Development of a Solar Potential Map and Web Mapping Application for Iowa

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Outline

- GeoTREE overview
- Project goals
- Background
- Methods/Results
  - Modeling
  - Web application
    - Demo
- Conclusion/Discussion

UNI GeoTREE Center

- GeoInformatics Training, Research, Education, and Extension Center
  - In UNI Geography Department
- Support the use of geospatial (GIS, RS, GPS, web mapping) technologies at UNI and throughout Iowa
- Provide real world training opportunities for Geography and other students
- www.geotree.uni.edu

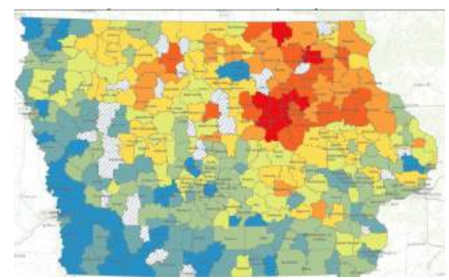
Project Background

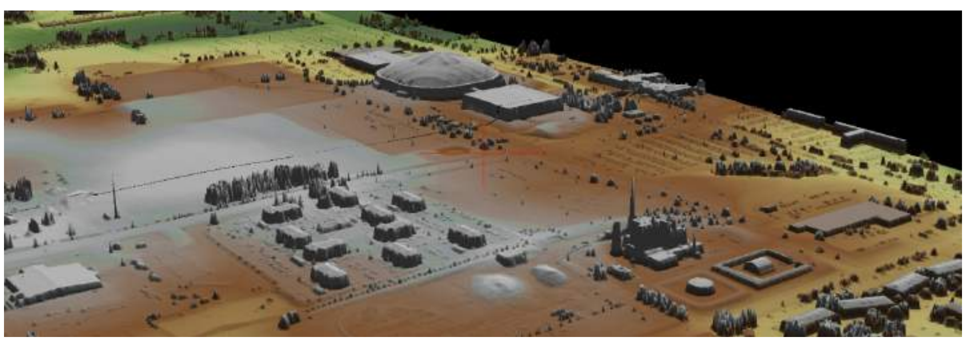
- Small funded project from Iowa Economic Development Authority, Energy Office
  - July 1 2015 – June 30, 2016
- Goals:
  - Model solar radiation values for the entire state of Iowa using the ArcGIS Desktop Solar Radiation toolset
    - Results will improve on present solar resource characterization in Iowa
  - Develop a public facing web mapping/GIS application to display modeled solar radiation results

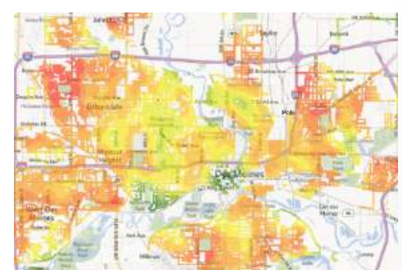
Background on ArcGIS Desktop Area Solar Radiation modeling tools, Iowa LiDAR data, and other GIS solar modeling examples

GIS basics

- Geographic Information Systems are software used to create, manage, and analyze geographic information
- Used across many governmental, non-profits, and private corporations

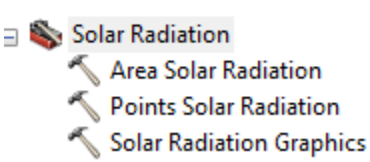






ArcGIS Solar Radiation tools

- ArcGIS is the most popular GIS software in the world
- Contain a toolset called Solar Radiation
- Area Solar Radiation tool was used for this project based on Iowa LiDAR data
- Based on algorithms developed by Fu and Rich in 2000 and 2002



References

Fu, P. 2000. A Geometric Solar Radiation Model with Applications in Landscape Ecology. Ph.D. Thesis, Department of Geography, University of Kansas, Lawrence, Kansas, USA.

Fu, P., and P. M. Rich. 2000. The Solar Analyst 1.0 Manual. Helios Environmental Modeling Institute (HEMI), USA.

Fu, P., and P. M. Rich. 2002. "A Geometric Solar Radiation Model with Applications in Agriculture and Forestry." Computers and Electronics in Agriculture 37:25–35.

Area Solar Radiation tool

- Calculates insolation across landscape based on a topographic surface (LiDAR data)
  - Calculation is repeated for every location producing an insolation map or entire geographic area (Iowa in our case)
  - Variation in elevation, orientation, and shadows cast by topographic features affect amount of insolation received at any location

Area Solar Radiation tool

- Calculates total insolation or solar radiation as sum of diffuse and direct radiation
- Steps
  - Calculates a hemispherical viewshed based on the topography (LiDAR data)
    - Basically looking around to see amount of visible sky
  - Overlay viewshed on direct sun map and diffuse sky map
    - Viewhseds used in conjunction with sun position through different hours and days of year based on latitude
  - Repeat this process for every location

The figure below depicts the calculation of a viewshed for one cell of a DEM. Horizon angles are calculated along a specified number of directions and used to create a hemispherical representation of the sky. The resultant viewshed characterizes whether sky directions are visible (shown in white) or obstructed (shown in gray). The viewshed is shown overlaid on a hemispherical photograph to demonstrate the theory.

