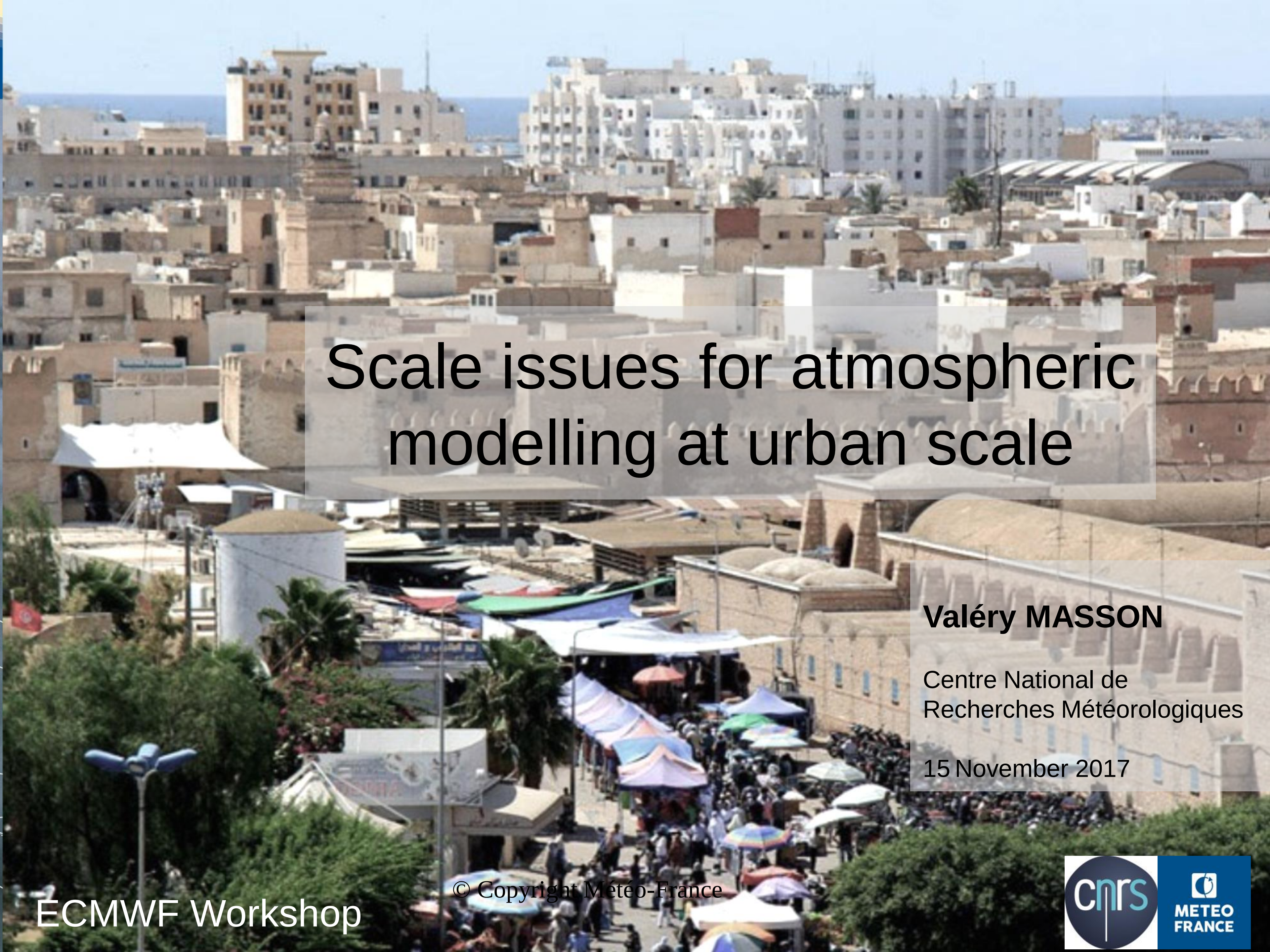

Scale issues for atmospheric modelling at urban scale

Valéry MASSON

Centre National de Recherches Météorologiques

15 November 2017

ECMWF Workshop

Cities & Climate

- 2.7% of land areas
- 55% of world population
- 80% of GDP
(gross domestic product)
- 70% of Green-House Gases emissions

IPCC synthesis report (2014):
In urban areas climate change is projected to increase **risks** for **people**, **assets**, **economies** and ecosystems, including risks from **heat stress**, storms and **extreme precipitation**, inland and coastal **flooding**, landslides, air **pollution**, drought, water scarcity, **sea level rise** and storm surges *(very high confidence)*

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Cities & Climate

Several actions at international scale

World Weather Research Programme has 4 objectives, 2 related to urban:

1. High Impact Weather and its socioeconomic effect in the context of global change

Urban floods,
Heat & Pollution
in megacities, …

2.Urbanization:
Research & services for megacities and large urban complexes

Source: Baklanov, WMO, (2015)
Source: https://public.wmo.int

Cities & Climate

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Urban floods,
Heat & Pollution
in megacities, …

2.Urbanizarion:
Research & services for megacities and large urban complexes

scientific issues: […]
high-resolution modelling,
Grey zone, […]

Source: Baklanov, WMO, (2015)
Source: https://public.wmo.int

Scale issues for modelling at urban scale

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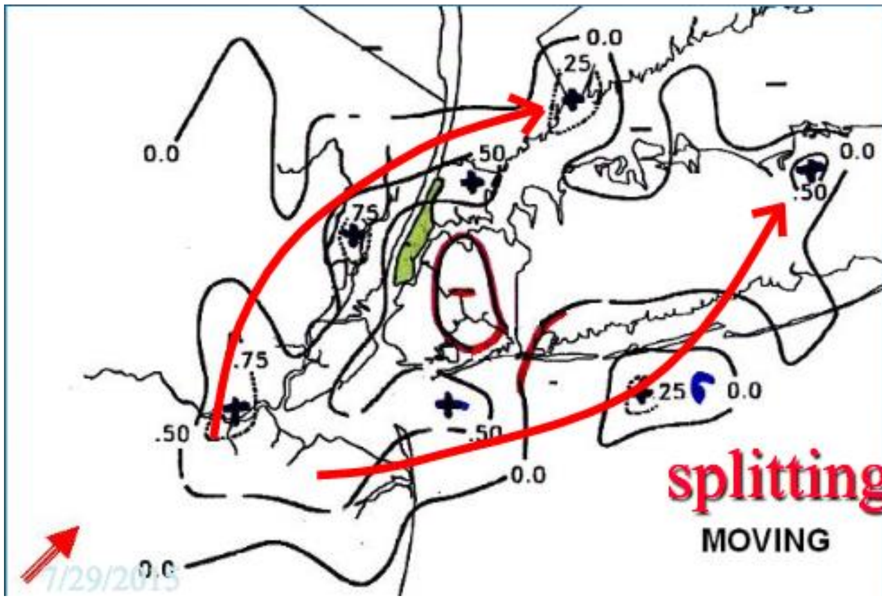
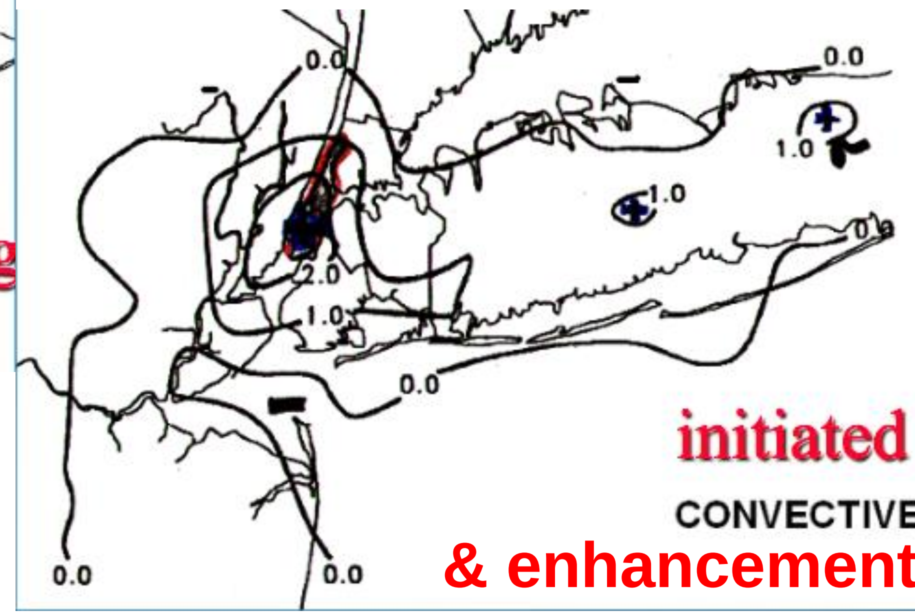
Meso-scale Impacts on Thunderstorms

2 mains urban effects



Analysis of 2 summers
of convection above NYC



SJSU SAN JOSÉ STATE UNIVERSITY

Source: Bornstein and Leroy (1985)

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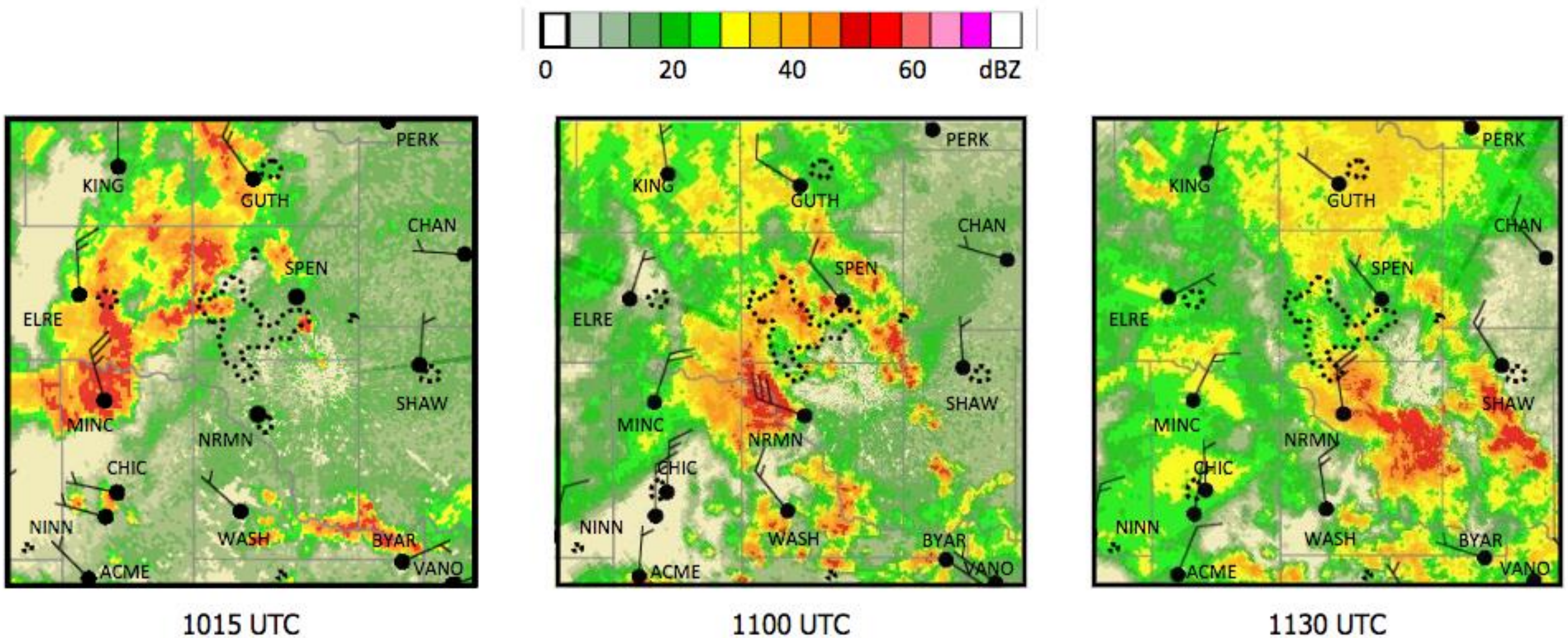
Meso-scale Impacts on Thunderstorms: splitting

The splitting effect is mainly due to the **increased roughness**.

