Assignment 4

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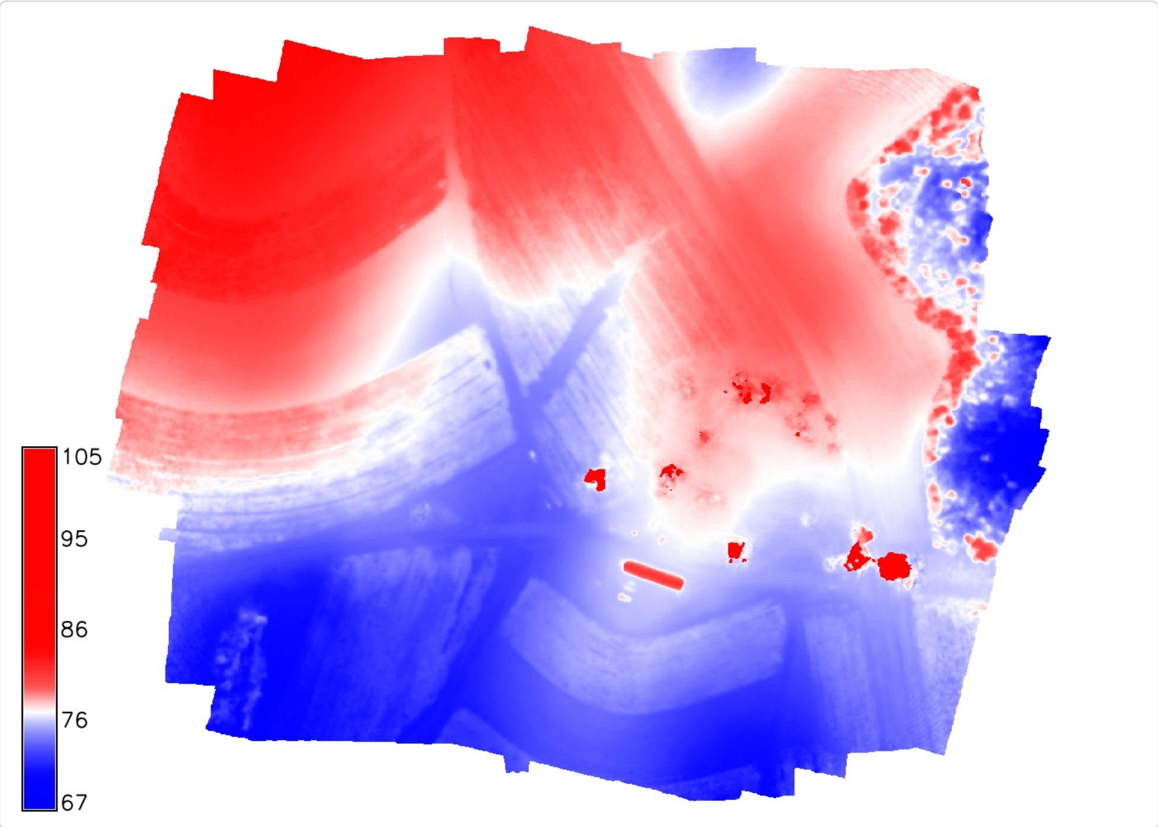
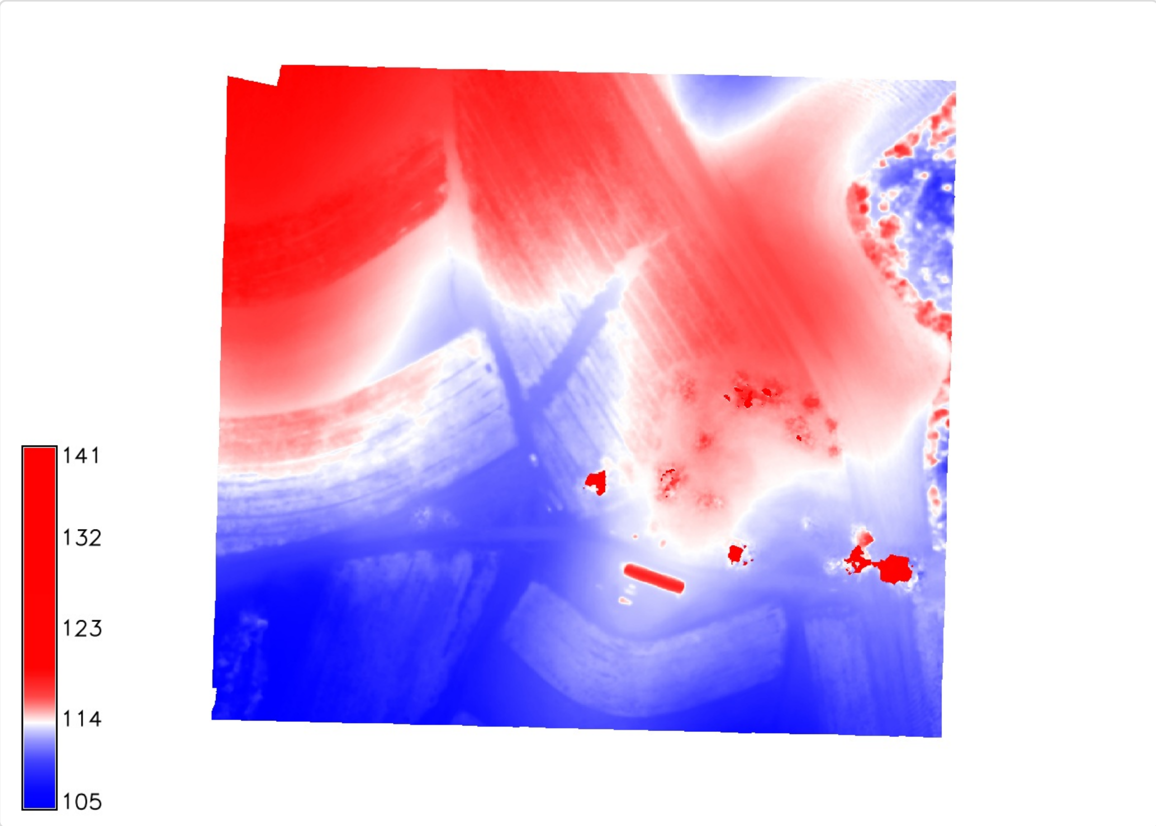
In this assignment we analyze the DSMs derived from the UAS imagery in terms of their accuracy and type of distortions based on the use of GCPs and different processing software. Additionally, we explore methods for discovering and displaying in GRASS GIS the artifacts introduced by certain software when generating the DSMs. Then we map the terrain change (due to vegetation growth, erosion, and other impacts using two different UAS surveys).

DSM Comparison - Influence of GCPs

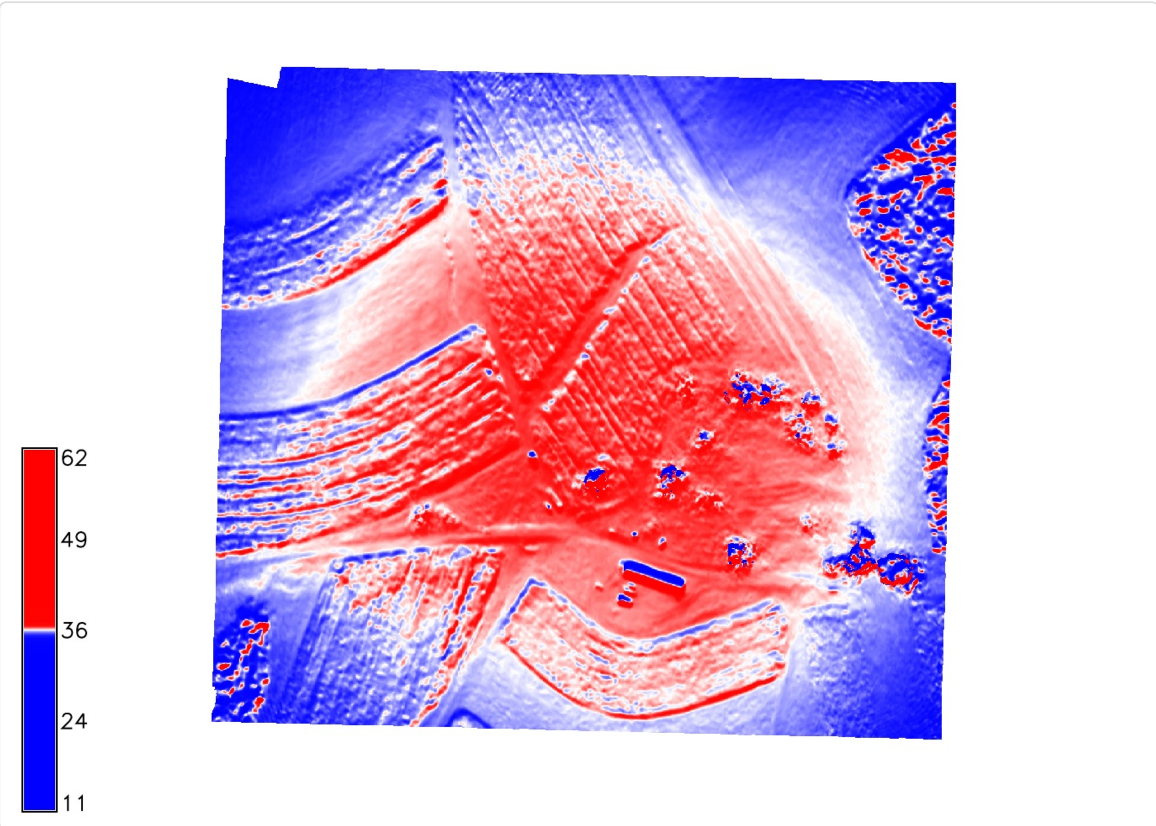
In order to determine the effect of GCPs (Ground Control Points) on the DSMs generated using UAS imagery processing techniques, we can simply generate two DSMs for a single dataset, one using GCPs and the other without using GCPs. A third DSM can then be calculated to show the difference between the two datasets. The following images show this technique using sample data from the Lake Wheeler flight:



Without GCPs



With GCPs



The bowl effect in the Lake Wheeler sample data, processed using Agisoft Photoscan

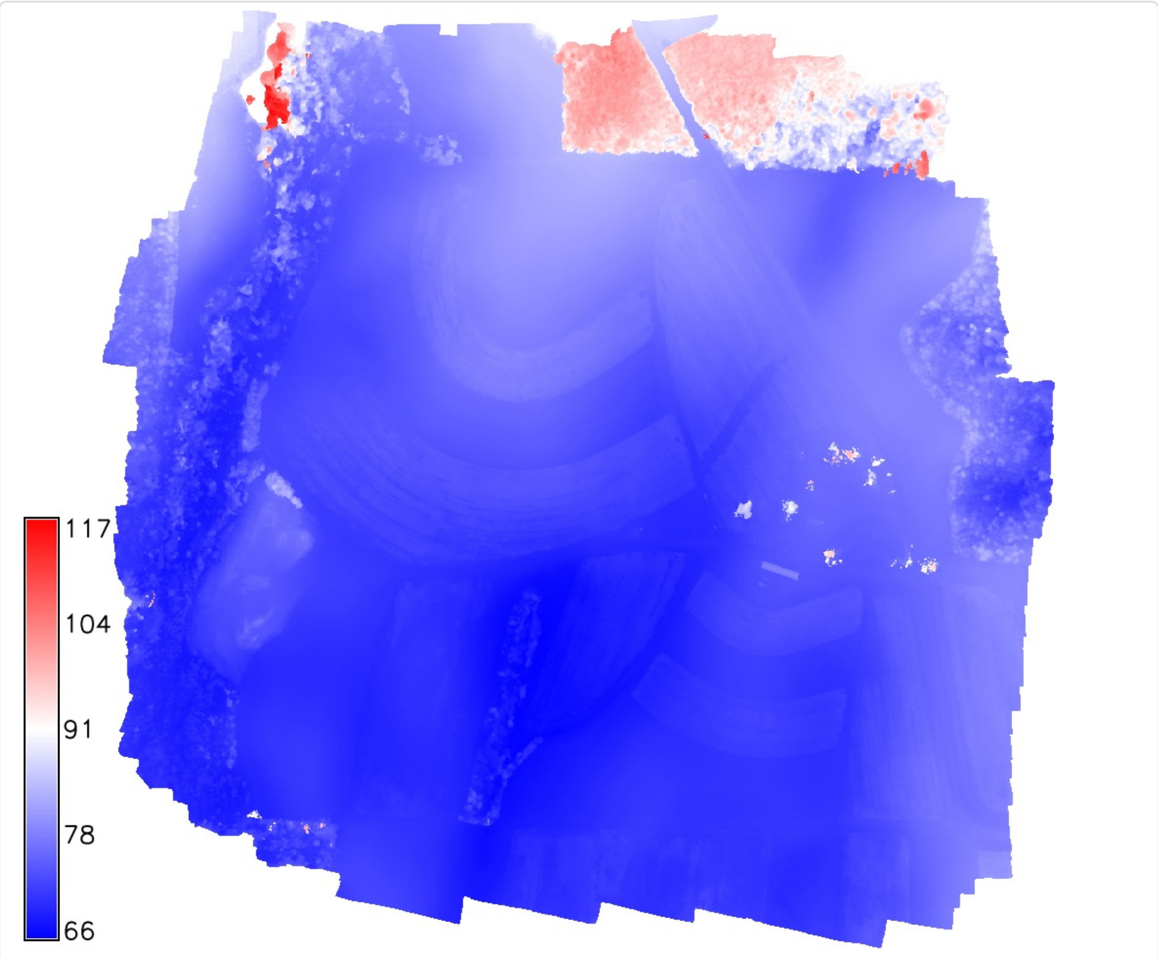
The first two images show the DSMs and the third shows the difference between the two, calculated using the following commands:

```
g.region rast=sample_DSM -p
r.mapcalc expression="GCP_noGCP = sample_DSM - sample_DSM_noGCPs"
```

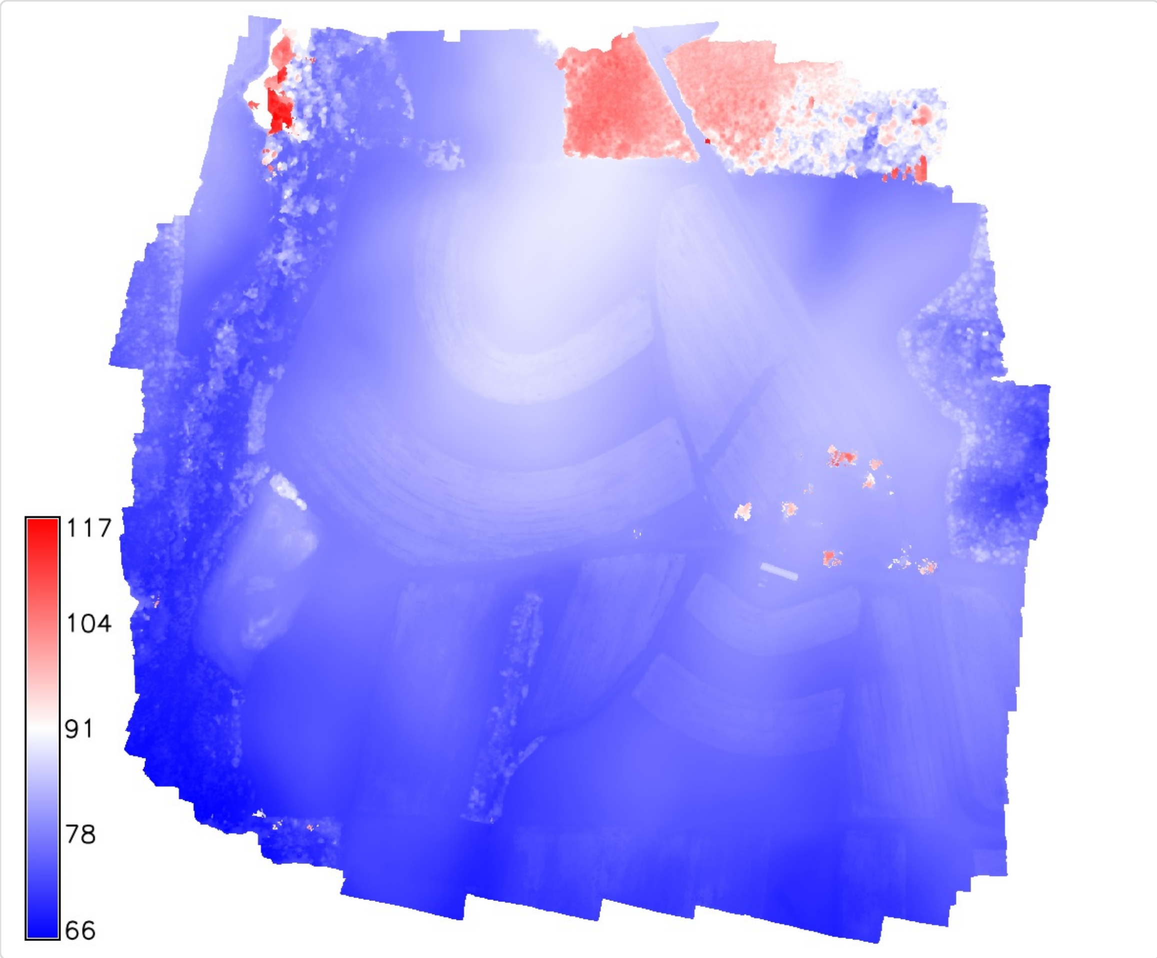
Comparing the results in the first two images by eye, it appears that they are essentially identical. However, if we perform a subtraction, we can reveal the 'bowl effect' that is introduced to the data when GCPs are not used, as seen in the image on the right.

