Australia's National
Science Agency

Procedure to produce gridded individual moorings products

East Australian Current moorings, 2012 to 2022

Rebecca Cowley and Bernadette Sloyan, (updated) November, 2023

Contents

Figures

Tables

1 Data source & data product location

Data is sourced from the AODN data portal (direct link to the Deep Water Moorings [DWM] data is https://portal.aodn.org.au/search?uuid=f7e49e83-4579-413c-b092-2187dca8395d), where the FV01 version of the files is used.

An alternative location for download or direct use of the data is via the AODN THREDDS server: http://thredds.aodn.org.au/thredds/catalog/IMOS/DWM/DA/catalog.html.

The FV01 (quality controlled) version of the files is used in this process. FV00 files do not contain quality control flags.

Code used to produce this dataset is available on GitHub: https://github.com/BecCowley/IMOSMooringGridding

The hourly and daily gridded products are available in netcdf format from the CSIRO Data Access Portal (DAP), from the Australian Ocean Data Network (AODN) THREDDS server and the OceanSITES Organisation site.

CSIRO DAP:

Sloyan, Bernadette; Cowley, Rebecca (2022): East Australian Current individual mooring gridded product - hourly and 10-20m depth gridded. v8. CSIRO. Data Collection. https://doi.org/10.25919/yycf-ed65

Sloyan, Bernadette; Cowley, Rebecca; Chapman, Chris (2021): East Australian Current individual mooring gridded product - daily and 10-20m depth gridded. v14. CSIRO. Data Collection. https://doi.org/10.25919/egsf-yh54

AODN THREDDS Server:

http://thredds.aodn.org.au/thredds/catalog/IMOS/DWM/DA/CSIRO_gridded_all_variables/catalog.html

OceanSITES network:

http://www.oceansites.org/data/index.html

2 Collation of individual instrument data on each mooring

2.1 Moorings deployment overview

The East Australian Current (EAC) Moorings array has been in place since 2012 and will continue until September, 2022. There was no deployment between 2013 and 2015 and the locations of the moorings changed from 2015 deployment (Table 1).

While the EAC deepwater moorings were deployed as a group, there were also coastal moorings deployed in the region by the Australian National Mooring Network. The North Stradbroke Island (NSI) mooring was deployed at 60m depth from 2012 to 2021 and the South East Queensland (SEQ) moorings were deployed in 2012-2013 at 200m and 400m depth. In the final EAC0500 product, we have included the SEQ400 mooring data as it was deployed 2.47km away from the EAC0500 site. In addition, we created a product for the NSI site.

Table 1. Deployment summary and naming conventions for all EAC, NSI and SEQ mooring deployments.

Deployment period	Nominal Depth							
	60m	**500 m**	**1500 m**	**2000 m**	**3200 m**	**4200 m**	**4700 m**	**4800 m**
EAC 2012-13	-	-	EAC1520 (EACM1)	EAC2000 (EACM2)	-	EAC4200 (EACM3)	EAC4700 (EACM4)	EAC4800 (EACM5)
SEQ 2012-13	-	SEQ400	-	-	-	-	-	-
EAC 2015-16	-	EAC0500	-	EAC2000	EAC3200	EAC4200	EAC4700	EAC4800
EAC 2016-18	-	EAC0500	-	EAC2000	EAC3200	EAC4200	EAC4700	EAC4800
EAC 2018-19	-	EAC0500	-	EAC2000	EAC3200	EAC4200	EAC4700	EAC4800
EAC 2019-21	-	EAC0500	-	EAC2000	EAC3200	EAC4200	EAC4700	EAC4800
EAC 2021-22	-	EAC0500	-	EAC2000	EAC3200	EAC4200	EAC4700	EAC4800
NSI 2012-2021	NSI	-	-	-	-	-	-	-

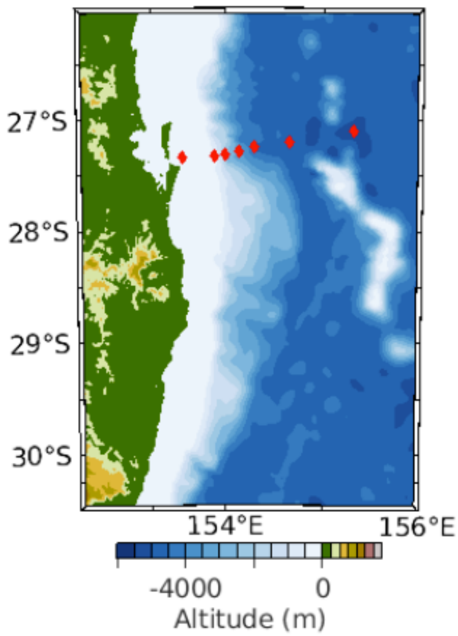
The EAC mooring array and NSI and SEQ coastal stations were deployed across the shelf near Brisbane, as shown in Table 2 and Figure 1.

Table 2. Approximate location of each mooring

Mooring	Location	
	Latitude	**Longitude**
NSI	-27.34	153.56
EAC0500	-27.32	153.90
SEQ400	-27.33	153.87
EAC2000	-27.31	153.99
EAC3200	-27.28	154.13

Mooring	Location	
	Latitude	Longitude
EAC4200	-27.25	154.29
EAC4700	-27.20	154.64
EAC4800	-27.10	155.30

Figure 1. Location of the six EAC moorings, the North Stradbroke Island and South East Queensland 400m moorings.



Full details of the instrumentation used on each deployment of the EAC deepwater array, including mooring diagrams and quality control details, are available in the quality control reports (Cowley, 2021; Lovell & Cowley, 2021a; Lovell and Cowley, 2021b; Cowley, 2022a, b, c).

Instrumentation on each mooring was a mix of Seabird 37 CTDs, Seabird 39 temperature and temperature/pressure recorders, Star Oddi (Starmon Mini) temperature recorders, RDI ADCP current meters and Nortek Aquadopp DW current meters. For example, on the EAC3200 mooring during 2019 to 2022, there were 14 Seabird 37s, 3 RDI ADCPs, 5 Seabird 39s, 2 Star Oddis and 4 Nortek Aquadopps (see Appendix A). Each instrument type has different recording intervals, some have bad data and failures flagged and the moorings are subject to movement through the water column (blow-overs). Some instruments do not record pressure and have an inferred depth linearly using differences in deployment depths from adjacent instruments that do record pressure. The instruments are distributed along the depth of the mooring with more instrumentation in the top 500m and fewer at depth. To make the data useful, we aim to put it together with a regular time stamp and with data flagged as bad removed. We can further interpolate the data onto a regular depth grid.

The following sections describe how the data is collated together (stacked) into a gridded product, one for each mooring. The final product covers the entire time period from 2012 to 2022 and has a regular time stamp (hourly and daily products) and depth grid (10m from surface to 400m and 20m from 420m to deepest instrument).

3 Initial stacking procedure

The term 'stacking' is used in this document to describe the process of joining individual instrument data from one mooring, collected during a single deployment, into a matrix of data with a single time-stamp for all instruments. During this process, data identified as 'bad' in the FV01 instrument files is removed from the dataset. The final stacked moorings files contain all the 'good' depth, temperature, salinity and currents data that can be plotted with a single time variable.

The code developed at CSIRO is in Matlab, and the following description will refer to Matlab scripts and functions. The code can be found in this repository:

https://github.com/csiro-oceandata-code/IMOSMooringGridding

What follows is a summary of the stacking processing steps, with more details given in the next section.

Overview:

- Download FV01 files from IMOS for each mooring, all deployments
- Put FV01 files into separate folders for ease of handling, one folder contains all instruments for a single deployment of a single mooring.
- Using Matlab tools, and working on **one mooring deployment at a time**:
    - Create a csv file with essential metadata (one file per deployment), with information for all moorings [make_insinfo_fromdeploymentcsv.m]. Can be done from the IMOS deployment database, or could equally be done from the FV01 files by reading the global attributes. The latest instrument_info.csv files for each deployment are included in the github repository.
    - Read all the FV01 instrument files and save as a Matlab structure (one file per instrument). File name is the instrument serial number [get_imosdata.m].
    - **For each mooring:** decide on one instrument to use as a time-base for all instruments, it <u>must have good temperature and depth records for the entire deployment</u>, have the slowest sample rate, and be in the upper 500m. Usually, we select one of the ADCPs as we use hourly ensemble averages and all other instruments sample at a faster rate. If a complete record on an hourly timestamp is not available, create an hourly time base for another instrument with complete temperature and depth records (usually a SBE37) and interpolate the selected instruments temperature and depth data onto the hourly time base. Create variables with the time base and matching depth and temperature records for matching all other instruments to.

