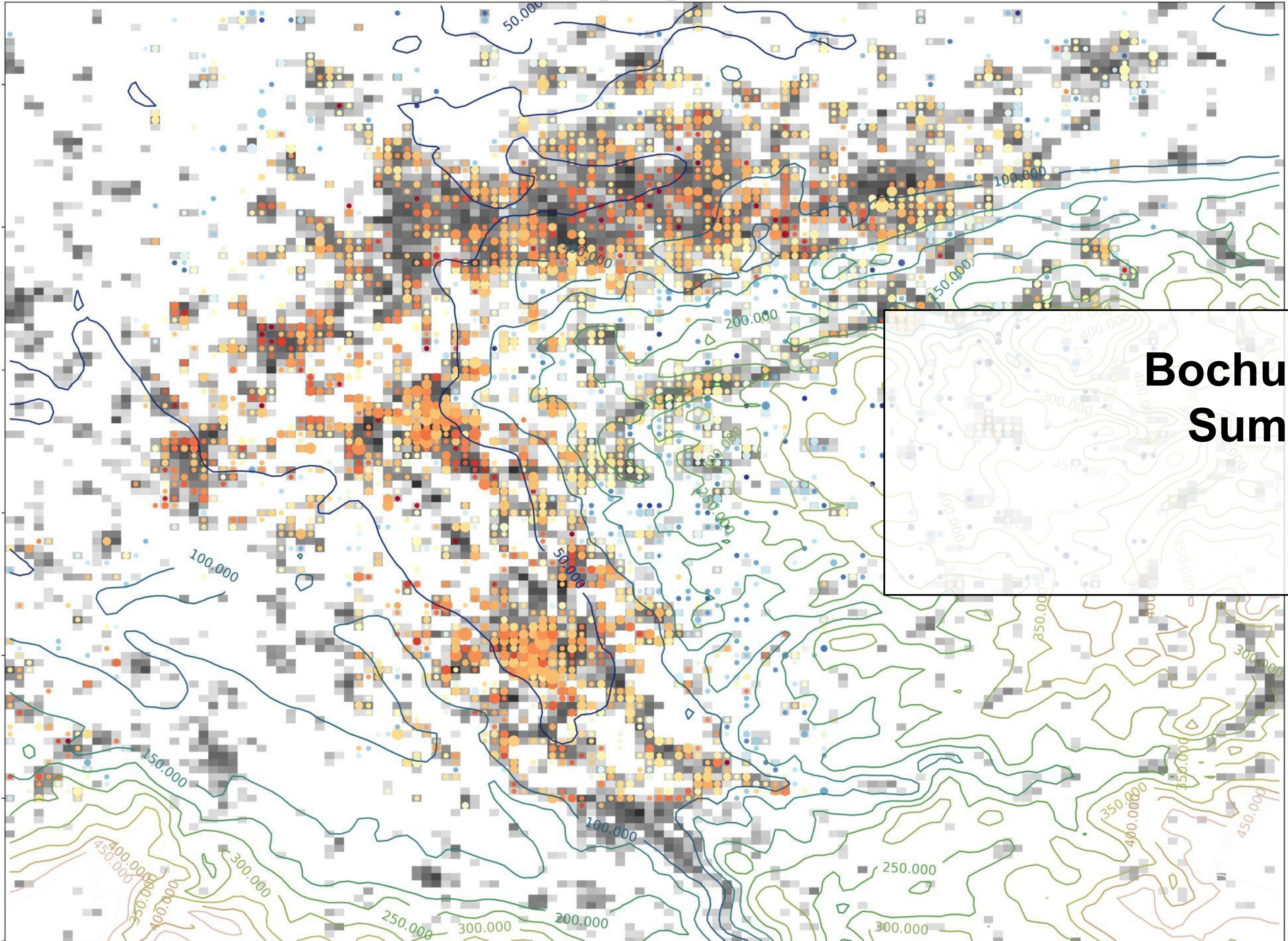


Bochum Urban Climate Summer School 2022

WRF Hands-on

Demuzere, Matthias
Andrea Zonato

Challenges of the day

- Familiarize yourself with Google Colab and the output from the Weather Research Forecasting (WRF) climate model
- Evaluation, visualisation, … of WRF output using observations from citizen weather stations
- The role of the urban description therein (Local Climate Zones)
- Investigate the impact of rooftop mitigation strategies, that include cool roofs, green roofs and photovoltaics

WRF

- Weather Research Forecasting (WRF) model is a state-of-the-art atmospheric modeling system
- Supported “community model”, i.e free and open source code with distributed development and centralized support.
- Development is lead by National Centre Atmospheric Research (NCAR) and National Oceanic and Atmospheric Administration (NOAA)
- Idealized simulations, real-time forecasting, weather and climate research (including urban applications!)
- Suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers (typically used at ~1 km)
- WRF users page

MODELS (settings)	**WRF 4.4**
Period	19-28/07/2019
Analysis Period	20-28/07/2019
Number of domains	3
Parent grid ratio	1, 3, 3
Lat, long (grid center)	51.24, 6.97
Horizontal resolution	9, 3, 1 km
Domain size	(99x99), (100x100), (133x133) pixels
Vertical levels	44
Model / Forcing time step	54s / 6h, 18s , 6s / 1h
Forcing data	ERA-5 (30 km resolution)
Urban descriptor	Local climate zones (LCZs) (10 urban classes), interpolated . List of parameter values here.
Vegetation	MODIS
Urban	BEP+BEM & RMS (Martilli 2002, Zonato 2021)
Spectral nudging	OFF
Air Conditioning	ON

Available WRF simulations

geo_em name	Simulation name	Description
geo_em.d03		
geo_em.d03_NoUrban	NOURBAN_SIM	Basic run, where the urban land cover is replaced by its neighbouring natural land cover (*W2W*)
geo_em.d03_LCZ_extent	LCZ_NORMS_EXTENT_SIM	*LCZ* extent only, yet binary urban class with default urban parameters (*W2W*)
geo_em.d03_LCZ_params	LCZ_NORMS_SIM	*LCZ* urban description, including intra-urban heterogeneity and spatially explicit urban parameters (*W2W*)
geo_em.d03_LCZ_params	LCZ_CR_SIM	*LCZ* urban description, cool roofs, total coverage(*Zonato et al., 2021*)
geo_em.d03_LCZ_params	LCZ_GR_SIM	*LCZ* urban description, green roofs, total coverage (*Zonato et al., 2021*)
geo_em.d03_LCZ_params	LCZ_PVP_SIM	*LCZ* urban description, rooftop photovoltaic panels, total coverage (*Zonato et al., 2021*)

