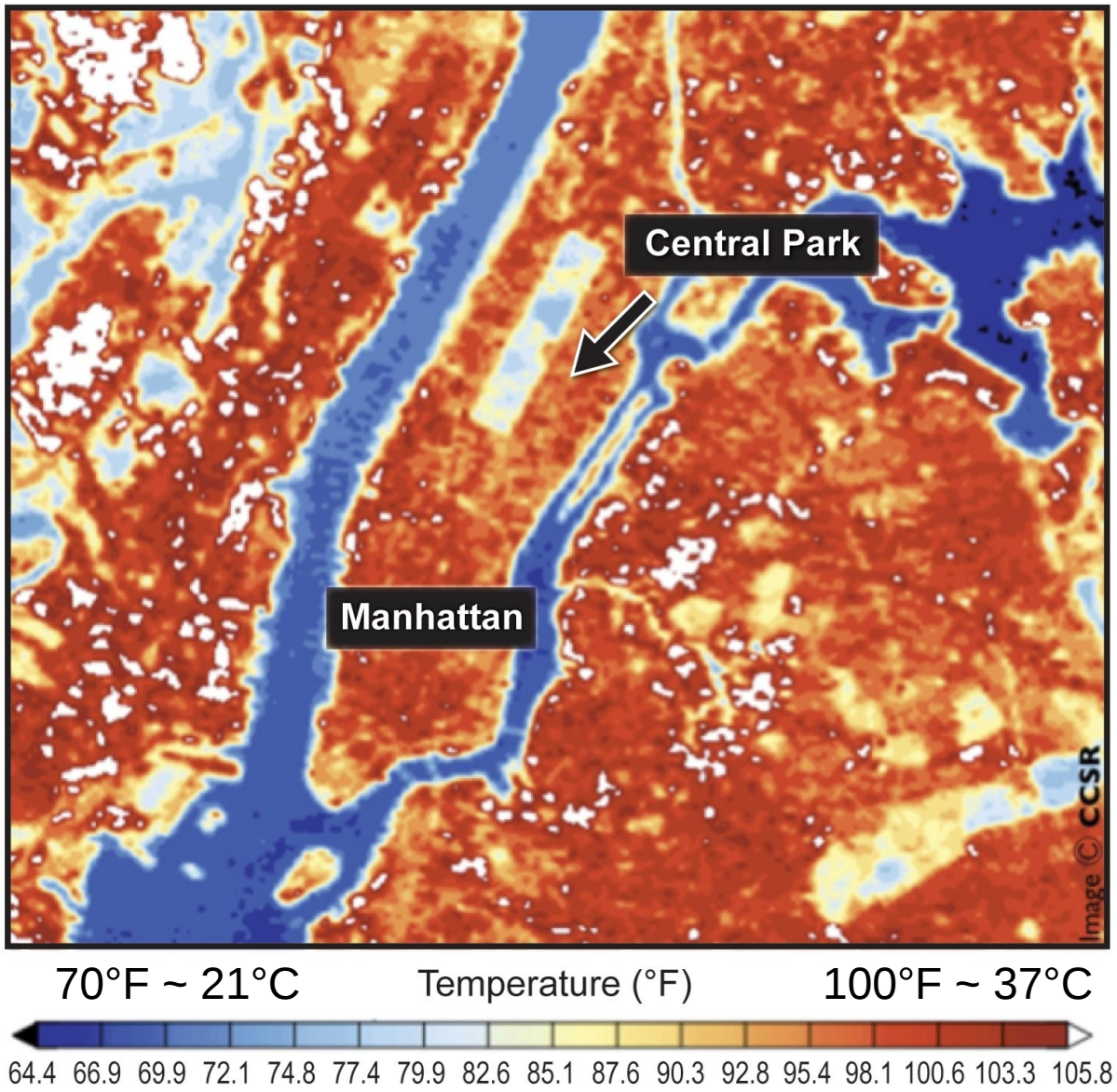
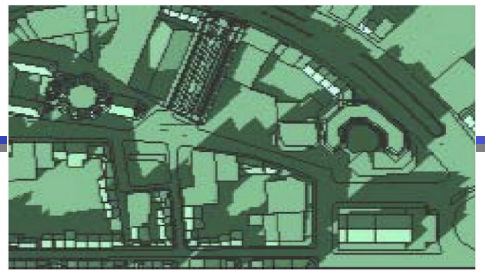
CLIM0026: Urban Heat Island (UHI)

0. Introduction



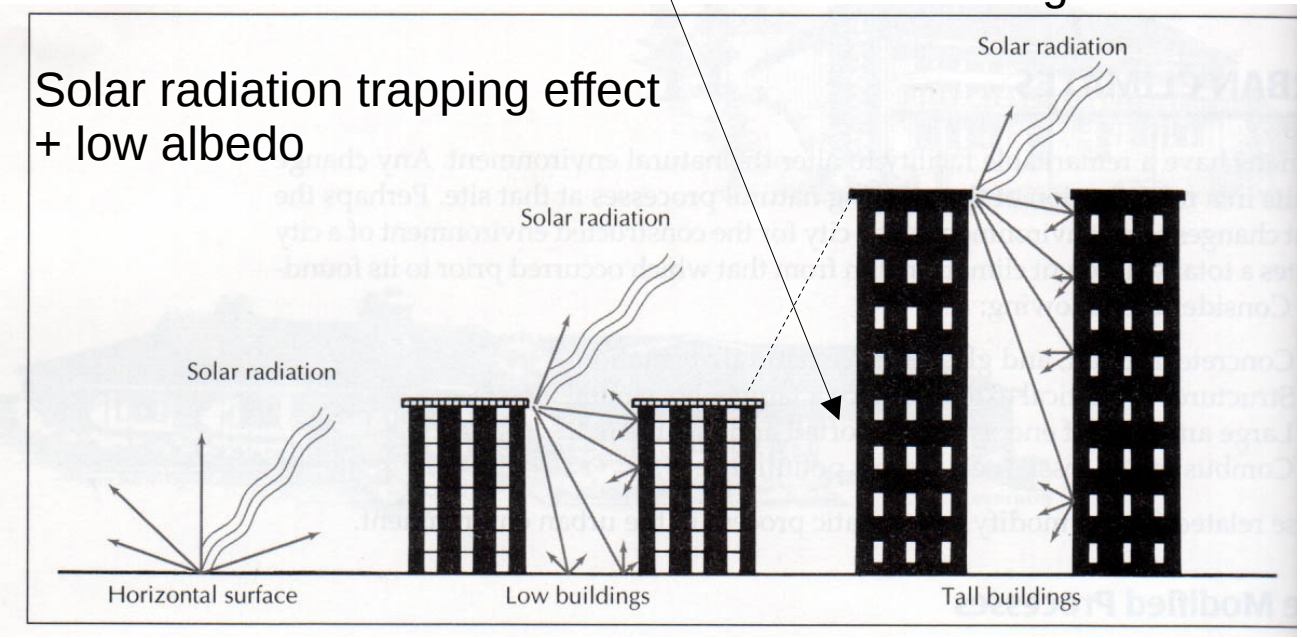
An **Urban Heat Island (UHI)** is an urban area that is significantly warmer than its surrounding rural areas due to human activities

1. Energy flux

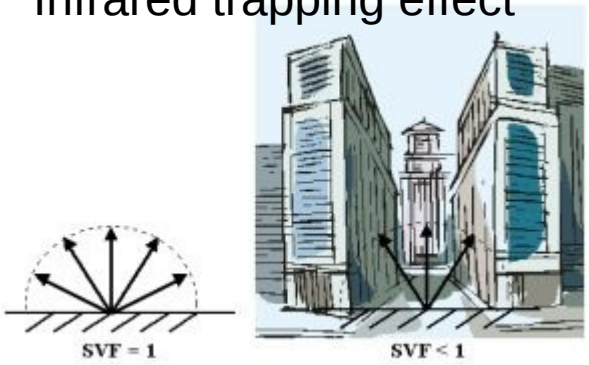


cast shadows behind the building

Solar radiation trapping effect + low albedo

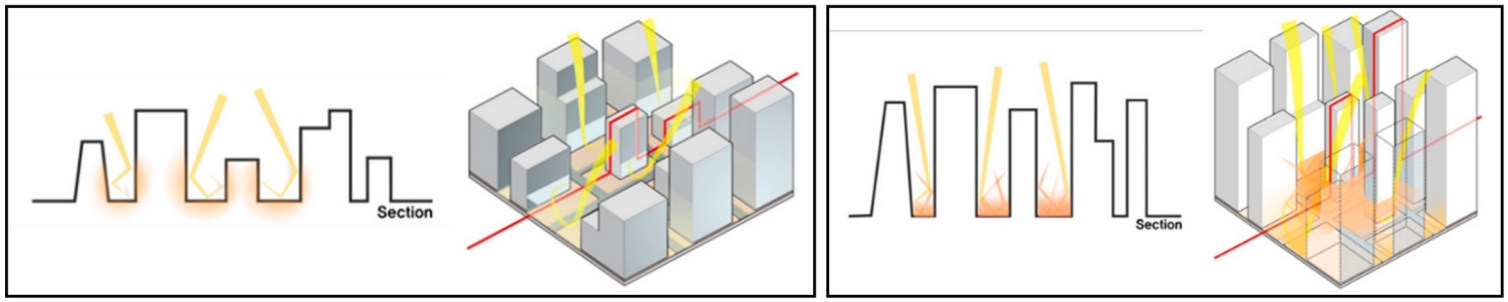


Infrared trapping effect



Longwave (LWD)

Shortwave (SWD)

