Using Optech LMS to Calibrate Survey Data Without Ground Control Points

Challenge

An Optech client conducted an airborne lidar survey over a sparsely developed river valley. The data processors were finding that the data acquired in this survey was particularly difficult to calibrate. Because the terrain in the surveyed area was so rugged and undeveloped, there were almost no regular geometric structures on the ground to serve as references for the establishment of ground control points (Figure 1).

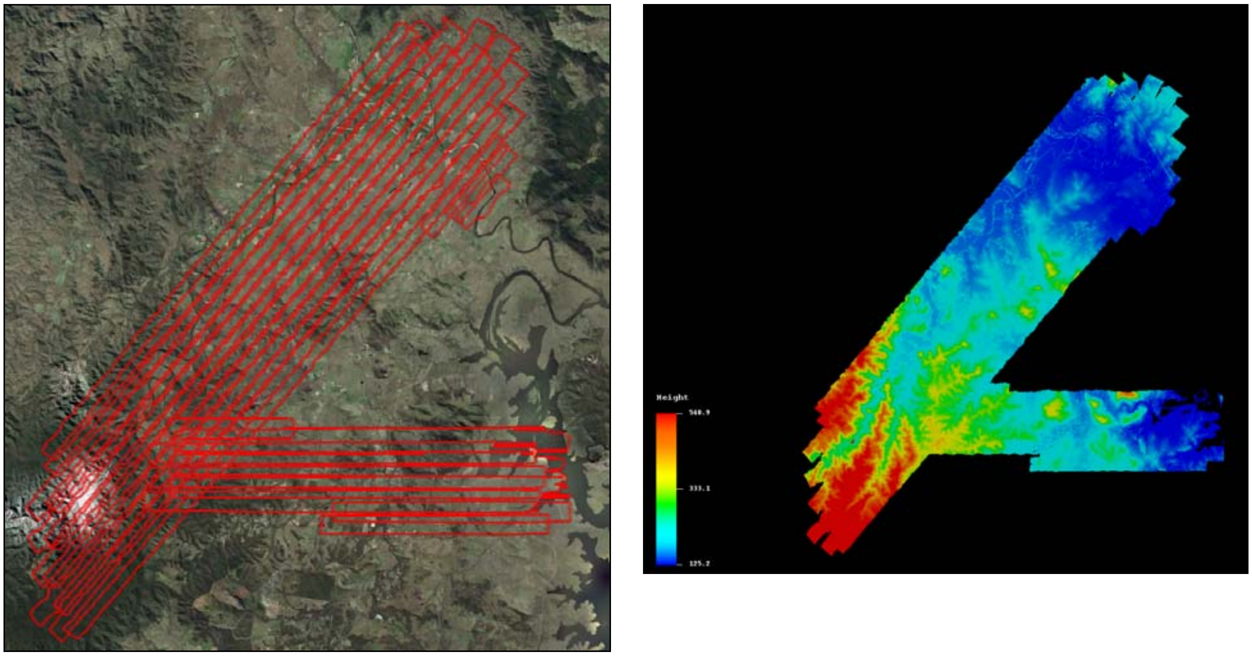


Figure 1: Google Earth image of survey area (left), and elevation in meters (right)

To support its client, Optech re-processed the raw survey data in Optech LMS, a recently released lidar data processing software application that excels at identifying and defining regular planar surfaces from which reliable ground control points can be determined. A regular production survey workflow was set up in Optech LMS to ascertain differences between data processed in the customer's program and the same data processed in Optech LMS.

After an airborne lidar survey is carried out, the acquired position data (XYZ points) must be calibrated; relative calibration is typically performed in the lidar data post-processing software. One reason that Optech LMS was used to re-process the data is that it features a robust auto-calibration tool not available in the other software.

The full survey was processed in Optech LMS Pro to auto-calibrate the lidar data and align the finished product accurately and efficiently.

Adjustments

One reason the customer found the survey difficult to properly calibrate is that no cross-strips were included in the data. Ideally, an airborne survey should include cross-strips as this data can be used as a reference to assist in the calibration process.

