

DY026 CTD processing report

March 2014

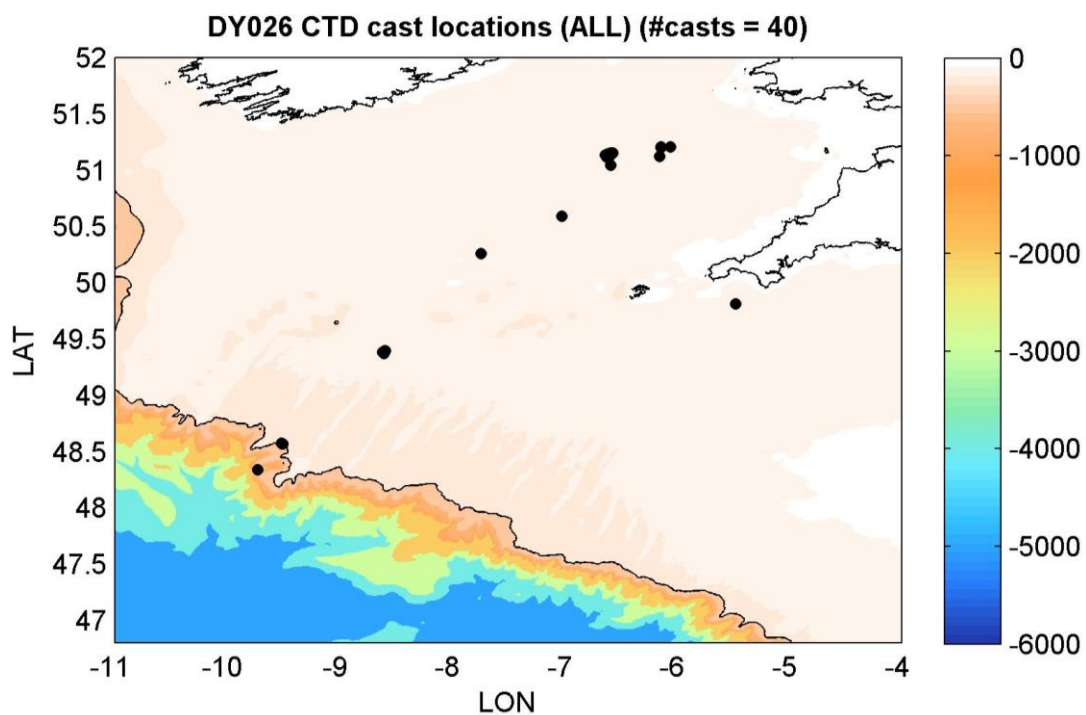
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This report documents the sequential processing carried out on CTD profiles from cruise DY026 on RRS Discovery, including bin averaging, despiking and calibrations. A total of 40 CTD casts (1-37, 40-42) with the stainless steel CTD were completed. See technical reports for sensor serial numbers and channels. The cruise was split into two halves, A and B. Casts 1-33 were conducted on leg A. Casts 34-42 on leg B.

Map of CTD cast locations



The oxygen sensor SBE43 was swapped between the two legs.

Leg A: SBE43 SN 430619 (casts 1-33)

Leg B: SBE43 SN 431624 (casts 34-42)

Raw data files:

The following raw data files were generated:

DY026_001.bl (a record of bottle firing locations)

DY026_001.hdr (header file)

DY026_001.hex (raw data file)

DY026_001.xmlcon (configuration file)

Where _001 is the CTD 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 through 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 m²]
- 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.

The output was saved to DY026_XXX.btl for each CTD cast, and a summary excel spreadsheet of the bottle data was created as the cruise progressed as an uncalibrated reference.

3. **Wild Edit:** Removal of pressure spikes
 - Standard deviations for pass 1: 2
 - Standard deviations for pass 2: 20

Scans per block: 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 2.5 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), no further adjustment was applied.

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 DY026_001.cnv (24 Hz resolution)

7. **Derive:** Variables selected are
Salinity and Salinity 2 (PSU, PSS-78)
Oxygen SBE43 [$\mu\text{mol/l}$]
Oxygen Tau correction: yes (2 second window)

Output saved to DY026_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 DY026_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. DY026
STNNBR (as per BODC data management guidance for the Shelf Sea Biogeochemistry programme)
DATE and TIME of the cast at the START 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: DY026_metadata.mat

- (2) Extract data from 2Hz averaged files (e.g. DY026_001_derive_2Hz.cnv), merge with metadata and save into a matlab structure for each cast. Each file (DY026_001_derive_2Hz.mat) contains the following un-calibrated channels.

