9.2 Implementing WUDAPT product into urban development impact analysis by using WRF simulation result - A case study of the Pearl River Delta Region (1980-2010)

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1. INTRODUCTION:

Recently the Habitat III organized by United Nations has made a new global urban agenda for next 20 years in last Oct 2016[1]. According to the Quito Declaration, it is calling for' Sustainable Cities and Human Settlements for All' and its transformative commitments for sustainable urban development are mainly from social, economic and environmental dimensions[2].

With advanced data science and informatics technology, people now can do various applications and implementation for climatic-sensitive planning and design[3]. Based on the simulations or forecasting results, government officials and policy makers can make evidence-based decision or policy change correspondingly. Eventually these could lead to sustainable urban development and benefit to improve urban living quality.

The Pearl River Delta (PRD) Region in China has experienced fast urbanization since the 1980s. Now it is the most densely populated and urbanized region in the world. However, its urban expansion and intensive development will continue according to "The PRD region reform and Development Plan (2008-2020)". In the process of past urbanization, on one hand the whole region has created unique compact and dense urban morphological forms, on the other hand its local urban climatic conditions have also been inevitably and gradually changed. Thus, understanding the urban development impact on local urban climatic changes from the 1980's to the 2010's will allow planners have a perspective for gaining an insight into the future. However, land use information is sensitive and not easy to be accessed in mainland China.

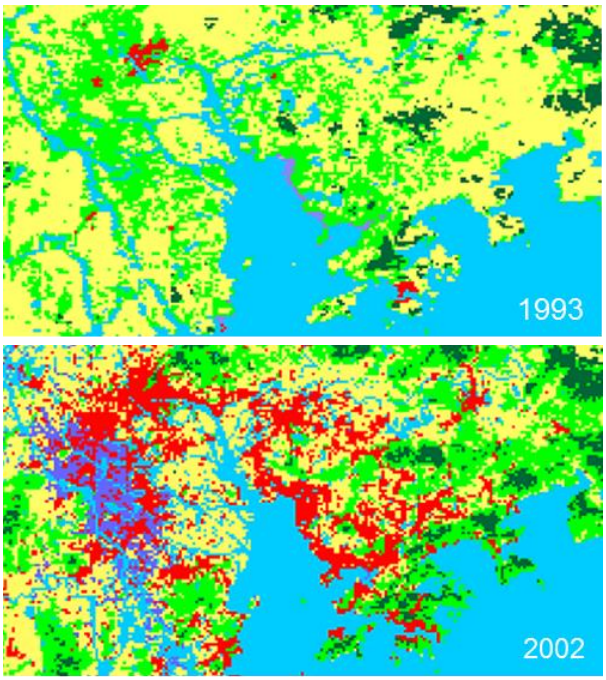

Fig. 1 Urbanization in the Pearl River Delta (PRD) region between 1993 and 2002 (based on the default USGS land use data; red color shows urban area)

2. METHOD:

2.1 Research Plan

This study firstly collects historical Landsat images to detect land cover and urban morphological information of the 1980's and the 2010's by using

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WUDAPT method (Bechtel, et.al, 2015). Secondly, according the USGS land use category, the WUDAPT level 0 product can be re-classified. Especially for urban category, three sub-categories of high-roughness, mid-roughness and low-roughness will be developed and their corresponding settings in WRF simulation model will be updated and redefined. Thirdly, the WRF simulation with the default setting up for the year of 2010 will be run for the summer period and its results will serve as the benchmark. And two new WRF simulations by using the WUDAPT products as input data will be conducted and their results will be compared with the benchmark one. So the pure urbanization (1980-2010) impact on local climate conditions of summer time (June-july) can be analyzed.

2.2. Data

The World Urban Database and Access Portal Tools or WUDAPT (www.WUDAPT.org) is a global initiative to collect urban morphology and land use data for climate studies and model application[4-8]. Its product has been strategically designed for 3-level. In this study level 0 product is developed for WRF simulation.

First, selected Landsat 5 Images of 1988 and 2009 are collected and preprocessed to resample and clip (Tab. 1). In Google Earth, training samples of each Local Climatic Zone (LCZ)[9] are created. Then, in SAGA GIS, processed Landsat 5 images are loaded. After setting parameters, LCZ classification can be conducted[10]. Subjective correction is conducted to delete noise data caused by Landsat images and data in-consistence is also corrected by referring local urban plans and city development information[11, 12]. Fig. 2-3 show the final result of LCZ map for the PRD region as WUDAPT level 0 product.

