WUDAPT Global Initiative: Census of Global Cities

I Background and Challenges

We are living in an urbanized world, yet we know very little about most cities on the planet, especially how they are built (urban form) and occupied (urban function). Urban residents are especially vulnerable to current and future climate hazards because of the concentration of people, infrastructure and social-economic activities in landscapes that are exposed to sea-level rise, river flooding, storms, heatwaves and so on (WMO, 2003, WMO, 2016, WHO and UN-Habitat, 2016, UN-Habitat, 2011). In addition, the character of urban development (e.g. extensive paving) and the attendant emissions of pollutants has profoundly altered the natural setting and exacerbated natural hazards. These changes have led to a series of urban environmental problems, such as the urban heat island effect, the pollution of rivers and seas, air pollutant effects and air quality degradation that directly impact urban citizens (UN, 2016b, Mills, 2007). Moreover, the emissions of greenhouse gases (GHG) globally is concentrated in cities; although less than 3% of global land-cover can be described as urban, over 75% of human-sourced CO_2 arises from these places. Thus, there is increasing international focus on cities as a nexus for many global problems including urban environmental conditions, living quality and human well-being, the challenges and risks for human population health in cities, and global climate change (WHO and UN-Habitat, 2016, WHO, 2010, UN, 2016a, UN, 2016b, Cleugh et al., 2009, Corburn, 2015).

Most cities operate like management systems that respond by mitigating the actions that cause undesirable changes and then adapt the system to cope with environmental hazards. Since cities have different capacities to respond based on their political cultures, economic base, socio-cultural make-up and so on, there needs to be a common language to describe urban landscapes globally. Members of the scientific community (e.g. climatologists, geographers, ecologists, environmental engineers and technologists) are looking for more standardized information on the urban form and function of cities so that they can devise solutions to aid architects, designers and municipal governments (i.e. City Planning Departments, Public Works Departments, Zoning Boards, Transportation Offices) in developing evidence-based design guidelines for best practices related to mitigation and adaptation to climate change (Cleugh et al., 2009). However, a consistent database on global cites at scales suitable for scientific inquiry and policy formulation does not exist (see Table 1 and Figure 1). The analysis of such data is critical as it represents the only way to solve cause-and-effect urban problems before they become crises (Mills, 2005). Even the most recent report from the Intergovernmental Panel on Climate Change (IPCC) notes the dearth of such information on urban areas (IPCC, 2014).

Table 1. Problems and needs of urban data (Oke, 2006b, Oke, 2006a, Stewart and Oke, 2009):

Problems & Needs	Facts
Urban Data Availability & Accessibility	• Few or no data sets available globally on cities, especially for rapidly growing places in economically developing countries and regions.
Climate Relevant Urban Data	• No consistency in existing urban databases on spatial and temporal resolution and the variables to characterize the urban landscape
Data Standardization & Harmonization	• No standard classification to represent land use and land cover of cities and surroundings landscapes (e.g., densities, heights, functions and natural coverage for distinction)
Modelling Needs	• Need a global database that offers multiple properties on urban morphologies and landscapes (e.g., morphologies, geometrics, thermal / physical information, surface cover, etc.)
Application Needs	• Should be applicable globally and transferable to each city (e.g, transdisciplinarity for scientific research, urban planning, disaster & risk management, health impact analysis and response, etc.)

II The Urban Data Gap

From a climate perspective, we need to capture urban information on the spatial character of different types of urban form and function (Batty, 2009, Raven et al., 2017). The **form** of a city can be described in terms of:

1. **Land surface cover** including vegetation, soil, water and impervious/paved surface cover. Surface cover is related to the ability of the landscape to intercept, store and dispose of water, for example.
2. **Construction materials** including the concrete, steel, brick, glass, asphalt, etc. used to build the city. These fabrics have distinctive properties related to their ability to absorb, store and release heat, for example.
3. **Urban morphology** including the dimensions of individual buildings and their position in relation to each other. Morphology creates a complex three-dimensional geometry that controls access to daylight and sunshine, modifies the flow of air and traps pollutants at street-level.

