JC105 CTD processing report

June 2014
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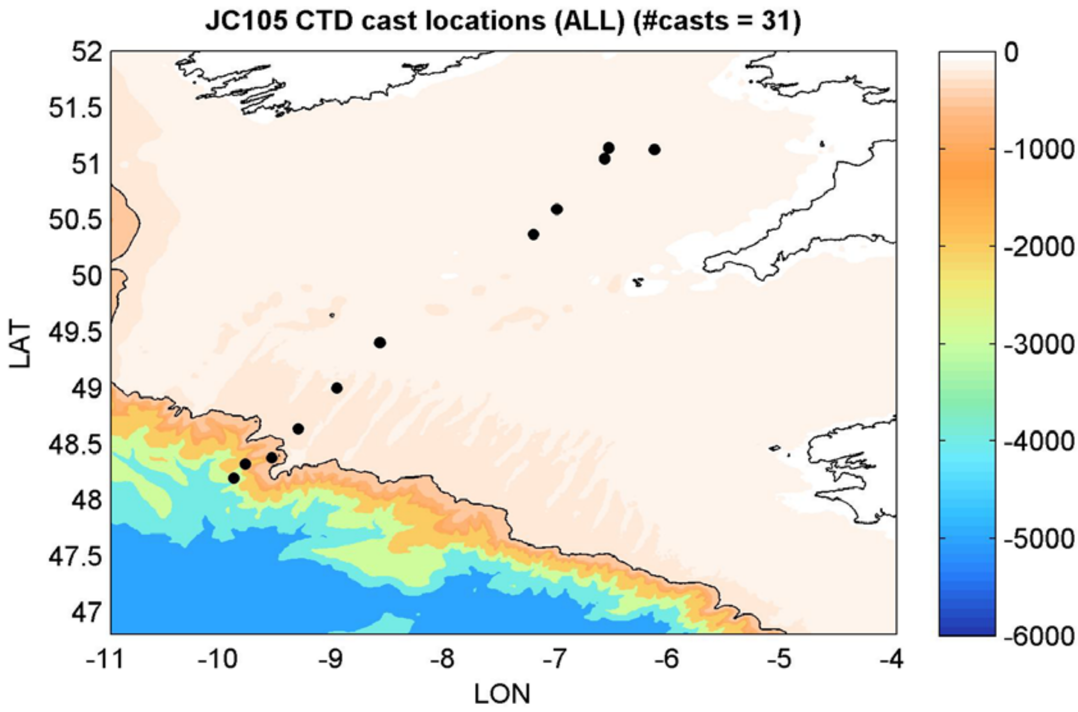
A total of 31 casts with the stainless steel were completed. See technical reports for sensor serial numbers and channels.

Map of CTD cast locations



Raw data files:

The following raw data files were generated:

JC105_001.bl (a record of bottle firing locations)
JC105_001.hdr (header file)
JC105_001.hex (raw data file)
JC105_001.con (configuration file)

Where _001 is the cast number (not STNNBR)

SBEDataProcessing steps

The following processing routines were run in the SBEDataProcessing software (Seasave Version 7.23.2):

1. **DatCnv:** A conversion routine to read in the raw CTD data file (.hex) containing data in engineering units output by the CTD hardware. Calibrations as appropriate though the instrument configuration file (.CON) are applied.

   Data Setup options were set to the following:

   Process scans to end of file: yes

Scans to skip: 0
Output format: ascii
Convert data from: upcast & downcast
Create file types: both bottle and data
Source of scan range data: bottle log .BL file
Scan range offset: -2.5 seconds
Scan range duration: 5 seconds for
Merge separate header file: No
Apply oxygen hysteresis correction: yes (2 second window)
Apply oxygen Tau correction: yes

Selected output variables:

- Time [seconds]
- Pressure [db]
- Temperature [ITS-90, °C] and Temperature 2 [ITS-90, °C], referring to primary and secondary sensors)
- Conductivity and Conductivity 2 [S/m]
- Salinity and salinity 2 [PSU, PSS-78]
- Oxygen raw, SBE 43 [V]
- Oxygen, SBE 43 [µmol/l]
- Beam attenuation [1/m]
- Fluorescence [µg/l]
- PAR/irradiance, downwelling [W m^2]
- Turbidity [m^{-1} sr^{-1}]
- Altimeter [m]
- Voltage channel 2: Downwelling Irradiance sensor (DWIRR)
- Voltage channel 3: Upwelling Irradiance sensor (UWIRR)
- Voltage channel 4: Altimeter
- Voltage channel 5: Light scattering Wetlabs BBRTD
- Voltage channel 6: Transmissometer
- Voltage channel 7: Fluorometer

2. **Bottle Summary** was run to create a .BTL file containing the average, standard deviation, min and max values at bottle firings. .ROS files were placed in the same directory as the .bl files during this routine to ensure that bottle rosette position was captured in the .btl file.

