New tools for ADCP processing

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2021

Canadian Technical Report of Hydrography and Ocean Sciences 336

Fisheries and Oceans Canada   Pêches et Océans Canada

Canada

Canadian Technical Report of Hydrography and Ocean Sciences

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Cat. No. Fs 97-18/336E-PDF ISBN 978-0-660-40199-7 ISSN 1488-5417

Correction citation for this publication:

Hourston, H. G., Wan, D., and Guan, L. 2021. New tools for ADCP data processing. Can. Tech. Rep. Hydrogr. Ocean Sci. 336: vi + 36 p.

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Abstract

Hourston, H. G., Wan, D., and Guan, L. 2021. New tools for ADCP data processing. Can. Tech. Rep. Hydrogr. Ocean Sci. 336: vi + 36 p.

This report describes the Python package, *pycurrents_ADCP_processing*, we have developed for processing Acoustic Doppler Current Profiler (ADCP) data at the Institute of Ocean Sciences (IOS). The package allows a user to perform three different levels of processing on raw ADCP data, filter out tides, plot the data, and combine the data with corresponding metadata to export the whole in self-describing netCDF file format. The IOS ADCP netCDF files are now accessible on the IOS Water Properties website and on the CIOOS Pacific ERDDAP server. Raw ADCP data can be processed using the Python package or using the new web app developed from the package.

Résumé

Hourston, H. G., Wan, D., and Guan, L. 2021. New tools for ADCP data processing. Can. Tech. Rep. Hydrogr. Ocean Sci. 336: vi + 36 p.

Ce rapport détaille le paquet Python, *pycurrents_ADCP_processing*, que nous avons developpé pour faire la traitement de données des courantomètres acoustiques à effet doppler (ADCP, Acoustic Doppler Current Profiler) à l'Institut de sciences océanographiques (IOS, Institute of Ocean Sciences). Ce paquet permet aux utilisateurs de réaliser trois niveaux de traitement des données brutes d'ADCP, de filtrer les courants des données, de tracer les données, et de combiner les données avec les métadonnées enfin de les exporter en format netCDF auto-descriptif. Les données d'ADCP à IOS sont maintenant disponibles en ce format-là sur le site web IOS Water Properties, ainsi que sur le serveur ERDDAP de SIOOC Pacifique. La traitement des données d'ADCP peut être réaliser utilisant le paquet Python ou utilisant la nouvelle application web qui fut developpée de ce paquet.

1 Introduction

Acoustic Doppler Current Profilers (ADCPs) are oceanographic instruments that use sound to measure current velocities. ADCPs emit pings of sound that reflect off particles suspended in the water column, and the instrument uses the travel time to calculate the speed and direction in which the water is travelling. Ship-bourne, lowered, and moored varieties of this instrument exist, the third being the variety primarily used by the Ocean Sciences Division, Institute of Ocean Sciences (OSD IOS). The OSD has been deploying moored ADCPs off the coast of British Columbia since 1998, at a total of 85 stations located in waters around Vancouver Island and as far north as Hecate Strait. The data from these ADCPs continues to help build a better picture of the tides and currents in the area and improve our understanding of how these influence the surrounding environment.

Little had been done until recently to package the raw ADCP data and metadata into a more accessible format. Following the launch of the IOS Water Properties website, an online collaboration and data holdings tool, ASCII-format (.adcp) files containing both raw ADCP data and metadata were made to enable the ADCP data to be searchable on Water Properties. This was an important step for the data, as the .adcp files had also undergone high-level processing. However, the .adcp format itself does not support multidimensional data (such as ADCP data) well and is difficult to parse. Following organisations such as the British Oceanographic Data Centre (BODC), the decision was made to produce netCDF-format files from the OSD ADCP data given their greater ease of access, support for multidimensional data and support for other languages besides English.

This report will describe the Python package we have developed for processing and plotting ADCP data and exporting them as netCDF files, along with the decision-making process behind the three different levels created, the tidal filtering features, and future plans for the package.

2 Methods

2.1 Accessibility

In order to keep accessibility a priority, we chose to create a processing package in Python using the UHDAS *pycurrents* package to decode raw binary ADCP data, following the suggestion of Jody Klymak. For users unfamiliar with Python, we also present a web app for processing ADCP data based on the Python package.

2.2 Processing levels

We decided to create three different levels of processing, so that users would have the option to apply their own processing methods if preferred.

Level 0 (L0) processing would consist of no processing, only the translation of raw ADCP data to netCDF format and the addition of metadata to make the dataset self-describing.

From there, users could choose to apply their own processing methods to the output netCDF data.

Level 1 (L1) would be provide an alternative to L0 in that it would include low-level processing on the raw ADCP data in addition to adding metadata in the same way as in L0. Processing would consist of corrections for magnetic declination, flagging of data collected before deployment and after recovery of the instrument as “bad”, flagging of negative pressure values as “bad”, calculation of sea surface height from pressure values and latitude, flagging remaining data as “no quality control” and rotation into ENU coordinates if the data were in beam or xyz coordinates. All flagging would be performed following the BODC SeaDataNet Quality Control flagging scheme (BODC, 2020) given in Table 1. The flagging methods are robust in that they require limited expertise on the data type and little human intervention during processing. For files without pressure sensor data, pressure would be calculated from static instrument depth using the computationally-efficient 75-term expression for specific volume from the TEOS-10 Gibbs Seawater toolbox (McDougall et al., 2011).

Level 2 (L2) would build on L1 processing and consist of flagging bins where calculated pressure is negative and flagging bins where beam-averaged backscatter increases. Both methods are performed time step by time step to maximize flagging accuracy. The latter method was performed on the original .adcp files using the median bin over time where backscatter started increasing, but by proceeding time step by time step and by flagging those data as "probably_bad" and keeping them instead of removing them, less good data is likely to be lost. The remaining data would be flagged as “probably good” under the BODC SeaDataNet Quality Control flagging scheme. For files without pressure sensor data, an additional variable for pressure would be created containing pressure data derived from CTD pressure sensor data from the same mooring line. These methods require more expert interpretation of the data and more "human intervention", particularly for calculating pressure from CTD data, hence why they are classed within a higher processing level than L1.

2.3 ADCP header files

Having ADCP files in netCDF format eliminates the need for including their data in the ASCII .adcp files, but files in the ASCII IOS header file format are still required for searching data on the IOS Water Properties website. Hence, a Python function to produce .adcp files containing metadata but not data was identified as a priority. Such a function would need an input L1 netCDF file and would output an ASCII .adcp file containing only metadata, which would replace the original .adcp file that contained data, if it existed.

2.4 Tidal analysis methods

Tidal filtering is often applied to time series data. Applying a running (or rolling) average to time series data serves to filter out tides, which can allow longer-term trends in the time series to stand out. Such options for filtering out tides would be useful for interpreting Northward and Eastward current velocity data from ADCPs. We opted to offer three low-pass filters (filters that eliminate higher frequencies in data) that could be applied to any of L0-, L1-, or L2-processed ADCP data.

Two of the options for filtering would be the 30-hour and 35-hour running averages, which are some of the simplest tidal filters. The other option offered is the more robust, "tide-killer" Godin filter. The Godin filter consists of applying a 24-24-25-hour running average (Godin, 1972). While this filter is known for its relatively slow transition between the pass- and stop-bands leading to unwanted attenuation of nontidal variability in the range of 2-3 days (Thomson and Emery, 2014), it is sufficient for our purposes given its effectiveness in removing tidal signals from time series data.

3 Results

3.1 Processing

The L0, L1, and L2 processing scripts were tested on the whole of the IOS ADCP data holdings. After the completion of this testing, the scripts were uploaded to GitHub as part of a Python package called *pycurrents_ADCP_processing* (Hourston et al., 2020), named after the University of Hawaii's *pycurrents* package that was used to read raw ADCP data into Python. *pycurrents_ADCP_processing* is freely available for download on GitHub. An example of the header section of an L1 netCDF ADCP, showing all dimension names, variable names, and attributes contained within the file, is given in Appendix B.

A script for producing IOS header format files from L1 netCDF ADCP files was written by Lu Guan of the IOS Data Product Team. An example of such a file, containing all variable names and metadata in the file, is shown in Appendix C.

To date, all L1-processed ADCP data is available for download on the IOS Water Properties Website and on the Canadian Integrated Ocean Observing System (CIOOS) Pacific ERDDAP (Environmental Research Division's Data Access Program) server. The IOS Water Properties website provides access to all of the Institute's data holdings. CIOOS Pacific, a regional association of CIOOS, is a rapidly-growing open-access platform for a multitude of biological, biogeochemical, and physical oceanographic data collected in the Pacific Ocean off the coast of Canada (CIOOS, 2020).

Out of the 330 L1-processed netCDF ADCP files, 240 underwent L2 processing. 21 of the remaining files have not yet been processed since they were from the recently recovered 2019-2020 deployment, and the other 69 files originated from ADCPs without pressure sensors and were not processed because a CTD file containing pressure sensor data from the same mooring line as those ADCPs could not be found. A sample plot comparing pressure data derived from static instrument depth and from CTD pressure sensor data is given in Figure 1. A sample plot showing the result of flagging by negative pressure and by beam-averaged backscatter increases is shown in Figure 2. Flag values of 3, denoting “probably bad” values under the BODC SeaDataNet flagging scheme, are used to indicate increasing backscatter, while flag values of 4, denoting “bad values” under the same flagging scheme, are used to indicate negative calculated pressure values at that depth (i.e., depth is above the sea surface; Table 1). Backscatter increases in the second bin from the upward-facing instrument are ignored during flagging. The code for both plots is included in *pycurrents_ADCP_processing*.

3.2 Level-independent plotting and tidal filtering

pycurrents_ADCP_processing contains functions for making plots of backscatter data, principal component data, and velocity data (both raw and filtered), which can help the user better interpret ADCP data. These plots can be produced from any of L0-, L1-, or L2-processed netCDF ADCP data.

One type of plot that can be produced is a diagnostic plot that contains subplots of backscatter; Eastward, Northward, and upward velocity components; and principal component; each averaged over time and plotted over depth (Figure 3). The code for these plots was originally written in MatLab by David Spear and Roy Hourston and was translated into Python by the authors.

The other class of plots focuses on the Eastward and Northward currents, which can be plotted raw as in fig. 4. The Eastward and Northward currents can also be converted to along- and cross-shore currents and plotted (Figure 5). The along-shore angle, measured counter-clockwise from geographic East, is determined by iterating through the range of 0-180°, rotating the Eastward and Northward velocities by each angle in that range. The angle where the root-mean-square of those rotated velocities is maximized is taken as the along-shore angle.

These plots can be reproduced with tidal filtering applied, with filter options being 30-hour averaging, 35-hour averaging, and Godin filtering (24-24-25-hour averaging; Figures 6 and 7). Month-long bin plots comparing raw and filtered data can also be made, which show the effect of filtering on time series data up close (Figure 8).

As an example, a case study on station A1 involving the interpretation of these types of plots is given in Appendix A.

3.3 IOS ADCP processing web app

The web app, developed by Tom Roe, implements both L0 and L1 processing, along with all plotting capabilities listed in section 3.2. A screenshot of the web app page is shown in fig. 9. In the app, the user can generate a L0- and/or L1-processed netCDF file from an input raw ADCP file, with the option of creating the diagnostic and raw and filtered velocity plots from section 3.2. In the upper box of the landing page (“Process Acoustic Doppler Current Profiler (ADCP) Files”), users can select a raw ADCP file from their computer along with the file's associated CSV metadata file. A link to a CSV metadata template is also given in this box, along with the link to the *pycurrents_ADCP_processing* GitHub repository for reference. In the bottom box (“Plot Files”), the user can input an existing netCDF ADCP file and have plots created from this file. All outputs are packaged into a zip file which is downloaded automatically onto the user’s device. The IOS ADCP Processing web app can be accessed from the IOS Data Management (DM) Apps landing page at https://dmapps.waterproperties.ca/en/.

4 Discussion

4.1 Limitations

The main limitation of *pycurrents_ADCP_processing* is that the UHDAS *pycurrents* package used in *pycurrents_ADCP_processing* for reading in raw binary ADCP files only has support for Teledyne RDI ADCPs and not for instruments of other makes (e.g., SonTek, Nortek, etc.). As the University of Hawaii uses RDI ADCPs exclusively, it is unlikely that support for those other ADCPs will be added to *pycurrents* anytime soon. However, most of the code that does the processing could be reused for processing non-RDI ADCP data if a Python package for decoding raw, non-RDI ADCP data can be found. The DOLfYN package may be one such possibility for Nortek instruments (Kilcher, 2014), but this requires more research.

Another limitation of *pycurrents_ADCP_processing* concerns the orientation and deployment type of ADCPs whose data the package can process. Currently, only upwards- and downwards-facing moored ADCPs are supported, and not horizontal ADCPs, lowered ADCPs, or ship-bourne ADCPs.

The web app is limited for use on files below 100 MB in size, given that processing files of that size and larger can use around 22 GB of RAM. The majority of the ADCP files at IOS were below this size, making the web app a good alternative for those not familiar with Python.

