Comparing SilviMetric and FUSION outputs

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Load packages

```
library(terra)
library(sf)
library(mapview)
```

Setup

```
HAGVRTfolder <- "C:/Users/bmcgaughey/SilviMetricTesting/TestOutput/plumas_vrt_tifs/"
#HAGVRTfolder <- "C:/Users/bmcgaughey/SilviMetricTesting/TestOutput/plumas_VRT_bilinear_vrt_tifs/"
HAGNNfolder <- "C:/Users/bmcgaughey/SilviMetricTesting/TestOutput/plumas_nn_tifs/"
HAGFUSIONfolder <- "C:/Users/bmcgaughey/SilviMetricTesting/TestOutput/plumas_normalized_tifs/"
FUSIONfolder <- "H:/FUSIONTestMetrics/Products_FUSIONTestMetrics_2024-05-16/FINAL_FUSIONTestMetrics_2024

SMfile <- "m_Z_max.tif"
#SMfile <- "m_Z_mean.tif"
FUSIONfile <- "elev_max_2plus_30METERS.img"
```

Read raster data and display extent and summary info

```
## FUSION raster:     ncol= 160    nrow= 134    cells= 21440
## HAGVRT raster:     ncol= 158    nrow= 134    cells= 21172
## HAGNN raster:      ncol= 158    nrow= 134    cells= 21172
## HAGFUSION raster: ncol= 158    nrow= 133    cells= 21014
## FUSION raster:     SpatExtent : 634695, 639495, 4400265, 4404285 (xmin, xmax, ymin, ymax)
## HAGVRT raster:     SpatExtent : 634725, 639465, 4400265, 4404285 (xmin, xmax, ymin, ymax)
## HAGNN raster:      SpatExtent : 634725, 639465, 4400265, 4404285 (xmin, xmax, ymin, ymax)
## HAGFUSION raster: SpatExtent : 634725, 639465, 4400295, 4404285 (xmin, xmax, ymin, ymax)
```

Adjust extent

The rasters produced when using PDAL's hag_nn are different from those produced using other hag filters.
I don't know for sure why but suspect it has to do with the extent of ground points compared to the extent
of non-ground points.

The HAGNN raster requires an extra operation to make it match the other rasters.

FUSION rasters are assigned a srs using an ESRI's projection file. The format of these files differs from the format used for the srs in the point cloud files so SilviMetric's srs doesn't exactly match FUSION's. To overcome this, I forced the srs for FUSION rasters to match those from SilviMetric.

```
## adjusted FUSION raster:    SpatExtent : 634725, 639465, 4400295, 4404285 (xmin, xmax, ymin, ymax)
## adjusted HAGVRT raster:    SpatExtent : 634725, 639465, 4400295, 4404285 (xmin, xmax, ymin, ymax)
## adjusted HAGNN raster:     SpatExtent : 634725, 639465, 4400295, 4404285 (xmin, xmax, ymin, ymax)
## adjusted HAGFUSION raster: SpatExtent : 634725, 639465, 4400295, 4404285 (xmin, xmax, ymin, ymax)
```

Extent and summary information for adjusted rasters

```
## FUSION output:    ncol= 158    nrow= 133    cells= 21014
## HAGVRT output:    ncol= 158    nrow= 133    cells= 21014
## HAGNN output:     ncol= 158    nrow= 133    cells= 21014
## HAGFUSION output: ncol= 158    nrow= 133    cells= 21014
## FUSION raster:
##     Layer_1
##  Min.   : 2.408
##  1st Qu.:36.595
##  Median :44.817
##  Mean   :43.495
##  3rd Qu.:51.475
##  Max.   :88.718
##  NA's   :7415
## HAGVRT raster:
##     m_Z_max
##  Min.   : 2.551
##  1st Qu.:36.706
##  Median :44.930
##  Mean   :43.586
##  3rd Qu.:51.575
##  Max.   :88.835
##  NA's   :7409
## HAGNN raster:
##     m_Z_max
##  Min.   : 2.44
##  1st Qu.:36.67
##  Median :44.89
##  Mean   :43.59
##  3rd Qu.:51.61
##  Max.   :89.66
##  NA's   :7401
## HAGFUSION raster:
##     m_Z_max
##  Min.   : 2.41
##  1st Qu.:36.59
##  Median :44.81
##  Mean   :43.49
##  3rd Qu.:51.47
##  Max.   :88.72
##  NA's   :7414
```

## Compare raster values for maximum height

This metric (maximum HAG) doesn't involve any calculation so it basically tests that FUSION and Silvi-Metric are using the same HAG values and same point for the cells.

This is a plot of the FUSION output for maximum height.

FUSION −− maxHt
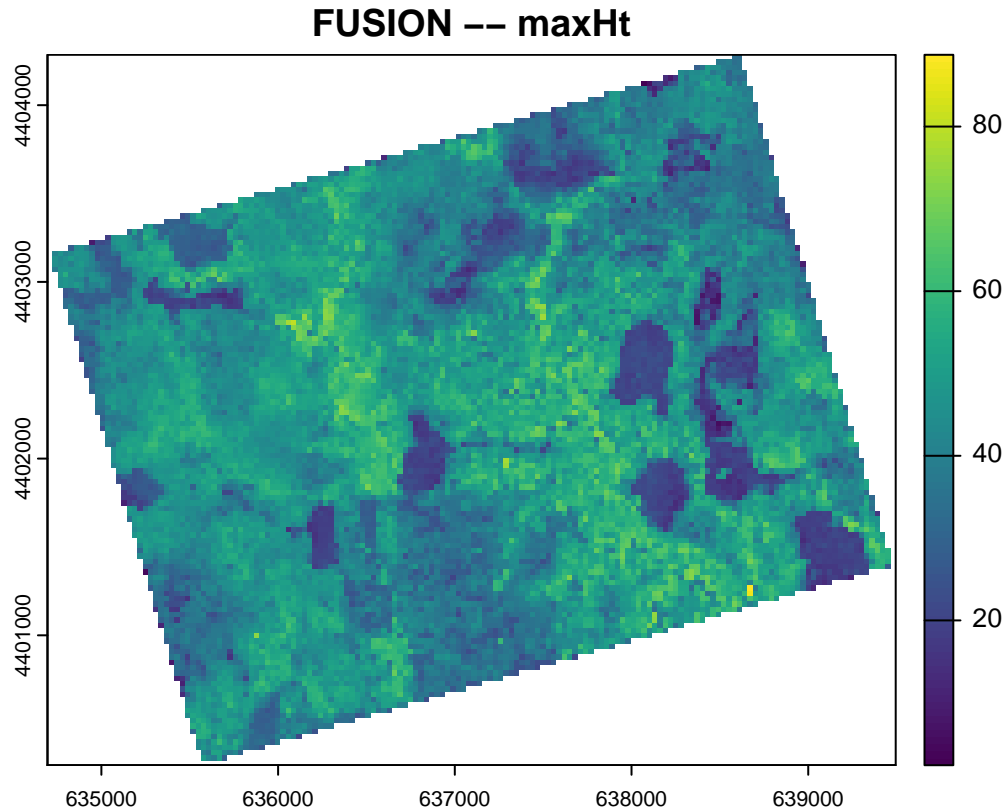
The first test uses HAG computed using the VRT with PDAL's hag_dem filter. The interpolation problem with PDAL mentioned above leads to small differences between HAG compute by FUSION and using the VRT. In general, these differences are largest at the edge of the coverage area but there are patterns related to topogrphic features visible in the difference raster.

