UAV Mounted Lidar Exploration and Analysis of Sunnyside Park

1. Motivation

Lidar is one of the most powerful tools in the world of remote sensing. According to NOAA's "Lidar 101"(2012) "Lidar instruments can rapidly measure the Earth's surface, at sampling rates greater than 150 kilohertz (i.e., 150,000 pulses per second). The resulting product is a densely spaced network of highly accurate georeferenced elevation points often called a point cloud—that can be used to generate three-dimensional representations of the Earth's surface and its features. Many lidar systems operate in the near-infrared region of the electromagnetic spectrum, although some sensors also operate in the green band to penetrate water and detect bottom features."
With Lidar becoming increasingly more accessible as it becomes relatively more affordable, we have the opportunity to explore and analyze the topography of our local Sunnyside Park. The primary objectives in this exploration include collecting data, processing lidar point clouds, producing digital surface and elevation models, creating insightful maps, and conducting a comparative analysis with a prior SfM elevation dataset of Sunnyside Park.

2. Methods

2.1 Data Collection

To capture the topographic details of Sunnyside Park we conducted two UAV lidar flights at the location on November 14th 2023. The flights were conducted from the period of 12pm - 2pm, the weather was sunny, clear skies, minimal wind, and a temperature of around 61 degree fahrenheit. We used a DJI Matrice 300 Zenmuse L1 for our flights.

Prior to our flights Professor Ackryod made the appropriate phone calls to ensure we had clearance for the flight, made note of the study plot surroundings to avoid any potential hazards for the UAV while in flight. She also created an automated flight mission using the provided software in the UAV's remote controller. The flight path followed a “lawn-mower” pattern. The flight software gave the following estimations concerning the flight:

- Total flight distance: 2117m
- Estimated flight time: 6 minutes 31 seconds
- Waypoints: 30
- Total amount of photos: 88
- Mapping Area: 29136.0 m^2

2.1.1 Flight Altitudes and Point Cloud Density

The two flights were conducted at 2 different altitudes of 50 meters and 100 meters. The decision to have two differing flight altitudes allows us to assess how variations in altitude effect point cloud density and resolution. For this project we will be primarily analyzing the 50m flight. Lidar data collection is already highly accurate, as stated by the Federal Geographic Data Committee “Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.”.

2.2 Point Cloud Processing

Prior to processing the data collected, it was necessary to change the OBS file produced by the drone’s software with data from the Continuously Operating Reference Station (CORS) Network. This would ensure more accurate GNSS values when processing our data.

To actually process the data we imported our data into the software program “ENVI + IDL”. We are then able to view our point cloud through different representations (RGB, Color by Height, and shade by intensity), using ENVI we created both our DSM and DTM and exported for further analysis in ArcGIS Pro.

2.2.1 Cross-Section Analysis

The cross-section analysis tool within ENVI gives a visual representation of the study site's slope and elevation variations. This representation gives a general idea of these characteristics before actually analyzing them in ArcGIS Pro.

2.3 Mapping and Analysis

The next step was to analyze our DSM and DTM within ArcGIS pro and create corresponding maps. Our analysis consisted of a slope map, a hillshade map, an aspect map and a difference surface map using a dataset collected using a DTM of Sunnyside Park weeks prior to this project.

The first 3 maps were fairly straightforward using ArcGIS Pro's spatial analysis tools. These maps give us insight into the topography of Sunnyside Park which can aid in understanding the local environment and identifying areas that might be more subjected to erosion.

The difference surface map required us to import a DTM of Sunnyside Park produced a few weeks prior using a different data collection method, Structure from Motion(SfM). This map gives insight into the differences in accuracy and resolution between active-remote sensing Lidar and the passive remote sensing of SfM.

3.0 Results

3.1 Point Cloud Visualization

The screenshots captured of the lidar point cloud in ENVI presented very useful information early in data processing. The Color by Height showed us the varying elevation of the site as well as the height of surrounding objects on the terrain such as trees and manmade structures, this essentially shows a preliminary DSM and DTM.

The shade by intensity presents the intensity of the site, "Intensity is defined as the ratio of strength of reflected light to that of emitted light, and is influenced mainly by the reflectance of the reflecting object." (Song et al.)

The RGB visualization gave us a preliminary model of the site using actual photos collected alongside the point cloud. This is useful for showing differences in materials of different characteristics(?) at the site. (grass, roads, sidewalks) which in conjunction with the intensity can be used to classify land-cover (Song et al.)

