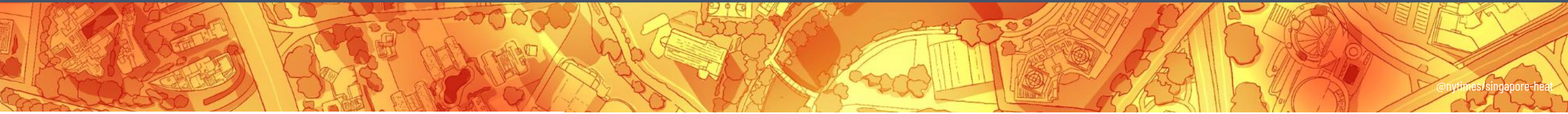
World Bank City Resilience Program
Urban Heat Hackathon

Nick Jones, Matthias Demuzere, Jonas Blancke, Daniel Zepeda, Nils Wallenberg | July 8, 2025



@nytimes/singapore-heat

City Resilience Program

GFDRR Global Facility for Disaster Reduction and Recovery

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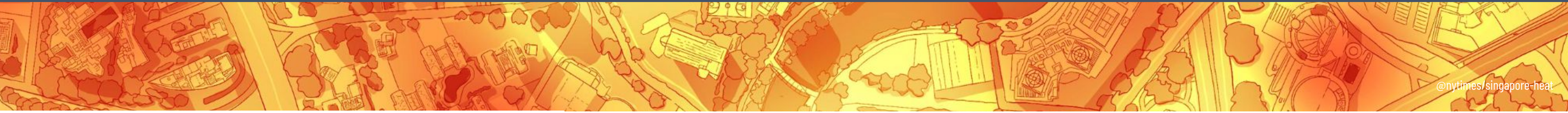
ICUC12

The missions …



@nytimes/singapore-heat

The missions

Should you choose to accept ...

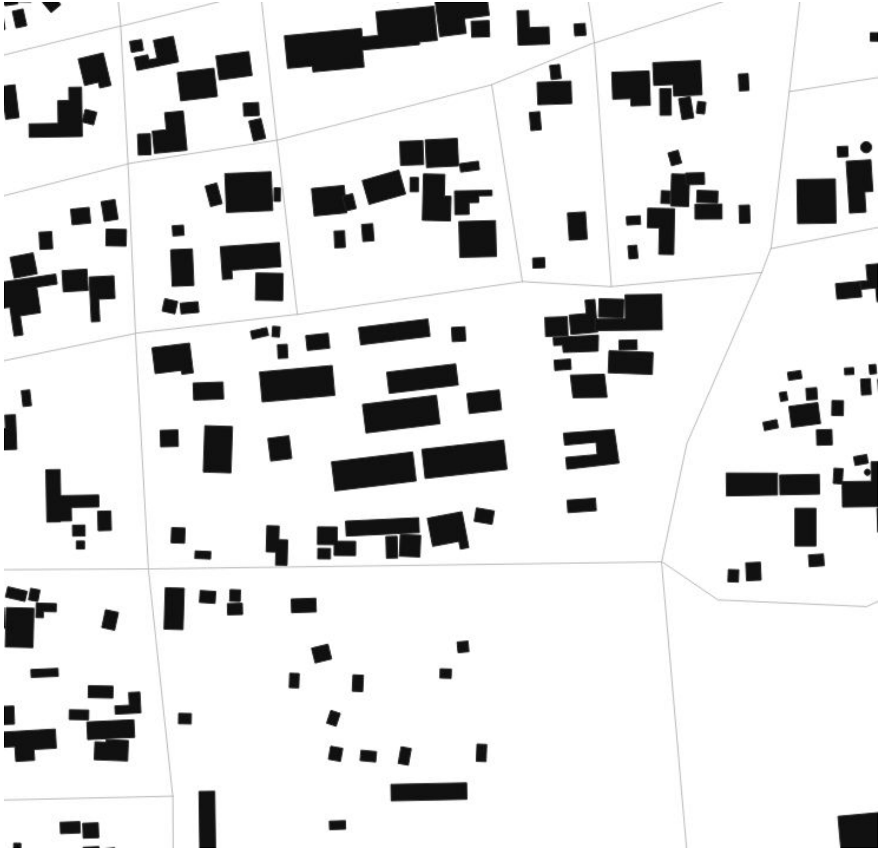
City-scale

Can you recommend to the government which parts of the city need cooling interventions?

- → What are the hotspots of the city?
- → What causes these areas to become hotter than others?
- → What amount of cooling can be achieved?
- → By what type of interventions?

The missions

Should you choose to accept ...



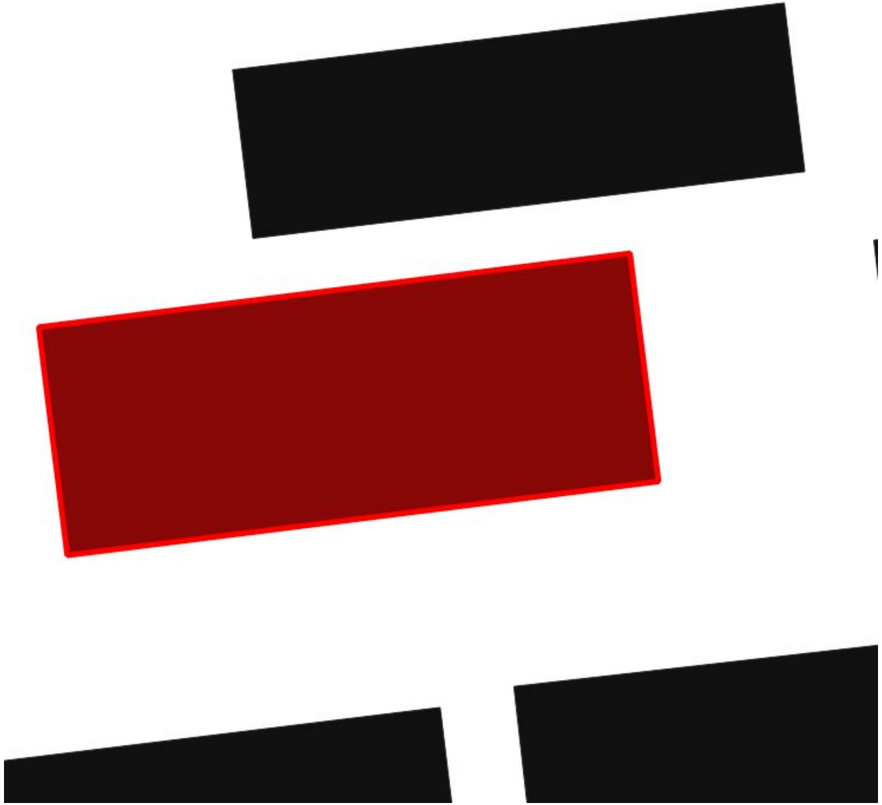
Neighbourhood-scale

What to advise the local government of a city on the heat stress reduction benefits?

- ➔ Which parts of a neighbourhood are susceptible to thermal discomfort?
- ➔ What are the likely causes of that?
- ➔ How much heat stress could be alleviated by targeted interventions?
- ➔ How should these interventions look like?

The missions

Should you choose to accept ...



School building - class room

What to advise to local authorities to reduce indoor heat stress?

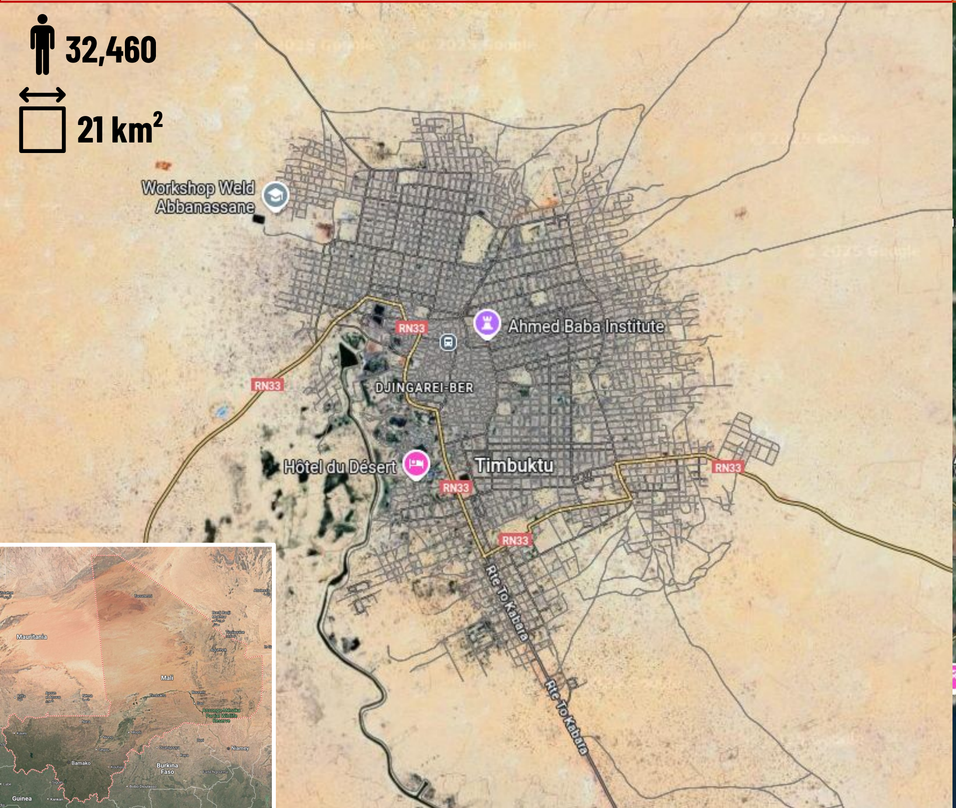
- ➔ When are the hottest periods—both seasonally and throughout the day?
- ➔ What existing features contribute to worsening the current thermal sensation?
- ➔ How much thermal comfort can be achieved through passive strategies?
- ➔ What are the key passive design strategies to prioritize?

