AWI Moored ULS Data, Weddell Sea (1990-1998), Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Harms, S., E. Fahrbach, and V. H. Strass. 2001. *AWI Moored ULS Data, Weddell Sea (1990-1998), Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. https://doi.org/10.7265/N58G8HM9. [Date Accessed].

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1 DETAILED DATA DESCRIPTION

1.1 Data Sources

These data from moored Upward Looking Sonar (ULS) were contributed to NSIDC by the Alfred Wegener Institute for Polar and Marine Research in 1999. Dr. Sabine Harms provided material for this documentation in addition to the data. See the cited references for more information on the instruments used to collect these data and the research program that allowed these data to be produced.

1.2 Summary of Parameters

- Water pressure at depth of instrument
- Water temperature at depth of instrument
- Draft (Distance between the ocean surface and the bottom of the ice.)
- A flag that indicates if the draft is a measurement of the water surface, or of sea ice

Measurements have a sample interval of between 3 and 15 minutes. Data record length for individual stations ranges from under a year to about two years.

1.3 Mooring Summary Table

Cruise	Station	SN[1]	Instrument Model	Version	Latitude	Longitude	WD[2]	ID[3]	SI[4]	Start	End
ANT XIII/4	206-4	9	ES-300 V	3.00	S63°29.6'	W52°06.1'	960	157	15	May 8, 1996	Jan. 8, 1998
ANT IX/2	207-2	6	ES-300 V	1.00	S63°45.1'	W50°54.3'	2461	125	8	Nov. 22, 1990	Nov. 26, 1992
ANT XIII/4	207-4	8	ES-300 V	3.00	S63°43.3'	W50°49.2'	2510	174	15	April 27, 1996	Nov. 7, 1997
ANT X/7	208-3	24	ES-300 V	1.00	S65°37.7'	W36°29.4'	4766	150	8	Jan. 4, 1993	July 25, 1994
ANT X/7	209-3	25	ES-300 V	1.00	S66°37.4'	W27°07.2'	4860	132	8	Dec. 31, 1992	Nov. 10, 1993
ANT IX/2	210-2	7	ES-300 V	1.00	S69°39.6'	W15°42.9'	4750	125	8	Dec. 11, 1990	Dec. 16, 1992

Cruise	Station	SN[1]	Instrument Model	Version	Latitude	Longitude	WD[2]	ID[3]	SI[4]	Start	End
ANT IX/2	212-2	9	ES-300 V	1.00	S70°54.7'	W11°57.8'	1550	125	8	Dec. 14, 1990	Dec. 18, 1992
ANT IX/2	217-1	10	ES-300 V	1.00	S64°25.1'	W45°51.0'	4390	125	8	Nov. 24, 1990	Nov. 26,1992
ANT X/7	227-3	10	ES-300 V	1.00	S59°01.8'	E 00°00.0'	4605	156	8	April 4, 1996	Jan. 10, 1997
ANT XIII/4	227-4	37	ES-300 VI	4.00	S59°01.8'	W00°OO.9'	4600	145	3	Jan. 9, 1997	April 11, 1998
ANT XIII/4	229-1	7	ES-300 V	3.00	S64°00.0'	W00°OO.0'	5186	165	15	April 18, 1996	Dec. 24, 1997
ANT XIII/4	231-1	26	ES-300 V	3.00	S67°00.0'	W00°00.4'	4510	160	15	April 12, 1996	Dec. 27, 1997
ANT XIII/4	232-1	24	ES-300 V	3.00	S69°00.0'	E 00°00.0'	3361	147	15	April 21, 1996	Feb. 16, 1997
ANT XIII/4	233-2	34	ES-300 VI	4.00	S69°24.0'	E 00°00.0'	1960	154	3	Feb. 16, 1997	March 12, 1998

Notes:

1. Serial number.
2. Water depth, meters.
3. Instrument depth, meters.
4. Sample interval, minutes.

Comments:

206-4: No pressure and temperature readings, strong tilt; used pressure and temperature from RCM at 246 m.
207-4: Strong non-linear pressure drift after Nov. 7, 1997.
227-3: No pressure reading; used pressure from RCM at 262 m.
229-1: Pressure at ULS corrected for drift; very strong vertical motion (>100m) of upper instruments.
231-1: Pressure at ULS corrected for drift.
208-2, 217-2, 230-1: Instrument failure.
207-3, 209-2, 210-3, 212-3, 232-2, 233-1: Instrument lost.