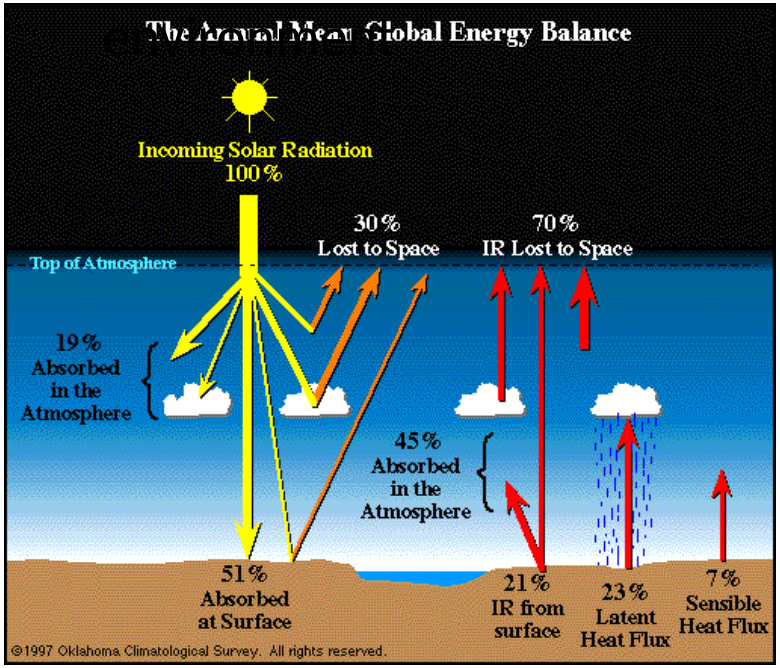


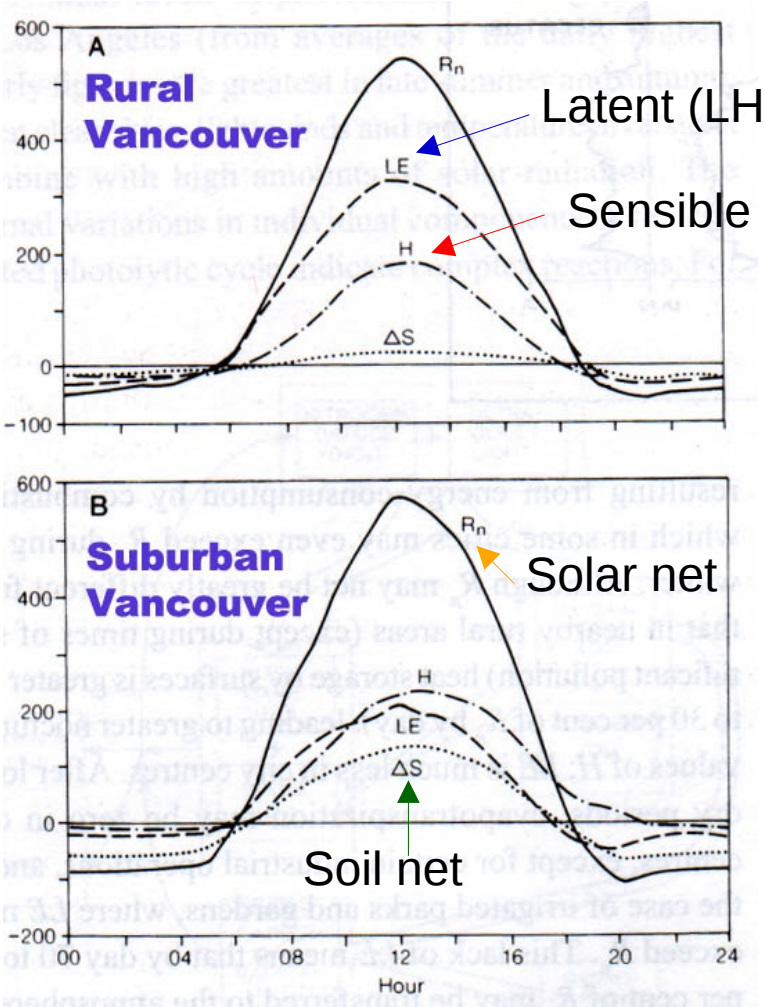
(a) (b)

urban canyon albedo/effect but also cast shadows

1. Energy flux

- Latent heat flux (LHF) typically much smaller in a city
- Sensible heat flux (SHF) thus increases
  - Also increases due to increased turbulence in urban





Latent (LHF or LE)

Sensible (SHF or H)

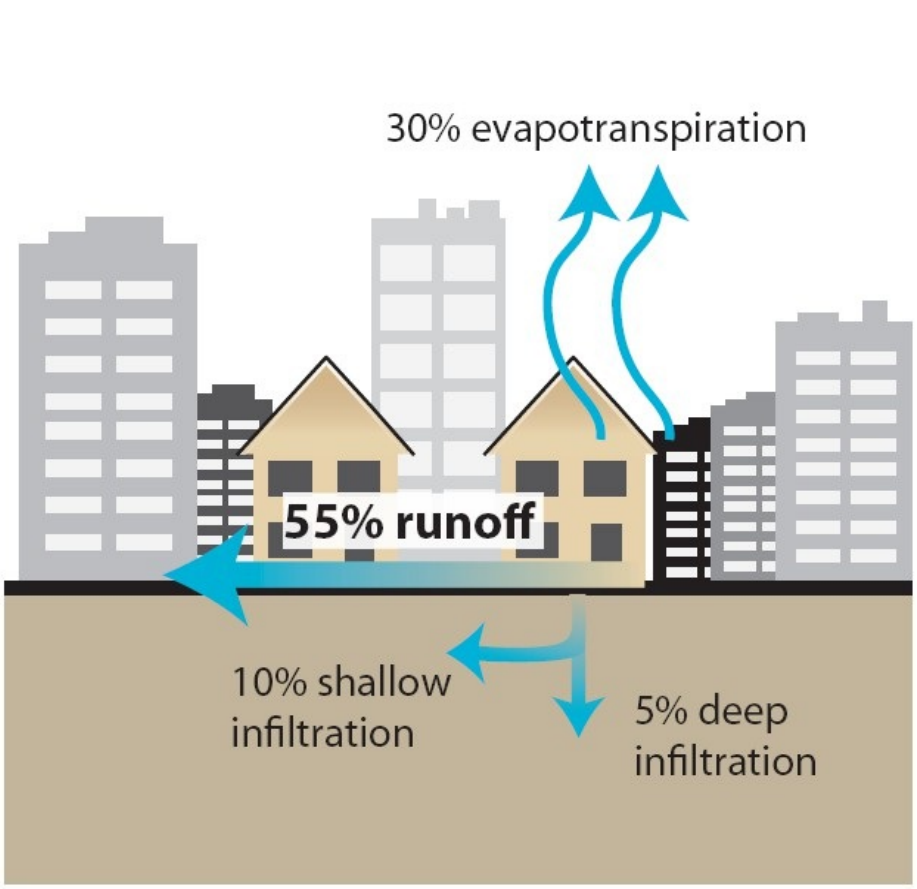
Solar net

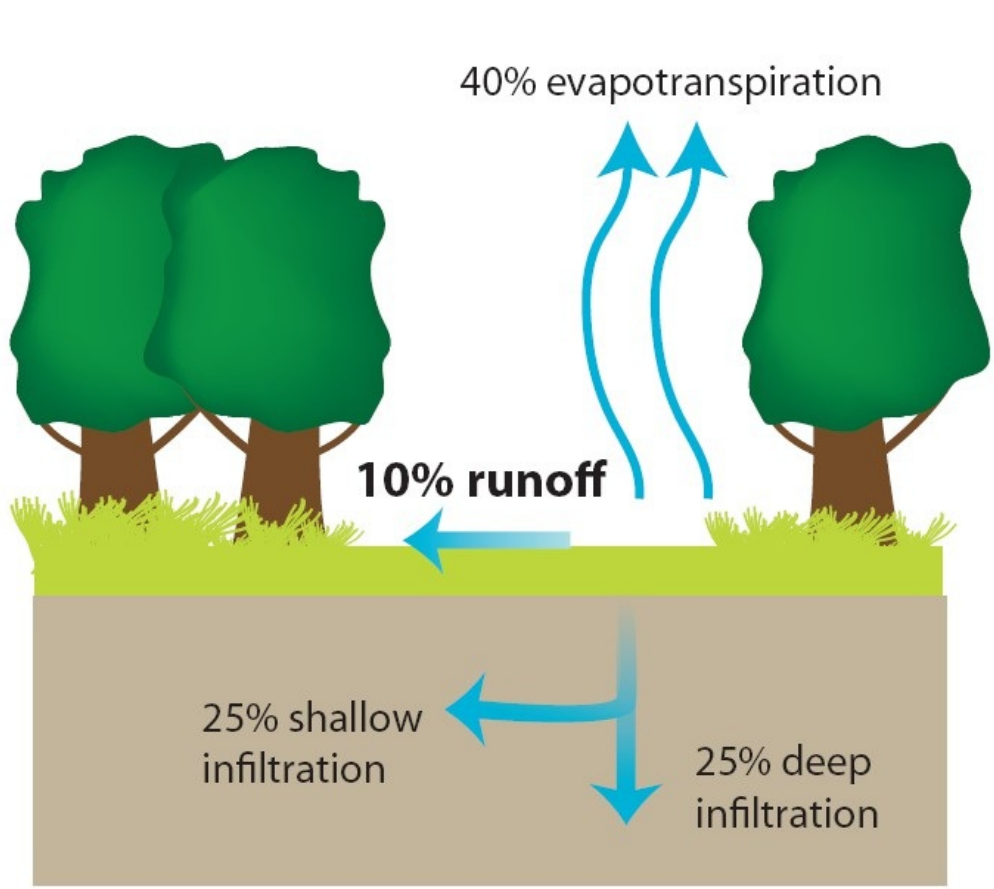
Soil net

SHF ~ WS * Δ T

LHF ~ WS * Δ Q

1. Energy flux





Modified from the Federal Interagency Stream Restoration Workin

Less water to cool the city during an heat wave ...

