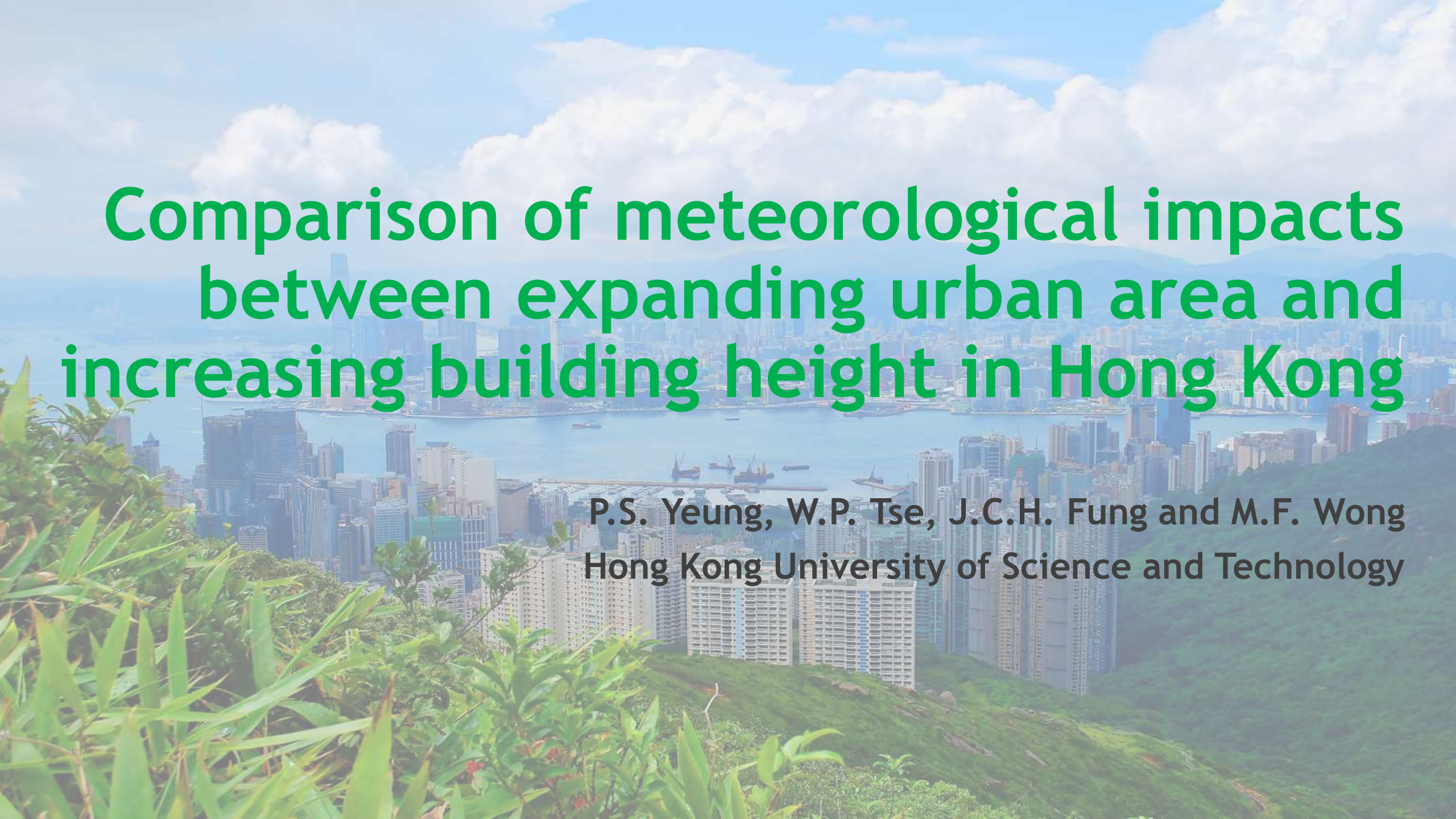

Comparison of meteorological impacts between expanding urban area and increasing building height in Hong Kong

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Motivation

- **Landscape of Hong Kong**
  - Lots of steep hilly terrain
  - Urban development are limited

- Development is also limited by laws
  - Around 44,300 hectares (40% of total land area) are protected according to ***Country Parks Ordinance***

Situation

- **What if Hong Kong's population increased by 30%?**
- Two of the solutions to accommodate the increased population:
  1. **Expand urban area by 30% more**
  2. **Increase the buildings height by 30%**
  - Either of this will bring impact towards the urban environment (for example increase **urban heat island effect**)

Objective:

How each type of aforementioned urban development will affect the urban weather?

Why important?

