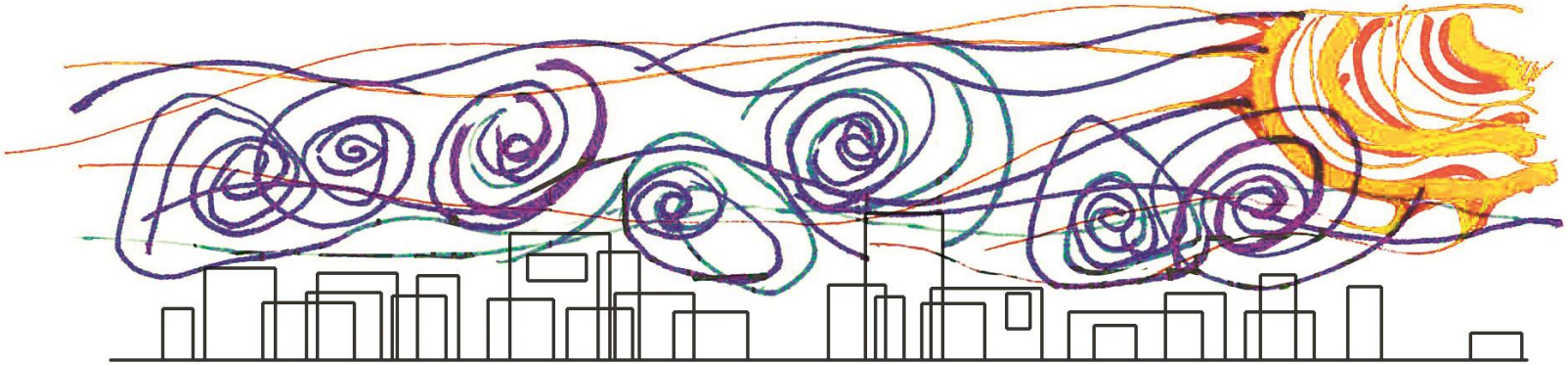


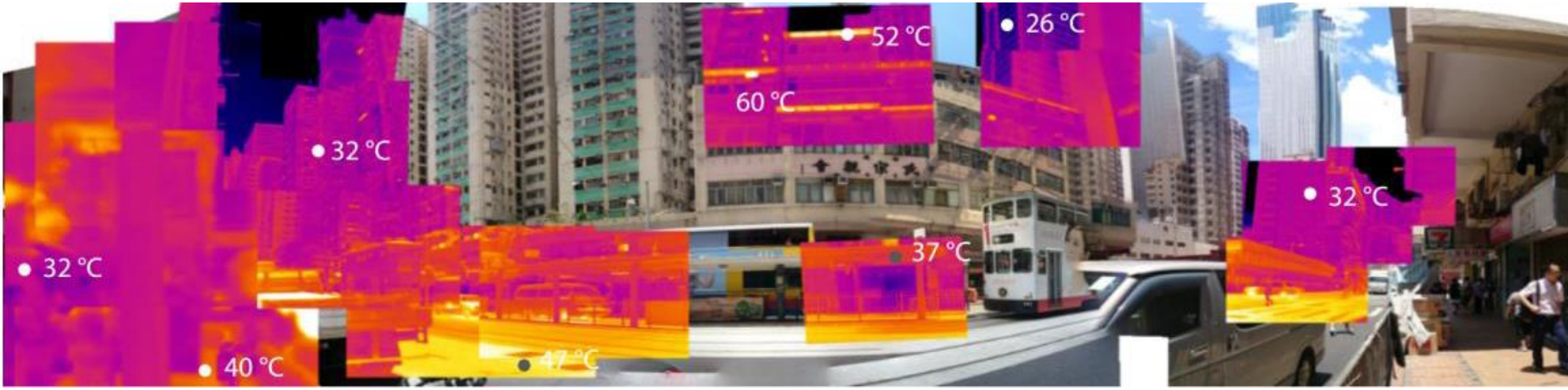
Assessment and Management of Urban Micro-climate for the Public Realm

Jianxiang Huang
LEED AP, AICP (Certified Planner)
Assistant Professor
The University of Hong Kong

John D. Spengler
Akira Yamaguchi Professor of Environmental Health and Human Habitation
Harvard University
TH Chan School of Public Health

Mar. 04 2015

Assessment and Management of Urban Micro-climate for the Public Realm



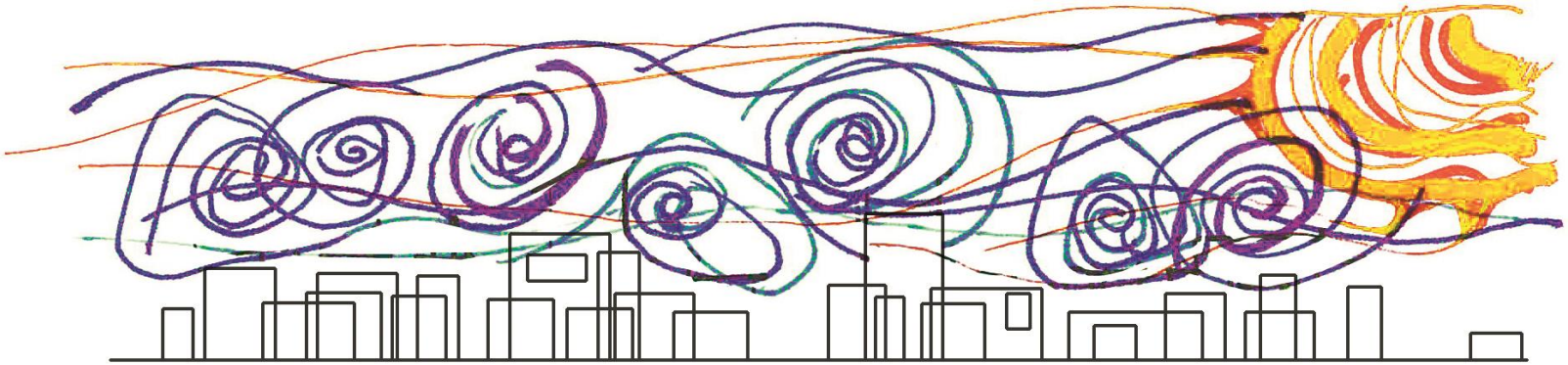
Infrared Imaginary of Sai Ying Pun in Hong Kong

Urban Form alters the climate on a various scales

- Precipitation
- Heat
- Wind

Intentional Design can mitigate and possible enhance the Micro-climates of cities

CityComfort+: Modeling Comfort for the Public Realm

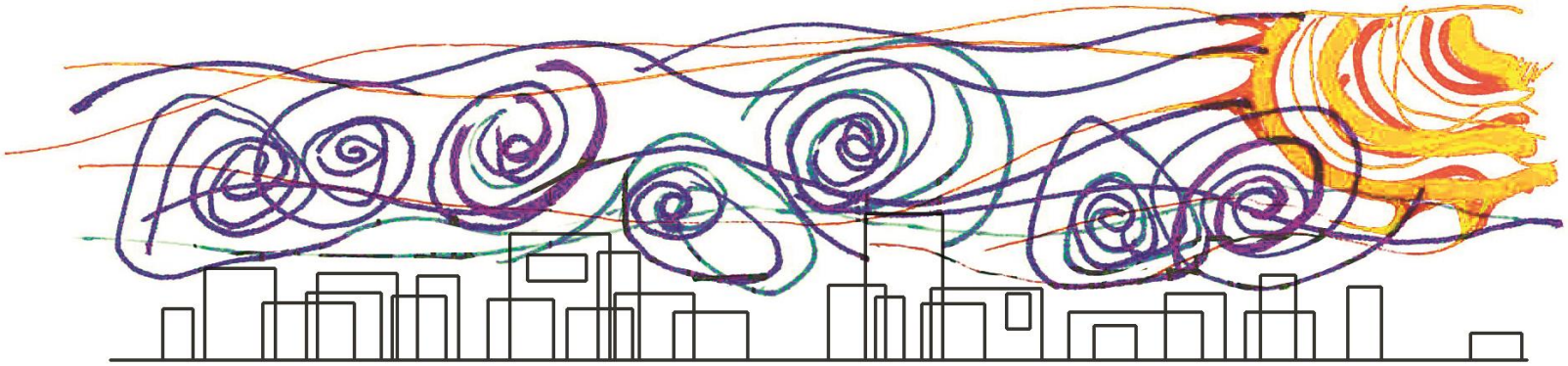


Presenting a New Approach to Predicting Human Comfort in Urban Settings

WHY?

- Human Comfort is an Attribute of outdoor places
- Currently there is no systematic or acceptable method for quantifying comfort in outdoor places—Noise and Shading Studies are used as proxies
- Important to anticipate future conditions with sophisticated and reliable models

CityComfort+: Modeling Comfort for the Public Realm

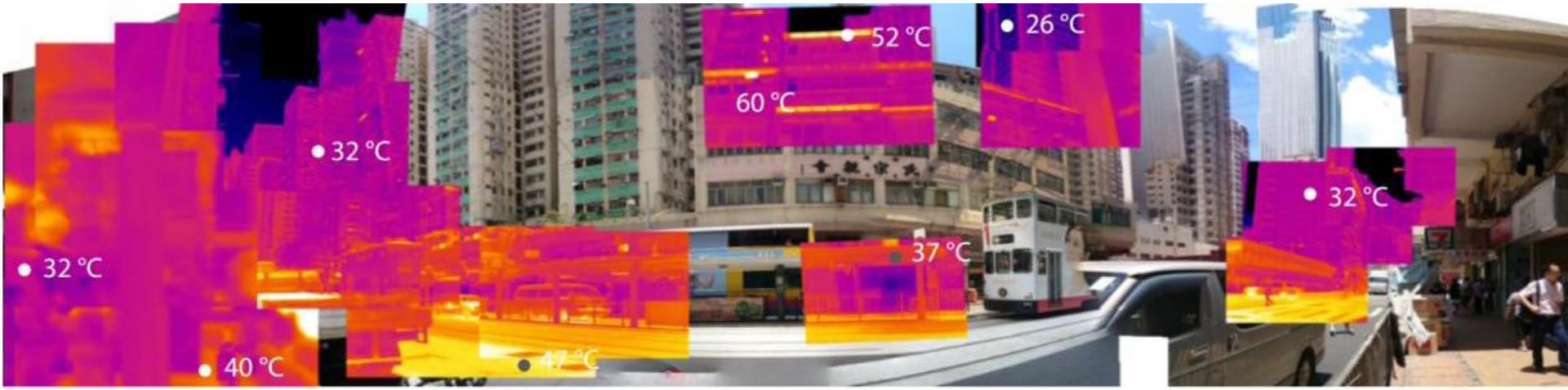


What is Human Comfort?

- Physiology, thermal equilibrium, social context, aesthetic appeal, inspiration, location

- Tapestry of physical, psychological and social factors

Assessment and Management of Urban Micro-climate for the Public Realm



Infrared Imaginary of Sai Ying Pun in Hong Kong

OUTLINE

- THERMAL COMFORT – elusive
- NEED FOR A MODEL OF THERMAL COMFORT – for today and future
- CITYCOMFORT+ -- Theory, physics and modules
- VALIDATION -- Instruments and people
- APPLICATION – Copley Plaza, Boston, MA USA
- APPLICATION – Hong Kong, China

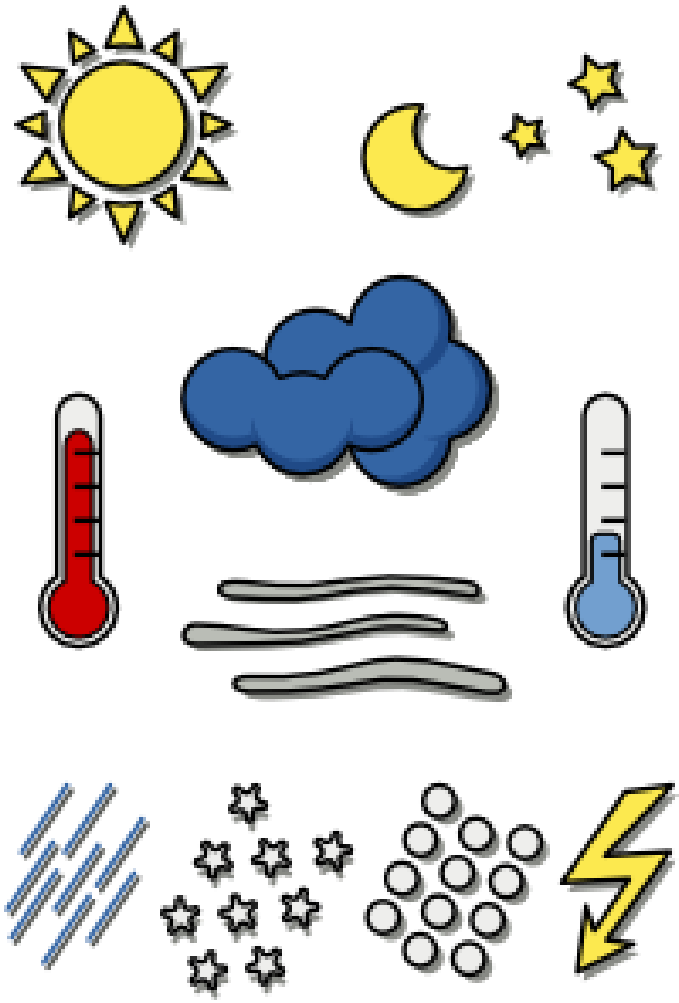
Eat Food,
Burn Calories,
Do Work, Produce Heat

