W-UCP - an Open-source Tool for deriving Urban Canopy Parameters for the Pearl River Delta region & Examples of its application

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DENVER & ONLINE
AMERICAN METEOROLOGICAL SOCIETY

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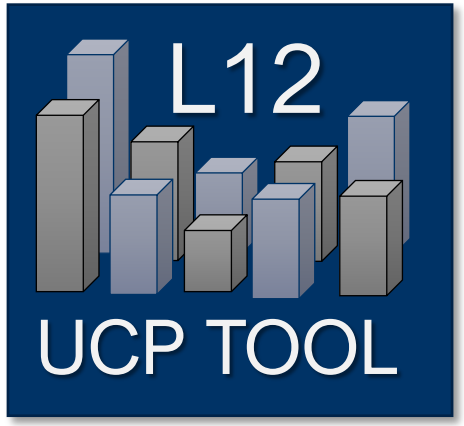
*Hong Kong University of Science and Technology



UCP = Urban Canopy Parameters

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

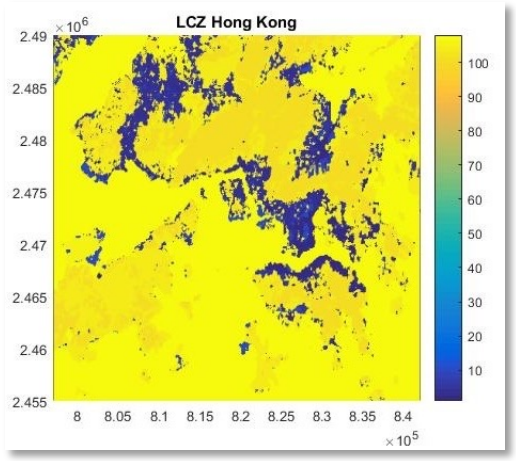
OUTLINE

1. Introduction
2. Methodology
3. Examples of application
4. Guidance on WRF's application
5. Discussion

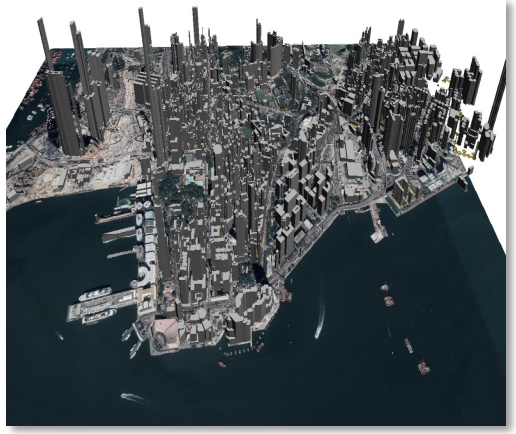
WUDAPT OVERVIEW AND WRF MODELING

A TOOL FOR THE COMMUNITY TO PROCESS DATA FOR WRF MODELING

WUDAPT L0

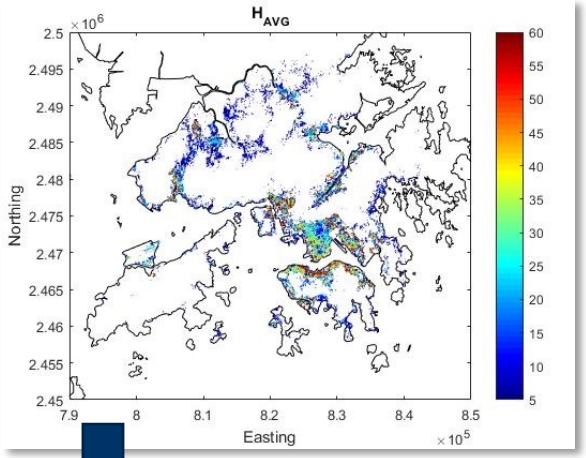


WUDAPT L1-L2

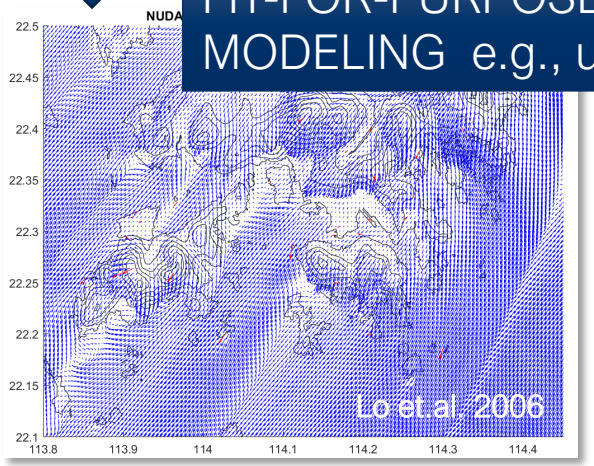


L12 UCP TOOL

Gridded UCP values



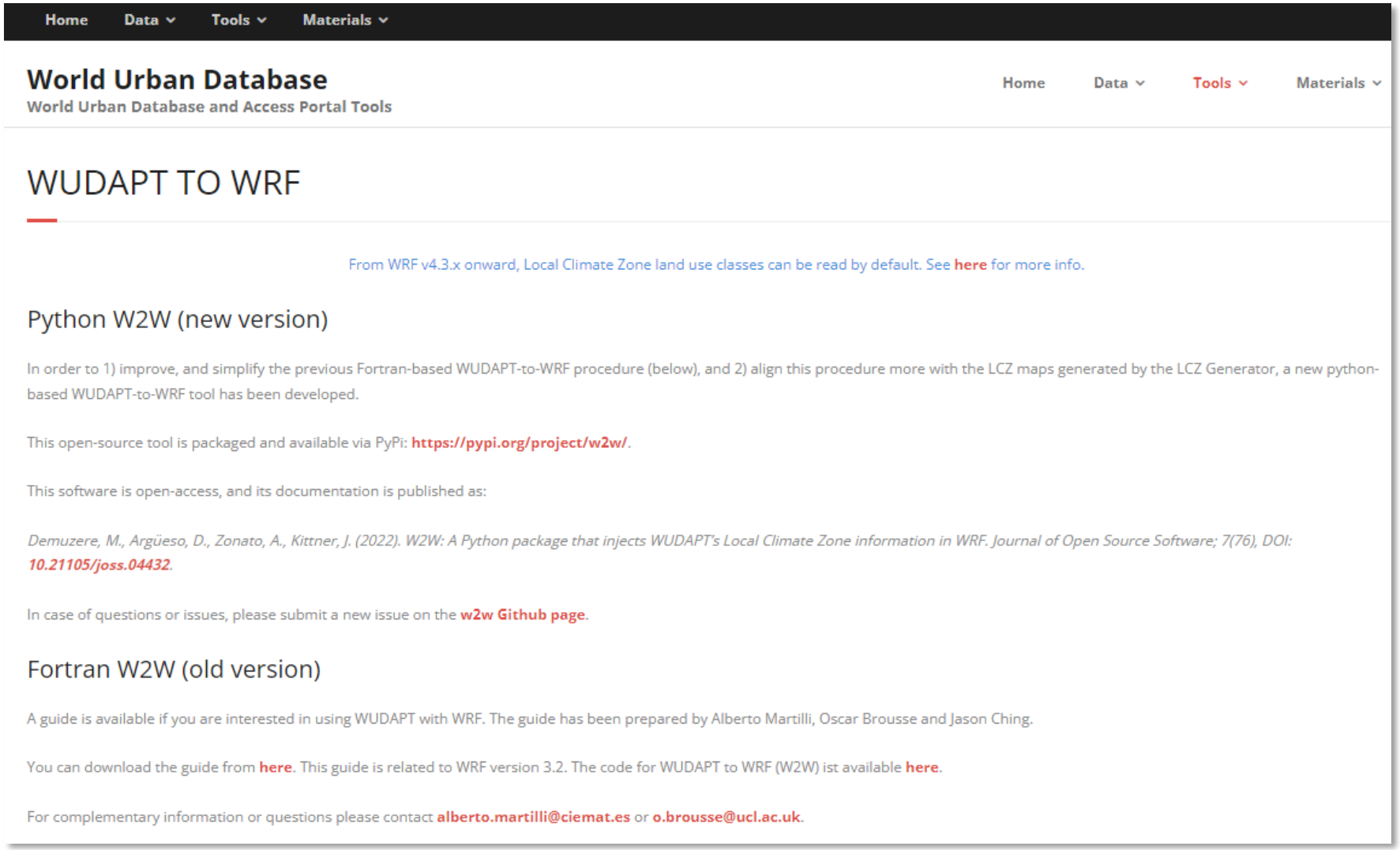
FIT-FOR-PURPOSE MODELING e.g., uWRF



We're getting closer to WUDAPT L12, e.g., the DSC (Dan Aliaga et al. 2022)

WUDAPT PORTAL

W2W UCP TOOL DEMUZERE ET AL. 2022 FOR LEVEL-0 DATASET



Home Data Tools Materials

World Urban Database
World Urban Database and Access Portal Tools

Home Data Tools Materials

WUDAPT TO WRF

From WRF v4.3.x onward, Local Climate Zone land use classes can be read by default. See **here** for more info.

Python W2W (new version)

In order to 1) improve, and simplify the previous Fortran-based WUDAPT-to-WRF procedure (below), and 2) align this procedure more with the LCZ maps generated by the LCZ Generator, a new python-based WUDAPT-to-WRF tool has been developed.

This open-source tool is packaged and available via PyPi: **https://pypi.org/project/w2w/**.

This software is open-access, and its documentation is published as:

*Demuzere, M., Argüeso, D., Zonato, A., Kittner, J. (2022). W2W: A Python package that injects WUDAPT's Local Climate Zone information in WRF. Journal of Open Source Software; 7(76), DOI: **10.21105/joss.04432**.*

In case of questions or issues, please submit a new issue on the **w2w Github page**.

Fortran W2W (old version)

A guide is available if you are interested in using WUDAPT with WRF. The guide has been prepared by Alberto Martilli, Oscar Brousse and Jason Ching.

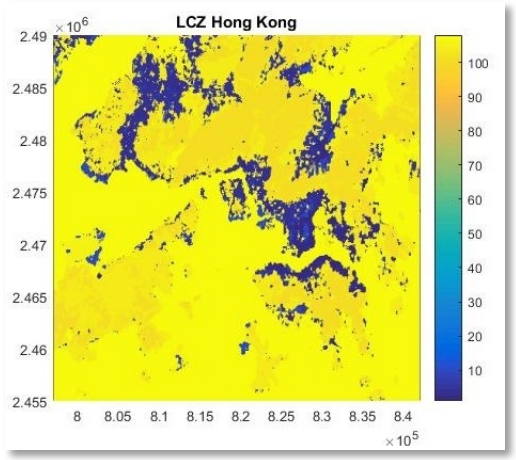
You can download the guide from **here**. This guide is related to WRF version 3.2. The code for WUDAPT to WRF (W2W) ist available **here**.

For complementary information or questions please contact **alberto.martilli@ciemat.es** or **o.brousse@ucl.ac.uk**.

