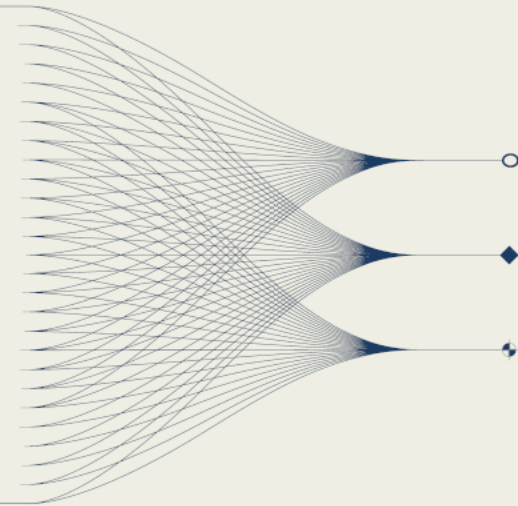
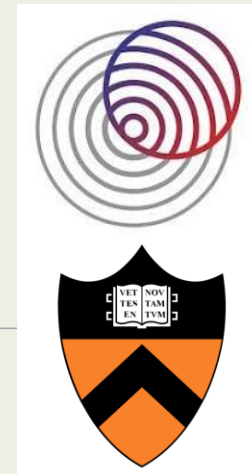

Rapidly Changing Metadata (RCM): A Project to Add FAIR Metadata to Existing Standards

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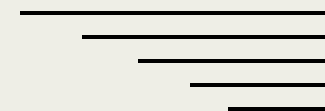
Presentation Date: 10 September 2025





Rapidly Changing Metadata (RCM): A Project to Add FAIR Metadata to Existing Standards

- The FDSN SEED format has been a major format used for data distribution since the late 1980s.
 - Earlier recorded digital data from many data centres have converted from their native format to SEED
 - Conversion tools exist to allow SEED and CTBTO data to be used seamlessly
 - It is a format that assumes static or slowly-changing metadata--it was not designed for stations that move
- This talk describes a straightforward method where Rapidly Changing Metadata (RCM) can be captured ensuring the data are Findable, Accessible, Interoperable, and Reproduceable (FAIR) using the GeoCSV format
- Comma Separated Values or CSV
 - Many disciplines use comma separated values (CSV) styles to capture data
 - GeoCSV came from the NSF EarthCube GeoWS project which identified a structure that made earth science data with additional metadata able to use GeoCSV for its data.
 - EarthScope/IRIS supports GeoCSV output in some of its web services

