The 2008 North Atlantic Bloom Experiment Calibration Report #8 Intercalibration of the CTD Sensors from Seagliders 140, 141, 142 and 143, R/V Knorr and R/V Bjarni Saemundsson cruises

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Version 2.1

June 23, 2010

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1 Summary

The conductivity and temperature (CT) sensors on all four Seagliders, the Knorr cruise 193, the instrument deployment and recovery cruises on the Bjarni Saemundsson, and the pre- and post-cruise lab calibrations performed by Sea-Bird Electronics (for SG140, 141 and 143) were compared. As with Floats 47 and 48 (Calibration Report #1), the Knorr CTD was used as the absolute standard, but due to the relative scarcity of designated CTD calibration casts, formulae applied to bring the Seaglider CT measurements into alignment (as of Seaglider Timeseries v1.1) were validated among the Seagliders across the duration of the experiment.

2 Analysis of Seaglider CT Data

2.1 NAB Seagliders

2.1.1 Instrumentation

NAB Seagliders were outfitted in a variety of configurations: SG140 and SG141 carried the original high voltage(24V) batteries and the new big low voltage (10V) batteries, whereas SG142 and SG143 carried the "extended range" or big versions of both batteries. All gliders were outfitted with custom Sea-Bird Electronics CT sails (section 2.1.3), and both the Sea-Bird Electronics SBE43f and Aanderaa Optode dissolved oxygen sensors. Seagliders 141, 142 and 143 carried WetLabs custom "EcoPucks" or "Triplets" with 3 channels each: high-sensitivity Chl-a fluorescence, CDOM fluorescence, and optical backscatter at 532 nm.

Table 1: NAB Seaglider Sensor Assignments

Seaglider	Seabird C/T	? Pressure	WetLabs BB2F	WetLabs ECO-Triplet	Seabird SBE43f	Aanderaa Optode
140	0062	2458946	392	-	127	769
141	0063	2458945	388	449	131	016
142	0069	?	395	448	125	013
143	0036	2237115	387	447	126	014

2.1.2 Sampling Scheme

From the Seaglider Pilot's Guide: "The Seaglider flight control scheme has two guiding principles: maintain constant vertical velocity and minimize the total energy expenditure

during a dive." The Seaglider sampling scheme is set by timing, not depth, so to get profiles of measurements that are sampled evenly in depth as oceanographers are familiar with the glider needs to descend and ascend at a constant rate. This rate is calculated from parameters set by the pilot: the dive cycle's target depth (**$D_TGT**) and the time in which to complete it (**$T_DIVE**) (not including the time required to pump the VBD at the bottom of the dive). A **$D_TGT : $T_DIVE** ratio of 1:3 yields a $w_d = 10$ cm/s.

The sampling rate of sensors on-board the glider is set by the pilot through the **science** file. Here are two example files from SG141's NAB2008 deployment:

science.100: All sensors are turned on to a depth of 150m; the BB2F measures to a depth of 900m (even though it is rated for 600m depth); the Aanderaa optode samples to a depth of 600m, and again between 900 and 975m depth); and the SBE CT and Oxygen sensors sample at each gc (guidance & control) interval at all depths.

```
/CT,SBE43f,Optode,WL-BB2F,WL-VMT
/depth  time   sample    gcint
50       5     11111     120
150      5     11123     300
350      5     11440     300
600      10    11880     300
900      20    11000     300
975      20    11800     300
1500     20    11000     300
```

science.169: the SBE CT and Oxygen sensors and the Aanderaa optode sample as before. The triplet (WL-VMT) was turned off because there was no discernible CDOM signal, chl-a fluorescence measurements were verified to be redundant with those taken by the WL-BB2F, and backscatter in 532nm effectively repeated backscatter in 470 and 700.

```
/CT,SBE43f,Optode,WL-BB2F,WL-VMT
/depth  time   sample    gcint
50       5     11110     120
150      5     11120     300
350      5     11440     300
600      10    11840     300
900      20    11080     300
975      20    11800     300
1500     20    11000     300
```

SG141d100: 25 Apr 2008. SG141d169: 11 May 2008.

The mean time and depth interval between temperature and salinity samples for the bins defined above during SG141's dive 100 are listed below (table 2.1.2).

Table 2: NAB2008 SG141 dive 100

Depth Bin	desc/ascent	dt (s)	dz (m)
5-50	descent	5.34	0.64986m
	ascent	5.4468	-0.73268m
50-150	descent	5.5347	0.62005m
	ascent	5.6279	-0.69261m
150-350	descent	5.6188	0.59247m
	ascent	5.6063	-0.54391m
350-600	descent	10.616	1.0091m
	ascent	10.6384	-1.0655m
600-900	descent	20.4843	1.8204m
	ascent	20.4812	-2.17m

Note: **NAB_get_sampling_rate.m** does not take into account NaNs in the sensor data. In general, this does not affect T and S sample rates since T and S are measured at every sampling interval, but it does affect auxiliary sensors such as the WL-BB2F, which may make a measurement once every n sampling intervals.

2.1.3 Unpumped Sea-Bird CT Sails

From Eriksen, et al. 2001:

- Temperature
  A Sea-Bird Electronics SBE 3 thermistor is mounted on the leading edge of a small fin that penetrates the top of the fairing between the wings. It is wired to electronics boards in the aft portion of the pressure hull.

- Conductivity
  A Sea-Bird Electronics SBE 4 conductivity cell is mounted on the top of the sensor fin in close proximity to the thermistor. To save power, the cell is flushed by flow past the glider instead of being pumped as is normally the case for profiling SBE conductivity sensors. This is possible because glider speed changes only slowly, providing a nearly steady flushing rate of the conductivity cell, just as provided conventionally by a pump.

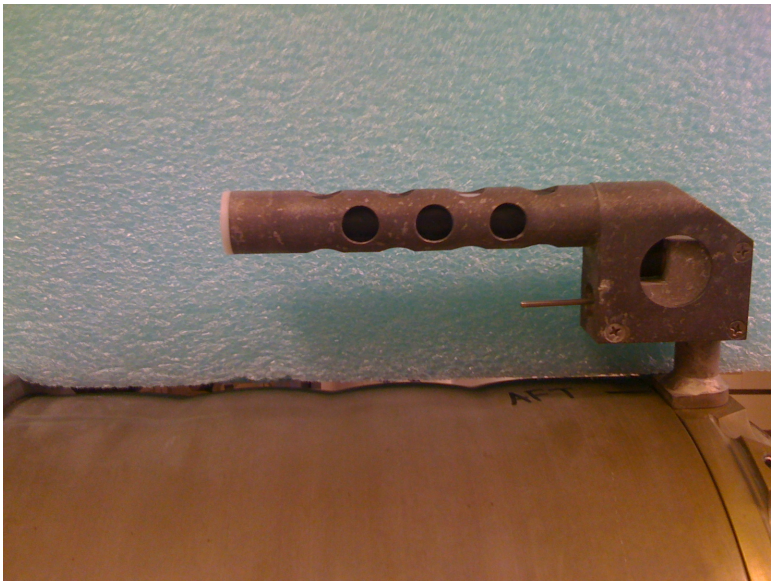


Figure 1: Sea-Bird Electronics"GliderAPL" custom CT sail installed on pressure hull.

Accuracies should be similar to those seen on the Sea-Bird CTD modules deployed on ALACE / Argo floats, but off by a factor of 2 or so (from conversations with Norge Larson and Carol Janzen at Sea-Bird Electronics, 20 August 2009). From `http://www.seabird.com/alace.htm`, detailing the Sea-Bird CTD module deployed on ALACE / Argo floats:

Table 3: Sea-Bird CTD Module (pumped) Sensor Calibrations

Sensor	Calibration to . . .	Accuracy
Temperature	ITS-90	0.002 deg C
Conductivity	Standard Seawater	0.005 psu equivalent

2.1.4 T/S Calculation

A mistake in the calibration sheets for SN0062 (SG 140) and SN0063 (SG 141) was corrected in the post-deployment calibrations for SN0062 and SN0063 (section 2.3); thus v1.0 of the Seaglider timeseries temperature and salinity data uses the post-deployment calibration coefficients for SG140 and SG141 and pre-deployment for SG142 and SG143. A further correction applied to temperature and conductivity frequency was applied to SG140 in v1.1, based on the Knorr process cruise calibration cast. This correction is applied to the raw data, prior to processing by the Seaglider Basestation.

It is assumed that most users of the NAB data would like clean, smooth data to work with, and this is provided in the fields `T`, `S`, `Th` and `Sig0`. Down-stream calculations that rely on temperature and salinity, such as optical backscatter, are performed using the corrected data.

The following algorithm (`IOP_smooth_glider_TS.m` and `sg14[0-3]_remove_baddata.m`) was applied on a per-dive basis:

1. Flag `temp`, `conductivity` and `salinity` measurements that the Seaglider basestation determined were out of range and replaced with NaNs.
2. Flag and replace all measurements beyond minimum and maximum values with NaNs.
   Temperature: [2 13]
   Salinity: [34.2 36]
3. Flag spikes (3 IQR above or below the median in windows of 15 contiguous measurements) and replace with NaNs.
4. Linearly interpolate over NaNs.
5. Smooth the result with an 11-point median filter.

`Th` and `Sig0` are calculated from the smoothed, degapped `T` and `S` fields. The ability to go back to the raw (v1.1) data is preserved via the fields: `temp`, `salinity`, `sigma_0`, and `sigma_theta`. Additionally, quality flags are provided in the fields: `temp_flags`, `conductivity_flags` and `salinity_flags`. The flags are defined:

Table 4: NAB Seaglider Data Quality Flags

flag	description
0	nothing to report (fine)
1	out-of-range as defined by preliminary data processing code (for Seaglider this is a hardcoded range in the basestation code)
2	out-of-range as defined by NAB project
3	local outlier
4	uncorrectable sensor issue (something stuck in the conductivity sensor to some depth)
5	correctable sensor issue (an obvious offset or pressure dependance)

2.1.5 Example Description of TS Calibrations Suitable for Methods Section

Seaglider T/S processing includes first-order lag corrections to raw (frequency) measurements of temperature and conductivity to reduce salinity spikes due to temperature latency

(cite?). Outliers and spikes (3 IQR above or below the median in windows of 15 contiguous measurements) were interpolated over, uncorrectable sensor issues (typically extended periods of bad data in the conductivity sensor) were removed, and the resulting timeseries smoothed with an 11-point median filter. Comparing TS diagrams of Seaglider and CTD calibration casts avoided the variation of depth-dependence of TS properties with horizontal separations >1km; SG140 required additional offsets of 5.0392 in temperature frequency and 0.0046 in conductivity frequency. Pre- and post-deployment calibrations by SBE of 3 CTs showed drifts on the order of of nnC temperature and nn salinity.

2.2 SG 143: Noise

The C /T sail on SG 143 was very noisy from nearly the first NAB dive. From an email on 17 April 2007:

```
I double-checked the calibrations for all the gliders' CT sails, and they check out.

However, the story on SG143 is:
1) The thermistor on CT Sail was broken sometime around freshwater tank testing
2) It was replaced w/ CT Sail # 36.
3) It flew with CT Sail #36 in Port Susan (8 Mar) and did not have the noise issue
   it is having now.

#36 came off of sg123 (after flying in the Kuroshio mission) and had been sent to
Sea-Bird for post-cruise calibration. They (Sea-Bird) accidentally broke the
conductivity cell, replaced it at no charge, and re-calibrated it. These new
calibration constants are correctly entered into the sg_calibration_constants.m
file in sg143's home directory on IOPBASE.
```

Looking at the CTD calibration cast and SG143's corresponding dive 165, it appears that conductivity has only a limited spikiness due to lagging issues, but that salinity is very noisy. This noisiness apparently comes from the temperature. The noise issue is further explored in section 6.

The post-cruise calibrations on 23 Oct 2008 showed that SN0036 drifted +0.00100 PSU/Month and -0.04137 degC/yr. No noise problems were noticed by the quality assurance technicians at Sea-Bird Electronics performing the calibrations.

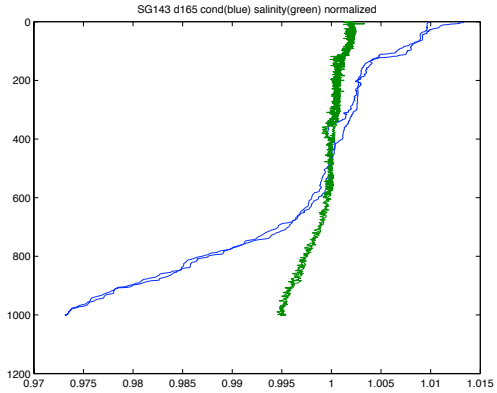


Figure 2: SG 143 Conductivity and Salinity (Dive 165) (post

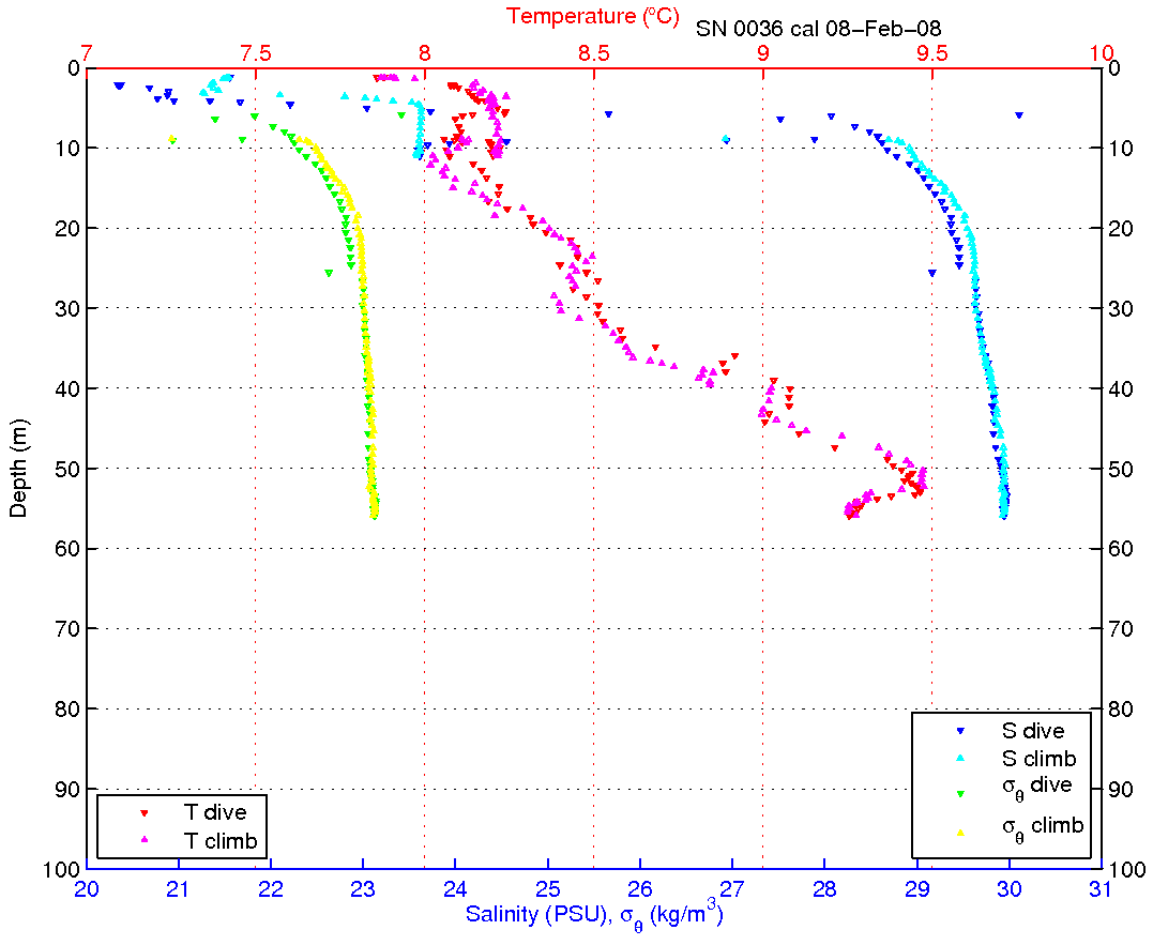


Figure 3: SG 143 Temperature and Salinity, Port Susan 8 March 2008 26:43 - 17:23 (Dive 25)

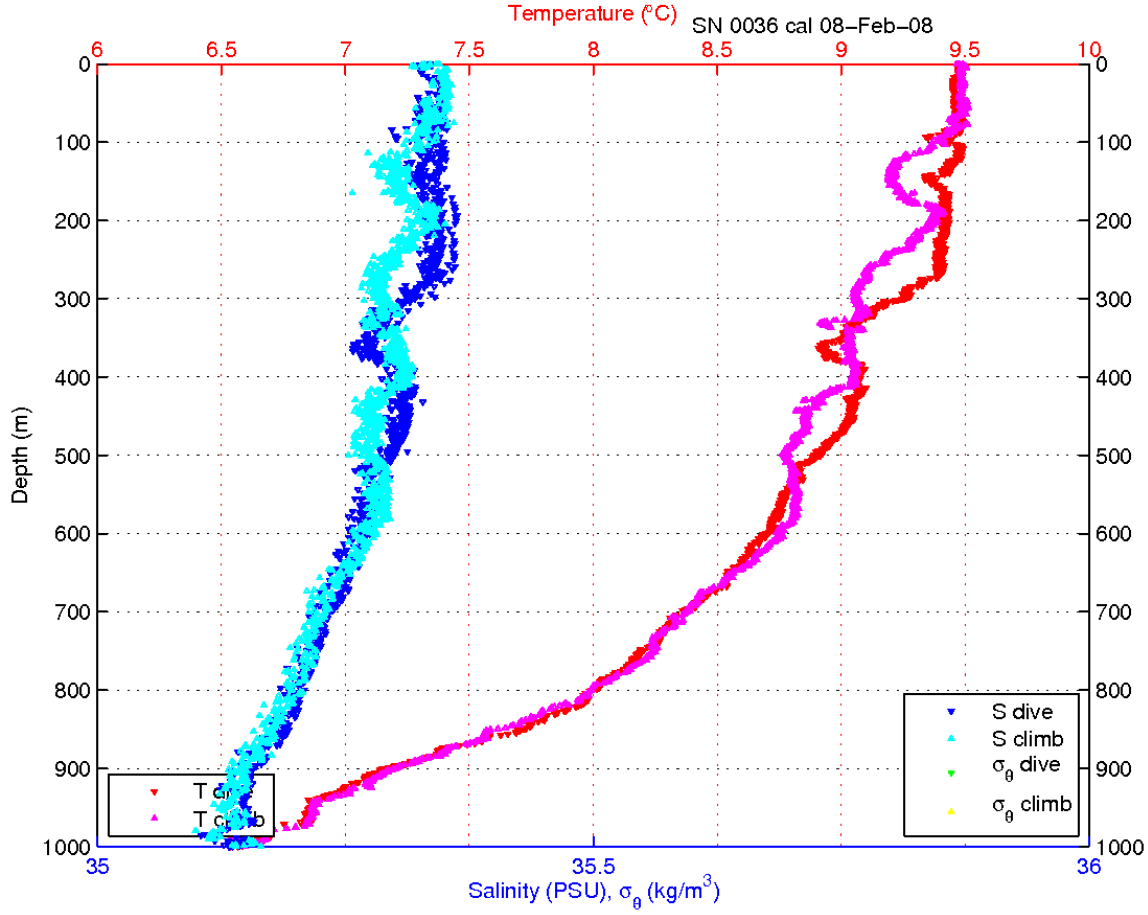


Figure 4: SG 143 Temperature and Salinity, NAB 10 Apr 2008 10:25 - 15:21 (Dive 3)