- Trim the out of water times from these base time, depth and temperature variables.
- Begin stacking [stack_mooring.m]. Using the instrument_info.csv metadata file created earlier, and working on one mooring at a time, loop through each instrument in the list, building matrices of temperature, salinity and velocity with the same time base and a matching sized depth matrix (one for each of temperature, salinity and velocity).
    - Load the matlab structure for the instrument
    - Clean the data by replacing data with NaN where the quality flag > 2 for each variable
    - Include uncertainty estimates (see uncertainties section for details).
    - Interpolate the temperature data onto the time base [match_timebase.m] and add to the interpolated temperature matrix. This procedure projects raw data onto the selected time base by low pass filtering first (if the sampling rate is faster than the time base) and performing a simple linear interpolation.
    - Interpolate the depth (measured or inferred) data onto the time base [match_timebase.m] and add to the interpolated depth matrix (to match the temperature matrix). If the FV01 files do not have depth calculated, this can be done at this point, but this is complicated if the depth has to be inferred from adjacent instruments. In this case, refer the issue back to the person who created the FV01 files.
    - **QC assessment step:** Calculate a time lag and correlation for the instrument by comparing the fluctuations in the interpolated depth record (or temperature if depth is incomplete) to the base depth (temperature) record. [find_timeoffset.m]. Low correlations (<0.5) should be investigated and may indicate an issue with the instrument's time stamp that has not been corrected in the FV01 files.
    - If instrument measures salinity, interpolate the salinity data onto the time base [match_timebase.m] and add to the interpolated salinity matrix. Add the interpolated depth for this instrument to the depth matrix for salinity.
    - If instrument measures currents (UCUR, VCUR, WCUR), interpolate these onto the time base [match_timebase.m] and add to the interpolated currents matrix. Add the interpolated depth for this instrument to the depth matrix for currents. For RDI and profiling Nortek instruments, this process has to be done for every depth bin.
- After looping through all instruments:
    - Remove the Aquadopp and RDI temperatures from the final interpolated temperature matrix (also remove the depths in the matching depth matrix).
    - Sort all matrices by planned depth

- In the currents matrix, remove overlapping bins. Remove bins from overlapping profiling instruments by prioritising bins closer to the source. Remove Aquadopp data in preference to RDI data where the RDI records are mostly complete (ie, have more than 75% coverage in the closest bin).
- **QC assessment step:** Perform some plots to visually check for consistency between instruments in temperature, salinity and currents, for any bad data that was not flagged correctly and for drifts in pressure, temperature and salinity across the deployment that were not identified correctly. Any quality control issues identified should be addressed by re-visiting the FV01 files, fixing at the AODN, then begin the import and stacking process again.
- Save to a *.mat file the time base, interpolated matrix variables (temperature, salinity, currents and corresponding depth matrices for each), matching instrument names, mooring name and location and bottom depth.

At the end of this process, there is one *.mat file for each deployment at each mooring site (eg, for the 2019-21 deployment, we have 6 *.mat files, one for each mooring site). Each *.mat file contains matrices for temperature, salinity and velocity that all have the same size in the time dimension, but different sizes in the depth dimension, as they have one record for each instrument that records the variable. We have not yet interpolated the data in the depth dimension.

Figures 2 to 7 show examples of plots that can be made from the stacked files and these files can also be used to check the quality of the data to ensure that bad data has not been missed, that the time stamps are correct and that there is consistency between the instruments on the mooring.

Figure 2. Temperature with time in the 2019-21 EAC4200 stacked Matlab file.

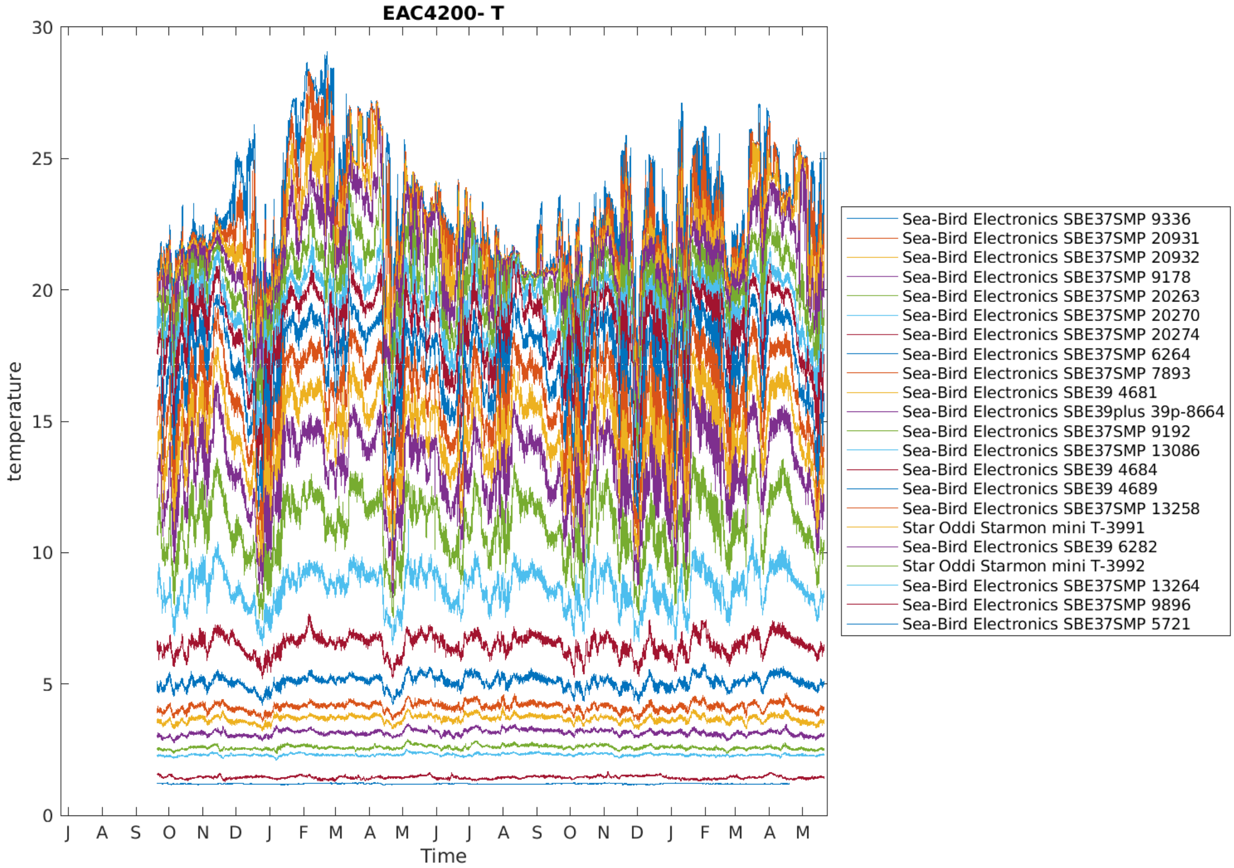


Figure 3. Salinity with time in the 2019-21 EAC4200 stacked Matlab file.