4.2 Future plans

ADCP data collected in future deployments can be processed using either the Python package or the web app, provided that the raw ADCP files do not exceed 100 MB for the latter option.

In L1, automation of the flagging of ensembles recorded before deployment and after recovery may be implemented to further facilitate processing for users, but this requires further discussion.

Next steps for L2 processing would be to find CTD files from the same mooring lines as the remaining unprocessed L1 ADCP files (if they exist) and process those L1 files, upload all L2 ADCP files to Water Properties and to the CIOOS ERDDAP server, and make L2 processing available on the web app.

There are several other improvements that could be made to the web app. 30- and 35-hour averaging for current velocity data are other options for tidal filtering in the *pycurrents_ADCP_processing* package that can be added. The user could then choose between these options and Godin filtering. Further, an option could be made for users to input their own along-shore angle for plotting along- and cross-shore current velocities, so that plots of that data using both the user-entered angle and the angle calculated with RMS analysis by the program can both be generated for the user to compare.

Higher levels of processing that would build upon L2 have not yet been discussed in detail. One possibility is to flag data by a certain percent good threshold, but there are no immediate plans for this.

5 Conclusion

The *pycurrents_ADCP_processing* Python package and the IOS ADCP Processing web app are two new tools for processing raw ADCP data and exporting them in netCDF format. Using the Python package, all ADCP data collected by the IOS OSD between 1998 and 2020 have now undergone L1 processing and are available for download from the IOS Water Properties website and from the CIOOS Pacific ERDDAP server. ADCP data collected on future deployments can be processed using either the Python package or the web app.

Acknowledgements

The authors would like to thank the IOS Mooring Group for their work in deploying and recovering the ADCPs. The authors are also grateful to David Spear for answering questions about moorings, to Roy Hourston for his early work on processing ADCP data, and to both for their ADCP data plotting code contributions. Special thanks go to Tom Roe for his work in implementing the package in the IOS ADCP Processing web app. The authors would also like to thank Pramod Thupaki and Jessy Barrette for their feedback during the package beta-testing process, Eric Firing and Jules Hummon at the University of Hawaii for answering questions about decoding raw ADCP data, and Jody Klymak for his useful suggestions on ADCP processing that helped the development of this work.

Table 1: The British Oceanographic Data Centre (BODC) SeaDataNet Quality Control flagging scheme (BODC, 2020).

Flag	Description
0	No quality control
1	Good
2	Probably good value
3	Probably bad value
4	Bad value
5	Changed value
6	Value below detection
7	Value in excess
8	Interpolated value
9	Missing value
A	Value phenomenon uncertain
B	Nominal value
Q	Value below limit of quantification

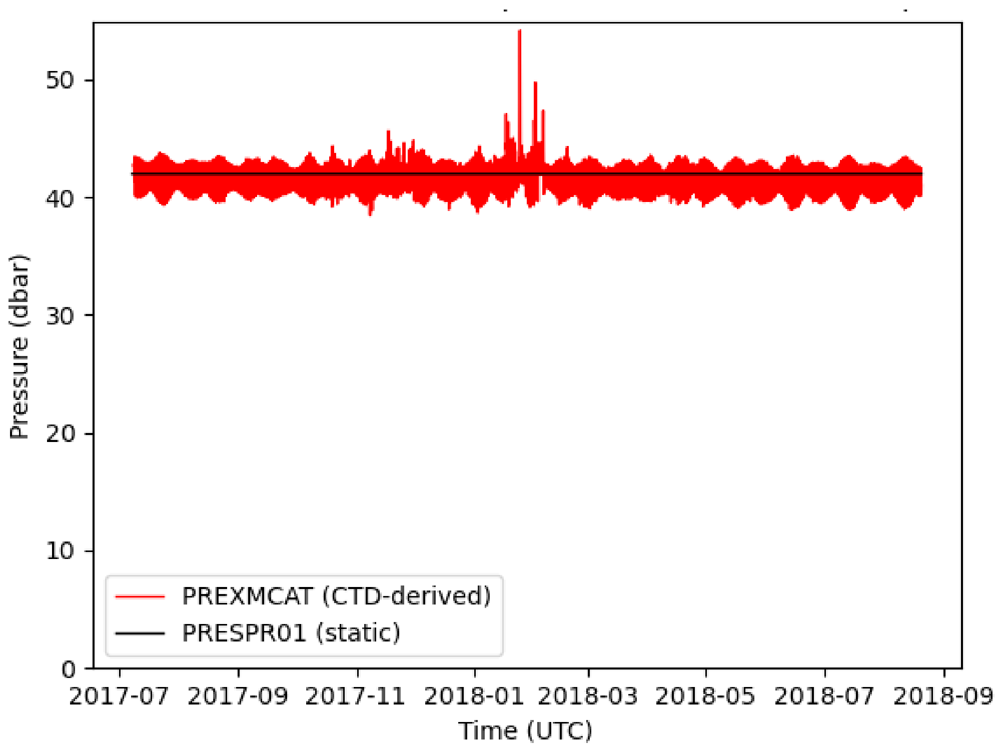

Figure 1: SCOTT2-2 WH3694 at 41.2 m depth with pressure data derived from static instrument depth using the TEOS-10 75-term equation for specific volume and pressure data derived from CTD pressure from the same mooring line.

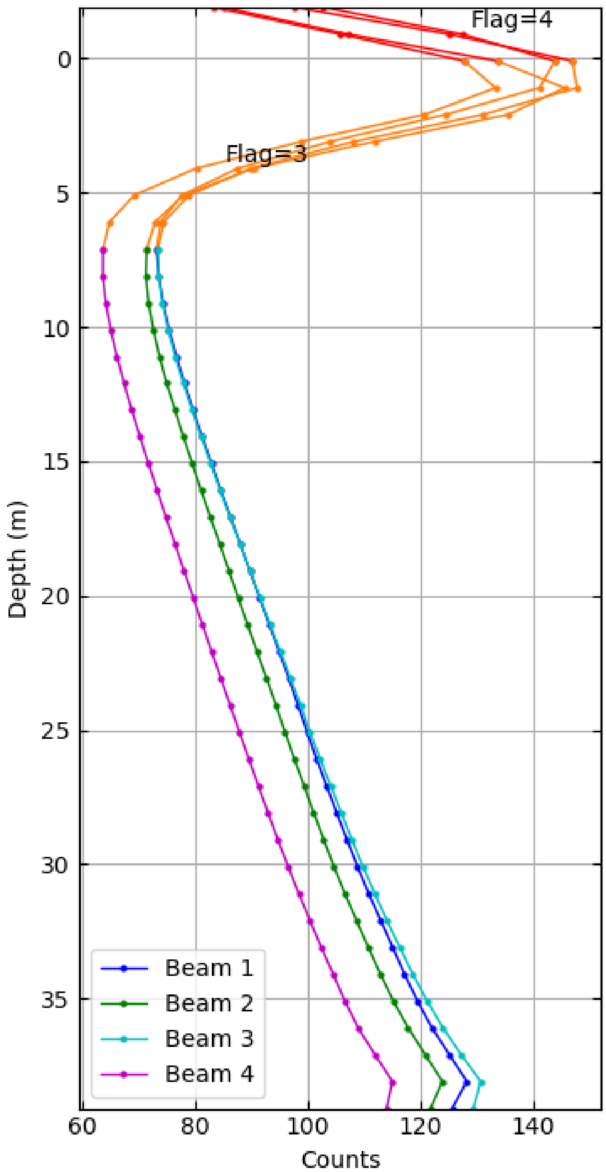

Figure 2: SCOTT2-2 WH3694 at 41.2 m depth with L2 flagging by beam-averaged backscatter increases and pressure mapped over backscatter over depth. Flagging follows the British Oceanographic Data Centre (BODC) SeaDataNet Quality Control flagging scheme; flag = 3 indicates a "probably bad value" and flag = 4 indicates a "bad value".

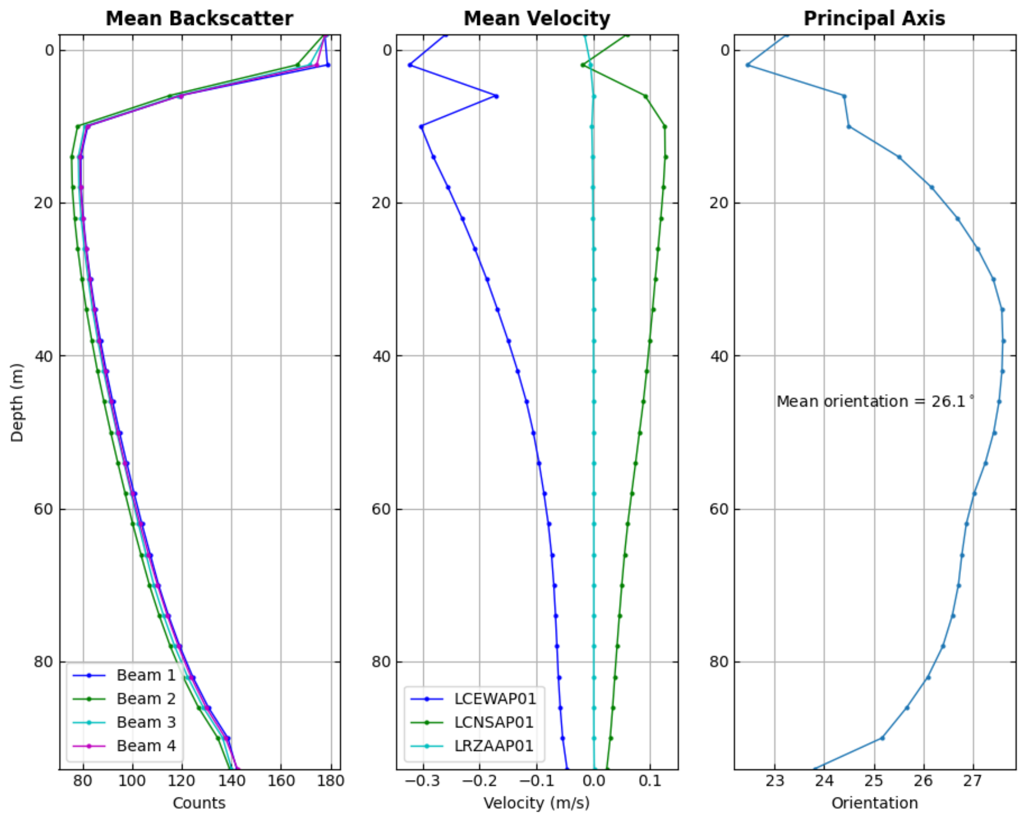

Figure 3: Diagnostic plot of BP1-51 WH8942 at 100.0 m depth showing time-averaged beam backscatter, velocity, and principal component plotted over depth. The code was adapted from David Spear and Roy Hourston. LCEWAP01: BODC P01 code for the Eastward current velocity component; LCNSAP01: BODC P01 code for the Northward current velocity component; LRZAAP01: BODC P01 code for the upward current velocity component.

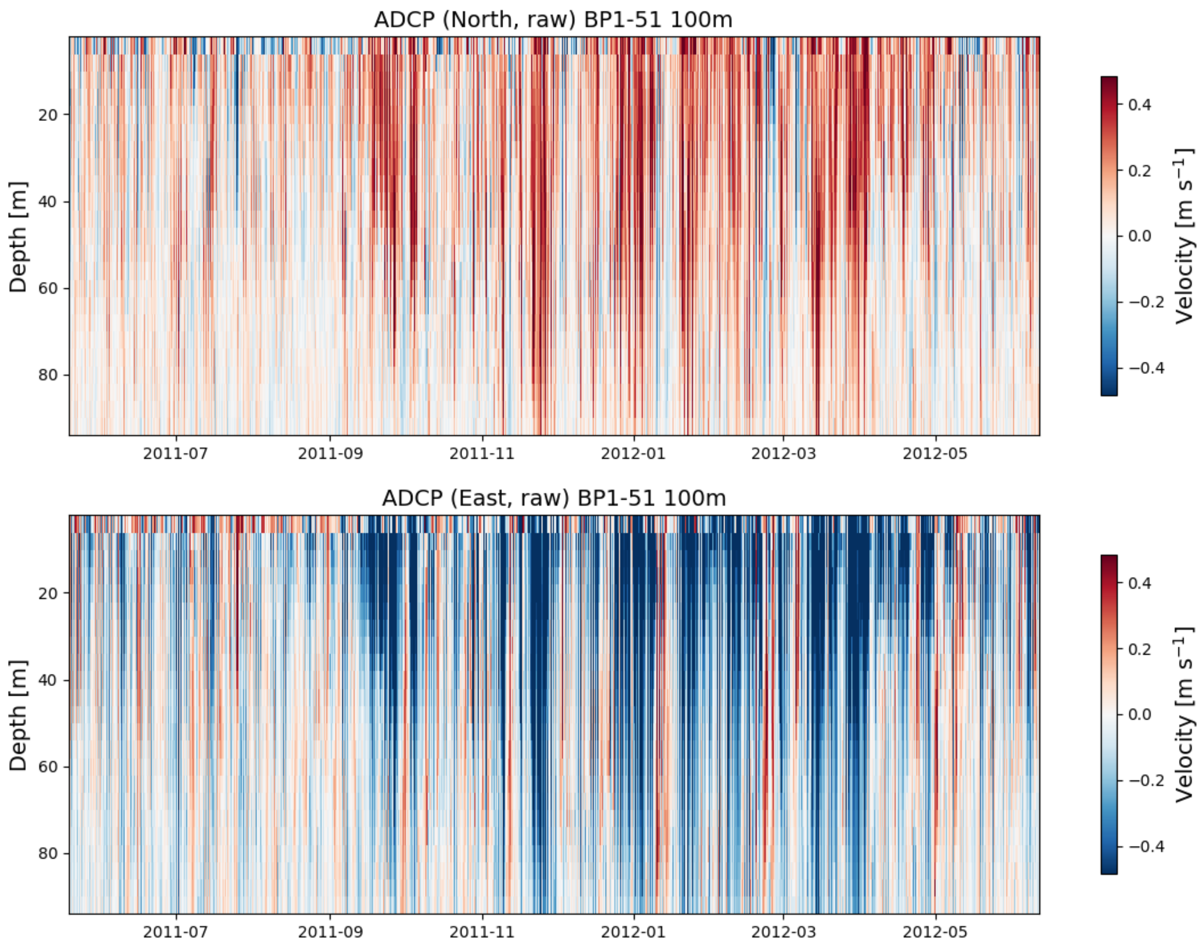

Figure 4: BP1-51 Northward and Eastward current velocity components (raw).

