An Introduction to the WUDAPT project

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WUDAPT
World Urban Database and Portal Tool

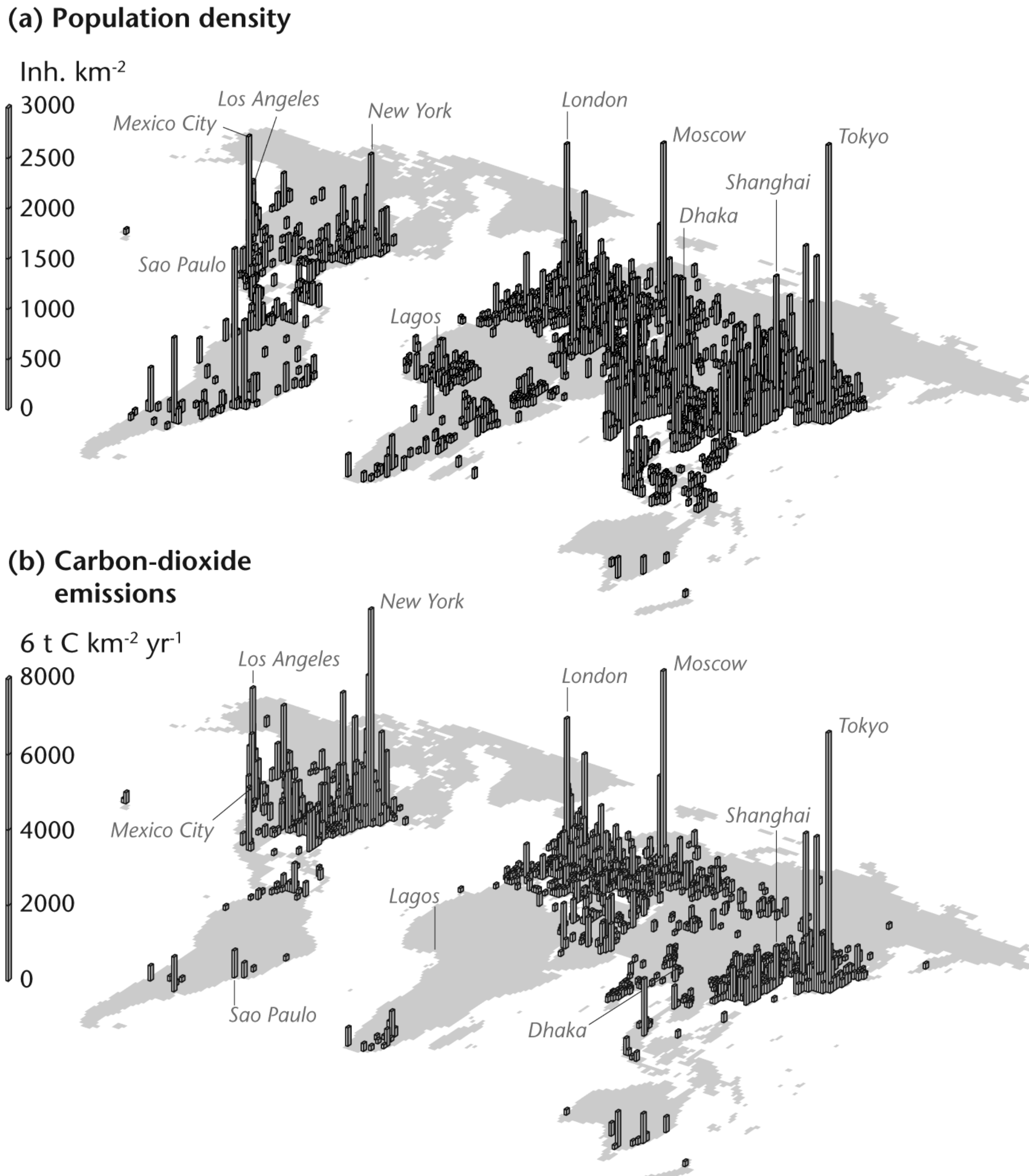
Objectives

1. Acquire information on aspects of form and functions of cities relevant to climate studies.
2. Database: Store the data in a geographic framework that is searchable and widely accessible.
3. Portal: Build tools to extract parameters and analyse urban properties for cross-urban comparison and model building.

Why is it needed?

The Global Knowledge Gap

Currently available global urban databases provide information on the limits of cities with no internal character. These data have limited value for climate studies.



Form & Function

Key urban form drivers of energy and GHG emissions are density, land use mix, connectivity, and accessibility. These factors are interrelated and interdependent. Pursuing one of them in isolation is insufficient for lower emissions.

Source: IPCC, 2014 AR5 III

Maps created by Andreas Christen, UBC

Cities in the IPCC 5th Assessment Report AR5 Mitigation (Urban)

This assessment highlights six key knowledge gaps. Three are especially relevant

- There is lack of consistent and comparable emissions data at local scales, making it particularly challenging to assess the urban share of global GHG emissions as well as develop urbanization typologies and their emissions pathways.
- There is little scientific understanding of the magnitude of the emissions reduction from altering urban form, and the emissions savings from integrated infrastructure and land use planning.
- There are few evaluations of urban climate action plans and their effectiveness.