CO_2

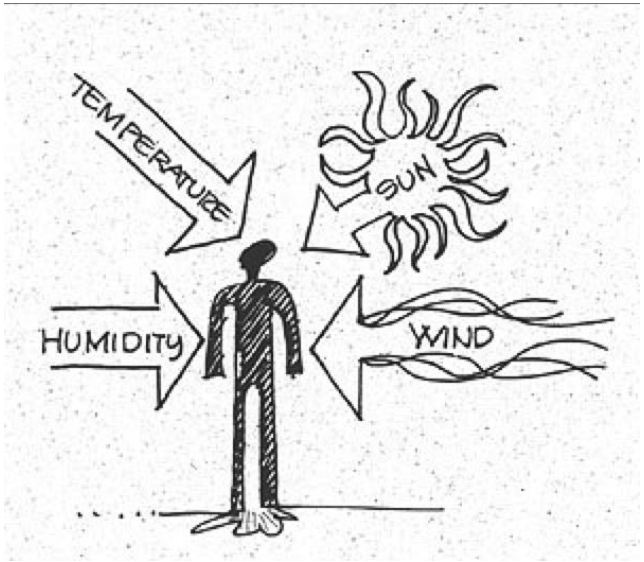
H_2O

100 Watts

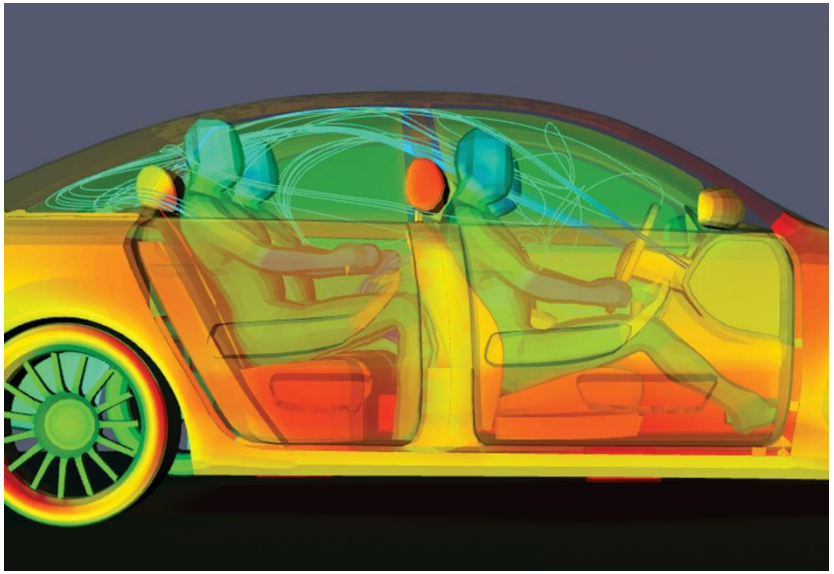
Adapt To Conditions To Maintain Comfort

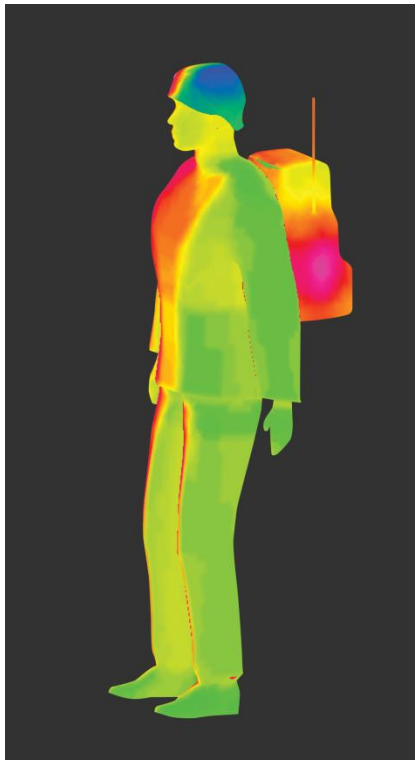


We know a great deal about thermal regulation and modeling comfort



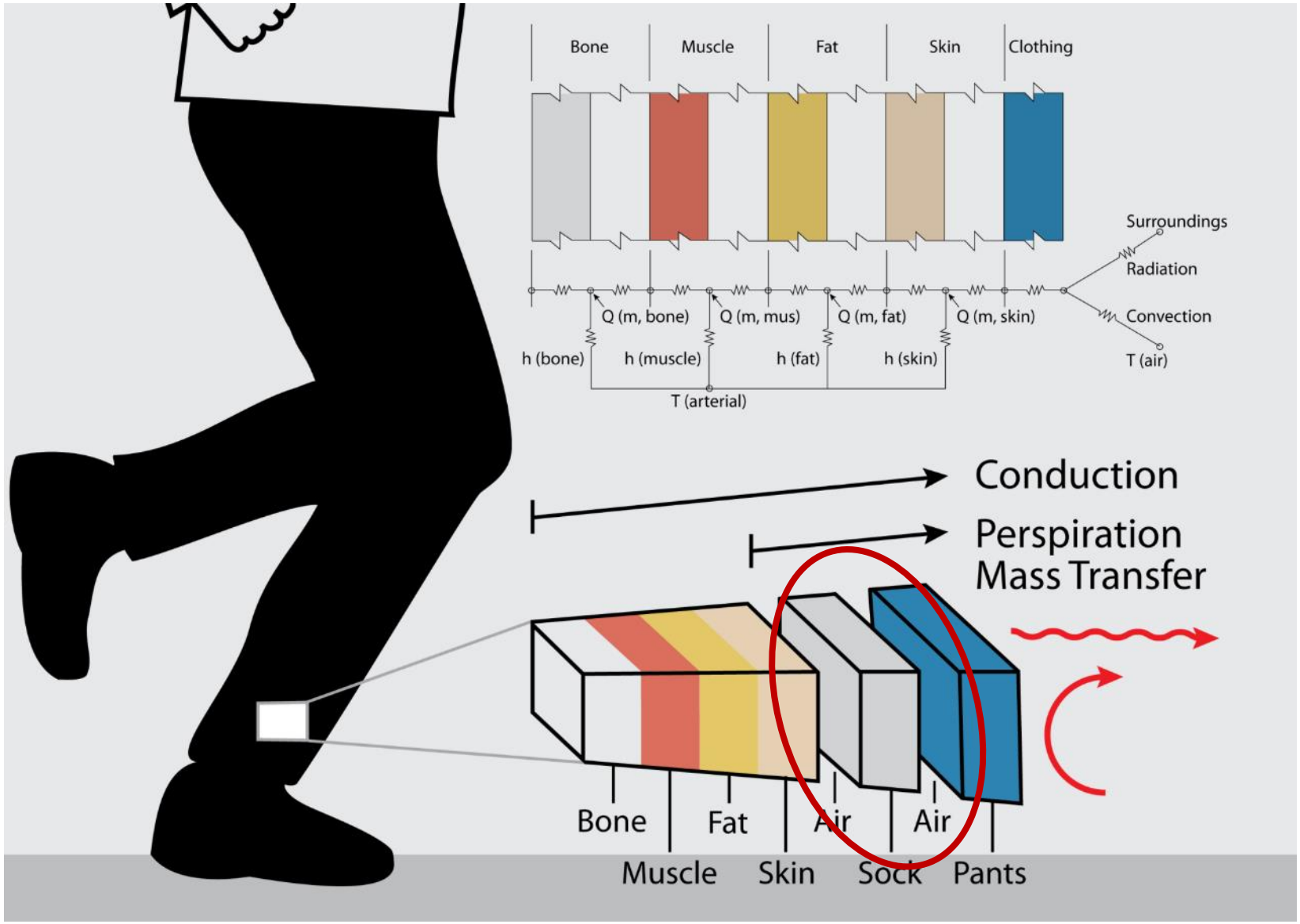
- **Metabolic Activity**
- **Environmental conditions**
- **Age**
- **Gender**
- **Clothing**
- **Activities**
- **Preference**
- **Locations**





www.thermoanalytics.com

Balance between Internal Heat and Environment

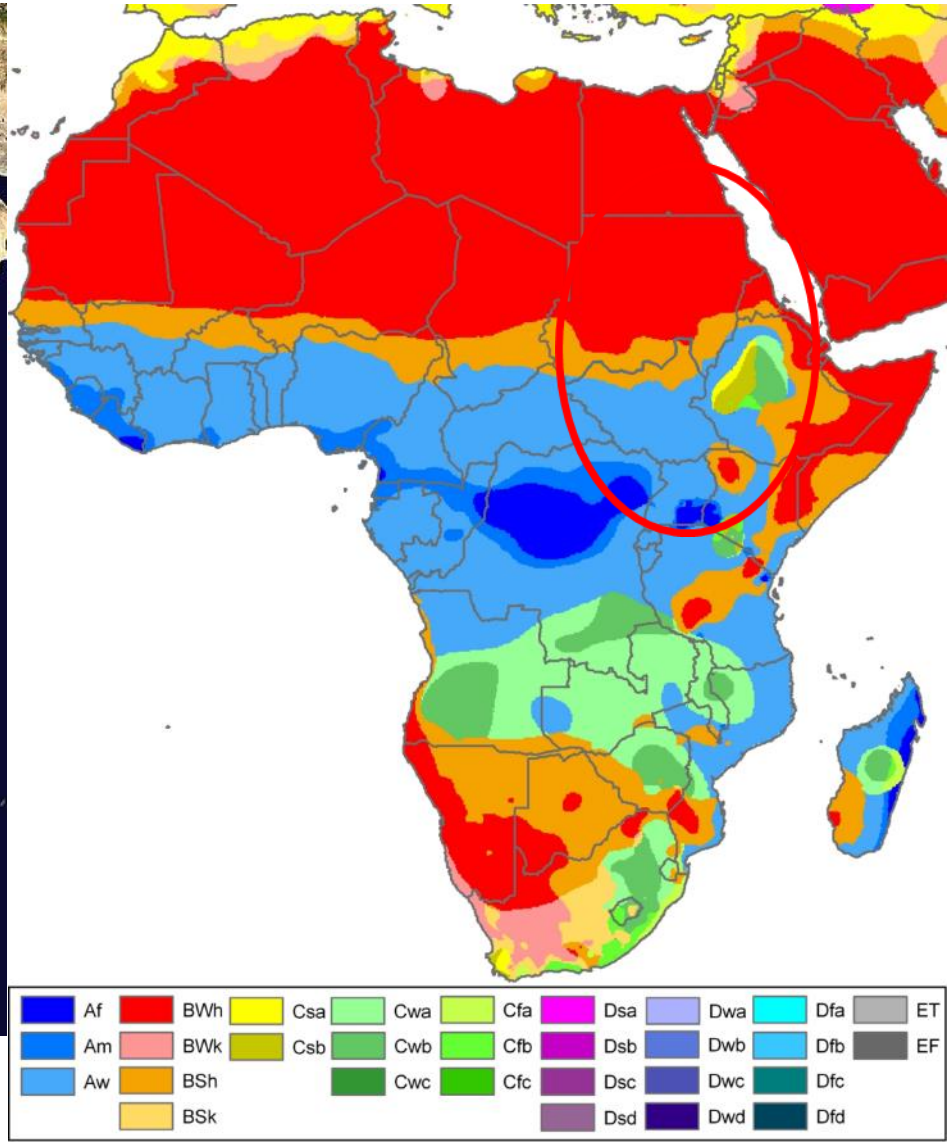


http://www.thermoanalytics.com/human_thermal_comfort

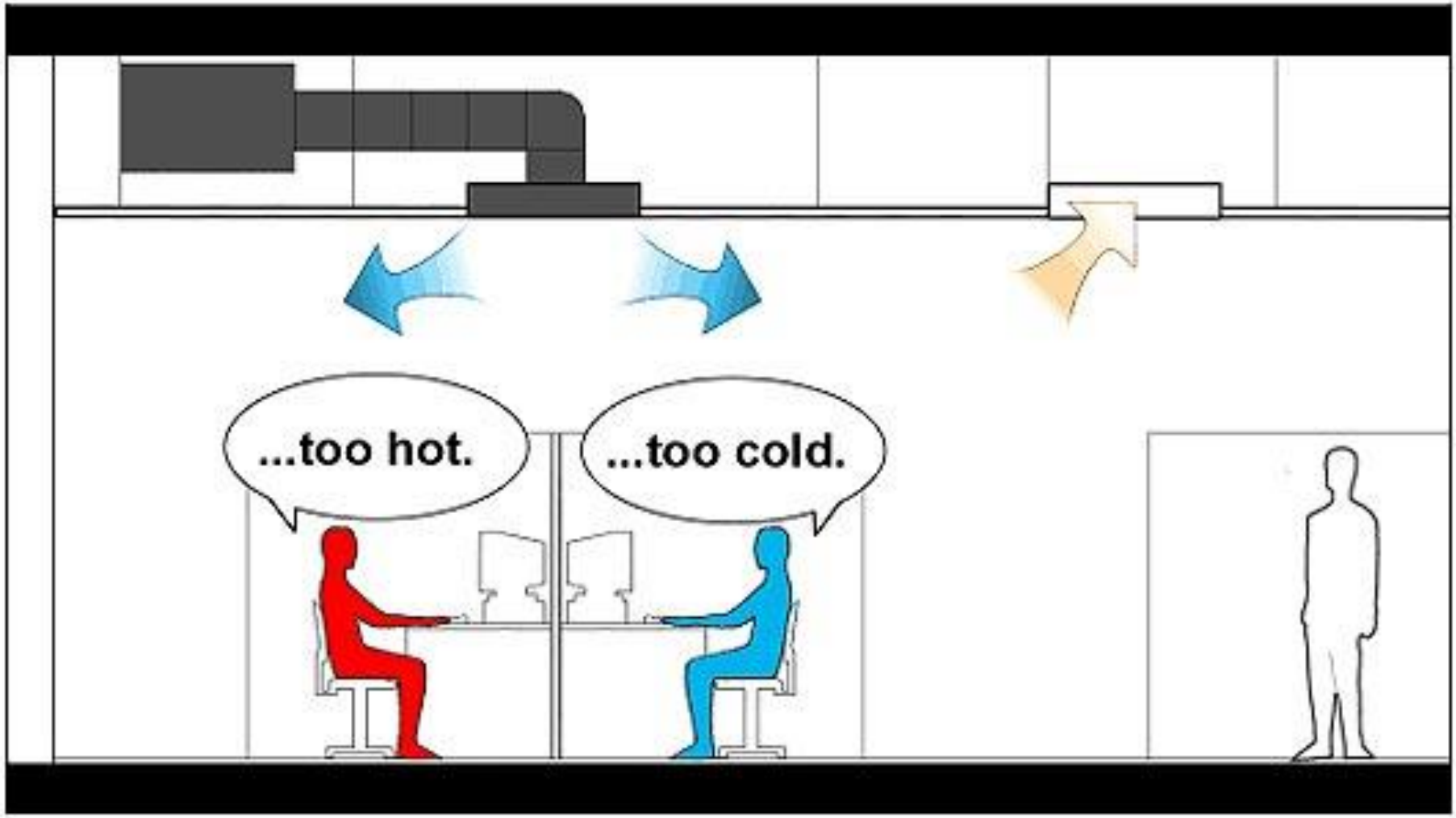
Nakuru National Park, Kenya

http://www.getintravel.com/lake-nakuru-national-park-kenya/
rainbow-over-the-savannah-lake-nakuru-national-park-kenya/

