

# A Standard for Exchangeable Magnetotelluric Data and Metadata

Working Group for Data Handling and Software - PASSCAL Magnetotelluric Program<sup>1</sup>

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for Seismology

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# 1 Introduction

Researchers using magnetotelluric (MT) methods lack a standardized format for storing time series data and metadata. Commercially available MT instruments produce data in formats that range from proprietary binary to ASCII, and recent datasets from the U.S. MT community have utilized institutional formats or heavily adapted formats like miniSEED. In many cases, the available metadata for these time series are incomplete and only loosely standardized, and overall these datasets are not "user friendly". This lack of resources impedes the exchange and broader use of these data beyond a small community of specialists.

The [IRIS PASSCAL MT facility](#) maintains a pool of MT instruments that are freely available to U.S. Principal Investigators (PIs). Datasets collected with these instruments are subject to data sharing requirements, and an [IRIS working group](#) advises the development of sustainable data formats and workflows for this facility. Following in the spirit of the standard created for [MT transfer function](#) datasets, this document outlines a new metadata standard for MT time series. This standard is a key pillar of MTH5, a new data format which we propose for the international community of MT practitioners. Further information regarding MTH5 will be available later in 2020.

The Python 3 module written for these standards are found at <https://github.com/kujaku11/MTarchive/tree/tables>.

## 2 General Structure

The metadata for a full MT dataset are structured to cover details from single channel time series to the full survey. For simplicity each of the different scales of an MT survey and measurements have been categorized starting from largest to smallest (Figure 1). These categories are: **Survey**, **Station**, **Run**, **DataLogger**, **Electric Channel**, **Magnetic Channel**, and **Auxiliary Channels**. Each of these are described in subsequent sections.

### 2.1 Metadata Keyword Format

The metadata key names should be self explanatory and they are structured as follows: `{category}.{name}`, where:

- **category** refers to a metadata category that has common parameters, such as **location** which will have a latitude, longitude, and elevation  $\rightarrow$  `location.latitude`, `location.longitude`, and `location.elevation`. These can be nested, for example `positive.location.latitude`
- **name** is the description name, where words should be separated by an underscore, e.g. `data_quality`.

Alternatively, the metadata names can be nested under category headings as commonly done in XML or JSON formats. See examples below for various flavors of ways to represent the metadata.

Table 1: Permissible values for data types

Data Type
String
Double (float)
Integer
Boolean

### 2.2 Formatting Standards

Specific and required formatting standards for location, time and date, and angles are defined below.

#### 2.2.1 Time and Date Format

All time and dates are given as an ISO formatted date-time string in the UTC time zone. The ISO date time format is `YYYY-MM-DDThh:mm:ss.ms+00:00`. Milliseconds can be accurate to 6 decimal places. Dates are formatted `YYYY-MM-DD`.

