



Comparison of XBT vs CTD Data



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OC - 3570**

**Submitted by:
Haris Sarwar Rana
LT Pakistan Navy**

INTRODUCTION

In Today's Modern Times when the world is shrinking and becoming a global village, gives us the blessings of being close to each other but at the same time it has exponentially increased the security concerns all over the world. Securing ones homeland requires meticulous planning, ample resources and most important of all good knowledge about the surrounding. Now a days Naval assets are becoming more and more vital in terms of providing sustainable security to a nation. Now if we look into the world of Naval warfare we can very distinctly say that, underwater warfare is its most vital part. Good knowledge of Submarine environment gives a submarine warrior edge on its adversaries. The most important underwater search and detection source of energy is sound. The ray path of sound is very much dependant on the surrounding temperature profile. Thus we can say that the most important environmental factor for someone interested in underwater warfare is knowing the temperature profile of that certain area. The two most common methods in use today of determining ocean temperature profiles are via a Conductivity, Temperature, and Depth (CTD) profiler or via an Expendable Bathythermograph (XBT) probe. CTD profilers are regarded as highly accurate and are used by the scientific community for research purposes. Using the measured temperature values and derived salinity values from a given CTD cast, the sound speed profile

over a depth can be computed. The sound velocity profile can then be used to describe the local acoustic environment and predict naval acoustic sensor performance.

An XBT probe is a less sophisticated instrument than the CTD profiler, only measuring temperature as it descends through the water column. Depth is computed based on a standard fall rate and a constant, standard salinity is assumed during processing.

The Naval Postgraduate School's winter quarter 2008 Operational Oceanography class (OC3570) went on a two-leg research cruise aboard the RV Point Sur from 23-30 January, 2008. Leg I departed from Moss Landing, CA on 23 January with half the student class and transited along the coast to San Francisco, CA; arriving on 26 January. The second half of the class met the ship in San Francisco and relieved the students from Leg I. Leg II surveyed San Francisco Bay from 27-28 January and then transited to Monterey Bay; arriving at Moss Landing, CA on 30 January. During the cruise, various different environmental measurements were taken in support of student projects including several CTD and XBT casts.

The aim of this project is to compare the temperature versus depth profiles collected by XBT probes with those measured by the CTD profiler in order to see any differences or biases which may then in turn impact sound velocity profiles.

DATA COLLECTION

CTD profiles were obtained using the Sea Bird 911+CTD/Rosette (12 position) with standard sensor suite. XBT profiles were obtained using the Sippican Mark 12 XBT system which included the LM-3A Hand Held Launcher. Sippican T-10, T-7 and DB XBT probes were used which have a maximum operational depth of 200 m, 760 m and 760 m respectively.

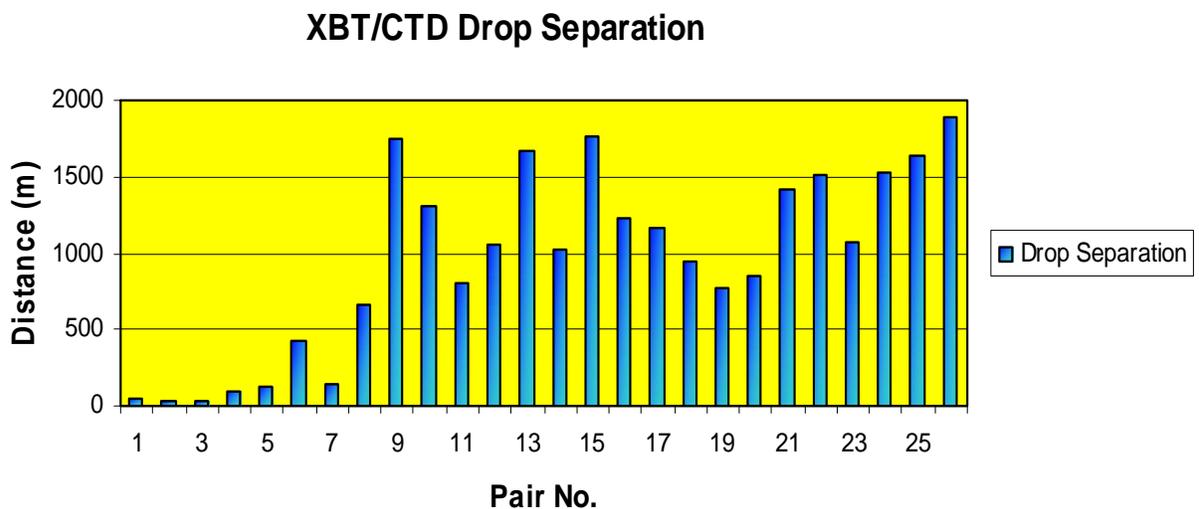
During Legs I and II, XBT probes were dropped in the vicinity of selected CTD casts. To make full use of the T-7's and DB's maximum operational depth, these XBTs were only deployed when the corresponding CTD cast exceeded 760 m, whereas T-10 were deployed where we have max depths less than 760 m. Over the course of the cruise, 26 pairs of CTD/XBT profiles were identified.

Appendix A contains the location of each CTD/XBT pair. Appendix B contains a graphical depiction of the location of each CTD/XBT pair.

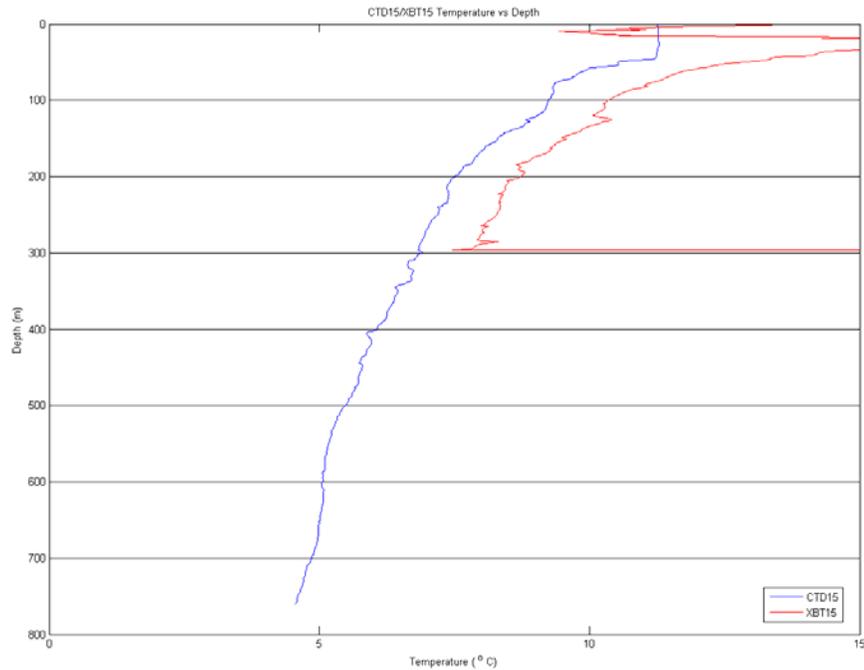
DATA SELECTION AND QUALITY CONTROL

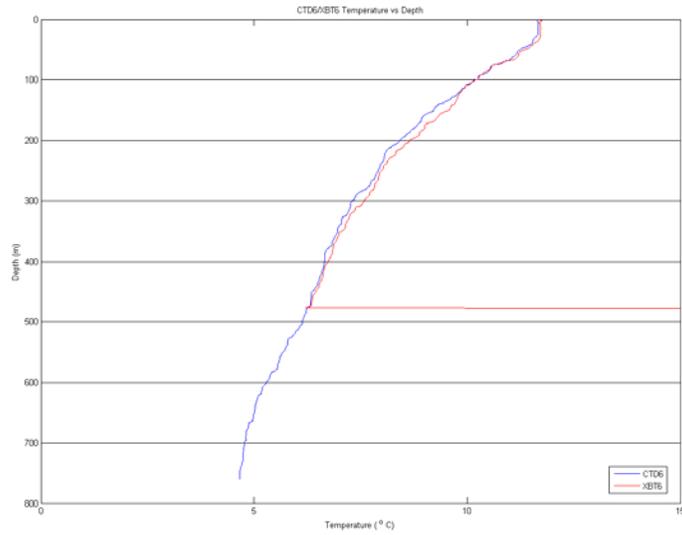
Once the 26 available pairs of CTD/XBT profiles were identified, the raw data for each cast was examined. CTD data is recorded in an ASCII text format (.asc) while XBT data is recorded in European data format (.edf). It should be noted that CTD depth data is recorded in dbars while XBT depth data is recorded in meters and must be adjusted accordingly when processing the data.

Using the final cruise report and looking at the raw data files, first of all it was necessary to find drop separation distance between the each pair. After extracting all the positions of the drops the separation distance was plotted against each drop and it was found that all the drops are within 2 km of distance which was considered acceptable in conjunction to the sea state during the cruise, whereas 5 pairings were marked as being 1.5 km apart to further see the comparison with or without these pairs. In the future cruises it may be considered to drop the XBT during the CTD cast as it will considerably reduced the separation distance between them. The separation distance table is shown below:

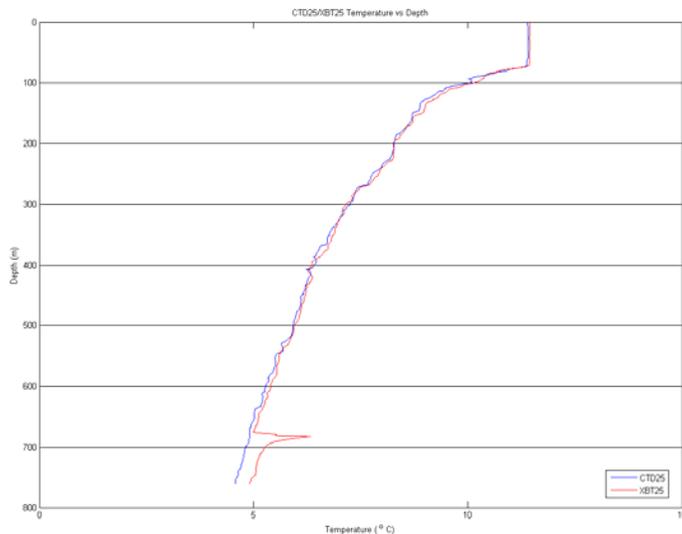


After finding the Separation distance the next step was to visually identify the presence of any erroneous data set. MATLAB was used to plot temperature vs depth profiles for each of the 26 CTD/XBT pairs and then visually inspected. Initial, visual inspection suggested to exclude pair 6, 12, 14 and 15 as XBT data in these pairs revealed erroneous temperature profiles. Pair 6 and 12 both labeled as T-7 were probably processed wrong as they never achieved their max depth of 760 m. Example of such a profile in each case is given below.





Pair 8 and 25 showed a warming trend below 630 m and 670 m depths respectively. A visual inspection of these pairs was made and was concluded that the warming trend is not gradual therefore the pairs were included in the overall comparison set but were not considered for further investigation. A sample plot can be seen below:



Beside this, comparison of all other CDT/XBT temperature plots did not indicated substantial differences and thus were included for comparison.

DATA PROCESSING AND ANALYSIS

Because of the high accuracy and known calibration of the Sea Bird CTD profiler, the CTD profiler is considered to represent the true temperature and salinity depth profile for the stations sampled during this cruise. Temperature comparisons were made between the CTD and XBT for the same depth and any differences were assumed to be, due to the inaccuracy of the XBT.

Because the XBT probe measures depth in meters and the CTD profiler measures depth in decibars, the first necessary step was to convert the CTD pressure readings to meters to allow for direct comparisons. A MATLAB routine was used to extract the CTD pressure values and convert them to depth in meters.

The second step was to adjust for sampling rates between the CTD and XBT. In order to compare the temperature values between the CTD and XBT, the temperature values from each data set must be at the same depth. The CTD profiler took temperature readings approximately every meter as it descended, while the XBT probe took temperature readings approximately every 0.6 meters. An interpolation routine was run in MATLAB to allow for temperature comparisons at equal depths. Beside this it was important to limit

the CTD cast to the max depth of XBT because after that no comparison could be made.

Once all the above adjustments were made to the data, a direct comparison could be made between CTD and XBT temperature readings. In order to calculate the Sound speed for CTD Matlab function soundspeed.m was used and the option for equation of state was selected.

In order to analyze the data in pairs, 6 plots were made for each data set, Appendix C contains all the plots made from each sample. A brief description of each plot is given below:

Plot (1)

Shows the temperature profiles of both CTD and XBT against the depth in meters.

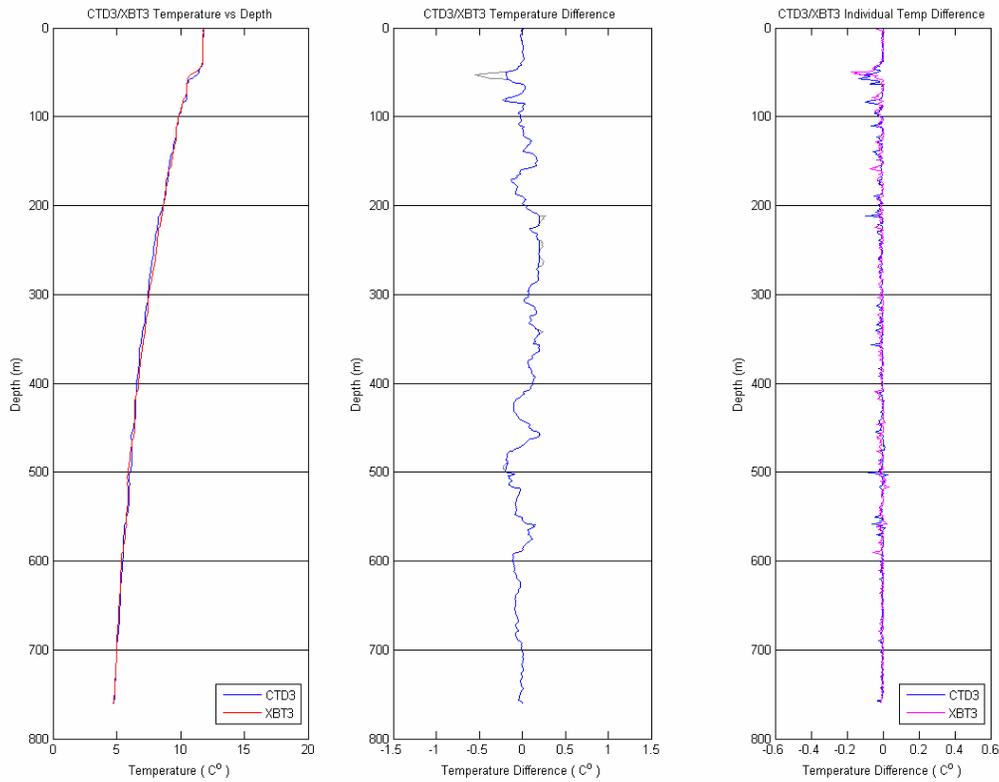
Plot (2)

Shows temperature difference plot of CDT/XBT. Another line was plotted in order to show potential points where temperature difference was more than 0.2 C'. Data was stored for the plot with removed points for each set and finally analysed in the results.

Plot (3)

Shows 2 plots of CDT and XBT temperature difference within their own array of data. This was done to see that at which points within the array there was a time when temperature difference was

more than 0.2 C' amongst two vertical levels. A sample figure for the first three plots can be seen below:



Plot (4)

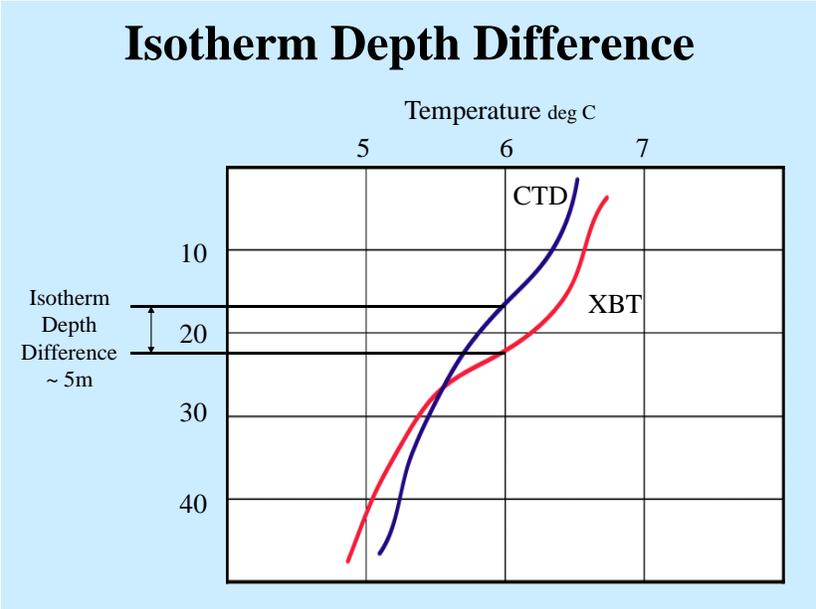
Shows the sound speed profile of CTD and XBT against depth.

Plot (5)

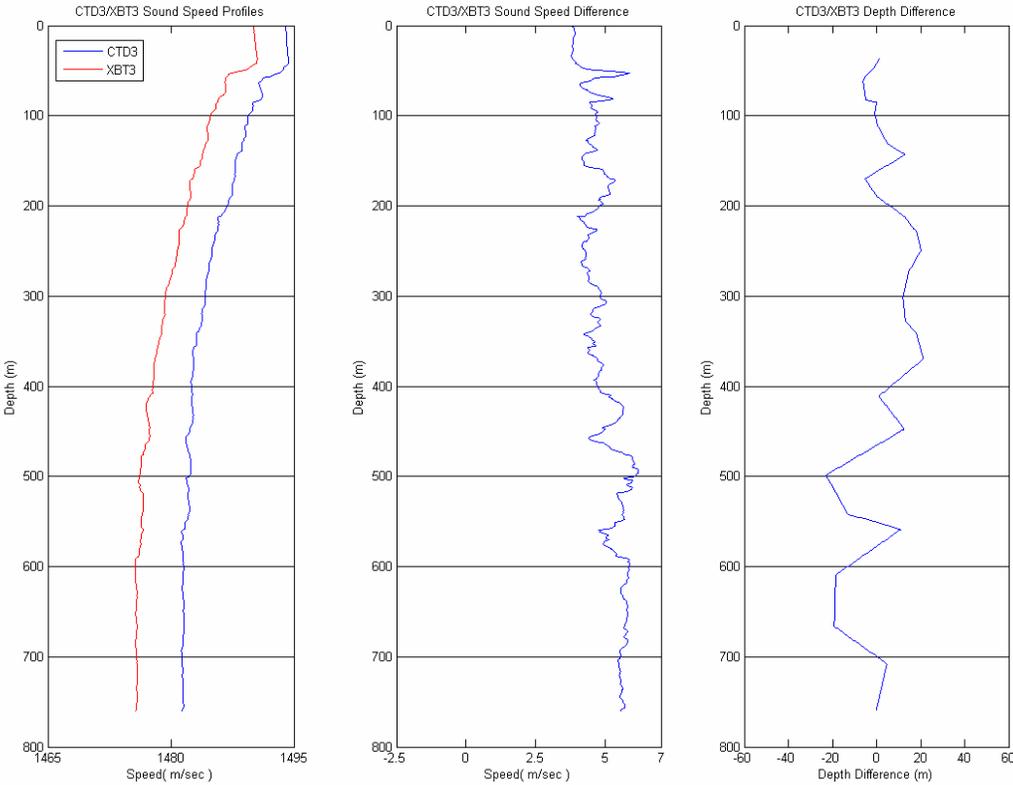
It shows the sound speed difference between CTD and XBT

Plot (6)

IT shows the Isotherm Depth difference between CTD and XBT. Isotherm Depth difference was calculated at an increment of 0.2 C'.



