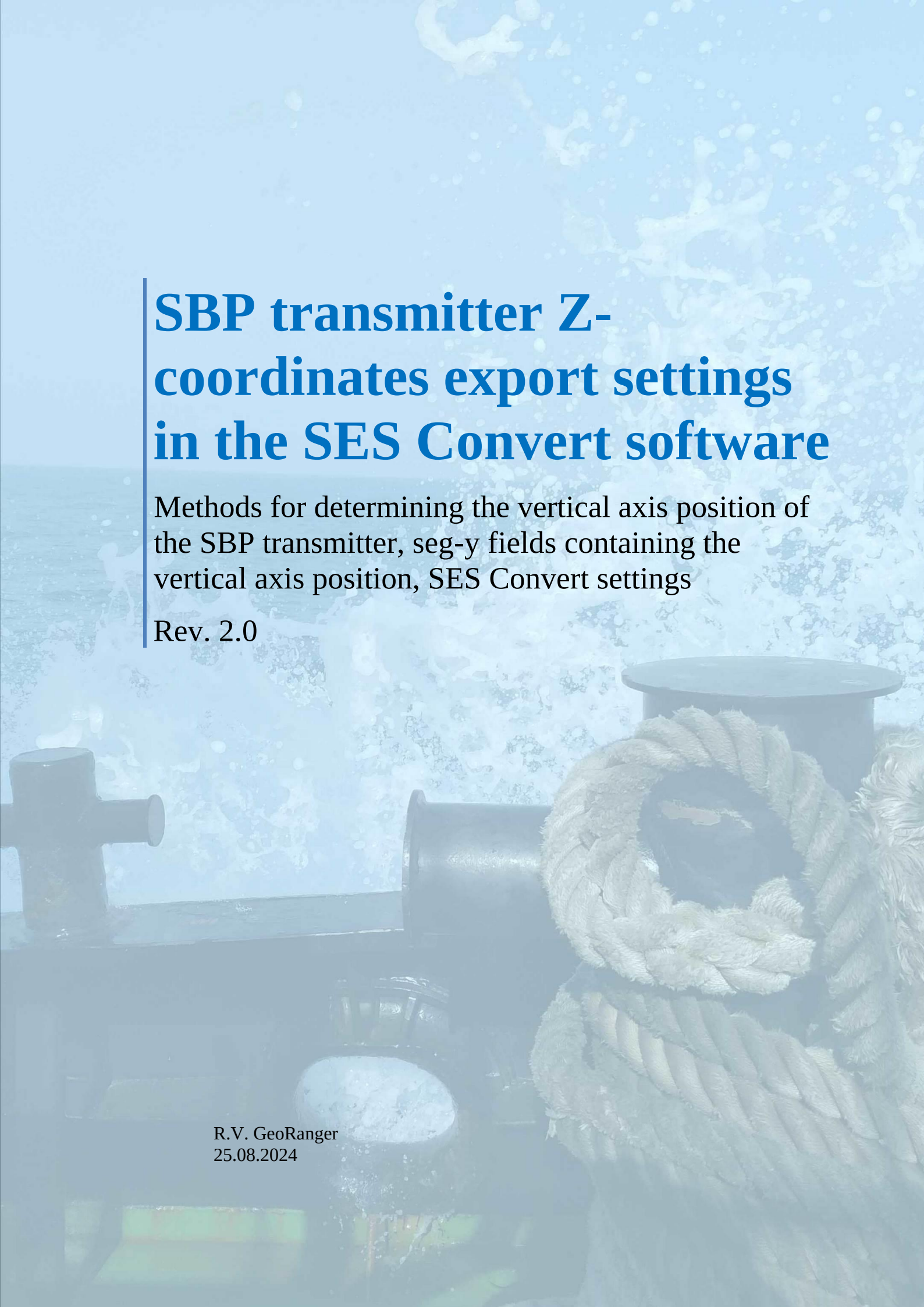




SBP transmitter Z-coordinates export settings in the SES Convert software

Methods for determining the vertical axis position of the SBP transmitter, seg-y fields containing the vertical axis position, SES Convert settings

Rev. 2.0

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Revision History

Version	Date	Description of changes
1.0	2024-05-22	Document created // Ivan D.
2.0	2024-08-25	Added description of converting ses3 files // Ivan D.

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Introduction

This document discusses the settings made in the SES Convert software to convert *.raw and *.ses3 files (SBP Innomar format) to seg-y format. More specifically, it discusses settings related to the position of the SBP transmitter in the vertical Z axis. The following issues are covered in the document:

- methods for calculating the SBP transmitter position in the Z-axis;
- information related to Z-axis elevations that is contained in seg-y files;
- settings in the SES Convert software related to Z-axis elevations.

The document also discusses the SES Convert operation features when converting files:

- the “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox effect on conversion results (the checkbox was added in SES Convert version 2.3.3.7);
- a difference between the *.raw and *.ses3 files conversion results under the same conversion settings in SES Convert;
- a possibility of exporting SIS navigation messages to a text file using the SES Convert program;
- an application of the seismic transmitter Z elevation correction to seg-y files outside the SES Convert using MatLab / Octave script;
- an appearance of artifacts and seismic section level shifts in the converted seg-y file depending on the “Apply range correction” and “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkboxes status.

1. Methods for estimating the SBP transmitter vertical axis coordinates

Methods for estimating the position of a particular instrument placed on a vessel relative to the vertical axis have evolved with the state of the art. Generally, there are three steps that can be distinguished:

- relative estimates (tidal control), when the first step was to determine the “sea level” and the second one to determine the position of the instrument relative to the sea level (related to the depth of the instrument mounting point, the roll and vertical roll of the vessel);
- transient estimates (DGPS mode), when satellite navigation systems allowed the GPS antenna Z-coordinate to be determined “relative to the ellipsoid surface”, however, the determination accuracy was relatively low;
- absolute estimates (RTK mode), when satellite navigation systems and ionospheric correction technology allowed the GPS antenna Z-coordinate to be determined with a sufficient accuracy for direct recalculations when determining the instrument Z-coordinate.

1.1 Relative estimates (operation with tides)

Classical calculations did not allow the absolute position of the instrument placed on the vessel to be determined along the vertical axis. The “current sea level” or, more specifically, the “height of sea level relative to the accepted zero mark” was used as an intermediate level of reference.

Sea level slowly changes in accordance with tides, so this value is not referred to as a “change in sea level height relative to the accepted zero mark”, but “tides”. This terminology substitution is generally true for the open ocean; however, sea level near-shore is affected by many additional factors such as wind-driven and surge waves, effects associated with river runoff (e.g., standing waves at river confluences) and other “near-shore effects”. So, the term “tides” used below should be understood in a broad sense as “the change in sea level height in the area of operations performed by the vessel relative to the accepted zero mark”.

Tidal measurement can be performed by two methods, where measuring devices are positioned outside the vessel on a “fixed base”:

- 1) Using measurements from the gauging stations installed on the shore. In this case, conditionally, a rail by which the water level value is taken is installed on the pier. If the rail zero is tied to the notional sea level zero and it is assumed that the pier is fixed, the value taken from the rail will correspond to the “current sea level relative to the zero mark”. When the area of operations performed by the vessel is moved away from the gauging stations, the difference between “sea level for the vessel” and “sea level for the gauging station” will increase because, as noted above, sea level near the shore is affected by local near-shore factors. The use of gauging station data “provides good results” when a near-shore survey is performed at a short distance from such stations.
- 2) Using measurements from the bottom tide gauges installed in the survey area. A bottom-mounted tide gauge records the pressure sensors readings, from which the water column thickness can be calculated. For more accurate calculations, when converting pressure sensor readings into depth, the results of submerged SVP and CTD measurements performed from the shipboard (these measurements give an

idea of the water column properties change in depth) and atmospheric pressure measurements are used. Binding of the sea surface to a zero mark, when measuring with tide gauges, is a separate problem *with several ways of solution*.

In fact, for both methods, the sea level is recorded relative to a fixed point on the Earth's surface, which is tied in some way to the notional “zero mark of sea level”.

Having obtained the values of “tides” (sea level), which vary over “long periods of time”, we need to take into account the short-period fluctuations (movements) of the instrument position point onboard, for this purpose:

- 1) using the averaged readings of the draft-sensor (Draft) we can find out the height of the vessel's metacenter above the water surface;
- 2) using MRU (Heave) data we can find out the height of short-period vertical movements of the vessel's metacenter due to wave action;
- 3) using MRU data (Pitch-Roll-Heading) and Lever (Lever) we can find out the vertical displacement of the instrument relative to the vessel's metacenter due to the vessel's rolling.

As a result of such calculations the instrument Z-coordinate will be calculated as a sum of long-period and short-period components of vertical displacements:

$$Z = Z_long(Tide) + Z_short(Pitch, Roll, Heading, Heave, Lever, Draft).$$

1.2 Transient estimates (DGPS mode)

With the advent of satellite navigation, it became possible to determine the GPS antenna vertical coordinate relative to satellites in geostationary orbit. That is, to use satellites as a “fixed base” instead of the Earth's surface (which was used in relative estimates). However, the vertical position of the GPS antenna (GPS_H) was determined with a large error and 1 time per second, which did not allow to “directly” use its coordinates. The long-period trend of GPS-antenna height was used as an intermediate reference level, which was interpreted as “tidal height”. The following assumptions were made:

- 1) the GPS antenna height error follows a normal distribution, so averaging reduces the height error (standard deviation) inversely proportional to the root of the number of measurements in the sliding window during averaging;
- 2) the width of the sliding window is sufficient to average the GPS-antenna oscillations caused by the vessel's rolling with approximation to zero.

The GPS-antenna height error, given by the first condition, depends mainly on the ionosphere state and is corrected by “ionospheric corrections”, which cannot be described as a “normally distributed random variable” on a short time interval. Therefore, there is a “compromise” for the width of the averaging window when calculating - during the time in the window “tides should not change much”, however, the window should be wide enough so that “GPS antenna height fluctuations caused by ionospheric error” are averaged, and the height value is close to the true value.

As a result, the instrument Z-coordinate will be calculated as the sum of the long-period and short-period components of the vertical movements:

$$Z = Z_long(GPS_H) + Z_short(Pitch, Roll, Heading, Heave, Lever, Draft).$$

The use of GPS-antenna height allowed, for example, the measurements to be referenced to the Z-axis when the vessel moves in the open sea along the profile with the length of hundreds of kilometers, when it is impossible to install bottom tide gauges or use data from onshore gauging stations.

