S-111

Surface Currents Product Specification

Edition 2.0.0-20240212

IHO

International Hydrographic Organization

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Document History

Changes to this Specification are coordinated by the Tides, Water Levels and Currents Working Group (TWCWG). New editions will be made available via the IHO web site. Maintenance of the Specification shall conform to IHO Resolution 2/2007 (as amended).

Version Number	Date	Author/Editor	Purpose
Draft 1.0	December 2012	D. O'Brien, Auth.	Demonstration Version.
Draft 1.1	April 2014	L. Maltais, Ed.	Revision for currents.
Draft 1.2	August 2014	L. Maltais, Ed	Additional revision of previous version.
Draft 1.3	December 2014	L. Maltais, Ed	Additional revision of previous version.
Draft 1.4	March 2015	L. Maltais, Ed	Additional revision of previous version.
Draft 1.5	March 2015	K. Hess, B. Sullivan, C. Kammerer, E. Mong, Eds.	Put into template format, numerous changes.
Draft 1.6	September 2015	SCWG members, Eds.	Changes as result of SCWG3 discussions.
Draft 1.7	December 2015	K. Hess, Ed.	Changes per review of Draft 1.6.
Draft 1.8	February 2016	K. Hess, Ed.	Changes per review of Draft 1.7.
Draft 1.9	September 2016	K. Hess, TWCWG members, Eds.	Changes as result of TWCWG1 discussions.
Draft 1.10	January 2017	K. Hess, TWCWG members, Eds.	
Draft 1.11	October 2017	K. Hess, TWCWG members, Eds.	Changes as result of TWCWG2 discussions.
Draft 1.12	April 2018	K. Hess, TWCWG, DQWG members, Eds.	Changes per review of v1.11.
Edition 1.0.0	December 2018	K. Hess, TWCWG, Eds.	Changes per review of v1.12 and TWCWG3.
Edition 1.0.1	June 2019	K, Hess, TWCWG, Eds.	Changes per TWCWG, review of test HDF5 files.
Edition 1.1.0	September 2020	K, Hess, TWCWG, Eds	Edits after JPN, others review. Use enumerations in Tables 12.1, 12.2, 12,3. Add dataCodingFormat=8.
Edition 1.1.1	February 2021	G. Seroka, TWCWG, Eds.	
Edition 1.2.0-20220831	August 2022	R. Malyankar	Aligned with S-100 5.0.0; harmonized document structure and content with S-104 1.1.0 (Aug. 2022); new enumeration dictionary material

Edition 1.2.0-20230131	February 2023	R. Malyankar, G. Seroka	Added attribute surfaceCurrentTime for DCF 8; specified datatype size for HDF5 attributes; harmonized structure and text with S-104 1.1.0; updated references; updated rules for dataset and support file names; guidance on (optional) ISO metadata; adjusted language on use of Schematron and digital signatures; added emphasis for differences between S-100 and S-111 exchange catalogues; added productIdentifier metadata attribute; new remarks for depth type index; clarification of attribute dimension in feature type metadata; added Res. 3/1919 as a separate reference; harmonized attribute multiplicity and remarks with S-104 in feature instance metadata (Tables 12.3, 12.4). Figures in Annex E removed.
Edition 1.2.0	April 2023	R. Malyankar	Removed DCF4 from DCEG remarks for surface current time; added remark for number of times attribute in values table overriding similar instance attribute; corrected S-100 error in digital signature types in metadata; applied feedback from TWCWG.

Edition 2.0.0-20240212	February 2024	R. Malyankar	Provide for non-uniform time series with moving platforms (DCF4); update references; registry producer code URL replaced with main page URL; citation of S-100 WG7 paper removed and usage sentences updated (register is now active in the GI registry); date fill value updated (table 10.3); Annex B (add. Terms) removed, selected terms added in 1.4; deleted 4.5.3 (summary of ISO/S-100 spatial types); added new WGS84 realizations and UTM codes (clause 5); aligned to S-100 5.2.0 (esp. Parts 17, 15, 8); added verticalCoordinateBase embedded metadata for S-100 consistency; updated validation check Annex for consistency with S-100 validation group; added information about digital signatures; added material on producing series datasets (7.4); clarifications for S-98 compliance (7.7); fileless cancellation (8.4); increased minimum speed in size formula for portrayal; guidelines for portrayal of time series point data and ungeorectified grids; updated portrayal catalogue structure (9.9); new fill value for date-time attribute; described encoding for optional data value attributes; removed ISO metadata files; added restriction on length of string attributes in metadata (12.3); added use case (Annex F); added paragraph about propelled platforms (G-4); new sample SVG (for new 5.2.0 SVG schema); added tabular pick report outline (J-7); updated UML diagrams.

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FOREWORD

The International Hydrographic Organization Tides, Water Level and Currents Working Group (TWCWG) remembers Kurt Hess, and acknowledges his invaluable and significant contributions in developing this Product Specification within the TWCWG.

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

The S-111 Product Specification describes the feature *Surface Current* and its two attributes *Surface Current Speed* and *Surface Current Direction* (see 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 sea surface (that is, air-sea interface) down to a given depth. The 'surface' (in the definition of Surface Current) is defined here as roughly the top 25 metres. The current values are obtained through in situ or remote measurement or by analytic methods or hydrodynamic modelling. The Product Specification 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.

1.1.1 Data types

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. Therefore, a Grid Coverage is appropriate for this type of data. 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 (for example 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.

1.1.2 Display

This Product Specification describes one way of displaying surface current information, as an arrow shape pointing in the direction of current flow whose colour and size are determined by the velocity of the current. This arrow shape is used by both gridded and point data types. For gridded data, the symbol is placed at the points constituting the grid and represents the speed and direction of currents at the grid point.

1.1.3 Encoding

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

HDF5	*Hierarchical Data Format version 5* – www.hdfgroup.org
M-3	*Resolutions of the International Hydrographic Organization, IHO Publication M-3,* 2nd Edition, 2010 (updated July 2023)
Res. 3/1919	IHO Resolution 3/1919 (as amended), IHO Publication M-3
S-44	*IHO Standards for Hydrographic Surveys,* 6th Edition, September 2020
S-62	List of Data Producer Codes (online), IHO GI registry, URL: https://registry.iho.int
S-97	*IHO Guidelines for Creating S-100 Product Specifications*, Edition 1.1.0, June 2020
S-98	*Data Product Interoperability in S-100 Navigation Systems*, Edition 1.1.0, September 2024 (in preparation)
S-100	*IHO Universal Hydrographic Data Model*, Edition 5.2.0, June 2024
S-158	S-100 Validation Checks (in preparation)

1.3.2 Informative

CO-OPS	*Tide and Current Glossary 2000*
IALA G1143	*Unique Identifiers for Maritime Resources, Edition 3.0.* International Association of Marine Aids to Navigation and Lighthouse Authorities, June 2021.
IOC 14-4	*Manual on Sea-level Measurements and Interpretation, Volume IV : An update to 2006.* Paris, Intergovernmental Oceanographic Commission of UNESCO. (IOC Manuals and Guides No.14, vol. IV; JCOMM Technical Report No.31; WMO/TD. No. 1339).
ISO 3166-1:1997	*Country Codes*
ISO 8601:2004	*Data elements and interchange formates - Information interchange - Representation of dates and times.* 2004
ISO 19101:2002	*Geographic information - Reference model.* 2002
ISO/TS 19103:2005	*Geographic information – Conceptual schema language*
ISO 19105:2000	*Geographic information - Conformance and testing.* 2000
ISO 19107:2003	*Geographic information - Spatial schema.* 2003
ISO 19108:2002	*Geographic information - Temporal schema.* 2002
ISO 19109:2005	*Geographic information - Rules for application schema.* 2005
ISO 19110:2005	*Geographic information - Methodology for feature cataloguing.* 2005
ISO 19111:2003	*Geographic information – Spatial referencing by coordinates*
ISO 19113:2002	*Geographic information - Quality principles.* 2002
ISO 19115-1	*Geographic information – Metadata – Part 1 – Fundamentals*. As amended by Amendment 1, 2018
ISO 19115-2:2009	*Geographic information – Metadata: Extensions for imagery and gridded data*
ISO 19115-3	*Geographic information – Metadata - XML schema implementation for fundamental concepts*. 2016
ISO 19116:2004	*Geographic information - Positioning services.* 2004
ISO 19117:2005	*Geographic information - Portrayal.* 2005
ISO 19118:2005	*Geographic information - Encoding.* 2005

ISO 19123:2005 *Geographic information – Schema for coverage geometry and functions*

ISO 19128:2005 *Geographic information - Web Map Server interface.* 2005

ISO 19129:2009 *Geographic information – Imagery gridded and coverage data framework*

ISO/TS 19130:2010 *Geographic information - Imagery sensor models for geopositioning.* 2010

ISO/TS 19130-2:2010 *Geographic information - Imagery sensor models for geopositioning - Part 2.* 2010

ISO 19131:2007 *Geographic information – Data product specifications*

ISO 19132:2007 *Geographic information - Location-based services – Reference model.* 2007

ISO 19133:2005 *Geographic Information - Location-based services - Tracking and navigation.* 2005

ISO 19136:2007 *Geographic information - Geography Markup Language (GML).* 2007

ISO/TS 19138:2006 *Geographic information - Data quality measures.* 2006

ISO 19142:2010 *Geographic information - Web Feature Service.* 2010

ISO 19144-1:2009 *Geographic information - Classification systems – Part 1: Classification system structure.* 2009

ISO 19145:2010 *Geographic information - Registry of representations of geographic point location.* 2010

ISO 19153:2010 *Geographic information - Geospatial Digital Rights Management Reference Model (GeoDRM RM) 1).* 2010

ISO 19156:2010 *Geographic information - Observations and measurements.* 2010

ISO 19157:2013 *Geographic information – Data Quality.* As amended by Amendment 1, 2018

ISO 19158:2010 *Geographic Information - Quality assurance of data supply.* 2010

ISO/IEC 19501-1 and 19505-2, *Information technology — Open Distributed Processing – Unified Modelling Language Version 2.4.1*

netCDF *Network Common Data Form Unidata* - www.unidata.ucar.edu/software/netcdf

NGA 2021 *Recent Update to WGS 84 Reference Frame and NGA Transition to IGS ANTEX*, NGA Office of Geomatics / GNSS Division, St. Louis, National Geospatial-Intelligence Agency, 2021.

NGA 2023 *WGS 84 (G2296) Terrestrial Reference Frame Realization*, Office of Geomatics, National Geospatial-Intelligence Agency, NGA-U-2023-02846, 2023.

RFC 3986 *Uniform Resource Identifier (URI): Generic Syntax. T. Berners-Lee, R. Fielding, L. Masinter. Internet Standard 66, IETF*. URL: http://www.ietf.org/rfc/rfc3986.txt or http://www.rfc-editor.org/info/std66

RFC 2141 *URN Syntax. R. Moats. IETF RFC 2141*, May 1997. URL: http://www.rfc-editor.org/info/rfc2141

S-101 *IHO Electronic Navigational Chart Product Specification*, Edition 2.0.0 (in preparation)

S-102 *IHO Bathymetric Surface Product Specification*, Edition 3.0.0 (in preparation)

S-104 *IHO Water Level Information for Surface Navigation Product Specification*, Edition 2.0.0, (in preparation)

Springer Handbook of Geographic Information. 2012.

Wikipedia *Wikipedia.* [Online]

XML Schema Part 2: *Datatypes*, Second Edition, W3C Recommendation, 28 October 2004, URL: https://www.w3.org/TR/xmlschema-2/

1.4 Terms, definitions and abbreviations

1.4.1 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.

accuracy
closeness of agreement between an observed value and the true value or a reference value accepted as true [ISO 19157, ISO 19116]

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

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

confidence level
the probability that the value of a parameter falls within a specified range of values

continuous coverage
coverage that returns different values for the same feature attribute at different direct positions within a single geometric object in its spatiotemporal domain [ISO 19123]

NOTE Although the spatiotemporal domain of a continuous coverage is ordinarily bounded in terms of its spatial extent, it can be subdivided into an infinite number of direct positions.

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

NOTE: In a **coordinate reference system**, the **coordinate** numbers are qualified by units.

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.

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.

coverage geometry
configuration of the **domain** of a **coverage** described in terms of **coordinates**

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.

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

dataset
identifiable collection of data [ISO 19115]

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 hardcopy map or chart may be considered a dataset.

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 [ISO 19111, ISO 19116]

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

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**

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.

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**.

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 Catalogue**, a **feature attribute** may include a value **domain** but does not specify **attribute** values for **feature** instances.

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**)

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***.

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

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**.

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

grid coordinates
sequence of two or more numbers specifying a position with respect to its location on a **grid**

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

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

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]

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**

point
zero-dimensional geometric primitive, representing a position

NOTE: The boundary of a point is the empty set [ISO 19107]

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

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

point set coverage
coverage function associated with point value pairs in 2 dimensions. [S-100]

NOTE: a coverage function is driven by a set of points (with X, Y position) together with a record of one or more values at that position.

portrayal
presentation of information to humans [ISO 19109, ISO 19117]

portrayal catalogue
collection of defined portrayals for a feature catalogue

NOTE: Content of a portrayal catalogue includes portrayal functions, symbols, and portrayal context. [ISO 19117]

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

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

NOTE: Portrayal context may influence the selection of portrayal functions and construction of symbols [ISO 19117]

portrayal function
function that maps geographic features to symbols

NOTE: Portrayal functions can also include parameters and other computations that are not dependent on geographic feature properties [ISO 19117]

portrayal 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]

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]

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

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

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

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.

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]

surface current
the horizontal motion of water at a navigationally significant **depth,** or the vertical average over a **depth,** represented as a velocity **vector** (that is, 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

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

timestamp
value of time at which an object's state is measured and recorded [ISO 19132]

uncertainty
the interval (u) about a given value (x) that will contain the true value (v) at a given **confidence level (CL).**

Thus, CL is the probability that $x - u \leq v \leq x + u$

NOTE: For practical purposes, the **confidence level** is taken to be 95% and the **uncertainty** is defined herein as either (a) twice the standard deviation of the differences between observed and predicted values (cf. S-44. *IHO Standards for Hydrographic Surveys*, 5th Edition, February 2008), or (b) the interval (that is, u) about the mean containing 95% of the differences.

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

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]

1.4.2 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
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 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.

1.6 General data product description

NOTE: This clause provides general information regarding the data product.

Title: Surface Currents

Abstract: Encodes information and parameters for use with surface current data.

Content: A conformant dataset may contain features associated with surface currents. The specific content is defined by the Feature Catalogue and the Application Schema.

Spatial Extent: **Description:** Global, marine areas only.
East Bounding Longitude: 180
West Bounding Longitude: -180
North Bounding Latitude: 90
South Bounding Latitude: -90

Purpose: The data shall be collected/produced for the purpose of providing information about navigationally significant surface currents to ECDIS and other applications.

1.7 Data Product Specification metadata and maintenance

1.7.1 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: Surface Currents

S-100 Version: 5.2.0

S-111 Version: 2.0.0

Date: 2024-06-30

Language: English

Classification: Unclassified

Contact: International Hydrographic Organization.
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Email: info@iho.int

Role: Owner

URL: https://registry.iho.int

Identifier: S-111

Maintenance: Changes to this Product Specification are coordinated by Tides, Water Level and Currents Working Group (TWCWG) of the IHO and made available via the IHO Publications website. Maintenance of the Product Specification must conform to IHO Technical Resolution 2/2007 (revised 2010). For reporting issues which need correction, use the contact information.

1.7.2 IHO Product Specification maintenance

1.7.2.1 Introduction

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

1.7.2.2 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.

1.7.2.3 Revision

Revisions are defined as substantive semantic changes to S-111. Typically, *revision*s 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.

1.7.2.4 Clarification

Clarifications are non-substantive changes to S-111. Typically, *clarifications*: remove ambiguity; correct grammatical and spelling errors; amend or update cross references; and insert improved graphics. 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.

1.7.2.5 Version numbers

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

New Editions denoted as **n**.0.0

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

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

2 Specification Scopes

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

Scope ID: Global

Level: 006 — series

Level name: Surface Current Dataset

3 Dataset Identification

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

Title: Surface Current Data Product

Alternate Title: None

Abstract: The data product is a file containing surface water current data for a particular geographic region and set of times, along with the accompanying metadata describing the content, variables, applicable times and locations, and structure of the data product. Surface current data includes speed and

direction of the current, and may represent observed or mathematically-predicted values. The data may consist of currents at a small set of points where observations and/or predictions are available, or may consist of numerous points organized in a grid as from a hydrodynamic model forecast. Measures of the quality of position, speed, direction, and time data are included.

Topic Category: Producing Authority to choose the most appropriate from the list below:

Concept Name	ISO 19115-1 Topic Category Number	ISO 19115-1 Topic Category Code	Definition	Remarks
Inland Waters	012	inlandWaters	Inland water features, drainage systems and their characteristics Examples: rivers and glaciers, salt lakes, water utilization plans, dams, currents, floods, water quality, hydrologic information	Use for datasets covering navigation on inland waterways
Oceans	014	oceans	Features and characteristics of salt water bodies (excluding inland waters) Examples: tides, tsunamis, coastal information, reefs	Use for datasets intended for coastal, offshore, or ocean navigation.
Transportation	018	transportation	Means and aids for conveying persons and/or goods Examples: roads, airports/airstrips, shipping routes, tunnels, nautical charts, vehicle or vessel location, aeronautical charts, railways	Use for datasets intended for navigation (inland or maritime)

Geographic Description: Areas specific to marine navigation

Spatial Resolution: Varies (for example, 0.1 km to 1000 km). The spatial resolution varies according to the model and the size of grid spacing, or on the number of observing locations adopted by the producer (Hydrographic Office)

Purpose: Surface current data are intended to be used as stand-alone data or as a layer in an ENC.

Language: English (mandatory)

Classification: Data can be classified as one of the following:

1) Unclassified;
2) Restricted;
3) Confidential;
4) Secret;
5) Top Secret;
6) Sensitive but Unclassified;
7) For Official Use Only;
8) Protected; or
9) Limited Distribution.

Spatial Representation Types: Coverage

Point of Contact: Producing Authority.

Use Limitation: Invalid over land. Some datasets may be designated as not for navigation.

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; and geometry.

Surface current data consist of one basic geographic feature type:

1. 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 (that is, one geographic location) or for an array of points. An optional time attribute is also provided for use with certain types of surface current information.

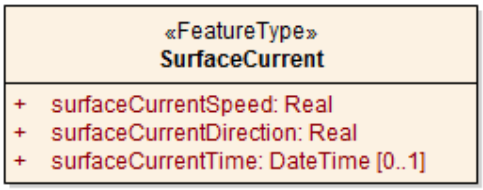


Figure 4.1 – SurfaceCurrent feature class

4.2 Application Schema

This Application Schema shall be expressed in UML. The single feature type, **SurfaceCurrent**, is depicted in Figure 4.1. The details of the Application Schema are given in Annex B, which also describes its relation to the conceptual model of coverage data described in ISO 19123 and S-100 Part 8.

4.3 Feature Catalogue

4.3.1 Introduction

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

The S-111 Feature Catalogue is available in an XML document which conforms to the S-100 XML Feature Catalogue Schema and can be downloaded from the IHO GI Registry 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. There are three common types of feature relationship: Association, Aggregation and Composition. In S-111 there are no relationships used.

4.3.4 Attributes

S-100 defines feature attributes as either simple or complex. In S-111 there are no complex attributes. S-111 uses two types of simple attributes, described in **Table 4-1**.

Table 4-1 – Simple feature attribute types

Type	Definition
Real	A signed Real (floating point) number consisting of a mantissa and an exponent
Date and Time	A DateTime is a combination of a date and a time type. Character encoding of a DateTime shall follow ISO 8601:1988 EXAMPLE 19850412T101530

4.3.5 Spatial quality

Spatial quality attributes (Figure 4-2) are encoded as horizontal and vertical uncertainty values. In S-100 Edition 5.2.0 they are encoded at the feature type level (see Figure 4-2 and Table 12-2), which means they apply uniformly to all **Surface Current** feature instances in the dataset and uniformly to all locations (grid points or station locations).

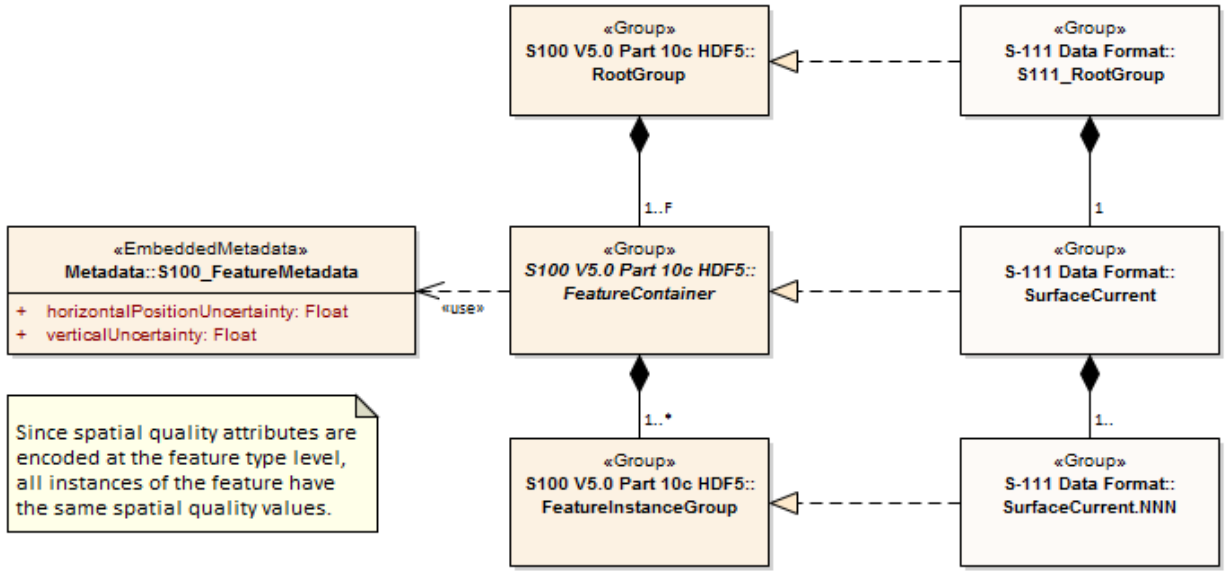


Figure 4-2 Spatial Quality

Note that uncertainty in currents pertains to the quality of data values, not to spatial quality as that term is used in S-100, and is encoded differently and at the instance level (see Table 10-2 and clause 10.2.2.4).

Surface currents are usually defined at one or more individual locations, so spatial quality applies to these locations. Individual uncertainty values apply uniformly to all spatial and temporal points.

NOTE: The **Spatial Quality** information type used in S-101 and other products is not used in this Edition of S-111 even for station-based data formats.

4.4 Dataset types

Datasets for S-111 include one basic type of dataset:

1. HDF5 files, which may contain: (a) time series of predicted or observed current velocities at one or more fixed stations; (b) gridded hydrodynamic model forecast fields; (c) values at multiple locations not in a regular grid (often from hydrodynamic models); or (d) time series of observed current velocities from one or more moving stations such as surface drifters.

4.5 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 (often from hydrodynamic models) 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_IF_PointCoverage and S100_IF_GridCoverage (S-100, Clause 8-7).

Grid Coverage: The class S100_IF_GridCoverage represents a set of values assigned to the points in a two-dimensional grid. The spatial structure is a regular grid, described by S100_IF_Grid (S-100 Edition 5.2.0, clause 8-7.5). The class S100_IF_Grid is a realization of CV_RectifiedGrid and CV_GridValuesMatrix from ISO 19123 and a component of ISO 19123 continuous quadrilatral grid coverages as realized by S100_IF_GridCoverage.

Point Coverage: The class S100_IF_PointCoverage represents a set of values, such as speed and direction values, assigned to a set of arbitrary X,Y points. The spatial structure is a point set described by s100_IF_PointSet. 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.

The types of data and their corresponding coverages are shown in Table 4-1.

Table 4-1 – Surface current data types and their coverages

N	Type of Data	Spatial Structure	Coverage
a	Time series data at one or more stationary locations	S100_IF_PointSet	S100_IF_PointCoverage
b	Regularly-gridded data at one or more times	S100_IF_Grid	S100_IF_GridCoverage
c	Ungeorectified gridded data or point set data at one or more times	S100_IF_PointSet	S100_IF_PointCoverage
d	Time series data for one moving platform	S100_IF_PointSet	S100_IF_PointCoverage

The spatial representations in S-111 are encoded using the implementation specification in S-100 Part 10c, which realises S-100 Part 8 and ISO 19123 conceptual models. The relationships are depicted in Figure 4-3 below.

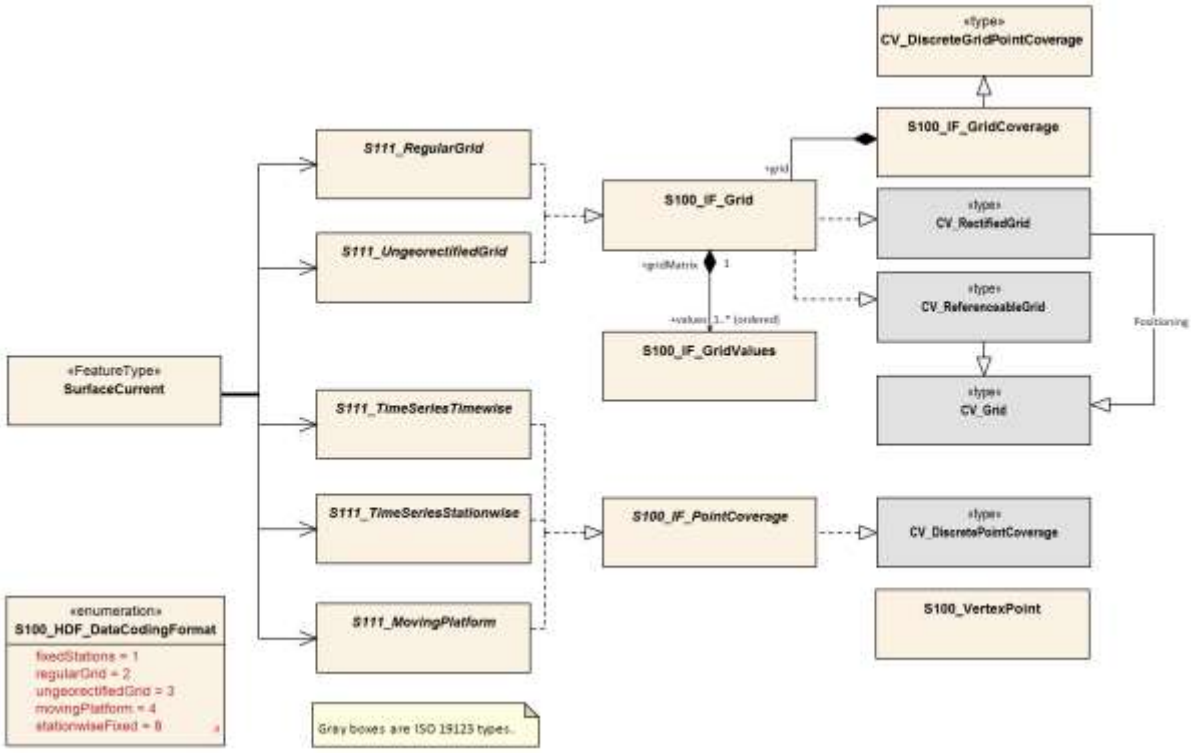


Figure 4-3 – Coverages and their realisation from S-100 Part 8 and ISO 19123

4.5.1 Regular grids

S-111 regular grid geometry is an implementation of S100_IF_Grid (S-100 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. Current speed and direction values apply at the vertices of the grid; that is, the intersections of the row and column lines. These parameters are explained in more detail below. A typical regular grid and some of its parameters are shown in Figure 4-4.

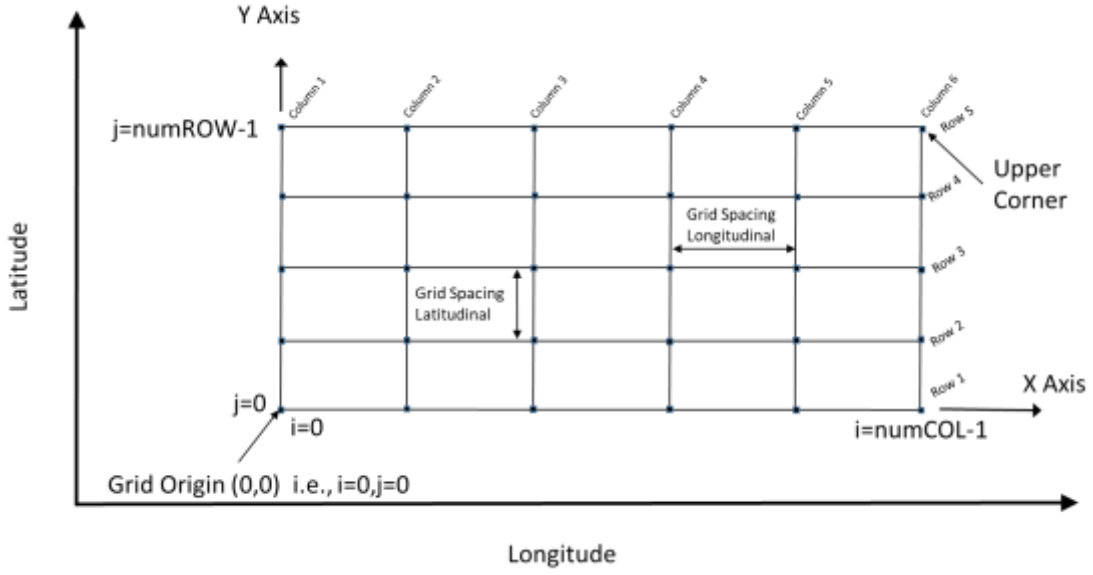


Figure 4-4 - Schematic of the regular grid and some of its attributes

Vertices are shown as the filled squares at the intersections of the rows and columns. 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 point at the lower left (southwest) extent of the grid. The upper corner is the north easternmost point in the grid. The attribute *dimension* is 2, and the variable *interpolationType* has the value of 'discrete', since there is no spatial interpolation used for surface currents.

S-111 grids allow for different spacing of points along the X (longitudinal) axis and the Y (latitudinal) 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 index values at 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. For example, if the number of rows is *numROWS* and the number of columns is *numCOLS*, then the index values for high would be '*numCOLS-1,numROWS-1'*. 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 all have the same dimensions, the cell index can be derived from the position of the Record within the sequence of Records. The attribute *sequencingRule* has two sub-attributes; *type* and *scanDirection*. The sub-attribute *type* carries the value "linear", and the sub-attribute *scanDirection* carries the value "X,Y". Together with the value "0,0" stored in the attribute *startSequence*, they indicate that for S-111 the grid values along the X axis at the lowest Y axis position are stored first, starting with the left most value going right, followed by the values along the X axis at the next increment upward along the Y axis, and so on till the top of the Y axis. The last value in the value sequence of the grid will be at the top rightmost position in the grid. In the Figure, first all columns in row 1 are selected, then all columns in row 2, and so on.

NOTE: since the origin is at *i_index* and *j_index* value 0, the location of any longitude and latitude in the grid is computed by:

$$Longitude = GridOriginLongitude + (i\_index)(gridSpacingLongitudinal). \quad \text{[Eqn 4.1]}$$

$$Latitude = GridOriginLatitude + (j\_index)(gridSpacingLatitudinal). \quad \text{[Eqn 4.2]}$$

4.5.2 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 4-5), 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 *gridSpacingLongitudinal* and *scanDirection* have no meaning. The position of the locations is carried in the one-dimensional arrays X and Y.

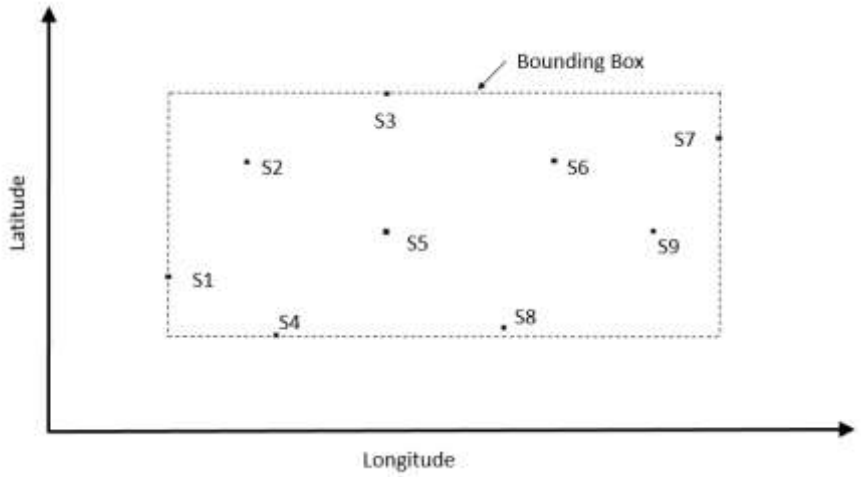


Figure 4-5 – Schematic of the Point Coverage and some of its attributes. Stations or nodes are denoted as "S1", etc

The points, which may represent fixed stations or nodes in an ungeorectified grid, appear as filled-in rectangles, are labelled and have a format such as 'S1'.

5 Coordinate Reference Systems (CRS)

To define the location of features using the S-100 Framework, one first needs to define a Coordinate Reference System (CRS). A Coordinate Reference System in two dimensions uses a coordinate pair, either X and Y for a Cartesian system or latitude and longitude for a geodetic/geographic system to define the location of a feature on a 2-D grid. However, if one wants to plot features in a 3-dimensional Coordinate Reference System, where we now want to include depths on a nautical chart or elevations on a map, one needs to assign the depth or elevation as the third component. For Cartesian systems, one would use X, Y, Z as the triplet or for geodetic/geographic systems, one would use latitude, longitude and height. The height can be the ellipsoid height or any of the other vertical references (see Vertical Reference System below). Geodetic/geographic coordinates are more intuitive for positioning and navigation applications on or near the Earth's surface while Cartesian coordinates are more appropriate if vectors are needed to accurately illustrate a graphical relationship between two or more points. If geodetic/geographic coordinates are specified, then the IHO recommends using the latest realisation of the World Geodetic System of 1984 (WGS 84).

5.1 Horizontal reference system

For products based on the S-100 Framework, including this Standard for S-111 products, the geodetic/geographic Coordinate Reference System must be of the form EPSG:xxxx (with WGS 84 as base datum). The generic form/code for the WGS 84 frame is EPSG:4326 while the latest and most widely adopted realisation of the WGS 84 reference frame as of 2022 was EPSG:9057. The full reference to EPSG can be found at https://epsg.org and other EPSG references for recent WGS 84 realisations are given below:

WGS 84 (generic)	ESPG:4326	
WGS 84(G2296)	(Not in EPSG registry at time of writing)	
WGS 84(G2139)	EPSG:9755	Valid epoch 2016:0
WGS 84(G1762)	EPSG:9057	Valid epoch 2005.0
WGS 84(G1674)	EPSG:9056	Valid epoch 2005.0
WGS 84(G1150)	EPSG:9055	Valid epoch 2001.0
WGS 84 / UTM Zone 1N to Zone 60N	EPSG:32601 – EPSG:32660	
WGS 84 / UTM Zone 1S to Zone 60S	EPSG:32701 – EPSG:32760	

WGS 84 / UPS North (E,N) EPSG:5041

WGS 84 / UPS South (E,N) EPSG:5042

Coordinate Reference System: EPSG:9057 (WGS 84) or another reference system listed above

Datum: WGS 84 defined by NGA

Projection: None / UTM / UPS

Horizontal Units: Decimal degrees / Easting and northing

Coordinate Reference System Registry: EPSG Geodetic Parameter Registry

Date type (according to ISO 19115-1): 002 - publication

Responsible party: International Association of Oil and Gas Producers (IOGP)

Producers of S-104 data must use the same projection as the underlying S-101 or S-102 dataset and should endeavour to use the same realisation.

5.2 Vertical reference system

For positioning and navigation applications, it is desirable to accurately plot depths, bathymetry, elevations and terrain on nautical charts and maps using one or more vertical reference systems. To do so, a vertical datum is defined and serves as a reference surface for vertical positions. Vertical datums come in three categories: 1) those based on Mean Sea Level (MSL); 2) tidal datums; and 3) 3-D datums (ellipsoid) which are realised through space-based systems such as GPS. Vertical datums can be regional (geoid, tidal, chart) or global (ellipsoid) in nature. The vertical axis of a vertical reference system is defined upwards (away from the Earth's centre) from its origin (EPSG code 6499) or downwards (EPSG code 6498) and is perpendicular to the horizontal surface where the observations or measurements are taken. As an example, a positive value for the level of water above the vertical datum in a vertical reference system with upward orientation (EPSG code 6499) means that the water level is above the vertical reference surface. For nautical charts, depths and tides are measured relative to a chart datum such as Lowest Astronomical Tide (LAT) or Mean Lower Low Water (MLLW).

Coordinate Reference System: Vertical component of a 3-D reference system

Datum: Chart, tidal, geoid, ellipsoid (WGS 84)

Projection: None

Horizontal Units: metres

Coordinate Reference System Registry: EPSG Geodetic Parameter Registry

Date type (according to ISO 19115-1): 002 - publication

Responsible party (vertical datums): National hydrographic and geodetic agencies

The vertical coordinate system is defined by three components. The first component defines the positive vertical direction (either an upward height or a downward depth). The second refers to the base or origin that is, the zero value) of the vertical coordinate; if the base is a tidal datum, the specific datum is defined from either the S-100 list of vertical datums (for example LAT, MLLW, MSL, etc) or the EPSG list. Finally the specific datum number from the appropriate list is given. The components are summarised in Table 5-1.