 **Metadata**

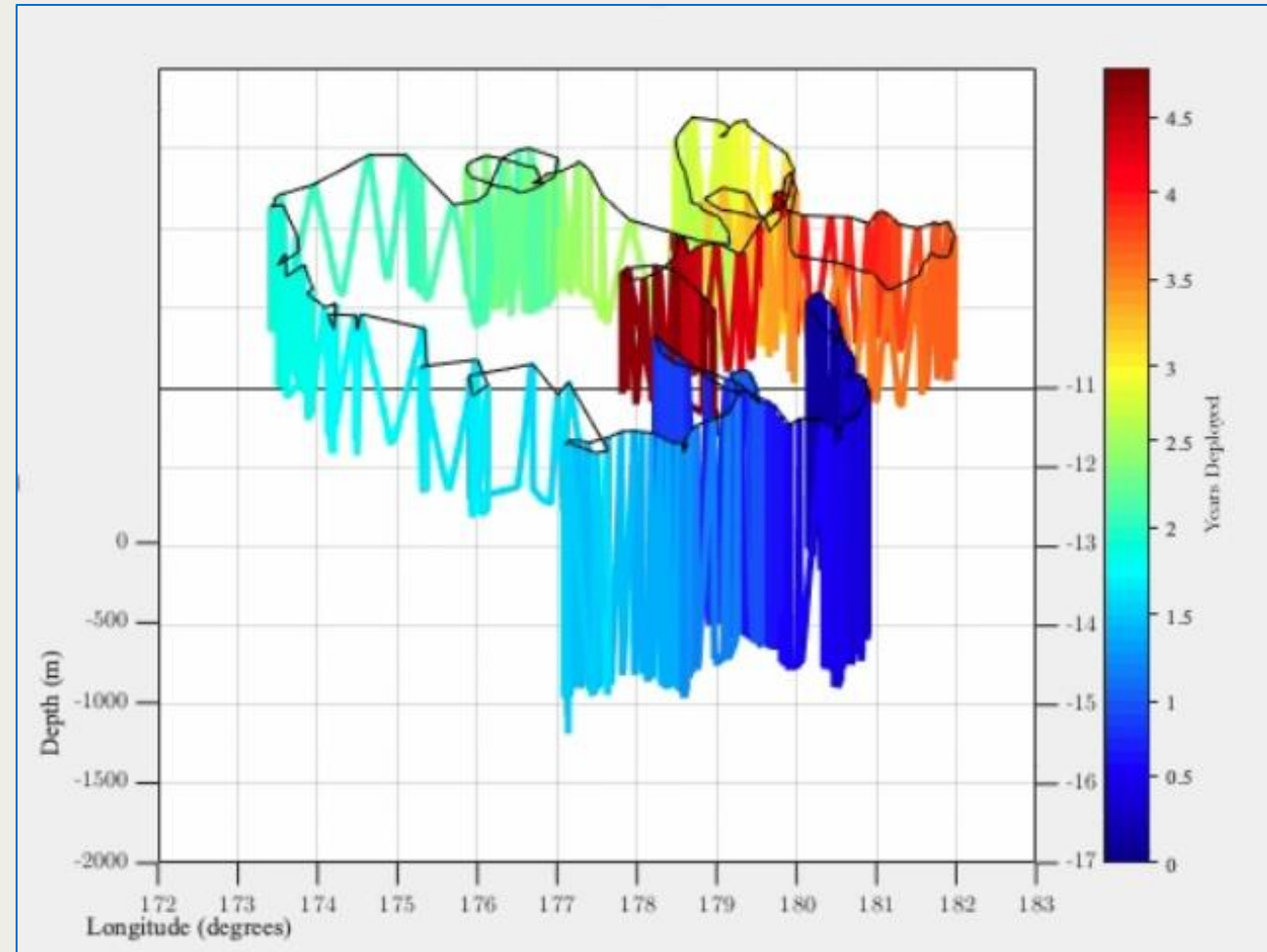
MERMAIDS Mobile Earthquake Recording in Marine Areas by Independent Divers

O4.3-165

- MERMAIDS are autonomous drifting floats
- Equipped with a hydrophone
- Operate at 1500m depth
- When a P wave is detected,
 - MERMAIDS rise to the surface
 - determines location via GPS,
 - synchronizes clock,
 - transmits data window
- The location at the time of recording is interpolated using data from multiple dives



GeoCSV was able to capture the metadata to allow others to reproduce their results



- Figure showing the 3D location of one MERMAID over the past 4.5 years



Introduction to GeoCSV files and RCM in Seismology

GeoCSV Headers

GeoCSV Column Headers and Fields

GeoCSV Fields

Time and
NSLC
Element

Position
Element

Sensor and
Gain Element

Timing
Element

Orientation
Element

Additional
Element

Start Time
End Time
Network
Station
Location
Channel

Latitude
Longitude
Elevation
Depth

Sensor Desc.
Scale Factor
Scale Freq.
Scale Units

Sample Rate
Time Delay
Time
Correction
Applied

Dip
Dip +/-
Azimuth
Az +/-

Parm 1
Parm 2
Parm 3
....
Parm N



GeoCSV Header

```
#dataset: GeoCSV
#created: 2025-06-09T22:15:37.918Z
#description: Metadata for drifting Mobile Earthquake Recording in Marine Areas by Independent Divers
(MERMAID) hydrophones, www.EarthScopeOceans.org
#attribution: automaid v4.3.2 (https://github.com/earthscopeoceans/automaid [doi:
10.5281/zenodo.5057096])
#matlab_reader: https://github.com/joelsimon/GeoCSV/blob/master/readGeoCSV.m
#waterpressure2depth: 100 mbar is approximately equal to the pressure of 1 meter of water
#frequency_response: http://ds.iris.edu/data/reports/MH/MH.Mermaids.Response.V3.pdf
#lineterminator: '\n'
#delimiter: ','
```



