QC of long term TS-chain mooring at CCS

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A long-term temperature and salinity (TS) chain had been deployed in the central Celtic Sea as part of the Shelf Sea Biogeochemistry program. Five continuous deployments (T1-T5) recorded data for 17 consecutive months, which span from March 2014 to July 2015. The aims of these observations were to capture a full seasonal cycle of vertical density structure. The mooring was deployed in a mean water depth of 145.4 m at a nominal location of 49.32° N and -8.49°E (Figure 1).

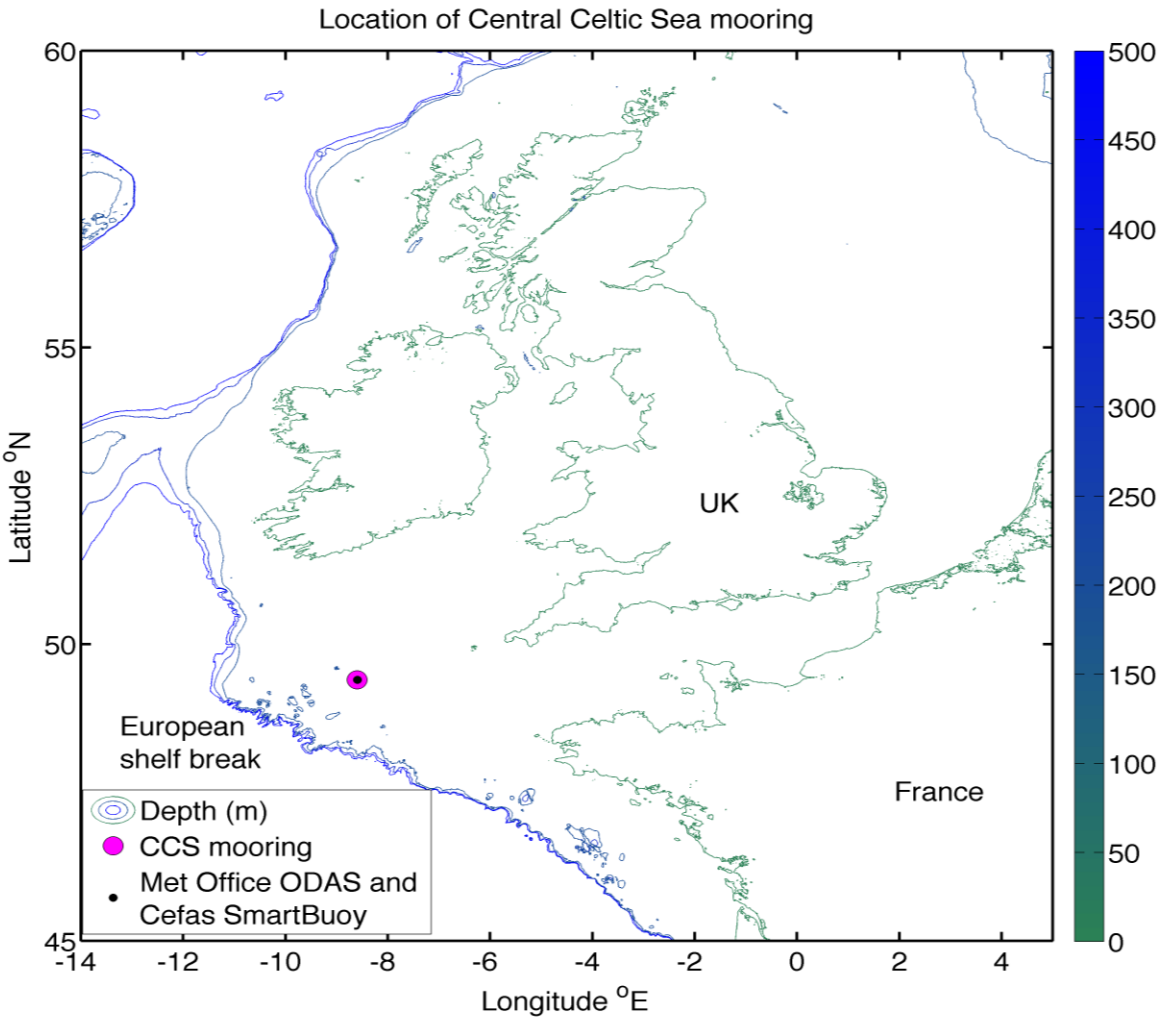

Figure 1 Map of the mooring location (magenta dot) in relation to the British Isles and the continental shelf break.