- Example: Urban heat island
- Human activities provide extra heat in urban area
  - Especially air-conditioning
- Buildings in urban area also play an important role
  - Trapping solar radiation
  - Concrete absorbs radiation during day time and release at night time
  - Heat is difficult to disperse due to bad ventilation
- These factors will greatly affect the temperature, **hence the weather**
- **A model which is capable to simulate urban physics is required**

Methodology

- **Weather Research and Forecast Model (WRF)** is used for simulations

- Simulations are performed with these three scenarios
  - Current scenario **(Control run)**
  - **Scenario 1**: Expand urban area by **30%** more in Hong Kong
  - **Scenario 2**: Increase all buildings height by **30%** in Hong Kong

- **Direct comparison of results** were made to evaluate the impacts of each scenario

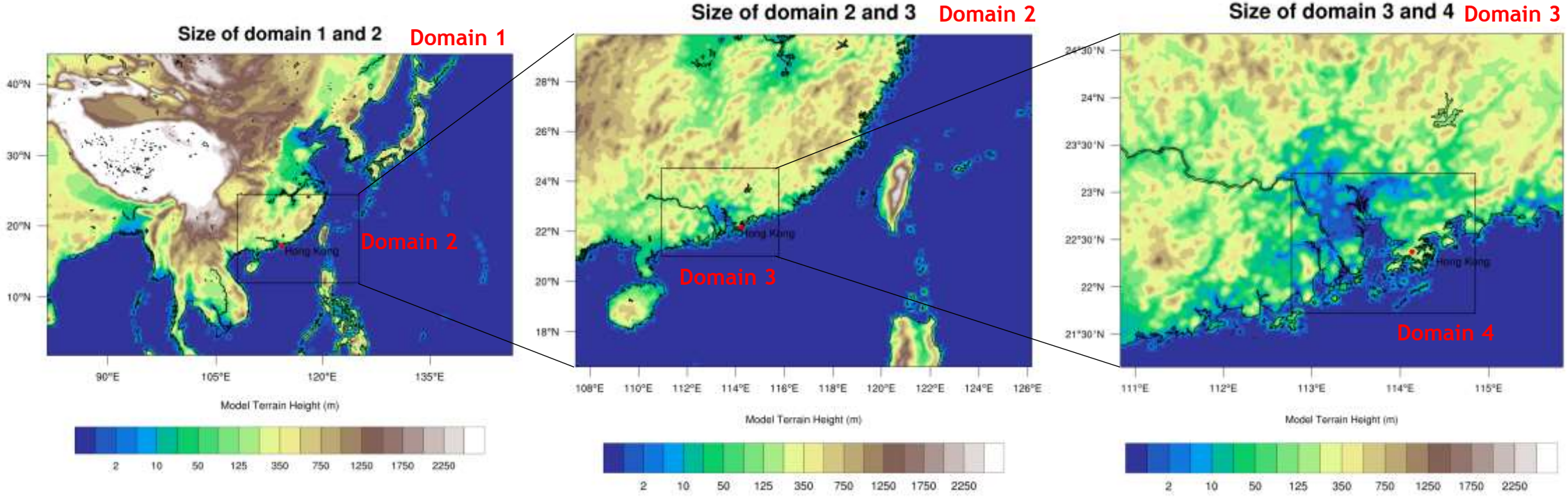
Methodology: Simulation period

- Simulation time: July 10, 2010 – July 14, 2010
  - Typical summer period
  - Weather condition: sunny and weak wind in Hong Kong
  - Allow significance heat island effect to occur

- First day of model results (10th July) are not used (Model spin-up time)

