DY030 CTD processing report

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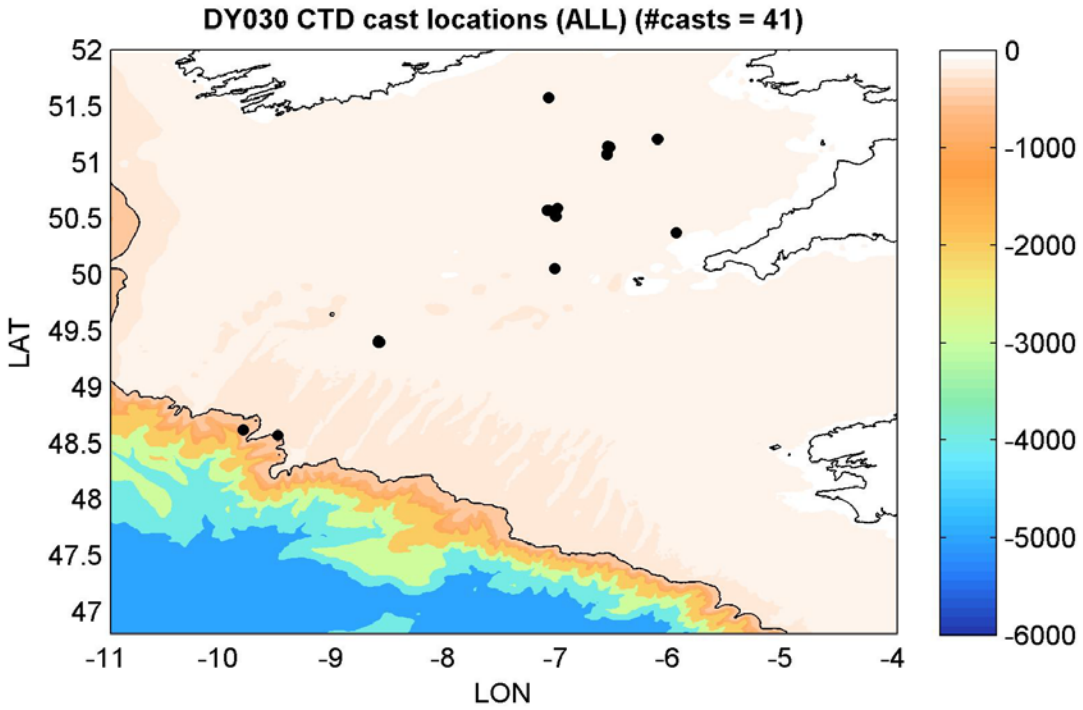
J Hopkins
National Oceanography Centre, Liverpool
jeh200@noc.ac.uk

A total of 33 casts with the stainless steel frame and 8 casts with the titanium CTD frame were completed. Most casts were to a depth of between 90m to 200m, with only one deeper cast; cast 036 which deployed to 960m. See technical reports for sensor serial numbers and channels.

Map of CTD cast locations



Raw data files:

The following raw data files were generated:

DY030_001.bl (a record of bottle firing locations)
DY030_001.hdr (header file)
DY030_001.hex (raw data file)
DY030_001.con (configuration file)

Where _CTD001 is the cast number (not STNNBR)

The secondary conductivity sensor on the S/S frame was swapped during the cruise:

s/n 04C-3054 for casts 2, 3, 5 and 7 (over reading salinity by approx. 1.8 psu)
s/n 04C-3873 for casts 6, 8-onwards

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 for stainless and titanium
   Scan range duration: 5 seconds for stainless and titanium
   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: Light scattering Wetlabs BBRTD *[S/S]*, Downwelling Irradiance sensor (DWIRR) *[Ti]*
   - Voltage channel 3:Altimeter *[S/S]*, Upwelling Irradiance sensor (UWIRR) *[Ti]*
   - Voltage channel 4: Fluorometer *[S/S]*, Altimeter *[Ti]*
   - Voltage channel 5: Transmissometer *[S/S]*, Light scattering Wetlabs BBRTD *[Ti]*
   - Voltage channel 6: Upwelling Irradiance sensor (UWIRR) *[S/S]*, Transmissometer *[Ti]*
   - Voltage channel 7: Downwelling Irradiance sensor (DWIRR) *[S/S]*, Fluorometer *[Ti]*

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 DY030_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 on the stainless steel CTD and 3 seconds for the titanium casts. 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.