CTD001 =

```

    CRUISE: 'DY026A'
      CAST: 1
    STNNBR: 1
      DATE: '04/08/2014'
      TIME: '11:21'
      LAT: 49.8133
      LON: -5.4777
    DEPTH: 90 [m]
    CTDtime: [5131x1 double] [seconds]
    CTDpres: [5131x1 double] [db]
    CTDtemp1: [5131x1 double] [°C]
    CTDtemp2: [5131x1 double] [°C]
    CTDcond1: [5131x1 double] [S/m]
    CTDcond2: [5131x1 double] [S/m]
    CTDoxy_raw: [5131x1 double] [V]
      CTDatt: [5131x1 double] [1/m]
    CTDfluor: [5131x1 double] [µg/l]
      CTDpar: [5131x1 double] [Wm2]
    CTDturb: [5131x1 double] [m-1 Sr-1]
      CTDalt: [5131x1 double] [m]
    CTDpar_dn_raw: [5131x1 double] [V]
    CTDpar_up_raw: [5131x1 double] [V]
      CTDalt_raw: [5131x1 double] [V]
    CTDturb_raw: [5131x1 double] [V]
      CTDatt_raw: [5131x1 double] [V]
    CTDfluor_raw: [5131x1 double] [V]
      CTDsal1: [5131x1 double] [PSU]
      CTDsal2: [5131x1 double] [PSU]
    CTDoxy_umoll: [5131x1 double] [µmol/l]
      CTDflag: [5131x1 double]

```

- (3) Extract data from 24Hz files (e.g. DY026_CTD001_derive.cnv), merge with metadata and save into a matlab structure for each cast. Each file (e.g. DY026_001_derive.mat) contains the following un-calibrated channels.

CTD001 =

```

    CRUISE: 'DY026A'
      CAST: 1
    STNNBR: 1
      DATE: '04/08/2014'
      TIME: '11:21'
      LAT: 49.8133
      LON: -5.4777
    DEPTH: 90 [m]
    CTDtime: [61569x1 double] [seconds]
    CTDpres: [61569x1 double] [db]
    CTDtemp1: [61569x1 double] [°C]

```

```

CTDtemp2: [61569x1 double] [°C]
CTDcond1: [61569x1 double] [S/m]
CTDcond2: [61569x1 double] [S/m]
CTDsal1_1: [61569x1 double] [PSU]
CTDsal2_1: [61569x1 double] [PSU]
CTDoxy_raw: [61569x1 double] [V]
CTD_oxy_umoll_1: [61569x1 double] [µmol/l]
CTDatt: [61569x1 double] [1/m]
CTDfluor: [61569x1 double] [µg/l]
CTDpar: [61569x1 double] [Wm2]
CTDturb: [61569x1 double] [m-1 Sr-1]
CTDalt: [61569x1 double] [m]
CTDpar_dn_raw: [61569x1 double] [V]
CTDpar_up_raw: [61569x1 double] [V]
CTDalt_raw: [61569x1 double] [V]
CTDturb_raw: [61569x1 double] [V]
CTDatt_raw: [61569x1 double] [V]
CTDfluor_raw: [61569x1 double] [V]
CTDsal1: [61569x1 double] [PSU]
CTDsal2: [61569x1 double] [PSU]
CTDoxy_umoll: [61569x1 double] [µmol/l]

CTDflag: [61569x1 double]

```

Note that ‘_1’ for the first instances of oxygen in this file are variables before re-derivation in the SeaBird Processing routines (e.g. AlignCTD for oxygen).

As observed in an earlier cruise (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. The converted ECO-BB output was being reported to a fixed precision. Direct conversion using the scale factor (SF) and dark counts (DC) supplied in the manufacturer’s calibration appeared to rectify this problem and retrieve the original resolution from the raw voltage. We therefore replace the original turbidity channel in the .MAT files with a corrected version using:

```

CTDturb = CTDturb_raw .* SF - (SF x DC);
Where the scale factor (SF) for this sensor = 0.002365
and the dark count (DC) = 0.061000

```

Two CTD casts had erroneous turbidity voltage outputs and thus turbidity was not calculated from the raw voltage either. These were CTD009 (event 56) and CTD034 (event 162).

- (4) Manual identification of the surface soak (the time taken while waiting for pumps to turn on) and the end of the downcast using the 2Hz files. Times to crop were saved to DY026_stainless_castcrop_times.mat.