The TS chain had a vertical resolution of 2.5 m in the main pycnocline region and 5-20 m vertical resolution in the surface and bottom layers. All instruments had a 5-minute temporal resolution.

The following list provides details of the mooring setup:

- SBE16+ SeaCAT CTD at 10, 45, 129, 145 m
- SBE37 MicroCAT CTD at 30, 49, 69, 99 m
- 16 temperature loggers (mixture of Star Oddi DST Centi Temperature loggers, Star Oddi Starmon mini - underwater temperature recorder and RBRsolo T Temperature Logger)

The lowest SBE16+ instrument (at 145 m) was not physically attached to the TS mooring, yet the data are included here as it was attached to an alongside bedframe. This bedframe was deployed at the same nominal location as the TS chain and the separation distance of both platforms was always < 1 km.

The exact set-up of instruments changed during every deployment, please see mooring tables for details.

QC Processing

Pressure and conductivity were only recorded by the SBE instruments (SBE16+, SBE37). For these instruments depth, salinity and potential density (for calibration purposes only) were derived using the Gibbs-SeaWater (GSW) Oceanographic Toolbox (McDougall & Barker, 2011).

Calibration

Every effort has been made to eliminate large sections of the water column being vertically unstable by calibrating all instruments to post-deployment and pre-recovery CTD casts. The table below shows which CTD casts were used to calibrate all instruments for each TS mooring:

Table 1 Calibration CTD casts used for each deployment

Deployment	Pre-deployment cast	Post deployment cast
T1	DY008_010	JC105_010
T2	JC105_011	DY026_040
T3	DY026_042	DY018_056
T4	DY018_058	DY029_007
T5	DY029_050	DY033_060T

The accuracies of the different instrument types differed between 0.1 and 0.002 °C ((Star Oddi, 2015) (Star Oddi, 2015), (Sea-Bird Electronics, 2015) (Sea-Bird Electronics, 2015) (RBR, 2015)), and were taken into consideration when applying corrections.

It was not possible to remove all small scale instances of vertical instability and it has been left to the end user to make any further corrections (or removal of data) that are appropriate for the type of analysis they wish to perform.

During periods of little or no stratification (March 2014, Nov 2014-April 2015) the CT - and SM - instruments' resolution appeared insufficient at times to resolve small scale temperature changes, please use with caution.

In tables 3-7 an overview of all available data is given and any comments regarding loss of data or suspect data quality.

Time drift

While time drift data were available for some instruments these were not applied as they are O(sec), which were considered negligible compared to the sampling resolution of 5 min and the deployment periods of O(months). If the end users wish to apply the drift themselves, all available time drift data (s) can be found in the mooring diagrams below. Here, a positive drift corresponds to the sensor being in advance of the ship's clock.

Data delivery

Individual instrument files

The data are delivered as individual files corresponding to each recording instrument, where the first two letters refer to the instrument type (SB, MC, etc.) and the following numbers to the serial number. All instrument files have been saved as a structured array (.mat). The table below shows which data channels have been quality controlled and are part of the instrument array:

Table 2 Data channels for each instrument

Instrument type	File identifier	Data channels
SBE16+	SB	Temperature (°C) Salinity/and or Conductivity Pressure (dbar) Depth (m)
SBE 37	MC	Temperature (°C) Salinity/and or Conductivity Pressure (dbar) Depth (m)
Star Oddi Starmon	SM	Temperature (°C) Depth (m)
Star Oddi DST	CT	Temperature (°C) Depth (m)
RBRsolo T Temperature Logger	RB	Temperature (°C) Depth (m)

For convenience a depth channel has been added to the SM, CT and RB instruments.