Where?

Timbuktu (Mali)

32,460

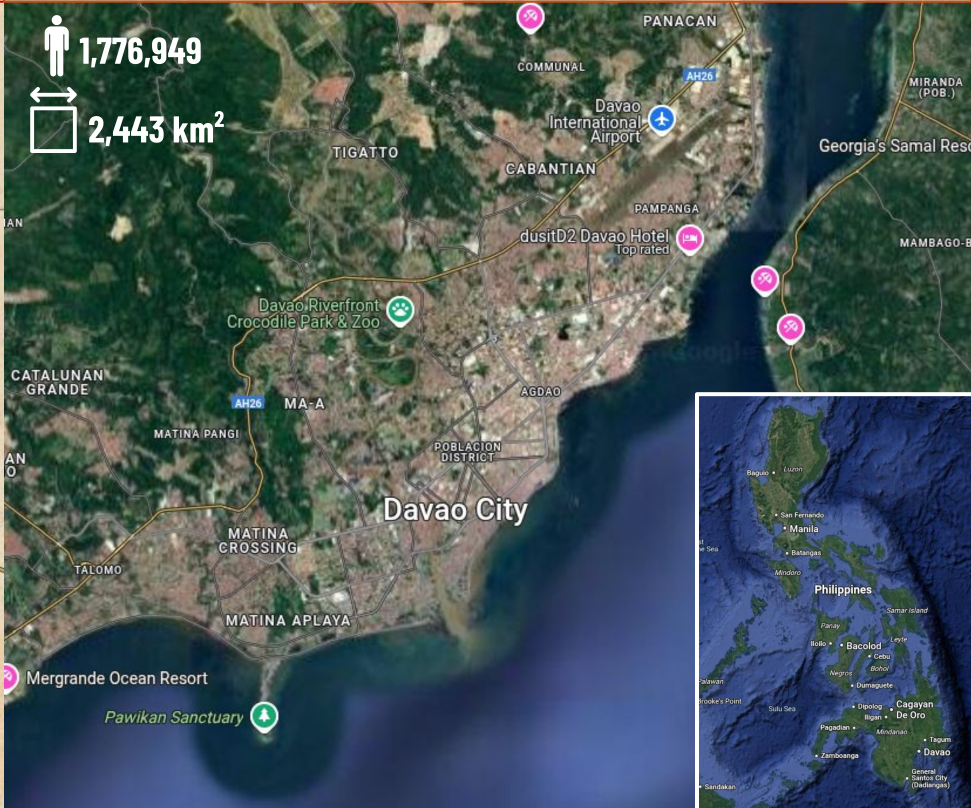
21 km^2



Davao (Philippines)

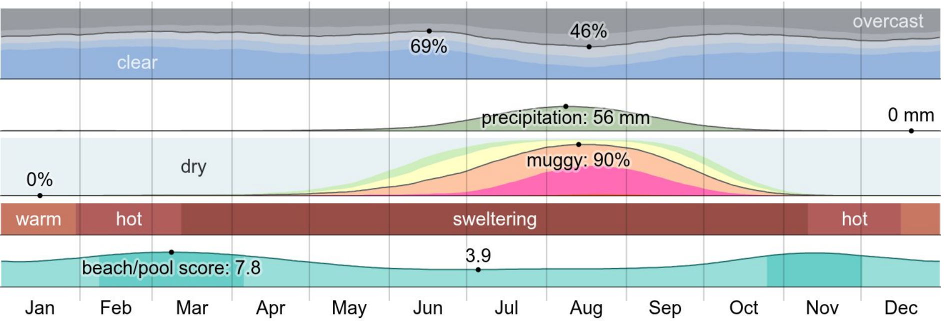
1,776,949

2,443 km^2



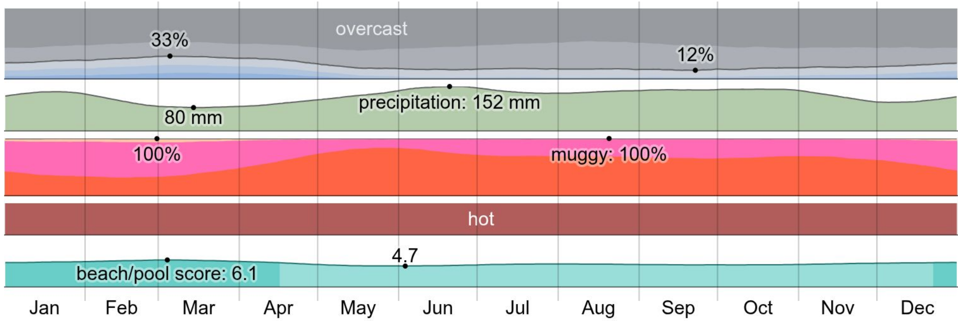
Where?

Timbuktu (Mali)



Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	28°C	32°C	36°C	40°C	41°C	41°C	38°C	36°C	38°C	38°C	34°C	29°C
Temp.	21°C	24°C	28°C	32°C	35°C	35°C	33°C	31°C	32°C	31°C	26°C	22°C
Low	14°C	17°C	20°C	25°C	28°C	29°C	28°C	27°C	26°C	24°C	19°C	15°C

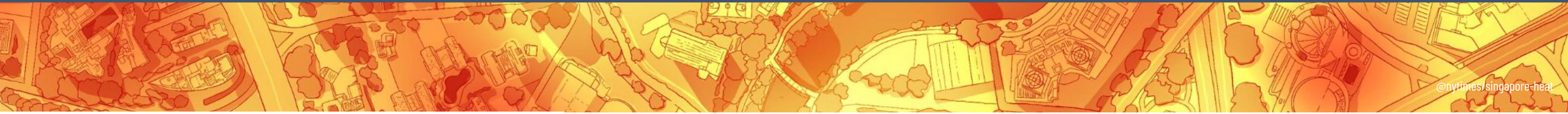
Davao (Philippines)



Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	31°C	31°C	32°C	33°C	32°C	32°C	31°C	32°C	32°C	32°C	32°C	31°C
Temp.	27°C	27°C	28°C	28°C	28°C	28°C	28°C	28°C	28°C	28°C	28°C	27°C
Low	24°C	24°C	24°C	25°C	25°C	25°C	25°C	25°C	25°C	25°C	25°C	24°C

What will climate feel like in 60 years? Check this CityApp, showing climate analogues based on the technique developed by Fitzpatrick & Dunn (2021)

Tools



@nytimes/singapore-heat

Disclaimer

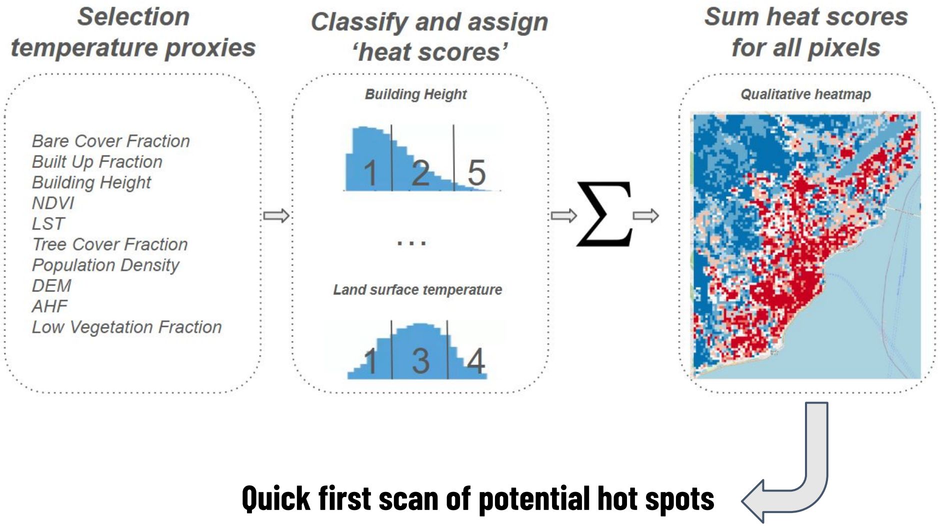
Before we dive into the tools we've prepared, it's important to stress: **you are free to use any approach, tool, or workflow you're comfortable with** - or that you believe fits best with the mission. Let your **creativity and expertise guide you** and surprise us and the **panel of dragons**.

We're simply offering a set of **well-established, open-source tools that are widely used in the community**, continuously maintained, and practical for tackling urban heat and resilience challenges. Several are also available through UMEP in QGIS, to ensure accessibility for all skill levels.

That said, **all tools come with limitations**, often more pronounced when working in extreme climate zones or data-scarce environments. Recognizing these constraints and adapting accordingly is part of the challenge, and part of the innovation we're hoping to inspire.

