Delineating Rooftops and Mapping Solar Radiation Potential: A Case Study in the Midtown Manhattan of New York City

Zhengjie Xie

Department of Geography, Binghamton University, Binghamton, NY, 13902

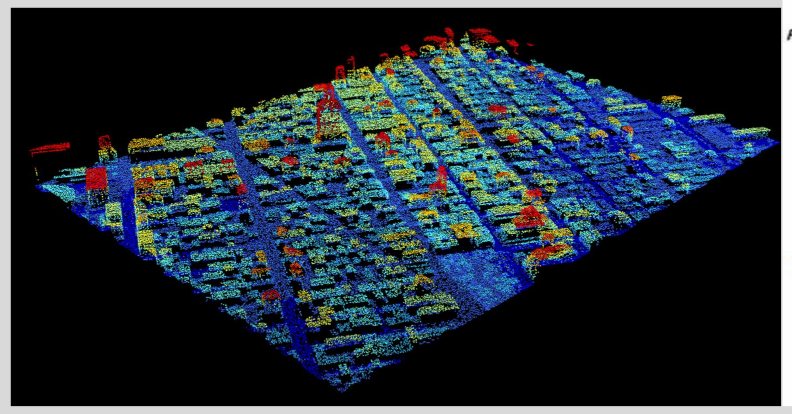
INTRODUCTION

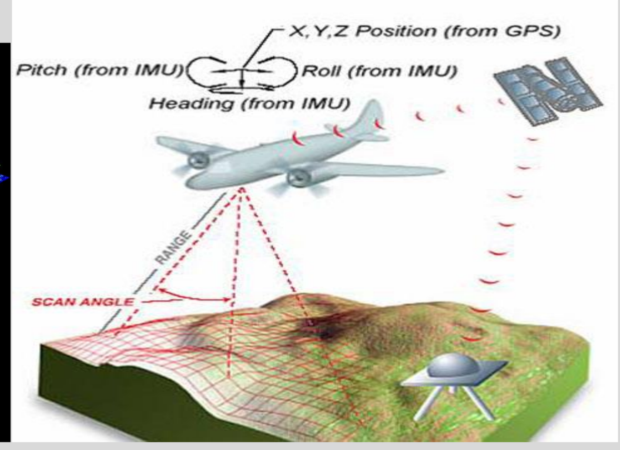
Solar energy as a clean and renewable resource is becoming increasingly important in the global context of climate change and energy crisis. Utilization of solar energy in urban areas is of great importance in urban energy planning, environmental conservation, and sustainable development. However, available spaces for solar panel installation in cities are quite limited except for building roofs. The objectives of this research are:

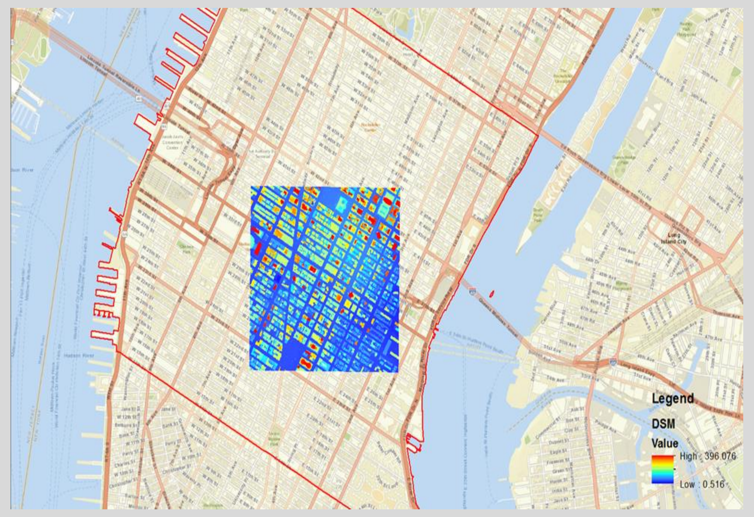
- Estimating the solar radiation on building roofs in the Midtown Manhattan of New York city.
- Select suitable spaces for installing solar panels that can effectively utilize solar energy.