Instrument Versions

Different instrument models used different instrument software versions, as follows:

Model ES-300V -- software version 1.0
Model ES-300V -- software version 3.0
Model ES-300VI -- software version 4.0
Model ES-300VIII -- software version 4.0

In version 1.0, four travel times are measured, but only the two most similar travel times are stored, and only one signal strength is stored. In higher versions, four travel times are measured and all four travel times are stored, and for each travel time the signal strength is stored.

1.4 Data Format

Data and information are stored in the following files:

- An ASCII file of processed data for each mooring (e.g. "`uls206_4.end`")
- An associated Postscript file with plots of draft mean values, draft mode values, and ice coverage (e.g. "`uls206_4_endout.ps`")
- An ASCII file of raw data for most moorings (e.g."`uls206_4.raw`"). There are no raw data files for data processed before October 1997, e.g. ULS 207-2, 217-1, 208-3, 209-3, 210-2, 212-2.

1.4.1 Data Sample – Processed Data

The following sample is taken from the file uls206_4.end . "NaN" indicates bad or no data.

```
ULS206-4 Processed Data (See ULS206_README.TXT for information)
 -63 -29.6 -52  -6.1
 96  5  8 14  7 12 00  900.0
  960
  157
   REC    PRES    TEMP   DRAFT  FLAG
 AWI206-4
 ULS206-4 (SN 09)
 #
     1     NaN   -2.09     NaN   NaN
     2     NaN   -2.09     NaN   NaN
     3     NaN   -2.09     NaN   NaN
     4     NaN   -2.09     NaN   NaN
     5     NaN   -2.09     NaN   NaN
     6     NaN   -2.09     NaN   NaN
     7     NaN   -2.09     NaN   NaN
     8     NaN   -2.09     NaN   NaN
     9     NaN   -2.09     NaN   NaN
    10     NaN   -2.09     NaN   NaN
    11     NaN   -2.09     NaN   NaN
    12     NaN   -2.09     NaN   NaN
```

```
    13      NaN   -2.09      NaN   NaN
    14      NaN   -2.09      NaN   NaN
    15      NaN   -2.09      NaN   NaN
    16      NaN   -2.09      NaN   NaN
    17      NaN   -2.09      NaN   NaN
    18      NaN   -2.09      NaN   NaN
    19      NaN   -2.09      NaN   NaN
    20      NaN   -2.09      NaN   NaN
    21      NaN   -2.09      NaN   NaN
    22      NaN   -2.09      NaN   NaN
    23      NaN   -2.09      NaN   NaN
    24   130.99   -1.05     0.22     1
    25   130.99   -1.04     0.06     0
    26   130.99   -1.03     0.14     1
    27   130.99   -1.01     0.15     1
    28   130.99   -1.00    -0.02     0
    29   130.99   -0.99     2.26     1
    30   130.99   -0.98     0.34     0
    31   130.99   -0.97     1.33     1
    32   130.99   -0.95     2.01     1
    33   130.99   -0.94      NaN   NaN
    34   130.99   -0.92     0.65     1
    35   130.99   -0.90    -0.30     0
```

The format is as follows:

Filename:

`ulsxxx_y.end`, where xxx = station ID, y = deployment number

Header example:

row1: ULS206-4 Processed Data (See `ULS206_README.TXT` for information)
row2: -63 -29.6 -52 -6.1
row3: 96 5 8 14 7 12 00 900.0
row4: 960
row5: 157
row6: REC PRES TEMP DRAFT FLAG
row7: AWI206-4
row8: ULS206-4 (SN 09)
row9: #

Header format:

row1: instrument ID and file identifier
row2: latitude(whole degrees, "-";indicates south) latitude (decimal minutes) longitude(whole degrees,"-"; indicates west) longitude (decimal minutes)
row3: startdate: yy mo dd hr min sec msec; sample interval(sec)
row4: water depth (m)
row5: instrument depth (m)
row6: data header

row7: station ID
row8: instrument ID and serial number
row9: the pound (#) sign marks the end of the header