   Output saved to JC105_001.btl

3. **Wild Edit:** Removal of pressure spikes
   Standard deviations for pass 1: 2
   Standard deviations for pass 2: 20
   Scans per black: 100
   Keep data within this distance of the mean: 0
   Exclude scans marked as bad: yes
4. **Filter:** Run on the pressure channel to smooth out high frequency data
   Low pass filter time B: 0.15 seconds
5. **AlignCTD:** Based on examination of different casts a 3 second advance was chosen for alignment of the oxygen sensor. This alignment is a function of the temperature and the state of the oxygen sensor membrane. The colder (deeper) the water the greater the advance needed. The above alignments were chosen as a compromise between results in deep (cold) and shallow (warmer) waters.

The deck unit was set to advance both the primary and secondary conductivity channels by + 1.75 scans (equivalent to 0.073 seconds at 24 Hz), but further testing of -1, -2, -3, +1 ,+2 and +3 scans (on both sensors) showed that an adjustment of -1 scan (= -0.0417 seconds) resulted in the greatest reduction in noise in the salinity channel.

6. **CellTM:** Removes the effect of thermal inertia on the conductivity cells. Alpha = 0.03 (thermal anomaly amplitude) and 1/beta = 7 (thermal anomaly time constant) for both cells.

   Output of steps 1-6 above saved in JC105_001.cnv (24 Hz resolution)

7. **Derive:** Variables selected are
   Salinity and Salinty 2 [PSU, PSS-78]
   Oxygen SBE43 [µmol/l]
   Oxygen Tau correction: yes (2 second window)

   Output saved to JC105_001_derive.cnv (24 Hz resolution)

8. **BinAverage:** Average into 2Hz (0.5 seconds),
   Exclude bad scans: yes
   Scans to skip over: 0
   Casts to process: Up and down

9. **Strip:** Remove salinity and oxygen channels from the 2 Hz file that were originally created by DatCnv, but then later regenerated by Derive.

   Output saved to JC105_001_derive_2Hz.cnv

Matlab processing steps
The following processing steps were performed in MATLAB:

(1) Create a .mat file of meta data extracted from the cruise Event Log with the following variables:

   CRUISECODE e.g. JC105
   STNNBR (as per BODC data management guidance for the Shelf Sea Biogeochemistry programme)
   DATE and TIME of the cast at the bottom of the profile
   LAT and LON when the CTD was at the bottom of the profile
   DEPTH (nominal water depth in metres from echo sounder)
   CAST (CTD cast number, e.g. 001)

   File created: JC105_metadata.mat

(2) Extract data from 2Hz averaged files (e.g. JC105_001_derive_2Hz.cnv), merge with metadata and save into a matlab structure for each cast. Each file (JC105_001_derive_2Hz.mat) contains the following <u>un-calibrated</u> channels.

```
CTD001 =

           CRUISE: 'JC105'
             CAST: 1
           STNNBR: 1
             DATE: '16/06/2014'
```

```
                TIME: '13:38'
                 LAT: 50.5928
                 LON: -7.0295
               DEPTH: 106                  [m]
             CTDtime: [3439x1 double]      [seconds]
             CTDpres: [3439x1 double]      [db]
            CTDtemp1: [3439x1 double]      [°C]
            CTDtemp2: [3439x1 double]      [°C]
            CTDcond1: [3439x1 double]      [S/m]
            CTDcond2: [3439x1 double]      [S/m]
          CTDoxy_raw: [3439x1 double]      [V]
              CTDatt: [3439x1 double]      [1/m]
            CTDfluor: [3439x1 double]      [µg/l]
              CTDpar: [3439x1 double]      [Wm2]
             CTDturb: [3439x1 double]      [m-1 sr-1]
              CTDalt: [3439x1 double]      [m]
       CTDpar_dn_raw: [3439x1 double]      [V]
       CTDpar_up_raw: [3439x1 double]      [V]
          CTDalt_raw: [3439x1 double]      [V]
         CTDturb_raw: [3439x1 double]      [V]
          CTDatt_raw: [3439x1 double]      [V]
        CTDfluor_raw: [3439x1 double]      [V]
             CTDsal1: [3439x1 double]      [PSU]
             CTDsal2: [3439x1 double]      [PSU]
        CTDoxy_umoll: [3439x1 double]      [µmol/l]
             CTDflag: [3439x1 double]
```