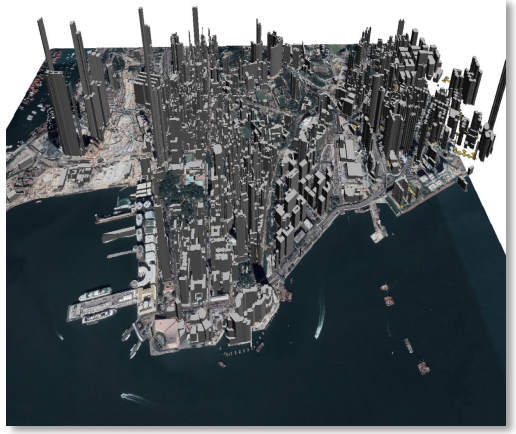
TOOLS DEVELOPMENT OVERVIEW

A TOOL FOR THE COMMUNITY TO PROCESS DATA FOR WRF MODELING

WUDAPT L0



WUDAPT L1-L2



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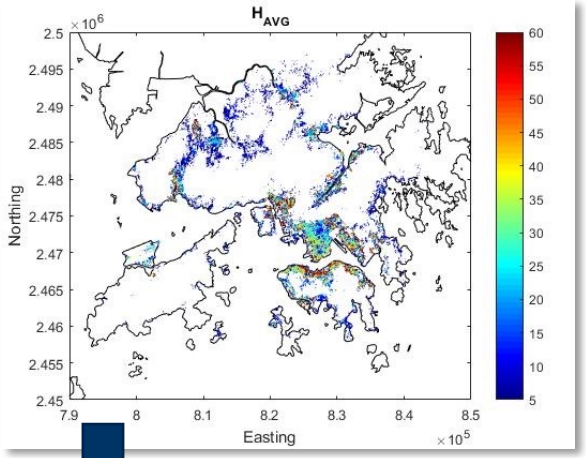
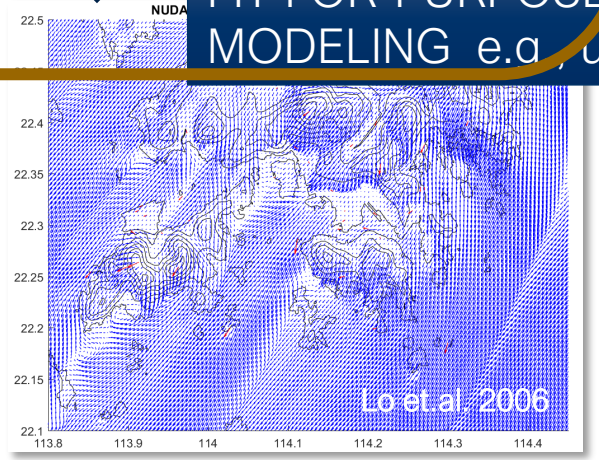
Gridded UCP values



FIT-FOR-PURPOSE MODELING e.g., uWRF



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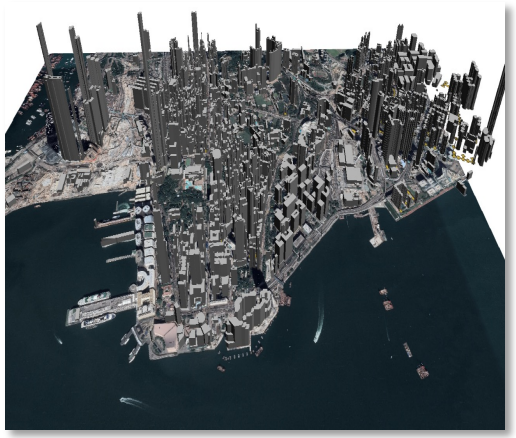
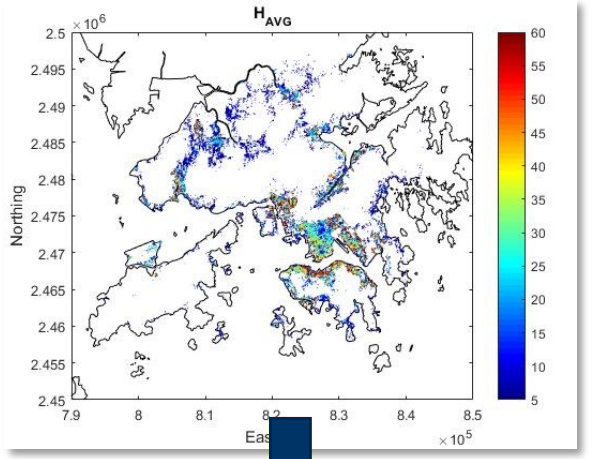


L12 UCP TOOL

Gridded UCP values



- Python based script *(open-source)*
- QGIS *(open-source and GUI)*
- User friendly for visualization of the data and statistics
- Under WUDAPT/NCAR/Github *(facilitate communication for further development)*
- Writing to WRF WPS tiles

WPS tiles

34801-36000.13201-14400-2020prdalbedo2020
34801-36000.13201-14400-2020prdalbedo2050
34801-36000.13201-14400-2020prdlanduse2020
34801-36000.13201-14400-2020prdlanduse2050
34801-36000.13201-14400-2020prdroughness2020
34801-36000.13201-14400-2020prdroughness2050

METHODOLOGY

INPUT DATA

- Building data in shape file format (e.g., own building data or DSC output)
- WUDAPT level-0 dataset
- Sentinel Satellite Vegetation output
- Google Satellite images/ OSM etc. (for visualization)

TOOLS

- Python and QGIS

OUTPUTs

e.g., WRF BEP/BEM

$$\boldsymbol{A_h} = \frac{\sum_i A_i \times H_i}{\sum_i A_i}$$

$$\boldsymbol{\lambda_p} = \frac{A_p}{A_T}$$

$$\boldsymbol{\lambda_b} = \frac{\sum_i A_i + Aw_i}{A_T}$$

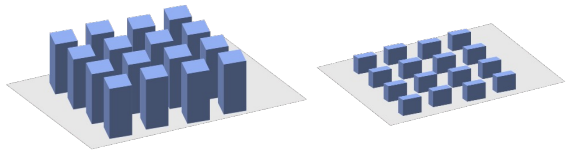
$$\boldsymbol{B_{pdf}}$$

$$\boldsymbol{U_{frac}} = \frac{A_U}{A_T}$$

URBAN CANOPY PARAMETERS ARE IMPORTANT TO RUN THE MULTI-LAYER BEP MODEL

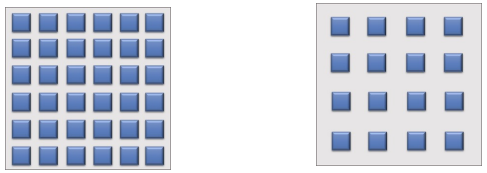
RUNNING THE URBAN MODULE (BEP) REQUIRES REAL BUILDING DATA

Area-weighted average building height



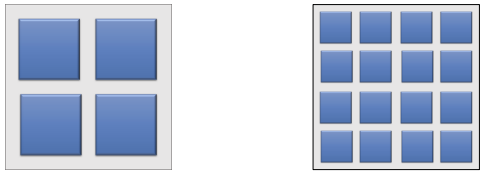
$$A_h = \frac{\sum_i A_i \times H_i}{\sum_i A_i}$$

Plan area ratio
(Ground coverage)



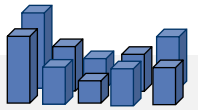
$$\lambda_p = \frac{A_p}{A_T}$$

Building surface-to-plan area ratio



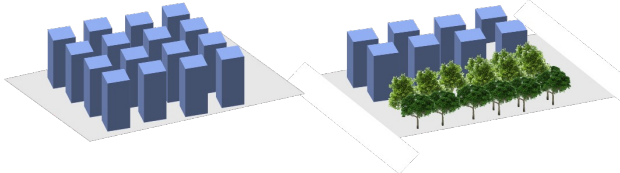
$$\lambda_b = \frac{\sum_i A_i + Aw_i}{A_T}$$

Building Height Distribution



$$B_{pdf}$$

Urban fraction



$$U_{frac} = \frac{A_U}{A_T}$$

Building width

$$B = \frac{2h\lambda_p}{\lambda_b + \lambda_p}$$

Street width

$$W = \frac{2h\lambda_p}{\lambda_b - \lambda_p}\left(\frac{U_{frac}}{\lambda_p} - 1\right)$$

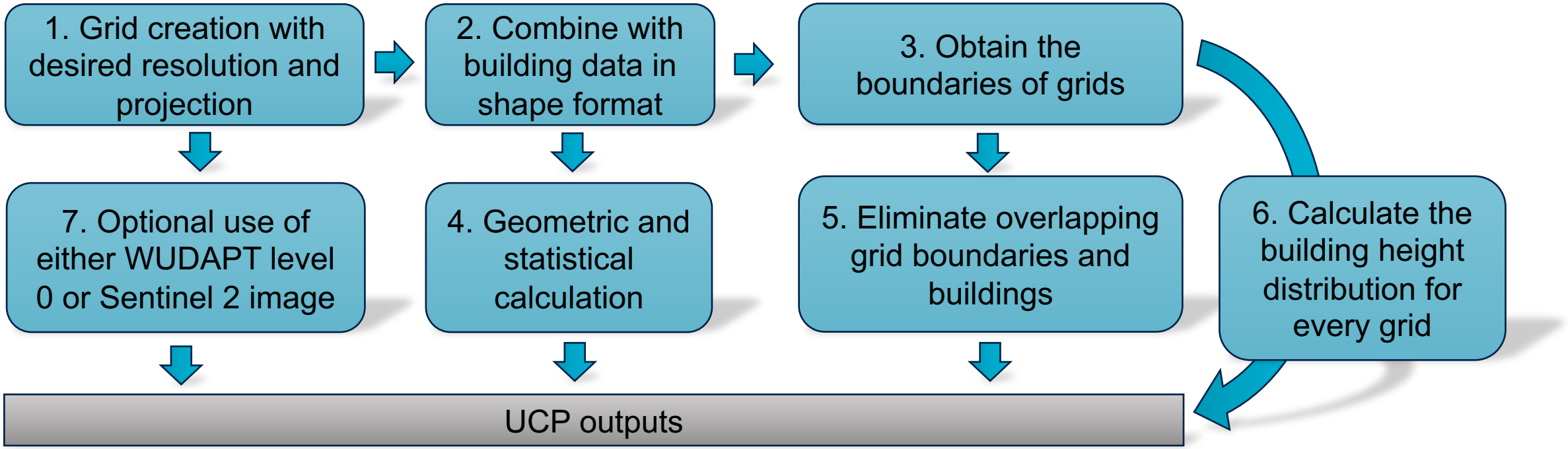
Martilli et. al. 2002

$$\vec{F}u_{iu}^{V} = -\rho C_d |U_{IU}^{ort}| \vec{U}_{IU}^{ort} S_{IU}^{V}$$

$$\vec{F}u_{iu}^{H} = -\rho \frac{k^2}{\left[\ln \frac{\frac{\Delta z_{IU}}{2}}{z_{oiu}}\right]^2} f_m\left(\frac{\frac{\Delta z_{IU}}{2}}{z_{oiu}}, Ri_B\right) |U_{IU}^{hor}| \vec{U}_{IU} S_{IU}^{H}$$

Ching et. al. 2009

WORKFLOW



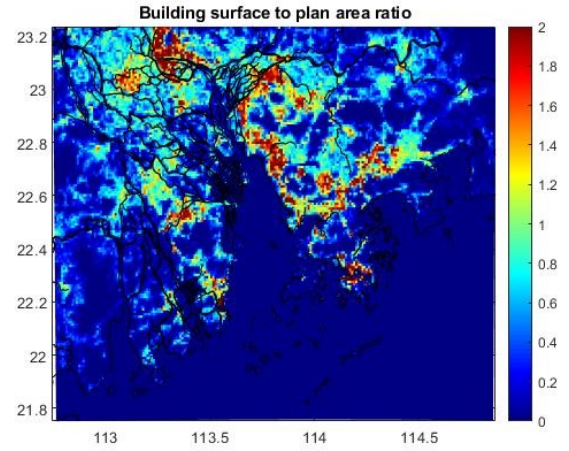
python + QGIS

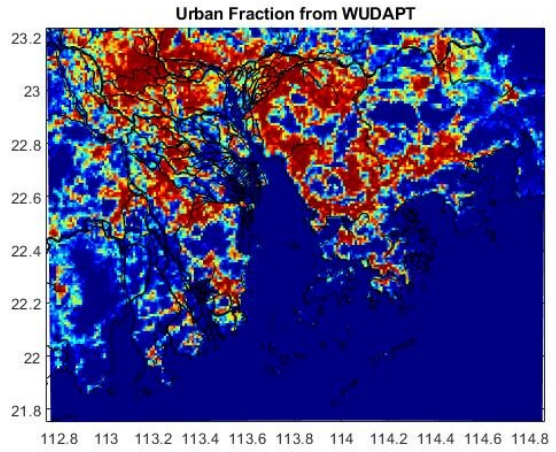
We automate and document this process, with PYTHON scripts & QGIS functions for end user.