Average Temperature in the 70s and 80s

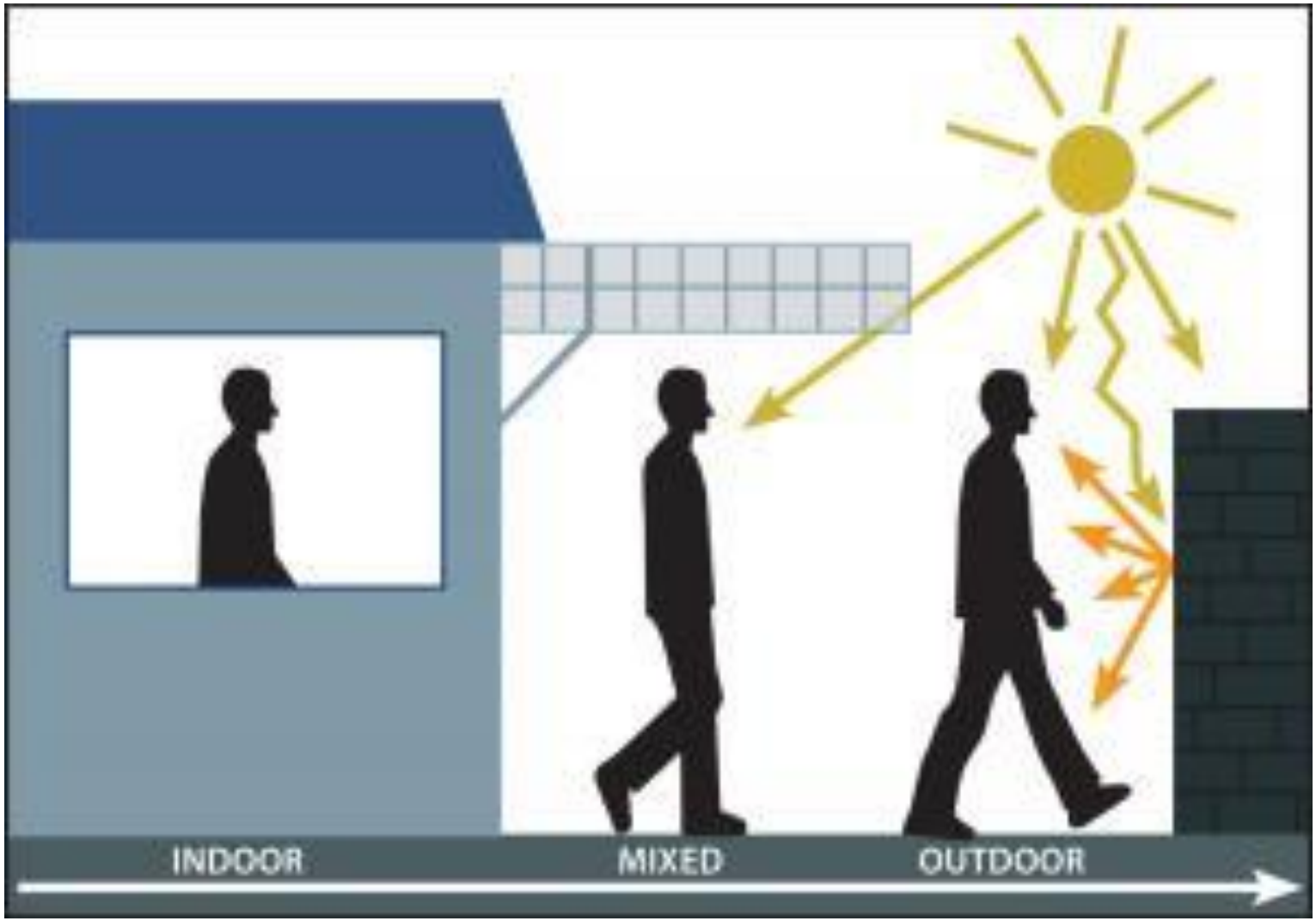


Making occupants "comfortable" is fundamental to HVAC Design for the Built Environment



Center for the Built Environment at UC-Berkeley

Modifying Indoor Comfort Models for Outdoors



Center for the Built Environment---UCal Berkeley

HARVARD CAMPUS

Urban Environments are complex

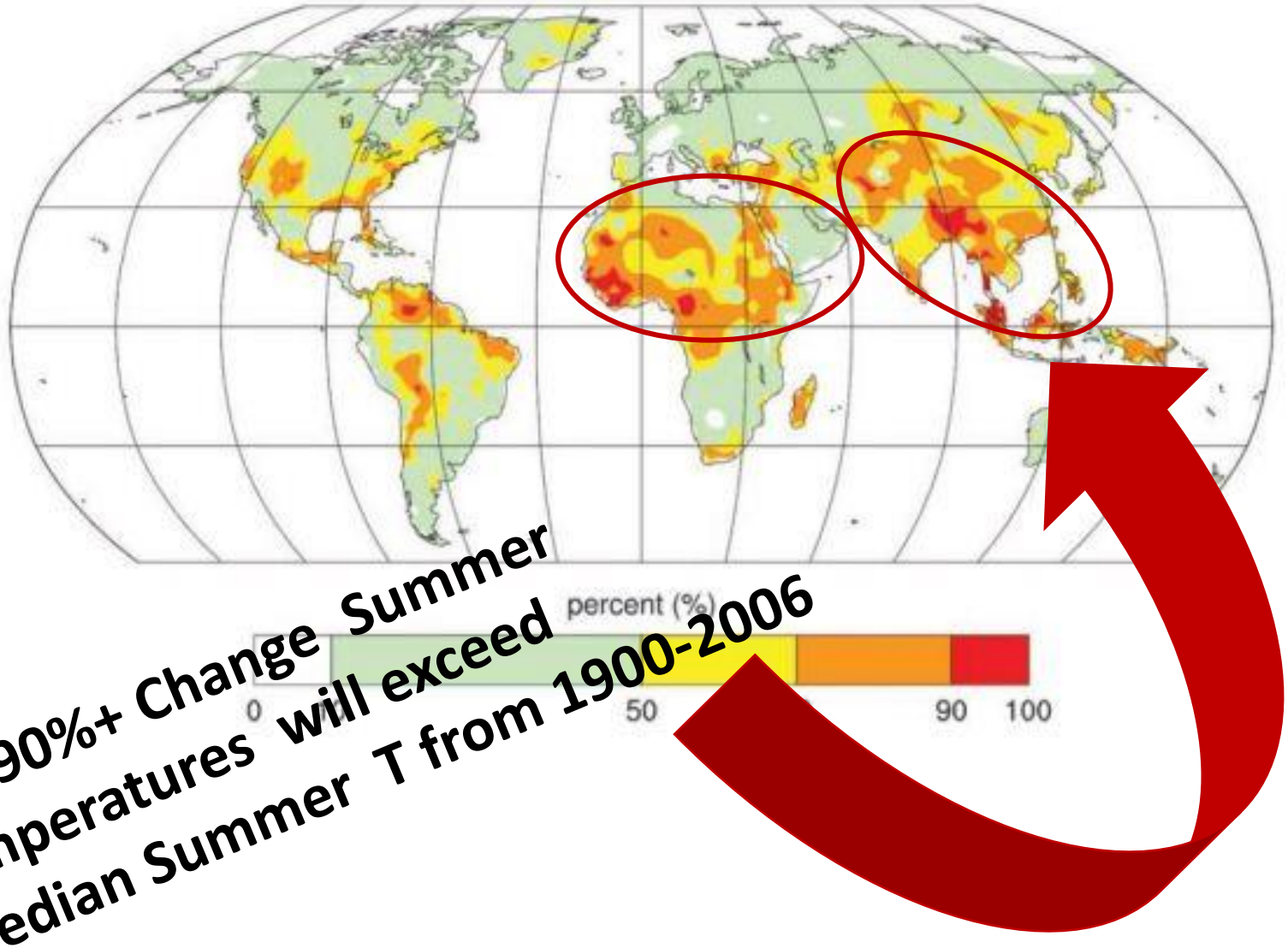

Conditions Change!
HARVARD SQUARE
JANUARY 2015

Boston Common: the Public Realm

Modeling Public Places: Now and for the Future

2014: One for the Record Books NASA and NOAA confirm that last year was the hottest in recorded history.

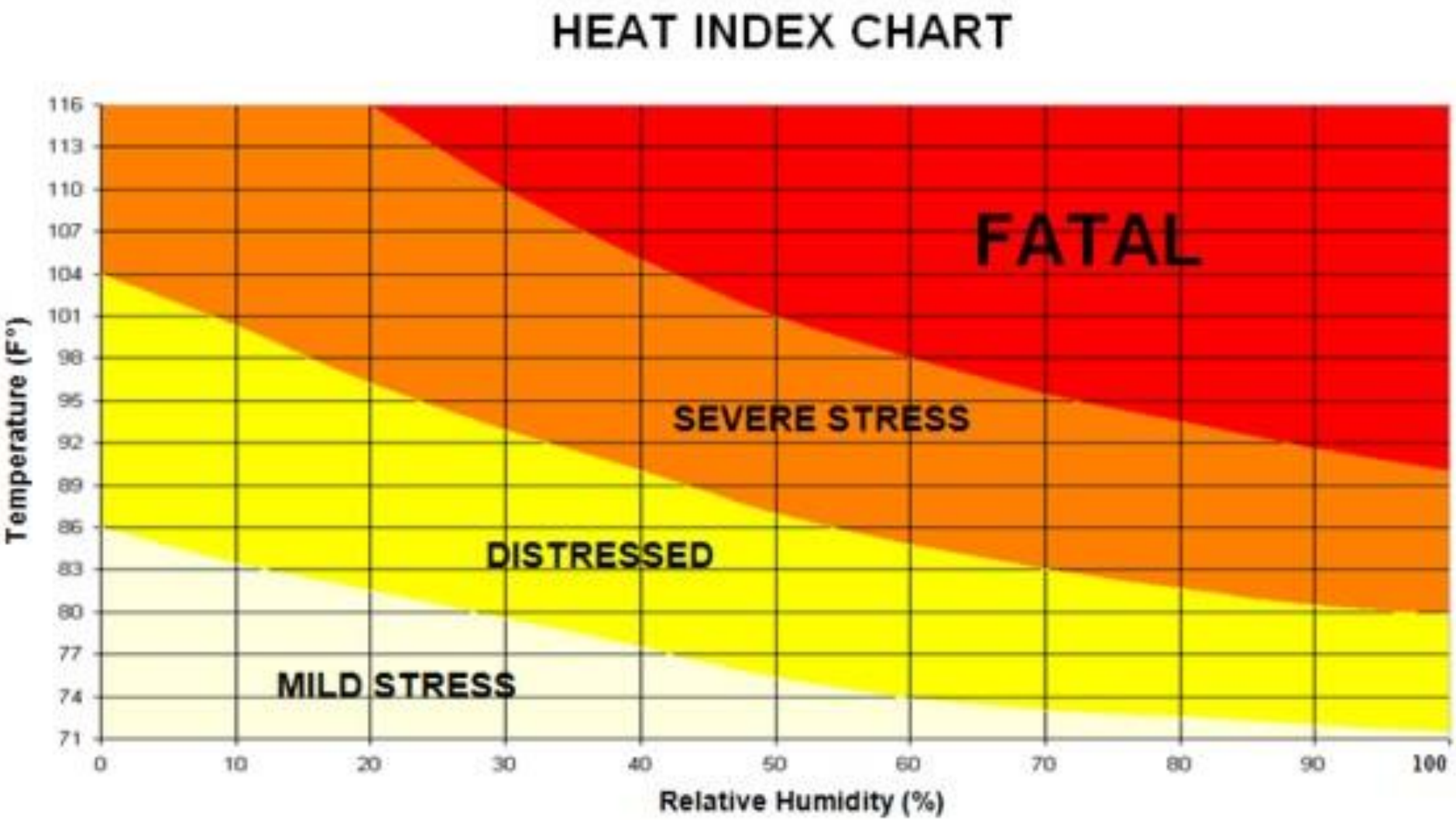
Climate Change and Heat Stress by 2050



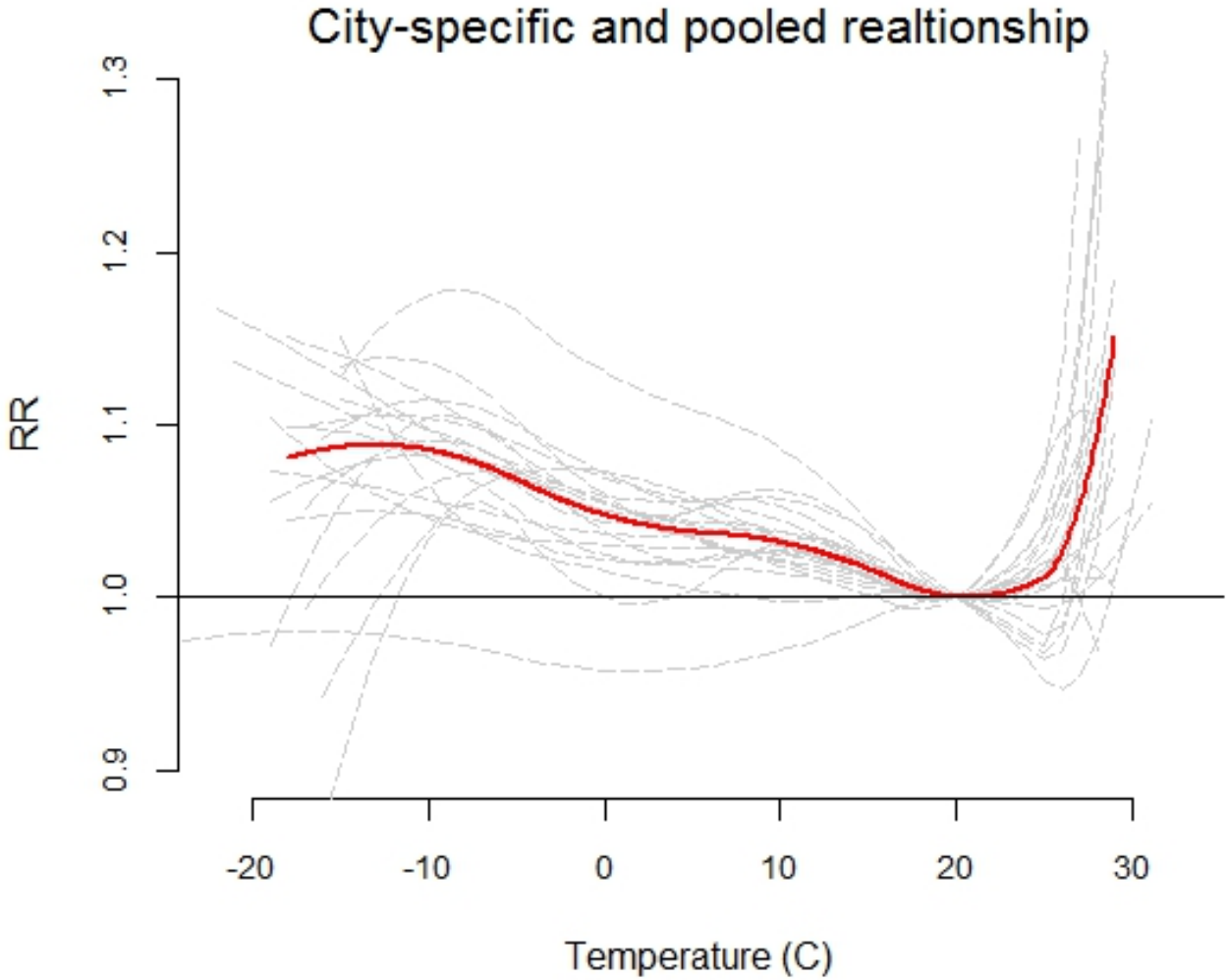
70 - 90%+ Change Summer Temperatures will exceed Median Summer T from 1900-2006

Battisti and Naylor 1999

Human Reponses to Heat Stress



Mortality and Temperature----Multi-City Analysis



(Gasparrini and Armstrong 2011b, Gasparrini et al. 2012)

Consequences of Heat Stress

HEAT STRESS IS SERIOUS FOR CROPS, ANIMALS AND HUMANS

Motivation for CityComfort+

- To quantify links between climate and its benefits/risks --- environmental, social and economic.