City-scale

Qualitative mapping via geospatial data layers



Quick first scan of potential hot spots

City-scale

TARGET: The Air-temperature Response to Green/blue-infrastructure Evaluation Tool

Geosci. Model Dev., 12, 785–803, 2019
https://doi.org/10.5194/gmd-12-785-2019

Geoscientific Model Development
Open Access

The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1.0): an efficient and user-friendly model of city cooling

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Received: 12 July 2018 – Discussion started: 8 October 2018
Revised: 3 February 2019 – Accepted: 4 February 2019 – Published: 20 February 2019

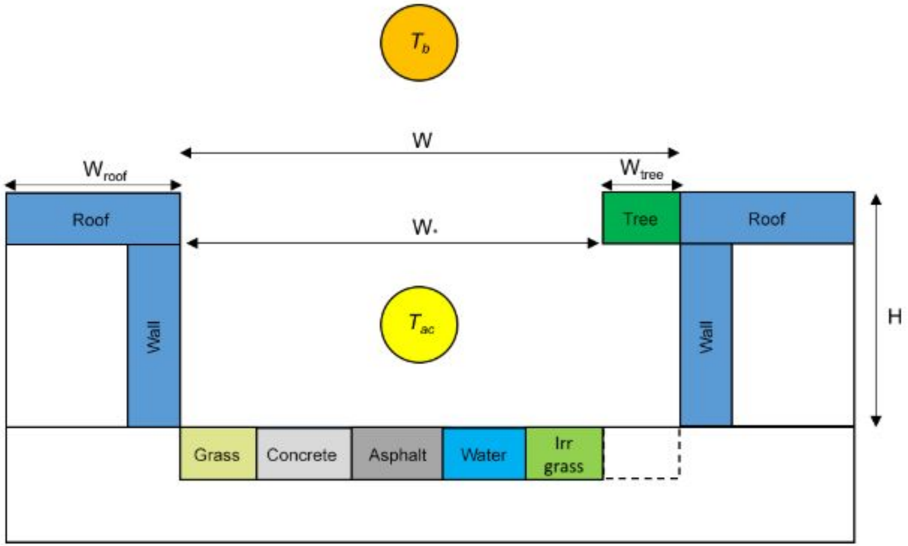
Abstract. The adverse impacts of urban heat and global climate change are leading policymakers to consider green and blue infrastructure (GBI) for heat mitigation benefits. Though many models exist to evaluate the cooling impacts of GBI, their complexity and computational demand leaves most of them largely inaccessible to those without specialist expertise and computing facilities. Here a new model called The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET) is presented. TARGET is designed to be efficient and easy to use, with fewer user-defined parameters and less model input data required than other urban climate models. TARGET can be used to model average street-level air temperature at canyon-to-block scales ... development, including a graphical user interface, is planned for future work.

1 Introduction

Policymakers and decision makers are increasingly aware of the cooling potential of green and blue infrastructure (GBI). Recent examples of this include the Australian Federal Government's 20 Millon Trees Program (Commonwealth of Australia, 2017) and Singapore Green Plan (Singapore Ministry of Environment and Water Resources, 2006). Governments and urban planners wish to evaluate the cooling effects of

City-scale

TARGET: The Air-temperature Response to Green/blue-infrastructure Evaluation Tool



Main inputs:

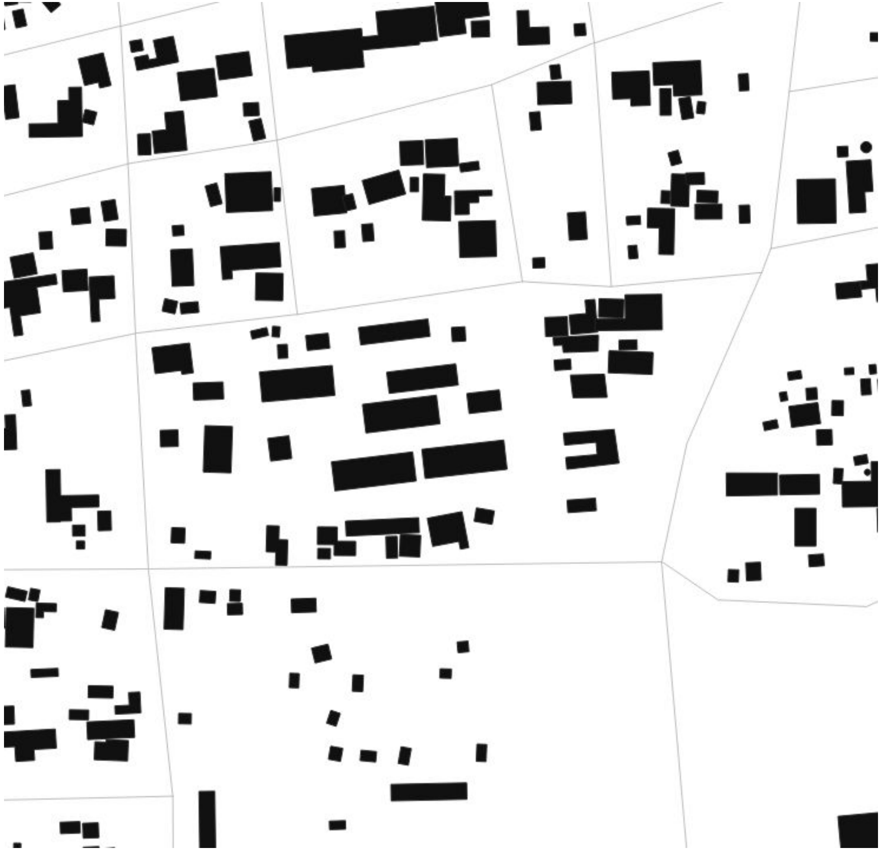
→ Land cover
→ Building geometry
→ Meteorological forcing

Main outputs:

→ Canyon air temperature
→ Yet also *Tmrt, UTCI, ...*

Neighbourhood-scale

SOLWEIG / UMEP: SOlar and LongWave Environmental Irradiance Geometry model, to estimate mean radiant temperatures



Int J Biometeorol (2008) 52:697–713
DOI 10.1007/s00484-008-0162-7

ORIGINAL PAPER

SOLWEIG 1.0 – Modelling spatial variations of 3D radiant fluxes and mean radiant temperature in complex urban settings

Fredrik Lindberg · Björn Holmer · Sofia Thorsson

Received: 6 August 2007 / Revised: 18 March 2008 / Accepted: 28 April 2008 / Published online: 4 June 2008

Abstract The mean radiant temperature, T_{mrt}, which sums up all shortwave and longwave radiation fluxes (both direct and reflected) to which the human body is exposed is one of the key meteorological parameters governing human energy balance and the thermal comfort of man. In this paper, a new radiation model (SOLWEIG 1.0), which simulates spatial variations of 3D radiation fluxes and T_{mrt} in complex urban settings, is presented. The T_{mrt} is derived by modelling shortwave and longwave radiation fluxes in six directions (upward, downward and from the four cardinal points) and angular factors. The model requires a limited number of inputs, such as direct, diffuse and global shortwave radiation, air temperature, relative humidity, urban geometry and geographical information (latitude, longitude and elevation). The model was evaluated using 7 days of integral radiation measurements at two sites with different building geometries – a large square and a small courtyard in Göteborg, Sweden (57°N) – across different seasons and in various weather conditions. The evaluation reveals good agreement between modelled and measured values of T_{mrt}, with an overall good correspondence of R^2= 0.94, (p<0.01, RMSE=4.8 K). SOLWEIG 1.0 is still under development. Future work will incorporate a vegetation scheme, as well as an improvement of the estimation of fluxes from the four cardinal points.