This same effect can be seen in the June 20th flight data by running the following commands:

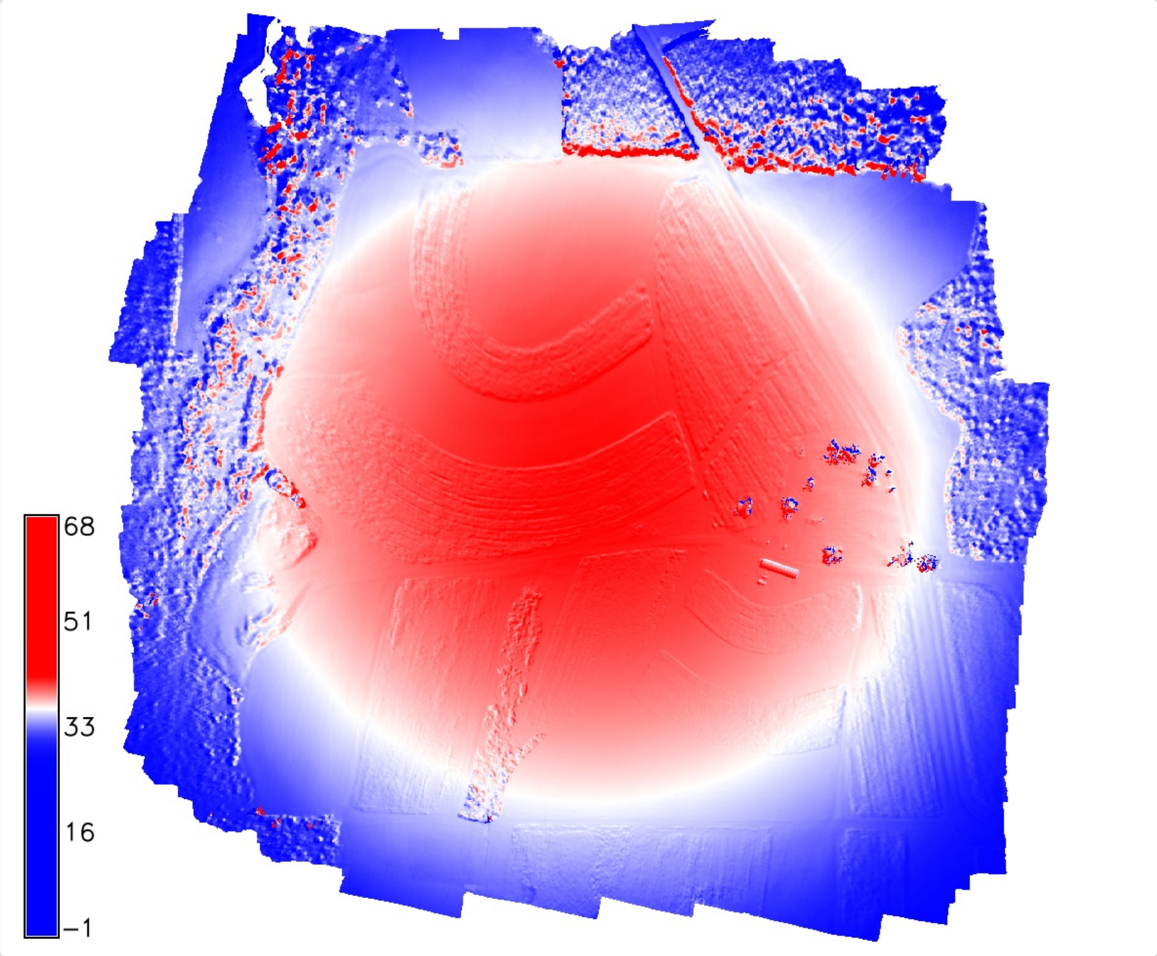
```
g.region rast=2015_06_20_DSM_agi_11GCP -p
r.mapcalc expression="agi_GCP_agi_noGCP = 2015_06_20_DSM_agi_11GCP -
2015_06_20_DSM_agi_noGCP"
```



June 20th Flight, Without GCPs



June 20th Flight, With GCPs

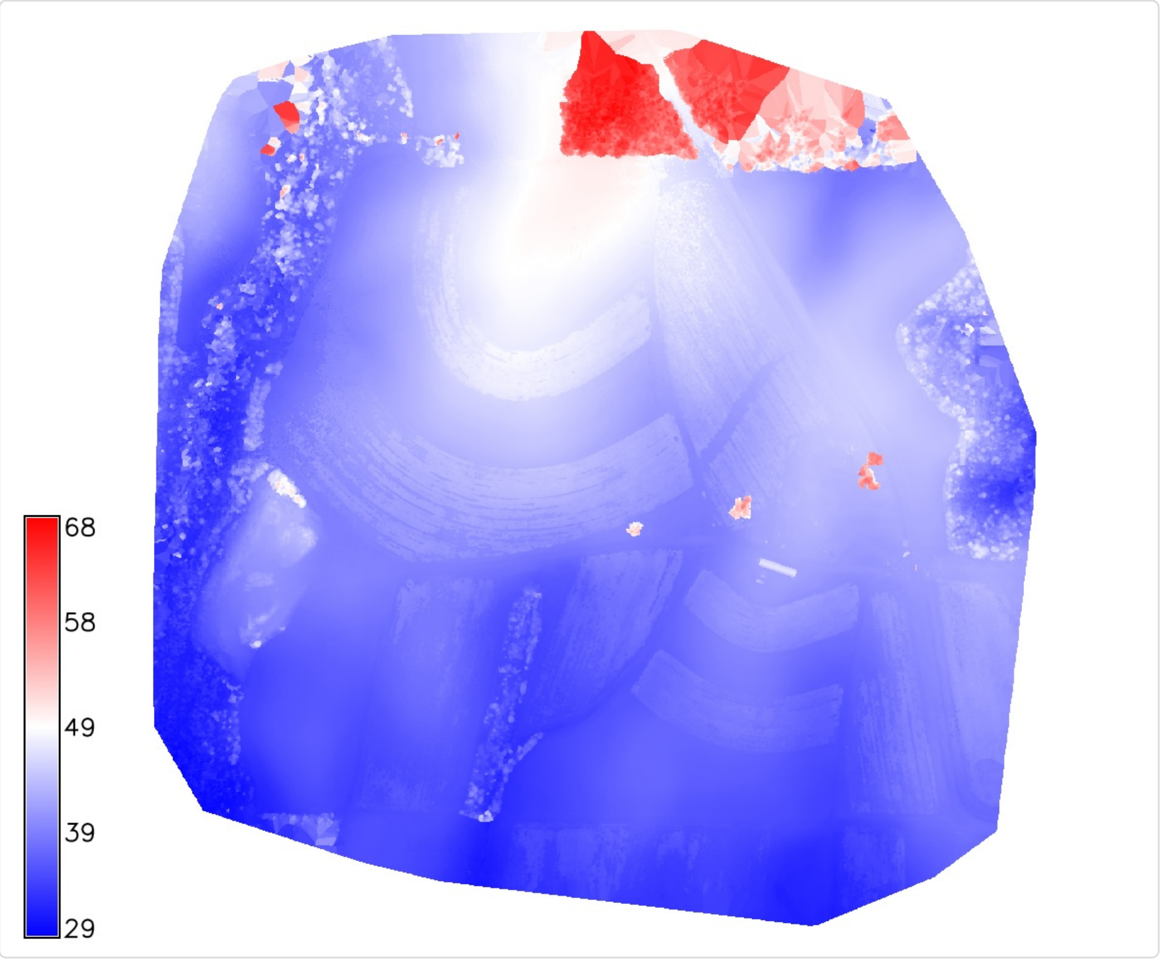


The bowl effect in the June 20th flight data, processed using Agisoft Photoscan

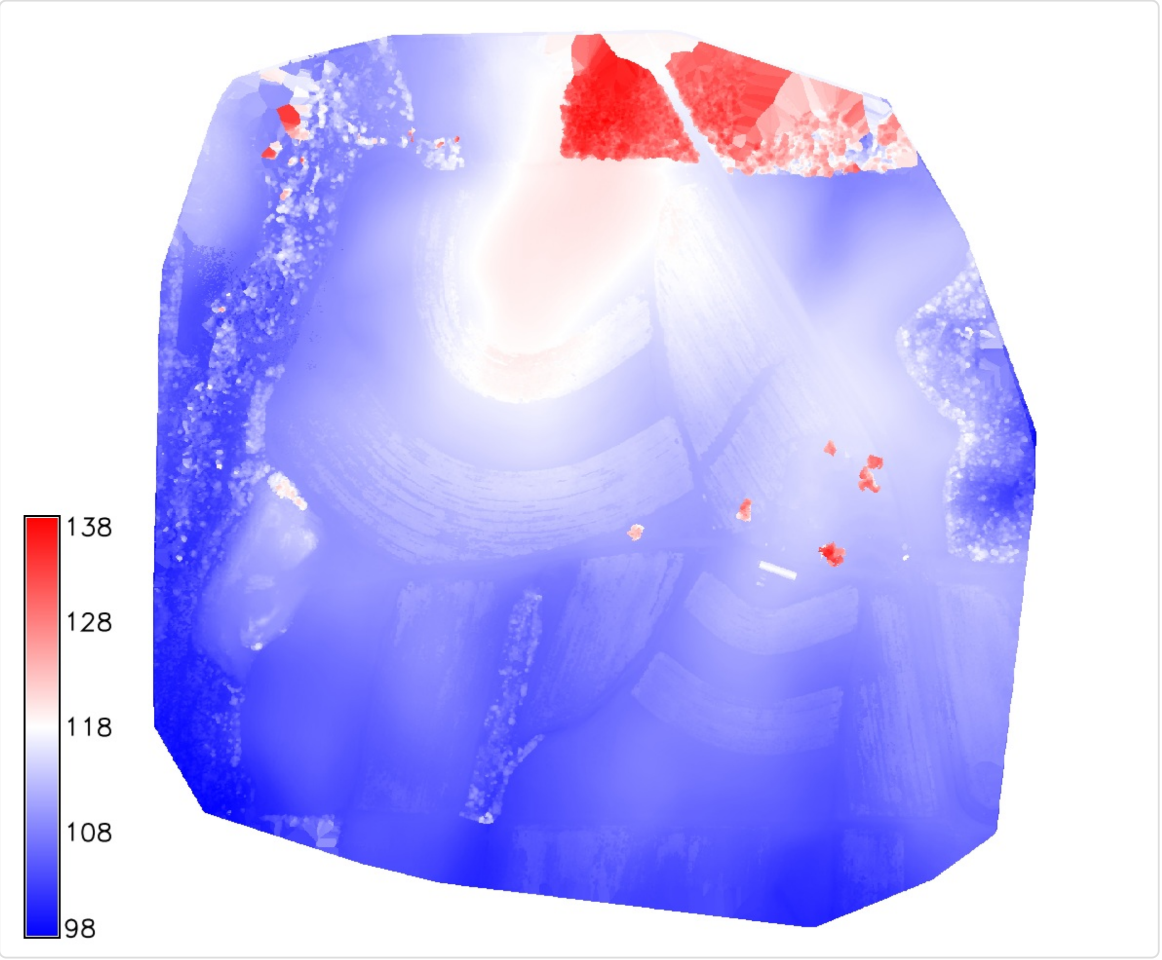
Because the left two images use the same color scale, it is actually easy to see the bowl effect before performing a subtraction. The DSM without GCPs clearly has an area of lower elevation in the center, as compared to the DSM with GCPs. The bowl effect can be seen clearly in the image on the right.