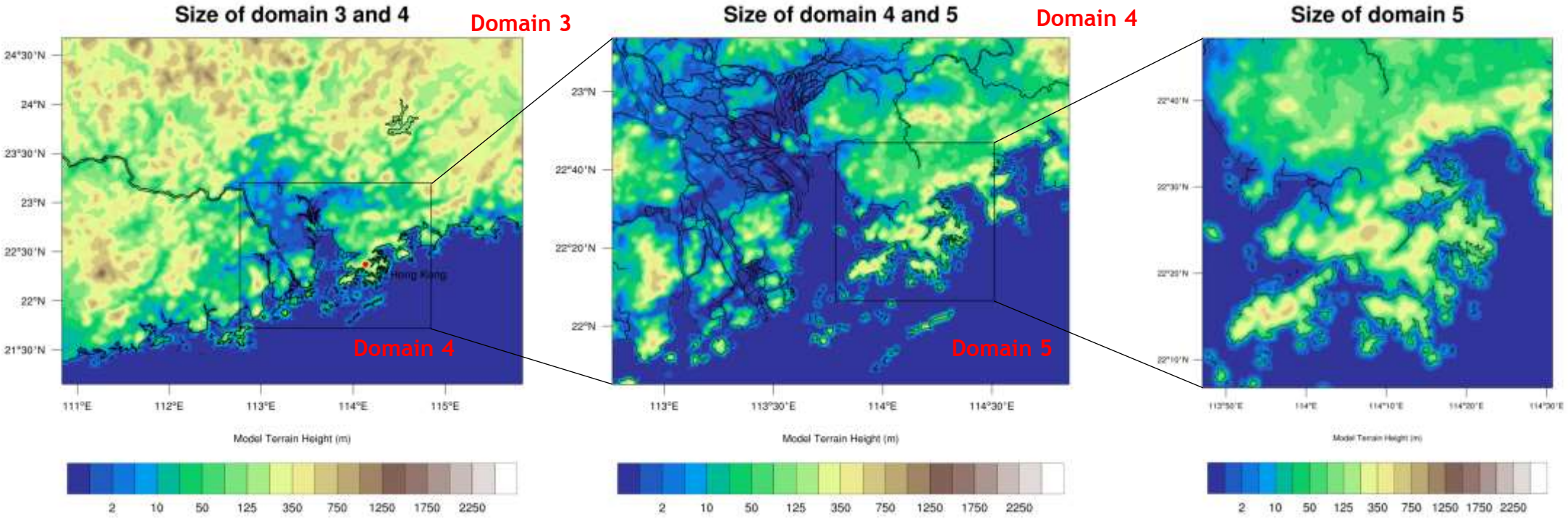
Methodology: Domain configuration

- There are total 5 domains in our simulation
- Decreasing covering range of domains allowing us to obtain the finer resolution of results
- **Domain 1 – 4 were first simulated**



Methodology: Domain configuration

- Domain 5 was simulated separately using domain 4 output
  - Different scenarios were simulated only in domain 5
  - Model settings are also different when compared with previous 4 domains



Methodology:
Model and Physics scheme configuration

- There are some changes between domain 1 – 4 and domain 5

	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5
Covering location	Asia	South China	Guangdong Province	Pearl River Delta	Southern Shenzhen & Hong Kong
Grid size (km)	27	9	3	1	0.5
Number of eta-levels	48				
Planetary Boundary Layer Scheme	Bougeault-Lacarrere Scheme (BouLac)				
Surface Layer Options	MM5 Similarity Scheme				
Land surface physics scheme	Unified Noah Land Surface Model				
Urban surface physics scheme	Turned off				Building Environment Parameterization (BEP) & Building Energy Model (BEM) Schemes

Methodology: Urban physics configuration

- Building Environment Parameterization (BEP) & Building Energy Model (BEM) Schemes
  - These schemes will perform calculation when the grid is classified as urban land use so as to include the urban physics
  - Amount of heat generated (or stored) is based numerous factors
    - **Types of urban land use available**
      - Low-rise
      - High-rise
      - Commercial and industrial

Scenario 1: Expanding urban area by 30% more

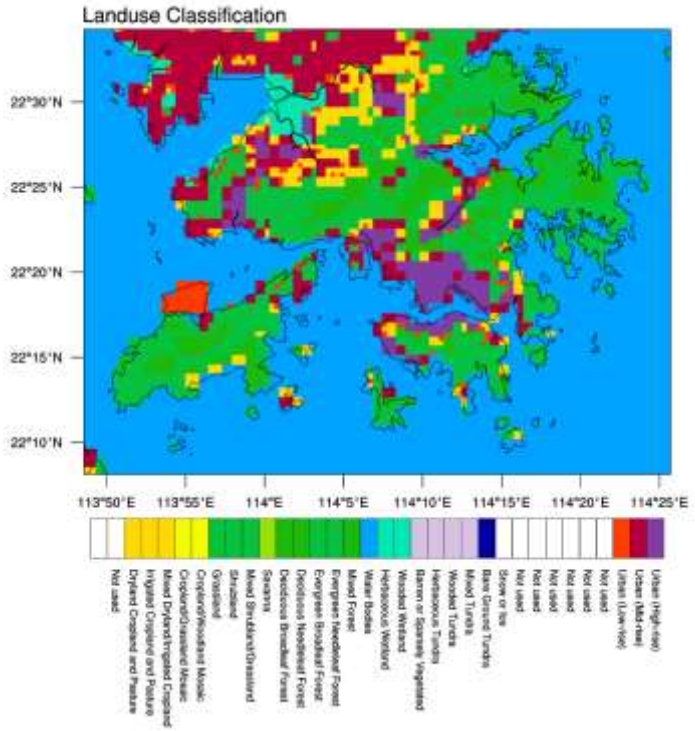
Scenario 2: Increasing building heights by 30%

- **Building height distribution with respective to urban land use**
- **Thermal property of buildings: Similar thermal property with concrete**

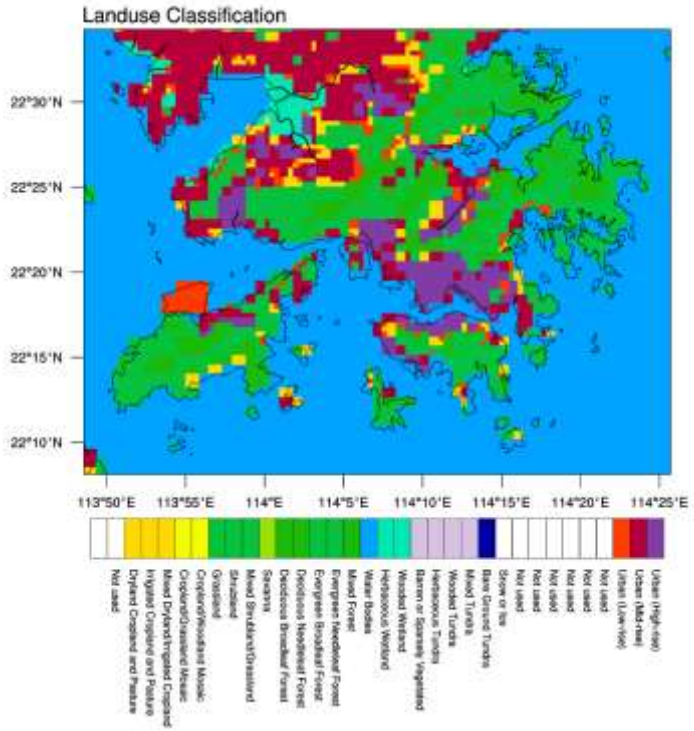
Methodology:
Preparation of Scenario 1: Urban expansion