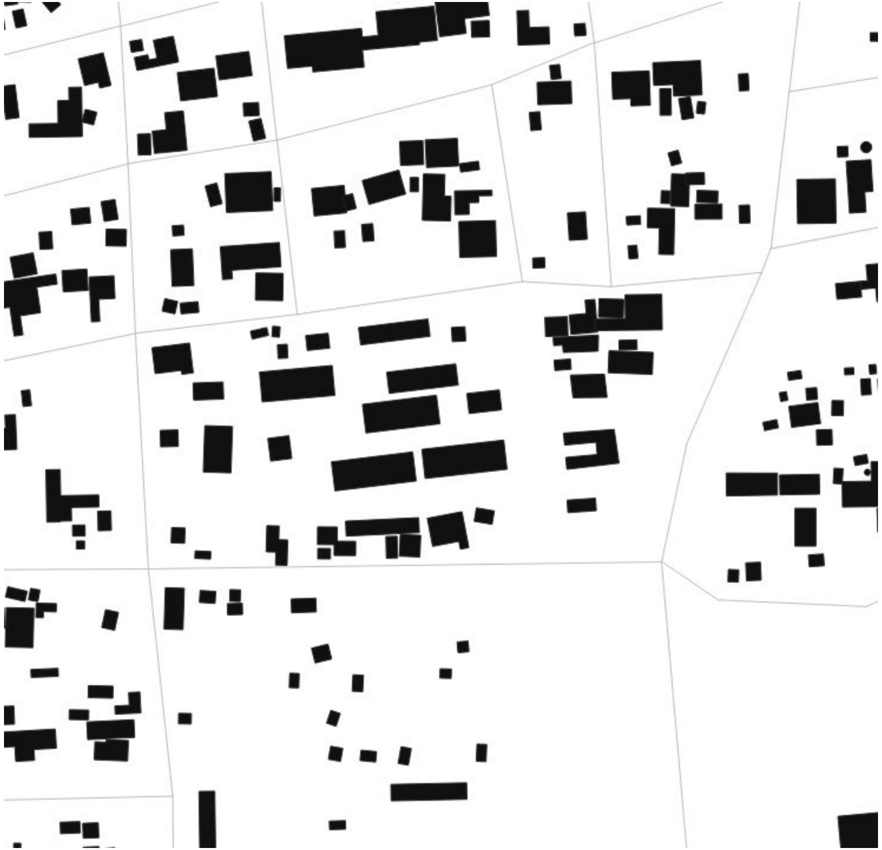
Introduction

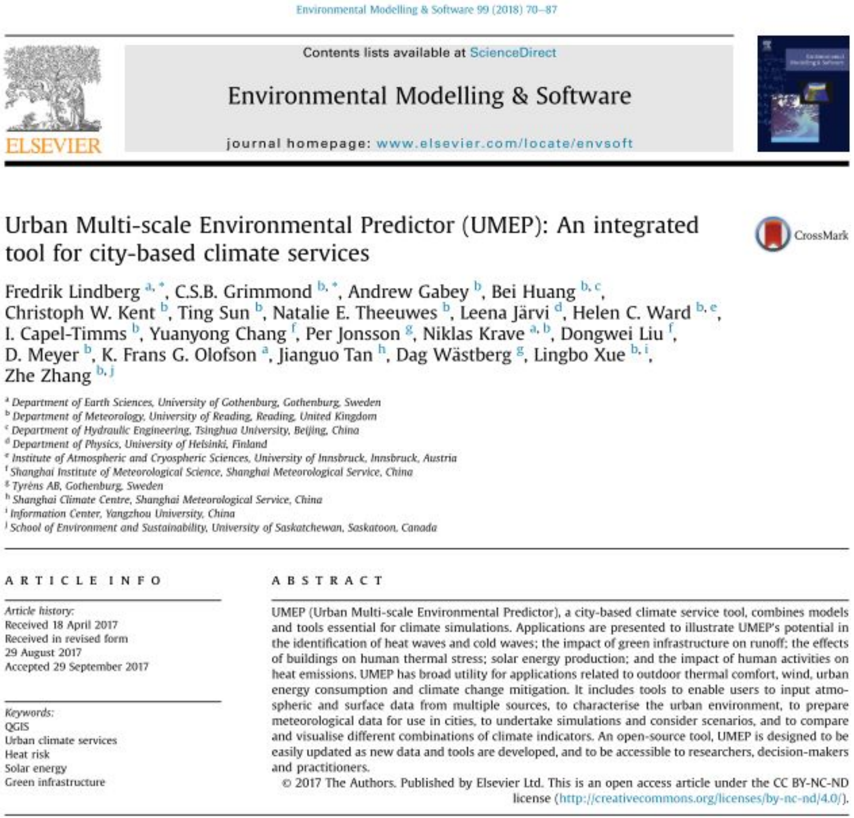
One of the most important meteorological factors governing human energy balance and the thermal comfort of man outdoors is the mean radiant temperature, T_{mrt}, which is the sum of all short- and longwave radiation fluxes (both direct and reflected), to which the human body is exposed. The T_{mrt} is defined as the "uniform temperature of an imaginary enclosure in which radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure" (ASHRAE 2001).

There are several different methods of measuring and modelling T_{mrt}. The most accurate of these includes all shortwave and longwave radiation fluxes (upward, downward and from the four cardinal points), angular factors, human shape, etc. (Höppe 1992). This, however, is also the most costly and complex technique that can be employed for these purposes. It requires the use of pyranometers and pyrgeometers, arranged in the six directions, which makes the method difficult to implement in extensive measuring campaigns (Thorsson et al. 2007). A simpler way of measuring the T_{mrt} is to use a globe thermometer (Vernon 1932; Kuehn et al. 1970; de Dear 1987; Nikolopoulou et al. 1999). Simply put, the temperature assumed by the globe thermometer at equilibrium

Neighbourhood-scale

SOLWEIG / UMEP: SOlar and LongWave Environmental Irradiance Geometry model, to estimate mean radiant temperatures





Environmental Modelling & Software 99 (2018) 70–87

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journal homepage: www.elsevier.com/locate/envsoft

ELSEVIER

Urban Multi-scale Environmental Predictor (UMEP): An integrated tool for city-based climate services

CrossMark

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A R T I C L E I N F O

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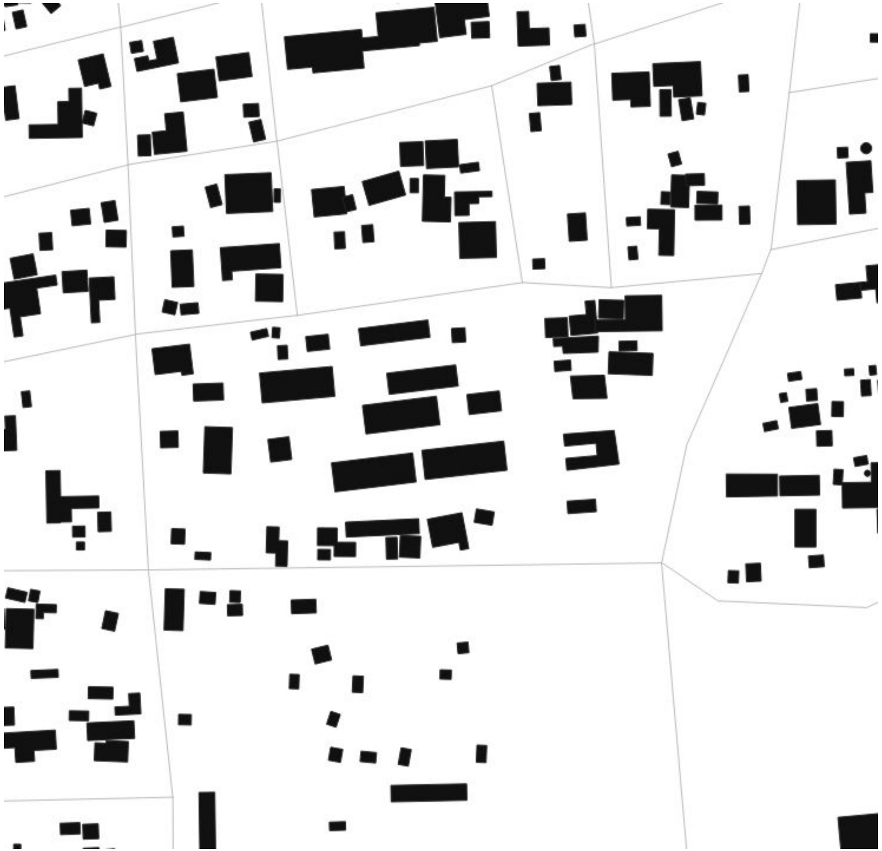
Urban climate services
Heat risk
Solar energy
Green infrastructure

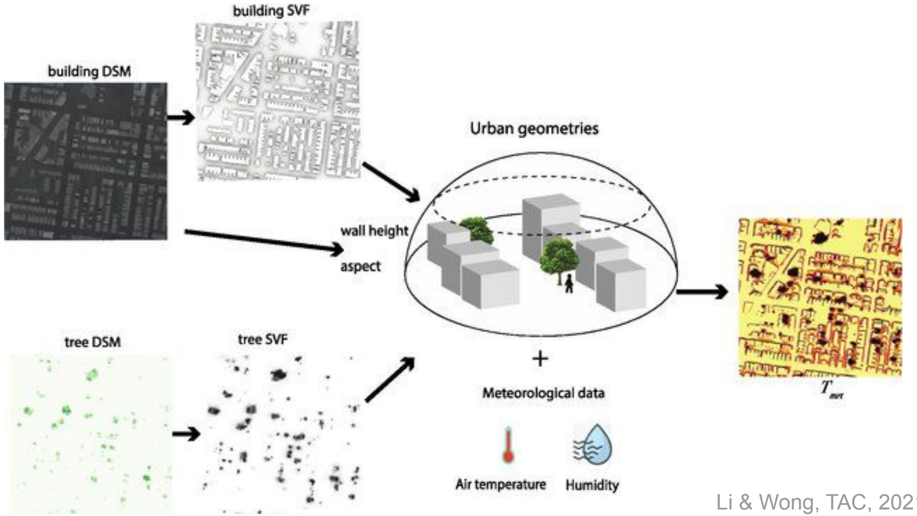
A B S T R A C T

UMEP (Urban Multi-scale Environmental Predictor), a city-based climate service tool, combines models and tools essential for climate simulations. Applications are presented to illustrate UMEP's potential in the identification of heat waves and cold waves; the impact of green infrastructure on runoff; the effects of buildings on human thermal stress; solar energy production; and the impact of human activities on heat emissions. UMEP has broad utility for applications related to outdoor thermal comfort, wind, urban energy consumption and climate change mitigation. It includes tools to enable users to input atmospheric and surface data from multiple sources, to characterise the urban environment, to prepare meteorological data for use in cities, to undertake simulations and consider scenarios, and to compare and visualise different combinations of climate indicators. An open-source tool, UMEP is designed to be easily updated as new data and tools are developed, and to be accessible to researchers, decision-makers and practitioners.

