Urban local climate zone mapping and apply in urban environment study

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Abstract. The city's local climate zone (LCZ) was considered to be a powerful tool for urban climate mapping. But for cities in different countries and regions, the LCZ division methods and results were different, thus targeted researches should be performed. In the current work, a LCZ mapping method was proposed, which is convenient in operation and city planning oriented. In this proposed method, the local climate zoning types were adjusted firstly, according to the characteristics of Chinese city, that more tall buildings and high density. Then the classification method proposed by WUDAPT based on remote sensing data was performed on Xi'an city, as an example, for LCZ mapping. Combined with the city road network, a reasonable expression of the dividing results was provided, to adapt to the characteristics in city planning that land parcels are usually recognized as the basic unit. The proposed method was validated against the actual land use and construction data that surveyed in Xi'an, with results indicating the feasibility of the proposed method for urban LCZ mapping in China.

1. Introduction
Rapid urbanization has significantly changed the morphology and local climate conditions in urban area. A series of environmental problems, such as air pollution and urban heat island, are seriously affecting on the daily life of urban residents. Till to the end of 2015, up to 56.1% of people live in city in China. On the other hand, people in urban areas are undergoing serious fog and haze pollution. Although air pollutants mainly come from industrial emission, motor vehicle exhaust and flying dust in construction sites, emerging tall buildings in cities give rise to increased underlying surface height of cities and roughness degree, leading to increased urban atmospheric stability and reduced average wind velocity. Thus, reasonable city planning is one of the means to alleviate the problem of city environment¹. However, affected by the technical conditions and industry differences, it is really rare in urban planning and development that applied the new research methods and achievements on city local climate study.

Steward and Oke developed “local climate zone” (LCZ) to study urban heat island (UHI) effect². The major advantage of LCZ is the new perspective of UHI, looking into the temperature differentiation among LCZ classifier rather than the traditional “urban” and “rural” classes. The LCZ method is expected as an international standard method to describe the effects of land cover and heat island effect³. The world urban database and access portal tools (WUDAPT) provided a method to mapping LCZ of cities with free satellite images and free software of Google Earth and SAGA-GIS⁴. WUDAPT aims to classify cities globally and generate a world urban morphology database. Worldwide urban climate researchers have applied WUDAPT for LCZ studies. Currently, several cities, such as Wuhan, Guangzhou and Hangzhou, have been studied with WUDAPT method³,⁵.
In fact, the WUDAPT method is a time-consuming process filled with image preprocessing and selecting training samples for each city. It is even a bulky workload to analyze cities globally. The existing methodology, therefore, need to be further developed. And also, beside the globally available Landsat satellite images, the detailed planning data and field observation results should be more reliable.

In the current work, the LCZ classification types and exhibition will be investigated with the characteristics of urban canopy layer in China was considered. A perspective on application of LCZ on urban environment study will be provided as well.

2. LCZ and mapping

2.1. LCZ and the classification

Each LCZ class can be defined quantitatively by using a standard set of parameters, including sky view factor, aspect ratio, impervious surface fraction, pervious surface fraction, height of roughness elements. Steward and Oke set LCZ classification as 17 standard types including two subsets: 10 built types and 7 land cover types. In all these types, buildings are divided into three types in height, which are: high-rise building (tall buildings to tens of stories), midrise building (buildings of 3-9 stories) and low-rise building (buildings of 1-3 stories). The situation in China cities is that, buildings are generally divided in four groups in height. Low-rise buildings of 1-3 stories, multi-storey buildings of 4-6 stories, low high-rise building of up to 12 (or 18) stories, and high-rise building of more than 18 stories. In recent years, most of high-rise buildings are built. Taking Xi’an city as an example, most of the residential areas developed in recent years are of high-rise buildings of about 33 stories. The height difference of buildings in China cities is very large, that the LCZ classification standard proposed by Stewart & Oke is difficult to distinguish the height distribution characteristics of buildings in China cities. The main difficulty is to distinguish between the multi-storey and the low high-rise buildings. Thus, it is necessary to adjust the original LCZ standard.

In the current work, a modification on the original LCZ classification standard was proposed according to the building height distribution characteristics. The “mid-rise building” was defined including two kinds of buildings: I, indicating the multi-storey building of 4-6 stories; II, indicating the low high-rise building of 7-18 stories. It follows that, LCZ 2 and LCZ 5 in the original LCZ classification standard are now including LCZ 2I and LCZ 5I, LCZ5II and LCZ 5II, respectively. And the high rise buildings in the new LCZ classification standard (LCZ 1 and LCZ 4) are of more than 18 stories.

2.2. LCZ mapping in Xi’an with WUDAPT method

WUDAPT was designed to be universal, simple and objective to be part of a global protocol to derive information about form and function of cities. It applies free satellite images, free software including SAGA GIS and Google Earth. This method was employed on the main urban area of Xi’an city. Landsat 8 level 1 images of the current study area with resolution of 30m was downloaded from the U.S. Geological Survey, as shown in Table 1. Urban morphology samples were derived from Google Earth, as shown in Table 2.

| Table 1 Landsat images information |
|-----------------------------------|
| Landsat Entity ID | Date            |
| LC81270362016057LGN00 | February 26, 2016 |
| LC81270362016137LGN00 | May 16, 2016        |
| LC81270362016169LGN00 | June 17, 2016       |

There are mainly three steps in LCZ mapping following the WUDAPT method.
(a) Pre-process of Landsat data: the selected Landsat images are firstly jointed into one fit in the study area. This pre-processed image is re-sampled into 120m to get a representation of the spectral signal of local-scale urban structures rather than smaller objects.

