ships4sst

shipborne radiometers for sea surface temperature

The Recommended ISFRN L2R Data Specification and User Manual

Version 1.2 Revision 0

Document Management			
Reference:	Recommended ISFRN L2R Data Specification and User Manual v1.2 rev0.doc		
Version:	1.2	**Document Revision:**	0
Date of issue:	Tuesday, 15 January 2019		
Document type:	Microsoft Word [Compatibility Mode]		
BookCaptain:	Tim Nightingale		
Author:	Ships4SST		
Master File Location:	**Approved on-line version:** www.ships4sst.org/documents		

Document approval record

This document has been approved for release only when signed and dated signatures are present for the entities listed below. Documents may be digitally signed.

Role	Name	Representing Entity	Signature(s)	Date(s)
Book Captain	Tim Nightingale			
ISFRN	TBD			
ISFRN Review Board	TBD			

Document History

Author	Version description	Version number	Date of Revision
Tim Nightingale	First released draft	v1.0 rev 1	14th March, 2012
Tim Nightingale	Multiple revisions, based on review and inputs from the ISSI Radiometer Group	v1.0 rev 2	29th May 2014
Tim Nightingale	Text updated to reflect adoption by ISRN	V1.1 rev 0	7th April 2017
Ruth Wilson	Text and logo updated to reflect adoption by ISFRN	V1.2 rev 0	1st October 2018

Document change record

Author	Reason for Change	Pages/paragraphs changed	Date of Revision
Tim Nightingale	First draft	All	14th March, 2012
Tim Nightingale	Text expanded. Coordinate fields updated in line with CF-1.6. Relative wind fields added. Viewing angles renamed.	Multiple	29th May 2014
Tim Nightingale	Summary updated. Most “GHRSST” instances replaced by “ISRN” and “L2i” instances replaced by “L2R”. Table 7.1 updated in line with ACDD 1.3: Time formats changed to ISO 8601 extended, “**`Metadata_Conventions`**” attribute deleted as it was a) incorrectly spelt and b) deprecated, **`geospatial_lat/lon_max/min`** explicitly added **`metadata_link`** changed to all lower case.	All	7th April 2017
Ruth Wilson	Front page and summary updated. Most "ISRN" instances replaced by "ISFRN".	All	1st October 2018

Executive summary

The Group for High Resolution Sea Surface Temperature (GHRSST) has established product specifications for a range of two-dimensional sea surface temperature (SST) fields, including satellite swaths and geographic regions. The common product formats enable unified access to SST data from a range of data providers and sources.

This document contains a complementary product format developed by the International SST Fiducial Reference Measurement (FRM) Radiometer Network (ISFRN) for *in situ* radiometric measurements of SST. *In situ* infrared radiometric measurements of skin SST constitute a fiducial dataset for the validation of SSTs derived from satellite infrared radiometers. *In situ* infrared skin SST measurements have been collected by a number of international groups for more than twenty years at the time of writing, in a variety of data formats. This document extends the GHRSST principle of unified access to *in situ* data. The document contains a specification for an *in situ* level 2 radiometric SST data format (L2R) optimised for data collection at a single geographic point or along a trajectory. Although it has been designed with radiometric data in mind, it can also be used for other single-source *in situ* SST measurements, including those from buoys and profilers.

The L2R specification follows the style of existing GHRSST products described in the GHRSST Data Specification (GDS) document [AD-1]. It adopts the standard GDS header and contains descriptions of mandatory, optional and user-defined data fields applicable to *in situ* measurements. In particular, given its intended use for satellite SST validation, the product contains estimates of SST measurement uncertainties. The specification is compatible with the Climate and Forecast (CF) metadata convention [AD-2] and the Attribute Convention for Dataset Discovery (ACDD) [AD-3].

This document should be read in conjunction with the GDS. It is referred to as “the Annex” within the document text. Some GDS information is repeated within the Annex for ease of use, but the document should be read in conjunction with the GDS.

Table of Contents

Table of Tables

1 Applicable documents

The following documents contain requirements and information applicable to this document and should be consulted together with this document.

[AD-1] GHRSST Data Specification (GDS), Version 2.0, revision 5.

[AD-2] NetCDF Climate and Forecast (CF) Metadata Convention

[AD-3] NetCDF Attribute Convention for Dataset Discovery (ACDD).

[AD-4] CF Standard Name Table.

[AD-5] NASA Global Change Master Directory (GCMD) Science Keywords.

[AD-6] Unidata UDUNITS-2 package.

2 Reference documents

The following documents can be consulted when using this document as they contain relevant information:

[RD-1] Universally Unique Identifier (Wikipedia)

[RD-2] ISO 8601:2004 Data elements and interchange formats – Information interchange – Representation of dates and times

3 Acronym and abbreviation list

AATSR	Advanced Along Track Scanning Radiometer
ACDD	Attribute Convention for Dataset Discovery (netCDF metadata convention)
AD	Applicable document (see section 1)
Auxiliary data	Dynamic data that are used in the preparation of ISFRN L2R data products including wind speed, surface solar irradiance, aerosol optical depth and sea ice.
CF	Climate and Forecast (netCDF metadata convention)
CTD	Conductivity, temperature, depth (*in situ* ocean measurements)
ECMWF	European Centre for Medium-range Weather Forecasting
GDAC	Global Data Assembly Centre
GDS	GHRSST Data processing Specification
GHRSST	Group for High Resolution SST
ISAR	Infrared Sea surface temperature Autonomous Radiometer
ISDP	*In situ* Data Provider
ISO	International Organization for Standardization
ISFRN	International SST FRM Radiometer Network
L2R	Level 2 *in situ* radiometric data product.
M-AERI	Marine - Atmosphere Emitted Radiance Interferometer
NCEP	National Center for Environmental Prediction (US)
netCDF	network Common Data Form
RD	Reference document (see section 2)
SISTeR	Scanning InfraRed Sea surface Temperature Radiometer
SLSTR	Sea and Land Surface Temperature Radiometer
SSI	Surface Solar Irradiance
SST	Sea Surface Temperature
TSG	ThermoSalinoGraph
UDUNITS	UniData UNITS
UKMO	United Kingdom Met Office
URL	Universal Resource Locator
UTC	Universal Time Coordinated
UUID	Universal Unique Identifier
WMO	World Meteorological Organisation
XBT	eXpendable BathyThermograph
XML	eXtensible Mark-up Language

4 Document conventions

The following sub-sections describe the notations and conventions that are used throughout this document. Implementation projects are expected to adhere to the nomenclature and style of the Annex in their own documentation so far as possible to facilitate international coordination of documentation describing the data products and services within the ISFRN and GHRSST frameworks.

4.1 Use of text types

The text styles defined in Table 4.1 are used throughout the Annex.

Table 4.1 Definition of text styles used in the Annex

Text type	Meaning	Example
Courier font	Denotes a variable name	`dt_analysis`

4.2 Use of colour in tables

The colours defined in Table 4.2 are used throughout the Annex.

Table 4.2 Definition of colour styles used in the Annex

Colour	Meaning	Example
Grey	Denotes a table column name	Variable
Blue	Denotes a mandatory variable or attribute	`analysed_sst`
Violet	Denotes an item mandatory for only certain situations	`dt_analysis`
Yellow	Denotes an optional variable	`experimental_field`
Green	Denotes a dimension	`time=1024`
Orange	Denotes a coordinate	`float lat(time)`
Pink	Denotes identity information	`char platform_name`

4.3 Definitions of storage types within the Annex

Computer storage types referred to in the Annex are defined in Table 4.3.

Table 4.3 Storage type definitions used in the Annex

Storage type	Definition
byte	8 bit signed integer
short	16 bit signed integer
int (or long)	32 bit signed integer
int64	64 bit signed integer
float	32 bit floating point
double	64 bit floating point

5 Scope and content of this document

This document contains the ISFRN L2R product specification. The specification is written for those wishing to implement a processing chain to produce ISFRN L2R data products, and for users that require detailed technical information on the content and specification of the L2R product. The document contains a detailed technical specification of the ISFRN file naming specification as applied to *in situ* instrumentation, and supporting definitions and conventions.

Where appropriate, this specification follows the style and content of the GHRSST GDS [AD-1] and should be read in conjunction with the GDS.

6 Annex Filenames and Supporting Conventions

An overview of the file naming convention is presented below in Section 6.1 along with example filenames. Currently, only one format (L2R) is described, though further formats may be added as required. Details on each of the filename convention components are provided in Sections 6.2 through 6.8.

In addition, a best practice has been established for creating character strings used to describe SST products and sources of ancillary data. These strings, and associated numeric codes for the SST products, are used within some data files but are not part of the filename convention itself. The best practice is described in Section 6.9.

6.1 Overview of Filename Convention and Example Filenames

The file naming convention for the Annex is shown below.

<Indicative Date><Indicative Time>-<ISDP Code>-<Processing Level>_ISFRN-<SST Type>-<Product String>-<Additional Segregator>-v<Annex Version>-fv<File Version>.<File Type>

The variable components within angle brackets (“< >”) are summarized in Table 6.1 below and detailed in the following sections. Note that dashes (“-“) **are reserved** to separate elements of the file name and **should not** be used in any GDS code or the <Additional Segregator> element. Example filenames are given later in this section. While no strict limit to filename length is mandated, ISDPs are encouraged to keep the length to less than 240 characters to increase readability and usability.

Table 6.1 Annex Filenaming convention components.

Name	Definition	Description
<Indicative Date>	YYYYMMDD	The identifying date for this dataset. See Section 6.2.
<Indicative Time>	HHMMSS	The identifying time for this dataset. The time used is dependent on the <Processing Level> of the dataset: L2R: start time of granule All times should be given in UTC. See Section 6.3.
<ISDP>	The ISDP who provided the dataset	The *In situ* Data Provider (ISDP) code, listed in Section 6.4.
<Processing Level>	The data processing level code (currently L2R only)	The data processing level code, defined in Section 1.1.
<SST Type>	The type of SST data included in the file.	Conforms to the ISFRN definitions for SST, defined in Section 6.6.
<Product String>	A character string identifying the SST product set. The string is used uniquely within an ISDP but may be shared across ISDPs.	The unique “name” within an ISDP of the product line. See Section 6.7

<Additional Segregator>	Optional text to distinguish between files with the same <Product String>. Dashes are not allowed within this element.	This text is used since the other filename components are sometimes insufficient to uniquely identify a file.
<Annex Version>	*nn.n*	Version number of the Annex used to process the file. For example, Annex 1.0 = "01.0".
<File Version>	*xx.x*	Version number for the file, for example, "01.3".
<File Type>	netCDF data file suffix (nc) or ISO metadata file suffix (xml)	Indicates this is a netCDF file containing data or its corresponding ISO-19115 metadata record in XML.

L2R_ISFRN Filename Example
20121205000001-RAL-L2R_ISFRN-SSTskin-SISTeR_A-QM2-v01.0-fv01.3.nc

The above file contains ISFRN L2R SST data collected from the beginning of 05 December 2012 with the SISTeR A ("Alice") instrument. The granule begins at 00:00:01 hours. It is version 1.3 of the file and was produced by the RAL ISDP in accordance with the Annex 1.0 specification. The <Additional Segregator> text is "QM2", for the Queen Mary 2 liner.

6.2 <Indicative Date>

The identifying date for this dataset in UTC, using the format YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12, and DD is the two-digit day of month from 01 to 31. The date used should best represent the observation date for the dataset. This could be the start date of a time series of measurements.

6.3 <Indicative Time>

The identifying time for this dataset in UTC, using the format HHMMSS, where HH is the two-digit hour from 00 to 23, MM is the two-digit minute from 00 to 59, and SS is the two-digit second from 00 to 59. For the L2R product, this should be the product start time. The time should be given in UTC. Note: ISDPs should ensure the applications they use to determine UTC properly account for leap seconds.