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 DY030_001.cnv (24 Hz resolution)

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

   Output saved to DY030_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 DY030_001_derive_2Hz.cnv

Cast 13 has been split into two recordings: DY030_013 and DY030_013a. There is therefore an approx. 20 m gap between 22 m and 44 m on the downcast.

File	Start time	Min pressure (db)	Max pressure (db)	End pressure (db)
DY030_013	10 May 2015 12:44:58	0 db (at surface)	22 db	22 db
DY030_013a	10 May 2015 12:49:51	44 db	91 db	0 db (at surface)

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. DY030
STNNBR (as per BODC data management guidance for the Shelf Sea Biogeochemistry programme)
DATE and TIME at the start of the CTD cast (taken from event log)
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: DY030_metadata.mat

(2) Extract data from 2Hz averaged files (e.g. DY030_001_derive_2Hz.cnv), merge with metadata and save into a matlab structure for each cast. Each file (DY030_001_derive_2Hz.mat) contains the following un-calibrated channels.

```
CTD002 =

           CRUISE: 'DY030'
             CAST: 2
           STNNBR: 3
             DATE: '06/05/2015'
             TIME: '13:57'
              LAT: 51.0742
              LON: -6.5844
            DEPTH: 98                   [m]
          CTDtime: [4413x1 double]      [seconds]
          CTDpres: [4413x1 double]      [db]
         CTDtemp1: [4413x1 double]      [°C]
         CTDtemp2: [4413x1 double]      [°C]
         CTDcond1: [4413x1 double]      [S/m]
         CTDcond2: [4413x1 double]      [S/m]
       CTDoxy_raw: [4413x1 double]      [V]
           CTDatt: [4413x1 double]      [1/m]
         CTDfluor: [4413x1 double]      [µg/l]
           CTDpar: [4413x1 double]      [Wm2]
          CTDturb: [4413x1 double]      [m-1 sr-1]
           CTDalt: [4413x1 double]      [m]
      CTDturb_raw: [4413x1 double]      [V]
       CTDalt_raw: [4413x1 double]      [V]
     CTDfluor_raw: [4413x1 double]      [V]
       CTDatt_raw: [4413x1 double]      [V]
    CTDpar_up_raw: [4413x1 double]      [V]
    CTDpar_dn_raw: [4413x1 double]      [V]
          CTDsal1: [4413x1 double]      [PSU]
          CTDsal2: [4413x1 double]      [PSU]
     CTDoxy_umoll: [4413x1 double]      [µmol/l]
          CTDflag: [4413x1 double]
```

(3) Extract data from 24Hz files (e.g. DY030_001_derive.cnv), merge with metadata and save into a matlab structure for each cast. Each file (DY008_001_derive.mat) contains the following un-calibrated channels.

```
CTD002 =

           CRUISE: 'DY030'
             CAST: 2
           STNNBR: 3
             DATE: '06/05/2015'
             TIME: '13:57'
              LAT: 51.0742
              LON: -6.5844
            DEPTH: 98                        [m]
```