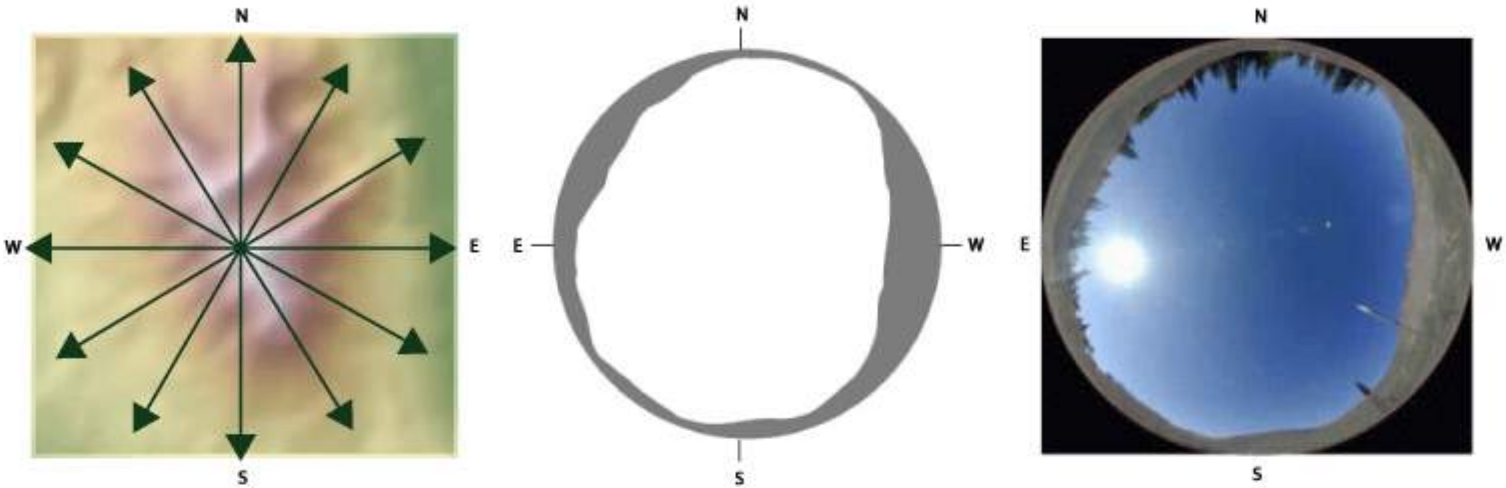
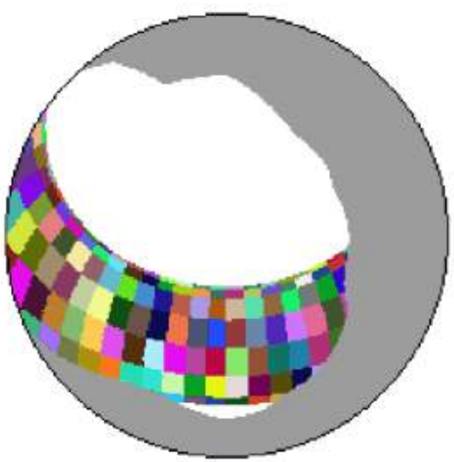
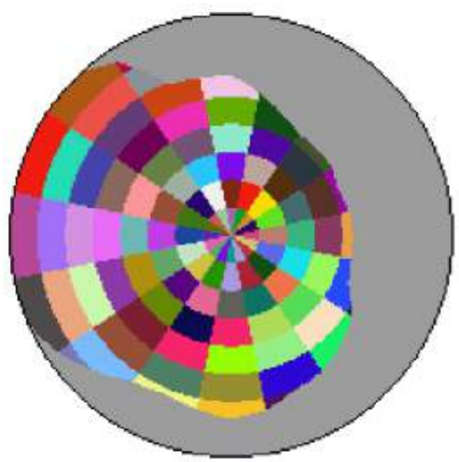


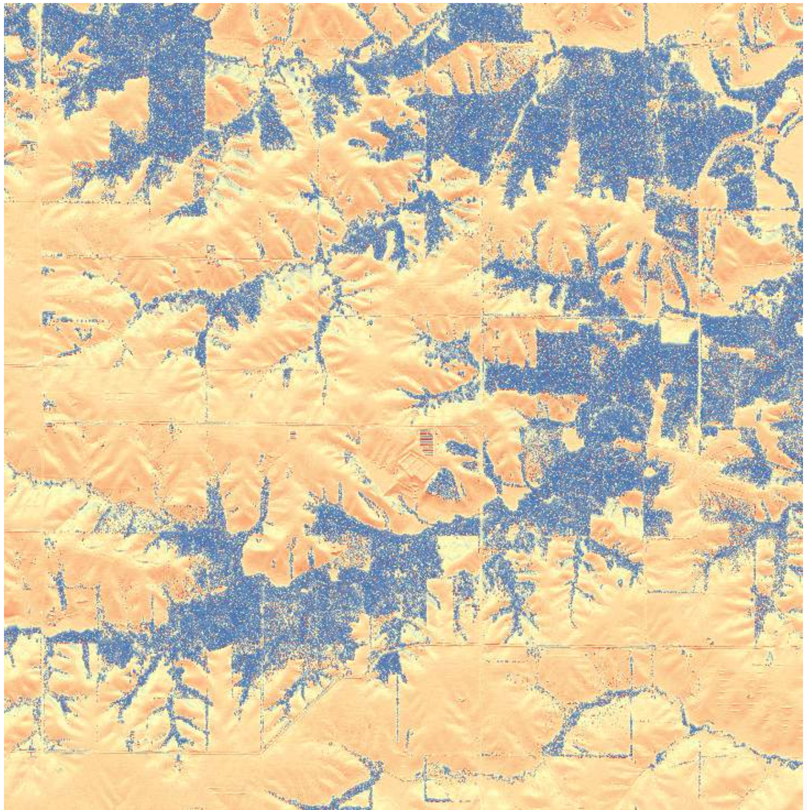
Illustration of the horizontal angles, resultant viewshed, and viewshed mapped onto sky view


Overlay of viewshed with sun map example


Overlay of viewshed with sky map example

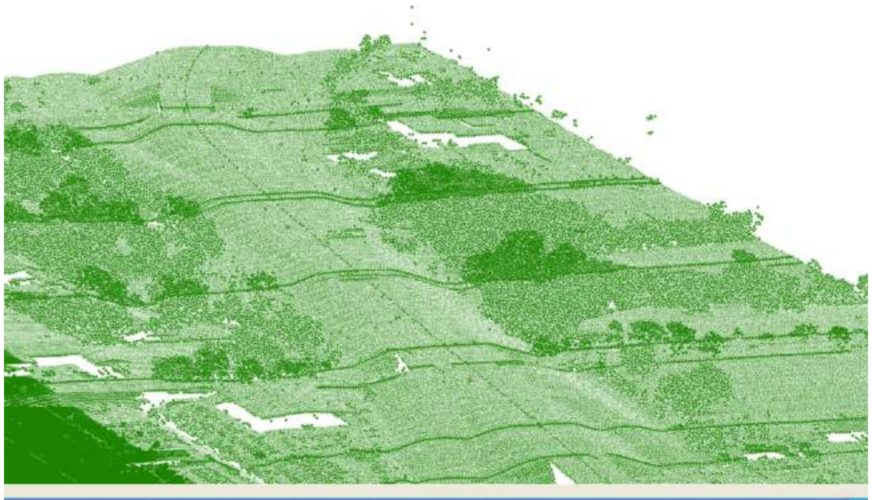
Area Solar Radiation tool details

- Very time consuming and computing intensive
- Output are GIS raster data for estimated total radiation in watt hours per square meter (WH/ m^2)