A sample figure for last three plots can be seen below:



Overall processing was carried out to see difference in CTD and XBT in three regimes which were temperature, Sound Speed and Isotherm Depth. As mentioned previously, the CTD temperature was assumed to represent truth against which the XBT was compared. XBT temperatures for each depth were subtracted from the CTD temperature values. Appendix C contains the plots of each pair of CTD/XBT temperature readings along with the temperature difference between the two instruments. For each CTD/XBT pair, the mean and standard deviation was calculated for each depth, which was then incorporated into an overall mean and standard deviation for the entire data set. Appendix D contains the mean and standard deviation results.

As mentioned earlier SSP of CTD data was calculated based on equation of state with a Matlab routine. This matlab routine takes the insitu measurements of depth, Temperature and salinity from the CTD and is considered to be a very accurate measurement. On the other hand XBT data file already has a data string for Sound Speed. In case of XBT ssp is calculated with an assumed standard salinity of 30 PPT. The sound velocity profile for each sample and the difference for each pair were plotted in MATLAB. Appendix C contains the plots for each pair. In addition, the mean and standard deviation of the sound Speed calculations were also made. Isotherm depths were calculated for CTD and XBT and difference was

plotted for each pair. The mean and standard deviation of the Depth difference were also calculated.

It was noted earlier that five of the CTD/XBT pairs had separation distances more than 1.5 km. In order to see if these five pairs had any significant impact on the overall mean and standard deviation, the comparisons were re-run excluding these suspect CTD/XBT pairs - resulting in 17 useable pairs. The results were not considerably different from the 22 Pair set so these pairs were kept within the master data set for comparison. Besides this mean temperature difference was also calculated with the data string obtained after removing the depth levels which show more than 0.2 c' difference between two levels and the results were compared with the raw data.

At the end all the statistical comparisons were made for each type (T10,T7&DB) of XBTs vs CTD in order to see the accuracy of each type against CTD. Composite plots were made for temperature difference, SSP difference and Isotherm depth difference for each type of XBT against CTD.

RESULTS

The results of the CTD/XBT temperature, sound Speed and Isotherm Depth comparison are summarized in table 1, 2 & 3.

Temperature Difference:

Temperature Diff	XBT (T7 & TD)	XBT (T10)
Mean Temp Diff ($^{\circ}\text{C}$)	0.0712	0.0362
Max(Warm)	0.1514	0.2083
Min	0.0183	-0.0362
Mean Temp Diff Std ($^{\circ}\text{C}$)	0.1242	0.1160
Max(Warm)	0.2949	0.2383
Min	0.0462	0.0514

Sound Speed Difference:

SSP Diff	XBT (T7 & TD)	XBT (T10)
Mean SSP Diff (m)	3.7887	3.7092
Max	4.2472	4.3545
Min	2.7023	2.6144
Mean SSP Diff Std (m)	2.0230	1.6894
Max	2.2895	1.9671
Min	1.4234	1.2897

Isotherm Depth Difference:

Isotherm Depth Diff	XBT (T7 & TD)	XBT (T10)
Mean Depth Diff (m)	8.3315	1.1094
Max	16.8433	6.0692
Min	-2.7709	-6.7639
Mean Depth Diff Std (m)	16.3902	5.1478
Max	32.3478	15.1997
Min	0	0

As a whole the set of 22 pairs ranged from 0.02083 °C warmer to -0.0362 °C colder, with a standard deviation from 0.2949 to 0.0462 °C. As mentioned earlier two means were calculated for the whole temperature difference data set one with raw data which gives the value of XBT overall reading 0.0537 °C and with the suspected bad points removed XBT reads 0.0370 °C warmer than CTD. In case of Sound Speed difference overall it ranges from 4.2474 m to 1.4234 m and standard deviation from 2.0230 m to 1.2897 m. The overall mean of Sound Speed difference for the whole data set was 3.7489 m slower than that of CTD. The Isotherm Depth difference ranges from 16.8433 m to -6.7639 m with the standard deviation ranging from 32.3478 m to 0(zero) m. The overall mean Isotherm Depth difference for the whole data set was 4.7204 m Deeper than the CTD depths.

In a nutshell we can say that after analysis of the considered data set on the average XBT in comparison to CTD possesses the following differences:

1. XBT has a warm bias of 0.0537°C over CTD.
2. XBT gives Sound Speed of the order of 3.7489 m slower than CTD.
3. XBT measures Isotherm Depths of the order of 4.7204 m deeper than CTD.

COMPARISON WITH PREVIOUS STUDIES

Previous student studies obtained similar results. All showed a warm bias in the XBT measured temperatures as compared to the temperatures measured by the CTD profiler and each study obtained similar standard deviations. Following table summarizes the mean temperature and standard deviations from this study and previous studies. The Sippican Corporation claims an accuracy of $\pm 0.1^{\circ}\text{C}$ in their XBT probe product brochure which this study verified, but is slightly outside the average deviation when combined with the results of the seven previous student studies.

But nevertheless the difference is of the order of 0.030 °C from the average which is acceptable.

Author, Yr (sample size)	Mean T diff(°C)	Std Dev (°C)
Schmeiser, 2000 (18)	0.1549	0.2151
Roth, 2001 (9)	0.0783	0.1047
Boedeker, 2001 (27)	0.0882	0.2147
Fang, 2002 (28)	0.1074	0.1546
Dixon, 2003 (24)	0.1275	0.0598
Laird, 2006 (13)	0.0407	0.0936
Whelan, 2007 (21)	0.0344	0.1012
Haris, 2008 (22)	0.0537	0.1790
Average	0.0856	0.1403

For the Sound Speed difference results were compared with the findings of Whelan (2007). He find the average Sound Speed difference to be of the order of 5.06 m/s, whereas this study find the average difference to be of the order of 3.7489 m/s which is close. Incase of Isotherm depth difference results were compared with findings of Dixon (2003). He find that for XBT(T-7) the average Isotherm Depth difference was 13.53 m deeper than that of CTD with mean standard deviation of 6.02 m, whereas this study found the average Isotherm depth difference of 8.3315 m deeper

than CTD with mean standard deviation of the order of 16.3902 m deeper (only for the data extracted from XBT(T-7)).

CONCLUSION

The results of this study are consistent with seven previous studies. All the studies found XBT having a Warm bias in comparison to the CTD. In this study the warm bias was of the order of 0.0537 °C. This slight warm bias in turn effect the SSP and the Isotherm depths of XBT. Still with all this bias XBT is a very practical operational piece of equipment as far as the Naval Operations are concerned. How XBT precedes the operational and tactical use of CTD is summarized in the following points:

1. XBT's are considerably less expensive than CTD and thus the job could be done in less money.
2. Launching of XBT has no sea state constraints, can be launched in any sea state.
3. Launching of XBT doesn't jeopardize the maneuverability of a warship.
4. A single XBT launch can be completed in minutes whereas one CTD cast require approx 45 mins (depending on the sampling depth)
5. Launching of CTD require multiple persons, whereas XBT can be Operated by a single person or from a Fixed launcher.

6. For XBT operation there's no need to have a dedicated superstructure for its launcher, whereas CTD requires a dedicated launching superstructure.
7. XBT can be deployed by both Ships and Submarines.
8. XBTs are smaller in size and can be stored easily onboard smaller vessels like Mine Hunters or Submarines.
9. Warm bias present in XBT readings is consistent throughout the depth, therefore it hampers less in terms of getting the sound speed profile for Operational and Tactical use.
10. The warm bias in XBT can be refined to get an accurate measurement.

A CTD may be preferred to be used for Scientific Research and precedes its importance over XBT in the following ways:

1. It gives the most accurate measurements of different ocean parameters at the same time.
2. For scientific Research most of the time accuracy of the measurements is more important than getting it more quickly.
3. CTD is a better piece of equipment to be used to develop strategic data bases to be used in future.

RECOMMENDATIONS

Recommendations for future cruises are delineated below:

1. It is recommended to drop the XBT during the CTD cast in order to get minimum drop separation.
2. Placement of a fixed XBT launcher may be considered at a suitable place on the ship, which could reduce occasional dropping errors.
3. In future a Project may be considered to Analyze the Results form all the Previous studies

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Valeport
<http://www.valeport.co.uk/Notes/CTD%20vs%20SV%20040915%20.htm>

Windows to the Universe, CTD Instruments
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APPENDIX A

XBT/CTD pair position - Depth - Drop Separation (All Pairs)

Comparison	Probe	Latitude	Longitude	Depth	Distance (m)
				XBT/CTD - m/dbar	
1	XBT 66	36-46.93	122-01.20	200.0	47
	CDT 2	36-44.48	122-01.06	1011.0	
2	XBT 67	36-42.30	122-03.08	200.0	30
	CDT 3	36-42.10	122-03.62	1423.2	
3	XBT 68	36-46.15	122-07.60	760.0	30
	CDT 4	36-46.11	122-07.93	1300.0	
4	XBT 69	36-38.97	122-06.95	200.0	97
	CDT 5	36-38.65	122-07.41	2128.0	
5	XBT 70	36-42.38	122-07.04	760.4	119
	CDT 6	36-41.72	122-06.34	200.0	
6	XBT 71	36-34.30	122-02.56	460.0	428
	CDT 8	36-33.97	122-02.22	911.0	
7	XBT 72	36-26.78	122-04.16	760.4	149
	CDT 9	36-26.65	122-04.38	883.0	
8	XBT 73	36-21.93	122-13.67	594.7	669
	CDT 10	36-22.24	122-13.90	1010.0	
9	XBT 74	36-17.08	122-24.26	760.4	1745
	CDT 11	36-17.65	122-25.19	1011.0	
10	XBT 75	36-23.32	122-29.18	448.0	1304
	CDT 12	36-23.86	122-29.74	1011.0	
11	XBT 76	36-28.41	122-18.82	760.4	805
	CDT 13	36-28.84	122-18.90	1013.0	
12	XBT 77	36-44.02	122-00.46	273.7	1059
	CDT 15	36-44.07	122-01.17	1264.9	
13	XBT 78	37-25.14	123-13.96	760.4	1674
	CDT 62	37-24.54	123-13.11	1011.0	
14	XBT 79	37-19.72	123-24.80	760.4	1016
	CDT 63	37-19.59	123-24.13	1013.3	
15	XBT 80	37-11.47	123-18.86	0.0	1761
	CDT 64	37-10.94	123-17.87	1010.0	
16	XBT 81	37-02.73	123-12.24	760.4	1233
	CDT 65	37-02.26	123-11.65	1008.0	
17	XBT 82	37-07.87	123-00.51	697.2	1163
	CDT 66	37-07.27	123-00.74	717.5	
18	XBT 83	37-12.72	122-49.39	200.0	942
	CDT 67	37-12.28	122-49.71	288.0	
19	XBT 84	37-03.11	122-43.57	200.0	770
	CDT 68	37-03.50	122-43.75	556.0	
20	XBT 85	36-51.14	122-19.01	200.0	85
	CDT 70	36-50.98	122-19.55	1009.0	
21	XBT 86	36-46.46	122-30.33	760.4	1420
	CDT 71	36-46.16	122-31.21	1007.8	
22	XBT 87	36-41.10	122-42.98	760.4	1517
	CDT 72	36-41.22	122-41.97	1009.9	
23	XBT 88	36-35.74	122-53.23	760.4	1063
	CDT 73	36-36.21	122-52.82	1009.0	
24	XBT 89	36-28.04	122-47.47	760.4	1524
	CDT 74	36-27.56	122-46.64	1011.0	
25	XBT 90	36-32.55	122-37.09	675.6	1638
	CDT 75	36-32.56	122-35.99	1008.0	
26	XBT 91	36-43.65	122-15.34	760.4	1896
	CDT 77	36-42.80	122-14.63	1091.0	

APPENDIX A

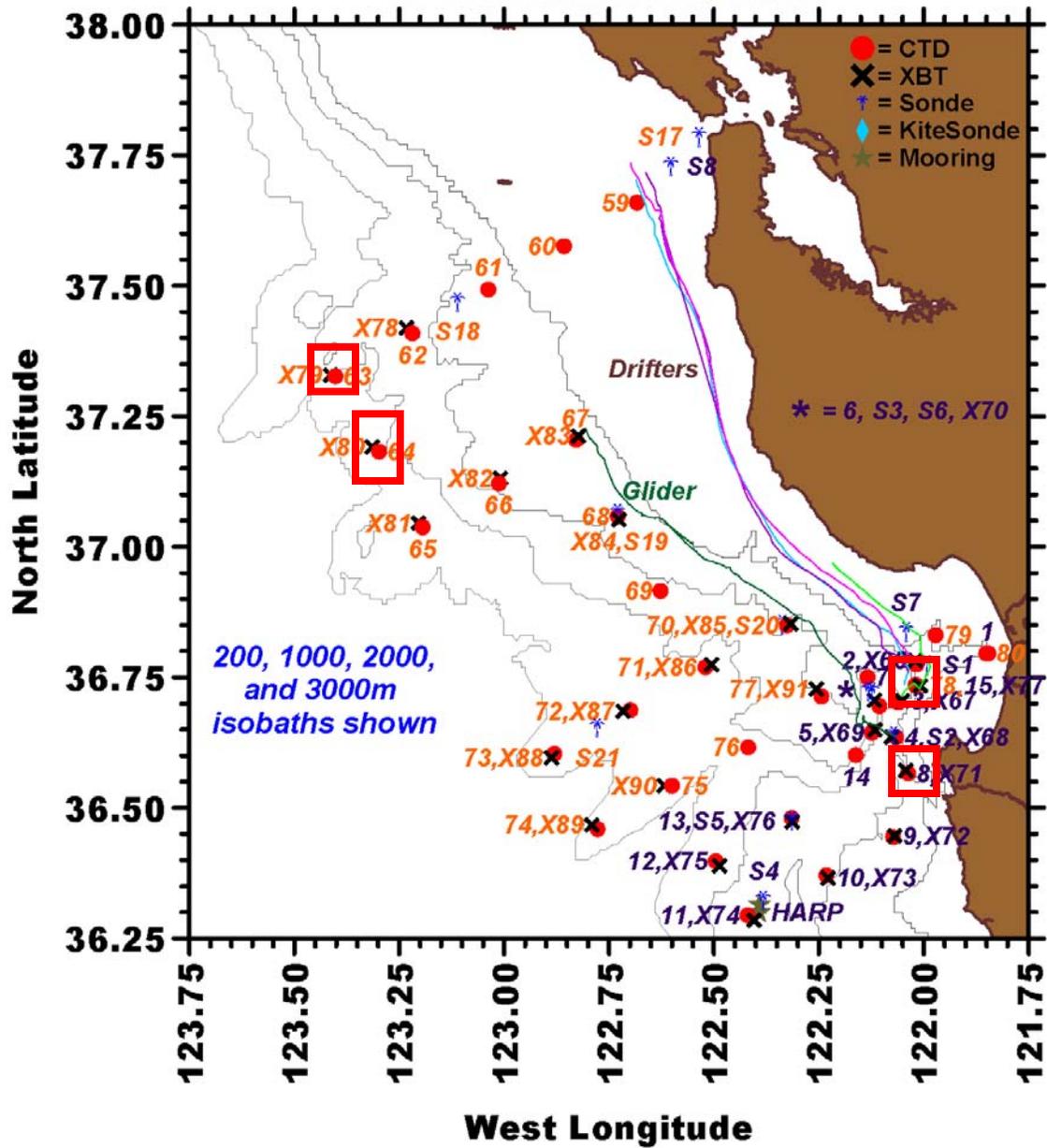
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	CDT 6	36-41.72	122-06.34	200.0	
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	CDT 62	37-24.54	123-13.11	1011.0	
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	CDT 65	37-02.26	123-11.65	1008.0	
13	XBT 82	37-07.87	123-00.51	697.2	1163
	CDT 66	37-07.27	123-00.74	717.5	
14	XBT 83	37-12.72	122-49.39	200.0	942
	CDT 67	37-12.28	122-49.71	288.0	
15	XBT 84	37-03.11	122-43.57	200.0	770
	CDT 68	37-03.50	122-43.75	556.0	
16	XBT 85	36-51.14	122-19.01	200.0	853
	CDT 70	36-50.98	122-19.55	1009.0	
17	XBT 86	36-46.46	122-30.33	760.4	1420
	CDT 71	36-46.16	122-31.21	1007.8	
18	XBT 87	36-41.10	122-42.98	760.4	1517
	CDT 72	36-41.22	122-41.97	1009.9	
19	XBT 88	36-35.74	122-53.23	760.4	1063
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OC3570, Pacific Ocean Activities

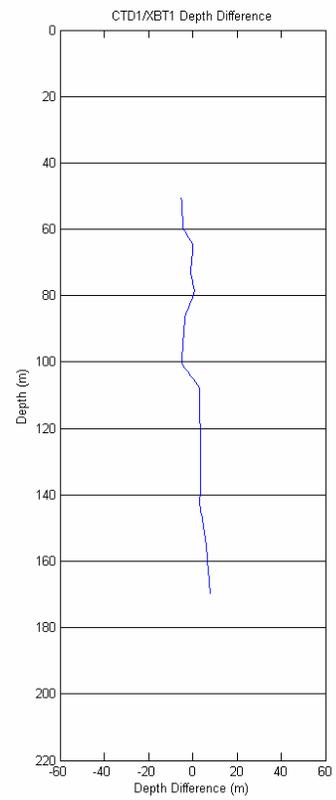
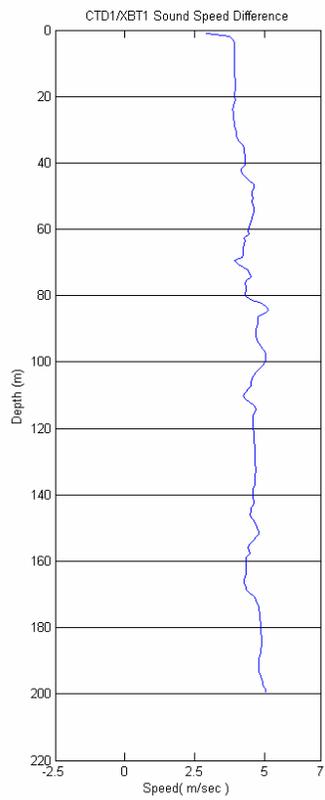
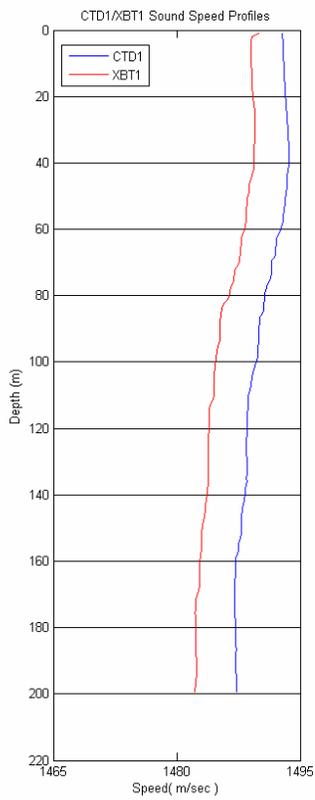
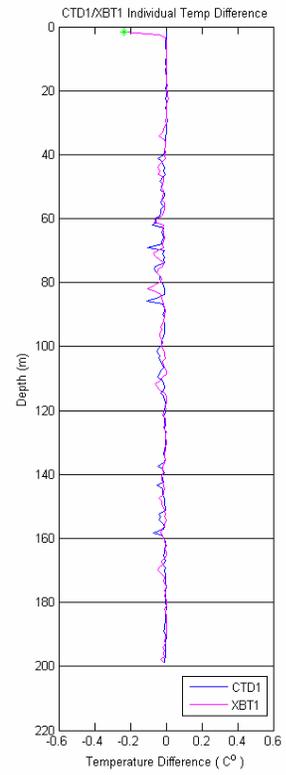
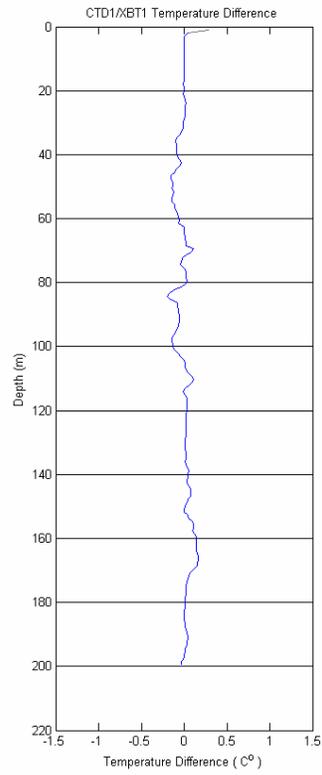
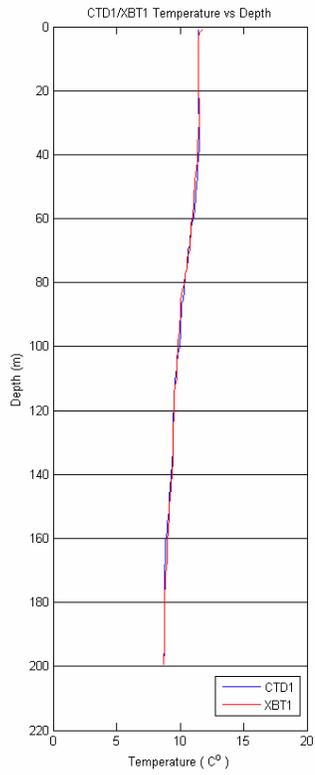
23-26 Jan. 2008 (Leg I)

