

LECTURES

May 08th and May 15th 2023, online

The multiple aspects of urban regeneration in the time of climate change

Climate modelling: from global to local

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The Cyprus Institute

08/05/2023

Lecture themes

Global/regional warming

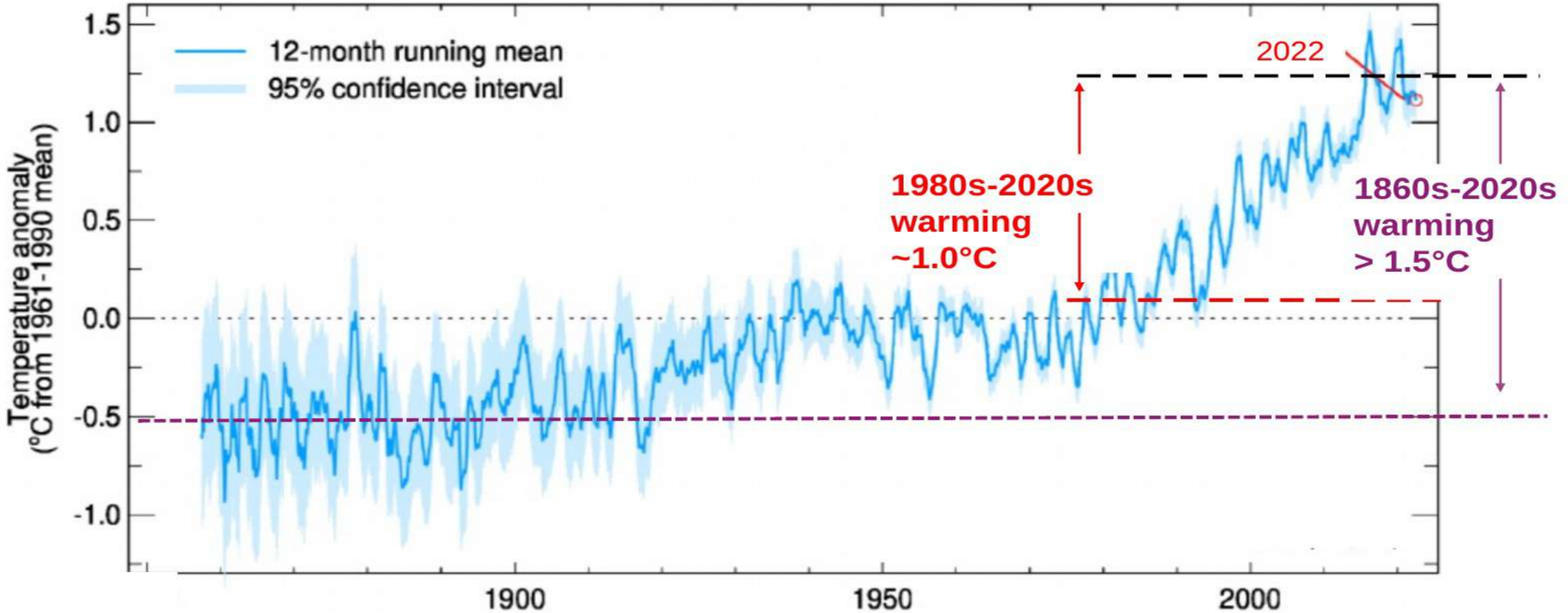
Urban warming

Climate modelling

Cascade of scales

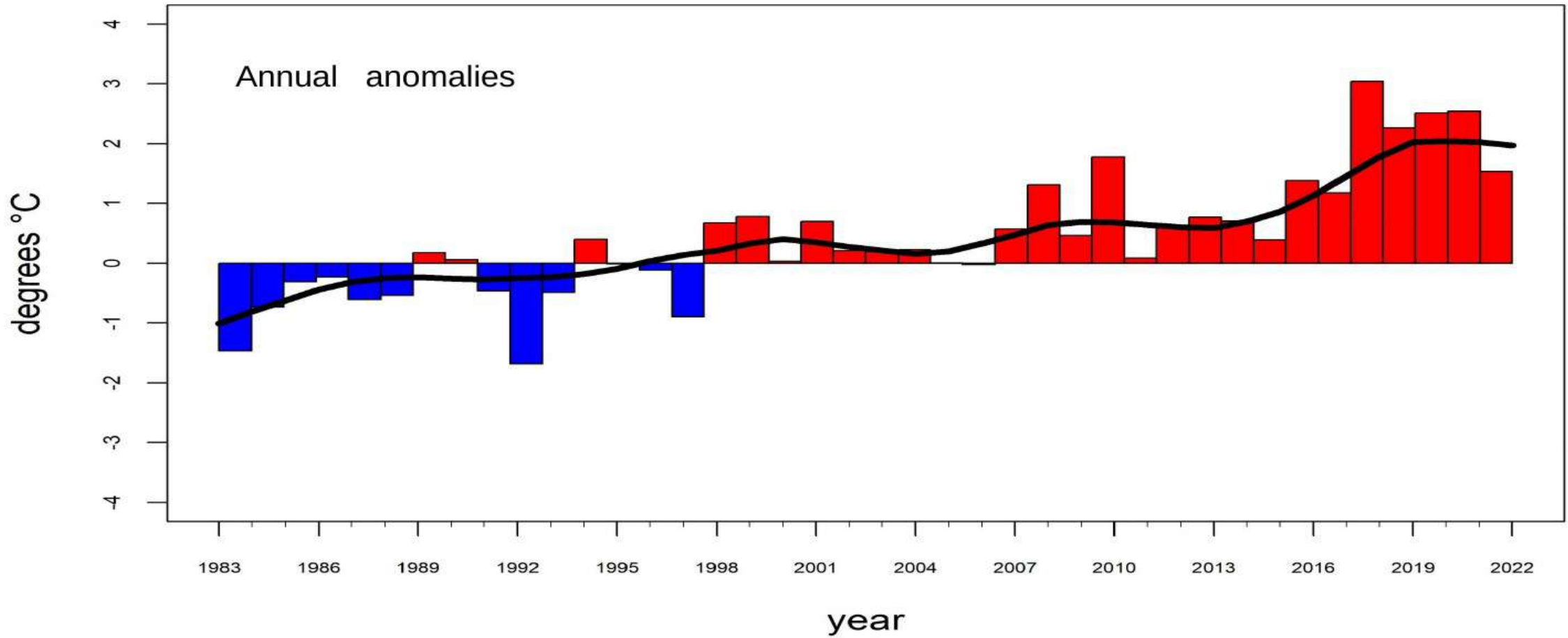


Global warming over land (observed)



<https://crudata.uea.ac.uk/cru/data/temperature/HadCRUT5.0NonInfilled.pdf>

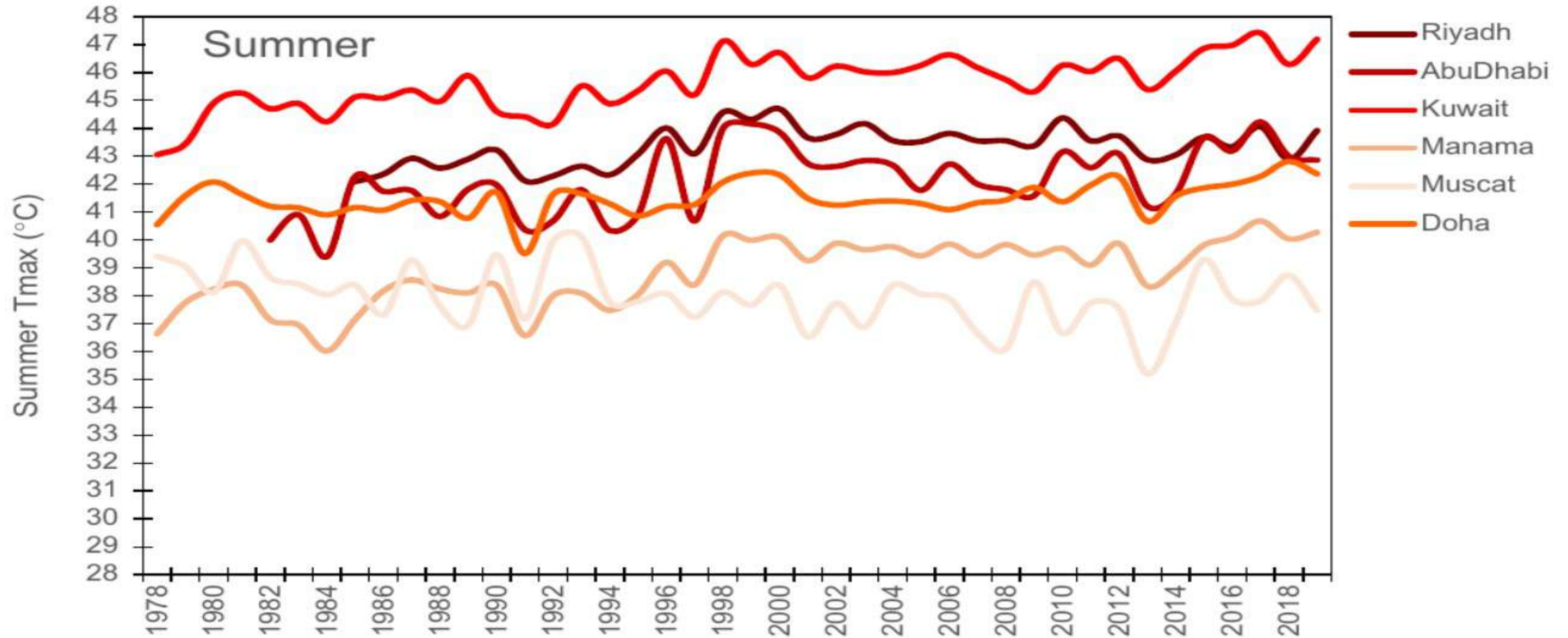
Tmax Nicosia (observed)