(3) Extract data from 24Hz files (e.g. JC105_CTD001_derive.cnv), merge with metadata and save into a matlab structure for each cast. Each file (DY008_001_derive.mat) contains the following <u>un-calibrated</u> channels.

```
CTD001 =

              CRUISE: 'JC105'
                CAST: 1
              STNNBR: 1
                DATE: '16/06/2014'
                TIME: '13:38'
                 LAT: 50.5928
                 LON: -7.0295
               DEPTH: 106                  [m]
             CTDtime: [41263x1 double]     [seconds]
             CTDpres: [41263x1 double]     [db]
            CTDtemp1: [41263x1 double]     [°C]
            CTDtemp2: [41263x1 double]     [°C]
            CTDcond1: [41263x1 double]     [S/m]
            CTDcond2: [41263x1 double]     [S/m]
           CTDsal1_1: [41263x1 double]     [PSU]
           CTDsal2_1: [41263x1 double]     [PSU]
          CTDoxy_raw: [41263x1 double]     [V]
      CTD_oxy_umoll_1: [41263x1 double]    [µmol/l]
```

```
          CTDatt: [41263x1 double]    [1/m]
        CTDfluor: [41263x1 double]    [µg/l]
          CTDpar: [41263x1 double]    [Wm2]
         CTDturb: [41263x1 double]    [m-1 sr-1]
          CTDalt: [41263x1 double]    [m]
    CTDpar_dn_raw: [41263x1 double]    [V]
    CTDpar_up_raw: [41263x1 double]    [V]
      CTDalt_raw: [41263x1 double]    [V]
     CTDturb_raw: [41263x1 double]    [V]
      CTDatt_raw: [41263x1 double]    [V]
    CTDfluor_raw: [41263x1 double]    [V]
         CTDsal1: [41263x1 double]    [PSU]
         CTDsal2: [41263x1 double]    [PSU]
    CTDoxy_umoll: [41263x1 double]    [µmol/l]
         CTDflag: [41263x1 double]
```

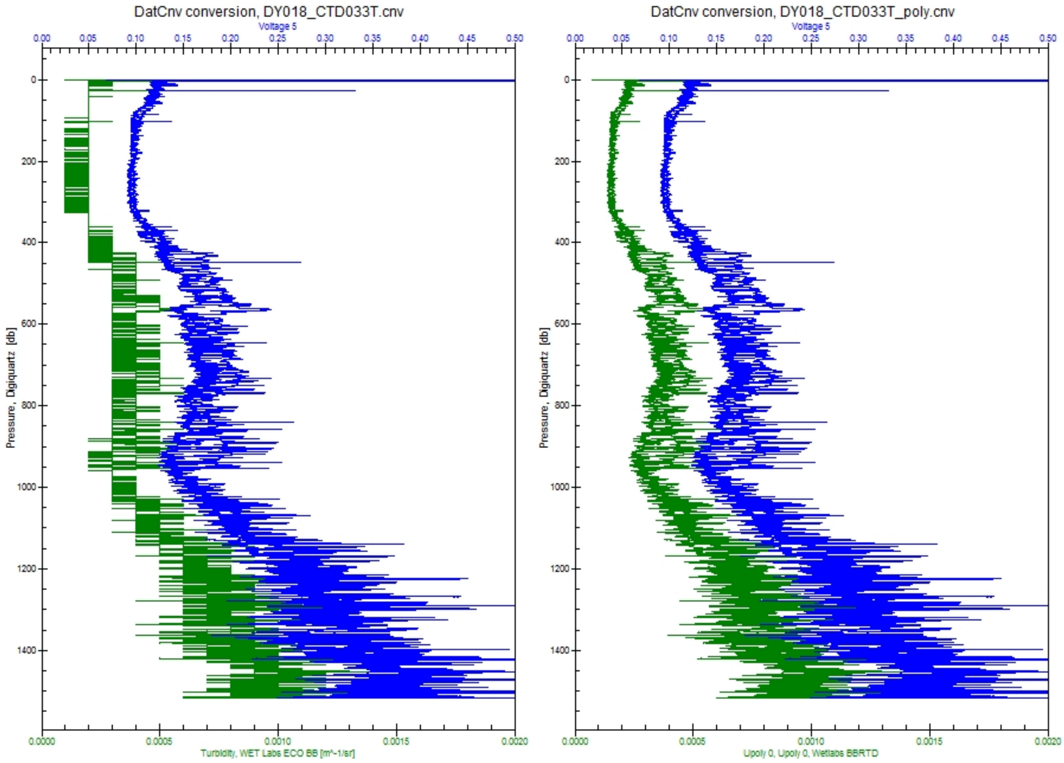
Note that '_1' for the first instances of salinity and oxygen in this file are variables before re-derivation in the SeaBird Processing routines.

The PAR sensor was removed for deep casts CTD027 and CTD028. The PAR channel is therefore zero for these two profiles.