Information from sg_calib_constants.m in the sg143 directoy:

```
% CT sensors cal constants
calibcomm ='SN 0036 cal 08-Feb-08';     % SN and cal date
t_g     =       4.3273757E-03   ;
t_h     =       6.4184016E-04   ;
t_i     =       2.4188148E-05   ;
t_j     =       2.4070987E-06   ;
c_g     =       -1.0197048E+01  ;
c_h     =       1.1695373E+00   ;
c_i     =       -1.5330453E-03  ;
c_j     =       1.5523175E-04   ;
```

```
sbe_cond_freq_min =     2.7     ; % kHz, from cal for 0 salinity
sbe_cond_freq_max =     8.5     ; % kHz, est for greater than 32.5
sbe_temp_freq_min =     2.7     ; % kHz, from cal for 1 deg T
sbe_temp_freq_max =     6.3     ; % kHz, from cal for 32.5 deg T
```

Near the end of its mission, SG143 suffered an alarming number of pitch errors and so was piloted such that it dove very steeply (70 degrees downward) and climbed at a slightly less pitch (60 degrees downward) to a maximum of 500 m depth, essentially floating upwards tail-first. Thus the flow through the conductivity cell is atypical, and the turbulence during the climb renders the salinity and temperature values extremely noisy – therefore the temperature and salinity values from sg143 during all climbs are highly suspect from dive 253 (25 May, YD 146) to the end of its mission (3 June, YD 155).

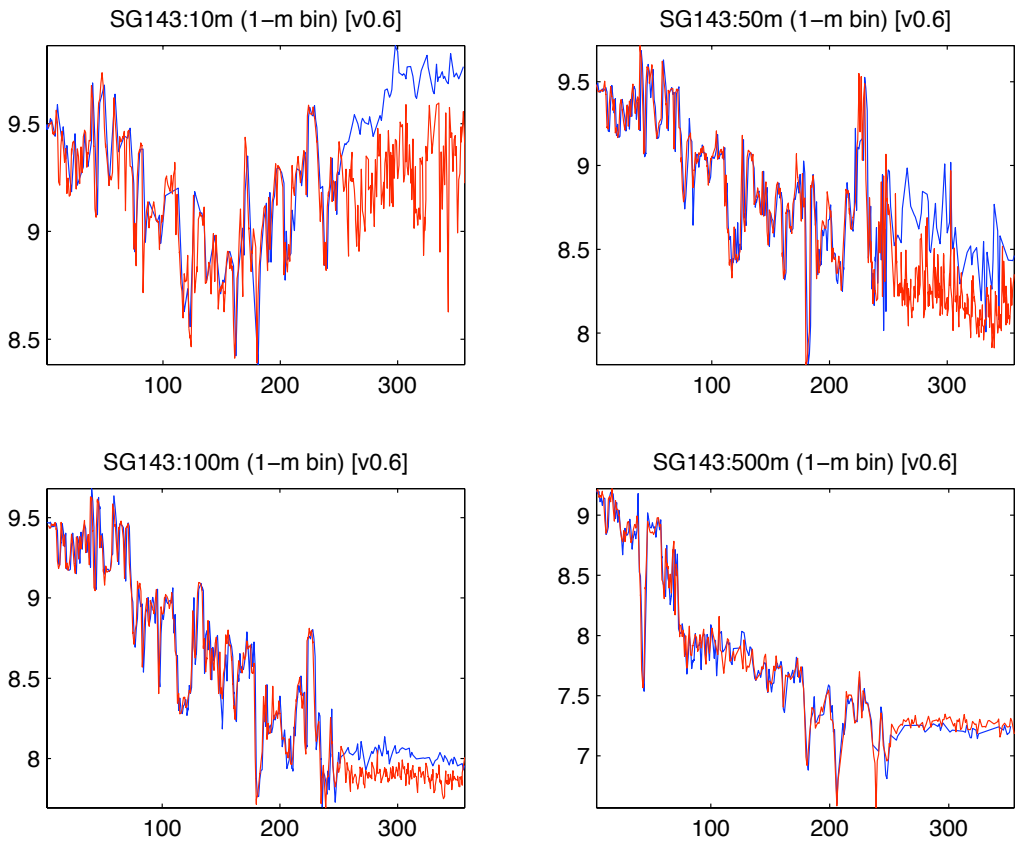


Figure 5: v0.6 Temperature measurements by SG 143 during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bins, separated into descending (blue) and ascending (red) portions of the dives.

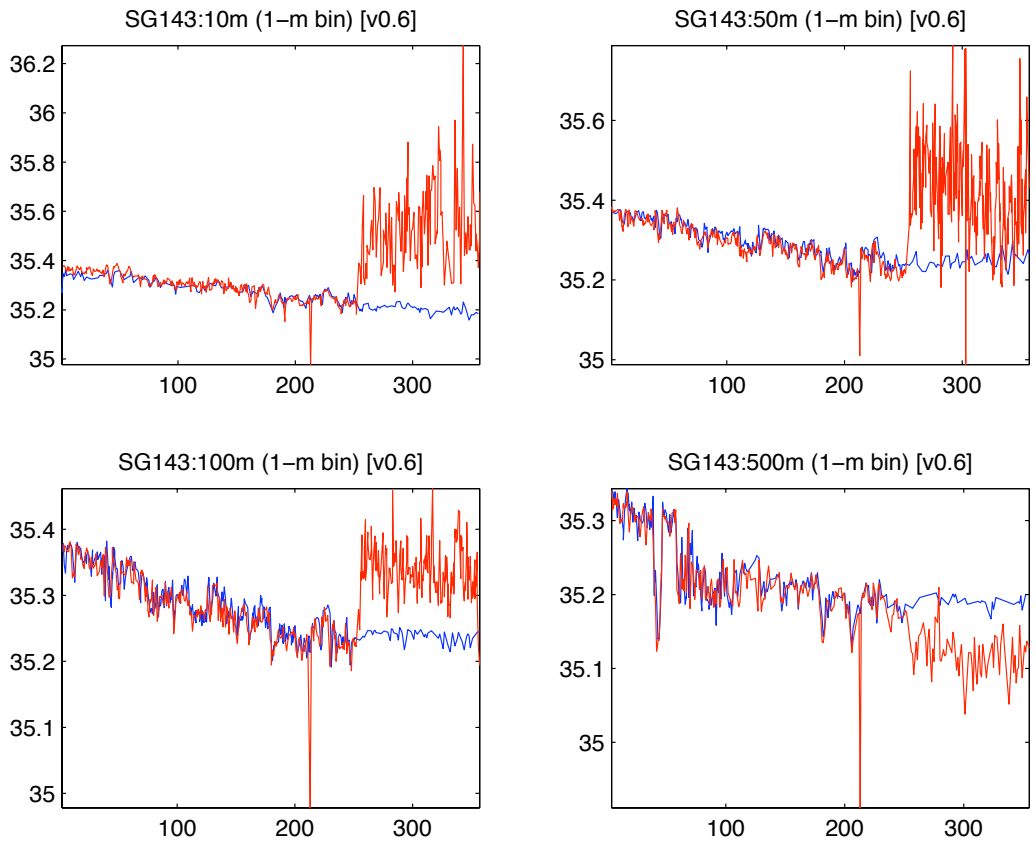


Figure 6: v0.6 Salinity measurements by SG 143 during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bins, separated into descending (blue) and ascending (red) portions of the dives.

Dives 253+ should be removed from the published dataset

2.3 SG140 and SG141: Flipped Calibrations

A mistake occurred during the initial pre-cruise calibrations for the CT sails installed on SG140 and SG141; the serial numbers of the two CTs were switched on the pre-deployment calibration sheets.

The post-cruise calibrations showed that SN0063 drifted 0.0000 PSU/Month and -0.01245

degC/yr, and SN0062 drifted +0.0004 PSU/month and -0.00469 degC/yr. But the calibration constants for the pre-cruise SN62 and the post-cruise SN63 are more similar than the original SN62 and the post-deployment SN62; the same is true for the original SN63 and the post-deployment SN62.

This was verified by Carol Janzen at Sea-Bird; the pre-cruise calibrations were performed the same week that Sea-Bird was switching their internal record-keeping system from one database to another. The NAB Seaglider timeseries data for SG140 and SG141 have been built from re-processed source data using the post-cruise calibrations; the source data on Sahale (the IOP site) has not yet been re-processed and made publicly available (as of 2 Mar 2010).

The dates on the cal sheets are:
SN062 24-Jun-07, SN062 23-Oct-08
SN063 17-Jun-07, SN063 22-Aug-08

The errors in the cal sheets resulted in temperature measurements by SG140 and SG141 that were off by nearly 2 degrees C compared to SG142 and SG143:

```
From: "Gliders" <Gliders@ocean.navo.navy.mil>
Date: April 17, 2008 12:48:17 PM PDT
To: "Geoff Shilling" <gbs@apl.washington.edu>
Cc: <craig@apl.washington.edu>, "Gliders" <Gliders@ocean.navo.navy.mil>
Subject: RE: Glider data feeds


Geoff/Craig,

We are getting the glider data feeds...Thanks!  While looking at the
data for 141, we are noticing a large offset with both the temperature
and salinity data compared with both climo and the other nearby gliders.
You may want to double check the coefficients of the sensors in the
sg_constants.m file.  The reason I say this is because we saw this in
two of our gliders the first time we flew them, although ours were just
in the conductivity sensor.  Let me know if you find anything or if
there is a very large variability in the area.

Thanks,
Steve Crossland
```

3 Pre and Post- Cruise Sea-Bird Electronics Calibrations

Sea-Bird Electronics maintains a history of sensor calibrations in-house; when an instrument is returned for post-deployment calibration, its current calibration is compared to the previous one, and the difference reported as drift in the T and C sensors :

`NAB_calculate_CT_drift_over_experiment.m`

```
SG140: SN0062
approximately -0.0062576 degC and
0.0064044 PSU equivalent over the experiment

SG141: SN0063
approximately -0.0022512 degC and
0 PSU equivalent over the experiment

SG143: SN0036
approximately -0.029242 degC and
0.0084822 PSU equivalent over the experiment
```

Recall that these sensors are considered accurate to 0.002 deg C and 2x0.005 psu.

Calibration at the Sea-Bird Electronics Facility in Bellevue/Redmond, WA:

- C gets pumped at 2k (whatever usual units, pretty fast): guessing this mimics the flow gliders experience in-situ.
- The instrument is placed in a net for filtration (figure 7)
- There is one reference thermistor in the bath; the bath is circulated.
- NaCl is used for glider CTD.
- if there's a lot of drift, especially if sand or diatomaceous "junk" was run through the sensor, it will "get C&P" (cleaned and platinized) and re-calibrated before being returned.

After the calibration, there is a final salinity check for the glider CTs in which the CTs are placed back in the bath to verify the cal coefficients result in correct readings (since we do the frequency output).

Sea-Bird also performs pressure testing of sensors to ensure the security of seals, etc., but not to check the validity of measurements at depth. Deep pressure testing (3 pressure bombs on-site) is performed down to 10k PSI, and there is one shallow pressure tester for testing cycling of seals and such.

Data processing how-tos are on the training section of the site: `http://www.seabird.com/training/TrainingHandouts.htm`

DoE has matlab scripts with seabird's algorithms, More technical data is in application notes.

Figure 7: Glider CTD prepared for calibration at Sea-Bird Electronics: a pump is placed on the back end of the conductivity cell to maintain a 2k flow, and the entire unit is placed in a bag to serve as a filter.

4 Temperature and Salinity Offsets

4.1 Methods for Determining the Offsets

In the following analysis, the Knorr CTD Calibration casts are favored because there was an individual high-quality calibration cast performed at the start of the process cruise on board the Knorr for all four Seagliders, and the Knorr dual-CT sensors were more recently calibrated and (it is assumed) generally better maintained than those aboard the Bjarni Saemundsson. Furthermore, only SG140 and SG141 received calibration casts at recovery, and there was only one calibration cast for all four gliders during the deployment cruise.

Because salinity depends on temperature, the temperature measurement must be fixed before salinity; but then salinity may need to be re-adjusted. Four methods for determining

the offsets were tried (prior to the discovery of the calibration mistake). First, an offset to be added to the glider temperature value was selected by eye that would line up the features in the water column seen during the Knorr process cruise calibration casts (Figure 8). Second, temperature and salinity offsets were determined by taking the mean difference between the values reported by each glider and SG 142, the Seaglider most aligned with the Knorr CTD without modification, at select depth bins over the course of the experiment. Third, the calibration casts were used to select temperature offsets in θ_{35}-S space, by eye. Finally, Jason Gobat suggested looking for offsets in *frequency* between the gliders and the CTD calibration casts (back-calculated from salinity and temperature using the glider's own frequency calibrations): `NAB_CT_freqoffset_JGobat.m`. The mean difference (error, either algebraic mean difference or root mean square difference for the entire profile, the homogenous zones) between the frequency recorded for temperature and conductivity of the glider and the CTD, from the surface to the depth reached by the CTD, is taken to be the offset and added back to the original data.

This last technique avoids the temperature-salinity dependency problem and calculates the offsets in the units to be applied, but it compares a lag-corrected measurement from the CTD to the uncorrected measurements from the Seaglider. However, lag corrections make very small changes to the raw Seaglider profiles, and this small effect is not significant. After the cal sheet problem was discovered and the "new" calibration coefficients applied (v1.0), the frequency-offsets were calculated for each Seaglider against its R/V Knorr calibration cast; the results (v1.1) were verified in θ_{35}-S space and by intercomparing Seaglider temperature and salinity in select bins across the duration of the experiment.

4.2 History: Lining up Original (pre-v1.0) Data

4.2.1 Frequency and Calculated Value Offsets

Table 5: Original data: difference between glider C/T frequency and Knorr calibration cast C/T frequency.

Offset	SG 140	SG 141	SG 142	SG 143
Mean Temperature	-1.6233	1.6796	-0.0024529	0.020568
Mean T Frequency	-125.5055	129.9897	-0.19345	1.5355
Mean Conductivity	-0.16303	0.17891	8.5018e-05	0.00064526
Mean C Frequency	-0.11525	0.12062	5.7452e-05	0.00043708
Mean Salinity	-0.14654	0.21249	0.0052028	-0.011799

4.2.2 Making the well-mixed (homogenous) regions match in Θ_{35} "by eye":

```
Bulk Offsets:
~~~~~~~~~~
Lining up / matching well-mixed portions of SG and Knorr calibration CTD cast
Theta_35 profiles:

SG140:  1.6902
SG141: -1.6968
SG142:  0.0053
SG143: -0.0535
```

The original, raw data was not released to the wiki, due to data quality concerns. The temperature offsets calculated above were used to generate v0.5 of the Seaglider mission timeseries, posted on the IOP wiki. For comparison with Figures 9 and 10 (temperature) and Figures 11 and 12 (salinity). This approach was abandoned for v1.0 and after; the plots of the original data are included here for completeness.

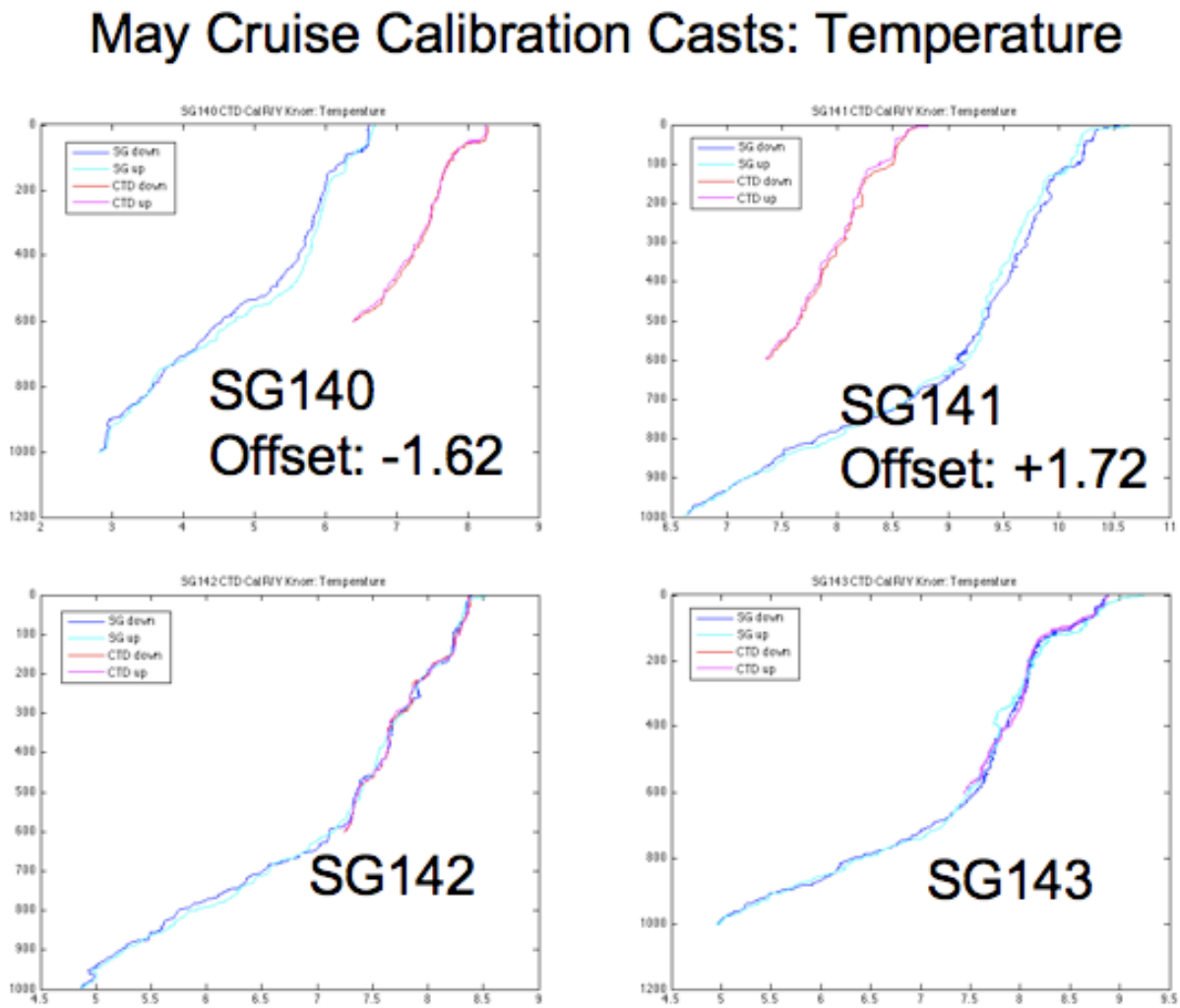
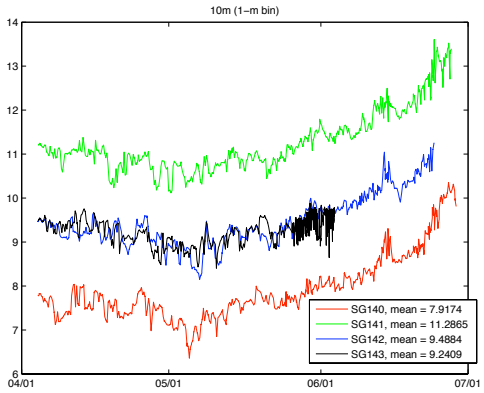
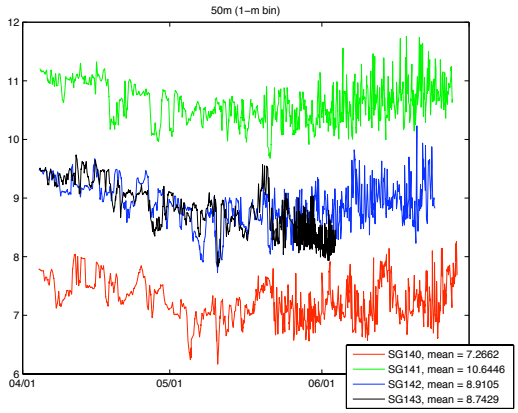


Figure 8: Knorr Process Cruise Calibration Casts and Seaglider Descents: Temperature.

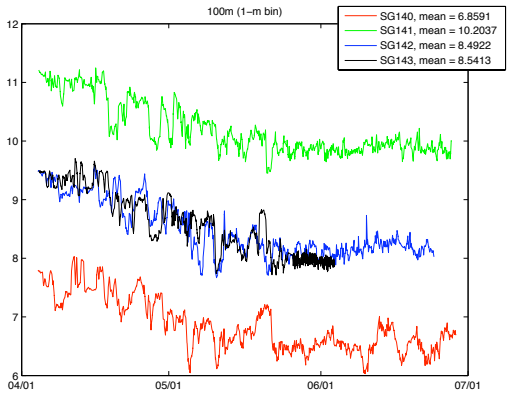
4.2.3 Mean Difference in Temperature / Salinity at Depth m



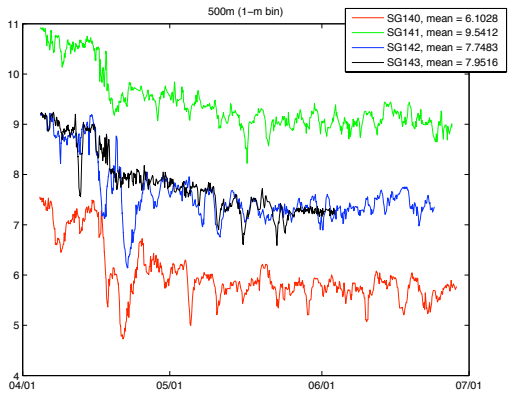
(a) Temperature at 10m



(b) Temperature at 50m



(c) Temperature at 100m



(d) Temperature at 500m

Figure 9: Original Temperature measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 10 m (9a), 50 m (9b), 100 m (9c), and 500 m (9d) .

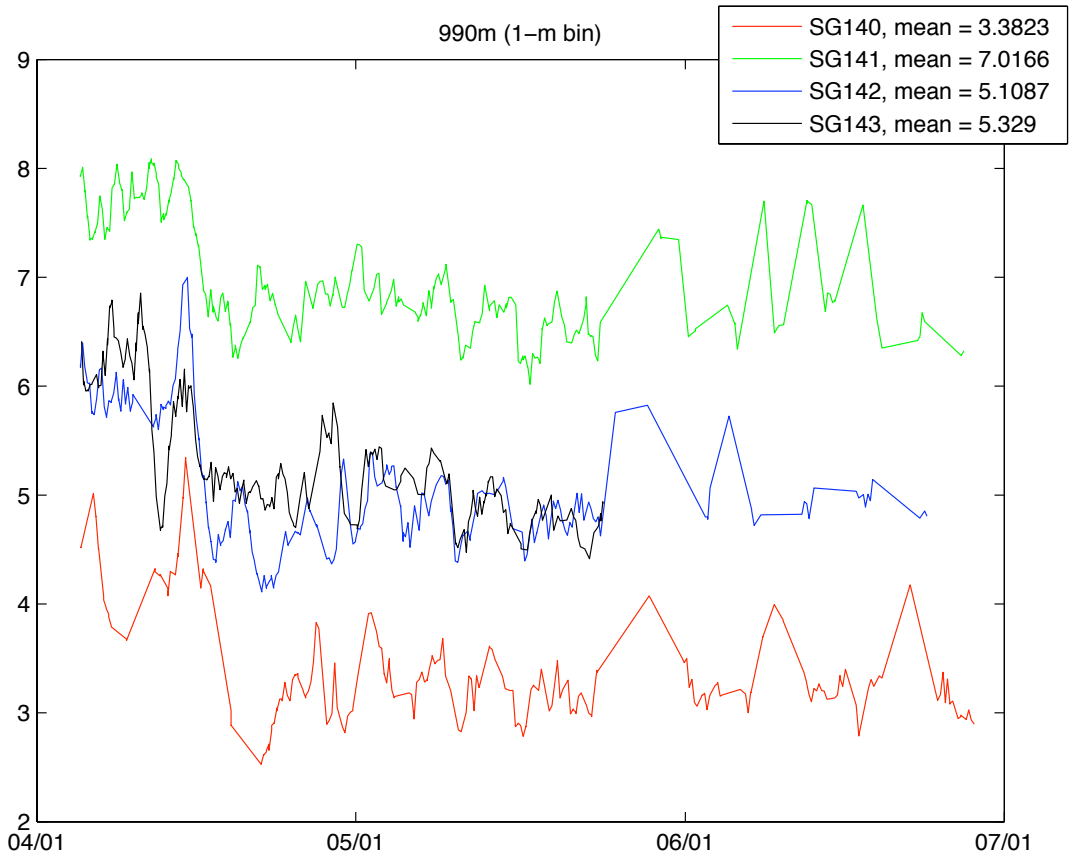
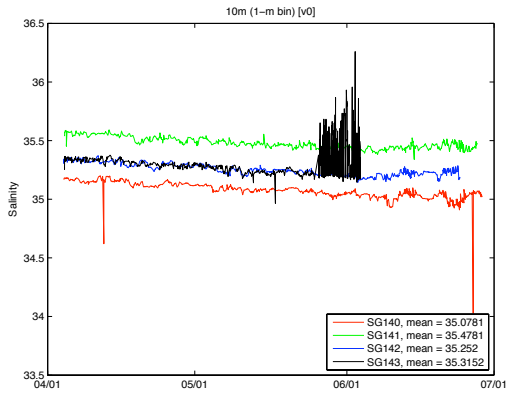
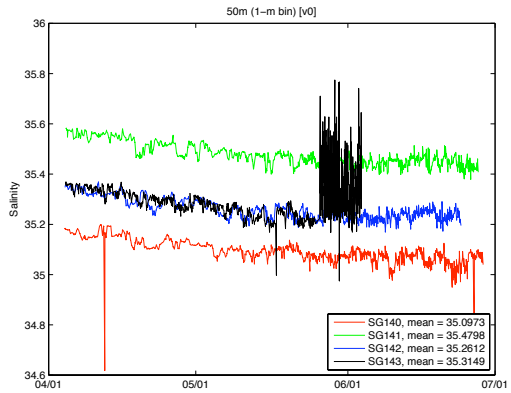


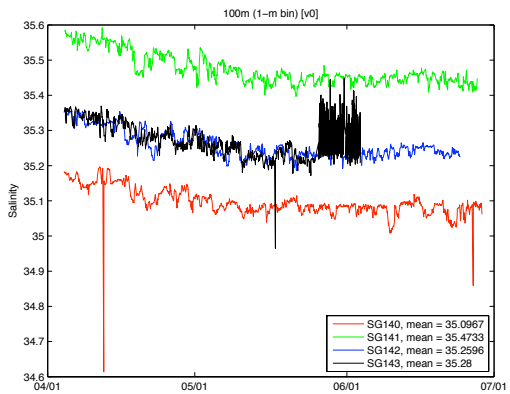
Figure 10: Original Temperature measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 990 m. The jagged look to the data, especially during the final month of the record, is due to an increase in shallow dives as the gliders moved onto the face of the Reykjanes ridge.



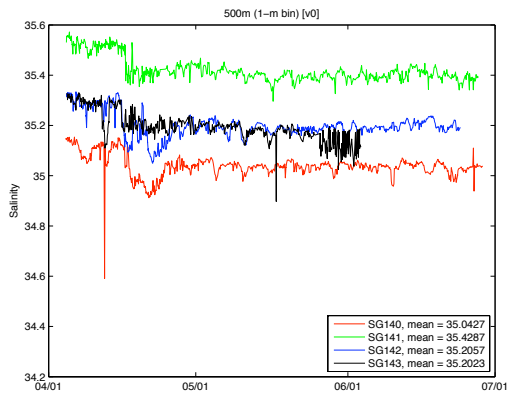
(a) Salinity at 10m



(b) Salinity at 50m



(c) Salinity at 100m



(d) Salinity at 500m

Figure 11: Original Salinity measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1m depth bin centered at 10 m (11a), 50 m (11b), 100 m (11c), and 500 m (11d). The large variability seen in SG 143 (black) starting on 26 May 2008 dive 254 is due to the extreme pitch of the glider's descent and ascent, and resulting poor flow characteristics through the conductivity cell (See Figures 5 and 6).

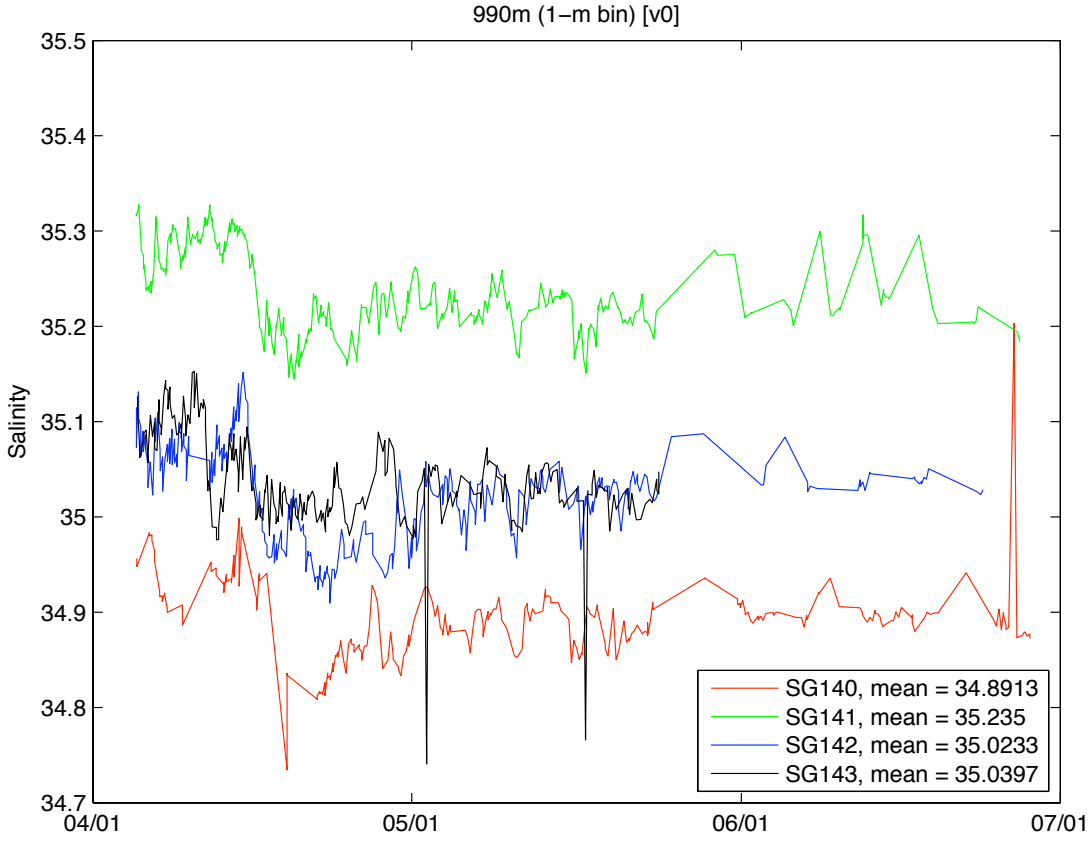
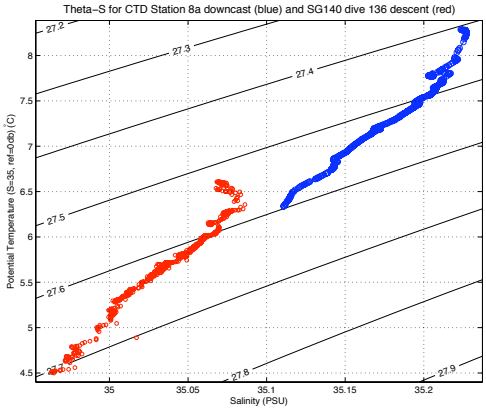
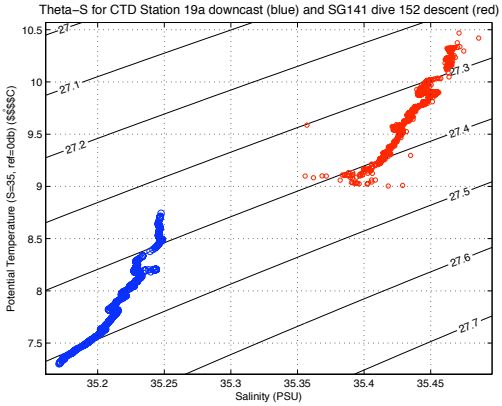


Figure 12: Original Salinity measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 990 m. The jagged look to the data, especially during the final month of the record, is due to an increase in shallow dives as the gliders moved onto the face of the Reykjanes ridge.

4.2.4 θ_{35}-S Space

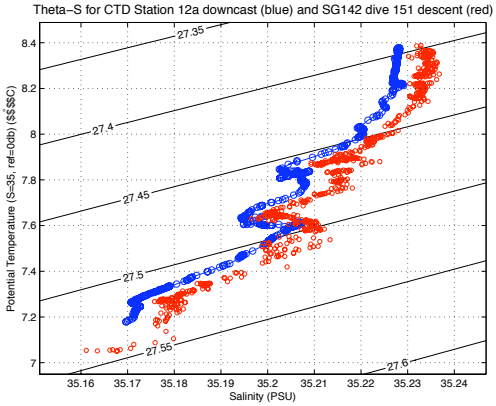


(a) SG140 θ_{35}-S Original Data

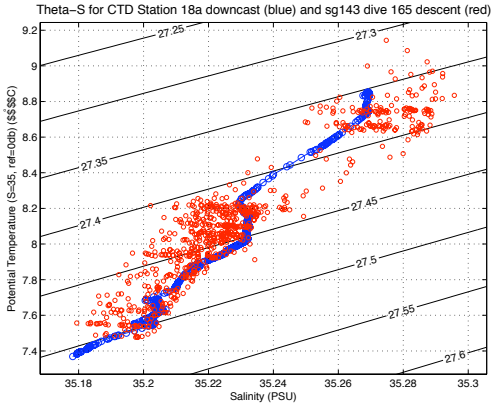


(b) SG141 θ_{35}-S Original Data

Figure 13: Original data. SG 140: Comparison of θ_{35}-S of dive 136 with Process Cruise Calibration Cast 8a. SG 141: Comparison of θ_{35}-S of dive with Process Cruise Calibration Cast.



(a) SG142 θ_{35}-S Original Data



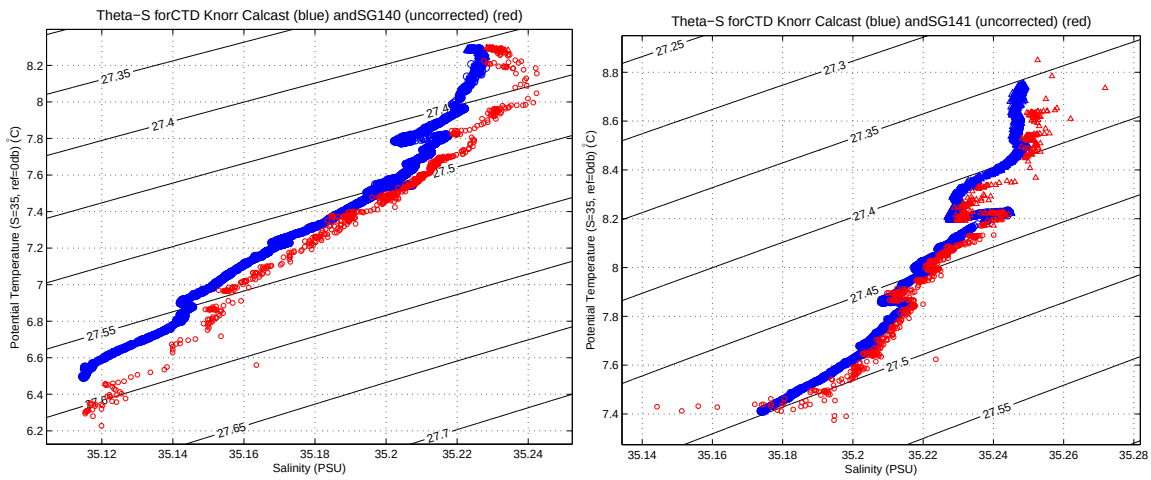
(b) SG143 θ_{35}-S Original Data

Figure 14: Original data. SG 142: Comparison of θ_{35}-S of dive with Process Cruise Calibration Cast . SG 143: Comparison of θ_{35}-S of dive with Process Cruise Calibration Cast, original data. No offsets could be chosen using this method due to the noise issue.

4.3 v1.0 - correct (post-deployment) calibration coefficients for sg140 and sg141

4.3.1 θ_{35}-S comparison plots for SG140 and SG14

New "original" data: sg140 and sg141 using post-deployment cal sheets, but before any additional offsets added. It is clear from the θ_{35}-S comparison plots that an offset applied to SG140 could be beneficial.



(a) SG140 θ_{35}-S Post-deployment Calibration

(b) SG141 θ_{35}-S Post-deployment Calibration

Figure 15: "v1.0 Original Data" calculated using post-deployment calibration coefficients for SG140 and SG141. SG 140: Comparison of θ_{35}-S of dive 136 with Process Cruise Calibration Cast 8a. SG 141: Comparison of θ_{35}-S of dive with Process Cruise Calibration Cast.

4.3.2 Frequency Offsets for v1.1 determined by comparing SG dive to CTD Cal Cast