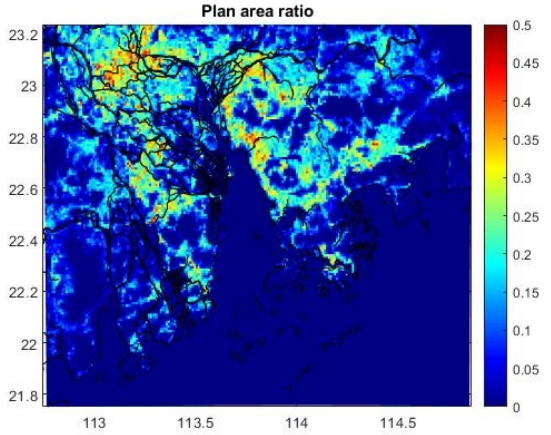
LIST OF UCPS CAPABILITY SO FAR

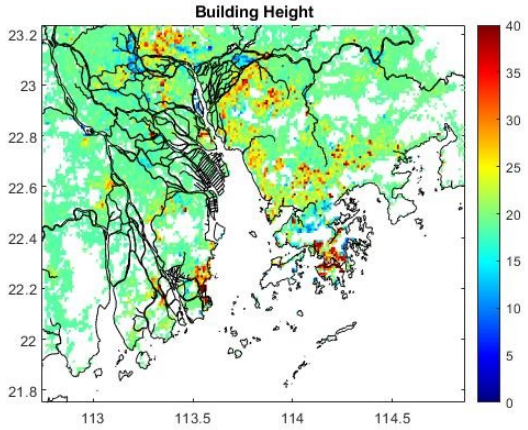
PREDOMINANTLY FOR WRF-BEP

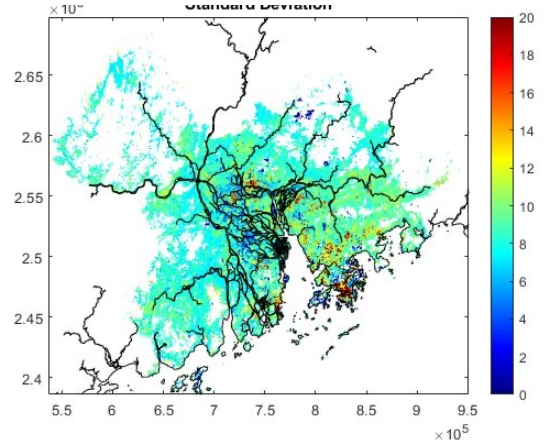
- Building Height
- Plan area ratio
- Building surface to plan area ratio
- Standard deviation of building height
- Urban Fraction
- Building Height Distribution

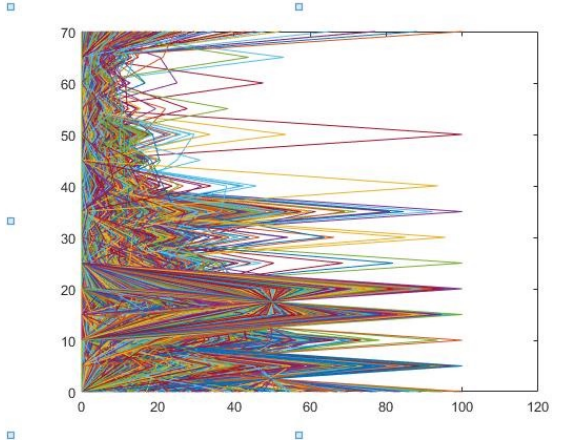










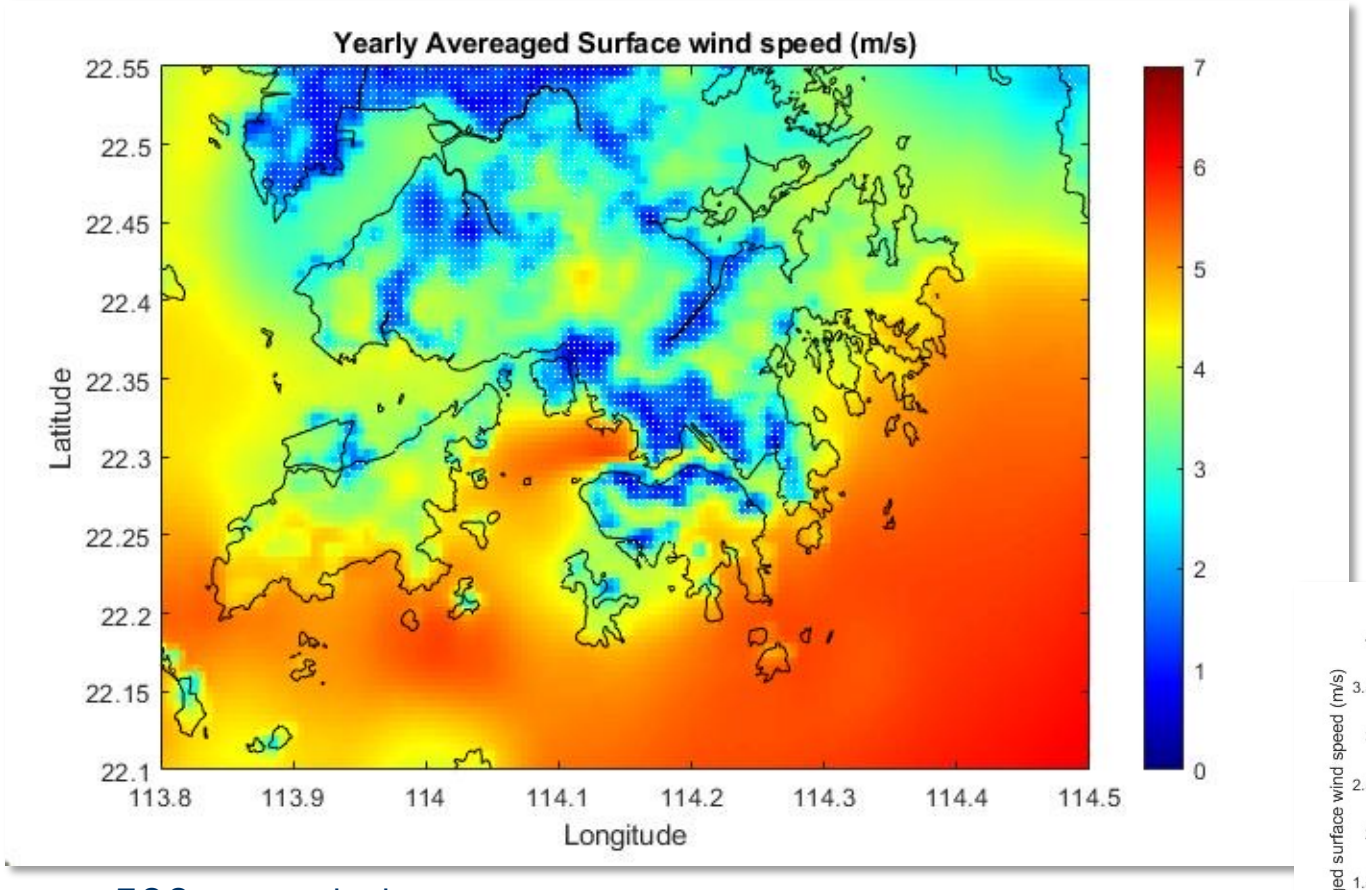


APPLICATION EXAMPLES

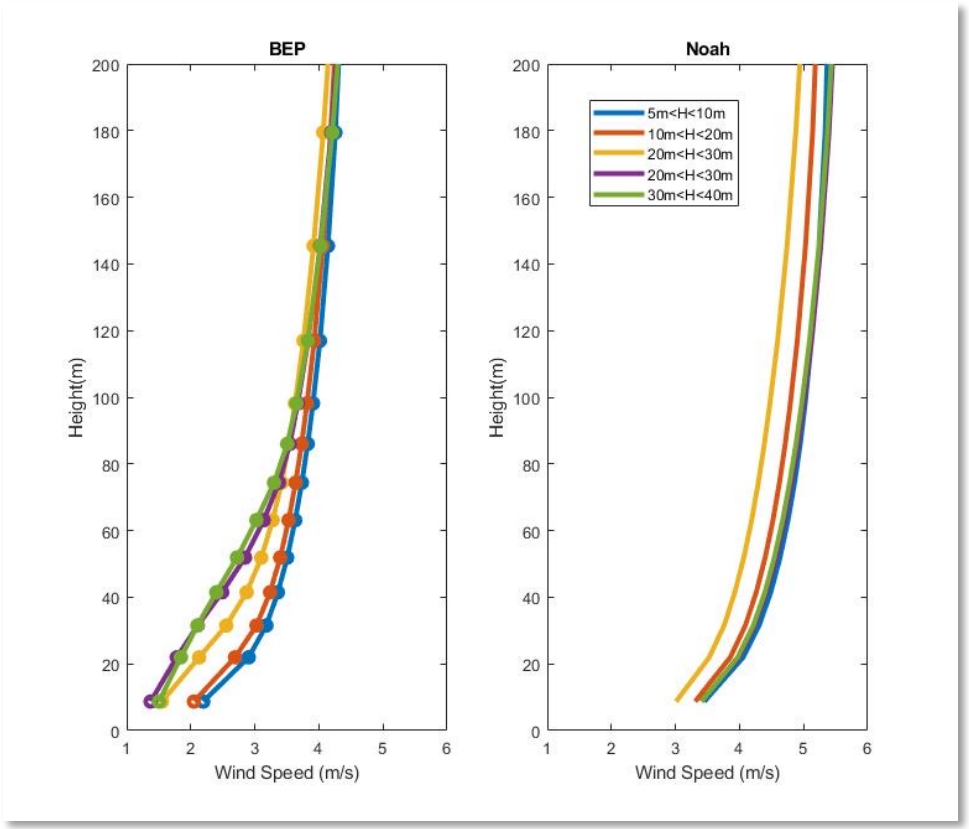
1. WRF BEP/BEM simulation
2. Apply to other regions
3. UCPs at different resolutions
4. Update one's look-up table
5. Other schemes
6. Studies with Satellite images/ surface stations

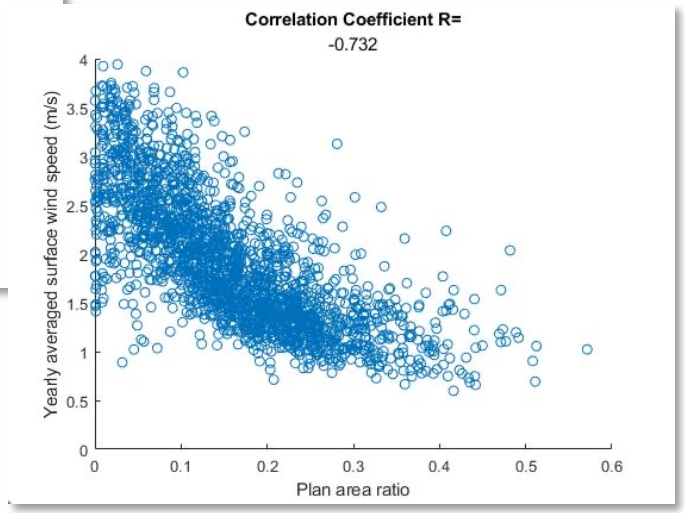
WRF BEP/BEM SIMULATION

APPLICATION 1



500m resolution

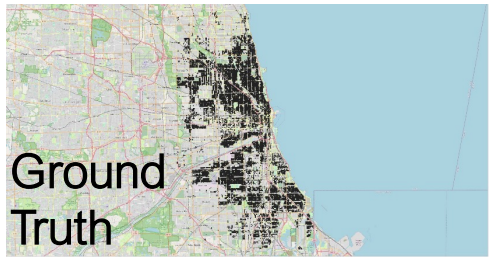


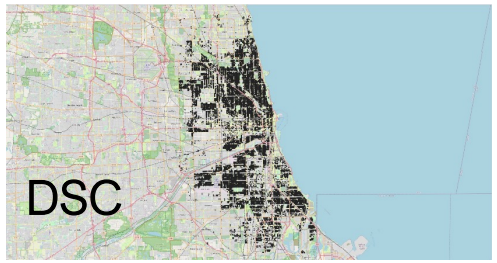


L12
UCP TOOL

OTHER REGIONS (E.G., CHICAGO)