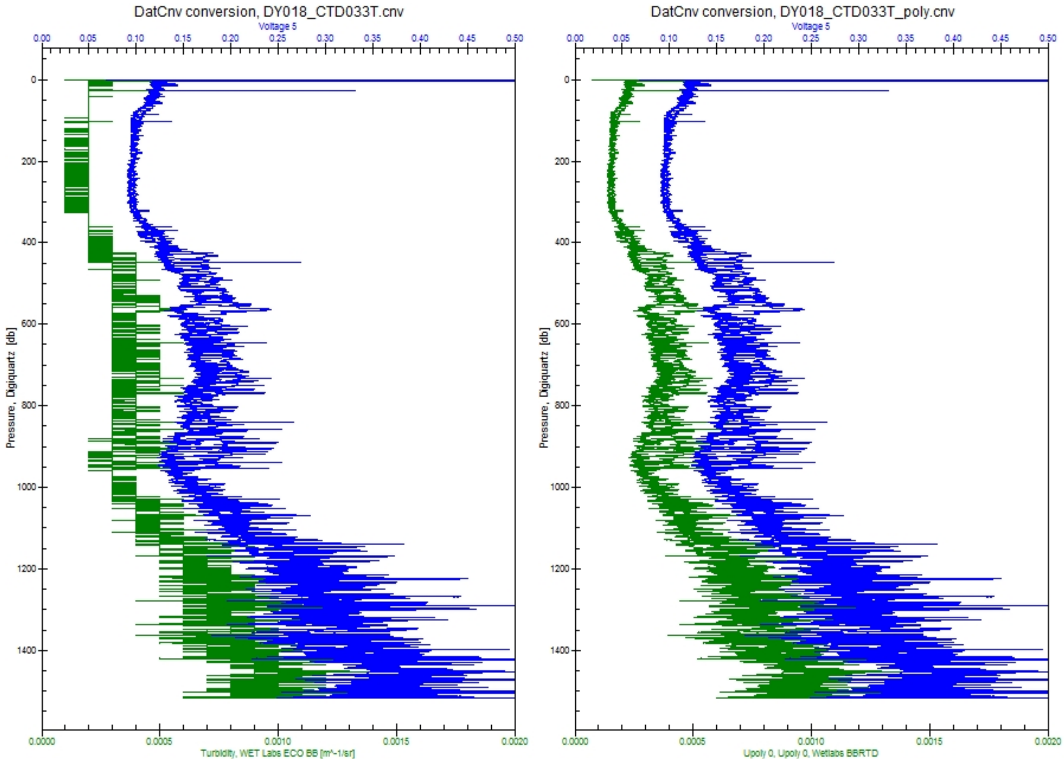
```
           CTDtime: [52948x1 double]       [seconds]
           CTDpres: [52948x1 double]       [db]
          CTDtemp1: [52948x1 double]       [°C]
          CTDtemp2: [52948x1 double]       [°C]
          CTDcond1: [52948x1 double]       [S/m]
          CTDcond2: [52948x1 double]       [S/m]
         CTDsal1_1: [52948x1 double]       [PSU]
         CTDsal2_1: [52948x1 double]       [PSU]
        CTDoxy_raw: [52948x1 double]       [V]
   CTD_oxy_umoll_1: [52948x1 double]       [µmol/l]
            CTDatt: [52948x1 double]       [1/m]
          CTDfluor: [52948x1 double]       [µg/l]
            CTDpar: [52948x1 double]       [Wm2]
           CTDturb: [52948x1 double]       [m-1 sr-1]
            CTDalt: [52948x1 double]       [m]
       CTDturb_raw: [52948x1 double]       [V]
        CTDalt_raw: [52948x1 double]       [V]
      CTDfluor_raw: [52948x1 double]       [V]
        CTDatt_raw: [52948x1 double]       [V]
     CTDpar_up_raw: [52948x1 double]       [V]
     CTDpar_dn_raw: [52948x1 double]       [V]
           CTDsal1: [52948x1 double]       [PSU]
           CTDsal2: [52948x1 double]       [PSU]
      CTDoxy_umoll: [52948x1 double]       [µmol/l]
           CTDflag: [52948x1 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.

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 in DY018 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 DY030_stainless_castcrop_times.mat and DY030_titanium_castcrop_times.mat

```
     CAST: [34x6 char]
   STNNBR: [34x1 double]
 CTDstart: [34x1 double] [seconds]
  CTDstop: [34x1 double] [seconds]
```

This was then used to crop both the 2Hz and 24Hz files and output (i.e. just the downcast recordings) saved to DY030_001_derive_2Hz_cropped.mat and DY030_001_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	100	2	200	3

Auto-despiking saved to DY030_001_derived_cropped_autospike.mat

After the auto-despike function DY030_013_ derive_cropped_autospike.mat and DY013a_derive_cropped_autospike.mat were spliced together. The original files are preserved and the remainder of processing carried out on a newly created file DY030_013_ derive_cropped_autospike.mat.

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) any 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 DY030_001_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: DY030_001_1db_dn.mat

All the 1 db profiles (except PAR) are then further smoothed with a 10 m running median window.

File output: DY030_001_1db_dn_smth.mat

(7) Application of calibrations to salinity, chlorophyll and oxygen in 1db smoothed downcasts. Calibrated files saved to DY030_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: 'DY030'
            CAST: 1
          STNNBR: 1
            DATE: '10/11/2014'
            TIME: '05:12'
             LAT: 49.4013
             LON: -8.5802
           DEPTH: 151
            pres: [140x1 double] [db]
            time: [140x1 double] [seconds]
           temp1: [140x1 double] [°C]
           temp2: [140x1 double] [°C]
            sal1: [140x1 double] [PSU] – S/S only calibrated
            sal2: [140x1 double] [PSU] – S/S only calibrated
           cond1: [140x1 double] [S/m] – not calibrated
           cond2: [140x1 double] [S/m] – not calibrated
       oxy_umoll: [140x1 double] [µmol/l] – calibrated
           fluor: [140x1 double] [µg/l] – S/S only calibrated
             par: [140x1 double] [Wm2]
            turb: [140x1 double] [m-1 sr-1]
             att: [140x1 double] [1/m]
     sigma_theta: [140x1 double]
```