1. Energy flux

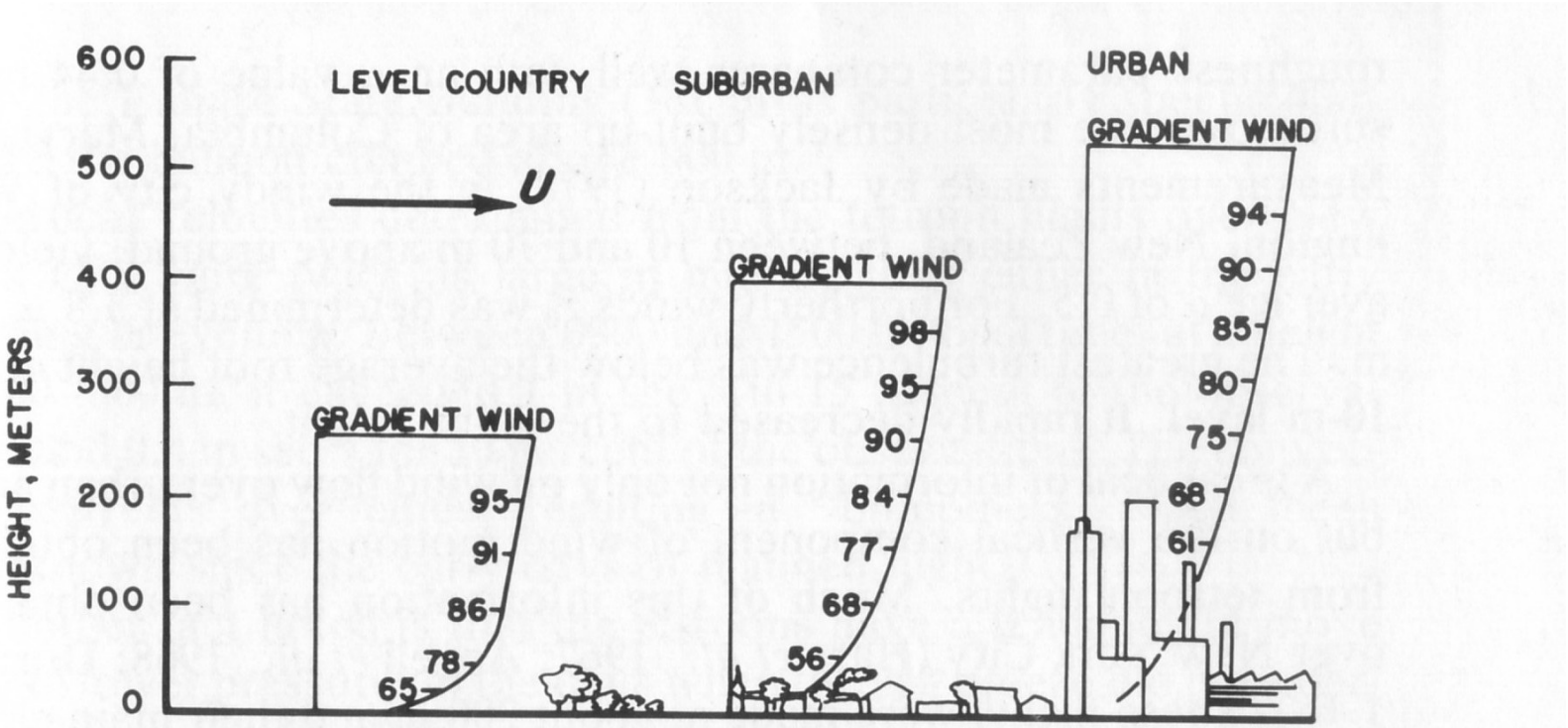


Fig. 6.7 Vertical wind speeds, in percent of the gradient wind at various heights over terrain of different roughness (after Davenport, 1965).

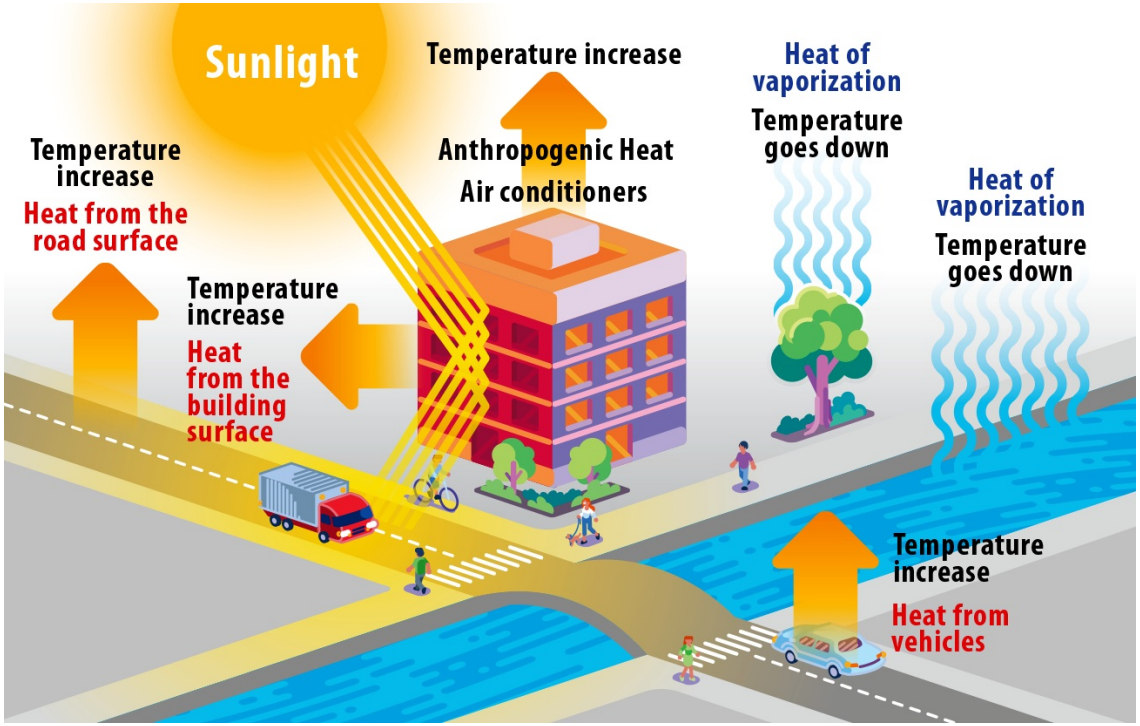
- Local circulation develops
- Wind decreases overall
- Wind tunnels + Rugosity>>

Impacts on SHF and LHF

1. Energy flux

Anthropogenic heat (from combustion processes)

- In wintertime: thermal rejection from heaters
  - 2 x energy received from sun
- In summertime: thermal rejection from coolers
  - 20% energy received from sun
- All year, thermal rejections of
  - Vehicle
  - Industry
  - Commerce
  - …