1.3 Absolute estimates (RTK and PPP mode)

With the development of satellite navigation, it became possible to determine ionospheric corrections and transmit them to the vessel. At first, such measurements were performed near the shore (RTK, local base stations), and later in the open sea (PPP, a special network of “global” base stations). When receiving ionospheric corrections, the GPS antenna Z-coordinate can be determined with relatively high accuracy (5-20 cm for PPP and $1.5 \text{ cm} + 0.1 \text{ cm} \cdot \text{distance}$ from the base station for RTK) and the GPS data logging frequency can be 10 Hz. This is sufficient to use the GPS-antenna height “directly” to estimate the instrument Z-coordinate, i.e., without dividing the vertical movements into long-period and short-period components (without determining the “intermediate reference level” or tides).

There are two possible methods of calculating the instrument Z-coordinate, depending on the equipment composition and configuration:

- 1) “Classic RTK calculations”, using Pitch-Roll-Heading values measured by MRU (Heave value and vessel draft are not taken into account). In this case, the error in determining the instrument Z-coordinate will be close to the error in determining the GPS antenna Z-coordinate and will be calculated as:

$$Z = Z(GPS_H, Pitch, Roll, Heading, Lever).$$

- 2) Calculations that are performed by “internal MRU algorithms”, which additionally use Heave and acceleration values. In this case, the error of determining the instrument Z-coordinate will be smaller; however, with today's state of the art, there are still possible “unexpected effects” leading to the large Z-coordinate “deviations” from the true value and associated with the operation of the MRU algorithms. The instrument Z-coordinate will be calculated as:

$$Z = Z(GPS_H, Pitch, Roll, Heading, Heave, Lever, Draft, Accelerations).$$

2. Seismic receivers and sources position along the Z-axis in seg-y

In the seg-y file the vertical axis position for the transmitter/receiver of the seismic signal (in our case, the SBP transmitter) is recorded in several ways. Accordingly, “shifting” of the SBP transmitter's Z-coordinate in the vertical axis to bring it to the “accepted zero mark” can be accomplished in several ways:

- 1) Shifting by adding “empty measurements” to the beginning of the seismic traces (when empty measurements are added, the seismic traces are shifted along the vertical axis in time; [Figure 2.1](#)). The shift value is calculated as the added empty measurements number multiplied by the time of one measurement. Since the time of one measurement is small, adding empty measurements shifts the seismic traces on “small values”;
- 2) Changing the “recording start delay”, which is written in milliseconds in the header for each seismic trace (header “Delay Recording Time”, bytes 109-110; according to the seg-y specification, this offset should be set in milliseconds, but sometimes it is agreed to use hundredths of milliseconds). In this case, to shift the seismic traces along the vertical axis in time the part of the offset multiple of milliseconds can be recorded in “Delay Recording Time”, and the part less than a millisecond can be recorded in seismic trace shift;
- 3) Changing one of the “vertical axis position in meters” values recorded in the header for each seismic trace. Byte numbers and names of seg-y headers responsible for “vertical axis position in meters” are given in [Table 2.1](#).

Table 2.1 Seismic traces headers in the seg-y file containing “vertical axis position”

Bytes	Description
41-44	Receiver group elevation (all elevations above the Vertical datum are positive and below are negative)
45-48	Surface elevation at source.
49-52	Source depth below surface (a positive number).
53-56	Datum elevation at receiver group.
57-60	Datum elevation at source.
61-64	Water depth at source.
65-68	Water depth at group.
69-70	Scalar to be applied to all elevations and depths specified in Trace Header bytes 41-68 to give the real value. Scalar = 1, +10, +100, +1000, or +10,000. If positive, scalar is used as a multiplier; if negative, scalar is used as a divisor. The scalar in Trace Header bytes 69-70 applies to values from bytes 41-68. The units are feet or meters as specified in Binary File Header bytes 3255-3256. The Vertical Datum should be defined through a Location Data stanza (see section D-1, SEG-Y rev.1 specification).
109-110	Delay Recording Time, ms – Time in milliseconds between initiation time of energy source and the time when recording of data samples begins. In SEG Y rev 0 this entry was intended for deep-water work if data recording does not start at zero time. The entry can be negative to accommodate negative start times (i.e. data recorded before time zero, presumably as a result of static application to the data trace). If a non-zero value (negative or positive) is recorded in this entry, a comment to that effect should appear in the Textual File Header.

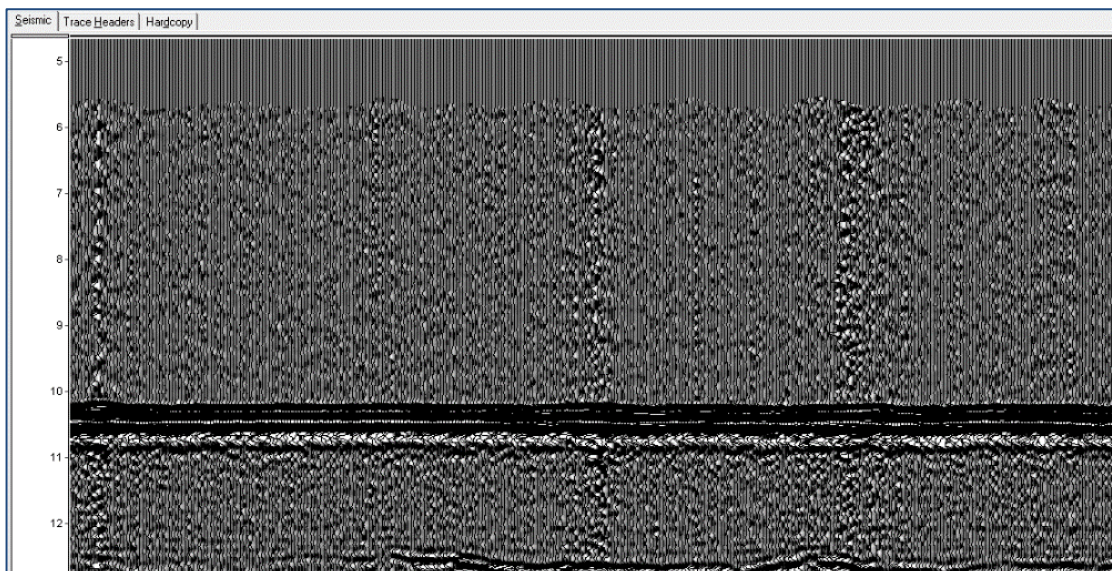
Given the available methods, **it is reasonable** to record “shifts in distance units” in the header fields of the seismic data shown in [Table 2.1](#), and “shifts in time units” in the “Delay Recording Time” field and by adding empty measurements to the beginning of the seismic data. **However**, not all seismic data processing and interpretation software allow to “work” with the values of the headers given in [Table 2.1](#). Therefore, converters provide the possibility to enter “shift-distance” into “shift-time” (i.e., “Delay Recording Time” and “shift seismic survey by adding empty measurements”). To convert values given in units of length to units of time, the sound velocity in water will be required (and it is necessary to use the sound velocity exactly for the depth interval for which the distance-to-time conversion is being made).

Drawing seismic section in SeiSee software

The paper presents figures with the seismic sections obtained using the SeiSee program.

When drawing a seismic section (seismic traces) in the SeiSee software, the latter are drawn ignoring the shifts specified in the seismic trace headers. This means that there is no seismic traces “shift” in the seismic section image, so the time offset from the “Delay Recording Time” field and the distance shifts from bytes 41-68 ([Table 2.1](#)) are not displayed. The seismic section fragment drawn in SeiSee is shown below in [Figure 2.1](#). The section upper part shows the “empty measurements” added to the beginning of the seismic traces.

Seismic sections with the “Delay Recording Time” value changed during their registration are shown in [Figure 4.1](#) and [Figure 4.2](#). In the mentioned figures, the moments of “Delay Recording Time” change in the seg-y headers correspond to the “steps” in the seismic section shown in the SeiSee window due to the seismic trace registration start time change (this time is not displayed in the SeiSee window, and the seismic trace always starts at 0 seconds).



[Figure 2.1](#) Example of the seismic section displayed in SeiSee

3. RAW format, operation with SES Convert

Attention! There are files of *.raw, *.ses3 and ses formats mentioned in the current section, however, the described conversion results refer only to *.raw format. They will be different for ses3 format (see “[SES3 format, operation with SES Convert](#)“ for the results description).

There are three file formats into which seismic data are recorded by the Innomar SBP: *.raw and *.ses3 (data containing the “full form” of seismic oscillations) as well as ses (data containing the “envelope” - the result of seismic oscillations convolution). The SES Convert software is used to convert *.raw, *.ses3 and *.ses files to seg-y. It can change the fields in the seismic headers corresponding to the vertical position of the SBP transmitter, which are contained in bytes 53–56, 57–60 and 109–110 ([Table 2.1](#)).

SES Convert windows are shown in [Figure 3.1 – Figure 3.4](#).

The *.raw and *.ses3 files contain eight navigation messages, which are labelled as SIS in [Figure 3.1](#); these messages are exported to seg-y headers or used to “modify” the seismic section. Also, there are MRU data (usually received by SBP Innomar from the TSS1 message) within the *.raw and *.ses3 files (outside the navigation messages). SIS and MRU data can be exported to text files using the options shown in [Figure 3.4](#). In addition, some of the hardware settings contained in the *.raw and ses3 files are exported to the seg-y text header ([Figure 3.5](#)).