Column Identifiers- example for Geographic Position Fields

#field_unit: unitless	degrees_north	degrees_east	meters	meters
#Field_type: string	float	float	float	float
#MethodIdentifier	latitude	longitude	elevation	depth



A Sample MERMAID GeoCSV file

#dataset: GeoCSV																
#created: 2025-06-09T22:15:37.918Z																
#description: Metadata for drifting Mobile Earthquake Recording in Marine Areas by Independent Divers (MERMAID) hydrophones, www.EarthScopeOceans.org																
#attribution: automaid v4.3.2 (https://github.com/earthscopeoceans/automaid [doi: 10.5281/zenodo.5057096])																
#matlab_reader: https://github.com/joelsimon/GeoCSV/blob/master/readGeoCSV.m																
#waterpressure2depth: 100 mbar is approximately equal to the pressure of 1 meter of water																
#frequency_response: http://ds.iris.edu/data/reports/MH/MH.Mermaids.Response.V3.pdf																
#lineterminator: '\n'																
#delimiter: ','																
#field_unit: unitless	iso8601	unitless	unitless	unitless	unitless	unitless	degrees_north	degrees_east	meters	mbar	unitless	hertz	unitless	seconds	seconds	
#field_type: string	datetime	string	string	string	string	string	float	float	float	float	string	float	integer	float	float	
MethodIdentifier	StartTime	Network	Station	Location	Channel	DataQuality	Latitude	Longitude	Elevation	WaterPressure	InstrumentDescription	SampleRate	SampleCount	TimeDelay	TimeCorrection	
Measurement:GPS:u-blox_NEO-M8N	2018-06-27T19:16:42.000Z	MH	P0006	nan	nan	nan	-14.453383	-179.485031	nan	nan	MERMAIDHydrophone(452.020)	nan	nan	0	nan	
Measurement:GPS:u-blox_NEO-M8N	2018-06-27T19:16:53.000Z	MH	P0006	nan	nan	nan	-14.4534	-179.485031	nan	nan	MERMAIDHydrophone(452.020)	nan	nan	0	nan	
Measurement:GPS:u-blox_NEO-M8N	2018-06-27T19:21:53.000Z	MH	P0006	nan	nan	nan	-14.45365	-179.485153	nan	nan	MERMAIDHydrophone(452.020)	nan	nan	-0.000031	nan	
Measurement:GPS:u-blox_NEO-M8N	2018-06-27T19:22:04.000Z	MH	P0006	nan	nan	nan	-14.453667	-179.485153	nan	nan	MERMAIDHydrophone(452.020)	nan	nan	-0.000031	nan	
Measurement:Pressure:KELLER_Series_6	2018-06-27T19:28:03.000Z	MH	P0006	nan	nan	nan	nan	nan	nan	730	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	
Algorithm(thermocline):automaid:v4.3.2	2018-06-27T19:35:41.808Z	MH	P0006	nan	nan	nan	-14.454387	-179.485443	nan	5000	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	
Measurement:Pressure:KELLER_Series_6	2018-06-27T19:43:55.000Z	MH	P0006	nan	nan	nan	nan	nan	nan	9590	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	
Measurement:Pressure:KELLER_Series_6	2018-06-27T20:00:10.000Z	MH	P0006	nan	nan	nan	nan	nan	nan	16050	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	
Measurement:GPS:u-blox_NEO-M8N	2018-08-02T11:40:17.000Z	MH	P0006	nan	nan	nan	-14.131583	-179.773087	nan	nan	MERMAIDHydrophone(452.020)	nan	nan	0	nan	
Measurement:GPS:u-blox_NEO-M8N	2018-08-02T11:40:28.000Z	MH	P0006	nan	nan	nan	-14.131567	-179.773087	nan	nan	MERMAIDHydrophone(452.020)	nan	nan	0	nan	
Measurement:Pressure:KELLER_Series_6	2018-08-02T11:47:53.000Z	MH	P0006	nan	nan	nan	nan	nan	nan	560	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	
Algorithm(thermocline):automaid:v4.3.2	2018-08-02T11:58:36.069Z	MH	P0006	nan	nan	nan	-14.130936	-179.773331	nan	5000	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	
Measurement:Pressure:KELLER_Series_6	2018-08-02T12:09:09.000Z	MH	P0006	nan	nan	nan	nan	nan	nan	9370	MERMAIDHydrophone(452.020)	nan	nan	nan	nan	



