

February 28, 2019

SPECIFICATION SHEET: MEGAN3 Biogenic 2016beta Platform

Description: 2016 biogenic emissions from the Model of Emissions of Gases and Aerosols from Nature (MEGAN) version 3.0

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1. EXECUTIVE SUMMARY

This document describes the process of creating hourly 2016 biogenic emission inputs for photochemical modeling using the Model of Emissions of Gases and Aerosols from Nature (MEGAN). MEGAN version 3.0 (downloaded September 11, 2017) was used (Guenther, et al., August 2017). The MEGAN model code, User's Guide, and input data can be found at: <https://bai.ess.uci.edu/megan>.

2. INTRODUCTION

The [Texas Air Quality Research Program \(AQRP\)](#) funded project [16-011](#) to create a next generation modeling system, MEGAN3, for estimating Texas biogenic volatile organic compound emissions by improving MEGAN version 2.1. The three main parts of the new code package are:

- A preprocessor, `prepmegan4cmaq`, was created to generate landcover growth form and ecotype, leaf area index (LAI), and ozone W126 index data for a user's grid and episode definitions.
- A Python emission factor processor with an SQLite database, `MEGAN_EFP`, was created to generate emission factors and light dependence fractions according to emission factor confidence ratings.
- The MEGAN3 emission rate estimator was updated to use new input landcover and emission data. Meteorological data (MCIP WRF output) is also processed. Eight shell scripts control FORTRAN programs to process the emissions.

3. INVENTORY DEVELOPMENT METHODS

Input Processing

Growth Form and Ecotypes

Following the [MEGAN3 Preprocessor Users Guide](#), the downloaded global 30 arc-second growth form (crop, grass, shrub, total tree, needleleaf tree, and tropical tree) and ecotype files were processed to EPA's 12US2 domain. The domain is defined by setting offset coordinates from a WRF meteorological modeling file. An example of the parameter settings file is shown below:

&control

```
start_lai_mnth = 1,  
end_lai_mnth   = 12,  
wrffile       = './input/epa_transport_wrfout_d01_2016-09-26_00_00_00'  
megan_dir     = './input',  
out_dir       = './output',
```

```
/  
&windowdefs  
x0          = 18,  
y0          = 15,  
ncolsin     = 396,  
nrowsin     = 246,  
/
```

Comma separated value (csv) output files were created for the growth form and ecotypes (e.g., grid_ecotype.epa_12km.csv, grid_growth_form.epa_12km.csv, CT3.epa_12km.csv). The user can create W126 ozone stress (optional) and leaf area index (LAI) inputs at this step. Because LAI data is only available up to 2012 from the MEGAN3 website, LAI was processed separately as detailed below.

Fractional Vegetated Leaf Area Index (LAIv)

The processing of the LAIv is described in

Attachment 1: Leaf Area Index Processing for MEGAN.

Emission Factors and Light Dependent Fractions

The MEGAN3 Emission Factor Processor (MEGAN_EFP) uses an SQLite database to store vegetation and emission factor information. The database has 42603 individual vegetation types (trees, shrub, grasses, or generic families) but only 2158 of those have emission factors. Python scripts calculate the vegetation light dependent fractions and emission factors per grid cell. The grid-specific ecotype and growth form csv files created by the preprocessor are used as input.

A quality rating flag can be set in the master python script (MEGAN_EFP.py) to limit the emission factors to those determined by the authors to be of high quality (J4) or to use all available emission factors (J0). Because J4 emission factors do not exist for all vegetation types, the 2016beta MEGAN3 emission inventory used the J0 emission factors.

During processing and initial MEGAN3 runs, the emission factor for nitric oxide (NO) was found to be very low. After discussion with the model author, it was confirmed the NO emission factor had a unit issue causing it to be low by 10000. The NO emission factor was corrected and output files with 'NOchange' indicate the correction was included.

Following the [MEGAN EFP user's guide](#), the appropriate file input and output paths were declared with the domain name.

Meteorological Input

Version 3.8 of the Weather Research and Forecasting (WRF) meteorological model was run by EPA for 2016. The WRF output was processed through the Meteorology-Chemistry Interface Processor (MCIP) version 4.3 by EPA and was used as input to MEGAN3. Soil moisture, soil temperature, soil type, 2-meter temperature, atmospheric pressure, water vapor mixing ratio, wind speed, 24-hour accumulated precipitation, and photosynthetically active radiation (PAR) are used by MEGAN3 from the METCRO2D, METCRO3D, and METDOT3D MCIP files.

Emission Rate Estimator

Eight shell scripts control FORTRAN programs to calculate the biogenic emission rates from the inputs described above. The scripts require pointing to the correct input files and compiled executables. Options are noted within each step, if available. The [Emission Rate Estimator user's guide](#) has additional details.

Step 1: TXT2IOAPI

TXT2IOAPI converts the csv input files to NetCDF format.

Step 2: MET2MGN

MET2MGN converts the meteorological model data into the MEGAN format. Flag options exist to control the source of photosynthetically active radiation (PAR) and temperature variable (MCIP-dependent). The 2016 EPA MCIP data was used as input in Step 2.

Step 3: DAYMET

DAYMET calculates daily average meteorological data from the MET2MGN output for use in the emission activity factors.

Step 4: MEGCAN

MEGCAN converts the hourly MET2MGN meteorological output, which is assumed to be above the vegetation canopy, to within-canopy estimates. The canopy vegetation type, LAI, and hourly meteorological data are input to this processor.

Step 5: MEGSEA

MEGSEA calculates soil moisture activity factors for isoprene adjustment and NO emissions. The canopy vegetation type, LAI, and hourly meteorological data are input to this processor.

Step 6: MEGVEA

MEGVEA is the main processor and calculates emission activity factors for the vegetation types. Optional stress factors for air quality, carbon dioxide, high winds, high temperatures, low temperatures, soil moisture, and bidirectional exchange by LAI can be applied. Additional parameters can be chosen for the temperature and wind stresses.

No optional stress factors were applied to the 2016beta MEGAN3 emission inventory. The LAI, canopy meteorology, daily meteorology, soil moisture activity factors, and light dependence factors are input to this processor.

Step 7: MGN2MECH

MGN2MECH converts the MEGVEA output VOC species to the chosen chemical mechanism. The Carbon Bond 6 mechanism (CB6X) was used for the 2016beta MEGAN3 emission inventory. The output is an IOAPI NetCDF file, suitable for input to the Community Multiscale Air Quality Model (CMAQ).

Step 8: IOAPI2UAM

IOAPI2UAM converts the IOAPI NetCDF file to the Urban Airshed Model (UAM) binary format used in the Comprehensive Air Quality Model with extensions (CAMx).

4. ANCILLARY DATA

Typical ancillary data is not used for biogenic emission modeling.

5. EMISSIONS PROJECTION METHODS

Biogenic emissions are not projected for this project.

6. EMISSIONS PROCESSING REQUIREMENTS

The processing steps are detailed in Input Processing.

7. EMISSIONS SUMMARIES

Below are emission density plots comparing isoprene emissions for MEGAN3 and BEIS3. On average over the entire 12US2 domain, MEGAN3 had a higher isoprene emission rate than BEIS3. In certain eastern US areas MEGAN3 had a higher isoprene emission rate than BEIS3, such as along the Mississippi river in Louisiana and Mississippi. In the west where isoprene emission rates are lower, MEGAN3 predicted higher isoprene emission rates than BEIS3.

