L O C E A N

LABORATOIRE D'OCEANOGRAPHIE ET DU CLIMAT :
EXPERIMENTATIONS ET APPROCHES NUMERIQUES

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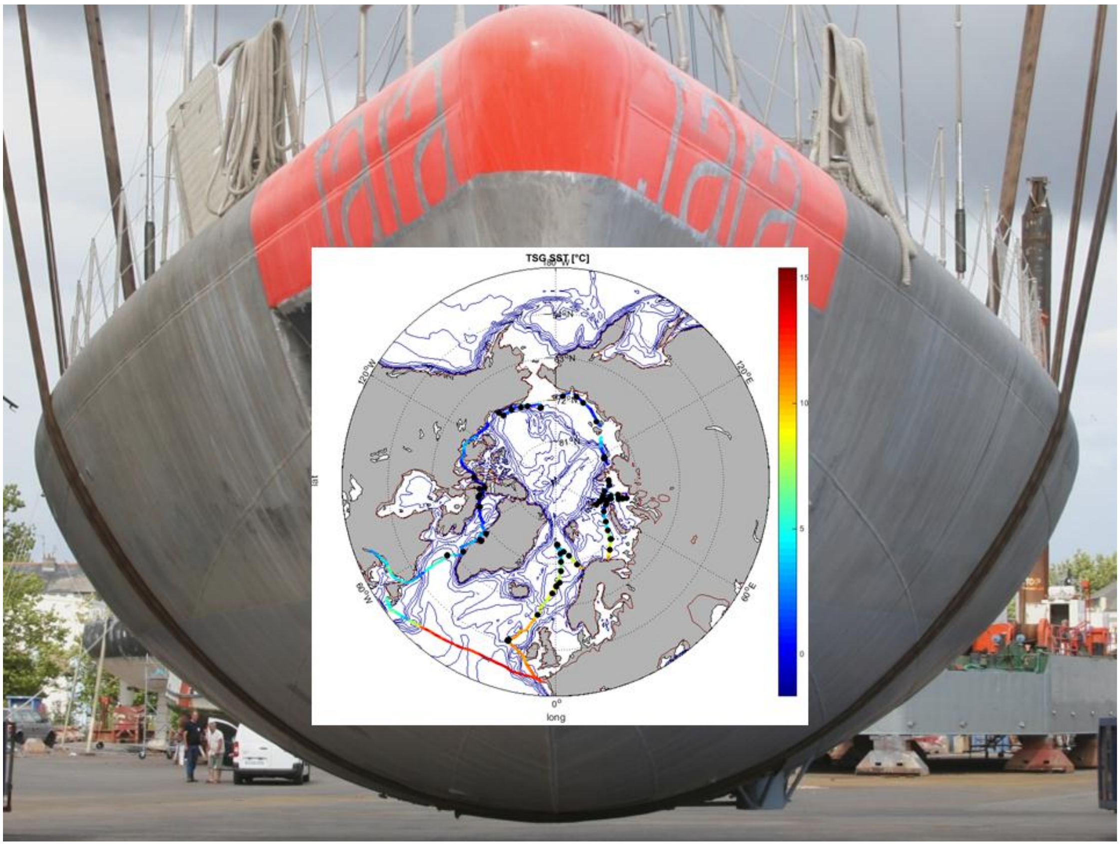
TSG data collected during Tara Polarcircle expedition (2013)
QC validation process and SSS/SST data analysis



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Summary report and conclusions on the whole expedition

I- Summary

The Tara Polarcircle started in Lorient on 19/05/13 and ended in the same French harbour on 06/12/13 achieving a circumnavigation of the Arctic basin with stop-overs in Norway, Russia, Canada and Greenland.
A thermosalinograph (TSG , Seabird SB45) and a temperature sensor (SBE38) have been recording sea surface temperature (SST) and salinity(SSS) during the whole cruise .

54 hydrological stations have been achieved along the cruise, providing 163 CTD profiles to a maximum depth of 1000m. The CTD rosette was a Seabird 9plus system with double C and T sensors, which have been factory calibrated before and after the expedition .CTD profiles have been processed and QC validated by Vincent Taillandier (Laboratoire dôOcéanographie de Villefranche) . Details about this validation process appear in *reference [1]*.

Raw TSG data (recorded at 0.1 Hz) have been processed using pre and post campaign calibrations.
Those calibrated data have been then filtered and median averaged every 1mn.
They have been compared to SSS and SST averaged from surface bins of each CTD profile (when available) . For those CTD profiles who were validated as significant for inter-comparison, TSG data have been corrected from the (CTD-TSG) differences.
Through this full process, Quality Controlled (QC) data for SSS and SST have been produced and are presented in this report .

A technical appendix details the data processing methodology, including Seabird Calibration reports and hardware configuration for SBE45 and SBE38.

II- Comments and conclusions on global results

Figures 1 &2 show SSS and SST data for the whole cruise with positions for the 54 stations.
Comments :

- there was no CTD station during the last North Atlantic leg ,only salinity samples were taken on the TSG line, whose quality is discussed in appendix ***ñleg 7ò***
- Significant gaps are visible on TSG data: Tromsoe to Murmansk ,Kara Sea to Laptev Sea passing Tcheliuskin Cape, New Siberia Islands, Wrangel Island area. Reasons for those gaps may be :
  - Instrument purposely stopped due to ice conditions, too much sediments in coastal waters or geopolitical issues
  - Instrumental problems or bad data suppressed in post processing
  - Operational conditions need to be checked in the log books (I was not on board during Polar Circle).
- Very low SSS data (10-15 PSU) are generated by fresh water fluxes coming from the large Siberian rivers .

Figure 3 shows (CTD-TSG) differences on SST and SSS obtained from 3 and 4 dbars CTD data , when available : among 159 CTD profiles available for inter-comparison, 17 were discarded (= 11%, red dots on graph) due to large differences, physically non relevant.
For the valid profiles ONLY, (CTD-TSG) differences distributions appear on the histograms of *figure 4.*
Statistics are summarized in the following table :

after CTD to TSG corrections		**CTD profiles**	**(CTD-TSG) SST difference [°C]**		**(CTD-TSG) SSS difference [PSU]**	
Leg	**date**	**valid / all**	**median**	**std deviation**	**median**	**std deviation**
all legs	19/05 06/12	142 / 159	-0,041	0,158	0,001	0,053

These are statistics on the final TSG-QC data , including those (slightly) corrected from CTD inter-calibration on leg1 and leg6.
Median SSS difference of 0.001 PSU is less than the SBE45 sensors initial accuracy (0.005 PSU) .
Median SST difference of -0.041 C is 20 times higher than SBE38 initial accuracy (0.002 C), hence significant of a bias : Even if the SBE38 temperature sensor was positioned upstream from the pump as close as possible from the seawater intake (å 3m on Tara), the SST signal was randomly biased by the shipôs bilge temperature.The negative median value shows that the bilge was generally warmer than the polar seawater.
Table 5 shows the same statistics computed for each leg before TSG data have been corrected from CTD inter-comparison (see details in *appendix **ñ**leg by leg analysis**ò***).

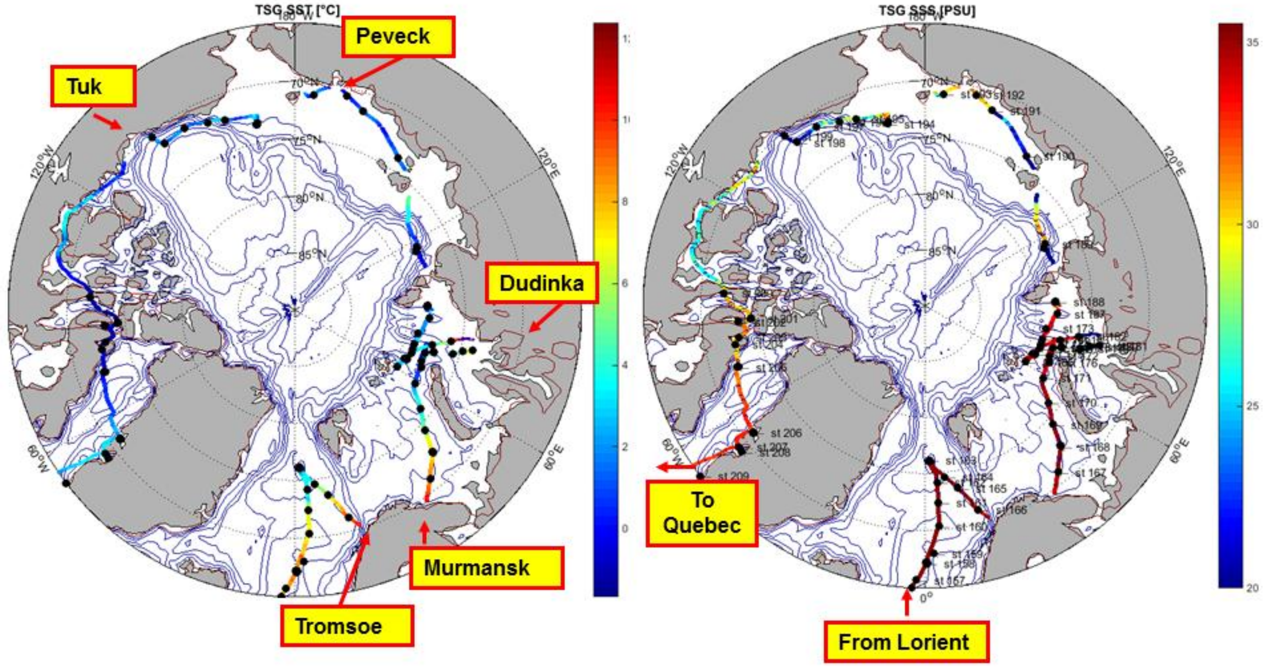


Figure 1: SSS and SST charts, limited to Arctic Basin. SSS colorbar is limited to 20 PSU for visibility purpose. See time series for full range values .

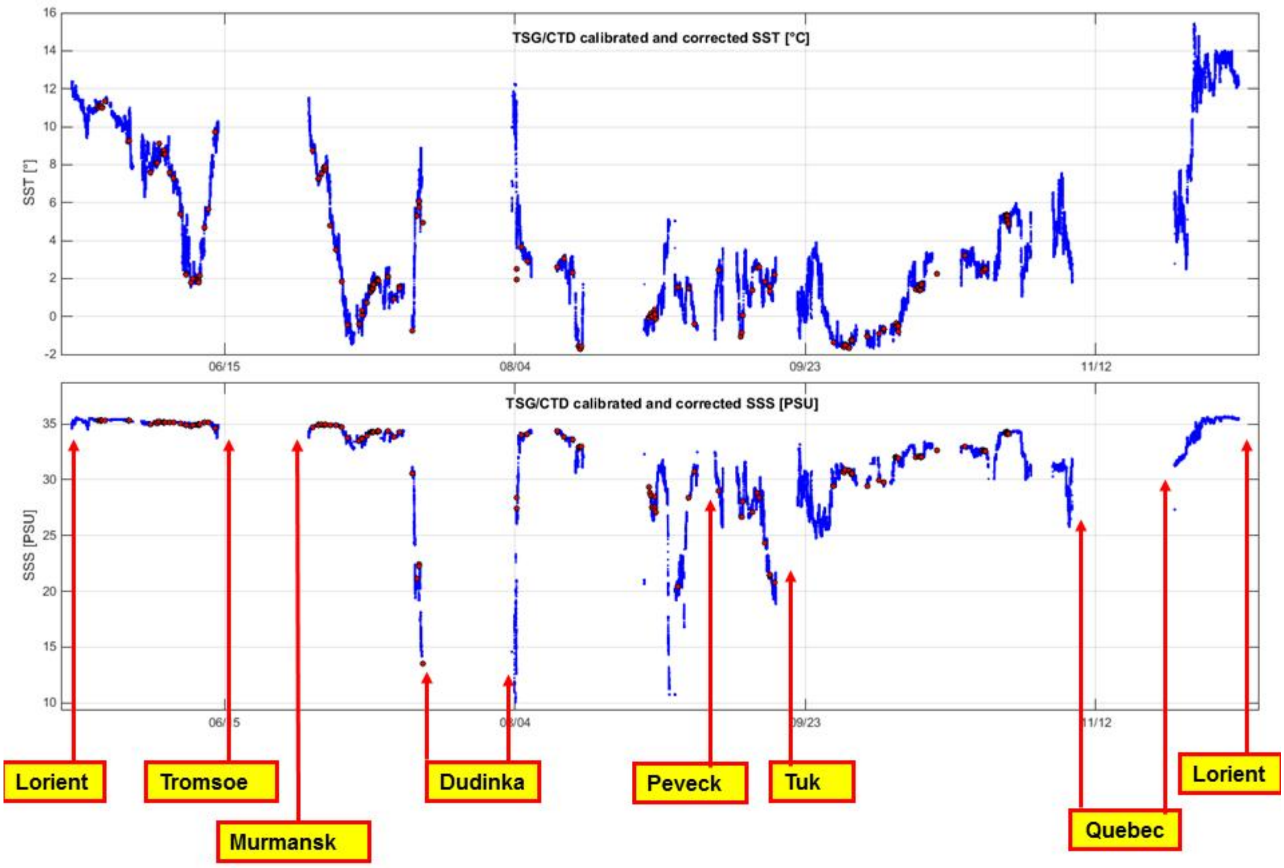


Figure 2: SSS and SST time series for the whole PolarCircle cruise.

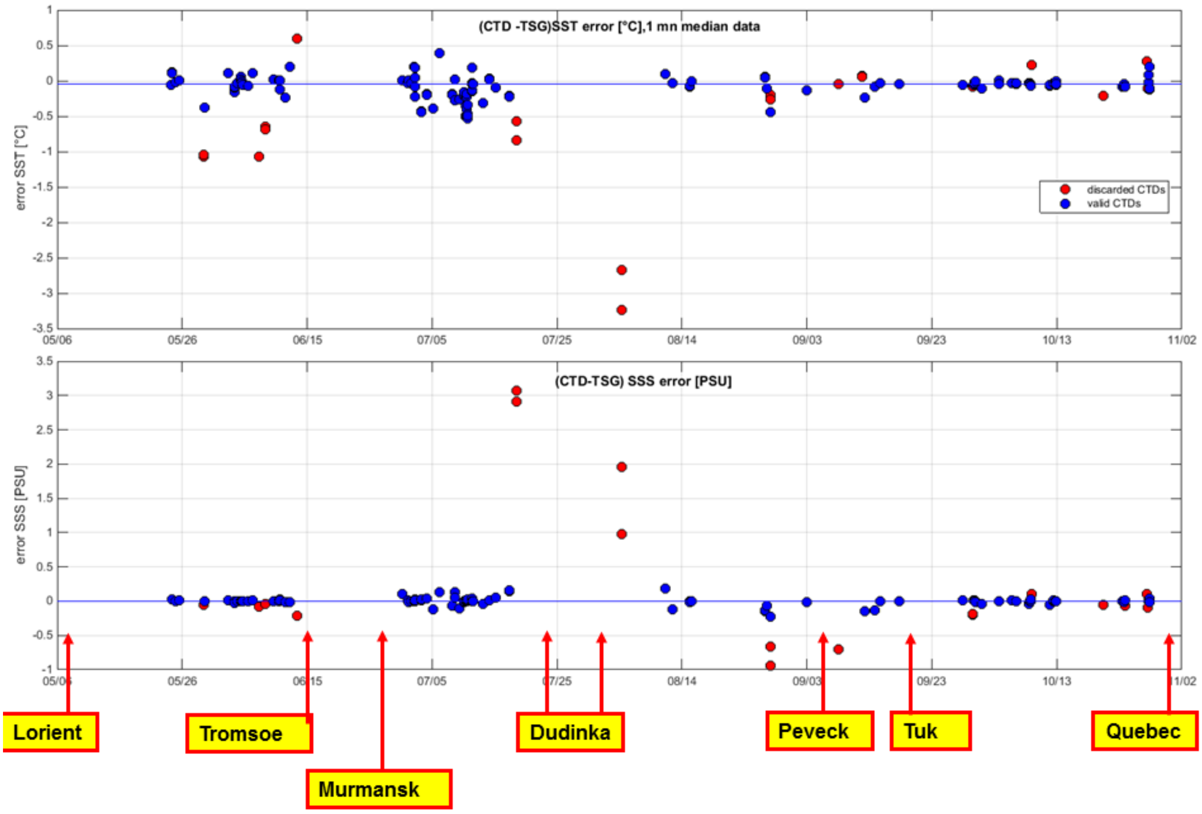


Figure 3: (CTD-TSG) differences for SSS and SST(final QC data, all CTD profiles) time series for the whole Polar Circle cruise.