```
SG140: v1.1
       temp_freq_offset: 5.0392
       cond_freq_offset: 0.0046
```

The Matlab script `NAB_compare_ThS.m` calculates mean and root mean square differences of the CTD calibration cast (downcast only) and Seaglider descent (measurements interpolated to the CTD's depth). 3 depth ranges were used for making the comparison: the entire CTD depth range (All Depths), surface to 50m (Surface), and the "homogenous

zones," which for SG140 dive 136 were the surface to 50m and 150 to 300m (Homog.). Coefficients from linear regressions (by depth) were also calculated for the three selected depth ranges, but the resulting corrections did not look as good as the simple offset. The output of the script was saved to `sg_140_output_v1.0.txt`. The "corrected data" refers to calculations made off the raw frequencies with the various offsets applied, not to v1.1 which was processed by the basestation with the specific offsets listed above applied prior to lag-correction.

```
SG 140
25-Aug-2009 17:05:44
SN0062 23 Oct 08
Apogee around 990.1 m... (glide angle changes @ 345 m, wobbles afterward)
Depth of CTD cast (min/max): 3.648 / 585.383
```

Table 6: SG140: Offsets determined from Uncorrected Data (v1.0)

Depth Range	temp freq	temp (degC)	cond freq	cond (siemens)	salinity (PSU)
All Depths (mean)	-5.0392	0.0666	-0.0046	0.0067	0.0058
All Depths (rms)	-10.2892	0.1361	-0.0092	0.0135	0.0086
Surface (mean)	-1.7246	0.0228	-0.0016	0.0023	0.0022
Surface (rms)	-2.1070	0.0278	-0.0019	0.0028	0.0019
Homog. (mean)	-3.6120	0.0477	-0.0033	0.0047	0.0033
Homog. (rms)	-4.0336	0.0533	-0.0037	0.0054	0.0043

Table 7: SG140: Coefficients from linear regression (by depth) Uncorrected Data (v1.0)

coeff	All Depths	Surface	Homog.	All Depths	Surface	Homog.
	TempFreq			CondFreq		
gain	0.0230	-0.0657	-0.0135	2.63e-05	-5.67e-05	-1.18e-05
offset	-12.1831	-0.2847	-1.7010	-0.0109	-0.0003	-0.0016

Table 8: SG140: Mean error of Corrected Data

Depth Range	temp freq	temp (degC)	cond freq	cond (siemens)	salinity (PSU)
All Depths (mean)	-1.65e-13	-0.0005	9.95e-17	2.97e-05	0.0029
All Depths (rms)	-5.2500	-0.0700	-0.0046	-0.0067	2.01e-05
Surface (mean)	3.3146	0.0432	0.0030	0.0044	0.0066
Surface (rms)	2.9322	0.0382	0.0027	0.0040	0.0068
Homog. (mean)	1.4272	0.0183	0.0014	0.0020	0.0055
Homog. (rms)	1.0057	0.0128	0.0009	0.0014	0.0045

Table 9: SG140: RMS error of Corrected Data

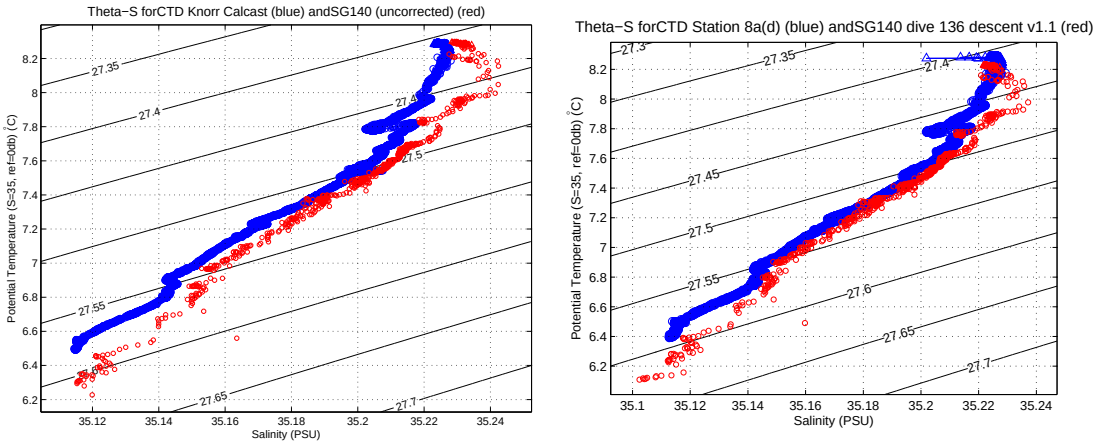
Depth Range	temp freq	temp (degC)	cond freq	cond (siemens)	salinity (PSU)
All Depths (mean)	8.9707	0.1190	0.0080	0.0116	0.0083
All Depths (rms)	10.3940	0.1383	0.0092	0.0134	0.0076
Surface (mean)	9.5635	0.1264	0.0086	0.0125	0.0103
Surface (rms)	9.4378	0.1248	0.0084	0.0123	0.0104
Homog. (mean)	9.0835	0.1203	0.0081	0.0118	0.0096
Homog. (rms)	9.0269	0.1196	0.0080	0.0117	0.0090

4.4 v1.1 - temperature and conductivity offsets added for SG140

4.4.1 SG140 comparison between v1.0 and v1.1

θ_{35}-S Space

The script `NAB_compare_ThS_v1_0.m` was used to produce the following figures comparing Th-S, temperature and salinity using the timeseries files, picking up the actual, frequency-offset published version of the data (but not otherwise despiked, degapped, smoothed values; ie, using `temp` and `salinity`, not `T` and `S`).



(a) SG140 θ_{35}-S v1.0

(b) SG140 θ_{35}-S v1.1

Figure 16: SG 140: Comparison of θ_{35}-S of dive 136 (red) with Process Cruise Calibration Cast 8a (blue). Post-deployment calibration coefficients (v1.0, 16a) and Post-deployment calibration coefficients plus an offset applied to temperature and conductivity frequency (v1.1, 16b)

Goodness of Fit of SG140's dive 136 to its Calibration Cast

Still, this is a slight change to SG140 garnering only a slight improvement. Bear in mind that the near-surface values for SG140's calibration dive were quite different than what was seen by the CTD.

Comparing SG140's v1.0 (with post-deployment calibration coefficients) to v1.1 (post-deployment calibration coefficients and temperature and conductivity frequency offsets determined using `NAB_freq_offset.m`).

Table 10: Stats: CTD Station 8a downcast vs. SG140 dive 136 descent

stat	v1.0	v1.1
mean (diff temp)	-5.634642413408734e-02	1.025189852286446e-02
rms (temp)	1.414278474088448e-01	1.305756719900102e-01
mean (diff Th_{35})	-5.632726422579139e-02	1.013876697248280e-02
rms (Th_{35})	1.411616965362565e-01	1.302225032177846e-01
mean (diff Salt)	-8.641469681249030e-03	-2.874072018137131e-03
rms (Salt)	1.185305878786342e-02	8.380509852848304e-03
mean (diff Cond)	-5.938597144426222e-03	7.928917599768836e-04
rms (Cond)	1.398010802480262e-02	1.265403200302021e-02

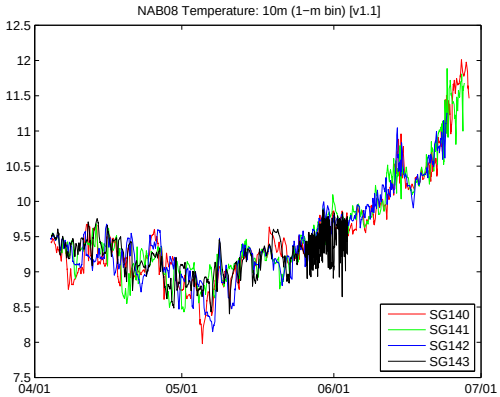
4.4.2 v1.1: Goodness of Fit of all Seagliders to their Calibration Casts

Table 11: v1.1 Stats: Seaglider Descent vs. CTD Station Downcast

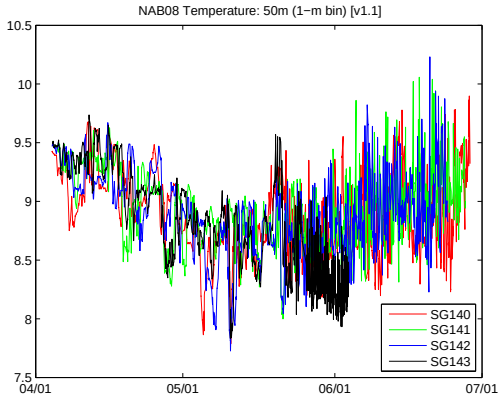
stat	SG140	SG141	SG142	SG143
	dive 136	dive 152	dive 151	dive 165
	CTD 8a	CTD 19a	CTD 12a	CTD 18a
mean (diff temp)	1.025e-02	-4.822e-04	1.292e-02	-1.59e-02
rms (temp)	1.306e-01	2.595e-02	4.077e-02	4.621e-02
mean (diff Th_{35})	1.014e-02	-5.787e-04	1.289e-02	-1.596e-02
rms (Th_{35})	1.302e-01	2.591e-02	4.063e-02	4.612e-02
mean (diff Salt)	-2.874e-03	-2.250e-03	-5.369e-03	-8.059e-04
rms (Salt)	8.381e-03	5.897e-03	6.359e-03	9.846e-03
mean (diff Cond)	7.929e-04	-2.857e-05	8.765e-04	-1.33e-03
rms (Cond)	1.265e-02	2.674e-03	3.93e-03	4.670e-03

4.4.3 v1.1: Seaglider Intercalibrations: Mean Temperature and Salinity at Depth m

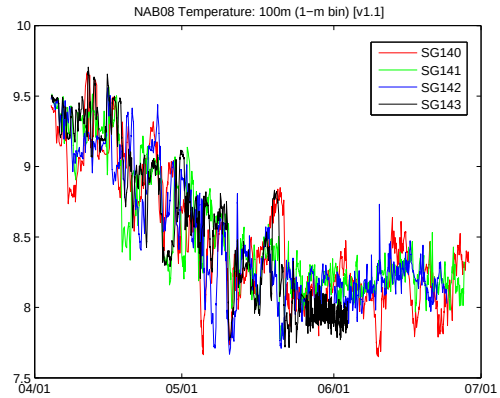
`NAB_temp_cal.m`, using `temp` and `salinity`, not the smoothed `T` and `S`.



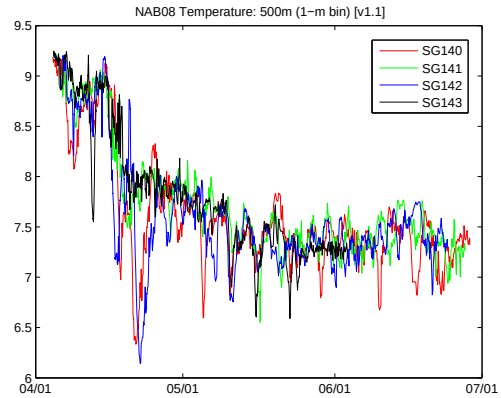
(a) Temperature at 10m



(b) Temperature at 50m



(c) Temperature at 100m



(d) Temperature at 500m

Figure 17: v1.1 Temperature measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 10 m (17a), 50 m (17b), 100 m (17c), and 500 m (17d) .

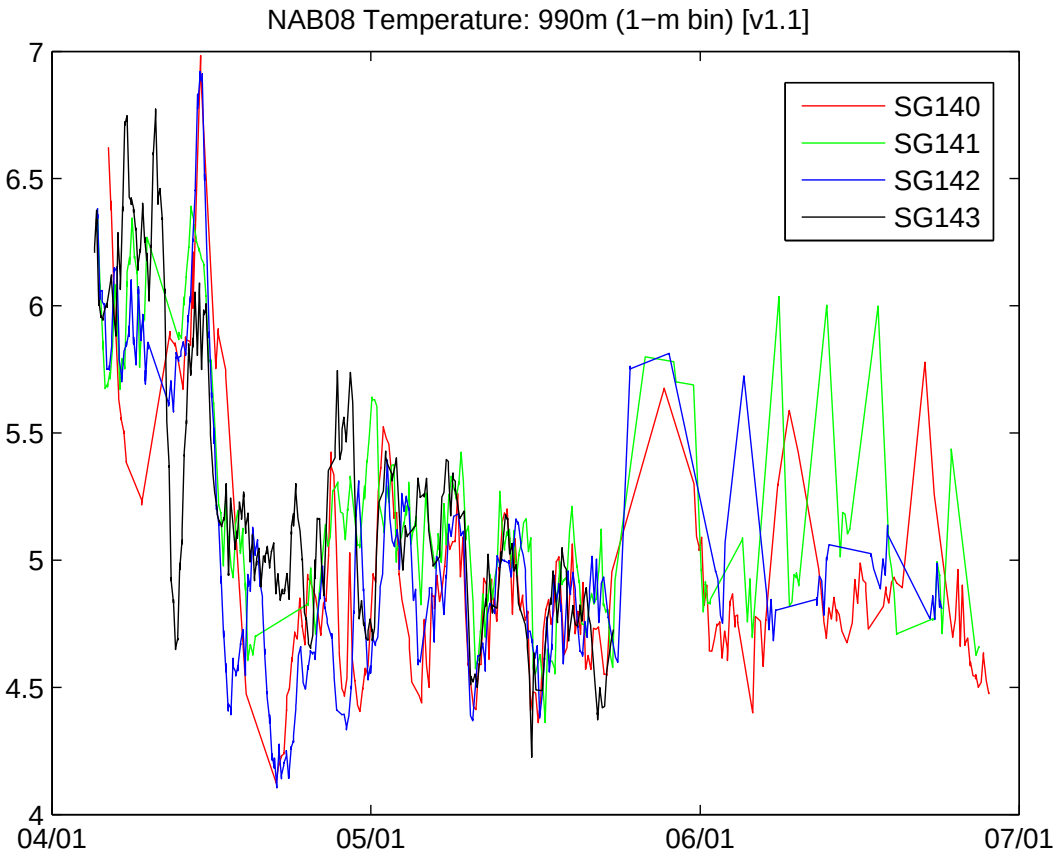
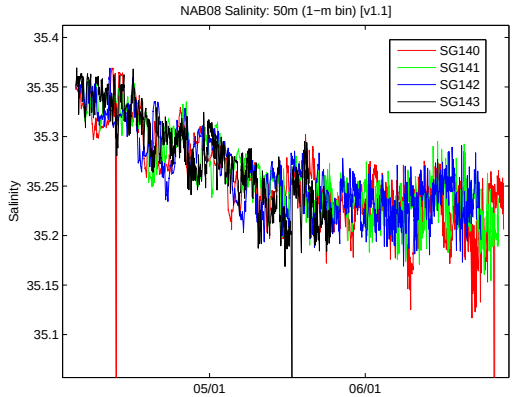
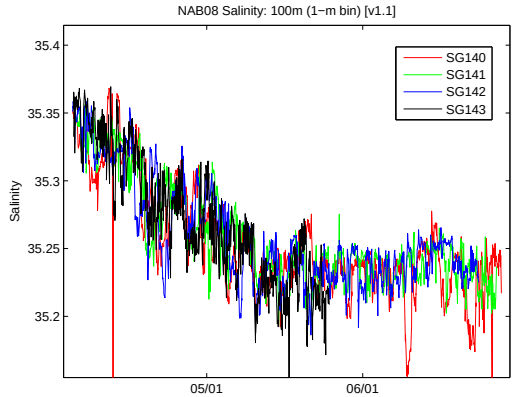


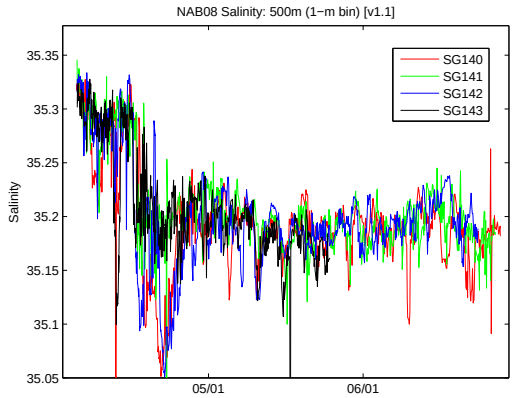
