THE JOINT RUSSIAN-AMERICAN LONG-TERM CENSUS OF THE ARCTIC (RUSALCA)

Chukchi Sea Expedition
1-15 September 2012
CTD Data Processing Report

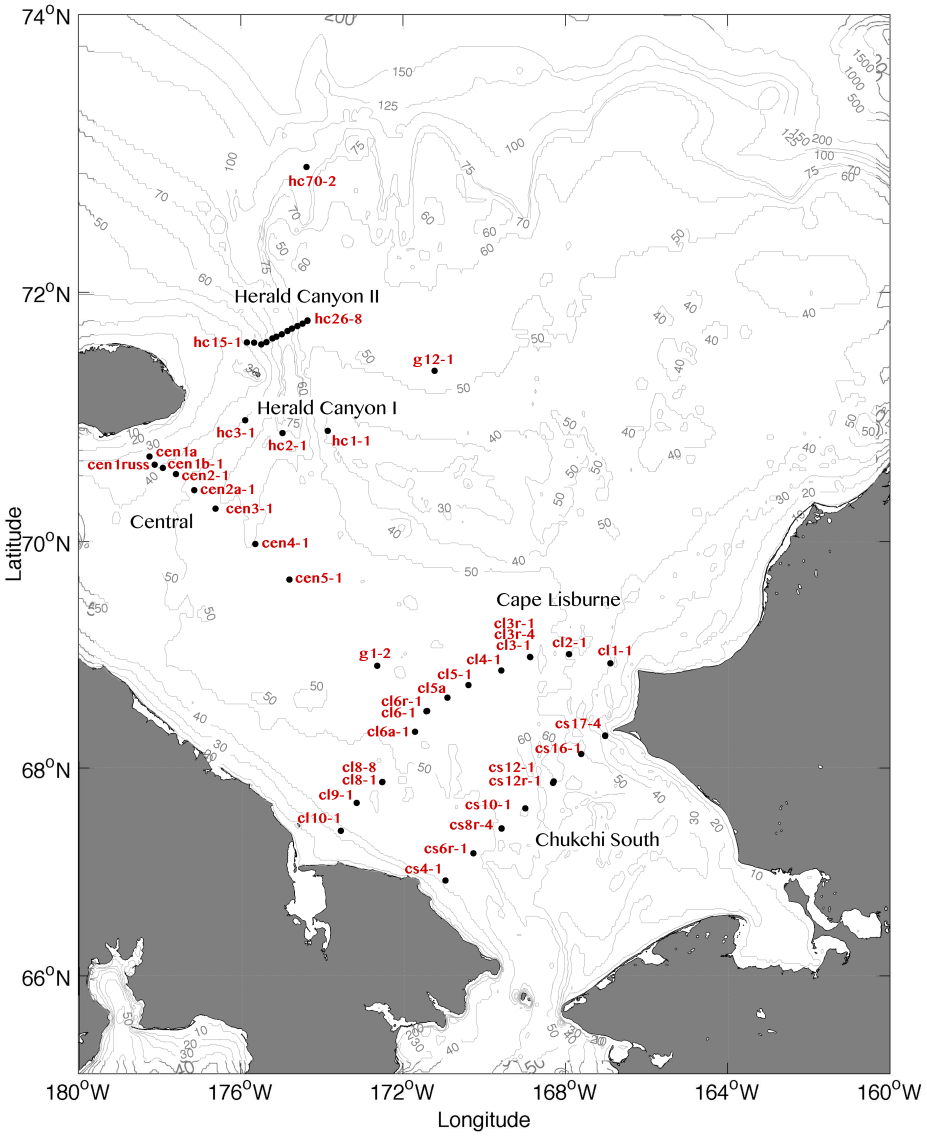


Figure 1. RUSALCA 2012 CTD station positions are shown as black circles. The complete listing of station positions can be found in the last section of this report.

