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Utilisation des données LCZ de WUDAPT pour la représentation de l'occupation des sols dans les modèles de prévision météorologique WRF

Utilizing WUDAPT LCZ Data for Land Use Representation in Weather Research and Forecasting (WRF) Models

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RÉSUMÉ. En utilisant la méthodologie WUDAPT de niveau 0, cette étude élabore une carte LCZ de Lyon à partir d'images satellitaires et d'outils open source. Le processus comprend la collecte de données d'apprentissage, la classification et la validation des résultats. La carte LCZ met en évidence la diversité des structures urbaines de Lyon, offrant ainsi des informations précieuses pour les études climatiques et la planification urbaine durable. Cette étude souligne l'utilité des ensembles de données LCZ pour relever les défis posés par l'urbanisation et le changement climatique.

ABSTRACT. Local Climate Zones (LCZs) classify urban areas based on their morphology and thermal properties. Using the WUDAPT Level 0 methodology, this study develops an LCZs map for Lyon by leveraging satellite imagery and open-source tools. The process involves collecting training data, performing classification, and validating results. The LCZs map reveals Lyon's diverse urban structures, offering valuable insights for climate studies and sustainable urban planning. This study highlights the utility of LCZs datasets in addressing challenges posed by urbanization and climate change.

MOTS-CLÉS. Zones Climatiques Locales (LCZs), morphologie urbaine, imagerie satellitaire, planification urbaine durable, urbanisation, changement climatique, Lyon.

KEYWORDS. Local Climate Zones (LCZs), urban morphology, satellite imagery, sustainable urban planning, urbanization, climate change, Lyon.

1. Introduction

Land-use data play a crucial role in atmospheric numerical modeling by quantifying the physical properties of various land types. These properties, such as albedo (α), emissivity (ε), surface roughness length (z_0m), soil heat capacity (C), thermal inertia (λ), and soil moisture availability (M), significantly influence land-atmosphere exchanges. These exchanges affect the energy balance, heat fluxes, and moisture dynamics, which are essential for modeling near-surface meteorological variables such as temperature and humidity [1,2].

Accurate land-use representation is vital for ensuring the reliability of numerical models like the Weather research and forecasting (WRF) model. Land-use variability directly impacts predictions of temperature, precipitation, and humidity [3,4]. Existing datasets, such as the USGS global land-use map (30″ spatial resolution, ~1 km) [6] and the CORINE dataset for Europe (100 m resolution) [5], provide a baseline for land-use representation. However, these datasets lack the granularity needed to capture urban heterogeneity, particularly in densely populated areas.

The LCZ framework addresses this limitation by offering detailed classifications of urban and natural areas into distinct categories based on morphology and land cover [10]. This fine-grained approach improves the representation of urban effects on climate variables, such as near-surface air temperature (T2) [9].

The World urban database and access portal tools (WUDAPT) project provides a standardized methodology for generating LCZs maps globally using open-source tools and satellite imagery [14,15]. The workflow involves collecting training data, applying supervised classification algorithms, and validating results with local knowledge. LCZs maps have significantly improved urban climate modeling, particularly when integrated with the WRF Urban Canopy Model (WRF-UCM) [10]. For example, WRF-UCM modifies urban surface parameters, enabling the simulation of diverse urban morphologies and their impacts on T2 [8].

Despite its advantages, the WUDAPT approach faces challenges, including variability in mapping quality due to inconsistent training data and classification errors [18,19,20]. Differentiating between similar LCZ types (e.g., compact high-rise vs. compact mid-rise) remains difficult due to limited building height data. Ground-truth data scarcity also complicates validation. Despite these challenges, WUDAPT has been applied to over 100 cities, showcasing its scalability and utility for urban climate research [14,15].

This study applies the WUDAPT LCZs methodology to develop a detailed map for Lyon, France. By integrating the LCZs map with the WRF model, we aim to assess its quality, spatial resolution, and applicability in capturing urban thermal environments, particularly near-surface air temperature variations.

2. Study Area and Model Configuration

The study focuses on Lyon, France, characterized by diverse urban development, including low-rise residential zones and high-density areas such as compact low-rise and mid-rise LCZs types. Lyon's temperate oceanic climate, with August being the warmest month (26–30°C average temperatures), experiences pronounced urban heat island (UHI) effects due to dense infrastructure and limited green spaces.