The calibrations were also applied to the 24 Hz data (cropped and de-spiked) and output to .mat files DY030_001_derive_cropped_autospike_manualspike_calib.mat containing the same variables as above.

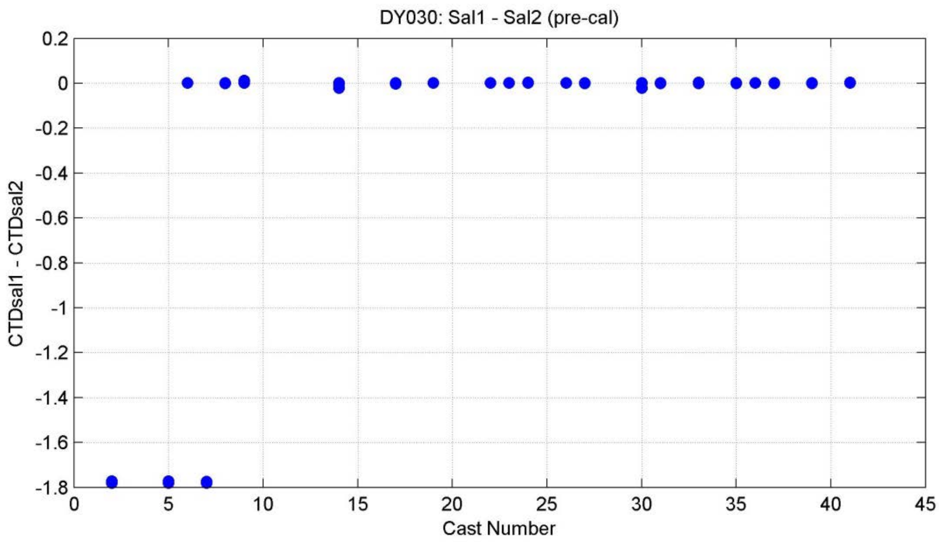
(8) Application of salinity, chlorophyll and oxygen calibrations to bottle firing data. A new file, DY030_stainless_btl_calib.mat/ DY030_titanium_btl_calib.mat, with variables CTDsal1_cal, CTDsal2_cal, CTDoxy_umoll_cal and CTDfluor_cal where appropriate was created.