6.4 <ISDP>

Codes used for ISFRN *In situ* Data Providers (ISDPs) are listed in the table below. New codes are assigned by the ISFRN Project Office and entered into the table upon agreement by the PO, and relevant ISDPs.

Table 6.2: *In situ* Data Provider (ISDP) code table.

ISDP Code	ISFRN ISDP Name
UoS	University of Southampton
RAL	Rutherford Appleton Laboratory, Science and Technology Research Council
RSMAS	Rosenstiel School of Marine and Atmospheric Science, University of Miami
New codes	Please contact the ISFRN Project Office if you require new codes to be included in future revisions of the Annex.

6.5 <Processing Level>

The Annex currently currently establishes standards for a single level 2 *in situ* product, known as L2R.

Table 6.3 Annex Processing Level Conventions and Codes

Level	<Processing Level> Code	Description
Level 2 *in situ*	L2R	Geophysical variables derived from Level 1 source data at the same resolution and location as the Level 1 data, typically along an ocean track. These data require ancillary data and uncertainty estimates.

6.6 <SST Type>

The Annex <SST_Type> field maps to the CF standard names for SST shown in Table 6.4. These names are a subset of the GDS SST type names. The CF definitions are described in more detail below. The names were first included in CF-1.3. The current version of the CF standard name table can be found at [AD-4].

Table 6.4 Annex <SST Type> code and summary table.

Annex <SST Type>	CF standard name	Approximate depth	Typically observed by…
SSTskin	**`sea_surface_skin_temperature`**	10 µm – 20 µm	Infrared radiometers operating in a range of wavelengths from 3.7 µm to 12 µm
SSTsubskin	**`sea_surface_subskin_temperature`**	1 mm – 1.5 mm	Microwave radiometers operating in a range of frequencies from 6 GHz to 11 GHz
SSTdepth	**`sea_water_temperature`**	Specified by vertical coordinate (e.g., SST_{5m})	Immersion thermometers

`sea_surface_skin_temperature` (ISFRN <SST Type>: SSTskin):

CF Definition: *The surface called "surface" means the lower boundary of the atmosphere. The sea surface skin temperature is the temperature measured by an infrared radiometer typically operating at wavelengths in the range 3.7 µm – 12 µm. It represents the temperature within the conductive diffusion-dominated sub-layer at a depth of approximately 10 µm – 20 µm below the air-sea interface. Measurements of this quantity are subject to a large potential diurnal cycle including cool skin layer effects (especially at night under clear skies and low wind speed conditions) and warm layer effects in the daytime.*

Additional Details: The sea surface skin temperature (SSTskin) as defined above represents the temperature of the water across a very small depth of approximately 20 µm, with the temperature profile in the thermal skin layer weighted by the exponential envelope of Beer's Law along the emission path within the electromagnetic skin layer. This definition is chosen for consistency with the majority of infrared radiometer measurements, but the value will be dependent on the wavelength of electromagnetic radiation used in the measurement (as the emission/absorption coefficient is wavelength dependent), and the emission angle (adjusted for the subsurface propagation direction using Snell's Law). The emission angle is the area weighted average of the tilts of the facets of the

sea surface within the radiometer field of view, measured relative to the zenith angle of the radiometer measurement and adjusted for the spread of the beam for a radiometer with a large acceptance angle.

`sea_surface_subskin_temperature` (ISFRN <SST Type>: SSTsubskin):

CF Definition: *The surface called "surface" means the lower boundary of the atmosphere. The sea surface subskin temperature is the temperature at the base of the conductive laminar sub-layer of the ocean surface, that is, at a depth of approximately 1 mm – 1.5 mm below the air-sea interface. For practical purposes, this quantity can be well approximated to the measurement of surface temperature by a microwave radiometer operating in the 6 GHz – 11 GHz frequency range, but the relationship is neither direct nor invariant to changing physical conditions or to the specific geometry of the microwave measurements. Measurements of this quantity are subject to a large potential diurnal cycle due to thermal stratification of the upper ocean layer in low wind speed high solar irradiance conditions.*

Additional Details: The sea surface subskin temperature (SSTsubskin) represents the temperature at the base of the thermal skin layer. The difference between SSTint and SSTsubskin is related to the net flux of heat through the thermal skin layer. SSTsubskin is the temperature of a layer approximately 1 mm thick at the ocean surface.

`sea_water_temperature` (ISFRN <SST Type>: SSTdepth or SST_z):

CF Definition: *The general term, "bulk" sea surface temperature, has the standard name* ***`sea_surface_temperature`*** *with no associated vertical coordinate axis. The temperature of sea water at a particular depth (other than the foundation level) should be reported using the standard name* ***`sea_water_temperature`*** *and, wherever possible, supplying a vertical coordinate axis or scalar coordinate variable.*

Additional Details: Sea water temperature (SSTdepth or SST_z, for example $SST_{1.5m}$) is the terminology adopted by ISFRN to represent *in situ* measurements near the surface of the ocean that have traditionally been reported simply as SST or "bulk" SST. For example SST_{6m} would refer to an SST measurement made at a depth of 6 m. Without a clear statement of the precise depth at which the SST measurement was made, and the circumstances surrounding the measurement, such a sample lacks the information needed for comparison with, or validation of satellite-derived estimates of SST using other data sources. The terminology has been introduced to encourage the reporting of depth (z) along with the temperature.

All measurements of water temperature beneath the SSTsubskin are obtained from a wide variety of sensors such as drifting buoys having single temperature sensors attached to their hull, moored buoys that sometimes include deep thermistor chains at depths ranging from a few meters to a few thousand meters, thermosalinograph (TSG) systems aboard ships recording at a fixed depth while the vessel is underway, Conductivity Temperature and Depth (CTD) systems providing detailed vertical profiles of the thermohaline structure used during hydrographic surveys and to considerable depths of several thousand meters, and various expendable bathythermograph systems (XBT). In all cases, these temperature observations are distinct from those obtained using remote sensing techniques and measurements at a given depth should be referred to as **`sea_water_temperature`** qualified by a depth in meters rather than sea surface temperatures.

6.7 <Product String>

The current set of ISFRN L2R product strings is listed in table below. New strings are assigned by the ISFRN Project Office (PO) and entered into the table upon agreement by the PO and the relevant ISDPs. These product strings are used within the ISFRN filename convention and within the ISFRN unique dataset codes described in Section 6.9. The *in situ* sensor entry is also used in the netCDF global attribute, **`sensor`**, for all ISFRN product files. See Section 1.1 for more information on the required **`global attributes`**.

Table 6.5 ISFRN L2R <Product String> Table

L2R <Product String>	*In Situ* Sensor	Description
ISAR_<X>	ISAR	Infrared Sea surface temperature Autonomous Radiometer, where <X> is the instrument serial number (1, 2, 3…)
M_AERI_<X>	M-AERI	Marine - Atmosphere Emitted Radiance Interferometer, where <X> is the instrument serial code (1, 2, 3, A, B…)
SISTeR_<X>	SISTeR	Scanning Infrared Sea surface Temperature Radiometer, where <X> is the instrument serial code (A, B…)
New codes		Please contact the ISFRN Project Office if you require new codes to be included in future revisions of the Annex.

6.8 <Additional Segregator>

It is possible for the preceding combination of filename components to result in a non-unique file name. In those situations, the use of the <Additional Segregator> must be used to ensure that each distinct file has a unique file name. In addition, ISDPs are free to use this component to add other information to their file names. Some providers, for example, use the name of the original L1b file. Others enter start and stop times of the file in this component.

6.9 ISFRN Unique Text Strings and Numeric Codes

This section describes the best practices that have been developed for creating unique text strings and numeric codes that are needed in various places within some ISFRN files. Note that these strings are not part of the filename convention described above, but, like filenames, they apply to all ISFRN product levels and so are described in this part of the Annex.

SST Variable Text Strings and Numeric Codes
For each official ISFRN product, a unique numeric code and associated text string is defined. The string is listed in the global attribute **`id`** (see Section 1.1) for each netCDF file in the product collection. The unique numerical values and text strings for ISFRN SST datasets are identified in Table 6.6 below and are established by agreement with the relevant ISDP, following the Best Practice defined later in this Section.

Ancillary and Optional Variable Text Strings and Numeric Codes
The Annex also requires the providing ISDP to indicate text strings and associated numeric codes directly within the netCDF global and variable attributes for the ancillary sea ice fraction, aerosol depth indicator, climatologies, surface solar irradiance, wind speed, and when relevant, for optional and experimental variables. These text strings and codes do not need to be unique across different datasets, but must be consistent within a given dataset and clearly specified within each netCDF file. In these cases, the variable in question should contain an attribute called **`flag_meanings`** together with an attribute called **`flag_values`**. The **`flag_values`** attribute shall contain an array of the numeric codes for the sources of data used whose order matches the space-separated text strings in the **`flag_meanings`** attribute.

Best Practice for Establishing Character Strings
A best practice has been established for defining unique text strings to be used in ISFRN dataset **`id`** global attributes (Section 7.1). While a rigid standard for the text strings is not possible, the following best practice should be applied wherever practicable:

<Product String>-<ISDP Code>-<Processing Level>[-<Additional Segregator>]-v<Product Version>

The definitions of the components match the definitions from the file naming convention, found in Table 6.1. The component <Product Version> is used to distinguish different versions of the same dataset and should be of the form *x.y* where *x* is the major and *y* is the minor version. For ancillary and optional variables, an attempt should be made to follow these conventions to the extent possible. If there is no ISDP to use in the string, then it is recommended that a commonly used acronym for the centre responsible be used. An optional <Additional Segregator> can be used to disambiguate distinct datasets that would otherwise share the same dataset string.

New codes are assigned by the ISFRN Project Office and are entered into the table upon agreement by the PO and the relevant ISDPs.

Table 6.6 Example ISFRN Unique SST Dataset Strings and Numeric Codes.

Unique Dataset String	Product Version	Numeric Code	Description
ISAR_1-UoS-L2R-v1.0	1	1	University of Southampton ISAR 1 L2R product
M_AERI_1-RSMAS-L2R-v1.0	1	2	Rosenstiel School of Marine and Atmospheric Science M-AERI 1 L2R product.
SISTeR_A-RAL-L2R-v1.1	1.1	3	STFC Rutherford Appleton Laboratory SISTeR A (“Alice”) full resolution L2R product
New codes			Please contact the ISFRN Project Office if you require new codes to be included in future revisions of the Annex.

7 Annex netCDF 4 common data product file structure

Annex data files follow the Climate and Forecast netCDF conventions [AD-2] because these provide a practical standard for storing oceanographic data and are implemented in netCDF 4. The netCDF data format is extremely flexible, self-describing and has been adopted as a *de facto* standard for many operational and scientific oceanography systems. It is also actively maintained including significant discussions and inputs from the oceanographic community (see http://cfconventions.org/discussion.html).

The Annex netCDF files are based on the attribute data tags defined by the Climate and Forecast (CF) metadata conventions [AD-2]. The purpose of the CF conventions is to require conforming datasets to contain sufficient metadata that they are self-describing in the sense that each variable in the file has an associated description of what it represents, including physical units if appropriate, and that each value can be located in space (relative to earth-based coordinates) and time.

In the context of netCDF, a variable refers to data stored in the file as a scalar or as a multidimensional array. Global attributes are used to hold information that applies to the whole file, such as the dataset title. Each individual variable can also have its own attributes, referred as variable attributes. The dimensions of each variable must be explicitly declared in the dimension section.

Variable attributes can include, for example, an offset, scale factor, units, a longer descriptive version of the variable name, and a fill value. Where applicable, SI units should be used and described by a character string that is compatible with the Unidata UDUNITS package [AD-6]. The variable's attribute fill value is used to indicate array elements that do not contain valid data. Several different attributes and associated tags can be defined for Annex variables. The reserved variable attribute **`_FillValue`** contains a default value to be used for array elements that do not contain a valid measurement. The following CDL extract provides an example.

```
double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name = "sea surface skin temperature" ;
    sea_surface_temperature:standard_name = "sea_surface_skin_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:coordinates = "lon lat" ;
```

In this example, the variable **`sea_surface_temperature`** is a 1-D array of type double, the CF standard name has been specified as **`sea_surface_skin_temperature`**, the units are kelvin, and **`_FillValue`** and **`coordinates`** attributes have also been set.

