**NASA DEVELOP National Program**



NASA Langley Research Center

*Spring 2016*

Arizona Health & Air Quality II

Enhancing Extreme Heat Intervention and Preparedness Activities in Maricopa County, Arizona with NASA Earth Observations

 **Technical Report** 

Rough Draft – Feb 18, 2016

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# I. Abstract

Extreme heat causes and exacerbates a number of health problems, leading to hospitalization and death in some cases. The problem of severe heat is notably felt in Maricopa County, Arizona, where the socially disadvantaged and physically vulnerable are especially susceptible to the effects of extreme heat. Within the Maricopa County limits is the city of Phoenix, a dense urban area surrounded by 300-2,000 m ridge lines above the valley floor. The volume of impervious surfaces, lack of shade and vegetation, and the high ridge lines surrounding the city exacerbate the heat stress by a phenomenon known as the urban heat island effect (UHI). After the sun sets, heat retained by impervious building materials is released at a decreased rate compared to natural vegetation and soil coverage. Ambient air temperatures in urban areas tend to be higher than the surrounding rural areas. Several organizations, including the Arizona Department of Health Services and the Phoenix Heat Relief Network, are working to create more effectively placed cooling centers and heat warning systems to aid those with the highest risk of exposure. This project created a Python tool using Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature parameters to generate heat maps that reference demographics data on extreme heat days. In addition to this, using the resources available at the Atmospheric Science Data Center (ASDC) will allow for access to near real-time data acquisition, which will aid the partners in providing spatially distributed relief during extreme heat events.

**Keywords**

Public Health, Urban Heat Island, MODIS, Land Surface Temperature, Landsat

# II. Introduction

**Community Concern and Study Area**

For over a decade, academics and decision-makers have recognized the dangers that extreme heat pose to human health and, as a result, many researchers have explored its effects as well as possible mitigation strategies (McMichael et al., 2008; Harlan et al., 2013). The desert ecoregions in the southwest U.S. - including southern California, Arizona, New Mexico, southwest Texas, Nevada, and Utah - are seeing a rise in temperature due to global climate change. The effects of high temperature are particularly felt in urban areas where the urban heat island effect (UHI) is putting citizens at increasing risk of heat related illness and death (Grossman et al., 2010). UHI is caused by the prevalence of impervious surfaces within the city, such as concrete and asphalt, trap heat from incoming solar radiation. In a typical UHI, heat trapped during the day will be released into the lower atmosphere at night. Thus, the effects of the UHI are relatively greater at night than during the day (Hardegree, 2006).

The city of Phoenix and its surrounding metropolitan areas within Maricopa County, Arizona are greatly affected by UHI (Grossman et al., 2010), and so it has been chosen as the area of interest for this project. Elevated temperatures within Maricopa County have an adverse effect on the health of its citizens. While populations in arid climates can be more acclimated to elevated temperatures, demographics that are typically disadvantaged or isolated- such as the elderly, the poor, the homeless, and non-native English speakers - are all more vulnerable to heat related illness and death (MCDPH, 2014). In addition to causing heat stroke, elevated temperatures can lead to cramps, exhaustion, heat syncope, and can exacerbate pre-existing respiratory and circulatory conditions (Scott et al., 2004). Temperatures of 104-128 °F

are NOAA’s Heat Index “danger” zone and serve as an appropriate threshold for severe heat

stress as anything higher will likely result in sunstroke and heatstroke (Harlan et al., 2003, Harlan et al. 2014). The majority of heat related service calls are made during the monsoon season in the later summer months of July and August, when elevated temperatures and high humidity are most prevalent (Golden et al., 2008). According to the Maricopa County Department of Public Health (MCDPH) 2013 annual report, there were 632 confirmed heat related deaths between 2006 to 2013.