3.2 Maps

The maps created in ArcGIS Pro gave us a more accurate and in-depth representation of Sunnyside Park's terrain and topography. Here is an initial report from each of the maps:

- Digital Terrain Model: The DTM map shows that the site in total has an approximate 20m difference in elevation with the highest side being at the farthest Northeast end and the lowest point being on the furthest Southwest side.
- Hillshade: The hillshade map visually shows 3 hills at the actual park section of Sunnyside park. We see two hills running vertically (North-to-South) in the middle of the site and a more subtle vertical (East-to-West) map at the upper right section of the park.
- Slope: The slope map shows all the vertical slopes at Sunnyside Park. The steepest slope is at the Northern edge on the East side with a slope degree range between 8.53 and 11.3.
- Aspect: The aspect map shows us the orientation of the slopes at Sunnyside Park. Interpreting it visually, we can see that the majority of the slopes face South and West.

3.3 Difference Map Analysis

The difference map produced in this project is meant to show the elevation differences in the DTM produced by Lidar and the DTM produced by photogrammetry/SfM at a height of 45m in project 2. The purpose of this comparative analysis is to assess the accuracy and resolution differences between the two methods. The difference is difficult to access visually but accessing a handful of points within ArcGIS the average difference in elevation between the two models is 68 meters. This is quite substantial depending on your objectives of collecting and creating a DTM.

4. Discussion (Lessons Learned)

4.1 Data Quality and Limitations

While the data collected was high quality and both data collection and data processing was quite convenient, it is important to remember the limitations of the UAV Lidar data collection method.

Firstly, price is one of the larger limitations when it comes to Lidar of any kind. Other methods are considerably more affordable and depending on your objectives can be sufficiently accurate.

Secondly, we are limited by the capabilities of the UAV drone itself. The unit used in this project had a battery life of approximately 40 min(?), while the flight time was 6 min, it covered an area of 29136.0 m^2 and we used two flights. If you were wanting to cover a larger area you would likely need to conduct multiple flights using separate batteries (which also have a cost implication).

4.2 Comparative Analysis

The comparative analysis between our 50m lidar flight and our 45m SfM flight is one of the most interesting things to come out of this project. The SfM collected data at a slightly lower elevation(which can correlate to more accurate data), required more field work, took considerably more time in post-processing, yet resulted in a ~68 meter difference to the much more convenient Lidar method. Now it can’t be said for certain which DEM was closest to the true elevation, we can assume Lidar was closest as stated by NOAA in the quote presented in my introduction.

5. Conclusions

In conclusion, the exploration and analysis of Sunnyside Park through Lidar data collection methodology has given a great insight into the terrain and topography of

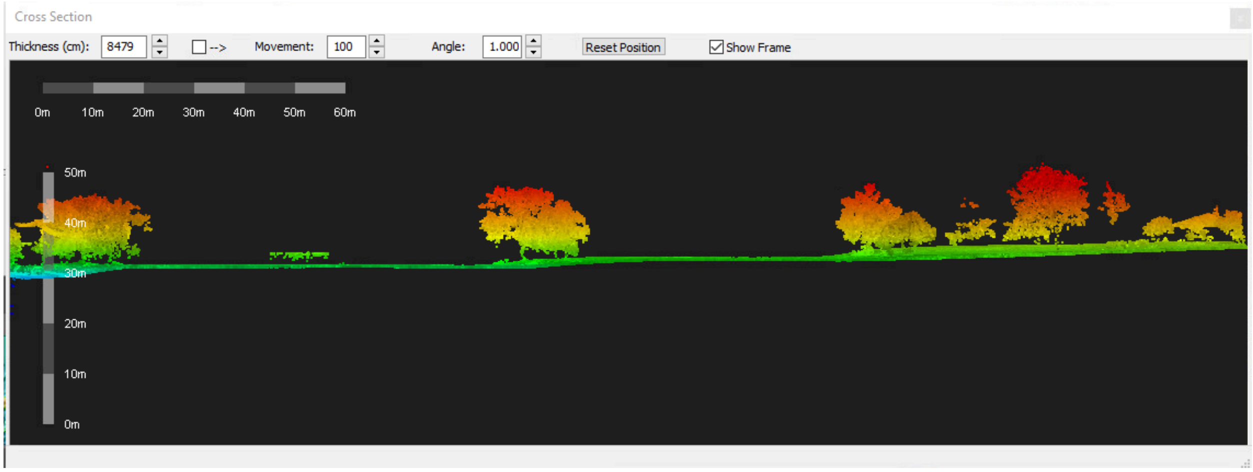
Sunnyside Park. It has also solidified my ability and confidence to both collect and analyze elevation data using multiple methods and software. In addition to this, it has shown the superiority and accuracy of Lidar in the world of remote sensing.