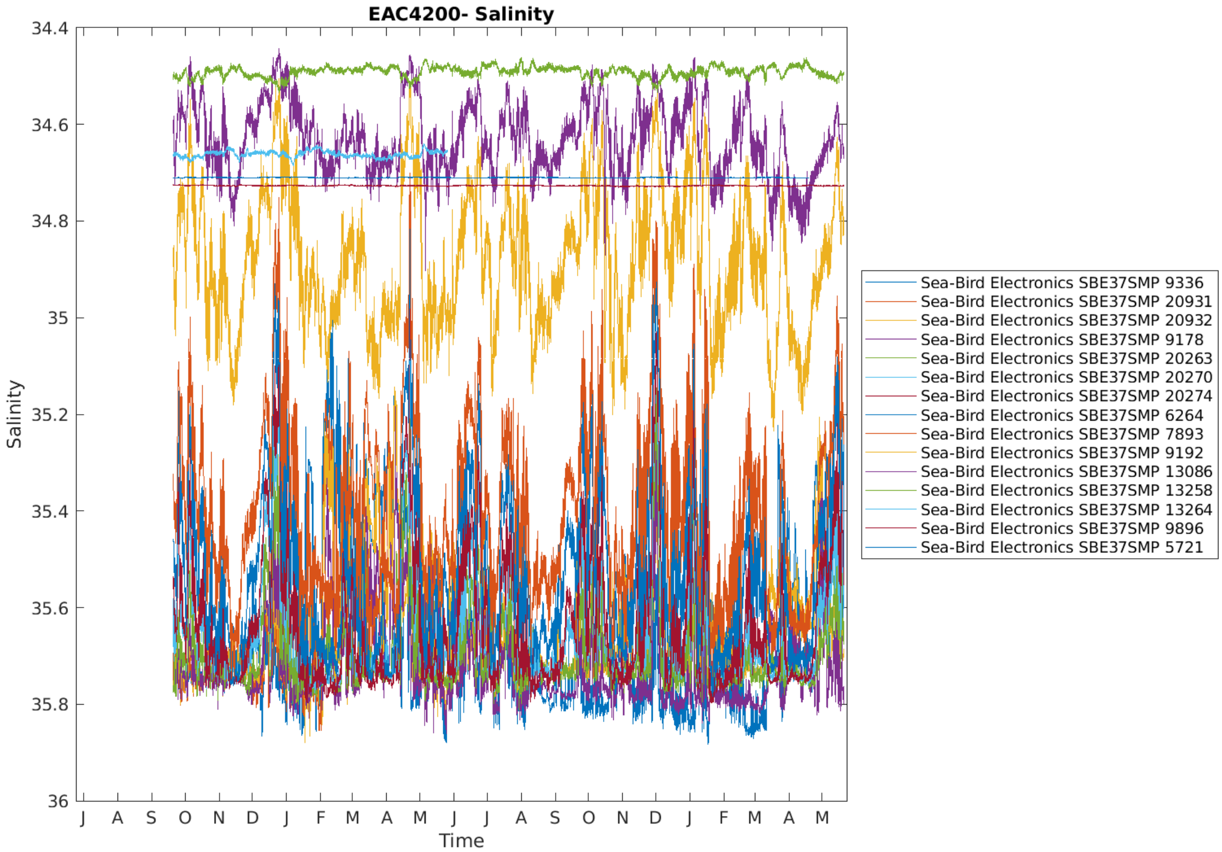


Figure 4. T-S relationship at the 2019-21 EAC4200 site. Grey dots show outliers that have been flagged as bad.

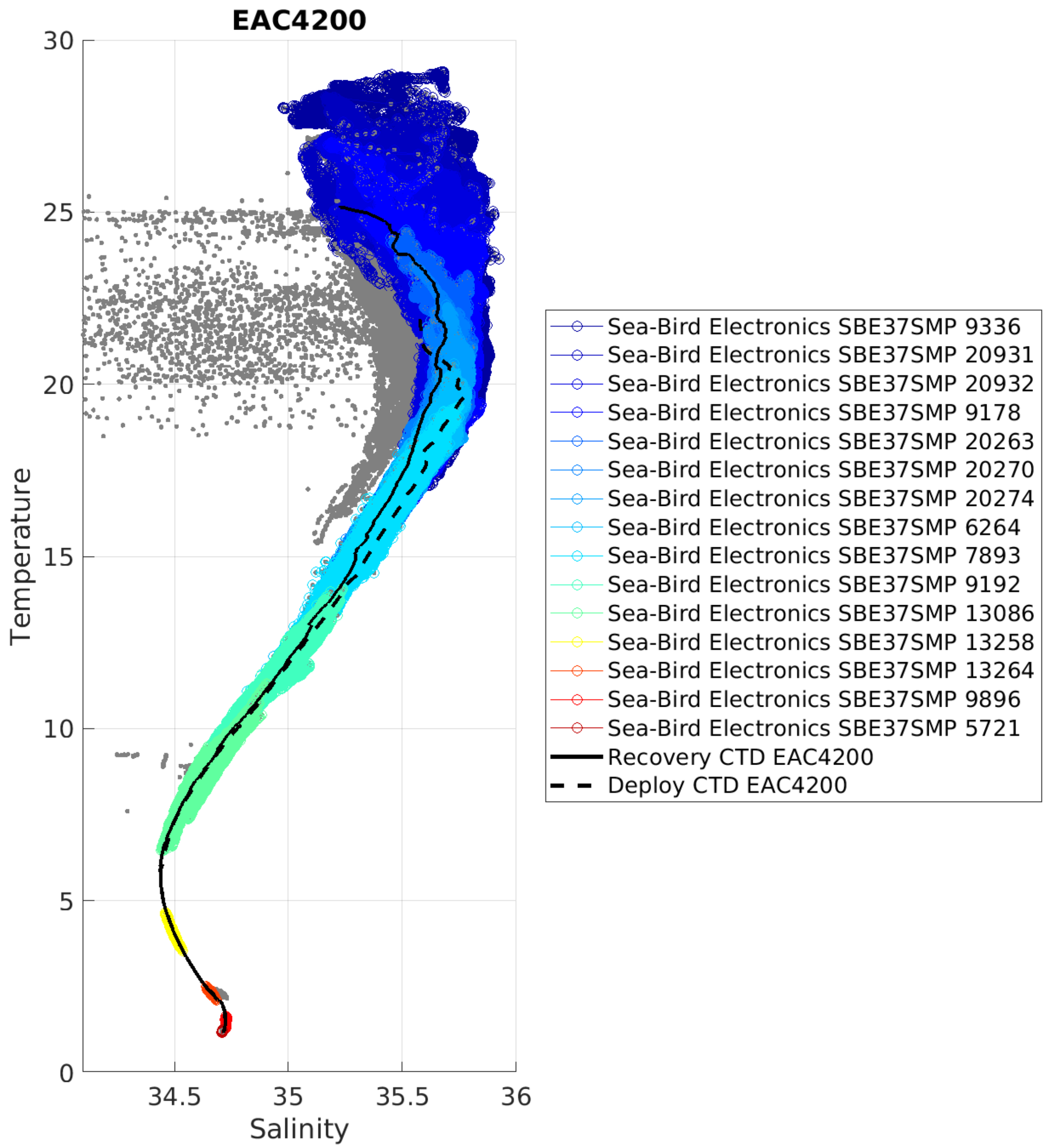


Figure 5. U-velocity vs Depth in the 2019-21 EAC4200 stacked Matlab file.