DATA

- Airborne Light Detection and Ranging (LiDAR) data
- High-resolution aerial imagery
- Administrative boundary of Manhattan
- Rooftop footprint shapefile

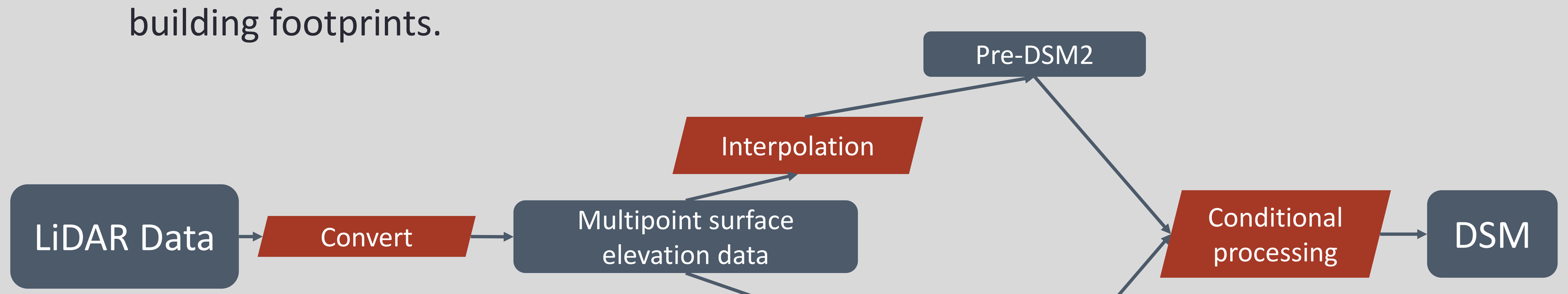






DELINEATING ROOFTOPS

- Airborne LiDAR Produces High-Precision, Multipurpose Data
  - For decades, aerial data collection techniques have been essential for mapping purposes. Traditional high-resolution orthophotography provides a powerful data layer for analysis, but alone its 2D dataset limits the amount of features that can be extracted. With the ability to create 3D digital surface models (DSM), light detection and ranging (LiDAR) offers much more precise datasets that enable exponentially more detailed feature extraction potential.
- The semi-automated feature extraction process combines the LiDAR dataset, high-resolution four-band digital imagery (Red, Green, Blue, Near Infrared) and existing building footprints.



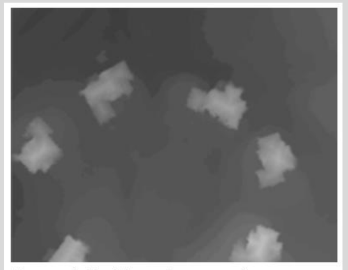


Figure 1. Building detection from LiDAR point cloud

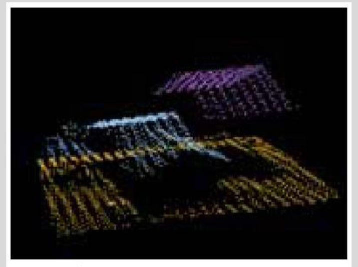


Figure 2. Unstructured point cloud segmentation, perspective view

Figure 3. Roof plane fitting model

SOLAR POTENTIAL ANALYSIS

- With rooftop polygonal delineation and obstructions identified, a normalized DSM is created to analyze the effects of the sun over a one-year period. The data gathered throughout the year tracks the angle or slope of the roof in conjunction with the azimuth of the sun, calculates the insolation across the entire landscape and considers the obstructions that may occlude the roof plane throughout the year. Figures 4-6 demonstrate the progression of feature extraction from an aerial image to a solar radiation map.