For surface currents, the vertical reference system would apply to currents at a specific depth/height relative to a vertical datum, but not to vertically-averaged currents; these are an average from the surface down to a given depth.

Table 5-1 – Attributes describing the vertical coordinate system

Name	Remarks
Vertical Coordinate System	EPSG Code; Allowed Values • 6498 (Depth – Metres – Orientation Down) • 6499 (Height – Metres – Orientation Up)
Vertical Datum Reference	1 – S-100 vertical datum 2 – EPSG

Vertical Datum	If verticalDatumReference = 1 this is a value from S100_VerticalAndSoundingDatum If verticalDatumReference = 2 this is an EPSG code for vertical datum

In S-111, the vertical datum is relevant only if the dataset encodes the nominal depth at which the current values are recorded or predicted. If this nominal depth is encoded, producers should endeavour to use a vertical datum consistent with the CRS in the underlying S-101 and S-102 datasets, except when the S-111 datum is in terms of water surface or sea bottom.

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 TM_Calendar dates and TM_Clock time in accordance with ISO 19108:2002, Temporal Schema clause 5.4.4. A date variable will have the following 8-character format (ISO 8601): *yyyymmdd*. A time variable will have the following 7-character format: *hhmmssZ*. A date-time variable will have the following 16-character format: *yyyymmddThhmmssZ*.

6 Data Quality

6.1 Introduction

6.1.1 Data quality metadata (informative)

The data quality information will list the following:

For Single station data product:

1) Sigma confidence of predictions/models; or
2) Instrument measuring accuracy for observed.

For Gridded data product:

1) Sigma confidence of predictions/model.

6.1.2 Data quality elements and data quality measures

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.

For S-111 the following Data Quality Elements have been included :

- Conformance to this Product Specification;
- Intended purpose of the data product;
- Completeness of the data product in terms of coverage;
- Logical Consistency;
- Positional Uncertainty and Accuracy;
- Thematic Accuracy;
- Temporal Quality;
- Aggregation measures;
- Validation checks or conformance checks including:
    - General tests for dataset integrity;
    - Specific tests for a specific data model.

Table 6-1 below indicates which of the data quality measures recommended in S-97 Part C have been identified as applicable to S-111. Columns 1-4 are taken as-is from S-97; the contents of column 5 are from S-97, annotated with whether the measure applies to S-111. Note that for attributes which allow fill values (see clause10.2) the presence of a fill value is not counted as an error for the purposes of the data quality measures.

1 **Table 6-1 – Quality measures applicable to S-111 (from S-97 Part C, clause 7)**

Data Quality Measure	Definition	DQ measure / description	Evaluation scope	S-111 Applicability
Completeness / Commission	Excess data present in a dataset, as described by the scope.	numberOfExcessItems / This data quality measure indicates the number of items in the dataset, that should not have been present in the dataset.	dataset/data set series	Yes (All S-100 based PS)
Completeness / Commission	Excess data present in a dataset, as described by the scope.	numberOfDuplicateFeatureInstances / This data quality measure indicates the total number of exact duplications of feature instances within the data.	dataset/data set series	Yes (All S-100 based PS)
Completeness / Omission	Data absent from the dataset, as described by the scope.	numberOfMissingItems / This data quality measure is an indicator that shows that a specific item is missing in the data.	dataset/data set series/spatial object type	Yes (All S-100 based PS) See clause 6.2 below
Logical Consistency / Conceptual Consistency	Adherence to the rules of a conceptual schema.	numberOfInvalidSurfaceOverlaps / This data quality measure is a count of the total number of erroneous overlaps within the data. Which surfaces may overlap and which must not is application dependent. Not all overlapping surfaces are necessarily erroneous.	spatial object / spatial object type	No (S111 does not define vector surface features) (Applies to PS with geometric surfaces)
Logical Consistency / Domain Consistency	Adherence of the values to the value domains.	numberOfNonconformantItems / This data quality measure is a count of all items in the dataset that are not in conformance with their value domain.	spatial object / spatial object type	Yes (All S-100 based PS)
Logical Consistency / Format Consistency	Degree to which data is stored in accordance with the physical structure of the dataset, as described by the scope.	physicalStructureConflictsNumber / This data quality measure is a count of all items in the dataset that are stored in conflict with the physical structure of the dataset.	dataset/data set series	Yes (All S-100 based PS)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	rateOfFaultyPointCurveConnections / This data quality measure indicates the number of faulty link-node connections in relation to the number of supposed link-node connections. This data quality measure gives the erroneous point-curve connections in relation to the total number of point-curve connections.	spatial object / spatial object type	No (Applies only for PS with curves)

Data Quality Measure	Definition	DQ measure / description	Evaluation scope	S-111 Applicability
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfMissingConnectionsUndershoots / This data quality measure is a count of items in the dataset within the parameter tolerance that are mismatched due to undershoots.	spatial object / spatial object type	No (Applies only for PS with curves)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfMissingConnectionsOvershoots / This data quality measure is a count of items in the dataset within the parameter tolerance that are mismatched due to overshoots.	spatial object / spatial object type	No (Applies only for PS with curves)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfInvalidSlivers / This data quality measure is a count of all items in the dataset that are invalid sliver surfaces. A sliver is an unintended area that occurs when adjacent surfaces are not digitised properly. The borders of the adjacent surfaces may unintentionally gap or overlap to cause a topological error.	dataset / dataset series	No (Applies to PS with geometric surfaces)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfInvalidSelfIntersects / This data quality measure is a count of all items in the dataset that illegally intersect with themselves.	spatial object / spatial object type	No (Applies to PS with curves / geometric surfaces)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfInvalidSelfOverlap / This data quality measure is a count of all items in the dataset that illegally self-overlap.	spatial object / spatial object type	No (Applies to PS with curves / geometric surfaces)
Positional Accuracy / Absolute or External Accuracy	Closeness of reported coordinative values to values accepted as or being true.	Root Mean Square Error / Standard deviation, where the true value is not estimated from the observations but known a priori.	spatial object / spatial object type	Yes, for data coding formats 1 and 8 (PS with objects that have coordinative values associated)

Data Quality Measure	Definition	DQ measure / description	Evaluation scope	S-111 Applicability
Positional Accuracy / Vertical Position Accuracy	Closeness of reported coordinative values to values accepted as or being true.	linearMapAccuracy2Sigma / Half length of the interval defined by an upper and lower limit in which the true value lies with probability 95%.	spatial object / spatial object type	No. S-111 Ed. 1.2 does not contain vertical positions (Layer depth is nominal, not a measured value)
Positional Accuracy / Horizontal Position Accuracy	Closeness of reported coordinative values to values accepted as or being true.	linearMapAccuracy2Sigma / Half length of the interval defined by an upper and lower limit in which the true value lies with probability 95%.	spatial object / spatial object type	Yes. (PS with objects that have a horizontal coordinative values associated)
Positional Accuracy / Gridded Data Position Accuracy	Closeness of reported coordinative values to values accepted as or being true.	Root mean square error of planimetry / Radius of a circle around the given point, in which the true value lies with probability P.	spatial object / spatial object type	Yes, for data coding formats 2, 3 (Applies to PS with objects that have a gridded coordinative values associated)
Temporal Quality / Temporal Consistency	Consistency with time.	Correctness of ordered events or sequences, if reported.	dataset/data set series/spatial object type	Yes, for time series features. (Applies to PS with objects that have a time value associated)
Thematic Accuracy / ThematicClassificationCorrectness	Comparison of the classes assigned to features or their attributes to a universe of discourse.	miscalculationRate / This data quality measure indicates the number of incorrectly classified features in relation to the number of features that are supposed to be there. [Adapted from ISO 19157] This is a RATE which is a ratio, and is expressed as a REAL number representing the rational fraction corresponding to the numerator and denominator of the ratio. For example, if there are 1 items that are classified incorrectly and there are 100 of the items in the dataset then the ratio is 1/100 and the reported rate = 0.01.	dataset/data set series/spatial object type	Yes (All S-100 based PS)

Data Quality Measure	Definition	DQ measure / description	Evaluation scope	S-111 Applicability
Aggregation Measures / AggregationMeasures	In a data Product Specification, several requirements are set up for a product to conform to the Specification.	DataProductSpecificationPassed / This data quality measure is a boolean indicating that all requirements in the referred data Product Specification are fulfilled.	dataset/data set series/spatial object type	Yes (PS that a require a complete pass of all elements of a dataset, dataset series or spatial object types)
Aggregation Measures / AggregationMeasures	In a data Product Specification, several requirements are set up for a product to conform to the Specification.	DataProductSpecificationFailRate / This data quality measure is a number indicating the number of data Product Specification requirements that are not fulfilled by the current product/dataset in relation to the total number of data Product Specification requirements.	dataset/data set series/spatial object type	Yes (PS that a require a complete pass of all elements of a dataset, dataset series or spatial object types)

6.2 Additional components of data quality

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, clause E-6 (Test Cases and Methods).

Logical Consistency ensures that the data are stored in a consistent manner: The HDF structure used to hold the data 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 ensures that the values represented (speed and direction) are representative of the true situation. Measurement and modelling errors may put limits on these values.

Aggregation describes global quality values related 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*.

6.3 Assessment of data quality

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 (that is, 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 6.2. Information of the quality of the components of the data is normally available in field survey reports, QC analyses, or other technical reports.

Table 6.2 – Data types and accuracy factors

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

Data quality measures for the entire data set are described in clause 10.2.3 and Table 12-3. These include *horizontalPositionUncertainty*, *verticalUncertainty* and *timeUncertainty*. The additional data quality measures for uncertainty in *surfaceCurrentSpeed* and *surfaceCurrentDirection* are described in clause 10.2.4.

6.4 Validation checks

Validation checks (Annex E) are intended for production systems designed to produce S-111 Surface Currents datasets. Validation checks apply to either datasets (HDF5 dataset files) or exchange sets. Validation checks for S-111 datasets and exchange sets are defined in two locations:

- General validation checks for all S-100-based product specifications intended for use on navigation systems are defined in S-158.
- Product-specific validation checks are defined in Annex E of this doecument.

In addition, there are cross-product compatibility checks intended to verify suitability of combinations of products for use together on ECDIS. These checks will be defined in either S-98 or S-158.

Validation checks can be administered at any time during the production phase. They can also be applied downstream in the distribution and end user systems to test the conformance of a dataset to the format rules specified in S-100 Part 10c and the S-111 Product Specification.

For example, checks will be made for: inclusion of mandated variables; variable values being within accepted ranges; inclusion of optional values when required; matches between number of array elements and array dimension specifications; timeliness of data; etc. Error severity may be, for example, that the dataset unusable, that the dataset is of degraded utility but otherwise safe to use, or that the dataset has one or more small and inconsequential inconsistencies.

Fill values must be considered as allowed values for attributes which allow them (see clause 10.2.2), even though the fill value will be outside the allowed range in the Feature Catalogue.

Cross-product compatibility checks, if any, need to be adminstered to combinations of S-111 and S-1XX datasets belonging to other products, as indicated in the check specification. Their administration should be coordinated with producers of the S-1XX dataset.

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 Producing Authority 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 approved Producing Authority (IHO Resolutions A6.3 & A6.9, S-62), they are suitable for inclusion in the Surface Current data product. See Annex G – Surface Current Data.

Observational Data: Observational surface current data comes initially from *in situ* sensors in the field (for example current meters or drifting platforms) or from high-frequency radar, and such sensors are monitored by the data collecting authority. After reception, the data are quality-controlled and stored by the Producing Authority. 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 analysed by the Producing Authority 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 Producing Authority into a gridded field or a tidal atlas.

Analysed and Hybrid Values: Analysed 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 Producing Authority.

These descriptions are summarized in Table 7-1. (Note that the encoding format does not designate observation data as "historical" or "real-time".)

Table 7-1 – Types of surface current data, based on the sources of the data

Type	Name	Description
1	Historical observation	Observation made hours, days, etc, in the past
2	Real-time observation	Observation no more than a few minutes old

3	Astronomical prediction	Value computed using harmonic analysis or other proven method of tidal analysis [IHO Res. 3/1919, as amended]
4	Analysis or hybrid method	Calculation by statistical or other indirect methods, or a combination of methods
5	Hindcast	Gridded data from a two- or three-dimensional dynamic simulation of past conditions using only observed data for boundary forcing, via statistical method or combination
6	Forecast	Gridded data from a two- or three-dimensional dynamic simulation of future conditions using predicted data for boundary forcing, via statistical method or combination

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 blocks (clause 12.3) with the relevant data and (b) reorganizing the speed and direction data when using the encoding rules (see also Annex D – Sample HDF5 Encoding).

7.2.1 Metadata

Metadata is derivable from the information available from the approved Authority. Recall that the definition of uncertainty (clause 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 approved Authority'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 approved Authority; otherwise they must be calculated.
- If a previously issued data file is being cancelled or replaced, the *replacedData* and/or *dataReplacement* attributes in the exchange catalogue must be populated.
- The metadata file name in carrier metadata (attribute *metadata* in Table 12.3) must be populated with the empty string (equivalent to "" – without quotes – in many programming languages) because Edition 2.0.0 exchange sets do not use ISO metadata;

All mandatory metadata in carrier metadata (clause 12.3) must be populated with appropriate values. In cases where the attribute is mandatory but inapplicable, the appropriate fill or null value described in clause 12.3 must be used.

Similarly, when the Exchange Set is being compiled, all mandatory metadata or information fields in the discovery metadata and Exchange Catalogue (clauses 12.1 and 12.2) must be populated. In cases where the attribute is mandatory but inapplicable, or the value is unknown or not included in the relevant enumeration list, the appropriate fill or null value described must be used.

NOTE (informative): Running the S-100 level validation checks and product-specific validation checks (Annex E) should detect missing metadata, but as of the preparation of this document the checks are yet to be completely defined and automated, and visual checking of metadata may be necessary. The Tables in clauses 12.2 and 12.3 describe the mandatory requirements and allowed values.

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 modelled data grid points and for observational data (such as for moored current meters) may 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 Producing Authority.

7.2.4 Validation

Dataset and Exchange Set validation tests must be passed before the Exchange Set is published.

For numeric attributes, the fill value will be outside the allowed range of values specified in the Feature Catalogue, if any. Similarly, for enumerations, the fill value will not be a member of the enumeration as listed in the Feature Catalogue. Validation checks for datasets must allow for the presence of fill values.

Validation must apply both the S-100 level validation checks defined in the S-100 validation specification (only those checks applicable to S-104 need be applied) and the product-specific validation checks provided as part of the S-104 Edition 2.0.0 Product Specification package.

7.2.5 Digital signatures

Digital signatures are required for datasets and exchange sets intended for use on ECDIS. S-100 Part 15 describes the required signature algorithm and procedure for creating signatures. S-100 Part 17 describes where signatures must be provided. Additional guidance common to all datasets and exchange sets intended for ECDIS is being developed by the IHO. In the absence of this common guidance, the following guidance applies to S-104 datasets and exchange sets:

- The signature algorithm must be as specified in S-100 Part 15.
- In discovery metadata, the **S100_SE_SignatureOnData** element should be used to encapsulate digital signatures for datasets, with the *dataStatus* attribute set to *unencrypted* or *encrypted* according to whether the signature is for an unencrypted or encrypted HDF5 file.
- All resources in the exchange set must be signed, including any catalogue(s) and support files.
- At least one signature is required for each resource (dataset, catalogue, or support file) in the exchange set (the ECDIS will ignore unsigned resources or resources for which signature verification fails).
- Additional signatures may optionally be provided, or added downstream in the distribution chain, as provided for in S-100 Parts 17 and 15.

7.3 Guidance for chunking and compression (informative)

Chunking affects both dataset size and optimised data retrieval, the latter in the sense of how an ECDIS would most efficiently retrieve relevant chunks of a dataset when a user pans and zooms.

Product Specification developers may desire to assess typical profiles and volumes of data for their datasets and develop guidance for the use of chunking and compression in their data products. Common practice is provided below. Product teams should assess its applicability to their own products and use, omit, and adapt it accordingly.

The development of guidance on how to optimally and correctly do chunking and compression is ongoing; however, current best practice is:

- For gridded data with 2 dimensions, for example *dataCodingFormat* = 2 (regular grids), choosing roughly-square rectangular chunk sizes will result in better performance when reading subsets of the data, and will probably result in better compression (one reason being that because **NoData** areas tend to be clustered together geographically, geographically-tiled chunks will compress out all those repetitive values).
- Producers may use "auto-chunking", where this functionality is available (for example, in the production toolset's HDF5 library). Auto-chunking will choose chunk sizes automatically.

- Choosing the right chunk sizes depends on the type of data and what the use of chunking is trying to accomplish. Auto chunking is more ideal for compression and is less ideal for time-critical access patterns.

Auto-chunking means different datasets may be chunked differently. Applications cannot expect a standardised chunk size and will have to handle whatever chunk sizes they encounter in datasets.

Data Producers should note experiences from preliminary testing (on water level data (S-104), but which should also apply to surface current data):

- 2D arrays - Need to be chunked based on how the data is read. If applications need to hold the entire grid in memory, use no chunking; otherwise estimate a reasonable size for data extraction. It is probably better to have the chunking set a little smaller than to make it too big, for I/O purposes.
- 1D arrays – Do not chunk unless they are enormous (for S-111 this is not an issue since clause 11.2.1 limits datasets to well below the size where chunking matters).
- Given the relatively small sizes of datasets for S-11 (for example, 10 MB limit guidelines in clause 11.2.1) chunking will not be of great benefit in read performance for S-111.

Producers should determine the compression scheme that is optimal for their own use case, as needed.

7.4 Datasets in a series

Datasets in a time series (for example, 4X daily, 1X daily, etc.) may be distributed by any appropriate means, such as transfer to an accessible Internet service or via a licensed distrbution channel.

Each release by the producer should be accompanied by an exchange catalogue and bear the appropriate producer digital signatures as specified in S-100 Part 17 and S-98.

Route monitoring applications require up-to-date information and periodic forecasts should be issued in a timely manner (meaning, a successor dataset should be released before the expiry of one full period after the starting date and time of its predecessor).

Multi-pack exchange sets containing multiple sequential datasets may also be prepared as determined necessary by the producer, for example, for uses other than route monitoring on ECDIS. For multi-packs a single exchange catalogue containing discovery metadata for all datasets should be prepared.

7.5 Data use purpose

7.5.1 Datum requirements

Datasets intended for use in navigation must use the same CRS as the underlying ENC. Particular care should be taken to ensure that the horizontal datum is the same as the underlying ENC (with preference for S-101 over S-57). The epoch of realization should be included in this assessment.

NOTE: Conformant datums are a requirement for display on ECDIS, as described in S-98.

7.5.2 Spatial type recommendations

Forecast datasets (type = astronomicalPrediction, analysisOrHybrid, hydrodynamicForecast) intended for use in navigation should be issued as regular grids if possible and if sufficiently high-quality gridded forecasts can be produced (regular grids being most suitable for water level adjustment, cf. S-98, and under the presumption that co-located current data would be desirable). Station-based forecasts must also be issued if the quality of the data so produced is better than the gridded product in the vicinity of a station (for example, if the local uncertainty is lower than the gridded product, or in case of anomalous local currents).

Observation datasets will usually be issued in one of the point formats (DCF 1 or 8).

7.5.3 Suitability for navigation

Datasets may be marked for use in navigation if the Producer is able to consistently produce data of sufficiently high quality.

7.5.4 Use purpose metadata

Datasets not intended for navigation purposes must have the discovery metadata attribute *notForNavigation* in the corresponding **S100_DatasetDiscoveryMetadata** block set to *true*.

Datasets intended for navigation must have the discovery metadata attribute *notForNavigation* in the corresponding **S100_DatasetDiscoveryMetadata** block set to *false.*

7.6 Compliance categories

Compliance categories are described in S-100 clause 4a-5.5. Datasets intended for use on ECDIS must meet the requirements for category4 and the compliance category must be encoded accordingly.

7.7 Compliance with S-98

S-98 consists of a specification for visual interoperability (S-98 Main, S-98 Parts A/B/C/D, and S-98 Annexes A and B) and a specification for harmonised display of S-100 products on ECDIS (S-98 Annex C). The requirements for datasets to be compliant with each aspect of interoperability are described below. Compliance to this edition of S-111 is a fundamental requirement and will not be explicitly listed.

7.7.1 Requirements for visual interoperability

S-111 datasets must satisfy the following requirements:

- The S-111 dataset uses the same CRS as an underlying (or overlapping) S-101 ENC or S-104 dataset.
- Current data should be consistent with water levels; at grid points located on land or when the location is uncovered by tidal action, current speed and direction should be the fill values.

7.7.2 Requirements for harmonised user experience

S-111 datasets must also comply with the requirements for harmonised user experience:

- There must be no spatial overlap between S-111 datasets created by the same producer.
- Temporal overlap is permitted only for datasets which are members of the same temporal series, when a forecast for a specific period is followed by a forecast for a later period. S-111 provides for a dataset naming convention that distinguishes successive datasets in a temporal series.
- Any checks for cross-compatibility of S-101/S-102/S-104 and S-111 datasets must also be satisfied. Cross-compatibility checks will be defined in S-98 and S-158.

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. New dataset may distinguished by a unique datetime in the file name.

Table 8-1 summarizes this information.

Table 8-1 – Typical update/revision intervals and related information for S-111 products produced by a single Producer

Data Types	Update Interval	Number Of Spatial Locations	Typical Number Of Time Values Per Location in a Dataset
Astronomical Predictions	1 year	10 to 1,000	8,760 (hourly data)
Model Forecasts	6 hr	100,000 to 1,000,000	1 to 48

Real-time Observations	0.1 hr	1 to 10	1 to 240
HF Radar Observations	0.1 hr	10,000 to 100,000	1 to 24

NOTE: Population of the resource maintenance information in metadata will indicate to the ECDIS when new data can be expected to be available.

Data Source: Data is produced by the Producing Authority 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.

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. Producers routinely collect observational data and maintain an analysis and/or forecast capability. When new data becomes available (often several times per day), the data is reformatted and made available for dissemination.

8.1.1 Update of tidal atlases and harmonic constants (informative)

Tidal atlas or harmonic constant data are updated much less often, typically on an annual basis.

Harmonic constants change their values if the environment changes (typically the bathymetry). Since this rarely happens an update of the harmonic constants has to be made only in rare occasions. If a long time series of level data is available, a statistical analysis of the harmonic constants can be made in order to use their standard deviations to decide if an update is really necessary, for example if their differences exceed three times the standard deviations.

Tidal atlas or harmonic constant data should be updated only if the values of the harmonic constants differ from previous ones by a given amount (for example three times their standard deviations).

Since this Edition of S-111 does not include harmonic constants in datasets, updates to harmonic constants will affect S-111 datasets only as and when the updated harmonic constants are used in generating S-111 datasets. Producers may use the *comment* attribute of dataset discovery blocks in the exchange catalogue to indicate which version of harmonic constants was used for the dataset.

8.2 Metadata related to dataset maintenance

8.2.1 Elements used in S-111

S-100 Edition 5.2.0 metadata related to maintenance that may be used in S-111 metadata consists of metadata elements specifying:

- The purpose (of issuing the dataset);
- The Edition number of the dataset;
- When its successor will be available;
- The issue date and time of the dataset; and
- The date of the metadata record for the dataset.

Some types of S-111 datasets use only some of these elements. Clauses 8.2.2 *ff.* provide guidance for selecting the values of these elements for the corresponding discovery metadata blocks in the Exchange Catalogue.

8.2.2 New datasets

8.2.2.1 Classification as new datasets

S-100 Part 17 (Table S100_Purpose) defines a new dataset as a “Brand new dataset” with a remark clarifying that “No data has previously been produced for this area”. The factors that should be considered in determining whether a dataset should be classified as a new dataset are:

- Whether any S-111 surface current datasets are currently being produced for the region.
- Whether a new type of information (Table 7-1) is being made available. For example, if real-time observations are made available for a region where only astronomical predictions were formerly issued, the real-time dataset should be considered a new dataset.
- Changes to spatiotemporal representations:

- Changes in the grid spacing for gridded data or interval for time series data should not be considered a new dataset.
- Minor adjustments to spatial extent such as a small adjustment to a grid's boundaries or the addition of a new station to station-based data (DCFs 1 and 8) should not be considered new datasets.
- Significant adjustments to spatial extent should be considered for classification as a new dataset.
- The determination of whether an adjustment to spatial extent is minor or significant is left to the Producer.

- Additional factors: The effect on the end user, change of designation ("not for navigation" vs. "for navigation"), change of navigation purpose, effects on data distribution and data management on ECDIS.
- Local factors, such as the S-111 cell scheme used by the Producer.

8.2.2.2 Metadata for new datasets

Dataset discovery metadata (clause 12.2) for a new dataset must be encoded as follows:

- *editionNumber* in dataset discovery metadata (12.2.4) must be 1.
- *purpose* in dataset discovery metadata must be *newDataset*.

8.2.3 New Editions

8.2.3.1 Classification as New Edition

S-100 Part 17, clause 17-4.5 (S100_Purpose) states that a New Edition "Includes new information which has not been previously distributed by updates".

New Editions of S-111 datasets are issued either when part or all the dataset is erroneous and must be replaced, or when better data become available. In either case, the dataset is replaced as a whole.

New Editions are not used for successor datasets (for example, when a forecast for a specific period is followed by a forecast for a later period). Instead, S-111 provides for a dataset naming convention that distinguishes successive datasets in a temporal series.

8.2.3.2 Metadata for new editions

For a New Edition, set:

- *purpose* = *newEdition*
- edition number: increment by 1

8.2.4 Cancellations

8.2.4.1 Classification as cancellation

S-100 Part 17, clause 17-4.5 (S100_Purpose) states that a cancellation "Indicates the dataset or Catalogue should no longer be used and can be deleted".

S-111 datasets are cancelled only when a dataset or data sequence (such as a sequence of forecasts) is terminated. This might happen for various reasons, for example if Producers reorganise their S-111 cell scheming or replace one type of currents information by another.

Cancellation of a dataset in S-111 is interpreted consistently with S-100 Part 17, with additional conditions arising from the time-dependent nature of surface currents datasets. Cancellation of an S-111 dataset must be treated as described below:

- Surface current information in the cancelled dataset for times beginning and after the effective date and time of cancellation must not be used. The effective date and time are the issue date and time in the discovery metadata for the cancellation record.
- Producers must ensure that date/time information for surface current records in the dataset commences with the issue date and time.
- Surface current information in the cancelled dataset for times preceding the effective date/time of cancellation may be used only in the absence of an uncancelled dataset covering the area and time in question.

- Cancellation of a dataset that is part of a sequence of forecasts also cancels preceding datasets in that sequence as described above. The sequence should be treated as terminated - there can be no successors to the cancelled dataset in the same sequence.
- There may be a successor sequence that starts with a new dataset. If there is, the fields *dataReplacement* and *replacedData* should be populated accordingly in the cancellation record.
- The retention, archiving or removal of cancelled datasets or sequences from the system shall be according to the common principles for retention, archiving or removal set forth in S-98 or other applicable documents.

8.2.4.2 Metadata for cancellation

S-104 uses the fileless cancellation method described in S-100 5.2.0 Part 17 clause 17-4.4.1. For a cancellation, set:

- *purpose* = *cancellation*
- edition number = 0
- issue date and time = the issue date and time of the cancelled dataset
- digital signature = the digital signature of the cancelled dataset (for a series, the digital signature of the last dataset in the series
- *replacedData* = *true* if and only if the cancelled dataset or sequence is replaced by another dataset/sequence, otherwise *false*. This attribute must be populated for a cancellation.
- *dataReplacement* = Cell name of the replacement dataset (if and only if the cancelled dataset/sequence is replaced by another dataset/sequence). This attribute must be populated when *replacedData* = *true*.

8.2.5 Other *S100_Purpose* values (Informative)

S-111 does not use the *reissue, update* and *delta* values of the **S100_Purpose** enumeration.

S-100 Part 17, clause 17-4.5 (S100_Purpose) states that a re-issue “Includes all the updates applied to the original dataset up to the date of the re-issue. A re-issue does not contain any new information additional to that previously issued by updates”. Since S-111 does not include a format for dataset updates, S-111 datasets are not reissued. Corrections to datasets, if required, should be addressed by cancellation of the old dataset accompanied by a New Edition with the same name and an incremented Edition number.

S-100 Part 17, clause 17-4.5 (S100_Purpose) states that an update is for “Changing some information in an existing dataset”. S-111 does not provide for replacing part of a dataset; instead, if changing information is necessary, the whole dataset is replaced.

8.2.6 Maintenance of support files

The Edition number is 1 for the first issue of a support file for a particular dataset. In the event that the file is updated or replaced (for example for a correction) the Edition number is incremented by 1.

The Edition number for language packs changes if and only if the language pack file is updated.

8.2.7 Encoding update frequency

The encoding of information about when the next update to a dataset will be released (cf. clause 12.2.4 - *resourceMaintenance*) is mandatory for datasets that are updated or replaced monthly or more frequently.

The provision of this information for datasets that contain information updated less frequently than monthly (such as astronomical predictions when these are issued annually) is left to the discretion of the Producer, with the expectation that if it is not encoded in discovery metadata the expected release dates will be communicated to distributors and end-users by other means.

For datasets that are continually updated on a fixed cycle, timing information should be encoded as the interval from the issue date and time of the current dataset (that is, using the *userDefinedMaintenanceFrequency* sub-attribute - cf. S-100 Part 17, clause 17-4.9).

Data Producers or metadata compilers must consult S-100 clause 17-4.9 for the rules on encoding information about release timing.

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 current 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.

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 (for example 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.

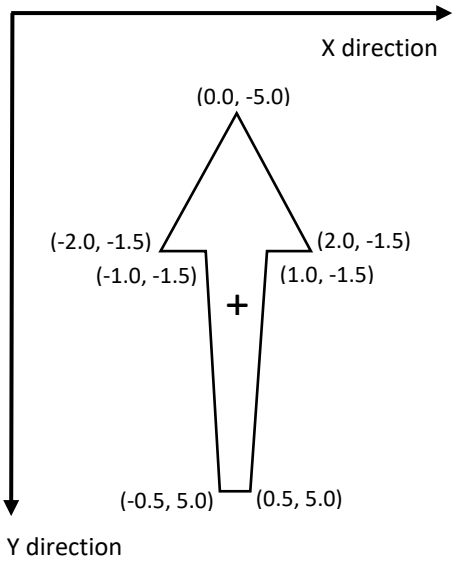
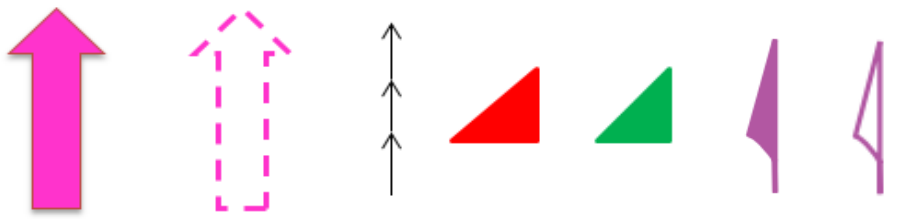


Figure 9-1 – Standard arrow symbol for use in representing surface currents

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.



(a) (b) (c) (d) (e) (f) (g)

Figure 9-2 – Existing arrow types and approximate colours approved for use in ECDIS: (a) and (b) for Traffic Separation Schemes; (c) for recommended (one-way) tracks; (d) and (e) for conical buoys; and (f) and (g) for magnetic variation and anomaly

9.2.2 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.

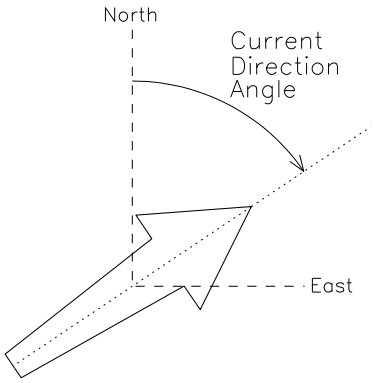


Figure 9-3 – Portrayal of the arrow's direction, based on the current direction

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

Speed Band	Minimum Speed (kn)	Width of Band (kn)
1	0.00	0.50
2	0.50	0.50
3	1.00	1.00
4	2.00	1.00
5	3.00	2.00
6	5.00	2.00
7	7.00	3.00
8	10.00	3.00
9	13.00	86.00

Colours are associated with each speed band, and must be distinguishable in the three viewing environments: day, dusk, and night. Colour 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 9-2 – Colour Schema for day conditions

Speed Band	Colour	Colour Scale Intensity			Hex RBG	Displayed Colour
		Red	Green	Blue		
1	purple	118	82	226	7652E2	
2	dark blue	72	152	211	4898D3	
3	light blue	97	203	229	61CBE5	
4	dark green	109	188	69	6DBC45	
5	light green	180	220	0	B4DC00	
6	yellow-green	205	193	0	CDC100	
7	orange	248	167	24	F8A718	
8	pink	247	162	157	F7A29D	
9	red	255	30	30	FF1E1E	

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_{high}. The recommended value for S_{high} is the minimum speed in the highest group in Table 9-1, which is 13.0 kn. The value of

S_{high} should be the same for all data sets from multiple sources so that the same speed in different data will be displayed with the same arrow length.

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

It is also desirable that the symbol displayed for weak currents should be distinguishable as a current arrow, rather than a generic dark point or short line. Applying the results of experimental investigations[1] and a rule of thumb requiring a dimension of 3.5 mm for viewing at 1 metre distance[2], the recommended[3] value of S_{low} is 1.50 knots[4].

A third parameter is the reference speed, S_{ref}, at which the arrow symbol has a length equal to the scaling height parameter, H_{ref}. Here S_{ref} is chosen to be 5 kn and H_{ref} is taken to be 10.0 mm. Let S be the current speed to be displayed. If S exceeds S_{high}, then S_{high} is substituted for that speed, since areas of extremely high current speeds are rare and are likely to be avoided by navigators anyway. Therefore, a current with a speed of S will be displayed with a height, H (mm), computed by:

$$H = H_{ref} \cdot \min\{\max(S_{low}, S), S_{high}\} / S_{ref}. \qquad \text{[Eqn 9.1]}$$

The arrow width is scaled in a similar fashion. A summary of recommended scaling values is given in Table 9-3. Note that this formula and constants apply only to the size of the symbol, not its colour.

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

Constant	Description	Recommended Value
H_{ref}	Reference height for arrow scaling	10 mm
S_{ref}	Reference speed for arrow scaling	5 kn
S_{low}	Minimum speed to be used for arrow length computations	1.50 kn
S_{high}	Maximum speed to be used for arrow length computations	13 kn

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.

---

[1] Courtesy NAUDEQ.

[2] IEC 60945 as cited in S-52 specifies that character size in mm be not less than 3.5 x the viewing distance in metres. According to this criterion "readable from 1 metre" requires that characters be not less than 3.5 mm in size. A 3.5mm symbol or character subtends an angle of approximately 12 arc minutes at a distance of 1 metre.

[3] Note that this is a recommended value; manufacturers may adjust it as necessary in particular circumstances, such as a lower or higher normal viewing distance. The basic requirement is that the symbol should be distinguishable as an arrow.

[4] Calculated using Eqn. 9.1 and an allowance for the border extending outside the filled area of the arrow symbol.

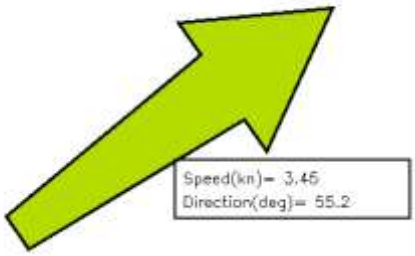


Figure 9-4 – Example of the display of the first level of numerical information available by cursor selection. Note: Arrow length is not to scale

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

Priority Level	Text Information Displayed
1	Speed, Direction
2	Data source, Latitude, Longitude, Depth of current, Valid Date, Valid Time
3	Uncertainty in speed, Uncertainty in direction, Uncertainty in horizontal position, Uncertainty in vertical position, Uncertainty in time

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 9-5 - Alpha (opaqueness) values for arrows with various display backgrounds. Transparency is 1.0 minus the alpha value

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

9.2.7 Scalable Vector Graphics

In ECDIS, the arrow symbol (for example 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, using the image coordinates shown in Figure 9-1, 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 (SVG) Coding) 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 Producer must ensure that the arrow's pivot point does not lie on the displayed representation of land; that is, that the current data and the shoreline are consistent.

NOTE 2: The Producer must ensure 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.

9.2.9 Application to time series and moving platform data

The portrayal described in this clause applies to all non-gridded coverage types. The following guidelines must be applied for values selection and display:

- Time series at fixed stations (dataCodingFomat 1): Display arrows at the locations of the stations, using the temporal rules described in clause 9.4 and Annex J.
- Moving platform (dataCodingFomat 4): Display arrows at the platform location closest to the selected time as well as preceding and following points within user or system selected spatial and temporal buffers (the same buffers as for route monitoring or planning as appropriate). Arrows may be thinned if necessary using the point-by-point method described at the end of clause 9.3.2, using the distance to preceding displayed location as the cell spacing.
- Stationwise time series (dataCodingFomat 8): Display arrows at station locations for the selected time, using the temporal rules described in clause 9.4 and Annex J.

Cursor pick at a platform or station location should display current information in any format determined by the application developer. An informative format is described in Annex J (J-7 – Pick Report for Time Series Data).

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 (that is, 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.

