LOCAL URBAN CLIMATE MODELLING IN THE TROPICS

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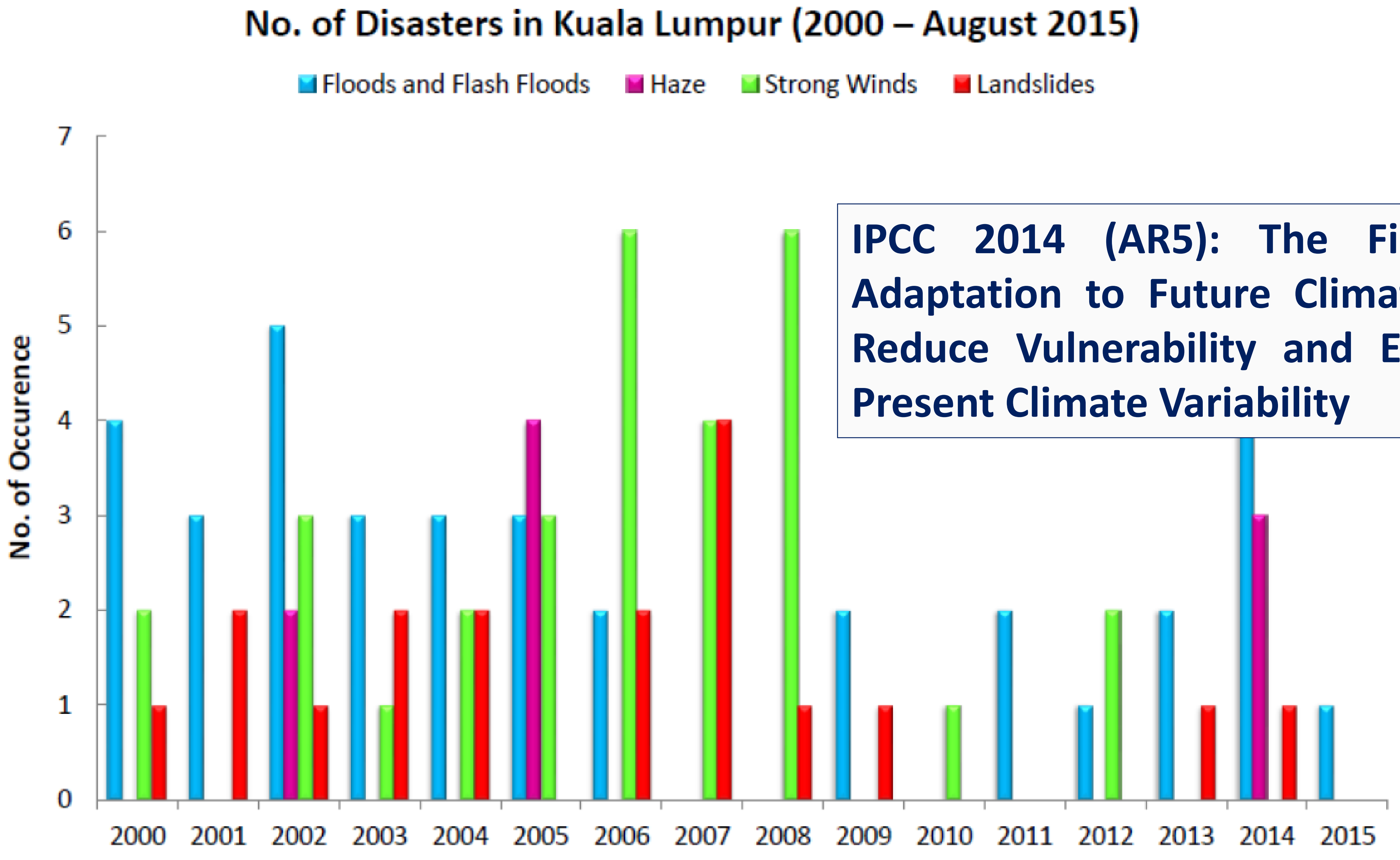


IPCC 2014 (AR5): The First Step in Adaptation to Future Climate Change – Reduce Vulnerability and Exposure to Present Climate Variability

Disaster Resilient Cities:

Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur

- **10 organisations from Malaysia**

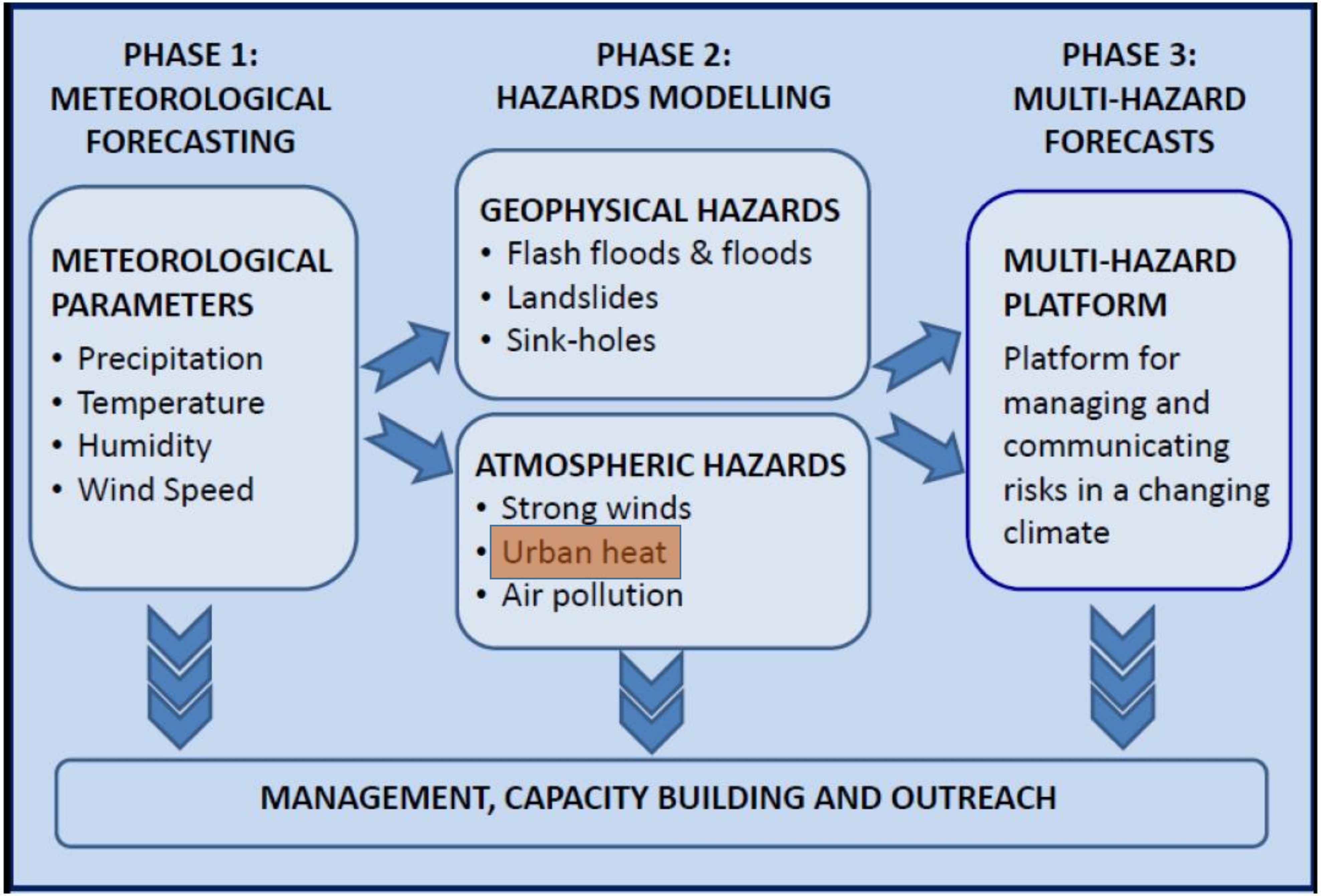
5 Research Organisations: Universiti Kebangsaan Malaysia, SEADPRI-UKM; University of Malaya, UM; Meteorology Department of Malaysia, MetMsia; Minerals and Geoscience Department of Malaysia, JMG; Department of Environment Malaysia, DoE

5 Business Partners: UKM Pakarunding Sdn. Bhd., UKMP; Geomapping Technology Sdn. Bhd.; Param Agricultural Soil Surveys (M) Sdn. Bhd; Geological Society of Malaysia; CoRE Expert Systems Sdn. Bhd.