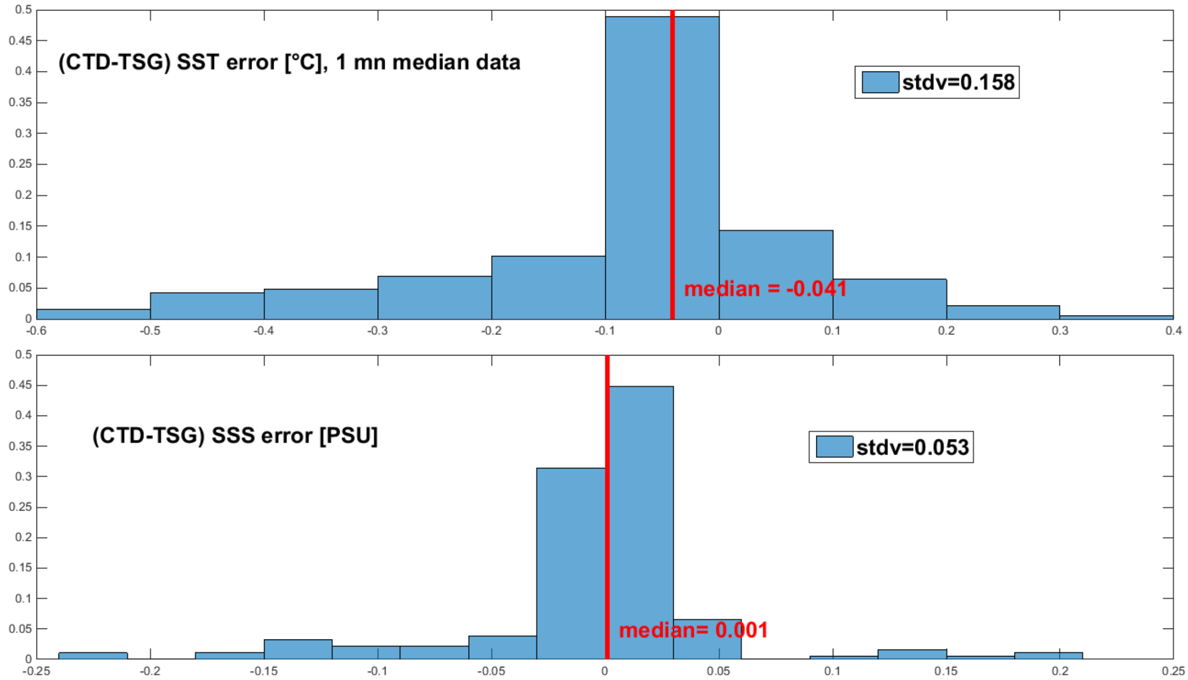


Figure 4: (CTD-TSG) differences for SSS and SST(final QC data, valid CTD profiles only) histograms of distribution for the whole Polar Circle cruise.

before CTD to TSG corrections			CTD profiles	(CTD-TSG) SST difference [°C]		(CTD-TSG) SSS difference [PSU]	
Leg		**date**	**valid / all**	**median**	**std deviation**	**median**	**std deviation**
1	Lorient Tromsoe	19/05 14/06	29 / 33	-0,007	0,116	-0,001	0,012
2	Tromsoe Murmansk	17/06 21/06	0	nan	nan	nan	nan
3	Murmansk Dudinka	29/06 19/07	36 /37	-0,183	0.218	0,005	0,053
4	Dudinka Peveck	03/08 04/09	18 / 21	-0,054	0,148	-0,014	0,112
5	Peveck Tuk	07/09 18/09	7 / 9	-0,061	0,086	-0,068	0,078
6	Tuk Quebec	21/09 07/10	52 / 59	-0,041	0,056	0,002	0,018
7	Quebec Lorient	25/11 06/12	6 salinity samples	nan	nan	0,006	0,018

Table 5 : (CTD-TSG) statistics computed leg by leg on the filtered and calibrated data, but before CTD to TSG corrections.

Comments on *table 5:*
As discussed in the leg by leg analysis in appendix, many CTD profiles performed in the Arctic Basin (legs 2 to 5) shows large and random SSS & SST deviations with TSG data.
This is obvious on the median differences and their standart deviations for those legs.
Therefore we did NOT apply inter-calibration corrections to TSG for those legs.
Leg 1 (North Atlantic) and Leg 6 (Baffin and Labrador seas) show better statistics on SST/SSS differences so that we decided f to apply the median corrections to TSG data for those 2 legs only :

-corrections on SSS (-0.001 & +0.002 PSU) are in fact neglectible, being smaller than the sensors accuracy (0.005 PSU)

- corrections on SST (-0.007 & -0.041 C) are significant , and reflect the ñbilge warming biasò on SBE38 sensor.

For the last North Atlantic return leg (Leg7, no CTD stations) , the comparison with 6 salinity samples gives a good statistic , therefore we apply the (+0.006 PSU) correction on the whole leg .

III- Deliverables

This report gives an analysis of TSG QC data for the whole Tara Polar Circle expedition from start to end.
The QC data are delivered as ASCII files with the following format:

JJ	Decimal JJ	date	UTC	latitude	longitude	SSS	SST	fluo
(julian date)				(dec. Degree)	(dec. Degree)	(PSU)	(°C ITS 90)	
23149	61922	19/05/2013	17:12:02	47.64688	-3.61531	34.64740	12.35998	1.07920
23149	61967	19/05/2013	17:12:47	47.64668	-3.61724	34.64657	12.35998	1.07160
23149	62021	19/05/2013	17:13:41	47.64655	-3.61954	34.64132	12.36828	1.11720
23149	62631	19/05/2013	17:23:51	47.64449	-3.64516	34.60928	12.33698	1.45160
23149	62696	19/05/2013	17:24:56	47.64425	-3.64779	34.60277	12.33028	1.29200
23149	62756	19/05/2013	17:25:56	47.64411	-3.65025	34.59625	12.33028	1.34520

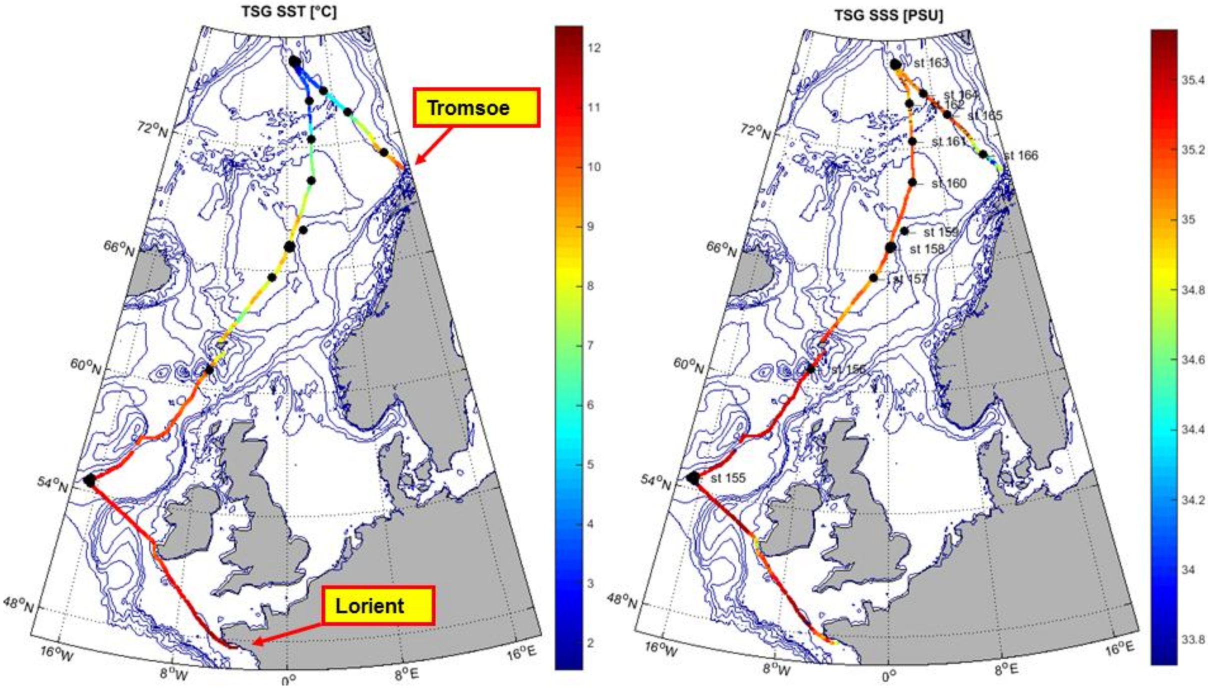
Data are available on our web page :
https://skyros.locean-ipsl.upmc.fr/~Tara2013TSG/

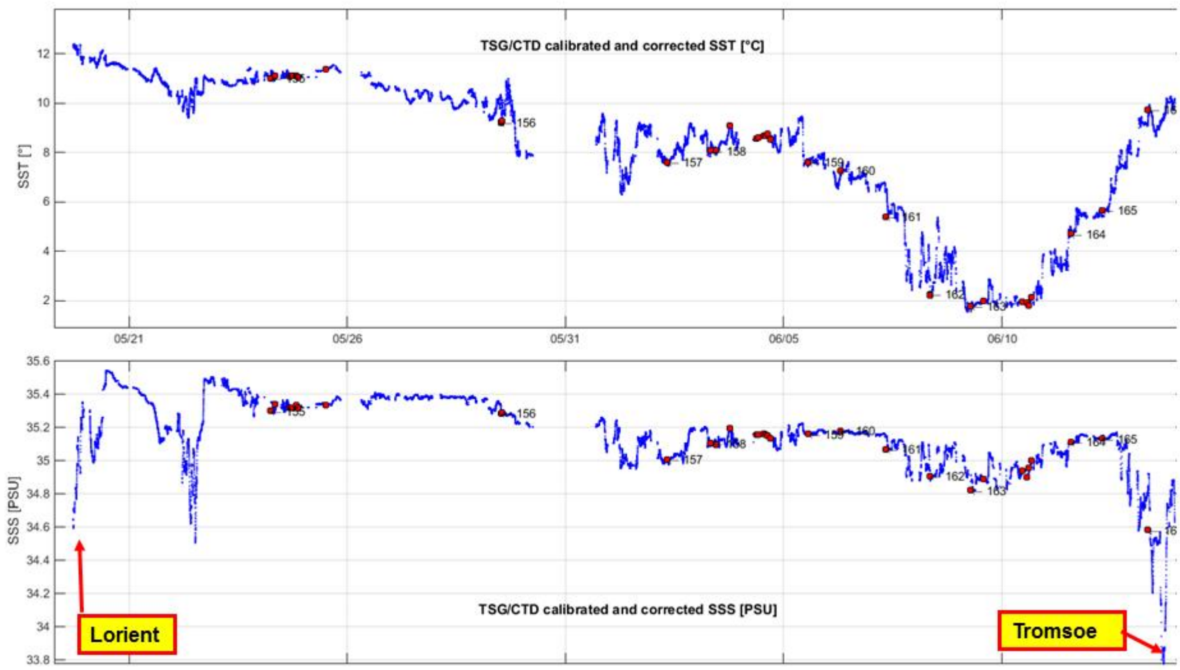
References

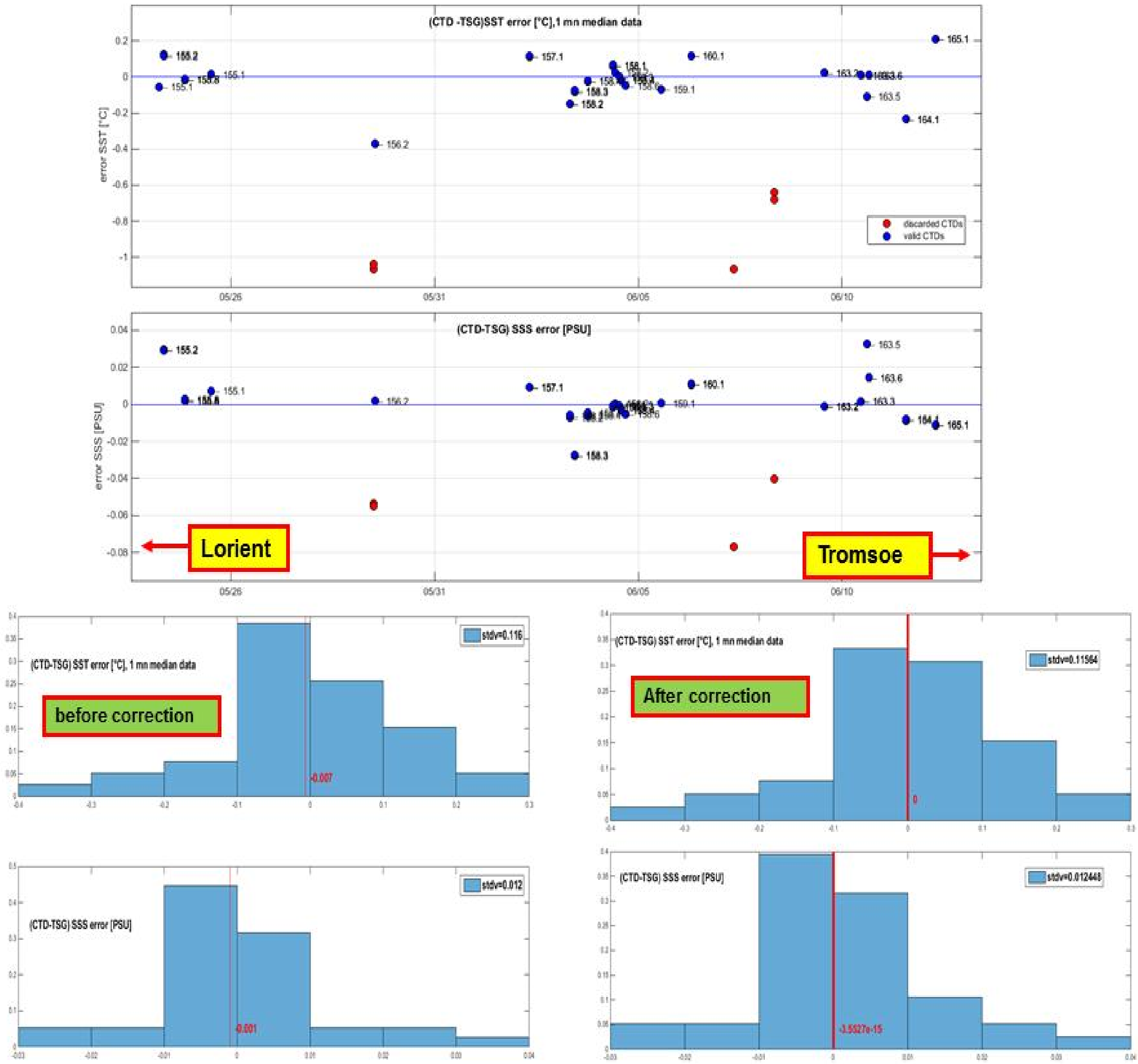
[Ref 1] : **Post-processing physical data acquired during the expedition TARA Polar circle** *V. Taillandier,LOV, March 2014*

