# DY021 CTD processing report

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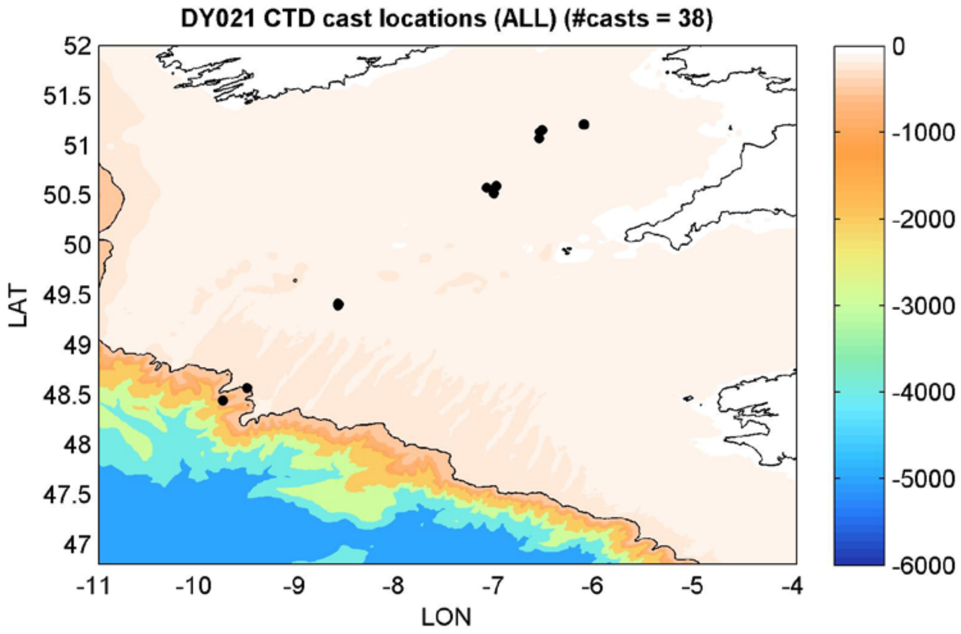
A total of 30 casts with the stainless steel frame and 8 casts with the titanium CTD frame were completed. See technical reports for sensor serial numbers and channels.

Stainless cast numbers are 1-2, 6-11, 13-17, 19-24, 26-30, 32-35, and 37-38.
Titanium cast numbers are 3-5, 12, 18, 25, 31 and 36.

**Map of CTD cast locations**




**Raw data files:**

The following raw data files were generated:

DY021_001.bl (a record of bottle firing locations)
DY021_001.hdr (header file)
DY021_001.hex (raw data file)
DY021_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 for stainless, -1 second for titanium (fired on the fly)
Scan range duration: 5 seconds for stainless, 1 second for titanium (fired on the fly)
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 [V0]
- 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 BBRTD *[S/S]*, Downwelling Irradiance (DWIRR) *[Ti]*
- Voltage channel 3: Altimeter *[S/S]*, Upwelling Irradiance (UWIRR) *[Ti]*
- Voltage channel 4: Fluorometer *[S/S]*, Altimeter *[Ti]*
- Voltage channel 5: Transmissometer *[S/S]*, Light scattering BBRTD *[Ti]*
- Voltage channel 6: Upwelling Irradiance (UWIRR) *[S/S]*, Transmissometer *[Ti]*
- Voltage channel 7: Downwelling Irradiance (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 DY021_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 2 second advance was chosen for alignment of the oxygen sensor on the stainless steel CTD and 4 seconds for the titanium casts. Note that there was very little stratification during the cruise so these values were tricky to determine. 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 DY021_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 DY021_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 DY021_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. DY021
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: DY021_metadata.mat

(2) Extract data from 2Hz averaged files (e.g. DY021_001_derive_2Hz.cnv), merge with metadata and save into a matlab structure for each cast. Each file (DY021_001_derive_2Hz.mat) contains the following un-calibrated channels.

```
CTD001 =

           CRUISE: 'DY021'
             CAST: 1
           STNNBR: 1
             DATE: '03/03/2015'
             TIME: '07:00:00'
              LAT: 51.2117
```

```
             LON: -6.1330
           DEPTH: 109                    [m]
         CTDtime: [4895x1 double]        [seconds]
         CTDpres: [4895x1 double]        [db]
        CTDtemp1: [4895x1 double]        [°C]
        CTDtemp2: [4895x1 double]        [°C]
        CTDcond1: [4895x1 double]        [S/m]
        CTDcond2: [4895x1 double]        [S/m]
      CTDoxy_raw: [4895x1 double]        [V]
          CTDatt: [4895x1 double]        [1/m]
        CTDfluor: [4895x1 double]        [µg/l]
          CTDpar: [4895x1 double]        [Wm2]
         CTDturb: [4895x1 double]        [m-1 sr-1]
          CTDalt: [4895x1 double]        [m]
     CTDturb_raw: [4895x1 double]        [V]
      CTDalt_raw: [4895x1 double]        [V]
    CTDfluor_raw: [4895x1 double]        [V]
      CTDatt_raw: [4895x1 double]        [V]
   CTDpar_up_raw: [4895x1 double]        [V]
   CTDpar_dn_raw: [4895x1 double]        [V]
         CTDsal1: [4895x1 double]        [PSU]
         CTDsal2: [4895x1 double]        [PSU]
    CTDoxy_umoll: [4895x1 double]        [µmol/l]
         CTDflag: [4895x1 double]
```