This was then used to crop both the 2Hz and 24Hz files and output (i.e. just the downcast recordings) saved to DY026_CTD001_derive_2Hz_cropped.mat and DY026_CTD001_derive_cropped.mat respectively.

```

CAST: [40x6 char]
STNNBR: [40x1 double]
CTDstart: [40x1 double] [seconds]
CTDstop: [40x1 double] [seconds]

```

- (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.

<i>Channel</i>	<i>Pass 1 window</i>	<i>Pass 1 nstd</i>	<i>Pass 2 window</i>	<i>Pass 2 nstd</i>
Temperature, conductivity, fluorescence	100	3	200	3
Salinity, turbidity	200	2	200	3
Oxygen	100	2	200	3

Auto-despiking saved to DY026_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 regularly 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 DY018, 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. A few CTDs experienced this issue worse than others, particularly casts CTD022 to CTD029.

The largest and most significant warm anomalies identified in the primary CT sensors were removed from all variables after being visually checked and manually selected (incl. turbidity, oxygen, chlorophyll and attenuation since these sensors would also be sampling ‘old’ water during these periods). This was at times up to 5 m of the profile. Anomalies identified in the secondary sensors were only removed from the secondary temperature, salinity and conductivity channels. 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.

Individual, isolated spikes within each channel were only removed (NaN’d) from that particular variable.

Output saved to DY026_CTD001_derived_cropped_autospike_manualspike.mat

Additional channels added into this file:

```
Pindex: [5832x3 double]
Sindex: [5832x3 double]
Aindex: [5832x4 double]
```

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.

- (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: DY026_001_1db_dn.mat

- (7) Smoothing of the 1db casts using zsmth.m, this helps clean up a lot of the noise that may have been missed in the auto and manual de-spiking process. A smoothing filter of 10m (5m for oxygen and chlorophyll) was used to clean up noise but preserve natural variability in profiles.

Files for each cast were created: DY029_001_1db_dn_smoth.mat

- (8) Application of calibrations to salinity, chlorophyll and oxygen in 1db downcasts. Calibrated files saved to DY026_001_1db_dn_calib.mat. Calibration samples of suspended particulate matter were taken to calibrate the turbidity sensor on the CTD, however this regression was particularly bad and therefore has NOT been applied (see notes below).

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: 'DY026'
CAST: 1
STNNBR: 1
DATE: '04/08/2014'
TIME: '11:21'
LAT: 49.8133
LON: -5.4777
DEPTH: 90
pres: [84x1 double] [db]
time: [84x1 double] [seconds]
temp1: [84x1 double] [°C]
temp2: [84x1 double] [°C]
sal1: [84x1 double] [PSU] - calibrated
sal2: [84x1 double] [PSU] - calibrated
cond1: [84x1 double] [S/m] - not calibrated
cond2: [84x1 double] [S/m] - not calibrated
oxy_umoll: [84x1 double] [µmol/l] - calibrated
fluor: [84x1 double] [µg/l] - calibrated
par: [84x1 double] [Wm2]
turb: [84x1 double] [m-1 s-1] - not calibrated
```