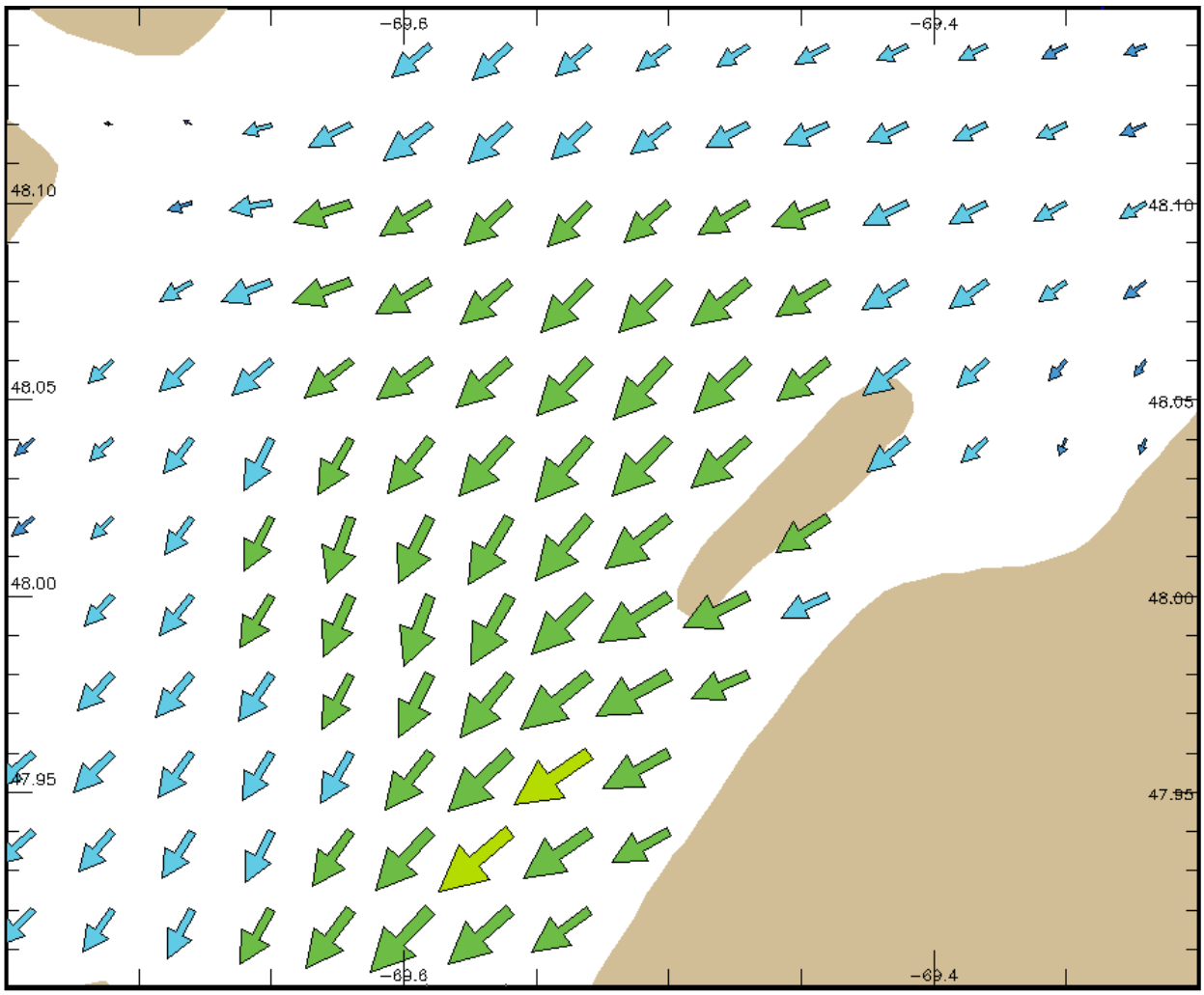


Figure 9-5 – Arrows representing gridded surface current data, with length increasing with speed, and S_{ref} is 5 kn, H_{ref} is 20 mm, and the maximum speed in the data in the image is 3.15 kn. Coastline added for clarity. (Data courtesy of St. Lawrence Global Observatory, Canada)

NOTE: Although some portions of the arrow symbol lie over land, the pivot point does not.

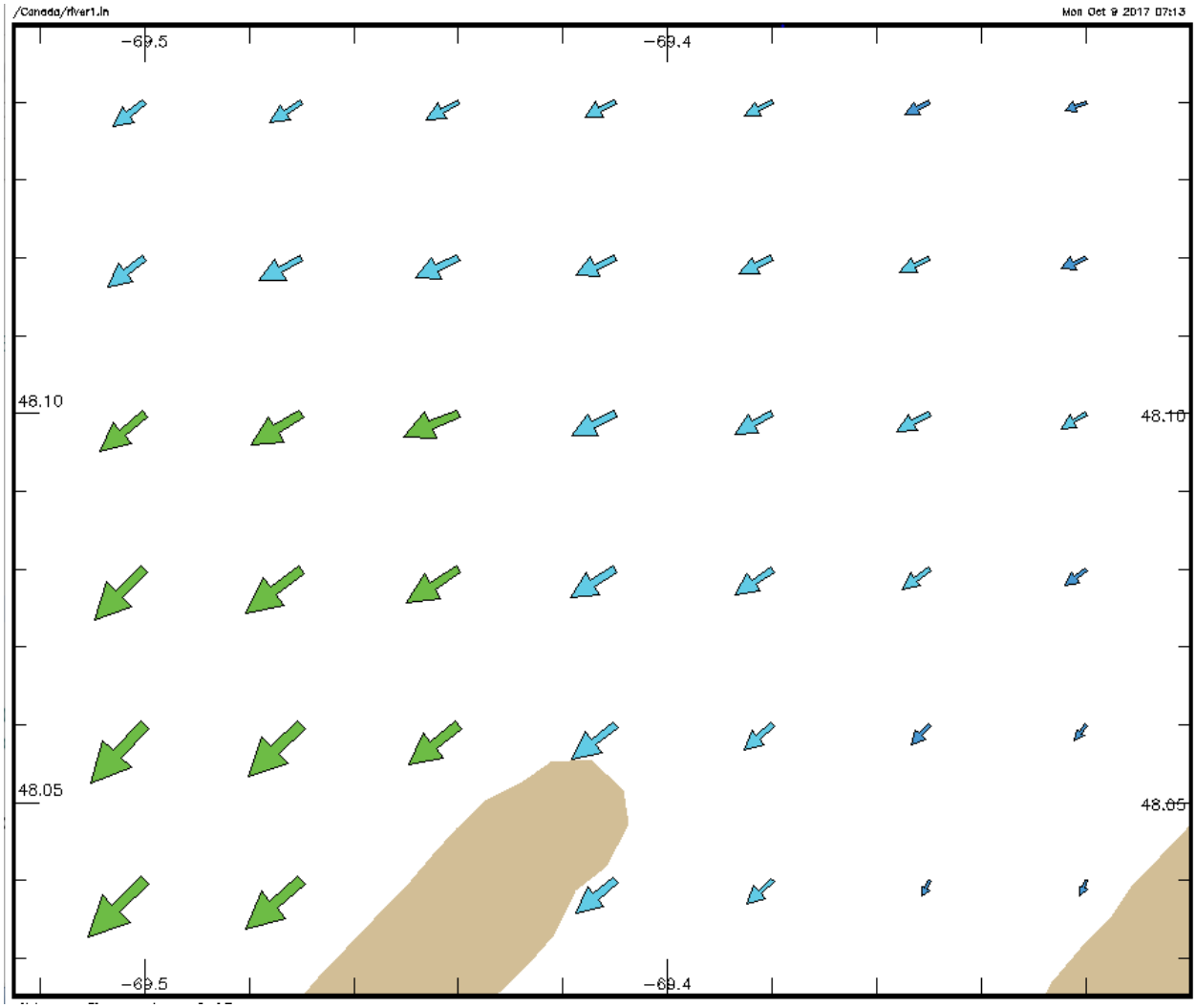


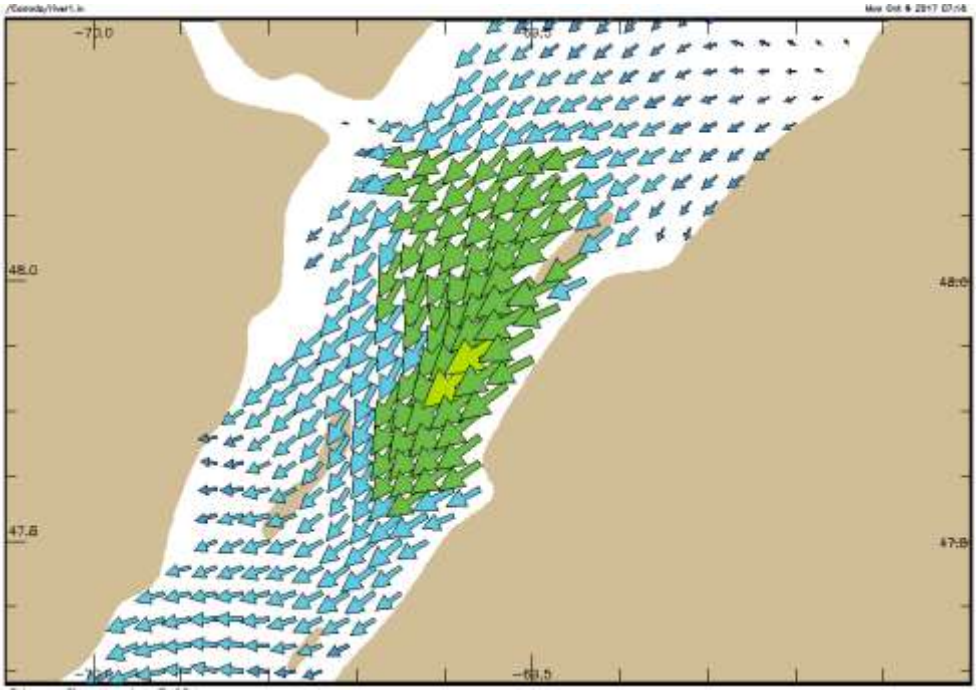
Figure 9-6 – Display of surface current data (see Figure 9-5) but at a higher resolution (data courtesy of St. Lawrence Global Observatory, Canada)

9.3.2 Low resolution

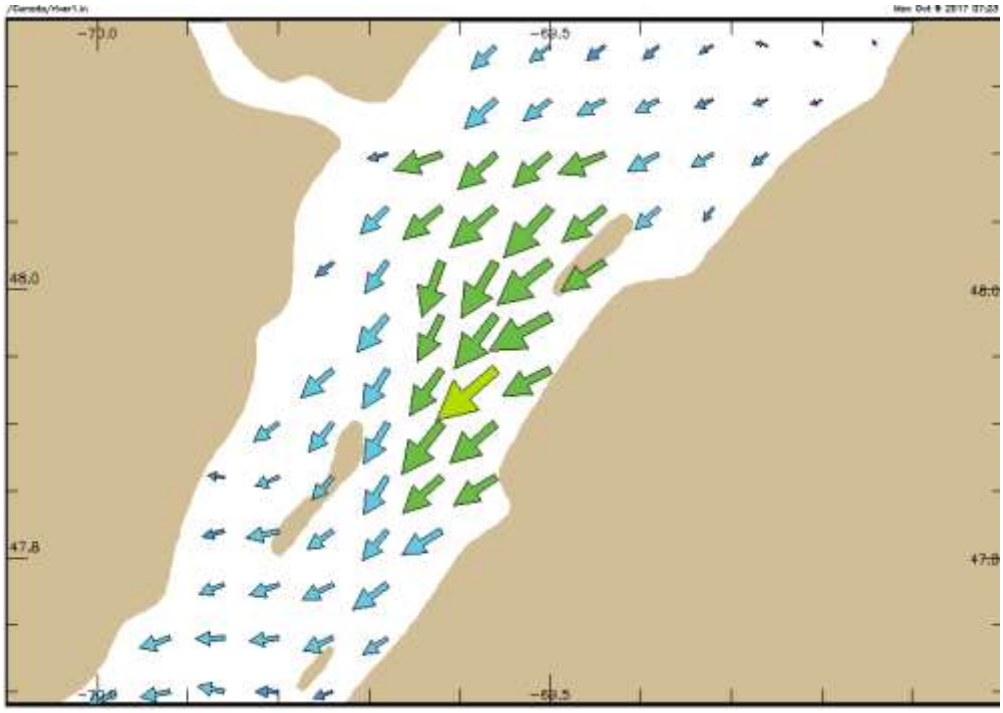
Displaying at a low resolution (that is, zooming out) increases the density of symbols (Figure 9-7a). However, by applying a thinning algorithm, the number of vectors may be reduced (Figure 9-7b). In this case, every fourth vector was plotted.

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^{th} cell is displayed, the displayed spacing is nD. Next, suppose the length of the arrow representing the maximum speed in the displayed field is L_{smax} mm. Then the ratio of the maximum arrow length to the displayed grid spacing is constrained to be less than a prescribed maximum value, R_{max}, here taken to be 0.5. Thus:

$$R = L_{smax}/(nD) \leq R_{max} \qquad \text{[Eqn 9.2]}$$



(a)



(b)

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:

$$n = 1 + \text{fix}(L_{smax}/(DR_{max})) \qquad \text{[Eqn 9.3]}$$

Where 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_{ref} or increase the reference speed S_{ref} (Table 9-3).

9.3.3 Application to ungeorectified grid data

Portrayal for ungeorectified grids must also display a field of multiple arrows using the same principles as for regular grids, with thinning based either on the point-by-point method described at the end of clause 9.3.2 or the same method as for regular grids but using an average resolution, calculated either over the whole grid or sections of the grid. Application developers may substitute their own thinning heuristics for the methods described in clause 9.3.2 and 9.3.3.

9.4 Temporal rules

The metadata variables related to time are the *dateTimeOfFirstRecord*, *dateTimeOfLastRecord*, *timeRecordInterval*, and *numberOfTimes*. The time selected for display (that is 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 (for example 5 minutes). For a single record, the variable *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 (for example the value of the variable *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.

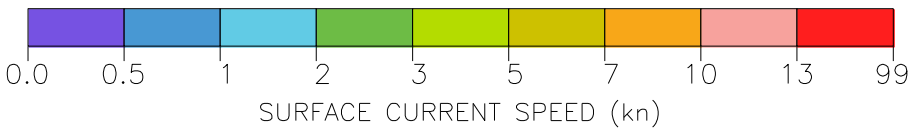


Figure 9-8 – Sample surface current speed scale based on the colours and speed bands in Table 9-2

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 must conform to interoperability rules established in S-98.

9.6.1 Symbol priority

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

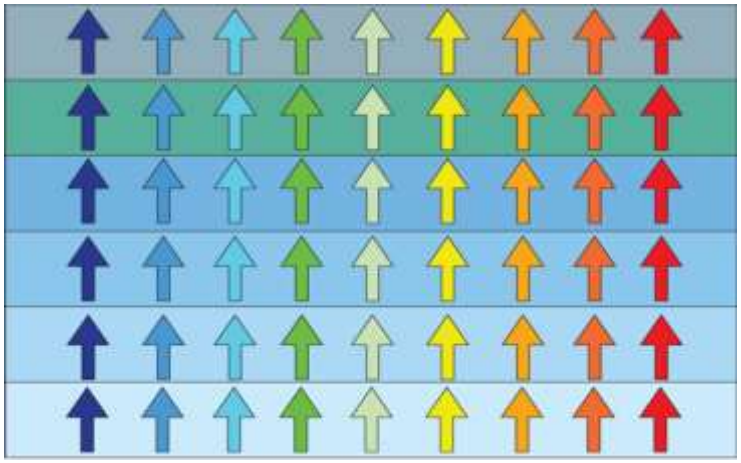
One example involves the use of the older charting symbol for currents. When an S-111 dataset is displayed, symbols from the S-101 ECDIS nautical charting suite, in the area where the new data is displayed, must not be displayed. Such symbols include those for tidal stream tables (plus their points and 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.

9.6.2 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 9-6 - Chart background colours in two colour scales (courtesy of Korean Hydrographic and Oceanographic Administration)

Name	sRGB			xyL			Displayed Colour
	Red	Green	Blue	x	y	L	
Deep Water	201	237	255	0.28	0.31	80	
Medium Deep Water	167	218	252	0.26	0.29	65	
Medium Shallow Water	130	202	255	0.23	0.25	55	
Very Shallow Water	97	184	255	0.21	0.22	45	
Intertidal	88	175	156	0.26	0.36	55	
No Values	147	174	187	0.28	0.31	40	



(a)

(b)

Figure 9-9 – Arrows displayed against the (daytime) background colours in Table 9-6. Arrows (a) with borders and (b) without borders. (Figures courtesy of University of New Hampshire)

9.7 Sample representation

Surface current 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.

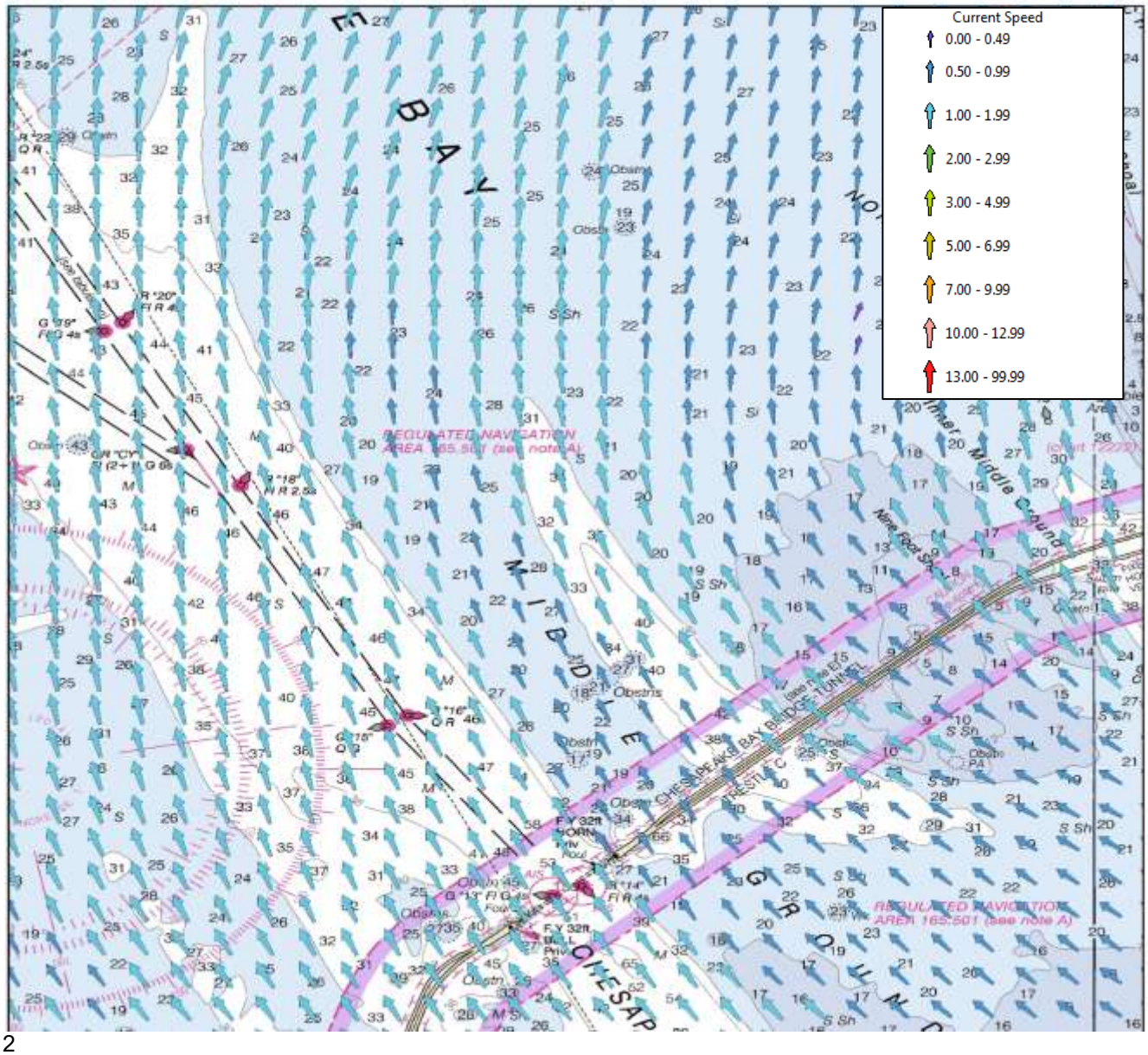


Figure 9-10 – Sample depiction of gridded surface current data in an electronic chart. Note that arrow height in scale may not strictly conform to the portrayal rules. (Image courtesy of the University of New Hampshire, US)

9.8 Portrayal rules

A summary of the portrayal rules appears in Annex J – Surface Current Portrayal Rules.

9.9 Construction and packaging of Portrayal Catalogues

The Portrayal Catalogue must be constructed as a main Portrayal Catalogue XML file (see S-100 Part 9, clause 9-13) and other files in subfolders. The structure is described in S-100 clause 9-13.2. The main Portrayal Catalogue XML file and portrayal subfolders described in S-100 must be placed in a

single subfolder named 111_E_R_C_PC/YYYYMMDD[5]. When distributed within an Exchange Set, the entire Portrayal Catalogue may be packaged as a zip archive named 111_E_R_C_PC_YYYYMMDD.ZIP. The YYYYMMDD component in the folder and archive names denotes a "build date" and allows distinguishing Portrayal Catalogues corresponding to the same version of the S-111 Product Specification (for example, correcting a discrepancy between a portrayal rule and a stable version of the S-111 Product Specification).

Figure 9-11 depicts a hypothetical S-111 Edition 1.2.0 Portrayal Catalogue, with the build date 01 January 2023. The Portrayal Catalogue is located under the folder 111_1_2_0_PC which is a container for all S-111 Edition 1.2.x Portrayal Catalogues. If a new Portrayal Catalogue is defined for the same Edition of S-111, it must receive a new build date and would be placed under 111_1_2_0_PC in a folder named with the new build date. S-111 uses the same layout with updated numbering components and dates.

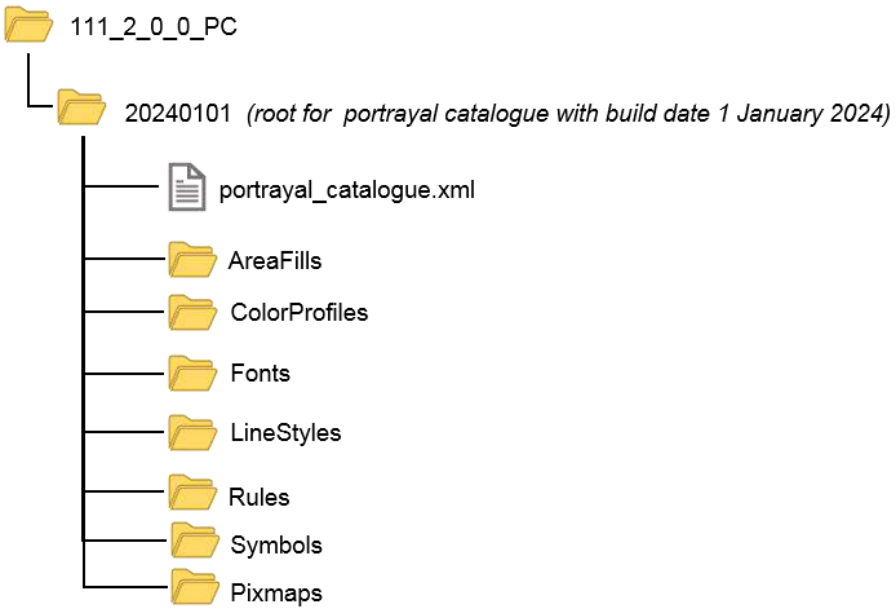


Figure 9-11 - Typical structure for S-111 Portrayal Catalogue

Note that some of the sub-folders will be empty since S-111 defines only coverage features and does not need all the components definable in S-100 Portrayal Catalogues.

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: HDF-5

Character Set: MD_CharacterSetCode (ISO 19115) should be set to utf8

Specification: S-100 profile of HDF-5

[5] E, R, C represent the edition, revision, and clarification numbers of this edition of the Product Specification (for example, for S-111 Edition 2.1.0, E = 2, R = 1, C = 0. YYYYMMDD is a build suffix for the catalogue as year, month, and day in numeric form, for example 202301015 for January 15, 2023. It is not necessary that the build suffix be precisely the date the catalogue was compiled, only that it follow the previous build and precede the next build of the portrayal catalogue for this edition of S-111.

10.2 HDF5 product structure

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.

10.2.1 Data type definition

These data types and their codes are shown in Table 10.1.

Table 10-1 – S-111 data types and values of the variable *dataCodingFormat* (see S-100 Edition 5.0.0, Table 10c-23)

dataCodingFormat	Type of Data
1	Time series data at one or more fixed stations (organized by time)
2	Regularly-gridded data at one or more times
3	Ungeorectified gridded data or point set data at one or more times
4	Time series data for one moving platform
8	Stationwise time series at one or more fixed stations (organised by station) - type (a)

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).

10.2.2 Product structure

The structure of the data product follows the form given in S-100 Part 10c – 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.

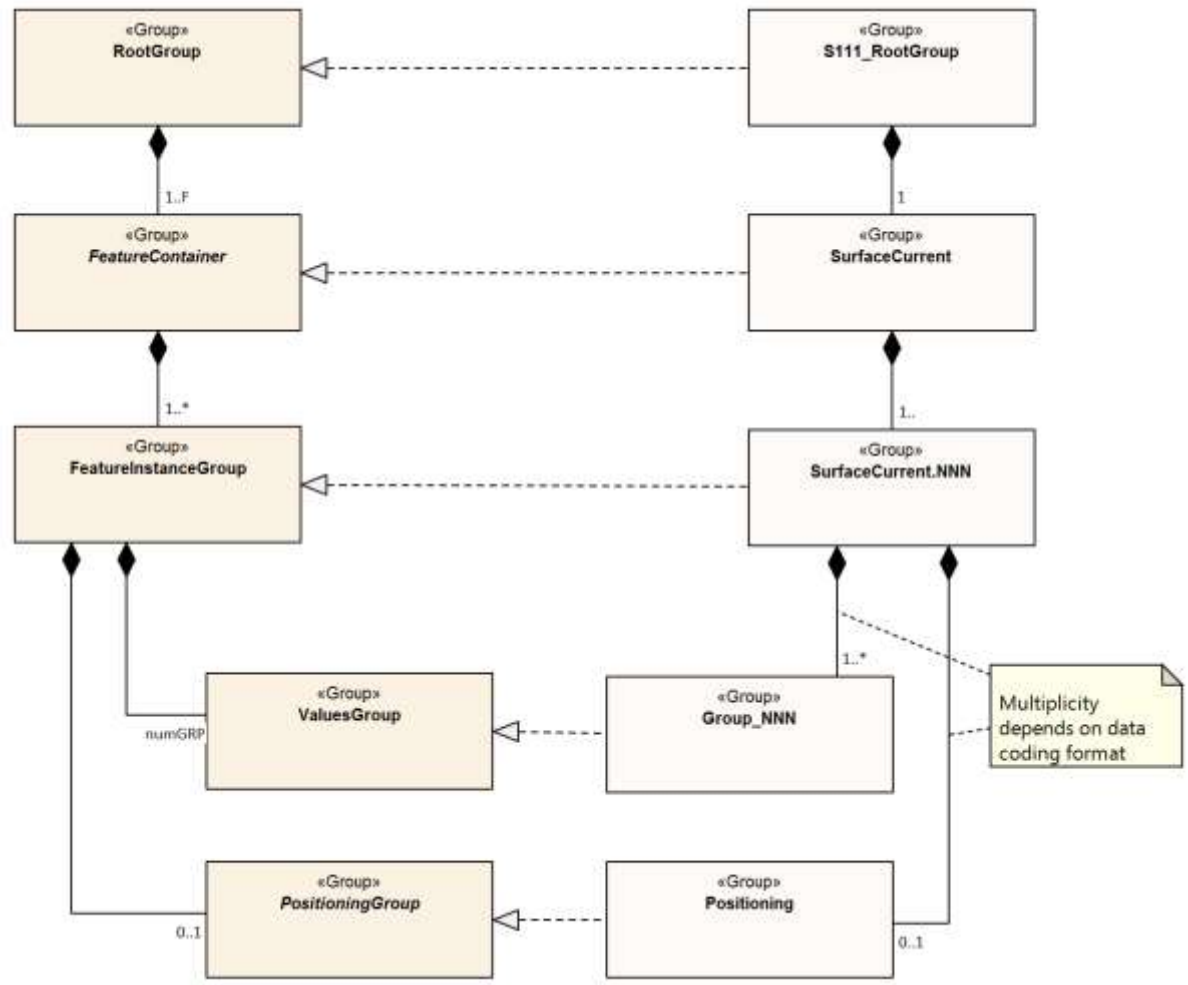


Figure 10-1 – Outline of the data file structure for S-111 data files, showing the realisation of S-111 structure from the generic structure described in S-100 (see Part 10c, Figure 10c-7). Note that there are four levels from top to bottom

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 two datasets: the *featureCode*, which has the name of the S-100 feature (here **SurfaceCurrent**), and the feature information dataset (*SurfaceCurrent*) which contains a compound array with eight parameters for each S-100 feature attribute (speed and direction). 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. Levels refer to HDF5 structuring. (C.f. S-100 Part 10c, Figure 10c-9). Naming in each box below header line is as follows: **Generic name**; S-100 or S-111 name; and (*HDF5 type*) group, attribute or attribute list, or dataset.

Table 10-2 – Overview of an S-111 dataset

LEVEL 1 (ROOT) CONTENT	LEVEL 2 CONTENT	LEVEL 3 CONTENT	LEVEL 4 CONTENT
General Metadata (see Table 12-1) *(h5_attribute)*			
Feature Codes Group_F (*h5_group)*	**Feature Type Name** SurfaceCurrent *(h5_dataset)*		
	Feature Type Codes featureCode *(h5_dataset)*		
Feature Type SurfaceCurrent *(h5_group)*	**Feature Type Metadata** (see Table 12-2) *(h5_attribute)*		
	Horz. & vert. Axis Names axisNames *(h5_dataset)*		
	First Feature Instance SurfaceCurrent.01 *(h5_group)*	**Feature Instance Metadata** (see Table 12-.3) *(h5_attribute)*	
		Location Data Positioning *(h5_group)*	**Lon+lat Array** geometryValues *(h5_dataset)*
		Uncertainty Data uncertainty *(h5_dataset)*	
		First data group Group_001 *(h5_group)*	**Time Attribute** timePoint *(h5_attribute)*
			Speed+direction Array values *(h5_dataset)*
		Second data group Group_002 *(h5_group)*	**Time Attribute** timePoint *(h5_attribute)*
			Speed+direction Array values *(h5_dataset)*
		Third data group Group_003 *(h5_group)*	**Time Attribute** timePoint *(h5_attribute)*
			Speed+direction Array values *(h5_dataset)*
	Second Feature Instance SurfaceCurrent.02 *(h5_group)*	**Feature Instance Metadata** (see Table 12-3) *(h5_attribute)*	

The following clauses explain entries in Table 10-2 in more detail.

10.2.2.1 Root group

The Root group contains the Feature Codes group, the Feature Type group, and the simple attributes shown in Table 12-1.

10.2.2.2 Feature type codes (Group_F)

This group specifies the S-100 feature to which the data applies. The group has no attributes and consists of two components:

featureCode – 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 – this is a dataset with the name contained in the **featureCode** dataset. The dataset contains a one-dimensional compound array of length 3 (one for each of the three current attributes: speed, direction and time). Each of the three elements of string values has 8 values, as shown in Table 10-3.

NOTE: Values provided in Table 10-3 are required.

Table 10-3 – Sample contents of the one-dimensional compound array (length=3, compound elements=8) SurfaceCurrent. All values are strings

N	Name	Explanation	Attribute 1	Attribute 2	Attribute 3
1	code	Camel Case Name	surfaceCurrentSpeed	surfaceCurrentDirection	surfaceCurrentTime
2	name	Plain text	Surface Current Speed	Surface Current Direction	Surface Current Time
3	uom.name	Units of Measurement	knot	degree	DateTime
4	fillValue	Denotes missing data	-9999.00	-9999.0	00000000T000000Z
5	datatype	HDF5 datatype	H5T_FLOAT	H5T_FLOAT	H5T_STRING
6	lower	Lower bound on attribute	0.00	0.0	19000101T000000Z
7	upper	Upper bound on attribute		359.9	21500101T000000Z
8	closure	Open or Closed data interval. See S100_IntervalType in S-100 Part 1	geSemiInterval	closedInterval	closedInterval

The values in this array must be consistent with the corresponding entries in the Feature Catalogue, with the exception that Attribute 3 has no uom.name value in the Feature Catalogue.

Optional attributes (here, surfaceCurrentTime) are encoded in Group_F only if they are actually used in feature instance value records. If encoded in Group_F, they must be present (populated with the fill value, if necessary) in all feature instances in this dataset.

10.2.2.3 Type group (SurfaceCurrent)

This group contains a dataset called *axisNames* and one or more instances of the single feature **SurfaceCurrent**. A single instance may contain a gridded forecast at multiple hours, a set of time series predictions at several stations, or moving station data for a single station. This group has the simple attributes shown in Table 12-2. For S-111, *axisNames* consists of two elements, the strings ‘longitude’ and ‘latitude’. The contents of the *axisNames* array must be exactly the same as the axis names used by the appropriate registry entry for the coordinate system specified in the metadata; for EPSG, the axis names in the corresponding EPSG registry entry must be used.

10.2.2.4 Instance group (SurfaceCurrent.nn)

This group contains a single instance of the feature (see clause 10.2.2.3). The groups are numbered from 01 to 99. This group has the simple attributes shown in Table 12-3, as well as the (speed and direction) values groups, the (conditional) positioning group, and a dataset called ‘uncertainty’.

Uncertainty Dataset – The (optional) uncertainty data is contained in a compound HDF5 dataset named ‘uncertainty’. There is a name and an uncertainty value for surface current speed and direction, which are, respectively, s*urfaceCurrentSpeed* and *surfaceCurrentDirection*. The units of speed

uncertainty are knots and the units of direction are arc-degrees. The default, denoting a missing value, is -1.0.

10.2.2.5 Value groups (Group_nnn)

These groups each contain an attribute (the date-time stamp), and the compound data arrays containing surface current speed and direction and optionally surface current time. These groups have the simple attributes shown in Table 12-4. These components are explained below.

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 (*dataCodingFormat* = 1 or 4), the time stamp is the time of the first value.

Value Arrays - The speed and direction values (surfaceCurrentSpeed and surfaceCurrentDirection) are stored in arrays named *values,* with a prescribed number of rows (*numROWS*) and, if two-dimensional, columns (*numCOLS*). If Group_F describes the time attribute surfaceCurrentTime this attribute must also be present in the values record.

For a time series of fixed or moving stations (*dataCodingFormat* = 1, 4, and 8), the speed and direction values will be for times in the series as determined by the starting date-time and the data time interval. If the time intervals are non-uniform (only for *dataCodingFormat* = 4 or 8), then the time for each height and trend value is given by surfaceCurrentTime.

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.

NOTE: The requirement that the values record include all the attributes described in Group_F means that all feature instances in the dataset must:

- include any optional attribute encoded in Group_F
- omit any optional attribute not encoded in Group_F

10.2.2.6 Conditional geography group (Positioning)

The group named **Positioning** contains all the locations (longitude and latitude values) that have associated data values. This group has no attributes. In S-111, this group is present in the data product only for *dataCodingFormat* values of 1, 3, 4, or 8.

The geographic values are stored in the single, one-dimensional compound array named *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.

NOTE: the variable names in this Group (longitude, latitude) must match in case and spelling those in axisNames.

Table 10-4 - Values of *numPOS* for the group Positioning

Data Coding Format	Data Type	Location Data	Array Size: Value of numPOS
1	Time series at fixed stations	Position of stations	*numberOfStations*
2	Regular grid	(Not applicable)	(Not applicable)
3	Ungeorectified gridded data	Location of the grid nodes	*numberOfNodes*
4	Time series at a single moving station	Position of station over time	*numberOfTimes*
8	Stationwise time series at fixed stations	Position of stations	*numberOfStations*

10.2.2.7 Summary of generalized dimensions

To summarize, there are data groups containing the speed and direction data, which are stored in either one-dimensional arrays of size *numROWS* or two-dimensional arrays of size *numROWS* by *numCOLS*. The total number of data Groups is *numGRP*.

The four variables that determine the array sizes (*numROWS*, *numCOLS, numPOS,* and *numGRP)* 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

Data Coding Format	Data Type	Positioning	Data Values		
		numPOS	numCOLS	numROWS	numGRP
1	Fixed Stations	numberOfStations	1	numberOfStations	numberOfTimes
2	Regular Grid	(not used)	numPointsLongitudinal	numPointsLatitudinal	numberOfTimes
3	Ungeorectified Grid	numberOfNodes	1	numberOfNodes	numberOfTimes
4	Moving Platform	numberOfTimes	1	numberOfTimes	1
8	Stationwise Fixed Stations	numberOfStations	1	numberOfTimes	numberOfStations

10.2.2.8 Mandatory naming conventions

The following group and dataset names are mandatory in S-100: ‘Group_F’, ‘featureCode’, and (for S-111) ‘SurfaceCurrent’, ‘axisNames’, ‘Positioning’, (for S-111) ‘SurfaceCurrent.nn’, and ‘Group_nnn’ (n is an integer from 0 to 9) Attribute names shown in clause 12.3 are also mandatory.

10.2.2.9 Summary of product structure

For regularly gridded data, the Surface Current array is two dimensional, with dimensions *numPointsLongitudinal* and *numPointsLatitudinal*. These attributes are part of feature instance metadata described in Table 12-3 and S-100 Part 10c, Table 10c-12. By knowing the grid origin and the grid spacings, the position of every point in the grid can be computed by simple formulae.

