-regular. Otherwise the tessellation is irregular.

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).

ungeorectified grid
grid with non-uniform point spacing in any coordinate system. Includes triangular and curvilinear coordinate grids whose node positions cannot be calculated from the positions of other nodes.
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**: 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**: 4.0.0

**S-111 Version**: 1.0.0

**Date**: 2018-9-15

**Language**: English

**Classification**: Unclassified

**Contact**:

International Hydrographic Bureau, 4 quai Antoine 1er,
1.6.2 HO 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
Revisions denoted as n.n
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. Measures of the quality of position, speed, direction, and time data are included.

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).
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.

4.2 Application Schema

This application schema shall be expressed in UML. The details of the Application Schema are given in ANNEX C.

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. See ANNEX D – FEATURE CATALOGUE.

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.
### 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.

### 4.3.5 Spatial Quality

Spatial quality attributes (Figure 4.1) are carried in an information class called **spatial quality**.

![Figure 4.1 - Spatial Quality Information Type](image)

Figure 4.1 - Spatial Quality Information Type. Note that ‘horizontalUncertainty’ has been replaced by the preferred ‘horizontalPositionUncertainty’.
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, so spatial quality applies to these locations.

### 4.3.6 Attributes

S-100 defines attributes as either simple or complex. S-111 uses eight types of simple attributes; they are listed in Table 4.1. There are no complex attributes. A compound attribute is an array containing multiple simple, and possibly dissimilar, attribute types.

#### Table 4.1 - Simple feature attribute types.

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enumeration</td>
<td>A fixed list of valid identifiers of named literal values</td>
</tr>
<tr>
<td>Boolean</td>
<td>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.</td>
</tr>
<tr>
<td>Real</td>
<td>A signed Real (floating point) number consisting of a mantissa and an exponent</td>
</tr>
<tr>
<td>Integer</td>
<td>A signed integer number. The representation of an integer is encapsulation and usage dependent.</td>
</tr>
<tr>
<td>CharacterString</td>
<td>An arbitrary-length sequence of characters including accents and special characters from a repertoire of one of the adopted character sets</td>
</tr>
<tr>
<td>Date</td>
<td>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)</td>
</tr>
<tr>
<td>Time</td>
<td>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</td>
</tr>
<tr>
<td>Date and Time</td>
<td>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</td>
</tr>
</tbody>
</table>

#### 4.4 Spatial Schema

Surface current data are represented in two ways: arrays of points contained in a regular grid, and sets of points not described by a regular grid. Further details on the data product are given in Clause 10 – DATA PRODUCT FORMAT.

Surface current data has four basic types, based on their sources:

1. observed or predicted values at a number of stationary locations,
2. predicted values (often from hydrodynamic models) arranged in a regular grid,
3. values at multiple locations but not in a regular grid, and
4. observed values at a moving station (such as a surface drifter).

The four types of data have structures that can be described by two S-100 coverages: S100_Point Coverage and S100_Grid Coverage (S-100 v 4.0.0, Clause 8-7).

**Grid Coverage** The class S100_Grid Coverage represents a set of values assigned to the points in a two-dimensional grid. Attributes include interpolationType, dimension, axisNames, origin, coordinateReferenceSystem, offsetVectors, origin, extent, sequencingRule, startSequence, and rangeType.

**Point Coverage** The class S100_Point Coverage represents a set of values, such as speed and direction values, assigned to a set of arbitrary X,Y points. Each point is identified by a horizontal coordinate geometry pair (X,Y) and assigned one or more values as attribute values. These values are organized in a record for each point. Attributes include domainExtent, rangeType, metadata, commonPointRule, geometry, and value.

The types of data and their corresponding coverages are shown in Table 4.2.

<table>
<thead>
<tr>
<th>N</th>
<th>Type of Data</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Time series data at one or more stationary locations</td>
<td>S100_Point</td>
</tr>
<tr>
<td>2</td>
<td>Regularly-gridded data at one or more times</td>
<td>S100_Grid</td>
</tr>
<tr>
<td>3</td>
<td>Ungeorectified gridded data or point set data at one or more times</td>
<td>S100_Point</td>
</tr>
<tr>
<td>4</td>
<td>Time series data for one moving platform</td>
<td>S100_Point</td>
</tr>
</tbody>
</table>

**4.4.1 Regular Grids**

S-111 regular grid geometry is an implementation of S100_Grid Coverage (Part 8 – Imagery and Gridded Data). The spatial grids for the regular grid type are two dimensional, orthogonal, and georeferenced (with the X axis directed toward the east), and are defined by several attributes, including grid origin, spacing, and grid indexing. These parameters are explained in more detail below. A typical regular grid and some of its parameters are shown in Figure 4.2.

The attribute dimension is 2, and the variable interpolationType has the value of ‘discrete’, since there is no spatial interpolation used for surface currents.
Figure 4.2 – Schematic of the regular grid and some of its attributes. The *offsetVectors* are shown as the Latitudinal Spacing and Longitudinal Spacing. The *origin* is shown at the lower left corner of the grid.

The grid is oriented to the Earth by the Coordinate Reference System (CRS), with the variable *coordinateReferenceSystem*. The *origin* contains the latitude and longitude as a *DirectPosition* and is located at the lower left (southwest) extent of the grid.

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 (Latitudinal Spacing and Longitudinal Spacing). 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. The distances are given in degrees.

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 southwest (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.

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 *sequencingRule* 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 Points

The S-111 Point Coverage is quite flexible and is used herein to describe three broad categories of spatial data: one or more current stations at fixed locations, ungeorectified gridded data, and drifting platform data.

For this type of data (Figure 4.3), the axisNames are the same as for the regular grid. However, the origin is arbitrary, and the extent (cf. the bounding rectangle) may be defined by the minimum and maximum of the geographic positions of the stations. The total number of locations (tidal current stations, ungeorectified grid points, or drifter locations) must be specified. Also, attributes like spacing and scan direction have no meaning. The position of the locations is carried in the one-dimensional arrays X and Y.

![Figure 4.3](image)

Figure 4.3 – Schematic of the point coverage and some of its attributes. Stations, or nodes in an ungeorectified grid, appear as filled-in rectangles, are labeled and have a format such as ‘s1’.

4.4.3 Summary

The spatial schema information from the previous two sections is summarized in Table 4.3.
Table 4.3 – Attributes and their values for S100_Grid Coverage and S100_Point Coverage.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_Grid Coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dimension</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>origin</td>
<td>gridOriginLongitude, gridOriginLatitude</td>
<td>Values from Carrier Metadata</td>
</tr>
<tr>
<td>axisNames</td>
<td>'Longitude', 'Latitude'</td>
<td></td>
</tr>
<tr>
<td>offsetVectors</td>
<td>gridSpacingLongitudinal, gridSpacingLatitudinal</td>
<td>Values from Carrier Metadata</td>
</tr>
<tr>
<td>extent: low</td>
<td>'0, 0'</td>
<td></td>
</tr>
<tr>
<td>extent: high</td>
<td>'numROW-1, numCOL-1'</td>
<td>Values from Carrier Metadata</td>
</tr>
<tr>
<td>sequencingRule: type</td>
<td>'linear'</td>
<td></td>
</tr>
<tr>
<td>sequencingRule: startSequence</td>
<td>'0, 0'</td>
<td></td>
</tr>
<tr>
<td>commonPointRule</td>
<td>'average'</td>
<td></td>
</tr>
<tr>
<td>interpolationType</td>
<td>'discrete'</td>
<td>There is no spatial interpolation for surface currents</td>
</tr>
<tr>
<td>rangeType</td>
<td>name:data type</td>
<td>Pairs which describes an attribute type included in the range of the coverage: e.g., 'surfaceCurrentSpeed: real'</td>
</tr>
<tr>
<td>S100_Point Coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>domainExtent</td>
<td>EX_GeographicExtent (ISO 19115)</td>
<td>Envelope based on all longitudes and all latitudes.</td>
</tr>
<tr>
<td>axisNames</td>
<td>'Longitude', 'Latitude'</td>
<td></td>
</tr>
<tr>
<td>rangeType</td>
<td>name:data type</td>
<td>Pairs which describes an attribute type included in the range of the coverage</td>
</tr>
<tr>
<td>metadata</td>
<td>URI</td>
<td>Link to metadata</td>
</tr>
<tr>
<td>commonPointRule</td>
<td>'average'</td>
<td></td>
</tr>
<tr>
<td>geometry</td>
<td>GM_Point</td>
<td></td>
</tr>
<tr>
<td>value</td>
<td>Real number</td>
<td>Corresponds to speed and direction values</td>
</tr>
</tbody>
</table>

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.
5.2 Vertical Reference System

The vertical coordinate is directed upward (i.e., 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 vertical, sounding, or chart datum (MSL, LAT, etc.), or (c) the sea floor. Since these vertical datums can have significant spatial variation, there may be a comparable spatial variation in data quality. Any quality measure may represent a regional average or an extreme ‘worst case’ value.

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 variable will have the following 8-character format: yyyyymmdd. A time variable will have the following 7-character format: hhmmssZ. A date-time variable will have the following 16-character format: yyyyymmddThhmmssZ.

6. DATA QUALITY

6.1 Assessment of Data

Data quality allows users and user systems to assess fitness for use of the provided data. Data quality measures and the associated evaluation are reported as metadata of a data product. This metadata improves interoperability with other data products and provides usage by user groups that the data product was not originally intended for. The secondary users can make assessments of the data product usefulness in their application based on the reported data quality measures. The prescribed precision (see ANNEX A – DATA CLASSIFICATION AND ENCODING GUIDE) of current speed (0.01 kn) and direction (0.1 arc-deg) is close to the perceived accuracy of the data, but the increased precision is useful for time integration of current vectors and for the computation of spatial gradients (i.e., non-navigational uses).

Important factors in the quality of surface current data for navigation consists of the quality of

- the observed data,
- the predicted/forecast data,
- the positional data, and
- the time stamp.

Factors determining the accuracy of the data are shown in Table 6.1. Information of the quality of the components of the data is normally available in field survey reports, QC analyses, or other technical reports.

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Factors Influencing Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed Current</td>
<td>Accuracy of the sensors</td>
</tr>
<tr>
<td></td>
<td>Processing techniques</td>
</tr>
<tr>
<td>Predicted/forecast Current</td>
<td>Quality of input data</td>
</tr>
<tr>
<td></td>
<td>Timeliness of input data</td>
</tr>
<tr>
<td></td>
<td>Mathematical modelling techniques</td>
</tr>
<tr>
<td></td>
<td>Accuracy of harmonic constants</td>
</tr>
<tr>
<td>Horizontal Position</td>
<td>Accuracy of geolocation techniques</td>
</tr>
<tr>
<td></td>
<td>Model grid accuracy</td>
</tr>
<tr>
<td>Vertical Position</td>
<td>Accuracy of vertical datum</td>
</tr>
<tr>
<td>Time stamp</td>
<td>Sensor accuracy</td>
</tr>
<tr>
<td></td>
<td>Data time tagging accuracy</td>
</tr>
</tbody>
</table>

Data quality measures for the entire data set are included in Table 12.2. These include speedUncertainty, directionUncertainty, horizontalUncertainty, verticalUncertainty, and timeUncertainty.

### 6.2 Additional Components

Additional data quality measures include Completeness, Logical Consistency, Thematic Accuracy, Aggregation, and Usability.

Completeness consists of commission and omission of data. For surface current data in gridded form, there is likely to be an excess of data for a region. For observed or historical, there is likely to be a dearth of data. In each case, missing data or points over land are tagged with a unique value. 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 E - TESTS OF COMPLETENESS (NORMATIVE).

Logical Consistency ensures that the data are stored in a consistent manner: the HDF structure used to hold the data is was designed to enforce such consistency. In addition, the placement of current arrow symbols is consistent with the accepted coastline so that the centroid of the arrow is place within the water domain (see Figure 9.1), and if the water depth is zero, the symbol is not shown.

Thematic Accuracy insures that the values represented (speed and direction) are representative of the true situation. Measurement and modeling errors may put limits on these values.
Aggregation describes global quality values relate to a particular dataset. For surface currents, each dataset will be evaluated separately.

Usability will be continually assessed through user and manufacturer response to the symbols and analysis presented in the latest Product Specification.

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 a few specific sources: observations, astronomical predictions, analyses, and forecast models. When such data are produced and quality-controlled by an HO, they are suitable for inclusion in the Surface Current data product. See ANNEX F – SURFACE CURRENT DATA.

Observational Data Observational surface current data comes initially from \textit{in situ} sensors in the field (e.g. current meters or drifting platforms) 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. Other data may be days or years old, and are called historical data.

Astronomical Predictions 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. There may be a single set of constants to represent flood and ebb currents along a principal direction, or two sets of constants to represent the northward and eastward components of the current. 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 gridded field or a tidal atlas.

Analyzed and Hybrid Values Analyzed current values may be produced from sea-surface topography, data assimilation, statistical correlations, or other means. A hybrid method combines two or more approaches.