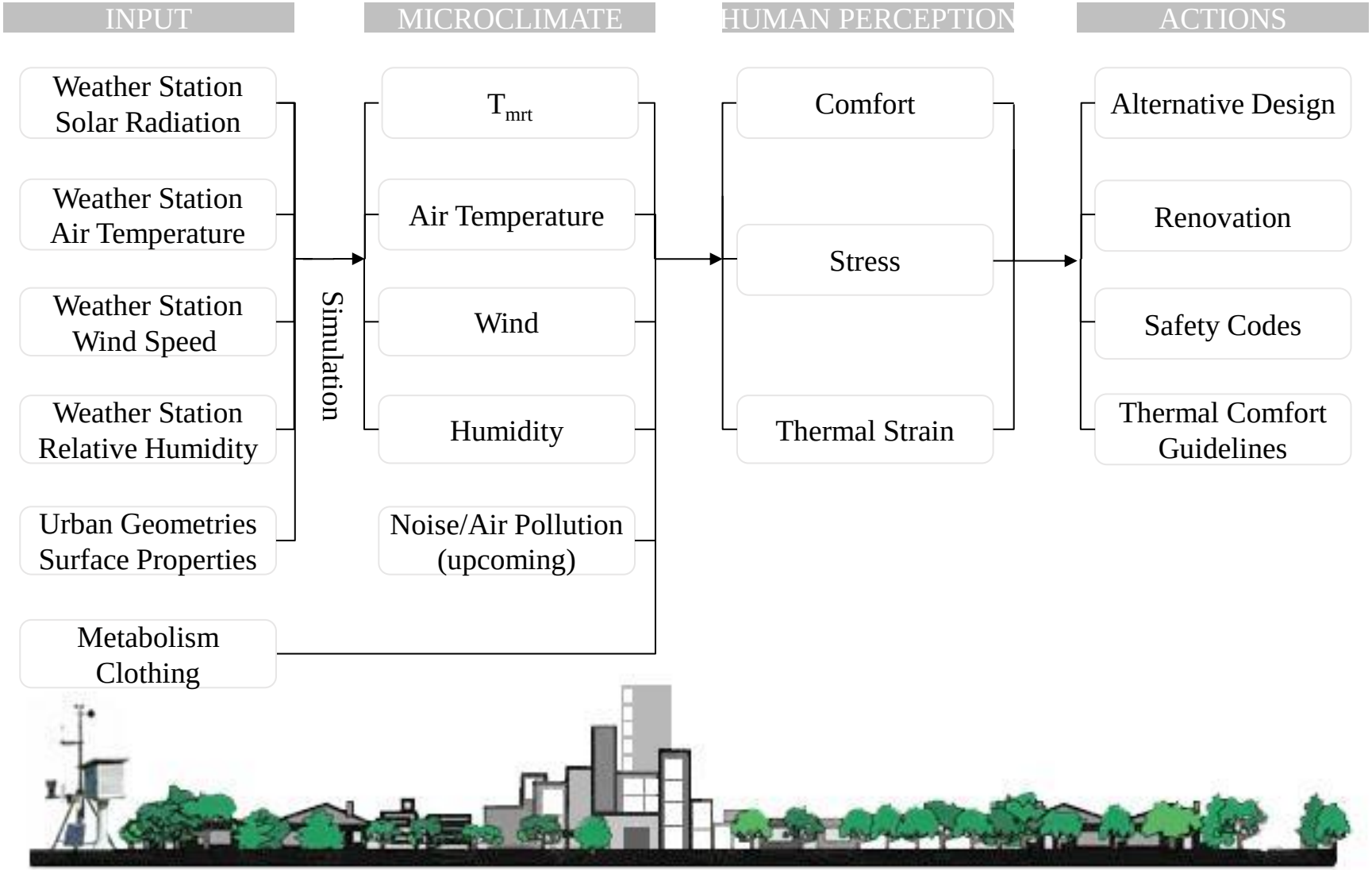
- For a design tool that quickly assess microclimates --- for proposed/existing urban development.

- For support tools to management urban microclimates --- through building codes, standards, and guidelines.

Existing Tools Are Limited

Tools	Author Institutions	Radiation	Wind Speed	Air Temp.	Human Responses
Rayman	Univ. Freiburg (Germany)				
SOLWEIG	Univ. Gothenburg (Sweden)				
DIVA	Harvard GSD (USA)				
FlowDesigner	AKL (Japan)				
Fluent	ANSYS (USA)				
ENVI-met	Univ. Mainz (Germany)				
UMI/UWG	MIT (USA)				
CityComfort+	**HKU/Harvard**				

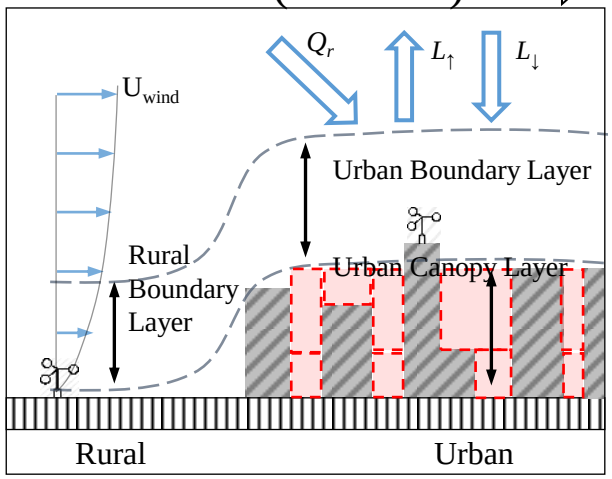
CityComfort+: A Model For Urban Thermal Environment



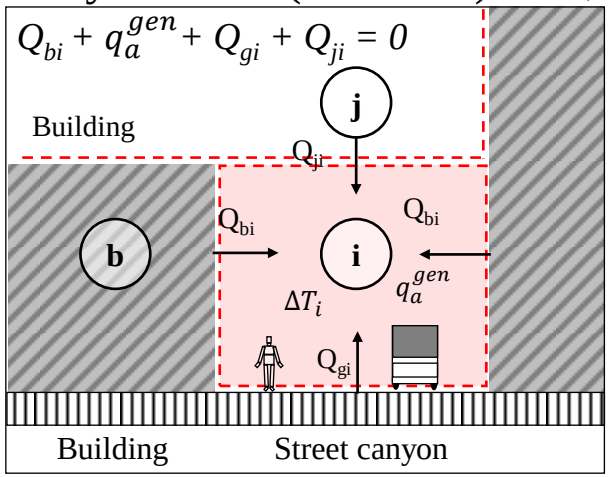
CityComfort+ Key Components

1) a physics-based model to assess heat transfer and diffusion with the urban canopy layer,
2) a statistically-adjusted human biometeorology model to predict thermoregulation and responses of local inhabitants.
3) inputs are weather data, 3D urban geometries, anthropogenic heat source profiles, and personal parameters (metabolic rate, bodily posture, clothing, etc.);
4) the outputs are urban thermal parameters and indices for human thermal sensation, comfort, and stress in high spatial-temporal resolution.

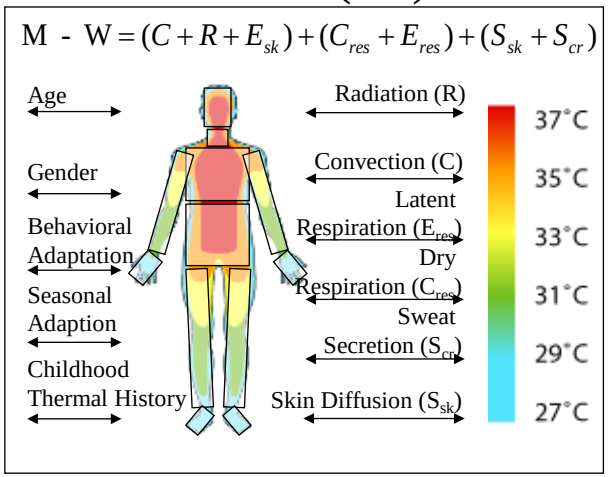
District Scale (>1000m) ⇨



Canyon Scale (10-100m) ⇨



Pedestrian Scale (1m)



Assessment of Human Thermal Regulation

One Node Model

PMV-PPD
The Predicted Mean Vote (fanger, 1972) is derived from the physics of heat transfer combined with an empirical fit to sensation.

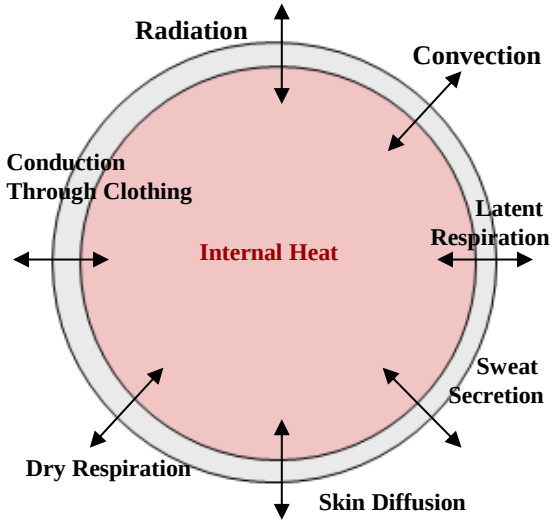
COMFA
The COMFA model (Brown & Gillespie,1995) provides a swift comfort index in landscape areas based on a person thermal balance

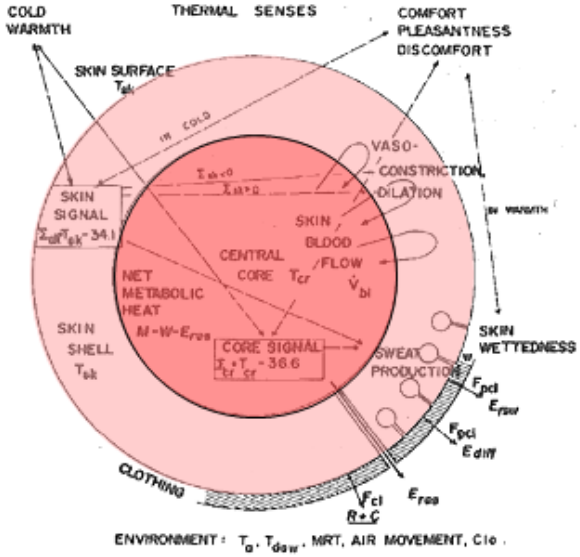
Two Node Model

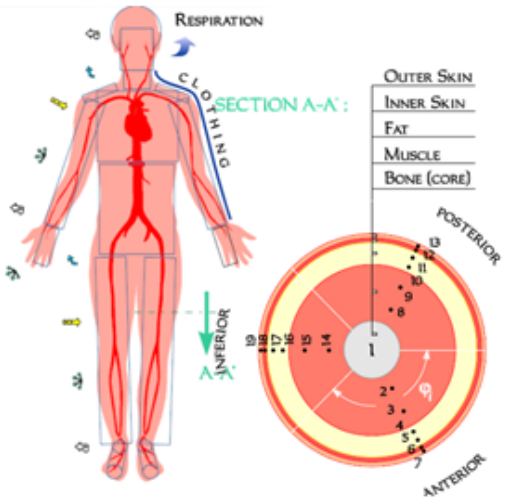
SET* & ET* & PET
Standard Effective Temperature (SET) (Gagge, 1971, 1986) is the equivalent air temperature of an isothermal environment at 50% RH in which a subject, while wearing clothing standardized for the activity concerned, has the same heat stress and thermoregulatory strain as in the actual environment

Multi-Node Model

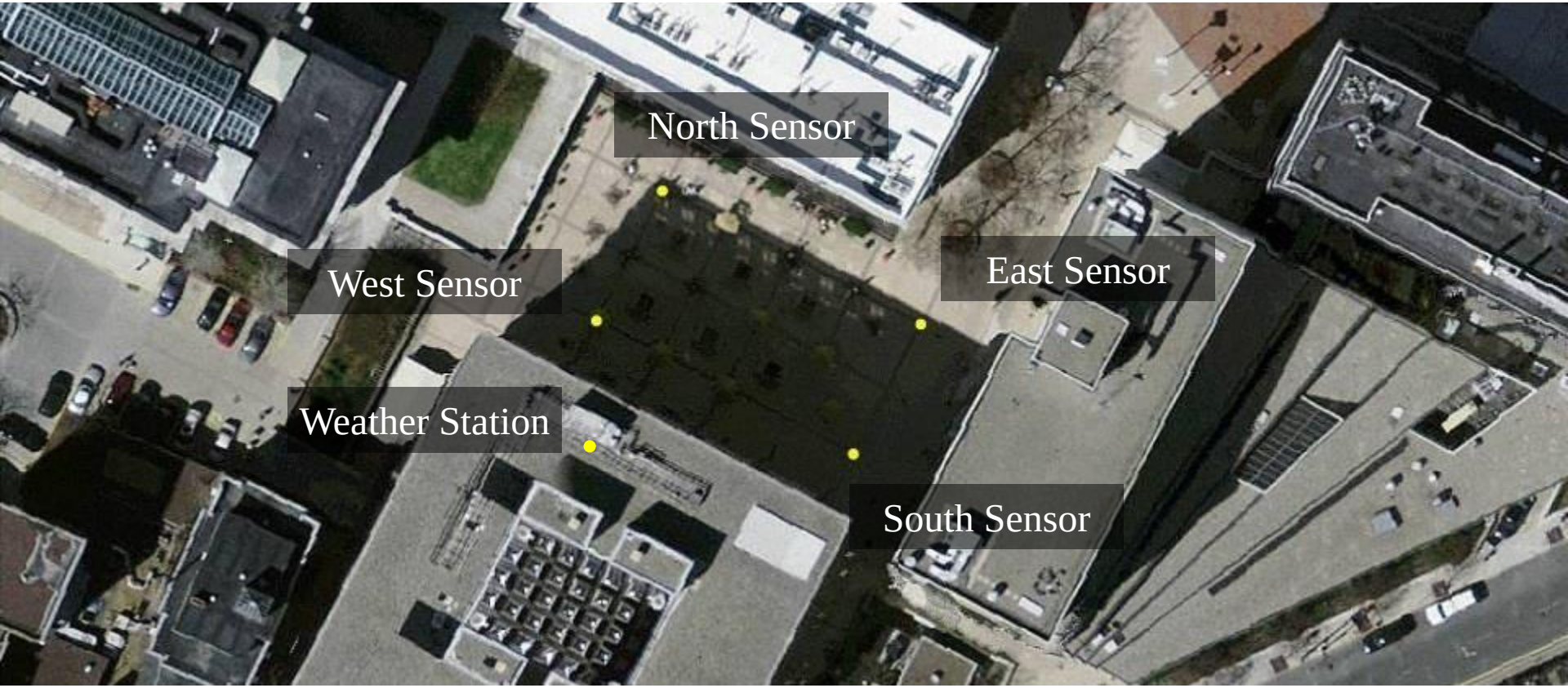
UTCI
The Universal Thermal Climate Index is the air temperature of the reference condition with the same physiological response as the actual condition. The index is base on the UTCI-Fiala human biometeorological model that is the most complex compared with previous ones.







