

## StripAlign 2.23-2.24 - XYZ GCP support, ASPRS compliance

**Support for XYZ GCP was added in version 2.23.** The main purpose is to constrain horizontal accuracy using at least one point.

The user needs to supply not only the GPS collected GCP coordinates, but also the **measurement** made in at least one of the swaths in the dataset to be corrected. This measurement can be made manually in another software able to display point clouds, and help find the optimal location of geometric or intensity features. For instance, a XYZ GCP can be a building corner (geometry), a manhole (intensity), portable UAV targets etc.

Only a few such measurements are needed to constrain a full dataset. All collected GCP can be used for the vertical GCP feature that makes automatic height measurements (and can eliminate outliers with `-gcp_out`). **XYZ and Z GCP can be used together**, and usually the XYZ GCP help constrain the horizontal location for the Z GCP to be measured more accurately. When both types are present, the absolute horizontal QC is done with the XYZ GCP, while the absolute vertical QC is done as usual with the Z GCP.

**Compliance with ASPRS accuracy standard in version 2.24.** See "*Options specific to Z GCP*" below.

### Example of XYZ GCP input file format (ASCII)

Compared to previously supported GCP files, the XYZ GCP files require **4 extra columns** for each point: the XYZ measurements in a specific swath, and a string that uniquely identifies that swath (usually a substring of the file name that contains the timestamp).

The full swath names are `3127_210712_084642_Channel_1.laz` and `3127_210712_093421_Channel_1.laz`.

There are 2 swaths, 2 GCP collected, and 4 measurements total. Here only GCP1 is used as control.

Column format (use with `-xyz_gcp_parse`) **ixyzfXYZc** (index, collected xyz, swath id string, measured XYZ, control flag).

GCP1	801.24	1253.97	453.21	210712_084642	801.11	1253.83	453.31	1
GCP1	801.24	1253.97	453.21	210712_093421	801.34	1253.77	453.29	1
GCP2	717.92	1282.41	491.57	210712_084642	717.79	1282.34	491.50	0
GCP2	717.92	1282.41	491.57	210712_093421	717.82	1282.68	491.68	0

### Example of command line using both Z and XYZ GCP, with specific column formats

There is a new set of options related to XYZ GCP, similar to previous GCP options, they start with `-xyz_gcp` instead of `-gcp`.

Commands `-align` and `-reg` use GCP input, as well as the manual correction command `-corr` (without argument), which can run QC and correct GCP-related biases by simply applying a shift to each swath.

This is an **alignment** command (input and directory options omitted) using both types of GCP:

```
stripalign -align ... -gcp gcp.txt -gcp_parse ixyzc -xyz_gcp xyzgcp.txt -xyz_gcp_parse ixyzfXYZc
```

This type of run produces both types of reports `_GCP.log` `_GCPcorr.log` and `_XYZGCP.log` `_XYZGCPcorr.log`.

The bias computed from GCP is now a **3D** vector with X and Y components derived from the XYZ GCP data. By default this bias is subtracted from the correction to maximize horizontal and vertical absolute accuracy.

## Z GCP options

### Options having a XYZ GCP equivalent:

**-gcp** to specify the GCP input file (ASCII) and enable the GCP feature at the same time. Requires at least the XYZ coordinates for each point. Index, accuracy, control flag optional

**-gcp\_dz** enabled by default, controls the Z GCP bias correction (only uses points flagged as control)

**-gcp\_parse** to specify the column format of the Z GCP input file. The default parse string is `ixyz` with respective columns: index, collected point coordinates. The index is optional in general. Other optional columns are `s` for accuracy and `c` for control flag. Use `.` or `#` to ignore a column

**-gcp\_check** disabled by default, treats all GCP as check instead of control points if enabled, and if the control column is missing or ignored

**-gcp\_sigma** sets the vertical accuracy of XYZ GCP measurements when the respective column is missing or ignored (default 0.005)

**-gcp\_equal** disabled by default (0), uses equal weights for all XYZ GCP when computing stats (by default points are inverse variance weighted with variance from local roughness and GCP sigma, use 2 to ignore the roughness component)

### Options specific to Z GCP:

**-gcp\_out** disabled by default, when enabled (no argument) the GCP statistics become robust to outliers, which helps the entire correction become more robust to obstructed or displaced GCP

**-gcp\_r\_max** sets the maximum roughness for GCP filtering (default 2)

**-gcp\_d\_min** sets the minimum density for GCP filtering (default 0.1)

**-ogcp\_pc** disabled by default, to export LiDAR points (filtered during tiling) within a certain distance of each GCP (distance is 2.6xGGSD or 1.3xFWHM, FWHM given in GCP report header). File name suffixes: `_GCP_PC.txt` (original) `_GCP_PC_corr.txt` (after correction). Column format: X Y Z Swath# Group#