These depths were estimated based on a) the pressure/depth record from the nearest or most appropriate SBE instrument, and b) the log sheets and the separations to the nearest pressure measuring instruments. Please also note that .dd is the date stamp in GMT and .daynum is the Julian Date with reference to 2014. Hence, 1.5 corresponds to 12 pm on 1st Jan of 2014 and please note that 366.5 corresponds to 12 pm on 1st Jan of 2015.

Instrument Setup

T1

Start: 26.03.2014 19:30:00 GMT
Stop: 19.06.2014 09:10:00 GMT

Table 3 Available instrument data from T1

Planned deployment depth	Instrument	Serial #	Time drift (s)	Comments
10	SBE 16+	4597	41	
15	Star Oddi DST	5753	-2	
20	Star Oddi Starmon	3578	-12	
25	Star Oddi DST	5768	-5	
30	SBE 37	4998	17	
35	Star Oddi Starmon	3584	-10	
37	Star Oddi DST	3278	-7	
40	Star Oddi Starmon	3580	-20	
42	Star Oddi DST	3654	-17	
45	SBE 16+	5309	18	
47	Star Oddi DST	3653	-7	
49	SBE 37	7459	13	
54	Star Oddi Starmon	3890	-5	
59	Star Oddi Starmon	3581	-8	
64	Star Oddi Starmon	3891	-4	
69	SBE 37	2010	-28	
79	Star Oddi Starmon	3582	-8	
89	Star Oddi Starmon	3583	-2	
99	SBE 37	4550	17	Instrument stopped recording on 05.06.2014 at 05:20:01
109	Star Oddi DST	5284	-6	
120	Star Oddi DST	5264	-6	
129	SBE 16+	4738	42	
145	SBE 16+	4596	0	

T2

Start: 19.06.2014 17:20:00 GMT
Stop: 21.08.2014 13:50:00 GMT

Table 4 Available instrument data from T2

Planned deployment depth	Instrument	Serial #	Time drift (s)	Comments
10	SBE 16+	4848	8	
15	Star Oddi DST	5286		
20	Star Oddi Starmon	3893		
25	Star Oddi DST	5763		
30	SBE 37	2506	16	
35	Star Oddi Starmon	3894		
37	Star Oddi DST	3614		
40	Star Oddi Starmon	3896		
42	Star Oddi DST	3271		
45	SBE 16+	5310	14	
47	Star Oddi DST	3270		
49	SBE 37	7460	0	
54	Star Oddi Starmon	3897		
59	Star Oddi Starmon	3899		
64	Star Oddi Starmon	3901		
69	SBE 37	2081	10	
74	Star Oddi DST	3655		
79	Star Oddi Starmon	3903		
89	Star Oddi Starmon	3905		
99	SBE 37	7458	6	
109	Star Oddi DST	3269		
120	Star Oddi DST	5263		
129	SBE 16+	4737	6	
145	SBE 16+	4736	4	The bedframe was deployed 3 days after the TS chain.

T3

Start: 22.08.2014 13:20:00 GMT

Stop: 20.11.2014 14:40:00 GMT

Table 5 Available instrument data from T3

Planned deployment depth	Instrument	Serial #	Time drift (s)	Comments
10	SBE 16+	4597	27	
15	Star Oddi DST	5753		
20	Star Oddi Starmon	3578		
25	Star Oddi DST	5768		
30	SBE 37	4998	23	
35	Star Oddi Starmon	3584		
37	Star Oddi DST	3278		
40	Star Oddi Starmon	3580		
42	Star Oddi DST	3654		
45	SBE 16+	5309	25	
47	Star Oddi DST	3653		
49	SBE 37	7459	6	
54	Star Oddi Starmon	3890		
59	Star Oddi Starmon	3581		
64	Star Oddi Starmon	3891		
69	SBE 37	2010	42	
74	Star Oddi DST	3661		
79	Star Oddi Starmon	3582		
89	Star Oddi Starmon	3583		
99	SBE 37	4550	35	
109	Star Oddi DST	5284		
120	Star Oddi DST	5264		
129	SBE 16+	4738	26	
145	SBE 16+	4596	19	Pressure data were suspect after 13.11.2014 19:15:03 and have been reconstructed using harmonic analysis using M2, S2, N2 and K1 constituents, which were obtained form the remaining pressure record. Use caution when using temperature and salinity data after this date.