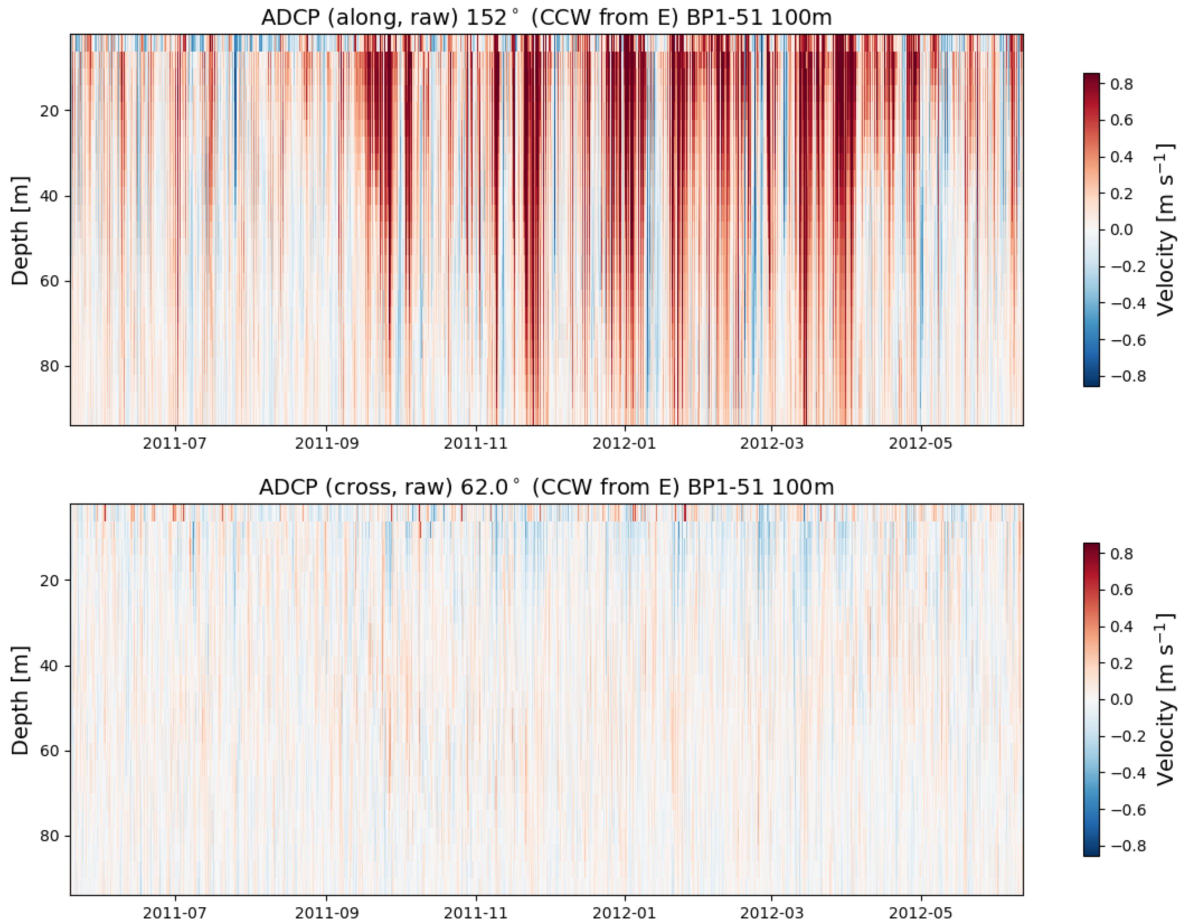

Figure 5: BP1-51 along- and cross-shore current velocity components (raw).

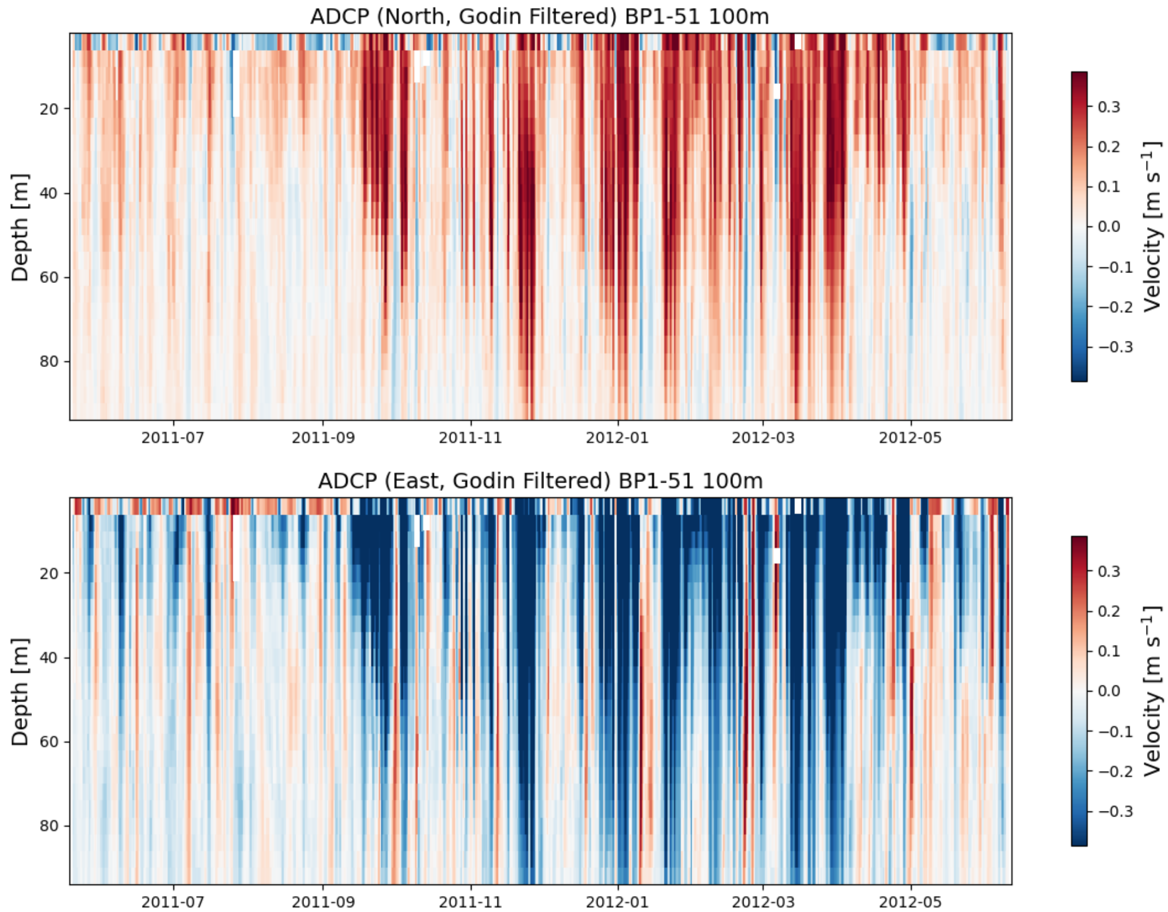

Figure 6: BP1-51 Eastward and Northward current velocity components (Godin-filtered).

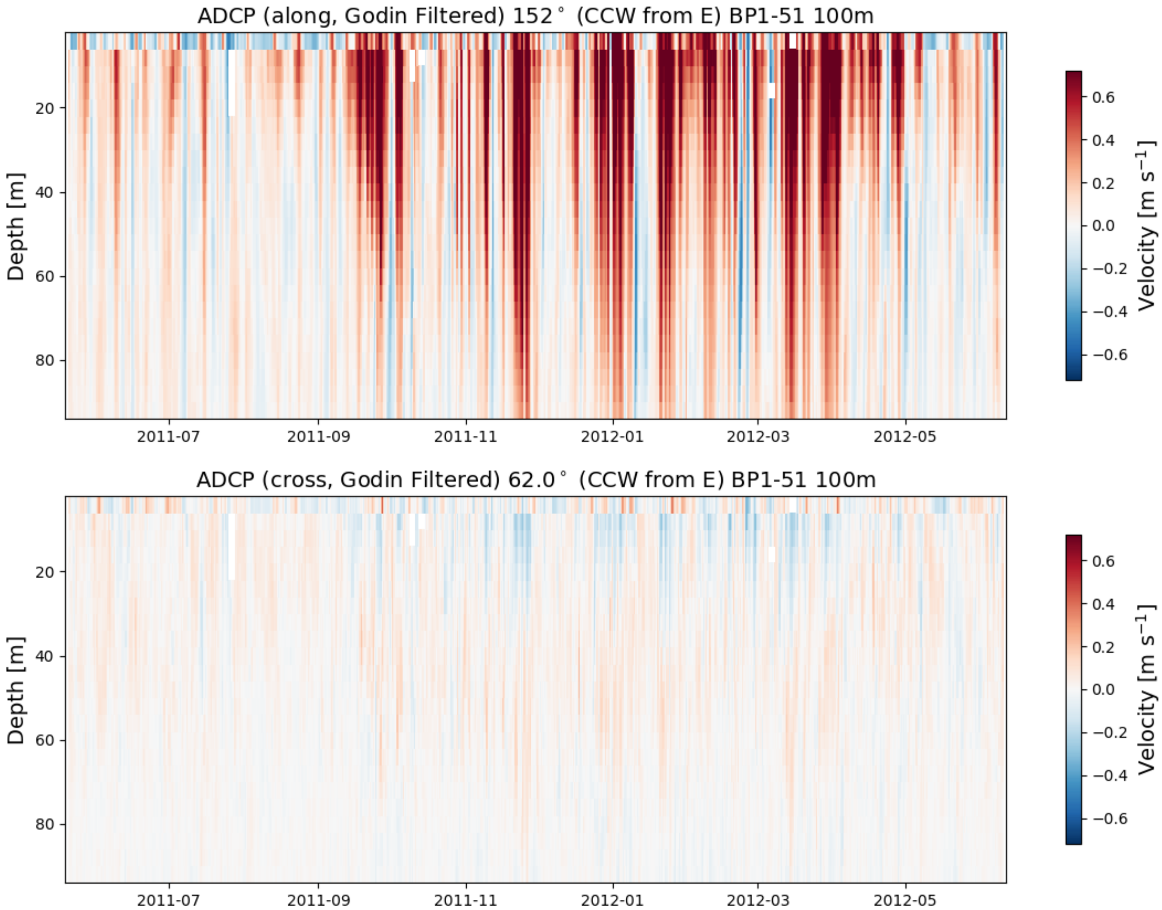

Figure 7: BP1-51 along- and cross-shore current velocity components (Godin-filtered).