Variable in output from the simulations:

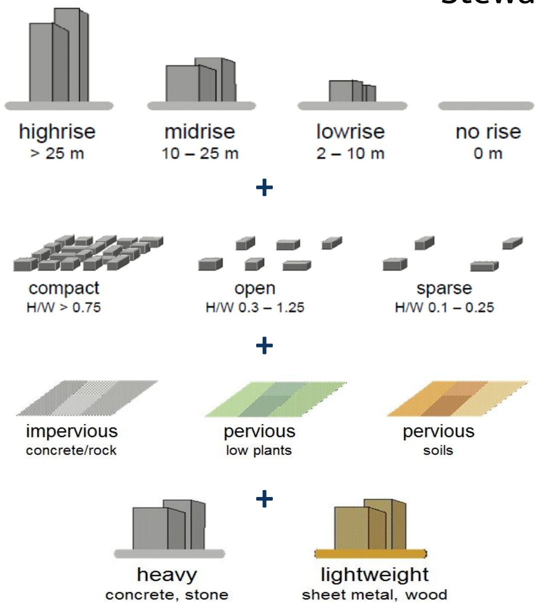
- XLAT, XLONG: Coordinates of the center of the grid cell
- T2, TSK, T: 2m air temperature, skin temperature, vertical potential temperature
- HGT: Terrain Height
- U10,V10,U,V: 10-m wind speeds, vertical profiles
- CM_AC_URB3D: Energy consumption by air conditioning
- EP_PV_URB3D: Energy produced by RPVPs
- HFX,LH: Sensible/Latent heat fluxes
- PBLH: PBL height
- SWDOWN,GLW: Short/Long-wave radiation at the surface
- TKE_PBL: Turbulent kinetic energy

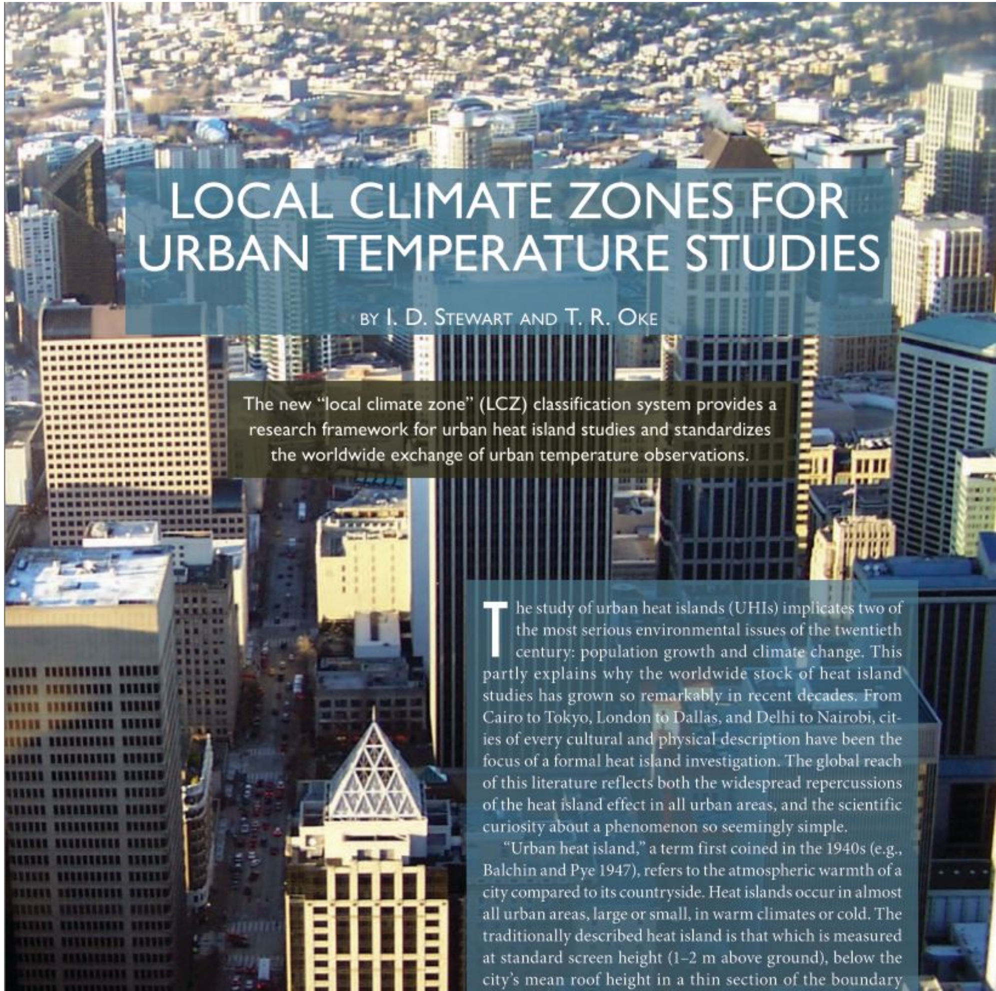
How to setup WRF …

Local Climate Zones

"75% of the 190 reviewed urban heat island studies published between 1950-2007 **failed to communicate basic metadata** regarding instrumentation and field site characteristics.