Tab. 1 Selected Landsat 5 images in1988, 1999 and 2009

Year	Entity ID of Landsat 5	Acquisition Date
1988	LT51210441988354BKT00	1988-12-19
	LT51210451988354BKT00	1988-12-19
	LT51220441988345BJC01	1988-12-10
	LT51220451988329BKT00	1988-11-24
2009	LT51210442009283BJC00	2009-10-10
	LT51210452009283BJC00	2009-10-10
	LT51220442009306BKT00	2009-11-02
	LT51220452009306BKT00	2009-11-02

Fig. 2 WUDAPT level 0 product of the PRD region in 1988

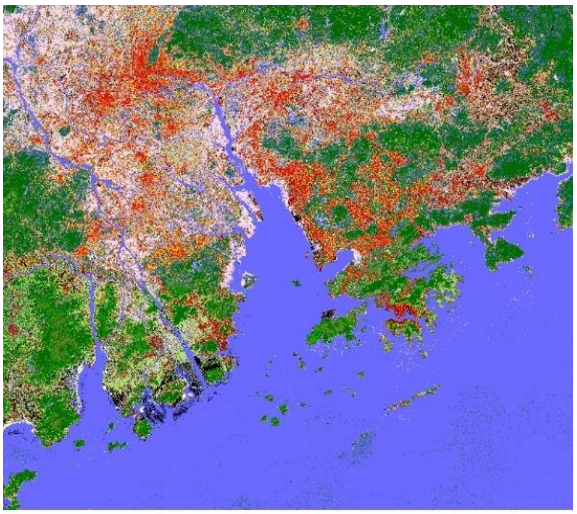

Fig. 3 WUDAPT level 0 product of the PRD region in 2009

2.3. WRF SIMULATION

For the WRF simulation configuration, there are three domains. The outer domain covers Asia, with 27km grid. The second one covers South China, with 9km gird and then Guangdong Province with 3km grid. The inner one is our interested domain, covering the whole Pearl River Delta region with 1km. Fig. 4 shows the details of the set-up of WRF modelling.

ACM2 PBL Scheme coupled with Noah land surface model is adopted. There are 3 urban categories of input data based on the WUDAPT level 0 product to present high, mid and low urban roughness.

Domain	Asia(1)	South China(2)	Guangdong Province(3)	Pearl River Delta(4)
Grid size	27km	9km	3km	1km
Simulation period		June to August		

Urban Day time	**2pm – 4pm (Local time zone)**
Urban Night time	**8pm – 10pm (Local time zone)**

WRF Physics Options	
Microphysics	WRF Single-Moment 3-class scheme
Longwave Radiation	RRTM scheme
Shortwave Radiation	Dudhia scheme
Surface Layer	MM5 surface layer scheme
Land surface	**Noah land surface model***
Planetary Boundary layer	ACM2 PBL scheme
Cumulus Parameterization	Grell-Freitas scheme

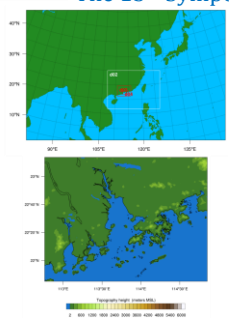

Fig. 4 basic information about the set-up of WRF modelling and 3 domains

3. RESULTS:

3.1 Temperature

Fig 5-6 are obtained by averaging whole month's result of June and July in 1988 and 2010. As we expected, due to large urbanization over Pearl River Delta region, 2m temperature is significantly increased over the urban area. Not only occur in day-time (Fig.5), but also in night-time (Fig.6). This is because large amount of heat is stored in the land and retain in the land so that the temperature is still higher than rural area during night-time.

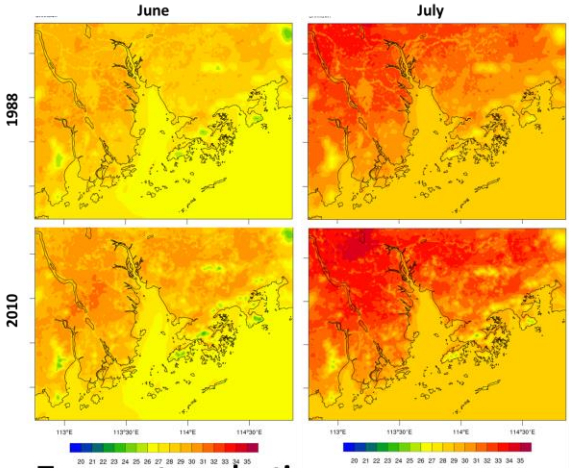

Fig.5 Daytime temperature of June and July in 1988 and 2010 at 2m height above ground

