Comment on essd-2022-92
Jason Ching (Referee)

Referee comment on "A global map of Local Climate Zones to support earth system modelling and urban scale environmental science" by Matthias Demuzere et al., Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2022-92-RC3, 2022

Preface to this review: A decade ago at the Croucher Advanced Study Institute in Hong Kong, this Reviewer and Gerald Mills (coauthors of this paper) reflected upon a presentation by Iain Stewart (also co-author on Local Climate Zones (LCZ), topic of his PhD research. The LCZ is a universal classification scheme that differentiates urban surfaces into different combinations of building form and function features. Together with associated values of urban canopy parameters (UCPs) the LCZ provided the conceptual framework that inspired the startup of WUDAPT, an urban climate community collaborative project. WUDAPT scope is worldwide, in principle the global LCZ map with its companion UCPs provides model inputs that describe the underlying embedded canopy features of the urban boundary layer for any and all cities in the world. This paper describes efforts leading to the generation of the Global LCZ map, an achievement that culminates an effort a decade in the making and satisfies the major goal and is a key milestone of the WUDAPT. This global LCZ map product support “fit for purpose” applications of environmental models capable of addressing urban induced environmental issues exacerbated by climate changes.

Overview: This paper is a significant contribution; it represents the product at 100-meter resolution designed to provide urban canopy data, making possible a means to generate uniformly consistent urban canopy parameters for all cities in the world as inputs to a wide variety of models such as meteorology (e.g., WRF_Surface energy budgets (e.g., SUEZ), etc. The implication of this result is a capability for making possible fit for purpose (FFP) modeling for assessment at intra-urban scales impacted by climate changes for any and all cities in the world. The LCZ scheme is the cornerstone of this paper; it defines 10 distinct classes each having unique land cover and physical form and function aspects describing the built environment along with 7 other nonurban land cover types. For each of the built classes, there is a corresponding range of values of urban canopy parameters suitable as modeling inputs for urbanized WRF and other environment modeling systems. The research team has been engaged in developing and establishing methods and techniques at the outset of WUDAPT; their creating of an LCZ generator facilitated upscaling LCZ maps based on sets of Training Areas (TA) representing each LCZ class by urban experts for individual cities upscaled to regional/continental scale maps for different regions of the world. Their R&D trajectory has provided the experiential base
and creating approaches and methods that extend TA transferability from individual cities to regional and continental maps. This paper describes in detail the adjustments and modifications to the methodology that generated regional-continental LCZ maps thus enabling the creation of this global LCZ map. This achievement fulfills a major objective of the WUDAPT (www.Wudapt.org) Project.

**Key Points:** The article provides the reader with (i) a concise discourse describing the approach and methods and inputs to generate this product; and (ii) provide suggestions on its utility to supporting modeling and urban scale environmental science. The context of my review will reflect perspectives based on the WUDAPT initiative, a collaborative venture of the urban community. This article is thoughtful, and well organized, I briefly highlight and summarize key points of each section below.

- **The Title is accurate and appropriate.** The focus of this paper in on the development and implementation details of the methodologies that makes possible the resulting global LCZ map. LCZ is an universal urban typology and classification scheme to representing unique properties of form and function variables in the urban canopy layer of cities along with 7 other classes representing non-urban landscapes. The complementary urban canopy parameters values associated with each LCZ class provide a globally consistent framework for data on the form and function of morphological features in urban canopies. This effort extends LCZ maps progressing from original city specific sets to recent mapping of cities and the surrounding non-urban areas within regional domains to global coverage. The impact of this achievement supports urban scale modeling systems and their applications anywhere in the globe, achieving the primary objective of the Level 0 approach of WUDAPT. Implementation procedures to generating the upscaled Global product required appropriate modification and innovations to previous efforts for the regional scale prototypes.