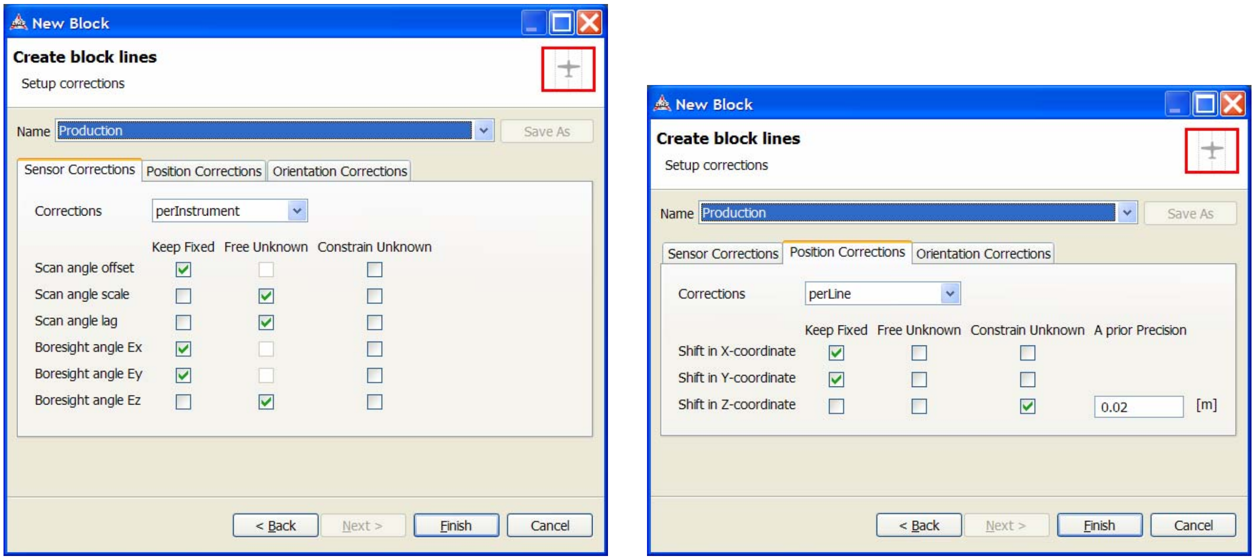
Table 1 shows the parameter settings used in the survey.

Table 1: Parameter settings used in survey

Parameter	Setting
Laser pulse repetition frequency (PRF)	70 kHz
Laser scan frequency	37 Hz
Scan angle	±21°
Altitude above ground level	1200 - 1500 m
Desired accuracy	<12 cm

To correct position errors the Optech LMS processor started with three parameters that require systematic adjustments. These **Sensor Corrections** are made in the Optech LMS interface window, **Create block lines** (Figure 2, left):

- Scan angle scale
- Scan angle lag
- Boresight angle Ez.



Name: Production

Corrections: perInstrument

	Keep Fixed	Free Unknown	Constrain Unknown
Scan angle offset	☑	☐	☐
Scan angle scale	☐	☑	☐
Scan angle lag	☐	☑	☐
Boresight angle Ex	☑	☐	☐
Boresight angle Ey	☑	☐	☐
Boresight angle Ez	☐	☑	☐

Name: Production

Corrections: perLine

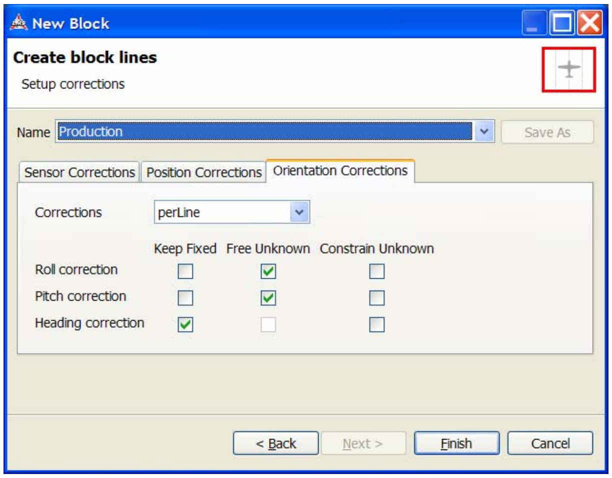
	Keep Fixed	Free Unknown	Constrain Unknown	A prior Precision
Shift in X-coordinate	☑	☐	☐	
Shift in Y-coordinate	☑	☐	☐	
Shift in Z-coordinate	☐	☐	☑	0.02 [m]

Figure 2: Create block lines, Sensor Corrections (left), Position Corrections (right)

The parameter, **Boresight angle Ez**, corrects heading error on a *per instrument* basis. The other corrections are done on a *per flightline* basis, and due to the nature of the terrain, coupled with the absence of a true cross-strip in this survey, it was deemed best to calculate the heading value on a *per sensor* basis.