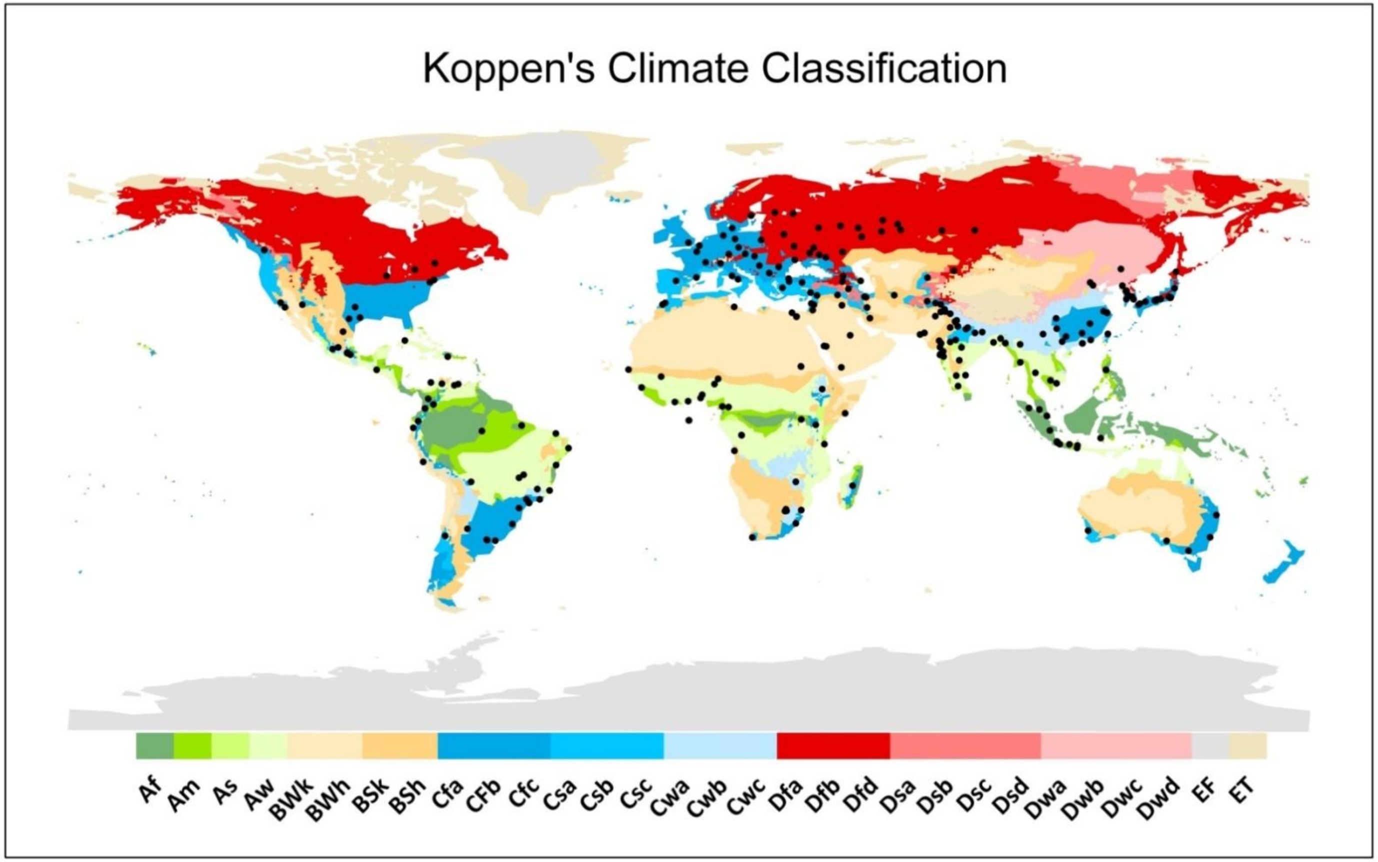
Source: IPCC, 2014 AR5 III

Cities in the IPCC 5th Assessment Report AR5 Adaptation (Urban)

Five key uncertainties and research priorities are identified, three are directly relevant:

- the limits to understanding and predicting impacts of climate change at a fine grained geographic and sectoral scale;
- inadequate knowledge on the vulnerability of the built environment … to the direct and indirect impacts of climate change and of the most effective responses for new-build and for retrofitting;
- 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

We know least about cities in tropical climates



Large cities are located in C climates, mostly many of which have colder winters (heating demand) rather than warmer summers (cooling demand) Cool cities would benefit from the UHI and heat gain. Cities (>1 million) over a map of global climates sourced from http://koeppen-geiger.vu-wien.ac.at/.