However, for time series data, moving platforms, and ungeorectified gridded data (that is, when *dataCodingFormat* is 1, 3, 4, or 8), the location of each point must be specified individually. This is accomplished by the data in Positioning Group, which gives the individual longitude (X) and latitude (Y) for each location. For time series data, the X and Y values are the positions of the stations; the number of stations is *numberOfStations.* For ungeorectified-gridded data, the X and Y values are the positions of each point in the grid; the number of grid points is *numberOfNodes*. For moving platforms, the X and Y values are successive positions of the platform, the number of positions is *numberOfTimes*.

NOTE: If *dataCodingFormat* is 2, the Positioning group is not present.

The remaining groups each contain a title, a date-time value (attribute *timePoint*, except for *dataCodingFormat* = 8), and the current data array. The title can be used to identify each individual station with time-series data. For *dataCodingFormat* = 2 or 3, the date-time is for the entire grid. The current data array is two dimensional, with a number of columns (*numCOLS*) and rows (*numROWS*). For a time series, the current data value record will be for each time in the series. For a grid, the data record will be for each point in the grid.

The format allows features encoding data stationwise (dataCodingFormat=8) or for a moving platform (dataCodingFormat=4) to be encoded with either uniform or non-uniform time intervals.

- For non-uniform time intervals, each record has a date-time encoded in the current data array.
- For uniform time intervals, the time interval is encoded as an attribute of the Values group. In this case, the date-time of individual records is omitted from the current data array.

The groups are numbered 1, 2, etc, up to the maximum number of groups, *numGRP*. For fixed station stationwise data (*dataCodingFormat* = 8), the number of groups is the number of stations. For regular

and ungeorectified grids and TINs (*dataCodingFormat* = 2, 3, and 7), and for fixed station timewise data (*dataCodingFormat* = 1) the number of groups is the number of time records.

The overall structure of the data product is created by assembling the data and metadata. The product structure is compliant with the HDF5 data architecture, which allows multi-dimensional arrays of data to be grouped with metadata. The format of the data product (cf. Figure 10-1) described above is portrayed in Figure 10-2. The Carrier Metadata is discussed in clause 12.3 (Tables 12-1 - 12-4), and the Values group attributes are discussed in clause 12.3 (Table 12-4).

NOTE: The name of each Group is the 'Group_nnn', where nnn is numbered from 1 to *numGRP*.

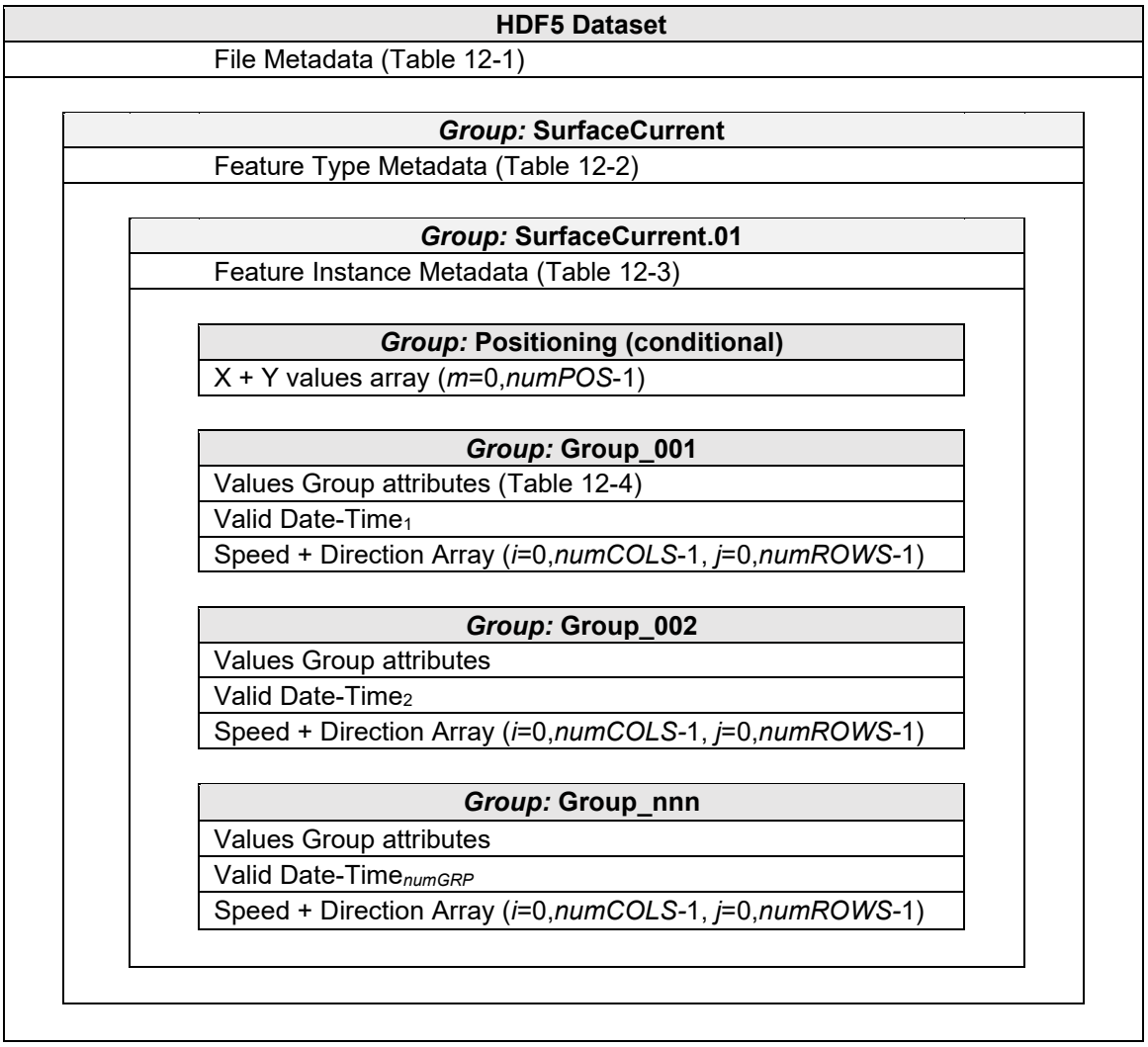


Figure 10-2 – Schematic of the S-111 HDF5 data product structure. The four parameters *numPOS*, *numCOLS*, *numROWS*, and *numGRP* are explained in Table 10-5.

Group 'Positioning' appears only for *dataCodingFormat* = 1, 3, 4, or 8 (Table 10-5).
Valid Date-Time$_{1,2,...numGRP}$ have different meanings and encodings for *dataCodingFormat*=1, 2, and 3 compared to *dataCodingFormat*=8 (see Table 12-4)

10.2.2.10 Digital Certification Block

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

This Edition does not provide for inclusion of certificates or digital signatures within the HDF5 file. When necessary, certificates and digital signatures must be provided for the HDF5 file as a whole, using the mechanisms described in S-100 Parts 15 and 17.

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 D – 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 Producer to the end user (that is 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 Producer or through a third party supplier.

Due to the cost of transmitting data via the internet, it is desirable to limit file size and updating frequency whenever possible. Considerations here are the size of each transfer as well as the total volume of data transferred over time (the latter particularly applies to datasets which are issued daily or more frequently, such as forecasts). The following recommendations are therefore proposed:

1) Each exchange data file, as created by the Producer and after compression, is recommended to be limited to 10 MB.
2) The “cell scheming” (geographic extents covered) for datasets, especially datasets which are issued frequently (for example, daily or more frequent forecasts) should be determined so as to reduce the transfer of unnecessary data (information not needed for route planning or monitoring within reasonable time windows). It is recommended that cell scheming and grid density take into account the navigation purposes defined in S100_NavigationPurpose, reproduced below:
    a. port - For port and near shore operations
    b. transit - For coast and planning purposes
    c. overview - For ocean crossing and planning purposes

S-100 Part 15, clause 15-5.2 allows one data compression scheme: Zip (note that this may not provide a significant reduction due to internal compression applied within the HDF file). In addition, the file may be encrypted.

Updating of files typically means issuing a new forecast, or disseminating the latest observed current data 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 (that is, hourly or less) availability of new datasets, the ECDIS system may need to check for new data at a similar frequency. The “resource maintenance” information in external metadata and “delivery interval” in internal metadata should therefore be populated whenever possible.

11.2 HDF5 Dataset Packaging

The HDF5-formatted datasets are packaged with metadata and an Exchange Catalogue, and then combined into an Exchange Set. HDF5 files for time series or gridded current data may require internet transmission, since they change several or more times a day.

11.2.1 Exchange Sets

Exchange Sets produced by the Producer 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.

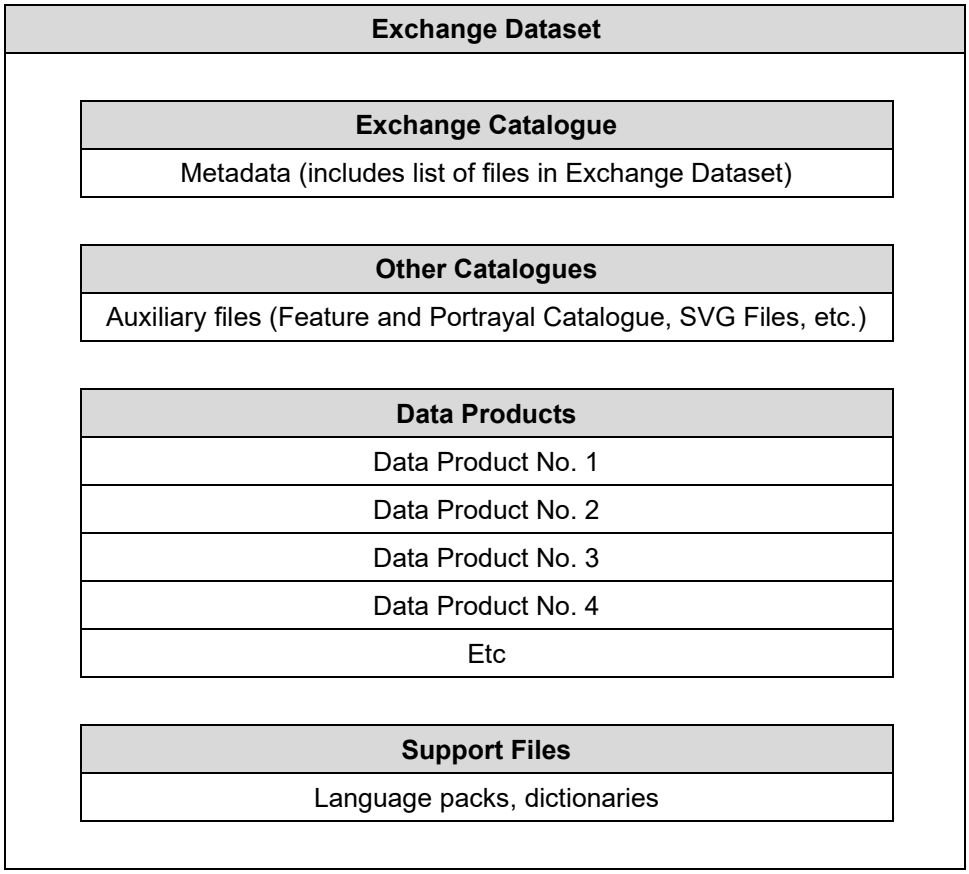


Figure 11-1 – Schematic diagram of the Exchange Set

The Exchange Set size is limited to 10 MB. The size of datasets (HDF5 data files) can vary widely, depending on the data. Exchange files may be compressed using the DEFLATE compression algorithm commonly used in ZIP archives (cf. S-100 Part 15, clause 15-5.2). Doing so can reduce file size by 80% or more.

11.2.1.1 Exchange Set structure

The structure of an S-111 Exchange Set must be according to the structure described below, which is based on S-100 Part 17, clause 17-4.2. The S-111 Exchange Set structure is depicted in Figure 11-2.

1) All content must be placed inside a top root folder named S100_ROOT. This is the only top level root folder in an Exchange Set containing only S-100 products.
2) The S100_ROOT folder must contain a subfolder for S-111 which holds content specific to S-111.
3) An S-111 Exchange Set must contain an Exchange Set Catalogue, CATALOG.XML, its digital signature CATALOG.SIGN and may contain any number of S-111 conformant dataset files and Catalogue files.
4) The S-111 subfolder must contain subfolders for the component dataset files (DATASET_FILES) and Catalogues (CATALOGUES) as required:
    a. The DATASET_FILES subfolder is required if and only if the Exchange Set contains an S-111 HDF5 dataset.
    b. The CATALOGUES subfolder is required if and only if the Exchange Set contains a Feature or Portrayal Catalogue. (This Edition of S-111 does not include Interoperability Catalogues, which are described by S-98 and will be part of the exchange set structure described in that specification.)
5) The DATASET_FILES folder must contain a subfolder named according to the Producer Code.
6) Individual data files must be placed under the Producer subfolder, either directly in the Producer folder, or within a lower-level subfolder hierarchy. Individual data files may be optionally placed in their own subfolders or grouped with other data files.

7) An Exchange Set may carry Feature and Portrayal Catalogues in different versions, which should also be grouped together in the CATALOGUES folder.
8) If a Portrayal Catalogue is included in the Exchange Set, it should be packaged as either a ZIP archive containing all Portrayal Catalogue files, or a filesystem structure of folders and files. The structure of Portrayal Catalogues is described in S-100 Part 9, clause 9-13.2 and guidance on packaging Portrayal Catalogues is provided in clause 9.9.
9) Except for the signature of the Exchange Catalogue file (CATALOG.XML), which is in the CATALOG.SIGN file, all digital signatures are included within their corresponding resource metadata records in CATALOG.XML.
10) Dataset and Catalogue file and/or folder names should be such as to avoid inadvertent overwriting of files.
11) Digital signatures are required for Exchange Sets and datasets intended for navigation on ECDIS. All resources included within an Exchange Set intended for navigation, including support files and catalogues, must be signed (S-100 Part 17).
12) It is not necessary for an Exchange Set to contain more than one build of a Feature or Portrayal Catalogue for the same version of a Product Specification. For example, an Exchange Set will not contain both 111_2_0_0_FC/20210630/ and 111_2_0_0_FC/20220101/ folders for Edition 2.0.0 Feature Catalogues. The presence of both in Figure 11-2 is only for illustrative purposes.
13) Inclusion of the dictionary of enumerations in any particular Exchange Set is optional, since it will be the same for all datasets from all producers. For similar reasons, inclusion of the Feature Catalogue and Portrayal Catalogue in any particular Exchange Set is optional. Producers may distribute dummy Exchange Sets containing only the Feature Catalogue, Portrayal Catalogue, and enumerations dictionary, when any of them is updated or when a new version of the Product Specification is released. Validation checks should ensure that these files are present on the system if they are not included in any particular Exchange Set.

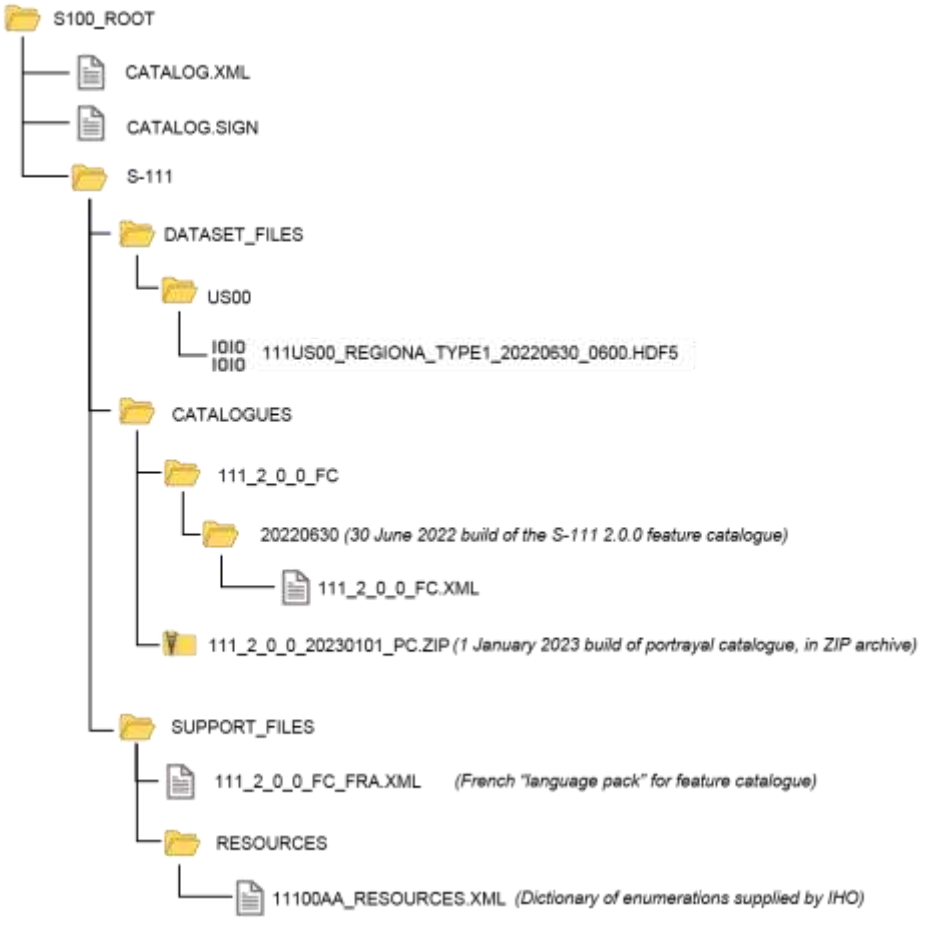


Figure 11-2 – Typical Exchange Set structure

General guidelines for Exchange Set structure are included in S-100 Part 17.

Note that the names and locations of files are coded within the CATALOG.XML or Portrayal Catalogue files, and therefore files and folders should not be renamed or relocated by Producers or end-user systems unless these references can be updated. Portrayal and Feature Catalogues can be relocated to a common system location if their internal structure is maintained.

11.2.2 Exchange Catalogue

The Exchange Catalogue which is in XML format acts as the table of contents for the Exchange Set. The catalogue file of the Exchange Set must be named CATALOG.XML (as specified in S-100 Part 17); no other file in the Exchange Set may have the same name. The contents of the Exchange Catalogue are described in Section 12.

The Exchange Catalogue Schemas for S-111 are the same as for S-100 and may be obtained from the IHO S-100 Schema server: https://schemas.s100dev.net. The S-111 Exchange Catalogue uses an additional product-specific constraints file implementing product-specific restrictions, which is also available from the same site. Use of the additional product-specific constraints file is optional; developers may implement the constraints using any convenient method.

11.2.3 Dataset file naming

The dataset file contains both metadata and one or more sets of speed and direction arrays (see Section 10 – Data Product Format). The dataset name must begin with the three-character Product Specification, followed by the four-character Producer Code (CCCC)[7]. Thus surface current datasets begin with the seven-character string '111CCCC'.

The characters between this string and the extension are nominally unrestricted in S-100 and S-97 Edition 1.1.0. However, S-111 restricts the "unrestricted" characters as follows:

- Alphabetic characters in the "Latin alphabet"; that is, A-Z and a-z;
- Numeric characters; that is, the characters 0-9;
- The hyphen and underscore characters ("-" and "_").

The unrestricted characters may be used to denote geographical region, valid time, source of the data, version numbers, and/or any other relevant information. Characters may be lower or upper case[8]. For real-time and forecast data, it is recommended that the dateTime of the first record be part of the dataset name, to help distinguish the most recent files.

The filename extension for HDF5 (.h5) must be used to denote the file format.

The total length of the file name shall be no more than 64 characters, including the extension.

EXAMPLE 1: 111US00_CHES_TYPE1_20210630_0600.HDF5 for observational data (see clause 12.3.5, Table 12-10) produced by NOAA for Chesapeake Bay (CHES), observations beginning from 06:00 UTC on 30 June 2021.

EXAMPLE 2: 111US00_ches_dcf8_20190703T00Z.h5 for a dataset produced by NOAA containing data for NOAA fixed stations in the Chesapeake Bay (ches) organised stationwise (dcf8) beginning from midnight at the beginning of 3 July 2019.

Each producer should adopt a naming scheme that is consistent across its entire S-111 product line. While the examples above are hypothetical, they illustrate how the principles of this clause can be applied by Producers.

11.2.3.1 Dataset MRN (Informative)

The dataset file name may be mapped to an MRN as follows:

---

[7] Producer Codes may be obtained from the IHO Producer Code Register in the IHO GI Registry. The four-character S-100 "Alpha" codes must be used.

[8] Exceptions: (1) Producer Codes must use the same case as the IHO Producer Code Register. (2) A name component taken from an external Specification, must follow the rules in that Specification (for example, "20190703T00Z" for a time component in ISO 8601 basic format, not "20190703t00z").

urn:mrn:iho:s111:1:2:0:<cccc>:<region>:<type>:<dtg>

where:

- The first part “urn:mrn:iho:s111” is common to all dataset URNs for S-111;
- The product specification version is represented by the “1:2:0” part;
- <cccc> represents the 4-character Producer Code;
- <region> represents the geographical region;
- <type> represents the data coding format, for example “type2” for regular grids;
- <dtg> represents the date/time component in the name.

This is an interim rule pending definition of an “S-100-wide” rule for MRNs and will be superseded by the “S-100-wide” rule when it is published.

11.2.4 Support Files

Only the following types of support files are allowed in S-111:

- Optional ‘language packs’ for Feature Catalogues. Each language pack contains a translation of the Feature Catalogue into a specified language.
- Dictionary resource files listing the allowed values and codes of enumerations. There will generally be a single dictionary file for each version of the Product Specification (corrections, if any, will be issued through the usual mechanism for corrections). Inclusion of the dictionary resource file in Exchange Sets is optional, since the Internet location is standardised and manufacturers are permitted to obtain it by other means and install it in an application-specific location.

11.2.5 Support File Naming

11.2.5.1 General

Support file names are subject to the same naming rules as dataset file names (clause 11.2.3), except that the extension is determined by the support file format.

This clause covers names of language packs and enumeration dictionaries, which are the only support files allowed in this Edition of S-111. Producers who discover a need for other types of support files should conform to the general rule above and consult TWCWG as necessary.

11.2.5.2 Names of language packs

If a language pack created by a data Producer for the S-111 Feature Catalogue is included, it must have the standard 7-character “104CCCC” prefix and the same base name as the standard IHO-issued Feature Catalogue with the 3-letter ISO 639-2/T language code suffixed. The language codes must be exactly those in the S-100 codelist for languages (**S100_MD_LanguageCode**, which can be found in the S-100 Edition 5.0.0 Schema distribution). The file extension must be “.XML”.

NOTE: A language pack issued by the IHO for the IHO Feature Catalogue will use the IHO Producer Code.

11.2.5.3 Names of enumeration dictionaries

Enumeration dictionaries are supplied by IHO as part of this Product Specification and should not be renamed.

NOTE (informative): Substitute or extended enumeration dictionaries may be developed if translations are needed. Producers who desire to provide translations of enumeration dictionaries with S-111 Exchange Sets should consult with TWCWG.

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, for example decrypt, decompress, load etc.

Catalogues (Feature and Portrayal Catalogues) can be included in the Exchange Set in support of the datasets. If included, discovery metadata about the Catalogues must also be provided.

NOTE: S-111 datasets do not reference support files. The only support files allowed in the Exchange Set are “language packs” for Feature Catalogues and enumeration dictionaries, and these are not referenced from within the HDF5 datasets.

Discovery metadata for each HDF5 dataset is given in an XML block within the Exchange Set Catalogue file, and can be accessed without opening the HDF5 file. In addition to discovery metadata, S-111 also provides for carrier metadata that is embedded within the HDF5 file, which provides information needed to process and display the data. Discovery metadata is described in clause 12.2; carrier metadata in clause 12.3.

This clause defines the mandatory and optional metadata needed for S-111. In some cases (if provided by the Producer or Exchange Set packager) the metadata may be repeated in a language other than English. See S-100 Part 17, clauses 17-4.6 – 17-4.8 for guidance on encoding of metadata in languages other than English.

12.1.1 Realisation of Exchange Set components and metadata classes (informative)

The realization of S-111 Exchange Sset components and metadata classes from ISO 19115-1 and ISO 19115-3 is the same as in S-100 Part 17, depicted in Figure 12-1. The Figure depicts, from left to right:

(i) The relevant ISO data exchange structural classes;

(ii) The relevant ISO metadata classes for metadata for exchange;

(iii) S-100 structure classes representing the S-100/S-111 exchange set components;

(iv) The relevant S-100/S-111 Exchange Set metadata classes.

Note that the only support files in S-111 are language packs, enumeration dictionaries, or ISO metadata files, represented by **S100_SupportFile** or **ISOMetadataFile**. The corresponding metadata blocks are represented by **S100_SupportFileDiscoveryMetadata** elements.

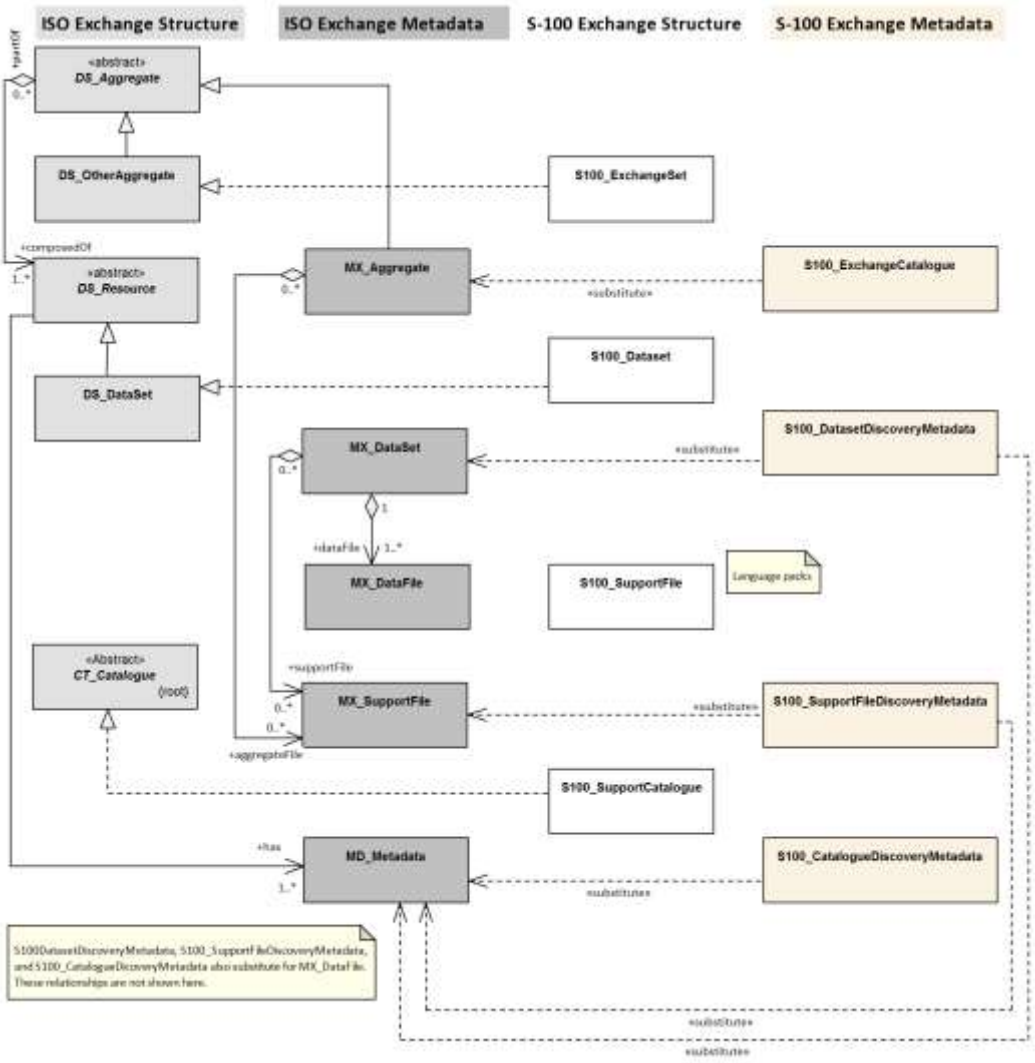


Figure 12-1 – Realisation of the Exchange Set classes (S-100 Part 17, Figure 17-1 with relationships not used in S-111 omitted)

12.1.2 Exchange Set components and related metadata

Figure 12-2 depicts the relationships of Exchange Set "core" elements (datasets and Feature/Portrayal Catalogues) and Exchange Set metadata. This Figure is derived from S-100 Part 17, Figure 17-2. Relationships not applicable to S-111 have been omitted (for example, the link between datasets and support files in S-100 Figure 17-2, because S-111 datasets do not reference support files). Note also that the link between **S100_Dataset** and **S100_CatalogueMetadata** is implicit by means of the S-111 version to which the Feature Catalogue, Portrayal Catalogue and dataset conform, which must have the same Edition and revision components.

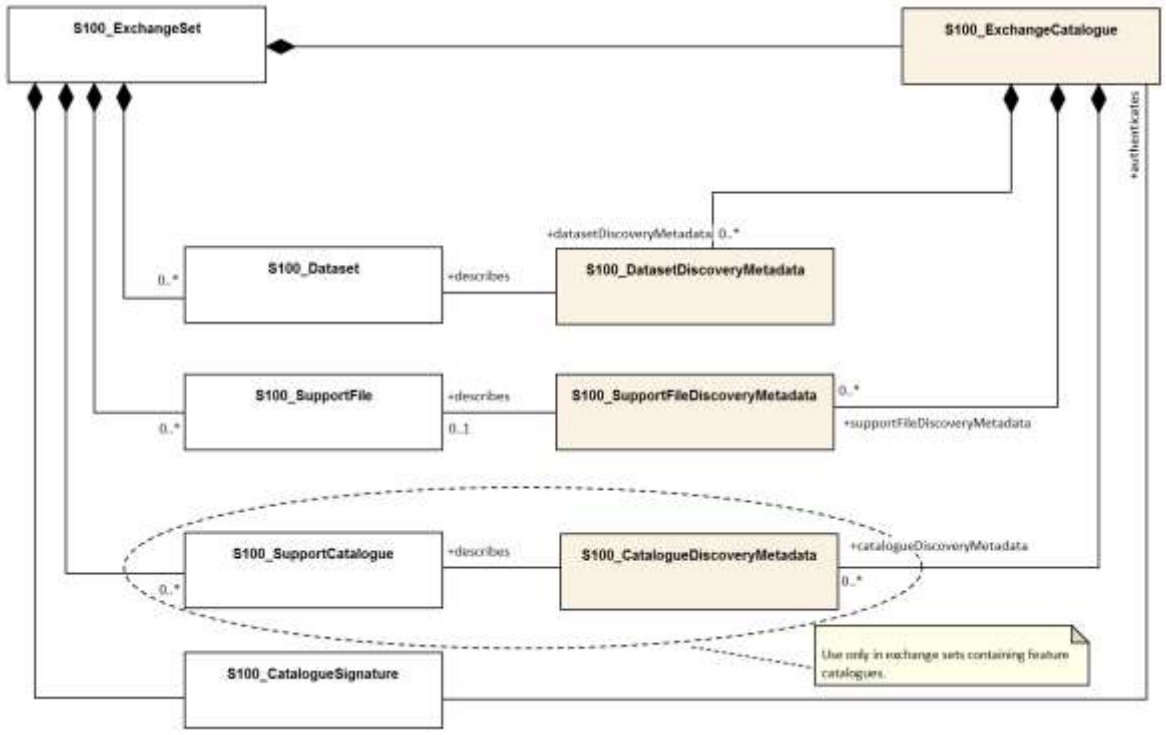


Figure 12-2 – Components and associated metadata for the S-111 Exchange Set (S-100 Part 17, Figure 17-2 with relationships not used by S-111 omitted)

The rules governing the presence and roles of the exchange set components depicted in Figure 12.2 are given below.

1) Every exchange set must contain an Exchange Catalogue, represented by **S100_ExchangeCatalogue** in Figure 12-2.
2) Dataset discovery metadata (**S100_DatasetDiscoveryMetadata**) must be provided in the exchange catalogue for each S-111 dataset in the exchange set.
3) Catalogue metadata (**S100_CatalogueDiscoveryMetadata**) must be provided in the exchange catalogue for any feature and portrayal catalogues included in the exchange set.
4) The only support files allowed are language packs and enumeration dictionaries (both represented by **S100_SupportFile**). Their inclusion in exchange sets is optional.
5) The file represented by the class **ISOMetadataFile** is an XML file conforming to ISO 19115-3 format as specified in the ISO 19115-3 XML schemas supplied by the ISO. Each ISO metadata file, if present, must correspond to an S-111 dataset in the exchange catalogue.
6) Producers must not include ISO metadata files to convey information for ECDIS application processing, since processing these files is not an ECDIS requirement. All information necessary for ECDIS processing must be in CATALOG.XML.
7) Language packs are described in S-100 Part 18 and provide translations of feature catalogues.
8) A signature file for the Exchange Catalogue must also be included in the Exchange Set[9] (**S100_CatalogueSignature**).

Since S-111 does not add product-specific metadata attributes, the S-100 metadata classes and Schema are used in S-111 Exchange Sets without extension. The constraints S-111 impose on generic S-100 metadata are described in the documentation tables in clause 12.2.

NOTE: The distribution package implements the additional S-111 constraints on metadata attributes (and many of the S-100 constraints) as Schematron rules in files available from the IHO Schema server.

[9] Temporarily suspended; S-97 1.1.0 states digital signatures are essential only for technical readiness level 3.

Implementers may substitute any implementation method to apply or check constraints instead of using Schematron-capable processing software.

The tangible representations of the structure classes in Figure 12-2 within actual Exchange Sets are the digital files or folders containing the Exchange Set, dataset(s), Catalogue(s), and support files. The tangible representations of their roles as depicted in Figure 12-2 are the inclusion of the respective components within the Exchange Set. Documentation tables for the structure classes are not provided since the Exchange Set structure is described in clause 11.2.1.

The metadata classes in Figure 12-2 are represented by XML files or XML blocks and are documented in clause 12.2.

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 clauses 11.2.1 and 12.1. The place of metadata in the Exchange Set is summarised in clause 12.1.2.

Figure 12-3 depicts the structure of the Exchange Catalogue and its component discovery metadata blocks. The structure is the same as in S-100 Part 17.

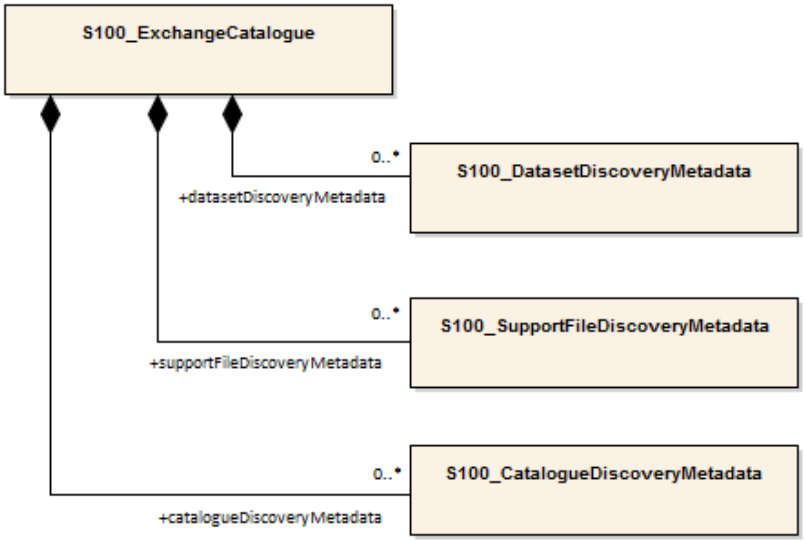


Figure 12-3 – Relationship between Exchange Catalogue, discovery metadata, and dataset (from S-100 Part 17, Figure 17-6)

The detailed structure of the S-111 Exchange Catalogue is depicted in Figure 12-4. This Figure is derived from S-100 Part 17, Figure 17-7, with the following restrictions:

- Elements that are optional in the generic S-100 catalogue model but not used in S-111 are not shown; for example, the *updateNumber* and *updateApplicationDate* attributes in the dataset discovery class are not used in S-111.
- Constraints that are specific to S-111 are summarised in a diagram note. Details about constraints are provided in the documentation tables following the diagram.

In S-111 Edition 2.0.0 only Feature and Portrayal Catalogues are allowed.

The language used for the metadata is English.

Time reference for all data will be UTC.

All depth or height values to be given in metres (up to two decimal places for real values).

More detailed information about the various classes and textual descriptions of the constraints are in the Tables in clauses 12.2.1 – 12.2.30 following Figure 12-4. Differences from generic S-100 metadata are emphasized for developer convenience in **bold** text.