The **function of a city describes** the residential, commercial, and industrial activities and all that these entail (i.e., the water, materials, food and energy requirements). Together these capture the metabolism of a city, that is, the throughput of resources and wastes needed to sustain its operations and to maintain and extend its buildings and infrastructure (Batty, 2009, Mills, 2005). The form and functions of a city are strongly correlated; for example, international evidence indicates that cities that are more densely built and occupied have lower transportation costs.

Ideally, information on the form and functions of cities should be collected and analysed at **multiple temporal and spatial scales** to meet different needs and to tackle cause-and-effect problems (Raven et al., 2017).

III WUDAPT

The World Urban Database and Access Portal Tools (WUDAPT) project seeks to acquire and store urban data using a common framework and to link these data to available methods for climate analysis and for current and what-if scenario development. Present global-scale urban data and land use at the city level is derived from global land cover data sets; examples include AVHRR, MODIS GLCF and ESA GlobCover as shown in Figure 1. Their resolutions ranges from 300 m to 10 km and they only have one land use category for urban/built up areas, which may overestimate or underestimate urban forms and functions, and also cannot represent the actual situation of cities. Figure 1 shows the case of Delhi, India, using different existing land cover information; the final map in this sequence shows the WUDAPT product, which provides improved spatial detail. There are other newly available global urban layers from the German Aerospace Agency (DLR) (Global Urban Footprint) and the Joint Research Centre of the European Commission (Global Human Settlement Layer) but similarly, they show only one category of urban, i.e. built-up areas, even though these products are at a much higher spatial resolution.

The WUDAPT initiative is a global, bottom up, self-organized effort to begin filling the data gaps needed to solve the global challenges of sustainable cities and communities, and as a guide to facilitate climate-based actions (Mills et al., 2015); (See et al., 2015). It builds upon innovative approaches,

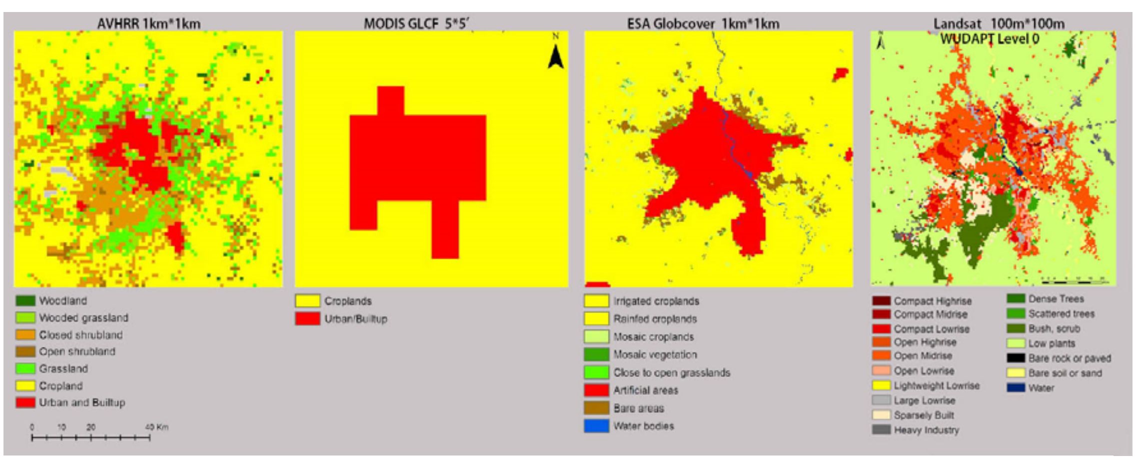

Figure 1: Urban data challenges – some examples of global scale data sets compared to a WUDAPT level 0 map for the city of Delhi, India

employs community-based collaborations, and utilizes existing and publicly available data, where it exists (Ching et al., 2016). Given the urgent need for urban data to support climate research, WUDAPT has adopted a pragmatic approach to structuring these data according to the level of detail (Figure 2). Table 2 shows the details about the WUDAPT products, such as their coverage, data sources, resolution, applications and potential users.