6. References

National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. (2012). Lidar 101: An Introduction to Lidar Technology, Data, and Applications (Revised). Charleston, SC: NOAA Coastal Services Center.

Subcommittee for Base Cartographic Data, Federal Geographic Data Committee. (n.d.). Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy.

Song, J.-H., Han, S.-H., Yu, K., & Kim, Y.-I.. Assessing the Possibility of Land-Cover Classification Using Lidar Intensity Data. School of Civil, Urban and Geo System Engineering, Seoul National University, South Korea. Email addresses: newssong@hotmail.com, scivile@hanmail.net, kiyun@plaza.snu.ac.kr, yik@snu.ac.kr.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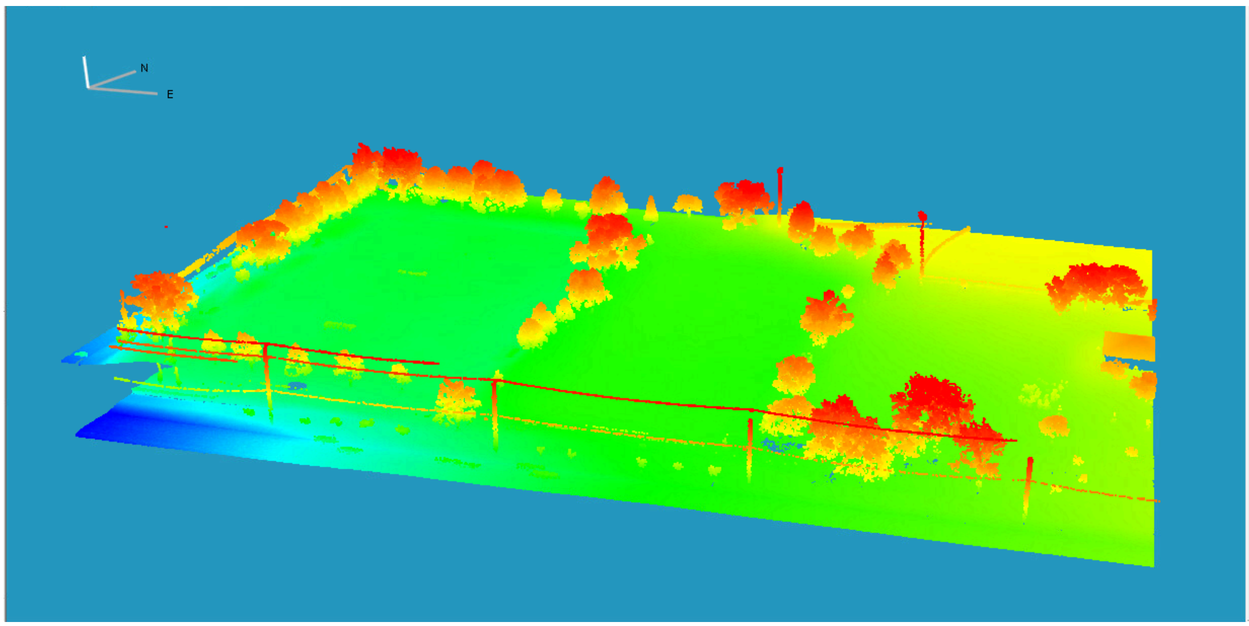