1

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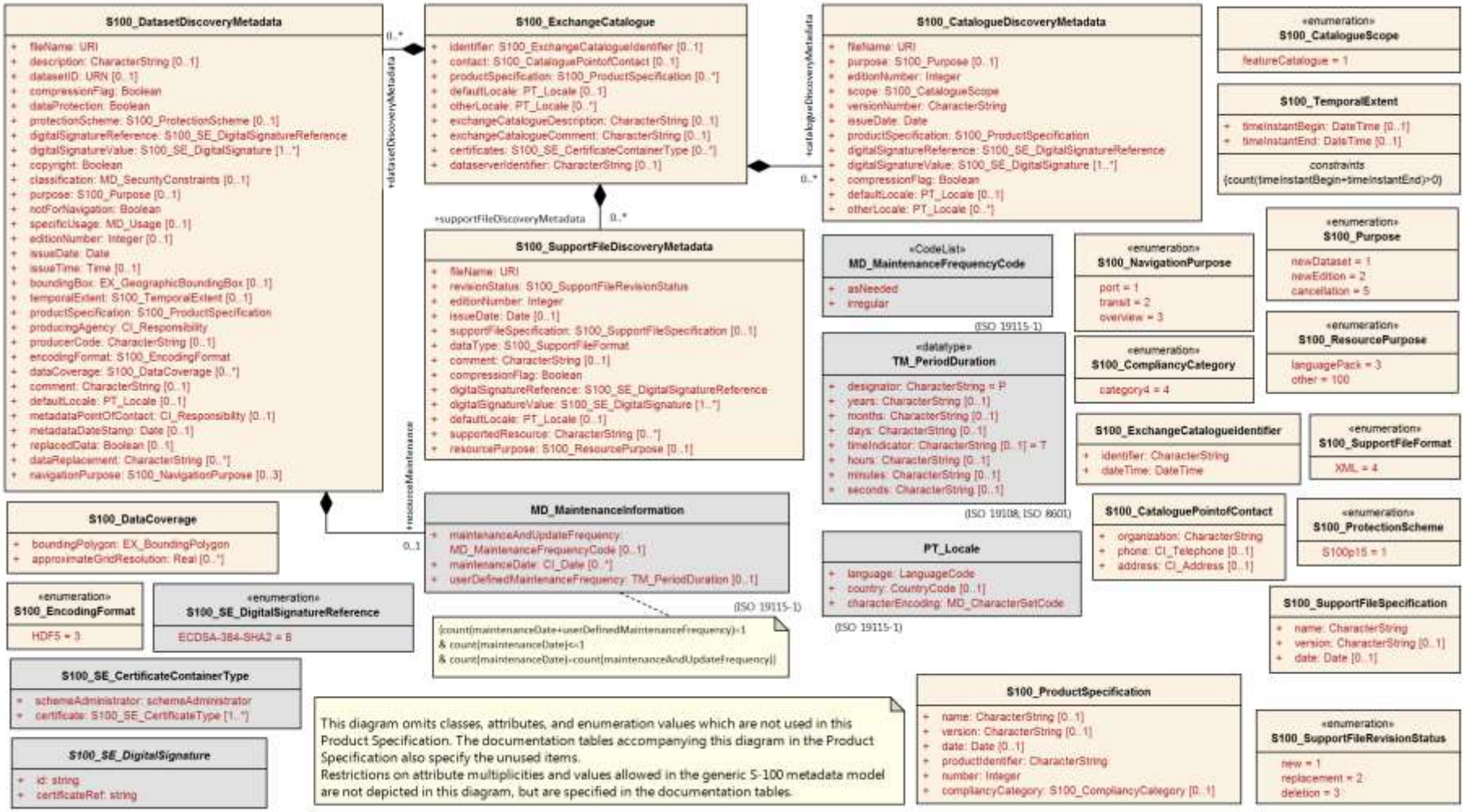

Figure 12-4 - Details of Exchange Set Catalogue classes. Based on S-100 Part 17, Figure 17-7

12.2.1 S100_ExchangeCatalogue

Each Exchange Set has a single S100_ExchangeCatalogue which contains meta information for the data and support files in the Exchange Set. S-104 restricts the S-100 class as described in the Remarks column.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_ExchangeCatalogue	An exchange catalogue contains the discovery metadata about the exchange datasets and support files	-	-	**The optional S-100 attributes *identifier*, *contact*, and *productSpecification* are mandatory in S-111**
Attribute	identifier	Uniquely identifies this Exchange Catalogue	**1**	S100_ExchangeCatalogueIdentifier	**Mandatory in S-111**
Attribute	contact	Details about the issuer of this Exchange Catalogue	**1**	S100_CataloguePointOfContact	**Mandatory in S-111**
Attribute	productSpecification	Details about the Product Specifications used for the datasets contained in the Exchange Catalogue	**1**	S100_ProductSpecification	**Mandatory in S-111**
Attribute	defaultLocale	Default language and character set used for all metadata records in this Exchange Catalogue	0..1	PT_Locale	Default is English and UTF-8
Attribute	otherLocale	Other languages and character sets used for the localized metadata records in this Exchange Catalogue	0..*	PT_Locale	Required if any localized entries are present in the Exchange Catalogue
Attribute	exchangeCatalogueDescription	Description of what the Exchange Catalogue contains	0..1	CharacterString	
Attribute	exchangeCatalogueComment	Any additional Information	0..1	CharacterString	
Attribute	certificates	Signed public key certificates referred to by digital signatures in the Exchange Set	0..*	S100_SE_CertificateContainerType	Content defined in S-100 Part 15. All certificates used, except the SA root certificate (installed separately by the implementing system) shall be included
Attribute	dataServerIdentifier	Identifies the data server for the permit	0..1	CharacterString	
Role	datasetDiscoveryMetadata	Exchange Catalogues may include or reference discovery metadata for the datasets in the Exchange Set	0..*	Aggregation S100_DatasetDiscoveryMetadata	
Role	catalogueDiscoveryMetadata	Metadata for Catalogue	0..*	Aggregation S100_CatalogueDiscoveryMetadata	Metadata for the Feature and Portrayal Catalogues, if any
Role	supportFileDiscoveryMetadata	Exchange Catalogues may include or reference discovery metadata for the support files in the Exchange Set	0..*	Aggregation S100_SupportFileDiscoveryMetadata	The only support files allowed in S-111 are enumeration dictionaries and language packs for Feature Catalogues

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12.2.2 S100_ExchangeCatalogueIdentifier

S-111 uses **S100_ExchangeCatalogueIdentifier** without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_ExchangeCatalogueIdentifier	An Exchange Catalogue contains the discovery metadata about the exchange datasets and support files	-	-	The concatenation of identifier and dateTime form the unique name
Attribute	identifier	Uniquely identifies this Exchange Catalogue	1	CharacterString	**See Note 1 for the naming convention**
Attribute	dateTime	Creation date and time of the Exchange Catalogue, including time zone	1	DateTime	Format: yyyy-mm-ddThh:mm:ssZ

NOTE: Use the file name component of the dataset according to the convention in clause 11.2.3. For example, if the dataset file is named 111ABCDXYZ_1_20_20210420.HDF5 the metadata identifier should be 111ABCDXYZ_1_20_20210420. In the event of an Exchange Set containing multiple datasets, use the name of the dataset of largest extent with a “+N” suffix (without quotes), where N is the number of additional datasets in the Exchange Set. If the Exchange Set contains only Feature and/or Portrayal Catalogues, use 111ABCD+N where “ABCD” is the 4-character code of the producer of the Feature or Portrayal Catalogue.

12.2.3 S100_CataloguePointofContact

S-111 uses **S100_CataloguePointOfContact** without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_CataloguePointOfContact	Contact details of the issuer of this Exchange Catalogue	-	-	-
Attribute	organization	The organization distributing this Exchange Catalogue	1	CharacterString	This could be an individual producer, value added reseller, etc
Attribute	phone	The phone number of the Organization	0..1	CI_Telephone	
Attribute	address	The address of the Organization	0..1	CI_Address	

12.2.4 S100_DatasetDiscoveryMetadata

Data in the Discovery Metadata are used to identify the relevance of the dataset to the particular application. S-111 restricts the multiplicity and contents of **S100_DatasetDiscoveryMetadata** as described in the Remarks column.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_DatasetDiscoveryMetadata	Metadata about the individual datasets in the Exchange Catalogue	-	-	**The optional S-100 attributes *updateNumber*, *updateApplicationDate*, *otherLocale*, and *referenceID* are not used in S-111** **The optional S-100 attributes *datasetID dataCoverage*, and *editionNumber* are mandatory in S-111**
Attribute	fileName	Dataset file name	1	URI	See S-100 Part 1, clause 1-4.6
Attribute	description	Short description giving the area or location covered by the dataset	0..1	CharacterString	For example a harbour or port name, between two named locations etc
Attribute	datasetID	Dataset ID expressed as a Maritime Resource Name	**1**	URN	The URN must be an MRN **Made mandatory in S-111** See clause 11.2.3.1
Attribute	compressionFlag	Indicates if the resource is compressed	1	Boolean	*true* indicates a compressed dataset resource *false* indicates an uncompressed dataset resource
Attribute	dataProtection	Indicates if the data is encrypted	1	Boolean	*true* indicates an encrypted dataset resource *false* indicates an unencrypted dataset resources
Attribute	protectionScheme	Specification of method used for data protection	0..1	S100_ProtectionScheme	In S-100 the only allowed value is “S100p15”
Attribute	digitalSignatureReference	Specifies the algorithm used to compute digitalSignatureValue	1	S100_SE_DigitalSignatureReference (see S-100 Part 15)	
Attribute	digitalSignatureValue	Value derived from the digital signature	1..*	S100_SE_DigitalSignature (see S-100 Part 15)	The value resulting from application of *digitalSignatureReference* Implemented as the digital signature format specified in Part 15 **At least one S100_SE_SignatureOnData is required**

Role Name	Name	Description	Mult	Type	Remarks
Attribute	copyright	Indicates if the dataset is copyrighted	1	Boolean	*true* indicates the resource is copyrighted *false* Indicates the resource is not copyrighted
Attribute	classification	Indicates the security classification of the dataset	0..1	MD_SecurityConstraints> MD_ClassificationCode (codelist)	1. unclassified 2. restricted 3. confidential 4. secret 5. top secret 6. sensitive but unclassified 7. for official use only 8. protected 9. limited distribution
Attribute	purpose	The purpose for which the dataset has been issued	0..1	S100_Purpose	
Attribute	notForNavigation	Indicates the dataset is not intended to be used for navigation	1	Boolean	*true* indicates the dataset is not intended to be used for navigation *false* indicates the dataset is intended to be used for navigation
Attribute	specificUsage	The use for which the dataset is intended	0..1	MD_USAGE>specificUsage (character string)	Information about specific usage(s) for which the dataset is intended.
Attribute	editionNumber	The Edition number of the dataset	**1**	CharacterString	**Mandatory in S-111** See clause 8.2
Attribute	issueDate	Date on which the data was made available by the data producer	1	Date	
Attribute	issueTime	Time of day at which the data was made available by the data producer	0..1	Time	**Mandatory when the interval between datasets is shorter than 1 day, such as 6-hourly forecasts**
Attribute	boundingBox	The extent of the dataset limits	0..1	EX_GeographicBoundingBox	

Role Name	Name	Description	Mult	Type	Remarks
Attribute	temporalExtent	Specification of the temporal extent of the dataset	0..1	S100_TemporalExtent	The temporal extent is encoded as the date/time of the earliest and latest data records (in coverage datasets) or date/time ranges (in vector datasets) If there is more than one feature in a dataset, the earliest and latest time values of records in all features are used, which means the earliest and latest values may be from different features If date/time information for a feature is not encoded in the dataset, it is treated for the purposes of this attribute as extending indefinitely in the appropriate direction on the time axis, limited by the issue date/time or the cancellation or supersession of the dataset This attribute is encoded if and only if at least one of the start and end of the temporal extent is known
Attribute	productSpecification	The product specification used to create this dataset	1	S100_ProductSpecification	
Attribute	producingAgency	Agency responsible for producing the data	1	CI_ResponsibleParty>CI_Organisation	See S-100 Table 17-3
Attribute	producerCode	The official IHO Producer Code from S-62	0..1	CharacterString	
Attribute	encodingFormat	The encoding format of the dataset	1	S100_EncodingFormat	**Must be HDF5**
Attribute	dataCoverage	Area covered by the dataset	**1**..*	S100_DataCoverage	**Mandatory in S-111.**
Attribute	comment	Any additional information	0..1	CharacterString	
Attribute	defaultLocale	Default language and character set used in the dataset	1	PT_Locale	
Attribute	otherLocale	Other languages and character sets used in the dataset	0..*	PT_Locale	
Attribute	metadataPointOfContact	Point of contact for metadata	0..1	CI_Responsibility > CI_Individual or CI_Responsibility > CI_Organisation	Only if metadataPointOfContact is different from producingAgency
Attribute	metadataDateStamp	Date stamp for metadata	0..1	Date	May or may not be the issue date
Attribute	replacedData	Indicates if a cancelled dataset is replaced by another data file(s)	0..1	Boolean	See Note **Mandatory when purpose = cancellation**

Role Name	Name	Description	Mult	Type	Remarks
Attribute	dataReplacement	Dataset name	0..*	CharacterString	A dataset may be replaced by 1 or more datasets See Note **Mandatory when replacedData = true**
Attribute	navigationPurpose	Classification of intended navigation purpose (for Catalogue indexing purposes)	0..3	S100_NavigationPurpose	**Mandatory when *notForNavigation* = *false*.**
Role	resourceMaintenance	Information about the frequency of resource updates, and the scope of those updates	0..1	MD_MaintenanceInformation	S-100 restricts the multiplicity to 0..1 and adds specific restrictions on the ISO 19115 structure and content. See clause **MD_MaintenanceInformation** in S-100 Part 17 Format: PnYnMnDTnHnMnS (XML built-in type for ISO 8601 duration). See S-100 clause 17-4.9 for encoding guidance If present, the duration must match the duration encoded in embedded metadata (Table 12-1)

NOTE: *replacedData* and *dataReplacement*: The intended use of the attributes replacedData and dataReplacement could be, for example, to provide a mechanism for service providers to build automation when providing replacement data sets to customers within existing subscription periods.

12.2.5 S100_NavigationPurpose

Item	Name	Description	Code	Remarks
Enumeration	S100_NavigationPurpose	The navigational purpose of the dataset	--	
Value	port	For port and near shore operations	1	
Value	transit	For coast and planning purposes	2	
Value	overview	For ocean crossing and planning purposes	3	

12.2.6 S100_DataCoverage

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_DataCoverage	A spatial extent where data is provided; and the display scale information for the provided data	-	-	**The S-100 attributes *optimumDisplayScale*, *minimumDisplayScale*, *maximumDisplayScale*, and *temporalExtent* are not used**

Attribute	boundingPolygon	A polygon which defines the actual data limit	1	EX_BoundingPolygon	**See the notes below this Table**
Attribute	approximateGridResolution	The resolution of gridded or georeferenced data (in metres)	0..*	Real	A single value may be provided when all axes have a common resolution For multiple value provision, use axis order as specified in dataset May be approximate for ungeorectified data For example, for 5 metre resolution, the value 5 must be encoded **See Note 6. Mandatory in S-111 for grid formats**

NOTE 1: If there are multiple grid or TIN features in the dataset, each feature should have a separate *dataCoverage* attribute in dataset discovery metadata, except that the coverages for intersecting or adjacent features with the same grid resolution may be combined at producer discretion.

NOTE 2: Bounding polygons for grid features should be the same as the spatial extent of the grid.

NOTE 3: Bounding polygons for TIN features may either be the union of all triangles defined in the TIN, or the bounding box covering all the vertexes of the TIN.

NOTE 4: Bounding polygons for multipoint features (DCF 1 and 8) may be one or more reasonably minimized polygons or bounding boxes that together cover all data points.

NOTE 5: A boundingPolygon is restricted to a single GML Polygon with one exterior and 0 or more interiors expressed as Linear Rings using SRS EPSG:4326. The exterior and optional interiors shall be composed of a closed sequence of >=4 coordinate positions expressed individually or as a list (posList). The GML polygon shall have a valid GML identifier

NOTE 6: For *approximateGridResolution*, if the grid cell size varies over the extent of the grid, an approximated value based on model parameters or production metadata should be used.

12.2.7 S100_Purpose

Role Name	Name	Description	Code	Remarks
Enumeration	S100_Purpose	The purpose of the dataset	-	See clause 8.2. **The S-100 values update and delta are not used.**
Value	newDataset	Brand new dataset	1	No data has previously been produced for this area
Value	newEdition	New Edition of the dataset or Catalogue	2	Includes new information which has not been previously distributed by updates
Value	cancellation	Dataset or Catalogue that has been cancelled	5	Indicates the dataset or Catalogue should no longer be used and can be deleted

12.2.8 S100_TemporalExtent

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_TemporalExtent	Temporal extent	--		At least one of the *timeInstantBegin* and *timeInstantEnd* attributes must be populated; if both are known, both must be populated. The absence of either begin or end indicates indefinite validity in the corresponding direction, limited by the issue date/time or the cancellation or supersession of the dataset
Attribute	timeInstantBegin	The instant at which the temporal extent begins	0..1	DateTime	
Attribute	timeInstantEnd	The instant at which the temporal extent ends	0..1	DateTime	

NOTE 1: In case of overlap in temporal extent between predecessor and successor datasets, the successor dataset prevails. For example, water level or weather forecast datasets may have a temporal extent of N days or hours, but be replaced by new forecast at N – X.

NOTE 2: Precedence and succession can be determined from information in dataset discovery metadata (in particular, issue date, time and temporal extent).

12.2.9 S100_EncodingFormat

Item	Name	Description	Code	Remarks
Enumeration	S100_EncodingFormat	Encoding format	-	**Only the HDF5 format is used in S-111**
Value	HDF5	The HDF5 data format as defined in Part 10c	-	

12.2.10 S100_ProductSpecification

S-111 uses S100_ProductSpecification without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_ProductSpecification	The Product Specification contains the information needed to build the specified product	-	-	**The optional S-100 attributes *name*, *version* and compliancyCategory are mandatory in S-111.**
Attribute	name	The name of the Product Specification used to create the datasets	**1**	CharacterString	The name in the Product Specification Register, in the IHO Geospatial Information (GI) Registry. **For S-111, this is "Surface Currents Product Specification"** **Mandatory in S-111**

Attribute	version	The version number of the Product Specification	**1**	CharacterString	For example, 2.0.0 for S-111 Edition 2.0.0 **Mandatory in S-111**
Attribute	date	The version date of the Product Specification	0..1	Date	From the Product Specification Register of the IHO GI Registry. For interim drafts use the version date in Product Specification Metadata
Attribute	productIdentifier	Machine readable unique identifier of a product type	1	CharacterString (Restricted to Product ID values from the IHO Product Specification Register, in the IHO Geospatial Information Registry)	**For S-111 this must be the string "S-111" (without quotes)**
Attribute	number	The number used to lookup the product in the Product Specification Register of the IHO GI registry	1	Integer	From the Product Specification Register in the IHO Geospatial Information Registry Encode as "0" until this Edition is added to the GI Registry and receives a Registry number. Do not use the number of any other Edition
Attribute	compliancyCategory	The level of compliance of the Product Specification to S-100	**1**	S100_CompliancyCategory	See S-100 Part 4a, clause 4a-5.5 and clause 7.6 in this Product Specification **Mandatory in S-111**

12.2.11 S100_CompliancyCategory

S-111 uses only Category 4 as defined in S-100 Part 4a, clause 4a-5.5.

Role Name	Name	Description	Code	Remarks
Enumeration	S100_CompliancyCategory		-	**S-111 does not use category1, category2 or category3**
Value	category4	IHO S-100 and IMO harmonized display compliant	4	

12.2.12 S100_ProtectionScheme

S-111 uses S100_ProtectionScheme without modification.

Item	Name	Description	Code	Remarks
Enumeration	S100_ProtectionScheme	Data protection schemes	-	-
Value	S100p15	IHO S-100 Part 15	-	See S-100 Part 15

12.2.13 S100_SupportFileDiscoveryMetadata

The only support files in S-111 are enumeration dictionaries and language packs for Feature Catalogues.

Role Name	Name	Description	Mult.	Type	Remarks
Class	S100_SupportFileDiscoveryMetadata	Metadata about the individual support files in the Exchange Catalogue	-	-	**S-111 does not use *otherDataTypeDescription***
Attribute	fileName	Name of the support file	1	URI	See S-100 Part 1, clause 1-4.6 and clause 11.2.5 in this Product Specification
Attribute	revisionStatus	The purpose for which the support file has been issued	1	S100_SupportFileRevisionStatus	For example new, replacement, etc
Attribute	editionNumber	The Edition number of the support file	1	Integer	See clause 8.2.6
Attribute	issueDate	Date on which the data was made available by the Data Producer	0..1	Date	Date on which the support file was made available by its producer
Attribute	supportFileSpecification	The Specification used to create this file	0..1	S100_SupportFileSpecification	
Attribute	dataType	The format of the support file	1	S100_SupportFileFormat	
Attribute	comment	Optional comment	0..1	CharacterString	
Attribute	compressionFlag	Indicates if the resource is compressed	1	Boolean	*true* indicates a compressed resource *false* indicates an uncompressed resource
Attribute	digitalSignatureReference	Specifies the algorithm used to compute digitalSignatureValue	1	S100_SE_DigitalSignatureReference (see S-100 Part 15)	
Attribute	digitalSignatureValue	Value derived from the digital signature	1..*	S100_SE_DigitalSignature (see S-100 Part 15)	The value resulting from application of digitalSignatureReference Implemented as the digital signature format specified in S-100 Part 15
Attribute	defaultLocale	Default language and character set used in the support file	0..1	PT_Locale	In absence of defaultLocale the language is English in UTF-8 A support file is expected to use only one as locale. Additional support files can be created for other locales

Attribute	supportedResource	Identifier of the resource supported by this support file	0..*	CharacterString	Conventions for identifiers are still to be developed in S-100. S-100 allows file URI, digital signature or cryptographic hash checksums to be used. **In the interim, S-111 will reference the Feature Catalogue file. For enumeration dictionaries, use the Product Specification identifier and version in URI form**
Attribute	resourcePurpose	The purpose of the supporting resource	0..1	S100_ResourcePurpose	Identifies how the supporting resource is used

12.2.14 S100_SupportFileFormat

Item	Name	Description	Code	Remarks
Enumeration	S100_SupportFileFormat	The format used for the support file	-	**S-111 uses only XML**; language packs and enumeration dictionaries are XML files
Value	XML	Extensible Markup Language	4	

12.2.15 S100_SupportFileRevisionStatus

S-111 uses S100_SupportFileRevisionStatus without modification.

Item	Name	Description	Code	Remarks
Enumeration	S100_SupportFileRevisionStatus	The reason for inclusion of the support file in this Exchange Set	-	-
Value	new	A file which is new	1	Signifies a new file
Value	replacement	A file which replaces an existing file	2	Signifies a replacement for a file of the same name
Value	deletion	Deletes an existing file	3	Signifies deletion of a file of that name

12.2.16 S100_SupportFileSpecification

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_SupportFileSpecification	The Standard or Specification to which a support file conforms	-	-	-
Attribute	name	The name of the Specification used to create the support file	1	CharacterString	S-100 for language packs and enumeration dictionary

Attribute	version	The version number of the Specification	0..1	CharacterString	Use the applicable edition of the Standard in the *name* attribute For example, “5.0.0” for language packs conforming to S-100 Edition 5.0.0
Attribute	date	The version date of the Specification	0..1	Date	Omit or use the publication date in the GI Registry or ISO Catalogue

12.2.17 S100_ResourcePurpose

Item	Name	Description	Code	Remarks
Enumeration	S100_ResourcePurpose	Defines the purpose of the supporting resource	-	**S-111 allows only language packs and enumeration dictionaries as support files and the allowed values of the S-100 enumeration are restricted accordingly**
Value	languagePack	A Language pack	3	
Value	productVersion	All datasets conforming to a specific version of an S-100 Product Specification	100	For an enumeration dictionary, which supports all datasets for a particular version of the Product Specification

12.2.18 S100_CatalogueDiscoveryMetadata

S-111 uses S100_CatalogueDiscoveryMetadata without modification. This class is used to provide metadata about Feature and Portrayal Catalogues.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_CatalogueDiscoveryMetadata	Class for S-100 Catalogue metadata	-	-	-
Attribute	fileName	The name for the Catalogue	1	URI	See S-100 Part1, clause 1-4.6
Attribute	purpose	The purpose for which the Catalogue has been issued	0..1	S100_Purpose (codelist)	The values must be one of the following: *2* new edition *5* cancellation Default is new edition
Attribute	editionNumber	The Edition number of the Catalogue	1	Integer	Initially set to 1 for a given productSpecification.number Increased by 1 for each subsequent New Edition Uniquely identifies the version of the Catalogue
Attribute	scope	Subject domain of the Catalogue	1	S100_CatalogueScope	
Attribute	versionNumber	The version identifier of the Catalogue	1	CharacterString	Human readable version identifier
Attribute	issueDate	The issue date of the Catalogue	1	Date	

Attribute	productSpecification	The Product Specification used to create this file	1	S100_ProductSpecification	
Attribute	digitalSignatureReference	Specifies the algorithm used to compute digitalSignatureValue	1	S100_SE_DigitalSignatureReference (see S-100 Part 15)	
Attribute	digitalSignatureValue	Value derived from the digital signature	1..*	S100_SE_DigitalSignature (see S-100 Part 15)	The value resulting from application of *digitalSignatureReference* Implemented as the digital signature format specified in S-100 Part 15
Attribute	compressionFlag	Indicates if the resource is compressed	1	Boolean	*true* indicates a compressed resource *false* indicates an uncompressed resource
Attribute	defaultLocale	Default language and character set used in the Catalogue	0..1	PT_Locale	In absence of *defaultLocale* the language is English in UTF-8
Attribute	otherLocale	Other languages and character sets used in the Catalogue	0..*	PT_Locale	

12.2.19 S100_CatalogueScope

Item	Name	Description	Code	Remarks
Enumeration	S100_CatalogueScope	The scope of the Catalogue	-	**S-111 Exchange Sets do not contain Interoperability Catalogues and the value *interoperabilityCatalogue* is removed**
Value	featureCatalogue	S-100 Feature Catalogue	-	
Value	portrayalCatalogue	S-100 Portrayal Catalogue	-	

12.2.20 MD_MaintenanceInformation

Role Name	Name	Description	Mult	Type	Remarks
Class	MD_MaintenanceInformation	Information about the scope and frequency of updating	-	-	S-100 restricts the ISO 19115-class to: • Prohibit *maintenanceScope*, *maintenanceNote*, and contact attributes; • Define restrictions on *maintenanceAndUpdate Frequency*, *maintenanceDate*, and *userDefinedMaintenanceFrequency* attributes

Attribute	maintenanceAndUpdateFrequency	Frequency with which changes and additions are made to the resource after the initial resource is completed	0..1	MD_MaintenanceFrequencyCode (codelist)	Must be populated if *userDefinedMaintenanceFrequency* is not present, otherwise optional. See Table **MD_MaintenanceFrequencyCode** in this Section for values allowed in S-100 metadata
Attribute	maintenanceDate	Date information associated with maintenance of the resource	0..1	CI_Date	Exactly one of *maintenanceDate* and *userDefinedMaintenanceFrequency* must be populated Allowed value for *dateType*: *nextUpdate*
Attribute	userDefinedMaintenanceFrequency	Maintenance period other than those defined	0..1	TM_PeriodDuration	Exactly one of *maintenanceDate* and *userDefinedMaintenanceFrequency* must be populated Only positive durations allowed

12.2.21 MD_MaintenanceFrequencyCode

Item	Name	Description	Code	Remarks
Enumeration	MD_MaintenanceFrequencyCode	Frequency with which modifications and deletions are made to the data after it is first produced	-	S-100 is restricted to only the following values from the ISO 19115-1 codelist. The conditions for the use of a particular value are described in its Remarks
Value	asNeeded	Resource is updated as deemed necessary	1	Use only for datasets which normally use a regular interval for update or supersession, but will have the next update issued at an interval different from the usual Allowed if and only if *userDefinedMaintenanceFrequency* is not populated
Value	irregular	Resource is updated in intervals that are uneven in duration	2	Use only for datasets which do not use a regular schedule for update or supersession Allowed if and only if *userDefinedMaintenanceFrequency* is not populated

12.2.22 PT_Locale

Role Name	Name	Description	Mult	Type	Remarks
Class	PT_Locale	Description of a locale	-	-	From ISO 19115-1
Attribute	language	Designation of the locale language	1	LanguageCode	ISO 639-2/T 3-letter language codes.
Attribute	country	Designation of the specific country of the locale language	0..1	CountryCode	ISO 3166-2 2-letter country codes

Attribute	characterEncoding	Designation of the character set to be used to encode the textual value of the locale	1	MD_CharacterSetCode	UTF-8 is used in S-100

LanguageCode, *CountryCode* and *MD_CharacterSetCode* are codelists which are defined in resource files within the S-100 XML schemas package and described in the documentation for the S-100 XML Schemas.

12.2.23 S100_SE_CertificateContainer

S-111 uses S100_SE_CertificateContainer without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_SE_CertificateContainer	A set of signed public key certificates	-	-	Used in S-100 Part 17 Exchange Catalogues
Attribute	schemeAdministrator	The scheme administrator identity	0..1	CharacterString	The identity of the Scheme Administrator is contained in the “id” attribute of the schemeAdminstrator element. The Scheme Adminstrator certificate is NOT included in catalogue metadata as it is independently verified by the implementing system
Attribute	certificate	A signed public key certificate	1..*	Base 64 encoded Character String	Conforms to X.509 encoding. Contains a digitally signed identifier of an entity

12.2.24 S100_SE_DigitalSignatureReference

S-111 uses only the *ECDSA-384-SHA2* value of S100_SE_DigitalSignatureReference, in conformity with the restriction in S-100 Part 15, clauses 15-8.7 and 15-8.11.7.

Item	Name	Description	Code	Remarks
Enumeration	S100_SE_DigitalSignatureReference	Algorithm used to compute the digital signature	-	Only ECDSA is currently used in implementations of S-100 for file based transfer of data to ECDIS. Other values are included for interoperability with other implementations by external standards. See S-100 Part 15, clause 15-8.4
Value	ECDSA-384-SHA2		8	384 bits ECDSA: SHA2-384

12.2.25 S100_SE_DigitalSignature

S-111 conforms to S-100 Part 15, clause 15-8-11.4, which states: “The class S100_SE_DigitalSignature is realized as one of either S100_SE_SignatureOnData (a digital signature of a particular identified resource) or an additional digital signature defined using the [same class] which is either a S100_SE_SignatureOnData or S100_SE_SignatureOnSignature element as described in clause 15-8.8. S-100 Part 17 metadata thus allows for multiple digital signatures, a single mandatory S100_SE_SignatureOnData and any number of additional signatures, either of the data or other signatures.” (In S-100, this class is not documented separately.)

S-104 uses the class S100_SE_DigitalSignature without modification; however, in exchange catalogues it is implemented by one of its subclasses S100_SE_SignatureOnData or S100_SE_SignatureOnSignature.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_SE_DigitalSignature		-	Base64 encoded digital signature value	See S-100 Part 15, clause 15-8 Abstract class substituted by one of its subclasses.
Attribute	id	Identifier of the digital signature	1	CharacterString	Every signature entry has a unique identifier
Attribute	certificateRef	Signed Public Key	1	CharacterString	Identifier of the certificate against which the digital signature validates

12.2.26 S100_SE_SignatureOnData

S-111 uses S100_SE_SignatureOnData without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_SE_SignatureOnData		-	Base64 encoded digital signature value	See S-100 Part 15, clause 15-8 Subclass of S100_SE_DigitalSignature
Attribute	id	Identifier of the digital signature	1	CharacterString	Every signature entry has a unique identifier (Inherited attribute)
Attribute	certificateRef	Signed Public Key	1	CharacterString	Identifier of the certificate against which the digital signature validates (Inherited attribute)
Attribute	dataStatus	The digital signature	1	DataStatus	

12.2.27 S100_SE_SignatureOnSignature

S-111 uses S100_SE_SignatureOnSignature without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_SE_SignatureOnSignature		-	Base64 encoded digital signature value	See S-100 Part 15, clause 15-8 Subclass of S100_SE_DigitalSignature
Attribute	id	identifier of the digital signature	1	CharacterString	Every signature entry has a unique identifier (Inherited attribute)

Attribute	certificateRef	Signed Public Key	1	CharacterString	Identifier of the certificate against which the digital signature validates (Inherited attribute)
Attribute	signatureref	The digital signature referenced	1		

12.2.28 DataStatus

S-111 uses the S-100 enumeration DataStatus defined in S-100 Part 15 without modification.

Item	Name	Description	Code	Remarks
Enumeration	DataStatus	The state of data when a digital signature is created	-	
Value	unencrypted	The data is unencrypted and uncompressed	-	For example, supporting resources
Value	encrypted	The data is compressed and encrypted	-	For example, copy protected datasets
Value	compressed.	The data is compressed only	-	For example, archives of multiple resources

12.2.29 EX_GeographicBoundingBox

From ISO 19115-1.

Role Name	Name	Description	Mult	Type	Remarks
Class	EX_GeographicBoundingBox	Geographic position of the dataset	-	-	Defined in ISO 19115-1: geographic position of the resource
Attribute	westBoundLongitude	Western-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east)	1	Real	Arc degrees
Attribute	eastBoundLongitude	Eastern-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east)	1	Real	Arc degrees
Attribute	southBoundLatitude	Southern-most coordinate of the limit of the dataset extent, expressed in latitude in decimal degrees (positive north)	1	Real	Arc degrees
Attribute	northBoundLatitude	Northern-most, coordinate of the limit of the dataset extent expressed in latitude in decimal degrees (positive north)	1	Real	Arc degrees

NOTE (from ISO 19115-1): This is only an approximate reference so specifying the Coordinate Reference System is unnecessary and need only be provided with a precision of up to two decimal places.

12.2.30 EX_BoundingPolygon

From ISO 19115-1.

Role Name	Name	Description	Mult	Type	Remarks
Class	EX_BoundingPolygon	Boundary enclosing the dataset, expressed as the closed set of (x,y) coordinates of the polygon (last point replicates first point)	-	-	Defined in ISO 19115-1: enclosing geometric object which locates the resource, expressed as a set of (x,y) coordinate(s)
Attribute	polygon	Sets of points defining the bounding polygon	1	GM_Object	Must be a GML polygon with one exterior and 0 or more interiors expressed as Linear Rings using SRS EPSG:4326 (See S-100 Part 17)

NOTE (from ISO 19115-1): If a polygon is used it should be closed (last point replicates first point).

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12.3 Carrier metadata

The metadata for the S-111 product is divided in three sections, corresponding to the General Metadata (Table 12-1), the Feature Type Metadata (Table 12-2), and the Feature Instance Metadata (Table 12-3 and Table 12-4). The Instance Metadata is subdivided into metadata attached to the instance as a whole (Table 12-3) and metadata attached to individual values groups (Table 12-4). Since these values do not reside in the Metadata blocks, but are in the HDF files, they are referred to as Carrier Metadata. The Carrier Metadata consists of the data and parameters needed to read and interpret the information in the Surface Current product even if the other S-111 Metadata files are unavailable.

Note that in Tables 12-1 – 12-4, some of the metadata variables have restrictions on their core values (that is, whether they are optional or mandatory, the specific values allowed, etc) that are not imposed in S-100. These are grouped under the heading '*Metadata for S-111 with restrictions on core metadata values*.'

Mandatory attributes in a section of a Table that is designated for one or more specified *dataCodingFormat* values are mandatory only for the specified *dataCodingFormat* value(s).

It is suggested for any enumeration in S-111, to use unsigned integer types (preferably standard integer type H5T_STD_U8LE) for the base type of the numeric code when creating the enumeration[10].

Figures 12-5 – 12-9 depict the carrier metadata at each level of the structural hierarchy in an HDF5 dataset. The elements (groups and metadata) defined in S-100 are distinguished from those defined in S-111 by prefix and shade. Figure 12-5 is a summary diagram depicting all levels of the structural and their associated metadata components for all the coverage types used in S-111. Figures 12-6 – 12-9 show the details for each structural level and each coverage type.

The same information as in Figures 12-6 – 12-9 is depicted in Annex B (Figures B-6 – B-10) but organised by type of coverage instead of levels in the HDF5 structural hierarchy.

The maximum length of all string HDF5 attributes is 300 characters.

[10] See the guidance on HDF5 datatypes (https://support.hdfgroup.org/HDF5/Tutor/datatypes.html, retrieved 20 August 2021) for more information on the use of standard vs native types when creating a dataset and for memory operations (read/write).