An important component of WUDAPT is the development of portal tools, which allow the data to be extracted in formats suited to climatic analysis. This includes sophisticated models such as the Weather

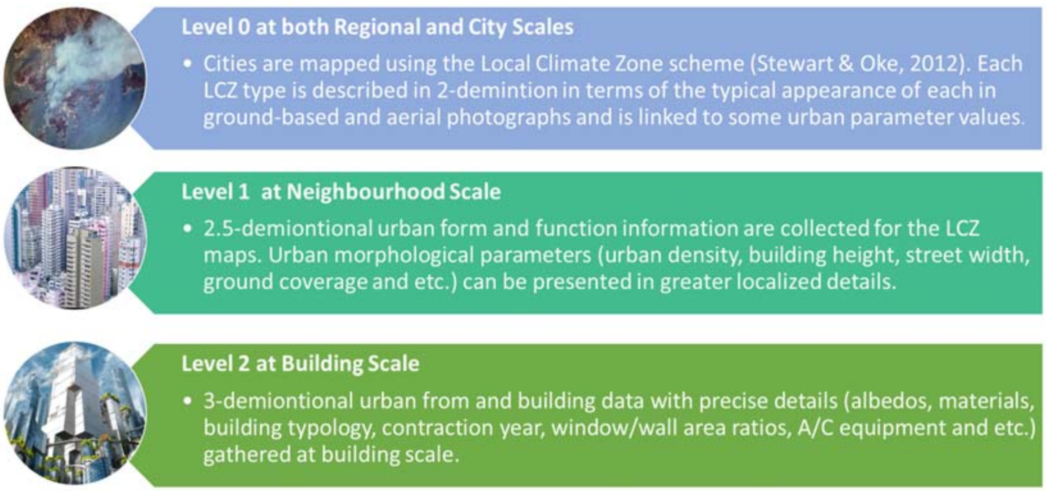

Figure 2: The WUDAPT levels 0, 1 and 2 products

Research and Forecasting (WRF) model, a widely employed community-based model that is capable of simulating all the parameters of climate and, depending on the setup, air quality and climate change scenarios. In fact, the major impediment to applying these models - which represent decades of research knowledge - is the lack of supporting data.

The WUDAPT approach is underpinned by a community-based approach and relies on freely available data and tools. The lowest level of detail (L0) consists of decomposing urban (and surrounding landscapes) into common Local Climate Zone (LCZ) types using local expertise, Landsat remote sensing data and software tools (Figure 3). The net result is an LCZ map of an urban region where each LCZ type is associated with a universal range of values that describe aspects of urban form and function. Currently, L0 data are available for more than 120 city regions across all continents. L0 data can be used as a sampling framework to gather more detailed information on cities (L1 data).

Table 2: WUDAPT Levels 0, 1 & 2 data and their potential applications

WUDAPT Data			
Product	Level 0	Level 1	Level 2
Coverage	Over 120 cities and regions	Data gathering methods testing based on MApUCE underway	Any city by using our new 3-D mapping technology
Data source	Landsat + Google Earth	Landsat + Google Earth + local data & expert evaluation	World-view Stereo Data + Terra-SAR data
Resolution	100-500 m	100-500 m	2 m
Format	kml, tiff	GIS shapefiles	GIS shapefiles
Applications	Environment and Energy (Weather Research and Forecasting (WRF) Modelling, Urban heat island) Urban and Regional planning (population density)	• Environment and Energy (weather and climate, urban air flows, urban radiation, mean radiant temperature, urban energy consumption, air pollution, CO2 and GHG emission) • Ecology (biodiversity) • Urban and Regional planning (master plan, land use plan, green master plan, new town plan)	• Environment and Energy (building energy cost) • Building and community design (visibility analysis, building development) • Disaster and risk management (Flooding, heatwave) • Pedestrian and citizen’s mobility (walkability, thermal comfort) • Public health (polluted areas)
Potential Users	• Anyone • Education Institutions; • Researchers & Scientists	• Researchers & Scientists (Environment scientists, Climatologists, Meteorologists) • Engineering Consultant Companies and design firms; • Education Institutions; • NGOs; • Urban designers, town planners, • City government (planning departments, transportation office, public works departments, zoning boards and etc.),	• Researchers & Scientists; • Engineering Consultant Companies and design firms; • NGOs; • Education Institutions; • Architects, urban designers, town planners, • City government (planning departments, transportation office, public works departments, zoning boards, infrastructure facilities and etc.),