APPENDIX 1 : Leg by Leg analysis

Leg 1 : Lorient to Tromsoe



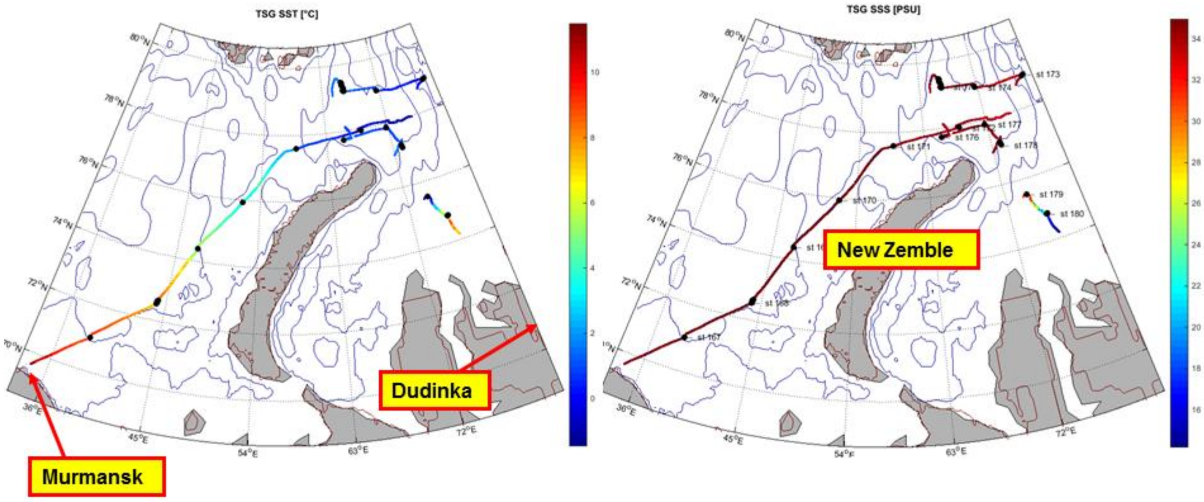


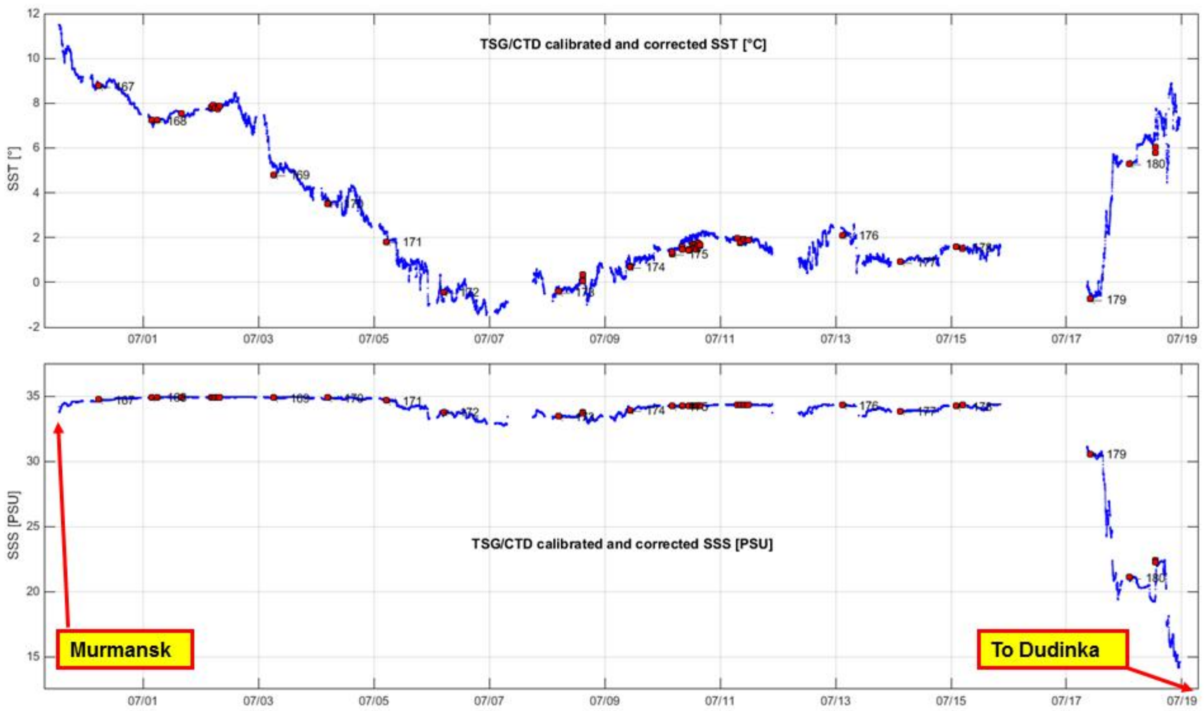


(CTD-TSG) Differences show good statistics for 29 CTD profiles, therefore median corrections are applied on TSG time series .

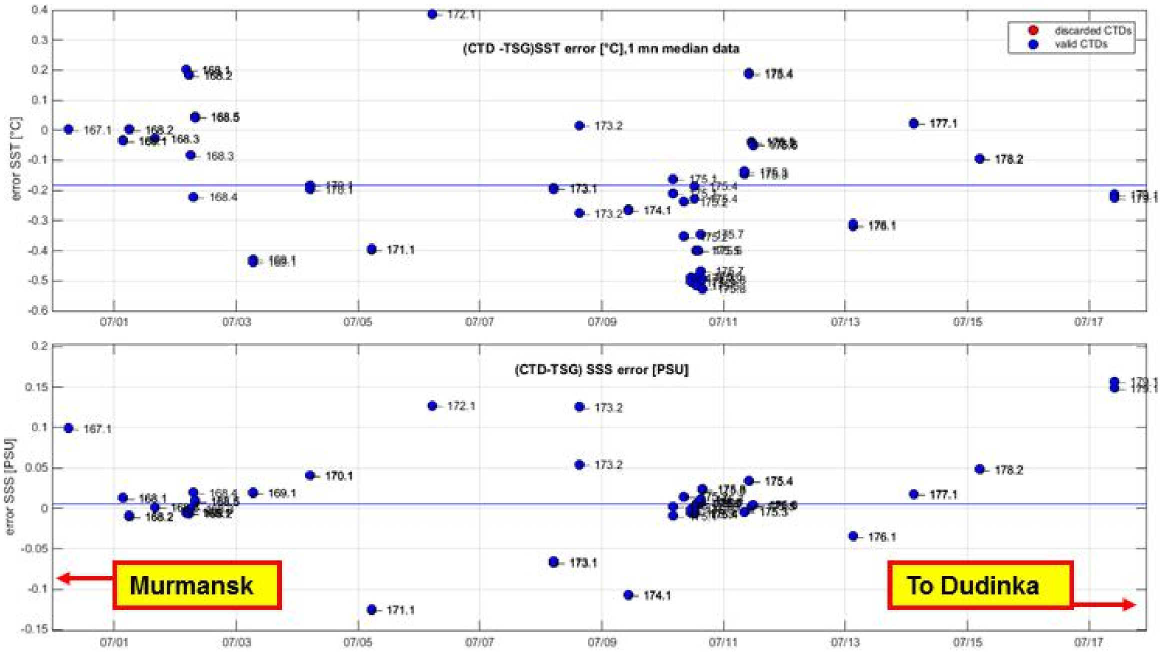
From Tromsoe to Murmansk on, there were NO TSG data recorded.

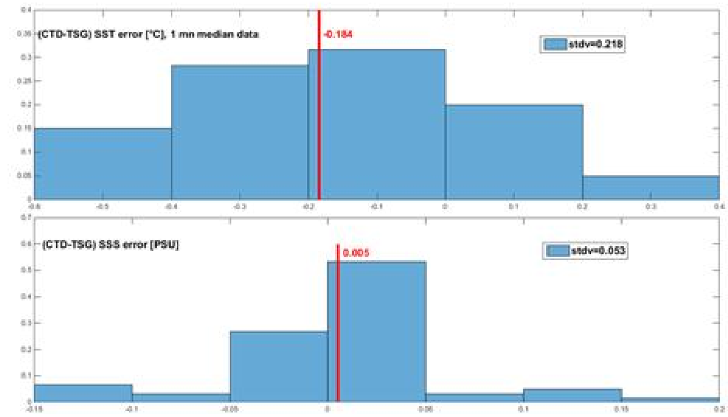
Leg 3 : Murmansk to Dudinka





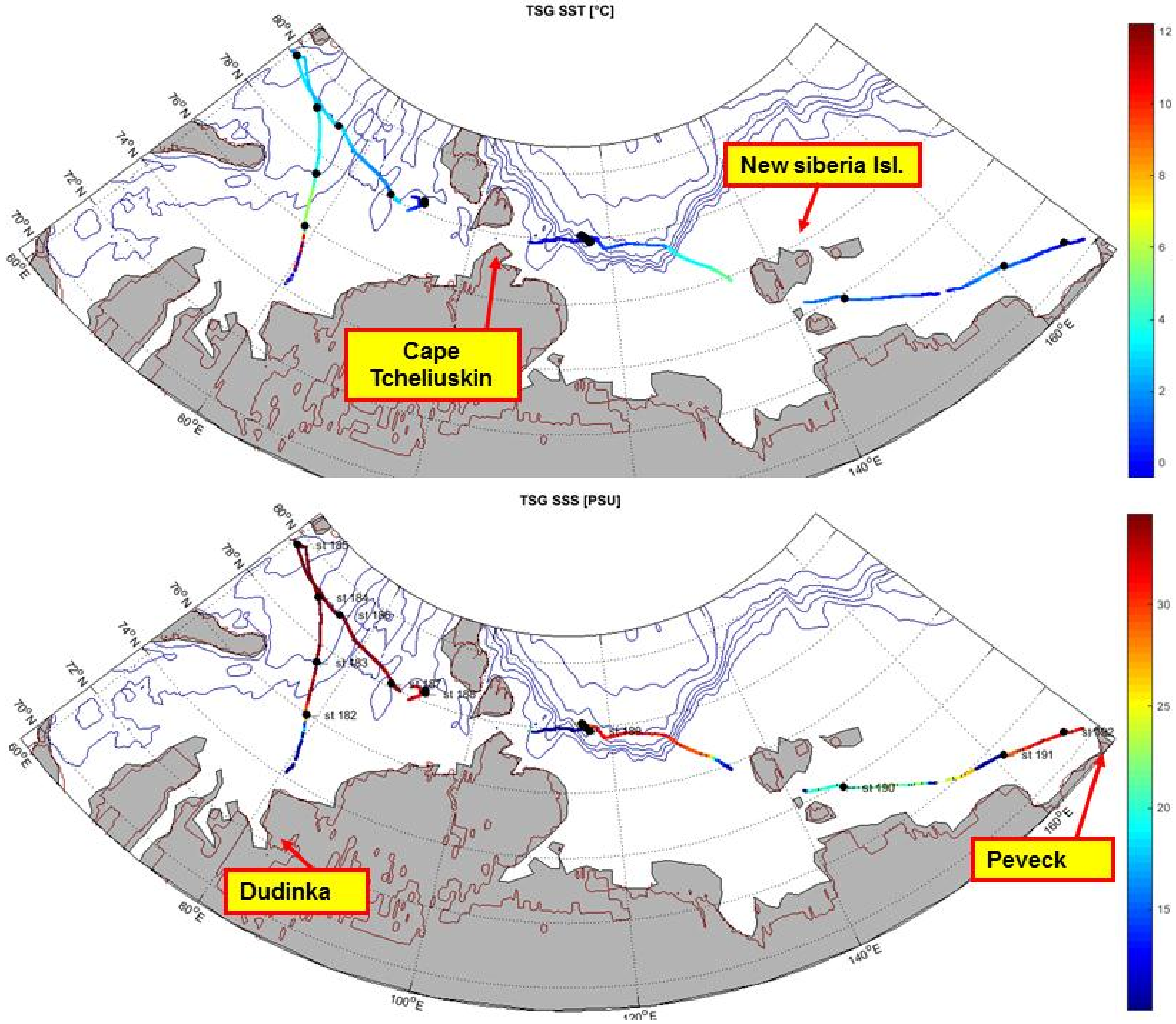
Some gaps in the TSG data in NE of Novaya Zemlya (due to sea ice ??). Massive fresh water input from Yenisseï and Ob rivers in the southern part Kara Sea, but unfortunately TSG data stop 120 milles N of Yenisseï estuary (entrance to Dudinka).

