

Briefing of Inclinometer Data Correction In GeoSmart Monitoring Software (24/08/2025)



Error Correction of Inclinometer

Source of Error:

- ❖ **Random error** are accumulates at a rate equal to the square root of the number of reading intervals and cannot be corrected.
- ❖ **systematic error** accumulates directly with the number of reading increments and can be corrected. The sources of systematic error:

1. **Bias Shift Error**

The Bias Shift Errors always happen due to the change of bias between standard two pass survey . This is a common error and easy to correct for A & B direction of each data.

2. **Depth Error**

The Depth Errors shall cause the movement profile to become snaked shape by comparison with previous movement due to the combination of significant curvature and vertical placement error of probe.

3. **Rotation error**

The Rotation Error shall produce curved movement at A & B direction by comparison with the previous movement due to the combination of casing inclination and sensor axis alignment shift.

4. **Sensitivity Drift**

The sensor drift is the least common error and seldom happen.



Bias Shift Error of Inclinometer

1. Bias-Shift Errors:

Bias Errors: This is related to a small change in the bias of the inclinometer probe. It is usually eliminated during data reduction by two-pass surveys.

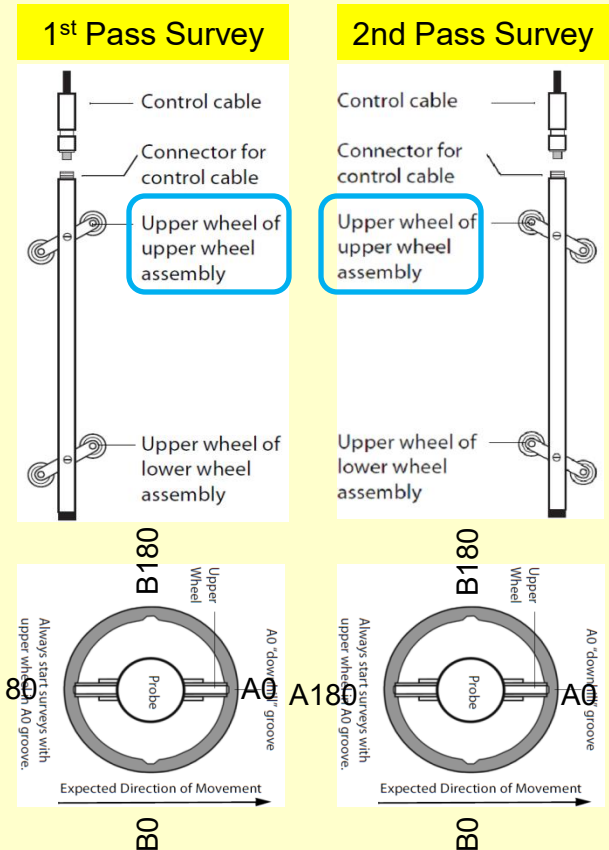
But if there is a change in the bias during the surveys, the bias shall cause error, call it as **Bias-Shift Errors**.

If Bias-Shift Error happens between two pass survey, it can be corrected. This is the most common error.

If Bias-Shift Error happens during 1 pass survey, this is not the systematic error and cannot be corrected.

The reasons causing the Bias-Shift Errors:

- (1) Rough Handling of the probe, i.e. dropping or bumping the probe, not hold wheels when retrieving sensor from casing.
- (2) Warm-Up Drift, the sensor has not been stabilized by the surrounding temperature when start to take reading, this cannot be corrected.



As the sensor has a bias, so true reading is:

1st pass

$$A0_t = A0 + \text{Bias1}$$

2nd pass

$$A180_t = A180 + \text{Bias2}$$

Where: Bias1 is sensor bias at 1st survey, and Bias2 is sensor bias at 2nd survey.

Incremental Deviation (at A Axis) = $[(A0_t - A180_t)/(25000 \times 2)] \times 500 \text{ (mm)}$

$$= (A0 + \text{Bias1} - A180 - \text{Bias2})/100 = [(A0 - A180) + (\text{Bias1} - \text{Bias2})]/100$$

When Bias1 = Bias2, the bias will be removed, **but if not, then shall produce Bias Shift Error**

Depth Error of Inclinometer

2. Depth Errors:

This is error due to the casing curvature and a change in the vertical placement of the probe.

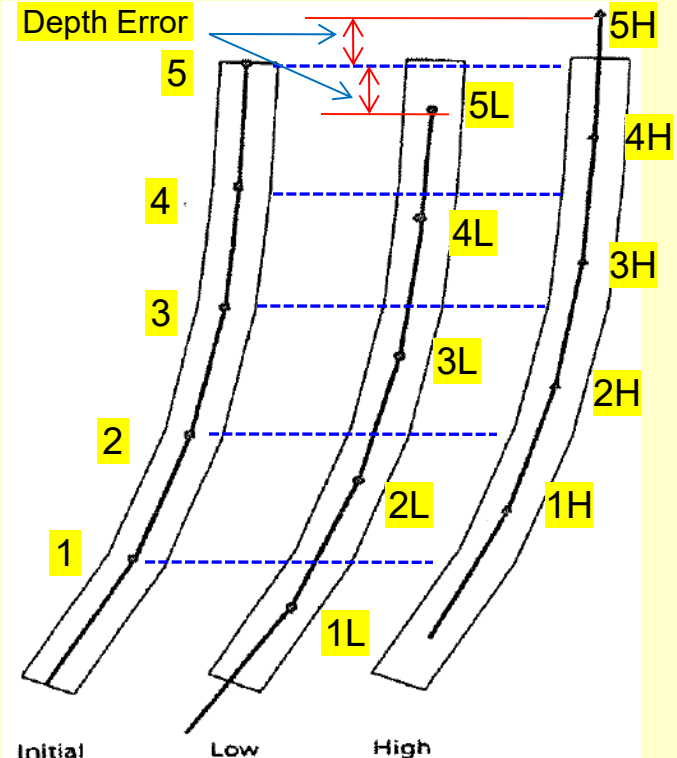
Depth change can cause a significant errors. According to slope indicator reference, if the probe is located less precisely (larger than 6mm), Depth Errors shall result during data reduction by two-pass surveys.

