The SONAR-netCDF4 file format for omni-sonar data

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# Executive Summary

A convention for the storage of omni-sonar data in netCDF4-formatted computer files is documented. The intention is to provide a well-founded convention that is supported by multiple sonar systems and multiple sonar analysis software packages, with the aim of facilitating the use of omni-sonar data for research and survey purposes. The name of this convention is SONAR-netCDF4.

# Introduction

Fisheries sonars have long been used for studying and understanding the aquatic environment, but it is only recently that they have directly provided digital data for quantitative analysis. Each manufacturer typically provides such data in a proprietary, but usually open, file format specific to their sonar system. This hinders the effective use and exchange of such data by requiring the development and maintenance of file reading software for each sonar data analysis system.

We document here a convention for the storage and exchange of fisheries sonar data. It is sufficiently generic and flexible to contain all foreseeable fisheries sonar data, along with necessary meta-data. It also serves as a statement of the minimum set of data and meta-data required to use omni-sonar data in a quantitative manner.

## Background

Many purpose-built file formats exist for storing and exchanging data from scientific and industrial equipment. Formats have been created by sonar and echosounder manufacturers, as well as more generic acoustic formats such as the Generic Water-column Format (GWF) (Gee *et al.*, 2012), the eXtended Triton Format (XTF) (Triton, 2008), and the HydroACoustics (HAC) format (McQuinn *et al.*, 2005). These formats store a time-ordered sequence of datagrams which makes it easy to append new data. Other data, such as geographical position, are typically interleaved into the sequence of datagrams. However, this is not optimal for analysis purposes when data are viewed and analysed as a set of pings and metadata from a time period or spatial grouping. In addition, efficient random read access to individual pings is not possible unless an index is available or created.

We have no desire to invent yet another sonar-specific file format – the knowledge required to do this well is not within the expertise of this ICES Topic Group. However, the group does have the expertise to specify what data must be stored to allow for unambiguous use of backscatter data during quantitative analysis.

Accordingly, we utilise an existing file format definition and specify what should be stored. Our requirements for such a file format definition were:

* Ability to adequately represent the content and structure of sonar data and associated meta-data,
* Standardised, open file format,
* Fast random access to data stored in the file,
* Ability to store multiple types of data (e.g., positon and backscatter),
* Ability to store meta-data (e.g., sonar settings),
* Freely available and open libraries to read the data files into programming languages and technical computing environments (e.g., Java, C, C++, Python, Matlab, and R),
* Reliable and space-efficient format for data exchange and storage,
* Self-describing file format,
* Backwards compatibility upon modification of the file contents specification (i.e., old software/tools can still read relevant parts of a newer version),
* Computer platform independent,
* Long-term support and extensive use in other scientific fields,
* Support for very large datasets.

Other scientific communities that collect and produce voluminous amounts of data have experienced and addressed very similar needs, resulting in the Hierarchical Data Format (The HDF Group, 2017), currently at version 5 (HDF5). This is the only file format that meets all the listed needs and we utilise this for our omni-sonar data. There are two realisations of the HDF5 file format – HDF5 itself and netCDF4 (Unidata, 2017), which is a subset of HDF5. Either is sufficient for our needs, but netCDF4 is more widely used and has slightly wider language support and implementation diversity. Accordingly, we chose to use netCDF4.

Using a well-supported file format has the significant benefit that many data exploration, query, extraction, and analysis tools already read such files. This eliminates the need to develop and maintain sonar-specific file-reading software, and facilitates the use of existing tools for data management, distribution, and analysis (a pertinent example is OPeNDAP, which provides a network transparent standard for distributing scientific data).

An attractive feature of netCDF4 is the ease and transparency with which data can be added to an existing netCDF4 file. For example, processed data and how it was obtained can be included in the same file as the raw data. In addition, netCDF4 files can be very large while still providing fast access to data subsets. This allows a single SONAR-netCDF4 file to contain data from a transect or entire survey. These features would simplify data management, improve traceability and long-term storage of analysis, enhance the sharing of processed datasets, and facilitate analysis of large disparate datasets. In general, any amount of additional data can be stored in the files without affecting the ability to use the data specified by the SONAR-netCDF4 convention.