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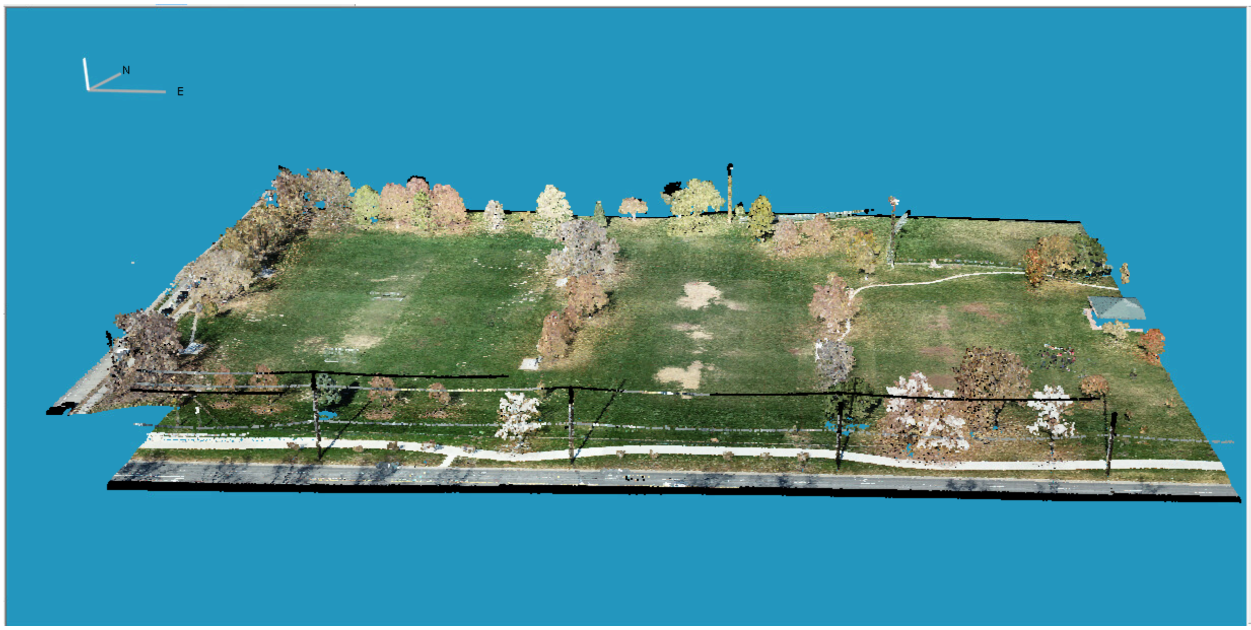
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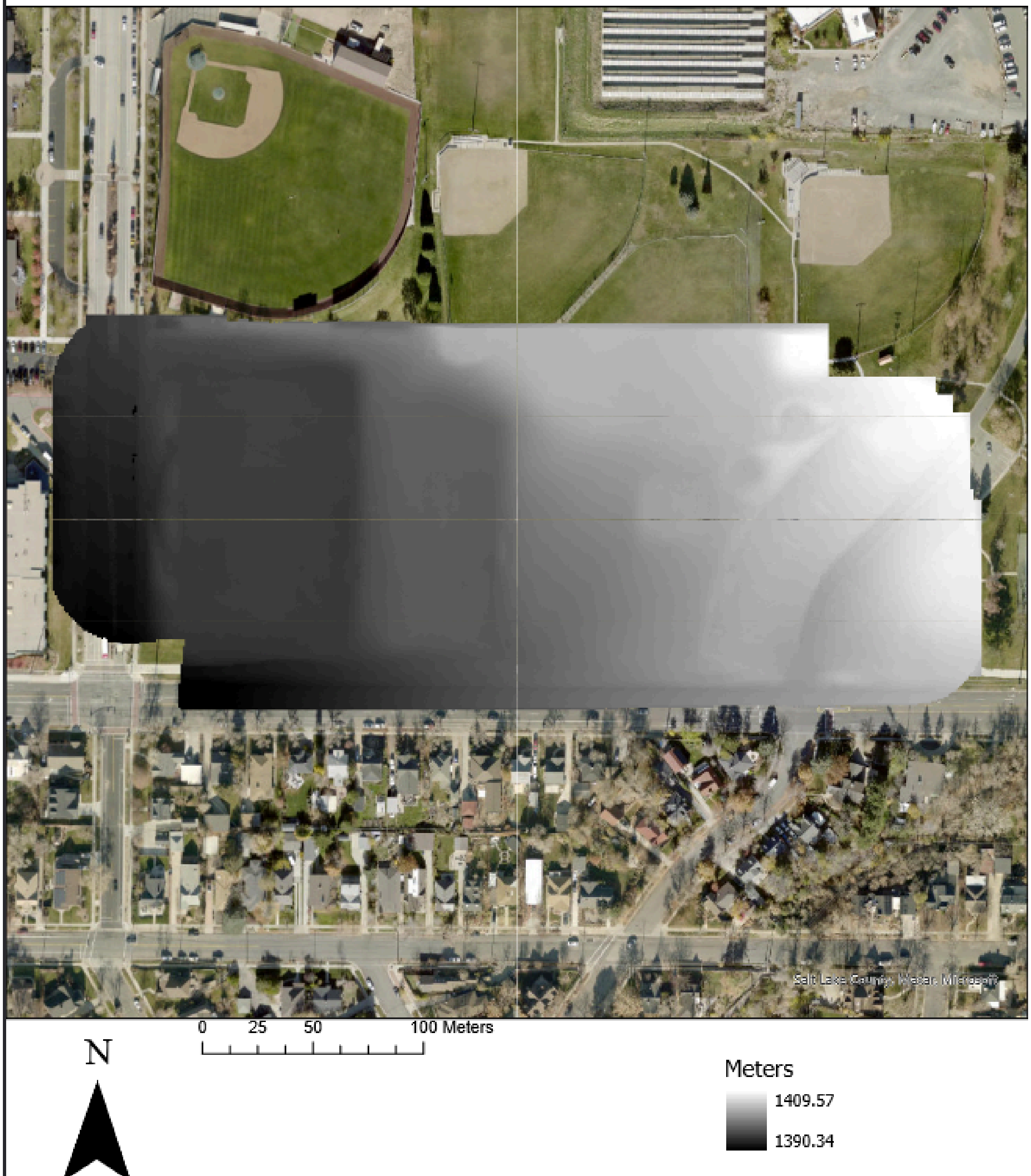
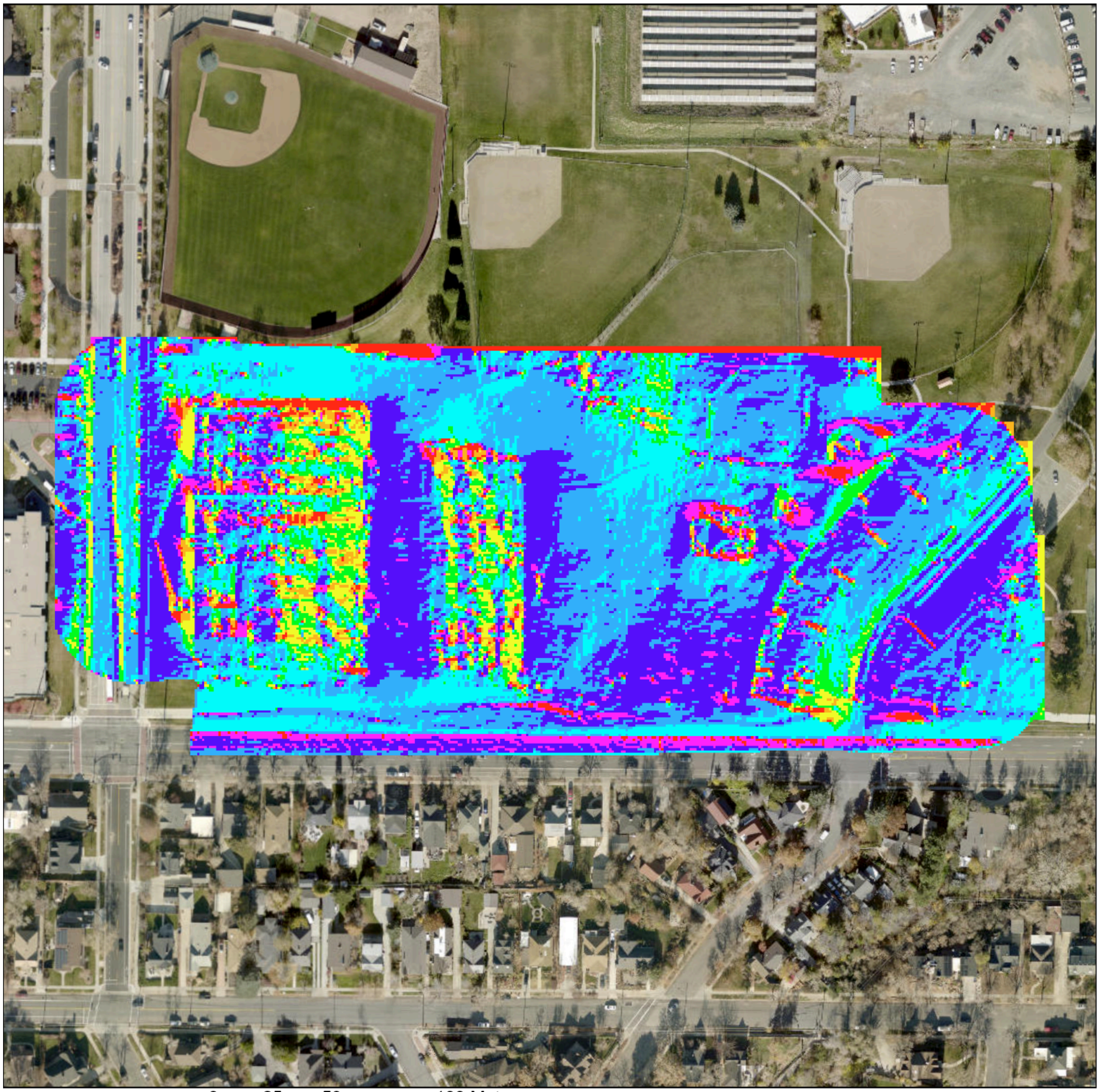
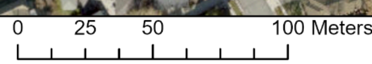
Sunnyside Park DTM November 14th 2023