- **6 organisations from the UK:**

3 Research Organisations: University of Cambridge, UoC; British Geological Survey, BGS; University College London, UCL

3 Business Partners: Cambridge Environmental Research Consultants, CERC, Cuesta Consulting and JBA


PHASE 1:
METEOROLOGICAL
FORECASTING
PHASE 2:
HAZARDS MODELLING
PHASE 3:
MULTI-HAZARD
FORECASTS
METEOROLOGICAL PARAMETERS
• Precipitation
• Temperature
• Humidity
• Wind Speed
GEOPHYSICAL HAZARDS
• Flash floods & floods
• Landslides
• Sink-holes
ATMOSPHERIC HAZARDS
• Strong winds
• Urban heat
• Air pollution
MULTI-HAZARD PLATFORM
Platform for managing and communicating risks in a changing climate
MANAGEMENT, CAPACITY BUILDING AND OUTREACH

URBAN MICRO-CLIMATE

- Building materials with larger sensible heat storage
- Increased anthropogenic heat (traffic, A/C etc.)
- Reduced latent heat flux (less evapotranspiration)
- Less open spaces and green areas
    - More short-wave radiation trapped within narrow streets
    - Less wind*

HENCE WARMER AND MORE PARTICLE/POLLUTANT INTENSIVE

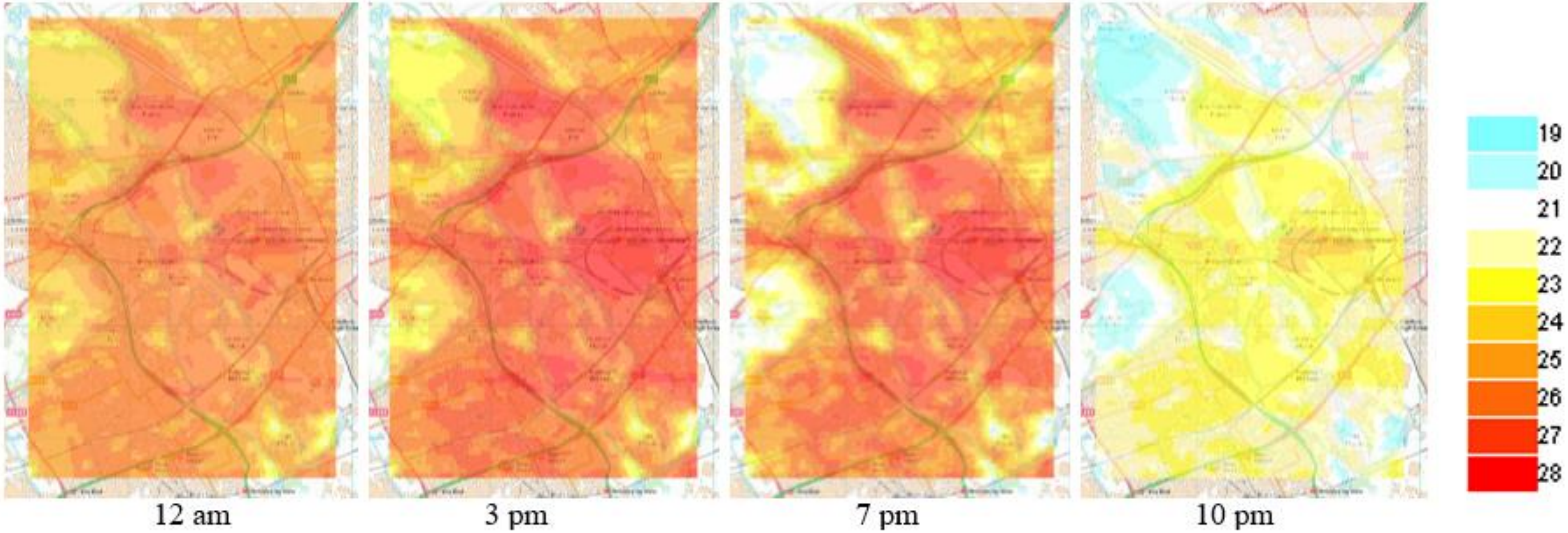
*Oke, T. R., 1982. The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society,* 108(455), pp. 1-24.