We know least about poor cities

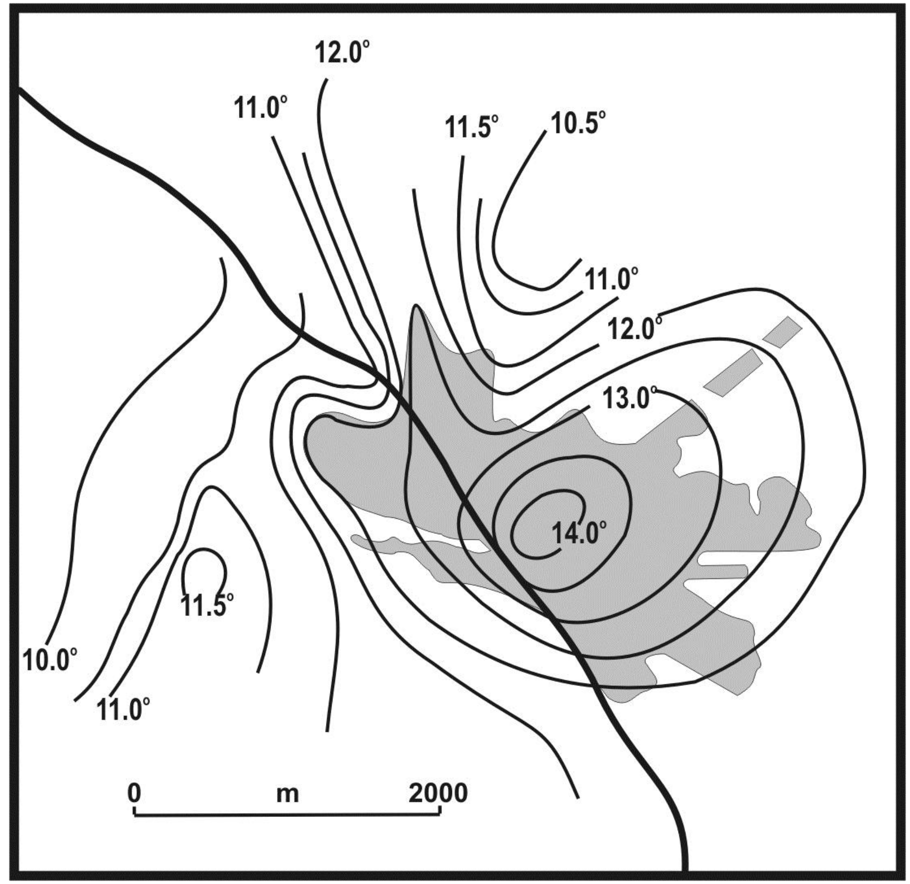
Koeppen climate type	Pop 1950	Pop 2010	Pop 2050	Number of cities Per capita income ($)				Total number of cities
				High	Upper middle	Lower middle	Low	
Equatorial (A) **$T_{min} \geq +18°C$**	52010	319360	464791	4	38	65	20	127
Arid (B)[1]	24650	169430	247964	12	37	29	4	82
BSh	7240	9250	11640	2	10	17	4	33
BWh	9810	12510	16300	7	5	8	0	20
Warm temperate (C) **$-3°C < T_{min} < +18°C$**	241330	725700	890317	101	144	40	5	290
Snow (D) **$T_{min} \leq -3°C$**	72350	182140	217004	43	35	8	4	90
Polar (E)[2] **$T_{max} < +10°C$**	370	1590	2178	0	0	1	0	1
Total	390710	1398220	1822254	160	254	143	33	590

[1]Arid climates are defined principally on the basis of precipitation; Steppe (BS) and Desert (BW) climates with $T_{min} \geq +18°C$ are warm (h) .
[2]The only city in this category is LaPaz (16.5°N) which has an altitude of 3500m ASL

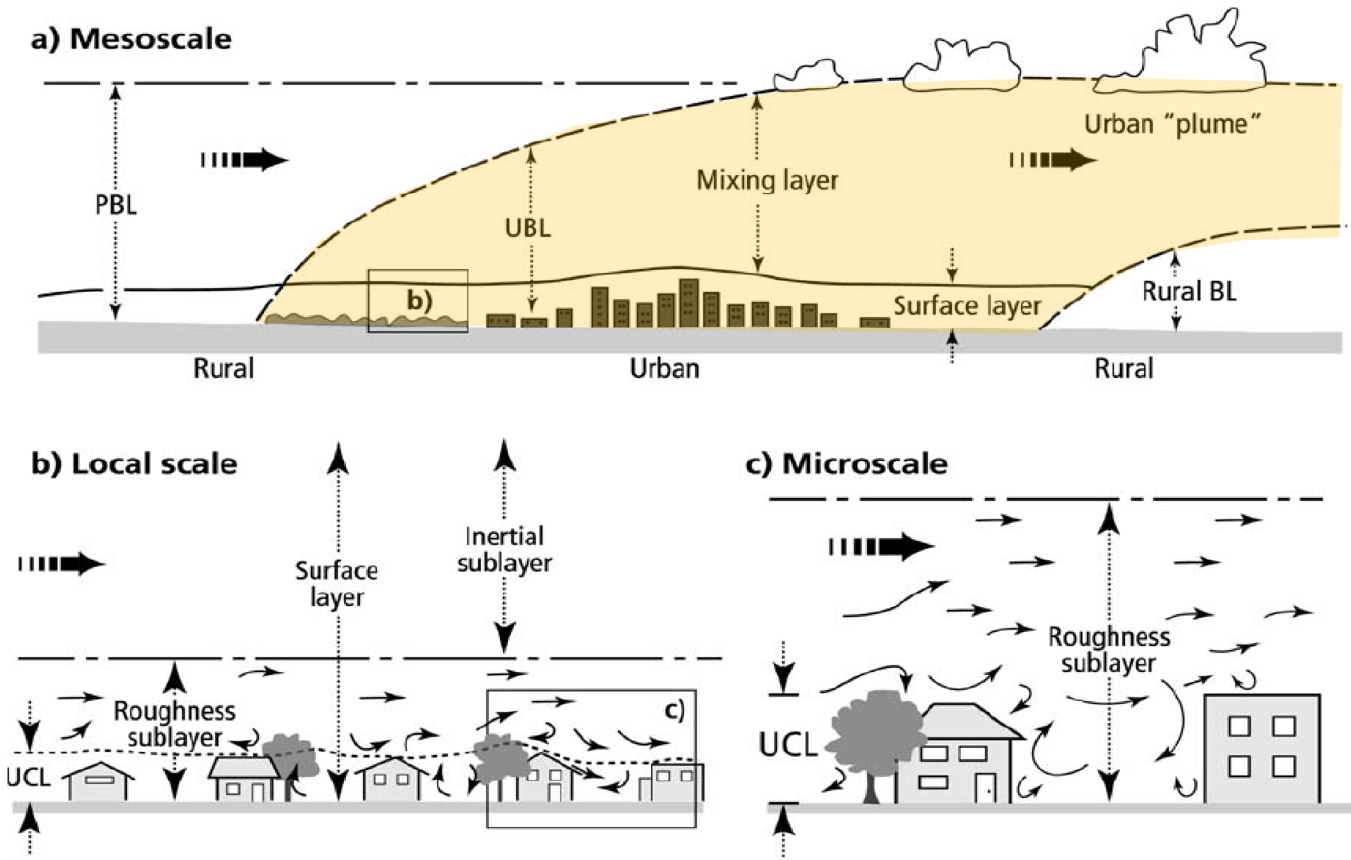
There are 590 cities with populations over 750,000; these are home to 20% of the world's population. 100 cities account for 10% of population.

