Importance of correction of surface temperature maps in urban environment

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Introduction / Context & Objectives

Due to more frequently severe climatic events leading to urban heat-islands phenomenon in summer and enhanced risks of ice occurrence in pavements in winter, there is an increasing need for surface temperature measurements in urban environment.

IR thermography is a common tool for monitoring heat losses of building facades. The surface temperature evaluation depends on several influencing parameters, especially the surface emissivity and the contribution of surrounding radiation. It is of great importance to quantify the errors on surface temperature measurements due to influencing parameters values.

The objective of this work is to illustrate the difficulty to obtain an accurate surface temperature on a low emissivity specular surface of a building and the need for an adequate modelling of the environment contribution.

Measurement basics

As building surfaces are assumed to be opaque, the intensity $I_{\Delta\lambda}$ measured for each pixel (in the wavelength domain $\Delta\lambda$) is the sum of three contributions: emission of the surface, reflexion of the surrounding radiation by the surface of interest, contribution of the atmosphere:

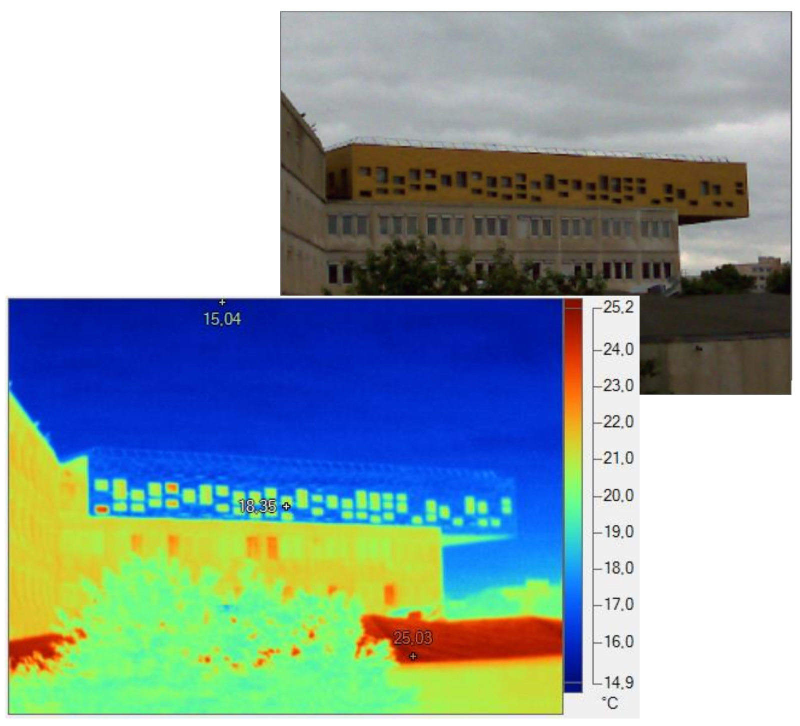
$$I_{\Delta\lambda} = \tau\varepsilon I_{\Delta\lambda}(T_0) + \tau(1-\varepsilon) I_{\Delta\lambda}(T_{env}) + (1-\tau) I_{\Delta\lambda}(T_{air})$$

- T_0 : surface temperature
- T_{air} : air temperature
- ε : surface apparent emissivity
- τ : atmosphere transmittance.

Measurement hypotheses

Most of materials of building facades are considered as grey, highly emissive and diffuse surfaces.

- A "standard" value of the emissivity is generally considered
- Surrounding environment contribution is simplified to an equivalent black-body emitting at a mean-radiant temperature T_{env}