BUILT UP vs GREEN AREAS: Mid-latitudes

Case Study: LONDON
Mostly concrete, low-rise, sparsely built-up central area (Olympic parkland)
Surrounded by low-rise, compact, residential area, and Lee Valley Park to the north

Green areas are coolest with up to 9°C of difference compared to built-up core of the modelling domain!

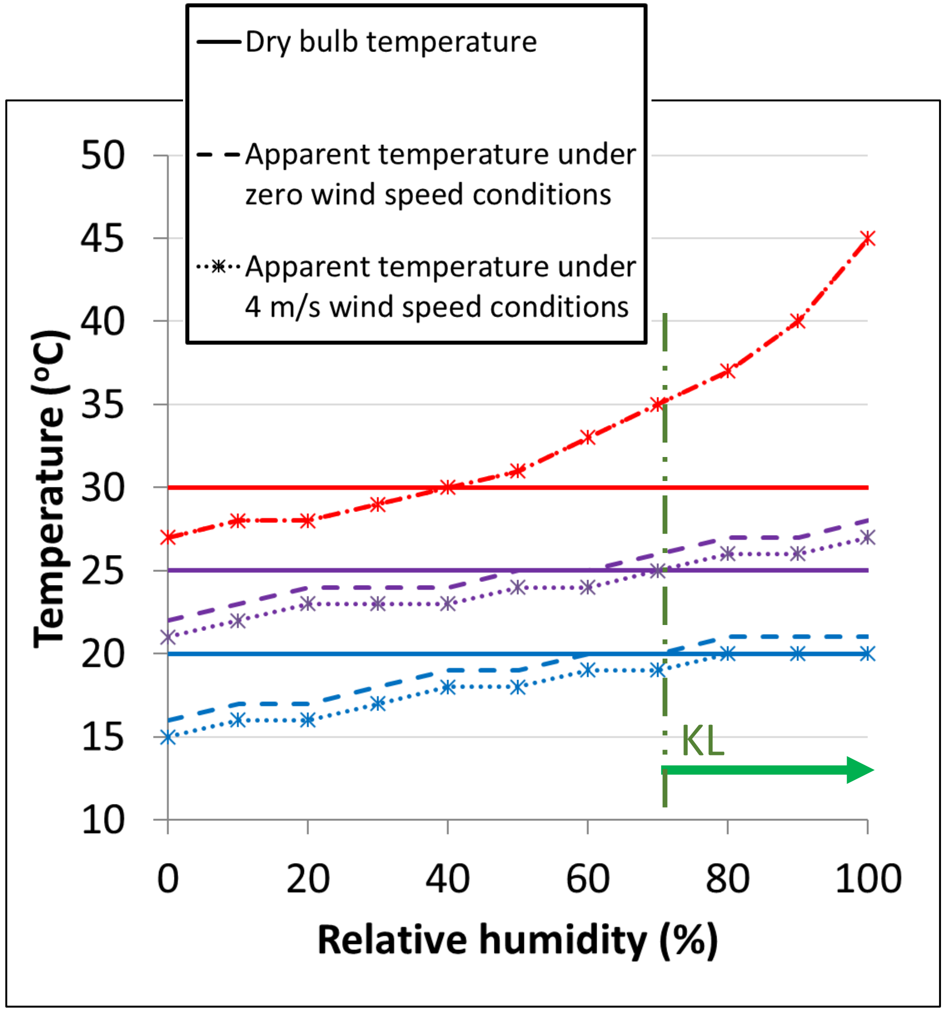
*Aktas, Stocker, Carruthers, Hunt (2017) A sensitivity study relating to neighbourhood-scale fast local urban climate modelling within the built environment, *forthcoming*



BUILT UP vs GREEN AREAS: the Tropics

"Apparent temperature is a construct intended to reflect the physiological experience of combined exposure to humidity and temperature and thereby better capture the response on health than temperature alone"
(Wichmann, Andersen, Ketzel, Ellermann & Loft (2011) Apparent Temperature and Cause-Specific Emergency Hospital Admissions in Great Copenhagen, Denmark, PLoS ONE 7, e22904)

