# XBT Data Processing – STAR 2000 DSJ

XBT data were collected with Sippican WinMK12 software, version 1.5, on the NOAA Ship *David Starr Jordan*, from July 28 to December 9, 2000. Typically, XBT drops were conducted every three hours during daylight operations at 0900, 1200, and 1500 (local ship time). Some XBT drops were performed in lieu of CTD casts at 0400 or 2000 (local ship time). Sippican Deep Blue and T-10 expendable bathythermograph (XBT) probes were used to measure the temperature of the water column. The terminal depth for Deep Blue probes is 760 m while the terminal depth of the T-10 probes is 200 m.

Raw data files were checked for date/time and position and then edited to remove erroneous temperature data. All valid and edited profiles were then combined into final files. The XBTCorrect file has depth and temperature corrections according to Cheng et al. (2016, Bull. American Meteorological Soc., June 2016, 923-933). The XBTArchive file has depths calculated with the fall rate equation of Hanawa et al. (1995, Deep-Sea Research I 42:1423-1451) and excludes incomplete profiles that do not extend through the thermocline. This file is for archiving and allows for optional correction of depth and temperature by users.

All data are stored in a Raw\DSJ, Current_Version\Intermediate\DSJ, and Current_Version\Final\DSJ folder within P:\Surveys\Data\ ETP\2000_STAR\Oceanographic\XBT. Files stored in the raw or final folders are specifically designated in the text below; all other files may be found in the intermediate folder. File names are **bolded**. The programs used to process the data do not change between years and can be located in P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\, unless otherwise specified. The programs read year-specific information from *.ini files, which are stored in the intermediate folder with the output files.

## Raw Data Files

Sippican raw (*.RDF) and export (*.EDF) data files are in P:\Surveys\Data\ ETP\2000_STAR\Oceanographic\XBT\Raw\DSJ\. All files appear to be accounted for relative to the XBT log sheets (the PDF file stored in P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Raw\DSJ\Log_Sheets).

### XBTRawFileInfo

Perl program XBTRawFileInfo was used to review the raw data files. A total of 327 XBT files were processed. It noted 74 errors as documented below:

- Drop numbers 255a and 255b (files Td_00255aNG.edf/.rdf and Td_00255bNG.edf/.rdf) caused 11 errors because these drops were not numbered in a typical manner. These drops represent the first two probes for Drop #255 which were deemed “no good” according to the log sheet.
- One error is related to no binary file present for Drop #45 (i.e., no .RDF file). The only file present is TD_00045.EDF. We did not find an .RDF file in our search of the original

raw files. The XBT log sheet notes a problem with files being overwritten here and that the .RDF did not appear to be written to disk by the program. So, this appears to be explained by the notes.

- There are 50 "errors" related to drop times recorded outside the appointed hours (09:00, 12:00, 15:00 local time) for XBT drops. These issues are explained as follows:
    - 0600 hour
        - Drop #3 (06:01; this drop appears to have been associated with testing of a new version of the Sippican software that was installed during the initial hours at sea)
    - 0800 hour
        - Drops #96, 180, 190, 200, 203, 206, 219 (all of these occurred within approximately 5 minutes of 09:00)
    - 1000 hour
        - Drops #70(*), 74(*), 77(*), 80(*), 83(*), 86(*), 89(*), 327 (this is last entry in ODL as ship is nearing San Diego so may have been delayed; XBT Log entry is incomplete including no bottom depth recorded)
    - 1100 hour
        - Drops #195 and 244 (both of these occurred within approximately 5 minutes of 12:00)
    - 1300 hour
        - Drops #26 (delays noted in ODL/XBT Log due to helicopter operations and turtle satellite tagging), 71(*), 72(*), 75(*), 78(*), 81(*), 84(*), 87(*), 90(*), 191/192 (both 191 and 192 were delayed by one hour due to fishing according to ODL; 191 was first attempt with a bad probe and then redone at same station with 192)
    - 1400 hour
        - Drops #24, 121, 124, 144, 153, 193, 196, 208, 211, 218 (all of these occurred within 5 minutes of 15:00)
    - 1600 hour
        - Drops #73(*), 79(*), 82(*), 85(*), 88(*), 91(*)
    - 1800 hour
        - Drops #225 (performed at 18:50 coming out of in-port; note in ODL about "no CTD due to shallow depth only 51 m" so this appears to be done in lieu of CTD) and 326 (18:05; probably done in lieu of CTD station at very end of survey while heading toward San Diego)
    - 2000 hour
        - Drops #48 (20:59:56; note in ODL that "no p.m. station due to steaming east NE to outrun path of tropical storm Iliana (did XBT & chloro instead at 0256/9pm local)") and 50 (20:29; note in ODL that "no regular evening station (in Bahia de Banderas – Puerto Vallarta)" so apparently done in lieu of CTD)
    - *Starting at Drop #70 there is a note in the ODL: "Changed XBT/chloro station to 10:00, 1:00, 4:00, 7:00 due to ship time. Ship did not want to change time; Bob agreed." Later in the ODL another note at Drop #92 says "Switched back to