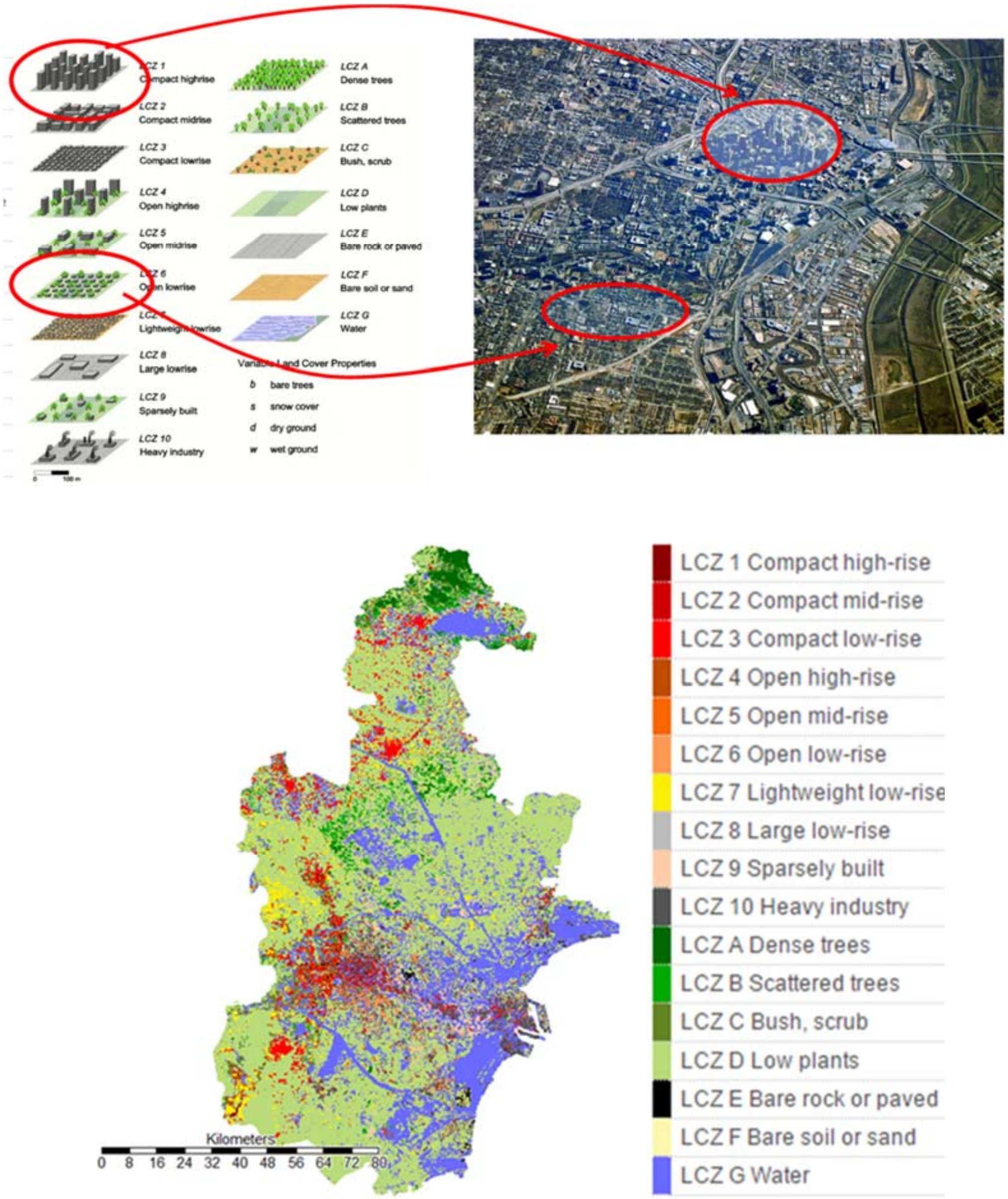

Figure 3: Generating L0 data. The top image shows how parts of the urban landscape are identified according to LCZ type. These data are used to automatically classify an entire urban region into common LCZ types (lower map).

Level 2 (L2) data provide complete coverage of the urban landscape and include information on individual urban elements (buildings, trees, etc.); see Figure 4 as an example of urban morphology. Ideally, this information would be supplemented by information on the occupation patterns of buildings (commercial, residential, mixed) and on their material composition. While the morphology can be acquired through remote sensing, other properties require a more holistic approach that may need traditional census data and crowd-sourced information.