LiDAR data

- Light Detection and Ranging
  - Use airborne laser technology to record topographic surface of earth – i.e. buildings, trees, ground
  - Order of magnitude higher level of detail compared to other topographic data
- Iowa one of first states to have statewide coverage



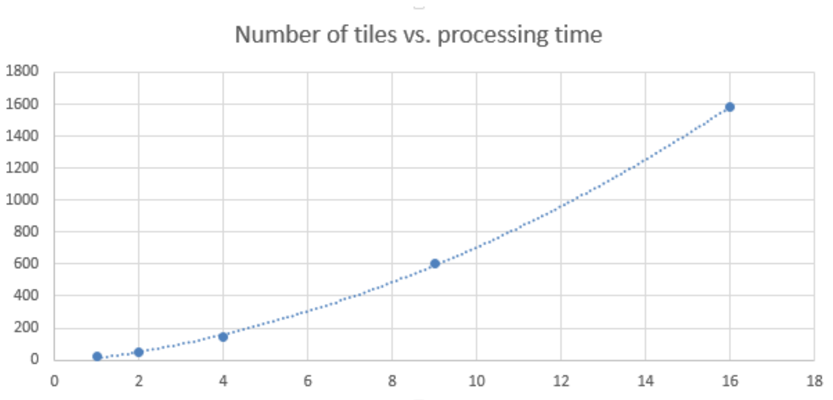
Other similar examples

- Numerous municipalities and larger areas have carried out solar radiation modeling using LiDAR
- Specifically using ArcGIS Solar Radiation tools include
  - State of Minnesota (only other complete state I know of - http://solar.maps.umn.edu/app/)
  - New York City (http://www.nycsolarmap.com/)
  - Los Angeles County (http://solarmap.lacounty.gov/)
  - Salt Lake County (http://solarsimplified.org/solar-resources/solar-map)

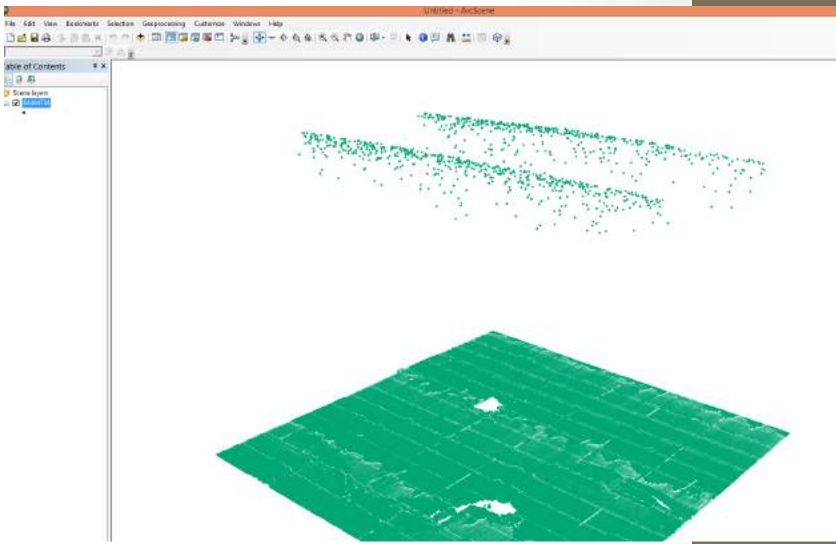
Methods/Results

Methods

- Considerable time testing and developing efficient processing routines
- Develop series of programs/scripts to carry out preprocessing and modeling
  - Preprocessing and monthly and annual solar radiation calculations for >4300 4x4 km tiles
  - Spread across ~30 computers in our GIS Lab (thousands of hours of computing time)
- Quality control
  - Had to deal with numerous issues from LiDAR data
- Build into web mapping application using open source technologies



Testing

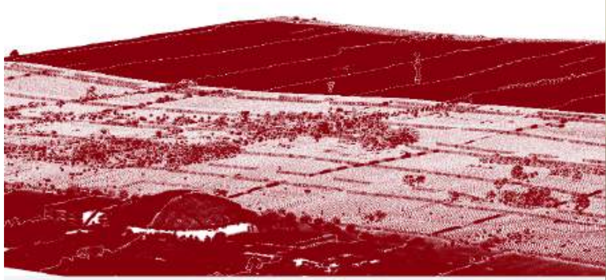


Quality Control – LiDAR issues

```
prjFile = path.join(BASE_PATH, 'NAD83_UTM15N.prj')

def calcCenter(xid, yid):
    x = XORIGIN + (xid + 1 - XTILEMIN) * XDIST / 2
    y = YORIGIN + (yid + 1 - YTILEMIN) * YDIST / 2
    return x, y

class LineSegment(object):
    """LineSegment represents a line segment. It can calculate its length and
       divide itself into a series of shorter line segments of equal length.
    """
    def __init__(self, p1, p2):
        self.p1 = p1
        self.p2 = p2

    def length(self):
        (x,y) = self.p1
        (x2, y2) = self.p2
        xdiff = x2 - x
        ydiff = y2 - y
        return (xdiff * xdiff + ydiff * ydiff)**0.5

    def divide(self, segments):
        (x,y) = self.p1
        (x2, y2) = self.p2
        lines = []
        xdiff = float(x2 - x) / segments
        ydiff = float(y2 - y)
        for i in range(segment
            segment = LineSegm
            lines.append(segme
        return lines

class Box(object):
    """Box represents a box.
       It can buffer itself, c
       (such as arcpy polygons
```

```
    def subbox(self, divisions):
        'Passing 3 will divide this box into 9 subboxes (3x3). 2 will result in 2x2'
        north = LineSegment(self.nw, self.ne).divide(divisions)
        south = LineSegment(self.sw, self.se).divide(divisions)
        west = LineSegment(self.sw, self.nw).divide(divisions)
        east = LineSegment(self.se, self.ne).divide(divisions)

        snlines = zip(south, north)
        welines = zip(west, east)
        results = []
        for s, n in snlines:
            for e, w in welines:
                sw = s.p1[0], w.p1[1]
                nw = s.p1[0], w.p2[1]
                se = s.p2[0], w.p1[1]
                ne = s.p2[0], w.p2[1]
                results.append(Box(sw, nw, ne, se))
        return results

lass Http404Exception(Exception):
    pass

lass LidarURL(object):
    "LidarURL can download any given tile id."

    def __init__(self, tile_id):
        self.url = 'http://geotree2.geog.uni.edu/IowaLidar/%s.las.7z' % tile_id.strip()

    def download(self, work_directory):
        import urllib
        fname = self.url.split('/')[-1]
        (filename, header) = urllib.urlretrieve(self.url, path.join(work_directory, fna
        if header['Content-Type'] != 'application/x-7z-compressed':
            raise Http404Exception('Not a 7zip archive')
        return filename
```