Sunnyside Park Aspect Map November 14th 2023





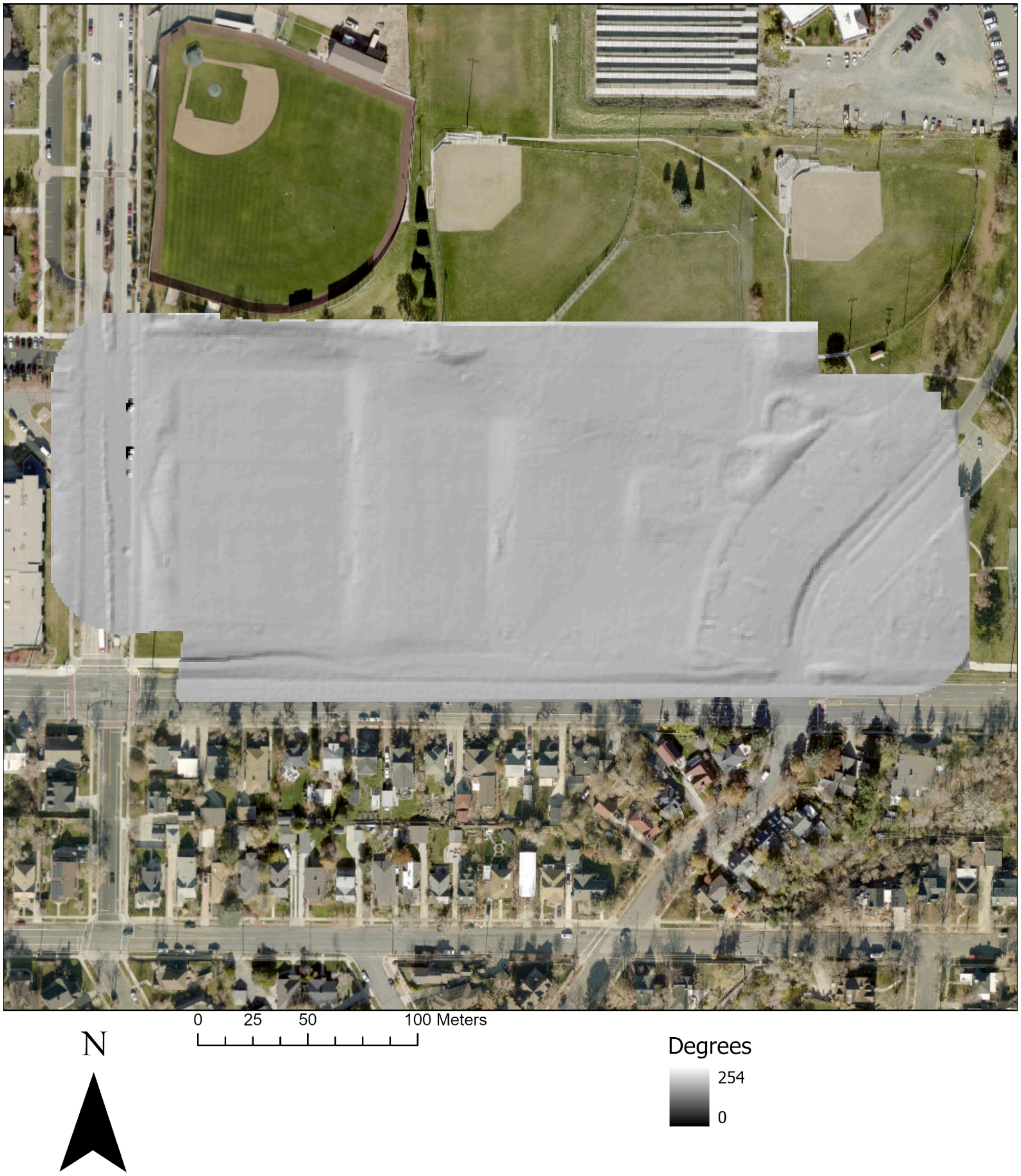
Flat (-1)	South (157.5 - 202.5)
North (0 - 22.5)	Southwest (202.5 - 247.5)
Northeast (22.5 - 67.5)	West (247.5 - 292.5)
East (67.5 - 112.5)	Northwest (292.5 - 337.5)
Southeast (112.5 - 157.5)	North (337.5 - 360)

