TJ15.4: WUDAPT (WORLD URBAN DATABASE AND ACCESS PORTAL TOOLS): AN INTERNATIONAL COLLABORATIVE PROJECT FOR CLIMATE RELEVANT PHYSICAL GEOGRAPHY DATA FOR THE WORLD'S CITIES

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1. INTRODUCTION

Given rapid population growth and urbanization, it might be apt to characterize this and the last few centuries as the Urban Epoch of the Anthropocene, Earth's most recent and human influenced geologic time period (Crutzen and Stoermer, 2000). Human activities in this urban epoch have enormous influence and consequence on current and future climate. Urbanization is unavoidable and without proper management can lead to disastrous, extreme, and unexpected events. We now design powerful computer models for use as tools applicable on a global scale for guidance on climate change. More than half of the planet's population resides in urban areas and the degree of urbanization is projected to increase rapidly; thus it is important that modeling tools be available and suitable for urban applications to develop rational urbanization approaches and guidance to mitigate deleterious effects of urbanization and supporting design for urban resiliency.

The form and function of structures in urban area creates its own unique climate, which influences and impacts the quality of life, and associated environmental impacts and risks to its inhabitants. Cities and their climate will further evolve to accommodate global and regional climate changes, further population increases and availability of resources. Computer models have the potential to be applied to simulate weather, climate and air and water quality for any and all urban areas around the globe, they are strategically important tools available to the global modeling communities; moreover, they continue to evolve soas with the expectation to provide enhanced capabilities, results and guidance at increasingly finer grid resolutions. A review of several widely available community based state of science modeling systems and their requirements such as WRF, CLMU and CMAQ and the initial concepts and data collection methodologies for the WUDAPT (World Urban Database and Access Portal Tools) Project was described in Ching (2013), Ching et al., 2014, Mills et al, 2015, Bechtel et al. 2015, and See et al, 2015. The WUDAPT design concept is to acquire and make accessible coherent and consistent descriptions and information on aspect of urban morphological structures, aspects of their forms and functions relevant to climate studies on worldwide bases and to build portal (tools) that will extract relevant urban parameters and properties for models and for model applications at appropriate scales for various climate, weather, urban planning purposes. Much progress on WUDAPT has been made; we now briefly review the concepts, operational methodologies, and some initial results and near term plans. Further, a website has been created to serve its growing community of collaborators and other interested parties (www.wudapt.org).

2. WUDAPT OVERVIEW

2.1 *Generating the Database*

State-of-science community-based grid models can provide important tools to inform, provide improved understanding and guidance on current and future evolutions of the urban habitat in this Urban Epoch. What are required are the model inputs to apply these models successfully.

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For this purpose, we review several important features that should constitute such inputs. First, the spatial complexity of the underlying surfaces must resolve the temporal and the multi-scale spatial characteristics of the urban boundary and canopy layers (Fig 1).

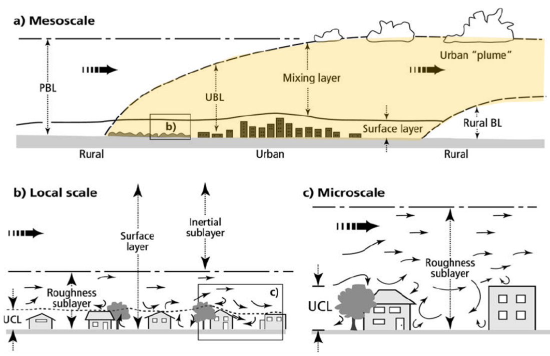

Fig 1. Schematic of the urban boundary layer depicting the multiscale aspects of urban areas. (Source: Oke, 2004).

Second, the grid resolution must be commensurate with the desired outcome (e.g., "fit for purpose"); spatial gradients of both the inputs and thus the output fields tend to be highly complex in urban areas. So, for any grid resolution, the unresolved subgrid information content can be quite large and should somehow be captured. Third, for worldwide applicability, the data should be collected, generated and their outcomes exhibiting internal consistency and reliability to the greatest extent possible. Fourth, the generation of this database should be as practicable and availability achievable on a reasonably short time frame for greatest impact. Fifth, data requirements for urban models can be highly specialized. Commensurate with current urban models, models are cast in terms of the underlying urban morphology in each grid. Given the existence of urban building-street canyons and the interspersed vegetation, the fundamental equations for flow, thermodynamics and radiation are required, and moisture has now been recast with treatment for the influences of these morphological features using urban canopy parameters or UCPs (Martilli et al., 2002,DuPont et al., 2004; Otte et al., 2004), Jackson et al., 2010 (see Table 1).