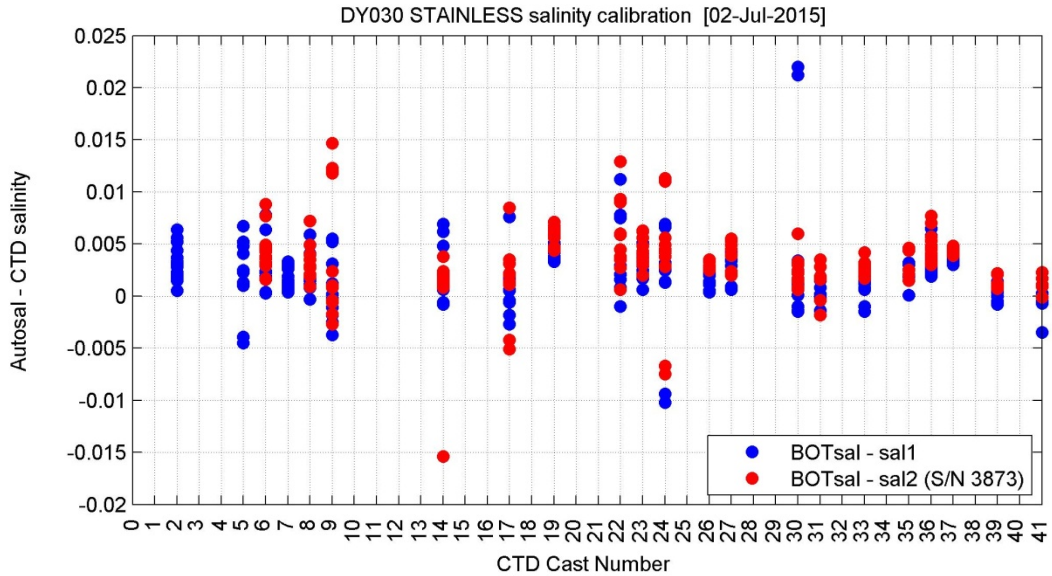
Calibrations

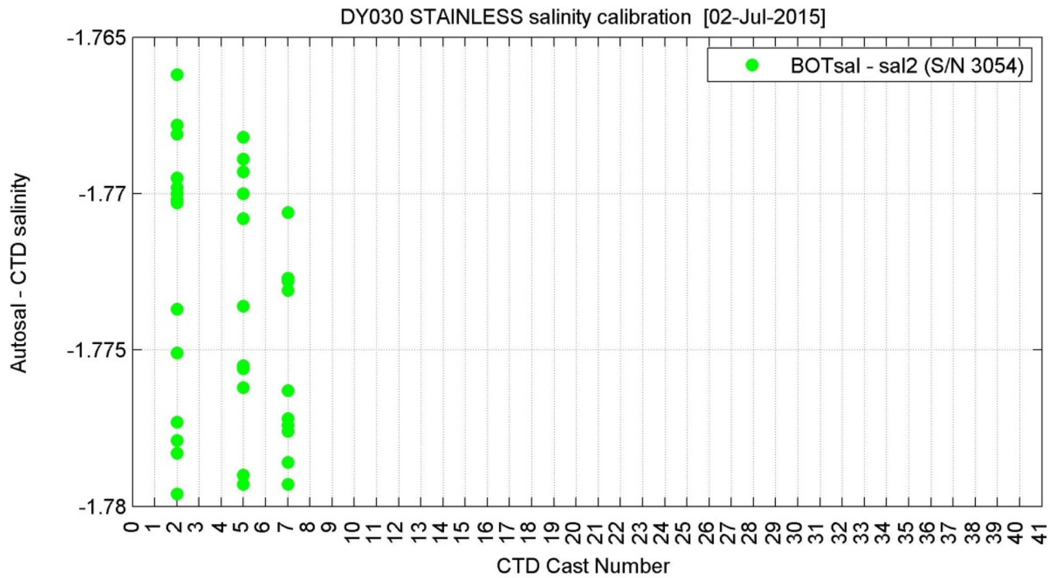
Salinity

Stainless CTD

A total of 239 salinity samples were taken from the stainless CTD and were anlaysed on a Guildline 8400B SN: 71126. Two different secondary conductivty sensors were used (s/n 04C-3054 for casts 2, 3, 5 and 7 and s/n 04C-3873 for casts 6, 8-onwards). SN 3054 was almost 1.8 PSU different to the primary sensor. Two different calibrations are therefore required.


DY030: Sal1 - Sal2 (pre-cal)
CTDsal1 - CTDsal2
Cast Number


DY030 STAINLESS salinity calibration [02-Jul-2015]
Autosal - CTD salinity
BOTsal - sal1
BOTsal - sal2 (S/N 3873)
CTD Cast Number