- Land use data is updated base on HKUST landuse data
  - 30% more urban is created according to Hong Kong government's development plan

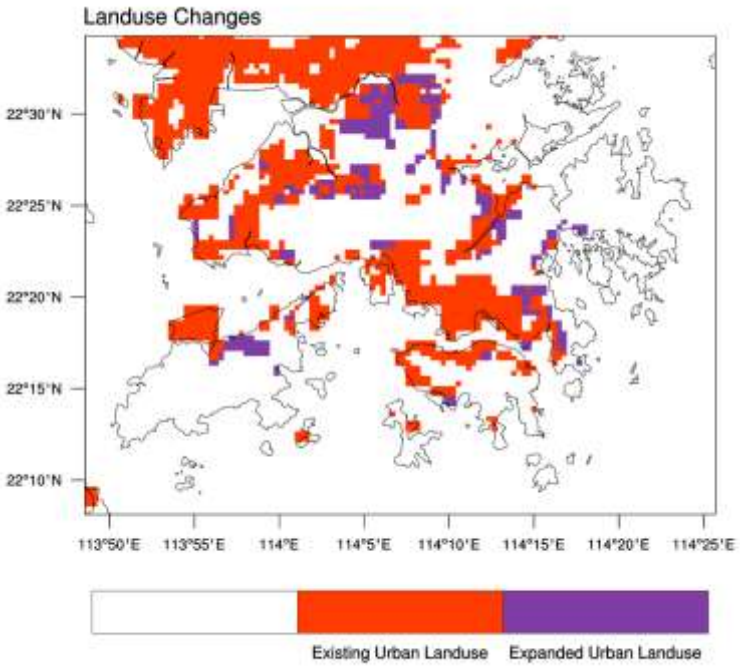
Original urban landuse



Expanded urban landuse



Changes in urban landuse



Methodology:
Preparation of Scenario 2: Increasing Building Height

- Based on a rough estimation in ArcGIS
- Each urban land use type has its own distribution of building heights
  - Building height is increased by 30%

Classification	Average height (original)	Average height (increased)
Low-rise	~5m	~6.5m
High-rise	~22.5m	~29.3m
Commercial and industrial	~40.5m	~52.7m

Result & Analysis

- **Due to time constraint, we mainly focus on temperature**

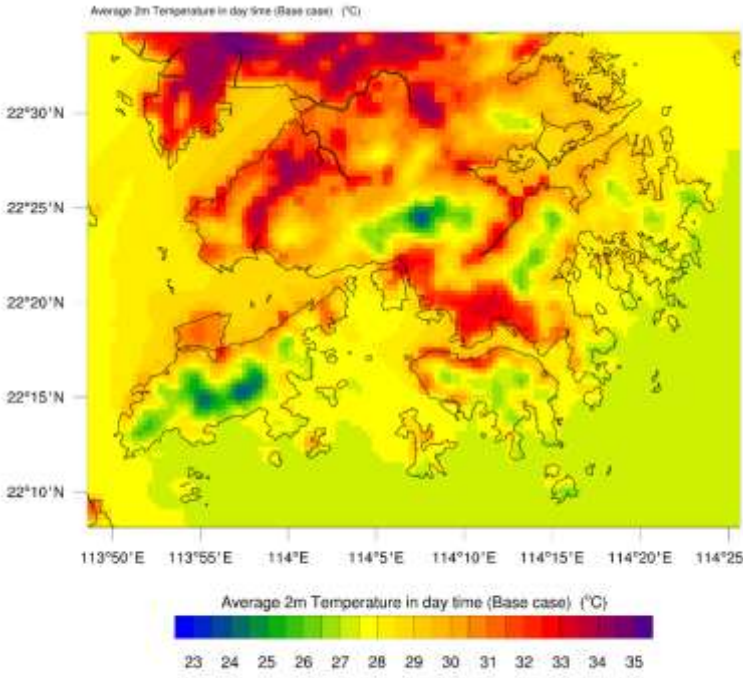
- **Two representative time periods** are picked for evaluating impacts on temperature
  - **2:00 pm – 4:00 pm: Day time**
  - **8:00 pm – 10:00 pm: Night time**