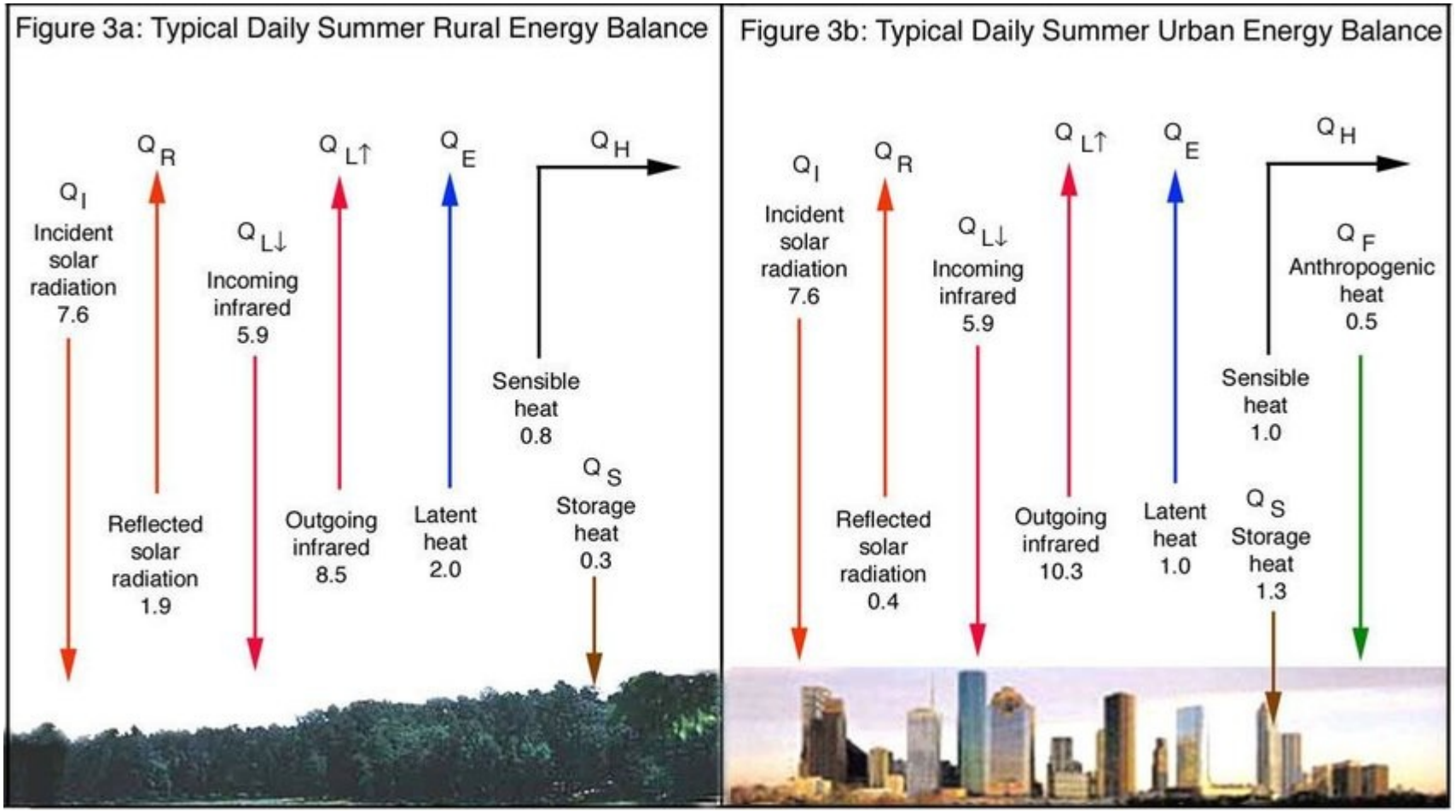


1. Energy flux

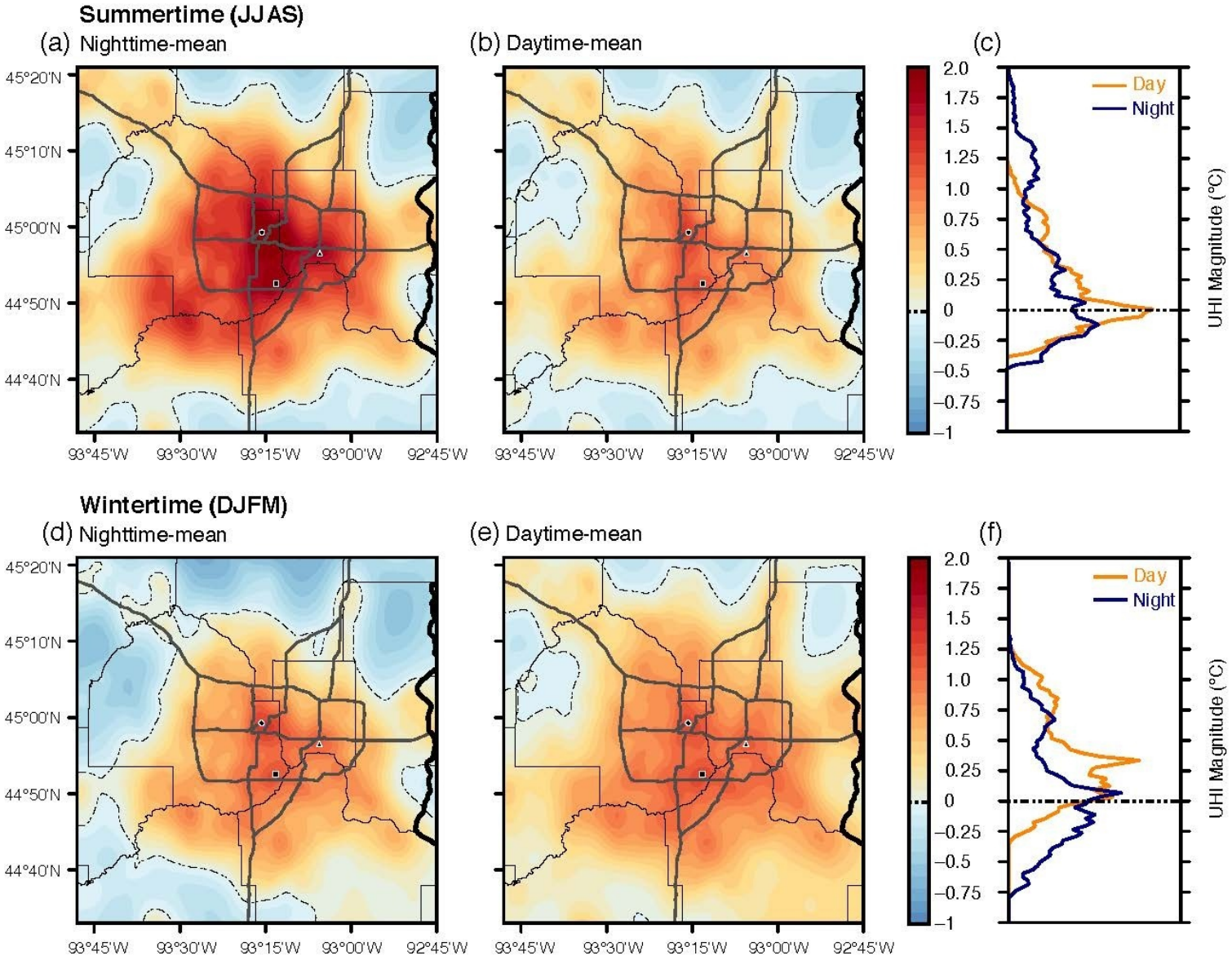
- **Albedo** (–; net solar radition ++)
- **Conductivity** of materials (G ++)
- **Impermeability** of materials (LHF --)
- **Sensible heat flux** (SHF ++)
- **Rugosity** (++; turbulence/mixing ++)
- **Anthropogenic heat flux** (AHF ++)

Urban Heat Island (UHI)

1. Energy flux



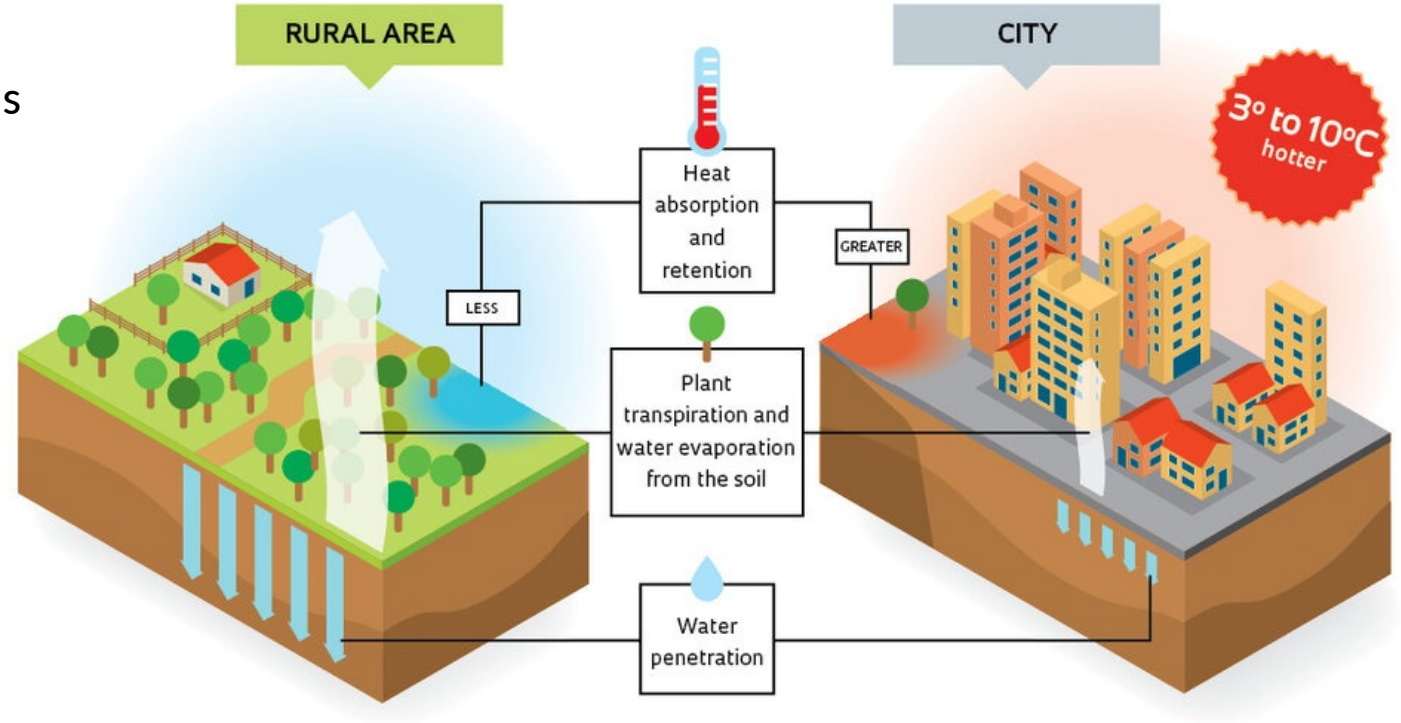
2. Temperature



2. Temperature

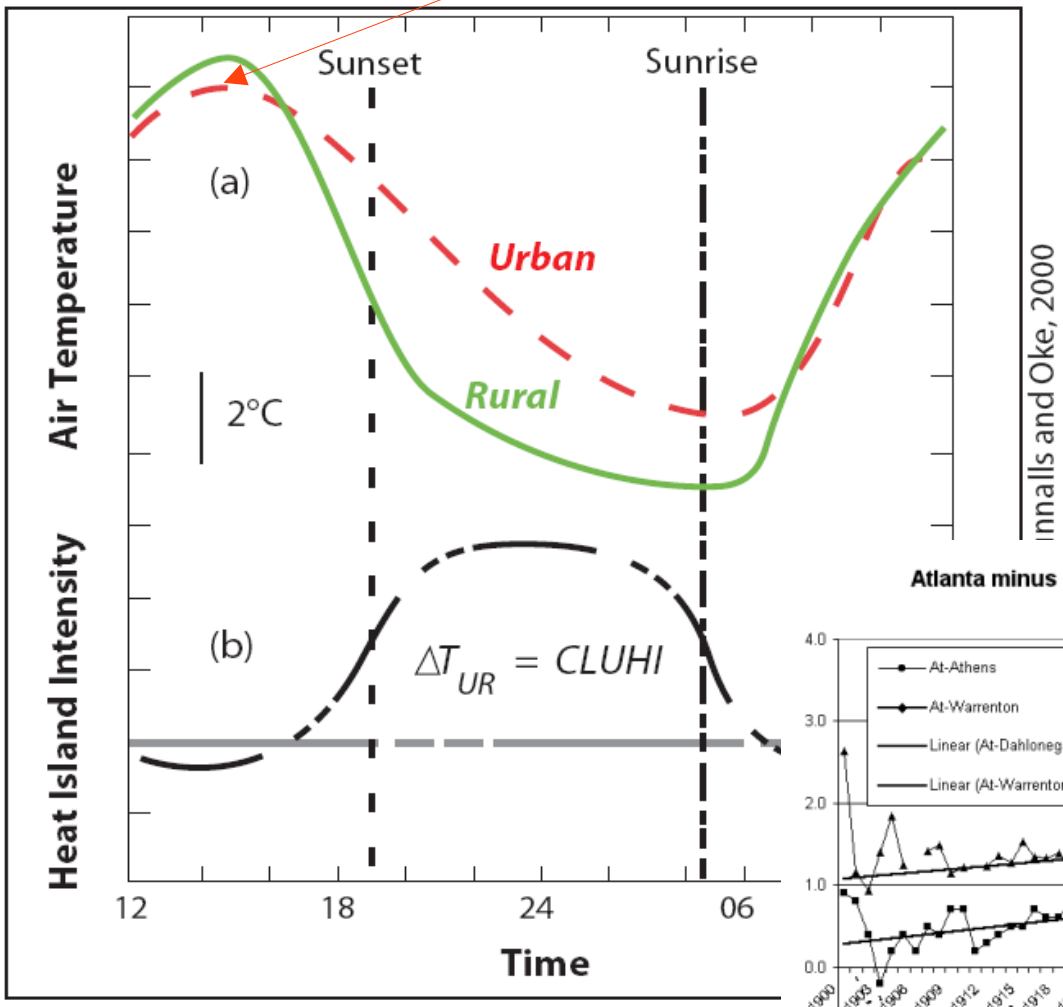
- Annual scale :
  - Temperature increase of ~+1°C warmer (depend on the city)
- During heatwave events :
  - Temperature increase of more than 10°C

- Most significant heat island
  - At night
  - Clear sky conditions
  - Calm wind
  - Winter
  - During the week