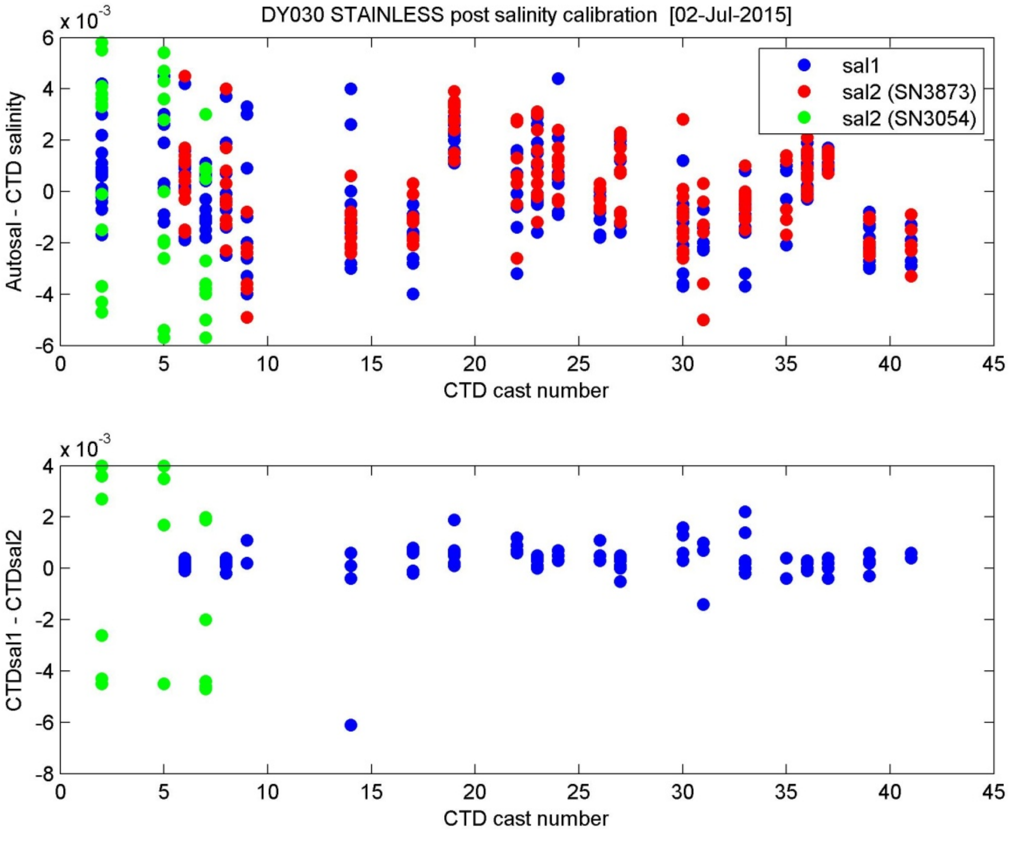

DY030 STAINLESS salinity calibration [02-Jul-2015]
Autosal - CTD salinity
BOTsal - sal2 (S/N 3054)
CTD Cast Number

Using all samples the mean and standard deviation of residuals (Autosal-CTD) from the primary and secondary sensors were:
Primary: 0.0022335 ± 0.0030984
Secondary (SN 3054): -1.7736 ± 0.0039822
Secondary (SN 3873): 0.0032278 ± 0.0034767

After removal of outliers where the difference between Autosal and CTD values was greater than 1.5 standard deviations the mean ± standard deviations reduced to:
Primary: 0.0021886 ± 0.0018464
Secondary (SN 3054): -1.7736 ± 0.0037822
Secondary (SN 3873): 0.0031917 ± 0.0018327

These are the offsets applied.

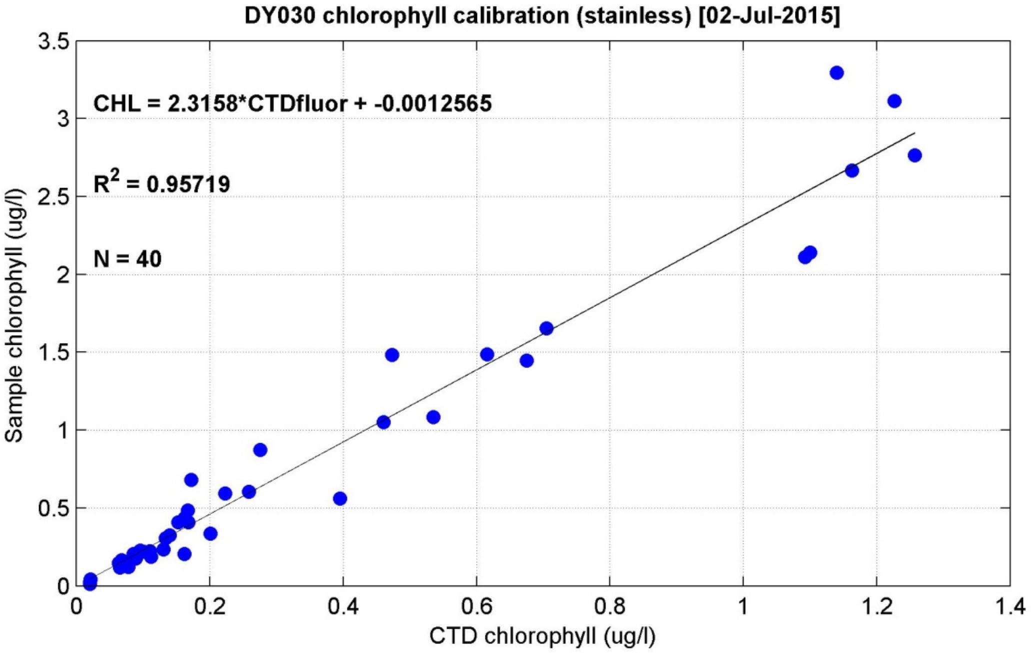
Pre-calibration the differences between the primary and secondary CTD salinity values were: -1.776 (casts with SN 3054) and 0.0010354 (casts with SN 3873). After calibration these differences reduced to -0.00044407 and 0.00031489 respectively. Given the large scatter of points however the secondary salinity on casts 2, 3, 5 and 7 should be treated with caution.



