Mooring processing of PS99.2/PS100/PS101 recoveries

The processing documented here applies to the following 21 moorings recovered during:
PS99.2:
FEVI-31
FEVI-32
TD-2015-LT
Lander-2015
PS100:
F2-17
F3-16
F4-16
F5-16
F6-17
F9-12
F10-13
BG1-1
BG2-1
BG3-1
BG4-1
BG5-1
BG6-1
BG7-1
BG2-2
PS101:
Nansen-2015
Karasik-2015

Directory structure of raw data

The data has been sorted into folders of the following structure:
2016_[cruise_ID]/[instrument_type]/[mooring_name]/[instrument_SN]*
where
[cruise_ID] = PS99.2, PS100, PS101
[instrument_type] = ADCP, Aquadopp, BPR, IPS, Microcat, RCM, Seaguard
[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 and Long Ranger RDI Workhorse ADCPs
.000 Native binary data file
.mat Matlab binary file converted from .000 with RDI WinADCP, not for BG3-1 to BG7-1, which are in instrument coordinates that WinADCP cannot read

Aquadopp: Nortek Aquadopp Deep Water without 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 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

IPS: ASL Ice Profiling Sonar
.001 Native binary data files, one file per day
.DPL ASCII deployment summary file
.XML ASCII configuration information
.hdr.txt ASCII header information of data converted with ASL Ips5LinkE, one file per month
.trg.txt ASCII target data converted with Ips5LinkE
Further processing of the IPS data has not been performed. The data is only archived here.

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 RCM7/8 rotor current meter and RCM11 acoustic current meter with optional pressure sensors, oxygen 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
.cdb for AWI deep sea section instruments, native binary calibration information file to be read with data reading program or custom Matlab read_cdb.m

Seaguard: Aanderaa Seaguard acoustic current meter with optional oxygen sensor
Subfolder named [instrument_SN] with contents of SD card in instrument: DDNodes.dsc, DT000000.dat, NodeConfiguration.dsc, NodeConfiguration.xml, SensorHeads.dsc, Timetags.dat
.txt ASCII data file converted with Aanderaa Seaguard Studio; this does not work in a virtual machine; it encompasses two steps: 1. Import data from memory card, 2. Export value type data to text file

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

Mooring_info_2016.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_2016.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
Unique for 2016 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 one folder 2016_processing. 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_2016.m – driver function calling the 4 steps and 3 plotting programs
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_2016.xlsx into Matlab
read_mooring_info.m – import Mooring_info_2016.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_2016.m and are:
/Applications/Matlab_Toolboxes/LDEO_IX_11/load000.m
/Applications/Matlab_Toolboxes/tools/read_cnv.m
/Applications/Matlab_Toolboxes/science/find_current_ellipse.m
/Applications/Matlab_Toolboxes/pickart/salt.m
/Applications/Matlab_Toolboxes/seawater/sw_* Seawater toolbox
/Applications/Matlab_Toolboxes/science/reshape_vec.m
/Applications/Matlab_Toolboxes/LDEO_IX_11/rditype.m
/Applications/Matlab_Toolboxes/igrf/igrf.m
/Applications/Matlab_Toolboxes/igrf/loadigrfcoefs.m
/Applications/Matlab_Toolboxes/science/pltstmp.m
/Applications/Matlab_Toolboxes/contouring_in_matlab/datetick2.m
/Applications/Matlab_Toolboxes/contouring_in_matlab/suptitle.m

Step 1 (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
time – double horizontal vector: Matlab date format
pre – vector: pressure in dbar
tem – vector: temperature in °C
con – vector: conductivity ratio
sal – vector: salinity
time_mat – double matrix: time information ADCP profile measurements
z – matrix: depth in meters corresponding to ADCP profile measurements
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
ea – vector or matrix: echo amplitude
pg – vector or matrix: percent good
pitch – vector: instrument pitch in °
roll – vector: instrument roll in °
heading – vector: instrument heading in ° w.r.t. north
spd – vector or matrix: speed in m/s
dir – vector or matrix: current direction in ° mathematical
oxy – vector: oxygen concentration in µmol/l (micro mol per liter)
oxy_tem – vector: temperature in °C recorded by oxygen sensor
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 blowdown

Step 2 (find_start_end.m):
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_2016.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
% None of the Aquadopps have pressure sensores: Remove pressure = 0 from AQD

% Define time for RCM 11 314 on F6-17
% In the file, there is also data from a 2003-2004 mooring deployment
% (F10-6). At the end, the data from the 2015-2016 deployment is attached,
% but with a completely wrong time stamp. Thus it is generated as below.
% Since the RCM was located directly next to an Aquadopp, it can be shown
% that the temperature time series agree exactly, but with a constant
% offset. This provides confidence in the generation of the time stamps.