- **The Introduction** provides a perspective on the value and importance of urban science to addressing global climate change issues. The enabling science behind current models is the physics algorithms for the vertical exchange processes of momentum, energy and moisture pollutant emission influenced by the myriad of urban morphological (UM) features. These exchange processes take place in the so-called urban canopy layer which extends from the surface to the top of UM features. Typically, modeling with urban canopy physics requires special sets urban data but heretofore is only available for limited number of cities; thus a large information gap exists which severely limits environmental models as tools intended and needed to addressing climate induced risks issues at urban scales. The introduction of the LCZ framework and its companion range of values of urban canopy parameters (UCPs) is what the Global LCZ map achieved here and generated at 100m resolution makes possible myriad of practical “fit for purpose” environmental modeling applications at a reasonably fine scale addressing climate change issues impacting weather, climate, air quality at both inter and intraurban scales for each and all cities worldwide.

- **Section 2** describes in several subsections, specific details of each of the various methodology and approaches employed to generate this global LCZ map. In general, the approach pertinent to each aspect is described in detail, thoroughly, albeit, many supporting technical details were provided in cited references.
Section 2.1 Training Areas (TAs) This subsection describes the methods to generate this Global LCZ map. It is based on incorporating TAs of LCZs from various sources, mainly from (a) archived community generated TAs representing hundreds of different cities around the world and additionally (b) a special set prepared for another hundred or more other Regions of Interest (ROIs) cities around the world and (c) from TA samples generated by a unique LCZ Generator employed earlier for regional mapping projects (reference cited). The archived TAs required a curation effort to rectify the issue of unevenness in the quality and physical size of TAs submitted into the WUDAPT archives. Their approach adopted in the curation processing is logical, and sound towards assuring uniformity and consistency in quality of the TAs. It clearly builds upon insights and experience gained in prior efforts including the HUMINEX project, implementing such approach contributing to the successful generating of regional to continental scale LCZ maps. The efforts described in this section extends the approach used for the regional maps to assure a uniformity in the quality of this global product.

Section 2.2 describes special treatments to extend the handling of the added and supplementary Earth Observations (EO) needed as inputs for the Global LCZ supervised random forest classifier from the regional mapping stage. Here updates or additions to the original 33 Global Earth Observation were incorporated to the LCZ Generator.

Section 2.3: Classification schemes This section describes what the authors call a Lightweight Global Random Forest model based on various pixel-based mapping methods; however, upscaling such methods to the global product was apparently not straightforward. For this, the default LCZ Generator from earlier studies required significant modifications. This was apparently a huge classification challenge (given >10^6 labelled TA and other inputs); it was facilitated by incorporating this dual sequential pathways approach, another innovative advancement.

The important QA assessment builds upon their recent continental scale LCZ mapping efforts; its procedures are based on (a) five (5) traditional accuracy metrics (Section 2.4.1) and (b) incorporating a novel but indirect thematic benchmarking (Section 2.4.2) involving comparing mapped outcomes of several urban canopy parameters (% built, % impervious surface and sum of built and impervious total plan area, building heights and AH (anthropogenic heating) associated with each LCZ class with other sets of global and open source databases reflecting urban form and functions. The level of comparability provided a relative qualitative assurance measure of the outcomes of UCPs associated with the LCZ maps. Clearly, the success of these relative outcomes varied for the different UCP analyzed (Fig 10). In this regard, future effort associated with other independent means including outcomes of UCPs generated by WUDAPT Level 1 and 2 approaches described in Ching et al, (2019) will be helpful, going forward.

Section 3: Results The Global LCZ map is shown in Fig 4. While the 7 non-urban LCZ classes are not as discriminating in the number of classes as in other mapping schemes, the major value is that all urban areas herein are discriminated into the 10 universally based LCZ scheme, a product consistent for all urban areas in the world, e.g., Figure 5-7, are examples of zoomed LCZ maps for various cities extracted from this Global LCZ maps. It was noted that these sets of cities display and support earlier observations that that each and all cities has its uniquely characteristic LCZ signature (or fingerprint). This is a feature that was apparent and evident in the UCPs generated for the NUDAPT project (Ching et al, 2010), and for LCZ and UCP maps for individual cities studies and from the recent regional LCZ mappings. From such observations, it is probably reasonable to infer that all cities in the world have unique LCZ fingerprints, and by extension, a commensurate unique set of UCPs. This is an important consideration as it provides the rationale and bases of conducting fit-for-purpose intraurban modeling studies based on the Global LCZ map applicable to each and every
city in the world. Support for the contention is expressed in Section 4 indicating how this Global LCZ map can serve earth system modeling and urban scale environmental science, and extend its utility to intraurban scale. However, as noted in the paragraph beginning at line 492, much more need to be done for full effectiveness especially at the intraurban scale in this regard. The UCPs provision in LCZ is currently manifested in lookup tables of ranges of values in the UCPs of each LCZ class. Remedies include path forward innovative cyber-based approaches are currently underway to generate block scale gridded UCPs of both form and function parameters in WUDAPT Level 1 and 2 staged efforts already referred to in the reference list (Ching et al. 2019) to complement the global LCZ mapping efforts.