Data format (all software versions):

column 1: record number
column 2: water pressure (dbar) at the instrument
column 3: water temperature (degrees Celsius) at the instrument
column 4: draft (m) (average of two (version 1.0) or four (higher versions) drafts)
column 5: flags - 0 = water, 1 = ice <= 20M, 2 = ice > 20m, NaN = bad or no data

NOTE: ice drafts greater than 20 m may be outliers that were not associated with obvious outliers in the raw data (that is, outliers in pressure, temperature, tilt, signal strength, etc.)

1.4.2 Data Sample – Raw Data

The following sample is from the file `uls206_4.raw`. "NaN" indicates bad or no data.

```
ULS206-4 Raw Data (See ULS206_README.TXT for information)
 -63 -29.6 -52  -6.1
 96  5  8 14  7 12 00  900.0
  960
  157
   REC    PRES    TEMP TILT   VENV1   VENV2   VENV3   VENV4  TIME1  TIME2  TIME3  TIME4    ATMP SPEEDSP  DRAFT1  DRAFT2  DRAFT3  DRAFT4 ERR
 AWI206-4
 ULS206-4 (SN 09)
 #
     1     NaN   -2.09  0.0   15.00   15.00   15.00   15.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
     2     NaN   -2.09  0.0   16.00   15.00   16.00   16.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
     3     NaN   -2.09  0.0   16.00   15.00   16.00   15.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
     4     NaN   -2.09  0.0   16.00   15.00   16.00   16.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
     5     NaN   -2.09  0.0   15.00   16.00   15.00   16.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
     6     NaN   -2.09  0.0   15.00   16.00   15.00   16.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
     7     NaN   -2.09  0.0   16.00   16.00   15.00   15.00 393216 393216 393216 393216    0.00     NaN     NaN     NaN     NaN     NaN 2
```

The format is as follows:

Filename:

`ulsxxx_y.raw`, where xxx = station ID, y = deployment number

Header example

row1: ULS206-4 Raw Data (See `ULS206_README.TXT` for information)
row2: -63 -29.6 -52 -6.1
row3: 96 5 8 14 7 12 00 900.0
row4: 960
row5: 157
row6: REC PRES TEMP TILT VENV1 VENV2 VENV3 VENV4 TIME1 TIME2 TIME3 TIME4 ATMP SPEEDSP DRAFT1 DRAFT2 DRAFT3 DRAFT4 ERR
row7: AWI206-4
row8: ULS206-4 (SN 09)
row9: #

Header format:

row1: instrument ID and file identifier
row2: latitude(whole degrees,"-" indicates south) latitude (decimal minutes) longitude(whole degrees,"-" indicates west) longitude (decimal minutes)
row3: startdate: yy mo dd hr min sec msec; sample interval(sec)
row4: water depth (m)
row5: instrument depth (m)
row6: data header
row7: station ID
row8: instrument ID and serial number
row9: the pound (#) sign marks the end of the header

Data stored (software version 1.0):

column 1: record number
column 2: water pressure (dbar) at the instrument
column 3: water temperature (degrees Celsius) at the instrument
column 4: tilt of the instrument (angle in degrees from vertical)
column 5: signal strength (0-255) of one of the four returned pulses
column 6: travel time 1 \ these are the two most similar
column 7: travel time 2 / travel times
column 8: atmospheric pressure (dbar) interpolated from 6-hourly ECMWF pressures
column 9: sound velocity (m/sec) averaged over the water column above the instrument
column 10: raw draft 1 (m)
column 11: raw draft 2 (m)
column 12: flags for obvious outliers:

- 1 = draft <= -100 M
- = water temperature < -2.3 deg C or > 2 deg C or instrument pressure < dbar or raw pressure > upper limit of pressure sensor
- = signal strength < 20 in a range 0-255 or instrument tilt > 5 degrees
- = mean of both drafts < -10 m or > 200 m
- = difference between both drafts > 2 m
- If more than one of these errors occur, only the smallest flag is stored.