T4

Start: 21.11.2014 11:05:00 GMT
Stop: 04.04.2015 10:25:00 GMT

Table 6 Available instrument data from T4

Planned deployment depth	Instrument	Serial #	Time drift (s)	Comments
10	SBE 16+	4848	3	
15	RBR Solo	76789	-9	
20	Star Oddi Starmon	3893		
25	RBR Solo	76790	-10	
30	SBE 37	2506		Only data that was recorded from 26.11.2014 10:10:01 onward is available as some of the initial data had been overwritten.
35	Star Oddi Starmon	3894		
37	RBR Solo	76791	-7	
40	Star Oddi Starmon	3896		
42	RBR Solo	76792	-12	
45	SBE 16+	5310	4	
47	Star Oddi DST	3613		
49	SBE 37	7460		
54	Star Oddi Starmon	3897		
59	Star Oddi Starmon	3899		
64	Star Oddi Starmon	3901		
69	SBE 37	2081		Only data that was recorded from 27.11.2014 13:45:01 onward is available as some of the initial data had been overwritten.
74	RBR Solo	76794	-15	
79	Star Oddi Starmon	3903		
89	Star Oddi Starmon	3905		
99	SBE 37	7458		
109	RBR Solo	76795	-9	
120	RBR Solo	76796	-6	
129	SBE 16+	4737	4	
145	SBE 16+	4736	43	Due to recovery problems the bedframe stayed deployed during T4 and T5.

During this deployment the pressure signals had some high frequency oscillations superimposed on the tidal signal, which have been observed throughout the whole water column. These were retraced to originate from very high waves of H1/3 ≤ 15 m during winter storms, which an alongside MetOffice ODAS buoy observed (Figure 2). It has been left to the end user to decide whether any smoothing or despiking is necessary for the type of analysis they wish to perform.