27-30 Jan. 2008 (Leg II)

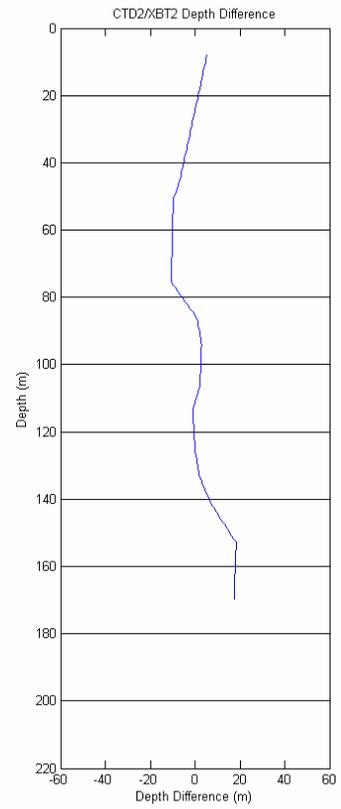
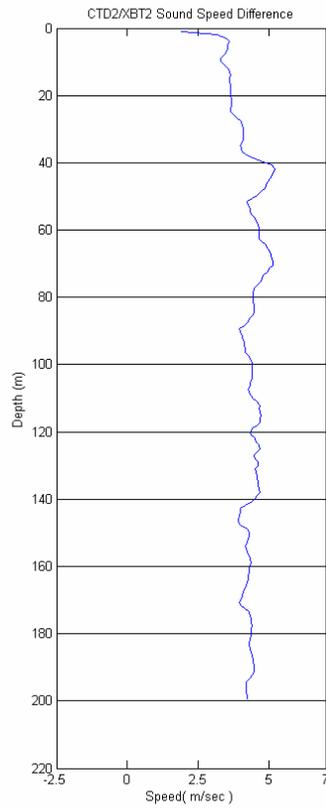
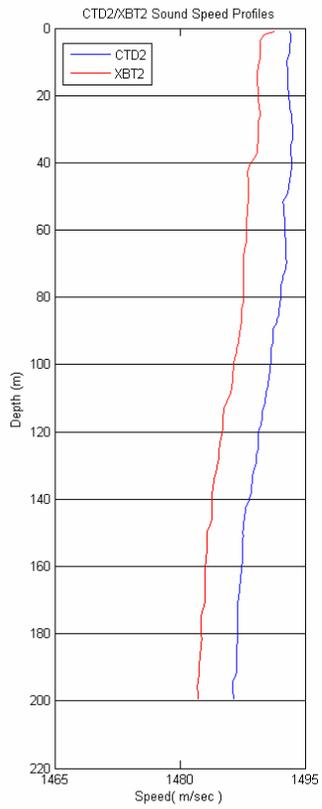
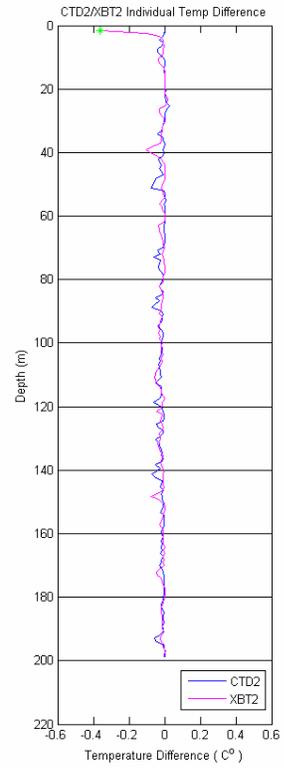
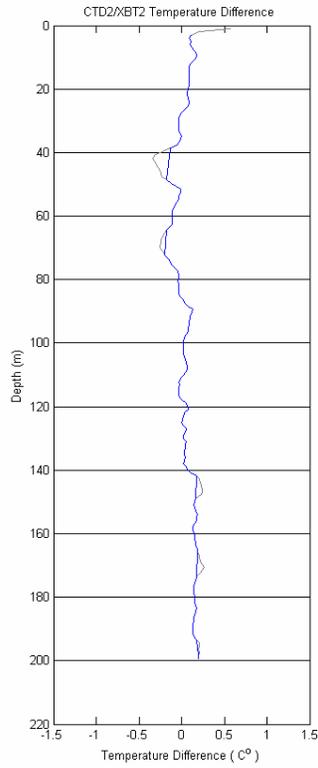
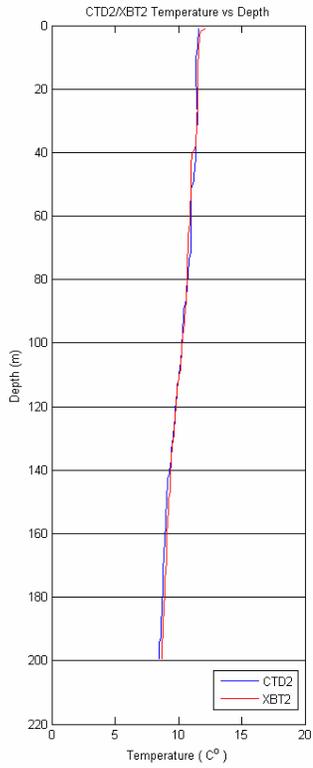


□ → Data Pairs Not Considered For Comparison

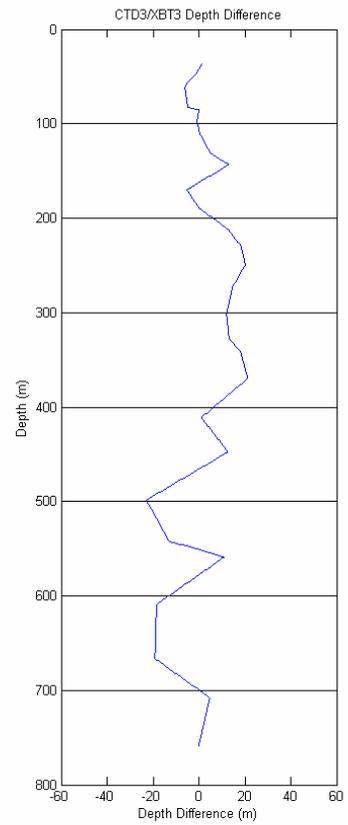
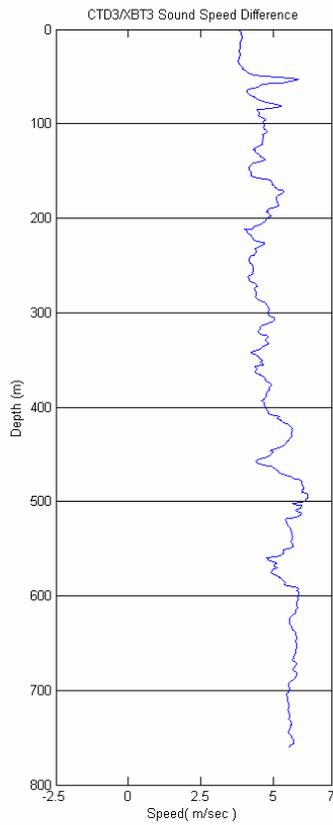
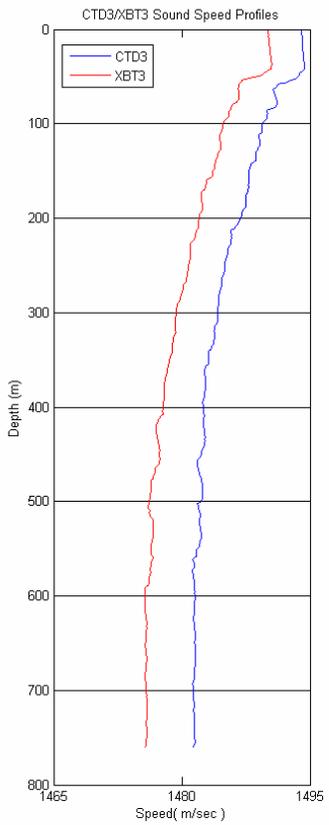
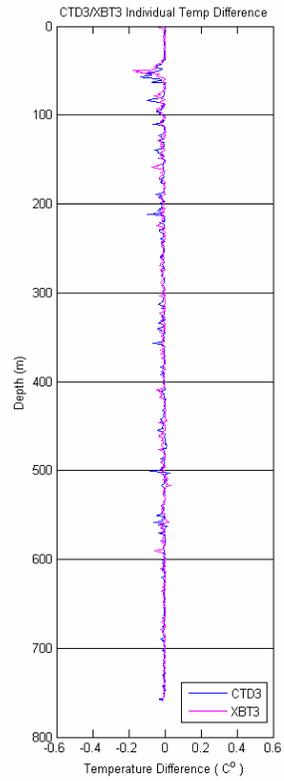
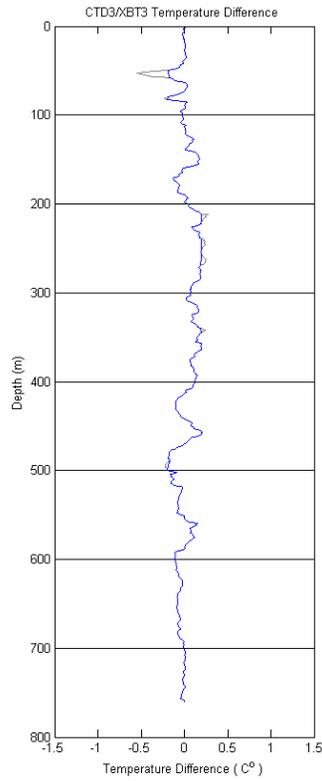
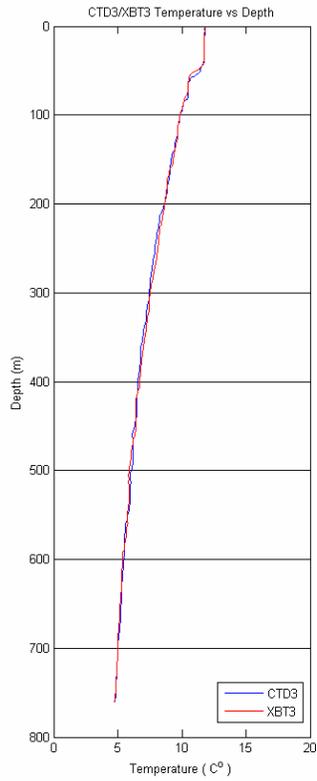
APPENDIX C