Data stored (software versions 3.0 and 4.0:)

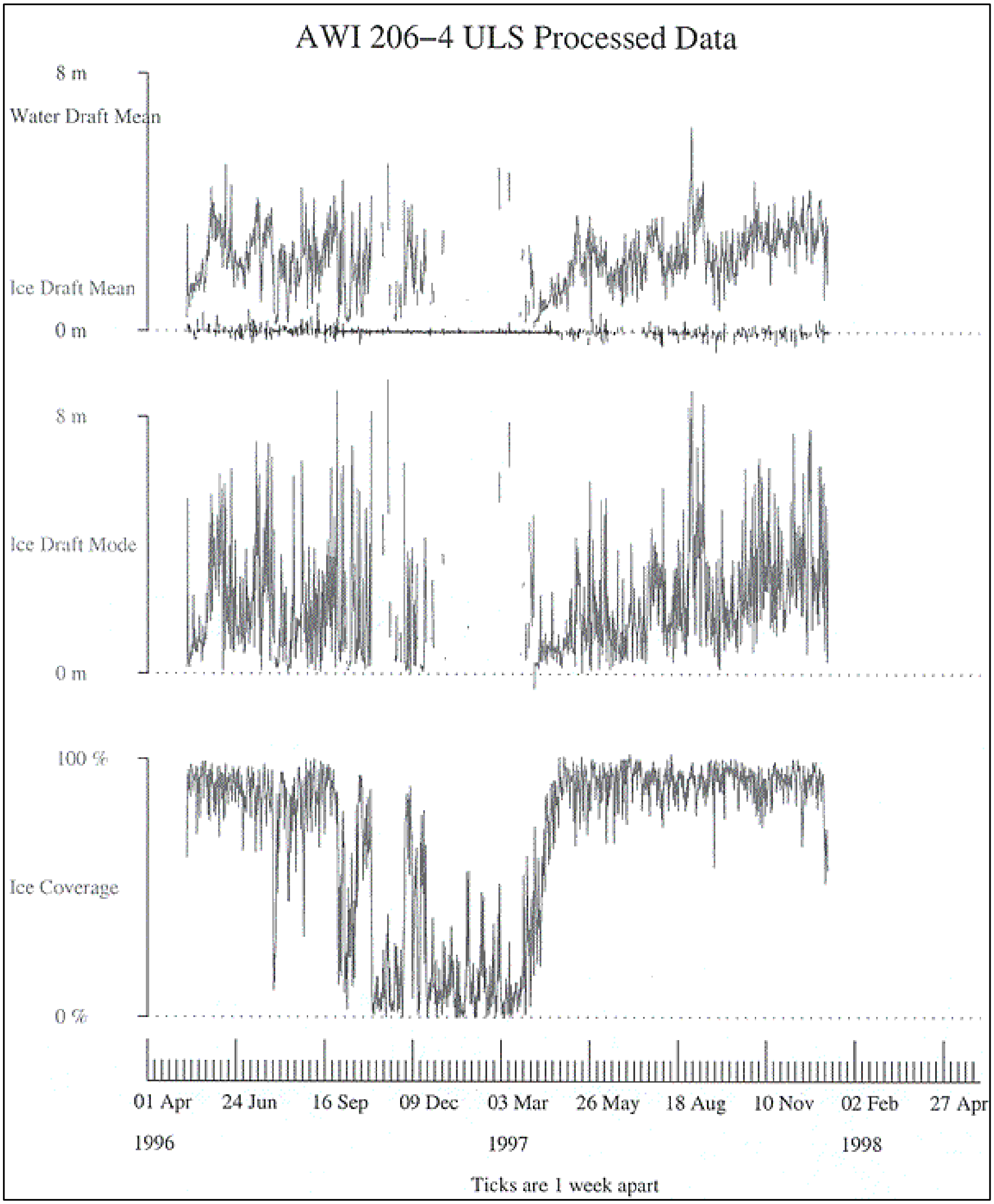
column 1: record number
column 2: water pressure (dbar) at the instrument
column 3: water temperature (degrees Celsius) at the instrument
column 4: tilt of the instrument (angle in degrees from vertical)
column 5: signal strength (0-255) of the returned first pulse
column 6: signal strength (0-255) of the returned second pulse
column 7: signal strength (0-255) of the returned third pulse
column 8: signal strength (0-255) of the returned fourth pulse
column 9: travel time of the first pulse
column 10: travel time of the second pulse
column 11: travel time of the third pulse
column 12: travel time of the fourth pulse
column 13: atmospheric pressure (dbar) interpolated from 6-hourly ECMWF pressures