% Remove false pressure values from BG2-1 SBE37 10941 record. These are
% individual values much greater than 50dbar in a time period of weak
% currents and no relation to other previous/succeeding events.

% The clock of the Microcat 13012 on Nansen-2015 is delayed by an hour.
% Move it.

% The QMADCP 23456 on Karasik-2015 has weird temperature and internal
% temperature sensor readings before 10-Sep-2015: remove all data before
% that date.

% Fix the time stamp of RCM8 on Karasik mooring 9391. Its time stamp is
% completely out of bounds: Use time stamp of RCM7 8050 on same mooring
% instead.

% Remove the stall speed from the RCM7/8

%% Remove data before start and after end
% Decimate before deployment and after recovery
% Deployment plus 1 hour for Heincke deployments
% Recovery minus 1 hour for Münchow moorings

% The clocks of the Münchow LRADCPs 3654, 3656, and 3655 are all slow, but
% by less than 30 minutes over the two year deployment. Don't correct time
% stamps, but cut off recovery minus 1 hour for them.
% Allow for anchor last deployment during Heincke deployments:
% Remove first hour of record
% Allow for slow LRADCP clock of Münchow LRADCPs:
% Remove last hour of record

%% 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_2016.xlsx. Based on the mismatches as well as missing data, the information in Instrument_info_2016.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.

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]

% Remove data with depth_bins_nominal < 10m

% Remove data beyond the 99.98%th speed percentile

% 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

%% 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 the for out of bounds check, will be overwritten below
% after out of bounds checks.

% Drift in the deep microcat salinites on F6-17 SN 216 and F10-13 SN 218,
% detrending does not appear to be sufficient: Remove

% Deep microcat salinity on Nansen-2015 appears to have returned
% possibly reasonable values for ~7 days. Thereafter, they are widely
% out of reasonable bounds: Remove entirely SN 12477

% Some unrealistic salinities below a certain values recorded by
% different microcats: Remove

SN	maximum acceptable salinity
2932	34.5
2925	34.4
215	34.7
2611	34.5

% For the microcat on BG7-1 SN 2925, there are hysteresis values at ~1.4°C
% and 34.7 in the time period of June/July/August 2015: Remove

% For the microcat on F10-13 SN 10952, a time drift starts after 01-May-2016,
% For the microcat on Nansen-2015 SN 12479, a time drift starts after 26-Jun-2016:
% Remove

% For microcats remove values where sal <= 34.25 and the >= 0
% and also where sal >= 35.15

% BG2-2:
% There are no pressure sensors on the microcats in the water column.
% Checked whether the calculated salinities using the nominal depths
% from the drawings show unreasonable values due to mooring blowdowns.
% This does not appear to be the case.
% Microcat above ground in Atlantic Water SN 233: Remove out of bounds values where sal <= 33.66 or sal >= 34.9
% Shallowest microcat in Polar Water SN 2383: Remove out of bounds values where sal <= 31.9 or sal >= 33.86
% Even though the nominal depths of BG2-2 seem to be sufficient for
% calculation, the salinities are rather noisy, thus implement a simple
% 5 point box median smoothing of salinity for the microcats in the water column SN 2383, SN 2087, and SN 233

%% Potential temperature and density
% Calculate potential temperature and potential density

%% Oxygen
% Microcats report oxygen as ml/l; typical values around 7
% RCM/Seaguard report oxygen as micro mol / l; typical values around 300
% According to http://ocean.ices.dk/Tools/UnitConversion.aspx
% 1 ml/l = 1e3/22.391 = 44.661 ?mol/l
% Detect microcats from median oxygen values below 20 and then convert their values to mico mol / l

% Remove first two days from oxygen records to allow for slow sensor
% adjustment at depth. Many of the sensors have an exponential
% adjustment over several months. We do not correct for this, but just
% provide the measurements with that exponential drift.
% Also remove negative oxygen values.

Step 5 (plotting):
plot_spd_dir
plot_sal_the
plot_oxy
As the last step of the processing, plots for verification purposes are produced:
Eastward versus northward velocity scatter plots with current ellipses for the individual instruments.
TS plots for the individual instruments as well as for all instruments <= 500m nominal depth, for all >= 500m & <= 2000m, and for all >= 2000m.
Timeseries of oxygen concentration and temperatures used to calculate oxygen.

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.