A distinction is commonly made between file formats designed for archiving of data in the original form, formats designed for storing partially or fully processed data, and formats for data exchange (Jackson *et al.*, 2014). The SONAR-netCDF4 format is intended to be suitable for all of these uses.

The initial focus of the SONAR-netCDF4 format has been to specify the storage of raw data from omni-sonars. We envisage that future versions could specify how to store derived data, such as bottom and school detections, categorisation of backscatter, as well as integrated backscatter at multiple resolutions. Ancillary information such as sonar display screen-grabs could also be stored.

# The SONAR-netCDF4 format

## Introduction

NetCDF4 is a data model, Application Programming Interface (API) library, and file format for storing and managing data. It is developed and maintained by Unidata which is part of the USA’s University Corporation for Atmospheric Research ([UCAR](http://www2.ucar.edu/)) Community Programs ([UCP](http://www.ucp.ucar.edu/)). Unidata is funded primarily by the USA’s National Science Foundation.

SONAR-netCDF4 is a data and meta-data convention for the storage of data from active omni-sonars in netCDF4 formatted files. SONAR-netCDF4 consists primarily of a naming convention and a data storage structure within the netCDF4 data model.

Additional datasets can be added to SONAR-netCDF4 files if they do not conflict with the SONAR-netCDF4 datasets. If such additions are potentially of use to other users of the file format, it is recommended that they be proposed for inclusion in this or additional file format specifications.

Each SONAR-netCDF4 file is intended to store data from one sonar mounted on one platform. The storage of data from multiple sonars and multiple platforms in the one SONAR-netCDF4 is not in the scope of this file format.

A design principle of SONAR-netCDF4 has been to focus on describing the acoustic backscatter data, not the overall purpose and context of why the data were collected. Such broader meta-data is better stored in separate meta-data systems and schema (e.g., ISO, 2003; ICES, 2016).

## Hierarchical structure

NetCDF4 has two main organisational concepts – 1) the variable, which can contain a variety of data structures, and 2) groups, being a collection of variables. Groups and variables can have attributes attached to them. Groups can be arranged into a hierarchy.

SONAR-netCDF4 divides sonar data into seven netCDF4 groups:

1. Top-level. Contains meta-data about the SONAR-netCDF4 file format,
2. **Annotation.** Contains time-stamped annotations,
3. **Environment.** Contains information relevant to acoustic propagation through water,
4. **Platform**. Contains information on the platform that contains the sonar,
5. **Provenance.** Contains meta-data about how the SONAR-netCDF4 version of the data were obtained,
6. **Sonar**. Contains the backscatter and associated meta-data. Groups under **sonar** are used for storing data from different sonar operating modes,
7. **Vendor specific.** Contains vendor-specific information about the sonar and the data.

These groups contain variables and variable attributes with prescribed names and contents.

## Obligations

Some variables and attributes in SONAR-netCD4 are mandatory – these form the minimal set of data required to quantitatively use backscattering amplitude data. The remaining variables and attributes have various levels of optionality and provide enhanced context and information about the sonar data. The obligations are:

**M** – Mandatory

**MA** – Mandatory if applicable

**R** – Recommended

**O** – Optional

## Meta-data and authorities

The fisheries acoustic community has developed a meta-data convention for processed acoustic data (ICES, 2016). Where relevant, attribute and variable names have been re-used from this convention. The NetCDF Climate and Forecast (CF) Metadata Conventions (Eaton *et al.*, 2017) have been used where sensible (the efficient storage of unprocessed active sonar data has not been a design goal of the CF convention). Terms and concepts from other meta-data conventions have also been used where appropriate. The use of existing conventions and standards is indicated in this document in the individual description entries.

## Units

All relevant variables and attributes in SONAR-netCDF4 files are required to have a textual netCDF4 attribute with the name of ‘units’ that specifies the units. The International System of Units (SI) is used. For simplicity the data format mandates the use of particular units and their textual form, as per the definitions and conventions of the UDUNITS-2 package (UCAR, 2014).

## Datatypes

Each item has a datatype, being **numeric**, **long**, **boolean, text**,ora NetCDF4 enumeration data type. If the type is given as ‘numeric’ any suitable NetCDF4 numeric type can be used. Type ‘long’ must be an unsigned 64-bit integer (NC\_UINT64). Type ‘boolean’ should be an 8-byte signed integer (NC\_BYTE) that is interpreted as a boolean (0 = false, 1 = true). Text should be of type NC\_STRING and contain text in the UTF-8 encoding and should be treated as case sensitive during any comparisons. Enumerated datatypes are used for some of the controlled vocabularies.