Chloro/XBT sampling @ 9, 12, 3, 6." This alteration of the schedule appears to explain a number of time departures above.

- Additionally, Drop#2 (TD0002.EDF) had an erroneous time of 7/30/2000 19:43 UTC recorded due to error in time registered in Sippican software according to the ODL and XBT log sheet. The actual time was 7/30/2000 01:07 UTC according to the ODL and the XBT log sheet. This is a drop time outside the expected hours, but this may be explained as part of a series of early drops to validate that the system was working before the scheduled routine was followed. The time was edited/corrected in the .EDF file and the original files (.EDF/.RDF) were moved to the Files_With_Errors subfolder.
- We encountered non-consecutive drop numbers from 126 and 128. Drop# 127 cast data appears to have been lost due to being overwritten based on notes in ODL/XBT Log and missing file.
- Latitude and longitude values for drops #191 and 192 are blank. Drop #191 has missing coordinates in XBT Log and ODL notes it involved a bad probe. Drop #192 was then done with a good probe to capture data at station. We will enter the coordinates from the ODL for the surface chlorophyll sampling at 1758 UTC as the coordinates for drop #191 and we will enter the coordinates for drop #192 as recorded in the XBT Log. We edited the .EDF files to reflect these positions. The original .EDF files are saved in the Files_With_Errors subfolder.
- The drops for #191-194 were inadvertently recorded by the software to use T-7 probes. This was noted in the ODL for Drops #191/192. Also, the XBT Log notes Deep Blue probe types for #191-194. All .EDF files had filenames renamed from "T7" to "TD" and the files were edited to change the probe type from "T-7" to "Deep Blue". The original files (.EDF/.RDF) are saved in the Files_With_Errors subfolder.
- One error was indicated because the drop number inside the file called Td_00201.edf was 202 and did not match the filename. This also triggered two drop sequence errors (i.e., non-consecutive drop numbers). The ODL, XBT Log, and EDF file contents were reviewed and compared. As a result, the contents of the file has been corrected to reflect drop #201(and the filename was changed to TD_00201.EDF). The original .EDF/.RDF files are saved in the Files_With_Errors subfolder.
- There are two errors in which drop numbers inside the files Td_00226.edf and Td_00227.edf do not match the file names (i.e., the drop numbers inside the files are 227 and 228, respectively). This also caused two errors with non-consecutive drop number sequences. We reviewed the ODL, XBT Log, and the EDF file contents and determined that the file contents should identify the drops to be 226 and 227 to match the filename. We made this change and saved the original files to the Files_With_Errors subfolder. The filenames were changed to TD_00226.EDF and TD_00227.EDF for consistency with other files.

**Data Checks**

Position Check

Station locations were checked against edited TSG files by Perl program XBTPositionCheck. This program wrote comparisons between XBT stations and TSG positions to the files **XBTPositionCheck_2000_STAR_DSJ.txt** and **XBTPositionCheck_2000_STAR_DSJ.err** in P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermediate\DSJ The ***.txt** file has time and distance information between XBT and TSG. The ***.err** file has records that have more than 1 nautical mile between XBT and TSG based on time and/or records that did not match to TSG records within the time period specified (120 seconds).