The reasons causing Depth Errors:

- (1) A change in cable reference, i.e., casing cut off or extend or a pulley is not used.
- (2) A change in cable length, i.e., cable shrink over time, use different cable which may not be the same length, or repair cable.
- (3) A change in casing length, i.e., casing compress, or survey may be started at the wrong depth by mistake, or material fill the bottom of the casing.
- (4) Change of cable length or chirper of depth marking

Unless the vertical displacement errors are known precisely, this kind of error is difficult to correct. Even when the error is known, correction are also not perfect. So at the survey time, the operator must take care to avoid the depth error.

Casing Profile at A Direction



For sensor is High case, then

$$\begin{aligned} \text{Cum. Mov} &= \text{Cum. Dev}_{(4H)} - \text{Cum. Dev}_{(4)} \\ &\approx \text{Cum. Dev}_{(5)} - \text{Cum. Dev}_{(4)} \\ &= \text{Inc. Dev} \end{aligned}$$

That is to say: the cumulative movement has a similar shape with Incremental Deviation

Rotation Error of Inclinometer

3. Rotation Error:

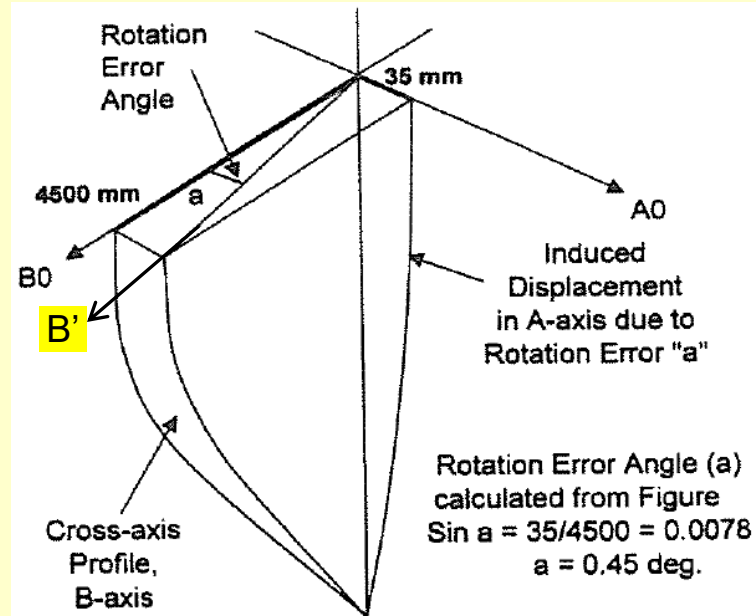
This is caused by a small change in the alignment of the probe's measurement axis (the change is usually less than 1 degree). The rotation errors become important when tow conditions combine:

- (1) There is significant inclination in the cross axis.
- (2) The alignment change occurs after the initial set was taken (otherwise, error would not be visible).

The reasons causing Rotation Errors:

- (1) Wear and tear on wheel yokes and bearings. This affects A & B readings equally.
- (2) Change in the accelerometer's meter movement , usually caused by bumps to the probe. This affects A & B readings separately.
- (3) Change in the alignment of the accelerometer package within the probe, i.e. change occurs during a repair, or using the different probe to survey the same inclinometer.

Casing Profile at A Direction



The formula for Rotation Error:

$$\text{A-axis Rotation Error} = B' \times \sin(a)$$

$$\text{B-axis Rotation Error} = -A' \times \sin(a)$$

Where:

A is Cumulative Deviation at A - Axis

B is Cumulative Deviation at B- Axis

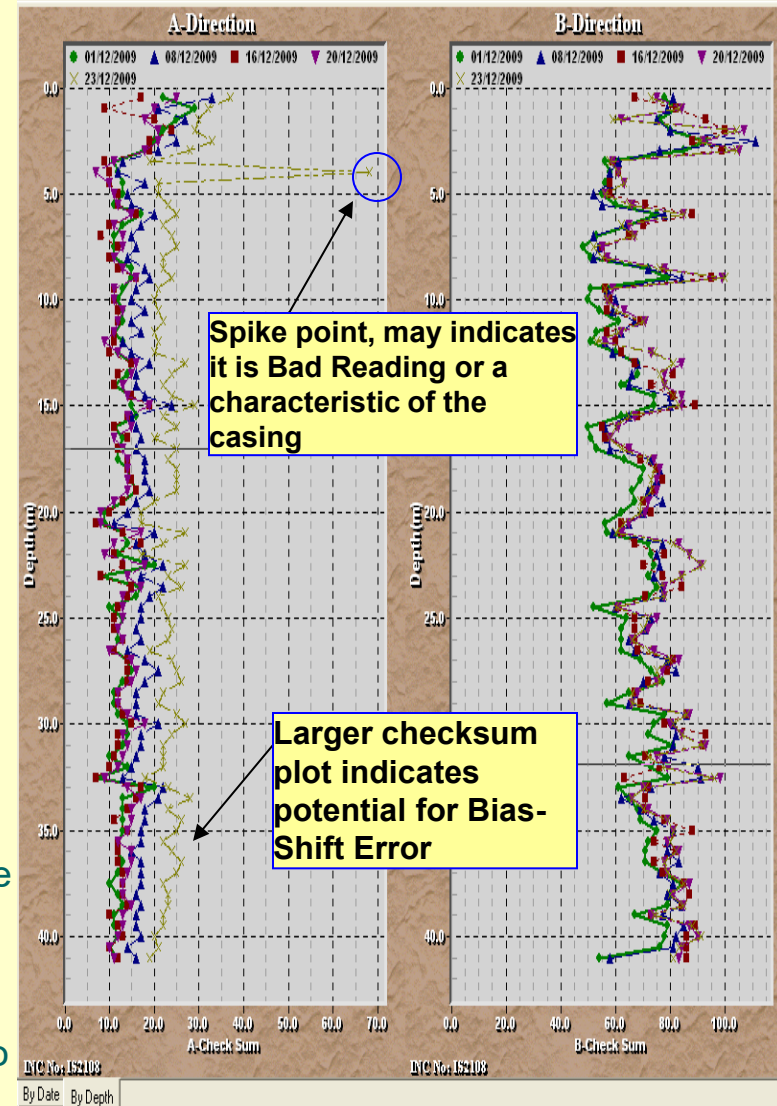
That is to say: the cumulative movement has a similar shape with Cumulative Deviation

