URBAN CLIMATOLOGY

2. Factors controlling urban climate, urban climate scales, layers, energy balance

2.1 Factors controlling urban climate

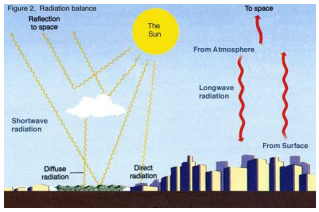
- Urban climate is a typical example of the **local climate**. However, it can be studied on different scales from **mesoclimate** to **microclimate** (see further for urban climate scales)
- For these categories it is typical that processes in lower layers of the atmosphere are primarily formed by radiative, thermal, aerodynamic, and moisture **properties of active surfaces**

Main factors controlling urban climate are:

- Thermal properties of the surface materials
- Surface geometry
- Surface waterproofing
- Anthropogenic heat
- Air pollution

Thermal properties of the surface materials (radiation balance)

- Thermal and radiative properties of active surfaces control intensity of short-wave (**absorption** and **reflection**) and long-wave radiation (**emission**)



- **Albedo** of urban areas is lower (10–15 %) that that of rural areas
- Thermal properties of typical urban surfaces cause **accumulation** of thermal energy during the day ant its **release** during the night

Thermal properties of the surface materials

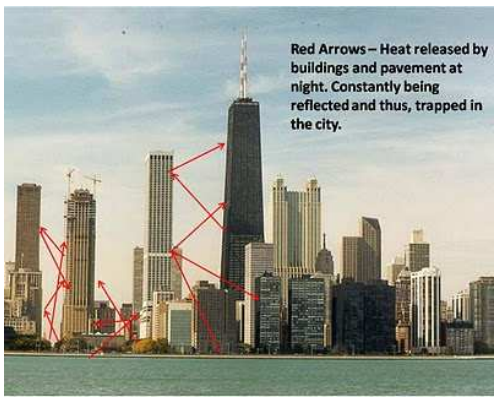
Comparison of selected thermal characteristics for typical urban and rural surfaces (modified after Oke, 1987 and Zmarsly et al. 2002)

Material	Density ρ/kg m^{-3}	Specific heat c/J kg^{-1} K^{-1}	Heat capacity cp/J m^{-3} K^{-1}	Thermal conductivity λ/W m^{-1} K^{-1}	Thermal diffusivity a/m^2 s^{-1}	Thermal admittance b/J s$^{-0.5}$ m^{-2} K^{-1}
Asphalt	2,100	920	$2.0 \cdot 10^6$	0.75	$0.4 \cdot 10^6$	1.200
Loamy soil (40 % pore space; dry)	1,600	900	$1.4 \cdot 10^6$	0.25	$0.2 \cdot 10^6$	600
Ratio Asphalt/ Loamy soil	1.3	1.02	1.4	3.0	2.0	2.0

Albedo values of urban surface materials

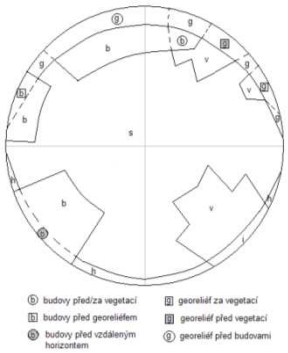
Material	Albedo (%)
Concrete	27.1
Blacktop/asphalt	10.3
Brick, red	32.0
Brick, yellow/buff	40.0
Brick, white/cream	60.0
Glass	9.0
Paint, dark	27.5
Paint, white	68.7
Roofing shingles	25.0
Snow, weathered	55.0
Stone	31.7
Tar-gravel roof	13.5
Yard (90% lawn, 10% soil)	24.0

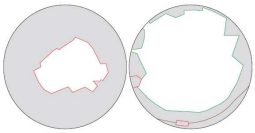
Surface geometry



Surface geometry

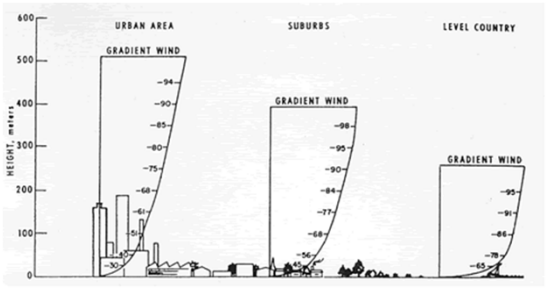
Sky View Factor (SVF)





Urban SVF Rural SVF

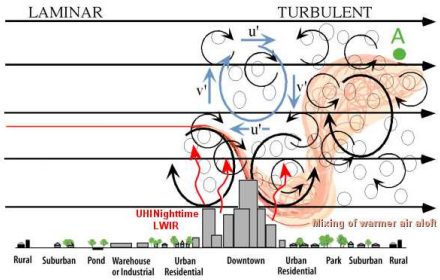
Surface roughness



source: http://www.mfe.govt.nz/

- general decrease of wind speed in „strong flow“ situations

Surface roughness

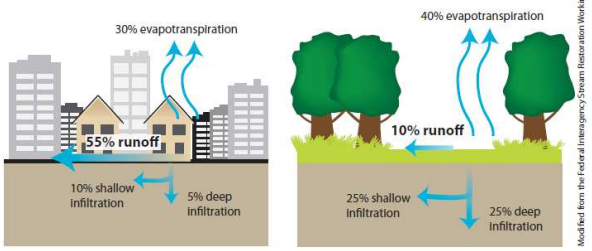


source:https://www.quora.com/

- higher turbulence due to higher air instability (strong local winds in „UHI situations“)