Titanium CTD
Due to a logging error the salinity samples from the titanium CTD could not be matched to the cast and rosette positions. The salinity has not therefore been calibrated.

Chlorophyll

A total of 75 samples were taken for calibration of the stainless CTD fluorometer. After removal of samples taken during daylight in the surface 30 m, the following calibration was applied.

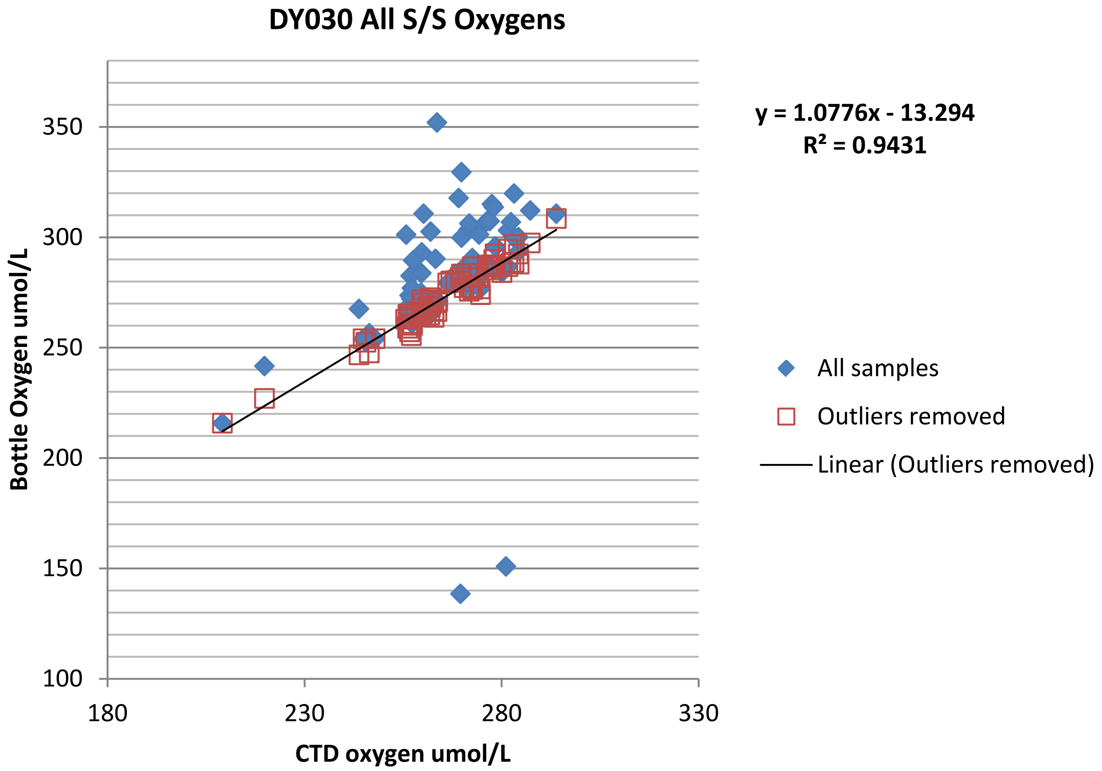


No samples were taken for CHL from the titanium CTD.