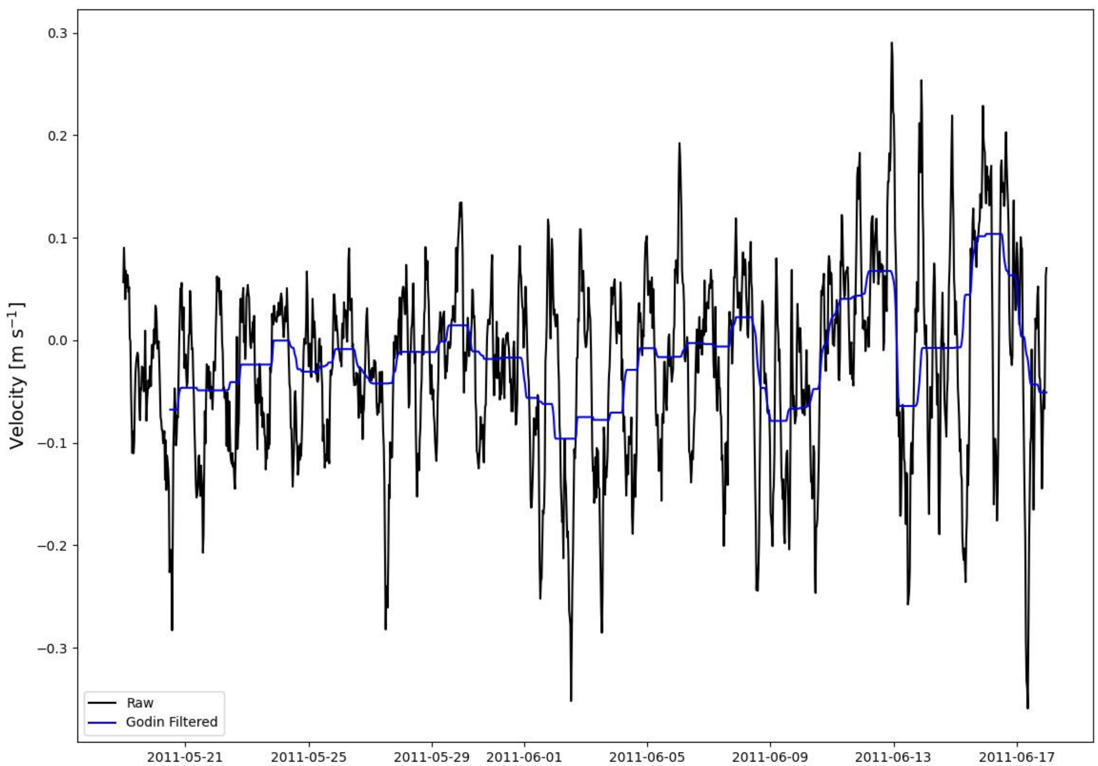

Figure 8: BP1-51 bin 1 Eastward current velocity component (LCEWAP01): Godin-filtered and raw.

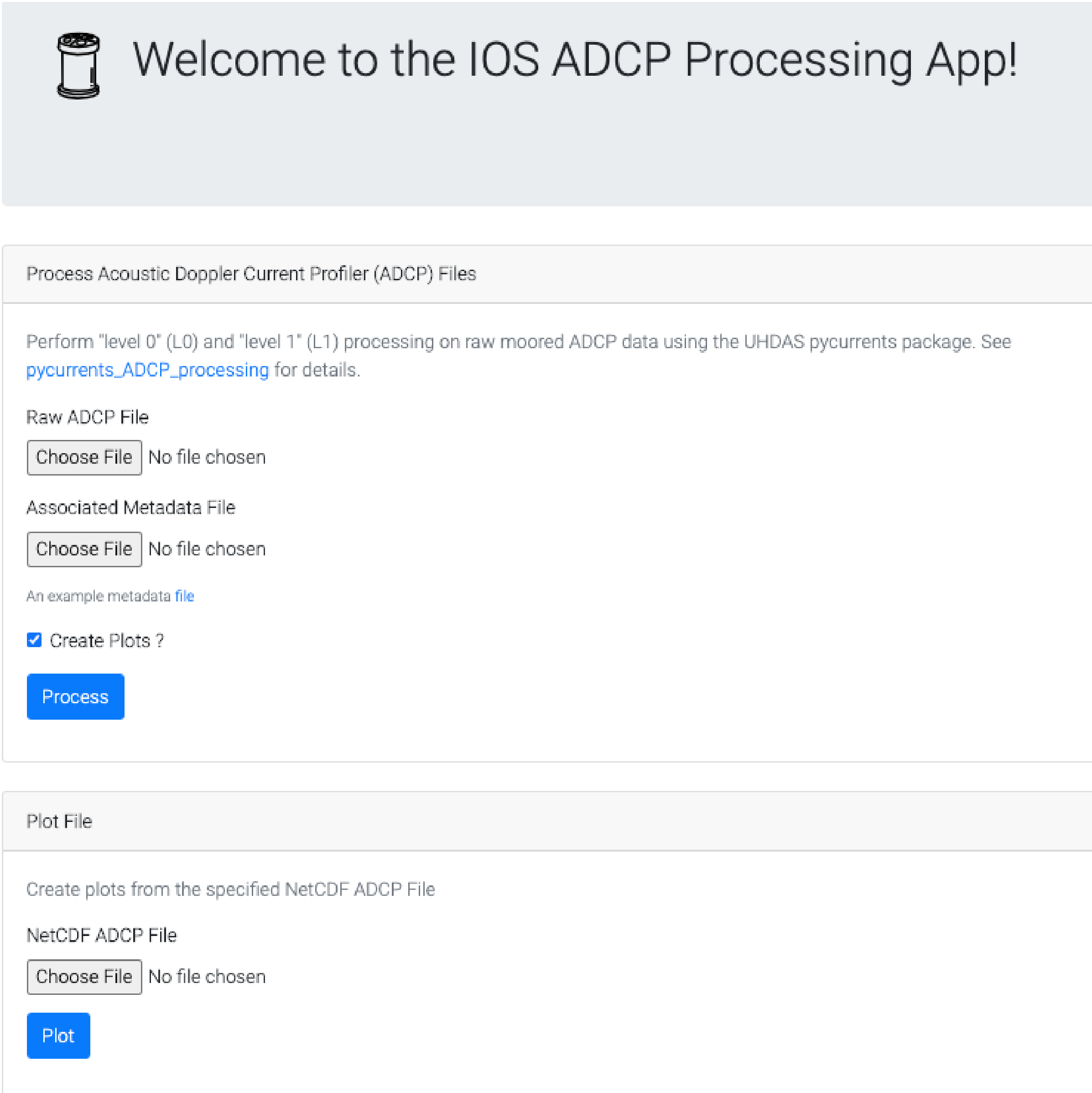

Figure 9: The IOS ADCP Processing App landing page. The app can be accessed from the IOS Data Management (DM) Apps home page at https://dmapps.waterproperties.ca/en/.

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National Oceanographic Data Centre: British Oceanographic Data Centre (BODC). Metadata Report for BODC Series Reference Number 37006. https://www.bodc.ac.uk/data/documents/series/37006/. Accessed: 2020-09-04.

Thomson, R. E., and Emery, W. J. Data Analysis Methods in Oceanography. Elsevier, Waltham, Massachusetts and Kidlington, Oxford and Amsterdam, The Netherlands, 2014.

Appendix A Case study at station A1

The following sample study centering on station A1 (Figure A.1) will demonstrate how the diagnostic and tidal-filtered ADCP plots can contribute to the understanding of longer-term trends in current speeds in the area.

The diagnostic plots are particularly useful for interpreting ADCP data. In Figure A.2, L1-processed data from the A1-56 upwards-facing ADCP are shown. The first subplot shows backscatter increases towards the sea surface which are indicative of "probably bad" data (flag value = 3 under the BODC SeaDataNet flagging scheme; Table 1) and are used for flagging in L2 processing. In the second subplot, increased variation in current velocity towards the sea surface may also be indicative of "bad data" (flag value = 4 under the BODC SeaDataNet flagging scheme), but variation is also expected at the surface where the influence of wind is a more significant factor.

In the third subplot, a decrease in principal axis angle from the surface towards the ocean floor provides evidence of an Ekman spiral. Indeed, the median principal component of winds over the period of 2005-2017 measured by the nearby Environment and Climate Change Canada buoy 46206 was 26.6° counter-clockwise from geographic North, while the median principal axis at station A1 over that same period was measured to be 6.0° counter-clockwise from geographic North, or 20.6° clockwise from the wind principal axis.

Evidence of long-term net transport in the along-shore direction is evident in the third subplot. This follows the North Pacific Current off the coast of British Columbia (Figure. A.3), whose flow direction is influenced by Coriolis force (e.g., Checkley et al., 2009 and Cheng et al., 2014). Figure A.4 also shows evidence of this: along-shore transport is primarily in the positive direction near the top of the water column during the fall months through mid-spring.

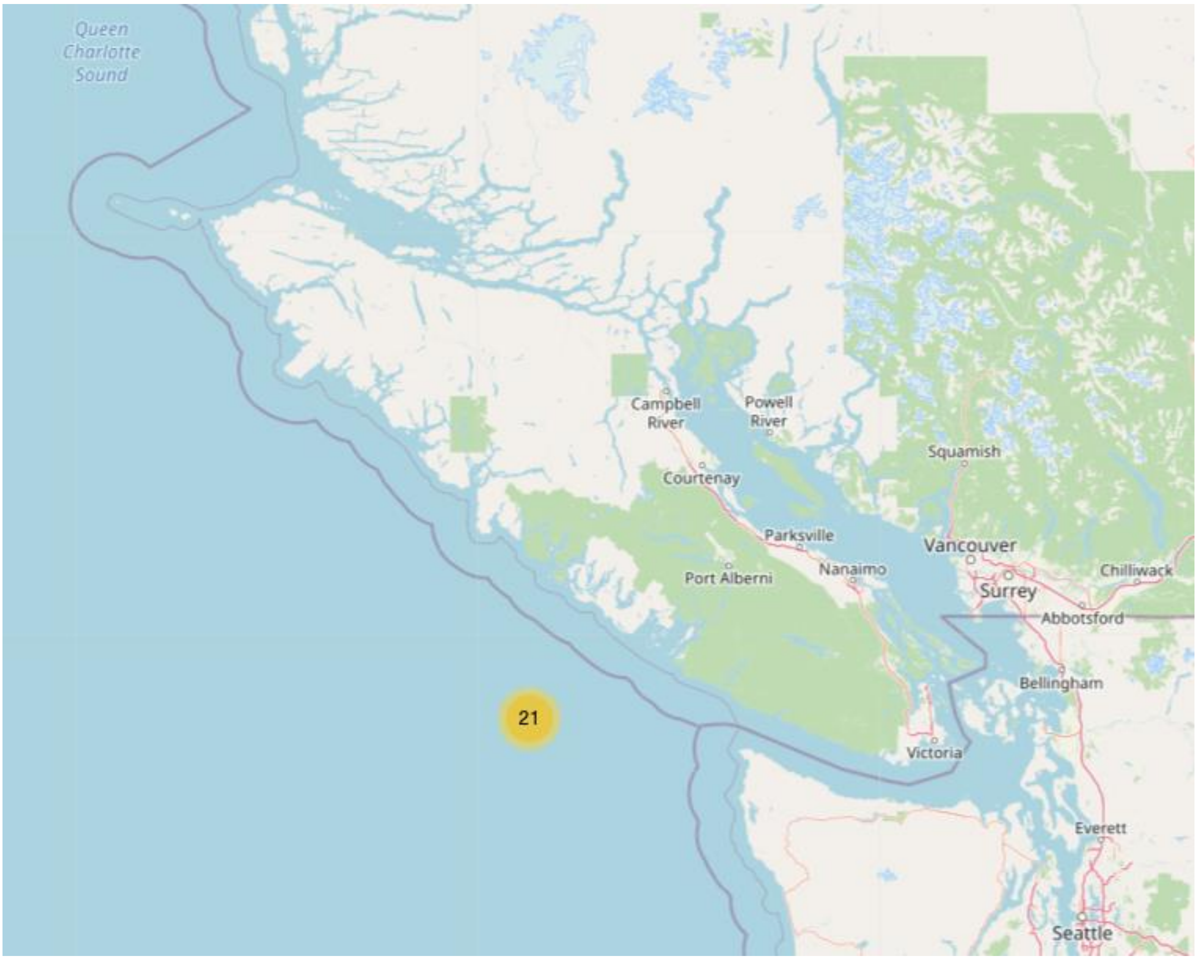

Figure A.1: Water Properties map showing the location of station A1 (latitude = 48.5°, longitude = -126.2°) and the number of ADCP data files on the website from that station (21).