Additional cmv_c1c2 plots and maps are available online through the LADCO website¹ and the Intermountain West Data Warehouse².

¹ <https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/>

² <http://views.cira.colostate.edu/iwdw/eibrowser2016>

EMIS_TOTAL, MEGAN v3 VS BEIS3, ISOP, 0501-0531

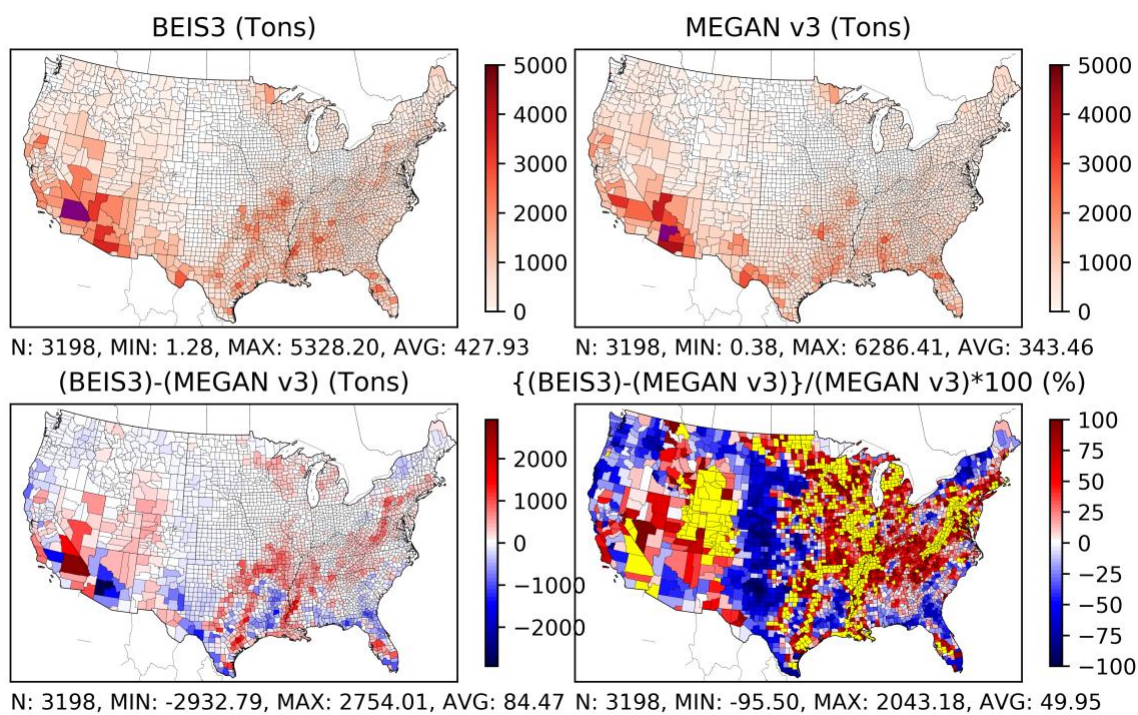


Figure 1: May 2016 MEGAN3 vs BEIS Isoprene Emission Density Plots

EMIS_TOTAL, MEGAN v3 VS BEIS3, ISOP, 0601-0630

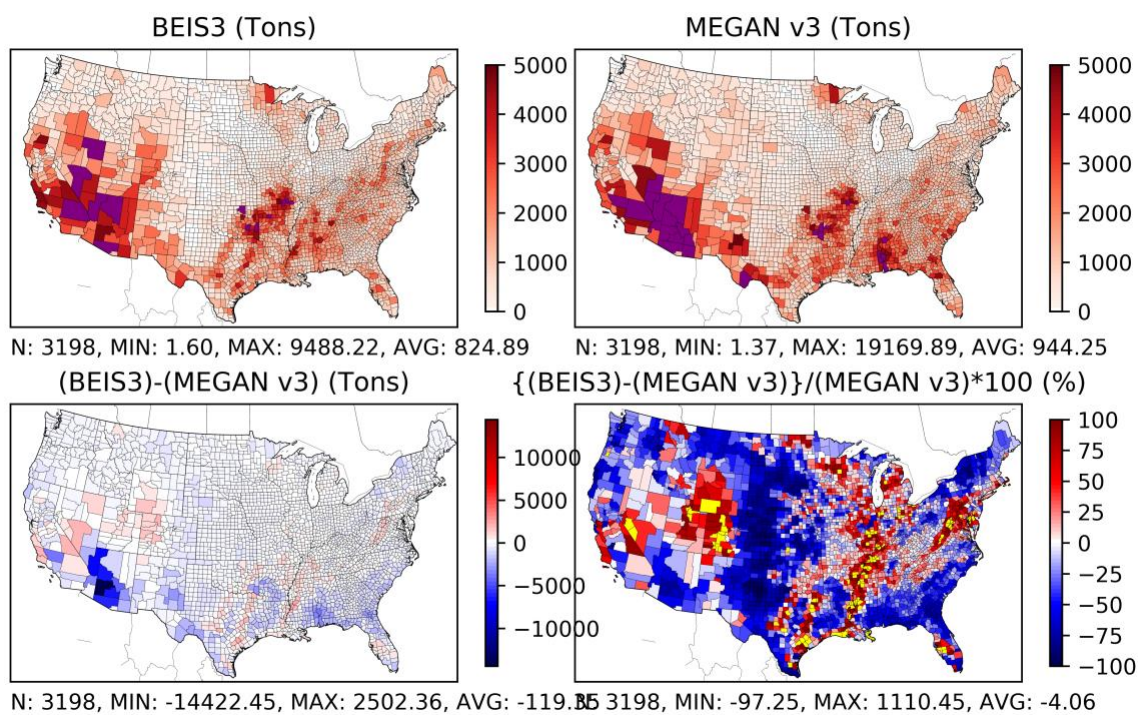


Figure 2: June 2016 MEGAN3 vs BEIS Isoprene Emission Density Plots

EMIS_TOTAL, MEGAN v3 VS BEIS3, ISOP, 0701-0731

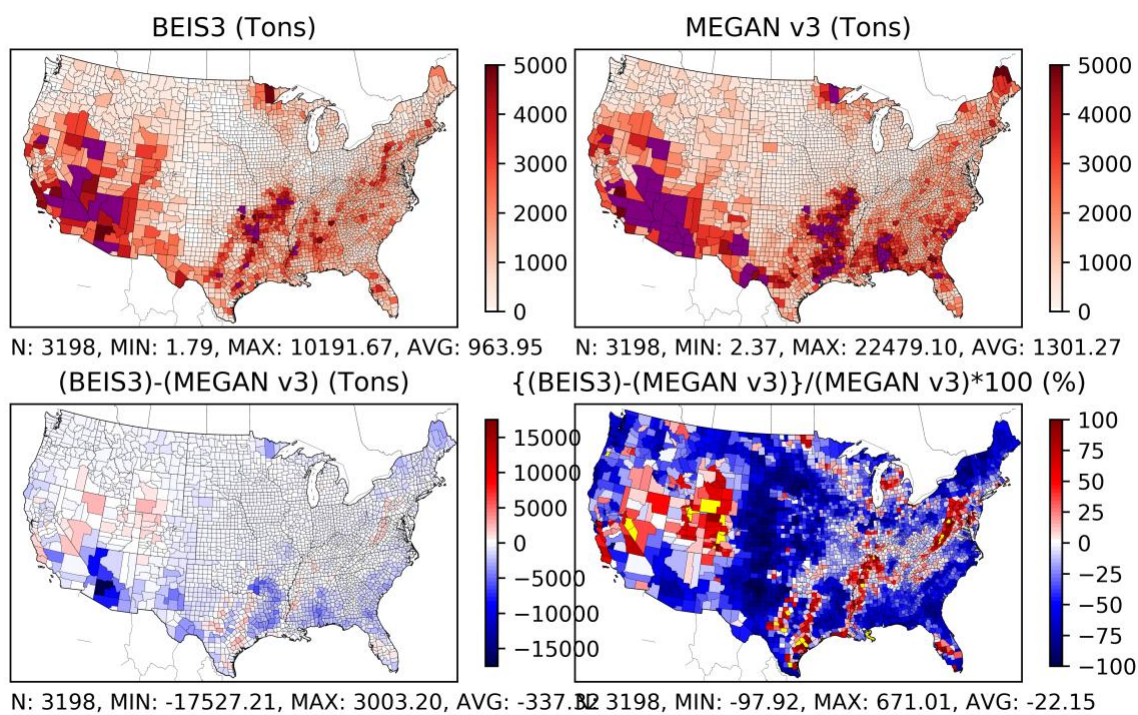