Figure 18: v1.1 Temperature measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 990 m. The jagged look to the data, especially during the final month of the record, is due to an increase in shallow dives as the gliders moved onto the face of the Reykjanes ridge.



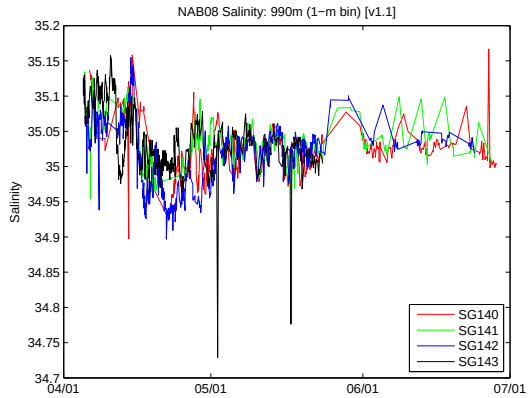
(a) Salinity at 50m



(b) Salinity at 100m



(c) Salinity at 500m



(d) Salinity at 990m

Figure 19: v1.1 Salinity measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1m depth bin centered at 50 m (19a), 100 m (19b), 500 m (19c), and 990 m (19d). Large variability (errors) in SG 143 (black) starting on 26 May 2008 dive 254 is due to the extreme pitch of the glider's descent and ascent, and resulting poor flow characteristics through the conductivity cell (See Figures 5 and 6); thus SG143 data from dive 253 and after is not included in these plots.

4.4.4 v2.2: Seaglider Intercalibrations: Mean Difference in Smoothed Temperature / Salinity at Depth m

`NAB_temp_cal_v2_2.m`, using the smoothed `T` and `S`.

Smoothed, degapped temperature (T) and salinity (S) measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 were binned into 1-m wide depth bins centered at 10, 50, 100, 500 and 990m depth. These binned timeseries were used to calculate mean temperature and salinity, as well as standard deviations from that mean. To better characterize these statistics, the separation in kilometers of each Seagliders' measurements from the mean location of all 4 measurements was calculated.

Temperature

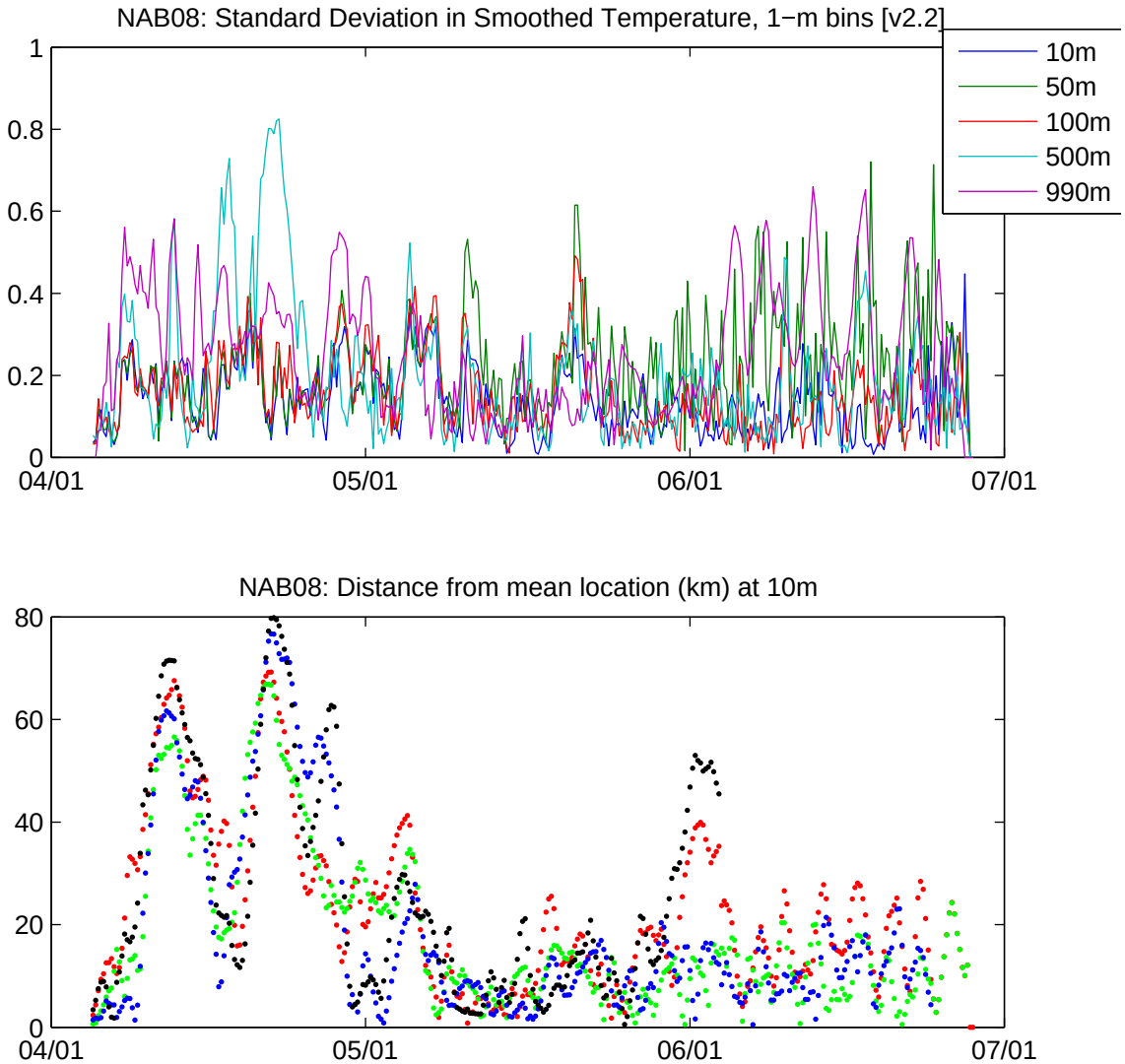
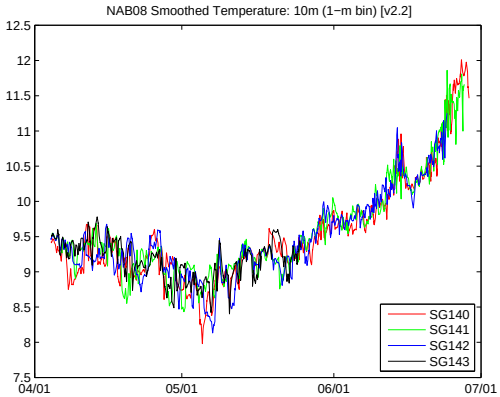
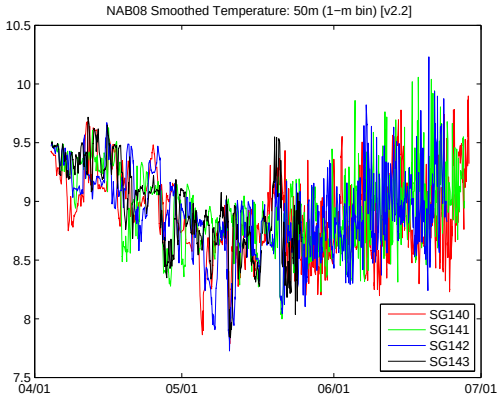


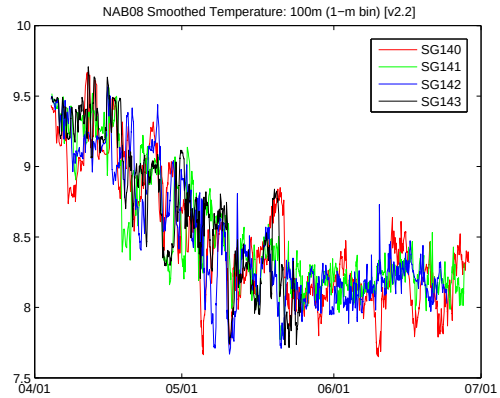
Figure 20: v2.2 Top: Standard deviation of the smoothed, degapped temperature measurements (T, degC) for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at several 1-m wide depth bins (see legend). Bottom: Distance separation (km) of SG140 (red), SG141 (green), SG142 (blue), and SG143 (black) from the mean location of measurements for the 10m depth bin (separation of other depth bins are typically within 3km of the values presented here).



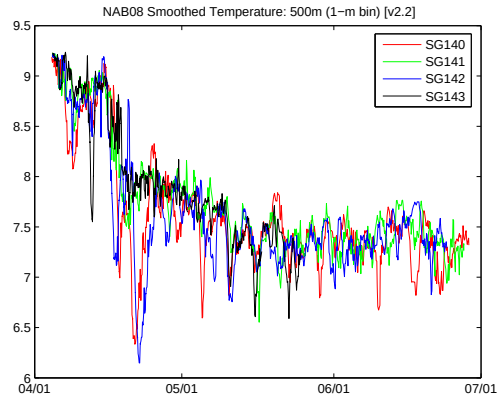
(a) Temperature at 10m



(b) Temperature at 50m



(c) Temperature at 100m



(d) Temperature at 500m

Figure 21: v2.2 Temperature measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 10 m (21a), 50 m (21b), 100 m (21c), and 500 m (21d) .

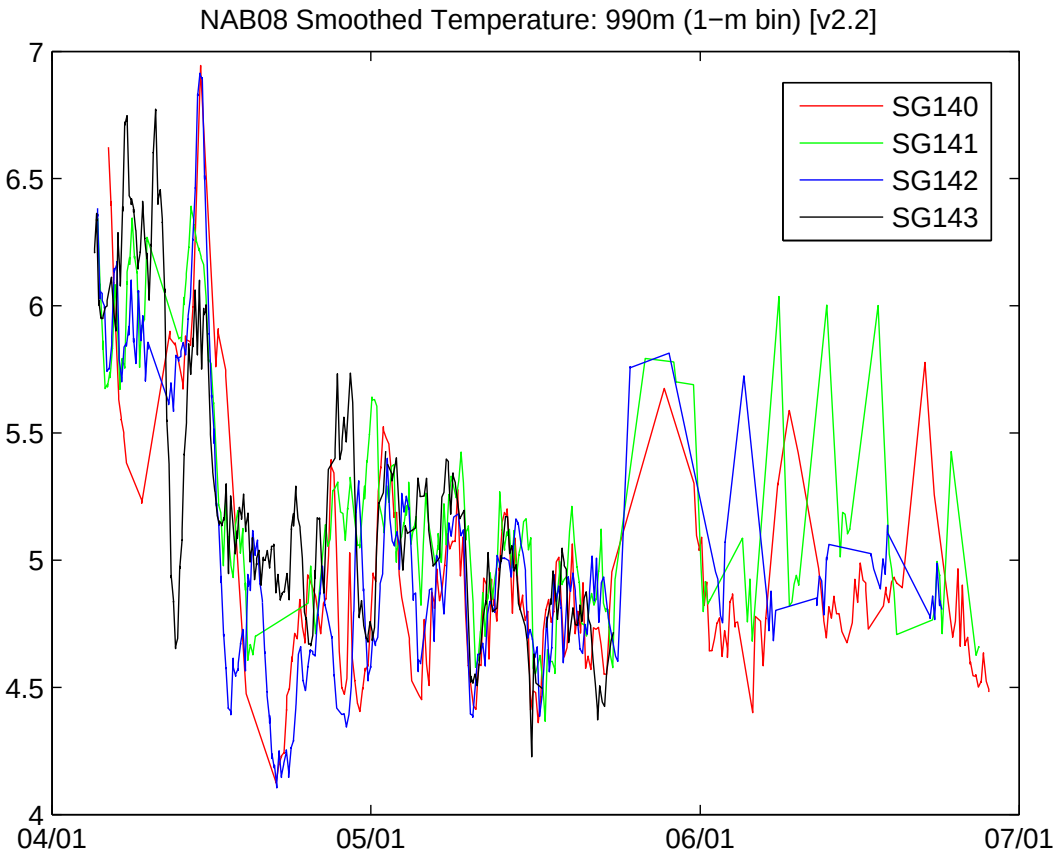


Figure 22: v2.2 Temperature measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1-m depth bin centered at 990 m. The jagged look to the data, especially during the final month of the record, is due to an increase in shallow dives as the gliders moved onto the face of the Reykjanes ridge.

Salinity

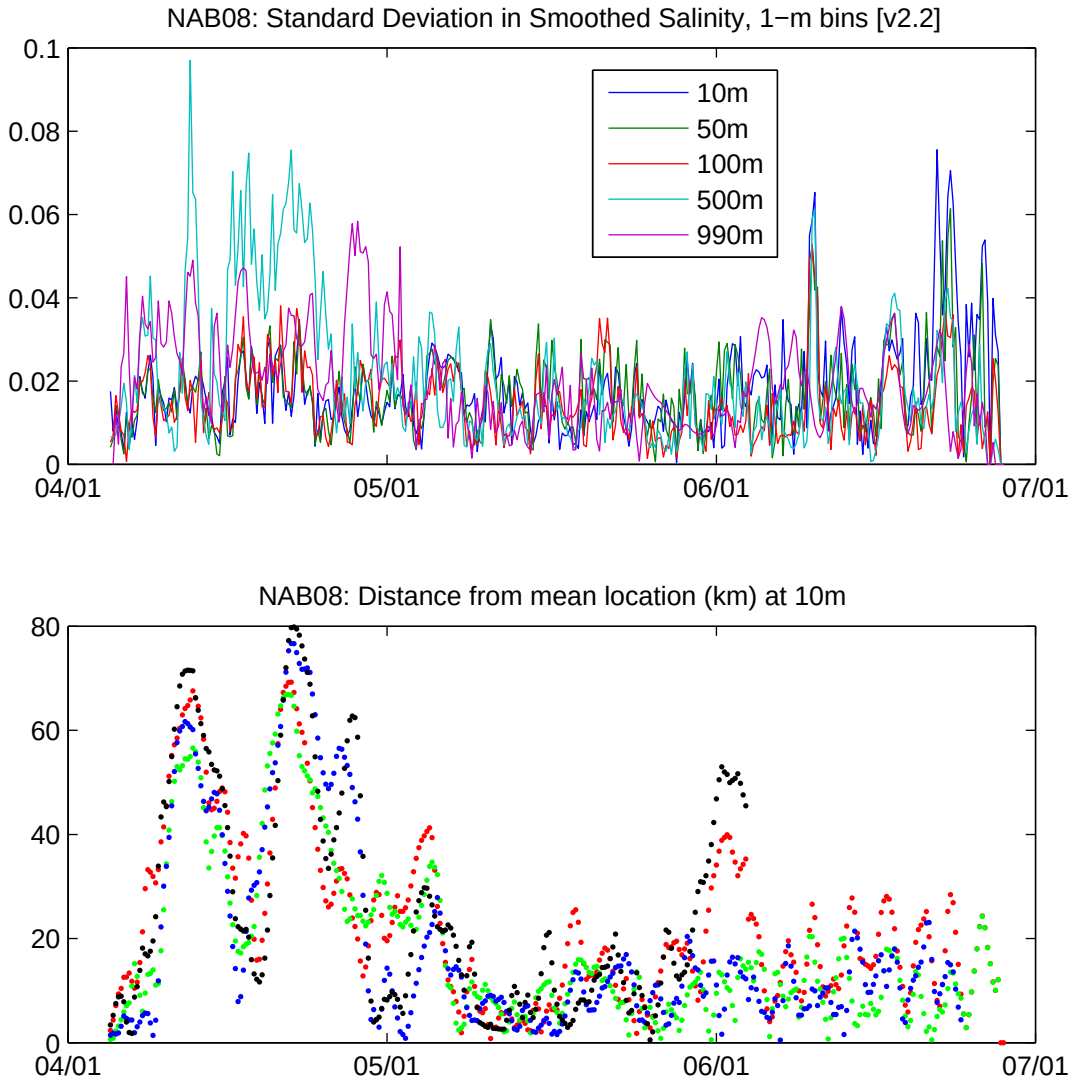
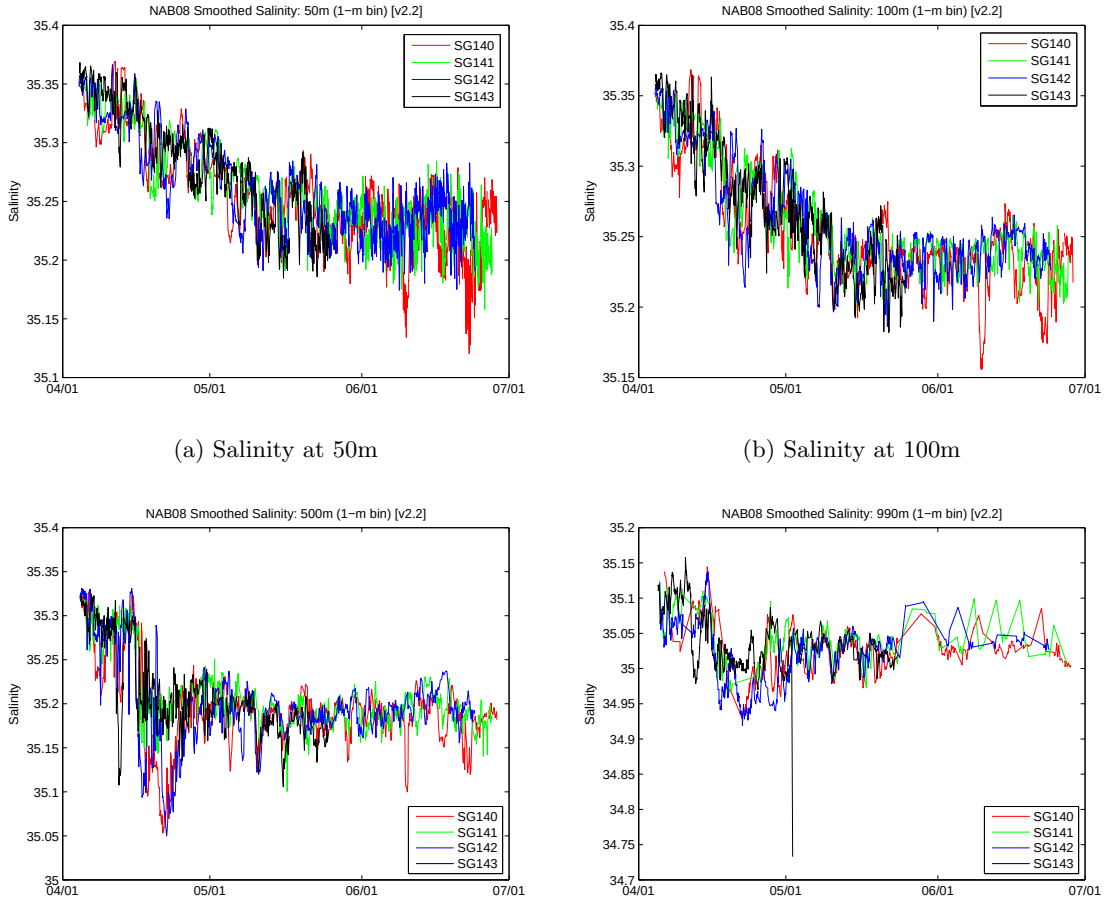


Figure 23: v2.2 Top: Standard deviation of the smoothed, degapped salinity measurements (S, PSU equivalent) for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at several 1-m wide depth bins (see legend). Bottom: Distance separation (km) of SG140 (red), SG141 (green), SG142 (blue), and SG143 (black) from the mean location of measurements for the 10m depth bin (separation of other depth bins are typically within 3km of the values presented here).



(a) Salinity at 50m

(b) Salinity at 100m

(c) Salinity at 500m

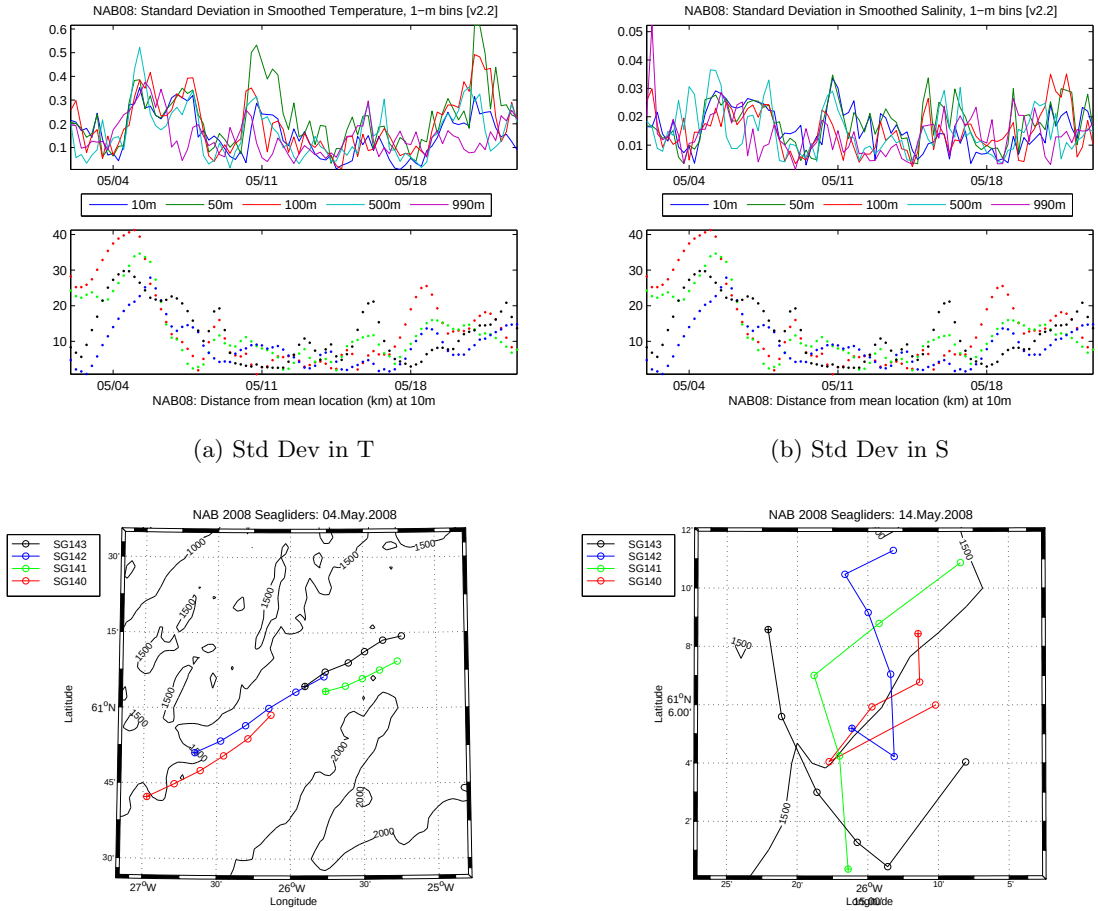
(d) Salinity at 990m

Figure 24: v2.2 Salinity measurements for all Seagliders during the duration of the North Atlantic Bloom Experiement 2008 at a 1m depth bin centered at 50 m (24a), 100 m (24b), 500 m (24c), and 990 m (24d). Large variability (errors) in SG 143 (black) starting on 26 May 2008 dive 254 is due to the extreme pitch of the glider's descent and ascent, and resulting poor flow characteristics through the conductivity cell (See Figures 5 and 6); thus SG143 data from dive 253 and after is not included in these plots.

4.4.5 v2.2: Horizontal Variability: Along and Across Gradients during the Process Cruise

Seaglider measurements taken along regions of high gradients will necessarily see apparently longer correlation lengthscales than those taken across gradients. This is apparent in the measurements around 4 May (high separation, low deviation) and 14 May (low separation, higher deviation).

TODO: Make a plot of the "gliderpod" location for 11 May, which was the day of low separation and really high deviation.



(a) Std Dev in T

(b) Std Dev in S

(c) GliderPod 4 May

(d) Std Dev in S

Figure 25: v2.2 Top Row: Standard deviation of the smoothed, degapped salinity measurements (T, degC, fig. 25a; S, PSU equivalent, fig. 25b) for all Seagliders during the process cruise of the North Atlantic Bloom Experiement 2008 at several 1-m wide depth bins (see legend) above the distance separation (km) of SG140 (red), SG141 (green), SG142 (blue), and SG143 (black) from the mean location of measurements for the 10m depth bin (separation of other depth bins are typically within 3km of the values presented here). Bottom Row: Locations of Seagliders during 4 May (YD 125, fig. 25c) and 14 May (YD 135, fig. 25d).

5 Seaglider Calibration Casts

5.1 T and S Profiles: Deployment, Process and Recovery Cruises

Over the course of the experiment, seven CTD casts were performed for calibrating the Seagliders (figures 26 and 27). One "cal cast" was performed on the deployment cruise for all four gliders at once (fig. 29); a separate cast for each Seaglider was performed on the R/V Knorr (fig. 36), and the two remaining Seagliders likewise each received a cal cast before being retrieved during the recovery cruise (fig. 41).

Plots from `NAB_plot_CTD_cal_casts.m`, `NAB_compare_ThS.m`, and ... ?

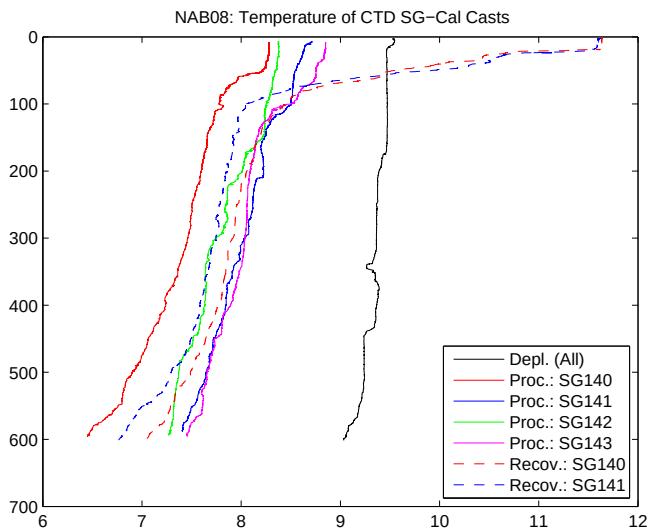


Figure 26: Temperature from CTD calibration casts for Seagliders. The two recovery casts have the highest surface temperatures.

5.2 Deployment Cruise - R/V Bjarni Saemundsson

The R/V Bjarni Saemundsson left Reykjavik on 1 April and returned on 6 April. The science team on the deployment cruise aboard were: Craig Lee (chief scientist), Mary Jane Perry, Adam Huxtable, Eric Rehm, and others. The two bio-heavy floats were deployed first, followed by the 4 gliders in quick succession on 4 Apr 2008.