To simulate atmospheric conditions during the peak UHI period (17–22 August), the WRF model is employed with three nested domains. The outermost domain (D1, 3.5 km resolution, 150x150 grid) captures regional meteorology, while the second domain (D2, 1.17 km, 130x130 grid) focuses on urban and peri-urban areas. The innermost domain (D3, 0.39 km, 100x100 grid) resolves localized UHI effects and urban-atmosphere interactions, ensuring detailed, multi-scale analysis. This hierarchical domain configuration ensures comprehensive and accurate coverage of meteorological processes across multiple spatial scales, as depicted in **Error! Reference source not found.**.

The initial and boundary conditions for the WRF model are derived from the ERA5 reanalysis dataset, which provides high-quality atmospheric data with a temporal resolution of 1 hour and a spatial resolution of approximately 31 km. ERA5 data accurately represents the large-scale meteorological conditions influencing the study area. The WRF model is coupled with the Building Effect Parameterization (BEP) and Building Energy Model (BEM) to represent urban canopy processes accurately. The BEP accounts for the effects of urban structures on wind flow, turbulence, and energy exchange, while the BEM simulates the thermal properties of buildings.

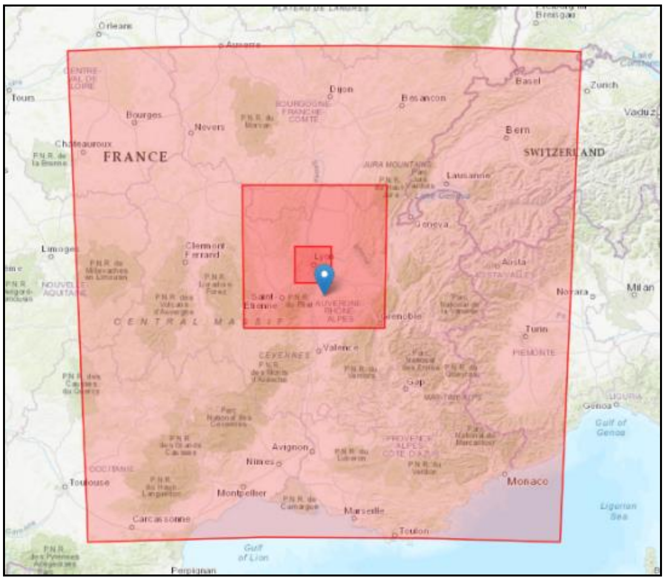

Figure 1. *Study area of Lyon and Domains*

3. Land Use Data

The WUDAPT LCZs dataset, with a spatial resolution of 100 meters, is employed to assess its influence on UHI simulations. Google Earth has been employed to provide initial mapping by collecting training data for various urban and peri-urban zones as shown in **Error! Reference source not found.** . This data is then integrated into the WUDAPT platform, which facilitates the creation of the LCZs map through its standardized community-driven mapping workflow. The high granularity of the resulting LCZs dataset enables precise representation of urban morphology and land-use patterns. By incorporating this dataset into the WRF-UCM model, the study investigates its effectiveness in capturing urban-atmosphere interactions and its influence on UHI effects.

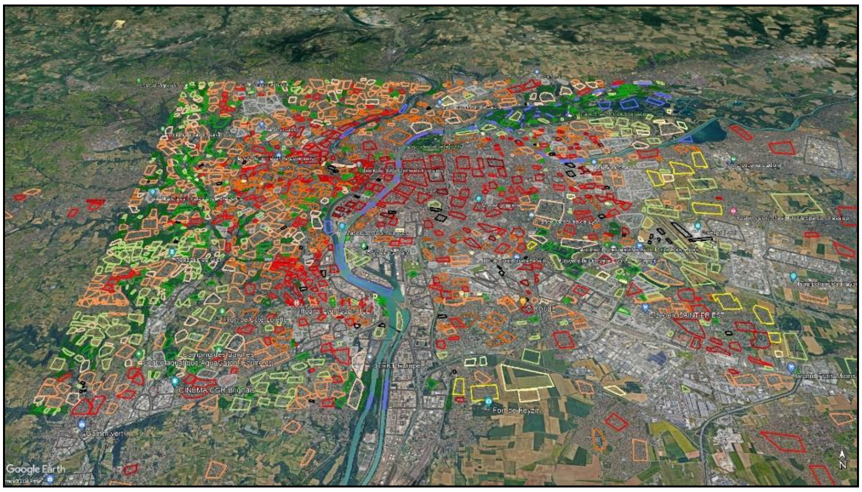

Figure 2. *Training data and LCZs Classification*

4. Results

4.1. *Land Use Classification Analysis of LCZs*

The classification of urban land use and land cover is a crucial factor in understanding the spatial heterogeneity of urban morphology and its implications for climatic processes. The WUDAPT LCZs dataset categorizes urban zones using values from 1 to 10. These categories include compact highrise, open lowrise, and compact midrise. The dataset further categorizes natural surfaces from category A to category G. This high granularity enables precise differentiation of localized urban features, as shown in **Error! Reference source not found.**.

