Methodology

The Urban Heat indicator was developed by performing a weighted raster analysis using ArcGIS V.10 Spatial Analyst. Various features of Civic Center park were measured and represented in GIS shapefile format. These features included urban surface materials (roads, parking lots, and sidewalks) green infrastructure (ground vegetation and canopy), urban form (building roofs and shadows) and topography. Each surface was assigned a value describing its capacity to store heat. The method for assigning this value was derived by finding the albedo of each surface material and recording the inverse of the albedo to describe the percentage of heat the is stored by the surface material type. The inverse albedo describes an estimate of the surface material's capacity to absorb the heat that it receives from the Sun's radiance.

Surface data was collected largely from the city of Boulder's GIS database. Databases that were key to the urban heat indicator included; impervious surfaces and building footprints with heights. Other data included a 1/9 arc second Digital Elevation Model extracted from the USGS National Elevation Data set and the civic center tree canopy which was digitized from an aerial image by the urban heat student group. The DEM provided information about the topography of the site in order to perform a solar radiance analysis and estimate the intensity of sunlight reaching the surface of the Civic Center study area.

Urban form was analyzed using a 3D building shadow model developed by ESRI and modified slightly to fit this analysis. Building footprints were extruded to their heights and the building shapefile was converted to a multipatch file for a 3D analysis using ArcScene. ArcScene provides tools to estimate the Sun's position in the sky at a given time of day and year. The map of Sun's location can be used to perform a viewshed analysis against the 3D building multipatch file. Areas where the view from sun points were blocked were exported as a multipatch file and areas where the 3D shadow file interest with the ground were converted to a shapefile and served to represent shadows generated by buildings.

For this specific analysis, building shadows and solar radiance were projected for 12:00pm on June 20, 2012. This date was chosen because it is the summer solstice and was assumed to provide an example of the highest potential solar radiance. For future analysis, it would be valuable to perform shadow and solar radiance projections for several days in equal intervals throughout the year. This would allow for the identification of average solar radiance and shade locations throughout the entire study area.

The output raster generated by solar radiance analysis describes the intensity of Sun in watts per square meter. This output raster was multiplied by the composite of weighted rasters representing the capacity for each surface material type to retain heat from the Sun. The capacity for heat of each surface was represented on a scale from 0 to 100 in an attempt to describe the amount of heat stored as a percentage of the Sun's radiance value. The result of multiplying the solar radiance value by the weighted heat capacity raster was a new raster grid displaying areas with a range of projected heat values.

From the resulting raster output, the urban heat group was able to identify areas of concern where the projected heat values were abnormally high or low. These areas of concern were then used as case study areas to test the effects of different urban design and green infrastructure mitigation strategies. The case studies chosen for this particular analysis included a portion of the civic center recreation area near the old library, the intersection of Broadway and Canyon, and the block of public property which contains the Dushanbe Tea House. These areas demonstrated abnormally high projected heat values and represent three types of design morphologies that can be applied to the site as a whole.

Mitigation strategies that were chosen included adding additional canopy cover by planting deciduous trees, changing rooftop material, and resurfacing impervious surfaces. Impervious urban surfaces such as asphalt parking lots, concrete streets and sidewalks were projected to have been resurfaced by the most effective high albedo material as defined by the EPA. Each scenario contained the most advanced mitigation strategies defined by a quick review of literature. Resurfacing of entire impervious urban surface areas were projected without regard to cost or implementation feasibility.

Results were analyzed based on the average projected heat value for all cells within each case study. The product of multiplying the solar radiance raster by the weighted surface raster was expressed in the unit Watt per meter squared. This number was converted to the British Thermal Unit (BTU) to be more manageable and easily interpreted. The mean heat in BTU's were compared for before and after the implementing the urban heat mitigation strategy. This comparison results in a percentage lost in heat projected for each case study area as well as for the study area as a whole.

Results

Upon creation and review of the urban heat analysis it was determined that certain areas within the civic center study area do consist of features that are likely to absorb abnormally high amounts of heat from the Sun's radiation. After a visual review of the projected heat surface, three areas were selected as scenario case studies. Heat mitigation strategies were input into the GIS data through digitizing and changing heat absorption values. The modified data was then re-entered into the urban heat indicator model and review to identify changes in the average projected heat, measured in BTU. The mitigation strategies as well as the resulting heat values are displayed in the table above.

Connection to BVCP

The Urban Heat Indicator is an attempt to respond to a section of the Boulder Valley Comprehensive plan which defines sustainable urban form in the context of the planning and design of the city of Boulder. The definition of sustainable urban form is divided into components which include; compact, connected, complete, inclusive and green, attractive, and distinct. The Urban Heat Indicator is designed to perform analysis within the green, attractive and distinct component. The definition of green, attractive and distinct ensures the “location and design of buildings, streets, utilities and other infrastructure to protect natural systems, minimize pollution and urban heat island effects and support clean energy generation.” (BVCP update 2010) The Urban Heat Indicator is intended to identify the relationship between features of urban form, urban surfaces, green infrastructure and natural systems as they react to the natural energy produced by the Sun. Through performance and modification of the Urban Heat Indicator, patterns of understanding will emerge that will enable urban planners and designers to make informed decisions when trying to create public places that satisfy the objectives described by the green, attractive and distinct component of sustainable urban form.

Conclusion

In sum, the Urban Heat Indicator provides a model for systematically taking inventory of the various features of urban form, surface material and green infrastructure that contribute to urban heat island effect. The use of GIS allows for the creation and storage of high resolution data which can be modified to project different design scenario's. Building on the existing model will require a more precise and accurate collection of all data. Some data used for this analysis may not be 100% accurate and rough estimations were used for the purpose of completing the general framework for the indicator. The solar radiance tools provided by ArcGIS provided a basis for understanding the influence that topography may have on the intensity of sunlight impacting the Earth, but the accuracy of solar radiance would be improved drastically by taking measurements of solar radiance in the field.

Upon use and modification of this indicator, it can be refined and packaged to provide a very quantifiable understanding of urban design features and urban heat. It seems that this tool used in combination with an individual's personal knowledge of a site will produce a very unique and complete urban design tool. Results of the urban heat indicator describe areas with abnormally as well as abnormally low heat. The same process and analysis can be used to identify areas where little sun is absorbed and snow and ice will accumulate during the winter months. The flexibility of the urban heat indicator allows for input of a wide variety of data and can even incorporate scenario data created by the analyst.

Recommendations

Civic Center Site

- The site contains areas where design features are likely to produce abnormally high heat
- The blocks between 14th-16th and Arapahoe-Canyon contain a large area of exposed asphalt parking lots and were identified to be the areas of greatest concern.
- Intersections along Canyon Blvd. Are exposed to Sun and do not provide pedestrian refuge
- Best mitigation strategies include; increasing deciduous tree canopy cover, resurfacing existing impervious areas, and designing buildings with green roofs and an understanding of the effects their shadows will have have on the public realm.

Urban Form Indicator

- Results depend on the accuracy and precision of the data provided or collected.
- ArcGIS solar radiance tools provide a basis for analysis but field measurement of solar radiance is likely to provide more accurate results
- Combining GIS data with feature heat capacity values provides a dynamic system for inventorying existing urban design features
- The tool can be used at a variety of scales from the comprehensive plan to individual project management.