FUSION minus SilviMetric −− maxHt

Frequency

HAG computed using VRT

**FUSION minus SilviMetric –– maxHt**
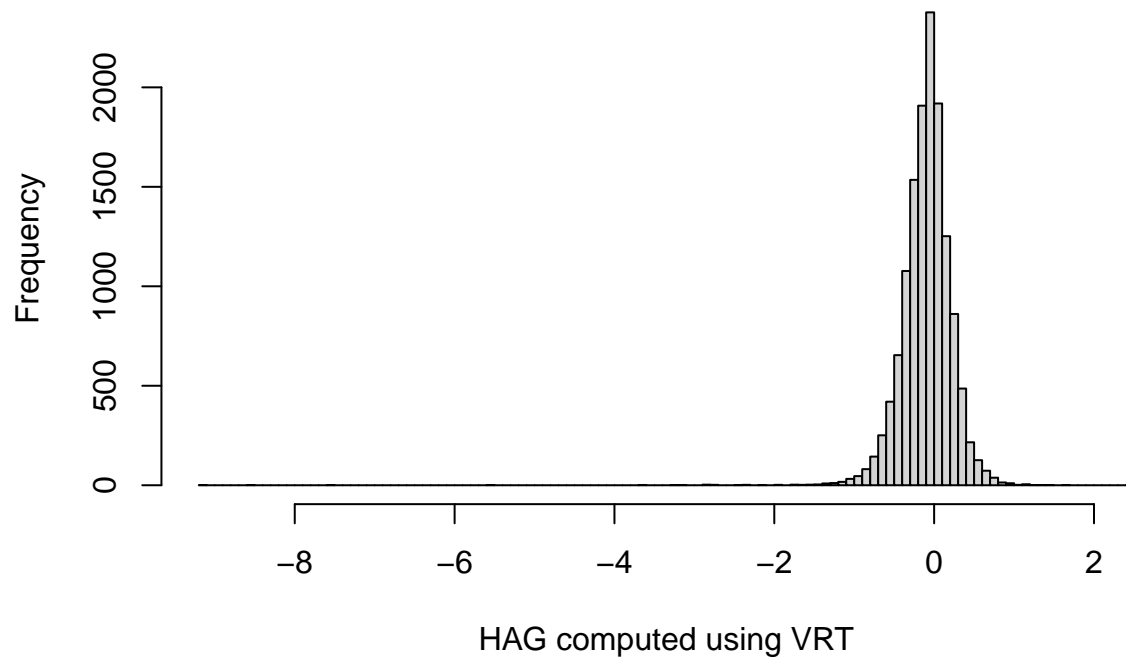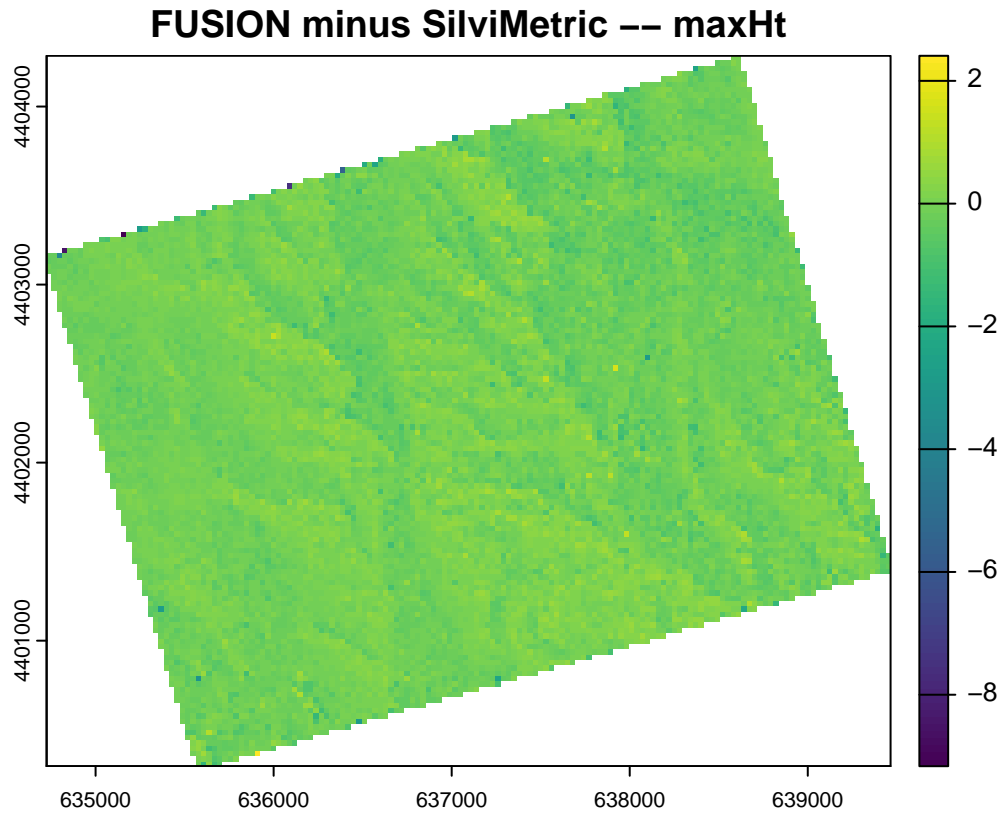

```
##      Layer_1
##  Min.   :-9.164
##  1st Qu.:-0.255
##  Median :-0.075
##  Mean   :-0.095
##  3rd Qu.: 0.080
##  Max.   : 2.409
##  NA's   :7415
```

The second test uses HAG computed using PDAL's hag_nn filter. This produces similar differences compared to the VRT method. Again, differences are largest at the edge of the coverage area. Interesting, topographic patterns are not reflected in the differences but are when using the VRT approach.

FUSION minus SilviMetric -- maxHt

HAG computed using hag_nn

FUSION minus SilviMetric -- maxHt
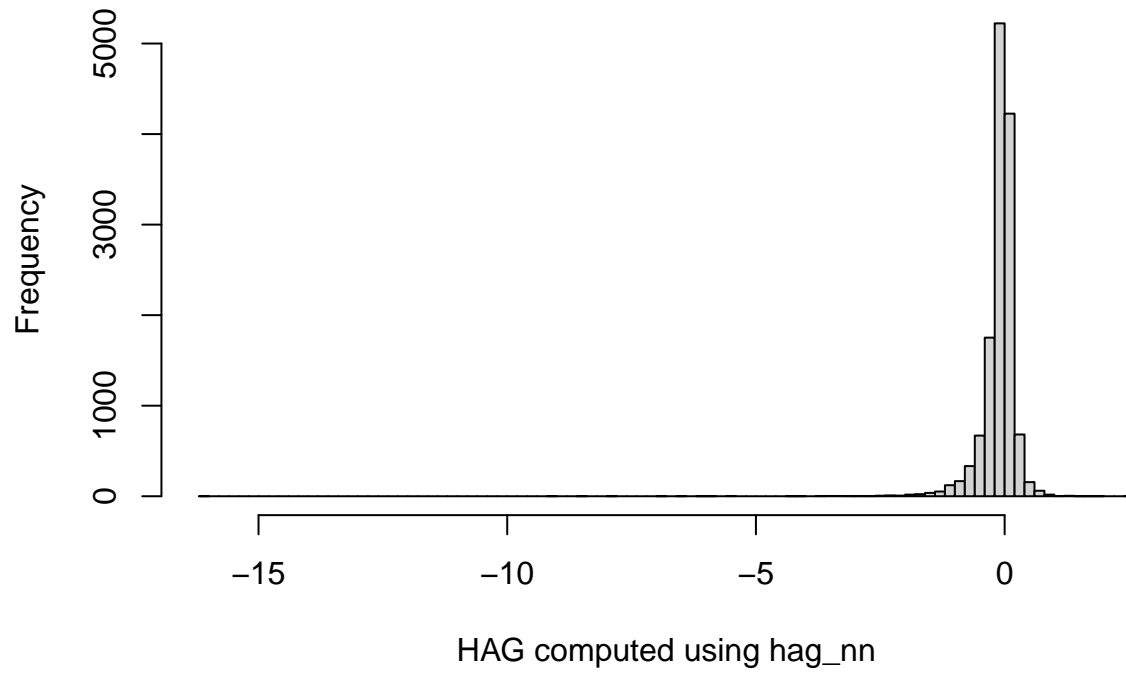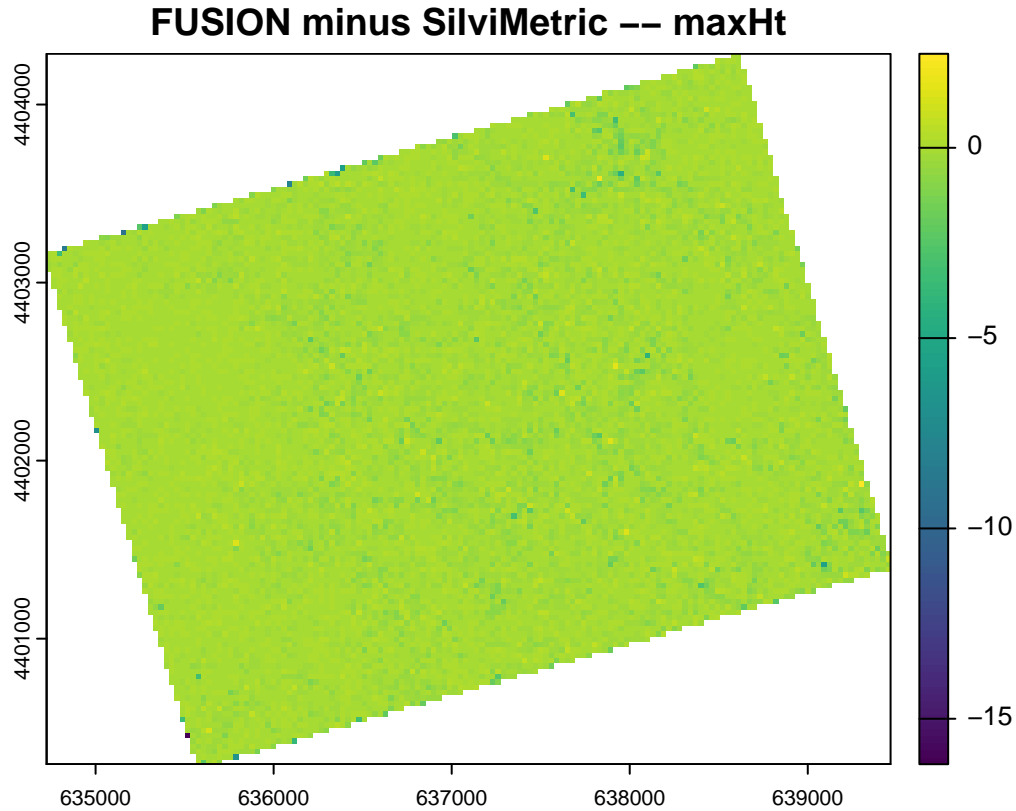


```
##      Layer_1
##  Min.   :-16.194
##  1st Qu.: -0.187
##  Median : -0.043
##  Mean   : -0.110
##  3rd Qu.:  0.049
##  Max.   :  2.469
##  NA's   :7415
```