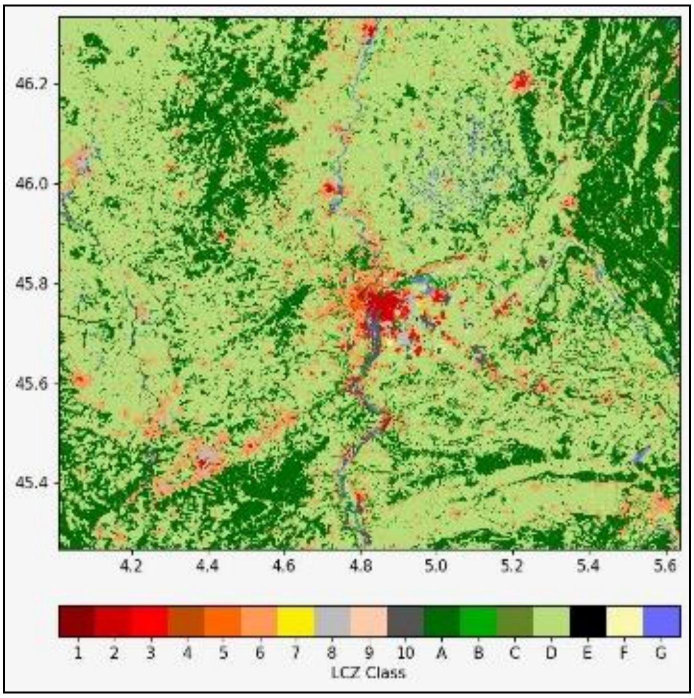

Figure 3. *LCZ Classification Map*

The LCZs dataset demonstrates its ability to capture fine-scale variability in urban morphology. For example, it records 1928 pixels for open lowrise and 308 pixels for compact midrise, reflecting its detailed representation of urban characteristics. Categories such as compact highrise and open highrise are well-represented, further highlighting LCZs superior capacity for resolving diverse urban morphologies.

4.2. *Evaluation of Temperature Simulations*

The statistical evaluation of temperature simulations using the LCZs dataset against observational data at two distinct locations (Bron and LFLL) reveals key insights into its performance and suitability for urban climate modeling. As depicted in Figure 4 and Figure 5, the LCZs dataset demonstrates strong alignment with observational data, with correlation coefficients of R=0.96 for Bron and R=0.94 for LFLL.

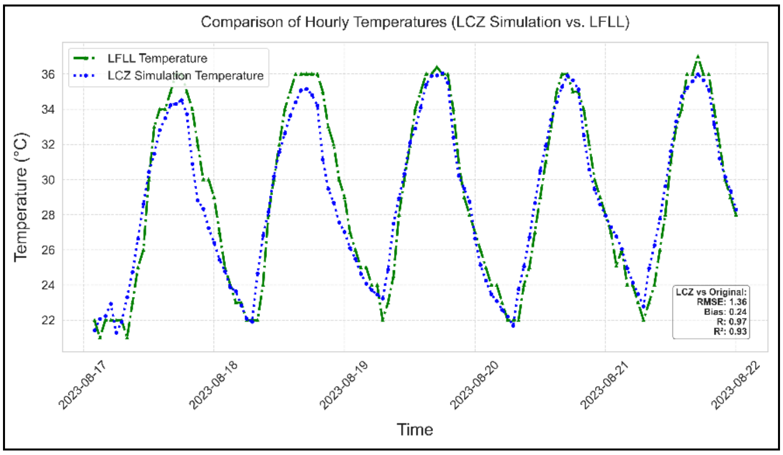

Figure 4. *Comparison of simulated temperature against observational data (LFLL station)*