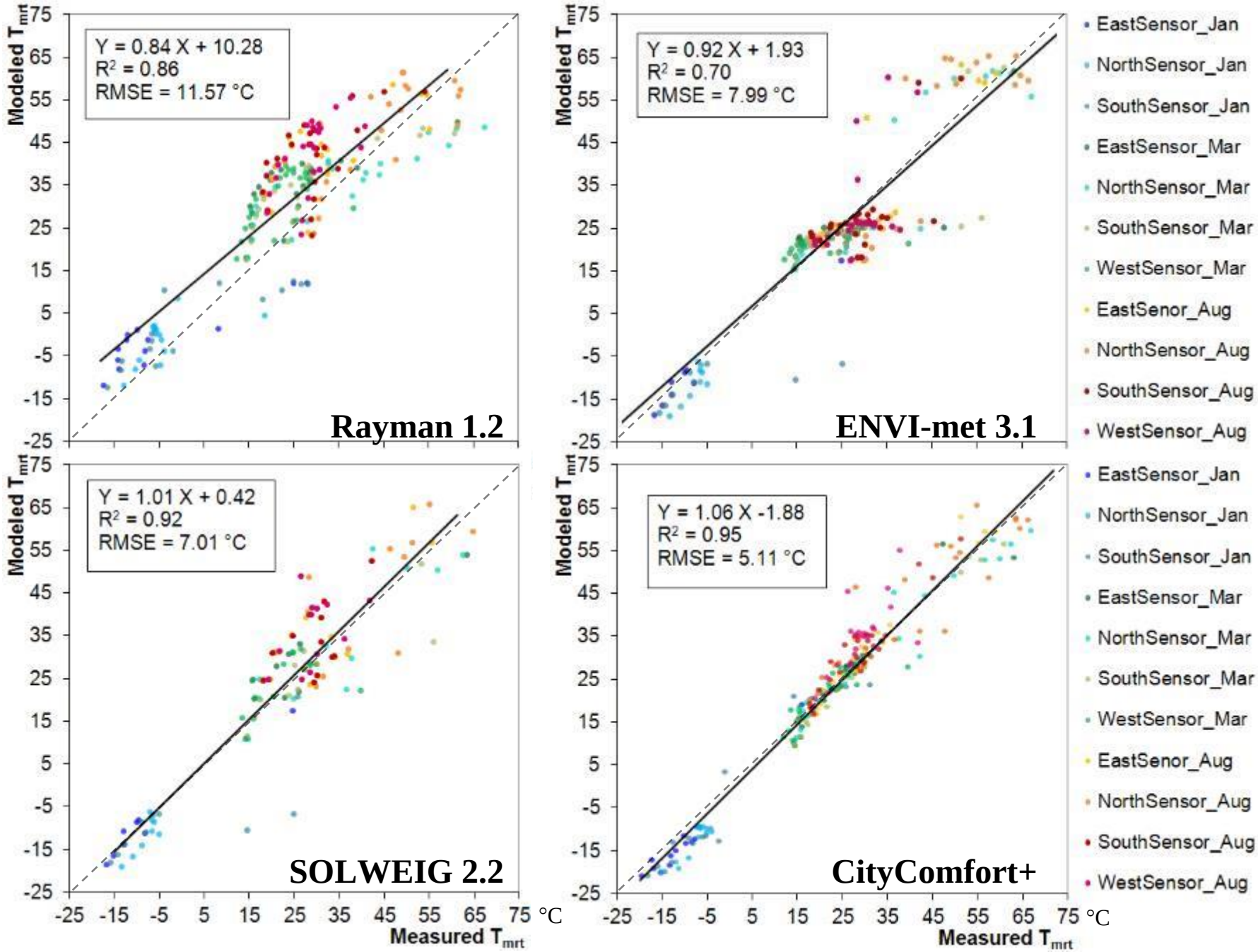
Validation with Instruments



USGS Color Ortho Imagery 2008, Source: MassGIS

Predicted & Measured T_{mrt}

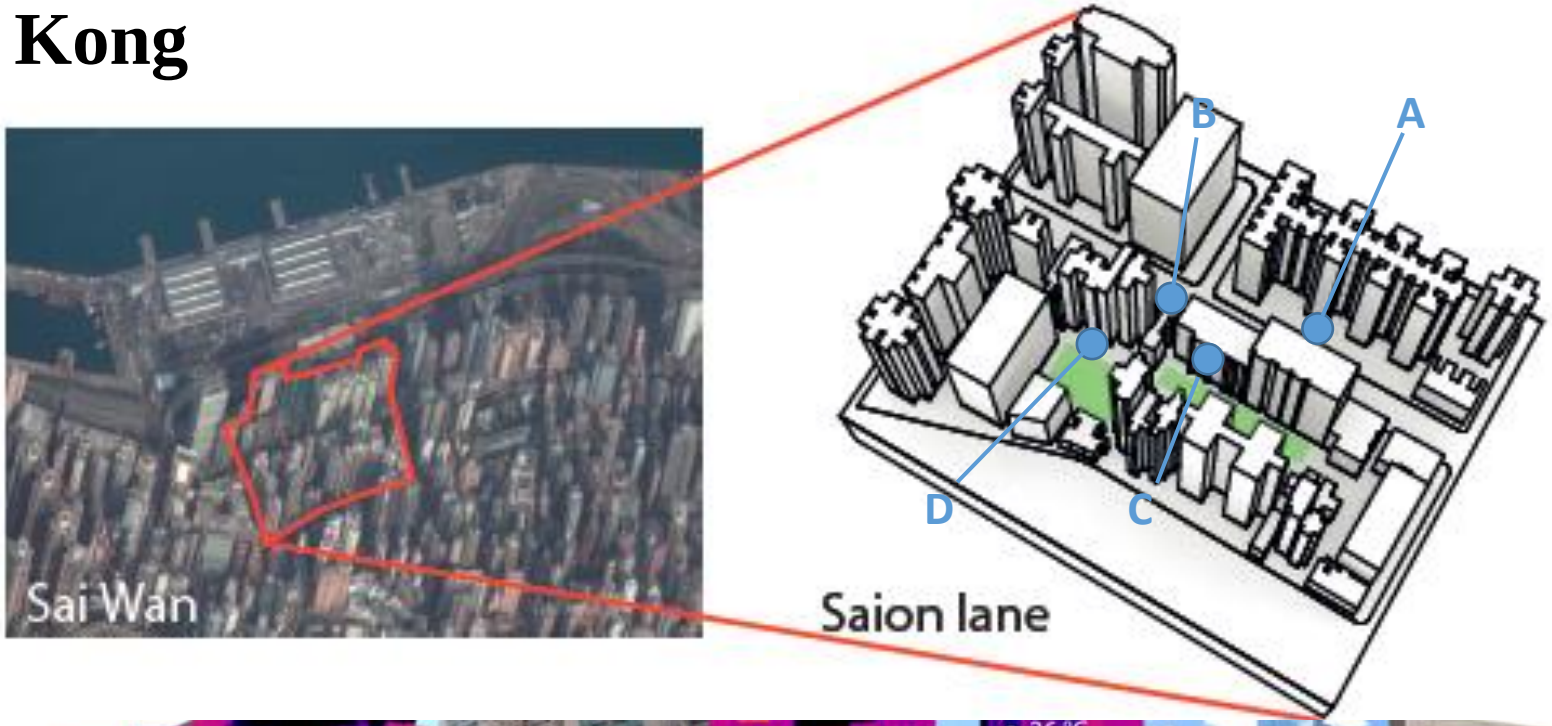
Harvard Countway Library, 30 minute time-step

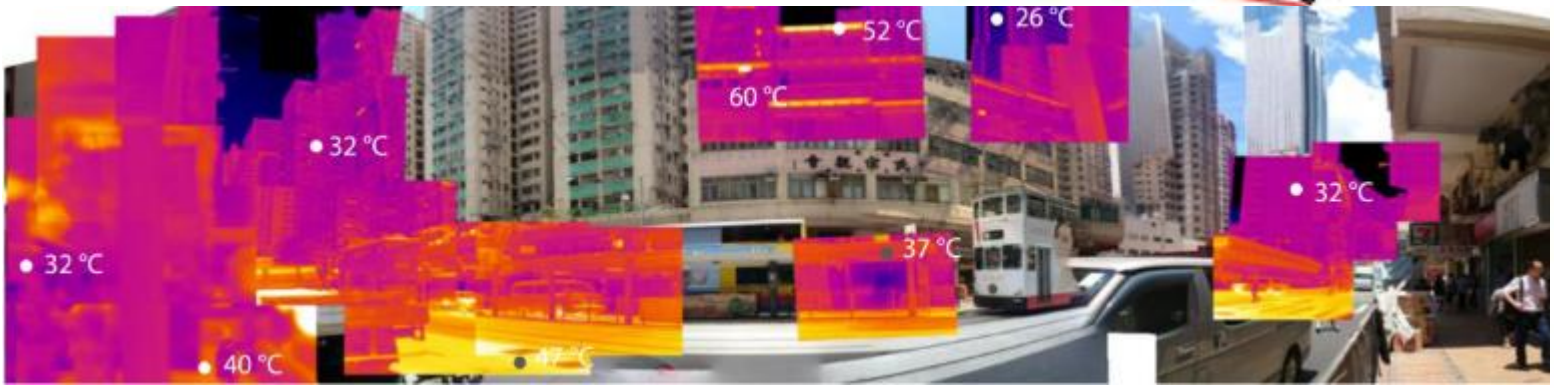


Validation with People

Harvard University Campus

Field Studies in Hong Kong



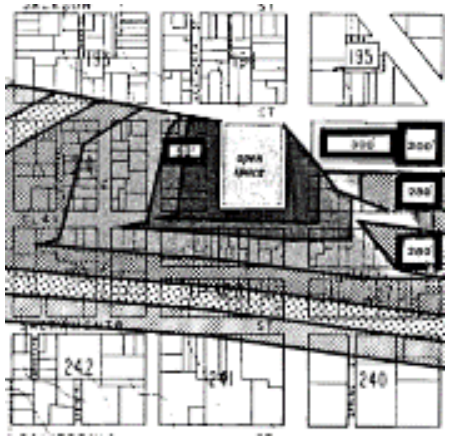


Pilot Studies at Sai Ying Pun in Hong Kong. Images taken 12:00pm 16/07/2014, Source: Yali Wang

CityComfort+ Application

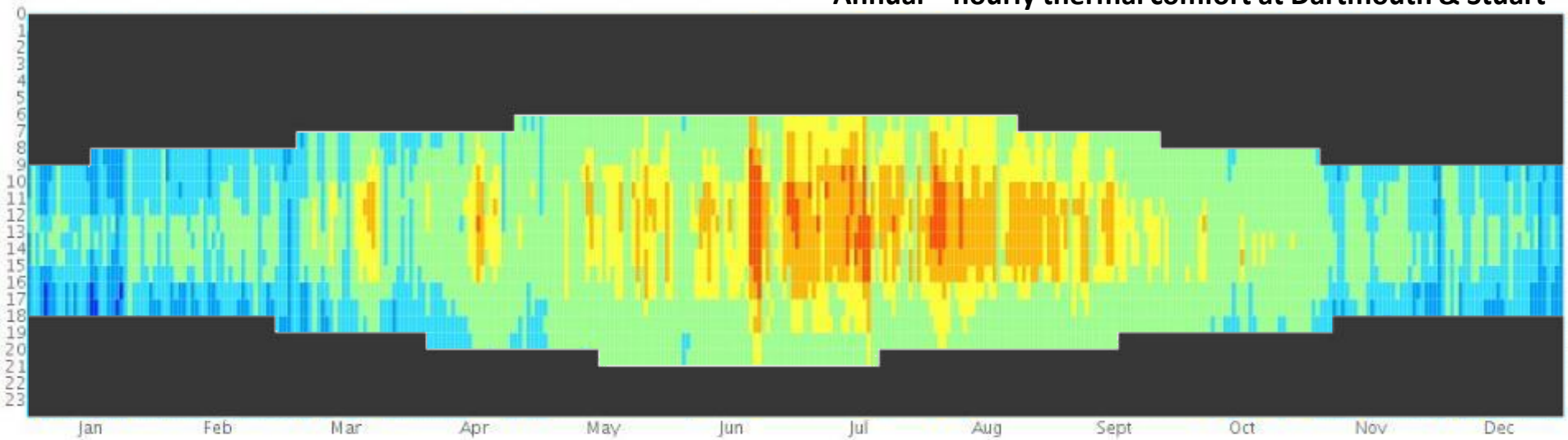
Rapid assessment of a proposed urban development at early stages; design professionals can compare the performance of alternative urban layouts based on quantifiable evidences.

Supports design and urban planning policies by providing examples of safety codes and thermal comfort guidelines for the study sites, which can reduce safety risks for vulnerable population and extend comfortable seasons.



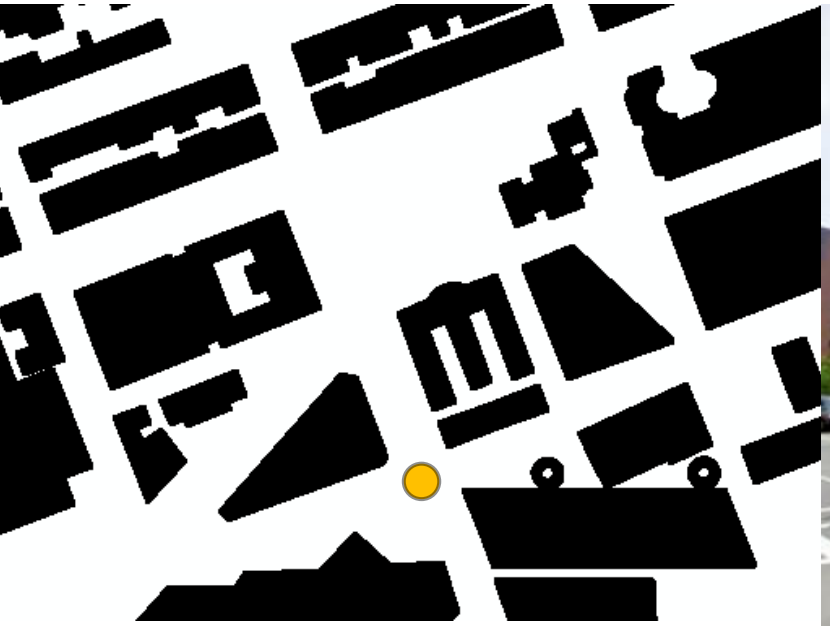
Before the Copley Place Residential Tower

Annual – hourly thermal comfort at Dartmouth & Stuart



0 5 10 15 20 25 30 35 40 UTCI Index.

mod. cold str. | slight cold stress | no thermal str. | mod. heat str. | strong heat str. | very strong heat str.