## Vocabularies

The contents of some variables and attributes are restricted to defined vocabularies. These are listed where required. Desired additions to the vocabularies should be proposed for incorporation into this document. Some of the vocabularies have been represented as netCDF4 enumeration data types.

## File naming convention

SONAR-netCDF4 files should always end with a .nc suffix to indicate that they are a netCDF file. It is recommended that the main part of the filename should sort alphanumerically into chronological order. This facilitates file management and use in analysis systems.

## CDL version of SONAR-netCDF4

A Common Data form Language (CDL) version of the SONAR-netCDF4 format is available. This provides a more formalised and structured representation of the data format. CDL files can be converted into a NetCDF file using the ‘ncgen’ utility (available as part of the netCDF software distribution).

## Groups

### Top-level group

This group contains meta-data about the SONAR-netCDF4 file, all of which are represented as attributes on the group. The netCDF4 group name is **/**.

Table 1. Attributes on the top-level group.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Datatype | Description | Obligation |
| Conventions | text | The convention that is followed in the file. Use ‘CF-1.6’. | M |
| file\_created | text | Timestamp of creation of the file in ISO8601:2004 extended format, including the time zone (e.g., 2017-05-06T20:21:35Z). | M |
| file\_format\_authority | text | Name of the organisation that manages and distributes the file format specification. Currently ‘ICES’. | M |
| file\_format\_name | text | Formal name of this file format: ‘SONARnetCDF4’. | M |
| file\_format\_version | text | SONAR-netCDF4 version number of the form ‘major.minor’, where major and minor are non-negative integers. | M |
| file\_licensing | text | Description of any licence applied to the data in the file. | O |
| file\_rights | text | Description of the usage rights of the data in the file. | O |

### Annotation Group

The annotation group contains time-stamped annotations with optional identification code. The netCDF4 group name is **/Annotation**. Variables are given in Table 2.

Table 2. Variables in the Annotation group.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Datatype | Description | Obligation | Attributes |
| annotation\_id | text | Vector of annotation classification codes. Must use the ‘time’ variable as its dimension. | O | long\_name = "Annotation classification" |
| annotation\_text | text | Vector of annotation text. Must use the ‘time’ variable as its dimension. | MA | long\_name = "Annotation text" |
| time | text | Vector of annotation timestamps. Must be defined as a NetCDF dimension variable. | MA | units = "100 nanoseconds since 1601-01-01 00:00:00Z"  long\_name = "Timestamps of annotations" |

### Environment group

The environment group contains information on environmental conditions, especially speed of sound in water and acoustic absorption. The netCDF4 group name is **/Environment**. Variables are given in Table 3. Sound speed, absorption, and current profiles can also be stored in this group, as can profile measurements of salinity, temperature, and pressure. Such profile data should use the NCEI NetCDF ‘profile’ template, v2.0 or greater.

Table 3. Variables in the Environment group.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Datatype | Description | Obligation | Attributes |
| absorption\_indicative | numeric | Vector of indicative absorption values to be used for calculating TVG, in the absence of more detailed data. Must use the ‘frequency’ variable as its dimension. | M | units = "dB/m"  long\_name = "Indicative acoustic absorption" |
| frequency | numeric | Vector of frequencies at which the absorption\_indicative values are valid. Must be defined as a NetCDF dimension variable. | M | units = "Hz"  long\_name = "Acoustic frequency"  standard\_name = "sound\_frequency" |
| sound\_speed\_indicative | numeric | Mean sound speed to be used for calculating range, in the absence of more detailed sound speed data. | M | units = "m/s"  long\_name = "Indicative sound speed"  standard\_name = "speed\_of\_sound\_in\_sea\_water" |

### Platform group

This group contains information about the sonar platform (e.g., ship). The netCDF4 group name is **/Platform**. Attributes are given in Table 4 and variables in Table 5. The coordinate system convention, including the definition of pitch and roll, is detailed in Section 5.