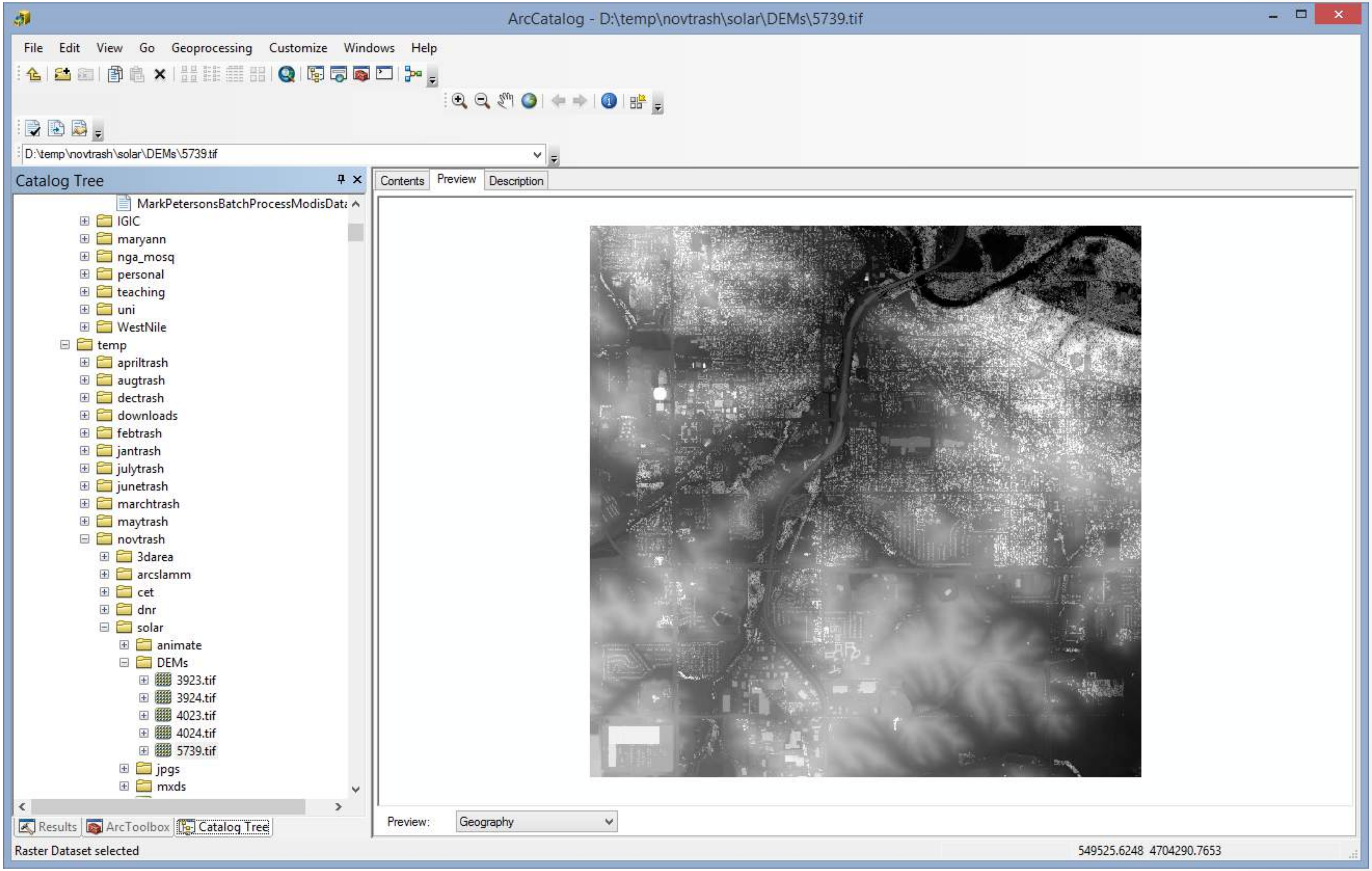
Scripts



Results

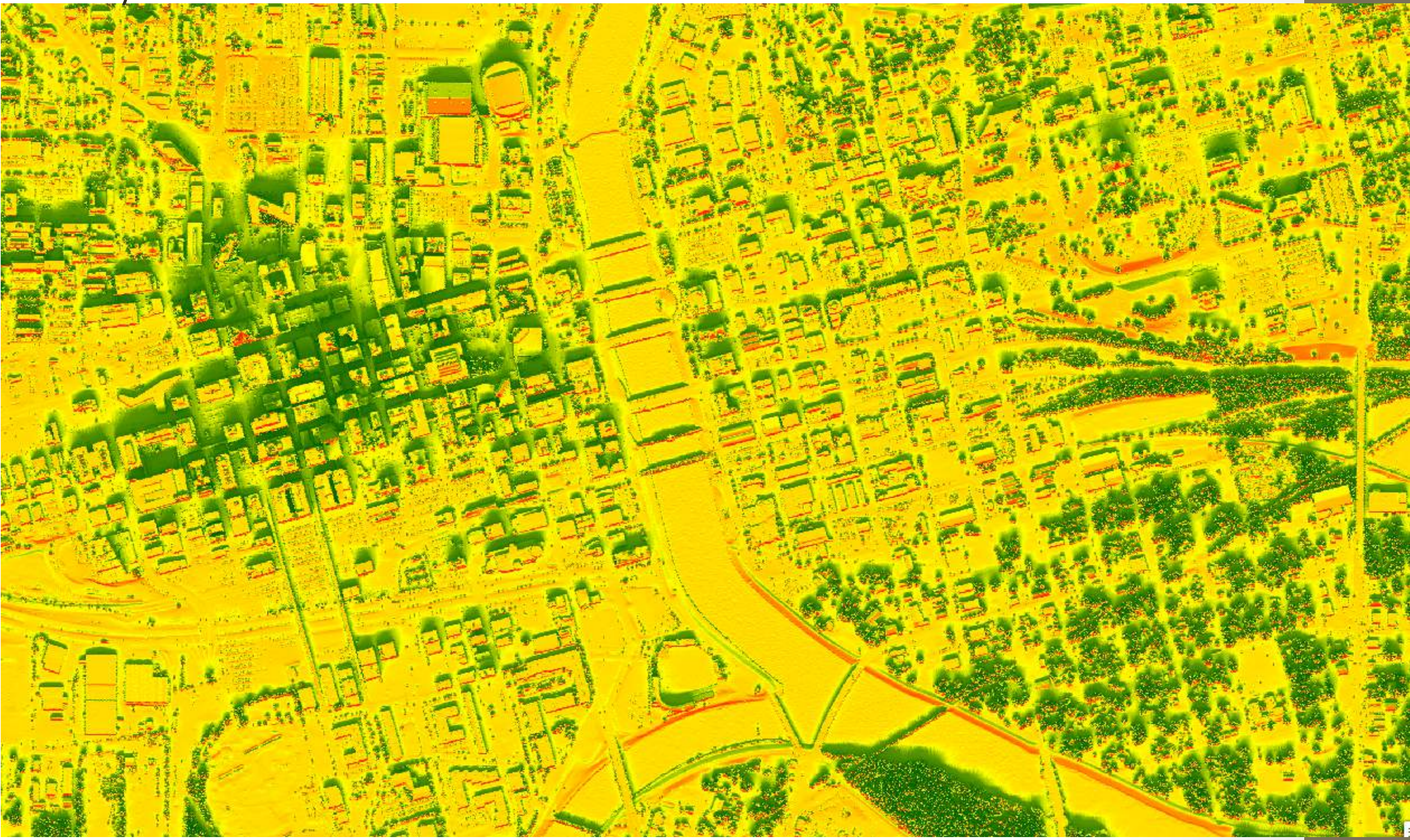
- We have carried out solar radiation modeling for the entire state resulting in
  - Digital Surface Models (DSMs) derived from Light Detection and Ranging (LiDAR) .las files
    - Approximately 275 gb of data
  - Modeled annual and monthly solar radiation values
    - Approximately 3.3 terabytes of data

A DSM tile in the Cedar Falls area. At the end the state is broken into ~4300 4x4 km tiles – one DSM for each tile



An example of one month's modeled solar radiation near downtown Des Moines

In total there are ~56,000 solar radiation raster images - one annual and 12 monthly for each of the ~4300 4x4 km tiles