Surface waterproofing

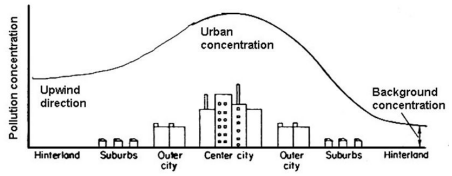
Higher proportion of impervious surfaces in urban areas



Modified from the Federal Interagency Stream Restoration Working Group (FISRWG)

Air pollution

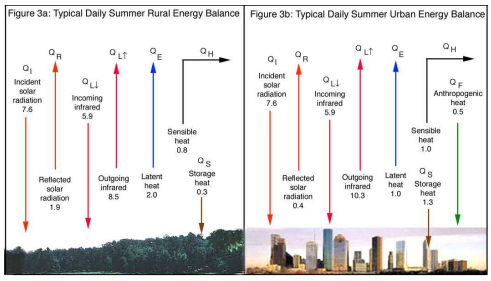
Average air pollution concentration over an urban area



Factors increasing urban air pollution:

- Higher concentration of sources (vehicles, industry, heating)
- Lower wind speed due to surface roughness
- Role of relief (basins, concave shapes of urban relief)
- Higher stability of urban atmosphere (temperature inversions)

Energy balance of urban/rural areas

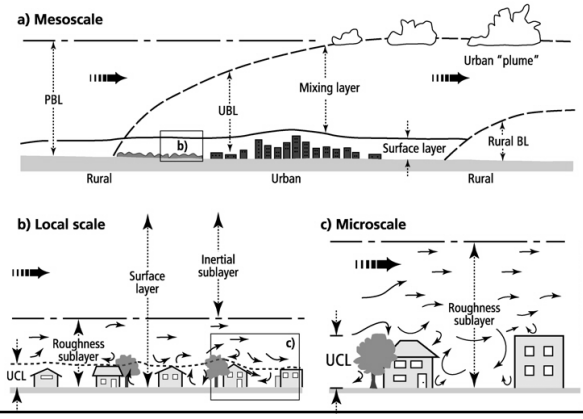


The city energy balance can be simplified to:

$$Q^* + Qf = Qe + Qh + \Delta Qs + \Delta Qa$$

where: Q^* = net all-wave radiation
$= K^* + L^*$ (net shortwave and longwave radiation)
Qf = anthropogenic heat emission ($Qfv + Qfh + Qfm$)
Qe = latent heat flux
Qh = sensible heat flux
ΔQs = net heat storage in the city
ΔQa = net advection into or out of the city.

2.2 Urban Climate Scales (Oke 1997)



Typical features of urban climate

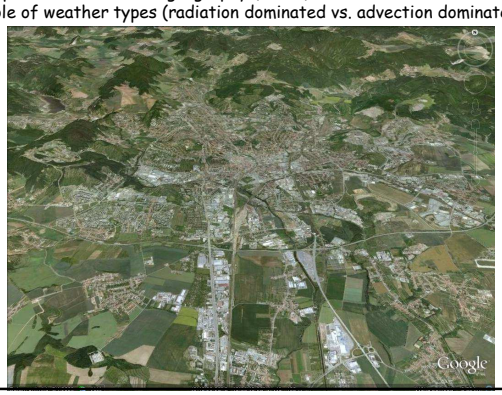
Table U2 Urban climate effects for a mid-latitude city with about 1 million inhabitants (values for summer unless otherwise noted)

Variable	Change	Magnitude/comments
Turbulence intensity	Greater	10–50%
Wind speed	Decreased	5–30% at 10 m in strong flow
	Increased	In weak flow with heat island
Wind direction	Altered	1–10 degrees
UV radiation	Much less	25–90%
Solar radiation	Less	1–25%
Infrared input	Greater	5–40%
Visibility	Reduced	
Evaporation	Less	About 50%
Convective heat flux	Greater	About 50%
Heat storage	Greater	About 200%
Air temperature	Warmer	1–3°C per 100 years; 1–3°C annual mean up to 12°C hourly mean
Humidity	Drier	Summer daytime
	More moist	Summer night, all day winter
Cloud	More haze	In and downwind of city
	More cloud	Especially in lee of city
Fog	More or less	Depends on aerosol and surroundings
Precipitation		
Snow	Less	Some turns to rain
Total	More?	To the lee of rather than in city
Thunderstorms	More	

(Landsberg 1981)

2.3 Final remarks and questions

- important role of local geography (relief)
- role of weather types (radiation dominated vs. advection dominated)



2.3 Final remarks and questions

1. What are the main factors controlling urban climate?
2. What are the main terms of urban climate energy balance?
3. How we can define urban climate scales?
4. What are other factors forming typical urban climates (besides the relief and weather types)?