A. Tzyrkalli, data from DoM

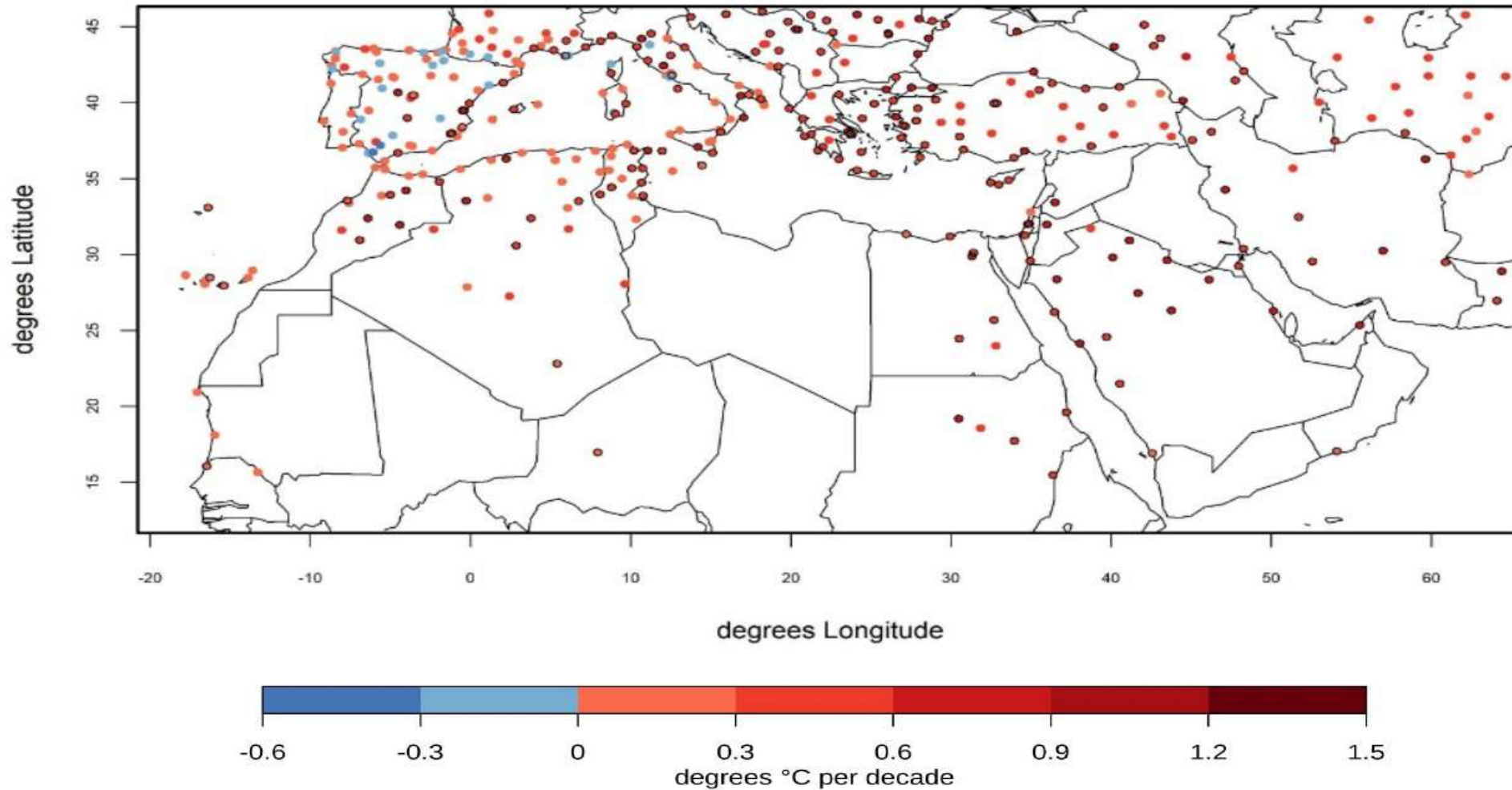


Tmax Gulf (observed)



Almazroui, 2020

Tmean MENA warming (observed)



1981-2020

~ 0.4°C/decade

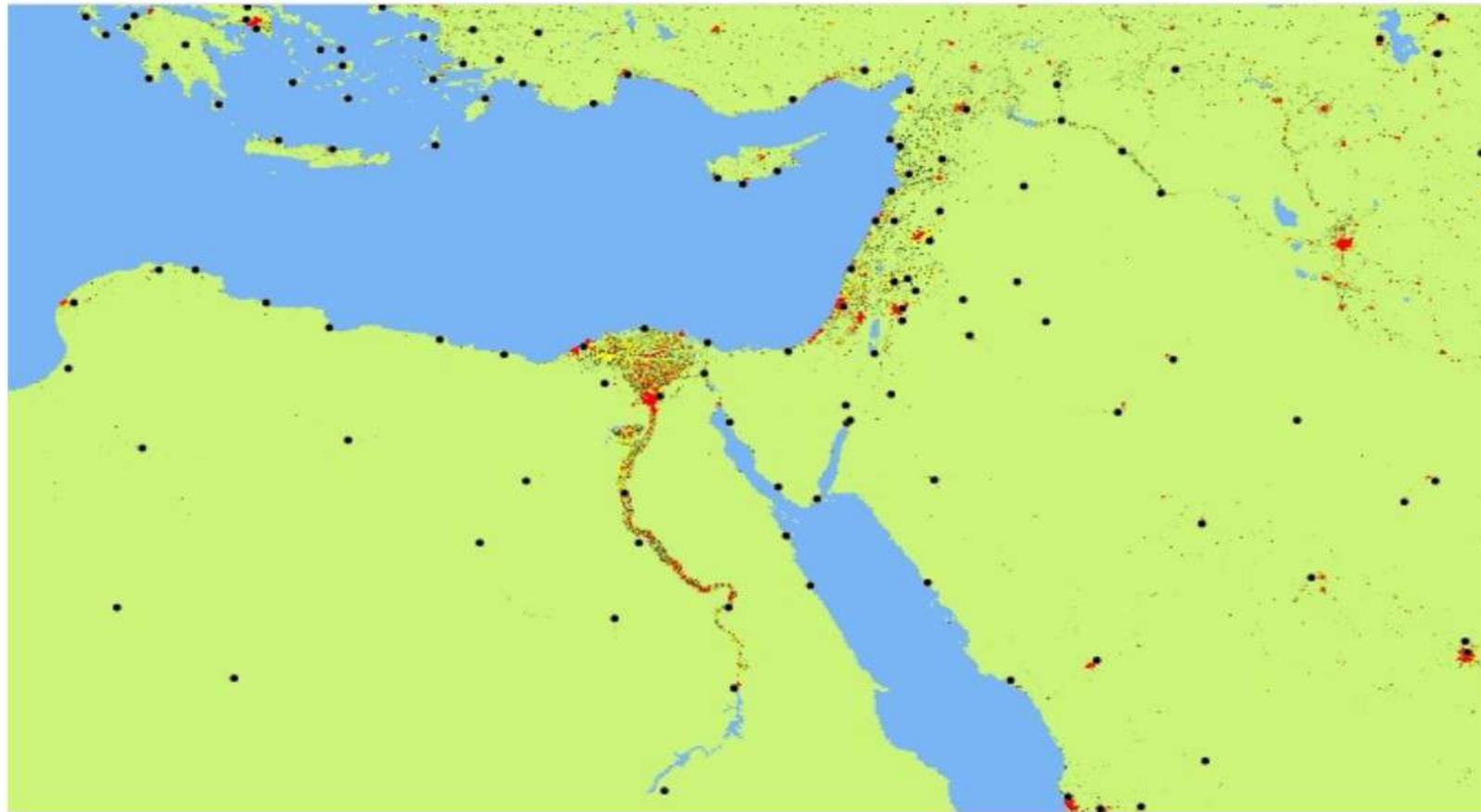
= +1.6°C total

~ 0.5 °C larger
than global
average

Stronger in
EMME

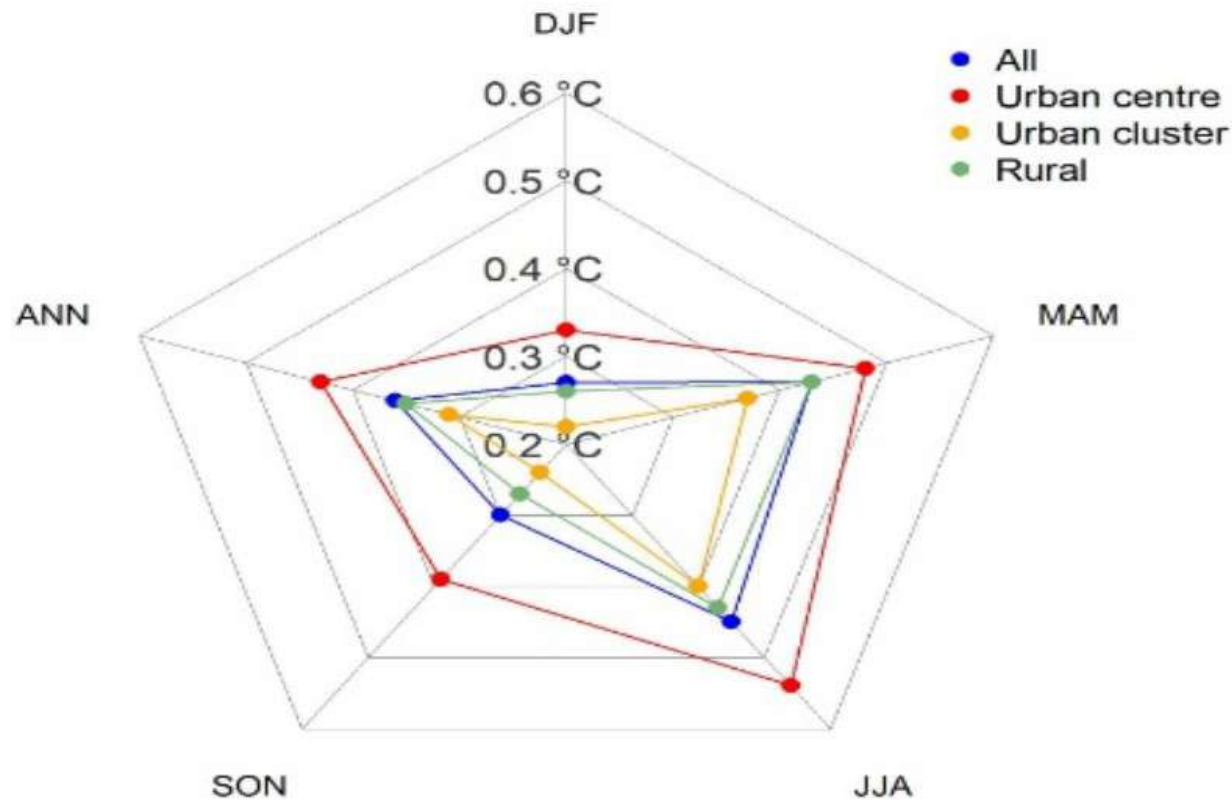
Hadjinicolaou et al., 2023

Urban characterization from GHS data



Tzyrkalli et al., 2023

Signature of urbanization



Urban
characterization from
GHS

Summer trend:

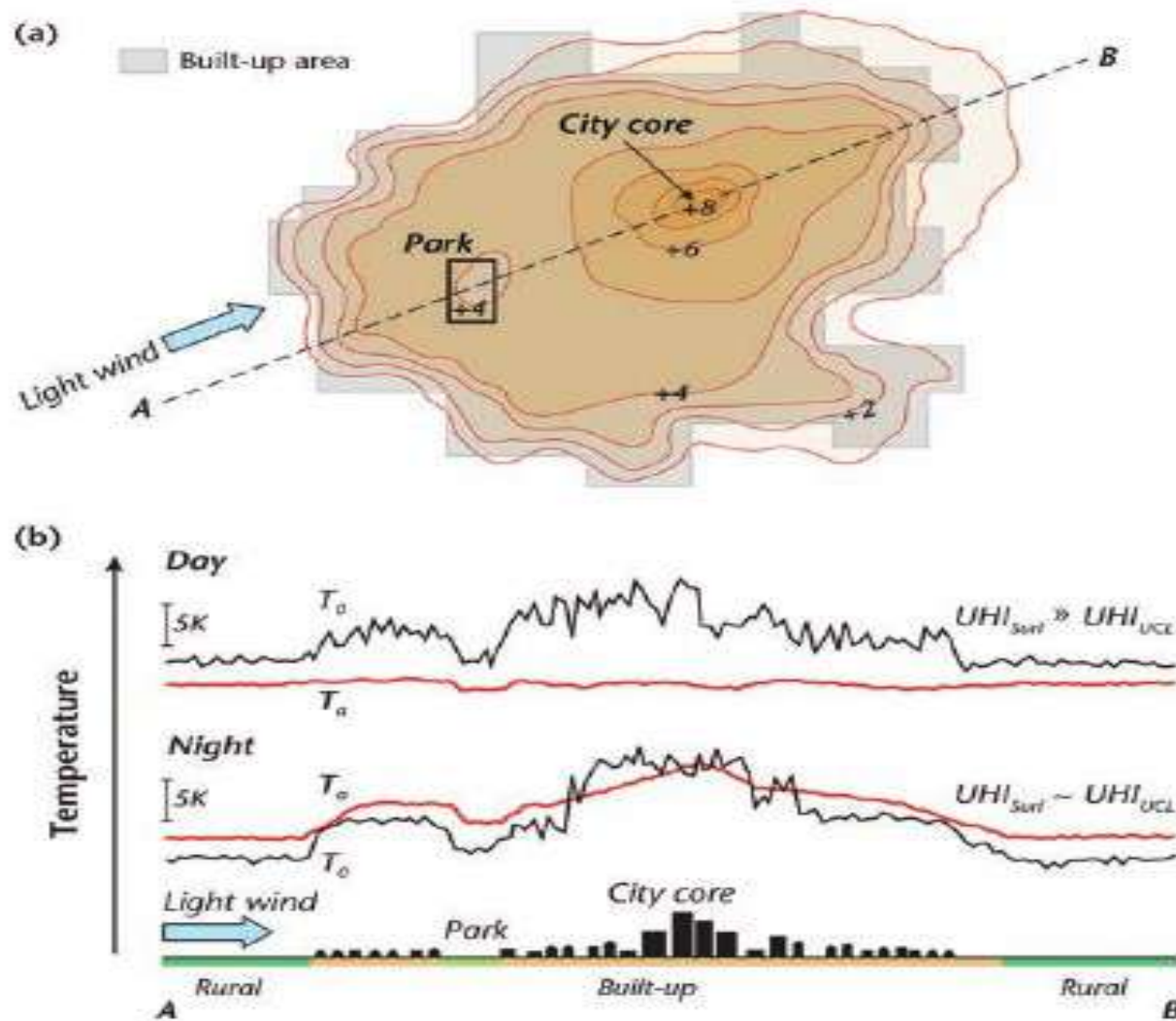
All stations:
0.45°C/decade

Rural:
0.43°C/decade

Urban centre:
0.54 °C/decade

Hadjinicolaou et al., 2023

Urban Heat Island morphology



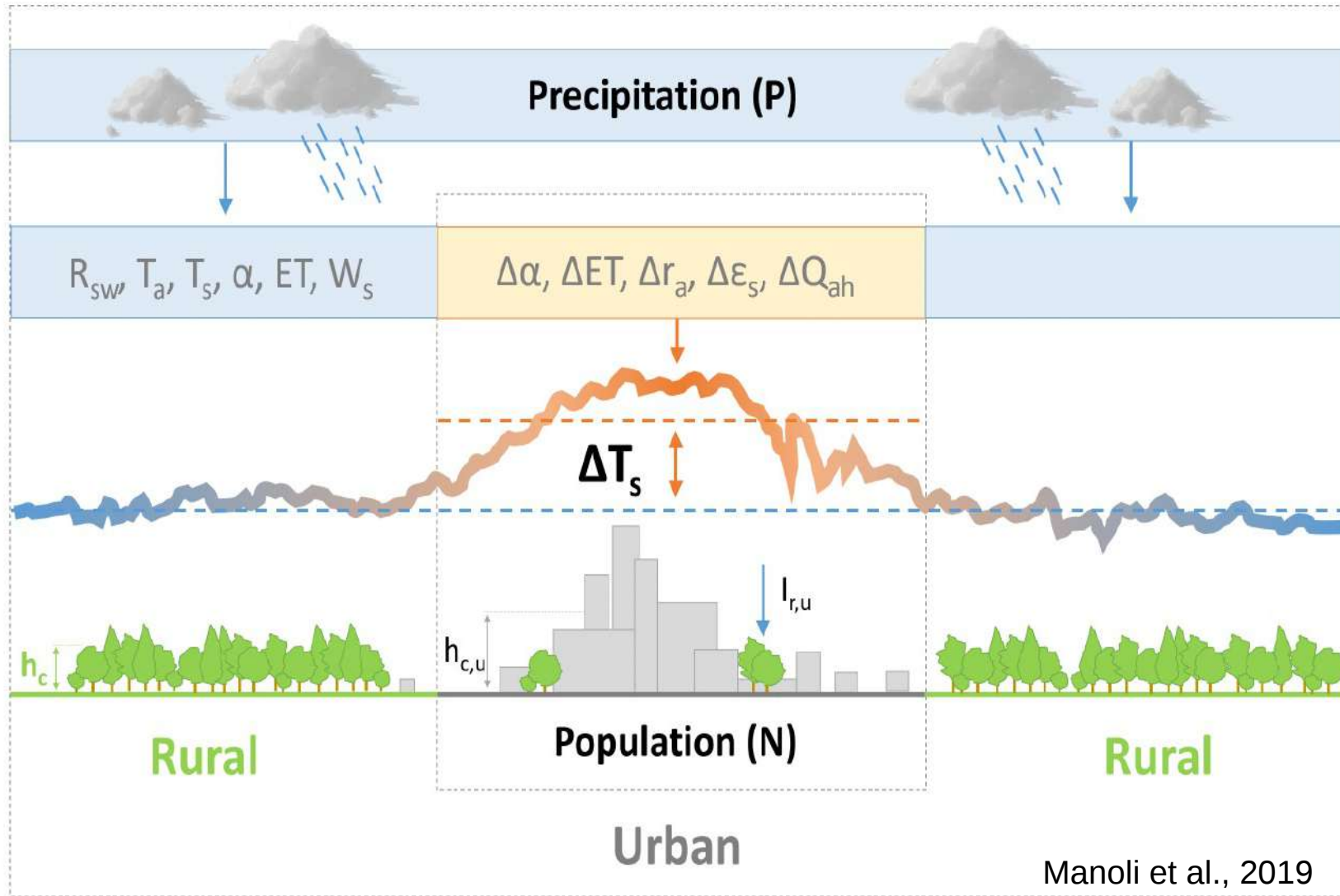
Schematic depiction of a typical UHI at night in calm and clear conditions in a city on relatively level terrain

(a) Isotherm map illustrating typical features of the UHI and their correspondence with the degree of urban development

(b) 2D cross-section of both **surface** and **screen-level air temperature** in a traverse along the line A-B shown in (a)

Oke et al., 2017

Urban Heat Island drivers



Urban-rural **surface temperature** differences (ΔT_s) depend on:

Mean annual precipitation (P)
 Urban population (N)

that force urban-induced changes in:

albedo ($\Delta\alpha$),
 evapotranspiration (ΔET),
 convection efficiency (Δr_a),
 surface emissivity ($\Delta\epsilon_s$),
 anthropogenic heat (ΔQ_{ah})

relative to the rural surroundings

Manoli et al., 2019

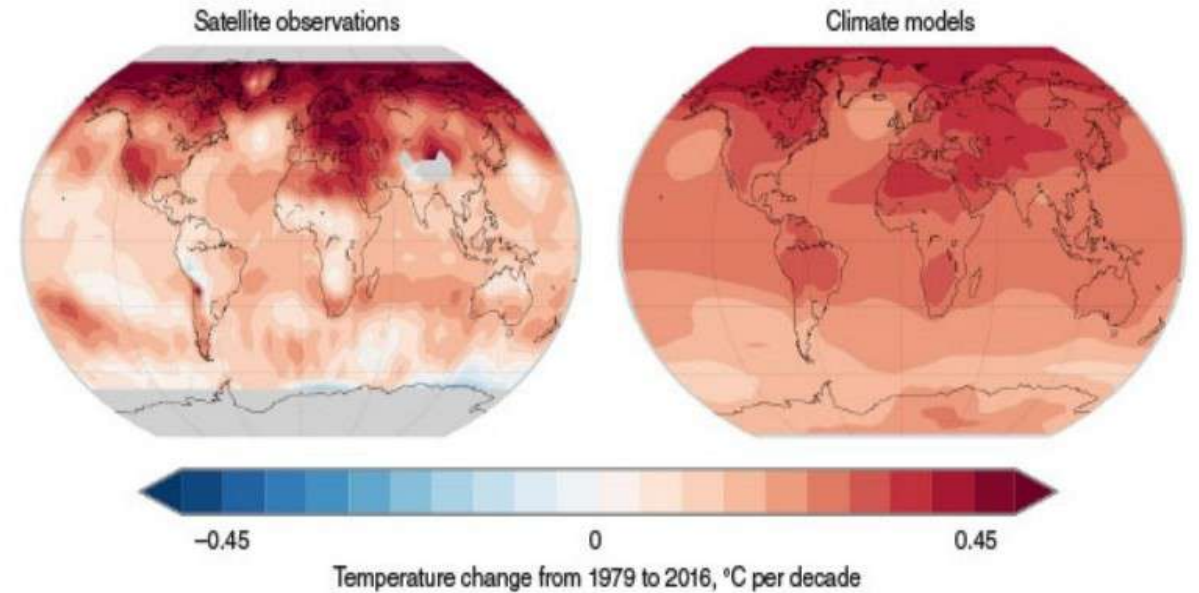
Theoretical world temperature (modelled)

Global climate model



Model grid-box → horizontal resolution
(100-200 km)