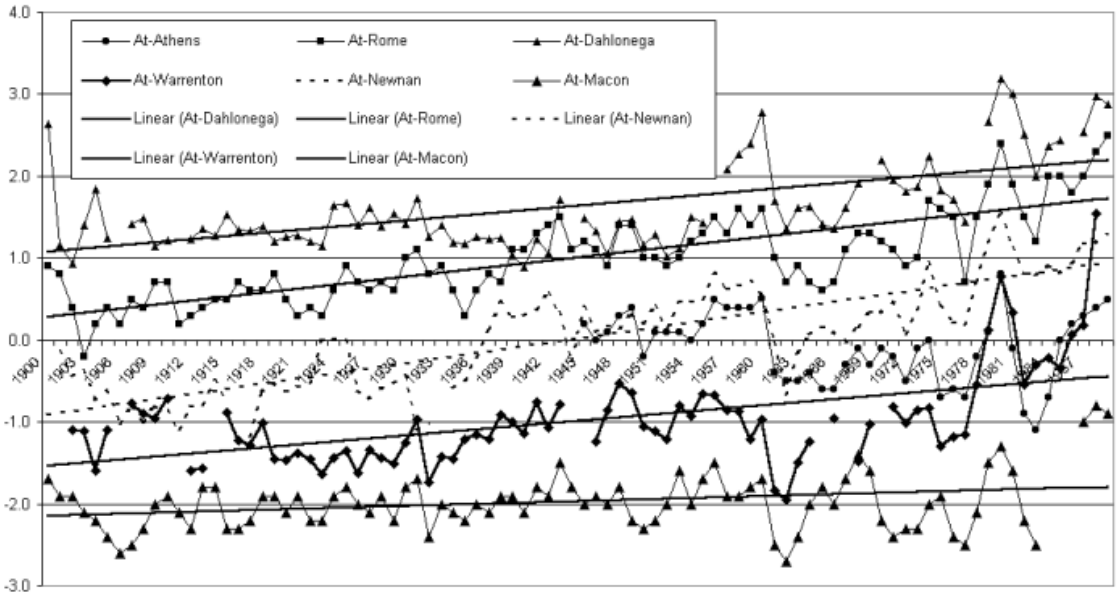
2. Temperature

Decrease of solar radiation due to pollution



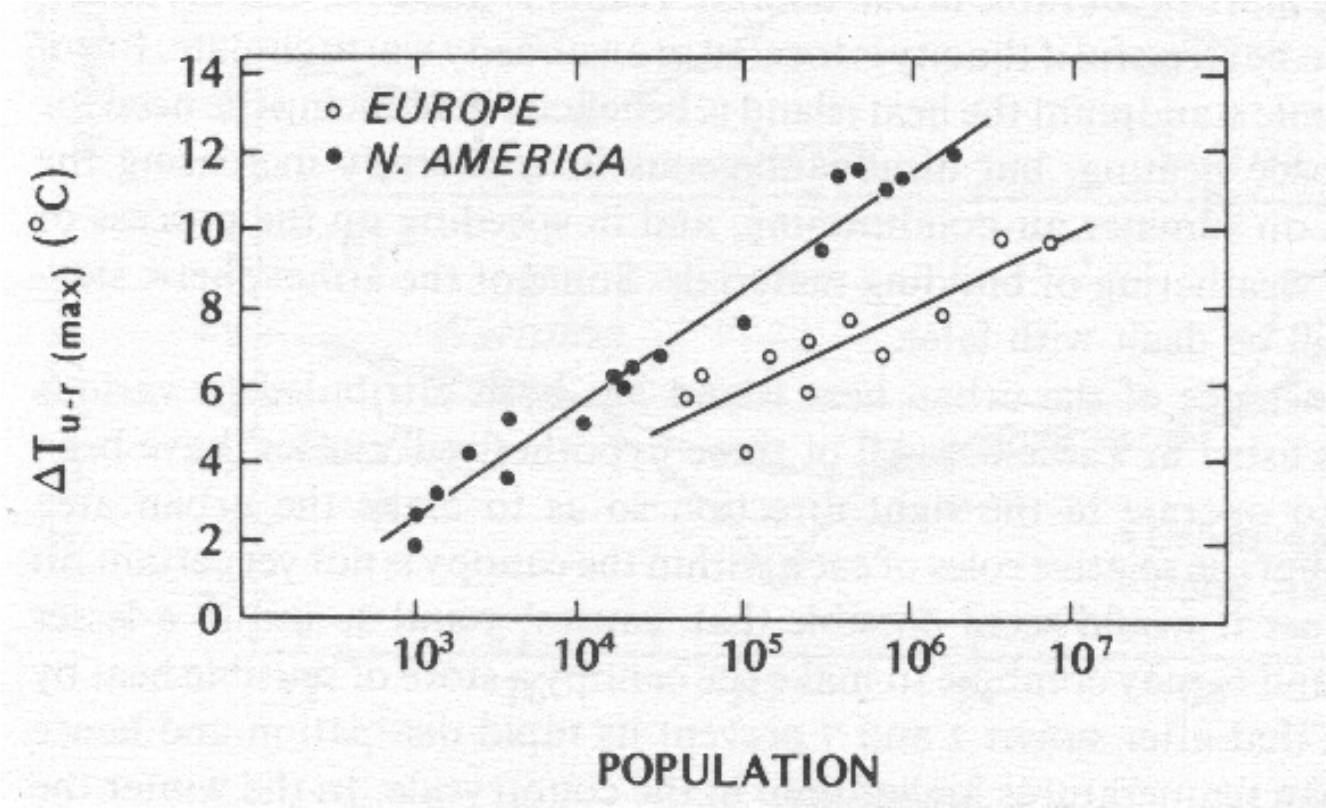
innalls and Oke, 2000

Atlanta minus six neighbours, demonstrates heat island contamination in Atlanta, Macon and Athens.



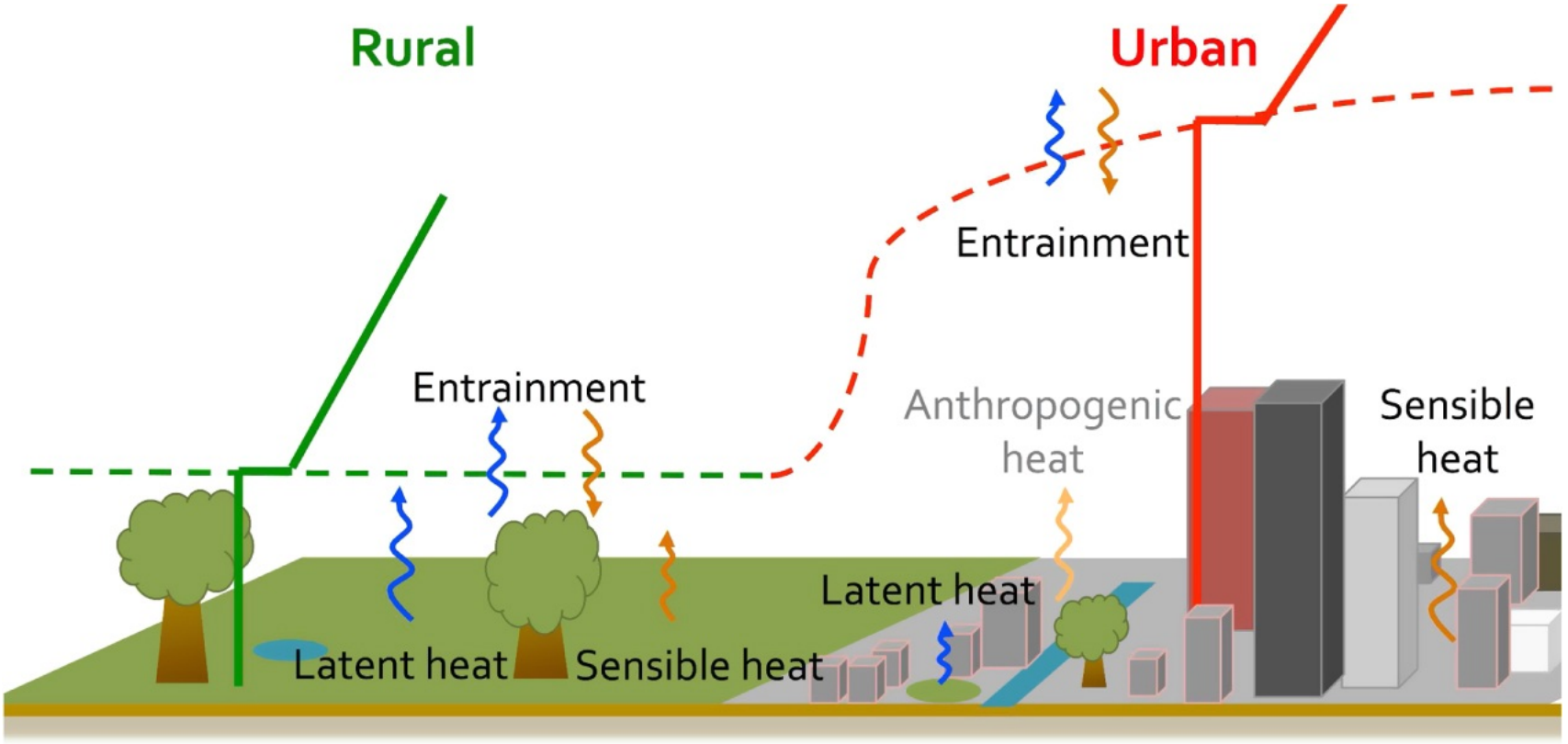
2. Temperature

Heat islands noted in cities of only 1,000 people



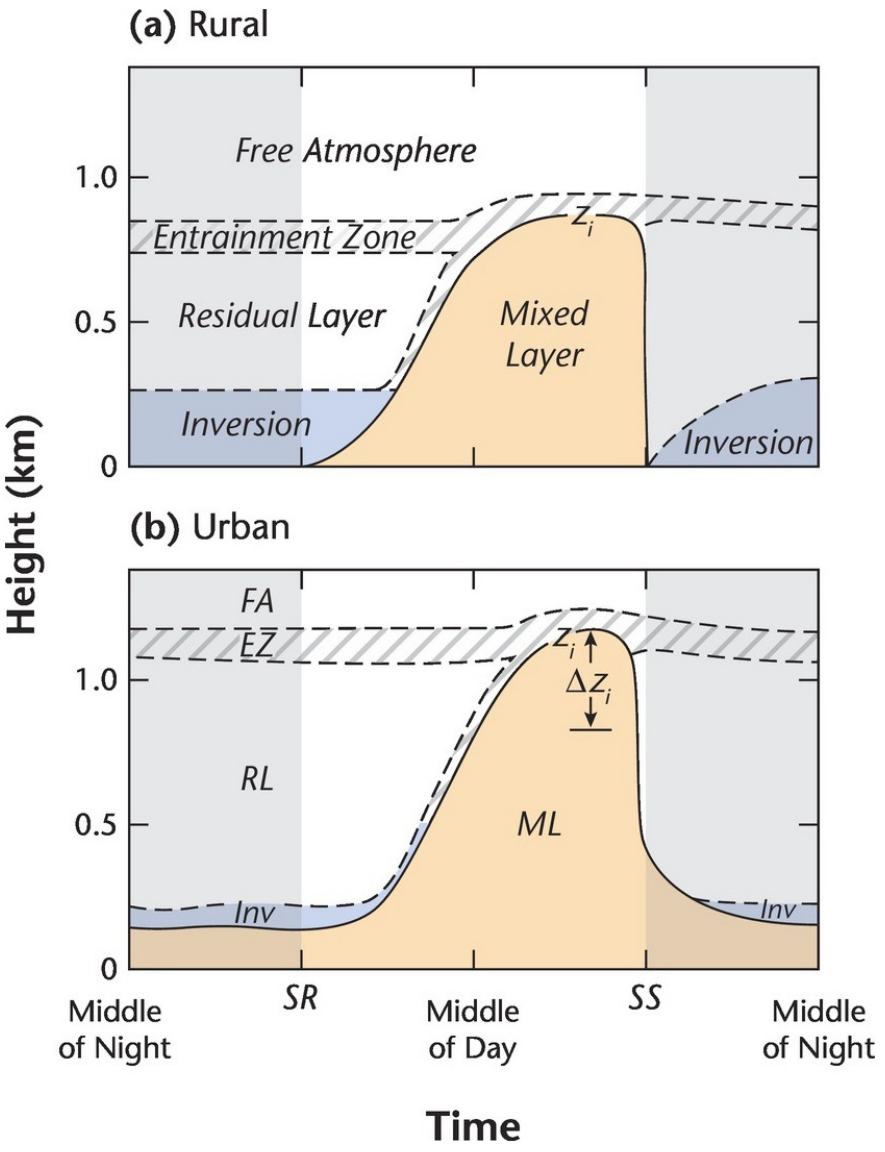
Europe: warmer climate in winter
and more isolated houses
than USA