Stewart et al. (2011)





LOCAL CLIMATE ZONES FOR URBAN TEMPERATURE STUDIES

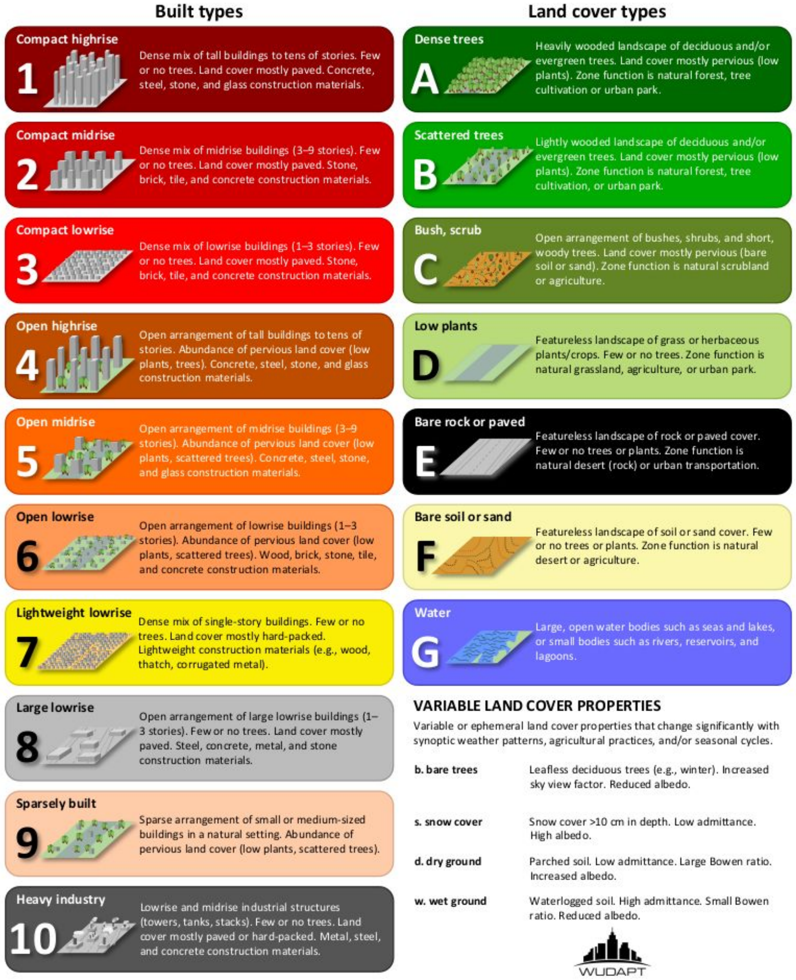
BY I. D. STEWART AND T. R. OKE

The new "local climate zone" (LCZ) classification system provides a research framework for urban heat island studies and standardizes the worldwide exchange of urban temperature observations.

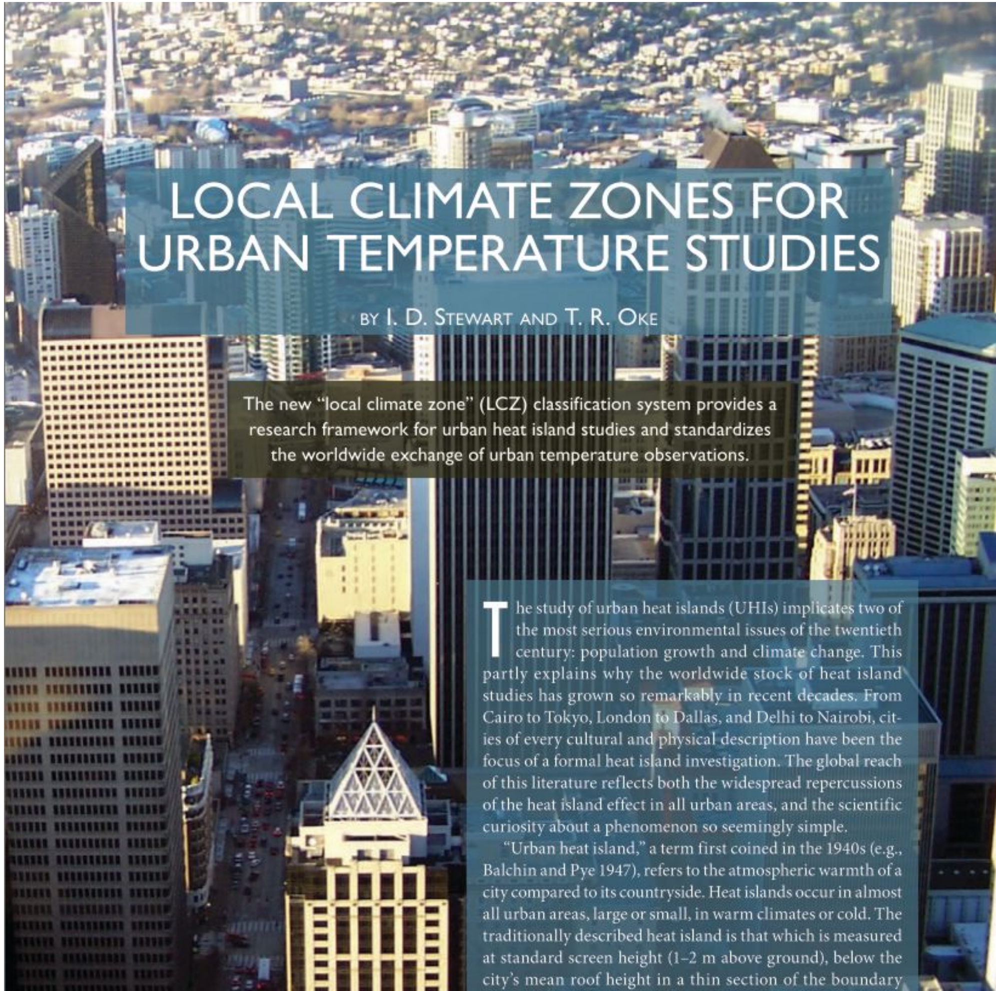
The study of urban heat islands (UHIs) implicates two of the most serious environmental issues of the twentieth century: population growth and climate change. This partly explains why the worldwide stock of heat island studies has grown so remarkably in recent decades. From Cairo to Tokyo, London to Dallas, and Delhi to Nairobi, cities of every cultural and physical description have been the focus of a formal heat island investigation. The global reach of this literature reflects both the widespread repercussions of the heat island effect in all urban areas, and the scientific curiosity about a phenomenon so seemingly simple.