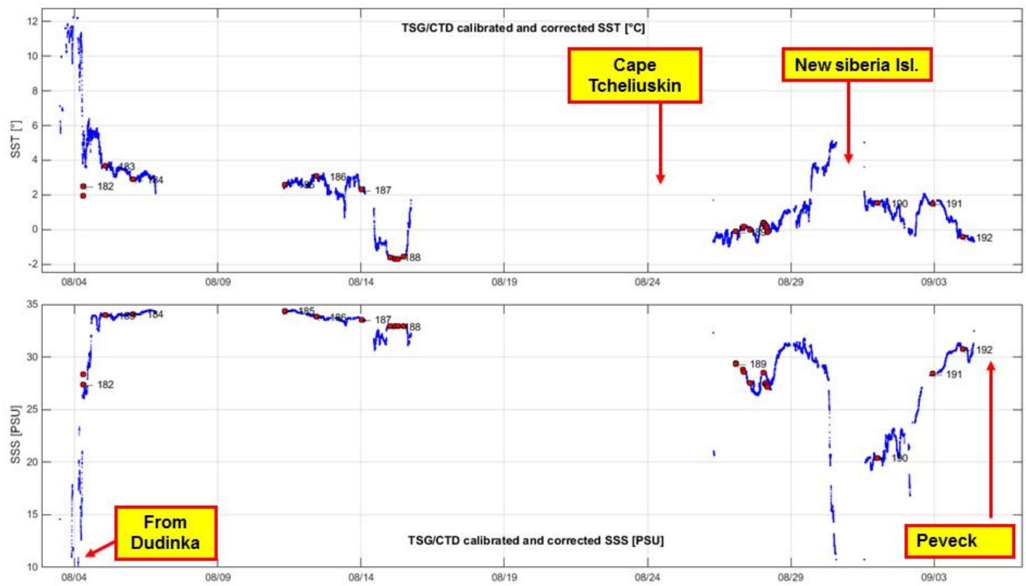




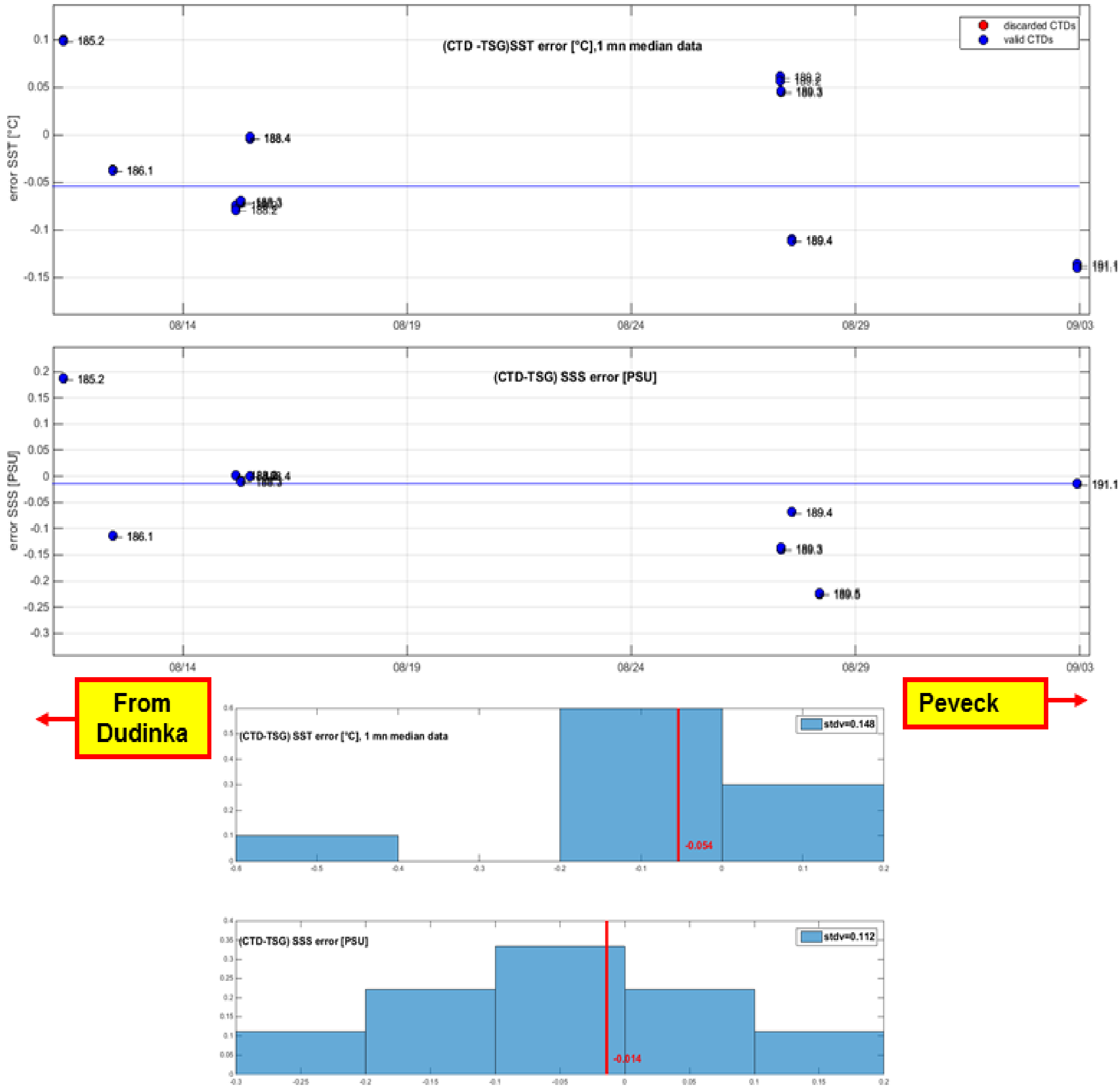
(CTD-TSG) Differences show high standart deviations , therefore NO corrections are applied to TSG time series .

Leg 4 : Dudinka to Peveck



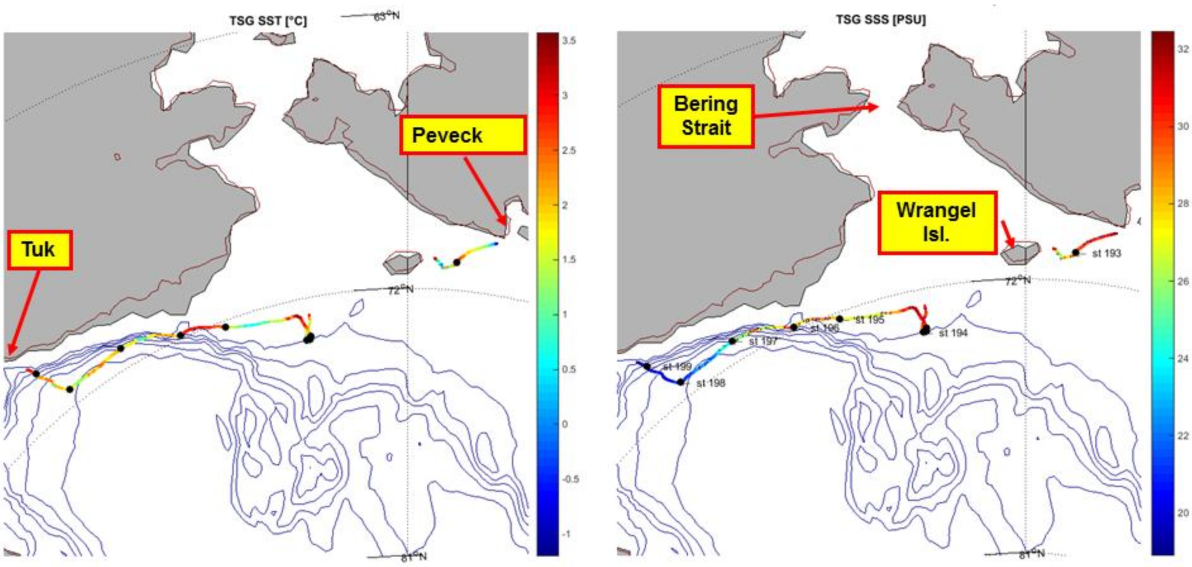


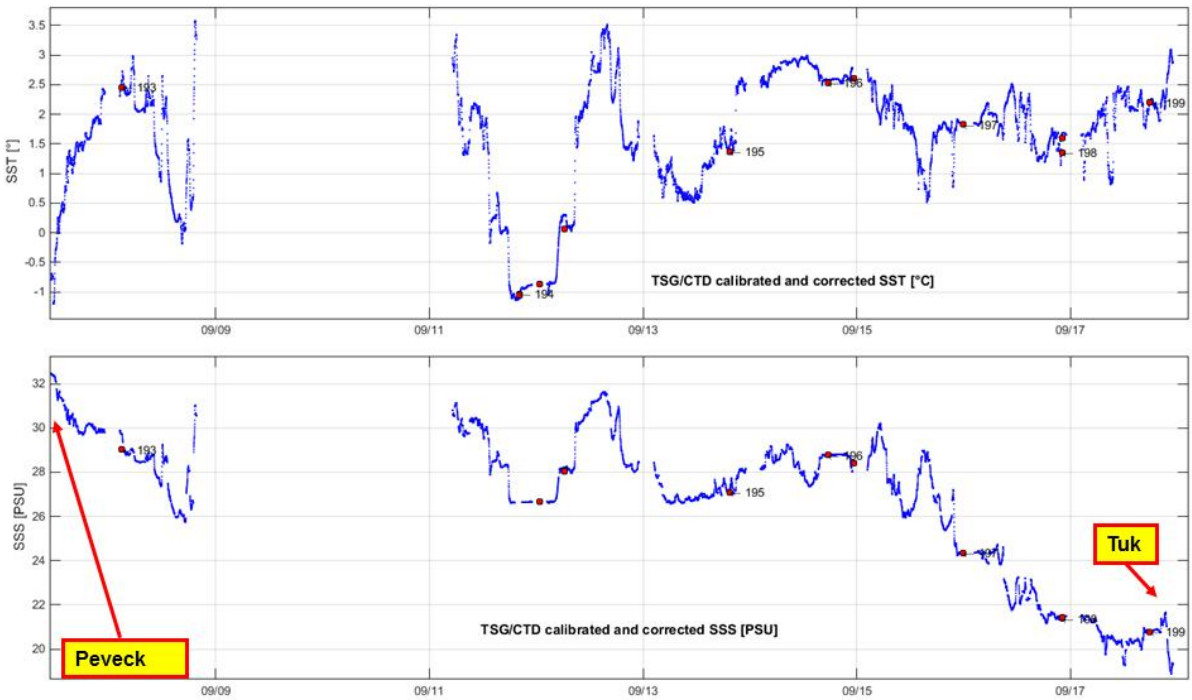
Long TSG data gaps passing from Kara Sea to Laptev Sea through Tcheliuskin Cape and around New Siberia Islands (sea ice ?). Massive fresh water input from Yenisseï and Ob rivers at start of leg in the southern part of Kara Sea, and later in the Laptev Sea from the Lena River.



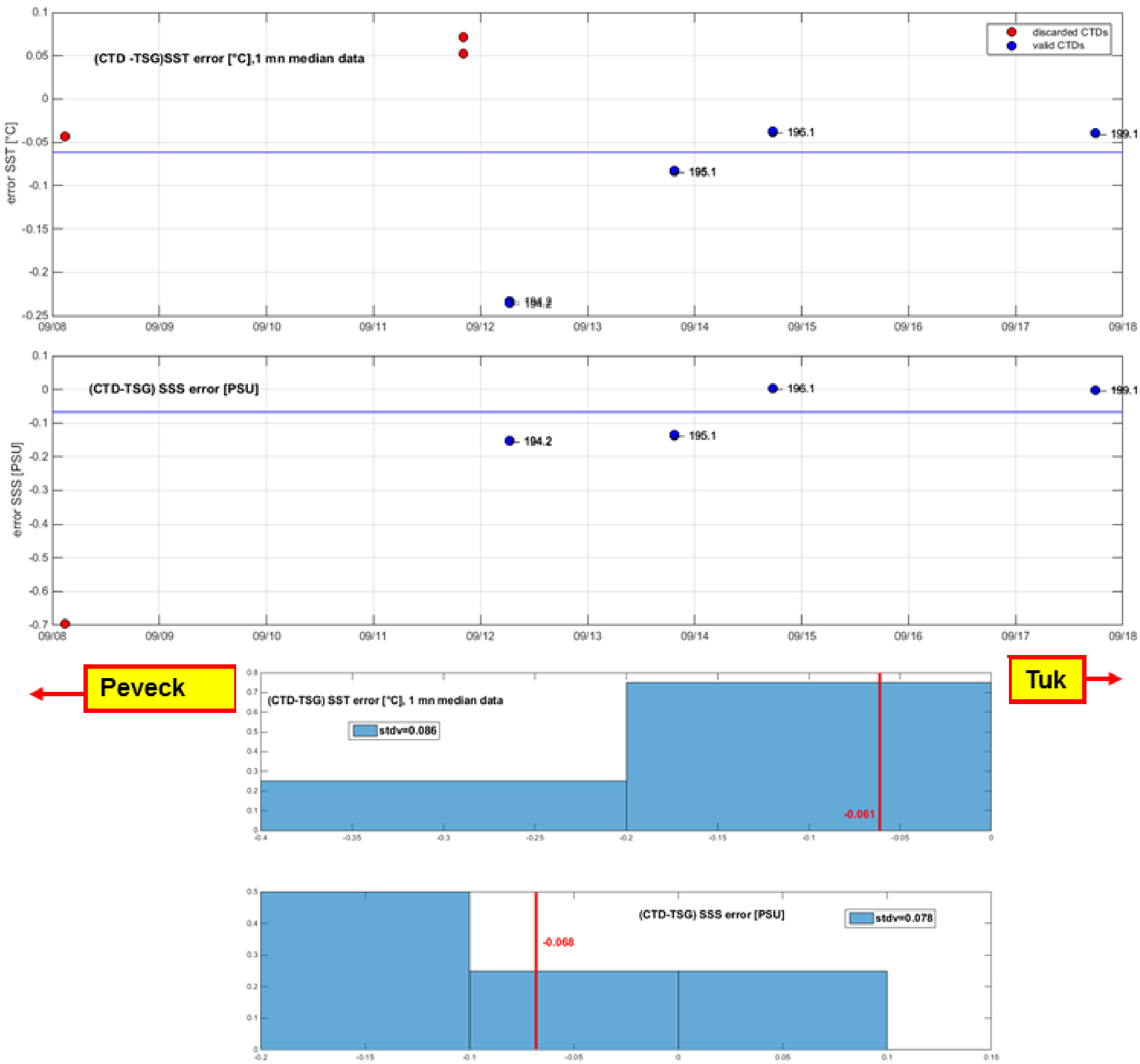
Only 18 valid CTD profiles on this leg where (CTD-TSG) Differences show high standart deviations , therefore NO corrections are applied to TSG time series.