T ↘ RH ↗ U↘



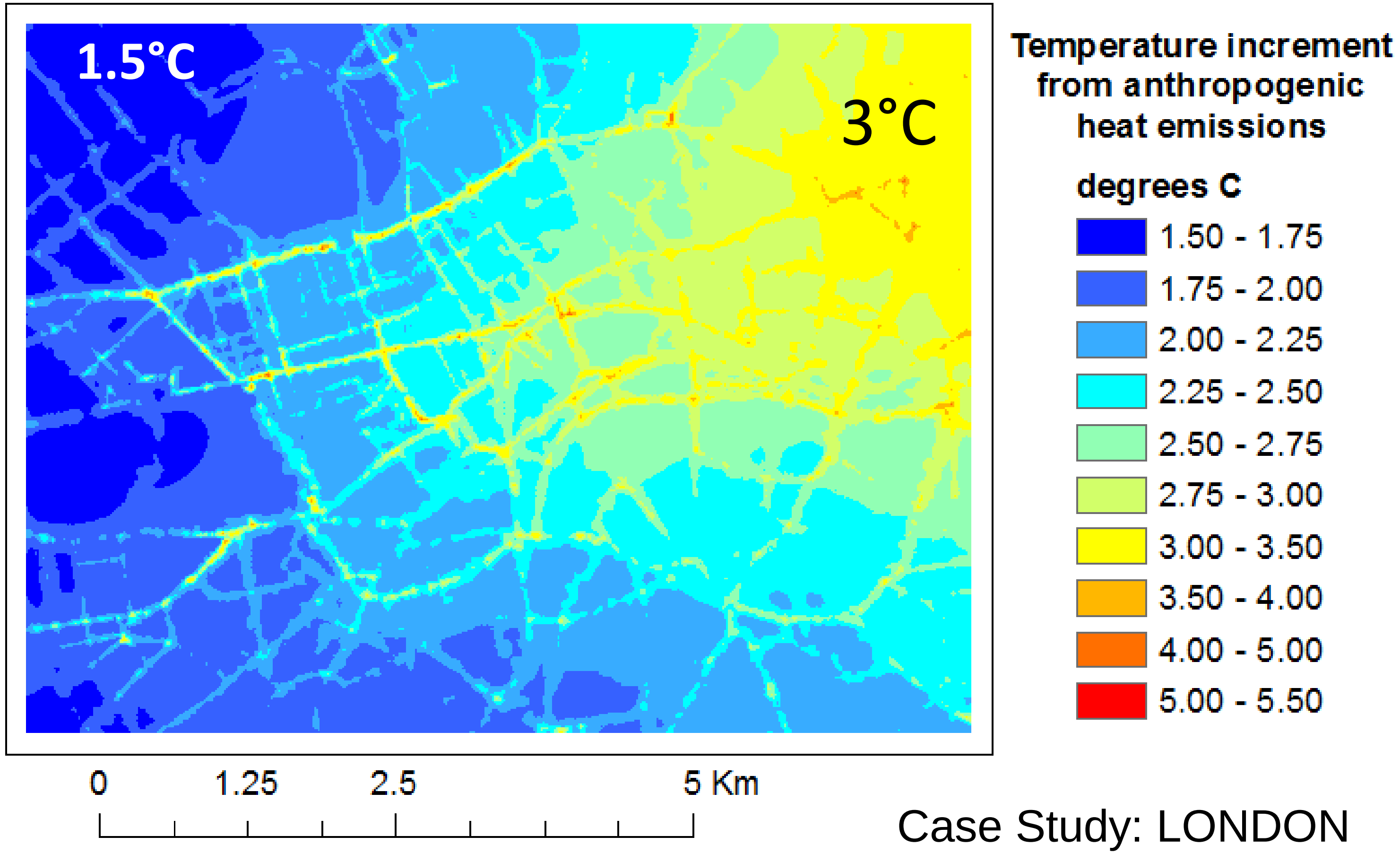
Plotted based on "Steadman, R. G. (1979). The assessment of sultriness. Part II: Effects of wind, extra radiation and barometric pressure on apparent temperature. *Journal of Applied Meteorology, 18*, 874-885"

ANTHROPOGENIC HEAT SOURCES: the Tropics

- In the high-rise and dense, compact cities, anthropogenic impact govern the UHI.