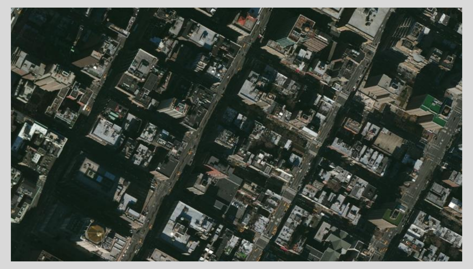


Figure 4. Aerial image

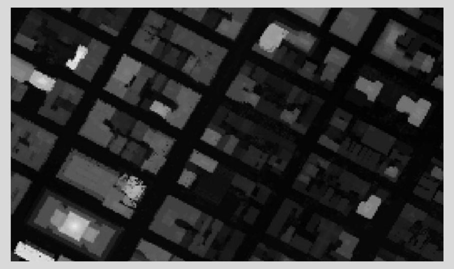


Figure 5. Normalized digital surface

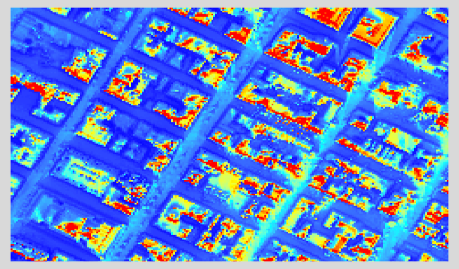


Figure 6. Solar radiation map

- Calculating diffuse radiation, direct radiation and duration of incoming solar radiation (Figures 7-9)
- Extract rooftop solar potential map (Figures 10 & 11)
- Zonal statistics
  - Getting monthly solar radiation energy in kWh of each building in 2015
  - Area of each building
- Calculate aspect of buildings
- Calculate slope of buildings