Table 4. Attributes on the Platform group.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Datatype | Description | Obligation |
| platform\_code\_ICES | text | ICES code for the platform. Use the defined vocabulary from the ICES SISP 4-TG-AcMeta. | O |
| platform\_name | text | Name of the platform that the sonar is part of. | O |
| platform\_type | text | Type of platform that the sonar is part of. Use the defined vocabulary from the ICES SISP 4-TG-AcMeta. | M |

Table 5. Variables in the Platform group.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Datatype | Description | Obligation | Attributes |
| distance | numeric | Distance travelled by the platform from an arbitrary location. | O | units = "m"  long\_name = “Distance travelled by the platform" |
| heading | numeric | Platform heading. Measured clockwise from north. | MA | units = "degrees\_north"  long\_name = "Platform heading (true)" standard\_name = "platform\_orientation" |
| heave | numeric | Platform heave. Positive values indicate a heave above the nominal zero value (Section 5). Heave is applied at the position given by MRU\_offset. | R | units = "m"  long\_name = "Platform heave" |
| latitude | numeric | Platform latitudes in the WGS-84 coordinate reference system. | MA | units = “degrees\_north”  long\_name = “Platform latitude”  standard\_name = “latitude” |
| longitude | numeric | Platform longitudes in the WGS-84 coordinate reference system. | MA | units = “degrees\_east”  long\_name = “Platform longitude”  standard\_name = “longitude” |
| MRU\_offset | numeric | 3-element vector that gives the offset between the platform coordinate system origin and the motion reference unit origin along the x-, y-, and z-axes (elements 1, 2, and 3 respectively). See Section 5.3. | R | units = "m"  long\_name = "Offset between the platform coordinate system origin and motion reference unit sensor origin" |
| MRU\_rotation | numeric | 3-element vector that gives angular rotations about the x-, y-, and z-axes that compensate for any deviations from the platform coordinate system (see section 5). | R | units = "arc\_degree"  long\_name = " Rotations offset of the MRU roll, pitch and heading" |
| pitch | numeric | Platform pitch. Positive values indicate a bow up pitch (see Section 5). | R | units = "arc\_degree"  long\_name = "Platform pitch"  standard\_name = "platform\_pitch\_angle" |
| position\_offset | numeric | 3-element vector that gives the offset between the platform coordinate system origin and the latitude and longitude position origin along the x-, y-, and z-axes (elements 1, 2, and 3 respectively). See Section 5.3. | R | units = "m"  long\_name = "Offset between the platform coordinate system origin and latitude/longitude sensor origin" |
| roll | numeric | Platform roll. Positive values indicate a roll to starboard (Section 5). | R | units = "arc\_degree"  long\_name = "Platform roll"  standard\_name = "platform\_roll\_angle" |
| speed\_ground | numeric | Platform speed over ground. | MA | units = "m/s"  long\_name = "Platform speed over ground"  standard\_name = "platform\_speed\_wrt\_ground" |
| speed\_relative | numeric | Platform speed relative to water. | O | units = "m/s"  long\_name = "Platform speed relative to water"  standard\_name = "platform\_speed\_wrt\_sea\_water” |
| time | long | Time axis for other variables in the Platform group. Must be defined as a NetCDF dimension. Multiple time variables (with different names) can be used if the Platform group variables are collected with differing timestamp series. | MA | units = "100 nanoseconds since 1601-01-01 00:00:00Z"  long\_name = "Timestamps for XXX data" |
| transducer\_offset | numeric | 3-element vector that gives the distance and direction between the platform coordinate system origin and the sonar transducer along the x-, y-, and z-axes (elements 1, 2, and 3 respectively). See Section 5.3. | R | units = "m"  long\_name = "Offset between the platform coordinate system origin and the sonar transducer" |
| water\_level | numeric | Distance from the origin of the platform coordinate system to the nominal water level measured along the z-axis of the platform coordinate system (positive values are below the origin). | R | units = "m"  long\_name = " Distance from the platform coordinate system to the water level along the z-axis" |

Optionally, Platform subgroups can be included to store data from individual instruments. This is intended to provide a formalised place to store the rawer instrument data from multiple GPS sensors, motion reference units, etc. The format of the data is not prescribed but could, for example, be NMEA-style text and/or numeric values. Subgroups must have one attribute called ‘description’ that provides a short description of the contents. Other attributes can be added as desired. The variables under the subgroup should have appropriate names and an attribute that gives the units where appropriate. If NMEA telegrams are stored it is suggested that the group name is NMEA and contains the variables as given in Table 6.