```
att: [84x1 double] [1/m]
sigma_theta: [84x1 double]
```

The calibrations were also applied to the 24 Hz data (cropped and de-spiked) and output to .mat files DY026_001_derive_cropped_autospike_manualspike_calib.mat containing the same variables as above.

- (9) Application of salinity, oxygen and turbidity calibrations to bottle firing data. A new file, DY026_stainless_btl_calib.mat, with variables CTDsal1_cal, CTDsal2_cal, CTDfluor_calib, and CTDoxy_umoll_cal was created.

Notes:

Calibrations

Salinity

Due to an issue with the sampling of salinity with the Guildline Autosol salinometer, many samples could not be used for calibration purposes. However, 8 autosol were deemed good for calibration use by NMF, and these values were plotted against the measurement and a good relationship between the primary and secondary samples was found (Fig. 2 and 3). Applying these calibration coefficients to the CTD salinity measurements evidently improved sensor precision, with a small difference between both sensor measurements after calibration (Fig. 4).

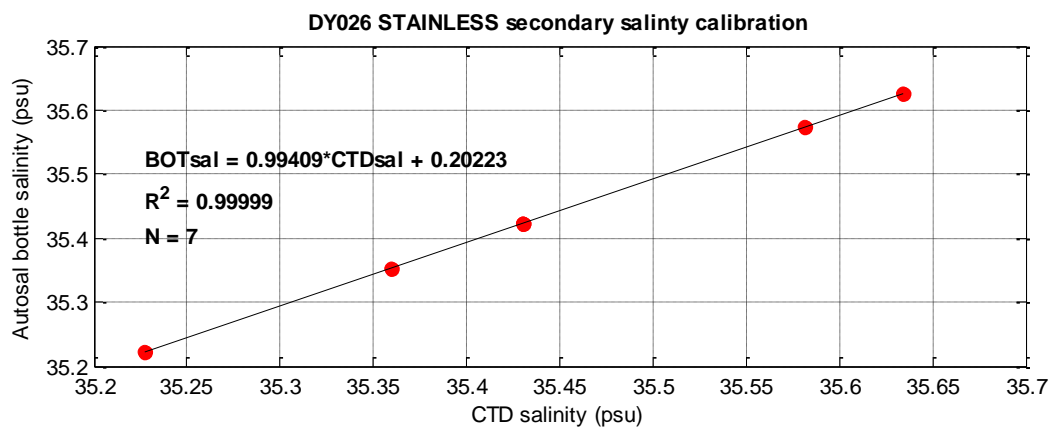
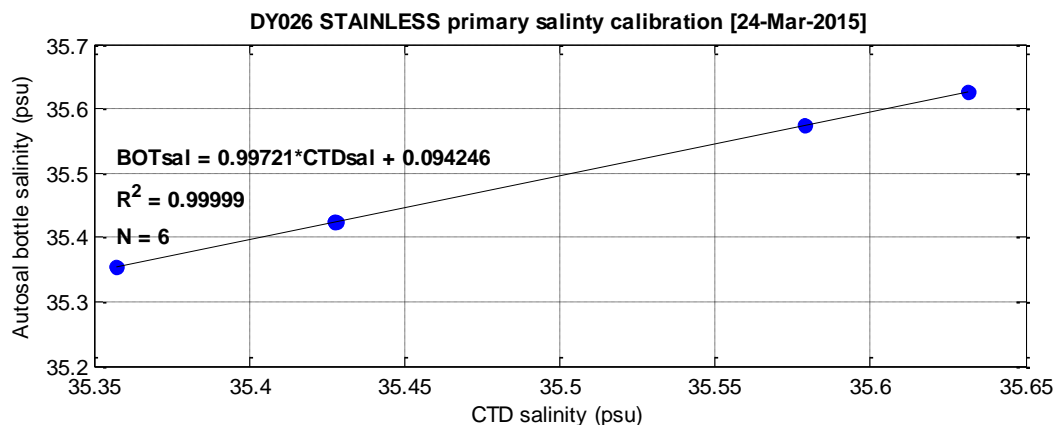


Figure 2: CTD salinity measurements from sensors 1 and 2 versus discrete salinometer sample.

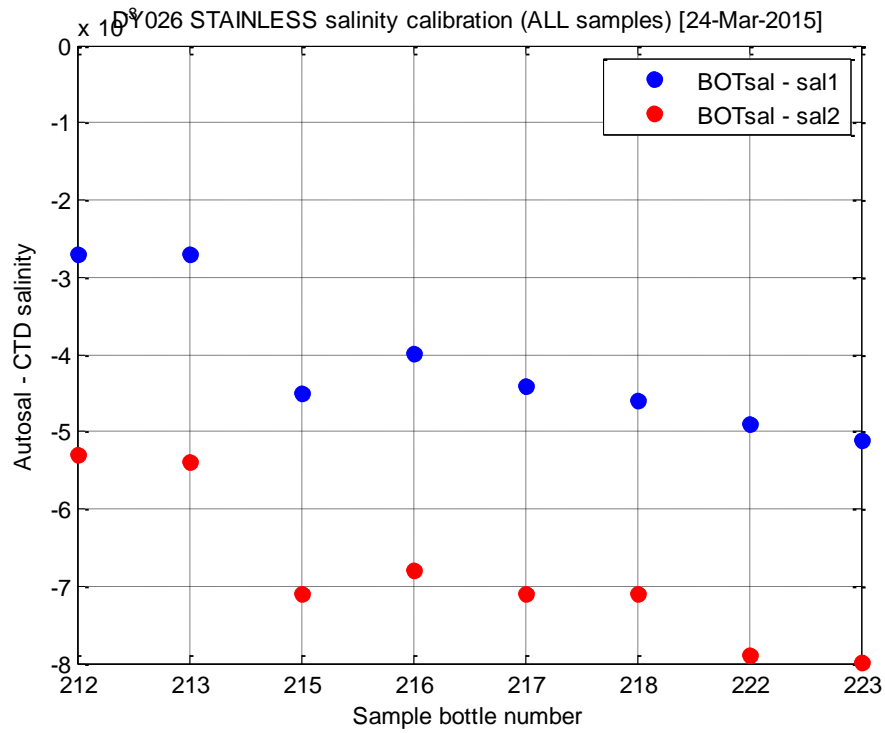


Figure 3: Difference between discrete salinometer samples and CTD salinity measurement for both CTD conductivity sensors pre calibration.

