XBT Data Processing – 2009 DELPHINUS MACII

XBT data were collected with Sippican MK21 software on the NOAA Ship McArthur II (MACII), 8 Sep 2009 through 6 Dec 2009. Typically, XBT drops were conducted every three hours during daylight operations at 0900, 1200, and 1500 (local ship time). Some XBT drops were conducted just prior to CTD stations to confirm XBT drop rates. Sippican Deep Blue Expendable Bathythermograph (XBT) probes measured the temperature of the water column to 760 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 either a raw, intermediate, or final folder within
P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\MACII\
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 were copied from the leg folders in the Leg1_Leg3 DVD to

P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Raw\MACII\

Upon review, it was determined that file TD_00016.RDF was effectively a duplicate of TD_00017.rdf. The information for drop 16 was found on the Leg1_Orange DVD.

The XBT drops were recorded in ELog file

P:\Surveys\Data\WestCoast\2009_DELPHINUS\Year_Specific_Projects\ELog\MACII**Oceanographic_Elog_DELPHINUS_MACII_2009.xls**

This list was compared to the raw files. Files TD_00018.* and TD_00042.* were not listed in the ELog. These drops were determined to be bad. For files TD_00097.* and TD_00098.*, the ELog listed the drop numbers as 96 and 97, respectively. The file names were assumed to be correct.

Information about XBT drops, such as time, date, latitude, longitude, and comments about the profile by the at-sea oceanographer, was recorded at sea in an ELog, which is an Excel spreadsheet located at:

P:\Surveys\Data\WestCoast\2009_DELPHINUS\Year_Specific_Projects\ELog\MACII**Oceanographic_Elog_DELPHINUS_MACII_2009.xls**

Raw File Checks

Perl program **XBTRawFileInfo.pl** was run against the raw files. It created an error file, which reported that the drop numbers on several raw files did not match the file names. Specifically, files TD_00001, TD_00003, TD_00004, TD_00007 had one drop number higher, TD_00013 had drop number 12, and TD_00021 had drop number 19. The ELog was used to confirm that the number in the file names should be used for the drop numbers. The uncorrected files were all copied to the Raw\Files_With_Errors folder, the drop numbers corrected in the *.RDF files in Raw, then the *.EDF files were re-exported to Raw. Perl program **XBTRawFileInfo.pl** was re-run, and reported no errors.

Files **TD_00022.*** and **TD_00095.*** were missing latitude and/or longitude information. The files were copied to the Raw\Files_With_Errors folder, then the latitude and longitude were filled in from ELog. Files **TD_00042.*** were also missing latitude/longitude information. But drop 42 doesn't show up in ELog. So its latitude and longitude were extrapolated from the TSG positions based on time. Again, the unmodified files were copied to Raw\Files_With_Errors.
All drops had a probe type of Deep Blue, and used coefficients 6.472, 0.00216.

Data Checks

Position Check

XBTPositionCheck. This program wrote comparisons between XBT stations and TSG positions to the files **XBTPositionCheck_2009_DELPHINUS_MACII.txt** and **XBTPositionCheck_2009_DELPHINUS_MACII.err** in P:\Survey\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Intermediate.
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.

Results:

```
          99    XBT lines read from
P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\In
termediate\XBTStation_2009_DELPHINUS_MACII.txt
           0    XBT lines started with an apostrophe, so were skipped
           1    XBT lines were headers, so were skipped
           3    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\WestCoast\2009_DELPHINUS\Oceanographic\TSG\Current_Version\In
termediate\TSGTrackCheck_2009_MACII_Edited.dat

          95    lines were compared to TSG
```

```
   703.75015    Root-mean-square-error of distances
           9    Distances >= 1 nautical mile
  6896.08719    Max distance
```

Of the nine that had a distance greater than 1 nautical mile, four were because the time was entered as local time rather than UTC (stations 1 through 4). Since the Sippican software does not give the option to change the date and time, the *.RDF files could not be edited, so were moved to the Raw\Original folder. But the time was updated in the *.EDF files. For the remaining five (stations 10, 24, 37, 44, and 47), the files were copied to Raw\Original, then the lat/lons were corrected to match the ELog spreadsheet.