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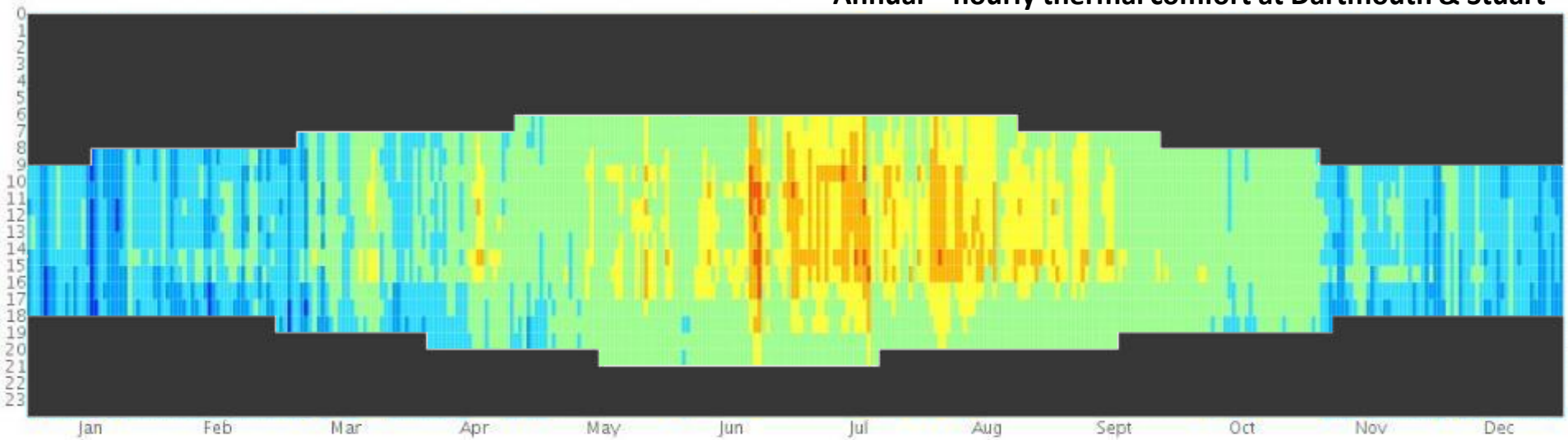
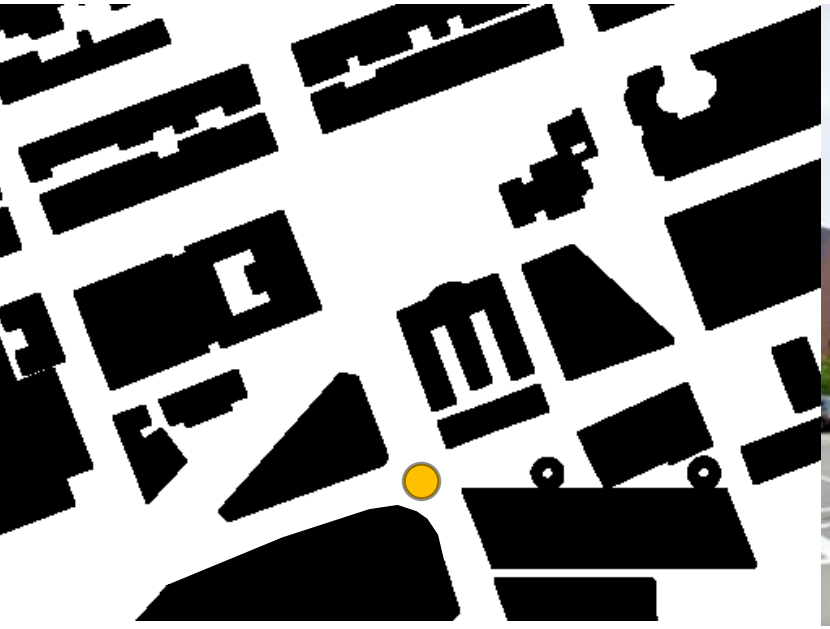
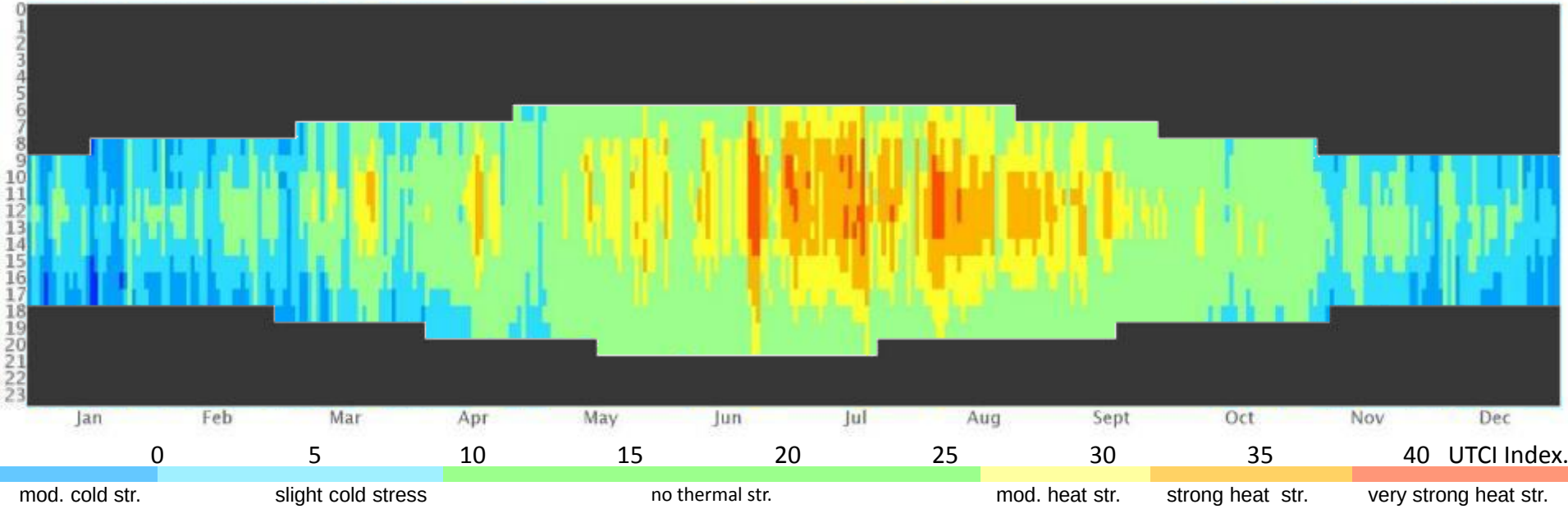


0	5	10	15	20	25	30	35	40 UTCI Index.
mod. cold str.	slight cold stress		no thermal str.			mod. heat str.	strong heat str.	very strong heat str.



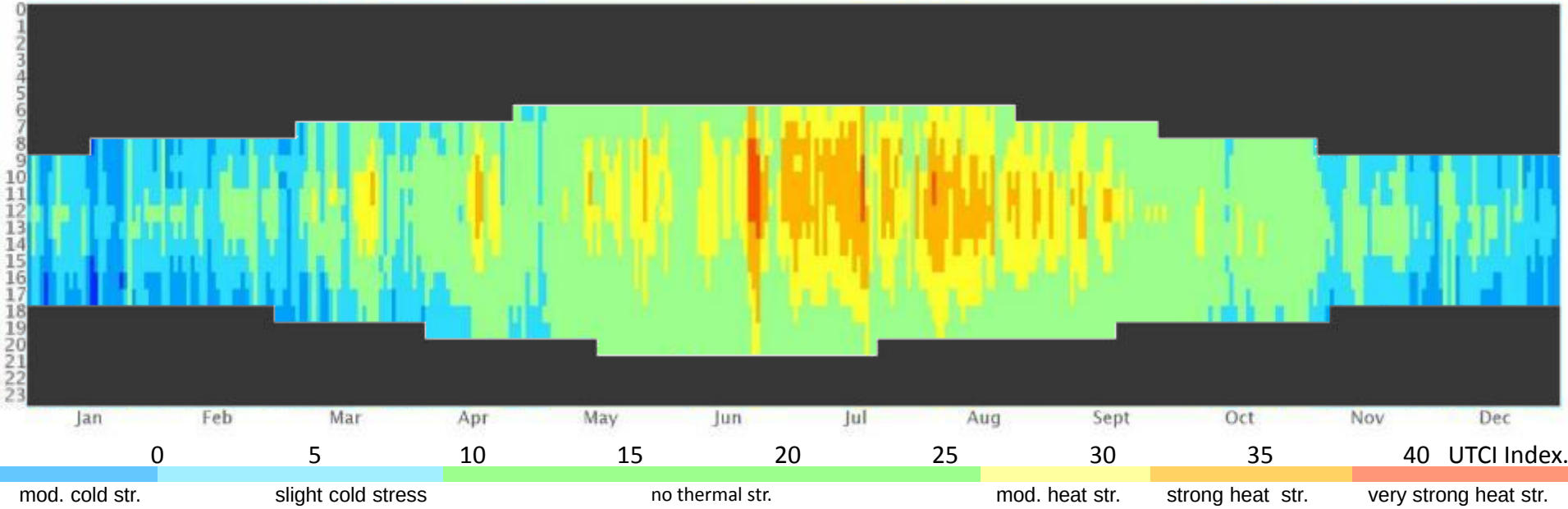
Pre-1984 Design

Annual – hourly thermal comfort at Copley Square



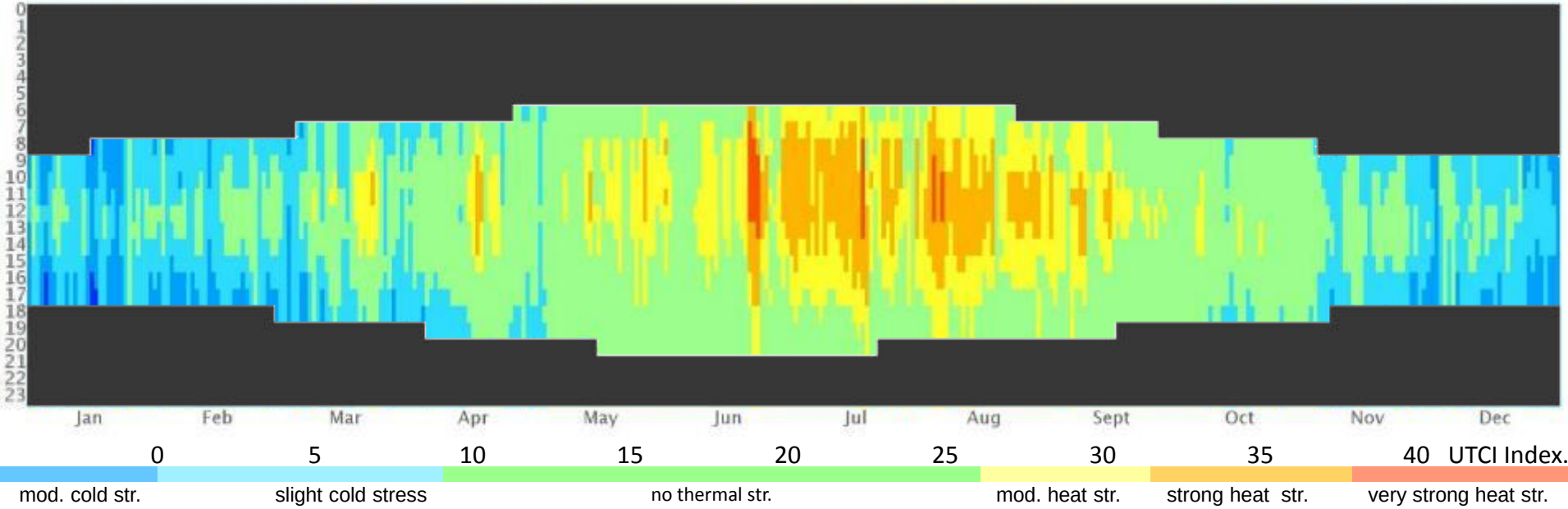
Present Condition

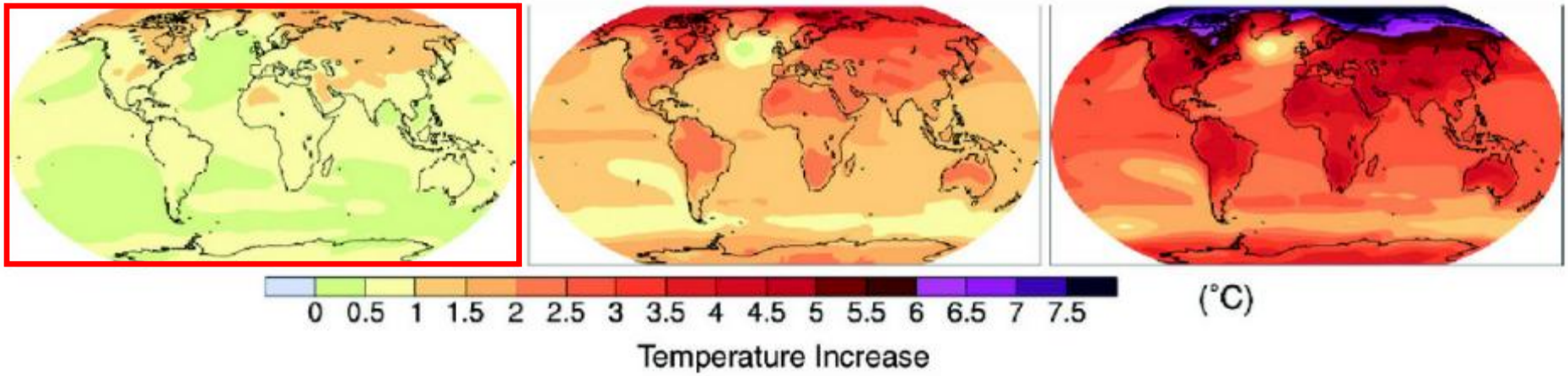
Annual – hourly thermal comfort at Copley Square



2020 A2 Scenario

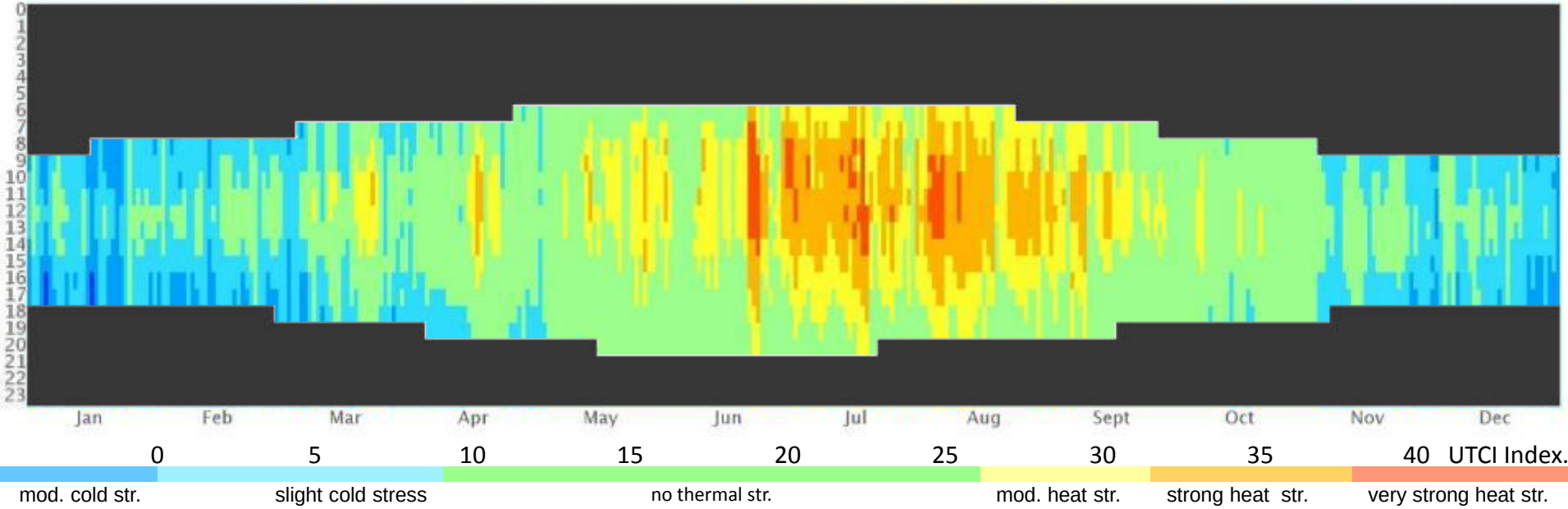
Annual – hourly thermal comfort at Copley Square