"Urban heat island," a term first coined in the 1940s (e.g., Balchin and Pye 1947), refers to the atmospheric warmth of a city compared to its countryside. Heat islands occur in almost all urban areas, large or small, in warm climates or cold. The traditionally described heat island is that which is measured at standard screen height (1–2 m above ground), below the city's mean roof height in a thin section of the boundary

Local Climate Zones



Stewart et al. (2012), Demuzere et al. (2020)



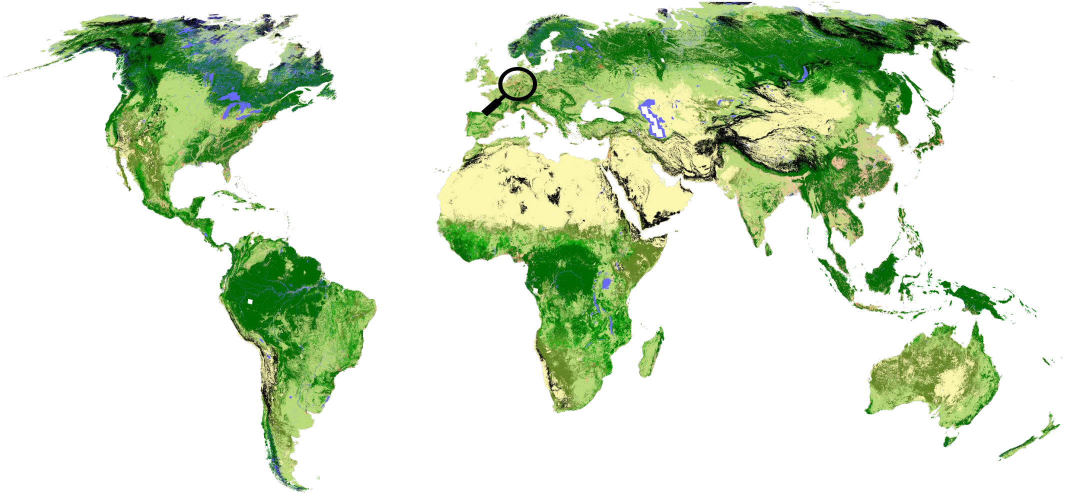
Local Climate Zones

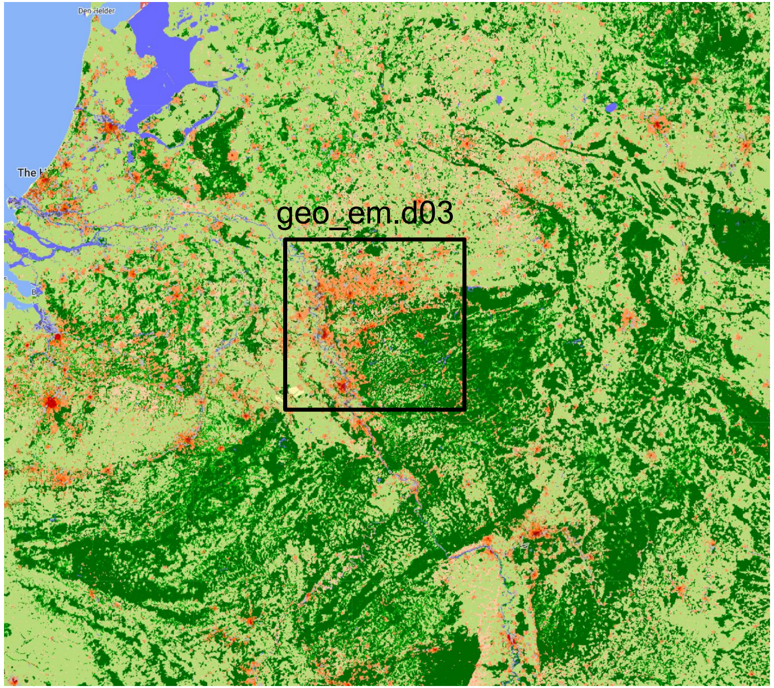
Earth Syst. Sci. Data, 14, 3835–3873, 2022
https://doi.org/10.5194/essd-14-3835-2022

Open Access Earth System Science Data

A global map of local climate zones to support earth system modelling and urban-scale environmental science

Matthias Demuzere[1], Jonas Kittner[1], Alberto Martilli[2], Gerald Mills[3], Christian Moede[1],
Iain D. Stewart[4], Jasper van Vliet[5], and Benjamin Bechtel[1]





W2W: WUDAPT-to-WRF

The Journal of Open Source Software

W2W: A Python package that injects WUDAPT's Local Climate Zone information in WRF

Matthias Demuzere[1¶], **Daniel Argüeso**[2], **Andrea Zonato**[3], and **Jonas Kittner**[1]

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DOI: 10.21105/joss.04432

Software

- Review
- Repository
- Archive

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- @erexer

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Summary

The Python-based WUDAPT-to-WRF (`W2W`) package is developed to translate Local Climate Zone (LCZ) maps into urban canopy parameters readable by WRF, the community "Weather Research and Forecasting" model (Skamarock et al., 2021). It is the successor of the Fortran-based `W2W` package developed by Brousse et al. (2016) and Martilli et al. (2016), and provides an improved, simpler, and more efficient procedure to use LCZ information in WRF. Some important changes include direct manipulation of the geogrid files without the creation of temporary files, and the use of average LCZ-based urban morphological parameters instead of assigning them to the modal LCZ class.

This development of this package is in line with the objectives of WUDAPT, the World Urban Database and Access Portals Tools community project, that aims to 1) acquire and make accessible coherent and consistent information on the form and function of urban morphology relevant to climate weather and environmental studies, and 2) provide tools that extract relevant urban parameters and properties for models and model applications at appropriate scales for various climate, weather, environment, and urban planning purposes (Ching et al., 2018).