Inspection of the turbidity channel (CTDturb) and comparison to the original raw voltage (CTDturb_raw) revealed a potential bug in the SeaBird DatCnv conversion module. After correspondence with SeaBird, it was confirmed that the converted ECO-BB output was being reported to a fixed precision (see email chain at the end of the report). This is demonstrated below (left) where the raw voltage channel (blue) is compared to the SeaBird DatCnv output (green). Direct conversion using the scale factor (SF) and dark counts (DC) supplied in the manufacturer's calibration appears to rectify this problem (right plot). We therefore replace the original turbidity channel in the .cnv files with a corrected version using:

CTDturb = CTDturb_raw .* SF - (SF x DC);

This appears to reinstate the original resolution.



(4) Manual identification of the surface soak (while waiting for pumps to turn on) and the end of the downcast using the 2Hz files. Times to crop were saved to JC105_ castcrop_times.mat.

```
    CAST: [31x6 char]
  STNNBR: [31x1 double]
CTDstart: [31x1 double] [seconds]
 CTDstop: [31x1 double] [seconds]
```

This was then used to crop both the 2Hz and 24Hz files and output (i.e. just the downcast recordings) saved to JC105_CTD001_derive_2Hz_cropped.mat and JC105_CTD001_derive_cropped.mat respectively.

(5) De-spiking of downcast 24 Hz data. The salinity, conductivity, temperature, oxygen, attenuation, turbidity and fluorescence channels were all de-spiked. The worst spikes were identified using an automated routine (similar to WildEdit) where the data was scanned twice and points falling outside a threshold of *nstd* x standard deviations from the mean within a set window size were removed (turned into NaNs).

Window size (#scans) and number of standard deviations from the mean (nstd) used for each channel.

Channel	*Pass 1 window*	*Pass 1 nstd*	*Pass 2 window*	*Pass 2 nstd*
Temperature, conductivity, fluorescence	100	3	200	3
Salinity, turbidity	200	2	200	3
Oxygen, attenuation	100	2	200	3

Auto-despiking saved to JC105_CTD001_derived_cropped_autospike.mat

Manual de-spiking was then performed to remove larger sections of bad data or any remaining isolated spikes in each channel.

Large ‘spikes’ were often observed in the CT sensors lasting a few seconds, predominantly in the thermocline. This is a persistent problem in shallow water with strong property gradients (e.g. see for example D352, D376); particularly where a large CTD package carrying large volume bottles is used. The spikes coincide with a decrease in the decent rate of the CTD package and are therefore likely associated with inefficient flushing of water around the sensors. It is caused by the pitch and roll of the boat, so is accentuated in rough weather. As the decent rate of the CTD package slows on the downcast ‘old’ water (from above and therefore typically warmer) is pushed back passed the sensors. As the decent rate increases again ‘new’ water is flushed past the sensors. A similar problem can occur if the veer rate on the CTD winch varies (as was the case on CD173).

The largest and most significant warm anomalies identified in the primary and secondary CT sensors were removed. This was at times up to 5 m of the profile. The impact of smaller scale anomalies that were not removed is mostly minimised during the averaging processes, but care should be taken when interpreting smaller scale features, particularly through the thermocline. The casts are more than good enough for looking at large scale trends and anomalies but should probably not be used for Thorpe scale analysis and interpretation of fine scale structures. To achieve this in a shelf sea environment free fall profiling techniques are more suitable.

Although ‘old’ water would also have been flushed back past the auxiliary sensors (turbidity, oxygen, chlorophyll, attenuation) the coincident measurements in these channels were (a) not always anomalous and/or (b) the associated anomaly did not always exactly coincide (or could even be confidently identified, especially for oxygen). As such removal of data from auxiliary channels using scans flagged as bad in the primary/secondary CT channels was not always appropriate or did not improve data quality. The worst individual spikes within these channels however were manually identified and removed (NaN’d).

Output saved to JC105_CTD001_derived_cropped_autospike_manualspike.mat

Additional channels added into this file:

Vectors of 0’s and 1’s indicating data that has been NaN’d (=1). Outputs depend on channels loaded and viewed so each column may have variable meaning and is saved for processing archive purposes only.

```
Pindex: [18900x3 double]
Sindex: [18900x3 double]
Aindex: [18900x4 double]
```

(6) Average 24Hz (cropped and de-spiked data) into 1 db. Linear interpolation used when no data available for averaging.

Files for each cast were created: JC105_001_1db_dn.mat

All the 1 db profiles (except PAR) are then further smoothed with a 10 m running median window. The chlorophyll is smoothed with a 5 m window to better preserve the subsurface chlorophyll maximum.

File output: JC105_001_1db_dn_smth.mat

(7) Application of calibrations to salinity, chlorophyll and oxygen in 1db smoothed downcasts. Calibrated files saved to JC105_001_1db_dn_smth_calib.mat.

