LiDAR Workshop

Ex #2: Viewshed Analysis and solar radiation simulation based on LiDAR data

I. Viewshed Analysis

1. Introduction

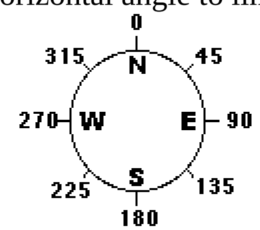
A viewshed is an area on terrain surface that is visible from a specific location. Viewshed analysis is a common function of most GIS software for determining the surface visibility based on elevation values of a DEM. The analysis uses the elevation value of each cell of the DEM to determine visibility to or from a particular cell.

A viewshed is created from a DEM by using an algorithm that estimates the difference of elevation from the viewpoint cell to the target cell. To determine the visibility of a target cell, each cell between the viewpoint cell and target cell is examined for line of sight. Where cells of higher value are between the viewpoint and target cells the line of sight is blocked. If the line of sight is blocked then the target cell is determined to not be part of the viewshed. If it is not blocked then it is included in the viewshed.

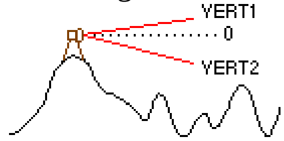
In ArcGIS, the user can control nine parameters for a viewshed analysis:

1) Spot: the surface elevations for the observation points;
2) OffsetA: the vertical distance in surface units to be added to the z-value of the observation points;
3) OffsetB: the vertical distance in surface units to add to the z-values of each cell as it is considered for visibility;

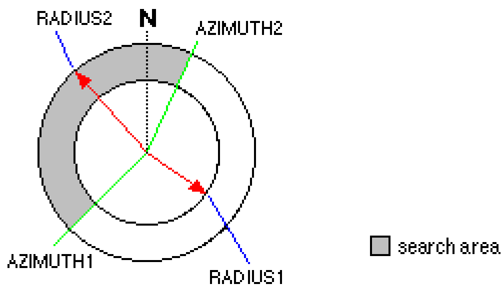
4) Azimuth1: the start of the horizontal angle to limit the scan;
5) Azimuth2: the end of the horizontal angle to limit the scan;



6) Vert1: the top of the vertical angle to limit the scan;
7) Vert2: the bottom of the vertical angle to limit the scan;



8) Radius1: the inner radius that limits the search distance when identifying areas visible from each observation point; and
9) Radius2: the outer radius that limits the search distance when identifying areas visible from each observation point.



In ArcGIS, each cell in the output raster that can see that observer point is given a value of one. All cells that cannot see the observer point are given a value of zero.

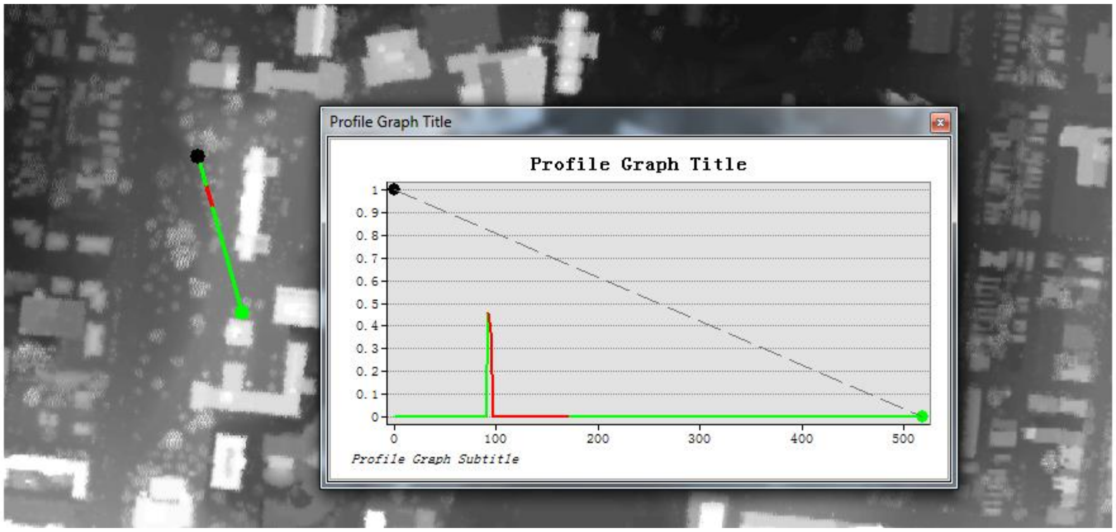
Default settings for the options controlling Viewshed Option	**Default setting**
SPOT	Estimated using BILINEAR interpolation
OFFSETA	1
OFFSETB	0
AZIMUTH1	0
AZIMUTH2	360
VERT1	90
VERT2	-90
RADIUS1	1
RADIUS2	Infinity