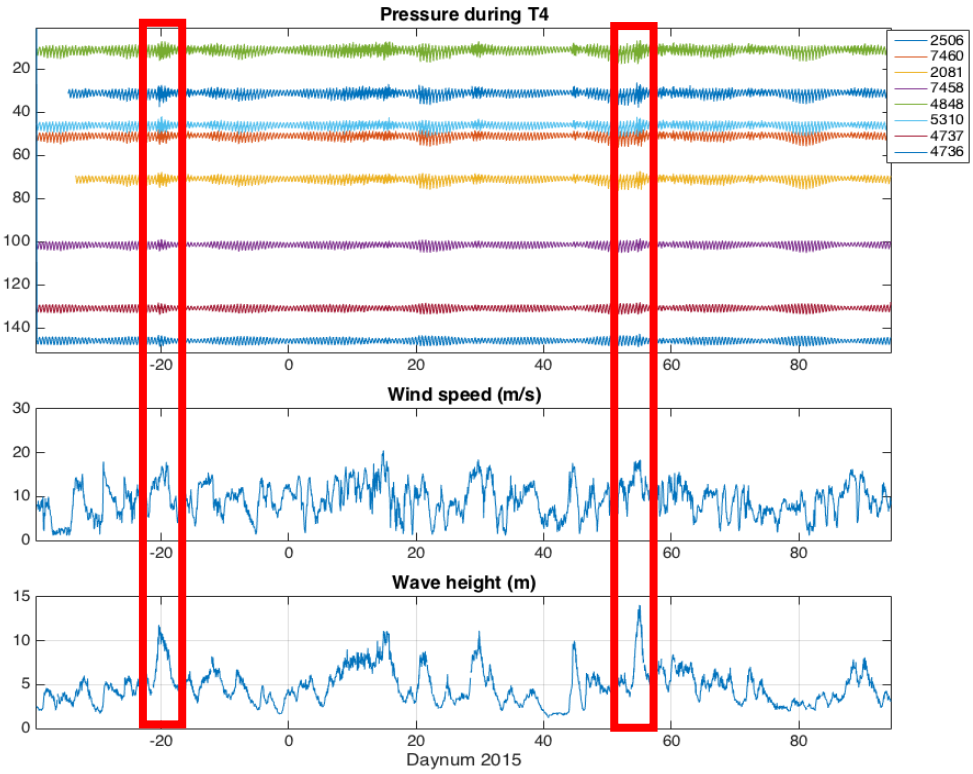

Figure 2 Observed pressure during T4, colours denote different instruments. Wind speed and significant wave height from an alongside MetOffice ODAS buoy. The red boxes are examples of when high waves are believed to cause the anomalous pressure signal.

T5

Start: 11.04.2015 10:25:00 GMT
Stop: 25.07.2015 08:40:00 GMT

Table 7 Available instrument data from T5

Planned deployment depth	Instrument	Serial #	Time drift (s)	Comments
10	SBE 16+	4597		
15	RBR Solo	76797		
20	Star Oddi Starmon	3578		
25	RBR Solo	76806		
30	SBE 37	4998	12	
35	Star Oddi Starmon	3584		
37	RBR Solo	76807		
40	Star Oddi Starmon	3580		
42	RBR Solo	76798		
45	SBE 16+	5309		
47	Star Oddi Starmon	2836		
49	SBE 37	7459	6	
54	Star Oddi Starmon	3890		
59	Star Oddi Starmon	3581		
64	Star Oddi Starmon	3891		
69	SBE 37	2010	37	
74	RBR Solo	76799		
79	Star Oddi Starmon	3582		
89	Star Oddi Starmon	3583		
99	SBE 37	5434	27	
109	RBR Solo	76800		
120	RBR Solo	76801		
129	SBE 16+	4738	26	Pressure data were suspect after 9th June 2015, 11:40 and have been reconstructed using harmonic analysis using M2, S2, N2 and K1 constituents, which were obtained form the remaining pressure record. Temperature, conductivity and salinity data have been blanked (NaN) after this date.
145	SBE 16+	4596	43	

Gridded data product

In addition to the individual files, gridded data products of **Θ (conservative temperature, °C), absolute salinity (g kg^{-1}) and σ_0 (potential density anomaly with reference sea pressure of 0 dbar, kg m^{-3})** have been created for each deployment.

These gridded data sets have been interpolated on a regular depth (0 to 147.5 m with a 2.5 m vertical resolution) and time grid (5 min temporal resolution). In order to compute salinity values for all depths and time steps a salinity surface was fitted as a function of all simultaneous observations of temperature and time. Scattered interpolation was then used to evaluate salinity for all available temperature measurements. For methods see (Hopkins , et al., 2014). Conservative temperature, absolute salinity and σ_0 were then derived using the Gibbs-SeaWater (GSW) Oceanographic Toolbox (McDougall & Barker, 2011). If pressure data recorded by the SB/MC instruments were faulty, it has been reconstructed using a harmonic analysis using the M2, S2, N2 and K1 constituents from the remaining pressure record.

The final structured array contains the following fields:

.dd	Date
.daynum	Julian Date with reference to 2014 (**where 1.5 corresponds to 12 pm on 1st Jan of 2014, note that 366.5 corresponds to 12 pm on 1st Jan of 2015**)
.lat	Latitude (°N)
.lon	Longitude (°E)
.mab	Metres above bed
.temp	Θ (conservative temperature, °C)
.depth	Depth (m)
.pres	Pressure (dbar)
.sal	absolute salinity (g kg^{-1})
.sig0	σ_0, potential density anomaly with reference sea pressure of 0 dbar, kg m^{-3}

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