Figure 3: July 2016 MEGAN3 vs BEIS Isoprene Emission Density Plots

EMIS_TOTAL, MEGAN v3 VS BEIS3, ISOP, 0801-0831

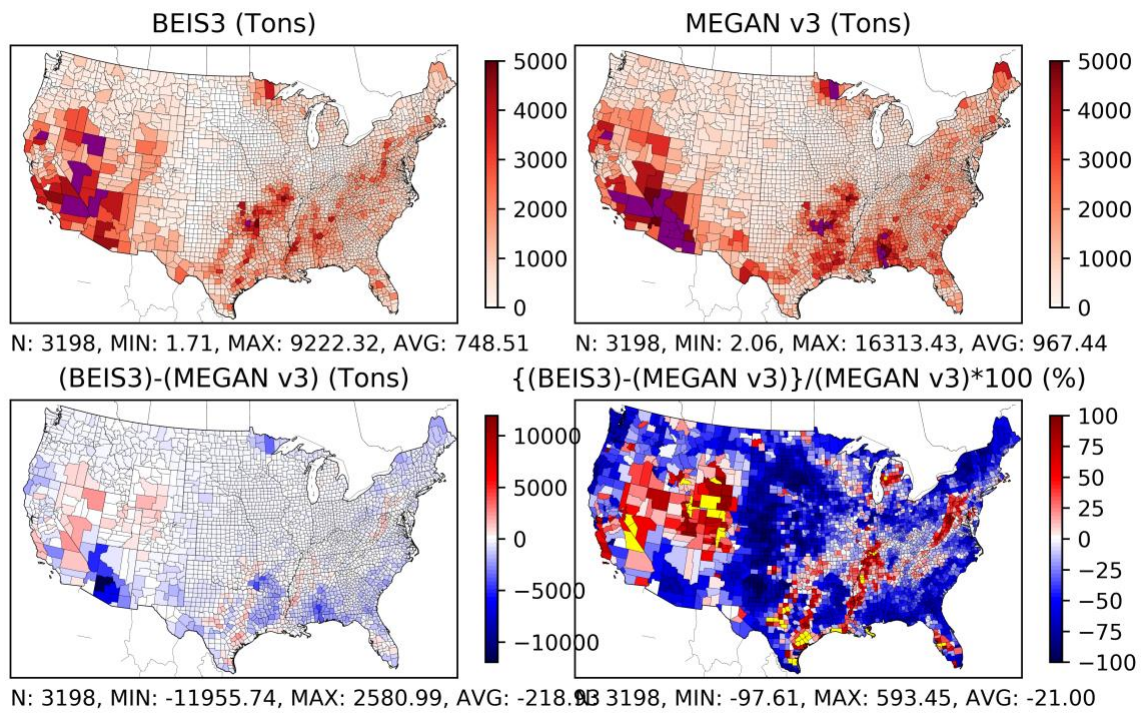


Figure 4: August 2016 MEGAN3 vs BEIS Isoprene Emission Density Plots

EMIS_TOTAL, MEGAN v3 VS BEIS3, ISOP, 0901-0930

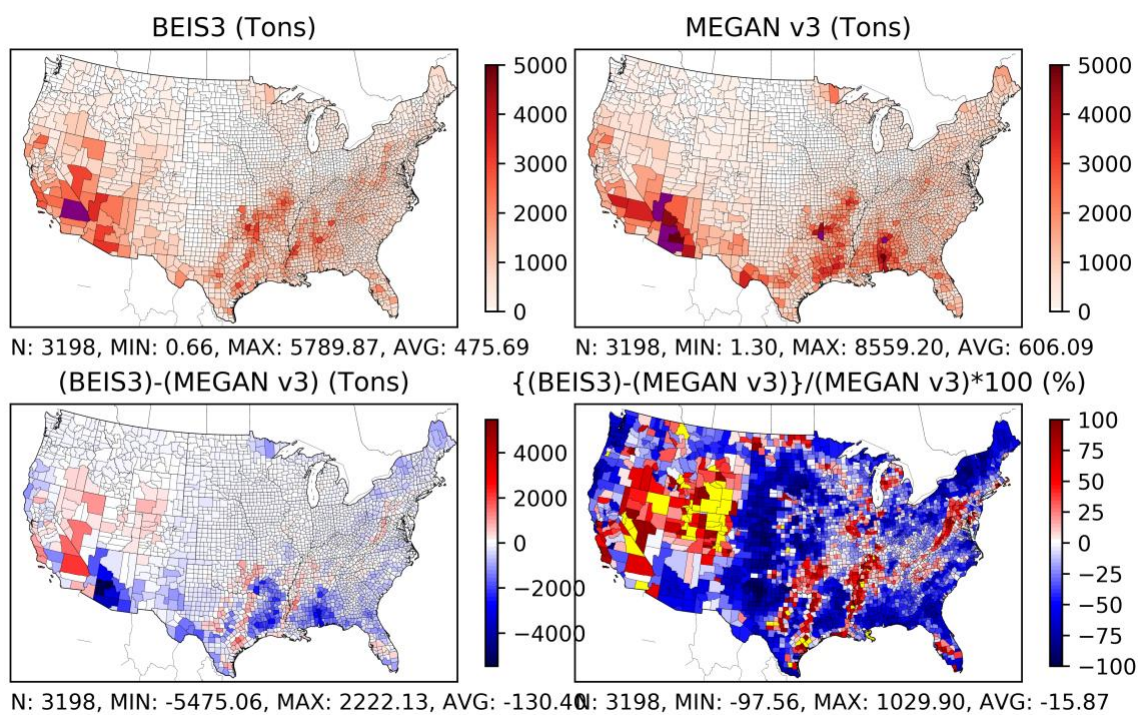


Figure 5: September 2016 MEGAN3 vs BEIS Isoprene Emission Density Plots

Attachment 1: Leaf Area Index Processing for MEGAN

Leaf Area Index processing for MEGAN3

This document describes the process of creating fractional vegetated Leaf Area Index (LAIv) input for the Model of Emissions of Gases and Aerosols from Nature (MEGAN).