Additionally, we can see that the bowl effect is not unique to Agisoft Photoscan. Processing the data in Pix4D results in a similar effect:

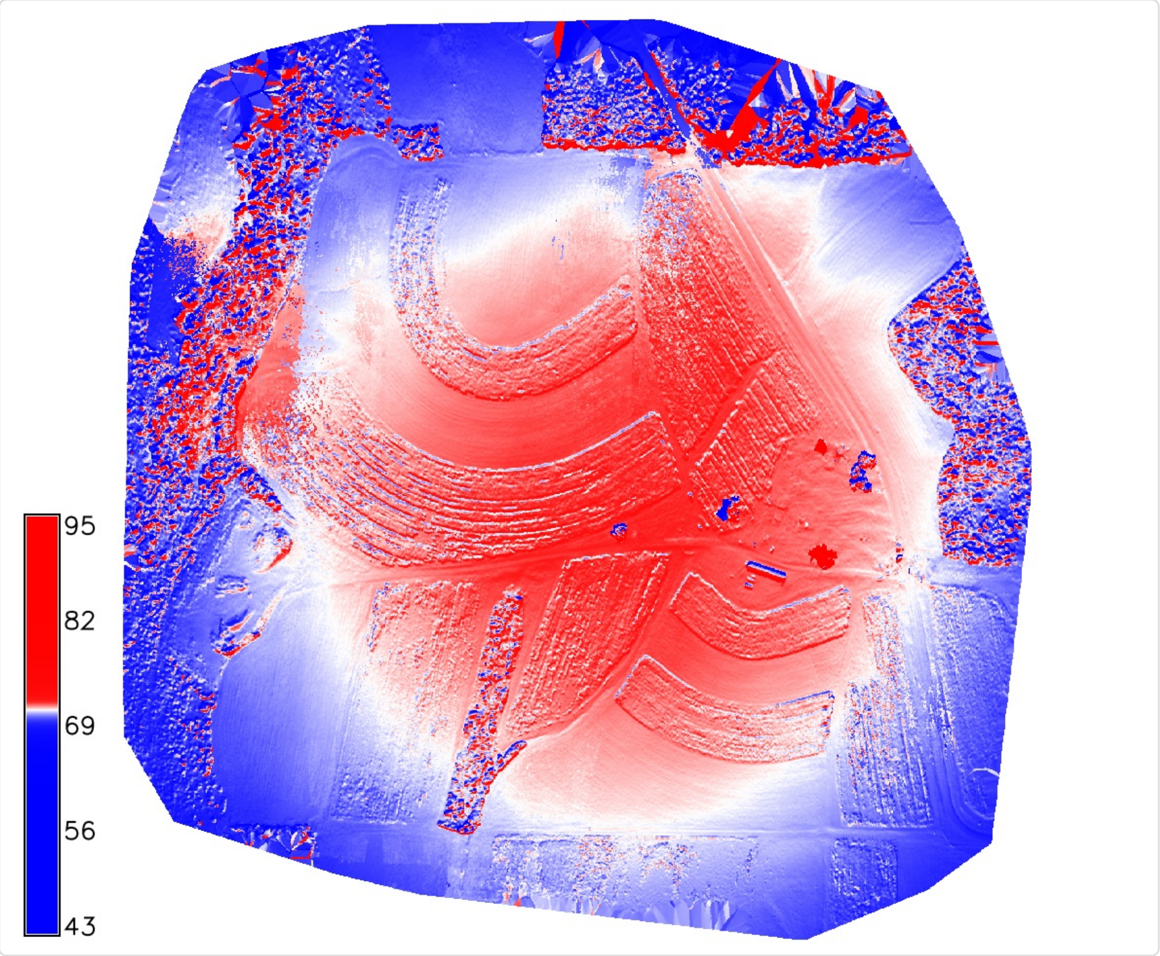
```
g.region rast=2015_06_20_pix4d_11GCP_dsm -p
r.mapcalc expression="p4d_GCP_p4d_noGCP = 2015_06_20_pix4d_11GCP_dsm - 2015_06_20_DSM_pix4d_NoGCP"
```



June 20th Flight, Without GCPs

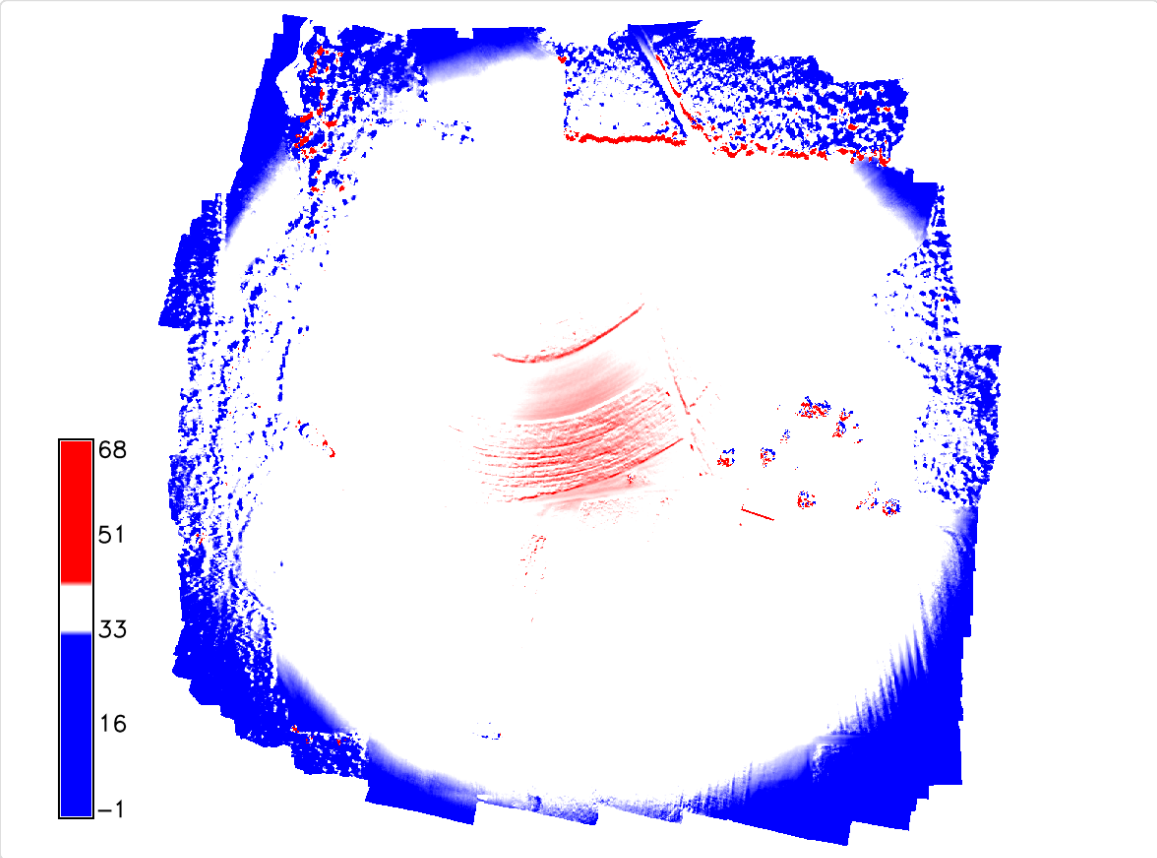


June 20th Flight, With GCPs

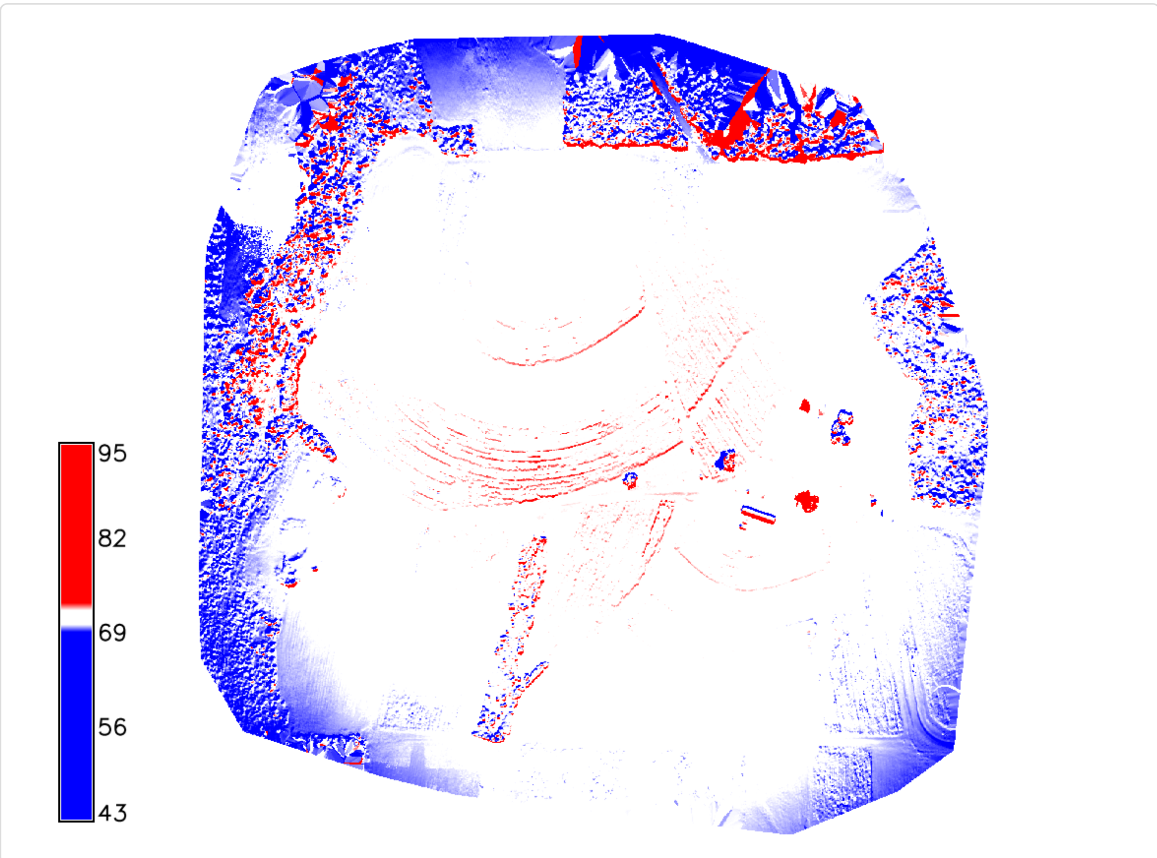


The bowl effect in the June 20th flight data, processed using Pix4D

Comparing the bowls from the two softwares, it appears that the bowl generated in Pix4D is slightly smaller in size. In order to get a better idea for which software package produces a larger bowl, we can play with the color tables so that the 'rim' and 'bottom' (which is actually the 'top', as these are inverted bowls) are shown.



The bowl effect in Agisoft Photoscan



The bowl effect in Pix4D

The color tables used to produces these images are as follows:

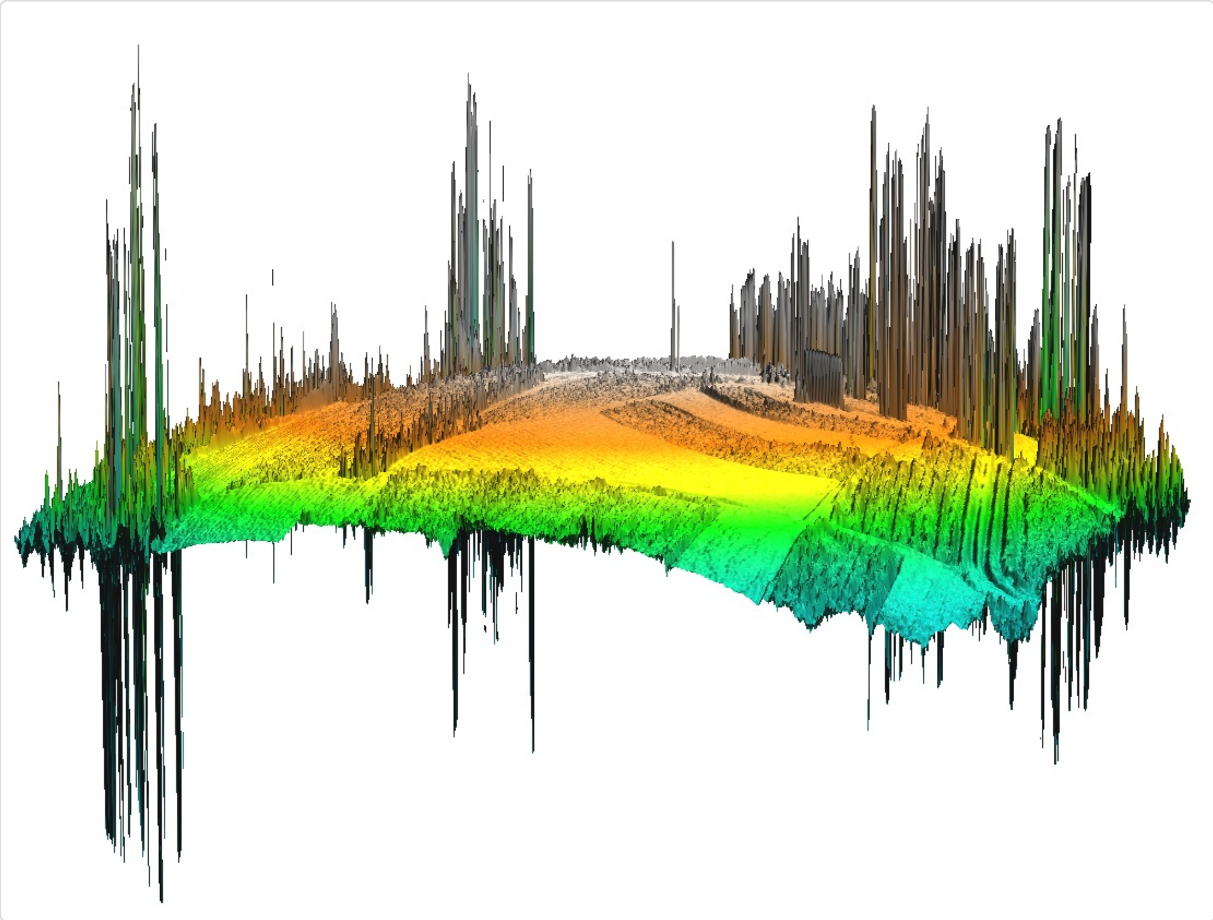
```
0% blue
32 blue
33 white
41 white
42 red
100% red
```

Agisoft Photoscan Color Table

```
0% blue
69 blue
70 white
72 white
73 red
100% red
```

Pix4D Color Table

Clearly the Agisoft bowl is much more pronounced. The vertical distance from the rim to the bottom of the bowl is approximately 9 meters, whereas the vertical distance from the rim to the bottom of the bowl produced by Pix4D is approximately 3 meters. The effect can be seen even more clearly when viewing the Agisoft bowl in 3D with a high z-exaggeration:

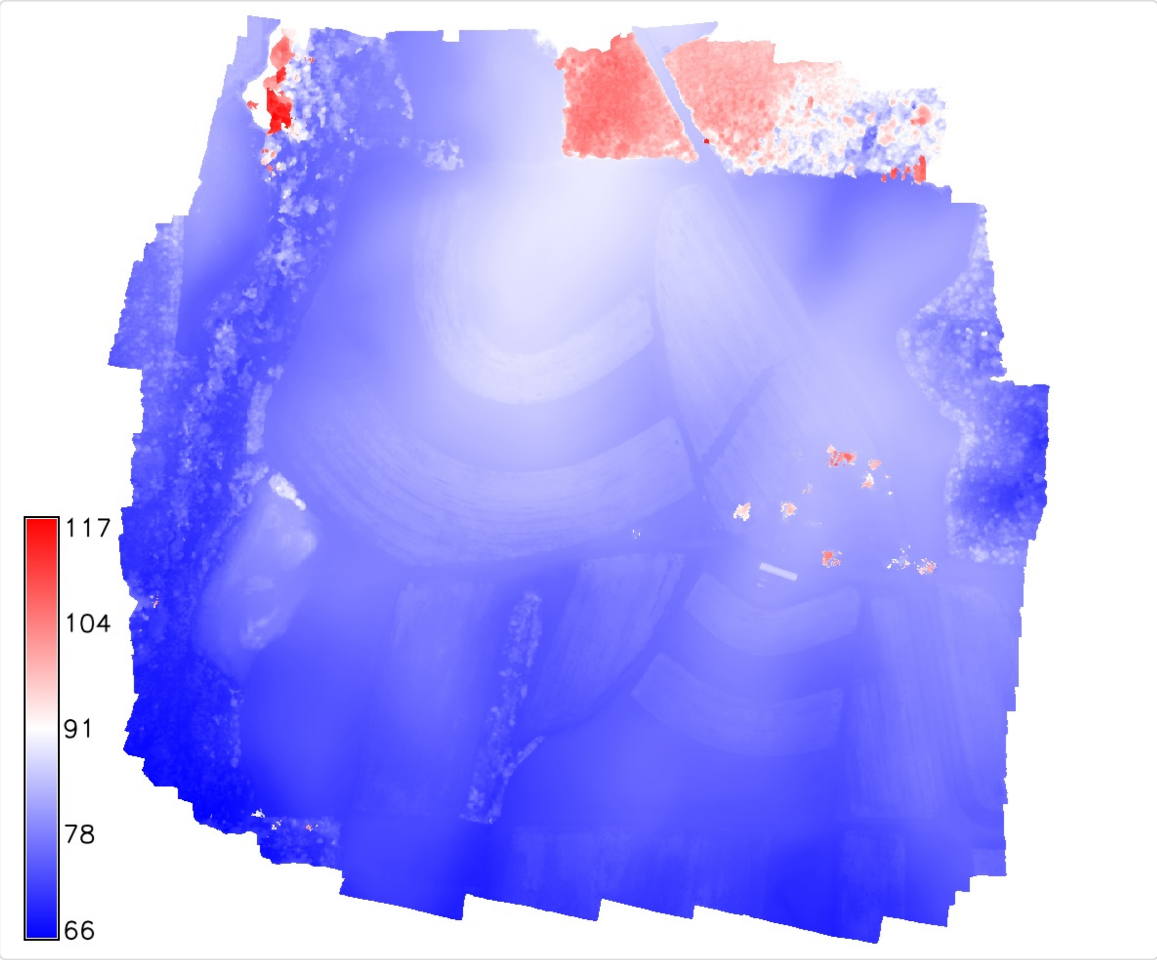


The bowl effect in Agisoft Photoscan (viewed in 3D)