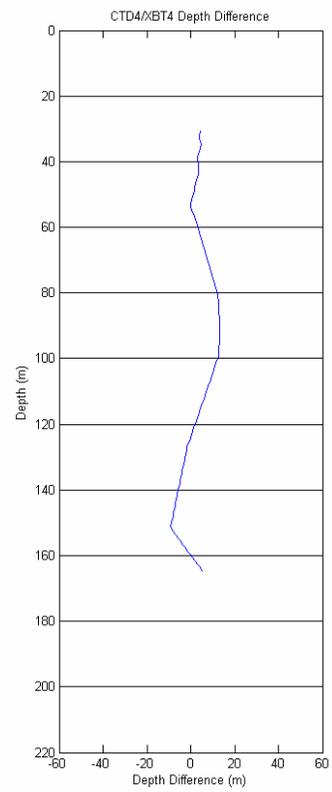
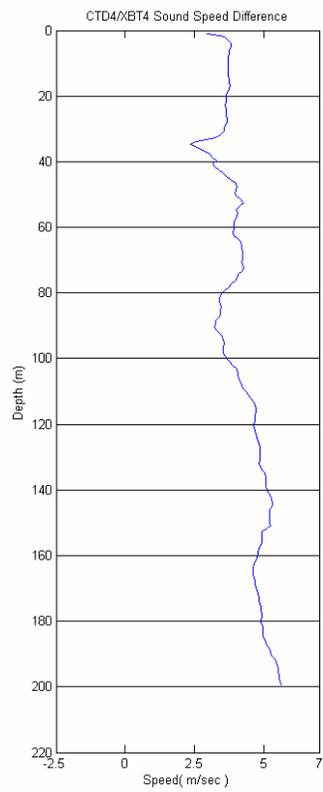
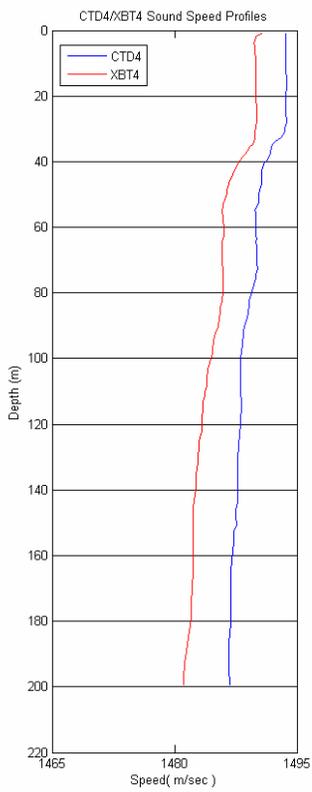
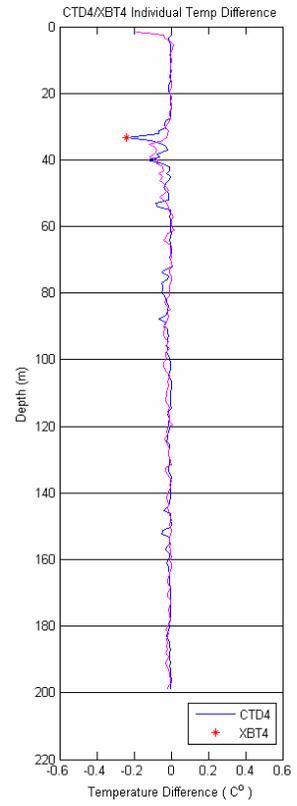
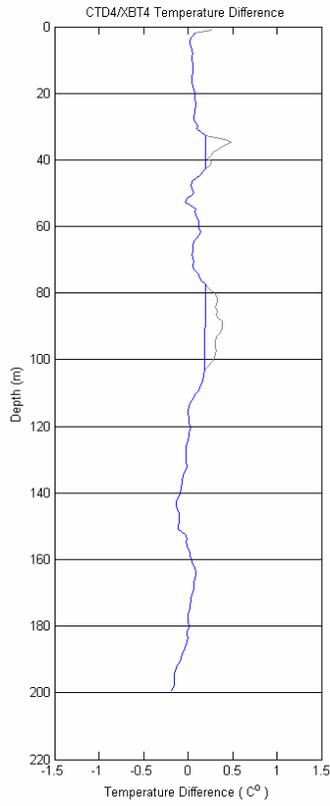
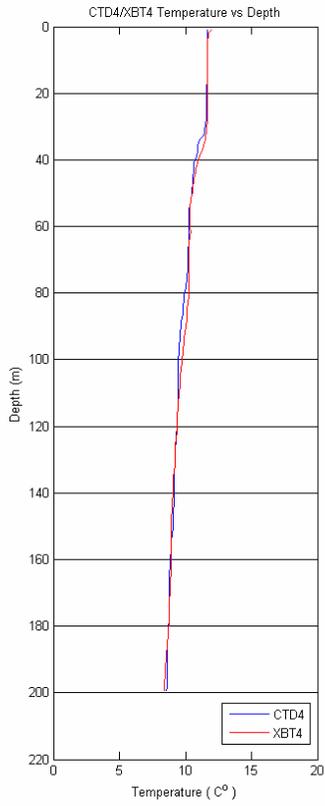
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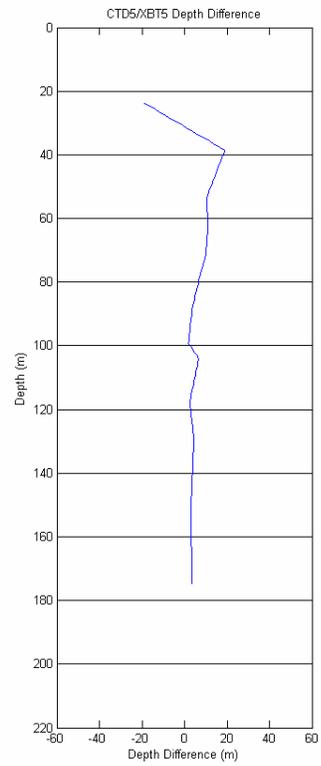
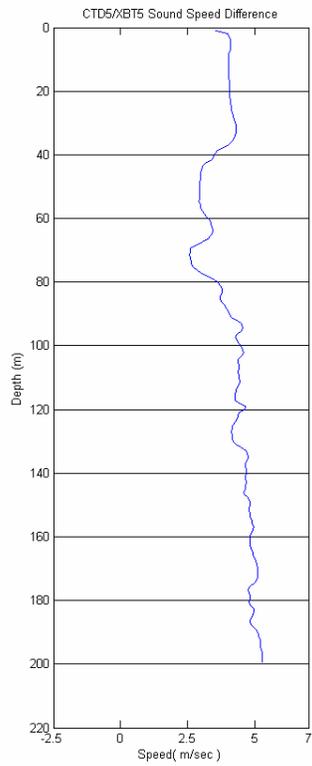
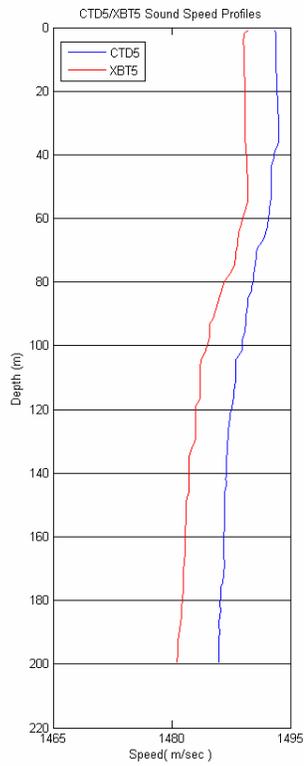
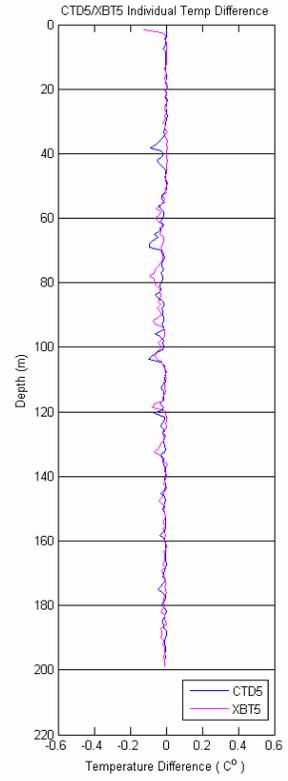
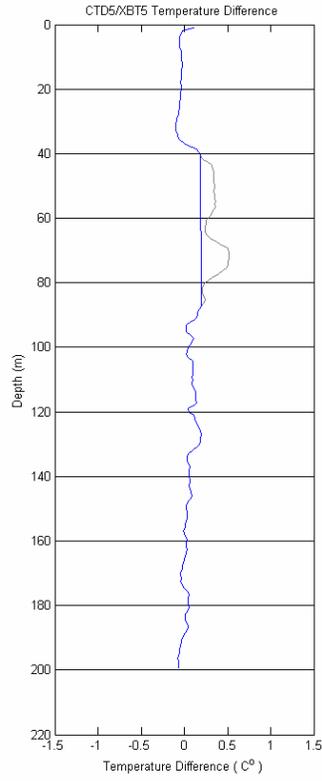
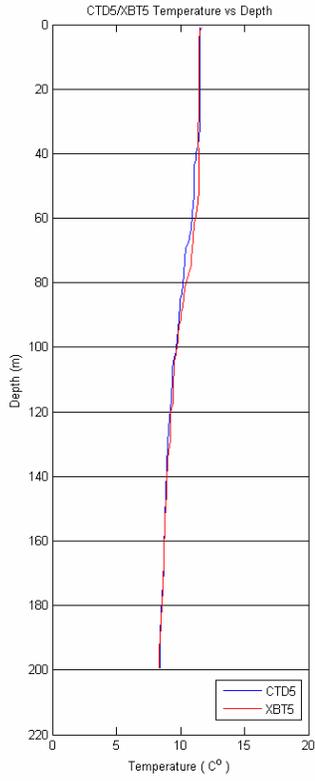
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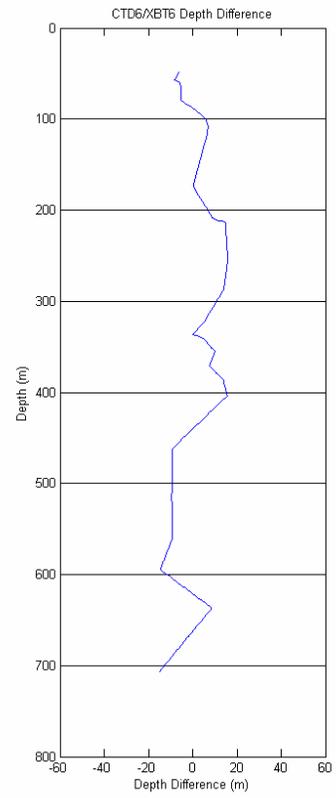
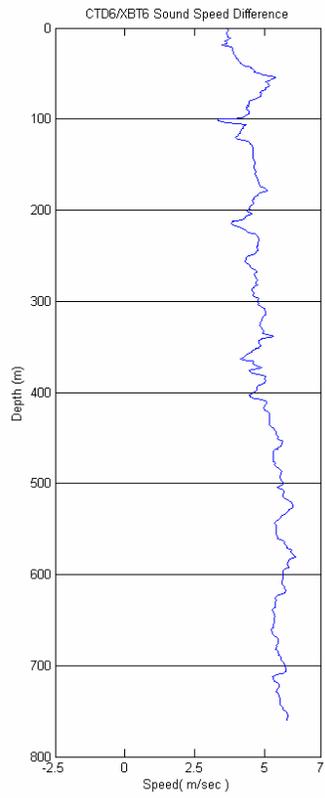
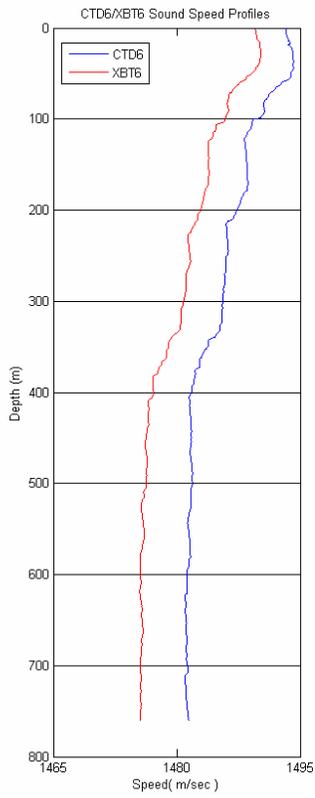
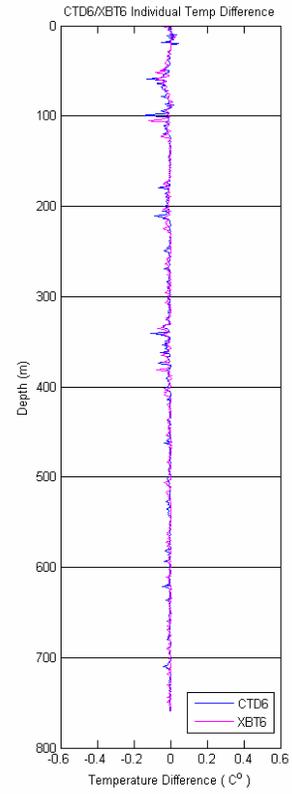
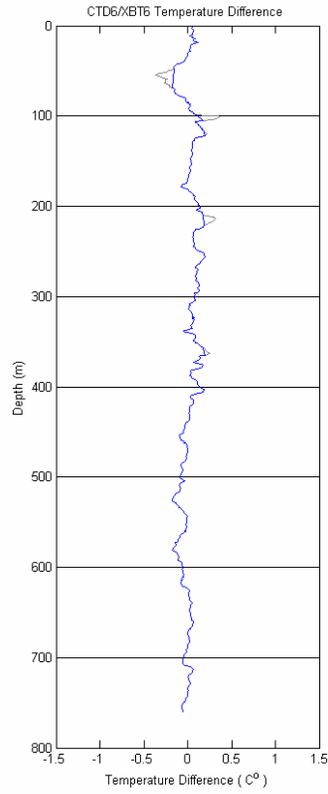
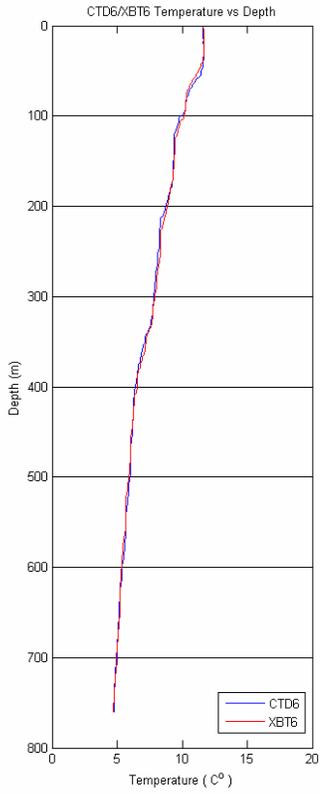
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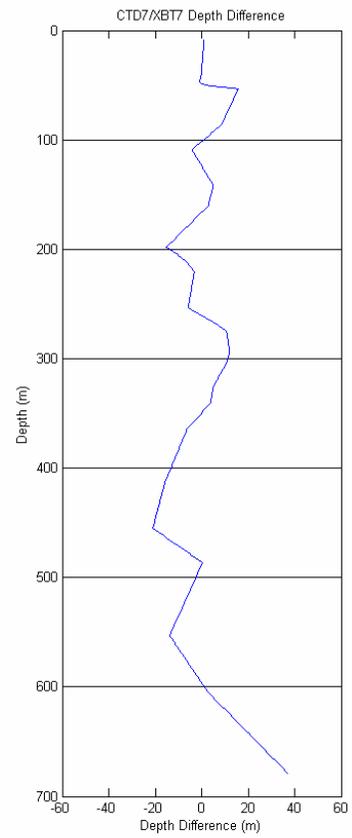
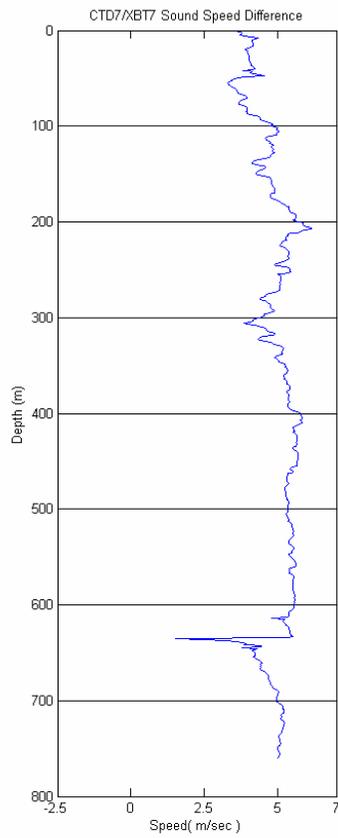
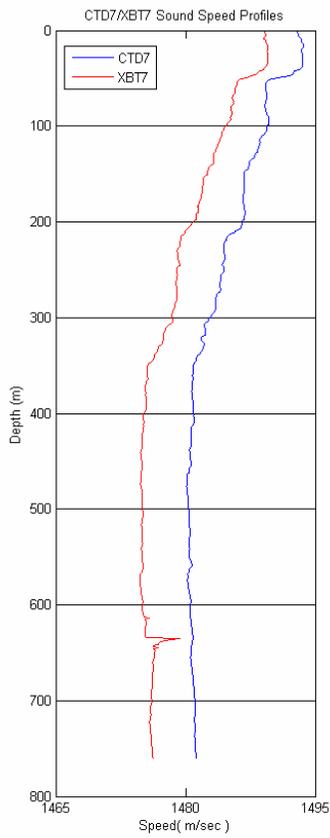
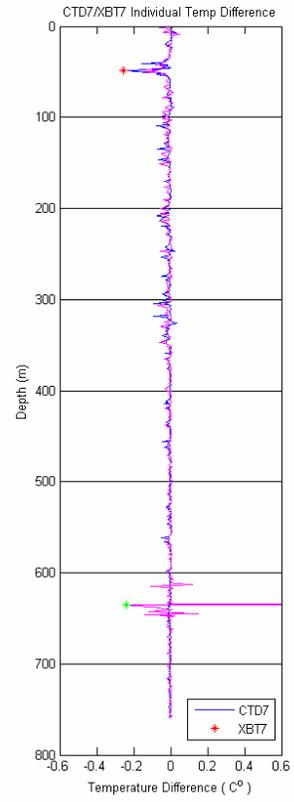
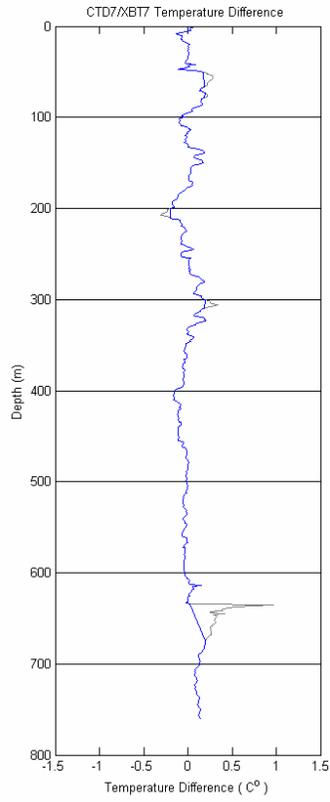
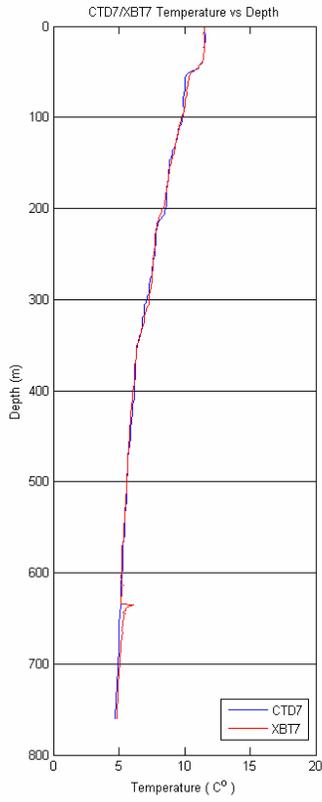
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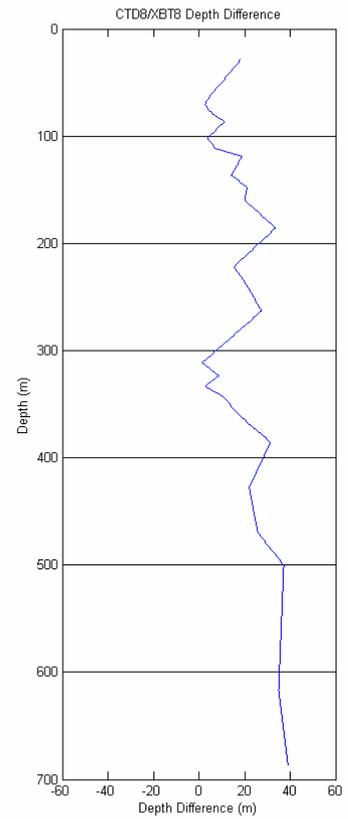
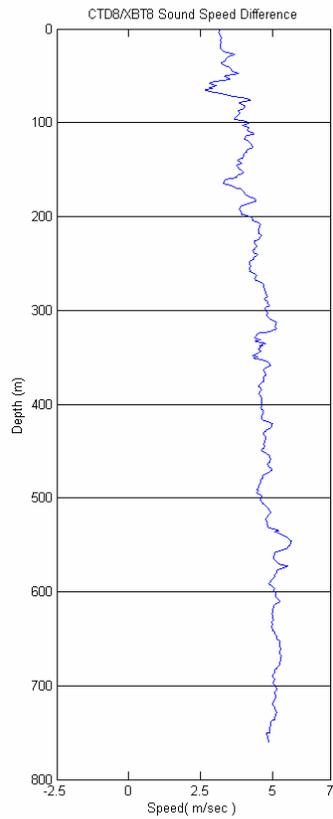
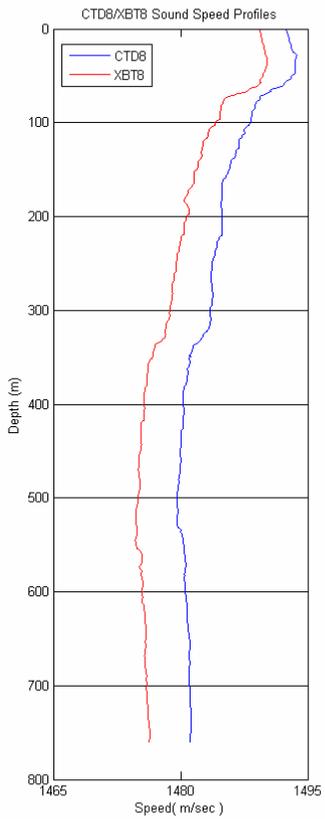
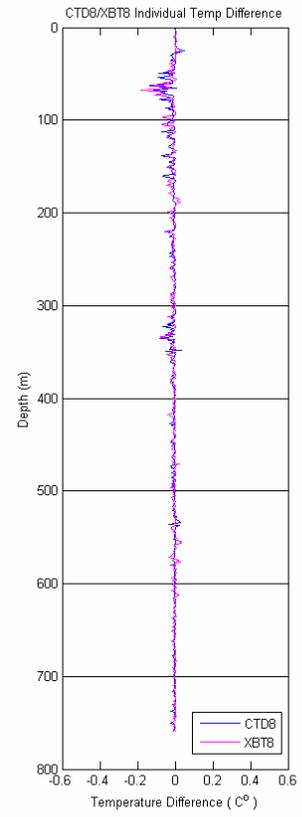
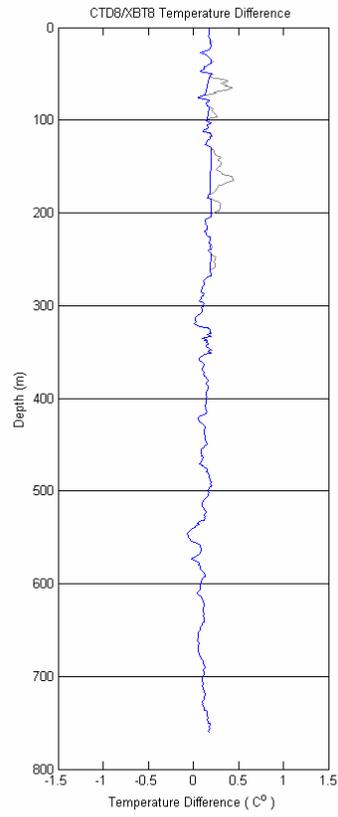
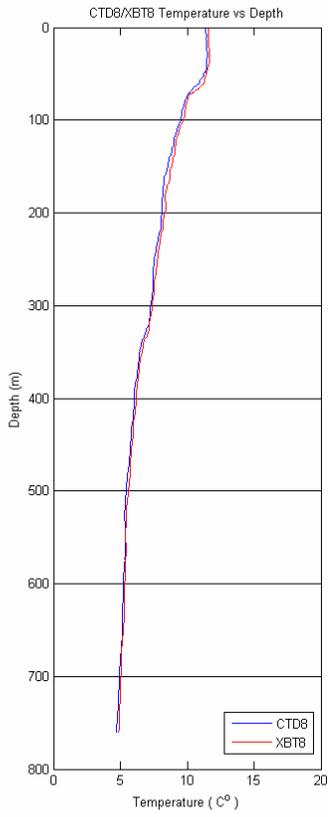
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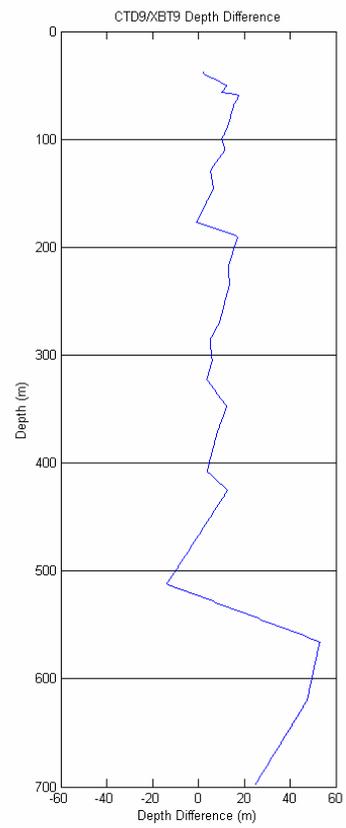
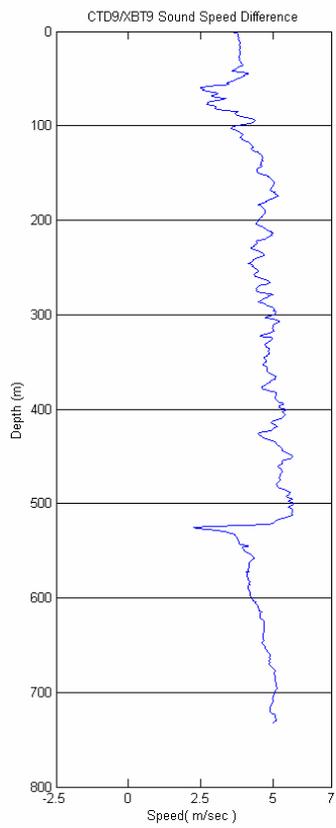
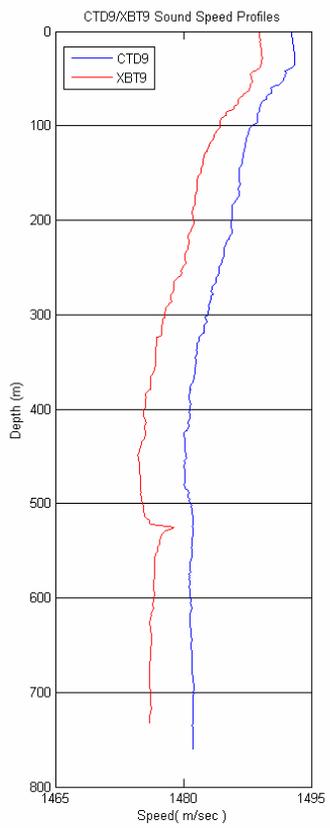
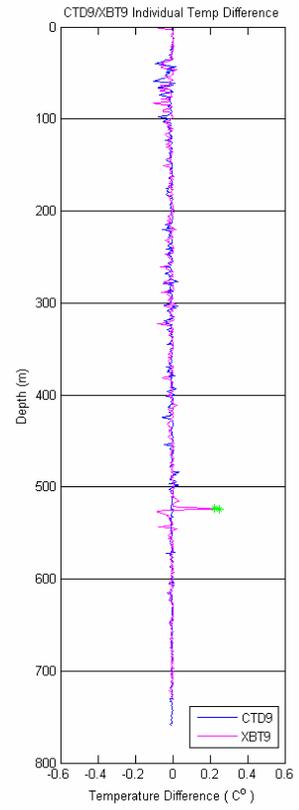
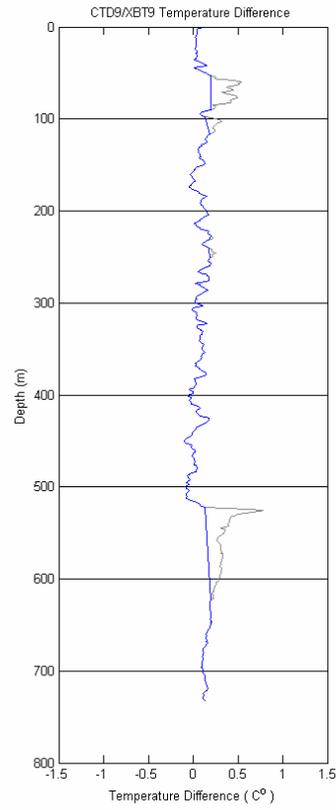
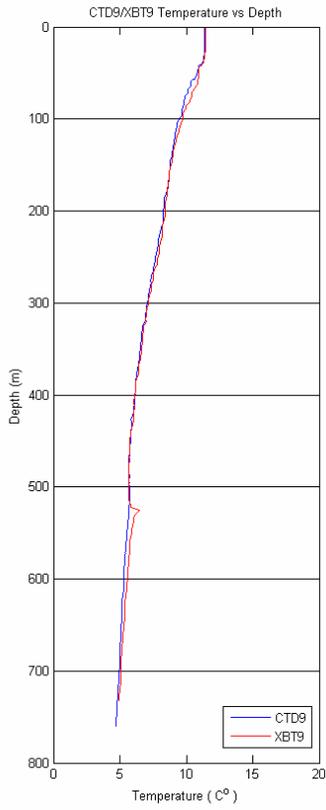
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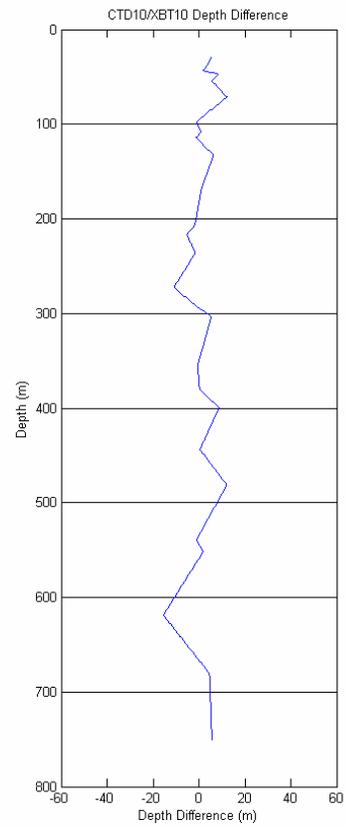
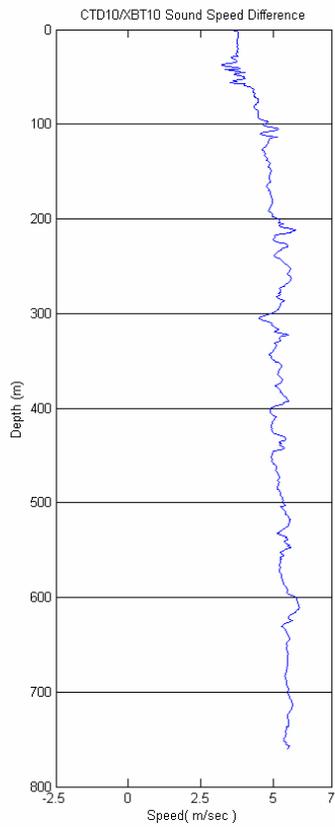
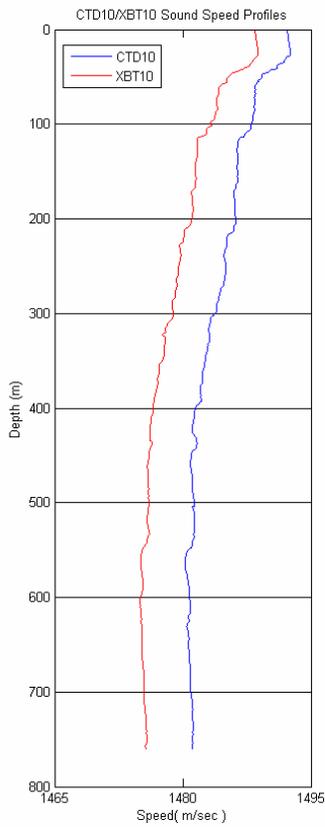