Leg 5 : Peveck to Tuk



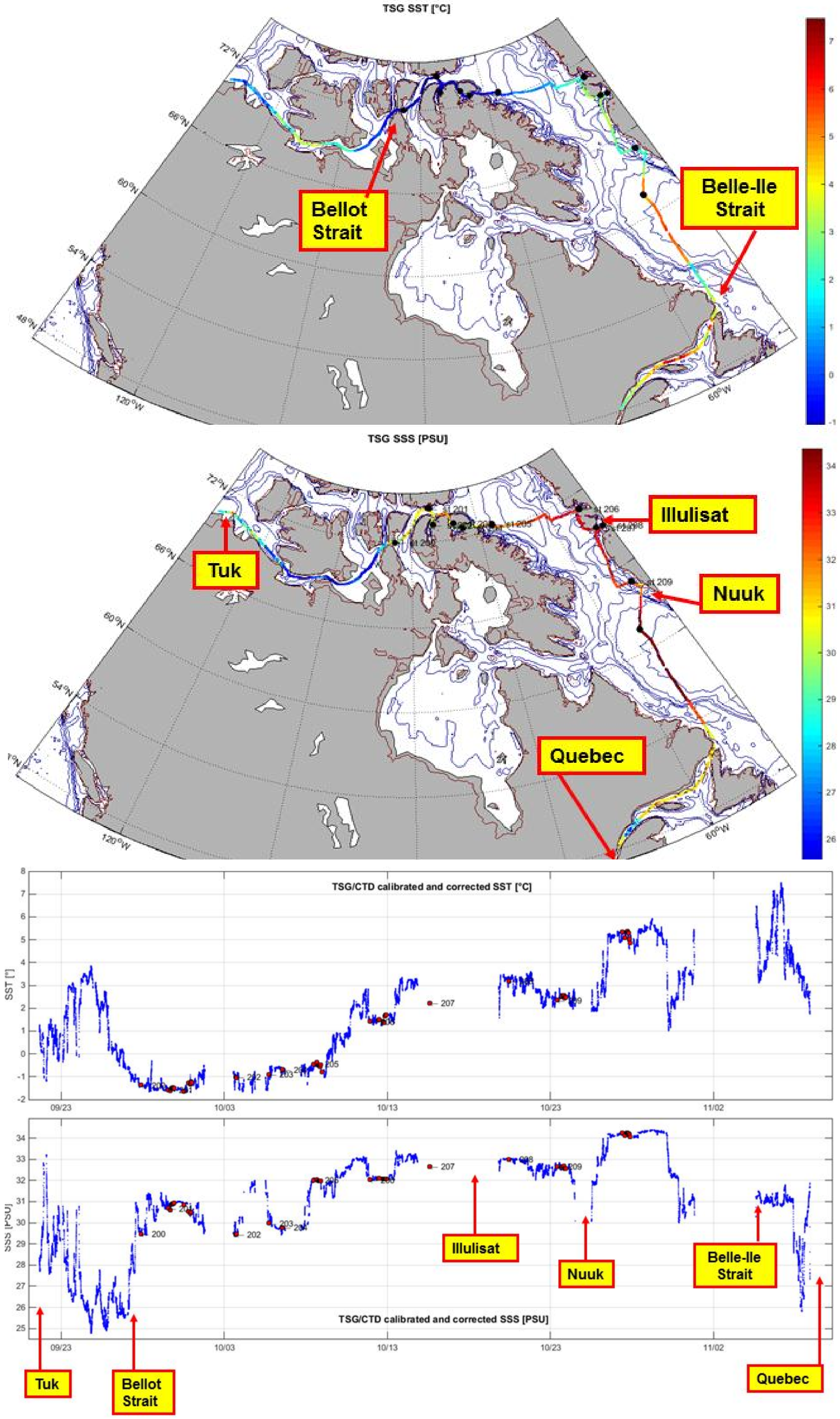


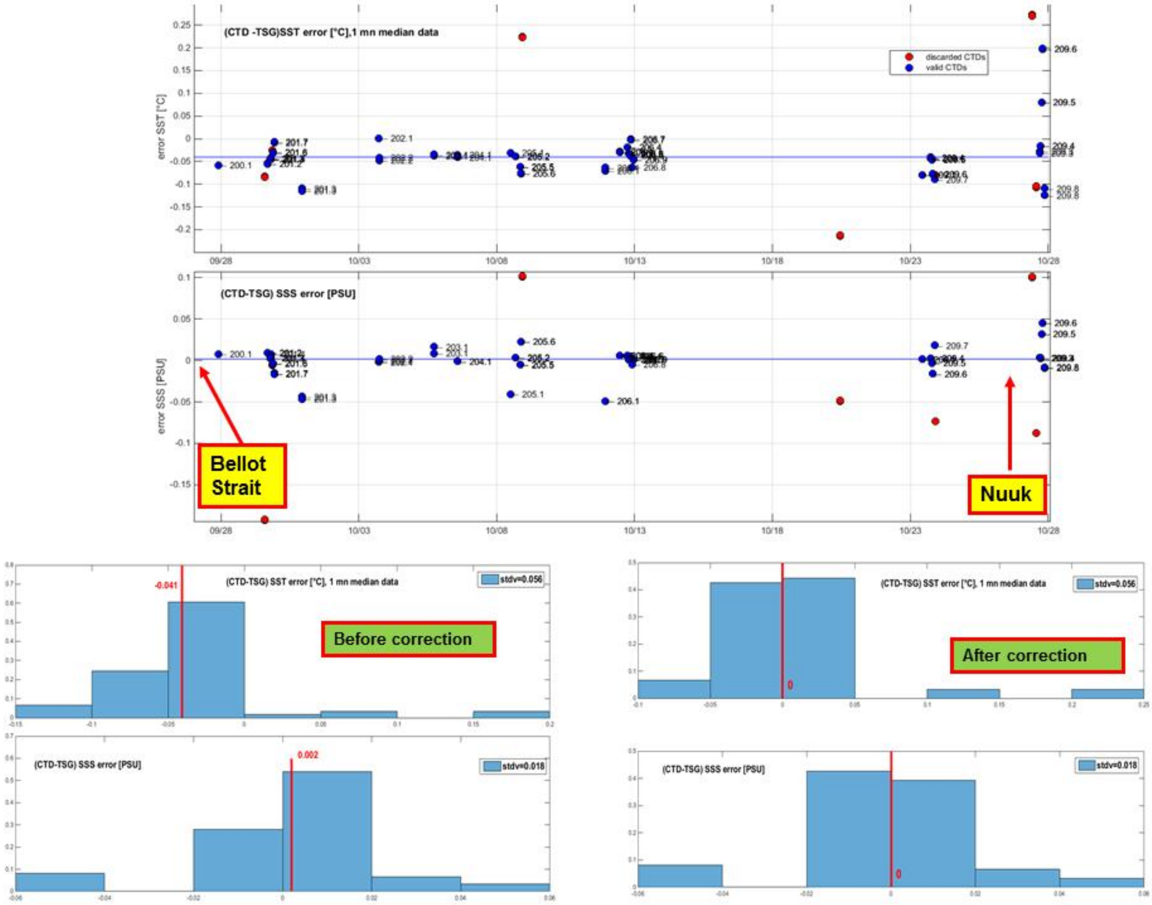
A long gap in TSG data from Wrangel Island to the eastern limit of Russian waters (authorisation issuesé).
Low salinities at the end of leg caused by fresh water input from Mackenzy River .



Only 7 valid CTD profiles on this leg where (CTD-TSG) Differences show high standart deviations , therefore NO corrections are applied to TSG time series.

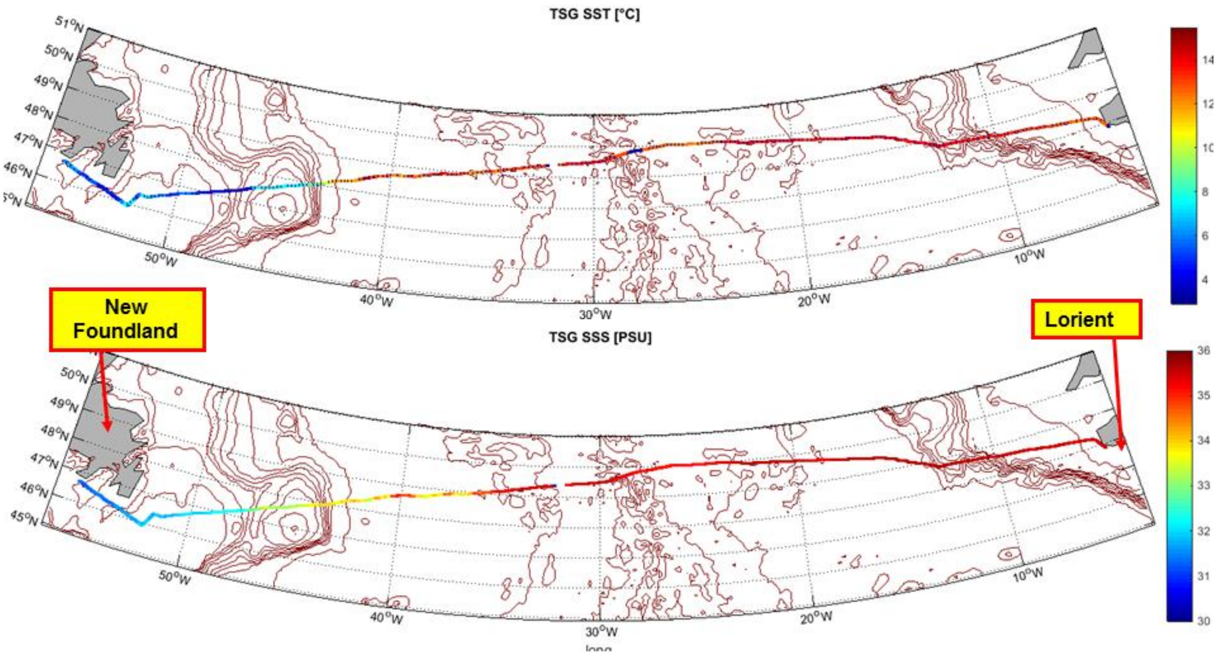
Leg 6 : Tuk to Quebec

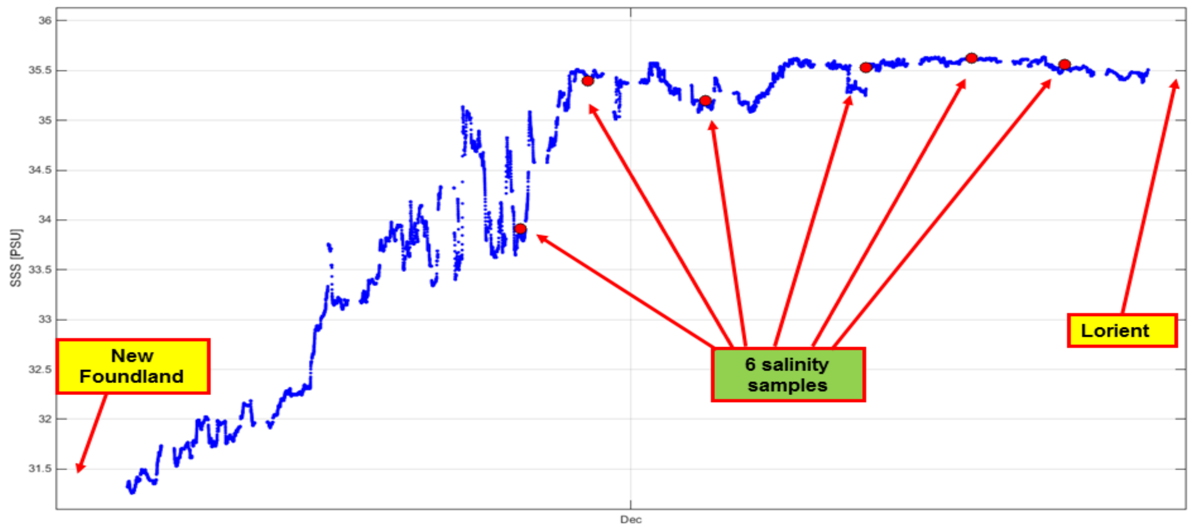


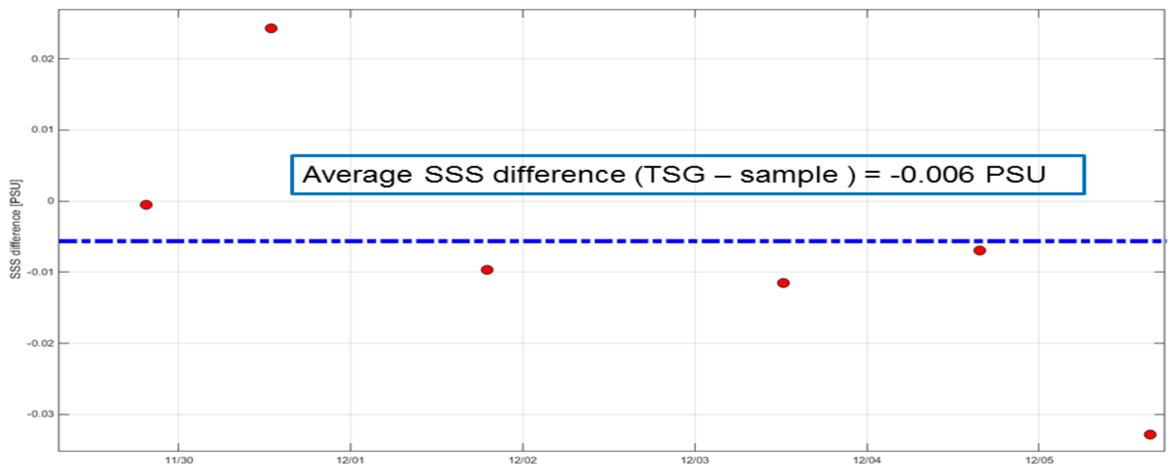


Most of the CTD stations happen in Baffin Sea and Greenland waters . AS (CTD-TSG) differences show good statistics for the 59 CTD profiles, median corrections are applied on TSG time series .

Leg 7 : Quebec to Lorient







No CTD station occurred during this last leg but 6 salinity samples were taken on the TSG sea water line during the North Atlantic return crossing . They were analysed on our Autosal in LOCEAN (see *appendix 3*)**.**
Comparison with the TSG SSS time serie appears on the graph:

- SBE45 has been already corrected from post-campaign Seabird calibration : +0.01 PSU

- Though the average difference with samples is still significant (-0.006 PSU) but close to the SBE45 initial accuracy (0.005 PSU)

- The differences variability along the 6 days of sampling does not show any significant trend

So we decide to apply a constant correction (+ 0.006 PSU) on the whole North Atlantic crossing (leg 7) .

APPENDIX 2: data processing methodology

Seabird calibration reports and hardware configurations for TSG
Final report on CTD profiles validation

I- Hardware configuration

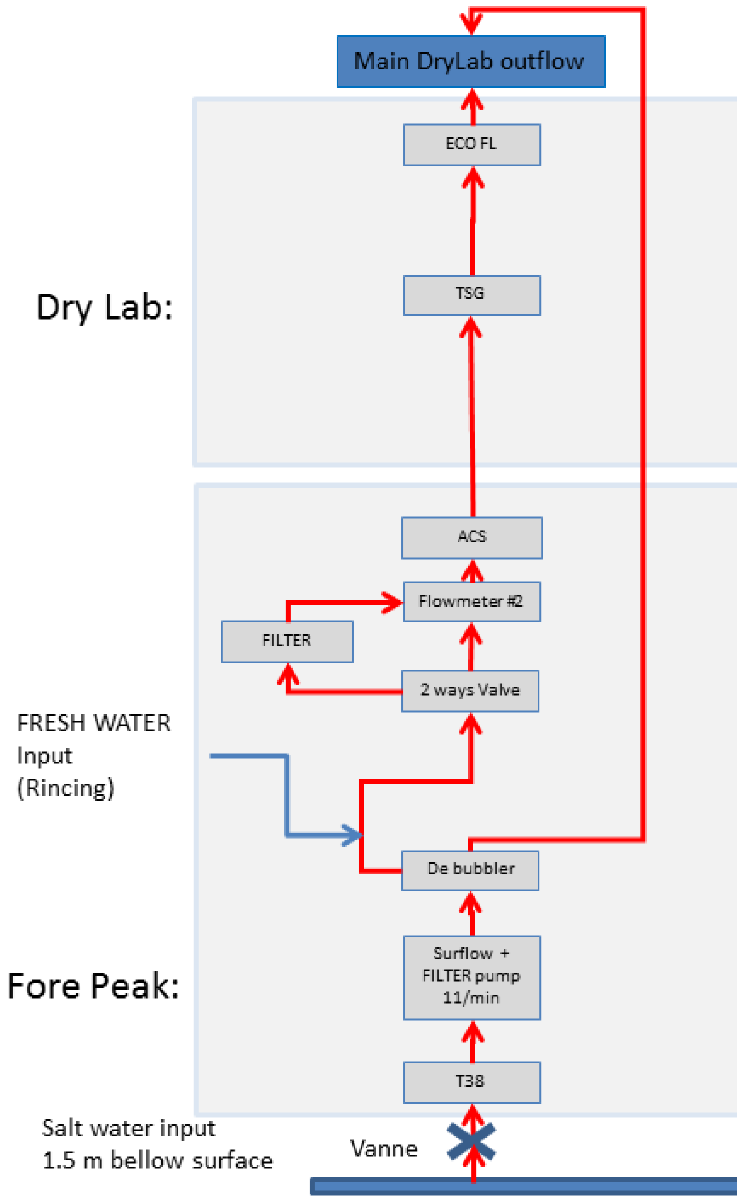


Figure 1 :Sea water plumbing feeding the flowthrough instruments (ACS,TSG,Fluo)

II- TSG raw data calibration

II-1 Subsampling the raw data set

Starting from the 10s raw data from SBE45 and SBE38 , we apply the following process :

- sub sampling SST (from SBE 38 sensor) at 1mn , using a running median on a 1mn window
- extracting T , C, S data (from TSG SBE45) corresponding to the 1rst occurrence of the median SST inside each 1mn window .This is the reason why sampling period in the final QC data is not exactly constant and equal to 1 mn.