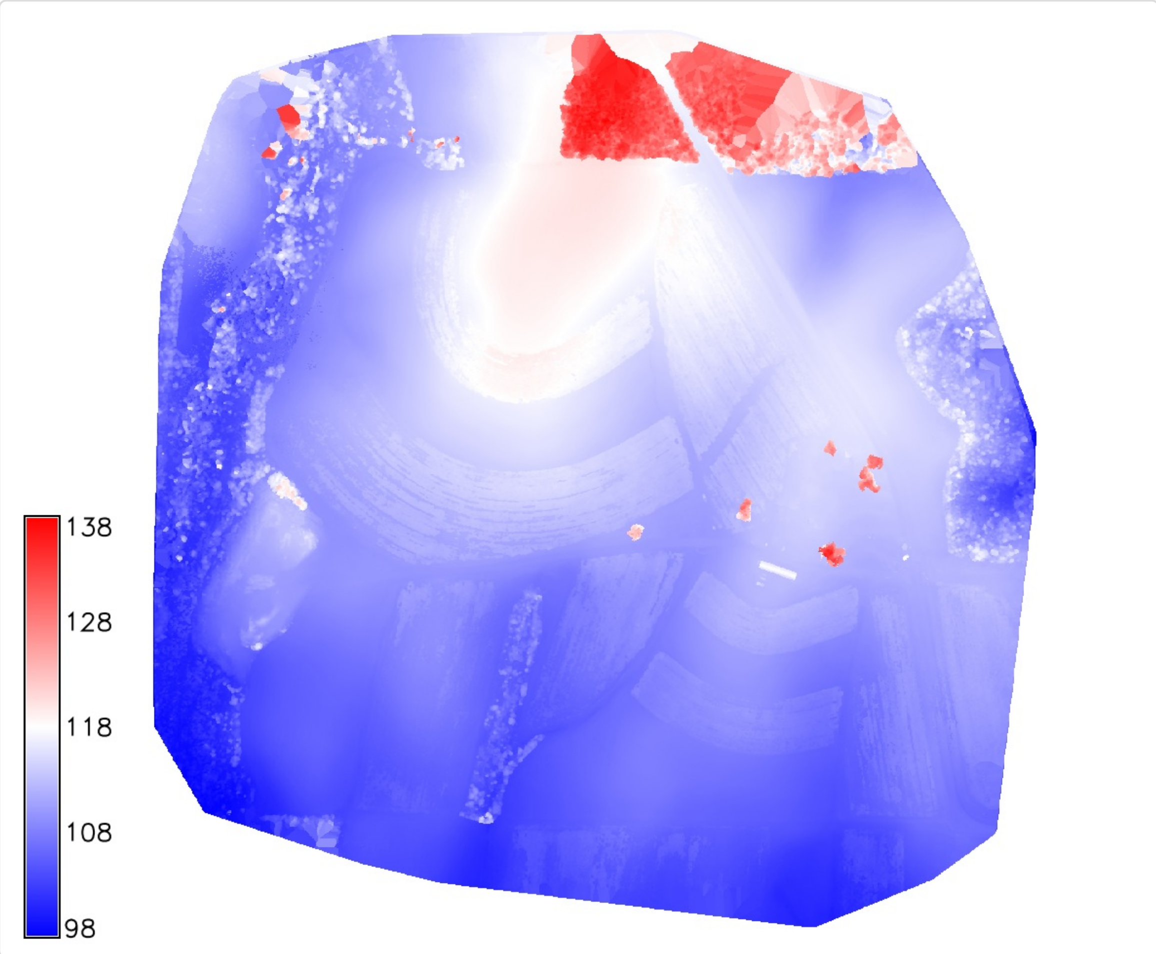
Regardless of bowl size, it is clear that we need to avoid introducing this effect into the data. If GCPs are not used and the bowl effect is in the resulting DEM, any processing performed on the data will propagate these errors and could have a negative effect on the results. For example, a watershed analysis could be heavily influenced by the bowl effect because water will always tend to flow to the bottom of the bowl.

Software Comparison - Photoscan, Pix4D, and Trimble

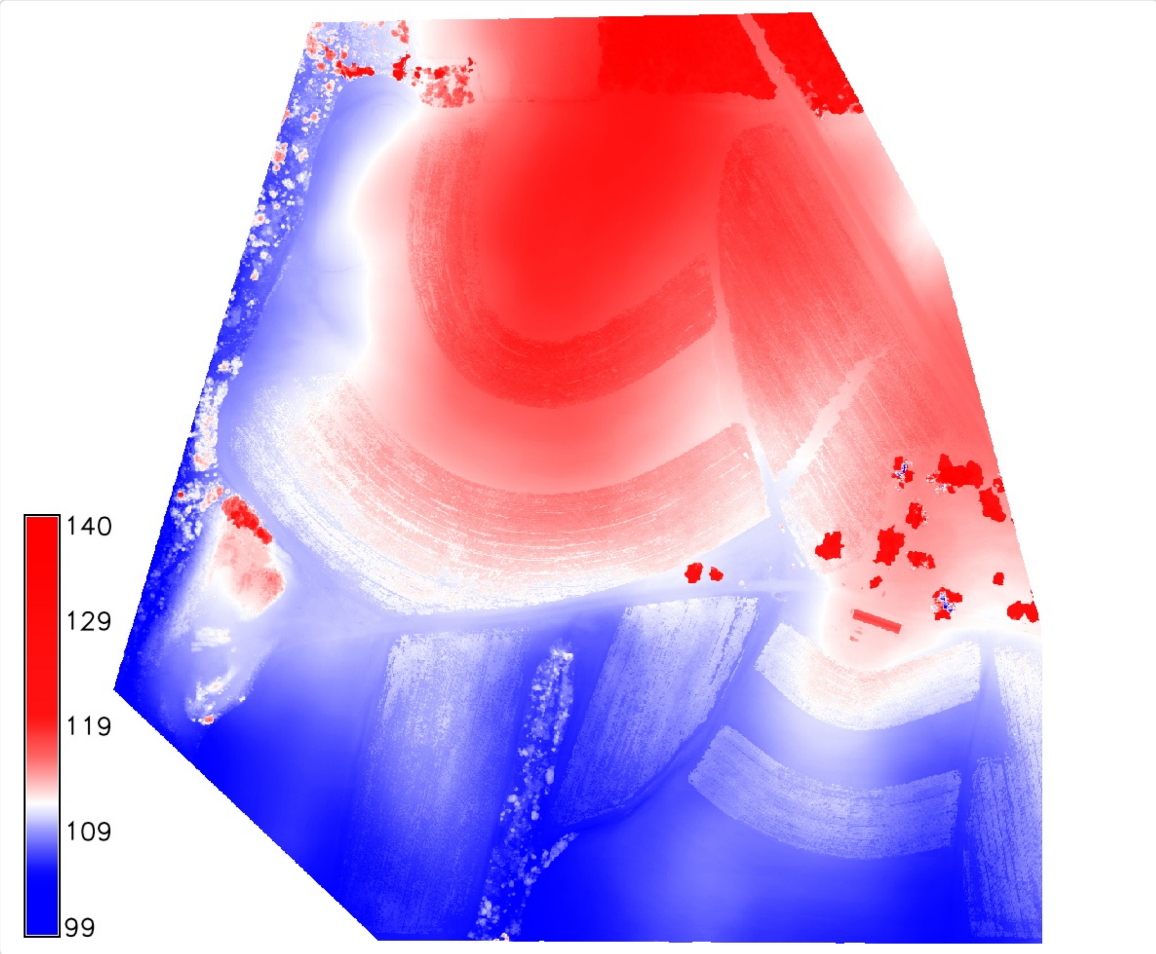
DSMs have been generated using the June 20th flight data in three different software packages. Agisoft Photoscan and Pix4D data have been seen in the previous section, and the third software package, Trimble Business Center can produce similar DSMs. All three DSMs, generated with the use of GCPs, are pictured below:



Agisoft Photoscan DSM

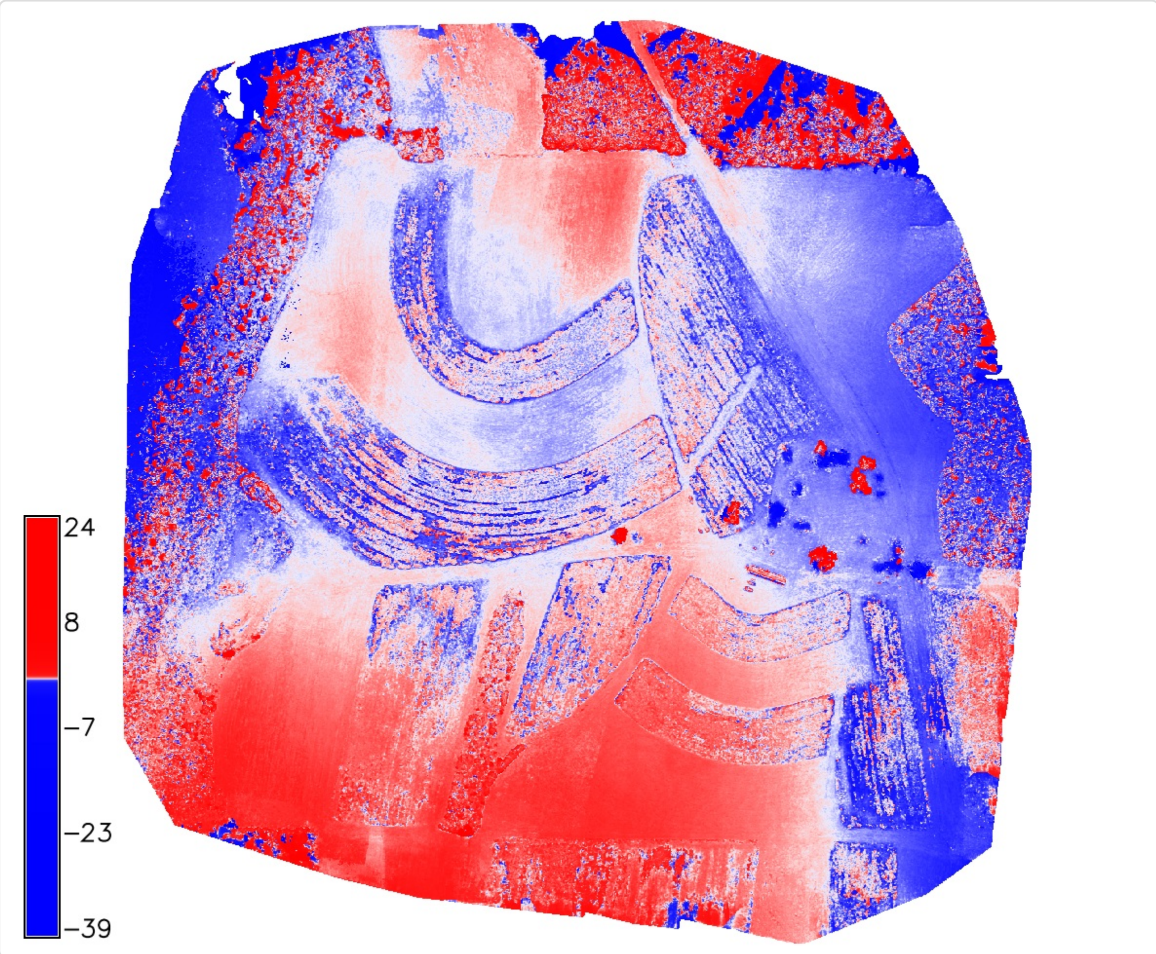


Pix4D DSM

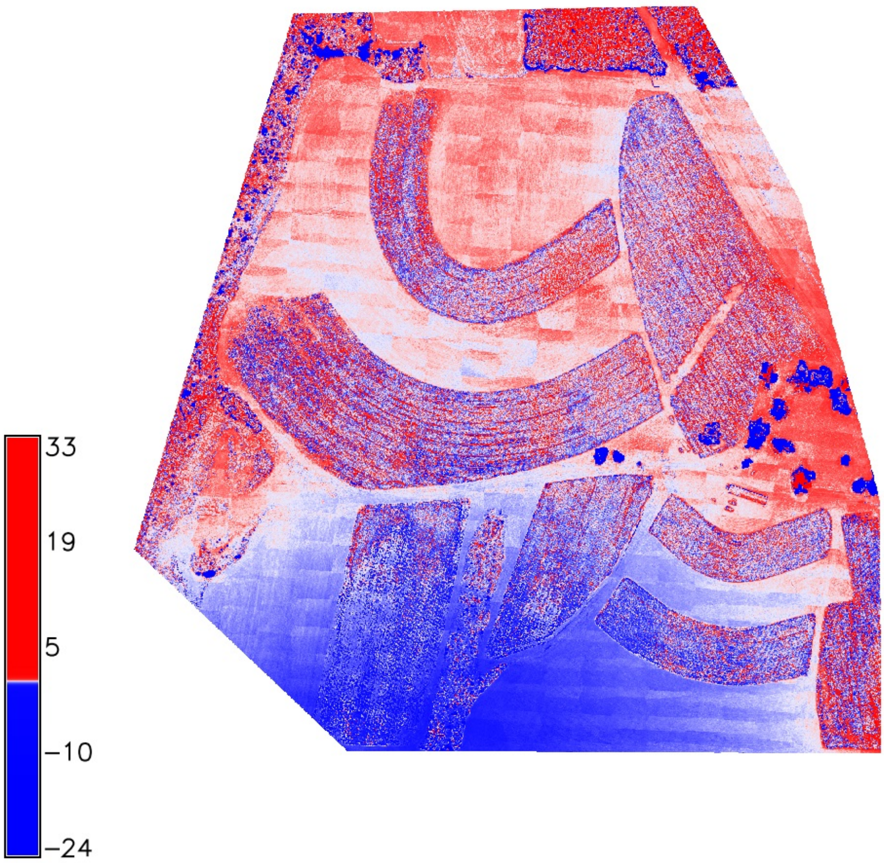


Trimble Business Center DSM

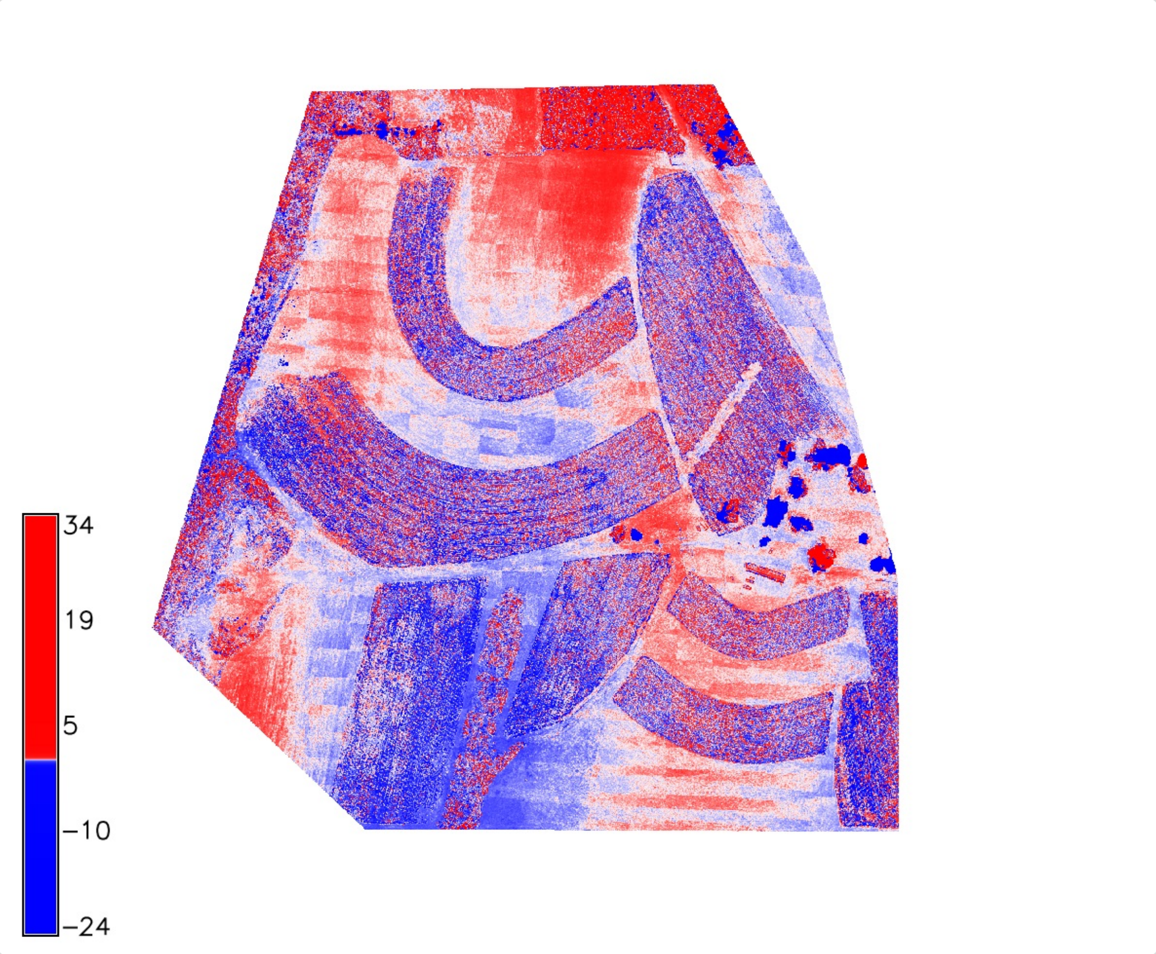
To the naked eye, the results of all three DSMs appear very similar. However, comparing each of the three DSMs to each other by performing a subtraction reveals some interesting artifacts:



Agisoft Photoscan DSM subtracted from the Pix4D DSM



Trimble DSM subtracted from the Agisoft Photoscan DSM



Trimble DSM subtracted from the Pix4D DSM

This comparison reveals that one of software packages is leaving artifacts in the DSM, generated at the edges of the images used to produce the DSM. Because the Trimble software is a common baseline in both of the images presenting artifacts, we can conclude that it is the software introducing these errors.

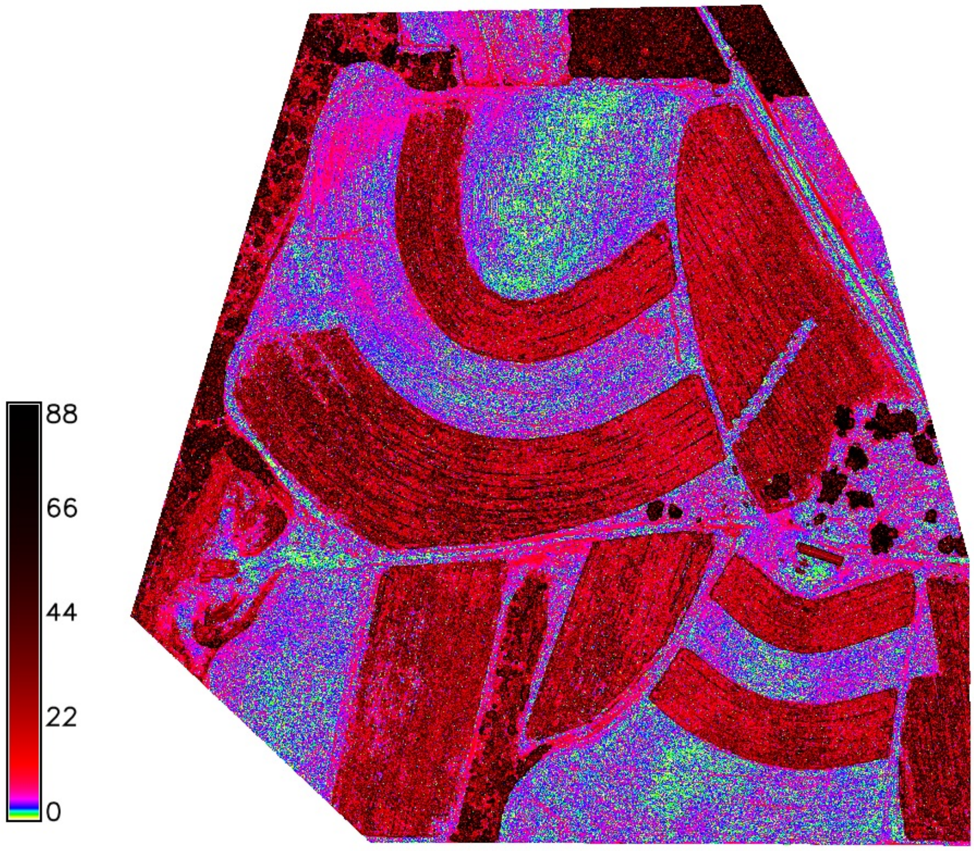
Processing Artifacts

Now that we are aware of the artifacts introduced by the Trimble software, it would be useful if we were capable of detecting those artifacts without having to compare the DSM with one generated using another software package. In this section, we explore processing techniques used in GRASS GIS which could reveal these artifacts.

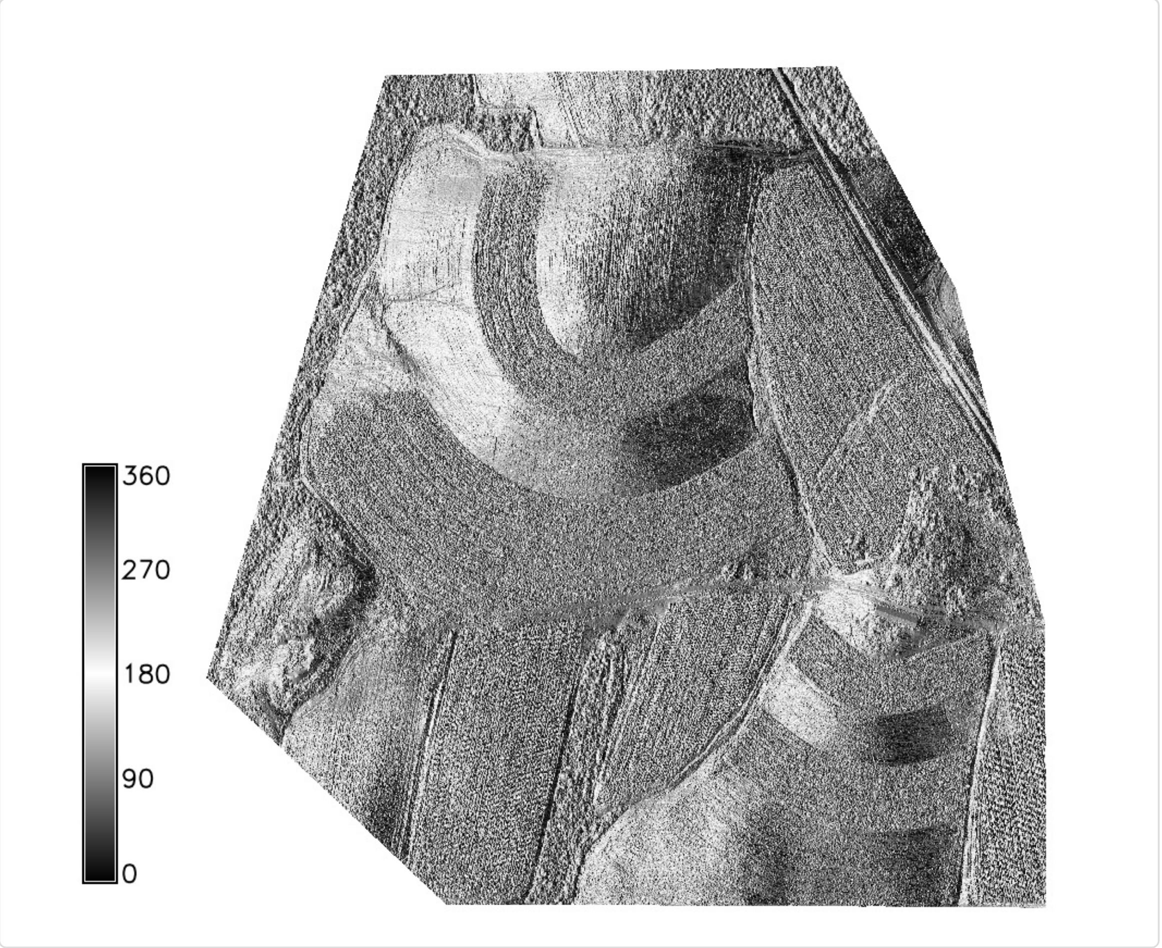
`r.slope.aspect`

In GRASS GIS, `r.slope.aspect` generates raster maps of slope, aspect, curvatures and first and second order partial derivatives from a raster map of elevation values (doc). The slope raster contains slope values in degrees of inclination, the aspect raster indicates direction that slopes are facing, and the curvature raster contains curvature values in the direction of the steepest slope. Here we use `r.slope.aspect` to generate slope, aspect, and profile curvature rasters:

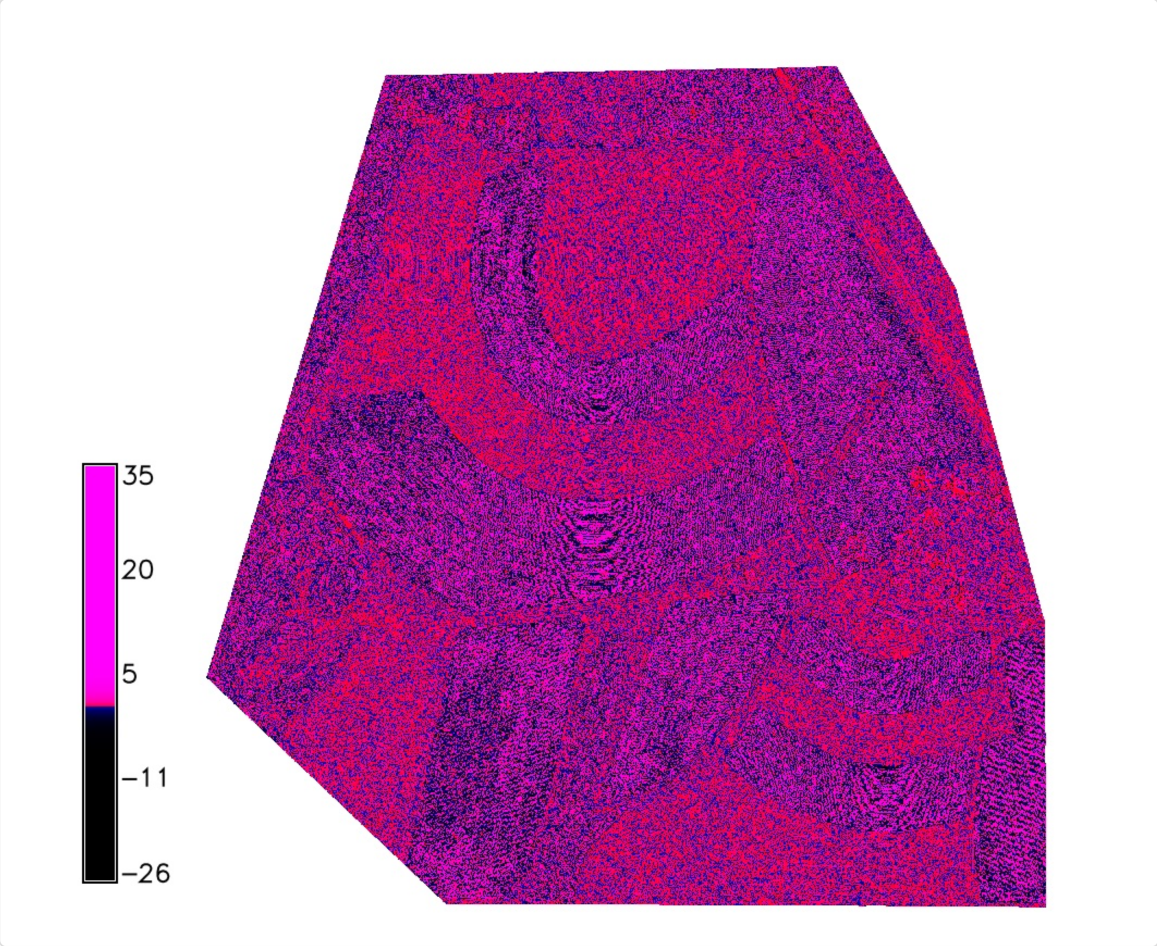
```
r.slope.aspect elevation=2015_06_20_DSM_Trimble_11GCP slope=trimble_slope
aspect=trimble_aspect pcurvature=trimble_curve
```



