AWI Moored ULS Data, Greenland Sea and Fram Strait, 1991-2002, Version 1

USER GUIDE

How to Cite These Data

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

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National Snow and Ice Data Center

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1 OVERVIEW

These data from moored upward looking sonar (ULS) instruments were contributed to NSIDC by the Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, Germany, in 2002 and 2004. Dr. Eberhard Fahrbach oversaw the program that produced the data, and is making these data available as a contribution to the World Climate Research Programme's Arctic Climate System Study/Climate and Cryosphere (ACSYS/CliC) Project, for which NSIDC is the ULS data archive.

In preparing these data, the contributors have been guided by recommendations set forth at the ACSYS/CliC Moored Upward Looking Sonar Workshop, in Tromsø Norway, 1-3 July 2002. Hannelore Witte, AWI, prepared the data and provided material for this documentation. The ULS instruments used for this AWI field program are of a type developed by the Applied Physics Laboratory (APL), University of Washington, Seattle. See the cited references for more information on the instruments and research program that produced these data.

Upward looking sonar instruments (sometimes called ice profiling sonar, or IPS) 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.

Data files are arranged by mooring. Each mooring has data files of three types: time series of 'raw' files, with the mean travel times for acoustic signals, time series of 'ice' files, with calculated ice draft, and 'mod' files, with ice draft frequency distribution. In addition, there is a single 'stat' file for each mooring, with statistics on ice draft, open water percentage, pressure, and temperature summarized by month, and a directory containing raw draft and temperature data for each mooring.

2 DETAILED DATA DESCRIPTION

2.1 Mooring List

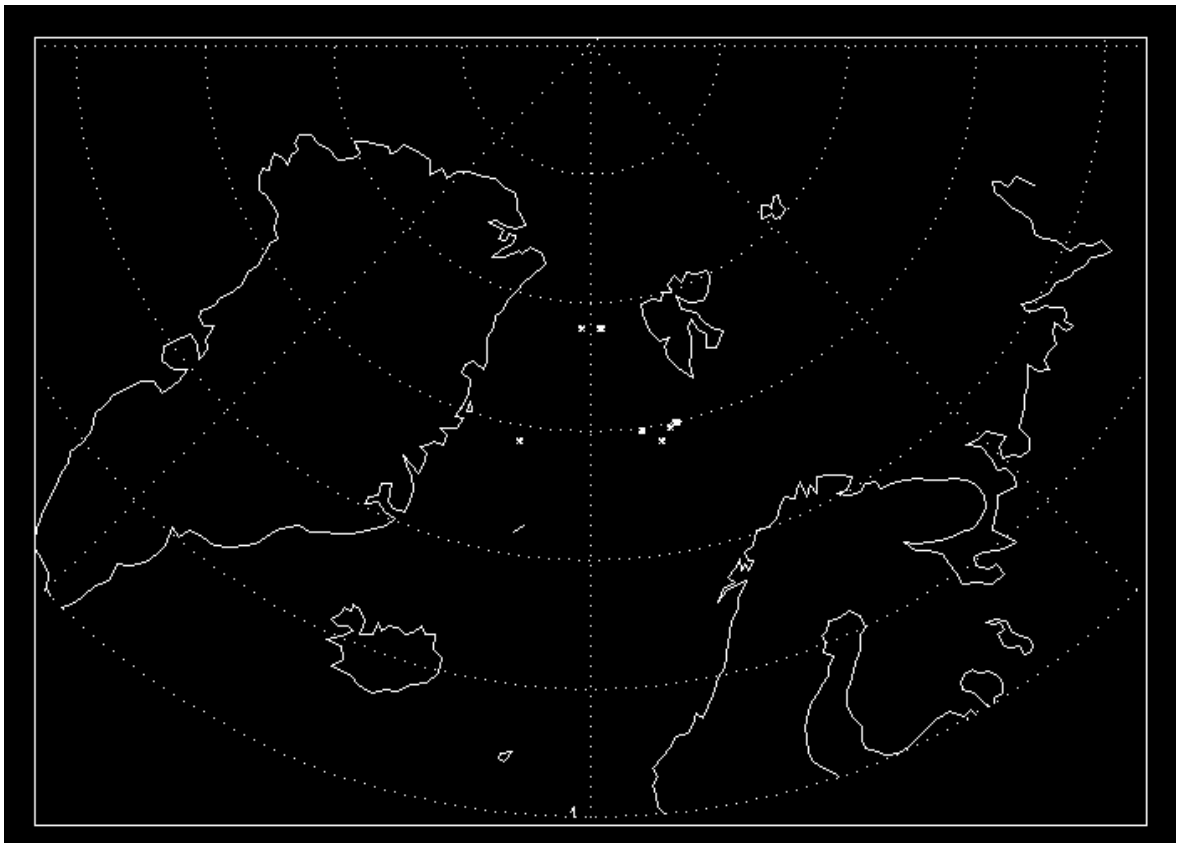
Refer to the next page for the Mooring List.