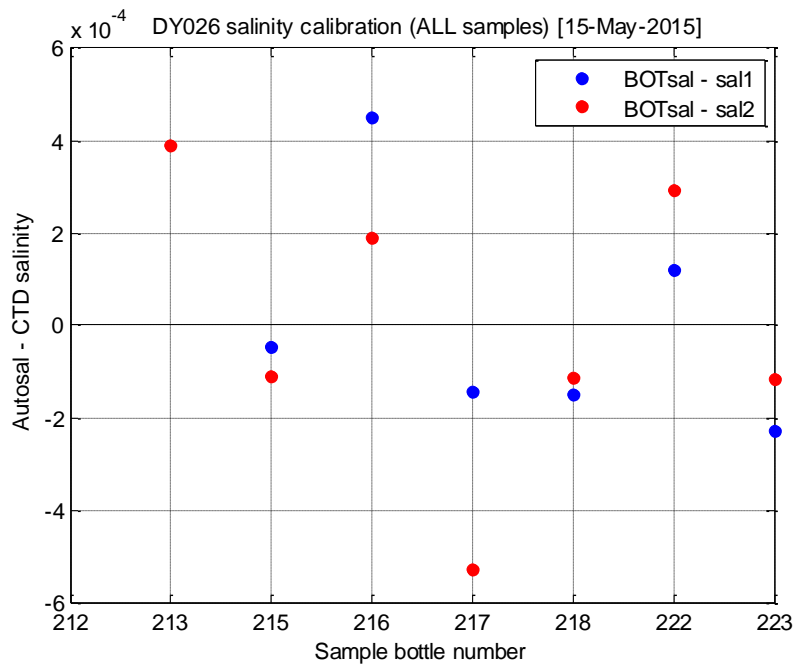
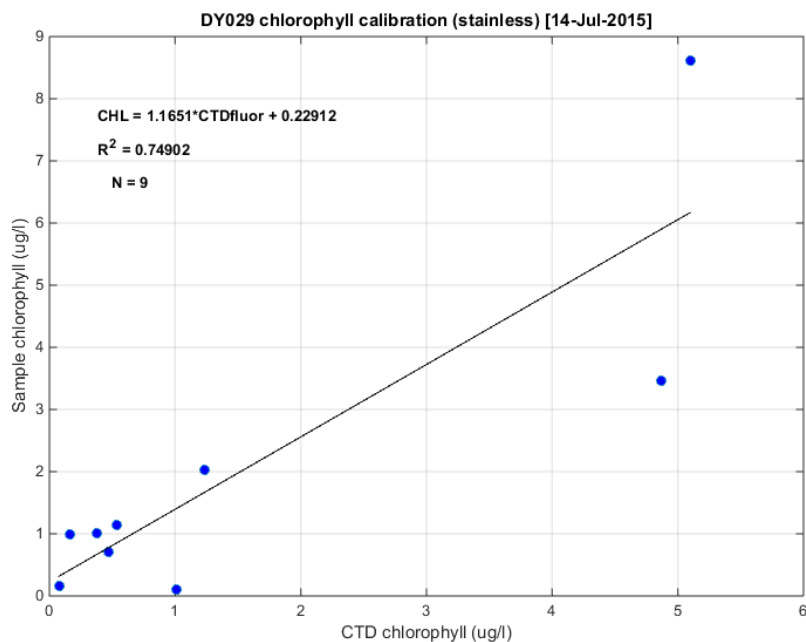


Figure 3: Difference between discrete salinometer samples and CTD salinity measurement for both CTD conductivity sensors post calibration.

Chlorophyll

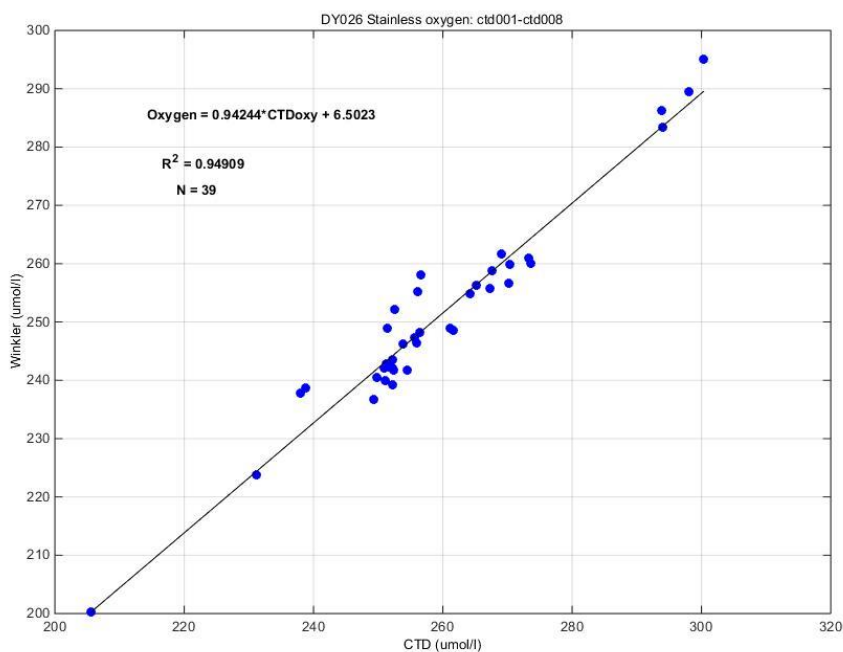
19 samples for bulk chlorophyll were provided, however the measurements that were taken at shallower than 30 an during hours of high sunligth were omitted due to quenching affecting fluorescence values. This left 9 values to be used for calibration (see below). This was calibration was applied to the fluorescence data.



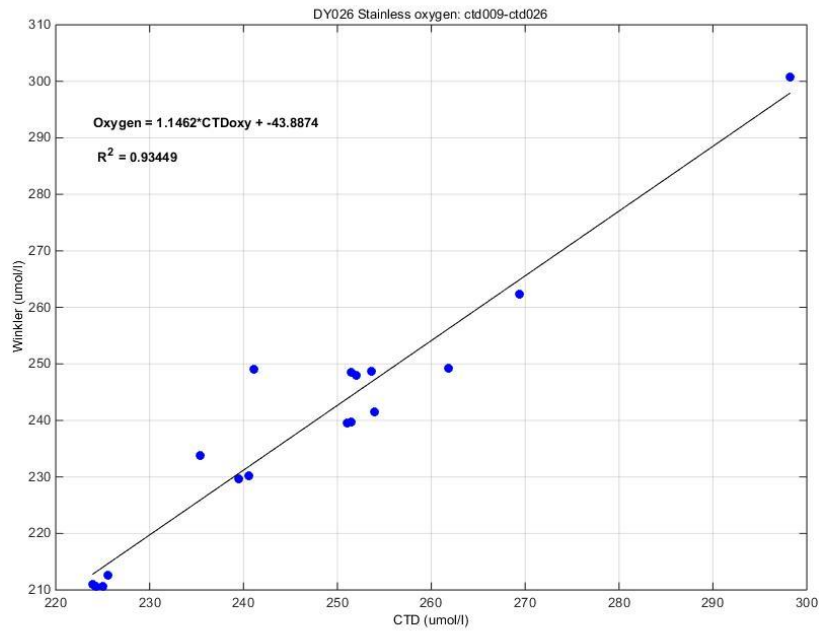
Oxygen