Slope

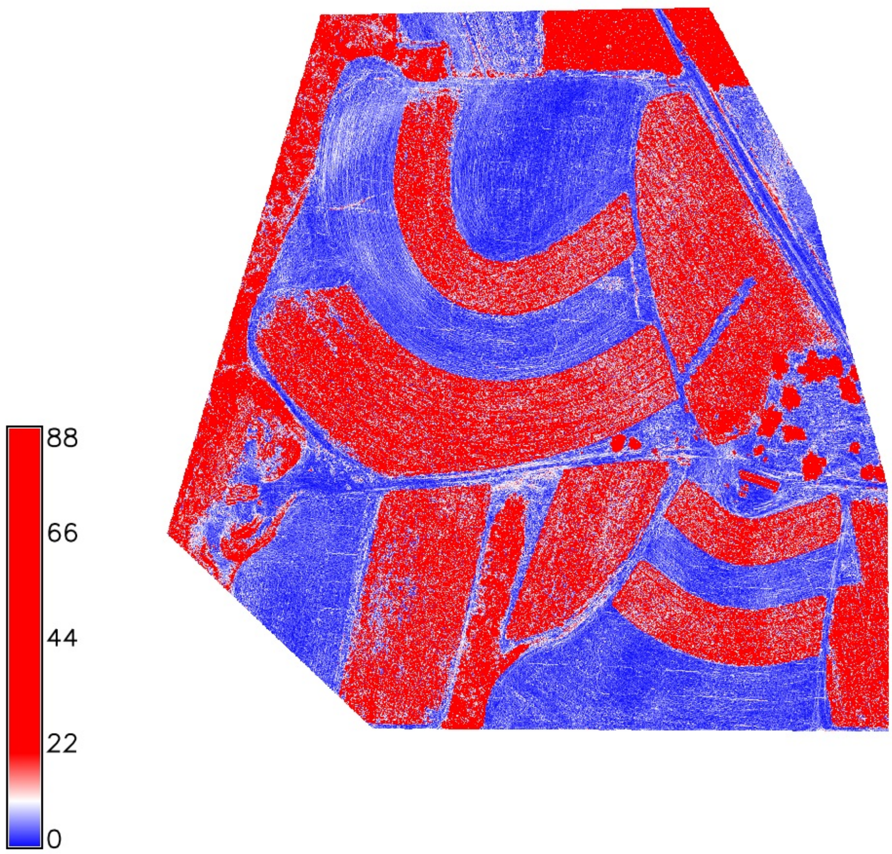


Aspect

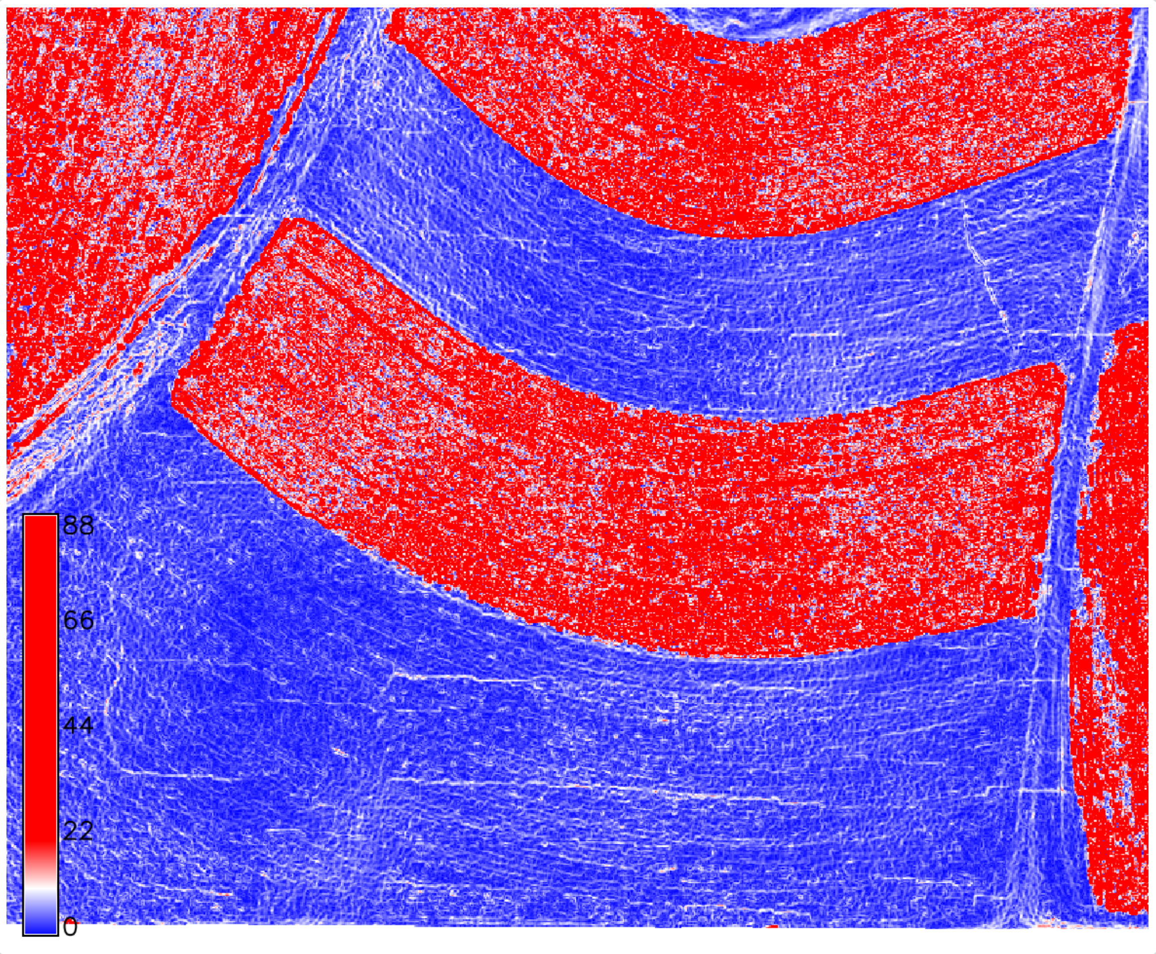


Curvature

The image stitching artifacts are somewhat visible in the slope raster, and by playing with the color table, we can make them really stand out.



Slope raster with new color table

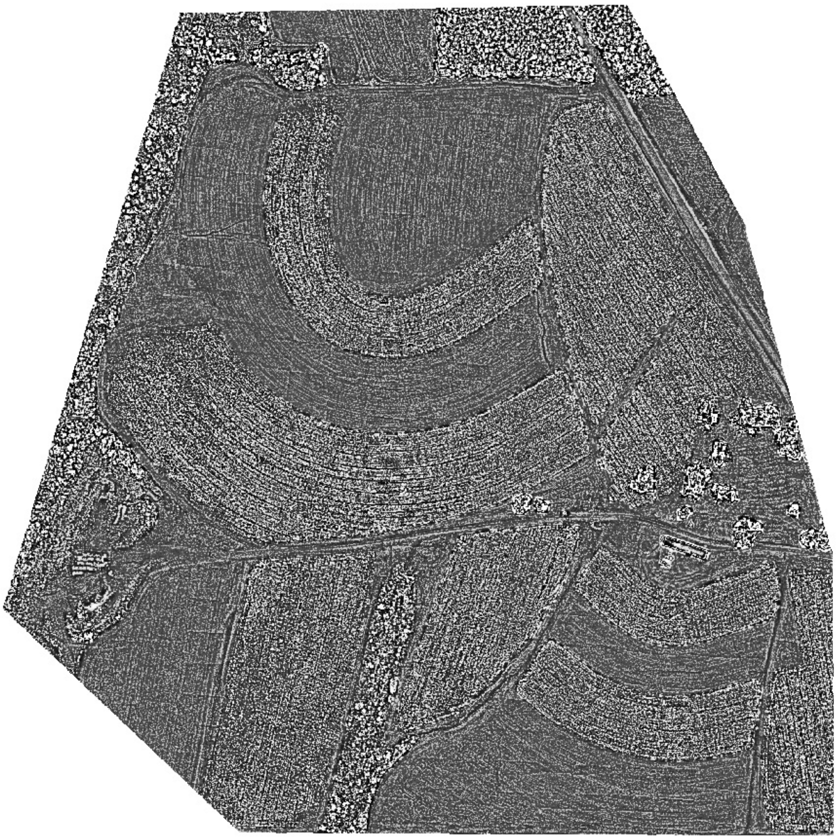


Zoomed view of slope raster to show artifacts

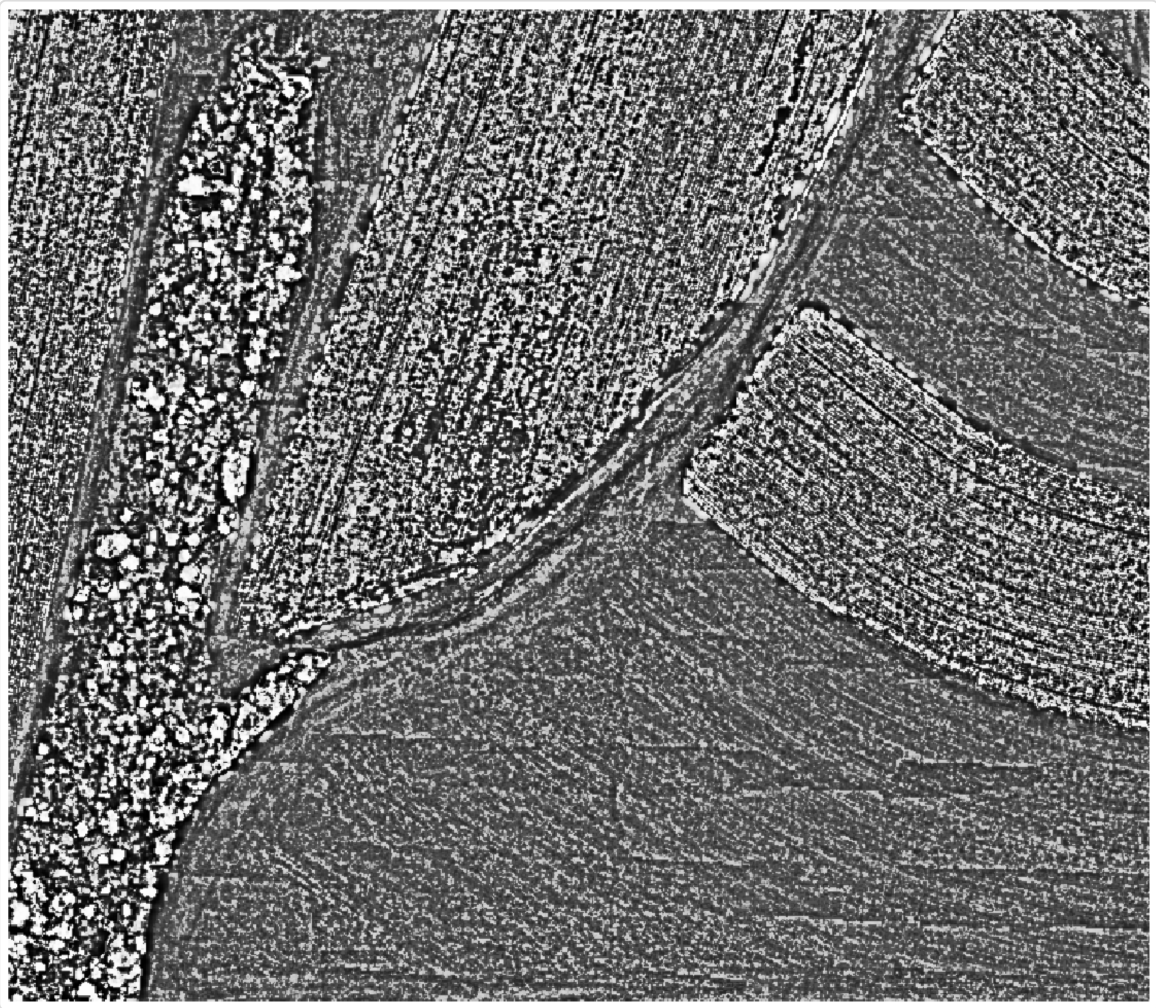
r.local.relief

In GRASS GIS, `r.local.relief` is used to create a local relief model from LIDAR derived DEMs in order to enhance the visibility of small-scale surface features by removing large-scale landforms from the DEM (doc). This is particularly useful in our case, because it will reveal the stitching artifacts generated by the Trimble software:

```
r.local.relief input=2015_06_20_DSM_Trimble_11GCP
output=trimble_local_relief
```