Figure 4: Level 2 product: 3-D urban morphological data of Kowloon Peninsula, Hong Kong based on innovative technology (under patent) can extract and detect 3-D urban morphological data by adopting multi-source satellite images. The overall accuracy of developed level 2 data can reach to 70-90%. This new technology has a low case and a large spatial coverage, which can be update efficiently.

IV Ongoing International Collaborations and Applications

Since its inception, the WUDAPT project has established working relationships with a number of other organizations. We have a close association with the International Association for Urban Climate (IAUC), which has a diverse (e.g. architects, designers & planners, climatologists & meteorologists) and globally distributed membership with interests in urban environmental issues, weather/climate prediction, air pollution and risk management. Many of the local experts that we draw upon to provide city-specific information are IAUC members. In addition, WUDAPT has established strong collaborations with the Human Planet Initiative, the Global Carbon Project (GCP) and the Digital Belt and Road Initiative (DBAR). With funding from the Research Grant Council of Hong Kong, an extensive study of the Pearl River Delta has been undertaken using the WUDAPT methodology. Also, an informal collaboration with WMO (World Meteorological Organization) is underway to provide supporting infrastructure to assist in their recent Urban Mandate for providing urban services.

1. Human Planet Initiative

WUDAPT is an active member of the Human Planet Initiative, which is headed by Dr. Martino Pesaresi of the Joint Research Centre (JRC) of the European Commission on behalf of the intergovernmental Group on Earth Observations. WUDAPT members have contributed to an evaluation of the Human Planet Atlas (Figure 5) and have used the Global Human Settlement Layer (GHSL) produced by the JRC to help validate the WUDAPT L0 product. The GHSL currently consists of built-up areas (GHS-BU), the population grids (GHS-POP) and the urban/rural classification model (GHS-SMOD). For the classification of settlements, there are only 4 categories: no data, rural, urban clusters and the urban centre (Figure 6). The WUDAPT data complement the GHSL by providing a far richer description of the urban landscape.