Such effects are mostly studied in USA and China
→ This may be because megacities are prominent obstacles in flat regions



Observed radar reflectivity (dBz) from OKC radar

PURDUE UNIVERSITY

Source: Niyogi et al, 2006

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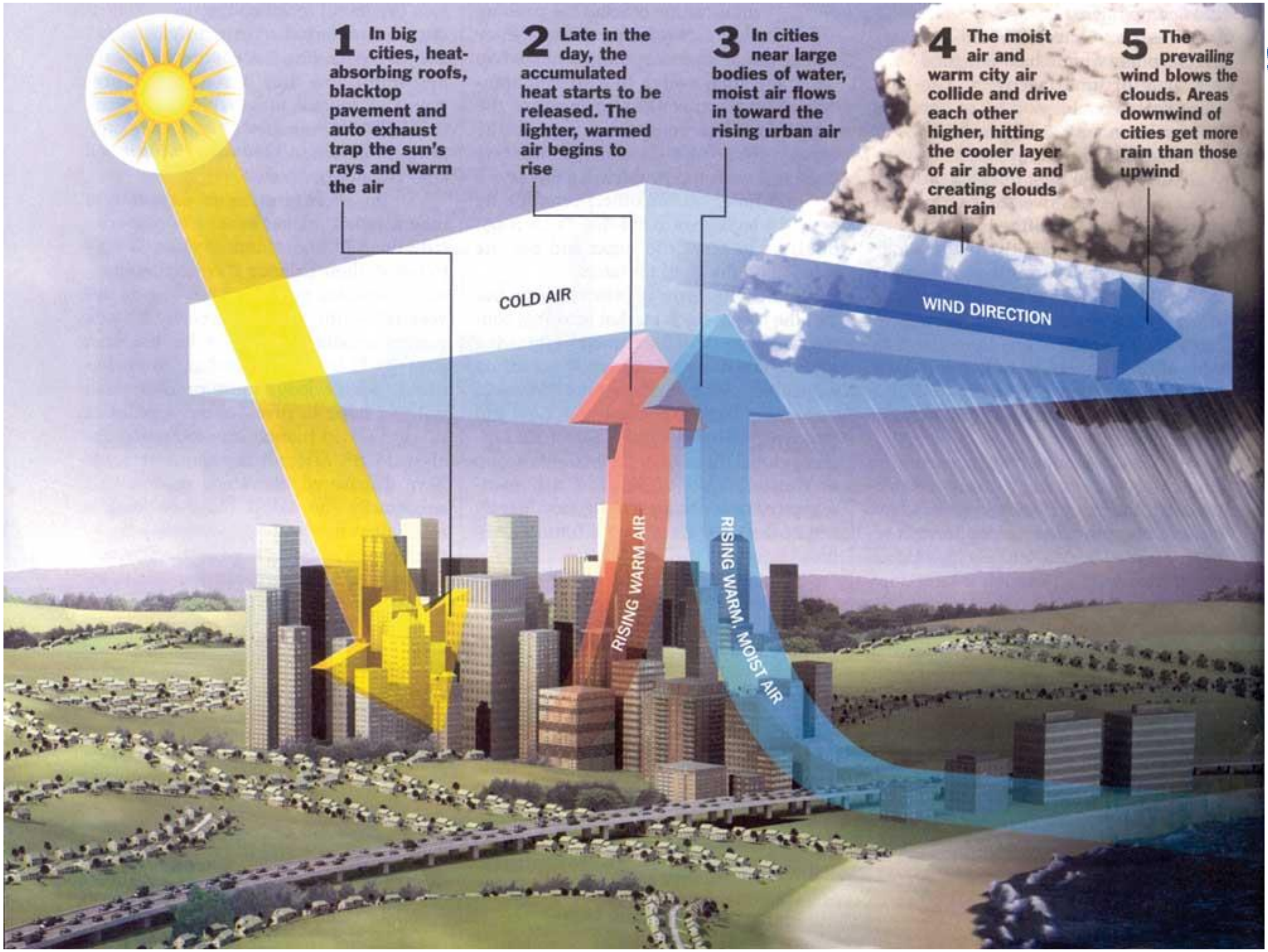
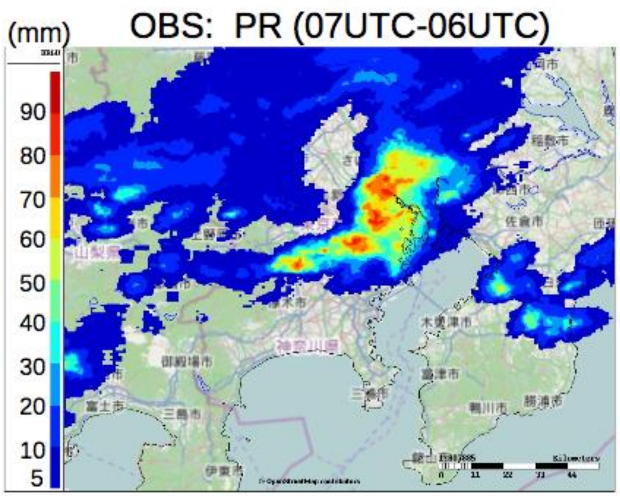
Meso-scale Impacts on Thunderstorms: enhancement



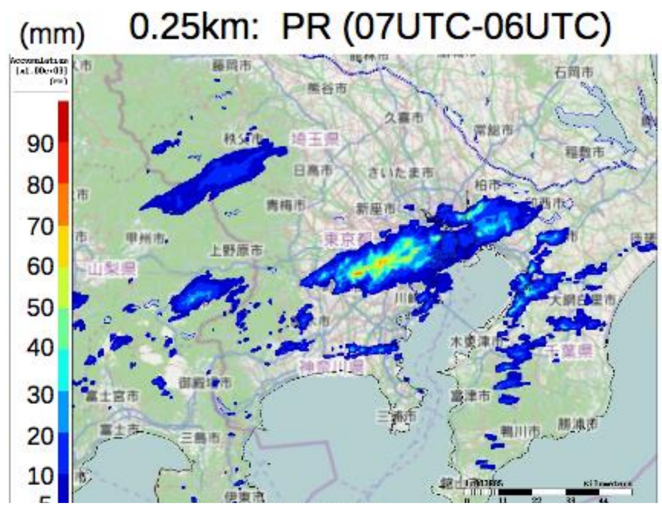
Source: WMO website

Meso-scale Impacts on Thunderstorms: enhancement

Cas study of 26 August 2011 of flash flood on Tokyo (TOMACS campaign)

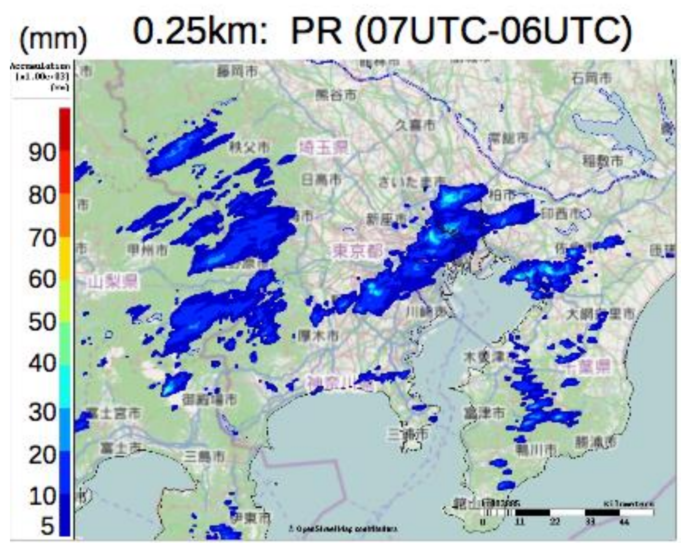


Radar observations



Canadian model GEM at 250m

with
urban scheme



without
urban scheme

Environment and Climate Change Canada

Source: Bélair et al, 2015

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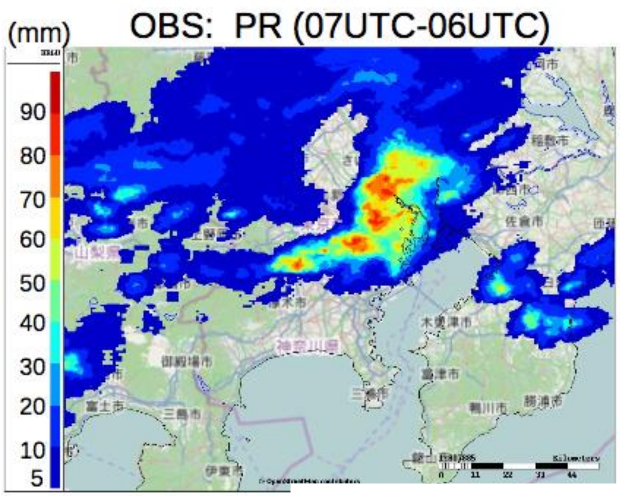

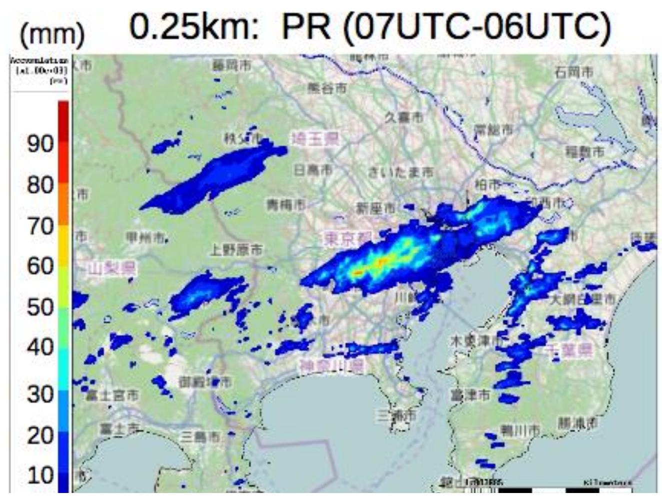

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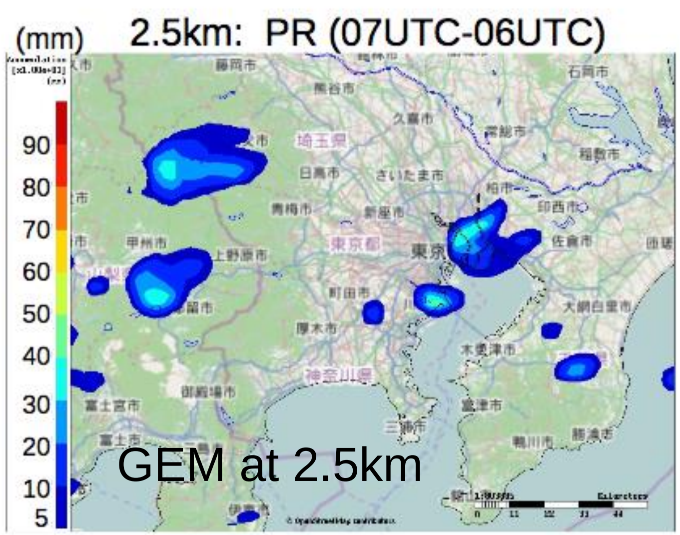

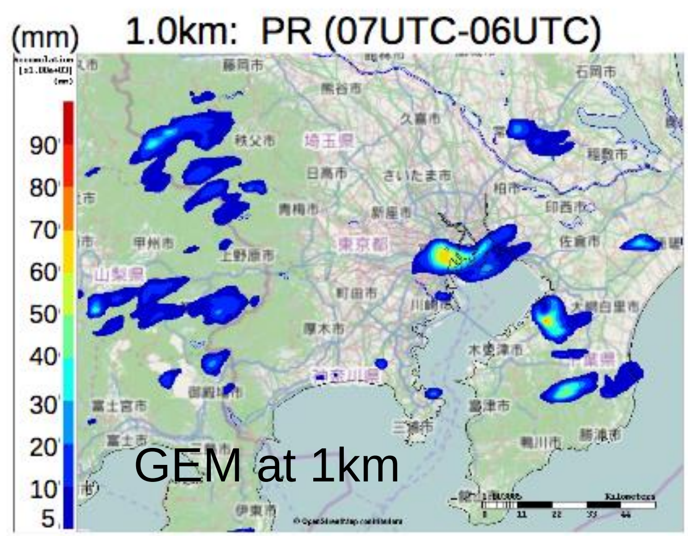

Source: Bélair et al, 2015

Scale issues for modelling at urban scale

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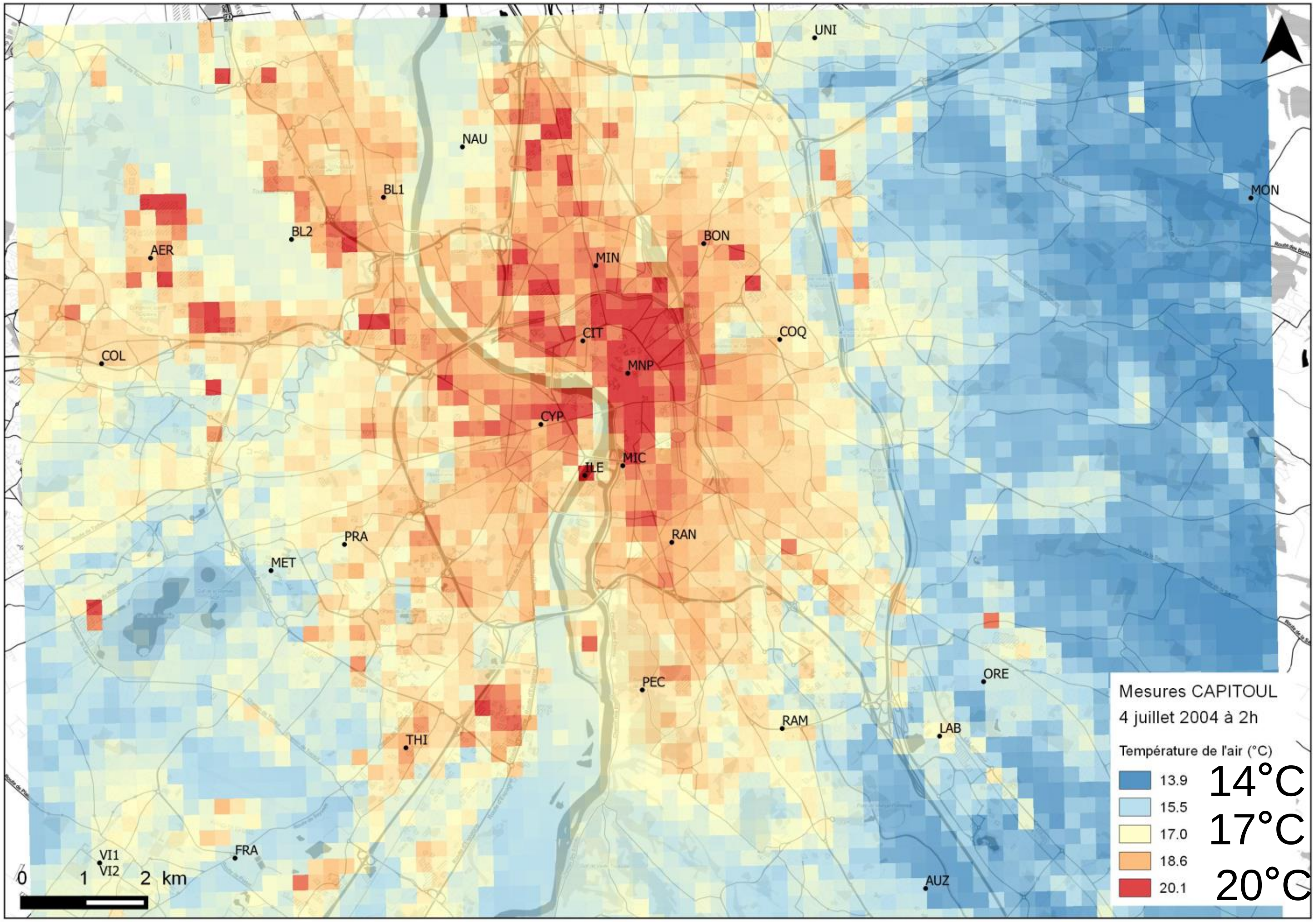
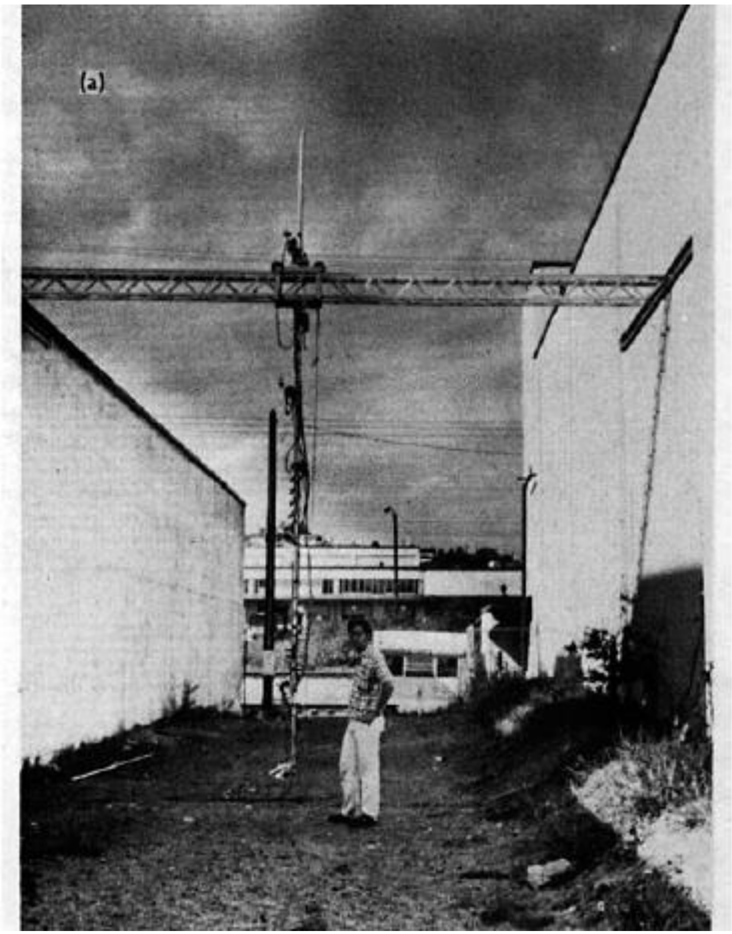
Urban Heat Island (UHI)