The Urban Climate Knowledge Gap

Fig. 2. The instrument mounted on the automobile roof.



In the early stage of urban climatology, case-study city experiments formed the corpus of knowledge.



Our current understanding is now based on scale as an important determinant of processes and outcomes. These produce distinct atmospheric layers.

Source: Oke 'Urban Observations', Chapter 11 in WMO guidelines on meteorological observations.

Grappling with scale and heterogeneity

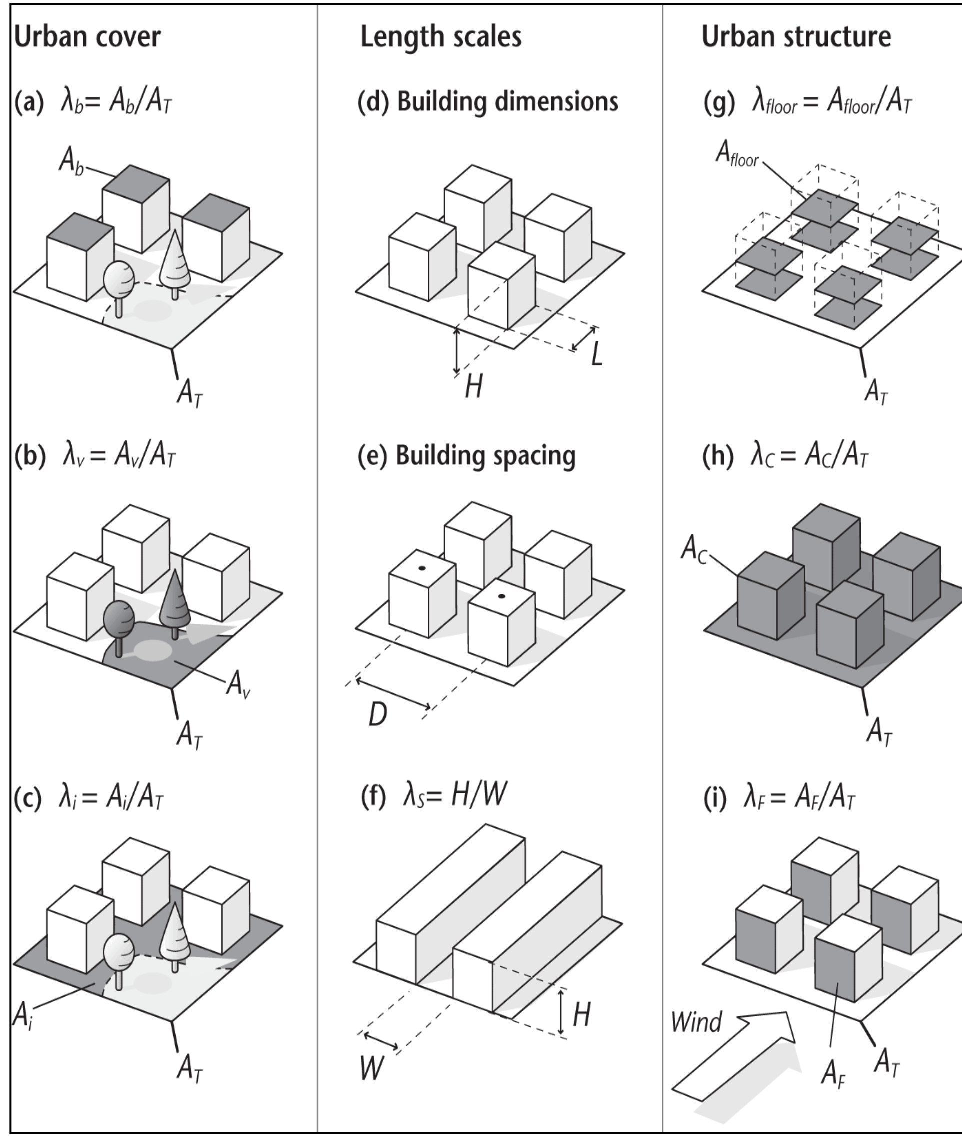
Measuring the effects of a simplified city on the atmosphere using an outdoor model; scaled model (1/5) used for establishing form-climate links. The Kanda Lab Japan.

Progress in the field of urban climatology has been achieved by controlling aspects of urban form and examining the atmospheric response through models and measurement.