(3) Extract data from 24Hz files (e.g. DY021_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.

```
CTD001 =

             CRUISE: 'DY021'
               CAST: 1
             STNNBR: 1
               DATE: '03/03/2015'
               TIME: '07:00:00'
                LAT: 51.2117
                LON: -6.1330
              DEPTH: 109                      [m]
            CTDtime: [58732x1 double]         [seconds]
            CTDpres: [58732x1 double]         [db]
           CTDtemp1: [58732x1 double]         [°C]
           CTDtemp2: [58732x1 double]         [°C]
           CTDcond1: [58732x1 double]         [S/m]
           CTDcond2: [58732x1 double]         [S/m]
          CTDsal1_1: [58732x1 double]         [PSU]
          CTDsal2_1: [58732x1 double]         [PSU]
         CTDoxy_raw: [58732x1 double]         [V]
    CTD_oxy_umoll_1: [58732x1 double]         [µmol/l]
             CTDatt: [58732x1 double]         [1/m]
           CTDfluor: [58732x1 double]         [µg/l]
             CTDpar: [58732x1 double]         [Wm2]
            CTDturb: [58732x1 double]         [m-1 sr-1]
```

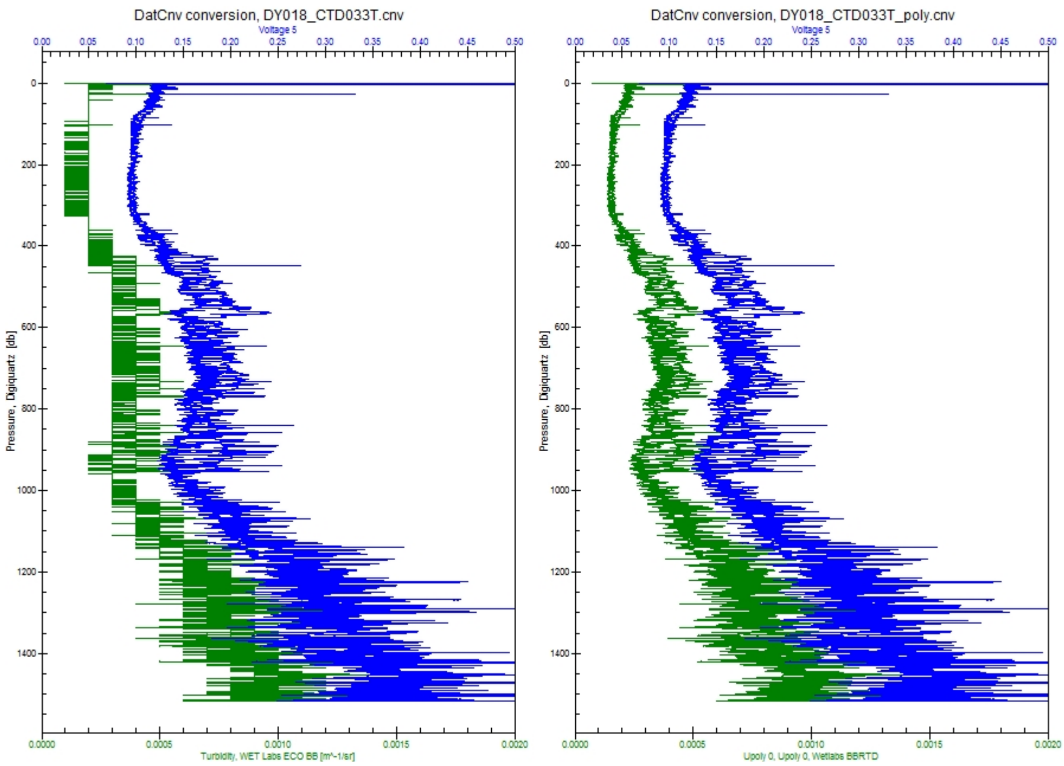
```
         CTDalt: [58732x1 double]       [m]
    CTDturb_raw: [58732x1 double]       [V]
     CTDalt_raw: [58732x1 double]       [V]
    CTDfluor_raw: [58732x1 double]      [V]
     CTDatt_raw: [58732x1 double]       [V]
   CTDpar_up_raw: [58732x1 double]      [V]
   CTDpar_dn_raw: [58732x1 double]      [V]
        CTDsal1: [58732x1 double]       [PSU]
        CTDsal2: [58732x1 double]       [PSU]
    CTDoxy_umoll: [58732x1 double]      [µmol/l]
        CTDflag: [58732x1 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.

As per DY018, 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 DY021_stainless_castcrop_times.mat and DY021_titanium_castcrop_times.mat