One summer night in Toulouse (using measurements from 20 met stations)



Source: J. Hidalgo

Modification of the Surface Energy Balance



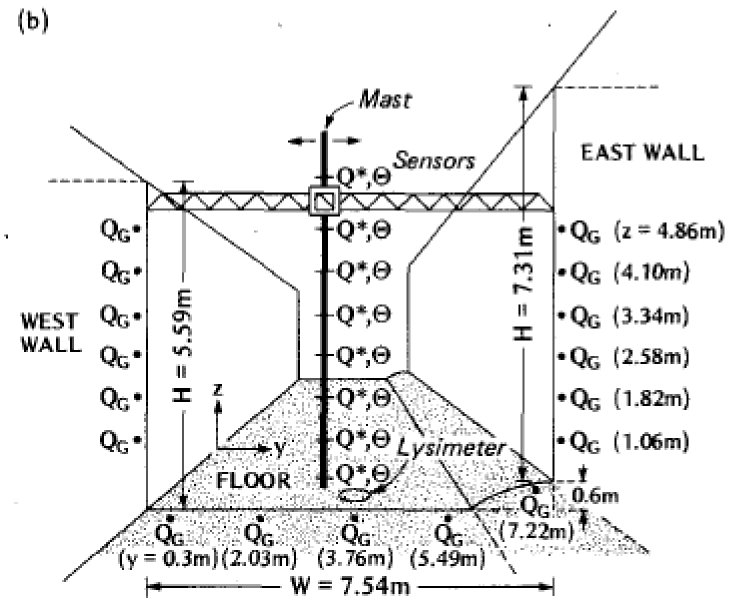
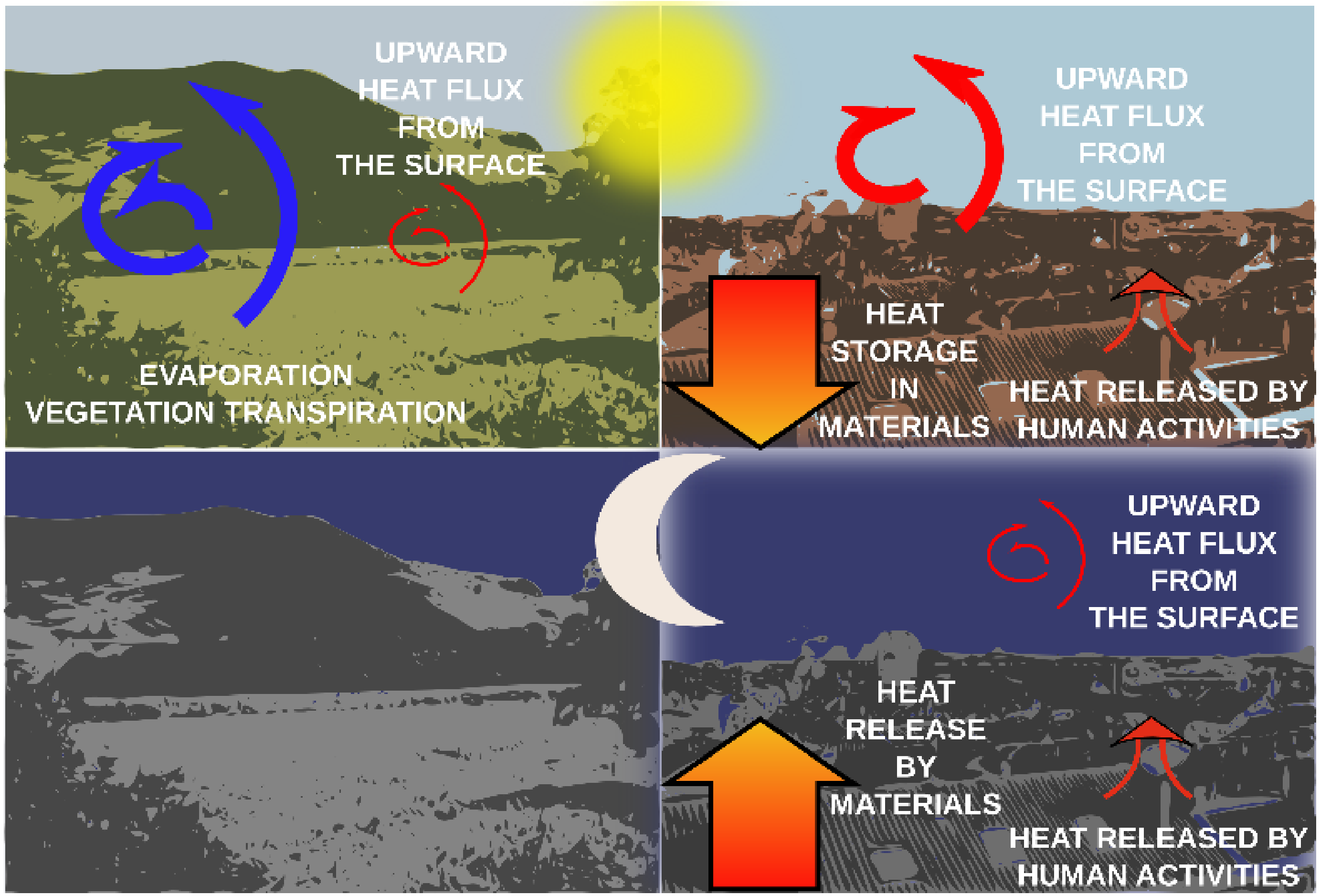


FIG. 2. The experimental urban canyon: (a) actual conditions (note the superstructure shadow on the east wall) and (b) schematic of instrument deployment, dimensions and coordinates.