The final test used FUSION to compute HAG for the point tiles. Then PDAL to convert the tiles back to COPC format (FUSION doesn't write COPC format). The normalized point tiles were then used with SilviMetric (so no HAG computation was needed). This test, compared to the first test, highlights the difference in the HAG values computed in FUSION and PDAL. The maximum heights for cells are nearly identical with differences attributable to numeric precision used for the HAG values (FUSION carries more significant digits...not necessarily more accurate values).

FUSION minus SilviMetric −− maxHt

Frequency

HAG computed using points normalized by FUSION
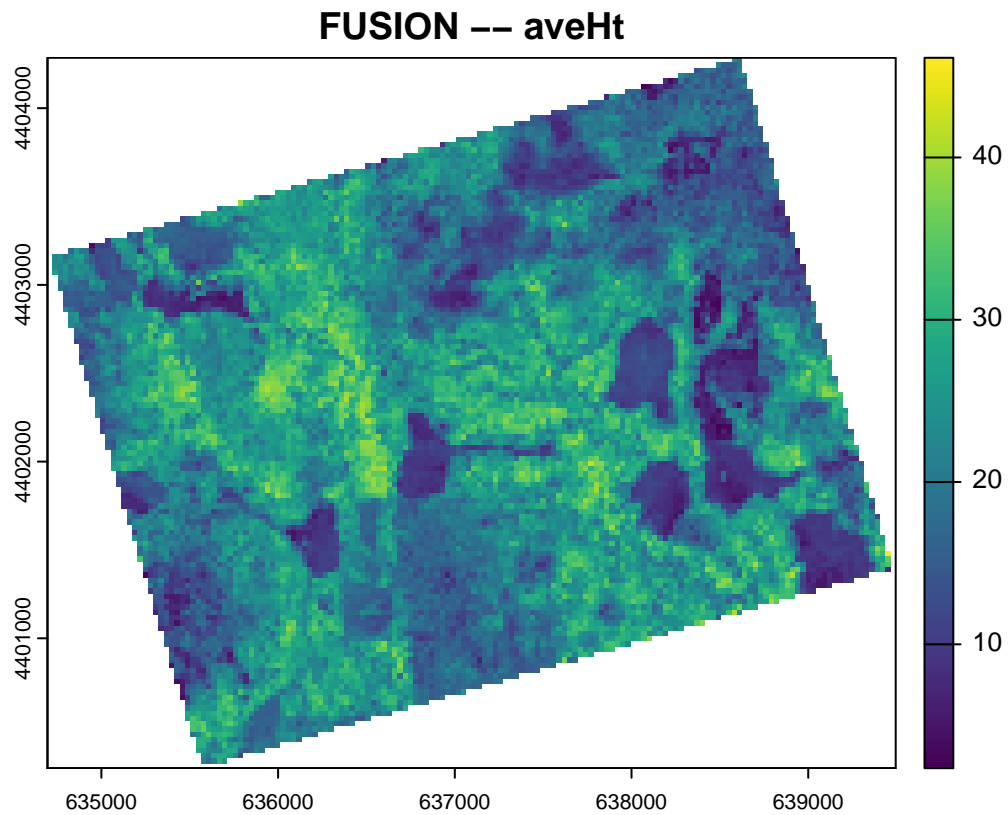
FUSION minus SilviMetric –– maxHt
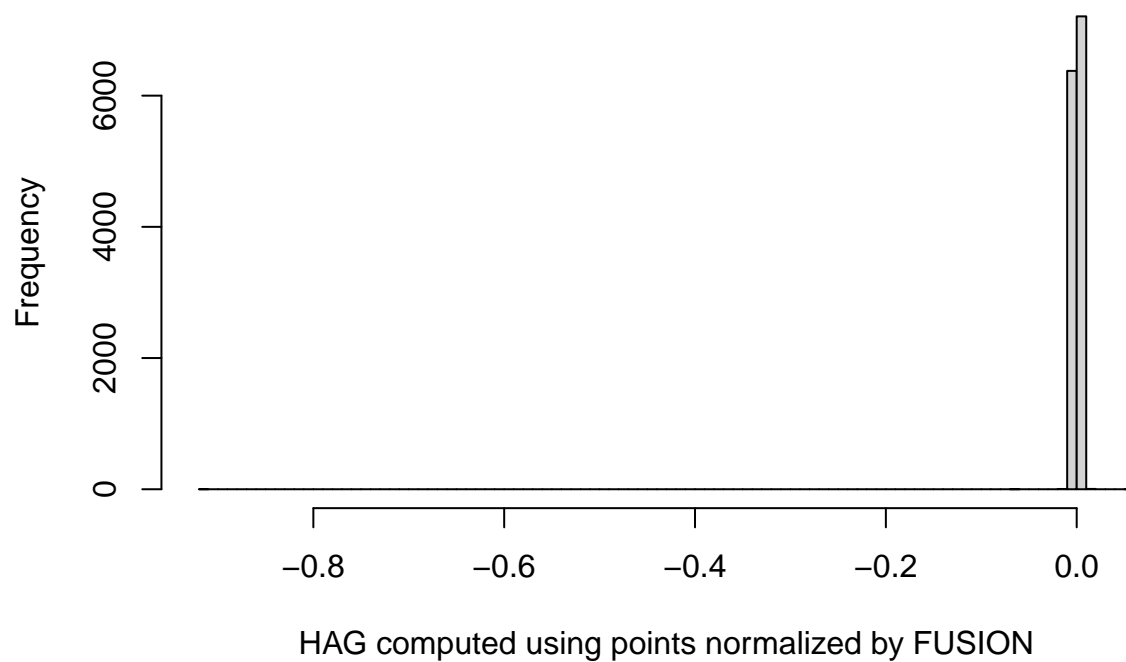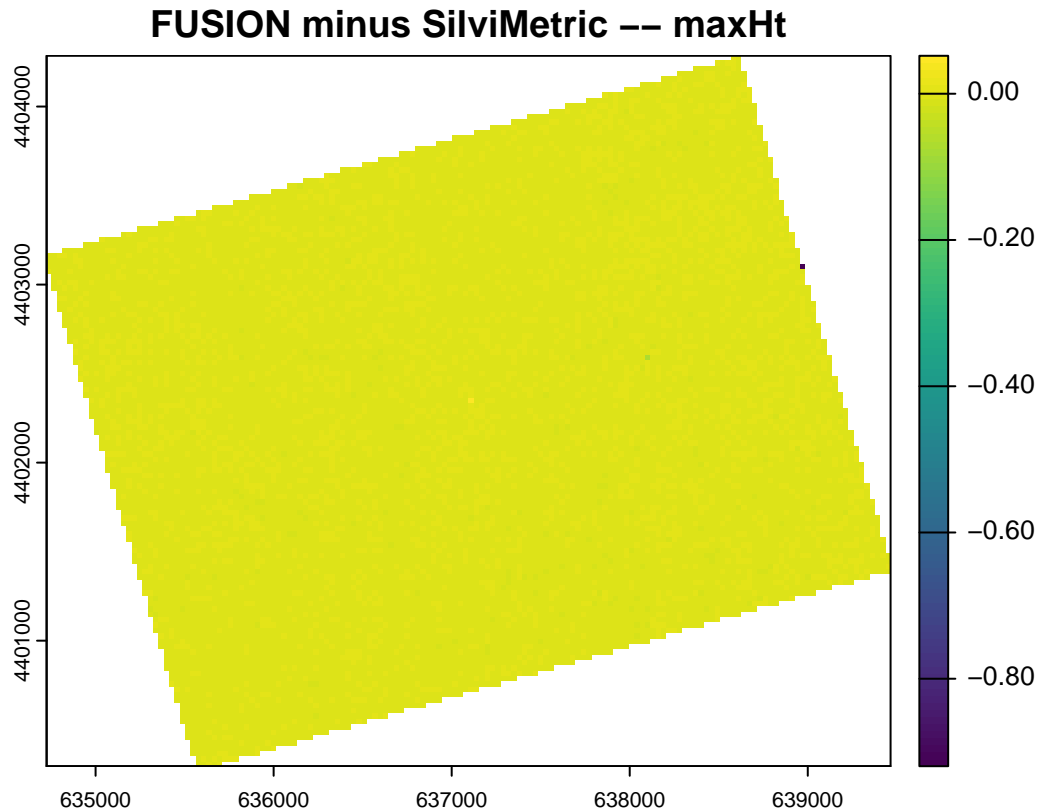
```
##      Layer_1
##  Min.   :-0.920
##  1st Qu.:-0.002
##  Median : 0.000
##  Mean   : 0.000
##  3rd Qu.: 0.003
##  Max.   : 0.052
##  NA's   :7415
```

I suspect that differences in the third test also result from the rules used to select point for a cell. FUSION does not include points that excatly fall on the top and right edges of a cell whereas, PDAL includes these points. While this does produce slightly different values for metrics, I don't think it affect the utility of the metrics. It is debatable which method is more "correct" but I don't expect to see large difference in metrics over large areas because of this difference. . . only for scattered individual cells.