7.1 Annex netCDF global attributes

Table 7.1 summarizes the global attributes that are mandatory for every ISFRN netCDF data file. The sources of mandated attribute requirements (CF [AD-2], ACDD [AD-3] and this document, Annex) are indicated the Source column.

Table 7.1 Mandatory global attribute tags for ISFRN netCDF data product files

Global Attribute Name	For mat	Description	Source
Conventions	string	A text string identifying the netCDF conventions followed. This attribute should be set to the version of CF used and should also include the ACDD. For example: "CF-1.6, ACDD-1.3".	CF
title	string	A descriptive title for the ISFRN dataset	CF, ACDD
summary	string	A paragraph describing the dataset.	ACDD
references	string	Published or web-based references that describe the data or methods used to produce it.	CF
institution	string	ISFRN ISDP code for the *in situ* data provider. See Table 6.2 for available codes.	CF, ACDD
history	string	History of all applications that have modified the original data to create this file.	CF, ACDD
comment	string	Miscellaneous information about the data or methods used to produce it.	CF, ACDD
license	string	Describe any restrictions to data access, use, and distribution. ISFRN datasets should be freely and openly available and have minimal restrictions. However if, for instance, web registration is required, the URL could be given here. Default to “ISFRN protocol describes data use as free and open.”	ACDD
id	string	The unique ISFRN character string for this product. All ISFRN SST products have one, and they are listed in Table 6.6.	ACDD
naming_authority	string	Fixed as “org.shipborne-radiometer” following ACDD convention	ACDD
product_version	string	The product version of this data file, which may differ from the file version used in the file naming convention (Section 6).	Annex
uuid	string	A Universally Unique Identifier (UUID) [RD-1]. Numerous, simple tools can be used to create a UUID, which is inserted as the value of this attribute	Annex
l2r_version_id	string	Annex version used to create this data file. For example, “1.1”.	Annex
netcdf_version_id	string	Version of netCDF libraries used to create this file. For example, “4.1.1”	Annex
date_created	string	The date and time the data file was created, in ISO 8601 [RD-2] extended format and including a time zone (“Z” for UTC is recommended) “yyyy-mm-ddThh:mm:ssZ”.	ACDD

file_quality_level	integer	A code value: 0 = unknown quality 1 = extremely suspect (frequent problems, e.g. with known instrument problems) 2 = suspect (occasional problems) 3 = excellent (no known problems) The criteria used to determine the code value should be fully described in the documentation referenced by global attribute **:references**.	Annex
spatial_resolution	string	A string describing the approximate resolution of the product. For example, “10 m”	Annex
start_time	string	Date and time of the first measurement in the granule, in ISO 8601 [RD-2] extended format and including a time zone (“Z” for UTC is recommended) “yyyy-mm-ddThh:mm:ssZ”.	Annex
time_coverage_start	string	Identical to **start_time**. Included for increased ACDD compliance.	ACDD
stop_time	string	Date and time of the last measurement in the granule, in ISO 8601 [RD-2] extended format and including a time zone (“Z” for UTC is recommended) “yyyy-mm-ddThh:mm:ssZ”.	Annex
time_coverage_end	string	Identical to **stop_time**. Included for increased ACDD compliance.	ACDD
northernmost_latitude	float	Decimal degrees north, range -90 to +90.	Annex
geospatial_lat_max	float	Identical to **northernmost_latitude**. Included for increased ACDD compliance.	ACDD
southernmost_latitude	float	Decimal degrees north, range -90 to +90	Annex
geospatial_lat_min	float	Identical to **southernmost_latitude**. Included for increased ACDD compliance.	ACDD
easternmost_longitude	float	Decimal degrees east, range -180 to +180.	Annex
geospatial_lon_max	float	Identical to **easternmost_longitude**. Included for increased ACDD compliance.	ACDD
westernmost_longitude	float	Decimal degrees east, range -180 to +180.	Annex
geospatial_lon_min	float	Identical to **westernmost_longitude**. Included for increased ACDD compliance.	ACDD
geospatial_lat_units	string	Units of the latitudinal resolution. Typically “degrees_north”	ACDD
geospatial_lat_resolution	float	Latitude Resolution in units matching **geospatial_lat_units**.	ACDD
geospatial_lon_units	string	Units of the longitudinal resolution. Typically “degrees_east”	ACDD
geospatial_lon_resolution	float	Longitude Resolution in units matching **geospatial_lon_units**.	ACDD
source	string	Comma separated list of all source data present in this file. List SST sources first, followed by Auxiliary sources. If the source is an Annex product, use the Annex unique string listed in Table 6.6. For other sources, use the GDS unique string where defined, or follow the best practice described in Section 6.9.	CF
platform	string	Observing platform (e.g. a ship name) used to create this data file. Provide as a comma separated list if there is more than one.	Annex
sensor	string	Sensor(s) used to create this data file. Select from the entries found in the *In Situ* Sensor column of Table 6.5 and provide as a comma separated list if there is more than one.	Annex
metadata_link	string	Link to collection metadata record at archive	ACDD

keywords	string	Typically GCMD Science Keyword: “Oceans > Ocean Temperature > Sea Surface Temperature”	ACDD
keywords_vocabulary	string	“NASA Global Change Master Directory (GCMD) Science Keywords” as defined in	ACDD
standard_name_vocabulary	string	“NetCDF Climate and Forecast (CF) Metadata Convention”	ACDD
acknowledgment	string	Information about funding source and how to cite the use of these data.	ACDD
creator_name	string	Provide a name and email address for the most relevant point of contact at the producing ISDP, as well as a URL relevant to this dataset.	ACDD
creator_email	string		ACDD
creator_url	string		ACDD
project	string	“International Shipborne Radiometer Network”	ACDD
publisher_name	string	“The ISFRN Project Office”	ACDD
publisher_url	string	“http://www.shipborne.radiometer.org”	ACDD
publisher_email	string	“info@shipborne-radiometer.org”	ACDD
processing_level	string	The Annex defines the single option, “L2R”.	ACDD, Annex
cdm_data_type	string	THREDDS dataType “Station” or “Trajectory”	ACDD
featureType	string	CF featureType “timeSeries” or “trajectory”	CF

7.2 Annex netCDF variable attribute definitions

Table 7.2 lists the variable attributes which shall be used in Annex data files. Some may not be relevant for certain variables and reference to the variable requirements (as defined in the CDL description of each variable) should be made to establish which are required. The **add_offset** and **scale_factor** variable attributes may vary from one dataset to another, depending on the resolution or the characteristics of the sensor in question. Each data provider is free to adjust these attributes to suit their own requirements, since it does not matter to data reading tools which all have to unpack the data.

Table 7.2 Mandatory continuous variable attributes used within Annex L2R data files

Variable Attribute Name	Format	Description	Source
_FillValue	Must be the same as the variable type	A value used to indicate array elements containing no valid data. This value must be of the same type as the storage (packed) type; should be set as the minimum value for this type. Note that some netCDF readers are unable to cope with signed bytes and may, in these cases, report fill as 128. Some cases will be reported as unsigned bytes 0 to 255. Required for all but flag and quality level variables.	CF
units	string	Text description of the units, preferably SI, and must be compatible with the Unidata UDUNITS-2 package. For a given variable (e.g. wind speed), these must be the same for each dataset. Required for all quantitative variables.	CF, ACDD

scale_factor	Must be expressed in the unpacked data type	Multiplies the variable to recover the original value. Defined by the producing ISDP. Valid values within **value_min** and **valid_max** should be transformed by **scale_factor** and **add_offset**, otherwise skipped to avoid floating point errors.	CF
add_offset	Must be expressed in the unpacked data type	Added to the variable after multiplication by the scale factor to recover the original value. If only one of **scale_factor** or **add_offset** is needed, then both should be included to avoid ambiguity. **scale_factor** defaults to 1.0 and **add_offset** defaults to 0.0. Defined by the producing ISDP.	CF
long_name	string	A free-text descriptive variable name.	CF, ACDD
valid_min	Expressed in same data type as variable	Minimum valid value for this variable once they are packed (in storage type). The fill value should be outside this valid range. Note that some netCDF readers are unable to cope with signed bytes and may, in these cases, report valid min as 129. Some cases as unsigned bytes 0 to 255. Values outside of **valid_min** and **valid_max** will be treated as missing values.	CF
valid_max	Expressed in same data type as variable	Maximum valid value for this variable once they are packed (in storage type). The fill value should be outside this valid range. Note that some netCDF readers are unable to cope with signed bytes and may, in these cases, report valid min as 127	CF
standard_name	string	Where defined, a standard and unique description of a physical quantity. For the complete list of standard name strings [AD-4]. **Do not** include this attribute if no **standard_name** exists.	CF, ACDD
comment	string	Miscellaneous information about the variable or the methods used to produce it.	CF
source	string	For a data variable with a single source, use the Annex unique string listed in Table 6.6 if the source is a Annex SST product. For other sources, use the GDS unique string where defined, or follow the best practice described in Section 6.9 to create the character string. If the data variable contains multiple sources, set this string to be the relevant “sources of” variable name. For example, if multiple wind speed sources are used, set **source** = **sources_of_wind_speed**.	CF
references	string	Published or web-based references that describe the data or methods used to produce it. Note that while at least one reference is required in the global attributes (See Table 7.1), references to this specific data variable may also be given.	CF

axis	String	For use with coordinate variables only. The attribute 'axis' may be attached to a coordinate variable and given one of the values "X", "Y", "Z", or "T", which stand for a longitude, latitude, vertical, or time axis respectively [AD-2].	CF
positive	String	For use with a vertical coordinate variables only. May have the value "up" or "down". For example, if an oceanographic netCDF file encodes the depth of the surface as 0 and the depth of 1000 meters as 1000 then the axis would set positive to "down". If a depth of 1000 meters was encoded as -1000, then positive would be set to "up". See the section on vertical coordinates in [AD-2].	CF
coordinates	String	Identifies auxiliary coordinate variables, label variables, and alternate coordinate variables. See the section on coordinate systems in [AD-2].	CF
flag_meanings	String	Space-separated list of text descriptions associated in strict order with conditions set by either **flag_values** or **flag_masks**. Words within a phrase should be connected with underscores.	CF
flag_values	Must be the same as the variable type	Comma-separated array of valid, mutually exclusive variable values (required when the bit field contains enumerated values; i.e. a list of conditions). Used primarily for **quality_level** and **sources_of_xxx** variables.	CF
flag_masks	Must be the same as the variable type	Comma-separated array of valid variable masks (required when the bit field contains independent Boolean conditions; i.e., a bit mask). Used primarily for **sst_flags** variable. *Note: CF allows the use of both flag_masks and flag_values attributes in a single variable to create sets of masks that each have their own list of flag_values (see [AD-2] for examples), but this practice is discouraged.*	CF

7.3 Annex coordinate and identity variable definitions

NetCDF coordinate variables provide the spatial and temporal locations for the *in situ* data arrays. Coordinate variables must always include the time coordinate **time** and the geodetic coordinates **lat** and **lon**. They must also include a vertical coordinate **depth** for all non-surface measurements.

The **time** variable contains the reference time stamp of the data. Time is a 1-D array and is indexed with the **time** dimension. The **time** variable increases monotonically. The **time** dimension may be either a fixed value or unlimited. All times should be UTC.