Table 6. Suggested variables for storing NMEA datagrams from marine instruments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Datatype | Description | Obligation | Attributes |
| NMEA\_datagram | text | NMEA datagrams. Uses the ‘time’ variable as its dimension. | O | long\_name = "NMEA datagram" |
| time | long | Vector of datagram timestamps. Should be defined as a NetCDF dimension variable. | O | units = "100 nanoseconds since 1601-01-01 00:00:00Z"  long\_name = "Timestamps for GPS datagrams" |

### Provenance group

The provenance group provides information on how the SONAR-netCDF4 version of the data were created. The netCDF4 group name is **/Provenance**. Variables are listed in Table 7 and attributes in Table 8.

Table 7. Variables in the Provenance group.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Datatype | Description | Obligation | Attributes |
| source\_filenames | text | Vector of data file names that were used to generate the data in this SONAR-netCDF4 file. | MA | long\_name = "Source filenames" |

Table 8. Attributes on the Provenance group.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Datatype | Description | Obligation |
| conversion\_software\_name | text | Name of the software used to do the conversion. | MA |
| conversion\_software\_version | text | Version of the software used to do the conversion. | MA |
| conversion\_time | text | Time of the start of the conversion process in extended ISO8601:2005 extended format, including timezone (e.g., 2017-05-06T20:21:21Z). | MA |

### Sonar group

This group contains the sonar backscatter data and associated meta-data. The netCDF4 group name is **/Sonar**. Attributes are given in Table 9. The defined vocabulary for sonar\_type is given in Table 10.

Data from each beam mode (e.g., horizontal and vertical beam modes) are stored in sub-groups under the **Sonar** group, see Table 12. The form of the backscatter data can vary between different sonar systems, for example, some provide a complex-valued amplitude while others provide a real- or integer-valued amplitude. Variable definitions for data from split-beam systems are not currently specified. The defined vocabulary for beam\_mode is given in Table 13 and the defined data types in Table 14.

Table 9. Attributes on the Sonar group.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Datatype | Description | Obligation |
| sonar\_manufacturer | text | Name of the manufacturer of the sonar. | R |
| sonar\_model | text | Name of the sonar model. | R |
| sonar\_serial\_number | text | Serial number of the sonar | R |
| sonar\_software\_name | text | Name of the sonar software. | R |
| sonar\_software\_version | text | Version of the sonar software. | R |
| sonar\_type | text | Type of sonar, chosen from defined vocabulary given below. | R |

Table 10. Defined vocabulary for sonar\_type.

|  |  |
| --- | --- |
| Vocabulary | Description |
| omni-sonar | A sonar which projects acoustic energy along a conical surface. Such sonars can often also project acoustic energy in a fan. |

Table 11. Attributes for beam mode subgroups of the Sonar group

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Datatype | Description | Obligation |
| beam\_mode | text | Mode of the beam in this sub-group, taken from the defined vocabulary given in Table 13. | M |
| conversion\_equation\_type | text | Type of equation to be used to convert backscatter measurements into sv and TS. Should be chosen from the defined vocabulary given in Table 15. | M |