column 14: sound velocity (m/sec) averaged over the water column above the instrument
column 15: raw draft 1 (m)
column 16: raw draft 2 (m)
column 17: raw draft 3 (m)
column 18: raw draft 4 (m)
column 19: flags for obvious outliers:

- 1 = draft <= -100 m
- = water temperature < -2.3 deg C or > 2 deg C or instrument pressure < 50 dbar or raw pressure > upper limit of pressure sensor
- = signal strength < 20 in a range of 0 to 255 or instrument tile > 5 degrees
- = mean of all drafts < -10 m or > 200 m
- = standard deviation of all drafts > 2 m
- If more than one of these errors occur, only the smallest flag is stored.

1.4.3 Data Sample – Postscript Files

The image below is an example of the file for processed data from mooring 206-4.



1.5 Instrument and Measurement Technique

Information for this section of the documentation was obtained from Strass (1998).

Moored upward looking sonars measure sea ice draft by transmitting pulses of sound toward the surface, and measuring the time elapsed until the echo of a pulse is received back at the instrument. Time is converted to distance using assumptions about the profile of sound speed in the water between the instrument and the surface. If the depth of the instrument is known, and the location of the open water surface is apparent in the echo record, the depth (or draft) of the under-ice surface can be calculated.

Processing raw upward looking sonar data to produce draft measurements involves accounting for factors that introduce errors. For example, sound velocity depends on water density, which in turn depends on temperature and salinity. These parameters vary seasonally and on shorter time scales. The depth of the instrument is measured by a pressure sensor, and this measurement must be corrected for variations in pressure caused by variations in water density and air pressure. These factors and others are accounted for in the following processing steps:

1. Modeling the sound distribution
2. Correcting ULS pressure readings for air pressure variations
3. Calculating raw drafts from the corrected pressure readings and sound pulse travel times using the sound velocity model
4. Rejecting obviously erroneous data
5. Making an initial discrimination between open water and ice drafts
6. Adjusting the surface level based on identified open water drafts, and arriving at a final discrimination between ice and open water drafts
7. Determining and removing the ice draft bias

Notes on Step 1: Modeling the sound distribution

Temperature profiles are determined for each mooring location individually using profiles measured at the mooring positions during deployment and recovery. These are adjusted over time with temperature measured continuously at the ULS. The salinity distribution is approximated using salinity profiles measured during deployment and recovery, adjusted over time using an assumed linear relationship between temperature and salinity. Approximated seasonal cycles of temperature and salinity are combined with the vertical temperature and salinity distributions. Density and sound velocity are then calculated from standard oceanographic formula using the vertically and temporally varying temperature and salinity profiles.

Notes on Step 2: Correcting ULS pressure readings for air pressure variations

Continuous time series of air pressure at the mooring locations are produced by interpolating values from European Centre for Medium Range Weather Forecasting six hour air pressure fields. Variations in air pressure are then removed from the ULS pressure readings before instrument depth is calculated.

Notes on Step 4: Rejecting obviously erroneous data

Data are rejected if (a) the measured temperature or pressure is out of range (b) the strength of the echo falls below a threshold or the tilt of the instrument exceeds five degrees (c) the difference between the two most similar draft measurements obtained from a single pulse exceeds 2 m, or (d) the draft is larger than the ULS depth or less than -10 m.

Notes on Step 5: Making an initial discrimination between open water an ice drafts

At this stage in data processing a draft of zero does not necessarily correspond to the water surface because the sound velocity model is not accurate enough for discrimination between thin ice and open water, and because waves distend the water surface. An initial discrimination between ice and open water is based on a measure of echo strength (larger for echoes from open water) and a measure of short term draft variability (higher for open water), as well as on draft.