**-ogcp\_pc** also exports a GCP Z measurement file when the GCP point cloud is exported with option above. File name suffixes: `_GCP_sw.txt` (original) `_GCP_sw_corr.txt` (after correction). Column format: `index_sw_# X Y Z_LiDAR sw`

**-ogcp\_tin** adds a section at the end of each GCP report to comply with the current ASPRS vertical accuracy standard, which requires point elevations to be interpolated from a triangular irregular network (TIN). This section repeats the GCP occurrence list with GCP names, swath and group, coordinates, and also the coordinates of the 3 vertices of the triangle containing the GCP. The last column gives the z difference as computed from triangle interpolation. This information is not used in any of the computed statistics and is only provided for compliance. If `-obj` is used, triangles are exported along with the point clouds and measurements (`out_GCP_tin.obj`)

## XYZ GCP options (new)

**-xyz\_gcp** to specify the XYZ GCP input file (ASCII) and enable the XYZ GCP feature at the same time. Compared to previously supported GCP files, the XYZ GCP files require 4 extra columns for each point: the XYZ measurements in a specific swath, and a string that uniquely identifies that swath (usually a substring of the file name that contains the timestamp)

**-xyz\_gcp\_corr** enabled by default, controls the XYZ GCP bias correction (only uses points flagged as control)

**-xyz\_gcp\_parse** to specify the column format of the XYZ GCP input file. The default parse string is `ifxyzXYZ` with respective columns: index, swath id string, collected point coordinates, measured point coordinates in the swath. The index is optional. Other optional columns are `h` for horizontal accuracy, `v` for vertical accuracy and `c` for control flag (same meaning as corresponding Z GCP options but horizontal and vertical accuracies are separate). Use `.` or `#` to ignore a column, same syntax as option `-gcp_parse`

**-xyz\_gcp\_check** disabled by default, treats all XYZ GCP as check instead of control points if enabled, and if the control column is missing or ignored

**-xyz\_gcp\_sxy** sets the horizontal accuracy of XYZ GCP measurements when the respective column is missing or ignored (default 0.02)

**-xyz\_gcp\_sz** sets the vertical accuracy of XYZ GCP measurements when the respective column is missing or ignored (default 0.02)

**-xyz\_gcp\_equal** disabled by default, uses equal weights for all XYZ GCP when computing stats (by default points are inverse variance weighted)

## Common options

**-gcp\_grp** disabled by default, for both Z and XYZ GCP per group (instead of global) bias cancellation

## Notes

**Robust measurement of height for Z GCP:** GCP Z measurements are done directly on the point clouds, robust to overhead structures and vegetation or nearby buildings. In version 2.20, a robust algorithm replaced the previous one that was based on gridded intermediate products. GCP stat files now contain accurate local roughness and uncertainty estimates, and the local slope. If the horizontal error is too large, the neighborhood of the point may be in a different area (eg. over instead of near a building) and the feature below is recommended.

**Robust GCP statistics for Z GCP (-gcp\_out):** when enabled, this automatically removes outliers or abnormal z-differences when computing GCP statistics and the global z-bias correction. Even if the GCP measurements are robust to noise and vegetation and objects above the ground, robust statistics are essential when some of the points are unreliable, exhibiting a gross error due to the presence of objects during collection (cars on parking lot) or due to horizontal error (point on the roof ending up on the ground). Requires at least 4 GCP in each group for robust statistics, otherwise regular statistics are used. Two columns in the GCP occurrence list, `In` and `InGrp`, were added in version 2.24 to show if the occurrence was used for summary and group statistics, respectively. 1 means the measurement was used, and 0 means it was rejected as an outlier.

**Use XYZ GCP to constrain horizontal location for Z GCP measurements:** for optimal height measurement by the software for Z GCP, the horizontal error must be reasonable especially in complex areas (near buildings, cliffs, vegetation) where the horizontal location strongly affects height. Using a few XYZ GCP should help constrain the horizontal locations well enough to minimize gross measurement errors.

**Use XYZ GCP instead of Z GCP if points are not in a locally planar area.** GCP acquired over targets, building corners or other features should never be used as Z GCP because the automatic measurement process is inadequate, assuming a (noisy) local plane covered by some outliers. Instead, these points should be treated as XYZ GCP and the user should provide a XYZ measurement for each swath where a point is visible.