Hindcast and Forecast Data Hydrodynamic models numerically solve a set of fluid dynamic equations in two or three dimensions, and rely on observational data, including water levels and winds, to supply boundary conditions. Model grids may be either regular or ungeorectified. Such
models are often run several times per day, and in each run there is usually a hindcast and a forecast. The hindcast is a model simulation that attempts to recreate present conditions by using the most recent observational data, while a forecast is a simulation made for many hours into the future using predicted winds, water levels, etc. The results are saved for a limited number of times, and are stored as arrays that derive from the model’s grid. These models and methods are developed, run, and monitored by the HO.

These descriptions are summarized in Table 7.1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Historical observation</td>
<td>O</td>
<td>Observation made hours, days, etc., in the past</td>
</tr>
<tr>
<td>2</td>
<td>Real-time observation</td>
<td>R</td>
<td>Observation no more than a few minutes old</td>
</tr>
<tr>
<td>3</td>
<td>Astronomical prediction</td>
<td>A</td>
<td>Value computed using harmonic constants only</td>
</tr>
<tr>
<td>4</td>
<td>Analysis or hybrid method</td>
<td>Y</td>
<td>Calculation by statistical or other indirect methods, or a combination of methods</td>
</tr>
<tr>
<td>5</td>
<td>Hydrodynamic model hindcast</td>
<td>M</td>
<td>Gridded data from a two- or three-dimensional dynamic simulation of past conditions using only observed data for boundary forcing</td>
</tr>
<tr>
<td>6</td>
<td>Hydrodynamic model forecast</td>
<td>F</td>
<td>Gridded data from a two- or three-dimensional dynamic simulation of future conditions using predicted data for boundary forcing</td>
</tr>
</tbody>
</table>

### 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 (Clause 10). This means (a) populating the carrier metadata block (Clause 12.3) with the relevant data and (b) reorganizing the speed and direction data when using the encoding rules (see also ANNEX G – HDF5 ENCODING).

#### 7.2.1 Metadata

Metadata is derivable from the information available from the HO. Recall that the definition of uncertainty (Sec. 1.3.2) is based on the 95% confidence level. The following variables may require additional processing:

- The bounding rectangle is computable from either the distribution of stations or nodes, or from grid parameters
- Position uncertainties may be available from the HO’s metadata; otherwise they must be calculated
- Speed and direction uncertainties, if specified as a single value for the dataset, 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 must normally be reformatted to fit the S-111 standard. The following may require additional calculations:

- Current depth values for modeled data grid points and for observational data (such as for moored current meters) may be require re-referencing to a different vertical datum.
- For gridded data, 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 are not considered new editions, but new datasets. New editions may occur in predicted time series data.

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

<table>
<thead>
<tr>
<th>Data Types</th>
<th>Interval</th>
<th>Number Of Spatial Locations</th>
<th>Number Of Time Values Per Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmonic Constant Tidal Predictions</td>
<td>1 year</td>
<td>100 to 1,000</td>
<td>8,760 (hourly data)</td>
</tr>
<tr>
<td>Model Forecasts</td>
<td>6 hr</td>
<td>100,000 to 1,000,000</td>
<td>1 to 24</td>
</tr>
<tr>
<td>Real-time Observations</td>
<td>0.1 hr</td>
<td>1 to 10</td>
<td>1 to 240</td>
</tr>
<tr>
<td>HF Radar Observations</td>
<td>0.1 hr</td>
<td>10,000 to 100,000</td>
<td>1 to 24</td>
</tr>
</tbody>
</table>
NOTE: Because of the possibility of hourly release of new datasets, the ECDIS system must check on the availability of new data at a similar frequency.

8.2 Data Source
Data is produced by the HO by collecting observational values, predicting astronomical tides, or running analysis or hindcast/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 navigation, route planning and route monitoring. Two types of data are discussed in depth. They are:

- point data, which would apply to historical data, astronomical predictions, and real-time data at a small number of locations, and

- sets of multiple points, which would apply to analyses, coastal radar observations, and model-based hindcasts and forecasts. For multiple point data, the current vector portrayal characteristics used for single-point data can be adapted to displaying data at individual points.

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 multiple-point 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 each portrayal category (single point and multiple point) 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. **9.2.1 Arrow Shape**

The generalized arrow shape must be created using the input dimensions shown (Figure 9.1) and scaled according to the current speed and the display area. 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 arrow’s ‘pivot point’ is located on the arrow symbol along the vertical centreline and is at a distance from the bottom equal to one-half the quantity ‘al’. The pivot point is placed at the corresponding position (longitude and latitude) on the chart image.

The arrow must be drawn with a black border so that the symbol stands out against backgrounds of similar colours.

![Figure 9.1 – Standard arrow symbol for use in representing surface currents. The coordinates of the vertices (x, y) are shown in mm. The ‘+’ shows the location of the pivot point at (0.0, 0.0) and the y axis is pointing downward. Maximum height is 10 mm and maximum width is 4 mm.](image-url)

---

**Figure 9.2** – Examples of approved arrow-like shapes for use in ECDIS.
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.

9.2.2 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. True north has a direction of 0 degrees.

9.2.3 Arrow Colour and Speed Bands

The colour of the arrow must be based on the speed value of the data, and must have 9 bands corresponding to the speed ranges (Table 9.1). The range of speeds (Table 9.1) was selected to (a) emphasize differences at low speeds (0.0 to 3 kn), and (b) 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.

Table 9.1 – Speed ranges (knots) for the 9-band display.

<table>
<thead>
<tr>
<th>Speed Band</th>
<th>Minimum Speed (kn)</th>
<th>Width of Band (kn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>3.00</td>
<td>2.00</td>
</tr>
<tr>
<td>6</td>
<td>5.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>
Colours are associated with each speed band, and must be distinguishable in the three viewing environments: day, dusk, and night. Color values for day conditions are shown in Table 9.2. Colours for dusk and night conditions are given in ANNEX H – COLOUR TABLES. (The monitor gamma values need to be taken into account – refer to IHO standards).

<table>
<thead>
<tr>
<th>Speed Band</th>
<th>Colour</th>
<th>Colour Scale Intensity</th>
<th>Hex RBG</th>
<th>Displayed Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Red</td>
<td>Green</td>
<td>Blue</td>
</tr>
<tr>
<td>1</td>
<td>purple</td>
<td>118</td>
<td>82</td>
<td>226</td>
</tr>
<tr>
<td>2</td>
<td>dark blue</td>
<td>72</td>
<td>152</td>
<td>211</td>
</tr>
<tr>
<td>3</td>
<td>light blue</td>
<td>97</td>
<td>203</td>
<td>229</td>
</tr>
<tr>
<td>4</td>
<td>dark green</td>
<td>109</td>
<td>188</td>
<td>69</td>
</tr>
<tr>
<td>5</td>
<td>light green</td>
<td>180</td>
<td>220</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>yellow-green</td>
<td>205</td>
<td>193</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>orange</td>
<td>248</td>
<td>167</td>
<td>24</td>
</tr>
<tr>
<td>8</td>
<td>pink</td>
<td>247</td>
<td>162</td>
<td>157</td>
</tr>
<tr>
<td>9</td>
<td>red</td>
<td>255</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

### 9.2.4 Arrow Size

The arrow size (height and width) must be a function of the current speed, and for a given speed must be the same regardless of the source of the data. The standard arrow symbol (Figure 9.1) is scaled up or down in size, depending on the speed it is intended to represent.

Let \( S \) represent the value of the current speed. An upper limit on the size of the arrow is imposed by requiring the scaling input speed value not to exceed a reference high value, \( S_{\text{high}} \). The recommended value for \( S_{\text{high}} \) is the lower limit value in the highest group in Table 9.2, which is 13.0 kn. The value of \( S_{\text{high}} \) 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.

It is desirable to display a small arrow at a location where data is usually available (e.g., a grid point) but the speed is less than 0.01 kn. This can be accomplished by setting a minimum reference speed, \( S_{\text{low}} \), so that, as a result, a ‘point’ is displayed. When the speed \( S \) falls below \( S_{\text{low}} \), then \( S_{\text{low}} \) is substituted for \( S \).

A third parameter is the reference speed, \( S_{\text{ref}} \), at which the arrow symbol has a length equal to the scaling height parameter, \( H_{\text{ref}} \). Here \( S_{\text{ref}} \) is chosen to be 5 kn and \( H_{\text{ref}} \) is taken to be 10.0 mm. Let \( S \) be the current speed to be displayed. If \( S \) exceeds \( S_{\text{high}} \), then \( S_{\text{high}} \) 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 height, \( H \) (mm), computed by:
\[ H = H_{\text{ref}} \min(\max(S_{\text{low}}, S), S_{\text{high}})/S_{\text{ref}}. \]  

[Eqn. 9.1]

The arrow width is scaled in a similar fashion. A summary of recommended scaling values is given in Table 9.3.

Table 9.3 – Summary of recommended values for arrow display size (see Eqn. 9.1). With these values, an arrow representing 5 kn will have a length of 10 mm.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
<th>Recommended Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H_{\text{ref}})</td>
<td>Reference height for arrow scaling</td>
<td>10 mm</td>
</tr>
<tr>
<td>(S_{\text{ref}})</td>
<td>Reference speed for arrow scaling</td>
<td>5 kn</td>
</tr>
<tr>
<td>(S_{\text{low}})</td>
<td>Minimum speed to be used for arrow length computations</td>
<td>0.01 kn</td>
</tr>
<tr>
<td>(S_{\text{high}})</td>
<td>Maximum speed to be used for arrow length computations</td>
<td>13 kn</td>
</tr>
</tbody>
</table>

9.2.5 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 (Figure 9.4). The data are invisible initially, and when the cursor is placed on the arrow, the data will be shown temporarily. 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 (or other colour for dusk and/or night viewing) background and a black border with a 1 pixel line thickness. The box must have zero transparency.

Figure 9.4 – Example of the display of the first level of numerical information available by cursor selection. Note: Arrow length is not to scale.

There should be at least three levels of detail of information (Table 9.4). 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 9.4. The additional levels are accessed by a cursor pick capability (cf. S-101. IHO Electronic Navigational Chart Product Specification).

Table 9.4 – Sample of numerical information displayed in text at the location of a current vector,
organised into levels of priority.

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Text Information Displayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Speed, Direction</td>
</tr>
<tr>
<td>2</td>
<td>Data source or station name, Latitude, Longitude, Depth of current, Valid Date, Valid Time</td>
</tr>
<tr>
<td>3</td>
<td>Uncertainty in speed, Uncertainty in direction, Uncertainty in horizontal position, Uncertainty in vertical position, Uncertainty in time</td>
</tr>
</tbody>
</table>

NOTE: The text box in Figure 9.4 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.

### 9.2.6 Transparency

The symbol transparency must be adjusted according to the background chart/image used (Table 9.5). 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>
<thead>
<tr>
<th>Background</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite image</td>
<td>1.0</td>
</tr>
<tr>
<td>Raster Nautical Chart</td>
<td>1.0</td>
</tr>
<tr>
<td>ENC Day</td>
<td>1.0</td>
</tr>
<tr>
<td>ENC Dusk</td>
<td>0.4</td>
</tr>
<tr>
<td>ENC Night</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 9.5 - Alpha (opaqueness) values for arrows with various display backgrounds. Transparency is 1.0 minus the alpha value.

### 9.2.7 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. L -0.5, 5.0 -1.0,-1.5 -2.,-1.5 0.,-5.0 2.0,-1.5 1.0,-1.5 0.5,5.0 -0.5, 5.0 Z

where M is the moveto instruction, L is the lineto instruction, and Z denotes the end of the drawing. The coordinates are given in mm. See ANNEX I – SCALABLE VECTOR GRAPHICS for more details.

### 9.2.8 Symbol Placement

The arrow symbol is placed on the georeferenced background so that the pivot point of the symbol (Figure 9.1) is positioned at the geographic coordinates of the current station or grid point.

**NOTE 1:** The HO must insure that the arrow’s pivot point does not lie on the displayed representation of land, i.e., that the current data and the shoreline are consistent.

**NOTE 2:** The HO must insure that the arrow’s pivot point does not lie in a geographic area designated as intertidal when the time-varying water depth has gone to zero.

However, since some stations or grid points are near land, and depending on arrow size, on occasion it is unavoidable that occasionally some part of the arrow symbol will overlie the land or intertidal area.

### 9.3 Display of Regularly Gridded Data

The display of gridded data depicts a surface current field of multiple arrows (Figure 9.5), with each individual 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 speed. That is, interpolation must be of the east/west and north/south components of speed separately, with the interpolated components then used to calculate speed and direction.