Table 12. Variables for beam mode subgroups of the Sonar group.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Datatype | Description | Obligation | Attributes |
| backscatter\_i | numeric | 2D matrix of imaginary part of backscatter measurements. Axis 1 is time and 2 is beam. Each element in the 2D matrix is a variable length vector (of type sample\_t, Table 14) that contains the samples for that beam and ping time. | MA | units = *as appropriate*  long\_name = "Raw backscatter measurements (imaginary part)" |
| backscatter\_r | numeric | 2D matrix of real part of backscatter measurements. Axis 1 is time and 2 is beam. Each element in the 2D matrix is a variable length vector (of type sample\_t, Table 14) that contains the samples for that beam and ping time. | M | units = *as appropriate*  long\_name = "Raw backscatter measurements (real part)" |
| beam\_direction\_vector | numeric | 3D-matrix of size (3 by number of beams by number of pings) that gives the x, y, and z coordinates of a unit vector in the beam direction for each beam and ping, as per the sonar beam coordinate system (see Section 5). | M | units = "m"  long\_name = "Vector that gives the pointing direction of the beam, in sonar beam coordinate system" |
| beam\_stabilisation | boolean | Vector of size (number of pings) that indicates whether the sonar beams are compensated for platform motion (true) or not (false). See Section 5. | M | long\_name = “Presence (or not) of beam stabilisation” |
| beam\_type | beam\_t | Type of beam (Table 14). | M | long\_name = "Type of beam" |
| beamwidth\_major | numeric | One-way beam width at 3 dB down in the horizontal direction. 2D matrix, per beam and per ping. | M | units = "arc\_degree"  long\_name = "3dB one-way beam width along major (horizontal) axis of beam" |
| beamwidth\_minor | numeric | One-way beam width at 3 dB down in the vertical direction. 2D matrix, per beam and per ping. | M | units = "arc\_degree"  long\_name = "3dB one-way beam width along minor (vertical) axis of beam" |
| equivalent\_beam\_angle | numeric | Equivalent beam angle. 2D matrix, per beam and per ping. | M | units = "sr"  long\_name = "Equivalent beam angle" |
| first\_sample\_delay | numeric | Time delay between start of transmission and timestamp of first recorded sample. Can be used to apply a range correction to data caused by, for example, sonar data processing delays. | M | units = "s"  long\_name = "Time delay between start of transmission and start of recorded data" |
| noise\_filter | noise\_filter\_t | Setting of a noise filter that is applied prior to recording of backscatter data. This is a vendor-specific setting. | MA | long\_name = "Noise filter setting (vendor specific)" |
| receiver\_sensitivity | numeric | Sensitivity of the sonar receiver for the current ping. Necessary for conversion equation type 2 (Section 4.2). | MA | units = "V/uPa", or  units *=* "1/uPa" (use for ADC counts per uPa)  long\_name = “Receiver sensitivity" |
| sample\_interval | numeric | Time between individual samples along a beam. | M | units = "s"  long\_name = "Interval between recorded raw data samples" |
| time | long | Vector of time for each ping. Must be defined as a NetCDF dimension variable. | M | units = "100 nanoseconds since 1601-01-01 00:00:00Z"  long\_name = "Timestamp of each ping" |
| time\_varied\_gain | sample\_t | Time varied gain (TVG) used for each ping. Should be a vector of length time that contains TVG coefficient vectors of type sample\_t (Table 14). Necessity depends on value of conversion\_equation\_type attribute. | MA | units = "1"  long\_name = "Time-varied-gain coefficients" |
| transducer\_gain | numeric | Gain of the transducer beam. This is the parameter that is set from a calibration exercise. Necessary for conversion equation type 1 (Section 4.1). | MA | units = "1"  long\_name = "Gain of transducer" |
| transmit\_bandwidth | numeric | Estimated bandwidth of the transmitted pulse. For CW pulses this is a function of the pulse duration and frequency. For FM pulses this will be close to the difference between transmit\_frequency\_start and transmit\_frequency\_stop. | O | units = "Hz"  long\_name = "Nominal bandwidth of transmitted pulse" |
| transmit\_duration\_equivalent | numeric | Equivalent duration of the transmit pulse. This is the square pulse containing the same energy as the actual transmitted pulse. Necessary for conversion equation type 1 (Section 4.1). | MA | units = "s"  long\_name = "Equivalent duration of transmitted pulse" |
| transmit\_duration\_nominal | numeric | Nominal duration of the transmit pulse. This is not the equivalent pulse duration. | M | units = "s"  long\_name = "Nominal duration of transmitted pulse" |
| transmit\_frequency\_start | numeric | Frequency at the start of the transmit pulse. When vector, changes are only per ping. When matrix, changes are in both per beam and per ping. | M | units = "Hz"  long\_name = "Start frequency in transmitted pulse"  standard\_name = "sound\_frequency" |
| transmit\_frequency\_stop | numeric | Frequency at the end of the transmit pulse. When vector, changes are only per ping. When matrix, changes are in both per beam and per ping. | M | units = "Hz"  long\_name = "Stop frequency in transmitted pulse"  standard\_name = "sound\_frequency" |
| transmit\_power | numeric | Electrical transmit power used for the ping. Is typically used in the conversion from backscatter amplitude to Sv or TS. | M | units = "W"  long\_name = "Nominal transmitter power" |
| transmit\_source\_level | numeric | Source level generated by the transmit ping. Necessary for conversion equation type 2 (Section 4.2). | MA | units = “dB 1 uPa^2 m^2”  long\_name = “Transmit source level” |
| transmit\_type | transmit\_t | Type of transmit pulse (Table 14). | M | long\_name = "Type of transmitted pulse" |