II-2 Filtering the 25mn periodic noise

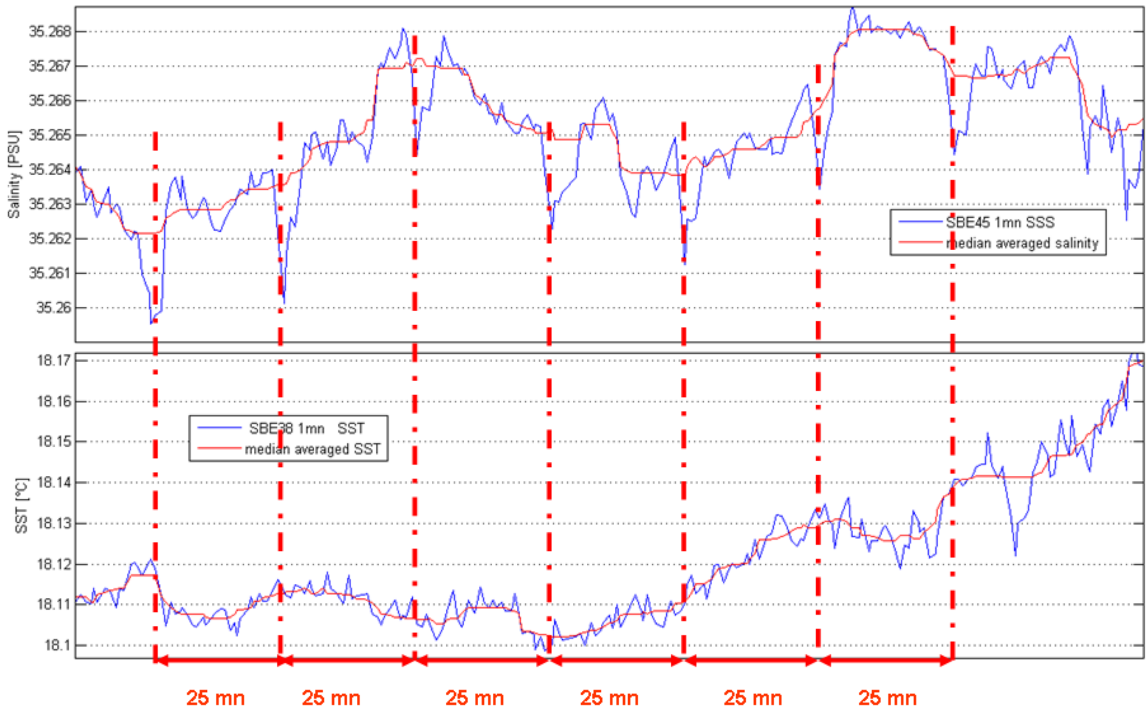
We already faced this problem during Tara Ocean

- A 25 mn periodic noise on the salinities (figure2 up , blue data) is due to the 0.2 µ filter from ACS positioned upstream on the seawater circuit feeding SBE45 and activated every 25mn during 5mn through an automatic 2 ways valve .
- This periodic noise is visible on C and T1 from SBE45 but not on T2 from SBE38 , which is positioned close to the sea cock and upstream from the ACS filter (see figure 1: plumbing hardware).
- This is the reason why we start the process with sub sampling the raw T2 from SBE38 (by running median), and afterwards choose the corresponding C and T1 in the 1mn window
- During Tara Oceans, we filtered that noise by a running median on the final calibrated data, which was effective at the cost of some lost variability on the data é .
- As an improvement for Polarcircle , we tried to use the time serie of Flowstate data (provided by Alison Chase/Maine Univ.), which indicates the 2 ways valve's position (filtered/non filtered) , in order to kill (Nan) TSG data during the periods of filtered flow (flowstate=0 time window + 2mn).
- *This method works fine as long as the TSG acquisition PC and the flowstate-ACS acquisition PC are well synchronized*: it was apparently not the case during the whole cruise, we faced some periods with random clock drifts. Therefore, we still use a running median on the final set of data, although a good part of it (but not all) has been efficiently cleaned by the flowstate filter.

The whole filtering process includes:

- suppressing outliers with min/max and lowpass filters
- filtering the 25 mn periodic noise with a running median on a ± 6mn window centred on the data

Filtered data are shown in figure 2, where the periodic noise has disappeared. As Tara is never sailing at high speed (8 knts or less), the SSS/SST spatial variability is not much reduced by that process.



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- *Figure 2: influence of the filtering (flowstate and ± 6mn running median) on SSS and SST*
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II-3 Calibrating TS data with pre and post-cruise Seabird calibrations

T1 and C sensors on SBE45 and T2 sensor on SBE38 have been factory calibrated before and after Polarcircle cruise .

Calibration sheets returned by Seabird are copied in the next pages. Postslope on C and Temperature offsets are summarized in the following table, from the TSG purchase date in 2009 (start of Tara Ocean):

		Tara Oceans				storage ashore		Tara Polar Circle	
		postcruise cal Capetown		**postcruise cal Lorient**		**precruise cal Lorient**		**postcruise cal Lorient**	
Sensors	**Correction**	07/05/09	04/08/10	04/08/10	13/06/12	13/06/12	03/04/13	03/04/13	21/12/13
SBE45 - T1	**offset millideg**	0.72	0	-0.12	0	0.62	0	-1.31	0
SBE45 - C	**slope C**	0.9993577	1.00000	1.0004614	1.00000	0.9999451	1.00000	0.9996878	1.00000
SBE38- T2	**offset millideg**	0.09	0	0.14	0	0.18	0	-0.44	0

It appears that after 3 years of continuous operation at sea and 1 year of dry storage, the 4 successive factory calibrations always show small drift and offset on the 3 sensors **:** those sensors look reliable ! .

Using pre and post cruise calibrations for Polar Circle , we assume that sensors are drifting linearly between calibrations and we apply the calibration process recommended by Seabird in its ñ*application note n°31*ò :

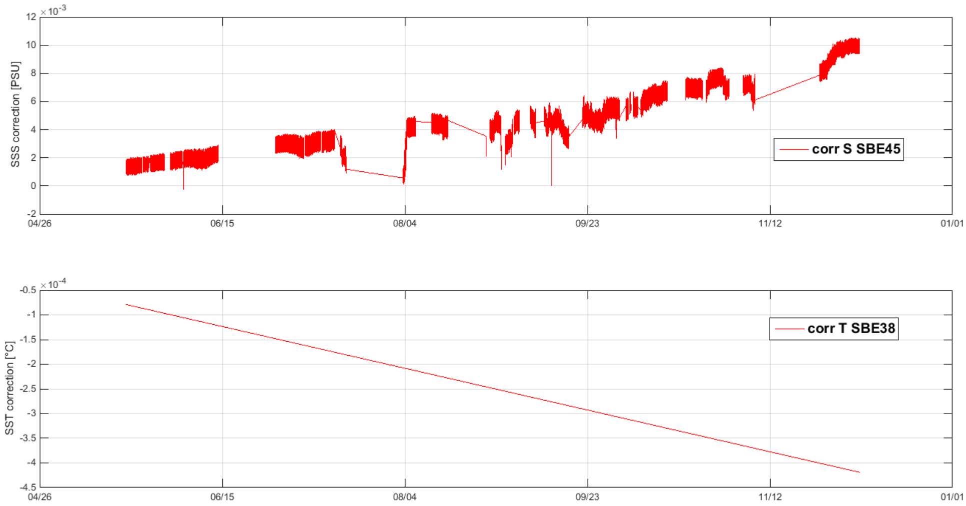
- By linear interpolation between calibration dates, we compute C islope and offsets on T45 and T38 for the julian date of each data.
- We apply the T offset to each T45 and T38 data to compute T45cal and SSTcal
- We apply the islope to C to compute Ccal
- Using Unesco equation (with ITS90 to ITS68 conversion on T45cal) , we compute a calibrated salinity SSScal (T45cal,Ccal)

Corresponding code :

```
%declare Seabird calibrations:
time1=datenum('04/03/2013') % precruise calibration date
time2=datenum('12/19/2013') % postcruise calibration date

dtime=time2-time1 % elapsed time btw pre and post calibrations
ps=0.9996878      %postcruise slope  on C for SBE45
DT38= -0.00044    % postcruise delta T for SBE38
DT45= -0.00131    % postcruise delta T for SBE45
% compute linear regression on C slope: slope(x)= 1- alpha*x . Then Ctrue= Ctsg * slope. x is
the number of elapsed days since precalibration.
alpha= (1-1/ps)/dtime % the true Seabird note formula , same as Vincent with postslope for the
CTD sensors.
% compute linear regression on T offset : R(x)=  beta*x .Then : Ttrue= Ttsg- R(x)
beta38=DT38/dtime
beta45=DT45/dtime
```

Correction values applied all along the Polar Circle cruise appear in figure 3:
T corrections range from 0.1 to 0.4 milliC, hence 10 times smaller than the SBE38 initial accuracy.(2 milliC)
S corrections range from 2 to 10 milliPSU, hence in average around the SBE45 initial accuracy. (0.005 PSU)



- *Figure 2: corrections on SSS and SST issued from the sensors pre-post cruise calibrations*

III- CTD data assimilation and inter calibration process

Vincent Taillandier has processed the 163 CTD downcast profiles, binaveraged to 1m for the Polar Circle campaign. Data are calibrated and quality controlled ,using cross-comparison between the double sensors (C,T) on the rosette *[ref 1]*.

In each CTD profile:

- We extract T/S data for depth range 2-4m (when availableé not always) with their julian date
- they are compared to simultaneous TSG data (SST and SSS median averaged on a ± 10 mn window around CTD time
- (CTD- TSG) differences on SST and SSS are plotted against time and on distribution histograms

Those difference graphs allow to:

- identify atypical CTD profiles , which will be discarded for the further intercalibration process
- Identify difference trends, possibly caused by TSG duct obstruction, freezing etc..
- decide if we apply corrections to the TSG data

Computing Temperature and Conductivity *Slope* and *Offset* Correction Coefficients from Laboratory Calibrations and Salinity Bottle Samples

Conductivity Sensors

The conductivity sensor *slope* and *offset* entries in the configuration (.con or .xmlcon) file in SEASOFT permit the user to make corrections for sensor drift between calibrations. The correction formula is:

(corrected conductivity) = slope * (computed conductivity) + offset

where :
slope = (true conductivity span) / (instrument reading conductivity span)
offset = (true conductivity - instrument reading conductivity) * slope *measured at 0 S/m*

For newly calibrated sensors, use slope = 1.0, offset = 0.0.

Sea-Bird conductivity sensors usually drift by changing span (the slope of the calibration curve), and changes are typically toward lower conductivity readings with time. Any offset error in conductivity (error at 0 S/m) is usually due to electronics drift, typically less than ±0.0001 S/m per year. Offsets greater than ±0.0002 S/m per year are symptomatic of sensor malfunction. **Therefore, Sea-Bird recommends that conductivity drift corrections be made by assuming no offset error, unless there is strong evidence to the contrary or a special need.**

Correcting for Conductivity Drift Based on Pre- and Post-Cruise Laboratory Calibrations

Suppose a conductivity sensor is calibrated (pre-cruise), then immediately used at sea, and then returned for post-cruise calibration. The pre- and post-cruise calibration data can be used to generate a slope correction for data obtained between the pre- and post-cruise calibrations.

If α is the conductivity computed from the **pre-cruise bath data** (temperature and frequency) using **post-cruise calibration coefficients** and β is the true conductivity in the **pre-cruise bath**, then:

$$\textbf{postslope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)} \qquad \text{(postslope is typically < 1.0)}$$

Sea-Bird calculates and prints the value for postslope on the conductivity calibration sheet for all calibrations since February 1995 (see *Appendix I: Example Conductivity Calibration Sheet*)

To correct conductivity data taken between pre- and post-cruise calibrations:

islope = 1.0 + (b / n) [(1 / postslope) - 1.0]

where

islope = interpolated slope; this is the value to enter in the configuration (.con or .xmlcon) file
b = number of days between pre-cruise calibration and the cast to be corrected
n = number of days between pre- and post-cruise calibrations
postslope = slope from calibration sheet as calculated above (see *Appendix I: Example Conductivity Calibration Sheet*)

In the configuration (.con or .xmlcon) file, use the **pre-cruise calibration coefficients** and use **islope** for the value of slope.*

Note: In our SEASOFT V2 suite of programs, edit the CTD configuration (.con or .xmlcon) file using the Configure Inputs menu in Seasave V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

For typical conductivity drift rates (equivalent to -0.003 PSU/month), islope does not need to be recalculated more frequently than at weekly intervals.

Temperature Sensors

The temperature sensor *slope* and *offset* entries in the configuration (.con or .xmlcon) file in SEASOFT permit the user to make corrections for sensor drift between calibrations. The correction formula is:

corrected temperature = slope * (computed temperature) + offset

where :

slope = (true temperature span) / (instrument reading temperature span)
offset = (true temperature - instrument reading temperature) * slope *measured at 0.0 °C*

For newly calibrated sensors, use slope = 1.0, offset = 0.0.

Sea-Bird temperature sensors usually drift by changing offset (an error of equal magnitude at all temperatures). In general, the drift can be toward higher or lower temperature with time; however, for a specific sensor the drift remains the same sign (direction) for many consecutive years. Many years of experience with thousands of sensors indicates that the drift is smooth and uniform with time, allowing users to make very accurate drift corrections to field data based only on pre- and post-cruise laboratory calibrations.

Span errors cause slope errors, as described in the equation for slope above. Sea-Bird temperature sensors rarely exhibit span errors larger than 0.005 °C over the range -5 to 35 °C, even after years of drift. Temperature calibrations performed at Sea-Bird since January 1995 have slope errors less than 0.0002 °C in 30 °C. Prior to January 1995, some calibrations were delivered that include slope errors up to 0.004 °C in 30 °C because of undetected systematic errors in calibration. A slope error that increases by more than ±0.0002 [°C per °C per year] indicates an unusual aging of electronic components and is symptomatic of sensor malfunction. **Therefore, Sea-Bird recommends that drift corrections**
to temperature sensors be made assuming no slope error, unless there is strong evidence to the contrary or a special need.

Calibration checks at-sea are advisable for consistency checks of the sensor drift rate and for early detection of sensor malfunction. However, data from reversing thermometers is rarely accurate enough to make calibration corrections that are better than those possible by shore-based laboratory calibrations. **For the SBE 9*plus***, a proven alternate consistency check is to use dual SBE 3 temperature sensors on the CTD and to track the difference in drift rates between the two sensors. In the deep ocean, where temperatures are uniform, the difference in temperature measured by two sensors can be resolved to better than 0.0002 °C and will change smoothly with time as predicted by the difference in drift rates of the two sensors.

Correcting for Temperature Drift Based on Pre- and Post-Cruise Laboratory Calibrations

Suppose a temperature sensor is calibrated (pre-cruise), then immediately used at-sea, and then returned for post-cruise calibration. The pre-and post-cruise calibration data can be used to generate an offset correction for data obtained between the pre- and post-cruise calibrations.