Ross Ice Shelf Example of Time & NSCL, Position

#dataset: GeoCSV 2.0									
#created: 2023-06-17T12:25:20Z									
#Reference url: http://ds.iris.edu/data/reports/XH_2014_2017/									
#delimiter: ','									
#lineterminator: '\n'									
#field_unit	ISO8601	unitless	unitless	unitless	unitless	degrees_north	degrees_east	meters	meters
#field_type	datetime	string	string	string	string	float	float	float	float
Method/Identifier	StartTime	Network	Station	Location	Channel	Latitude	Longitude	Elevation	Depth
GPS Q330 GPS Clock	2014-12-31T23:00:40Z	XH	DR01	*	*	-77.77508	178.34172	30	0
GPS Q330 GPS Clock	2015-12-31T03:10:28Z	XH	DR01	*	*	-77.76594	178.34611	19	0
GPS Q330 GPS Clock	2016-01-20T01:08:44Z	XH	DR01	*	*	-77.75806	178.34989	16	0
GPS Q330 GPS Clock	2014-12-31T23:30:38Z	XH	DR05	*	*	-78.64047	-179.09994	19	0
GPS Q330 GPS Clock	2015-12-31T22:50:24Z	XH	DR05	*	*	-78.63164	-179.09239	9	0
GPS Q330 GPS Clock	2016-11-16T17:53:01Z	XH	DR05	*	*	-80.86433	178.43481	8	0
GPS Q330 GPS Clock	2014-12-31T23:43:19Z	XH	RS01	*	*	-78.18889	169.96239	14.3	0
GPS Q330 GPS Clock	2015-12-31T17:58:39Z	XH	RS01	*	*	-78.18333	169.965	1.4m	0