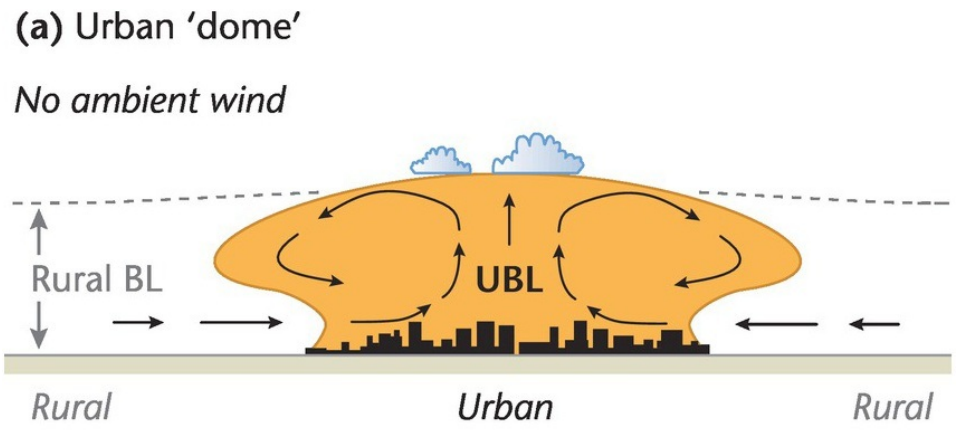
2. Temperature

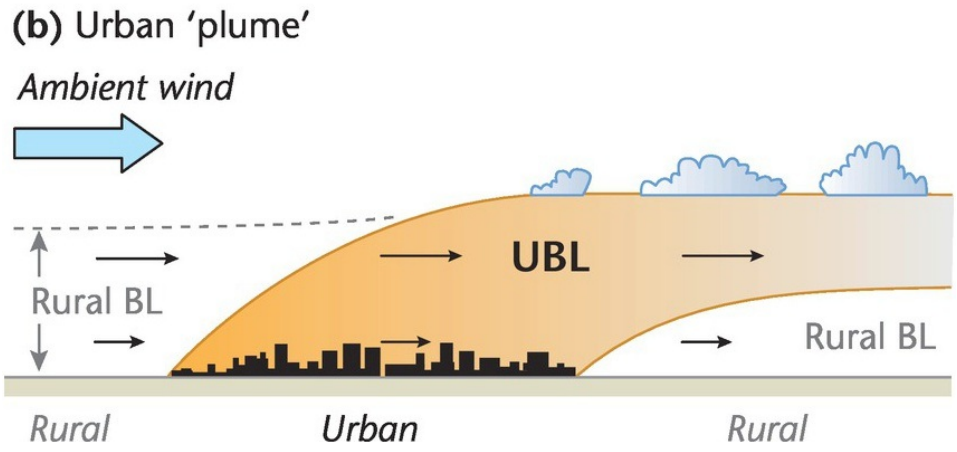


Atmospheric boundary layer (ABL/PBL): thickness of atmosphere of the same behaviours (due to mixing/turbulence) which are in contact with surface

2. Temperature







3. Precipitation

Urban modification of moisture

- Relative humidity 6% lower
  - Larger decreases in summer
- Cloud cover increases 10%
  - Condensation nuclei
- Fog/smog more frequent

Urban modification of precipitation

- Up to 10% higher in city
- Up to 33% higher within 50 km of city DOWNWIND

Peak of precipitation after the city

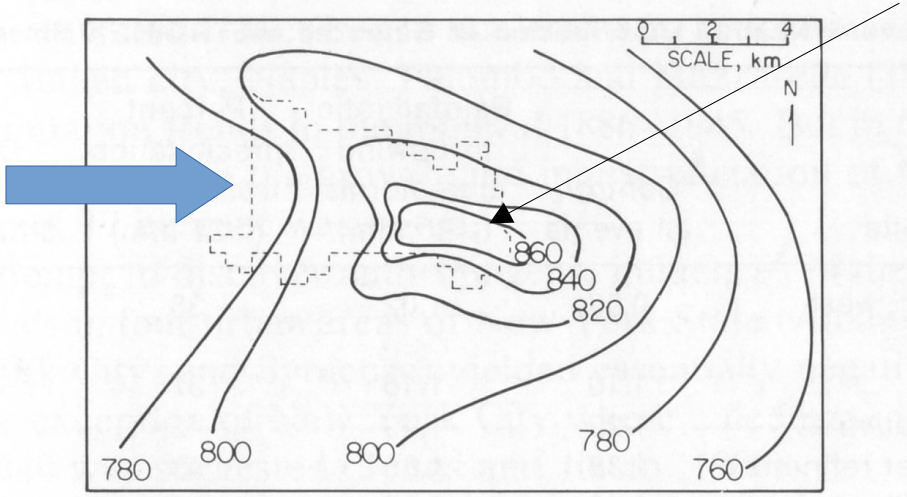


Fig. 8.4 Isohyets of annual precipitation (mm) at Urbana, Illinois (a Changnon, 1962). **Dashed line marks urban limits.**

Weekly signal

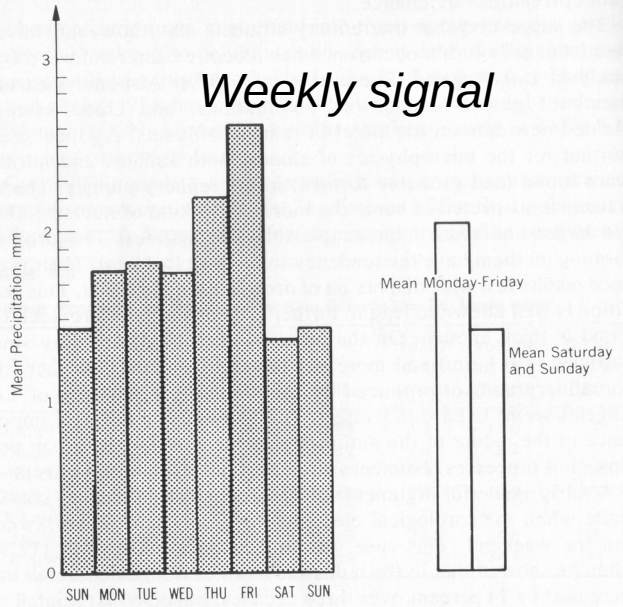
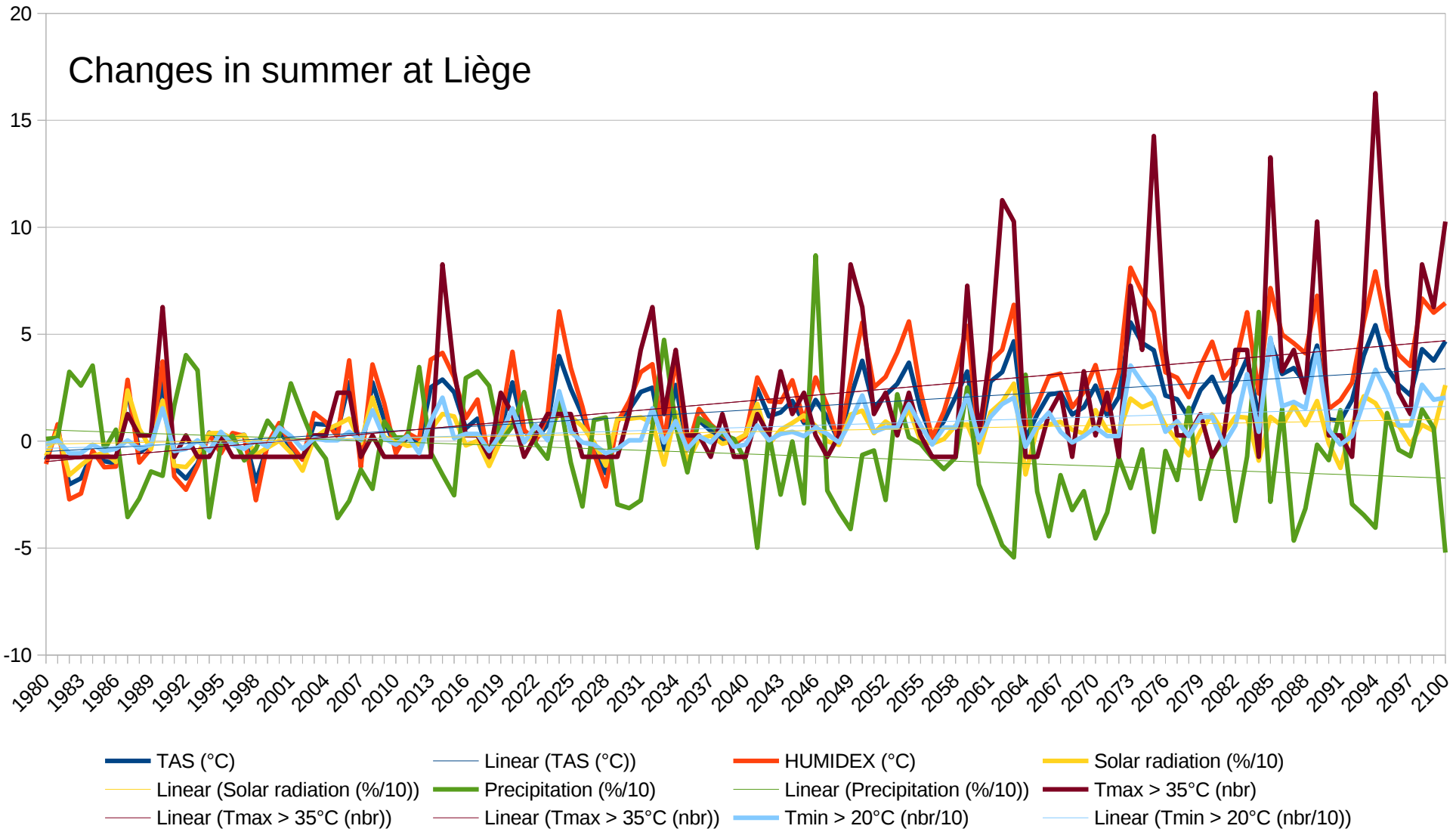


Fig. 8.6 Precipitation in Paris, France, averaged by day of week.