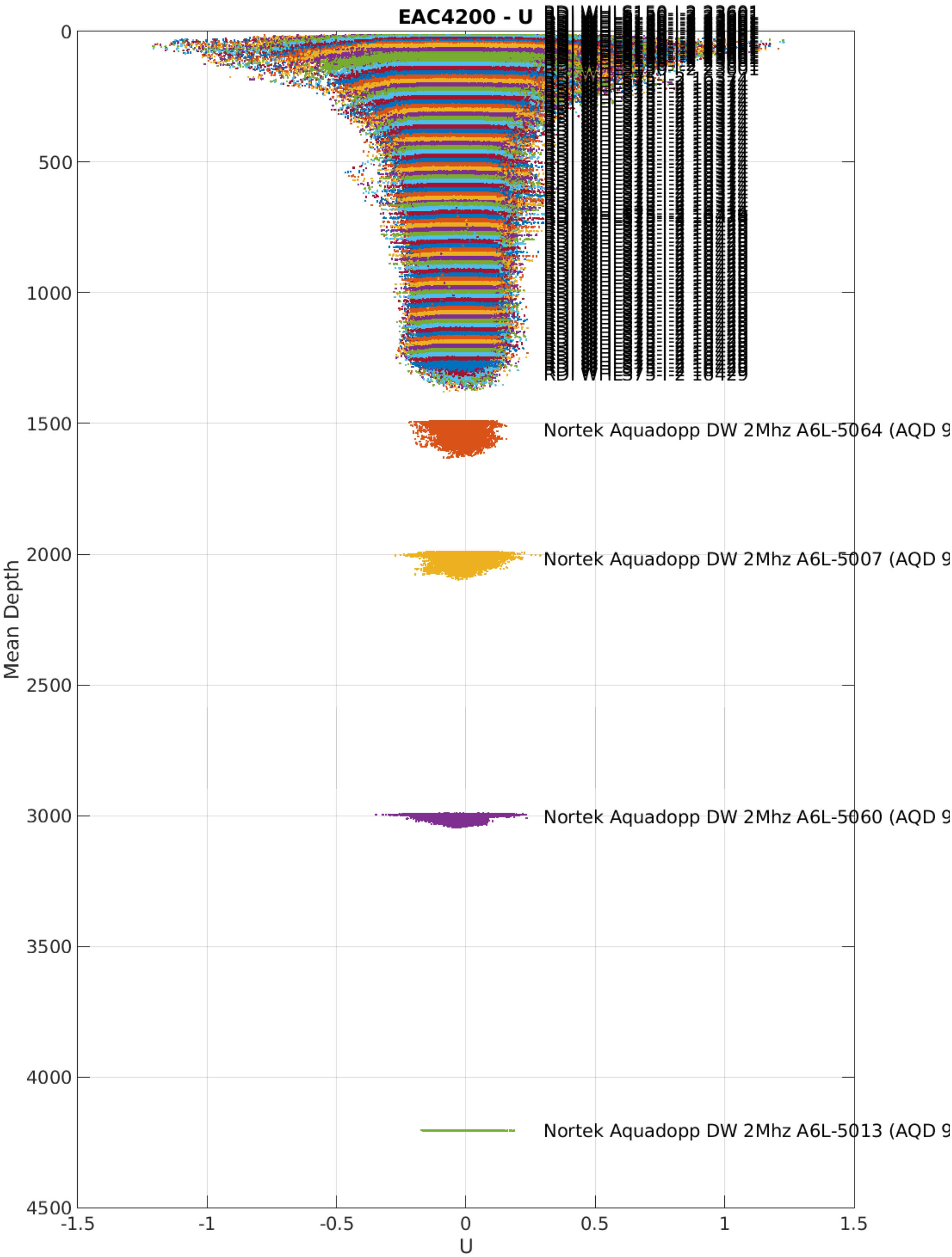


Figure 6. V-velocity vs Depth in the 2019-21 EAC4200 stacked Matlab file.

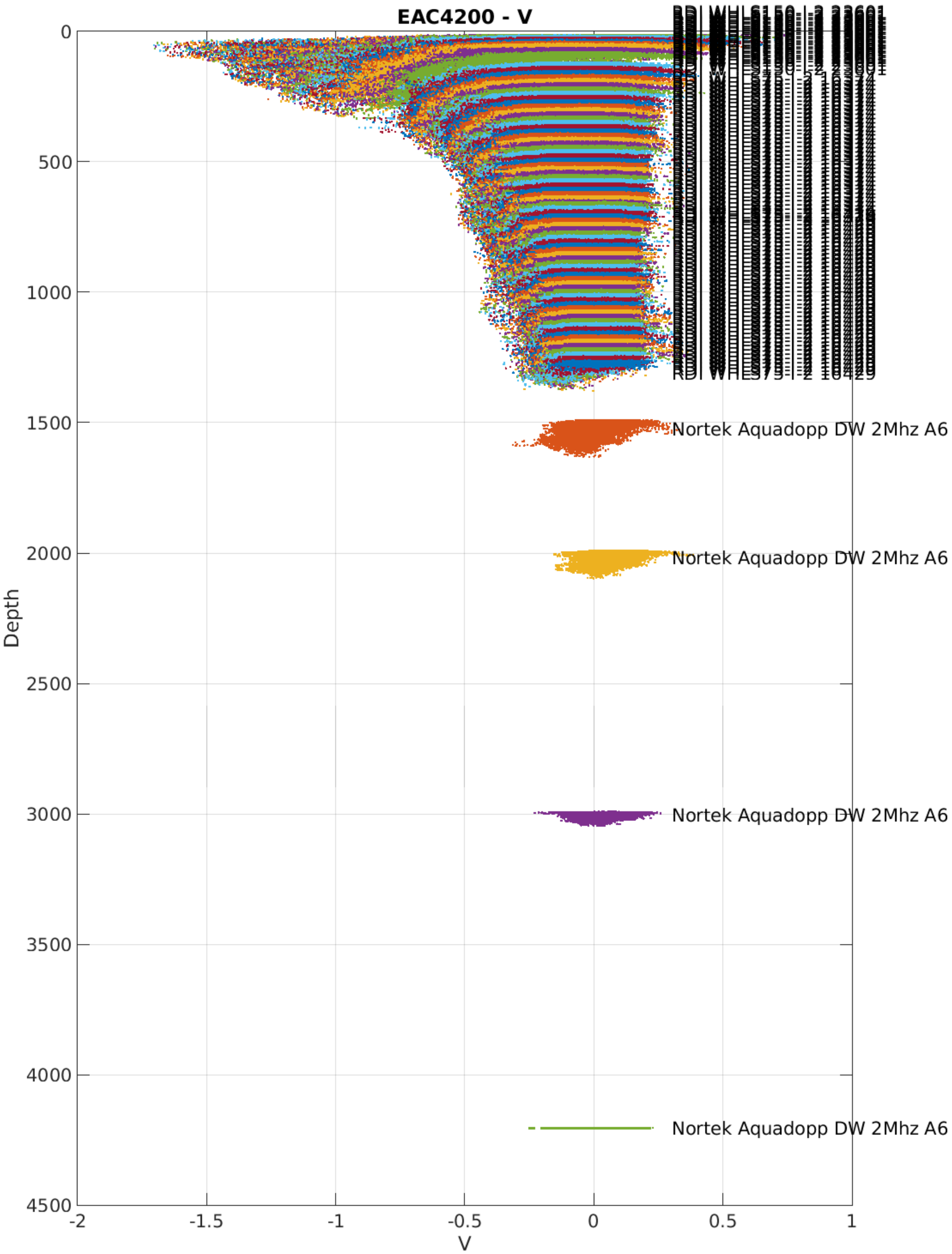
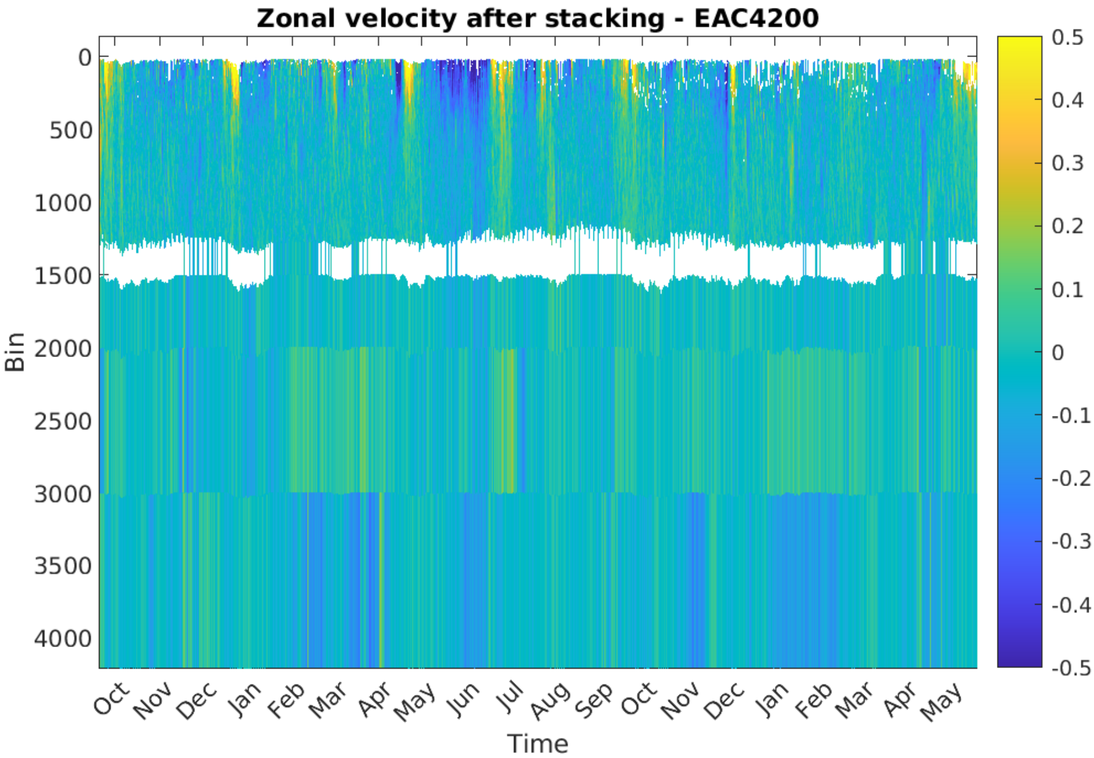
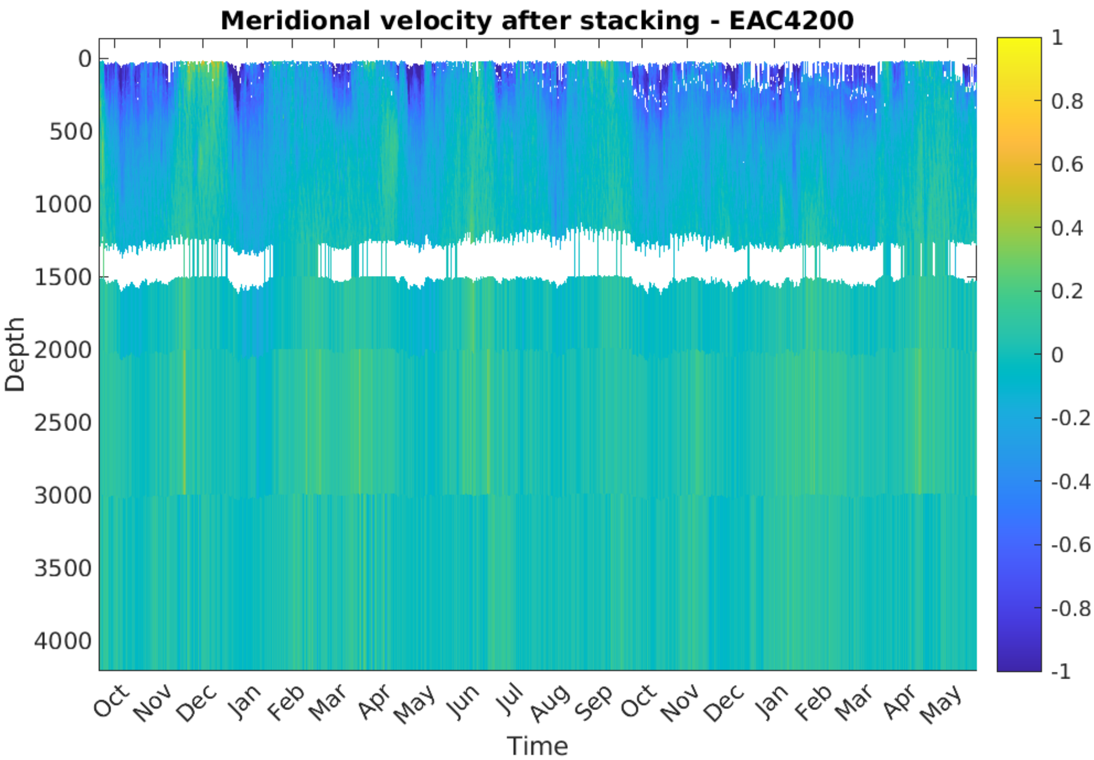