```
        CAST: [30x6 char]
      STNNBR: [30x1 double]
    CTDstart: [30x1 double]
     CTDstop: [30x1 double]
```

This was then used to crop both the 2Hz and 24Hz files and output (i.e. just the downcast recordings) saved to DY021_001_derive_2Hz_cropped.mat and DY021_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, attenuation | 100 | 2 | 200 | 3 |

Auto-despiking saved to DY021_001_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 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 DY021_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:  DY021_001_1db_dn.mat

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

File output: DY021_001_1db_dn_smth.mat

(7) Application of calibrations to salinity, chlorophyll and oxygen in 1db smoothed downcasts. Calibrated files saved to DY021_001_1db_dn_smth_calib.mat.

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

```
CTD001 =

         CRUISE: 'DY021'
           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] - calibrated
           sal2: [140x1 double] [PSU] - 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 DY021_001_derive_cropped_autospike_manualspike_calib.mat containing the same variables as above.

* A calibration could not be determined for the titanium chlorophyll so this variable remains un-calibrated in these final files*

(8) Application of salinity, chlorophyll and oxygen calibrations to bottle firing data. A new file, DY021_stainless_btl_calib.mat/ DY021_titanium_btl_calib.mat, with variables CTDsal1_cal, CTDsal2_cal, CTDoxy_umoll_cal and CTDfluor_cal was created. **Note that the titanium CTD has NOT had a chlorophyll calibration so the CTDfluor_cal variable does not exist**

**Notes:**

CTD009 (S/S) just a surface soak – no profile

## Calibrations

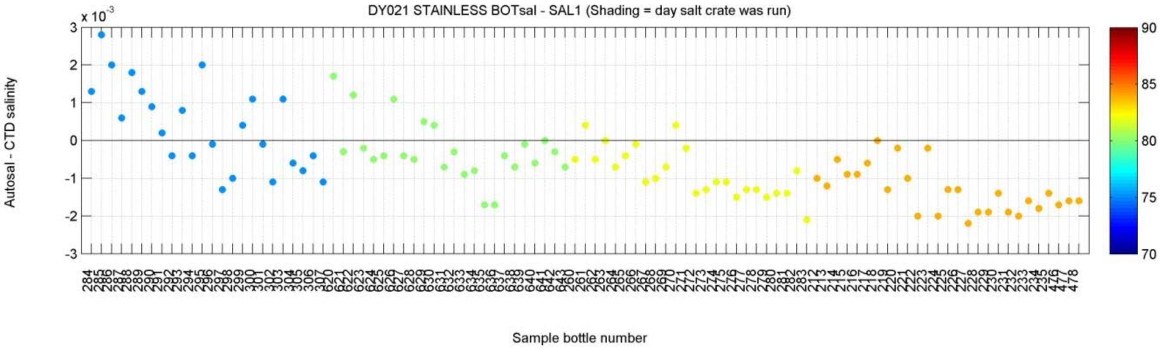
### Salinity

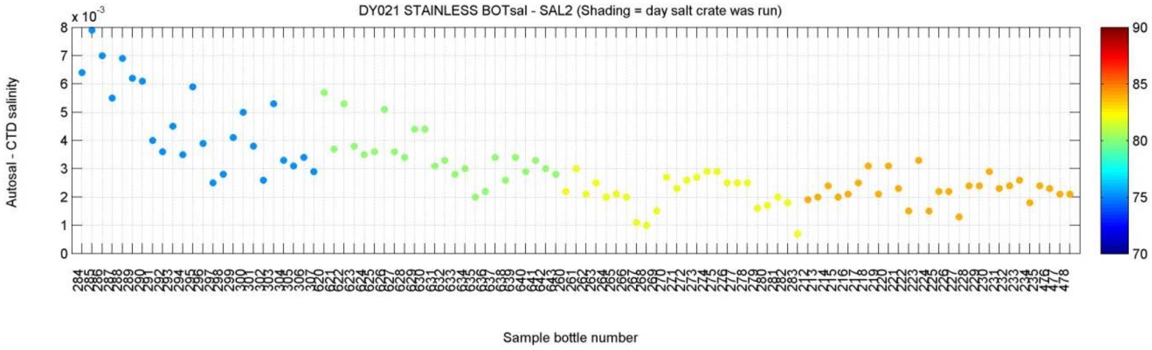
99 salinity samples were taken from the stainless steel CTD and 38 samples from the titanium and analysed on a Guildline 8400B Autosal salinometer (s/n 71126).