The **time:units** attribute string has the form "**<units> since <reference time>**". The time stamps in the **time** variable are defined relative to the reference time in the **time:units** attribute. The Annex makes the following recommendations for the **time:units** attribute:

- The reference time should be January 1st 1981, 00:00:00 UTC,
- The reference time should be encoded in the ISO 8601 [RD-2] extended time format ("**YYYY-MM-DDThh:mm:ssZ**"),
- The unit of time should be **seconds** or smaller (**milliseconds** or **microseconds**) to avoid ambiguity with leap seconds.

The remaining coordinate variables may be either scalars, if the value is invariant (e.g. the latitude and longitude of a stationary platform), or 1-D arrays indexed with the **time** dimension. Scalar and array variables can be mixed as required.

Where possible, all coordinate and time variables (**lat**, **lon**, **depth** and **time**) should be recorded with a precision which is sufficient to distinguish individual measurements from each other. Coordinate variables must be complete (no fill values allowed).

The only required coordinate attributes are **standard_name** and **units**. Coordinate variables can be of any numeric type and scaling may be implemented if required.

A **:coordinates** attribute with value "**lon lat**" or "**lon lat depth**" as appropriate must be attached to all 1-D data array variables.

The CF convention strongly recommends the addition of a station variable with the attribute **cf_role**. The **cf_role** attribute should have the value "**cf_timeseries**" or "**cf_trajectory**". Further, the convention recommends station variables with the standard name attributes **platform_name** and **platform_id** respectively. The Annex implements these variables as null-terminated character strings. The **cf_role** attribute is attached to the **platform_name** variable and an **id_type** attribute is attached to the **platform_id** variable. Examples of the **platform_id** string and required values for the **id_type** string are given in Table 7.3.

Table 7.3 The platform_id variable and platform_id:id_type attribute

platform_id example string	**id_type string**	**Description**
ZCEF6	**call_sign**	Radio call sign
9241061	**IMO**	International Maritime Organization (IMO) number
310627000	**MMSI**	Maritime Mobile Service Identity (MMSI)
10044	**WMO**	World Meteorological Organisation (WMO) number
	none	No unique identity code available
new **platform_id** type		Please contact the ISFRN Project Office if you require a new **platform_id** type to be included in future revisions of the Annex.

7.3.1 Static sensor surface measurement time series

This is the simplest case. The format describes a time series of surface measurements at a single location, e.g. skin temperatures recorded from a fixed platform. Data are represented as a CF time series with scalar geodetic variables and a 1-D time variable.

Table 7.4 Example CDL for a static surface time series

```
netcdf example {
dimensions:
  time = 86400 ;
  name_strlen = 80 ;
  id_strlen = 20 ;
variables:
  double lat ;
    lat:long_name = "station latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon ;
    lon:long_name = "station longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  long time(time) ;
    time:long_name = "measurement time" ;
    time:standard_name = "time" ;
    time:units = "seconds since 1981-01-01T00:00:00Z" ;
  char platform_name(name_strlen) ;
    platform_name:standard_name = "platform_name" ;
    platform_name:cf_role = "timeseries_id" ;
  char platform_id(id_strlen) ;
    platform_id:standard_name = "platform_id" ;
    platform_id:id_type ="IMO" ;
  double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name="sea surface skin temperature";
    sea_surface_temperature:standard_name="sea_surface_skin_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:valid_min = 260.0 ;
    sea_surface_temperature:valid_max = 320.0 ;
    sea_surface_temperature:coordinates = "lon lat" ;
  attributes:
    :cdm_data_type = "Station" ;
    :featureType = "timeSeries" ;
}
```

7.3.2 Static sensor measurement time series at fixed depth

This format describes a time series of measurements at a single location and fixed depth, e.g. temperatures recorded below a moored buoy. Data are represented as a CF time series with scalar geodetic and depth variables and a 1-D time variable.

Table 7.5 Example CDL for a static time series at depth

```
netcdf example {
dimensions:
  time = 86400 ;
  name_strlen = 80 ;
  id_strlen = 20 ;
variables:
  double lat ;
    lat:long_name = "station latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon ;
    lon:long_name = "station longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  double depth ;
    depth:long_name = "measurement depth" ;
    depth:standard_name = "depth" ;
    depth:units = "metres" ;
    depth:positive = "down" ;
    depth:axis = "Z" ;
  long time(time) ;
    time:long_name = "measurement time" ;
    time:standard_name = "time" ;
    time:units = "seconds since 1981-01-01T00:00:00Z" ;
  char platform_name(name_strlen) ;
    platform_name:standard_name = "platform_name" ;
    platform_name:cf_role = "timeseries_id" ;
  char platform_id(id_strlen) ;
    platform_id:standard_name = "platform_id" ;
    platform_id:id_type ="WMO" ;
  double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name="sea water temperature";
    sea_surface_temperature:standard_name="sea_water_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:valid_min = 260.0 ;
    sea_surface_temperature:valid_max = 320.0 ;
    sea_surface_temperature:coordinates = "lon lat depth" ;
  attributes:
    :cdm_data_type = "Station" ;
    :featureType = "timeSeries" ;
}
```

7.3.3 Sensor measurement profiles at a fixed location

This format describes a time series of measurements at a single location and at varying depth, e.g. a moored ocean profiler. Data are represented as a CF trajectory with scalar geodetic variables and 1-D depth and time variables.

Table 7.6 Example CDL for a static profile

```
netcdf example {
dimensions:
  time = 86400 ;
  name_strlen = 80 ;
  id_strlen = 20 ;
variables:
  double lat ;
    lat:long_name = "station latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon ;
    lon:long_name = "station longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  double depth(time) ;
    depth:long_name = "profile depth" ;
    depth:standard_name = "depth" ;
    depth:units = "metres" ;
    depth:axis = "Z" ;
    depth:positive = "down" ;
  long time(time) ;
    time:long_name = "measurement time" ;
    time:standard_name = "time" ;
    time:units = "seconds since 1981-01-01T00:00:00Z" ;
  char platform_name(name_strlen) ;
    platform_name:standard_name = "platform_name" ;
    platform_name:cf_role = "trajectory_id" ;
  char platform_id(id_strlen) ;
    platform_id:standard_name = "platform_id" ;
    platform_id:id_type ="WMO" ;
  double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name="sea water temperature";
    sea_surface_temperature:standard_name="sea_water_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:valid_min = 260.0 ;
    sea_surface_temperature:valid_max = 320.0 ;
    sea_surface_temperature:coordinates = "lon lat depth" ;
  attributes:
    :cdm_data_type = "Trajectory" ;
    :featureType = "trajectory" ;
}
```

7.3.4 Moving sensor surface measurement time series

This format describes a time series of surface measurements from a moving platform, e.g. skin temperatures recorded from a ship. Data are represented as a CF trajectory with 1-D geodetic variables and a 1-D time variable.

Table 7.7 Example CDL for a moving surface time series

```
netcdf example {
dimensions:
  time = 86400 ;
  name_strlen = 80 ;
  id_strlen = 20 ;
variables:
  double lat(time) ;
    lat:long_name = "station latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon(time) ;
    lon:long_name = "station longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  long time(time) ;
    time:long_name = "measurement time" ;
    time:standard_name = "time" ;
    time:units = "seconds since 1981-01-01T00:00:00Z" ;
  char platform(name_strlen) ;
    platform:standard_name = "platform_name" ;
    platform_name:cf_role = "trajectory_id" ;
  char platform_id(id_strlen) ;
    platform_id:standard_name = "platform_id" ;
    platform_id:id_type ="call_sign" ;
  double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name="sea surface skin temperature";
    sea_surface_temperature:standard_name="sea_surface_skin_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:valid_min = 260.0 ;
    sea_surface_temperature:valid_max = 320.0 ;
    sea_surface_temperature:coordinates = "lon lat" ;
  attributes:
    :cdm_data_type = "Trajectory" ;
    :featureType = "trajectory" ;
}
```

7.3.5 Moving sensor measurement time series at fixed depth

This format describes a time series of measurements at fixed depth measured from a moving platform, e.g. ship inlet temperatures. Data are represented as a CF trajectory with 1-D geodetic variables, a scalar depth variable and a 1-D time variable.

Table 7.8 Example CDL for a moving time series at depth

```
netcdf example {
dimensions:
  time = 86400 ;
  name_strlen = 80 ;
  id_strlen = 20 ;
variables:
  double lat(time) ;
    lat:long_name = "station latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon(time) ;
    lon:long_name = "station longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  double depth ;
    depth:long_name = "inlet temperature" ;
    depth:standard_name = "depth" ;
    depth:units = "metres" ;
    depth:positive = "down" ;
    depth:axis = "Z" ;
  long time(time) ;
    time:long_name = "measurement time" ;
    time:standard_name = "time" ;
    time:units = "seconds since 1981-01-01T00:00:00Z" ;
  char platform_name(name_strlen) ;
    platform_name:standard_name = "platform_name" ;
    platform_name:cf_role = "trajectory_id" ;
  char platform_id(id_strlen) ;
    platform_id:standard_name = "platform_id" ;
    platform_id:id_type ="MMSI" ;
  double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name="sea water temperature";
    sea_surface_temperature:standard_name="sea_water_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:valid_min = 260.0 ;
    sea_surface_temperature:valid_max = 320.0 ;
    sea_surface_temperature:coordinates = "lon lat depth" ;
  attributes:
    :cdm_data_type = "Trajectory" ;
    :featureType = "trajectory" ;
}
```

7.3.6 Free motion sensor measurement time series

This format describes a time series of measurements at varying location and depth, e.g. an Argo float. Data are represented as a CF trajectory with 1-D geodetic, depth and time variables.

Table 7.9 Example CDL for a free motion time series

```
netcdf example {
dimensions:
  time = 86400 ;
  name_strlen = 80 ;
  id_strlen = 20 ;
variables:
  double lat(time) ;
    lat:long_name = "station latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon(time) ;
    lon:long_name = "station longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  double depth(time) ;
    depth:long_name = "measurement depth" ;
    depth:standard_name = "depth" ;
    depth:units = "metres" ;
    depth:positive = "down" ;
    depth:axis = "Z" ;
  long time(time) ;
    time:long_name = "measurement time" ;
    time:standard_name = "time" ;
    time:units = "seconds since 2000-01-01T00:00:00Z" ;
  char plarform_name(name_strlen) ;
    platform_name:standard_name = "platform_name" ;
    platform_name:cf_role = "trajectory_id" ;
  char platform_id(id_strlen) ;
    platform_id:standard_name = "platform_id" ;
    platform_id:id_type ="WMO" ;
  double sea_surface_temperature(time) ;
    sea_surface_temperature:long_name="sea water temperature";
    sea_surface_temperature:standard_name="sea_water_temperature";
    sea_surface_temperature:units = "kelvin" ;
    sea_surface_temperature:_FillValue = -1.0 ;
    sea_surface_temperature:valid_min = 260.0 ;
    sea_surface_temperature:valid_max = 320.0 ;
    sea_surface_temperature:coordinates = "lon lat depth" ;
  attributes:
    :cdm_data_type = "Trajectory" ;
    :featureType = "trajectory" ;
}
```

8 Level 2 *in situ* Radiometric (L2R) Product Specification

8.1 Overview description of the L2R data product

The L2R product holds time series of *in situ* temperature measurements, either at a single point or along a trajectory. The product contains SST data together with estimates of the measurement uncertainty, quality flags and, optionally, a number of ancillary fields that assist interpretation of the SST data. No resampling or other adjustments are applied to the SST measurements. The common format of L2R products allows *in situ* data from multiple sources to be used in a consistent fashion through a consistent interface.