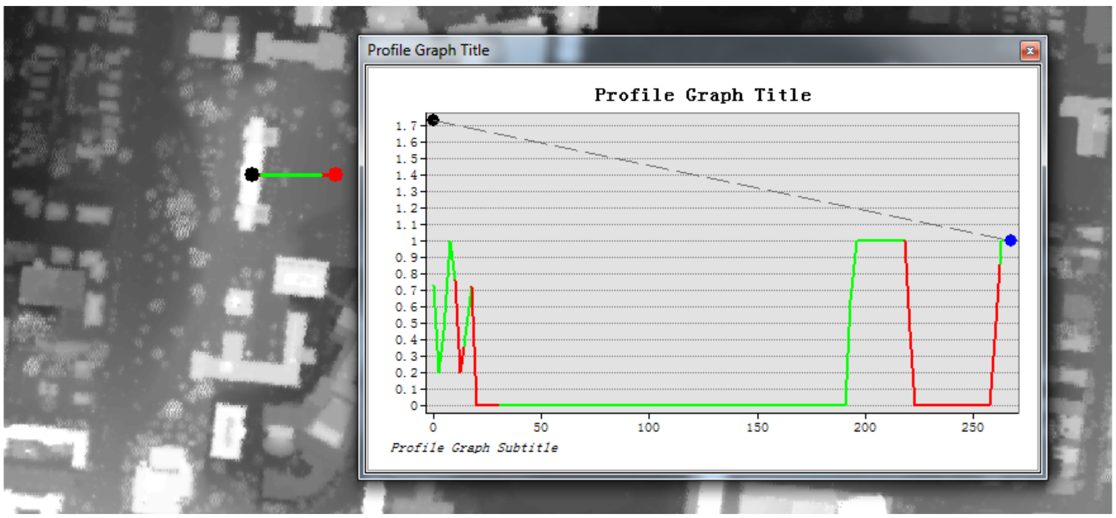
2. Data sets

An airborne LiDAR DEM is available for University of Cincinnati campus under the directory **\EX2\UC_LiDAR\.** The digital elevation model "**uc_tif.tif**" has a spatial resolution of 2.5 feet. The DEM is in state plane coordinate system (Lambert conformal conic projection, distance unit: foot, vertical unit: feet) and referenced to the NAD83 datum.

3. Requirements and instructions

The easiest way to do viewshed analysis is to use **Line of Sight** function in 3D Analyst extension to determine whether one cell is visible from another cell and the line of sight between them.