Three calibration CTD casts were performed during the deployment cruise: casts 157 and 159 for the two floats, and cast 158 for all four gliders. CTD Cast 158 (lat:59.0053 lon:-

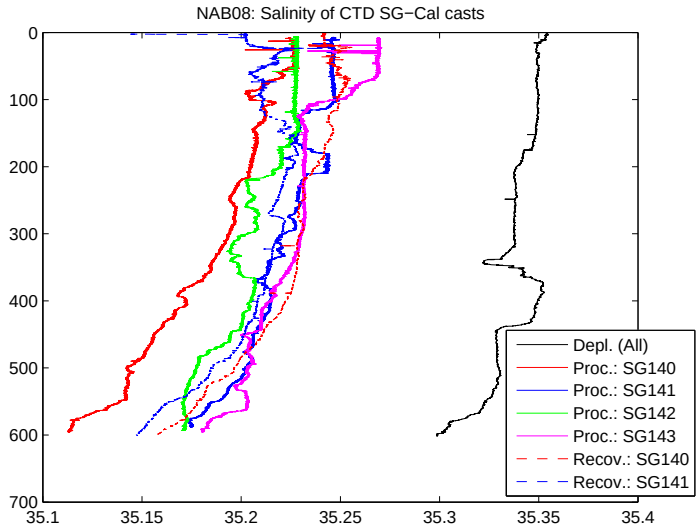


Figure 27: Salinity from CTD calibration casts for Seagliders. The two recovery casts have the highest surface temperatures.

20.4870, or 59°0.3200' N, 20°29.22'W) occurred on 4 Apr 2008 at 19:47 UTC. Three of the four gliders were within one kilometer of the cast (figure 29). The CTD cast was not timed to coincide with the gliders' dives, and was unfortunately performed in a region of high gradients, so its usefulness as a standard against which to compare the seagliders' CT measurements is very low. However, comparing the gliders against each other is a potentially useful exercise.

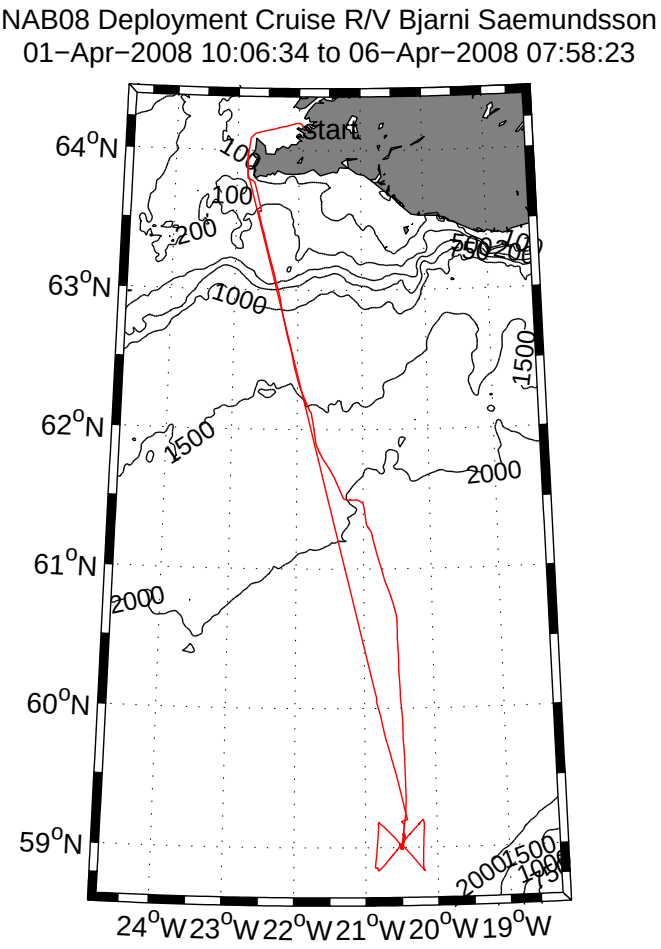


Figure 28: Deployment Cruise: Location of R/V Bjarni Saemundsson

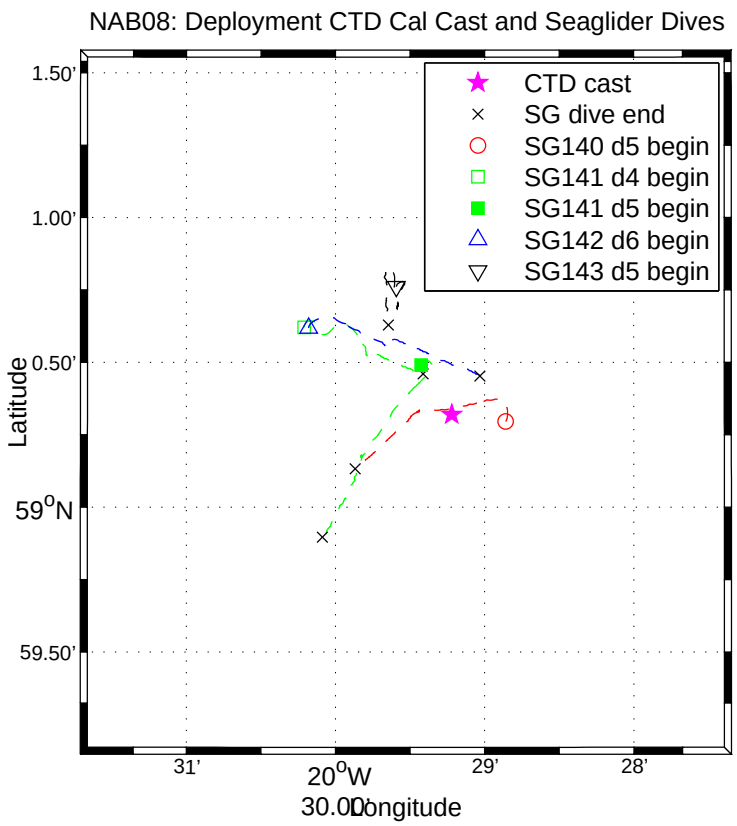


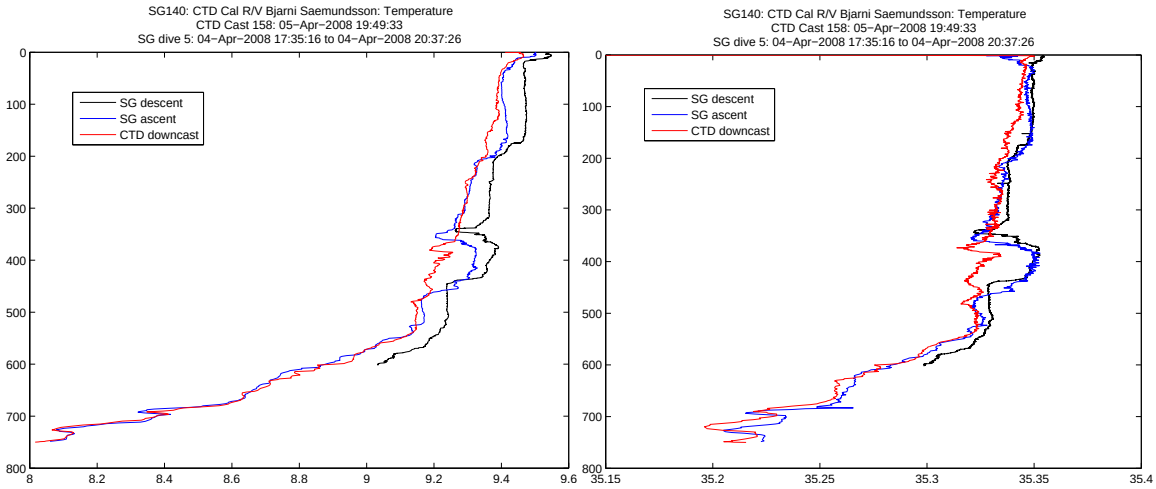
Figure 29: Deployment Cruise: CTD Cast 158 and Nearby Seaglider Dives. The 'x' marks the end of each dive; the colored marker denotes the start of the dive. The dashed lines indicate the estimated location of the Seaglider underwater, as calculated using the glider's own internal flight (hydrodynamic) model.

Table 12: NAB Seaglider Dives for Comparison with Calibration CTD Casts on 4-Apr-2008

Seaglider	Dive		Time	Lat	Lon	Dist (km)
SG140	5	start	17:35	59.0049	-20.4810	0.3462
		end	20:37	59.0022	-20.4978	0.7075
SG141	4	start	17:00	59.0103	-20.5035	1.0962
		end	19:50	59.0077	-20.4902	0.31813
SG141	5	start	20:00	59.0082	-20.4904	0.37134
		end	22:47	58.9983	-20.5015	1.1404
SG142	6	start	17:51	59.0103	-20.5030	1.0695
		end	20:51	59.0076	-20.4839	0.30576
SG143	5	start	18:30	59.0127	-20.4932	0.89154
		end	21:40	59.0105	-20.4941	0.70202
CTD	158		19:47	59.0053	-20.4870	

5.2.1 SG140

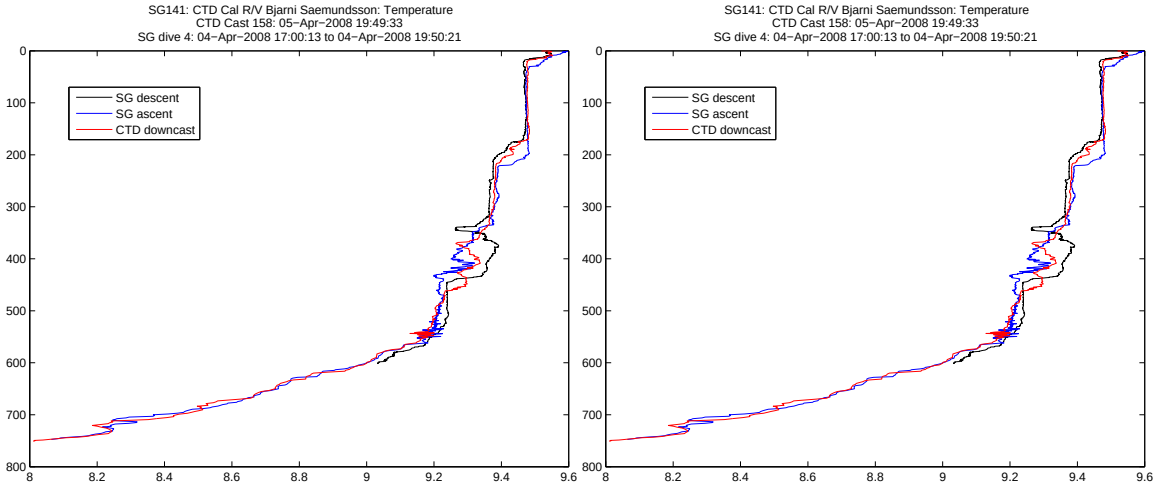
Although the ascent portion of dive 5 is closer to the CTD calibration cast in both time and space, it looks like it is in the wrong patch of water. The descent does a better job of matching the temperature and salinity structure seen by the ship-board CTD (Figure 30).



(a) Temperature (b) Salinity

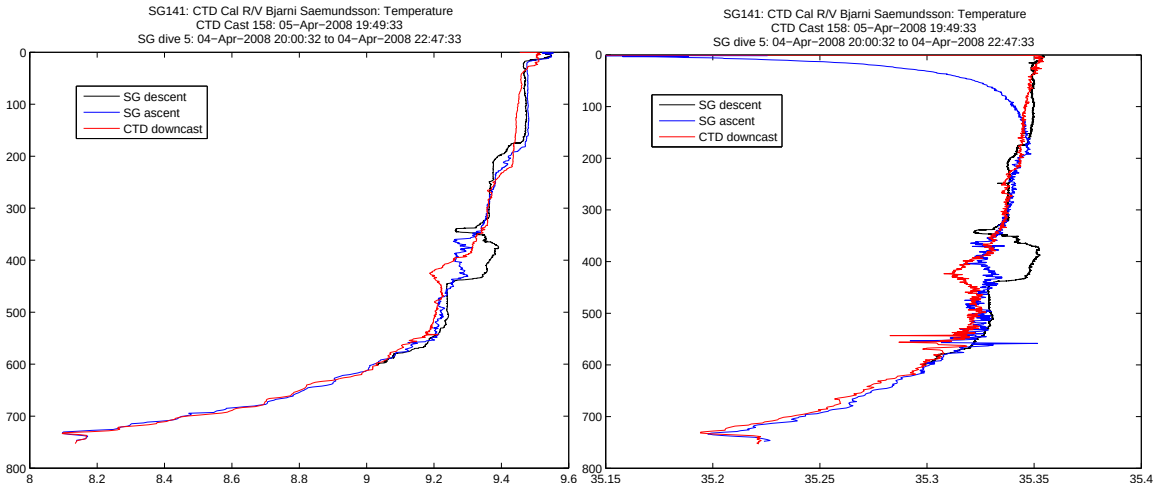
Figure 30: v1.1 SG140 Dive 5 and CTD Cast 158 profiles of temperature (30a) and salinity (30b) from both descent (blue) and ascent (red) using post-deployment lab calibrations and additional temperature and conductivity frequency offsets, compared to the ship-board CTD (black).

5.2.2 SG141



(a) Temperature (b) Salinity

Figure 31: v1.1 SG141 Dive 4 and CTD Cast 158 profiles of temperature (31a) and salinity (31b) from both descent (blue) and ascent (red) using post-deployment lab calibrations, compared to the ship-board CTD (black).

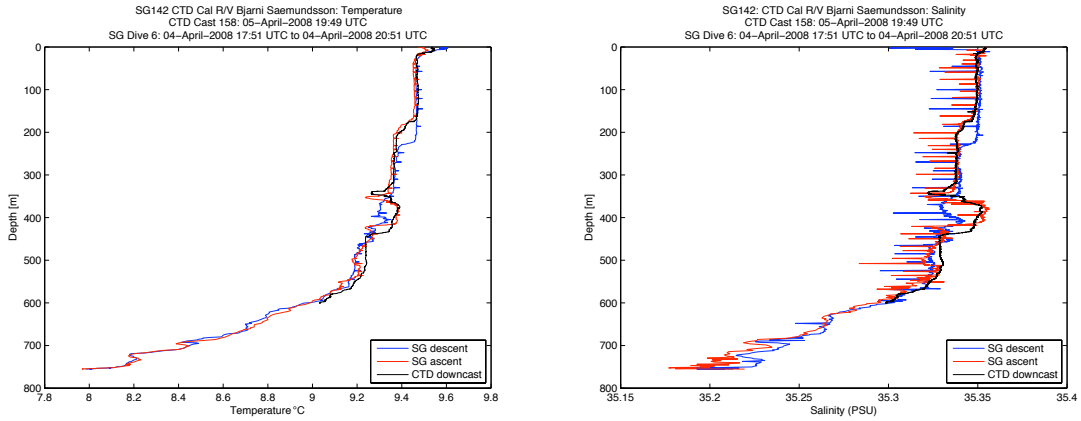


(a) Temperature (b) Salinity

Figure 32: v1.1 SG141 Dive 5 and CTD Cast 158 profiles of temperature (32a) and salinity (32b) from both descent (blue) and ascent (red) using post-deployment lab calibrations, compared to the ship-board CTD (black).

5.2.3 SG142

Dive 6 (Ascent?).



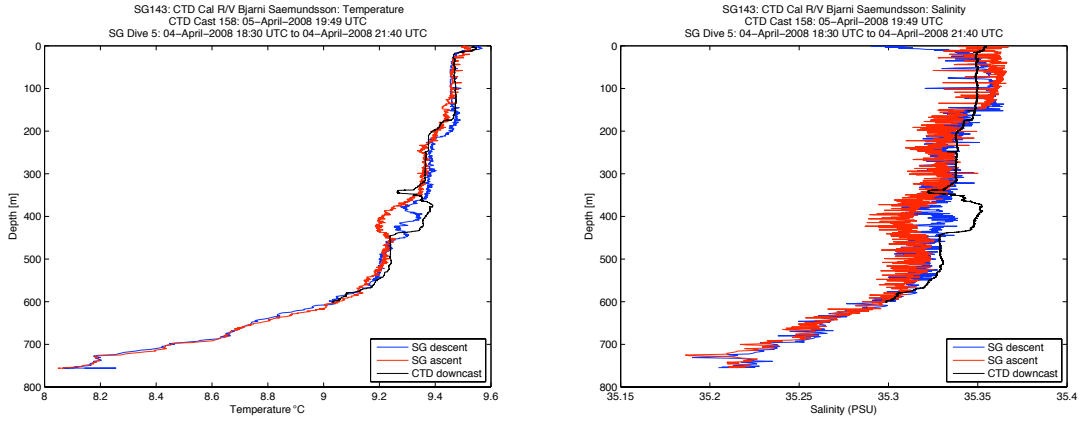
(a) Temperature

(b) Salinity

Figure 33: SG142 Dive 6 and CTD Cast 158 profiles of temperature (33a) and salinity (33b) from both descent (blue) and ascent (red) using pre-deployment lab calibrations, compared to the ship-board CTD (black).

5.2.4 SG143

Dive 5 (Ascent).



(a) Temperature

(b) Salinity

Figure 34: SG143 Dive 5 and CTD Cast 158 profiles of temperature (34a) and salinity (34b) from both descent (blue) and ascent (red) using pre-deployment lab calibrations, compared to the ship-board CTD (black).

5.3 Process Cruise

The R/V Knorr left Reykjavik on 1 May 2008 and returned on 22 May 2008. The science team on the deployment cruise aboard were: Mary Jane Perry (chief scientist) [lots of others].

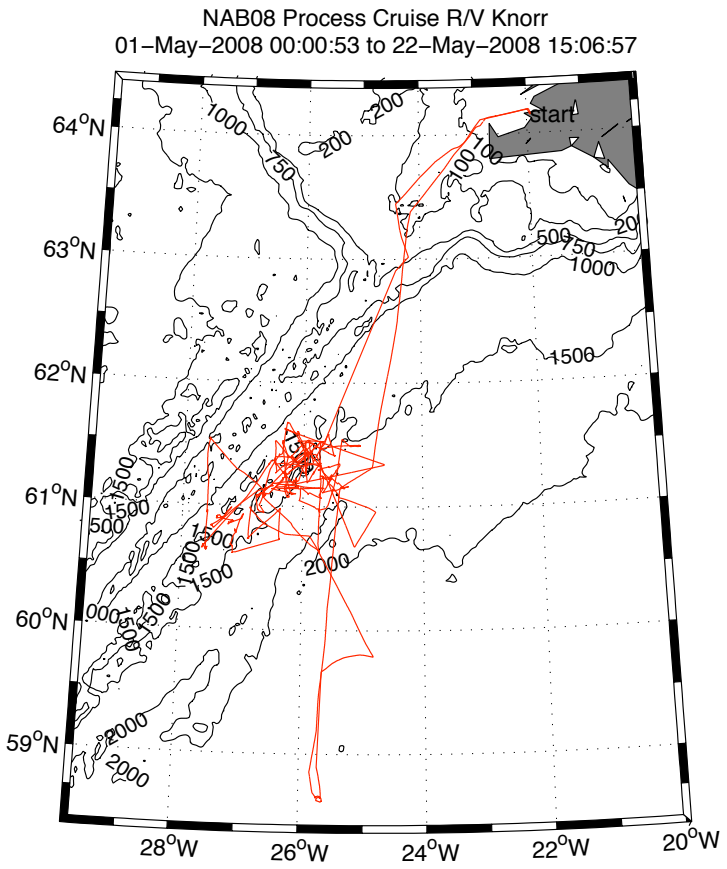


Figure 35: Deployment Cruise: Location of R/V Knorr

Knorr cruise 193 carried an SBE-911plus CTD with pumped dual pairs of conductivity and temperature sensors (SN 2774 and 2900 for temperature, 1474 and 1859 for conductivity). One calibration CTD cast was performed individually for each glider, located 200-700m from the glider (visual contact maintained with the glider during its stay at the surface) and timed so the descent of the CTD would begin within minutes of the start of the Seaglider's dive (figure **??**).

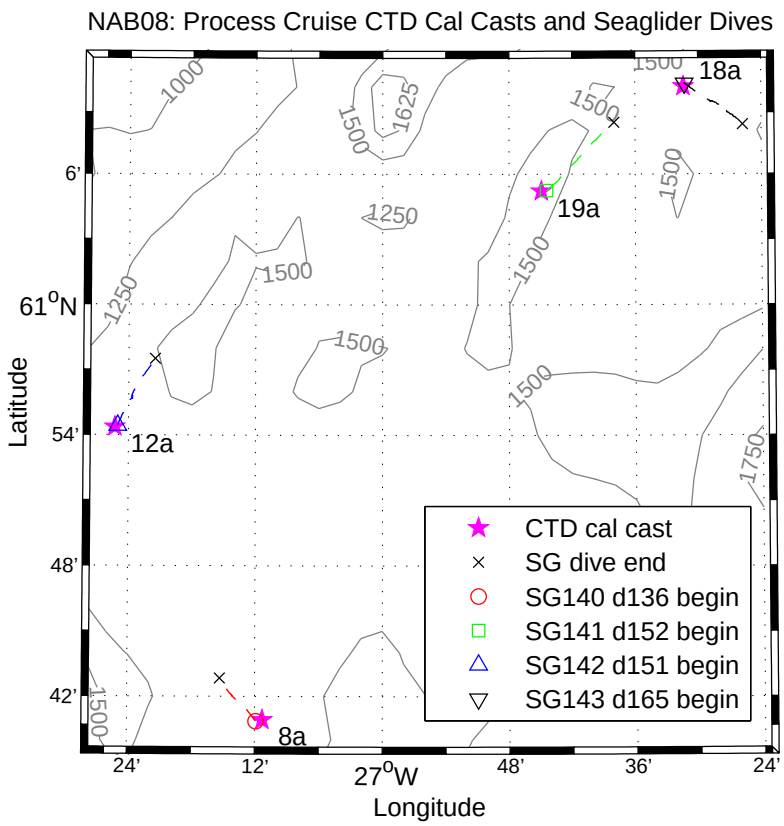


Figure 36: Process Cruise: CTD Calibration Casts and Seaglider Dives. The 'x' marks the end of each dive; the colored marker denotes the start of the dive. The dashed lines indicate the estimated location of the Seaglider underwater, as calculated using the glider's own internal flight (hydrodynamic) model.

Stats for the "SBE 911 plus CTD"
(from `http://www.seabird.com/pdf_documents/ProductOverviewBrochureMar09.pdf`)
Accuracy: 0.0003S/m, 0.001°C, 0.015% full scale pressure;
Resolution: 0.00004S/m, 0.0002°C, 0.001% full scale pressure.

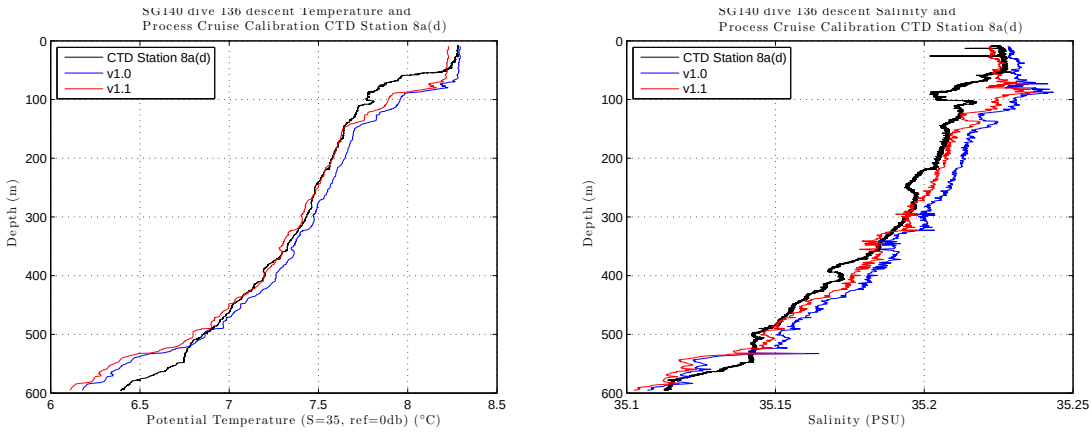
Compared to the (expected) Seaglider accuracies of 0.002 deg C and 2x0.005 psu (section 2.1.3).

Table 13: NAB Seaglider Dives and Process Cruise Calibration CTD Casts

Instrument	Dive/Station		Date	Time	Lat	Lon	Dist (km)
SG140	136	start	5 May	10:10	60.6809	-27.1980	0.56422
		end		15:19	60.7140	-27.2549	5.0925
CTD	8a			10:02	60.6820	-27.1878	
SG141	152	start	7 May	12:33	61.0874	-26.7407	0.43045
		end		17:53	61.1396	-26.6334	8.5111
CTD	19a			12:32	61.0870	-26.7487	
SG142	151	start	6 May	09:39	60.9072	-27.4171	0.25358
		end		14:56	60.9586	-27.3583	6.744
CTD	12a			09:32	60.9062	-27.4213	
SG143	165	start	7 May	08:46	61.1692	-26.5217	0.23695
		end		13:37	61.1381	-26.4295	5.968
CTD	18a			08:47	61.1672	-26.5232	

See `NAB_temp_cal.m` for determination of mean temperature (using lab calibrations) at depths of seagliders.

5.3.1 SG140



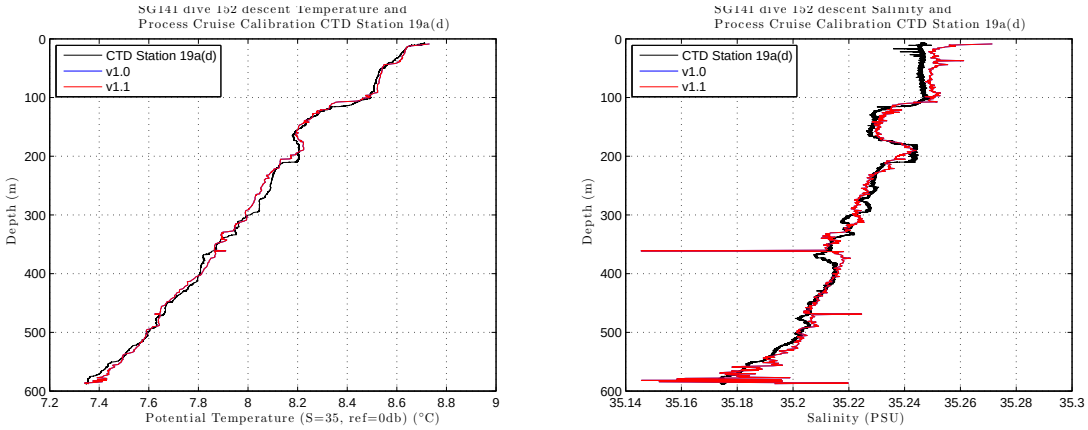
(a) Temperature

(b) Salinity

Figure 37: Knorr CTD Station 8a profiles (black) and SG140 Dive 136 descent v1.0 (blue) and v1.1 (red), for temperature (37a) and salinity (37b).