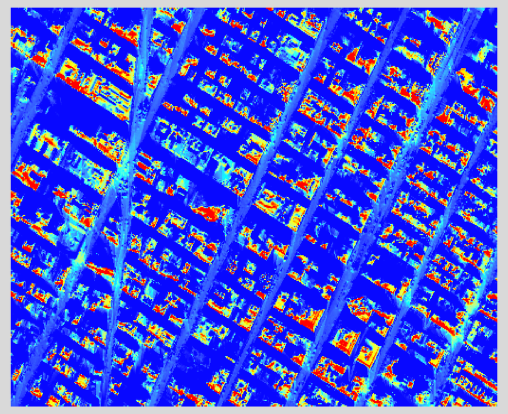


Figure 7. Direct radiation map

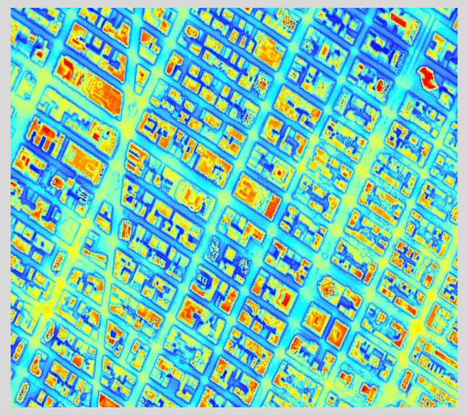


Figure 8. Diffuse radiation map

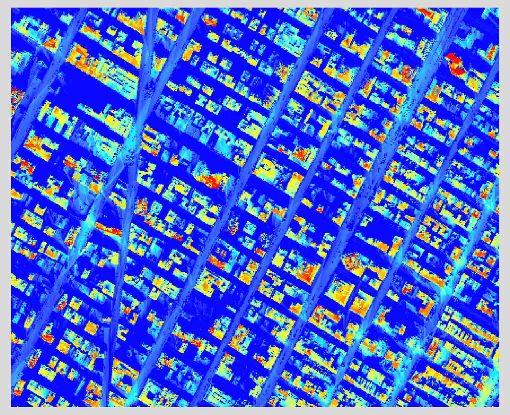


Figure 9. Duration map

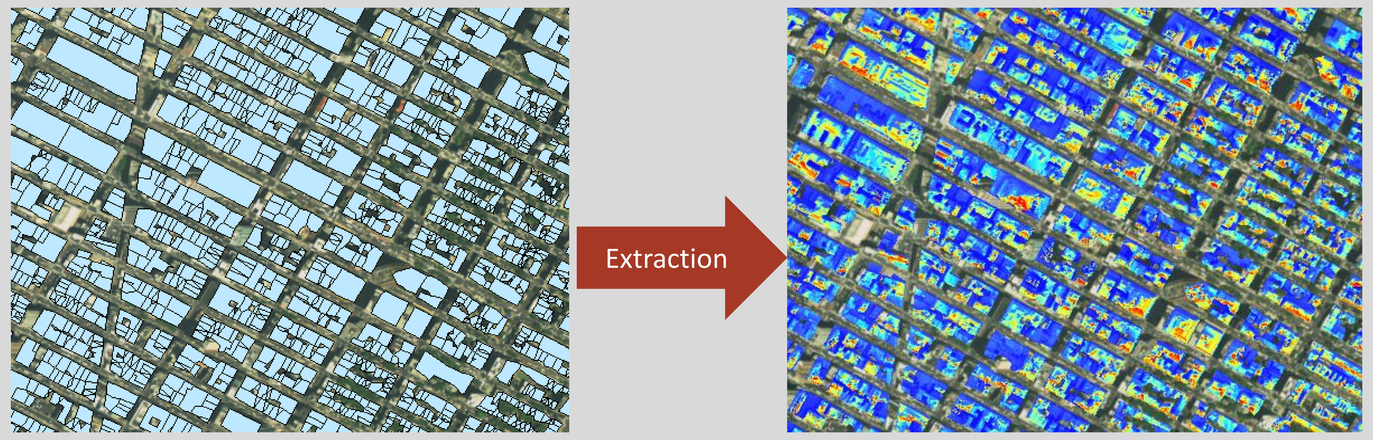


Figure 10. Rooftop footprint

Figure 11. Rooftop solar radiation map

Table — Jan

OBJECT	Shape *	Shape_Leng	Shape_Length	Shape_Area	BIN *	COUNT	AREA	SUM radiation/ KWh
978	Polygon	491.770538	460.268192	5473.084006	1017600	85	5440	283.816557
1408	Polygon	184.742775	117.516916	662.770449	1019473	10	640	99.403987
839	Polygon	268.685266	317.43547	5452.096018	1017017	83	5312	959.371468
2012	Polygon	551.924744	373.878496	7972.913901	1087841	125	8000	2370.523977
1003	Polygon	277.84312	255.447206	3964.391531	1018138	63	4032	993.867701
1160	Polygon	142.97887	150.914459	1033.112389	1018343	17	1088	197.290795
1064	Polygon	124.42514	134.240316	1034.602776	1018218	17	1088	252.591707
1106	Polygon	173.925343	182.634174	2089.725095	1018272	33	2112	737.055232
256	Polygon	640.7846	635.066866	19860.049978	1015211	310	19840	1578.834027

22 (0 out of 2039 Selected)