Compare raster values for mean height

This metric (mean HAG) involves calculation so it tests that FUSION and SilviMetric are using the same points and calculation methods.
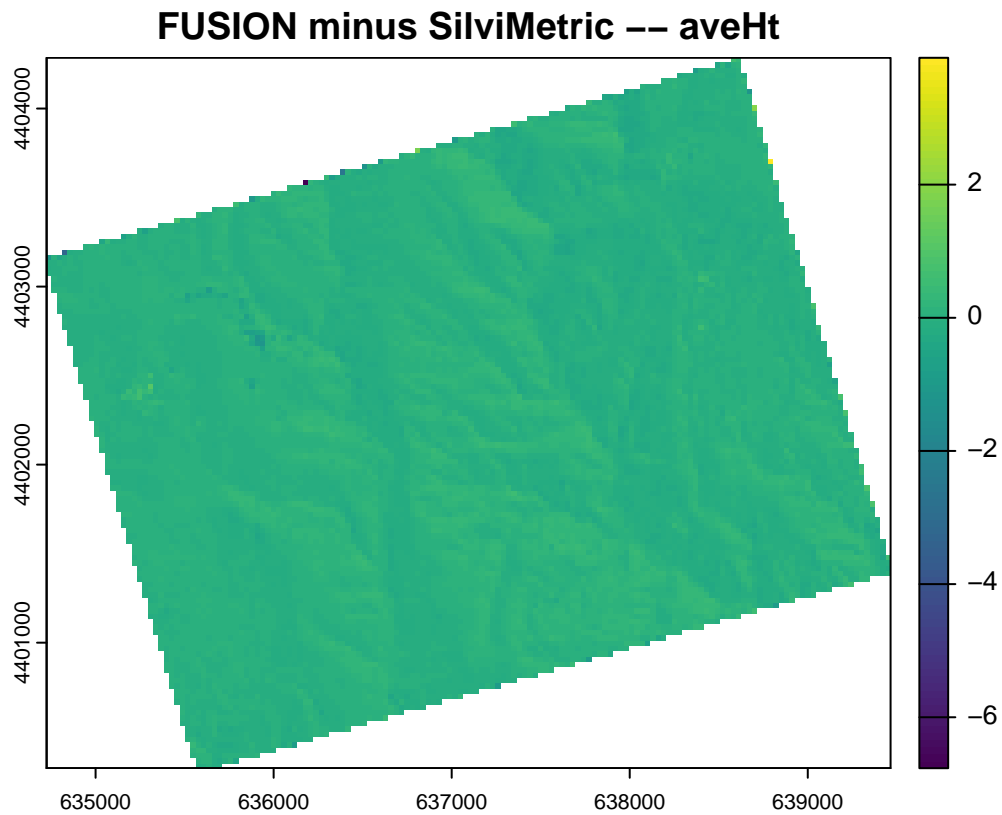
This is a plot of the FUSION output for average height.

FUSION −− aveHt

This is the difference using HAG computed using a VRT with FUSION-derived DEM tiles.

FUSION minus SilviMetric –– aveHt

Frequency (y-axis) versus HAG computed using VRT (x-axis)
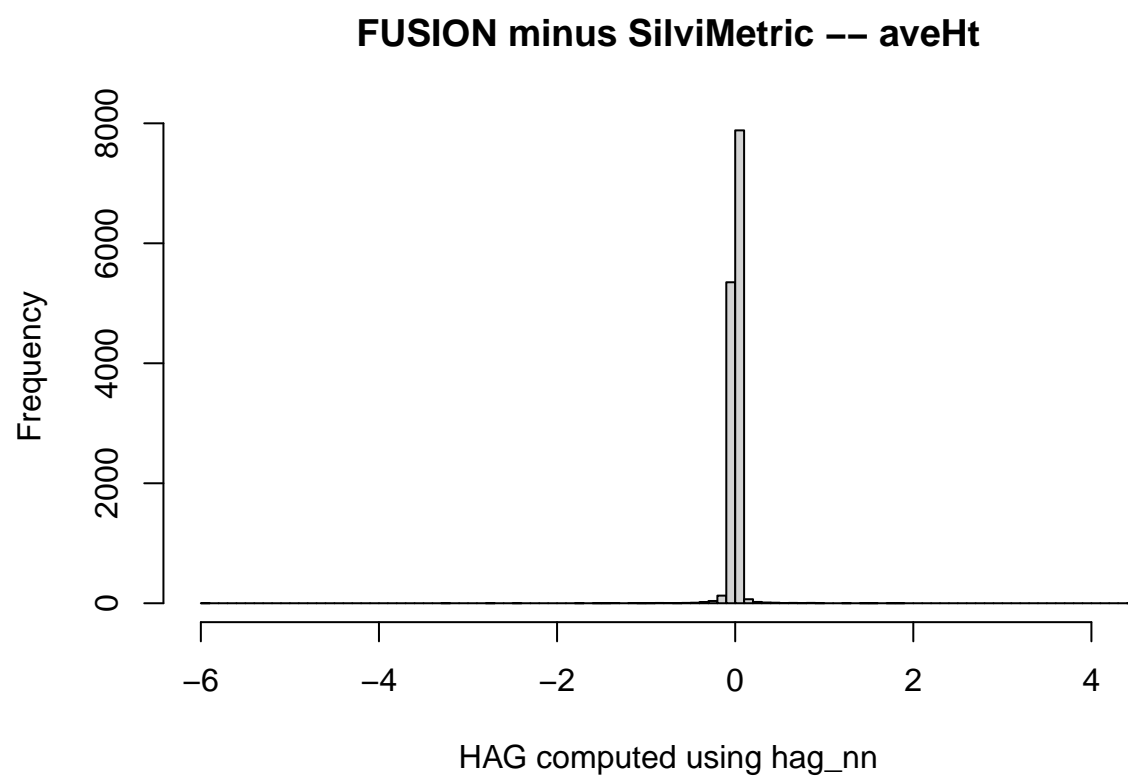
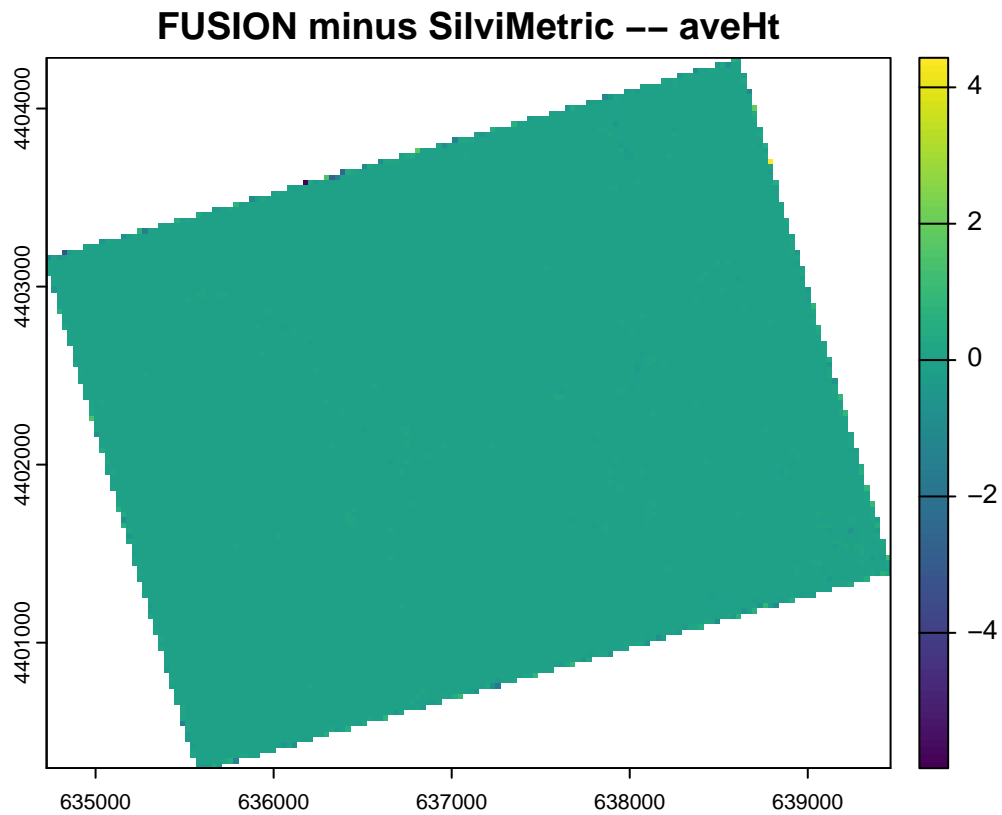**FUSION minus SilviMetric –– aveHt**
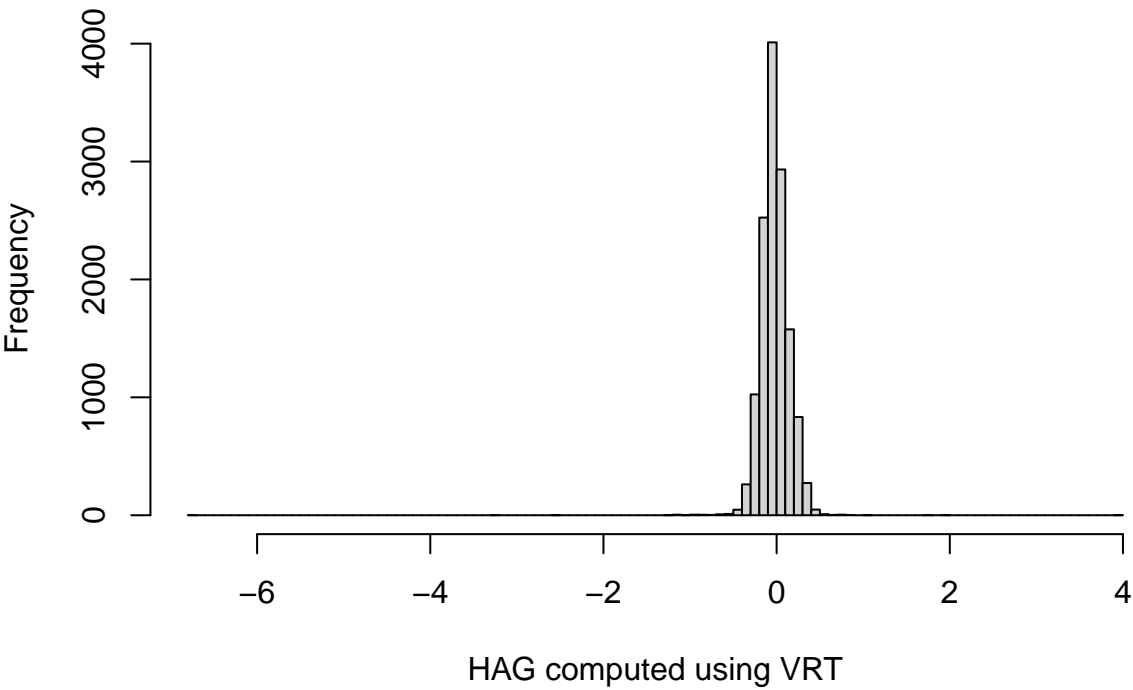

```
##      Layer_1
##   Min.   :-6.765
##   1st Qu.:-0.114
##   Median :-0.025
##   Mean   :-0.019
##   3rd Qu.: 0.071
##   Max.   : 3.905
##   NA's   :7415
```