Sigma theta (σ_θ) (relative to 0 pressure) is also calculated at this stage using the matlab function `sw_pden-1000` from the `SEAWATER` toolkit.

```
CTD001 =

         CRUISE: 'JC105'
           CAST: 1
         STNNBR: 1
           DATE: '16/06/2014'
           TIME: '13:38'
            LAT: 50.5928
            LON: -7.0295
          DEPTH: 106             [m]
           pres: [102x1 double]  [db]
           time: [102x1 double]  [seconds]
          temp1: [102x1 double]  [°C]
          temp2: [102x1 double]  [°C]
           sal1: [102x1 double]  [PSU] - calibrated
           sal2: [102x1 double]  [PSU] - calibrated
          cond1: [102x1 double]  [S/m] – not calibrated
          cond2: [102x1 double]  [S/m] – not calibrated
      oxy_umoll: [102x1 double]  [µmol/l] – calibrated
          fluor: [102x1 double]  [µg/l] – calibrated
            par: [102x1 double]  [Wm2]
           turb: [102x1 double]  [m-1 sr-1]
            att: [102x1 double] [1/m]
    sigma_theta: [102x1 double]
```

The calibrations were also applied to the 24 Hz data (cropped and de-spiked) and output to .mat files JC105_001_derive_cropped_autospike_manualspike_calib.mat containing the same variables as above.

(8) Application of salinity, chlorophyll and oxygen calibrations to bottle firing data. A new file, JC105 _btl_calib.mat, with variables CTDsal1_cal, CTDsal2_cal, CTDoxy_umoll_cal and CTDfluor_cal was created.