Fractional Vegetated Leaf Area Index

Leaf Area Index is the one-sided leaf coverage over the same area of land. A typical dense forest maximum value would be $7.0 \text{ m}^2/\text{m}^2$. A barren area would have LAI of $0.0 \text{ m}^2/\text{m}^2$.

LAIv is the LAI divided by the fraction of land defined as vegetated. LAIv files for every eight-day period of 2008 are provided on [the MEGAN website](#). Details on how these files were created are lacking, so they were not used for TCEQ biogenic emission modeling.

To create the 2016 LAIv, the version 6 Moderate-Resolution Imaging Spectroradiometer (MODIS) Level 4 global LAI MCD15A3H product was downloaded from NASA's ftp site: <ftp://ladsweb.nascom.nasa.gov/allData/6/MCD15A3H/2016/>. The data is in [HDF format](#).

For each four-day period, the satellite tiles covering North America in a Sinusoidal grid were mosaicked together using the [MODIS Reprojection Tool \(MRT\)](#) into one HDF file. The LAI data (bit 4) and LAI quality control flag (bit 2) were kept as separate files.

Urban LAI Processing: Step 1

The MODIS satellite data does not produce an LAI value for areas it defines as urban; a fill value of 250 is used³ (Figure 6). Without LAI in the urban areas, MEGAN would produce zero biogenic emissions and dry deposition would be limited in the photochemical model (e.g., CAMx or CMAQ) where urban trees and other vegetation exist. Urban LAI was added according to the following method using a Python script to automate ArcMap tools.

³ Fill values are also produced for other features such as water or ice (see https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd15a3).

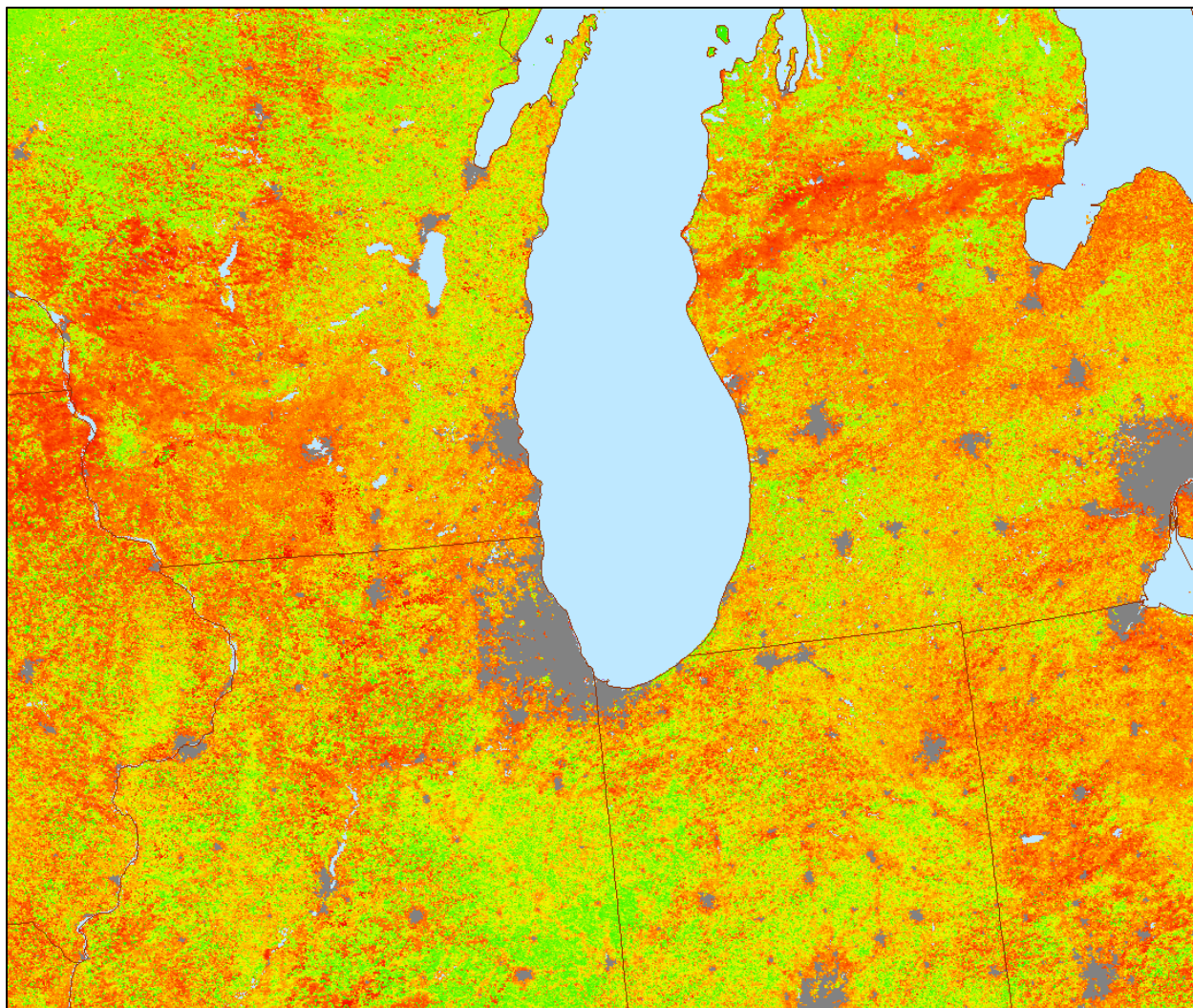


Figure 6: MODIS MCD15A3H LAI (Gray: Urban Areas)

Using the ArcGIS *Extract by Attributes* tool, the urban areas from the LAI file were extracted as a mask (Figure 7).