Table 13. Defined vocabulary for beam\_mode.

|  |  |
| --- | --- |
| Vocabulary | Description |
| horizontal | The group of omni-sonar beams that radiate nominally horizontally from the sonar (usually with configurable tilt below horizontal). |
| inspection | A single beam with configurable pointing direction. |
| vertical | The group of omni-sonar beams that form a vertical fan. |

Table 14. Datatypes specific to the Sonar group.

|  |  |  |
| --- | --- | --- |
| Data type name | Data type | Description |
| beam\_t | enumeration | Enumeration values, labels, and explanation:  0, single, a beam with no direction sensing ability  1, splitbeam, a beam split into multiple sectors that permits calculation of echo arrival angle |
| sample\_t | variable length | Variable length data type of numeric type that stores data from one ping of one beam. Used for echo data samples and, where applicable, the time varied gain. |
| transmit\_t | enumeration | Enumeration values, labels, and explanation:  0, CW, Continuous Wave. A pulse nominally of one frequency.  1, LFM, Linear Frequency Modulation. A pulse which varies from transmit\_frequency\_start to transmit\_frequency\_stop in a linear manner over the nominal pulse duration (transmit\_duration\_nominal).  2, HFM, Hyperbolic Frequency Modulation. A pulse which varies from transmit\_frequency\_start to transmit\_frequency\_stop in a hyperbolic manner over the nominal pulse duration (transmit\_duration\_nominal). |
| noise\_filter\_t | enumeration | Enumeration values, labels, and explanation:  0, off\_Simrad, no noise filtering applied (Simrad SX90, SU90, and SH90 sonars)  1, weak\_Simrad, weak noise filtering (Simrad SX90, SU90, and SH90 sonars)  2, medium\_Simrad, medium noise filtering (Simrad SX90, SU90, and SH90 sonars)  3, strong\_Simrad, strong noise filtering (Simrad SX90, SU90, and SH90 sonars) |

Table 15. Defined vocabulary for the conversion\_equation\_type attribute.

|  |  |
| --- | --- |
| Vocabulary | Description |
| type1 | The equation presented in Section 4.1. |
| type2 | The equation presented in Section 4.2. |

### Vendor specific group

The vendor-specific group contains information about the sonar and its data that is specific to the sonar. Data in this group must not be necessary for normal quantitative use of the sonar data. The contents of this group are not prescribed and are at the complete discretion of the sonar and software that writes the SONAR-netCDF4 file. Consequently, there are no suggested variables or attributes. The netCDF4 group name is **/Vendor\_specific**.

# Conversion equations

This section provides detailed formulae on how to convert the backscatter data in the Sonar group into calibrated target strength and volume backscatter strength.

## Type 1

The type 1 conversion equation is used for data recorded by the Simrad SU90, SX90, and SH90 omni-sonars and is presented in detail by Macaulay *et al.* (2016).

The complex-valued backscatter data is converted into calibrated target strength via:

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|  |  |  |

where is linearly proportional to the received power (square of the magnitude of the complex number given by backscatter\_r and backscatter\_i, W) and *r* the range between the transducer and target, calculated from

|  |  |  |
| --- | --- | --- |
|  |  |  |

where *c* is sound speed (NetCDF4 variable is sound\_speed\_indicative, m/s), *dt* the time between recorded samples (sample\_interval, s), *i* the sample number (from zero to one less than the number of samples) and *t0* a time offset (first\_sample\_delay, s).

The absorption coefficient of sound in water is *α* (absorption\_indicative, dB/m), *Pt* the transmit power (transmit\_power, W), *λ* the acoustic wavelength (derived from the average of transmit\_frequency\_start and transmit\_frequency\_stop, and sound\_speed\_indicative, m), *G* the transducer gain (transducer\_gain, dB)*,* and the beam tilt angle (derived from beam\_direction\_vector, degrees from horizontal).