All L2R products should contain, at a minimum, the variables:

- Sea Surface Temperature data（**sea_surface_temperature**）
- Estimates of the total uncertainty in each SST sample (**sst_total_uncertainty**)
- Flags specific to each L2R dataset that help users interpret data（**sst_flags)**
- A quality level for each measurement (**quality_level)**
- For radiometers, the viewing angle from nadir (**view_elevation**)

In addition, a number of auxiliary fields are recommended:

- An alternative time variable (**julian_day**)
- Estimates of the random uncertainty in each SST sample (**sst_random_uncertainty**)
- Estimates of the systematic uncertainty in each SST sample (**sst_systematic_uncertainty**)
- Measurements or estimates of the surface wind speed and direction (**wind_speed**, **wind_direction)**
- Measurements of the platform orientation and motion (**speed_over_ground**, **course_over_ground**, **speed_through_water**, **true_bearing**)
- For radiometers, the azimuthal orientation of the instrument view (**view_azimuth**)

Array variables should implement the **:coordinates** attribute.

Continuous variables may be of any appropriate stored type. **:scale_factor** and **:add_offset** attributes may be used as required to reproduce values with at least the resolution of the specified type.

Optional experimental fields may be used for additional information at the data provider's discretion. It is permitted to use additional netCDF coordinate variables where required when including experimental fields.

ISFRN L2R data products are configured as shown in Table 8.1, which can be used to locate appropriate information in this document.

Table 8.1 Summary description of the contents of a ISFRN L2R data file

netCDF File Contents	Description	Units	Section	Required
Global attributes	A collection of required global attributes describing general characteristics of the file	Various	7.1	Mandatory
Geolocation and identity data	Information to permit locating data on non-orthogonal grids	ISDP defined	7.3	Mandatory

julian_day	Alternative time	Julian day	8.21	Optional
speed_over_ground	The platform speed over the geoid	ms^{-1}	8.15	Optional
course_over_ground	The platform track over the geoid relative to true north	degrees	8.16	Optional
speed_through_water	The platform speed relative to the surface water	ms^{-1}	8.17	Optional
true_bearing	The platform bearing relative to true north	degrees	8.18	Optional
view_azimuth_angle	Azimuthal orientation of sea view relative to the platform bearing, or the absolute orientation for fixed platforms.	degrees	8.19	Optional for radiometric measurements
view_nadir_angle	Instrument sea view angle from nadir	degrees	8.20	Mandatory for radiometric measurements
sea_surface_temperature	SST measurement	K	8.3	Mandatory
sst_total_uncertainty	Estimate of the total uncertainty in the SST measurement	K	8.4	Mandatory
sst_random_uncertainty	Estimate of the random uncertainty (“noise”) in the SST measurement	K	8.5	Optional
sst_systematic_uncertainty	Estimate of the systematic uncertainty (“bias”) in the SST measurement.	K	8.6	Optional
sst_flags	Data flag values	flags	8.7	Mandatory
quality_level	Overall indication of L2 data quality	code	8.8	Mandatory
wind_speed	Local wind speed measurement or 10 m surface wind speed closest in time from satellite or analysis	ms^{-1}	8.9	Optional
wind_direction	Local wind direction measurement or 10 m surface wind speed closest in time from satellite or analysis	degrees	8.10	Optional
wind_speed_dtime_from_sst	Time difference of **wind_speed** data from L2 SST measurement	hours	8.11	Required when wind speed provided
sources_of_wind_speed	Sources of **wind_speed** data	code	8.12	Required for multiple wind speed sources
relative_wind_speed	Directly measured anemometric wind speed relative to platform motion	ms^{-1}	8.13	Optional
relative_wind_direction	Directly measured wind direction relative to platform bearing	degrees	1.1	Optional
Optional and experimental fields defined by ISDP	Optional/experimental data	ISDP defined	8.22	Optional

8.2 L2R data record format specification

Table 8.2 provides an overview of the ISFRN L2R product pixel data record that should be created for each input L2 SST measurement contained within a L2R file. In the following sections, each variable within the L2R data file is described in detail.

Table 8.2 L2R SST data record content.

<table>
<tr><th>Variable Name
(Definition Section, CDL Example)</th><th>Description</th><th>Units / data type</th></tr>
<tr><td>sea_surface_temperature

(Section 8.3, Table 8.3)</td><td>The native unmodified L2 SST of the in situ instrument</td><td>kelvin
double</td></tr>
<tr><td>sst_total_uncertainty

(Section 8.4,Table 8.5)</td><td>An estimate of the total uncertainty (that is, the combined systematic and random uncertainties) associated with each SST measurement.</td><td>kelvin
float</td></tr>
<tr><td>sst_flags

(Section 8.7, Table 8.9)</td><td>The variable sst_flags is used to (a) specify the SST measurement technique (either thermometric or radiometric), (b) provide information directly relevant to the quality of each SST measurement and (c) record any additional information considered important for the user of an L2R dataset.

The variable sst_flags is split into two sections: the first 10 bits of the L2R variable sst_flags are generic flags that are common to all L2R data files; bits 10 - 15 are defined by the L2R data provider and are specific to each L2R input data stream.

The tables below define the bit field and their meanings. The least significant bit (bit 0) starts on the right.

If a flag cannot be implemented in the processor, it should be set to zero. A full description of the flags implemented and algorithms used should be included in the :references document.

<table>
<tr><th>Bit</th><th>Common flags</th></tr>
<tr><td>0</td><td>0 if thermometric, 1 if radiometric</td></tr>
<tr><td>1</td><td>0 if night, 1 if day</td></tr>
<tr><td>2</td><td>Set if cloudy</td></tr>
<tr><td>3</td><td>Set if raining or spray detected</td></tr>
<tr><td>4</td><td>Set for an instrument exception</td></tr>
<tr><td>5</td><td>Set for a processing exception</td></tr>
<tr><td>6</td><td>Set if the platform speed is low</td></tr>
<tr><td>7</td><td>Set if the wind speed is low</td></tr>
<tr><td>8</td><td>Land proximity</td></tr>
<tr><td>9</td><td>(reserved)</td></tr>
<tr><td>10 –15</td><td>Defined by L2R data provider and described in the flag_meanings, and flag_masks variable attributes.</td></tr>
</table>
</td><td>Flags
Short</td></tr>
</table>

quality_level (Section 8.8, Table 8.10)	The L2R variable **quality_level** is used to provide an overall indication of L2R data quality. The L2R variable **quality_level** will reflect CEOS QA4EO (Quality Indicator) guidelines. An incremental scale from 0 no data,1 (bad e.g. cloud, rain, to close to land – under no conditions use this data) 2 (worst quality usable data), to 5 (best quality usable data) shall be used.	Code byte
view_nadir_angle (Section 1.1, Table 8.23)	For radiometers, the variable **view_nadir_angle** contains the elevation of the instrument view from nadir.	Code float
Optional fields and experimental fields defined by data provider	Optional/experimental data	Defined by provider

8.3 Variable `sea_surface_temperature`

The variable **`sea_surface_temperature`** contains the native unmodified L2 SST of the *in situ* instrument. The **`sea_surface_temperature`** variable shall be included in a L2R product with the format requirements shown in Table 8.3.

Table 8.3 CDL description of `sea_surface_temperature` variable

Storage type definition	Variable name definition	Description	Unit
double	**`sea_surface_temperature`**	Sea surface temperature value	K
Example CDL description			
`double sea_surface_temperature(time) ;` **`sea_surface_temperature:long_name = "sea surface skin temperature" ;`** **`sea_surface_temperature:standard_name="sea_surface_skin_temperature" ;`** **`sea_surface_temperature:units = "kelvin" ;`** **`sea_surface_temperature:_FillValue = -1.0 ;`** **`sea_surface_temperature:valid_min = 250.0 ;`** **`sea_surface_temperature:valid_max = 320.0 ;`** **`sea_surface_temperature:coordinates = "lon lat";`** **`sea_surface_temperature:ancilliary_variables = "sst_total_uncertainty sst_random_uncertainty sst_systematic_uncertainty sst_flags";`**			
Comments			
The **`standard_name`** attribute should be CF compliant as described in Table 8.4.			

Table 8.4 ISFRN short SST names and CF standard names for `sea_surface_temperature`

ISFRN name	CF-1.6 standard name definitions [AD-2]
SSTint	**`sea_surface_temperature`**
SSTskin	**`sea_surface_skin_temperature`**
SSTsubskin	**`sea_surface_subskin_temperature`**
SSTfnd	**`sea_surface_foundation_temperature`**
SSTdepth	**`sea_water_temperature`** The "**`depth`**" coordinate variable should be declared to indicate the depth for which the SST data are valid (see Section 7.3).

8.4 Variable `sst_total_uncertainty`

The variable **`sst_total_uncertainty`** contains an estimate of the total uncertainty (that is, the combined systematic and random uncertainties) associated with each SST measurement. As *in situ* data are a primary source of validation information, all estimates of the systematic component of the total uncertainty should be derived from the user's understanding of the performance of the measuring instrument and any associated algorithms, and not by reference to external reference measurements of water temperature.

The variable **`sst_total_uncertainty`** shall be included with the format requirements shown in Table 8.5.

Table 8.5 CDL description of `sst_total_uncertainty` variable

Storage type definition	Variable name definition	Description	Unit
float	**`sst_total_uncertainty`**	The total uncertainty (systematic and random) associated with each SST measurement.	kelvin
Example CDL description			
`float sst_total_uncertainty (time) ;` **`sst_total_uncertainty:long_name = "sea surface temperature total uncertainty" ;`** **`sst_total_uncertainty:standard_name = "sea_surface_skin_temperature standard_error" ;`** **`sst_total_uncertainty:units = "kelvin" ;`** **`sst_total_uncertainty:_FillValue = -1.0 ;`** **`sst_total_uncertainty:valid_min = 0.0 ;`** **`sst_total_uncertainty:valid_max = 5.0 ;`** **`sst_total_uncertainty:coordinates = "lon lat" ;`**			
Comments			

8.5 Variable `sst_random_uncertainty`

The variable **`sst_random_uncertainty`** contains an estimate of the random uncertainty (the "noise") associated with each SST measurement. Typically, this value will be obtained from the standard deviation of a number of measurements of a constant temperature, or by the propagation of known noise sources through an instrument model.

The variable **`sst_random_uncertainty`** shall be included with the format requirements shown in Table 8.5.

Table 8.6 CDL description of `sst_random_uncertainty` variable

Storage type definition	Variable name definition	Description	Unit
float	**`sst_random_uncertainty`**	The total uncertainty (systematic and random) associated with each SST measurement.	kelvin
Example CDL description			
`float sst_random_uncertainty (time) ;` **`sst_random_uncertainty:long_name = "sea surface temperature random uncertainty" ;`** **`sst_random_uncertainty:units = "kelvin" ;`** **`sst_random_uncertainty:_FillValue = -1.0 ;`** **`sst_random_uncertainty:valid_min = 0.0 ;`** **`sst_random_uncertainty:valid_max = 5.0 ;`** **`sst_random_uncertainty:coordinates = "lon lat" ;`**			
Comments			

8.6 Variable `sst_systematic_uncertainty`

The variable **`sst_systematic_uncertainty`** contains an estimate of the systematic uncertainty associated with each SST measurement. As *in situ* data are a primary source of validation information, all estimates of the systematic uncertainty should be derived from the user's understanding of the performance of the measuring instrument and any associated algorithms, and not by reference to external reference measurements of water temperature.

The variable **`sst_systematic_uncertainty`** shall be included with the format requirements shown in Table 8.5.

Table 8.7 CDL description of `sst_systematic_uncertainty` variable

Storage type definition	Variable name definition	Description	Unit
float	**`sst_systematic_uncertainty`**	The total uncertainty (systematic and random) associated with each SST measurement.	Kelvin
Example CDL description			
`float sst_systematic_uncertainty (time) ;` **`sst_systematic_uncertainty:long_name = "sea surface temperature systematic uncertainty" ;`** **`sst_systematic_uncertainty:units = "kelvin" ;`** **`sst_systematic_uncertainty:_FillValue = -1.0 ;`** **`sst_systematic_uncertainty:valid_min = 0.0 ;`** **`sst_systematic_uncertainty:valid_max = 5.0 ;`** **`sst_systematic_uncertainty:coordinates = "lon lat" ;`**			
Comments			

8.7 Variable `sst_flags`

The L2R variable **`sst_flags`** is used to:

- Specify the SST measurement technique (either thermometric or radiometric),
- Provide information directly relevant to the quality of each SST measurement,
- Record any additional information considered important for the user of an L2R dataset.