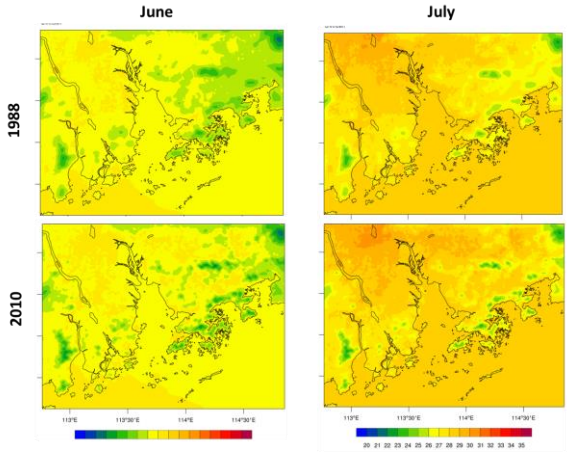

Fig.6 Night time temperature of June and July in 1988 and 2010 at 2m height above ground

3.2 Wind

Fig 7-8 are 10m wind plots of WRF simulation results. It can be found that the strength of the sea breeze is increasing after urbanization. This is because the land become much hotter, the temperature gradient between land and sea is much higher. Also, it might be expected that the sea breeze cannot penetrate to in-land area since large urban area would increase the surface roughness.

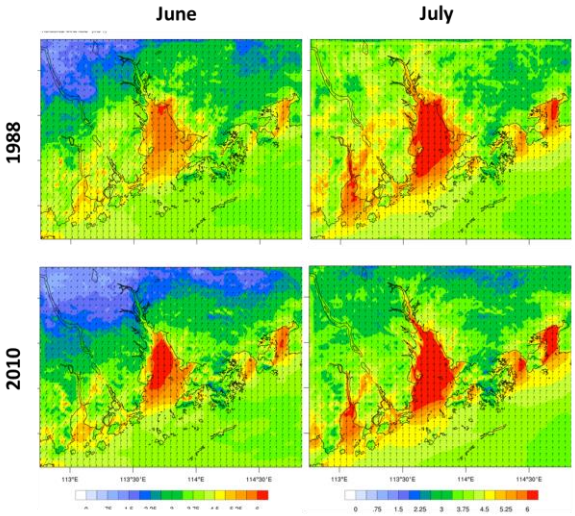

Fig.7 Daytime wind simulation results of June and July in 1998 and 2010 at 10m height above ground

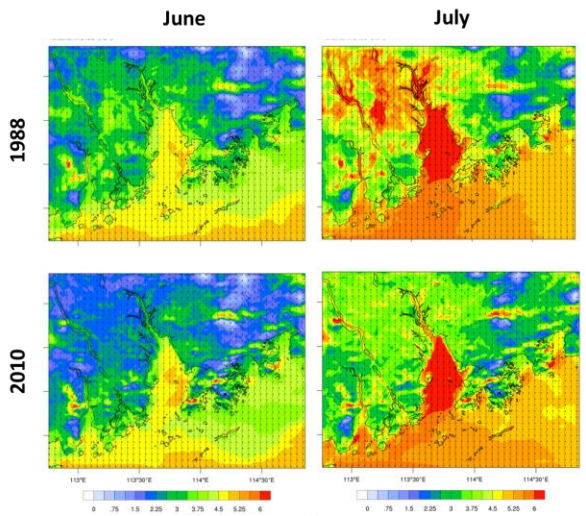

Fig.8 Night time wind simulation results of June and July in 1998 and 2010 at 10m height above ground

3.3 Heat Stress

A Heat Index, defined by US National Weather Service (NWS) is adopted in this study. It is a function of 2m temperature and 2m relative humidity. We can see that there is a significant increase in heat index near coastal area during day-time. While heat index increase in inland area during night time.

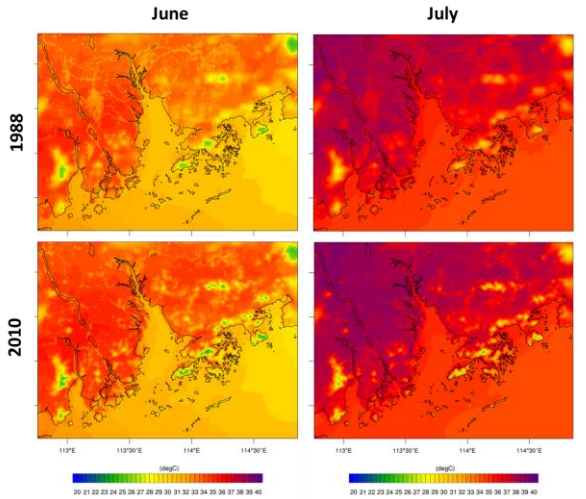

Fig.9 Daytime heat index based on the WRR simulation results of June and July in 1998 and 2010 at 2m height above ground