(b) Digitization of training areas in Google Earth according to the LCZ scheme: the representative areas of each LCZ class are selected by polygons as training samples (Table 2) and save in “.KML” format.

(c) Classification in SAGA-GIS: the pre-processed Landsat images and the selected training areas are input into SAGA-GIS. The LCZ classification of study areas is calculated and conducted by the random forest classifier according to comparing the similarity between the training samples and the rest of study areas.

This mapping process is shown in Figure 1.

Table 2  Training samples for each LCZ (snapshots on Google maps)

| LCZ type | snapshot | LCZ type | snapshot |
|----------|----------|----------|----------|
| LCZ1     |          | LCZ8     |          |
| LCZ2I    |          | LCZ B    |          |
| LCZ3     |          | LCZ D    |          |
| LCZ4     |          | LCZ E    |          |
| LCZ5I    |          | LCZ F    |          |
| LCZ5II   |          | LCZ G    |          |
| LCZ6     |          |          |          |

2.3. LCZ map of Xi’an

Figure 2 is the LCZ map of Xi’an. A total of 13 LCZ categories were identified in Xi’an from the remote sensing image, without LCZ 7, LCZ 9, LCZ A and LCZ C. In general, Figure 2 reflected the
“bowl” shape structure of the canopy layer of Xi’an city, as a lot of high-rise buildings are constructed in the new developed areas in recent years. However, the whole map has too many spots and no clear landmarks. It is difficult to meet the need of convenient application, thus it is necessary to carry out effective post-processing.

Figure 1 Diagram on classification process of the remote sensing

Figure 2 Local climate zone map for Xi’an based on the satellite remote sensing image

3. Discussion on the application of LCZ
It is now well agreed that adapting to climate change is better addressed at the city scale in planning stage. Generally, the basic control objects in urban planning are land parcels that divided by road net. LCZ map that given on land parcels that divided by road net would be convenient for consideration by professional planners. Main road networks (roads of four or more traffic lanes) divide the urban areas of Xi’an into about 2771 land parcels. LCZ map on these land parcels are shown in Figure 3. Figure 3 give the LCZ map from an automation process, with less human resources and
artificial influence, thus reduced the serious problem of spots. The most important improvement is that, LCZ map based on road net parcels is more easily acceptable by city planners.

Now, LCZ maps in many cities have been used in investigating urban heat island problems. It also has been shown have advantages in urban wind simulation and urban pollutant dispersion studies 6.

![Figure 3 LCZ map for Xi’an that combined with the city road network](image)

4. Conclusion
The WUDAPT method could map city LCZ distribution. The mapping process was very convenient. The LCZ maps can capture the morphology characteristics of urban area, which would detect the potential UHI distribution. Thus the LCZ are widely used in UHI studies. Further development of LCZ should combine with the road net divided parcels, so as it is easier for city planners to refer.

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References
[1] Zhang, Y.; Gu, Z., Air quality by urban design. *Nature Geoscience* 2013, 6, (7), 506-506.
[2] Stewart, I.D., Oke, T.R. Local Climate Zones for Urban Temperature Studies. *Bulletin of the American Meteorological Society*, 2012, 93(12):1879-1900.
[3] Ren, C., Cai, M., Wang, R., Xu, Y., Ng, E. Local Climate Zone (LCZ) Classification by Using the World Urban Database and Access Portal Tools (WUDAPT): A Case Study in Wuhan and Hangzhou. *The 4th International Conference on Countermeasure to Urban Heat Islands, 30 May-1 June, 2016*, Singapore.
[4] Bechtel, B., Alexander, P.J., Bohner, J., Ching, J., Conrad, O., Feddema, J., Mills, G., See, L., Stewart, I. Mapping local climate zones for a worldwide database of the form and function of cities. *ISPRS International Journal of Geo-Information*, 2015, 4:199-219.
[5] Cai, M., Ren, C., Xu, Y., Dai, W., Wang, X.M. Local climate zone study for sustainable megacities development by using improved WUDAPT methodology-a case study in Guangzhou. *Procedia Environmental Science*, 2016, 36: 82-89.
[6] Zhang, Y., Gu, Z., Zhou, D. Simulation on urban wind environment based on local climate zones and its parameterization. *Journal of Earth Environment*, 2016, 7(5): 480-486.
[7] Georgescu, M., Moreffield, P.E., Bierwagen, B.G., Weaver, C.P. Urban adaptation can roll back warming of emerging megapolitan regions. In. *PNAS*, 2014, 111(8): 2909-2914.
[8] Perera, N.G.R., Emmanuel, R. "Local Climate Zone" based approach to urban planning in Colombo, Sri Lanka. Urban Climate, 2016, https://doi.org/10.1016/j.uclim.2016.11.006.