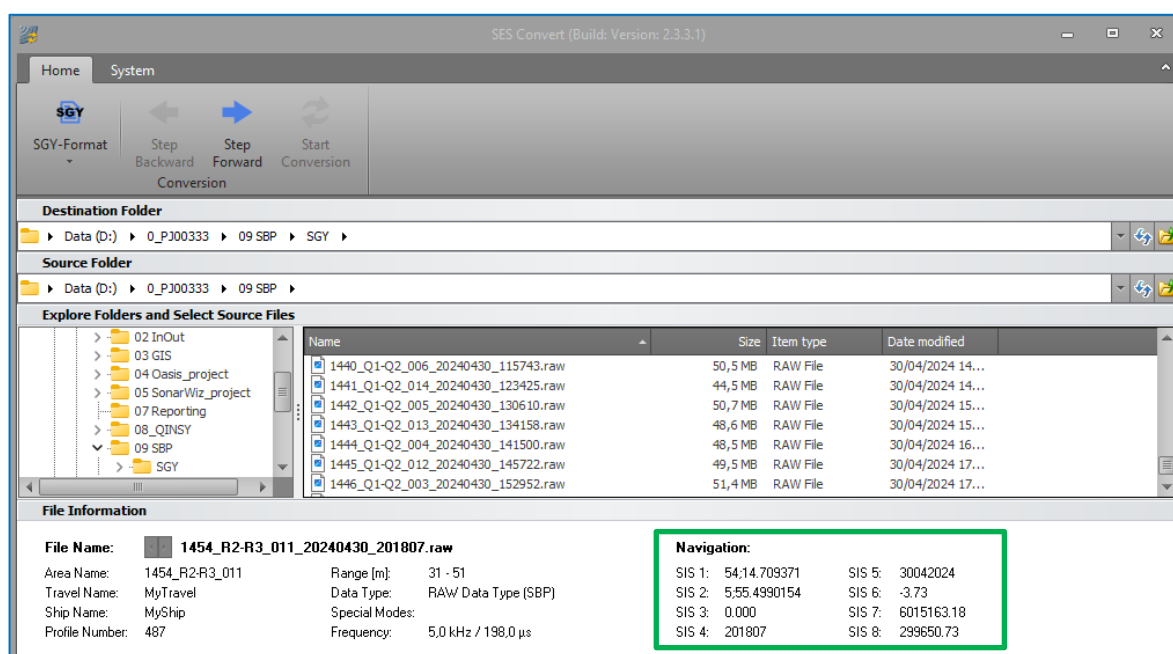


Figure 3.1 SES Convert, screen 1

Consider the settings below regarding the position of the Innomar transmitter along vertical axis. There are three settings for working with the SBP transmitter's Z-coordinate:

-- ”SIS-ID with Z value in source file(s)” field, that specifies which navigation message contains the Z value. The navigation can send either the “tide height” or the SBP transmitter Z-coordinate in an “absolute coordinate system” in a message with a Z value. The Z value is always written in bytes 53-56 and 57-60 of the seismic headers in the seg-y file;

- "Apply heave correction" checkbox; when it is checked, the Heave values passed in the MRU data (usually TSS1 message) are applied to the seismic traces;
- Two checkboxes "Apply tide correction with Z value [m] from SIS data" and "Apply flying depth correction with Z value [m] from SIS data". These checkboxes cannot be enabled at the same time. They implement two different ways in which the Z value from "SIS-ID with Z value in source file(s)" (specified in distance units) is "inserted" into the time in the seg-y file.

3.1 "SIS-ID with Z value in source file(s)" field

Figure 3.2 shows the "SIS-ID with Z value in source file(s)" field. Both navigation messages containing "tide" values and the SBP transmitter Z-coordinate relative to the notional zero (calculated "directly using the GPS antenna Z-coordinate") can be recorded to this field. The values are exported by SES Convert in seg-y file seismic headers: "Datum elevation at receiver group" (bytes 53-56) and "Datum elevation at source" (bytes 57-60). The Z values are exported in centimeters (even though bytes 69-70 will contain a value of 1 and the seg-y binary header will contain the dimension in "meters").

SES Convert (Build: Version: 2.3.3.1)

Home System

SGY-Format Step Backward Step Forward Start Conversion

SEG-Y Conversion Settings

Navigation Source

Select the SIS ID's of the SES files where the navigation data was stored during acquisition. The source coordinates may consist of LAT/LON values or metric values, such as UTM coordinates. Select the chosen format of the coordinates accordingly. Furthermore, select the SIS ID of a stored Z value which might be used for a depth correction.

String format of coordinates in source file(s):

☒ SIS-ID's of coordinates in source file(s):
 8
 7
☒ SIS-ID with Z value in source file(s): 6
☐ SIS-ID with KP value [float] in source file(s): 6
☐ SIS-ID with Fix marker [int32] in source file(s): 5

Time Source

Select the SIS ID of the SES files where the time information was stored during acquisition. Alternatively, the automatically stored time of the acquisition PC can be used during data conversion. Please check that the Date/Time format of the target machine matches the Date/Time format of the source file(s).

☒ SIS-ID of time string in source file(s): 4
☐ Use PC time stored in source file(s)
☐ Interpolate time and write milliseconds to SEG-Y trace header [Bytes 233-234]

Coordinate Scale Factor

SEG-Y files do not support floating point values. This requires a scaling of coordinates to become integer values. Choose an appropriate scale factor which is supported by the SEG-Y processing software after data conversion. An example of the scaled coordinates from the source file(s) is given below.

☒ Apply scale factor: 100
 Example of scaled coordinates: SIS 8: 302809.77 --> 30280977
 SIS 7: 6017034.22 --> 601703422

Conversion Parameter

Select the byte order of the target machine on which the SEG-Y files will be processed. Normal PC's usually require the Intel format, whereas UNIX workstations require the Motorola format. Please note, the CODA package always requires the Motorola format. Furthermore, select the channels to be converted. In many cases just the low frequency channel (LF) is necessary for

Byte order of target machine:

☒ Convert and write LF channel(s)
☐ Convert and write HF channel(s)