This is the difference using HAG computed using dem_nn.

FUSION minus SilviMetric -- aveHt

Frequency (y-axis)

HAG computed using hag_nn (x-axis)

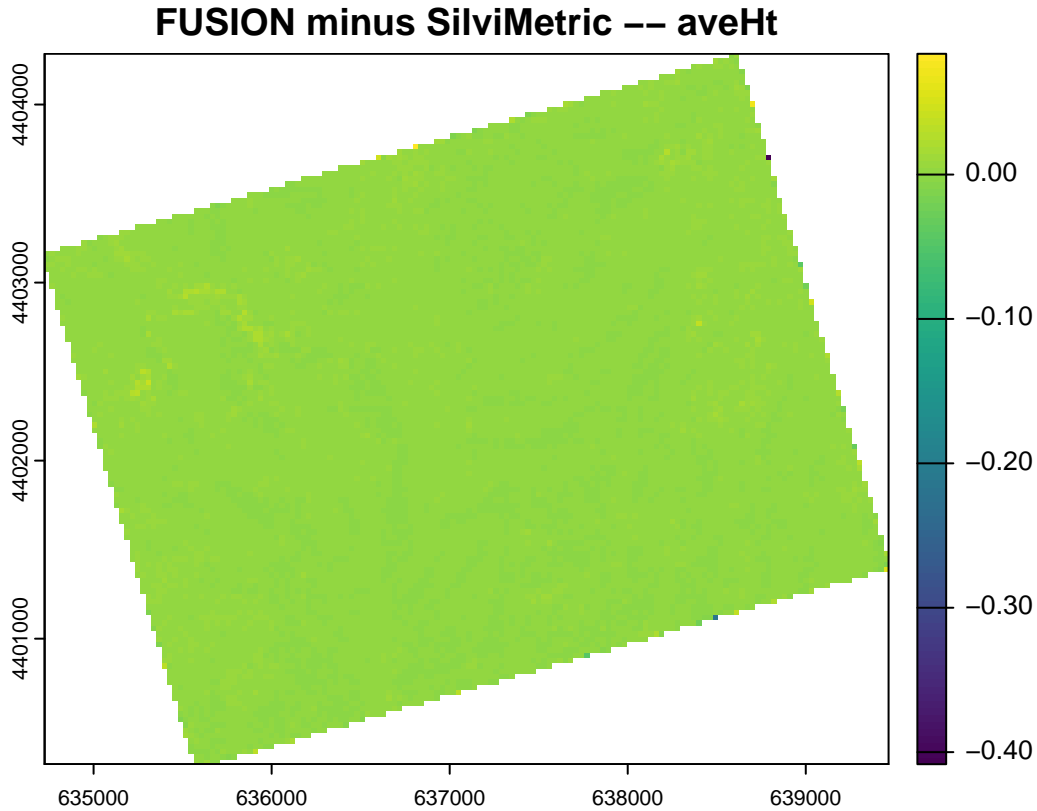**FUSION minus SilviMetric –– aveHt**


```
##      Layer_1
##  Min.    :-5.985
##  1st Qu.:-0.006
##  Median : 0.003
##  Mean    : 0.000
##  3rd Qu.: 0.011
##  Max.    : 4.433
##  NA's    :7415
```

This is the difference using HAG computed by FUSION.

FUSION minus SilviMetric −− aveHt

HAG computed using points normalized by FUSION

FUSION minus SilviMetric –– aveHt
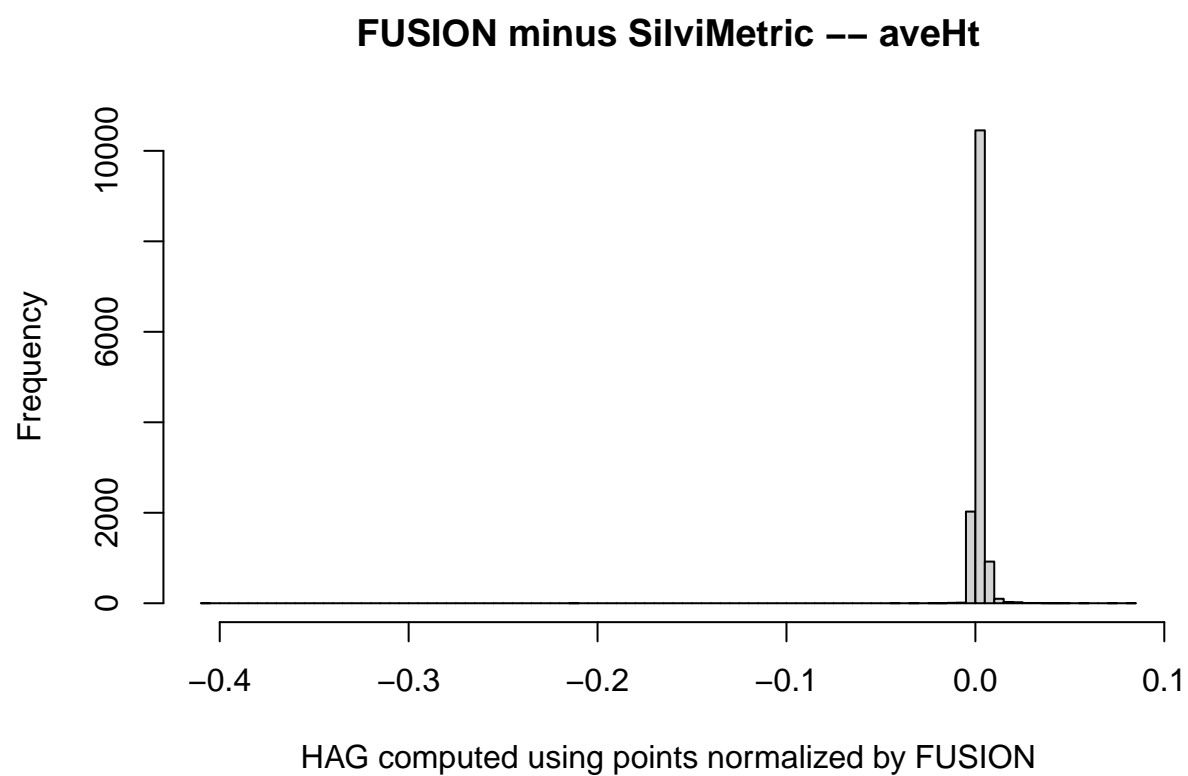

```
##      Layer_1
##  Min.   :-0.408
##  1st Qu.: 0.001
##  Median : 0.002
##  Mean   : 0.002
##  3rd Qu.: 0.003
##  Max.   : 0.084
##  NA's   :7415
```