The corrected raw files were compared to TSG using program **XBTPositionCheck.pl**, which reported no distances > 1 nmi.

```
          98    EDF files read
           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\WestCoast\2009_DELPHINUS\Oceanographic\TSG\Current_Version\In
termediate\TSGTrackCheck_2009_DELPHINUS_MACII_Final.dat

          98    lines were compared to TSG

     0.24201    Root-mean-square-error of distances
           0    Distances >= 1 nautical mile
     0.92544    Max distance
```

Station and Drop Lists

Perl program **XBTStationAndDrops.pl** was run to create the “Station” and "Drops" files. The "Station" file has a single line for each drop, with its time and location, probe type, depths, and fall rate equation coefficients. The "Drops" File has a single line for each drop, with only the file name. These files were saved as **XBTStation_2009_DELPHINUS_MACII.txt** and **XBTDrops_2009_DELPHINUS_MACII.txt**, respectively, in

P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Intermediate\

Profile Review and Edit

XBT temperature vs depth profiles were examined by Dan Prosperi (Database Manager), 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 decided what edits need to be made, and recorded that information in file **XBTDrops_2009_DELPHINUS_MACII PF.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.

Positions for stations without corresponding TSG data were checked against the XBT Log and ODL. No editing was necessary. [Edits are noted in **XBTsta*YYs*e.txt**.] [Describe any general problems such as “Many positions had to be edited because the position entered into the SEAS files header had been recorded several minutes (often 10 to 20 minutes) before the drop was made and recorded by SEAS”.]

Apply Profile Edits

Program XBTEdits was used to apply the editing codes. It reported the following:

```
98      lines read from input file
        P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Intermedi
        ate\XBTDrops_2009_DELPHINUS_MACII PF.txt
0       lines started with an apostrophe, so were ignored
3       lines had an RJ code, so were ignored
```

```
95      records written to
        P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Intermedi
        ate\XBTEdited_2009_DELPHINUS_MACII.dat

1       lines were not good enough for NODC, so their drop numbers were negated
94      records written to
        P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Intermedi
        ate\XBTNODC_2009_DELPHINUS_MACII_6.691_0.00225.dat

8.94    Average temperature of all 51112 output points whose drops met the Min To Avg depth
16.19   Average temperature of all 10512 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
```

The average temperature values were used in the fall rate equations below.

Correct Depth and Temperature

XBT depths and temperatures were re-calculated using Perl program **XBTCorrect.pl**. The corrections are based on Cheng et al 2014, as described in
P:\Surveys\Data_Processing_Resources\Oceanographic\XBT\Fall rate**XBT Depth Errors Due to Changing Fall Rates.pdf**.

Results:

```
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\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Interme
        diate\XBTEdited_2009_DELPHINUS_MACII.dat...
Deep Blue: Thermal Bias = 0.02492, A = 6.611, B = 0.00228, Offset = 1.862

96      lines read from
        'P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Interm
        ediate\XBTEdited_2009_DELPHINUS_MACII.dat'
0       lines started with an apostrophe, so were ignored
95      records written to
        P:\Surveys\Data\WestCoast\2009_DELPHINUS\Oceanographic\XBT\Current_Version\Interme
        diate\XBTCorrected_2009_DELPHINUS_MACII_Deep Blue.dat

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

Final data files

The NODC file created in the XBTEdit step was copied to \Final and was renamed as:
XBTArchive_2009_DELPHINUS_MACII_Deep Blue.dat

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 file that had depth and temperature corrected based on Cheng et al was also copied to \Final. This file is:

XBTCorrected_2009_DELPHINUS_MACII_Deep Blue.dat

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, 2.8, 3.4, 4.1, 4.7, 5.4, 6.1, 6.7, 7.4, 8.0, 8.7,...
```

Paul Fiedler
Dan Prosperi
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