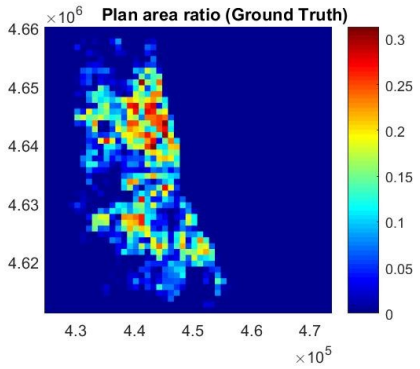
APPLICATION 2

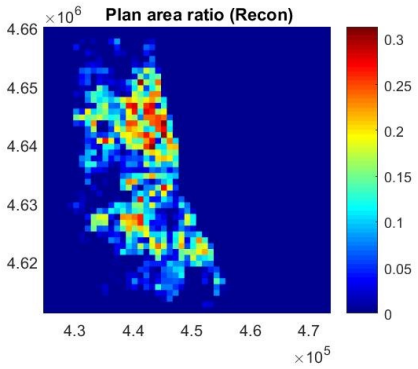


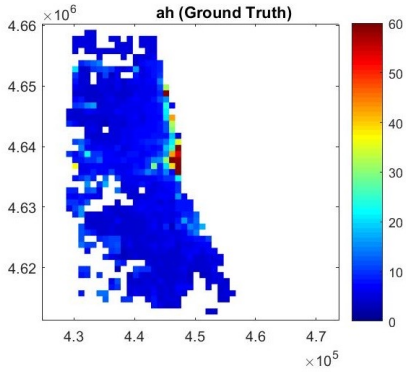


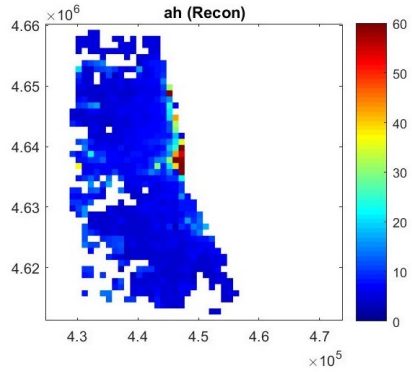
e.g., plan area ratio and area weighted building height

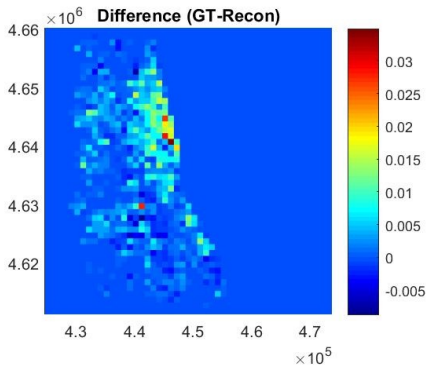
He et al. 2022

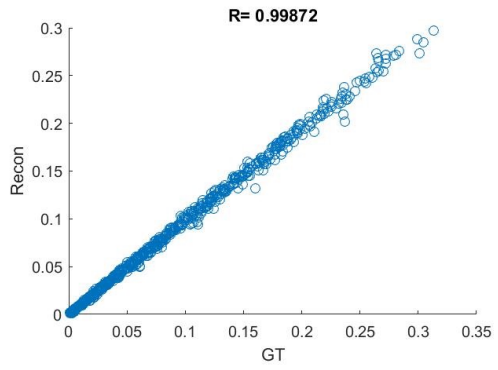


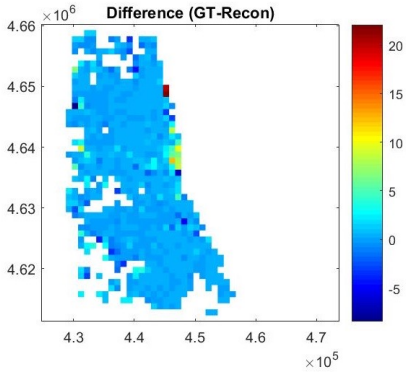


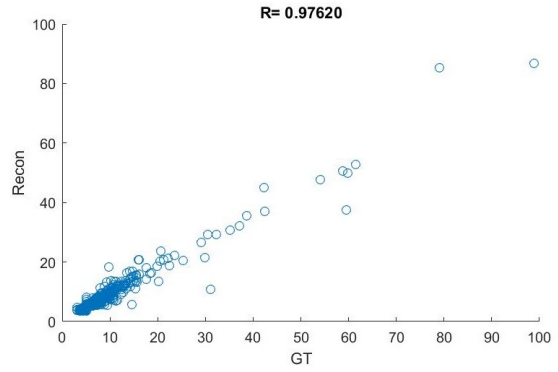






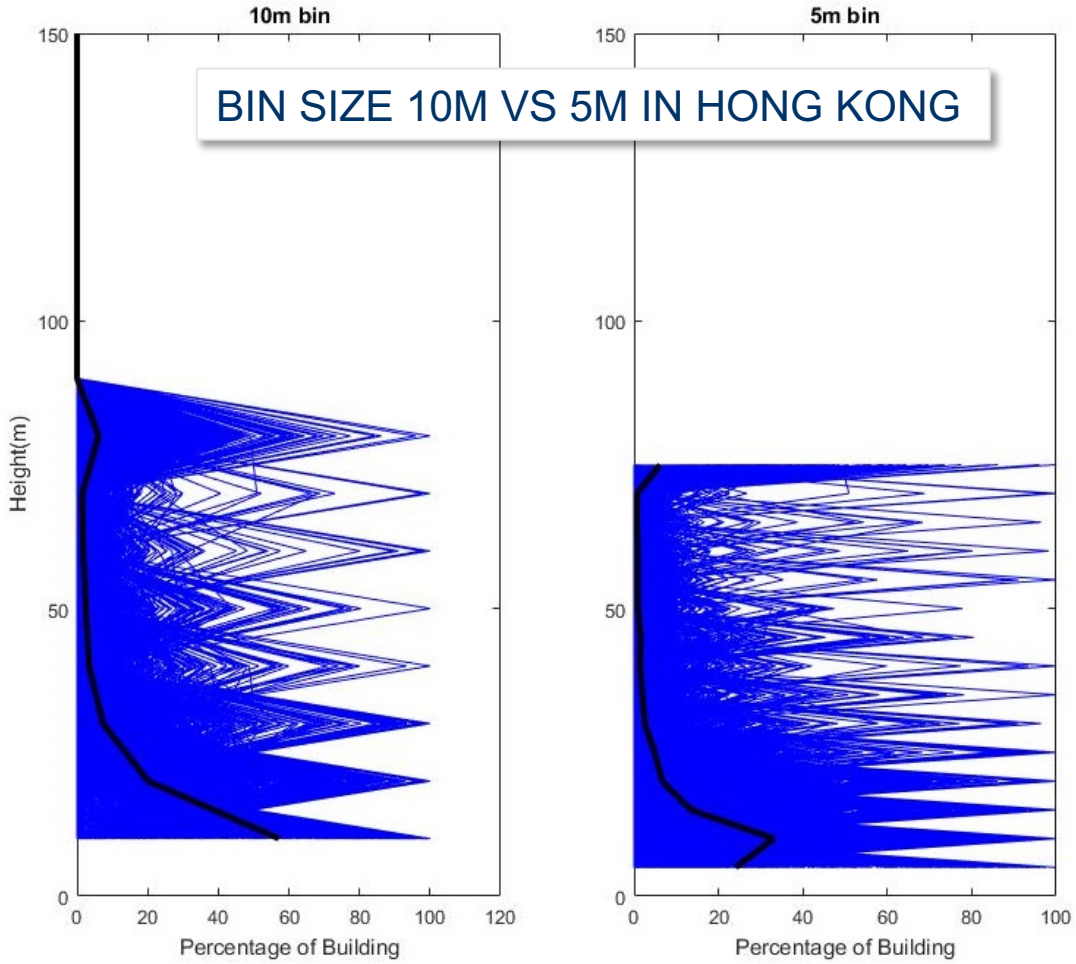


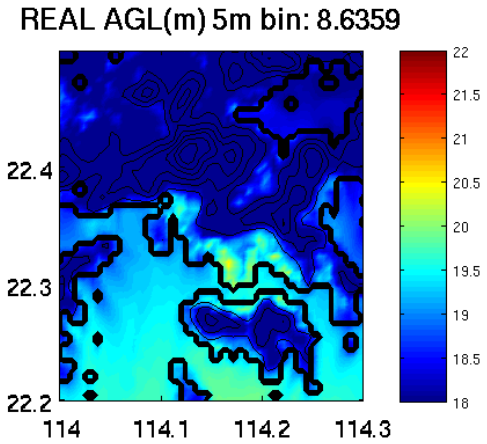


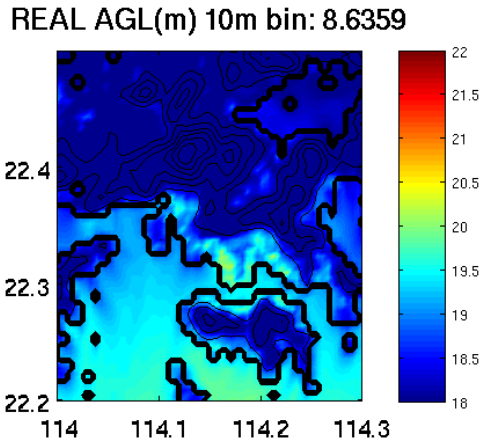


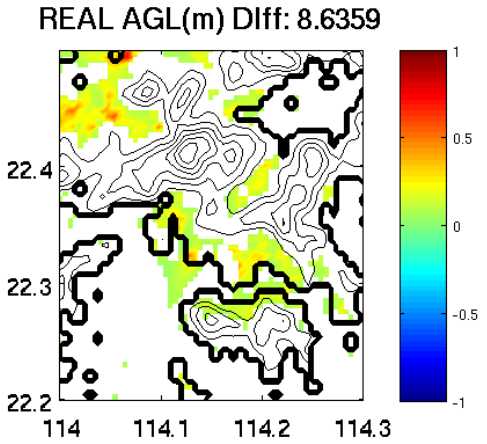
COMPUTING DIFFERENT VERSIONS OF UCPS FOR WRF BEP BEM (VERTICAL AND HORIZONTAL)