The oxygen optode on the CTD package experienced problems and was very noisy on the cruise. It was cleaned by NMF after CTD008, which made the optode look noisier. After CTD026 the optode measurements started to look better. On leg B of the cruise the optode was changed (CTD034 onwards). Therefore 4 different regressions were used for calibrating oxygen (Figure 5-a-d):

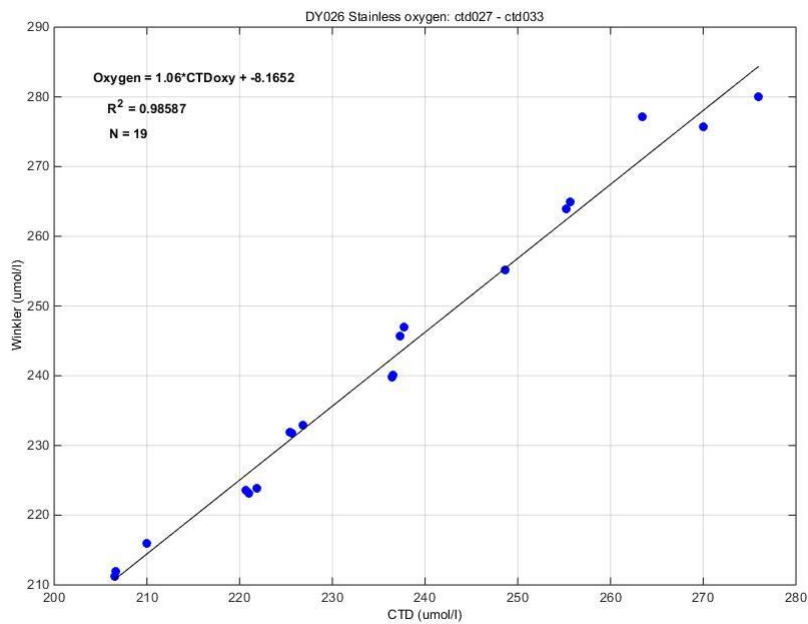
CTD001 – CTD008 (leg A):



CTD009 – CTD026 (leg A):



CTD027 – CTD033 (leg A):



CTD034 – CTD042 (leg B)

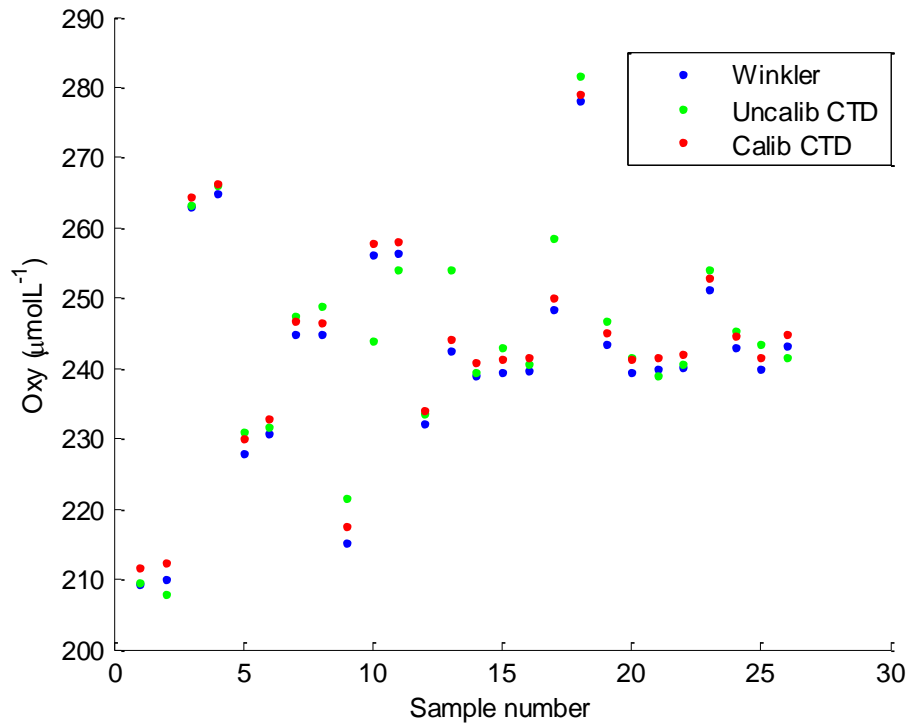
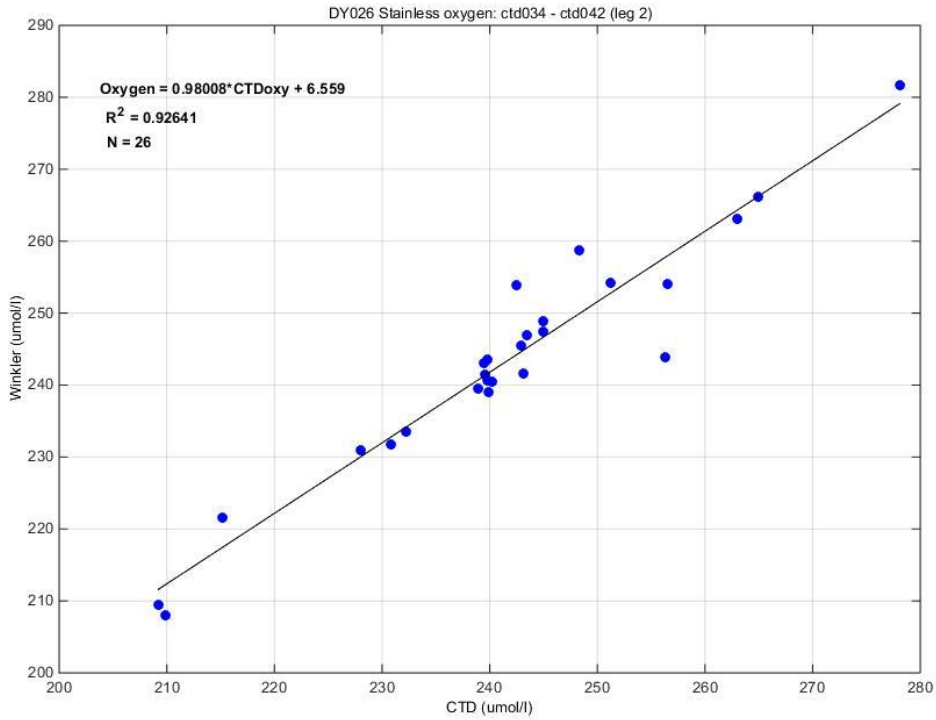


Figure 6: Difference between all Winkler measurements (blue) and CTD oxygen measurement pre (green) and post (red) calibration.