1. Cruise Overview

The third broad-scale survey of the Joint Russian-American Long-Term Census of the Arctic (RUSALCA) program took place from 1-15 September, 2012 aboard the research vessel Khromov. A total of 55 conductivity-temperature-depth (CTD) casts, comprising several sections, were occupied between Bering Strait and the vicinity of Herald Canyon. The original plan called for more sections, but a combination of inclement weather, significant pack-ice, and logistical challenges limited the number of stations. Figure 1 shows the station locations, and the table at the end of this document (Section 7) lists the pertinent information for each cast. The CTD package was provided by the Woods Hole Oceanographic Institution (WHOI) and consisted of a 21-place rosette with 10-liter bottles. The sensor suite contained a Sea-Bird model SBE911plus CTD with dual temperature and conductivity sensors, a dissolved oxygen sensor, 660-nm transmissometer, chlorophyll-α and two CDOM fluorometers, underwater and surface PAR sensors, and an altimeter. The package also included an upward- and downward-facing RDI Workhorse 300kHz lowered ADCP system, and a SeaScan Video Plankton Recorder. See http://www.whoi.edu/science/PO/pickart/rusalca/docs/rusalca12_cruise_report_Hydrography.pdf for a complete report of the instrumentation used during the cruise. Here we describe the processing and editing of the CTD data, and explain the structure of the final pressure-averaged downcast files. The data can be downloaded from http://www.whoi.edu/science/PO/pickart/rusalca/php/rusalca.php, which also contains vertical profiles of the individual stations and vertical section plots.

2. Data Quality Control

The CTD data were processed using the recommended post-acquisition sequence of SeaBird routines for an SBE 9. This included removing out-of-water records, editing parameters to exclude outliers, filtering pressure, temperature, and conductivity, and deriving salinity and oxygen from the edited values. The result is a one-decibar averaged profile in Seabird ascii format with a lengthy header that contains the processing history for that file. Files were then converted to a different ascii format with a simple three-line header for continued processing using WHOI Matlab scripts. The objective of the final processing was to assess conductivity and temperature sensor performance and to remove bad conductivity and/or temperature values as indicated by density inversions in the downcast portion of the profile. To accomplish this, plots of salinity, potential temperature, and potential density versus pressure were created for each CTD station and inspected for bad data points, which were identified and dealt with according to the following criteria:

1. Erroneous surface or bottom points that could not be interpolated were removed.
2. Faulty data due to sensor problems were removed and replaced with data from the alternate sensor (for temperature and conductivity).
3. In cases where the value in a particular bin was -9 (SeaBird flag for bad data), that entry was removed entirely from the final calibrated file.

All the modifications made based on criteria 1 and 2 listed above are reported in Table 1.

Station	Pressure (db)	Modified
cen1russ	1-3	removed (spike in salinity)
cl5a	1-2	removed (spike in salinity)
cl8-8	4	removed (spike in salinity)
hc2-1	27 - 43	used value from secondary salinity sensor
hc1-1	25 - 36	used value from secondary salinity sensor
hc3-1	20 - 30	used value from secondary salinity sensor
hc19-1	50	removed (spike in o2)

Table 1 – Data that were modified or removed due to bad quality.

As noted above, in select CTD stations throughout the cruise, SeaBird processing routines flagged some of the bins as -9, indicating bad data. This was a result of increased ship heave at certain locations, which meant that specific data bins did not have enough points to constitute an accurate value. Table 2 lists all the pressure bins flagged as bad, in which cases the entire row was removed.

Station	Pressure (db)	Modified
hc18-1	47-50	removed (bad data flag)
hc19-1	17-22, 24-28, 30	removed (bad data flag)
hc20-1	34,38,39,50,55-66	removed (bad data flag)
hc21-1	5-10,12,14,16-17,20,27,48-49,52,54,58,62-65	removed (bad data flag)
hc26-1	14	removed (bad data flag)
hc70-2	87-91	removed (bad data flag)

Table 2 – Data that were removed due to bad data flags from SeaBird processing.

3. WOCE Quality Flags

The quality flag in the last column of each record indicates modifications made to the original data. Each bit of the quality word corresponds to a column in the data file. Quality codes are interpreted as such:

0 replaced
1 measured but not quality controlled
2 good data.
3 questionable data.
4 bad data. *(Note: for this cruise, all bad data were removed so no quality flag of 4 was assigned)*
7 interpolated data. *(Note: for this cruise, no data were interpolated)*

QC 1 was used for all measurements other than Temperature and Salinity.