#### 9.3.1 High Resolution

A high-resolution display (i.e., zooming in) of regularly gridded data display produces a lower density of data (Figure 9.6). It is not recommended that spatial interpolation be used to estimate current values at locations between grid points or point coverage locations.
Figure 9.5 - Arrows representing gridded surface current data, with length increasing with speed, and $S_{ref}$ is 5 kn, $H_{ref}$ is 20 mm, and the maximum speed in the data in the image is 3.15 kn. Coastline added for clarity. Note that although some portions of the arrow symbol lie over land, the pivot point does not.
(data courtesy of St. Lawrence Global Observatory, Canada)
9.3.2 Low Resolution

Displaying at a low resolution (i.e., zooming out) increases the density of symbols (Figure 9.7a). However, by applying a thinning algorithm, the number of vectors may be reduced (Figure 9.7b). In this case, every fourth vector was plotted.

An example of thinning of 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\textsuperscript{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\textsubscript{max} 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\textsubscript{max}, here taken to be 0.5. Thus

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

[Eqn. 9.2]
Figure 9.7 – (a) Surface 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. Note that the coastline data in the figure may differ from that used to determine model boundaries; in practice, the arrow pivot point must not be placed over land. (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:

\[
n = 1 + \text{fix}(\frac{L_{\text{max}}}{D_{\text{Rmax}}})
\]  
[Eqn. 9.3]

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 9.7b).

Thinning of irregularly-spaced vectors is more difficult. For each on-screen point the distance to all other on-screen points would have to be calculated, so that the closest point can be determined. The size and direction of the arrow symbols at the point and its nearest point would be compared for overlap. If overlap occurred, one of the symbols would be eliminated. This procedure would be carried out for all on-screen points, keeping track of which points and their symbols had been eliminated. An alternate solution would be to reduce the reference height \( H_{\text{ref}} \) or increase the reference speed \( S_{\text{ref}} \) (Table 9.3).

**9.4 Temporal Rules**

The metadata variables related to time are the \( \text{dateTimeOfFirstRecord} \), \( \text{dateTimeOfLastRecord} \), \( \text{timeRecordInterval} \), and \( \text{numberOfTimes} \). The time selected for display (i.e., past, present, or future) of the surface currents by the display system will typically not correspond exactly to the timestamp of the input data. For a correct display, the ECDIS will have to select the correct data.

For data with only a single record (where the timestamp of the earliest value equals that of the latest value) such as real-time data, the surface current values are displayed only if the display time is later than the timestamp and the absolute time difference between the display time and the data timestamp is less than a discrimination interval (e.g., 5 minutes). For a single record, the variable \( \text{timeRecordInterval} \) (see Clause 12.3) can be used to set the discrimination interval.

For data with multiple times, if the selected display time is later than the first timestamp and earlier than the last timestamp, then the closest but immediately preceding values in the data are displayed. However, if the selected display time is earlier than the first timestamp then the data is not displayed. If the selected time is later than the last timestamp, then surface current values at that time are displayed only if the absolute time difference between the display time and the data timestamp is less than a discrimination interval (e.g., the value of the variable \( \text{timeRecordInterval} \)).

**9.5 Placement of Legend**

The legend, which is to be displayed as an option, must show the relationship between the arrow colours and the speed values. A sample is shown in Figure 9.8. The precise position of the legend if it appears on the monitor will be determined so as to minimize the obscuring of other important navigational information.
9.6 Interoperability

Interoperability principles determine priority in display of elements so that important image elements, such as depth numerals, are not obscured by current vectors. Surface current portrayal will conform to interoperability rules as they are established.

Symbol Priority

Details about symbol priority will be determined in accordance with S-100 standards when they are developed.

One example involves the use of the older charting symbol for currents. When an S-111 dataset is displayed, symbols from the S-101 ECDIS nautical charting suite, in the area where the new data is displayed, must not be displayed. Such symbols include those for tidal stream tables (plus their points and boundary areas), flood and ebb tide stream arrows and their values and boundary areas, and other symbols for rip currents, eddies, breakers, and non-tidal currents.

Colour Discrimination

Another criterion is that the arrows colours be distinct when displayed against a background of similar colour. Table 9.6 shows the background colours for various water depth types, and Figure 9.9 shows typical arrows for the nine speed bands. The black arrow border allows the arrow symbol to stand out against the blue and green backgrounds.

<table>
<thead>
<tr>
<th>Name</th>
<th>sRGB</th>
<th>xyL</th>
<th>Displayed Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red</td>
<td>Green</td>
<td>Blue</td>
</tr>
<tr>
<td>Deep Water</td>
<td>201</td>
<td>237</td>
<td>255</td>
</tr>
<tr>
<td>Medium Deep Water</td>
<td>167</td>
<td>218</td>
<td>252</td>
</tr>
<tr>
<td>Medium Shallow Water</td>
<td>130</td>
<td>202</td>
<td>255</td>
</tr>
<tr>
<td>Very Shallow Water</td>
<td>97</td>
<td>184</td>
<td>255</td>
</tr>
<tr>
<td>Intertidal</td>
<td>88</td>
<td>175</td>
<td>156</td>
</tr>
<tr>
<td>No Values</td>
<td>147</td>
<td>174</td>
<td>187</td>
</tr>
</tbody>
</table>

Table 9.6 - Chart background colours in two colour scales (courtesy of Korean Hydrographic and Oceanographic Administration).

Figure 9.8 – Sample surface current speed scale based on the colours and speed bands in Table 9.1.
Figure 9.9 – Arrows displayed against the (daytime) background colours in Table 9.6. (a) Arrows with borders and (b) without borders. (Figures courtesy of University of New Hampshire)

9.7 Sample Representation

Surface currents vectors comprise a layer to be displayed on demand and, possibly, 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 or colours similar to those in other layers. Figure 9.10 shows a sample display.

Figure 9.10 – Sample depiction of gridded surface current data in an electronic chart. Note that arrow height in scale may not strictly conform to the portrayal rules. (Image courtesy of the Univ. of New Hampshire, US).

9.8 Portrayal Rules

A summary of the portrayal rules appears in ANNEX J – SURFACE CURRENT PORTRAYAL RULES.
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).

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

The key idea at the core of the S-111 data product structure is this: the organization of the information is substantially the same for each of the four types of surface current data, but the information itself will be interpreted differently. These data types and their codes are shown in Table 10.1.

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>dataCodingFormat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time series data at one or more fixed stations</td>
<td>1</td>
</tr>
<tr>
<td>Regularly-gridded data at one or more times</td>
<td>2</td>
</tr>
<tr>
<td>Ungeorectified gridded data or point set data at one or more times</td>
<td>3</td>
</tr>
<tr>
<td>Time series data for one moving platform</td>
<td>4</td>
</tr>
</tbody>
</table>

For the use of HDF5, the following key concepts (10c.5.1) are important:

- **File** - a contiguous string of bytes in a computer store (memory, disk, etc.), and the bytes represent zero or more objects of the model;
- **Group** - a collection of objects (including groups);
- **Dataset** - a multidimensional array of data elements with attributes and other metadata;
- **Dataspace** - a description of the dimensions of a multidimensional array;
- **Datatype** - a description of a specific class of data element including its storage layout as a pattern of bits;
- **Attribute** - a named data value associated with a group, dataset, or named datatype;
- **Property List** - a collection of parameters (some permanent and some transient) controlling options in the library;
- **Link** - the way objects are connected.

In addition, a dataset may have one, two, or more dimensions, and each element in the dataset may be a compound. That is, each element may itself be an array of possibly different datatypes (float, integer, string, etc.).

10.2 Product Structure

The structure of the data product follows the form given in S-100 v. 4.0.0 – PART10C – HDF5 DATA MODEL AND FILE FORMAT. The general structure, which was designed for several S-100 products, not just surface currents, is given in Figure 10.1.
Notice that in Figure 10.1 there are four levels:

**Level 1** At the top level lies the Root Group, and it contains the Root Metadata (Table 12.1) and two subsidiary groups. The Root Metadata applies to all S-100 type products.

**Level 2** The next Level contains the Feature Information Group and the Feature Container Group. The Feature Information Group contains the feature name (Surface Current) and the feature attribute codes. The Feature Container Group contains the Feature Metadata (Table 12.2) and one or more Feature Instance Groups. The Feature Metadata is common to all surface current products.

**Level 3** This contains one or more Feature Instances. A feature instance is, for example, a time series of gridded data for a single region, or a time series of astronomical predictions for a set of stations.

**Level 4** This contains the actual data for the feature. S-111 uses only the Values Group and, for only some data, the Positioning Group.

The basic structure of the S-111 data product is shown in Table 10.2.
<table>
<thead>
<tr>
<th>LEVEL 1 CONTENT</th>
<th>LEVEL 2 CONTENT</th>
<th>LEVEL 3 CONTENT</th>
<th>LEVEL 4 CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Metadata (metadata) (h5_attribute)</td>
<td>Feature Name SurfaceCurrent (h5_attribute)</td>
<td>Feature Codes featureCode (h5_attribute)</td>
<td>Feature Instance SurfaceCurrent.01 (h5_group)</td>
</tr>
<tr>
<td>Feature Codes Group_F (h5_group)</td>
<td>Type Metadata (metadata) (h5_attribute)</td>
<td>Feature Codes featureCode (h5_attribute)</td>
<td>Instance Metadata (metadata) (h5_attribute)</td>
</tr>
<tr>
<td>Feature Type SurfaceCurrent (h5_group)</td>
<td>Feature Codes featureCode (h5_attribute)</td>
<td>Feature Codes featureCode (h5_attribute)</td>
<td>Location Data Positioning (h5_group)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lon+lat Array geometryValues (h5_dataset)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>First data group Group_001 (h5_group)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time Attribute timePoint (h5_attribute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Name Attribute Title (h5_attribute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Speed+direction Array values (h5_dataset)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Second data group Group_002 (h5_group)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time Attribute timePoint (h5_attribute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Name Attribute Title (h5_attribute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Speed+direction Array values (h5_dataset)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Third data group Group_003 (h5_group)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time Attribute timePoint (h5_attribute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Name Attribute Title (h5_attribute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Speed+direction Array values (h5_dataset)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feature Instance SurfaceCurrent.02 (h5_group)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Instance Metadata (metadata) (h5_attribute)</td>
</tr>
</tbody>
</table>
The following sections explain entries in Table 10.2 in more detail.

10.2.1 Feature Codes (Group_F)

This group specifies the S-100 feature to which the data applies, and consists of two components:

**featureName** – a dataset with the name(s) of the S-100 feature(s) contained in the data product. For S-111, the dataset has a single element, the string “SurfaceCurrent”.

**SurfaceCurrent** – the feature described in the featureName. This is a dataset containing a two-dimensional array (one dimension for each of the two current attributes: speed and direction) of string values (Table 10.3).

<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
<th>S-100 Attribute 1</th>
<th>S-100 Attribute 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>code</td>
<td>Camel Case Name</td>
<td>surfaceCurrentDirection</td>
<td>surfaceCurrentSpeed</td>
</tr>
<tr>
<td>name</td>
<td>plain text</td>
<td>Surface Current Direction</td>
<td>Surface Current Speed</td>
</tr>
<tr>
<td>uom</td>
<td>Units of Measurement)</td>
<td>Knots</td>
<td>arc-degrees</td>
</tr>
<tr>
<td>fillValue</td>
<td>Denotes missing data</td>
<td>-999.0</td>
<td>-999.0</td>
</tr>
<tr>
<td>datatype</td>
<td>HDF5 datatype</td>
<td>H5T_FLOAT</td>
<td>H5T_FLOAT</td>
</tr>
<tr>
<td>lower</td>
<td>Lower bound on attribute</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>upper</td>
<td>Upper bound on attribute</td>
<td>360.0</td>
<td>[ ]</td>
</tr>
<tr>
<td>closure</td>
<td>Open or Closed data interval.</td>
<td>closedInterval</td>
<td>geSemiInterval</td>
</tr>
</tbody>
</table>

See S100_IntervalType in Part 1.

10.2.3 Conditional Geography Group (Positioning)

The group Positioning contains all the locations (longitude and latitude values) that have associated data values. In S-111, this group is present in the data product only for `dataCodingFormat` values of 1, 3 or 4.

The geographic values are stored in the single, one-dimensional compound array `geometryValues`, of size `numPOS`. Each element in the compound array `geometryValues` contains the pair of float values (longitude, latitude).

The value of `numPOS` and the interpretation of the kinds of locations depends on the `dataCodingFormat` as well. The values and number of stations/drifters (respectively) for each data type are explained in Table 10.4.

<table>
<thead>
<tr>
<th>Data CodingFormat</th>
<th>Data Type</th>
<th>Location Data</th>
<th>Array Size: Value of NumPOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Time Series at fixed stations</td>
<td>Position of current stations</td>
<td><code>numberOfStations</code></td>
</tr>
<tr>
<td>3</td>
<td>Ungeorectified gridded data</td>
<td>Location of the grid nodes</td>
<td><code>numberOfNodes</code></td>
</tr>
<tr>
<td>4</td>
<td>Time Series at a single moving station</td>
<td>Position of the station over time</td>
<td><code>numberOfTimes</code></td>
</tr>
</tbody>
</table>
10.2.4 Values Groups (Group_nnn)

These groups each contain a date-time stamp, and the compound data arrays containing surface current speed and direction. These components are explained below.