Checksum of Inclinator Data

Checksums: (equal to 2 x Bias)

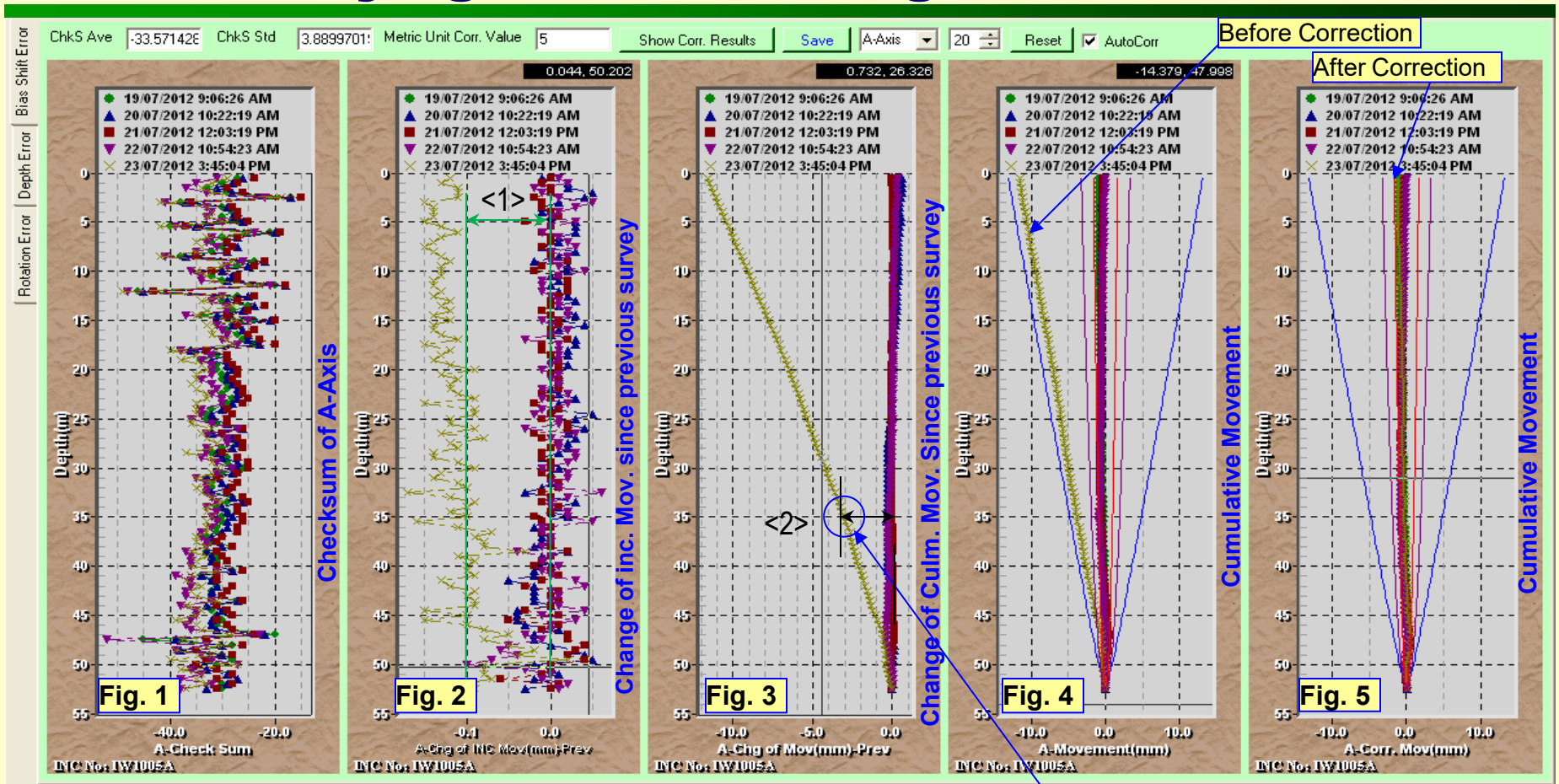
It is the sum of a “0” reading and a “180” reading at the same depth. Ideally, the sum would be zero since the two readings have opposite signs. In practice, checksums are not zero because of bias in the probe, variations in casing grooves, and the positioning of the probe. The checksum plot can be used to:

- ❖ To evaluate the quality of data. An abnormally large checksum (spikes) may indicate a bad reading, or they may be a characteristic of the casing.
- ❖ To check the random error. The standard deviation of checksums is a measure of the random error in the survey. The standard deviation of checksums should not exceed 10 for the A axis and 20 for the B axis (for Sinco inclinometer).
- ❖ To detect the Bias-Shift Error. Larger than normal checksum may indicate a bias-shift between the 0 and 180 pass. A drifting checksum (tilting checksum plot) within a dataset indicates a bias-shift during one pass of the survey, the readings cannot be used.
- ❖ To check probe quality. Frequent shifts of the checksum plot may indicate a weak probe and the potential for bias-shift errors. This probe may need to check and calibrate.