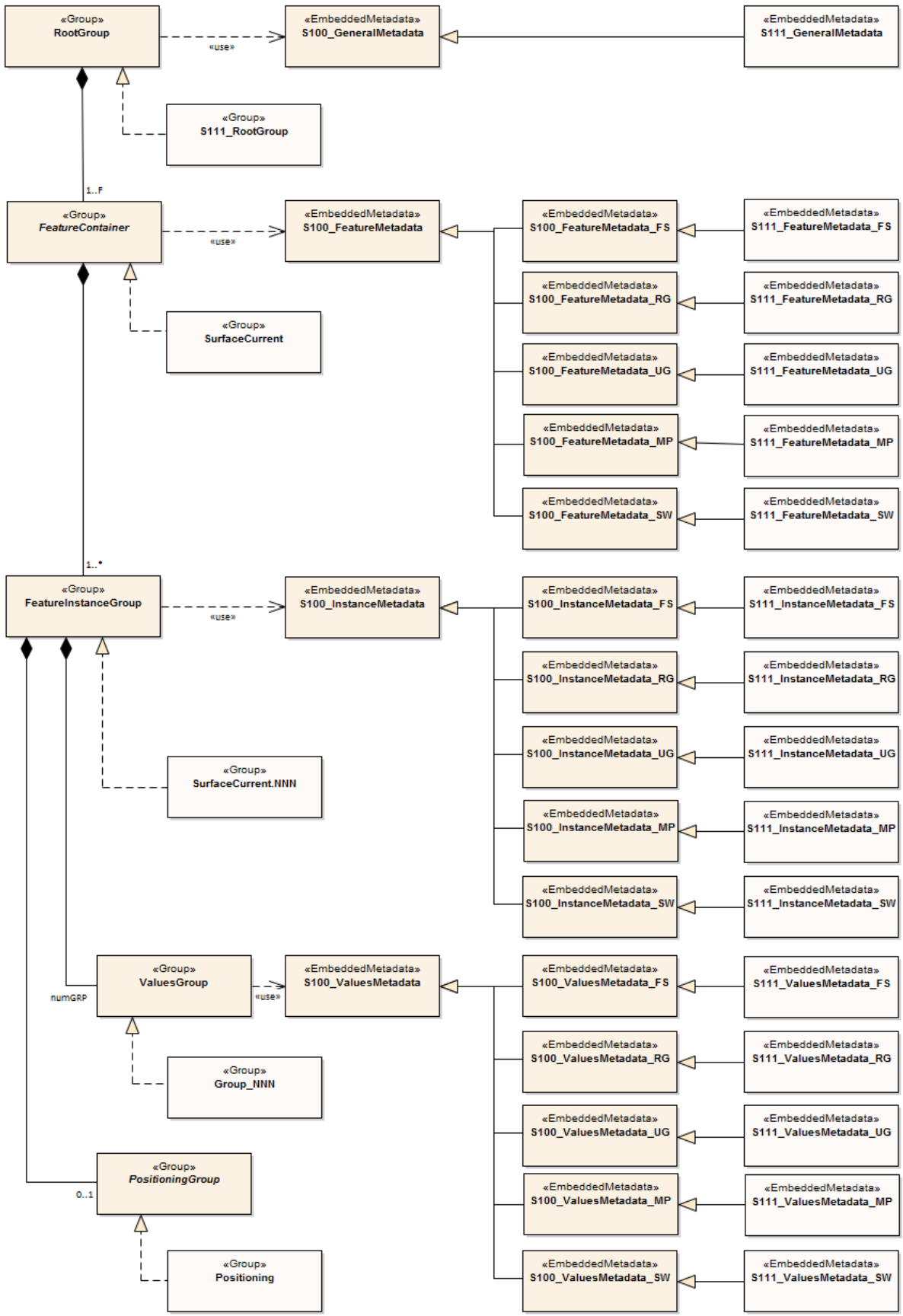

Figure 12-5 – Carrier metadata for the S-111 HDF5 group hierarchy

Figure 12-6 – General metadata - Carrier metadata for the root group

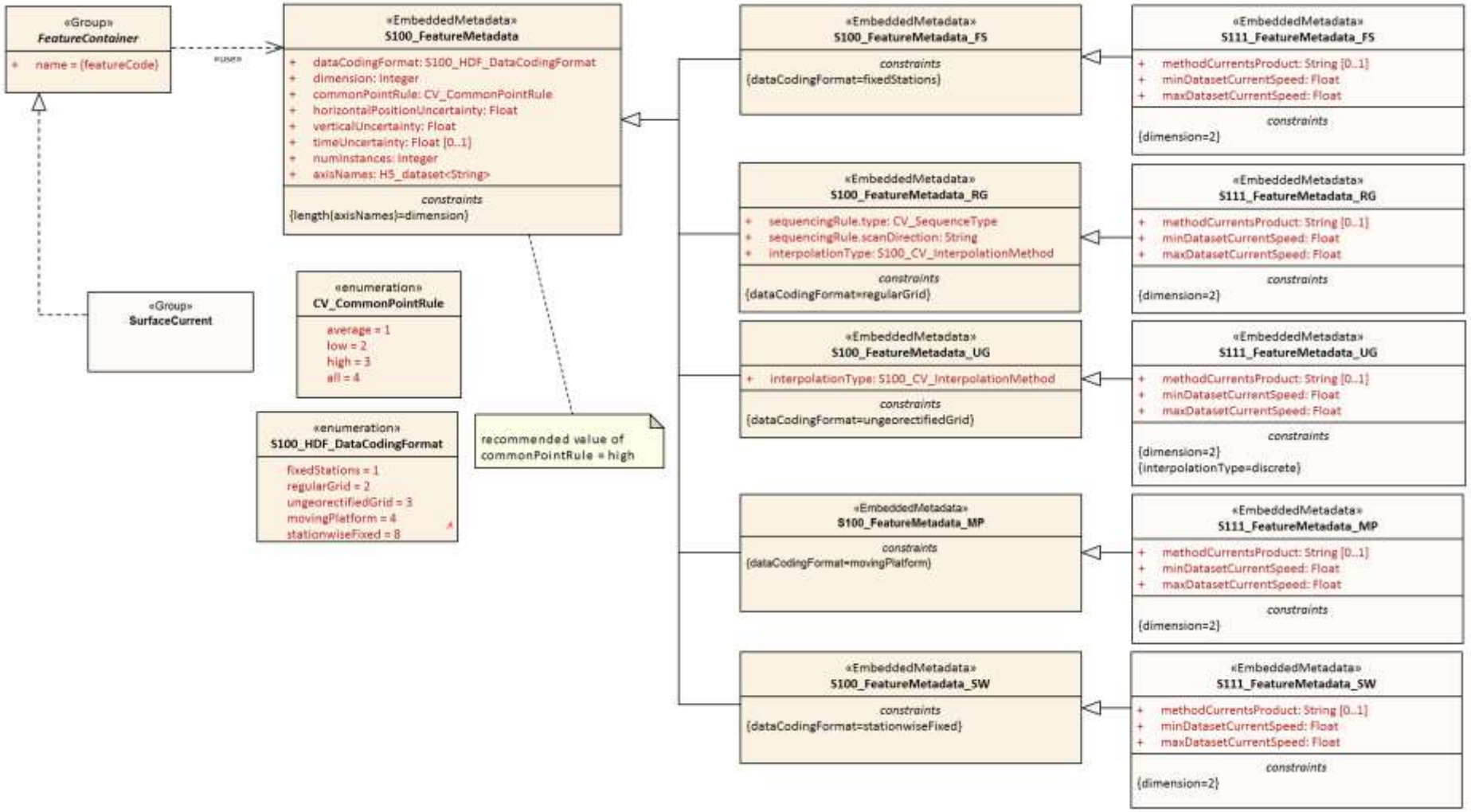

Figure 12-7 – Feature Type metadata - Carrier metadata for the Feature Container group

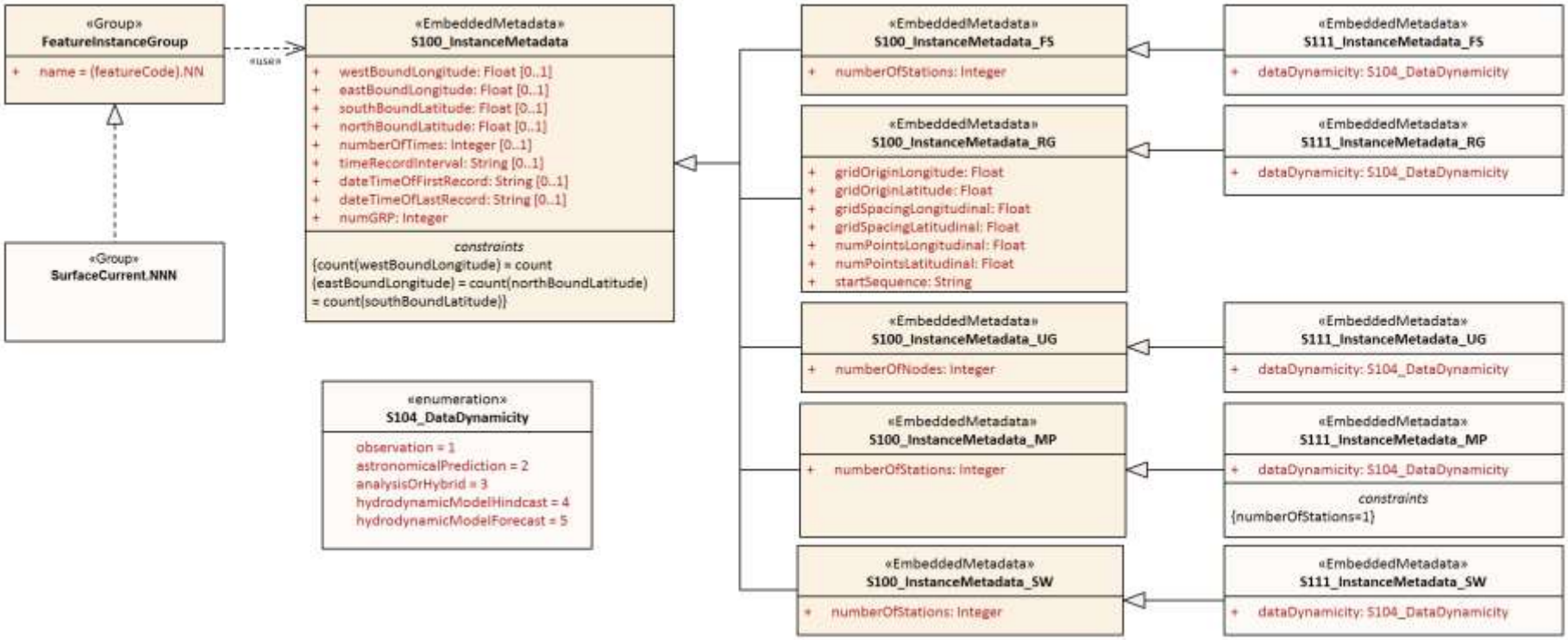

Figure 12-8 – Feature Instance metadata - Carrier metadata for the Feature Instance group

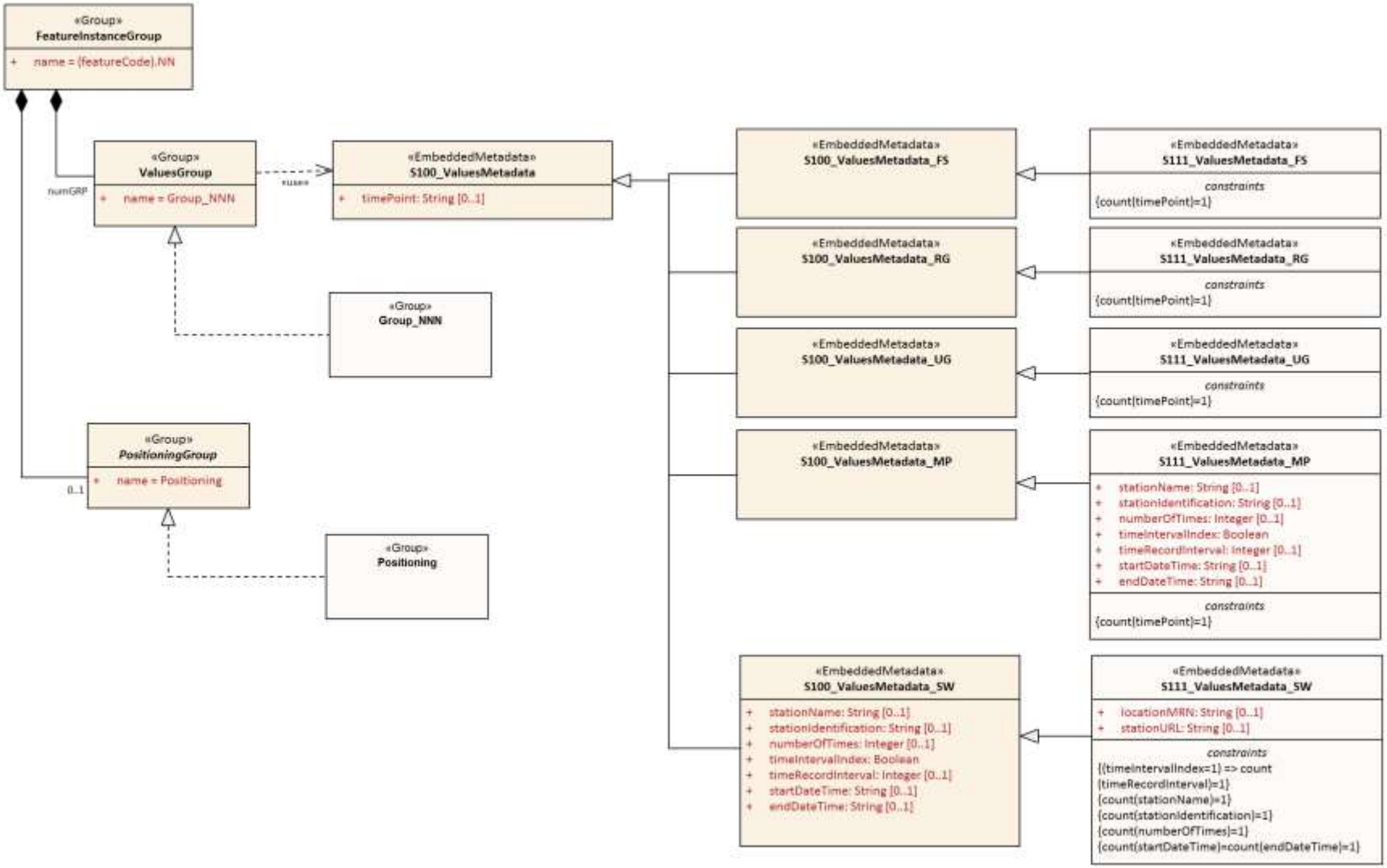

Figure 12-9 – Feature Instance metadata - Carrier metadata for the Values group in each Feature Instance group

For all carrier metadata, latitude and longitude values are precise to 10^{-7} degrees except where noted. All times are in UTC format.

All enumeration attributes in carrier metadata must be implemented as HDF5 enumerations. The base type for all enumeration attributes in the following tables must be 8-bit unsigned integer in the HDF5 standard integer type H5T_STD_U8LE.

Integer types are signed integers unless designated as “unsigned”.

Strings must use UTF-8 character encoding. String padding is not specified in this edition of the Product Specification due to the diversity of API framework treatment of padding.

12.3.1 General metadata - details

Table 12-1 - General metadata, related to the entire HDF5 file (see S-100 Part 10c, Table 10c-6). All times are in UTC format

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
1	Product Specification number and version	productSpecification	1	String	This must be encoded as ‘INT.IHO.S-111.X.Y’, with X representing the Edition number and Y the revision number. See Note 6
2	Date of data product issue	issueDate	1	String	Date must be consistent with issueDate in discovery metadata
3	Horizontal Coordinate Reference System	horizontalCRS	1	Integer 32-bit	EPSG code (clause 5.1) or -1 if user defined EXAMPLE 1: 4326 (for WGS84) See https://spatialreference.org/ref/epsg/?page=1 EXAMPLE 2: EPSG:9057 is WGS 84 (G1762) realization with valid epoch 2005.0
4	Bounding box	westBoundLongitude	1	Float 32-bit	Area encompassing all feature instances Units are Decimal Degrees in the EPSG 4326 CS. In accordance with ISO 19115-1 these coordinates need be accurate only to two decimal places
5		eastBoundLongitude	1	Float 32-bit	
6		southBoundLatitude	1	Float 32-bit	
7		northBoundLatitude	1	Float 32-bit	
8	Geographic location of the resource (by description)	geographicIdentifier	0..1	String	Description, or location code from list agreed by data producers (In S-100: EX_Extent > EX_GeographicDescription.geographicIdentifier > MD_Identifier.code)
9	Metadata file name[11]	metadata	1	String	Name of XML metadata file for the HDF5 file Form: MD_<hdf file name>.XML. The empty string means this file is not provided
10	Name of the horizontal CRS	nameOfHorizontalCRS	0..1	String	Mandatory if horizontalCRS = -1

[11] As of February 2024 it is possible that the final version of S-100 5.2.0 might make this attribute optional, in which case it should be removed from S-104 2.0.0.

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
11	Type of the horizontal CRS	typeOfHorizontalCRS	0..1	Enumeration	Mandatory if horizontalCRS = -1 See Table 12-5
12	Horizontal coordinate system	horizontalCS	0..1	Integer 32-bit	Mandatory if horizontalCRS = -1 Allowed values if typeOfHorizontalCRS = 1 (Geodetic CRS 2D): • 6422 (Lat, Lon – degree) Allowed values if typeOfHorizontalCRS = 2 (Projected CRS): 4400 (Easting, Northing – metres) 4500 (Northing, Easting – metres)
13	Horizontal datum	horizontalDatum	0..1	Integer 32-bit	Mandatory if horizontalCRS = -1 EPSG code or -1 if user defined
14	Name of horizontal datum	nameOfHorizontalDatum	0..1	String	Mandatory if horizontalDatum = -1
15	Prime meridian	primeMeridian	0..1	Integer 32-bit	Mandatory if horizontalDatum = -1; EPSG Code
16	Spheroid	spheroid	0..1	Integer 32-bit	Mandatory if horizontalDatum = -1; EPSG Code
17	Projection method	projectionMethod	0..1	Integer 32-bit	Mandatory if typeOfHorizontalCRS = 2; EPSG Code, see Table 12-7
18	Projection parameter 1	projectionParameter1	0..1	Float 64-bit	Only if projectionMethod is used. See Table 12-7
19	Projection parameter 2	projectionParameter2	0..1	Float 64-bit	Only if projectionMethod is used. See Table 12-7
20	Projection parameter 3	projectionParameter3	0..1	Float 64-bit	Only if projectionMethod is used. See Table 12-7
21	Projection parameter 4	projectionParameter4	0..1	Float 64-bit	Only if projectionMethod is used. See Table 12-7
22	Projection parameter 5	projectionParameter5	0..1	Float 64-bit	Only if projectionMethod is used. See Table 12-7
23	False northing	falseNorthing	0..1	Float 64-bit	Only if projectionMethod is used. To be applied to the coordinates at axis Northing. [m]
24	False easting	falseEasting	0..1	Float 64-bit	Only if projectionMethod is used. To be applied to the coordinates at axis Easting. [m]
25	Epoch of realization	epoch	0..1	String	Code denoting the epoch of the geodetic datum used by the CRS. For example, 2005.0 for the G1762 realization of the geodetic datum for WGS84. Must match epoch denoted by horizontalCRS.
Additional metadata for S-111					

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
26	Dataset delivery interval	datasetDeliveryInterval	0..1	String	The expected time interval between availability of successive datasets for time-varying data. Must be formatted as PnYnMnDTnHnMnS (ISO 8601 duration). See Note 8
27	Index for type of depth	depthTypeIndex	1	Enumeration	See Table 12-11 – S111_DepthTypeIndex
28	Depth value	surfaceCurrentDepth	1	Float 32-bit	Depth/height value or layer thickness (m)
Additional restrictions on core general metadata for S-111					
29	Time of data product issue	issueTime	1	String	Mandatory for S-111. S-100 Time format. All times are in UTC. For example 123000Z
30	Vertical coordinate system	verticalCS	1	Integer 32-bit	Mandatory for S-111 if and only if *depthTypeIndex*=1. EPSG Code; Allowed Values • 6498 (Depth– Metres– Orientation Down) • 6499 (Height– Metres– Orientation Up)
31	Vertical coordinate base	verticalCoordinateBase	1	Enumeration	**Mandatory in S-111** **The only allowed value is verticalDatum (see S-100 Table 10c-22)**
32	Vertical datum reference	verticalDatumReference	1	Enumeration	Mandatory for S-111 if and only if *depthTypeIndex*=1. 1: S-100 vertical datum 2: EPSG
33	Vertical datum	verticalDatum	1	Integer 32-bit	Mandatory for S-111 if and only if *depthTypeIndex*=1. If verticalDatumReference = 1 this is one of the standard values from S100_VerticalAndSoundingDatum. If verticalDatumReference = 2 this is an EPSG code for vertical datum

NOTE 1: If the CRS is user defined only the following coordinate systems are supported:

a. Geodetic CS (Latitude, Longitude) – Degrees; and
b. Cartesian CS (Northing, Easting or Easting, Northing) – Metres.

NOTE 2: For the horizontal Datum all EPSG predefined Datums are allowed or any combination of predefined Prime Meridians or predefined Spheroids.

NOTE 3: The projection methods are limited to those given in Table 12-7.

NOTE 4: If the horizontal CRS is defined by the EPSG code, the defined CRS should not use any other elements than the one allowed for user defined CRSs; (for example, no projection method that is not in the Table).

NOTE 5: The bounding box is the data set bounding box; the coverage data feature instances may or may not cover the entire bounding box. If there is only a single coverage feature, its extent may or may not be the same as the data set.

NOTE 6: Beginning S-100 Edition 5.0.0, class **S100_ProductSpecification** (S-100 Part 17) contains a *productIdentifier* field whose value must be the Product ID value from the IHO Product Specification Register in the IHO Geospatial Information Registry. Attribute *productSpecification* in Table 12-1 must use exactly the same value.

NOTE 7: Beginning S-100 Edition 5.0.0, *seaSurface* and *seaFloor* have been added to the **S100_VerticalAndSoundingDatum** enumeration, which makes attribute *verticalCoordinateBase* redundant. It is included in order to ensure compliance with generic validation checks for attribute verticalDatum.

NOTE 8: Dataset delivery interval is encoded only if the dataset is part of a sequence delivered at known intervals (for example, daily, weekly, or 6-hourly forecasts). S-100 Part 17, clause 17-4.9 contains detailed guidance for encoding the discovery metadata equivalent of this attribute (*userDefinedMaintenancefrequency*) and the same guidelines apply to encoding this attribute. If this attribute and its discovery metadata equivalent are both encoded (in the HDF5 dataset and discovery metadata block respectively), the durations encoded by them must be the same. Intervals greater than monthly may be encoded at Producer discretion.

12.3.2 Feature Type metadata - details

Table 12-2 – Feature Type metadata, pertaining to the SurfaceCurrent feature type (See S-100 Part 10c, Table 10c-10)

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
1	Data organization index (Used to read the data. See Table 10-1)	dataCodingFormat	1	Enumeration	See Table 12-9. The allowed values are: 1: Time series at fixed stations 2: Regularly-gridded arrays 3: Ungeorectified gridded arrays 4: Moving platform 8: Stationwise time series (This Product Specification allows the use of only 1-4 and 8 from S-100)
2	Dimension	dimension	1	Integer 8-bit unsigned	The (spatial) dimension of the feature instances. For currents, use 2 This is the number of coordinate axes, not the rank of the HDF5 arrays storing coordinates or values
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. Recommend using 3 (‘high’) 1: average 2: low 3: high 4: all
4	Horizontal position uncertainty	horizontalPositionUncertainty	1	Float 32-bit	-1.0 (unknown) or positive value (m)
5	Vertical position uncertainty	verticalUncertainty	1	Float 32-bit	-1.0 (unknown) or positive value (m)
6	Time uncertainty	timeUncertainty	0..1	Float 32-bit	-1.0 (unknown) or positive value (s)
7	Number of feature instances	numInstances	1	Integer 32-bit unsigned	Num. of stations, gridded forecasts, etc
Additional metadata for S-111					

8	Methodology	methodCurrentsProduct	0..1	String	Brief description of current meter type, forecast method or model, etc
9	Min. current speed in dataset	minDatasetCurrentSpeed	1	Float 64-bit	-1.0 (unknown) or positive value (kn). Use the same precision as the corresponding attribute in the values record
10	Max. current speed in dataset	maxDatasetCurrentSpeed	1	Float 64-bit	-1.0 (unknown) or positive value (kn). Use the same precision as the corresponding attribute in the values record
dataCodingFormat = 1 (fixed stations)					
--	(none)				
dataCodingFormat = 2 (regular grid)					
11	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 For example 1 (for 'linear')
12		sequencingRule.scanDirection	1	String	scanDirection: String <axisNames entry> (comma-separated) For example "longitude,latitude"
Metadata with restrictions on core metadata values					
13	Interpolation Type	interpolationType	1	Enumeration	Interpolation method recommended for evaluation of the S100_GridCoverage Values: CV_InterpolationMethod (ISO 19123). For S-111, must use 10 (for 'discrete')
dataCodingFormat = 3 (ungeorectified grid)					
Metadata with restrictions on core metadata values					
11	Interpolation Type	interpolationType	1	Enumeration	Must use 10 (for 'discrete')
dataCodingFormat = 4 (moving platform)					
--	(none)				
dataCodingFormat = 8 (fixed stations, stationwise)					
--	(none)				

12.3.3 Feature Instance metadata - details

Table 12-3 – Feature Instance metadata, pertaining to the feature instance (see S-100 Part 10c, Table 10c-12). All times are in UTC format

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
1	Bounding box	westBoundLongitude	0..1	Float 32-bit	Area of specific grid, set of stations, etc
2		eastBoundLongitude	0..1	Float 32-bit	
3		southBoundLatitude	0..1	Float 32-bit	
4		northBoundLatitude	0..1	Float 32-bit	

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
5	Number of time records	numberOfTimes	0..1	Integer 32-bit unsigned	The total number of time records. For dataCodingFormat = 8, this variable may be overridden by the corresponding one in the values group attributes (Table 12-4)
6	Time interval	timeRecordInterval	0..1	Integer 16-bit unsigned	The interval between time records. Units: Seconds. For dataCodingFormat = 8, this variable may be overridden by the corresponding one in the values group attributes (Table 12-4)
7	Valid time of earliest value	dateTimeOfFirstRecord	0..1	String	DateTime, UTC format. First record in the Instance
8	Valid time of latest value	dateTimeOfLastRecord	0..1	String	DateTime, UTC format
9	Number of value groups	numGRP	1	Integer 32-bit unsigned	Number of Group_nnn dataCodingFormat = 1, 2, and 3, equals the number of time points. For dataCodingFormat = 4, fixed at 1. For dataCodingFormat = 8, equals the number of stations
Additional metadata for S-111					
10	Data dynamicity	dataDynamicity	1	Enumeration	See Table 12-10. The allowed values are: 1: Observation 2: Astronomical prediction 3: Analysis or hybrid method 4: Hydrodynamic model hindcast 5: Hydrodynamic model forecast
dataCodingFormat = 1 (fixed stations)					
11	Number of fixed stations	numberOfStations	1	Integer 32-bit unsigned	Number of individual fixed stations in this instance
dataCodingFormat = 2 (regular grid)					
11	Longitude of grid origin	gridOriginLongitude	1	Float-Double (64-bit)	Degrees
12	Latitude of grid origin	gridOriginLatitude	1	Float-Double (64-bit)	Degrees
13	Grid spacing, long.	gridSpacingLongitudinal	1	Float-Double (64-bit)	Degrees
14	Grid spacing, lat.	gridSpacingLatitudinal	1	Float-Double (64-bit)	Degrees
15	Number of points, long.	numPointsLongitudinal	1	Integer 32-bit unsigned	numCOLS
16	Number of points, lat.	numPointsLatitudinal	1	Integer 32-bit unsigned	numROWS
17	Start sequence	startSequence	1	String	For example, “0,0” (without quotes) for lower left. For upper left, “0,n”, where n is the value of numROWS-1. First character represents first axis in sequencingRule.scanDirection.(Table 12-2), which here is longitude
dataCodingFormat = 3 (ungeorectified grid)					

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
11	Number of nodes	numberOfNodes	1	Integer 32-bit unsigned	The total number of grid points
dataCodingFormat = 4 (moving platforms)					
11	Number of stations	numberOfStations	1	Integer 32-bit unsigned	Value is always 1
dataCodingFormat = 8 (fixed stations, stationwise)					
11	Number of fixed stations	numberOfStations	1	Integer 32-bit unsigned	Number of individual fixed stations in this instance

12.3.4 Values Group attributes - details

An expanded new metadata block is required for the Values Groups (Table 12-4). The variables *stationName* and *stationIdentification* have been added for both identification and possibly for inclusion in the text of the graph. The series start and end times, number of records, and time interval index are included since they may differ for each series.

Table 12-4 – Values Group attributes (see S-100 Part 10c, Table 10c-19). This table also shows text and an entry of non-uniform time intervals are allowed

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
dataCodingFormat = 1 (fixed stations), 2 (regular grid), 3 (ungeorectified grid), 4 (moving platform)					
1	Time stamp	timePoint	1	String	DateTime. All times are in UTC. See clause 10.2.2.5
dataCodingFormat = 8 (fixed stations, stationwise) and 4 (moving platform)[12]					
2	Index for time interval	timeIntervalIndex	1	(Integer) 8-bit unsigned	1 (TRUE) denotes uniform time interval; interval provided by *timeRecordInterval*. 0 (FALSE) denotes non-uniform time interval This is a boolean implemented as described in S-100 Part 10c, Table 10c-1
3	Time interval	timeRecordInterval	0..1	Integer 16-bit unsigned	Only if *timeIntervalIndex* = 1 and numberOfTimes > 1 The uniform interval between time records. Units: Seconds. Value here overrides corresponding value at Instance level
4	Name of the station	stationName	0..1	String	Descriptive text, or 'Not Available'
5	Station identification number	stationIdentification	0..1	String	Letter-number combination, or 'Not Available'
6	Number of time records	numberOfTimes	1	Integer 32-bit unsigned	Use at Values Group level only for dataCodingFormat = 8 (Only mandatory if *timeIntervalIndex*=1.) Value here overrides corresponding value at Instance level

[12] For moving platforms, these are technically additional attributes defined by S-111.

7	Valid time of earliest value	startDateTime	1	String	Mandatory for S-111. DateTime format
8	Valid time of latest value	endDateTime	1	String	Mandatory for S-111. DateTime format
dataCodingFormat = 8 (fixed stations, stationwise)					
9	Location Maritime Resource Name	locationMRN	0..1	String	The Maritime Resource Name assigned to the station, if any Must be formatted as an MRN (cf. IALA G1143)
10	URL to station or data portal.	stationURL	0..1	String	URL to station or data portal Must be an *http* or *https* URL (S-100 Part 1, clause 1-4.6; RFC 3986)

12.3.5 Additional enumerations used in carrier metadata

Table 12-5 – Type of the horizontal CRS

Item	Name	Description	Code	Remarks
Enumeration	typeOfHorizontalCRS	Codes for describing the type of the two-dimensional horizontal CRS	-	
Literal	geodeticCRS2D	Two-dimensional geodetic CRS	1	
Literal	projectedCRS	Projected CRS	2	

Table 12-6 – Vertical datum reference

Item	Name	Description	Code	Remarks
Enumeration	verticalDatumReference		-	
Literal	s100VerticalDatum	The vertical datum is one of those listed in S100_VerticalAndSoundingDatum	1	
Literal	EPSG	The vertical datum is one of those listed in the EPSG Registry	2	

Table 12-7 – Projection methods and their parameters

Name	EPSG Code	Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5
Mercator	9805	Latitude of 1st standard parallel	Longitude of natural origin	-	-	-
Transverse Mercator	9807	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Oblique Mercator	9815	Latitude of projection centre	Longitude of projection centre	Azimuth of initial line	Angle from Rectified to Skew Grid	Scale factor on initial line
Hotline Oblique Mercator	9812	Latitude of projection centre	Longitude of projection centre	Azimuth of initial line	Angle from Rectified to Skew Grid	Scale factor on initial line
Lambert Conic Conformal (1SP)	9801	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Lambert Conic Conformal (2SP)	9802	Latitude of false origin	Longitude of false origin	Latitude of 1st standard parallel	Latitude of 2nd standard parallel	-

Oblique Stereographic	9809	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Polar Stereographic	9810	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Krovak Oblique Conic Conformal	9819	Latitude of projection centre	Longitude of projection centre	Azimuth of initial line	Latitude of pseudo standard parallel	Scale factor on pseudo standard parallel
American Polyconic	9818	Latitude of natural origin	Longitude of natural origin	-	-	-
Albers Equal Area	9822	Latitude of false origin	Longitude of false origin	Latitude of 1st standard parallel5	Latitude of 2nd standard parallel6	-
Lambert Azimuthal Equal Area	9820	Latitude of natural origin	Longitude of natural origin	-	-	-

Table 12-8 – S100_VerticalAndSoundingDatum

Item	Name	Description	Code	Remarks
S100_Codelist	S100_VerticalAndSoundingDatum	Allowable vertical and sounding datums	-	S-111 allows only the standard values of this codelist, which makes it effectively an enumeration for S-111 purposes
Value	meanLowWaterSprings		1	(MLWS)
Value	meanLowerLowWaterSprings		2	-
Value	meanSeaLevel		3	(MSL)
Value	lowestLowWater		4	-
Value	meanLowWater		5	(MLW)
Value	lowestLowWaterSprings		6	-
Value	approximateMeanLowWaterSprings		7	-
Value	indianSpringLowWater		8	-
Value	lowWaterSprings		9	-
Value	approximateLowestAstronomicalTide		10	-
Value	nearlyLowestLowWater		11	-
Value	meanLowerLowWater		12	(MLLW)
Value	lowWater		13	(LW)
Value	approximateMeanLowWater		14	-
Value	approximateMeanLowerLowWater		15	-
Value	meanHighWater		16	(MHW)
Value	meanHighWaterSprings		17	(MHWS)
Value	highWater		18	(HW)
Value	approximateMeanSeaLevel		19	-
Value	highWaterSprings		20	-

Item	Name	Description	Code	Remarks
Value	meanHigherHighWater		21	(MHHW)
Value	equinoctialSpringLowWater		22	-
Value	lowestAstronomicalTide		23	(LAT)
Value	localDatum		24	-
Value	internationalGreatLakesDatum1985		25	-
Value	meanWaterLevel		26	-
Value	lowerLowWaterLargeTide		27	-
Value	higherHighWaterLargeTide		28	-
Value	nearlyHighestHighWater		29	-
Value	highestAstronomicalTide		30	(HAT)
Value	balticSeaChartDatum2000	Baltic Sea Chart Datum 2000	44	-
Value	internationalGreatLakesDatum2020	The 2020 update to the International Great Lakes Datum, the official reference system used to measure water level heights in the Great Lakes, connecting channels, and the St Lawrence River system	46	Unlike the previous two IGLDs, this datum update will use a geoid-based vertical datum that will be accessible using global navigation satellite systems (GNSS) such as the Global Positioning System (GPS)
Value	seaFloor	The bottom of the ocean and seas where there is a generally smooth gentle gradient. Also referred to as sea bed (sometimes seabed or seabed), and sea bottom	47	-
Value	seaSurface	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	48	-
Value	hydrographicZero	A vertical reference near the lowest astronomical tide (LAT), below which the sea level falls only very exceptionally	49	Deviation between LAT and hydrographic zero may be due to a strong anticyclonic atmospheric condition, adding weight to the water column that may exceptionally cause the lowest sea level to fall below the astronomical low water level

Table 12-9 – S100_HDF_DataCodingFormat

Item	Name	Description	Code	Remarks
Enumeration	S100_HDF_DataCodingFormat	Data coding formats for S-100 HDF5 data	-	S-111 does not use TIN, irregularGrid, or variableCellSize data coding formats

Value	fixedStations	Data at multiple discrete fixed point locations	1	
Value	regularGrid	Data at grid points forming a regular grid with constant cell spacing	2	Regular grids are commonly composed of perpendicularly crossing lines of equal spacing on each dimension, creating square or rectangular cells
Value	ungeorectifiedGrid	Data that does not include any information that can be used to determine a cell's geographic coordinate values, or in which cell spacing is variable, and there is no predefined association between one cell's location and that of another	3	For example, a digital perspective aerial photograph without georectification information included
Value	movingPlatform	Data at sequential discrete point locations of a moving sensor platform	4	
Value	stationwiseFixed	Time series at fixed stations (stationwise)	8	Data at multiple discrete fixed point locations organized by station

Table 12-10 – S104_DataDynamicity

Item	Name	Description	Code	Remarks
Enumeration	S104_DataDynamicity	Classification of data according to the relationship between the time of its collection, generation, or calculation of generation parameters, in relation to the time of publication of the dataset	-	See Notes 3 and 4 below
Value	observation	Values from in-situ sensor(s); may be quality controlled and stored after collection	1	Includes both historical and real-time observations. See also Notes 1 and 2 below
Value	astronomicalPrediction	Values computed using harmonic analysis or other proven method of tidal analysis	2	IHO Res. 3/1919, as amended
Value	analysisOrHybrid	Values calculated by statistical or other indirect methods, or a combination of methods	3	A hybrid method combines two or more approaches
Value	hydrodynamicHindcast	Values calculated from a two- or three-dimensional dynamic simulation of past conditions using only observed data for boundary forcing, via statistical method or combination	4	A hindcast is a model simulation that attempts to recreate present conditions by using the most recent observational data

Value	hydrodynamicForecast	Values calculated from a two- or three-dimensional dynamic simulation of future conditions using predicted data for boundary forcing, via statistical method or combination	5	A forecast is a simulation made for many hours into the future using predicted winds, water levels, etc

NOTE 1: The time period covered by the observations should be encoded in the metadata attribute *temporalExtent*.

NOTE 2: Sensors (for example tide gauges deployed along a channel) are monitored by the data collecting Authority. After data acquisition, the data are quality controlled and stored by the Producing Authority.

NOTE 3: Data dynamicity being the same in S-104 and S-111, the original “S104” prefix is retained. The relevant values are defined so as to be applicable to both products.

NOTE 4: S-111 uses only codes 1 – 5.

See clause 7.1 for detailed descriptions of the types of data based on the time-dependence of the source.

Table 12-11 – S111_DepthTypeIndex

Item	Name	Description	Code	Remarks
Enumeration	S111_DepthTypeIndex	Index for type of depth	-	See Annex G, clause G-6.1
Value	heightOrDepth	Height or depth	1	The level of the current is referenced to a datum, which can be the sea surface, the sea bottom, or a standard tidal datum. 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
Value	layerAverage	Layer average	2	The thickness of the layer is specified as a positive value

13 Language

The language used for the Discovery Metadata and the Carrier Metadata is English.

ANNEX A – Data Classification and Encoding Guide

A-1 Features

Surface Current (*SurfaceCurrent)*

IHO Definition: FEATURE: **SURFACE CURRENT:** A current that does not extend more than a few (2-3) metres below the surface.			
S-111 Geo Feature: Surface Current			
Primitives: pointSet, coverage			
S-111 Attribute	**Allowable Encoding Values**	**Type**	**Multiplicity**
Surface Current Speed	Must be in decimal knots, minimum resolution of at least 0.01 knot	RE	1
Surface Current Direction	Must be in decimal arc-degrees, minimum resolution of at least 0.1 arc-degree	RE	1
Surface Current Time	YYYYMMDDTHHMMSSZ	DT	0..1

A-2 Feature Attributes

The number of attributes is three.