Salt Lake County, Maxar, Microsoft, University of Utah Geography

Sunnyside Park Lidar v SfM Difference November 14th 2023

Salt Lake County, Maxar, University of Utah Geography

Sunnyside Park Hillshade Map November 14th 2023



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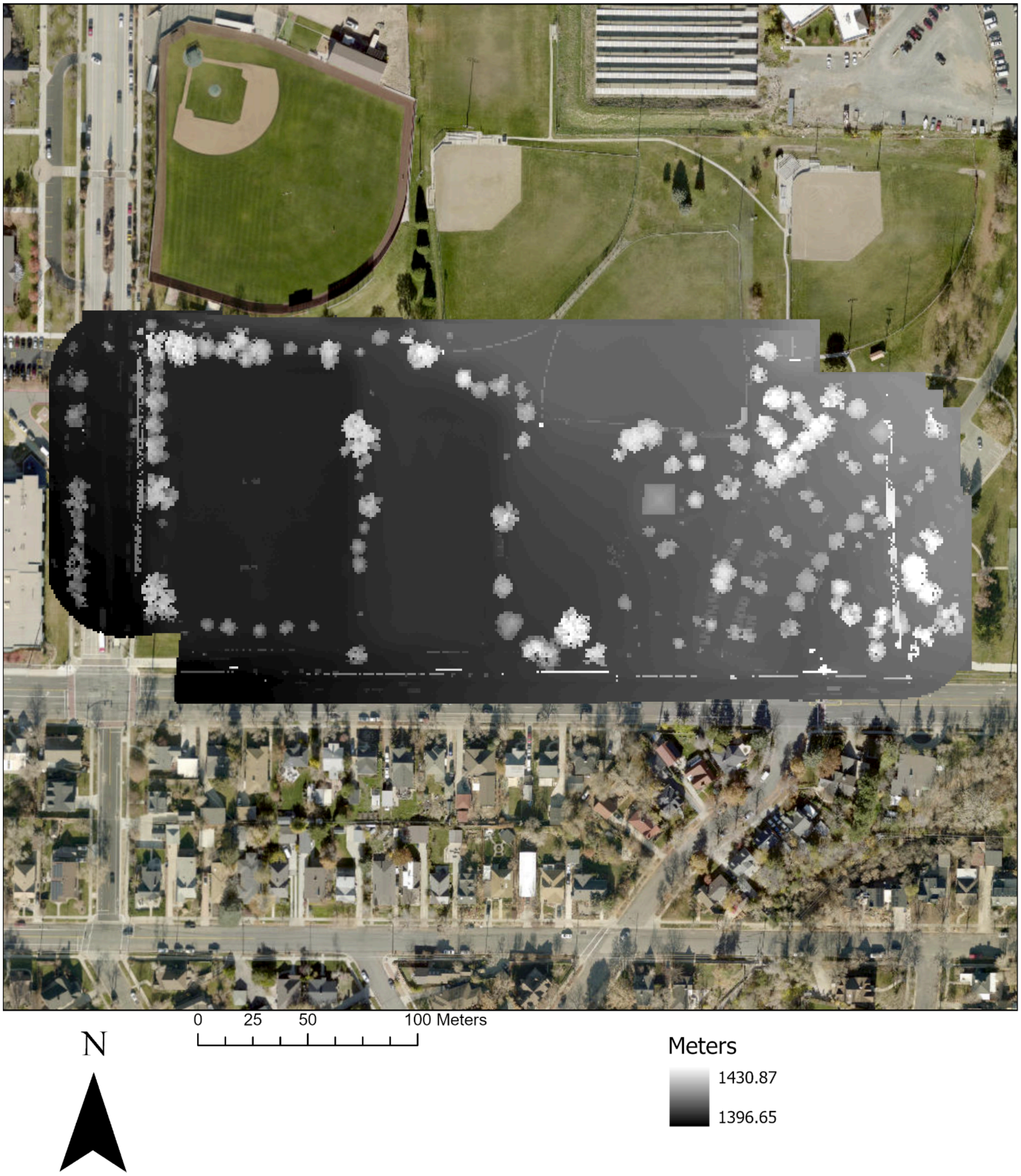
Sunnyside Park DSM Difference November 14th 2023