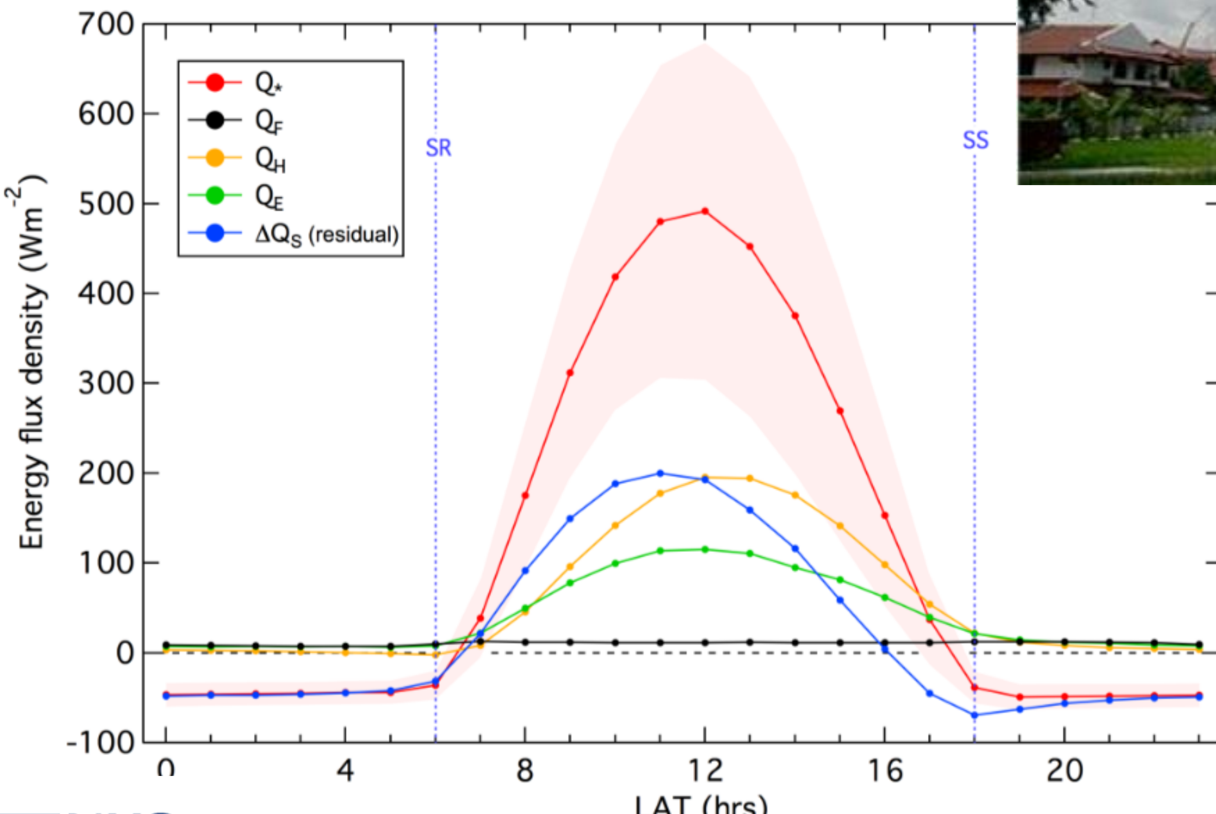
Source: Nunez & Oke, 1976

Modification of the Surface Energy Balance



Modification of the Surface Energy Balance

Surface Energy Balance, Singapore



Source: Roth et al, 2015

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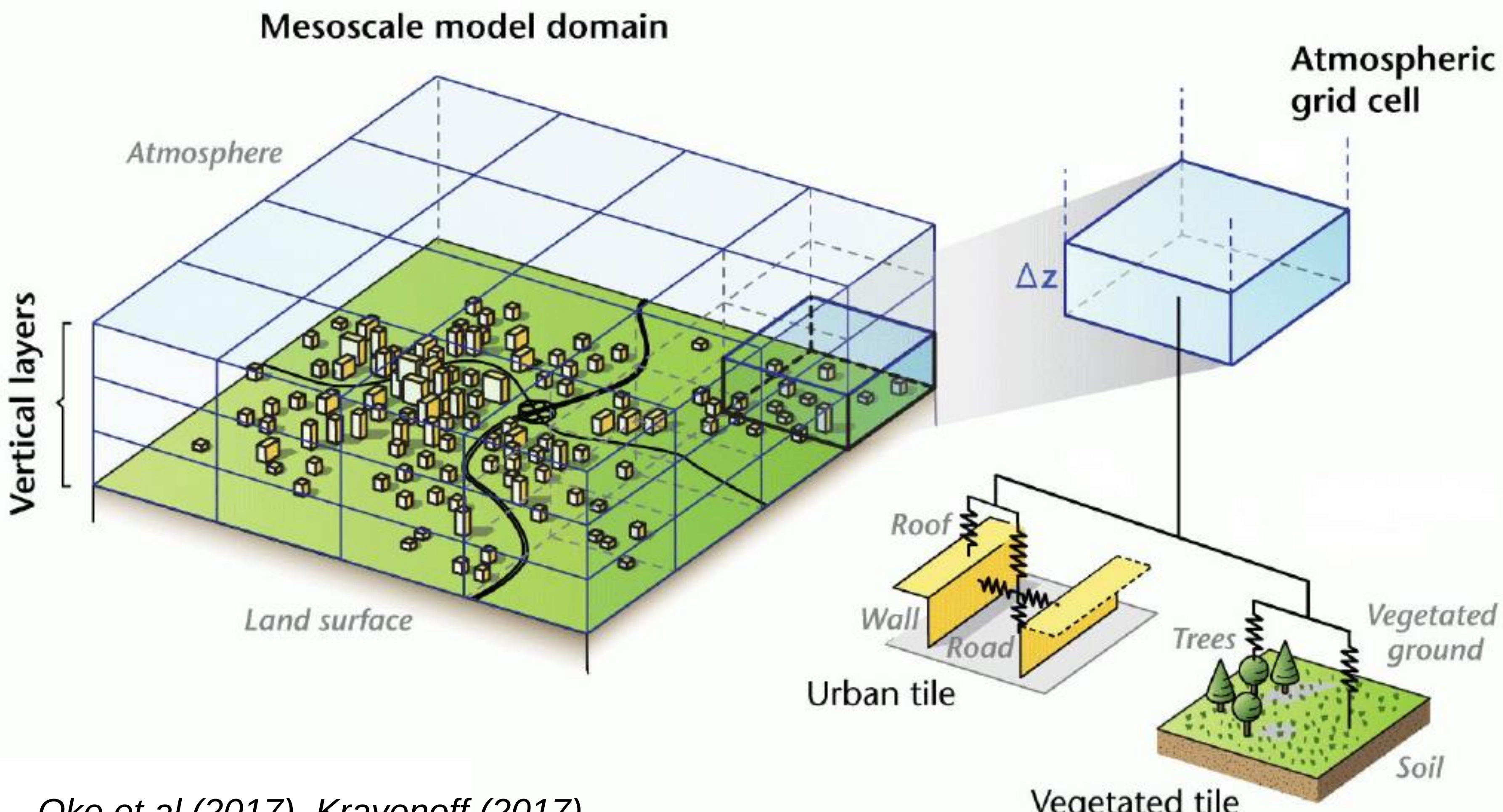
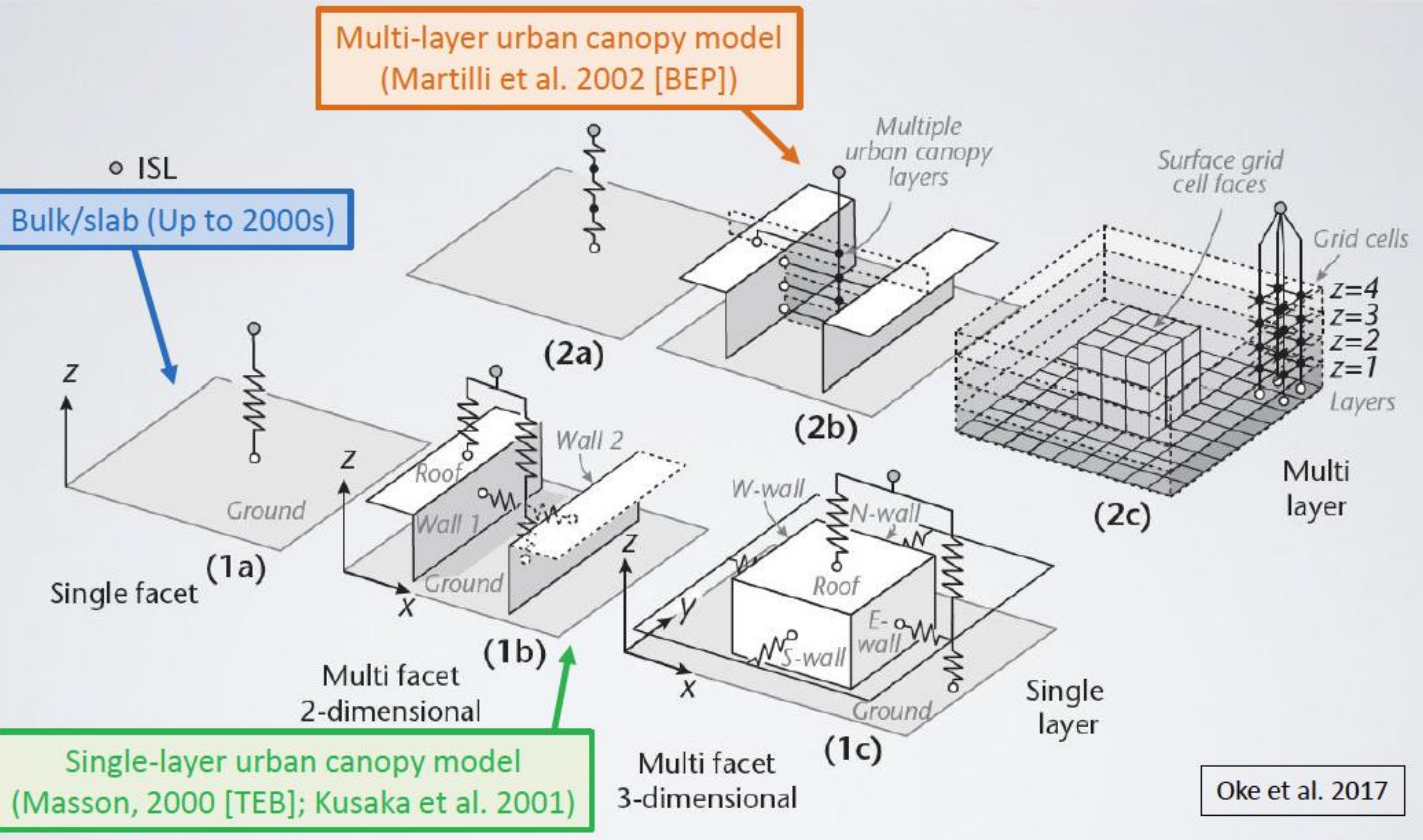
The old modelling way: rocks !

The Urban Canopy Models (UCM)



Oke et al (2017), Krayenoff (2017)

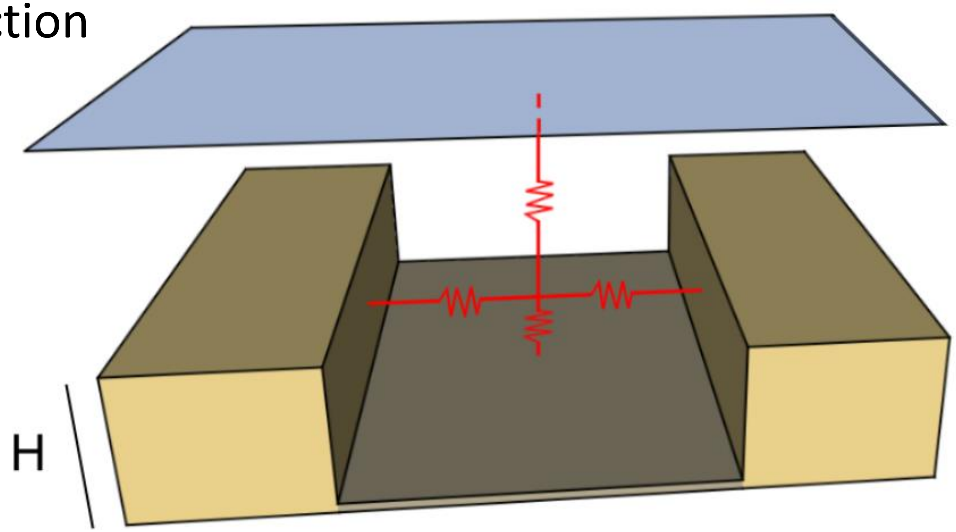
The Urban Canopy Models (UCM)



Modelling the Surface Energy Balance: TEB

The Town Energy Balance (TEB) model

- **Key physical processes of urban climate**
  - 3D surface (street canyon)
  - Radiative exchanges between walls & roads
  - Heat Fluxes, Water & Snow, Friction
- **Allows simulation of :**
  - Impact on Boundary Layer
  - Street micro-climate
  - Urban Heat Island



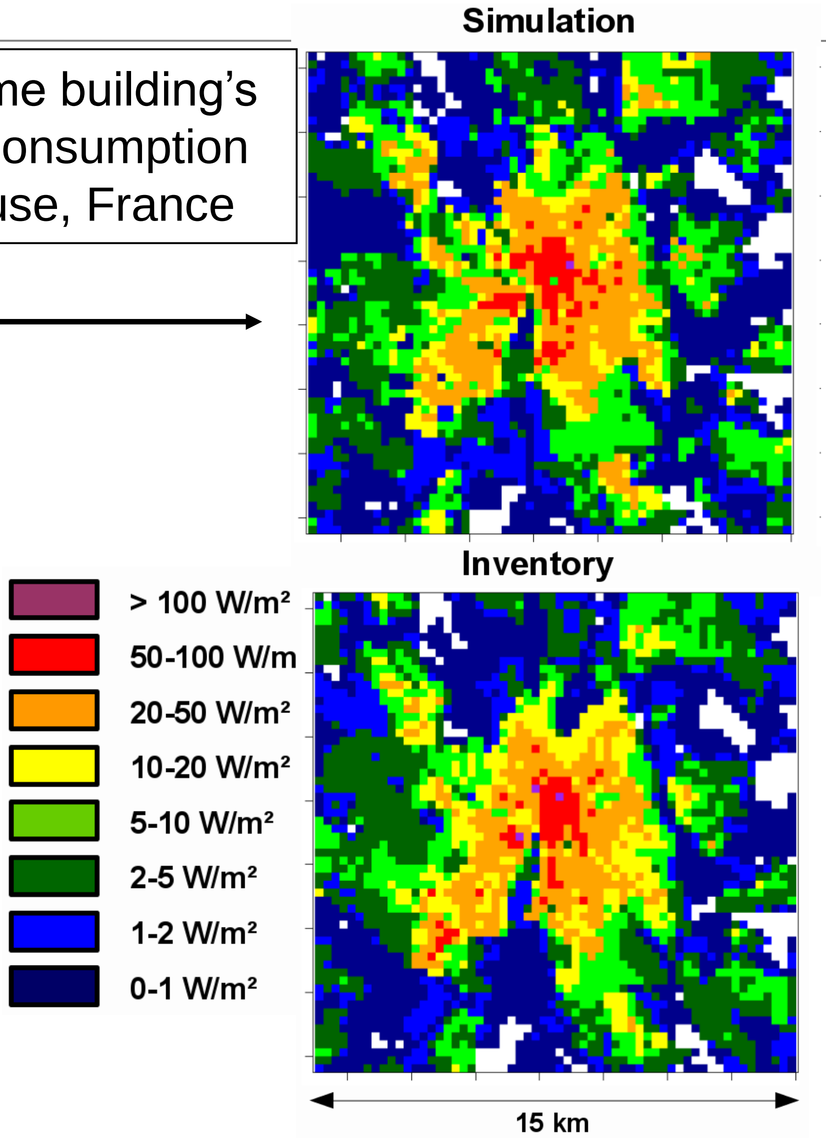
- **Coupled in many meteorological models**

Modelling the Surface Energy Balance: TEB

1) Building Energy Module

- **Energy consumption of buildings** →

Wintertime building's energy consumption in Toulouse, France



(Bueno et al 2012, Pigeon et al 2014, Schoetter et al 2017)

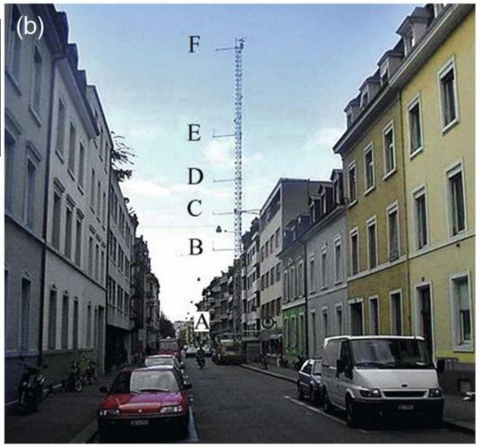
Modelling the Surface Energy Balance: TEB

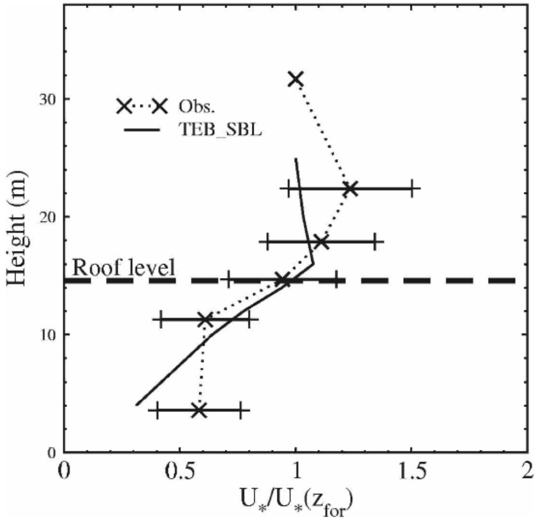
1) Building Energy Module

Validation on Basel (BUBBLE experiment)