APPLICATION 3







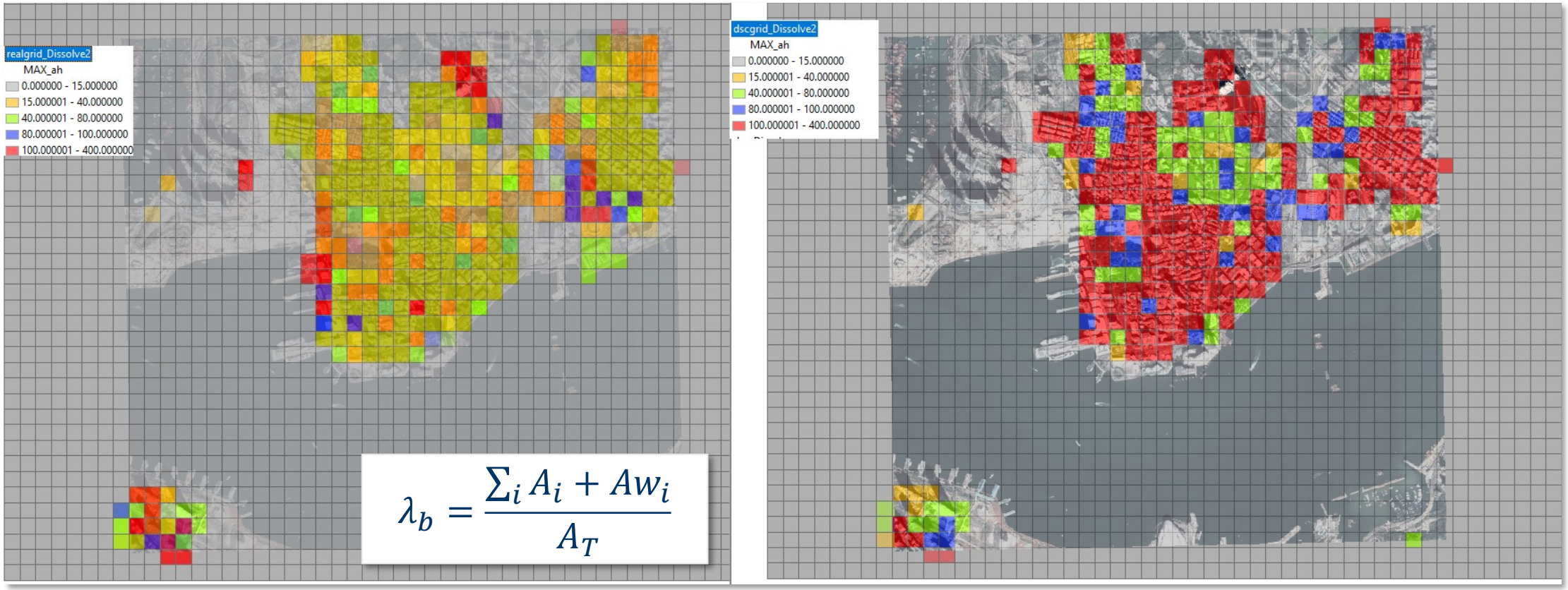


WRF wind field over Hong Kong for different bin sizes

COMPUTING DIFFERENT VERSIONS OF UCPS FOR WRF BEP BEM (VERTICAL AND HORIZONTAL)

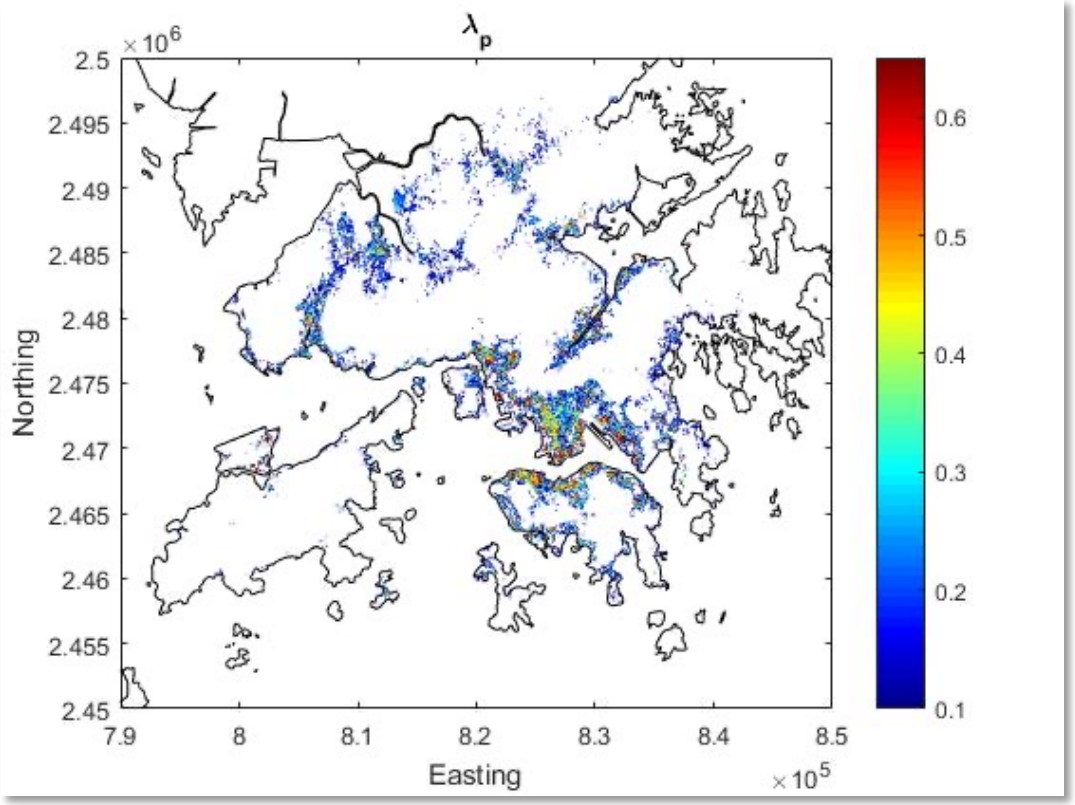
APPLICATION 4

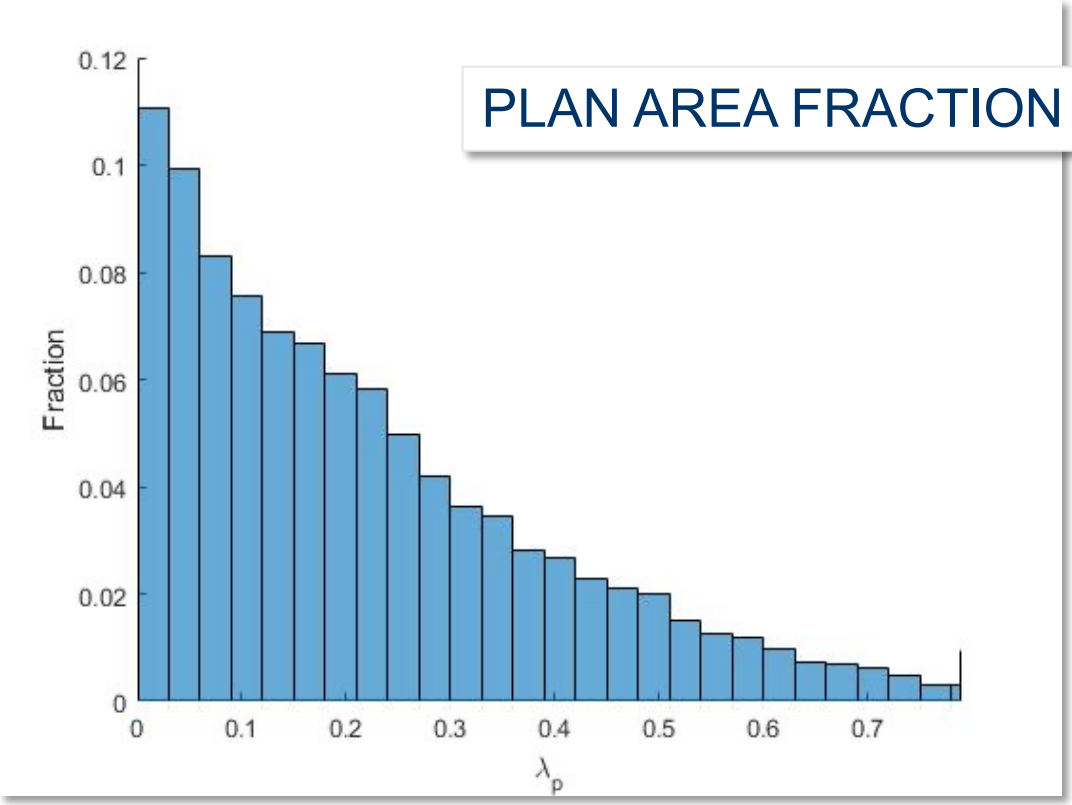
After the calculations, we obtain the UCP values from DSC for every grid



OWN LOOK UP TABLE

APPLICATION 4

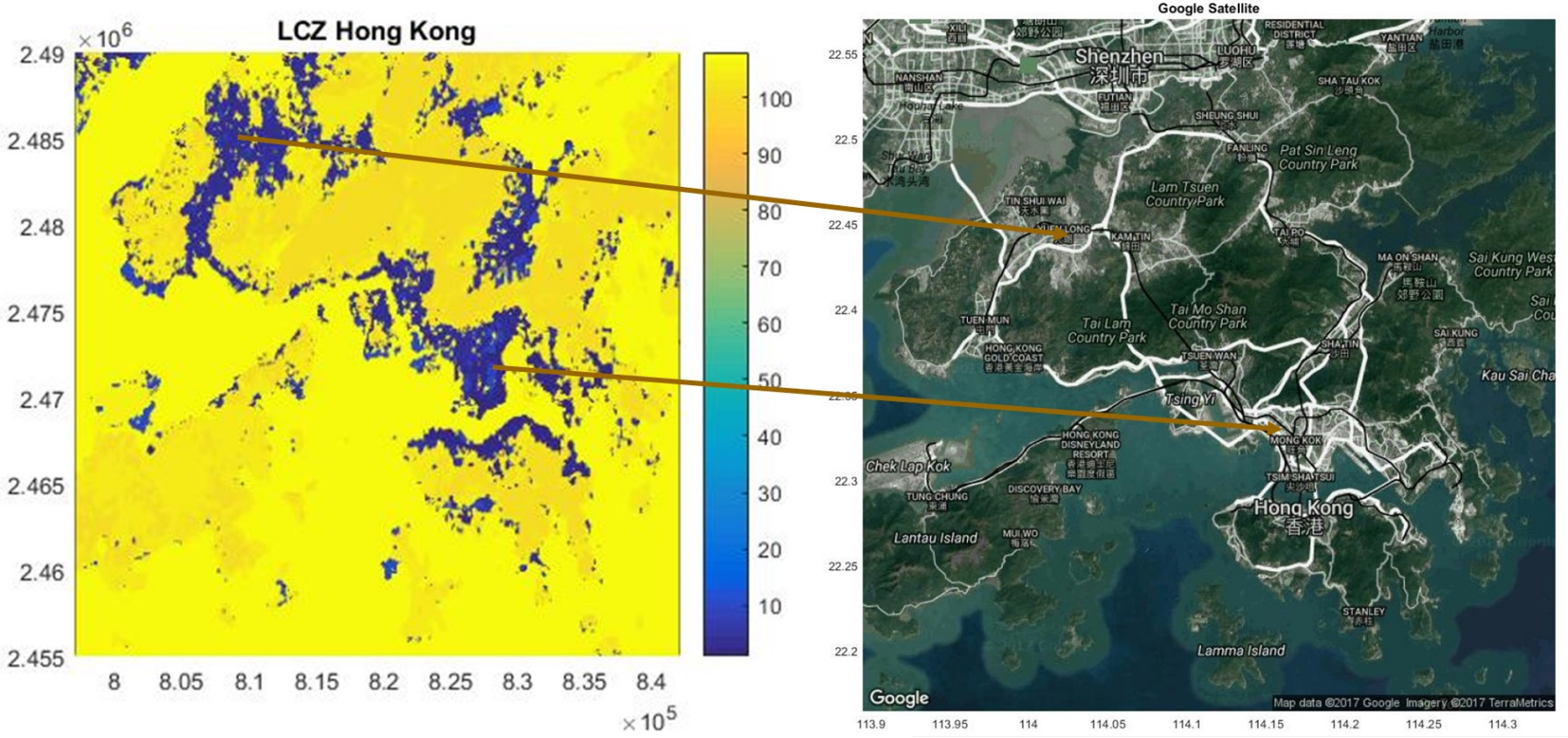




PLAN AREA FRACTION (λ_p)