- Averaged data is used for analysis
  - For each time period, the data are first averaged across the corresponding hours, then averaged across the simulation days

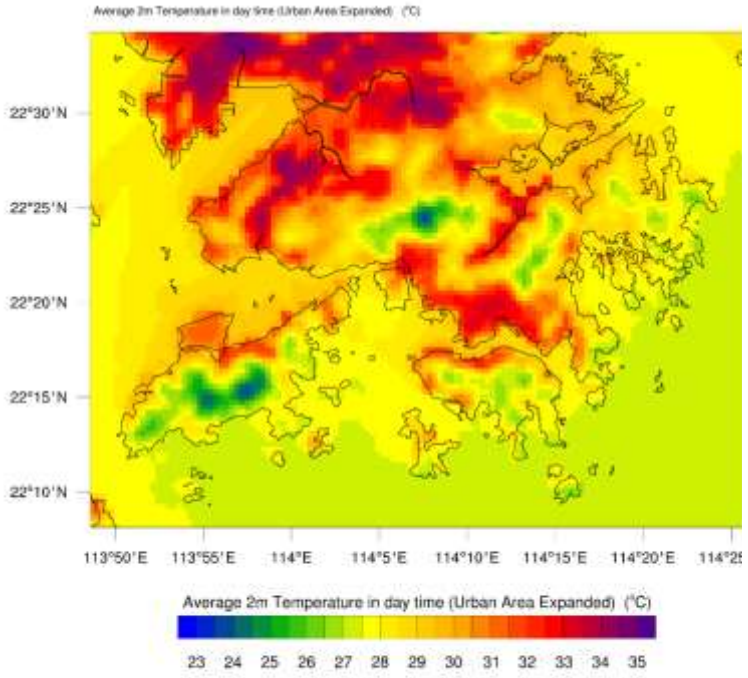
Result & Analysis:
Averaged 2m Temperature during day time

- As expected, urban area has a higher temperature

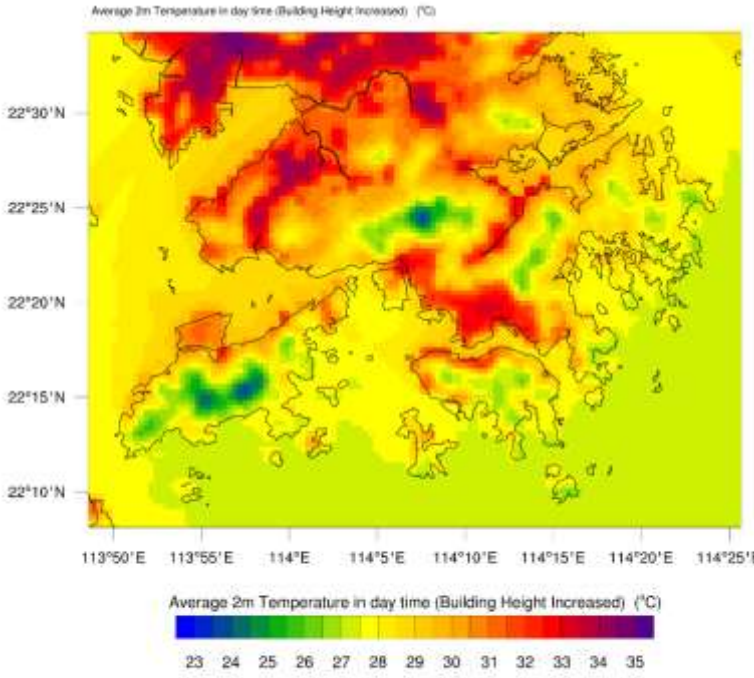
Control run



Scenario 1: Expanded urban landuse



Scenario 2: Building height increased



Result & Analysis

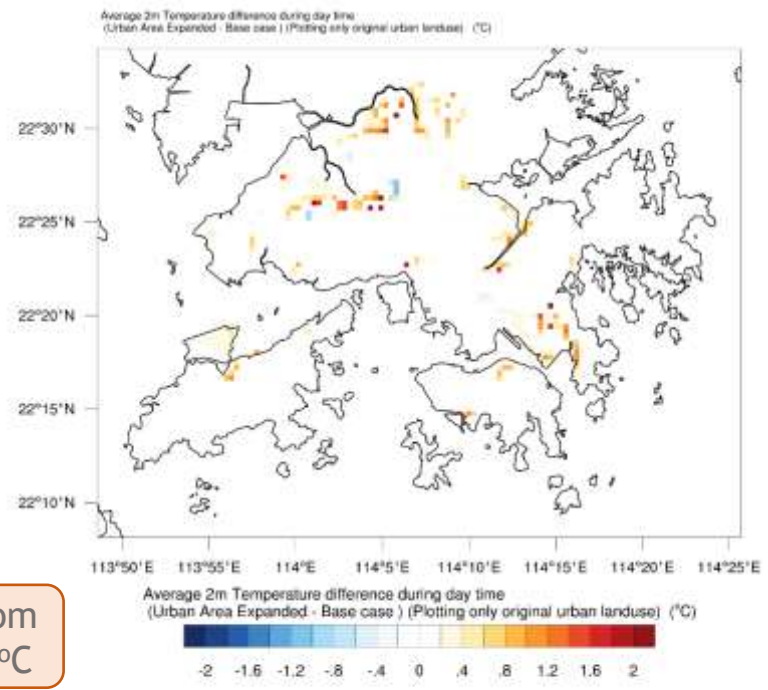
- To evaluate the changes in temperature, temperature difference between the scenarios and control run are calculated spatially
  - Temperature difference has to be **calculated at the area which land use is unchanged with respect to different scenarios**
    - **So as to evaluate the impacts towards the original, unchanged area**
  - Then the **analysis are performed by looking into two types of land use separately**
    - **The unchanged urban land use**
    - **The unchanged rural (non-urban) land use**