Figure 7. Meridional (V) and zonal (U) velocity in the 2019-21 EAC4200 stacked Matlab file. Data above 1200m is from RDI ADCPs and below is from Aquadopp point-source ADCPs. Plots are created with Matlab's pcolor.





3.1 Details of the stacking process

3.1.1 Code details

Matlab code: *make_insinfo_fromdeploymentcsv.m*

To begin, a csv file with metadata for each instrument on each mooring in a deployment is used in the stacking process (one csv file per deployment containing all the information for each mooring (up to 6 moorings)). It enables controlled gathering of the correct instruments for each mooring and each deployment. This information can be extracted from the FV01 netcdf files and compiled into a csv file which is loaded at the beginning of the stacking process. The information gathered includes:

- Mooring name
- Mooring latitude
- Mooring longitude
- Instrument type
- Instrument name
- Instrument serial number
- Instrument planned depth/deployment depth
- Bottom depth
- Clock offset at start of deployment
- Clock offset at end of deployment
- In water time
- Out water time

For the EAC moorings, the latest instrument_info.csv file used in the process is included for each mooring deployment in the matlab* folders.

Matlab code: *get_imosdata.m*

In addition to creating a permanent metadata list for the moorings, we read each FV01 file and add the critical metadata and data (temperature, salinity, pressure, depth and U/V (currents)) to individual Matlab structures. These structures are saved as a *.mat file (one file per instrument, with the file name the serial number).

Matlab code: *mooring_EACxxxx.m (xxxx = site name, eg 4200)*

For each deployment, a single script file is used to set up parameters for each mooring. The script files do the following:

1. Set path for:
    a. Location of the imported Matlab instrument data structures.
    b. Location of output directory for the final stacked *.mat file

    c. Location of output directory for any plots

2. Read in the metadata from the csv file
3. Load the single instrument *.mat file to set the time base that all instruments will be interpolated onto (see Table 3 for the instrument used for each mooring).
    a. Assign the time, temperature and depth data to new variables.
    b. Remove 'bad' data (flags 3 and 4) from the temperature and depth data.
    c. Result is time base, depth and temperature variables for a single instrument on the mooring that contain only good data.

Matlab code: *find_timeoffset.m called in stack_mooring.m*

Every instrument on the mooring has temperature recorded, many have pressure (converted to depth). Depth is calculated from pressure using the TEOS10 Matlab tool 'gsw_z_from_p' for all instruments except RDI ADCPs, which have Depth for each bin calculated on-board using the two-way transit time and sound speed. One way to identify time problems with instruments is to calculate time lags between instruments. The easiest way to do this is to look at pressure, and if pressure is not available, temperature. The moorings move up and down during the deployment and pressure changes should occur at the nearly same time for adjacent instruments. As the distance between instruments increases, we expect that the movement in pressure will be offset in time somewhat. Instruments closer to the surface have a greater range of movement, while those at the deepest parts of the moorings move very little. Matching the pressure records to determine a time lag is successful for instruments closer together, but less so for those further apart. This is the same for temperature. Temperature records generally don't match as well as pressure and we expect that the correlations determined will be somewhat lower for temperature-matched instruments.

If the correlation from the time lag calculation is less than 0.5, a warning is shown. It is up to the operator to fix any problems if they are discovered, which may involve re-QC of the FV01 files or on-the-fly QC fixes.

Matlab code: *stack_mooring.m*

For each instrument on the mooring, including the one used as our time-base starting instrument (we know the serial number information from the loaded csv metadata file):

- Remove data flagged with flag 3 or 4 from all variables ('bad' data).
- Interpolate temperature, salinity, currents (u/v) and depth onto the common time base and record the time-lag and time correlation (*match_timebase.m* and *find_timeoffset.m*).
- Record if depth is calculated from the instrument's measured pressure, or inferred from adjacent instruments (either because of no pressure record or bad pressure record).
- Concatenate by depth the resulting interpolated depth, temperature, salinity, u/v onto the previous instrument's interpolated depth, temperature, salinity, u/v variables.
- Retain the serial number and instrument name for identification.

Once all instruments have been added to the combined matrices for temperature, depth, salinity and u/v, they are all sorted by depth (shallowest to deepest). Serial number/instrument name information is also sorted. Uncertainties are sorted.

3.1.2 Temperature

Temperature data from RDI and Nortek instruments is not included in the final stacked product as the accuracy of the sensors is lower than that of the Seabird CTD and Star Oddi instruments. After all the temperatures have been interpolated onto the common time-base, RDI and Nortek temperatures are removed.