W2W: WUDAPT-to-WRF

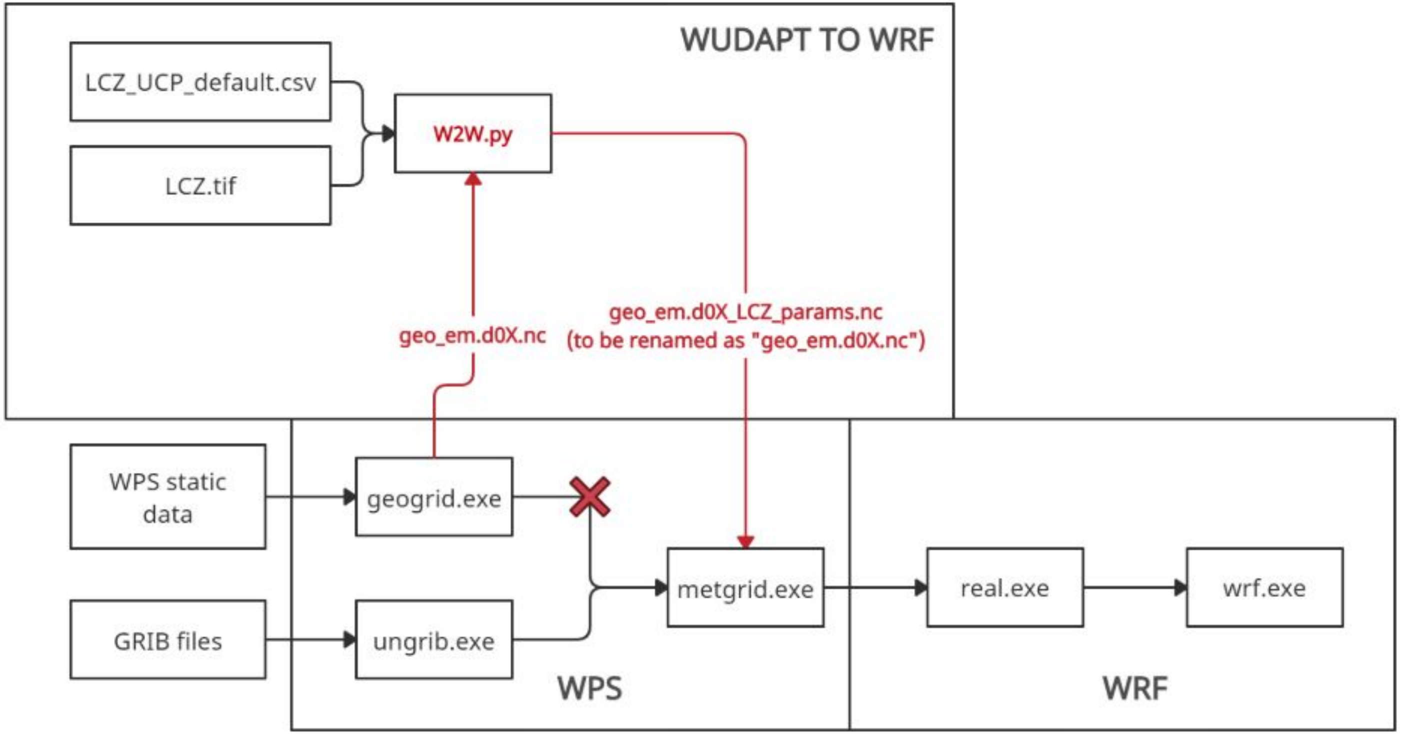
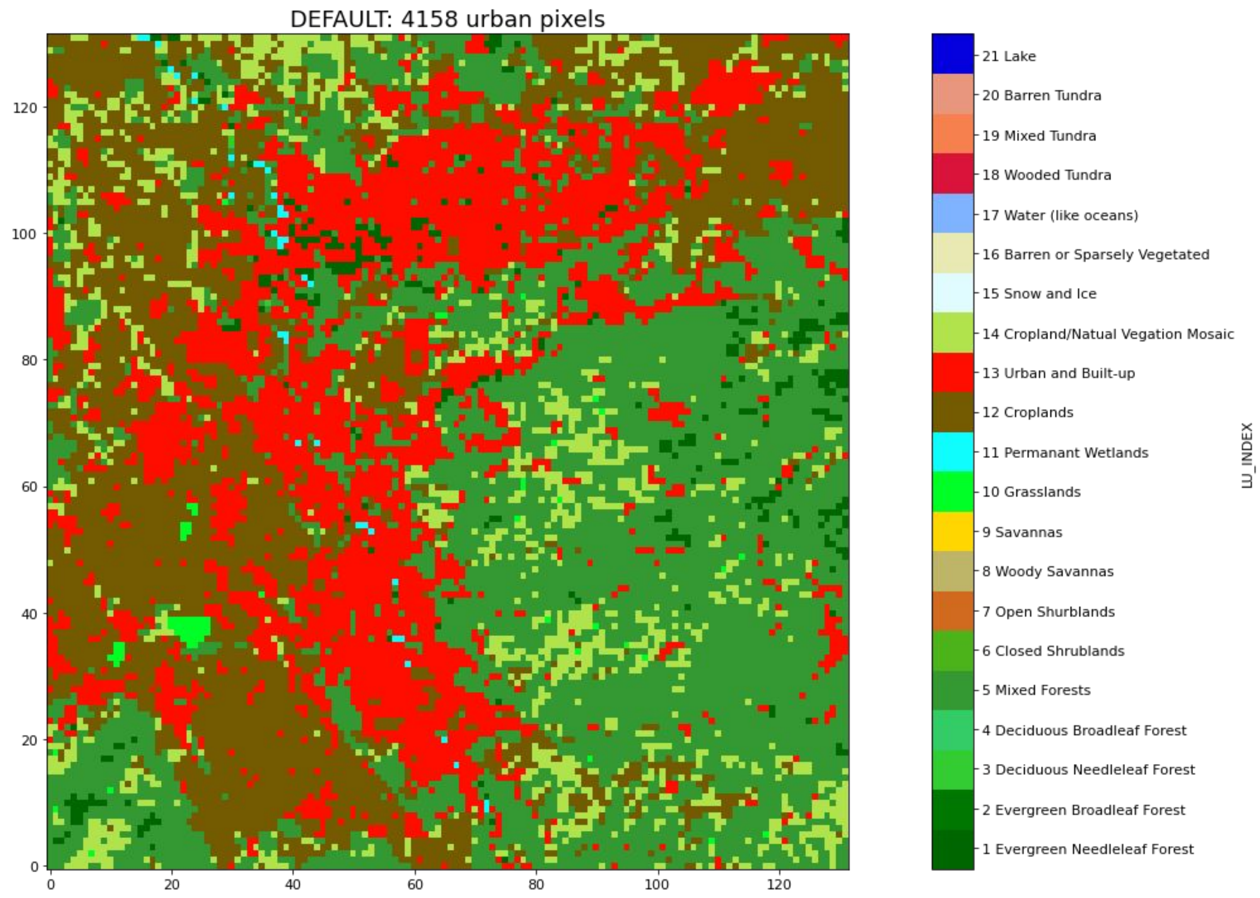