Yang, X, Li, Y, Luo, Z, Chan, PW (2017) The urban cool island phenomenon in a high-rise high-density city and its mechanisms, International Journal of Climatology 37; 890–904

- Waste heat from A/C systems
  - High A/C use in the tropics
- Fuel use from traffic generates heat
  - Traffic congestion in all urban areas; larger reliance on personal vehicles in tropical urban areas.
- Low wind speed in the tropics amplifies impact of anthropogenic heat sources
  - U↘ T↗

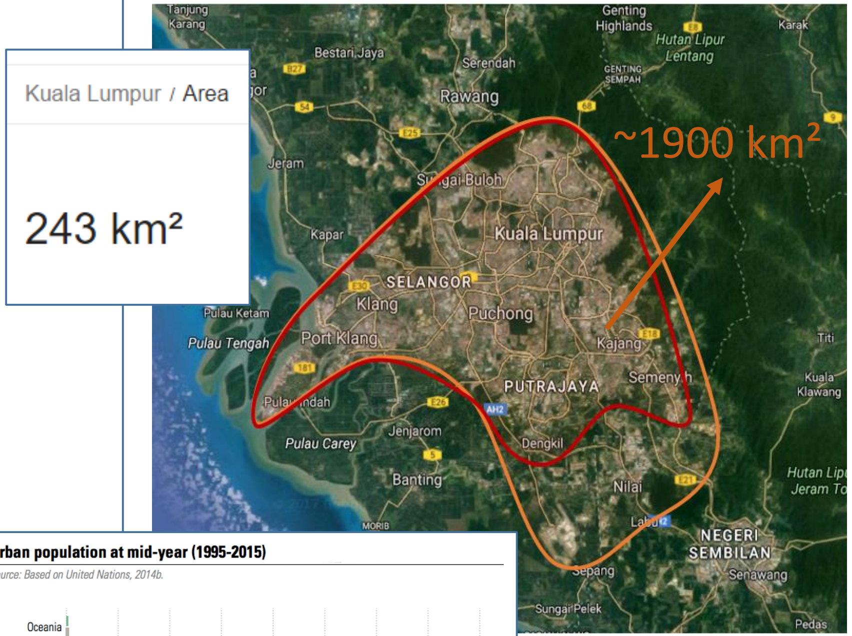


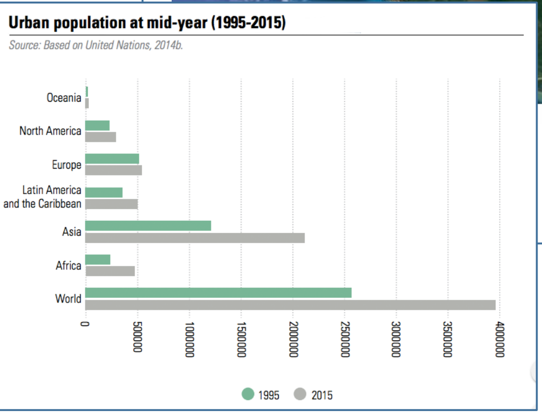
Case Study: LONDON

Temperature increment due to anthropogenic heat sources : 18th August, ambient rural temperatures ~ 24°C & upwind rural wind speed ~ 0.5 m/s

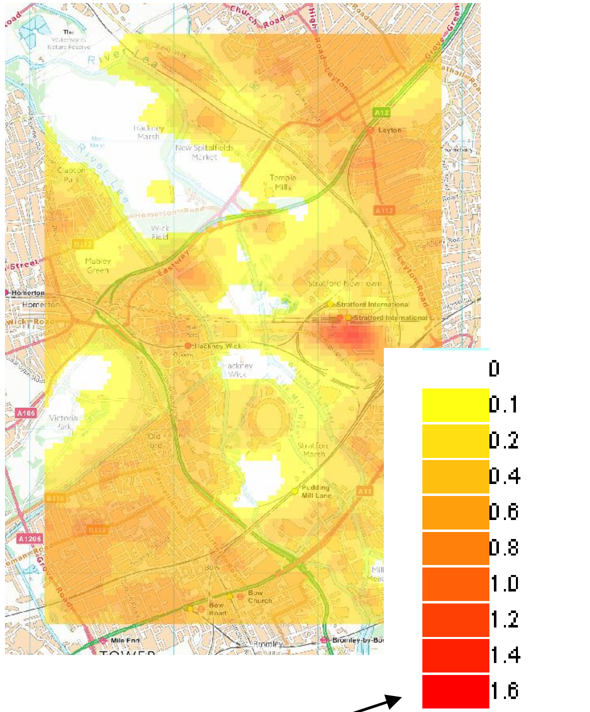
Other critical factors intrinsic to tropical Asian megacities

- Size and population





- Low wind speed



Change in the calculated temperature values by up to 1.6 degrees when wind speeds are halved!