Descriptions of urban form

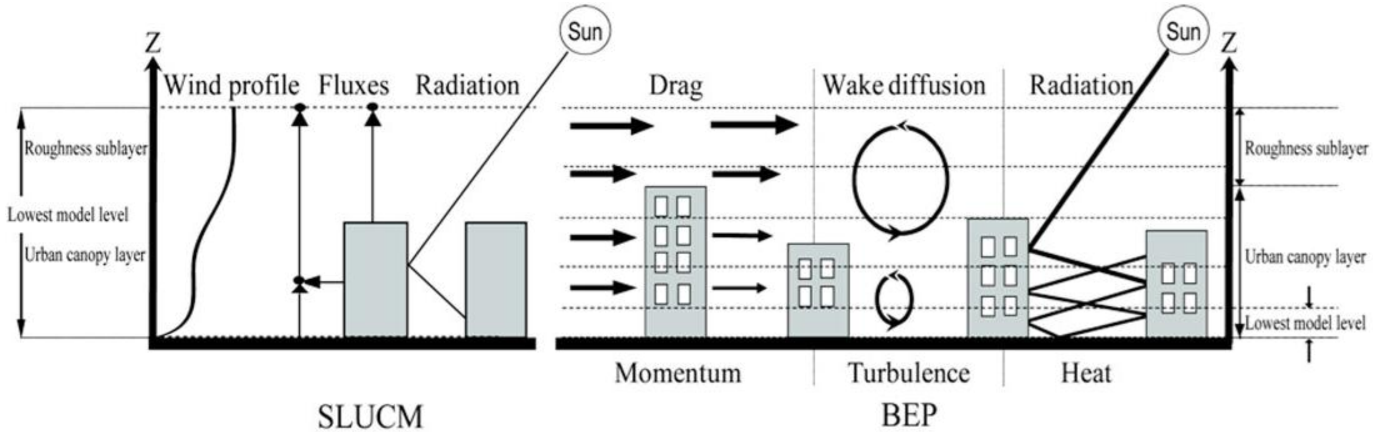
The nature of the urban effect can be related to a number of descriptors of the urban form: these include information on the radiative and thermal properties of materials, and measures of the geometry of the urban surface (such as street dimensions) and the surface cover (vegetated, impervious, etc.)

These descriptors are examples of urban canopy parameters (UCPs) that can usefully be employed to seek causal relationships in measurements and to parameterise models.



Oke et al (2016) in preparation

Models embody urban climate knowledge



CANOPY UCPs	**BUILDING UCPs**	**VEGETATION, OTHER UCPs**
		Mean vegetation height
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
*computed as a function of height (1-m increments)		

NUDAPT: Ching et al., BAMS 2009

2. WUDAPT

- One of the impediments to progress on examining the urban climate effect and the global climate affect on settlements is the absence of useful information on cities.
- **This data needs to use a coherent and consistent description of cities that can be applied internationally.** This information can be used to compare cities and transfer knowledge more effectively.
- The LCZ classification provides a scheme for describing the neighbourhoods of cities.
- It can be used as a *sampling frame* to gather more detailed urban data (e.g. building materials, cooking fuel, etc.).
- It is possible to use freely available tools and databases to decompose a city into LCZ zones. It requires locally-based urban experts that can apply the LCZ scheme to their city.

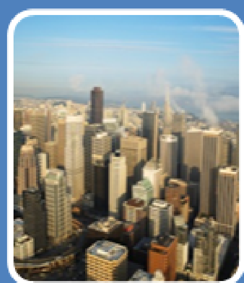
http://www.wudapt.org/

Strategy

Increasing detail

Level 2

- Detailed description of urban landscape parameters at a scale suited to boundary-layer models
- Use of all available databases (e.g. building footprints)