As with the comparison of maximum height values, the smallest differences occur when FUSION was used to normalize the point data. For this metric, the HAG and the set of points due to inclusion of points on the right and top edges of cells affect the comparison.

CHM comparison

SilviMetric was used to produce a CHM using 1.5m resolution. HAG was computed using the FUSION-derived DEM tiles and below ground points were dropped from the data. As with the metric rasters, some cropping of the FUSION output was needed to match the extent of the SilviMetric CHM. FUSION's normal logic fills holes (areas with no points) using bilinear interpolation. This was turned off when creating this CHM.

FUSION's alignment for surfaces is different from the alignment for raster layers. For the CHM, the cell edges are a multiple of the cell size rather than the cell centers. This originated due to differences between lattice and raster (or GRID) formats and alignment. A version of SilviMetric that matched this alignment was used to create the SilviMetric CHM.

Looking closely at the following plots for my first run, I didn't see many empty (red) cells (NODATA or NA values for cells) in the FUSION output but did see some in the SilviMetric output. FUSION's behavior (CanopyModel) is to replace any valid negative point height value with 0.0. The logic in my build_pipeline() function drops points if there HAG is below 0.0. I set the min_HAG value to -100.0 and added an assign filter to set the Z (HAG) value for points below 0.0 to 0.0 and the empty cells were eliminated.

As with the HAG metrics, I suspect the interpolation process is causing the bulk of the difference. The remainder is due to the right and top edge points in cells in SilviMetric but these should be small differences.
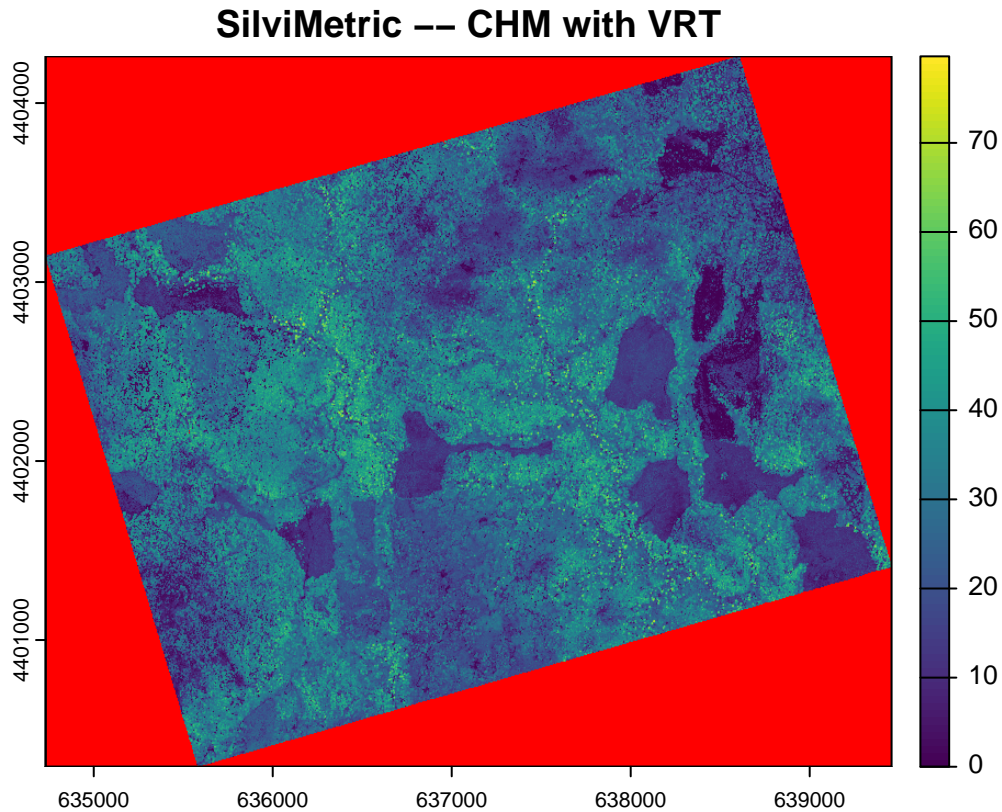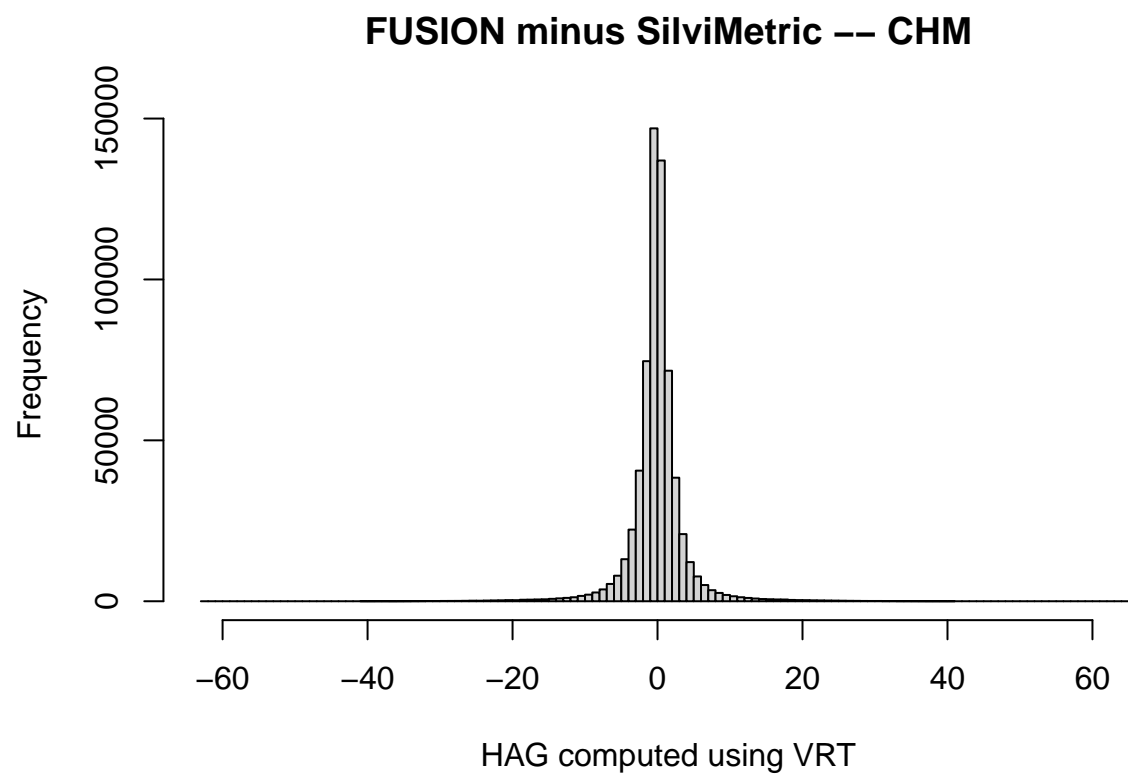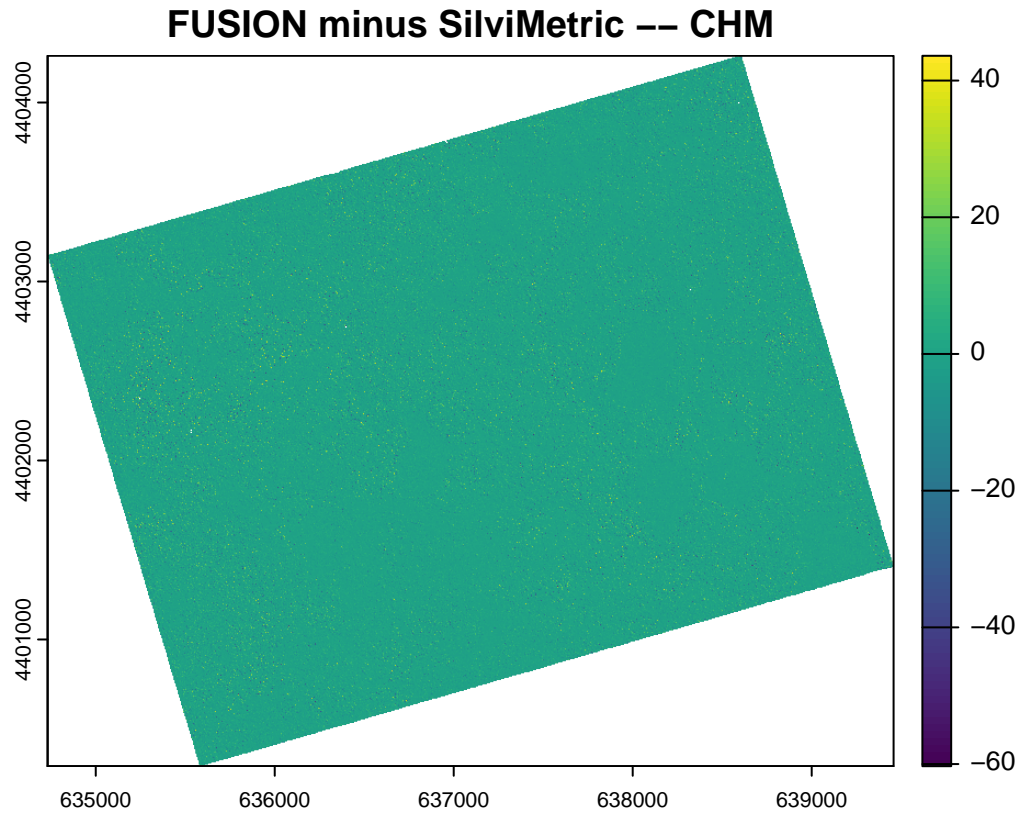
FUSION −− CHM
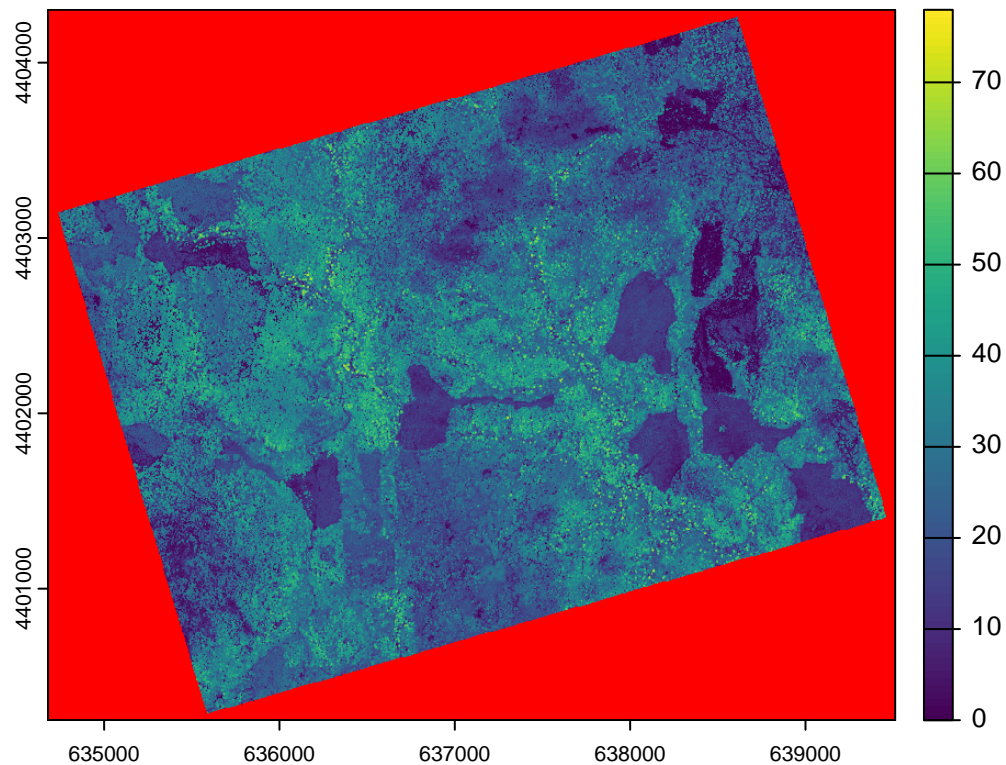

```
## Warning: [summary] used a sample
## Warning: [summary] used a sample
## Warning: [summary] used a sample

## Warning: [hist] a sample of 12% of the cells was used (of which 36% was NA)
```