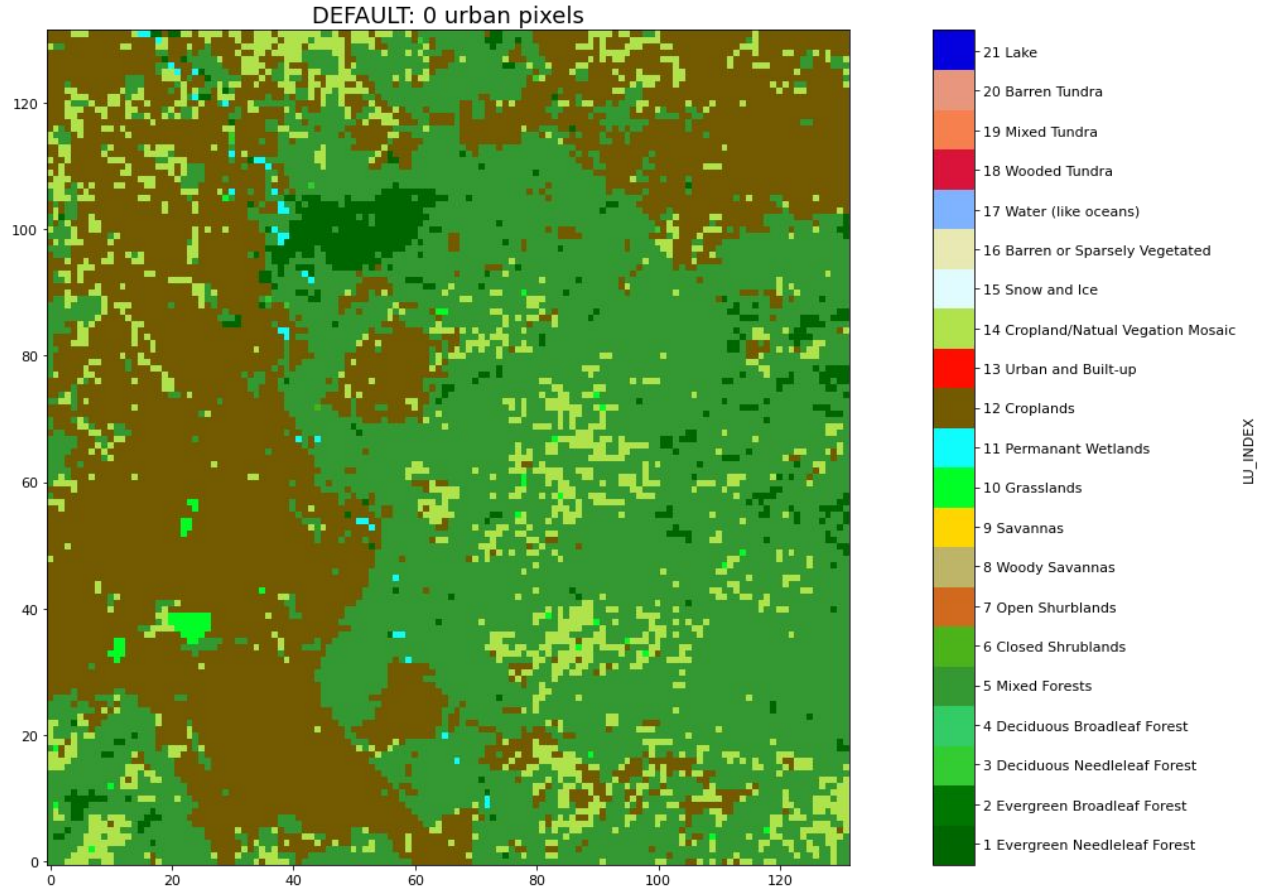
Figure 1: Modified workflow to set up and run a WRF simulation including urban parameters derived from LCZs using W2W.