There was some uncertainty over which niskin bottles salinity samples from cast 12, 18 and 25 (titanium casts) were taken from. The bottle positions (ROSPOS) in the .btl files do not match the numbers recorded on the  hand written log sheets from NMF. In some instances bottles supposedly sampled were not even fired. The best possile matches were found and used.

*Stainless sensors*

There was a drift in the Autosal – CTDsal salinities in both the primary and secondary conductivity senosors. The ‘drift’ in the stainless samples was O(0.005) PSU (see Figure below).

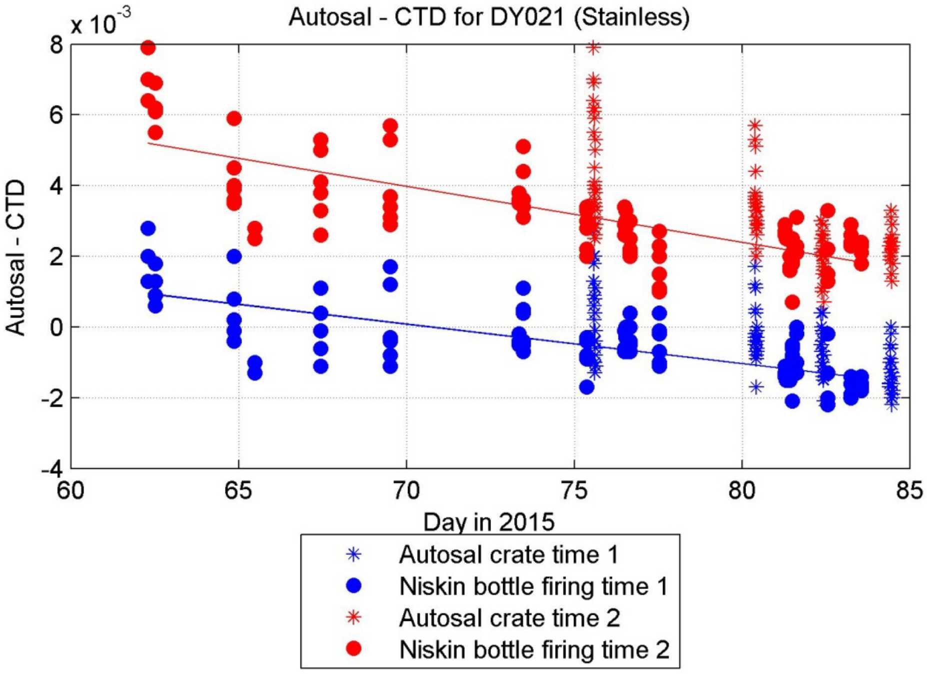



This magnitude of drift can not be accounted for by instability in the autosal readings. The table below shows the conductivity ratios and salinities of the standards run before and after each crate and the corresponding conductivities and salinities measured by autosal. The differences between them are an order of magnitude smaller than the drift. Correction for these small offsets does not remove the ‘drift’ in Autosal-CTDsal differences.

| | | | STANDARD | | MEASURED | | | Measured-Standard | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Crate | Bottles | 2 x K15 | Salinity | 2 x K15 | Salinity | | Sal. Offset | Average |
| 16/03/15 | TSG01 | | 1.9997 | 34.994 | 1.99967 | 34.9936 | Start | -0.0004 | -0.00045 |
| | | | 1.9997 | 34.994 | 1.999664 | 34.9935 | End | -0.0005 | |
| 16/03/15 | CTD11 | 284-307 | 1.9997 | 34.994 | 1.99967 | 34.9936 | Start | -0.0004 | -0.00045 |
| | | | 1.9997 | 34.994 | 1.999664 | 34.9935 | End | -0.0005 | |
| 21/03/15 | CTD25 | 620-643 | 1.9997 | 34.994 | 1.999677 | 34.9938 | Start | -0.0002 | -0.00025 |
| | | | 1.9997 | 34.994 | 1.999672 | 34.9937 | End | -0.0003 | |
| 21/03/15 | CTD22 | 548-568 | 1.9997 | 34.994 | 1.999672 | 34.9937 | Start | -0.0003 | -0.00035 |
| | | | 1.9997 | 34.994 | 1.999669 | 34.9936 | End | -0.0004 | |
| 23/03/15 | CTD10 | 260-283 | 1.9997 | 34.994 | 1.999652 | 34.9933 | Start | -0.0007 | -0.0008 |
| | | | 1.9997 | 34.994 | 1.999641 | 34.9931 | End | -0.0009 | |
| 25/03/15 | TSG02 | | 1.9997 | 34.994 | 1.999646 | 34.9931 | Start | -0.0009 | -0.0009 |
| | | | 1.9997 | 34.994 | 1.999645 | 34.9931 | End | -0.0009 | |
| 25/03/15 | CTD1819 | 452-478 | 1.9997 | 34.994 | 1.999645 | 34.9931 | Start | -0.0009 | -0.00075 |
| | | | 1.9997 | 34.994 | 1.999657 | 34.9934 | End | -0.0006 | |
| 25/03/15 | CTD08 | 212-235 | 1.9997 | 34.994 | 1.999657 | 34.9934 | Start | -0.0006 | -0.00065 |
| | | | 1.9997 | 34.994 | 1.999652 | 34.9933 | End | -0.0007 | |

The trend is significant (pvalues << 0.05) and appears to be a temporal drift associated with each conductivty sensor. If the drift was in Autosal then the offsets within each crate should be more consistent/stable. There are also significant trends with CTD temperature and salinity although these are slightly weaker than for time and have potentilly been introduced coincidentally by the spatial sampling pattern on the cruise.