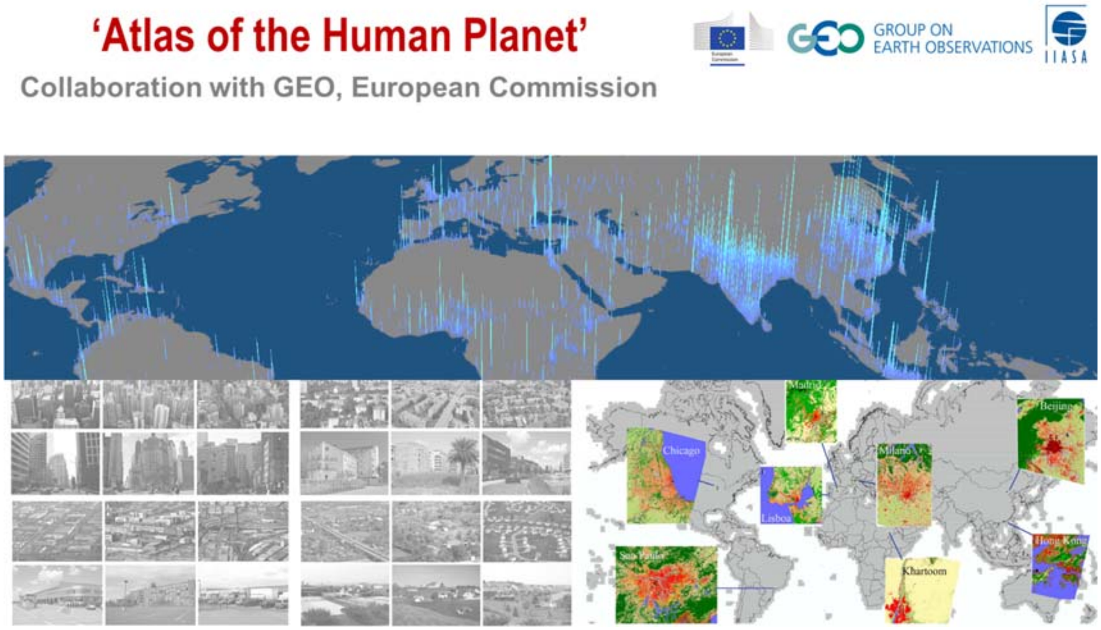

Figure 5: Atlas of the Human Planet and validation of WUDAPT level 0 products

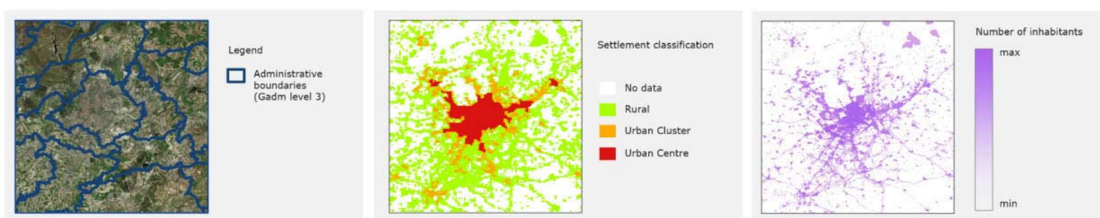

Figure 6: Urban data in the GHSL

2. Global Carbon Atlas Project

The WUDAPT team is working with the Global Carbon Project, which is one of the flagship projects of the new Future Earth initiative, to help build a database of carbon emissions for 55 cities. WUDAPT level 0 products can be a key input to creating maps of carbon emissions across a city, which will become part of the Global Carbon Atlas (Figure 7). WUDAPT and GCP have also written a proposal to develop a carbon action platform to help cities share their carbon action plans and develop plans when no data are available, using WUDAPT level 0 products as a spatial platform.

3. The Digital Belt and Road (DBAR) Initiative

DBAR is an international, open and inclusive 'big-science' program to demonstrate and foster the smart uses and applications of "Big Earth Data" in support of the sustainable development of people and economies at local, national and regional levels (Figure 8). The WUDAPT team has been invited to join the working group of the 'Urban' section of this initiative. Current plans are to develop an urban database and to conduct relevant urban climate applications for 80 selected cities in the next 3-5 years.

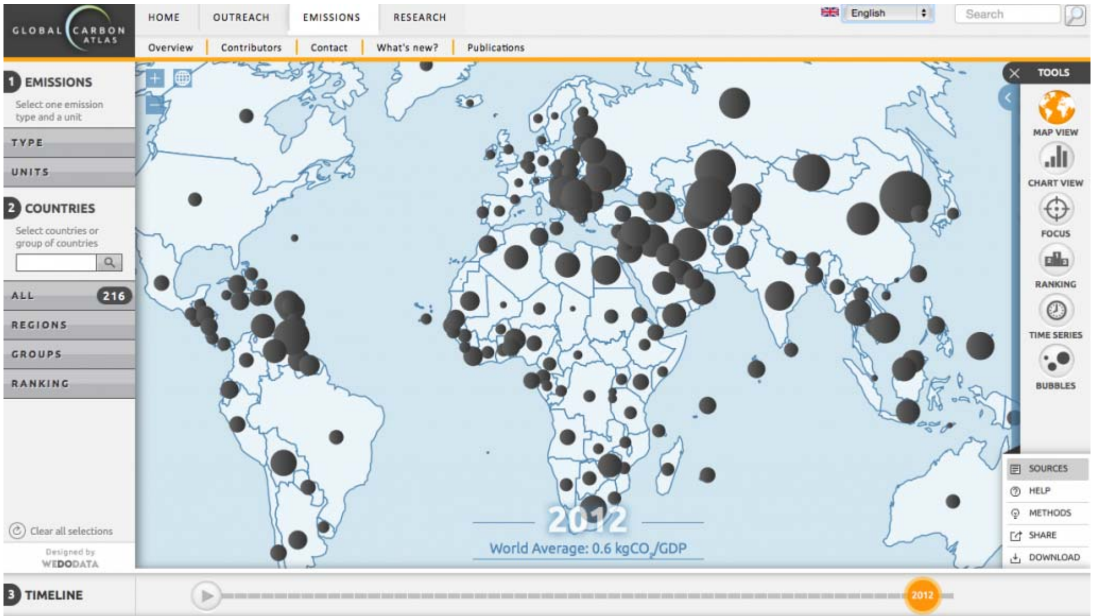

Figure 7: Current national carbon emissions (relative to GDP) displayed in the Global Carbon Atlas

