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APPLICATION NOTE NO. 73 **Revised July 2005**

Using Instruments with Pressure Sensors at Elevations Above Sea Level

This application note covers use of a Sea-Bird instrument that includes a pressure sensor at elevations above sea level, such as in a mountain lake or stream.

Background

Sea-Bird pressure sensors are absolute sensors, so their raw output includes the effect of atmospheric pressure. As shown on the Calibration Sheet that accompanies the instrument, our calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in engineering units, most of our instruments output pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). Sea-Bird uses the following equation in our instruments and/or software to convert psia to decibars:

Pressure (db) = [pressure (psia) – 14.7] * 0.689476

where 14.7 psia is the assumed atmospheric pressure (based on atmospheric pressure at sea level).

This conversion is based on the assumption that the instrument is being used in the ocean; the surface of the ocean water is by definition at sea level. However, if the instrument is used in a mountain lake or stream, the assumption of sea level atmospheric pressure (14.7 psia) in the instrument and/or software can lead to incorrect results. Procedures are provided below for measuring the pressure *offset* from the assumed sea level atmospheric pressure, and entering the offset in the instrument and/or software to make the appropriate correction.

- **Perform the correction procedure at the elevation at which the instrument will be deployed.** Allow the instrument to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the instrument to equilibrate before starting will provide the most accurate calibration correction.

Inclusion of calibration coefficients in the instrument itself or in a file used by our software to interpret raw data varies, depending on the instrument. Commands used to program the instrument vary as well. Therefore, there are variations in the correction procedure, depending on the instrument. These instruments are addressed below:

- SBE **9*plus*** CTD and SBE **25** SEALOGGER CTD
- SBE **16*plus* (RS-232 version)** SEACAT C-T (pressure optional) Recorder, SBE **19*plus*** SEACAT Profiler CTD, and SBE **49** FastCAT CTD Sensor
- SBE **16*plus* (RS-485 version)** SEACAT C-T (pressure optional) Recorder and SBE **16*plus*-IM** SEACAT C-T (pressure optional) Recorder
- SBE **37** MicroCAT (all models – IM, IMP, SI, SIP, SM, SMP)
- SBE **50** Digital Oceanographic Pressure Sensor
- SBE **52-MP** Moored Profiler CTD and DO Sensor
- SBE **39-IM** Temperature (pressure optional) Recorder
- SBE **39** Temperature (pressure optional) Recorder
- SBE **26*plus*** SEAGAUGE Wave and Tide Recorder and SBE **53** BPR Bottom Pressure Recorder

SBE 9*plus* and 25

Sea-Bird software (SEASAVE or SBE Data Processing) uses calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEASAVE, in the .con file, set the pressure offset to 0.0.
3. Acquire data in SEASAVE, and display the pressure sensor output in decibars.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the .con file.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file.

SBE 16*plus* (RS-232 version), 19*plus*, and 49

Sea-Bird software (SEASAVE or SBE Data Processing) uses calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units. These instruments are also able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEASAVE, in the .con file, set the pressure offset to 0.0.
3. Acquire data in SEASAVE, and display the pressure sensor output in decibars.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the .con file.
6. Also enter the calculated offset in the instrument (use the **POFFSET=** command in SEATERM).

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file and in instrument.

SBE 16*plus* (RS-485 version) and 16*plus*-IM

Sea-Bird software (SEASAVE or SBE Data Processing) uses calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units. These instruments are also able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEATERM, set the pressure offset to 0.0 (**#iiPOFFSET=0**) and set the output format to converted data in decimal form (**#iiOUTPUTFORMAT=3**).
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the instrument (use **#iiPOFFSET=** in SEATERM).
6. Also enter the calculated offset in the .con file, using SBE Data Processing.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file and in instrument.

SBE 37 (all models)

The SBE 37 is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 37 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 37 in the air, place it in the orientation it will have when deployed.
2. In SEATERM, set the pressure offset to 0.0 and pressure sensor output to decibars. *
3. Acquire data. *
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 37 in SEATERM. *

   Offset Correction Example:
   Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 37.