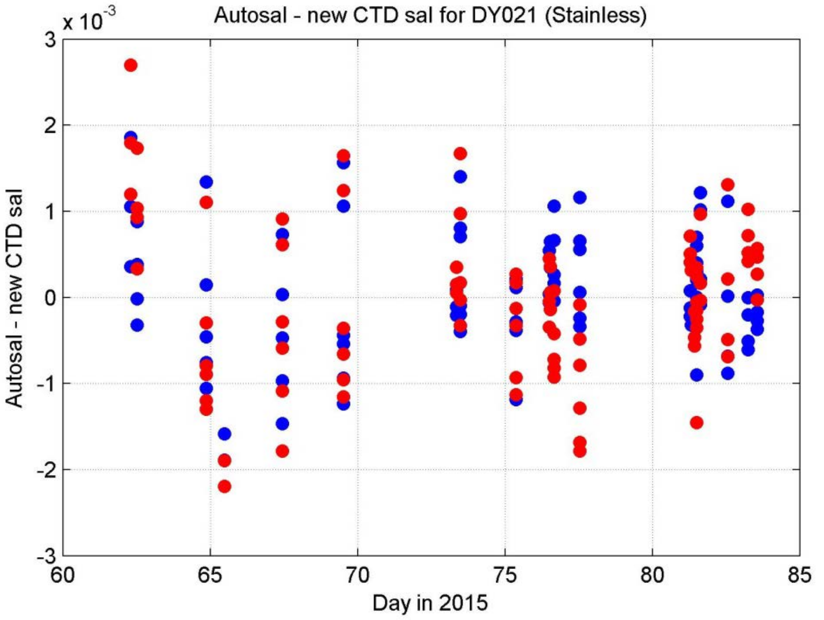
Regression applied for <u>temporal</u> dift to stainless sensors:

*CTDsal_cal1 = CTDsal + (intercept + (slope × daynumber))*

Primary intercept = 0.007896260752417
Primary slope = -1.116230843654996e-04

Secondary intercept = 0.015087956132598
Secondary slope = -1.586872897987173e-04

After the above temporal drift correction the mean and standard deviation of residuals (Autosal - CTD) from the primary and secondary sensors were 5.024e-16 ± 0.0007009 and -7.1772e-17 ± 0.0008825 respectively. The trends with temperature and salinity became insignificant after this correction.



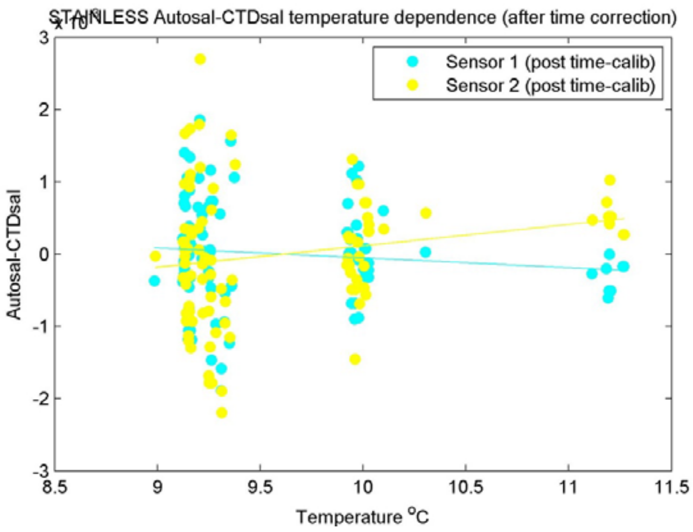

A correction for the slight temperture related drift however was applied in order to better align the readings between the primary and secondary sensors.