Simulated temperature trend



<https://str.llnl.gov/december-2017/bader>

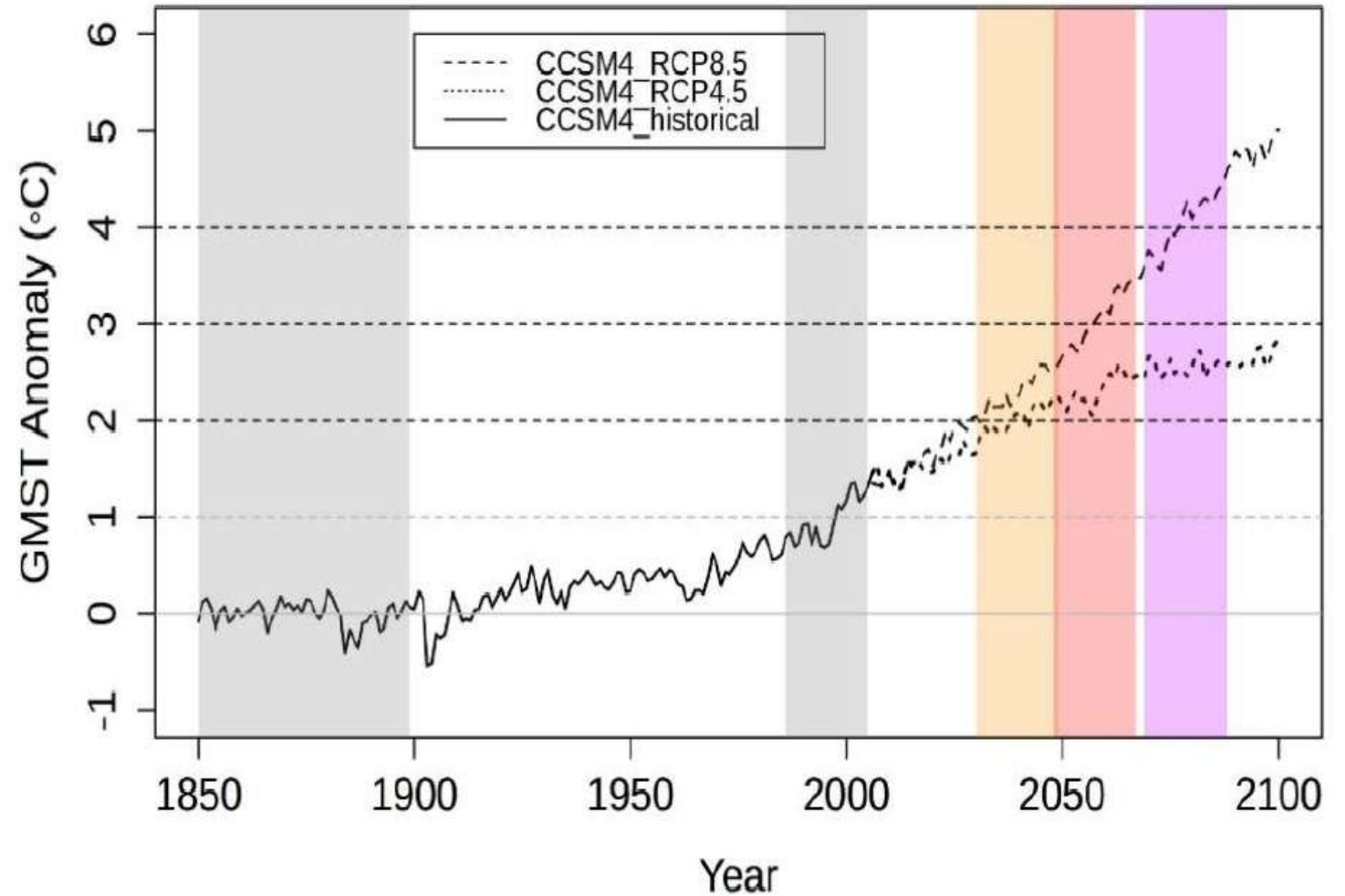
Global warming levels:

(20-year average)

+2 °C 2030 - 2049

+3 °C 2048 - 2067

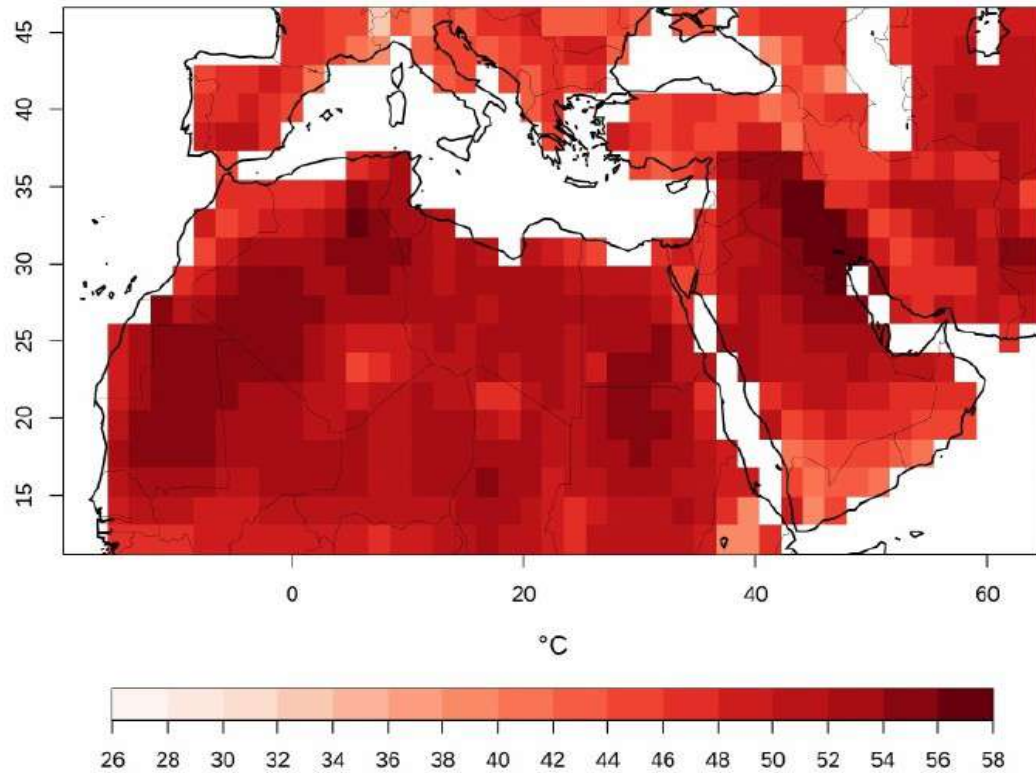
+4 °C 2069 - 2088



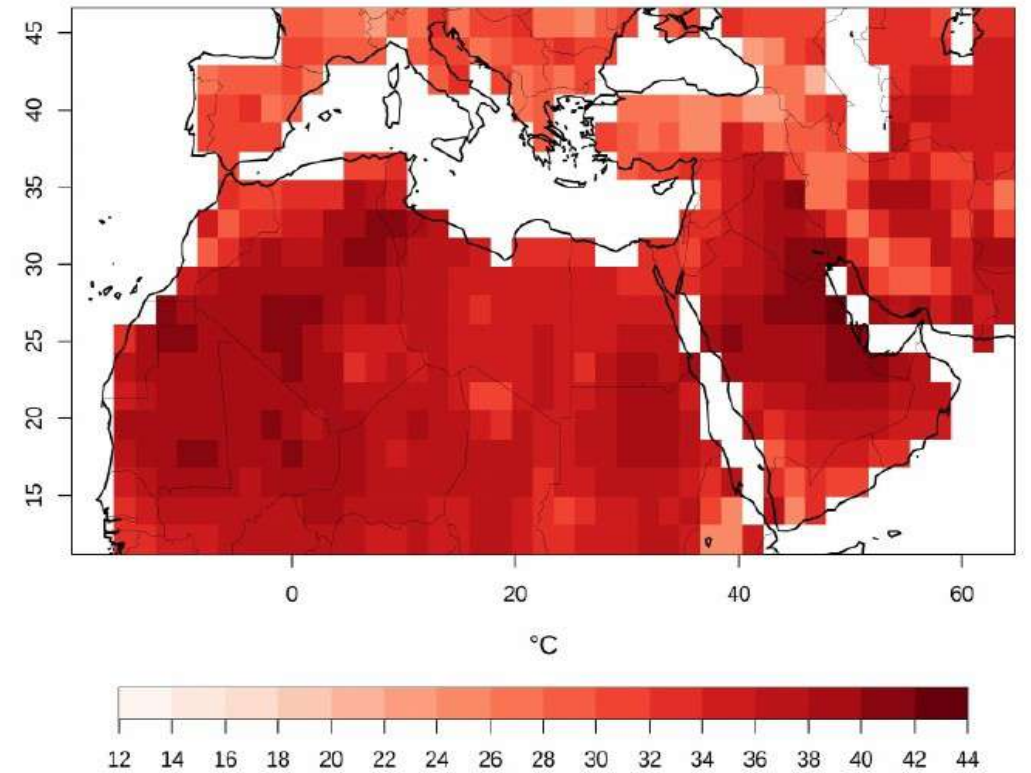
Highest Tmax, Tmin (projected)