For **Position Corrections** the only variable that required adjustment was a shift in the Z-coordinate (Figure 2, right). “Constrain Unknown” is used to shift the Z-coordinate. This matches the lines in the Z-coordinate to an accuracy within 0.02 m.

The **Orientation Corrections** tab is where pitch and roll are adjusted. In this case, because the heading was adjusted in the **Sensor Corrections** tab, it remains fixed here (Figure 3).



Name: Production

Corrections: perLine

	Keep Fixed	Free Unknown	Constrain Unknown
Roll correction	☐	☑	☐
Pitch correction	☐	☑	☐
Heading correction	☑	☐	☐

Figure 3: Create block lines - Orientation corrections

Results

After approximately 18 hours, 20 GB of data was processed in Optech LMS and output as georeferenced XYZ points. Optech LMS produces output reports that show the standard deviation values of the sensor corrections: scan scale, scan lag and heading. Reports for the flightline corrections—elevation, roll and pitch—are also shown. Statistics for all planes are also available on a per flightline basis. These show the flightline number, the number of points associated with each flightline, the mean deviation, the RMS deviation and the standard deviation for each.

To an experienced lidar data processor, significant differences can be seen when comparing before-and-after statistics. To someone unfamiliar with comparing such statistics the differences in these values are not readily apparent, but when viewing the summary plots that Optech LMS also outputs, the graphical representations illustrate the differences visually, making them immediately more evident (Figure 4, Figure 5).

In Figure 4 the distances of all the tie planes are shown relative to each other. On the Y-axis *Frequency* represents the percentage of data found at a given distance. For example, the distance of -0.01 m comprises 8% of the data after Standard Processing (top), and 12% of the data after Refined Processing (bottom).