OWN LOOK UP TABLE

APPLICATION 4



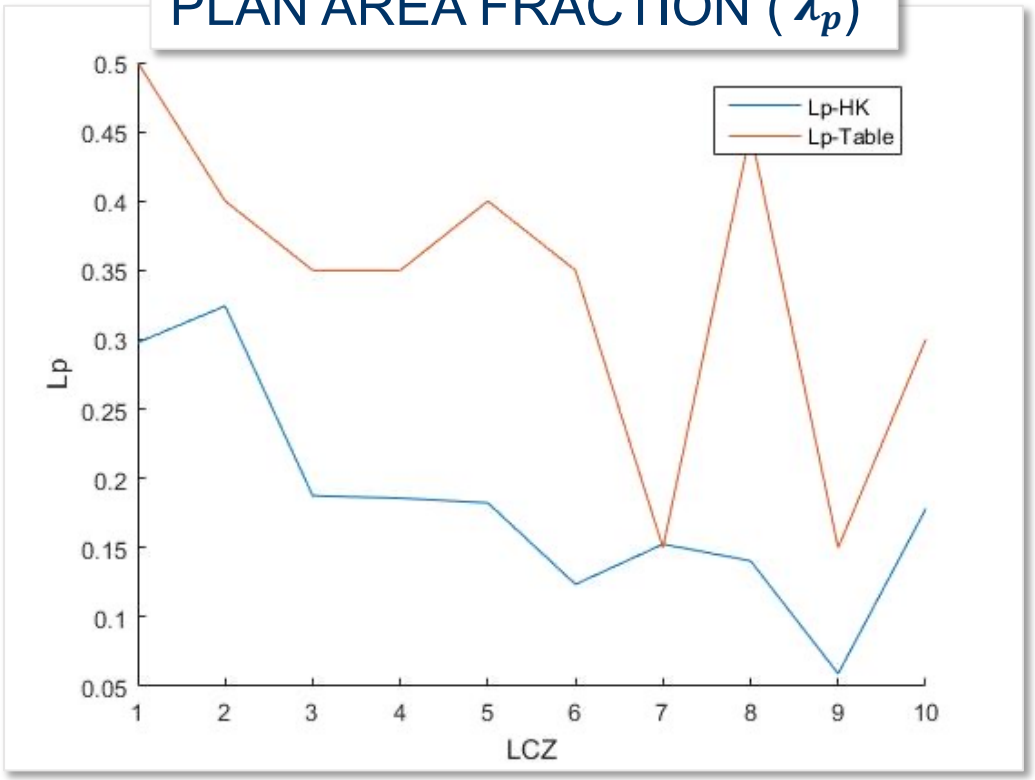
Ren et al. 2016

The WUDAPT level-0 data is promising in identifying the urban area in Hong Kong when compared to Google Satellite image

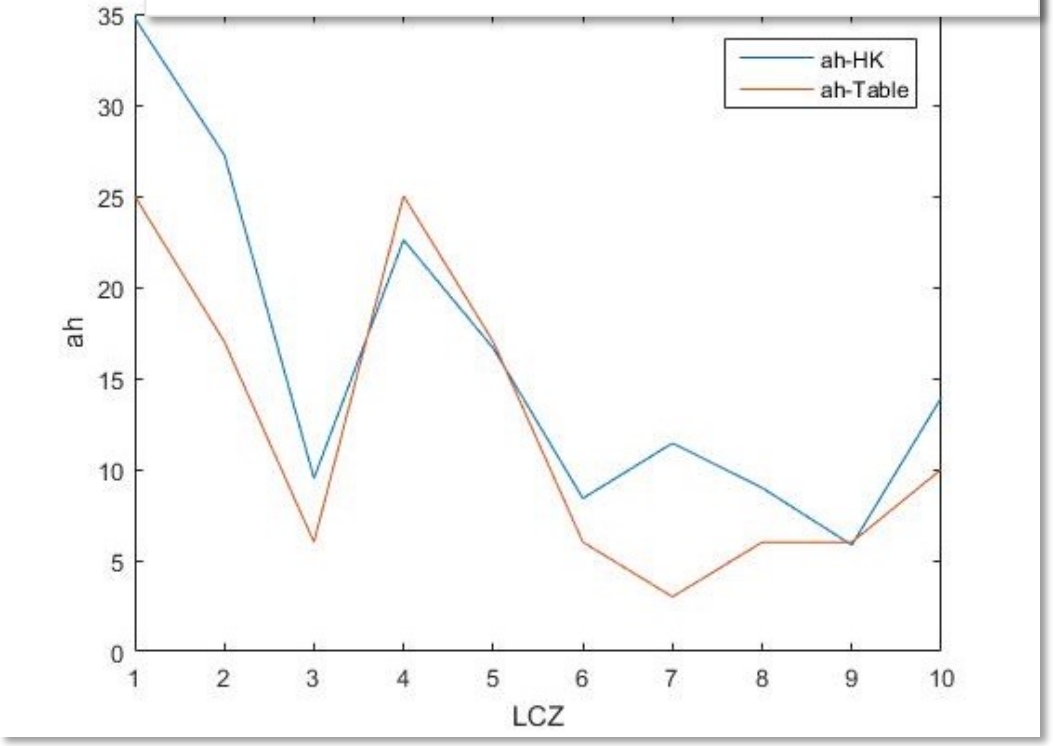
COMPARISON: LOOKUP TABLE VS. MEDIAN
(HK BUILDING DATA & WUDAPT LEVEL-0)

APPLICATION 4

PLAN AREA FRACTION (λ_p)



AREA WEIGHT BUILDING HEIGHT



- Look up table has a higher plan area fraction than the median in Hong Kong
  (possible reason: WUDAPT level-0 identified region with not many building to LCZs 1-6).
- Area weighted building height match well with the look up table *(Hong Kong buildings should be taller)*

EXTENSION TO OTHER VARIABLES

APPLICATION 5

Macdonald's Method, and Kanda's Method

$$z_{0_{Kanda}} = (a_1 + b_1\left(\frac{\lambda_p \sigma_H}{H_{ave}}\right)^2 + c_1(\frac{\lambda_p \sigma_H}{H_{ave}}))H_{ave}A^{-\lambda_p}(1-\lambda_p)\exp[-\left\{0.5\beta\frac{C_{1b}}{k^2}A^{-\lambda_p}(1-\lambda_p)\lambda_f\right\}^{-0.5}]$$

$$z_{0\_Mac} = H_{ave}A^{-\lambda_p}(1-\lambda_p)exp[-\left\{0.5\beta\frac{C_{1b}}{k^2}A^{-\lambda_p}(1-\lambda_p)\lambda_f\right\}^{-0.5}]$$

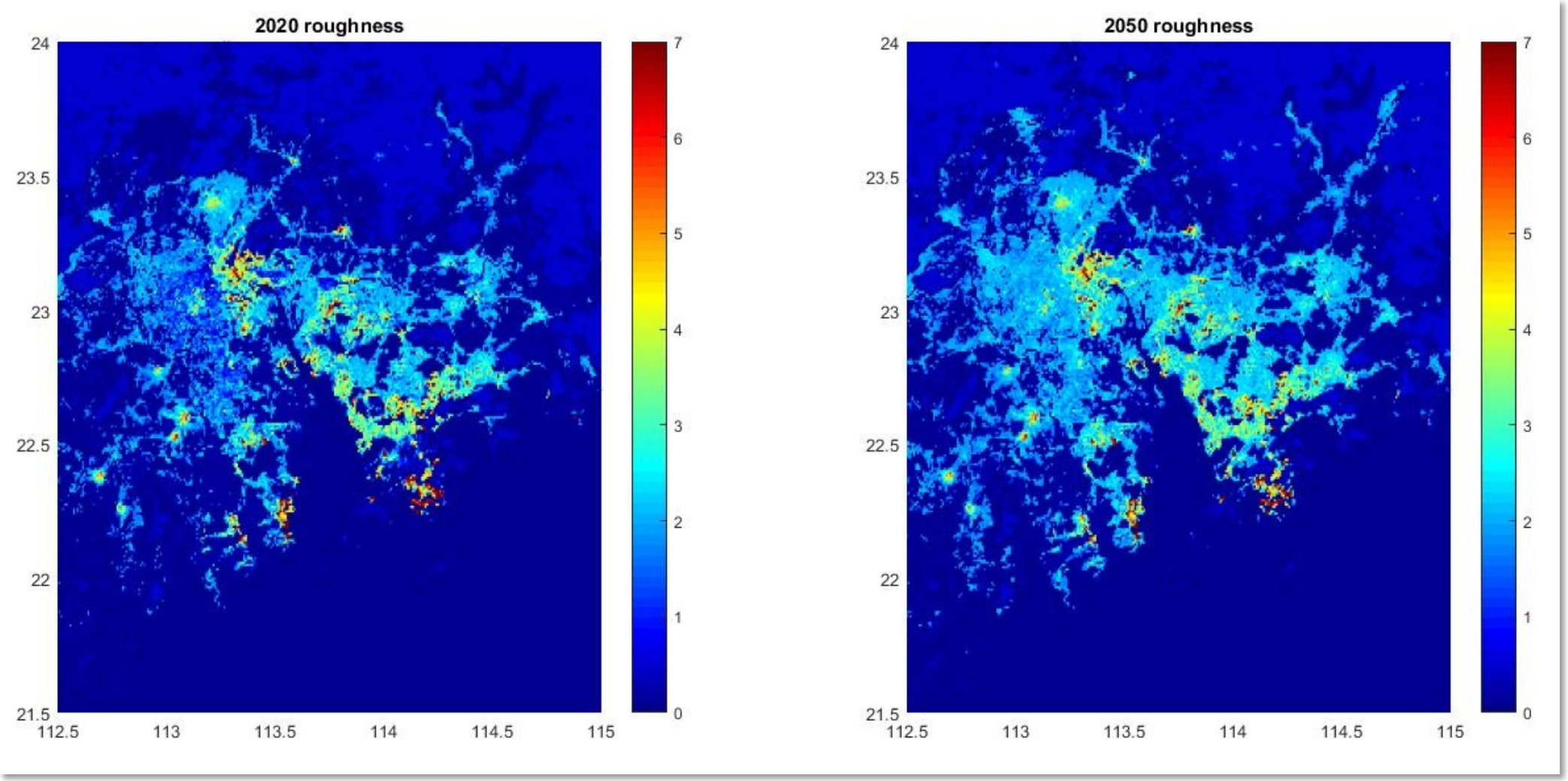
where

$$(a_1, b_1, c_1, C_{1b}, k, A, \beta) = (1.29, 0.36, -0.17, 20.21, -0.77, 1.2, 0.4, 4.43, 1.0)$$