1. Surface Current Speed (*surfaceCurrentSpeed*)

Surface Current 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: xxx.xx

Example: **2.54**

Remarks:
- Valid speed always non-negative.
- Negative number denotes land mask or missing value.
- 0.01 kn equals 0.5144 cm/s.

2. Surface Current Direction (*surfaceCurrentDirection*)

Surface Current Direction: The direction toward which a surface current is flowing, called the set of the surface current.

Unit: degree (˚)

Minimum Resolution: 0.1 ˚

Format: xxx.x

Example: **298.3**

Remarks:
- Direction clockwise from true north.
- Valid direction always non-negative.
- Negative number denotes land mask or missing value.

3. Surface Current Time (*surfaceCurrentTime*)

Surface Current Time: The time of the surface current data, expressed in ISO 8601 Date-time format.

Unit: Years, months, days, hours, minutes, seconds

Resolution: 1 second

Format: YYYYMMDDTHHMMSSZ, where Y is year, M is month, D is day, H is hour, M is minute, and S is second

Example: **19850412T101530Z** denotes 10 hours, 15 minutes, and 30 seconds, Universal Time on 12 April 1985.

Remarks:

- Required only for fixed station (stationwise) time series data (*dataCodingFormat* = 8) with non-uniform time intervals and moving platform time series (dataCodingFormat = 4) with non-uniform time intervals.
- All times are in UTC (Universal Time Coordinated).

ANNEX B – Comprehensive Model Including Application Schema and Carrier Metadata (UML Diagrams)

Figure B-1 depicts the various components of the S-111 model. The Meta-features and Exchange Set Metadata components are empty because S-111 does not define any meta-features or extend S-100 Exchange Catalogue classes. Figure B-2 depicts the derivation of the S-111 packages from various S-100 components.

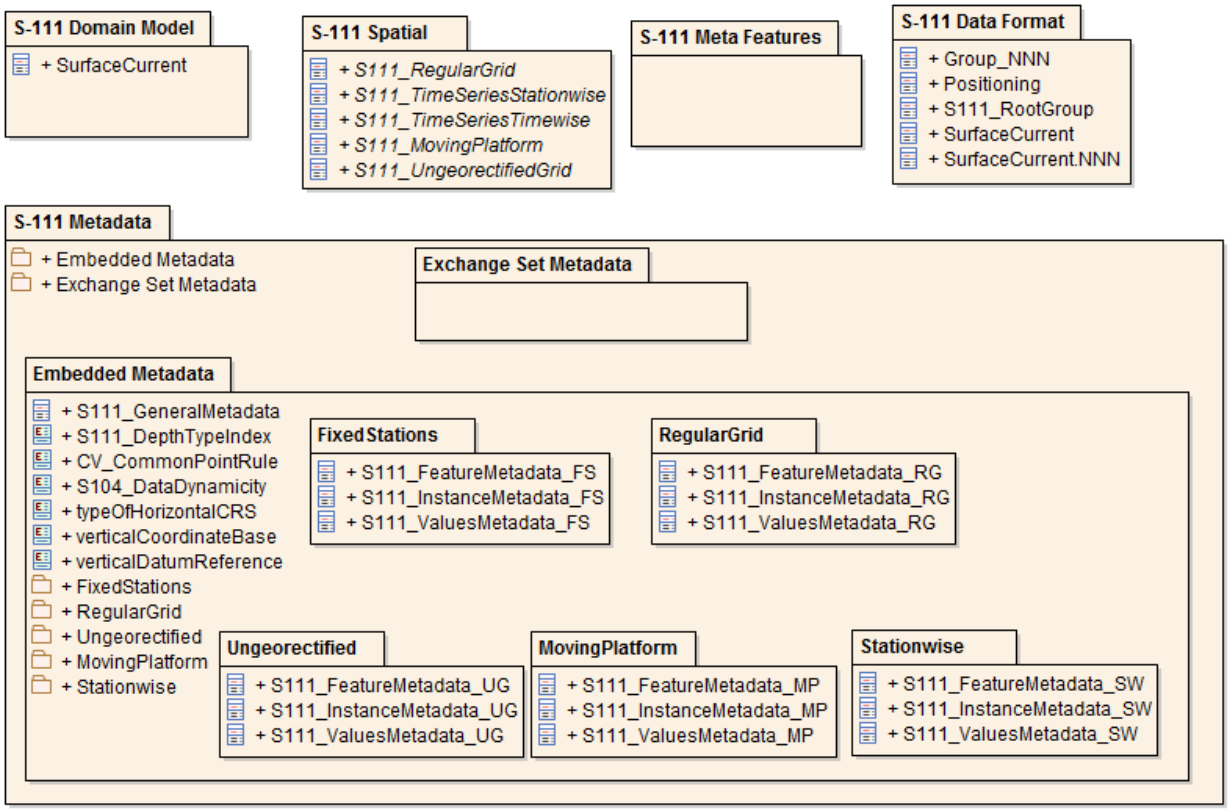

Figure B-1 – S-111 Model components

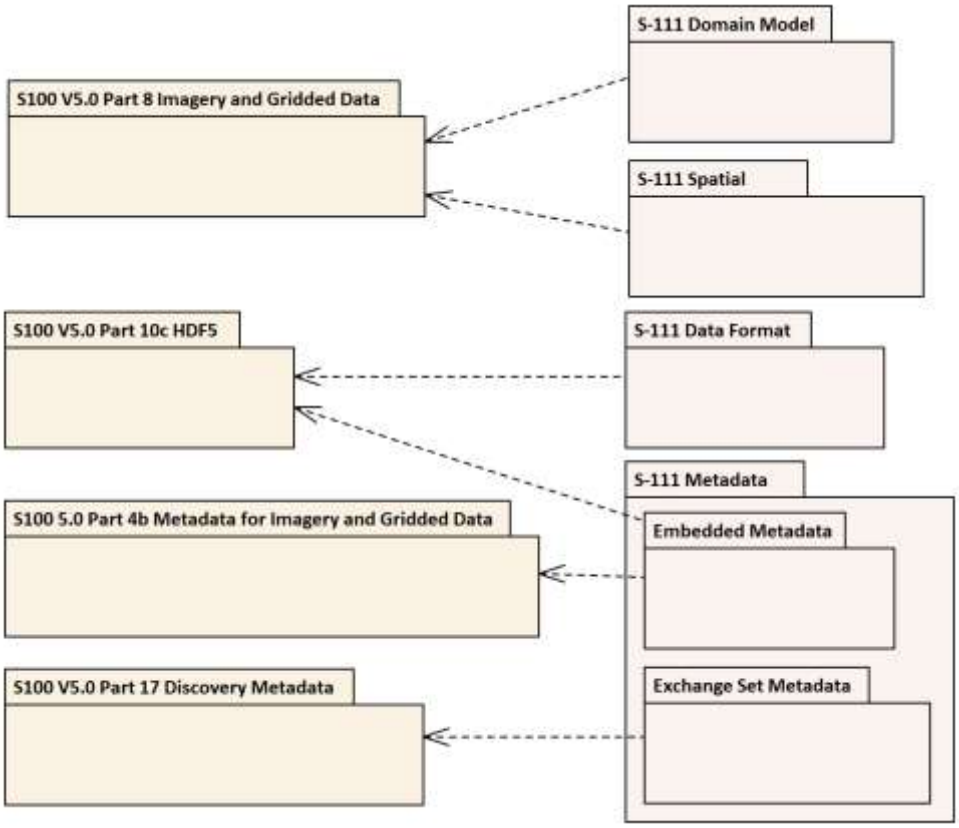

Figure B-2 – Derivations from S-100

Figure B-3 depicts the coverage types used in S-111 and their realizations from the conceptual coverages in S-100 Part 8 and ISO 19123. This is a more detailed version of Figure 4-3. Note that the realizations are not directly from the Part 8 and ISO 19123 classes, but via corresponding notional classes for the HDF5 implementations of the various data coding formats (not included in this diagram). For example, **S111_RegularGrid** is a notional extension of a notional S-100 class Part10c::S100_HDF_RegularGrid which encapsulates the encoding of *dataCodingFormat* 2 in HDF5. The notional classes are omitted to reduce diagram clutter.

The implementation of most attributes in the S-100 Part 8 model by S-100 Part 10c closely follows the names and types of the attributes. Certain attributes in the S-100 Part 8 and ISO 19123 models are simplified in S-100 Part 10c HDF5 implementation, as follows:

- HDF5 Regular Grid and Ungeorectified Grid (data coding formats 2 and 3) implement S100_Grid and CV_ReferenceableGrid respectively:
  - The attribute *origin* is implemented in the form of two HDF5 attributes, *gridOriginLatitude* and *gridOriginLongitude*.
  - The attribute *offsetVectors* is implemented in the form of two HDF5 attributes, *gridSpacingLongitudinal* and *gridSpacingLatitudinal*.
- The *rangeType* attribute common to all coverage types is implemented implicitly in the S-100 Feature Catalogue's binding of attributes to a feature and in the name/datatype information in feature information datasets in the Feature Information group (S-100 Part 10c, Table 10c-8).

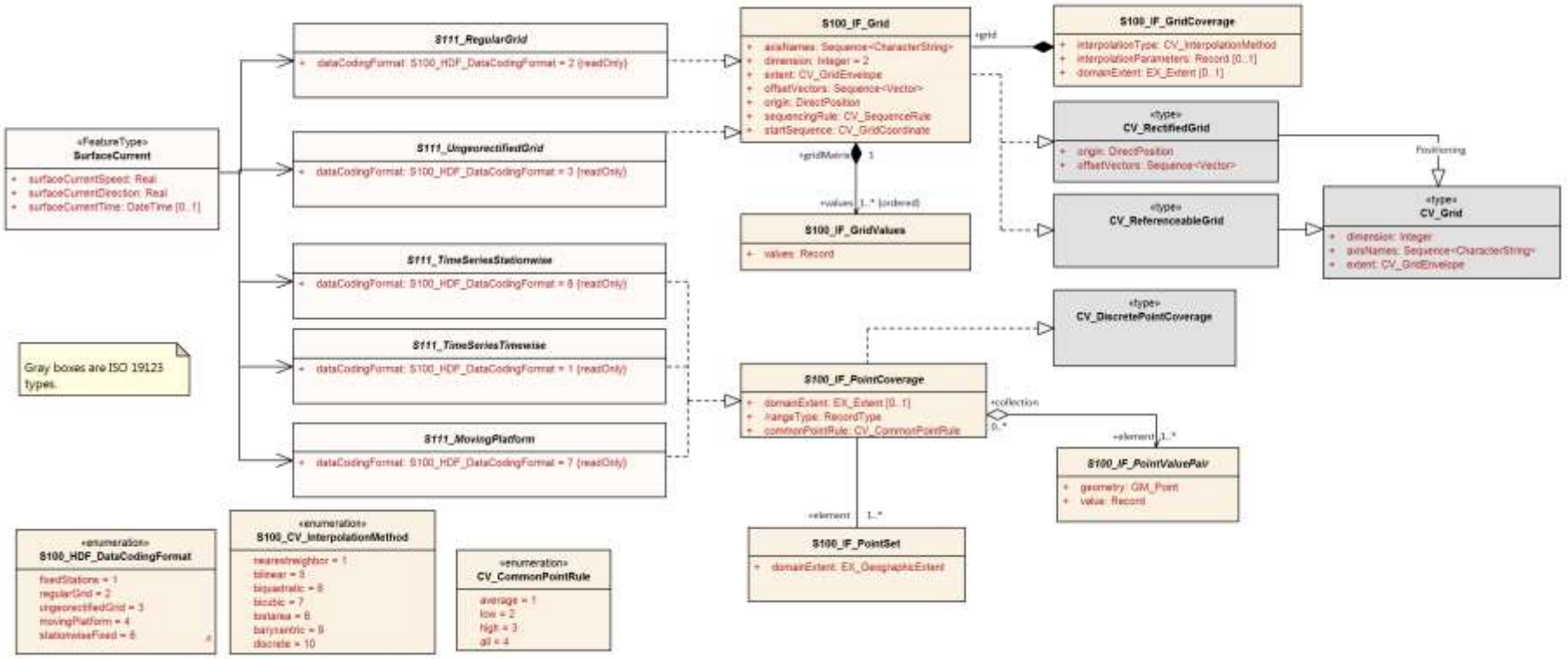

Figure B-3 Spatial Types – Coverages with Realizations from S-100 Part 8 and ISO 19123

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Figure B-4 depicts the single domain feature type. The **SurfaceCurrent** feature class (Figure B-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. An instance of **SurfaceCurrent** may be part of a time series, as described in the metadata.

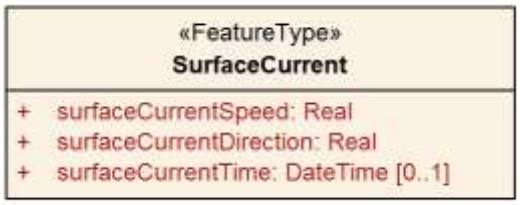

Figure B-4 – Surface Current feature class

Figure B-5 depicts the external Catalogue metadata classes (the same information as Figure 12-4).

Figures B-6 through B-10 depict the same information as Figures 06.0 through 03.0, organised by coverage type instead of structural level. Different levels in the HDF5 structure (root, feature type, feature instance, and value) are indicated by backgrounds of different colours.

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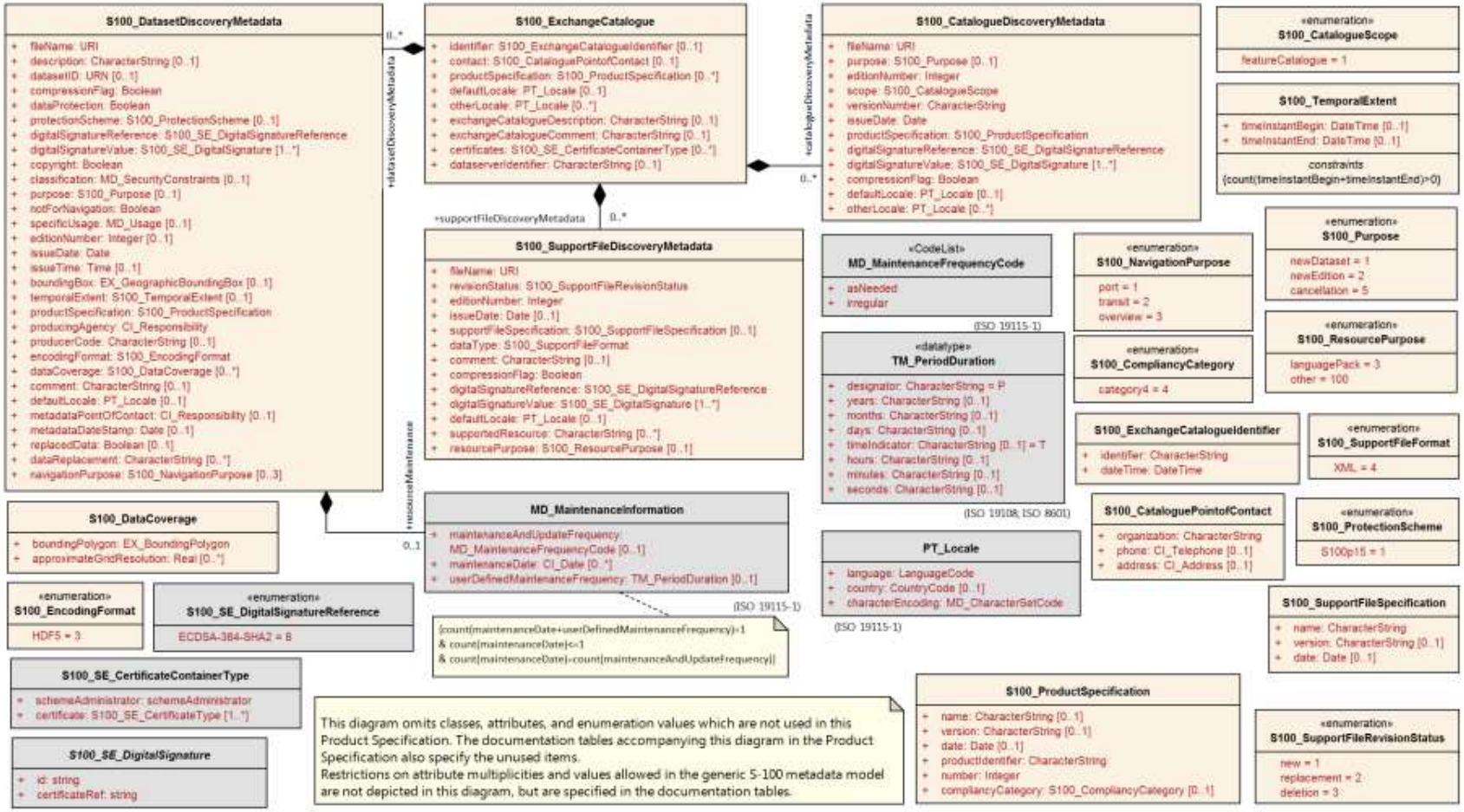

Figure B-5 – Exchange Set class details

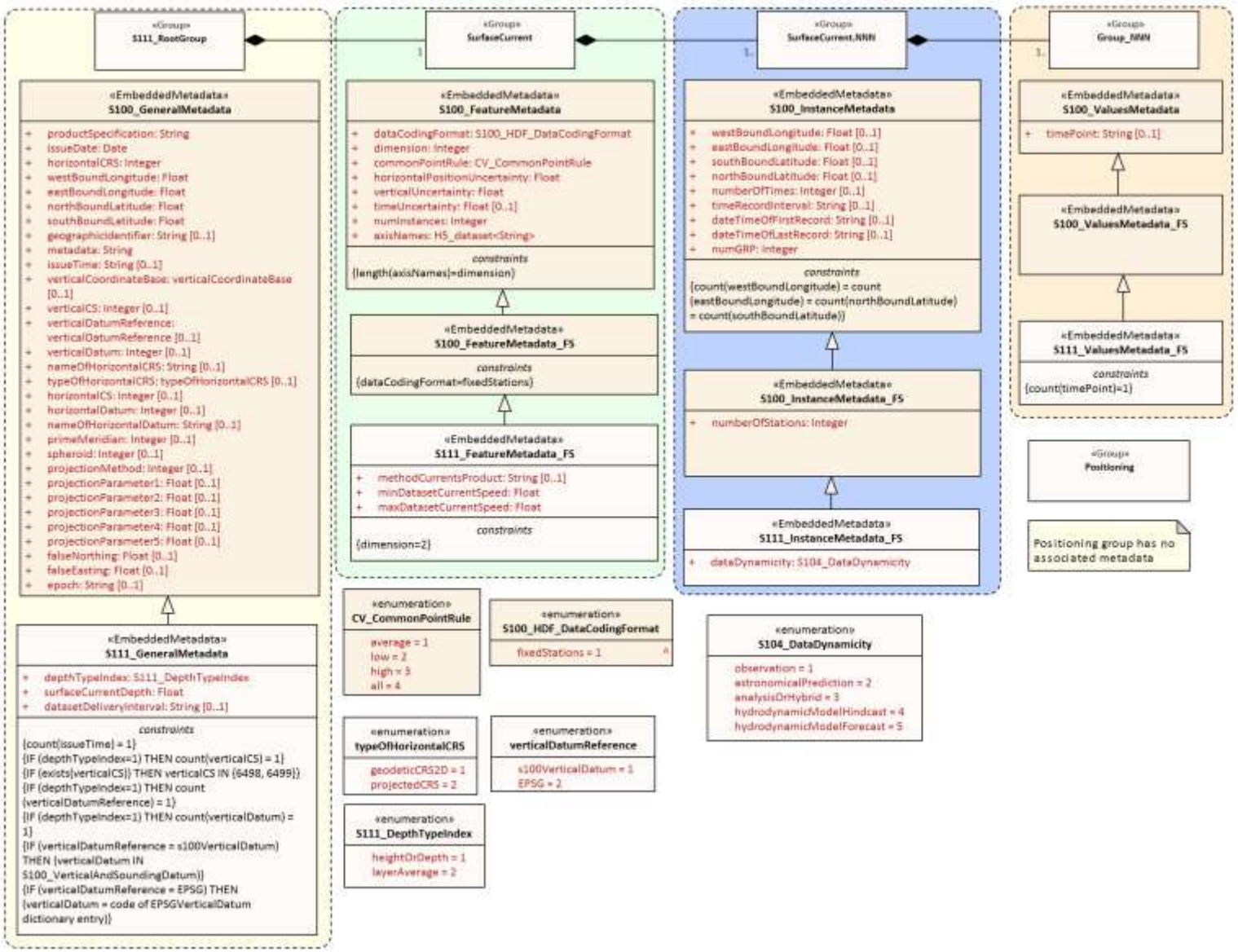

Figure B-6 – All carrier metadata for coverage type Fixed Stations (data coding format 1)

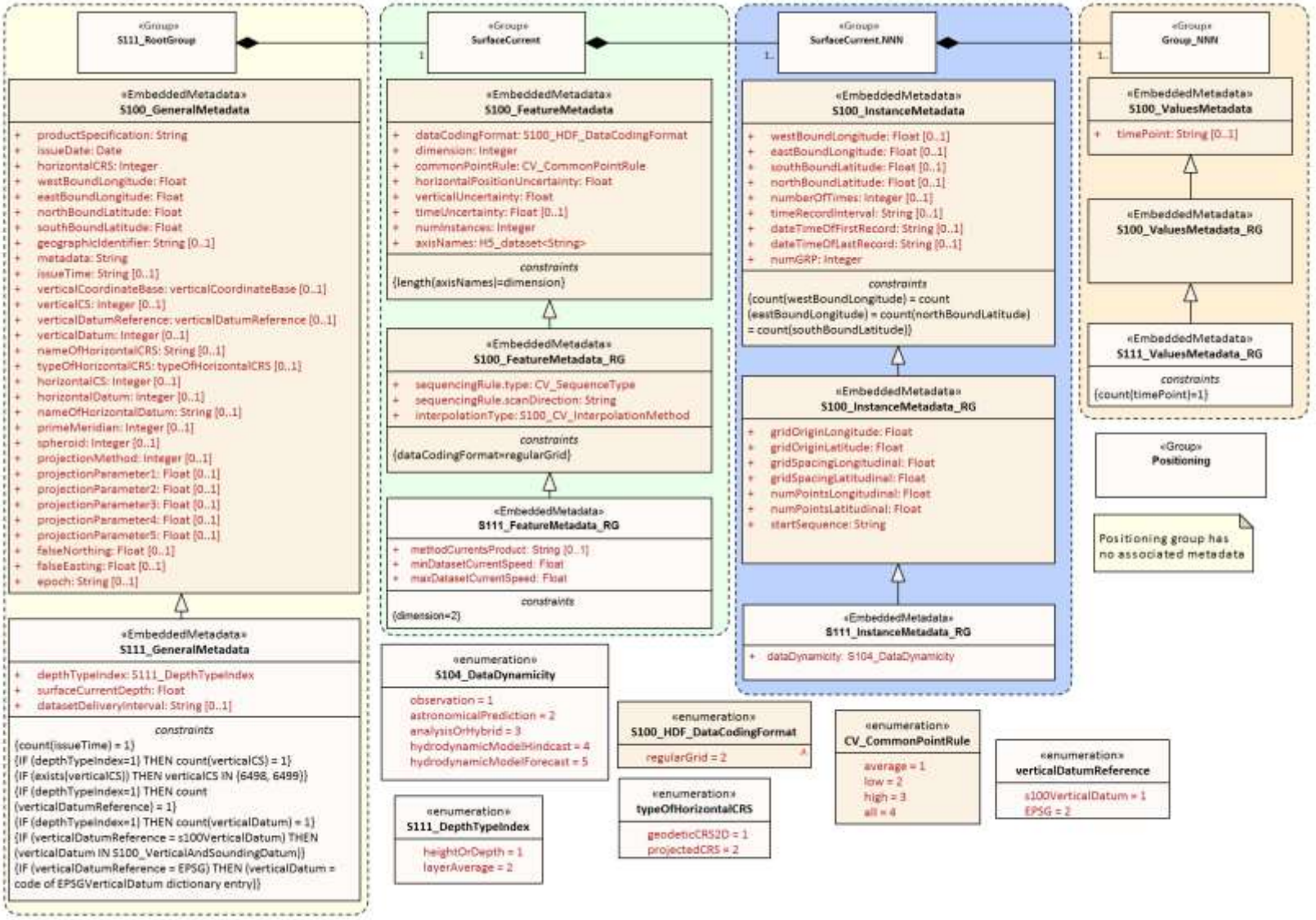

Figure B-7 – All carrier metadata for coverage type Regular Grid (data coding format 2)

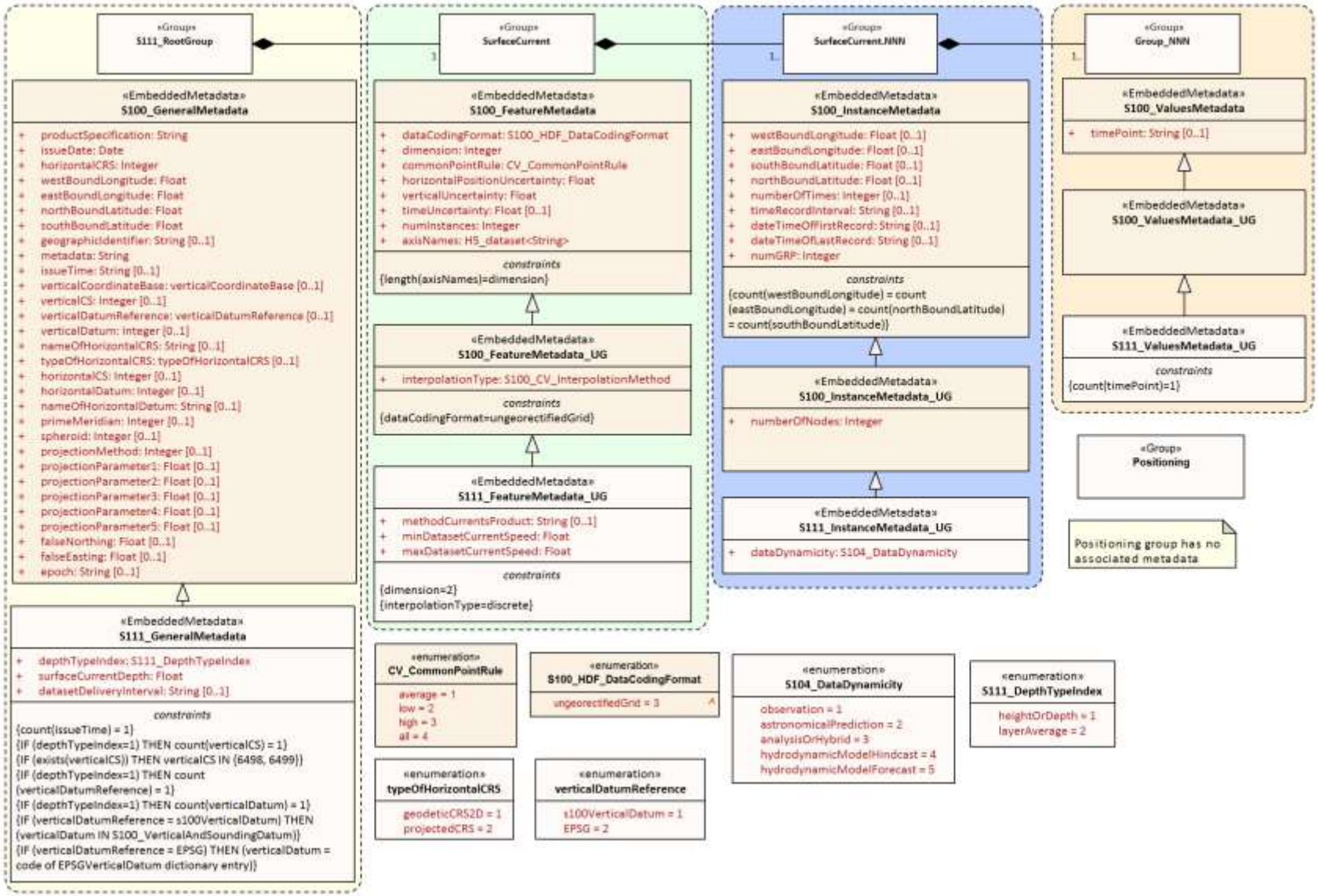

Figure B-8 – All carrier metadata for coverage type Ungeorectified Grid (data coding format 3)

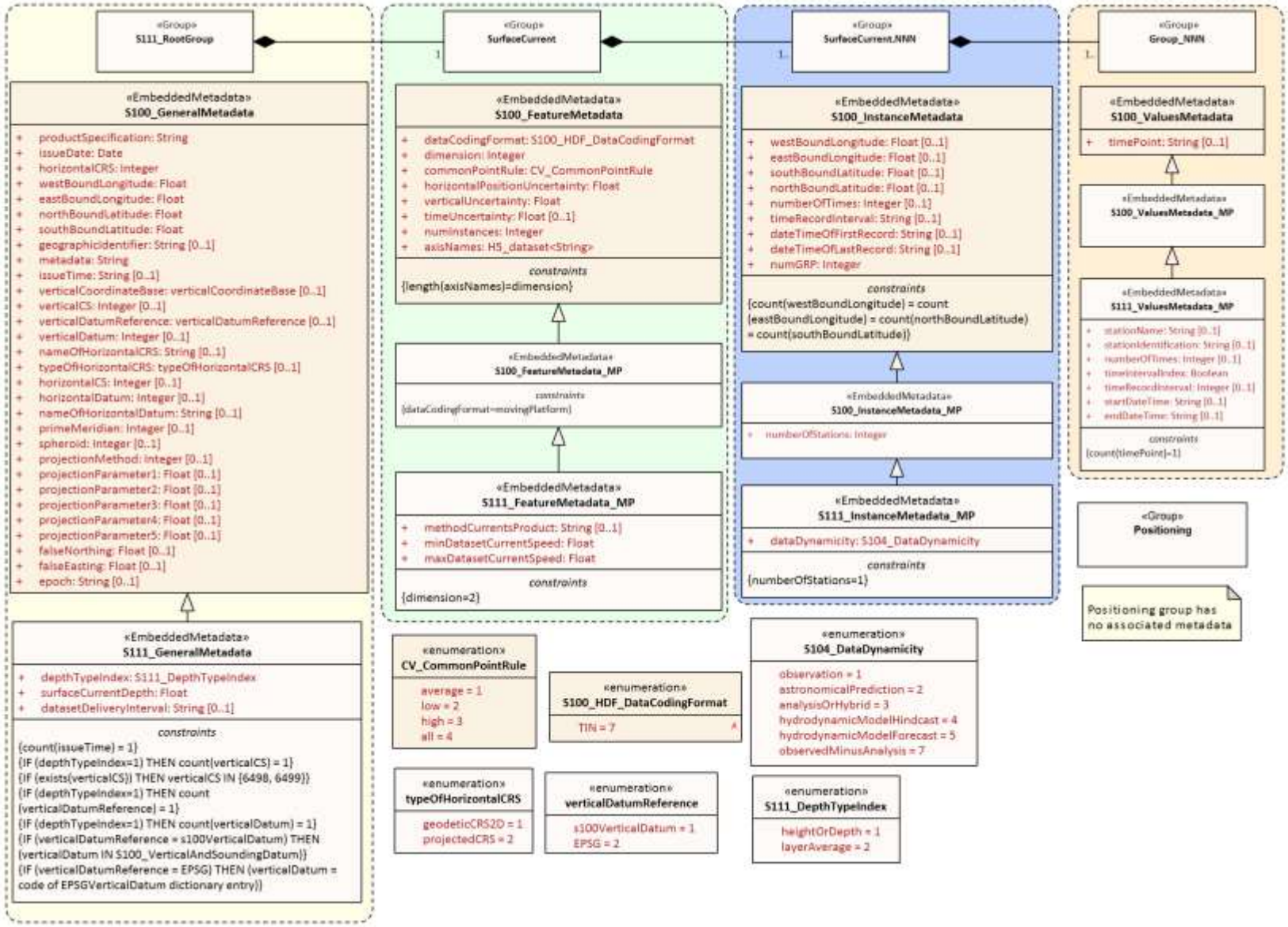

Figure B-9 – All carrier metadata for coverage type Moving Platform (data coding format 4)

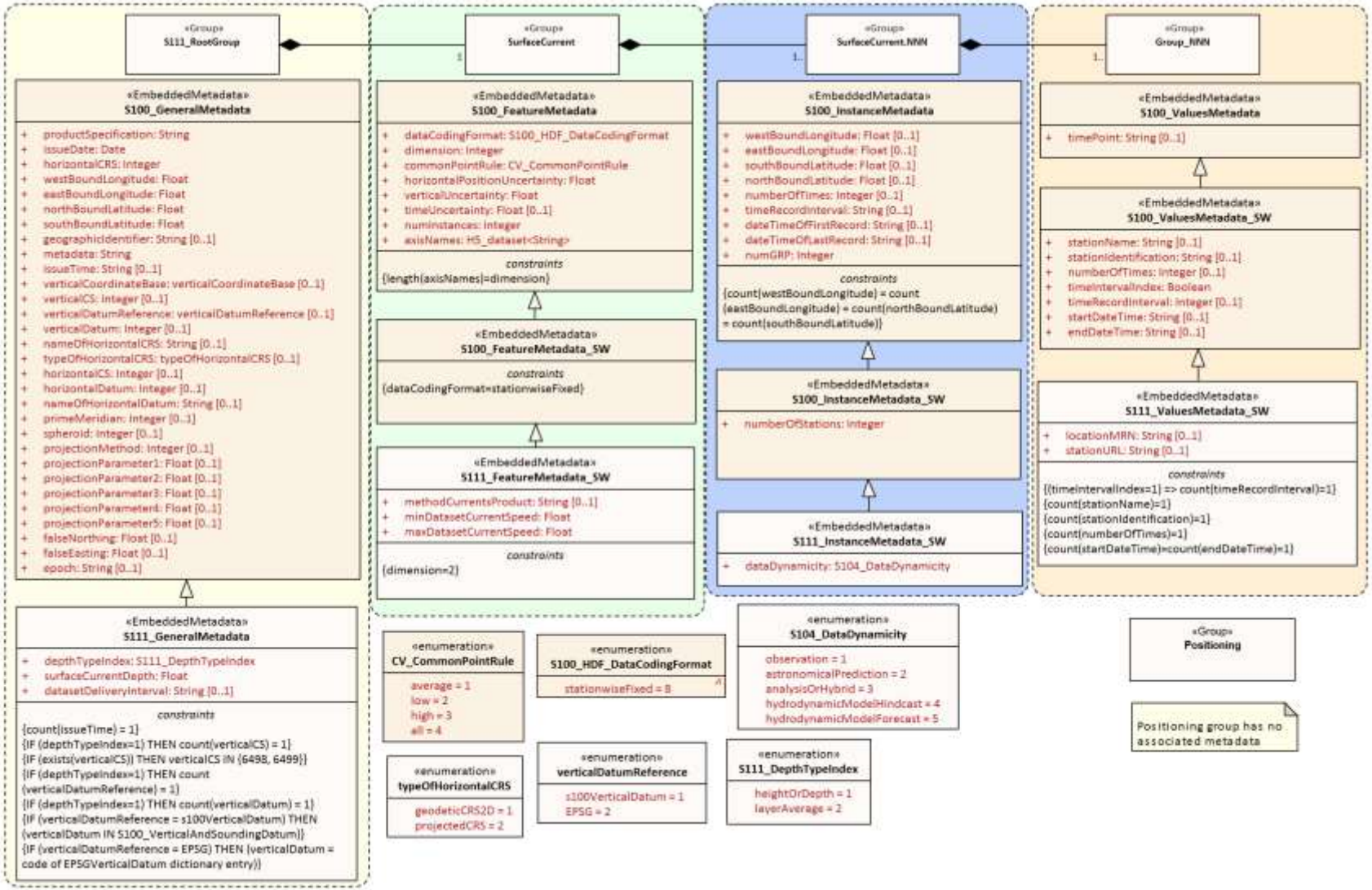

Figure B-10 – All carrier metadata for coverage type Fixed stations (Stationwise) (data coding format 8)

ANNEX C – Feature Catalogue

C-1 Meta Feature Types

[None]

C-2 Geo Feature Types

C-2.1 Surface Current

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

CamelCase: SurfaceCurrent

Alias:

Super type:

Feature use type: geographic

Primitive: coverage pointSet

Remarks: No remarks.

Attribute Bindings:

S-111 Attribute	Allowable Encoding Value	Type	Multiplicity
Surface Current Speed		RE	1, 1
Surface Current Direction		RE	1, 1
Surface Current Time		DT	0, 1

C-3 Carto Feature Types

[None]

C-4 Information Types

[None]

C-5 Simple Attributes

C-5.1 Surface Current Direction

Definition: The direction toward which a surface current is flowing, called the set of the surface current.

CamelCase: surfaceCurrentDirection

Alias:

Value type: real

Remarks: No remarks.

Unit of measure name: degree **definition**: Degrees of arc (compass direction) **symbol**: °

Quantity specification: planeAngle

Constraints:

String Length	Text Pattern	Range		Precision
(not specified)	(none)	lowerBound	0.0	1
		upperBound	359.9	
		closure	closedInterval	

C-5.2 Surface Current Speed

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 direction. Speed may either be the ship's speed through water, or the speed made good over ground.

CamelCase: surfaceCurrentSpeed

Alias:

Value type: real

Remarks: No remark.