Start	End	Latitude (degrees, minutes)	Longitude (degrees, minutes)	Mooring	Instrument	Water Depth	Instrument Depth	Data File Names	Data directory
August 1991	November 1992	75° 00' N	12° 40' W	AWI411	APL26	1002 m	48 m	aug91.raw, aug91.ice, aug91.mod...nov92.raw, nov92.ice, nov92.mod; stat26-91-92.stat	uls26-91-92
August 1992	December 1992	74° 52' N	11° 43' W	AWI412-2	APL31	2362 m	50 m	aug92.raw, aug92.ice, aug92.mod...dez92.raw, dez92.ice, dez92.mod; stat31-92.stat	uls31-92
August 1993	July 1994	74° 53' N	07° 38' W	AWI414-2	APL32	3425 m	70 m	aug93.raw, aug93.ice, aug93.mod...jul94.raw, jul94.ice, jul94.mod; uls32-93-94.stat	uls32-93-94
July 1994	October 1995	74° 58' N	12° 59' W	AWI410-2	APL49	413 m	73 m	jul94.raw, jul94.ice, jul94.mod...okt95.raw, okt95.ice, okt95.mod; uls49-94-95.stat	uls49-94-95
August 1997	September 1998	79° N	02° W	V10-1	APL32	2600 m	58 m	aug97.raw, aug97.ice, aug97.mod...sep98.raw, sep98.ice, sep98.mod; uls32-97-98.stat	uls32-97-98

Start	End	Latitude (degrees, minutes)	Longitude (degrees, minutes)	Mooring	Instrument	Water Depth	Instrument Depth	Data File Names	Data directory
September 1998	September 1999	79° N	02° 03' W	V10-2	APL47	2609 m	54 m	sep98.raw,sep98.ice, sep98.mod...sep99.raw, sep99.ice, sep99.mod; uls47-98-99.stat	uls47-98-99
September 1999	August 2000	79° N	02° 03' W	V10-3	APL25	2582 m	53 m	sep99.raw, sep99.ice, sep99.mod...aug00.raw, aug00.ice, aug00.mod; stat25-99-00.stat	uls25-99-00
October 1999	September 2000	74° 25' N	10° 15' W	AWI419-1	APL32	3229 m	63 m	oct99.raw, oct99.ice, oct99.mod ...sep00.raw, sep00.ice, sep00.mod;uls32-99-00.stat	uls32-99-00
August 2000	October 2001	79° 02' N	02° 03' W	F10-4	APL48	2554 m	67 m	aug00.raw, aug00.ice, aug00.mod, ...oct01.raw, oct01.ice, oct01.mod, uls48-00-01.stat	uls48-00-01
September 2000	September 2001	74° 24' N	10° 12' W	AWI419-2	APL31	3160 m	65 m	sep00.raw, sep00.ice, sep00.mod...sep01.raw, sep01.ice, sep01.mod,uls31-00-01.stat	uls31-00-01
September 2001	September 2002	74° 24' N	10° 12' W	AWI419-3	APL47	3160 m	82 m	sep01.raw, sep01.ice, sep01.mod...sep02.raw, sep02.ice, sep02.mod, uls47-01-02.stat	uls47-01-02