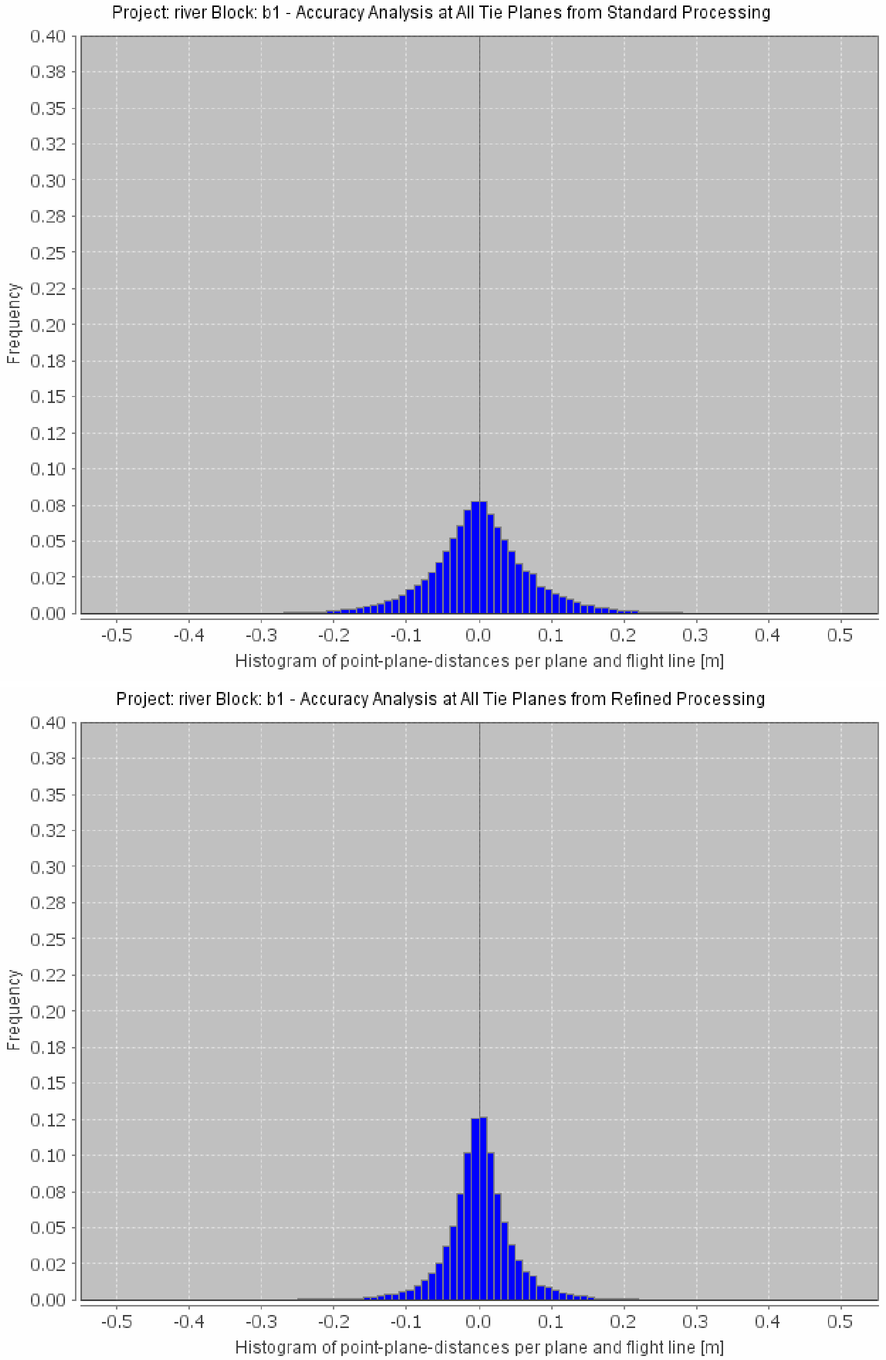


Figure 4: Two plots showing the distances of all tie planes relative to each other

Figure 5 shows the distances of error between all tie planes compared with the scan angle. If the tie plane lines up at 20° and is 0.10 m off, it is placed within the scatter plot. The scatter plot is similar to the histogram but uses the scan angle as the X-axis.