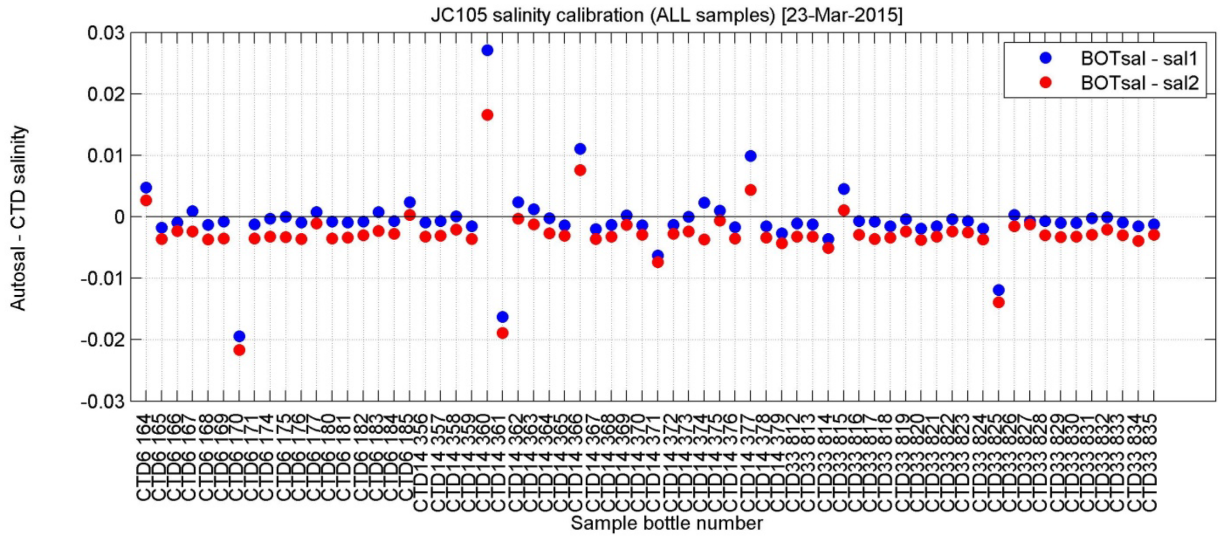
Calibrations

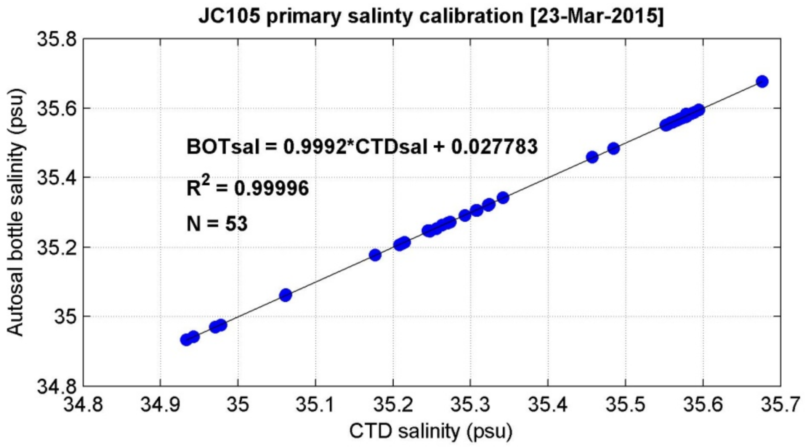
Salinity

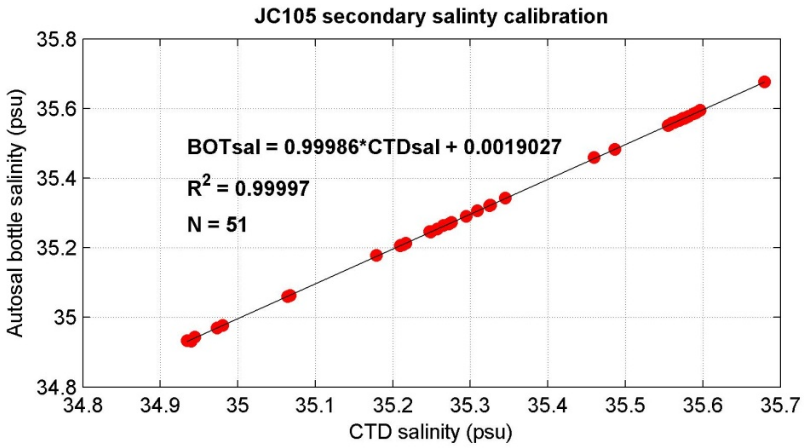
4 samples (bottle # 173, 174, 178 and 179) were removed because it was unclear which cast and niskin bottle the sample was taken from.

66 salinity samples were taken and analysed on a Guildline Autosal salinometer. Using all samples the mean and standard deviation of residuals from the primary and secondary sensors were -0.00051667± 0.0054088 and -0.0029061± 0.0046362 respectively. After removal of outliers where the difference between Autosal and CTD values was greater than 1standard deviation and where the

standard deviation of the temperature at bottle firing was > 0.01 °C the mean ± standard deviations for the primary and secondary sensors became -0.00051887± 0.001313 and -0.0029157±0.0011321 respectively.