2.2 Spatial and Temporal Coverage

The AWI moorings were located in the Norwegian Sea and Greenland Sea, Arctic Ocean. Measurements were taken between August 1991 and September 2002 (excepting 1996). Generally, moorings were in place for about one year. Travel time and pressure measurements were taken every five minutes. Temperature measurements were taken every 60 minutes, with the exception of data acquired from August 1991 to July 1994. For this interval the temperature measurements were taken only once a day.



2.3 File Directory Structure and Naming Convention

Data files are in directories tarred by mooring and month. Examples of file and directory names are given in the mooring list table. The naming convention is as follows.

Velocity time series: `monYY.raw`, where mon is the month abbreviation, YY is the last two digits of the year

Ice draft frequency distribution: `monYY.mod`

Ice draft time series: `monYY.ice`

Statistics: `ulsxx-y1-y2.stat` (or `statxx-y1-y2.stat`), where xx is the ULS instrument number, y1 is the last two digits of the start year, and y2 is the last two digits of the end year

2.4 File Size

Sizes range from 1.1Kb to 307Kb, with total data set volume of 315Mb.

2.5 Sample Data Records and Formats

Each mooring has the following types of data files.

- Ice draft time series
- Velocity time series
- Ice draft frequency distribution
- Statistical data

Raw data are stored in directory ulsrawdata in three files for each mooring: one for data collected at 10 second intervals (in a file called ulsxx-y1-y2.highdraft), one for data collected at 5 minute intervals (ulsxx-y1-y2.lowdraft) and one for the temperature data (ulsxx-y1-y2.temperature), where xx-y1-y2 is the instrument number, y1 is the last two digits of the start year, and y2 is the last two digits of the end year.

The ice draft data files contain a column labeled flag, which indicates if the estimated value of ice draft is classified as open water (0), ice (1), or not classified (2).

Every data file has general header information, followed by header information specific to that data type.

2.5.1 General header (one example)

```
% 78.9957                      latitude
% -2.0547                      longitude
% 21  9 99  6  8 00            start(day month year)  end(day month year)
% 25 APL                       SNo model
% Alfred Wegener Institute      responsible agency
% AWI algorithm                processing algorithm
% no footprint correction
% 5                            sampling interval travel time,
pressure (minutes)
% 60                           sampling interval temperature (minutes)
% 31 264                       ND (# days in data series) start day (Julian)
% -99.99                       = no measurement
% +/- 0.20                     accuracy of ice draft[m]
```

```
% paros.dat                      used calibration data
% 5.854276                       paros.dat U (microsec)
% -3962.737                      paros.dat Y1 (deg C/microsec)
% -11110.85                      paros.dat Y2 (deg C/microsec**2)
% 0.0                            paros.dat Y3
% 2017.651                       paros.dat C1 (psia)
% 22.35947                       paros.dat C2 (psia/microsec)
% -3602.087                      paros.dat C3 (psia/microsec**2)
% 0.010515                       paros.dat D1
% 0.0                            paros.dat D2
% 27.71413                       paros.dat T1 (microsec)
% 0.2206964                     paros.dat T2 (microsec/microsec)
% 18.13468                       paros.dat T3 (microsec/microsec**2)
% 54.77654                       paros.dat T4 (microsec/microsec**3)
% 0.0                            paros.dat T5
% 12002750.0                     paros.dat clock ozcillator frequency
```

2.5.2 Ice draft time series sample data file

```
dec91.ice

[General Header]

%  day draft [m] press[bar] temp[C] flag
  335.0000    0.01   6.671 -1.09  0
  335.0035    1.04   6.668 -1.09  2
  335.0069   -0.02   6.670 -1.09  0
  335.0104    0.19   6.666 -1.09  0
```

2.5.3 Ice draft frequency distribution sample data file

```
dec91.mod

[General Header]

% size[<=]  number
   0.00     1539
   0.10      925
   0.20      336
   0.30      209
   0.40      162
   0.50      106
```