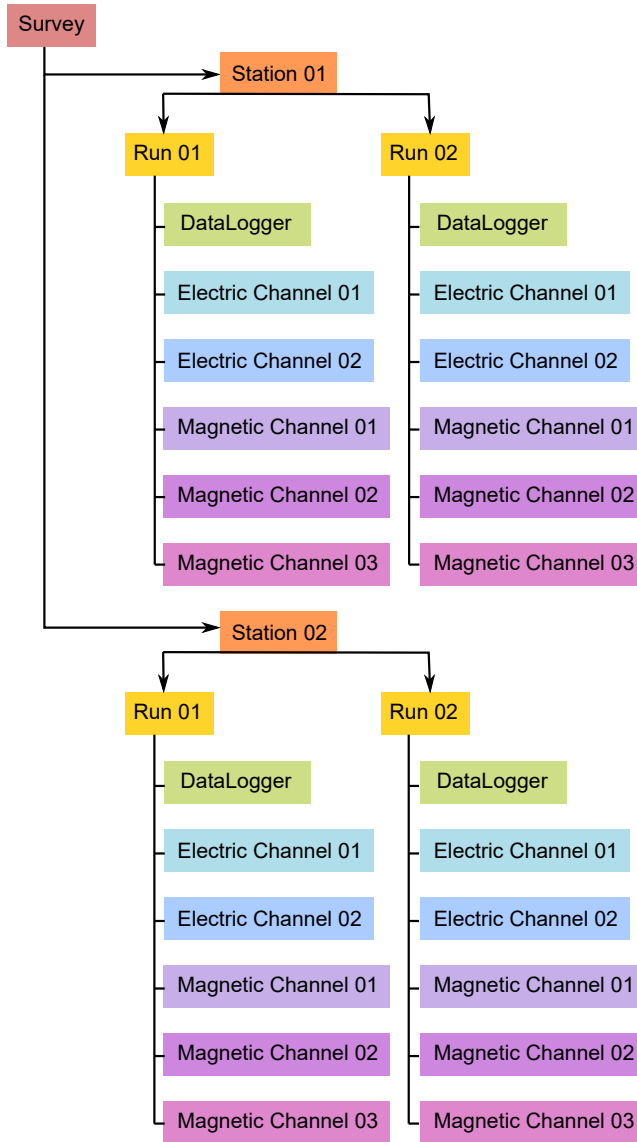


Figure 1: Schematic of a MT time series file structure with appropriate metadata.

### 2.2.2 Location

All latitude and longitude locations are given in decimal degrees in the well known datum **The entire survey should use only one datum that is specified at the Survey level.**

- All latitude values must be  $< |90|$  and all longitude values must be  $< |180|$ .
- Elevation and other distance values are given in meters.
- Datum should be one of the well known datums, WGS84 is preferred, but others are acceptable.

### 2.2.3 Angles

All angles of orientation are given in degrees. Orientation of dipoles and magnetometers should be given in geographic coordinates where angles are assumed to be clockwise positive from Geographic North = 0. If a station was collected not in geographic coordinates this needs to be specified in `station.orientation.option`.

## 2.3 Units

Units should all be from the metric system. Abbreviations and full names are acceptable, for example `mV` and `millivolts`. Below are a summary of common acceptable units:

Table 2: Acceptable units

Measurement Type	Unit Long Name	Unit Short Name
Angles	degrees	deg
Distance	meters	m
Latitude/Longitude	decimal degrees	deg
Resistance	Ohms	Ohms
Resistivity	Ohm-meters	Ohm-m, Ohmm
Temperature	Celsius	C
Time	seconds	s
Voltage	Volts	V

## 2.4 String Formats

Any list should be comma separated.

Table 3: Acceptable String Formats

Style	Description	Example
free form	an unregulated string that can contain {a-z, A-Z, 0-9} and special characters	This is free form!
alpha numeric	a string that contains no spaces and only characters {a-z, A-Z, 0-9, -, /, _}	WGS84 or GEOMAG-USGS
controlled vocabulary	Only certain names or words are allowed	station.orientation.option = geographic
url	a full URL that a user could put into a web browser	<a href="https://www.passcal.nmt.edu/">https://www.passcal.nmt.edu/</a>
date	ISO formatted date YYYY-MM-DD in UTC	2020-02-02
date time	ISO formatted date time YYYY-MM-DDThh:mm:ss.ms+00:00 in UTC	2020-02-02T12:20:45.123456+00:00
Temperature	Celsius	C
Time	seconds	s
Voltage	Volts	V

### 3 Survey

A survey describes an entire dataset that covers a specific time span and region. This may include multiple PIs in multiple data collection episodes but should be confined to a specific experiment. The **Survey** metadata category describes the general parameters of the survey.

Table 4: Attributes for Survey category

Metadata Key	Description	Type	Required	Style
acquired_by.author	principal investigator(s) responsible for survey	string	true	free form
acquired_by.comments	comments about who acquired the data, could include the various groups or contractors	string	true	free form
archive_id	alphanumeric name for the project e.g USGS-GEOMAG	string	true	alpha numeric
archive_network	network code given by PASS-CAL/IRIS/FDSN	string	true	alpha numeric
citation_data_set.doi	citation dataset doi number	string	true	url
citation_journal.doi	citation journal doi	string	false	url
comments	comments about survey that are not in the summary	string	false	free form
country	country/countries survey located in, if multiple they should be comma separated	string	false	free form
datum	datum of latitude and longitude coordinates, should be a well-known datum [ WGS84 ] and will be the reference datum for all location	string	true	alpha numeric
geographic_name	geographic location(s) of survey in general terms	string	true	free form
name	descriptive name of the survey	string	true	free form
northwest_corner.latitude	location of northwest corner of survey [ degrees ]	float	true	number
northwest_corner.longitude	location of northwest corner of survey [ degrees]	float	true	number
project	alphanumeric name for the project e.g USGS-GEOMAG	string	true	alpha numeric
project_lead.email	email address of the project lead	string	true	email
project_lead.name	name of the project lead	string	true	free form
project_lead.organization	name of the organization for the project lead	string	true	free form
release_status	defined status of how the data can be used. Options are [ Unrestricted Release   Paper Citation Required   Academic Use Only   Conditions Apply ]	string	true	controlled vocabulary
southeast_corner.latitude	location of southeast corner of survey [degrees]	float	true	number
southeast_corner.longitude	location of southeast corner of survey [degrees]	float	true	number
summary	summary paragraph of survey including the purpose, difficulties, data quality, summary of outcomes if the data have been processed and modeled	string	true	free form
time_period.end_date	end date of survey in UTC	string	true	date
time_period.start_date	start date of survey in UTC	string	true	date