Figure 3.2 SES Convert, screen 2

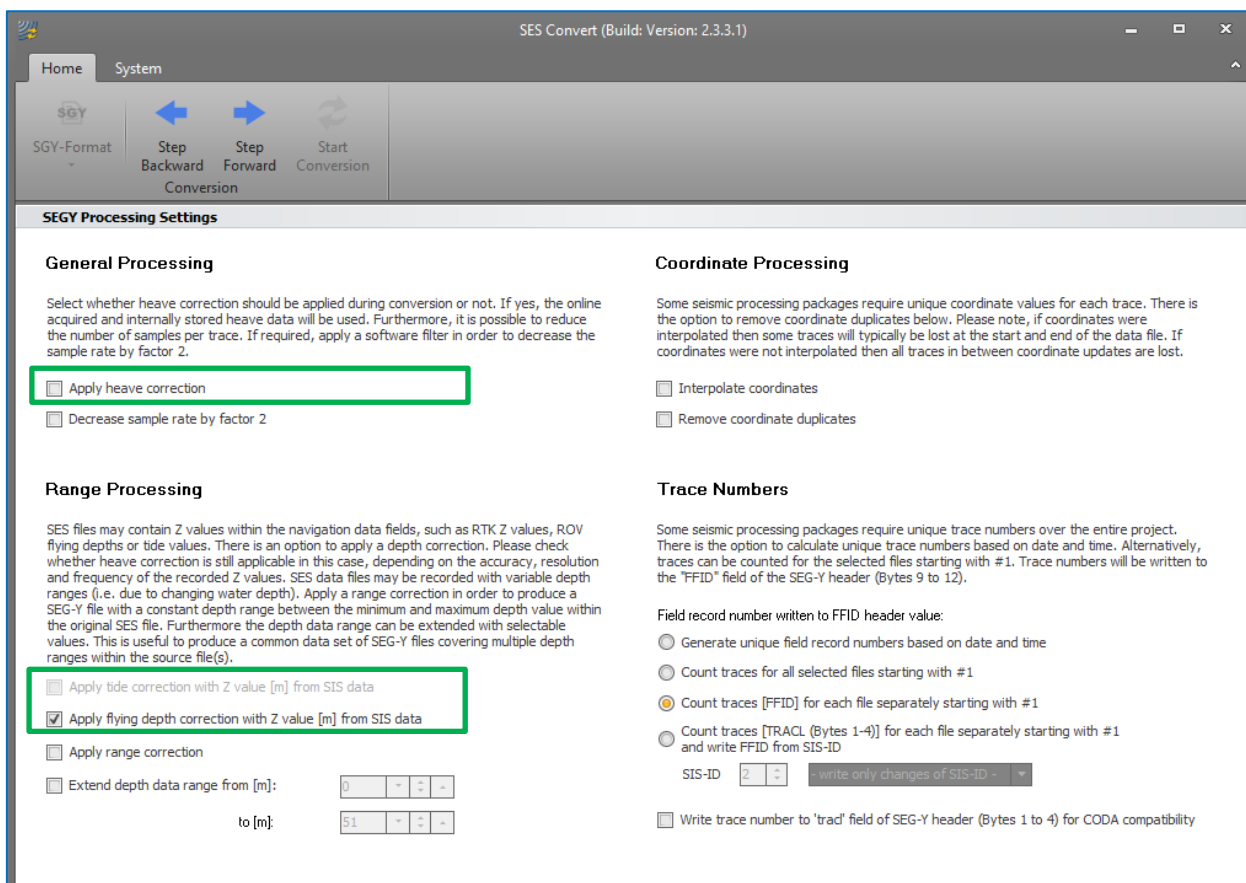


Figure 3.3 SES Convert, screen 3

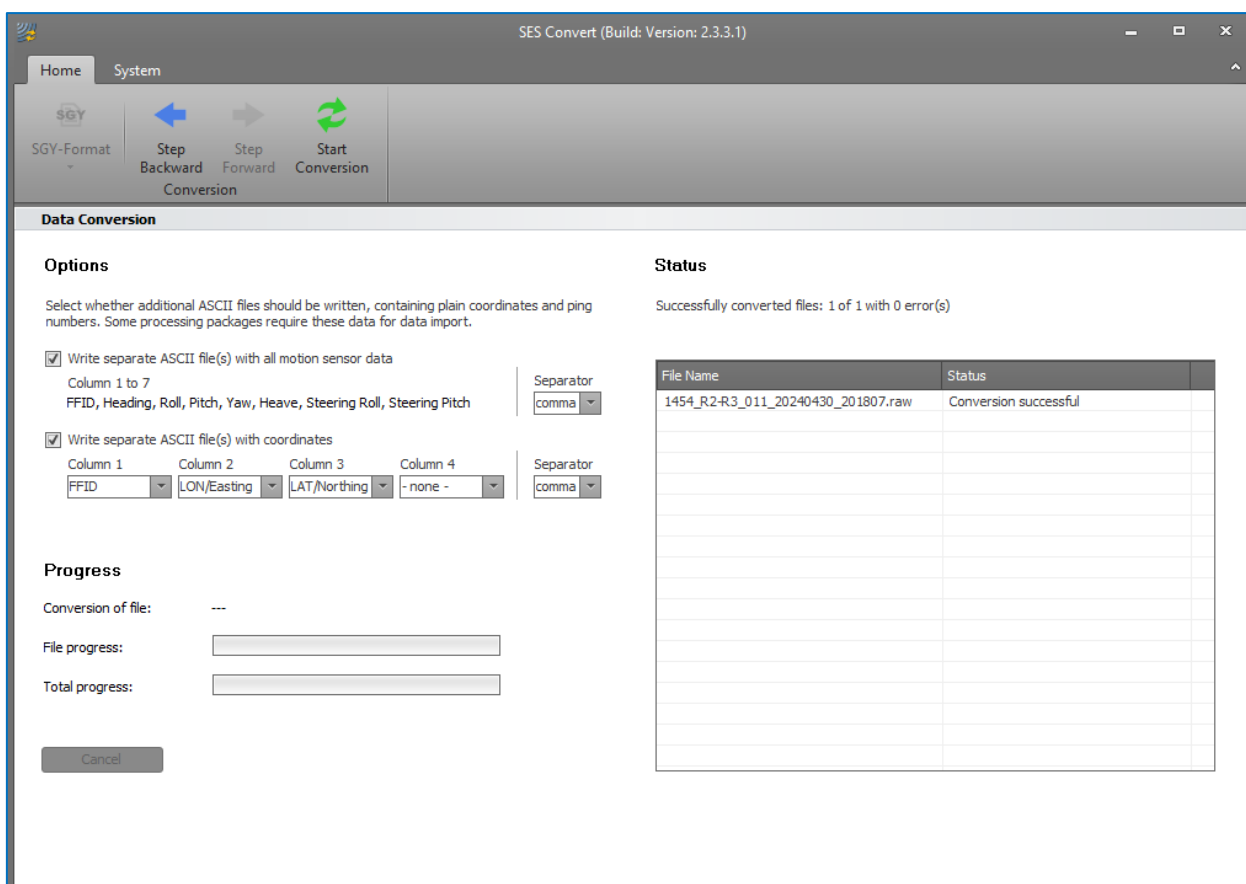


Figure 3.4 SES Convert, screen 4

3.2 “Apply heave correction” checkbox

Figure 3.3 shows the “Apply heave correction” checkbox. When it is checked, the Heave values transmitted to the SBP hardware using the MRU data (most often the TSS1 messages format is used) are added to the seismic section. Note that the Heave value must be transmitted exactly for the SBP transmitter installation point onboard. Heave values are applied by SES Convert as a “seismic traces shift” by adding empty measurements to them. The conversion of distance (Heave values) to units of time uses the sound velocity entered in the settings of the software logging *.ses3 and *.raw files. This sound velocity value is exported by SES Convert to the seg-y text header (**Figure 3.5**, Sound Velocity). Due to the relatively small movements contained in Heave, the sound velocity error will give a relatively small “Z-axis” error after conversion to time units.

If the Z value (field “SIS-ID with Z value in source file(s)”) contains “Heave” values, then the “Apply heave correction” checkbox should be checked in order to apply Heave.

If “ the SBP transmitter absolute Z-coordinates” are written in the Z value (field “SIS-ID with Z value in source file(s)”), it is very likely that the *tides will be applied twice* either during conversion or during loading into the seismic interpretation software when the “Apply heave correction” checkbox is checked . The double application of tides is caused by the fact that their values are already contained in the Z values.

```
C1 Innomar Technologie GmbH
C2 Original File: 1454_R2-R3_011_20240430_201807.raw
C3 Ship Name: MyShip
C4 Area: 1454_R2-R3_011
C5 Travel: MyTravel
C6 Profilnumber: 487
C7 transmitted Frequency: 5000 Hz
C8 transmitted Pulses: 1
C9 Start Gain: 18 dB
C10 Traces: 8860
C11 Navigation-Example:
C12 SIS-String1: 54;15.790503
C13 SIS-String2: 5;58.3297868
C14 SIS-String3: 0.000
C15 SIS-String4: 204219
C16 SIS-String5: 30042024
C17 SIS-String6: -3.61
C18 SIS-String7: 6017034.22
C19 SIS-String8: 302809.77
C20 -----
C21 Range Start(org.): 31 m
C22 Range Stop(org.): 51 m
C23 Transducer Depth: 0 cm
C24 Sound Velocity: 1488 m/sec
C25
C26 Innomar SEG-Y-Format (2.20 - 0312)
C27
C28
C29
C30
C31
C32
C33
C34
C35
C36
C37
C38
C39
C40
```

Figure 3.5 Example of a seg-y text header generated by SES Convert

3.3 “Apply flying depth correction with Z value [m] from SIS data” checkbox

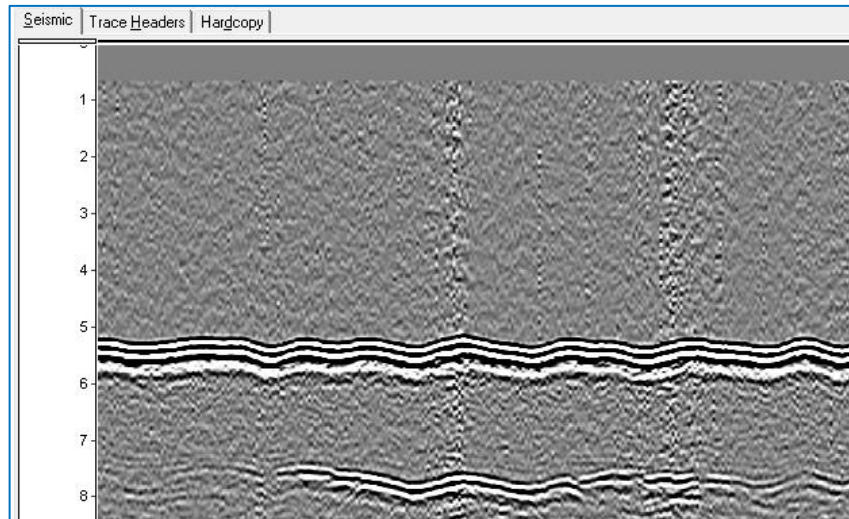
When the checkbox “Apply flying depth correction with Z value [m] from SIS data” is checked, Z values are recalculated in time units using the sound velocity entered in the settings of the software logging *.ses3 and *.raw files ([Figure 3.5](#), Sound Velocity). The resulting values are entered into the *.ses3 as “shift-in-time” by adding “empty measurements”. In this case, “measurements adding” corresponds to negative Z values.

[Figure 3.6](#) shows three conversion results for the same seismic section, for which “absolute Z-coordinate values” are recorded in the “SIS-ID with Z value in source file(s)” field:

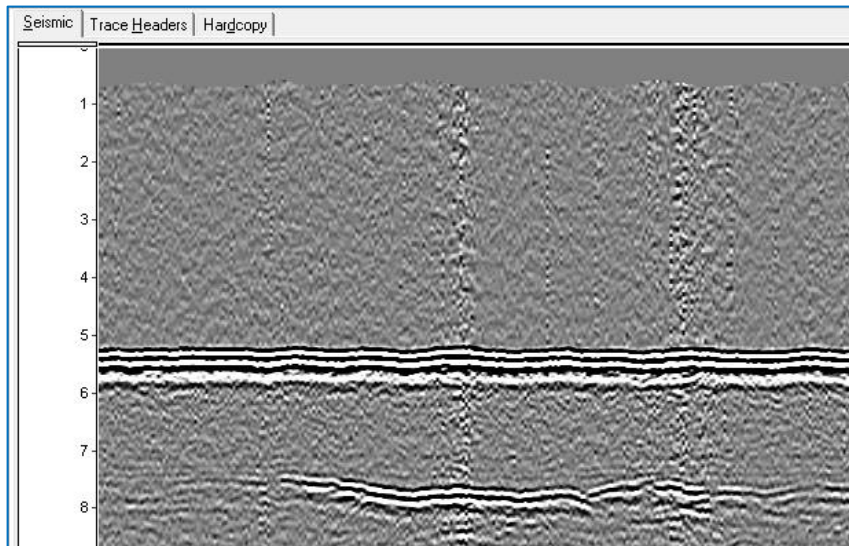
- (a) with the “Apply heave correction” checkbox cleared and the “Apply flying depth correction with Z value [m] from SIS data” checkbox cleared, i.e., without any shift of the seismic traces;
- (b) with the checkbox “Apply heave correction” checked and the checkbox “Apply flying depth correction with Z value [m] from SIS data” cleared, with the seismic traces shifted by the Heave value obtained from the MRU messages and converted to time units;
- (c) with the “Apply heave correction” checkbox cleared and the “Apply flying depth correction with Z value [m] from SIS data” checkbox checked, the seismic traces are shifted by the Z value, which already contains the Heave values.

The seismic bottom in [Figure 3.6-c](#) is shifted by 5 milliseconds (about 3.5 meters) relative to the seismic bottom in [Figure 3.6-b](#) because the Z value was set in “absolute coordinates” (Heave values, SBP head depth below sea level, and “tide” values are included in Z). If we recalculate [Figure 3.6-c](#), with the “Apply heave correction” checkbox checked, we will get a double Heave compensation, where Heave will appear on the seismic section in the bottom topography with the opposite sign (like on [Figure 3.7-b](#)).

a)



b)



c)

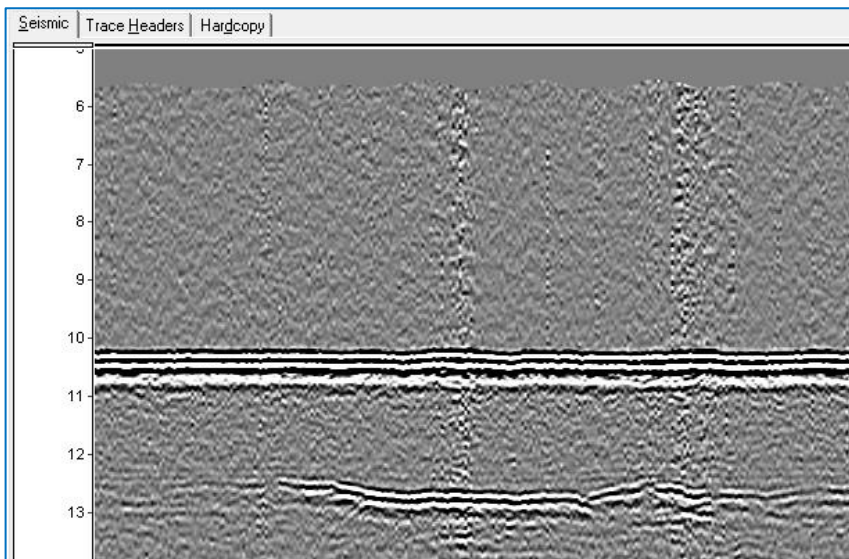


Figure 3.6 Seismic section: (a) without seismic traces shift, (b) Heave applied from MRU, (c) GPS antenna Z-coordinate applied

3.4 “Apply tide correction with Z value [m] from SIS data” checkbox

To understand the operations performed by SES Convert when the checkbox “Apply flying depth correction with Z value [m] from SIS data” is checked, let us perform the conversion with different settings for a seismic section with “absolute Z-coordinate values” written in the “SIS-ID with Z value in source file(s)” field. The conversion results are shown in [Figure 3.7](#):

- (a) with the checkbox “Apply tide correction with Z value [m] from SIS data” cleared;
- (b) with the checkbox “Apply tide correction with Z value [m] from SIS data” checked.