Regression applied for <u>thermal</u> dift to stainless sensors:

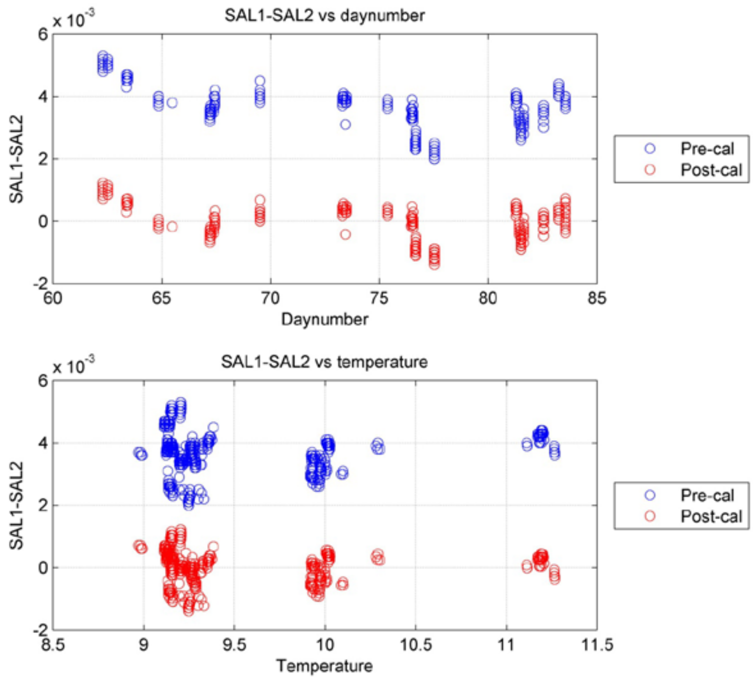
*CTDsal_cal2 = CTDsal_cal1 + (intercept + (slope × temperature))*

Primary intercept = 0.001308186425552
Primary slope = -1.360663649035130e-04

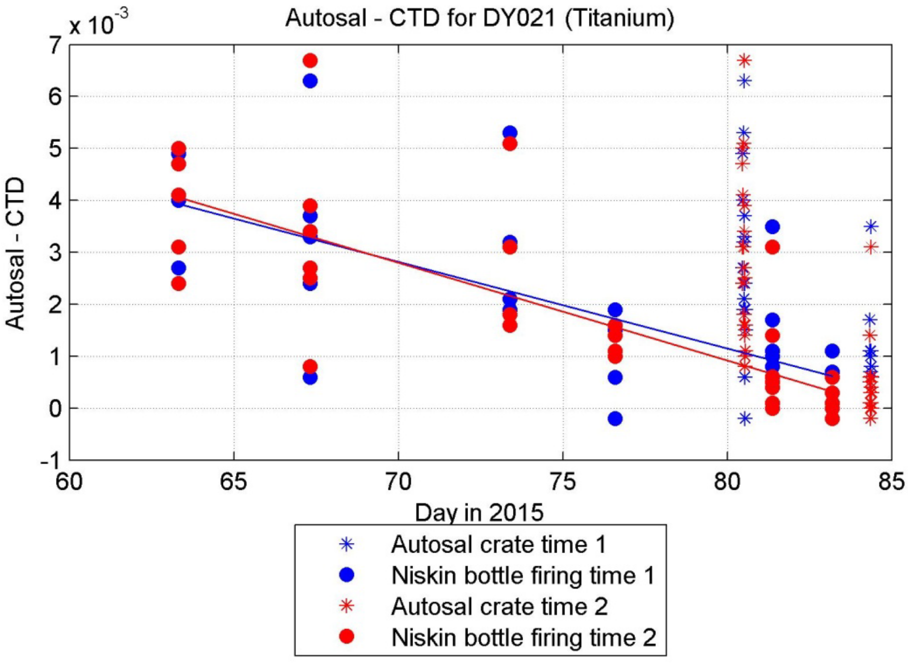
Secondary intercept = -0.002849682684898
Secondary slope = 2.963393480742600e-04




After these two corrections the mean difference between the primary and secondary sensors was 4.0603214e-05 (std = 0.00054561)



*Titanium*
A temporal drift was also present in the titanium sensors.



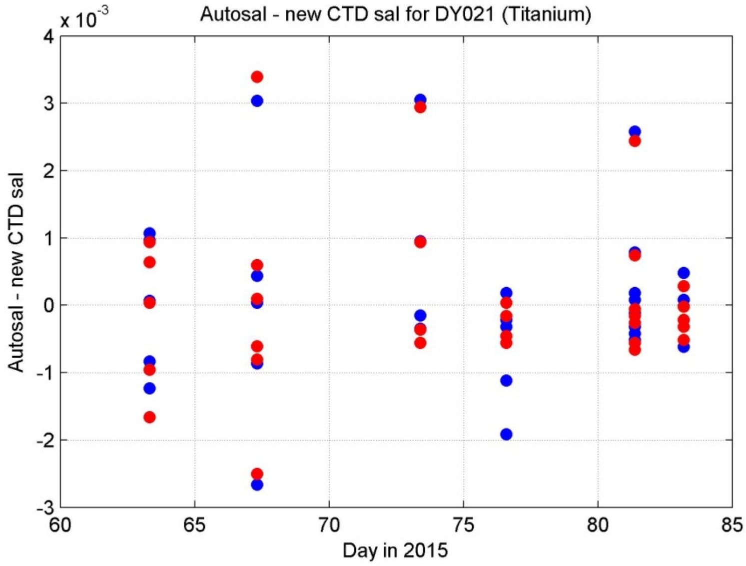

Regression applied for <u>temporal</u> dift to titanium sensors:

*CTDsal_cal = CTDsal + (intercept + (slope × daynumber))*

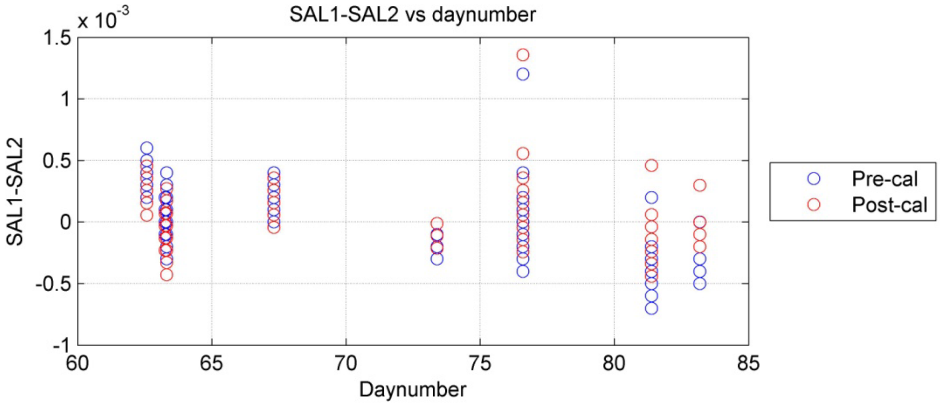
Primary intercept = 0.014492859793267
Primary slope = -1.668293686343925e-04

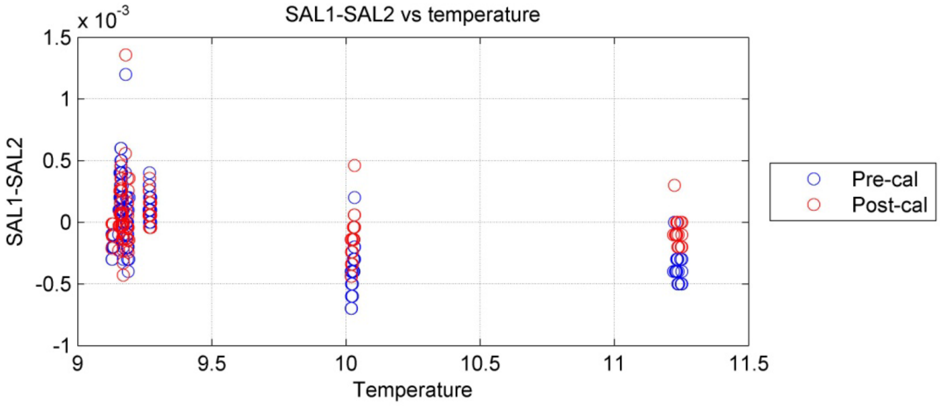
Secondary intercept = 0.015985420500784
Secondary slope = -1.883672231497256e-04

After the above temporal drift correction the mean and standard deviation of residuals (Autosal - CTD) from the primary and secondary sensors were 5.6095e-16 ± 0.0011251and -2.2438e-15 ± 0.00108 respectively. The trends with temperature and salinity became insignificant after this correction. No further corrections were applied.



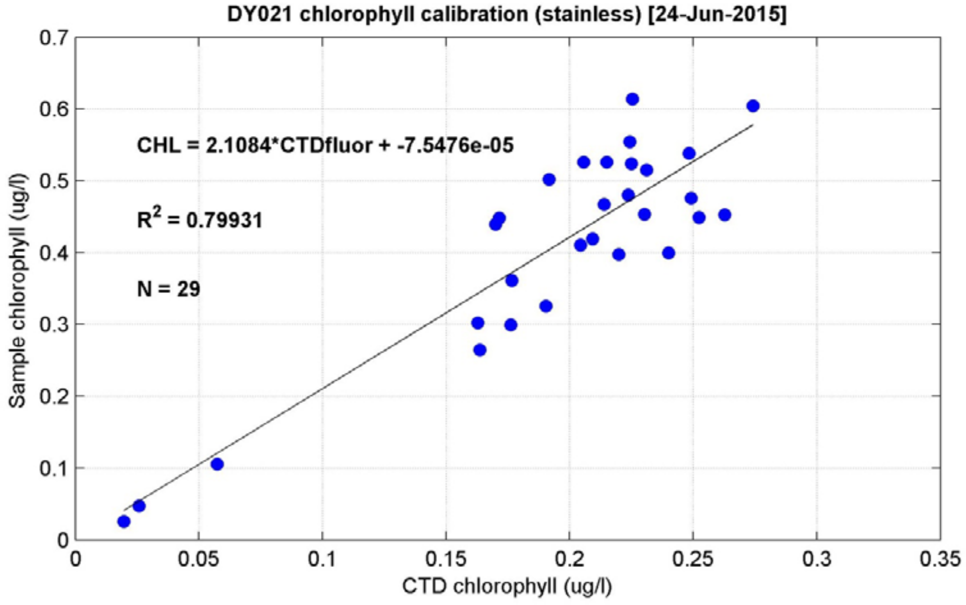

After calibration the mean difference between the primary and secondary sensors was 7.3301e-06 (std = 0.00022084).