### 3.1 Example Survey XML String

```
<?xml version="1.0" ?>
<survey>
  <acquired_by>
    <author>None</author>
    <comments>None</comments>
  </acquired_by>
  <archive_id>None</archive_id>
  <archive_network>None</archive_network>
  <citation_dataset>
    <doi>None</doi>
  </citation_dataset>
  <citation_journal>
    <doi>None</doi>
  </citation_journal>
  <comments>None</comments>
  <country>None</country>
  <datum>None</datum>
  <geographic_name>None</geographic_name>
  <name>None</name>
  <northwest_corner>
    <latitude type="float" units="decimal degrees">None</latitude>
    <longitude type="float" units="decimal degrees">None</longitude>
  </northwest_corner>
  <project>None</project>
  <project_lead>
    <email>None</email>
    <organization>None</organization>
    <author>None</author>
  </project_lead>
  <release_status>None</release_status>
  <southeast_corner>
    <latitude type="float" units="decimal degrees">None</latitude>
    <longitude type="float" units="decimal degrees">None</longitude>
  </southeast_corner>
  <summary>None</summary>
  <time_period>
    <end_date>1980-01-01</end_date>
    <start_date>1980-01-01</start_date>
  </time_period>
</survey>
```

## 4 Station

A station encompasses a single site where data are collected. If the location changes during a run, then a new station should be created. If the sensors, cables, data logger, battery are replaced during a run but the station remains stations, then this can be recorded in the **Run** metadata but does not require a new station entry.



## 4.1 Example Station JSON String

```
{
  "station": {
    "acquired_by": {
      "author": "mt",
      "comments": null
    },
    "archive_id": "MT012",
    "channel_layout": "L",
    "channels_recorded": "Ex, Ey, Hx, Hy",
    "comments": null,
    "data_type": "MT",
    "geographic_name": "london",
    "id": "mt012",
    "location": {
      "latitude": 10.0,
      "longitude": -112.98,
      "elevation": 1234.0,
      "declination": {
        "value": 12.3,
        "comments": null,
        "model": "WMM"
      }
    },
    "orientation": {
      "method": "compass",
      "option": "geographic",
      "layout_rotation_angle": 0.0
    },
    "provenance": {
      "comments": null,
      "creation_time": "1980-01-01T00:00:00+00:00",
      "log": null,
      "software": {
        "author": "test",
        "version": "1.0a",
        "name": "name"
      },
      "submitter": {
        "author": "name",
        "organization": null,
        "email": "test@here.org"
      }
    },
    "time_period": {
      "end": "1980-01-01T00:00:00+00:00",
      "start": "1980-01-01T00:00:00+00:00"
    }
  }
}
```

## 5 Run

A run represents data collected at a single station with a single sampling rate. If the dipole length or other such station parameters are changed between runs, this would require adding a new run. If the station is relocated then a new station should be created. If a run has channels that drop out the start and end period will be the minimum time and maximum time for all channels recorded.