Figure 8: The research framework of the 'Digital Belt and Road (DBAR)' Initiative

4. Pearl River Delta (PRD) Megalopolis Project

Over 60 million people occupy the cities of the PRD region. This project uses satellite data from the 1970s onwards to map the growth of cities in the PRD at regular intervals. This mapping allows us to run complex climate models to gauge the impact of urbanization on climate at local, city and regional scales; Figure 9 shows the urban cover used by the WRF model to simulate air temperature, wind patterns, and heat stress. WUDAPT maps were created at regular intervals going backward in time, permitting the development of a consistent time series and analysis of urbanization in this area. Based on the extracted and developed historical urban morphological information, future land use patterns can be predicted as a reference for local planners and government officials. This project has been funded by a Research Grant Council of Hong Kong and similar exercises are planned for other regions in China (e.g., the Beijing-Tianjin-Hebei region and the Yangzi River Delta Region) and other developing countries, where urbanization is taking place quickly but there is no useful urban data to explore the consequences and evaluate alternative development paths.

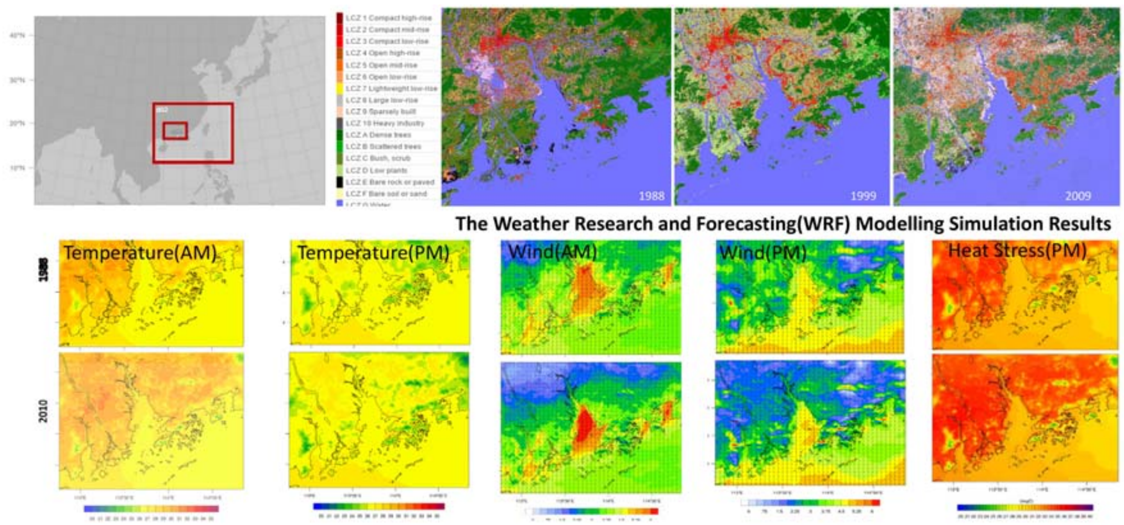

Figure 9: An application of WUDAPT to extraction of historical morphology of the Pearl River Delta and the results of running WRF.

We have an **Idea**.

We have the **Technology** and we have the **Team**.

All we need is further **Collaborations** and **Resources**.

Will **YOU** join us?

This document is prepared by the below core team members of the WUDAPT initiative

Prof. Chao REN ,The Chinese University of Hong Kong, Hong Kong
Prof. Edward NG, The Chinese University of Hong Kong, Hong Kong
Prof. Gerald MILLS, University College Dublin, Ireland
Dr. Jason CHING, University of North Carolina (Chapel Hill), US
Dr. Benjamin BECHTEL, University of Hamburg, Germany
Dr. Linda SEE, International Institute for Applied Systems Analysis, Austria
Dr. Valéry MASSON, Meteo France, France
Prof. Johannes FEDDEMA, University of Victoria, Canada
Prof. Daniel G. ALIAGA, Purdue University

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