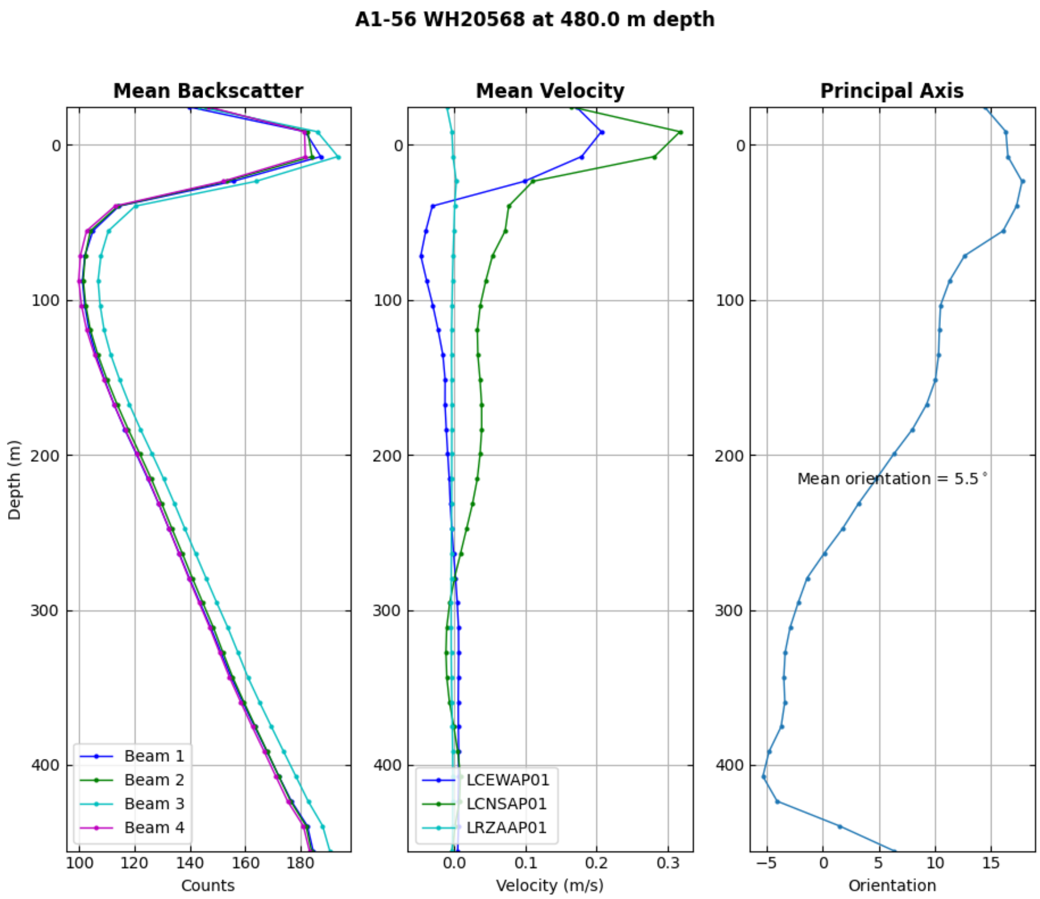

Figure A.2: Diagnostic plot of A1-56 WH20568 at 480.0 m depth (raw). LCEWAP01=BODC P01 code for the Eastward current velocity component; LCNSAP01=BODC P01 code for the Northward current velocity component; LRZAAP01=BODC P01 code for the upward current velocity component.

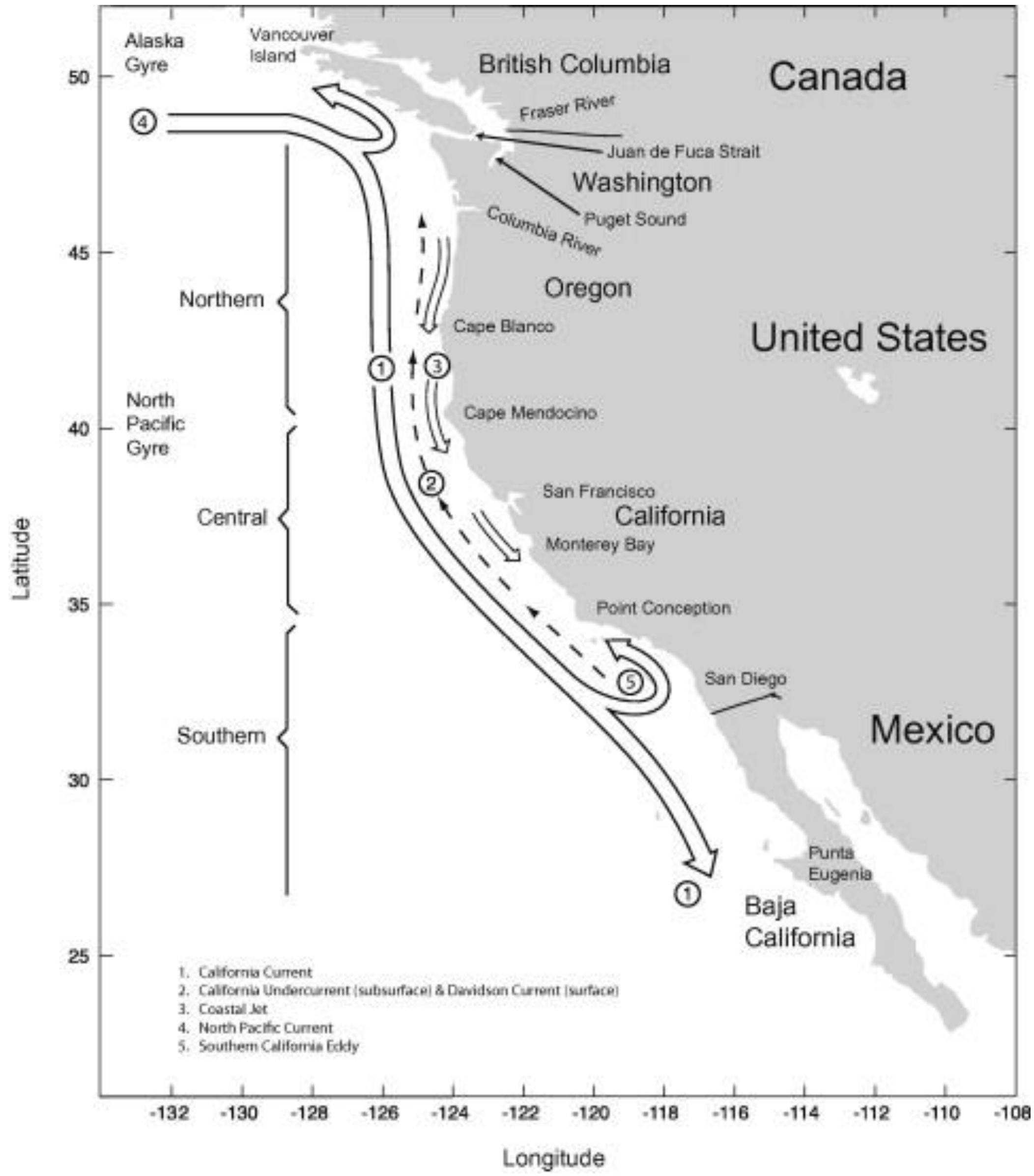

Figure A.3: Map of the California Current System (Checkley et al., 2009).

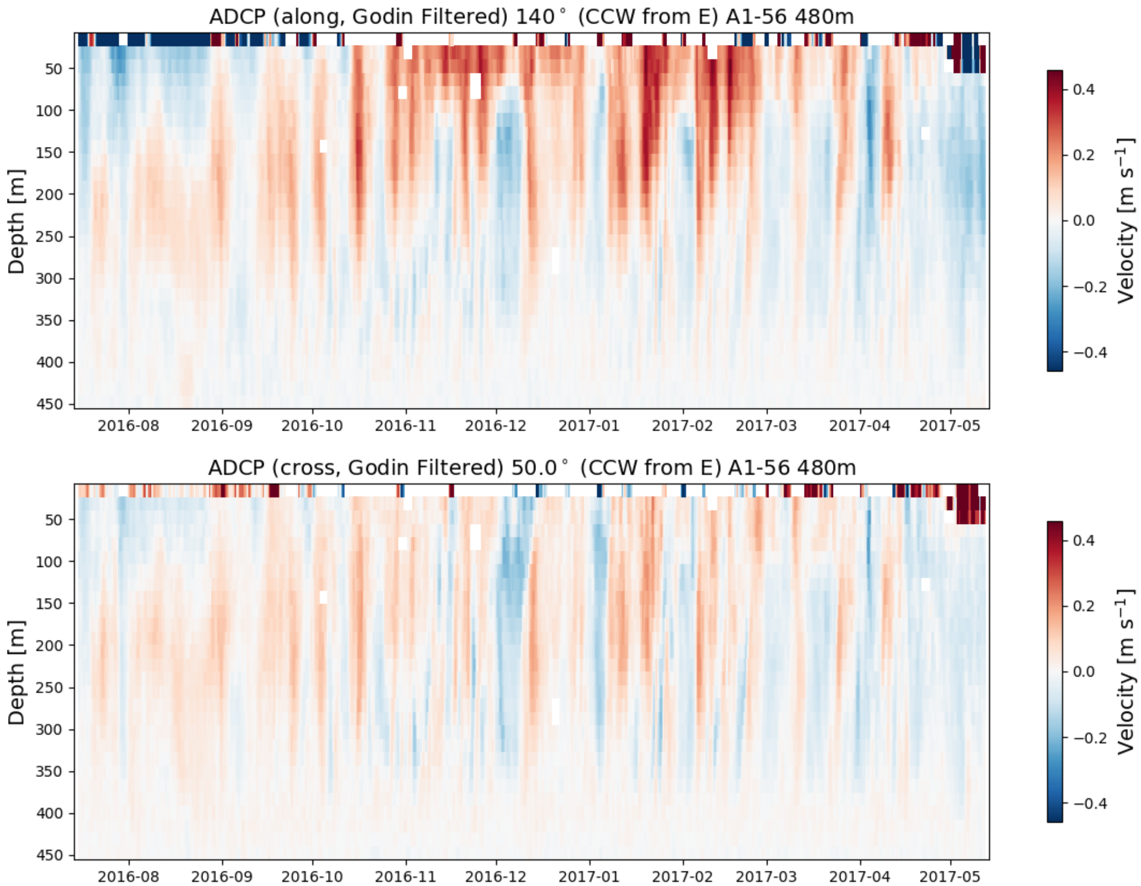

Figure A.4: A1-56 along-shore and cross-shore velocities (Godin-filtered). The bad data in the top right corner of each subplot is the result of the mooring being struck and displaced to shallower water by a vessel, such that two additional bins are moved above the sea surface.