The variable **`sst_flags`** is split into three sections:

- Bits 0 – 8 of the L2R variable **`sst_flags`** are generic flags that are common to all L2R data files as defined in Table 8.8,
- Bit 9 is reserved for future use,
- Bits 10 –15 can be defined by the L2R data provider and are specific to each L2 input data stream.

Bit 0 is the least significant bit.

Table 8.8 Bit field definitions for the L2R variable `sst_flags`

Bit	Common flags
0	0 if thermometric data 1 if radiometric data
1	0 if night 1 if day
2	Set if cloudy
3	Set if rain or spray is detected
4	Set if an instrument exception is detected
5	Set if a processing exception is detected
6	Set if the platform speed is low
7	Set if the wind speed is low
8	Set if near to land
9	(reserved)
10:15	User defined

The Annex requires the following:

The L2R variable **`sst_flags`** should hold Boolean (single bit) codes only.

The meanings of flag bits in the L2R variable **`sst_flags`** shall be detailed in its **`flag_meanings`** and **`flag_masks`** attributes.

The **`flag_meanings`** attribute shall contain a space-separated list of descriptions for each distinct flag value. For descriptions containing multiple words, the words shall be linked by underscores.

The **`flag_masks`** attribute shall contain an array of mask values that identify each implemented bit, and whose order matches that of the **`flag_meanings`** values.

Bit 0 of the L2R **`sst_flags`** is used to record if an SST measurement is derived from a thermometer or a radiometer. The Annex specifies the following:

If an SST measurement is derived from a thermometer, bit 0 of the L2R **`sst_flags`** variable should be set to 0.

If an SST measurement is derived from a radiometer, bit 0 of the L2R **`sst_flags`** variable should be set to 1.

Bit 1 of the L2R **`sst_flags`** variable is used to record if an SST measurement was taken in the day or night. The Annex specifies the following:

If an SST measurement was taken in daylight, bit 1 of the L2R **`sst_flags`** variable should be set to 1 otherwise bit 1 of the L2R **`sst_flags`** variable should be set to 0.

Bit 2 of the L2R **`sst_flags`** variable is used to record if cloud was detected overhead at the time of the SST measurement. The Annex specifies the following:

If cloud was detected overhead at the time of the SST measurement, bit 2 of the L2R **`sst_flags`** variable should be set to 1 otherwise bit 2 of the L2R **`sst_flags`** variable should be set to 0.

Bit 3 of the L2R **`sst_flags`** variable is used to record if rain or spray was detected at the time of the SST measurement. The Annex specifies the following:

> If rain or spray was detected at the time of the SST measurement, bit 3 of the L2R **sst_flags** variable should be set to 1 otherwise bit 3 of the L2R **sst_flags** variable should be set to 0.

Bit 4 of the L2R **sst_flags** variable is used to record if the instrument was in a state that could invalidate the SST measurement. For a radiometer, examples might include anomalous instrument states, interruptions for a calibration measurement or periods when a weather door was closed. The Annex specifies the following:

> If an instrument exception was detected at the time of the SST measurement, bit 4 of the L2R **sst_flags** variable should be set to 1 otherwise bit 4 of the L2R **sst_flags** variable should be set to 0.

Bit 5 of the L2R **sst_flags** variable is used to record if the processing software could not generate a valid SST measurement. The Annex specifies the following:

> If a processor exception is raised for the SST measurement, bit 5 of the L2R **sst_flags** variable should be set to 1 otherwise bit 5 of the L2R **sst_flags** variable should be set to 0.

Bit 6 of the L2R **sst_flags** variable is used to record if the instrument platform was moving slowly at the time of the measurement. A low platform speed threshold of 2 ms^{-1} is recommended. The Annex specifies the following:

> If the platform speed at the time of the SST measurement, bit 6 of the L2R **sst_flags** variable should be set to 1 otherwise bit 6 of the L2R **sst_flags** variable should be set to 0.

Bit 7 of the L2R **sst_flags** variable is used to record if the wind speed was low at the time of the measurement. A low wind speed threshold of 2 ms^{-1} is recommended. The Annex specifies the following:

> If the wind speed was low at the time of the SST measurement, bit 7 of the L2R **sst_flags** variable should be set to 1 otherwise bit 7 of the L2R **sst_flags** variable should be set to 0.

Bit 8 of the L2R **sst_flags** variable is used to record if the measurement was taken near to land. A land separation threshold of 5 km is recommended. The Annex specifies the following:

> If the SST measurement was taken near to land, bit 8 of the L2R **sst_flags** variable should be set to 1 otherwise bit 8 of the L2R **sst_flags** variable should be set to 0.

Any flag that cannot be implemented in the product processor should be set to zero.

The thresholds and any other criteria used to determine the states for flag bits 1 – 8 should be fully described in the documentation referenced by global attribute **:references**.

Flag bit 9 is reserved and should not be used. Flag bits 10 – 15 may be defined by the data provider. Any such flag must be represented in the **flag_meanings** and **flag_masks** attributes and should be fully described in the documentation referenced by global attribute **:references**.

The L2R variable **sst_flags** shall be included in Annex L2R data files with the format requirements shown in Table 8.9.

Table 8.9 CDL description of `sst_flags` variable

Storage type definition	Variable name definition	Description	Unit
short	**`sst_flags`**	The variable **`sst_flags`** is used to specify the type of input SST data, provide information directly relevant to the quality of each SST measurement and record any additional information considered important for the user of an L2R dataset.	Bit field
Example CDL description			
`short sst_flags(time) ;` **`sst_flags:long_name = "sea flags" ;`** **`sst_flags:standard_name = "sea_surface_skin_temperature status_flag" ;`** **`sst_flags:coordinates = "lon lat" ;`** **`sst_flags:flag_meanings = "skin day cloud rain instrument_exception processing_exception low_platform_speed low_wind_speed land_proximity" ;`** **`sst_flags:flag_masks = 1s, 2s, 4s, 8s, 16s, 32s, 64s, 128s, 256s;`**			
Comments			
The meaning of each bit of the L2R variable **`sst_flags`** shall be detailed in its **`flag_meanings`** and **`flag_masks`** attributes. The bit allocations are summarised in Table 8.8.			

8.8 Variable `quality_level`

The L2R variable **`quality_level`** provides an indicator of the overall quality of an SST measurement in an L2R file. The Annex requires the following:

> The L2R variable **`quality_level`** shall use an incremental scale from 0 to 5 to provide the user with an indication of the quality of the L2R SST data. The value 0 must be used to indicate missing data and the value 1 must be used to indicate invalid data (e.g. rain, in port - under no conditions use this data). The remaining values from 2 – 5 are set at the discretion of the L2R provider with the proviso that the value 2 must be used to indicate the worst quality of usable data and the value 5 must be used to indicate the best quality usable data. The L2R provider is required to provide a description of the quality levels provided as part of the product documentation referenced by global attribute **`:references`**.
>
> The L2R variable **`quality_level`** reflects the quality of SST data from a single sensor and does not provide an indication of the relative quality between sensors.
>
> The L2R variable **`quality_level`** shall be included with the format requirements shown in Table 8.10.

Table 8.10 CDL description of L2R variable `quality_level`

Storage type definition	Variable name definition	Description	Unit
byte	**`quality_level`**	Overall indicator of SST measurement quality	None

Example CDL description

```
byte quality_level (time) ;
  quality_level:long_name = "measurement quality value" ;
  quality_level:coordinates = "lon lat" ;
  quality_level:flag_meanings = "no_data bad_data worst_quality
                                 low_quality acceptable_quality
                                 best_quality" ;
  quality_level:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
```

Comments

8.9 Variable `wind_speed`

The L2R variable **`wind_speed`** contains a best estimate of the 10m surface wind speed at the time of SST data acquisition. Wind speed measurements are required within the Annex as an indicator of the turbulent state of the air sea interface to interpret the relationship between *in situ* and subsurface SST data and assess the severity of any skin SST temperature deviation, thermal stratification and for use in diurnal variability adjustment schemes. At low wind speeds, especially in clear sky conditions, stronger diurnal variability is expected leading to higher surface layer temperature gradients and the potential for significant de-coupling of the skin/sub-skin SST from the SST at depth.

Wind speed may be derived from one of (at least) three sources, in order of preference:

- Local, contemporaneous anemometer measurements,
- Near-contemporaneous satellite measurements of wind speed near to overpass times,
- NWP estimates.

Anemometer measurements must be corrected for platform motion and also, if possible, for airflow distortion about the platform. All measurements should be adjusted to a reference height of 10m. Where this is not possible, the alternative reference height or the true height of the measurement should be given in the **`wind_speed:height`** attribute. All processing steps, including any corrections and adjustments, should be fully described in the documentation referenced by global attribute **`:references`**.

The Annex specifies the following rules:

> A surface wind speed value may be assigned to each SST measurement pixel using the variable **`wind_speed`**. The following criteria shall apply:
>
> > Where available, local, contemporaneous anemometer measurements of wind speed, corrected for platform motion and airflow distortion, should be used,
> >
> > In the absence of anemometer measurements, and where available, near-simultaneous satellite microwave 10m wind speed measurements obtained from an instrument overflying the *in situ* position may be used,
> >
> > In the absence of a simultaneous surface wind speed measurement, an NWP estimated 10m surface wind speed may be used.

Where possible, wind speed values should be adjusted to a reference height of 10m and his value shall be reported in the attribute **wind_speed:height**. Where this is not possible, the alternative reference height or the true measurement height shall be reported.

The difference in time expressed in hours between the time of SST measurement and the time of wind speed data should be entered into the L2R confidence data variable **wind_speed_dtime_from_sst** as described in Section 8.11. In the case of an NWP field, this should be the central (mean) time of an integrated value.

If the wind speed is derived from local, contemporaneous anemometer data, the time difference between the time of SST measurement and the time of wind speed data is always zero and the variable **wind_speed_dtime_from_sst** may be omitted.

If a single source of data is used in the L2R variable **wind_speed**, the L2R variable **sources_of_wind_speed** is not required and instead the **wind_speed:sources** attribute value shall be a single source text code from Table 8.15.

If multiple sources of data are used, source information should be indicated in the L2R variable **sources_of_wind_speed** as defined in Table 8.15, and the **windspeed:sources** attribute shall have the value **"sources_of_wind_speed"**.

The Annex variable **wind_speed** shall be included in ISFRN L2R products with the format requirements shown in Table 8.11.

Table 8.11 CDL description of wind_speed variable

Storage type definition	Variable name definition	Description	Unit
float	**wind_speed**	Surface wind speed at 10m height. Resolution should be no less than 1 ms^{-1}	$m\ s^{-1}$
Example CDL description			
float wind_speed (time); **wind_speed:long_name = "10m corrected local wind speed" ;** **wind_speed:standard_name = "wind_speed" ;** **wind_speed:units = "m s-1" ;** **wind_speed:height = "10 m" ;** **wind_speed:_FillValue = -1.0 ;** **wind_speed:valid_min = 0.0 ;** **wind_speed:valid_max = 50.0 ;** **wind_speed:coordinates = "lon lat" ;** **wind_speed:sources = "anemometer" ;**			
Comments			
A single source of wind data is shown in this example which is reported as **wind_speed:sources = "anemometer"** following the codes described in Table 8.15.			

8.10 Variable wind_direction

Where L2R variable **wind_speed** is defined, an additional **wind_direction** variable may be included. Variable **wind_direction** contains a best estimate of the 10m surface wind direction at the time of SST data acquisition. It contains the direction in which the wind vector points, measured in degrees clockwise from true north. Note that this is the opposite direction from some common wind direction descriptions: a south-westerly wind will have a **wind_direction** value of 45°.