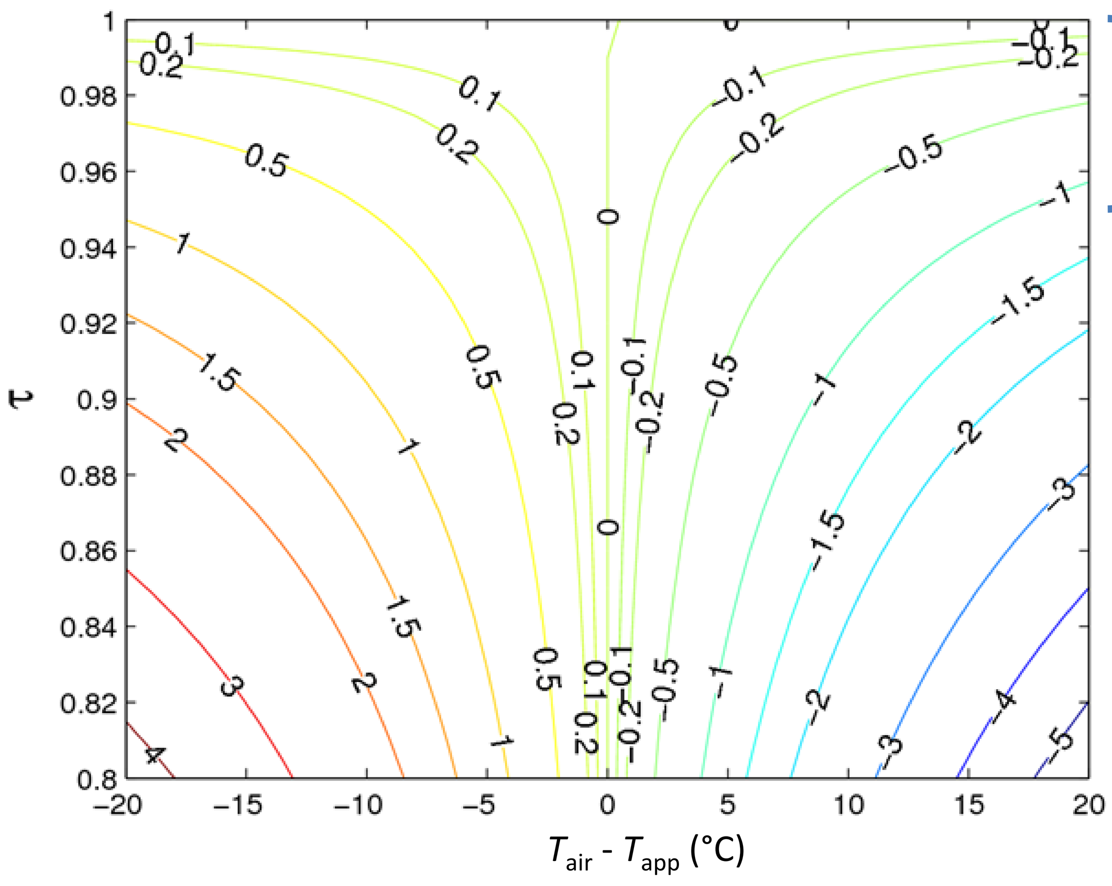
Difficulties

- Use of low emissivity materials and specular surfaces on buildings façades or roofs (metallic claddings, selective paints…) to lower heat losses
- Erosion, soiling and ageing of materials

- Highly heterogeneous environments and possible parasitic multiple reflexions
- Temporal evolution of surface radiative properties