Neighbourhood-scale

SOLWEIG / UMEP: SOlar and LongWave Environmental Irradiance Geometry model, to estimate mean radiant temperatures





Li & Wong, TAC, 2021

Main inputs:

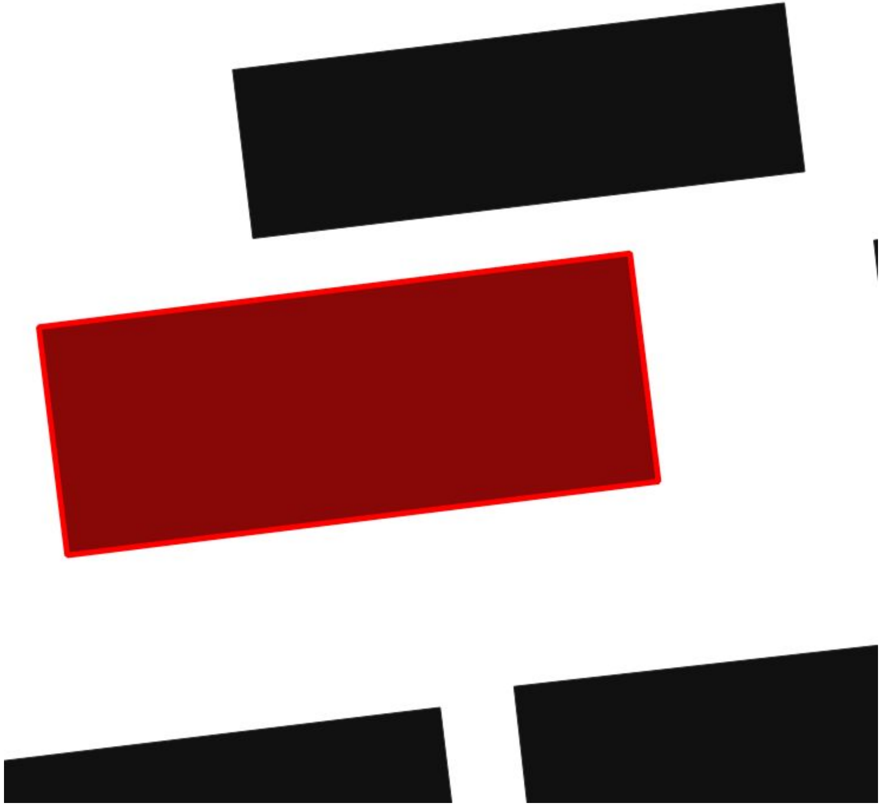
- ➔ DEM, DSM, CDSM
- ➔ Land cover
- ➔ Meteorological forcing

Main outputs:

- ➔ UTCI
- ➔ Yet also *K*, *L*, *Tmrt*, ...

School building - classroom

ENERGYPLUS: building energy simulation software



STANDARD

ASHRAE

ANSI/ASHRAE Standard 140-2020
(Supersedes ANSI/ASHRAE Standard 140-2017)
Includes ANSI/ASHRAE addenda listed in Annex C

Method of Test for Evaluating Building Performance Simulation Software

See Informative Annex C for approval dates.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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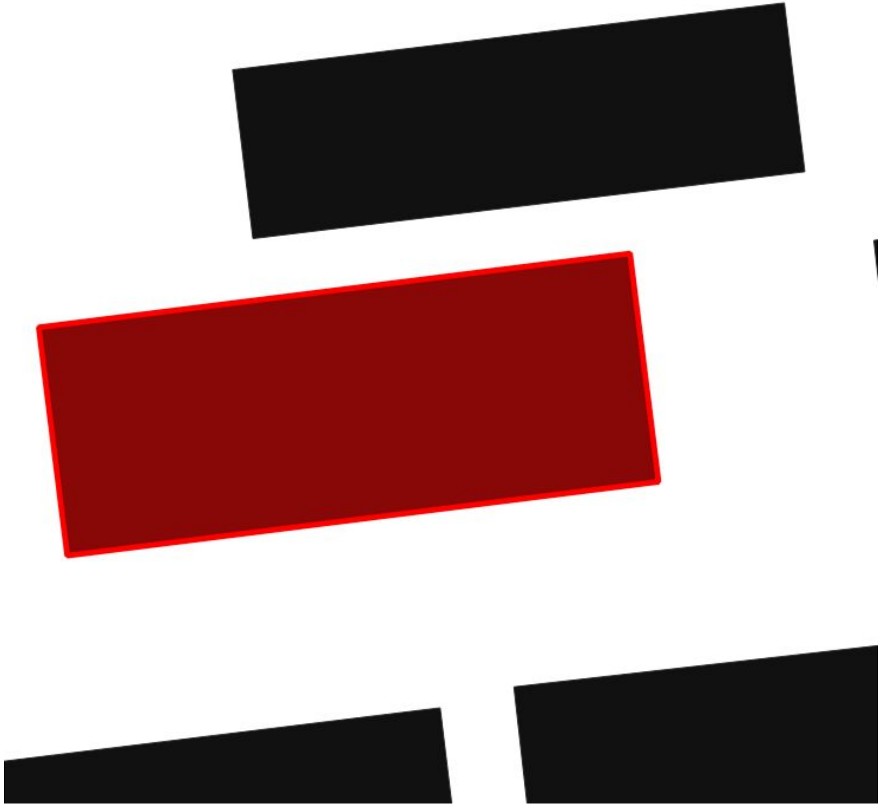
ISSN 1041-2336

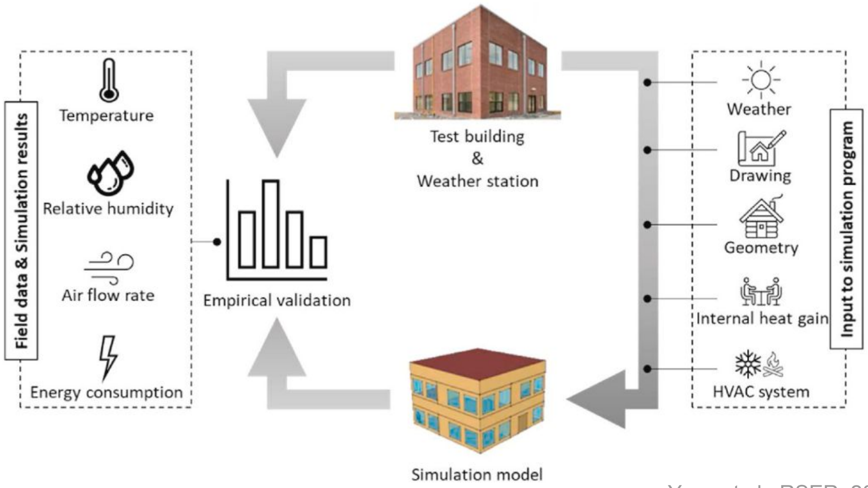
Includes Web-based access to normative and informative electronic supplemental files.

ANSI

School building - classroom

ENERGYPLUS: building energy simulation software





Yoon et al., RSER, 2023

Main inputs:

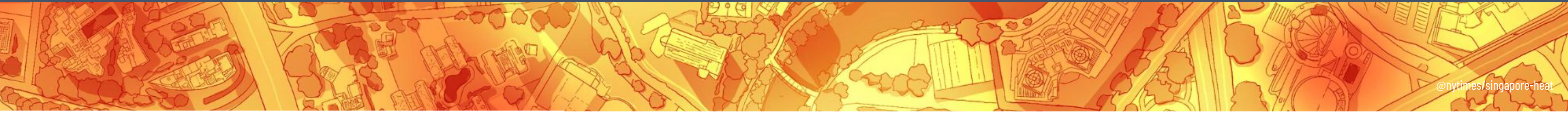
- → Weather files
- → Building and contextual geometry
- → Occupancy patterns

Main outputs:

- → Indoor temperature
- → Surface temperatures

(Yearly or seasonal results)

Inputs to the tools



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Meteorological forcing

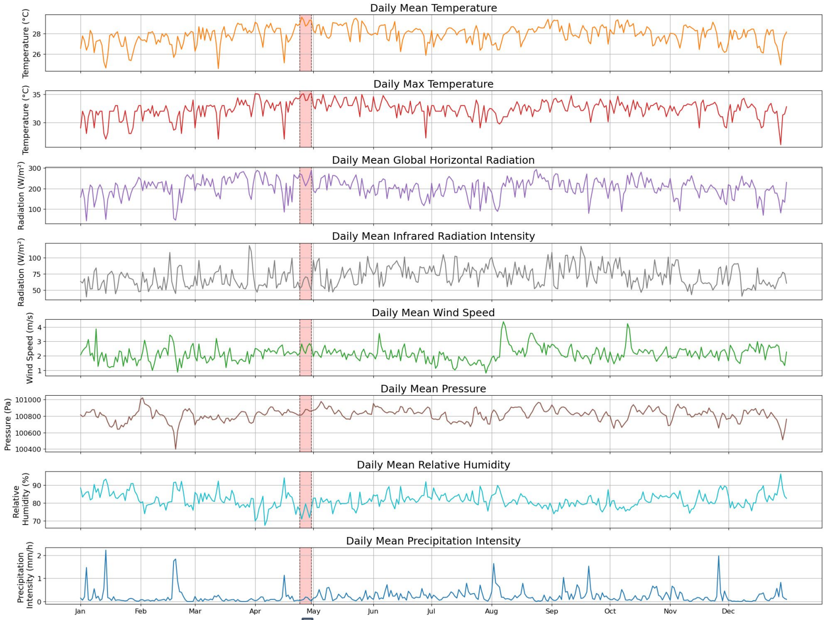
Timbuktu (Mali)