Variable **wind_direction** should be derived from the same data source(s) as **wind_speed**, and attributes **wind_direction:height** and **wind_direction:sources** should have the same values as attributes **wind_speed:height** and **wind_speed:sources**.

The Annex variable **wind_direction** shall be included in ISFRN L2R products with the format requirements shown in Table 8.12.

Table 8.12 CDL description of wind_direction variable

Storage type definition	Variable name definition	Description	Unit
float	**wind_direction**	Surface wind direction at 10m height.	Degrees
Example CDL description			
float wind_direction (time); **wind_speed:long_name = "10m corrected local wind direction" ;** **wind_speed:standard_name = "wind_to_direction" ;** **wind_speed:units = "degrees" ;** **wind_speed:height = "10 m" ;** **wind_speed:_FillValue = -1.0 ;** **wind_speed:valid_min = 0.0 ;** **wind_speed:valid_max = 360.0 ;** **wind_speed:coordinates = "lon lat" ;** **wind_speed:sources = "anemometer" ;**			
Comments			
A single source of wind data is shown in this example which is reported as **wind_direction:sources = "anemometer"** following the codes described in Table 8.15			

8.11 Variable wind_speed_dtime_from_sst

The variable **wind_speed_dtime_from_sst** reports the time difference between wind speed data and SST measurement in hours. In the case of an NWP field, the central (mean) time of an integrated value should be used. For local, contemporaneous wind measurements, the time difference is always zero and the variable **wind_speed_dtime_from_sst** may be omitted.

The variable **wind_speed_dtime_from_sst** shall be included with the format requirements shown in Table 8.13.

Table 8.13 CDL description of wind_speed_dtime_from_sst variable

Storage type definition	Variable name definition	Description	Unit
float	**wind_speed_dtime_from_sst**	This variable reports the time difference of wind speed measurement from SST measurement in hours.	Hour
Example CDL description			
byte wind_speed_dtime_from_sst (time) ; **wind_speed_dtime_from_sst:long_name = "time difference of wind speed measurement from sst measurement" ;** **wind_speed_dtime_from_sst:units = "hour" ;** **wind_speed_dtime_from_sst:_FillValue = -99f ;** **wind_speed_dtime_from_sst:valid_min = -6f ;** **wind_speed_dtime_from_sst:valid_max = 6f ;** **wind_speed_dtime_from_sst:coordinates = "lon lat" ;** **wind_speed_dtime_from_sst:grid_mapping = "polar_stereographic" ;**			
Comment			

8.12 Variable `sources_of_wind_speed`

When wind speeds are included in the L2R product, and when more than one source of wind speed data is used, the sources of data used to set the L2R confidence data variable **`wind_speed`** shall be indicated in the L2R variable **`sources_of_wind_speed`**. The Annex requires the following:

The appropriate numeric code value from Table 8.15 shall be used to fill the L2R variable **`sources_of_wind_speed`**,

The **`flag_meanings`** attribute shall contain a space-separated list of *at least* the text codes for the sources of data used in the **`wind_speed`** variable,

The **`flag_values`** attribute shall contain an array of *at least* the numeric codes for the sources of data used in the **`wind_speed`** variable, whose order matches the text codes in the **`flag_meanings`** attribute,

The variable **`sources_of_wind_speed`** shall conform to the format requirements shown in Table 8.14.

Table 8.14 CDL description of `sources_of_wind_speed` variable

Storage type definition	Variable name definition	Description	Unit
byte	**`sources_of_wind_speed`**	Source of **`wind_speed`** value	none
Example CDL description			
`byte sources_of_wind_speed (time) ;` **`sources_of_wind_speed:long_name = "sources of wind speed" ;`** **`sources_of_wind_speed:coordinates = "lon lat" ;`** **`sources_of_wind_speed:flag_meanings = "no_data UKMO_A UKMO_F ECMWF_A ECMWF_F NCEP_A NCEP_F anenometer" ;`** **`sources_of_wind_speed:flag_values = 0b, 1b, 2b, 3b, 4b, 5b, 6b, 99b ;`**			
Comments			
In this example, **`flag_meanings`** and **`flag_values`** contain all the NWP codes listed in Table 8.15, though not all will necessarily be used in **`sources_of_wind_speed`**.			

Table 8.15 Text and numeric code values used to identify the sources of data in `wind_speed:sources` and `sources_of_wind_speed`

Numeric Code	Text Code	Description
0	no_data	No data available
1	UKMO_A	Met Offfice NWP analysis 10m wind, United Kingdom
2	UKMO_F	Met Offfice NWP forecast 10m wind, United Kingdom
3	ECMWF_A	European Centre for Medium Range Weather Forecast analysis 10m wind
4	ECMWF_F	European Centre for Medium Range Weather Forecast forecast 10m wind
5	NCEP_A	National Center for Environmental Prediction 10m analysis wind, USA
6	NCEP_F	National Center for Environmental Prediction 10m forecast wind, USA
99	anemometer	Wind speed derived from local, contemporaneous anemometer measurements

8.13 Variable `relative_wind_speed`

The L2R variable **`relative_wind_speed`** contains a direct anemometric measurement of wind speed relative to the platform's motion (if any). This wind speed provides information about the operating environment of instrumentation installed on the platform.

If the wind speed measurements are corrected for platform airflow distortion, they should be adjusted to a reference height of 10m. This reference height shall be reported in the attribute **`relative_wind_speed:height`**. If the measurements are unadjusted, or if an alternative reference height is used, the true measurement height or the alternative reference height shall be reported. A description of the measurement and of any adjustments applied must be included in the document referenced by the **`:references`** attribute.

The Annex variable **`relative_wind_speed`** shall be included in ISFRN L2R products with the format requirements shown in Table 8.11.

Table 8.16 CDL description of `wind_speed` variable

Storage type definition	Variable name definition	Description	Unit
float	**`relative_wind_speed`**	Surface wind speed relative to platform motion. Resolution should be no less than 1 ms^{-1}	m s^{-1}
Example CDL description			
`float relative_wind_speed (time);` **`relative_wind_speed:long_name = "wind speed relative to platform motion" ;`** **`relative_wind_speed:units = "m s-1" ;`** **`relative_wind_speed:height = "10 m" ;`** **`relative_wind_speed:_FillValue = -1.0 ;`** **`relative_wind_speed:valid_min = 0.0 ;`** **`relative_wind_speed:valid_max = 50.0 ;`** **`relative_wind_speed:coordinates = "lon lat" ;`** **`relative_wind_speed:comment = "unadjusted anemometer wind speed" ;`**			
Comments			

8.14 Variable `relative_wind_direction`

Where L2R variable **`relative_wind_speed`** is defined, an additional variable **`relative_wind_direction`** may be included. Variable **`relative_wind_direction`** contains the direction of the directly measured wind vector relative to the platform bearing in degrees clockwise, or relative to true north for static platforms.

Any adjustments made to variable **`relative_wind_direction`** shall be consistent with those for variable **`relative_wind_speed`**.

The Annex variable **`relative_wind_direction`** shall be included in ISFRN L2R products with the format requirements shown in Table 8.12.

Table 8.17 CDL description of `relative_wind_direction` variable

Storage type definition	Variable name definition	Description	Unit
float	**`relative_wind_direction`**	Apparent wind direction	degrees
Example CDL description			
`float relative_wind_direction (time);` **`relative_wind_direction:long_name = "wind direction relative to platform bearing" ;`** **`relative_wind_direction:units = "degrees" ;`** **`relative_wind_direction:height = "10 m" ;`** **`relative_wind_direction:_FillValue = -1.0 ;`** **`relative_wind_direction:valid_min = 0.0 ;`** **`relative_wind_direction:valid_max = 360.0 ;`** **`relative_wind_direction:coordinates = "lon lat" ;`** **`relative_wind_direction:comment = "unadjusted apparent wind direction" ;`**			
Comments			

8.15 Variable `speed_over_ground`

Variable **`speed_over_ground`** contains the platform speed over the geoid, regardless of surface water currents. At sea level, this is the speed returned by GPS receivers.

The variable **`speed_over_ground`** will be included with the format requirements shown in Table 8.18.

Table 8.18 CDL description of `speed_over_ground` variable

Storage type definition	Variable name definition	Description	Unit
float	**`speed_over_ground`**	Platform speed over the geoid	m s-1
Example CDL description			
`float speed_over_ground(time) ;` **`speed_over_ground:long_name = "platform speed over ground" ;`** **`speed_over_ground:standard_name = "platform_speed_wrt_ground" ;`** **`speed_over_ground:units = "m s-1" ;`** **`speed_over_ground:coordinates = "lon lat" ;`** **`speed_over_ground:_FillValue = -1.0 ;`**			
Comments			

8.16 Variable `course_over_ground`

Variable **`course_over_ground`** contains the platform course on the geoid relative to true north. This is the course value returned by GPS receivers.

The variable **`course_over_ground`** will be included with the format requirements shown in Table 8.19.

Table 8.19 CDL description of `course_over_ground` variable

Storage type definition	Variable name definition	Description	Unit
float	**`course_over_ground`**	Platform course	Degrees
Example CDL description			
`float course_over_ground(time) ;` **`course_over_ground:long_name = "platform course over ground" ;`** **`course_over_ground:standard_name = "platform_course" ;`** **`course_over_ground:units = "degrees" ;`** **`course_over_ground:coordinates = "lon lat" ;`** **`course_over_ground:_FillValue = -1.0 ;`**			
Comments			

8.17 Variable `speed_through_water`

Variable **`speed_through_water`** is the speed of the platform relative to the water through which it moves. This is the value returned by devices such as pitot tubes and impeller logs.

The variable **`speed_through_water`** will be included with the format requirements shown in Table 8.20.

Table 8.20 CDL description of `speed_through_water` variable

Storage type definition	Variable name definition	Description	Unit
float	**`speed_through_water`**	Platform speed through water	m s-1
Example CDL description			
`float speed_through_water(time) ;` **`speed_through_water:long_name = "platform speed through water" ;`** **`speed_through_water:standard_name = "platform_speed_wrt_sea_water" ;`** **`speed_through_water:units = "m s-1" ;`** **`speed_through_water:coordinates = "lon lat" ;`** **`speed_through_water:_FillValue = -1.0 ;`**			
Comments			

8.18 Variable `true_bearing`

Variable **`true_bearing`** is the actual pointing of the measurement platform required to maintain a course in the presence of surface water currents. This is the value returned by gyro and magnetometer units.

The variable **`true_bearing`** will be included with the format requirements shown in Table 8.21.

Table 8.21 CDL description of `true_bearing` variable

Storage type definition	Variable name definition	Description	Unit
float	**`true_bearing`**	Orientation of platform	degrees
Example CDL description			
`float true_bearing(time) ;` **`true_bearing:long_name = "platform true bearing" ;`** **`true_bearing:standard_name = "platform_orientation" ;`** **`true_bearing:units = "degrees" ;`** **`true_bearing:coordinates = "lon lat" ;`** **`true_bearing:_FillValue = -1.0 ;`**			
Comments			

8.19 Variable `view_azimuth_angle`

For radiometers, the variable **`view_azimuth_angle`** contains the azimuthal orientation of the instrument view in degrees clockwise, relative to the ship's bearing or, for fixed platforms, the orientation relative to true north.

The variable **`view_azimuth_angle`** will be included with the format requirements shown in Table 8.22.

Table 8.22 CDL description of `view_azimuth_angle` variable

Storage type definition	Variable name definition	Description	Unit
float	**`view_azimuth_angle`**	Instrument view azimuth angle	degrees
Example CDL description			
`float view_azimuth_angle ;` **`view_azimuth_angle:long_name = "instrument view azimuthal orientation" ;`** **`view_azimuth_angle:units = "degrees";`** **`view_azimuth_angle:comment = "The azimuthal orientation of the instrument view wrt to the platform bearing, degrees clockwise.";`**			
Comments			

8.20 Variable `view_nadir_angle`

For radiometers, the variable **`view_nadir_angle`** contains the elevation of the instrument view from nadir.