- **Energy consumption of buildings**

2) Surface Boundary Layer scheme →

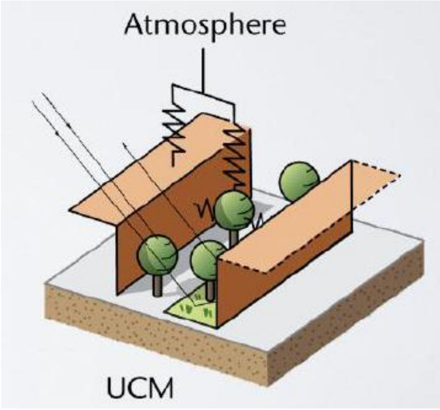




Hamdi and Masson 2008

3) Three types of Urban vegetation

- **Gardens, Street trees, green roofs**

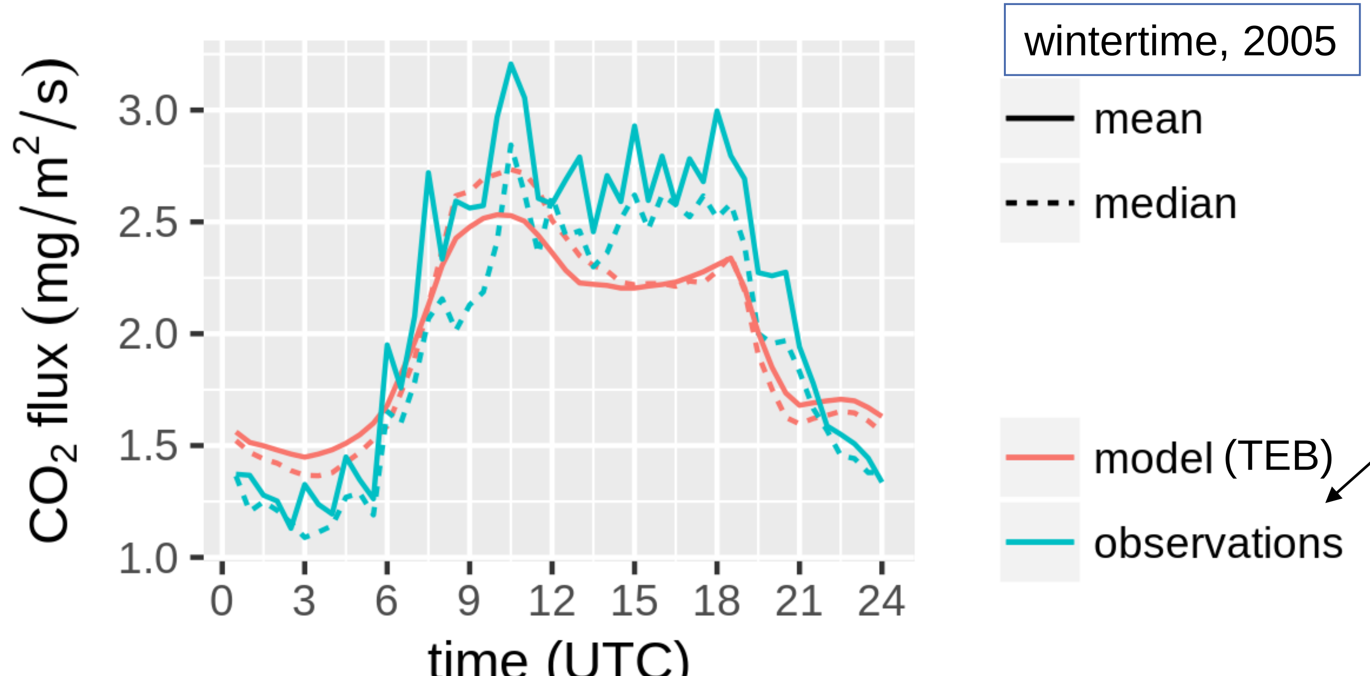


Lemonsu et al 2012, De Munck et al 2013, Redon et al 2017

Modelling the Surface Energy Balance: TEB

4) Exemple of applications

- **CO2 fluxes in cities**
  - **Simulated Buildings + vegetation CO2 fluxes**



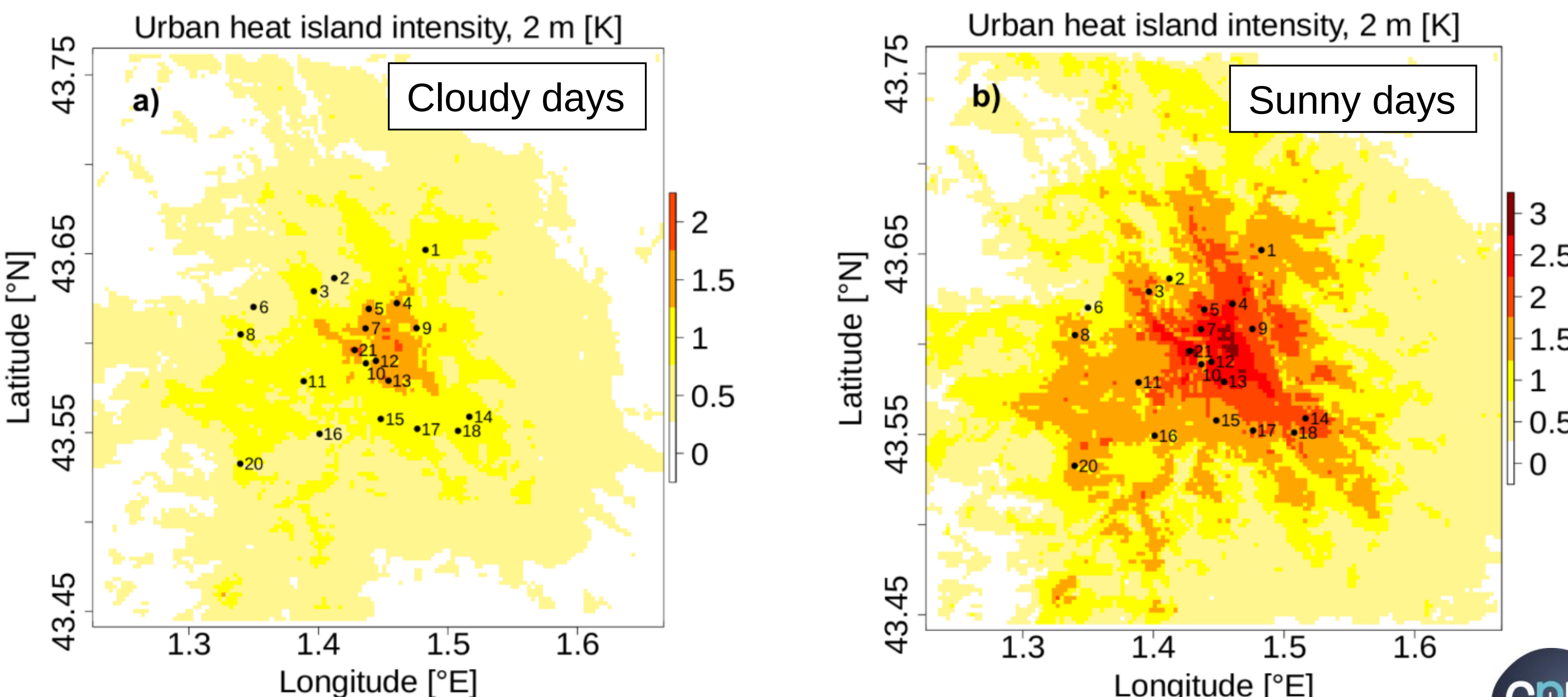
(Goret et al 2018 in prep.)

Modelling the Surface Energy Balance: TEB

UHI simulation in Toulouse (France)

MesoNH model, 250m of resolution

average UHI on 2004 summer



Source: R. Schoetter

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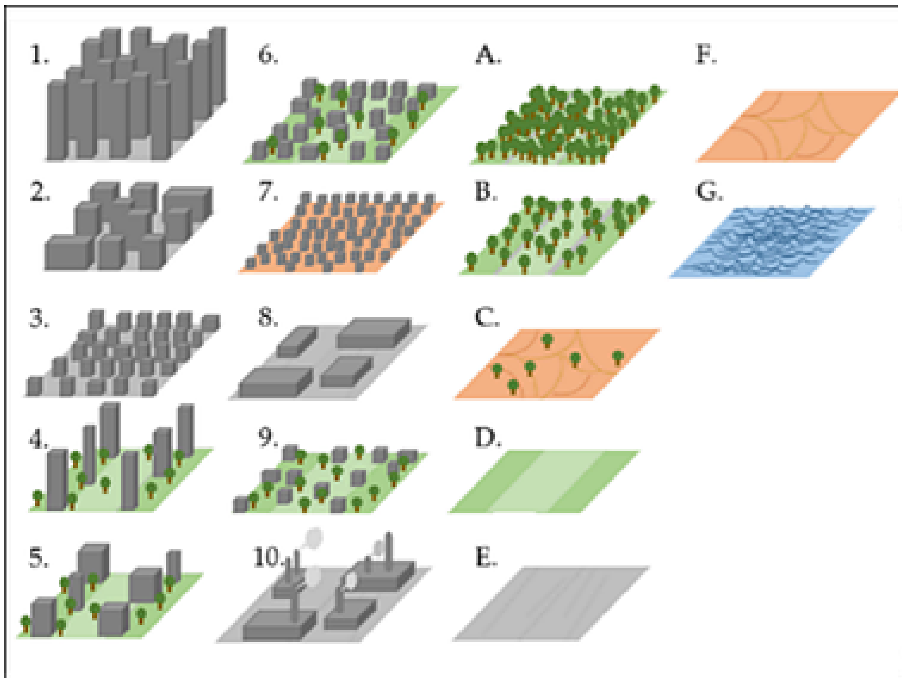
Description of cities: the « Local Climate Zones »

A typology :
-recognized by the Urban Climate community

-10 urban classes

-Link with atmospheric models being developed



From: Steward and Oke (2012)

LCZ COMPACT MID-RISE 2

DEFINITION

Form: Attached or closely spaced buildings 3–9 stories tall. Buildings separated by narrow streets and inner courtyards. Buildings uniform in height. Sky view from street level significantly reduced. Heavy construction materials (stone, concrete, brick, tile); thick roofs and walls. Land cover mostly paved or hard-packed. Few or no trees. Moderate space heating/cooling demand. Moderate to heavy traffic flow. ***Function***: Residential (multi-unit housing; multistorey tenements); commercial (office buildings, hotels, retail shops); industrial (warehouses, factories). ***Location***: Core (old city, old town; inner city, central business district); periphery (high-density sprawl). ***Correspondence***: UCZ2 (Oke 2004); A1, A2, A4, Dc2 (Ellefsen 1990/91).

ILLUSTRATION

High angle

Low level

PROPERTIES

Sky view factor	0.3 – 0.6
Canyon aspect ratio	0.75 – 2
Mean building height	10 – 25 m
Terrain roughness class	6 – 7
Building surface fraction	40 – 70 %
Impervious surface fraction	30 – 50 %
Pervious surface fraction	< 20 %
Surface admittance	1,500 – 2,200 J m^{-2} s$^{-1/2}$ K^{-1}
Surface albedo	0.10 – 0.20
Anthropogenic heat flux	< 75 W m^{-2}

World Urban Database initiative

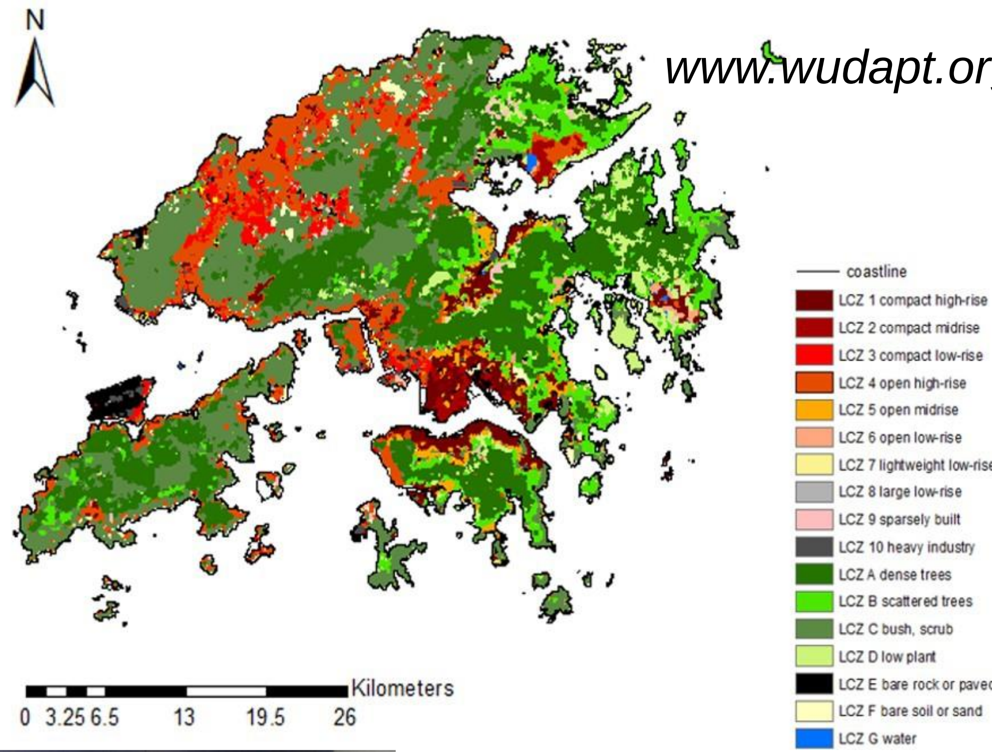
A methodology to map cities:
-Using satellite images