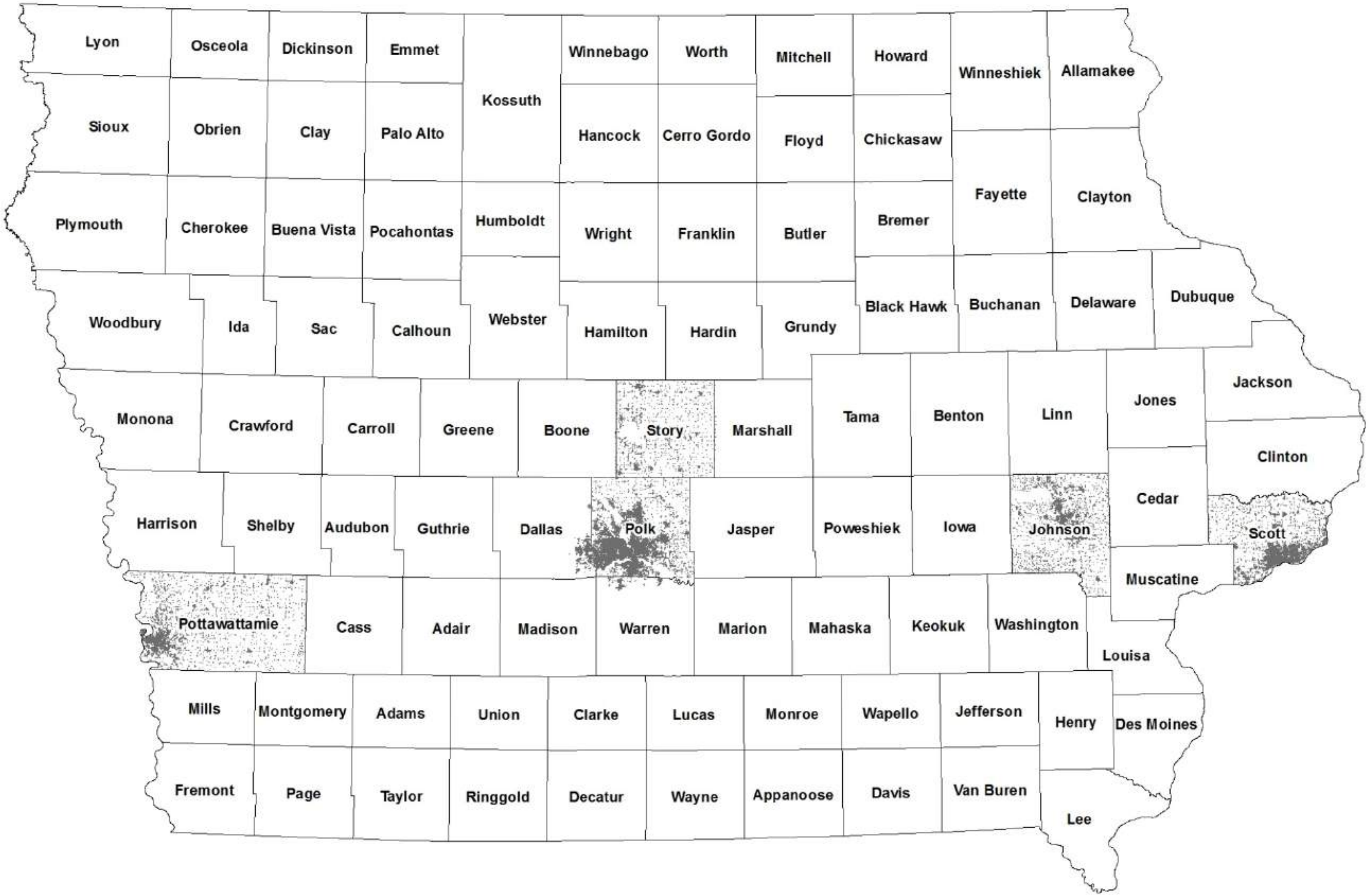
Example solar modeling

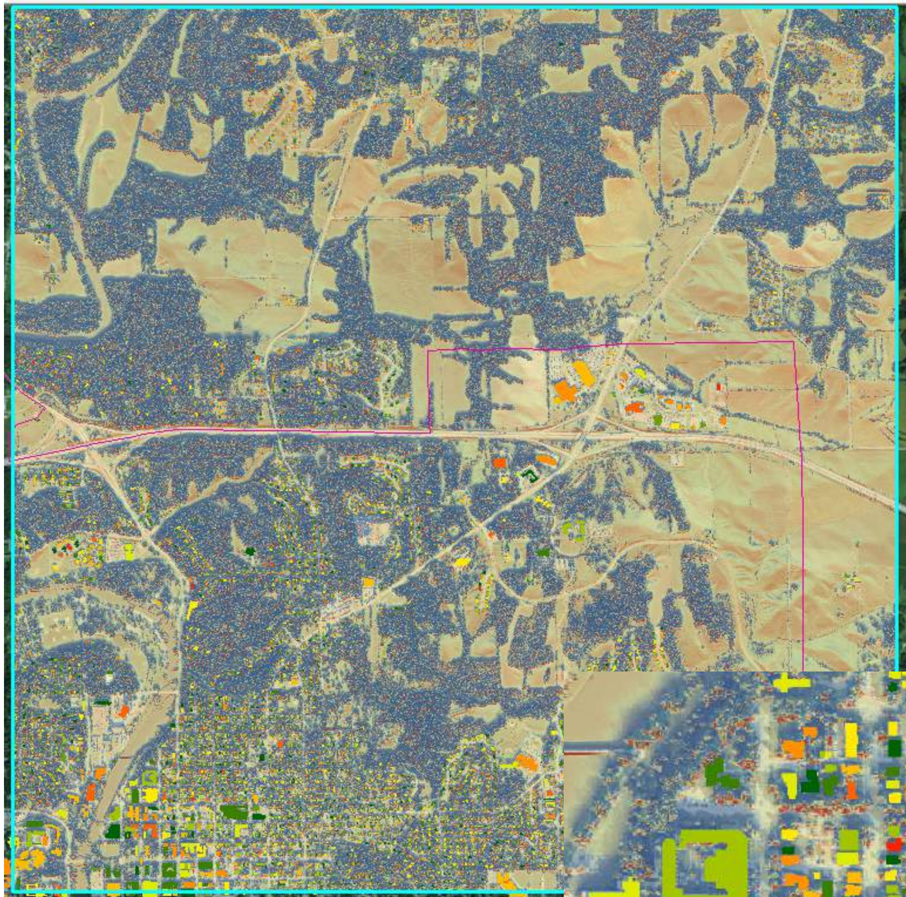
http://arcg.is/1lrR718

Building data

- Compiling building footprint data from the Iowa GIS Data Repository
  - https://www.iowagisdata.org/
- Will derive statistics per building from solar radiation modeling data