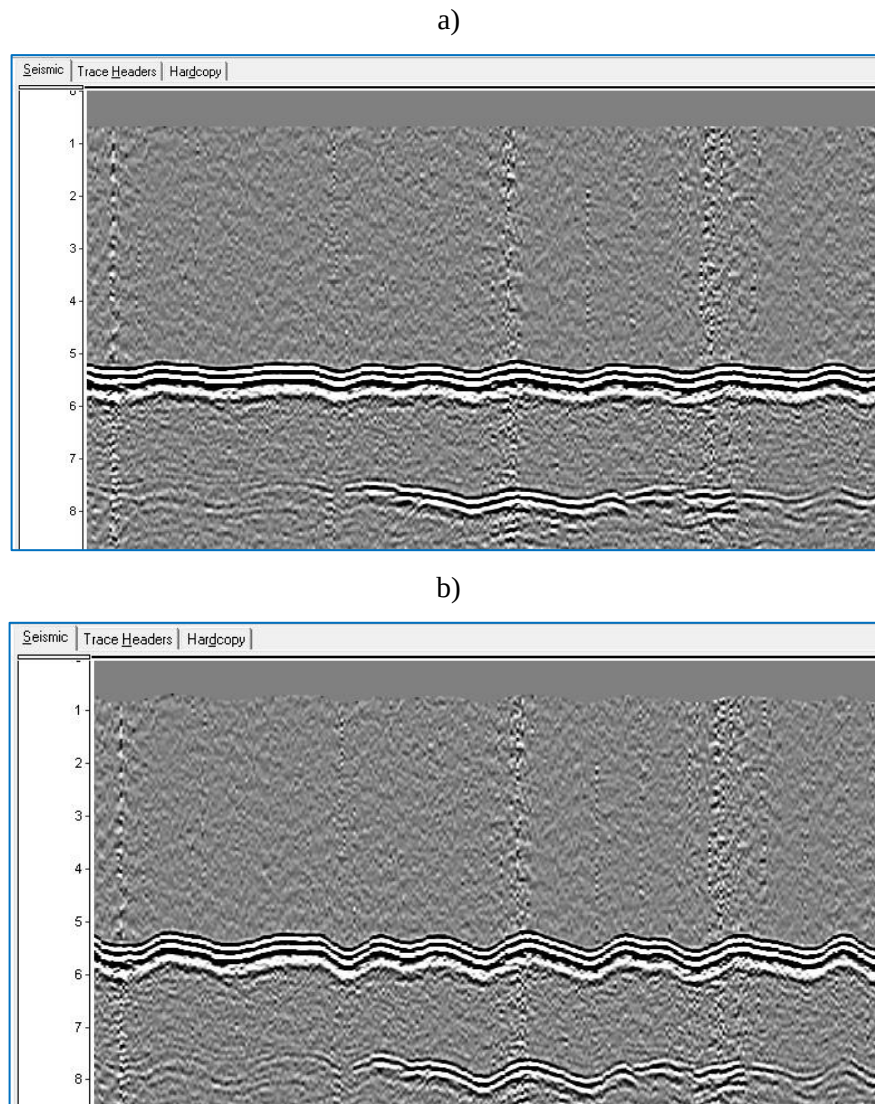


Figure 3.7 Seismic section for which the checkbox “Apply tide correction with Z value [m] from SIS data” is (a) cleared, (b) checked

The seismic bottom in [Figure 3.7-b](#) is twice more affected by Heave than the seismic bottom in [Figure 3.7-a](#), while there is no shift in the vertical axis on the section (the “Delay Recording Time” values in the seismic headers do not change as well). Based on these patterns, it can be assumed that when the checkbox “Apply tide correction with Z value [m] from SIS data” is checked, SES Convert version 2.3.3.1 performs the following calculations:

- 1) Calculates the arithmetic mean for Z and subtracts it from the Z values, that can be written as $Z_n = Z - \text{mean}(Z)$;
- 2) Converts the values of Z_n into units of time using the sound velocity;
- 3) Applies Z_n into the seismic traces by adding “empty measurements”. In this case, “measurements adding” corresponds to positive Z values.

Thus, when using the checkbox “Apply tide correction with Z value [m] from SIS data”:

- a constant component is “lost” from the Z values by which seismic traces are shifted;
- the shift of seismic traces is performed “with the opposite sign” in relation to the shift with the checked “Apply flying depth correction with Z value [m] from SIS data” checkbox.

3.5 “Apply range correction”, “Extended depth data range” checkboxes and changes for seg-y in the “Delay Recording Time” field

SES Convert version 2.3.3.1 does not change the values in the “Delay Recording Time” headers (bytes 109-110 for seismic traces in the seg-y file) when the “Apply tide correction with Z value [m] from SIS data” or “Apply flying depth correction with Z value [m] from SIS data” checkboxes are checked.

The values in the “Delay Recording Time” headers of seismic traces are changed by two additional checkboxes shown in [Figure 3.3](#):

- The “Apply range correction” checkbox exports seg-y files so that the “Delay Recording Time” value is set uniform for all seismic traces in the file;
- The “Extended depth data range” checkbox adjusts the “Delay Recording Time” so that the seismic traces are in the specified depth range, using the sound velocity entered in the software settings when surveying the seismic profile. Using this checkbox, you can set a common depth range for all seismic profiles at the site (in this case, the lower boundary of time for seismic traces will be calculated using the sound velocity in water).

3.6 “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox

The SES Convert version 2.3.3.1 (or perhaps an earlier version) has an additional “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox appeared on the 3rd screen ([Figure 3.3](#)) and shown in [Figure 3.8](#). When this checkbox is checked together with the “Apply tide correction with Z value [m] from SIS data” checkbox, two differences appear between the converted seismic files and the files converted without the additional checkbox:

- The “recording start delay” value is written to the “Delay Recording Time” headers in hundredths of a millisecond.
- An additional shift along the vertical axis is added to the seismic section.

If the Z value is set using absolute reference (see “[“SIS-ID with Z value in source file\(s\)” field](#)”), then if the “Apply flying depth correction with Z value [m] from SIS data” and “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkboxes are checked simultaneously, the seismic bottom appears closer to its position in absolute marks [Figure 5.2-f](#). In other words, one can say that if these two

checkboxes are checked simultaneously, a “partial arithmetic mean subtraction” from the Z values considered as “tides” is performed (i.e., the constant component is “subtracted”, but not completely).

Range Processing

SES files may contain Z values within the navigation data fields, such as RTK Z values, ROV flying depths or tide values. There is an option to apply a depth correction. Please check whether heave correction is still applicable in this case, depending on the accuracy, resolution and frequency of the recorded Z values. SES data files may be recorded with variable depth ranges (i.e. due to changing water depth). Apply a range correction in order to produce a SEG-Y file with a constant depth range between the minimum and maximum depth value within the original SES file. Furthermore the depth data range can be extended with selectable values.

☒ Apply tide correction with Z value [m] from SIS data

☐ Apply flying depth correction with Z value [m] from SIS data

☒ Apply range correction

☐ Extend depth data range from [m]:

1	-	-	-
100	-	-	-

 to [m]:

1	-	-	-
100	-	-	-

☒ Apply scale factor of 100 to SEG-Y trace header value DELRT

Figure 3.8 “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox

3.7 SES Convert settings for *.raw files if the SBP transmitter Z-coordinate is specified using absolute estimates

If the SBP transmitter Z coordinates are calculated using the GPS antenna (absolute estimates obtained relative to zero elevation mark using PPP correction for GPS). Thus, the SBP transmitter Z coordinate already contains: “tidal”, Heave and “SBP transmitter depth” corrections.

When using SES Convert version 2.3.3.1 to convert *.raw files to seg-y (but not *.ses3 files!), the checkboxes must be checked as shown in [Figure 3.9](#). For this checkbox position, Z values will be entered into the seismic traces by adding “empty measurements” to the beginning of the seismic traces. At the same time, the length units will be converted to time units at the rate of 1488 m/s set in the seismic data acquisition software ([Figure 3.5](#)).

The necessity of checking the “Apply range correction” checkbox is described in the “[Artifacts in the seismic section for the moments of the Delay Recording Time values change \(“Apply range correction” checkbox\)](#)” section.

When loading seg-y files into the seismic data processing/interpretation software, it is necessary NOT to use Z values from the “Datum elevation at receiver group” (bytes 53-56) and “Datum elevation at source” (bytes 57-60) seg-y seismic data headers, since these values are already contained in the seismic trace shift by adding “empty measurements”.

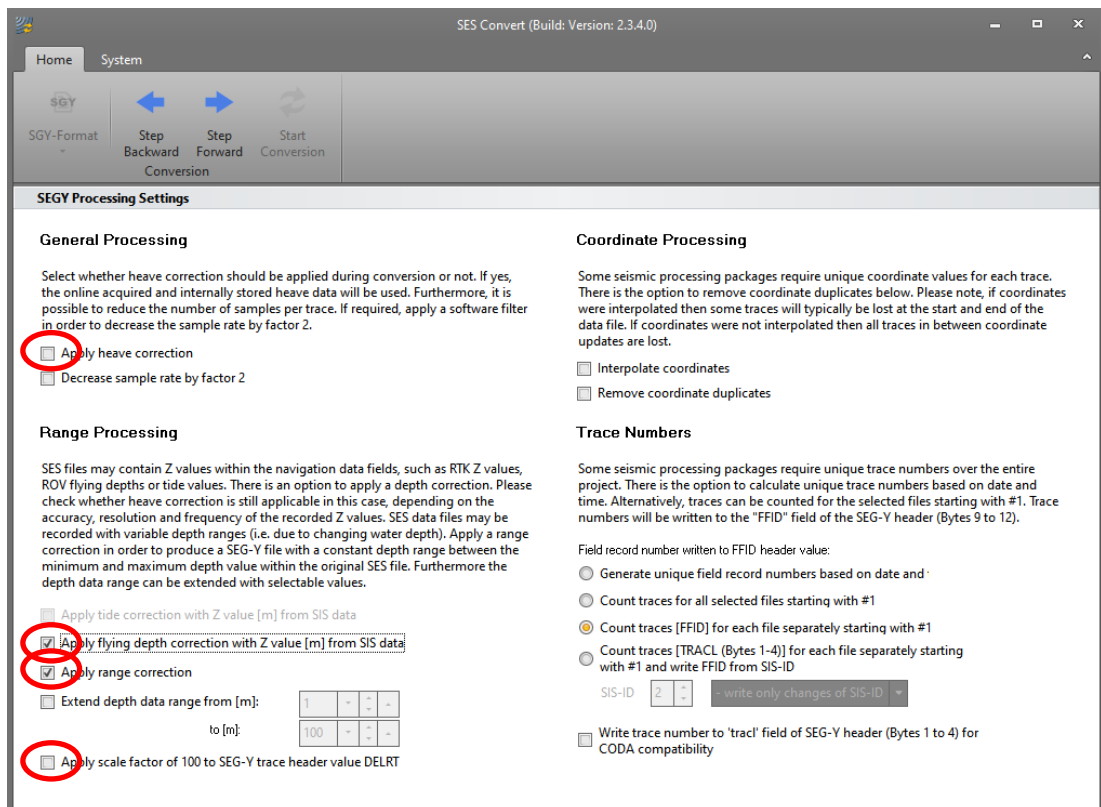


Figure 3.9 The checkboxes for calculating the SBP transmitter Z coordinates from GPS antenna Z coordinate

4. SES3 format, operation with SES Convert

Attention! When working with *.ses3 format, the conversion results will be different from *.raw format if the same checkboxes are checked. To compare *.ses3 and *.raw formats conversion we used converters of versions 2.3.3.1 and 2.3.4.0.

