An Introduction to the WUDAPT project


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1. Introduction

Most of humanity now lives in cities of varying sizes and although they are human constructs, we know remarkably little about urban areas globally; how they are built and how they function. Much of the information that does exist is for administrative areas that rarely coincide with the built-up area. Where spatial data is available, it tends to focus on identifying the urban footprint, that is, where the city ends and begins (e.g. Schneider et al., 2009). While these data have proved useful for some climate studies, such as estimates of settlement exposure to projected sea-level rise (McGranahan, 2009), they lack the detail needed for a range of needed climate studies at global, regional and urban scales. In many cities and even

In global climate change (GCC) science, cities represent a critical scale owing to both the concentration of energy use and greenhouse gas emissions and their exposure to the projected effects of GCC. In addition they often have planning mechanisms to mitigate and to adapt. However, the lack of data is impediment to progress that has been recognized in the urban chapters of the 5th Assessment Report of the IPCC which identified significant 'gaps' in research that included for example, *serious limitations on geophysical, biological and socio-economic data needed for adaptation at all geographic scales, including data on nature-society links and local (fine-scale) contexts and hazards* (Revi et al, 2014). At regional and urban scales, urban climate (UC) science has made significant progress in the last couple of decades that is evident in the improved abilities of models to capture urban processes and in our capacity to observe in complex urban settings. Our understanding of the link between landscape change and climate impacts is based on work completed in relatively few cities; extending the value of this research to other places requires suitable urban data. This need is especially great in the rapidly urbanizing poorer parts of the world where the resources are scarce and the consequences of poor urban development will be longstanding.

The World Urban Database and Portal Tool (WUDAPT) has been conceived as an international collaborative project for the acquisition, storage and dissemination of climate relevant data on the physical geographies of cities worldwide. The project has three distinct parts:

1. The acquisition of basic data on cities that has been gathered in a consistent manner (Bechtel et al, 2015; See et al., 2015)
2. The storage of these data in a format that is readily accessible (Ching et al., 2015)
3. The extraction of data suited to running models or deriving parameters (Feddema et al, 2015)

The fundamental data that is acquired represents information on the form and functions of cities. The form includes the surface cover, the construction materials and urban geometry. The functions are those activities that drive the consumption of energy, water and materials and drive the emission of waste heat, gases, particulates and water.

The template for this approach is based on the National Urban Database and Portal Tool (NUDAPT) that was created specifically for the purpose of supporting models (such as the Weather Research Forecasting model) that need spatially detailed 3D information on cities (Ching et al., 2009). In addition to available city-based information, Lidar technology was employed to get precise information on urban topography. The NUDAPT database stores the 'raw' data (e.g. building height) but critically also allows users to extract derived parameters (such as roughness length) at a scale that is commensurate with model grid resolution. WUDAPT cannot replicate this process for cities globally. Instead it takes a pragmatic approach to the acquisition of urban data using a variety of techniques including satellite imagery data coupled with the knowledge of local urban experts. The data that is gathered will be stored in a geographically referenced database and can be downloaded to support a variety of urban studies.

WUDAPT is still being developed; in this paper we will show progress to date. Other papers at ICUC9 outline

2. WUDAPT

The data that is relevant for climate research reports on aspects of urban form and function (UFF). Urban form describes three aspects of cities: surface cover (e.g. impervious area); properties of construction materials and; surface geometry (e.g. building dimensions and layout). Urban form describes the energy demands of the city, which may be represented by the anthropogenic heat flux. To capture these data at a useful spatial scale, WUDAPT categorizes data gathering into different levels, each of which represents a level of detail and a distinct methodology (Figure 1):

- Level 0 data describes a city in terms of its constituent neighbourhood types using the Local Climate Zone (LCZ) scheme (Stewart and Oke, 2012). The LCZ types represent a culturally neutral description of urban landscapes based on their effect on the local air temperature. However, they are also associated with ranges of values for some UFF variables that may be used to run some types of urban climate models.
- Level 1 data refines the parameters for each LCZ through sampling. These data will capture information on UFF at a finer spatial resolution and in greater detail. In particular it will provide information on the three-dimensional urban form.
- Level 2 data refines the data still further by integrating available data sources that can provide precise parameter values at a fine spatial resolution suited for boundary-layer (and canopy-layer) modelling.