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

**Date-Time Stamp**

The date-time stamp is an attribute named timePoint with a single (string) value. For gridded (regular and ungeorectified: dataCodingFormat = 2 or 3), the time stamp is the time of validity for all points in the grid. For a time series at fixed and moving platforms, the time stamp is the time of the first value.

**Data Arrays**

The speed and direction values (surfaceCurrentSpeed and surfaceCurrentDirection) are stored in two dimensional arrays named values, with a prescribed number of columns (numCOL) and rows (numROW).

For a time series of fixed or moving stations (dataCodingFormat = 1 or 4), the speed and direction values will be for times in the series as determined by the starting date-time and the data time interval. Each array is virtually one-dimensional, as the number of rows is set to 1.

For a regular grid (dataCodingFormat = 2), the speed and direction values will be for each point in the grid, the data array values is two-dimensional, and for the time for all points in the grid given by the date-time stamp.

For an ungeorectified grid (dataCodingFormat = 3), the speed and direction values will be for each point in the grid, the data array values is one-dimensional, and for the time for all points in the grid given by the date-time stamp.

10.2.5 Summary of Generalized Dimensions

To summarize, 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 10.5.
Table 10.5 – The array dimensions used in the data product.

<table>
<thead>
<tr>
<th>Data Coding Format</th>
<th>Data Type</th>
<th>numPOS</th>
<th>numCOL</th>
<th>numROW</th>
<th>numGRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixed Stations</td>
<td>numberOfStations</td>
<td>numberOfTimes</td>
<td>1</td>
<td>numberOfStations</td>
</tr>
<tr>
<td>2</td>
<td>Regular Grid</td>
<td>(not used)</td>
<td>numPointsLongitudinal</td>
<td>numPointsLatitudinal</td>
<td>numberOfTimes</td>
</tr>
<tr>
<td>3</td>
<td>Ungeorectified Grid</td>
<td>numberOfNodes</td>
<td>numberOfNodes</td>
<td>1</td>
<td>numberOfTimes</td>
</tr>
<tr>
<td>4</td>
<td>Moving Platform</td>
<td>numberOfTimes</td>
<td>numberOfTimes</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

10.2.6 Mandatory Naming Conventions

The following group and attribute names are mandatory in S-100: Group_F, featureCode, and (for S-111) SurfaceCurrent, axisNames, Positioning, (for S-111) SurfaceCurrent.01, and group_nnn. Attribute names shown in Annex G are also mandatory.

10.3 Sample HDF5 Encoding

The product structure has been designed for compatibility with the HDF5 capabilities. The HDF5 encoding of the data set is discussed in ANNEX G – SAMPLE HDF5 ENCODING.

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.).

Method of transfer will be primarily web-based, including ftp, although some products (astronomical predictions) may be delivered via storage media. The data will be supplied either directly from the HO or through a third party supplier.

Due to the cost of transmitting data via Internet, it is desirable to limit file size and updating frequency whenever possible. The exchange dataset file size, as created by the HO and before compression, is limited to 10 MB. Two common data compression schemes are Zip and Rar (Radio acoustic ranging). In addition, the file may be encrypted.

Updating of files typically means issuing a new forecast, or disseminating the latest observed currents for a specific geographic region. This may occur several times per day. Therefore, all files must contain a date-time of issuance of the product. Because of the potentially high frequency (i.e., hourly or less) availability of new datasets, the ECDIS system must check for new data at a similar frequency.
11.2 Exchange Datasets

Exchange Sets produced by the HO consist of files containing an XML Exchange Catalogue, the HDF5 Data Products, and auxiliary files (Figure 11.1). The auxiliary files include an XML Feature Catalogue, an XML Portrayal Catalogue, SVG files, and additional supporting XML files for alarms and indications, and for interoperability.

The Data Products include one or more data sets (but of the same S-100 Product Specification types), with each product covering a specific geographic region and specific period of time. The Exchange Catalogue lists the products and contains the discovery metadata.

<table>
<thead>
<tr>
<th>Exchange Dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange Catalogue</td>
</tr>
<tr>
<td>Metadata (includes list of files in Exchange Dataset)</td>
</tr>
<tr>
<td>Auxiliary files (Feature and Portrayal Catalogue, SVG Files, etc.)</td>
</tr>
<tr>
<td>Data Products</td>
</tr>
<tr>
<td>Data Product No. 1</td>
</tr>
<tr>
<td>Data Product No. 2</td>
</tr>
<tr>
<td>Data Product No. 3</td>
</tr>
<tr>
<td>Data Product No. 4</td>
</tr>
<tr>
<td>Etc.</td>
</tr>
</tbody>
</table>

Figure 11.1 – Schematic diagram of the Exchange Dataset.

The dataset size, even after compression, is limited to 10 MB. This size was chosen due to the cost of transmitting data via the internet.

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, which includes the metadata, are described in Clause 12.

11.4 Data Product File Naming

The data product file contains both a carrier metadata block and one or more sets of speed and direction arrays (see Clause 10 – Data Product Format). There is no generally accepted file
naming convention. However, the filename extension for HDF5 (e.g., .h5 or .hdf5) must be used to denote the file format. Characters may be lower or upper case.

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 dataset and catalogue,
- discovery metadata about each of the datasets contained in the catalogue, and
- discovery 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.

12.2 Discovery Metadata

An outline of 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 the 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. Whether the individual metadata parameters are mandatory or optional is defined in the individual tables.
Figure 12.1 - Realization of the exchange set classes. Note that there are no support files.

Figure 12.2 - S-111 ExchangeSet Catalogue.
Figure 12.3 – S-111 ExchangeSet.
Figure 12.4 - S-111 Exchange Set: Class details.
12.2.1 S111_ExchangeCatalogue

Each exchange set has a single S100_ExchangeCatalogue which contains meta information for the data and support files in the exchange set.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Value</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_ExchangeCatalogue</td>
<td>An exchange catalogue contains the discovery metadata about the exchange datasets and support files</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Identifier</td>
<td>Uniquely identifies this exchange catalogue</td>
<td>1</td>
<td>S100_CatalogueIdentifier</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Contact</td>
<td>Details about the issuer of this exchange catalogue</td>
<td>1</td>
<td>S100_CataloguePointOfContact</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>productSpecification</td>
<td>Details about the product specifications used for the datasets contained in the exchange catalogue</td>
<td>0..1</td>
<td>S100_ProductSpecification</td>
<td>Conditional on all the datasets using the same product specification</td>
<td></td>
</tr>
<tr>
<td>exchangeCatalogueName</td>
<td>Catalogue filename</td>
<td>1</td>
<td>CharacterString</td>
<td>In S-101 it would be CATLOG.101</td>
<td></td>
</tr>
<tr>
<td>exchangeCatalogueDescription</td>
<td>Description of what the exchange catalogue contains</td>
<td>1</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
<tr>
<td>exchangeCatalogueComment</td>
<td>Any additional Information</td>
<td>0..1</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
<tr>
<td>compressionFlag</td>
<td>Is the data compressed</td>
<td>0..1</td>
<td>Boolean</td>
<td>Yes or No</td>
<td></td>
</tr>
<tr>
<td>algorithmMethod</td>
<td>Type of compression algorithm</td>
<td>0..1</td>
<td>CharacterString</td>
<td>Eg. RAR, ZIP, h5repack</td>
<td></td>
</tr>
<tr>
<td>sourceMedia</td>
<td>Distribution media</td>
<td>0..1</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
<tr>
<td>replacedData</td>
<td>If a data file is cancelled is it replaced by another data file</td>
<td>0..1</td>
<td>Boolean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dataReplacement</td>
<td>Cell name</td>
<td>0..1</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 12.2.2 S100_CatalogueIdentifier

<table>
<thead>
<tr>
<th>Role Name</th>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>S100_CatalogueIdentifier</td>
<td>An exchange catalogue contains the discovery metadata about the exchange datasets and support files</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Attribute</td>
<td>identifier</td>
<td>Uniquely identifies this exchange catalogue</td>
<td>1</td>
<td>CharacterString</td>
<td></td>
</tr>
<tr>
<td>Attribute</td>
<td>editionNumber</td>
<td>The edition number of this exchange catalogue</td>
<td>1</td>
<td>CharacterString</td>
<td></td>
</tr>
<tr>
<td>Attribute</td>
<td>date</td>
<td>Creation date of the exchange catalogue</td>
<td>1</td>
<td>Date</td>
<td></td>
</tr>
</tbody>
</table>

### 12.2.3 S100_CataloguePointOfContact

<table>
<thead>
<tr>
<th>Role Name</th>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>S100_CataloguePointOfContact</td>
<td>Contact details of the issuer of this exchange catalogue</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Attribute</td>
<td>organization</td>
<td>The organization distributing this exchange catalogue</td>
<td>1</td>
<td>CharacterString</td>
<td>This could be an individual producer, value added reseller, etc.</td>
</tr>
<tr>
<td>Attribute</td>
<td>phone</td>
<td>The phone number of the organization</td>
<td>0..1</td>
<td>CI_Telephone</td>
<td></td>
</tr>
<tr>
<td>Attribute</td>
<td>address</td>
<td>The address of the organization</td>
<td>0..1</td>
<td>CI_Address</td>
<td></td>
</tr>
</tbody>
</table>
### 12.2.4 S100_DatasetDiscoveryMetaData

Data in the Discovery Metadata are used to identify the relevance of the dataset to the particular application.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Value</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_DatasetDiscoveryMetadata</td>
<td>Metadata about the individual datasets in the exchange catalogue</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>fileName</td>
<td>Dataset file name</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td>Path relative to the root directory of the exchange set. The location of the file after the exchange set is unpacked into directory <code>&lt;EXCH_ROOT&gt;</code> will be <code>&lt;EXCH_ROOT&gt;/&lt;filePath&gt;/&lt;filename&gt;</code></td>
</tr>
<tr>
<td>filePath</td>
<td>Full path from the exchange set root directory</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td>-</td>
</tr>
<tr>
<td>description</td>
<td>Short description giving the area or location covered by the dataset</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td>E.g. a harbour or port name, between two named locations etc.</td>
</tr>
<tr>
<td>dataProtection</td>
<td>Indicates if the data is encrypted</td>
<td>0..1</td>
<td></td>
<td>Boolean</td>
<td>0 indicates an unencrypted dataset 1 indicates an encrypted dataset</td>
</tr>
<tr>
<td>protectionScheme</td>
<td>specification or method used for data protection</td>
<td>0..1</td>
<td></td>
<td>CharacterString</td>
<td>Eg S-63</td>
</tr>
<tr>
<td>digitalSignature</td>
<td>Indicates if the data has a digital signature</td>
<td>0..1</td>
<td></td>
<td>Boolean</td>
<td>0: unsigned 1: datafile is digitally signed [to be reconciled when S-100 finalizes digital signature elements]</td>
</tr>
<tr>
<td>digitalSignatureValue</td>
<td>Digital signature</td>
<td>0..1</td>
<td></td>
<td>CharacterString</td>
<td>This contains a base64 encoding of the hexadecimal numbers comprising the digital signature itself. The content of these fields are defined, along with the algorithms for their calculation, in S-63 ed2.0 Part (C). [to be reconciled when S-100 finalizes digital signature elements]</td>
</tr>
<tr>
<td>classification</td>
<td>Indicates the security classification of the dataset</td>
<td>0..1</td>
<td></td>
<td>Enumeration</td>
<td>One of the following from ISO 19115  MD_SecurityConstraints&gt;  MD_ClassificationCode (codelist)  1. unclassified 2. restricted 3. confidential 4. secret 5. top secret</td>
</tr>
<tr>
<td>purpose</td>
<td>The purpose for which the dataset has been issued</td>
<td>1</td>
<td></td>
<td>MD_Identification &gt;purpose</td>
<td>E.g. new, re-issue, new edition, update etc.</td>
</tr>
<tr>
<td>specificUsage</td>
<td>The use for which the dataset is intended</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td>E.g. in the case of ENCs this would be a navigation purpose classification.</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Mult</td>
<td>Value</td>
<td>Type</td>
<td>Remarks</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
<td>-------</td>
<td>---------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>editionNumber</td>
<td>The edition number of the dataset</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td>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-issu.</td>
</tr>
<tr>
<td>issueDate</td>
<td>Date on which the data was made available by the data producer</td>
<td>1</td>
<td></td>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>productSpecification</td>
<td>The product specification used to create this dataset</td>
<td>1</td>
<td></td>
<td>S111_ProductSpecification</td>
<td></td>
</tr>
<tr>
<td>producingAgency</td>
<td>Agency responsible for producing the data</td>
<td>1</td>
<td></td>
<td>CI_ResponsibleParty</td>
<td></td>
</tr>
<tr>
<td>horizontalDatumReference</td>
<td>Reference to the register from which the horizontal datum value is taken</td>
<td>1</td>
<td></td>
<td>characterString</td>
<td>EPSG</td>
</tr>
<tr>
<td>horizontalDatumValue</td>
<td>Horizontal Datum of the entire dataset</td>
<td>1</td>
<td></td>
<td>Integer</td>
<td>4326</td>
</tr>
<tr>
<td>verticalDatum</td>
<td>Vertical Datum of the entire dataset</td>
<td>1</td>
<td></td>
<td>S100_VerticalAndSoundingDatum</td>
<td></td>
</tr>
<tr>
<td>soundingDatum</td>
<td>Sounding Datum of the entire dataset</td>
<td>1</td>
<td></td>
<td>Enumeration S100_VerticalAndSoundingDatum</td>
<td>Not relevant to S-111. Fixed value corresponding to literal localDatum from S100_VerticalAndSoundingDatum.</td>
</tr>
<tr>
<td>dataType</td>
<td>The encoding format of the dataset</td>
<td>1</td>
<td></td>
<td>S100_DataFormat</td>
<td></td>
</tr>
<tr>
<td>otherDataTypeDescription</td>
<td>Encoding format other than those listed.</td>
<td>0..1</td>
<td></td>
<td>CharacterString</td>
<td></td>
</tr>
<tr>
<td>dataTypeVersion</td>
<td>The version number of the data type.</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td></td>
</tr>
<tr>
<td>dataCoverage</td>
<td>Area covered by the dataset</td>
<td>1</td>
<td></td>
<td>S100_DataCoverage</td>
<td></td>
</tr>
<tr>
<td>comment</td>
<td>Any additional information</td>
<td>0..1</td>
<td></td>
<td>CharacterString</td>
<td></td>
</tr>
</tbody>
</table>