Checksum Plot

Identifying and Correcting Bias Shift Error



Note: <1> Constant change for each reading due to bias shift error

<2> Inclination similar linear line due to bias shift error, its slope value = $2 \times <1>$

Bias-Shift Error:

❖ Typical Characteristics of Plot:

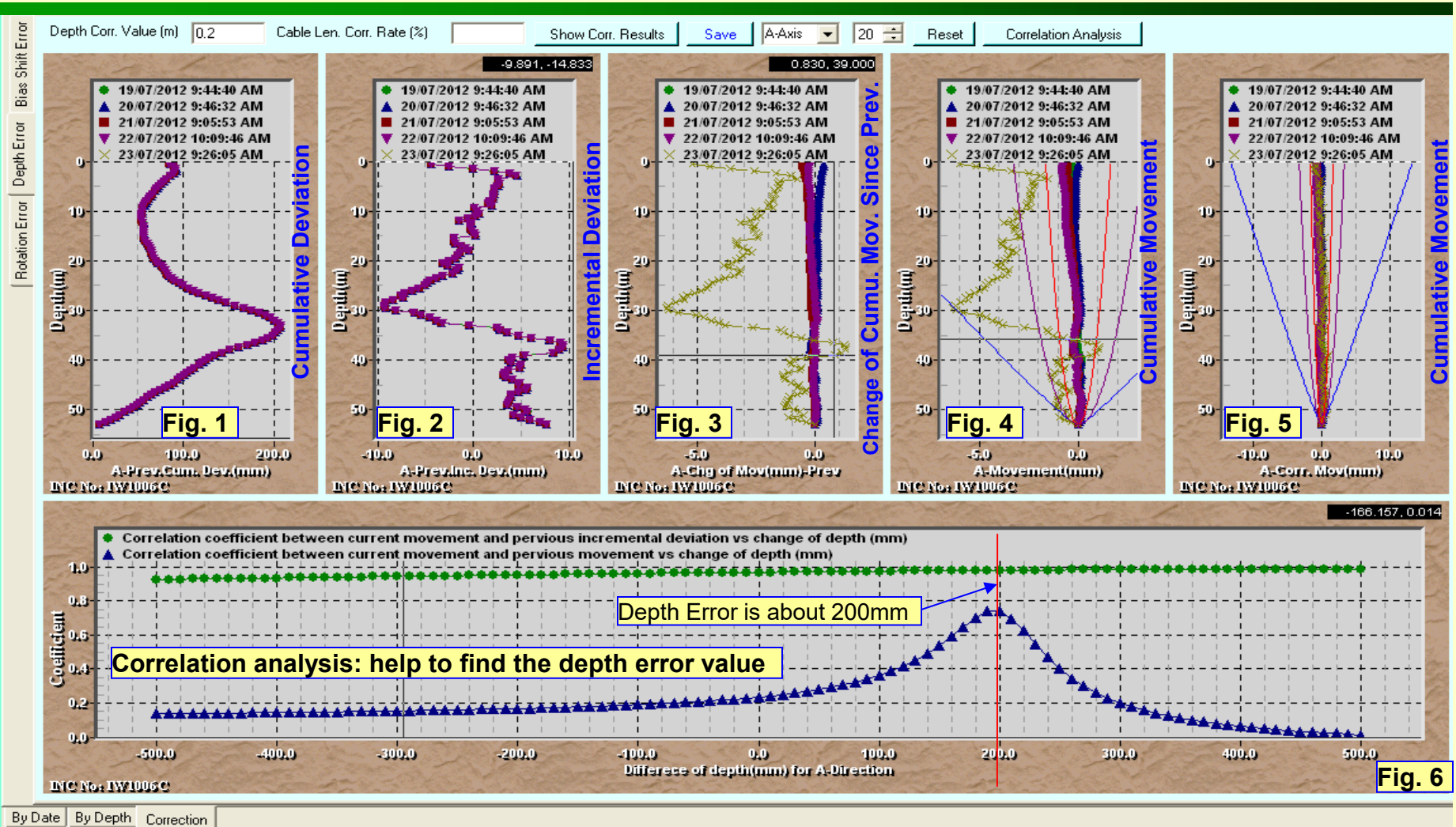
- (1) Fig.2 show approximate constant incensement (**Constant increase**);
- (2) Fig.3 is most likely inclined line (bottom part) (**Inclined linear line**);
- (3) Fig.4 shows tilting from previous results (**Tilting**);

❖ Move mouse to <2> point, GeoSmart shall show recommended value. The bias shift error correction is 5 reading units.

❖ Fig.4 & 5 shows the result before and after the bias-shift error correction.