**Project Partners and National Application Area**

In this study, the UHI effect in Maricopa County was analyzed using Aqua MODIS Land Surface Temperature (LST) data acquired during the summer months of April through October from 2006 to 2015. Because the UHI effect so adversely affects the health of the population, this project falls under the NASA Applied Science Program’s Health & Air Quality Application Area. The project maintained its partnership with the Arizona Department of Health Services (ADHS), the Phoenix Heat Relief Network, the National Weather Service (NWS), Phoenix Forecast Office, the Environmental Remote Sensing and Informatics Lab (ERSL) at Arizona State University (ASU), and the Center for Policy Informatics (CPI) at ASU. The project objectives allowed for the creation of an automated python tool that will download MODIS data in near real-time to create heat maps of Maricopa County. The partners will be able to use this tool to understand spatial and temporal patterns of extreme heat events, which will better inform their heat mitigation strategies.

# III. Methodology

**Data Acquisition**

Manual collection of Aqua MODIS MYD11A1 version 005 data were available through the NASA EarthData Search Client. A case study was conducted in conjunction with the Atmospheric Science Data Center (ASDC) to include OPeNDAP data collection. Connection to the data portal was made available through PyDAP code which allowed users of the python tool to acquire near real-time imagery for processing.

104°F is the threshold for heat related illness; therefore, only MODIS data for days at or above this threshold were analyzed. In order to identify days over 104°F, the air temperature readings from Phoenix Sky Harbor International Airport (PHX) were acquired through the University of Utah’s Mesowest API. Shapefiles of Maricopa County census tracts were obtained from the Maricopa County Health Department.

The study period was chosen to be 2006 to 2015 because it was the study period used by the previous term. It was necessary to use the same data for proof of concept and to establish a baseline for continued analysis during demonstrations of the tool. However, term 1 only acquired data for the months of May to September. The current term expanded on this period in order to ensure that data for all days over 104°F were acquired (Figure 1).

**Figure 1:** The number of study days (days over 104°F) by month and year.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| April | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May | 3 | 1 | 3 | 4 | 0 | 0 | 5 | 0 | 4 | 2 |
| June | 27 | 20 | 20 | 10 | 16 | 16 | 20 | 27 | 26 | 21 |
| July | 23 | 21 | 21 | 28 | 21 | 23 | 19 | 20 | 26 | 21 |
| August | 12 | 23 | 20 | 22 | 18 | 28 | 18 | 19 | 15 | 28 |
| September | 2 | 11 | 4 | 8 | 15 | 13 | 5 | 8 | 6 | 4 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Total** | **67** | **76** | **68** | **72** | **70** | **80** | **67** | **74** | **77** | **77** |

**Data Processing**

In order to process the data and create heat severity maps, a python script was compiled using scripts from the previous term - shared via Google Drive - and scripts written during the current term. The compiled script was named LaSTMoV (Land Surface Temperature MODIS Visualization), and it was written in python to create heat severity maps from raw MODIS input. The first step was convert the MODIS HDF files to tiff files, which was done using tools from the DEVELOP National Program python library (dnppy). Next, LaSTMoV automatically downloaded data from Mesowest API, used the data to identify days over 104°F - which it then compiled into a list of study days - and deleted the MODIS data for days that did not correspond to the study days. Once the data for the correct study days has been accumulated, LaSTMoV proceeds to clip the tiffs to the area of Maricopa County and convert the LST from decimal number to Fahrenheit. This conversion was initially accomplished using ArcGIS model builder, and the model was exported into python and reformatted to fit into LaSTMoV. Analysis of the data was accomplished using an R script subsetted into LaSTMoV.

**Data Analysis**

Once the data was processed using the python portion of LaSTMoV, an R subset used zonal statistics to compute the average LST value by census tract. By making a folder connection to any of the years in the collected historical data at the beginning of the script the user creates a location for files to be read and written into. For ease of use the census file is copied to the new directory. The user only has to change the file path of the variables TempDIR (Were .tiff modis layers are stored) and Current.folder (Where the Census files are stored) respectively. The Census.shp file is then loaded into the script and a new projection is applied. The rasters list is then read for the specified folder that creates a file sample to be run through the for loop. Before the for loop can be run a new table called Newatt must be created with two columns and and the same number of rows in the raster list. Newatt is essentially a storage container for the percentage of cloud cover over the census tracts. Then the for loop begins, calling on one raster at a time for every raster in the length of the raster list specified previously. Each raster that is currently an image ( .tiff file) is then converted to a true raster using the function raster. A true raster layer contains cell (pixel) values in (RAM) memory. The rasters are then projected against the Coordinate Reference System (CRS) of the Census file. Using the extract command and the function mean we were able to apply the daily mean LST values to the Census shapefile. Values were appended to the end of the census files by creating a command named last.col. This command was also useful in replacing NaN values, representative of cloud cover, with -9999 a values that can be read in ArcMap. To generate a table of the percent of clouds that covered the census tracts we needed to define what and how many NaN values on each day and night there were. This is represented by the formula below were 916 is the number of rows in the census file.