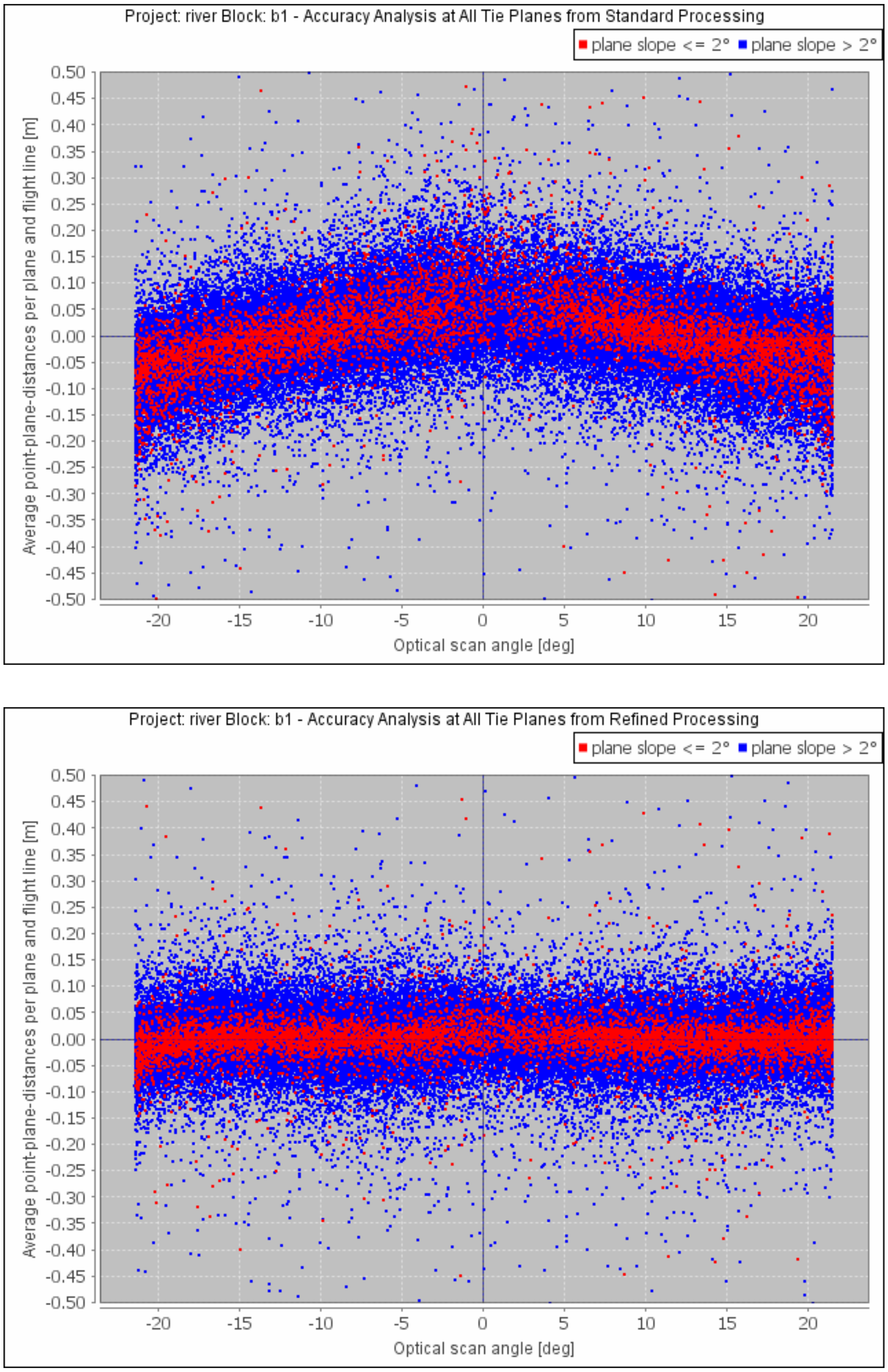


Figure 5: Two plots showing the distances of error between all tie planes compared with the scan angle

Visual checks

Visual checks consist of examining the data visually after it is output in a graphical format to make sure that it corresponds to the accuracy indicated in the statistics. Some processors handle this differently, but mainly it involves judging that the output LAS files line up with each other and satisfy the criteria specified in the deliverables.

All the data was processed with no cut-off applied to the swath. The three visual checks shown in Figure 6 are from the east-west strips, the center overlap, and north-south strips. A Ground Classification feature was used to remove vegetation and buildings for analysis (Figure 7, Figure 9).

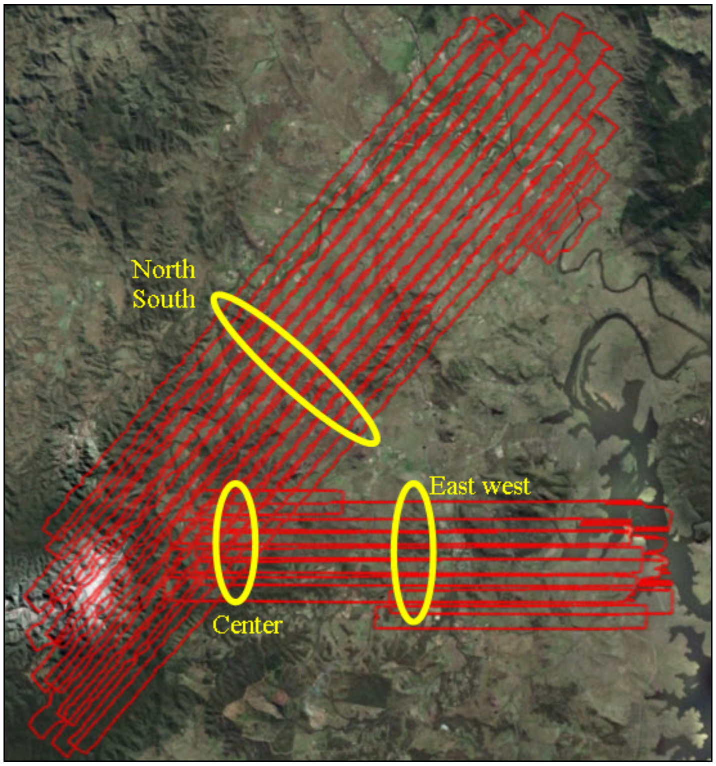


Figure 6: Sample areas for visual check

To show vegetation for analysis, a Height-Above-Ground feature was used to reveal all areas that are 3 m or higher above the ground (Figure 7, Figure 9).