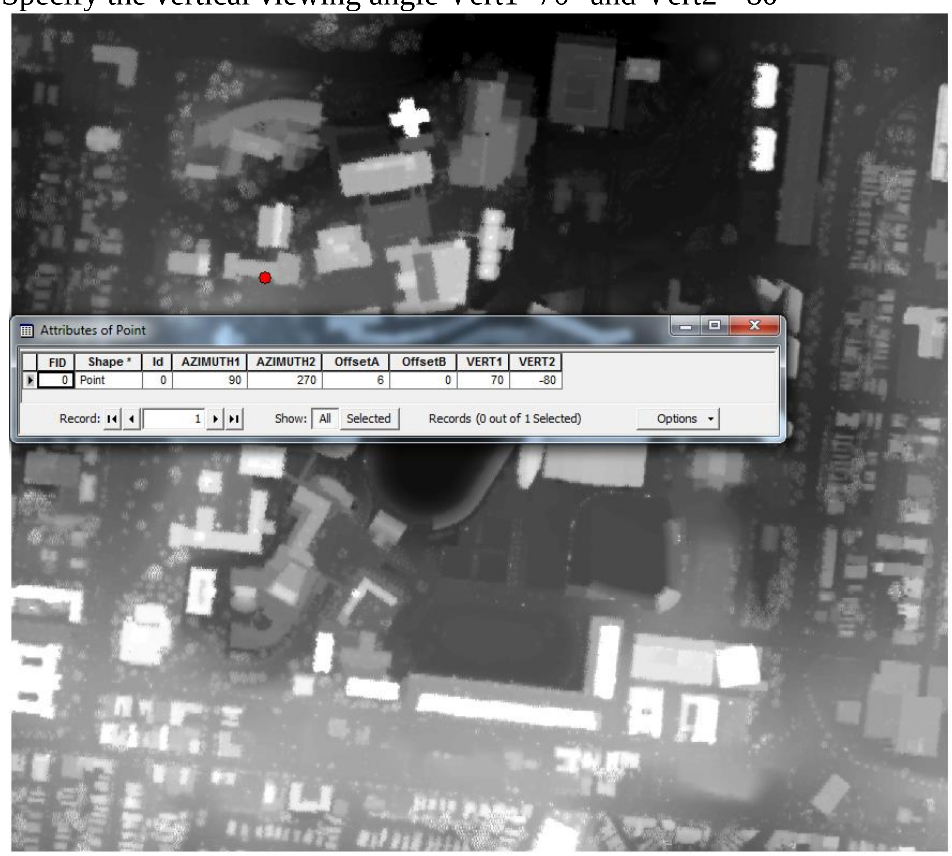




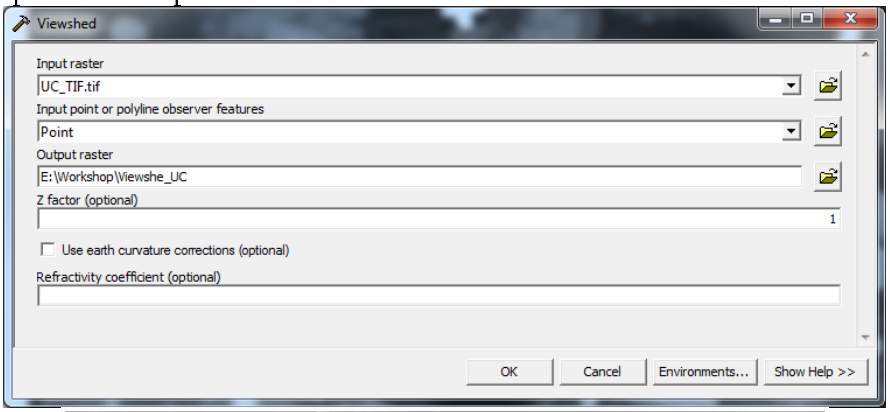
The regular way to perform viewshed analysis is using the Spatial Analyst/Surface Analysis. Assume that an observer is facing a window in room 426, Braunstein Hall and looking at the campus, calculate the observer's viewshed using the LiDAR DEM. You need to do the following operations:

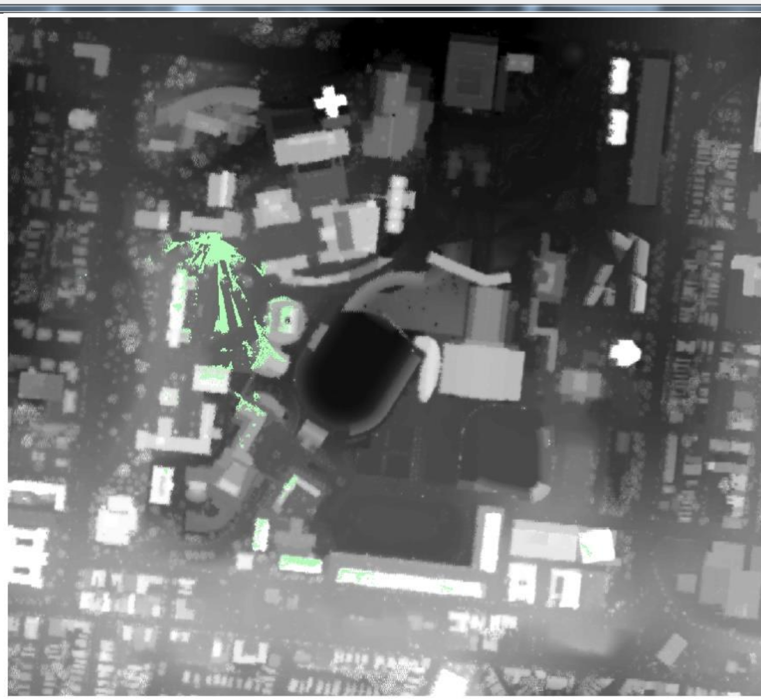
1) Visually locate the observer's position (x, y) and elevation using the LiDAR DEM as the background;

2) Use ArcEdit to create a point shape file to specify the observer's position and elevation;
3) Use the orientation of Braunstein Hall to determine the viewing azimuth angle Azimuth 1 and Azimuth 2;
4) Specify the vertical viewing angle Vert1=70° and Vert2=-80°