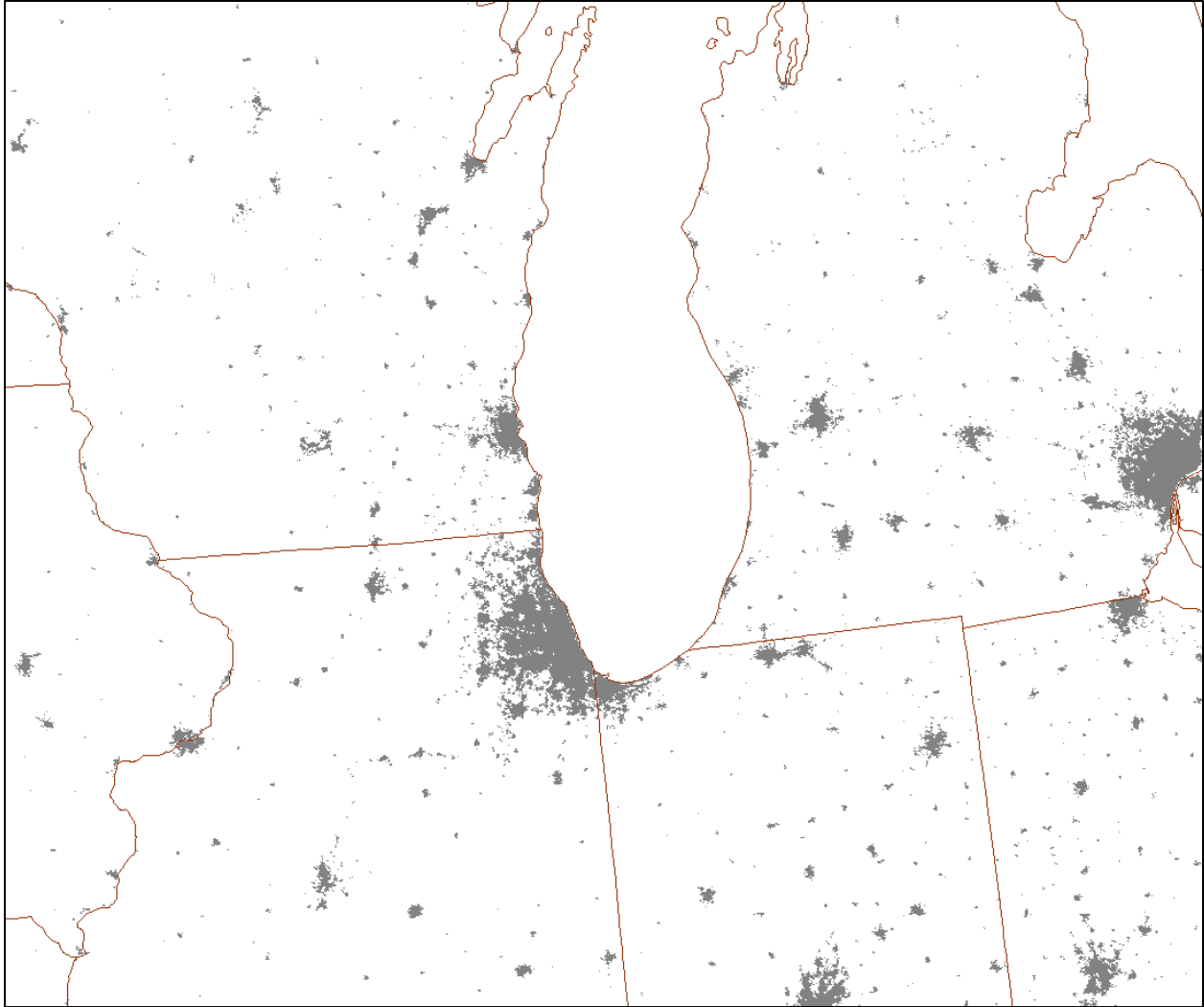


Figure 7: MODIS LAI Urban Mask

Urban LAI Processing: Step 2

The [2011 National Land Cover Database \(NLCD\) data](#) includes four urban classes: open spaces (parks or areas with little impervious cover), low intensity development, medium intensity development, and high-intensity development (roads and downtown buildings with no trees). The urban mask from Step 1 was applied to the 2011 NLCD data using the ArcGIS *Extract by Mask* tool (Figure 8). This results in a layer with MODIS-defined urban areas having additional classifications, which LAI profiles can be applied.

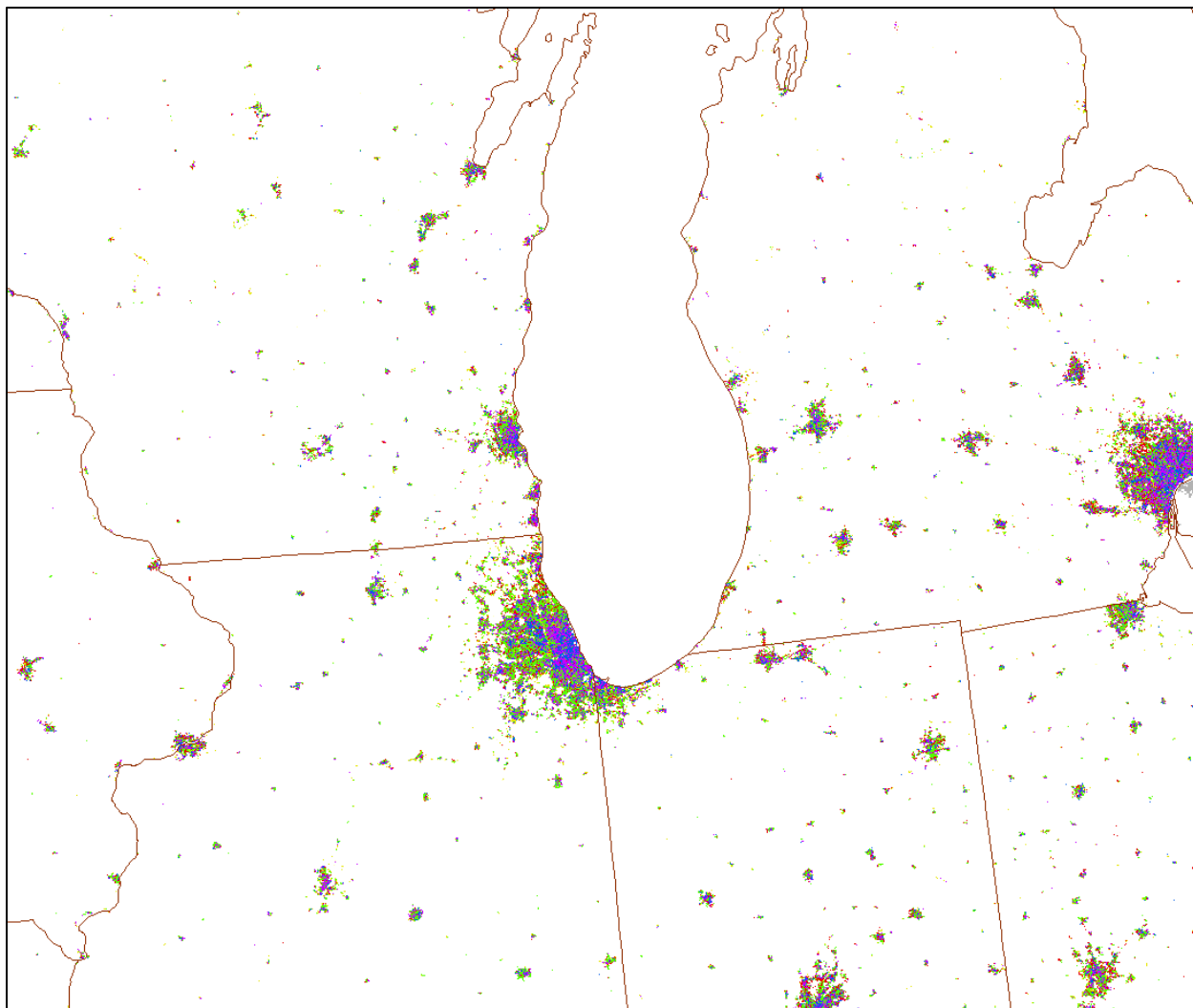


Figure 8: Masked 2011 NLCD Layer from Urban MODIS Data

Urban LAI Processing: Step 3

To make use of the new urban detail, each urban class needed a corresponding LAI value. Loughner et al, 2012 used 3.31 for urban tree LAI in WRF- urban canopy modeling work that was based on the USGS “deciduous broadleaf forest” land cover type. Urban trees are usually selected for their shade (and other attributes) so the 3.31 value appears appropriate for urban trees. While a portion of urban areas have trees, much is buildings, roads, and other impervious material. To estimate the LAI for the four NLCD urban classes, a function was created that followed the average MODIS LAI over North America for each eight-day period. Loughner’s 3.3 estimate was used as the maximum LAI value for the NLCD ‘Open Areas’ land cover class, 2.3 for the ‘Low Intensity Development’ class, 1.3 for the ‘Medium Intensity Development’ class, and 0.3 for the ‘High Intensity Development’ class (Figure 9). For other

areas in the masked NLCD data output from Urban LAI Processing: Step 2, the 'Open Areas' profile was used. ASCII files of the urban classes' LAI for each eight-day period were created to be used in the next step.