Local Relief

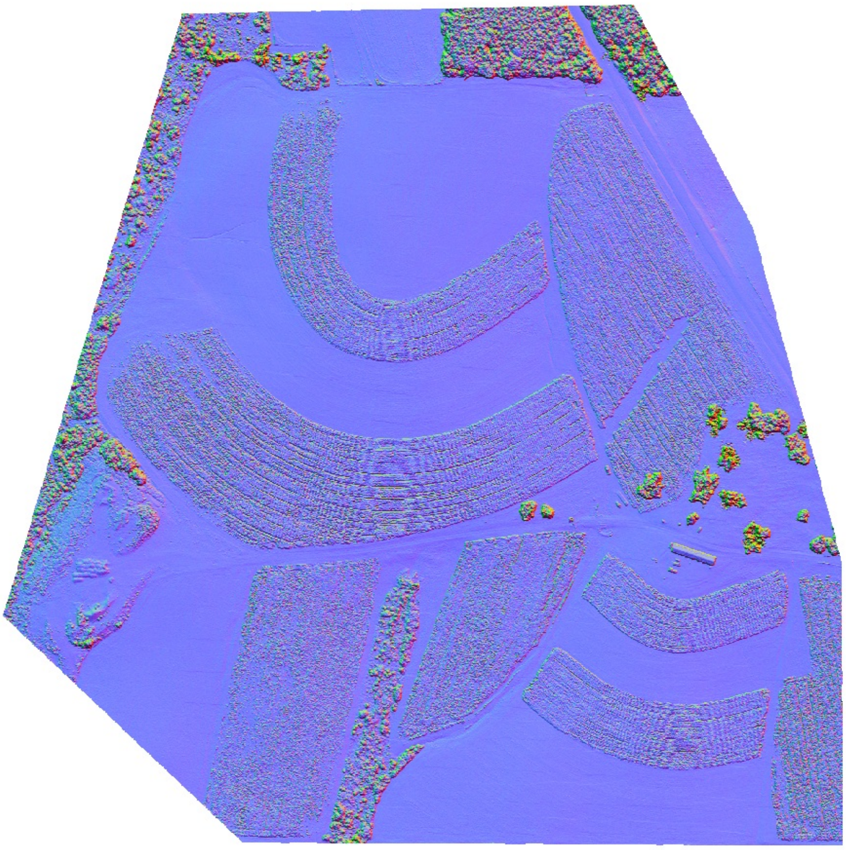


Zoomed view of local relief to show artifacts

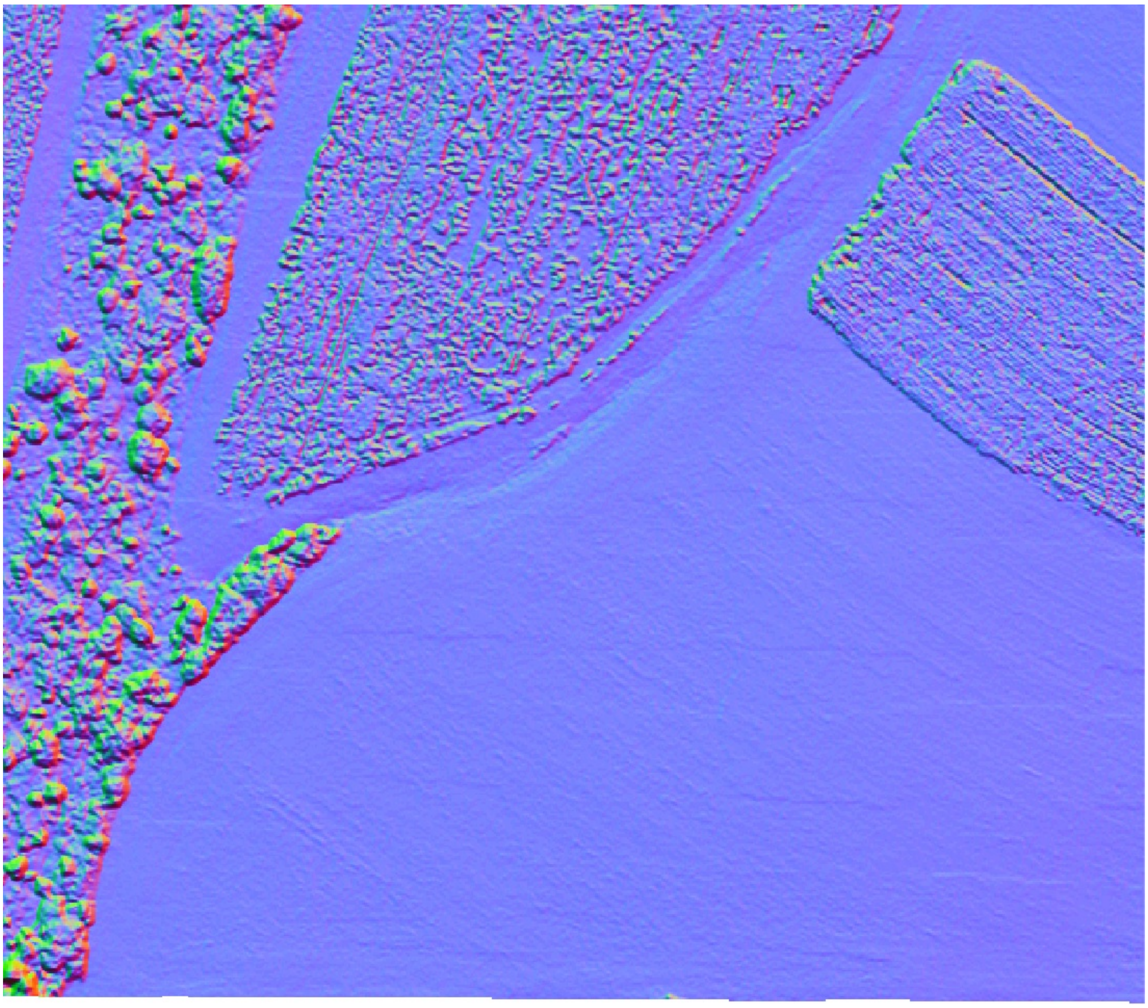
r.shaded.pca

In GRASS GIS, `r.shaded.pca` creates a shaded relief (created by `r.relief`) from various directions and combines them into an RGB composition (doc). This helps reveal artifacts such as the ones generated by Trimble better than `r.relief` can on it's own.

```
r.shaded.pca input=2015_06_20_DSM_Trimble_11GCP output=trimble_pca
```



PCA

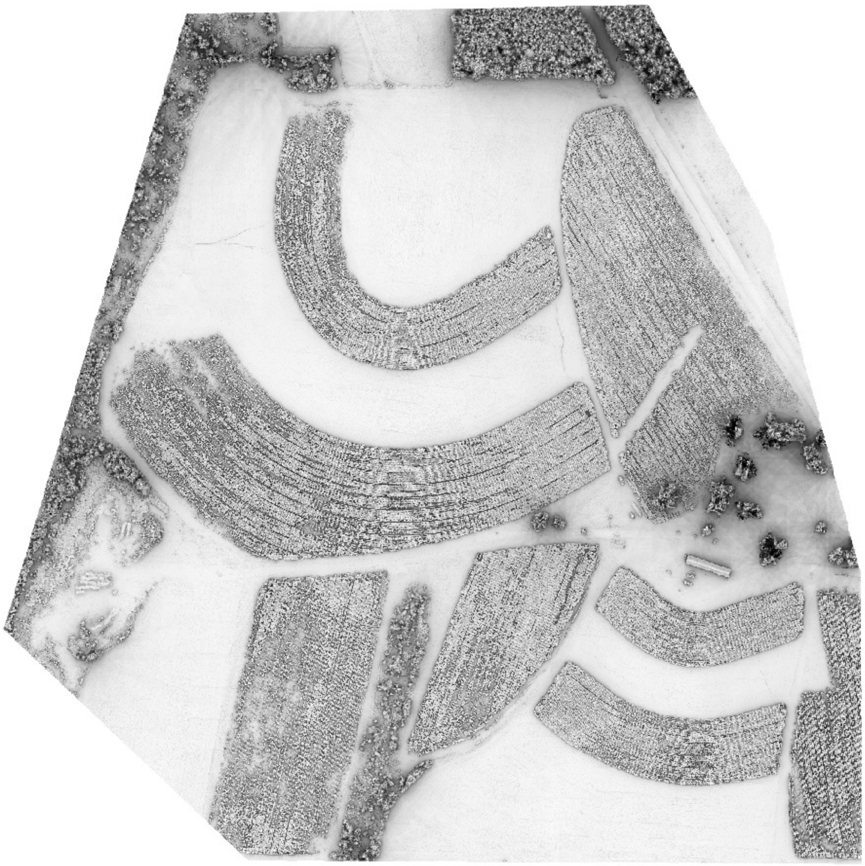


Zoomed view of PCA to show artifacts

r.skyview

In GRASS GIS, `r.skyview` computes the Sky-View factor for each cell. The value of each cell is given by the portion of visible sky (from that cell) limited by the surrounding relief (ranging from 0 to 1). The lighter a value is, the more open the terrain is (doc). This technique is not great at emphasizing the stitching artifacts generated by Trimble, although playing with the input parameters (e.g. increasing the number of directions or modifying the maximum distance to consider when finding the horizon) could possibly generate better results.

```
r.skyview input=2015_06_20_DSM_Trimble_11GCP output=trimble_skyview
```



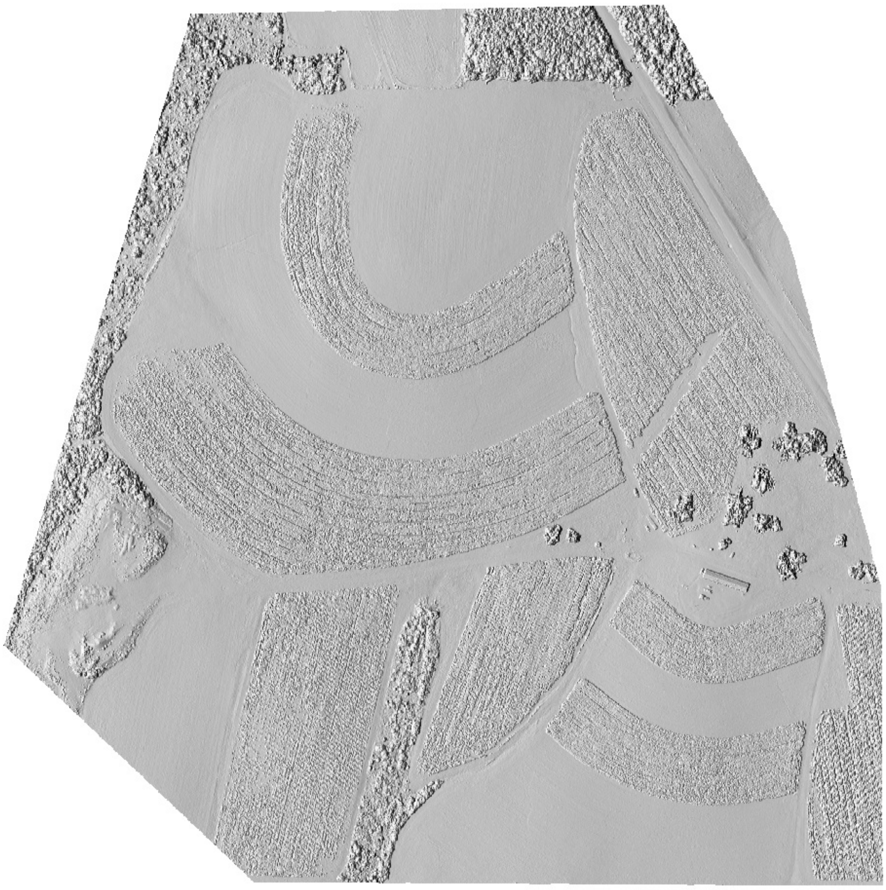
Skyview

Zoomed view of skyview to show artifacts

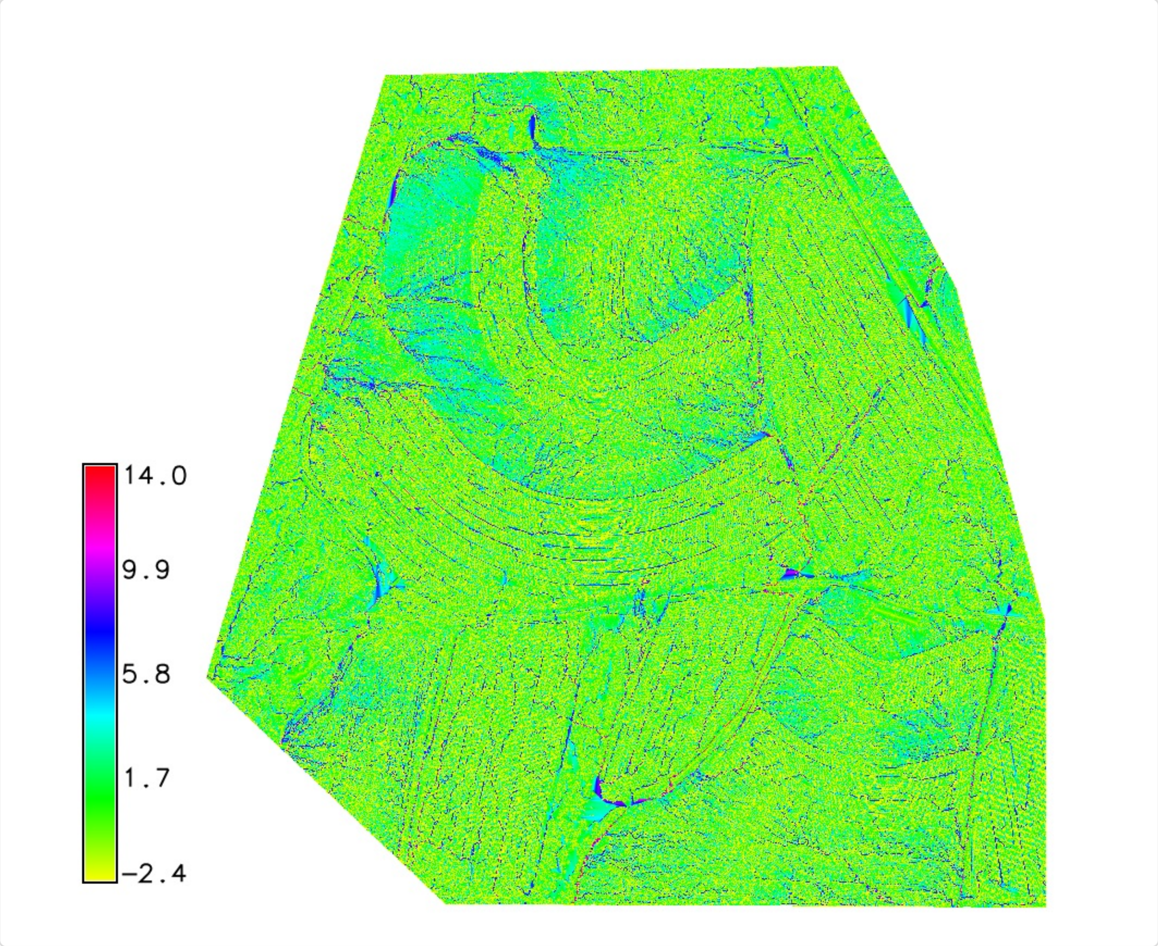
Others

I attempted to use a few other GRASS functions to reveal the processing artifacts, but for the most part the following functions didn't show much:

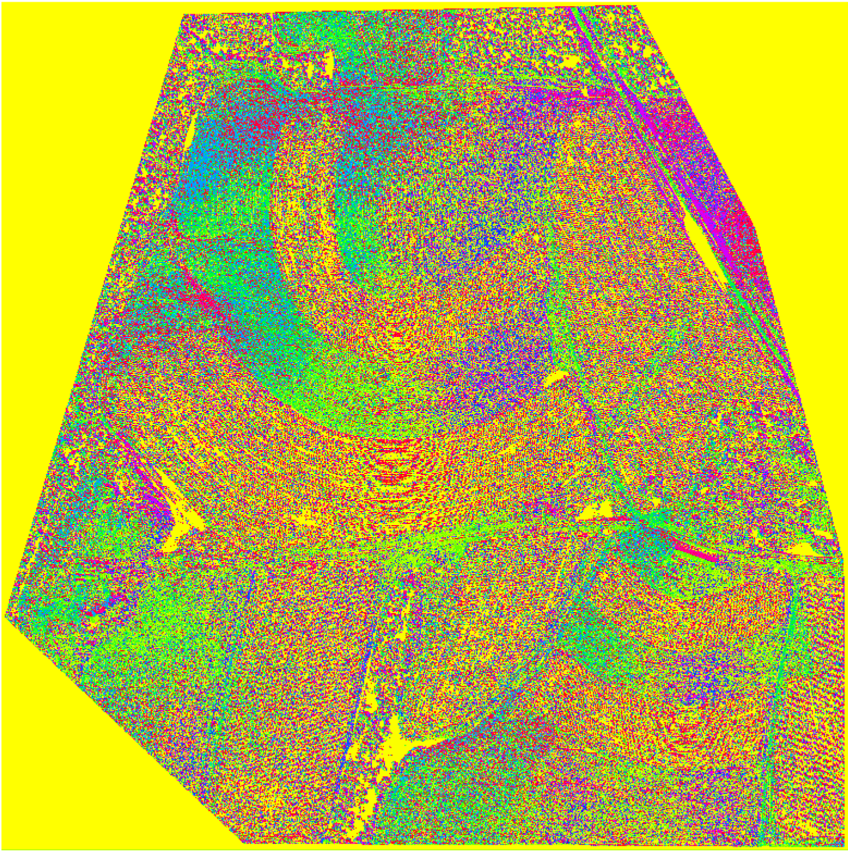
```
r.relief input=2015_06_20_DSM_Trimble_11GCP output=trimble_relief
r.terraflow elevation=2015_06_20_DSM_Trimble_11GCP tci=trimble_tci
direction=trimble_direction accumulation=trimble_accum
```