4.1 “Apply flying depth correction with Z value [m] from SIS data” checkbox

The following checkboxes combination was used to convert *.raw files recorded when calculating the SBP transmitter Z coordinates using the GPS antenna Z coordinate (absolute estimates):

“Apply heave correction” – Off,

“Apply tide correction with Z value [m] from SIS data” – Off,

“Apply flying depth correction with Z value [m] from SIS data” – On,

“Apply range correction” – Off,

“Apply scale factor of 100 to SEG-Y trace header value DELRT” – Off.

The result of converting *.raw files to seg-y is shown in [Figure 3.6-c](#).

The result obtained by checking these checkboxes when converting the *.ses3 file is shown in [Figure 4.1](#). As can be seen from the lack of heave compensation for the seafloor in the seismic section, the Z value was not applied to the seismic traces, when converting the *.ses3 files.

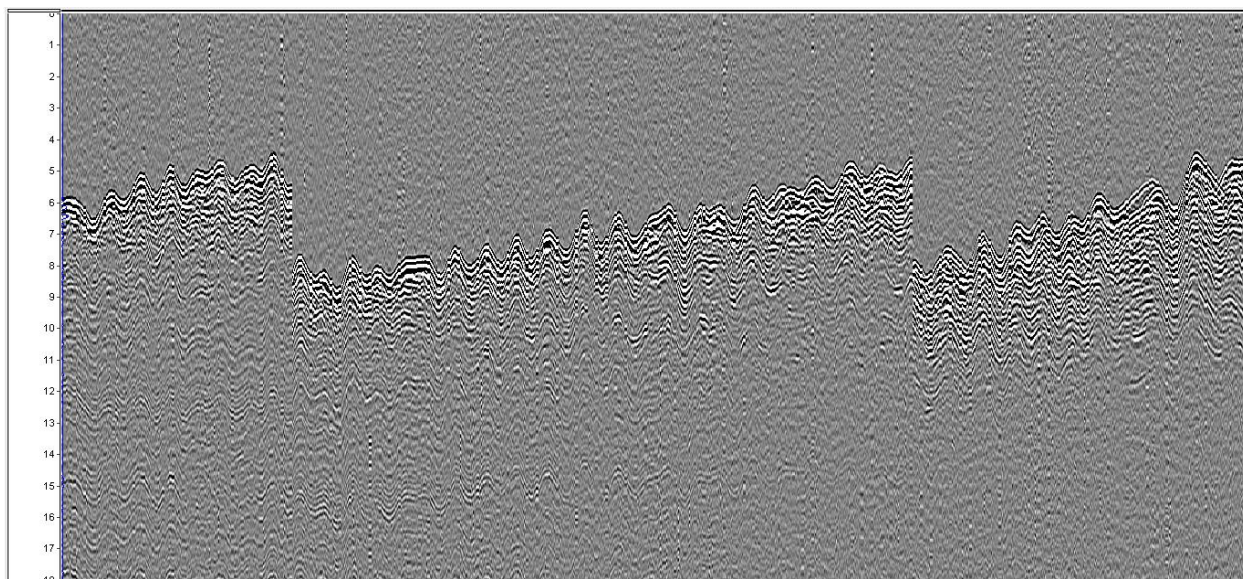


Figure 4.1 The result of the *.ses3 files conversion with the “Apply flying depth correction with Z value [m] from SIS data” checkbox checked

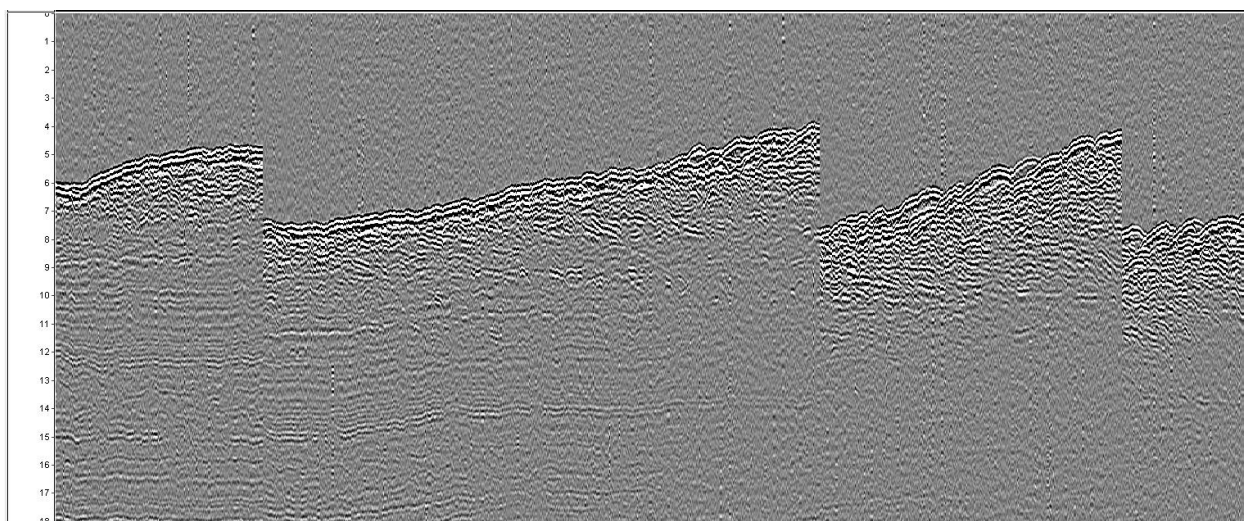
The seismic section screenshot in [Figure 4.1](#) is made in the SeiSee program. Two vertical steps in the seismic section are due to the Delay Recording Time value change, which is not displayed in the SeiSee window.

4.2 Чек-бокс “Apply tide correction with Z value [m] from SIS data”

If we check the “Apply tide correction with Z value [m] from SIS data” checkbox when converting the *.ses3 file (the “Apply flying depth correction with Z value [m] from SIS data” checkbox will be cleared), we will get the result shown in [Figure 4.2](#) (the same portion of the seismic section as in [Figure 4.1](#) is shown; the vertical steps appearing in the seismic section are due to the Delay Recording Time value change, which is not displayed in the SeiSee window).

As we can see from the [Figure 4.2](#), the Z value was applied and heave compensation was performed during the conversion. If we compare [Figure 4.2](#) with [Figure 3.7](#), we can see that the Z value was applied with the “reverse” sign for *.raw files when the “Apply tide correction with Z value [m] from SIS data” checkbox was checked. Accordingly, the seismic bottom distortion due to heave in [Figure 3.7-b](#) was doubled. However, when converting the *.ses3 file, the Z sign is considered by the SES Convert program as “correct” and the distortion due to heave is “removed” ([Figure 4.2](#)).

Moreover, if the “Apply tide correction with Z value [m] from SIS data” checkbox is checked, the Z value is applied exactly as “tide” during *.ses3 conversion, i.e., the constant component is pre-subtracted from the Z values.



[Figure 4.2](#) The result of the *.ses3 files conversion with the “Apply tide correction with Z value [m] from SIS data” checkbox checked

Based on the experience with field data, the following “unexpected features” occurred when converting the *.ses3 format for multiple SBP survey sessions with checkboxes checked as in [Figure 4.2](#):

- When converting in SES Convert version 2.3.3.1, the bottom depth was doubled, so the seismic section was outside the seg-y file recording time. The only way to output the seismic section to seg-y was to check the “Extend depth data range from/to” checkbox, forcing the bottom boundary for the seismic section;
- When converting in SES Convert version 2.3.4.0, the bottom depth was quadrupled.

Comparison of *.ses3 files with “double bottom depth” in ISE2 and files converted without this feature did not reveal the causes of this effect (the hardware settings available for viewing in ISE2 and the data fields nature were the same).

As a result, the MatLab / Octave script described below was used to make Z corrections in the seg-y file for files recorded in *.ses3 format.

4.3 Applying Z using MatLab / Octave

The script in Appendix 1 generates seg-y files identical to the SES Convert results for *.raw files (applying Z with “Apply flying depth correction with Z value [m] from SIS data” checked) when the SBP transmitter Z-coordinates are calculated using the GPS antenna Z-coordinate (absolute estimates obtained relative to zero elevation mark using PPP correction for GPS).

To apply Z values outside the SES Convert, do the following:

- 1) convert a *.raw file or a *.ses3 file to seg-y with cleared checkboxes responsible for applying Z or heave compensation;
- 2) unload Z value from a *.raw file or a *.ses3 file into a text file;
- 3) shift each seismic trace in the seg-y file by the Z value converted from distance units to time units.

To get a text file with Z values from *.raw or *.ses3 files without using the ISE program, one can use the option left in SES Convert - set the Z value instead of one of the coordinates and output this “coordinate” to an ASCII file as shown in [Figure 4.3](#). The result of the conversion is a file similar to the one shown in [Figure 4.4](#), containing the Z value in the second column.