CMIP5
mean

CMIP5 maximum TXx

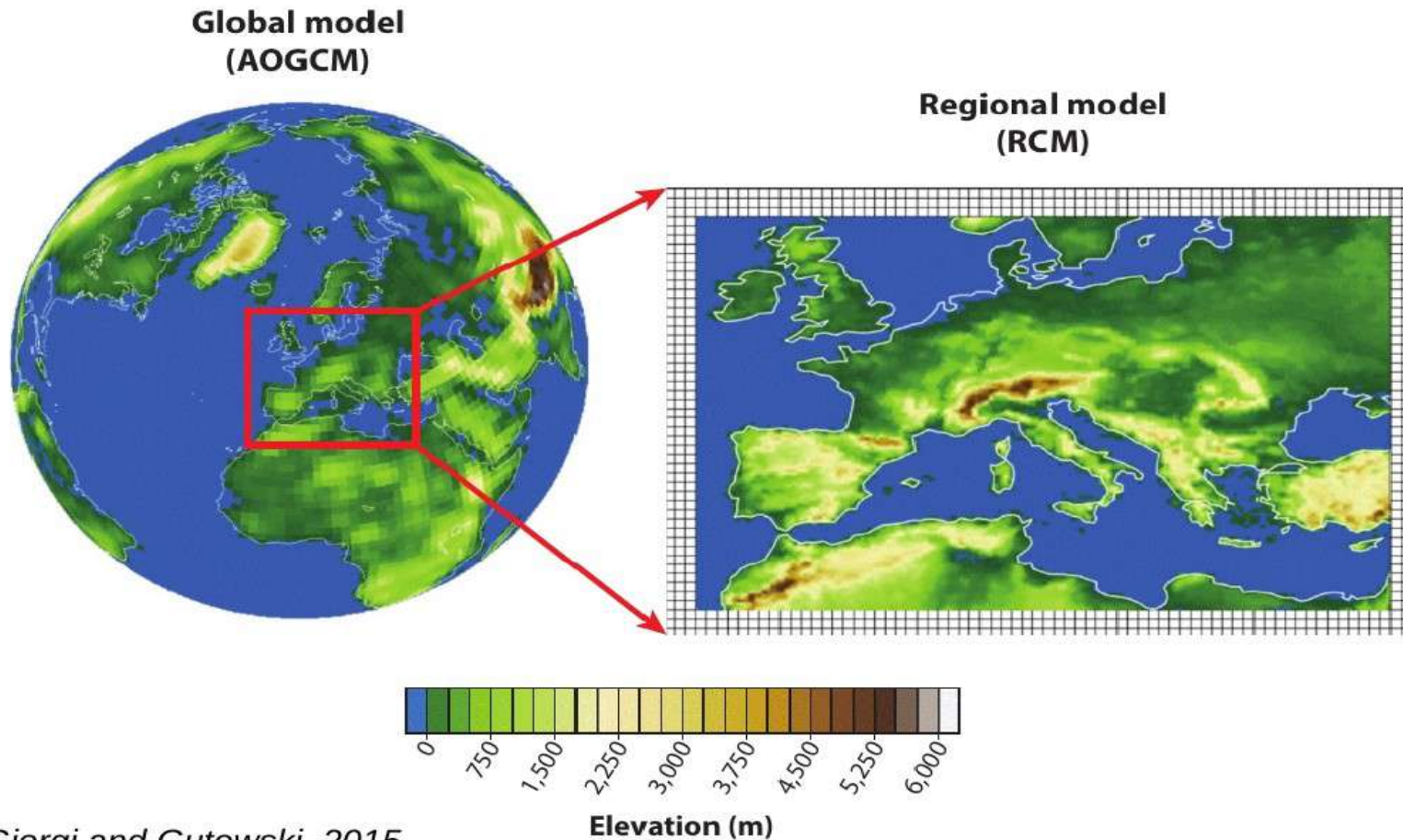


CMIP5 maximum TNx



Ntoumos et al., 2022a

Climate downscaling (RCM)



- Smaller model grid size
- Higher horizontal resolution (10-50 km)
- Small-scale meteorological features
- Finer-scale simulated climate

Giorgi and Gutowski, 2015

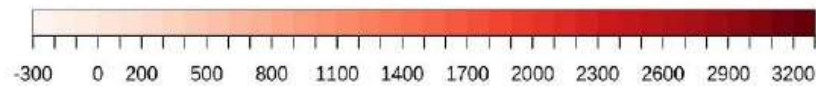


Higher model resolution resolves
with more detail:

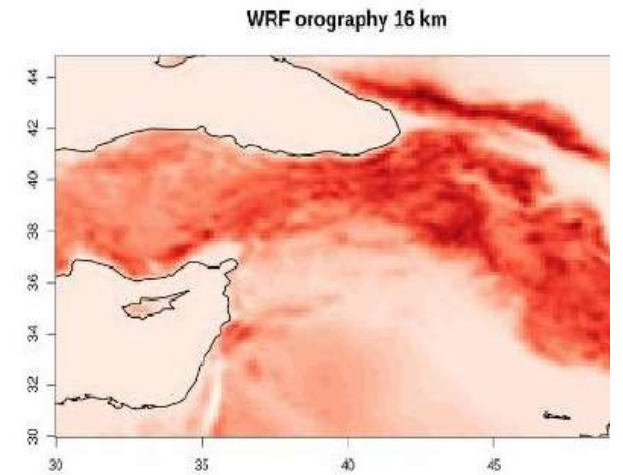
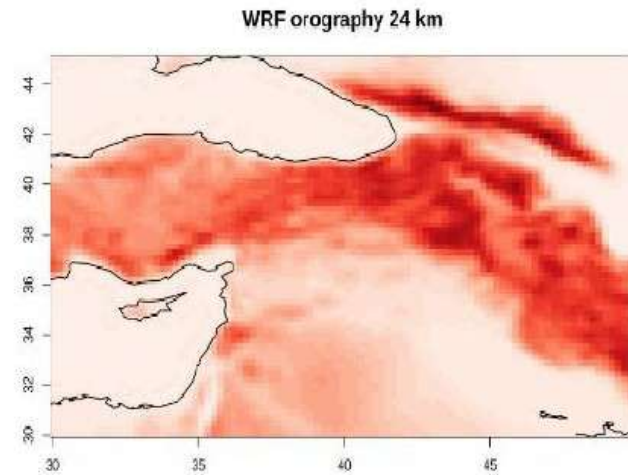
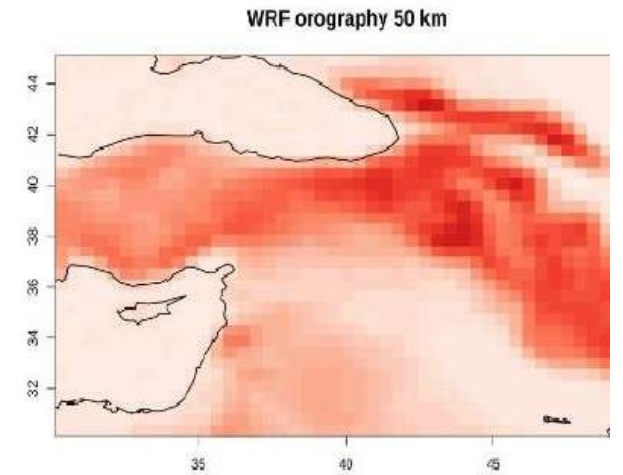
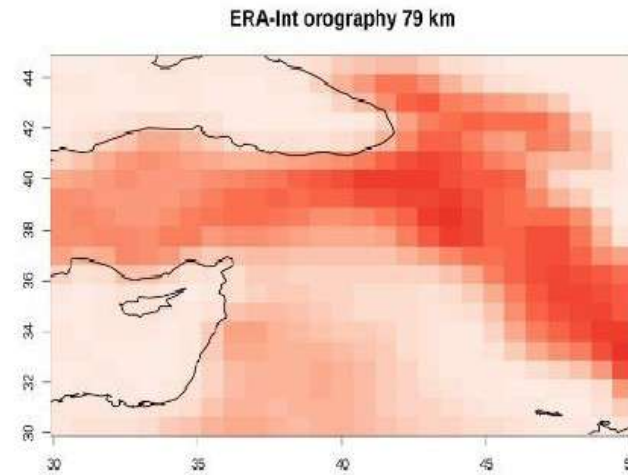
orography

islands

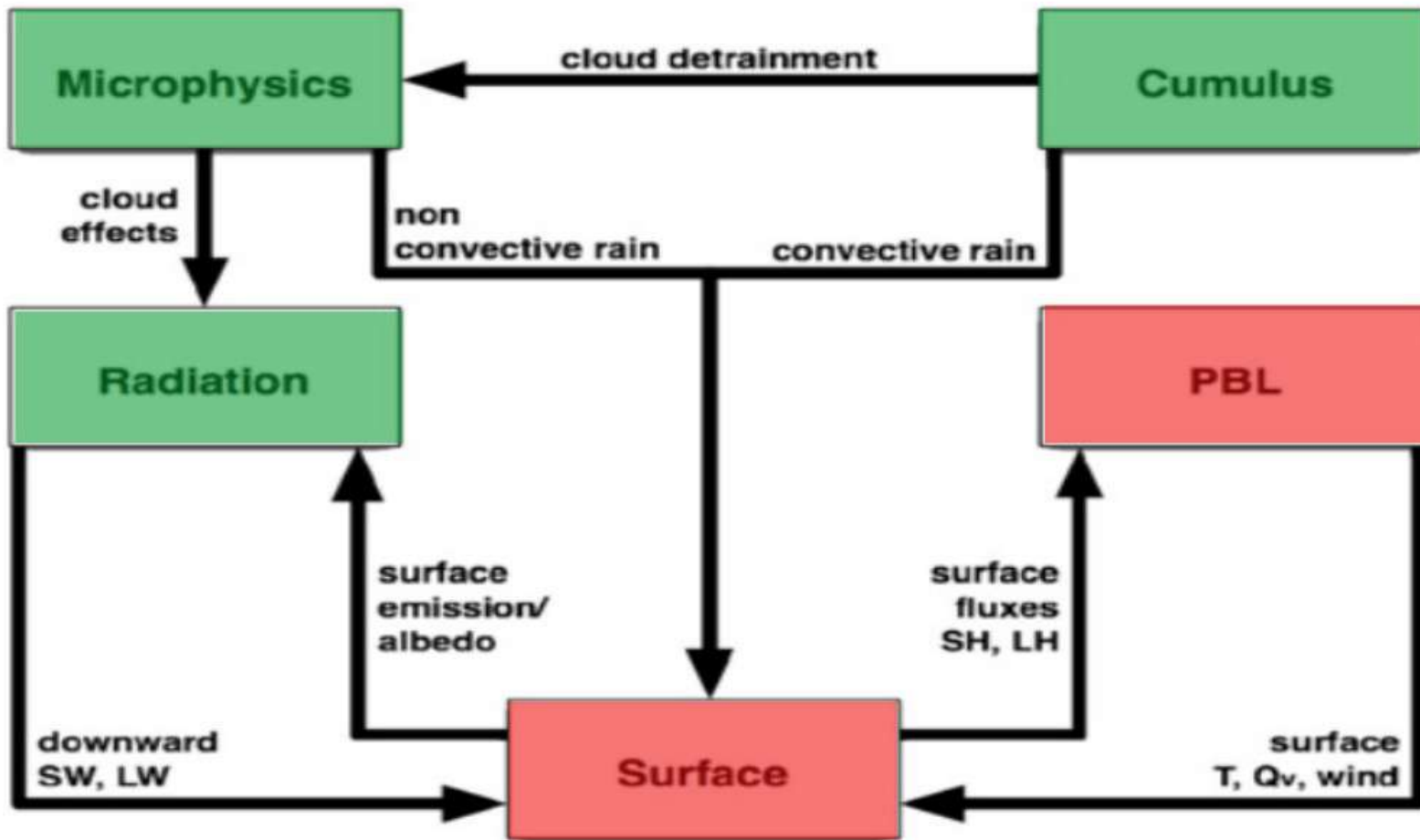
coastlines



1: Orography (in metres) in parts of eastern Mediterranean and Middle East of ERA-Interim 79 km (top left) and WRF 50 km (top right), 24 km (bottom left), and 16 km (bottom right).