FUSION minus SilviMetric −− CHM

Frequency

HAG computed using VRT

## FUSION minus SilviMetric –– CHM


```
## SilviMetric raster:
##     m_Z_max
##  Min.   : 0.00
##  1st Qu.:16.83
##  Median :25.64
##  Mean   :25.84
##  3rd Qu.:34.55
##  Max.   :79.06
##  NA's   :36147
##
##
## FUSION raster:
##     Layer_1
##  Min.   : 0.00
##  1st Qu.:16.78
##  Median :25.66
##  Mean   :25.83
##  3rd Qu.:34.53
##  Max.   :72.75
##  NA's   :38793
##
##
## Difference raster:
##     Layer_1
##  Min.   :-49.62
##  1st Qu.: -1.25
```

```
##   Median : -0.04
##   Mean   : -0.05
##   3rd Qu.:  1.15
##   Max.   : 48.16
##   NA's   :36174
```
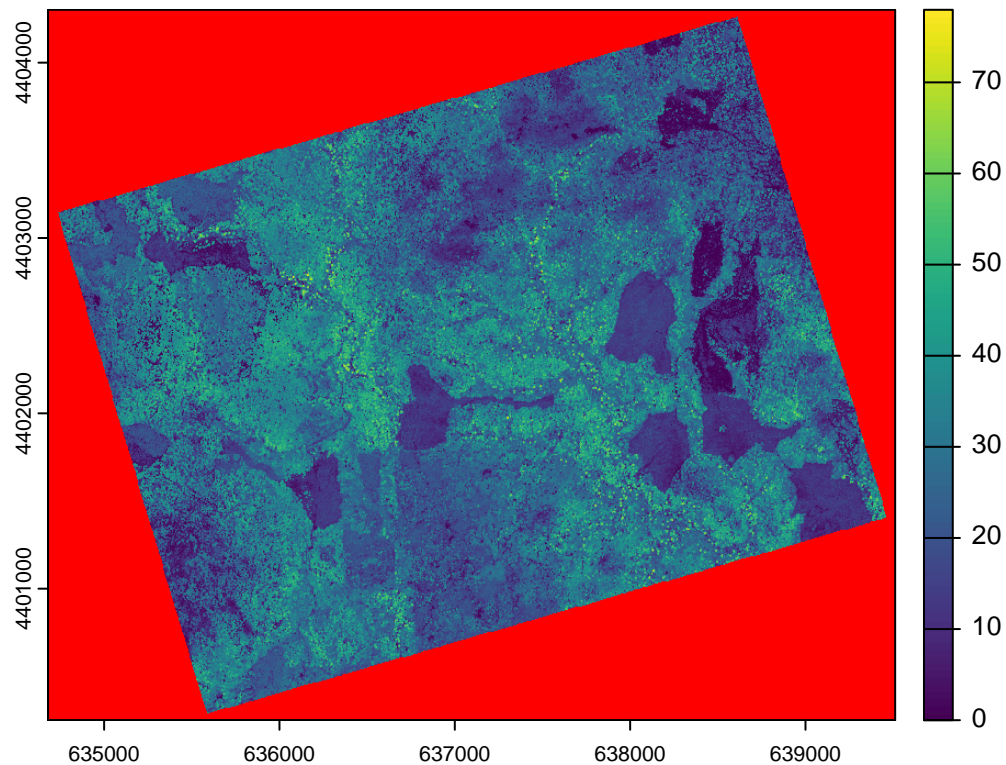
SilviMetric CHM using fusion-normalized points