Notes on Step 6: Adjusting the surface level based on identified open water drafts, and arriving at a final discrimination between ice and open water drafts

A final determination of the open water surface level is made manually with an interactive graphics program. Open water drafts resulting from this step are used to produce a continuous time series of the draft of open water. This time series of the surface level offset is then used to correct all drafts.

Notes on Step 7: Determining and removing the ice draft bias

The width of the acoustic beam results in an ensonified window on the under-ice surface of about 10 m in diameter (for instruments moored at between 100 and 150 m deep). Within this window, ice draft can vary considerably. Travel time is measured as the time it takes for a pulse echo to exceed a threshold. Since the deepest part of the ice will return the pulse first, ice draft measurements are biased to larger values. This bias can be estimated using an estimate of the draft probability distribution. Ice draft from a large data set of Weddell Sea drill holes was analyzed and the overall mean bias was determined to be 0.20 +- 0.02 m. The mean bias was then subtracted from all ice draft measurements.

After processing raw data using the steps above, and assuming Gaussian distribution of errors, the total resulting error in ice draft measurements is about 4 cm (Strass, 1998).

Note:
In July 2009, H. Witte informed us of an error in the bias correction. This was the formula originally used to calculate the draft:

*draft(corrected) = draft(measured) - bias*draft(measured)*
where bias = 0.215

Further correspondence did not clarify what the correct bias should be.

2 REFERENCES AND RELATED PUBLICATIONS

WCRP Informal Report No. 15/2004. 2004. Workshop on Sea-Ice Thickness Measurements from Moored Ice-Profiling Sonars: Calibration, Data Processing and Application. Tromsø, Norway, 1-3 July, 2002.

Information on instruments:

Johannessen, A. A. 1990. CMI ES-300 User's Guide. Christian-Michelsen Institut, N-5036 Fantoft, Bergen Norway. 21 pp.

Johannessen, A. A. 1995. CMI ES-300V User's Guide. Christian-Michelsen Institut, N-5036 Fantoft, Bergen Norway. 19 pp.

Lothe, T. 1997. CMI ES-300VIII User's Guide. Christian-Michelsen Institut, N-5036 Fantoft, Bergen Norway. 24 pp.

Information on data processing procedures:

Strass, V. H. 1998. Measuring sea ice draft and coverage with moored Upward Looking Sonars, *Deep-Sea Res*, I 45:795-818.

Results, moored ULS observations:

Drucker, R., S. Martin, and R. Moritz. 2003. Observations of ice thickness and frazil ice in the St. Lawrence Island polynya from satellite imagery, upward looking sonar, and salinity/temperature moorings. *J. Geophys. Res.*, 108: C5, 3149, doi:10.1029/2001JC001213.

Strass, V. H., and E. Fahrbach. 1998. Temporal and regional variation of sea ice draft and coverage in the Weddell Sea obtained from Upward Looking Sonars, Antarctic Sea Ice: Physical Processes, Interactions and Variability. *Antarctic Res.* Ser.74:123-139.

Harms, S. E. Fahrbach, and V.H. Strass. 2001. Sea ice transports in the Weddell Sea, *J. Geophys. Res.* 106(C5):9057-9073.

NOAA at NSIDC. 2004. *Moored Upward Looking Sonar Data.* Boulder: CO. National Snow and Ice Data Center. [http://nsidc.org/noaa/moored_uls/]. Accessed 2004-11-02.

2.1 Related Data Collections

Ice Draft and Ice Velocity Data in the Beaufort Sea, 1990-2003

Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics

AWI Moored ULS Data, Greenland Sea and Fram Strait (1991-2000)

2003-2004 Mooring data from the Beaufort Gyre Exploration Project (BGEP)

3 CONTACTS AND ACKNOWLEDGMENTS

Sabine Harms

Formerly with Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12

D-27570 Bremerhaven, Germany

4 DOCUMENT INFORMATION

4.1 Publication Date

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4.2 Date Last Updated

March 2012; A. Windnagel added a note in Step 7 Notes section.