W2W: WUDAPT-to-WRF



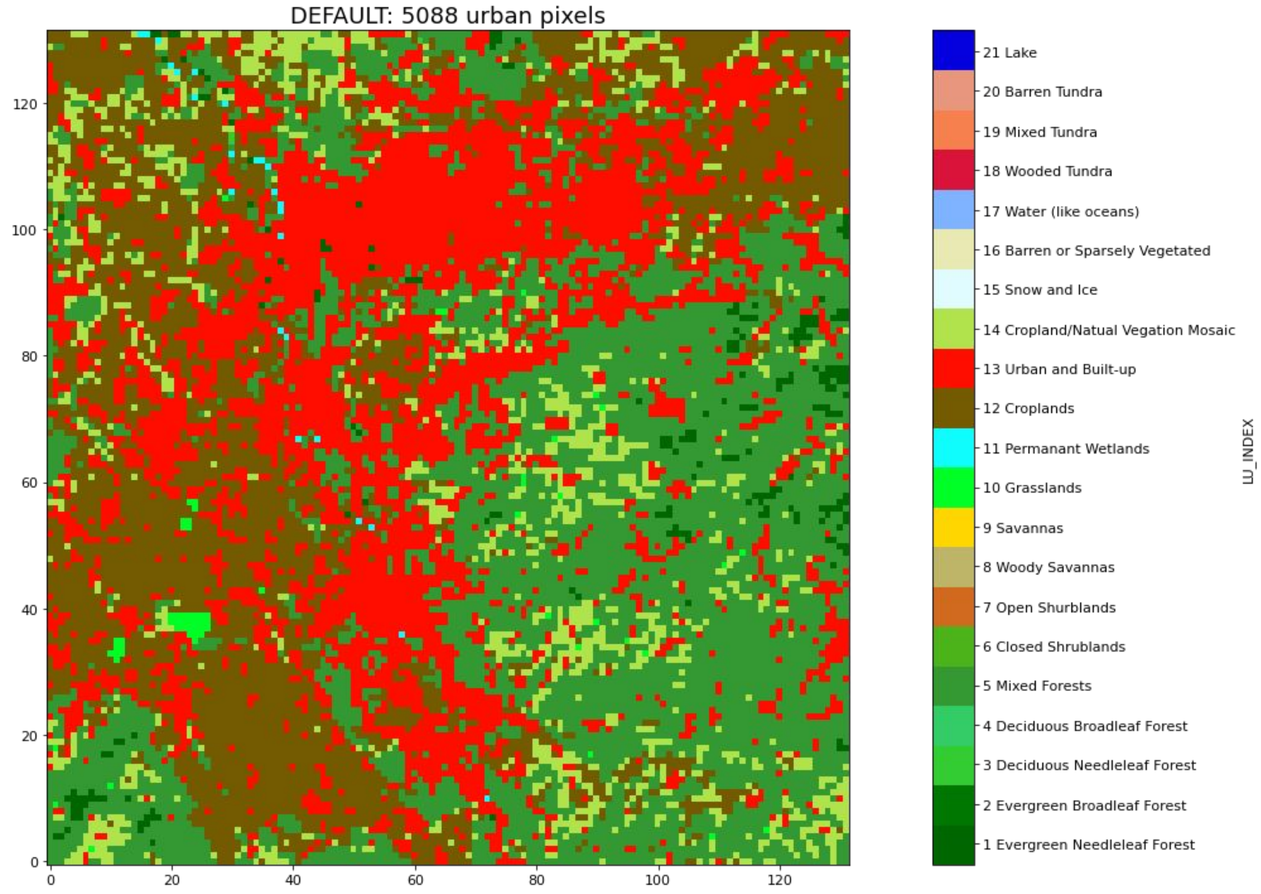
geo_em.d03

W2W: WUDAPT-to-WRF



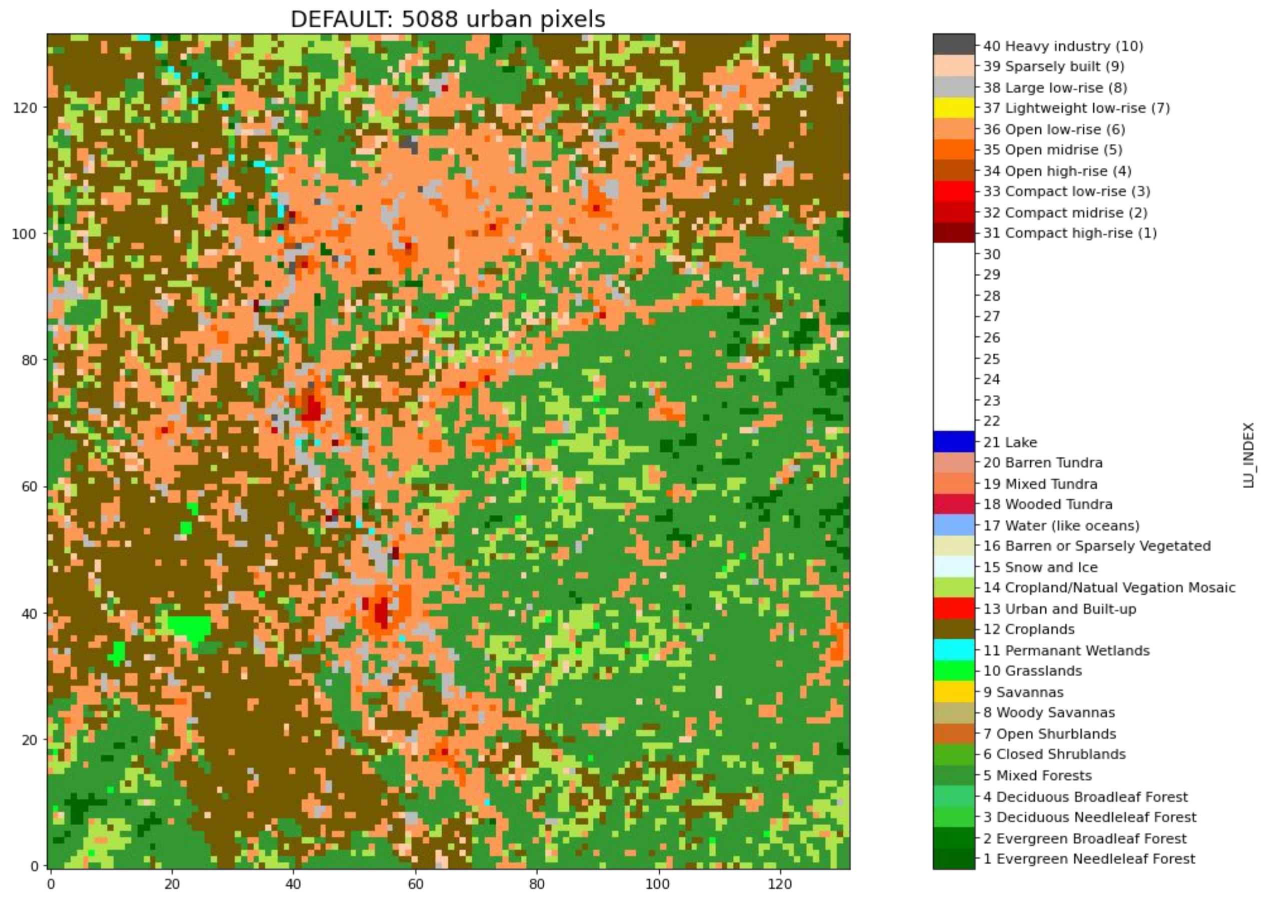
geo_em.d03_NoUrban

W2W: WUDAPT-to-WRF



geo_em.d03_LCZ_extent

W2W: WUDAPT-to-WRF



geo_em.d03_LCZ_params

WRF rooftop mitigation strategies

JGR Atmospheres

RESEARCH ARTICLE

10.1029/2021JD035002

Key Points:

- New parameterizations of rooftop mitigations strategies are developed and implemented into the Weather Research and Forecasting (WRF) model
- The new implementations include green roofs and photovoltaic panels, coupled with the BEP + BEM urban canopy models
- Sensitivity tests are conducted in order to evaluate the effect of RMSs on near-surface air temperature and energy consumption