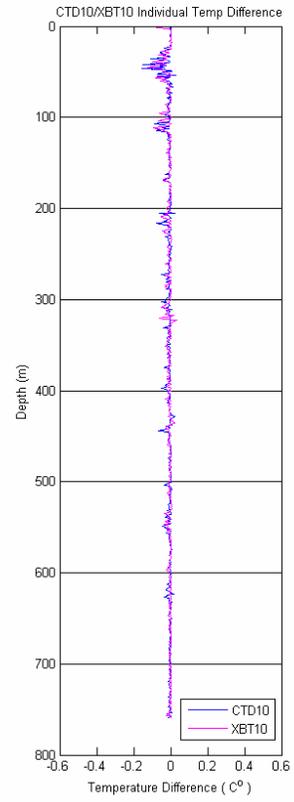
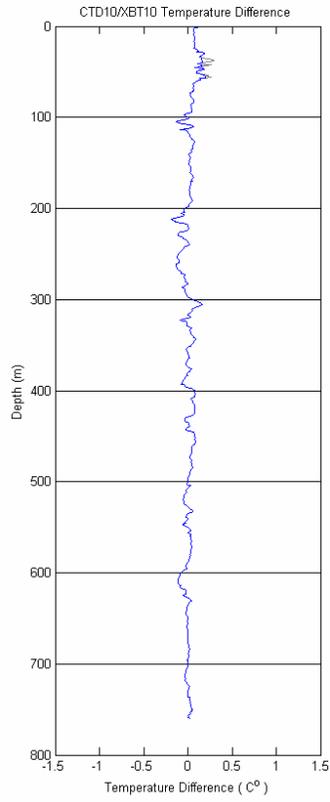
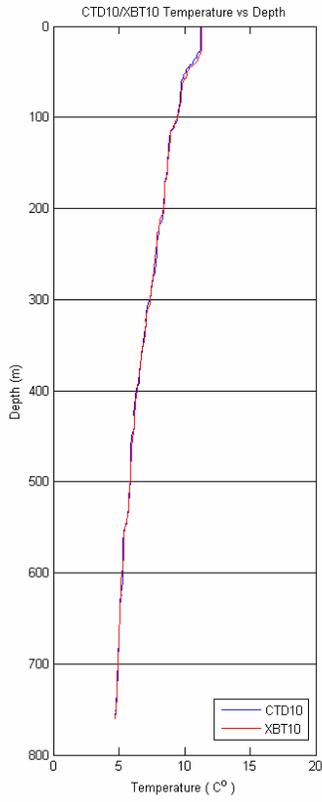
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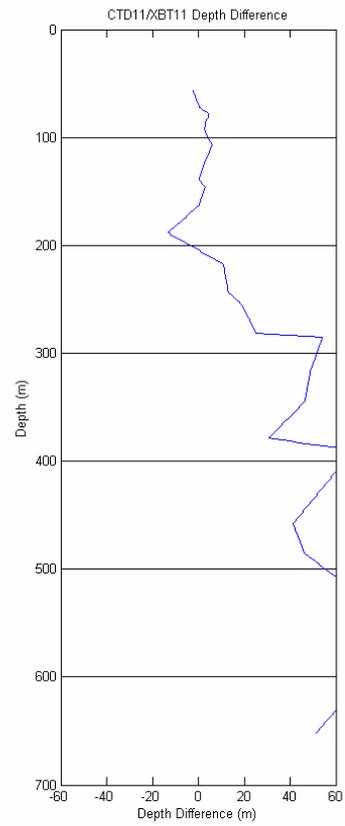
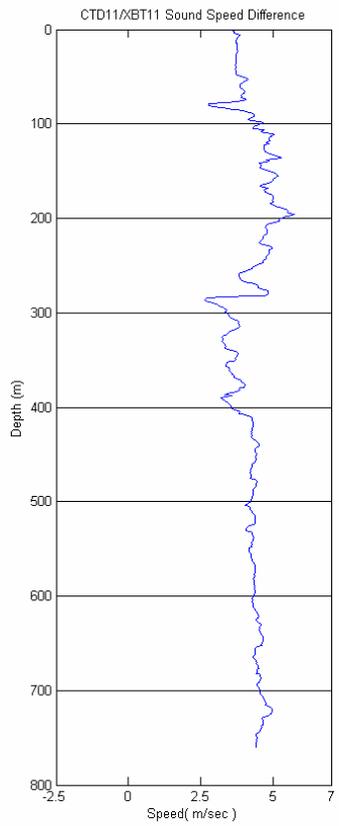
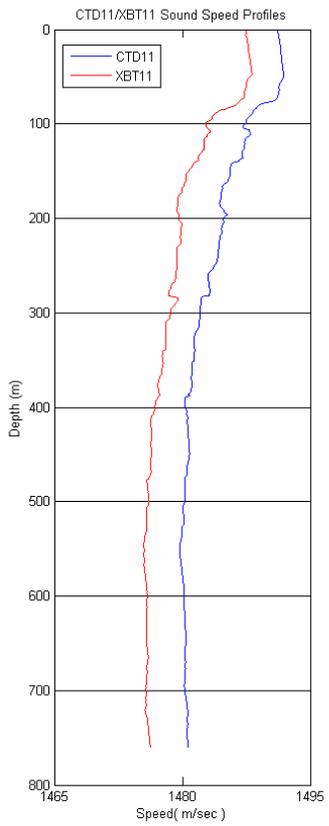
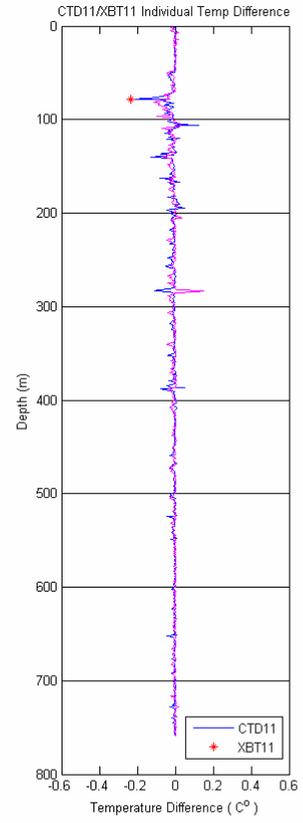
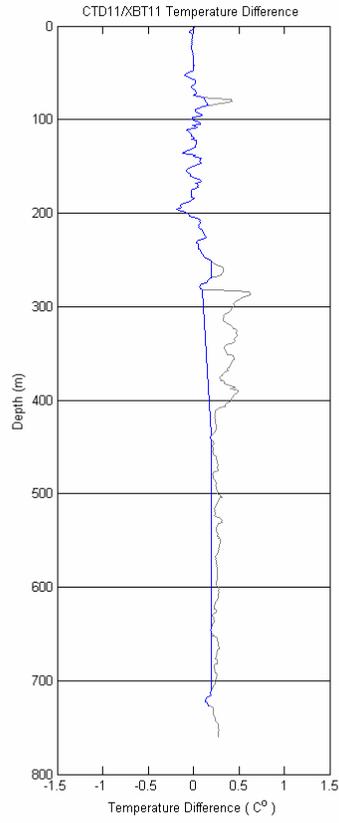
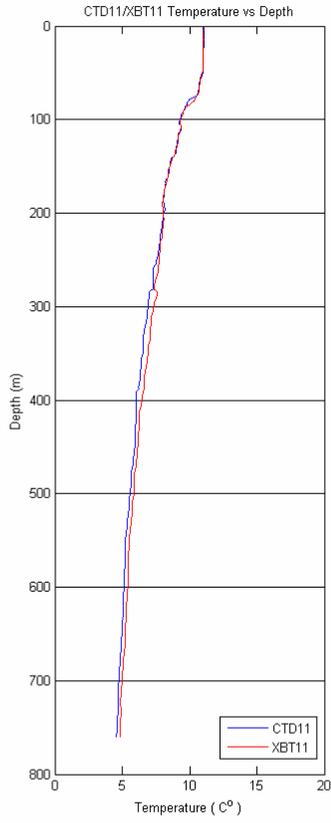
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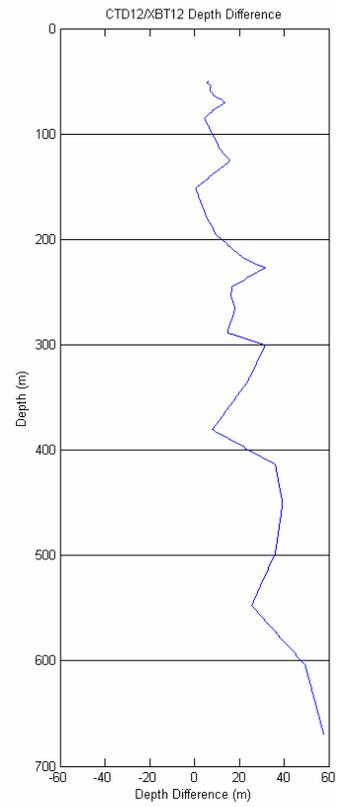
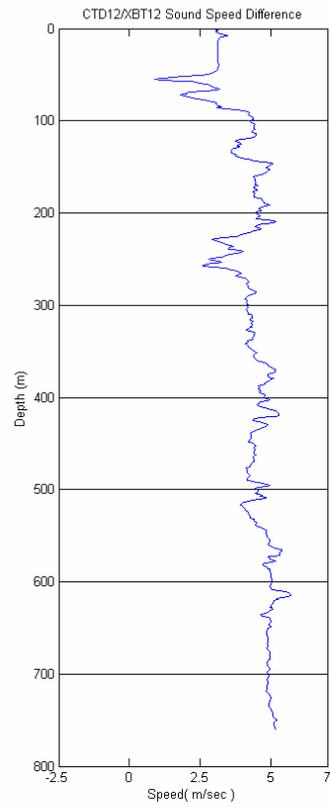
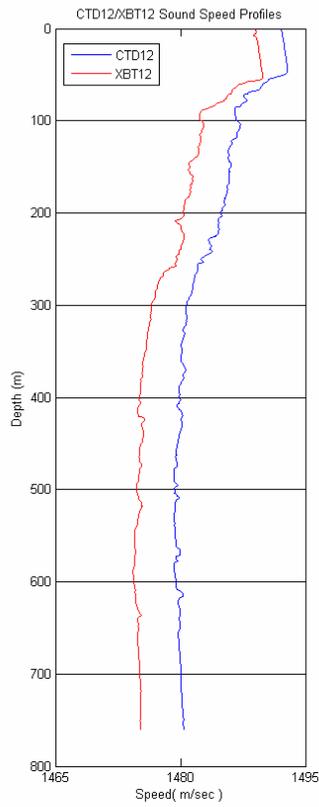
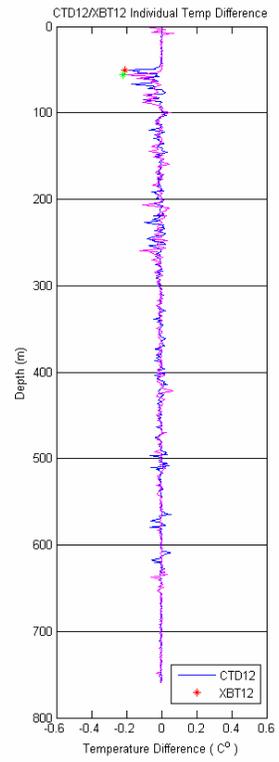
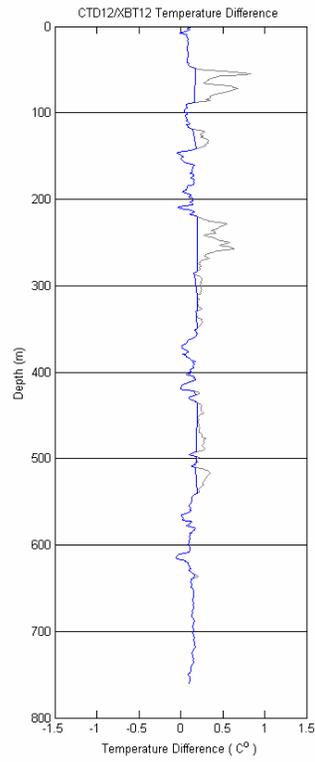
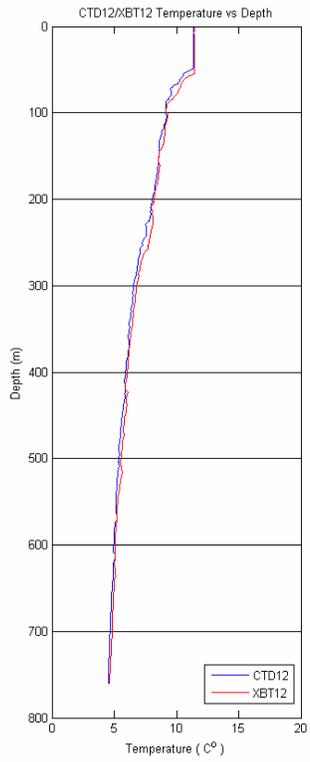
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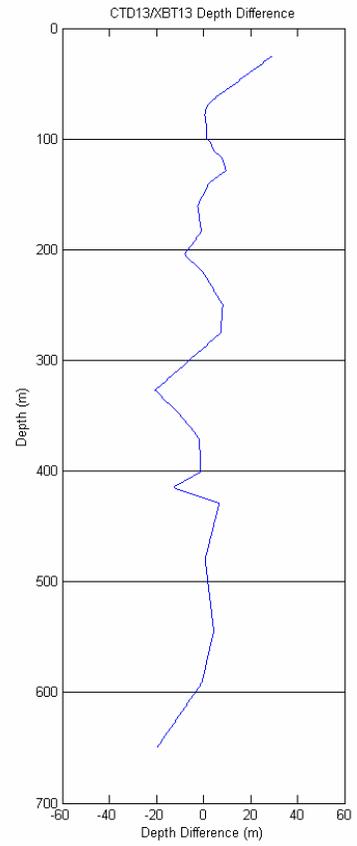
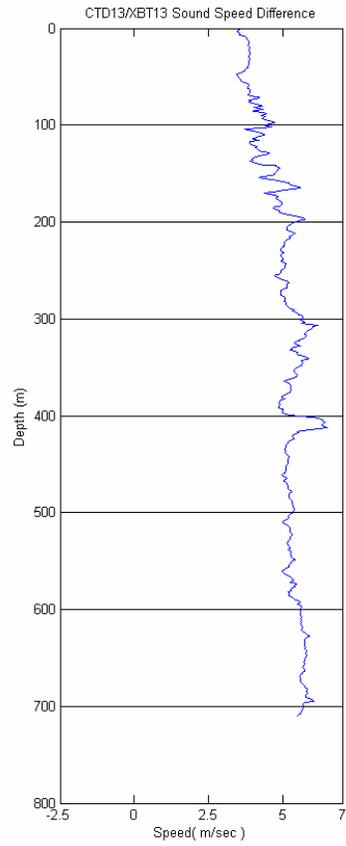
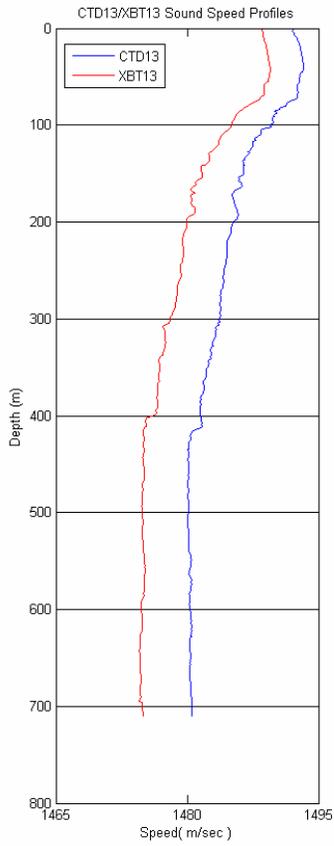
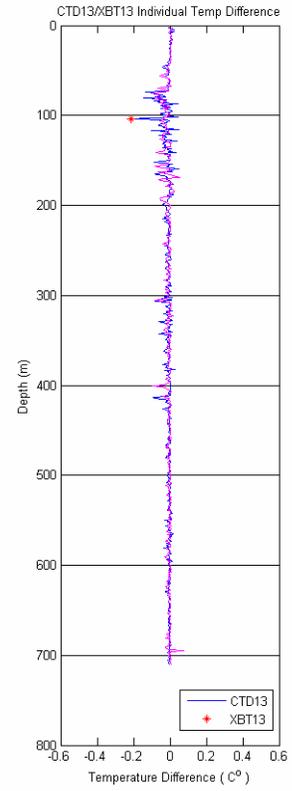
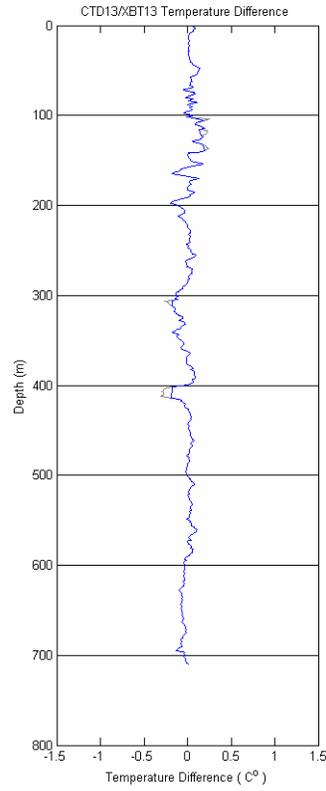
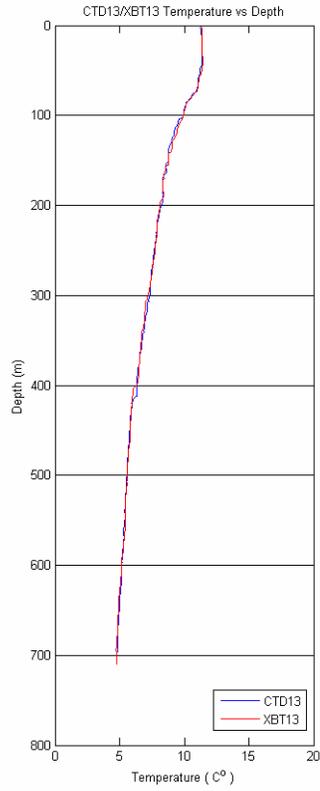
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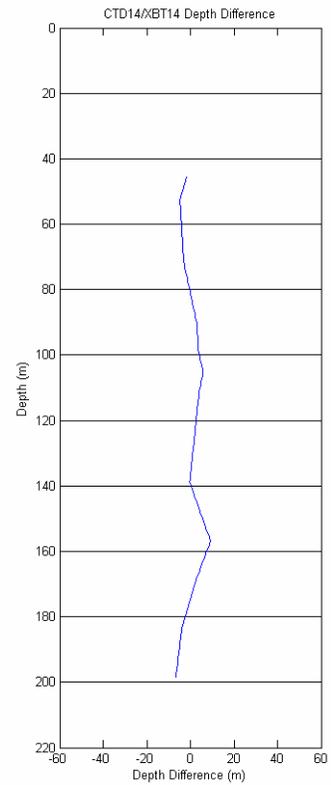
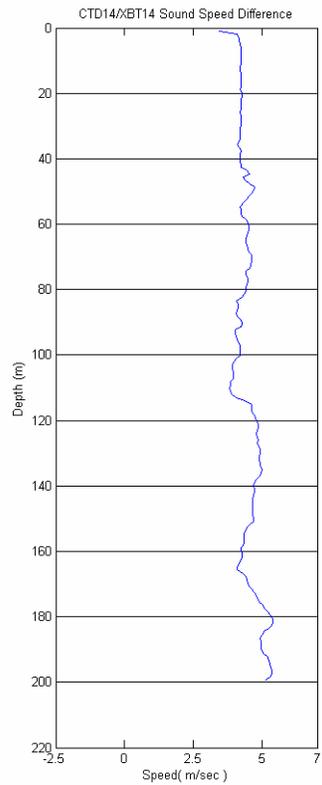
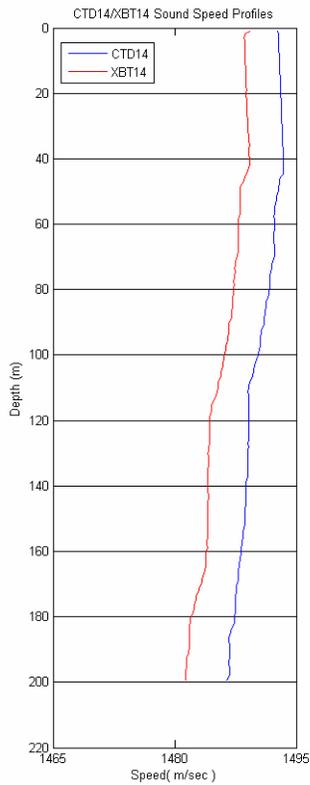
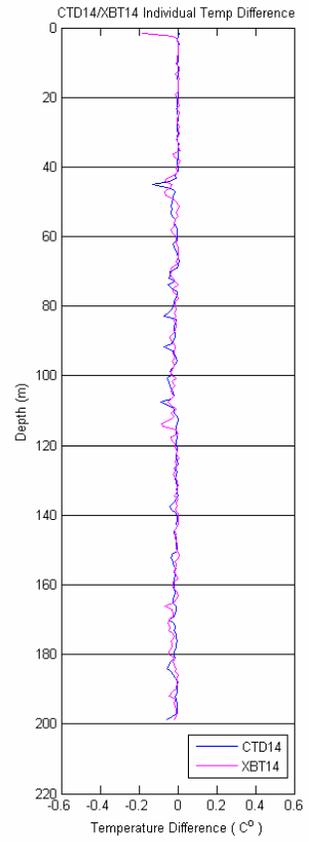
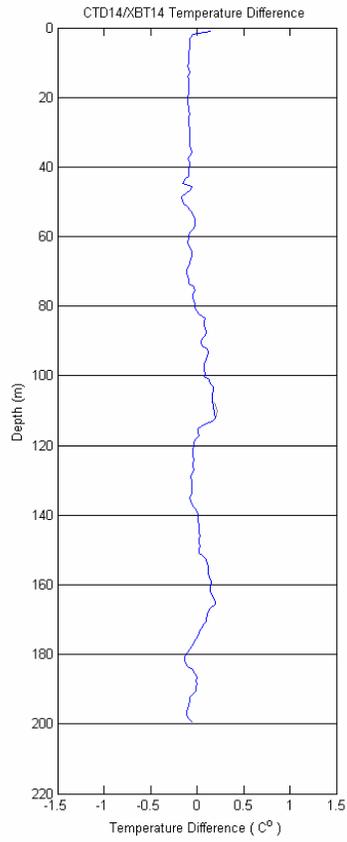
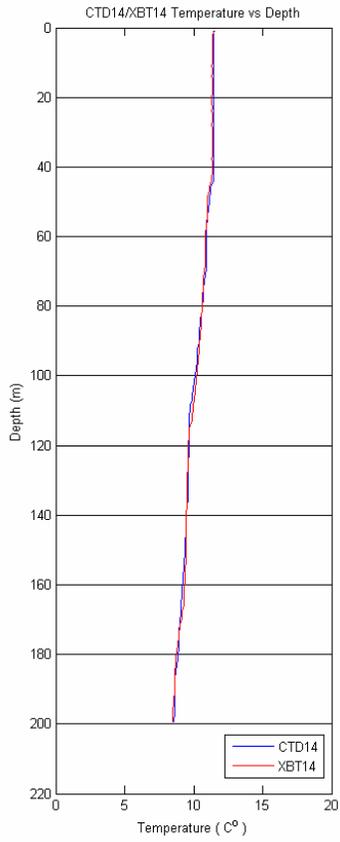
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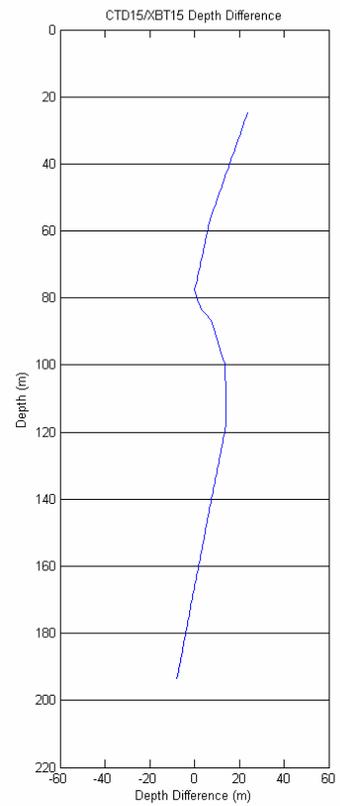
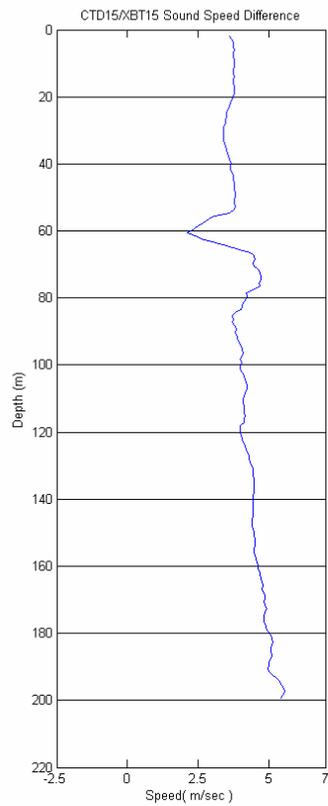
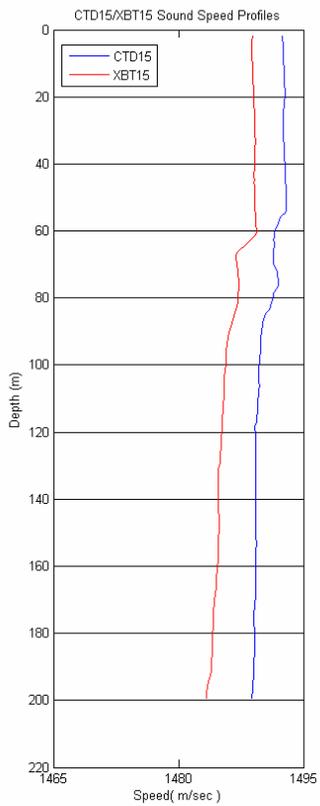
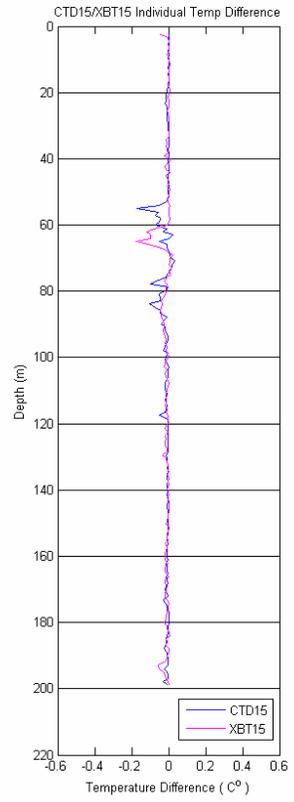
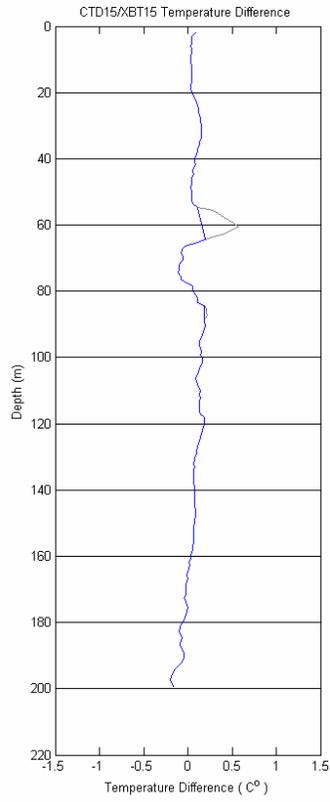
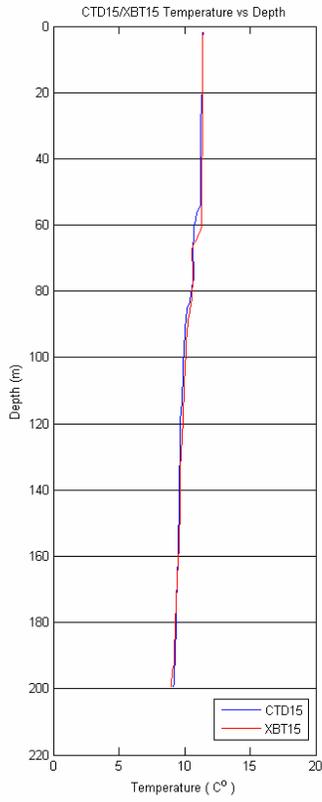
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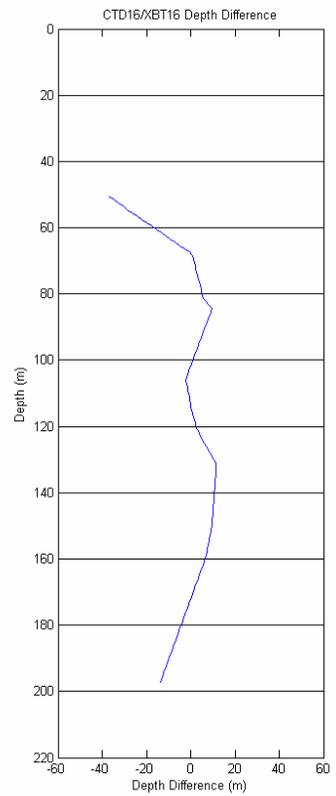
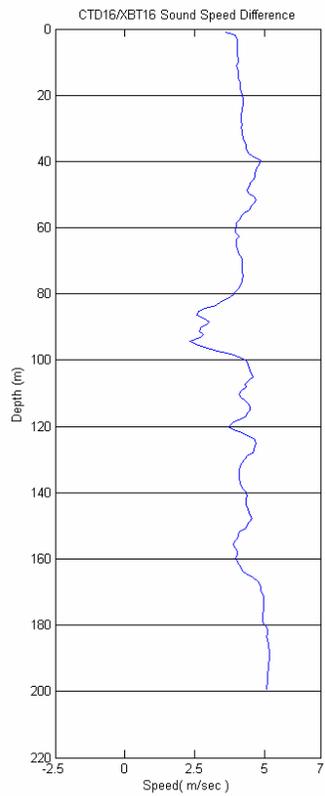
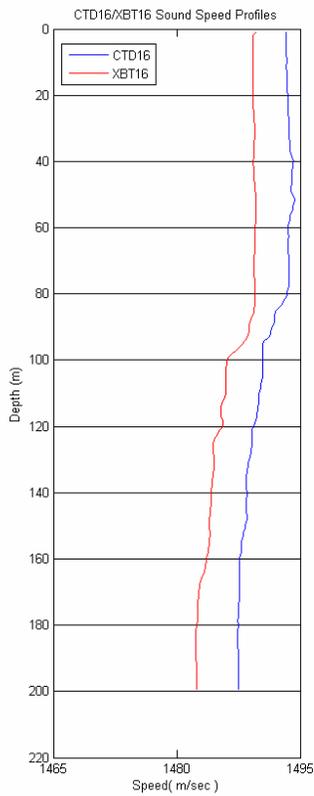
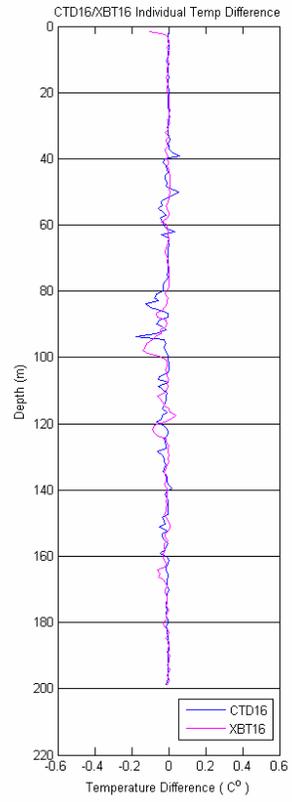
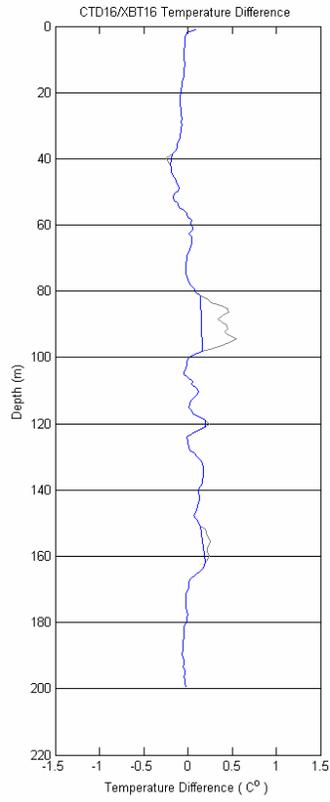
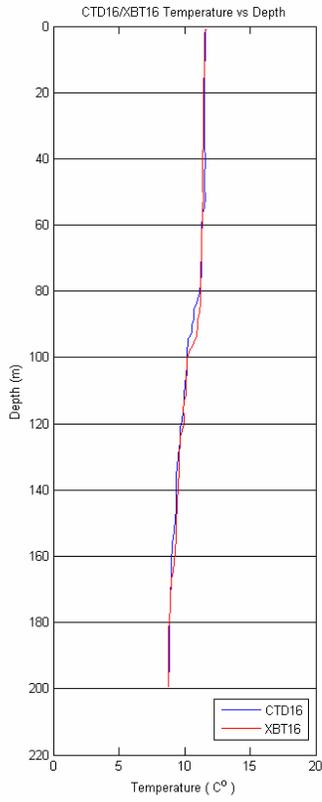
APPENDIX C