### 5.1 Example Run XML String

```
<run>
  <acquired_by>
    <author>T. Lurric</author>
    <email>mt@mt.org</email>
  </acquired_by>
  <channels_recorded>[EX, EY, HX, HY, HZ, temperature]</channels_recorded>
  <comments>None</comments>
  <data_logger>
    <power_source>
      <voltage>
        <start type="float" units="volts">14</start>
        <end type="float" units="volts">12</end>
      </voltage>
      <type>pb-acid</type>
      <id>10</id>
      <comments>solar panel</comments>
    </power_source>
    <id>mt01</id>
    <manufacturer>MT r' Us</manufacturer>
    <type>broadband</type>
    <timing_system>
      <type>GPS</type>
      <drift type="float" units="seconds">0.00001</drift>
      <uncertainty type="float" units="seconds">0.00001</uncertainty>
      <notes>None</notes>
    </timing_system>
    <firmware>
      <author>MT r' Us</author>
      <version>12.15.a</version>
      <name>FGDMT</name>
    </firmware>
  </data_logger>
  <data_type>MT</data_type>
  <id>mt01a</id>
  <provenance>
    <comments>None</comments>
    <log>None</log>
  </provenance>
  <sampling_rate type="float" units="samples per second">256.0</sampling_rate>
  <time_period>
    <start>1980-01-01T00:00:00+00:00</start>
    <end>1980-01-01T00:00:00+00:00</end>
  </time_period>
</run>
```

## 6 Electric Channel

Electric channel refers to a dipole measurement of the electric field for a single station for a single run.

## 6.1 Example Electric Channel JSON String

```
{
  "dipole_length": 59.7,
  "channel_number": "1",
  "component": "EX",
  "azimuth": 0,
  "time_period.start": 2020-01-02T12:30:15+00:00,
  "time_period.end": 2020-01-05T16:20:15+00:00,
  "positive.id": "101",
  "positive.latitude": 35.5578,
  "positive.longitude": -117.38754,
  "positive.elevation": 103.4,
  "positive.datum": "WGS84",
  "positive.type": "Ag-AgCl",
  "positive.manufacturer": "Zaps",
  "positive.comments": "Sitting on the shelf since last year",
  "negative.id": "102",
  "negative.latitude": 35.5588,
  "negative.longitude": -117.38754,
  "negative.elevation": 105.8,
  "negative.datum": "WGS84",
  "negative.type": "Ag-AgCl",
  "negative.manufacturer": "Zaps",
  "negative.comments": "Sitting on the shelf since last year",
  "contact_resistance_1.start": 1200.0,
  "contact_resistance_2.start": 1210.0,
  "contact_resistance_1.end": 1205.0,
  "contact_resistance_2.end": 1205.0,
  "ac.start": 0.03,
  "ac.end": 0.04,
  "dc.start": 0.001,
  "dc.end": 0.002,
  "units": "counts",
  "sample_rate": 256,
  "comments": "cables chewed on 2020-01-07",
  "data_quality.rating": 3,
  "data_quality.warning_comments": "cables chewed 2020-01-07",
  "data_quality.warning_flags": "Nan",
  "data_quality.author": "Q. Sea",
  "filter.name": "[counts2mv, datalogger024]",
  "filter.comments": "comments on filters applied",
  "filter.applied_b": "true"
}
```

## 7 Magnetic Channel

A magnetic channel is a recording of one component of the magnetic field at a single station for a single run.

## 7.1 Example Magnetic Channel JSON String

```
{
  "sensor.type": "Induction Coil",
  "sensor.manufacturer": "MT 'r Us",
  "sensor.comments": "new coil",
  "sensor.id": "2149",
  "channel_number": 5,
  "component": "HZ",
  "azimuth": 90,
  "time_period.start": "2020-01-02T12:30:15+00:00",
  "time_period.end": "2020-01-05T16:20:15+00:00",
  "location.longitude": -117.0,
  "location.latitude": 45.0,
  "location.elevation": 107.4,
  "location.datum": "WGS84",
  "units": "counts",
  "sample_rate": 256,
  "h_field_min.start": -10,
  "h_field_max.start": 10,
  "h_field_min.end": -9,
  "h_field_max.end": 9,
  "h_field.units": "nT",
  "comments": "not buried all the way ",
  "data_quality.rating": 4,
  "data_quality.warning_comments": "windy during the day",
  "data_quality.warning_flags": 0,
  "data_quality.author": "Q. Sea",
  "filter.name": "[counts2mv, datalogger024, coil2149]",
  "filter.comments": "Calibrated 2018-01-01",
  "filter.applied_b": "[true, false, false]"
}
```

## 8 Filters

Filters is a table that holds information on any filters that need to be applied to get physical units, and filters that were applied to the data to analyze the signal. This includes calibrations, notch filters, conversion of counts to units, etc. The actual filter will be an array of numbers contained within an array named **name** and formatted according to **type**. The preferred format for a filter is a look-up table which internally can be converted to other formats.