WUDAPT has adopted a pragmatic three-stage approach, each generate the requisite urban data characterized by different levels of precision and specificity, each collected with distinct methodologies and techniques (Fig. 2).

Urban Canopy parameters (UCPs)		
General	**Buildings**	**Vegetation**
Mean canopy height	Mean Height	Vegetation plan area density*
Canopy plan area density*	Std Dev of heights	Vegetation top area density*
Canopy top area density*	Height histogram	Vegetation frontal area density*
Canopy frontal area density*	Wall-to Plan area ratio	
Roughness Length	Height to width ratio	Mean Orientation of Streets
Displacement height	Plan area density*	Plan area fraction surface covers
Sky View Factor	Rooftop area density*	% connected impervious areas
	Frontal area density*	Building material fraction

Table 1. Examples of urban canopy parameters used in models such as The Building Energy Parameterization scheme (Martilli et al., 2002).

Level "0" provides a timely and comprehensive coverage to data acquisition, this methodology invokes free, readily available Landsat data, along with google-earth imagery, machine learning and the knowledge of local urban experts to generate the form and function data of constituent neighborhood types using a typology based on Local Climate Zones scheme (Stewart and Oke, 2012). The methodology is described in Bechtel and Daneke (2012) and Bechtel et al. (2015).

Fig 2. WUDAPT data acquisition strategic approach

This approach makes it possible to acquire worldwide urban coverage on a practical cost effective and timely manner thus supplanting the NUDAPT approach (Ching et al., 2009). This is achieved by using lookup tables that provide ranges of UCP values for models based on each LCZ class. Examples of subset of these inputs are shown Table 2.

LCZ	λ_I	λ_b	λ_V	z (m)
1. Compact high-rise	40–60	40–60	<10	>25
2. Compact midrise	40–70	30–50	<20	10–25
3. Compact low-rise	40–70	20–50	<30	3–10
4. Open high-rise	20–40	30–40	30–40	>25
5. Open midrise	20–40	30–50	20–40	10–25
6. Open low-rise	20–40	20–50	30–60	3–10
7. Lightweight low-rise	60–90	<20	<30	2–4
8. Large low-rise	30–50	40–50	<20	3–10
9. Sparsely built	10–20	<20	60–80	3–10
10. Heavy industry	20–30	20–40	40–50	5–15
101. Dense trees	<10	<10	>90	3–30
102. Scattered trees	<10	<10	>90	3–15
103. Bush, scrub	<10	<10	>90	<2
104. Low plants	<10	<10	>90	<1
105. Bare rock or paved	<10	>90	<10	<0.25
106. Bare soil or sand	<10	<10	>90	<0.25
107. Water	<10	<10	>90	–

Table 2. Some urban canopy values associated with Local Climate Zone (LCZ) types. Columns represent the percentage of impervious (λ_I), built (λ_b) and vegetated (λ_V) land-cover and mean height of building elements (Stewart and Oke, 2012).

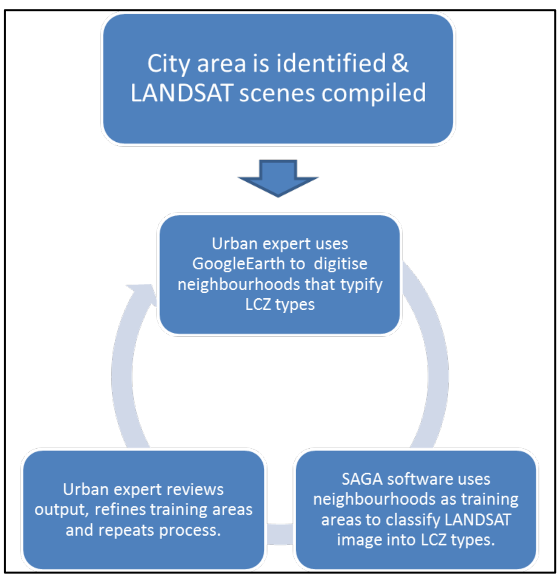

Fig 3. Schematic of WUDAPT Level"0" workflow

Fig. 3 illustrates Level "0" methodology from the perspective of an urban expert. Landsat imagery, (available since 1970) is downloaded for each of the urban areas to be studied. Using Google Earth type imagery, the urban "expert identifies representative areas of the city as exemplars of LCZ classes. These exemplar areas are treated as training areas using SAGA (Conrad et al. 2015), a freely available software that classifies the Landsat images into LCZ types. These maps are reviewed and the process is iteratively repeated to improve areas that are not accurately represented. When satisfied, the final maps are submitted to the database. Fig 4 illustrates examples of LCZs that enables the database generator to define the exemplars.