Macdonald et al. 1998 Kanda et al., 2013

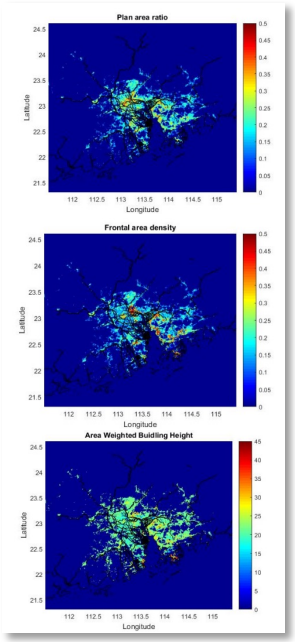
EXTENSION TO OTHER VARIABLES

APPLICATION 5

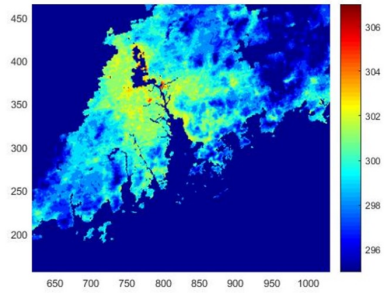


STUDIES WITH SATELLITE IMAGES/ SURFACE STATIONS

APPLICATION 6



Training area and data

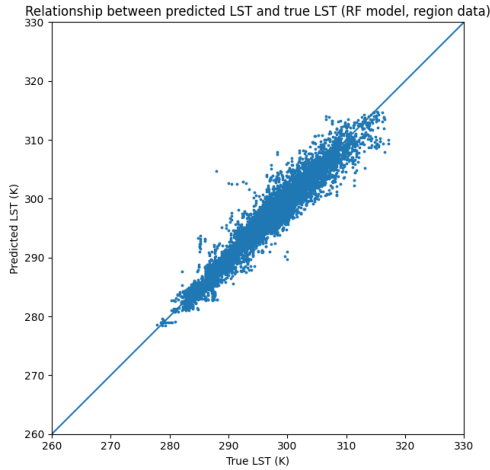


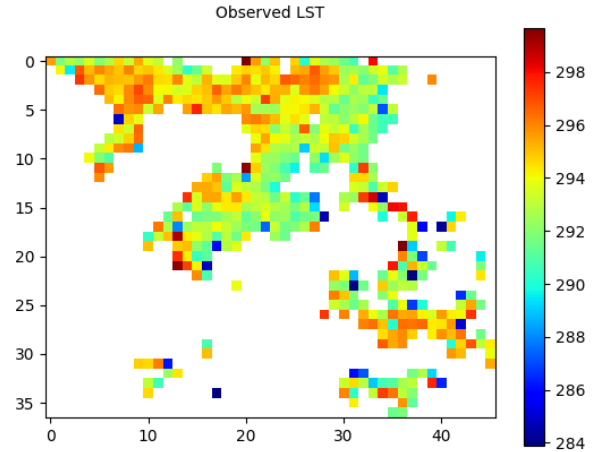
Morphology and satellite observed temperature

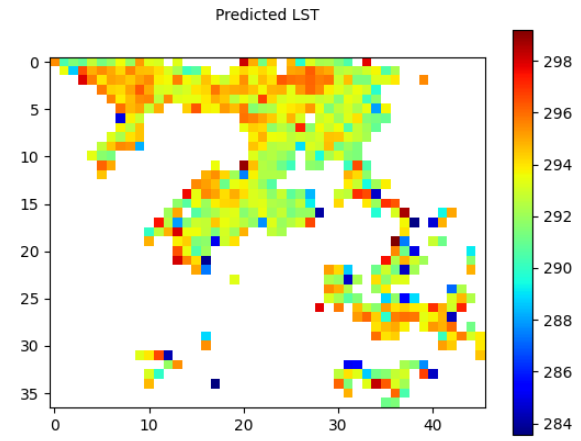
Machine learning or statistical methods

TensorFlow PyTorch Keras

Relationship between urban morphology and satellite observed temperature.



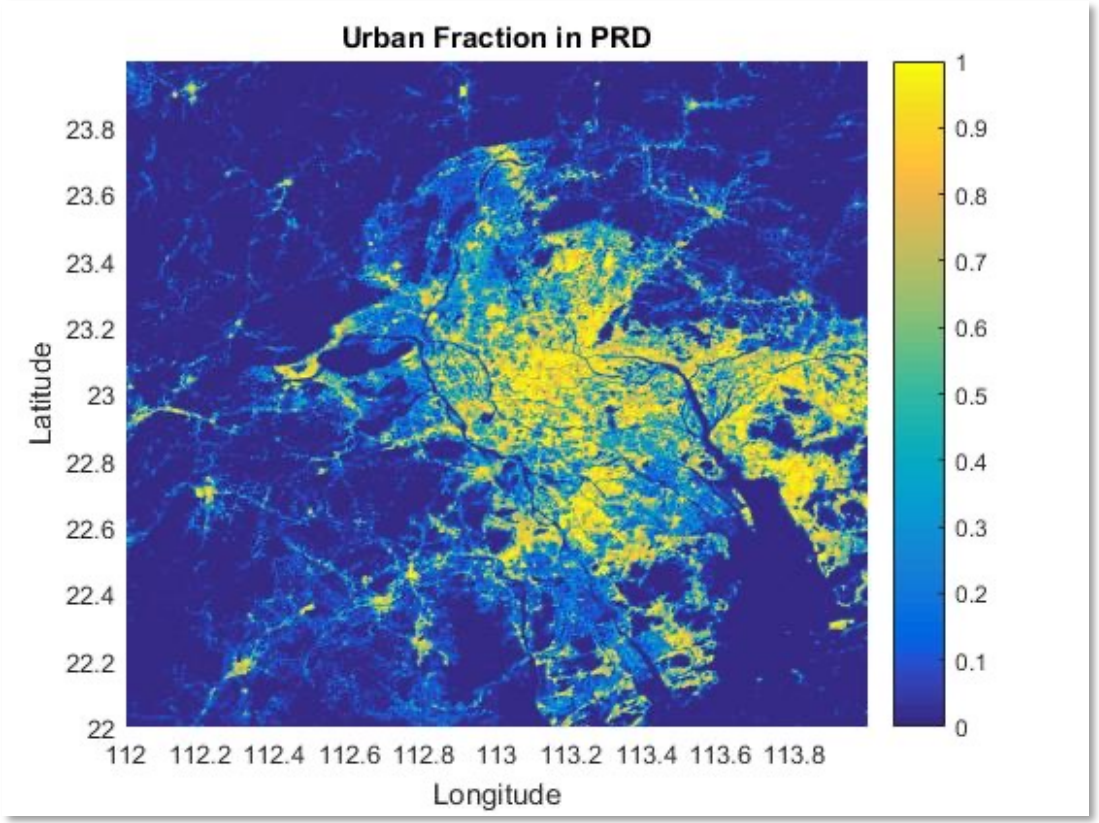




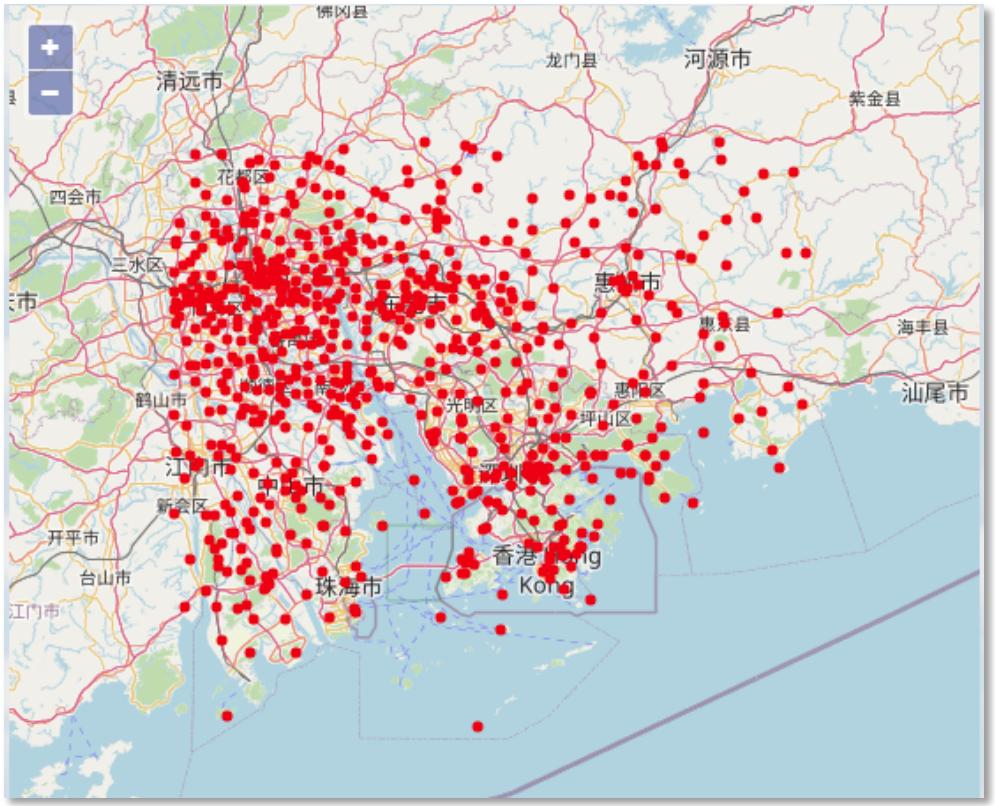
STUDIES WITH SATELLITE IMAGES/ SURFACE STATIONS

APPLICATION 6

Very high-resolution land use (10m)