- Increased precipitation

- During or right after precipitation events, the relationship between near surface temperatures and land use disappear*.

*Azid, S., Zaki, S. A., & Razak, K. A. (2015). Spatiotemporal Analysis on the Squatter Development: A Case Study in Kampung Baru, Kuala Lumpur. *International Joint Conference of Senvar-Inta-Avan*, (pp. 45-52). Johor.

- Soil saturation is important and need to be considered in modelling.

MITIGATION – urban morphology and street canyon geometry

MORPHOLOGICAL PROPERTIES ADVANTAGEOUS FOR URBAN HEATING ARE DEPENDENT ON LOCAL CLIMATE REGIME

- W/H ↗ UHI ↗ large radiation input (no shading) – case study: LECCE

*Maggiotto, Buccolieri, Santo, Leo & di Sabatino (2014) Validation of temperature-perturbation and CFD-based modelling for the prediction of the thermal urban environment: the Lecce (IT) case study, *Environmental Modelling & Software* 60, pp. 69-83

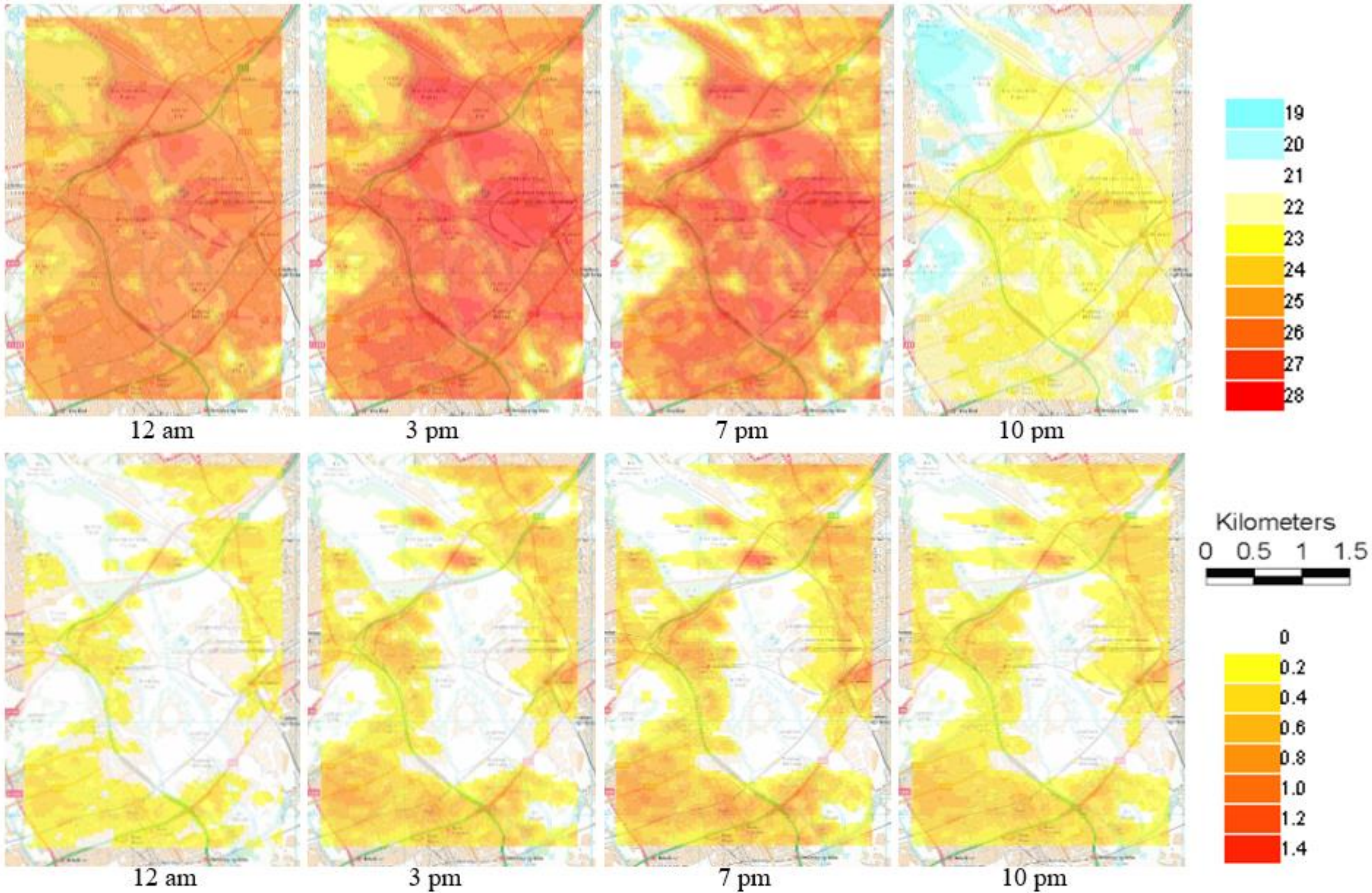
- W/H ↘ UHI ↗ for the hot and humid tropical areas as lack of openness results in stagnation