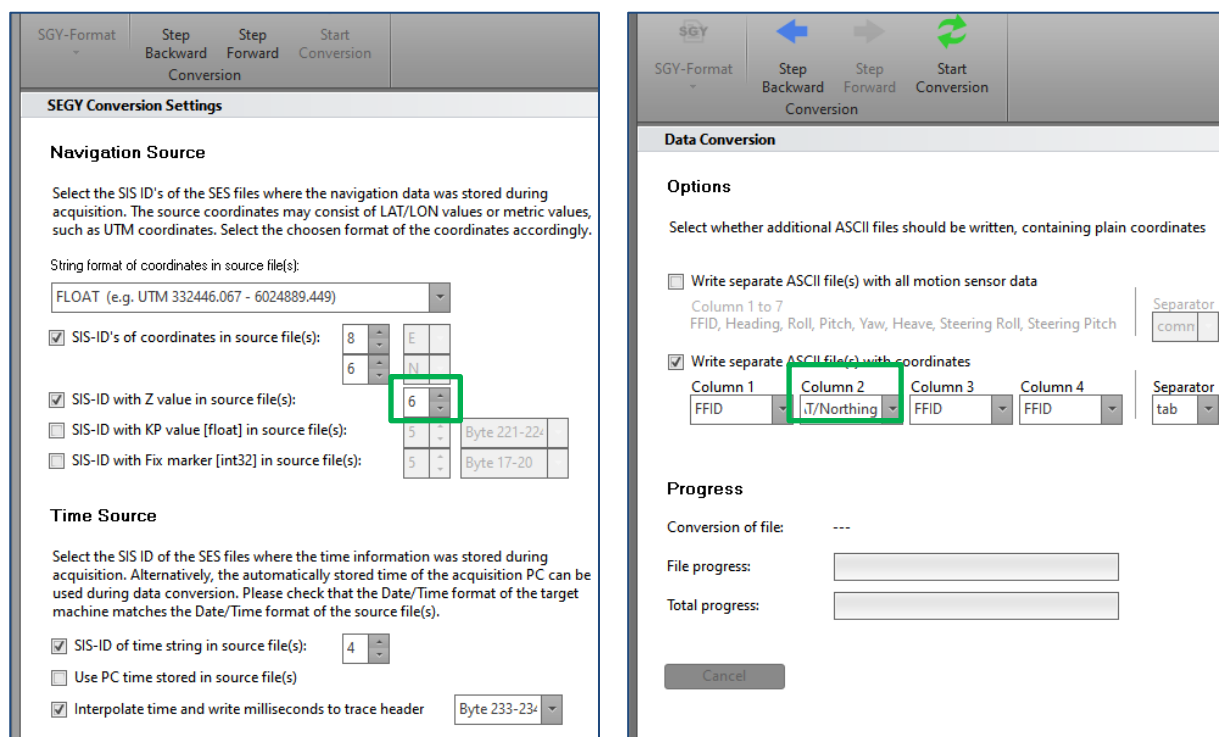


Figure 4.3 Exporting Z values from the *.raw or *.ses3 file using SES Convert

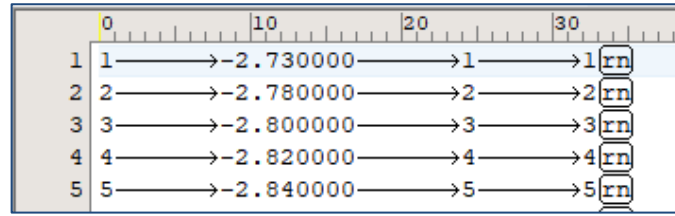


Figure 4.4 The contents example of the exported file with the Z values

Since after such a conversion the seg-y file will contain Z values instead of coordinates, it is necessary to convert the file again with correct “SIS-ID's of coordinates in source file” settings in order to get “seg-y file with coordinates”. It is also necessary to clear the “Apply heave correction”, “Apply tide correction with Z value [m] from SIS data”, “Apply flying depth correction with Z value [m] from SIS data” checkboxes responsible for applying Z or heave compensation. The “Apply range correction” checkbox should be checked for correct seg-y file creation (the reasons are described in the section below).

The seismic trace values are shifted using the MatLab / Octave script, the code of which is given in “[Appendix 1. MatLab / Octave code for shifting seismic traces by Z value](#)“. Besides shifting seismic traces, the script introduces an additional “gain factor” to bring the seismic signal gain in the *.ses3 files in line with the gain in the *.raw files.

The script sequentially does the following:

- 1) requests the seg-y file name (with coordinates in “SIS-ID's of coordinates in source file” fields and without applying Z or heave-compensation);
- 2) requests the name of the text file containing Z values in a second column;
- 3) assigns the value of sound speed to the SV variable to be used in the conversion of distance units to time units;
- 4) assigns the gain factor to the GainK variable for seismic traces (to bring the gain in *.ses3 files in line with the gain in *.raw files);
- 5) reads the contents of the seg-y file and the text file with Z values;
- 6) converts Z values into time units (taking into account the frequency of the seismic trace digitization);
- 7) shifts seismic traces by Z value (in time) and amplifies them;
- 8) saves the seg-y file to disk.

As a result of the actions described above, we get a seg-y file “converted” from *.ses3, for which -- Z values are mathematically entered in the same way as for the *.raw file when converting in SES Convert with the “Apply flying depth correction with Z value [m] from SIS data” checkbox checked (for absolute Z estimates, the SBP bottom will coincide the MBES bottom, [Figure 5.3](#));

-- seismic traces gain coincides with the gain in files converted from *.raw format.

The use of the described approach is convenient for bringing seg-y to a unified form, if the survey for one area was performed by Innomar SBP sets, recording in both *.ses3 and *.raw formats with absolute Z estimates.

5. Artifacts in the seismic section for the moments of the Delay Recording Time values change (“Apply range correction” checkbox)

Figure 5.1, *Figure 5.2* and *Figure 5.3* show the results of the *.ses3 file converting with different SES Convert settings. The portion of the seismic section is the same as in *Figure 4.2*, however, the section is plotted in KingDom program. Unlike plotting in SeiSee, the seismic traces are plotted taking into account the recording start time (i.e., shifted by the “Delay Recording Time” contained in the seismic trace headers in the seg-y file). The red line shows the seafloor position based on the MBES data, converted to time units and overlaid on the seismic section. The SBP survey was performed with an equipment configuration in which the SBP transmitter Z-coordinate is referenced to the Z-coordinate of the GPS antenna (absolute measurements). Thus, if the Z correction is entered correctly, the seafloor position based on the MBES data and the seafloor position on the seismic section should coincide.

Note that when converting the *.ses3 file, the seafloor levels do not coincide under any SES Convert settings; coincidence is only achieved when applying the MatLab / Octave script (*Figure 5.3*);

The incomplete “Delay Recording Time” compensation for all seismic sections, except for sections with the “Apply range correction” checkbox checked, is noteworthy.

The artifacts remaining after “Delay Recording Time” compensation are shown by blue arrows. After the “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox is checked, the artifacts amplitude changes, but does not decrease by a factor of 100, as one would expect when increasing the “accuracy” of “Delay Recording Time” values by a factor of 100.

Thus, when using SES Convert versions 2.3.3.1...2.3.4.0, the **“Apply range correction” checkbox should always be checked** to avoid the marked artifacts.

Based on the experience with field data, during the *.raw and *.ses3 files conversion without the “Apply range correction” checkbox checked and with artifacts-steps, the seismic section shift along the vertical axis is added for the time from 0.5 to 3 milliseconds approximately for one of fifteen seg-y files. The shift appears both when converting *.raw files under the settings described in the “*SES Convert settings for *.raw files if the SBP transmitter Z-coordinate is specified using absolute estimates*” section and when converting *.ses3 files with Z correction using MatLab / Octave. This means that the shift is not related to the Z correction, but is probably the result of an incorrect “Delay Recording Time” correction.

When the “Apply range correction” checkbox is checked, the shift disappears. However, if the “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox is also checked, it “introduces its own offset”. Therefore, the **“Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox must be always cleared**.

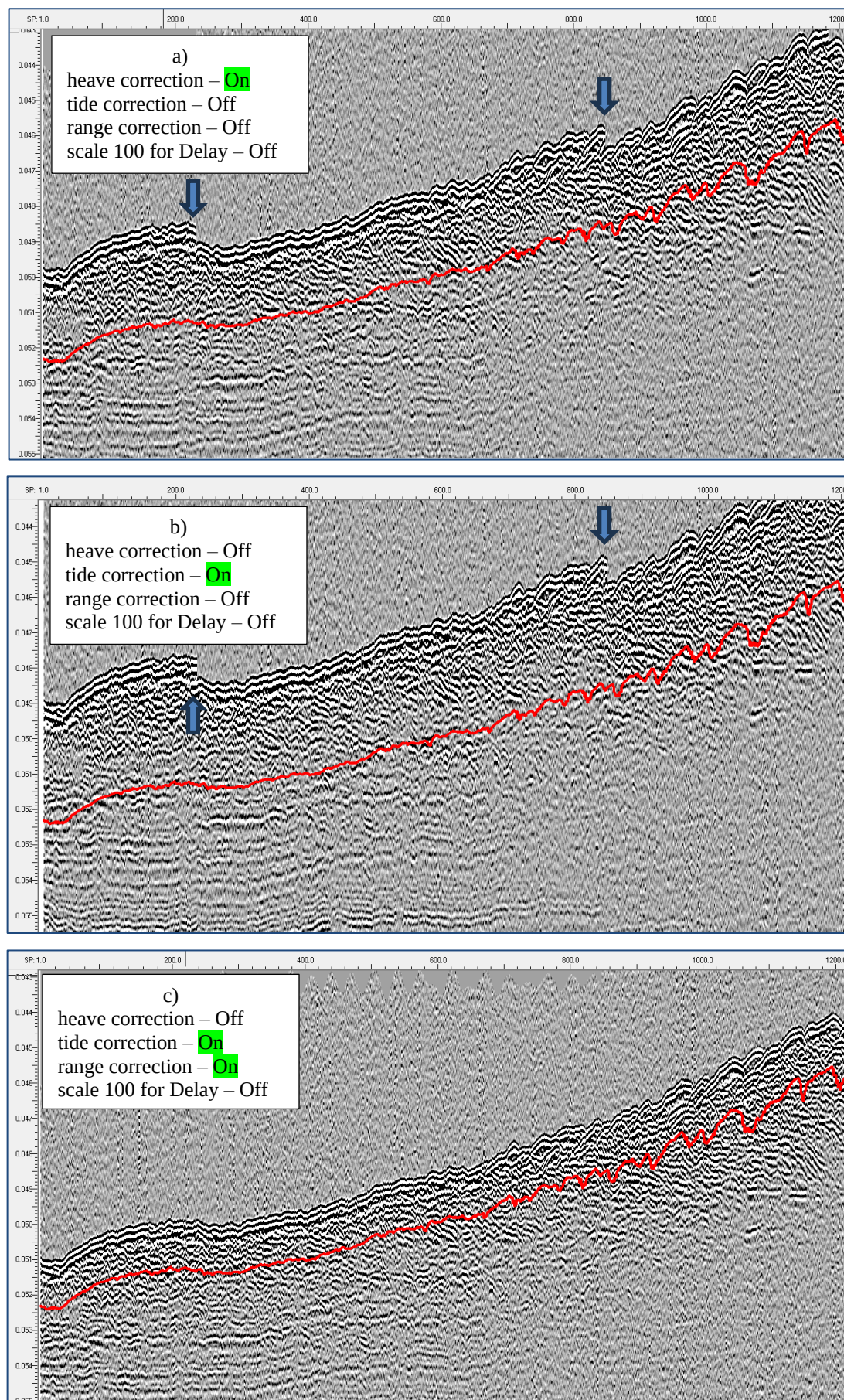


Figure 5.1 Results of the *.ses3 file conversion under different settings. Part 1