Selection forcing data out of Typical Meteorological year (TMY)

Maximum 7-day running window of temperature
20/05/2013 - 26/05/2013

Davao (Philippines)

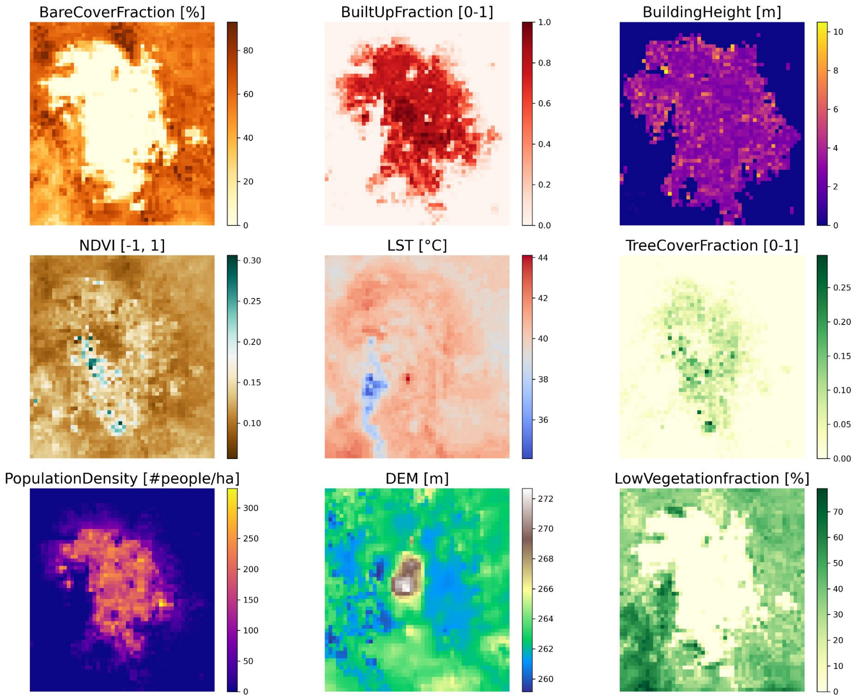
Selection forcing data out of Typical Meteorological year (TMY)



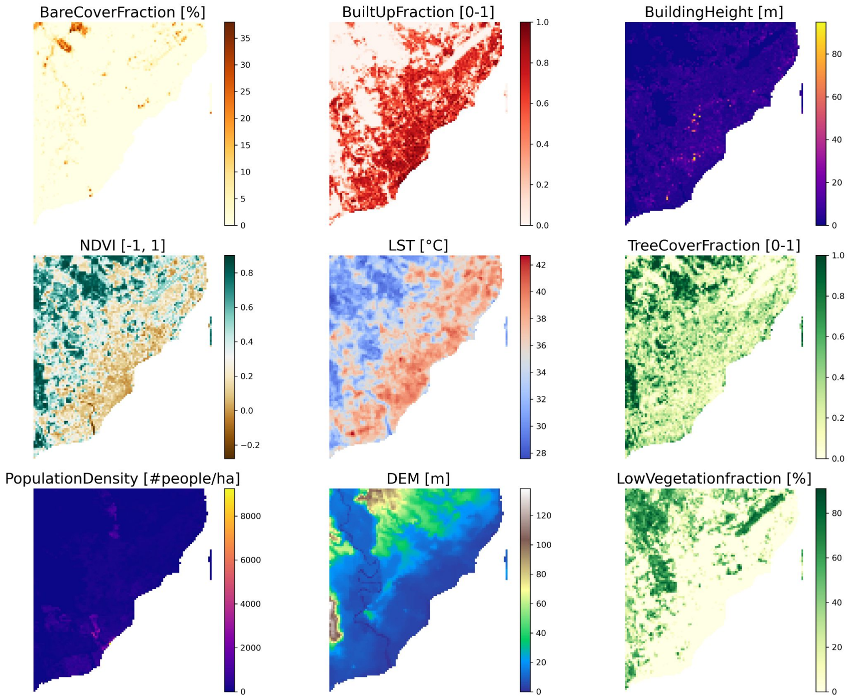
Maximum 7-day running window of temperature
24/04/2018 - 30/04/2018

Land cover characteristics - city

Timbuktu (Mali)



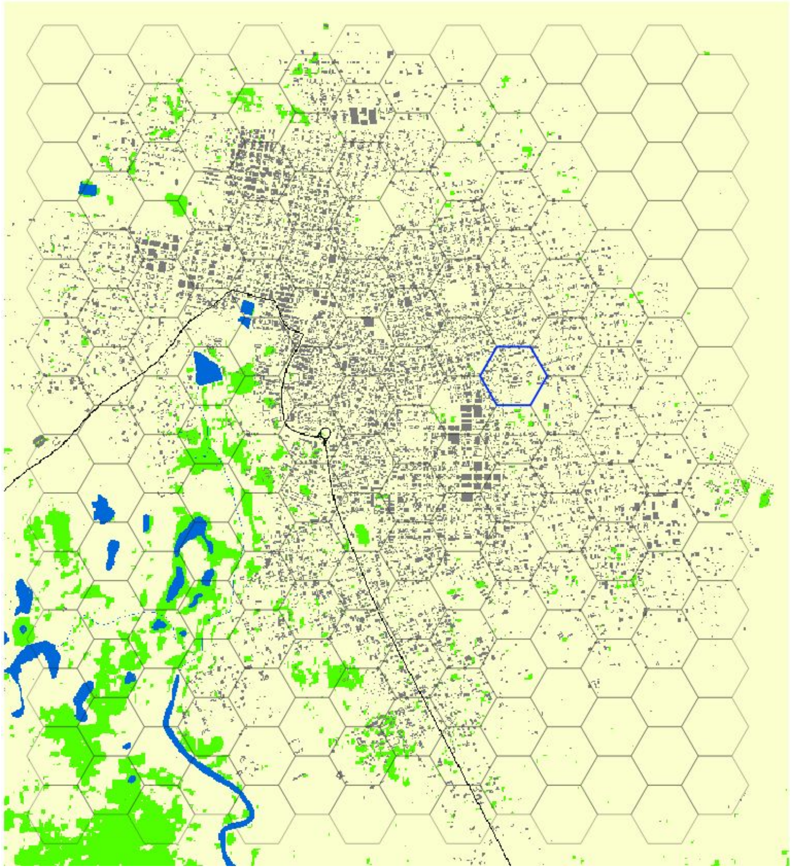
Davao (Philippines)



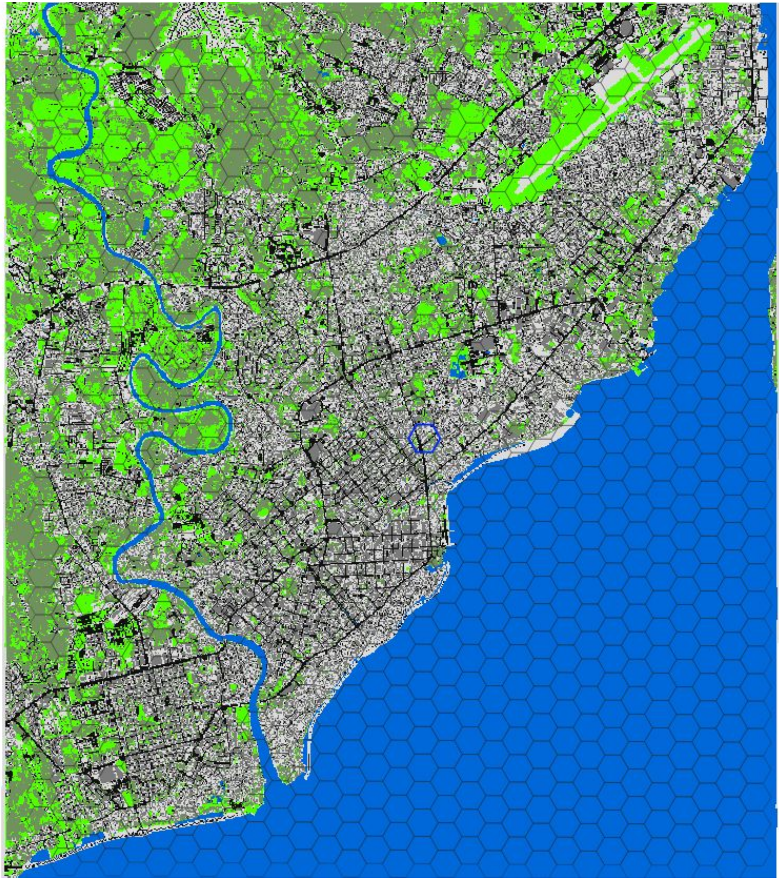
Land cover characteristics - city

- Paved (asphalt)
- Paved (concrete)
- Buildings
- Tree
- Grass
- Water
- Bare/Sand