23/07/2012 3:45:04 PM (Point 70: -3.05,35)
Metric Unit Correction Value: 4.357143
-3.05***105***70***500***25000

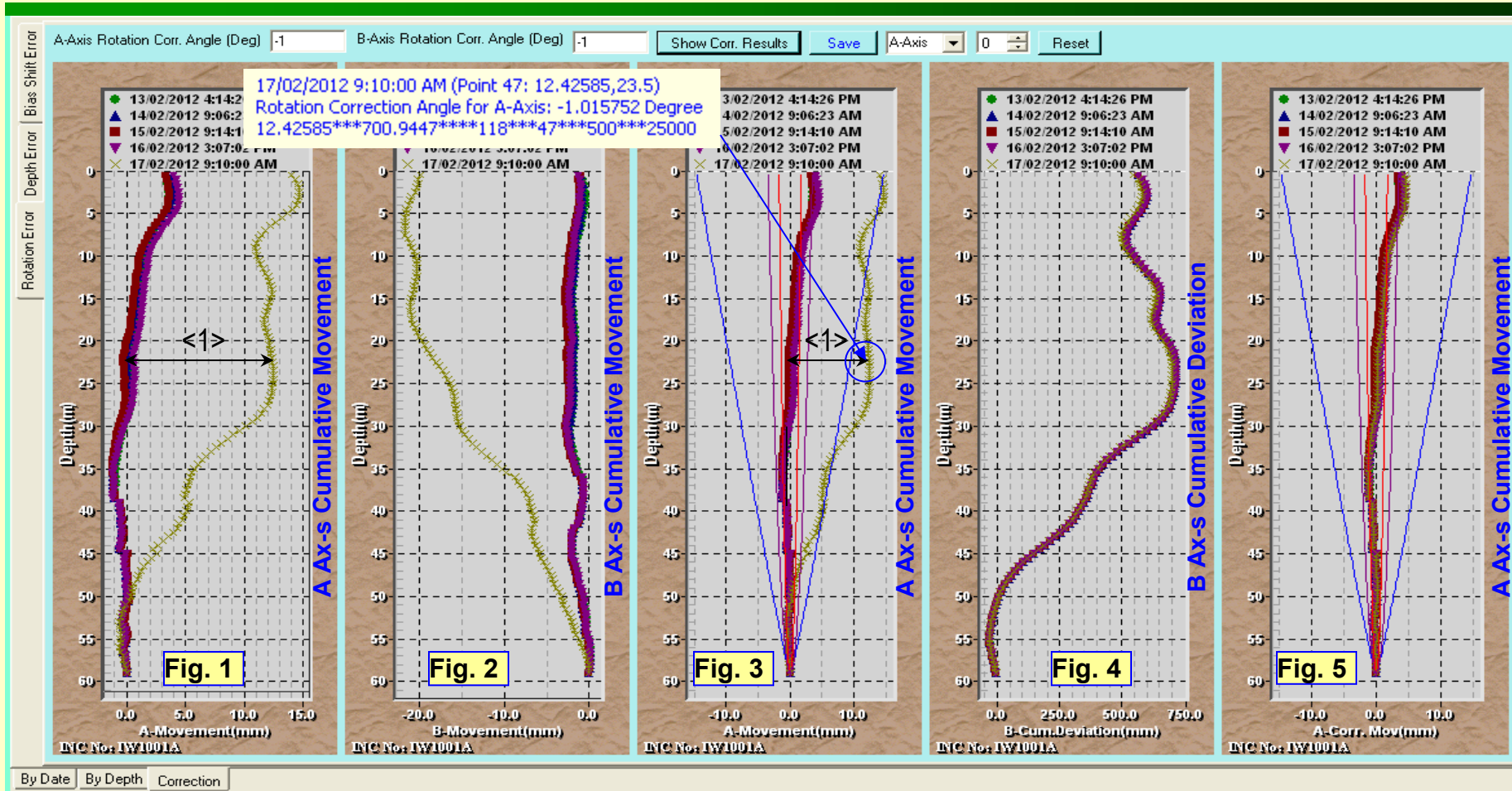
Identifying and Correcting Depth Error



Depth Error:

- ❖ Typical Characteristics of Plot : (1) Fig.4 has a **snaked shape**; (2) Fig.1 has **curvatures** (snaked casing profile) ; (3) Fig.4 & Fig.2 have a **similar shape**;
 - ❖ Fig.6 is a tool in GeoSmart to help **finding depth error**;
 - ❖ Fig.4 & 5 show the results before and after correction of the depth error (0.2m);
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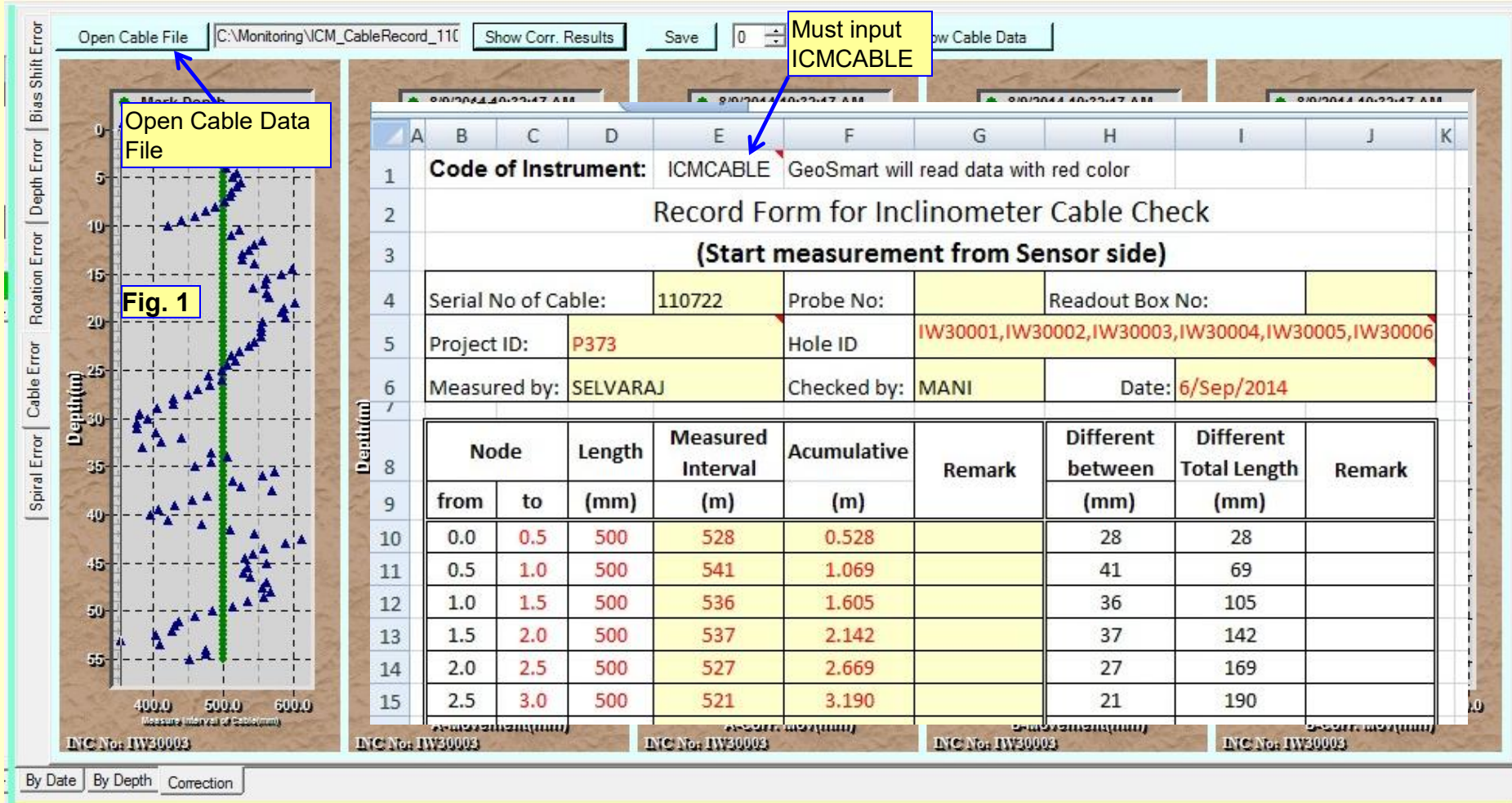
Identifying and Correcting Rotation Error