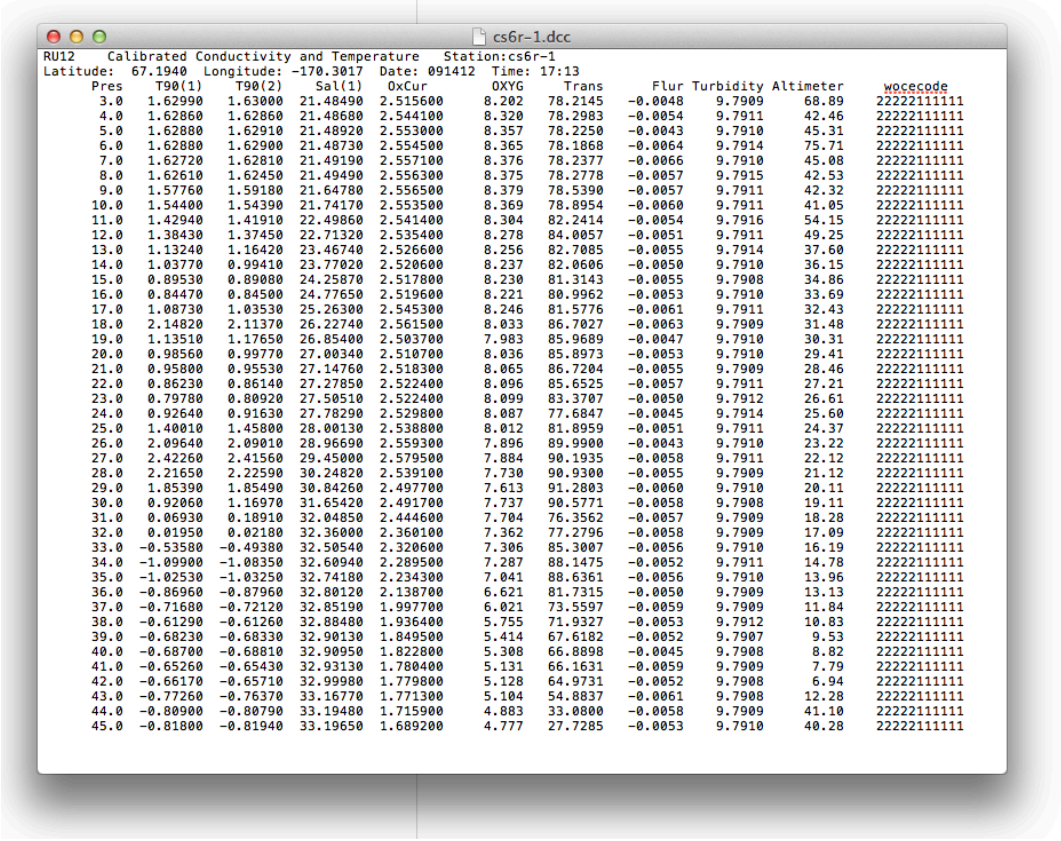
4. Sensor Accuracy

Since the cruise took place on the shallow Chukchi shelf, where spatial variation in water properties is strong, in-situ salinity calibration is ineffective. As such, no water sample salinity measurements were taken. In lieu of an in-situ calibration, the following procedure was performed to assess the accuracy of the CTD salinity measurements. The values measured by the dual sensors were regressed against each other, excluding depths shallower than 30 m. An initial regression line was determined, all values outside the three standard deviation envelope were discarded, and the regression was calculated again. The standard deviation of the resulting scatter, which is taken as a rough measure of the salinity accuracy, was .062. This analysis revealed a slight drift in one of the sensors as a function of increasing salinity. Consequently, the data from the secondary conductivity sensor have been removed from the final calibrated files. (We note, however, that for the few data bins where the primary conductivity sensor exhibited pronounced spikes, the secondary data were substituted, see Table 1).

Both temperature sensors have been sent to SeaBird for calibration. This report will be updated to reflect the calibration information once the sensors are returned from SeaBird.