Building footprint data compiled



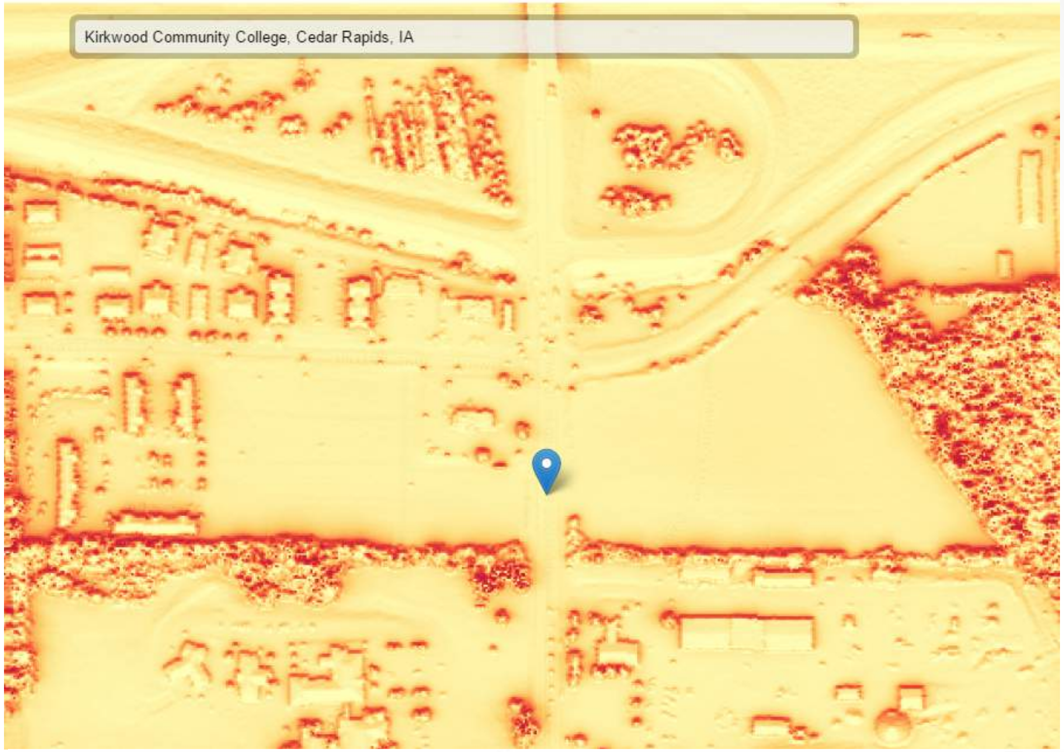


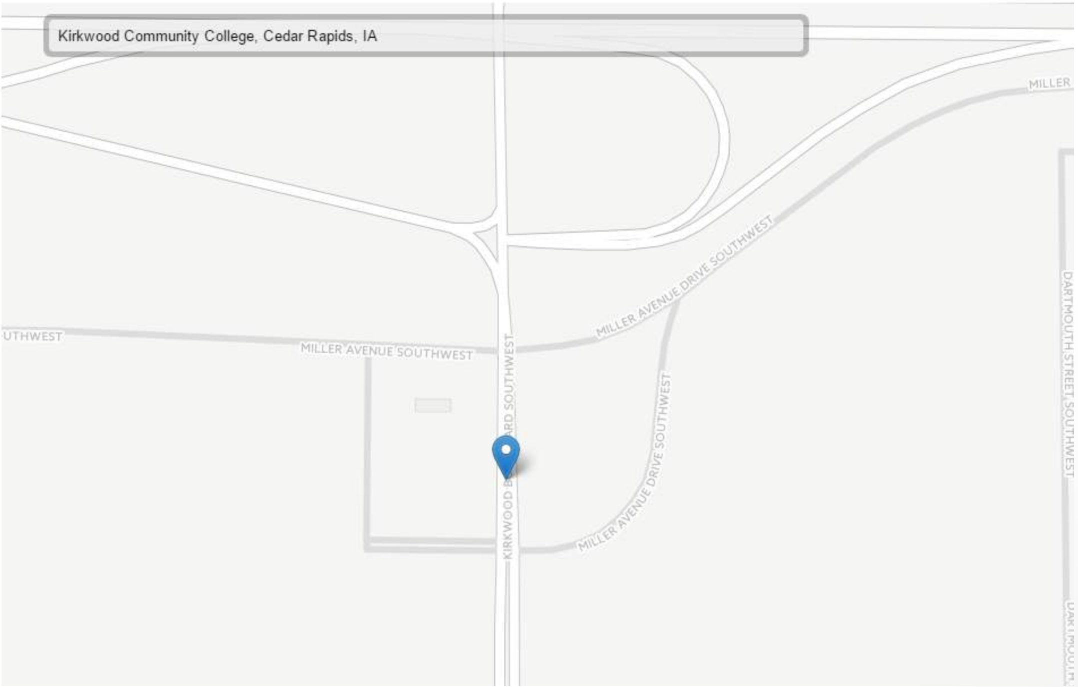
An example of calculating statistics on solar radiation per building based for building footprints. This example is in the Iowa City area

Web application

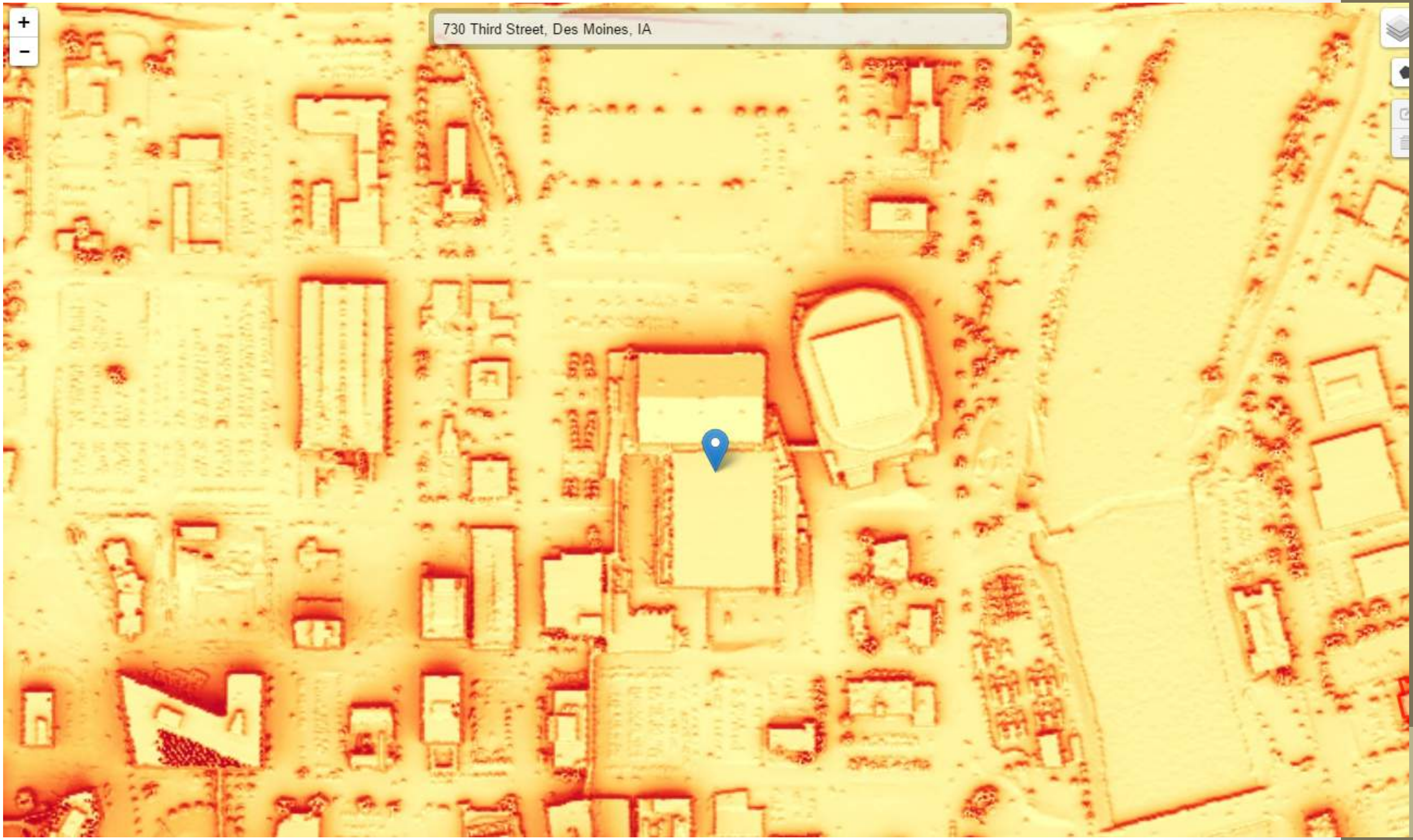
- Presently designing and testing web mapping application architecture
- Named *Iowa Solar Asset Mapping*
- Functionality
  - Display modeled solar radiation outputs for whole state
  - Base map choice – streets, aerial
  - Address search
  - Pre-compiled statistics for existing building footprints
  - User can draw polygon and will report back solar radiation statistics

