

1 naturf: a package for generating urban parameters for
2 numerical weather modeling

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9 Summary

10 The Neighborhood Adaptive Tissues for Urban Resilience Futures tool (NATURF) is a Python
11 workflow that generates files readable by the Weather Research and Forecasting (WRF) model.
12 NATURF uses *geopandas* ([Jordahl et al., 2020](#)) and *hamilton* ([Krawczyk & Izzy, 2022](#)) to
13 calculate 132 building parameters from shapefiles with building footprint and height information.
14 These parameters can be collected and used in many formats, and the primary output is a binary
15 file configured for input to WRF. This workflow is a flexible adaptation of the National/World
16 Urban Database and Access Portal Tool (NUDAPT/WUDAPT) ([Ching et al., 2009](#); [Mills et
17 al., 2015](#)) that can be used with any study area at any spatial resolution. The climate modeling
18 community and urban planners can identify the effects of building/neighborhood morphology
19 on the microclimate using the urban parameters and WRF-readable files produced by NATURF.
20 More information on the urban parameters calculated can be found in the [documentation](#).

Statement of Need

22 Fine-resolution, three-dimensional representations of urban surfaces are necessary to support
23 weather modeling at informative scales for understanding urban microclimate effects on public
24 health and energy use ([Best, 2006](#)). NUDAPT/WUDAPT were both created to address this
25 need, but data is only currently available for select regions ([Ching et al., 2009](#)) and using
26 inputs such as satellite data ([Ching et al., 2018](#)) that could introduce uncertainties in the
27 parameters produced ([Wong et al., 2019](#)). NATURF uses building-level data to represent
28 urban surfaces at sub-kilometer resolutions, allowing the user to conduct studies at a high
29 resolution at any location where building footprint and height data exist. A preliminary version
30 of NATURF was used to calculate urban parameters and demonstrate that simulated new
31 developments in the Chicago Loop neighborhood in Chicago, Illinois, USA affect temperature
32 and energy use both in the new developments and the preexisting neighborhoods ([Allen-Dumas
33 et al., 2020](#)). Their findings show that building effects on the microclimate can be modeled at
34 90m resolution, and they quantify how different configurations of urban developments affect
35 not only the developments themselves but also neighborhoods that already exist. In this way,
36 urban planners will be able to use NATURF to project how urban developments will affect
37 meteorology within and outside of the new growth.

38 Similar to NATURF, the open-source toolbox GeoClimate ([Bocher et al., 2021](#)) aims to quantify
39 the effect of urban features for climate models. Both tools provide outputs for WRF to be
40 used with the NUDAPT/WUDAPT framework, but at different resolutions. GeoClimate is
41 intended for the production of local climate zones, data classified as level 0 by WUDAPT used

42 to approximate urban parameters within the zone (Ching et al., 2018). NATURF produces
 43 level 2 data, precise urban parameter data at finer resolutions. The input data used by
 44 each tool influences the resolution of outputs; GeoClimate primarily uses OpenStreetMap
 45 data where building heights must be estimated while NATURF uses shapefiles with building
 46 height and footprint data included. For both tools, study areas at the neighborhood-scale
 47 have comparable memory usage and computational time. For larger areas, particularly at the
 48 city-scale, NATURF is more suited for use on high-performance computers (HPC) due to the
 49 number and complexity of interactions being calculated. Despite this, installation and execution
 50 of NATURF requires only a few minutes and edits to code, and the use of *hamilton* allows
 51 for the tracking of code execution progress. Additionally, NATURF can internally produce
 52 outputs ready for WRF whereas GeoClimate requires the installation and use of additional
 53 packages. While NATURF and GeoClimate both produce urban parameter data for urban
 54 microclimate modeling, NATURF does so at a higher resolution with flexibility to analyze
 55 complex interactions between buildings at multiple scales.

56 Design and Functionality

57 NATURF uses *hamilton* for organization and visualization of its workflow. Function names
 58 become inputs to other functions, allowing for a delineation of dependencies for every function.
 59 This code format allows for easier troubleshooting and visualization of the workflow (See
 60 Figure 1). Additionally, *hamilton* allows for the calculation of a specified subset of variables
 61 if the entire workflow is not desired. The calculation of parameters itself is done through
 62 *geopandas*. The input shapefile is loaded in as a GeoDataFrame that can handle calculation
 63 of parameters for each building in one process as opposed to using long “for” or “while”
 64 loops. Likewise, the geospatial features of *geopandas* are conducive to calculating the urban
 65 parameters for NATURF which are based on the geometry of each building and its neighbors.
 66 Figure 2 shows one of these parameters, mean building height at 100 meter resolution over Los
 67 Angeles County, California, USA using open-source building data from Model America (New et
 68 al., 2021). The calculated urban parameters can be found here (Sweet-Breu & Allen-Dumas,
 69 2024).