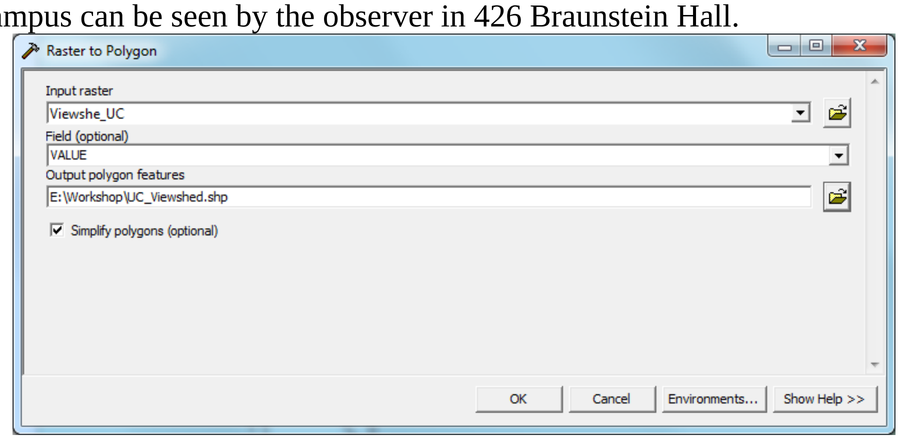


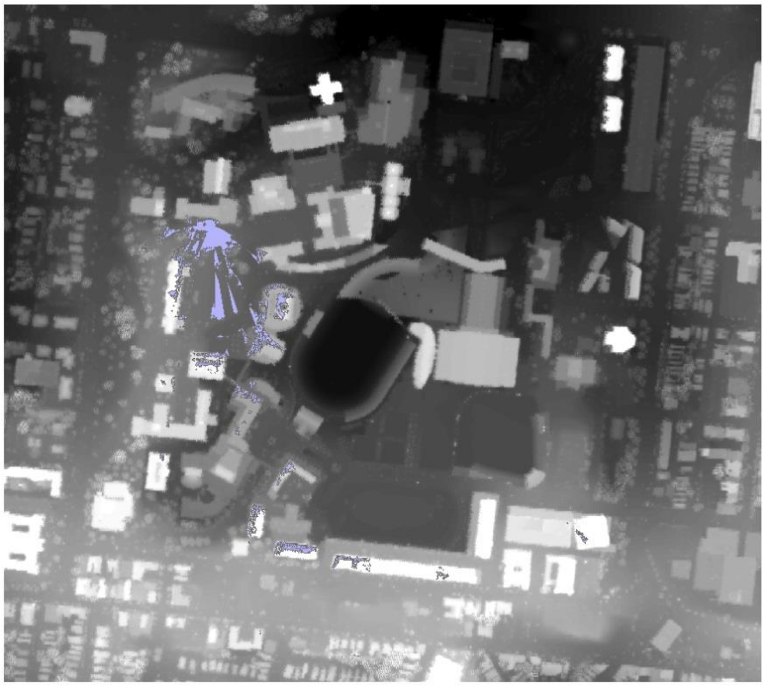
5) Calculate the viewshed using the Spatial Analyst Tools->Surface->Viewshed with the parameters specified above.





6) Convert the output viewshed grid into polygon shapefile, and overlay the viewshed polygon on top of the hill-shaded LiDAR DEM to determine which buildings on campus can be seen by the observer in 426 Braunstein Hall.





II. Solar Radiation Simulation

1. Introduction

Incoming solar radiation (insolation) received from the sun is the primary energy source that drives many of the earth's physical and biological processes. Understanding its importance to landscape scales is key to understanding a broad range of natural processes and human activities. Solar radiation amount and duration at a specific site are influenced by many factors, including its geographical location, atmospheric condition, season and time, and surface topography. Within a relatively small area, the spatial pattern of solar radiation at a given time and season is mainly determined by surface topography. With landscape scales, topography is a major factor that determines the spatial variability of insolation. Variation in elevation, orientation (slope and aspect), and shadows cast by topographic features all affect the amount of insolation received at different locations. This variability also changes with time of day and time of year, and in turn contributes to variability of microclimate, including factors such as air and soil temperature regimes, evapotranspiration, snow melt patterns, soil moisture, and light available for photosynthesis. Knowledge of the amount of insolation at specific geographic locations is helpful for application in diverse fields, such as agriculture, resource management, meteorology, civil engineering, and ecological research.

Incoming solar radiation (insolation) intercepted at the earth's surface include direct, diffuse, and reflected components. Direct radiation is intercepted in a direct line from the sun. Diffuse radiation is scattered by atmospheric constituents, such as clouds and dust. Reflected radiation is reflected from surface features. The sum of the direct, diffuse, and reflected radiation is called total or global solar radiation. Generally, direct radiation is the largest component of total radiation, and diffuse radiation is the second largest component. Reflected radiation generally constitutes only a small proportion of total radiation, except for locations surrounded by highly reflective surfaces such as snow cover.

The solar radiation analysis tools in the ArcGIS Spatial Analyst extension allow for mapping and analyzing the effects of the sun over a geographic area for specific time periods. It accounts for atmospheric effects, site latitude and elevation, steepness (slope) and compass direction (aspect), daily and seasonal shifts of the sun angle, and effects of shadows cast by surrounding topography. The resultant outputs can be integrated with other geographic information system (GIS) data and can help to model physical and biological processes as they are affected by the sun. The solar radiation tools in ArcGIS Spatial Analyst do not include reflected radiation in the calculation of total radiation. Therefore, the total radiation is calculated as the sum of the direct and diffuse radiation.

The solar radiation tools in ArcGIS can perform calculations for point locations or for entire geographic areas. Area solar radiation analysis is used to calculate the insolation across an entire landscape. The calculations are repeated for each location in the input topographic surface, producing insolation maps for an entire geographic area.