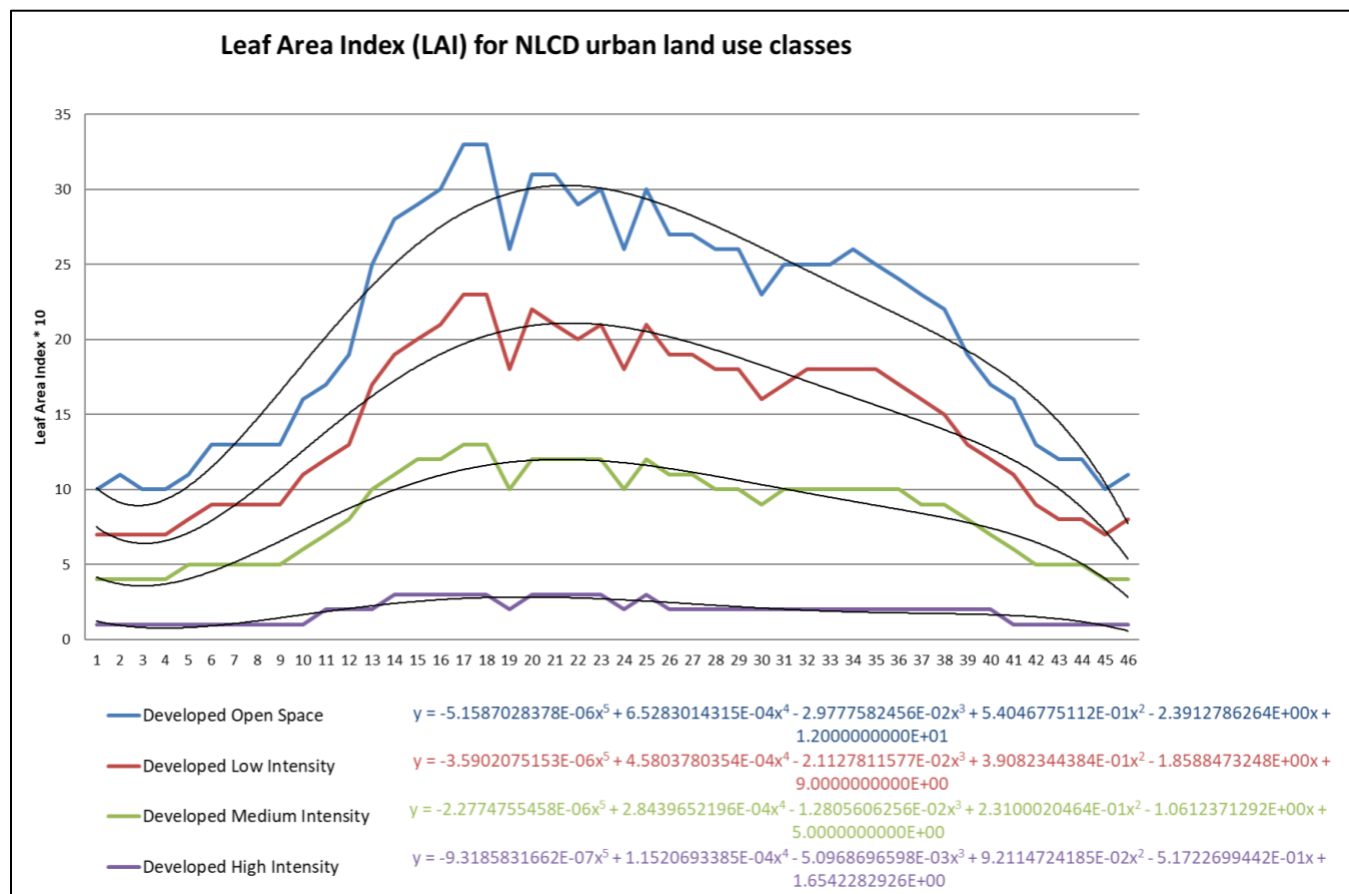


Figure 9: LAI for NLCD urban land use classes

Urban LAI Processing: Step 4

Using the ArcGIS *Reclassify by ASCII File* tool, the output of Urban LAI Processing: Step 2 was reclassified according to the urban class LAI function in Urban LAI Processing: Step 3 (Figure 10).

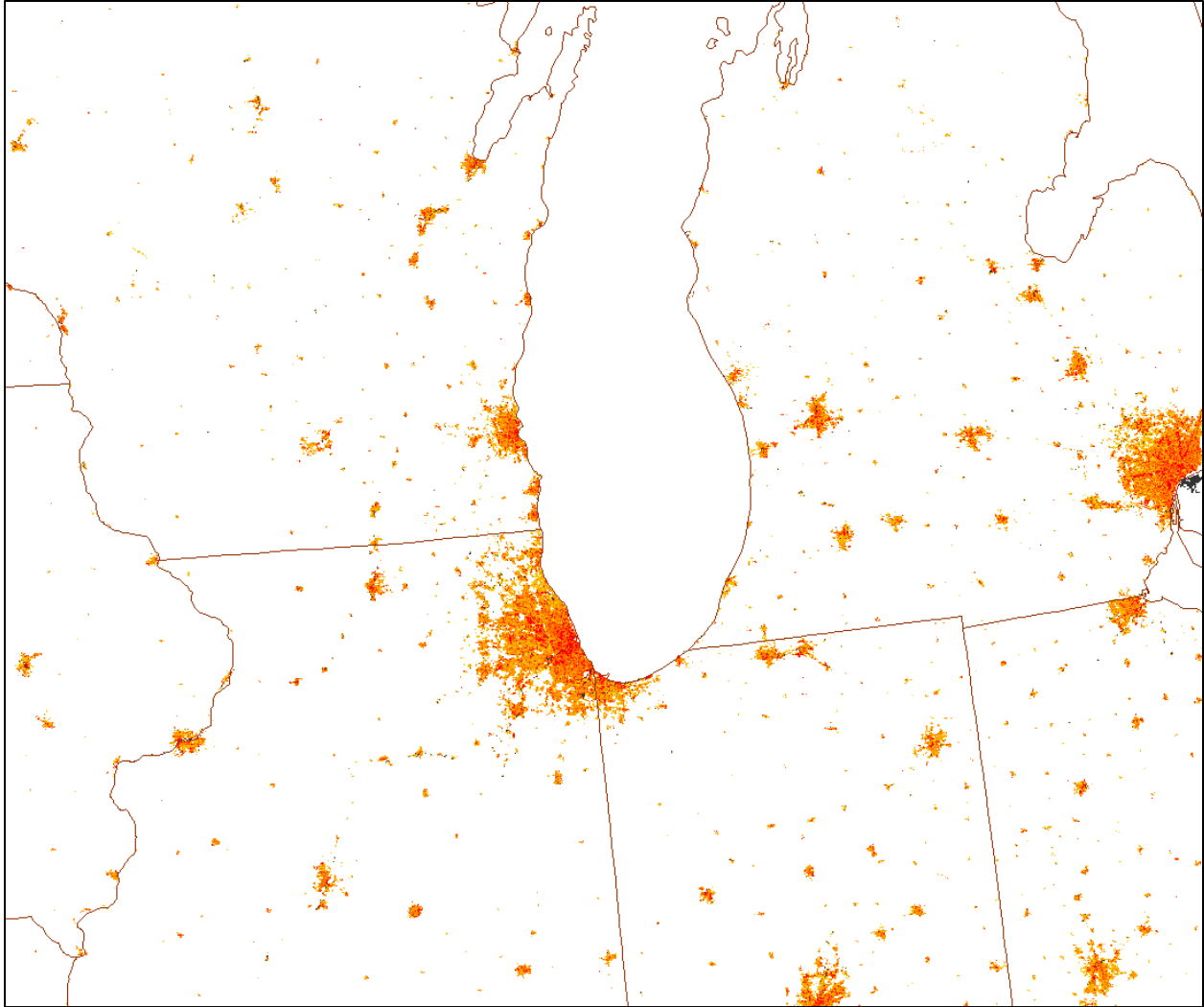


Figure 10: Reclassified Urban Areas

Urban LAI Processing: Step 5

The MODIS MCD15A3H product also contains quality control information per retrieved cell. Quality control flag values less than or equal to 108 are assumed to be of high quality from the main retrieval algorithm. Using the ArcGIS *Extract by Attributes* tool, only high-quality cells were extracted from the LAI quality control file as a mask (Figure 11).