5. DCC File Format

A sample of the format of the final "*d*owncast *c*onductivity *c*alibrated" file (.dcc) is shown below. The file contains three header lines, where the fist two lines contain the information for cruise ID, station number, latitude, longitude, date, and time. The third header line contains the column labels for the data. The last column of data contains the WOCE quality flags. A more detailed description of these quality flags can be found at the WOCE website - http://woce.nodc.noaa.gov/woce_v3/wocedata_1/woce-uot/document/qcflags.htm



cs6r-1.dcc

```
RU12    Calibrated Conductivity and Temperature   Station:cs6r-1
Latitude:  67.1940  Longitude: -170.3017  Date: 091412  Time: 17:13
      Pres    T90(1)    T90(2)    Sal(1)   OxCur      OXYG     Trans      Flur Turbidity Altimeter     wocecode
       3.0   1.62990   1.63000  21.48490  2.515600     8.202   78.2145   -0.0048    9.7909     68.89    22222111111
       4.0   1.62860   1.62860  21.48680  2.544100     8.320   78.2983   -0.0054    9.7911     42.46    22222111111
       5.0   1.62880   1.62910  21.48920  2.553000     8.357   78.2250   -0.0043    9.7910     45.31    22222111111
       6.0   1.62880   1.62900  21.48730  2.554500     8.365   78.1868   -0.0064    9.7914     75.71    22222111111
       7.0   1.62720   1.62810  21.49190  2.557100     8.376   78.2377   -0.0066    9.7910     45.08    22222111111
       8.0   1.62610   1.62450  21.49490  2.556300     8.375   78.2778   -0.0057    9.7915     42.53    22222111111
       9.0   1.57760   1.59180  21.64780  2.556500     8.379   78.5390   -0.0057    9.7911     42.32    22222111111
      10.0   1.54400   1.54390  21.74170  2.553500     8.369   78.8954   -0.0060    9.7911     41.05    22222111111
      11.0   1.42940   1.41910  22.49860  2.541400     8.304   82.2414   -0.0054    9.7916     54.15    22222111111
      12.0   1.38430   1.37450  22.71320  2.535400     8.278   84.0057   -0.0051    9.7911     49.25    22222111111
      13.0   1.13240   1.16420  23.46740  2.526600     8.256   82.7085   -0.0055    9.7914     37.60    22222111111
      14.0   1.03770   0.99410  23.77020  2.520600     8.237   82.0606   -0.0050    9.7910     36.15    22222111111
      15.0   0.89530   0.89080  24.25870  2.517800     8.230   81.3143   -0.0055    9.7908     34.86    22222111111
      16.0   0.84470   0.84500  24.77650  2.519600     8.221   80.9962   -0.0053    9.7910     33.69    22222111111
      17.0   1.08730   1.03530  25.26300  2.545300     8.246   81.5776   -0.0061    9.7911     32.43    22222111111
      18.0   2.14820   2.11370  26.22740  2.561500     8.033   86.7027   -0.0063    9.7909     31.48    22222111111
      19.0   1.13510   1.17650  26.85400  2.503700     7.983   85.9689   -0.0047    9.7910     30.31    22222111111
      20.0   0.98560   0.99770  27.00340  2.510700     8.036   85.8973   -0.0053    9.7910     29.41    22222111111