### 12.2.5 S111_DataCoverage

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Value</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_DataCoverage</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Uniquely identifies the coverage</td>
<td>1</td>
<td>Integer</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>boundingBox</td>
<td>The extent of the dataset limits</td>
<td>1</td>
<td>EX_GeographicBoundingBox</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>boundingPolygon</td>
<td>A polygon which defines the actual data limit</td>
<td>1..*</td>
<td>EX_BoundingPolygon</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>optimumDisplayScale</td>
<td>The scale with which the data is optimally displayed</td>
<td>0..1</td>
<td>Integer</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>maximumDisplayScale</td>
<td>The maximum scale with which the data is displayed</td>
<td>0..1</td>
<td>Integer</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>minimumDisplayScale</td>
<td>The minimum scale with which the data is displayed</td>
<td>0..1</td>
<td>Integer</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
### 12.2.5.1 EX_GeographicBoundingBox


<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX_GeographicBoundingBox</td>
<td>geographic position of the dataset</td>
<td>-</td>
<td>-</td>
<td>Defined in ISO 19115</td>
</tr>
<tr>
<td>westBoundLongitude</td>
<td>western-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east)</td>
<td>1</td>
<td>Real</td>
<td>Arc degrees</td>
</tr>
<tr>
<td>eastBoundLongitude</td>
<td>eastern-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east)</td>
<td>1</td>
<td>Real</td>
<td>Arc degrees</td>
</tr>
<tr>
<td>southBoundLatitude</td>
<td>southern-most coordinate of the limit of the dataset extent, expressed in latitude in decimal degrees (positive north)</td>
<td>1</td>
<td>Real</td>
<td>Arc degrees</td>
</tr>
<tr>
<td>northBoundLatitude</td>
<td>northern-most, coordinate of the limit of the dataset extent expressed in latitude in decimal degrees (positive north)</td>
<td>1</td>
<td>Real</td>
<td>Arc degrees</td>
</tr>
</tbody>
</table>

### 12.1.5.2 EX_BoundingPolygon


<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX_BoundingPolygon</td>
<td>boundary enclosing the dataset, expressed as the closed set of (x,y) coordinates of the polygon (last point replicates first point)</td>
<td>-</td>
<td>-</td>
<td>Defined in ISO 19115</td>
</tr>
<tr>
<td>polygon</td>
<td>sets of points defining the bounding polygon</td>
<td>1</td>
<td>GM_Object</td>
<td>Must be a GM_Polygon (See S-100 Part 7, ISO 19107, ISO 19136)</td>
</tr>
</tbody>
</table>
### 12.2.6 S100_VerticalAndSoundingDatum

<table>
<thead>
<tr>
<th>Role Name</th>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>S100_VerticalAndSoundingDatum</td>
<td>Allowable vertical and sounding datums</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td>meanLowWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Value</td>
<td>meanSeaLevel</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Value</td>
<td>meanLowerLowWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Value</td>
<td>lowestLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Value</td>
<td>meanLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Value</td>
<td>lowestLowWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Value</td>
<td>approximateMeanLowWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>Value</td>
<td>indianSpringLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Value</td>
<td>lowWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Value</td>
<td>approximateLowestAstronomicalTide</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Value</td>
<td>nearlyLowestLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>Value</td>
<td>meanLowerLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>Value</td>
<td>lowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>Value</td>
<td>approximateMeanLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Value</td>
<td>approximateMeanLowerLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>Value</td>
<td>meanHighWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>Value</td>
<td>meanHighWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>Value</td>
<td>highWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18</td>
</tr>
<tr>
<td>Value</td>
<td>approximateMeanSeaLevel</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
</tr>
<tr>
<td>Value</td>
<td>highWaterSprings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Value</td>
<td>meanHigherHighWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>Value</td>
<td>equinoctialSpringLowWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>Value</td>
<td>lowestAstronomicalTide</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>23</td>
</tr>
<tr>
<td>Value</td>
<td>localDatum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>Value</td>
<td>internationalGreatLakesDatum1985</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>Value</td>
<td>meanWaterLevel</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>26</td>
</tr>
<tr>
<td>Value</td>
<td>lowerLowWaterLargeTide</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>Value</td>
<td>higherHighWaterLargeTide</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>Value</td>
<td>nearlyHighestHighWater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>29</td>
</tr>
<tr>
<td>Value</td>
<td>highestAstronomicalTide</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30(HAT)</td>
</tr>
</tbody>
</table>

### 12.2.7 S111_DataFormat
<table>
<thead>
<tr>
<th>Role Name</th>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>S100_DataFormat</td>
<td>Encoding format</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td>HDF5</td>
<td>Format</td>
<td>1</td>
<td>Character</td>
<td></td>
</tr>
</tbody>
</table>

### 12.2.8 S100_ProductSpecification

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_ProductSpecification</td>
<td>The Product Specification contains the information needed to build the specified product</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>name</td>
<td>The name of the product specification used to create the datasets</td>
<td>1</td>
<td>CharacterString</td>
<td>S-111 Surface Current Product Specification</td>
</tr>
<tr>
<td>version</td>
<td>The version number of the product specification</td>
<td>1</td>
<td>CharacterString</td>
<td>1.0.0</td>
</tr>
<tr>
<td>date</td>
<td>The version date of the product specification</td>
<td>1</td>
<td>Date</td>
<td></td>
</tr>
</tbody>
</table>

#### 12.2.9 S100_CatalogueMetadata

Identifies components of the Catalogue.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Value</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_CatalogueMetadata</td>
<td>Description of the catalogue</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>filename</td>
<td>The name for the catalogue</td>
<td>1..*</td>
<td>CharacterString</td>
<td>Path relative to the root directory of the exchange set. The location of the file after the exchange set is unpacked into directory <code>&lt;EXCH_ROOT&gt;/&lt;filePath&gt;/&lt;filename&gt;</code></td>
<td></td>
</tr>
<tr>
<td>fileLocation</td>
<td>Full location from the exchange set root directory</td>
<td>1..*</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
<tr>
<td>scope</td>
<td>Subject domain of the catalogue</td>
<td>1..*</td>
<td>S111_CatalogueScope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>versionNumber</td>
<td>The version number of the product specification</td>
<td>1..*</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
<tr>
<td>issueDate</td>
<td>The version date of the product specification</td>
<td>1..*</td>
<td>Date</td>
<td></td>
<td></td>
</tr>
<tr>
<td>productSpecification</td>
<td>The product specification used to create this file</td>
<td>1..*</td>
<td>S100_ProductSpecification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>digitalSignatureReference</td>
<td>Digital Signature of the file</td>
<td>1</td>
<td>CharacterString</td>
<td>Reference to the appropriate digital signature algorithm</td>
<td></td>
</tr>
<tr>
<td>digitalSignatureValue</td>
<td>Value derived from the digital signature</td>
<td>1</td>
<td>CharacterString</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
12.2.10 S100_CatalogueScope

<table>
<thead>
<tr>
<th>Role Name</th>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>S100_CatalogueScope</td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td>featureCatalogue</td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td>portrayalCatalogue</td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

12.2.11 S100_19115DatasetMetadata

Information here pertains to the data product, and repeats some of the variables in the Carrier Metadata (Clause 12.3).

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Mult</th>
<th>Value</th>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100_19115DatasetMetadata</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>typeOfCurrentData</td>
<td>Type or source of current data (Table 7.1)</td>
<td>1</td>
<td></td>
<td>Enumeration</td>
<td>1: Historical observation 2: Real-time observation 3: Astronomical prediction 4: Analysis or hybrid method 5: Hydrodynamic model hindcast 6: Hydrodynamic model forecast</td>
</tr>
<tr>
<td>dataCodingFormat</td>
<td>Data organization index, used to read the data (Table 10.1)</td>
<td>1</td>
<td></td>
<td>Enumeration</td>
<td>1: Time series at fixed stations 2: Regularly-gridded arrays 3: Ungeorectifiedgridded arrays 4: Moving platform</td>
</tr>
<tr>
<td>methodCurrentsProduct</td>
<td>Methodology</td>
<td>1</td>
<td></td>
<td>CharacterString</td>
<td>Brief description of current meter type, forecast method or model, etc.</td>
</tr>
<tr>
<td>minSurfCurrentSpeed</td>
<td>Minimum current speed in the dataset</td>
<td>0..1</td>
<td></td>
<td>Real</td>
<td>-1.0 (unknown) or positive value (kn)</td>
</tr>
<tr>
<td>maxSurfCurrentSpeed</td>
<td>Maximum current speed in the dataset</td>
<td>0..1</td>
<td></td>
<td>Real</td>
<td>-1.0 (unknown) or positive value (kn)</td>
</tr>
</tbody>
</table>
12.3 Product Metadata

The metadata for the S-111 product is divided in three sections, corresponding to the General Metadata (Table 12.1), the Type Metadata (Table 12.2), and the Instance Metadata (Table 12.3).

Table 12.1 – General Metadata, related to the entire HDF5 file. NOTE: In addition to the 11 standard entries that apply to all S-100 products, there are two additional parameters in S-111. For the *Enumeration* data type, the entry is a single integer.

<table>
<thead>
<tr>
<th>N</th>
<th>Name</th>
<th>Camel Case</th>
<th>Mult.</th>
<th>Data Type</th>
<th>Remarks and/or Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Product specification number and version</td>
<td>productSpecification</td>
<td>1</td>
<td>Character</td>
<td>This must be encoded as ‘INT.IHO.S-111.X.X’, with Xs representing the version number</td>
</tr>
<tr>
<td>2</td>
<td>Time of data product issue</td>
<td>issueTime</td>
<td>1</td>
<td>Character</td>
<td>Time (UTC)</td>
</tr>
<tr>
<td>3</td>
<td>Date of data product issue</td>
<td>issueDate</td>
<td>1</td>
<td>Character</td>
<td>Date must be consistent with issueDate in discovery metadata.</td>
</tr>
<tr>
<td>4</td>
<td>Horizontal datum</td>
<td>horizontalDatumReference</td>
<td>1</td>
<td>Character</td>
<td>EPSG</td>
</tr>
<tr>
<td>5</td>
<td>Horizontal datum number</td>
<td>horizontalDatumValue</td>
<td>1</td>
<td>Integer</td>
<td>4326 (for WGS84)</td>
</tr>
<tr>
<td>6</td>
<td>Epoch of realization</td>
<td>epoch</td>
<td>0..1</td>
<td>String</td>
<td>Code denoting the epoch of the geodetic datum used by the CRS. E.g., G1762 for the 2013-10-16 realization of the geodetic datum for WGS84</td>
</tr>
<tr>
<td>7a</td>
<td>Bounding box</td>
<td>westBoundLongitude</td>
<td>1</td>
<td>Float</td>
<td></td>
</tr>
<tr>
<td>7b</td>
<td></td>
<td>eastBoundLongitude</td>
<td>1</td>
<td>Float</td>
<td></td>
</tr>
<tr>
<td>7c</td>
<td></td>
<td>southBoundLatitude</td>
<td>1</td>
<td>Float</td>
<td></td>
</tr>
<tr>
<td>7d</td>
<td></td>
<td>northBoundLatitude</td>
<td>1</td>
<td>Float</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Geographic locator</td>
<td>geographicIdentifier</td>
<td>1</td>
<td>Character</td>
<td>Description</td>
</tr>
<tr>
<td>9</td>
<td>Metadata file name</td>
<td>metadata</td>
<td>1</td>
<td>Character</td>
<td>Name of XML metadata file</td>
</tr>
<tr>
<td>10</td>
<td>Vertical datum reference</td>
<td>verticalDatum</td>
<td>1</td>
<td>Enumeration</td>
<td>See S111_VerticalAndSoundingDatum</td>
</tr>
<tr>
<td>11</td>
<td>Meta features</td>
<td>metaFeatures</td>
<td>1</td>
<td>Character</td>
<td>Name of metafeatures file</td>
</tr>
</tbody>
</table>

ADDITIONAL METADATA FOR S-111

<table>
<thead>
<tr>
<th>N</th>
<th>Name</th>
<th>enumeration</th>
<th>Mult.</th>
<th>Data Type</th>
<th>Remarks and/or Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Vertical reference</td>
<td>depthTypeIndex</td>
<td>1</td>
<td>Enumeration</td>
<td>1: Layer average 2: Sea surface 3: Vertical datum (see verticalDatum) 4: Sea bottom</td>
</tr>
<tr>
<td>13</td>
<td>Depth value</td>
<td>surfaceCurrentDepth</td>
<td>1</td>
<td>Float</td>
<td>Layer thickness (depthTypeIndex=1), or height (depthTypeIndex=2, 3, 4) (m)</td>
</tr>
</tbody>
</table>
Table 12.2 – Type Metadata, pertaining to the surface current feature. NOTE: In addition to the first 7 entries that apply to all S-100 products, there are up to 8 additional parameters in S-111.