Calibration coefficients are calculated with the post-cruise calibration. Using the pre-cruise bath data and the post-cruise calibration coefficients, a mean residual over the calibration temperature range is calculated.

residual = instrument temperature – bath temperature

Sea-Bird calculates and prints the value for the residual on the temperature calibration sheet (see *Appendix II: Example Temperature Calibration Sheet*).

To correct temperature data taken between pre- and post-cruise calibrations:

Offset = b * (residual / n)

where

b = number of days between pre-cruise calibration and the cast to be corrected
n = number of days between pre- and post-cruise calibrations
residual = residual from calibration sheet as described above (see *Appendix II: Example Temperature Calibration Sheet*)

II-1 SBE38 Temperature sensor calibrations

Sea-Bird GmbH
Postfach 1167, 87401 Kempten, Germany
Phone: +49 831 960994 701 Fax: +49 831 960994 709 Email: seabird.eu@seabird.com

SENSOR SERIAL NUMBER: 0497
CALIBRATION DATE: 21-Dec-13

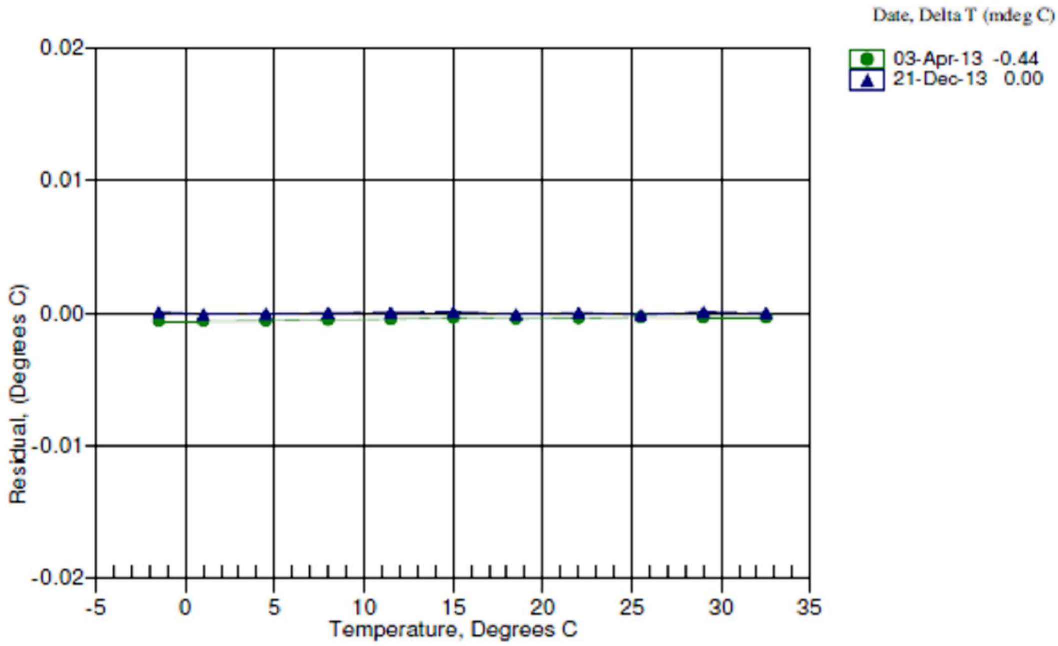
SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = 3.799732e-005
a1 = 2.717926e-004
a2 = -2.319423e-006
a3 = 1.469145e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50010	823741.8	-1.50003	0.00007
1.00000	733690.2	0.99992	-0.00008
4.50000	625754.9	4.49996	-0.00004
8.00000	535492.6	8.00001	0.00001
11.50000	459746.9	11.50004	0.00004
15.00000	395967.0	15.00009	0.00009
18.50000	342088.4	18.49994	-0.00006
22.00000	296422.7	22.00003	0.00003
25.50000	257602.8	25.49985	-0.00015
29.00000	224496.1	29.00009	0.00009
32.50000	196184.5	32.50000	-0.00000

Temperature ITS-90 = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



II-2 SBE45 Temperature sensor calibrations

Sea-Bird GmbH

Postfach 1167, 87401 Kempten, Germany

Phone: +49 831 960994 701 Fax: +49 831 960994 709 Email: seabird.eu@seabird.com

SENSOR SERIAL NUMBER: 0286
CALIBRATION DATE: 19-Dec-13

SBE45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

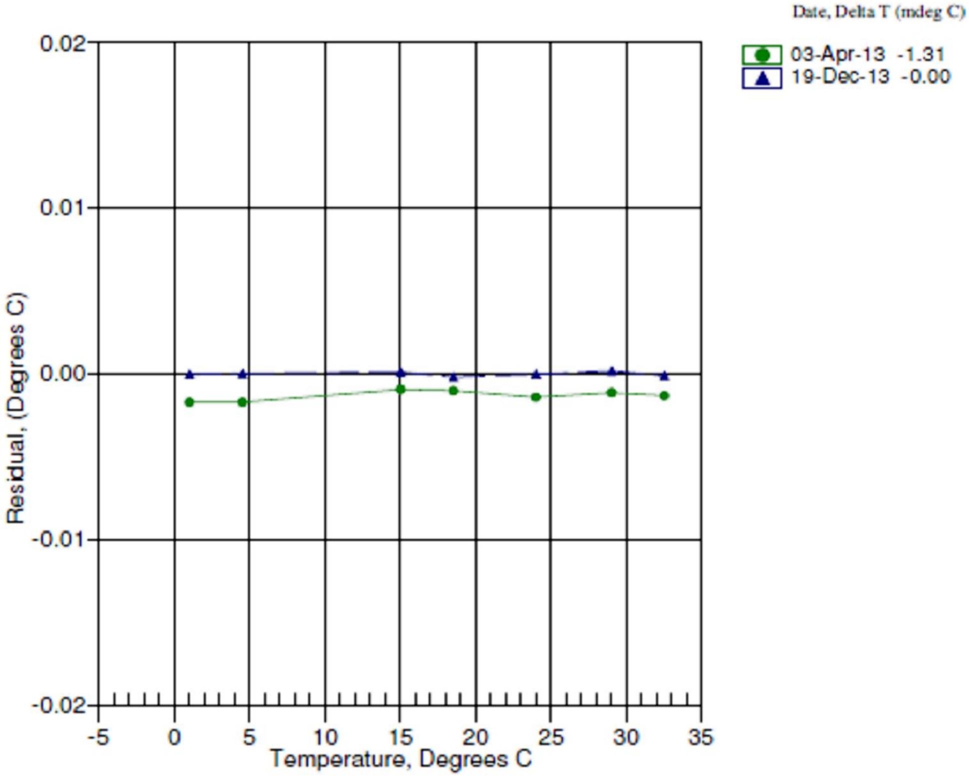
ITS-90 COEFFICIENTS

a0 = 1.325893e-004
a1 = 2.580898e-004
a2 = -1.173705e-006
a3 = 1.205314e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	610700.1	1.0000	-0.0000
4.4999	521277.0	4.4999	0.0000
15.0000	330614.9	15.0001	0.0001
18.5000	285839.1	18.4998	-0.0002
24.0000	228762.7	24.0000	-0.0000
29.0000	187968.6	29.0002	0.0002
32.5001	164369.8	32.5000	-0.0001

Temperature ITS-90 = $1/\{a0 + a1[\ln(n)] + a2[\ln^2(n)] + a3[\ln^3(n)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



II-3 SBE45 Conductivity sensor calibrations

Sea-Bird GmbH
Postfach 1167, 87401 Kempten, Germany
Phone: +49 831 960994 701 Fax: +49 831 960994 709 Email: seabird.eu@seabird.com

SENSOR SERIAL NUMBER: 0286
CALIBRATION DATE: 19-Dec-13

SBE45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.787756e-001
h = 1.538658e-001
i = -2.589456e-004
j = 4.537690e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = 2.6402e-007

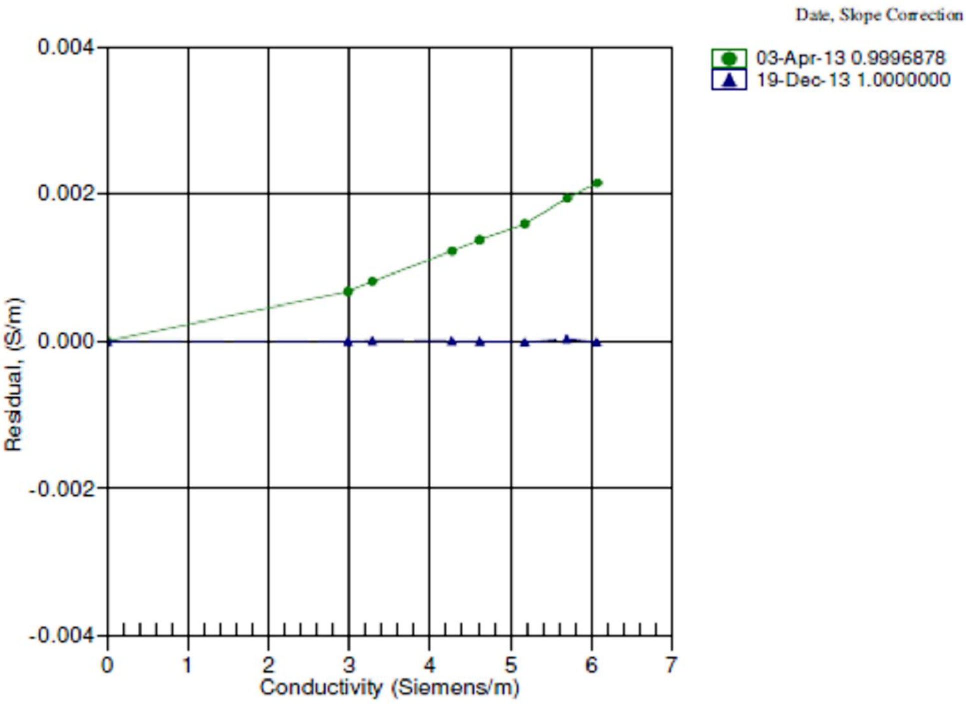
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2525.13	0.00000	0.00000
1.0000	34.8490	2.97849	5073.79	2.97849	-0.00000
4.4999	34.8294	3.28583	5266.47	3.28583	0.00001
15.0000	34.7863	4.26832	5839.11	4.26832	0.00000
18.5000	34.7767	4.61368	6027.21	4.61368	-0.00000
24.0000	34.7653	5.17188	6319.08	5.17186	-0.00002
29.0000	34.7561	5.69357	6579.87	5.69360	0.00003
32.5001	34.7410	6.06435	6758.87	6.06434	-0.00001

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



Post-processing hydrological data acquired during the expedition TARA ARCTIC

Laboratoire d'Océanographie de Villefranche

Vincent Taillandier, March 2014

Deliverable

SBE format configuration files are provided for every raw file of the dataset. Straightforward modification of processing tool would consist in changing the prior configuration file name by the profile ID.

Instrumental aspects

The expedition TARA ARCTIC was lead during the summer 2013 (from May to October), onboard a two-mast sailing ship of 36m equipped with a CTD-Carousel (SBE917 technology). In particular, this instrumentation was composed of a sole pressure sensor inside the SBE9 body, and of two independent water ducts crossing pairs of temperature-conductivity sensors entrained by their own pumps. The first parameter was measured by a thermal cell (SBE3 technology), the second parameter was measured by a resistive cell (SBE4 technology). Sensor calibrations were performed at the beginning and at the end of the expedition.

The field survey was lead over the Arctic Ocean, covering the different basins around the North pole with coastal stations and open ocean stations. Considering such a synoptic coverage and deep casts (from surface to bottom), this dataset would provide a reference for the hydrological state at the year 2013, together with a significant contribution to the evaluation of its climatological properties. Moreover, physical properties are mainly characterized by convective processes which observation requires high resolution and accuracy on hydrological profiles. This motivates a fine quality control to be addressed in this dataset, including a systematic evaluation of the uncertainties of measurements in order to retrieve data at the instrumental accuracy (in the range of 1 millideg for temperature and 1 centiPSU for practical salinity).

In this report, static corrections associated to sensor drifts are addressed and the way to include them in a proper way is provided in the deliverable.

Sensor drift corrections

Deployments of the CTD between sensor calibrations are welling to significant sensor drifts. However, measurements can be corrected a posteriori using calibration results between pre-cruise and post-cruise baths. Such uncertainties are now addressed considering measured drifts between TC pairs and factory reported drifts of individual sensors.

Differences obtained between two factory calibrations are exploited supposing linear drifts of the sensors during this period. In practice, static drift corrections are performed through [slope] and [offset] values specified in a post-processing instrumental configuration file of each profile (see log sheet below). These coefficients are computed with respect to the following formula:

[slope] = 1 + (t-ti)/(tn - ti).(1/[postslope] - 1)

[offset] = (t-ti)/(tn-ti).[residual]

where ti is the date of pre-cruise bath, tn the date of post-cruise bath, and t the time of the cast. [postslope] is slope from calibration sheet of the C sensors; [residual] is taken from calibration sheet of the T sensors.

The linear drifts obtained from factory calibrations are now compared with the measured misfits between pairs before and after drift corrections.

Considering temperature (Figure 1), the primary sensor SN2492 was used during the whole expedition, the secondary sensor was changed after the first leg. Static drifts (variables T1msT1P and T2msT2P) remained under 1mdegC, with slightly higher amplitude for the secondary sensor. The relative misfit associated to the static drift is about 0.4 mdegC at the beginning of the expedition, and 0.8 mdegC at the end of the expedition. This is in agreement with the relative drifts between pairs (variables T2msT1 and T2PmsT1P), which remained under 0.8 mdegC and maximum amplitude under 1 mdegC.

Considering salinity (Figure 2), the primary sensor has been changed for the two last legs, and the secondary sensor has been changed for the last leg. Note that the secondary sensor used in the fist part of the expedition has not been corrected in lack of post-cruise bath. Note also that salinity corrections account for contributions of both temperature and conductivity sensors. The analysis of the results shows that static drifts (variables S1msS1P and S2msS2P) follow the sensor permutations. Correction on primary salinity was larger considering that both temperature and conductivity were adjusted. The relative misfit associated with static drifts ranges between 0.5 and 2.5 mPSU during the first part of the expedition, then decreases to 0 during the last leg. This is in agreement with the relative drift between pairs (variables S2msS1 and S2PmsS1P) which relative misfit remained under 3mPSU. Overall, S2msS1 reached amplitude of 4mPSU although S2PmsS1P was limited to 2.5mPSU because the secondary conductivity sensor was not corrected for the first part of the expedition.

Conclusions

Leg-by-leg hydrographical profiles plotted in annex provide a first insight of the quality of this dataset. Hydrographic measurements reveal stable and consistent properties at the different sampled stations.

An analysis of relative drifts measured in-situ together with factory reported drifts reveal an overall agreement between misfits and well constrained uncertainties associated to static drifts. Overall, a nominal accuracy under 0.001 degC and under 0.005 PSU has been achieved.