4. Climate change

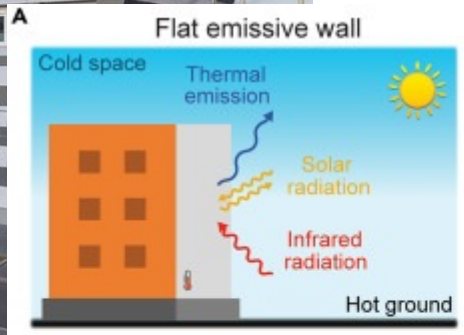


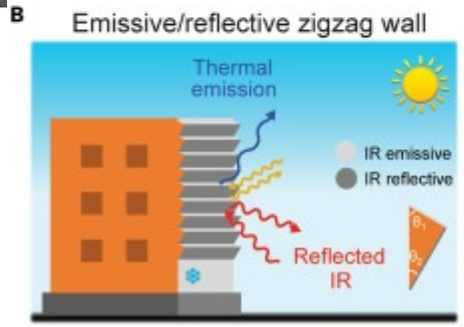
Climate change will enhance a lot the UHI in Belgium!

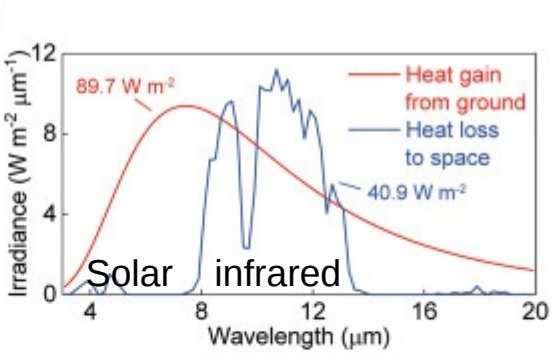
Data: MAR forced by MPI-ssp370

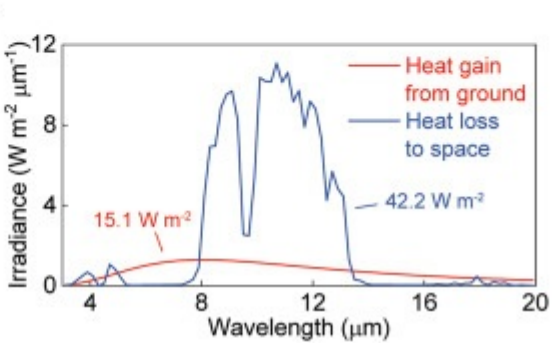
5. Mitigation

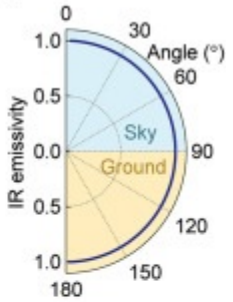
- Increase surface albedo of cities (solar radiation --)
  - Highly reflective roofs
  - Highly reflective roads
- Green and Blue infrastructures (latent heat flux ++)
  - Vegetated roofs
  - Vegetated facade
  - Add some vegetated parks in cities
  - Add some water bodies, ponds, lake ...
- Make the soils permeable (flood –- and LHF ++)
  - Green parking lots

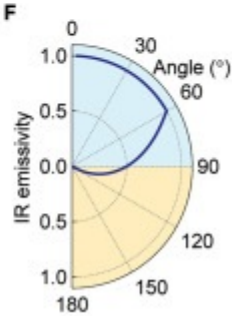


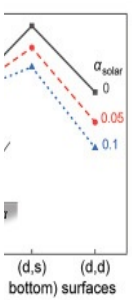


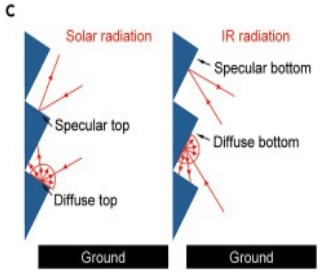










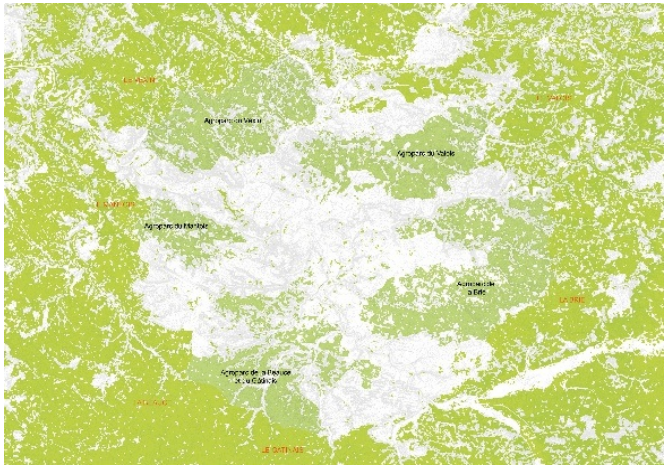


Ref: https://www.cell.com/nexus/fulltext/S2950-1601(24)00026-3

5. Mitigation

Example with Paris

- Urban scenario
  - Urban gardening
  - Forest extension
  - Setting up of lakes
- Technological scenario
  - Reflective paints



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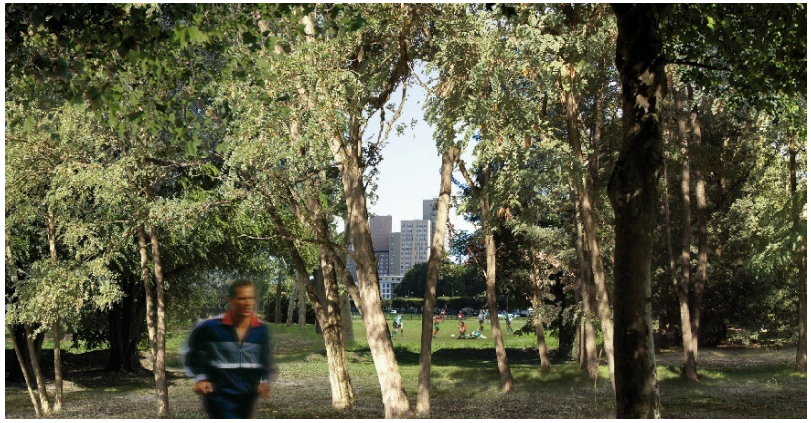

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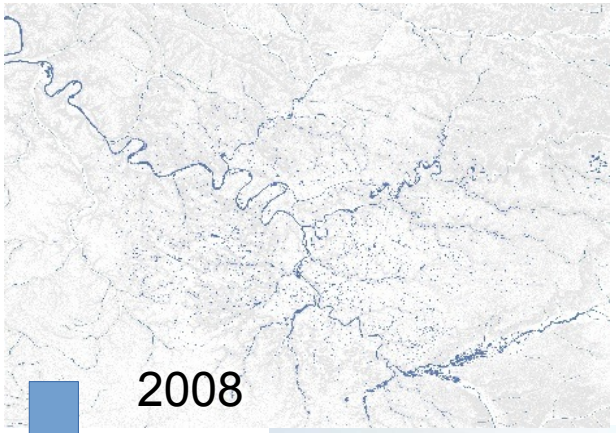