Percent Clouds = {(ΣNaN)/916}\*100

Columns were created to fill in the blanks in the Newatt table. The for loop was then closed and using write.dbf and write.csv tables of mean temperature for day and night Aqua MODIS LST and percent cloud cover were created and deposited into the TempDIR initially set by the user. Upon clicking on the folder the user will notice that the dbf file was the most recent file updated. The user can then open ArcMap, connect to the folder of the specified year and produce a visual of an LST heat map in seconds.

Analysis was also conducted in ArcMAP to generate semivariograms. Tiff images had to be converted to points to be read appropriately. Semivariograms generate a line of best fit that determines spatial similarity across a raster. The point layers were fed into the preexisting geostatistics tool for kriging in ArcMAP. The parameters were set to ordinary with no transformation type or order of trend removal selected.

# IV. Results & Discussion

LaSTMoV allows the user to specify a study period by year and then by month/day. In this manner, the user is able to compare a single month across multiple years, compare multiple months within a year, or both.

**Errors and Uncertainty**

LaSTMoV measures LST by census tract. LST is generally much higher than air temperature, so the output from LaSTMoV cannot be compared directly to weather station readings. It will only be useful in locating the hottest regions of the county, as well as trends in the data.

Even though Maricopa County is located in an arid region, there are cloudy days that have to be accounted for. LaSTMoV automatically generates a table for each day displaying the percent cloud cover by census tract; unfortunately, there is no mask to filter out clouds in the tiff images. The lack of a mask means that statistics are computed regardless of cloud cover, and the user must manually cross-reference each census tract with the cloud cover table to determine if the output is accurate.

Creating maps in near real-time proved impossible for the time being due to issues acquiring the MODIS imagery from OPeNDAP. The LPDAAC had two separate sites containing MODIS files. The main site using the opendap address generated NcML files but only to August 25 2013 at the time of writing this paper. (http://opendap.cr.usgs.gov/opendap/hyrax/MYD11A1.005/h08v05.ncml.html). A different site was found to have the most recent files but none of the same parameters as in the opendap site were able (http://e4ftl01.cr.usgs.gov/MOLA/MYD11A1.005/).

**Future Work**

OPeNDAP is currently in the process of beta-testing. When the interface has been finalized, it will be possible to use OPeNDAP to generate near real-time heat vulnerability maps. The first term of Arizona Health & Air Quality performed several statistical analyses, which we were unable to incorporate into our script due to time constraints. Additionally, we were unable to incorporate the locations of the heat relief centers maintained throughout Maricopa County by the MCDPH or the CASPER survey data on air conditioning use in different communities. Future work may also involve creating a cloud mask for the MODIS imagery.

# V. Conclusions

The primary goal of this project initially was to automate the process that were generated in the first term. We were able to complete a fair portion of the automation process with LaST MOV. One item that our final product lacks is the statistical analysis on the CASPER survey data that was conducted to generate AC use statistics. As mentioned earlier connection to the OpENDAP server to connect to near real-time data would have been ideal the date range was not viable for this term of the project.

With the LaST MOV software innovations the user is now able to easily organize and run batch analysis large sets of compiled MODIS LST files starting from the HDF file form. The user has the freedom to explore the data appended to the Census.dbf file in either ArcMAP to get a useful visual or in Excel. The user also has the ability to see which days were affected by clouds with the output of a percent clouds csv. This gives them the opportunity to decide if statistical analysis is a productive venture or if most of the data for the area they are looking to explore is cover by clouds and cloud shadow.

# VI. Acknowledgments

* Kate Goodin (Maricopa County Department of Public Health)
* Dave Hondula (Arizona State University)
* Dr. Kenton Ross (NASA DEVELOP National Program)
* Lance Watkins (Arizona State University)

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

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