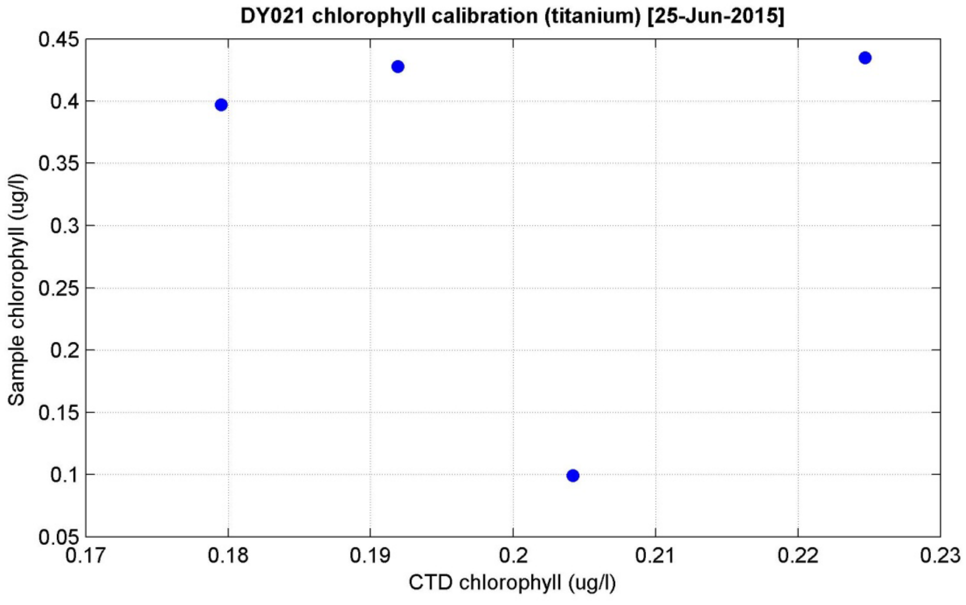



**Chlorophyll**

A total of 63 samples were taken for CTD calibration. For the stainless CTDs, after removal of samples taken during daylight in the surface 30 m, the following calibration was applied.

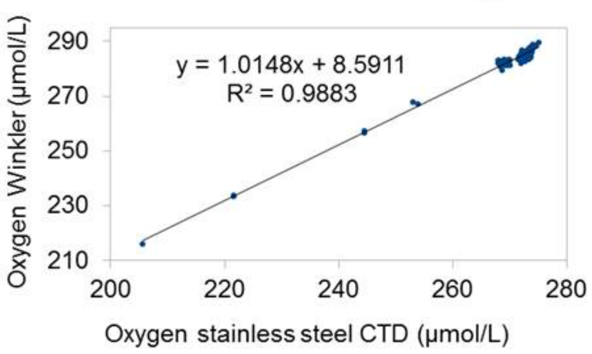


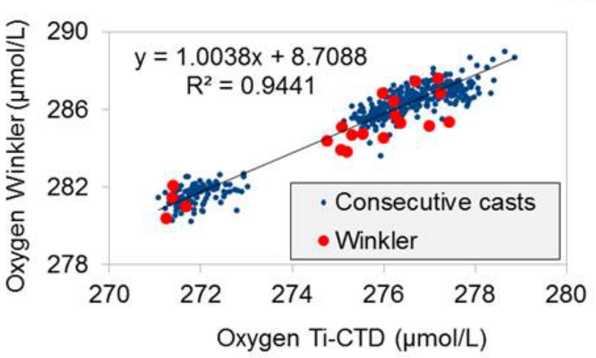

Of the 63 samples taken only 4 were from the titanium CTD (all from cast 31). This was not enough to perform a reliable calibration.



**Oxygen**

The necessary oxygen calibration for both CTDs was calculated by Vassilis Kitidis (PML). Full details can be found in his cruise report. His calibrations are shown in the plots below and are applied to the CTD profiles here.




**Turbidity**

Following discussion at a workpackage meeting the turbidity (Wetlabs Scatering BBRTD) sensor was not calibrated (to SPM in g/l). The scattering signal and therefore calibration is dependent upon (a) the wavelength of the sensor, which has not always remained consistent within or between cruises, (b) the size and shape of the scattering particles and (c) the angle at which the scattering is being measured.

It is thought that the attenuation (from the transmissometer)  is potentially a better channel to calibrate using the SPM samples that are being taken. This needs further investigation.