Mooring processing of PS109/PS114 recoveries
(*Northeast Greenland continental shelf*)

The processing documented here applies to the following 18 moorings recovered during:

PS109:
EGN-1
EGS-1
IdF1-1
IdF2-1
IdF3-1
IdF4-1
79N1-1
79N2-1
79N3-1
79N4-1
79N5-1
PS114:
EGS1-2
EGS2-1
EGS3-1
EGS4-1
79N6-1
79N7-1
79N8-1

Directory structure of raw data
The data has been sorted into folders of the following structure:
[year]_[cruise_ID]/[instrument_type]/[mooring_name]/[instrument_SN]*
where
[cruise_ID] = PS109, PS114
[instrument_type] = ADCP, Aquadopp, BPR, Microcat, RCM, SBE56
[mooring_name] = F2-17, … Karasik-2015
[instrument_SN] = serial number of the instrument

The following file conversions have been performed and the following ancillary files are available for each instrument type:

ADCP: Quarter Master, Long Ranger, 300kHz, and 600 kHz RDI Workhorse ADCPs (recording in burst mode)
.000 Native binary data file. For some moorings there existed two sequent native binary files (named _0.000 and _1.000). The data sets were not split up correctly during the ADCP recording (i.e., the second hex-file _1.000 should start with a new burst: "7F7F [...]"). Thus all readings before the first "7F7F" were deleted manually (Use iHex to open and change the hex-files _1.000.)
.mat Matlab binary file converted from .000 with read_ADCP_burst.m, not for IdF2-1, IdF4-1, and 79N5-1, where data has been recorded in instrument coordinates

Aquadopp: Nortek Aquadopp Deep Water with pressure sensor
.aqd Native binary data file to be read with Nortek Aquadopp DW
.dat, .dia, .hdr, .ssl ASCII files that were converted from .aqd with Aquadopp DW
.dat has been copied and renamed to be named after the instrument serial number; the files were otherwise named after the head ID

BPR: Seabird SBE26 and SBE53 bottom pressure recorders with temperature sensor
.hex Native hex-ASCII data file
.tid (tide sampling), .wb (wave burst sampling) ASCII files that were converted with Seabird Seasoft for Waves

Microcat: Seabird SBE37 microcats with optional pumps, pressure sensors, oxygen sensors
For old instruments:
.asc ASCII capture info and data files from data upload with Seabird Seaterm V1
For new instruments:
.hex Native hex-ASCII data file
.xmlcon ASCII calibration info
.cnv ASCII data file converted with Seabird Data Processing

RCM: Aanderaa RCM8 rotor current meter with pressure sensors
.dsu Native binary data files
.txt ASCII data files converted with Aanderaa 5059 Data Reading Program, data is highlighted in data reading program, copied to clipboard, pasted into text editor
.xlsx for AWI physical oceanography section instrument, Excel file with calibration information extracted from RCM_Call_all.xlsx

SBE56: Seabird SBE56 temperature logger
.xml native ASCII data file
.cnv ASCII data file converted with Seaterm V2/Instrument/P.SBE 56 Temperature Logger

Two Excel files are generated and adjusted during the processing that contain information on the moorings and the instruments in the moorings:

Mooring_info_PS109.xlsx
Name of the mooring
Longitude and latitude of deployment location as well as water depth at deployment location
Deployment and recovery dates, times, ships, Polarstern ARK campaigns, regular (e.g. PS*) campaigns, station name
Authors of the data set to be deposited in Pangaea

Instrument_info_PS109.xlsx
Name of the mooring

Instrument type with nomenclature as used in cruise report
Serial number of instrument
Depth in meters of the instrument according to the mooring drawing
Instrument ID
Assignment which pressure record should be associated with an instrument (=0 own pressure record, =-1 depth from mooring drawing, =ID unique ID of instrument to use)
Constant offset in meters to be applied to the assigned pressure record

The mooring info is primarily syndicated from the station books of the respective cruises. The instrument info is primarily syndicated from the mooring drawings of the respective moorings. The available info is then checked and corrected against the data and several consistency checks during the processing.