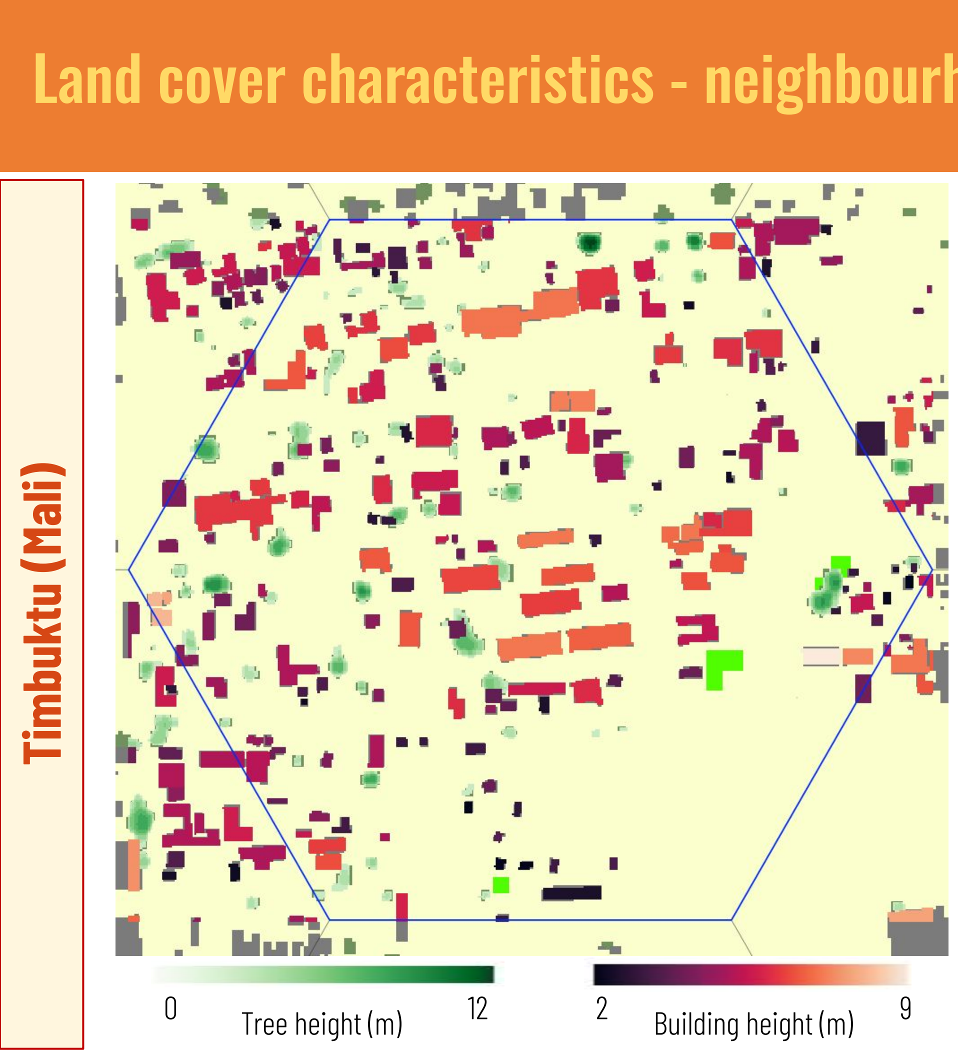
Timbuktu (Mali)

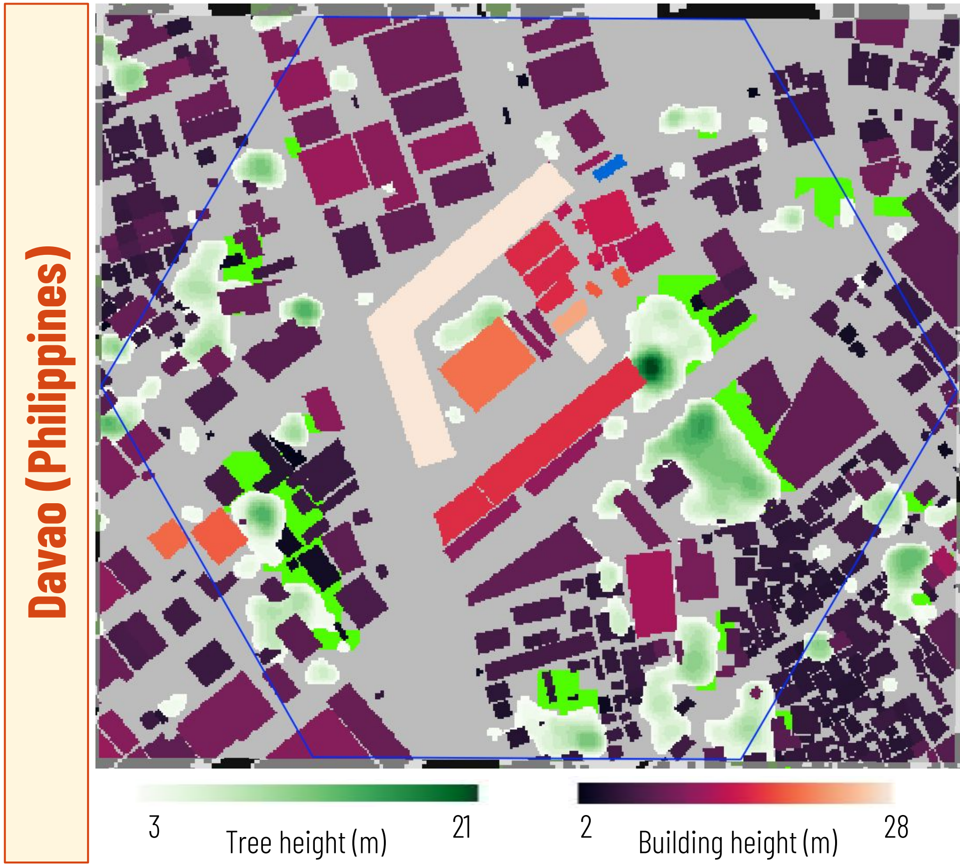


Davao (Philippines)



Land cover characteristics - neighbourhood





School building / classroom archetype

Timbuktu (Mali)

Davao (Philippines)

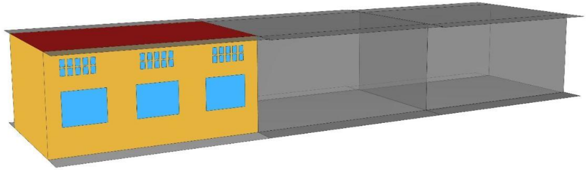
School building / classroom archetype

Timbuktu (Mali)

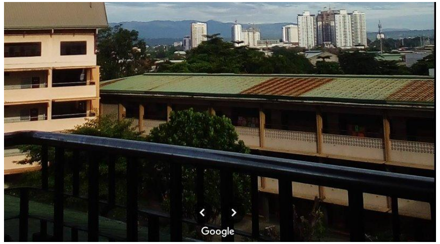
Davao (Philippines)

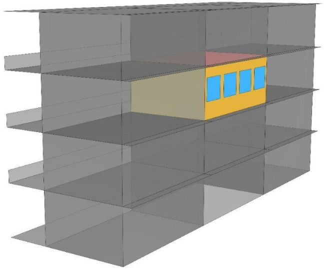
School building / classroom archetype

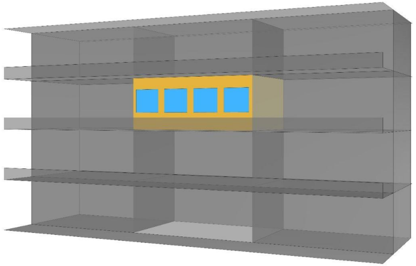
Alpha Daouna, Timbuktu



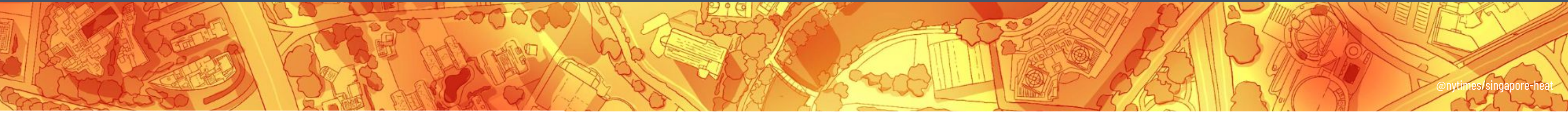
Assumption College of Davao







Technical guidelines



@nytimes/singapore-heat

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Google Colab

No installation required

Colab runs in the cloud, so participants don't need to install Python, libraries, or any special software locally. Just open the notebook and start coding!

Accessible to all devices

Whether you're on a laptop, tablet, or even a phone - Colab works in the browser and connects to Google Drive for seamless access.