The variable **`view_nadir_angle`** will be included with the format requirements shown in Table 8.23.

Table 8.23 CDL description of `view_nadir_angle` variable

Storage type definition	Variable name definition	Description	Unit
float	**`view_nadir_angle`**	Elevation of the instrument view from nadir	Degrees
Example CDL description			
`float view_nadir_angle (time);` **`view_nadir_angle:long_name = "instrument viewing angle from nadir";`** **`view_nadir_angle:standard_name = "sensor_view_angle";`** **`view_nadir_angle:units = "degrees";`** **`view_nadir_angle:_FillValue = -1.0;`** **`view_nadir_angle:coordinates = "lon lat";`**			
Comments			

8.21 Variable `julian_day`

The variable **`julian_day`** contains an alternative representation of the measurement time in units of Julian day. Julian day is the interval of time in days and fractions of a day since Greenwich noon on the 1st January, 4713 BC.

The variable **`julian_day`** may be included as a supplement to the time axis variable, but not as a replacement, as it cannot be represented in the CF scheme. The variable **`julian_day`** will be included with the format requirements shown in Table 8.24.

Table 8.24 CDL description of `julian_day` variable

Storage type definition	Variable name definition	Description	Unit
double	**`julian_day`**	Julian day (fractional days since noon, January 1st 4713 BC)	Days
Example CDL description			
`double julian_day(time);` **`julian_day:long_name = "Julian day";`** **`julian_day:units = "days";`** **`julian_day:coordinates = "lon lat";`**			
Comments			

8.22 Optional or experimental L2R variables included by the data provider

Flexibility of L2R product content is provided through the netCDF API which allows fully self-describing fields and additional L2R variables may be included by L2R data providers if they are considered relevant for L2R users. The Annex also permits the inclusion of R&D variables e.g. channel radiance datasets, estimates of chlorophyll_a or fields that facilitate flagging of diurnal variability. The Annex does not place an upper limit on the number of optional or experimental variables that can be included, but the variables should usually be scalar fields or one-dimensional fields with a time coordinate, and should inform the interpretation of the principal **sea_surface_temperature** field. The inclusion of large two-dimensional fields is strongly discouraged.

The Annex issues the following guidance on the inclusion of optional or experimental variables within L2R data products:

CF compliance should be maintained for all optional/experimental variables. Where available, a **standard_name** attribute should be used.

It is permitted to use a provider defined-coordinate variable associated with experimental fields but this shall be documented in data provider documentation.

Time difference data (**xxx_dtime_from_sst** variables) should be provided for variables where appropriate.

The sources of data (**sources_of_xxx** variables or **sources** attributes) should be indicated: in the single source case as a variable attribute; or as a dedicated variable when mixed data sources are present.

Optional/experimental variables require documentation. Data providers shall provide adequate documentation that describes each variable following the CDL examples provided in this document. The variable should be fully described in the documentation referenced by global attribute **:references**.

Optional/experimental variables if present in an L2R product will be included with the minimum format requirements shown in Table 8.25.

Additional global variables may be declared within the L2R product.

Table 8.25 CDL template for data provider defined L2R variables

Storage type definition	Variable name definition	Description	Unit
int	Provide a variable name in lower case using underscore separators e.g. **my_variable**	Provide a description of **my_variable** stating content and purpose.	Units of **my_variable**
CDL example description			
int my_variable (time); **my_variable:long_name = "discombobulation factor" ;** **my_variable:units = "1" ;** **my_variable:_FillValue = 666 ;** **my_variable:coordinates = "lon lat" ;**			
Comments			
Variable **my_variable** should be fully described in the documentation referenced by global attribute **:references**. CF compliance should be maintained when using optional/experimental fields (particularly for the variable attribute **standard_name**).			

9 CDL example L2R dataset >>> TODO <<<

The following CDL description has been generated for an SST dataset generated by the SISTeR *in situ* radiometer.

```
netcdf 20140517230001-RAL-L2R_ISFRN-SSTskin-SISTeR_A-QM2-v01.0-fv01.3.nc {
  dimensions:
    time = 108033 ;
    name_strlen = 80 ;
    id_strlen = 20 ;
  variables:
    int64 time(time) ;
      time:long_name = "measurement time" ;
      time:standard_name = "time" ;
      time:units = "milliseconds since 1981-01-01T00:00:00Z" ;
    double lat(time) ;
      lat:long_name = "latitude" ;
      lat:standard_name = "latitude" ;
      lat:units = "degrees_north" ;
    double lon(time) ;
      lon:long_name = "longitude" ;
      lon:standard_name = "longitude" ;
      lon:units = "degrees_east" ;
    double julian_day(time) ;
      julian_day:long_name = "Julian day" ;
      julian_day:units = "days" ;
      julian_day:coordinates = "lon lat" ;
    char platform(name_strlen) ;
      platform:standard_name = "platform_name" ;
      platform_name:cf_role = "trajectory_id" ;
    char platform_id(id_strlen) ;
      platform_id:standard_name = "platform_id" ;
      platform_id:id_type ="call_sign" ;
    double sea_surface_temperature(time) ;
      sea_surface_temperature:long_name = "sea surface temperature" ;
      sea_surface_temperature:standard_name = "sea_surface_skin_temperature" ;
      sea_surface_temperature:units = "kelvin" ;
      sea_surface_temperature:valid_min = 260.0 ;
      sea_surface_temperature:valid_max = 330.0 ;
      sea_surface_temperature:_FillValue = -1.0 ;
      sea_surface_temperature:coordinates = "lon lat" ;
      sea_surface_temperature:ancillary_variables = "sst_total_uncertainty
sst_flags" ;
    float sst_total_uncertainty(time) ;
      sst_total_uncertainty:long_name = "sea surface temperature total
uncertainty" ;
      sst_total_uncertainty:standard_name = "sea_surface_skin_temperature
standard_error" ;
      sst_total_uncertainty:units = "kelvin" ;
      sst_total_uncertainty:valid_min = 0.0f ;
      sst_total_uncertainty:valid_max = 10.0f ;
      sst_total_uncertainty:_FillValue = -1.0f ;
      sst_total_uncertainty:coordinates = "lon lat" ;
    short sst_flags(time) ;
      sst_flags:long_name = "sea surface temperature status flags" ;
      sst_flags:standard_name = "sea_surface_skin_temperature status_flag" ;
      sst_flags:flag_masks = 1s, 2s, 4s, 8s, 16s, 32s, 64s, 128s, 256s ;
      sst_flags:flag_meanings = "skin day cloud rain instrument_exception
processing_exception low_platform_speed low_wind_speed land_proximity" ;
      sst_flags:coordinates = "lon lat" ;
    float speed_over_ground(time) ;
```

```
      speed_over_ground:long_name = "platform speed over ground" ;
      speed_over_ground:standard_name = "platform_speed_wrt_ground" ;
      speed_over_ground:units = "m/s" ;
      speed_over_ground:valid_min = 0.0f ;
      speed_over_ground:valid_max = 30.0f ;
      speed_over_ground:_FillValue = -1.0f ;
      speed_over_ground:coordinates = "lon lat" ;
    float course_over_ground(time) ;
      course_over_ground:long_name = "platform course over ground" ;
      course_over_ground:standard_name = "platform_course" ;
      course_over_ground:units = "degrees" ;
      course_over_ground:valid_min = 0.0f ;
      course_over_ground:valid_max = 360.0f ;
      course_over_ground:_FillValue = -1.0f ;
      course_over_ground:coordinates = "lon lat" ;
    float view_nadir_angle(time) ;
      view_nadir_angle:long_name = "instrument viewing angle from nadir" ;
      view_nadir_angle:standard_name = "sensor_view_angle" ;
      view_nadir_angle:units = "degrees" ;
      view_nadir_angle:valid_min = 2.0f ;
      view_nadir_angle:valid_max = 180.0f ;
      view_nadir_angle:_FillValue = -1.0f ;
      view_nadir_angle:coordinates = "lon lat" ;
    float view_azimuth_angle(time) ;
      view_azimuth_angle:long_name = "instrument view azimuthal orientation" ;
      view_azimuth_angle:units = "degrees" ;
      view_azimuth_angle:valid_min = 0.0f ;
      view_azimuth_angle:valid_max = 360.0f ;
      view_azimuth_angle:_FillValue = -1.0f ;
      view_azimuth_angle:comment = "The azimuthal orientation of the
instrument view wrt to the platform bearing, degrees clockwise" ;
      view_azimuth_angle:coordinates = "lon lat" ;

// global attributes:
  :Conventions = "CF-1.6 ACDD-1.0" ;
  :title = "SISTeR level 2 SST product" ;
  :summary = "SISTeR in-situ skin SST data, collected for the validation of
AATSR and SLSTR SST products" ;
  :references =
"http://www.sstd.rl.ac.uk/sg/projects/sister/SISTeR_handbook.pdf" ;
  :institution = "Science and Technology Facilities Council (STFC)" ;
  :history = "Tim on sstdmtjn98-2 at 2014-05-20T01:05:17Z: IDL>
SIS_FILE_PROCESS, \'/Volumes/SISTeR/Aux Files\',
\'Alice_L0_20140517T230001Z_QM2.sis\'" ;
  :comment = " " ;
  :license = "These data may be used freely, EXCEPT as inputs to assimilated
SST products." ;
  :id = " RAL-L2R-SISTeR_A" ;
  :naming_authority = "org.ISFRN" ;
  :product_version = "Processor: v1.8.0 (build 1, sha ge1c77cc)\nAux files:
v1.2.1 (build 0, sha gc28e667)" ;
  :uuid = "64EA7259-C274-48D5-85B4-72D5825C30F7" ;
  :L2R_version_id = "1.0" ;
  :netcdf_version_id = "4.1.1" ;
  :date_created = "2014-05-20T01:06:14Z" ;
  :file_quality_level = 0L ;
  :spatial_resolution = "7 m" ;
  :start_time = "2014-05-17T23:06:26Z" ;
  :time_coverage_start = "2014-05-17T23:06:26Z" ;
  :stop_time = "2014-05-18T23:06:28Z" ;
  :time_coverage_end = "2014-05-18T23:06:28Z" ;
```

```
  :northernmost_latitude = 40.82476f ;
  :southenmost_latitude = 40.51062f ;
  :easternmost_longitude = -52.3578f ;
  :westernmost_longitude = -63.18348f ;
  :source = "RAL-L2R-SISTeR_A" ;
  :platform = "RMS_Queen_Mary_2" ;
  :sensor = "SISTeR_A" ;
  :metadata_conventions = "Unidata Observation Dataset v1.0" ;
  :metadata_link = "???" ;
  :keywords = "Oceans > Ocean Temperature > Sea Surface Temperature" ;
  :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
Keywords" ;
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
Convention" ;
  :geospatial_lat_units = "degrees_north" ;
  :geospatial_lat_resolution = 1.f ;
  :geospatial_lon_units = "degrees_east" ;
  :geospatial_lon_resolution = 1.f ;
  :acknowledgment = "Collection of these data was funded by the UK Department
of Energy and Climate Change. Ship time and services were provided by Cunard
Line." ;
  :creator_name = "STFC Rutherford Appleton Laboratory" ;
  :creator_email = "tim.nightingale@stfc.ac.uk" ;
  :creator_url = "http://www.sstd.rl.ac.uk/sg/projects/sister" ;
  :project = " Group for High Resolution Sea Surface Temperature" ;
  :publisher_name = " The ISFRN Project Office" ;
  :publisher_url = "http://www.ISFRN.org" ;
  :publisher_email = " ISFRN-po@nceo.ac.uk" ;
  :processing_level = "L2R" ;
  :cdm_data_type = "Trajectory" ;
  :featureType = "trajectory" ;
}
```