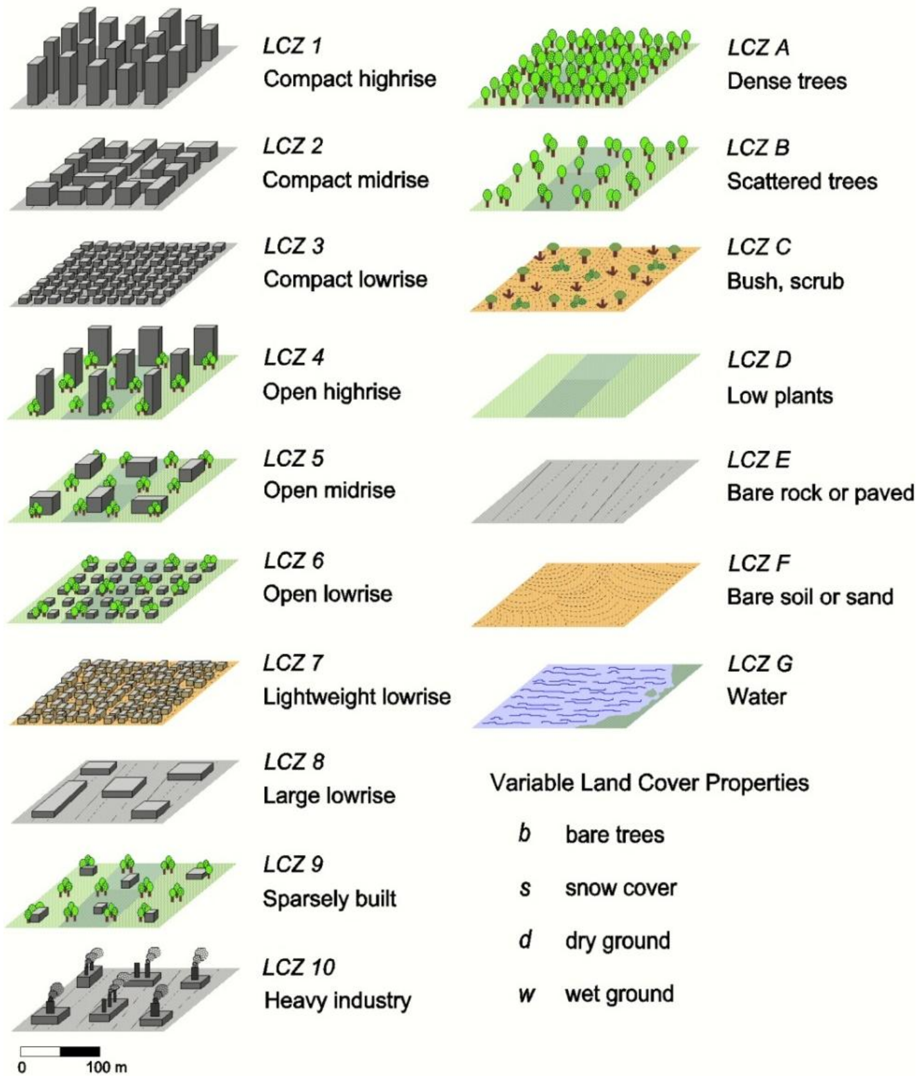
Level 1

- More precise parameter values for each LCZ
- Focus on aspects of form (e.g. building heights, street width) and functions (e.g. building use).
- Sampling of LCZ using GeoWiki

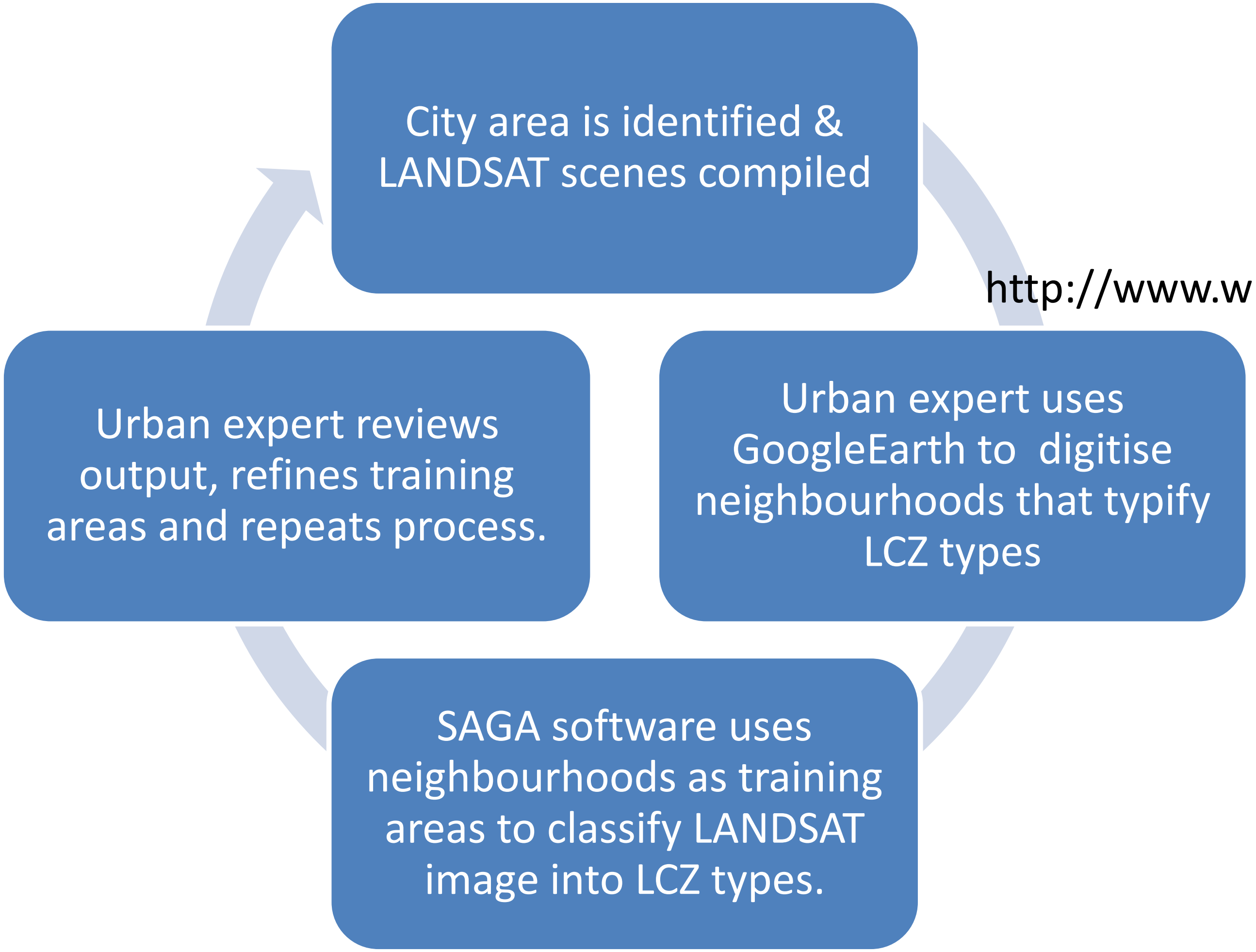
Level 0

- Local Climate Zones (LCZ) along with parameter ranges
- Categorise city neighbourhoods into LCZ types
- Local experts provide training areas
- GoogleEarth, Landsat8 and Saga

LCZ Type	Mean Height (m)	Building Surface Fraction	Impervious Surface Fraction	QF (Wm^{-2})
1	>25	40-60%	40-60%	50-300
2	10-25	40-70%	30-50%	<75
3	3-10	40-70%	20-50%	<75
4	>25	20-40%	30-40%	<50
5	10-25	20-40%	30-50%	<25
6	3-10	20-40%	20-50%	<25
7	2-4	60-90%	<20%	<35
8	3-10	30-50%	40-50%	<50
9	3-10	10-20%	<20%	<10
10	5-15	20-30%	20-40%	>300



The **Local Climate Zone** approach developed by Iain Stewart and Tim Oke builds on other approaches and provides a classification scheme for urbanised and natural landscapes that can be used to describe **neighbourhoods** within cities.