-100m of resolution

-Produces LCZ maps by local experts

-Approx. 100 cities

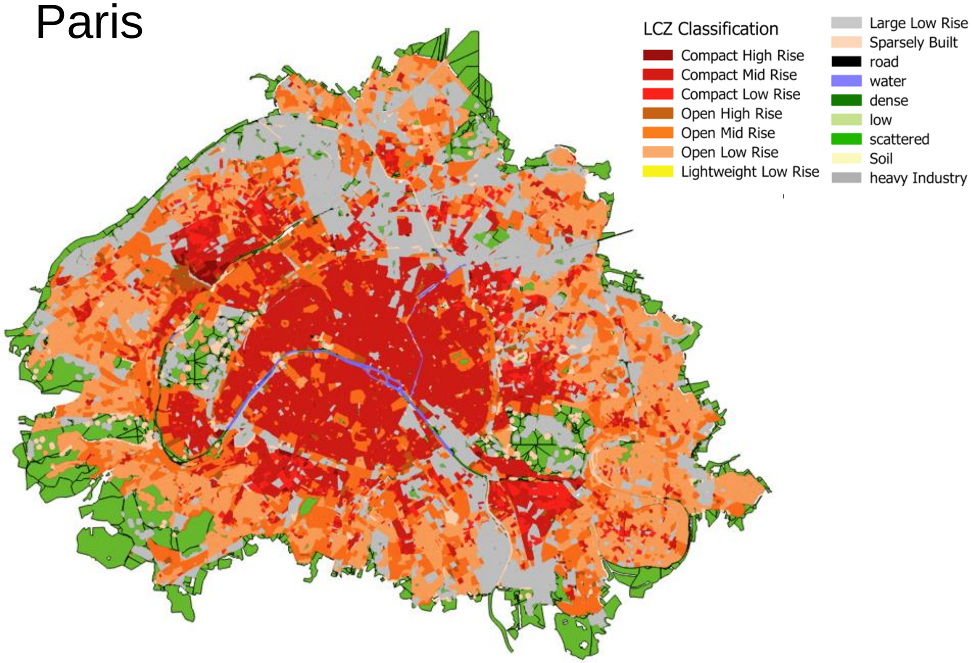
www.wudapt.org



From Buildings data, e.g. Open Street Map

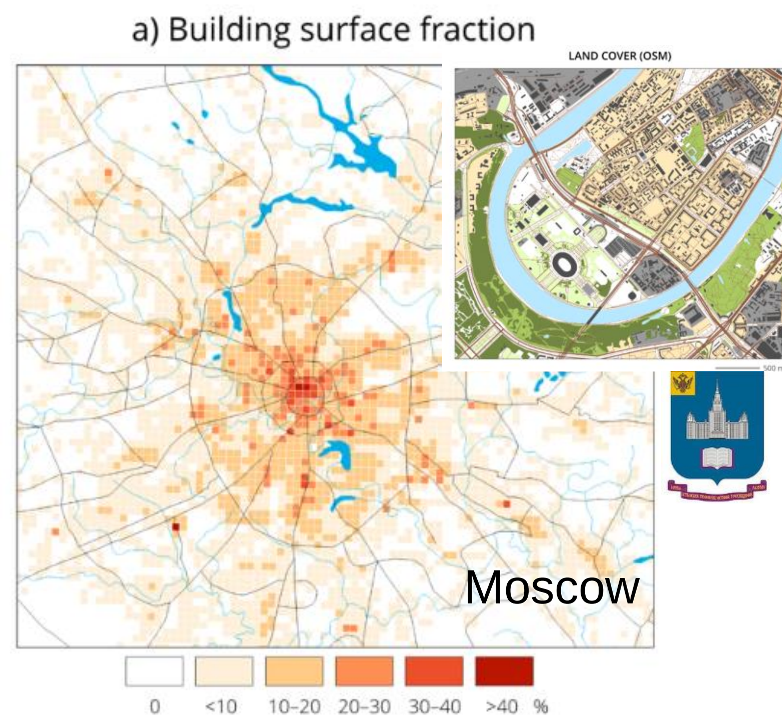
Determination of model urban parameters from building's databases

Paris



LCZ from French Building's Database

Source: Hidalgo et al (2017)



Urban parameters from OSM

Source: Samsonov et al (2015)

Architecture varies from one location to another

At world scale

Architecture for mid-rise buildings

Scale issues in building's description

Architecture varies from one location to another

At world scale)

WUDAPT

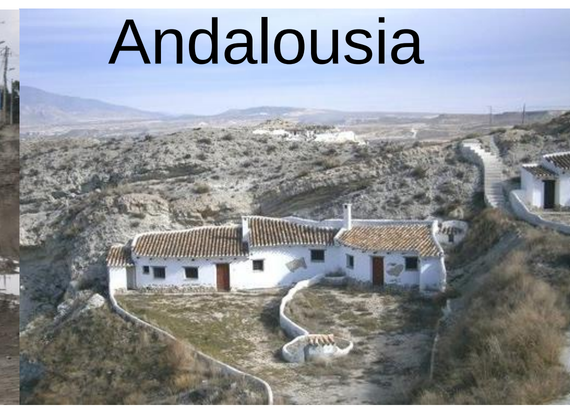

Seattle


Copenhagen

Architecture for houses


Shanghai


Quito, Equador


Andalousia

Scale issues in building's description


Tombouctou,Mali

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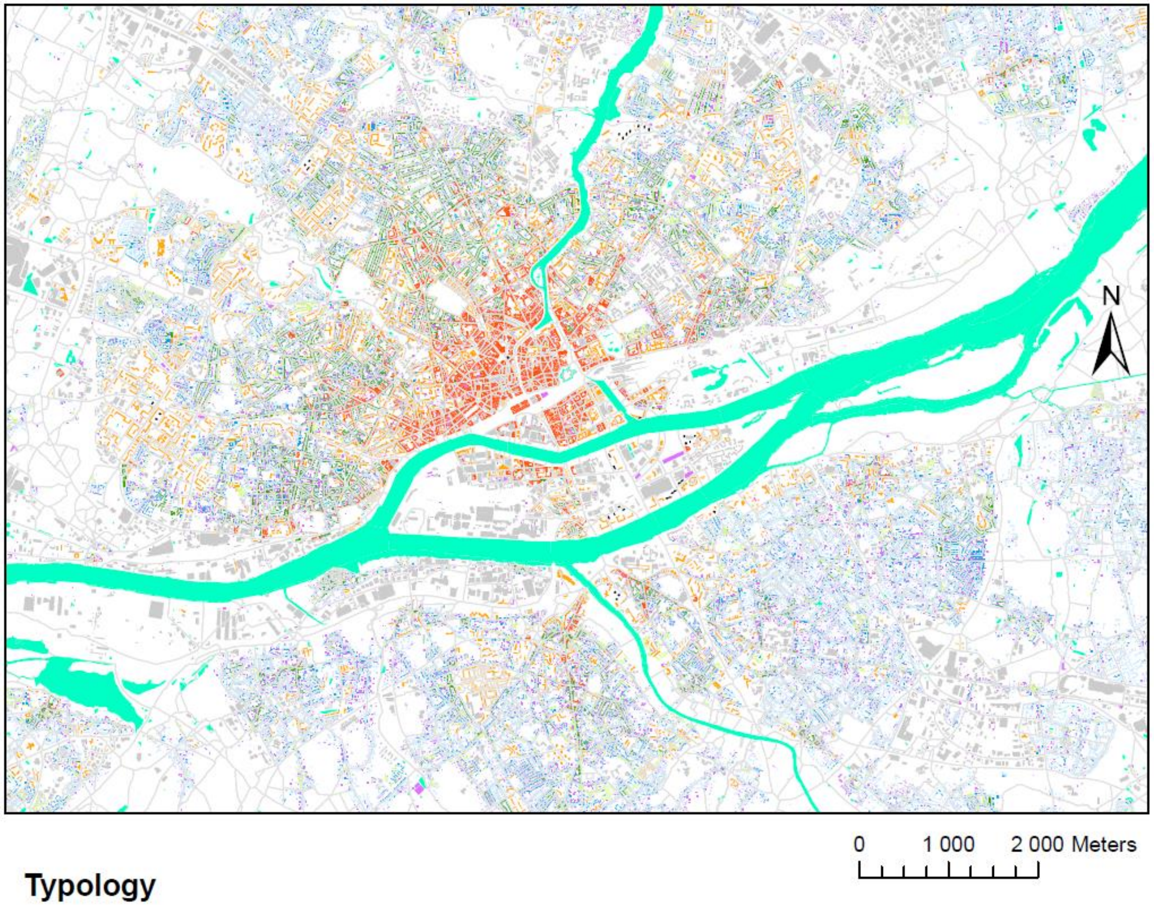
What scale urban planners wish

- In order to do the link with urban planners and stake holders
  - The pertinent spatial scale is …



City of Nantes

	Industrial / recreational building
	High-rise building
	Linear block in closed island
	Linear block in open island
	Isolated block
	Outbuilding
	Row house in closed island
	Row house in open island
	Detached house
	Semi-detached house

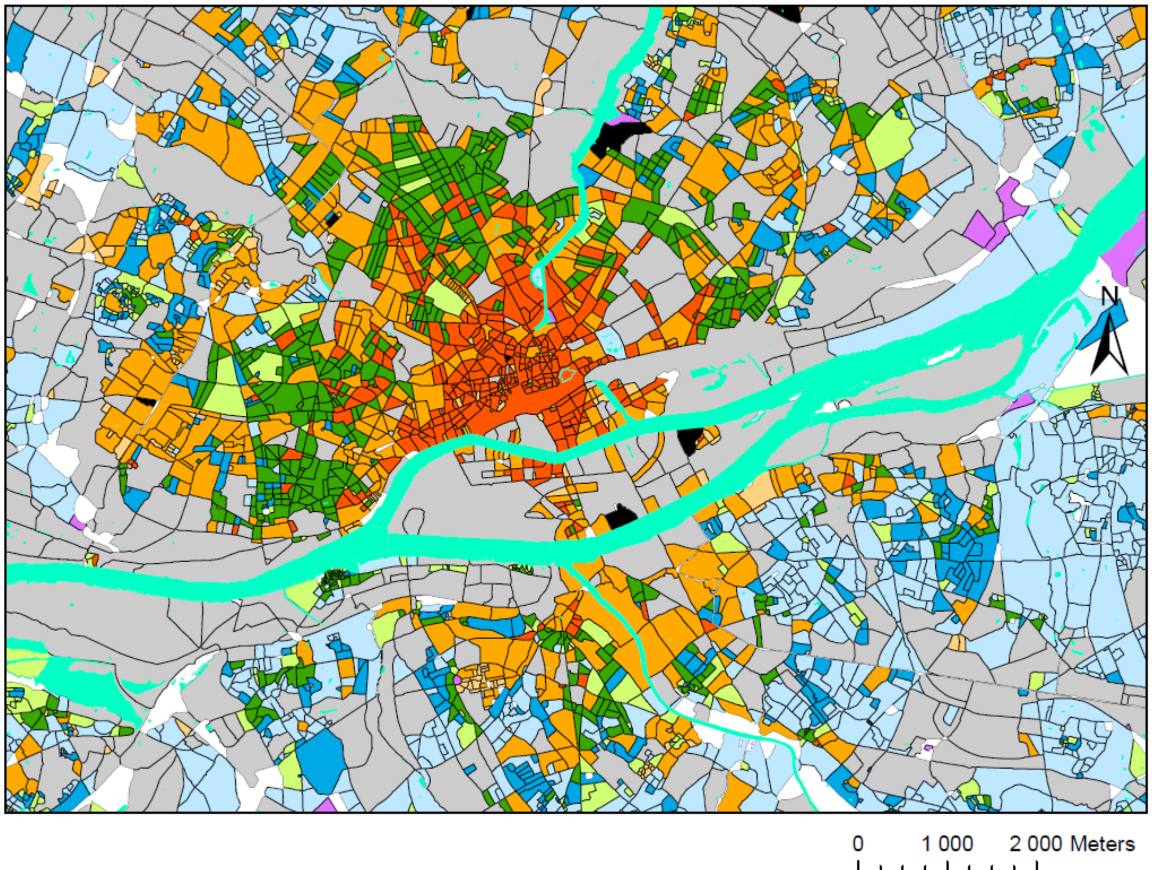
GAME
FNAU
IRSTV
LATTS
LIENSs
LIEU
LISST
LRA

What scale urban planners wish

- In order to do the link with urban planners and stake holders
  - The pertinent spatial scale is … **the urban block** !!!

GAME
FNAU
IRSTV
LATTS
LIENSs
LIEU
LISST
LRA

City of Nantes



Typology

Adaptation of cities to climate change

- In 2100, air-conditioning will probably be necessary

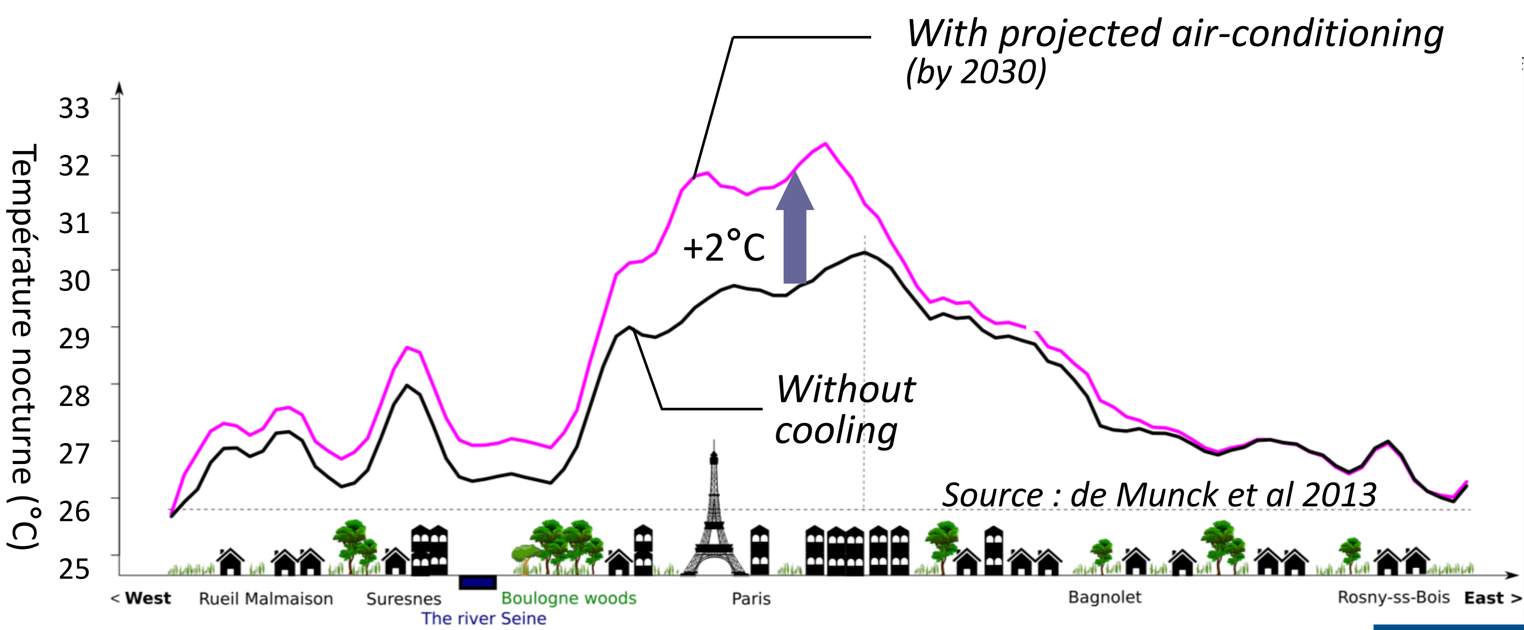
Air-conditioning

Adaptation of cities to climate change

- In 2100, air-conditioning will probably be necessary

→Air conditioning increases heat outside
→Needs even more cooling !
→Impacts people without access to air-conditioning