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Exploring the Effects of Rooftop Mitigation Strategies on Urban Temperatures and Energy Consumption

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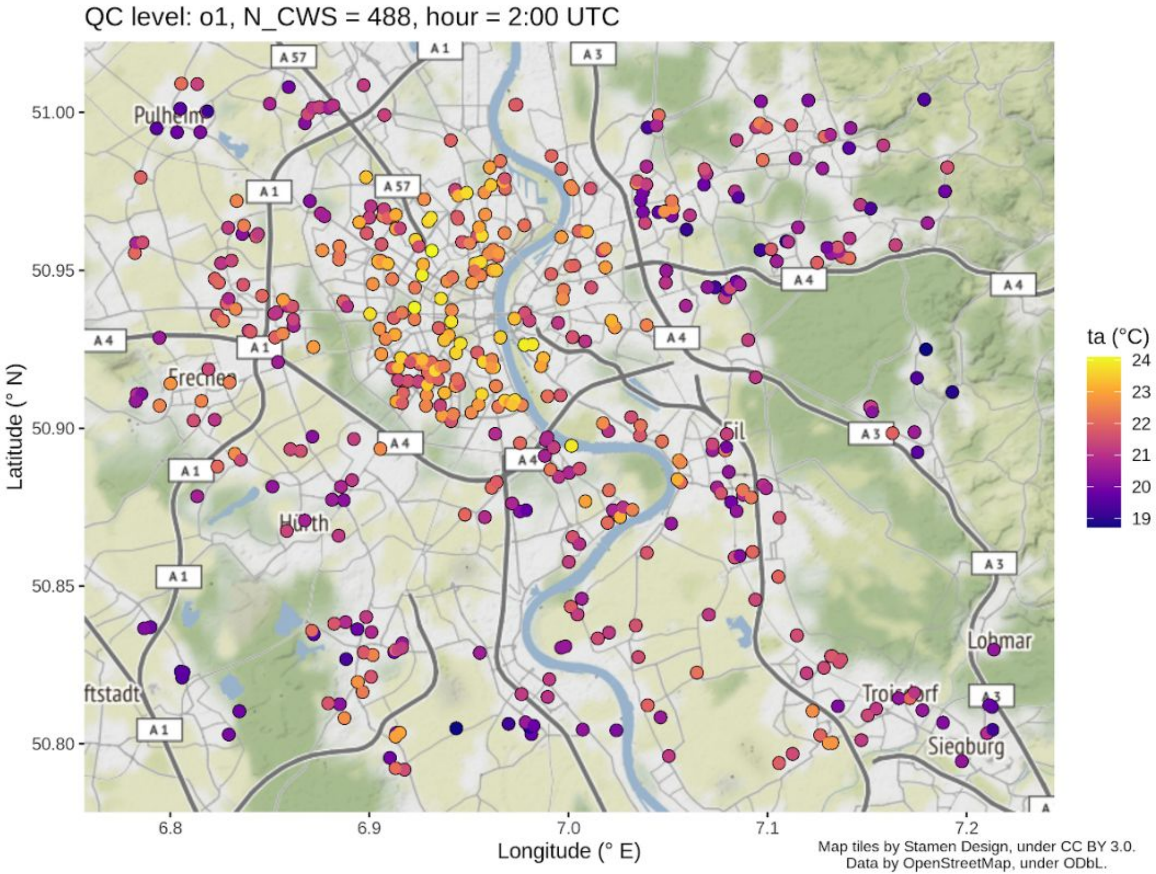
Abstract This paper describes and evaluates physical parameterizations accounting for the effect of rooftop mitigation strategies (RMSs) on the urban environment, in the context of the mesoscale model Weather Research and Forecasting (WRF). Through the new implementation, the sensitivity of near-surface air temperature and building energy consumption to different RMSs is evaluated by means of numerical simulations in idealized urban areas, for typical summer and winter conditions. Rooftop mitigation strategies considered include cool roofs, green roofs, and rooftop photovoltaic panels. The reference case simulations are performed assuming buildings made by bricks, with roof composed of clay tiles. Results indicate that near-surface air temperature is reduced by cool and green roofs during summer: cool roofs are the most efficient in decreasing air temperature, followed by irrigated green roofs. Photovoltaic panels, instead, induce a temperature increase during daytime and a small decrease during nighttime. Cool roofs reveal to be the most efficient strategy in reducing the energy consumption by air conditioning systems. During wintertime, green roofs maintain a higher near-surface air temperature than clay tile roofs and largely decrease energy consumption. Even PVPs increase air temperature, as in the summer case. On the other hand, cool roofs reduce near-surface air temperature during daytime, inducing an increase in energy consumption. The results presented here show that the parameterization schemes implemented in the WRF model can be a valuable tool to evaluate the effects of mitigation strategies in the urban environment.

Observations

Quality-controlled Netatmo observations (N=5000+)



Visualizations

- A number of python routines are available to plot various WRF input/output, where possible together with available observations.
- These scripts will be explained in Google Colab directly!

Student presentations

At the end of the WRF hands-on session, we’d like all of you to present some of your results. This does not have to be done individually, but can be done as a team (4 to 5 people).

Some guidance:

- What are the research question(s) you tried to address?
- How did you tackle this (these) questions
- What are the results?
- Can you provide a physical interpretation of these results?
- What are the caveats? E.g. what type of information would have been beneficial to interpret the results, but that was not available?

Feel free to use the above-mentioned guidelines to prepare a ~ 3 to 5 slide presentation, as a team!

Potential research questions?

- Understand the urban morphology features at the mesoscale meteorological model scale
- Understand the dependence of UHI on LCZs form netatmo measurements
- Evaluate the model skills and weaknesses in reproducing observed temperatures
- Estimate the city-wide impact of various rooftop mitigation strategies
- Estimate the dependence of rooftop mitigation strategies on LCZs
- Identify the effect of various rooftop mitigation strategies on the consumption by air conditioning systems (ACS)
- Estimate the modification induced by rooftop mitigation strategies on land-surface and boundary layer variables (Sensible/Latent heat flux, PBL height…)