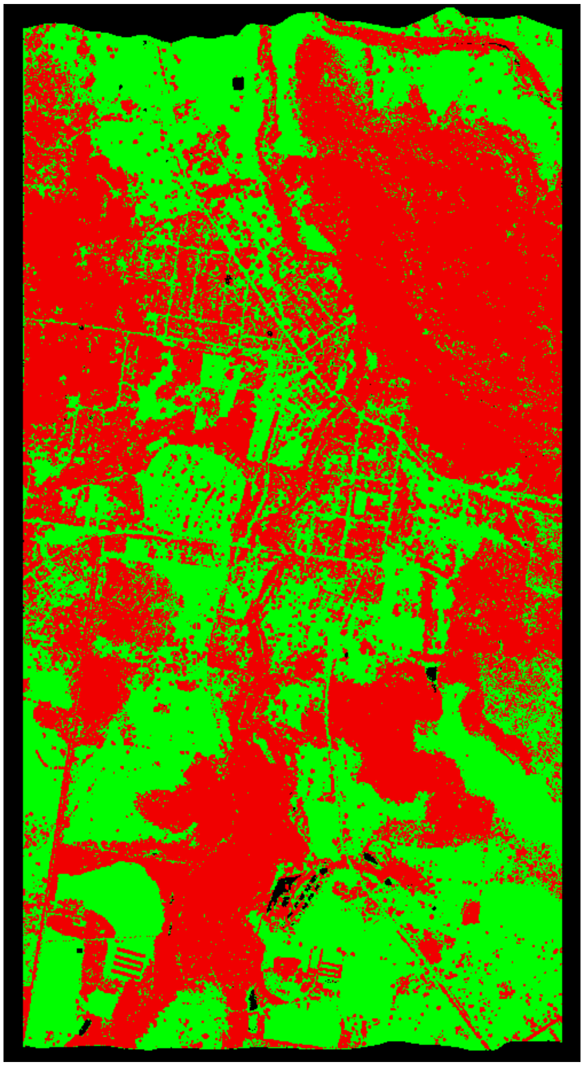


Figure 7: Vegetation on east-west area

A Distance Analysis feature was used to compare overlap regions visually (Figure 10) while a Measure-Match feature was used to get an average magnitude of the overlapped regions. Measure-Match is a tool that judges elevation differences on overlap regions between different flightlines. It provides an average magnitude of the overlapped regions, average magnitude being the average distance among all samples (in an absolute sense). The end result is closer to an RMS/Std Deviation value.

In Figure 8 the gradient scale at right shows the correspondence between color and average flightline distance. The colors in the image show the distance from the flightline average on the overlapped regions. A preponderance of yellow and green is better because yellow and green are ±5 cm apart from the average distance.

Table 2: Measure match statistics

Area of interest	Average magnitude (m)
North-south	0.03425
Center	0.03875
East-west	0.04761