Oxygen

Data was supplied by Helen Smith (NOC) for calibration of the oxygen sensors. Due to unreliable thermometer temperatures at the time of fixing the samples on deck the temperature at the time of bottle firing (from the .btl files) was used to calculate the final oxygen values.

Stainless
Two to four replicate samples were taken per niskin bottle for the S/S CTD. The mean at each depth/niskin bottle was then calculated and used in the calibration. Samples were removed if the difference between the CTD and sample oxygen was > 15 umol/L (this often left just one sample per bottle).

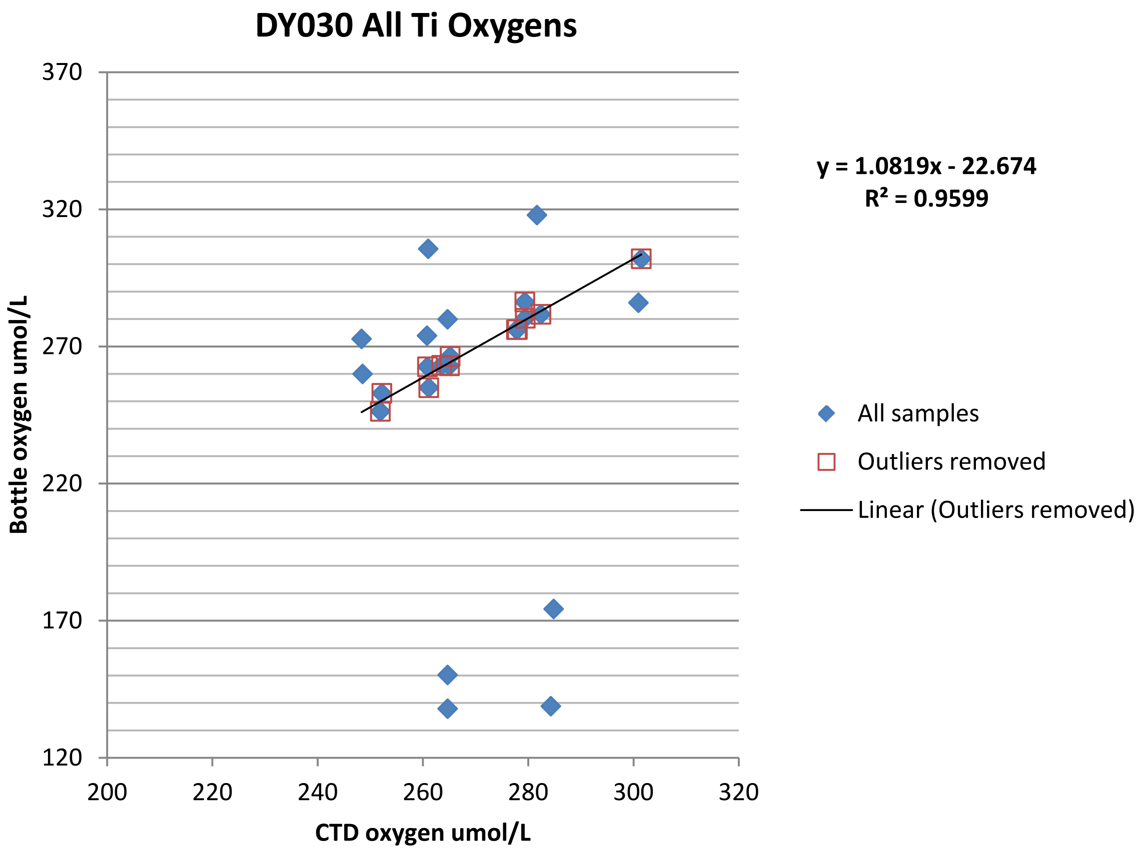


(Above). S/S CTD oxygen vs. sample oxygen. All data points shown in blue. Those used for calibration (outliers reomved) shown in red.

Following this calibration the median difference between the CTD and bottle sample reduced from -7.25 umol/L to -0.79 umol/L.

Titanium

Due to pressure on water requirements only one sample per bottle was generally taken on the titanium casts. Two different niskins fired at the same depth on the titanium profiles were both sampled but these are not treated as replicates. Any samples where the difference between the CTD and bottle sample was > 12 umol/L were removed.



(Above). Ti CTD oxygen vs. sample oxygen. All data points shown in blue. Those used for calibration (outliers reomved) shown in red.