Processing

The processing is carried out in the folder [year]_[cruise_ID]/Processing/m_files. It contains the following required m-files:
calculate_sal_u_v_oxy.m – step 4 to calculate derived variables
find_depths.m – step 3 to determine the pressure/depth records
find_start_end.m – step 2 to remove data before deployment/after recovery
get_time.m – time conversion
import_cal_info.m – import RCM .xlsx calibration called by read_RCM_xlsx.m
plot_oxy.m – plot oxygen timeseries
plot_sal_the.m – plots TS diagrams
plot_spd_dir.m – plots scatter plots of u/v velocities and current ellipses
process_[cruise_ID].m – driver function calling the 4 steps and 3 plotting programs
read_ADCP_burst.m - read ADCP hex-files (burst mode) and save .mat-files
read_all.m – step 1 to read all the ASCII data files described above
read_aqd.m – read Aquadopp ASCII data files
read_asc.m – read old Microcat ASCII data files
read_BPR.m – read BPR ASCII data files
read_cdb.m – import RCM .cdb calibration called by read_RCM_cdb.m
read_instrument_info.m – import Instrument_info_PS109.xlsx into Matlab
read_mooring_info.m – import Mooring_info_PS109.xlsx into Matlab
read_RCM_cdb.m – read RCM ASCII data files with calibration info in .cdb
read_RCM_xlsx.m – read RCM ASCII data files with calibration info in .xlsx
read_seaguard.m – read Seaguard ASCII data files

Further m-files needed are listed in process_[cruise_ID].m and are:
datetick2.m
existf.m
find_current_ellipse.m
/igrf/igrf.m
/igrf/loadigrfcoefs.m
load000.m
pltstmp.m

rditype.m
read_cnv.m
reshape_vec.m
salt.m
setdefv.m
/sw_* Seawater toolbox
suptitle.m
burst2ensemble.m

Step 1 (read_ADCP_burst.m)
Uses the mooring and instrument information supplied in the two Excel files to read all ADCP hex-files using load000.m. If two sequent data sets are available it merges these into one. The data is saved in a .mat file for further processing. This routine is called separately before reading all mooring data because it takes long (size of burst files is large).
Some additional information: In general, the ADCP data from all AWI instruments were recording in burst mode (e.g., one burst may be 20 pings in 5 s once per hour) and beam coordinates and thus required some additional processing steps. Usually using WinADCP the data (recorded in beam coordinates) is already transformed into earth coordinates. Here we do the transformation on our own (in read_ADCP_burst.m):
- In case of two raw data files (e.g., .000 and .001) make sure that both hex-files start with a new burst, i.e., 7F7F. The raw data sets can be opened, e.g., with Hex Edit (iHex). If required delete lines above the first 7F7F writing.
- In load000.m beam coordinates are transformed to earth coordinates and the velocity data are processed.
- Subsequently, in burst2ensemble.m the mean from each burst is calculated.

Step 2 (read_all.m):
This uses the mooring and instrument information supplied in the two Excel files to read all ASCII data files. No adjustments are applied here. The output is a structure D. D(ii) corresponds to the data from the instrument with the unique ID defined in the instrument information file. The variables of D are as follows; if an instrument does not record the respective variable, the variable is empty:
mooring – string: mooring name
type – string: instrument type
SN – double: serial number of instrument
dep_draw – double: instrument depth in meters according to mooring drawing
lat – double: mooring position, latitude
lon – double: mooring position, longitude
elev – double: mooring position, anchor depth in m
time – double horizontal vector: Matlab date format
pre – vector: pressure in dbar
tem – vector: temperature in °C
con – vector: conductivity ratio
sal – vector: salinity
d – structure: all mooring data
u – vector (non-ADCP) or matrix (ADCP): eastward velocity in m/s

v – vector or matrix: northward velocity in m/s
w – vector or matrix: vertical velocity in m/s
e – vector or matrix: error velocity in m/s
z – matrix: depth in meters corresponding to ADCP profile measurements

pitch – vector: instrument pitch in °
roll – vector: instrument roll in °
heading – vector: instrument heading in ° w.r.t. north
time_mat – double matrix: time information ADCP profile measurements
pg – vector or matrix: percent good
ea – vector or matrix: echo amplitude
spd – vector or matrix: speed in m/s
dir – vector or matrix: current direction in ° mathematical

In the subsequent routines (Step 2-4) furthermore the following variables are calculated and additionally stored in D:
dep – vector: instrument depth in meters
the – vector: potential temperature w.r.t. 0 in °C
sig – vector: potential density w.r.t. 0 in kg/m^3 - 1000 kg/m^3
depth_bins_nominal – double vertical vector: depth in m of ADCP bins according to mooring drawing without blow-down

ADCP data is corrected based on criteria chosen from the echo amplitude, percent good and the error velocity using
apply_oceansurface.m - remove data close to/above water surface
apply_err_pg.m - apply error velocity (0.05 m/s), percent good threshold (30%), and horizontal velocity limit (1 m/s), defaults are given in brackets
(use check_ea_and_pg.m to plot corresponding figures)

<u>Step 2 (find_start_end.m):</u>
The detection and check of measured values before the end of the deployment and after the beginning of the recovery are carried out here. The deployment and recovery times in Mooring_info_PS109.xlsx are iteratively adjusted to agree with the signature in the pressure, temperature, and speed records in the data.
The following steps and adjustments are documented in find_start_end.m and copied here from the file’s comments:

% Calculate speed and direction if only u/v exist

%% Remove selected values based on below criteria

% PS109:
% The SBE37 SN 438 in EGS-1 did not record any data.