Address search



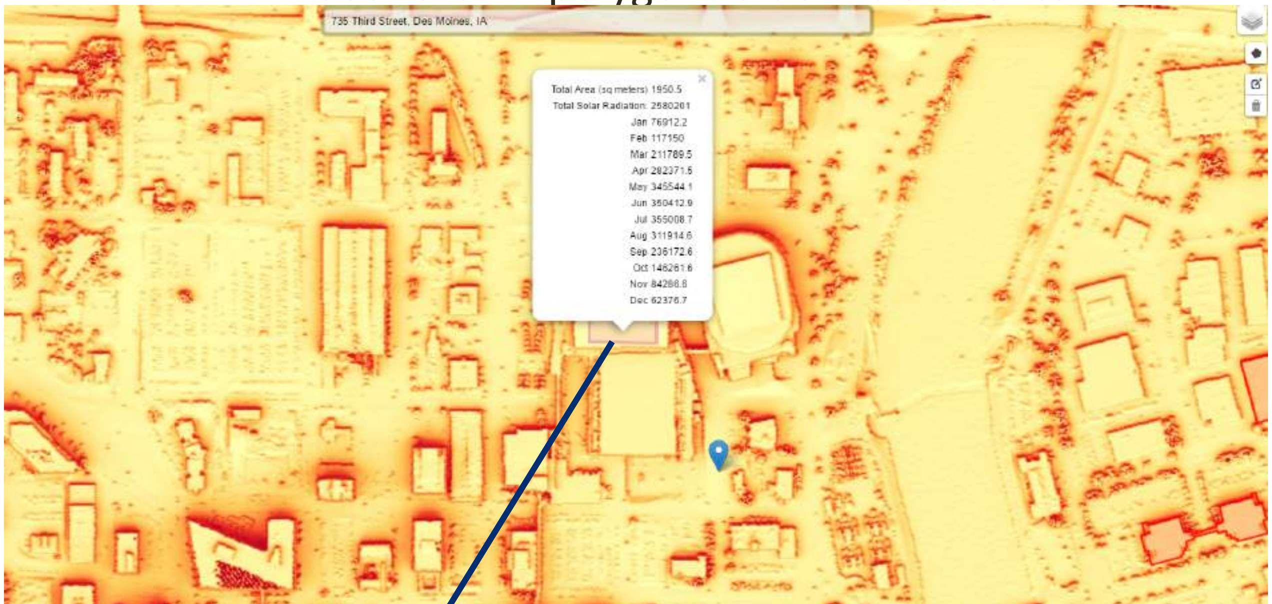


Address search

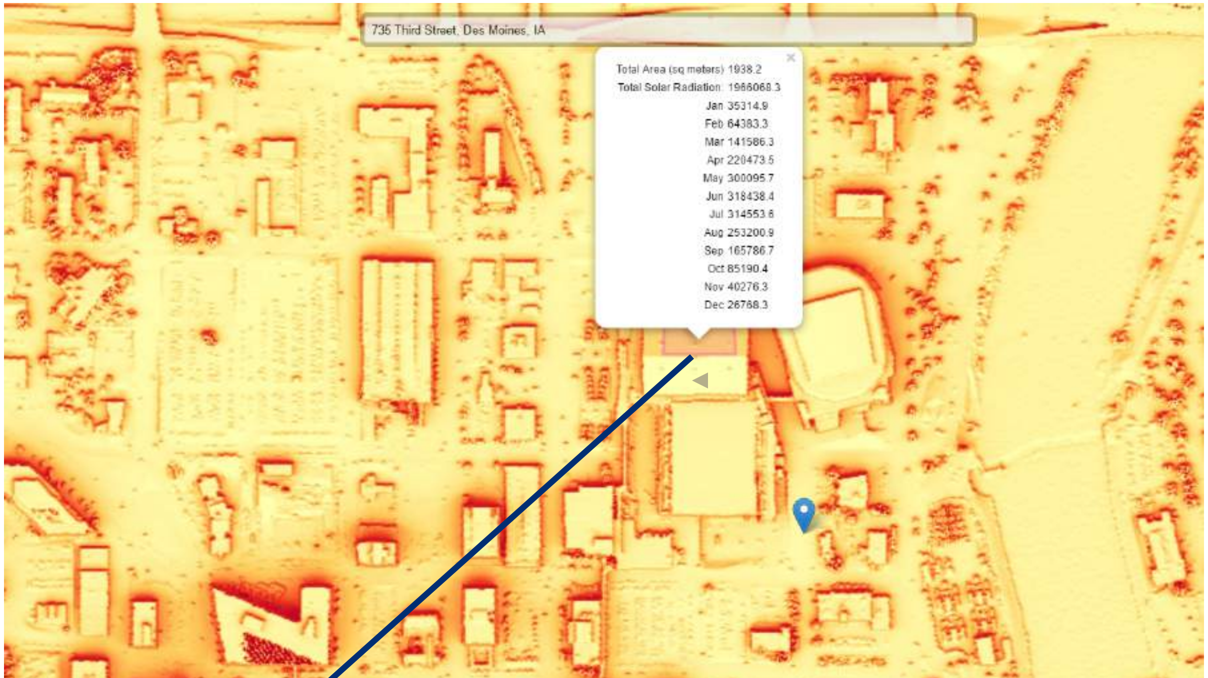


Pre-compiled statistics for existing building footprints

User drawn polygon to derive statistics



Sunny side


735 Third Street, Des Moines, IA
Total Area (sq meters) 1938.2
Total Solar Radiation: 1986068.3
Jan 35314.9
Feb 64383.3
Mar 141586.3
Apr 220473.5
May 300095.7
Jun 318438.4
Jul 314553.6
Aug 253200.9
Sep 165786.7
Oct 85190.4
Nov 40276.3
Dec 26768.3

Shady side

Short dem

This site is not live and this is just a very preliminary demo

Disclaimers/Assumptions

- LiDAR data was collected mainly from 2008-2010
- Area Solar Radiation tool is just providing an aggregated estimate of potential solar radiation with various assumptions
  - E.g. have to make assumption for atmospheric conditions – generally clear sky conditions used so possibly a bit of overestimation
- Results seen in web mapping application should only be used as a preliminary planning tool and not used for installation or design purposes

Conclusion

- Greater than 3.5 terabytes of data produced
  - Digital Surface Models
  - Modeled solar radiation aggregated by month and annually
- Web mapping application v 1.0 will be done soon
  - Check http://www.geotree.uni.edu/ for update when site goes live in next month or so
  - Feel free to email me if you want to be alerted when it is live

THANK YOU
DISCUSSIONS/QUESTIONS?

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