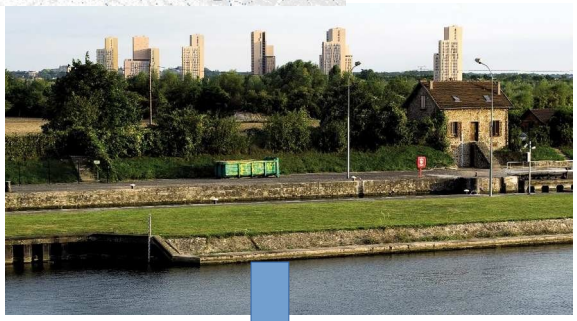

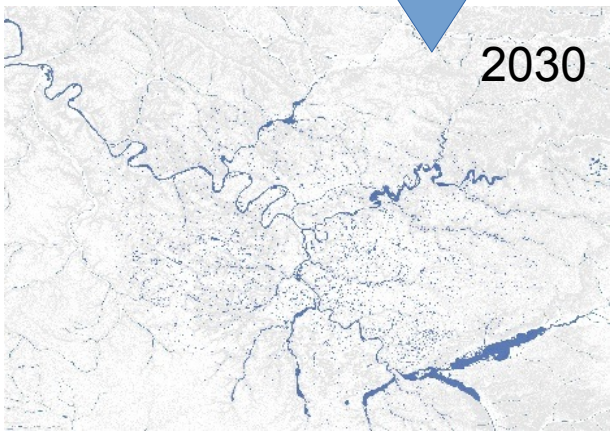

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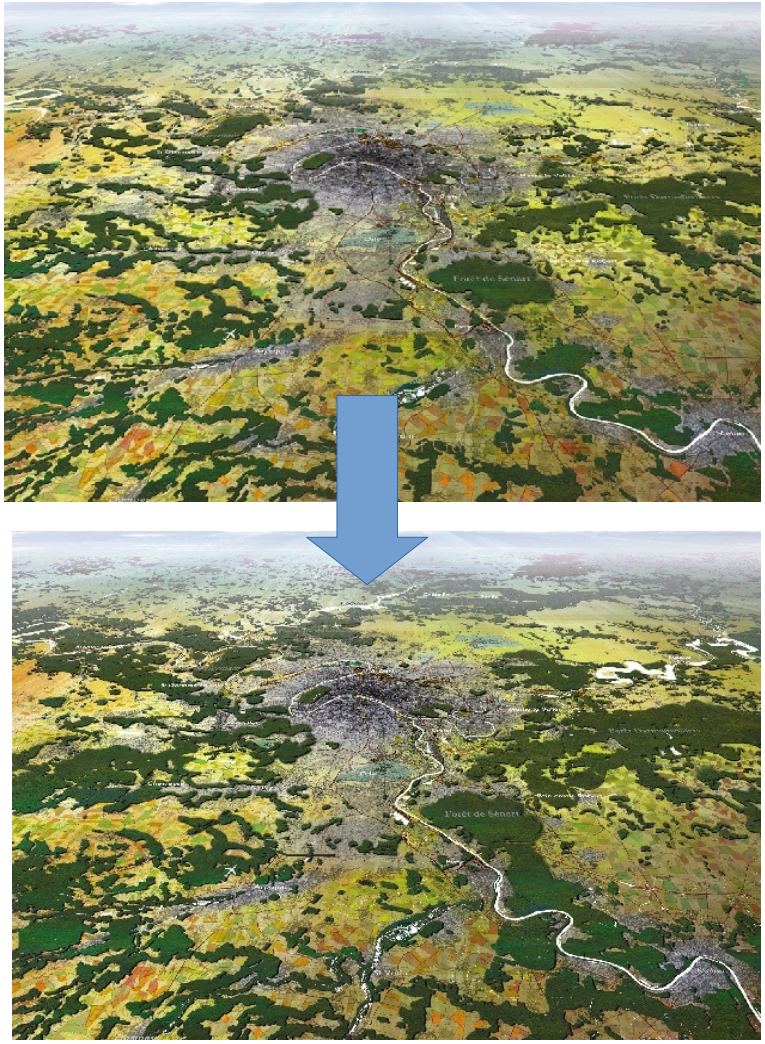
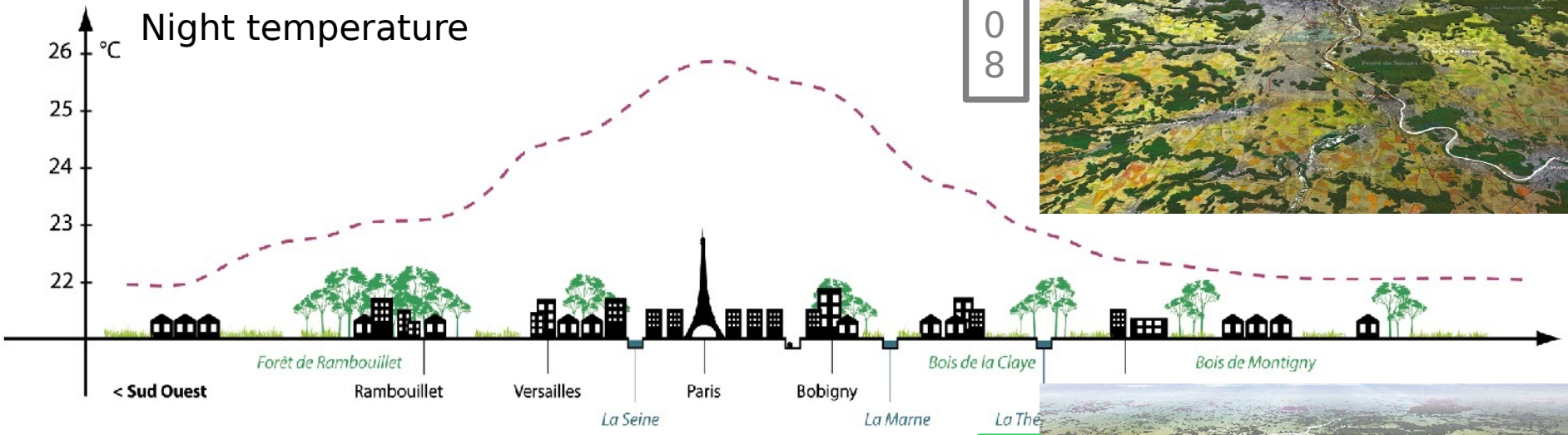


5. Mitigation

The great deal of the Parisian agglomeration
Le Grand « Pari » de l'agglomération parisienne

2008

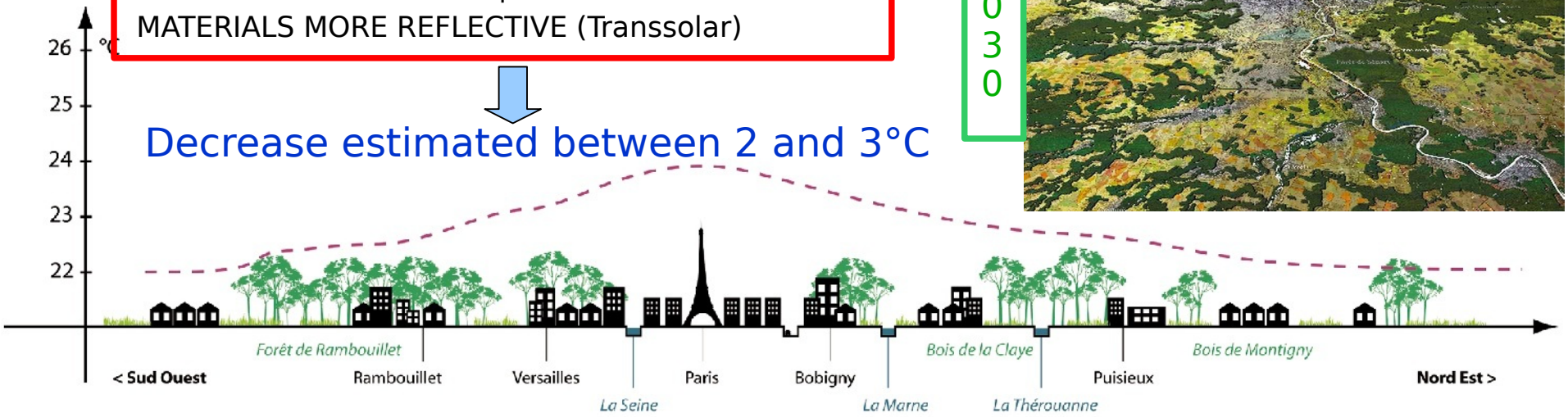
Night temperature



FORETS (A. Peter)
+
MATERIALS MORE REFLECTIVE (Transsolar)

Decrease estimated between 2 and 3°C

2030



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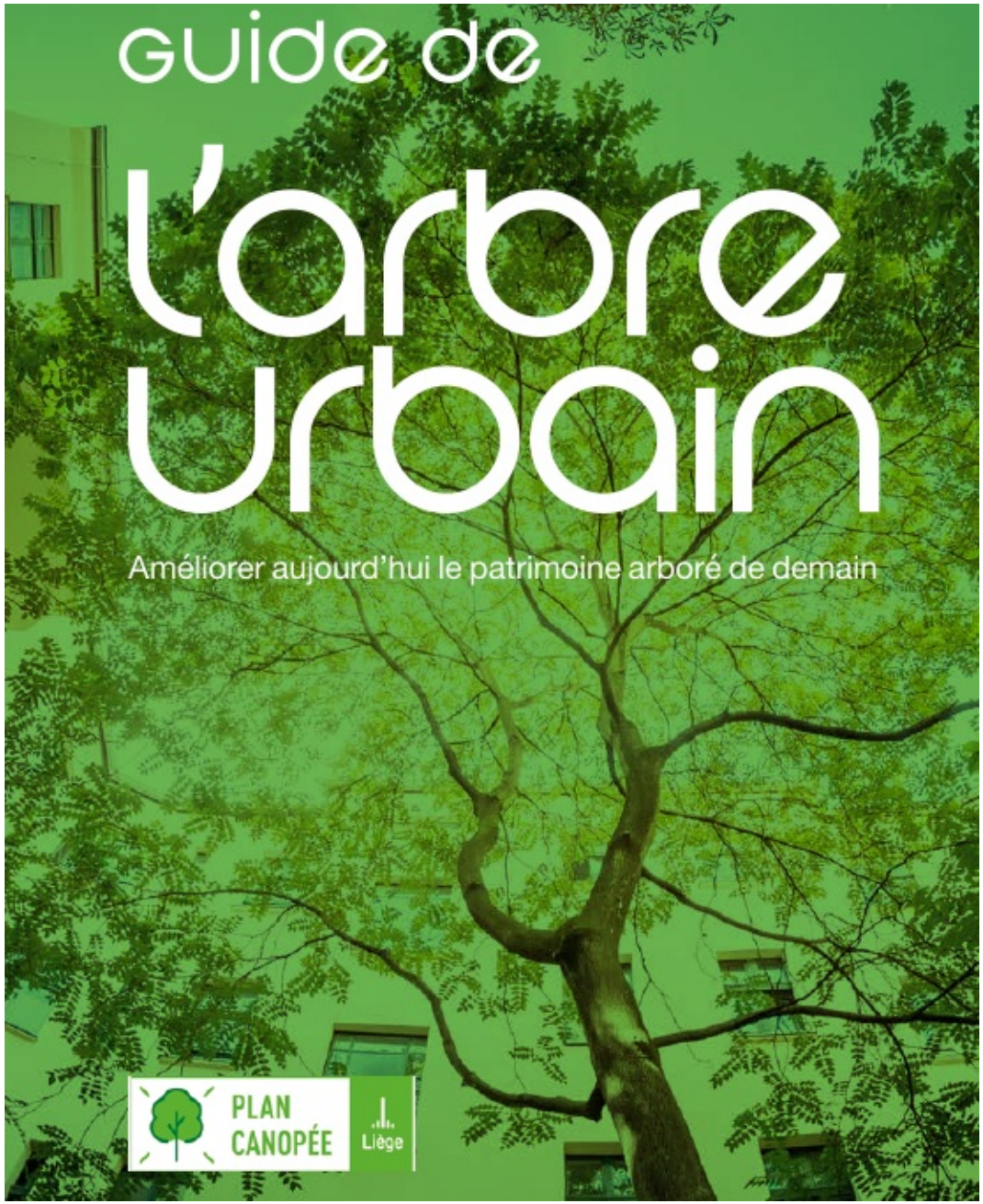

Growing more trees in Liège needs to choice trees which are suited to climate change.

See: https://canopee.liege.be/

But, adding trees need more man power for taking care and increase the risk of forest fire during heat wave if trees are dying ...

Aim: 24.000 new trees in 2032 at Liège!