3.1.3 Salinity

The earlier EAC deployments did not have many instruments with the capability of recording salinity. Later deployments do have more instrumentation on them, but many are subject to failures due to cracked cells, instrument drift, battery failures, pump failures and various other reasons. Salinity has many of the obvious failures flagged, but very subtle changes may not be accounted for, and we recommend that the user take care with the salinity gridded product if high accuracy in the data is required. Future work is aimed at improving the salinity dataset, incorporating offsets and comparisons with ship CTD measurements.

3.1.4 Velocity

In some cases, velocity measurements from different instruments on the moorings overlap. These overlaps provide opportunities for comparisons of the data from each instrument, but for the stacked product, we remove overlapping bins. Preference is given as follows:

- An Aquadopp record will be retained if there is less than 75% coverage from an overlapping RDI ADCP bin. Overlapping bins from the depth of the Aquadopp to the end bin of the RDI will be removed. Otherwise, the Aquadopp record is removed.
- Aquadopp records are removed where overlapping RDI ADCP records come from an upward-facing RDI (only occurs in EAC4800 where there is an ADCP LR75 facing up and an Aquadopp at a shallower depth).
- Where two RDI instruments have overlapping bins, data from bins closest to the originating instrument are retained.

3.1.5 Selection of a time-base instrument for each mooring deployment

For all moorings, we aim to use the instrument type with the longest time between records to interpolate the data from all instruments onto. In nearly every case, this was the RDI ADCP instruments. In the first 3 deployments, the RDIs were set up to ensemble average the data on board and the averaging period was 3600s (1 hour). In later deployments, data is collected in single ping mode, but after processing through the IMOS Toolbox, the FV01 data produced is also in hourly ensemble averaged time steps. If there is no ADCP deployed on the mooring, or the temperature or pressure data from the RDI was incomplete or flagged as bad, an alternative instrument with good temperature and pressure data is required to begin the stacking process. This situation occurs in two cases.

Table 3 lists all the moorings and the instruments selected for each for matching instruments on the mooring to the selected time base.

Table 3. Instruments selected for the time base during stacking

Deployment	Mooring	Instrument & serial number used for time base	Comments
2012/04 to 2013/08	EAC1520	RDI ADCP 16072	
	EAC2000	RDI ADCP 16431	
	EAC4200	RDI ADCP 16432	
	EAC4700	RDI ADCP 16429	
	EAC4800	AQD 9893	No RDI on the mooring, used 1800s time base.
2012/03 to 2013/06	SEQ400	RDI ADCP 17055	
2015/05 to 2016/11	EAC0500	RDI ADCP 16431	
	EAC2000	RDI ADCP 14253	
	EAC3200	RDI ADCP 14292	
	EAC4200	RDI ADCP 17054	
	EAC4700	RDI ADCP 17055	
	EAC4800	RDI ADCP 14890	
2016/11 to 2018/05	EAC0500	SBE37 9167	ADCP data not available for entire deployment. Use SBE data after interpolation onto an hourly time base.
	EAC2000	RDI ADCP 17742	
	EAC3200	RDI ADCP 17677	
	EAC4200	RDI ADCP 16429	

Deployment	Mooring	Instrument & serial number used for time base	Comments
	EAC4700	RDI ADCP 16374	
	EAC4800	RDI ADCP 16072	
2018/05 to 2019/08	EAC0500	RDI ADCP 14254	
	EAC2000	RDI ADCP 24473	
	EAC3200	RDI ADCP 17959	
	EAC4200	RDI ADCP 14345	
	EAC4700	RDI ADCP 14434	
	EAC4800	RDI ADCP 14890	
2019/08 to 2021/05	EAC0500	RDI ADCP 16431	
	EAC2000	RDI ADCP 17958	
	EAC3200	RDI ADCP 23160	
	EAC4200	RDI ADCP 16374	
	EAC4700	RDI ADCP 17677	
	EAC4800	RDI ADCP 17742	
2012-2021	NSI	RDI ADCPs at 60m, except for the 2013/02 deployment which used the WQM 177 and 044 combined record.	Multiple 6-month deployments for NSI location.

3.1.6 Notes on the stacking of the North Stradbroke Island mooring dataset

The NSI dataset comprises of multiple 6-month deployments from 2012 to 2021 and the design, instruments used and deployment techniques are different from the EAC deepwater moorings.

We used the FV01 files and the flags in them, but some adjustments and concatenation of files was required to help with the construction of the stacked files.

Table 4. Details of the NSI file preparations for stacking

Deployment	Instruments	Details
2012/04	WQM 173 and 174 @ 20m WQM 044 and 044 @ 60m	WQM instruments were deployed twice in the six-month period and other instruments on the mooring have one-six-month file. The two deployments of the WQMs were joined together into one file before stacking.
2012/09	WQM 176 and 176 @ 20m WQM 173 and 044 @ 60m WQM 173 has some bad salinity that was not flagged.	WQM instruments were deployed twice in the six-month period and other instruments on the mooring have one-six-month file. The two deployments of the WQMs were joined together into one file before stacking. Clean up the bad salinity after stacking by replacing the bad section with NaNs.
2013/02	WQM 175 and 176 @ 20m WQM 174 and 044 @ 60m	WQM instruments were deployed twice in the six-month period and other instruments on the mooring have one-six-month file. The two deployments of the WQMs were joined together into one file before stacking.

4 Uncertainty estimates

4.1 Temperature, Salinity, Pressure instruments

SBE37, SBE39 and Star Oddi instrument uncertainties are taken from CSIRO calibration certificates which are the **expanded uncertainty.** Ideally, we can source this information for each instrument and each deployment, but as we are doing this in retrospect and quickly, we use these values which are from a sub-set of calibration certificates.

Salinity uncertainty for SBE37 instruments is calculated using the TEOS-10 tool gsw_SP_from_C as follows:

C1 = 42.918 mS/cm (selected to represent seawater salinity)

C2 = 42.916 mS/cm

Temperature = 15 °C

Pressure = 10.1325 dBar

Salinity uncertainty = gsw_SP_from_C(C1, 15, 10.1325) - gsw_SP_from_C(C2, 15, 10.1325)

In regions with strong temperature gradients the pressure uncertainty will translate to a temperature uncertainty. For our product, we have not included depth uncertainties.

Star Oddi Starmon Mini instruments don't measure pressure, therefore depth is inferred from SBE instruments. Therefore, they inherit SBE pressure uncertainties + 0.5 dbar to allow for mooring wire measurement uncertainty. However, we are not accounting for pressure uncertainty in the final product.

For the WQM instruments, we use same values for TEMP, PSAL, PRES as SBE37. The WQM uncertainty and instrument information is not documented well online. I have generously used the SBE values as the instruments use SBEs. However, the uncertainties from these instruments are potentially much higher, as we know that they have had some operational issues. They are also run in burst mode and the data averaged. We could obtain the raw data and do some uncertainty calculations from the bursts to estimate uncertainty better.

Indeed, with the raw data the Type A uncertainties ("random errors") could be specified.

4.2 Current instruments

Nortek Aquadopp uncertainties are taken from setup log files and are instrumental uncertainty from the manufacturer (Nortek, 2023). Temperature measurements from RDI and Aquadopp instruments are not used in the gridded products. Most Nortek instruments have inferred depths, and therefore should inherit SBE instrument uncertainties for pressure. Again, the pressure uncertainties are not accounted for in the products.

RDI ADCP uncertainties for currents are calculated from the standard deviation of error velocity (RDI, 1996). Other values are taken from RDI specification sheets (Teledyne Marine, 2023), but temperature and pressure uncertainties are not included in the products (as temperature measurements are not used and pressure uncertainties are not accounted for).

Heading, beam measurement and tilt uncertainties are not calculated independently, but tilt should be accounted for within the error velocity as it includes bin mapping. There are many papers available that calculate uncertainties in different ways (eg Kim and Yu, 2010), these could be explored in future releases.

Table 5. Uncertainty budgets for EAC mooring instruments.