It is important to note that filters will be identified by name and must be consistent throughout the file. Names should be descriptive and self evident. Examples:

- `coil_2284` → induction coil number 2284
- `counts2mv` → conversion from counts to mV
- `e_gain` → electric field gain
- `datalogger_024` → data logger number 24 response
- `notch_60hz` → notch filter for 60 Hz and harmonics
- `lowpass_10hz` → low pass filter below 10 Hz

In each channel there are keys to identify filters that can or have been applied to the data to get an appropriate signal. This can be a list of filter names or a single filter name. An **applied\_b** key also exists for the user to input whether that filter has been applied. Can be a single Boolean **true** if all filters have been applied, **false** if none of the filters have been applied. Or can be a list the same length and the filter name list identifying if the filter has been applied. `name: "[counts2mv, notch60hz, e_gain]"` and `applied_b: "[true, false, true]"`.

### 8.1 Example Filter JSON String

```
{
  "type": "look up",
  "name": "coil_8897",
  "units_in": "mV",
  "units_out": "mV",
  "calibrationate": "2015-07-01",
  "comments": "interpolated from poles and zeros"
}
```

## 9 Auxiliary Channels

Auxiliary channels include state of health channels, temperature, etc.

### 9.1 Example Auxiliary JSON String

```
{
  "auxiliary": {
    "azimuth": 0.0,
    "channel_number": 1,
    "comments": null,
    "component": "temperature",
    "data_quality.author": "mt",
    "data_quality.rating": 5,
    "data_quality.warning_comments": null,
    "data_quality.warning_flags": "0",
    "filter.applied": [false],
    "filter.comments": null,
    "filter.name": ["counts2mv"],
    "location.datum": "WGS84",
    "location.elevation": 1200.3,
    "location.latitude": 40.12,
    "location.longitude": -115.767,
    "sample_rate": 256.0,
    "time_period.end": "2010-01-04T07:40:30+00:00",
    "time_period.start": "2010-01-01T12:30:20+00:00",
    "type": "auxiliary",
    "units": "celsius"
  }
}
```



Table 5: Attributes for Station category

Metadata Key	Description	Type	Required	Style
acquired_by.author	person who acquired the station	string	true	free form
acquired_by.comments	comments about who acquired the data, could include the various groups or contractors	string	true	free form
archive_id	5 char name {A-Z; 1-9} for station	string	true	controlled vocabulary
channel_layout	how the station was laid out e.g. X or L	string	true	controlled vocabulary
channels_recorded	list of channels recorded as a list of comma separated channels. e.g. 'Ex, Ey, Hx, Hy'	string	true	controlled vocabulary
comments	any comments about station	string	false	free form
data_type	type of data collected, options: [ BB   LP   AMT   Combo   ...]	string	true	controlled vocabulary
geographic_name	closest geographic reference name to station	string	true	free form
id	alphanumeric name of the station	string	true	alpha numeric
location.declination.comments	comments on the declination	string	true	
location.declination.model	name of the declination model, options: [ EMAG2   EMM   HDGM   IGRF   WMM ]	string	true	controlled vocabulary
location.declination.value	declination value	float	true	
location.latitude	longitude location [ degrees (hh.mmss) ]	float	true	
location.longitude	latitude location [ degrees (hh.mmss) ]	float	true	
location.elevation	elevation [ m ]	float	true	
orientation.option	orientation coordinate system [ geographic   channel-measurement specific   ...]	string	true	
orientation.method	[ compass   differential GPS   gyroscope  ...]	string	false	
orientation.layout.rotation_angle	if the data were collected in a coordinate system not geographic, this will specify the angle at which all channels were rotated by.	float	false	number
provenance.creation_time	creation time of time series data for storing	string	true	date time
provenance.comments	any comments on the history of the data	string	false	free form
provenance.log	log of any changes made to time series data	string	false	free form
provenance.software.author	author of software used to store time series	string	true	free form
provenance.software.name	name of software used to store time series	string	true	free form
provenance.software.version	version of software used to store time series	string	true	free form
provenance.submitter.author	name of person or group submitting archive data	string	true	free form
provenance.submitter.email	email of person or group submitting archive data	string	true	email
provenance.submitter.organization	name of organization or institution submitting archive data	string	true	free form
time_period.start	start time and date of data logging [ISO UTC ]	string	true	date time
time_period.end	stop time and date of data logging [ ISO UTC ]	string	true	date time