The protocol for gathering Level 0 data has been established and is discussed in the next section. The methodology for gathering data at Levels 1 & 2 is being established currently (See et al, 2015), but it is intended to employ the Level 0 data as a sampling framework for subsequent data gathering. What distinguishes WUDAPT is: its use of a consistent methodology for acquiring urban data; its reliance on freely available data and software for processing the data and; the involvement of a network of urban experts.

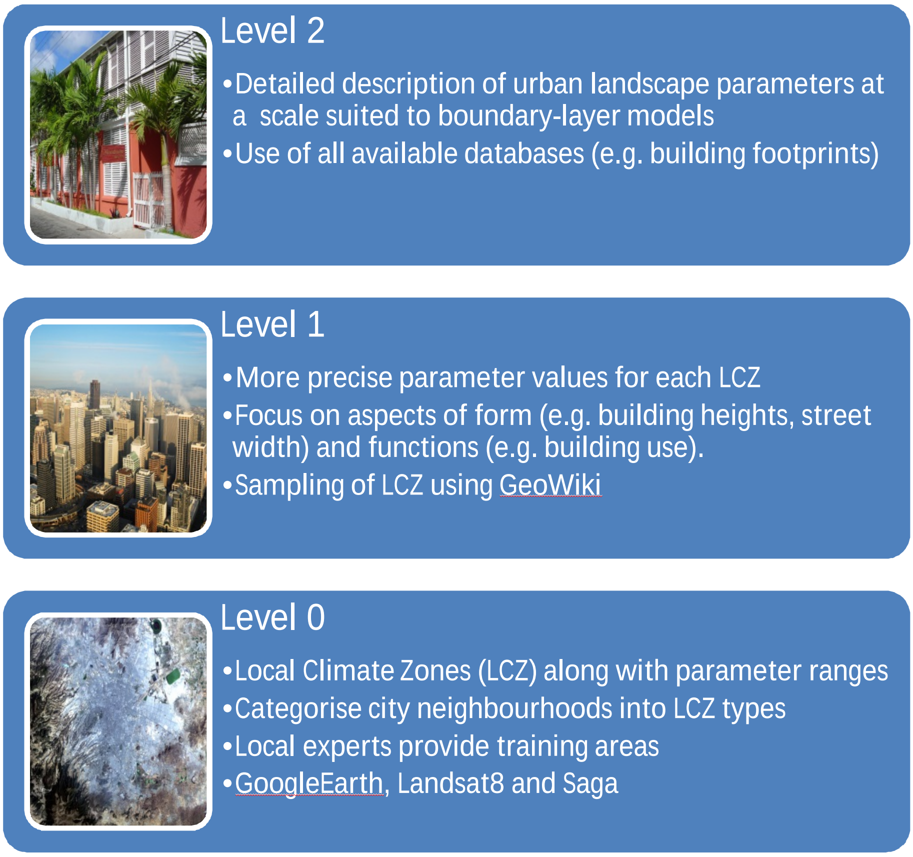

Fig. 1.WUDAPT's data hierarchy

3. WUDAPT Progress

3.1 Level 0 urban data

The protocol for gathering Level 0 data is as follows (Bechtel et al., 2015); for each city:

1. An individual who knows the city (the expert) defines a domain that encloses the urban area and identifies parts of the natural and urban landscape that typify LCZ types. These training areas are created as polygons using GoogleEarth, which are then imported into SAGA software.
2. Landsat 8 scenes (http://landsat.usgs.gov/landsat8.php) for the urban domain are extracted and imported into SAGA software, which has GIS and remote sensing capabilities. These images have nine spectral bands at 30 m resolution that can be used to distinguish between surface covers. Ideally, the urban domain falls entirely within several cloud-free scenes so that the analysis can draw upon maximum information.
3. The LCZ training areas are used to classify the entire urban domain into neighbourhood types using the random forest classification scheme. The expert examines the map and adds to (or modifies) the LCZ training areas to account for misclassifications and repeats the process until satisfied. The accuracy of the final product is evaluated by comparing the predicted and observed LCZ type for selected areas.