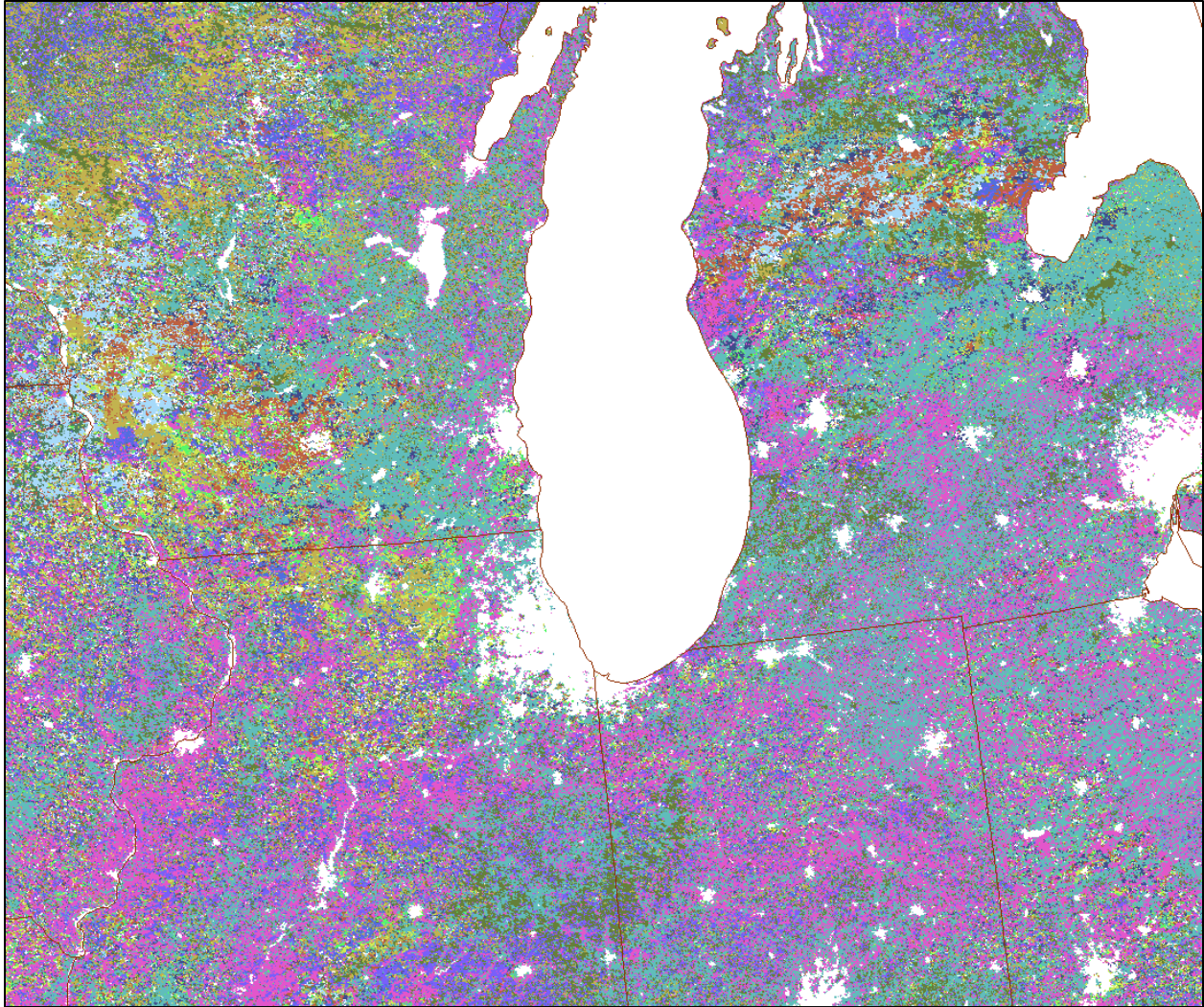


Figure 11: High Quality LAI Quality Control Mask (QC ≤ 108 ; colors are per QC flag)

Urban LAI Processing: Step 6

The urban area mask from Urban LAI Processing: Step 1 and the quality control mask from Urban LAI Processing: Step 5 were merged using the ArcGIS *Single Output Map Algebra* tool. The resultant mask was applied to the original MODIS LAI file using the ArcGIS *Extract by Mask* tool to yield only high-quality LAI data and the urban areas.

Urban LAI Processing: Step 7

For urban areas outside of the NLCD domain, LAI of 1.0 was given using the ArcGIS *Reclassify* tool on the output from Urban LAI Processing: Step 6.

Urban LAI Processing: Step 8

Finally, the NLCD-defined urban LAI from Urban LAI Processing: Step 4 was merged with the output of Urban LAI Processing: Step 7 to produce a complete file with updated urban LAI data (Figure 12).