Fig 4. Examples illustrating how exemplar LCZ types are identified from imagery.

Levels 1 and 2 capture information at increasingly finer resolutions, details and precision, and using top-down geo-wiki techniques and augmented using crowdsourcing techniques, smart phone technology, Geowiki APPS and invoking crowdsourcing and citizen science means (See et al., 2015). The methodology for WUDAPT level 1 and 2 is under development. Its objective is to satisfy grid model applications that requires customized and thus specific values for each and all model parameters, material composition and building, transportation and industrial energy usage information for each grid in the modeling domain. One option currently being pursued is based on recognizing and collecting information based on establishing representative building typologies for each city and facilitated using crowdsourcing apps (See et al., 2015, Masson et al., 2015).

2.2 WUDAPT *infrastructure*

The scope of WUDAPT includes an infrastructure with Portal tools to make the database accessible for urban applications (Fig 5).

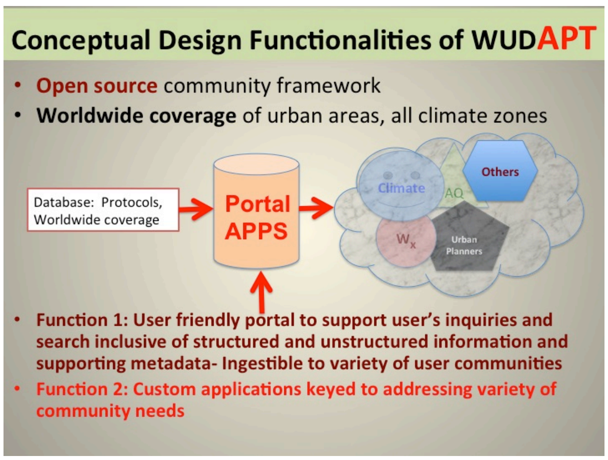

Fig 5. Schematic of WUDAPT portal concept.

The WUDAPT portal will serve two basic functionalities:

a) To facilitate data collection at level 1 and 2 with APPS for implementing crowdsourcing approaches (See et al., 2015) and provide effective access to the database and
b) To facilitate actionable utilization of this data. Currently, WUDAPT's data servicing portal, "Geopedia" provide the means to ingest and make WUDAPT Level "0" information accessible.

To facilitate basic applications such as the processing of data in terms of gridding, scaling and establishing model inputs to various modelling systems. WUDAPT will be incorporating the MRA tool (Neophytou et al., 2015) to facilitate handling multi-scale grid requirements, further empowering the processing of Levels "0," "1" and "2" data into specific model accepted formats. An example of an application portal is a development by Brousse et al. (2016) where WUDAPT Level "0" data was used in proof of concept demonstration mode to run the BEP and BEP-BEM urban physics option of WRF for Madrid (Fig. 7).

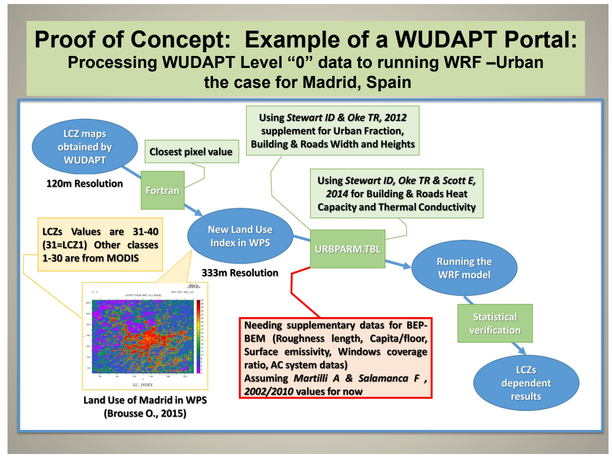

Fig. 6. Schematic of prototype portal to illustrate processing WUDAPT level "0" for running WRF urban options.