Air-conditioning



CLIM2 Climat Urbain & Climatisation
Climespace - CNAM - CNRM

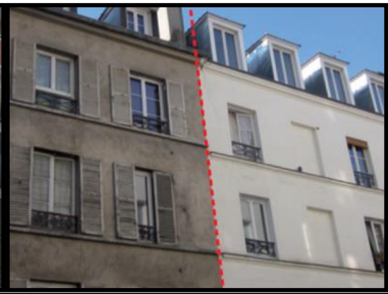
CNRS METEO FRANCE

Adaptation of cities to climate change

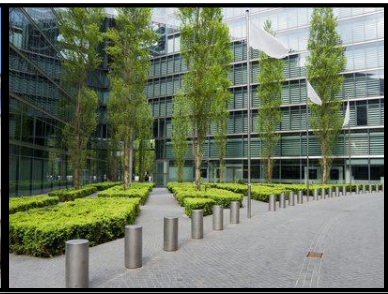
- In 2100, air-conditioning will probably be necessary
- <u>But one can reduce its use !</u>

Air-conditioning

Heat wave Emergency practices



Buildings renovation



Urban Vegetation, water ressources

Urban planning

- **Levers that combine mitigation and adaptation**

CIRED GAME CSTB
VURCA
ANR - VMCS 2008
EPICE
ACCLIMAT
CLIM2 Climat Urbain & Climatisation
Climespace - CNAM - CNRM
MUSCADE
ANR Ville Durable 2009
cnrs
METEO FRANCE

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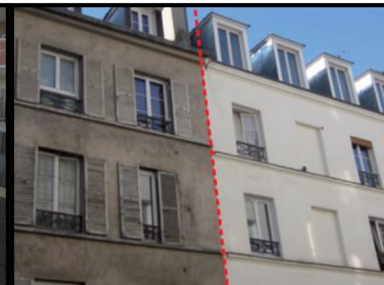

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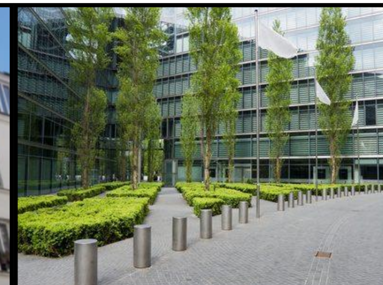


Urban Vegetation, water ressources

Urban planning

- **Levers that combine mitigation and adaptation**

- **Evolution of behaviours : very efficient**

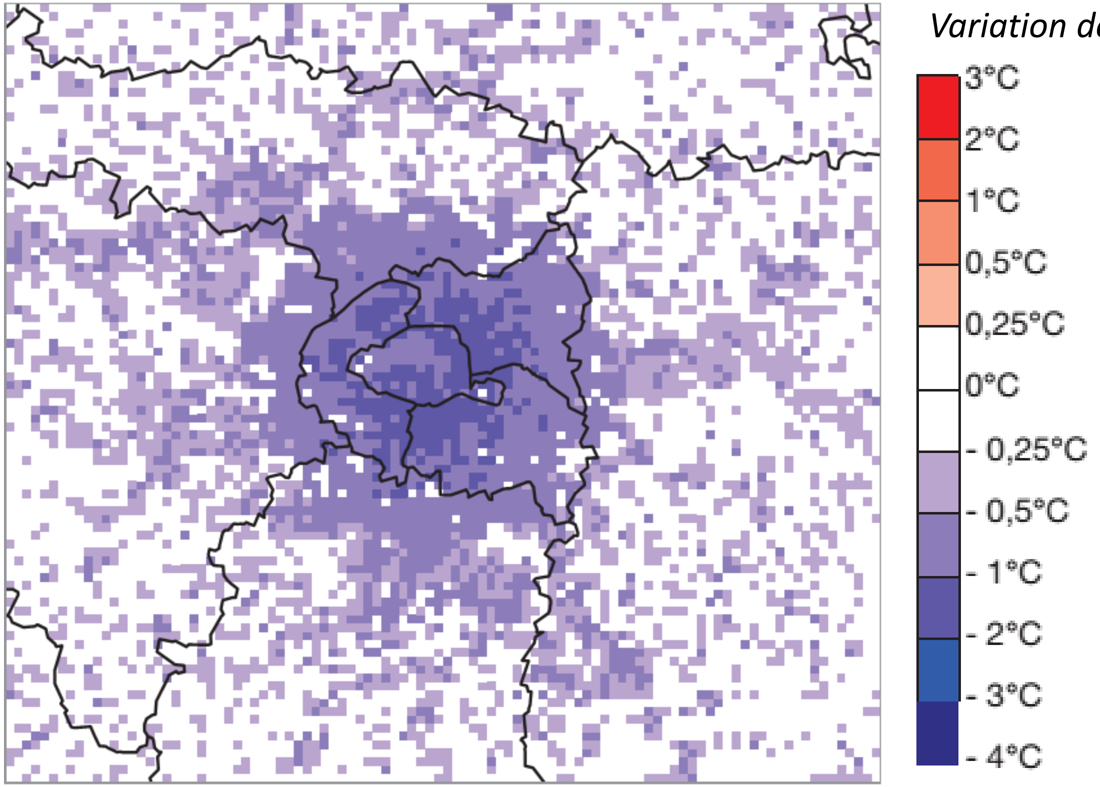
Comportements et usages

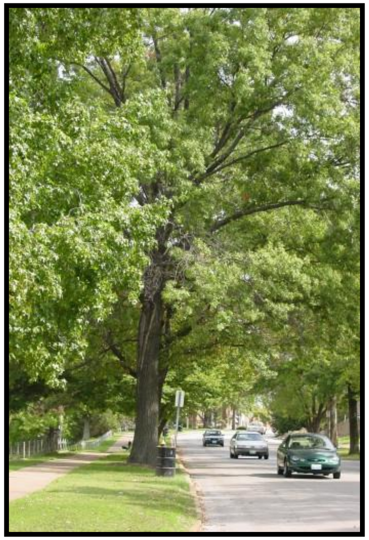
CIRED GAME CSTB
VURCA
ANR - VMCS 2008
EPICE
ACCLIMAT
CLIM2 Climat Urbain & Climatisation
Climespace - CNAM - CNRM
MUSCADE
ANR Ville Durable 2009
cnrs
METEO FRANCE

Urban vegetation

- Green roofs contribute to building insulation

- Ground vegetation and trees are efficient to cool the air





Source : de Munck 2015

Variation of temperature caused by an increase of 50% of ground vegetation in available spaces (car parks, sidewalks, places,...)

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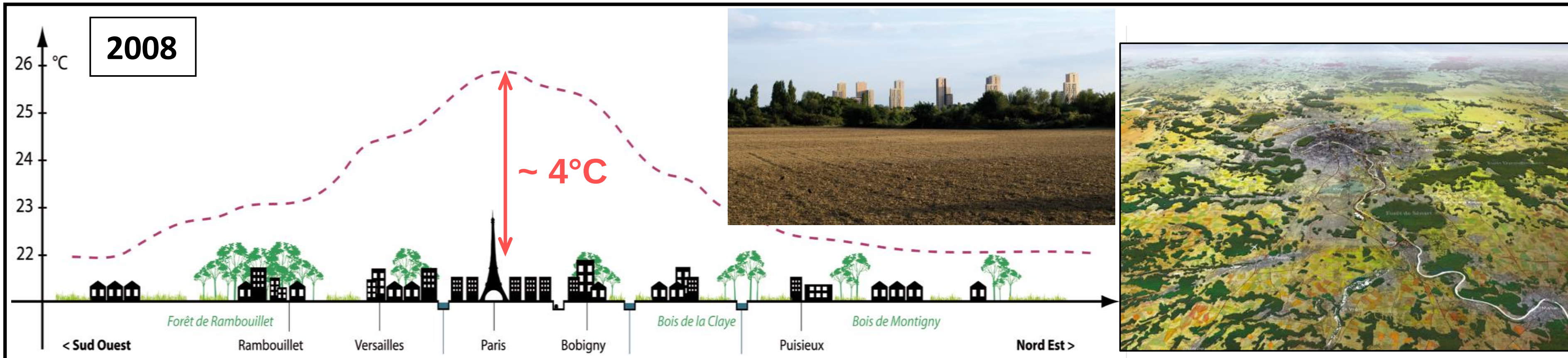
The countryside can cool the city

LE GRAND PARI(S)

Grand Paris (Groupe Descartes)

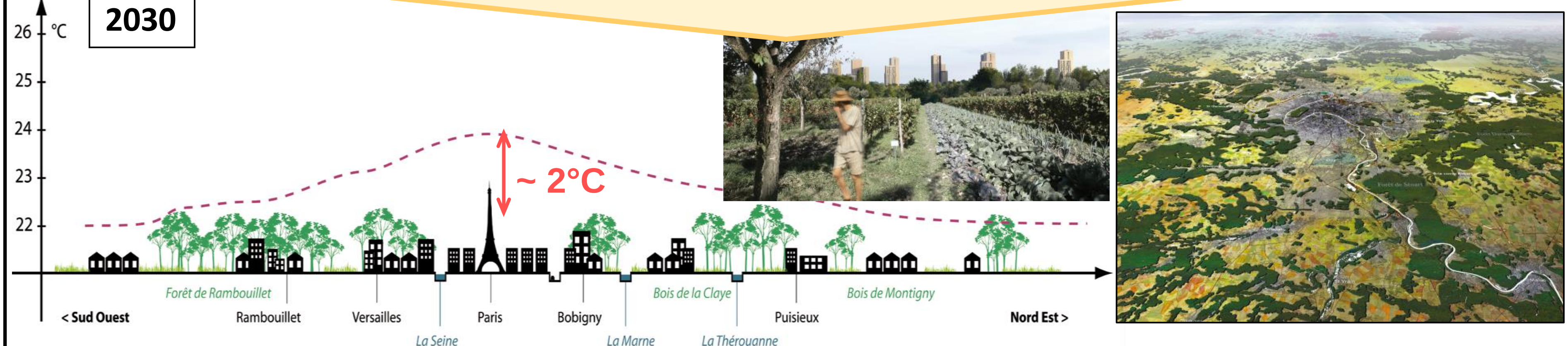
Source : Yves Lion et coll. 2009



Scenario: Local vegetable farming around the city

→ Short supply chains & food governance

→ Cooling of 2 to 3°C

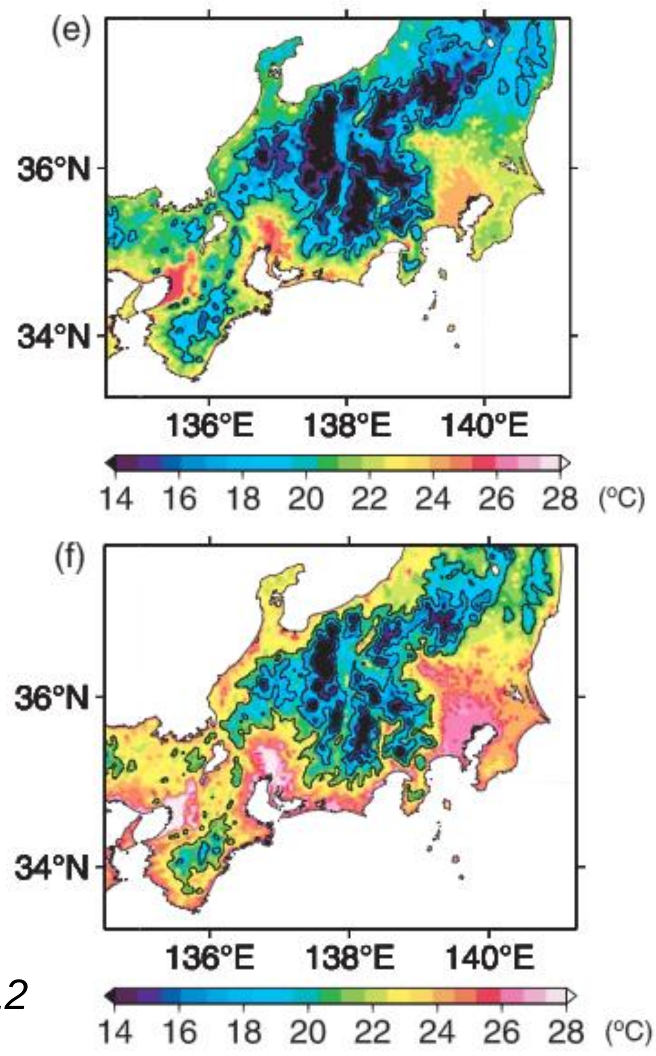


Urban Climate Modelling … only starting

1 month 3km-resolution simulation in present and future climate in Japan

August Tmin 2000s

August Tmin 2070s



→ Need of downscalling methods

筑波大学 University of Tsukuba

Kusaka et al 2012

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1 month 3km-resolution simulation in present and future climate in Japan