WRF (RCM) physics parametrizations



Optimised for MENA-CORDEX domain:

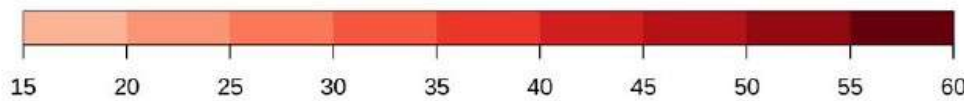
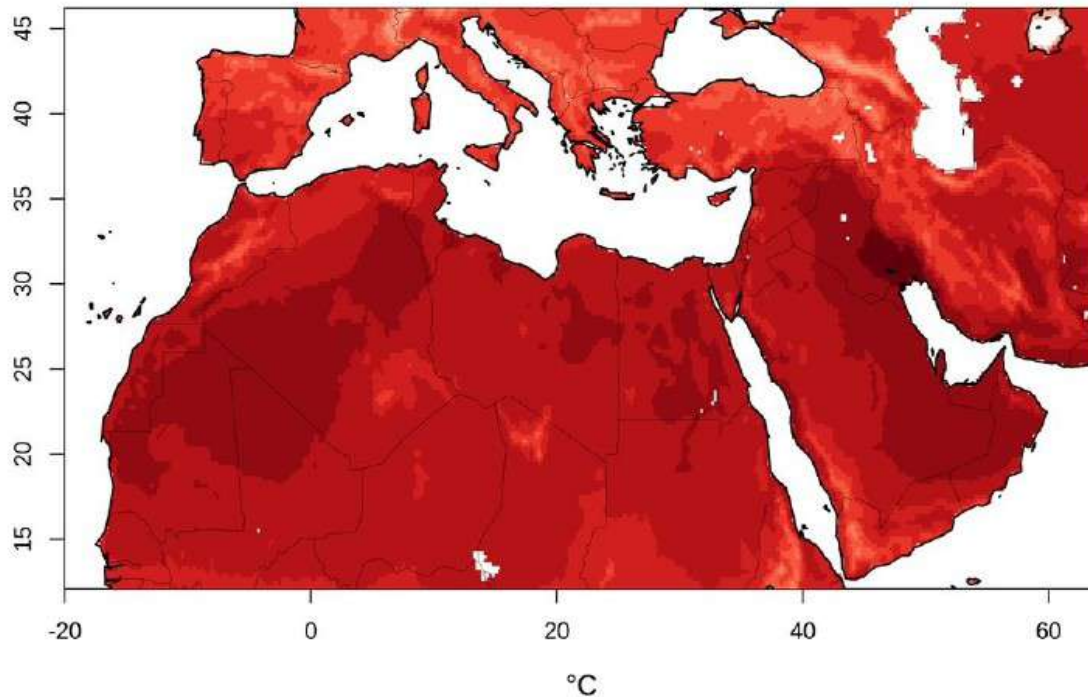
Previous work

CELSIUS work

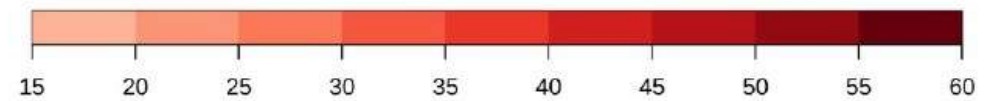
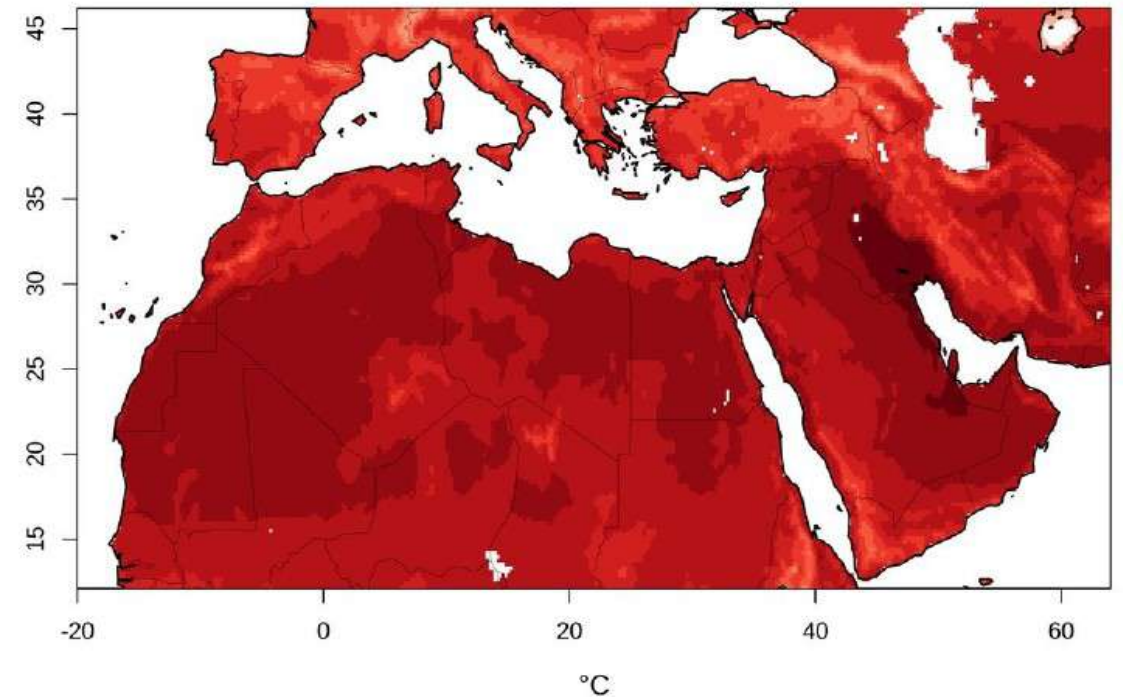
celsius.cyi.ac.cy

WRF projections at 24 km: Warmest Day

TXx 2 degree warming



TXx 3 degree warming



Representation of urban areas in models

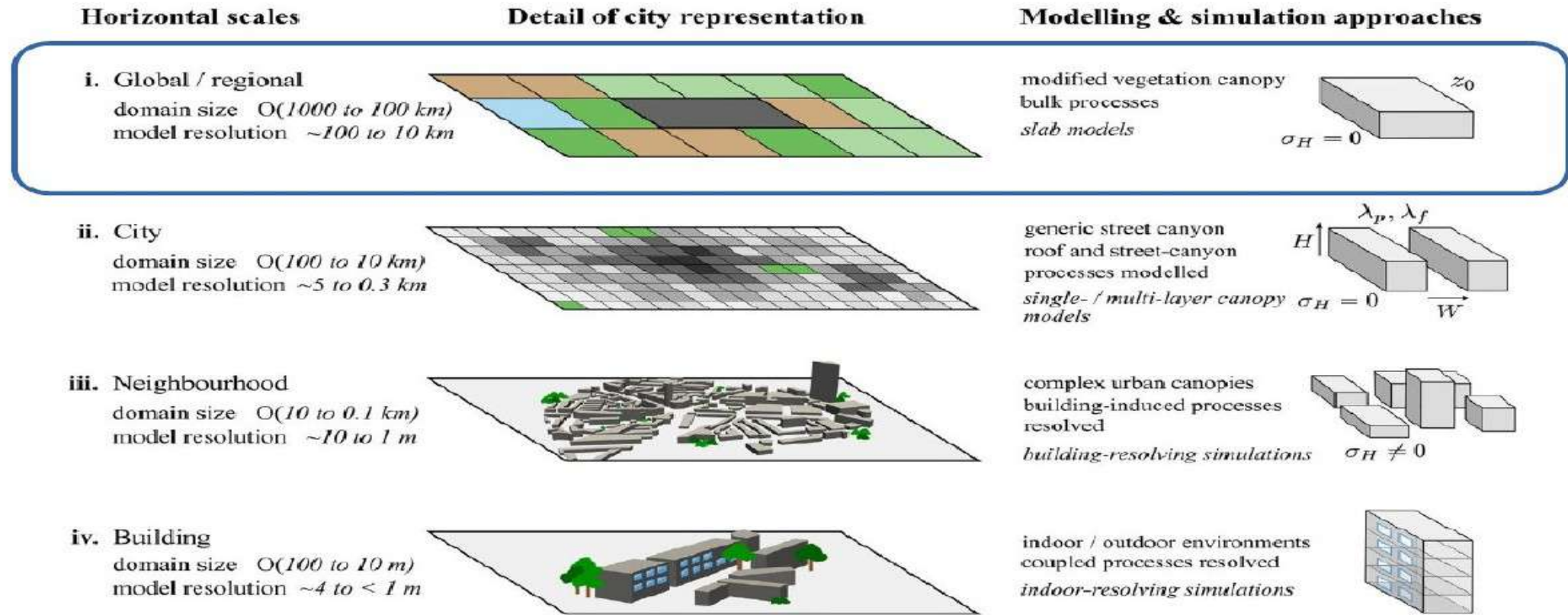


Fig. 1 Representation of urban areas at different spatial scales (domain sizes from $\mathcal{O}(1000 \text{ km})$ to $\mathcal{O}(10 \text{ m})$) and model resolutions together with prevailing modelling approaches, with H , mean building height;

σ_H , standard deviation of building heights; W , street-canyon width; z_0 , roughness length for momentum; λ_p , plan-area fraction; λ_f , frontal-area fraction