Uncertainty budgets EAC moorings						
SBE37	**PSAL (PSU)**	**TEMP (°C)**	**UCUR (m/s)**	**VCUR (m/s)**	**PRES (dBar)**	**PRES (% of reading)**
Calibration certificate average	0.0018	0.0015	NA	NA	0.5	0.01
SBE39						
Calibration certificate average	NA	0.0015	NA	NA	0.5	0.01
Synthetic salinity, RMSE from rosette CTD data and mooring CTD data comparison within a +/- 5 hour window						
EAC0500, NRSNSI	0.0527	NA	NA	NA	NA	NA
EAC2000	0.0444	NA	NA	NA	NA	NA
EAC3200	0.0410	NA	NA	NA	NA	NA
EAC4200	0.0382	NA	NA	NA	NA	NA
EAC4700	0.0384	NA	NA	NA	NA	NA
EAC4800	0.0402	NA	NA	NA	NA	NA
Star Oddi						
Calibration certificate average	NA	0.01	NA	NA	NA	NA
Inferred depth, inherited from SBE3x	NA	NA	NA	NA	0.5	0.01
Mooring wire measurement uncertainty	NA	NA	NA	NA	0.5	NA
RDI ADCP						
Manufacturer documentation, instrumental (RDI 1992; Teledyne Marine, 2023)	NA	0.4	RDI formula	RDI formula	0	0.1
Manufacturer documentation, error velocity (RDI, 1996)	NA	NA	Moving std dev of error	Moving std dev of error	NA	NA

			velocity. +/-3 hours	velocity. +/-3 hours		
Nortek Aquadopp DW						
TEMP and PSAL, from Nortek, 2023). Currents, from manufacturer values in instrument log files.	NA	0.1	0.009	0.009	0	0.5
WQM						
Based on SBE37 data	0.0018	0.0015	NA	NA	0.5	0.01
SOM uncertainty - RMSE from multiple iterations	0.0364	0.3848	0.0299	0.0601	NA	NA

4.3 Procedure to incorporate uncertainty estimates into gridded products:

A: Hourly stacked data (on hourly time stamp and instrument-measured (or inferred) depths)

1. Create arrays the same size as the PRES, TEMP and PSAL data and add instrumental uncertainty estimates for these. Same for Aquadopp currents.
2. For RDI currents (UCUR, VCUR), create arrays the same size as the data and calculate the instrumental uncertainties based on the setup for each RDI instrument. Add to the uncertainty arrays for each variable.
3. For RDI instruments, calculate the moving standard deviation of the error velocity values within a 6 hour window (+/- 3 hours from each hourly measurement). Add this to the instrumental uncertainty for UCUR and VCUR. Moving standard deviation window was chosen to be representative of the temporal variation as the mooring moves up and down in the water column. A standard deviation for the entire period is not representative of uncertainties at each time step.

B: Hourly data interpolated onto a regular depth grid

1. Create a synthetic salinity based on the T-S relationship for each mooring. Fill the data gaps in instrumental salinity with the synthetic salinity. Update the PSAL uncertainties with the synthetic salinity uncertainties where synthetic salinity is used.
2. Linearly interpolate data and uncertainties onto the depth grid.

C: Daily data interpolated onto a regular depth grid and filled with self-organising Maps (SOM) data

1. Apply the same filter and interpolation to uncertainties from product B as done for variable data.

2. Where data gaps are filled from the SOM model data, fill uncertainty values with SOM RMSE values added to the mean instrument uncertainty for the entire period (10 years) at each depth.

5 Filtering and interpolation process to create the per-mooring time and depth gridded products

The stacked files created as outlined in the previous section are now used to create the final products for each mooring. The first product is the stacked data on an hourly time grid and regular depth grid. The second is the stacked product on a daily time grid and regular depth grid, with a SOM-filled version of each variable included. The variables included in both the hourly and daily products are UCUR, VCUR, TEMP and PSAL. The daily product also includes the variables UCUR_filled, VCUR_filled, TEMP_filled and PSAL_filled.

Matlab code: *grid_filter_mooring_EAC.m*

- Two time stamps are created, an hourly and daily time stamp, from the start time of the first mooring deployed in the first deployment (2012) to the time of the last mooring recovered in the final deployment (2021).
- A depth grid is created from the surface to the maximum depth of each instrument on each mooring (one depth grid for each mooring location). For each site, the depth grid is 10m intervals from 0 to 400m and 20m intervals from 420m to the maximum depth of the deepest instrument deployed.
- **For each mooring**
  - Cycle through **each deployment** and:
    - Load the stacked *.mat file.
    - For each variable (currents, temperature, salinity) we perform a linear interpolation onto the depth grid for that mooring at every time step (hourly) only if there are more than 2 data points available.
    - Missing data chunks (where instruments failed or were lost) are then masked by replacing the interpolated values with NaN, so we don't get bad interpolation in gaps.
    - Concatenate the deployments in time. Consecutive deployments are concatenated into one matrix for each variable from 2012 to 2021.
    - Save each mooring (hourly depth gridded data) in a *.mat file
  - Working on the concatenated matrices for currents, temperature and salinity:
    - For each variable at every depth grid point, we interpolate across all the times, but only if there is more than 1 month of data.

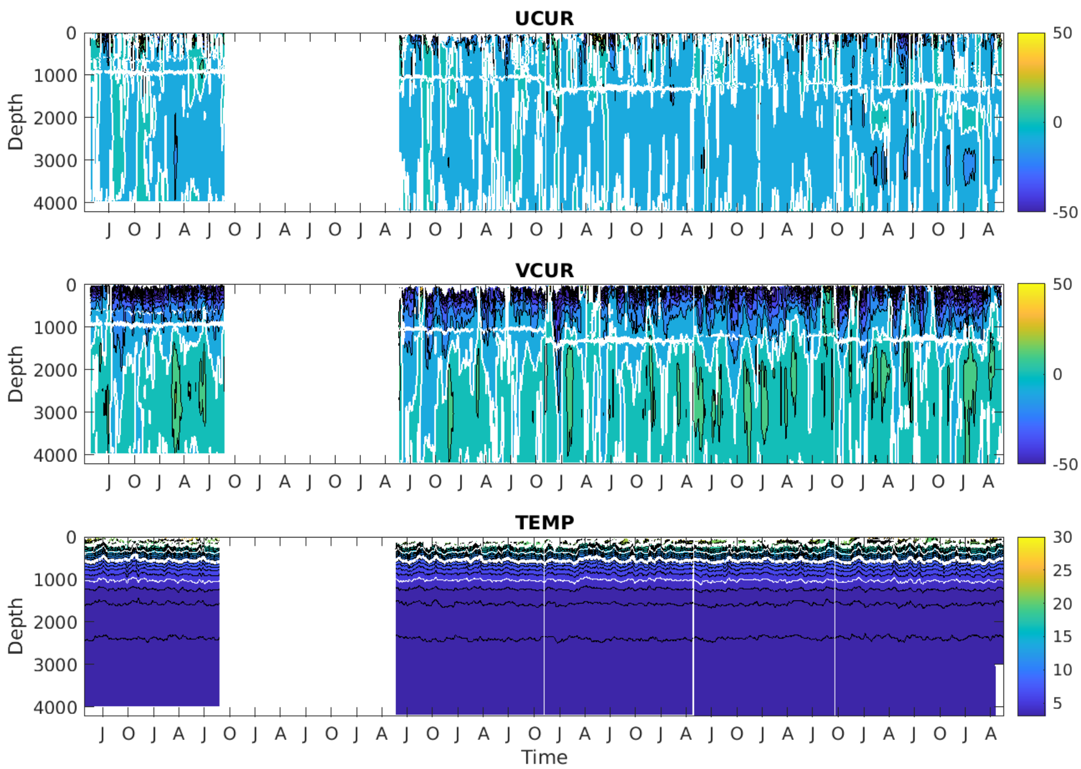
- Missing data due to failed instruments are masked by replacing the interpolated data with NaN.
- Times where mooring re-deployment occurs are masked out with NaN (when the mooring is not in the water during mooring turnarounds).
- A low-pass filter (hamming with a 5-day window) is performed at each depth for each mooring.
- Finally, linearly interpolate from hourly to daily.
- Remove temperature inversions from the daily product. When applying this step to other mooring sites, care should be taken if inversions are expected in the area.
- Save each mooring (daily, filtered, depth gridded data) in a *.mat file

- Load each *.mat file and translate into a netcdf file, one per mooring. Both hourly and daily gridded netcdf files are created.

The netcdf files are published in Sloyan et al (2021) and Sloyan et al (2022). Some simple plots of this product for the EAC4200 mooring are shown in Figure 8.