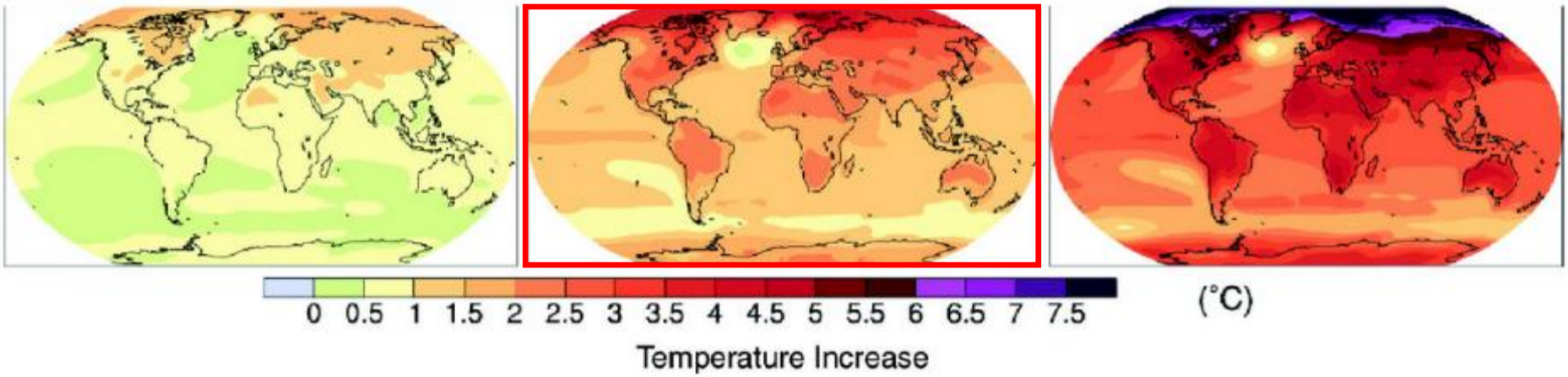




2050 A2 Scenario

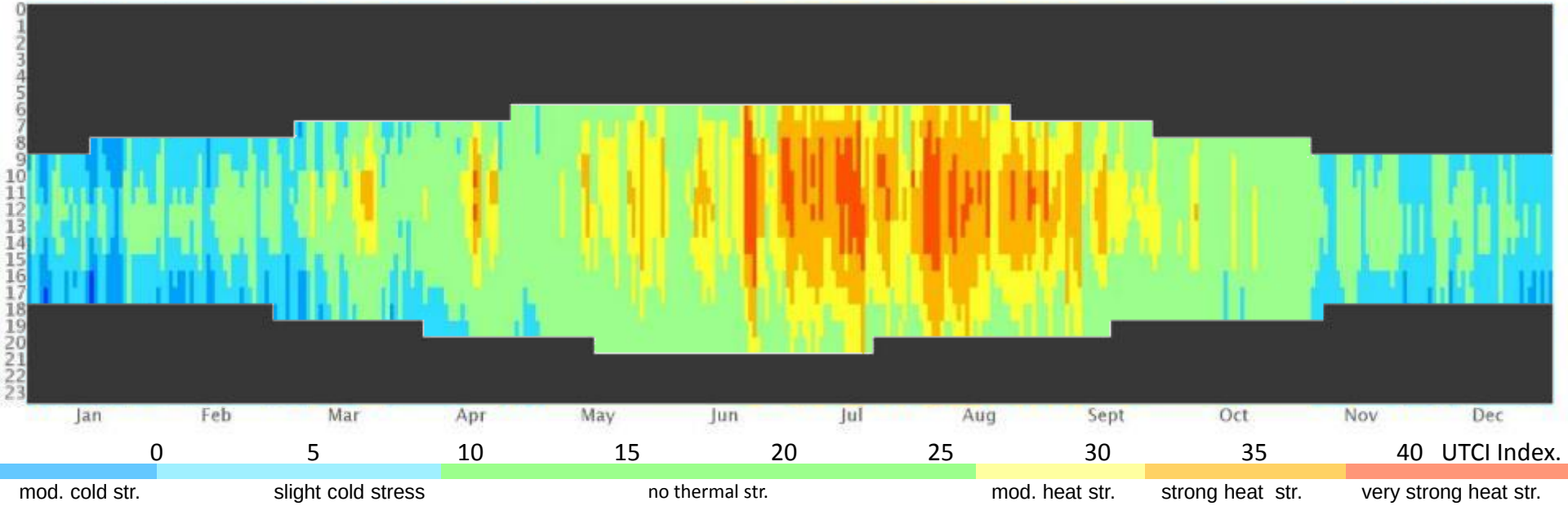
Annual – hourly thermal comfort at Copley Square

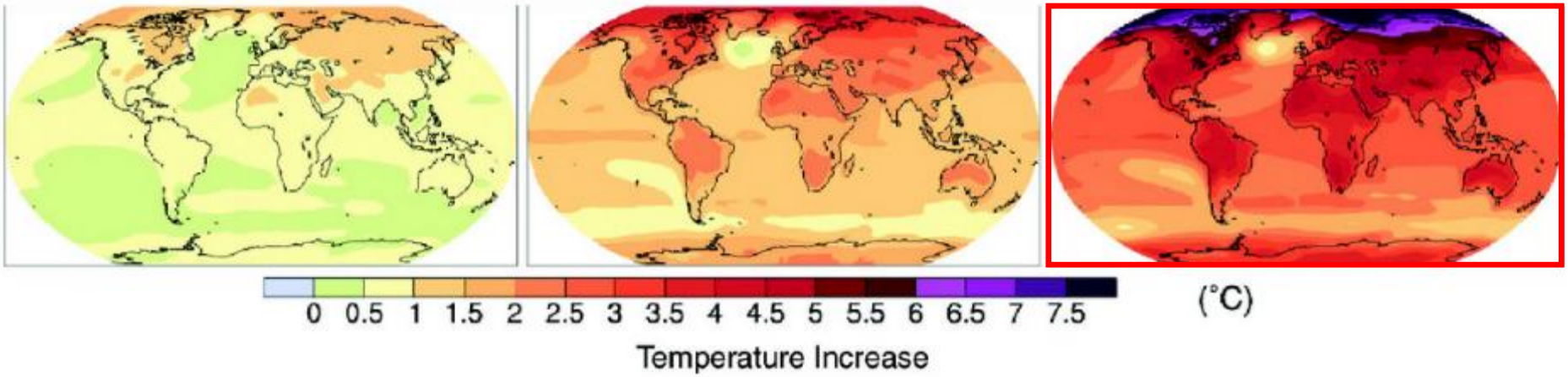




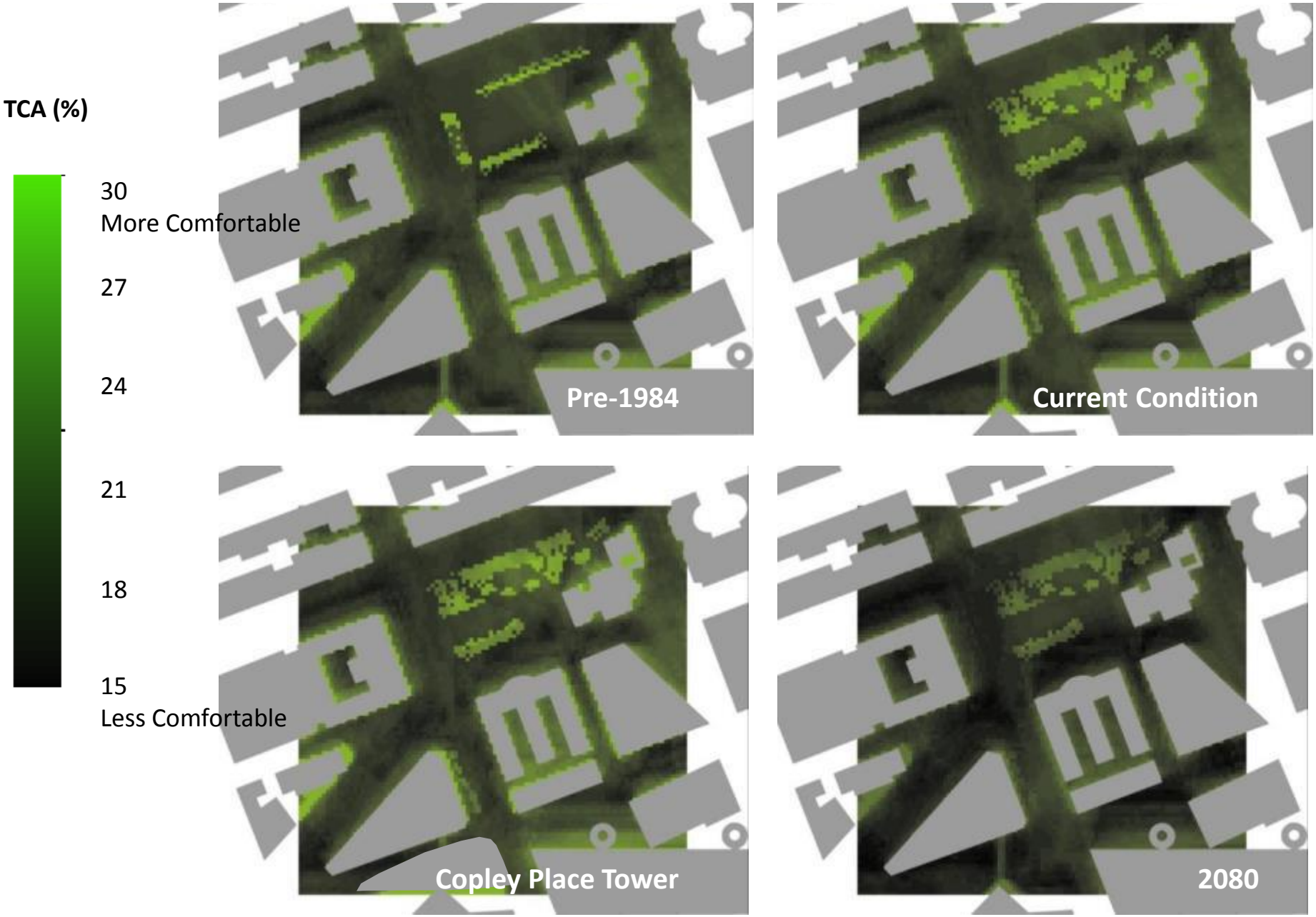
2080 A2 Scenario

Annual – hourly thermal comfort at Copley Square





Thermal Comfort Autonomy: Percentage of Comfortable Hours on Annual Basis



Informed Design

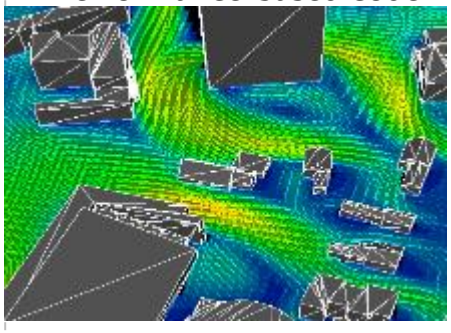
Annual – hourly thermal comfort at Copley Square

0	5	10	15	20	25	30	35	40 UTCI Index.
mod. cold str.	slight cold stress		no thermal str.			mod. heat str.	strong heat str.	very strong heat str.

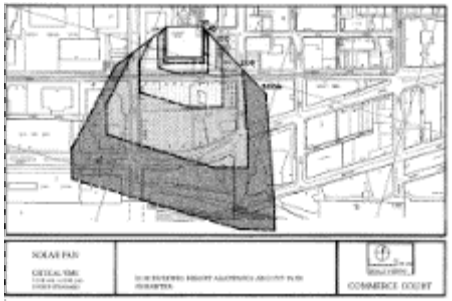
Application: Design & Urban Planning Practices

Codes & Guidelines

- Performance-based code



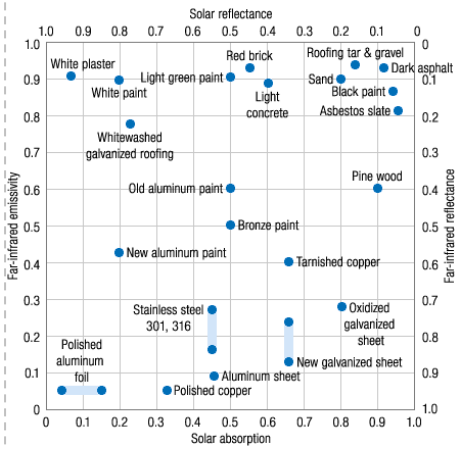
CFD simulation of Harvard Campus
Source: Jianxiang Huang

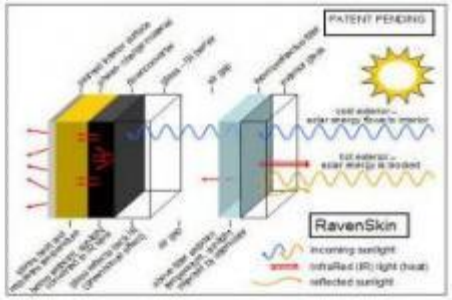


Solar Fan for Toronto
Source: Bosselman,1991

Surface Material

- Material Emissivity / Albedo / Thermal Massing





Thermal Properties of Material

Passive Design

- Shading Devices
- Vegetation

Shading devices
Source: Lutz Katzschner

Windbreaks in the Netherlands
Source: Christoph Reinhart

Active Design

- Evaporative Cooling
- Radiant Cooling/Heating

Radiant Heater in GreenAcre Park
Manhattan, New York

Evaporative Cooling System
Shanghai World Expo

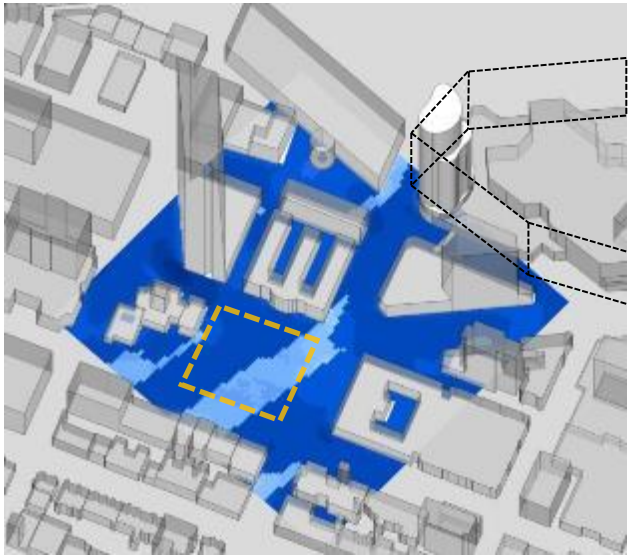
Application: Safety Codes & Thermal Comfort Guidelines

CityComfort+ can inform urban planning and design practices to enhance the safety and comfort of inhabitants by taking full advantage of the sun, wind, and the modifying effects of cities.