The volume backscatter strength (*Sv*, MacLennan *et al.*, 2002) is derived from a similar equation:

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| --- | --- | --- |
|  |  |  |

where is the equivalent beam angle (equivalent\_beam\_angle, sr), *τe* the effective pulse duration (transmit\_duration\_equivalent, s), and *G* the transducer gain (transducer\_gain, dB).

## Type 2

*Additional conversion equations go here*.

# Coordinate systems

## Platform coordinate system

The coordinate system for the platform uses the right-handed cartesian convention (Figure 1) with:

* x-axis parallel to the main axis of the platform, positive values toward the front of the platform (e.g., toward the bow for a ship),
* y-axis perpendicular to the main axis of the platform, positive values to the starboard side of the platform,
* z-axis vertical, positive values down from the platform,
* the origin is the common reference point where all three axes meet and is arbitrary.

Roll is positive with port side up, pitch is positive with bow up, and heading/yaw is positive clockwise. More specifically:

* looking along the positive x-axis, a positive rotation (roll) is clockwise (to starboard),
* looking along the positive y-axis, a positive rotation (pitch) is clockwise (bow up),
* looking along the positive z-axis, a positive rotation (yaw) is clockwise (to starboard).

The platform heading variable (degrees clockwise from North) can be used to obtain the sonar orientation in world coordinates. This applies to stationary and mobile sonar platforms.

The orientation of the platform is represented using the z-y’-x’’ Tait-Bryan intrinsic rotation convention ([en.wikipedia.org/wiki/Euler\_angles](https://en.wikipedia.org/wiki/Euler_angles)), corresponding to yaw, pitch, and roll respectively. Intrinsic means that rotations about the y-axis are measured after any rotation about the z-axis, and rotations about the x-axis are measured after rotations about the y-axis. This is the rotation convention most often used in the maritime field and the main effect is that roll is measured relative to the plane tilted by the pitch angle.

C:\Users\gavinj\Google Drive\SONAR-netCDF4\coordinate system figure.emf

Figure 1. Platform coordinate system. The arrows on the axes indicate the positive direction and the arrows around each axis indicate positive rotations (acknowledgements to the Simrad SN90 manual for the hull drawing).

## Sonar beam coordinate system

The coordinate system for the beam direction uses the same convention as the platform coordinate system, but with the origin at the transducer. Sonar beams can be compensated or uncompensated for motion of the platform. If uncompensated, the sonar beam coordinate system follows the pitch and roll of the platform. If the beams are compensated, the sonar beam coordinate system is translated and rotated per ping so that the y-axis is always horizontal and the z-axis is always vertical. The x-axis always is always parallel to the platform’s x-axis. The beam\_stabilisation variable indicates whether the beams are compensated or uncompensated.

## Coordinate system offsets and rotations

Several coordinate systems offsets can be given in the Platform group. These allow for precise specification of the origin of sensors, such as the position and attitude sensors, and sonar transducer. The offset is a (x,y,z) tuple in the platform coordinate system. Offsets are always given as a vector that starts at the platform coordinate system origin and ends at the sensor position. For example, an offset of (1, 2, -3) indicates a position that is 1 m toward the bow, 2 m to starboard, and 3 m above the origin of the platform coordinate system origin.

Some sensors (e.g., the attitude sensor) can have a rotation relative to the platform coordinate system. This is represented as the rotation required from the platform coordinate system’s x-, y-, and z-axes to arrive at the sensor’s x-, y-, and z-axes.

# Revision history

|  |  |  |  |
| --- | --- | --- | --- |
| Document version | SONAR-netCDF4 version | Date | Changes |
| 1.3 | 1.0 | 21 June 2016 | Extensive and significant modifications derived from feedback on v1.2, from creation of test SONAR-HDF4 files, and from implementation of reading in LSSS. |
| 1.2 | 1.0 | 2 February 2017 | Further modifications after internal review. |
| 1.1 | 1.0 | 13 January 2017 | Modifications after generation of test datasets. |
| 1.0 | 1.0 | 22 December 2016 | Draft version for distribution to the ICES WGFAST Topic Group on “Defining a data format for omni fisheries sonar”. |

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