<table>
<thead>
<tr>
<th>N</th>
<th>Name</th>
<th>Camel Case</th>
<th>Mult</th>
<th>Data Type</th>
<th>Remarks and/or Units</th>
</tr>
</thead>
</table>
| 1  | Data organization index, used to read the data      | dataCodingFormat      | 1    | Enumeration | 1: Time series at fixed stations  
2: Regularly-gridded arrays  
3: Ungorrectified gridded arrays  
4: Moving platform |
| 2  | Dimension                                            | dimension             | 1    | Integer   | The dimension of the feature instances (usually 2 in S-111)                          |
| 3  | Common Point Rule                                    | commonPointRule       | 1    | Enumeration | The procedure used for evaluating the coverage at a position that falls on the boundary or in an area of overlap between geometric objects.  
1: average  
2: low  
3: high  
4: all  
5: start  
6: end |
| 4  | Horizontal position uncertainty                      | horizontalPositionUncertainty | 1    | Float      | -1.0 (unknown) or positive value (m)                                                 |
| 5  | Vertical position uncertainty                         | verticalUncertainty   | 1    | Float      | -1.0 (unknown) or positive value (m)                                                 |
| 6  | Time uncertainty                                     | timeUncertainty       | 1    | Float      | -1.0 (unknown) or positive value (s)                                                  |
| 7  | Number of feature instances                          | numInstances          | 1    | Integer    | Num. of stations, gridded forecasts, etc                                              |

**ADDITIONAL METADATA FOR S-111**

| 8  | Speed uncertainty                                    | speedUncertainty      | 1    | Float      | -1.0 (unknown) or positive value (kn)                                                 |
| 9  | Direction uncertainty                                 | directionUncertainty  | 1    | Float      | -1.0 (unknown) or positive value (arc deg)                                             |
| 10 | Methodology                                           | methodCurrentsProduct | 0..1 | Character  | Brief description of current meter type, forecast method or model, etc.                |
| 11 | Min. current speed in dataset                         | minDatasetCurrentSpeed | 1    | Float      | -1.0 (unknown) or positive value (kn)                                                  |
| 12 | Max. current speed in dataset                         | maxDatasetCurrentSpeed | 1    | Float      | -1.0 (unknown) or positive value (kn)                                                  |
| 13 | Type of current data (Table 7.1)                      | typeOfCurrentData     | 1    | Enumeration | 1: Historical observation (O)  
2: Real-time observation (R)  
3: Astronomical prediction (A)  
4: Analysis or hybrid method (Y)  
5: Hydrodynamic model hindcast (M)  
6: Hydrodynamic model forecast (F) |

**dataCodingFormat = 1**  
(none)

**dataCodingFormat = 2**

| 14a | Sequencing Rule                                      | sequencingRule.type   | 1    | Enumeration | Method to be used to assign values from the sequence of values to the grid coordinates. Components:  
type: Enumeration CV_SequenceType  
E.g., 1 (for 'linear') |
| 14b |                                                    | sequencingRule.scanDirection | 1    | String      | scanDirection: String <axisNames entry> (comma-separated).  
E.g., “latitude, longitude” |

**dataCodingFormat = 3**  
(none)

| 15  | Interpolation Type                                   | interpolationType     | 1    | Enumeration | Interpolation method recommended for evaluation of the S100_GridCoverage Values: CV_InterpolationMethod (ISO 19123). For S-111, use 10 (for discrete) |

**dataCodingFormat = 4**  
(none)
Table 12.3 – Instance Metadata, pertaining to the feature instance. NOTE: In addition to the first 7 standard entries, there are as many as 9 additional parameters in S-111, depending on the data type.

<table>
<thead>
<tr>
<th>N</th>
<th>Name</th>
<th>Camel Case</th>
<th>Mult.</th>
<th>Data Type</th>
<th>Remarks and/or Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bounding box</td>
<td>boundingBox</td>
<td>1</td>
<td>Compound (Double X 4)</td>
<td>westBoundLongitude, eastBoundLongitude, southBoundLatitude, northBoundLatitude</td>
</tr>
<tr>
<td>2</td>
<td>Number of time records</td>
<td>numberOfTimes</td>
<td>1</td>
<td>Integer</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Time interval</td>
<td>timeRecordInterval</td>
<td>1</td>
<td>Integer</td>
<td>Seconds. Cf. discrimination time</td>
</tr>
<tr>
<td>4</td>
<td>Valid Time of Earliest Value</td>
<td>dateTimeOfFirstRecord</td>
<td>1</td>
<td>Character</td>
<td>DateTime</td>
</tr>
<tr>
<td>5</td>
<td>Valid Time of Latest Value</td>
<td>dateTimeOfLastRecord</td>
<td>1</td>
<td>Character</td>
<td>DateTime</td>
</tr>
<tr>
<td>6a</td>
<td>Vertical extent</td>
<td>verticalExtent.minnumumZ</td>
<td>0..1</td>
<td>Float</td>
<td>Vertical extent of 3-d grids (not used in S-111)</td>
</tr>
<tr>
<td>6b</td>
<td>Vertical extent</td>
<td>verticalExtent.maxunumZ</td>
<td>0..1</td>
<td>Float</td>
<td>Vertical extent of 3-d grids (not used in S-111)</td>
</tr>
<tr>
<td>7</td>
<td>Number of value groups</td>
<td>numGRP</td>
<td>1</td>
<td>Integer</td>
<td>Number of Group_nnn</td>
</tr>
</tbody>
</table>

**DataCodingFormat = 1**

| 8 | Number of fixed stations | numberOfStations         | 1     | Integer                 |                                   |

**DataCodingFormat = 2**

| 8 | Longitude of grid origin | gridOriginLongitude      | 1     | Double                  | Arc Degrees                       |
| 9 | Latitude of grid origin  | gridOriginLatitude       | 1     | Double                  | Arc Degrees                       |
| 10| Vertical grid origin     | gridOriginVertical       | 0     | Double                  | Not used in S-111                 |
| 11| Grid spacing, long.      | gridSpacingLongitudinal  | 1     | Double                  | Arc Degrees                       |
| 12| Grid spacing, lat.       | gridSpacingLatitudinal   | 1     | Double                  | Arc Degrees                       |
| 13| Grid spacing, vert.      | gridSpacingvertical      | 0     | Double                  | Not used in S-111                 |
| 14| Number of points, long.  | numPointsLongitudinal    | 1     | Integer                 | jMax                               |
| 15| Number of points, lat.   | numPointsLatitudinal     | 1     | Integer                 | jMax                               |
| 16| Start sequence           | startSequence            | 1     | Character               | “0,0” (without quotes)            |

**DataCodingFormat = 3**

| 8 | Number of nodes          | numberOfNodes            | 0..1  | Integer                 |                                   |

**DataCodingFormat = 4**

| 8 | Number of stations       | numberOfStations         | 0..1  | Integer                 | Always equal to 1                 |

### 12.4 Language

The language used for the metadata is English.
ANNEX A. DATA CLASSIFICATION AND ENCODING GUIDE

A.1 Features

Surface Current \((surfaceCurrent)\)

<table>
<thead>
<tr>
<th>IHO Definition: FEATURE: SURFACE CURRENT: a set of value items required to define a dataset representing direction and speed of the surface water current.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-111 Geo Feature: Surface Current</td>
</tr>
<tr>
<td>Primitives: S-100_Grid Coverage, S-100_PointSet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S-111 Attribute</th>
<th>Allowable Encoding Value</th>
<th>Type</th>
<th>Multiplicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Current Speed</td>
<td>must be in decimal knots, max resolution 0.01 knot</td>
<td>RE</td>
<td>1</td>
</tr>
<tr>
<td>Surface Current Direction</td>
<td>must be in decimal degrees, max resolution 0.1 degree</td>
<td>RE</td>
<td>1</td>
</tr>
</tbody>
</table>

A.2 Feature Attributes

The number of attributes \((numberAttributes)\) is 2.

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)
- Minimum Resolution: 0.01 kn
- Format: xx.xx
- Examples: 2.54
- Remarks:
  - Valid speed always non-negative
  - Negative number denotes land mask
  - 0.01 kn equals 0.5144 cm/s

1. 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) (˚)
- Minimum 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
ANNEX B. 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 a set of objects
NOTE: Characteristics are used for describing concepts [ISO 1097-1, ISO 19140]
distinguishing feature
NOTE 1: A characteristic can be inherit 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 describing 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

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 &lt;XML&gt;
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.

ISO 100 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.

geographic location
longitude, latitude, and elevation of a ground or elevated point
[ISO/TS 19129]
NOTE: For the purpose of this document elevated point will be a depth based on a specified datum.

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.

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.

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.

georectified
corrected for positional displacement with respect to the surface of the Earth

gridded data
data whose attribute values are associated with positions on a grid coordinate system

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.

implementation
realization of a specification
NOTE: In the context of the ISO geographic information standards, this includes specifications of geographic information services and datasets.

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

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.

object that realizes a class
layer
basic unit of geographic information that may be requested as a map from a server.

lineage
chain of legal ownership of content; history of ownership

metadata
data about data

metamodel <UML>
model that defines the language for expressing other models
NOTE: A metamodel is an instance of a meta-metamodel.

model
abstraction of some aspects of reality

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.

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.

object <UML>
a discrete entity with a well-defined boundary and identity that encapsulates state and behavior; an instance of a class

point
zero-dimensional geometric primitive, representing a position
NOTE: The boundary of a point is the empty set.

point coverage
coverage that has a domain composed of points

point set
set of 2, 3 or n dimensional points in space.

point set coverage
coverage function associated with point value pairs in 2 dimensions.

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.

[ISO 19109] [ISO 19110]

**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 C. APPLICATION SCHEMA

Feature Class

The Surface Current feature class (Figure C.1) has two mandatory attributes: surfaceCurrentSpeed and surfaceCurrentDirection. These variables capture the speed of current over ground and the general direction of the current at the location of the data. 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 metadata.

Surface Current Models

Surface Currents are described for the area of interest as a coverage, using either (1) a regularly spaced grid or a (2) point coverage. The Surface Current Model (SCM) is described in Figure C.2.
Figure C.2 - Surface Current Model.