Quantification of errors due to influencing parameters

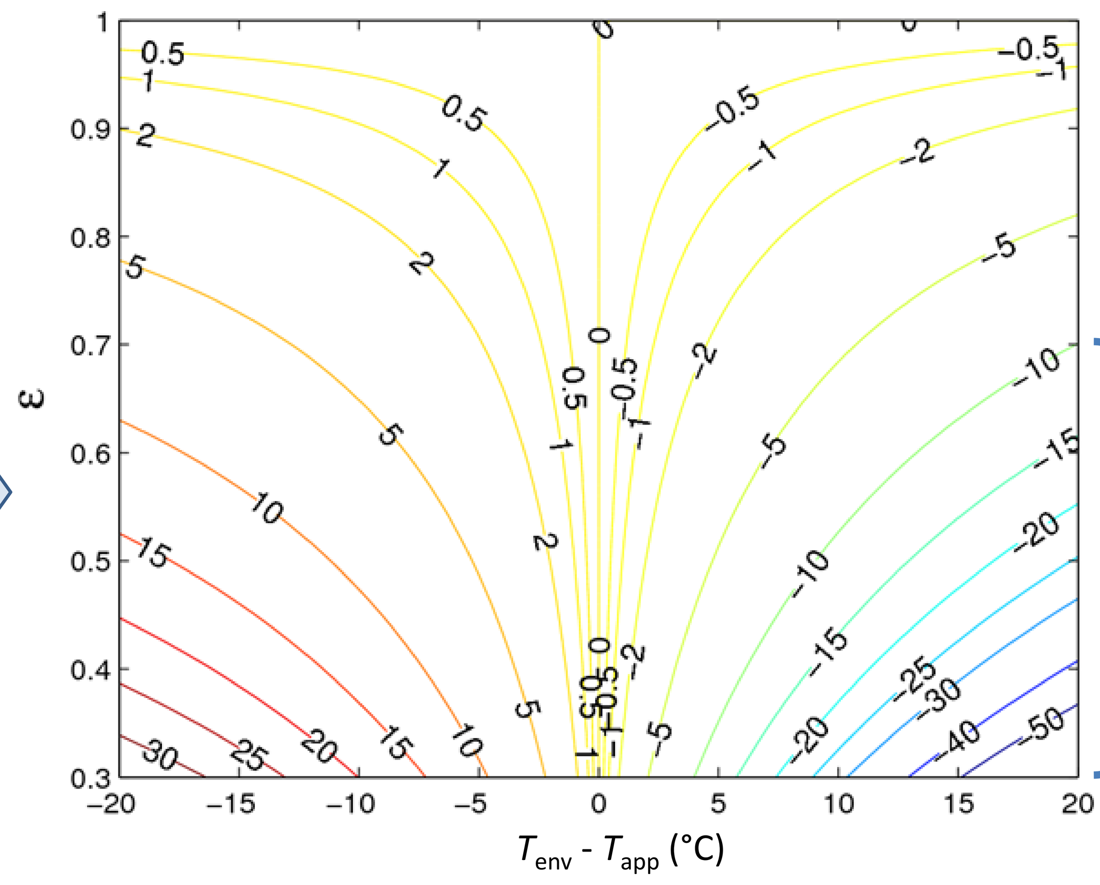
Influence of atmospheric transmittance



Small errors due to the atmosphere contribution: $\tau > 0.95$ for distances < 50m and classical RH conditions.

Difference in °C between apparent and true surface temperature

Influence of emissivity



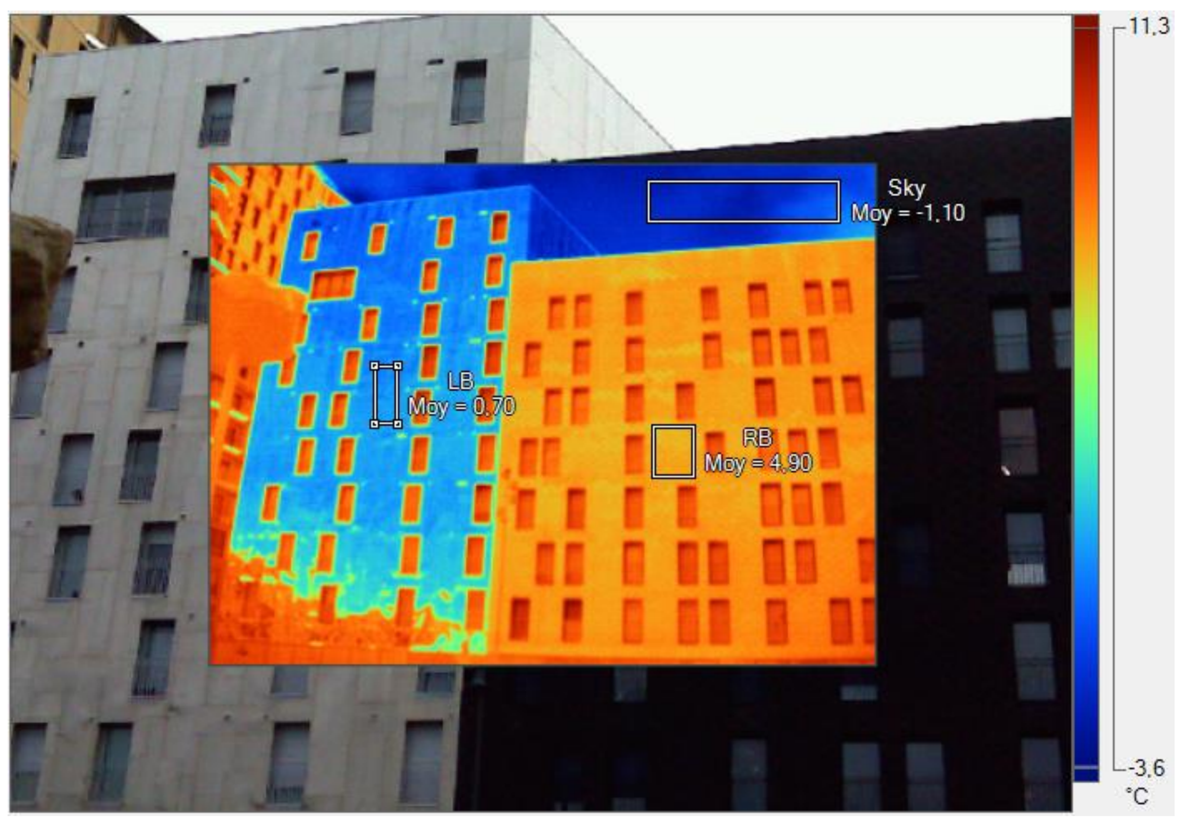
Moderate corrections for high emissivity surfaces (concrete, stone, paintings…)