Turbidity

For CTD turbidity sensor calibration there were 25 calibration samples filtered for suspended particulate matter (SPM). The corresponding turbidity measurements (calculated from the raw voltage

as described earlier in the report) are plotted against SPM samples in Figure 7. The calibration curve has a bad fit with poor regression ($R^2=0.136$). **No calibration was applied to the turbidity sensor therefore, and all turbidity data supplied is raw.**

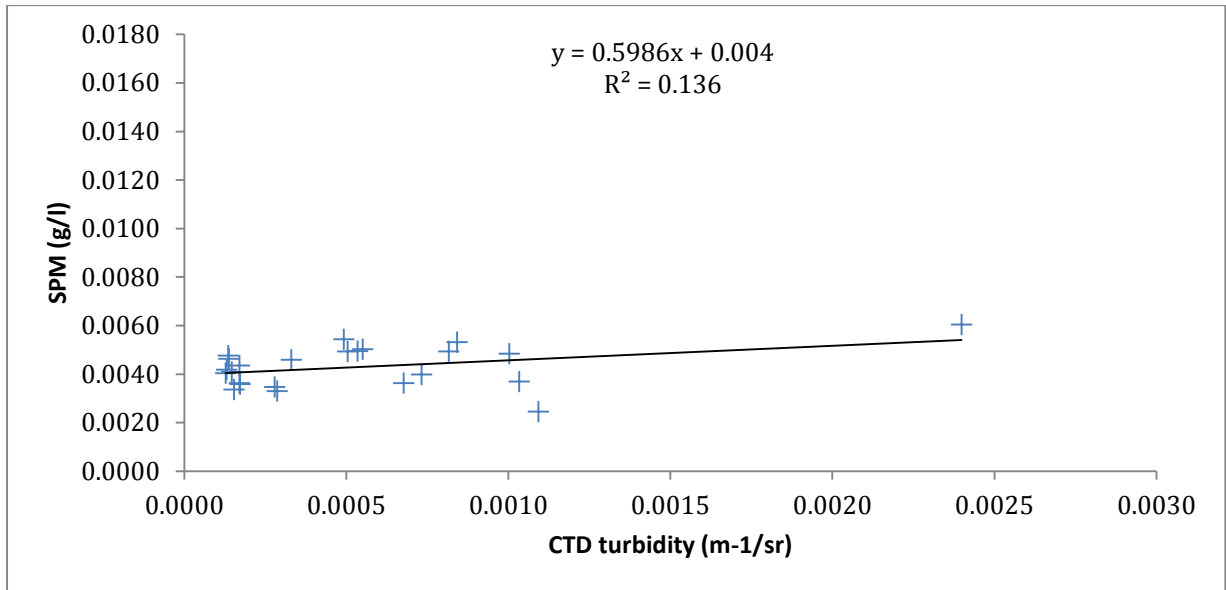


Figure 7: Discrete measurements of suspended particulate matter versus turbidity calculated from the raw turbidity voltage as described earlier in the report.