The next step is to create a single product gridded in time, as well as across all the moorings. The description of how this is done is in Sloyan et al (2023), and the data product is published in Sloyan, Cowley and Chapman (2023).

Figure 8. Zonal (U) velocity (top), Meridional (V) velocity (centre) and Temperature (bottom) for the gridded, filtered and concatenated EAC4200 mooring (2012 to 2021). Units for velocity are cm/s and for temperature, °C.



6 References

Cowley, R. (2021) Report on the Quality Control of the IMOS East Australian Current (EAC) Deep Water moorings array. Deployed: April 2012 to August, 2013. Version 3.0. CSIRO Oceans and Atmosphere, Australia. DOI: 10.26198/N3XJ-SY16 (https://doi.org/10.26198/N3XJ-SY16)

Cowley, R. (2022a). Report on the Quality Control of the IMOS East Australian Current (EAC) Deep Water moorings array. Version 1.4. Deployed: April/May 2018 to September, 2019. CSIRO Oceans and Atmosphere, Australia. DOI: 10.26198/5r16-xf23 (https://doi.org/10.26198/5r16-xf23)

Cowley, R. (2022b). Report on the Quality Control of the IMOS East Australian Current (EAC) Deep Water moorings array. Version 1.0. Deployed: September 2019 to May 2021. CSIRO Oceans and Atmosphere, Australia. DOI: 10.26198/rgns-v363 (https://doi.org/10.26198/rgns-v363)

Cowley, R. (2022c). Report on the Quality Control of the IMOS East Australian Current (EAC) Deep Water moorings array. Version 1.1. Deployed: May 2021 to July 2022. CSIRO Oceans and Atmosphere, Australia. DOI: https://doi.org/10.26198/5pzy-cm87

Kim, D., Yu, K. Uncertainty estimation of the ADCP velocity measurements from the moving vessel method, (I) development of the framework. *KSCE J Civ Eng* **14**, 797–801 (2010). https://doi.org/10.1007/s12205-010-0950-6

Lovell, J & Cowley, R. (2021a). Report on the Quality Control of the IMOS East Australian Current (EAC) Deep Water moorings array. Deployed: May 2015 to November 2016. Version 3.1. CSIRO, Australia. DOI:10.26198/5d3fb95821dda (https://doi.org/10.26198/5d3fb95821dda)

Lovell, J. and Cowley, R. (2021b). Report on the Quality Control of the IMOS East Australian Current (EAC) Deep Water moorings array. Version 1.2. Deployed: November 2016 to May, 2018. CSIRO Oceans and Atmosphere, Australia. DOI: 10.26198/5ec1df4b25cca (https://doi.org/10.26198/5ec1df4b25cca)

Nortek (2023). Aquadopp Technical Specifications. https://www.nortekgroup.com/export/pdf/Aquadopp%203000%20m.pdf

RDI (1996). Acoustic Doppler Current Profiler Principles of Operation. A Practical Primer. Second Edition for Broadband ADCPs. P/N 951-6069-00. January 8, 1996.

Sloyan, Bernadette; Cowley, Rebecca; Chapman, Chris (2021): East Australian Current individual mooring gridded product - daily and 10-20m depth gridded. v14. CSIRO. Data Collection. https://doi.org/10.25919/egsf-yh54

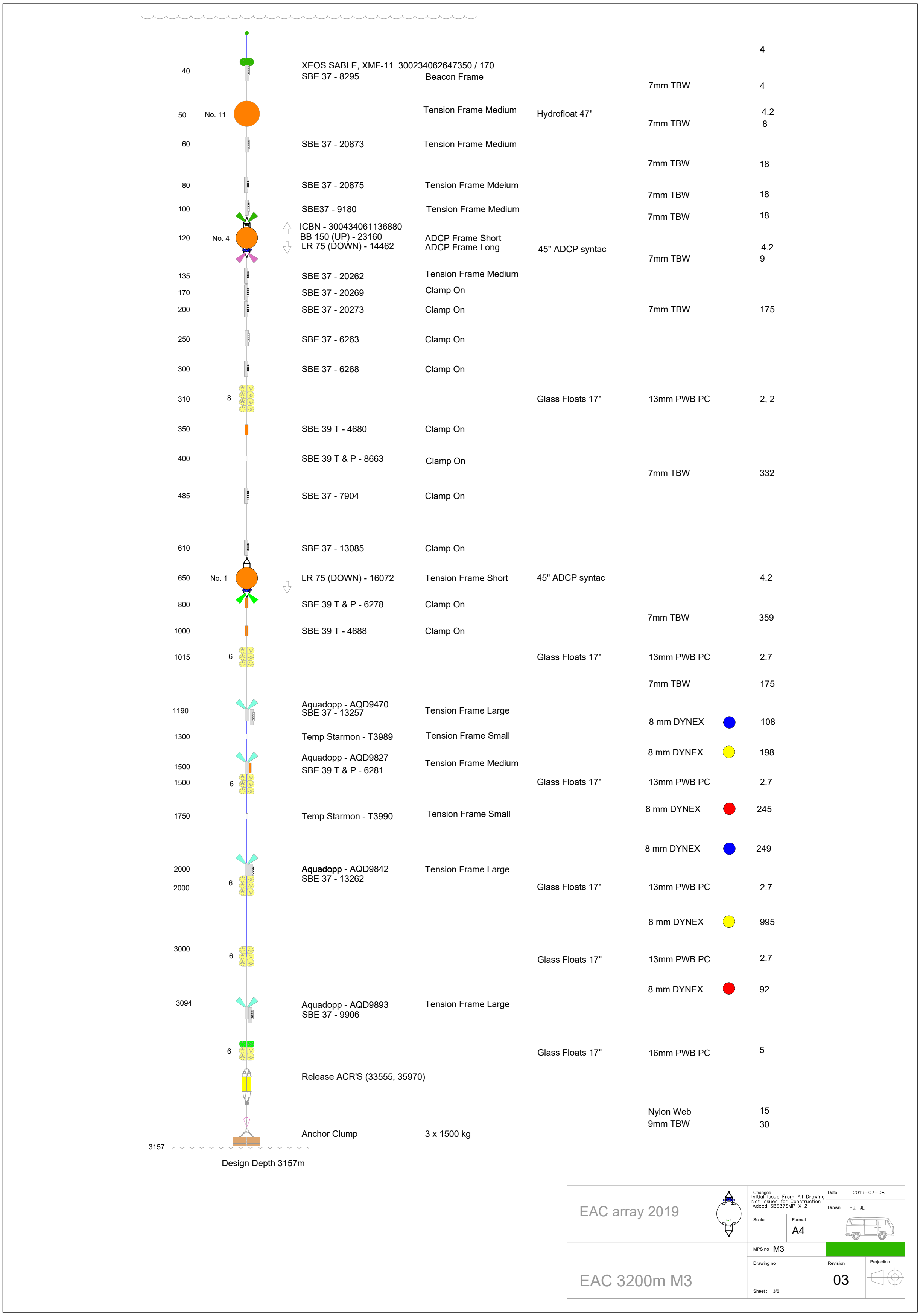
Sloyan, Bernadette; Cowley, Rebecca (2022): East Australian Current individual mooring gridded product - hourly and 10-20m depth gridded. v8. CSIRO. Data Collection. https://doi.org/10.25919/yycf-ed65

Sloyan, Bernadette; Cowley, Rebecca; Chapman, Chris (2023): East Australian Current gridded (depth, distance and time) mooring product. v18. CSIRO. Data Collection. https://doi.org/10.25919/wg81-e165

Sloyan, B. M., C. C. Chapman, R. Cowley, and A. A. Charantonis, 2023: Application of Machine Learning Techniques to Ocean Mooring Time Series Data. *J. Atmos. Oceanic Technol.*, **40**, 241–260, https://doi.org/10.1175/JTECH-D-21-0183.1.

Teledyne Marine (2023). Workhorse II Product Datasheet. https://www.teledynemarine.com/en-us/products/SiteAssets/RD%20Instruments/wh_ii_datasheet_04_2023.pdf

Appendix A. EAC 2019-2022 3200m mooring diagram



As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us

1300 363 400
+61 3 9545 2176
csiro.au/contact
csiro.au

For further information

Oceans and Atmosphere
Rebecca Cowley
rebecca.cowley@csiro.au