Result & Analysis:
Difference in Avg. 2m Temperature (day time)

- Consider **only urban landuse in Hong Kong**

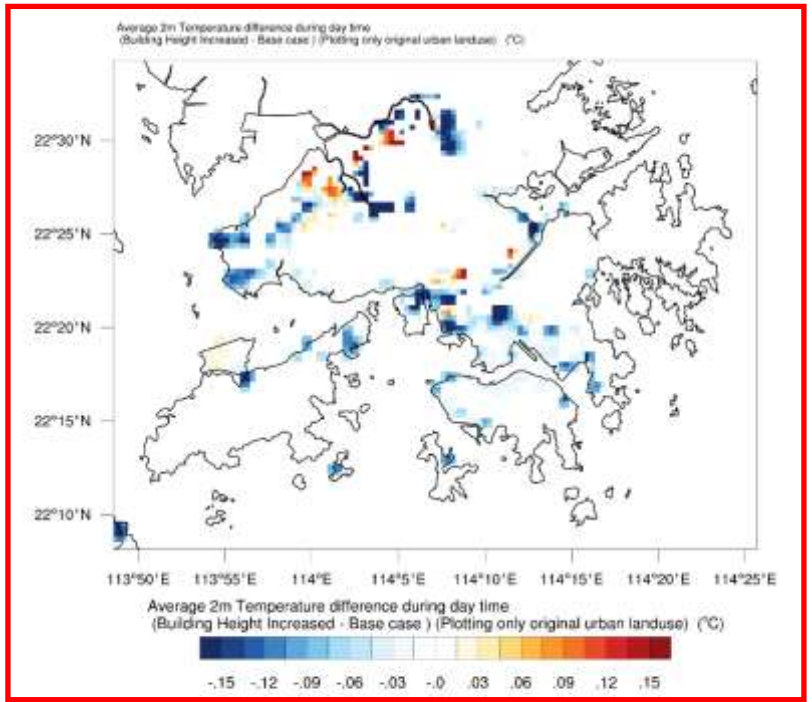
Statistics	Expanded urban landuse - Control run	Building height increased - Control run
Max temperature difference (°C)	2.48	0.352
Area with 0.2°C temperature increased (HK only) (km²)	71	0.5

Expanded urban landuse - Control run



Range from -2°C to 2°C

Building height increased - Control run



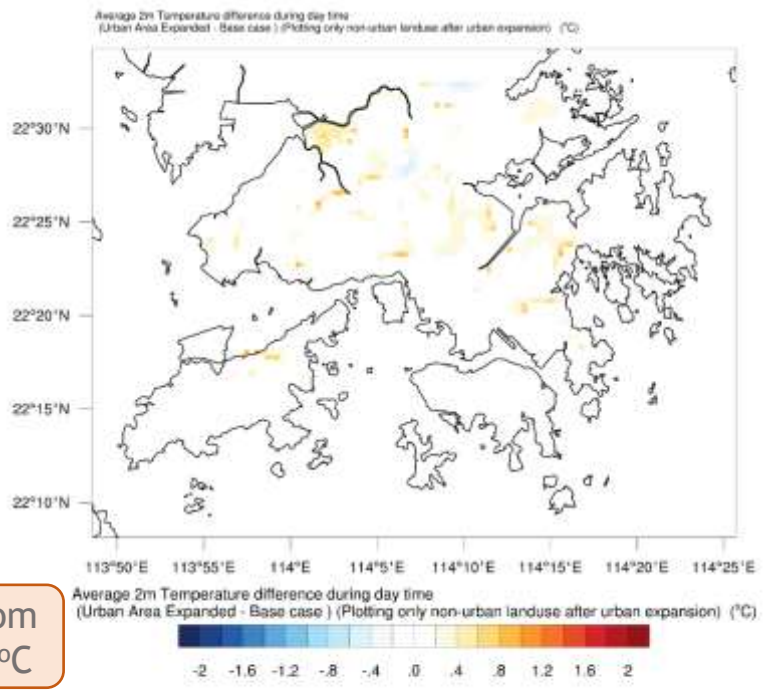
Range from -0.15°C to 0.15°C

Result & Analysis:
Difference in Avg. 2m Temperature (day time)