Metadata

The metadata for the SCM is shown in Figure C.3.
Figure C.3 – Metadata model for Surface Currents. Note that ‘horizontalUncertainty’ has been replaced by the preferred term ‘horizontalPositionUncertainty’
ANNEX D. FEATURE CATALOGUE

<?xml version="1.0" encoding="utf-8"?>
<S100FC:S100_FC_FeatureCatalogue xmlns:S100FC="http://www.iho.int/S100FC"
xmlns:S100Base="http://www.iho.int/S100Base" xmlns:S100CI="http://www.iho.int/S100CI"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:S100FD="http://www.iho.int/S100FD"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.iho.int/S100FC S100FC.xsd">
  <S100FC:name>S111</S100FC:name>
  <S100FC:scope>Navigationally Significant Surface Current which may be used alone or as an auxiliary layer of data with an ENC.</S100FC:scope>
  <S100FC:fieldOfApplication>Ocean Navigation</S100FC:fieldOfApplication>
  <S100FC:versionNumber>0.1</S100FC:versionNumber>
  <S100FC:versionDate>2016-12-15</S100FC:versionDate>
  <S100FC:producer>
    <S100CI:organisationName>IHO</S100CI:organisationName>
    <S100CI:contactInfo>
      <S100CI:phone>
        +337 93 10 81 00
      </S100CI:phone>
      <S100CI:address>
        via TWCWG
        B.P.445
        MONACO
      </S100CI:address>
    </S100CI:contactInfo>
    <S100CI:role>pointOfContact</S100CI:role>
  </S100FC:producer>
  <S100FC:classification>unclassified</S100FC:classification>
  <S100FC:S100_FC_SimpleAttributes>
    <S100FC:S100_FC_SimpleAttribute>
      <S100FC:name>Surface current direction</S100FC:name>
      <S100FC:definition>DIRECTION OF CURRENT. The direction toward which a CURRENT is flowing, called the SET of the CURRENT. Also called current direction</S100FC:definition>
      <S100FC:code>surfaceCurrentDirection</S100FC:code>
      <S100FC:valueType>Real</S100FC:valueType>
    </S100FC:S100_FC_SimpleAttribute>
    <S100FC:S100_FC_SimpleAttribute>
      <S100FC:name>Surface current speed</S100FC:name>
      <S100FC:definition>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
    </S100FC:S100_FC_SimpleAttribute>
  </S100FC:S100_FC_SimpleAttributes>
</S100FC:S100_FC_FeatureCatalogue>
direction. Speed may either be the ship’s speed through water, or the SPEED MADE GOOD over
ground. <S100FC:definition>
  <S100FC:code>surfaceCurrentSpeed</S100FC:code>
  <S100FC:valueType>Real</S100FC:valueType>
</S100FC:S100_FC_SimpleAttribute>
</S100FC:S100_FC_SimpleAttributes>
</S100FC:S100_FC_FeatureTypes>
</S100FC:S100_FC_FeatureCatalogue>
ANNEX E. TESTS OF COMPLETENESS (NORMATIVE)

E.1 Coverage Consistency

E.1.1 Test case for coverage geometry

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

Conformance class: Gridded coverage, point coverage

Test method: Check that the coverage geometry type complies with one of the two coverage types defined in the Application Schema defined in Annex C.

Test type: Basic

E.1.2 Test case for extra data

Test purpose: Verify that a Gridded 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.

Verify that a Point Coverage is complete by testing that the points containing direction and speed values are matched with a longitude-latitude pair, 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 have corresponding values.

Test type: Basic

E.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 data values for the grid or point coverage established in the metadata are provided.

Test type: Basic
E.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. Check that the point coverage envelope is consistent with the minimum and maximum point locations.

E.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.

E.2.2 Domain Consistency
The attributive values are validated to ensure they are within defined range.

Test purpose: Verify that attribute values are within specified ranges
Test method: Check that the surface current direction value attribute is within the range 0 to 360 degrees or are a null value and that the speed values are within the range specified or are a null value for the particular product specification defined by a producer. This would be validated by means of test software
Test type: Basic

E.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. For a Point Coverage the positional accuracy for the point is defined in the metadata.

Test purpose: Verify that the grid reference point and offset vector in a grid coverage, and the points in a point 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 is within the accuracy established for the data set by the producer, in particular the Hydrographic Office, by the use of test software.
Test type: Basic
E.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 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 (e.g., a 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.

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).
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 F.2b.

![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 hindcasts 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.
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 ungeorectified 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.
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.

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

Moving platforms (e.g., surface 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.

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 Preliminary Data Product Format

Two forms of data (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. Other forms of data (Figures F.4 and F.5) must be processed to fit the format.

<table>
<thead>
<tr>
<th>Metadata Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location Data</td>
</tr>
<tr>
<td>Time and Location 1</td>
</tr>
<tr>
<td>Surface current speed(s)</td>
</tr>
<tr>
<td>Surface current direction(s)</td>
</tr>
<tr>
<td>Time and Location 2</td>
</tr>
<tr>
<td>Surface current speed(s)</td>
</tr>
<tr>
<td>Surface current direction(s)</td>
</tr>
</tbody>
</table>

Figure F.6 – Schematic of the preliminary product data set. The product can represent either a time series
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.

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. SAMPLE HDF-5 ENCODING

The following are examples of HDF5 files data for each of the four data coding formats. The general structure of the data product is shown in Figure 10.2, and the specific variables contained in the attributes is explained in Tables 12.1, 12.2, and 12.3. The sample files were produced by Matlab® and were displayed in HDFView.

G.1 Stationary Platform (dataCodingFormat=1)

Figure G.1 – Screen-capture image showing (left side) the overall structure of the HDF5 file, and (right side) the Group_F SurfaceCurrent attributes (top panel) (see Table 10.3), the Group_F SurfaceCurrent feature code (middle panel) and the SurfaceCurrent axisNames (bottom panel).

Figure G.2 – Compound array values for speed and direction in Group_001 (top panel) and the longitudes and latitudes in the group Positioning (bottom panel).
Figure G.3 – Images showing attributes in the Root directory (top panel) and attributes for the group SurfaceCurrent (bottom panel).
Figure G.4 – Image showing attributes in the instance group SurfaceCurrent.01 (top panel) and attributes in the group Group_001 (bottom panel).

G.2 Regular Grid (dataCodingFormat=2)

Figure G.5 – Image showing (left side) the structure of the file and (right side) the two-dimensional compound array of values for regularly gridded data.
Figure G.6 - Images showing attributes in the Root directory (top panel) and attributes for the group SurfaceCurrent (bottom panel).
Figure G.7 – Images showing attributes for the group SurfaceCurrent.01 (top panel) and in the instance group Group_001 (bottom panel).
G.3 Ungeorectified Grid (dataCodingFormat=3)

Figure G.8 – Image showing (left side) the structure of the file, and (right side) the one-dimensional compound array of values for ungeorectified gridded data (top panel) and the data in the group Positioning (bottom panel).
Figure G.9 - Images showing attributes in the Root directory (top panel) and attributes for the group SurfaceCurrent (bottom panel).
Figure G.10 – Images showing attributes for the group SurfaceCurrent.01 (top panel) and in the instance group Group_001 (bottom panel).

G.4 Moving Platform (dataCodingFormat=4)

Figure G.11 – Image showing (left side) the structure of the file, and (right side) the one-dimensional compound array of values for ungeorectified gridded data (top panel) and the data in the group Positioning (bottom panel).
Figure G.12 - Images showing attributes in the Root directory (top panel) and attributes for the group SurfaceCurrent (bottom panel).
Figure G.13 – Images showing attributes for the group SurfaceCurrent.01 (top panel) and in the instance group Group_001 (bottom panel).
ANNEX H. COLOUR TABLES

Below are the colour tables for the day, dusk, and night conditions. The estimates for dusk and night were obtained by first converting the values for RGB colours for day conditions (Clause 9.2.3) to xyL values, where L is luminance. Existing xyL data for dusk and night conditions for approximately 50 colors from S-52 (S-52 Presentation Library Edition 4.0.0, Part 1, Appx. A) demonstrate that luminance is reduced while the x and y values (mostly) remain constant. For each S-111 colour, the closest S-52 colour for day conditions (based on the x and y values) was then found, and that colour’s luminance reduction factors for other conditions were used to calculate the xyL values. Finally, the new xyL values were converted back to RGB.

Table H.1 – Colour parameters for DAY conditions for each speed band.

<table>
<thead>
<tr>
<th>Band</th>
<th>Token</th>
<th>Colour</th>
<th>x</th>
<th>y</th>
<th>L</th>
<th>R</th>
<th>G</th>
<th>B</th>
<th>RGB Hex</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCBN1</td>
<td>purple</td>
<td>0.21</td>
<td>0.14</td>
<td>15</td>
<td>118</td>
<td>82</td>
<td>226</td>
<td>7652E2</td>
</tr>
<tr>
<td>2</td>
<td>SCBN2</td>
<td>dark blue</td>
<td>0.21</td>
<td>0.24</td>
<td>29</td>
<td>72</td>
<td>152</td>
<td>211</td>
<td>4898D3</td>
</tr>
<tr>
<td>3</td>
<td>SCBN3</td>
<td>light blue</td>
<td>0.23</td>
<td>0.29</td>
<td>51</td>
<td>97</td>
<td>203</td>
<td>229</td>
<td>61CB5E</td>
</tr>
<tr>
<td>4</td>
<td>SCBN4</td>
<td>dark green</td>
<td>0.33</td>
<td>0.52</td>
<td>40</td>
<td>109</td>
<td>188</td>
<td>69</td>
<td>6D8C45</td>
</tr>
<tr>
<td>5</td>
<td>SCBN5</td>
<td>light green</td>
<td>0.39</td>
<td>0.53</td>
<td>61</td>
<td>180</td>
<td>220</td>
<td>0</td>
<td>B4DC00</td>
</tr>
<tr>
<td>6</td>
<td>SCBN6</td>
<td>yellow-green</td>
<td>0.43</td>
<td>0.50</td>
<td>51</td>
<td>205</td>
<td>193</td>
<td>0</td>
<td>CDC100</td>
</tr>
<tr>
<td>7</td>
<td>SCBN7</td>
<td>orange</td>
<td>0.49</td>
<td>0.45</td>
<td>48</td>
<td>248</td>
<td>167</td>
<td>24</td>
<td>F8A718</td>
</tr>
<tr>
<td>8</td>
<td>SCBN8</td>
<td>pink</td>
<td>0.40</td>
<td>0.33</td>
<td>48</td>
<td>247</td>
<td>162</td>
<td>157</td>
<td>F7A29D</td>
</tr>
<tr>
<td>9</td>
<td>SCBN9</td>
<td>red</td>
<td>0.64</td>
<td>0.33</td>
<td>21</td>
<td>255</td>
<td>30</td>
<td>30</td>
<td>FF1E1E</td>
</tr>
</tbody>
</table>

Table H.2 – Colour parameters for DUSK conditions for each speed band.

<table>
<thead>
<tr>
<th>Band</th>
<th>Token</th>
<th>Colour</th>
<th>x</th>
<th>y</th>
<th>L</th>
<th>R</th>
<th>G</th>
<th>B</th>
<th>RGB Hex</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCBN1</td>
<td>purple</td>
<td>0.21</td>
<td>0.14</td>
<td>7</td>
<td>81</td>
<td>55</td>
<td>159</td>
<td>51379E</td>
</tr>
<tr>
<td>2</td>
<td>SCBN2</td>
<td>dark blue</td>
<td>0.21</td>
<td>0.24</td>
<td>3</td>
<td>20</td>
<td>52</td>
<td>76</td>
<td>14344C</td>
</tr>
<tr>
<td>3</td>
<td>SCBN3</td>
<td>light blue</td>
<td>0.23</td>
<td>0.29</td>
<td>1</td>
<td>6</td>
<td>24</td>
<td>29</td>
<td>06181C</td>
</tr>
<tr>
<td>4</td>
<td>SCBN4</td>
<td>dark green</td>
<td>0.33</td>
<td>0.52</td>
<td>13</td>
<td>64</td>
<td>114</td>
<td>39</td>
<td>3F7126</td>
</tr>
<tr>
<td>5</td>
<td>SCBN5</td>
<td>light green</td>
<td>0.39</td>
<td>0.53</td>
<td>21</td>
<td>110</td>
<td>136</td>
<td>0</td>
<td>6E8700</td>
</tr>
<tr>
<td>6</td>
<td>SCBN6</td>
<td>yellow-green</td>
<td>0.43</td>
<td>0.50</td>
<td>18</td>
<td>126</td>
<td>119</td>
<td>0</td>
<td>7E7600</td>
</tr>
<tr>
<td>7</td>
<td>SCBN7</td>
<td>orange</td>
<td>0.49</td>
<td>0.45</td>
<td>15</td>
<td>147</td>
<td>97</td>
<td>1</td>
<td>936100</td>
</tr>
<tr>
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<td>SCBN8</td>
<td>pink</td>
<td>0.40</td>
<td>0.33</td>
<td>5</td>
<td>86</td>
<td>53</td>
<td>51</td>
<td>553533</td>
</tr>
<tr>
<td>9</td>
<td>SCBN9</td>
<td>red</td>
<td>0.64</td>
<td>0.33</td>
<td>9</td>
<td>178</td>
<td>1</td>
<td>1</td>
<td>B10101</td>
</tr>
</tbody>
</table>

Table H.3 – Colour parameters for NIGHT conditions for each speed band.