Easy collaboration

By using a shared Google Drive folder, everyone can access the same datasets, code templates, and outputs.

```python
from datetime import datetime
from glob import glob

# Ignore some warnings
warnings.filterwarnings("ignore", message=".*find_spec.*", category=ImportWarning)
for warning_type in [ImportWarning, SyntaxWarning, DeprecationWarning, UserWarning, RuntimeWarning]:
    warnings.filterwarnings("ignore", category=warning_type)
```

```python
# Mount Google Drive, to access the datasets and write your results.
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

```
Mounted at /content/drive
```

```python
# ===> SETTINGS TO ADJUST <====

# Your name - refers to the Google Drive folder name
YOUR_NAME = "Matthias"

# city of interest
# city = "Timbuktu"
city = "Davao"

# the simulation's run name
scenario_name = "baseline"

# Your own baseline directory - check where you have mounted the ICUC12_Hackathon folder
BASE_DIR = os.path.join('/content/drive/MyDrive/ICUC12_Hackathon')
print('> BASE_DIR: ',BASE_DIR)
```

```
> BASE_DIR:  /content/drive/MyDrive/ICUC12_Hackathon
```

```python
# ===> SETTINGS NOT TO CHANGE <====

# Setting files and directories, based on personal folder, city, and scenario
model = "SOLWEIG"

# Create a link to your personal directory
PERSONAL_FOLDER = os.path.join(BASE_DIR, YOUR_NAME)
print('> PERSONAL_FOLDER: ', PERSONAL_FOLDER)

# Figure folder, to store all your nice visuals
FIGURE_FOLDER = os.path.join(PERSONAL_FOLDER, "figures")
print('> FIGURE_FOLDER: ', FIGURE_FOLDER)

# Create link to shared directory
SHARED_DIR = os.path.join(BASE_DIR, "SHARED_FOLDER")
```

Google Drive folder > ICUC12_Hackathon

Access

Those who provided a google email should have received access to the ICUC12_Hackathon folder.

ICUC12_Hackathon

- SHARED_FOLDER
- Participants 1
- Participants 24

Google Drive folder > ICUC12_Hackathon

Access

Those who provided a google email should have received access to the ICUC12_Hackathon folder.

- ICUC12_Hackathon
  - SHARED_FOLDER
    - data
      - Davao ⟶ Input data for all tools
      - Timbuktu ⟶ Input data for all tools
    - functions
      - solweig_functions.ipynb
      - target_functions.ipynb
      - ...
    - docs
      - Readme_Inputdata.pdf
      - ICUC12_UrbanHeatHackathon_Overview.pdf
      - Teams_Presentations
    - certificates

Google Drive folder > ICUC12_Hackathon

Access

Those who provided a google email should have received access to the ICUC12_Hackathon folder.

- ICUC12_Hackathon
  - Participant 1…24
    - notebooks
      - Qualitative_hotspotmapping_functions.ipynb
      - TARGET_city.ipynb
      - SOLWEIG_neighbourhood.ipynb
      - ENERGYPLUS_school.ipynb
    - Davao
    - Timbuktu
    - models
    - figures

Will be created when running a notebook …

Google Drive folder > ICUC12_Hackathon

Access

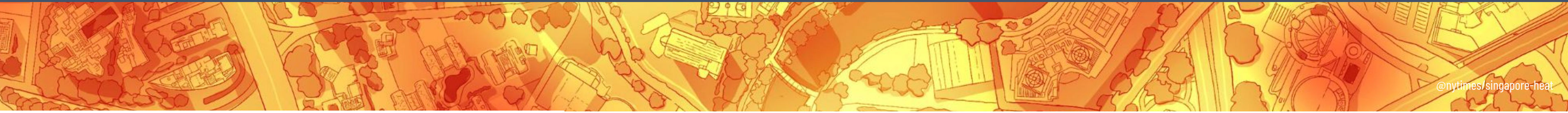
Those who provided a google email should have received access to the ICUC12_Hackathon folder.

! Important !

> Do <u>not</u> change anything in the SHARED_FOLDER
> Only change files in your own folder
> When opening the ICUC12_Hackathon folder in your own google drive, make sure to put it in your own drive, via “Organize > add shortcut” under “My Drive”.

- ICUC12_Hackathon
  - SHARED_FOLDER
  - Participants 1
  - ⋮
  - Participants 24

Support team



@nytimes/singapore-heat

Jonas Blancke

Urban heat analyst @ the World Bank
Urban climate services @ B-Kode

Nicholas Jones

Program Lead for Extreme Heat Resilience at the World Bank's Global Unit for Disaster and Climate Risk Management

Nils Wallenberg, Ph.D.

Post-doctoral researcher @ University of Gothenburg
Core developer SOLWEIG / UMEP

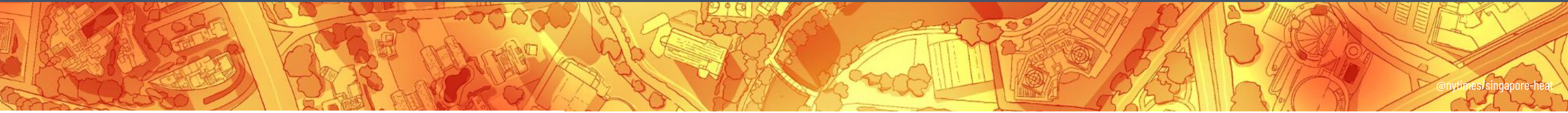
Matthias Demuzere, Ph.D.

Urban heat specialist @ the World Bank
Urban climate services @ B-Kode

Daniel Zepeda Rivas, Ph.D.

Indoor heat specialist @ the World Bank
Building Performance Consultant @ cli-mat

The teams

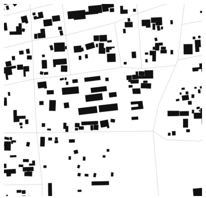


Hackathon personas

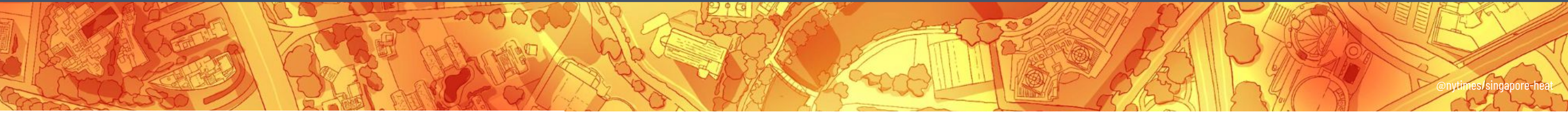
Based on the inputs provided during registration, **we've developed a loose 'role' for each of you - just to help with the composition of the teams** and to bring out everyone's strengths.

These roles aren't fixed labels, just starting points. So take them with a grain of salt and feel free to go beyond them!

- **The spark** - Brimming with fresh energy and ideas, bringing a creative match to the challenge.
- **The Builder** - Loves tools, code, and tinkering. If it's broken, they'll fix it. If it doesn't exist, they'll build it.
- **The Navigator** - seasoned perspective, knows how to chart the bigger picture.
- **The Connector** - Brings people and perspectives together and keeps ideas grounded in real-world needs.

	Timbuktu	Davao
City 		
Neighbourhood 		
School/classroom 		

Q&A



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> Can we work across teams?
Absolutely! Collaboration is encouraged—cross-pollination of ideas often leads to the best outcomes.

> Where can I find more information about the input datasets?
We've prepared a document with input data description, documentation and metadata links, available under *SHARED_FOLDER/docs/Readme_Inputdata.pdf*

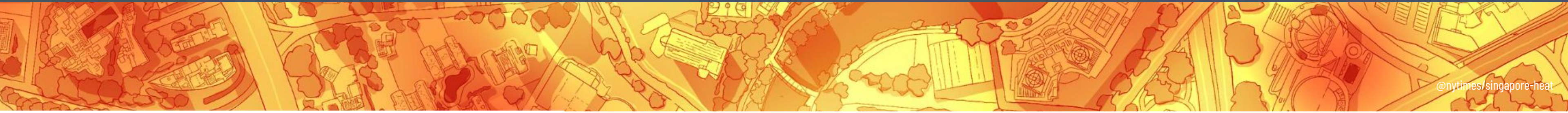
> Can we use tools other than the ones provided?
Of course. If you have your own go-to workflows or favorite packages, go for it. If you want to approach the mission more conceptually, please do. The tools are provided as a starting point, not to limit your creativity.

> Something broke and I have no idea why?
Welcome to modeling! No worries, the Builder of support team is here to help.

> Are snacks provided?
Yes, snacks should be available throughout the hackathon. No formal breaks are planned, just help yourself whenever you need a boost.

> What's with the "panel of dragons"?
At the end of the hackathon, each team has the opportunity to present their work, insights, or boldest ideas to a panel of experts - our 'dragons' - through a 5-minute presentation. The dragons will ask curious questions, offer feedback, and might challenge you to think one step further. While it's not about winning, they will select the team whose work shows the greatest potential for real-world impact. That team will be featured on the World Bank's Data Blog.

Panel of dragons



Ariane Middel, Ph.D.

Associate Professor @ Arizona State University (USA)
School of Arts, Media and Engineering (AME) & School of Geographical Sciences and Urban Planning (SGSUP)
Director, SHaDE Lab
President, International Association for Urban Climate (IAUC)
Board member, AMS Built Environment
Global Futures Scientist, Julie Ann Wrigley Global Futures Laboratory

Gerald Mills, Ph.D.

Professor @ University College Dublin (Ireland)
Review Editor AR7 Special Report on Cities & Climate Change
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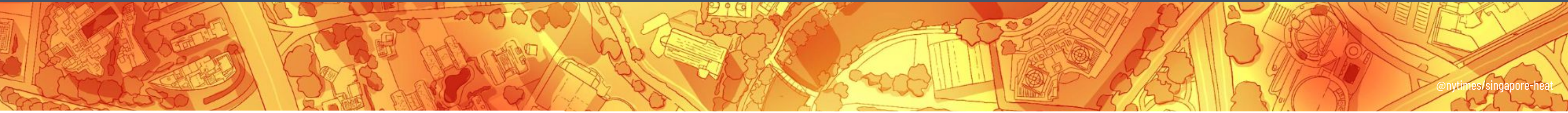
Lead of Climate-Resilient Cities lab
Chief Investigator at the ARC Centre of Excellence for Climate Extremes
IPCC Lead author AR7 Special Report on Cities & Climate Change
Board member, AMS Built Environment

Technical guidelines - demo



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