Figure 1

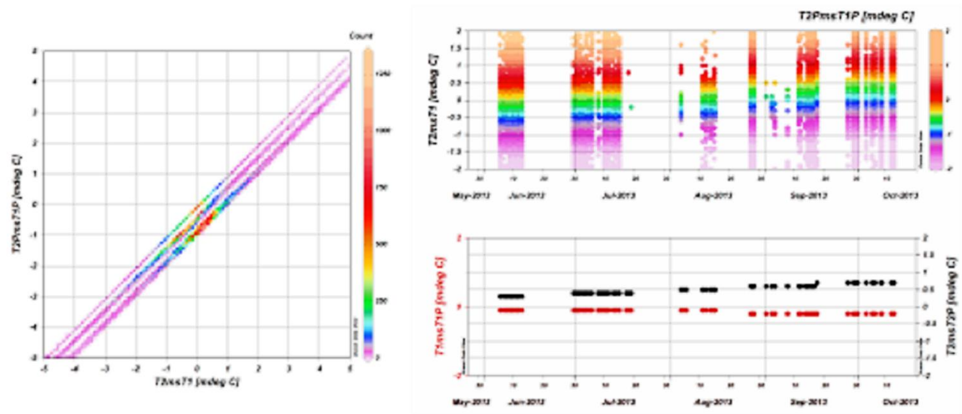
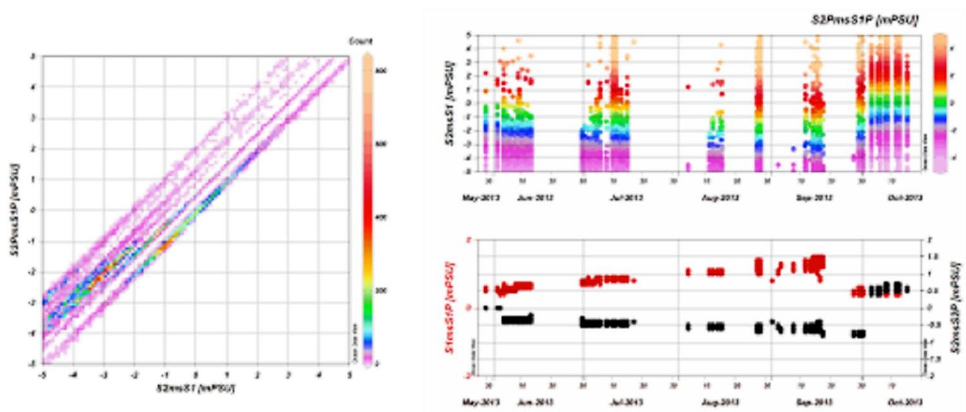
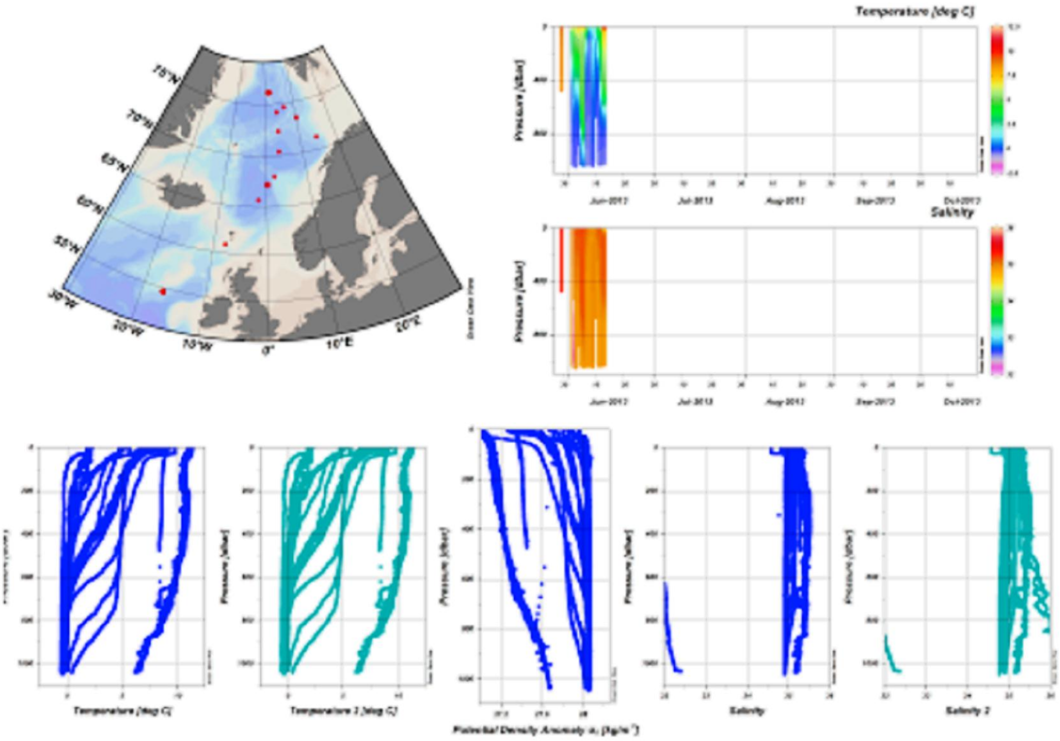
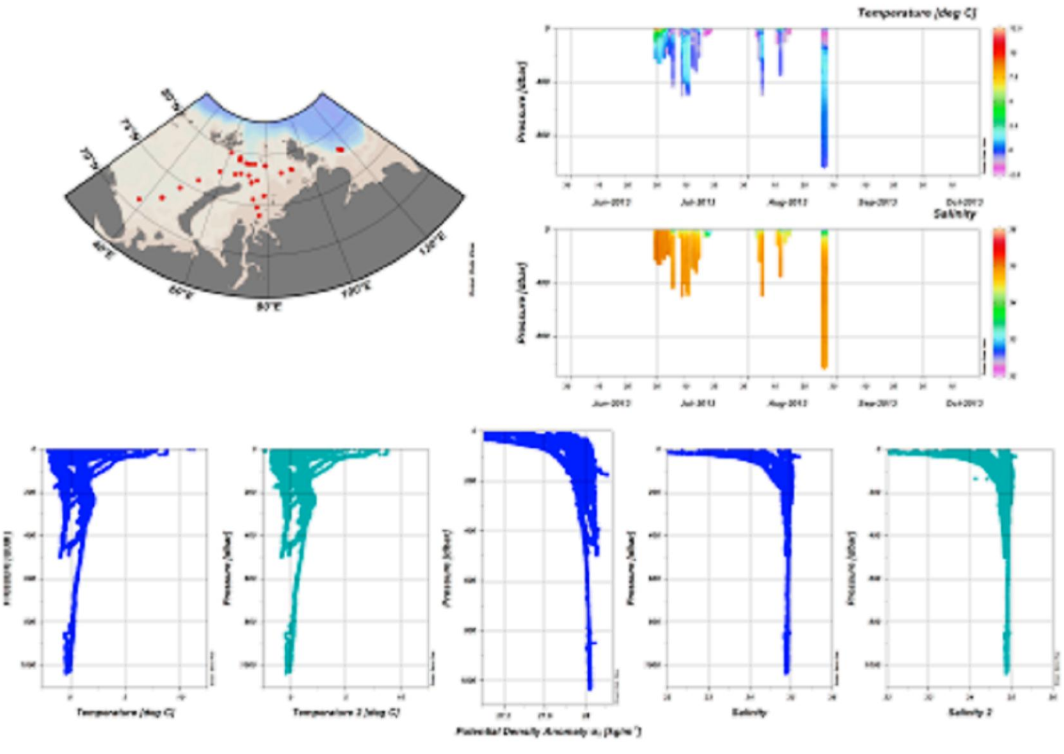
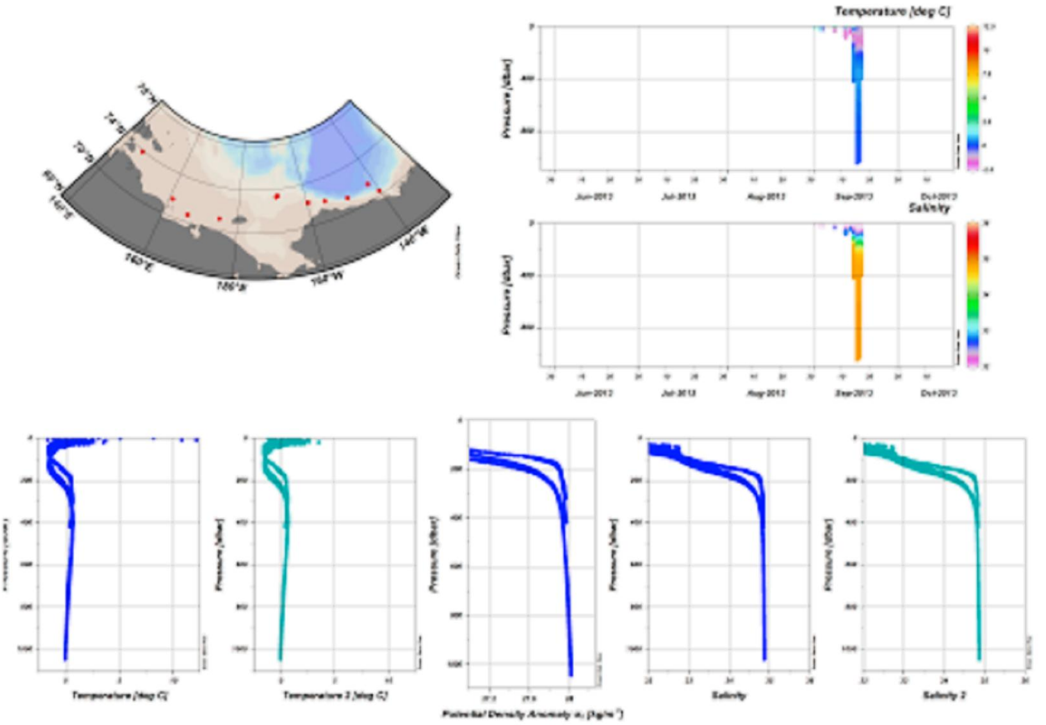


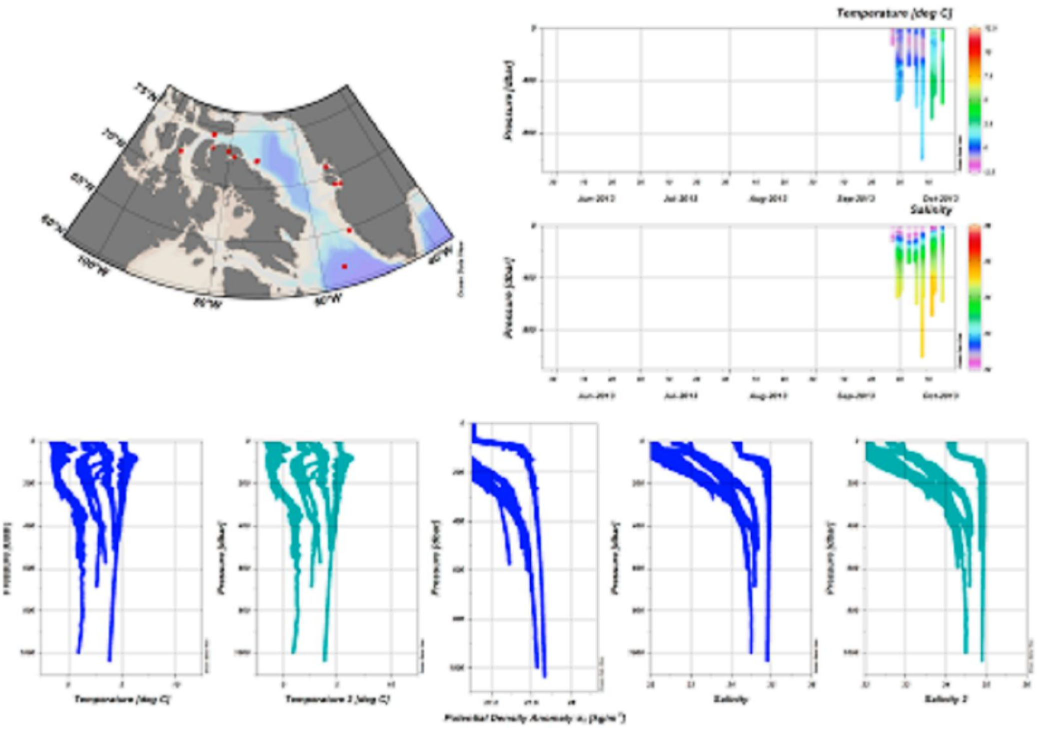
Figure 2




Temperature [deg C]
Salinity
Jun-2013
Jul-2013
Aug-2013
Sep-2013
Oct-2013
Temperature [deg C]
Temperature 2 [deg C]
Potential Density Anomaly σ₀ [kg/m³]
Salinity
Salinity 2


Temperature [deg C]
Salinity
Jun-2013
Jul-2013
Aug-2013
Sep-2013
Oct-2013
Temperature [deg C]
Temperature 2 [deg C]
Potential Density Anomaly σ₀ [kg/m³]
Salinity
Salinity 2


Temperature [deg C]
Salinity
Pressure [dbar]
Jun 2013
Jul 2013
Aug 2013
Sep 2013
Oct 2013
Temperature [deg C]
Temperature 2 [deg C]
Potential Density Anomaly
Salinity
Salinity 2


Temperature [deg C]
Salinity
Pressure [dbar]
Jun 2013
Jul 2013
Aug 2013
Sep 2013
Oct 2013
Temperature [deg C]
Temperature 2 [deg C]
Potential Density Anomaly
Salinity
Salinity 2

APPENDIX 3: Salinity samples analysis for leg 7

Instrument : Autosal sn 60134
Bath at controlled temperature for 24h
Standard water patch 147: K15=0,99982
(2Rt=1,99964) sal=34,993 PSU

sampling number	**T° de consigne (°C)**	**4 digits control**	**hour measure (hh:mm)**	**T° ambiant (°C)**	measure 2xRT	**calculated Salinity***	**Corrected salinity****	**2xRT corr.*****	**Corrected salinity******
K5	27	5040	14:53	24,6	2,03153	35,6222	35,6220	2,0315	**35,6220**
K4	27	5041	15:00	24,6	2,02845	35,5615	35,5610	2,0284	**35,5610**
K3	27	5041	15:06	24,9	2,01024	35,2020	35,2013	2,0102	**35,2013**
K6	27	5041	15:15	24,9	2,02676	35,5280	35,5271	2,0267	**35,5271**
K2	27	5041	15:23	24,9	2,02005	35,3955	35,3944	2,0200	**35,3944**
K1	27	5041	15:30	24,9	1,94467	33,9122	33,9109	1,9446	**33,9109**

* : function sw_sals from seawater toolbox with T °C (ITS-90):

S = 0,0080 + (-0,1692 + (25,3851 + (14,0941 + (-7,0261 + 2,7081*RACINE(Rt))*RACINE(Rt))*RACINE(Rt))*RACINE(Rt))*RACINE(Rt) + (((T) * 1,00024 - 15)/(1+0,0162*((T) * 1,00024 - 15)))* (0,0005 + (-0,0056 + (-0,0066+ (-0,0375 + (0,0636 + (-0,0144)*RACINE(Rt))*RACINE(Rt))*RACINE(Rt))*RACINE(Rt))*RACINE(Rt))

** : Scorr= Scalc- (delta psu/delta t)*(t-tinit)
*** : Cond_corr = Cond_meas. - (delta Cond/delta t)*(t-t_init)

sample	year	month	day	hour	latitude	longitude
K1	2013	11	29	19:27	48,92	-36,96
K2	2013	11	30	12:53	49,31	-33,18
K3	2013	12	1	19:06	49,97	-26,73
K4	2013	12	3	12:21	49,64	-18,01
K5	2013	12	4	15:44	48,78	-12,89
K6	2013	12	5	15:33	48,58	-8,67