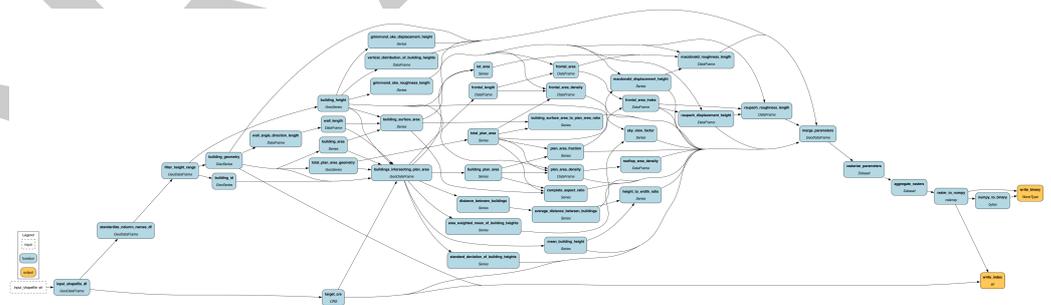


Figure 1: NATURF workflow visualization. Desired variables can be specified as inputs and all dependent functions will be executed.

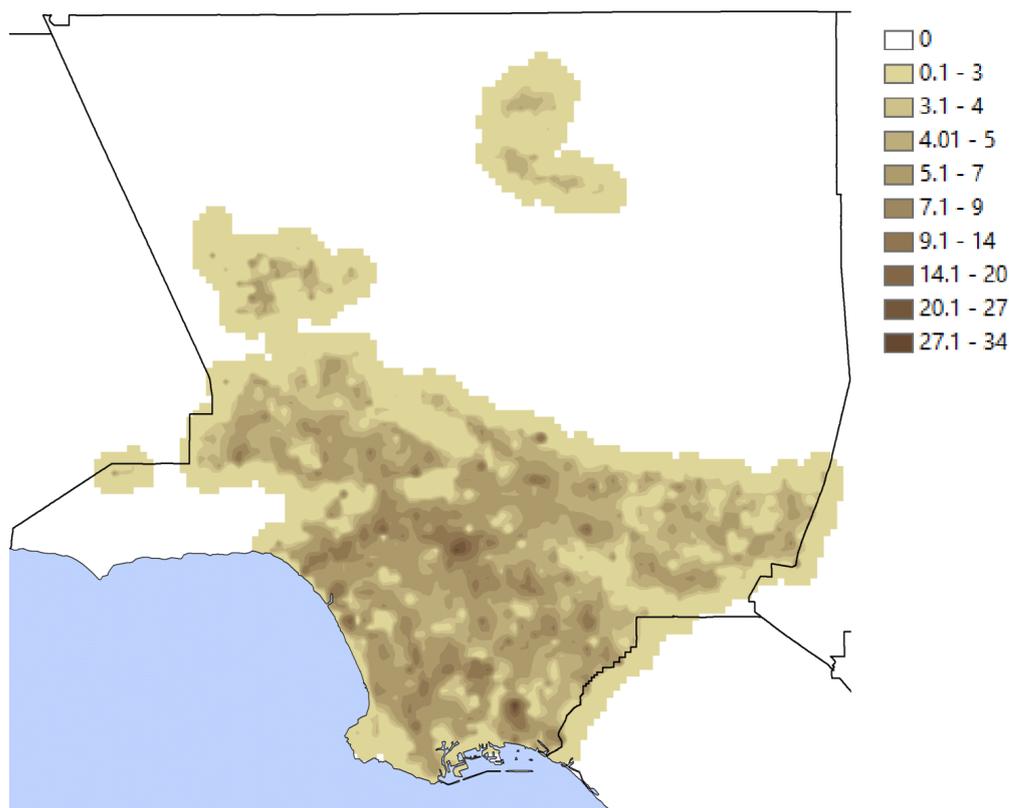


Figure 2: Average building height at 100 meter resolution for Los Angeles.

70 The primary functionality of NATURF is the calculation and preparation of building parameters
 71 to be input to WRF for enhanced understanding of the effect of building morphology on the
 72 urban microclimate. The final two functions in the NATURF workflow create a binary file
 73 and index file that can be linked into the “URB_PARAM” section of WRF’s GEOGRID.TBL.
 74 However, the urban parameters calculated can be retrieved and used for any other user purposes.
 75 Users can define the desired parameters for calculation and then export them to a CSV for use
 76 in other software. This flexibility allows NATURF to serve audiences inside and outside of the
 77 climate modeling community.

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