Table 6: Attributes for Run category

Metadata Key	Description	Type	Required
id	run ID	string	true
comments	comments on run, commonly station name with 0-90-9 or a-z, mt01a or mt01.01	string	false
time_period.start	start date and time of data logging [ ISO UTC ], should be the minimum time between all channels recorded	string	true
time_period.end	stop date and time of data logging [ ISO UTC ], should be the maximum time between all channels recorded	string	true
sampling_rate	sampling rate of run (samples per second)	float	true
channels_recorded	list of channels recorded as components [ [EX, EY, HX, HY]   ...]	string	true
data_type	type of data collected [ BB   LP   AMT   Combo   ...]	string	true
acquired_by.author	person(s) responsible for run this can be different from the PI's listed at the survey level	string	true
acquired_by.email	email of lead run operator	string	false
provenance.comments	any comments on the history of the data for the run	string	false
provenance.log	log of any changes made to time series data	string	false
data_logger.manufacturer	data logger manufacturer name	string	true
data_logger.model	data logger model name	string	true
data_logger.serial	data logger serial number	string	true
data_logger.comments	comments about data logger	string	true
data_logger.timing_system.type	type of timing system [GPS   internal   ... ]	string	true
data_logger.timing_system.drift	any drift in internal clock [ seconds ]	float	true
data_logger.timing_system.uncertainty	uncertainty associated with internal clock [seconds]	float	true
data_logger.timing_system.comments	comments on timing system	string	false
data_logger.firmware.version	firmware version	string	true
data_logger.firmware.date	date on firmware	string	true
data_logger.firmware.author	author of firmware	string	false
data_logger.power_source.type	power source type [ Pb-acid battery   solar panel   Li battery   ...]	string	true
data_logger.power_source.id	power source id	string	false
data_logger.power_source.voltage.start	starting voltage of power source	float	true
data_logger.power_source.voltage.end	ending voltage of power source	float	true
data_logger.power_source.comments	comments on power source	string	false

Table 7: Attributes for Electric category

Metadata Key	Description	Type	Required
dipole_length	length of dipole [ m ]	float	true
channel_number	channel number [ 1   2   3   4   5   6  ...]	int	true
component	[ Ex   Ey   Ez ]	string	true
azimuth	azimuth of dipole N = 0, E = 90 [ degrees ]	float	true
time_period.start	start date and time of data logging [ ISO UTC ]	string	true
time_period.end	stop date and time of data logging [ ISO UTC ]	string	true
positive.id	sensor id number	string	true
positive.latitude	positive sensor location latitude [ degrees (hh.mmss) ]	float	false
positive.longitude	positive sensor location longitude [ degrees (hh.mmss) ]	float	false
positive.elevation	positive sensor location elevation [ m ]	float	false
positive.datum	positive datum for location [ WGS84 ]	string	false
positive.type	type of electric sensor [ Ag-AgCl   Pb-PbCl   ...]	string	true
positive.manufacturer	electric sensor manufacturer	string	true
positive.comments	comments on electric sensor	string	false
negative.id	sensor id number	string	true
negative.longitude	negative sensor location latitude [ degrees (hh.mmss) ]	float	false
negative.latitude	negative sensor location longitude [ degrees (hh.mmss) ]	float	false
negative.elevation	negative sensor location elevation [ m ]	float	false
negative.datum	negative datum for location [ WGS84 ]	string	false
negative.type	type of electric sensor [ Ag-AgCl   Pb-PbCl   ...]	string	true
negative.manufacturer	electric sensor manufacturer	string	true
negative.comments	comments on electric sensor	string	false
contact_resistance_1.start	contact resistance at beginning of measurement, positive polarity [ Ohm ]”	float	false
contact_resistance_2.start	contact resistance at beginning of measurement, negative polarity [ Ohm ]	float	false
contact_resistance_1.end	contact resistance at end of measurement, positive polarity [ Ohm ]	float	false
contact_resistance_2.end	contact resistance at end of measurement, negative polarity [ Ohm ]	float	false
ac.start	AC at start of measurement [ V ]	float	false
ac.end	AC at end of measurement [ V ]	float	false
dc.start	DC at start of measurement [ V ]	float	false
dc.end	DC at end of measurement [ V ]	float	false