2.5.4 Velocity time series sample data file

```
*.raw
[General Header]

%  day travel-time[s] press[bar] temp[C]
  335.0000 0.03864288   6.671 -1.09
  335.0035 0.03790734   6.668 -1.09
  335.0069 0.03864871   6.670 -1.09
  335.0104 0.03848211   6.666 -1.09
  335.0139 0.03870952   6.687 -1.09
```

2.5.5 Statistical sample data file

```
*.stat

[General Header]

% aveiow = average ice draft including open water [m]
% stdiow = standard deviation including open water [m]
% aveeow = average ice draft excluding open water [m]
% stdeow = standard deviation excluding open water [m]
% aveP   = average Pressure [bar]
% stdP   = standard deviation of Pressure [bar]
% aveT   = average temperature [deg C]
% stdT   = standard deviation of temperature [deg C]
% maxid  = maximum ice draft [m]
% owpc   = period of open water (percent)
% icpc   = period of ice (%)
% ncpc   = period not classified (%)
% tot    = Total number of observations
% clsN   = Number of classified observations
% iceN   = Number of ice observations
% nocN   = Number of not classified observations
% y mon aveiow stdiow aveeow stdeow aveP  stdP   aveT   stdT  maxid owpc  icpc  ncpc    tot   clsN   iceN   nocN
  91 08 0.27   0.73   0.58   0.98   6.37   0.39  -1.15   0.72   6.54  47.3  41.5  11.2   4032   3580   1672    452
  91 09 0.02   0.15   0.16   0.36   6.82   1.13   0.34   1.55   3.60  71.0  11.8  17.2   8640   7151   1019   1489
```

3 DATA ACQUISITION AND PROCESSING

3.1 Instrument Description

The Applied Physics Laboratory instrument used by AWI is fitted with an acoustic transducer enclosed in a fluid-filled lens. When the instrument is submerged in seawater near the freezing point, the lens focuses the acoustic pulse (300 kHz, 1 ms width) into a narrow beam. The transducer is mounted on a weighted damped gimbal. The gimbal keeps the beam vertical.

The transducer emits an acoustic pulse of 300 kHz frequency and 1 ms duration. The return window in time during which the instrument will listen for acoustic reflections from the ice is set to correspond approximately to reflections from the range 20 m below sea level to 1 m above sea level. It is adjusted for the depth of the instrument according to the reading from the Paros pressure sensor. The pressure sensor is located 0.42 m below (deeper than) than the transducer.

The instrument records data in two modes. In ’lowdraftdata’ mode, the instrument records a set of parameters every five minutes. In ’highdraftdata’ mode, the instrument records a set of parameters every 10 seconds for 25 minutes at midnight and noon (UTC). The recorded data are:

- Pressure
- Pulse reflection times (the time of the first sonar echo, and time of the last valid sonar echo from the transmitted pulse)

- 'Tc', or the total number of sonar threshold crossings (number of times the echo signal crossed the threshold value during the return time window)
- 'pc', or the total number of valid pings (a ping is the pulse reflection heard from the uls)
- 'm', or match flag (set to 1 if two valid echoes matched, set to 0 if the valid echo did not match another valid echo)

When the target is very well-defined (that is, 'flat' and a strong reflector) and the sonar is working well, tc, pc and m are 2, 2, 1. Rough ice or a weak, variable echo is associated with larger values). The ULS does not make a direct measurement of the target strength (that is, of the strength of the sonar pulse reflected back from the surface).

In addition to the parameters above, temperature is recorded every hour in the ULS (for data acquired after July 1994. For earlier data, temperature is recorded every day). Temperature is measured using clock crystal oscillator counts converted to temperature with a calibration coefficient.

3.2 Data Processing

Please note that the detailed information in this section is included only for completeness. It is not necessary to have this information in order to use the data.

3.2.1 Software Used

At AWI, processing takes place using the following data files and executable files.