Results:

327 EDF files read from P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Raw\DSJ\

0 were missing date, time, latitude, or longitude

0 were not in a valid format

0 did not have a TSG record within 120 seconds in P:\Surveys\Data\ETP\2000_STAR\Oceanographic\TSG\Current_Version\Intermediate\TSGTrackCheck_2000_STAR_DSJ_Final.dat

327 lines were compared to TSG

0.17802 Root-mean-square-error of distances

0 Distances >= 1 nautical mile

0.85911 Max distance

The initial run of the program identified two drops (189 and 190) which had erroneous geographic coordinates in the .RDF/.EDF files which caused spurious placement of the position near 0 degrees longitude and around -9 to +9 degrees latitude (and a maximum separation distance of over 5500 nautical miles). We then edited the .EDF file to include geographic coordinates for both drops as recorded in the XBT Log. This properly corrected the position to reasonable proximity, in space and time, to the trackline indicated by the TSG data for Drop #189. However, Drop #190 was approximately 31 nautical miles away from the likely position on the TSG trackline. We then reviewed the ODL and found geographic coordinates for the surface chlorophyll sample conducted ten minutes before Drop #190 and determined this location was near the expected position for the drop on the trackline. At this point we edited the .EDF file to reflect the geographic coordinates for the TSG position that had a recorded time closest to the time contained within the .EDF file for Drop #190. The final summary results are included above and deemed acceptable.

Station and Drop Lists

After correcting all of the issues that could be corrected, program XBTStationAndDrops was run to create corrected Edit and Station files. The Edit file (**XBTDrops_2000_STAR_DSJ.txt**) is a simple list of all of the drop (.EDF) files. This is used during the profile review step. The Station file (**XBTStation_2000_STAR_DSJ.txt**) gives details about each drop, including its time, position, probe type, drop coefficients, etc. These files were both saved to P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermediate\DSJ.

Most drops (313 of 327) used Deep Blue probes. The coefficients used were 6.691, -0.00225, which are the coefficients from Hanawa et al (1995). Some drops (14 of 327) used the T-10 probe type which is designed for a maximum depth of 200m for sampling in shallower waters. The coefficients used were 6.301, -0.00216, which are the manufacturer's original fall rate coefficients.

Profile Review and Edit

At the lab, profiles were examined by T.J. Moore, and checked by Paul Fiedler (Senior Oceanographer) using the Visual Basic program ProfileViewer, which is located in P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\ProfileViewer.

The reviewer decides what edits need to be made, and records that information in file XBTDrops_2000_STAR_DSJ.txt. Each XBT drop has a line in that file, with the EDF file name. If the profile requires any editing, the reviewer added codes for the edits to be applied. Codes are based on Bailey et al. (Quality Control Cookbook for XBT Data, CSIRO Marine Laboratories Report 221, 1994). The Quality Control Cookbook can be found in P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\. Codes are as follows, where ddd.d is the depth exactly as recorded in the .edf file:

| | |
|---|---|
| >RJ | Reject profile. |
| >NN | The profile is not suitable for submission to the NCEI World Ocean Database, but is good enough for deriving surface temperature and mixed layer depth, and perhaps thermocline variables, for MMTD purposes. |
| >XD ddd.d ddd.d | Exclude data within the profile. Reject data between the first and second specified depths. |
| >BD ddd.d | Exclude data at the bottom end of the profile. Reject data deeper than ddd.d. |
| >FT ddd.d | False trigger, data recorded before the probe entered the water. This error is rare. Reject all data above ddd.d and change the depth at ddd.d to 0.7m, which is the starting depth for all drops (and then increment the depth |

estimates per Hanawa et al. 1995).

| | |
|---|---|
| >ST ddd.d | Surface transient, identified by warming or cooling as the probe temperature equilibrates. Reject data before depth ddd.d. All temperatures at depths ≤4.0 m are rejected to routinely dismiss surface transients, so this flag is only effective if a depth >4.0 m is indicated. If the profile also contains an FT error, ddd.d is an integer that indicates the number of records after the FT correction that should be rejected. |

Profile rejections and data exclusions are usually explained in a comment following an apostrophe (‘): wb = wire break, ws = wire stretch, hb = the probe hit the bottom, ip = insulation penetration.

Information about XBT drops, such as time, date, latitude, longitude, and comments about the profile by the at-sea oceanographer, were recorded at sea in a logsheet. A PDF copy of this logsheet is stored here:
**P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Raw\DSJ\Log_Sheets\STAR2000_DSJ_XBT_Log.pdf**
This document was helpful during the review and interpretation of the recorded data.