*Oke, T R (1978) Boundary Layer Climates

MITIGATION – high vs low thermal admittance materials

All concrete
(absolute temperatures)

Surrounding area masonry
(temperature differences)



CONCRETE (high thermal admittance) vs MASONRY (low thermal admittance)

Case Study: LONDON

*Aktas, Stocker, Carruthers, Hunt (2017) A sensitivity study relating to neighbourhood-scale fast local urban climate modelling within the built environment, *forthcoming*
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MITIGATION – cool/green roofs

	Green	Green Dry	Cool
Largest temperature perturbation (°C)			
Cloudy days	–0.96	–0.34	–0.58
Partly cloudy days	–1.01	–0.38	–1
Clear-sky days	–1.05	–0.38	–1.27
Period of largest perturbation			
Cloudy days	18:15–23:15	21:00–24:00	09:15–13:45
Partly cloudy days	19:00–21:00	21:00–01:00	08:30–13:00
Clear-sky days	19:45–24:00	24:00–03:00	09:00–11:00
Mean daily perturbation (°C)			
Cloudy days	–0.45	–0.14	–0.2
Partly cloudy days	–0.49	–0.15	–0.33
Clear-sky days	–0.48	–0.16	–0.44

*Virk, Jansz, Mavrogianni, Mylona, Stocker & Davies (2014). The effectiveness of retrofitted green and cool roofs at reducing overheating in a naturally ventilated office in London: Direct and indirect effects in current and future climates . *Indoor and Built Environment* 23(3), pp. 504-520.

MITIGATION – sustainable building/urban design

- Locally available material (preferably high heat capacity material, such as wood), local building knowledge readily available within the community.
- Window openings oriented to make the most out of winds and breezes. Other openings that will facilitate air flow within and around the building, enhanced by fans if needed to avoid stagnation.
- Use of shade by external elements such as trees or overhanging eaves (a veranda?).
- Buildings placed not too close to each other, creating large aspect ratio street canyons, for ventilation.
- **Building materials with high albedo, low surface resistance to evaporation, cool or green roofs.**
- **High heat capacity materials.**
- **Insulation designed so as to minimize cooling demand to avoid waste heat emissions from AC systems.**
- **Scatter of small scale green areas and water bodies through the cityscape?**

USE RESOURCES EFFICIENTLY, PRIORITISE, TRADE OFF, ACCOMMODATE DIVERSE NEEDS

Future modelling

- Modelling tools can assess mitigation options

	Anthropogenic heat emissions scenarios	**Building materials** scenarios	**Land use & building density** scenarios
Example scenarios	Actual and reduced values for W/m^2 or converted from CO_2 emissions for road	Different thermal admittance values to assess heat storage (including insulation)	Alter the urban morphology to assess impact on the wind and turbulence field, and hence temperatures
	Actual and reduced values for estimated waste heat from AC systems	Different albedo values to assess re-radiation (green walls/roofs, cool roofs)	Effect of the green areas on the overall urban temperatures, as well as on human wellbeing

Thanks for listening!

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