Point solar radiation analysis is used to calculate the amount of radiant energy for a given location. Locations can be stored as point features or as x,y coordinates in a location table. Solar radiation calculations can be performed for specified locations only. The output radiation raster datasets will always be floating-point type and have units of Watt-Hours per square meter (WH/m^2). The direct duration raster output will be integer with unit hours. Inputs to the solar radiation analysis are a digital elevation model (DEM), the latitude of the scene center, and the date and time that you wish to accumulate insolation. You can specify a portion of a day, or a range of days such as a week or month.

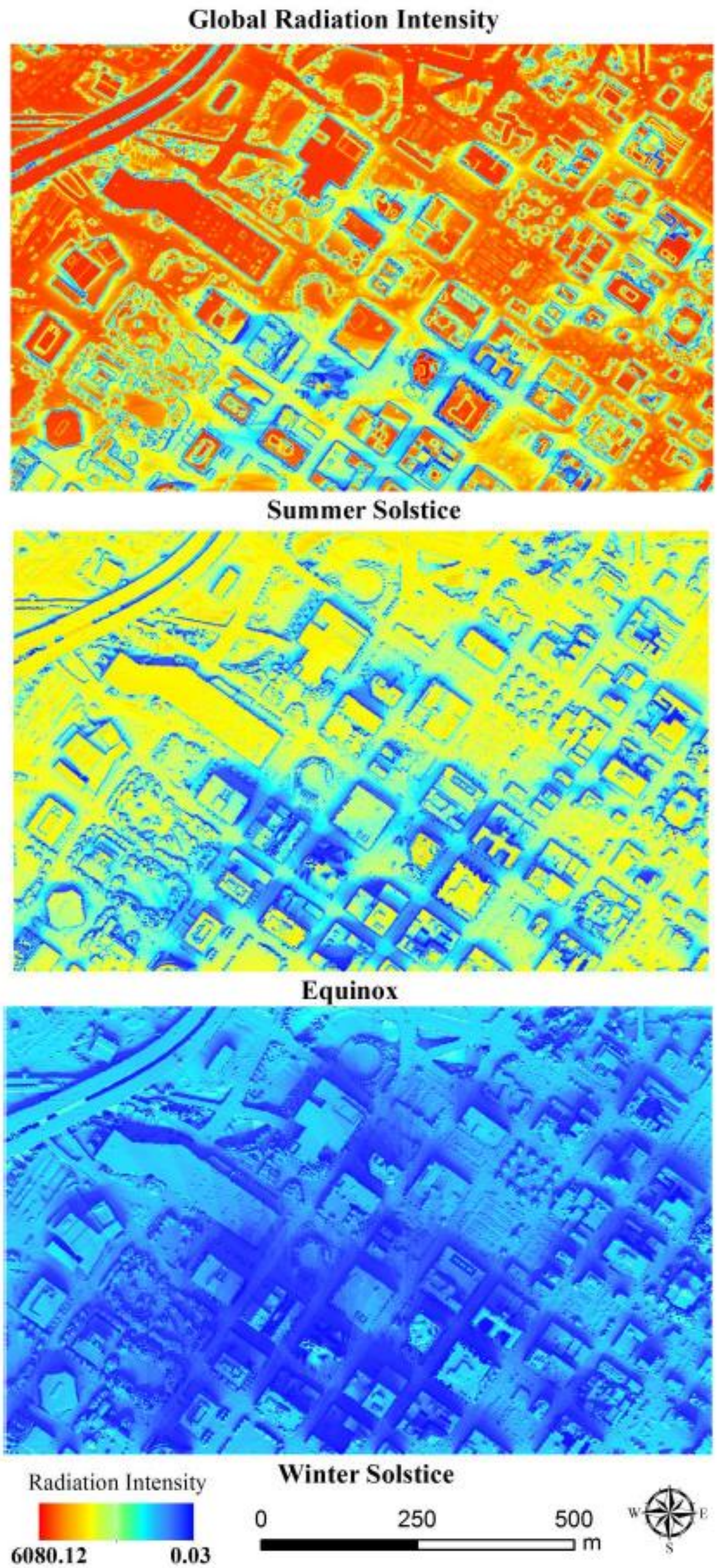
2. Data sets

In the directory **Ex2\houston**\, there are four files: lidar_dem, lidar_dsm, usgs_dem30, and doqqcir2004. These data sets cover a small part of downtown Houston, Texas and have been georeferenced in UTM (Zone 15N) coordinate system with reference to WGS84 ellipsoid. "lidar_dem" is the bare earth digital elevation model processed from the airborne LiDAR survey, and "lidar_dsm" is the digital surface model from original airborne LiDAR survey in 2001. "usgs_dem30" is the bare-earth digital elevation model extracted from the USGS National Elevation Dataset (NED). "doqqcir2004" is a false color near infrared aerial photograph acquired in 2004. The Root Mean Squares Error (RMSE) of LiDAR measurements is estimated to be 11.6 cm through comparing with a set of ground control points in different types of terrains. You can read more about the LIDAR project at http://www.hcfcd.org/downloads/ProfSurvrMagLiDAR-FloodMaps.pdf. The LiDAR point measurements of the last return are provided by the Harris County Flood Control District (HCFCD) as x, y, z lists in an ASCII file. We interpolate the point measurements into a Digital Surface Model (DSM) grid by using the linear TIN interpolation method. The DSM contains elevation information for all objects and ground features, including buildings and trees.

3. Instructions

In this exercise we will visualize the LiDAR DEM, derive the normalized DSM, and calculate the solar insolation intensity and duration using Spatial Analyst for four seasons for Downtown Houston and evaluate how urban morphology influence the spatial distribution of solar radiation for different seasons based on the LiDAR DSM. More specifically, we will calculate area solar radiation distributions for four special days: winter solstice, spring equinox, summer solstice, and autumn equinox, assuming a very clear-sky condition on these days. The task can be completed with the following operations:

1) Use Spatial Analyst to create a hill-shading image from the digital surface model “lidar_dsm”, and make a 3D perspective view by draping the CIR aerial photograph “doqqcir2004” on the top of the digital surface model “lidar_dsm” with the ArcScene.
2) The spatial interpolation of original LiDAR point measurements results in the Digital Surface Model, which contains elevation information for all man-made objects and vegetation canopy. A bare-Earth digital elevation model (DEM) is produced by removing all elevated features (typically buildings and trees). The bare-earth DEM is important for hydrological applications. Normalized Digital Surface Model (nDSM) is the difference between DSM and the bare-earth DEM. nDSM contains relative height information of man-made objects (buildings, bridges, towers, power lines) and natural objects (trees) rising above the ground. Use the ArcGIS Raster Calculator to subtract “lidar_dem” from “lidar_dsm” to create the normalized Digital Surface Model (nDSM). Find out the minimum, maximum, and average heights of the LiDAR nDSM. Use the CIR aerial photograph to identify one shrub area, one tree line, and one building, and then use nDSM to calculate the average heights for the shrub, tree areas and the building.
3) Determine the latitude of the scene center. The latitude for the site area (units: decimal degree, positive for the northern hemisphere) is used for the entire study area in calculations such as solar declination and solar position.
4) Set radiation parameters. Set Time_Configuration to “Special Days”. The diffuse proportion is the fraction of global normal radiation flux that is diffuse. This value should be set according to atmospheric conditions. A typical value is 0.2 for very clear sky conditions for generally clear sky conditions. Transmittivity is the fraction of solar radiation outside the atmosphere to that reaching the earth's surface for the shortest path. A typical value is 0.7 for very clear sky conditions. For other parameters, use the default values.
5) Create output global radiation grid and output direct solar illumination duration grid respectively for winter solstice, spring equinox, summer solstice, and autumn equinox.
6) Compare and interpret the seasonal variation of solar radiation intensity and illumination hours and the effects of urban morphology on the spatial distribution of solar radiation.



Global Radiation Intensity
Summer Solstice
Equinox
Winter Solstice
Radiation Intensity
6080.12
0.03
0
250
500
m
W
E
S