Orientation Element Onshore/Offshore OBS Example

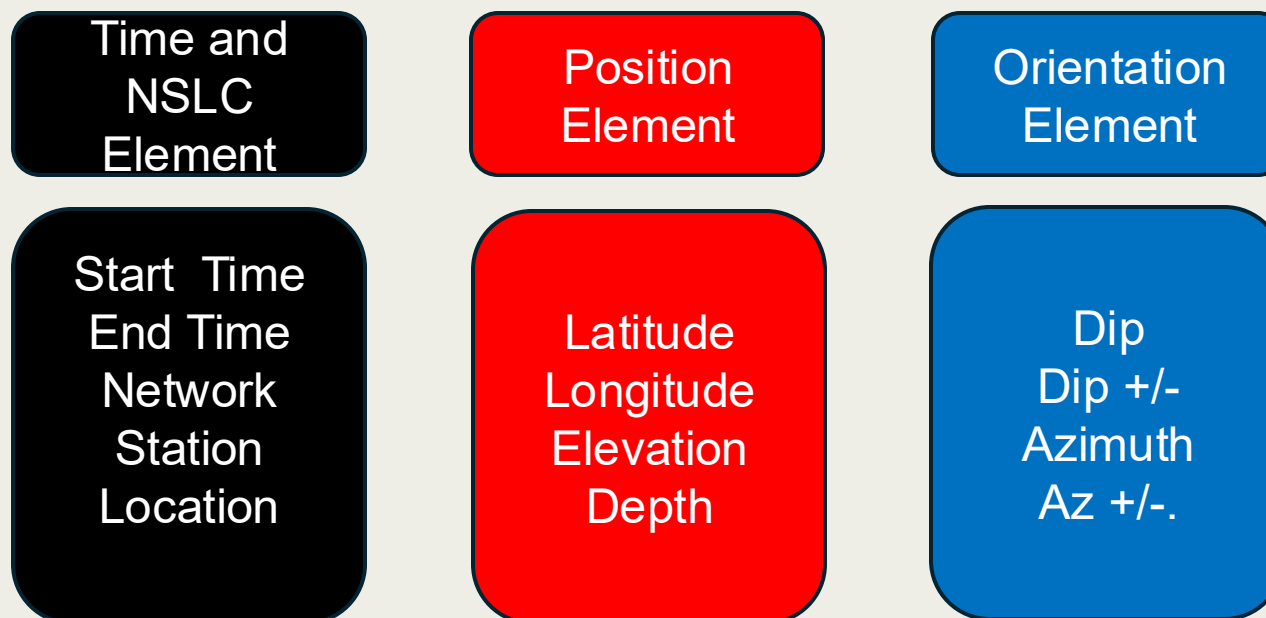
#dataset: GeoCSV 2.0								
#created: 2023-06-19T18:52:20Z								
#Reference doi: 10.1785/0120160165								
#delimiter: ','								
#lineterminator: '\n'								
#field_unit	ISO8601	unitless	unitless	unitless	unitless	SEED Convention	Seed Convention	azimuth uncertainty
#field_type	datetime	string	string	string	string	float	float	float
Method/Identifier	StartTime	Network	Station	Location	Channel	dip	azimuth	azimuthal uncertainty
DLOpy	2006-04-22T00:00:00Z	YS	PL38	0	BH1	-90	179.37	2.20
STACH	2006-04-22T00:00:00Z	YS	PL38	0	BH1	-90	179.58	7.10
Laske et al	2006-04-22T00:00:00Z	YS	PL38	0	BH1	-90	178.60	0.73
DLOpy	2006-04-22T00:00:00Z	YS	PL40	0	BH1	-90	168.32	1.00
STACH	2006-04-22T00:00:00Z	YS	PL40	0	BH1	-90	278.38	3.61
Laske et al	2006-04-22T00:00:00Z	YS	PL40	0	BH1	-90	277.14	0.87
DLOpy	2006-04-22T00:00:00Z	YS	PL47	0	BH1	-90	277.13	1.14
STACH	2006-04-22T00:00:00Z	YS	PL47	0	BH1	-90	278.38	3.61

Orientation Element



Include only the RCM elements you need

- For instance, consider a seismometer on a glacier that is changing position rapidly and whose orientation is also changing due to changes in the direction of the surface of the glacier





Making GeoCSV information Available

- Including GeoCSV into SEED StationXML
 - Option 1: append needed GeoCSV information at the end of a StationXML file
 - Option 2: provide a pointer to an external file at the station or channel level in SEED StationXML at the station or channel level of StationXML.
- **RECOMMENDATION:** Due to the large size of some GeoCSV files and aware that other use cases have modest sizes, the path forward should support both options 1 and/or 2 above.



Summary

- GeoCSV files have enabled projects to capture RCM in a straightforward and efficient manner
- The format enables FAIRness by identifying what the fields contain and what variable types they are
- GeoCSV is flexible as new elements can be added when needed
- GeoCSV can document how derived metadata was obtained to even the level of what algorithms were used
- GeoCSV is an easy way to capture objects that make the data FAIR
- GeoCSV can be included in StationXML in a straightforward manner supporting both external links or appended directly at the end of StationXML files.



Thank you for your attention