Name	Description
*.dmp	Binary data file from the instrument
*.paros.dat	Calibration data, with pre-deployment coefficients
*.in.dat	
*.presSea	Air pressure data are 6 hourly data from the European Centre for Medium-Range Weather Forecasts (ECMWF)
rawuls.exe	Program to translate binary data to hexadecimal. The hexadecimal output format is useful in quality control of start time, time to water and time marks and in looking for gaps in the data.

Name	Description
sepuls.c	Program to change binary data to ASCII (written by APL). Modified by H. Witte for each mooring to skip gaps and change the output from ice draft to travel time. Outputs four files: ulsxx.highdraft, ulsxx.lowdraft, ulsxx.temperature and ulsxx.hourly (ulsxx.hourly is the measured pressure every hour and is not used for further work).
tindraftl.for andtindrafth.for	Puts linearly interpolated temperature data in the lowdraft (tindraftl.for) and, if necessary, highdraft (tindrafth.for) data files.
trickyt.for	Program to find sound speeds
eislauf.for	Program to calculate ice draft using travel time and sound speed data files. The program eislauftest.for flags the drafts as ice or water, and outputs monthly files.
statistik.m	A MATLAB ® program (written by H. Witte) that splits the output of eislauftest.for into four monthly files: *.raw, *.ice, *.mod. *.stat.

Quality control for binary and ASCII data output files takes place as follows.

Binary-data: Start time, sample time, time to water and time marks are controlled with rawuls.exe. Days with missing time marks are left out and binary data are converted to ASCII data with sepuls.c.

ASCII-data: Start and end time of lowdraftdata (the data acquired at 5 minute intervals) are controlled. Start and end time of highdraftdata (the data acquired at 10 second intervals for 25 minutes at 0000 and 1200 UTC) are controlled. Temperature and pressure data are plotted.

3.2.2 Note on Processing Steps

Processing raw upward looking sonar data to produce draft measurements involves accounting for factors that introduce errors. For example, sound velocity 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. Recalibrating the instrument crystal frequency parameter if necessary for reducing error in time and temperature measurements. Adding temperature and pressure along with travel time to the output files.
2. Calculating sound velocity.

3. Refining the sound velocity estimate by calibrating it based on distance to level water.
4. Calculating ice draft for 5 minutes measurements.
5. Recalculating drafts where needed by adjusting sound velocity estimates.

1. Recalibrating the instrument crystal frequency parameter if necessary.

Each instrument has a set of associated calibration coefficients for temperature, pressure, and time recorded in file paros.dat. The calibration coefficients are set and recorded before deployment, and the clock oscillator frequency is measured at room temperature. When the ULS is operating in the ocean, the temperature is usually not too far from 0 C. This difference in temperature changes the clock crystal frequency by a significant amount. When the mooring is retrieved, recorded temperature is examined for differences with that recorded by other instrumentation on the same mooring (generally the temperature sensor on a nearby current meter). If an offset exists, the clock oscillator frequency constant (ÔxtalÕ) is adjusted until the temperature is corrected. Note that this correction also has an effect on the travel time (pulse reflection times).

Example: If T(ULS)= -2.1 ; T(currentm.)= -1.8 at P(ULS)= 50db and P(currentm.)= 70db, then the adjustment is T(ULS)= T(ULS)+0.3

The adjustments to xtal that were made for the moorings in this data set are given below:

(uls32 1997/1998: T=Tuls-0.15 -> xtal cal = 12004380.0 -> xtal(changed)= 12004350.0)

(uls32 1993/1994: T=Tuls-0.35 -> xtal cal = 12004400.0 -> xtal(changed)= 12004205.0)

(uls49 1994/1995: T=Tuls+0.17 -> xtal cal = 12002560.0 -> xtal(changed)= 12002650.0)

(uls31 1992/1993: not changed xtal=12004400.0)

(uls47 1998/1999: not changed xtal=12002400.0)

(uls25 1999/2000: T=Tuls+0.7 -> xtal cal=12002400.0 -> xtal(changed)= 12002750.0)