Figure 2 shows the results for Beijing, one of 16 cities completed during the Dublin workshop. Even as Level 0 coverage, the ranges of urban canopy parameter (UCP) values associated with LCZ types will provide some initial guidance for modeling work. Importantly these LCZ maps will provide a spatial sampling frame for further urban work, including designing urban observation projects and gathering more detailed (Level One and Level Two) urban data on building heights, energy use, etc. efficiently.

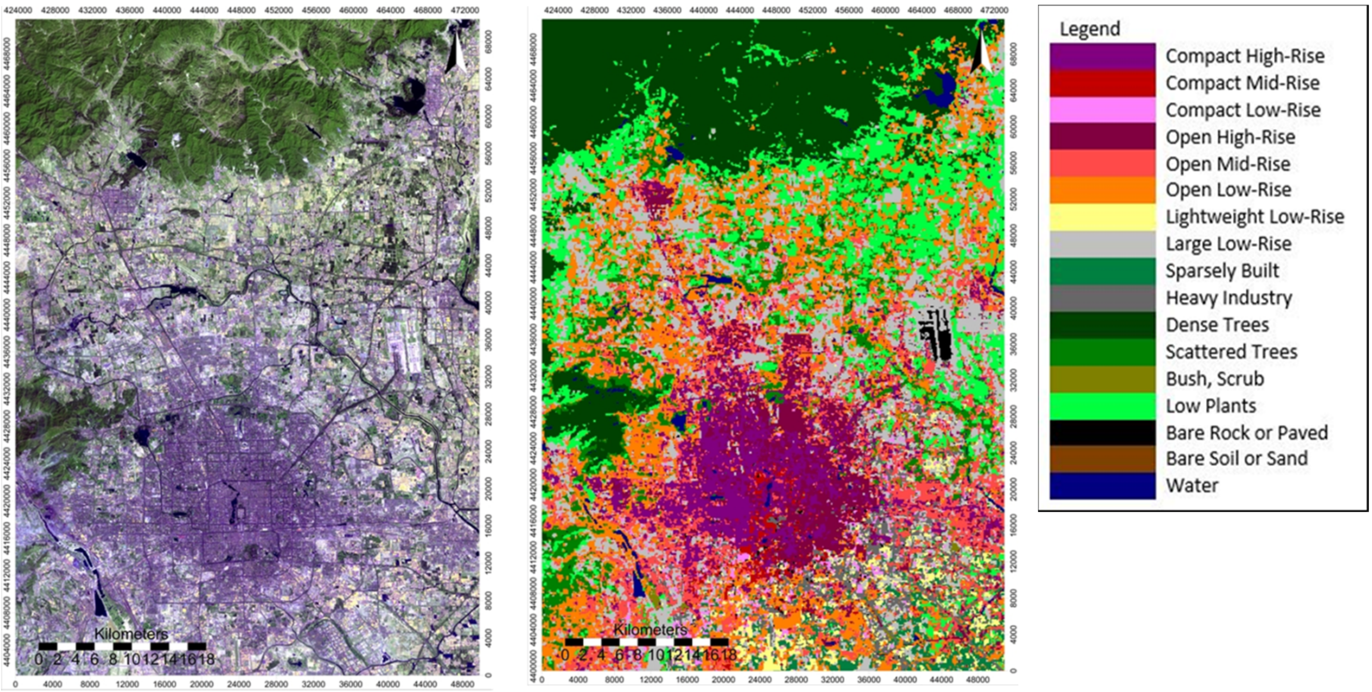

Fig 2. The Landsat 8 image (left) and LCZ map and legend for Beijing, China. Completed by Weibu Liu and Micháel Foley.

Table 1 shows the estimated LCZ coverage for 11 cities; the final rows provide a measure of accuracy (Kappa value) and the total urban area (the number of cells in LCZ 1-10). Kappa values over 0.60 indicate substantial agreement between the predicted and actual LCZ class. These statistics are preliminary but they do show large differences in how cities are constructed. Note for example, the differences between cities in terms of the compact and sparely built categories.

3.2 Level 1 & Level 2 urban data

Level 0 data provides a basic description of the urban area in terms of Local Climate Zones. Each of these zones is linked to a range of parameters. The full list of parameters is to be found in Table 3 of Stewart and Oke (2012) and include the plan fractions occupied by buildings (λ_b), impervious (λ_I) and vegetative (λ_V) cover, sky view factor, building height and anthropogenic heat flux. However, the ranges of values associated with each parameter are quite large (see Table 2) and lack the precision that may be needed for much modelling work. To evaluate the potential for gathering more detailed spatial information an experiment was carried out for the Dublin urban area using a Geo-Wiki (See et al., 2015) that samples the landscape.