<table>
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<th>Band</th>
<th>Token</th>
<th>Colour</th>
<th>x</th>
<th>y</th>
<th>L</th>
<th>R</th>
<th>G</th>
<th>B</th>
<th>RGB Hex</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCBN1</td>
<td>purple</td>
<td>0.21</td>
<td>0.14</td>
<td>1</td>
<td>26</td>
<td>15</td>
<td>59</td>
<td>190F3A</td>
</tr>
<tr>
<td>2</td>
<td>SCBN2</td>
<td>dark blue</td>
<td>0.21</td>
<td>0.24</td>
<td>1</td>
<td>4</td>
<td>17</td>
<td>28</td>
<td>03101B</td>
</tr>
<tr>
<td>3</td>
<td>SCBN3</td>
<td>light blue</td>
<td>0.23</td>
<td>0.29</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>010607</td>
</tr>
<tr>
<td>4</td>
<td>SCBN4</td>
<td>dark green</td>
<td>0.33</td>
<td>0.52</td>
<td>2</td>
<td>19</td>
<td>40</td>
<td>8</td>
<td>122708</td>
</tr>
<tr>
<td>5</td>
<td>SCBN5</td>
<td>light green</td>
<td>0.39</td>
<td>0.53</td>
<td>3</td>
<td>38</td>
<td>49</td>
<td>0</td>
<td>263000</td>
</tr>
<tr>
<td>6</td>
<td>SCBN6</td>
<td>yellow-green</td>
<td>0.43</td>
<td>0.50</td>
<td>2</td>
<td>45</td>
<td>42</td>
<td>0</td>
<td>2C2900</td>
</tr>
<tr>
<td>7</td>
<td>SCBN7</td>
<td>orange</td>
<td>0.49</td>
<td>0.45</td>
<td>2</td>
<td>54</td>
<td>33</td>
<td>0</td>
<td>352000</td>
</tr>
<tr>
<td>8</td>
<td>SCBN8</td>
<td>pink</td>
<td>0.40</td>
<td>0.33</td>
<td>1</td>
<td>33</td>
<td>17</td>
<td>17</td>
<td>201110</td>
</tr>
<tr>
<td>9</td>
<td>SCBN9</td>
<td>red</td>
<td>0.64</td>
<td>0.33</td>
<td>1</td>
<td>63</td>
<td>0</td>
<td>0</td>
<td>3F0000</td>
</tr>
</tbody>
</table>
ANNEX I. SCALABLE VECTOR GRAPHICS (SVG) CODING

The following shows a sample XML file for creating a layer with surface current arrows, along with a sample figure showing the arrows, and the Cascading Style Sheet (.CSS) file.

NOTE: symbol and colour names in the following examples are for illustration only; the final names and instructions in the Portrayal Catalogue may be different.

I.1 Sample SVG Image

A sample image showing the vector arrows generated by the SVG and CSS codes appears in Figure I.1. The image was created by opening the file in Microsoft Internet Explorer©.

I.2 Sample SVG File to Display Arrows

The sample .svg file shown describes a screen measuring 200 mm wide by 130 mm high. The basic arrows are 10 mm high, and are rotated clockwise by a certain number of degrees to show the current direction. They are also translated in the x- and y-directions by a number of mm to show position, and scaled in length to denote speed relative to the reference speed. The color is denoted by the fstep parameter (see the .css file).

```xml
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet href="SVGStyle_S111.css" type="text/css"?>
<svg xmlns="http://www.w3.org/2000/svg" version="1.2" baseProfile="tiny"
     xml:space="preserve" style="shape-rendering:geometricPrecision; fill-rule:evenodd;"
```
Below is the .css file used in the above display.

```
.layout {display:inline} /* used to control visibility of symbolBox, svgBox, pivotPoint (none or inline) */
.symbolBox {stroke:none;stroke-width:0.03;} /* show the cover of the symbol graphics */
.svgBox {stroke:none;stroke-width:0.01;} /* show the entire SVG cover */
.pivotPoint {stroke:none;stroke-width:0.01;} /* show the pivot/anchor point, 0,0 */
.sl {stroke-linecap:round;stroke-linejoin:round} /* default line style elements */
.f0 {fill:none} /* no fill */
.sSTEP1 {stroke:#7652E2} /* sRGB line colour for colour token STEP1: S111 Step 1 color */
.fSTEP1 {fill:#7652E2} /* sRGB line colour for colour token STEP1: S111 Step 1 color */
.sSTEP2 {stroke:#4898D3} /* sRGB line colour for colour token STEP2: S111 Step 2 color */
.fSTEP2 {fill:#4898D3} /* sRGB line colour for colour token STEP2: S111 Step 2 color */
.sSTEP3 {stroke:#61CBE5} /* sRGB line colour for colour token STEP3: S111 Step 3 color */
.fSTEP3 {fill:#61CBE5} /* sRGB line colour for colour token STEP3: S111 Step 3 color */
.sSTEP4 {stroke:#6DCBA5} /* sRGB line colour for colour token STEP4: S111 Step 4 color */
.fSTEP4 {fill:#6DCBA5} /* sRGB line colour for colour token STEP4: S111 Step 4 color */
.sSTEP5 {stroke:#B4DC00} /* sRGB line colour for colour token STEP5: S111 Step 5 color */
.fSTEP5 {fill:#B4DC00} /* sRGB line colour for colour token STEP5: S111 Step 5 color */
.sSTEP6 {stroke:#CD1C00} /* sRGB line colour for colour token STEP6: S111 Step 6 color */
.fSTEP6 {fill:#CD1C00} /* sRGB line colour for colour token STEP6: S111 Step 6 color */
.sSTEP7 {stroke:#F8A718} /* sRGB line colour for colour token STEP7: S111 Step 7 color */
.fSTEP7 {fill:#F8A718} /* sRGB line colour for colour token STEP7: S111 Step 7 color */
.sSTEP8 {stroke:#F7A29D} /* sRGB line colour for colour token STEP8: S111 Step 8 color */
.fSTEP8 {fill:#F7A29D} /* sRGB line colour for colour token STEP8: S111 Step 8 color */
.sSTEP9 {stroke:#FF1E1E} /* sRGB line colour for colour token STEP9: S111 Step 9 color */
.fSTEP9 {fill:#FF1E1E} /* sRGB line colour for colour token STEP9: S111 Step 9 color */
```
ANNEX J. SURFACE CURRENT PORTRAYAL RULES

J.1 Introduction

This section summarizes the rules and formulae discussed in SECTION 9 – PORTRAYAL for display of the surface current arrow symbol. The placement of the color scale and the pick report boxes are not discussed.

The surface current feature is characterized by (1) a speed (knots) and (2) a direction (arc-degrees clockwise from north). Speed values are given to the nearest 0.01 knot, and direction values to the nearest 0.1 arc-deg. The speed and direction values are stored in the HDF file as a dataset (DS). The current speed and direction values are applicable to a specific geographic location, denoted by (1) a longitude (arc-degrees) and (2) a latitude (arc-degrees). The current is valid for a specific depth, or as a vertical average over a depth. The the depth and datum, or the averaging depth, are given in the Carrier Metadata. The current is also valid for a specific date and time, the values of which are given either as an attribute of the DS (a time stamp) or must be calculated using the time of the first value, the length of time interval, and the number in the series.

J.2 The Surface Current Symbol

Rule 1. The basic symbol for SVG is as shown in Figure J.1. The nominal height of the symbol is 10.0 mm.

![Surface current arrow symbol, showing x- and y-coordinates of the vertices (mm) and the pivot point (+).](image)
Rule 2. A null value for speed and direction (see Table 12.1, gridLandMaskValue) means that the point represents land, or the value is missing. In either case, no arrow symbol is displayed.

Rule 3. The colour of the arrow is set by the band within which the speed falls. The colours for nine speed bands are shown in Table J.1.

NOTE 1: Within any speed band, the lower speed is given as the Minimum Speed in Table J.1, and the upper speed is just less that the Minimum Speed in the next higher band. Therefore in Band 2,

\[ 0.5 \leq \text{speed in band 2} < 1.0 \]  \hspace{1cm} \text{[Eqn. J.1]}  

NOTE 2: As an option, the speed bands may be adjusted to provide more colour contrast. For example, to emphasize lower speeds, the bands 3 and 4 could be 1.00 to 01.50 and 1.50 to 2.00. Of course, in this example, the minimum speed for band 5 would have to be reduced to 2.00 to maintain coverage for all speeds.

Table J.1 - Speed bands, colour names, RGB colour values, and resulting day colours for current speeds.

<table>
<thead>
<tr>
<th>Speed Band</th>
<th>Min Speed (kn)</th>
<th>Speed Speed Width (kn)</th>
<th>Colour</th>
<th>Colour Scale Intensity</th>
<th>Displayed Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Red</td>
<td>Green</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.5</td>
<td>purple</td>
<td>118</td>
<td>82</td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>0.5</td>
<td>dark blue</td>
<td>72</td>
<td>152</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>1.0</td>
<td>light blue</td>
<td>97</td>
<td>203</td>
</tr>
<tr>
<td>4</td>
<td>2.00</td>
<td>1.0</td>
<td>dark green</td>
<td>109</td>
<td>188</td>
</tr>
<tr>
<td>5</td>
<td>3.00</td>
<td>2.0</td>
<td>light green</td>
<td>180</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>5.00</td>
<td>2.0</td>
<td>yellow-green</td>
<td>205</td>
<td>193</td>
</tr>
<tr>
<td>7</td>
<td>7.00</td>
<td>2.0</td>
<td>orange</td>
<td>248</td>
<td>167</td>
</tr>
<tr>
<td>8</td>
<td>10.00</td>
<td>3.0</td>
<td>pink</td>
<td>247</td>
<td>162</td>
</tr>
<tr>
<td>9</td>
<td>13.00</td>
<td>99.0</td>
<td>red</td>
<td>255</td>
<td>30</td>
</tr>
</tbody>
</table>

Rule 4. Colours for dusk and night are given in ANNEX H – COLOUR TABLES.

Rule 5. There is a separate symbol for each speed band. Each symbol has a unique colour.

J.3 Symbol Size and Orientation

Rule 6. The size of the arrow symbol is scaled in proportion to the current speed. The height of the arrow, \( H \) (mm), is a function of the speed of the current, \( S \) (knots). Allowances are made to (a) display a small symbol even if the speed to near zero and (b) enforce a maximum arrow size. The scaling relationship is:

\[ H = H_{\text{ref}} \cdot \min\{\max(S_{\text{low}}, S), S_{\text{high}}\}/S_{\text{ref}}. \]  \hspace{1cm} \text{[Eqn. J.2]}
The following table gives the nominal values for the four constants.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
<th>Recommended Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_{\text{ref}}$</td>
<td>Reference height for arrow scaling</td>
<td>10 mm</td>
</tr>
<tr>
<td>$S_{\text{ref}}$</td>
<td>Reference speed for arrow scaling</td>
<td>5 kn</td>
</tr>
<tr>
<td>$S_{\text{low}}$</td>
<td>Minimum speed to be used for arrow length computations</td>
<td>0.01 kn</td>
</tr>
<tr>
<td>$S_{\text{high}}$</td>
<td>Maximum speed to be used for arrow length computations</td>
<td>13 kn</td>
</tr>
</tbody>
</table>

**Rule 7.** The arrow is rotated to show the direction of current using the value for direction (Figure J.2).

![Figure J.2](image)

Figure J.2. 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. True north has a direction of 0 degrees.

**J.4 Placement of the Symbol**

**Rule 8.** The surface current arrow is placed in the display so that the pivot point corresponds to the given values of longitude and latitude.

**Rule 9.** The HO must insure that the pivot point shall not be located over land. That a portion of the arrow symbol lies over land is acceptable.

**Rule 10.** The HO must insure that if the arrow’s pivot point lies in a geographic area designated as intertidal, then when the time-varying water depth has gone to zero the symbol is not displayed.

**J.5 Thinning of a Field of Arrows**

Displaying at a low resolution (i.e., zooming out) increases the density of symbols. However, by applying a thinning algorithm, vector symbol overlap can be reduced. The algorithm discussed below works for regularly gridded data only.
Suppose that the grid cell has a width of $gridSpacingLongitudinal$ and height of $gridSpacingLatitudinal$ (see Table 12.1), and has a diagonal distance of $D$ mm. Note that $D$ is dependent on the map scale of the display. Also suppose that the height of the arrow symbol for the maximum speed in the display area is $H_{\text{max}}$.

**Suggested Rule 1**. For thinning regularly gridded data, 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. With a $R_{\text{max}}$ value of 0.5,

$$n = 1 + \text{fix}\{H_{\text{max}}/(0.5D)\}$$  \hspace{1cm} [Eqn. J.3]

**Suggested Rule 12**. For thinning non-regularly spaced data, a potential solution would be to reduce the reference height $H_{\text{ref}}$ or increase the reference speed $S_{\text{ref}}$ (Table J.2).

**J.6 Temporal Rules**

Let $T_s$ be the time selected by the user or the ENS for display of data, and let $T_E$ be equal to $dateTimeOfLastRecord + timeRecordInterval$.

**Rule 13a.** If $T_s$ is *earlier* than the timestamp of the first data in the series, $dateTimeOfFirstRecord$, no arrows are displayed.

**Rule 13b.** If $T_s$ is *later* than $T_E$, no arrows are displayed.

**Rule 13c.** If $T_s$ is *later* than the first timestamp and *earlier* than $T_E$, then the arrows for the data are plotted if the timestamp is (a) later than $T_s$, but (b) less than $T_s + timeRecordInterval$. 