For low emissivity surfaces, predominance of surrounding radiation contribution.

Accurate characterization of the environment radiation required to minimize the measurement bias on corrected temperature.

Illustration of the importance of environment radiation modeling for outdoor in-situ situations

Measurement case



Conditions:

- Winter conditions before sunrise (no influence of solar radiation)
- Mean radiant temperature computed from thermal images of the surroudings: +2°C (mean value)
- Sky temperature: -1.1°C
- Air temperature: +1°C

Left building:

- Low emissivity specular surface (~0.2)
- Apparent temperature on ROI considered: +0.7°C

Right building:

- High emissivity diffuse surface (~0.9)
- Apparent temperature on ROI considered: +4.9°C

Computed corrected surface temperature values as a function of the choice of T_{env} and ε values

Influence of T_{env} choice for assumed emissivity value			Left building (T_{env} = 2°C)		Right building (T_{env} = 2°C)	
T_{env}	Left building T_0 (ε=0.2)	Right building T_0 (ε=0.9)	ε	T_0	ε	T_0
-1.1 °C	+11.44 °C	+5.67 °C	0.1	-1.69 °C	0.8	+5.88 °C
+2 °C	-0.35 °C	+5.35 °C	0.2	-0.35 °C	0.9	+5.35 °C
+5 °C	-13.71 °C	+5.39 °C	0.3	+0.09 °C	1.0	+4.92 °C

Expected observations

- Both buildings were built at the same time (2017 in Paris), so they are supposed to meet the same requirements regarding heat losses limitations.
- Both buildings are occupied. So, we expect to obtain a quite similar external surface temperature.

Corrections / Conclusions

T_{env} values considered:

- -1.1°C: sky temperature
- +2°C: average value of surroundings T° (buildings, sky, pavements)
- +5°C: average value of surrounding building surfaces only

- Great importance of T_{env} value for the lowest emissive surface.
- To obtain a corrected surface temperature equal to the one of the right building, we have to use either: T_{env} = +0.6°C (with ε = 0.2) or T_{env} = +1.2°C (with ε = 0.1) or T_{env} = -0.2°C (with ε = 0.3).
- Whatever the emissivity considered (in the expected range), T_{env} optimal value is intermediate between sky and mean radiant temperatures, which can be explained by the highly specular character of this surface.

- How to reach such accuracy on T_{env} value due to metrological uncertainties?
- Importance of the modelling of environment radiation for low emissivity and/or specular surfaces.

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