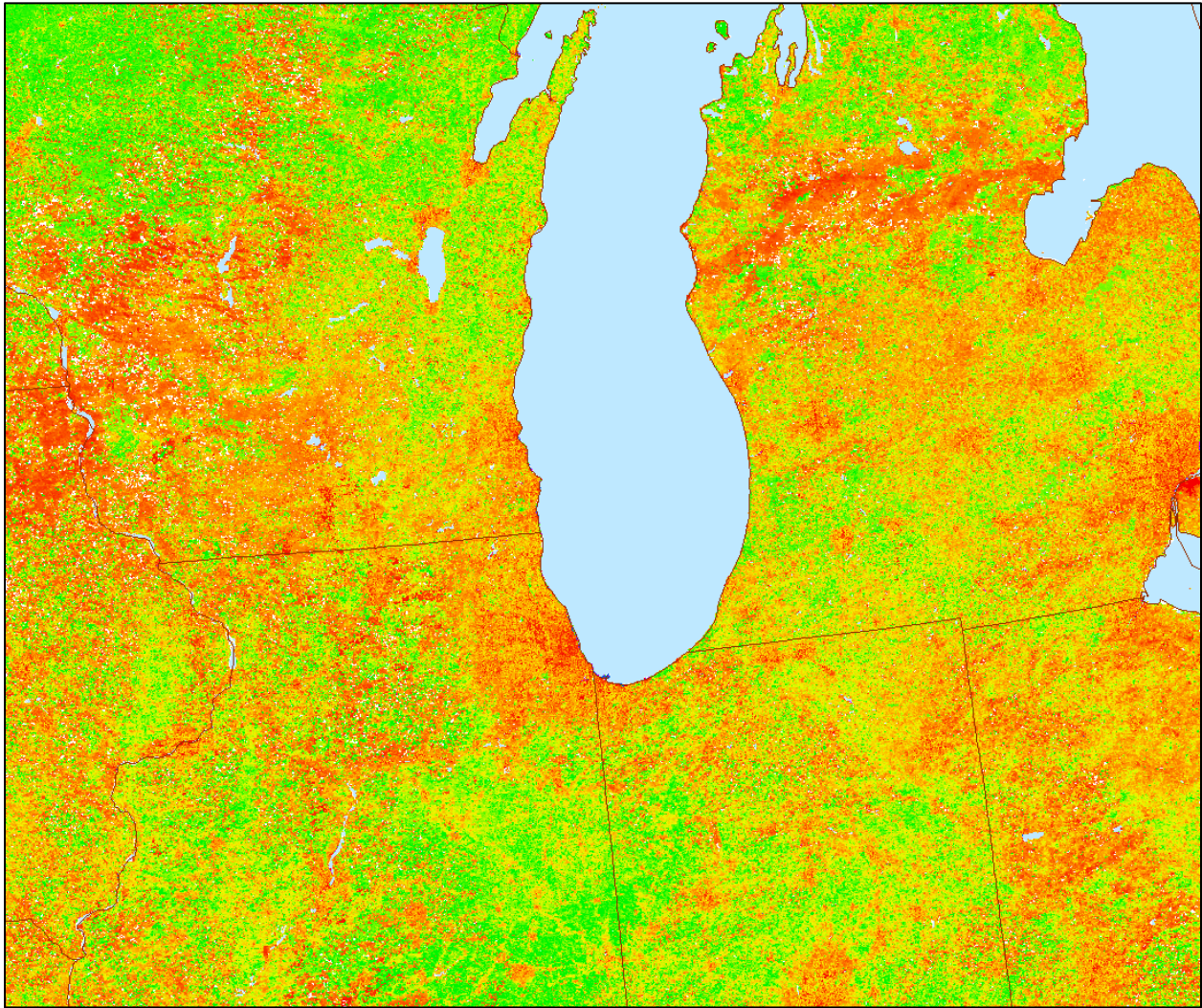


Figure 12: Final LAI with NLCD Urban Class Profiles

LAI Grid Cell Averages

The *Zonal Statistics as Table* tool was used to tabulate averages per grid cell of the EPA 12US2 domain for each eight-day LAI period. The output was a dbf ASCII file.

Grid Cell Vegetation Fraction

To create the fractional vegetated LAI (LAI_v), the LAI grid cell averages need to be divided by the fraction of vegetated land in the grid cell. The [1 km MODIS-based Maximum Green Vegetation Fraction product](#) from 2012 was used. It was resampled to the 500m MODIS LAI resolution and then masked according to the land/water features in the MODIS LAI product (Figure 13). The *Zonal Statistics as Table* tool was used to tabulate vegetation fraction averages per grid cell of the EPA 12US2 domain. The LAI was divided by the vegetation fraction per grid cell and output in csv format for MEGAN input.

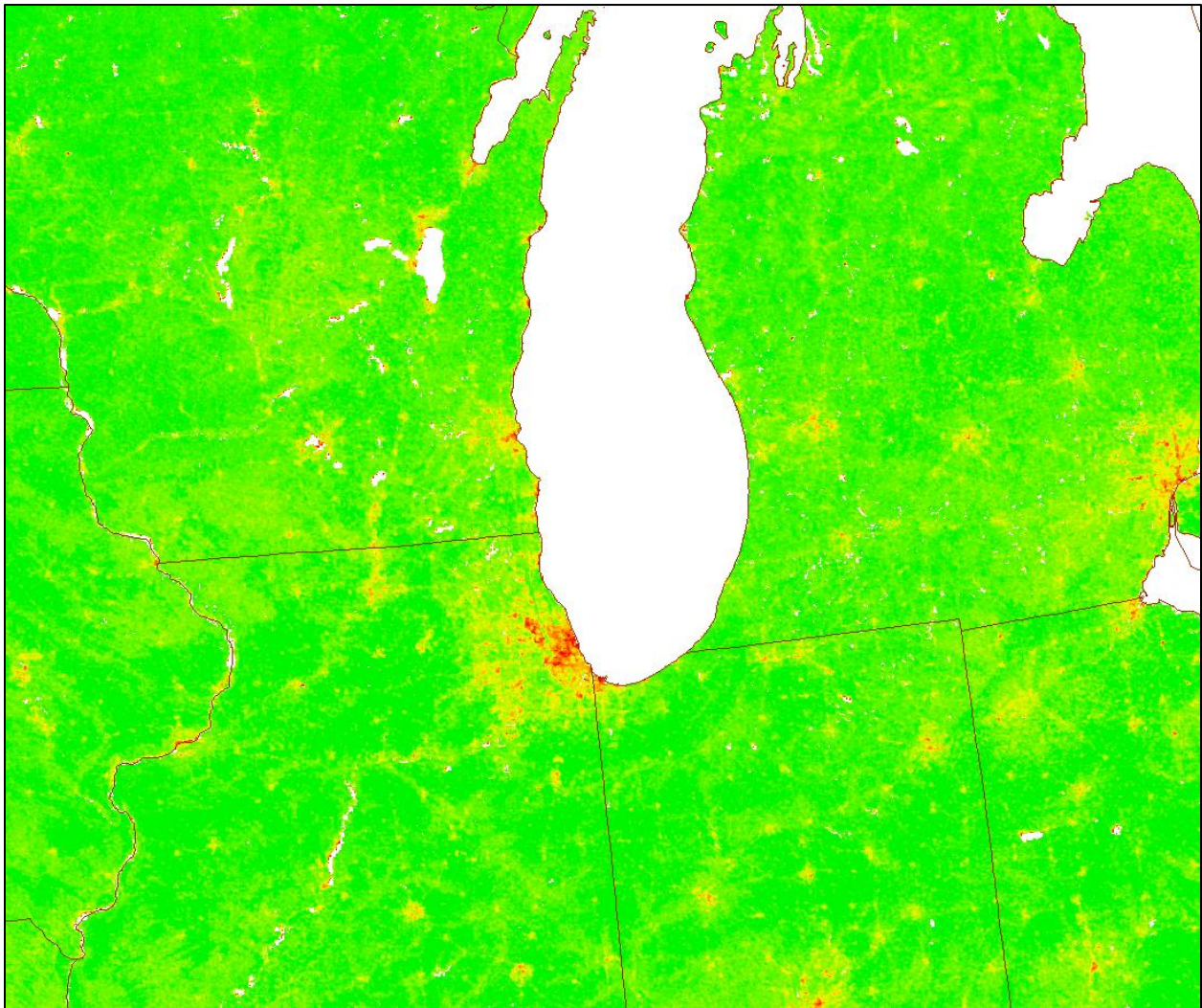


Figure 13: USGS MODIS Vegetation Fraction (Green is more vegetated, Red less)

References

Loughner, Christopher P., Dale J. Allen, Da-Lin Zhang, Kenneth E. Pickering, Russell R. Dickerson, Laura Landry, 2012: Roles of Urban Tree Canopy and Buildings in Urban Heat Island Effects: Parameterization and Preliminary Results. *J. Appl. Meteor. Climatol.*, 51, 1775–1793.