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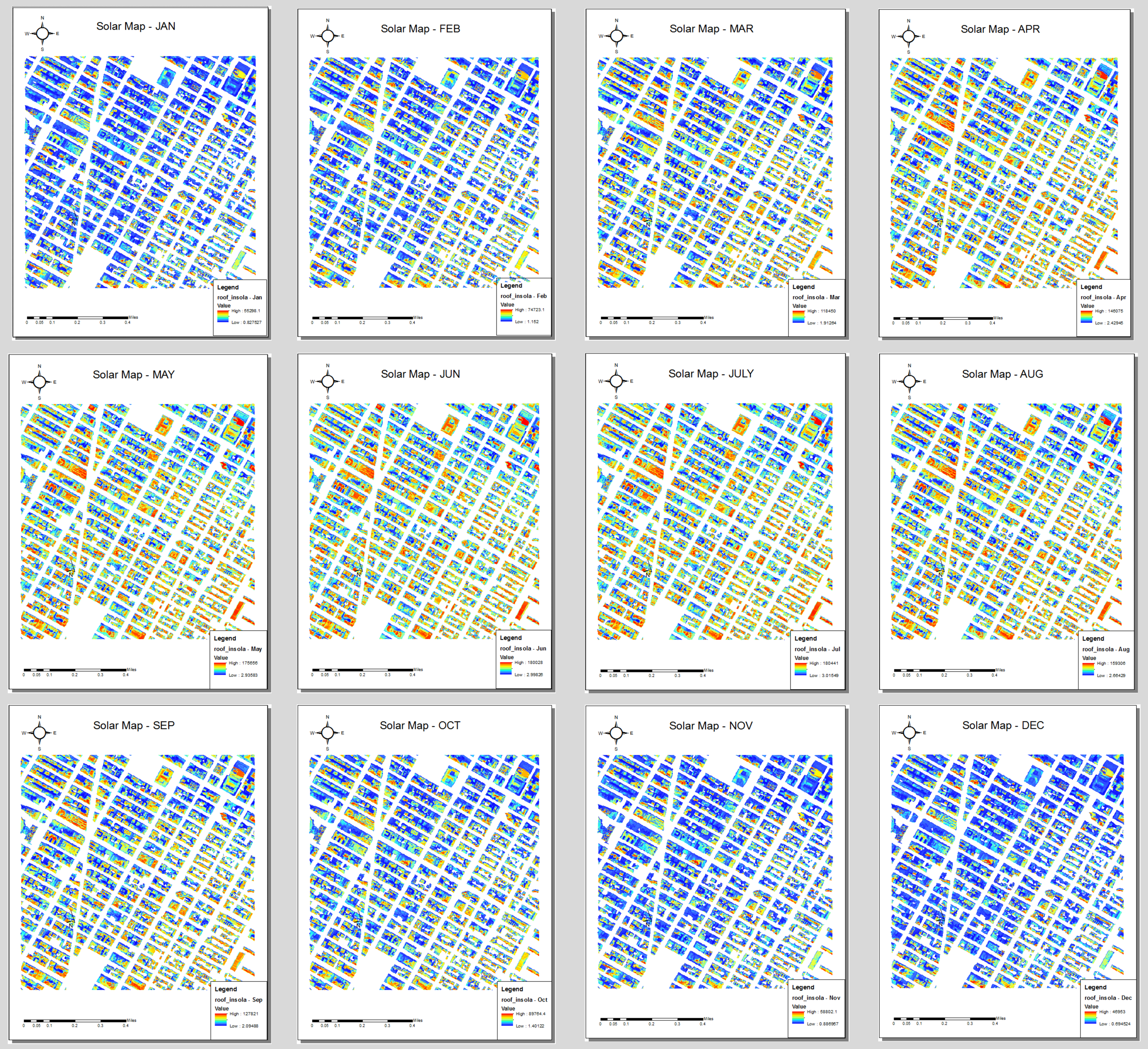
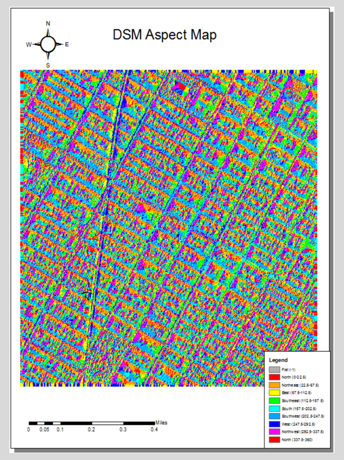
Figure 12. Zonal statistics as a table

RESULTS

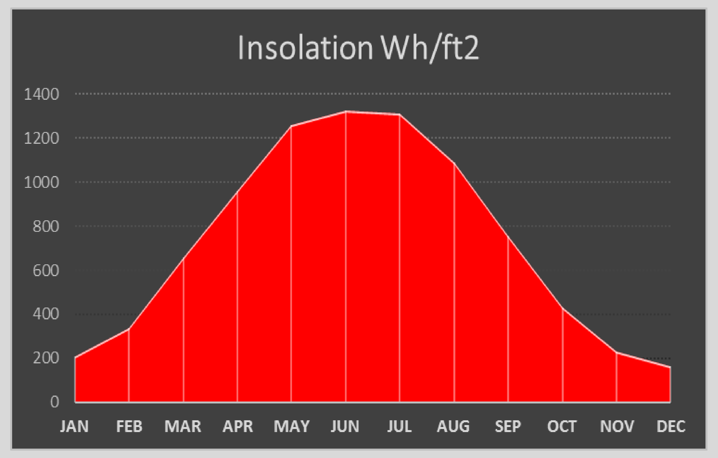
Maps of monthly solar radiation in 2015



Slope and Aspect map of DEM



Monthly average radiation changes in the study area



CONCLUSIONS

- The total rooftop area in Midtown sample area is 12,203,065 ft^2 (1133.7 m^2), which are high potential available space resources.
- Conclude from 12 months solar potential maps and average solar energy trend chart that May, June, and July had much higher radiation energy in 2015. Because the New York city is located at northern hemisphere, in this three months the incident angle of solar rays is closest to 90 degrees. The weather condition is better have less diffuse radiation.
- Further, according to various requirements of customers, suitable rooftops could be extracted by using DSM (elevation) data combine with solar maps, aspect and slope maps.

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