Rotation Error::

- ❖ Typical Characteristics of Plot : (1) Fig.1 & Fig.2 show larger curved movements by comparison with previous ones; (2) Fig.1 & Fig.4 have a similar shape; (3) Fig.4 shows inclined casing profile;
- ❖ <1> movement is caused by rotation error, move mouse to the point, GeoSmart shall calculate Rotation Error Value for your reference (about -1.015752 degree);
- ❖ Fig4 & Fig.5 show the results before & after the correction.

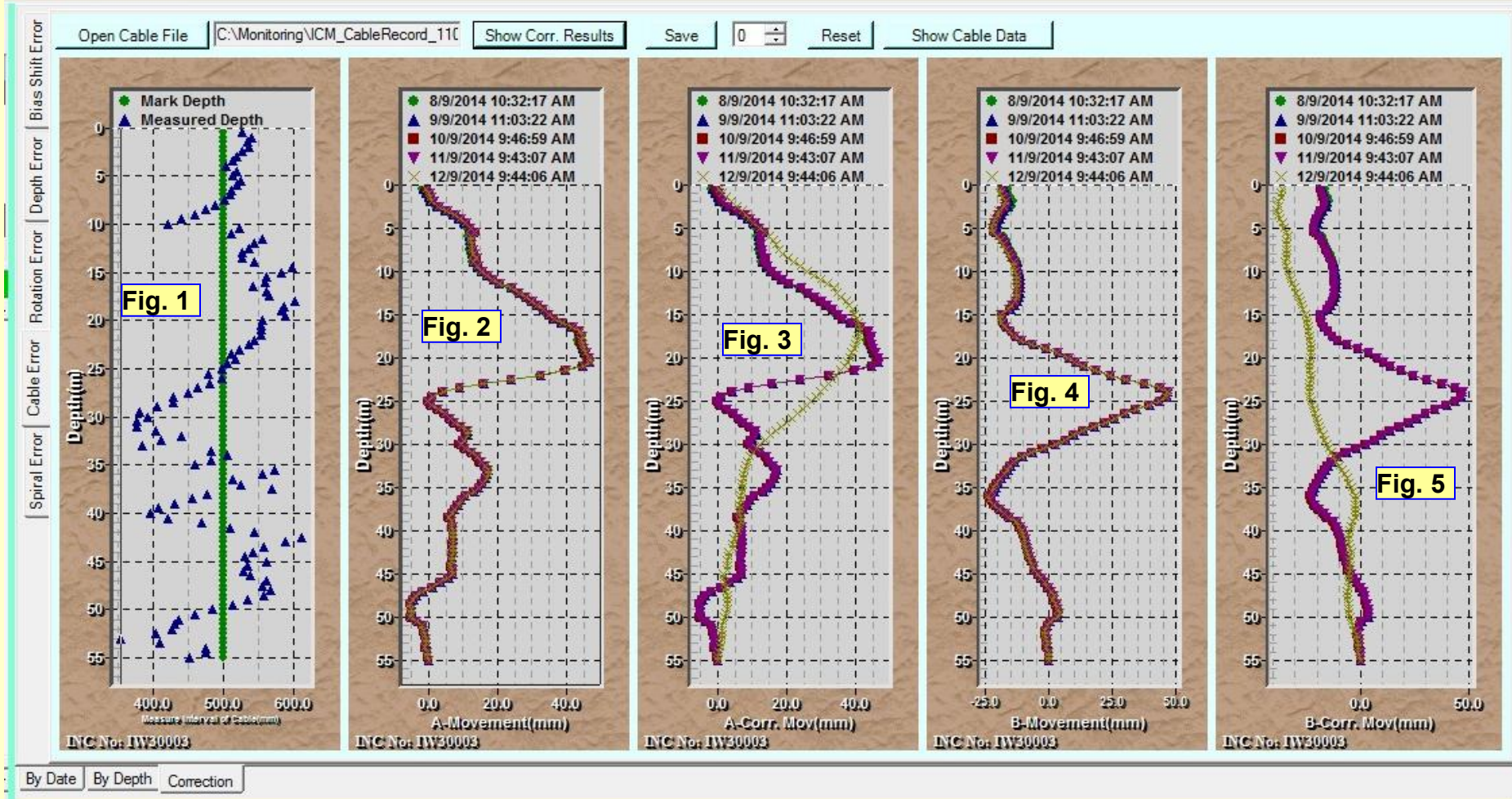
Cable Error



Cable Measurement Data:

- ❖ Input Project ID, Instrument ID using this cable, Measure Date, Cable Serial No
- ❖ Input the measured interval values, check and make sure the data are correct and complete
- ❖ GeoSmart only accept the file if the Project ID and Hole ID match between the cable data file and GeoSmart Database

Cable Error Correction



Cable Error Correction:

- ❖ Fig.1: Actual measured length for each 0.5m section of cable (Blue color) and green color line is exactly 0.5m interval.
- ❖ Fig. 2 & Fig. 3 are A-Direction Movement before and after cable correction.
- ❖ Fig. 4 & Fig. 5 are B-Direction Movement before and after cable correction

Spiral Error Correction

Open Spiral File: C:\Monitoring\ICM_SpiralRecord_B2_ Show Corr. Results Save 20 Reset Show Spiral Data

7.749, 46.044 -151.54

Must input ICMSPIRAL

Open Cable Data File

Code of Instrument: ICMSPIRAL GeoSmart will read data with red color

Record Form for Inclinator Spiral Check

Probe No:		Azimuth:	0
Project ID:	P373	Hole ID:	IW29001
Measured by:	SELVARAJ	Date:	10/Jul/2013
Depth Adjust Value:	1.25 (m)	Zero Offset:	-5.75 (Minute)

Depth (m)	Adjusted Depth (m)	A0	A180	AVGERAGE	Corrected Data	ΣSpiral	Angle (Degree)
	1.25					0	0.00
1.5	2.75	11	60	35.5	41.25	41.25	0.69
3	4.25	26	86	56	61.75	103	1.72
4.5	5.75	39	36	37.5	43.25	146.25	2.44
6	7.25	58	25	41.5	47.25	193.5	3.23
7.5	8.75	51	35	43	48.75	242.25	4.04
9	10.25	42	58	50	55.75	298	4.97
10.5	11.75	41	64	52.5	58.25	356.25	5.94
12	13.25	35	43	39	44.75	401	6.68