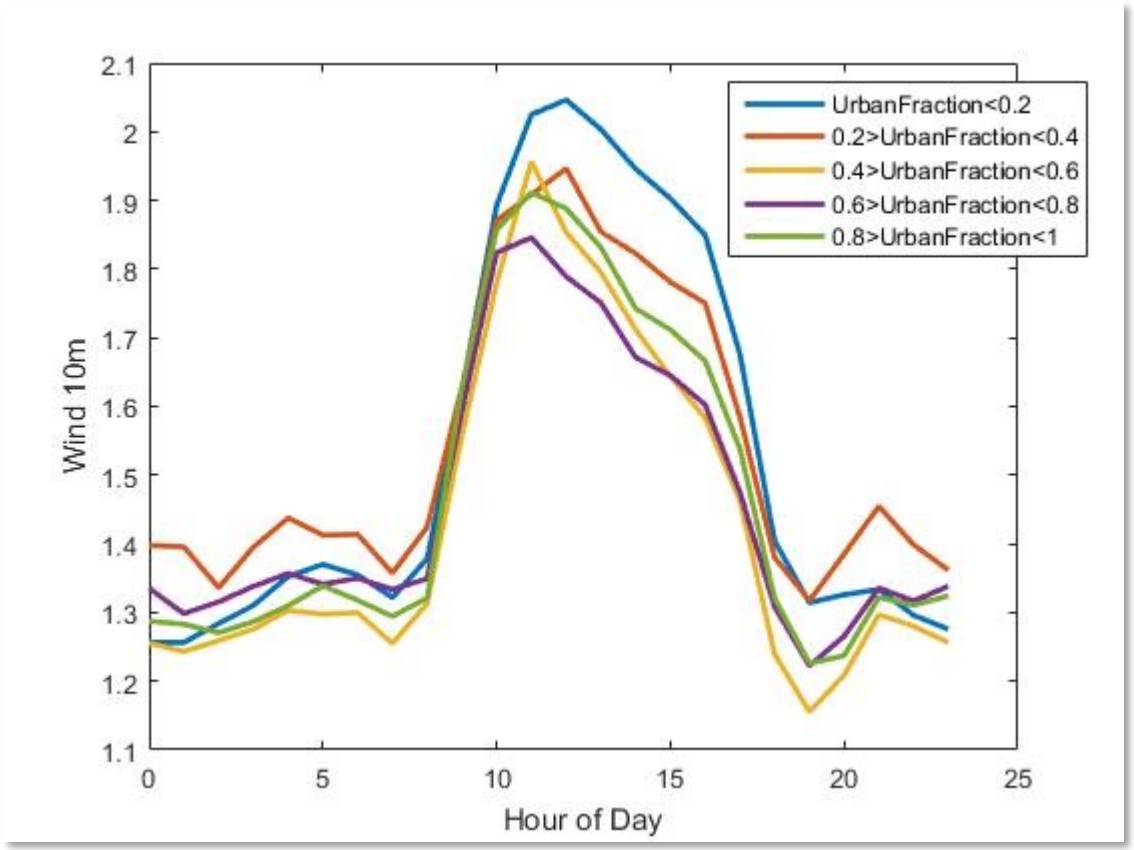


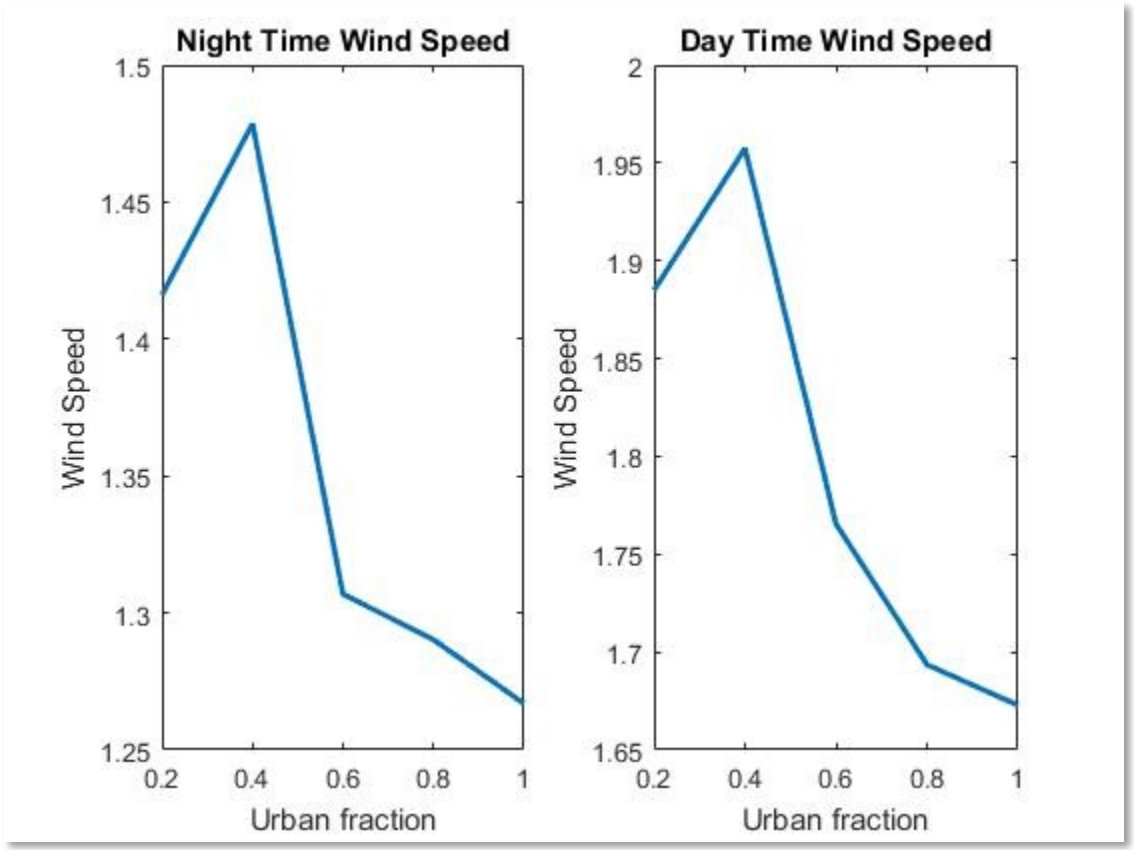
Observation Network 717 stations



STUDIES WITH SATELLITE IMAGES/ SURFACE STATIONS

Over the whole month, the observed average wind speed in PRD decreases with the increase in urban fraction.





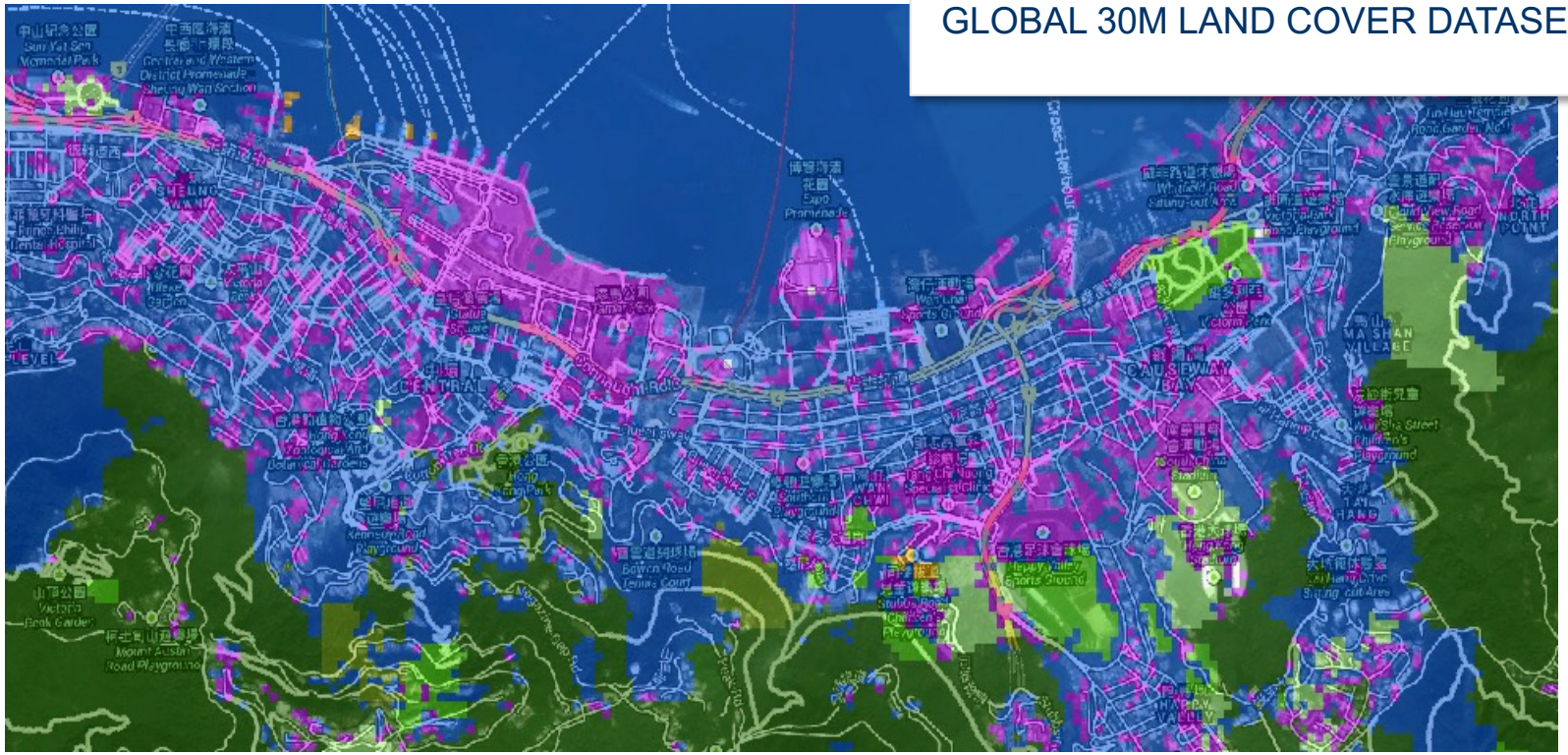
APPLICATION EXAMPLES

1. WRF BEP/BEM simulation
2. Apply to other regions
3. UCPs at different resolutions
4. Update one's look-up table
5. Other schemes
6. Studies with Satellite images/ surface stations

Many more……

GUIDANCE FOR USING URBAN FRACTION DATA

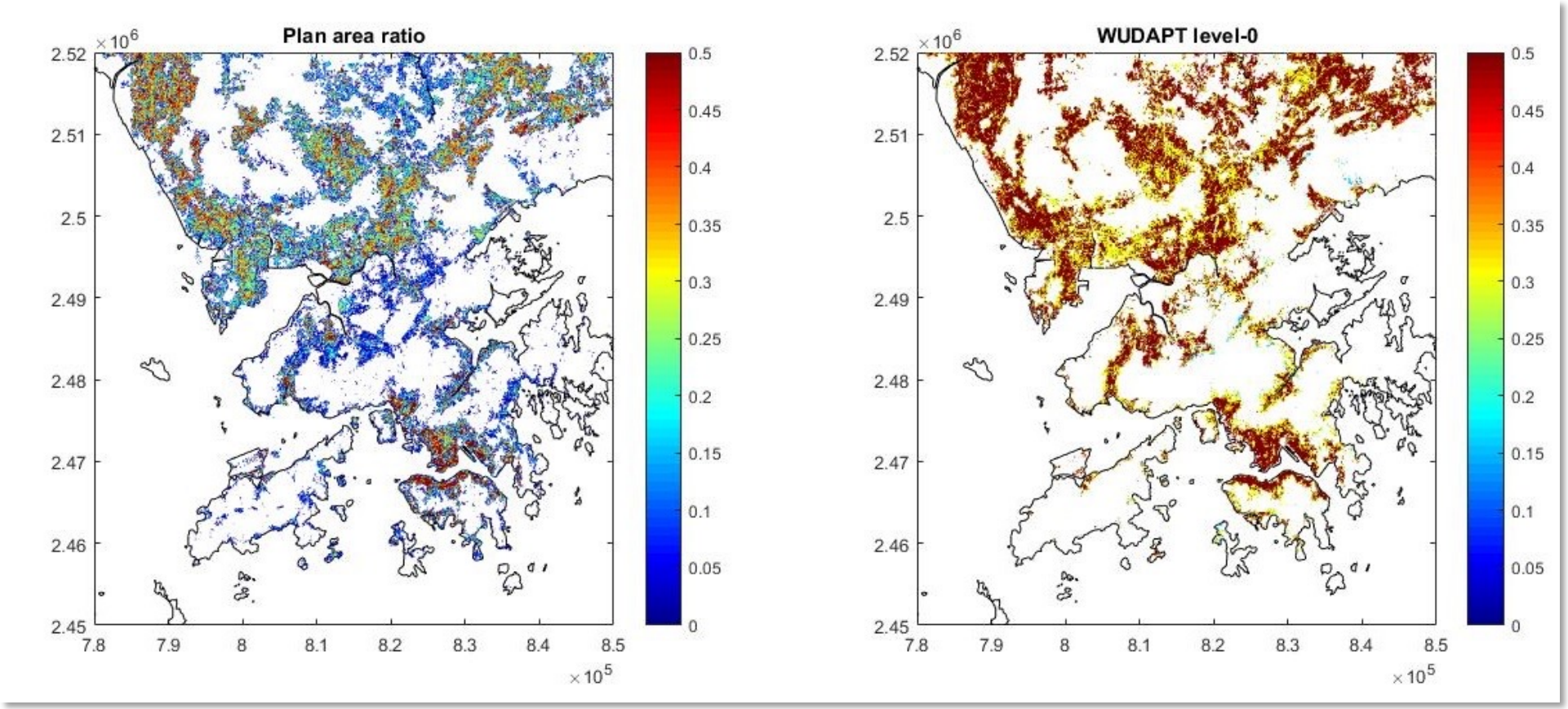
- UCP tool obtains building related parameters and urban fraction data separately
- Inconsistence exists sometimes



Chen J et al. ,2014

GUIDANCE FOR USING URBAN FRACTION DATA

- Zoomed-in view of Shenzhen and Hong Kong, much more heterogenous information than the WUDAPT level-0 look up table



Wong et al. 2019

SUMMARY AND PLAN

SUMMARY

1. We build a open source UCP tool for the community
2. The tool would be made available soon after publication
3. The tool can facilitate a lot of urban related research for different interested parties (as illustrated in the examples)

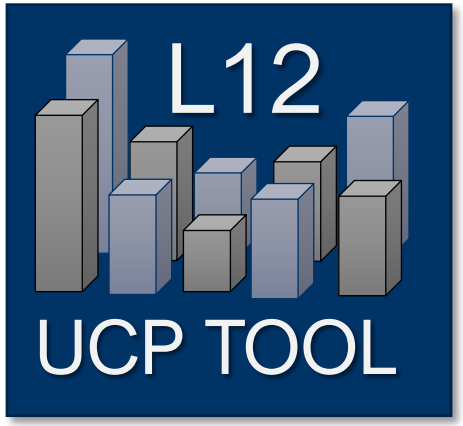
PLAN

1. Extend the tools capability to other variables
2. Combine with map's API to get other urban information
3. Extend the tool to other models (e.g., MPAS)

THANK YOU!

Michael M.F. Wong

Hong Kong University of Science and Technology



UCP = Urban Canopy Parameters

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