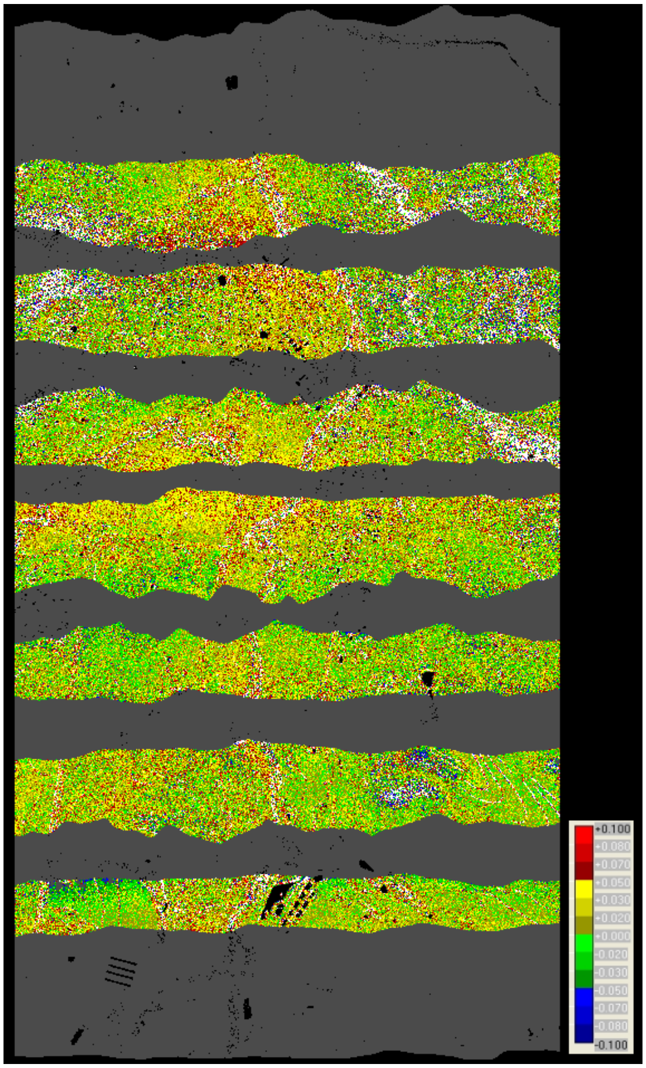


Figure 8: Flightline average distance analysis on east-west strips

In Figure 9 the color red indicates vegetation, while green indicates ground. Knowing where vegetation is in relation to bare ground helps in judging the distance analysis.

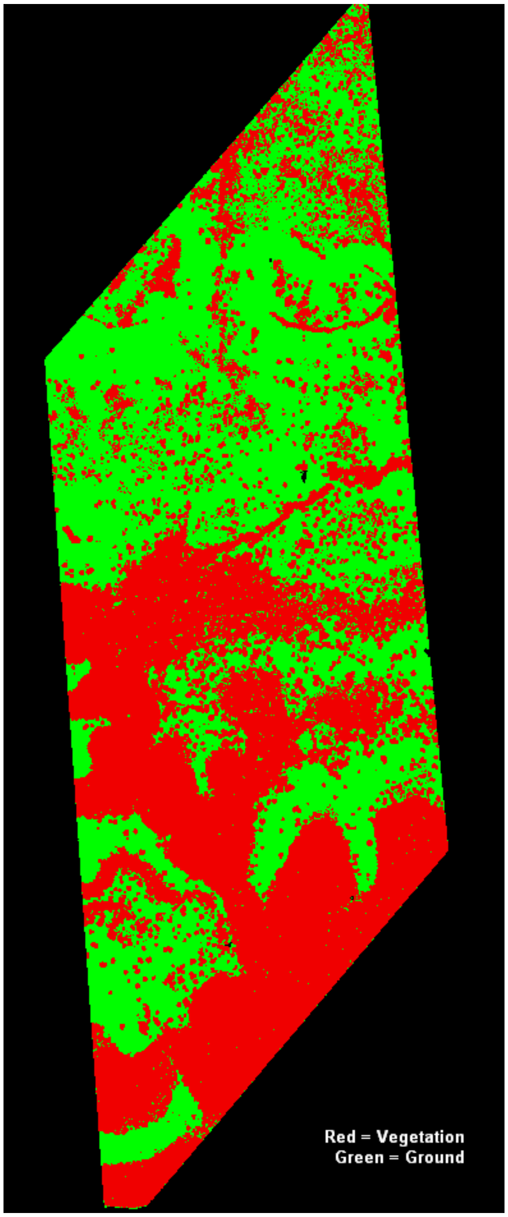


Figure 9: Vegetation on center area

Figure 10 shows that the overlap regions line up properly, which is the purpose of the visual check and why it is needed.