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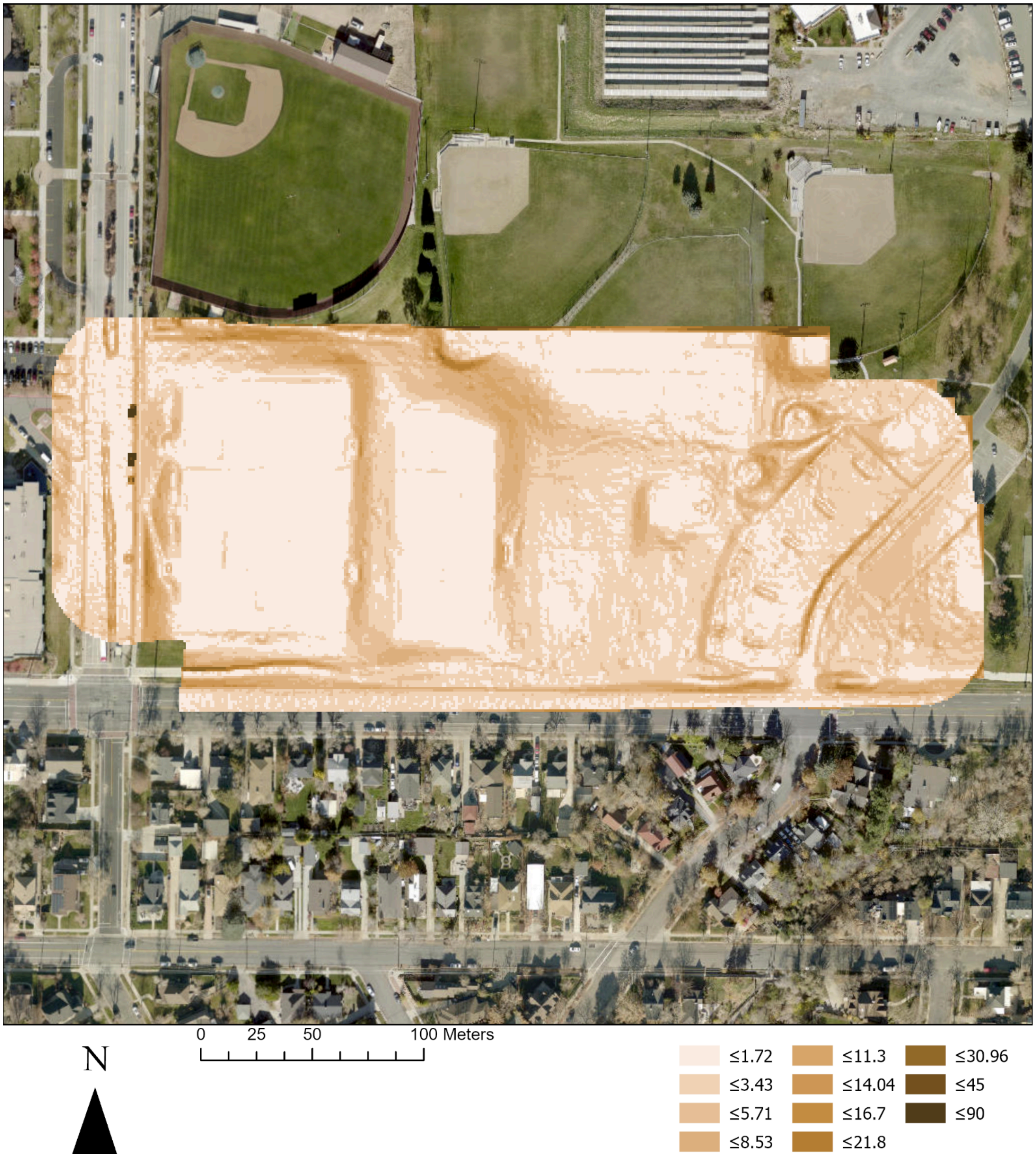
Sunnyside Park Slope Map November 14th 2023



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