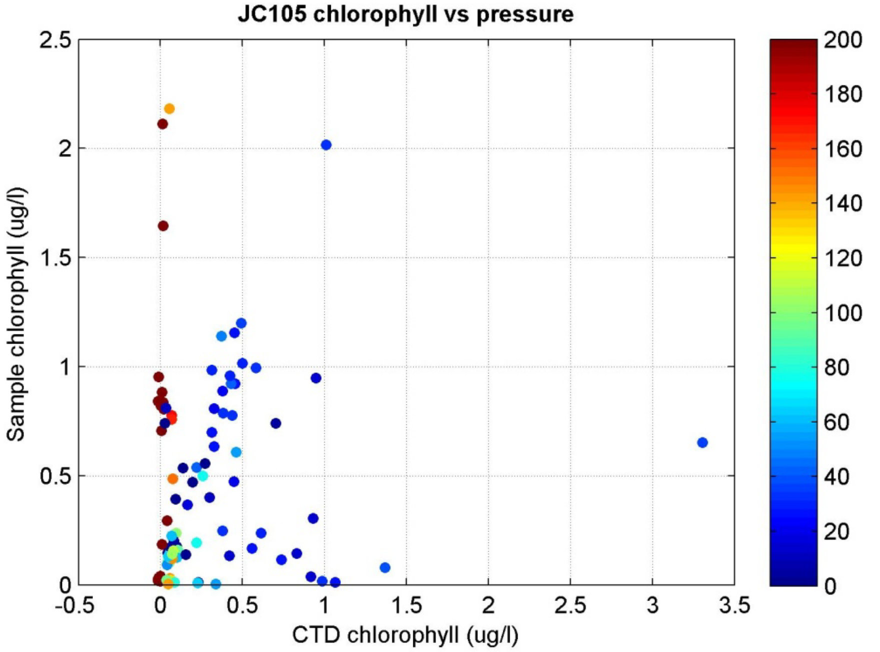




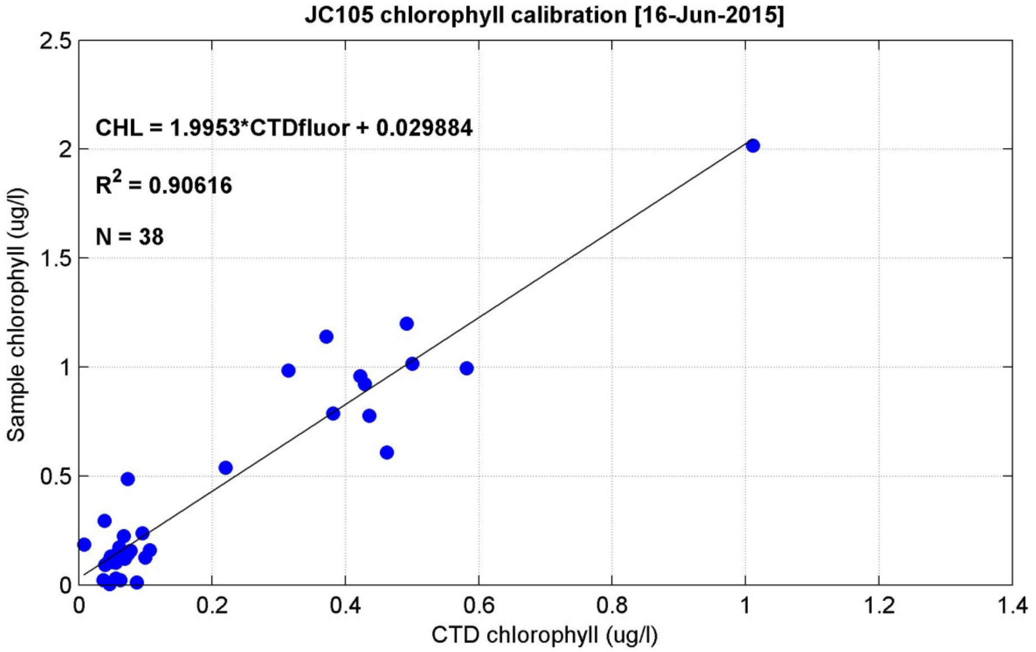


Chlorophyll

In total 94 chlorophyll samples were taken. However, there are a large number of suspect points (e.g. high concentrations at depth, >200m).

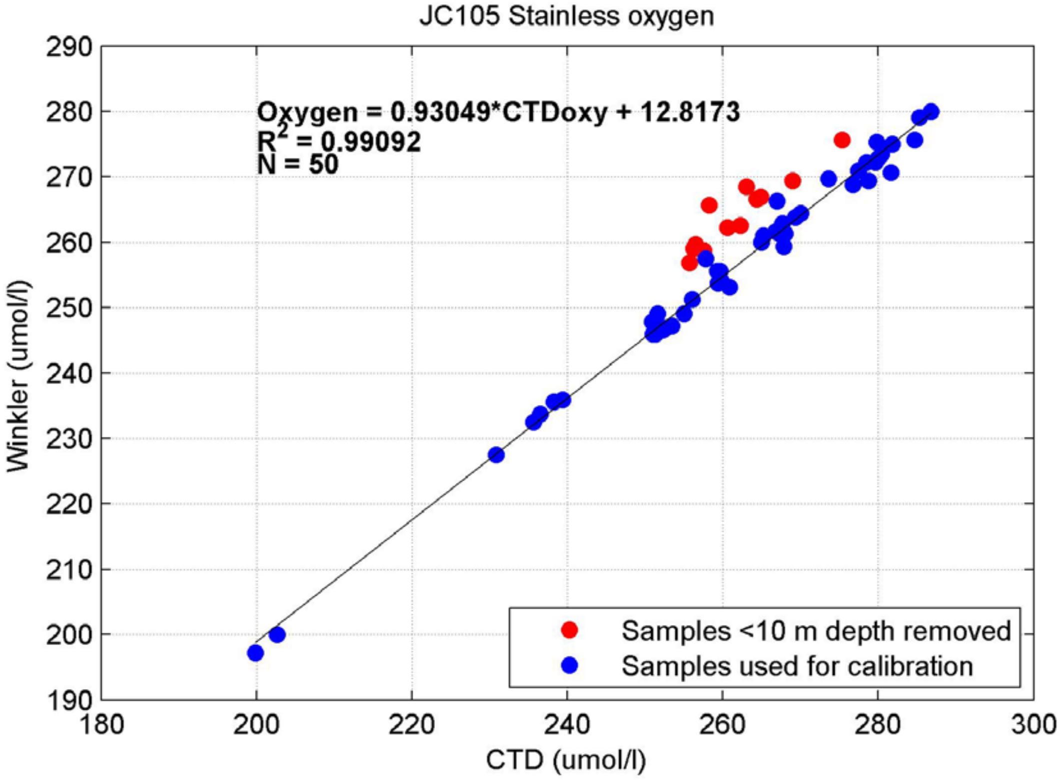


After removal of these points and samples taken during daylight in the surface 30 m, only 38 points remained. The following calibrations were applied to the fluorometer.



Oxygen

A total of 62 samples were taken for oxygen calibration and reported in units of mg/l. A conversion to umol/l was applied using mg/l x 0.69976 x 44.661. A total of 12 samples were removed, all taken within the top 10 m since the oxygen titration reported concentrations less than the CTD optode. The following calibration based on 50 samples was applied.