LCZ	Bei	Chi	Col	Dub	Kol	Kua	Mad	Med	Mil	Sao	Van
Compact high-rise	18.2	7.4	1.5	2.3	4.5	8.2	0.0	1.3	0.0	9.0	3.6
Compact mid-rise	5.7	2.4	28.7	8.5	14.1	2.2	28.6	1.7	20.2	1.2	0.8
Compact low-rise	2.8	3.9	13.3	3.6	14.6	18.6	1.6	5.3	0.2	11.3	9.5
Open high-rise	17.9	6.0	6.2	0.1	7.9	15.7	3.3	9.2	5.6	6.0	10.4
Open mid-rise	14.4	3.5	9.8	5.3	7.6	10.0	24.0	6.4	18.8	4.3	5.9
Open low-rise	12.4	30.9	28.1	31.5	12.4	14.4	13.6	1.8	13.2	25.3	22.2
Lightweight low-rise	6.0	0.0	0.9	0.0	0.6	0.6	0.0	1.1	0.0	4.3	0.0
Large low-rise	14.9	13.0	11.5	44.7	9.2	10.6	24.5	11.1	19.9	18.8	14.8
Sparsely built	4.1	19.7	0.0	0.0	29.1	13.7	4.3	62.3	22.1	16.7	32.8
Heavy industry	3.8	13.3	0.0	4.0	0.0	6.0	0.0	0.0	0.0	3.1	0.0
Kappa	0.90	0.91	0.64	0.82	0.62	0.73	0.98	0.79	0.84	0.82	0.89
Total area	3406	3479	338	2396	622	1406	5908	1917	1630	4141	1408

Table 1. A preliminary comparison of the LCZ make-up of 12 cities (Bei – Beijing, Chin; Chi – Chicago, US; Col – Colombo, Sri Lanka; Dub – Dublin, Ireland; Kol – Kolkata, India; Kua – Kuala Lumpur, Malaysia; Mad – Madrid, Spain; Sao – Sao Paolo, Brazil and; Van – Vancouver, Canada. The kappa value is a measure of accuracy and Total Area is expressed in terms of satellite cell number (each cell is 120m on a side).

The Geo-Wiki used in this experiment provided a top-down view of the city suitable for classifying the urban landscape into different categories of building, vegetated (tree, grass, etc), impervious (road, other), water and barren. A systematic sampling scheme was used over the urbanized area using an interval of 30m. Altogether, approximately 300,000 sampling points were categorized. Figure 3 shows the distribution of impervious surface cover based on aggregating the sampled information to a cell size of 250 m.

Fig 3.Impervious surface cover across Dublin for 250m cells

The sampled data was also aggregated by LCZ type for Dublin and the results are presented in Table 2 alongside the equivalent value ranges from Stewart and Oke (2012). In general you will see that there is considerable agreement in that the observed values fall within the LCZ ranges; the advantage of the more detailed sampling is that the parameter values are much more precise. In future work, the variation within LCZ categories will be examined and the value of using the LCZ map as a sampling framework for urban data gathering will be explored.

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 2. The plan fraction (%) of vegetation (λ_V), buildings (λ_b) and impervious (λ_I) surface for the Dublin urban area based on the Geowiki and the ranges from Stewart and Oke (2012).

4. Conclusions

WUDAPT will capture a synoptic picture of cities around the world and improve communication among urban climate researchers by using a common lexicon to describe the urban landscape (Oke, 2006). It has the capacity to greatly improve our science by providing comparative data that can be used for climate modelling, adaptation and mitigation studies and knowledge transfer. It also provides an opportunity for establishing a global network of researchers with interests in the urban environment and could provide a basis for international research, training and education projects.

We have made significant progress so far in establishing the methodology for acquiring useful urban data in a consistent manner and the project is sufficiently well developed that we can start the process of building a global urban database of cities. To do this we need the engagement of the urban climate community, which has a geographically dispersed and knowledgeable membership that can be brought to bear of the subject matter by organizing, gathering and evaluating WUDAPT's evolving database. We issue an open invitation to the IAUC community to participate.

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