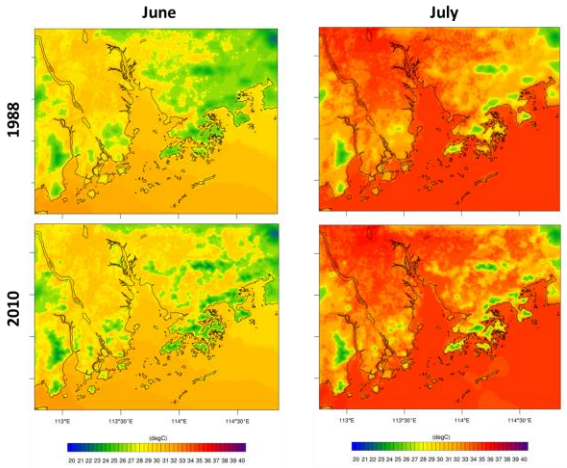

Fig.10 Night time heat index based on the WRR simulation results of June and July in 1998 and 2010 at 2m height above ground

4. VALIDATION

King's Park station of Hong Kong Observatory is a representative urban station. Its weather records including wind speed and air temperature were collected and used for the validation. The green line represents observation while the blue line represents model result. It can be found that the wind prediction is very close to the observation. Also, the temperature still can follow the trend even though the peak value is not very close.

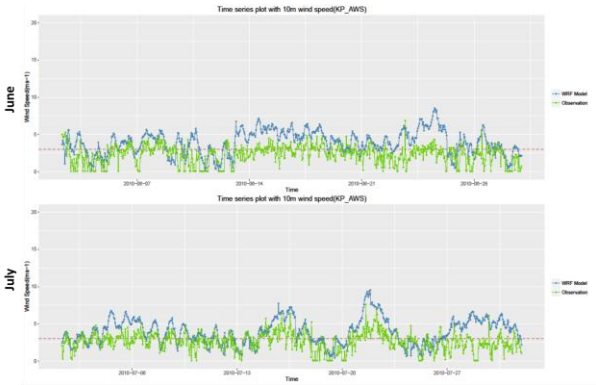

Fig. 11 wind speed validation results of June and July at 2m height above ground using the temperature records from King's Park Station (KP)

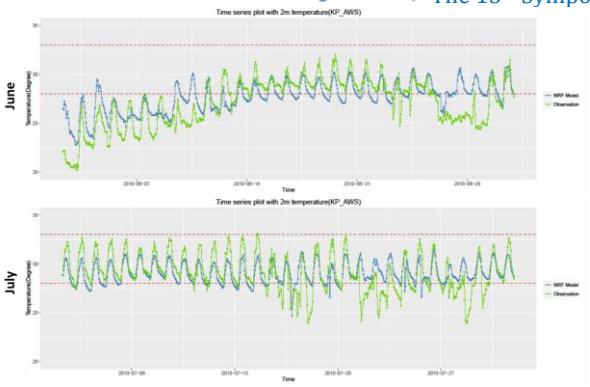

Fig. 12 Temperature validation results of June and July at 2m height above ground using the temperature records from King's Park Station (KP)

5. SUMMARY AND FUTURE WORK:

- WUDAPT products has capability to enhance the simulation by providing more detail urban categories rather than 1 category for urban (In Noah)
- Due to rapid urbanization from 1988 to 2010, large grass land with cooler surface was replaced by urban area with hotter surface in this region. Therefore, the ambient temperature and heat index are significantly increased, whatever during daytime or nighttime (~1.5 degree for 2m temperature) , this is because significantly increase in heat storage in the building and on the ground. This is a pure urbanization's impact on local climate.
- Consequently, because of the hotter surface over the land, the temperature gradient between land and sea is much higher, hence the strength of the sea breeze is increasing.
- Noted that the sea breeze cannot penetrate to in-land area since large urban area would increase the surface roughness.
- For the future work, although the quality of historical Landsat images of the 1960's-the 1970's is not good, based on collected local urban development plans, land use information and the developed 1988's LCZ map, the 1960's will be created. Then, future land use changes (until 2030) can be statistically predicted by using Change Analyst based on the developed LCZ maps from 1960-2010.
- The lessons learnt from this study will provide local policy makers and planners with a quantitative understanding on urban development of the PRD region. It also can serve as useful reference for developing countries in sub-tropical climate regions which are also facing fast urbanization. The findings will inform "The environmental performance assessment guide of urban ecological development of China (Trial Version)" and "The PRD region reform and Development Plan (2008-2020)".

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