* NOTE: Commands for setting pressure offset, setting output format, and acquiring data vary:

Instrument	Pressure Offset Command	Output Format Command	Command to Acquire Data
SBE 37-IM and 37-IMP, and RS-485 version of SBE 37-SM, 37-SMP, 37-SI, and 37-SIP	**#iiPOFFSET=**	**#iiFORMAT=1** or **#iiFORMAT=2**	**#iiTP** (measures and outputs pressure 30 times)
RS-232 version of SBE 37-SM, 37-SMP, 37-SI, and 37-SIP	**POFFSET=**	**FORMAT=1** or **FORMAT=2**	**TP** (measures and outputs pressure 100 times)

SBE 50

The SBE 50 is able to directly output data that is already converted to engineering units (psia, decibars, or depth in feet or meters), using calibration coefficients that are programmed into the instrument. The SBE 50 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 50 in the air, place it in the orientation it will have when deployed.
2. In SEATERM, set the pressure offset to 0.0 (**POFFSET=0**) and set the output format to the desired format (**OUTPUTFORMAT=**).
3. Acquire data using the **TS** command a number of times.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 50 (use **POFFSET=** in SEATERM). The offset must be entered in units consistent with **OUTPUTFORMAT=**. For example, if the output format is decibars (**OUTPUTFORMAT=2**), enter the offset in decibars.

   Offset Correction Example:
   Pressure displayed at elevation with **OUTPUTFORMAT=2** (db) is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 50.

SBE 52-MP

The SBE 52-MP is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 52-MP does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 52-MP in the air, place it in the orientation it will have when deployed.
2. In SEATERM, set the pressure offset to 0.0 (**POFFSET=0**).
3. Acquire data using the **TP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 52-MP (use **POFFSET=** in SEATERM).

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in the SBE 52-MP.

SBE 39-IM

The SBE 39-IM directly outputs data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the SBE 39-IM. The SBE 39-IM does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 39-IM in the air, place it in the orientation it will have when deployed.
2. In SEATERM, set the pressure offset to 0.0 (**#iiPOFFSET=0**).
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 39-IM (use **#iiPOFFSET=** in SEATERM)

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in the SBE 39-IM.

SBE 39

The SBE 39 directly outputs data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the SBE 39. The SBE 39 does not use a .con file. The SBE 39 is a special case, because its programmed calibration coefficients do not currently include a pressure offset term. The lack of a pressure offset term creates two difficulties when deploying at elevations above sea level:

- After the data is recorded and uploaded, you must perform post-processing to adjust for the pressure offset. Sea-Bird software cannot currently perform this adjustment for the SBE 39.
- Without adjusting the instrument range, internal calculation limitations prevent the SBE 39 from providing accurate data at high elevations. Specifically, if (0.1 * sensor range) < (decrease in atmospheric pressure from sea level to elevation), an error condition in the SBE 39's internal calculations occurs. The table below tabulates the atmospheric pressure and approximate elevation at which this calculation limitation occurs for different pressure sensor ranges.

Range (m or db) *	**Range (psi) = Range (db) / 0.689476**	**0.1 * Range (psi)**	**Atmospheric Pressure (psi) at elevation at which error occurs = [14.7 – 0.1 * Range (psi)]**	**Approximate Corresponding Elevation (m)**
20	29	2.9	11.8	1570
100	145	14.5	0.2	7885
350	507	50.7	-	-
1000	1450	145	-	-
2000	2900	290	-	-
3500	5076	507	-	-
7000	10152	1015	-	-

* Notes:

- Although decibars and meters are not strictly equal, this approximation is close enough for this Application Note. See Application Note 69 for conversion of pressure (db) to depth (m) for fresh or salt water applications.
- Equations used in conversions -
  As shown on page 1: pressure (db) = [pressure (psia) – 14.7] * 0.689476;
  Rearranging: pressure (psia) = [Pressure (db) / 0.689476] + 14.7
  Measuring relative to atmospheric: pressure (psi; relative to atmospheric pressure) = Pressure (db) / 0.689476

From the table, it is apparent that the only practical limitation occurs with a 20 meter pressure sensor. To use the SBE 39 in this situation, change the sensor range internally to 100 meters by entering **PRANGE=100** in the SBE 39 (using SEATERM). This changes the electronics' operating range, allowing you to record pressure data at high elevations, but slightly decreases resolution. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset. Note that Sea-Bird software cannot currently perform this adjustment for the SBE 39.

CAUTION: Changing **PRANGE** in the SBE 39 does not increase the actual maximum water depth at which the instrument can be used (20 meters) without damaging the sensor.

> *Example 1*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 1400 meters (4590 feet). This is lower than 1570 meters shown in the table, so you do not need to adjust the sensor range. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset.
>
> *Example 2*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 2000 meters (6560 feet). This is higher than 1570 meters shown in the table, so you need to adjust the sensor range. In SEATERM, set **PRANGE=100** to allow use of the SBE 39 at this elevation. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset.

SBE 26*plus* and 53

Unlike our other instruments that include a pressure sensor, the SBE 26*plus* and 53 output absolute pressure (i.e., at the surface the output pressure is atmospheric pressure at the deployment elevation). Therefore, no corrections are required when using these instruments above sea level. SBE 26*plus* / 53 software (SEASOFT for Waves) includes a module that can subtract measured barometric pressures from tide data, and convert the resulting pressures to water depths.