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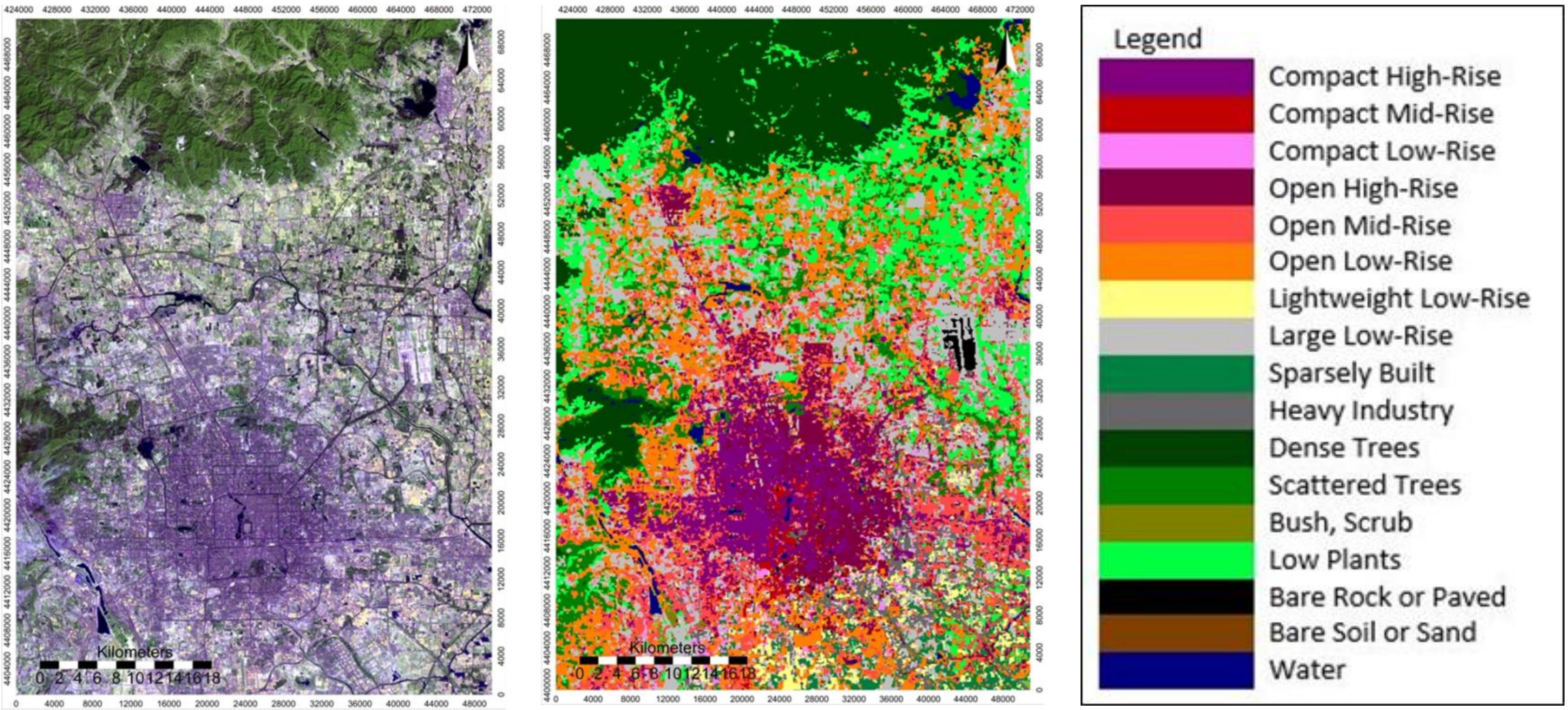
Level 0 workflow model. The Urban Expert is someone who knows the city under study. All of the tools developed are free to use.



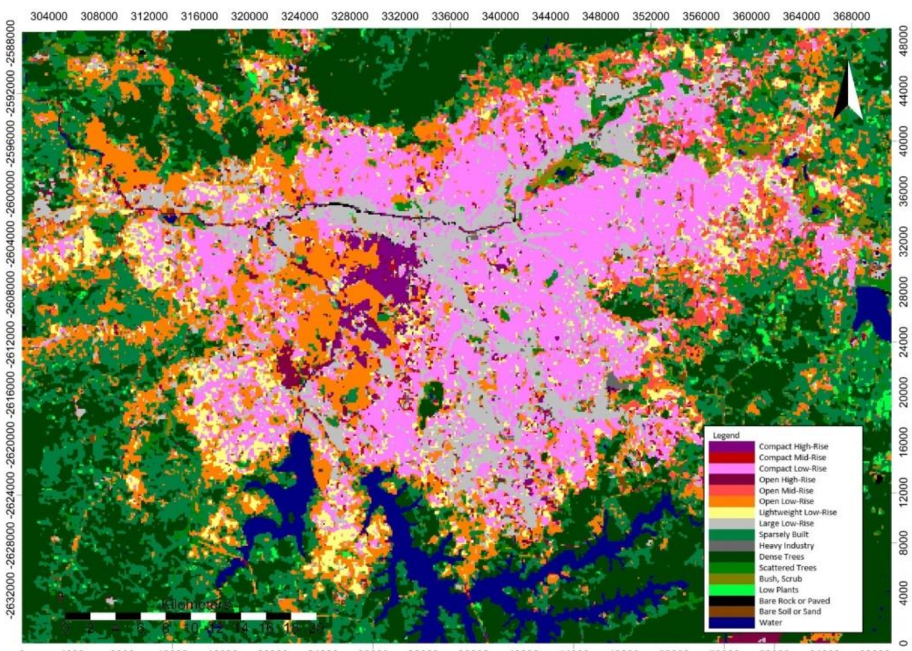
The Landsat 8 image (left) and LCZ map and legend for Beijing, China. Completed by Weibu Liu and Micháel Foley.