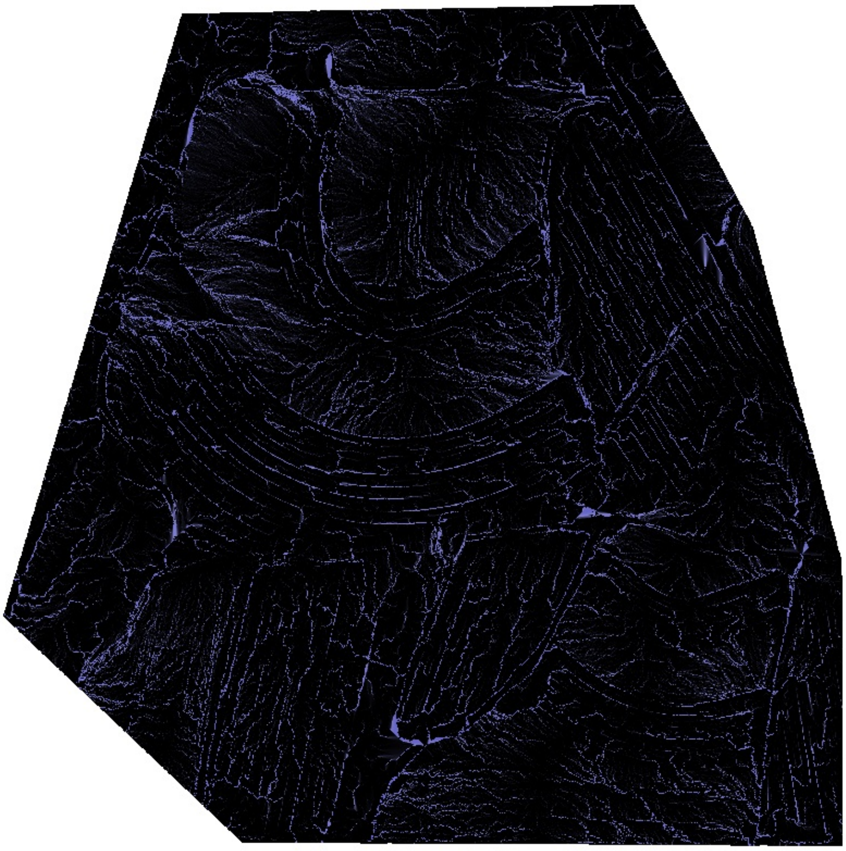
r.relief



`r.terraflow` **Topographic Convergence Index**



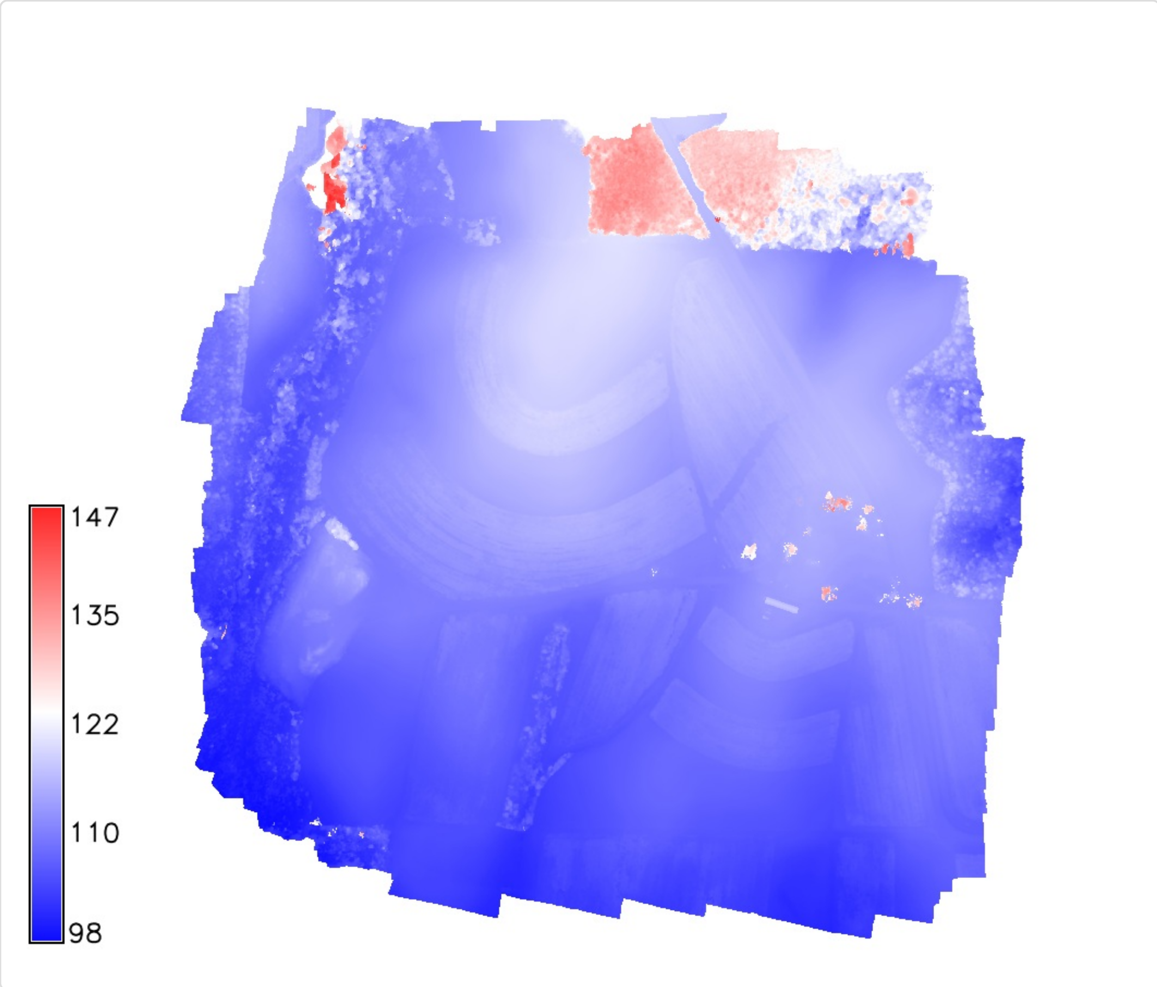
`r.terraflow` **Direction**



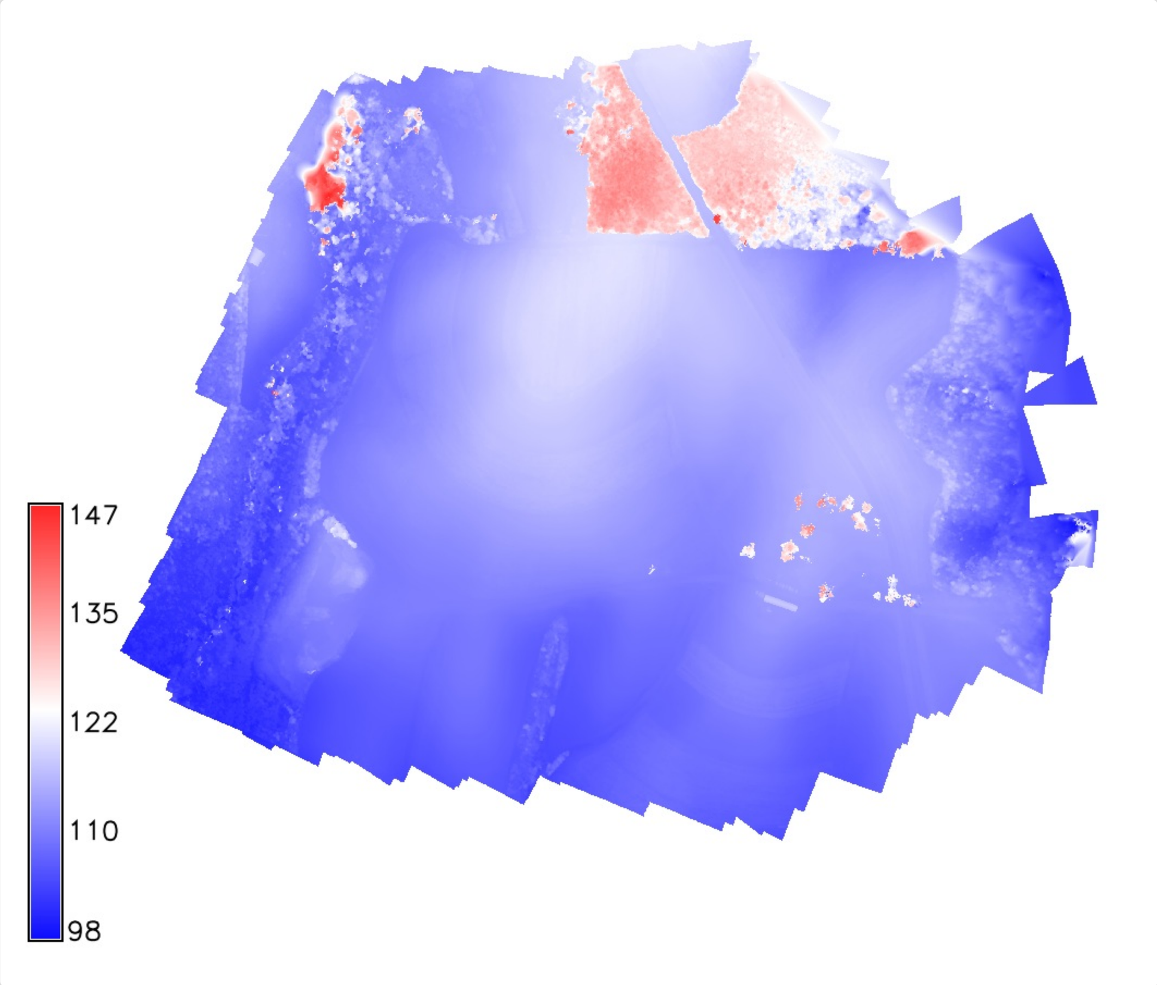
`r.terraflow` **Accumulation**

Terrain Analysis - Change Detection

If multiple flights have been used to collect data over the same area on different dates, the DSMs generated from aerial imagery can be used to detect change in the topography over time. In this example, we have data from flights conducted over the Lake Wheeler site on June 20th and October 6th.



June 20th Flight

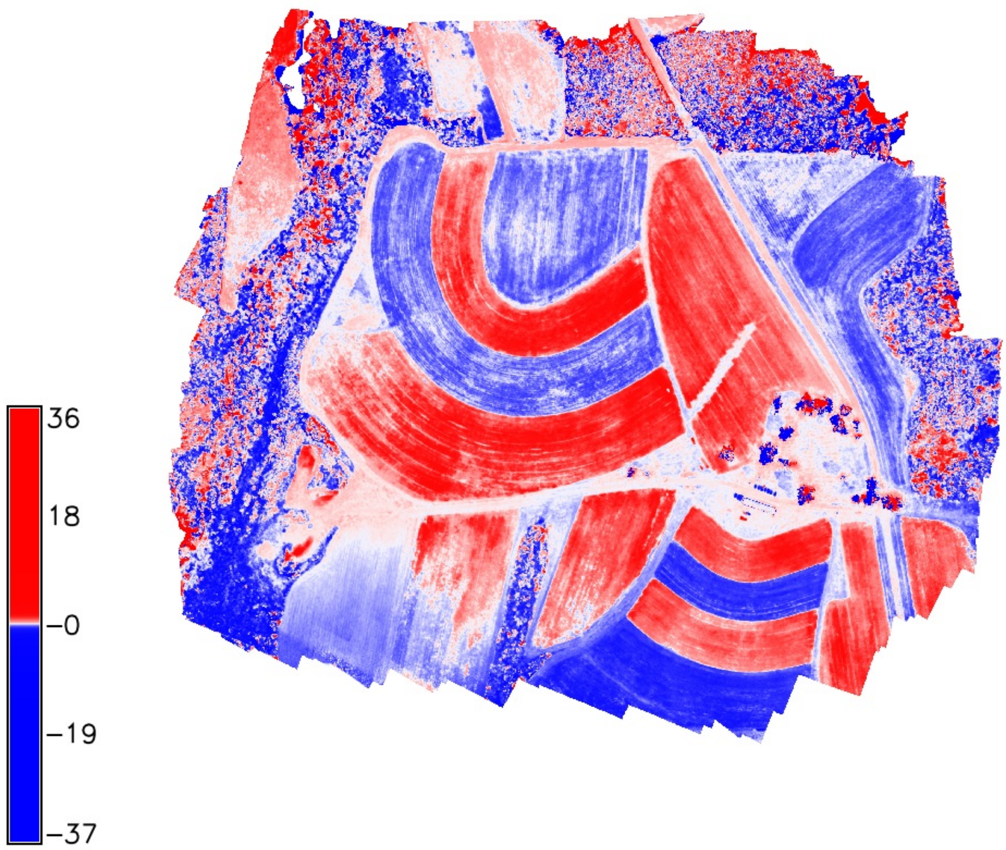


October 6th Flight

By performing a simple subtraction, we can see how the terrain has changed over time. Because we subtract the December DSM from the June DSM, positive values will indicate erosion or removal of material, and negative values will indicate accretion or the addition of material.

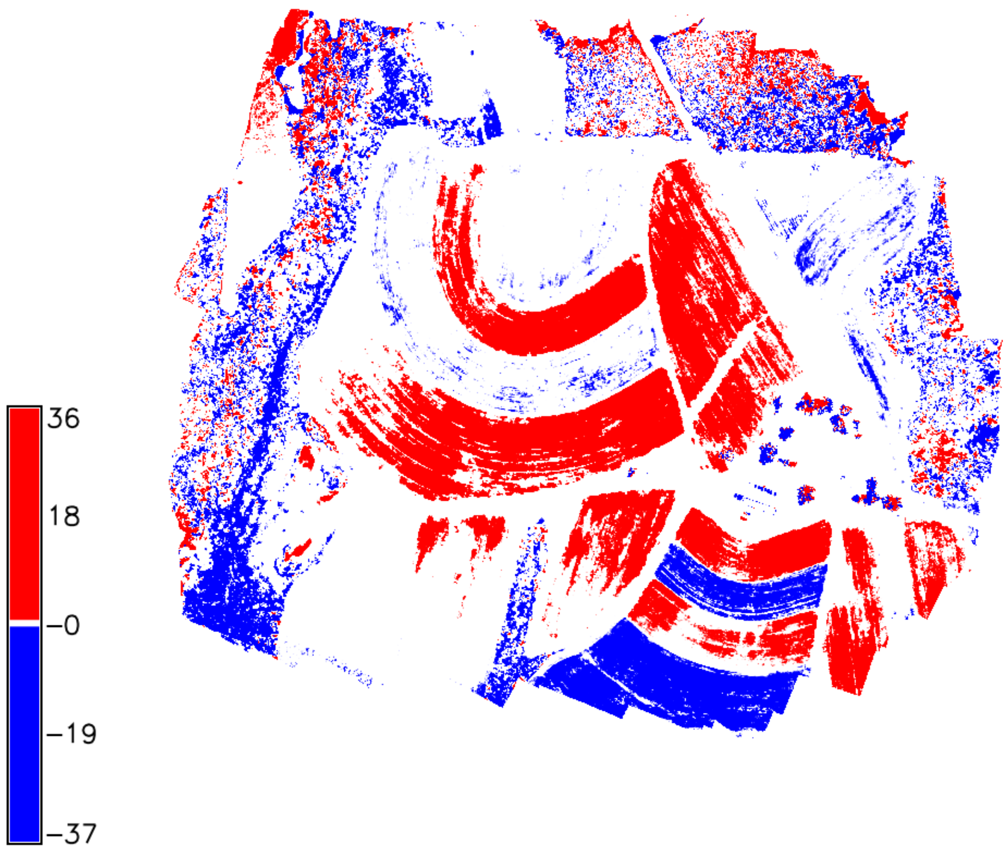
```
g.region rast=2015_06_20_DSM_agi_11GCP -p
r.mapcalc "diff_jun_oct_agis = 2015_06_20_DSM_agi_11GCP -
2015_10_06_DSM_agi_8GCPs"
```

We can see clearly that about half of the fields (in red) were subject to either erosion or removal of crops, while the other half (in blue) were likely tilled to raise the soil. However, we can see that the road appears to have sunk, and while this is entirely possible, it is unlikely to have sunk that uniformly over such a small period of time. This likely indicates inaccuracies in the computations used to generate the DSMs. Additionally, if we modify the color table as follows, we can see the majority of the significant change (i.e. greater in magnitude than 0.5 meters) in the fields was due to erosion or removal of crops.



June flight minus October flight

```
0% blue
-0.6 blue
-0.5 white
0 white
0.5 white
0.6 red
100% red
```



June flight minus October flight (custom color table)