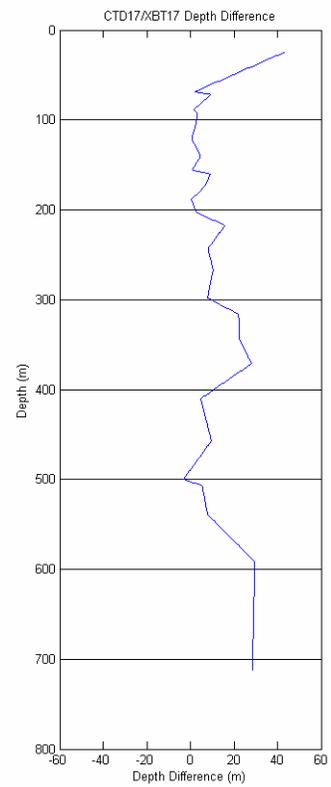
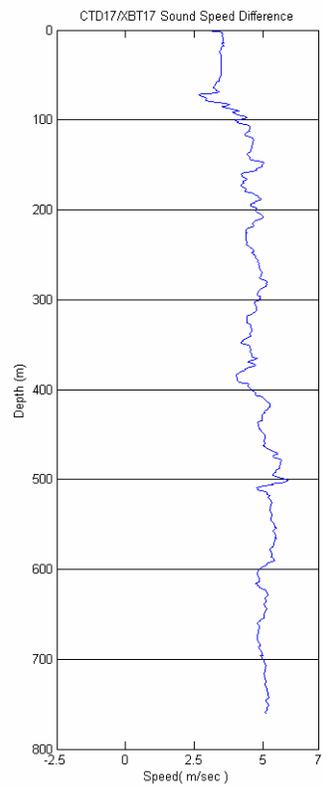
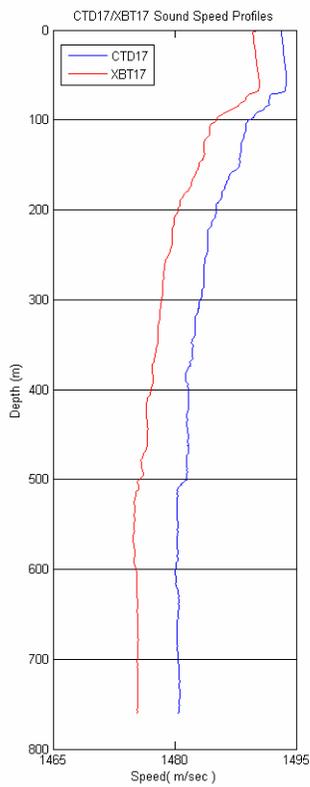
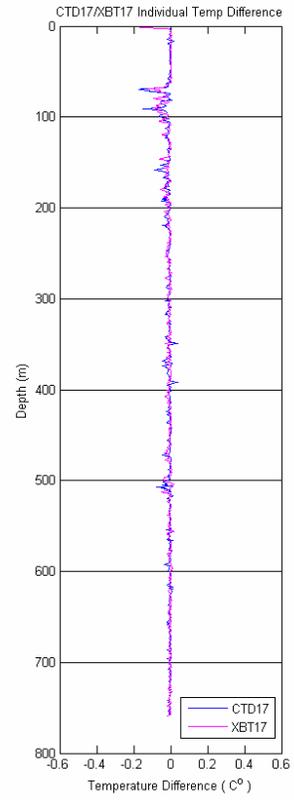
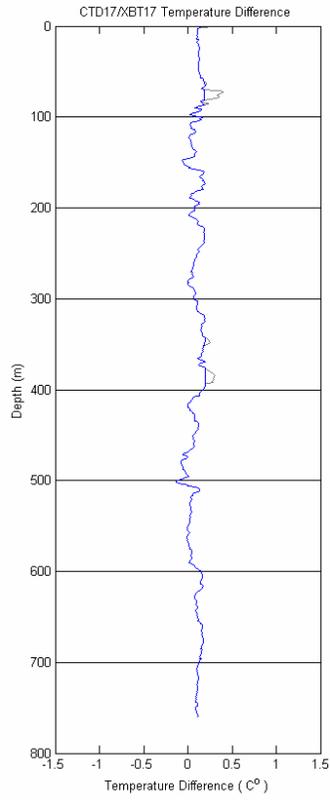
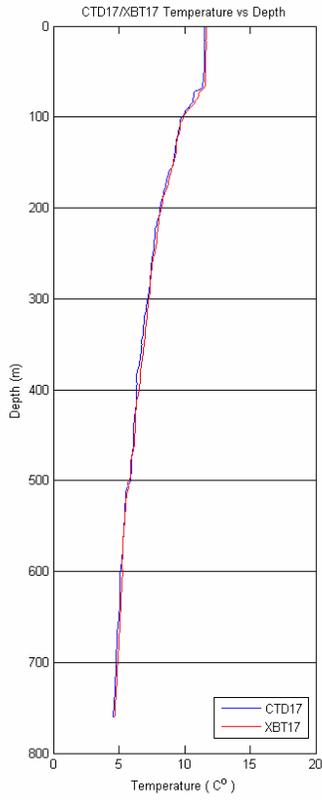
APPENDIX C