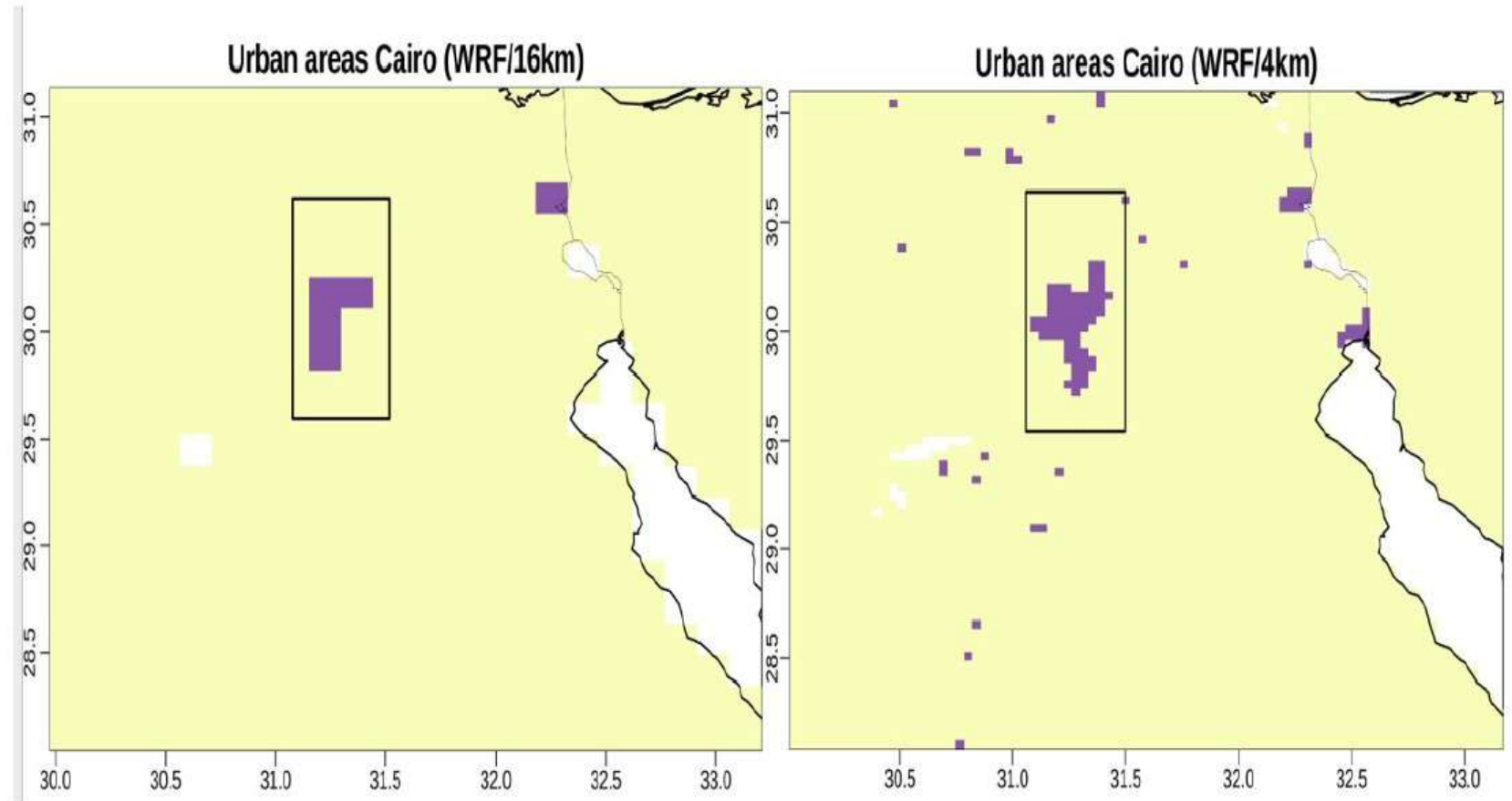
Hertwig et al., 2021

WRF hindcast at 16 and 4 km: urban representation

WRF bulk urban scheme

Urban land type

4 km finer description of urban area



Constantinidou et al., 2023

WRF hindcast at 16 and 4 km: urban heat island

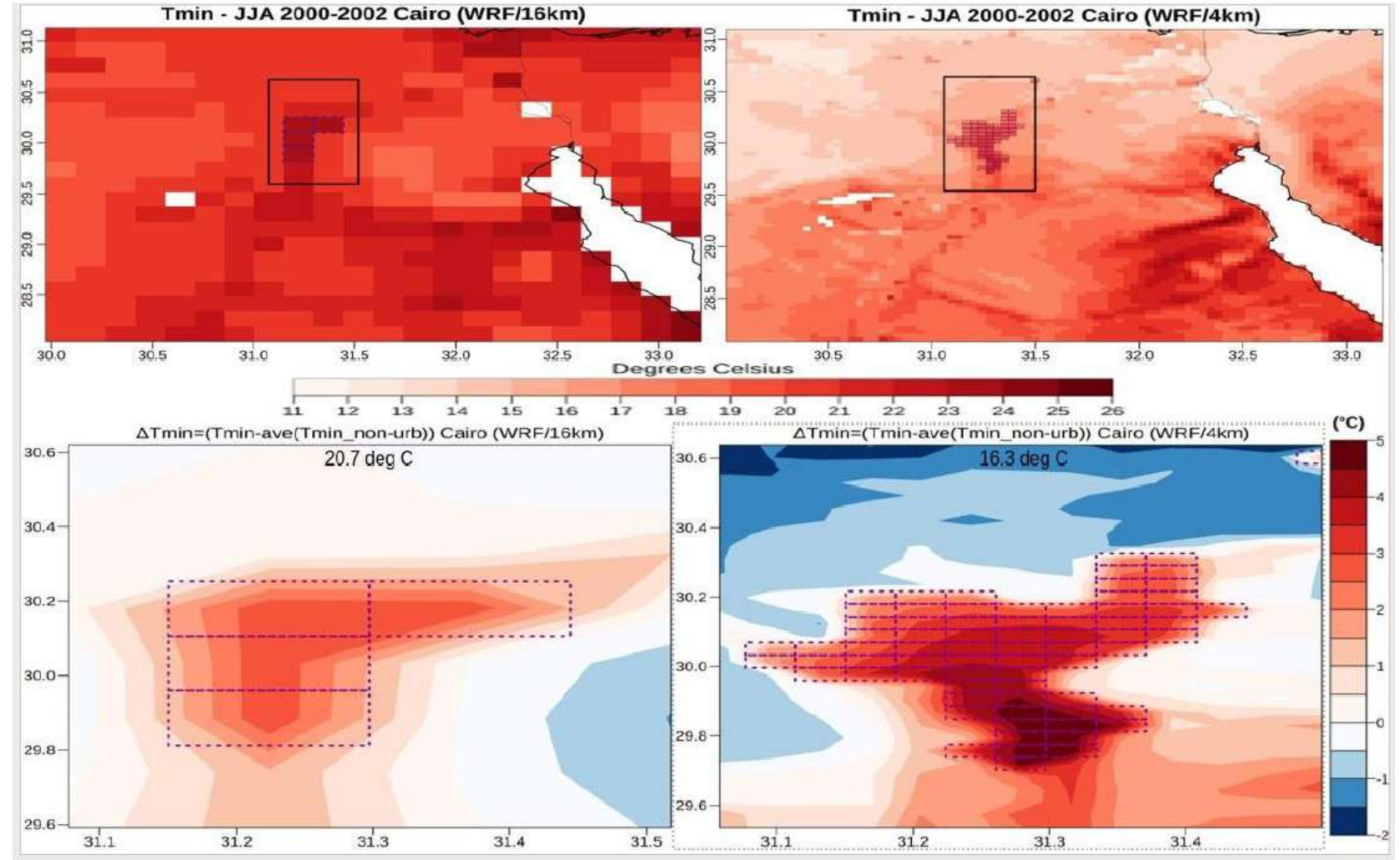
Tmin summer

Urban signature

Urban heat island:

4 km: + 3-4 °C

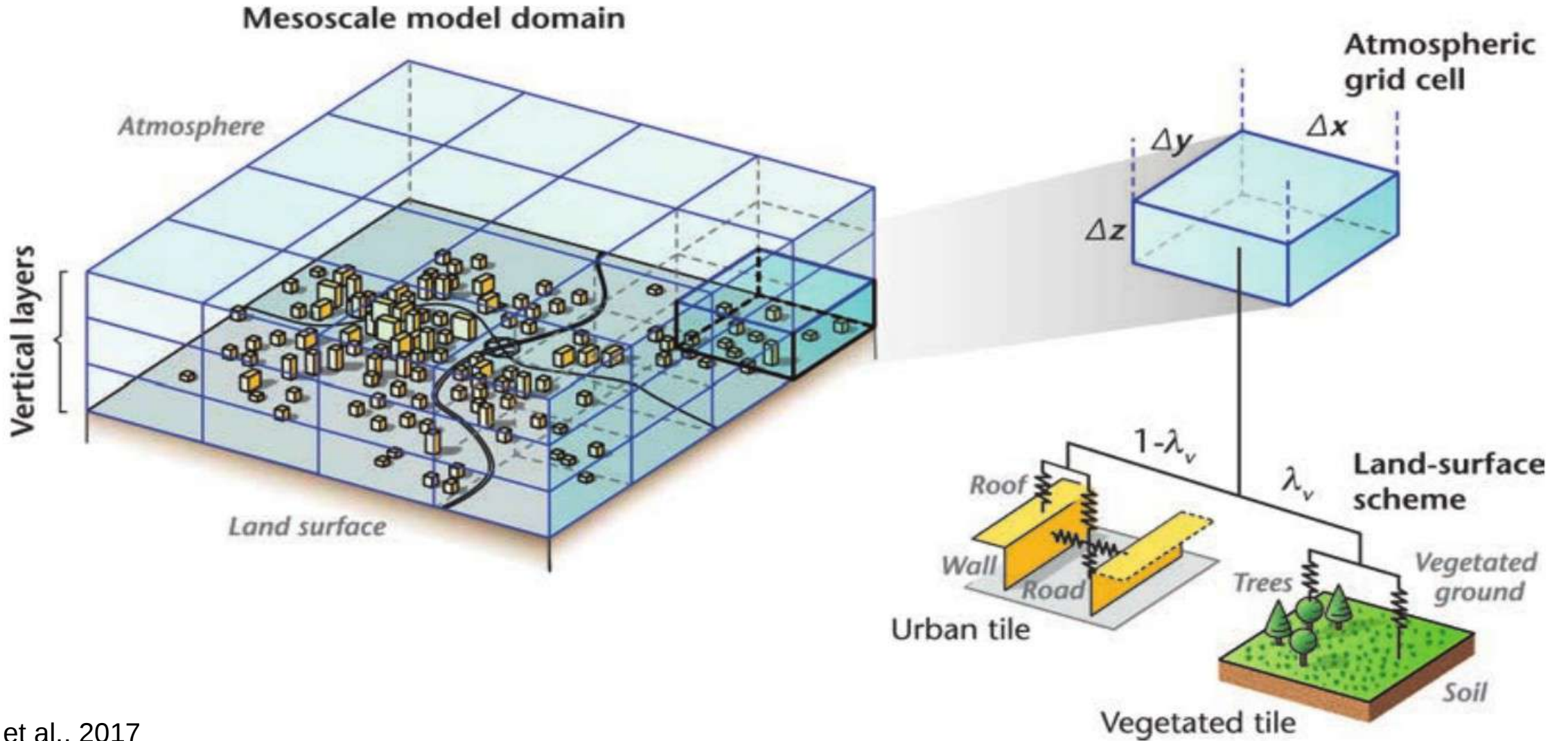
16 km: + 1-3 °C



Constantinidou et al., 2023



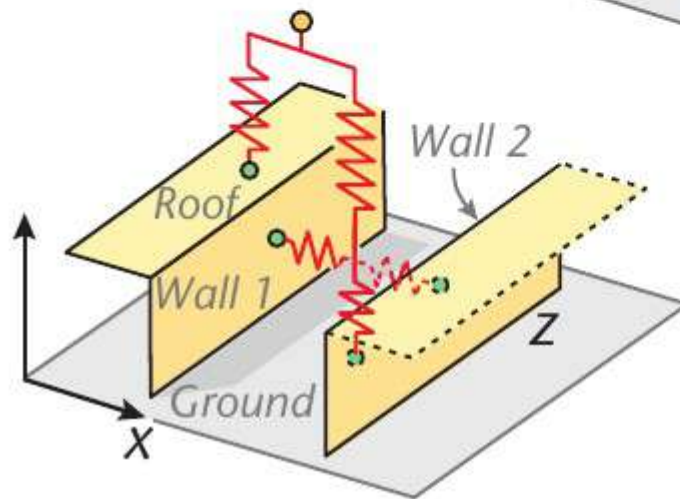
Coupled Urban Climate Models



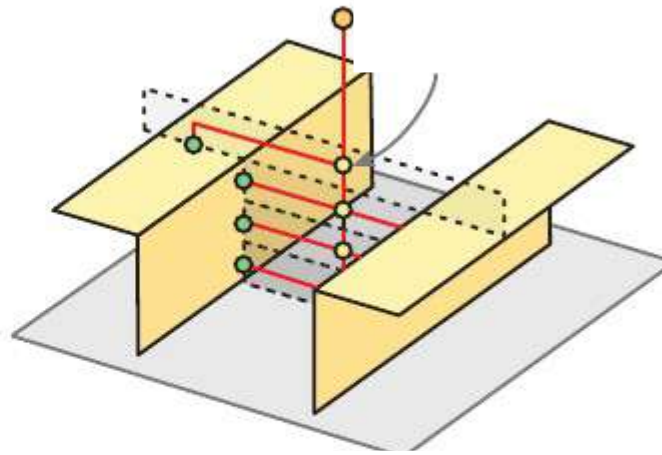
Oke et al., 2017

Urban Canopy Models

Single layer



Multi-layer

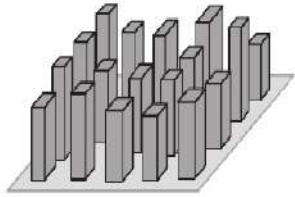


Oke et al., 2017



Local Climate Zones

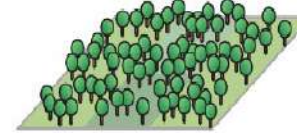
LCZ 1
Compact
highrise



LCZ 6
Open
lowrise



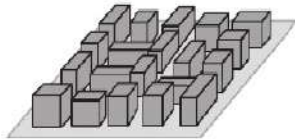
LCZ A
Dense trees



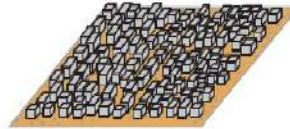
LCZ F
Bare soil
or sand



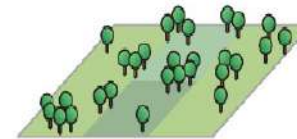
LCZ 2
Compact
midrise



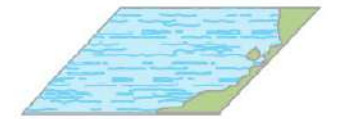
LCZ 7
Lightweight
lowrise



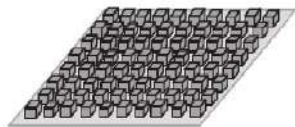
LCZ B
Scattered
trees



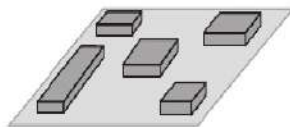
LCZ G
Water



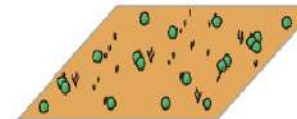
LCZ 3
Compact
lowrise



LCZ 8
Large
lowrise



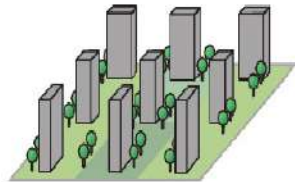
LCZ C
Bush, scrub



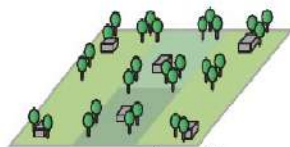
Variable land cover properties:

b bare trees (i.e., deciduous, leafless)
increased sky view factor, reduced albedo

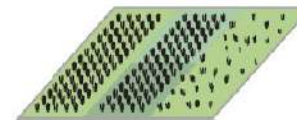
LCZ 4
Open
highrise



LCZ 9
Sparsely
built



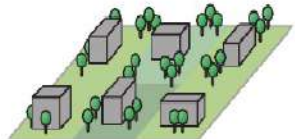
LCZ D
Low plants



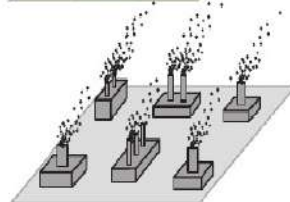
s snow cover
low admittance, high albedo

d dry ground (e.g., parched soil)
low thermal admittance, small latent
heat flux, increased albedo

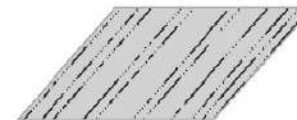
LCZ 5
Open
midrise



LCZ 10
Heavy
industry



LCZ E
Bare rock
or paved

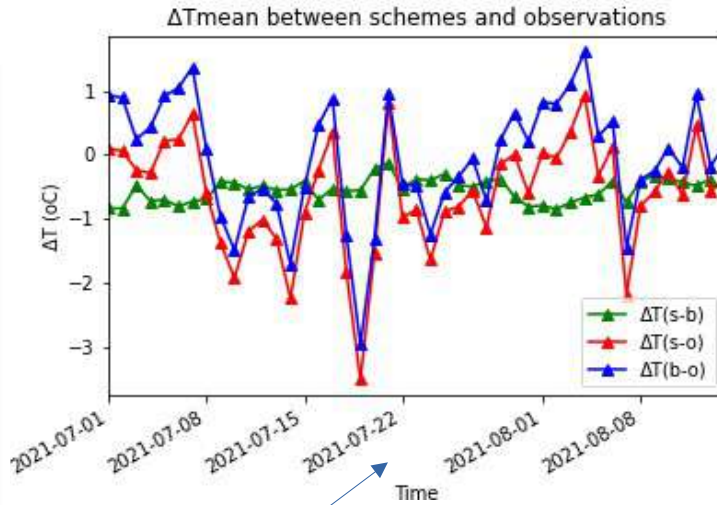
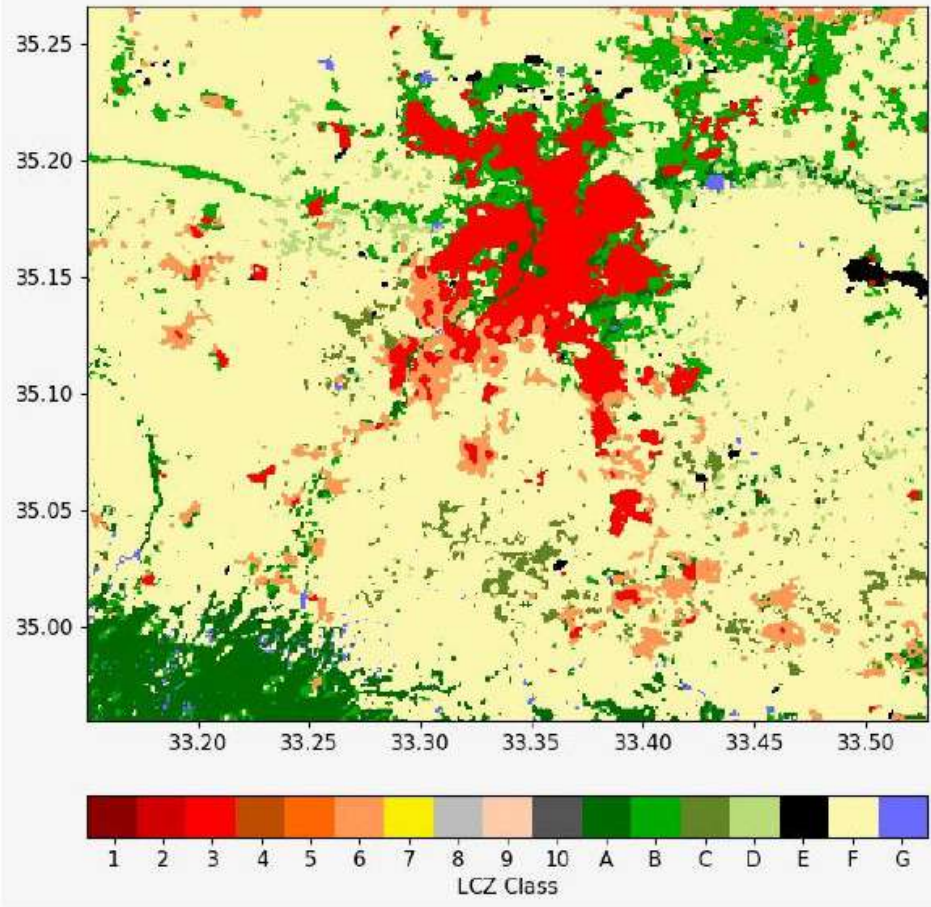


w wet ground (e.g., waterlogged soil)
high thermal admittance, large latent
heat flux, reduced albedo

Oke et al., 2017



WRF/UCM application for Nicosia



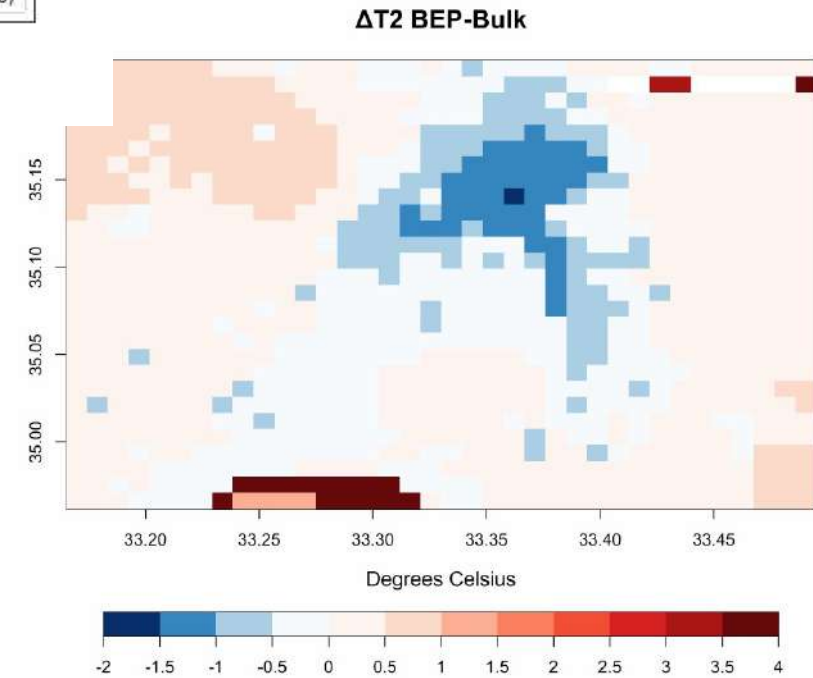
Single layer

Koutroumanou et al., 2023

Multi-layer

Vurro et al., 2023

Test runs
(preliminary results)



Thank you for your attention!

p.hadjinicolaou@cyi.ac.cy

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<https://clicche.org>

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