For completeness, I created another CHM using SilviMetric using the points normalized by FUSION. Differences are slightly smaller than the CHM created using VRT for normalization. Both CHMs are adequate for all applications.
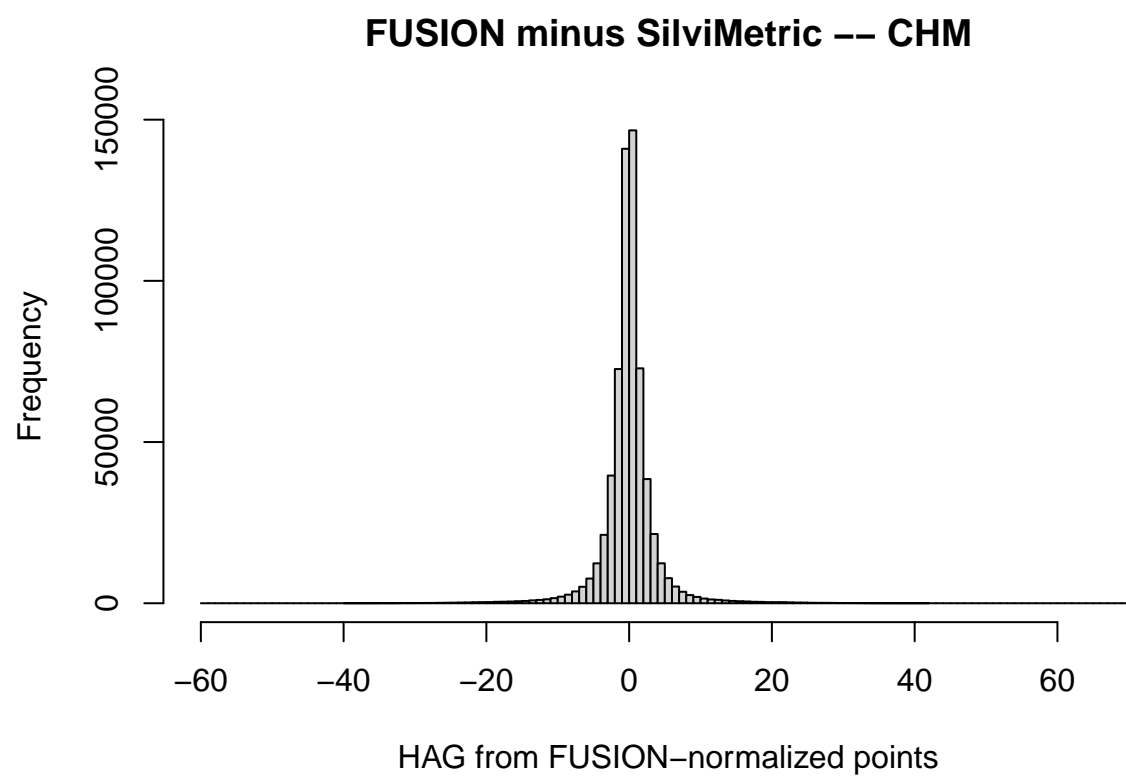
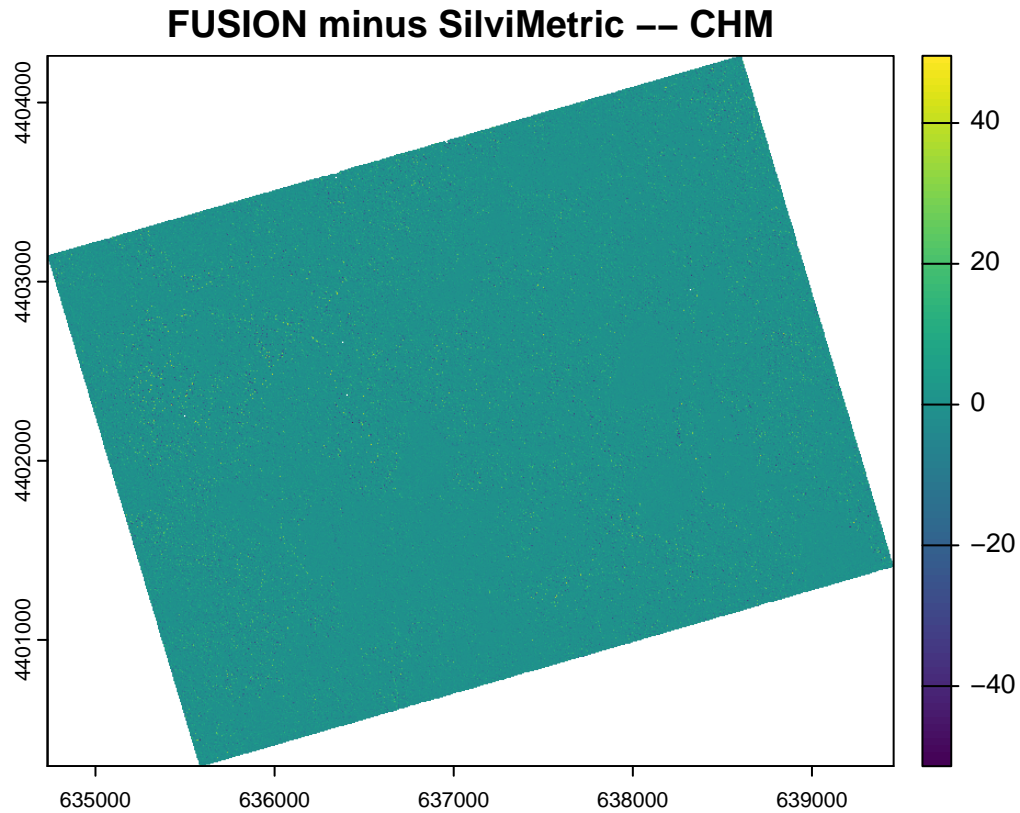**SilviMetric –– CHM with FUSION–normalized points**
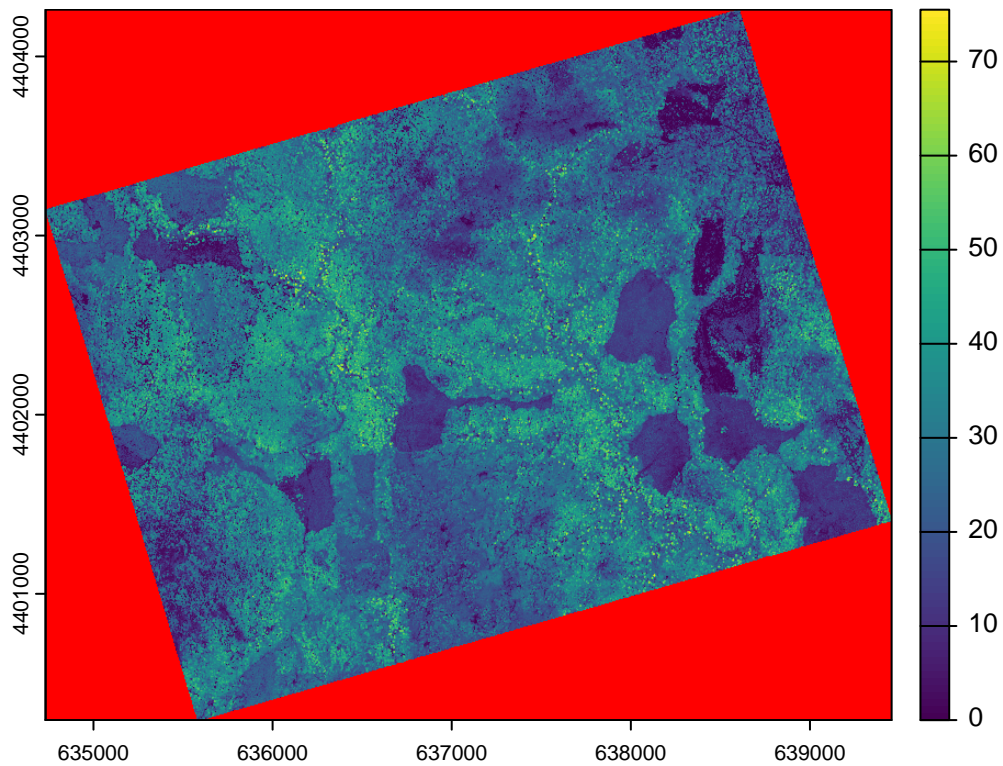
FUSION –– CHM

```
## Warning: [summary] used a sample
## Warning: [summary] used a sample
## Warning: [summary] used a sample

## Warning: [hist] a sample of 12% of the cells was used (of which 36% was NA)
```

FUSION minus SilviMetric –– CHM

Frequency

HAG from FUSION−normalized points

FUSION minus SilviMetric –– CHM


```
## SilviMetric raster:
##     m_Z_max
##  Min.   : 0.00
##  1st Qu.:16.73
##  Median :25.59
##  Mean   :25.79
##  3rd Qu.:34.56
##  Max.   :78.78
##  NA's   :36089
##
##
## FUSION raster:
##     Layer_1
##  Min.   : 0.00
##  1st Qu.:16.78
##  Median :25.66
##  Mean   :25.83
##  3rd Qu.:34.53
##  Max.   :72.75
##  NA's   :38793
##
##
## Difference raster:
##     Layer_1
##  Min.   :-47.67
##  1st Qu.: -1.18
```

```
##  Median :  0.00
##  Mean   :  0.00
##  3rd Qu.:  1.18
##  Max.   : 45.17
##  NA's   :36106
```