- Consider **only rural landuse in Hong Kong (excluding water bodies)**

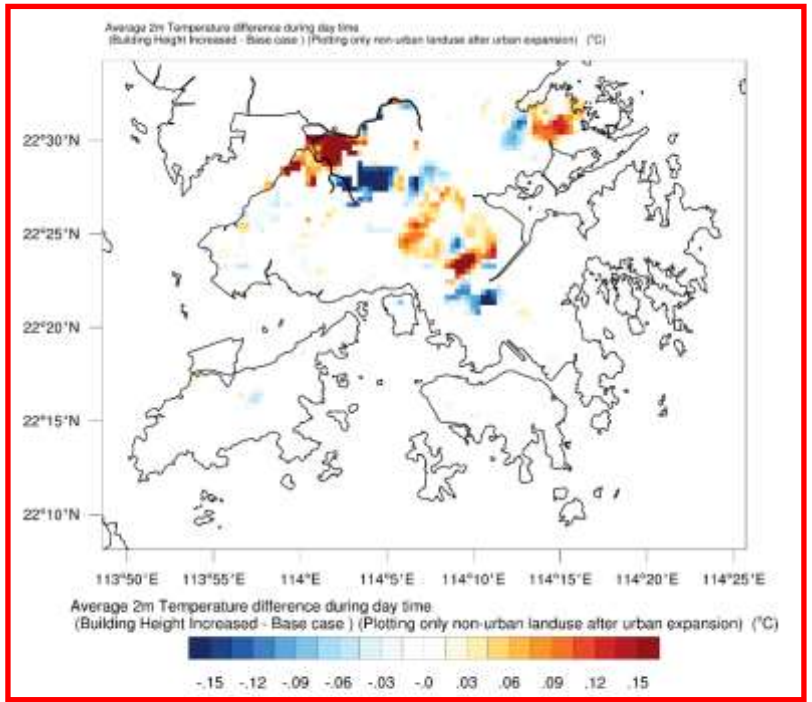
Statistics	Expanded urban landuse - Control run	Building height increased - Control run
Max temperature difference (°C)	0.996	0.384
Area with 0.2°C temperature increased (HK only) (km²)	84.5	12.5