% The clock of the BPR 227 on IdF1-1 is delayed by 16 years.
% Move it.

% The SBE37 SN2382 stopped recording 12. October 2016 19:30 due to low

% battery (however the Aquadopp temperature data compares very well).

% Remove the stall speed from the RCM8.

% 300kHz/600kHz ADCPs have no pressure sensor. Remove pressure = 0

% ADCP SN951 stopped recording 8. March 2017 1:00 due to low battery
% ADCP SN3194 stopped recording 7. August 2017 2:00 due to low battery
% ADCP SN3655 stopped recording 27. August 2017 17:30 due to low battery

% Remove all temperatures recorded by ADCPs, BPRs (SBE53, SBE26), and RCM

% PS114:
% ADCP SN22388 stopped recording 11. February 2018 6:00 because there was no more space on the memory card.

% EGS2-1: AQD 11328 was programmed to start 9:00, while AQds SN11333 and 12699 were programmed to start 9:15 with an interval of 20min. Thus AQDs did not record at same point in time.

% ADCP SN3751 stopped recording 3. May 2018 4:00 due to low battery. After recovery time difference of ADCP-UTC was -15min 4s.

% SBE SN2927 had a time difference of +4min 14s (MC-UTC) after recovery. However, pressure records of ADCP and SBE37 (79N6-1) correlate.

% ADCP SN3654 stopped recording 11. August 2017 19:30 due to low battery. After recovery time difference of ADCP-UTC was -9min 51s.

% SBE SN2921 had a time difference of +5min 33s (MC-UTC) after recovery. However, pressure records of ADCP and SBE37 (79N7-1) correlate.

% RCM11 SN458 is not recording properly after 8 July 2017 00:00. Record has been deleted already when transforming the .dsu file.
% The pressure of RCM11 SN458 jumps between two constant values of 198 and 201 m. Delete record.

% RCM11 SN314 is not recording properly after 10 January 2018 00:00 and stops recording mid-April. Data is deleted accordingly.

% SBE37 7727 stopped recording 7. February 2018 due to low battery. Some time steps are missing in the record but the timing still seems to be correct (well correlated with other instruments).

%% Plot pre, tem, spd to show whether deployment or recovery is still
% present in the records. This can also be plotted in the beginning before
% the removal of the respective values above.

Step 3 (find_depths.m):

All the pressure records are plotted versus instrument number for each mooring as well as the water depth from Mooring_info_PS109.xlsx. Based on the mismatches as well as missing data, the information in Instrument_info_PS109.xlsx is assigned that determines how the instrument depth is determined:
From the instrument's own pressure sensor or
From the depth in the mooring drawing or
From another instrument's pressure sensor with a constant vertical offset applied.
For some instruments, the own pressure sensor is also corrected by a constant vertical offset. In case pressure records from SBE37 did not fit the expected depth, information from the CTD calibration cast were used to apply the vertical offset.

%% Special cases (corrected in Instrument_info_PS109.xlsx)
% EGS-1: seafloor 4 m shallower - corrected
% EGS-1: RCM8 pressure is adjusted to LRADCP (-13 m)
% EGS-1: SBE37 2393 adjusted using additional calibration cast information (+4m)
% IdF1-1: SBE37 2396 adjusted using additional calibration cast information (+2m)
% IdF2-1: SBE37 is adjusted to seafloor & LRADCP pressure (+6m), AMünchow
% IdF3-1: seafloor 6 m deeper - corrected
% IdF4-1: SBE37 is adjusted to seafloor and LADCP pressure (+4m), AMünchow
% 79N2-1: seafloor ~7 m shallower - corrected; Aquadopp should be about 10m below LRADCP
% -> added 18m to pressure record
% 79N2-1: SBE37 10934 adjusted using additional calibration cast information (-1m)
% 79N3-1: seafloor 1 m shallower - corrected
% 79N5-1: SBE37 is adjusted to seafloor and LADCP pressure (+4m), AMünchow
% EGS1-2: seafloor 3 m shallower - corrected
% EGS3-1: seafloor 1 m deeper - corrected
% EGS4-1: seafloor 2 m deeper - corrected
% 79N6-1: seafloor 11 m deeper - corrected, LADCP needs to sit 6m above MC, thus correct ADCP depth (-4 m)
% 79N7-1: seafloor 8 m shallower - corrected, LADCP needs to sit 6m above MC, thus correct ADCP depth (+15 m)
% 79N7-1: seafloor 2 m shallower - corrected