      21.0   0.95800   0.95530  27.14760  2.518300     8.065   86.7204   -0.0055    9.7909     28.46    22222111111
      22.0   0.86230   0.86140  27.27850  2.522400     8.096   85.6525   -0.0057    9.7911     27.21    22222111111
      23.0   0.79780   0.80920  27.50510  2.522400     8.099   83.3707   -0.0050    9.7912     26.61    22222111111
      24.0   0.92640   0.91630  27.78290  2.529800     8.087   77.6847   -0.0045    9.7914     25.60    22222111111
      25.0   1.40010   1.45800  28.00130  2.538800     8.012   81.8959   -0.0051    9.7911     24.37    22222111111
      26.0   2.09640   2.09010  28.96690  2.559300     7.896   89.9900   -0.0043    9.7910     23.22    22222111111
      27.0   2.42260   2.41560  29.45000  2.579500     7.884   90.1935   -0.0058    9.7911     22.12    22222111111
      28.0   2.21650   2.22590  30.24820  2.539100     7.730   90.9300   -0.0055    9.7909     21.12    22222111111
      29.0   1.85390   1.85490  30.84260  2.497700     7.613   91.2803   -0.0060    9.7910     20.11    22222111111
      30.0   0.92060   1.16970  31.65420  2.491700     7.737   90.5771   -0.0058    9.7908     19.11    22222111111
      31.0   0.06930   0.18910  32.04850  2.444600     7.704   76.3562   -0.0057    9.7909     18.28    22222111111
      32.0   0.01950   0.02180  32.36000  2.360100     7.362   77.2796   -0.0058    9.7909     17.09    22222111111
      33.0  -0.53580  -0.49380  32.50540  2.320600     7.306   85.3007   -0.0056    9.7910     16.19    22222111111
      34.0  -1.09900  -1.08350  32.60940  2.289500     7.287   88.1475   -0.0052    9.7911     14.78    22222111111
      35.0  -1.02530  -1.03250  32.74180  2.234300     7.041   88.6361   -0.0056    9.7910     13.96    22222111111
      36.0  -0.86960  -0.87960  32.80120  2.138700     6.621   81.7315   -0.0050    9.7909     13.13    22222111111
      37.0  -0.71680  -0.72120  32.85190  1.997700     6.021   73.5597   -0.0059    9.7909     11.84    22222111111
      38.0  -0.61290  -0.61260  32.88480  1.936400     5.755   71.9327   -0.0053    9.7912     10.83    22222111111
      39.0  -0.68230  -0.68330  32.90130  1.849500     5.414   67.6182   -0.0052    9.7907      9.53    22222111111
      40.0  -0.68700  -0.68810  32.90950  1.822800     5.308   66.8898   -0.0045    9.7908      8.82    22222111111
      41.0  -0.65260  -0.65430  32.93130  1.780400     5.131   66.1631   -0.0059    9.7909      7.79    22222111111
      42.0  -0.66170  -0.65710  32.99980  1.779800     5.128   64.9731   -0.0052    9.7908      6.94    22222111111
      43.0  -0.77260  -0.76370  33.16770  1.771300     5.104   54.8837   -0.0061    9.7908     12.28    22222111111
      44.0  -0.80900  -0.80790  33.19480  1.715900     4.883   33.0800   -0.0058    9.7909     41.10    22222111111
      45.0  -0.81800  -0.81940  33.19650  1.689200     4.777   27.7285   -0.0053    9.7910     40.28    22222111111
```