Expanded urban landuse - Control run



Range from -2°C to 2°C

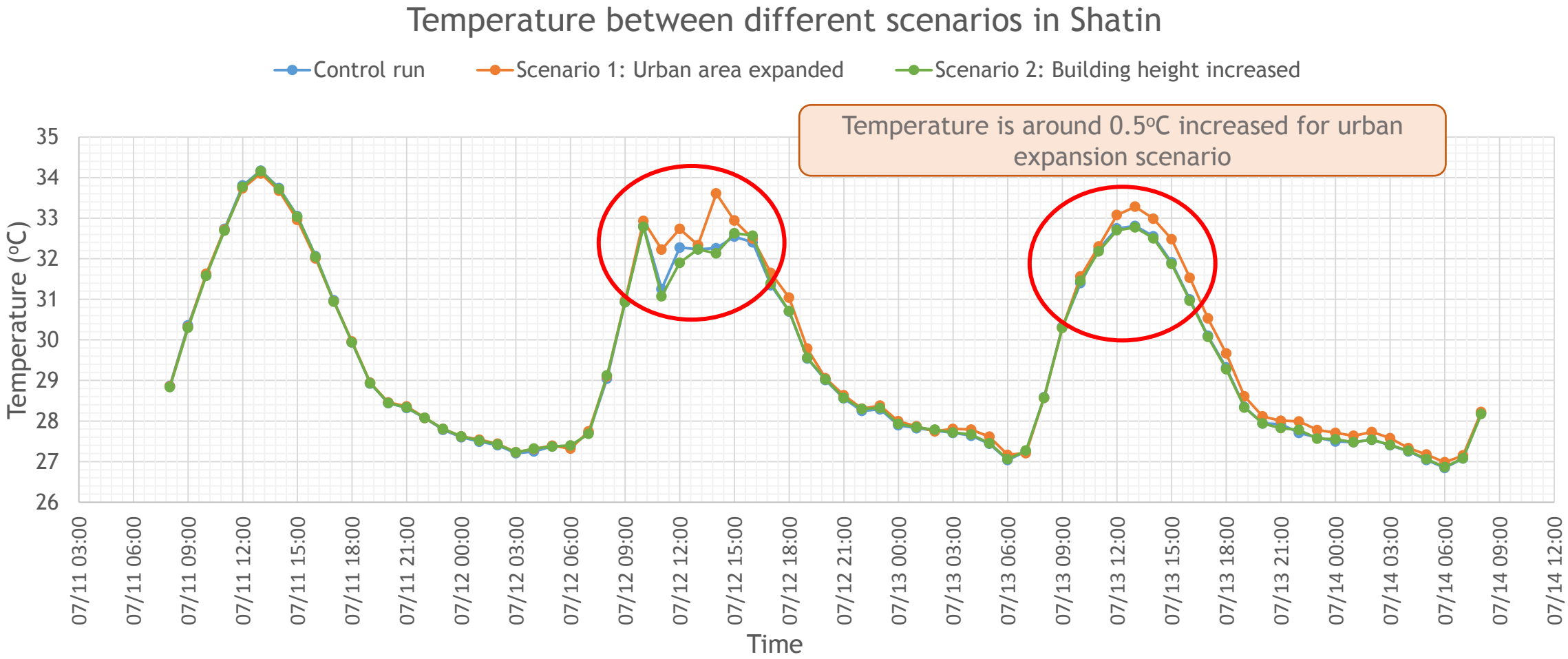
Building height increased - Control run



Range from -0.15°C to 0.15°C

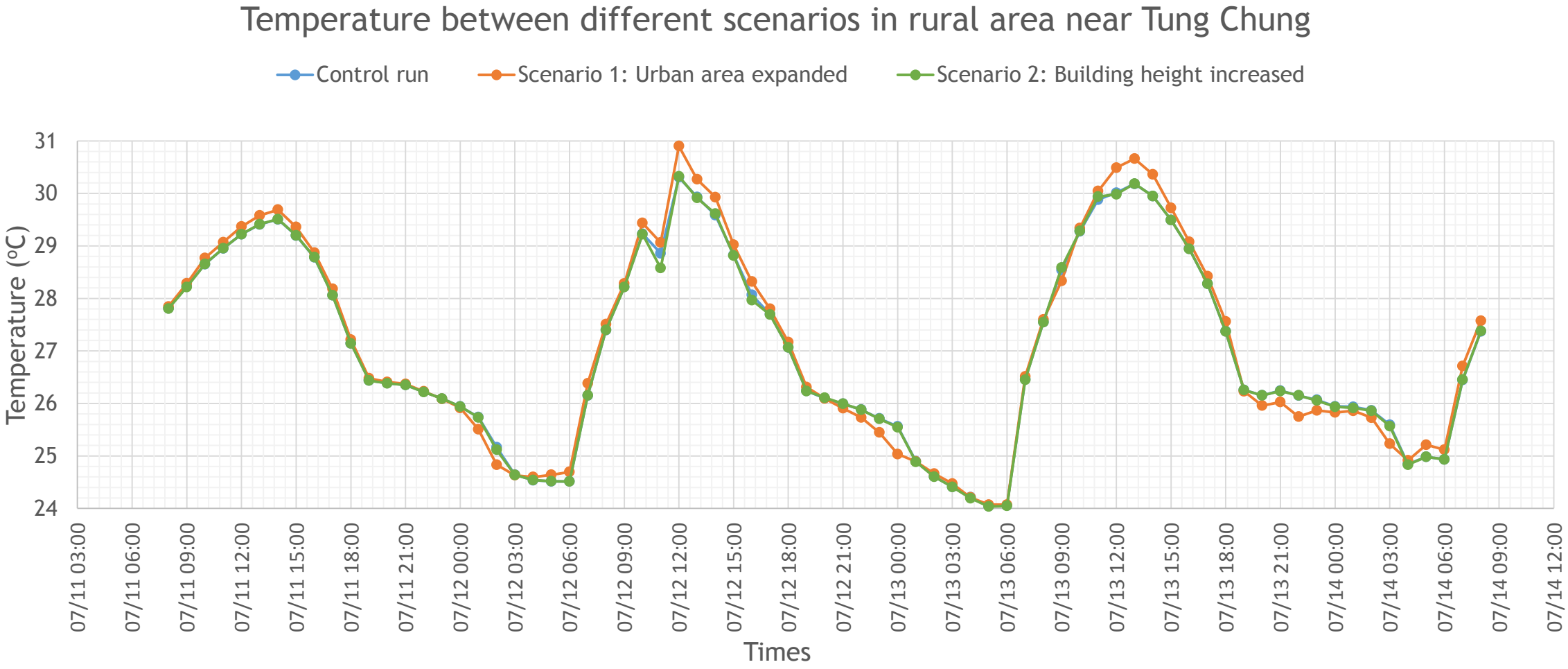
Result & Analysis: Time series plot of temperature

- We picked an urban grid at Shatin and compared with different scenarios



Result & Analysis:
Time series plot of temperature

- We picked an rural grid near Tung Chung and compared with different scenarios



Discussion

- **Comparing with expanding urban area**, the impact on surface temperature by **increasing building height is not as significant**
  - Both temperature difference and range of affected area
  - Not to mention that the newly urbanised area are not taken into account

- Other meteorological parameters are also changed
  - Wind speed & direction (which affected the temperature distribution)
  - Relative humidity

Further work

- Further investigations
  - Analysis other meteorological parameters
  - Why construct higher buildings will not increase the temperature significantly? Possible reasons:
    - Heat generated above may not be able to sink (i.e. reach to the ground)
    - Buildings may block the sunlight, therefore radiation cannot reach to the ground, resulting a lower temperature
  - What is the impacts of constructing taller buildings toward micro-climate other than temperature?
  - How about the winter case, or other meteorological conditions?