- **Section 4**: this Section, the article highlights and discuss the attributes and impact of the Global LCZ product. Herein, the significance in terms of objectives, and potential impacts and caveats of this study are explored. Since this global map has just been completed, the discussion refers to the Global LCZ maps support to wide range of potential modeling applications, some already underway, in concert with the WUDAPT perspectives.

- **Conclusion section**: The results of this Global LCZ map is an important and significant achievement culminating from the collaborative efforts of many activities and voluntary contributions from the urban climate and multidisciplinary science communities evolving and improving after over nearly a decade of efforts. The advances and contribution by this team has been impressive moving the LCZ framework from prototypic city specific mapping to the creation of regional maps and culminating in this impressive global product. Given the widespread and rapidly growing literature on LCZs we can anticipate much interest in this product. For a whole host of reasons, including projections of climate change impacts to enhancing weather extremes, to urbanization dynamics from increased population, the LCZ paradigm, and the various levels of coverage, and certainly, with this Global product provides an important and significant approach towards supporting science-based tools for myriad and wide ranges of modeling application and studies supporting local to international policies that addresses climate change issues.

- **Data availability**: In the last section, this map is available via link provided. While it was not mentioned, I would recommend the authors consider making the map and accessibility to the pixel generated LCZ in the WUDAPT Portal

**Suggestions on specific points** The following are a list of relatively minor issues and concern indicated below.

- Line 120-121. This sentence bears a burden of explanation; It will be necessary to provide objective measures and criteria to establish the objective quality indicators of the RUB produced TA vs other ARC sets.
- Line 123, page 6. Revise, eliminate term “old” in old WUDAPT Portal. This eliminates the need to explain or differentiate the progression of Portal versions.
- Line 131, “Third” used here is really “Fourth” as “Third is already used in line 129
- Line 189: To better understand and appreciate the value of the Lightweight global random forest model, herein, as regards the probability layer, please discuss the takeaway points of the meaning of a high vs low probability.
- Line 246 Functional Urban Area (FUA) are indicated by a reference (Schiavina et al. 2019); given the important role of FUAs in discussions in the remaining text it would be highly useful to introduce the key aspects of this FUA framework as in the Section 2.3 and 3.2.
- Line 433 pg 24. Clarification of introducing the Term “scaling laws”
Summary: The effort described in this article to creating this Global LCZ map is impressive. This product represents an achievement, culminating a decade of activity and efforts by the urban community through WUDAPT towards acquiring urban canopy layer data for models that provide a means for addressing climate change and urbanization issues for local to regional to global scales. Its paradigm incorporates the LCZ typology thus providing a unified and consistent basis for generating intraurban form and function type data paradigm (WUDAPT Level 0) for the urban canopy layer. This Global LCZ map supports the observation from earlier city specific studies and regional maps, that each city LCZ map signature (e.g. fingerprint) is unique. This “feature” provides a rationale for supporting a wide range of earth systems modeling, applications, and urban scale environmental science, e.g., urban modeling applications in which intraurban scale weather forecasting and assessments can be made based on implementing urban boundary layer parameterizations in models with universally consistent intraurban urban canopy descriptions unique to each and every urban area in the world. The rationale, requisite technical issues to the innovative approach toward generating this global map, the approach and results were well articulated and fully documented. The point to future work advancements some alluded to in the caveats provided of the current LCZ paradigm for balance. In particular, its incorporation into WRF for example through an improved WUDAPT to WRF link is underway as well as efforts along the lines of WUDAPT level 1 and 2 (Ching et al. (2019) will be to provide a pathway towards introducing refined city specific block scale gridded UCPs in future updates.