(uls32 1999/2000: T=Tuls-0.2 -> xtal cal=12004380.0 -> xtal(changed)= 12004280.0)

(uls26 1991/1992: T=Tuls+0.5 -> xtal cal=12004500.0 -> xtal(changed)= 12004800.0)

(uls48 2000/2001: T=Tuls+3.4 -> xtal cal=12002400.0 -> xtal(changed)= 12004150.0)

(uls47 2001/2002: T=Tuls-0.05 -> xtal cal= 12002400.0 -> xtal(changed)= 12002360.0)

(uls31 2000/2001: T=Tuls+3.7 -> xtal cal= 12002400.0 -> xtal(changed)= 12004300.0)

2. Adding temperature and pressure

The air pressure from ulsxx.presSea for every measurement was written to the output file in order to more accurately estimate instrument depth. Pressure at the instrument depth must be corrected for variations in air pressure using 6-hourly surface pressure analyses from the European Centre for Medium Range Weather Forecasting (ECMWF). These were used directly for the 'highdraftdata' and interpolated for the 'lowdraftdata.'

The temperature for every measurement was written to the output file along with pressure and travel time. Temperature recorded by the instrument was linearly interpolated to match the acquisition times for 'lowdraftdata'. For 'highdraftdata' the recorded midnight temperature was used, while the noon temperature was interpolated between 11.00 a.m. and 1.00 p.m. This interpolation is necessary, since the temperature is measured only 23 times a day.

3. Calculating the sound velocity 'first guess'

To calculate ice draft from travel time the sound velocity must be known. A constant velocity of 1442 meters per second was used as a starting point. It was assumed that in areas of open water the difference of two sequentially measured pulse travel times must be zero. A program was used (trickyt.for) to look in the highdraftdata for times where t1-t2 ~ 0 in any 25 minutes sample and to calculate sound velocity by c=depth/travel time. This estimate of sound velocities was used to calculate the ice draft.

4. Refining the sound velocity estimate by determination of distance to surface

Ice draft was calculated for the 'highdraftdata'c acquired in the burst sample mode (10 second intervals for 25 minutes) and the results were plotted on a screen. The plot should show areas of open water (which are usually identifiable by their chaotic profile, in contrast to the definite profile of ice) at a draft of zero. The offset of the open water level from zero was used to refine the sound velocity estimate. The program limits velocity to values between 1428 and 1467 meters per second. Calculated velocities falling outside of that range were fixed to an assumed value. The sound velocity was plotted to check for obviously erroneous values (spikes) that were then removed.

5. Calculating the ice draft for the 5 minute interval measurements.

The program 'eislauf.for' uses pressure recorded by the instrument (for the instrument depth), the air pressure (form ECMWF) and the sound velocity value in the output files of 'trickyt.for' to calculate the ice draft. (The refined sound velocity values from the 'highdraftdata' measurements were linearly interpolated to get one for every 'lowdraftdata' measurement)

6. Recalculating drafts based on adjusted sound velocity estimates

Potential errors in the ice drafts resulting from incorrect sound velocity estimates which were evident by unrealistic jumps in the ice draft profile were eliminated by adjusting the sound velocity to reestablish continuity.

4 REFERENCES AND RELATED PUBLICATIONS

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.

Harms, S., Fahrbach, E., Strass, V. 2001. Sea ice transports in the Weddell Sea. *Journal of Geophysical Research* 106 (C5): 9057-9073.

R.E. Moritz. 2004. Upward Looking Sonar ULS Mark-2 User Documentation. This infomal document is an instruction manual updated and provided with each APL ULS when shipped for deployment.

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

4.1 Related Data Collections

Ice Draft and Ice Velocity Data in the Beaufort Sea, 1990-2003
AWI Moored ULS Data, Weddell Sea (1990-1998)
Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics
Moored Upward Looking Sonar

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

6.1 Document Authors

This documentation was written by F. Fetterer based on information supplied by H. Witte, AWI.

6.2 Publication Date

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6.3 Date Last Updated

2005