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

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; 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).

Next Steps

1. Enrol urban experts from cities around the world to help develop training areas and evaluate results.
2. Develop methods for acquiring more detailed information on cities (GeoWiki, crowd-sourcing).
3. Test the robustness of the methods.
4. Focus on the largest cities in the world.



Maria De Fatima Andrade (Departamento de Ciências Atmosféricas do Instituto de Astronomia, Geofísica e Ciências Atmosféricas, USP) was the local urban expert for SaoPaolo.

GEOWIKI to refine LCZ parameter values

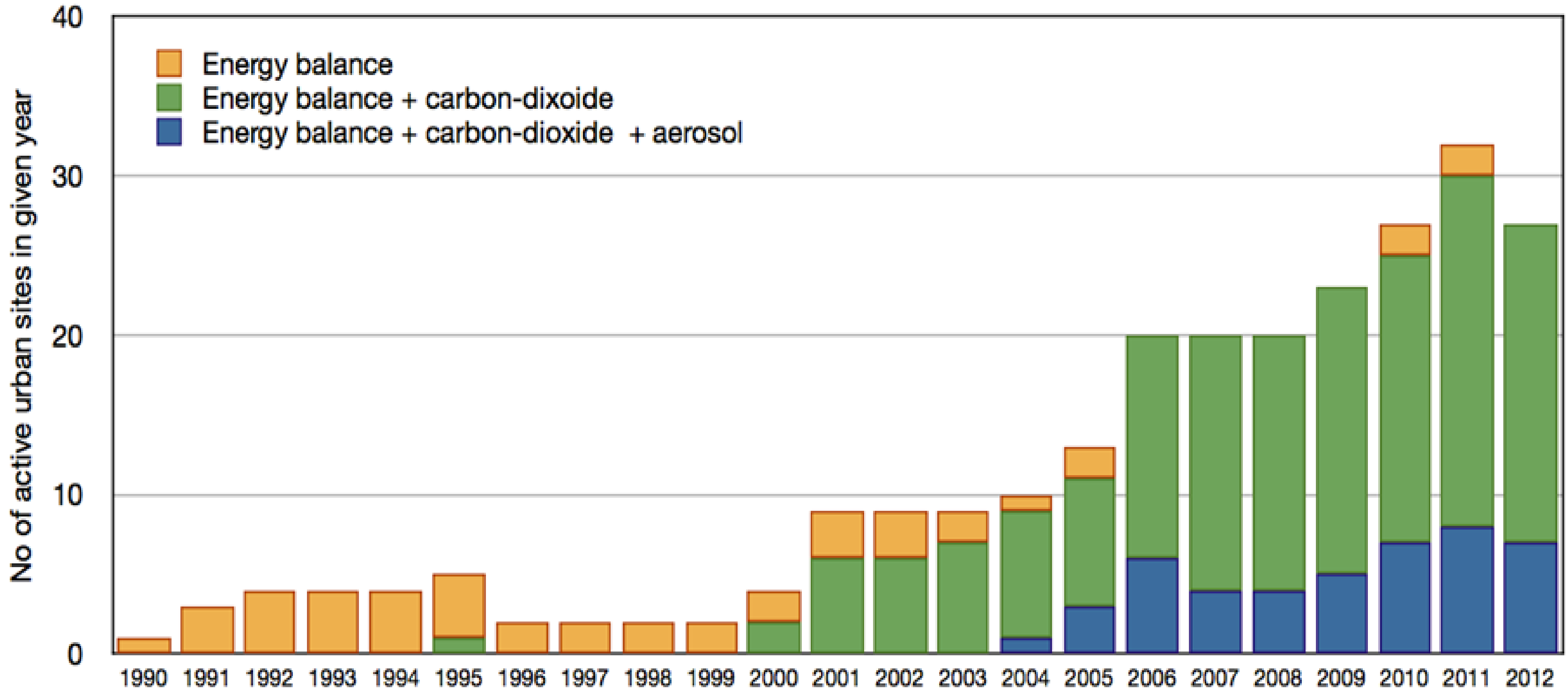
LCZ	Level 1data experiment			Stewart & Oke 2012		
	λ_V	λ_b	λ_I	λ_V	λ_b	λ_I
Compact high-rise	10.5	42.4	47.1	<10	40-60	40-60
Compact mid-rise	11.3	43.9	43.7	<20	40-70	30-50
Compact low-rise	17.6	36	45.1	<30	40-70	20-50
Open high-rise	25.9	24.3	48.9	30-40	20-40	30-40
Open mid-rise	39.1	19.8	36.8	20-40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

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

Conclusions

- A global database of cities is needed that captures the character of urban landscapes. It needs to be created quickly, given the pace of urbanisation in Asia and Africa.
- The approach described appears to be robust and the initial characterisation of large global cities will proceed using Landsat imagery.
- Next step will be to gather more detailed information on cities using other techniques, including crowd-sourcing and using available data sources (e.g. Google Streetview, open street map, etc.
- WUDAPT will be developed by the urban climate community and the results will be accessible for climate research.

Active urban flux sites active per year (1990-2012)



Number of active urban flux sites active per year (1990-2012) and measured turbulent fluxes. Source of data: Urban Flux Network database (May2012) (Grimmond and Christen, 2012).


Thank you.