Unit of measure name: Knot **definition**: Nautical miles per hour **symbol**: kn

Quantity specification: speed

Constraints:

String Length	Text Pattern	Range		Precision
(not specified)	(none)	lowerBound	0.00	2
		upperBound	(not specified)	
		closure	gtSemiInterval	

C-5.3 Surface Current Time

Definition: The time of the surface current data, expressed in ISO 8601 Date-time format.

CamelCase: surfaceCurrentTime

Alias:

Value type: dateTime

Remarks: Unit: Years, months, days, hours, minutes, seconds; Resolution: 1 second. Example: 19850412T101530Z denotes 10 hours, 15 minutes, and 30 seconds, Universal Time on 12 April 1985.

Constraints

String Length	Text Pattern	Range	Precision
(not specified)	(((((19)|(20))\d{2})|(21([0-4]\d)))(1[0-2]|0[1-9])(3[01]|0[1-9]|[12][0-9])T(2[0-3]|[01][0-9]):?([0-5][0-9]):?([0-5][0-9])Z)|(21500101T000000Z)	(not specified)	(not specified)

C-6 Complex Attributes

[None]

C-7 Roles

[None]

C-8 Information Associations

[None]

C-9 Feature Associations

[None]

C-10 Feature Catalogue XML

The feature catalogue is provided as a separate XML file and can be downloaded from the IHO Geospatial Information Registry.

ANNEX D – Sample HDF-5 Encoding

The following are examples of HDF5 surface currents data files for each of the five data coding formats. The general structure of the data product is shown in Table 10-2, and the specific variables contained in the attributes are explained in Tables 12-1, 12-2, 12-3 and 12-4.

[Reserved. Updated figures will be provided later.]

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ANNEX E – Validation (Informative)

E-1 Introduction

The following checks are intended for production systems designed to produce S-111 Surface Currents datasets. The checks can be administered at any time during the production phase. They can also be applied downstream in the distribution and end user systems to test the conformance of a dataset to the format rules specified in S-100 Part 10c and the S-111 Product Specification.

NOTE: S-100 validation checks are still under development at the time this Edition of S-111 is being prepared and this Annex is therefore designated “Informative” in this Edition of S-111.

E-2 Check Classification

Checks are classified as critical, error, or warning checks as described in the table below.

Table E-1 – Classification of checks

Category Code	Category Name	Category Description
C	Critical Error	An error which would make a dataset unusable in ECDIS through not loading or causing an ECDIS to crash or presenting data which is unsafe for navigation.
E	Error	An error which may degrade the quality of the dataset through appearance or usability but which will not pose a significant danger when used to support navigation.
W	Warning	An error which may be duplication or an inconsistency which will not noticeably degrade the usability of a dataset in ECDIS.

E.3 Check Application

Checks do not apply to dataset terminations or cancellations, except where the check description explicitly states it applies in case of a termination or cancellation.

The checks apply to each HDF5 file which constitutes a dataset (in the S-100 sense of “dataset” as an entire HDF5 file).

There being no update dataset format defined in S-111, checks are not designated as applying to “base” or “update” datasets.

E-4 Validation Steps

E-4.1 Dataset validation

Dataset validation checks the structure and content of individual HDF5 data files. The checks for each HDF5 dataset file are divided into five phases:

Table E-2 – Phases in validation processing for HDF5 datasets

Phase	Name	Description
1	Validate Dataset Root and Feature Information	Validation of root group of HDF5 file and feature type information.

2	Validate Feature Container Groups	Validation of metadata and structure for each feature type (“Feature Container”). In S-111 there is only one feature container, so this set of checks is executed only once. If future Editions introduce multiple feature container HDF5 groups, this set must be executed for each feature container HDF5 group.
3	Validate Feature Instance Groups	Validation of feature instances. This set of checks, along with Phase 4 and 5 checks, must be executed once for each feature instance group contained within a feature container.
4	Validate Position Information	Validation of positioning data. This set of checks is executed if and only if the data coding format requires the presence of explicit position arrays.
5	Validate Values Datasets	Validation of values data. This set of checks is executed for each values group in a feature instance group.

Figure E-1 below depicts the sequence of processing. Certain check failures in Phases 1-3 prevent progress to later phases (because information needed to test conditions is not available). If one of these checks fails, processing of other checks in the current phase is allowed to proceed, but subsequent phases cannot be executed due to a lack of necessary information.

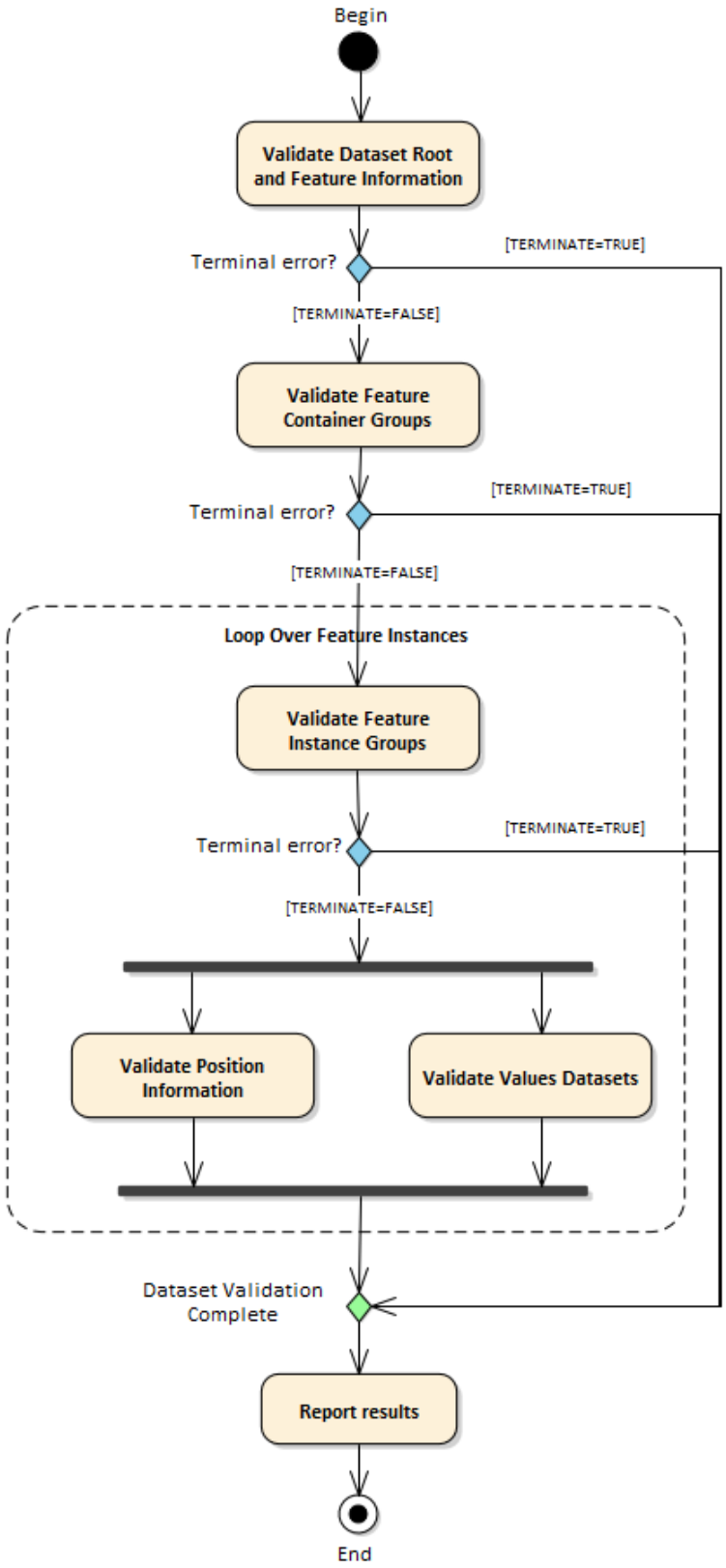

Figure E-1 – Phases of dataset validation processing

E-4.2 Exchange set validation

Exchange Set validation involves the following phases.

1) Checking the presence and correctness of the Exchange Catalogue (CATALOG.XML).
2) Verification of signatures, including the Exchange Catalogue signature and signatures for individual datasets, catalogues, and support files.
3) Checking the structure and contents of the Exchange Set package, including whether there is a discovery block for each file in the Exchange Set.
4) Checking that the metadata encoded in a discovery block and the headers and embedded metadata in the corresponding dataset or Catalogue are compatible.

Generalised checks for Exchange Set validation are being developed by the S-100WG and will be introduced into S-111 when ready.

E-5 Check Description Format

E-5.1 Specification of validation Checks

Individual checks are defined in the format described in Table E-3.

Table E-3 – Check specification format

Column	Description
Data Quality Measure or Theme	Quality measure or theme from S-97 Part C. If two measures are included in this column, the Comments column explains how the error should be classified.
Check ID	Identifier for check.
Prerequisite check(s)	Checks which must succeed (check condition evaluates to FALSE) before this check can be executed.
Context test (IF ...) or initialization (SET ...)	Combination of test conditions and initialization statements. Test conditions check for the existence of an HDF5 attribute, group, or other element (for example, an HDF5 array), or test the value of a metadata attribute. Initialization statements set the value of parameters used in the specific test in that row. The scope of the test condition or initialization is limited to the check described in that row.
Check condition description	Specification of check condition, written in structured English. The conditions are written so that if the condition evaluates to TRUE it indicates an error or other issue exists in the dataset.
Check message	Message to emit if dataset fails the check condition (condition evaluates to TRUE).
Check solution	Solution to be applied to correct the failure.
Classification	Whether check failure is a Critical, Error, or Warning issue. See Table F-1.

Column	Description
Post-condition	Action to be executed if the check condition evaluates to TRUE (that is, if the check fails). This action will generally either set a global flag to control check processing (for example, “SET TERMINATE=TRUE”) or set a variable in the processing context which is used in later checks (for example, set a context variable to store the value of the metadata attribute *dataCodingFormat*).
S-100 reference	Reference to place in S-100 where more information about the check can be found, for example lists of allowed values for enumerations. All S-100 references for checks conforming to this Edition of S-111 are to S-100 Edition 5.2.0.
S-111 reference	Reference to place in S-111 where more information about the check can be found, for example allowed values for attributes of enumeration types.
Comments	Explanatory remarks or additional notes.

E-5.2 Phase initialization

Certain parameters need to be initialized before processing of the phase begins. The required initialization statements are indicated in a sub-head row at the beginning of each phase.

E-5.3 List of checks

The individual checks are given in a spreadsheet file accompanying this Product Specification. The checks are a part of this Product Specification. Two sheets are included, for dataset checks and Exchange Set checks respectively.

Words in angle brackets <> indicate the content is a parameter which must be substituted by the appropriate value. For example, <FX> (Phase 1 in the dataset checks) should be replaced by the appropriate feature code (“SurfaceCurrent” for S-111).

Bold type indicates a literal name (for example **Group_F.featureCode** means the HDF5 array named “featureCode” in the HDF5 group named “Group_F”).

E-6 Test Cases and Methods

E-6.1 Coverage consistency

E-6.1.1 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 clause 4.2.
Test type:	Basic

E-6.1.2 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 (that is, fill 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-6.1.3 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-6.2 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-6.2.1 Conceptual consistency

The implementation of the Surface Current Product is required to align with one of the two conformance classes defined in S-100 Part 8, Appendix 8-A - Abstract Test Suite.

E-6.2.2 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 (that is, fill value) and that the speed values are within the range specified or are a null (fill) value for the particular Product Specification defined by a Producer. This would be validated by means of test software.
Test type:	Basic.

E-6.2.3 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.

1

2 **E-6.2.4 Temporal Accuracy**

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

5

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ANNEX F – Use Cases

F-1 Ferry Sailing Plan Optimization

F-1.1 Summary

Name:	Ecological Benefit of Route Planning with Surface Current Information (Courtesy HyunSoo Choi – KRISO; KHOA)
Description:	A ferry operator plies between locations subject to constraints on departure and arrival times, route, and speed restrictions. There is some flexibility as to the exact route travelled. S-111 Surface Current time series information covering the time of the planned transit is available to the operator. The ferry operator uses information about surface currents to establish a sailing plan based on dynamic waterway information, including determining a target speed for each section of a planned route so as to to optimise fuel consumption. Engine speeds at different sections of the route are planned to take advantage of current flow. The optimal sailing plan allows the ferry to complete the transit within acceptable parameters for time, speed restrictions, and routing, while reducing fuel consumption and pollutant emissions. Current predictions may also be utilized to prepare sailing plans that minimize vessel exposure to conditions which pose more demands on equipment and more risk to vessel safety. The main users are ferry operators, navigation officers, and pilots.
Potential Actors:	Marine Pilots, Navigation Officers, Shipping Companies, Ferry Operators.
Potential Applications:	1. Route monitoring. 2. Route planning. 3. Reduction of fuel consumption. 4. Reduction of pollutant emissions. 5. Increased vessel safety.
Data Requirements:	• High quality current forecast with adequate spatial and temporal resolution.
Technical Aspects and Post-Processing:	--

F-1.2 Additional details

Long-distance ferry routes between Mokpo and Jeju were selected to evaluate the impact of tidal currents on ship operations. The route is about 92 miles, which takes 4 hours and 30 minutes in general conditions. The ferry is a 9,832-ton ship with 900 people on board.

A simulation explored two scenarios:

- Scenario 1 considers general operating patterns for legal routes that actually operate.
- Scenario 2 optimizes RPM usage by section by taking into consideration S-111 seawater flow.

Fuel consumption during different sections of the routes for the two scenarios is compared in Figure F-1 below.

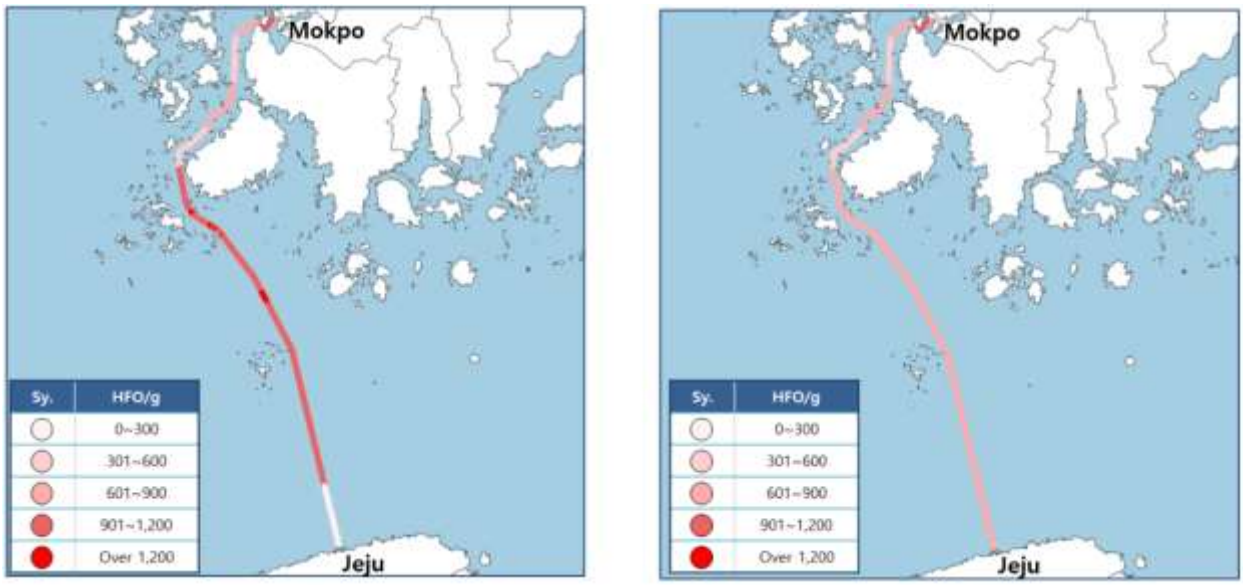

Figure F-1 Fuel consumption for route plan scenarios. Left: Scenario 1 (typical transit); Right: Scenario 2 (with RPM optimization)

Scenario 1 shows that fuel consumption is somewhat high because it operates at a high speed of 23-24 knots after leaving the speed limit area near Mokpo, and then approaches in time for entry by lowering RPM consumption from near Jeju Port. Scenario 2 optimized the RPM use plan by considering the flow of seawater in advance for each point where the ship moves. In addition, ships were allowed to use seawater flow near Jindo Island, where the maximum flow rate occurs.

- Normal Route Planning
  - Uses only the changing time of falling and rising currents
  - After departing from Mokpo, proceed at full speed and adjust speed near Jeju
- Optimal Route Planning
  - When establishing a sailing plan, the operator can check the predicted currents (direction, current speed) on an hourly basis.
  - After checking the dynamic waterway information for each time segment provided by S-100 data products, set the target speed for each section and arrive at Jeju.
- S-111 Surface Currents with 1hr interval
  - During sailing, there will be RPM differences under the influence of the flow.

F-1.3 Simulation Results

The amount of fuel consumed for 4 hours and 30 minutes was analyzed using the engine RPM log and fuel consumption rate used in the simulation. The fuel required 13.02 tons and 11.12 tons, respectively, which reduced fuel consumption by 14.6% when the ship was operated after establishing an optimized routing plan in consideration of S-111 seawater flow. Although the arrival time and average speed were almost the same, it can be seen that the route plan reflecting S-111 surface currents and considering Just-in-time is much more economical.

As fuel consumption was reduced by about 14.6%, the emission of pollutants such as carbon and nitrogen oxides was also reduced to a similar percentage.

F-1.4 Data

The range of S-111 data generated by KHOA's physical prediction model is 72 hours. Surface currents grids are 300m 2km and 3km, and 2km grids were used in this test.

Acknowledgements

All images and data in this use case are courtesy HyunSoo Choi (Korea Research Institute of Ships and Ocean Engineering) and KHOA (Korea Hydrographic and Oceanographic Agency). Further information is available in the following paper:

Ecological Benefit and Navigational Safety Study based on S-10X Data. Paper at S-100 WG8 (November 2023), submitted by: Republic of Korea (KHOA, KRISO) (S100WG8-32, https://iho.int/en/s-100wg8-2023. Downloaded 15 February 2024).

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ANNEX G – 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.

G-1 Data Sources

For the purposes of this Product Specification, surface current data is 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 (for example, 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.

G-2 Data Organization

Data are usually organized by the Data 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.

G-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 G-1.

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

Figure G-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 Centre 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 G-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 G-2a).

```
[Metadata block for station # 1]
Value of Time 1: 2014-12-01 00:00:00
Speed at Time 1 =       1.08
Direction at Time 1 = 215
Value of Time 2: 2014-12-01 00:06:00
Speed at Time 2 =       1.00
Direction at Time 2 = 225
Value of Time 3: 2014-12-01 00:12:00
Speed at Time 3 =       0.83
Direction at Time 3 =  226
```

Figure G-2a – Reformatted time series or real-time data

The data in Figure G-2a can be rearranged so that all the speeds and all the directions appear in a sequence, as in Figure G-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 G-2b – Reformatted time series data

G-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 (that is, 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 G-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 (for example -99.999), which is substituted for a gridded value which is on land, to represent land, thus reducing the number of arrays required.

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

Figure G-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 G-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 G-4). The data for speed in Figure G-3 is a series of values at grid points, starting from the lower left corner of the grid and proceeding along the first row until the end, then starting with the first point in the second row, and so on. Note that for the two fields (speed and direction) in this example, the memory required is 0.325 mb.

[Metadata block for gridded fields]

Value of Time 1

Speed at T1 = 0, 0, 0, 0.5191959, 0.5159838, 0.5159435, 0.5186388, 0.5209069, 0.5167338, 0.5114825, 0.4738558, 0.378551, 0.2911682, 0.204335, 0.1294665, …

Direction at T1 = 0, 0, 0, 32.7725, 30.33029, 27.84417, 26.28601, 26.46908, 26.46744, 26.56505, 25.9423, 24.28312, 23.54004, 24.69553, 28.52312, …

Figure G-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 G-3

G-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 G-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 G-2b), and thus into the S-111 format. This conversion is to the responsibility of the Data Producer.

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

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

G-4 Moving Platform Data

G-4.1 Drifting platforms

Moving platforms (for example, 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

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

list with locations and (usually non-equally-spaced) times (Figure G-5). The data are often telemetered from the drifter to a collection station.

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

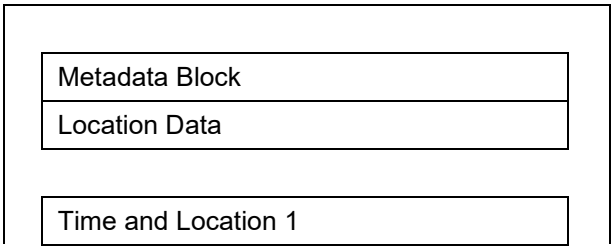
In the raw form, the data must be converted into speed and directions. This can be accomplished by cubic spline interpolation of the longitudes and latitudes separately, then dividing the difference in position by the differences in time. The data can be converted into time series data (see Figure G-2b),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

G-4.2 Propelled platforms

Other moving platforms such as ships or wave riders may be self-propelled to some degree or use a means of propulsion independent of drift, in which case instantaneous positions cannot be used to determine current speed and direction. Such platforms may carry hydroacoustic current meters which can be used to determine current speed and direction, such as acoustic Doppler current profilers. Data from such platforms includes locations associated with time stamped current speed and direction values, obtained after cleaning and processing of the raw sensor data. Time stamps may be at non-uniform intervals for various reasons. Such data can be carried in S-111 datasets as non-uniform moving platform data, with time stamps associated to each observation instead of a uniform time interval for the whole series.

G-5 Preliminary Data Product Format

Two forms of data (Figure G-2b and G-4) are similar, the main difference being that the multiple values for each variable in Figure G-4 correspond to multiple grid points, rather than the multiple times in Figure G-2b (at a single station). Thus the two forms can be combined into a single form (Figure G-6, although the data are interpreted differently. Other forms of data (Figures G-4 and G-5) must be processed to fit the format.



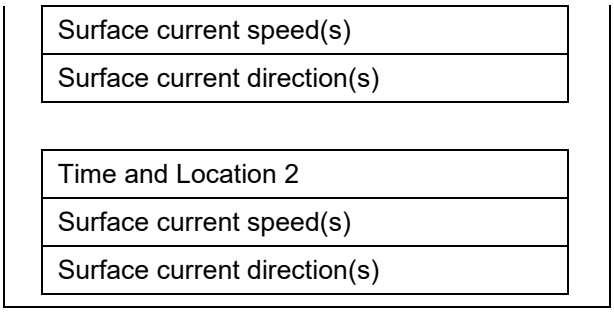


Figure G-6 – Schematic of the preliminary product data set. The product can represent either a time series at a number of stations or gridded data

G-6 Additional Features of the Data

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

G-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.

G-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.

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ANNEX H – Colour Tables

Below are the colour tables for the day, dusk, and night conditions (Tables G-1, G-2, and G-3). The estimates for dusk and night were obtained by first converting the values for RGB colours for day conditions (see clause 9.2.3) to xyL values, where L is luminance. The conversion assumes the colours are the standard RGB (sRGB) and the calculations follow the explanation in IEC 61966 (IEC 61966-2-1:1999 – *Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space - sRGB*. [See also Wikipedia: searched 'sRGB' in March 2017]) and in a TSMAD paper (TSMAD28/NIPWG6 – 11.3B – *Colour Tables in S-100, Part 9 – Portrayal Catalogue*). Note that in S-52 colours, the conversion from xyY to xyL requires that L=100Y.

Existing xyL data for dusk and night conditions for approximately 50 S-52 colours (*S-52 Presentation Library Edition 4.0.0, Part 1, Appx. A*) demonstrate that for the lower light conditions luminance is reduced while the x and y values remain approximately constant. Here, for each S-111 colour, the closest (that is, smallest root mean square of the sum of the squares of the difference in x values and y values) S-52 colour for day conditions was identified, and that colour's luminance reduction factors for the other light conditions were used to calculate the new S-111 xyL values. Finally, the new xyL values were converted to RGB values and their hexadecimal equivalents.

Table G-1 – Colour parameters for DAY conditions for each speed band. The last row (Band 'All') shows the colour for the arrow border

Band	Token	Colour	x	y	L	R	G	B	RGB Hex
1	SCBN1	purple	0.21	0.14	15	118	82	226	7652E2
2	SCBN2	dark blue	0.21	0.24	29	72	152	211	4898D3
3	SCBN3	light blue	0.23	0.29	51	97	203	229	61CBE5
4	SCBN4	dark green	0.33	0.52	40	109	188	69	6DBC45
5	SCBN5	light green	0.39	0.53	61	180	220	0	B4DC00
6	SCBN6	yellow-green	0.43	0.50	51	205	193	0	CDC100
7	SCBN7	orange	0.49	0.45	48	248	167	24	F8A718
8	SCBN8	pink	0.40	0.33	48	247	162	157	F7A29D
9	SCBN9	red	0.64	0.33	21	255	30	30	FF1E1E
All	CHBLK	black	0.28	0.31	0	0	0	0	000000

Table G-2 – Colour parameters for DUSK conditions for each speed band. The last row (Band 'All') shows the colour for the arrow border

Band	Token	Colour	x	y	L	R	G	B	RGB Hex
1	SCBN1	purple	0.21	0.14	7	81	55	159	51379F
2	SCBN2	dark blue	0.21	0.24	3	20	52	76	14344C
3	SCBN3	light blue	0.23	0.29	3	19	51	58	13333A
4	SCBN4	dark green	0.33	0.52	13	64	114	39	407227
5	SCBN5	light green	0.39	0.53	21	110	136	0	6E8800
6	SCBN6	yellow-green	0.43	0.50	18	126	119	0	7E7700
7	SCBN7	orange	0.49	0.45	15	147	97	1	936101
8	SCBN8	pink	0.40	0.33	5	86	53	51	563533
9	SCBN9	red	0.64	0.33	9	178	1	1	B20101

All	CHBLK	black	0.28	0.31	20	107	127	137	6B7F89

Table G-3 – Colour parameters for NIGHT conditions for each speed band. The last row (Band 'All') shows the colour for the arrow border

Band	Token	Colour	x	y	L	R	G	B	RGB Hex
1	SCBN1	purple	0.21	0.14	1	26	15	59	1A0F3B
2	SCBN2	dark blue	0.21	0.24	1	4	17	28	04111C
3	SCBN3	light blue	0.23	0.29	0	3	14	17	030E11
4	SCBN4	dark green	0.33	0.52	2	19	40	8	132808
5	SCBN5	light green	0.39	0.53	3	38	49	0	263100
6	SCBN6	yellow-green	0.43	0.50	2	45	42	0	2D2A00
7	SCBN7	orange	0.49	0.45	2	54	33	0	362100
8	SCBN8	pink	0.40	0.33	1	33	17	17	211111
9	SCBN9	red	0.64	0.33	1	63	0	0	3F0000
All	CHBLK	black	0.28	0.31	2.5	37	45	49	252D31

ANNEX I – Scalable Vector Graphics (SVG) Coding

The Surface Current arrow symbols have been converted to XML files and entered into the Portrayal Catalogue. The following is a sample of the files (courtesy of R. Malyankar, Portolan Sciences) and a few images created from the files.

I-1 Sample SVG Images

Sample images 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©.

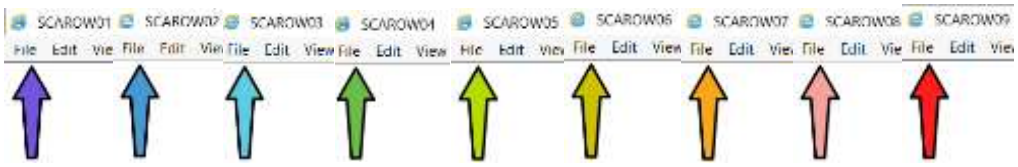

Figure I-1 – Web browser images of the arrows for speed bands 1 through 9 (day conditions), as generated by the .svg and .css codes in this Annex. Shown larger than actual size

I-2 Sample SVG File to Display Arrows

The sample .svg file shown (Figure I-2) describes the symbol SCAROW01, the arrow for speed band 1, day light conditions.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet href="style.css" type="text/css"?>
<svg xmlns:iho="http://www.iho.int/SVGMetadata/5.2"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns="http://www.w3.org/2000/svg"
    xsi:schemaLocation="http://www.w3.org/2000/svg
https://staging.s100dev.net/schemas/S100/5.2.0/S100PC/20231201/S100SVG.xsd"
    baseProfile="tiny"
    version="1.2"
    xml:space="preserve"
    shape-rendering="geometricPrecision"
    fill-rule="evenodd"
    width="6mm" height="11mm" viewBox="-3 -5.5 6 11">
    <title>SCAROW01</title>
    <desc>Surface Current and Speed Vector Band 1</desc>
    <metadata>
        <iho:S100SVG>
        <iho:Description iho:publisher="NOAA" iho:creationDate="2024-02-13"
iho:source="S-111" iho:format="S100SVG" iho:version="0.2" />
    </iho:S100SVG>
    </metadata>
    <rect class="symbolBox layout" fill="none" x="-3" y="-5.5" height="11" width="6"/>
    <rect class="svgBox layout" fill="none" x="-3" y="-5.5" height="11" width="6"/>
    <path d=" M 0,5 L -0.5,5 L -1.0,-1.5 L -2.0,-1.5 L 0,-5 L 2.0,-1.5 L 1.0,-1.5 L
0.5,5 L 0,5 Z" class="fSCBN1"/>
    <path d=" M 0,5 L -0.5,5 L -1.0,-1.5 L -2.0,-1.5 L 0,-5 L 2.0,-1.5 L 1.0,-1.5 L
0.5,5 L 0,5 Z" class="sl f0 sCHBLK" style="stroke-width:0.32;"/>
    <circle class="pivotPoint layout" fill="none" cx="0" cy="0" r="1"/>
</svg>
```

Figure I-2 – SVG code for the arrow symbol for speed band 1 (SCAROW01).

I.3 Sample CSS File

Below (Figure J-3) is the Cascading Style Sheet (css) file used in Figure I-1.

```
/*
 * CSS styles for S-111 Day color table
 * Source: S-111 V. 1.0.0-20180606
 * stroke style for symbolBox, svgBox, pivotPoint as in S-101 SVGStyle CSS
 */
.layout {display:none} /* used to control visibility of symbolBox, svgBox, pivotPoint
(none or inline) */
.symbolBox {stroke:black;stroke-width:0.32;} /* show the cover of the symbol graphics
*/
.svgBox {stroke:blue;stroke-width:0.32;} /* show the entire SVG cover */
.pivotPoint {stroke:red;stroke-width:0.64;} /* show the pivot/anchor point, 0,0 */
.sl {stroke-linecap:round;stroke-linejoin:round} /* default line style elements */
.f0 {fill:none} /* no fill */
.sCHBLK {stroke:#000000} /*  sRGB line colour for all surface current arrow tokens */

.fSCBN1 {fill:#7652E2} /* sRGB line colour for colour token STEP1: S111 Step 1 color */

.fSCBN2 {fill:#4898D3} /* sRGB line colour for colour token STEP2: S111 Step 2 color */

.fSCBN3 {fill:#61CBE5} /* sRGB line colour for colour token STEP3: S111 Step 3 color */

.fSCBN4 {fill:#6DBC45} /* sRGB line colour for colour token STEP4: S111 Step 4 color */

.fSCBN5 {fill:#B4DC00} /* sRGB line colour for colour token STEP5: S111 Step 5 color */

.fSCBN6 {fill:#CDC100} /* sRGB line colour for colour token STEP6: S111 Step 6 color */

.fSCBN7 {fill:#F8A718} /* sRGB line colour for colour token STEP7: S111 Step 7 color */

.fSCBN8 {fill:#F7A29D} /* sRGB line colour for colour token STEP8: S111 Step 8 color */

.fSCBN9 {fill:#FF1E1E} /* sRGB line colour for colour token STEP9: S111 Step 9 color */
```

Figure I-3 – CSS file for surface current arrow symbols, Day condition.

ANNEX J – Surface Current Portrayal Rules

J-1 Introduction

This Section summarizes the rules and formulae discussed in Clause 9 (Portrayal) for display of the surface current arrow symbol. The placement of the colour 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-degree. 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 depth and datum, or the averaging depth, are given in the Carrier Metadata (clause 12.3). 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 K-1. The nominal height of the symbol is 10.0 mm.

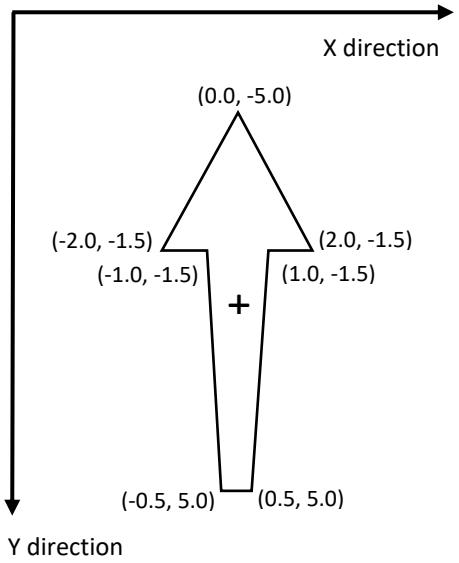

Figure J-1 - Surface current arrow symbol, showing x- and y-coordinates of the vertices (mm) and the pivot point (+)

Rule 2: A null value for speed and direction (see Table 10-3) 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 than the Minimum Speed in the next higher band. Therefore in Band 2,

$$0.5 \leq \text{speed in Band 2} < 1.0 \qquad \text{[Eqn J.1]}$$

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

Speed Band	Min Speed (kn)	Speed Band Width (kn)	Colour	RGB Colour Scale Intensity			Displayed Colour
				Red	Green	Blue	
1	0.0	0.5	purple	118	82	226	
2	0.5	0.5	dark blue	72	152	211	
3	1.0	1.0	light blue	97	203	229	
4	2.0	1.0	dark green	109	188	69	
5	3.0	2.0	light green	180	220	0	
6	5.0	2.0	yellow-green	205	193	0	
7	7.0	3.0	orange	248	167	24	
8	10.0	3.0	pink	247	162	157	
9	13.0	86.0	red	255	30	30	

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:

$$H = H_{ref} \cdot \min\{\max(S_{low}, S), S_{high}\} / S_{ref}. \quad \text{[Eqn J.2]}$$

The following table gives the nominal values for the four constants.

Table J-2 – Summary of recommended values for arrow display size. With these values, an arrow representing 5 kn will have a length of 10 mm

Constant	Description	Recommended Value
H_{ref}	Reference height for arrow scaling	10 mm
S_{ref}	Reference speed for arrow scaling	5 kn
S_{low}	Minimum speed to be used for arrow length computations	1.50 kn
S_{high}	Maximum speed to be used for arrow length computations	13 kn

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

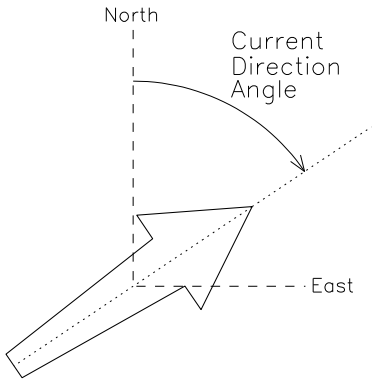

Figure J-2. Portrayal of the arrow's direction, based on the current direction. The dashed line is the arrow's centerline, and the origin of the East-North axis is at the arrow's pivot point. True north has a direction of 0 degrees

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 Data Producer must ensure 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 Data Producer must ensure 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 that is, 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 12-3), 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_{max}.

Suggested Rule 11: For thinning regularly gridded data, arrows at every n^{th} column and every n^{th} row are drawn, but making sure that the row and column with the maximum vector is drawn. With a R_{max} value of 0.5,

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

The value of *n* must be calculated by the ECDIS.

S-98 contains a detailed description of a suggested algorithm for implementing thinning by drawing symbols at only *n X n* grid points.

Suggested Rule 12: For thinning non-regularly spaced data, one potential solution would be to either reduce the reference height H_{ref} or increase the reference speed S_{ref} (Table J-2), so as to make each symbol smaller. Thus either S_{ref} of H_{ref}, or both, must be user-selectable.

Another method, based on the fact that non-regularly spaced data values are ordered in a nearly random manner, would be to reduce the number of symbols by plotting only every n^{th} vector. This method would require that the value of *n* be entered by the user.

J-6 Temporal Rules

Let T_s be the time selected by the user or the ENC 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 Ts, but (b) less than T_s + *timeRecordInterval.*

J-7 Pick Report for Time Series Data (informative)

In the absence of specific guidance in S-98 Annex C, the tidal stream panel display described in S-98 Annex C (for example, clause 15 4 in S-98 Edition 1.0.0) may be adapted for the purpose of displaying time series current information in response to a cursor pick by the user. A simple adaptation might consist of using the tabular format described in S-98 Annex C but replacing the “reference tide” attribute by the timestamp selected in the previous paragraph and omitting the “reference tide type” attribute. Figure J-3 depicts the concept. The table in Figure J-3 is an adaptation of the depiction of tidal stream tables for paper charts described in S-4 (B-407.3).

Tidal Station: (*station name*)			
Tidal Station Identifier: (*station identifier*)		Data From: SURF CUR (S-111)	
	Hours	Direction of stream (degrees)	Rates (knots)
Before	-6		
	-5		
	-4		
	-3		
	-2		
	-1		
YYYY-MM-DD HH:MM:SS Z	0		
After	+1		
	+2		
	+3		
	+4		
	+5		
	+6		

Figure J-3 – Notional pick report structure for data at multiple times

The time display (“Hours” column), the selection of time-value combinations to display, and the number of rows should be adapted to the time interval and number of records in the time series, so as to cover suitable periods before and after the selected display time.

NOTE: S-111 does not mandate a tabular display of data for any of its time series types. The tabular and described in this clause is intended only as a guideline for ECDIS developers desiring to implement a tabular format.