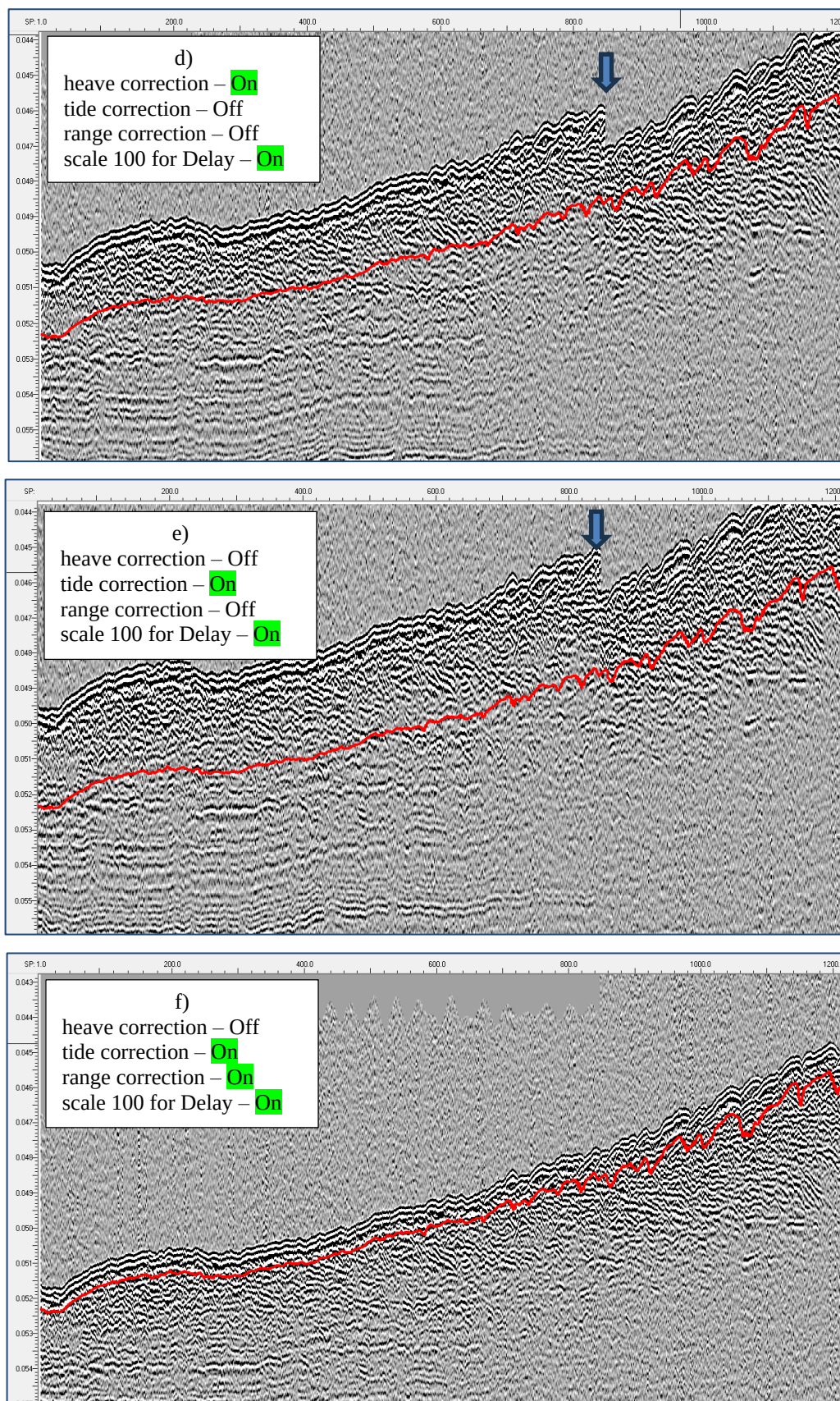


Figure 5.2 Results of the *.ses3 file conversion under different settings. Part 2

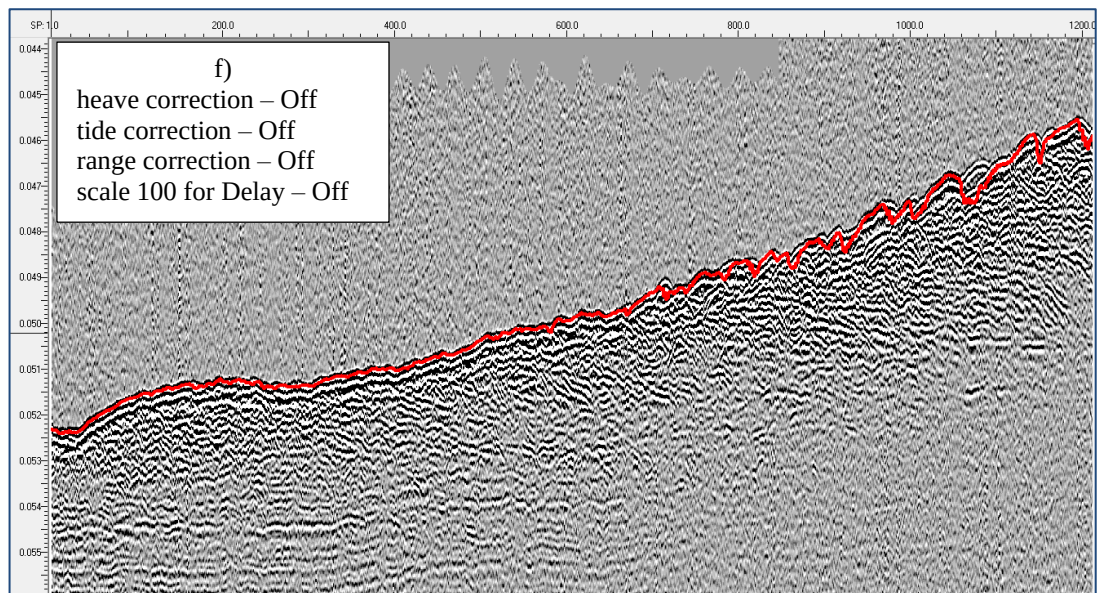


Figure 5.3 Results of the *.ses3 file conversion followed by Z correction using MatLab / Octave

Conclusion

When converting *.raw and *.ses3 files to seg-y using SES Convert, it is necessary to recognize which Z values have been transmitted by the navigation in the SIS messages. The Z values may contain:

- The “tides” magnitude (relative or transient estimates). In this case, the “Apply heave correction” checkbox must be checked to bring Heave from the MRU messages into the seismic trace shift;
- the SBP transmitter Z-coordinate value along the absolute scale. In this case it is not necessary to check the “Apply heave correction” checkbox, since when making corrections for Z ([Figure 3.6](#)), heave removal will be performed a second time (as a result, the seismic section will be complicated by a heave with the opposite sign).

The “Apply tide correction with Z value [m] from SIS data” checkbox is intended **for entering Z values as corrections for “tides”**. In this case, the constant component is preliminarily “subtracted”/deleted from the Z values, and the Z variable component is converted to time units and entered into the seismic data as a time shift by adding “empty measurements”. Such a conversion requires an additional correction for the SBP transmitter depth relative to sea level. If the converter has the additional “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox checked, the converter not only multiplies the “Delay Recording Time” values in the seg-y files by 100, but also adds a vertical scale shift to the seismic traces; this shift can be considered as an “incomplete subtraction of the constant component from Z” (see description in the “[Apply scale factor of 100 to SEG-Y trace header value DELRT](#)” [checkbox](#)“ section).

To enter Z values as the SBP transmitter coordinates along the absolute elevation scale, use the “Apply flying depth correction with Z value [m] from SIS data” checkbox. In this case, the Z values are converted to time units (using the sound speed entered in the settings of the SBP recording program), and the resulting values are entered into the seismic data as a time shift by adding “empty measurements”. The removal of the constant component from Z is not performed. If the additional “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox is checked, the seismic section will be shifted along the vertical scale relative to absolute marks.

If the “Apply tide correction with Z value [m] from SIS data” checkbox is mistakenly checked when entering Z values as the SBP transmitter coordinates along the absolute scale, the “tides” will be entered with the opposite sign. As a result, the heave will be amplified twice in the seismic section ([Figure 3.7](#)).

The checkbox checking described above is valid for converting *.raw files. SES Convert operates differently when converting *.ses3 files. “Apply flying depth correction with Z value [m] from SIS data” checkbox does not affect the conversion result ([Figure 4.1](#)). If the “Apply tide correction with Z value [m] from SIS data” checkbox is checked for “Z values as the SBP transmitter coordinates along the absolute scale”, the tides will be entered with the “correct sign” and the heave will be removed from the seismic section ([Figure 4.2](#)). Before entering the Z values, SES Convert will subtract the constant component from them and the seismic section in seg-y will be shifted relative to the absolute elevation scale.

The MatLab / Octave script ([Figure 5.1](#), [Figure 5.2](#), [Figure 5.3](#)) was created to correctly enter “Z values as the SBP transmitter coordinates along the absolute scale” (without additional shifts along the vertical axis).

Perhaps, SES Convert does not work correctly with the seg-y files “Delay Recording Time” field, since artifacts-steps appear in the seismic sections ([Figure 5.1](#), [Figure 5.2](#)) at the moments of the “Delay Recording Time” change when loading seismic sections into KingDom. Moreover, the seismic section is periodically shifted along the vertical scale (approximately one out of fifteen converted seg-y files is shifted). To avoid artifacts and shifts in seg-y files, the “Apply range correction” checkbox should always be checked. However, if the “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox is checked, it will introduce its own shift to the seismic section. Thus, to obtain seg-y without vertical axis shift, the “Apply range correction” checkbox must always be checked, and the “Apply scale factor of 100 to SEG-Y trace header value DELRT” checkbox must always be cleared.

Appendix 1. MatLab / Octave code for shifting seismic traces by Z value

```
%script SbpToolR01;

gKey=ans;

if strcmp(gKey{1},'SbpSgyApplyShift01') %Sgy folder

%{'SbpSgyApplyShift01','c:\Temp\014\0300_71_P75_20240707_121148_CH0_LF_nothing.sgy','c:\Temp\014\0300_71_P75_20240707_121
148_CH0_LF.txt'};SbpToolR01;
    try fName1=gKey{2};catch,fName1=input('SbpSgy =');end; try fName2=gKey{3};catch,fName2=input('SbpTxt =');end;
    SV=1506;GainK=30628;
    [SgyHead,Head,Data]=gSgyRead(fName1,'',[ ]);A=dlmread(fName2);
    zz=-round((A(:,2)'. /SV.*2) ./ (SgyHead.dt.*1e-6));
    Data1=gDataToPL(Data,1,zz).*GainK;
    gSgyWrite(SgyHead,Head,Data1,[fName1(1:end-4) '_applied_Z.sgy']);
    clearvars fName1 fName2 SV GainK SgyHead Head Data A zz Data1
end;
```