Appendix B Sample ADCP netCDF file header

```
netcdf a1_20160713_20170513_0480m.adcp.L1 {
dimensions:
        distance = 31 ;
        time = 16709 ;
variables:
        float LCEWAP01(distance, time) ;
                LCEWAP01:_FillValue = 1.e+15f ;
                LCEWAP01:units = "m s-1" ;
                LCEWAP01:long_name = "eastward_sea_water_velocity" ;
                LCEWAP01:ancillary_variables = "LCEWAP01_QC" ;
                LCEWAP01:sensor_type = "adcp" ;
                LCEWAP01:sensor_depth = 425.24 ;
                LCEWAP01:serial_number = "WH20568" ;
                LCEWAP01:generic_name = "u" ;
                LCEWAP01:comment = "Quality flag resulting from cleaning of the beginning and
end of the dataset" ;
                string LCEWAP01:flag_meanings = "no_quality_control", "good_value", "probably_
good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "val
ue_in_excess", "interpolated_value", "missing_value" ;
                LCEWAP01:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                LCEWAP01:References = "BODC SeaDataNet" ;
                LCEWAP01:legacy_GF3_code = "SDN:GF3::EWCT" ;
                LCEWAP01:sdn_parameter_name = "Eastward current velocity (Eulerian measurement
) in the water body by moored acoustic doppler current profiler (ADCP)" ;
                LCEWAP01:sdn_uom_urn = "SDN:P06::UVAA" ;
                LCEWAP01:sdn_uom_name = "Metres per second" ;
                LCEWAP01:standard_name = "eastward_sea_water_velocity" ;
                LCEWAP01:data_max = 5.60135854151793 ;
                LCEWAP01:data_min = -6.5255186761407 ;
                LCEWAP01:valid_max = 1000LL ;
                LCEWAP01:valid_min = -1000LL ;
        float LCNSAP01(distance, time) ;
                LCNSAP01:_FillValue = 1.e+15f ;
                LCNSAP01:units = "m s-1" ;
                LCNSAP01:long_name = "northward_sea_water_velocity" ;
                LCNSAP01:ancillary_variables = "LCNSAP01_QC" ;
                LCNSAP01:sensor_type = "adcp" ;
                LCNSAP01:sensor_depth = 425.24 ;
                LCNSAP01:serial_number = "WH20568" ;
                LCNSAP01:generic_name = "v" ;
                LCNSAP01:comment = "Quality flag resulting from cleaning of the beginning and
end of the dataset" ;
                string LCNSAP01:flag_meanings = "no_quality_control", "good_value", "probably_
good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "val
ue_in_excess", "interpolated_value", "missing_value" ;
                LCNSAP01:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                LCNSAP01:References = "BODC SeaDataNet" ;
                LCNSAP01:legacy_GF3_code = "SDN:GF3::NSCT" ;
```

```
                LCNSAP01:sdn_parameter_name = "Northward current velocity (Eulerian measuremen
t) in the water body by moored acoustic doppler current profiler (ADCP)" ;
                LCNSAP01:sdn_uom_urn = "SDN:P06::UVAA" ;
                LCNSAP01:sdn_uom_name = "Metres per second" ;
                LCNSAP01:standard_name = "northward_sea_water_velocity" ;
                LCNSAP01:data_max = 6.71806414508204 ;
                LCNSAP01:data_min = -5.10490428197932 ;
                LCNSAP01:valid_max = 1000LL ;
                LCNSAP01:valid_min = -1000LL ;
        float LRZAAP01(distance, time) ;
                LRZAAP01:_FillValue = 1.e+15f ;
                LRZAAP01:units = "m s-1" ;
                LRZAAP01:long_name = "upward_sea_water_velocity" ;
                LRZAAP01:ancillary_variables = "LRZAAP01_QC" ;
                LRZAAP01:sensor_type = "adcp" ;
                LRZAAP01:sensor_depth = 425.24 ;
                LRZAAP01:serial_number = "WH20568" ;
                LRZAAP01:generic_name = "w" ;
                LRZAAP01:comment = "Quality flag resulting from cleaning of the beginning and
end of the dataset" ;
                string LRZAAP01:flag_meanings = "no_quality_control", "good_value", "probably_
good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "val
ue_in_excess", "interpolated_value", "missing_value" ;
                LRZAAP01:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                LRZAAP01:References = "BODC SeaDataNet" ;
                LRZAAP01:legacy_GF3_code = "SDN:GF3::VCSP" ;
                LRZAAP01:sdn_parameter_name = "Upward current velocity (Eulerian measurement)
in the water body by moored acoustic doppler current profiler (ADCP)" ;
                LRZAAP01:sdn_uom_urn = "SDN:P06::UVAA" ;
                LRZAAP01:sdn_uom_name = "Metres per second" ;
                LRZAAP01:standard_name = "upward_sea_water_velocity" ;
                LRZAAP01:data_max = 1.678 ;
                LRZAAP01:data_min = -1.367 ;
                LRZAAP01:valid_max = 1000LL ;
                LRZAAP01:valid_min = -1000LL ;
        float LERRAP01(distance, time) ;
                LERRAP01:_FillValue = 1.e+15f ;
                LERRAP01:units = "m s-1" ;
                LERRAP01:long_name = "error_velocity_in_sea_water" ;
                LERRAP01:sensor_type = "adcp" ;
                LERRAP01:sensor_depth = 425.24 ;
                LERRAP01:serial_number = "WH20568" ;
                LERRAP01:generic_name = "e" ;
                LERRAP01:legacy_GF3_code = "SDN:GF3::ERRV" ;
                LERRAP01:sdn_parameter_name = "Current velocity error in the water body by moo
red acoustic doppler current profiler (ADCP)" ;
                LERRAP01:sdn_uom_urn = "SDN:P06::UVAA" ;
                LERRAP01:sdn_uom_name = "Metres per second" ;
                LERRAP01:data_max = 2.004 ;
                LERRAP01:data_min = -2.029 ;
                LERRAP01:valid_max = 2000LL ;
                LERRAP01:valid_min = -2000LL ;
        int64 LCEWAP01_QC(distance, time) ;
                LCEWAP01_QC:_FillValue = 0LL ;
                LCEWAP01_QC:long_name = "quality flag for LCEWAP01" ;
                LCEWAP01_QC:comment = "Quality flag resulting from cleaning of the beginning a
nd end of the dataset" ;
                string LCEWAP01_QC:flag_meanings = "no_quality_control", "good_value", "probab
```

```
ly_good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "
value_in_excess", "interpolated_value", "missing_value" ;
                LCEWAP01_QC:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                LCEWAP01_QC:References = "BODC SeaDataNet" ;
                LCEWAP01_QC:data_max = 4.f ;
                LCEWAP01_QC:data_min = 0.f ;
        int64 LCNSAP01_QC(distance, time) ;
                LCNSAP01_QC:_FillValue = 0LL ;
                LCNSAP01_QC:long_name = "quality flag for LCNSAP01" ;
                LCNSAP01_QC:comment = "Quality flag resulting from cleaning of the beginning a
nd end of the dataset" ;
                string LCNSAP01_QC:flag_meanings = "no_quality_control", "good_value", "probab
ly_good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "
value_in_excess", "interpolated_value", "missing_value" ;
                LCNSAP01_QC:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                LCNSAP01_QC:References = "BODC SeaDataNet" ;
                LCNSAP01_QC:data_max = 4.f ;
                LCNSAP01_QC:data_min = 0.f ;
        int64 LRZAAP01_QC(distance, time) ;
                LRZAAP01_QC:_FillValue = 0LL ;
                LRZAAP01_QC:long_name = "quality flag for LRZAAP01" ;
                LRZAAP01_QC:comment = "Quality flag resulting from cleaning of the beginning a
nd end of the dataset" ;
                string LRZAAP01_QC:flag_meanings = "no_quality_control", "good_value", "probab
ly_good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "
value_in_excess", "interpolated_value", "missing_value" ;
                LRZAAP01_QC:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                LRZAAP01_QC:References = "BODC SeaDataNet" ;
                LRZAAP01_QC:data_max = 4.f ;
                LRZAAP01_QC:data_min = 0.f ;
        double ELTMEP01(time) ;
                ELTMEP01:_FillValue = 1.e+15 ;
                ELTMEP01:long_name = "time_02" ;
                ELTMEP01:legacy_GF3_code = "SDN:GF3::N/A" ;
                ELTMEP01:sdn_parameter_name = "Elapsed time (since 1970-01-01T00:00:00Z)" ;
                ELTMEP01:sdn_uom_urn = "SDN:P06::UTBB" ;
                ELTMEP01:sdn_uom_name = "Seconds" ;
                ELTMEP01:standard_name = "time" ;
                ELTMEP01:units = "seconds since 1970-01-01T00:00:00+00:00" ;
                ELTMEP01:calendar = "proleptic_gregorian" ;
        float TNIHCE01(distance, time) ;
                TNIHCE01:_FillValue = 1.e+15f ;
                TNIHCE01:units = "counts" ;
                TNIHCE01:long_name = "ADCP_echo_intensity_beam_1" ;
                TNIHCE01:sensor_type = "adcp" ;
                TNIHCE01:sensor_depth = 425.24 ;
                TNIHCE01:serial_number = "WH20568" ;
                TNIHCE01:generic_name = "AGC" ;
                TNIHCE01:legacy_GF3_code = "SDN:GF3::BEAM_01" ;
                TNIHCE01:sdn_parameter_name = "Echo intensity from the water body by moored ac
oustic doppler current profiler (ADCP) beam 1" ;
                TNIHCE01:sdn_uom_urn = "SDN:P06::UCNT" ;
                TNIHCE01:sdn_uom_name = "Counts" ;
                TNIHCE01:data_min = 45UB ;
                TNIHCE01:data_max = 224UB ;
        float TNIHCE02(distance, time) ;
                TNIHCE02:_FillValue = 1.e+15f ;
                TNIHCE02:units = "counts" ;
```

```
                CMAGZZ02:long_name = "ADCP_correlation_magnitude_beam_2" ;
                CMAGZZ02:sensor_type = "adcp" ;
                CMAGZZ02:sensor_depth = 425.24 ;
                CMAGZZ02:serial_number = "WH20568" ;
                CMAGZZ02:generic_name = "CM" ;
                CMAGZZ02:legacy_GF3_code = "SDN:GF3::CMAG_02" ;
                CMAGZZ02:sdn_parameter_name = "Correlation magnitude of acoustic signal return
s from the water body by moored acoustic doppler current profiler (ADCP) beam 2" ;
                CMAGZZ02:data_min = 0UB ;
                CMAGZZ02:data_max = 143UB ;
        float CMAGZZ03(distance, time) ;
                CMAGZZ03:_FillValue = 1.e+15f ;
                CMAGZZ03:units = "counts" ;
                CMAGZZ03:long_name = "ADCP_correlation_magnitude_beam_3" ;
                CMAGZZ03:sensor_type = "adcp" ;
                CMAGZZ03:sensor_depth = 425.24 ;
                CMAGZZ03:serial_number = "WH20568" ;
                CMAGZZ03:generic_name = "CM" ;
                CMAGZZ03:legacy_GF3_code = "SDN:GF3::CMAG_03" ;
                CMAGZZ03:sdn_parameter_name = "Correlation magnitude of acoustic signal return
s from the water body by moored acoustic doppler current profiler (ADCP) beam 3" ;
                CMAGZZ03:data_min = 0UB ;
                CMAGZZ03:data_max = 143UB ;
        float CMAGZZ04(distance, time) ;
                CMAGZZ04:_FillValue = 1.e+15f ;
                CMAGZZ04:units = "counts" ;
                CMAGZZ04:long_name = "ADCP_correlation_magnitude_beam_4" ;
                CMAGZZ04:sensor_type = "adcp" ;
                CMAGZZ04:sensor_depth = 425.24 ;
                CMAGZZ04:serial_number = "WH20568" ;
                CMAGZZ04:generic_name = "CM" ;
                CMAGZZ04:legacy_GF3_code = "SDN:GF3::CMAG_04" ;
                CMAGZZ04:sdn_parameter_name = "Correlation magnitude of acoustic signal return
s from the water body by moored acoustic doppler current profiler (ADCP) beam 4" ;
                CMAGZZ04:data_min = 0UB ;
                CMAGZZ04:data_max = 143UB ;
        float PTCHGP01(time) ;
                PTCHGP01:_FillValue = 1.e+15f ;
                PTCHGP01:units = "degree" ;
                PTCHGP01:long_name = "pitch" ;
                PTCHGP01:sensor_type = "adcp" ;
                PTCHGP01:legacy_GF3_code = "SDN:GF3::PTCH" ;
                PTCHGP01:sdn_parameter_name = "Orientation (pitch) of measurement platform by
inclinometer" ;
                PTCHGP01:sdn_uom_urn = "SDN:P06::UAAA" ;
                PTCHGP01:sdn_uom_name = "Degrees" ;
                PTCHGP01:standard_name = "platform_pitch" ;
                PTCHGP01:data_min = -3.56 ;
                PTCHGP01:data_max = 7.66 ;
        float HEADCM01(time) ;
                HEADCM01:_FillValue = 1.e+15f ;
                HEADCM01:units = "degree" ;
                HEADCM01:long_name = "heading" ;
                HEADCM01:sensor_type = "adcp" ;
                HEADCM01:sensor_depth = 425.24 ;
                HEADCM01:serial_number = "WH20568" ;
                HEADCM01:legacy_GF3_code = "SDN:GF3::HEAD" ;
                HEADCM01:sdn_parameter_name = "Orientation (horizontal relative to true north)
```

```
 of measurement device {heading}" ;
                HEADCM01:sdn_uom_urn = "SDN:P06::UAAA" ;
                HEADCM01:sdn_uom_name = "Degrees" ;
                HEADCM01:standard_name = "platform_orientation" ;
                HEADCM01:data_min = 0.06 ;
                HEADCM01:data_max = 359.13 ;
        float ROLLGP01(time) ;
                ROLLGP01:_FillValue = 1.e+15f ;
                ROLLGP01:units = "degree" ;
                ROLLGP01:long_name = "roll" ;
                ROLLGP01:sensor_type = "adcp" ;
                ROLLGP01:legacy_GF3_code = "SDN:GF3::ROLL" ;
                ROLLGP01:sdn_parameter_name = "Orientation (roll angle) of measurement platfor
m by inclinometer (second sensor)" ;
                ROLLGP01:sdn_uom_urn = "SDN:P06::UAAA" ;
                ROLLGP01:sdn_uom_name = "Degrees" ;
                ROLLGP01:standard_name = "platform_roll" ;
                ROLLGP01:data_min = -4.76 ;
                ROLLGP01:data_max = 2.25 ;
        float TEMPPR01(time) ;
                TEMPPR01:_FillValue = 1.e+15f ;
                TEMPPR01:units = "degree_C" ;
                TEMPPR01:long_name = "ADCP Transducer Temp." ;
                TEMPPR01:generic_name = "temp" ;
                TEMPPR01:sensor_type = "adcp" ;
                TEMPPR01:sensor_depth = 425.24 ;
                TEMPPR01:serial_number = "WH20568" ;
                TEMPPR01:legacy_GF3_code = "SDN:GF3::te90" ;
                TEMPPR01:sdn_parameter_name = "Temperature of the water body" ;
                TEMPPR01:sdn_uom_urn = "SDN:P06::UPAA" ;
                TEMPPR01:sdn_uom_name = "Celsius degree" ;
                TEMPPR01:data_min = 4.48 ;
                TEMPPR01:data_max = 6.42 ;
        float DISTTRAN(distance) ;
                DISTTRAN:_FillValue = 1.e+15f ;
                DISTTRAN:units = "m" ;
                DISTTRAN:positive = "up" ;
                DISTTRAN:long_name = "height of sea surface" ;
                DISTTRAN:generic_name = "height" ;
                DISTTRAN:sensor_type = "adcp" ;
                DISTTRAN:sensor_depth = 425.24 ;
                DISTTRAN:serial_number = "WH20568" ;
                DISTTRAN:legacy_GF3_code = "SDN:GF3::HGHT" ;
                DISTTRAN:sdn_uom_urn = "SDN:P06::ULAA" ;
                DISTTRAN:sdn_uom_name = "Metres" ;
                DISTTRAN:data_min = -79.32 ;
                DISTTRAN:data_max = 400.68 ;
        float PPSAADCP(time) ;
                PPSAADCP:_FillValue = 1.e+15f ;
                PPSAADCP:units = "m" ;
                PPSAADCP:positive = "down" ;
                PPSAADCP:long_name = "instrument depth" ;
                PPSAADCP:xducer_offset_from_bottom = "" ;
                PPSAADCP:bin_size = 16. ;
                PPSAADCP:generic_name = "depth" ;
                PPSAADCP:sensor_type = "adcp" ;
                PPSAADCP:sensor_depth = 425.24 ;
                PPSAADCP:serial_number = "WH20568" ;
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		PPSAADCP:legacy_GF3_code = "SDN:GF3::DEPH" ;
		PPSAADCP:sdn_parameter_name = "Depth below surface of the water body" ;
		PPSAADCP:sdn_uom_urn = "SDN:P06::ULAA" ;
		PPSAADCP:sdn_uom_name = "Metres" ;
		PPSAADCP:standard_name = "depth" ;
		PPSAADCP:data_min = 446.99 ;
		PPSAADCP:data_max = 491.42 ;
	double ALATZZ01 ;
		ALATZZ01:_FillValue = NaN ;
		ALATZZ01:units = "degrees_north" ;
		ALATZZ01:long_name = "latitude" ;
		ALATZZ01:legacy_GF3_code = "SDN:GF3::lat" ;
		ALATZZ01:sdn_parameter_name = "Latitude north" ;
		ALATZZ01:sdn_uom_urn = "SDN:P06::DEGN" ;
		ALATZZ01:sdn_uom_name = "Degrees north" ;
		ALATZZ01:standard_name = "latitude" ;
	double ALONZZ01 ;
		ALONZZ01:_FillValue = NaN ;
		ALONZZ01:units = "degrees_east" ;
		ALONZZ01:long_name = "longitude" ;
		ALONZZ01:legacy_GF3_code = "SDN:GF3::lon" ;
		ALONZZ01:sdn_parameter_name = "Longitude east" ;
		ALONZZ01:sdn_uom_urn = "SDN:P06::DEGE" ;
		ALONZZ01:sdn_uom_name = "Degrees east" ;
		ALONZZ01:standard_name = "longitude" ;
	double latitude ;
		latitude:_FillValue = NaN ;
		latitude:units = "degrees_north" ;
		latitude:long_name = "latitude" ;
		latitude:legacy_GF3_code = "SDN:GF3::lat" ;
		latitude:sdn_parameter_name = "Latitude north" ;
		latitude:sdn_uom_urn = "SDN:P06::DEGN" ;
		latitude:sdn_uom_name = "Degrees north" ;
		latitude:standard_name = "latitude" ;
	double longitude ;
		longitude:_FillValue = NaN ;
		longitude:units = "degrees_east" ;
		longitude:long_name = "longitude" ;
		longitude:legacy_GF3_code = "SDN:GF3::lon" ;
		longitude:sdn_parameter_name = "Longitude east" ;
		longitude:sdn_uom_urn = "SDN:P06::DEGE" ;
		longitude:sdn_uom_name = "Degrees east" ;
		longitude:standard_name = "longitude" ;
	float PRESPR01(time) ;
		PRESPR01:_FillValue = 1.e+15f ;
		PRESPR01:units = "dbar" ;
		PRESPR01:long_name = "pressure" ;
		PRESPR01:sensor_type = "adcp" ;
		PRESPR01:sensor_depth = 425.24 ;
		PRESPR01:serial_number = "WH20568" ;
		PRESPR01:ancillary_variables = "PRESPR01_QC" ;
		PRESPR01:comment = "Quality flag indicates negative pressure values in the tim
e series" ;
		string PRESPR01:flag_meanings = "no_quality_control", "good_value", "probably_
good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "val
ue_in_excess", "interpolated_value", "missing_value" ;
		PRESPR01:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
		PRESPR01:References = "BODC SeaDataNet" ;
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```
		PRESPR01:legacy_GF3_code = "SDN:GF3::PRES" ;
		PRESPR01:sdn_parameter_name = "Pressure (spatial co-ordinate) exerted by the w
ater body by profiling pressure sensor and corrected to read zero at sea level" ;
		PRESPR01:sdn_uom_urn = "SDN:P06::UPDB" ;
		PRESPR01:sdn_uom_name = "Decibars" ;
		PRESPR01:standard_name = "sea_water_pressure" ;
		PRESPR01:data_min = 451.288f ;
		PRESPR01:data_max = 496.196f ;
	int64 PRESPR01_QC(time) ;
		PRESPR01_QC:_FillValue = 0LL ;
		PRESPR01_QC:long_name = "quality flag for PRESPR01" ;
		PRESPR01_QC:comment = "Quality flag resulting from cleaning of the beginning a
nd end of the dataset and identification of negative pressure values" ;
		string PRESPR01_QC:flag_meanings = "no_quality_control", "good_value", "probab
ly_good_value", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "
value_in_excess", "interpolated_value", "missing_value" ;
		PRESPR01_QC:flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
		PRESPR01_QC:References = "BODC SeaDataNet" ;
		PRESPR01_QC:data_max = 4.f ;
		PRESPR01_QC:data_min = 0.f ;
	float SVELCV01(time) ;
		SVELCV01:_FillValue = 1.e+15f ;
		SVELCV01:units = "m s-1" ;
		SVELCV01:long_name = "speed of sound" ;
		SVELCV01:sensor_type = "adcp" ;
		SVELCV01:sensor_depth = 425.24 ;
		SVELCV01:serial_number = "WH20568" ;
		SVELCV01:legacy_GF3_code = "SDN:GF3::SVEL" ;
		SVELCV01:sdn_parameter_name = "Sound velocity in the water body by computation
 from temperature and salinity by unspecified algorithm" ;
		SVELCV01:sdn_uom_urn = "SDN:P06::UVAA" ;
		SVELCV01:sdn_uom_name = "Metres per second" ;
		SVELCV01:standard_name = "speed_of_sound_in_sea_water" ;
		SVELCV01:data_min = 1473.f ;
		SVELCV01:data_max = 1481.f ;
	string DTUT8601(time) ;
		DTUT8601:note = "time values as ISO8601 string, YY-MM-DD hh:mm:ss" ;
		DTUT8601:time_zone = "UTC" ;
		DTUT8601:legacy_GF3_code = "SDN:GF3::time_string" ;
		DTUT8601:sdn_parameter_name = "String corresponding to format \'YYYY-MM-DDThh:
mm:ss.sssZ\' or other valid ISO8601 string" ;
		DTUT8601:sdn_uom_urn = "SDN:P06::TISO" ;
		DTUT8601:sdn_uom_name = "ISO8601" ;
	string filename ;
	string instrument_serial_number ;
	string instrument_model ;
	int64 time(time) ;
		time:long_name = "time" ;
		time:cf_role = "profile_id" ;
		time:units = "seconds since 1970-01-01T00:00:00+00:00" ;
		time:calendar = "gregorian" ;
	double distance(distance) ;
		distance:_FillValue = NaN ;
		distance:units = "m" ;
		distance:positive = "up" ;
		distance:long_name = "bin_distances_from_ADCP_transducer_along_measurement_axi
s" ;
	float PCGDAP00(distance, time) ;
```