Planned Orientation

Azimuth

A0

B180

B0

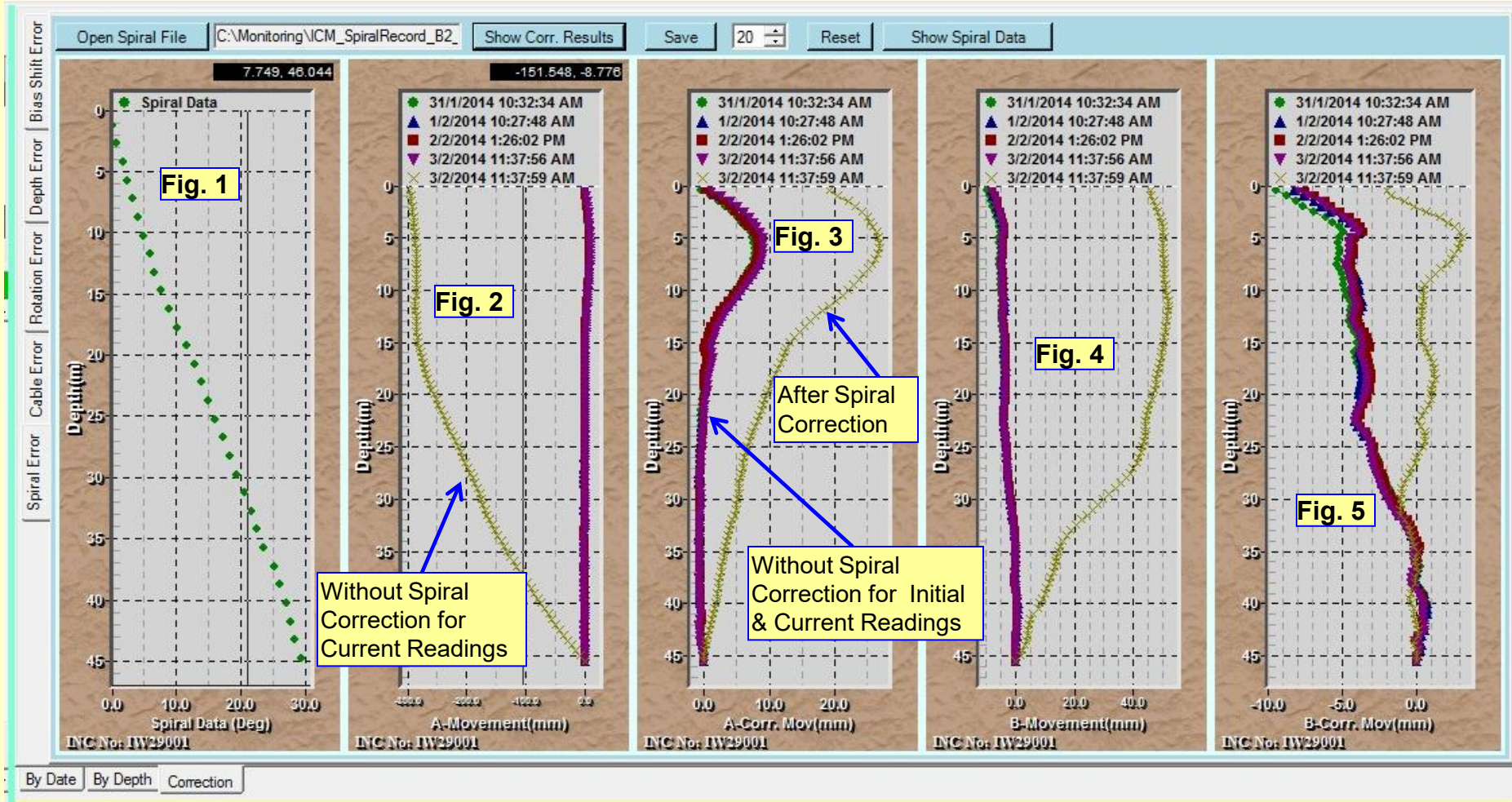
A180

By Date By Depth Correction

Spiral Measurement Data:

- ❖ Input Project ID, Instrument ID, Measure Date
- ❖ Input the measured data values, Depth Adjust Value, Zero Offset and Azimuth Angle
- ❖ GeoSmart only accept the file if the Project ID and Hole ID match between the spiral data file and GeoSmart Database

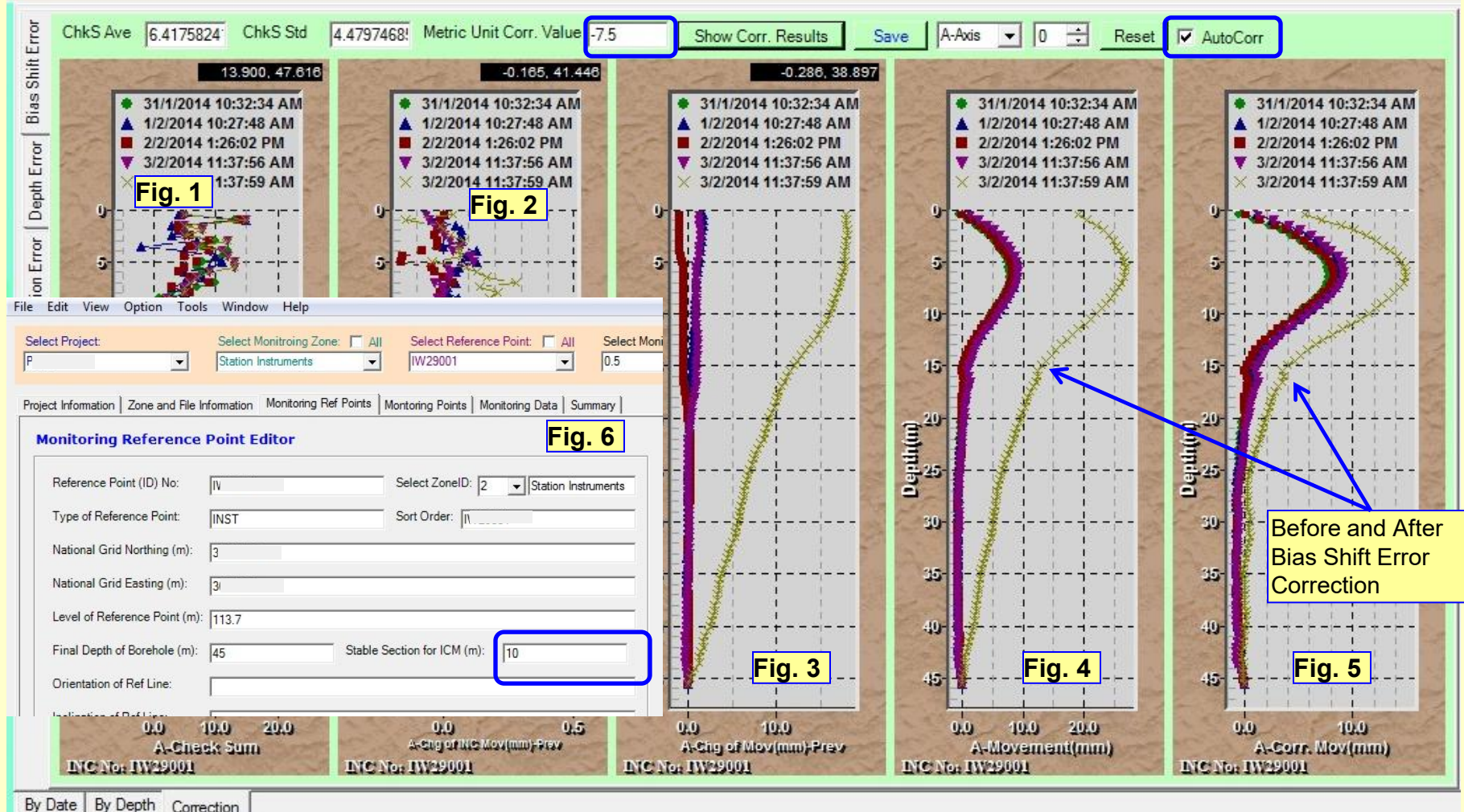
Spiral Error Correction



Cable Error Correction:

- ❖ Fig.1: Spiral Data for the measured inclinometer casing
- ❖ Fig. 2 & Fig. 3 are A-Direction Movement before and after spiral correction
- ❖ Fig. 4 & Fig. 5 are B-Direction Movement before and after spiral correction

Auto Bias Shift Error Correction



Auto Bias Shift Error Correction:

- ❖ Fig.6: Input the length of Stable Section for the inclinometer, Tick the AutoCorr, then GeoSmart will automatically calculate the Metric Unit Correction Value based on the bottom stable section. Refer to the area highlight by 
- ❖ Fig. 4 & Fig. 5 are A-Direction Movement before and after Bias Error Correction