Emails between Seabird and Dougal Mountifield regarding ECO-BB module conversion

```
Urgent: Wetlabs BB con file module SBE Data Processing problem
Date: Wed, 19 Nov 2014 08:28:13 +0000
From: Dougal Mountifield
To: SeaBird

Hi,

I am currently at sea on RRS Discovery. We are deploying 2 CTD packages which
both have Wetlabs BBrtd instruments installed as a 0-5V analog channel on a
SBE 9+ underwater unit. We are using the Wetlabs BB module in the con file.
9+ When acquiring the data in Seasave the data from the instrument looks fine,
however after data conversion in SBE data processing, and plotting in Seaplot,
the profile from the BB is quantised resulting in very poor resolution. The
voltage channel is fine (V5). If the BB module in the con file is replaced
with a user poly (as used prior to the introduction of the Wetlabs con file
module) the result is fine. Have you seen this problem before? Is it possible
that the RS-232 digital version of the Wetlabs BB module is applied in error
with a 9+ instead of the 0-5V analog version?

Please see the attached graphs, one with V5 and Wetlabs BB module and one with
V5 and user poly. Also attached is the cast specific con file with the BB
module selected and the associated instrument calibration sheet from Wetlabs.
We don't have sufficient network bandwidth to send the data file. We are using
v.7.23.2, but have also tried some older versions with the same result.
```

Urgent assistance would be appreciated.

Dougal Mountifield
National Marine Facilities - Sea Systems Sensors & Moorings Group National Oceanography Centre, Southampton UK.
Aboard RRS Discovery.

****

From: Stephanie Jaeger [mailto:sjaeger@seabird.com]
Sent: 19 November 2014 21:54
To: dm1@noc.ac.uk
Cc: techsupport@seabird.com; Benson, Jeffrey Ray; Hopkins, Joanne
Subject: RE: Urgent: Wetlabs BB con file module SBE Data Processing problem

Hi Dougal,

Thanks for bringing this to our attention. We haven't noted this issue before, and I will check with the software engineer to clarify the conversion formula that is currently used for the parameter "Turbidity Meter, WET Labs, ECO-BB" in the .xmlcon file. Has the data in the plot that you sent been processed at all beyond the data conversion step?

In the meantime, it sounds like you have found a workaround while on the cruise, using the user polynomial function. It should be a simple conversion step:

Turbidity = ?(?c) = (Output – Dark Output) * Scale Factor

When possible, it will be helpful to have the raw data, if you could send a copy of a HEX file? It could also work if you would like to send a short section of the cast (such as 100 m), as an example.

Let us know if you have any further questions on this.

Regards,

Stephanie

Stephanie Jaeger, M.Sc.
Technical Support
Sea-Bird Electronics

****

From: Stephanie Jaeger [sjaeger@seabird.com]
Sent: 12/10/2014 9:25 AM
To: dougal.mountifield@noc.ac.uk;
dm1@noc.ac.uk
Cc: daves@wetlabs.com; jeh200@noc.ac.uk; jrbn@noc.ac.uk
Subject: RE: Urgent: Wetlabs BB con file module SBE Data Processing problem [ref:_00D7096pT._50070vbxjt:ref]

Hi Dougal,

Thanks for the update. We were able to reproduce the issue that you mentioned. The software engineer found that the converted ECO-BB output is reported to a fixed precision. The user polynomial function reports a fixed number of significant figures, rather than a fixed precision, so it will provide the same resolution as raw data, regardless of the mean data level.

I'm checking in with Wetlabs directly about your question, in order to get further feedback about the best output to use, given the limits on data resolution for the ECO-BB.

Regards,
Stephanie

****

From: Stephanie Jaeger [sjaeger@seabird.com]
Sent: 18/12/2014 19:54
To: dougal.mountifield@noc.ac.uk;
dm1@noc.ac.uk
Cc: daves@wetlabs.com; jeh200@noc.ac.uk; jrbn@noc.ac.uk
Subject: RE: Urgent: Wetlabs BB con file module SBE Data Processing problem [ref:_00D7096pT._50070vbxjt:ref]

Hi Dougal,

I'm following up regarding your question on this processing the ECO-BB data. I did check in with Wetlabs, and they confirmed that the raw resolution (given in voltage on the A/D channel) should match the resolution of the converted engineering output. So, the output should show up as it does with the User Polynomial function, as you mentioned.

Also, we noted that the units of the output variable should be in "scattering" rather than "turbidity." So, the variable will be fixed to be named "OBS Meter, WET Labs, ECO-BB" rather than turbidity.

We have reported this to the software engineer, and he'll work to resolve this in a future version of SBE Data Processing.

Thank you for letting us know about this, and let me know if you have further questions.
Regards,
Stephanie