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                PCGDAP00:_FillValue = 1.e+15f ;
                PCGDAP00:units = "percent" ;
                PCGDAP00:long_name = "percent_good_beam_1" ;
                PCGDAP00:sensor_type = "adcp" ;
                PCGDAP00:sensor_depth = 425.24 ;
                PCGDAP00:serial_number = "WH20568" ;
                PCGDAP00:generic_name = "PGd" ;
                PCGDAP00:legacy_GF3_code = "SDN:GF3::PGDP_01" ;
                PCGDAP00:sdn_parameter_name = "Acceptable proportion of signal returns by moor
ed acoustic doppler current profiler (ADCP) beam 1" ;
                PCGDAP00:sdn_uom_urn = "SDN:P06::UPCT" ;
                PCGDAP00:sdn_uom_name = "Percent" ;
                PCGDAP00:data_min = 0UB ;
                PCGDAP00:data_max = 100UB ;
        float PCGDAP02(distance, time) ;
                PCGDAP02:_FillValue = 1.e+15f ;
                PCGDAP02:units = "percent" ;
                PCGDAP02:long_name = "percent_good_beam_2" ;
                PCGDAP02:sensor_type = "adcp" ;
                PCGDAP02:sensor_depth = 425.24 ;
                PCGDAP02:serial_number = "WH20568" ;
                PCGDAP02:generic_name = "PGd" ;
                PCGDAP02:legacy_GF3_code = "SDN:GF3::PGDP_02" ;
                PCGDAP02:sdn_parameter_name = "Acceptable proportion of signal returns by moor
ed acoustic doppler current profiler (ADCP) beam 2" ;
                PCGDAP02:sdn_uom_urn = "SDN:P06::UPCT" ;
                PCGDAP02:sdn_uom_name = "Percent" ;
                PCGDAP02:data_min = 0UB ;
                PCGDAP02:data_max = 38UB ;
        float PCGDAP03(distance, time) ;
                PCGDAP03:_FillValue = 1.e+15f ;
                PCGDAP03:units = "percent" ;
                PCGDAP03:long_name = "percent_good_beam_3" ;
                PCGDAP03:sensor_type = "adcp" ;
                PCGDAP03:sensor_depth = 425.24 ;
                PCGDAP03:serial_number = "WH20568" ;
                PCGDAP03:generic_name = "PGd" ;
                PCGDAP03:legacy_GF3_code = "SDN:GF3::PGDP_03" ;
                PCGDAP03:sdn_parameter_name = "Acceptable proportion of signal returns by moor
ed acoustic doppler current profiler (ADCP) beam 3" ;
                PCGDAP03:sdn_uom_urn = "SDN:P06::UPCT" ;
                PCGDAP03:sdn_uom_name = "Percent" ;
                PCGDAP03:data_min = 0UB ;
                PCGDAP03:data_max = 100UB ;
        float PCGDAP04(distance, time) ;
                PCGDAP04:_FillValue = 1.e+15f ;
                PCGDAP04:units = "percent" ;
                PCGDAP04:long_name = "percent_good_beam_4" ;
                PCGDAP04:sensor_type = "adcp" ;
                PCGDAP04:sensor_depth = 425.24 ;
                PCGDAP04:serial_number = "WH20568" ;
                PCGDAP04:generic_name = "PGd" ;
                PCGDAP04:legacy_GF3_code = "SDN:GF3::PGDP_04" ;
                PCGDAP04:sdn_parameter_name = "Acceptable proportion of signal returns by moor
ed acoustic doppler current profiler (ADCP) beam 4" ;
                PCGDAP04:sdn_uom_urn = "SDN:P06::UPCT" ;
                PCGDAP04:sdn_uom_name = "Percent" ;
                PCGDAP04:data_min = 0UB ;
```

```
                PCGDAP04:data_max = 100UB ;
        string geographic_area ;

// global attributes:
                :acknowledgement = "IOS Mooring Group; Roy Hourston, for metadata gathering an
d data processing; Emily Chisholm, for supplying the R script that performed the processing an
d netCDF file output." ;
                :agency = "IOS, Ocean Sciences Division, Sidney, B.C." ;
                :anchor_type = "2785 lbs w 2 m chain" ;
                :anchor_drop_time = "2016-07-13 20:59:00 UTC" ;
                :anchor_release_time = "2017-05-13 23:00:00 UTC" ;
                :comment = "Archived raw .000 files were used to make this data set." ;
                :country = "Canada" ;
                :country_institute_code = 1823LL ;
                :cruise_description = "The deployment cruise was taken on the John P. Tully. M
ooring A1-56 was hit and moved at around 1500 April 29, 2017 into 450 m depth, and was transmi
tting via Iridium from 48 degrees 32.111 minutes N 126 degrees 11.633 minutes W. The mooring w
as recovered by Environment Canada on the CCGS Laurier. " ;
                :deployment_cruise_number = "2016-12" ;
                :deployment_type = "Sub Surface" ;
                :error_threshold = "999" ;
                :featureType = "profileTimeSeries" ;
                string :flag_meaning = "no_quality_control", "good_value", "probably_good_valu
e", "probably_bad_value", "bad_value", "changed_value", "value_below_detection", "value_in_exc
ess", "interpolated_value", "missing_value" ;
                :flag_references = "BODC SeaDataNet" ;
                :flag_values = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 ;
                :history = "The metadata were extracted from the corresponding processed .adcp
 file provided by Roy Hourston. The data were extracted from the raw ADCP binary file using an
 R routine provided by Emily Chisholm. Instrument depth was derived from reconciling all trust
worthy pressure sensors on the mooring (i.e., Sea-Bird) and the mooring line length." ;
                :instrument_depth = 480. ;
                :keywords = "Oceans > Ocean Circulation > Ocean Currents" ;
                :keywords_vocabulary = "GCMD Science Keywords" ;
                :latitude = 48.5385 ;
                :longitude = -126.1952 ;
                :naming_authority = "BODC, MEDS, CF v72" ;
                :percentgd_threshold = "0" ;
                :platform = "John P. Tully" ;
                :project = "La Perouse" ;
                :publisher_email = "DFO.PAC.SCI.IOSData-DonneesISO.SCI.PAC.MPO@dfo-mpo.gc.ca"
;
                :return_cruise_number = "2017-23" ;
                :scientist = "Thomson R." ;
                :sea_code = "57A" ;
                :sea_name = "Northeast Pacific Ocean" ;
                :station = "A1" ;
                :deployment_number = "56" ;
                :variable_code_reference = "BODC P01" ;
                :water_depth = 500. ;
                :serial_number = "WH20568" ;
                :instrumentSubtype = "Workhorse" ;
                :magnetic_variation = 16.67 ;
                :manufacturer = "teledyne rdi" ;
                :instrumentModel = "RDI WH Long Ranger ADCP 75kHz (WH20568)" ;
                :processing_history = "Metadata read in from log sheet and combined with raw d
ata to export as netCDF file. Sensor depth and mean depth set to 425.24312107247596 based on t
rimmed depth values. Magnetic variation, using average applied; declination = 16.67. Quality c
```