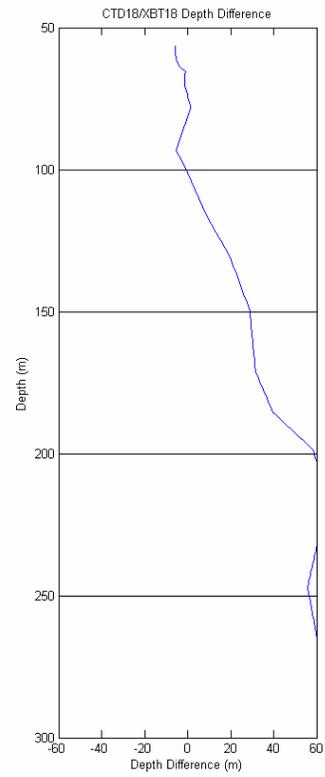
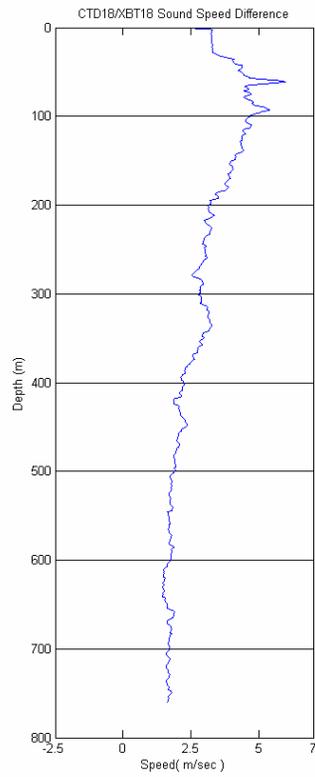
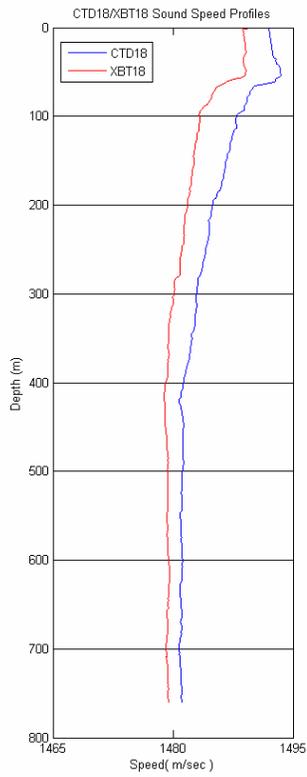
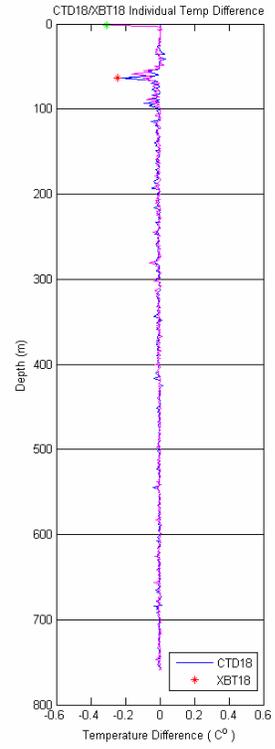
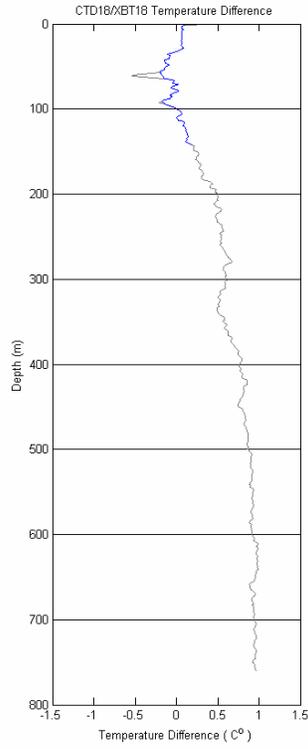
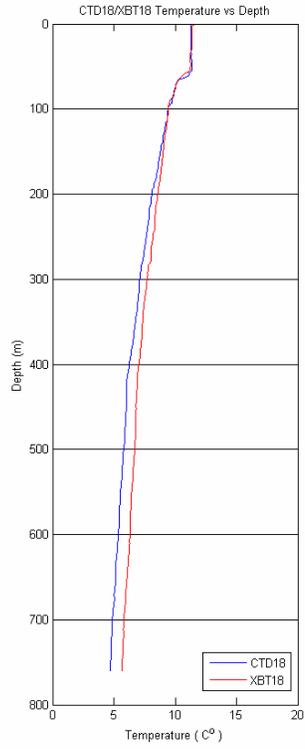
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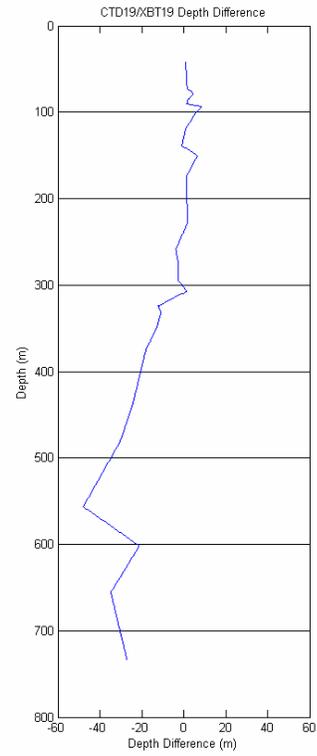
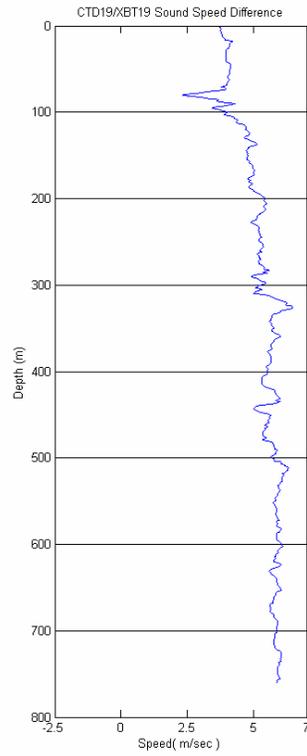
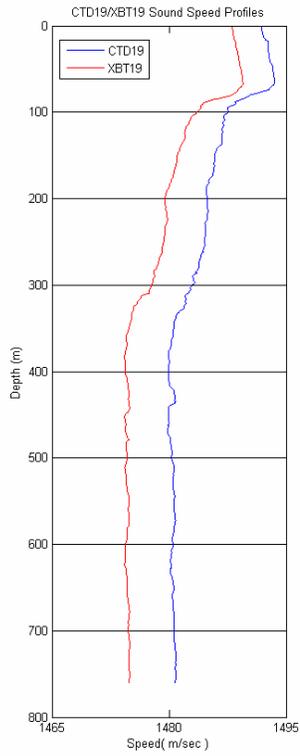
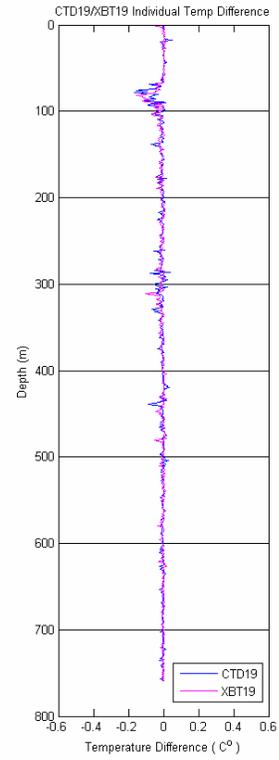
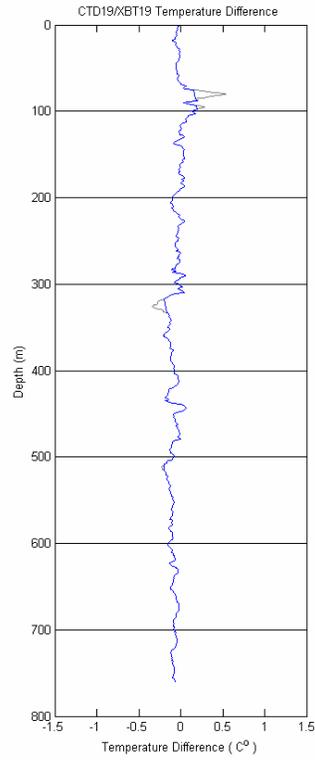
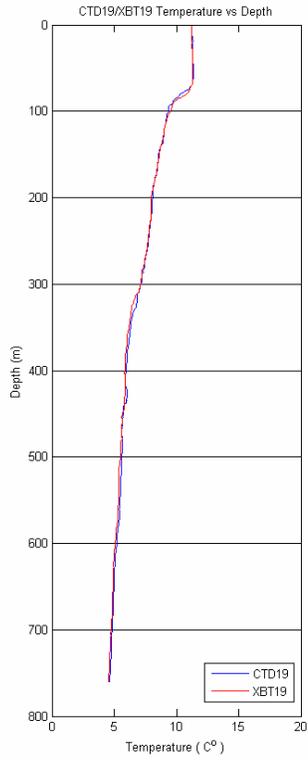
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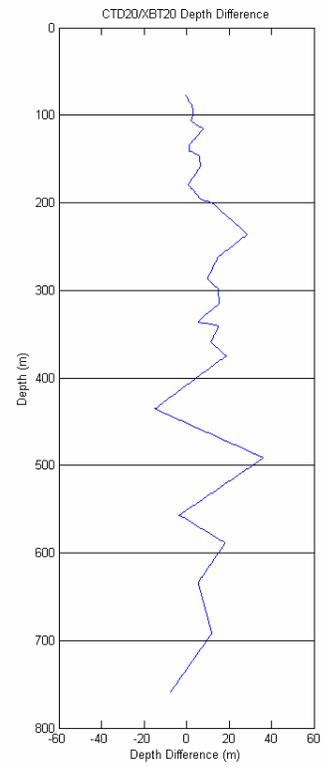
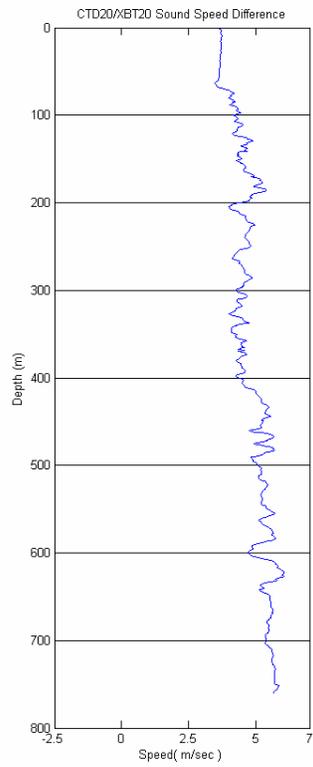
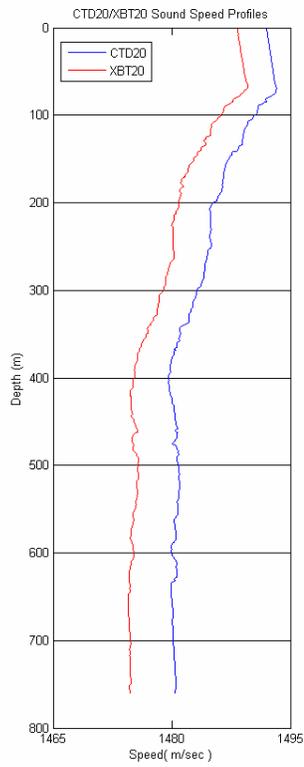
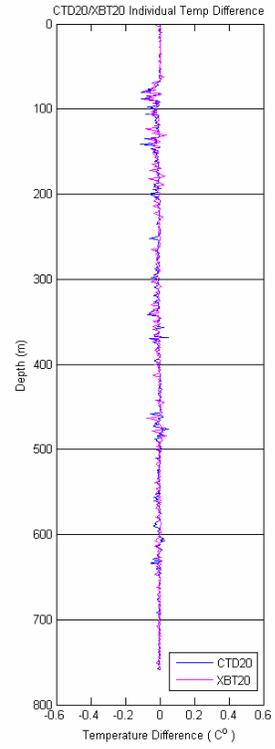
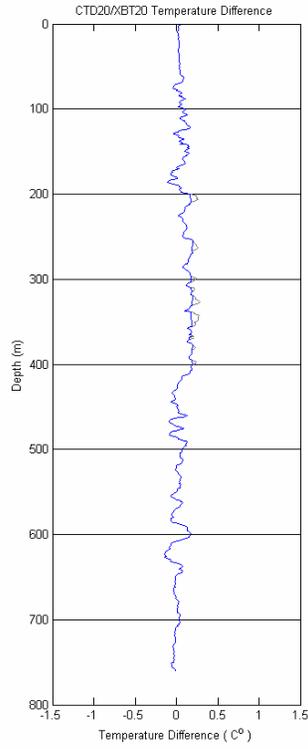
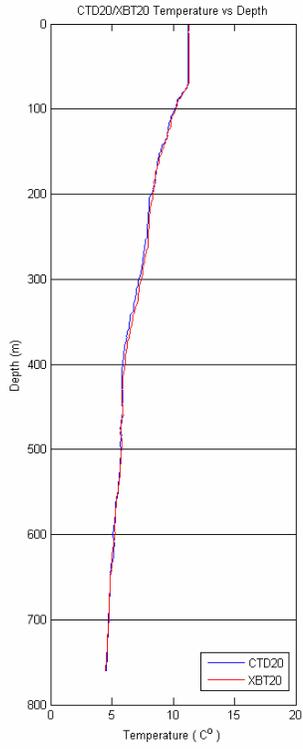
APPENDIX C