Step 4 (calculate_sal_u_v_oxy.m):

Calculate the derived variables such as salinity, depth, oxygen in the right units, apply the magnetic declination and calculate eastward/northward velocity.

Magnetic declination is calculated from the latitude/longitude and start/end time using the IGRF model using the Matlab toolbox igrf.
Salinity is calculated using the Matlab file salt.m.
Outliers and otherwise unreasonable data are removed throughout the following steps and adjustments documented in calculate_sal_u_v_oxy.m and copied here from the file's comments:

```
%% Depth
% Recalculate D(ii).z to depth units
% Only apply to ADCPs which have z defined
% D(ii).z is still in pressure units [dbar]
% Recast it depth units [m]

% no pressure records for 300/600kHz ADCPs,
% z records are nominal distance of bins from instrument,
% negative for upward-looking 300 kHz ADCP,
% positive for downward-looking 600 kHz ADCP,
% converted into true water depth

% Remove data with depth_bins_nominal < 10m

% Remove data beyond the 99.98%th speed percentile
% but not for SN24052, SN23613 and SN951 (strong velocity variations)

% Calculate pressure from depth

%% Magnetic declination
% Apply the magnetic deviation
% Only apply to velocity measurements
% Get magnetic declination
% Subtract the magnetic declination
% Convert the direction from nautical to mathematical
% Calculate u and v

%% Current direction
% Correct current directions based on mean flow direction (and tides)
% relative to the seafloor topography
% 1. Aquadopp data at 79N2-1 is very noisy, thus implement a lowpass
% filter
% 2. Based on our findings from CTD, LADCP, and AQD data we know that
% there is a strong bottom-intensified flow directed into the cavity (westward).
% In contrast, the LRADCP mean flow at depth is directed northward (102°),
% i.e., into the coastline.
% Largest mean current speeds at depths are reached when rotating the
% current vectors by -97° (i.e., pointing directly westward, 180°).

% Rotate the AQD data at 79N2-1 accordingly.

%% Current speed
% correct reflection from Benthos affecting ADCP bins 2 and 3 at 79N2-1
```

% by linear interpolation between bins 1 and 4

%% Temperature
% Remove temperatures below -3°C and above 30°C

%% Salinity
% Calculate salinity
% Only apply to instruments with conductivity measurements
% The above assumes that the conductivity is given in mS/cm. If in
% fact it is given in S/m, then the calculated salinities are way
% too large, thus they need to be recalculated with a factor of 0.1
% applied to the conductivity.
% Get rid of 0.02% and 99.98% percentiles
% Calculate theta for out of bounds check; will be overwritten below
% after out of bounds checks.

% Some unrealistic salinities below a certain values recorded by
% different microcats: Remove
% most records should be despiked/smoothed with more care during further post-processing

% Calculate potential temperature and density
% no oxygen records

Step 5 (plotting):
As the last step of the processing, plots for verification purposes are produced:
plot_tem_sal_p_time.m - Timeseries of all T, S, and p records of one mooring.
plot_sal_the_time.m - TS plots for the individual instruments as well as for all instruments and for all instruments >= 200m nominal depth.
plot_spd_dir.m - Eastward versus northward velocity scatter plots with current ellipses for the individual instruments.
plot_spd_time.m - Eastward and northward velocity timeseries.
plot_heading_pitch_roll.m - Timeseries of heading, pitch, and roll.
plot_current_ellipses_on_map_2.m - Current ellipses are plotted on a map based on RTopo-2.0.1.
plot_tidal_ellipses_on_map.m - Tidal ellipses from the moored velocities (t_tide) and a tidal model (TMD, Greenland8) are plotted on a map based on RTopo-2.0.1.
plot_pressure_from_BPR.m - Timeseries of pressure from all Bottom Pressure Recorder.

Step 6 (reformatting to fit Pangaea format):
Finally, the processed data is reformatted to agree with the formatting that Pangaea requires. The data from each of the moorings is then uploaded.