```
ontrol flags set based on SeaDataNet flag scheme from BODC. Negative pressure values flagged a
s \"bad_data\" and set to nan\'s. Velocity, pressure, depth, temperature, pitch, roll, heading
, and sound_speed limited by deployment (2016-07-13 21:29:59 UTC) and recovery (2017-05-13 23:
30:00 UTC) times. Level 1 processing was performed on the dataset. This entailed corrections f
or magnetic declination based on an average of the dataset and cleaning of the beginning and e
nd of the dataset. The leading 7 ensembles and the trailing 2106 ensembles were removed from t
he data set." ;
                :orientation = "up" ;
                :beam_pattern = "convex" ;
                :coord_system = "enu" ;
                :time_coverage_duration = 348.083333333333 ;
                :time_coverage_duration_units = "days" ;
                :cdm_data_type = "station" ;
                :number_of_beams = 4LL ;
                :numberOfCells = 31LL ;
                :pings_per_ensemble = 13LL ;
                :bin1Distance = 24.56 ;
                :cellSize = 16. ;
                :pingtype = "bb" ;
                :transmit_pulse_length_cm = 1710US ;
                :instrumentType = "adcp" ;
                :source = "R code: adcpProcess, github:" ;
                :date_modified = "2020-07-07 10:58:00" ;
                :_FillValue = 1.e+35 ;
                :firmware_version = "50.40" ;
                :frequency = "75" ;
                :beam_angle = "20" ;
                :systemConfiguration = "11001000-01000001" ;
                :sensor_source = "01111101" ;
                :sensors_avail = "00111101" ;
                :three_beam_used = "TRUE" ;
                :valid_correlation_range = 64UB ;
                :minmax_percent_good = "100" ;
                :error_velocity_threshold = "2000 m s-1" ;
                :false_target_reject_values = 50LL ;
                :data_type = "adcp" ;
                :pred_accuracy = 1LL ;
                :Conventions = "CF-1.8" ;
                :creator_type = "person" ;
                :n_codereps = 9UB ;
                :xmit_lag = 193US ;
                :time_coverage_start = "2016-07-13 21:29:59 UTC" ;
                :time_coverage_end = "2017-05-13 22:59:59 UTC" ;
                :geospatial_lat_min = 48.5385 ;
                :geospatial_lat_max = 48.5385 ;
                :geospatial_lat_units = "degrees_north" ;
                :geospatial_lon_min = -126.1952 ;
                :geospatial_lon_max = -126.1952 ;
                :geospatial_lon_units = "degrees_east" ;
                :geospatial_vertical_min = -79.32 ;
                :geospatial_vertical_max = 400.68 ;
}
```

Appendix C Sample ADCP ASCII header file

```
*2020/07/08 10:35:38.90
*IOS HEADER VERSION 2.0      2020/03/01 2020/04/15 PYTHON

100
*FILE
    START TIME          : UTC 2016/07/13 18:29:59.00
    END TIME            : UTC 2017/06/26 19:59:59.00
    TIME INCREMENT      : 0 0 30 0 0  ! (day hr min sec ms)
    TIME UNITS          : Minutes
    NUMBER OF RECORDS   : 16709
    DATA DESCRIPTION    : adcp
    NUMBER OF CHANNELS  : 30

    $TABLE: CHANNELS
    ! No Name                               Units           Minimum         Maximum
    !--- ---------------------------------- --------------- --------------- ---------------
       1 UTC Date                           YYYY-MM-DD                  n/a             n/a
       2 UTC Time                           HH:MM:SS                    n/a             n/a
       3 Eastward_Sea_Water_Velocity        m s-1           -6.525519E+00    5.601359E+00
       4 Northward_Sea_Water_Velocity       m s-1           -5.104904E+00    6.718064E+00
       5 Upward_Sea_Water_Velocity          m s-1           -1.367000E+00    1.678000E+00
       6 Error_Velocity_In_Sea_Water        m s-1           -2.029000E+00    2.004000E+00
       7 Quality Flag For Lcewap01                           0.000000E+00    4.000000E+00
       8 Quality Flag For Lcnsap01                           0.000000E+00    4.000000E+00
       9 Quality Flag For Lrzaap01                           0.000000E+00    4.000000E+00
      10 Adcp_Echo_Intensity_Beam_1         counts           4.500000E+01    2.240000E+02
      11 Adcp_Echo_Intensity_Beam_2         counts           4.700000E+01    2.220000E+02
      12 Adcp_Echo_Intensity_Beam_3         counts           4.800000E+01    2.300000E+02
      13 Adcp_Echo_Intensity_Beam_4         counts           4.500000E+01    2.210000E+02
      14 Adcp_Correlation_Magnitude_Beam_1  counts           0.000000E+00    1.430000E+02
      15 Adcp_Correlation_Magnitude_Beam_2  counts           0.000000E+00    1.430000E+02
      16 Adcp_Correlation_Magnitude_Beam_3  counts           0.000000E+00    1.430000E+02
      17 Adcp_Correlation_Magnitude_Beam_4  counts           0.000000E+00    1.430000E+02
      18 Percent_Good_Beam_1                percent          0.000000E+00    1.000000E+02
      19 Percent_Good_Beam_2                percent          0.000000E+00    3.800000E+01
      20 Percent_Good_Beam_3                percent          0.000000E+00    1.000000E+02
      21 Percent_Good_Beam_4                percent          0.000000E+00    1.000000E+02
      22 Pitch                              degree          -3.560000E+00    7.660000E+00
      23 Heading                            degree           6.000000E-02    3.591300E+02
      24 Roll                               degree          -4.760000E+00    2.250000E+00
      25 Adcp Transducer Temp.              degree_C         4.480000E+00    6.420000E+00
      26 Height Of Sea Surface              m               -7.932000E+01    4.006800E+02
      27 Instrument Depth                   m                4.469900E+02    4.914200E+02
      28 Pressure                           dbar             4.512880E+02    4.961960E+02
      29 Quality Flag For Prespr01                           0.000000E+00    4.000000E+00
      30 Speed Of Sound                     m s-1            1.473000E+03    1.481000E+03
    $END
```

```
    $TABLE: CHANNEL DETAIL
    ! No  Pad            Start  Width  Format      Type  Decimal_Places
    !---  -------------  -----  -----  ----------  ----  --------------
       1  ' '                   ' '    YYYY-MM-DD  D     ' '
       2  ' '                   ' '    HH:MM:SS    T     ' '
       3  -9.900000E+01         14     E           R4    6
       4  -9.900000E+01         14     E           R4    6
       5  -9.900000E+01         14     E           R4    6
       6  -9.900000E+01         14     E           R4    6
       7  -9.900000E+01         14     E           I     6
       8  -9.900000E+01         14     E           I     6
       9  -9.900000E+01         14     E           I     6
      10  -9.900000E+01         14     E           R4    6
      11  -9.900000E+01         14     E           R4    6
      12  -9.900000E+01         14     E           R4    6
      13  -9.900000E+01         14     E           R4    6
      14  -9.900000E+01         14     E           R4    6
      15  -9.900000E+01         14     E           R4    6
      16  -9.900000E+01         14     E           R4    6
      17  -9.900000E+01         14     E           R4    6
      18  -9.900000E+01         14     E           R4    6
      19  -9.900000E+01         14     E           R4    6
      20  -9.900000E+01         14     E           R4    6
      21  -9.900000E+01         14     E           R4    6
      22  -9.900000E+01         14     E           R4    6
      23  -9.900000E+01         14     E           R4    6
      24  -9.900000E+01         14     E           R4    6
      25  -9.900000E+01         14     E           R4    6
      26  -9.900000E+01         14     E           R4    6
      27  -9.900000E+01         14     E           R4    6
      28  -9.900000E+01         14     E           R4    6
      29  -9.900000E+01         14     E           R4    6
    $END

*ADMINISTRATION
    AGENCY              : IOS, Ocean Sciences Division, Sidney, B.C.
    COUNTRY             : Canada
    PROJECT             : La Perouse
    SCIENTIST           : Thomson R.
    PLATFORM            : John P. Tully

*LOCATION
    GEOGRAPHIC AREA     : Southern-Vancouver-Island-Shelf-(Stations-B-and-D)
    STATION             : A1
    LATITUDE            :  48  32.31000 N  ! (deg min)
    LONGITUDE           : 126  11.71200 W  ! (deg min)
    WATER DEPTH         : 500.0
    MAGNETIC DECLINATION: 16.67

*DEPLOYMENT
    MISSION             : 2016-12
    TYPE                : Sub Surface
    TIME ANCHOR DROPPED : 2016-07-13 20:59:00 UTC
    $REMARKS
        2785 lbs w 2 m chain
    $END

*RECOVERY
    MISSION             : 2017-23
    TIME ANCHOR RELEASED: 2017-05-13 23:00:00 UTC
```

```
*INSTRUMENT
    TYPE                : Workhorse-adcp
    SERIAL NUMBER       : WH20568
    DEPTH               : 480
    ORIENTATION         : up

    $ARRAY: BIN DEPTHS (M)
         24.56
         40.56
         56.56
         72.56
         88.56
        104.56
        120.56
        136.56
        152.56
        168.56
        184.56
        200.56
        216.56
        232.56
        248.56
        264.56
        280.56
        296.56
        312.56
        328.56
        344.56
        360.56
        376.56
        392.56
        408.56
        424.56
        440.56
        456.56
        472.56
        488.56
        504.56
    $END
    $REMARKS
        Instrument depth in meters.
    $END

*RAW
    START TIME          : UTC 2016-07-13 18:00:00.000
    FIRST GOOD REC TIME : UTC 2016-07-13 21:29:59.000
    END TIME            : UTC 2017-05-13 22:59:59.000
    TIME INCREMENT      : 0 0 30 0 0  ! (day hr min sec ms)
    NUMBER OF RECORDS   : 16709
    $REMARKS
        The data and following metadata were extracted from the raw ADCP binary file using
        a Python script adapted from Jody Klymak to perform the processing and netCDF file
output

        name:                           Workhorse-adcp
        sourceprog:                     instrument
        prog_ver:                       50.40
        config:                         NA
        beam_angle:                     20
        numbeams:                       4
        beam_freq:                      75
        beam_pattern:                   convex
        orientation:                    up
        n_beams:                        4
```

```
        n_cells:                      31
        pings_per_ensemble:           13
        cell_size:                    16.0
        corr_threshold:               64
        n_codereps:                   9
        min_pgood:                    0
        evel_threshold:               2000 m s-1
        time_between_ping_groups:     348.08333333333337
        coord:                        00011111
        coord_sys:                    enu
        use_pitchroll:                yes
        use_3beam:                    yes
        bin_mapping:                  yes
        xducer_misalign:              0
        magnetic_var:                 16.67
        sensors_src:                  01111101
        sensors_avail:                00111101
        bin1_dist:                    24.56
        xmit_pulse:                   17.10
        fls_target_threshold:         50
        xmit_lag:                     193
        h_adcp_beam_angle:            20
        ranges:
         24.56
         40.56
         56.56
         72.56
         88.56
        104.56
        120.56
        136.56
        152.56
        168.56
        184.56
        200.56
        216.56
        232.56
        248.56
        264.56
        280.56
        296.56
        312.56
        328.56
        344.56
        360.56
        376.56
        392.56
        408.56
        424.56
        440.56
        456.56
        472.56
        488.56
        504.56
    $END

*HISTORY

    !   Name     Vers  Date       Time     Recs In   Recs Out
    !   -------- ----  ---------- -------- --------- ---------
        ADCP2NC  1     2020-07-07 10:58:00     18822     16709
        NC2IOS   1.0   2020/07/08 10:35:38     16709     16709
    $END
    $REMARKS

        -ADCP2NC  processing: 2020-07-07 10:58:00
         The metadata were extracted from the corresponding processed .adcp file provided by
Roy Hourston.
         The data were extracted from the raw ADCP binary file using an R routine provided by
Emily Chisholm.
         Instrument depth was derived from reconciling all trustworthy pressure sensors on the
mooring (i.e., Sea-Bird) and the mooring line length..
        -NC2IOS  processing: 2020/07/08 10:35:38
         NetCDF file converted to IOSShell format.
    $END

*COMMENT
    To get the actual data, please see a1_20160713_20170513_0480m.adcp.L1.nc

*END OF HEADER
```