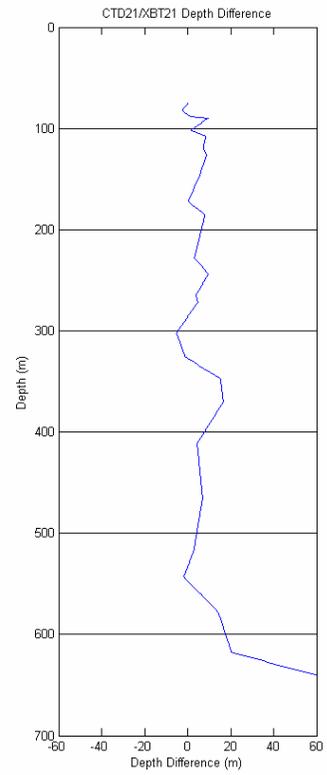
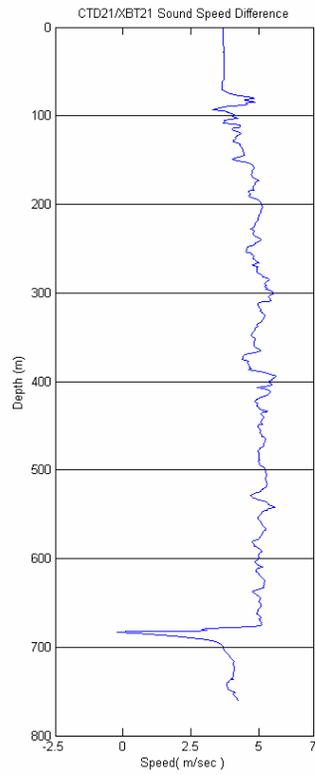
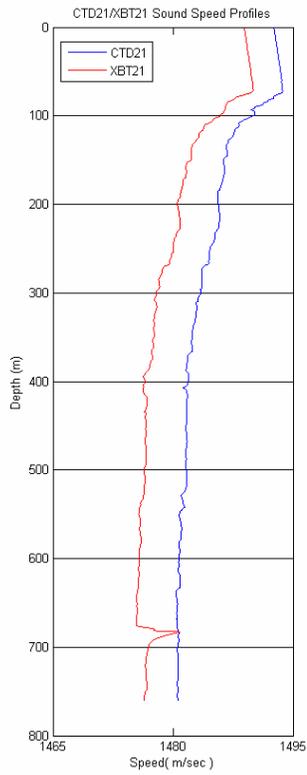
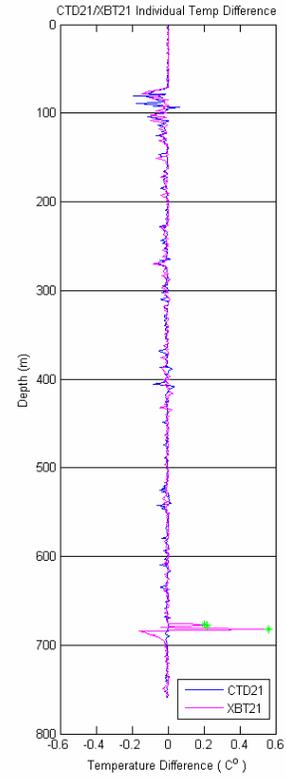
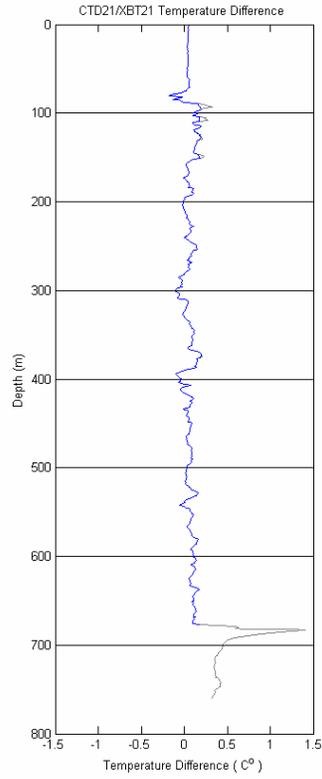
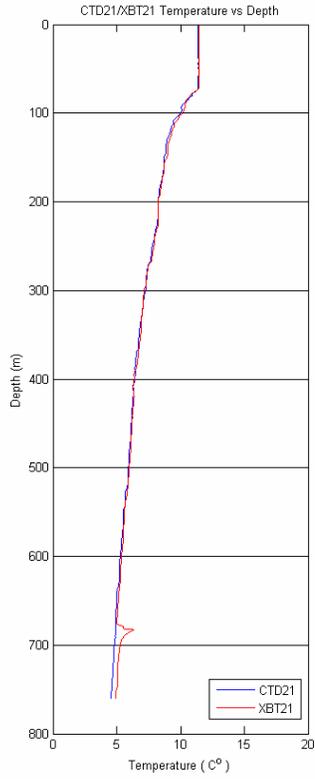
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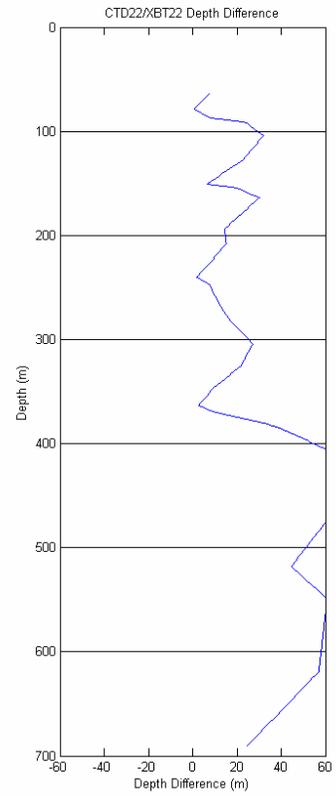
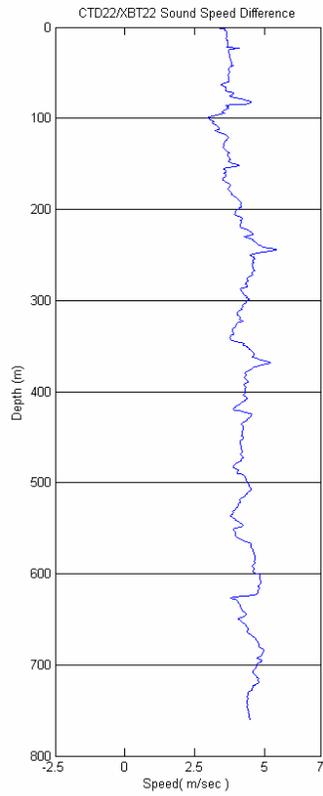
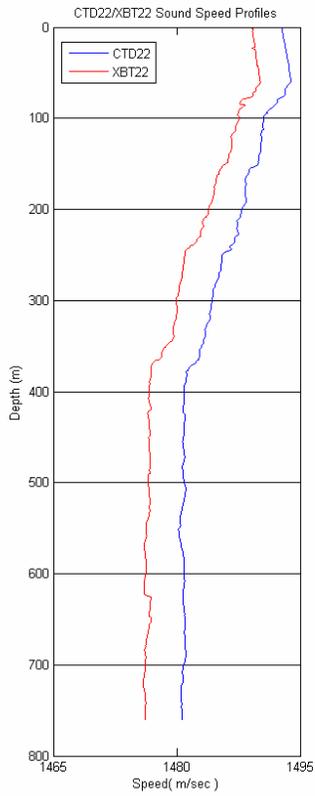
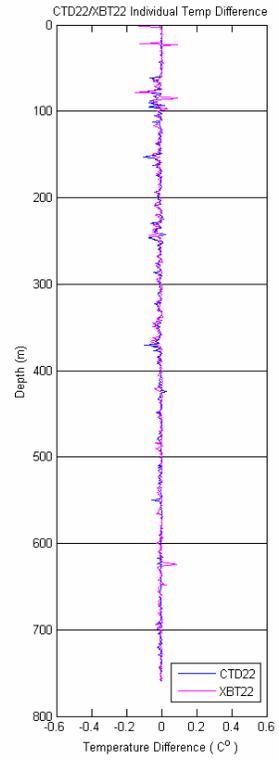
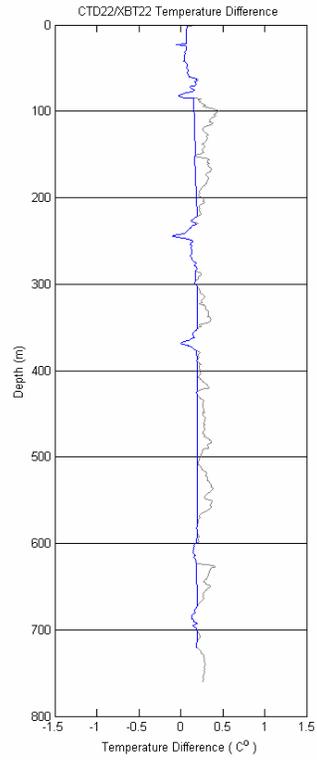
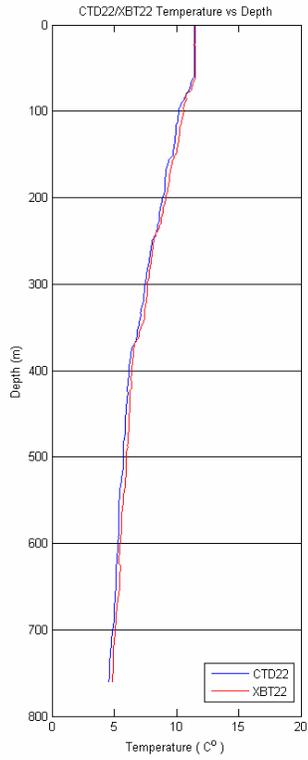
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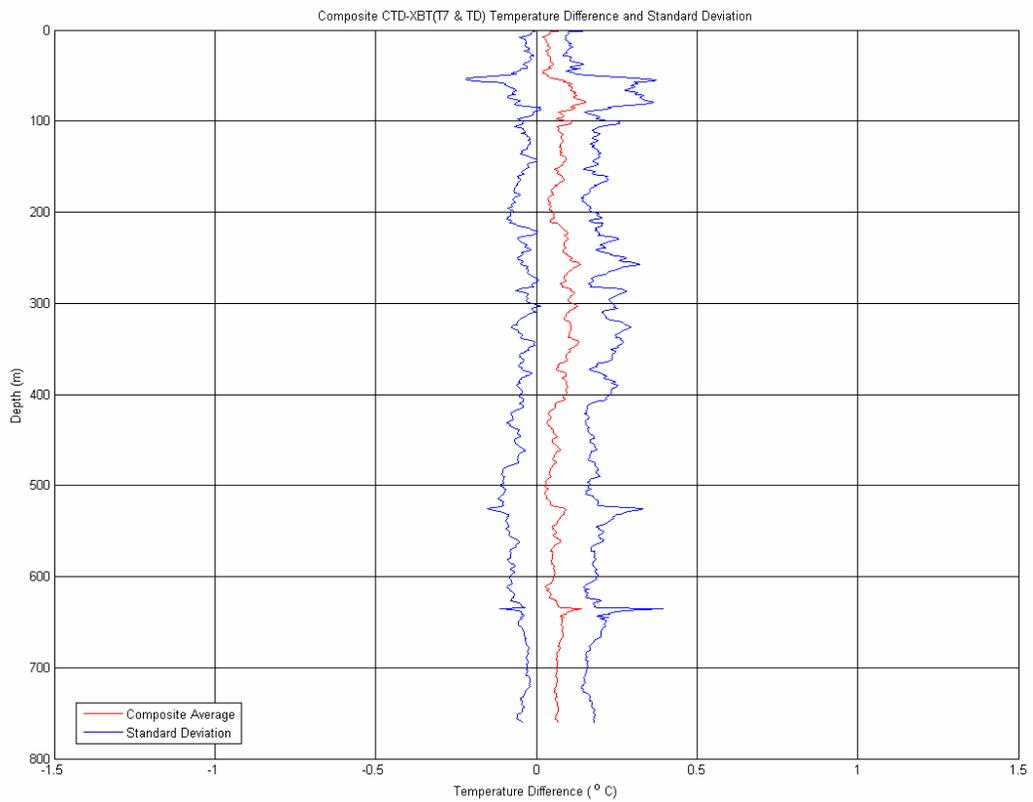
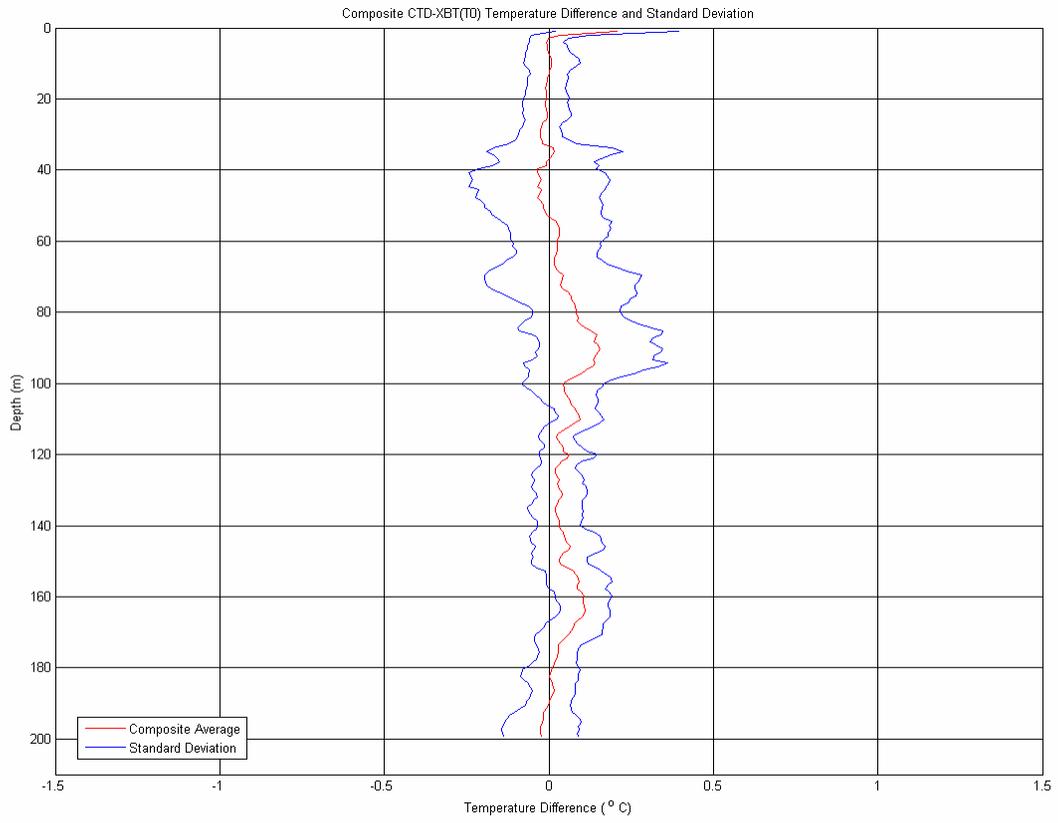
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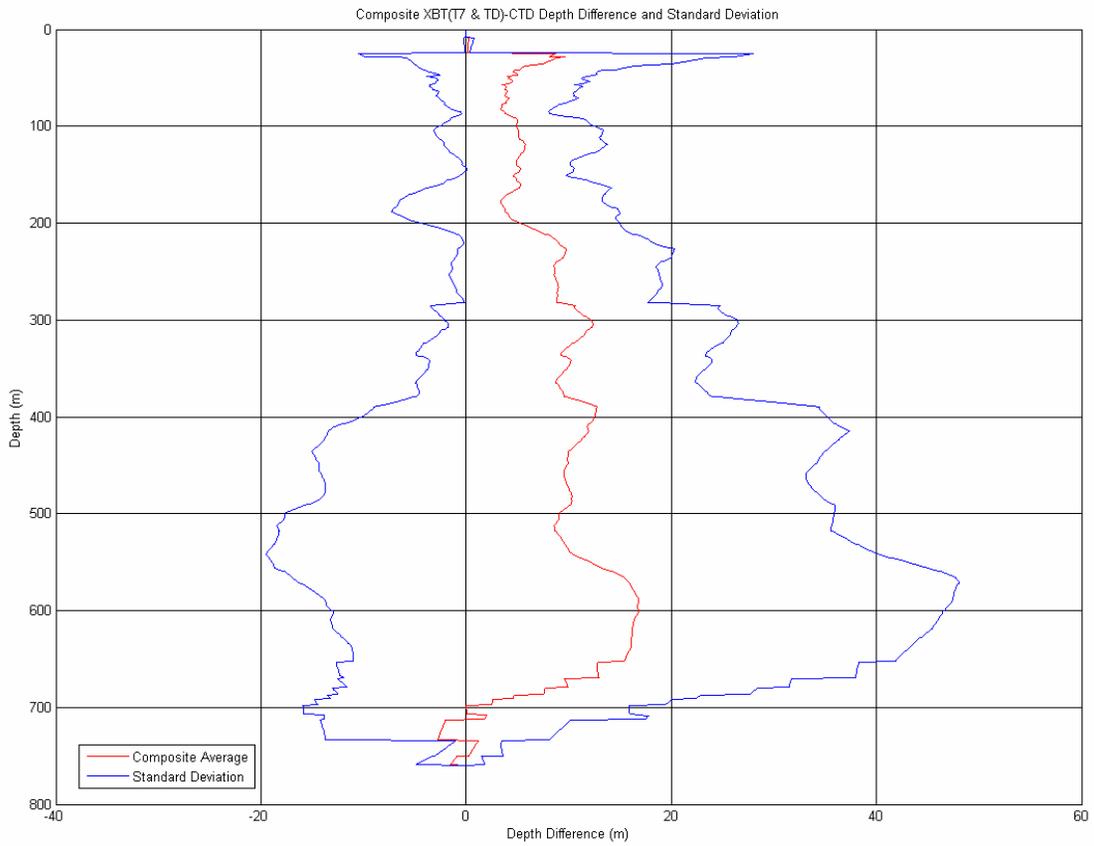
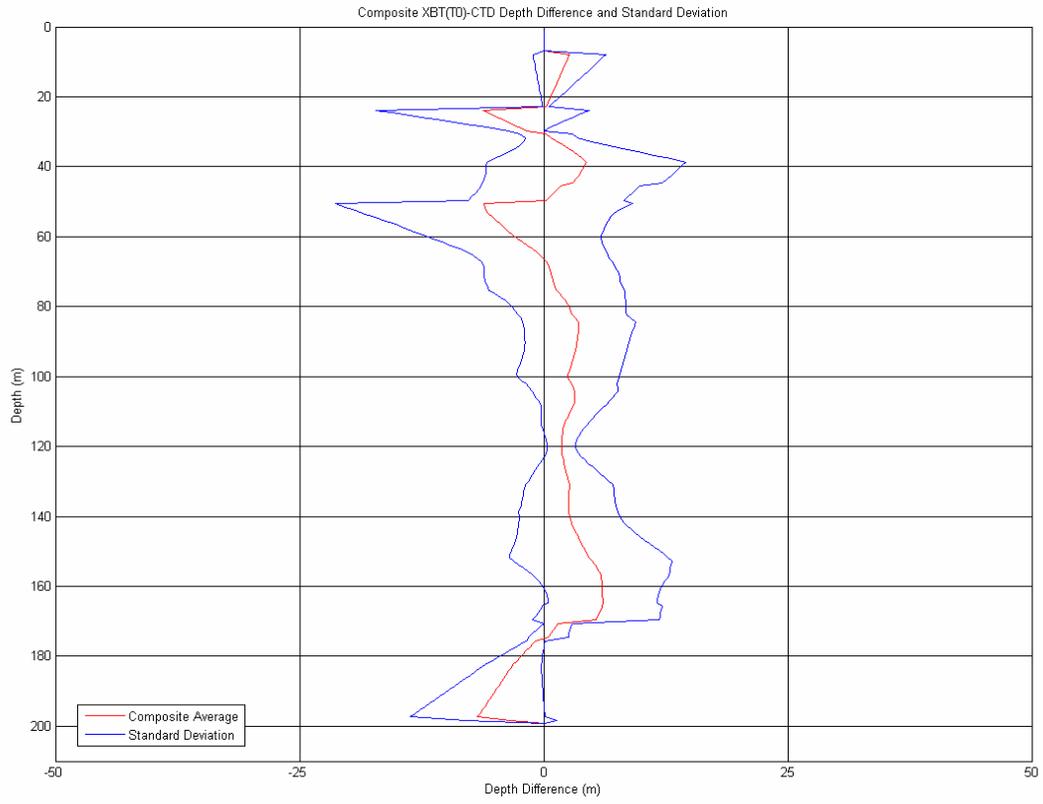
APPENDIX C



APPENDIX D



APPENDIX D



APPENDIX D