Shipboard CTD downcast data in: `d19303007.mat` (CTD Cast Station 8a, 05-May-2008 10:02 UTC 60.6820N 27.1878W).

5.3.2 SG141



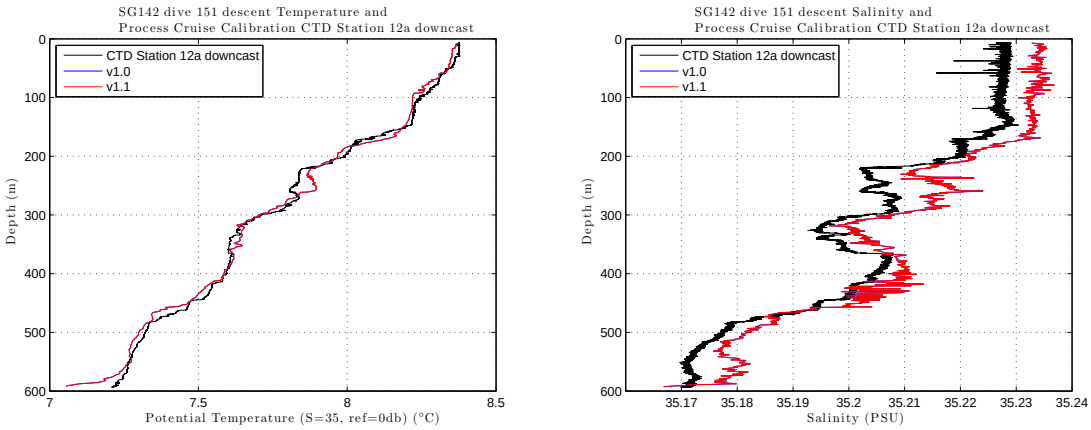
(a) Temperature

(b) Salinity

Figure 38: Knorr CTD Station 19a profiles (black) and SG141 Dive 152 descent v1.1 (red, same as v1.0), for temperature (38a) and salinity (38b).

Shipboard CTD downcast data in: d19303014.mat (CTD Cast Station 19a, 07-May-2008 12:32 UTC 61.0870N 26.7487W).

5.3.3 SG142



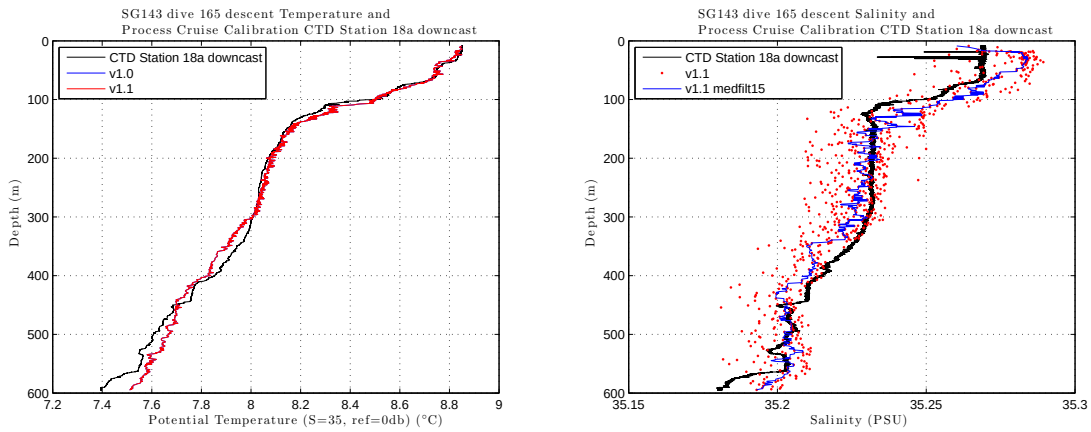
(a) Temperature

(b) Salinity

Figure 39: Knorr CTD Station 12a profiles (black) and SG142 Dive 151 descent v1.1 (red, same as v1.0), for temperature (39a) and salinity (39b).

Shipboard CTD downcast data in: d19303010.mat (CTD Cast Station 12a, 06-May-2008 09:32 UTC 60.9062N 27.4213W).

5.3.4 SG143



(a) Temperature

(b) Salinity

Figure 40: Knorr CTD Station 18a profiles (black) and SG143 Dive 165 descent v1.1 (red, same as v1.0), for temperature (40a) and salinity (40b). To make things more apparent, a median filter (filter length 15) is applied to the v1.1 salinity data (blue line)

Shipboard CTD downcast data in: d19303013.mat (CTD Cast Station 18a, 07-May-2008 08:47 UTC 61.1672N 26.5232W).

5.4 Rescue Cruise - R/V Bjarni Saemundsson

No calibration casts were performed during the "Rescue Cruise," in which the R/V Bjarni Saemundsson left Reykjavik on 2 June and returned on 6 June in order to recover two malfunctioning platforms: FL48 () and SG143 ().

5.5 Recovery Cruise - R/V Bjarni Saemundsson

The R/V Bjarni Saemundsson left Reykjavik on 25 June and returned on 1 July. The science team on the deployment cruise aboard were: Mary Jane Perry (Chief Scientist), Kristinn Gundmundsson studying primary productivity, Katja Fennel, Lindsay Dinsmore, and Keith Van Thiel as Seaglider field tech.

SG143 went into recovery on 25 May, and was pulled from the experiment on 3 June during the same rescue cruise that retrieved bio-float 48. The last contact from SG 142 occurred

on 24 June, after dive 385. Only SG 140 and 141 received calibration CTD casts before being recovered during the final cruise of NAB (figure 41).

Table 14: NAB Seaglider Dives and Recovery Cruise Calibration CTD Casts

Instrument	Dive/Cast		Date	Time	Lat	Lon	Dist (km)
SG140	368	start	28 Jun	09:57	61.6873	-25.6316	0.36342
		end		13:42	60.7140	-27.2549	4.0749
CTD	294			09:50	60.6820	-27.1878	
SG141	396	start	27 Jun	10:23	61.6562	-25.9215	0.44225
		end		13:56	61.6143	-25.8790	4.9376
CTD	291			10:12	61.6557	-25.9132	

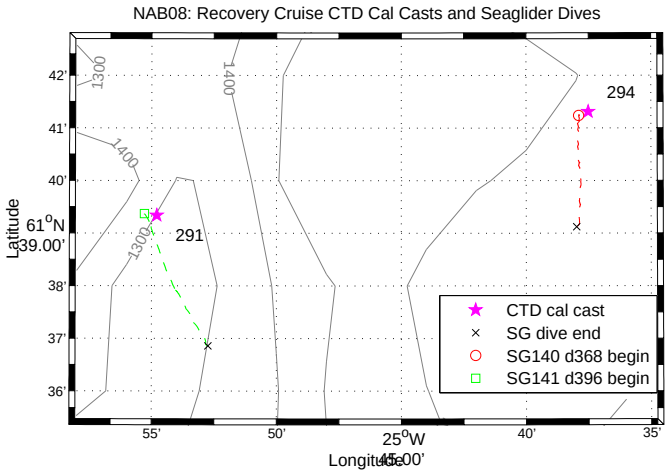
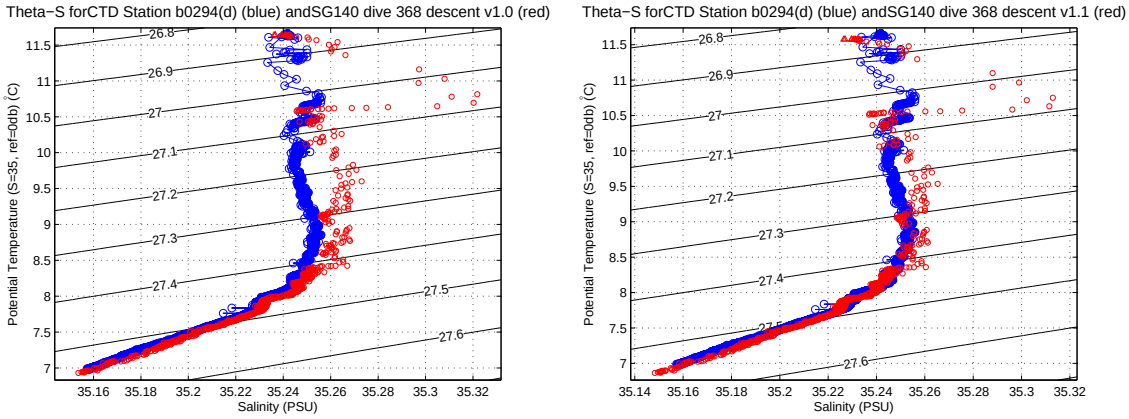


Figure 41: Recovery Cruise: CTD Calibration Casts and Seaglider Dives. The 'x' marks the end of each dive; the colored marker denotes the start of the dive. The dashed lines indicate the estimated location of the Seaglider underwater, as calculated using the glider's own internal flight (hydrodynamic) model.

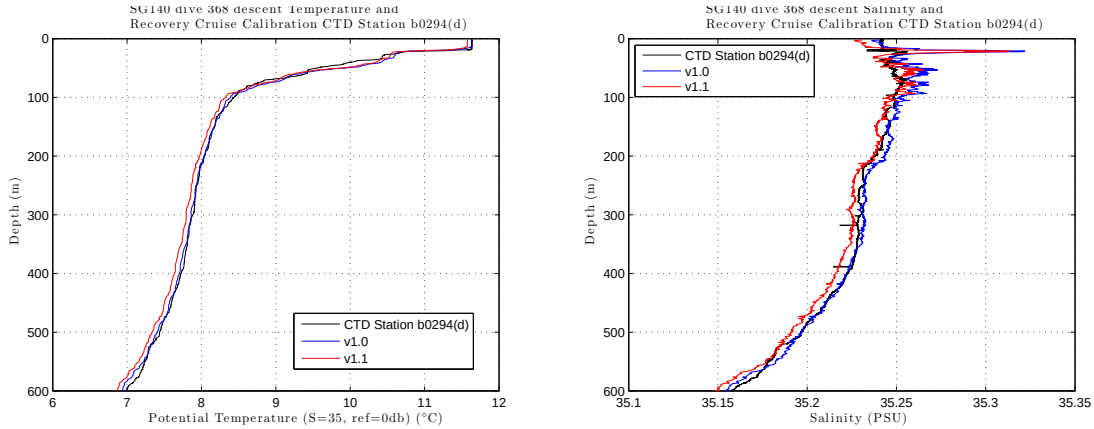
5.5.1 SG140



(a) SG140 θ_{35}-S v1.0

(b) SG140 θ_{35}-S v1.1

Figure 42: SG 140: Comparison of θ_{35}-S of dive 368 (red) with Bjarni Saemundsson CTD Station 294 (blue). Post-deployment calibration coefficients (v1.0, 42a) and Post-deployment calibration coefficients plus an offset applied to temperature and conductivity frequency (v1.1, 42b)



(a) Temperature

(b) Salinity

Figure 43: Bjarni Saemundsson CTD Station 294 profile (black) and SG140 Dive 368 descent v1.0 (blue) and v1.1 (red), for temperature (43a) and salinity (43b).

Shipboard CTD downcast data in: b0294.mat (CTD Cast 294, 28-Jun-2008 09:50 UTC 61.6885N 25.6252W).

Table 15: Stats: CTD Station b0294 downcast vs. SG140 dive 368 descent

stat	v1.0	v1.1
mean (diff temp)	-1.948e-03	6.397e-02
rms (temp)	8.5824e-02	1.074e-01
mean (diff Th35)	-2.095e-03	6.368e-02
rms (Th35)	8.573e-02	1.071e-01
mean (diff Salt)	-3.12e-03	3.233e-03
rms (Salt)	7.114e-03	6.824e-03

5.5.2 SG141

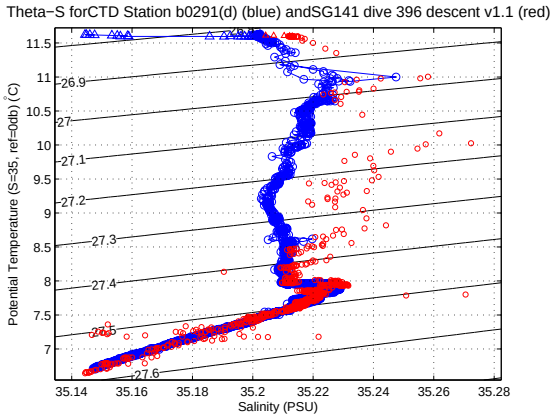
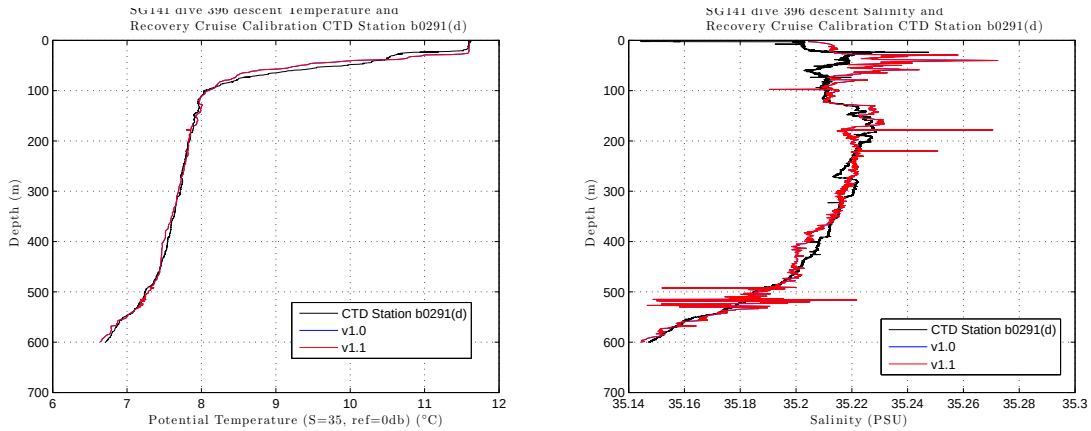


Figure 44: SG 140: Comparison of θ_{35}-S of dive 396 (red) with Bjarni Saemundsson CTD Station 291 (blue). Post-deployment calibration coefficients (v1.1).



(a) Temperature

(b) Salinity

Figure 45: Bjarni Saemundsson CTD Station 291 profile (black) and SG141 Dive 396 descent v1.0 (blue) and v1.1 (red), for temperature (45a) and salinity (45b).

Shipboard CTD downcast data in: b0291.mat (CTD Cast 291, 27-Jun-2008 10:12 61.6557N 25.9132W).

6 Noise in Temperature Sensor: SG143

Scatter plots of potential temperature (θ_{35}, calculated assuming a salinity of 35 PSU) versus salinity are shown in Section 4.1.3. Seaglider 142 (Figure 14a) provides an example of good correlation between the Seaglider data and ground-truth provided by the shipboard CTD, as well as a "healthy" Seaglider C/T sensor; the slight offset in salinity can be accounted for during calibration without additional explanation. The noise in SG143's C/T sensor (Figure 14b) appears to be primarily in salinity; but salinity is a function of both conductivity and temperature, such that noise in the temperature sensor is amplified in the calculated salinity. Looking at the mean variance in raw conductivity and temperature measurements across the duration of the experiment shows that the noise is primarily coming from the temperature sensor.

	SG142		SG143	
	Conductivity	Temperature	Conductivity	Temperature
Descent (med 5)	0.024629	0.098103	0.039233	51.9234
Descent (med 15)	0.12489	0.23902	0.19313	52.1315
Ascent (med 5)	0.032964	0.13285	0.035012	19.8037
Ascent (med 15)	0.14947	0.30731	0.24639	20.962

Table 16: Mean variances of noise determined by subtracting 5- or 15-point median filtered time series from the original time series of raw temperature and conductivity measurements (Hz).

7 Basestation 2.0

7.1 sigma_theta

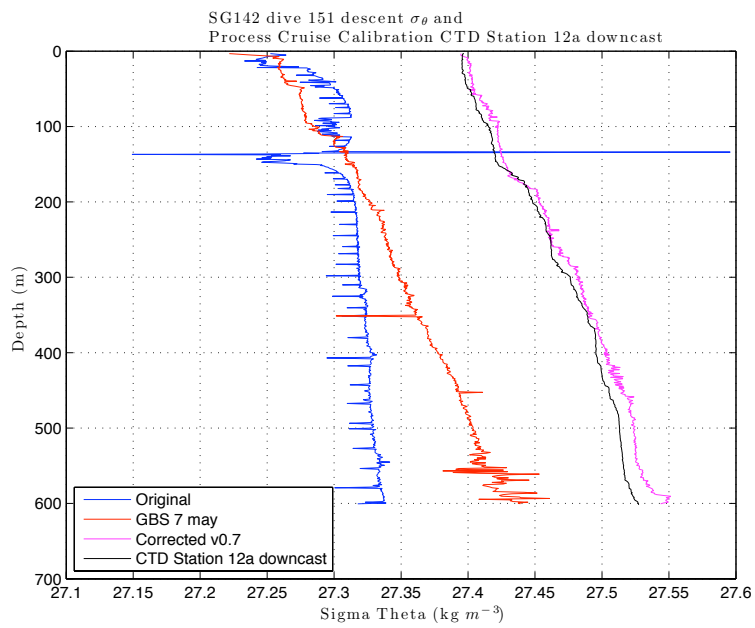


Figure 46: SG 142 sigma_theta: Knorr Process Cruise Calibration Cast (black) and SG 142 Descent: original Basestation 2.0 calculation (blue), new calculation as of 7 May 2009 (red), and calculation using frequency offsets (entire profile) from v0.7 (pink).

From NAB_compare_ThS.m:

```
ncload(['/Users/graya/Documents/seaglider/NAB_original_raw_data/original_raw/' ...
    'May6_GBS_fix_to_sigma_theta/p1410152.nc'], 'sigma_theta');

ptmp(4,:) = sw_ptmp(salinity(4,:),temp(4,:),press, 0);
pden0_v07 = sw_pden(salinity(4,iMatchDepth), ptmp(4,iMatchDepth), ...
    press(iMatchDepth), 0);

figure(2); clf;
plot(sg_ori.sigma_theta(iMatchDepth), depth(iMatchDepth), 'b', ...
    sigma_theta(iMatchDepth), depth(iMatchDepth), 'r', ...
     pden0_v07-1000, depth(iMatchDepth), 'm', ...
    ctd.sigma_theta, ctd.depth, 'k');
legend('Original', 'GBS 7 may', 'Corrected v0.7', ctd_label, 'Location', 'SouthWest');
set( get( gca, 'XLabel' ), 'Interpreter', 'latex' );
set( get( gca, 'YLabel' ), 'Interpreter', 'latex' );
set( get( gca, 'Title' ), 'Interpreter', 'latex' );
ylabel('Depth (m)');
xlabel('Sigma Theta (kg $m^{-3}$)');
title({[sgdive_label ' $\sigma_{\theta}$ and '], ['Process Cruise Calibration ' ctd_lab
axis ij;
grid on;
```

8 References

Eriksen, C. C., et al. (2001), Seaglider: A Long-Range Autonomous Underwater Vehicle for Oceanographic Research, IEEE Journal of Oceanic Engineering, 26, 424-436.

9 Document History

Date	Revision
20 June 2010	Created
22 June 2010	Updated v1.1 figures