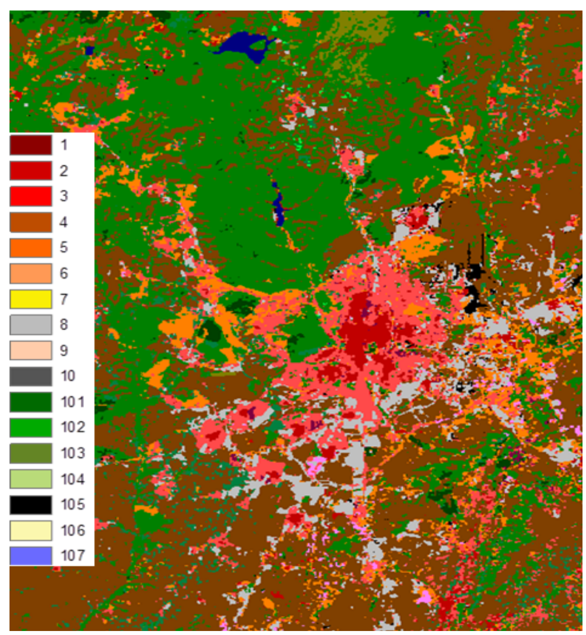

Fig 7. The LCZ map for Madrid using the WUDAPT level 0 methodology. The legend values refer to the LCZ types listed in Table 2. These were used to guide the UCP selection process.

3. RESULTS AND DISCUSSION

Fig. 8 shows an LCZ map of Milan alongside the existing urban footprint data from MODIS in 500 m resolution, which underlines the added value of the LCZ-based approach. The LCZ maps reveal considerably more detail about the urban structure, morphology and even functional organization and settlement development. LCZ map for a few selected cities, are shown in Fig 9. These samples illustrate that each city has distinct and unique LCZ signature palate, and rich diversity and complex distributions of urban structures. From a modeler's perspective, it would follow that the corresponding form (morphological) and composition and function model parameters will produce a unique climate and meteorological response for each city.

Table 2 shows the diversity of Level "0" derived LCZs for selected set of cities around the world. Note that some LCZ classes are not present in some cities. Interestingly, cities in China exhibit high percentages of LCZ 1, indicating the rapid urbanization occurring there and the tendency for tall building construction.

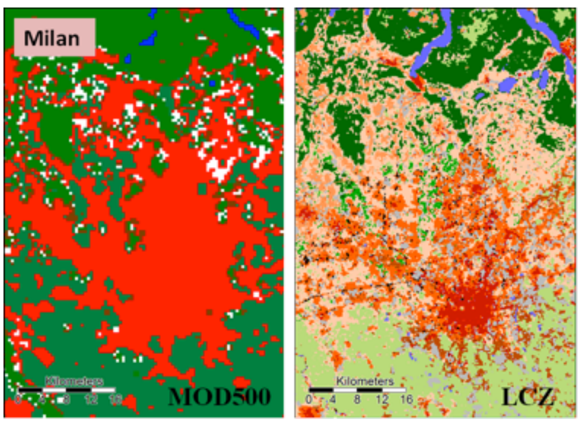

Fig 8. Comparison of LCZ map with existing urban footprint data from MODIS. The Milan map uses the same legend as Fig. 6.

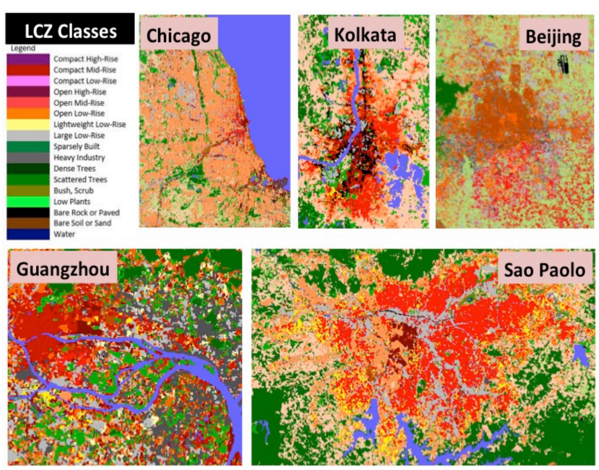

Fig 9. Level "0" maps of LCZs generated at WUDAPT workshop in Dublin 2014.