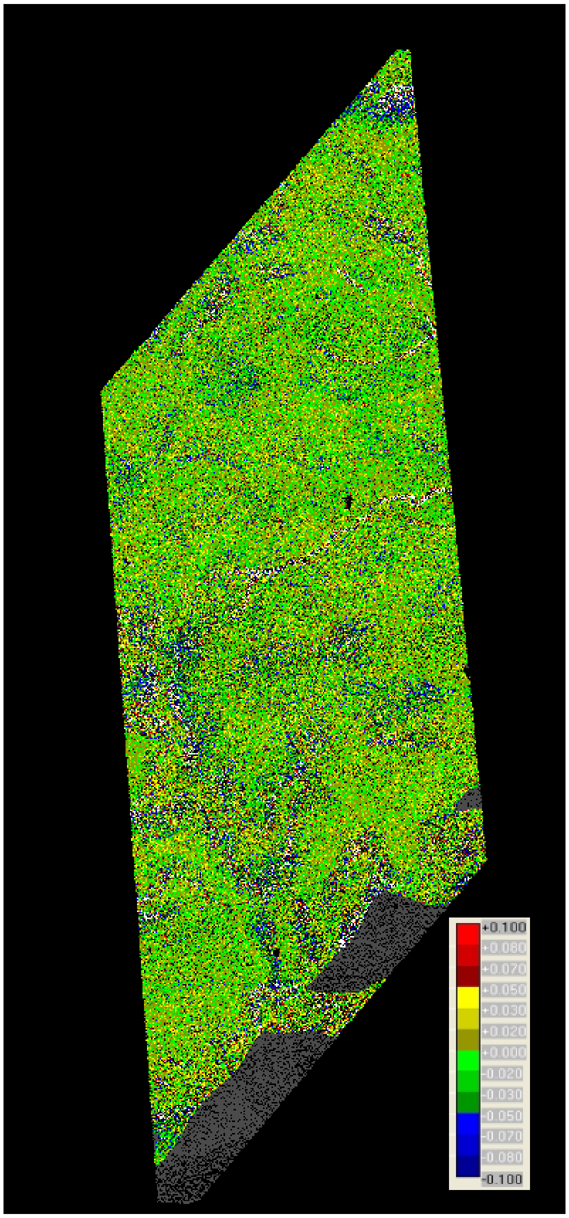


Figure 10: Flightline average distance analysis on center overlap area

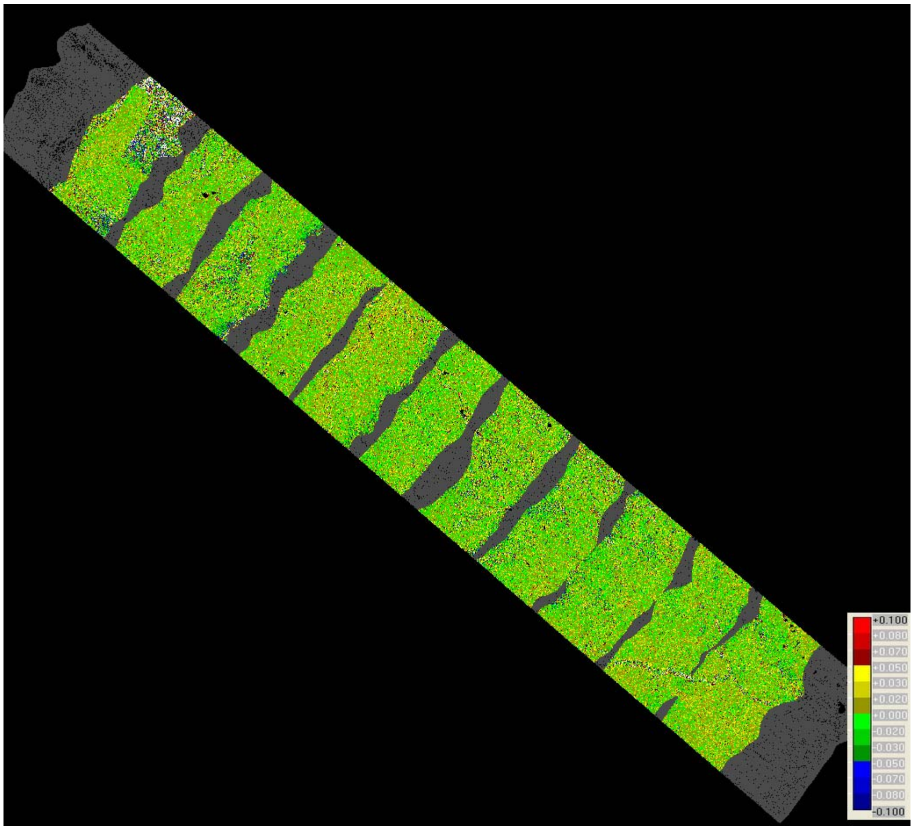


Figure 11: Flightline average distance analysis on north-south strips

Conclusion

Taking advantage of the tools included in the software—reports, statistics, charts—and using positive visual checks, the processors used Optech LMS to successfully calibrate the survey data to well within the 12 cm (relative) specification of the survey **without** control points. The full raw range data comprised 20 GB and covered an area of roughly 435 km^2. Even though there are very limited rooflines in this survey area, Optech LMS consistently determined planes to accurately calibrate the data.