6. Bottom Depth

The bottom depth values in the last column of the station positions table were calculated by using the data from the altimeter and pressure sensor on the package. For each cast, the maximum depth attained by the CTD was added to the altimeter value recorded at that time.

7. Station Positions Table

Filename	Latitude (Deg N)	Longitude (Deg W)	Date Time	Cast Depth(m)	Bottom Depth(m)
cen1a	70.7085	178.2988	06-Sep-2012 19:58:00	35.63	37.72
cen1b-1	70.6155	177.9713	06-Sep-2012 13:05:00	39.59	41.71
cen1russ	70.6437	178.1718	06-Sep-2012 22:22:00	22.76	43.42
cen2-1	70.5652	177.6443	06-Sep-2012 11:08:00	42.56	44.97
cen2a-1	70.4330	177.1943	06-Sep-2012 08:57:00	51.47	54.69
cen3-1	70.2797	176.6693	06-Sep-2012 04:02:00	53.45	57.13
cen4-1	69.9828	175.6857	06-Sep-2012 00:01:00	56.42	63.21
cen5-1	69.6790	174.8460	05-Sep-2012 18:33:00	51.47	57.41
cl1-1	68.9480	166.9178	02-Sep-2012 03:57:00	44.54	46.80
cl10-1	67.4093	173.5757	14-Sep-2012 03:25:00	30.69	33.51
cl2-1	69.0298	167.9342	02-Sep-2012 09:04:00	45.53	50.70
cl3-1	69.0032	168.8938	02-Sep-2012 12:45:00	50.48	53.57
cl3r-1	69.0048	168.9000	12-Sep-2012 23:34:00	50.48	57.34
cl3r-4	69.0045	168.9010	13-Sep-2012 01:27:00	48.50	55.94
cl4-1	68.8840	169.6088	02-Sep-2012 15:52:00	52.46	57.50
cl5-1	68.7535	170.4240	02-Sep-2012 18:32:00	53.45	61.36
cl5a	68.6407	170.9423	02-Sep-2012 20:38:00	51.47	59.04
cl6-1	68.5188	171.4615	02-Sep-2012 22:52:00	52.46	60.09
cl6a-1	68.3308	171.7430	03-Sep-2012 14:00:00	50.48	58.27
cl6r-1	68.5205	171.4412	13-Sep-2012 10:18:00	50.48	57.63
cl8-1	67.8692	172.5482	13-Sep-2012 17:58:00	45.54	52.64
cl8-8	67.8667	172.5510	13-Sep-2012 20:19:00	44.55	46.25
cl9-1	67.6733	173.1800	14-Sep-2012 01:04:00	44.55	48.71
cs10-1	67.6220	169.0145	15-Sep-2012 03:11:00	46.53	51.23
cs12-1	67.8737	168.3142	01-Sep-2012 00:14:00	52.46	57.56
cs12r-1	67.8602	168.3347	15-Sep-2012 05:58:00	53.45	60.21
cs16-1	68.1287	167.6362	01-Sep-2012 15:26:00	48.50	51.32
cs17-1	68.2983	167.0418	01-Sep-2012 18:16:00	23.76	39.58
cs17-4	68.2933	167.0430	01-Sep-2012 21:05:00	35.64	38.65
cs4r	66.9320	170.9892	14-Sep-2012 13:51:00	40.59	42.56
cs6r-1	67.1940	170.3017	14-Sep-2012 17:13:00	44.55	51.49
cs8r-1	67.4312	169.6030	14-Sep-2012 20:26:00	48.51	51.11
cs8r-4	67.4317	169.6042	14-Sep-2012 22:35:00	47.52	52.10
g1-2	68.9255	172.6725	03-Sep-2012 08:31:00	50.48	57.55
g12-1	71.3980	171.2597	11-Sep-2012 21:47:00	48.49	54.75
hc1-1	70.9192	173.8988	07-Sep-2012 12:12:00	35.63	39.97
hc15-1	71.6205	175.8960	09-Sep-2012 16:52:00	37.61	40.28
hc16-1	71.6177	175.7173	09-Sep-2012 15:48:00	41.57	44.89

hc17-1	71.6040	175.5417	09-Sep-2012 14:25:00	38.60	49.99
hc18-1	71.6213	175.4085	09-Sep-2012 06:51:00	50.47	54.52
hc19-1	71.6520	175.2660	09-Sep-2012 05:48:00	51.46	61.66
hc2-1	70.9000	175.0127	07-Sep-2012 19:45:00	66.31	74.40
hc20-1	71.6640	175.1650	09-Sep-2012 04:54:00	66.30	69.93
hc21-1	71.6838	175.0352	09-Sep-2012 03:17:00	65.31	71.57
hc22-1	71.7077	174.8898	08-Sep-2012 22:16:00	67.29	71.37
hc23-1	71.7275	174.7848	08-Sep-2012 21:27:00	66.30	69.92
hc24-1	71.7472	174.6465	08-Sep-2012 20:25:00	63.34	69.33
hc25-1	71.7670	174.5208	08-Sep-2012 19:30:00	55.42	61.26
hc26-1	71.7878	174.3945	08-Sep-2012 13:31:00	50.47	54.80
hc26-8	71.7902	174.3962	08-Sep-2012 18:14:00	50.47	52.13
hc3-1	71.0033	175.9335	08-Sep-2012 02:58:00	46.52	48.40
hc70-2	72.9398	174.4222	11-Sep-2012 04:31:00	91.03	100.17