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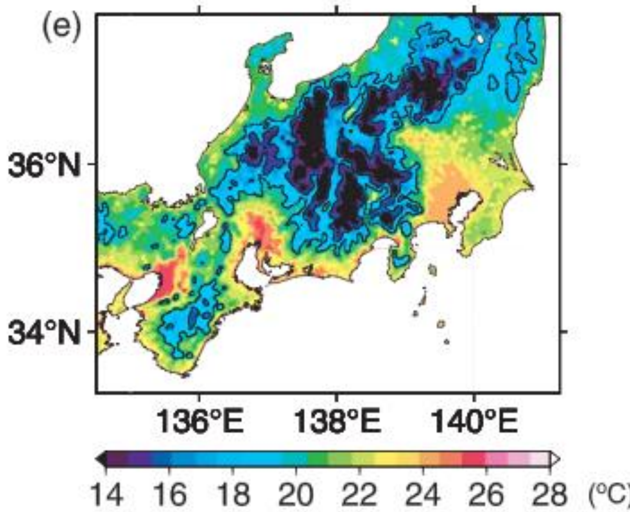
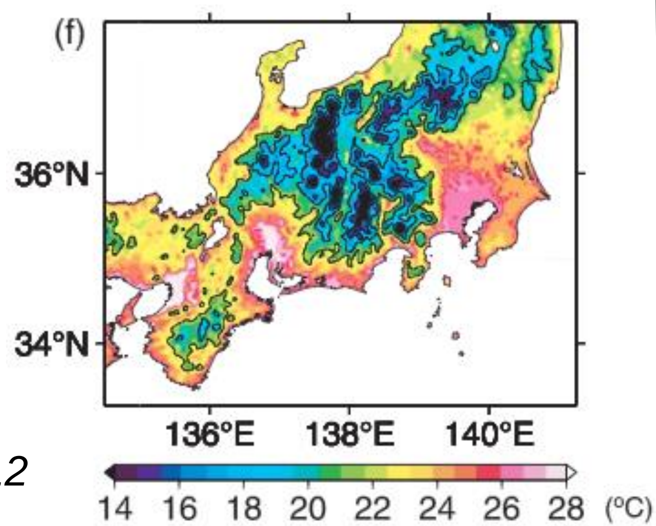
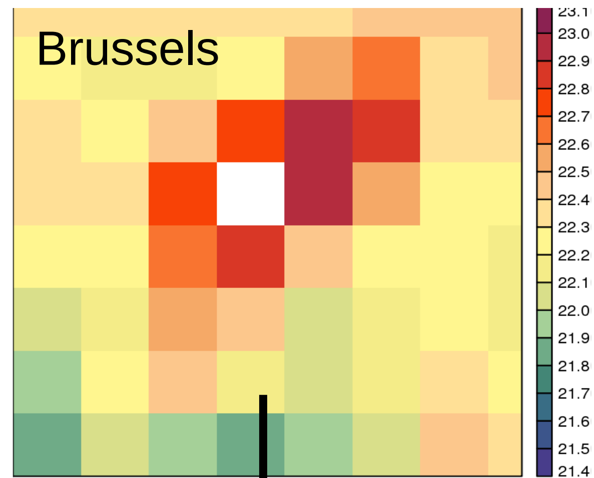


August Tmin 2070s

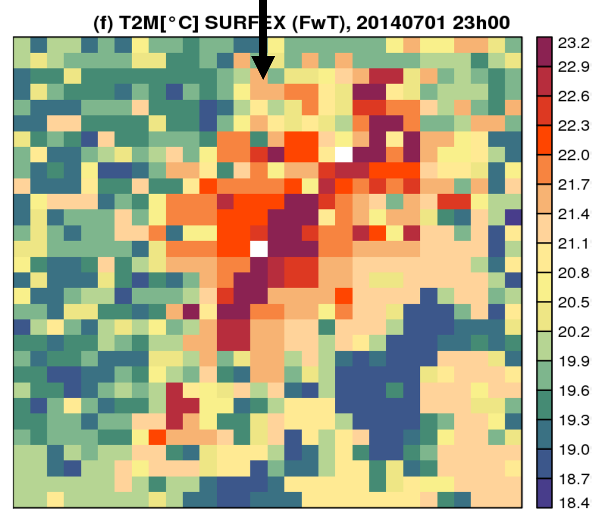


筑波大学
University of Tsukuba

Kusaka et al 2012



Climate simulation at 4km



Downscalling at 1km

IRM KMI

Hamdi et al, 2014

cnrs

METEO FRANCE

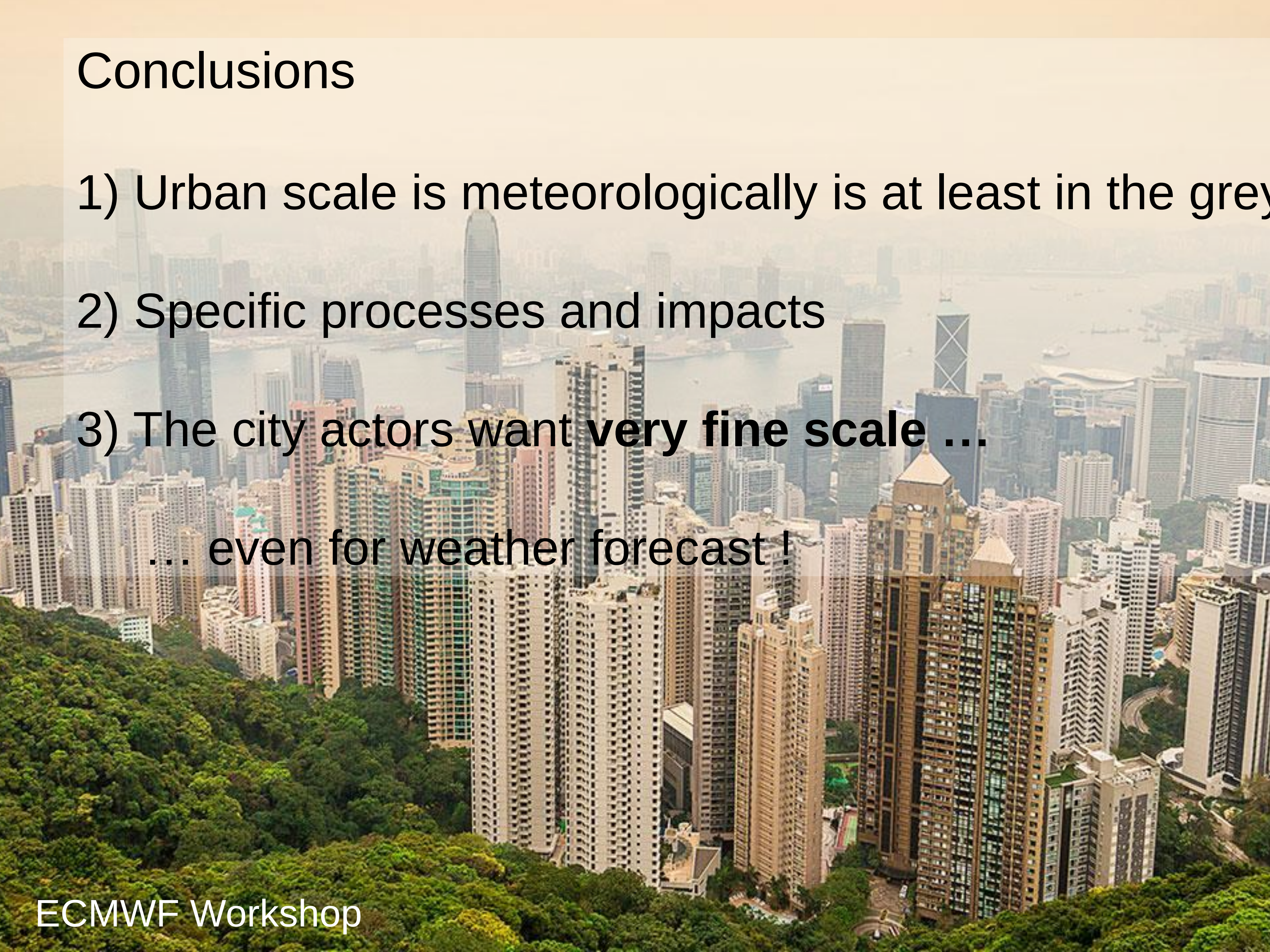
Conclusions

1) Urban scale is meteorologically is at least in the grey

2) Specific processes and impacts

3) The city actors want **very fine scale …**

… even for weather forecast !



Urban Weather Forecast

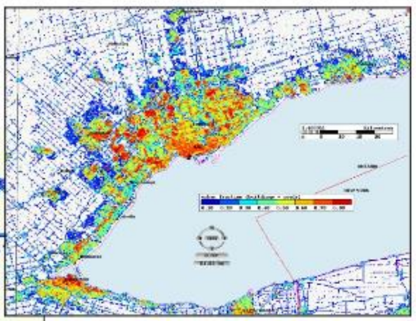
- Weather Forecast during the PAN-American games (Toronto 2015)

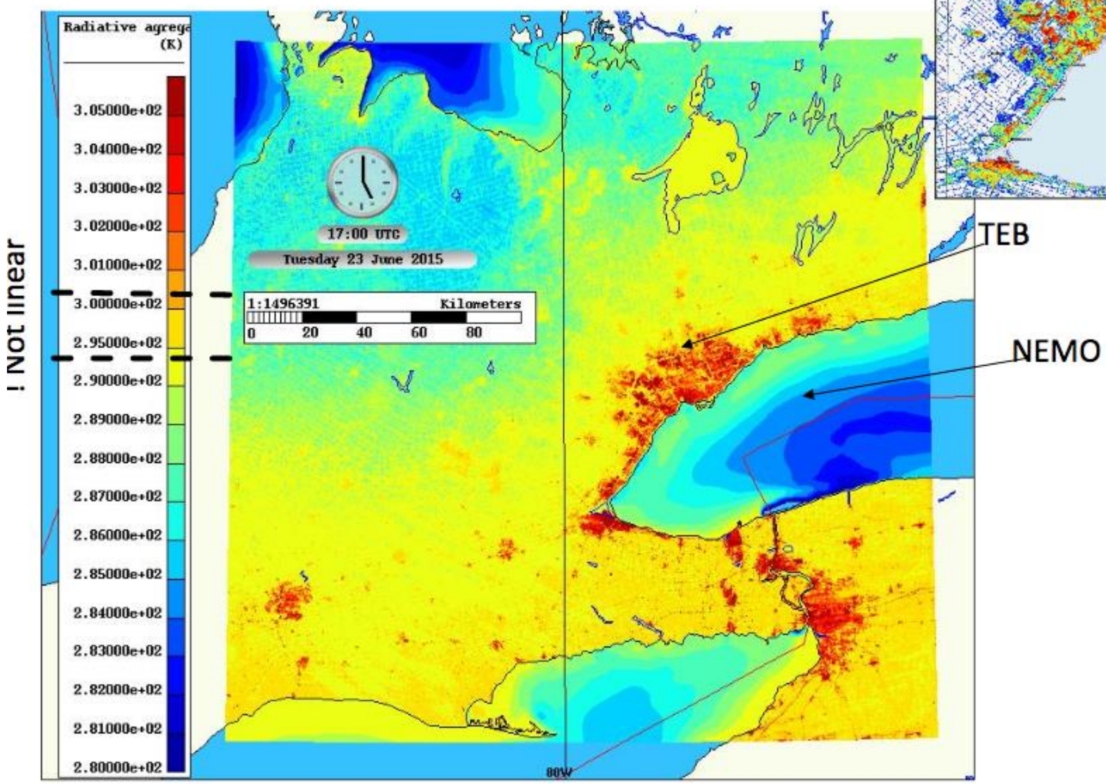
Environment and Climate Change Canada

Radiative Surface Temperature

250-m GRID SPACING, *Urban fraction (%)*

Simulations at 250m of resolution





Source: Leroyer et al 2015

Urban Weather Forecast

• Forecast during the PAN-American games (Toronto 2015)

Environment and
Climate Change Canada

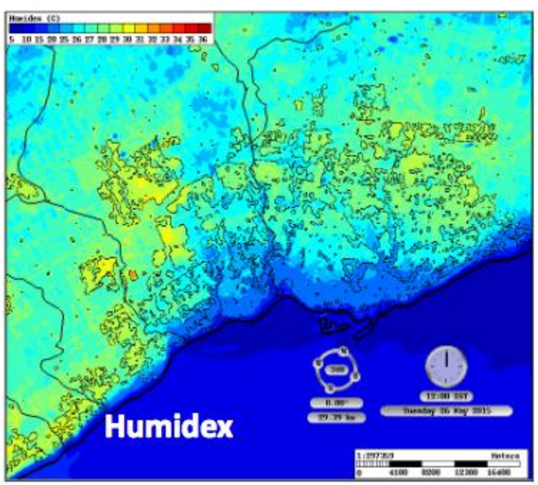
Heat stress indices

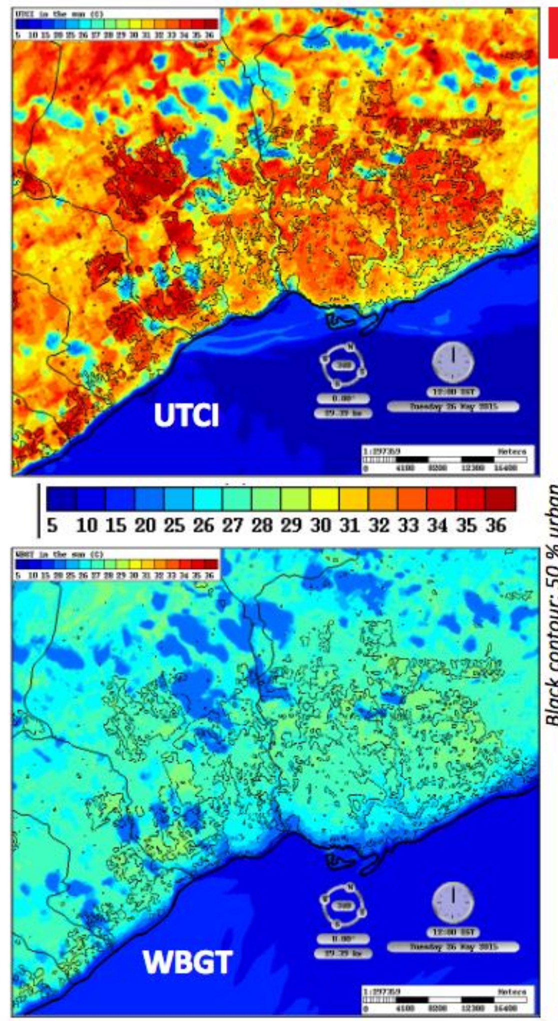
Humidex (equivalent dry air temperature)

UTCI (Universal Thermal and Climate Index)

WBGT (Wet-Bulb Globe Temperature)

to evaluate UTCI and WBGT : PanAm
Obs. of the globe temperature





Source: Leroyer et al 2015

Thank
You

ECMWF Workshop