Apply Profile Edits

Perl program XBTEdit reads the editing codes entered by the reviewer, and creates edited output files. From its ini file, it reads: The location of the edit file (created in the previous step), the location of the time offsets file, the location of the raw XBT files, the minimum depths to be included in the averages, and the coefficients for the fall rate equation. It creates output files with the editing codes applied. (e.g. Drops marked with RJ are excluded, depths marked with XD are removed, etc.) The script reported the following:

```
327     lines read from input file
      P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermedi
      ate\DSJ\XBTDrops_2000_STAR_DSJ_edit2.txt
0       lines started with an apostrophe, so were ignored
12      lines had an RJ code, so were ignored

315     records written to
      P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermedi
      ate\DSJ\XBTEdited_2000_STAR_DSJ.txt

5       lines were not good enough for NODC, so their drop numbers were negated
14      records written to
      P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermedi
      ate\DSJ\XBTNODC_2000_STAR_DSJ_6.301_0.00216.txt
296     records written to
      P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermedi
      ate\DSJ\XBTNODC_2000_STAR_DSJ_6.691_0.00225.txt

10.57   Average temperature of all 284348 output points whose drops met the Min
      To Avg depth
```

```
21.34   Average temperature of all 43717 output points <= 100 m whose drops met
       the Min To Avg depth
        Note that this is based on depths calculated using the Hanawa et al
       1995 formula
```

Depth and Temperature Corrections

Perl program XBTCorrect corrected depths and temperatures based on the method described in P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\CH XBT fall-rate method.pdf. The program reported the following:

```
Reading XBTCorrect.ini...
Reading CH14 table 'P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\Fall
       rate\CH14_table1.txt'...
Reading CH14 table 'P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\Fall
       rate\CH14_table2.txt'...
Processing
       P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermediate\DSJ\X
       BTEdited_2000_STAR_DSJ.txt...
Deep Blue: Thermal Bias = 0.03550, A = 6.614, B = 0.00230, Offset = 1.881
T-10: Thermal Bias = 0.11265, A = 6.520, B = 0.00149, Offset = 0.475

316    lines read from
       'P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermediate\DSJ\
       XBTEdited_2000_STAR_DSJ.txt'
0      lines started with an apostrophe, so were ignored
14     records written to
       P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermediate\DSJ\X
       BTCorrect_2000_STAR_DSJ_T-10.txt
301    records written to
       P:\Surveys\Data\ETP\2000_STAR\Oceanographic\XBT\Current_Version\Intermediate\DSJ\X
       BTCorrect_2000_STAR_DSJ_Deep Blue.txt

5      had negative drop numbers, which means their data was not good enough for NODC
```

**Final data files**

The NODC files created in the XBTEdit step were copied to \Final and were renamed as:

XBTArchive_2000_STAR_DSJ_Deep Blue.txt
XBTArchive_2000_STAR_DSJ_T-10.txt

Each drop record in a XBTArchive file starts with fields under the following column headers:

```
UTC Date, UTC Time, Time Offset, Local Date, Local Time, Latitude, Longitude,
Drop #, Probe Type, # Points, H95 FRE Coefficients...
```

The column headers after that are depths (m), based on the Hanawa et al 1995 fall rate equation, e.g:

```
..., 0.7, 1.3, 2.0, 2.7, 3.3, 4.0, 4.7, 5.4, 6.0, 6.7, 7.4, 8.0, 8.7,...
```

The drop records data in those columns are temperatures (ºC) at those depths. Missing data (e.g., surface transients) are blank.

The files that had depth and temperature corrected based on Cheng et al were also copied to \Final. These files are:

XBTCorrect_2000_STAR_DSJ_Deep Blue.txt
XBTCorrect_2000_STAR_DSJ_T-10.txt

Each drop record in a XBTCorrect file starts with fields under the following column headers:

```
UTC Date, UTC Time, Time Offset, Local Date, Local Time, Latitude, Longitude,
Drop #, Probe Type, CH14 Values, # Points...
```

The column headers after that are depths (m), based on the Cheng et al fall rate correction, e.g:

```
..., 0.1, 0.8, 1.4, 2.1, 2.7, 3.4, 4.1, 4.7, 5.4, 6.1, 6.7, 7.4, 8.0, 8.7,...
```

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