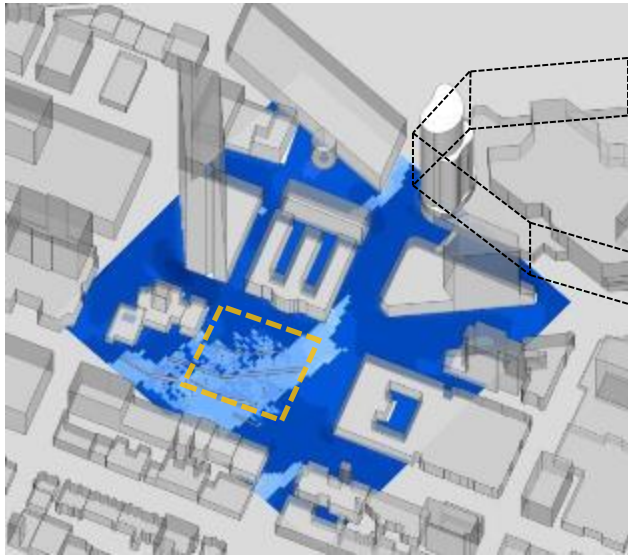
Thermal Stress

Thermal Comfort

APPROVAL
Compliance with prescribed envelope

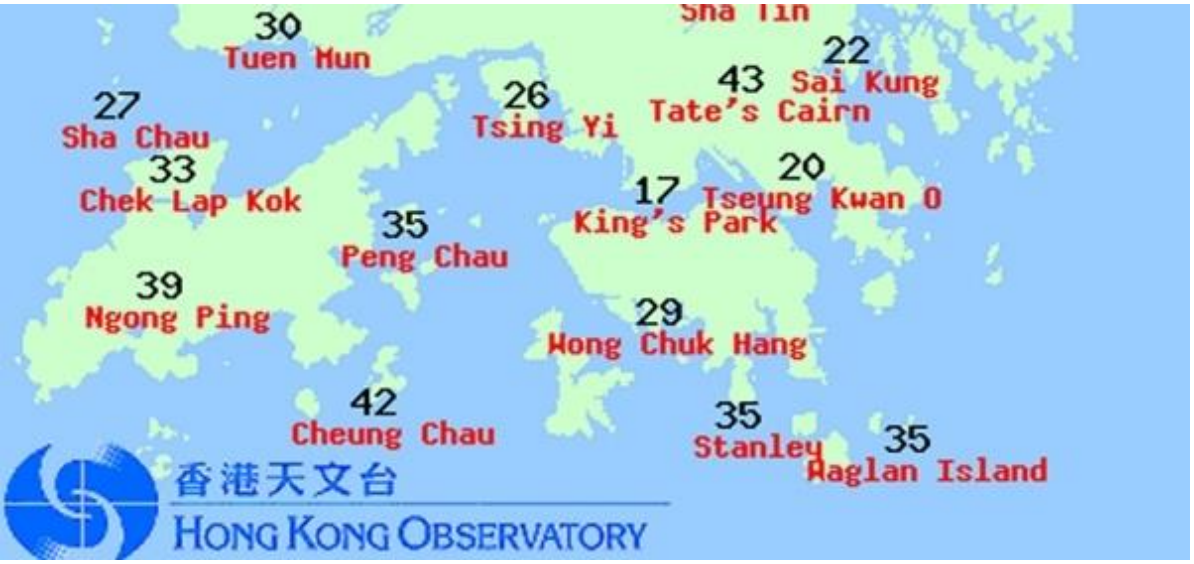


REJECTION
Infringement on comfort at key area



APPROVAL
Mitigation measures installed at key area

Other Application: Local – Specific Weather Services



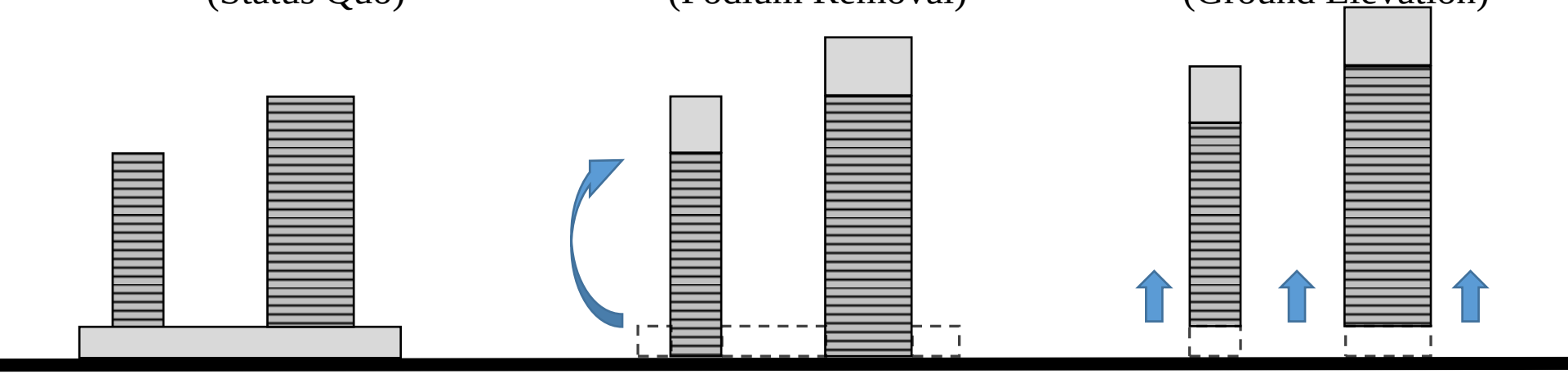
Design Recommendation

Informed Building Layouts Can Reduce Extreme Heat Stress

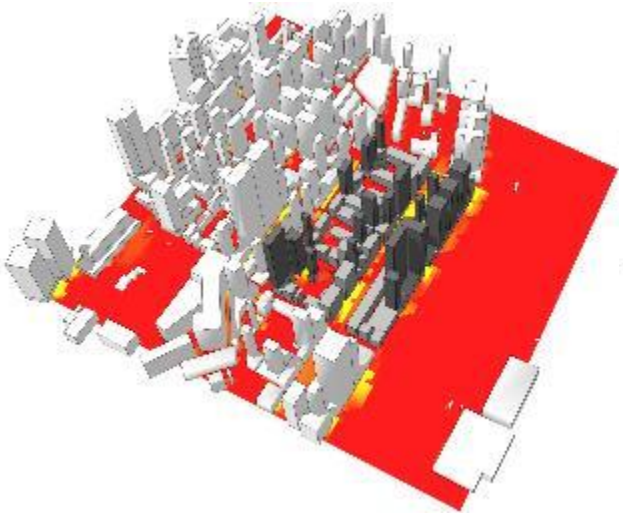
Scenario 1
(Status Quo)

Scenario 2
(Podium Removal)

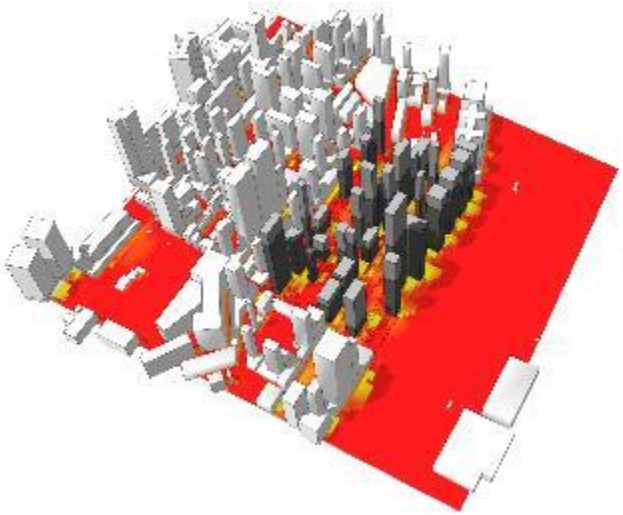
Scenario 3
(Ground Elevation)



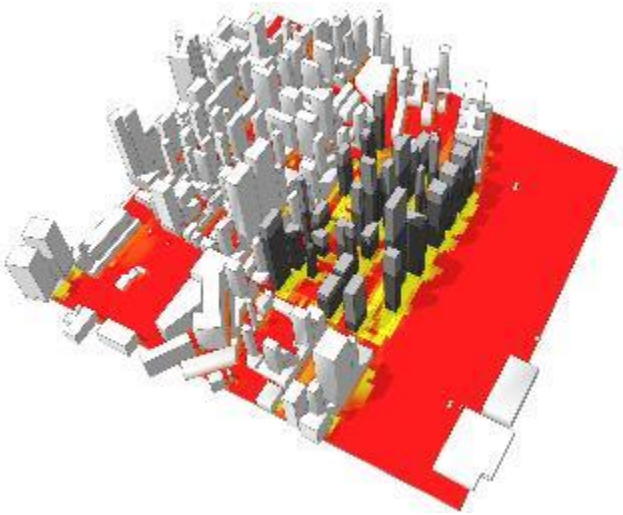
Sai Ying Pun, Hong Kong. 14:00 pm, August 14, 2014 Air Temp. 28.8 C, Relative Humidity 81% (average daily high temp. in August)



Extreme Heat Stress



Moderate Heat Stress



Slight Heat Stress

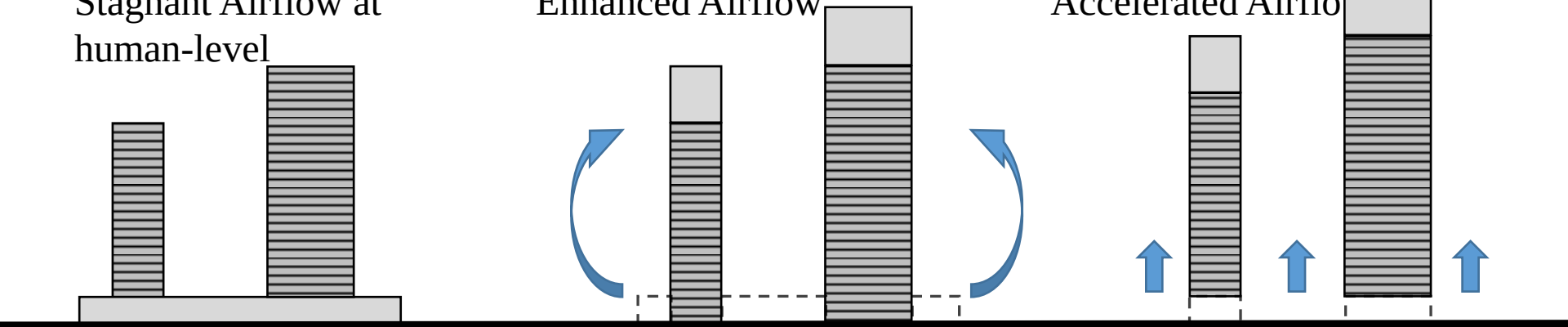
Design Recommendation

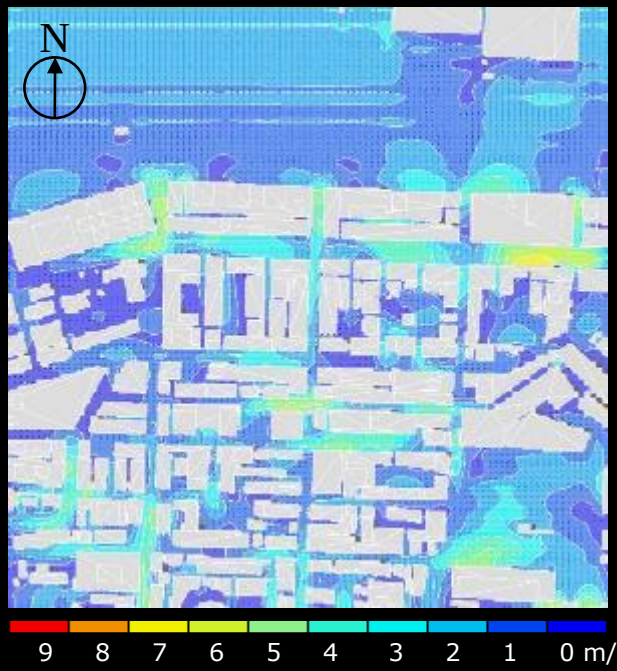
Informed Building Layouts Can Enhance Air Ventilation

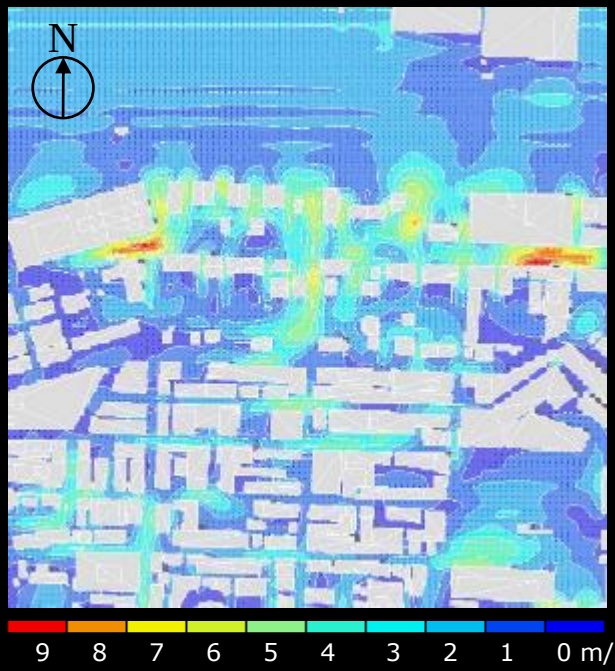
Scenario 1
(Status Quo)
Stagnant Airflow at
human-level

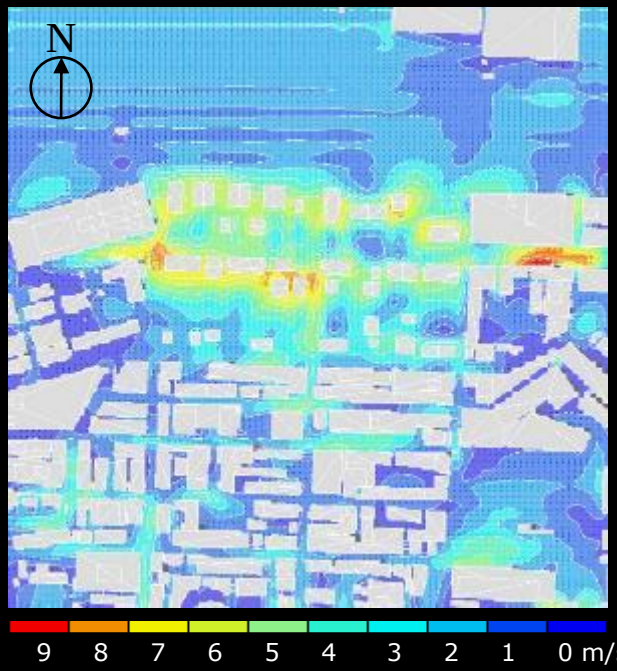
Scenario 2
(Podium Removal)
Enhanced Airflow

Scenario 3
(Ground Elevation)
Accelerated Airflo









HAPI

Health
And
Places
Initiative

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