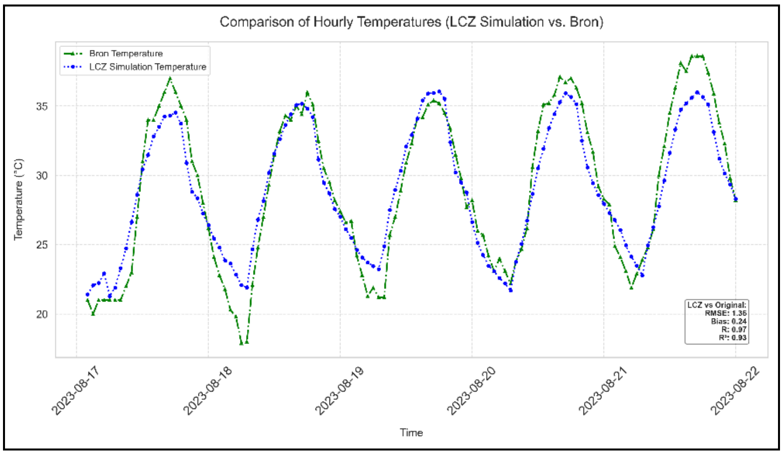

Figure 5. *Comparison of simulated temperature against observational data (Bron station)*

The statistical metrics, summarized in Table 3, underscore LCZs ability to resolve finer-scale temporal dynamics, albeit with slightly higher RMSE values compared to broader datasets.

LOCATION	DATASET	RMSE (°C)	BIAS (°C)	R	R^2
Bron	LCZ	1.80	0.65	0.96	0.90
LFLL	LCZ	1.36	0.24	0.97	0.93

Table 1. *Statistical Evaluation Data*

LCZs strength lies in its capacity to capture detailed diurnal temperature fluctuations and localized thermal variability. This is achieved through its precise classifications, such as compact highrise and lightweight lowrise zones, which are critical for microclimatic assessments. Figure 5 illustrates the temperature patterns for Bron, where LCZs exhibits significant variability in diurnal cycles, reflecting the nuanced impact of urban morphology on thermal dynamics. Similarly, Figure 4 highlights the LFLL location, where LCZs demonstrates its ability to represent complex thermal interactions in diverse urban and peri-urban environments.

Building on the statistical evaluation, the spatial temperature distribution maps further highlight the strengths of the LCZs dataset. As shown in Figure 6, LCZs captures highly localized temperature variations, emphasizing the impact of urban morphology and build materials on thermal profiles. WRF allows to specify build material properties according to land zone types and hence these detailed classifications allow for the identification of specific features, such as "High-Temperature Zones" in densely built areas and "Cooler Urban Fringes" influenced by vegetation. This granularity is essential for microclimatic studies and urban heat mitigation efforts, where understanding fine-scale dynamics is crucial.

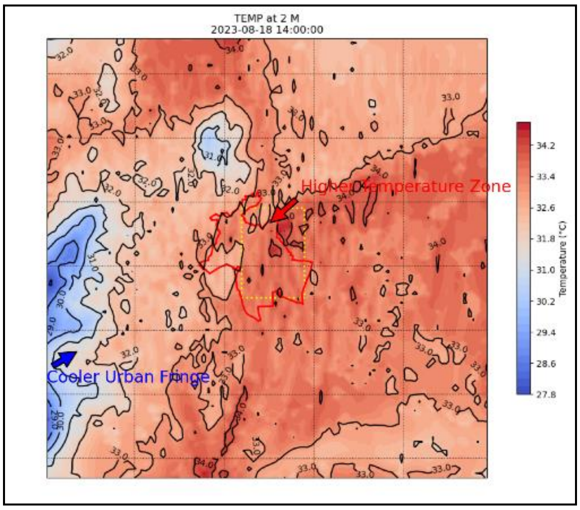

Figure 6. *Lyon Temperature Distribution*

The LCZs datasets high spatial resolution makes it ideal for detailed urban climate modeling and localized interventions. Its ability to capture fine-scale urban morphology and land-use impacts ensures that it is indispensable for studies focused on urban heat islands, microclimate assessments, and targeted mitigation strategies. The inclusion of detailed land-use types provides the necessary granularity for advancing urban climate research and supporting sustainable urban development initiatives.

5. Conclusion

This study demonstrates the effectiveness of the WUDAPT LCZs dataset in urban climate modeling. The dataset's high spatial resolution and detailed classifications enable precise representation of urban heat islands and microclimatic dynamics. Statistical evaluations reveal strong alignment with observational data, underscoring its suitability for urban climate research.

By capturing fine-scale urban morphology, the LCZs dataset supports sustainable urban planning and climate adaptation strategies. Future work should address challenges in training data quality and validation to further enhance LCZs mapping accuracy.

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