Table 3 shows preliminary results of plan fraction of vegetation, building and impervious surfaces based on a preliminary version of Level 1 methodology using a customized Geowiki (See et al., 2005). The mean values of the level "1" outcome for most LCZ classes appear to fall within or close to the range of values from Stewart and Oke, which is quite encouraging.

4. SUMMARY AND THE PATH FORWARD:

Preparatory efforts (Prototype) are now underway to test the full detailed development and deploying of the steps cartooned in Fig 6 for a set of city Prototypes representing a variety of cities around the world.

First, it is imperative that the methodology adopted to produce these "census of cities LCZ maps, the so-called Level "0" set, that the quality of the product be established. Efforts are now underway to evaluate and verify the Level "0" methodology to assure the quality of the final LCZ maps and results. At a minimum, derived maps should be reproducible by independent evaluators soas to achieve a high level of self-consistency.

LCZ	Bei	Chi	Mad	Mil	Sao	Van
Compact high-rise	18.2	7.4	0.0	0.0	9.0	3.6
Compact mid-rise	5.7	2.4	28.6	20.2	1.2	0.8
Compact low-rise	2.8	3.9	1.6	0.2	11.3	9.5
Open high-rise	17.9	6.0	3.3	5.6	6.0	10.4
Open mid-rise	14.4	3.5	24.0	18.8	4.3	5.9
Open low-rise	12.4	30.9	13.6	13.2	25.3	22.2
Lightweight low-rise	6.0	0.0	0.0	0.0	4.3	0.0
Large low-rise	14.9	13.0	24.5	19.9	18.8	14.8
Sparsely built	4.1	19.7	4.3	22.1	16.7	32.8
Heavy industry	3.8	13.3	0.0	0.0	3.1	0.0
Total area	3406	3479	5908	1630	4141	1408

Table 2. Percentage distribution by LCZ classes for selected cities based on the on Level "0" methodology ((Bei – Beijing, Chin; Chi – Chicago, US; Mad – Madrid, Spain; Sao – Sao Paolo, Brazil and; Van – Vancouver, Canada. The Total Area is expressed in terms of satellite cell number (each cell is 120m on a side).

LCZ	Level 1data experiment			Stewart & Oke 2012		
	λ_V	λ_b	λ_I	λ_V	λ_b	λ_I
Compact high-rise	10.5	42.4	47.1	<10	40-60	40-60
Compact mid-rise	11.3	43.9	43.7	<20	40-70	30-50
Compact low-rise	17.6	36	45.1	<30	40-70	20-50
Open high-rise	25.9	24.3	48.9	30-40	20-40	30-40
Open mid-rise	39.1	19.8	36.8	20-40	20-40	30-50
Open low-rise	39.4	22.2	38.1	30-60	20-40	20-50
Sparsely built	62.3	11.5	24.9	60-80	10-20	<20

Table 3. Preliminary results comparing mean Level 1 Geowiki derived values of several UCP parameters vs Level "0" values using lookup tables from Stewart and Oke (2012).

Second, given the diversity and uniqueness of the ((LCZ distribution for any given urban area, we confidently anticipate unique city-specific intra-urban spatial variability in UCP parameters. However, the current state of the art only provides parameter value ranges associated with each LCZ type. An additional source or mechanism (e.g., expert intervention and/or crowd-sourced Geowiki [See et al. 2015]) must be used to obtain explicit UCP values. Two optional approaches are being considered to satisfy this objective: (1) Guidance using as baseline, data for urban areas for which there exists gridded model parameters to inform the Level"0" LCZ maps, and (2) rebuild the Level "0" incorporating building typologies into Geowiki Apps in smartphones and developing strategies employing crowdsourcing to generate the detailed spatial data of form and function data. This may follow protocols along the lines of now being pursued in the MapUCE project (Masson et al., 2015). We see pursuing activities along these lines as a strategy to generate the Level 1 and 2 products. Momentum is building, judged by the interest and level of participation of the international community. There are a number of significant international collaborations that have already begun towards achieving the objectives of Levels 0, 1 and 2.

Third, future priorities include (a) enhancing the current portal to serve as an efficient and effective means to aid dissemination of the database, (b) streamlining the prototype methodology for using WUDAPT to running of WRF, (c) developing apps to explore strategies for adaptation strategies in light of extreme climate-induced hazards such as heat stresses (Hanna et al., 2015).

WUDAPT is a grass roots effort; community involvement is key to assuring success. Please engage in and/or following the progress on www.wudapt.org

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