Table 8: Attributes for Electric category continued

Metadata Key	Description	Type	Required
units	units of electric field data [ counts   mV/km   ... ]	string	true
sample_rate	sample rate of electric channel (samples.second)	float	true
comments	comments about electric field measurement	string	false
data_quality.rating	data quality rating based on some sort of statistic	integer	false
data_quality.warning_comments	any warnings about data quality	string	false
data_quality.warning_flags	a value flagging bad data	float	integer
data_quality.author	person who did QA/QC on data	string	false
filter.name	filter name in filter table, can be a list. Needs to be ordered in which filters were applied	string	false
filter.comments	any comments on the filtering	string	false
filter.applied_b	have filters been applied [ True   False ]	string	true

Table 9: Attributes for Magnetic category

Metadata Key	Description	Type	Required
sensor.type	type of magnetic sensor [ Induction Coil   flux gate   ...]	string	true
sensor.manufacturer	magnetic sensor manufacturer	string	true
sensor.comments	comments on sensor	string	true
sensor.id	sensor id number	string	true
channel_number	channel number [ 1   2   3   4   5   6  ...]	int	true
component	[ Hx   Hy   Hz ]	string	true
azimuth	azimuth in <code>station\_coordinates</code> [ degrees ]	float	true
time_period.start	start date and time of data logging [ ISO UTC ]	string	true
time_period.end	stop date and time of data logging [ ISO UTC ]	string	true
location.longitude	sensor longitude degrees	float	true
location.latitude	sensor latitude in degrees	float	true
location.elevation	sensor elevation in meters	float	true
location.datum	datum for location [ WGS84   ... ]	string	true
units	units of magnetic field data [ counts   mV   ... ]	string	true
sample_rate	sample rate of magnetic channel (samples.second)	float	true
h_field_min.start	minimum h-field value at beginning of measurement	float	false
h_field_max.start	maximum h-field value at beginning of measurement	float	false
h_field_min.end	minimum h-field value at end of measurement	float	false
h_field_max.end	maximum h-field value at end of measurement	float	false
h_field.units	units of h-field measurement [ nT   ...]	string	false
comments	comments on magnetic field measurements	string	false
data_quality.rating	data quality rating based on some sort of statistic	integer	false
data_quality.warning_comments	any warnings about data quality	string	false
data_quality.warning_flags	a value flagging bad data	integer	false
data_quality.author	person who did QC.QA on data	string	false
filter.name	filter name in filter table, can be a list. Needs to be ordered in which filters were applied	string	false
filter.comments	any comments on the filtering	string	false
filter.applied_b	have filters been applied [ True   False ]	string	true

Table 10: Attributes for Filters

Metadata Key	Description	Type	Required
type	type of filter [look up   poles-zeros   converter   FIR   ...]	string	true
name	unique name for the filter such that it is easy to query	string	true
units_in	units of data going in [ counts   mV/km   ... ]	string	true
units_out	units of data coming out [ counts   mV/km   ... ]	string	true
calibration_date	date of calibration	string	true
comments	any comments on the filtering	string	false

Table 11: Attributes for Auxiliary category

Metadata Key	Description	Type	Required
type	type of data recorded [ temperature   GPS   ...]	string	true
units	units of magnetic field data [ counts   mV   ... ]	string	true
channel_num	channel number [ 1   2   3   4   5   6  ...]	int	true
component	channel number [ ‘None’   ... ]	string	true
sample_rate	sample rate (samples.second)	float	true
comments	any comments on the auxillary channel	string	false
data_quality.rating	data quality rating based on some sort of statistic	integer	false
data_quality.warning_comments	any warnings about data quality	string	false
data_quality.warning_flags	a value flagging bad data	integer	false
data_quality.author	person who did QC.QA on data	string	false
filter.name	filter name in filter table, can be a list. Needs to be ordered in which filters were applied	string	false
filter.comments	any comments on the filtering	string	false
filter.applied_b	have filters been applied [ True   False ]	string	true